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ZGS INJECTOR LINAC

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We have been operating the linac for about a year now. The physics of the machine behavior has probably not been given the kind of emphasis that it really should have had, in order to have a well developed and well understood operation at this time. Now we have the hardward well in hand, and are ready to measure the characteristics of the beam transport elements as well as the beam emittance at various places. We find that we must improve our beam quality, both from the column and from the linac and are about to start on a planned program to accomplish this.

Last week we had the first attempt to run continuously. This period continued for 88 hours. There were no interruptions in operation as far as the injection system was concerned. We had four high voltage sparkovers in the preaccelerator column in that time. It took about a minute or so to recover from each of these. So far, this is the best that we have had an opportunity to do. The beam current from the linac depends upon just what we are trying to do at the time. Last week we were running from 10 to 12 mA which was as much beam as there was any reason to want at the time.

The most we have had is 17 mA. I don't think that at this point there is really anything fundamental about getting 25 to 30 mA if there were any real incentive for it. Right now we are putting far more beam into the synchrotron than it can handle and our real problems lie in the synchrotron itself.

One of the two major problems that we have been working on has been the high voltage regulation of the preaccelerator. This probably would have been less of a problem if we had done all of the design and fabrication work ourselves. The second major problem has been the rf regulation which is still troublesome. In the linac rf system (see block diagram in Fig. 1), we have a plate voltage power supply which charges a 32 μf storage capacitor to 50 kV. The stored energy from this capacitor is then switched by a hard tube modulator to provide 35 kV pulses. By feeding back a cavity signal into this pulsed driver, we can regulate the output waveform of the modulator, which in turn regulates the rf power drive into the tank and corrects for beam loading. We have been working on this on a part-time basis for about six months and finally have it working. The first efforts resulted only in oscillations as soon as we put a signal into the feedback system. We managed to get rid of the oscillations, except that it would ring a little bit after the beam pulse came on (or rather, the simulated beam pulse that we were using at that time). This has now been made to work reasonably well.

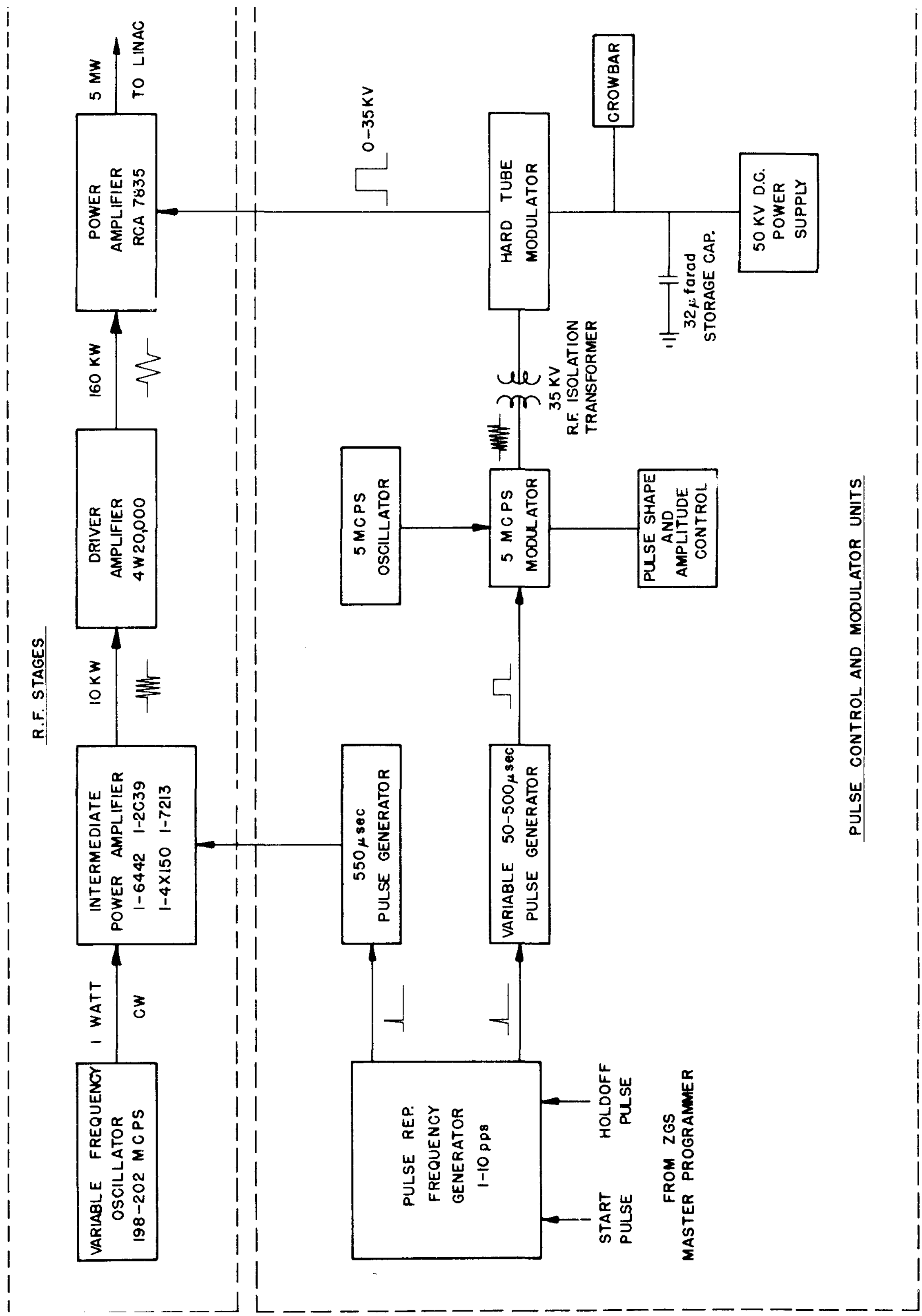

FIGURE 1

BLOCK DIAGRAM OF 200 MCPS LINAC R.F. POWER SYSTEM

A lot of problems have been associated with the stray rf. We finally got around this by moving the regulating circuits into the control room which introduced other problems because of the line lengths in the system, but I think these things are now pretty well completed. We have a reference power supply which we compare with our rectified cavity signal. The output of this comparison circuit goes into the amplitude modulator of the 5 Mc/sec system. It has thus far been necessary to block the feedback out for the first 100 μsec of the excitation of the cavity, so that there is a gating circuit. If you don't do this, the no-beam cavity signal during the first part of the pulse tries to drive the modulator output toward maximum and the standing waves in the coupling line into the cavity get to be very large. Then there will be an arc some place, usually in the coaxial line between the power amplifier and the waveguide. Our coupling system is physically the same as in the Minnesota linac system, the power amplifier system sits on top of about a 3λ section of waveguide which is fed with a coaxial transition into the waveguide.

There is one thing that we feel bears a great deal of investigation, and that is the acceptance matching into the front end of our tank. We are in fact operating in a situation where we are tailoring the acceptance of the tank to the emittance of the beam coming from the injector, which is not a very good thing to do. From now on we are going to have to concentrate on this area of investigation. It is entirely possible that by shifting our quadrupole triplets around in the front end, we may make some improvement.

We are operating in the (+-+-) mode of the quadrupoles which are divided into twelve groups along the linac. Within each group, the quadrupoles are all in series from one power supply. There are variable shunts across each quadrupole, which makes it possible to vary the currents individually and then make the gradients fits the design curve. If we try to operate at the design currents for the quadrupoles in the first group (No. 1 through No. 8) our total beam current through the linac is down by nearly a factor of 10. However, by lowering No. 1 by 20% and No. 2 by about 30% and then the rest of them to the order of 70 to 80% of their design value, we then can get the phase acceptance that one would expect, which is about 22% at our design gradient.

During this past week we actually measured, for the first time, a bunching factor of 3 in the buncher. We then increased the amount of beam current into the buncher by a factor of about 50% and the result was a more normal bunching factor of from 2 to 2.5 so we really didn't get any more beam out of the machine at all. We have operated for about the last six months without the buncher.

HUBBARD: Is this a multiple harmonic-type buncher?

LIVDAHL: No, it has only the first harmonic. We have a second harmonic cavity built and being tested. The frequency doubling amplifier that has been built for this has not met its acceptance tests as yet.

OHNUMA: You mentioned the change of the gradient of the quadrupole magnet and the corresponding change in intensity; I suspect what is happening here is that the quadrupole magnets between the linac and the buncher are not doing what they are supposed to do. In other words, the linac acceptance is different from what you think, and by changing the current in the quadrupole magnets, you change the acceptance of the linac.

LIVDAHL: We certainly agree that this is the case. That is what I meant when I said that we are tailoring our acceptance to what we are putting in, rather than the other way around. I think this is the wrong way to do it but for our immediate purposes it seemed to be a reasonable way to get around the problem.

WHEELER: How much power do you think you can get out of the 7835 power amplifier?

LIVDAHL: In the tests into the dummy load we have gotten 6.25 MW at 35 kV pulse voltage. At this point we ran out of time to optimize it. I doubt very much that we would have any trouble going to 7 or 7.5 MW, because we had just started to optimize some of the parameters on the power amplifier that seemed as though they should be varied to find the best operating conditions. For instance, the company that built the system was very worried about having enough bias on this tube to protect it. So they insisted that they had to keep the cathode resistance considerably higher than the RCA people would recommend. We're running at the present time with about 15 mA of accelerated beam and at a pulse voltage of about 28 kV. Now if we follow the curve of power delivery versus plate voltage that we had into the resistive load, we should get close to 7 MW at 35 kV. I don't know what's going to happen to the curve as the beam current goes up but I don't see any reason why we shouldn't be able to go to 5 MW at least and maybe a good deal more. Five MW would be equivalent to about 50 mA.

HAGERMAN: How long is the pulse length?

LIVDAHL: The rf pulse length is 500 μsec. The beam pulse length is 250 μsec. Recently, all of our operations have been at shorter pulse lengths. We can go as high as 300 μsec. We have been running at about 2.5 to 3 MW out of the power amplifier. The efficiency is of the order of 45% here. But it appears as though, when the shunt impedance of the cavity goes down with increasing beam current, the efficiency of the power amplifier seems to go up, which is a very lovely situation to be in. We were getting efficiencies of the order of 55% into the resistive load.

BLEWETT: When you're running this beam loading compensation, does the envelope on the probe look just the same as if there were no beam?

LIVDAHL: Yes.

BLEWETT: No discontinuity over 10%?

LIVDAHL: No. I think it's really a little early to make any claims on this yet, because we have just been operating this simulated signal. But it looks like it's going to be beautifully flat.

HOOVER: How do you simulate this?

LIVDAHL: It's easiest to put in sine waves into the regulating system. Yesterday, we had it running all day; this was the first time we had a real all-day opportunity to make adjustments with it on a full-shift basis, and we really had the flattest waveform I've ever seen in the tank. If you look at the top of the waveform, and you blow the tank waveform way up, there have always been some little notches on it. They are of the order of maybe a tenth of a percent or so. Yesterday, I didn't see any signs of these at all, and I think that it was because of the regulator in the circuit.

HUBBARD: Is the periodicity of those bumps uniform?

LIVDAHL: Yes, I think it's voltage in the tank. It must be coming from the tank.

BLEWETT: We have seen those on the linac at Brookhaven. They are very small on the probes both 1/3 and 2/3 of the way down the tank.

LIVDAHL: It does depend upon which position you're looking at.

QUESTION: What is the frequency of these notches?

LIVDAHL: Well, I think that it varies from time to time, but I remember it as being of the order of 50 to 100 kc/sec. They have presented no problems so that we just ignore them.

QUESTION: Are they there whether the regulator system is in or out?

LIBDAHL: They weren't there yesterday and I've always been able to see them before if I looked closely. I don't recall ever having seen the waveform without the little bumps on it. Where you really see them in a pronounced fashion is down further where the pulse is just starting to flatten off.

VOELKER: At the Hilac at Berkeley, where we have two tanks, we see the same phenomena and it is a function of the energy going into the mode. The periodicity can be changed by changing the relative resonant frequencies of the two tanks. I don't know if you have another energy source in the system.

LIVDAHL: No, we don't.

WHEELER: As a matter of interest, in the Heavy Ion Machine at Yale, where we don't have the two tanks coupled together, we don't see these notches.