October 25, 1963

REVIEW OF PARAMETERS FOR AN 100 MeV INJECTOR FOR THE 70 GeV USSR SYNCHROTRON

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The parameters for proton linear accelerators in use outside of the Soviet Union are well known. However, at the International Accelerator Conference at Dubna in August 1963, descriptions were given of components for the 70 GeV proton Synchrotron being constructed in Serpuchov and for the 100 MeV proton linear accelerator to be used as its injector.

The following table lists the important parameters. These were obtained from ITEP report NTD634A.

Output energy	100 MeV
Accelerator frequency	148.5 Mc/sec
Preinjector energy	0.7 MeV
Proton pulse duration	12 to 40 μsec
Pulse repetition rate	0.2 to 1 pulse per second
Pulsed proton current input	250 mA
Pulsed proton current output	100 mA
Number of longitudinal oscillations	6.5
Synchronous phase	-38^{o}
Quadrupole pulse length	600 μsec

The resonant cavity for the accelerator is constructed of three decoupled rf structures whose parameters are listed in the following table:

	Cavity I	Cavity II	Cavity III
Length (m)	29.9	27.6	21.9
Diameter (cm)	132.4	122.0	108.7
Number of drift tubes	1/2+93+1/2	1/2+41+1/2	1/2+26+1/2
Gap coefficient	.250 - .255	.185 - .284	.222 - .277
Drift tube diam. (cm)	23.2 - 10.0	10.0	10.0
Energy (MeV)	.7 to 37.8	37.8 to 72.7	72.7 to 100
Velocity of protons (β)	.039 to .276	.276 to .372	.372 to .428
Cavity Q	72,000	50,000	36,000
Shunt impedance (MΩ)	25.4	19.4	14.8
Power loss (MW)	2.0	2.4	2.5
No. of plates for field leveling	50	44	34
No. of servo field tuning plates	12	12	10
Quad. lens field gradients (kG/cm)	5.6 to .61	.58 to .45	.42 to .39

The tank diameters and drift tube diameters appear to have been obtained by optimizing the shunt impedance. The drift tube diameters are constant at 10 cm for the last two tanks. The drift tube aperture varies from 2 to

3 cm in the first tank, 3.5 cm in the second tank, and 4 cm in the last tank. Thus, in the last tank with a 10 cm O.D. drift tube and a 4 cm bore there is available radially only 3 cm for the bore tubes, quadrupole, water cooling and drift tube skin.

The average field gradient is reasonable at 1.8 MV/m. The average field gradient in the gaps is 7.4, 10, 8.2 MV/m but the maximum field at the 15 mm radius on the drift tube is 23 MV/m. This is quite high and might indicate difficulty from sparking.

The power loss in the cavities is 2.0, 2.4 and 2.5 MW, respectively. The amplifier tube, of which one will be used per cavity, has an output power of 5 MW. With an output beam current at 100 mA there will be 10 MW in the beam total, 6.9 MW in cavity excitation and only 15 MW available in rf power.

Each tank has a rough tuning system for controlling the resonant frequency, uniformity and tilt of the electric field. This rough tuning system consists of a series of radially moveable plates attached to the tank structure with flexible metal connections. These plates run the full length of each tank and are divided into 50 plates in the first tank, 40 in the second and 34 in the third. There is also a fine tuning system for adjusting the resonant frequency. This consists of a series of plates in each tank linked together and actuated by a servo control from the tank resonant frequency. The rough tuning plates are 50 x 50 cm and the fine tuning plates are 20 x 40 cm.

From the viewpoint of design, there are some interesting features. The resonant tank structure is built with a separate vacuum tank and resonant cavity structure. The major reason for this seemed to be that the Soviet Union does not produce copper-clad steel.

The tank is supported on a channel foundation structure while the drift tubes are on a completely independent foundation. This is done by having a separate support structure which runs underneath the tank and to which the drift tube stems are attached and aligned. The stems are vertical and the drift tubes are at the top.

The vacuum tank separates on a horizontal plane for access to the electrical structure. The inner tank is made of copper sheet with steel ribs and is to be placed in the outer tank in 5 meter lengths and welded together. Access to the inside of the cavity will then be through the tuning plate openings and the drift tubes will be installed through these openings. The copper tank will be temperature controlled to $0.2^{o}C$.

The vacuum system is rather interesting because it is planned to use a rough vacuum and high vacuum system. The inner tank will be evacuated with titanium getter pumps to a pressure of 10^{-6} Torr and the space between the inner and outer tanks will be evacuated to 0.1 mm. The inner tanks will be pumped by 36 pumps of 600 ℓ/sec capacity. There are three resonant tanks but only one rough vacuum tank about 300 ft long.

Since the linac operates at 150 Mc/sec, the drift tubes are longer than are usual in proton linacs and the drift tube stems are 7 cm diameter and quite stiff. As a result they are planning to put fluorescent screens in the bores of some drift tubes and view them through the drift tube stems.

The drift tube alignment system is quite complicated because it has adjustments in all degrees of freedom. This system is to give an accuracy of alignment of ± 0.002 in. which is better than has been done in any other linac. Also, this accuracy of alignment has not been maintained over a protracted period of time. This accuracy is not necessary to contain the proton beam but they felt that the emittance of the beam would be lower with greater accuracy of alignment.

The amplifier tube that is being used is their number GE27A triode. There is one tube per tank and this in its cavity is mounted right on the vacuum tank of the linac. The plate voltage is 40 kV, the filament power is 6 kW, the power gain 8 to 10, and the average power 20 kW. The modulator is a line type with an ignitron switch. This tube has been tested to 3.5 MW into an external load and also into a cavity with one drift tube.

The full responsibility for design and construction of this accelerator is in the hands of the machine group in Moscow. This group has a prototype of the 100 MeV linac under construction in Moscow. This is a new linac injector for the 7 GeV AG accelerator and consists of a tank 18 meters long with the first section being of $2\beta\lambda$ cell length and about 6 meters length. It is not understood why this was done.

GRAND: What is the wall thickness of the copper cavity?

POLK: The copper that we saw in Moscow appeared to be 1.5 to 2 millimeters.

GRAND: So, in this case, their differential vacuum pumping is not only for leaks but also mechanical reasons.

POLK: Surely, but if you are using the double tank construction, the standard technique has been to put holes in the inner liner and use one vacuum system. I think that they will have severe problems with the stem seals. They have to go through two tank walls and two sets of seals which also poses the problem of stiffness in the seals, which could effect alignment. It certainly presents more of a problem than the use of a common system.

YOUNG: Did you look at how the drift tubes were fabricated?

POLK: Nothing unusual: essentially they use spun or machined shapes for drift tube bodies. They also use two quadrupoles in each drift tube.

FEATHERSTONE: Do you recall what they were using for g/L?

POLK: Yes, it is about 0.250 in the first tank, and varies from 0.185 to 0.284 in the second tank, and from 0.222 to 0.277 in the last tank.

LAMB: Have they built a working model of this machine?

POLK: No, they have no working model in operation, but the 20 MeV machine that they're building as a new injector for the Moscow accelerator is essentially a prototype. I presume that they'll put it into operation before they go through with the rest of it. There are some critical items, for example, this 23 MV/m on the drift tube is very basic and may be a problem in the operation of the machine.

CARNE: What makes them think they can get away with it?

POLK: I don't think they are really sure. They have gone for this optimization of the shunt impedance and may not have looked at the field gradient particularly.

BITTNER: Did you see any high-power models?

POLK: No.

FEATHERSTONE: On this point about field strength, part of it may stem from the work of Poliakov, Sardoin and Kushin, who published tests in 1959 made at 99 Mc/sec. They ran at 45 to 50 MV/m in their test rig. 23 Mv/m would then be a reasonable value to choose. I don't think they would have done this without tests.

QUESTION: You say they were not doublets, they were actually running (+,-) in each drift tube.

LIVDAHL: In the 20 MeV linac, the $2\beta\lambda$ section has (+,+) in a drift tube and (-,-) in the next one, and then in the $\beta\lambda$ section they use (+,-) in each drift tube.

LAMB: I agree with Featherstone that the choice of gradient has to be qualified. In a large gap you can have much larger gradients without sparking. All the sparking occurs at the first few drift tubes, generally, in our experience.

POLK: I don't think anybody disagrees with that. This has been the general experience with linacs.

BITTNER: Are those three inner tanks inside the big one right together, end to end?

POLK: No, there is a double wall at the end of each tank with a space between.

BITTNER: Is some beam detection equipment between the tanks?

POLK: There may be.

BITTNER: That's a long way to get a beam down without an intermediate sight.

POLK: I can see a fair amount of difficulty with the relative motions of a single steel tank, which is expanding and contracting because the steel tank is not temperature controlled. The copper tanks inside are temperature controlled, but the steel tank will be moving around while the copper tank stays put. This is the sort of thing which causes difficulties. The drift tubes are supported on a separate spine running down the center, and the spine is going to be temperature controlled, but the foundation will not be.