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Linear accelerator mechanical construction

This discussion will be mainly limited to the various design aspects of the BNL linac. The linac consists of a single wall cylinder which serves simultaneously as a vacuum envelope and rf cavity. This structure is supported on 10" "H" beam piles driven 50 feet into the ground; the piles are covered with concrete pile caps. During a period of about 2 years these pilings have drifted slightly; at the high energy end a drop of about 0.005 inch and at the low energy end a rise of 0.008 inch has been measured.

These variations are traced back to the placing of a heavy shielding wall near the high energy end and excavations for a bubble chamber building in the vicinity of the low energy end. These inherently smooth variations have not much influence on the linac beam orbits, although from this it can be seen that for linac design proper foundations are of great importance.

The actual tank support on top of the concrete pile caps are constructed with linear bearings operating between a "V" and a flat on a support bar. The positions of the tanks in a direction perpendicular to the axis (horizontal plane) has been fixed by means of a key in the support bar. This type of construction allows for linear tank expansion while preserving alignment and also permits the removal and placement of a single tank without disturbance of adjacent ones and without affecting total alignment.

Each individual tank is about 10 feet long and its wall is copper clad steel with a 0.85 inch steel thickness and 0.15 inch copper thickness. This copper clad steel cost approximately as much as pure copper per unit weight. The advantage lies in the strength of the material. The great advantage of having a copper layer of this thickness is that machining directly into the copper is possible and also that edge connections can be made directly to the copper. For example, the sliding seal for electrical connection of the ball tuners makes use of spring rings which connect directly to the copper edge. It is worthwhile mentioning here that at BNL extensive use has been made of spring rings for electrical connections. These have proved to be very reliable in operation. They are also used for electrically connecting the individual linac tanks together. As an example the following specifications are given: beryllium copper wire of 0.015 inch diameter is close wound on a 0.125 inch diameter rod. After radial expansion the diameter is 0.140 inches. The spiral is then stretched so that the spacing between the wires is 0.015 inch. The groove to be used for this particular spring ring is 0.125 inch width by 0.125 inch depth.

The insides of the linac tanks were polished to an 8 microinch finish, this might be slightly better than strictly necessary; however, this is difficult to ascertain.

Each linac tank is connected electrically to the next by means of spring rings, as mentioned above, positioned in the copper layer. The vacuum seal is made by "O" rings in the steel part of the wall. The rf peak power dissipated in the tank is about 3 megawatts or 1.5 kilowatts average power. The total heat dissipation of the quadrupole focussing magnets in the drift tubes is about 500 watts average. The heat dissipated in the tank wall is carried off in cooling tubes of square cross-section welded to the tank. Most of the heat is essentially conducted via the welds used to fasten these to the tanks. Because of the low average power dissipated this is quite satisfactory for the BNL linac. If more power dissipation has to be absorbed by the cooling system a different method, for example whereby the cooling water is in direct contact with the tank wall, would be in order.

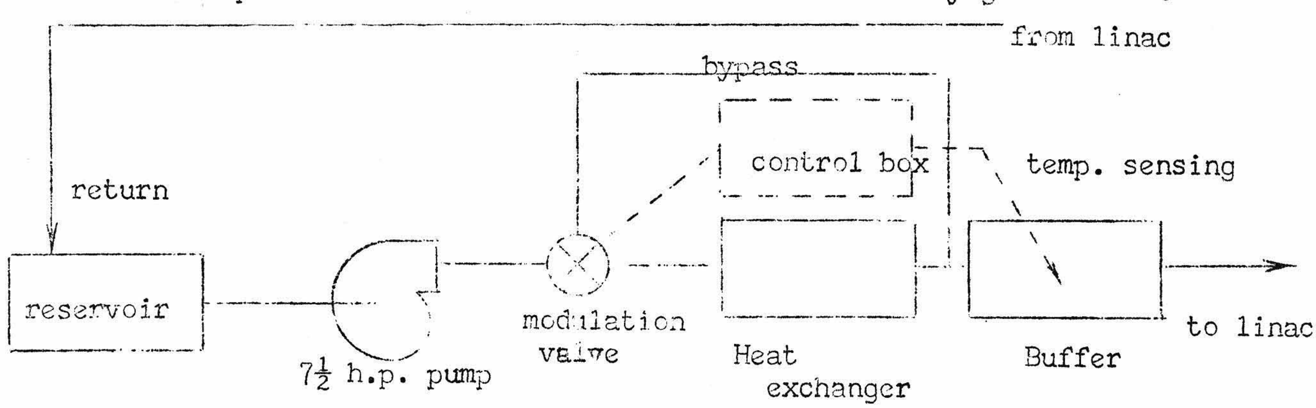
The frequency change of the cavity resonant frequency is approximately 2 $kc/_s$ per degree centigrade. During operation typical drifts in resonant frequencies of the order of 200 c/s have been observed. This would correspond to a temperature variation of 0.1°C.

The cooling system was actually designed for a 0.05°C maximum temperature variation in tank wall temperature.

An indication of the accuracy with which the tanks are fabricated can be gained from the fact that with fixed settings of the ball tuners, each individual tank had a resonance frequency within the range of 200.0 - 200.5 $Mc/_s$. Each tank was checked with drift tubes and ball tuners in place. To make the resonant frequency equal for all tanks a bar was placed in an axial direction 45 degrees below the horizontal plane. It was found that a frequency shift of about 0.5 $Mc/_s$ was obtained with a bar of cross-section 1" x 2". To equalize the resonant frequency, bars varying in thickness from 0 to 1 inch were needed. Therefore the design frequency was raised to 201.075 $Mc/_s$ to allow for bars in the range of thicknesses from 1" to 2".

The final resonant frequency tuning is being done with the ball tuners whereby a 5 inch motion from "0" position of a full block of ball tuners corresponds to a resonant frequency change of 0.2 $Mc/_s$.

The temperature control of the tank is schematically given below.



The three way modulating valve is a Taylor Instrument Company product and has operated very satisfactorily.

The drift tubes in the linear accelerator are supported by a vertical stem and a horizontal stem, which in turn are supported from the tank wall. Supporting fixtures provide the possibility of accurately positioning the drift tubes within the tank. In general the object was to hold alignment tolerances to within ±0.001. The horizontal stem has on its supporting end a T-bar of which the axis, by means of jigs, is carefully aligned with the axis of the quadrupole. Some misalignments found after about a year of operation as reported before* might be due to slight initial misalignments of the T-bar with respect to the supporting structure.

The drift tube shape varies along the accelerator, being disc shaped at the 750 Kev end with an axial thickness of $\cong$ 2", and being ellipsoidal with axial length of $\cong$ 16" at the 50 Mev end. These drift tubes are made of copper and the stems are brazed to the body in an hydrogen atmosphere. Both stems are stainless steel with a surrounding copper cylinder.

After placing the quadrupoles in the drift tubes, the copper covers were soldered on with indium-tin solder. This type of joint was tested on a drift tube in a rf power model and found satisfactory. However, during operation in the linac it seems that erosion takes place in this joint resulting in a leak between the partially evacuated stem boxes and the high vacuum in the tank. A small amount of gas evolved might precipitate sparking and consequent deterioration of the leak. Presently all repaired indium-tin joints are copper plated with no recurrence of leaks in the copper plated joints. It seems advisable though in future designs to eliminate these low temperature solder joints. A different design whereby the cover plate is screwed onto the copper body seems to work satisfactorily in the CERN linear accelerator.

*See J. Bittner BNL Linac Operation.

In general the 50 Mev alternating gradient synchrotron linac injector has worked well. However, in order to eliminate future leakage and to increase the initial aperture of the drift tubes, a program is to be started to modify the existing drift tube design and to increase the bore of the first eight drift tubes from 1/2" diameter to 3/4" diameter.