PS/LI/RF/Note 85-14
June 10, 1985

ELECTROMAGNETIC FIELD MEASUREMENTS IN THE 42 ACCELERATING GAPS OF TANK I OF THE CERN LINAC I

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1. Introduction

Over many years tank I of the original CERN Linac had suffered from two great disadvantages:

First, a large amount of multipactor phenomena had been encountered, sometimes producing a delayed pulse, sometimes a missing pulse. Often after a shutdown, when the tank had been open to air for an extended period, a rather long period of conditioning had been needed before anything like normal operation could be resumed.

Second, a disagreeable feature known colloquially as the "Dinosaur" effect tended to mar obervation of signals. This was clearly a beating between two frequencies excited simultaneously in the liner. Some efforts went into eliminating this phenomenon, without avail until January 1983.

2. Tests and Observations and Modifications on Liner I in January 1983

On 23rd January 1983 the vacuum lid of tank I was removed and some measurements were started. Flange adaptors for the probe flanges had been prepared in advance, these allowed 14 mm tubes or rods to be inserted via a pipe coupling fitting which served as a collet to clamp the tube or rod against rotation and depth of insertion.

The tank liner has 18 flange positions along the length of the resonator, some already occupied by diagnostic loops, but others free. Numbering these flange positions from 1 at the 500 keV end to 18 at the 10 MeV end, then nos. 3, 4, 5, 9 and 16 were free. Fortunately, no. 9 was in the centre of the length of the tank, whereas 4, 5 and 6 are opposite one of the two frequency tuner plates and nos. 13, 14 and 15 are opposite the other.

Using an electrostatic probe, and inserting it into probe positions 3, 4 and then 5, it was noticed that the coupling to the adjacent mode was higher than to the accelerating mode by about 20 dB. Furthermore, the frequency of the adjacent mode had been reduced by about 60 kHz whilst that of the accelerating mode had hardly been affected. The same was true for probe positions 15 and 16. But at probe position 9 there was no effect at all!

These results are consistent with the hypothesis that the adjacent mode is of H11 type, probably H112, with strong radial E near the tuner positions and a zero radial E at the centre of the length of the cavity. For the normal E010 accelerating mode radial E does not exist at the walls.

For the empty liner the H112 should occur at 172 MHz. Assuming that the shadow of the drift tube stems shields off this region inside the stems, then the H112 mode frequency could be calculated on the basis of an empty liner, a cylinder with an angular longitudinal segment cut out.

The liner lid was unbolted and removed. Sure enough the discoloured areas on the surface of the liner interior showed the signature of the mode H112. Since this mode is deflecting, no doubt, here was the reason for the enhanced multipactor effects observed in the past.

As the electric field of the H112 is small at the two ends of the tank, the tilt tuners at the two ends have negligible effect on this mode. However, the frequency tuners are opposite regions of higher electric field and move the frequency of the H112 in the opposite sense to that of the accelerating mode frequency.

So, about 20 rods of 14 mm diameter, about 20 cm long, were added longitudinally along the liner. Some on one side in the vacant probe holes and the rest along the other side of the liner. The H112 was now observed to have shited down in frequency by some 868 kHz, whereas the E010 had moved up by 20 KHz. As the change in resonant frequency of the E010 mode was too high for the available range of the tank tuners, one row of flatteners were uniformly adjusted to compensate. As it turned out later, one should have moved the flatteners even more as there was still an error in the E010 mode frequency.

Thanks to some help from W. Pirkl, another oscillator was made available and the Linac as a whole ran with a new frequency of 202.57 MHz as against the original of 202.56. W. Pirkl proposed a different method for separating the two modes, more elegant than the one that was used. His idea was to place ceramic plates on the tuners. Unfortunately, the correct sizes of ceramic plates were not available and as the metallic rods had already been put in place, that solution was left.

In this way the operating frequency for the E010 mode was obtained symmetrically between the next E mode the (E011) and the interfering H112, i.e. about 1 MHz between E010 and E011, also 1 MHz between E010 and H112.

Neither time nor effort allowed any field measurements during the shutdown in 1983. It was hoped that these might be done at some later date.

When high power was applied there was not the slightest evidence of multipactor, although the liner had been open for at least two weeks. The first pulse of RF took the tank field right up to the full operating voltage, thus confirming the hypothesis that the interfering mode had contributed greatly to the multipactor.

3. Field Measurements carried out in May 1985

It had been decided to move the Linac I back some 12 metres during

1985. Once tank I had been put into its new position it was planned to measure the field distribution in the 42 gaps.

Thanks to the efforts of a large number of helpers, and to the loan of a motor, its controls and a stable oscillator, two runs were quickly made using a metal sphere pulled through the length of the axis of the liner.

Contrary to the method used in 1959 where a lock-in oscillator was used and the frequency perturbation measured, this time a fixed oscillator excited the E010 mode and the phase perturbation was measured. This latter method seemed more rapid and errors due to temperature variations of the tank were negligible.

Now the tilt tuners for tank I have two settings. One the proton setting where the 500 KeV tilt tuner is set fully in (field depressed), and the 10 MeV tilt tuner is set fully out (field raised). The results showed a flat field apart form a 2% increase over the first few drift tubes. This is exactly the same result as had been obtained in 1959!

The other setting, which is that used for deuterons and alphas, has the 500 KeV tilt tuner fully out (field raised), and the 10 MeV tilt tuner fully in (field depressed). Here, the result was a 25% decrease in the field distribution over the tank apart from a slight increase over the first few drift tubes. Once again as in 1959! Hence the mode tuners used to move down the H112 mode have neligible effect on the field distribution, and the tank flattening is the same as was set in 1959.

It now remains to confirm on high power that even at the $O+16$ levels the mode tuners have neligible effect on the high power capability of the tank.

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