DRIFT TUBE ADJUSTMENT IN AN EVACUATED ALVAREZ LINAC

B.G. Chidley & J.G. Bayly
Atomic Energy of Canada Limited
Chalk River, Ontario, Canada

ABSTRACT

Measurements of drift tube positions in an evacuated linac tank are difficult and the final adjustments are usually made before final assembly.

Scale model experiments indicate that measurements of the tank's resonant frequency, which reaches a maximum when the tube spacings have their design values, permit longitudinal adjustments to be made after the structural changes caused by evacuation have taken place. Only the frequency change needs to be observed; the adjustments are made to the external drift tube support stems while the tank is under vacuum. Because of the interaction of each tube with its neighbours, repeated adjustments of all tubes in sequence were necessary. A tank containing 22 drift tubes required six passes.

We have examined the possibility of obtaining quicker convergence by using a computer to predict the final adjustments from the frequency shifts observed in an initial optimization. Second order interactions made this impractical and unnecessary considering the simplicity and reliability of the direct method.

Introduction

The task of aligning the drift tubes in an Alvarez linac is complicated by their inaccessibility. Ideally the final adjustments should be made with the tank evacuated to overcome distortions which may move the drift tubes, particularly if the drift tube stem support structure is mounted directly on the vacuum wall. Although the stem support structure makes it possible to move the tubes, it is difficult to determine their positions or what adjustments are needed.

The two transverse and two angular components of alignment error can be detected by sighting along the axis, but the longitudinal spacing of the tubes is difficult to measure. We have explored a method of longitudinal alignment which does not require either physical or optical access to the drift tubes and can be used while the tank is under vacuum.

Alignment Technique

In a perfectly aligned Alvarez tank the resonant frequency changes if one of the drift tubes is displaced longitudinally. Although we cannot prove that it invariably does so, we have found experimentally that the frequency always decreases and that the change is proportional to the square of the displacement.

If a single drift tube has been moved it can be re-aligned by adjusting it to maximize the resonant frequency. If many tubes are out of place we have found that they can be adequately aligned by adjusting the tubes sequentially several times.

Initially it seemed probable that the information obtained in the first pass could be used to predict the final amount by which each tube would have to be corrected. Two passes only would then be required. This has been investigated but the complexity of the interactions restricts its usefulness.

Experimental Equipment

Our results are based on a scale model of a 0.75 to 3 MeV Alvarez tank 0.508 m in diameter. The tank and the frequency measuring equipment were designed for field measurements by the bead pulling technique.

The supporting stems of the 22 drift tubes were pivoted at the tank wall and positioned by an adjustable collar mounted 0.12 m outside the tank. Although they would not be present in an actual accelerator, rows of holes on each side of the tank allowed the tube positions to be measured independently by a travelling telescope.

The equipment for measuring the resonant frequency consisted of an automatic frequency control (AFC) unit as described by J.G. Bayly and C.R. Bax (Report in Publication) and a frequency counter.

Measurements

Fig. 1 shows the variation of the resonant frequency of the tank as a function of the longitudinal position of one of the drift tubes. The resonance has a well defined maximum and by measuring the frequency to 100 Hz (at 372 MHz) the position can be defined to within $\pm$ 0.01 mm.

We have found that a tank in which the longitudinal positions were randomly set could be brought into adjustment by sequentially adjusting drift tubes for maximum frequency; after 6 passes no further improvement could be made. At this point the average distance from the design position was 0.03 cm. This difference probably is due more to constructional tolerances of our model than to residual error.

Interpretation

Considerable effort was devoted to calculating the shifts in one alignment pass to estimate the number of passes needed to attain a specified accuracy or to suggest shifts necessary to reach the final configuration.

To do this it is necessary to assess which factors exert an influence.

The position of the maximum depends primarily on the position of the adjacent drift tubes and is less dependent on the location of the second neighbours. Fig. 2 shows the effect of shifting one second neighbour in .05 cm steps. Another small effect depends upon the angle of the drift tube stem, and presumeably arises from changes in the current pattern on the stem when its angle is changed to move the drift tube. This can be studied by moving a set of drift tubes by equal amounts and noting that although a drift tube in the middle of the set is in its correct position relative to its neighbours, it is not at the position for maximum frequency because the stem angles have changed. Fig. 3 shows the shift of the position of one drift tube for maximum frequency as all other drift tubes are shifted. If the stem angle effect were not important the drift tube would shift with the others as indicated by the dashed line at 45°.

A transverse shift of a drift tube also decreases the resonant frequency so precautions were taken to prevent transverse motion during longitudinal adjustment. Attempts at transverse alignment by frequency maximization showed that it did not converge, as the drift tubes tended to positions alternating about the center line and were further off in each pass.

Other effects are relatively unimportant. For example a rotation about the stem gives less than 100 Hz for a 20 milliradian rotation.

We calculated that if only first neighbours affected the adjustment a smooth error was very difficult to eliminate by successive passes but that if second neighbours and stem effects were important convergence was much better. We could not obtain enough independent information on our tank to predict the number of passes needed, but we could show that 6 was plausible.

Prediction of the final position based on the first pass was rather more difficult as it demanded high precision. For example the frequency vs. position response shown in Fig. 1 is not unique but is different for each drift tube. Moreover it is influenced by adjacent drift tubes. Detailed measurements of a 6 cell portion of our tank showed that adequate alignment could be done in the second pass but this is not recommended for a larger number of cells.

Possible Limitations

The technique described appeared to work very well on our tank but lacking a firm mathematical basis it is risky to assume it will be generally useful. Our tank was quite general in that the length and g/ℓ ratio were different in each cell but as it was designed for low energy the electric field was largest at the middle of the gap. Higher energy tanks typically have a "double humped" field in the gap and it is possible that they would exhibit a different behaviour. Further investigation of the method is needed but the simplicity of the measurements is very attractive - not only for the initial installation but for periodic maintenance.

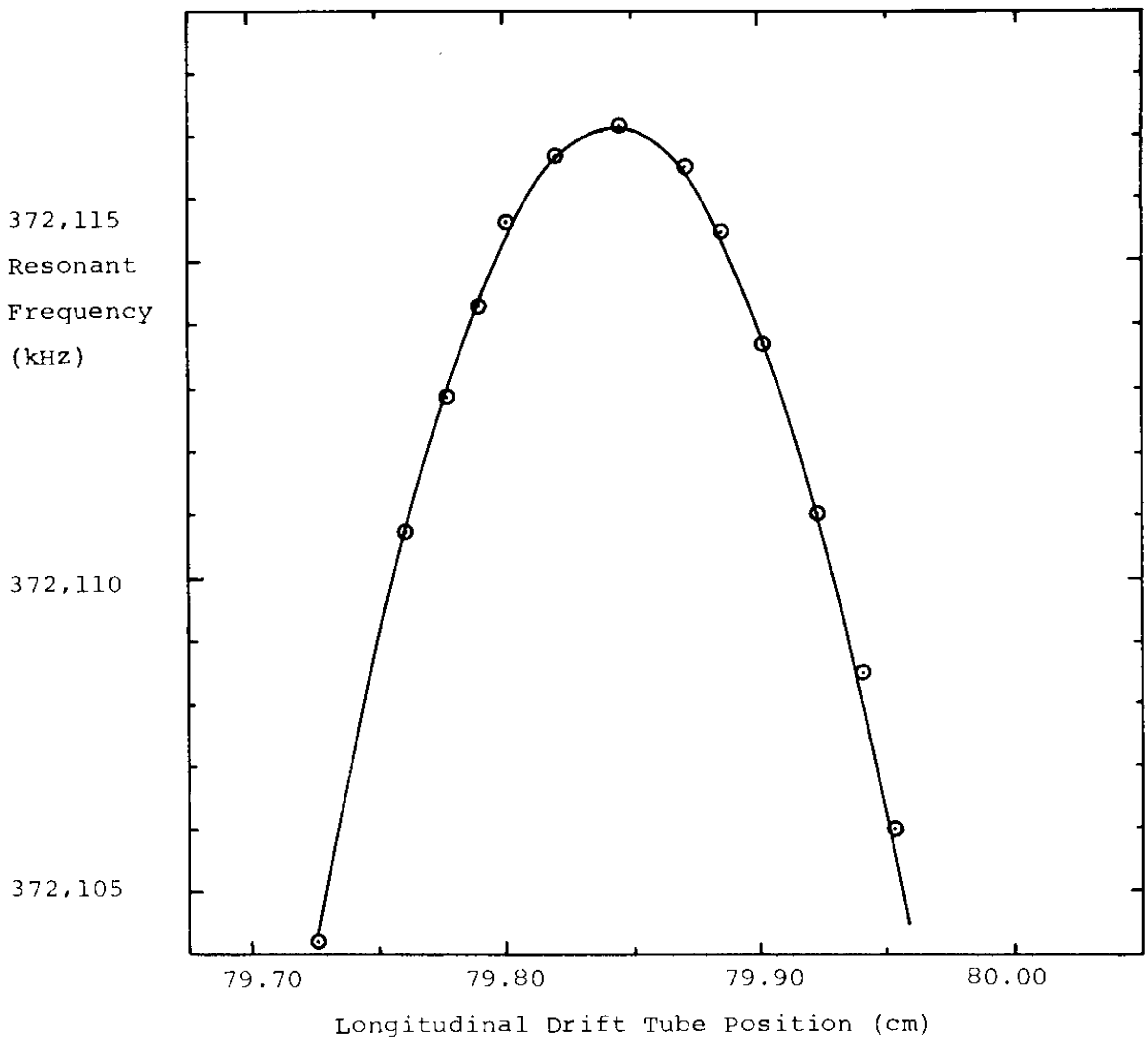

Fig. 1

Variation of resonant frequency with drift tube position.

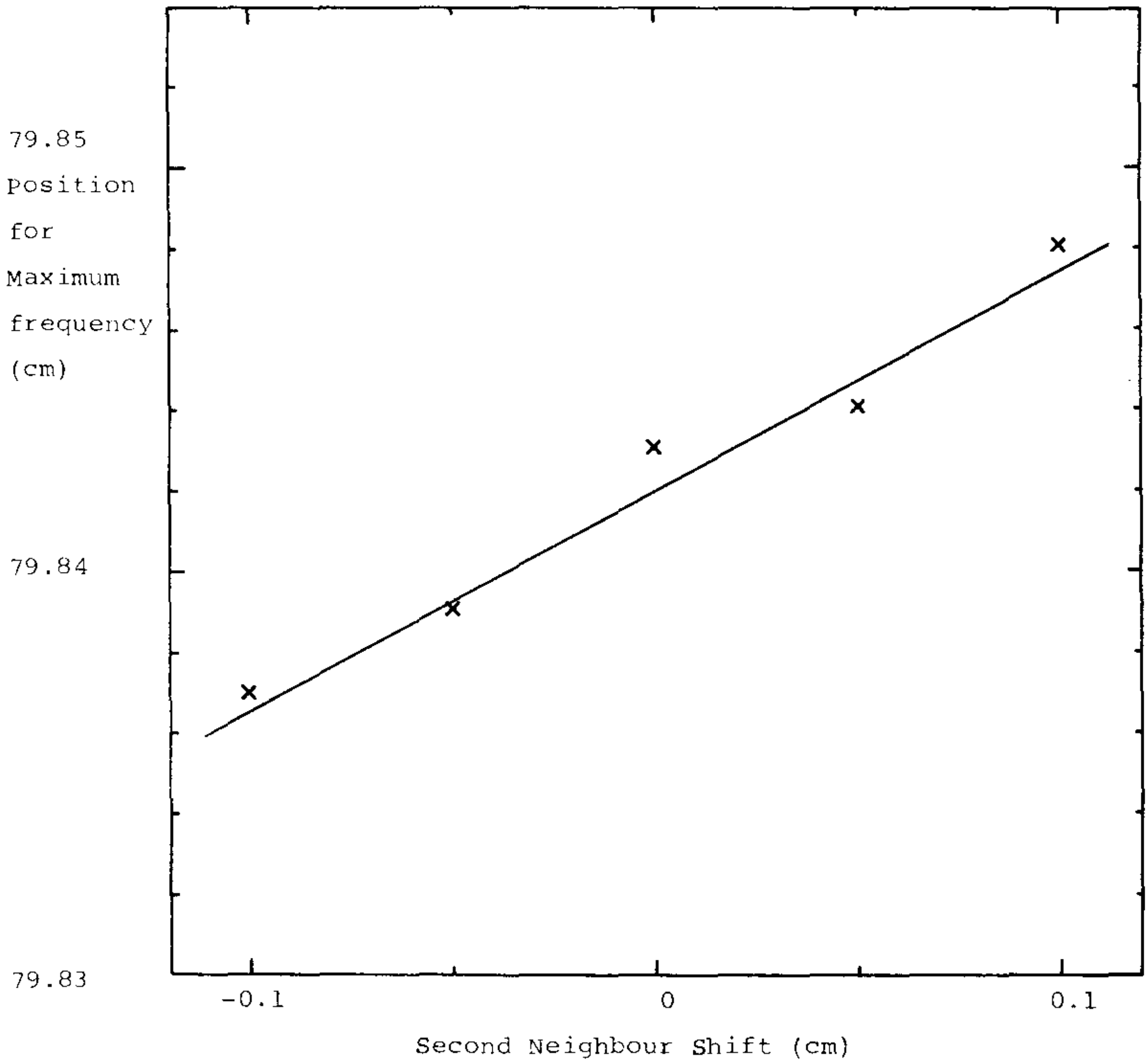

Fig. 2

Dependence of longitudinal position of a drift tube for maximum frequency on a second neighbour drift tube position.

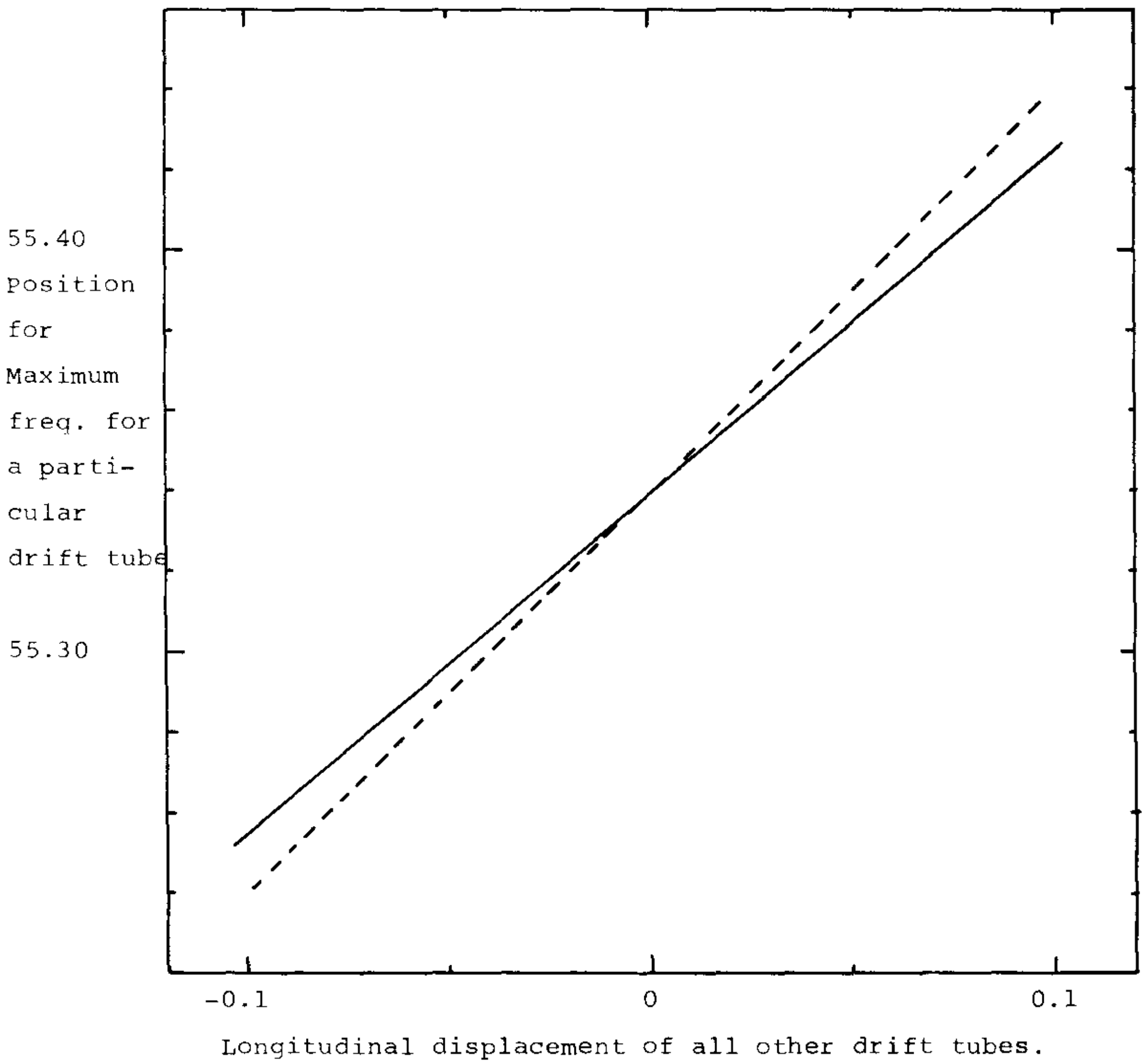

Fig. 3

Dependence of position of maximum frequency on neighbouring drift tubes. Departure from the dashed line is due to the stem angle effect.

DISCUSSION

R. H. Miller (SLAC): Does this method depend on the tanks being flat?

B. G. Chidley (AECL): Yes.

R. H. Helm (SLAC): I would think after the first two iterations it would be possible for a computer to predict the final adjustment. Does this seem likely?

B. G. Chidley: If one knew all the interaction parameters, one could in principle predict it after the first adjustment. But a mistake in the first adjustment could throw the calculations out. Even if the first adjustment is fairly rough, it is adequate for multiple-pass techniques, so one may or may not gain by such a prediction.