CONDITIONING EXPERIMENTS ON THE 100% DUTY FACTOR 3 MeV ALVAREZ LINAC

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Summary

A number of difficulties have developed in the course of rf conditioning the 3-MeV Alvarez linac of the Chalk River Nuclear Laboratories High Current Test Facility. The tank had been designed with the drift tube stems avoiding contact with the tank wall except via external vacuum bellows. This technique had been investigated in a prototype and although it gave satisfactory rf performance, overheating of the bellows limited operation to 25% of operating power. An internal rf shield has been developed which has allowed tank excitation up to the design field level.

Introduction

The 3-MeV Alvarez linac of the Chalk River Nuclear Laboratories High Current Test Facility is a 1.605 m long, 25 cell structure, designed to operate at 100% duty factor. The linac is part of an ongoing CRNL program for the development of high current accelerators which could be used for electro-nuclear breeding of fissile fuel.[1]

A number of problems have arisen related to the high average power dissipated in the linac tank walls. The most serious one has been rf heating of bellows on the drift tube stems of the linac. An improved stem-to-tank joint has been developed to solve this problem.

Description of Linac Tank

The linac tank is a 1.605 m long, by 0.711 m diameter, 25 cell structure, designed to operate at 268.3 MHz with an input energy of 750 keV. The design gradient is 2.0 MV/m. The calculated rf drive required is 112 kW with a Q ∿ 56,000. A detailed description of the tank has been presented at a previous conference.[2]

The tank design was based partly on experience gained on a 3-cell test model that was operated successfully up to 50 kW at 100% duty factor. One problem area on the 3-cell tank was the drift tube stem to tank wall joint. Originally copper skirts were welded from the stem to the tank. These skirts, however, were partially destroyed at ∿ 30 kW and the design shown in Fig. 1 was finally used. With fan cooling on the bellows, this design was able to operate up to 50 kW.

Computer calculations indicate that currents along the drift tube stems are not necessary for normal tank excitation and that wall currents can flow around the hole. Low power field measurements on a test tank showed no difference whether the stems were grounded to the tank or insulated from it.

The stem-to-tank joint first tried on the present tank is shown in Fig. 2. Because of the possible need to replace drift tubes, the vacuum seal to the tank was changed to an O-ring seal from the weld used in the test tank. One other significant feature is the size of the drift tube holes, which are 36-mm diameter in the present case as opposed to 76-mm in the test tank.

Low Power Tank Characteristics

Measurements on the tank with a network analyzer gave a Q ∿ 42,300, which is ∿ 75% of the calculated value for pure copper. The required rf power to produce the 2.0 MV/m accelerating field for this Q is ∿ 148 kW.

Multipactor levels in the cavity were encountered at tank power levels of 150 and 400 Watts and prevented direct cw turn-on of the rf power. A pulse technique developed for a cyclotron resonating cavity at CRNL[3] has been successful in breaking through the multipactor levels. In this technique rf pulses with a turn-on time much shorter than the tank fill-time and greater than 5 kW in amplitude are fed to the tank. The power level in the tank is monitored and if after a time of 200 μs a level greater than 1 kW is reached, the rf is kept on. If the pulse fails to puncture through the multipactor levels, the rf is turned off for ∿ 100 ms before the power is reapplied. It seems to be necessary to turn the rf level completely to zero for a comparatively long period between pulses to ensure that all stray ions from the previous discharge have been neutralized. It was found accidently that puncture through the multipactor levels often will occur only if the vacuum ion pump has been switched off. A sufficient number of ions can be scattered into the linac tank from the pump to trigger the multipactor process. After exposure to atmosphere, cw operation is normally possible at levels up to 20 kW within 30 minutes.

High rf Power Operation

Heating problems on the drift tube stem bellows were encountered at ∿ 15% of the required tank power level. At ∿ 25 kW the bellows, which could not be easily cooled because of water cooling connections and current leads to the drift tube quadrupoles, reached temperatures up to 100°C. The temperature distribution on the bellows suggested that wall currents were in fact flowing through the bellows in spite of the fact that this was a much higher resistance path than the detour around the stem hole. Therefore rf fields must exist in the bellows. The effects are as though wall currents are being driven by a "constant current" driver.

Bench tests on a spare drift tube bellows indicated that a current of ∿ 50 A was necessary to produce the observed bellows heating. This is about a factor of two higher than the current estimated to be intercepted by the stem hole on simple average power considerations. Calculations by Lee-Whiting[4] on rf cavities, however, indicate that any protrusion into a cylindrical cavity is likely to increase the current density on the protrusion and will increase local heating.

An initial attempt was made to reduce the bellows heating by using finger stock in the gap between the drift tube stem and the tank copper layer. This proved to be unsuccessful. The finger stock disintegrated completely at 30 kW. Tight fitting Cu-Be coil springs were tried next but resulted in a similar failure to produce the required shunting of the rf currents. In both cases the failure appeared to have occurred because the low total mass of the materials, which had small thermal contact areas, was unable to dissipate the heat produced by the current flowing into the stems through ohmic contacts to the tank.

A copper shorting collar design was tried next. This collar, which was more massive than the springs or finger stock, could be clamped onto the drift tubes and could be cooled by them. Indium wire was used to provide electrical contact to the tank surface and the stem. This design was successful up to 60 kW of rf power into the tank, but at higher powers melting of the indium occurred.

The final design developed is shown in cross-section in Fig. 3. Figure 4 shows the collar, which is made in two parts to allow installation in situ over the drift tube stem. The two halves are held together by screws and two set screws are used to fasten the collar tightly to the stem to prevent vertical motion because of thermal expansion. The cut in the collars was oriented along the tank axis so as not to interfere with the current flow. Finger stock with very short projections was brazed both on the inside and outside collar surfaces to provide good heat transfer and electrical contact. Figures 5 and 6 show photographs of the collars mounted in the linac tank.

With this collar design the required tank rf power level of 148 kW has been attained. The long term performance of the collars at this power level has not yet been determined because of a failure of the teflon window in the rf drive line to the tank. This failure, which occurred because of a blockage in the air-cooling circuit, resulted in a large amount of window material being deposited on the drift tube and on the tank walls and has required a complete cleaning of the tank.

On inspection of the collars during clean-up two drift tube collars showed slight burn marks on the finger stock and are being replaced. No problems, however, were seen in the operation of the tank at full design fields because of local rf heating.

<u>References</u>

1. P.R. Tunnicliffe, B.G. Chidley and J.S. Fraser, "High Current Proton Linear Accelerators and Nuclear Power", Proc. 1976 Proton Linear Accelerator Conf., Chalk River Nuclear Laboratories, Atomic Energy of Canada Limited, Report AECL-5677, 36 (1976).

2. B.G. Chidley, S.B. Hodge, J.C. Brown, J.H. Ormrod and J. Ungrin, "The Chalk River High Current Test Facility", Proc. 1972 Proton Linear Accelerator Conf., Los Alamos Scientific Laboratory, LASL-5115, 218 (1972).

3. C.B. Bigham, private communication.

4. G.E. Lee-Whiting, private communication.

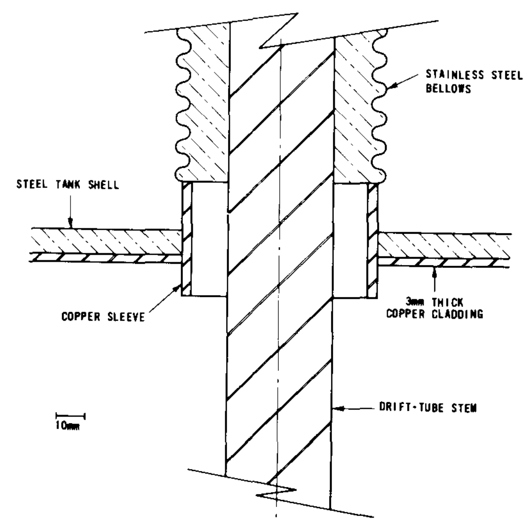

Fig. 1 Cross-sectional view of drift tube stem and bellows on test tank.

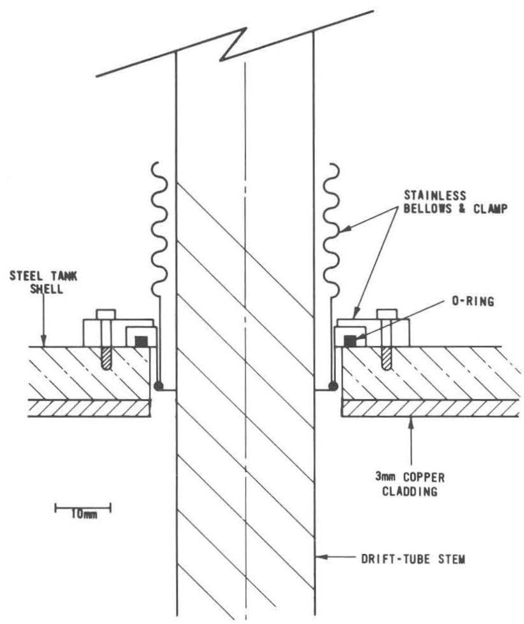

Fig. 2 Cross-sectional view of initial design of drift tube stem and bellows assembly for 3-MeV tank.

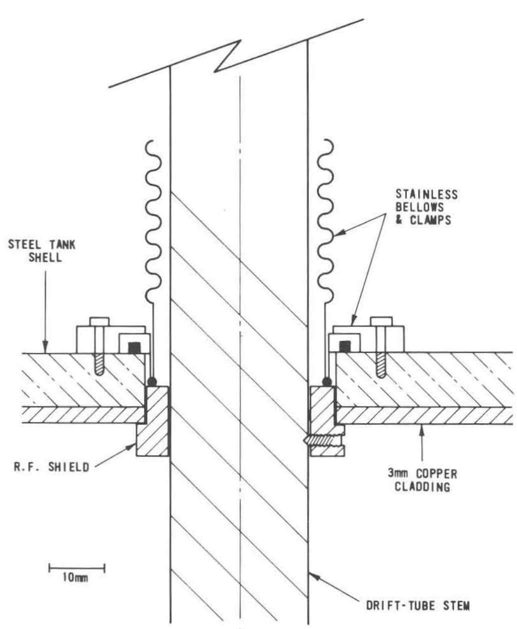

Fig. 3 Cross-sectional view of final design of drift tube stem and bellows assembly for 3-MeV tank.

Fig. 4 Bellows rf shield.

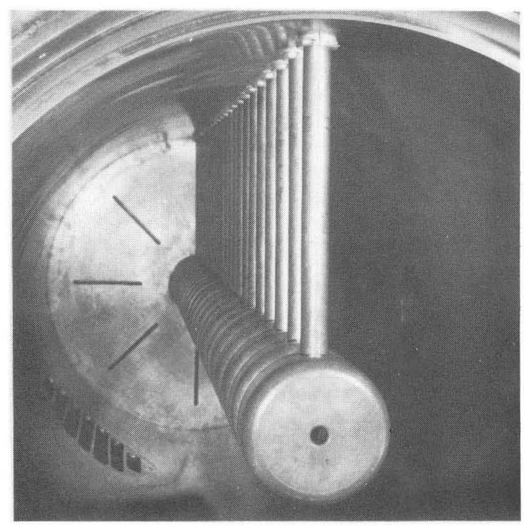

Fig. 5 Collars installed on drift tube stem.

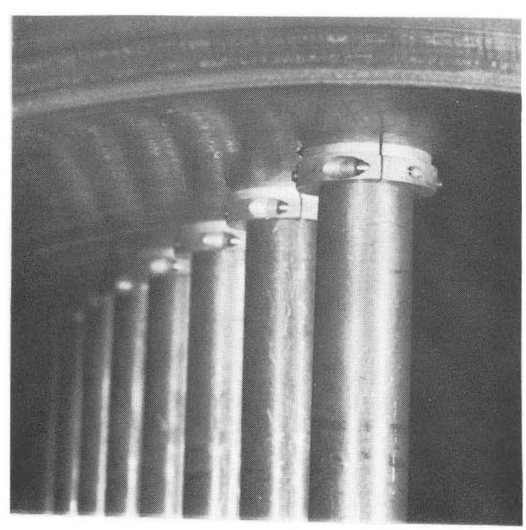

Fig. 6 Close-up view of installed collars.

Discussion

Böhne, GSI: How do you align those drift tubes with the very tight fit of this conical collar?

Ungrin: We did the alignment as carefully and as closely as we could, prior to putting the collars on. We clamped them very tightly up above. In some cases, as we put the collars in, we did get a very slight motion. It turns out that our drift tube has enough "give" that we just mechanically pushed it into place afterwards and it holds.

Boltezar, CERN: Why didn't you use aluminum joints as rf contacts between the drift tube stem and the tank wall?

Ungrin: On the drift-tube stem to the tank? We didn't envisage this problem as existing from the experiments that we did on the short tank. We thought that the problem wasn't going to come about, but were very much surprised at about 15 to 20 kilowatts. If we were doing it again, I think we would use something that would be able to take more heat than the rubber o-rings. Whether it would be aluminum or not, I don't know.