# TANK1 OF THE ISAC-DTL LINAC

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## *Abstract*

The first phase of the ISAC radioactive ion beam facility at TRIUMF is now completed. It combines an isotope separator-on-line with a post accelerator. In the second phase a drift-tube LINAC is required to accelerate ions with a charge to mass ratio ≥ 1/6 from E = 0.15 MeV/u to a final energy fully variable up to 1.5 MeV/u. Due to the relatively low intensities of some of the radioactive ion species continuous (cw) operation of the accelerator is preferred. An interdigital H type RF structure is chosen because of its very high shunt impedance. The ISAC-DTL is composed of five IH tanks and three rebunchers, operating at 105 MHz. The basic design of the structure is similar to other IH structures with the exception that the stems are water-cooled. The features of this mechanical design will be discussed and the first results of the RF tests are presented.

## 1 INTRODUCTION

A radioactive ion beam (RIB) facility has been built at TRIUMF [1-3]. The ISAC facility uses the isotope separation on line (ISOL) technique to produce radioactive ion beams (RIB). The ISOL system consists of a primary production beam, a target/ion source, a mass separator, and a low energy beam transport system. These systems together act as the source of radioactive ion beams to be provided to the accelerator or the low-energy experimental areas.

The accelerator complex comprises an RFQ [4] to accelerate beams of q/A ≥ 1/30 from 2 keV/u to 150 keV/u and a LINAC (DTL) to accelerate ions of q/A ≥ 1/6 to a final energy between 0.15 MeV/u to 1.5 MeV/u. Both LINACs are required to operate cw to preserve beam intensity.

A first proposal, in 1985 envisaged the use of a Wideroe structure for the ISAC DTL LINAC [5]. The idea was quickly abandoned because of the lack of funding and due to the high power consumption of the LINAC. A second study envisaged the use of a superconducting structure [6,7] for the post stripper LINAC. This proposal was also abandoned because the required time to build a superconducting LINAC was incompatible with the scheduled cash flow of the ISAC funding. After approval of the ISAC FIVE-YEAR plan in 1995 we came back to a room temperature solution. The interdigital H type RF structure (IH) was chosen because of its high shunt impedance compared to Alvarez or Wideroe RF structure. Due to the requirement of continuous energy variability and preservation of the time structure the DTL structure has been configured as a *separated function* DTL [8,9]. Five independently phased IH tanks operating at $\phi$s = 0° provide the main acceleration. Longitudinal focussing is provided by three independently phased, split-ring resonator structures positioned before the second, third and fourth IH tanks. Quadrupole triplets placed after each of the four IH tanks maintain transverse focussing.

## 2 DTL TANK 1 SPECIFICATION

The code LANA [10] has been used to study the beam dynamics and to set the general specifications for the DTL tanks. At full voltage the beam dynamics are typical for a $0^{\circ}$ accelerating structure [11] with the benefits of optimum acceleration efficiency and reduced RF defocusing.

Table 1 gives the basic specifications of the first IH tank for the design particle of q/A ≥ 1/6. The quantity of cells in each tank is chosen to satisfy both transverse beam size requirements and debunching constraints in variable energy mode. Tank apertures are chosen to give sufficient transverse acceptance while maintaining a gap-to- aperture ratio of at least 1.2 for efficient acceleration.

Table 1 : DTL tank1 specifications

| NO. Cells | L cm | A mm | $\beta_{IN}$ % | $\beta_{OUT}$ % | Q/A | $V_{EFF}$ MV | $E_{OUT}$ MeV/u |
|---|---|---|---|---|---|---|---|
| 9 | 26 | 10 | 1.5 | 2.2 | 1/6 | 0.5 | 0.23 |

## 3 MAFIA SIMULATIONS AND MODEL STUDY

The electromagnetic code MAFIA was used to simulate the DTL tank structure to assist in optimizing the dimensions of the selected configuration. This eliminates construction of a large number of scale models during the optimization process.

The calculations give power density information, which will then be used to determine the cooling requirements of the cw DTL. The electric field distribution inside a cylindrical cavity operating in the $H_{111}$-mode has a sinusoidal shape. The flatness of the gap voltage distribution along the beam axis is one main problem to solve. This means that we have to make the capacity and inductivity per unit length of the cavity constant. The capacity and/or inductivity per unit length of the cavity have to increase towards the ends. Several MAFIA simulations were performed to obtain the proper flux inducer shape at both ends of the cavity. MAFIA was also used to predict the appropriate g/L dependence to flatten the field distribution. Table 2 gives a summary of the RF characteristics of tank1.

Table 2 : Summary of the RF characteristics of tank1.

| Frequency MHz | Q | $Z_{eff}$ MΩ/M | $V_{eff}$ MV | P kW |
|---|---|---|---|---|
| 107.2 | 11500 | 356 | 0.5 | 2.6 |

A full-scale model of an 11-gap tank was built to test the tuning of the field distribution and the characteristics of various mechanical tuners. The tank was built from a rolled copper sheet 6 mm thick. The end plates were made from aluminum on which a thin foil of copper was glued. The ridge and the drift tube were made from brass to ease the fabrication. All pieces were bolted together to facilitate changes of the cavity geometry. The coupling loop and the tuner were installed in the median plane, one on each side of the tank. Two types of tuners were evaluated with this IH tank model. The first tuner uses a flat copper plate; 50 mm by 280 mm. Vibrations of that plate make the frequency stabilization extremely difficult. The second tuner uses a half cylinder 50-mm radius. Even if the frequency stabilization is much better the tuner vibration still has some effect. A larger radius of 100 mm does not show any frequency shift due to vibration. Contrary to the flat plate case the capacitance is mainly concentrated on the stem, not on the drift-tube region. Figure 1 shows the result of the frequency and Q value variation as a function of the distance from the stem.

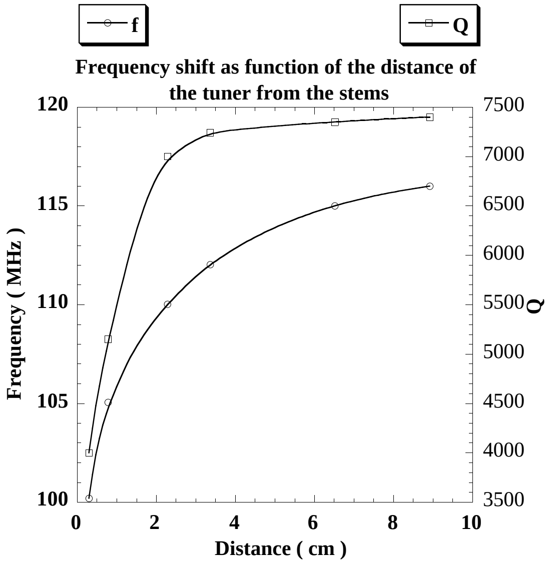


Fig. 1 : The frequency shift as a function of the tuner position from the stems.

Three NC machined models of a stem and drift-tube shown in fig. 2 were made to evaluate the fabrication cost. The first one was made from steel. The inner part was machined such that we obtain a cavity. The water comes in through a stainless steel pipe. The second one is made from a copper block. In that case the stem cooling is done only by heat conduction between the stem and the ridge. In the third case, two cooling channels were drilled at an angle such that they converge close to the drift-tube.

We used them also to measure the temperature of the stem under various heat and water loads. MAFIA simulations tell us that the maximum power loss on the stem is 200 Watts. Assuming only 75% of the calculated Q value input power of 265 Watts was used for temperature measurements.

Four thermocouples were used to measure the temperature on the tip of the drift-tube, at the base of the stem, into the input and output water channels. Figure 2 shows the thermocouples location used to measure the temperature. Table 3 shows the results of the cooling test on the stem models.

The tests show that a water flow of 3 l/min. is sufficient to cool the drift tube to a temperature below 50 °C. The water flow does not produce any measurable mechanical vibrations. From these models we found that the lowest cost stem is the one machined from a copper block.

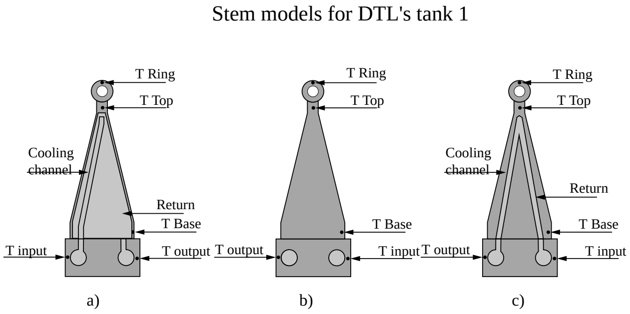


Fig. 2 : Schematic drawing of the three stem models used for the test.

Table 3 : Temperature distribution on the stems. Q = 3 l/min and W = 265 Watts.

| | Stem model<br>Temperature in °C | | |
|---|---|---|---|
| | a) | b) | c) |
| $T_{in}$ | 10 | 9.5 | 9.5 |
| $T_{out}$ | 12 | 11.5 | 11.5 |
| $T_{Base}$ | 21 | 75 | 14 |
| $T_{Top}$ | 14 | 108 | 23 |
| $T_{Ring}$ | 47 | 119 | 47 |

## 4 DTL FABRICATION

The first DTL-IH tank was built from mild steel plate 2.54 cm thick. It is 91.92 cm in diameter by 27.67 cm long. The two lids are 25 mm thick and the maximum deflection is estimated to be less than 0.3 mm. The IH cavity is made in four main components, the cylinder, the ridges, the lids and the stems. The eight drift-tubes and the two ridges are machined from bulk copper blocks. The tank and the two lids are made from mild steel. The interior faces are machined to a surface finish of 16 µinch and then copper plated. The copper plating thickness is larger than the necessary RF required penetration depth to assure a very nice finish.

Several options were investigated for the mounting of the ridges to the tank wall. Ridge made from mild steel welded onto the tank was discarded because of the difficulty of maintaining the proper alignment between the two ridge faces. We finally decided to bolt the ridges onto a flat surface machined on the inner tank wall. Four bolts clamp the ridges in place and the vacuum seal is done using an o-ring. The faces of the ridges and bases are machined and polished to a finish less than 5 µinches to assure a very good rf contact as demonstrated on a test cavity. Provision for alignment was made by allowing an extra 1.5 mm at the base of each stem. At first each stem was installed in the tank and the center of each drift-tube measure with precision. Then the base of each stem was machined to the right height as well as an o-ring groove to seal the vacuum from the cooling line. The stems are bolted down on the ridges at their final location and the alignment was checked to be better than ± 50 µm.

For the first IH tank we made provision for several ports. We have two ports on each lid, one for a turbo pump and the other three for windows if we need to investigate the inner parts of the cavity. On the side we have four small ports for vacuum gages, two probes and coupling loop. Two larger ports in the median plane will be used for frequency tuners , one fixed and one movable. Figure 3 shows a photograph of the first IH tank. We can see the stems installed on each ridge after proper alignment and the location of the ports.

### *4.1 Cooling*

The ridges are cooled by two channels drilled from the base and two manifolds running inside each ridge delivering cooling water to the stems. The drift tubes are cooled by a water circuit coming up through the ridge and into a drilled out portion of the stem, see fig. 2c. Two channels, 9.5 mm in diameter in each lid provide sufficient cooling. Operation of the LINAC at constant temperature may be required. This will be done by using four 6 mm cooling lines attached on the exterior of the tank.

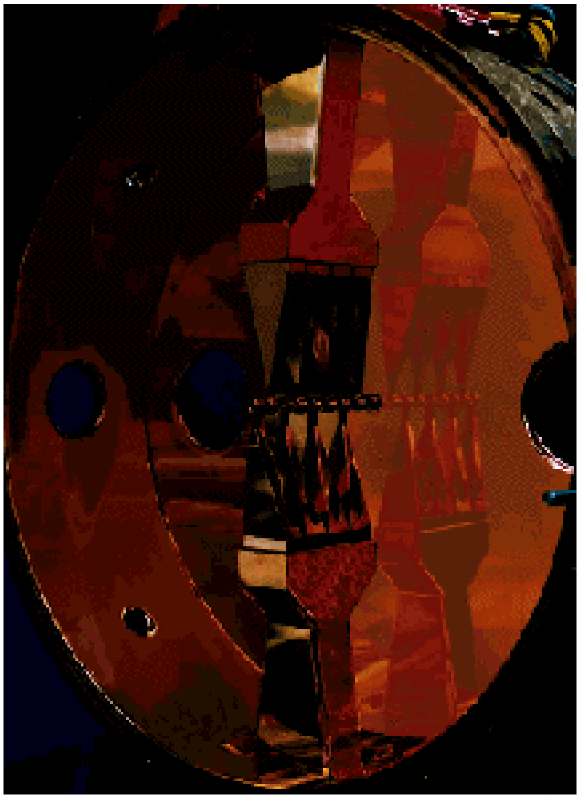


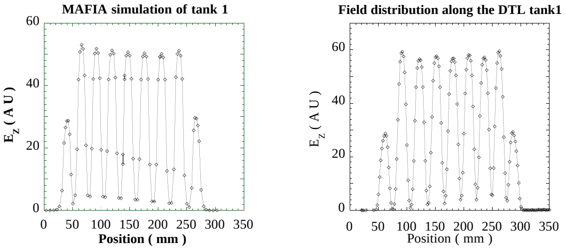
Fig. 3 : Photograph of the DTL tank 1 with the front lid open.

### *4.2 RF Measurements*

The measured frequency of the cavity is 109.7 MHz and the Q value is 9700. The frequency is 2% higher and the Q is about 85 % of the predicted values from MAFIA. The electric field distribution on axis has been measured along the DTL axis. Figure shows a comparison between the measurement and the MAFIA prediction. We obtain a very good agreement between the predicted and the measured field distribution, causing insignificant beam phase error. Figure 4 shows the comparison between the electric field distribution predicted by MAFIA and the measured filed distribution along the tank axis.

### *4.3 Power test*

Full power tests are under way. The RF amplifier was operated in self excited mode delivering 3.6 kW and 87.5 kVolts to the drift tube gap. Stable operation for more than 100 hours was achieved.



a) b)

Fig. 4 : Electric field distribution along the DTL IH tank. MAFIA field distribution a), measurement using perturbation technique b).

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