RF MEASUREMENT SUMMARY OF ISAC DTL TANKS AND DTL BUNCHERS*

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Abstract

In the ISAC radioactive ion beam facility at TRIUMF, a variable energy drift tube linac (DTL) is used to accelerate ions with a charge to mass ratio ≥ 1/6 from 0.153 MeV/u to 1.53 MeV/u. The accelerating tanks are five independent interdigital H type rf structures with high shunt impedances. The three bunchers are triple gap split-ring resonators placed between the first four accelerating tanks. Each structure is equipped with fine tuners to compensate for frequency drift during operation. Coarse tuners are installed in the DTL cavities to bring their resonant frequencies within the tuning range of the fine tuners. Except for the loop size, the same rf power couplers have been used in all the structures. All these structures operate at 106.08 MHz and have been tested at power. Signal level measurements have been done to characterize their rf properties. Drift tube gap voltages were measured with x-ray field emissions and compared with voltages estimated from input power and shunt impedance. RF power losses in the DTL tank walls were higher than calculated and hence additional cooling was provided. The results of the signal and power measurements are summarized in this paper.

1 INTRODUCTION

The ISAC drift tube linac (DTL) consists of five IH tanks and three triple gap split ring bunchers operating in cw mode at 106.08 MHz [1]. DTL tank 2 and buncher 2 are shown in Fig. 1 and Fig. 2 respectively prior to signal level measurements. The resonant frequency and Q measurements are followed by bead pull measurements to confirm the mechanical alignment and determine the shunt impedances of the tanks. The tanks and bunchers are then equipped with rf couplers, pick up probes and tuners. Power tests were carried out in an X-ray shielded test facility. Four DTL tanks and three bunchers [2] were tested in the test area before installing them in the ISAC facility. DTL tank 5 was tested to its full power rating after installation in the ISAC facility.

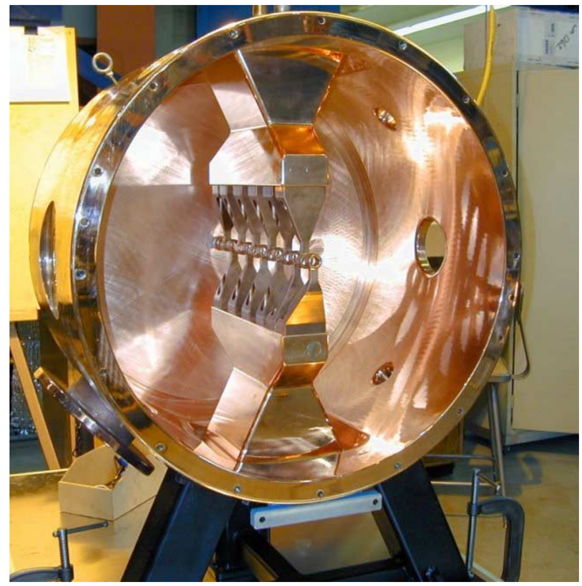

Figure 1: Photograph of DTL tank 2 during assembly.

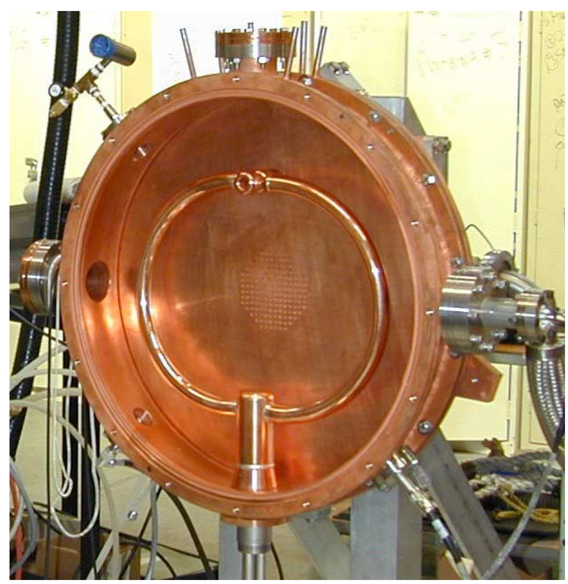

Figure 2: Photograph of Buncher 2.

2 SIGNAL LEVEL TEST

To estimate the power required to produce the specified design voltage at the gaps, shunt impedances of the cavities need to be evaluated accurately. Since all these structures are multigap cavities, a perturbation technique is employed to obtain shunt impedances. An automated system has been developed by which a dielectric bead is pulled along the beam axis and R/Q computed from the perturbed frequency measurement. R_{shunt} can be obtained from the measured values of R/Q and Q. Table 1 shows the measured R/Q and Q for five DTL tanks and three bunchers. R_{shunt} values obtained from the measurements are lower than the values predicted from MAFIA, leading to higher power requirements from the amplifiers. Measurements of buncher 1 and DTL tank1 are reported

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elsewhere [3,4]. Fig. 3 shows a typical bead pull measurement of DTL tank 4 where the relative field along beam axis is derived from the measured perturbed frequency shift.

Table 1: Summary of signal level measurements

DTL	MAFIA Values		Measured Values		Power Required
	Q	R/Q	Q	R/Q	kW
Tank 1	11000	13147	9000	12222	3.9
Tank 2	20050	23452	11260	18295	10.0
Tank 3	19790	27708	14350	24390	16.0
Tank 4	21920	23347	16250	21230	19.0
Tank 5	22970	20400	16600	19880	20.3
Buncher1	5700	1586	3950	1670	8.0
Buncher2	6660	1782	4880	1730	10.2
Buncher3	7730	1937	5700	1990	11.6

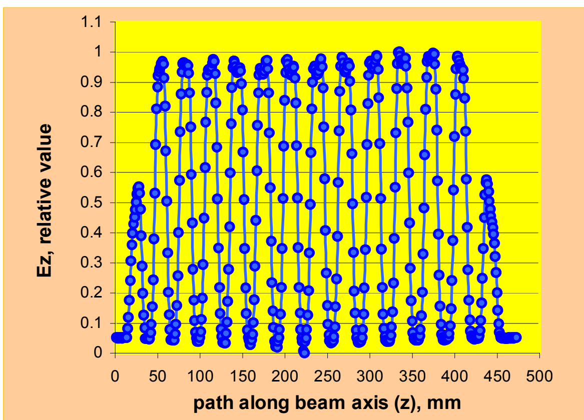

Figure 3: Bead pull measurement of DTL tank 4.

2.1 Voltage calibration

All the cavities are equipped with calibrated rf pick up probes. The voltage induced in the probes when terminated into 50 ohms is related to the input power to the cavity and measured transmission loss S_{21} between the probes and the rf coupler. When the rf coupler is matched to the cavity (critically coupled) the induced voltage at the probes is given by

$$V_{probe} = \sqrt{(2.P.R)}/(10^{S21/20}) \quad (1)$$

Where P is in Watts, S_{21} in dB and R is 50 Ω.

The power is related to the total cavity voltage and shunt impedance by

$$P = (V_{cavity})^2 / R_{shunt} \quad (2)$$

Where $V_{cavity} = V_{effective}/T_o$, and T_o is the transit time factor It can be shown that the pick up voltage and cavity voltage are related by

$$V_{probe} = [\sqrt{(2.R/R_{shunt})}/\ 10^{S21/20}].\ V_{cavity} \quad (3)$$

This equation has been used to predict the voltage on the DTL tanks and the bunchers. Insertion loss of the coaxial cables between the probes and the instrumentation racks have been included in the S_{21} values to arrive at the correct cavity voltage.

2.2 RF couplers

The rf coupler, consisting of a coaxial ceramic feedthrough and a loop, is installed on the cavity and a power amplifier is connected to it via a transmission line. The length of transmission line must be carefully adjusted to insure proper operation into a true parallel resonant load. The coupler is provided with a rotatable flange so that 50 Ω matching can be established between the power amplifier and the cavities. The loop size for a particular tank is determined from the rf magnetic-fields obtained from MAFIA calculations. The ceramic to metal joints at both ends of the feedthrough are cooled but the loop itself is not cooled. A generic design has been developed for the rf couplers and all the DTL tanks and bunchers are equipped with the same coupler except for the loop sizes.

2.3 Tuners

The resonant frequencies of DTL tanks 2 to 5 range from 0.4 % to 1.3% higher than the operating frequency of 106.08 MHz. DTL tank 1 frequency was 3.5% higher. Each Tank has a course tuner and a fine tuner consisting of a capacitive plate supported by a water cooled rod and symmetrically placed on each side of the tanks at beam axis height. The heat produced in the support rods is not due to the tuner currents but due to the presence of the rod in the tank rf magnetic flux. The course tuners are manually adjusted except for DTL tank 1, which is equipped with a fixed coarse tuner since an adjustable coarse tuner was not considered necessary at the time of installing this tank in ISAC. The fine tuners are controlled by stepping motor and form the frequency feedback loop for the rf control system. Travel for the plates of the coarse tuner and fine tuners are 1.25″ and 1.5″ respectively. DTL bunchers have no coarse tuners, but they are equipped with the same type of fine tuners as the DTL tanks except they have a larger tuning range to include the frequency shift from atmosphere to full power under vacuum. Careful adjustment of the initial position of the tuners and the tuning ranges was needed to compensate for this additional frequency shift. The tuners are shown in Fig. 4 where the top photograph is a coarse tuner for DTL tanks and the lower photograph is a fine tuner adapted for the bunchers.

3 POWER TEST

RF power required for the DTL tanks and the buncher cavities were estimated from the shunt impedance measurements. Table 1 shows the power at which all these cavities were tested. Power tests were carried out

Figure 4: Photographs of coarse and fine tuners.

in a concrete bunker to shield personnel from emitted x-rays from the cavities. The tanks were baked for a minimum of 5 hours with circulating hot water at 60 °C through the drift tube supports, tank walls and end plates. This baking minimizes the time required to condition the cavity against multipacting. Tank 1 was tested for 138 hours at 3.2 kW cw without any failures. The tank wall temperature was only 1.5 degree higher than the ambient temperature. When tank 2 was powered up the temperature of the tank wall reached 60 degrees C in some areas at half power. It was evident that additional cooling of the tank wall was necessary but the challenge was how to attach the cooling lines with good thermal conduction without heating the tank structure, which had been assembled and aligned. A result of a program of testing various epoxies and cements for thermal conductions is shown in figure 5. This lead to the use of “TRACIT-300” hardening cement [5] manufactured by CHEMAX Corporation, which yielded a thermal conduction ~ 84% of Certanium solder. The spacing of the cooling lines was chosen to maintain the temperature of any area of the tank wall below 45 °C at full power. Cooling lines were attached to tanks 3,4 and 5 in a similar manner.

3.1 x-ray measurements

X-ray measurements on the tanks were done mainly to verify shunt impedance values obtained from signal level measurements. These measurements were also used in determining the shielding requirements in the ISAC building where these tanks are installed. Solid state detectors were used for the above measurements which were calibrated against standard energy sources. Maximum voltage on the drift tube can be calibrated from the measurement of emitted x-ray energy from the cavities. Fig. 6 shows the voltage measured from x-ray energy emission and voltage estimated from the perturbation measurements for tank 3. X-ray measurements for tank 1, tank 2 and bunchers 1 to 3 agree with the computed values.

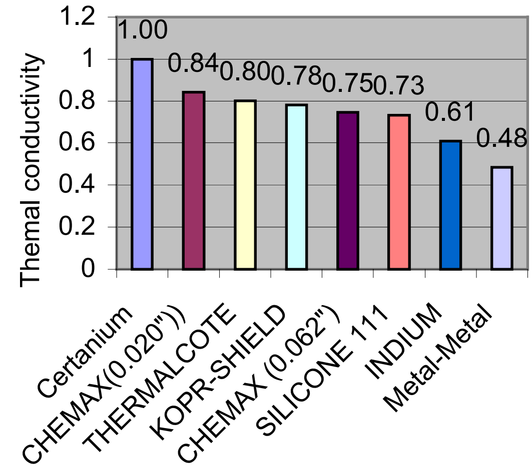

Figure 5: Test results of various epoxies and cements normalized to Certanium solder.

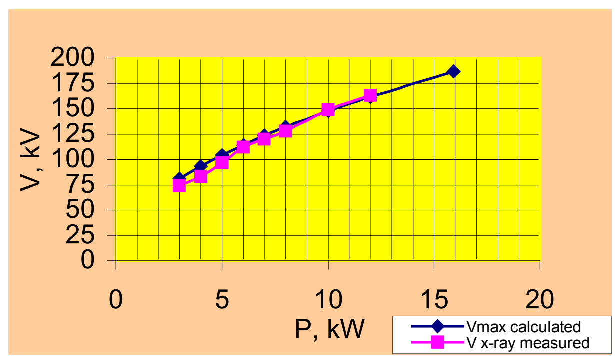

Figure 6: x-ray measurement of DTL tank 3.

4 CONCLUSION

Signal level measurements, verification of cavity voltages with emitted x-rays and testing of the cavities at full power in the test facility were essential for the successful operation of these cavities in the ISAC facility. The tanks and bunchers are now installed, tested and commissioned in the ISAC facility and have been used to deliver beam to the experimenters.

5 REFERENCES

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