

RESULTS AND EXPERIENCE WITH SINGLE CAVITY TESTS OF MEDIUM BETA SUPERCONDUCTING QUARTER WAVE RESONATORS AT TRIUMF

V. Zvyagintsev, K. Fong, M. Laverty, R. E. Laxdal, A. K. Mitra, T. Ries, I. Sekachev,

TRIUMF, Vancouver, Canada

Abstract

A heavy ion superconducting linac is being installed at ISAC/TRIUMF. A first stage of the ISAC-II upgrade will see the installation of 20 quarter wave bulk niobium cavities ($\beta_0=0.057, 0.071$). The cavities operate CW at 106MHz with design peak fields of $E_p=30\text{MV/m}$, $B_p=60\text{mT}$ while delivering an accelerating voltage of 1.08MV at $<7\text{W}$ power consumption. All cavities have been tested in a single cavity test stand with twenty of twenty-one meeting ISAC-II specifications. The cavity test results will be presented. In particular we will discuss our experience with BCP vs. EP surface treatments and with Q-disease. In addition the tuning plates of two of the cavities were modified to provide a unique compensation to the resonant frequency.

INTRODUCTION

A first stage of the new heavy ion linac at TRIUMF is equipped with 106 MHz bulk niobium quarter wave cavities. The cavities, originally developed at INFN-LNL [1] and fabricated at Zanon in Italy, are two-gap bulk niobium quarter wave cavities (Fig. 1-2).

Eight of the cavities have a design beta of 5.7 % with the remaining twelve having a design beta of 7.1 % (Fig. 1) to operate up to 6 MV/m across an 18 cm effective length with $P\sim 7\text{W}$.

The gradient corresponds to an acceleration voltage of 1.1~MV, a challenging peak surface field of $E_p=30\text{MV/m}$, a peak magnetic field of 60~mT and a stored energy of $U_0=3.2\text{J}$ and is a significant increase over other operating heavy ion facilities.

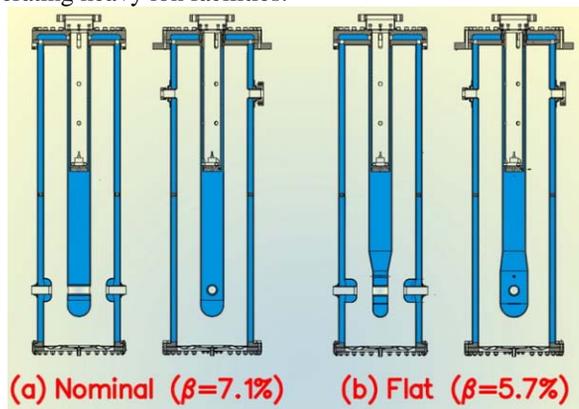


Figure 1. The TRIUMF medium- β 106 MHz QWRs.

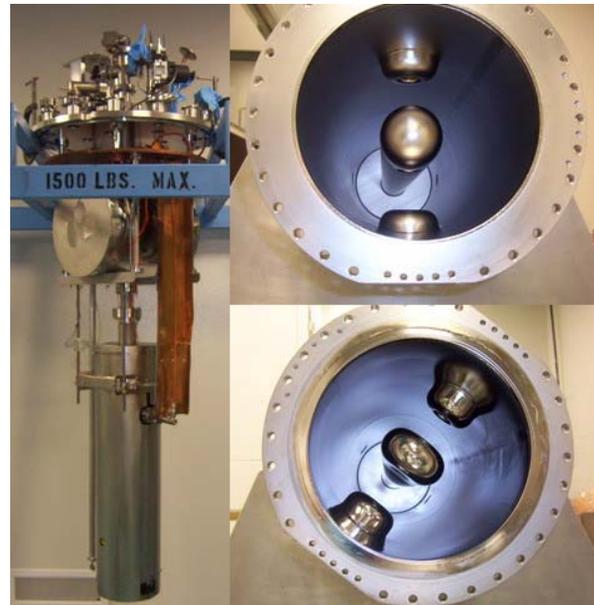


Figure 2. Test Cryostat and internal views of nominal after BCP and flattened after EP (shiny) QWRs.

The cavities are equipped with a mechanical damper which limits microphonics to less than a few Hz rms.

To achieve stable phase and amplitude control the cavity natural bandwidth of 0.1 Hz is broadened by overcoupling up to 20 Hz to accommodate detuning by microphonic noise and helium pressure fluctuation.

A new inductive coupler has been developed that reduces the helium load to less than 0.5 W at $P_f=200\text{W}$ [2][3].

The tuning plate on the bottom of the cavity is actuated by a permanent magnet linear servo motor at the top of the cryostat [4].

CAVITY PREPARATION AND TESTING

Cold tests are done in the SCRF Clean Room facility in the new ISAC-II building. A single cavity cryostat with LN2 thermal shield is used for all the cavity characterization studies (Fig. 2).

Typical treatment involves 30-40 minute high pressure water rinse and twenty four hour air dry in a clean room, followed by vacuum pumping and bake out at 95C for 48 hours. Then the cavities were pre-cooled two different ways:

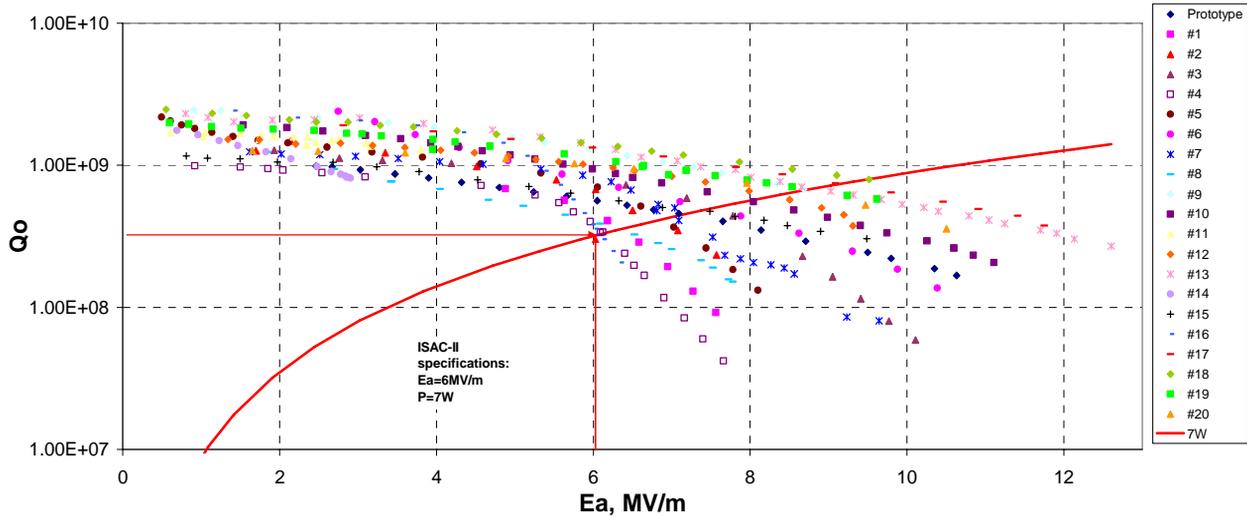


Figure 3. Test results from Single Cavity Test Stand. 20 from 21 cavities (except of cavity 14) meet ISAC-II specifications.

- LN2 flow to inner conductor brings the cavity to 170 K with. Recently we have found that this procedure is responsible for degradation in performance from Q-disease.
- Radiation and thermalization brings the cavity to 220 K. Then fast cooling from LHe flow brings the cavity below 50 K in less than 1 hour.

Cavity 14 is quenched at 3 MV/m. We did inspection of the cavity and suspect defect of outer conductor welding.

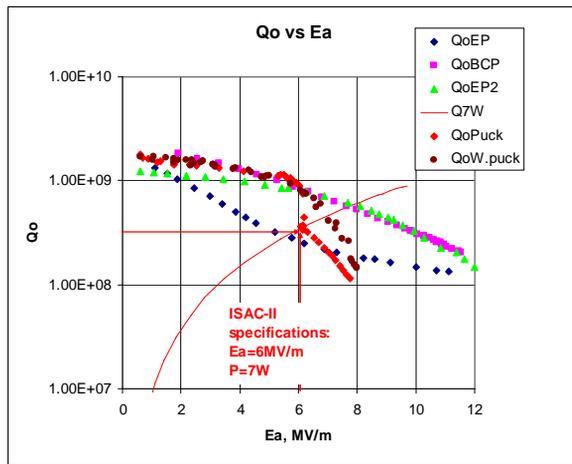


Figure 4. History of cavity 11: from BCP to frequency compensation after EP.

Test results are presented on Fig. 3. 20 from 21 cavities meet ISAC-II specifications and provide $E_a > 6$ MV/m across an effective length 0.18m at power dissipation 7W. Average E_a at 7 W for 20 cavities is of ~ 7.5 MV/m. Sensitivity for He pressure and Lorentz force detuning for the cavities are 1.2-2.4 Hz/Torr and 0.75-1.4 Hz/(MV/m)² respectively. Frequency change from room to helium temperature is ~ 200 kHz.

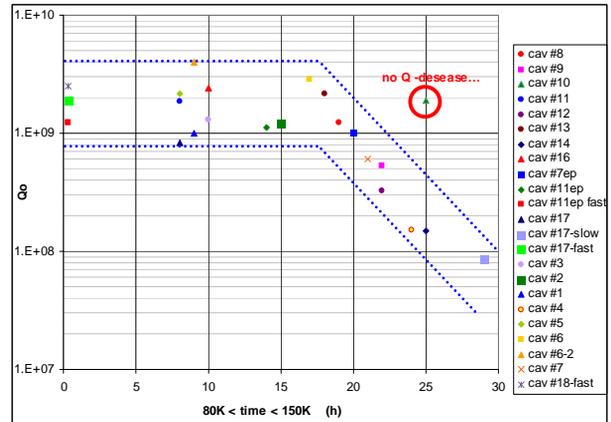


Figure 5. Correlation of cavity performance to the time which cavity remains at temperatures between 80K and 150K.

BCP, EP AND Q-DISEASE

One of the best and one of the worst cavities initially received BCP at J-Lab were taken to Argonne with purpose to recover the worst cavity and to make a comparison of BCP and Electro Polishing (EP) from the best cavity. But the result of this action exceeded our expectations. We found that the worst cavity became better but the best cavity became worse and these cavities occurred ~ 120 kHz higher in frequency.

The best cavity history is shown on Fig. 4. Here we can see that instead of initial Q_{oBCP} curve after EP we measured Q_{oEP} which is indicating poor performance. Obviously there is a difference in shapes; initial curve has 'concave down' slope while the curve after EP 'concave



Figure 6. Compensation puck assembled and welded to the tuning plate.

up'. From this kind of difference we suspected that the cavity is suffered from Q-disease. We did another test of the cavity with fast cool down. We slowly (about 48 hours) cooled the cavity up to 220K from radiation to N shield and then very fast (less than 1 hour) cooled from liquid He flow below 50K. QoEP2 curve shows that we have this best cavity back.

We retested some cavities after BCP with low performance at fast cooling and obtained much better results which show that these cavities suffered from Q-diseased.

A study was undertaken to correlate cavity performance to the time which cavity remains at temperatures between 80K and 150K (Fig. 5). It was found that degradation in the cavity Q can occur if this time exceeding 15 hours.

It is suspected that the hydrogen is picked up during fabrication.

Due to the unremarkable performance gains especially considering CW operation and large frequency swing TRIUMF has chosen BCP as the treatment method for the ISAC-II cavities. It is planned to add a treatment facility in the next year.

FREQUENCY COMPENSATION

One negative feature of the adopted electro-polishing procedure is that the treatment produces a large frequency shift. The frequency shift for cavity 7 and cavity 11 were 124 kHz and 143 kHz respectively. From HFSS sensitivity analysis we had 3 different scenarios for frequency compensation:

Beam port deformation; we should deform beam ports ~1.5 mm in from each side. This is very risky procedure because the deformation is too big and beam ports remaining thickness (after BCP and EP) is less than 1mm.

Compensation BCP of the resonator: 100 μm for top half and 10 μm for the bottom of the resonator.

Tuner plate reshaping: to increase QWR end capacitance.

We had chosen the 3rd way which is safe for the cavities. The compensation puck with diameter 60 mm and height 20 mm was calculated with HFSS and Slater

theorem and made from Nb (Fig. 6). Frequency measurements with the puck shown good agreement with calculations. According to calculations B_p/E_a doesn't change noticeably, E_p/E_a 4% more, magnetic field in contact between tuning plate and the cavity is increasing in 30% which could decrease cavity performance for high field but should not be a problem for nominal field 6 MV/m. Due to the puck sensitivity of tuner plate increased 3 times but during the test we didn't found any problem from tuning system.

The 1st test of cavity 11 was done with bolted puck. Curve QoPuck on Fig. 4 shows that there was a Q-switch at $E_a=6.25$ MV/m. This switch was due to poor thermal and rf contact between puck and tuning plate. The 2nd test with welded puck (QoW.Puck on Fig. 4) confirmed this conclusion and shown that cavity 11 can provide $E_a=7$ MV/m at $P=7$ W. The same result was achieved with cavity 7. These 2 cavities were installed in ISAC-II and shown good performance during linac commissioning.

CONCLUSIONS

All 20 cavities for ISAC-II 1st stage which meet specification and provide in average 7.5 MV/m field (at 0.18 m acceleration length) at power dissipation 7W.

Study of Q-disease was conducted for bulk Nb cavities Unique frequency compensation technique was developed for SC QWRs.

ACKNOWLEDGMENTS

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