PERFORMANCE LIMITATION STUDIES ON ISAC-II QWR'S AND E-LINAC ELLIPTICAL CAVITIES AT TRIUMF

D. Longuevergne, A. Grassellino, P. Kolb, R. E. Laxdal, V. Zvyagintsev, TRIUMF, Canada

Abstract

TRIUMF has been operating successfully for several years numerous 100MHz class superconducting quarter wave resonators on the ISAC-II heavy ion linac [1] and is now developing a 1.3 GHz activity to build the e-linac, a 50 MeV superconducting electron linac to produce radioisotopes by photofission [2]. Several studies on cavity treatments are ongoing to both enhance ISAC-II QWR performances and to meet the requirements on the e-linac elliptical cavities. This paper will summarize the main development efforts to understand performance limitations in these cavities.

INTRODUCTION

Two spare Quarter-Wave Resonator (QWR) built for ISAC-II upgrade are available to perform additional studies to improve their performance. These 141 MHz QWR have been repaired after a first etching as they both revealed a leak at the welding joint between the inner conductor and the drift tube (donut). The unique difference between a repaired and non-repaired cavity is that the inner conductor is cut out of the upper flange, repaired and then welded back into place.

A study loop [3] has been performed after repair that consists in sequencing a BCP etching, two tests at 4.2K, two 100K soaking and an in-situ baking at 120C for 48h as sketched on Figure 1. This loop has been repeated three times.

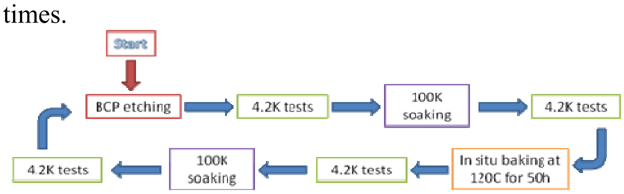

Figure 1: One loop study layout.

The cavity performances have barely improved and is still performing under the ISAC-II requirements (Qo of 3E8 corresponding to 7W dissipations at 6 MV/m). Some interesting observations have been made during this study and will be described here.

TRIUMF is also working on the development of 1.3 GHz nine cell elliptical cavities and the construction of the infrastructure to support 1.3 GHz activities for the ARIEL facility [4]. Two single cell cavity prototypes have been built by PAVAC Industries of Richmond, BC and are processed and tested at TRIUMF [5]. After several etching iterations, the cavity performances have been gradually improved but the requirements have not been reached yet (Qo of 1E10 corresponding to 10W dissipations at 10 MV/m for 9 cells). Several technical issues like leak opening after etching or "super-leaks" have significantly delayed our progress. The results will be exposed in this paper.

Recently, in collaboration with Fermilab, one QWR and one 1-cell cavity have been degassed above 600C and tested back at TRIUMF. These last results will be included in this paper.

RESULTS ON 141 MHZ QWR

Preparation

The surface conditioning of the cavity for each loop is the following:

- Etching is about 80 microns in high magnetic field regions and 20 microns near the beam tube. The acid temperature is kept below 13C. Some agitation is provided during the etching. The cavity is then rinsed thoroughly with deionised water and left for drying in a fume hood after an alcohol rinsing.
- The cavity is High Pressure Rinsed in a class 100 clean room and dried over night after some alcohol rinsing.
- The cavity is loaded in the cryostat in a class-1000 environment and pumped down to 1E-6 torr. A 24h drying at 50C is done in all cases before a 4.2K test. In some cases a 120C bake for 48 hours is done
- The cavity is cooled down as fast as possible to spend less than 30 min between 150K and 50K.
- After a test, the cavity is warmed to spend at least 2h between 80K and 110K to trigger Q-disease. The cavity is then tested at 4.2K
- During an in situ baking, the cavity is kept between 100C and 120C during 40h under vacuum.

Results and Observations

This cavity shows significant improvements between the first and second loop. Q-curves measured look all "Q-diseased" [3] meaning a significant Q-slope at low field even after a fast cooling down (see figure 2).

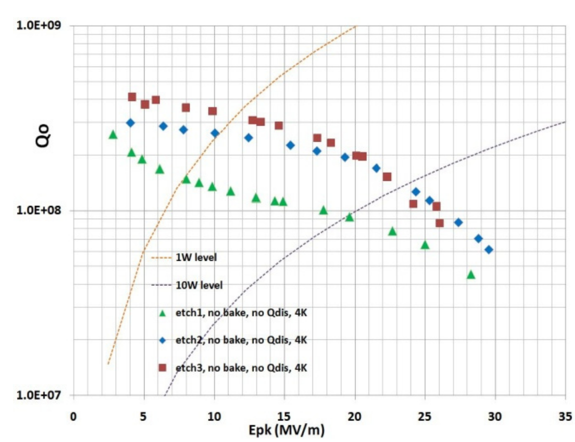

Figure 2: Q curves measured after each additional etching steps (86 µm, 74 µm and 78 µm).

Between the second and third etching, above 160 microns removal in high magnetic field region, no real improvements have been observed.

Another observation done during the third loop was that the cavity apparently didn't recover from Q-disease after a 120C baking (green triangle and blue diamond curves). This is surprising as the Niobium Hydride should be dissolving at room temperature.

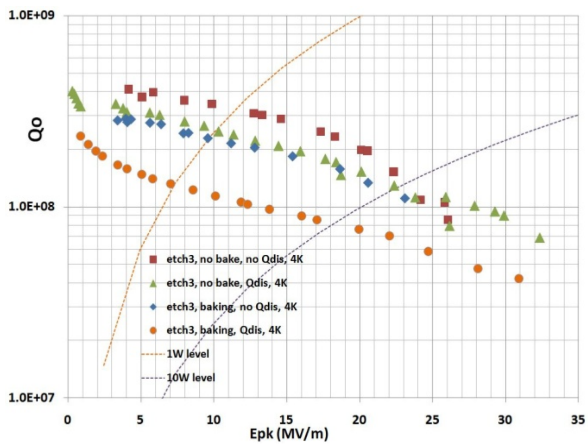

Figure 3: Q-curves measured in third loop.

As a general observation between different loops, the cavity tends to be less sensitive to Q-disease with etching depth.

The aim of this study was also to tell whether or not a baked cavity is more sensitive to Q-disease than an unbaked cavity. This can't be answered here as problems of repeatability have been encountered between each loop.

Results After Cavity Degassing

In collaboration with Fermilab, the cavity has been degassed at 600C during 10 hours. As a preparation, the cavity has been first degreased, rinsed with deionised water and dried in Class-100. The furnace has been pumped down to 5E-6 Torr before starting. During the baking procedure, some traces of oils have been detected with the residual gas analyser but vanished afterward. These oils reside in the helium tank and are very difficult to get rid of despite the degreasing bath. Once back at TRIUMF, the cavity has been degreased in ultrasonic bath for 30 minutes, followed by a light BCP etching of 30 microns, alcohol rinsing and drying. As a final surface conditioning, the cavity has been high-pressure rinsed with ultra pure water for 45 minutes, dried in a class-100 environment and finally baked in situ for 40h at 120C under vacuum.

Results are shown on figure 4. The green triangle and purple square curves indicate the cavity performances before degassing respectively without and with 100K soaking. The blue diamond curve shows results after degassing and all the preparation described previously. Unfortunately the cavity couldn't be conditioned due to a lack of liquid helium. The base quality factor didn't improve after degassing but the Q-slope below 3 MV/m appears to be flatter. The red round curve shows the results after 13h between 80K and 100K. This result proves that after such degassing the hydrogen responsible for Q-disease has been removed below the threshold of measurement. Moreover the light etching following didn't re-contaminate the cavity. As a comparison, the square purple curve gives an idea of the hydrogen contamination before degassing showing the Q degradation after holding the cavity around 100K for only 2 hours.

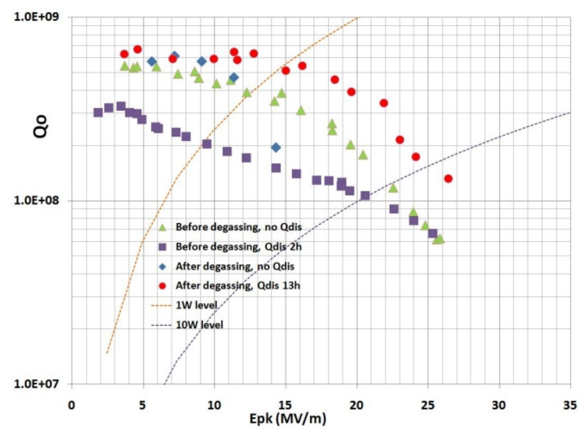

Figure 4: Q-curves comparison before and after degassing the cavity at 600C during 10h.

A quick high power pulse conditioning done after the Q-disease test improved the cavity. We finally reached the same gradient as before degassing but at higher Q.

1.3 GHZ 1-CELL CAVITY RESULTS

Status and Progress

TRIUMF is in possession of two 1.3 GHz single cell cavities fabricated in collaboration with PAVAC Industries. Six other single cell cavities have been fabricated by PAVAC during the same time period with pre-weld etching done by TRIUMF. To date two cavities of the series have been tested at FNAL with high performance [6]. The goal at TRIUMF is to use the cavities to qualify cavity preparation and testing procedures at 1.3GHz.

The same surface cleaning procedure as for ISAC-II QWR is applied in the case of the 1.3GHz cavities:

- BCP etching with acid circulation in continuous flow at a temperature below 13C.
- The cavity is thoroughly rinsed with deionised water, steamed, alcohol rinsed and dried in a fume hood.
- High Pressure Rinsing in a class-100 area for 30 minutes and dried with alcohol.
- 120C in situ baking during 48h

Several etching steps have been performed but the cavity is still not reaching the requirements (1E10 @ 10 MV/m), see figure 5. Many problems have been thus encountered slowing down significantly our development process. These include cold leaks at the Aluminum sealing gasket on the NbTi flange, coupler antenna overheating and discharge, glow discharge in coupler cable and leak opening during etching. The cavity leak occurred due to improper etching procedures at TRIUMF that exposed the NbTi flange to the etching acid. The cavity was repaired at PAVAC by cutting off then reprepping the flange and welding in a new beam tube extension piece. The glow discharge occurs in the RF connector below the feed-thru in the low pressure helium gas, manifested itself with a large reduction in the reflected power to near zero for a forward power above 10W and a heating of the connector. The cable and connector is not hermetically sealed from the helium gas. The possibility of discharge gives an uncertainty to the cavity test results. To this end an isolation chamber has been added to the top of the cryostat to prevent glow discharge at the connector. The chamber consists of a short pipe with an rf connector on one end and a drilled blank on the other end. The cable is passed intact through the drilled blank then epoxied in place to form a vacuum barrier while the cable is attached at the other end to the rf feedthrough. This chamber can be kept either under vacuum or filled with helium at atmospheric pressure. The plan is to replace the cable by a hermetically sealed unit.

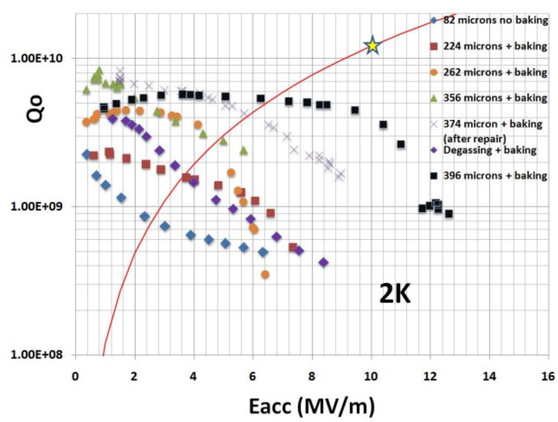

Figure 5: Q-curves evolution over etching steps and set-up improvements.

One single cell cavity has been degassed at Fermilab at 800C during 2 hours with the same procedure as described previously (see figure 6). The cavity has been tested at TRIUMF with only a High Pressure Water Rinsing and 120C baking with no additional etching. The cavity shows a significant Q-slope right from the beginning (see purple diamond curve). After an additional 20-micron etching, we obtained, a flat characterization curve at 5E9 up to 9 MV/m limited by a strong field emission. The cavity does not show any Q-disease symptoms after a 12-hour soaking between 50K and 120K.

Future improvements to be done would be first to replace the type-N feed-thru installed on the cavity, same as used on ISAC-II and good at 141 MHz, as these show an inferior Standing Wave Ratio (SWR~2) at 1.3 GHz. Finally, some work can be done to improve the cavity vacuum and cavity preparation in clean room to push back the field emission onset.

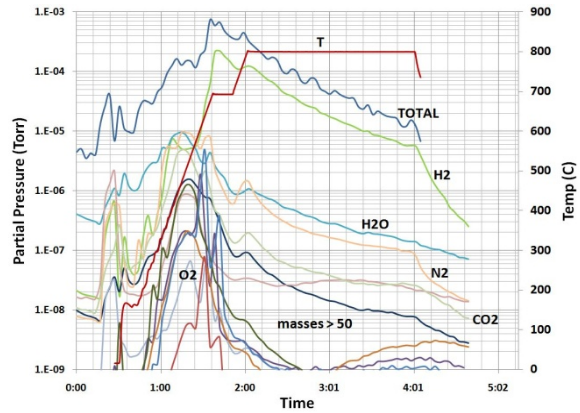

Figure 6: Partial pressure monitoring during 800C degassing.

CONCLUSION

The study done on our spare 141 MHz QWR showed that etching more than 160 microns doesn't improve anymore the cavity performances. Degassing the cavity helped flatten the Qo versus accelerating field but is not the solution to increase the base Qo. As for the 1.3 GHz elliptical cavity, the poor quality factor is then not due to the hydrogen content. The magnetic field in the cryostat has to be checked more carefully

Before degassing, our cavities show a significant sensitivity to Q-disease and thus a relatively high concentration of Hydrogen. After degassing, the Hydrogen has been removed below threshold. A light etch looks necessary (verified for the 1.3 GHz cavity) and is not a source of additional hydrogen pollution.

The next improvements we will target are on the cavity surface conditioning and vacuum.

ACKNOWLEDGMENTS

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