VERTICAL TEST RESULTS FOR VERTICALLY ELECTROPOLISHED 1.3GHz 5-CELL SUPERCONDUCTING CAVITIES*

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Abstract

15 years ago, a Cornell/Fermilab/DESY collaboration broke the 25 MV/m gradient barrier with several 5-cell 1.3 GHz cavities prepared by buffered chemical polish (BCP) treatment. We overcame field emission using high pulsed power processing (HPP). We have launched a new program to use these 5-cell cavities to answer generic SRF questions for high gradient projects such as ILC and Project X. The results of multiple vertical tests on a 5-cell vertically electropolished 1.3GHz superconducting cavity are presented. A combination of oscillating superleak transducer (OST) and Q measurements for various TM01 passband modes are used to infer the field-limiting mechanism. The vertically electropolished cavity reached a maximum CW peak surface magnetic field of 155 mT at 2.1K corresponding to 37 MV/m accelerating gradient.

INTRODUCTION

In 1994 a Cornell/Fermilab/DESY collaboration broke the 25 MV/m gradient barrier with several 5-cell 1.3 GHz cavities of a shape similar (but not identical) to the TESLA-shape [1]. At that time we applied BCP chemical treatment in vogue, and also post-purified two cavities to have the best residual resistance ratio (RRR) (about 600). Also at that time the technique of high pressure rinse (HPR) for field emission mitigation was not yet in practice, so that we eliminated field emission by rf processing enhanced by high (MWatt) pulsed (200 μs) power processing. Using the combination of these techniques we surpassed 25 MV/m in three cavities. The Q vs E curves for all the cavities was limited by a combination of high field Q-slope (expected for BCP) and some residual field emission.

Since that time HPR has become very effective against field emission and electropolishing (EP) plus 120^o C baking has become effective against the high field Q-slope. Therefore we decided to apply the later developed techniques to the same 5-cell cavities and push their gradients to the 35 MV/m level. Our aim was to use these 5-cell cavities as convenient work-horses for studying various questions such as the effectiveness of vertical EP to reach high gradients, the impact of post-purification (high RRR) on EP-prepared cavities, and gradient reproducibility with repeated cavity treatments. We are also in a position to reapply HPP to the 5-cell cavities to test the overall effectiveness of this approach on well cleaned cavities prepared by HPR. We aim to repeat some of our earlier tests on the efficacy of in-situ recovery after deliberately staged vacuum accidents.

We have equipped the test stand with 2nd sound thermometry to locate quench spots. We are in the process of equipping these cavities with full-scale thermometry so that we can detect quench spots and other defects which will be inspected optically. Ultimately we are prepared to dissect these cavities to extract information via surface analysis instruments. A convenient aspect of the 5-cell units is that these fit into the furnace at Cornell for H-degassing.

The program has just started and we report here the first results on two of the 5-cell cavities. One of the cavities reached a maximum CW peak surface magnetic field of 169 mT at 1.6K which corresponds to an accelerating field above 40 MV/m, thereby proving that vertical EP is capable of reaching high gradients in multi-cell cavities. The other cavity test was limited by field emission.

VERTICAL TEST RESULTS

The cavity was prepared with a bulk EP of 170 μm followed by 800^o C H-degassing for 2 hours. The cavity then received a light EP of 20 μm followed by ultrasonic degreasing and 10 hours of HPR. It has not been post-purified, yet; however, future post-purification may be done to study its combined effect with vertical EP. It has $E_{pk}/E_{acc} = 2.67$ and $B_{pk}/E_{acc} = 4.19\text{mT}/(\text{MV}/\text{m})$. The results of the first two vertical tests are shown in Fig. 1. After some processing events at low fields, continuous field emission started at a peak electric field of 34.1 MV/m. The cavity was then removed from the test insert and given an additional 14 hours of HPR, and the second vertical test showed some minor improvement. The onset of field emission occurred at 15.4 MV/m and the maximum field occurred at 26.8 MV/m; however, the cavity was still limited by field emission.

The cavity was then baked at 120^o C for 48 hours and tested again. The results are shown in Fig. 2. Initially, the results were the same as the unbaked cavity tests; however, in this test the field-emitting barrier was processed through and the cavity was able to reach a maximum accelerating field of 37.1 MV/m, corresponding to $E_{pk} = 99.1\text{MV/m}$ and $B_{pk} = 155\text{mT}$. The cavity was quench limited by a thermal defect. The quench was not caused by heating from the field emission as the $4\pi/5$ mode and $3\pi/5$ mode were both also caused to quench, but with much less field emission.

Eight OSTs [2] were attached to the test insert and the cavity was tested again with the aim of identifying the quench location. The helium bath temperature of 1.6 K during this test was lower than the previous tests, and the

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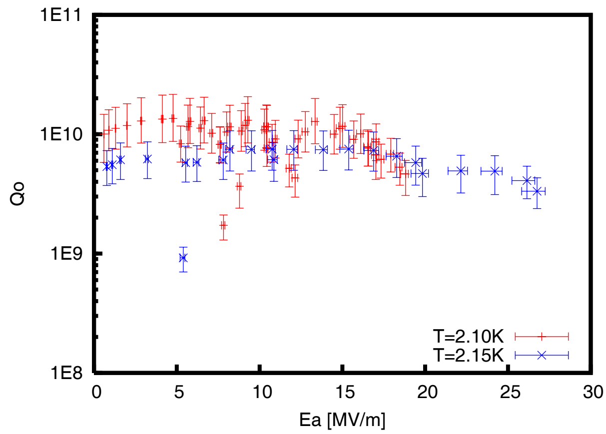

Figure 1: 5-Cell cavity vertical test results. Processing events were seen at low fields and the cavity was limited by field emission: 18.8 MV/m during the first test and 26.8 MV/m during the second test.

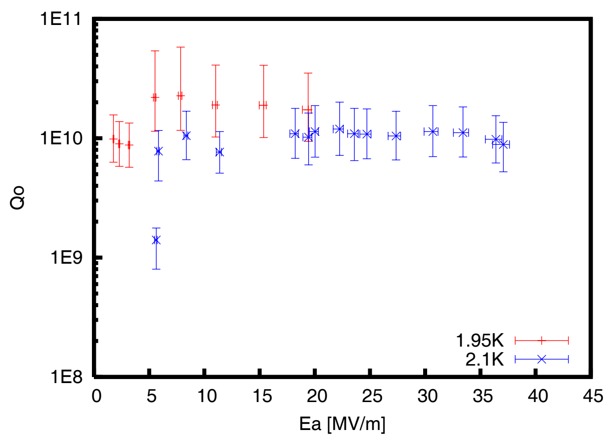

Figure 2: 5-Cell cavity vertical test results after baking at 120^{o}C for 48 hours. During the initial pumping down to 1.95 K, the cavity reached 20 MV/m. After a subsequent helium transfer and continued pumping back down below the lambda point, the cavity reached a maximum accelerating field of 37.3 MV/m. The cavity was limited by a thermal quench.

cavity was able to reach a quench field of $E_a = 40.4$MV/m and $B_{pk} = 169$mT. The OST signals shown in Fig. 3 verified that the quench was centered on a discrete point on the cavity surface. From the OST time-of-flight measurements, the location of the defect could be triangulated to the cell second from the top during the vertical test, approximately one inch from the equator weld. Optical inspection did not reveal any visible defect.

MULTI-CELL THERMOMETRY

Several changes were made to the original thermometer construction and layout successfully developed at Cornell for single-cell cold tests [4]. The new multi-cell thermometry system will utilize new multiplexing electronics under development to reduce the number of wires exiting the dewar top plate. A new thermometer housing of molded Stycast has replaced the original G10 housing, avoiding the problem of damaging thermometers when end milling the G10 boards during mass production. And small strings are bonded along the sides of the thermometers to maintain alignment (not shown in Fig. 4).

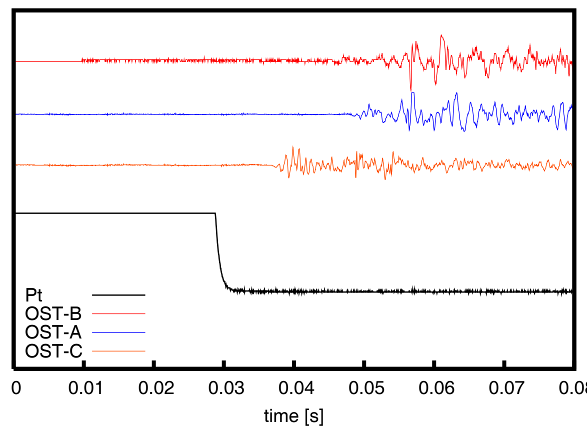

Figure 3: 5-Cell quench captured with OSTs. The transmitted power P_t drops to zero in 3 ms as the cavity stored energy is dissipated at the defect location. The OSTs' responses are delayed by the arrival time of the second sound wave front, traveling radially away from the defect at a speed of 20.3 m/s.

Our new temperature mapping system will have a total of 2040 thermometers fixed to the cavity surface with 24 2-cell boards (see Fig. 4) and 24 3-cell boards, similar to the multi-cell board arrangement for 9-cell thermometric measurements developed at Los Alamos [3].

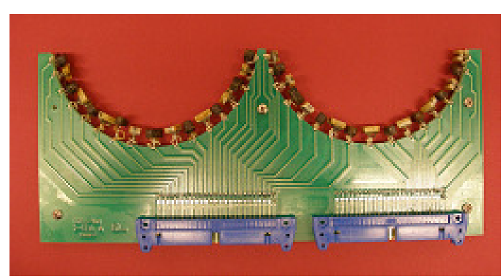

Figure 4: Temperature mapping thermometer board. A thermometer board for two cells containing 34 Allen-Bradley 120Ω resistive thermometers. The light colored thermometers have a G10 housing while the dark thermometers have a molded Stycast housing.

CONCLUSION AND FURTHER WORK

A vertically electropolished 5-cell cavity was able to reach $B_{pk} = 169$mT before undergoing a quench due to a thermal defect, as verified by multiple cold tests including OSTs.

This cavity may now be used for benchmarking a new resistive thermometry system for multi-cell cavities.

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REFERENCES

[1] C. Crawford et al., "High Gradients in Linear Collider Superconducting Accelerator Cavities by High Pulsed Power to Suppress Field Emission," Particle Accelerators, 1995, Vol. 49, pp. 1-13.

[2] Z.A. Conway et al., "Oscillating Superleak Transducers For Quench Detection in Superconducting ILC Cavities Cooled with He-II," LINAC 2007, Vancouver, British Columbia, Canada, September 2008, THP036, Pg. 850(2008);http://www.jacow.org.

[3] A. Canabal, et al.,"Development of a Temperature Mapping System for 1.3-GHz 9-Cell SRF Cavities ,"Proceedings of PAC07, Albuquerque, New Mexico, USA.

[4] Jens Knobloch et al., Rev Sci. Instruments,65:3521 (1995).