Superconducting Multicell Cavity Development Program at Los Alamos*

B. Rusnak, G. Spalek, E. Gray, J. N. DiMarco, R. DeHaven, J. Novak,
P. Walstrom, J. Zumbro, H. A. Thiessen, and J.Langenbrunner**
Los Alamos National Laboratory
Los Alamos, NM 87544 USA

Abstract

The Superconducting rf (SCRF) Cavity Development Program at Los Alamos has designed, fabricated, and tested single-cell niobium cavities at 3-GHz and 805-MHz. This work is being done in preparation for procuring and testing a multicell niobium cavity. The multicell cavity is designed to accelerate protons at $\beta = 0.9$; initial tests will be without beam. Programmatic changes have required us to modify our plans to install a 6800-liter helium cryostat and a 12.8-g/s helium pump. We will use an installed cryostat to test the multicell cavity. Also, the cavity will be modified from a seven-cell to a four-cell structure to match the dimensions of the installed cryostat. Previous reports concentrated on 3-GHz results. In this paper, some of the latest results of the 805-MHz cavity tests are presented. Modifications to allow high pulsed power (HPP) testing on 805-MHz single- and four-cell cavities are proceeding. Glow discharge cleaning of an 805-MHz niobium cavity resulted in a decrease in cavity performance. The cavity was restored to previous performance levels with buffered chemical polishing (bcp). Initial results with high-pressure water cleaning show the process is useful in restoring cavity performance.

I. INTRODUCTION

The primary goal of our SCRF program is development of the technical data base for the design, fabrication, handling, and testing of superconducting (SC) cavities that will apply to eventual fabrication of SCRF proton accelerators.

Information from the cavity development program was used to design and initiate fabrication of a multicell cavity. The cavity is to be fabricated by industry to our specifications. Programmatic considerations have resulted in the cavity having four $\beta = 0.9$ cells. This cavity will be tested at LANL and used to address technical feasibility questions regarding the use of superconducting structures in high-current proton accelerators.

Work reported at the 1991 PAC conference[1] concentrated on 3-GHz cavities. We have expanded the work to 805-MHz cavities; initial results[2] for the average of the peak surface electric fields were 29 MV/m and 23.5 MV/m at 2 K and 4 K, respectively. We now achieve 35 MV/m (Q of 5×10^{9}) and 30 MV/m (Q of 5×10^{8}) at 2 K and 4 K, respectively.

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**University of Minnesota.

Our investigation of cleaning techniques has concentrated on systems that could also be used on the four-cell cavity. High-pressure pure-water spray is a viable technique for removing particulates from the surface of the niobium. We have tested an 805-MHz single-cell cavity that was initially cleaned in the standard way by a bcp. The cavity was "dirtied" by exposure to room air. Performance of the cavity was restored after high-pressure cleaning. This equipment is being modified to clean the four-cell cavity.

II. MULTICELL CAVITY

A cavity structure consisting of seven niobium cavities, supporting structure, and tuning system has been described in a previous publication[3]. This structure consisted of seven $\beta = 0.9759$ cells. For programmatic reasons, the cell shape was changed to $\beta = 0.9$ to match 1200-MeV protons. Also, the number of cells in the cavity was reduced from seven to four. A four-cell cavity conforms to defined power handling constraints of windows/couplers in conceptual designs of some high power proton accelerators. The smaller structure also fits into a cryostat that is presently installed in the SC laboratory. The new cavity also includes high order mode (HOM) couplers mounted on the beam tubes, at each end of the cavity. Window and variable coupler tests have started in preparation for 100-kW pulsed rf power conditioning tests, initially with single 805-MHz cells.

III. SINGLE-CELL RESULTS

A. Summary of cavity testing results

Previous reports[2] concentrated on the results from 3-GHz single-cell cavities. The emphases of the SC lab work has moved to performance tests of 805-MHz cells. These cells are prepared with the same procedure as the 3-GHz cells. Primary surface treatment is a nitric acid bath followed by removal of approximately 70 mm of niobium using a 1,1,1 bcp. Two 805-MHz single-cell cavities are available for these tests. A total of 28 individual cavity tests are displayed in figure 1; figure 2 displays the results from eight cavity tests. All cavities are removed from the cryostat and reprocessed before running another test. Reprocessing typically starts with bcp and proceeds through a "standard"[1,2] treatment procedure. However, there are some cavities that were only wiped clean and rinsed with pure water and/or menthol. The statistics are insufficient to resolve differences in the processing techniques.

The measured Q's as a function of the peak surface electric fields are shown in figure 1 and figure 2 for operation at 2 K and 4.2 K, respectively. Some of the tests require an initial conditioning of the cell by gradually increasing rf power

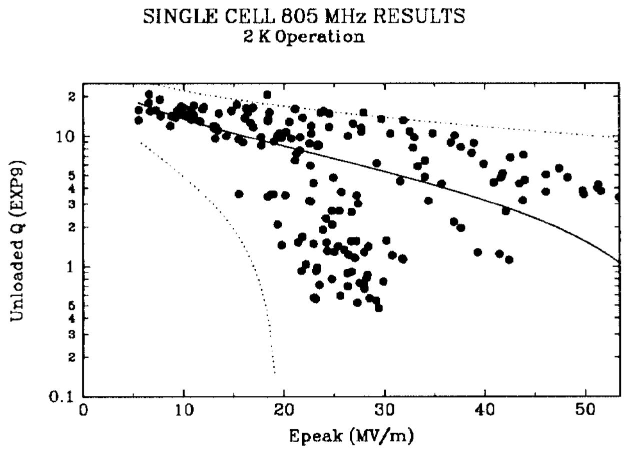

Figure. 1. Q vs. Peak surface electric field at 2 K. Dotted lines indicate 95% confidence level.

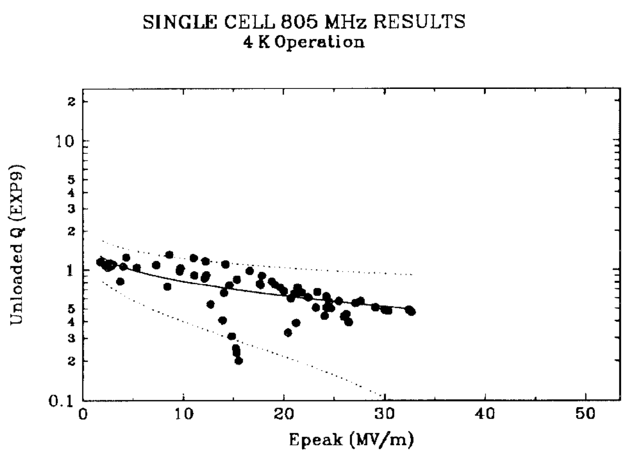

Figure 2. Q vs. Peak surface electric field at 4 K. Dotted lines indicate 95% confidence level.

until the cell "cleans up." The data shown in figures 1 and 2 are obtained after the conditioning process.

B. High Pressure Water Jet

A high-pressure pure water (HPPW) jet was used to recondition 805-MHz cavities. The cavities for these tests were previously used to obtain the data in figures 1 and 2. The HPPW cleaning was performed on a cavity that was exposed to room air, at room temperature. The pressure at the jet head was 800 psi; the pump is capable of 2000 psi. Cavitation at the pump inlet forced us to adjust the pressure to the lower value. Duration of the HPPW cleaning was 10 minutes for these tests. A single nozzle with three holes ejected the water in a horizontal direction. The nozzle head moved vertically inside the cavity, driven by a motorized drive screw at the rate of 5 cm/minute.

At this time, three cavity tests have been done. The results are shown in figure 3. After exposure to room air, the

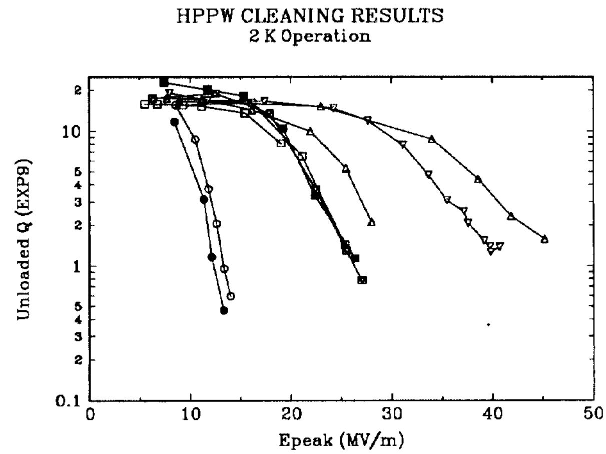

Figure 3. Q vs peak surface field at 2 K. a) Cavity performance after exposure to room air (circle), b) Cavity performance after first HPPW cleaning (box), c) Cavity performance after second HPPW cleaning (triangle).

cavity performance was degraded due to heavy electron loading. After cleaning with HPPW, the performance improved, attaining some of the highest values for all cavity tests.

C. Glow Discharge Cleaning

An 805-MHz cavity was cleaned using glow discharge cleaning in Argon. A niobium rod of 1.3-cm diam. was inserted axially to serve as the cathode. A niobium disk (7.6 cm dia., 0.9 cm thick) was mounted at the end of the rod and positioned in the center of the elliptical cavity. Currents of approximately 300 ma at voltages of 600 volts were maintained for 8 hours. Visual inspection of the vacuum-seal end plates on the cavity demonstrated that niobium had been sputtered from the cavity surface. The initial results, after glow discharge cleaning, show that the performance was reduced by a factor of approximately four (11 MV/m, at a Q of 0.5×10^9). The cavity was removed from the test system and vacuum baked at 200 C for 180 hours. After the bake, the partial pressure of the argon was reduced by a factor of 6. A subsequent test showed that the performance was still adversely affected (10 MV/m, at a Q of $0.5\mathrm{X}10^9$). After a 30-second dip in 1,1,1 bcp the performance improved (18 MV/m at a Q of $0.5\mathrm{X}10^9$). Our calculations indicate that a dip of this duration will only remove approximately 4 mm of niobium. These results are in accord with the idea that the sputtered niobium was the cause of the degraded performance of this cavity.

D. Superconducting Magnet to study cavities performance in a DC field

Compared to copper cavities, SC cavities can achieve substantially greater accelerating gradients with negligible thermal loss in the cavities. A parameter related to the accelerating gradient that must also be considered in accelerator facility design is the real-estate gradient (total potential change/total length of accelerator). Depending on the facility parameters maximizing the real-estate gradient can be of major importance. One possible way of doing this with SC structures is through the use of focusing elements that operate at cryogenic temperatures. Such focusing elements can eliminate transition to room temperature, and minimize the spacing between cavities. While this has the advantage of an increased real-estate gradient, there are several potential problems:

- how does the proximity of the DC fringe fields from the focusing elements to the iris of the SC cavities affect the performance of the cavity?
- how difficult is it to recover from a cavity quench?

To study these problems, we have constructed a small (5.7 cm long by 4.9 cm inside diameter) solenoid with superconducting wire[4]. This solenoid is about the size of a focusing solenoid for an accelerating structure made from the 3-GHz cavities. This solenoid has been tested to a current of 100 Amperes where the central, on-axis, field was measured to be 2 Tesla. With a 4-Tesla central field, we expect to generate fields at the cavity iris that approach the critical field in niobium. Experimentally for the initial test, we plan to cool a cavity and measure the cavity performance with the solenoid off. Then measurements of the cavity performance, at discrete values of the solenoid field, will be performed. These measurements are similar to measurements of Ref. 5 performed with a 50-MHz structure. Other studies will be performed to determine methods for recovery after a cavity quench in the presence of the DC magnetic field.

IV. REFERENCES

[1] B. Rusnak et al., "Superconducting Cavity Development at Los Alamos National Laboratory," Conference Record of the 1991 IEEE Particle Accelerator Conference, Vol. 2, pp. 1046-1047.

[2] B. Rusnak et al., "Evaluation of Surface Contamination and Cleaning Techniques on Superconducting RF Cavities," 1992 Linear Accelerator Conference Proceedings, Vol. 2, pp. 728-730.

[3] D. J. Liska et al., "Design Features of a Seven-Cell Cavity High-Gradient Superconducting Cavity," 1992 Linear Accelerator Conference Proceedings, Vol. 1, pp. 163-165.

[4] Wire used has 54 filaments of NbSn with a copper-to-superconductor ratio of 1.35 to 1, and is 0.035-in diameter (without insulation). Insulation of formvar was added to bring the wire diameter to 0.037 inches.

[5] R. Benaroya and K. W. Shepard, Rev. Sci. Instruments **59**, 2100 (1988).