Preparation and Testing of a Superconducting Cavity for CESR-B*

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Abstract

A 500 MHz niobium cavity was delivered to Cornell in January, 1992.† The key features of the cavity design are a large, i.e. 24 cm diameter, circular beam tube which allows all but two of the higher-order modes (HOM's) to propagate away from the cavity, a "fluted" beam tube which allows the remaining HOM's to propagate, and a waveguide fundamental input coupler [1]. The cavity was tested vertically in the as-received condition and almost achieved the design criteria. After this initial test the cavity was etched, rinsed and dried, and tested again. Modest helium processing enabled the cavity to exceed the design criteria of E_{acc} = 10 MeV/m and $Q_0 = 10^9$. No indication of multipacting was observed in any of the tests. Several warm-up/cool-down cycles have been made. A cool-down procedure which avoids the "Q-virus" problem has been identified.

I. INTRODUCTION

The first Cornell B-factory cavity is shown in Figure 1. The large beam tubes serve as higher order mode (HOM) couplers, allowing the HOM's to propagate to the HOM loads which are outside the cryostat [2]. The CESR-B design calls for each cavity to operate at an accelerating gradient of 10 MeV/m (25 MV/m peak surface field). To provide the necessary acceleration in CESR-B, 400 kW of RF power must flow through a room temperature window [3] and through the coupler. A waveguide, rather than coaxial, coupler was chosen because of the lower power densities and the relative ease of cooling the surfaces subjected to high fields [1].

Several vertical tests have been made to date. Two adjustable coxaial couplers were available for power input for these tests; both could achieve critical coupling. The coupler most often used was the one in the resonant waveguide shorting hat. Two more fixed couplers were used to monitor the cavity fields. Four titanium rods attached to the endplates braced the cavity against collapse while it was evacuated. Several thermometers were affixed to the cavity and X-radiation was monitored directly above the dewar. Our standard cool-down procedure took the cavity from room temperature to 4.2K in a couple of hours. After several tests with this cool-down procedure, several slower cool-downs were tried in an attempt to identify our susceptibility to the "Q-virus". All tests were performed at 4.2K.

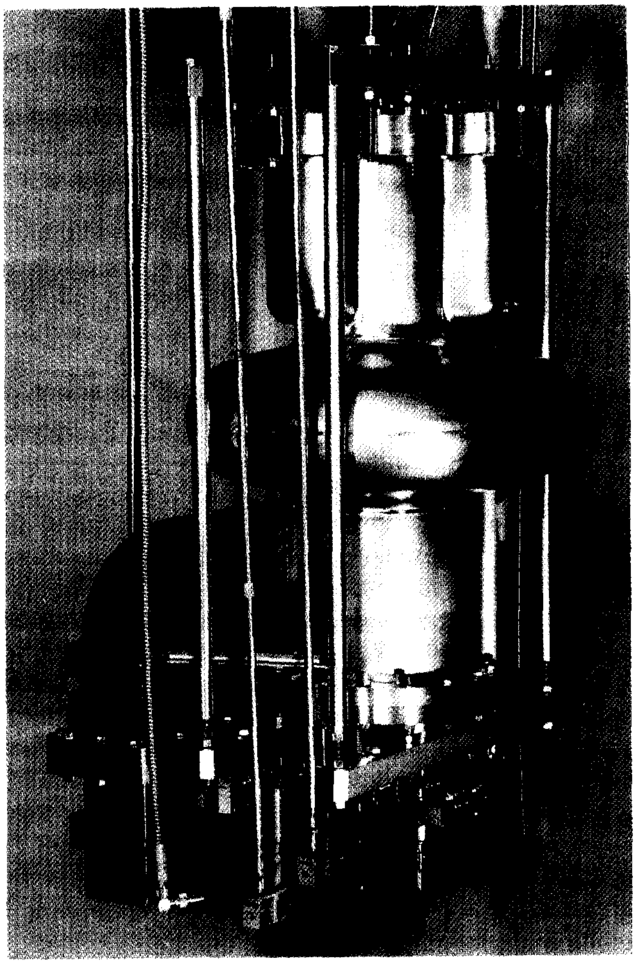

Figure 1. The 500 MHz cavity prepared for vertical testing.

II. TESTING WITH A FAST COOL-DOWN

The cavity received its initial chemical treatments at Dornier. Approximately 90 μm of the cavity surface was removed from the component parts prior to final welding. After welding, an additional 15 μm was removed from the inside surface using 112 BCP at 15-20°C. The cavity was vacuum dried, sealed in a class 100,000 room with ambient air, and shipped to Cornell. Upon receipt at Cornell the cavity was rinsed with methanol sprayed at ~40 psi, dried in a class 100 clean room and sealed for testing.

The results of the first test are shown in Figure 2. No helium processing was used, although a small cold leak developed during testing. It is remarkable that the performance of the cavity was so close to the design goal. Processable breakdown began at 2 MeV/m. This was later found to be

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† The cavity was fabricated by Dornier GmbH. The RRR of the niobium used was ~240.

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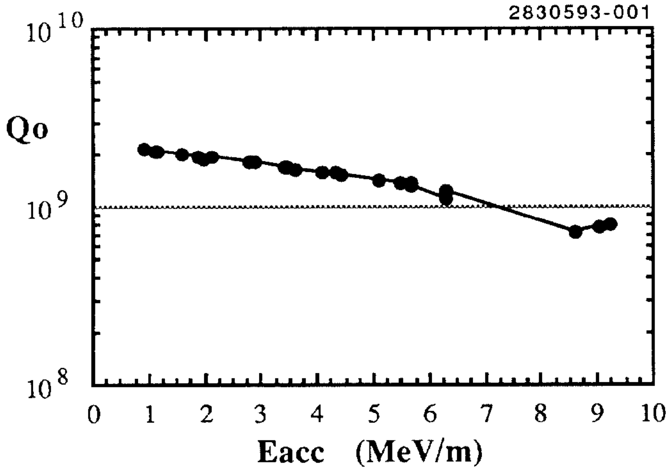

Figure 2. Q_o vs E_{acc} for the first cavity test. The cavity received only a methanol rinse following shipment.

caused by field emission heating of the coupler tongue. The coupler tongue had been hollowed to admit liquid helium for cooling. When tested vertically, heating of the tongue caused a gas pocket to form. The addition of a snorkel allowed the gas to vent and this problem was eliminated in all subsequent tests.

After the first test it was found that the waveguide indium seal was leaking. This was because the flanges were 0.030"-~0.060" (0.76-1.52 mm) thinner than specified and the flange clamps, therefore, could not apply sufficient pressure to compress the indium (shims were used in subsequent tests). The cavity was then disassembled for etching. Before etching, the external Q of the coupler was measured to be 1.75 x 10^5. The design value was 2 x 10^5.

The cavity was etched with 112 BCP. Four etch cycles of four minutes each were used to remove a total of ~32 μm. (Only the inside of the cavity is etched with our new etching facility.) Unfortunately, our acid thermometry was not properly calibrated so the temperature of the acid is unknown.

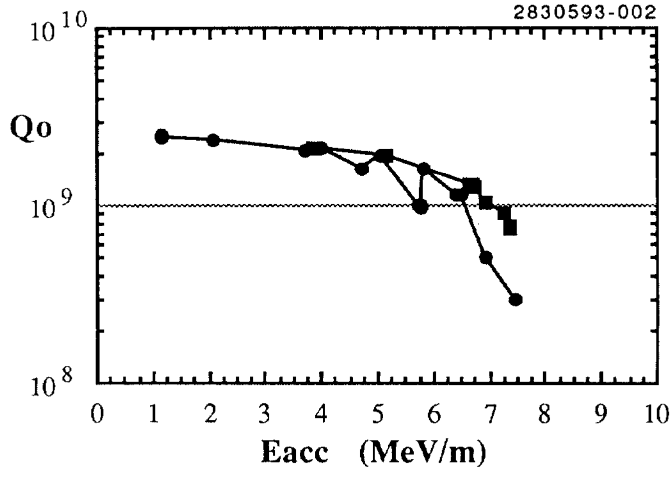

Figure 3. Q_o vs E_{acc} for the cavity test after etching. RF processing only. The field was increased twice.

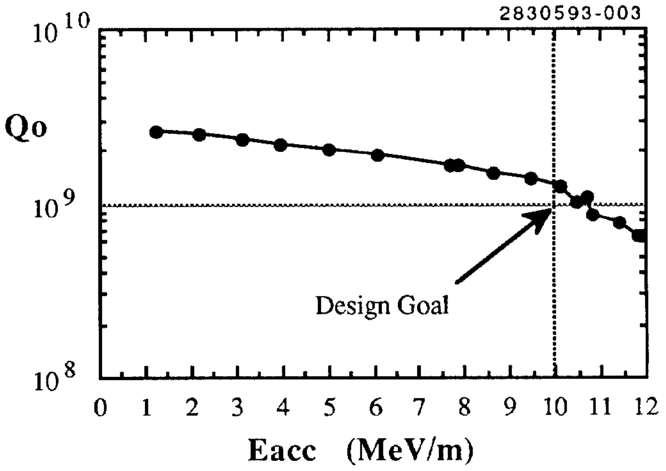

Figure 4. Q_o vs E_{acc} after modest helium processing.

The cavity performed quite well after this acid treatment. Figure 3 shows the efficacy of RF processing. After two attempts at RF processing, a small amount of helium was admitted to the cavity. Helium processing enabled us to exceed the design criteria, as shown in Figure 4. The effect of radiation pressure on the CW resonance frequency, f, is shown in Figure 5. The input coupling was fixed at high fields at $Q_{ext} \approx 10^9$. As the field was slowly lowered data were taken, portraying a parabolic dependence of f on E_{acc}. The field was increased again and then immediately lowered, yielding the two filled data points in Figure 5. The change in f shown in Figure 5 corresponds to a pressure change of less than 2 torr.

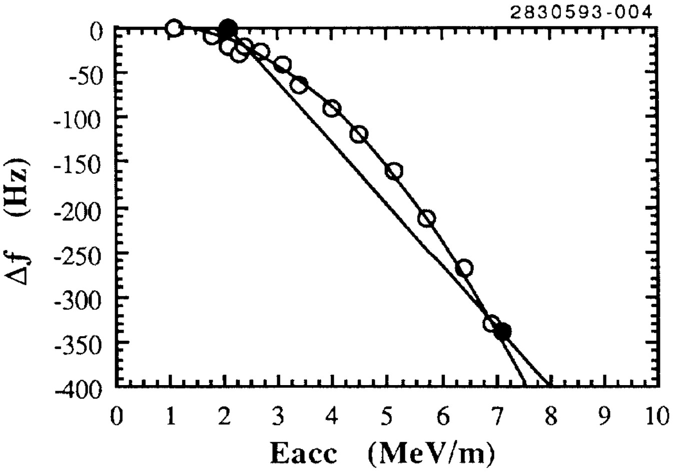

Figure 5. Effect of radiation pressure on the CW resonance frequency. The input coupling was fixed at $Q_{ext} \approx 10^9$.

III. EFFECT OF COOL-DOWN RATE

In the RF superconductivity literature there have been numerous references to the "Q-virus" (see [4] for the most recent summary of outbreaks and causes). The indication that a cavity is "infected" with this "virus" is that cooling the cavity quickly yields high Q_o values, while slow cooling yields Q values an order of magnitude lower. A series of tests was performed in order to understand the extent to which this cavity was affected.

With the cavity installed in its cryostat, an overall cool-down rate of ~10K/hr is anticipated. For deleterious Q effects, the sensitive temperature region during cooling is between 170K and 77K. Cooling at 10K/hr would keep the cavity in this danger zone for 10 hours. A uniform cool-down was approximated by quickly cooling the cavity to a temperature in the danger zone, holding it at that temperature for ~10 hours, and then quickly cooling it to 4.2K.

Our first attempt involved holding the cavity at ~130K. It was found that the low field Q_o had degraded to 10^9.

Because of the uncertainty of the acid temperature during the preceeding etch, it was decided to etch the cavity again, this time paying particular attention to the acid temperature. A total of ~6 µm was removed in two cycles. The acid temperature never exceeded 17°C.

The cooling curves of the next three cool-down tests are shown in Figure 6. Type E thermocouples were attached to the top and bottom flanges of the cavity for temperature measurement. The tests were performed in the following order: slow cool with a 130K hold; fast cool; slow cool with a 160K hold. The cavity was warmed to room temperature between each test. It should be noted that during the fast cool-down the temperature difference between the top and bottom flanges could be as high as 140K.

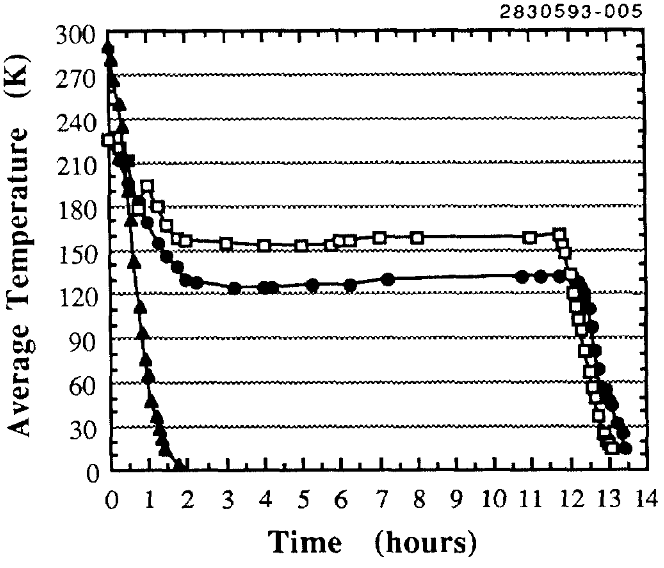

Figure 6. Average temperature of the cavity during the slow cool-down tests.

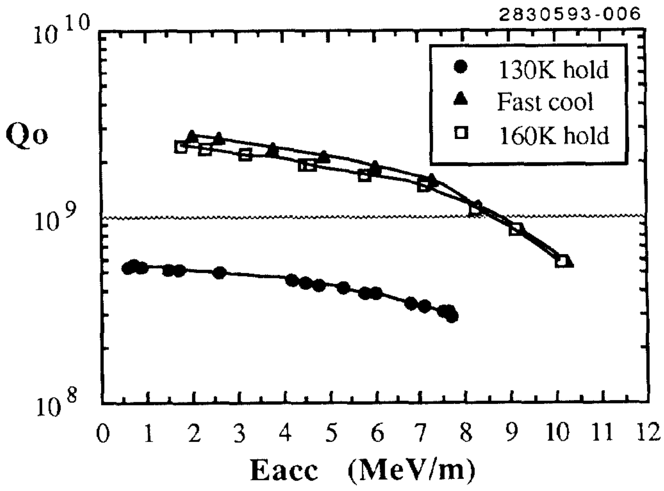

Figure 7. Q_o vs E_{acc} for the cool-downs shown in Figure 6.

The Q_o vs E_{acc} curves are shown in Figure 7. The effect of the "Q-virus" was readily apparent in the test with the 130K hold and, therefore, the test was cut short. Following the fast cool, the Q_o curve was comparable with that in Figure 3. Helium processing was not tried because the cavity performance was very close to the design goal. Reaching this goal will require only modest helium processing. The experience at DESY is that 150K is the critical temperature for the "Q-virus" [5]. We left a margin for error and held the cavity at 160K for the last test. As shown in Figure 7, the cavity performance was equivalent to that after a fast cool.

IV. SUMMARY

The Cornell B-factory cavity performed quite well "right out of the box." After brief helium processing the cavity exceeded the design goals of $Q_o = 10^9$ at $E_{acc} = 10$ MeV/m.

Tests of sensitivity to cool-down rate showed that a slow cool-down with a hold at 130K lowered the Q_o values at all fields by a factor of ~6. Holding at 160K did not adversely affect cavity performance. For the future beam line tests the cryostat will be cooled slowly to 160K and then cooled quickly to 4.2K. Helium processing is not anticipated because of the availability of RF power sufficient to process the cavity.

V. REFERENCES

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