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# TEST OF SUPERCONDUCTING ACCELERATOR STRUCTURES IN A CLOSED VACUUM SYSTEM

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## Abstract

During the installation of superconducting accelerator structures into the helium cryostat the evacuated cavities usually have to be let up to atmospheric pressure . This procedure represents a risk to the cavity performance and in many cases degradations have been observed .
An assembly scheme for superconducting accelerator structures has been devised , which avoids the exposure of the interior cavity surface to gases and minimizes the probability of accidental deposition of dust or debris on the cavity surface .
Two gate valves are mounted onto the cavity assembly at both beam - pipe ends and the rf - coupling port is closed with a vacuum tight rf - window . This assembly permits the pre - testing of accelerator sections in a laboratory test set - up and the evaluation of their performance prior to the installation into the cryostat. Tests on the CORNELL/CEBAF elliptical niobium cavity and the effects caused by actuating the gate valves are reported .
In an assembly of two 5 - cell cavities into a cavity pair of 1 m length an average accelerating gradient of $E_{acc}$ = 10.4 MV/m has been achieved .


## Introduction

Superconducting rf - cavities have in recent years shown significant improvements in their performance and several large scale applications are now under consideration [1] .
Nevertheless , the transfer of the technology from a laboratory scale to a large scale application as in an accelerator in a way , which avoids any degradation in performance of the cavities has not yet been fully demonstrated . The conditions of assembly of cavity units into cryostats are often more demanding than in a laboratory environment and challenge the sensitivity of the niobium rf - surface to long periods of exposure to atmosphere , to cleanliness and to accidental debris generation , which might result in Q - or field degradations or increased electron loading in these devices .
By hermetically sealing the cavities and keeping the inner surfaces under vacuum , one can avoid both multiple exposures and minimize the risk of contaminating the cavity during these operations .

## Sealed cavity concept

The experiments developing the sealed cavity concept have been carried out in two steps . In a first step a single 5 - cell elliptical , Cornell - type L - band cavity [2] is used and in a second step the concept is investigated with a cavity pair , which will eventually be the building bloc of the CEBAF accelerator [4] .

## Single 5 - cell cavity tests

Figure 1 shows the test set - up for the single 5 - cell cavity tests . The cavity is at both beam - pipe ends equipped with viton O - ring sealed gate valves , which in connection with an indium sealed Kapton rf - window in the fundamental power coupler waveguide hermetically seal the cavity and allow its evacuation at room temperature . This is a highly desirable feature , because it allows after a cryogenic test , during which the gate valves are open and the cavity is continuously pumped via an ion getter pump , the detachment of the cavity from the test set - up without exposing the interior cavity surface to any gas at atmospheric pressure . The cavity can than further be handled for subsequent tests .

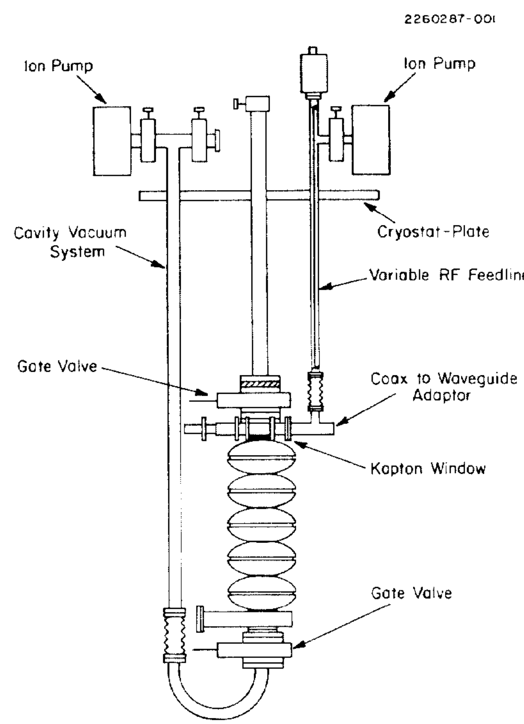


Figure 1: Experimental Test Set - up for 5 - Cell Cavity Test

The excitation of the rf - fields in the cavity is accomplished by means of a variable coaxial rf - feedline connected to a waveguide - to - coax - transition piece attached to the fundamental coupler of the cavity ( detail of assembly in figure 2 ) . The coupling hole is located at a distance of 128 mm from the beam line in a field of about 30% of the field maximum on center [3] , which permits a comfortable variation of the external Q - value between $3 \times 10^9$ and $6 \times 10^{10}$ by moving the feedline in the cut - off tube of figure 2 .
5 - cell cavity LE 5 - 4 , which was last used in the Cornell beam - test [5] , was chosen for this experiment . In the beam - test the cavity exhibited a Q - value of $Q = 1.6 \times 10^9$ and break - down occurred at an accelerating gradient of $E_{acc}$ = 6.5 MV/m .



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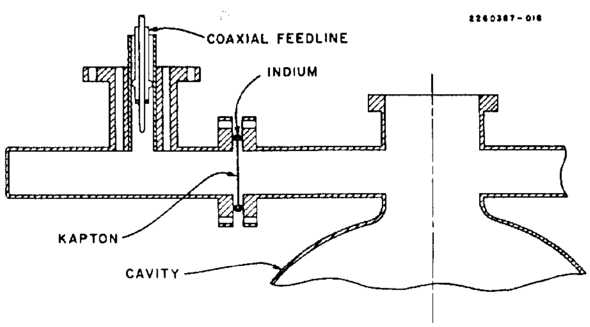


Figure 2 : Detail of Coax - to - Waveguide Assembly

Prior to the gate valve test the external Q - value of the fundamental power coupler was adjusted from 120 000 to $1.1 \times 10^6$ and the field profile on axis was adjusted to be flat within 3 % .
The cavity was first retested after 30 sec of buffered chemical polishing and assembly in the clean room with the Kapton rf - window and the coax - to - waveguide adaptor attached . The Kapton film ( Type "H" , 5 mil thickness ) had been baked for 12 hrs at a temperature of $150^{\circ}$ C in a vacuum of about $10^{-6}$ torr . At the end of the baking cycle the vacuum in the baking system had improved by at least one order of magnitude . Unfortunately , when attempting to install the assembled cavity to the test stand , we encountered mechanical problems with the fit - up of the cut - off tube in the coax - to - waveguide adaptor and the outer conductor of the feedline . This required additional machining of the niobium tube . Therefore the cavity had to be placed back in the clean room , the Kapton window/waveguide assembly was removed , the cavity was filled with methanol and left in the clean room for 12 hrs . A freshly baked Kapton window was assembled to the coax - to - waveguide transition before being attached to the cavity .
Even though the Kapton foil was exposed for less than 3 hrs to room air - after the baking Kapton is quite hydrolytic - it took several days to achieve a vacuum in the low $10^{-7}$ torr range both inside the cavity and the rf - feedline at room temperature .
The results of this test are listed in table 1 .

| TEST #/ T [K] | $Q_0$ (LOW FIELD) | $Q_0$ (AT BD) | $E_{ACC}$ [MV/m] | SURFACE TREATMENT | COMMENTS |
|---|---|---|---|---|---|
| 1 / 1.9 | $8 \times 10^9$ | $5.8 \times 10^9$ | 6.4 | 30 SEC BCP | KAPTON WINDOW + COAX-WAVEGUIDE TRANSITION |
| 2 | | | | DISASSEMBLY METHANOL RINSE | GATE VALVES ATTACHED FEEDLINE PROBLEMS |
| 3 / 2.0 | $5.6 \times 10^9$ | $3 \times 10^9$ | 6.6 | CAVITY VACUUM MAINTAINED | DISASSEMBLY FROM TEST STAND,GATE VALVE 6x CYCLED |
| 4 / 2.0 | $5.6 \times 10^9$ | $1.8 \times 10^9$ | 6.7 | CAVITY VACUUM MAINTAINED | GATE VALVES 10x CYCLED ON TEST STAND |

Table 1 : Summary of Test Results on 5 - Cell Cavity

At 2 K a Q - value of $7.5 \times 10^9$ was measured and the field level could continuously be raised to the break down level of $E_{acc}$ = 6.4 MV/m except for a very light multipacting level around 4.2 MV/m , which processed rapidly within 2 min . No field emission loading was observed .
The Kapton window itself does not seem to have introduced additional losses in the high Q system .
In preparation for the subsequent test with the gate valves the cavity as well as the coupling system was slowly let up to nitrogen gas through a 0.2 μm filter . The cavity was detached from the test stand and the indium sealed adaptor pieces were disassembled from the cavity in the clean room . During this operation it was made sure that always the pieces to be detached were located below the cavity to avoid accidental debris deposition in the cavity . After the removal of the indium gaskets from the flanges the cavity was carefully rinsed in methanol and any immersion of the Kapton foil into the methanol was avoided . The gate valve subassemblies , which had been ultrasonically cleaned in methanol , were attached to the cavity as shown in figure 1 and subsequently the cavity was mounted to the test stand . The upper gate valve was blanked off as indicated in figure 1 . Cavity and feedline system were evacuated separately . Even after several days of pumping the cavity vacuum did not improve significantly and remained in the high $10^{-7}$ torr range - about a factor of 10 worse than usually . This behaviour is probably caused in part by outgassing of the viton O - rings in the gate valves exposed for a short time to methanol [6] .
Because of a short in the feedline , the cavity had to be warmed up again after initial cool - down ; the gate valves were closed after the gate mechanism had been exercised 6 times and the cavity was detached from the test stand . After the feedline problems had been corrected , the cavity was reattached and test # 3 as indicated in table 1 was carried out .
In a forth test the cavity remained on the test stand after warm up and both gate valves were completely closed and opened 10 times . With the gate valves closed for more than 1 hour the vacuum in the cavity did not degrade .
Up to a gradient of $E_{acc}$ = 4 to 5 MV/m the Q - value was nearly independent of field level . Above 5 MV/m field emission loading was observed , which was in test # 4 significantly reduced within 30 min of rf - processing . In addition , the break - down field level increased to 7.4 MV/m indicating that the quench might have been initiated by field emission .

## Cavity pair test

To further investigate the feasibility of the sealed cavity concept in a more complex system , we have assembled two 5 - cell cavities - Cornell cavity LE 5 - 5 and Cornell type cavity Dornier I manufactured by Dornier Company - to a cavity pair as shown in figure 3 .
5 - 5 had been used in the Cornell beam test and LE exhibited a field of only 2.4 MV/m ; the low break - down field was probably caused by debris deposition during installation into the CESR storage ring . This cavity was recovered to a field level of $E_{acc}$ = 11.9 MV/m just by rinsing the surface with methanol - a further indication of contamination . Cavity Dornier I had originally an accelerating gradient of $E_{acc}$ = 7.9 MV/m and a resonant frequency , which was 15 MHz too low . By solid state gettering in the presence of Ti [7] at $1300^{\circ}$ C the interstitiell

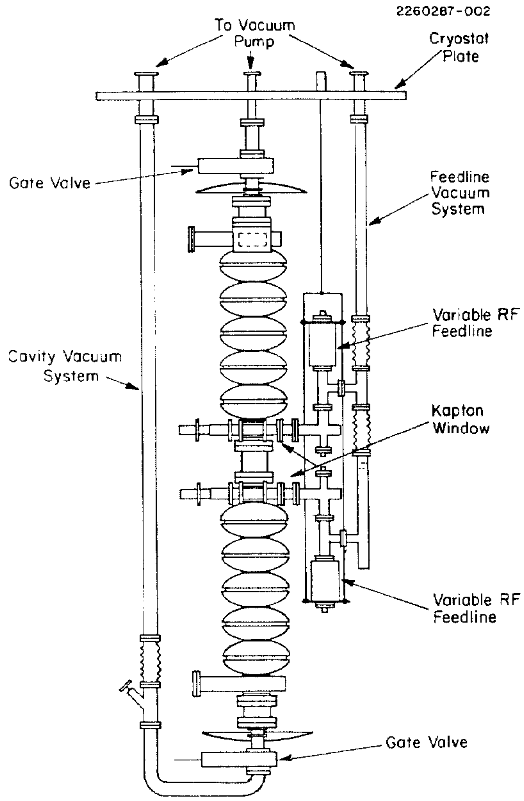


Figure 3 : Cavity Pair Test Set - Up

impurities in the niobium were partially removed re - sulting in a softer material with higher thermal con - ductivity . After tuning the cavity to the right frequency and surface preparation by buffered chemical polishing the cavity exhibited in a subsequent test an accelerating gradient of $E_{acc}$ = 10.4 MV/m . No quench was observed as in the original test , but the achievable gradient was limited by a high level of field emission loading.
After buffered chemical polishing for 1 min both cavi - ties were assembled in the clean room into a pair and then transferred to the test set - up . Cavity and feedline system were simultaneously evacuated by means of a turbomolecular pump before being switched to separate ion getter pumps . After several days of pumping the vacua did not improve beyond $10^{-6}$ torr . Test results are shown in figure 4 .

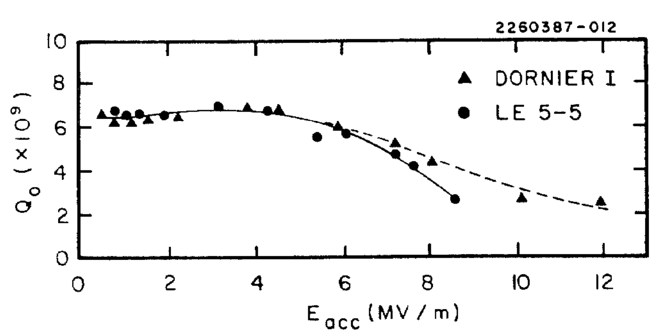


Figure 4 : Test Results on Cavity Pair

Both cavities had a Q - value of Q = 6.5 x $10^9$ at 2 K and at low field levels . In both cavities some multipacting was observed , which processed in less than 30 min and allowed the field levels to be raised continuously . In cavity LE 5 - 5 - this cavity was mounted below cavity Dornier I and probably absorbed most of the residual gas in the assembly on its surface when cooled down first - a field level of $E_{acc}$ = 8.9 MV/m was reached before strong field emission loading prevented a further increase in gradient . No break - down was observed as was also the case with Dornier I , in which the gradient could be raised up to $E_{acc}$ = 11.9 MV/m , before limitation by field emission loading was setting in . At this field level the Q - value had dropped to Q = 2.4 x $10^9$ .

## Conclusion

The experiments demonstrate the feasibility of the sealed cavity concept , even though in some of the tests a somewhat increased level of field emission loading has been observed . It is conceivable that this behaviour is partially caused by the mediocre room temperature vacuum in the cavity due to out - gassing of the viton O - rings in the gate valves and by poorly vented O - ring grooves in the present design . Improved pre - baking or the selection of a different O - ring material as well as the proper groove design should correct this problem .
The experiments indicate that very likely degradations in cavity performance can be avoided .
This sealed cavity concept will be implemented in the CEBAF accelerator . With a 1 m long cavity pair , which will be the building bloc of this accelerator , an average accelerating gradient of $E_{acc}$ = 10.4 MV/m has been obtained , a value , which is well above the design value of $E_{acc}$ = 5 MV/m .

## Acknowledgement

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## References

1. e.g. H.Lengeler, "Recent Developments in RF - Superconductivity for Linac Structures," Proc. 1986 Lin. Acc. Conf., Stanford , Cal., USA
2. P.Kneisel et al., "Performance of Superconducting Storage Ring Cavities at 1500 MHz," IEEE Trans. Mag.,Vol. MAG-21, pp 1000 , 1985
3. C.Reece, "Fundamental Power Coupler E - Field Pro - file Measurements," Internal Note SRF - 831201 , Cornell University
R.Sundelin, "Critical Coupling into Waveguide Hat," Internal Note SRF - 851102 EXA , Cornell University
4. C.W.Leemann,"The CEBAF Superconducting Accelerator - An Overview," Proc. 1986 Lin.Acc.Conf.,Stanford, Cal., USA
5. R.Sundelin,"High Gradient Superconducting Cavities for Storage Rings," IEEE Trans.Nucl.Sci,NS-32 , pp 3570, 1985
6. J.Parkinson,H.Padamsee,"Evaluation of the K.J.Lesker Gate Valve for CEBAF," Internal Note SRF - 860502 EXA , Cornell University
7. P.Kneisel,"Use of the Ti Solid State Gettering Process for the Improvement of RF - Cavities," J.Less Common Metals , to be published