DEVELOPMENTS OF 700-MHZ 5-CELL SUPERCONDUCTING CAVITIES FOR APT*

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Abstract

We have manufactured a total of six β=0.64, 700-MHz 5-cell cavities. The APT (Accelerator Production of Tritium) specification requires $Q_0 > 5 \times 10^9$ at an accelerating field of 5 MV/m. So far, the results of vertical tests have shown maximum accelerating fields of 12 MV/m (peak surface field of 41 MV/m) and maximum low-field Q_0 of 3.6×10^{10} at 2 K. The present limitations are available input power, field emission and quench. This type of cavities will also be used for an ADTF (Accelerator-Driven Test Facility) for AAA (Advanced Accelerator Applications) project.

1 INTRODUCTION

The APT accelerator, if it is built, is a 100-mA, 1.7-GeV CW proton linac [1]. A number of papers have been published on the development of APT superconducting cavities, power couplers and cryostats in the past [2-23]. Since APT was named as a backup option to the commercial light-water reactor program in December 1998 [24], the ED&D activities shrank significantly. Tests, however, of all the six 700-MHz 5-cell cavities manufactured as part of prototyping efforts have been performed in vertical cryostats at LANL and TJNAF (Thomas Jefferson National Accelerator Facility). This paper presents the results of these tests as well as brief future plans.

2 CAVITIES

Table 1 shows the names, niobium suppliers, manufacturer and the initial thickness of the niobium of all the cavities. The LANL cavity was made in house at LANL. AES stands for Advanced Energy Systems, an American company. The last four cavities were manufactured by CERCA, a French company, and the cavities were named after popular female names of the countries where niobium suppliers are located.

Table 2 shows the parameters of the cavity. CERCA cavities were manufactured after LANL and AES cavities and their parameters are slightly different due to the increase in radius of the end beam pipe from 6.5 cm to 8 cm. This modification was made to obtain sufficient coupling between power coupler and beam [26].

Cavities are made of RRR=250 niobium and their inner surfaces were chemically etched 150 μm at the manufacturers. Figure 1 shows a cavity installed in the cryostat insert.

Table 1: List of all the APT Prototype Cavities

Cavity Name	Nb Supplier	Manufacturer	Nb Thickness
LANL	Teledyne Wah Chang	LANL	3.175 mm
AES	Wah Chang	AES	3.5 mm
Ayako	Tokyo Denkai	CERCA	4 mm
Eleanore	Wah Chang	CERCA	4 mm
Germaine	Heraeus	CERCA	4 mm
Sylvia	Wah Chang	CERCA	4 mm

Table 2: Parameters of APT 5-cell Cavities

Frequency	700 MHz
β	0.64
R/Q	392(374) Ω
Geometrical Factor	149 Ω
E_p/E_{acc}	3.381 (3.272)
H_p/E_{acc}	69.6(68.6) Oe/MV/m

Note: the values in the parentheses are for LANL and AES cavities.

Figure 1: APT 5-cell cavity set on the cryostat insert.

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3 SURFACE TREATMENT AND PREPARATION AT LANL

After delivery to LANL, the cavities were chemically etched again with a standard BCP (Buffered Chemical Polishing) solution of 1:1:2 [3]. Then, they were rinsed with high-pressure deionized water at ~950 psi in a class-100 clean room and assembled with couplers, flanges and vacuum valve. Once sealed in the clean room, the cavity was moved to a measurement room, set on the cryostat insert, and pumped down and leak checked. Before cooled down, the cavities were baked at 150 °C for 48 hours. It should be noted that no cavities were baked at temperatures higher than this before testing.

4 TEST RESULTS

Figure 2 shows the Q-E curves of all the cavities. The tests conducted at TJNAF are marked as JLAB with the legend. The data for Eleanore cavity between 4 MV/m and 11.5 MV/m are missing since we could not take the final data due to damage to the driving coupler cable. As for the LANL cavity, there were difficulties in performing the final equator weld in the middle cell and we found the Q_0 drop shown in Fig. 2 was caused by some defect at this equator from heating detected by a temperature sensor. Before the LANL cavity was tested, low-field Q_0 obtained at LANL were lower than that recorded by TJNAF. We have been investigating the cause of these differences. Rinsing process right after BCP might have contributed to the better Q_0 since the LANL cavity was filled with DI water and kept overnight before HPR (High Pressure Rinse).

4.1 Limitations

At LANL, the available RF power was limited to ~ 250 W. Degradation of Q_0 due to field emission limited performance, although it appeared that most of the cavities would have quenched at fields slightly higher than their maximum fields due to heating at defects or heating by electron bombardment on the surface. At TJNAF, however, they stopped measurement of the AES cavity so as not to damage the driving coupler cable. Germaine and Sylvia cavities were limited by quench.

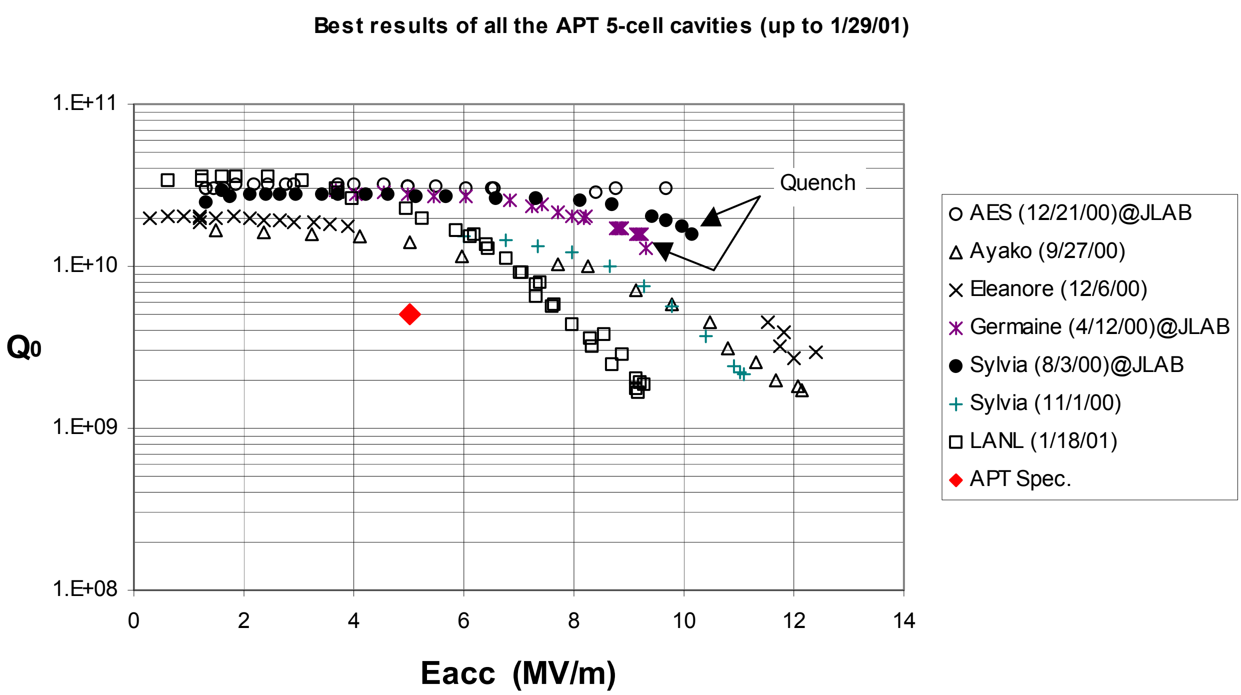

Figure 2: Vertical test results of all six 5-cell cavities developed for APT. Test temperature was 2 K.

5 DISCUSSION

The results shown in Fig. 2 are the best results for each cavity. Some cavities needed extra chemical etching (100-200 μm), RF processing and/or helium processing, although processing did not take more than a few hours. The problem we have to solve to get higher gradients for the next project such as AAA, that would want to operate at E_{acc} as high as 10 MV/m is, field emission. Unfortunately, we have not had good diagnostic tools, such as temperature and X-ray mapping of the cavity, to determine the loss distribution inside the cavity and identify the cause of Q_0 drops.

6 FUTURE PLANS

We are planning to identify the causes of field emissions that appear in most of the cavities using a temperature and X-ray mapping system being developed at LANL [25]. Moreover, a new 600 W power amplifier will be received soon and we will be able to do CW/pulse processing at higher power. In addition, if funded, we would like to perform a "guided repair" on the LANL cavity that indicated some defect on the equator region of the middle cell.

7 SUMMARY

The performance of all the six prototype APT 700-MHz 5-cell cavities is presented. All the cavities surpassed the APT goals with ample margin. The achievement of these results with relatively large 5-cell cavities (surface area = 0.858 m^2) and without high-temperature heat treatment (> 150 °C) is remarkable.

For the ADTF, however, the goals will be E_{acc} = 10 MV/m at $Q_0 = 5 \times 10^9$. To achieve this goal with enough margins for reliable operation, we will have to solve the field emission problem and reach a maximum field of 13-15 MV/m.

8 REFERENCES

[1] P. Lisowski, "The Accelerator Production of Tritium," Proc. PAC'97, Vancouver, B. C., Canada, May 1997, p. 3780.

[2] K. C. D. Chan, "LANL Activities" and "APT Power Couplers," Superconducting Proton Linac Workshop, Saclay, France, October 2000, http://www-dapnia.cea.fr/sea/Workshop-HPPA/index.htm

[3] T. Tajima, et al., "Results of Vertical Tests with 700 MHz 5-cell (β=0.64) Superconducting Cavities Developed for APT," Superconducting Proton Linac Workshop, Saclay, France, October 2000, ibid. [2].

[4] K. C. D. Chan, et al., "Status of Superconducting RF Linac Development for APT," LINAC2000, Monterey, CA, USA, August 2000. http://www.slac.stanford.edu/econf/C000821/authorindex.shtml

[5] J. Kuzminski, et al., "Industrial Fabrication of Medium-Beta SCRF Cavities for a High-Intensity Proton Linac," ibid. [4].

[6] E. N. Schmierer, et al., "High-Power Testing of the APT Power Coupler," ibid. [4].

[7] F. L. Krawczyk et al., "Status of the LANL Activities in the Field of RF Superconductivity," Proc. 9th Workshop on RF Superconductivity, Santa Fe, New Mexico, USA, November 1999. p. 46. http://laacg1.lanl.gov/rfsc99/rfsc99.pdf

[8] R. Mitchell et al., "Structural Analysis of the APT Superconducting Cavities," ibid. [6], p. 405.

[9] E. Newman et al., "APT Cryomodule Assembly and the Usefulness of the Mockup Model," ibid. [6], p. 459.

[10] W. B. Haynes et al., "High-Power Coaxial Coupler Design and Testing," ibid. [6], p. 570.

[11] R. C. Gentzlinger et al., "Design, Analysis and Fabrication of the APT Cavities," PAC'99, New York, Mar. 29 - Apr. 2, 1999.

[12] D. J. Katonak et al., "Superconducting RF Lab Facility Upgrades at Los Alamos," ibid. [10].

[13] J. Kuzminski et al., "Fabrication of a Prototype Medium-Beta, 700 MHz APT Superconducting RF Cavity with Industry," ibid. [10].

[14] E. Newman et al., "APT Cryomodule Assembly Process and Mockup Model," ibid. [10].

[15] K. C. D. Chan et al., "Progress of APT Superconducting Linac Engineering Development," LINAC'98, Chicago, Illinois, USA, August 1998. http://accelconf.web.cern.ch/accelconf/l98/Proceedings.html

[16] K. C. D. Chan et al., "Engineering Development of Superconducting RF Linac for High-Power Applications," EPAC'98, Stockholm, Sweden, June 1998. http://accelconf.web.cern.ch/accelconf/e98/contents.html

[17] B. Rusnak et al., "High Intensity Proton Linac Activities at Los Alamos," Proc. 8th Workshop on RF Superconductivity, Abano Terme, Italy, October 1997. p.1.

[18] W. B. Haynes et al., "Medium-Beta Superconducting Cavity Tests at Los Alamos National Lab for High-Current, Proton Accelerator," ibid. [16], p. 523.

[19] F. Krawczyk et al., "The Power Coupler Design for the APT Superconducting Accelerator," ibid. [16], p. 762.

[20] B. M. Campbell et al., "Design Status of the Cryomodules for the APT Linac," ibid. [16], p.774.

[21] B. Rusnak et al., "In-Situ Proton Irradiation and Measurement of Superconducting RF Cavities under Cryogenic Conditions," Proc. PAC'97, Vancouver, B. C., Canada, May 1997, p. 3096. http://accelconf.web.cern.ch/accelconf/pac97/papers/index.html

[22] F. L. Krawczyk et al., "Superconducting Cavities for the APT Accelerator," ibid. [20], p. 2914.

[23] F. L. Krawczyk, "Higher Order Mode Analysis of the APT Superconducting Cavities," ibid. [20], p. 3093.

[24] J. L. Anderson, "Technology Development for the Accelerator Production of Tritium," ibid. [10]

[25] T. Tajima et al., "A New Temperature and X-ray Mapping System for 700-MHz 5-cell Superconducting Cavities," this conference.

[26] P. Balleyguier, "External Q Studies for APT SC-Cavity Couplers," ibid. [14], p. 133.