CEBAF Cryomodule Testing

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Abstract

CEBAF is a 4 GeV 5-pass continuous electron accelerator. The superconducting accelerating system is based on 338 π-mode 5-cell niobium cavities. The cavities are arranged as four pair with end cans to a cryomodule. Each cryomodule results in a 20 MeV energy increase for the 200 μAmp electron beam. The injector contains 2 1/4 cryomodules for an energy of 45 MeV and each of the north and south linacs contain 20 cryomodules for a combined energy increase of 4 GeV. This paper describes the test results--Q's, gradients, static and dynamic heat loads, along with the electrical and mechanical performance of the cryomodules manufactured to date.

INTRODUCTION

The general cavity specifications are as follows: F_o = 1.497 GHz; $Q_o = 2.4 \times 10^9$ at a gradient 5 MV/m; $Q_{ext(FPC)}$ (Fundamental Power Coupler) 6.6×10^6; $Q_{ext(FP)}$ (Field Probe) $= 1.2 \times 10^{11}$. The active accelerating length is one meter per cavity pair. The design heat leak for a full cryomodule is 120 watts to the 40 K heat shield, a static loss of 15 watts to the 2 K circuit, and dynamic loss of 45 watts to 2 K for all 8 cavities at 5 MV/m.

ASSEMBLY

The cavities are checked for proper center frequency and field flatness upon arrival from the manufacturer, Interatom. They are then cleaned, chem polished, and assembled as a pair in our Class 100 cleanroom. The pair assembly includes ceramic waveguide windows, HOM (Higher Order Mode) loads, SMA field sampling probes, and gate valves. At this point, the cavities are pumped down and leak checked. The cavities remain hermetically sealed from this point on. The cavity pair's performance is checked at this point in a vertical dewar.[1]

Once the cavity pair passes the vertical acceptance test, it goes into the cryounit assembly area. Here the pair is fitted with elastic tuners. This tuner has a range of ±200 KHz (total travel= ±50 mils). This is driven by room temperature stepper motors with a rotary feedthrough at the vacuum shell and at the helium vessel. The position is monitored by an LVDT (Linear Variable Differential Transformer) and is interlocked with limit switches. Additionally, there are four temperature sensing diodes mounted to each cavity pair at the HOM load. This assembly is then inserted and welded in the helium vessel.[2]

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The cryounits are completed by inserting the leak checked helium vessel into a vacuum vessel and making the necessary electrical and mechanical connections. Four completed cryounits are connected together with three bridging ring assemblies and fitted with supply and return end cans. This completes the fundamental accelerator component, the cryomodule.[3]

TESTING

There is an area in the Test Lab building set aside for cryomodule acceptance testing. This facility includes refrigeration connections to both the shield and primary coolant circuits, a radiation shielded room, a pair of 2 kW klystron amplifiers, a waveguide switching system, and a control room. The cryomodule test facility allows one the opportunity to access the complete system performance prior to installation in the accelerator.

A VCO (Voltage Controlled Oscillator) system is used to phase lock to the cavities. The phase, amplitude, and frequency to lock on to the cavity is manually adjusted. A computer is used for capturing the test data via a spreadsheet to compute the performance parameters. The locking range for this system is a few KHz since the loaded bandwidth is in the mid 10^6 range.

Each of the two klystrons have "flapper" switches that allow them to be connected to any of four cavities at the press of a button. When one selects a cavity, the waveguide is switched to the VCO as well as the forward power, reflected power, and transmitted power. The switching system also connects the proper interlock channels to the RF system.

The interlocks for cryomodule testing include the following: Infrared Detector, a thermopile detector looking at the temperature of the cold and RF windows; an Arc Detector, a photomultiplier tube

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also for protection of the high power RF window; Waveguide and Beamline Vacuums; where the ion pump currents are used for window and cavity protection, and both helium level and pressure are also interlocked to the RF system for cavity safety.

RESULTS

There have been tests done on a total of four prototypical, three production, and a quarter (for the injector) cryomodules over the last three years.[4][5][6][7] Additionally, we have test results on the one and a quarter cryomodules currently installed in the injector. We have experienced a decrease in the Q_o of the cavities from the vertical test to the full cryomodule test. This degradation has recovered during the commissioning phase in the accelerator, although not completely up to its original value. We believe this reduction is due in part to ambient magnetic fields which are higher by a factor of 20 in the cryomodule test area.

CONCLUSION

The vertical tests have resulted in Q_o's > 10^{10} at 5 MV/m as well as gradient approaching > 16 MV/m. To this point, we have observed decreases in the Q_o in the cryomodule test area followed by a good recovery during commissioning to nearly twice design value. The gradient has not appreciably decreased during any of the testing. The static heat loads have also met or exceeded the design specification. The current installed injector cryomodules exceeds the design of 25 MeV/c.

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J. Lilley's help in typing the manuscript is greatly appreciated as is D. Machie's contribution.

REFERENCES

[1] P. Kneisel, J. Mammosser, G. Rao, K. Saito, R. Sundelin, "Performance of Superconducting Niobium Cavities for CEBAF", contributed to this conference.

[2] Work performed by members of the Cryounit Assembly Group.

[3] Work performed by members of the Cryomodule Assembly Group.

[4] W. Schneider, et.al., CEBAF Technical Note TN#010, February, 1991.

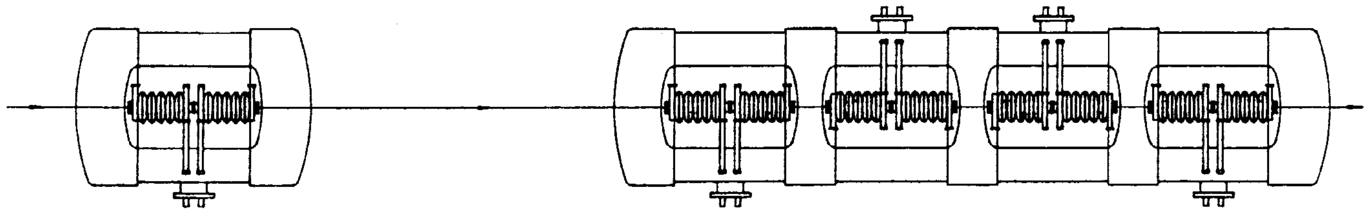
[5] W. Schneider, et.al., CEBAF Technical Note TN#009, February, 1991.

[6] W. Schneider, et.al., CEBAF Technical Note TN#021, April, 1991.

[7] W. Schneider, et.al., CEBAF Technical Note TN#023, April, 1991.

Table 1

Test Results for Injector Cryomodules



1/4 CRYOMODULE

FULL CRYOMODULE

DESIGN VALUE	CAVITY / MEASUREMENT @ 2K	IA #3	IA #2	IA #14	IA #15	IA #11	IA #9	(a) IA #8	(a) IA #7	IA #12	IA #13
2.4×10^{9}	Qo (VTA) @ 5 MV/m	4.1	5.4	12.0	7.0	25.0	10.8	9.0	6.0	20.0	19.0
5.0 MV/m	E max	11.6	8.5	8.5	9.0	7.4	8.1	7.5	7.5	14.1	12.5
2.4×10^{9}	(c) Qo (CMTF) @ 5 MV/m	1.4	5.3	1.7	1.7	1.5	3.8	2.1	2.1	2.8	2.4
5.0 MV/m	E max	8.6	8.4	7.7	6.6	7.7	6.6	4.0	3.6	12.4	9.5
2.4×10^{9}	Qo (INJ) @ 5 MV/m	>2.4	>5	4.1	6.0	6.0	5.3	1.8	1.3	4.5	4.8
5.0 MV/m	(d) E max operating	7.0	7.0	6.0	6.0	5.5	6.0	3.2	3.2	8.0	7.0
6.6×10^{6}	Qext (FPC)	(b) 7.2	6.2	9.6	7.6	4.6	5.5	8.8	8.0	9.6	6.0
1.2×10^{11}	Qext (FP)	0.9	0.9	0.7	0.7	0.5	0.6	0.8	0.8	0.5	0.7

(a) LIMITED BY WAVEGUIDE LEAK

(b) $\frac{\lambda}{4}$ TRANSFORMER

(c) LOWER Qo DUE TO HIGH AMBIENT MAGNETIC FIELD

(d) SET AT 90% OF BREAKDOWN OR FIELD EMISSION THRESHOLD

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