THE MEASUREMENTS OF STATIC HEAT LOSS AND UNLOADED Q_0 ON THE BEPCII SRF CAVITIES

BIAN Lin, LI Shaopeng, LIU Yaping
Cryogenic group, Accelerator Research Center, IHEP

Abstract

The static heat loss and unloaded Q_0 are most important values for both cryogenic system and RF system. The BEPCII SRF cavity operates in a liquid helium bath contained in a vacuum insulated, liquid nitrogen cooled radiation shielded vessel. During horizontal test at the test station, thermodynamic method is used to measure and calculate the static loss and Q_0 of SRF cavity. This paper has briefly introduced the method and process to measure the static loss and Q_0 of the SRF cavity. Results under different experimental conditions are also given. These results are also used as important data for acceptance test of the SRF cavities.

INTRODUCTION

The Beijing electron and positron collider upgrade (BEPCII) adopted the advanced double-ring scheme. It has two 500MHz superconducting RF cavities and one in each ring, called east and west cavity respectively. Before being installed in the tunnel, the cavities carried out their horizontal tests at the test station.

The static heat loss and unloaded Q_0 are most important values for both cryogenic system and RF system. Because of the characteristics of high Q value and narrow band, it is difficult to measure the unloaded Q_0 of SRF cavity by the usual microwave method. Therefore, in the horizontal tests, thermodynamic method is used to measure and calculate the static loss and unloaded Q_0 of SRF cavities. These results are also used as important data for acceptance test of the SRF cavities.

THE BEPCII SRF CAVITIES

The BEPCII SRF cavities are designed according to the KEKB type SRF cavity in Japan. As it shows in fig.1, the pure-niobium cavity is put in a 290L vessel filled with liquid helium, contained in a vacuum insulated, liquid nitrogen cooled radiation shielded vessel [1]. Helium input and output lines, nitrogen input and output lines, quench line and coupler cooling line are included.

The BEPCII SRF cavity operates in a liquid helium bath. When operating, the helium liquid level must be higher than the top of the niobium cavity, the fluctuation of liquid level must not exceed ±1%, and the range of pressure fluctuation should be within ±3mbar. In order to balance the heat load in the cavity, an adjustable KAPTON filmy heater is installed in the liquid helium vessel.

Before being installed in the tunnel, the cavities carried out their horizontal tests at the test station. The cryogenic transfer lines for horizontal tests are all multi-channel lines, which are totally about 20 meters long. Fig.2 and fig.3 show the test station flowchart, the valves box and 2000L dewar flowchart, respectively.

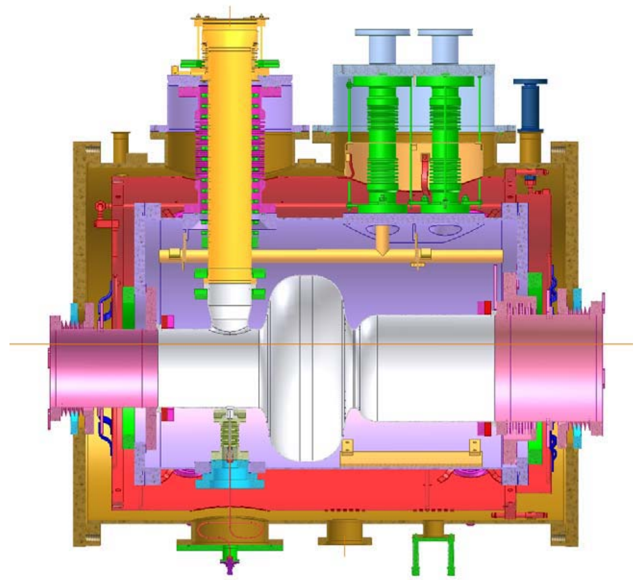

Figure 1: The section figure of SRF cavity and its cryomodule

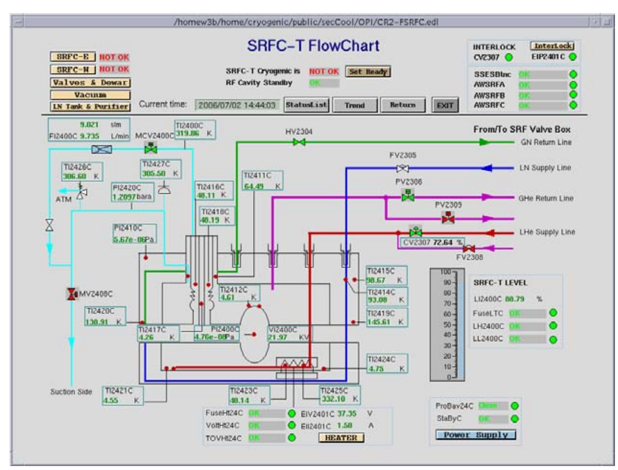

Figure 2: SRF Cavity Test station Flowchart

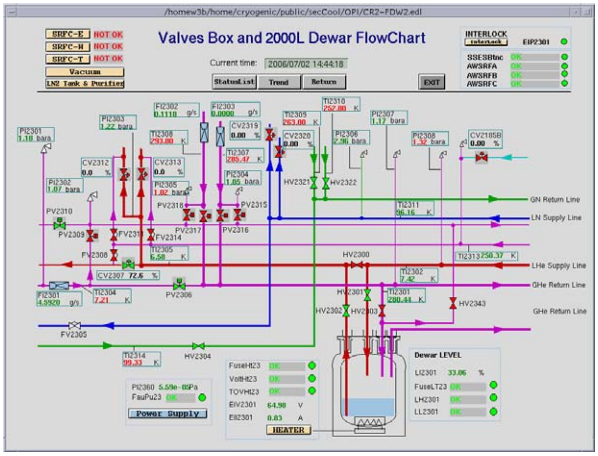

Figure 3: Valves Box and 2000L Dewar FlowChart

MEASUREMENT METHOD OF STATIC HEAT LOSS

Thermodynamic method is used for the measurements of static heat loss and total loss of SRF cavity. As known, the total loss leads to a certain consumption of liquid helium under balance state. So we can measure the consumption of liquid helium directly and then calculate the corresponding heat load. Under the normal operating state with the pressure of 1.2bara and the temperature of 4.4K, 1.498L liquid helium consumption equals to 1W heat loss [2,3]. The relations are as follows:

$$P_{total} = \frac{\Delta V(L) \times 3600(sec)}{\Delta t \ (sec) \times 1.498} \qquad (1)$$

$$P_{static} = \frac{\Delta V(L) \times 3600(sec)}{\Delta t \ (sec) \times 1.498} - P_{heater} \qquad (2)$$

In which,

ΔV——liquid helium volume consumed in the time Δt, (L);

P_{total}——total loss, (W);

P_{static}——static heat loss, (W);

P_{heater}——heater power, (W).

The details are as follows:

- Increase the liquid helium level to 98%, and meanwhile adjust the heater power to the required set point;
- Close the input valve CV2307 (as it shows in fig.2), check the cryostat pressure;
- Make a record every minute until the liquid helium level is lower than 85%;
- According to formula (1) and (2), we can get the static loss and RF loss (refer to the volume-level table of the cryostat [4]);
- Repeat the process above with different RF voltages or different heater power.

MEASUREMENT METHOD OF Q_0

According to the following formula (3), we can get the Q_0 value of SRF cavity [5]:

$$Q_0 = \frac{V_{rf}^2}{P_C * R_S / Q_0} = \frac{V_{rf}^2}{P_C * 95.3} \qquad (3)$$

In which, R_s/Q_0=95.3, V_{rf} is RF voltage from LLRF system, P_C is the RF loss.

The relation between total loss, static heat loss, RF loss and heater power is as follows:

$$P_C = P_{total} - P_{static} - P_{heater} \qquad (4)$$

RESULTS

According to the method introduced above, we have taken the measurements and calculation of the static heat loss and unloaded Q_0 for east and west SRF cavity respectively. The results are showed in tab.1~3 and fig.4, fig.5.

Table 1: Summary of static heat loss measurements

	P_{heater} (W)	Time (s)	ΔV (L)	P_{static} (W)
BEPCII East cavity	0	2322	27.8	28.8
	22.3	1242	27.8	31.5
	45.4	863	27.8	32.0
	0	2309	27.8	28.9
	54.7	787	27.8	30.2
	64	703	27.8	31.0
	73.3	658	27.8	28.2
	82.4	605	27.8	28.0
BEPCII West cavity	56.5	798	27.8	27.2

Table 2: Summary of Q measurements for east cavity

V_{rf} (MV)	Time (s)	ΔV (L)	P_{heater} (W)	P_{static} (W)	P_{total} (W)	P_C (W)	Q_O
2.00	623	27.8	0	28.85	107.2	78.4	5.35E+08
1.50	676	27.8	54.7	30.2	98.8	13.9	1.69E+09
1.00	656	27.8	64.0	31.0	101.8	6.8	1.53E+09
1.30	717	27.8	54.7	30.2	93.2	8.3	2.14E+09
1.80	1050	27.8	0	28.85	63.6	34.8	9.78E+08
1.40	715	27.8	54.7	30.2	93.4	8.5	2.41E+09
1.00	701	27.8	54.7	30.2	95.3	10.4	1.01E+09
1.20	371	16.3	61.1	31.0	105.6	13.5	1.12E+09

Table 3: Summary of Q measurements for west cavity

V_{rf} (MV)	Time (s)	ΔV (L)	P_{heater} (W)	P_{static} (W)	P_{total} (W)	P_C (W)	Q_O
1.50	1452	27.8	0	27.2	46.01	18.81	1.26E+09
1.60	1458	27.8	0	27.2	45.80	18.60	1.44E+09
1.80	1242	27.8	0	27.2	53.79	26.59	1.28E+09
2.00	978	27.8	0	27.2	68.30	41.10	1.02E+09
2.05	912	27.8	0	27.2	73.25	46.05	9.6E+08

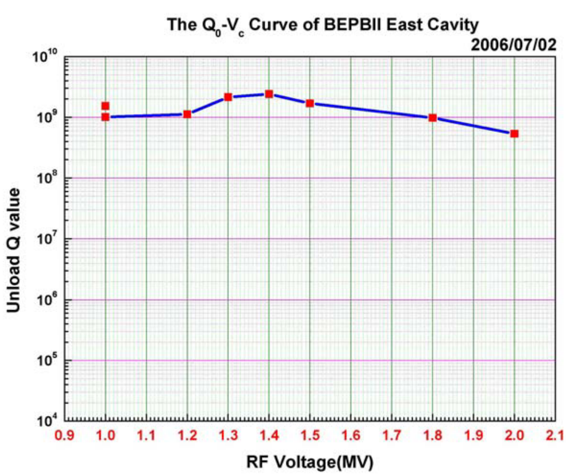

Figure 4: The Q_0-V_C Curve of BEPCII East Cavity

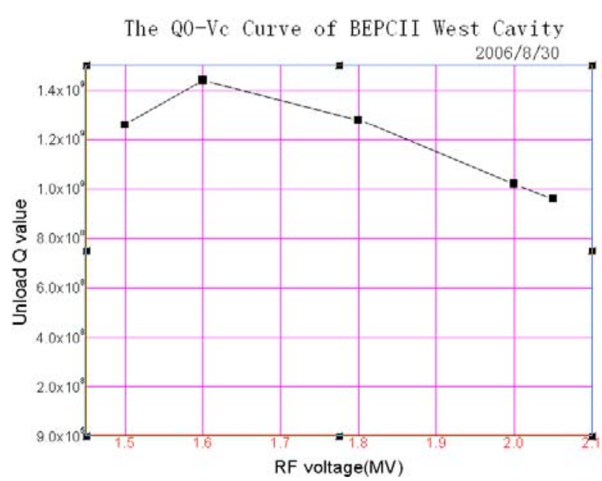

Figure 5: The Q_0-V_C Curve of BEPCII West Cavity

CONCLUSION

In the measurements and calculation of Static Heat Loss and Unloaded Q_0 on the BEPCII SRF Cavities, thermodynamic method is taken. The results show that the average static heat loss of BEPCII East Cavity is 29.8W; the average static heat loss of BEPCII West Cavity is 27.2W. The Q_0 value on 2MV RF voltage for BEPCII East Cavity is 5.35×10^8; the Q_0 value on 2MV RF voltage for BEPCII West Cavity reaches 1.02×10^9. These results are already used as important data for acceptance test of the SRF cavities.

REFERENCES

[1] Engineering Design Report on BEPCII Cryogenic System. IHEP-BEPCII-SB-03-1. IHEP, CAS, 2003

[2] Software Product: HEPAK. Version 3.40. Horizon Technologies. 25-JANUARY-2007

[3] ZHENG Dexin, YUAN Xiuling. Tables and figures of thermal characters for cryogenic matters. Mechanical industry publishing company, 1982

[4] LIU Yaping. The volume-level table of the BEPCII cryostat. Cryogenic group, Accelerator Research Center, IHEP,CAS. 2006.6

[5] HASAN PADAMSEE, JENS KNOBLOCH, TOM HAYS. RF Superconductivity for Accelerators. Cornell University, Ithaca, New York. 1998