# CRYOGENIC SYSTEM FOR BEPCII SUPERCONDUCTING CAVITIES

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*Abstract*

In order to improve the luminosity of the Beijing electron positron collider, two KEKB type 500MHz superconducting cavities are adopted in the upgrade project which is named as BEPCII. These two cavities are installed in e+ and e- ring, respectively. They are cooled in liquid helium bath contained in a vacuum insulated vessel. Cryogenic system is designed and constructed to provide the superconducting operating circumstance for the cavities. This paper is dedicated to briefly introduce the BEPCII rf side cryogenic system.

## INTRODUCTION

There are three different cooling requirements to the BEPCII cryogenic system from superconducting cavities (SCC), superconducting solenoid magnet (SSM) and superconducting inserting quadruple magnets (SCQ). The SCC is installed at the second colliding hall which is located at the middle of the north ring. The two types of magnets are installed at the first colliding hall which is located at the middle of the south ring. Two sets of 500W/4.5K LINDE refrigerator are employed in BEPCII cryogenic system. They are installed at the second and first refrigerator room respectively to provide cold energy to the SCC and magnets separately, but share one set of helium recovery system. Helium compressors, air compressors, water cooling system, control system and are located in the cryogenic hall. Figure 1 gives the layout of the BEPCII cryogenic system.

The main compressors are installed in the cryogenic hall and the gas tanks are installed near the cryogenic hall. The high pressure helium gas is transported to the refrigerators by the normal temperature transfer line. Two 30m$^3$ liquid nitrogen tanks are installed outside of the two refrigerator room respectively to provide $LN_2$ to the refrigerators and the $LN_2$ shield of the equipments.

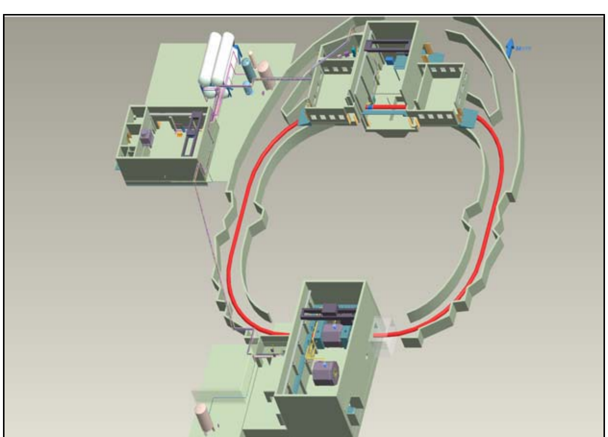

Figure 1: Layout of the BEPVCII Cryogenic System.

In the second refrigerator room (SCC side), one refrigerator, one 20K purifier, one 2000L liquid helium dewar and one valve box are installed. The valve box is used to distribute flux to three sites, two online positions and one offline test position, by multi-channel transfer line (eight or four channel) and single channel transfer line. The leak rate of these transfer lines is lower than $1\times10^{-10}$Pa · m$^3$/s. The section of the 4-channel transfer line is showed by figure 2.

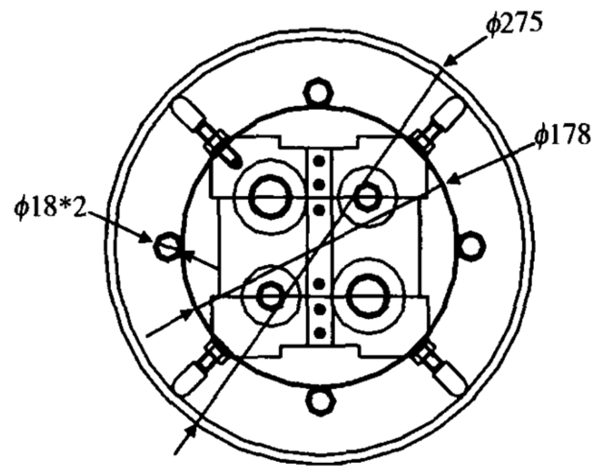


Figure 2: Section of the 8-channel transfer line of BEPCII cryogenic system.

## SUPERCONDUCTING CAVITY

Two 500MHz KEKB type superconducting cavities are employed to supply energy to the beam current of BEPCII. The cavities are cooled by saturated liquid helium in a 296L vacuum insulated cryostat. Because of the high pressure sensitivity of the SCC frequency, the piezoelectricity tuner is used to compensate for the frequency excursion by changing the cavity length. Due to the limited ability of the tuner, the pressure fluctuation of the cryostat should be controlled as small as possible. During the operation, the pressure is required to stabilize at 1.23bara±3mbar, the liquid level is controlled at 91±1%.

Four vacuum insulated single channel transfer line (two helium pipes and two nitrogen pipes), safety valve pipe and the coupler cooling pipe are connected to the cryostat of the SCC. There are many sensors fix in the cryostat. They are: six 4-300K PtCo temperature sensors ( 2 for spare), ten -200~250□ thermocouple sensors, two 20 inches helium level meters (one for spare), two 300W heaters (one for spare), two coupler heater and four photoelectric silicon diodes. The positions of these sensors are showed as figure 3.

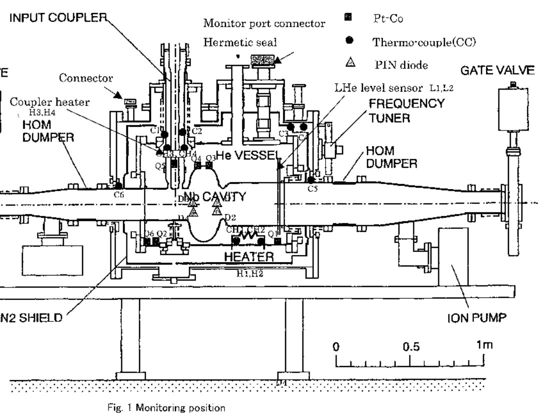

Figure 3: The sensors in the SCC cryostat.

The volume increase of the vaporized liquid helium is considerable large when quench happens. Due to the limited diameter of the recovery line and the limited main compressor ability, the pressure in SCC cryostat increases rapidly. The indium seal and the cavity shell may be distorted. The gas helium may leak into the inner side of the cavity and pollute the surface of cavity. In order to protect the SCC from damage, three type of pressure safety valve is employed. They are: 1.26bara electric safety valve, 1.30bara mechanical spring valve and a 1.98bara rupture disk. The diameter of the 1.26bara electric safety valve is 78mm, and it is connected with the suction of the main compressor. The diameter of the 1.30bara mechanical spring valve is also 78mm, and the helium gas is pour into the atmosphere outside of the tunnel through the valve. The rupture disk is the last insurance to the cavity, and the helium gas is directly pouring into the tunnel through the rupture disk.

## HEAT LOAD

BEPCII cryogenic system chooses two TCF50 LINDE refrigerators to serve cold energy for the users. The liquefaction rate of these two equipments is about 60L/Hr without nitrogen precooling. With nitrogen precooling, the liquefaction is about 200L/Hr.

The total heat load of two superconducting cavities is estimated as the following table.

| | | |
|---|---|---|
| Static loss of the cavities (W) | | 2×30 |
| Dynamic loss: | Rf loss (W) | 2×84* |
| | Coupler loss (W) | 2×12 |
| Others | Control valve box (W) | 20 |
| | Transfer line (W) | 24 |
| | LHe dewar and heater (W) | 30 |
| Margin 20% (W) | | 65.2 |
| Total heat loss (W) | | 391.2W |

*consider each cavity unload $Q_0$ =5×10$^8$ ,
rf voltage $V_{rf}$ =2MV,
R/Q=95.3,

so the rf loss $P_{rf}=V_{rf}^{\ 2}/(R/Q)Q_0$=84W

## COOLING DOWN AND WARMING UP

The helium gas of the cryogenic system must be purified before the operation. We use 80K outside purifier to purify helium gas in the gas tanks, pipeline & refrigerator and cryostat step by step. It is required that the content of water lower than 3vpm, nitrogen lower than 5vpm, hydrocarbon and oil almost become zero, the turbine could be start to work.

BEPCII SRF cavity operates in a liquid helium bath contained in a vacuum insulated, liquid nitrogen cooled radiation shielded cryostat. There is a 2000L dewar between the refrigerator and the cryostat. In order to control the cryostat pressure more safely, we usually choose the cooling method as following. Firstly, store about 50% liquid helium in the 2000L storage tank, and then transport liquid helium from the dewar to the cryostat by the pressure difference which is controlled by the heater in the dewar. Figure.4 shows the flow diagram of the rf side cryogenic system.

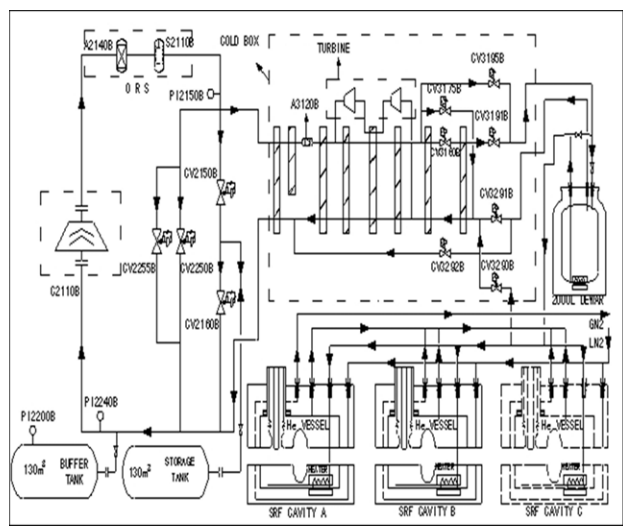

Figure 4: Flow diagram of the BEPCII RF side cryogenic system.

To protect cavity from heat stress damage caused by large temperature difference and keep the balance of cooling velocity and safety, we always keep the cooling rate at about 5K/Hr. During cooling down, we monitor the temperature all over the cavity. If any two points' temperature difference exceeds 30K, we will close the LHe input valve.

When warm up, we stop the turbine and increase the heater power in the 2000L dewar and SCC cryostat. Since the heater in the 2000L dewar is a metallic resistive stick, to avoid the heater from damage, the power supply of the heater will be interlocked off when the liquid level in the dewar lower than 10%. While the heater in the SRF cryostat is film structure, it can keep its power (normally lower than 100W) until room temperature if the heater temperature is lower than 300K, or it will be interlocked off.

## EXPERIENCE AND PROBLEMS

In March.2006, BEPCII RF side cryogenic system had reached its design target and passed the reception test. After several runs of test operation, the system goes to stable. From November.2006, BEPCII starts its beam commission and then the first synchrotron mode operation. Cryogenic system provide stable operation environment to the cavities, the failure ratio is only 2% during ten months' continuous operation.

Although we successfully finish the operating task, there are still some problems during the continuous operation. The main trouble is induced by the oil temperature of the main compressor. Owning to the high environment temperature in summer of Beijing, the compressor oil temperature was always high. The main compressor was easy to be automatically shut down. Many temporary measures had been tried to solve this problem. Such as clean the heat exchanger of the compressor, enhance the ventilation, close the $LN_2$ pre-cooling operation mode to decrease the load of the compressor, decrease the outlet pressure of the compressor and decrease all the heater power as low as possible.

During the summer shut down of 2007, we replaced a new heat-exchanger, installed air-conditioners in the cryogenic hall and installed a new ventilation pipe which directly exhausts the hot air from the compressor out of the hall to decrease the circumstance temperature. It can be estimated that this problem will be solved when we start to operate again.

## REFERENCE

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