OPERATION OF A HELIUM CRYOGENIC SYSTEM FOR A SUPERCONDUCTING CAVITY IN AN ELECTRON STORAGE RING

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Abstract

A 500 MHz superconducting cavity maintaining the energy of electrons in the storage ring of TLS light source started from the year 2005. A helium system dedicated to keep the niobium cavity at 4.5 K has begun its operation since the year 2003. The cryogenic system provides maximum refrigeration of 469 W or liquefaction rate of 134 l/hr. The constraint from the superconducting cavity leads to specific features of the cryogenic system. This paper presents the operation of the cryogenic system as the superconducting cavity at different conditions. The interaction in between the cryogenic system and the superconducting cavity and the constraints on the starting and shutdown of the cryogenic system are indicated.

INTRODUCTION

To enhance the photon flux and photon stability, NSRRC had implemented a project to replace the two copper cavities with one superconducting niobium cavity in the electron storage ring of TLS light source [1]. The project of superconducting cavity started in March 2000 and the commission finished in December 2004. A helium cryogenic plant to keep the niobium cavity at 4.5 K had the construction phase in the period from March 2001 to November 2003. The cryogenic plant is required to keep two superconducting cavities (one for spare) in full load condition at 4.5 K. Considering the heat loss during helium transfer and the heat load from the cavity cryostat, the cryogenic plant needs to provide a cooling power of 170 W to operate one superconducting cavity and it is 300 W for two superconducting cavities. The cryogenic plant is designed to provide the cooling capacity of 450 W, where the extra 50% cooling power reserves some flexibility for the operation of the cryogenic plant. The implemented cryogenic plant shows its maximum cooling power of 469 W and maximum liquefaction rate of 134 l/hr [2]. Variation of the cryostat pressure changes the length of the cavity so the operation frequency changes. The cavity cryostat needs to have a pressure variation within +/-3 mbar such that the tuner can regulate the shift of operation frequency without difficulty.

CONFIGURATION AND STATUS

Figure 1 shows the infrastructure of cryogenic system at NSRRC. The first cryogenic plant (MCP1) is dedicated for the cooling of superconducting cavities, which are operated at the refrigeration mode, and the second one (MCP2) is for superconducting magnets, which are operated at liquefaction mode. Construction of the cryogenic system performed within three separate periods. In the first period (October 2002 ~ January 2003) we finished the set up of MCP1. Later NSRRC decided using liquid helium to keep the superconducting magnets at 4.3 K. The second cryogenic plant is required, as the capacity of MCP1 is not sufficient to support the liquid helium to all the superconducting devices scheduled in TLS light source. A long transfer line, which provides six connecting ports, and a switch valve box, which connects two cryogenic plants, were installed in the second period (November 2004 ~ January 2005) [3]. Using the switch valve box, liquid helium from one dewar can backup the cooling of those superconducting devices supported by the other dewar. In the third period (December 2005 ~ February 2006) we finished the installation of MCP2 and currently MCP2 is under commission phase. During each period of installation, the devices at cold condition were warmed up to room temperature before the new devices were installed. Between the first and the second period, MCP1 had succeeded in providing helium cooling for the commission of two superconducting cavities and one superconducting magnet. After the second period, MCP1 has succeeded in providing helium cooling for the operation of one superconducting cavity and three superconducting magnets. There will be totally five superconducting magnets connected to the long transfer line after the MCP2 finishes its commission. As the MCP2 starts its operation, the helium circuit for the superconducting cavity will be separated from that for the superconducting magnets in order to minimize the interaction between the cryostats.

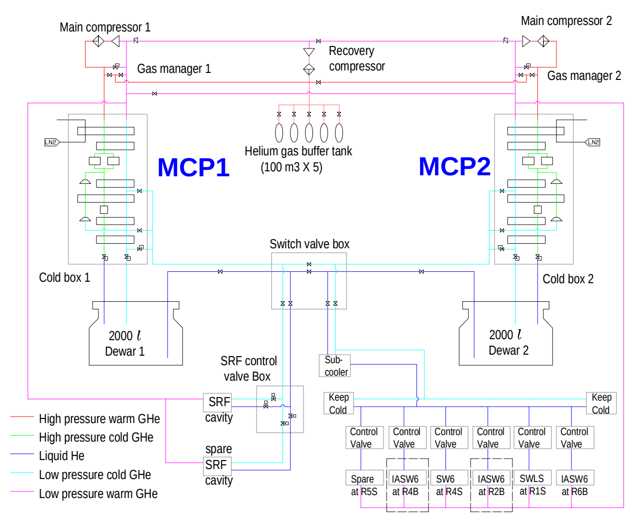

Figure 1: Configuration of cryogenic system.

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OPERATION EXPERIENCE

Operation with Superconducting Cavity

The operation frequency of the superconducting cavity is sensitive to the variation of cryostat pressure. Since the cold gas from cavity cryostat is returned to the cold box, there is strong interaction between the cold box and the cryostat. A stable condition of the cryogenic plant makes it easier the control of the cryostat pressure via the control valves at the downstream side of the helium dewar. In the cryogenic plant, the dewar pressure is kept constant to provide liquid helium with constant source pressure. Furthermore, a stable suction pressure near the compressor inlet is maintained via the control valves in the gas manage system. With some pressure increase along the suction line, the pressure at the cold return line of the cold box can be kept stable if there is no disturbance. The disturbance come from adsorber regeneration, re-cooling of standby adsorber, heater of the dewar, different setting of precooling temperature, and unsteady cold gas from cavity cryostat or the long transfer line. Figure 2 shows the trends of the controlled pressure of the dewar and the suction line. The pressure of the suction line keeps at 1.05 bar with +/-2 mbar fluctuation; the dewar pressure keeps at 1.4 bar with +8/-6 mbar fluctuation. These pressure fluctuations are compatible to the +/-3 mbar specified from the cavity cryostat. The pressure fluctuation increases when the dewar level is higher than 82 %.

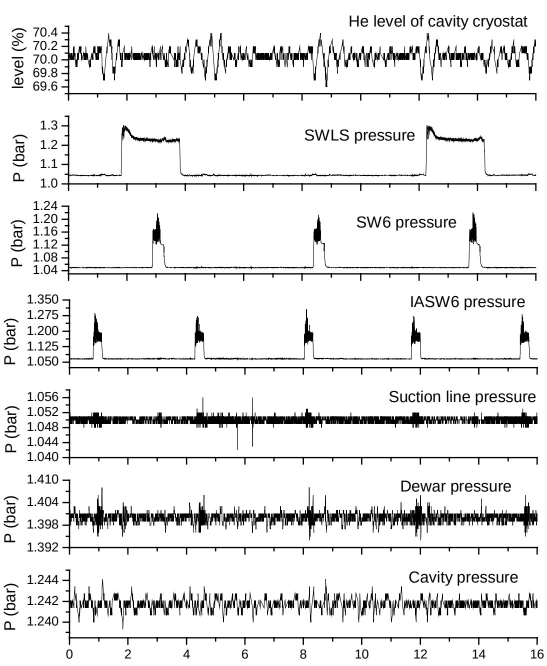

Figure 2: Trends during normal operation.

The mass flow rate increases during the period of adsorber regeneration. The regeneration should be avoided during full load operation as the flow rate will exceed the compressor capacity and thus lead to high suction pressure, which may trigger the safety interlock of cavity cryostat due to the low setting pressure from burst disk.

The level of the 2000 *l* dewar is kept within 65%~75% during normal operation. Since too high level will trigger the heater to turn on and the turbines turn down their speeds, we regulate the level by adjusting the precooling temperature at the first heat exchanger of cold box.

Because the capacity of the cold box is less than the consumption rate during the cooling down of the cryostats, storage of 80% level in the dewar is required before helium filling into the cryostats. The priority is cavity cryostat first and then magnet cryostat. The dewar level will fall down respectively to 55% and 39% after liquid helium being stored in the cavity cryostat and one of the magnet cryostats.

It takes several weeks to warm up the cavity cryostat or magnet cryostat since the cryostat is low heat load and there is no room temperature, low pressure, pure helium gas for the cryostat (the dewar is cold and the cold box stops during the shutdown period). A bypass line from the discharge line to the suction line with well pressure regulation, low flow rate, helium stream can shorten the time required to warm up the cryostat to room temperature. The connection port of this helium stream to cryostats is at the switch valve box.

Operation with Superconducting Magnets

In TLS the superconducting magnets are operated at 4.3 K to acquire more margin from the operation field to the critical field. The magnet cryostat is connected to the suction line to obtain a low operation pressure/ temperature and the vaporized helium is warmed up by a passive warmer before returning to the compressor. Since the magnet cryostat is operated in the liquefaction mode, a large loss occurs during the helium transfer from supply port of the long transfer line to the cryostat. Typical trends of the helium level in the dewar and the magnet cryostats are indicated in Fig. 3. Instead of continuous filling, liquid helium is filled into the cryostat as the level falls below the setting value. As currently only one cryogenic plant supplies all the liquid helium to the cavity and the magnets, we need to monitor the inventory of liquid helium in the storage dewar.

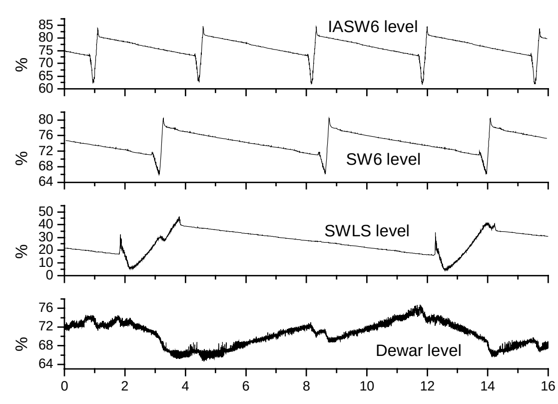

Figure 3: Helium level of magnet cryostats.

The stored energy in a superconducting magnet is near 50 kJ. The magnet quench vaporizes roughly 10 *l* liquid helium and the gas is dumped directly to the suction line. The compressor keeps running to recover the large amount of helium gas from magnet cryostat. Small impacts on the cryogenic system are observed as quench happens: a pressure fluctuation +4/-2 mbar in the suction line, a pressure fluctuation +/-3 mbar in main dewar; a temperature increase 0.4 K in cold return gas from the valve box; and a speed fluctuation +/-22 Hz at cold turbine.

Start and Stop of Compressor Station

As compressor being interrupted, the suction line pressure increases rapidly since the helium gas from the cold box, the long transfer line, the cavity cryostat, and the magnet cryostats are all dumped into the suction line. Figure 4 shows the trend of suction line pressure as the compressor stops. Though the recovery compressor recovers the helium gas to the buffer tanks, but the time required to drive the recovery compressor to its full speed is long enough for the suction pressure increasing to the relief pressure 1.5 bar, where the relief valve is placed near the oil removal module. It is necessary to start the recovery compressor before the scheduled shutdown of the compressor station.

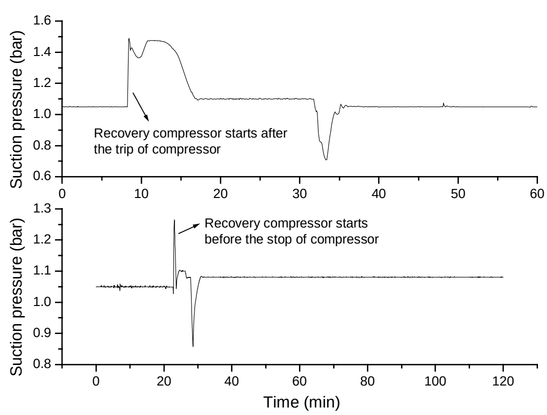

Figure 4: Suction pressure as compressor stops or starts.

The restart of the compressor will cause a negative gauge pressure in the suction line for a short period. It is hard to avoid the negative pressure by adjusting the control valves of the gas manage system since the adjustment depends on the available helium in the buffer tanks and the amount of return gas from the cryostats. The negative pressure induces the risk of air leakage into the system and the risk to damage the bust disk of cryostat. Our procedure is to isolate the cryostats from the suction line during the restart of compressor station.

Other Concerns

In NSRRC liquid nitrogen is supplied to the cold box, the cryostats, and the users. The nitrogen pressure is well regulated at the storage dewar in normal case, however it has a big fluctuation when liquid nitrogen is filled from the trailer to the storage dewar or the user extracts liquid nitrogen to his small dewar. The variation of nitrogen pressure changes the temperature of the thermal shielding for the cavity cryostat and thus changes the length and the frequency of the cavity. It happened the electron beam tripped due to the tuner could not accommodate the frequency change causing from the unstable nitrogen pressure. A phase separator with pressure control will be installed before the cryostat to isolate the fluctuation of nitrogen pressure at the source side.

The stability of electric power affects the operation of the cryogenic plant. Each year there happened several times the power surge with different voltage drop and duration period. Table 1 summarizes the status of the cryogenic plant as the power surge happened in the past years. The cold box is immune from the power surge since an UPS is installed for its operation. The rated power of the compressor station is 315 kW and no UPS is implemented. From Table 1 the compressor station is not interrupted by the power surge even the voltage drop is 41%.

Table 1: Status of cryogenic plant during power surge.

Voltage Drop (%)	Duration (msec)#	Count	Compressor Status	Cold box Status
X < -10	< 395	26	Run	Run
-10 <X< -20	< 793	14	Run	Run
-20 <X<-31.5	< 149	4	Run	Run
-41.3	102	1	Run	Run
-54.9	202	1	Trip	Trip by interlock
-61.4	53	1	Trip	Trip by interlock
-73.9	641	1	Trip	Stop

Trigger level: 95% nominal voltage

CONCLUSION

Reliability and stability are much more emphasized in the operation of a cryogenic system for the superconducting cavity in photon light source. Our experience shows the success in providing the cooling power to the superconducting cavity and the superconducting magnets. Further improvement will be enhancement of the stability of nitrogen pressure and separation of the helium streams for the cavity and the magnets.

REFERENCES

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