An Overview of the Cryogenic System at TLS

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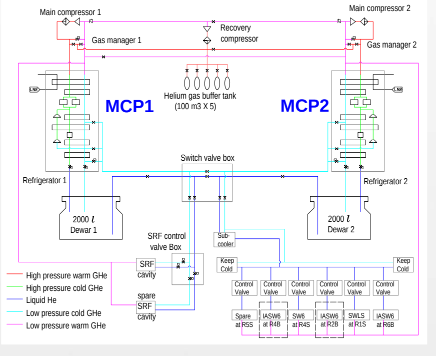
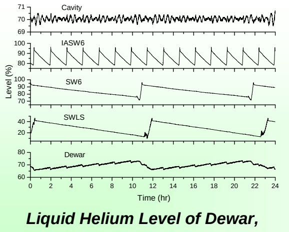
Introduction

In TLS a helium cryogenic system with refrigeration of 450 W started its operation from November 2003. One year later a superconducting radio frequency cavity cooled by the cryogenic system was installed in the storage ring and operated successfully. The thin shell niobium cavity requires stable helium pressure and stable nitrogen shielding temperature due to the limited range of compensation providing from cavity frequency tuner. The weak structure of thin shell cavity also leads to the stringent requirement of interlock on overpressure of helium or nitrogen streams whatever condition of the cryogenic system.



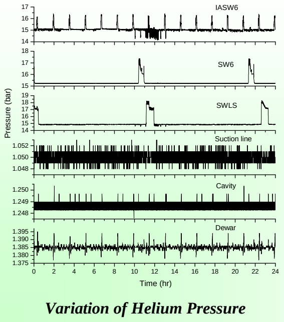
Flow Chart of the Cryogenic System

For lower operation cost currently a refrigerator provides helium cooling to one superconducting cavity, which is operated in refrigeration mode and three superconducting insertion magnets, which are operated in liquefaction mode to maintain the cryostat pressure as low as the compressor suction pressure and thus obtain a larger margin of magnet field between the operation field and the critical field. Two additional superconducting magnets are scheduled to be installed at TLS in year 2009. Using liquid nitrogen pre-cooling a refrigerator is capable of providing refrigeration 450 W or liquefaction rate 134 l/hr.



Liquid Helium Level of Dewar, Cavity and Magnets

The heat load from the cavity cryostat is 80 W and the transfer heat loss related to cavity for the transfer lines and valve boxes is 44 W. Refill of liquid helium to the three magnets takes 32, 80, and 85 liters within 4, 30, and 40 minutes for every 1.5, 11, and 11.5 hours respectively.

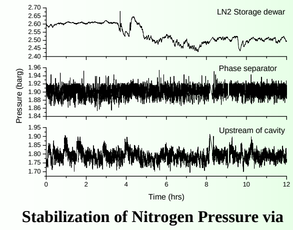


Variation of Helium Pressure

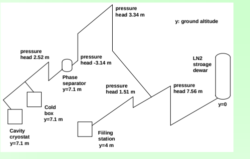
The dewar pressure is kept at 1.385 bar with fluctuation +/-3 mbar. The superconductive cavity and superconductive magnets share the same liquid helium dewar and the disturbance on transfer pressure appear during the period of filling liquid helium to the magnet cryostat. Nevertheless the control valves in front of the cavity cryostat succeed in regulating the liquid helium level and the cryostat pressure with fluctuation of +/-0.5 % and +/-1.5 mbar respectively. The vaporized helium from the magnet cryostat is returning to the compressor suction line. The suction line pressure can be kept within 1.05 bar +/- 2.5 mbar whether in normal operation or quench condition.

SUMMARY

The high reliability for TLS operation and the long recovery time for the cryogenic system have pushed the cryogenic system being operated as stable and reliable as possible. After years of operating experience and component improvement, the cryogenic system is capable of matching the requirement from the superconducting cavity and the superconducting magnets.



Stabilization of Nitrogen Pressure via the Phase Separator



Relative altitude of nitrogen system

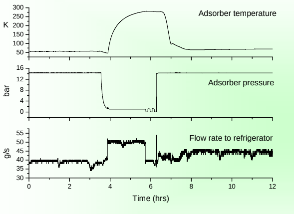
A storage dewar with volume of 20000 liters provides liquid nitrogen to the cryogenic system, superconducting cavity and magnets. A self-help nitrogen filling station is opened to users for applications at the end station of beamline. The operation pressure of the storage dewar is 2.6 barg. During the usage of filling station or the refill of liquid nitrogen to the storage dewar, the pressure surge, which is more than the interlock threshold, appears near the cavity side. A phase separator with volume of 250 liters is used to limit the maximum pressure and improve the pressure stability. Due to the limitation of available space, the phase separator is placed at the upstream side of both the refrigerator and the superconducting cavity. At the phase separator the pressure of liquid nitrogen is lowered to 1.8 barg and variation of supply pressure is reduced to +/- 0.04 bar. The pressure disturbances form the storage dewar and the filling station are isolated and the pressure drift is eliminated.

Table 1: Trip Records

Event	Count	Cause
Warm turbine failure	*4*	*Damaged by impurity or particle ingestion into the bearing circuit*
Cold turbine failure	*1*	*Impurity accumulation in the labyrinth due to too high labyrinth flow*
Dewar level too high	*1*	*False signal of liquid helium level*
Compressor motor damage	*1*	*Motor overheated due to poor bearing lubrication*
Motor bearing damage	*2*	*Bearing abnormally wear*
Frequency driver failure	*7*	*Output control card failure (1+3*)* *Failure of power card for ventilation fan (1)* Over current and reason unclear (2)
Overpressure at discharge line	*2*	*Malfunction of gas manager system*
Overpressure at suction line	*3*	*Belt slippage and rotor failed to take helium flow for few seconds (1)* Overflow during regeneration of cryogenic adsorber (2)
Electricity failure	*6*	*Voltage sag of electricity*
Cooling water failure	*3*	*Small flow rate (1)* Unstable water temperature (1) Over temperature on power switch board of water pump (1)

* Three trips occurred before identifying the malfunction of control card.

Several events interrupted the operation of the cryogenic system. Since several hours are required to restart the cryogenic system after trip happens, it is important in the analysis of component reliability. From table 1 the frequency driver causes largest number of trip events, the second one is voltage sag of electricity, and the third one is turbine. The strategy of preventive maintenance for the cryogenic system is adopted to meet the requirement of highly reliable operation. In table 1 the turbine failure happened during the early stage of operating the cryogenic system; temperature of the motor bearing is high and we add cooling water circuit to reduce the temperature from 100℃ to 80℃ at condition of full load operation. Except two events related to the frequency driver, most events have clear reason and can be solved. The voltage sag of electricity is unsolved since the frequency driver requires large uninterrupted power system (315 KW) to drive the compressor.



Flow Rate Increment during Regeneration of the Cryogenic Adsorber

Two cryogenic adsorbers are installed inside the refrigerator. The refrigerator automatically switches to the standby adsorber every Monday and the online regeneration is then carried out. During regeneration process the helium flow rate increases 10 g/s for two hours and the total flow rate will reach the extreme value that the compressor can supply, if the refrigerator provides maximum cooling power simultaneously. Under such condition the gas manager system will lose control and pressure oscillation appears in the suction line, which eventually causes a trip event.

Pressure fluctuation of suction line during trip and restart of the cryogenic system.

The high pressure or the negative gauge pressure in the suction line may damage the burst disk of the cryostat and then possibly bring in contamination to the helium stream. The high pressure happens when the cryogenic system trips or during the transient period that the compressor stops and restarts. The pressure increase of the suction line is usually over the interlock value because of the large vaporized helium, which comes from the cavity cryostat, the magnet cryostats, and the 100 m transfer line, and the depressurized helium from the discharge line and the refrigerator. The negative gauge pressure appears for several seconds when the compressor starts up to its operation speed. The idea of connecting a buffer tank to the suction line and evaluate fluctuation of the suction line pressure during periods of the compressor starting up and stop had been tested. The results show that, using a buffer tank with volume of 100 cubic meters, the negative gauge pressure was avoided and the peak pressure was reduced from 1.4 bar to 1.2 bar.