

# CONTINUOUS OPERATION OF CRYOGENIC SYSTEM FOR SYNCHROTRON LIGHT SOURCE

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## Abstract

In NSRRC two cryogenic plants are installed for liquid helium supply to the superconducting magnets and the superconducting cavity in the electron storage ring. The objective of continuous helium supply without interrupting operation of the storage ring is pursued by the cryogenic plant. This paper shows that our strategy on the scheduled maintenance of either the cryogenic plant or the utility system is capable to keep continuous liquid helium supply. Two tests to shorten the recovery time are presented: one is restarting the on duty cryogenic plant with the other dewar providing liquid helium to the superconducting devices; the other is liquid helium supply with both cryogenic plants operating simultaneously.

## INTRODUCTION

In NSRRC two cryogenic plants are installed for liquid helium supply to the superconducting magnets and the superconducting cavity in the electron storage ring [1]. From operation experience the component failure, the voltage sag of electric power, and the system maintenance are major reasons interrupting operation of the cryogenic plant [2]. It usually takes several hours to recover the cryogenic plant and keep stable helium stream after the trip event. Since the availability of user time is an important index for the performance evaluation of a synchrotron light source, as a subsystem of the storage ring the objective of continuous helium supply without interruption is important for the cryogenic plant. The target to shorten the recovery time of the storage ring, if the cryogenic plant trips, is another issue. This paper shows our strategy on the scheduled maintenance of either the cryogenic plant or the utility system to keep continuous liquid helium supply. Two tests to shorten the recovery time are presented: the first is liquid helium supply with both cryogenic plants in operation; the second is the other dewar providing liquid helium to the superconducting devices during restart of the on duty cryogenic plant.

## AUXILIARY UTILITY SYSTEM

Auxiliary utility system of instrument air, cooling water, and electric power shall be well planned to provide the backup function as shortage of the central utility system happens whatever the reason. The backup system of instrument air consists of an air compressor, a buffer tank, and a valve for pressure regulation. The flow rate required for cooling the turbines of cold box is small and a small backup chiller with manual switch valves provides the backup cooling water. We adopt a secondary cooling water circuit for the compressor cooling.

Figure 1 shows the process flow diagram of this circuit. A water pump drives the cooling water flowing through the coolers of the compressor and takes away the heat generated in the process of helium compressing. The water pump with power rating 5.6 KW is enough to provide the water flow required for the cooling of two main compressors and one recovery compressor. The chiller water from the central utility system is mixed with the heated up cooling water flowing from the helium compressor. A control valve regulates the flow rate of chiller water and reduces the temperature of cooling water to 26 °C before flowing into the compressor cooler. It takes less than three minutes for the temperature of cooling water being increased to the interlock level if shortage of the chiller water. During maintenance period of the electric substation of power plant, city water is taken to mix with the cooling water and the heated cooling water from the compressor cooler is then drained out. A flow rate of 15.7 m<sup>3</sup> is required to take away the heat generated from a main compressor and a recovery compressor; the temperature of the cooling water is 34 °C and 40 °C respectively at the inlet port and outlet port of the compressor cooler, in comparison with the temperature 26 °C and 34 °C for case of using chiller water.

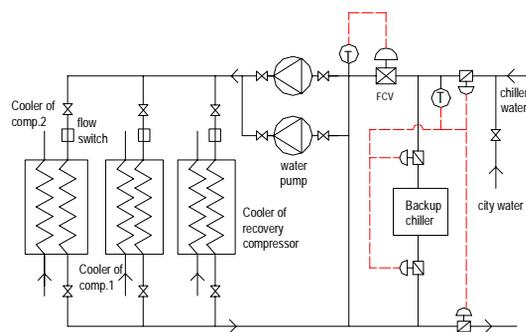


Figure 1: Flow diagram of cooling water for helium compressors.

It usually takes more than 8 hours for the annual maintenance of electric substation of power plant and the exact date of maintenance is uncontrolled such that the date may not be within the scheduled long shutdown period of the storage ring. The problem is whether the superconducting cavity and superconducting magnet can keep at low temperature for 14 hours if considering additional one hour for restarting the chiller of central utility system, one and four hours respectively for the shutdown and restart of the cryogenic plant. Table 1 shows the equipment and its power rating that shall be supported by emergency power in case of power shortage.

Capacity of current available emergency power is limited, if we do not rent the electric generator from outside company. The emergency power required for the operation of the cryogenic plant and its auxiliary utility system shall be considered carefully.

Table 1: Equipment Supported by Emergency Power

| Item   | Rated Power |
|--|-------------|
| Process controller, Dewar warmer, and Vacuum pump for cold box | 20 KW       |
| Backup chiller for cold box                                    | 4.9 KW      |
| Backup chiller for recovery compressor                         | 20 KW       |
| Cooling water pump for He compressor                           | 5.6 KW      |
| Backup compressor for instrument air                           | 5.6 KW      |
| Helium recovery compressor                                     | 55 KW       |
| Helium compressor station                                      | 315 KW      |

### Switch Operation Without Interruption of the Cryogenic System

Switching between the central utility system and the auxiliary utility system for the instrument air, the cooling water, and the electric power is pursued to avoid interrupting the operation of cryogenic plant. Utility signals such as the pressure of instrument air, the temperature and the flow rate of cooling water, the voltage sag and the power shortage are used as interlock signals to protect the cryogenic plant. A buffer tank of volume 0.25 m<sup>3</sup> is enough to keep the pressure of instrument air during the switch period. Since the water pressure of the central utility system is higher than that of the backup chiller for cold box, a water pump is added at the outlet flow of the backup chiller to increase the pressure and avoid the shortage of water flow rate during the switch period. The secondary cooling water circuit for compressor cooling keeps the required flow rate and the time for the temperature of cooling water increasing to the interlock value is longer than the time for switch operation. The time for switching between the emergency power and the regular power takes in between 7 to 20 seconds and all systems will stop due to the shortage of electric power during the switch period. On the other hand, the voltage sag is one of the major events causing trip of the cryogenic plant [2]. Since more than three hours is required to recover the cryogenic plant with steady helium supply to superconducting devices after trip event, it deserves to use the uninterrupted power system to raise the immunity to voltage sag. At current stage we install uninterrupted power systems for the cold box, the process controller and the secondary cooling water system. The cost and space of the uninterrupted power system required for the frequency driver of compressor station are large and the necessity requires evaluation. For unattended operation the recovery compressor, the backup chillers for cold box and recovery compressor, and the

backup compressor for instrument air must be default at the standby mode after the appearance of electric power.

Switch operation of the two cryogenic plants is necessary in cases of the maintenance of cryogenic plant or the inspection required from the authority. There is negligible influence on the superconducting cavity and superconducting magnets when performing the switch operation by the valves of the valve box, after ready of both cryogenic plants, for the liquid helium supply and the helium gas return.

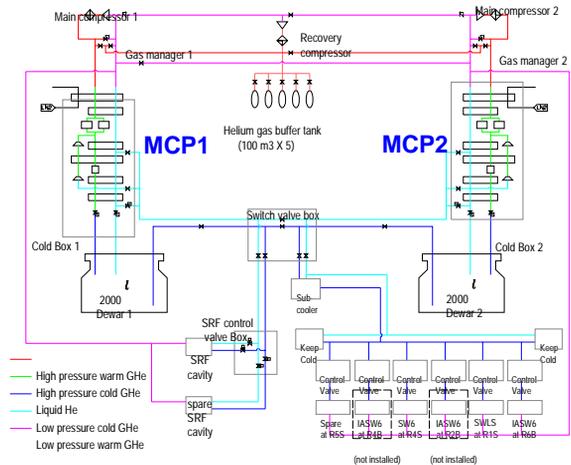
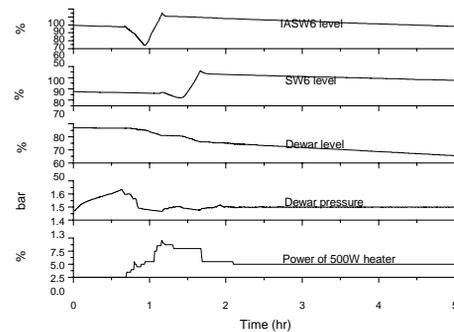
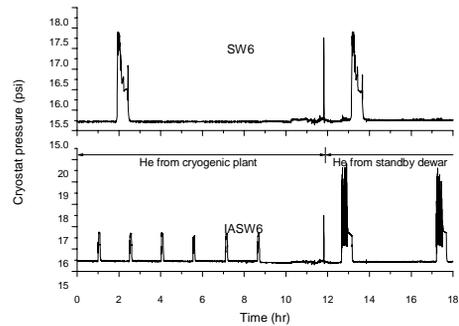


Figure 2: Flow chart of the cryogenic system.



(a) Status as liquid helium filling via standby dewar



(b) Cryostat pressure during different filling period

Figure 3: Liquid helium supplying to superconducting magnets when cold box stops.

## STRATEGY TO SHORTEN THE RECOVERY TIME

### *Liquid Helium from the Standby Dewar*

Figure 2 shows the process flow diagram for helium transfer to the superconducting devices. As there are two cryogenic plants, some ideas deserve to be explored for their possibility. Because of the heat load from the superconducting magnets being smaller than the design value, due to some of them are not installed yet, and the concern of operation cost, one cryogenic plant is in operation and the other one is shutdown as the dewar accumulates 80% level of liquid helium. Figure 3 shows the test for transferring liquid helium to the superconducting magnets from the standby dewar during the restart period of the on duty cold box. The vaporized helium is warmed up by a passive warmer and returns to the on duty compressor. The result shows that, by adjusting the heater power to keep the dewar pressure, the two superconducting magnets SW6 and IASW6 could take liquid helium via 8 m and 80 m transfer length respectively. For each filling of liquid helium the magnet SW6 consumes 86.2 liters for every 11 hours and the magnet IASW6 consumes 113.1 liters for every 4.5 hours. The cryostat pressure of IASW6 during filling period is 16.75 psi and 19.75 psi, which is acceptable to the magnet, for liquid helium from the on duty cryogenic plant and the standby dewar, respectively; for SW6 there is no difference in the cryostat pressure. After liquid helium filling to SW6 and IASW6, the heater needs to provide 12.5 W power for maintaining pressure of the standby dewar at 1.4 bar and the total liquid helium consumption rate, including heat loss form the long transfer line and the valve box, is 62 liters per hour.

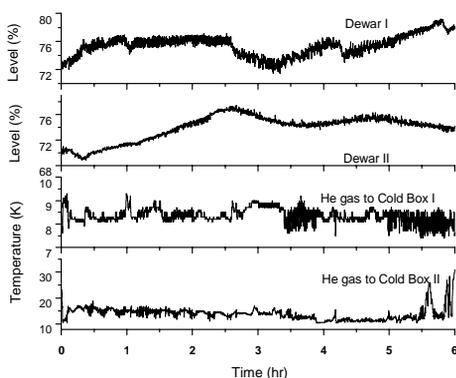


Figure 4: Two cryogenic plants simultaneously provide liquid helium to superconducting devices.

### *Liquid Helium from Operating Two Cryogenic Plants Simultaneously*

The idea of on-line redundancy leads to both cryogenic plants simultaneously supplying liquid helium to the superconducting devices. An attempt to open the valve on the interconnection line between the two suction lines induced the unbalance flow to the compressors such that one compressor took insufficient flow and failed to keep the pressure at discharge line. With one cryogenic plant supplying liquid helium to the superconducting devices, we started the second cryogenic plant and set small openings of the supply valve at the downstream side of the second dewar, with pressure the same as the first dewar, to join the liquid helium supply. Test result is indicated in Fig. 4, where the levels of both dewars increased initially until that of second dewar reached the value which triggered the heater for level regulation; also near end of this test the level of first dewar triggered the slow down of turbine speed for level regulation. During the test the vaporized helium gas from the superconducting devices was not returning to both cold boxes equally, so the increase of both dewar levels was quite different and the helium gas returning to the second cold box had big temperature variation near end of this test. The cryostat pressure of superconducting cavity will be interfered at the start period of the test, which implies the operation mode of supplying liquid helium from both cryogenic plants shall be performed during the shutdown period of the storage ring.

## CONCLUSION

The auxiliary utility system is successful to keep continuous operation of the cryogenic plant for scheduled maintenance of the central utility system except that of the electric power. Switch operation between the two cryogenic plants avoids the shortage of liquid helium to superconducting devices in periods of system maintenance and legality inspection. Operation of the dual cryogenic plants or liquid helium supplying from the standby dewar during restart of the on duty cryogenic plant both can shorten the interrupted time of the storage ring.

## REFERENCES

- [1] F. Z. Hsiao et al., "Helium Distribution for the Superconducting Devices in NSRRC," Proceedings of PAC'05, Knoxville, Tennessee, May 2005, pp.758-760.
- [2] F. Z. Hsiao et al., "An Overview of the Cryogenic System at TLS," MEDSI'08, Saskatoon, Saskatchewan, Canada, June 2008.