THE PILOT-RUNS OF THE HELIUM CRYOGENIC SYSTEM FOR THE TLS SUPERCONDUCTING CAVITY

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Abstract

At NSRRC the installation of a helium cryogenic system, which is tailor-made for the cooling of TLS superconducting cavity, was finished at the end of October 2002. The cryogenic system had finished its first phase commission work at the end of March 2003. This paper presents the first measurement result of the cryogenic system.

INTRODUCTION

A helium cryogenic system with cooling capacity of 450 W at 4.5 K was set up in National Synchrotron Radiation Research Center (NSRRC) at the end of the year 2002. This helium system is dedicated for the cooling of a 500 MHz superconducting radio frequency (SRF) cavity which is the key item of an upgrade project to enhance the beam current and stability of NSRRC electron storage ring. The cryogenic system is a turnkey system and provided by the Air Liquide Company; its configuration is shown in Fig. 1[1]. The system includes one 315 kW compressor, one 45 kW recovery compressor, one 10 kW refrigerator, one 2000 liter dewar, two 100 m3 gas helium storage tanks, and one 5 m multi-channel transfer line. The distribution valve box is included in the SRF cavity system since the inside control valves regulate the pressure and level of the cryostat. In normal operation the SRF cavity will require a cooling power of 80 W at 4.5 K and a liquefaction rate of 0.18 g/s for the cooling of cavity's wave guide[2].

SYSTEM INSTALLATION

Apparatus of the cryogenic system are installed at three areas, i.e., the platform, the gas yard, and the compressor room. Figure 2 shows the layout of these three areas. The refrigerator, the dewar, and the distribution valve box are located on the platform with 2.8 m height. The liquid helium is drawn off from the dewar and sent to the

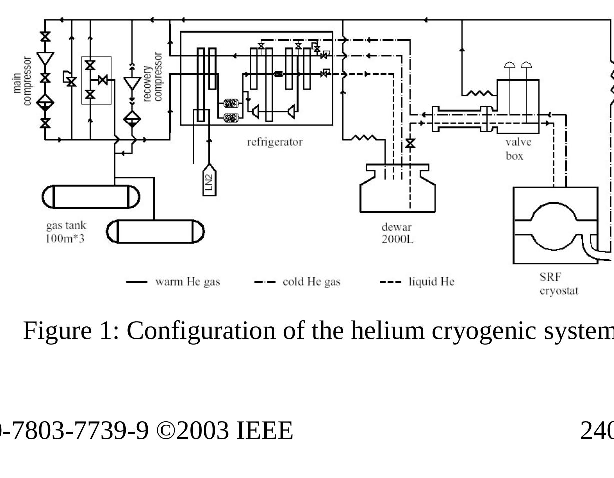

Figure 1: Configuration of the helium cryogenic system.

distribution valve box through the multi-channel transfer line; the helium is then sent to the cryostat of the SRF cavity via the 6 m flexible transfer line. The space under the platform is reserved for the cavity test before its installation into the storage ring.

The main compressor and its oil removal module, the various frequency driver for the main compressor, the recovery compressor and its oil removal module are installed in the compressor room, which is located in the basement of the utility building. The compressor room is constructed with soundproof wall and vibration isolation floor. A ventilation system is installed to provide the cooling air for the compressor motor and prevent the oxygen-poor condition. All the signals in the compressor room are collected in a cabinet and then sent to the PLC controller on the platform via the PROFIBUS communication protocol.

In the gas yard a nitrogen storage tank with a capacity of 20000 liter is installed and two helium tanks are located nearby. Liquid nitrogen is used for precooling the first heat exchanger of the refrigerator; it is also used for the thermal shielding of the multi-channel line, the distribution valve box, and the cavity cryostat. A local grounding network for pressure transmitters is installed in foundations of the nitrogen tank and the helium tanks. Another grounding network is constructed for the nitrogen tank to prevent a lightning strike.

COMMISSION RESULT

Before filling the grade-A helium into the gas tank, the dry nitrogen gas was flushed into the tank until the dew point of the tank was less than –59 ℃. The gas tank was then evacuated down to 0.13 mbar from 1 bar and this procedure took 48 hours. After two cycles of purge and pump down, the tank was filled with helium up to 10 bar. The charcoal of the oil removal module was dried using hot nitrogen gas (~70 ℃). It took more than one week for keeping the dew point down to –60 ℃; three days were required for the recovery oil removal module. The leakage test for the inner piping of the refrigerator shows a value lower than 1.3e-8 mbar-L/sec; the test for the interconnect piping among the compressor, the refrigerator, and the gas tank shows a leakage value lower than 7e-8 mbar-L/sec.

The capacity measurement at the dewar after optimizing parameters of the cryogenic system is shown in Fig. 3, where the dewar pressure was kept at 1.3 bar

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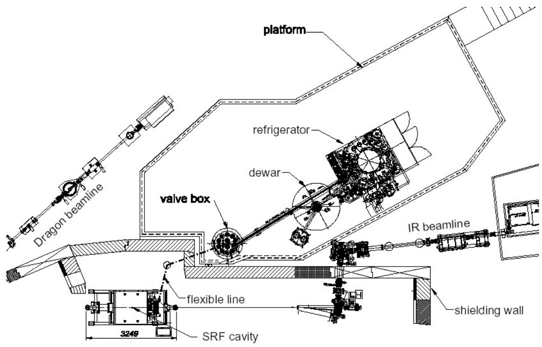
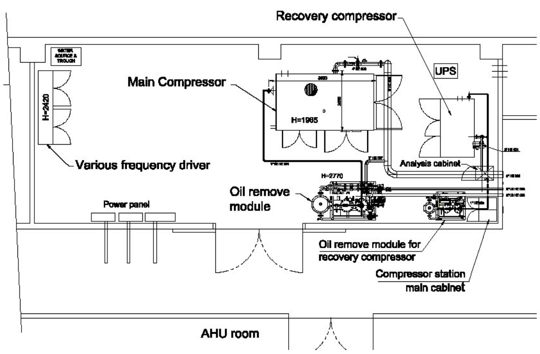
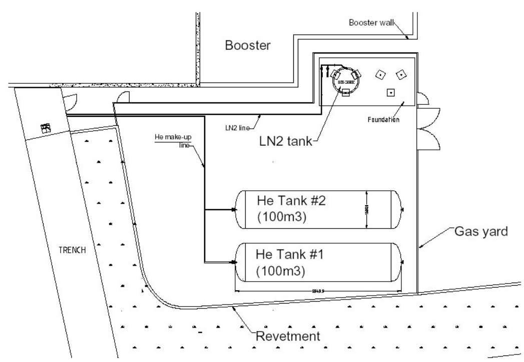


(a) platform.



(b) compressor room



(c) gas yard area

Figure 2: Cryogenic system layout.

(1.25 bar) as liquid nitrogen was (wasn't) used for precooling. In the test of liquefaction mode the dewar level increases 8 % (20.2 %) in 3 hours without (with) liquid nitrogen for precooling; i.e., the system provides liquefaction rate of 60.5 L/hr and 153 L/hr. In the refrigeration mode the system provides a cooling power of 255 W with 10.6 L/hr liquefaction rate without liquid nitrogen and 452 W with 5.6 L/hr liquefaction rate using liquid nitrogen. After linear extrapolation the data from the performance test one can know the system provides cooling power of 309 W (469 W) at refrigeration mode without (with) liquid nitrogen for precooling. The mass flow rates are 24 g/sec (39 g/sec) and 44 g/sec (82 g/sec) respectively during the test at liquefaction mode and refrigeration mode without (with) liquid nitrogen. During commission the system capacity can be automatically turned down either by changing the compressor discharging flow via a frequency driver or adjusting the mass flow in the expansion turbine via its inlet control valve. Table 1 summarizes the design and measured values of the helium cryogenic system. The system provides more capacity than the design value: a larger margin is provided as the system is operated either in refrigeration mode without liquid nitrogen or in liquefaction mode with liquid nitrogen.

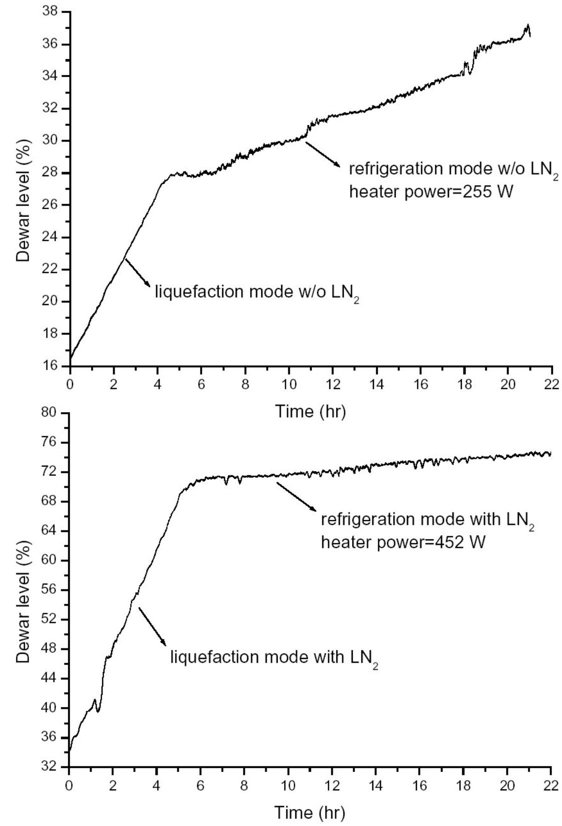


Figure 3: Capacity measurement at dewar.

Figure 4 shows the result of a stability test, where the test period lasted more than 72 hours. The resulting pressure of the suction line kept at 1.05 bar with +/-2 mbar fluctuation; the dewar pressure kept at 1.38 bar with +5/-3 mbar fluctuation. These pressure fluctuations are compatible to the +/-3mbar fluctuation requirement specified from the SRF cryostat. Figure 4 also shows an increase in the mass flow rate during the switch period of the two 80 K cryogenic absorbers. The pressure fluctuation increases when the dewar level is kept at a high value of 85 %, where the level fluctuates up to +/-0.4 % within 16 hours operation.

There happened several times system interrupt due to either the electric power was interrupted or the emergency push button was incidentally touched. Components of the cryogenic system are automatically isolated from each other during those interrupt events. The suction line pressure increases since the refrigerator depressurizes itself as system being interrupted. Each time the safety relief valve of the suction line, which is placed near the oil removal module, acts first due to its lowest setting pressure of 1.5 bar. During system interrupt period the suction line pressure increased up to 1.54 bar, which is lower than the setting pressure of the safety valve in SRF

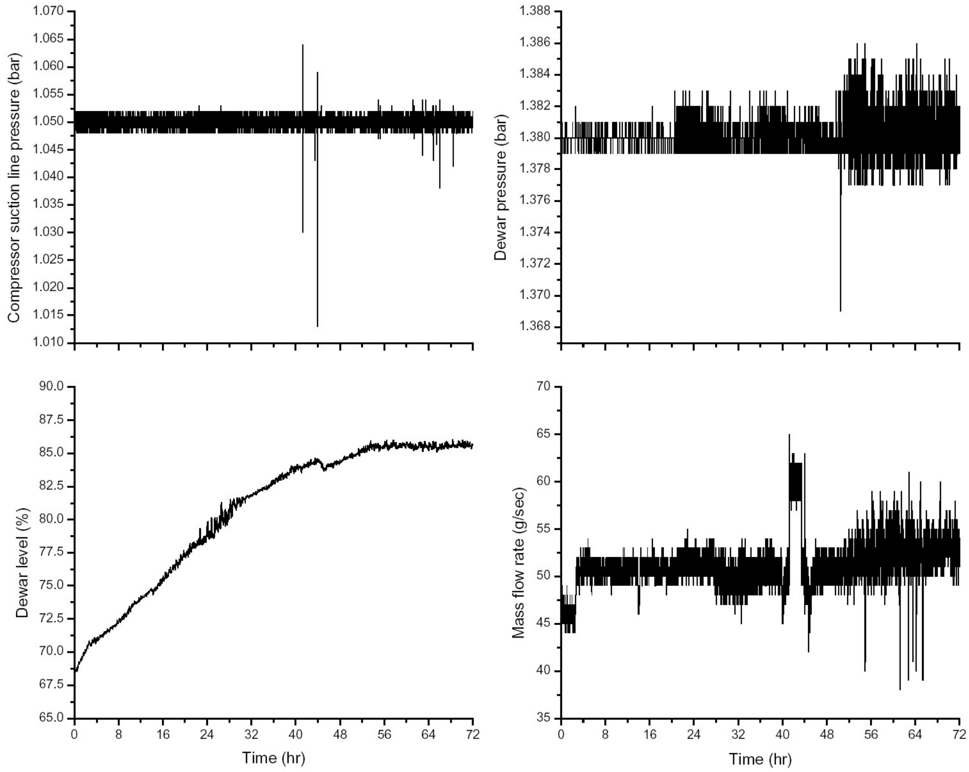


Figure 4: Stability and reliability test.

cryostat; thus the helium loss at cold condition could be prevented.

CONCLUSION

The cryogenic system provides a higher capacity than the specified value. Stability test shows acceptable level of pressure fluctuation at both the dewar and the compressor suction line. This system is ready for providing helium cooling for the operation SRF cavity, which will be installed at NSRRC in the near future.

ACKNOWLEDGEMENT

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REFERENCE

[1] F.Z., Hsiao, et al., “The Liquid Helium Cryogenic System for the Superconducting Cavity in SRRC”, PAC 2001, Chicago, June 2001, p. 1604.

[2] “Technical Specification of the Main Cryogenic Plant for a 500 MHz SRF Module,” SRRC Technical Report, Nov. 24, 2000.

Table 1: Characteristics of the helium cryogenic system.

Item	Units	Design value				Measurement value			
		Refrigeration		Liquefaction		Refrigeration		Liquefaction	
		w/o LN2	w/ LN2	w/o LN2	w/ LN2	w/o LN2	w/ LN2	w/o LN2	w/ LN2
Cooling capacity	W	255	450	-	-	309	469	-	-
Liquefaction rate	L/hr	-	-	51	115	-	-	60.5	153
Mass flow rate	g/s	51.2	73.9	42.3	59.6	44	82	24	39
Frequency driver	Hz	35	52	30	42	42	57.5	33.2	43.5
Discharge pressure	bar	12.2	15	15	15	15	15	15	15
Suction pressure	bar	1.05	1.05	1.05	1.05	1.05	1.05	1.05	1.05
Suction pressure fluctuation	mbar	+/−3	+/−3	+/−3	+/−3	+/−2	+/−1	+/−2	+1/−2
Dewar pressure	bar	1.25	1.3	1.25	1.3	1.25	1.272	1.25	1.25
Dewar pressure fluctuation	mbar	+/−3	+/−3	+/−3	+/−3	+/−1	+3/-2	+/−1	+/−1
Warm turbine speed	Hz	2724	2730	3340	2658	2912	2752	3200	2752
Cold turbine speed	Hz	-	2069	-	-	1842	1963	1846	1990