

THE INSTALLATION AND COMMISSIONING OF THE HELIUM CRYOGENIC SYSTEM FOR THE TPS PROJECT

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Abstract

The construction of an electron accelerator with energy 3 GeV for a highly brilliant and high-flux X-ray photon source is under way at NSRRC. There will be eventually four superconducting radio-frequency (SRF) cavities installed at the storage ring to maintain the electron energy. The helium cryogenic system has been designed and fabricated to provide the required liquid helium for the SRF cavities. The cryogenic system consists of a 700-W refrigerator and liquefier, a 315-kW variable-frequency compressor, an oil removal system, a recovery compressor system, gaseous-helium buffer tanks, and one 7000-L liquid helium dewar. The installation and commissioning of the overall system are presented and discussed in this paper.

INTRODUCTION

At NSRRC, the Taiwan Photon Source (TPS) project proposes to operate an electron accelerator with beam current 400 mA at 3 GeV and small emittance 2 nm rad. The circumference of the storage ring is 518.4 m and of the booster ring 496.8 m. In total, four superconductive RF (SRF) cavities will be installed in short straight sections of the storage ring to maintain the eventual energy level of the electrons. One 700-W cryogenic system will be installed to provide the required cooling power for these SRF cavities [1].

The cryogenic system is composed of compressors, an oil-removal system with gas management (ORS/GMP), two turbine refrigerator/liquefiers (RL), four 103-m³ helium buffer tanks, one 7000-L dewar, one 1000-L test dewar, one passive warmer, piping for gaseous helium at room temperature, transfer lines for helium distribution, and a liquid-nitrogen transfer system, which has tested cooling power 730.7 W at the test dewar and 725 W at the main dewar, respectively. The helium cryogenic system was contracted to Linde Company in 2009, and arrived in 2011 July [2]. The four 100-m³ helium buffer tanks were installed in 2010 with 9.50 barg helium gas inventory. Because of the delay of civil construction, one refrigerator/liquefier test area (RL area) was constructed to complete the assembly and test of a 700-W cryogenic system in year 2012. The 700-W cryogenic system was installed in 2012 March and completed in the test area in 2012 September. The system will be disassembled, removed to the TPS storage ring, reassembled and commissioned in 2013.

The aim of this paper is to describe the installation and commissioning result for the 700-W cryogenic system. The pre-commissioning process is presented; a summary

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of performance and pressure stability are also presented and discussed.

LAYOUT

Figure 1 shows the layout overview of the 700-W cryogenic system in the TPS storage ring and the RL test area.

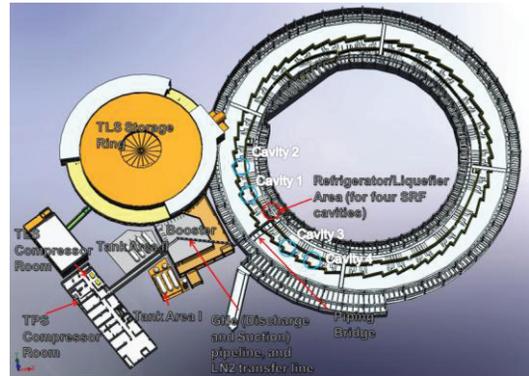


Figure 1a: Layout overview of the helium cryogenic system in the TPS storage ring.

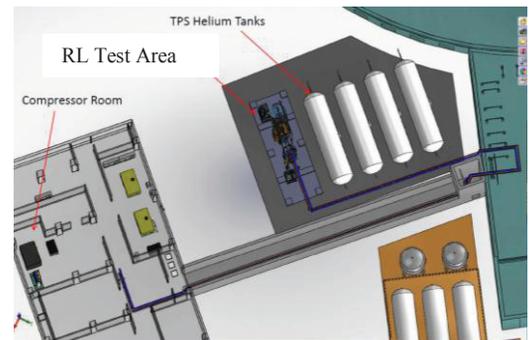


Figure 1b: Layout overview of the helium cryogenic system in the RL test area.

The warm helium gas is compressed from 1.05 bara to 13 bara with a compressor and transferred to the RL through a 3-inch discharge pipeline. The vaporized cold helium gas exchanges its heat with the high-pressure gas and returns to the compressor through a 8-inch suction pipeline. The only consideration involving two locations, which might affect the commissioning parameters, is the length of the pipelines for the warm helium discharge and the suction. The calculated pressure drops of the suction line and discharge line are 6 mbar and 116 mbar with 178 m and 175 m piping length, respectively, when the RL is located in the TPS storage ring [3]. The pressure drops of the suction line and discharge line are 5 mbar and 26 mbar with 122 m and 120 m piping length, respectively, when the RL is located at the RL test area. The pressure drop differences are 1 mbar and 90 mbar, respectively, for

the two locations, which might introduce cooling capacity difference 2.5 W based on previous experimental work.

Figure 2 shows the arrangement of the 700 W cryogenic system in the compressor area and the RL area. The compressor area is composed of one 315 kW compressor with a variable-frequency driver, one main ORS/GMP, one 63.6 kW recovery compressor, one recovery ORS/GMP, one secondary cooling-water system, one dryer and one gas analyzer. The RL area is composed of one 700-W RL, one adsorber regeneration skid, one 7000 L main dewar, one passive warmer and one 1000 L test dewar to simulate the heat load of the SRF cavities.



Figure 2a: Layout of the compressor area.

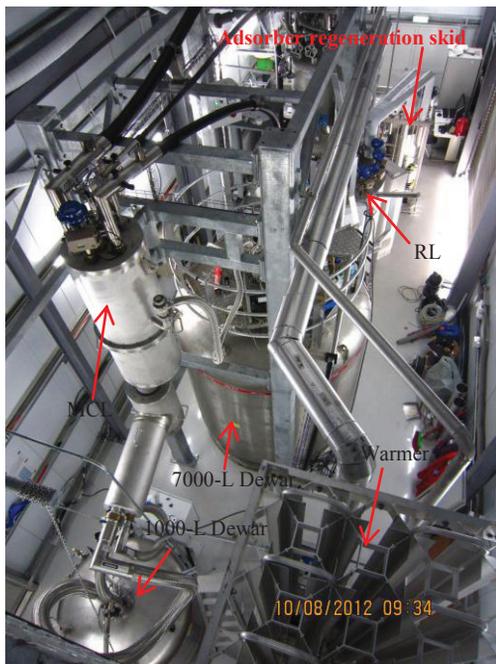


Figure 2b: Layout of the RL area.

INSTALLATION AND PRECOMMISSIONING

Installation of the Compressor Room

The piping was welded on site, requiring nearly 21 working days for the installation. The main compressor has power 315 kW and is operated with a variable-frequency-driver (VFD). The frequency of the VFD operates in a range 30 - 54 Hz according to the mass flow rate of the helium gas. The tested rate of mass flow is 106.3 g s^{-1} at 54 Hz. One ORS/GMP downstream from the compressor serves to adsorb the oil aerosol coming from the compressor station. The GMP regulates the discharge pressure and suction pressure of the process flow with four control valves. One gas analyzer monitors the content of N_2 , H_2O , C_nH_m and oil aerosol of the helium gas. One 63.6-kW recovery compressor is designed to recover the warmed helium gas to a buffer tank when the main compressor stops. The charcoal of the ORS/GMP was filled and regenerated during the installation. The charcoal was purged with nitrogen gas at $150 \text{ }^\circ\text{C}$ at the inlet, and $125 \text{ }^\circ\text{C}$ at the outlet after 6 h. The nitrogen was kept purging at $125 \text{ }^\circ\text{C}$ for 30 min to provide sufficient energy to remove the moisture from the charcoal.

Installation of the RL Area

The transfer line of the RL area was pre-fabricated in the workshop; eight working days were taken for the installation. There are five heat exchangers of plate type with two turbo expanders to provide cooling power 725 W and 201 L h^{-1} at the main dewar with liquid nitrogen precooling for the RL. Two 80 K adsorbers are switched by regeneration skid every 170 h automatically to adsorb the impurities during operation. The 80 K adsorber was dried in the workshop; the isolation valve must thus be kept closed during the installation. The 7000 L main dewar is to store the liquid helium produced from RL. The operating pressure 1.3 bara of the main dewar is maintained $\pm 3 \text{ mbar}$ to fulfil the operation of the SRF cavity. The 1000 L dewar is to simulate the heat load of SRF cavities for the cryogenic system with maximum heating power 1000 W during commissioning. The passive warmer provides maximum heat 300 W of vaporization from ambient to warm the returning gas from the main dewar and the distribution valve box in the future.

Precommissioning

Figure 3 shows an overview of the control system. One mobile 80 K cryogenic adsorber is installed between the discharge line and the suction line of the main ORS/GMP. The partial flow 3 g s^{-1} flows through the 80 K cryogenic adsorber to purify the helium gas by long-term circulation. The circulation loop is performed individually for the loop of the main compressor, the long warm helium piping, RL, adsorber regeneration skid, 7000 L

main dewar, 1000 L test dewar and recovery compressor. The contamination area is easily detected and isolated. Impurity N₂ was decreased from 40 ppm to 4 ppm and H₂O from 15 ppm to 1.5 ppm after circulation for 6 h.

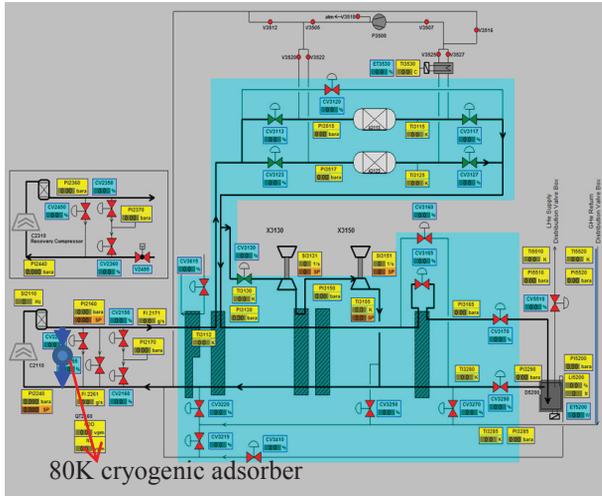


Figure 3: Overview of the control diagram.

RESULTS AND DISCUSSION

Liquefaction Rate and Refrigeration Power

Table 1 shows the test results for five modes. The maximum rate of liquefaction in the main dewar was 201 L h⁻¹ with LN₂ consumption 19.46 g s⁻¹.

Table 1: Rate of Liquefaction and Refrigeration Power of Various Modes

Mode	Dewar	Dewar Pressure	Consumption of LN ₂ / g s ⁻¹	Result
Liquefaction	Main Dewar	1.35 bara	19.46	201 L/h
Refrigeration	Main Dewar	1.35 bara	N/A	395 W
Refrigeration	Main Dewar	1.35 bara	17.66	725 W
Refrigeration	Main Dewar Test Dewar	1.4 bara	17.2	730.7 W
		1.35 bara		
Mixed	Main Dewar Test Dewar	1.4-bara	13.68	44.6 L/h 710 W
		1.35 bara		

The refrigeration power was 395 W with LN₂ consumption 17.66 g s⁻¹ and 725 W without LN₂ precooling at the main dewar. These tests were performed without a test dewar connected. The maximum cooling power at the test dewar was 730.7 W with LN₂ consumption 17.2 g s⁻¹. The operation of the SRF cavities is in mixed mode; the cavities operate in the refrigeration mode and the wave guide in the liquefaction mode at the

same time. The mixed mode has maximum simulated heating power 710 W in the test dewar and liquid helium production 44.6 L h⁻¹ in the main dewar. Because of the long time to stabilize the cryogenic system, the retention periods for the tests of liquefaction rate and refrigeration were 4 h and 24 h, respectively.

Pressure Stability

The operation of the SRF cavities required pressure fluctuation ±3 mbar of the liquid helium supply and the vaporized helium return. The critical condition for the pressure stability is at maximum cooling capacity at the main dewar because of the small latent heat of liquid helium. Figure 4 indicates the tested pressure stability of the suction line and the main dewar at 725 W cooling power at the main dewar. The pressure fluctuation of the suction line was +2 mbar and -3 mbar, respectively. The average pressure fluctuation of the main dewar was ±3 mbar. One fluctuation +6 mbar was found to be caused by the operation of the adsorber regeneration.

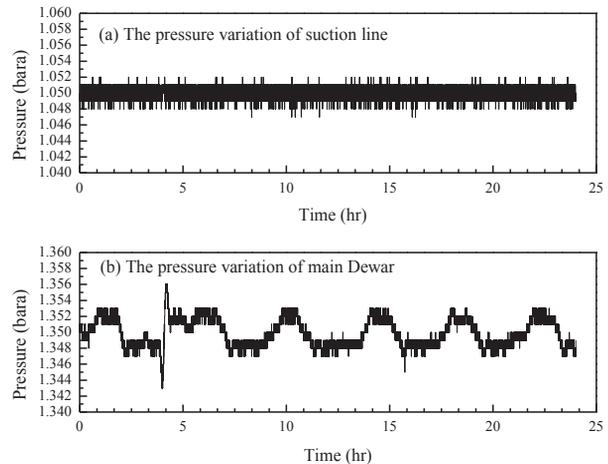


Figure 4: Pressure variation of the suction line and main dewar.

SUMMARY

The 700W cryogenic system was installed and commissioned at a temperate test area in 2012. The test results shows sufficient cooling power, liquefaction rate, and stability for the required operation of SRF cavities.

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