Commission and Operation Experience of Cryogenic System

A new cryogenic system was installed in September of year 2006 at NSRRC. Prior to the installation, two superconducting magnets and one superconducting cavity for RF are cooled by one 450W liquid Helium system which had already been installed during the year 2002. The new system is planned to supply the liquid helium up to five superconducting magnets and served as a backup of the first unit connected by a transfer valve box. This highlight presents the installation and the commission of the new cryogenic system under liquefaction, refrigeration and mixed mode. Part of our operational experience were also shown and discussed.

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The installation of cryogenic plant and the associate interconnect piping were completed in December 2005. Figure 1 shows the construction of the cryogenic plant. The compressor, the oil-removal module, and the frequency driver are installed in the compressor hall. Two buffer tanks of volume 100 m^3 each are located on a platform at a height 6 meter above the ground. The refrigerator and Dewar are located on a platform at height 2.8 m. A 2.5-inch discharge pipe and an 8-inch suction pipe, each with length of 160 m, connect the main compressor and the refrigerator. A 4-inch make-up pipe connects the buffer tanks and the compressor station. As the switch valve box connects Dewars of two cryogenic plants, each cryogenic plant could act as a back-up system of liquid helium supply for the superconducting cavity and superconducting magnets.

Compressor station

Helium buffer tanks

Refrigerators and Dewars

Fig. 1: Construction of the cryogenic system

Commissioning of this cryogenic plant started in January and finished in November 2006. Because of the scale of volume, it took one month to dry the buffer tanks by nitrogen gas and the dew points were controlled to be less than -55˚C inside

Tab. 1: Test results of gas helium piping

Test item	Suction pipe	Discharge pipe	Make-up pipe
24 hrs GN_2 pressure-keep test (bara)	10	22	10
12 hrs GHe pressure-keep test (bara)	5	19	5
30 minutes particles (<0.5μm) counting	16	21	5
Dew point control (°C)	-52.6	-51.3	-59.3
Leakage test with vacuum mode (mbar·l/s)	< 2.7e-10	<4.3e-10	<4.2e-10
Leakage test with sniffing mode (mbar·l/s)	6.5e-6 (Equal to background value)		
Vacuum test (mbar)	3.0e-6	1.8e-6	2.4e-6

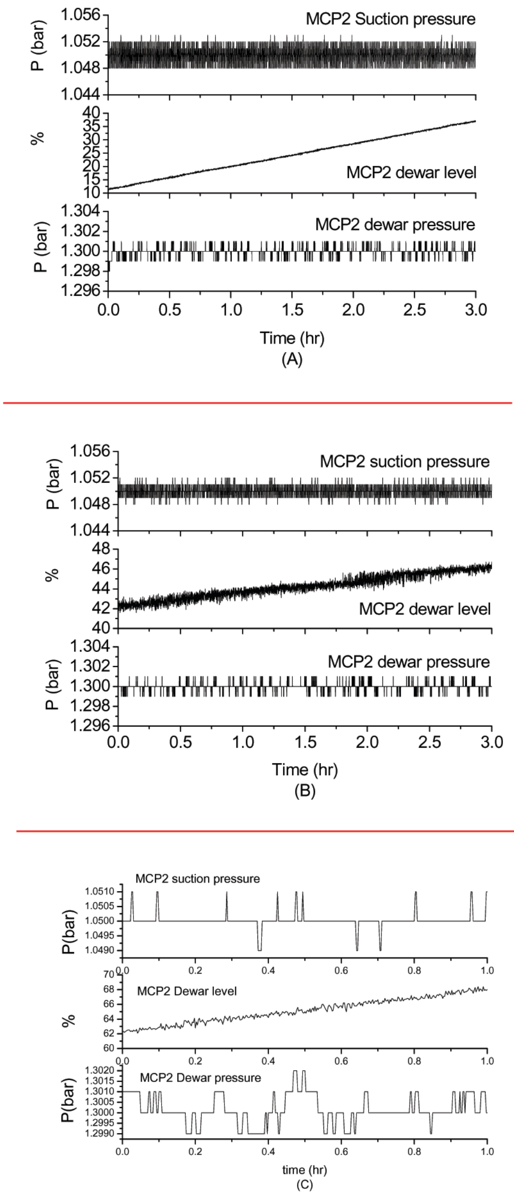

Fig. 2: (A) Liquefaction with LN_2 pre-cool at 80K, (B) Refrigeration with heater power 320W, (C) Mixed mode with LN_2 pre-cool at 90K and heater power 146W.

these two tanks. In addition, it took 10 days for three cycles of purge and pumping down of the buffer tanks using pure helium gas. The 315kW power of the compressor is supplied by a various-frequency-driver (VFD). The frequency of VFD operates from 30Hz to 60 Hz according to the requirement of the mass flow rate of helium gas. The VFD provides the advantages on power saving and lower start-up current. The mass flow rate is 85.9 g/s on full load operation. One oil removal system connected to the compressor is used to catch the oil aerosol coming from the compressor station. It is equipped with two coalescent filters and one charcoal filter. The charcoal filter was dried by hot nitrogen gas (67˚C) for one week to control the dew point value to -59.6˚C. Three control valves of the gas management regulate the discharge pressure and suction pressure. The gas management keeps the discharge pressure at 15 bar with fluctuation +13/-16 mbar and the suction pressure at 1.05 bar with fluctuation +/-3 mbar. One gas analyzer monitors the contents of N_2, H_2O, C_nH_m, and oil aerosol inside the helium gas. The alarm level of total impurity is set at 50 ppm. Piping for helium gas was carefully tested before their usage. Table 1 summarizes the items and testing results for the gas piping.

The capacity measurement at the Dewar during the commissioning is shown in Figure 2, where the Dewar pressure (suction pressure) was kept at 1.3 bar (1.05bar) with +/- 1mbar (+3/-2 mbar) fluctuation. In the test of liquefaction mode, the Dewar level increases 26.5 % in 3 hours with liquid nitrogen pre-cooling and the liquefaction rate is 170 L/hr. In the refrigeration mode, the system provides a cooling power of 320 W with 26 L/hr liquefaction rate without LN_2 pre-cooling. In the mixed mode, the liquefaction rate is 116 L/hr with 90K LN_2 pre-cooling temperature and 146W heating power.

LN_2 pre-cooling is used to increase system capacity by providing refrigeration for the first heat exchanger. However, during our operational experiments, it can also provide a constant outlet temperature for the first heat exchanger, which makes the downstream parameters (i.e. the absorber temperature, the turbine speed, the turbine inlet pressure etc.,) more stable. Figure 3 (A) shows the fluctuation for turbine speed and the first heat exchanger outlet temperature without LN_2 pre-cooling. During the commissioning period, the LHe level was controlled by auto regulation of heating power which induced the instable cold gas from Dewar. This would affect the heat transfer to the inlet warm Helium gas, which induced the fluctuations for the outlet temperature of first heat exchanger and the down stream parameters. To avoid the impact on operational capacity of refrigeration, a constant outlet temperature of the first heat exchanger is kept just a little bit lower than the cold gas temperature. The resulting stable parameters are indicated in figure 3 (B).

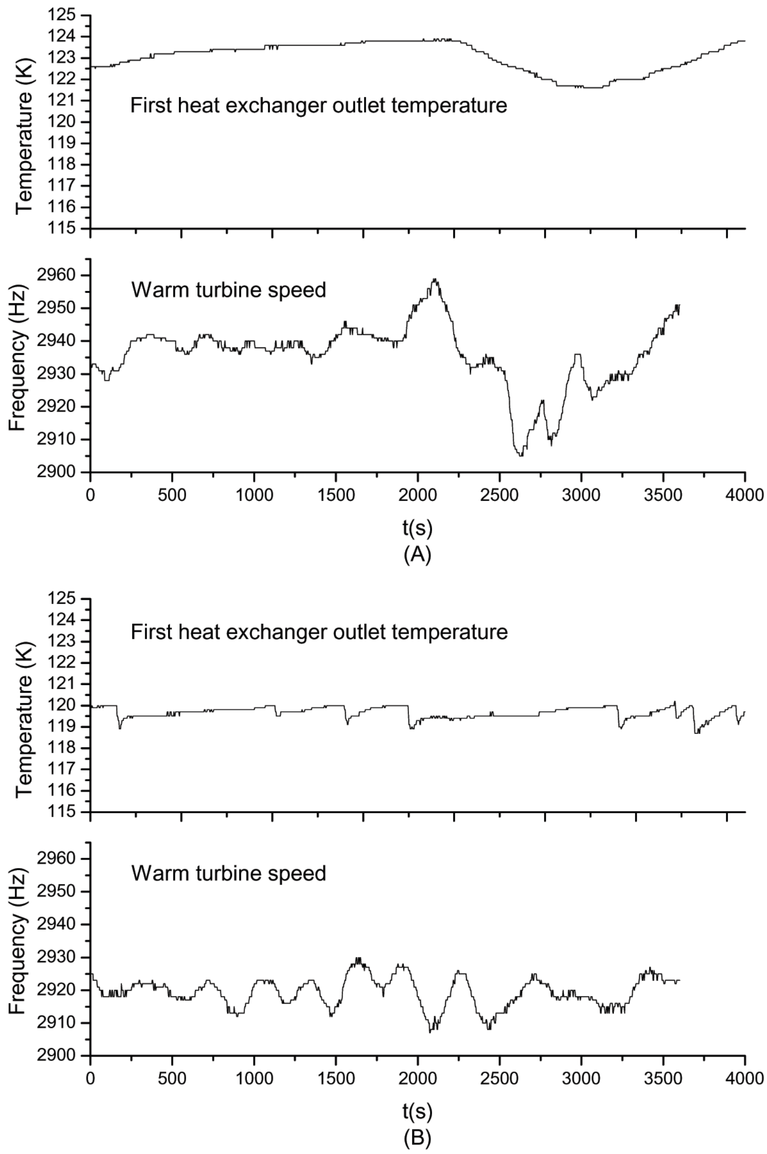

Fig. 3: (A) The variations for first heat exchanger outlet temperature without LN_2 pre-cooling, (B) The variations for first heat exchanger outlet temperature with 120K LN_2 pre-cooling.

Publications

- F. Z. Hsiao, H. C. Li, W. S. Chiou, and S. H. Chang, "Operation of a Helium Cryogenic System for a Superconducting Cavity in an Electron Storage Ring," Proceedings of EPAC2006, Edinburgh, Scotland, (2006).
- H. C. Li, F. Z. Hsiao, S. H. Chang, W. S. Chiou, M. C. Lin, "The Cryogenic System for Superconducting Magnets at NSRRC," the 21th International Cryogenic Engineering Conference (ICEC21), Praha, Czech, (2006).

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