STABILITY IMPROVEMENT OF THE CRYOGENIC SYSTEM AT NSRRC

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Abstract

Negative gauge pressure appears in the helium suction line during the period of compressor starting up. The negative pressure induces the risk of air leakage into the cryogenic system and the damage to the burst disk of cryostat. A buffer tank is connected to the suction line to avoid the negative gauge pressure. Variation of nitrogen pressure changes the thermal-shielding temperature of the cavity cryostat and thus changes the length and frequency of the cavity. A phase separator with pressure control is installed before the cryostat to isolate the fluctuation of nitrogen pressure at the source side and prevent the trip of electron beam due to the frequency change or the overpressure at the cavity side. The stability improvement after usage of the phase separator shows that variation of the nitrogen pressure to the cavity cryostat is reduced from +0.6/-0.4 bar to +/-0.08 bar and the drift of nitrogen pressure is eliminated. The stability after usage of the buffer tank shows that the negative gauge pressure is avoided in the suction line and the peak pressure was reduced from 1.4 bar to 1.2 bar.

INTRODUCTION

Reliability and stability are two important targets pursued for the machine operation of synchrotron light source. In the past year 2006, eight trip events were due to the unstable pressure of liquid nitrogen supply, four trip events were caused by the fault of helium cryogenic plant, and the remaining five trip events were due to the trial run of the second cryogenic plant [1]. In most events the overpressure of liquid nitrogen triggered the interlock of the cavity cryostat and led to trip of the electron storage ring. Few trips were owing to the fluctuation of nitrogen-shielding temperature, which disturbs the resonance frequency of superconducting radio frequency (SRF) cavity in the storage ring. The disturbed frequency was over the compensation range of cavity's tuner and thus led to trip. The temperature fluctuation is due to the unstable pressure of liquid nitrogen supply, which occurs when the storage dewar is filled by a trailer or when other users withdraw liquid nitrogen to their small dewars.

The SRF cavity operates at refrigeration mode and the superconducting magnets operate at liquefaction mode. The vaporized helium gas from the cryostat of superconducting magnet goes to a passive warmer and then to the suction line; while the helium from cavity cryostat goes to the cold box first and then to the suction line. Both pressures of cavity cryostat and magnet cryostat are strongly affected by the suction line pressure; thus a stable suction line pressure assists in keeping a stable resonance frequency of SRF cavity [2].

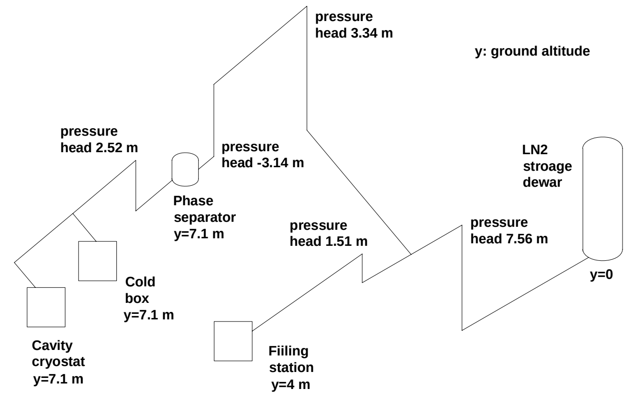

Figure 1: Relative altitude of nitrogen system.

PROBLEM DESCRIPTION AND STRATEGY

The relative altitude of the liquid nitrogen transfer line is indicated in Fig.1. The pressure head from the storage dewar to the cavity cryostat is 10.9 m and the pressure head from the storage dewar to the filling station, at upstream side of the cavity cryostat, is 9.1 m. Operation pressure of the storage dewar is kept at 2.6 barg. The pressures of the storage dewar and the cavity cryostat both decrease when the user takes liquid nitrogen from the filling station. After the usage of filling station or the refill of liquid nitrogen to the storage dewar, it happened sometimes that the nitrogen pressure at cavity side increased more than the interlock threshold 4.1 bar. During the usage of filling station the high altitude of the cavity cryostat and the low operation pressure of storage dewar cause some voids appearing in section of the transfer line toward the cavity cryostat. After using the filling station liquid nitrogen refills the voids and re-cools the transfer line; thus pressure surge is induced in the transfer line. Shortening the filling period and limiting the amount of liquid nitrogen taken from the filling station can reduce the pressure increase but introduce the inconvenience. Since there is a safety concern for the cavity cryostat, increasing the operation pressure of the storage dewar to avoid creation of void is abandoned. Instead, a phase separator with volume of 250 liter is used to limit the maximum pressure and improve the pressure stability. Due to the limitation of available space, the phase separator is placed 20 m from the cavity cryostat such that the phase separator is at the upstream side of both the cold box and the SRF cavity.

Since the burst disk protects the cryostat pressure, either the high pressure or the negative gauge pressure in the suction line may damage the burst disk 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

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stops and restarts. Though the recovery compressor will start up to keep the suction line at low pressure, 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 depressurised helium from the discharge line and the cold box. The negative gauge pressure appears for several seconds when the compressor starts up to its operation speed. The volume of the 180 m suction line is 5.6 m^3. We connect a 103 m^3 buffer tank to the suction line and evaluate fluctuation of the suction line pressure during periods of the compressor starting up and stop. The buffer tank is close to the compressor side and connected to the point at one-third length of the suction line.

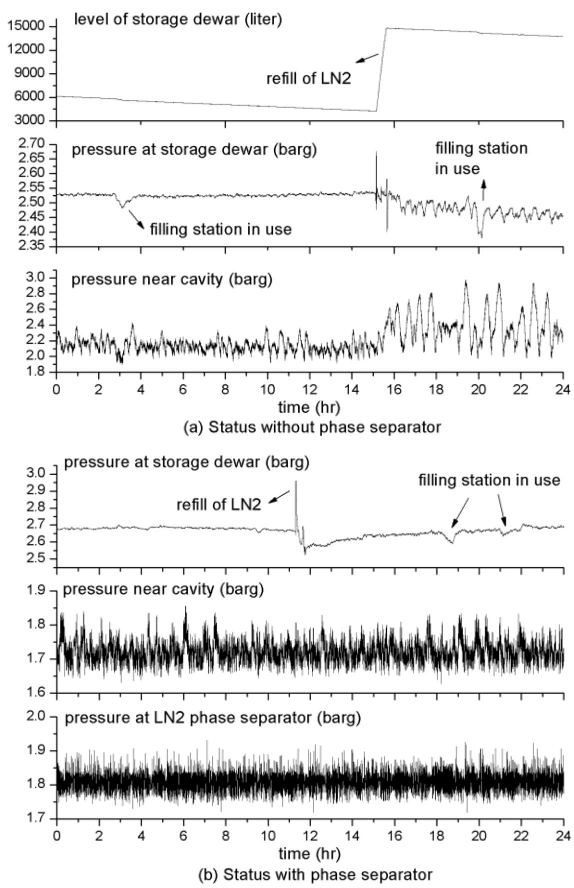

Figure 2: Stability of the nitrogen pressure.

RESULT AND DISCUSSION

A nitrogen phase separator was installed in January 2007, where an inlet valve regulates the liquid level, a vent valve limits the overpressure, and an auxiliary source of nitrogen gas prevents the pressure shortage [3]. Figure 2 shows the pressure status before and after the installation of phase separator. Pressure of the nitrogen storage dewar is disturbed during the usage of filling station or the refill of liquid nitrogen to the storage dewar; the pressure drift appears as the level of storage dewar decreasing. After installation of the phase separator, the pressure of liquid nitrogen is lowered from 2.6 barg to 1.8 barg and variation of supply pressure to SRF cavity is reduced from +0.6/-0.4 bar to +/-0.08 bar. The pressure disturbances form the storage dewar and the filling station are isolated and the drift of nitrogen pressure is eliminated.

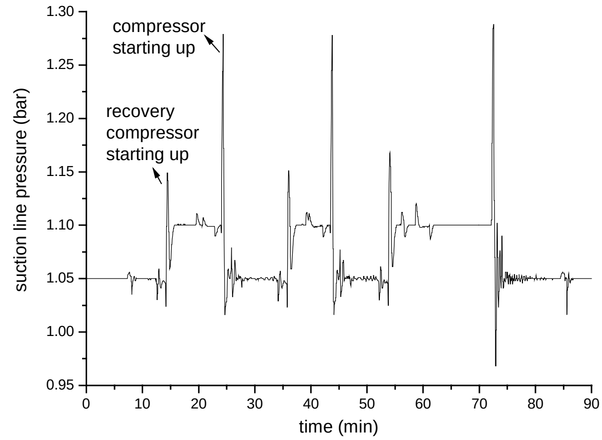

Figure 3: Effect of buffer tank on suction line pressure.

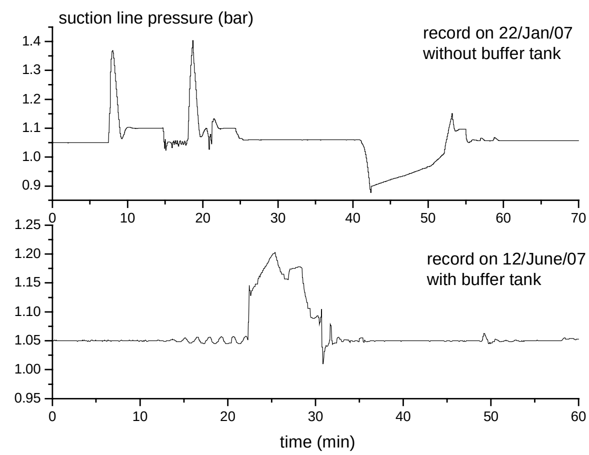

Figure 4: Pressure record during trip of cryogenic system.

Figure 3 shows the test result of connecting the buffer tank to the suction line, where the buffer tank was used in the first two cycles of compressor stop and starting up and it was not used in the third cycle. The pressure was recorded, with sampling time 3 second, at inlet of the compressor. No vaporized helium gas came from the magnet cryostats or cavity cryostat during the experiment. In normal operation the suction line pressure was regulated at 1.05 bar; as compressor stop the recovery compressor started up and maintained the pressure at 1.1 bar. During the compressor stop and starting up the suction line pressure increased to 1.28 bar with the buffer tank, and it was 1.29 bar without the buffer tank. With the buffer tank the minimum pressure was increased from 0.97 bar to 1.016 bar, so the negative gauge pressure was avoided. A long-term observation shows that the pressure fluctuation is further stabilized from +/-0.2 mbar to +/-0.1 mbar, which is within resolution of the pressure transmitter. Figure 4 compares the suction line pressure during two trip events with and without the buffer tank. In both events all the cavity cryostat and magnet cryostats were connected to the cryogenic system. From the result the negative gauge pressure was avoided with the buffer tank and the peak pressure was reduced from 1.4 bar to 1.2 bar.

REFERENCES

[1] H. C. Li, et al., "The Cryogenic System for Superconducting Magnets at NSRRC", ICEC21, Praha, Czech, July 2006.

[2] Ch. Wang, et al., "Successful Operation of the 500 MHz SRF Module at TLS", PAC'05, Knoxville, Tennessee, May 2005, p.3706.

[3] Pressure Reducing Phase Separator, NSRRC Technical Documents.

1-4244-0917-9/07/$25.00