

CURE OF TEMPERATURE FLUCTUATIONS ON THE NITROGEN-COOLED SECTIONS OF A CESR-TYPE SRF MODULE

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Abstract

A strong correlation between tuner motion of the SRF module and the pressure fluctuation of the shielding liquid nitrogen flow is observed. The double elbow waveguide section with nitrogen cooling channels is one of the possible fluctuation sources. Thus it is tested along to investigate the mechanism of pressure and temperature fluctuations, whereas a phase separator with pressure regulation function is used to stabilize the supply pressure of liquid nitrogen. Also it is tried to stabilize the pressure fluctuation by optimizing and regulating the vent flow rate. System setup and primary test results are presented herein.

INTRODUCTION

AS a major accelerator upgrade to increase the stored beam current and to eliminate the beam instability caused by higher-order modes of the cavity [1], an industrially manufactured superconducting radio-frequency module was installed into the storage ring at the Taiwan Light Source (TLS), in late 2004. The CESR-type SRF module[2], developed in the Newman Laboratory of Nuclear Studies, Cornell University, USA, was chosen for this project. During normal operation of the SRF module in 2005 and 2006, it is observed the cavity tuner motion has a strong correlation with the temperature variations of the thermal transition beam tubes of the SRF module [3].

The thermal transition beam tubes are located in between the room-temperature end plates and the nitrogen-cooled sections. Thus its temperature fluctuation must come from the temperature variation of liquid nitrogen shielding flow. As shown in Fig. 1, when the

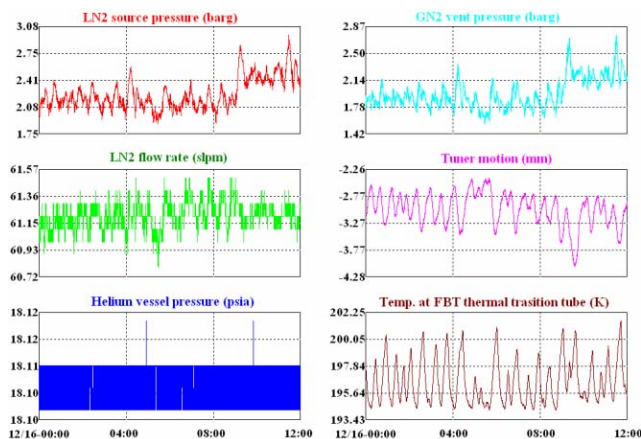


Figure 1: Tuner motion is correlated with the temperature of thermal transition tube and the nitrogen pressure, when the helium vessel pressure has a small variation.

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variation of helium vessel pressure is controlled within +/- 0.01 psia, correlations between the tuner motion, nitrogen supply pressure, nitrogen vent pressure, and the temperature at the thermal transition tube are observed.

For the CESR type SRF module, liquid nitrogen cools not only the thermal shielding layers and the thermal transition tubes, but also a double elbow waveguide section. The double elbow waveguide section has much bigger cooling channels than the 1/2" copper pipes for thermal shielding. Thus it is highly suspected to be the source of pressure fluctuation. A spare double elbow waveguide section is used to study the fluctuation mechanism herein. With the help of a phase separator as liquid nitrogen supply source and a bypass flow control valve, the test results shows the cure of temperature and pressure fluctuations is promising.

EXPERIMENT SETUP

Layout

The layout of experimental setup is shown in Fig. 2. A phase separator with pressure regulation supplies liquid nitrogen to the double elbow waveguide through the inlet valve and a vacuum-jacketed flexible line. The double elbow waveguide section is wrapped with super-insulation layers and then installed into a vacuum sealed vessel. Its lower end section is connected to the vacuum vessel through a dummy waveguide section. Temperatures at 3 locations are monitored: T_u at upper end near the inlet cooling channel, T_{out} on the surface of cooling channel outlet, and T_b on the bottom end near thermal transition section. The vent nitrogen is warmed up to room temperature by a passive warmer.

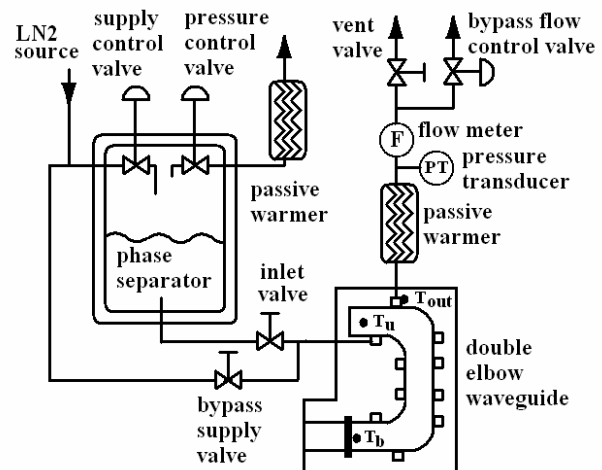


Figure 2: Layout of test setup, with a phase separator for supply pressure regulation.

Phase Separator (PS)

The phase separator is a 100-liter vessel with vacuum shielding. A bypass path for liquid nitrogen supply is constructed by ourselves for fail-safe operation. Liquid nitrogen comes from a huge outdoor container and flows through a 120-m transfer line and two valve boxes. Some small gas-vent devices have been installed along the long transfer path. But this 100-liter phase separator guarantees only liquid nitrogen is delivered to the downstream components, since the drain port is at its bottom. A pressure control valve, commanded by a PID controller, vents the gas out and regulates the vessel pressure to the setting value. With the supply control valve closed, the vessel pressure can achieve a variation of less than +/-5 mbar. A 500-W heater probe is installed inside. Note the safety devices, level sensor, and temperature probes are not shown in Fig. 2.

Passive Warmer

The passive warmer is constructed with finned tubes, with no active heater elements. A fan can raise the heat efficiency if necessary. The flow meter, pressure transducer, vent valve, and bypass flow control valve are all installed on the outlet port of the warmer, so that room-temperature devices can be used. The bypass flow control valve is commanded by a PID controller to regulate the warmer pressure by changing flow rate, while the vent valve guarantees a minimum flow rate.

TEST RESULTS AND DISCUSSIONS

Constant Flow Rate with PS Filled

The first try is to keep a constant flow rate of around 50 slpm at the warmer vent, while the phase separator is

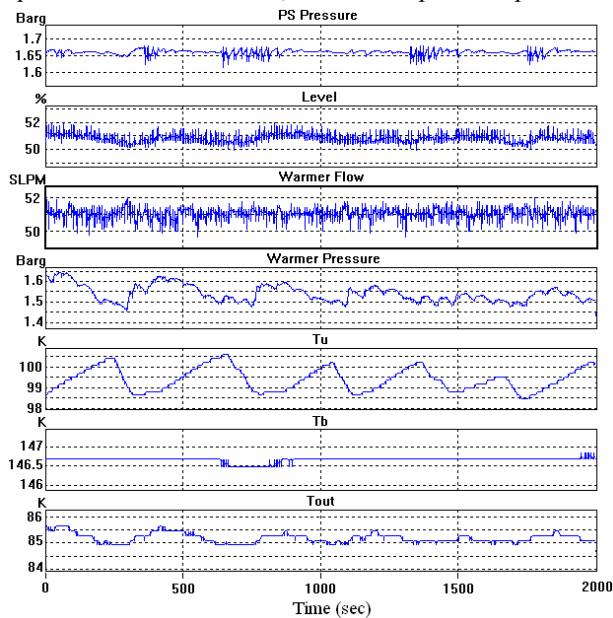


Figure 3: Variations of temperatures and warmer pressure at a constant warmer flow rate of about 50 slpm, while the liquid nitrogen level inside the phase separator is kept at +/-1% fluctuation by occasional filling.

operated with setting pressure of 1.66 barg and level of 51%. To keep the liquid nitrogen level at 51%, the phase separator must be filled with liquid nitrogen occasionally. As shown in Fig.3, a pressure fluctuation of +/- 30 mbar happens at the phase separator during each filling. It is also shown that the temperatures T_u and T_b vary periodically from 98.5 K to 100.5 K and from 85 K to 85.6 K, respectively. Meanwhile the warmer pressure also varies periodically between 1.45 barg to 1.65 barg, and highly correlated with the temperature fluctuations.

Constant Flow Rate with PS Not Filled

To eliminate the possible disturbance from the pressure fluctuation of phase separator, the supply control valve is fully closed. As shown in Fig. 4, the level is thus decreased gradually. When the flow rate is kept at 50 slpm as the previous test, the pressure inside the phase separator has a fluctuation of +/- 15 mbar. Obviously this fluctuation is also correlated with the warmer pressure fluctuation.

Then the warmer flow is increase to 80 slpm and finally to 100 slpm. It is clearly shown in Fig. 4 that all monitored parameters including the PS pressure, warmer pressure, T_u and T_{out} are getting stable at 100 slpm. Though, T_u still has a fluctuation of +/- 0.3 K at 100 slpm. It is thus concluded that not only the temperature, but also the warmer pressure, can be stabilized at a high flow rate of 100 slpm. This result also hints that high flow rate eliminates the thermal breath inside the warmer structure.

Another interesting observation is that the periodical variation of warmer pressure is actually composed of two fluctuations. The first one has a period of 7 to 8 minutes, dominates at flow rate less than 80 slpm. The other one has a period of about 50 seconds, varies within +/- 20 mbar and dominates the pressure fluctuation at 100 slpm.

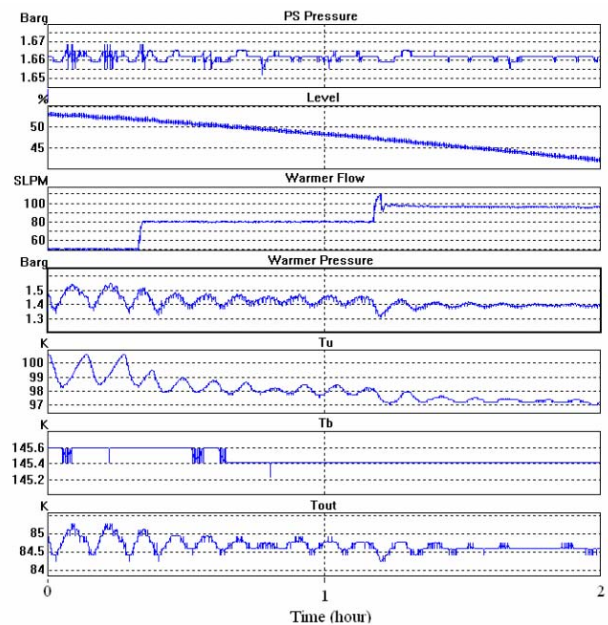


Figure 4: Variations of temperatures and warmer pressure at different warmer flow rates, while the phase separator is not filled with liquid nitrogen.

Unfortunately the real sources for these two periodical pressure variations can not be individually identified. Possible source structures are the double elbow waveguide section, passive warmer, and the vacuum jacketed flexible lines. Notice that a flow rate of 80 slpm equals a mass flow rate of 1.667 g/sec. The vacuum jacketed flexible lines have an inner pipe of diameter 0.5 inch. A calculation on the saturated nitrogen of 1.4 bar shows that the flow speed of pure liquid nitrogen and pure gas nitrogen is about 1.6 cm/sec and 210 cm/sec, respectively, inside the flexible line. Because only structures with slow flow speed are considered to induce pressure fluctuation, thus the double elbow waveguide section and the flexible line for liquid supply to it are suspected. But it needs more tests, like to use a flexible line of different length or a double elbow waveguide section with different cooling channel design, to prove this deduction.

Variable Flow Rate with PS Not Filled

Form the previous test results, it is shown the fluctuations of warmer pressure and T_u are correlated. This hints the temperature fluctuation on the double elbow waveguide section could be minimized by control the warmer pressure well. Thus the bypass flow control valve after the passive warmer is activated under a range of 10 to 40 slpm, while the vent valve guarantees a minimal flow rate of 65 slpm. The bypass flow control valve is set to maintain the warmer pressure at 1.47 barg. The bypass flow rate is increased as the warmer pressure grows up, and vice versa. Again the phase separator is

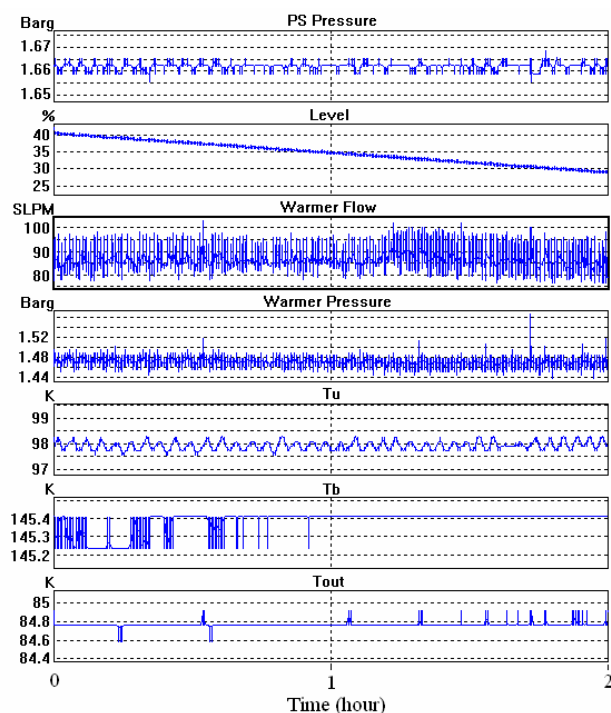


Figure 5: Variations of temperatures and warmer pressure at variable warmer flow rates to minimize the warmer pressure fluctuation, while the phase separator is not filled with liquid nitrogen.

not filled with liquid nitrogen to eliminate the possible disturbance from the vessel pressure of phase separator.

As shown in Fig. 5, the warmer pressure is mostly kept in between 1.44 and 1.50 barg, and the temperature T_u varies within ± 0.4 K. The spikes of warmer pressure have minor effect on the monitored temperatures. This test result shows the temperature fluctuation can also be minimized by regulating the warmer pressure with variable flow rate. Also it is noticeable that the time structure of the 50-second pressure fluctuation is terminated by the variable flow rate operation.

CONCLUSIONS

The test results prove the double elbow waveguide section is actually a source of temperature fluctuation. Thanks to the excellent performance of phase separator on pressure regulation, it is proven that the pressure and temperature fluctuations can not be cured by stabilizing the supply pressure only. Instead, increase of the vent nitrogen gas flow can reduce the temperature fluctuation. It is also proven that the warmer pressure fluctuation has a strong correlation with the temperature fluctuation. And a good regulation on the warmer pressure by the bypass flow control valve can also reduce the temperature fluctuation. However, a link between the cooling channel pressure of the double elbow waveguide section and the warmer pressure should be established to examine their correlation.

Based on the test results, a bypass flow control valve will be installed on the nitrogen vent port of the SRF module in operation. The nitrogen flow rate is currently 50 to 60 slpm, and it will be increase to 100 or 120 slpm. Both the effects of high flow rate and warmer pressure regulation will be tested. It is expected to stabilize the tuner motion by this simple modification. A further investigation is to modify the cooling channel of the double elbow section so that no temperature and pressure fluctuations will be induced at low flow rate.

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