FAILURE ANALYSIS FOR CRYOGENIC SYSTEM OPERATION AT NSRRC

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Abstract

Two 450W cryogenic systems were installed on the year 2002 and 2006, respectively at NSRRC. So far, one 450W cryogenic system is cooling three superconducting magnets and one superconducting cavity. The new system will serve for five superconducting magnets on the year 2007. This paper presents the abnormal operation for the system, which induces the fluctuations for pressure, temperature, and flow rate, respectively. Solutions for these failures are shown and discussed.

INTRODUCTION

A 450W cryogenic system has been already used at NSRRC for one 500 MHz superconducting cavity and three superconducting magnets since the year 2002. A second 450W cryogenic system was installed and planed to support the three scheduled superconducting magnets on the year 2006. The helium system includes one 315 kW compressor, one 10 kW refrigerator, one 2000 litter Dewar, and two 100 m3 gas helium buffer tanks. Inside the cold box two expansion turbines with industrial static gas bearing connected in series provide the major cooling power for helium gas stream. Two 80 K absorbers and one 20 K Absorber are installed in the cold box. These two systems supply liquid helium and been a backup with each other by a distribution valve box. The layout of these two systems and distribution valve box has been detailed in other specialised papers [1, 2]. The primary components (screw pump, oil removal module, cold box, etc.,) have been extensively used, improved and a wide operational experience is available at NSRRC. Based on these experiences, the instability and failure operation has been shown and analysed to improve the reliability of the system.

The system instability and failure operation is strongly related to maintenance policy (i.e., maintenance for the compressor, cryogenic valves, oil removal modules, cooling water system, compressed air system etc.,), and parameters regulation [3]. This paper focused on compressed air, and cold box operation which has an influence on the availability or stability of the cryogenic system.

RESULT

LN_2 Precooling to the Stability of the System

LN_2 pre-cooling is used to increase system capacity by providing refrigeration for the first heat exchanger. However, in our operation 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 stabilized. Figure 1 (A) shows the fluctuation for turbine speed and the first heat exchanger outlet temperature without LN_2 pre-cooling. During the commissioning period (no LHe consumption for downstream systems), 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 strong 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 1 (B)

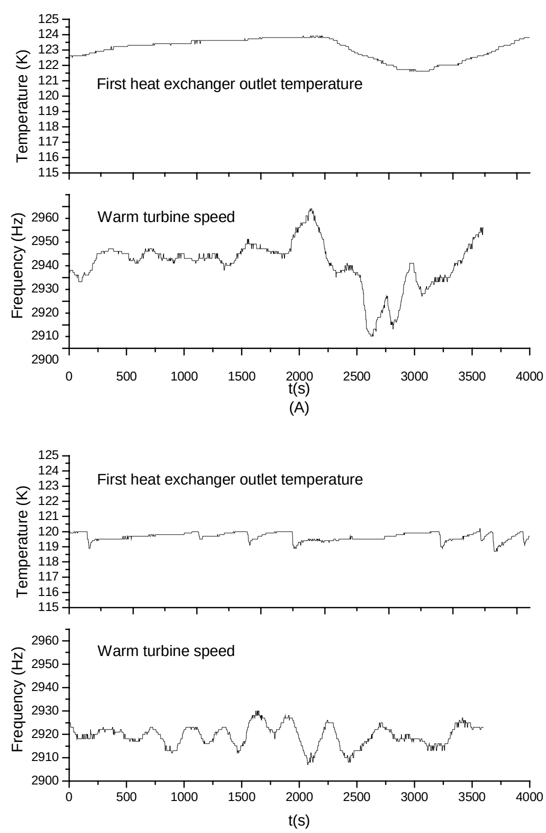

Figure 1: (A) The variations for first heat exchanger outlet temperature without LN_2 pre-cooling, (B) The variations for first heat exchanger outlet temperature with 120K LN_2 pre-cooling

Stability of Compressed Air for Gas Manager

Helium supply is automatically adjusted by gas manager as the refrigeration/liquefaction load changed. The gas management was consisted three pneumatic control valves. The complementary valve, which is automatically, adds helium to the system when liquefaction/refrigeration capacity is higher than flow recover from compressor. The valve which is sends excess helium to the storage tanks when warm-ups/or superconducting magnets done the LHe filling or quenches. The by-pass valve, which is recycles excess flow from discharge to suction line. The gas managers are controlled by a 0-3 bara pneumatic I-P converter which reduced from 5.8±.0.6% barg source pressure. The gas managers and mass flow rate might affected by instability compressed air supply. The instability of compressed air is perhaps due to the switch of air buffer or the leakage of pipeline for the system. Figure 2 (A) shows that when the upstream pressure been fluctuated (~13.8%), it might induced a fluctuation (~±7.7%) of by-pass valve, which was shown in figure 2(B). Figure 2 (C) shows that the mass flow rate was fluctuated (~± 11.9%) due to the failure act of gas manager. A pressure regulator should be installed near I-P converter and keep the setting value below the possible fluctuation to avoid the instability of valves.

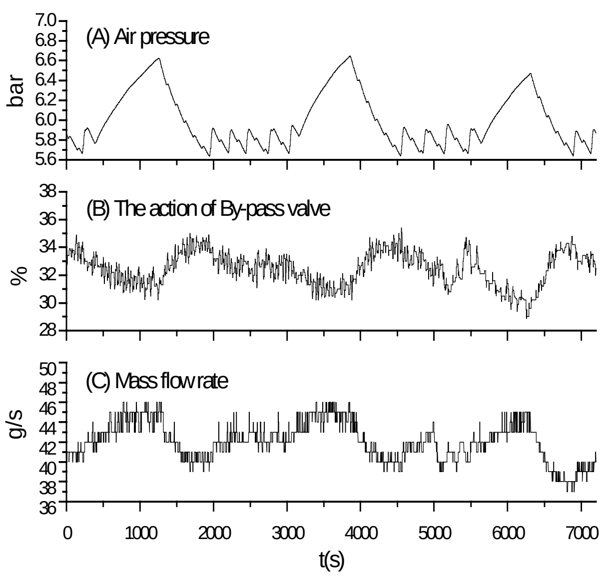

Figure 2: (A) The pressure of control air, (B) The variation of by-pass valve, (C) The variation of mass flow rate.

The Risk of Absorber Regeneration

Two 80K and one 20K absorbers, are installed inside the cold box to trap the impurities (i.e., N_2, O_2, etc.,) in solid phase to prevent impact directly and breakdown the turbine blade and the shaft [4]. The two 80K absorbers could be switched and done the regeneration process automatically in every 168 hrs setting period. The schematic of absorber pipe line was shown in figure 3. There are five steps for absorber regeneration process. Step 1, depressurization, which is to relief the gas helium to suction line until the pressure is lower than 1.15 bara and switched to another absorber. Step 2, warm up, which is to vaporize the solid impurities into gas phase by discharging the 297K gas helium throughout the absorber. The mass flow rate of cold box will be increased about 6 g/s due the discharge loop. Step 3, pump down, which is to remove the impurities from the system by preliminary pump. Step 4, pressurization, which is to recover the operation pressure by discharging the gas helium from process pipe line. Step 5, cool down, which is to keep the temperature difference in 15K by opening the downstream (solenoid type) valve and upstream (pneumatic type) valve. These actions can be switched on-line. However, these processes might also course the failure of operation. Figure 4 indicated that the related act of gas management, upstream valve for absorber and pressure variation for main compressor when pressurization process of absorber was finished. It is because that when finishing the pressurization process (step 4), the upstream valve and the complementary should be closed at t=34s and t=63s, respectively, and the discharged valve should be opened to relief the exceed gas flow to the buffer tank. However, from figure 4 (A), it is seen that the discharged valves didn't response properly at t=63s (maybe fault or responded not fast enough), the main compressor tripped due to the over pressure (>15 bara) which indicated in figure 4(B). This situ was happened once during commission period for the second cryogenic system. Except the well calibration for the gas managements, the tests which may induce the variations of refrigeration/liquefaction load changed should be avoided.

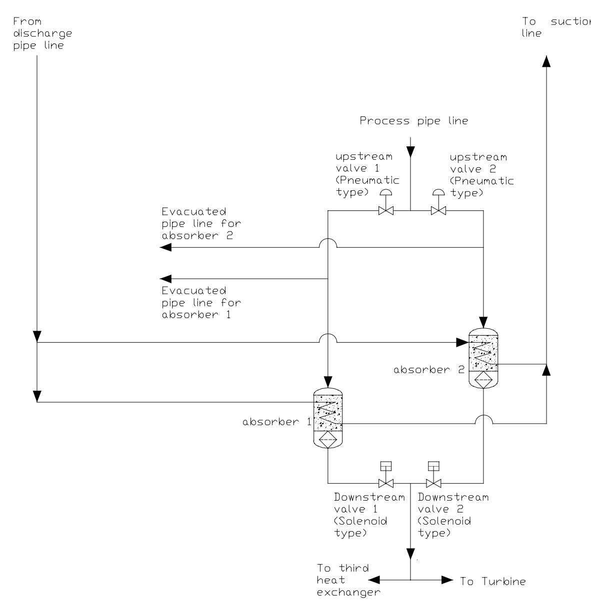

Figure 3 Schematic of pipeline for two 80K auto switched absorbers.

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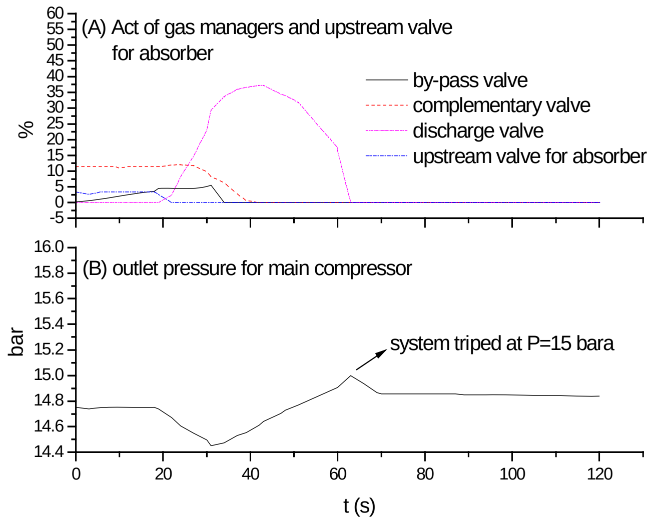

Figure 4 (A) The actions of gas managers and upstream valve for absorber, (B) Variation of outlet pressure for main compressor

SUMMARY

This paper presents three problems that easy to course the instabilities and failure for the cryogenic system.

1. To provide LN_2 precooling was helped for the stable operation of cold box.
2. To install the pressure regulator near I-P converter of pneumatic valve, this might be helped for the stable operation of valve.
3. The absorber regeneration is to remove the impurities of pipe line, however, it also induced an extra disturb (6 g/s mass flow rate was increased) to the system. Thus, any tests which may induce the variations of refrigeration/liquefaction load changed should be avoided during absorber regeneration.

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