THE CONTROL SYSTEM FOR THE PURIFICATION STATION AT NSRRC

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Abstract

A cryogenic adsorber uses liquid nitrogen to trap the impurities from gaseous helium in the helium cryogenic system. In year 2011 NSRRC connected five cryogenic adsorbers in parallel for the cryogenic system; five additional cryogenic adsorbers will be installed in 2013. In the original design, liquid nitrogen filling was monitored and controlled manually to maintain the efficiency of purification. The regeneration of the cryogenic adsorber must be performed manually as well as with use of a heater and vacuum pump after saturation of the cryogenic adsorber. NSRRC has developed a control system that is allowed to perform automatic liquid nitrogen filling and regeneration. This paper describes the construction of the control system and its installation.

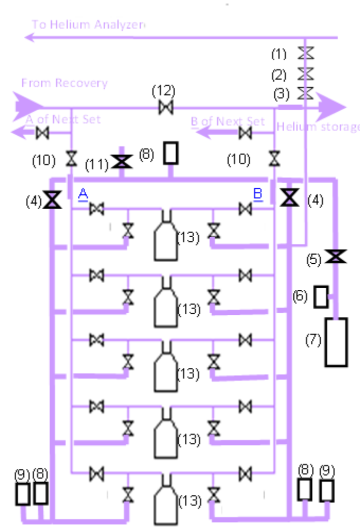
INTRODUCTION

The capacity of cryogenic processing plants and the supporting decontamination facilities in NSRRC have been boosted. Three cryogenic processing plants, including two 450-W and one 700-W plants, to supply liquid helium were installed in NSRRC to cool the superconducting cavity and the superconducting magnets in years 2002, 2006 and 2012 [1-3]. The current volume of gaseous helium for the three cryogenic plants is about 10,000 m^3 in total. Solid particles, along with impurities that condense and solidify at low temperature, might be accidentally added during installation; these impurities might clog the system or damage the expansion turbine. The decontamination of the cryogenic plant is therefore essential. In year 2010, we installed two purification systems, each comprising five cryogenic adsorbers, to remove gaseous contaminants from the gaseous helium in cryogenic plants. In general, the regeneration takes one day; with a decontamination system in two sets, when one set saturates and regenerates, we are able to switch to the other set and continuously purify the helium. The increased workload also results in a complicated control procedure, and thus a burden on personnel. We implemented a control system to purify automatically the helium cryogenic processing plants.

The automatic control system involves sub-systems for monitoring, refilling, regeneration and decision. We first summarized both the original standard operating process and rules of thumb based on previous experience into the decision flow chart. We then programmed the sub-systems with LabView following the decision flow. Each sub-system then underwent a few calibration processes to tune for the most stable parameters.

PURIFICATION SYSTEM

In NSRRC, we have a purification system in two identical sets as shown in Fig.1; each set includes the specified major components.



(1) manual valve
(2) check valve
(3) electro pneumatic valve
(4) manual isolating valve
(5) Electro exhaust valve
(6) vacuum meter
(7) air extracting pump
(8) pressure transmitter
(9) pressure meter
(10) manual main valve
(11) electro air escape valve
(12) bypass valve
(13) cryogenic adsorbers

Figure 1: Layout of the purification system.

AUTOMATIC CONTROL SYSTEM

The monitoring and control sub-systems are presented in Fig. 2. The control process begins with an initial stage of parameter setting that loads the default values into the system. The system then boots the monitoring sub-system and stores the current environmental parameters. The control system then proceeds through the monitor stage and waits for the personnel to trigger either the purifying sub-system or the regeneration of cryogenic adsorbers. We defined sets I and II; if both sets are triggered to enter the same mode, the system invalidates the selection and delivers a vocal warning. As the system was integrated with the management system, it is thus able to alarm; this warning-handling stage is essential to keep the process running smoothly. For example, the personnel might also set a warning when the environmental temperature or the oxygen reaches a low harmful threshold, to ensure the safety of the staff on duty.

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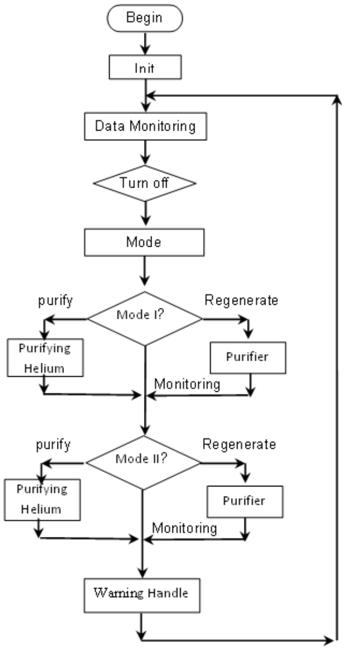

Figure 2: Decision flow of the control system.

AUTOMATIC SENSING AND ACTUATOR SUB-SYSTEM

The automatic sensing and actuator sub-system provides data for both manual and automatic control systems. The sensing devices include temperature, pressure transmitter and vacuum meters. In the manual mode, the environmental parameters can be sent to the remote control panel, so that the personnel can evaluate the condition and react. If the system is in automatic mode, the parameters are sent to the control sub-system to make a decision.

The actuator sub-system responds to a decision made by the control system. The corresponding actions are performed by the electro-pneumatic valve, electro-exhaust valve, relief valve, liquid nitrogen valve and the heater. The detailed implementation is presented in Fig. 3.

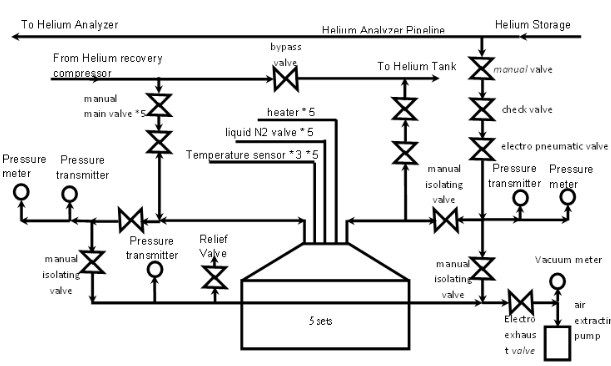

Figure 3: Sensing and actuator sub-system and purifier.

AUTOMATIC REFILLING SUB-SYSTEM

The liquid nitrogen refilling takes action only during the purification of the helium. The liquid nitrogen refilling system conforms to the following procedure:

1) The cryogenic adsorbers are cooled from room temperature to 5 °C with liquid nitrogen continuously;
2) The cryogenic adsorbers are cooled from 5 °C to -180 °C by intermittently refilling liquid nitrogen; with a period 1 min, liquid nitrogen is filled for 12 s and rests for 48 s; the temperature thereby decreases gradually;
3) After cooling to -180 °C, the liquid nitrogen is then refilled continuously until our target upper threshold is reached;
4) Purification of helium begins and the liquid nitrogen gradually evaporates; during this purification, the sub-system begins to refill liquid nitrogen whenever a targeting lower threshold is met; the refilling terminates at the upper threshold as in (3);
5) Step (4) is repeated until the carbon in the cryogenic adsorbers becomes saturated by contamination.

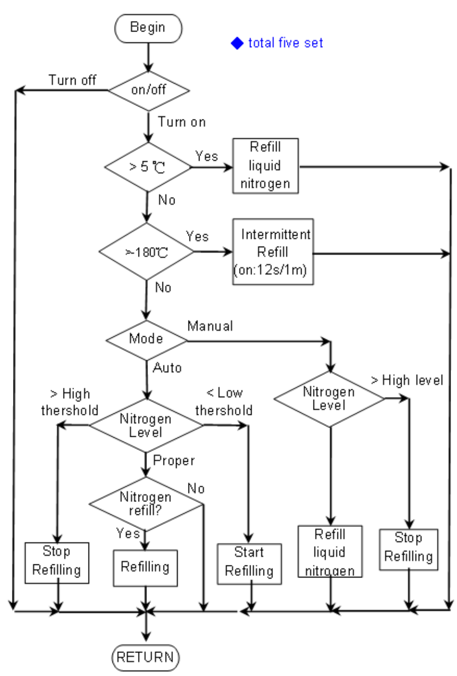

Figure 4: Flow chart of the refilling system.

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AUTOMATIC REGENERATION PROCESSING SUB-SYSTEM

When the carbon in the cryogenic adsorbers becomes saturated by impurities (i.e. step 5 in Automatic Refilling Sub-system), the regeneration of the cryogenic adsorbers begins. The regeneration proceeds as follows.

1) A heater warms the cryogenic adsorbers to 15 °C or above.

2) The electro-exhaust valve opens and lets the extraction pump begin pumping. The cryogenic adsorbers are heated to 110 -- 130 °C for more than 90 min at the same time.

3) The cryogenic adsorbers are filled with helium gas to 1.2 bara, and left for 30 min; the cryogenic adsorbers are then extracted until the pressure is less than 30 mTorr. The process of "purge-pump down" occurs three times.

4) The manual valves (number 10, as indicated in Fig. 1) are opened, and the cryogenic adsorbers are filled with helium gas to 2.5 bara for the next purification.

This process can be transformed into the flow chart as presented in Fig. 5.

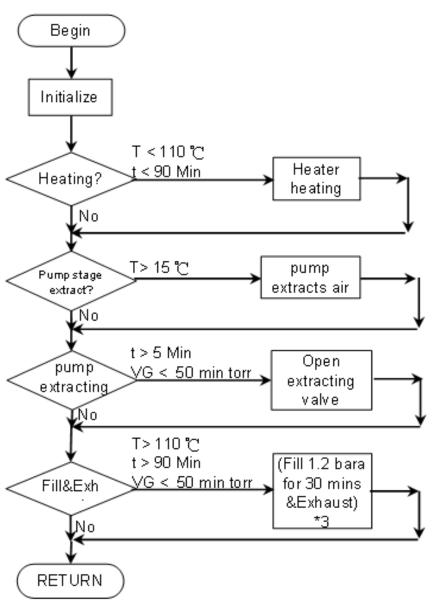

Figure 5: Flow chart of cryogenic adsorber regeneration.

CONCLUSION

NSRRC has increased the process capacity with five cryogenic adsorbers in parallel connections. To support continuous helium purification, the cryogenic adsorber requires regeneration after the carbon saturates. In this work, we introduce a novel control system along with the sub-systems to enable automatic control in detail. The flow chart of the sub-systems including automatic sensing, an automatic actuator, liquid nitrogen refilling and the regeneration are presented. We are pleased to report that the automatic system helps to maintain the purification system in an efficient way.

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