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The automatic liquid nitrogen filling system for GDA detectors

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Abstract. An indigenously developed automatic liquid nitrogen (LN2) filling system has been installed in gamma detector array (GDA) facility at Nuclear Science Centre. Electro-pneumatic valves are used for filling the liquid nitrogen into the high purity germanium detector cryostat. The temperature of the out-flowing gas/liquid from the cryostat is monitored using platinum resistor thermometer. The program allows for automatic filling at regular intervals with temperature monitoring from a remote terminal.

Keywords. Automation; liquid nitrogen; high purity germanium; electro-pneumatic.

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1. Introduction

The automatic liquid nitrogen (LN2) filling system is indigenously designed and installed at the gamma detector array (GDA) facility at Nuclear Science Centre. Electro-pneumatic valves have been used to control the LN2 flow into the dewars of high purity germanium (HPGe) detectors. This filling system is intended to ensure that the dewars of germanium detectors in the GDA beam line get automatically filled at predefined times. This automation has helped in improving the efficiency of the overall system by reducing the filling time for the array from one hour in manual filling to less than half an hour in automatic filling. In addition, no physical access to the beam hall is required during routine filling operation. The system consists of hardware, control system and software which are discussed.

2. Hardware

The gamma detector array (GDA) consists of twelve Compton suppressed Ge detectors mounted on two moveable stands on the opposite sides of the beam line. The supply of LN2 to the detectors is controlled by two manifolds with seven electrically controlled pneumatic valves (AVCON make) fixed firmly on the base of the HPGe detector support stand as shown in figure 1. The valves DV1-DV12 are used for filling the Ge detector dewars while the valves SV1 and SV2 are used to purge the lines at the beginning of operation.

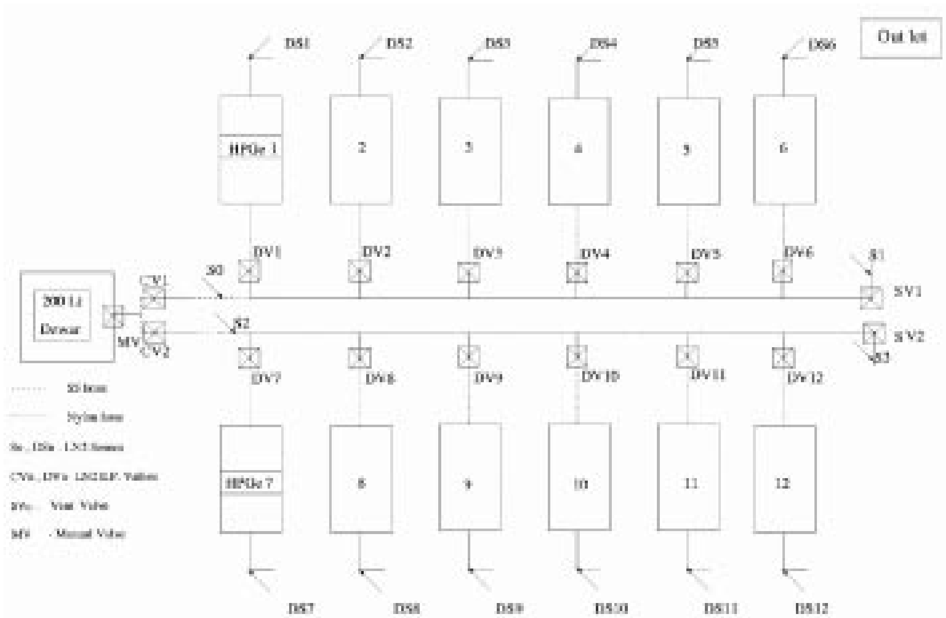

Figure 1. The schematic of the liquid nitrogen filling system.

Two vacuum insulated cryo hoses connect the manifolds with liquid nitrogen storage dewar through the control valves CV1 and CV2. The hoses from the electrically controlled valves to the HPGe detectors are made of PU (polyuthrine) tube with foam insulation to reduce the loss of liquid nitrogen. A dedicated compressed air manifold maintained at 6 PSI pressure is mounted on the stands and are connected with each electro-pneumatic valve. When these solenoid valves are activated with 24 Volt, supply of compressed air is allowed inside the valve which moves the spindle up and down.

Temperatures of the manifolds and of the outgoing vapor/liquid from the vent valves and liquid nitrogen dewars are sensed by PT100 platinum resistance thermometers (S0-S3, DS1-DS12). The PT100 sensor is enclosed in a small box made of teflon. Each sensor is provided mechanical support by placing inside a hollow copper tube which covers the sensor and avoids any stress on the sensor due to LN2 flow.

3. Control system

The control system controls all the main activities of the filling system. A PC-based controller with associated software has been developed for the automatic filling cycle. Each of the sixteen valves can be opened/closed through software actuated relays and the ON/OFF status of the relays can be read back through computer. The resistances of the sensors (PT100) are measured by passing a constant current of 1 mA. The resultant voltage drop is amplified using LM324 opamp and digitized by two 8 bit 8 channel multiplexed ADCs (ADC0809). Linear calibration is used to convert the digital readout into temperature (in

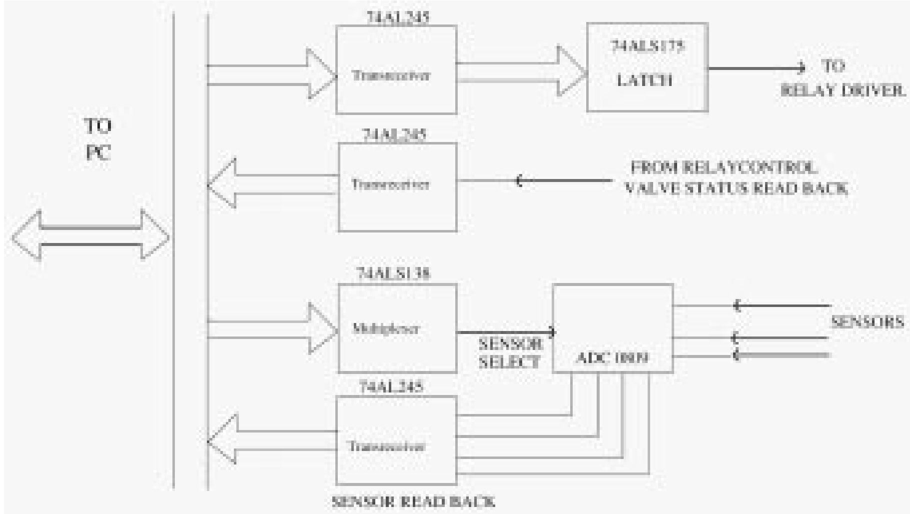

Figure 2. The block diagram of relay control, valve status and sensor read back.

Kelvin). The block diagram of the relay control, valve status and sensor read back is shown in figure 2. The detailed hardware configuration can be found in ref. [1].

4. Principle of operation

To start the LN2 filling process, the storage dewar tank is maintained at a pressure of 20 PSI with the manual valve (MV) on the dewar kept open. For filling the detectors on one side of the beam line, the corresponding control valve (CV1) and the purge valve (SV1) are opened. LN2 starts flowing out of the storage dewar towards the end of manifold resulting in a drop of the temperatures sensed by S0 and S1. When the temperature at S1 drops below 80 K, the purge valve is closed and the filling of the detectors in the array gets started one after another. To fill the first Ge detector, the valve DV1 is opened. The out going vapor temperature is measured at the sensor connected to the outlet of the detector (DS1) to confirm that the valve is actually open. The valve is closed when the temperature falls below the set point (80 K). This sequence is repeated for all six detectors for each side of array. After filling all the six detectors control valve CV1 is closed, and the purge valve SV1 is opened to release the pressure in the manifold and vacuum insulated hose. A similar procedure is adopted for filling the detectors connected to the second manifold.

5. Control software for automatic filling

A DOS based Auto Fill program has been operational for a year for controlling the filling of the dewar and monitoring of the outgoing gas temperature. The program can automatically

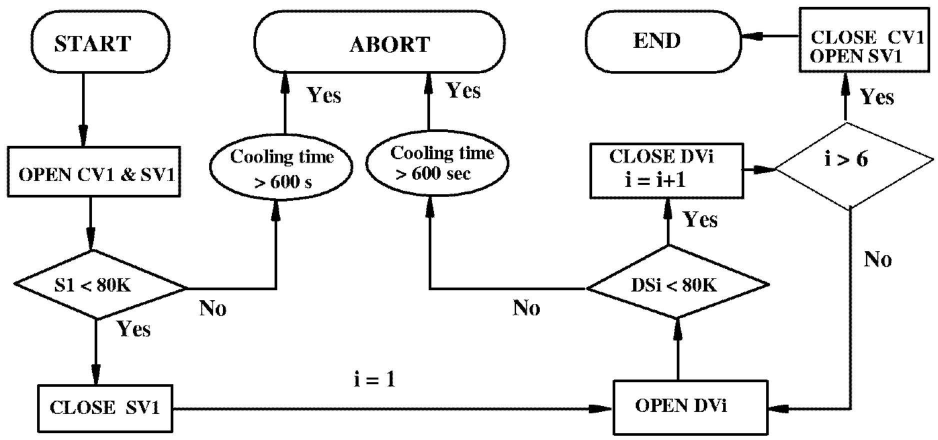

Figure 3. Simplified flow diagram of automatic filling system.

sequence the opening/closing of the valves depending upon the outlet temperature. By monitoring the time taken for initial cool down (to 200 K) and to LN2 temperature (80 K) it can detect common malfunctions like open/shorted sensor, clogged valve, incomplete fill or empty Storage tank. Calibration of the individual sensors, maximum allowed cool down period (from room temperature to 200 K) and maximum filling time for individual detectors are stored in a database. Two detectors can be filled simultaneously to save filling time. The total filling time for all twelve detectors is about 25 minutes. Program can be sequenced to initiate the filling at regular intervals (24 hours) without operator intervention and keep a log of the operation. The filling is aborted if the software detects any hardware malfunction and an alarm is sounded. A simplified flow chart of the control program for the filling of the first six detectors is shown in figure 3.

A LINUX based program has now been developed with graphical user interface. It uses client-server protocol to communicate between different processes. The server runs the software for the control of the valves, readout of the sensors and the auto fill sequence. The client allows for remote monitoring of the hardware status from multiple terminals. Remote manual operation of the filling process is also possible by issuing open/close commands to individual valves.

A vacuum-insulated transfer line from the main storage tank outside the building to the intermediate storage dewar in the beam hall has been installed. A larger capacity dewar (900 liter) has been procured to replace the existing dewar of 200 liter capacity.

References

[1] A J Malyadri *et al*, Technical Report NSC/TR/AJ/2000-2001/18