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Performance of the prototype gas recirculation system with built-in RGA for INO RPC system

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ABSTRACT

An open loop gas recovery and recirculation system has been developed for the INO RPC system. The gas mixture coming from RPC exhaust is first desiccated by passing through molecular sieve (3 Å+4 Å). Subsequent scrubbing over basic active alumina removes toxic and acidic contaminants. The Isobutane and Freon are then separated by diffusion and liquefied by fractional condensation by cooling up to −26 °C. A Residual Gas Analyser (RGA) is being used in the loop to study the performance of the recirculation system. The results of the RGA analysis will be discussed.

1. Introduction

The Proposed INO RPC detector [1] facility will contain nearly 27 000 detectors of 2 m × 2 m size and will be continuously flushed with a gas mixture consisting of Isobutane, R134a (1,1,1,2 tetrafluoro ethane), SF_6 (Sulphur hexafluoride) and Argon. The total internal volume of the detector stack will be in the range of 200 m^3. The prototype detector operates in avalanche mode with gas mixture R134a (95.0%), Isobutane (4.5%) and SF_6 (0.5%). The same prototype gas system can supply gas mixture suitable for streamer mode choosing Argon (30%), Isobutane (8%) and R134a (62%) [2].

To enhance the life and the performance of detectors, the gas content needs to be replaced at least once a day to keep harmful contaminants from accumulating. As direct consequence, 200 m^3 of fresh gas mixture has to be fed into the detector stack and an equal volume has to be removed and safely disposed on daily basis. This operation involves very high operating cost and also causes the concentrations of SF_6 and R134a in air to exceed TLV (Threshold Limiting Value: to which a worker can safely be exposed for 12 h a day) in the local working area. To overcome the problem of daily replenishment of fresh gas mixture, the gas mixture is reused by following methods:

2. Closed loop system

Gas mixture is re-circulated in RPC detectors and exhaust gas from RPC is purified to remove undesirable radicals and contaminants. Lost amounts of each gas component are measured continuously and topped up by gas flow systems. This technique involves maintaining precise pressure gradients across each element of the loop. Concentration changes at ppm level are to be measured. The system needs highly expensive measurement and control instrumentation.

3. Open loop system

In this method, component gases are separated from gas mixture by adsorption and condensation, purified and reused. During process of separation and condensation, the pressure, temperature and surface activation are maintained in such way that Isobutane is selectively adsorbed by the activated Palladium pellets in the first chamber and separated from the gas mixture by condensation while Freon R134a is carried out into the next chamber and condensed at the same pressure but at low temperature. Pressure versus condensation temperature curves are plotted in Fig. 1. Each curve represents vapour–liquid transition with respect to partial pressures and temperatures. For Isobutane, chamber temperature is typically −13 °C at 0.5 bar. After Isobutane is removed, the remaining gas mixture flows into next chamber where conditions (−26 °C and 0.5 bar) are set for Freon R134a to condense. The residual gas mixture coming out of

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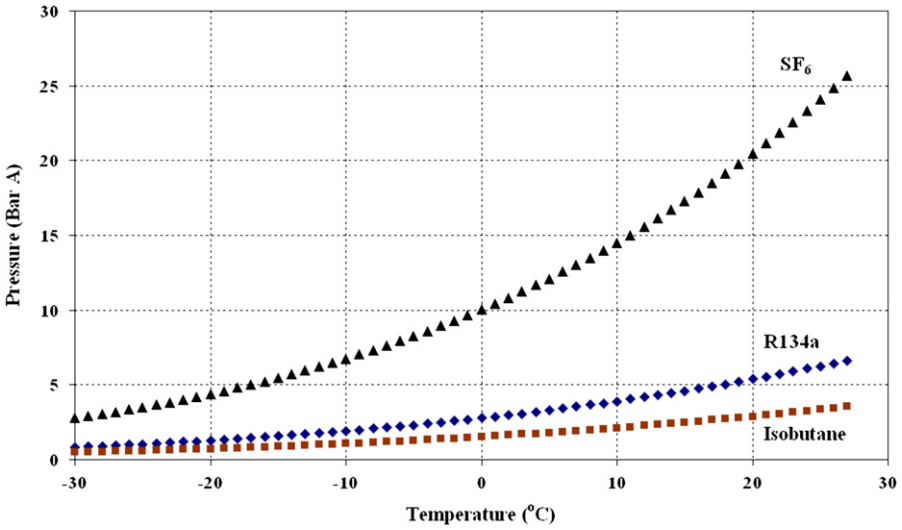

Fig. 1. Vapor Pressure versus condensation temperature.

fractional condensation column is concentrated with Argon and SF_6 along with some trace vapours of Isobutane and Freon R134a.

4. The performance of open loop system

The criteria for evaluating performance of open loop recovery system are:

4.1. Volumetric efficiency

Volumetric efficiency is defined as the ratio of gas volume collected in the system to gas volume entering into it, both measurements being at equal pressure and temperature. It indicates the residual volume of gas escaping the system. Presently bubbles are used to measure approximate volume flow rates of gas mixture entering the system, bypassing condensation chambers through safety vent and leaving the system as uncondensed gas mixture. It is observed that contamination due to radicals is nearly absent in the gas mixture coming out of the RPC detector. This could probably be due to low radiation intensity application. Major component of contamination is found to water vapour which is completely removed by adsorption to a residual concentration of 10 ppm without any loss of gas mixture. Due to this reason the efficiency of volumetric recovery is found to be in the range of 85–95%.

4.2. Analysis of gases: measurement by RGA

A residual gas analyser (RGA) is a mass spectrometer of small physical dimension that can be connected to a vacuum system and whose function is to analyse the gas inside the vacuum chamber. A small fraction of gas molecules are injected into the chamber which are ionised (positive ions), and the resulting ions are separated, detected and measured according to their molecular masses. In the present case the purity of gases is measured by RGA, manufactured by Standford Research Systems (SRS) model RGA 300 probe [3]. The probe is interfaced with the chamber and turbo vacuum pump as shown in the Fig. 2. This analyser has a capacity to detect and measure up to mass number 300. Operating pressure for measurement is fixed at 3.5×10^{-5} mbar where as background vacuum is at 1×10^{-7} mbar. Fig. 3 shows the analysis of background gases.

Reference scans for each pure constituent gas is generated by sampling the gas directly from the cylinders. As the library does not

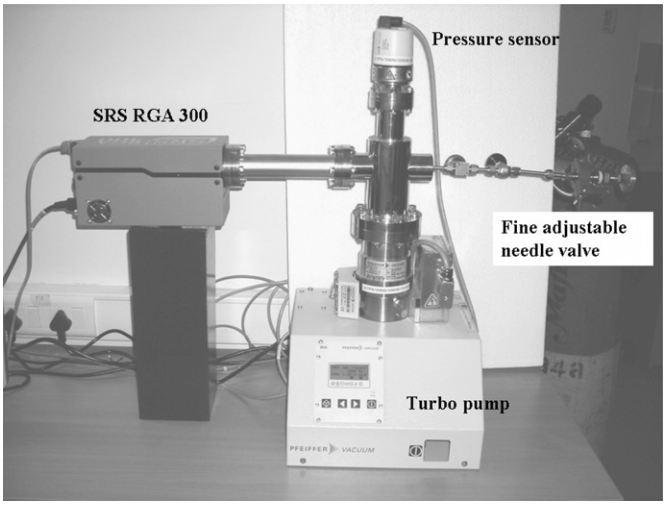

Fig. 2. RGA Setup.

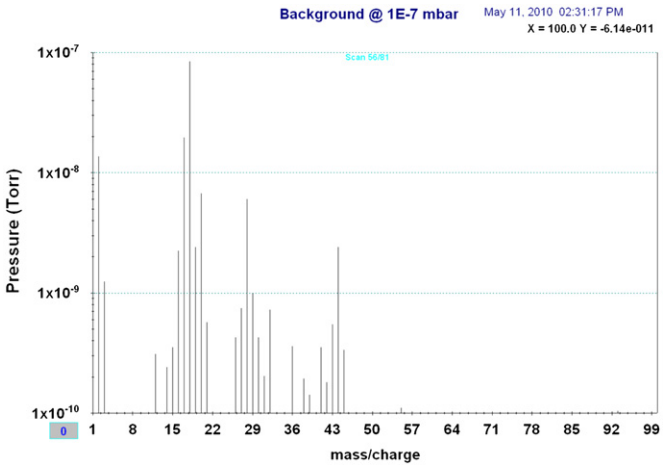

Fig. 3. Background mass spectrum.

contain for the R134a gas and Isobutane gas, scan for these gases were acquired and used as reference. It is seen that the plots for SF_6 gas does not fully agree very well with library values