Calibration of RPC gas mixture

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Introduction

Nuclear Physics Division, BARC is mandated to build test and characterize bakelite Resistive Plate Chamber (RPC) which will be installed as the fourth end-cap for Compact Muon Solenoid (CMS) detector at CERN Geneva (Switzerland) during the long shutdown next year. RPC is a large area gas detector consisting of two parallel resistive plates ($\rho \sim 10^{10}$ Ωcm - 10^{12} Ωcm) of 2mm thickness separated by line spacers and button spacers which provide a uniform gas gap of 2mm thickness. Similar RPCs with glass as resistive material shall be employed for the India-based Neutrino Observatory (INO) too.

These chambers can operate either in avalanche mode or streamer mode, each of which requires different composition of mixed gases. The chambers for CMS is going to be used in avalanche mode which requires gas combination of 95.2% R134a, 4.5% Iso-butane and 0.3% SF_6. For the INO project we are investigating the feasibility of operating the glass RPC's in streamer mode operation. As that has the potential of considerably reducing the expenditure on preamplifier. It requires the gas combination of 62% R134a, 30% Argon and 8% Iso-butane . In order to provide that, a Mass Flow Controller (MFC) based setup has been configured in RPC lab, NPD, BARC which mixes the required proportion of different gases.

MFCs are used wherever accurate measurement and control of a mass flow of gas is required independent of flow pressure change and temperature change in a given range.

In this setup we are using Tylan-made MFC (FC-2900) with dynamic range of 10 standard cubic centimeter per minute (SCCM) and MFC (D07-19A/ZM) with dynamic range of 1 litres per hour (lph). The control input to MFCs and the output from the same are both DC voltages (0 to 5 volts) which are linearly proportional to the mass flow.

MFC consist of 4 main components: a bypass, a sensor, an electronics board and a control valve. The main part of mass flow controller is a thermal sensor. It consists of a small bore tube with two resistance-thermometer elements wound around the outside of the tube. The sensor tube is heated by applying an electric current to the elements. A constant proportion of gas flows through the sensor tube, and the cooling effect creates a temperature differential between the two elements. The change in the resistance due to the temperature differential is measured as an electric signal. The temperature differential created between the elements is dependent on the mass flow of the gas and is a function of its density, specific heat, and flow rate.

MFCs are designed and calibrated to control a specific type of gas at a particular range of flow rates, hence calibrating the MFCs for different gases being flown through them is a prerequisite. All the MFCs employed in our gas mixing system are calibrated by water downward displacement method.

The gas under test is passed through MFC into a measuring jar filled with water. This jar is then inverted into a container filled with water. The gas tube from the MFC output is carefully inserted, and the gas collected in the jar from one known level V_0 to other known level V_1 as shown in figure 1, together with the start time t_0 to end time t_1 taken for the same are recorded using stop watch. The ratio of level difference and time taken is the average flow rate during calibration period.

$$\text{Average flow rate} = \frac{V_1 - V_0}{t_1 - t_0} = \frac{\Delta V}{\Delta t}$$

This calibration is done for R134a, Iso-butane and SF_6.

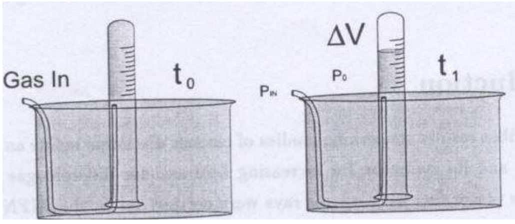

Figure 1 : Water downward displacement method

Figure 2, 3 & 4 shows the calibration for the gases. Our setup is used for R134a, Iso-butane and SF_6 gas which is required for RPCs. The gas combination is maintained at 40% relative humidity and flows at 40 liters per hour (lph).

The mass flow rate for SF_6 is presented in SCCM because its proportion in the mixture is very less (0.3%) as compared to R134a (95.2%) and Iso-butane (4.5%). With these three gases we have calibrated our system and the results show approximately the linear relationship between applied gas flow and measured gas flow. The X axis represents the applied flow rate and Y axis represents the measured flow rate. The data is fitted using linear fit function. The graph shows the expected linear relationship between applied flow rate and measured flow rate .

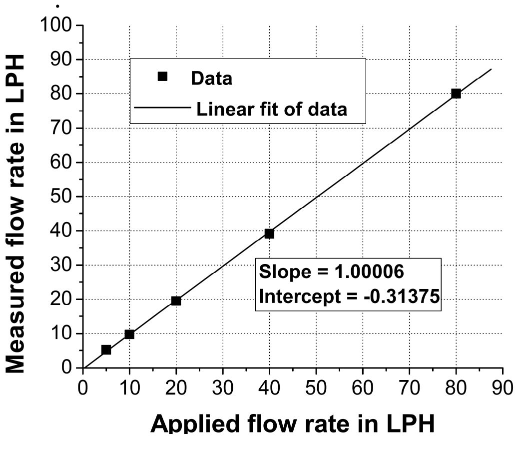

Figure 2 : MFC calibration of R134a gas

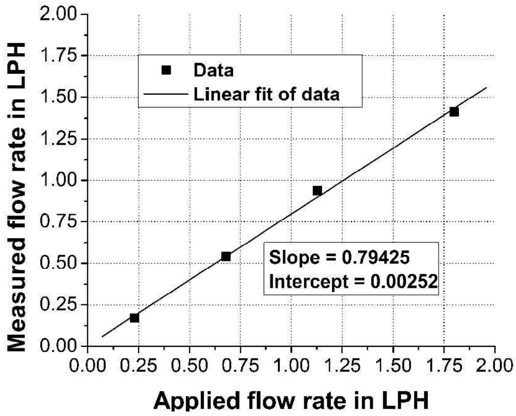

Figure 3 : MFC Calibration of Isobutane

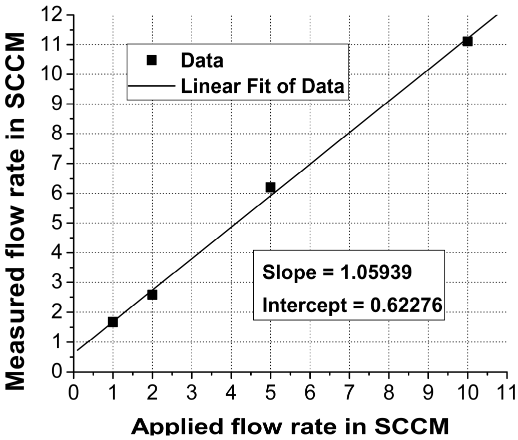

Figure 4 : MFC Calibration of SF6

Conclusion

A Mass flow controller based setup has been configured in RPC lab, NPD, BARC which is required to mix different gases in desired proportion. The setup is calibrated for R-134a, Isobutane and SF_6 gases.

References

[1] Performance of glass RPC's operating in streamer mode with SF_6 gas mixture. Nuclear Instruments and methods in physics research A 455 (2000) 397- 404.