Effect of environmental parameters on the performance of resistive plate chambers

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RPCs are parallel plate gaseous detectors using highly resistive material such as glass or bakelite which is coated with a conducting paint (graphite) to provide the anode and cathode. The gas-gap is usually kept quite small (~ 2 mm) in order to provide a high field for avalanche formation of minimum ionizing particles such as muons traversing the detector. The resistive electrodes of RPCs utilised in several current experiments (ATLAS, CMS, ALICE, BABAR and ARGO) are made of phenolic/melaminic polymers, with room temperature resistivities ranging from 10^{10} Ω cm (for high rate operation in avalanche mode), to 5×10^{11} Ω cm (for streamer mode operation at low rates). Glass is alternatively used as a high resistive medium for RPCs for low counting rates, such as in atmospheric neutrino studies (INO). These detectors are very sensitive to environmental parameters such as relative humidity, temperature and pressure. The monitoring of the leakage current from detectors while they are running is useful for having a diagnosis of the operating conditions. There are some studies on the ageing of Resistive Plate Chambers (RPC) [1], strictly related to their leakage current, that can range from a few nA to µA, at the end of their useful life.

India has delivered eight RPCs for the CMS experiment [2] at CERN, Geneva in 2008 and is mandated to build another 80 RPCs for the Upscope, scheduled in 2011-2012, where the fourth and last end-cap (±) shall be installed, as LHC goes for higher luminosity. These detectors shall be assembled in RPC Lab., in NPD-BARC and each detector needs to have an extensive data base of its leakage currents for a period of 96 hours in order to qualify, as per the QCs laid down (leakage currents < 5µA at 10kV), for its assembly and further installation and commissioning at CERN.

In the present work, we report here the behavior of leakage currents in RPC as a function of changes in relative humidity inside the lab. One of the glass RPCs (30 cm x 30 cm), coated with graphite (resistivity ~ 1 MΩ/) was ramped to 9 kV using a gas mixture of R134a and Iso-butane in the ratio of 96:4. The RH sensor was located about 3 metres away from the RPC. The leakage currents were recorded through the CAEN SY2725 power supply used for providing the HV to RPCs. The RPC lab is housed in the ground floor of the Van-de-Grraff building and the air-conditioning in the lab is via the centralized AC. The AC was kept ON continuously for about a week, before the measurements were recorded. The HV was ramped at the rate of 50V/s and then allowed to stabilize at each kV for several hours before reaching the desired voltage at 9 kV. Fig. 1, below shows the variation in leakage current (µA) in a glass RPC and the relative humidity (%) inside the lab., for a period of 33 hours. The data was collected in intervals of 30 seconds from 20th March 2010 (03h:06m:26s) to 21st March 2010 (11h:59m:46s).

We observe, that the leakage current pattern fluctuates evenly with the fluctuations in the relative humidity. It shows exactly the same behavior as the RH. As, expected, when the RH increases (or decreases), there is a decrease (or increase) in the resistivity of the material and this leads to increase (or decrease) in the leakage current of RPCs. The corresponding rise and fall in leakage current with RH is observed because the bulk resistivity of bakelite/glass changes as a function of temperature and humidity. It is desirable that the leakage currents remain stable during the extended use of such detectors and therefore it is very important to have a good control on RH and temperature of the environment where such detectors are housed or characterised. Fluctuations in relative humidity become more severe, especially during monsoon season in Mumbai, where the average RH reaches almost 90%. The relative humidity variations with the existing centralized AC is shown in Fig. 1, where one can also observe the periodic day night fluctuations in RH as the air is drawn from atmosphere and there are no optimum dehumidifiers installed in the line. Maximum humidity therefore generally occurs during early hours (around sunrise), at the time of minimum temperature. After sunrise, humidity drops rapidly and reaches a minimum at about the time of maximum temperature (noon time). It rises more gradually from late afternoon through the night. These measurements could go as vital inputs for designing the air conditioning and optimizing the environmental parameters, on a large scale, for the home based, INO project, where glass RPCs would be used as the active detector element. Keeping in mind the large fluctuations in RH, a dedicated AC sytem with special dehumidifiers working on a round the clock basis with a stand by arrangement is being planned for the RPC lab., for which the civil work is underway and the design for the AC system is being worked out for 250 m^3 of laboratory volume and a floor area of 75 m^2, to keep the relative humidity at 50 (±5) % level and lab temperature at 20 (±1) ^{o}C.

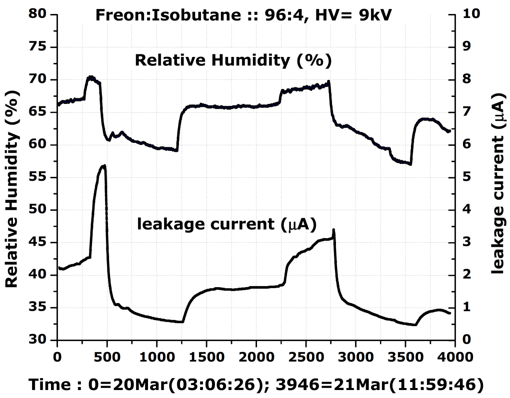

Fig. 1 : Fluctuations in RH (% - top curve, left axis) in the RPC lab., affecting the leakage current (μA - bottom curve, right axis) in RPCs

Table 1, shows the tolerances on the environmental parameters for optimized performance of RPCs at CMS experiment at CERN. The cavern, where CMS is housed in CERN, is located 100 metres below the ground and at 400 metres above mean sea level. It has a controlled RH of 35(± 5)%, as shown in Fig. 2, where the fluctuations are shown for a period of ten days (x-axis, 12-21 Sep 2010) ranging from 34% (y-axis, minimum) to 39% (y-axis, maximum). The environmental parameters shown in the table are controlled in such a way that the fluctuations in the leakage currents remain within ± 0.3 μA for optimal performance of RPCs.

Table 1

S N	environmental parameters	mean operating values with tolerances
1	Pressure	970 (± 10) mbar
2	Humidity	35 (± 5) %
3	Temperature	21 (± 1) ^{o}C
4	Gas Humidity	~ 8000 ppm

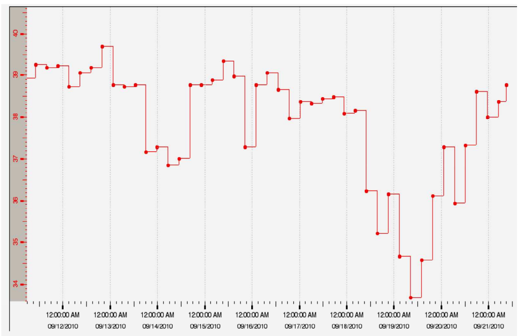

Fig. 2 : RH in CMS cavern at CERN. y-axis shows the RH(%) and x-axis is time for ten days (12-21 Sep 2010, with big ticks at 24 h interval)

Recent studies have shown that the performance, in particular the rate capability, of RPCs strongly depends on the bulk resistivity, ρ, of the electrodes, which could get altered by variations in the environmental parameters. Efforts are underway to measure the count rates and efficiency of RPCs as a function of temperature and RH in a controlled environment inside a localized hood in the laboratory.

References

[1] A. Candela, *et. al.*, Nucl. Instr. and Meth. A **533** (2004), p. 116

[2] L. M. Pant, Nucl. Instr. and Meth. A - 2010 Accepted (doi.10.1016j.nima.2010.08.082)