Development of linseed oil-free Bakelite Resistive Plate Chambers

S. Biswas [a], S. Bhattacharya [b,*], S. Bose [b], S. Chattopadhyay [a], S. Saha [b], Y.P. Viyogi [c]

[a] *Variable Energy Cyclotron Centre, 1/AF Bidhan Nagar, Kolkata-700 064, India*

[b] *Saha Institute of Nuclear Physics, 1/AF Bidhan Nagar, Kolkata-700 064, India*

[c] *Institute of Physics, Sachivalaya Marg, Bhubaneswar, Orissa-751 005, India*

Abstract

In this paper we would like to present a few characteristics of the Resistive Plate Chambers (RPC) made of a particular grade of bakelite paper laminates (P-120, NEMA LI-1989 Grade XXX), produced and commercially available in India. This particular grade is used for high voltage insulation in humid conditions. The chambers are tested with cosmic rays in the streamer mode using argon, tetrafluroethane and isobutane in 34:59:7 mixing ratio. In the first set of detectors made with such grade, a thin coating of silicone fluid on the inner surfaces of the bakelite was found to be necessary for operation of the detector. Those silicone coated RPCs were found to give satisfactory performance with stable efficiency of > 90% continuously for a long period as reported earlier. However, very recently RPCs made with the same grade of Bakelite but having better surface finish, are found to give equivalent performance even without any coating inside. Results of the crosstalk measurement of the silicone coated RPC will also be presented.

Key words: RPC; Streamer mode; Bakelite; Cosmic rays; Silicone
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1. Introduction

In the proposed India-based Neutrino Observatory (INO), the RPCs [1] have been chosen as the active detector for muon detection in an Iron Calorimeter (ICAL) [2]. As proposed presently, ICAL is a sampling calorimeter consisting of 140 layers of magnetized iron, each of 60 mm thickness, using RPCs of 2 m × 2 m area as active media sandwiched between them. A 50 kton ICAL is expected to consist of about 27000 RPC modules. For ICAL RPCs, main design criteria are (a) moderate position resolution (∼ 1 cm), (b) good timing resolution (∼ 1-2 ns) (c) ease of fabrication in large scale with modular structure and most importantly (d) low cost. Detailed R & D are being performed on glass RPCs for INO [3]. A parallel effort on building and testing of the RPC modules using the bakelite obtained from the local industries in India is also going on. The aim of the study is to achieve stable performance of the bakelite RPC detector without linseed oil for prolonged operation. Method of construction of the these RPCs and results of the long term test has been reported earlier [4]. In this article we report some other characteristics of the silicone coated bakelite RPC and the initial results of RPC without any coating.

2. Design of the prototype RPCs

The RPCs are made of two 300 mm × 300 mm × 2 mm bakelite sheets, used as electrodes, separated by 2 mm gas gap. Uniform separation of the electrodes are ensured by using five polycarbonate button spacers of 10 mm diameter and 2 mm thickness, and edge spacers of 300 mm × 8 mm × 2 mm dimension. Two polycarbonate made nozzles are used for gas inlet and outlet [5,6].

The high voltages (HV) to the RPC are applied on the graphite coating (surface resistivity ∼ 1 MΩ/□) made over the outer surfaces of the bakelite. Induced RPC signals are collected using copper and foam based pick-up strips, each of area 300 mm × 25 mm with a separation of 2 mm between two adjacent strips. The pick-up strips are covered with 100 μm thick kapton foils to isolate them from the graphite layers.

Premixed gas of Argon, Isobutane and Tetrafluroethane (R-134a) is used in 34:7:59 mixing ratio. A typical flow rate of 0.4 ml per minute resulting in ∼ 3 changes of gap volume per day is maintained by the gas delivery system

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Email address: sudeb.bhattacharya@saha.ac.in (S. Bhattacharya).

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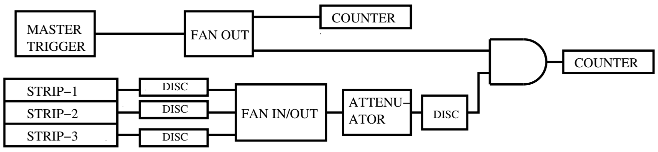

Fig. 1. Schematic representation of the crosstalk measurement setup.

as mentioned in Ref 7.

3. Cosmic ray test setup

The RPCs are tested in the same cosmic ray test bench described in Ref. 6. The coincidence between the signals obtained from the scintillator I (350 mm $\times$ 250 mm size), the finger scintillator(III) (200 mm $\times$ 40 mm size) placed above the RPC plane and scintillator II (350 mm $\times$ 250 mm size) placed below is taken as the Master trigger. Finally, the ORed signal obtained from two adjacent pick-up strips of the chamber is put in coincidence with the master trigger obtained above. This is referred to as the coincidence trigger of the RPC. The efficiency of the RPC detector, taken as the ratio between the coincidence trigger rates of the RPC and the master trigger rates of the 3-element plastic scintillator telescope is measured over an area 200 mm $\times$ 40 mm which is the window of the cosmic ray telescope. The average master trigger rate is $\simeq 0.005$ Hz/cm^2.

Fig. 1 shows the schematic of crosstalk measurement setup. The width of the finger scintillator covers one pick-up strip completely and two adjacent strips partially. Signals from these three strips after leading edge discriminator (LED, threshold : 40 mV) are send to the input of a fan in module. The output signal of the previous stage after attenuation is again put to another discriminator. The signal from this discriminator is taken in coincidence with the master trigger. The crosstalk is defined by the ratio of this coincidence count and the master trigger. The attenuation factor is set at 0.3. The fan out signal after attenuation, observed in the oscilloscope is $\sim$ 250 mV when one strip fires, $\sim$ 440 mV and 630 mV respectively when signal from two strips and 3 strips come simultaneously. To measure crosstalk between two and three adjacent strips the discriminator threshold to the fan out signal is set at 280 mV and 520 mV respectively.

4. Results

Following properties have been studied in the test setup for all the chambers: (a) efficiency of the chambers and their variation with change in different parameters *e.g.* HV, gas composition, laboratory environment etc., (b) variation of counting rate, (c) leakage current and their variation and (d) long term stability in streamer mode. Long term behavior of the silicone coated RPCs in streamer mode has been reported earlier [6]. Some more results are presented in this section.

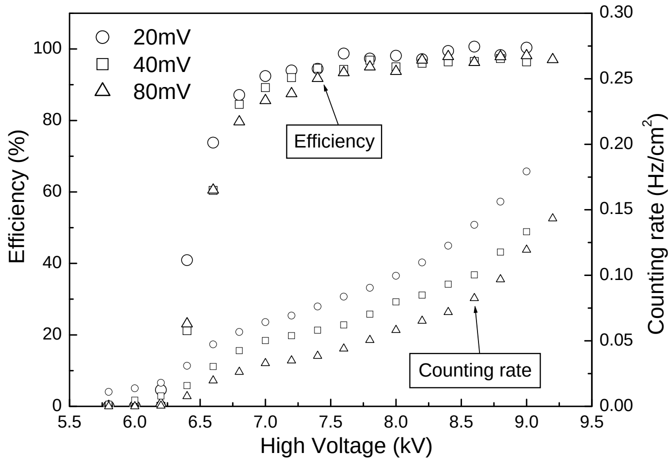

Fig. 2. The efficiency and the counting rate as a function of high voltage for a silicone coated RPC made of P-120 grade bakelite with discriminator threshold values of 20 mV, 40 mV and 80 mV. Used gas mixture is Argon (34%) + Isobutane (7%) + R-134a (59%).

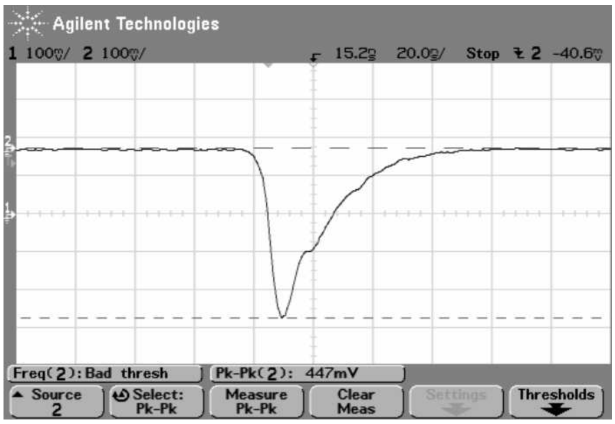

Fig. 3. Average induced pulse on a pick-up strip at 8 kV (100 mV/Div, 20 ns/Div, 50 Ω load) of a silicone coated P-120 grade bakelite RPC.

The efficiency and the counting rate which is also known as the noise rate of the silicone coated RPC detector have been studied by varying the applied HV and setting different discriminator threshold values. The variation of efficiency and the counting rates with the applied HV for three discriminator threshold value of a silicone coated RPC is shown in the Fig. 2. It is seen that counting rate of RPC decreases with the increase of threshold value which is expected with the suppression of noise at higher threshold value. However, the efficiency curves do not depend much on the threshold setting from 20 mV to 80 mV, except that the efficiency plateau is marginally higher at the lowest threshold setting of 20 mV. Typical screen dump of oscilloscope pulse at 8 kV is shown in Fig. 3. Figure shows rise time is about 6 ns, thereby suggesting fastness of the pulse.

The effect of environmental humidity on the efficiency curves has also been studied. This measurement has been done at relative humidities of 58% and 67% of the labora-

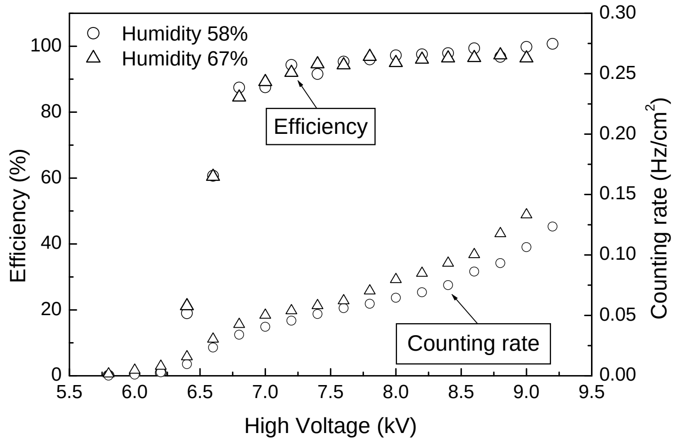

Fig. 4. The efficiency and the counting rate versus high voltage for different humidities for a silicone coated P-120 grade bakelite RPC.

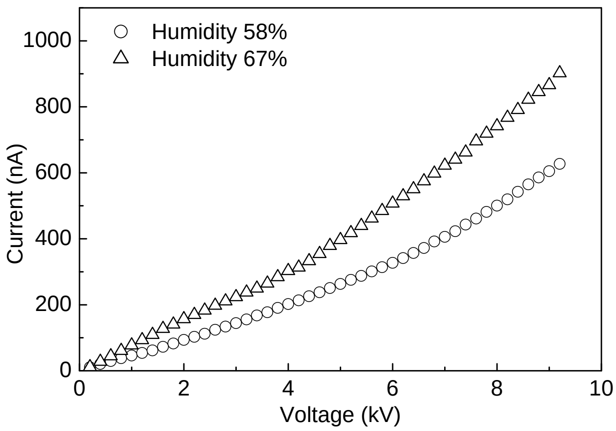

Fig. 5. Current versus high voltage for different humidities for a silicone coated P-120 grade bakelite RPC.

tory environment and at the room temperature of $\sim$ 22-25°C. These curves, plotted in the Fig. 4, indicate no effect of humidity on the efficiency. However, the counting rate (shown in Fig. 4) and the leakage currents, measured simultaneously and plotted in the Fig. 5, are a bit larger at higher humidity. This observation indicates that charge leakage through the exterior surfaces may be contributing more at higher humidity.

The long cable drive of RPC streamer pulse has been tested using RG-174/U coaxial cables. A maximum of 40 m RG-174/U coaxial cable has been used. The average pulse height of RPC in streamer mode is $\sim$ 300-500 mV as shown in Fig. 3. The signal amplitude is attenuated to $\sim$ 80% after 40 m cable drive. The rise time increases slightly at that length of cable. The variation of normalised pulse height and rise time are shown in Fig. 6.

The measurement of crosstalk (CT) for a silicone coated RPC has been carried out rigorously. When a single particle induces signal on two or more strips then the term crosstalk comes into the picture. The crosstalk between the

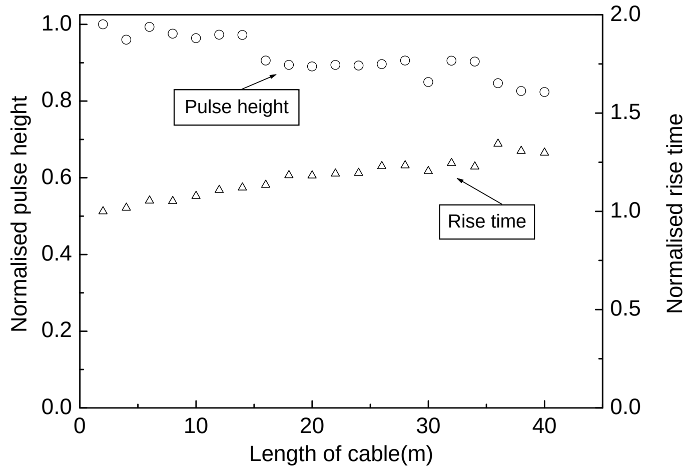

Fig. 6. Variation of the normalised pulse height and rise time with the cable length for a silicone coated P-120 grade bakelite RPC.

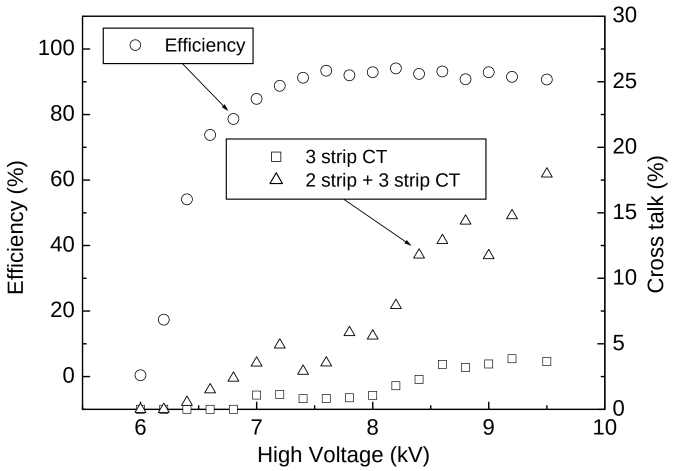

Fig. 7. Variation of the crosstalk with the high voltage in comparison with the efficiency for a silicone coated P-120 grade bakelite RPC.

two and three RPC strips, as defined in section 3 have been measured varying the applied HV and is shown in Fig 7. When the discrimination threshold after attenuation is set at 280 mV as stated in section 3, the signals coming from two adjacent strips as well as three adjacent strips simultaneously contributed to the crosstalk and it is found to be $<$ 20% as shown in the Fig 7. The crosstalk between the three adjacent strips is found to be $<$ 5%. These values of the crosstalk has been taken into account while estimating the final efficiency.

The time resolution of a silicone coated RPC was measured and it was found to be $\sim$ 2 ns (FWHM of the time spectra) at 8 kV. The variation of time resolution with HV of that particular silicone coated RPC is shown in Fig. 8.

Finally one module is made with 1.6 mm thick P-120 grade bakelite sheets with better surface finish. No coating was applied to that RPC. The efficiency curve and variation of counting rate with HV is plotted in Fig. 9. Current for

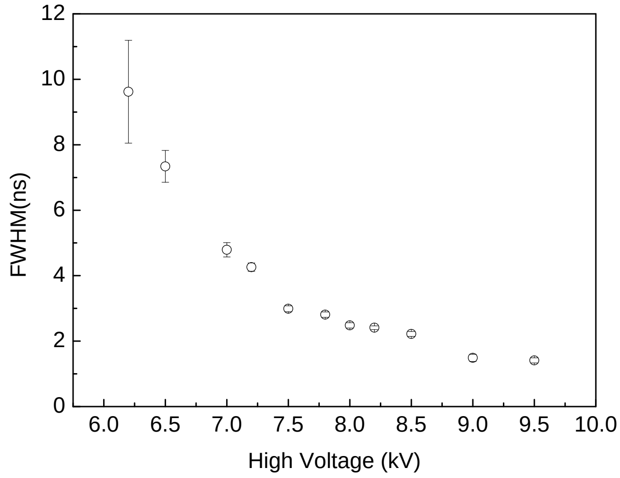

Fig. 8. The time resolution as a function of HV for a silicone coated P-120 grade bakelite RPC.

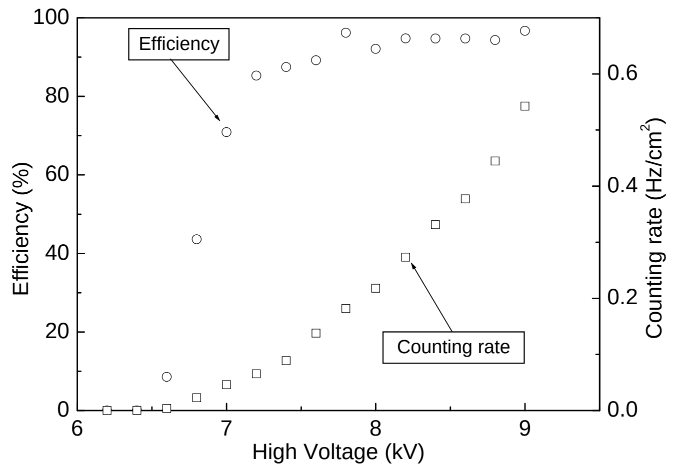

Fig. 9. The efficiency and the counting rate as a function of HV for uncoated P-120 grade bakelite RPC.

this particular RPC was found to be higher than the silicone coated one. It is about 2 μA at 8 kV.

5. Conclusions and outlook

In conclusion, a rigorous study of bakelite RPCs made from a particular grade of bakelite commercially available in India has been performed. An efficiency of $> 90\%$ is obtained for silicone coated P-120 grade bakelite RPC. The effect of threshold and external humidity on the performance of the RPCs are presented in this paper. The current as well as counting rate increases with increase of environmental humidity.

RPC streamer signal can be driven for a long distance without any significant attenuation. The crosstalk between two neighboring strips (which may be due to some real event) is found to be about 15% and that between three neighboring strips is about 5%. The measured time resolution of a particular silicone coated RPC is found to be ~ 2 ns which is comparable to any single gap glass or linseed oil coated bakelite RPC. Lastly the preliminary data of a uncoated RPC is reported which show encouraging results, as one can plan for large RPC (1 m $\times$ 1 m) with this particular grade of bakelite with better surface finish and without any coating.

Further studies in this direction are being carried out which include timing measurements of silicone coated RPCs and performance of oil-less RPCs. These will be reported at a later stage.

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