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On aging problem of glass Resistive Plate Chambers
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history

Abstract

Resistive Plate Chambers (RPCs) were chosen to be the active elements for a 50kton neutrino detector, which is proposed to be built by the India-based Neutrino Observatory (INO) collaboration. As part of the detector R&D programme, we have built a large number of prototype RPCs and studied their characteristics. While, the results obtained by us are in agreement with those reported in the literature, the RPCs were observed to suffer severe damage when operated continuously for a few months. We summarise here our studies on this problem.

keywords. *Key words:* INO Collaboration, Resistive Plate Chambers, Aging problem

1. Introduction

The INO collaboration is proposing a large magnetized iron tracking calorimeter of total weight 50 kton using atmospheric neutrinos as source[1]. The proposed detector will have a modular structure of lateral size 48m X 16m and will consist of a stack of 140 layers of 6cm thick iron plates interleaved with 2.5 cm gaps to house RPC detector layers. About 27000 RPCs of dimension 2m X 2m will be needed for his experiment. Shown in Fig. 1 is the INO detector concept.

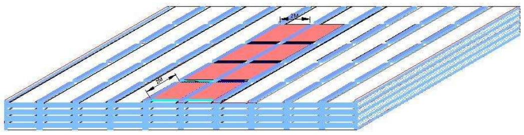

Fig. 1. INO detector concept

2. RPC R&D effort

A dedicated R&D effort is currently underway to develop and characterise RPCs which are needed for this experiment. A beginning has been made by building and testing several single gap (2 mm) glass RPCs of area 30cm X 30cm as well as a few of larger size, of area 120cm X 90cm. The Voltage-Current (V-I) characteristics of these detectors were studied. The noise rate was found to be a reliable way of monitoring the stability of the RPC. Streamer

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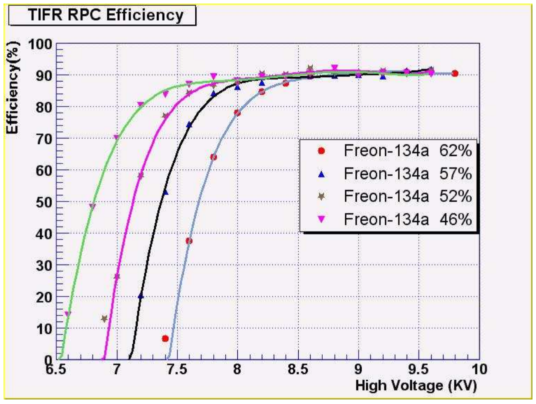

Fig. 2. Efficiency plateau plots obtained for various gas mixtures

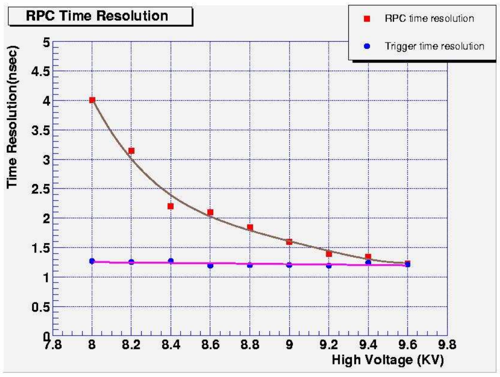

Fig. 3. Timing resolution plot of the RPC

plateau efficiencies of over 90% for various gas mixtures have been obtained for minimum ionising particles as seen from Fig. 2. For all these studies, while Argon fraction in the gas mixture was kept at 30%, R134a and Iso-butane were added to the rest of 70%.

Measurements of the charge linearity and time response of the RPC as a function of applied High Voltage have been made. The typical time resolution, σ, of the RPC when operated in the High Voltage plateau is about 1.2 nSec(Fig. 3). The cross talk between the adjacent pickup strips was found to be less than 6%.

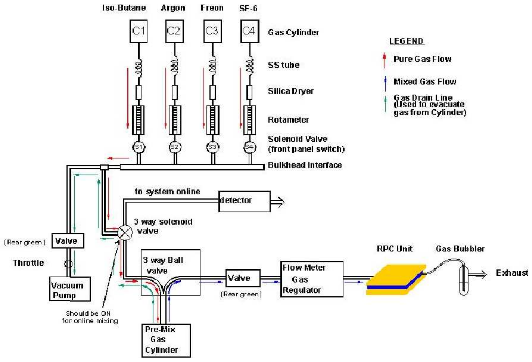

Fig. 4. Schematic of the gas system used

3. Infrastructure development

A gas system capable of mixing and distributing four input gases was developed. The gas is usually mixed in a buffer cylinder and flown from there into the RPCs under test. Alumina based moister filter and dust filters are mounted on the gas system's output line. Schematic of the gas system is shown in Fig. 4. RPC test system consisting of a scintillator paddle based Cosmic ray telescope as well as a NIM/CAMAC based DAQ system was also developed. Various tools and jigs needed for RPC assembly and their quality control were also developed.

4. Aging problem

The first encounter we had with the aging problem was when we operated the RPC, results of which are shown in Figs. 2 and 3, continuously for a few months. We had noticed that, while its efficiency dropped suddenly, the noise rate and chamber current have shot up. The chamber could not be revived. The problem was identical to that reported in the literature [2,3]. The chamber was broken open and the inner surfaces of the electrodes were scanned under Atomic Force Microscope (AFM) [4] and Scanning Electron Microscope (SEM). Shown in Fig. 5 are pictures of two (anode and cathode) damaged electrode and raw glass surfaces.

The SEM images of the same damaged electrode

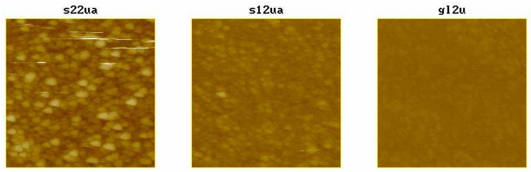

Fig. 5. AFM scans of damaged anode, damaged cathode and a raw glass sample

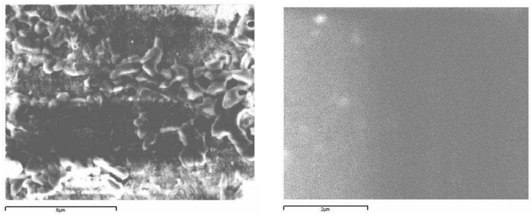

Fig. 6. SEM scans of damaged electrode and a raw glass sample

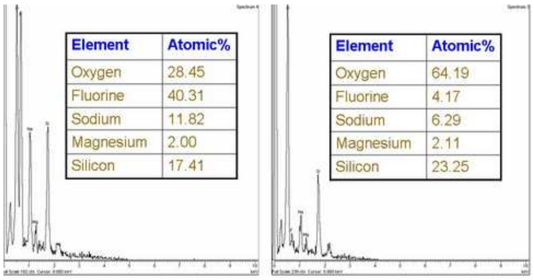

Fig. 7. Element analysis of a damaged electrode and of a raw glass sample

and a raw glass are shown in Fig. 6.

Element analysis was also performed again both on damaged electrode and raw glass sample, results of which are shown in Fig. 7 and the inset tables. The structures shown in the AFM and SEM scans were found to be rich in Fluorine, confirming the reasoning that Freon (R134a) gas contaminated with moister forms Hydro Fluoride (HF), which actually damages the RPC.

The structures on the damaged electrodes were found to be loose deposits on the electrodes rather than permanent damaged regions on the glass. This was demonstrated by the AFM images shown in Fig. 8. On the left plate, we have shown the damaged surface, while on the right, we show the same sample which was wiped clean by a dry rough tissue paper.

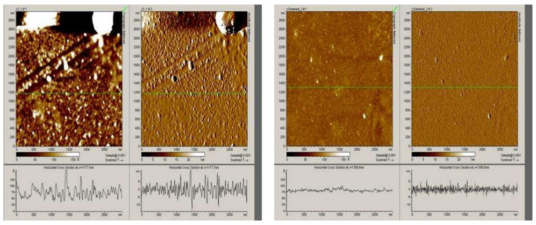

Fig. 8. AFM images of a damaged and cleaned electrodes

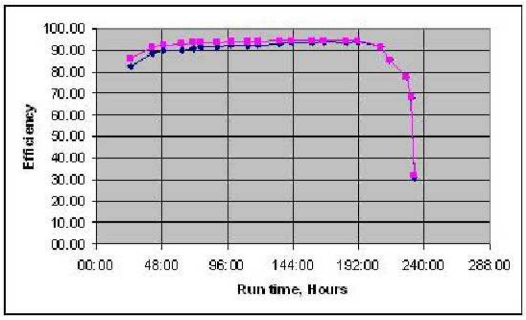

Fig. 9. Efficiency drop of an aging RPC

5. Further studies studies on aging

We have tried operating the RPCs in lower gain avalanche mode by changing the gas to a two-component mixture of Freon (R134a) and Isobutane in the ratio of 95.5:4.5. This didn't result in drastic improvement with regard to the aging of the chamber. Shown in Fig. 9 is an efficiency monitor for about last 10 days of a RPC before getting damaged.

A parameter called streamer size has been devised and was monitored during long term tests of the RPC. The streamer size indicates the fraction of single strip hits for a cosmic ray muon trigger to its sum with the adjacent strips. We find that the streamer size parameter increases monotonically with time, indicating that the size of region which is getting damaged is also increasing. This is ultimately leading to a run a way condition.

Shown in Fig. 10 are the noise rate history of the RPC and its individual strip rates. We see from the plot on the right, that the increase in the noise rate is not a local phenomenon.

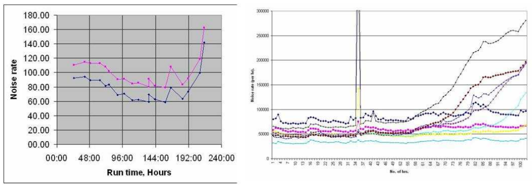

Fig. 10. Noise rate history of the RPC(left) and its individual strip rates(right)

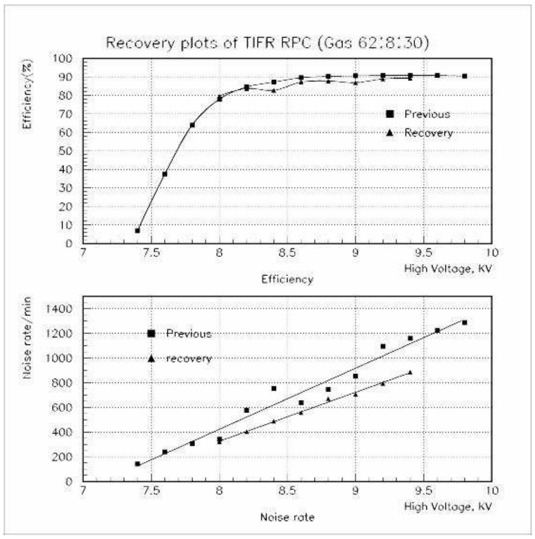

Fig. 11. Efficiency (top) and noise rate (bottom) recovery of a damaged RPC

6. Recovery of a damaged RPC

Following the recipe suggested by H.Sakai et al [2], i.e. purging the damaged chamber by pure Argon bubbled through 25% Ammonia solution for 24 hours without electric field, we could recover the efficiency and brought down the noise rate. In Fig. 11, we show the recovery characteristics of this chamber. However, the chamber did not sustain the recovery for long time later.

7. Conclusions

We have successfully developed and built many small and large area glass RPC prototypes. We have obtained results which are consistent with those reported in the literature. We are however, currently facing a serious problem with regard to their sudden aging after continuous operation. The problem was observed both with the streamer and avalanche modes of operation. We have made some preliminary measurements for the moister levels in the gas mixture that we use and found that the moister levels weren't high. We have also installed moister filters on the gas lines, but found that that it did not solve the problem either. We are currently working on better monitoring of moister levels using in-situ sensors, monitoring of various ambient parameters such as temperature, relative humidity and barometric pressure as well as trying with glasses from different manufacturers for the RPC electrodes etc.

Acknowledgements

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