Leak and Spacer tests for bakelite gas-gaps for RPCs

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For the RPC upgrade project for the CMS experiment, the RPCs shall be installed in the fourth end-cap during the proposed shut down in 2012 [1]. India is a collaborator for the upgrade project and would contribute to the RE4/2 type RPCs, with about 50 such chambers being assembled and integrated in NPD-BARC, Mumbai, in collaboration with Panjab University, Chandigarh. The bakelite gas-gaps are the heart of the RPCs as they are configured from high pressure laminates tailor made for the experiment, which can handle large count rates in the LHC environment and live to their expected life span of about ten years without much degradation in their functional parameters in terms of efficiency and dark currents. Each of these RPCs is a double layered RPC with three gas-gaps (Bottom, Narrow and Wide). The gas-gaps are fabricated in KODEL, Korea with bakelite sheets transported from Italy. The gas-gaps have graphite coating on the outer surfaces which provide the anode and cathode, have gas nozzles in four corners for gas flow and the uniform gap of 2 mm is maintained through a grid (10 cm x 10 cm) of button spacers (2 mm ± 0.02 mm) sandwiched between the bakelite sheets. It is very important that this 2 mm gap remains uniform over the entire area of the gas-gap in order to provide a uniform electric field for avalanches to take place on passage of muons through them. Since the gas-gaps are transported through a large distance via air freight and then handled at airports before delivery to the respective assembly sites, it is quite possible that if any mishandling occurs in between then there is a fair chance of some of the button spacers could get popped up. These spacers could also get popped up because of insufficient bonding of the glue at the fabrication site, though sufficient care is taken to keep the spacers pressed, guaranteed by water column, for 14 hours during curing. In either case a gas-gap with a popped spacer cannot be used and is to be rejected. In order to test these gas-gaps a new system has been designed at the RPC Lab. in NPD-BARC, where the gas-gaps on arrival from KODEL, Korea shall be subjected to a leak and spacer test. The gas-gaps are pressurised at 20 mbar above atmospheric pressure with Argon gas and this is recorded digitally through a pressure transducer. The QA/QCs as prescribed by the CMS experiment for the leak test need the gap to remain pressurised at 20 mbar for 10 minutes and calculate the dP/dt for each gas-gap, then reduce the overpressure to 3 mbar, which would be the operating pressure in the CMS cavern for the RPCs for next 10 minutes, re-calculate dP/dt at 3 mbar and then release the overpressure to zero. A plot of the same is shown in Fig.1 for the "Bottom" gas-gap (largest volume for RE4/2 type) for CMS-RPC, with a piezoelectric sensor with a 12 bit output resolution.

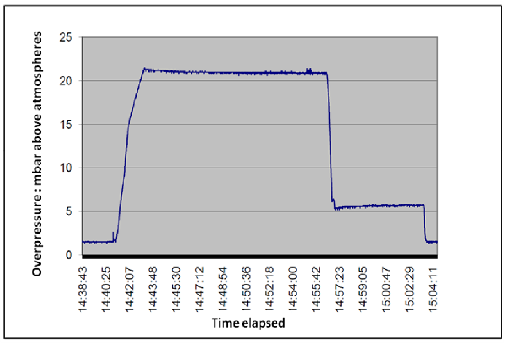

Fig. 1 Leak test for bakelite gas-gap at 20 mbar and 3 mbar of overpressure

The above plot shows a fairly stable pressure inside the gas-gap with an offset of 1.6 mbar which shall be corrected in due course with proper calibration. As the slope (dP/dt) at both ~ 21 mbar (actually 19.4 mbar) and ~ 6 mbar (actually 4.4 mbar) is almost zero, the gas-gap is therefore accepted in terms of the leak rate. The present data was recorded at 100 ms interval and would soon be converted to a data logging of 1 sec. Once the gas-gaps have passed the leak test they are then subjected to spacer test to look for any popped up spacer. If there is any popped up spacer, the gas-gap will not remain flat and will balloon out and get raised up in the region of popped spacer as shown in Fig. 2, on the left side, for one of the rejected gas-gaps.

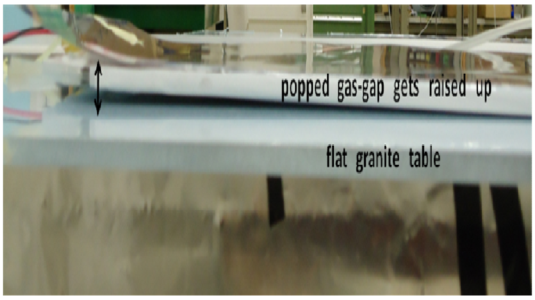

Fig. 2, A gas-gap with a popped spacer gets raised up on a flat granite table

For the spacer test, a grid on a mylar sheet with known spacer positions is placed over the gas-gaps. Table 1, shows the three different types of gas-gap with the respective number of spacers, their volumes and permissible leak rates, which are employed in configuring the RE4/2 type RPC for the CMS end-cap.

Table 1

Type of gas-gap (RE4/2)	Number of spacers	Volume of gas-gap (cm^3)	Leak rate (mbar/s)
Bottom	102	3,472	5.0×10^{-4}
Narrow	56	2,489	3.3×10^{-4}
Wide	39	784	2.5×10^{-4}

The spacer positions are then pressed gently and spikes are recorded in the spectrum again at an overpressure of 20 mbar as shown in Fig. 3. In this case a pressure transducer (CTE-7000) with better sensitivity is employed with a 20 bit ADC. These spikes are however quite small compared to a non-spacer region, where with the same applied force the fluctuations generated are quite large. Each spacer should then correspond to a single spike as shown in the figure. For Fig. 3, a "Wide" gas-gap for RE4/2 type chamber was employed, which consisted of 39 spacers and we can clearly see 39 distinct peaks in the plot. However, care is to be taken to apply uniform force on all the spacers and allow sufficient time for the fluctuations inside the gas-gap to settle down. An ideal condition would be to press a spacer position for 2 seconds and then wait for 5 seconds before moving to the next spacer.

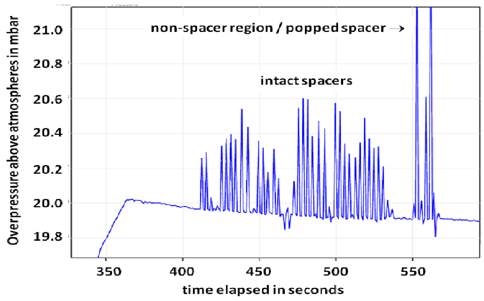

Fig. 3 Spacer test for a bakelite gas-gap (Wide gap : for RE4/2 type with 39 spacers)

In the above plot, we see the nominal spikes (~ 0.2 to 0.6 mbar) for 20 mbar of overpressure corresponding to the intact spacers. On the right hand side, certain non-spacer regions were pressed, to give an idea about the larger fluctuations in pressure (more than 1 mbar ~ 10 mm of water column) corresponding to the same force. A region where a spacer has popped up should behave exactly as a non-spacer region. These large fluctuations are also visible on the manometer columns. The larger fluctuations in the non-spacer regions are just for demonstration purpose and should be avoided in actual testing, as such forces in the non-spacer regions put unnecessary stress on the gas-gap and the adjoining intact spacers. A slight fall in the base pressure (1.44×10^{-4} mbar/sec) is also observed, which is well within the acceptable limits of the leak test.

It is mandatory, for each of the assembly sites at Mumbai, Ghent and CERN, to upload such plots in the data base, which tell us about the mechanical stability and acceptance of the gas-gap, before the assembly of RPCs is taken up.

References

[1] CMS Muon Tecnical Design Report [CERN/LHCC 97-32]