Resistivity measurement of RPC bakelite

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Goals

• Measure volume resistivity in the range $10^{11}$-$10^{12}$ $\Omega$cm

• Use a reliable and fast system for a mass production measurement at the factory
• We decided to use the system designed and realized by the INFN-Pavia group for testing the CMS RPC’s

• This measurement facility, currently installed at the bakelite factory, is now used by most of the experiments using bakelite for the RPC
Acknowledgment

• We want to thank the INFN-Pavia group of CMS
• in particular we want to thanks P. Torre and P. Vitulo for training us to the use of the system and for helping us in the start-up
Measurement Scheme

\[ V_0 = 1000V \]
\[ R = 1M \text{ ohm} \]

\[ \text{res} = k \frac{V_0}{(V/R)} \]

where \( k \) is a geometrical factor depending on electrodes geometry.
Measurement Scheme

• The electrical contact is assured by conductive rubber mounted on a piston.
• The measurement is taken after the Voltage has been applied for about 1 minute.
• Nine different spots of the bakelite slab are simultaneously measured
Courtesy of INFN-Pavia
A wet sponge electrode can be used to calibrate the measurement made using the conductive rubber electrodes.
First measurement system

Courtesy of INFN-Pavia
Critical point of the measurement

• The result of the measurement depend on:
  – Conductive material between electrodes and bakelite (water, gel, rubber)
  – Temperature
  – Humidity
  – Applied Voltage
  – ….

• We don’t expect a measurement more accurate than a 30%
Temperature dependence

- True resistivity of bakelite varies with temperature
- The measuring machine give as output the value of resistivity extrapolated to that at 20 degree using an empirical (exponential) function
- The resistivity at 20 degree ($R@20$) is used to classify the slabs
QC of bakelite mass production

- About 700 slabs of bakelite made at the PanPla factory have been processed
  - 1/2 in March (by people of Rome and Pisa)
  - 1/2 in June (by people of Genova, Rome and Pisa)
- 6/7 people have worked for about one week in every shift of measurement
QC of bakelite mass production

• Every slab was optically surveyed, to reject those having scratches or bubble
• The resistivity was measured and a slab was accepted if its resistivity at 20 degree was within spec: $(28-120) \times 10^{10} \, \Omega cm$
• The slab were divided in 5 categories according to their resistivity, and then coupled for the cut
Results

• 1st batch
  – 346 passed the optical inspection
  – 270 passed the resistivity test; 30 of those have been discarded after a further optical survey
  – \textbf{240} available for RPC production
Resistivity@20 degree

\[ \mu = 64; \sigma = 34 \quad (10^{10} \Omega \text{cm}) \]
Temperature and Humidity during the measurement
Results

• 2nd batch
  – 360 passed the optical inspection
  – 139 only passed the resistivity test
• What is the reason of such a low yield?
Resistivity @ 20 degree

\[ \mu = 102; \sigma = 84 \quad (10^{10} \Omega \text{cm}) \]
Temperature and Humidity

Very different from 1st Batch. Hotter and dryer
Is the low yield a temperature effect?

- The temperature was varying of several degree during the day.
- We measured 15 slabs at two different room temperature: 28 °C and 24 °C; the average value of the resistivity (extrapolated at 20 degrees) was different nearly by a factor 1.5.
- We take a reference slab and we measured it at different hours of the day; i.e. at different temperature.
R@20 degree vs room temperature

If the extrapolation is correct we expect a flat line for R@20 as a function of the temperature
• From the previous plot it seems that the extrapolation is overestimating the “true” resistivity at high temperature

• So we increase the higher limit of the spec by 50% (from 120 to $180 \times 10^{10} \Omega \text{cm}$) for the slabs measured at room temperature between 26 and 29 degrees; 17 more slabs were recovered

• Because the yield was still low we decided to decrease also the spec lower limit (from 28 to $15 \times 10^{10} \Omega \text{cm}$), recovering 42 more slabs
Further checks of the measurement procedure

- We divided our sample in two different set according to room temperature:
  - T < 22 degree
  - T > 26 degree

- If there is only a temperature effect we should be able to see it
Resistivity @ 20 degree

• R@20 distribution is wider than in the 1st batch also in the case of the measurements taken at lower room temperature
• What are other possible explanations?
Further checks of the measurement procedure

- We also divided the slab of 2nd batch in two different sample according to room humidity:
  - Humidity < 40 degree
  - Humidity > 40 degree
Resistivity @20 degree

No compelling evidence of a dependence of R@20 distribution from humidity
Measurement checks: conclusion

• The temperature alone doesn’t seem to explain the big difference between batch 1 and batch 2 yield

• Probably the humidity influenced the measurement as well, but we were not able to detect it

• Of course, it is also very likely that the higher resistivity of the 2nd batch is due to a production process at PanPla not well controlled
Summary

• About 700 slab have passed the optical inspection and their resistivity has been measured

• **438** have passed the resistivity QC
  – 240 of batch 1
  – 139 + 17 + 42 of batch 2
Summary

• To make the measurement more robust, a better environment with respect to the PanPla factory, where is now installed the INFN-Pavia measurement facility, is needed

• Further studies have to be made if we want to understand the resistivity of the bakelite