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The Compact Muon Solenoid Experiment

Conference Report

Mailing address: CMS CERN, CH-1211 GENEVA 23, Switzerland

27 February 2012

Production of RPC gaps for CMS upgrade

Sung.Keun Park for the CMS Collaboration

Abstract

The CMS collaboration intends to improve the muon trigger efficiency in the forward region.

In order to achieve this goal, 144 new Resistive Plate Chambers (RPCs) at RE4/2, RE4/3 will be installed on the existing york YE3 to trigger high momentum muons from the proton-proton interaction.

In this paper, we present the detailed procedures used in the production of the CMS RPC gas gaps adopted in the CMS upgrade.

Quality assurance is enforced as ways to maintain the quality of RPC gas gaps as the previous CMS endcap RPC chambers.

Both the production procedures and the quality assurance are mature and effective for the mass production of these RPC gas gaps.

Key words: CMS, Resistive Plate Chamber (RPC), Muon trigger detector, Production procedures, Quality assurance

Presented at *RPC2012: XI Workshop on Resistive Plate Chambers and Related Detectors*

PROCEEDINGS OF SCIENCE

Production of RPC gaps for the CMS upgrade

Sung Keun Park[*][†]
On behalf of the CMS collaboration
Korea Detector Laboratory, Korea University
Seoul, 136-701, Korea
E-mail: sungpark@korea.ac.kr

The CMS collaboration intends to improve the muon trigger efficiency in the forward region. In order to achieve this goal, 144 new Resistive Plate Chambers (RPCs) at RE4/2, RE4/3 will be installed on the existing york YE3 to trigger high momentum muons from the proton-proton interaction. In this paper, we present the detailed procedures used in the production of the CMS RPC gas gaps adopted in the CMS upgrade. Quality assurance is enforced as ways to maintain the quality of RPC gas gaps as the previous CMS endcap RPC chambers: RE1/2, RE1/3, RE2/2, RE2/3, RE3/2, and RE3/3. Both the production procedures and the quality assurance are mature, and effective for the mass production of these RPC gas gaps.

XI workshop on Resistive Plate Chambers and Related Detectors - RCP2012,
February 5-10, 2012
INFN Laboratori Nazionali di Frascati Italy

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[*] Speaker.
[†] I acknowledge the support of the Korean Research Foundation, and Korea University.

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1. Introduction

At the LHC, the bunch crossing frequency will be 40 MHz, which, at the nominal luminosity of $10^{34} cm^{-2} s^{-1}$, leads to about 800 million proton-proton collisions per second. The CMS experiment emphasizes the detection and identification of muons [1].

Every 25 ns some 1000 particles emerge from the interaction point into the CMS spectrometer. In less than 3μs a first level trigger has to reduce this rate to 100 kHz without losing potentially interesting collisions requiring further analysis.

The CMS first level muon trigger relies on RPCs. Six concentric layers of chambers are used in the barrel part, while four layers have been foreseen in total for the end caps to cover a rapidity up to η=2.1. But only 3 layers per end cap were installed with a limited rapidity coverage up to η=1.6. Therefore, the completion of the forward RPC system to 4 layers per end cap in the coverage up to η=1.6 is a priority.

Since the RPCs should provide an efficient muon trigger for CMS physics goals, the gas gap must meet the CMS requirement for RPCs as shown in Table 1. To produce the gas gap which meets the requirement of the performance, we should build the gap with two most important considerations in mind: an overall mechanical stability and an uniform electric field over the active gas volume. In this paper, we describe each step in detail following the same technology that Korea Detector Laboratory (KODEL) developed for the forward RPCs which have been already installed and operational since the turn on the LHC [2]. The basic structure of the CMS double gap RPC is shown in Fig. 1 and its robustness and high quality are well captured in Fig. 2 as in [3].

2. Production procedures

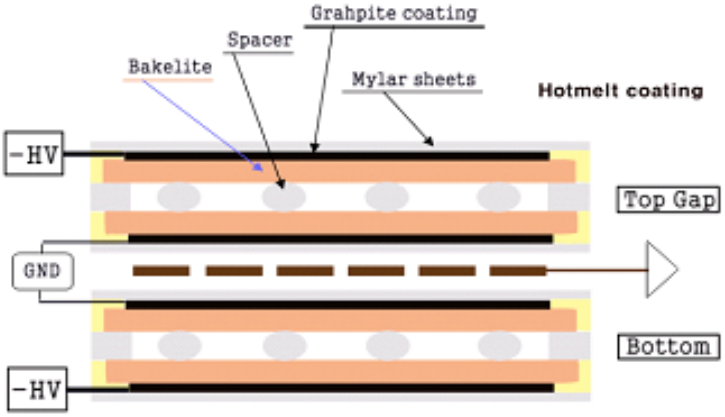


Figure 1: Cross sectional view of double gap RPC.

Once the bakelites are prepared for the gap production as shown in Fig. 3, the next step is the production of the electrodes. A thin layer of graphite is coated on the bakelite sheet by a silkscreen process. The thickness of the graphite layer is well maintained by the 20 micro-meter thick silk screen mesh. The surface resistivity of the graphite layer ranges from 100 to 250 kΩ/square. The measurement of the surface resistivity from 50 samples is shown in Fig. 4.

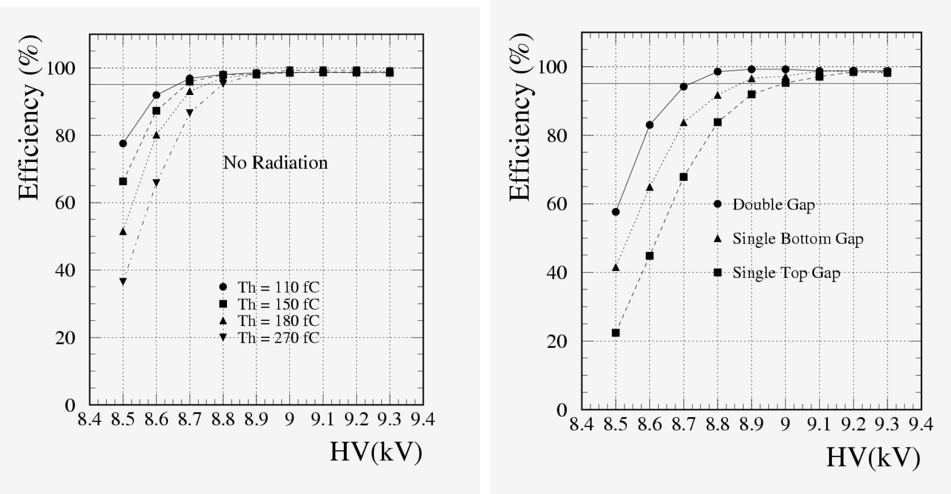


Figure 2: The efficiencies of the RPC in terms of charge thresholds (left), and number of gaps (right).

Table 1: CMS RPC requirements.

Parameters	Allowable ranges
Efficiency	$>95\%$
Time resolution	$\leqslant$ 1 ns
Average cluster size	$\leqslant$ 2 strips
Rate capability	2 kHz/cm^2
Mean avalanche charge	2.5 - 5 pC

Once the graphite layer is dried, a protective insulator sheet made of Mylar is pasted on the graphite layer by a thin film of hot adhesive based on ethylene vinyl acetate (EVA) . The Mylar film coating device is shown in Fig. 5.

Figure 3: Bakelites are cut for RE4/2 top narrow and top wide gaps (left), and bottom gaps (right).

Once the electrodes are prepared, the gas gap is assembled with two electrodes and spacers. The coin shaped spacers are placed between the two electrodes to form a uniform separation of 2 mm between the electrodes, and the edge of the gas gap is sealed by the edge strip. The mechanical support of the gas gap is provided by the coin shaped spacers placed 10 cm apart from adjacent spacers in two orthogonal directions. The edge strip that sealed the edge of the gas gap makes the gas volume leak-tight. The spacers and edge strips are placed in pre-determined locations guided

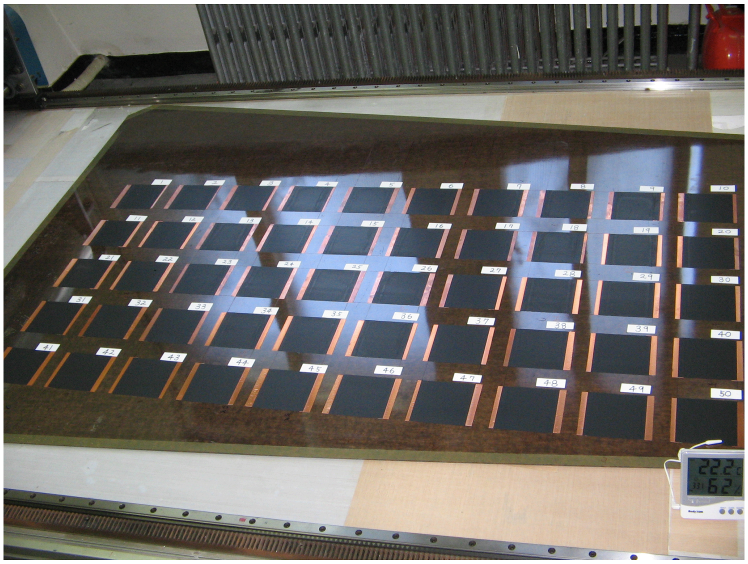


Figure 4: Measurement of the surface resistivity from 50 samples of bakelite pieces of 10cm x 10cm size.

Figure 5: The graphite layer of the electrode is covered with the Mylar film for the protection.

by a special jig and are bonded to the electrodes by an epoxy with a curing time of 24 hours.

To achieve the maximum bonding strength between the spacers and electrodes, they are placed in a device where an air pressure of 30 hPa is applied over the entire surface of the gas volume. The bonding facilities are shown in Fig. 6.

After 24 hours of hardening, the mechanical stability of the gas gap is checked by a test to see the stability of bonding and a test of gas tightness of the gas volume. For the mechanical stability test, the gas volume is over-pressured with 20 hPa. For a gas gap to be qualified, any loss of the

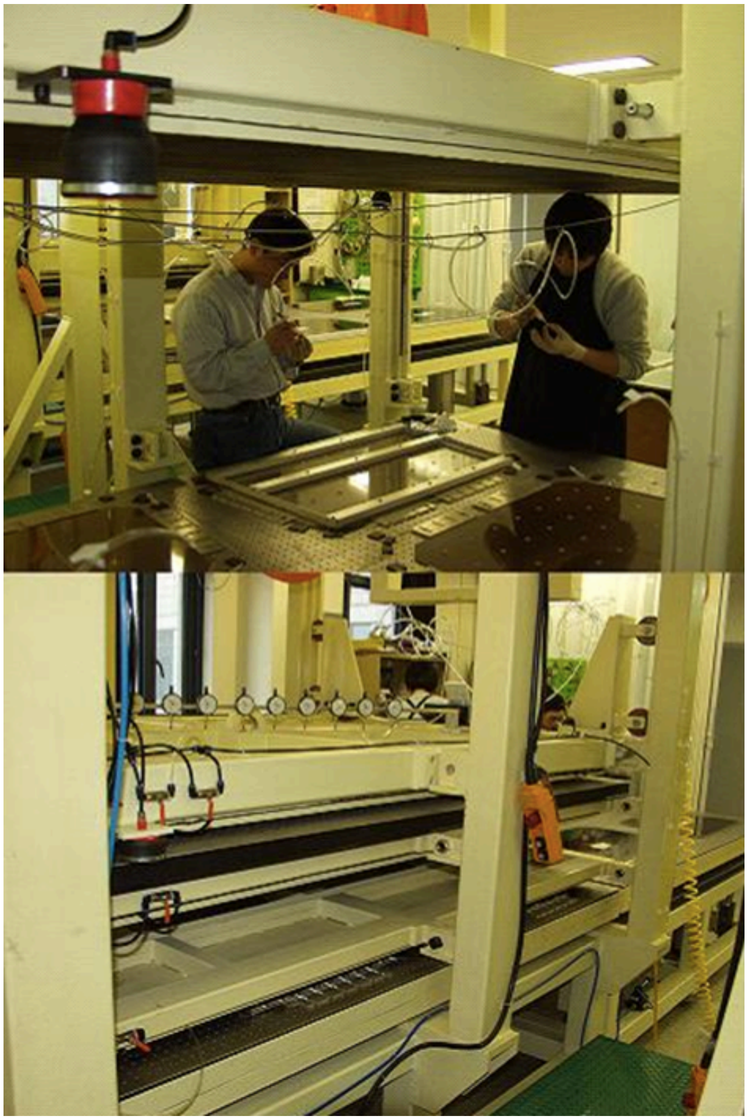


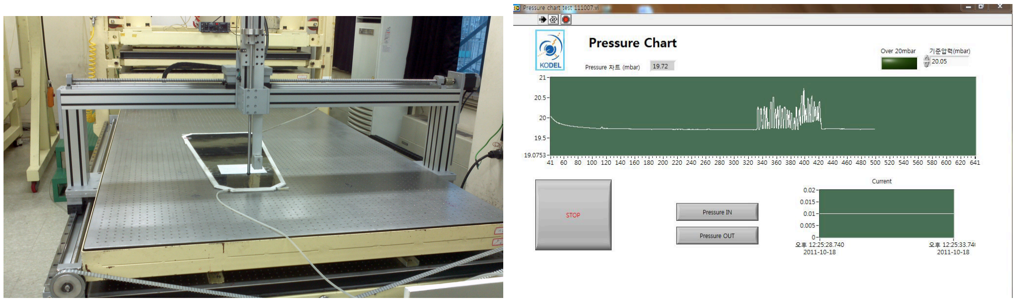
Figure 6: The bonding facility

applied pressure should be less than 0.2 hPa during a 10 minute period. In order for the gas gaps to pass the test, no single spacer should lose its bonding strength between two electrodes during the 20 hPa over-pressure.

All these mechanical tests are carried out by a robot built at KODEL as shown in Fig. 6. And the test results are kept at the CMS central ORACLE data base.

Once the gas gap passes the mechanical stability test, its gas volume is treated with linseed oil. It turns out that the polymerized linseed-oil layer on the surface of the bakelite inside the RPC reduces the spurious noise in the avalanche mode of operation. But this oiling procedure needs a cautious preparation due to the pressure built up by the linseed oil filling the gas gap. If this pressure is greater than 20 hPa, the gas gap will likely to lose its epoxy bonding strength.

The CMS gas gaps have six different sizes and shapes. They are three gaps in RE4/2 chamber


Pressure chart test 111007.vi

Pressure 차트 (mbar) 19.72

기준압력(mbar) 20.05

Figure 7: KODEL robot performing the pressure test(left), and test results (right).

Figure 8: The oil coating facility

and three gaps in RE4/3 chamber as shown in Fig. 3. Accommodation of this variety of physical dimensions to the oil coating facility is a difficult task due to the different orientation of the gas inlet and outlet depending on the shape of the gas gaps. Therefore, prior to the application of the linseed oil to the gas gap, a simulation with test gas gaps was performed. The oil coating facility is shown in Fig. 8.

Once the gas volume is treated with linseed oil, the current drawn by the gas gap is measured since the amount of current drawn by each gas gap is a good indicator to check for any electric short within the gas volume.

The gas mixture for the current measurement under high voltage is 95% tetrafluoroethane, 5%

Figure 9: Qualified gas gaps being loaded in a specially designed box. The extra space to absorb any impact on the box is shown near the bottom of the photo.

isobutane. The gas volume is purged by the flow of the gas mixture with flow rate of 20 l/h, whose total volume is as large as 15 times the gas volume of the gas gap, before applying high voltage. Total duration of the current measurement is about 7 days including the purging time.

At the beginning of the test, the high voltage is set to 1 kV to check for any electrical misconnection. If the gaps hold at 1 kV, then every 30 minutes, the HV is increased by 1 kV up to 6 kV. At each HV setting, the currents are measured and recorded in the data sheet. From 6 kV the HV is raised up to the maximum 10 kV. From 8.4 kV, the increasing step is 200 V, finer than the 1 kV step to see the current behaviors in the operation voltages. Once the HV reached the maximum 10 kV, it is lowed to 9.6 kV for 96 hours test.

3. Packing and transportation

Every 60 qualified gas gaps are vertically mounted into a wooden box equipped with four pre-loaded bars which were designed to horizontally press the surface of the gas gaps as shown in Fig. 9. Polystyrene foam sheets of 5mm thickness are placed between the layers of the gas gaps to absorb shocks which could occur during transportation. Extra protection from unexpected moisture is provided by wrapping the whole 60 gas gaps with a thin vinyl film. The pipes for the gas inlets and outlets are left open to adapt to sudden variations of pressure during air transport.

4. Conclusions

We report that the RPC production procedure and subsequent quality assurance procedure that Korea Detector Laboratory (KODEL) developed for the CMS forward RPC stations of RE1/2, RE1/3, RE2/2, RE2/3, RE3/2 and RE3/3 are being followed to produce 660 gas gaps that will be assembled into RE4/2 and RE4/3 stations of the CMS forward regions. We conclude that the production and subsequent quality assurance described here is mature for the mass production of the large RPC detectors for such as CMS.

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