Production of Gas Gaps for iRPCs & Quality Controls

Kyong Sei Lee, Minho Kang, Youngmin Jo at KODEL, Korea University
Gap production and QC2 Steps

1. Washing Bakelite surface with MEP (@Damia)
2. Graphite coating & inspection and sample measurement of resistivity (@Damia)
3. Final visual inspection for HPL panels (@Damia)
4. Cleaning Bakelite surface with IPA (@KODEL)
5. PET coating (EVA glue) and inspections (@KODEL)
6. Gluing gas gaps (@KODEL)
7. Gas Leak & spacer bonding test (@KODEL)
8. Linseed oiling and drying (@KODEL)
9. EVA-glue sealing along the peripheries of gas gaps (@KODEL)
10. Cabling (@KODEL)
11. HV tests (3 steps @KODEL)
12. Final visual inspection for gaps (@KODEL)
13. Packing & shipping
Testing linseed oiling and drying procedure

Flushing ~ 2 hours with air (~100 liter/hour/gap) before oiling to avoid potential out-gassing problem of epoxy.

Procedures (quick double oiling) Oil mixture = 50% linseed oil + 50% heptane

1) 1\textsuperscript{st} oil loading & draining (3 hours): speed of oiling filling and draining with a constant speed ~ 0.3 mm/s
2) 2\textsuperscript{nd} oil loading & draining (3 hours): speed of oiling filling and draining with a constant speed ~ 0.3 mm/s
3) 1\textsuperscript{st} oiling sucking from bottom two gas pipes (2 mins for each gap)
4) 1\textsuperscript{st} air drying for 96 hours (~100 liter/hour/gap) @ T= 30 C with H ~ 35 %
5) 2\textsuperscript{nd} oiling sucking from bottom two gas pipes (2 mins for each gap)
6) 2\textsuperscript{nd} air drying for 60 hours (~100 liter/hour/gap) @ room temperature without adding humidity
Drying air coming from an external compressor. The air used for drying oil layer is humidified (30 ~ 35%) and filtered. Total capacity of the drying air is maximum 3000 liter/hour.

This line is blocked during drying oil layers.

Depression compressor at 0.83 ~ 0.9 atm

Level lifting/descending speed of 0.3 mm/s

Air ventilation to outside

Oil mixture from the tank is inserted from the bottom of the gaps through a gas hole at the lowest corner.

Two bottom gas pipes of each gap are connected to air ventilation tubes to bring the air for drying the oil layers to outside.
Washing HPL plates with MEK @Damia

- Washing HPL plates delivered from CERN with MEK
  - Washing both surface to get rid of residual solid oil dirt
  - Have to purchase a washing part of the machine
- Checking surface conditions of HPL panels
  - Checking any defect of surfaces and corners
  - Checking the washing condition
- Good/Acceptable/Bad -> rejecting bad ones

Delivering HPL right after MEK washing
Damia delayed preparation of a brushing roller to 29\textsuperscript{th} of June. 

- So, the washing tool is expected to be finally assembled @ Damia on 30\textsuperscript{th} June.

So instead in the last Wednesday, we used glass papers to simulate ‘brushing’ effect and brought six ‘brushed and washed’ 100 cm x 70 cm Bakelite plates to KODEL for an oiling test. 

- So, the first oiling test will be initiate on next Monday.

We have to test the roughness of the blush to get a best condition of the blushed Bakelite surfaces like we got for the previous RE4. Thin solid production oil layer formed on the Bakelite should be effectively removed by blushing.

Top brush: Polystyrene
Bottom brush: metal (called wire bush, stainless steel ?) 

- This is the reason why only one side of Bakelite can be brushed.
First test using citric acid instead of MEK

Washing speed of the machine ~ 30 cm s$^{-1}$
-> Too fast

Sample #1
No brushing, a just little scratching using glass papers
Washing was done by a machine.

Result: found severe, condensation on the oil layer, at regions not only near spacers, but everywhere.

Conclusions:
1. Citric acid is useless -> should be MEK
2. Proper machine brushing is fairly important.
First test using citric acid instead of MEK

Washing speed of the machine $\sim 30 \text{ cm s}^{-1}$

$\rightarrow$ Too fast

Sample #2

No wire brushing, a just little scratching using glass papers
Washing was done by a machine.

Result: found severe, condensation on the oil layer, at regions not only near spacers, but everywhere.

Conclusions:
1. Citric acid is useless $\rightarrow$ should be MEK
2. Proper machine brushing is fairly important.
First test using citric acid instead of MEK

Washing speed of the machine $\sim 30 \text{ cm s}^{-1}$
$\rightarrow$ Too fast

Sample #3
No wire brushing, well scratched using glass papers
Washing was done by a machine.

Result: the bubble problem was found to be less severe, condensation on the oil layer, at regions not only near spacer but everywhere.

Conclusions:
1. Citric acid is useless $\rightarrow$ should be MEK
2. Proper machine brushing is fairly important.
Second test with acetone

Sample #3
No wire brushing, well scratched using glass papers
Washing was done by hands

Result: The oil layer seems to be much better, the condensation problem has disappeared on the oil layer. But, some oil drain marks below spacers are still there.

Conclusion:
1. Acetone acid is also a kind of MEN. -> much better
2. Proper machine brushing is essential.
Opened one RE4/2 gap

For this RE4/2 gap, the oiling seems to be done fairly well. I guess there is epoxy outgas problem:
- Many regions of chemical reaction around spacers.
- But, the oil thickness of these regions seem to be same with others (not thinner nor thicker)
- the epoxy out gas might prevent proper polymerization of the oil layer

The oil thickness near the gap edge seems to be OK.
No oil drain marks below spacers
New company @Gimpo to build the washing machine
Moving roller, solvent spray nozzle, and master controller
Overall conclusions for the oiling R&D

Bad oil pattern
1) Condensation bubbles on oil layers
2) Oil drain marks below spacers
3) Poor dryness of oil layers
4) Thinner oil thickness near spacers and gap edges
5) What else? -> non-uniform melamine skins and hygroscopic problem

1), 2), and 3) are due to contamination of production oil of Bakelite
-> should be well removed by using MEK and with a proper brushing and washing machine.
-> the proper brushing procedure is also necessary for better bonding strength of spacers
-> Stronger spacer bonding -> less spacer failure + less bending
4) is due to the material property of the plastic gap supporting materials (spacers and gap shielding strips made of PC)
-> should be minimize by a proper quick double coating method.

What have to be determined
How much shell we mill out the Bakelite surface (using a wire brush)?
Roughness of the wire brush and the rotation RPM
Moving speed of the Bakelite in the washer
-> The speed should be slower (~30 s per sheet) to get rid of the solid production oil layer stick on the Bakelite surface.
Graphite coating

- Silk screen method for graphite coating
  - New Silk screen ink mixture of conductive (50 kΩ/□) + Carbon resin
  - Mean value of the surface resistivity = 500 kΩ/□
  - Silk mesh: 20 μm thick with mesh number 220
  - Drying the graphite surface 100 °C for 10 mins
  - The thickness of dried graphite ~ 10 μm
- QC data: measuring surface resistivity values on 6 check points per HPL
  - Range of surface resistivity: 300 ~ 700 kΩ/□ -> 450 ~ 550 kΩ/□
- Drawing a conductive line (~ a few hundreds Ω/□, 5 mm wide) along each side of the graphited HPL
- Final visual inspection for HPL panels bft PET coating (@KODEL)
First test results for Graphite

Sample test (area = 30 cm × 30 cm)
Used a special tool to measure the surface resistivity
Needs a correction factor ~ 1.5 to get a true values
Measured mean 435 kΩ/□
→ Actual mean value ~ 650 kΩ/□

Two choices (we know the resistivity will drop by ~ 20 % after several years later. But no way to know the exact value.
1. Reduce the mean value to ~ 500 kΩ/□
2. Keep this value because of expecting the reduction as time go by.

<table>
<thead>
<tr>
<th>Panel 1</th>
<th>Panel2</th>
</tr>
</thead>
<tbody>
<tr>
<td>472</td>
<td>454</td>
</tr>
<tr>
<td>458</td>
<td>362</td>
</tr>
<tr>
<td>462</td>
<td>433</td>
</tr>
<tr>
<td>451</td>
<td>524</td>
</tr>
<tr>
<td>397</td>
<td>441</td>
</tr>
<tr>
<td>360</td>
<td>488</td>
</tr>
<tr>
<td>344</td>
<td>435</td>
</tr>
<tr>
<td>482</td>
<td>424</td>
</tr>
<tr>
<td>368</td>
<td>446</td>
</tr>
<tr>
<td>506</td>
<td>437</td>
</tr>
<tr>
<td>424</td>
<td>415</td>
</tr>
<tr>
<td>549</td>
<td>364</td>
</tr>
</tbody>
</table>

Mean 439.4167    Mean 435.25
Sigma 62.41716   Sigma 44.86976
**Schedule**

1st week of July: 1st brushing & washing

1) 30 1.4 mm thick Puricelli Bakelite with a size of 100 cm x 70 cm
2) 10 1.4 mm thick Puricelli Bakelite with a size of 194.4 cm x 124.4 cm for SHiP

2nd - 3rd weeks of July:

1) 1st Manufacture of ~ 5 gaps for oiling study. If successful,
2) Silk coating for all the Bakelite
   - 500 kΩ/□ for 100 cm x 70 cm Bakelite for iRPCs aging & echo gas study
   - 100 kΩ/□ for SHiP Bakelite for their new R&Ds -> 3 ~ 4 gaps

3rd July – 1st weeks of August:

1) 10 gaps with a size of 100 cm x 70 cm for iRPCs aging & echo gas study
2) 2nd week of August: HV test for the gaps iRPCs aging & echo gas study for a week
3) End of August: delivery of 10 small gaps to CERN to be finally delivered to CERN.

During the September: Production of 3 ~ 4 gaps for SHiP and ship them with new RE4.1 gaps on October.
Back ups
Cabling (HV and GND) (@KODEL) -> Nicolas

- Use of a coaxial HV cable for biasing the HV to the gap
- HV and ground connections are placed on opposite trapezoidal sides
  - To minimize the path of particle-induced ionization current
  - To maximize the rate capability

HVP model (NOT the final model for iRPCs)

Shielded HV Cable

3330007
30kVdc - AWG22 - PE

CONSTRUCTION

<p>| | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Conductor</td>
<td>AWG22 Cu/Sn (TxD.25)</td>
<td>0.75mm</td>
</tr>
<tr>
<td>B</td>
<td>Semicon</td>
<td>HDPE</td>
<td>1.45mm</td>
</tr>
<tr>
<td>C</td>
<td>Dielectric</td>
<td>HDPE (red)</td>
<td>5.9mm</td>
</tr>
<tr>
<td>D</td>
<td>Screen</td>
<td>CuSn, Coverage 3.97%</td>
<td>4.4mm</td>
</tr>
<tr>
<td>E</td>
<td>Jacket</td>
<td>PVC (red)</td>
<td>5.6mm</td>
</tr>
</tbody>
</table>