We got the length by measuring the thickness of the glass by using an electronic vernier caliper.

The length: L=0.2cm

The measured resistance from the mega-meter: R = $14x10^{9}\Omega$

3.2.4 The surface resistivity

Moving on the important part is measuring the surface resistivity. This test fixture is used on elastomers of all sizes as well as thin films and coatings. A blown-up view of the test specimen is sketched below with the induced current paths highlighted.

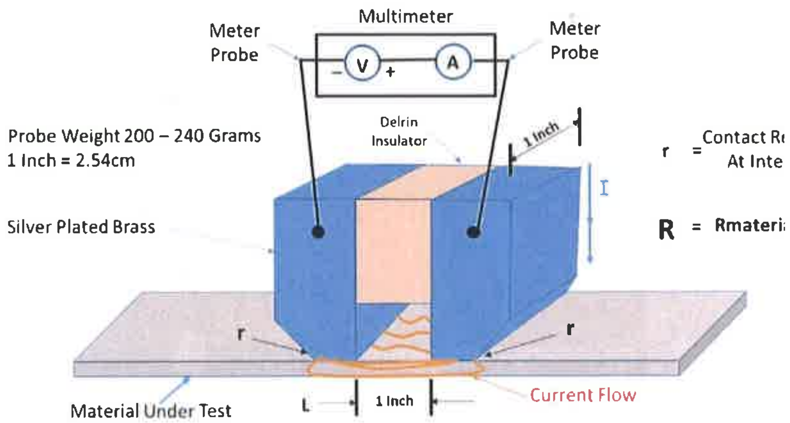

Figure 21: A blown-up view of the test specimen.

The circuit diagram would resemble that of the Pressure Probe, yet the current pathway within the material differs. The meter generates a voltage across the probe terminals, inducing a current that runs parallel to the material's surface. In shielding applications, the primary current flow takes place through the material's cross-section. Subsequently, the resistance within the material is gauged, referred to as the material's resistivity. The volume resistivity is determined using the following equation:

$$p = \frac{RA}{L}$$

Where: P = Volum Resistivity (Ω-cm)

R = Resistivity (Ω)

A = Cross-section area of the material = Thickness X Width (cm^2)

L = Distance between the probe Electrodes(cm)

We have done a measurement on four glass plates that were coated. I have taken three measurements for each plate and took the average.

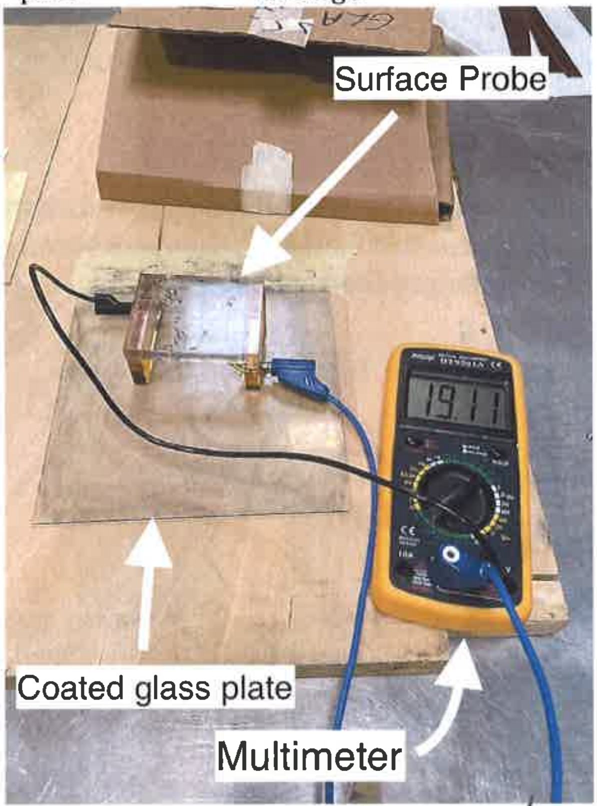

Figure 22: Surface probe measuring the ~~resistivity~~ Resistance. on a coated glass plate.

The Resistivity of the plates

Plate A

$R_1 = 136\ M\Omega$

$R_2 = 133\ M\Omega$ = $129\ M\Omega$

$R_3 = 118$

Plate B

$R_1 = 26.7\ M\Omega$

$R_2 = 74.5\ M\Omega$ } $R = 43.73\ M\Omega$

$R_3 = 30\ M\Omega$

Plate C

$R_1 = 3.36\ M\Omega$

$R_2 = 2.99\ M\Omega$ } $R = 3.33\ M\Omega$

$R_3 = 3.64\ M\Omega$

Plate D

$R_1 = 25.6\ M\Omega$

$R_2 = 35.8\ M\Omega$ } 43.6

$R_3 = 69.4\ M\Omega$

Surface OK.

∴ surface

check range of cheap multimeter.

As you can see there is a large difference in the measurements because we did the resistivity measurements in a rush.

3.2.5 Blueprint

After applying the coating on the plates and measuring the resistivity, we started building the first plate. As we did in the 20cm x 20cm carbonate gap, as you can see from Fig. 23 I have sketched on a piece of paper that is 30cm x 30cm position of the Bakelite side spacers and button spacers with three inlets on each side.

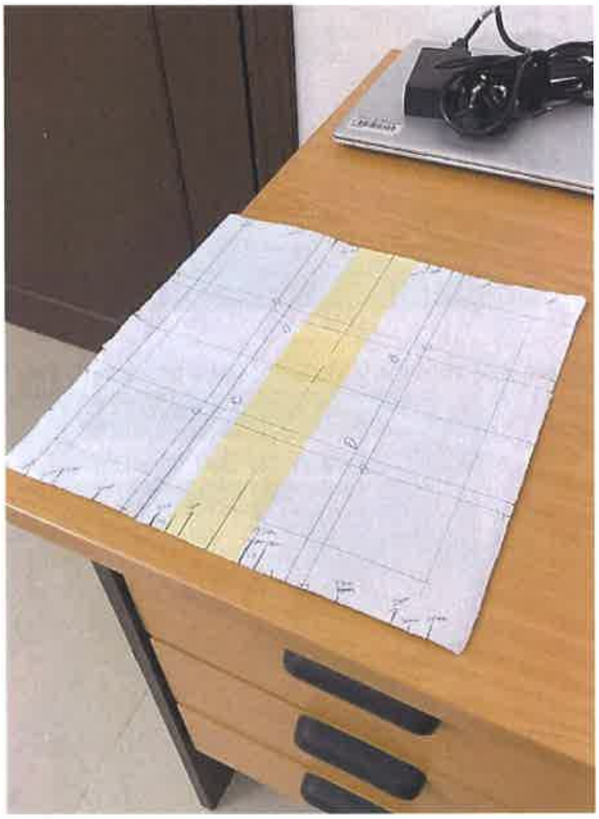

Figure 23: White paper having all measurements one the gap.

3.2.6 Making the First Plate

Gluing the gap by using epoxy adhesive, we went through the same procedure we did for the 20cm x 20cm polycarbonate gap but this time we have increased the number of lead bricks. We have ensured that the coating is facing outside.

The result was a cleanly aligned glass gap with three slots for the gas at two side

3.2.7 Making the Second Plate

In the second gap, we did the same thing but the only change we made was instead of using the paper under the gap, we sketched the placement of the spacers on the marble table as you can see in Fig. 25.

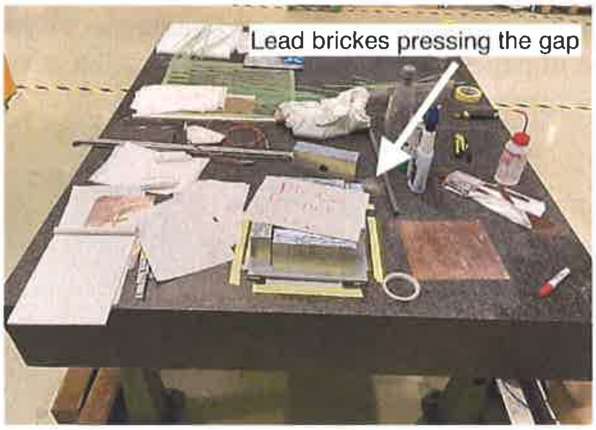

Figure 24: Working station, lead bricks on top of the gap.

Figure 25: Measurements of the gap drawn on the marble table.

When coming and applying the glue on the gap, you need to be careful about the amount. Too little glue will cause some gaps which causes leaks. And too much glue will make the glass gap glue with the marble table. Unfortunately, for the second glass gap, I applied much glass gap to glue to the marble table. I tried to apply acetone and heat the glue. But I Had no other choice other than to use a hammer and screw to remove the gap which lead to breaking the gap as you can see in Fig 27.

This is the result of our second glass gap.

For the third gap we have gone through the same procedure we did for the past the gap.

Figure 26: Tools used to remove the glued glass gap.

Figure 27: Broken glass plate.

The only difference is that we didn't have the coding on this gap because the aim is to use only two gaps to have one gap as a backup.

4 Solving the gas inlet question

4.1 Remove the fragile gas inlets in the present-day RPC gas chamber

Two of the main challenges that the CMS RPC experiment faces in today's chambers are maintaining gas-tight Chambers and the equally distributed gas flow inside the gaps. In the past years, CMS RPC has faced many times gas leaks and CERN scientists have worked to solve this problem. A significant increase in leak rate was detected in 2015 and 2016, bringing the leak rate from 600 l/h to 1200 l/h. Most of the leaky Chambers are located in the barrel region therefore, it is very difficult to have access to broken components. In September 2017, 26/480 Barrel RPCs were recorded for leaking, and all of these RPCs were not repairable because no access was available to these RPCs, therefore they were disconnected. Leaks in the RRCs are mainly caused by two main streams of gas. First, T or L polycarbonate gas connectors. Unfortunately, due to too much stress applied through the gas pipes, these connectors break. Second Polyethylene LD pipes are brittle and deteriorated therefore it gets cut. Several bad batches of pipes were identified in the detector and all Cracked pipes are coming from these batches. A combination with the environmental cavern conditions can lead to new leak development. In 2018, many efforts were put into reducing the leaky chambers, Were Scientists in the CERN CMS experiment accomplished to reduced the leak rate from 1200 l/h to 900 l/h and brought the replenishing gas rate from 12% to 10%. Fig. 28 shows the areas where these fragile components are.

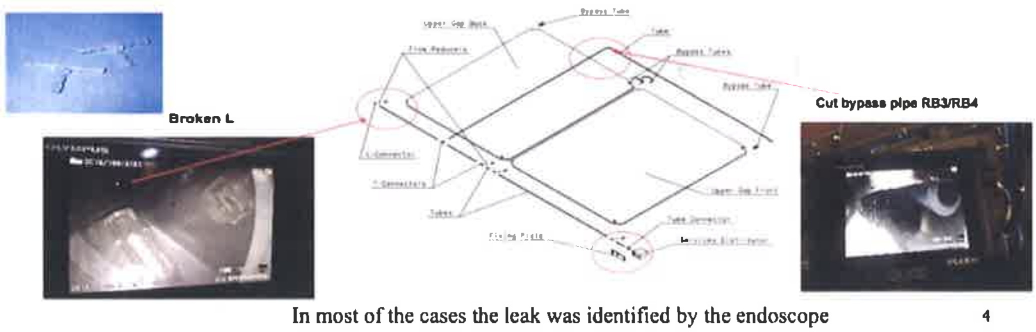

Figure 28: Shows a schematic view of the RPC with T and L connectors.

For the past years, the original RPC gas system design has faced many challenges and many efforts have been out to fix these problems. As in the new iRPC, the gap size has decreased from 2mm to 1.4mm, therefor it challenge gets harder than before. In the second part of this report, I talk about what is the idea of building a 1mm gap and what challenges we are going to face. And one of these obvious challenges is how to create a gas injection system that is going to have as less leaks as possible and equal gas flow distribution. And by the challenges that the RPC and RPC faced in the past years, here I'm going to explain what challenges we faced in the attempt of building a 1mm RPC.

4.2 The three main challenges in building a gas system distribution of the gas for the 1mm gap

Thinking and planning for a 1mm gap is considered easy. But when you come and apply this idea in reality you face many problems, and our goal is to solve these problems. Since the beginning of working on this project, we faced problems, and one of the first problems we faced was how to make the gas injection in a 1mm gap. it is way harder to apply than to have a theory because we have an area of 1mm to inject gas in and what materials we can use. Another challenge we have faced is removing the fragile inlet in the present-day RPC chamber that I mentioned In the first paragraph of this chapter. The most important goal of this project is improving the gas flow distribution in the gap. I will talk about these challenges separately in the coming paragraphs.

4.2.1 Making the gas injection in a 1mm gap

The main idea we had in mind while doing this project was making a gas injection with a polymer tube as you can see in Fig. 29. This concept helps us to have more than one gas injection slot and for each slot, we have small holes with different sizes to inject gas. Our main goal was to build this gas inject system first on a small scale, We used a 20cm x20 cm Bakelite gap because Bakelite material is available and transparent which helped us learn the gap. In this process, we learned what is the proper way to build the gap, what tools we need to build the gap, what steps we should take, and what product we use to clean the parts. It is important to clean the components of the gap before gluing it so we can get rid of any dust. After building the gap on a small scale, we go to the main goal which is a 30cm X30cm glass gap. Another challenge we faced was finding a 1mm polymer pipe with low impedance.

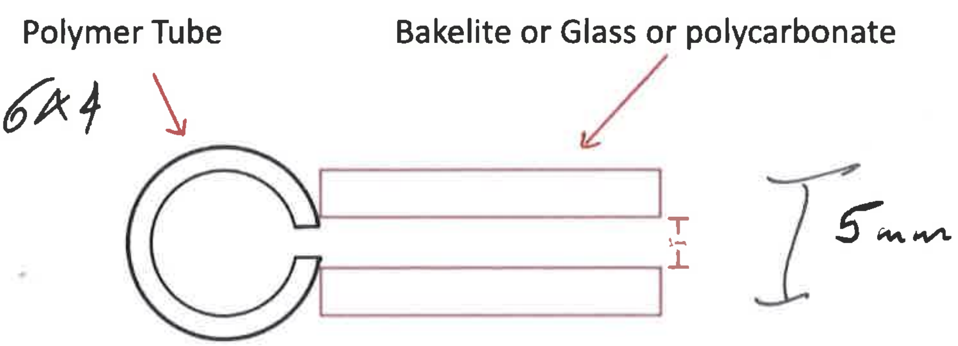

Figure 29: A side view of the polymer tube with a small opening to the 1mm gap.

In this project, we have tried three different ways of connecting the polymer pipe to the 1mm gap, and every idea has its advantages and disadvantages. The first way to install the

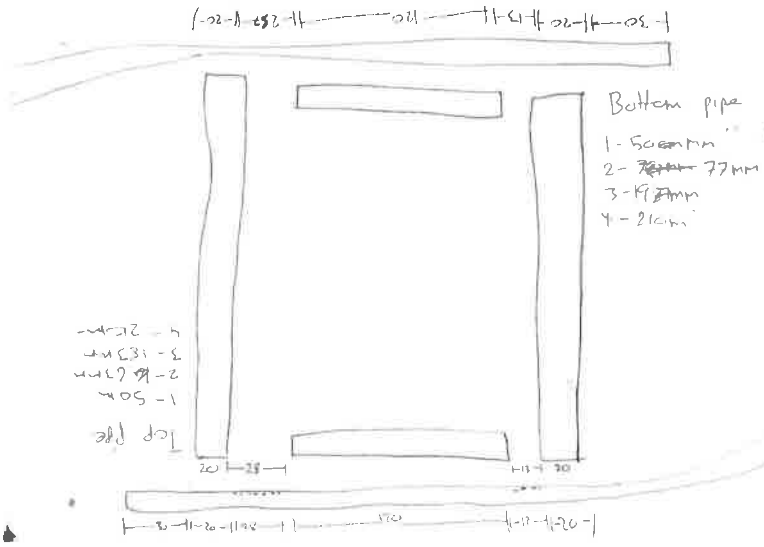

Figure 30: A conceptual top view of the measurement of the 20cm X20cm polycarbonate gap.

6mm polymer tube to the 1mm gap was in the 20cm X20cm polycarbonate gap. As shown in Fig.30 we have a conceptual diagram of the measurement that we wanted before building the gap, Because it was our first try at building a gap we had many offsets. After finishing our first trial in building a gap we got a 20cm X20cm polycarbonate gap with a thickness of 5.6mm and a gap thickness of 1.6mm and two inlets and outlets with a length of 28mm and 13mm. We have faced many issues that happened to the polycarbonate gap, making it hard to glue the tube to the gap. One of these issues was that the top polycarbonate plate was not aligned with the bottom plate. Therefore, when we came to gluing the tube, On one side of the gap we had extra space at the bottom of the tube, and on the other side we had extra space on the top of the tube as shown in Fig.31. And we had to fix this issue in some way. One idea was to add a small polycarbonate piece in the place where we have the inlet and outlet so we can seal the gap from gas leaks. Another idea is to have tape in the inlet and outlet to first seal the gap and second to hold the tube when glued to the gap. After we had solved these issues went to build the tube for the gas injection.

First, we got a polymer PU tube with an outer diameter of 6mm and an inner diameter of 4mm and cut it by using a cutter of 80cm length, This choice of tube was taken because this type of tube is used in the CMS and ATLAS experiment. By using the measurement in Fig.30 we have marked the inlet and outlet slot on the tube and then used a soldering sharp tip, We aim to have more or less 0.5mm holes, these small holes are for the gas to enter the gap, this method is chosen instead of drilling as having a poor result. We stabilized the polymer tube so we could align the small holes in a straight line, and then we used iron solder to make the small holes. Something that we have learned from this part of the project is to mark the inlet and outlet after making the gap. whereas don't make the measurement