Figure 33: The Polycarbonate gap connected to the PVC platform with the polymer tube by using clamps and screws.

used paper tape to stabilize the outer part of the polycarbonate pipe and tape to secure the inlet part of the polymer pipe and seal the inlet and outlet of the gas system. The technique in this process is to tape the bottom side of the gap and then tap the outer part of the polymer pipe to align the tube with the gap, then apply silicon adhesive under the tube and then above the tube as shown in Fig.34 and then tape the inlet and outlet of the gap.

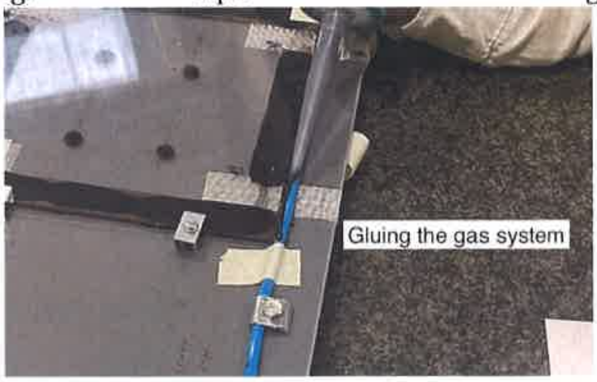

Figure 34: Applying the black silicon adhesive to the polymer pipe.

After this process, you wait for 24 hours for the silicon adhesive to dry. In Fig. 36 you can see the full setup connected to the ~~stander~~ standard gas mixture gas rack.

For each gap, we did a gas tightness test so we could check if there was any gas leak. We have used three ways of checking the gas tightness so we can be more accurate in the process. The first way to check if there is any leak was by using Bubbling soap. The product that was used in this experiment is 1000bulles. The concept of this experiment was to connect the gap

a product called "1000bulles"

knowing the amount of leaks. Therefore we use Other methods to measure the amount of leak.

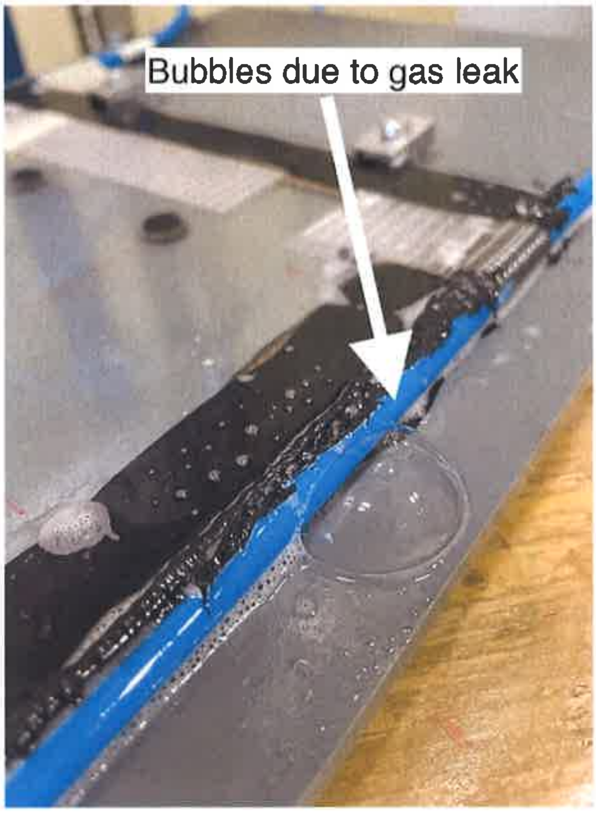

Figure 37: A bubble is created because of the gas leak from the tube/gap interface

To know the amount of leaking rate we use the RPC gas rack with standard RPC gas mixture. Basically, you connect the gap to the gas rack Fig. 36, flow standard mixture gas in the gap, and see at what flow rate you get gas flow through the gap. We have a gas rack that has a bubbler and a flow meter which measures the amount of gas flow inside the gap. As soon as you get bubbles through the bubbler, you know that at this flow rate, you have gas flow through the gap. For example, If you have a gap in the bubbles at 1 Litter per hour then that means that the leak rate of this gap is from 0.5 to 1 litter per hour. In our first gap, we had bubbles starting from 7 l/h which is not a bad flow rate. while doing this experiment, we drew a graph of the flow meter versus the pressure in millibar from the barometer and the pressure in millimeters from the pressure gauge to study how the gap acts as you can see in Fig. 43. We Connected the gap with an extra thin opaque pipe having 16cm on the return and 96cm on the supply as shown in Fig. 36.

A more precise way of measuring the gas leak rate is by using the dedicated gas R134a sniffer as shown in Fig. 39. You basically put the tip of the sniffer in the places where you have leaks, and you get the reading in part pre-million. This means that the number of of gas in

particles in ~~the volume of~~ the room. For this gap, we did not use this technique, because this was an idea that we developed later on in my stay at CERN.

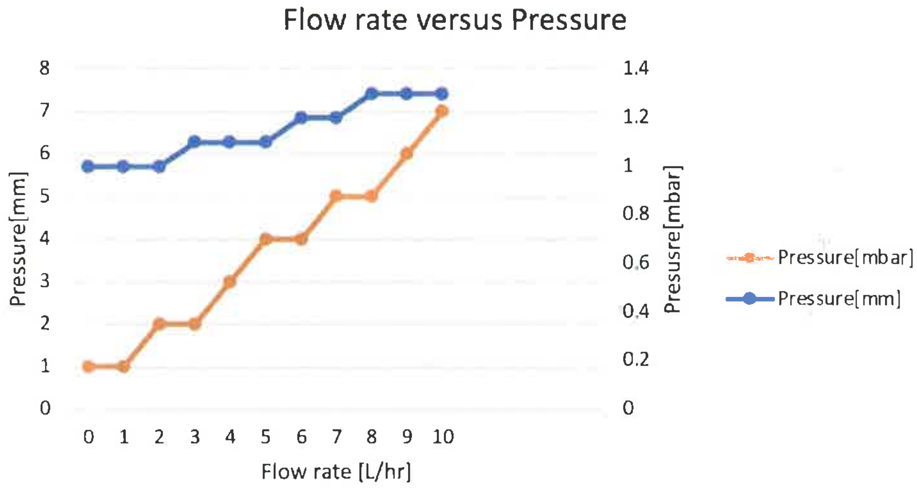

Figure 38: Flow rate versus the pressure in mbar and the pressure in mm.

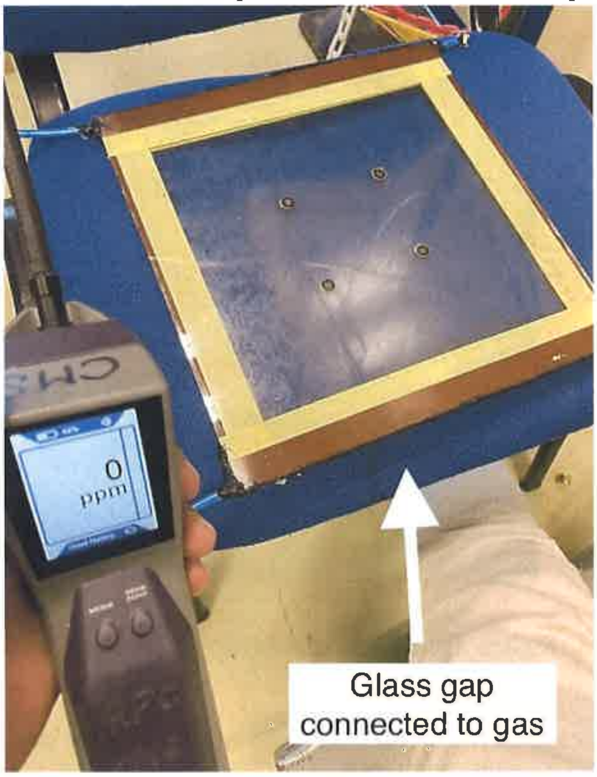

Figure 39: Dedicated gas R134a sniffer used on a 30cm X30cm gas gap.

After applying the three ways of testing the gas tightness for our first gap, by the results we got we have come to the conclusion that we need to improve the technique in building the gas system for the gap. We have successfully reached the goals that we had from the beginning, that is learning from the mistake of the first gap. We have come up with many ideas to improve the gas tightness of the gap. One of the ideas was to have holders and secure the outer part of the tube. One of the recommended ideas was to have a bigger tube that is cut on one side and then wrapped around the small tube and filler with silicone adhesive as shown in Fig 40. but this idea was challenging to apply because of the extra area we had inside the tube. Another idea that we apply is going to explain the second technique we used to build a gas system for the 1mm gap.

Figure 40: Large tube wrapped around 6mm tube.

The central concept of this idea was to have some outer piece that holds the tube on the gap and seals the gas from leaking. First, we prepared the tube as we did for the first gap. And we had the polymer piece cut to 20 cm to fit the side of the gap. Then we got some tape to stabilize the tube and the polymer piece when gluing them together with the gap. The process of this installation was first to have the tube aligned to the right length by using the marks on the tube, then applying silicone adhesive to the inner part of the plastic piece, and then installing the tube inside the plastic piece, and then applying it again on the tube silicone adhesive that is going to have contact with the gap. After that, install the plastic piece with the tube on the gap and then use tape to stabilize the gap After this process, we think that no we are going to have a gas-tight system but to just make things safer, we have applied more silicone adhesive to the parts, where we think that there can be a possibility of gas leaks.

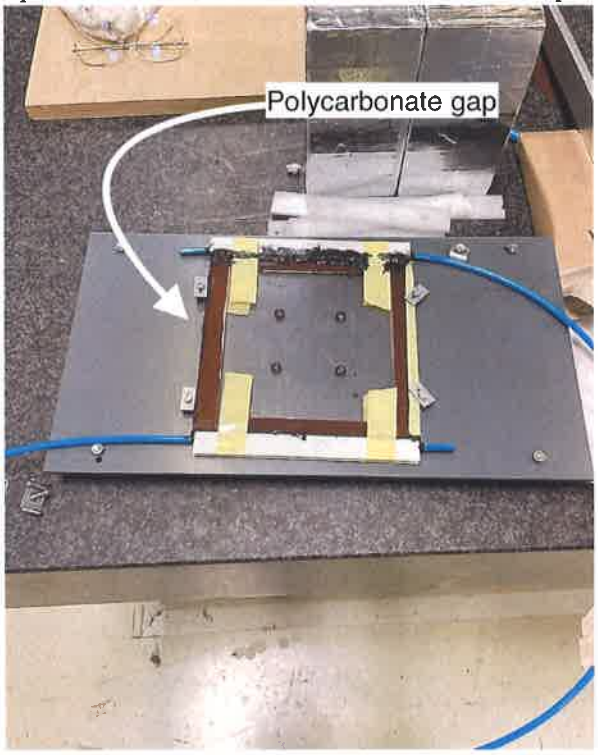

Figure 41: 20cmX 20cm Polycarbonate gap glued on the gas injection system.

After finishing building the gap system, it is important for the gap to go through a gas tightness test to check for any leaks. For this gap, we went through the three gas tightness tests. First started by using the gas rack after measuring the flow rate versus the pressure in millibars and millimeters we changed the next graph as you can see in Fig. 43. After that we went and tested the gap with the dedicated gas R134a sniffer. Fortunately, this technique of building the gas system for the 1 mm gap was the best out of the three ways.

The third way of building the gas system for a 1 mm gap was using two Bakelite strips with silicon adhesive to connect the blue tube to the 1 mm gap. This is the most complicated way of doing it from the three ways and it was the least efficient one. Compared to the second method which was the best method out of the three. The reason why this method was the least efficient out of the three because it was hard to build because you had to connect all the components together with a lot of tape before gluing them together. The steps of this method were first by taping the two Bakelite strips to the gap. What you want is to have half of the width of the strip glued on the gap and the other half extended outside the gap so you can connect the tube in between the two extended Bakelite strips. After taping the two big lights in the gap and having the polymer tube in between of them we added black adhesive on the outer part of the polymer tube.

Figure 42: 20cmX 20cm Polycarbonate gap connected to the gas supply rack.

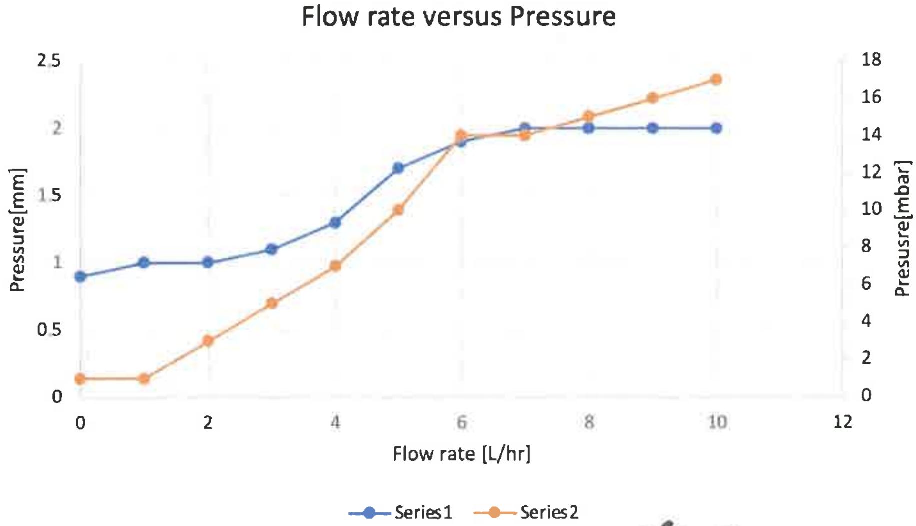

Figure 43: Measurements for the pressures with the chamber ~~on with extra thin opaque pipe having 9.7cm on the return and 87.4cm on the~~ supply

As regular, we went through three ways of testing the gas tightness of the gap. We have

Figure 44: Final stage of chamber assembly.

found that there are leaks. One major leak was coming from the tape part. We have solved this issue by removing the tape and adding epoxy glue in between the gap in the Bakelite.

One of the future plans for making a better gas system inlet is to make a 3-D printing of the gas injection system inlet. But in this case, we need a high-resolution 3-D printer.

5 The double 1mm gap chamber

After finishing building the gaps and having the resistive coat in the plates now come to building the rest of the Classical RPC chamber components as the readout strip and gas tube system. There were three main components in building a RPC chamber. One is the base for the chamber, which was made out of polymer material. The base had four stabilizers that were made out of polymer material and small Bakelite strips And some screws as you can see in Fig. 32.

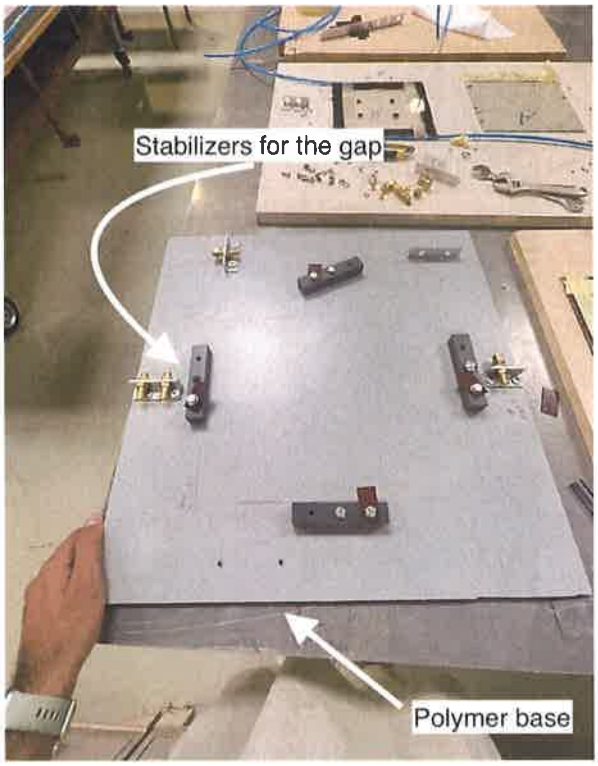

Figure 45: polymer base with the stabilization nodes clamps

Another important component is the readout strips. The little strips are made out of copper tape that is aligned in parallel on a Mylar 30 x 30 sheet. The copper was separated by 1.0mm mm and was placed on eight Mylar 26cm x 26cm square.

When coming and building the gap first we get a 60cm x 60cm polymer plate for the base and mark the place of the gap and and stabilizers and the outlet for the gas.

After marking everything down on the base we start placing all the components together. First place a 30cm x 30cm copper sheet and then place the first glass gap and then place the copper strips and then place a smaller mailer 30cm x 30cm sheet to insulate the two gaps and then place the second gap, at the end we place a 30cm x 30cm copper sheet to complete the Faraday cage. As you can see in the fig. 48, we have all the steps from the beginning to the end.

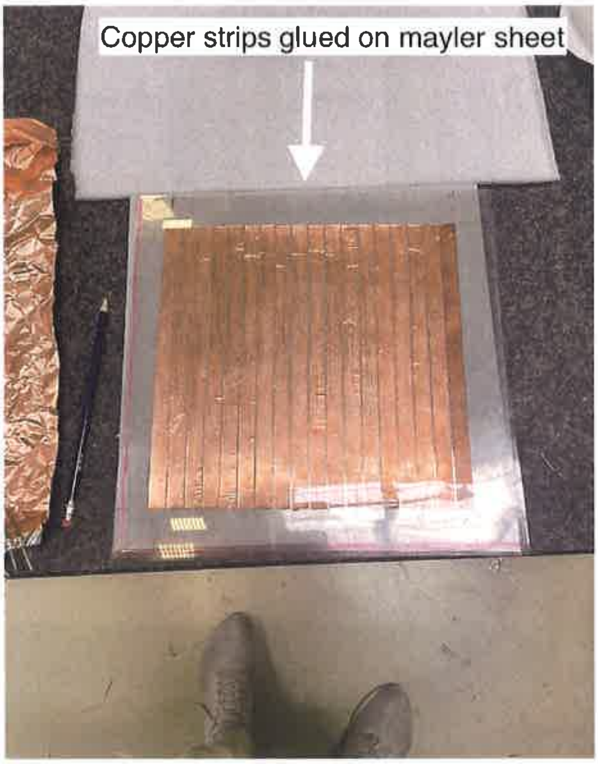

Figure 46: Mlyer sheet with 20mm copper strips.

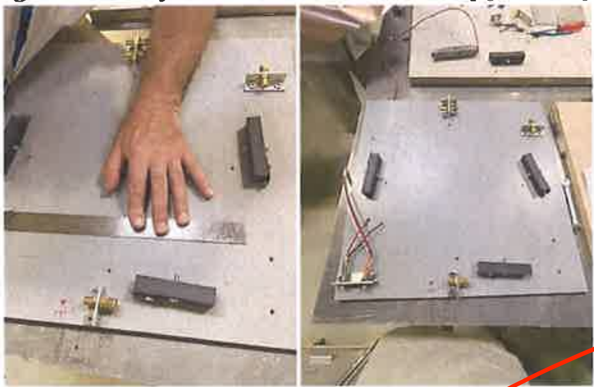

Figure 47: Progress in building the chamber

At the end of our project, we have a chamber that ~~is ready for testing~~. Because of my short time at CERN in 2023 summer, we couldn't do all the tests on the chamber. One of the future plans for this chamber is to have gas flow. we want to do a gas test and a current test and then collect some data gas flow measurement. We use the flow meter in the gas rack that is calibrated for Freon gas but it's not calibrated for other gases. Therefore we need to find the calibration factor to have a precise measurement of the gas flow so we can have the desired gas mixture flow in the gas and the gap. To achieve this calibration, we closely monitor all input and output parameters of the reaction to enhance reproducibility and reduce the occurrence of process rejections. However, the monitoring of the reaction depends on expensive analytical equipment, with costs exceeding $10,000, which is a significant factor hindering the broader adoption of continuous processes of gas mixing [1]. In the attempt to fix this issue in counting bubbles: precision process control of gas-liquid reactions in flow with an optical inline sensor research our colleagues got a solution where it can be achieved at high acquisition speed with low-cost equipment. A 10$ inline optical sensor can be used to control reaction conditions precisely by counting the bubble rate and instantaneously calibrating the gas flow.

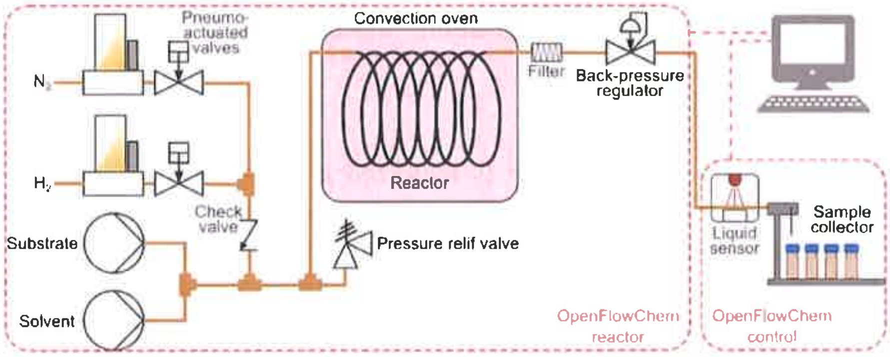

Figure 50: Scheme of the hydrogenation reactor with a feedback control and process monitoring with an optical sensor.

In my part of the experiment I did the same thing but in a different way. Instead if using an optical sensor to count the bubble I did it manually by capturing a video via my device and then counting the bubble in one minute for different gas flow rates. The main goal was to find the calibrate factor for different gasses by studying the bubble count in one minute and flow rate and finding the right calibration factor. I started by taking a one minute long video of gas Freon for flow rate of 2 L/h till 10 L/h. After conducting the experiment we can see from the graph that there slightly linear relationship.

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