The EEE MRPCs gas leak test procedure

The EEE MRPC leak rate is a fundamental parameter for a proper operation of the chambers and for avoiding a fast ageing process. The standard EEE mixture is CH_2FCF_3 / SF_6 (98/2). In case of leak a small contamination of air and water catalyses the production of HF by reacting with the SF_6 available in the mixture. The HF is extremely aggressive and fastens the ageing of the thin glasses separating the gas gaps of the MRPCs detector. A leak requires a higher gas flow is applied to the EEE telescopes, in order to minimize the air fraction, especially for the last chamber in the gas lines series, increasing the amount of gas needed for the telescopes operation as well as the pollution.
These are the main reasons why a measurement of the gas tightness for all the chambers of EEE detector is mandatory; actions will be taken subsequently in order to cure pathological chambers.

The gas leak test procedure

The measurement is performed by applying the pressure drop technique, therefore by injecting a known quantity of air and measuring the subsequent drop in pressure with the chamber isolated.
Even if the measurement is based on a simple principle, high accuracy in the measurement of pressure drop and temperature is needed to correctly size the leakage rate.

The tool set

The list of material needed for the measurement is the following:
- A differential manometer (accuracy better than 1 mbar)
- A plastic syringe (100 ml)
- Rilsan pipe 1 m (6-8 mm diameter)
- 2 fast gas connectors (same used for flushing the telescopes)
- A valve to open and close the air flow during the measurement procedure
- A thermometer (0.1 K)

The material is assembled in order to have two tools:

1. a pipe (0.5 m) interrupted by a valve and ending with the gas fast connector
2. A pipe (0.5 m) ending with the differential manometer

The two tools are shown in the pictures below.

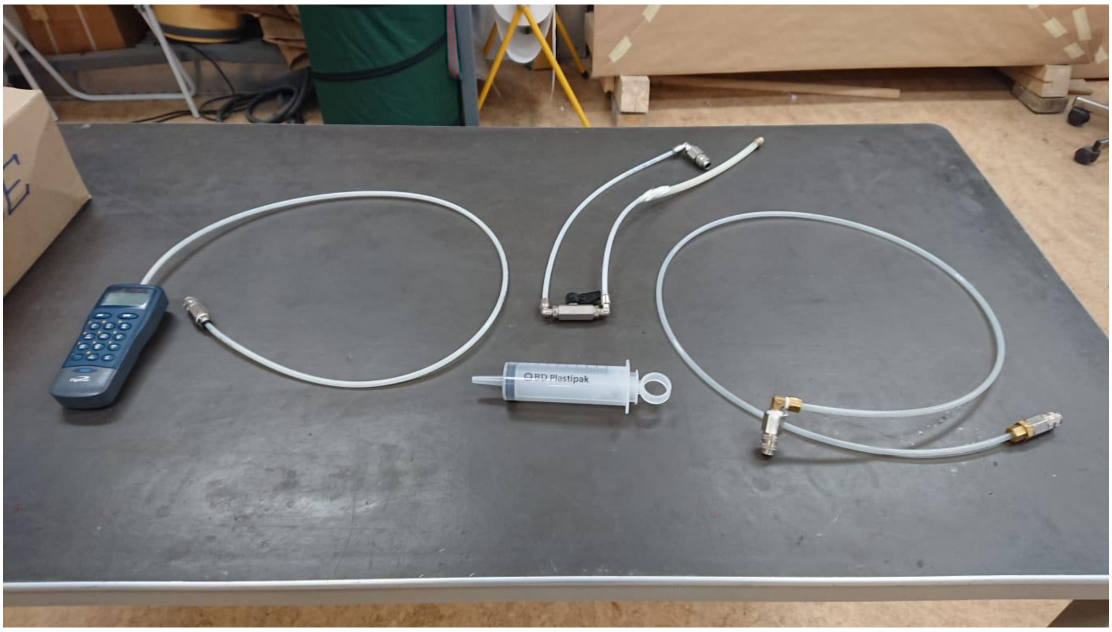


Fig. 1: left: manometer with pipe and fast gas connector, center: syringe and pipes with valve and fast connector, right: connection pipe between two chambers of the telescope (to be removed before the leak measurement)

Fig.2 and 3 : differenzial manometer and syringe

Measurement procedure

Part 1: calibration curve measurement

- Disconnect both sides of the chamber under test
- Plug on one side the manometer and switch it on
- Plug on the opposite side the the pipe equipped with the valve

Repeat the following steps until the overpressure you read on the manometer display is 1.5-2 mbar

1. Close the valve
2. Fill the syringe with 100 ml air
3. Plug the syringe into the free end of the pipe
4. Open the valve and inject the syringe content into the chamber
5. Immediately close the valve
6. Read the overpressure
7. Take note of both the air quantity injected and the overpressure measured
8. Repeat the steps from 1. to 7.

Part2: pressure drop measurement

Once the 1.5-2 mbar overpressure is reached, unplug the pipe with the valve and start a timer.
Wait 30 seconds and take the first overpressure measurement given by the differential manometer and take note of **time, overpressure** and **temperature** (we skip the first 30 seconds in order to avoid the effect of unplugging the pipe with the valve).
Each 5 minutes take note of time and overpressure values. Stop the procedure after 60 minutes (12 steps).

Notes on temperature measurement: the temperature variation strongly affects the measurement. A variation of 0.1 K during the measurement corresponds to a pressure variation of about 0.35 mbar, therefore a fictitious leak or gain of 6-7 ml for a EEE MRPC chamber. If the variation happens in example in 10 minutes, it will give a false leake/gain of about 36 ml/h; if the temperature variation is 1 K, the false leak/gain will appear to be 0.36 l/h!
The accuracy of the thermometer should be (at least) 0.1 K and the thermometer should be placed on top of the chamber.
In case the available manometer provides also the gas flow temperature with accuracy better than 0.1 K, this value is more accurate than the one given by the thermometer. If you are going to use the value provided by the manometer, please read carefully the instructions related to the corrections to be applied to the actual temperature with respect to the given one as a function of the gas

flow.

Data collection and analysis

A typical data set, with the calibration curve and the pressure drop measurement is shown in Fig.5, together with the subsequent steps for the leak rate extraction.

Calibration curve

The calibration curve gives the relation between the injected amount of air and the overpressure produced by the injection. In case of a rigid volume the expected relation is linear. This applies to chambers when they are in a pile (red curve in Fig.4, left plot), since the weight of chambers above the one under measurement increase its rigidity. In case the chamber is alone, the chassis is deforming and acting as a spring, therefore showing a typical second order polynomial curve.

Fitting the calibration curve with a second order polynomial (at a known temperature) will give us the right relation between overpressure and the remaining air inside the chamber volume, during the pressure drop measurement.

Drop Measurement

When the set of pressure values vs time has been collected (according to the Part 2 of the previous paragraph),

a. evaluate the remaining air volume (out of the injected volume) by simply applying the calibration curve.
b. correct the remaining air volume by the temperature variation. This can be done by applying the formula given in Fig. 4 right plot (simple derivation of the perfect gas law) or by simply applying the relation $P_0/T_0=P_1/T_1$ (again out of the perfect gas law), where the 0-indexed values are the ones given by the calibration curve (taken at temperature T_0) and the 1-indexed values are the actual pressure and temperature values during the drop measurement.

Leak Rate extraction

The corrected volume (referred to as Vcorr in Fig.5) is then plotted against the time. A good approximation of the expected curve is exponential, since the pressure (and volume) drop is proportional to the actual pressure at a given time (if P(T) is close to a linear trend):

$$dV = -k\,V\,dt$$
$$V(t)=V_0\exp(-kt)$$

The k parameter can be extracted by an exponential fit to the V(t) curve.
The leak rate has to be computed at the operational overpressure typical for the EEE telescopes, roughly 1 mbar. The value can be easily computed as follows, by evaluating the derivative of V(t) - actually the volume drop per unit time - at the time when the overpressure was 1 mbar.

$$dV/dt = -k\,V_0\exp(-kt')$$

where $t'|P=1$ mbar.
The t' time can be extracted by fitting the P(t) curve and imposing P=1 mbar.

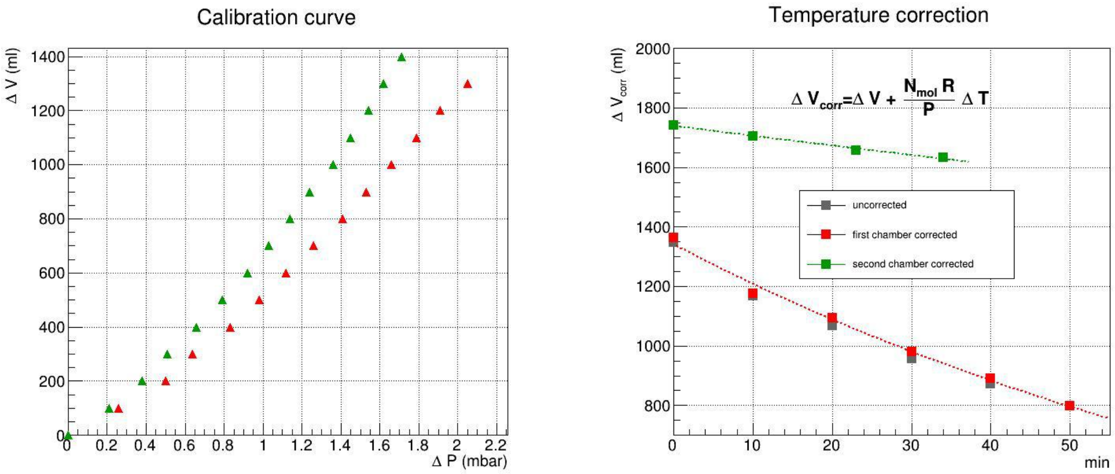
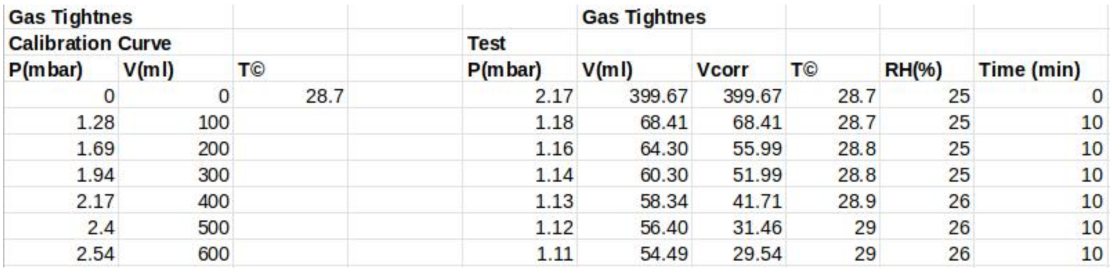


Fig.4: left: calibration curves for two different EEE MRPCs. Right: Air volume drop due to chambers leak. Temperature correction is applied as given in the plot.



Gas Tightnes					**Gas Tightnes**				
Calibration Curve				**Test**					
P(mbar)	**V(ml)**	**T©**		**P(mbar)**	**V(ml)**	**Vcorr**	**T©**	**RH(%)**	**Time (min)**
0	0	28.7		2.17	399.67	399.67	28.7	25	0
1.28	100			1.18	68.41	68.41	28.7	25	10
1.69	200			1.16	64.30	55.99	28.8	25	10
1.94	300			1.14	60.30	51.99	28.8	25	10
2.17	400			1.13	58.34	41.71	28.9	26	10
2.4	500			1.12	56.40	31.46	29	26	10
2.54	600			1.11	54.49	29.54	29	26	10

Fig.5: a typical data set. First two columns: calibration curve. P(mbar): pressure measured at the different time with the chamber isolated. V(ml) remaining air volume given by the second order polynomials for the actually measured pressure value. Vcorr: temperature corrected volume (according to formula in Fig. 4 right plot). T: temperature during the measurement. RH(%): relative humidity (not essential). Time: time span between two subsequent

measurement.

Acceptance limits

A chamber is accepted if the leak rate at 1 mbar is better than 0,1 l/h