An effective method for measuring the stiffness of a sealed vessel that can be applied to RPC gas volumes

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Abstract

A known volume of air is injected into or aspirated from a sealed vessel. In the ideal gas approximation, the corresponding vessel deformation is measurable. The linear correlation between pressure and deformation in the measurements carried out demonstrates the vessel elastic response. Measurements of several RPC gas volumes are reported. Different expansion and compression slopes of pressure vs volume plots, highlight a structure problem, for example unglued spacers. Defective stiffness values of the electrode materials are also highlighted by anomalous slope values.

Test Setup

System parameter

- V_{C0} *Gas Gap Volume @P_{atm}*
- V_{S0} *Syringe Start Volume*
- d_0 *Gas Volume gap distance @P_{atm}*
- P *Chamber Pressure with respect to the P_{atm}*
- V_C *Gas Gap Volume @P*
- V_S *Syringe final Volume*
- $V_{injected} = V_{S0} - V_s$
- $\Delta V = V_C - V_{C0}$ *Gas volume expansion*
- C_0 *Gas Volume capacitance @P_{atm}*
- C *Gas Volume capacitance @P*
- **$\Delta d = d - d_0$ *Gas volume average deformation***

The Test is very simple and can be performed with a digital manometer and a graduated syringe. The syringe is used to compress or expand a known volume of gas in the chamber, the differential digital manometer is used to measure the resulting increase or decrease of the chamber's internal pressure with respect to the atmosphere. Since this is an adiabatic process, to measure the pressure it is necessary to wait since the gas inside the chambers is thermalized. Experimentally after 30-60 seconds, the pressure value is already stable at the level of the instrument sensitivity of 0.01 mb. For this reason, the measure will be possible only if the gas volume is leak proof tight. The Multimeter has been used to measure the Gap capacitance at different internal pressure values obtaining a different method to estimate the Gas Volume stiffness.

In the approximation of an isothermal process for an ideal gas

$$P_{atm}(V_{C0}+V_{S0}) = (P_{atm}+P)(V_C+V_S)$$

$$V_C = \frac{P_{atm}(V_{C0}+V_{S0})}{(P_{atm}+P)} - V_S \qquad \Delta V = V_C - V_{C0} \qquad \Delta d = \frac{\Delta V}{S}$$

The obtained estimated sensitivity on deformation measurement is about 0.5 um for a single measurement. To validate the method the stiffness of a stainless-steel cylindrical Vessel has been measured and as expected, no deformation has been detected.

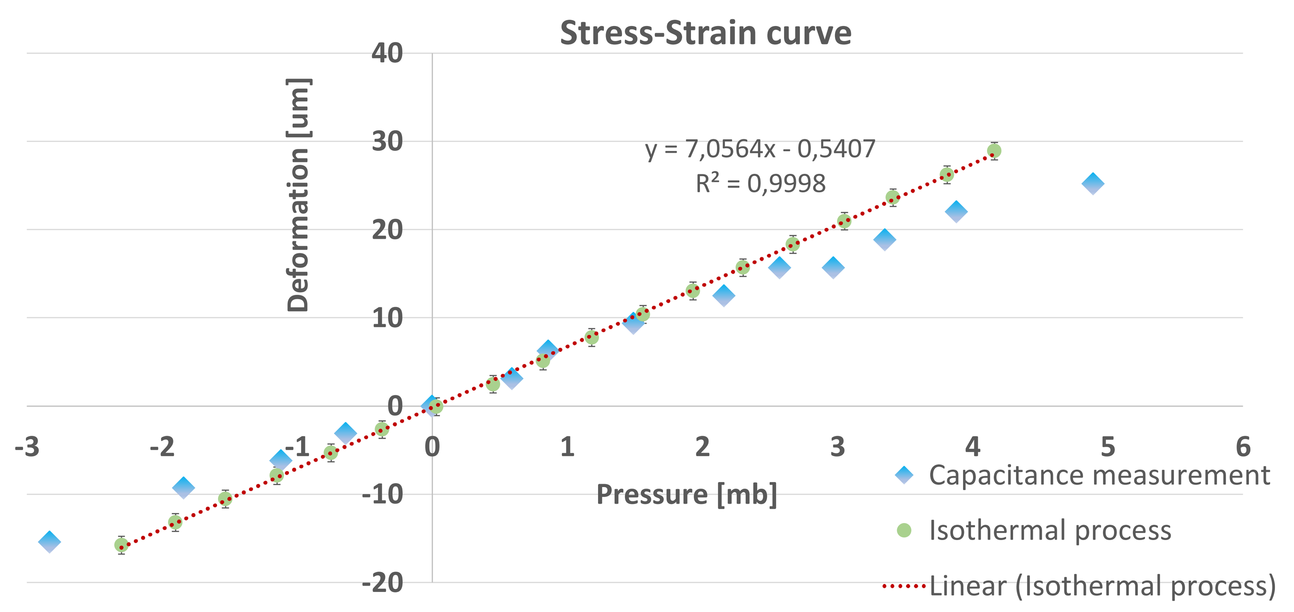
Capacitance measurement versus measured pressure

$$C = \varepsilon_0 \frac{S}{(d_0+\Delta d)} \qquad \Delta d = \frac{C_0 d_0}{C} - d_0$$

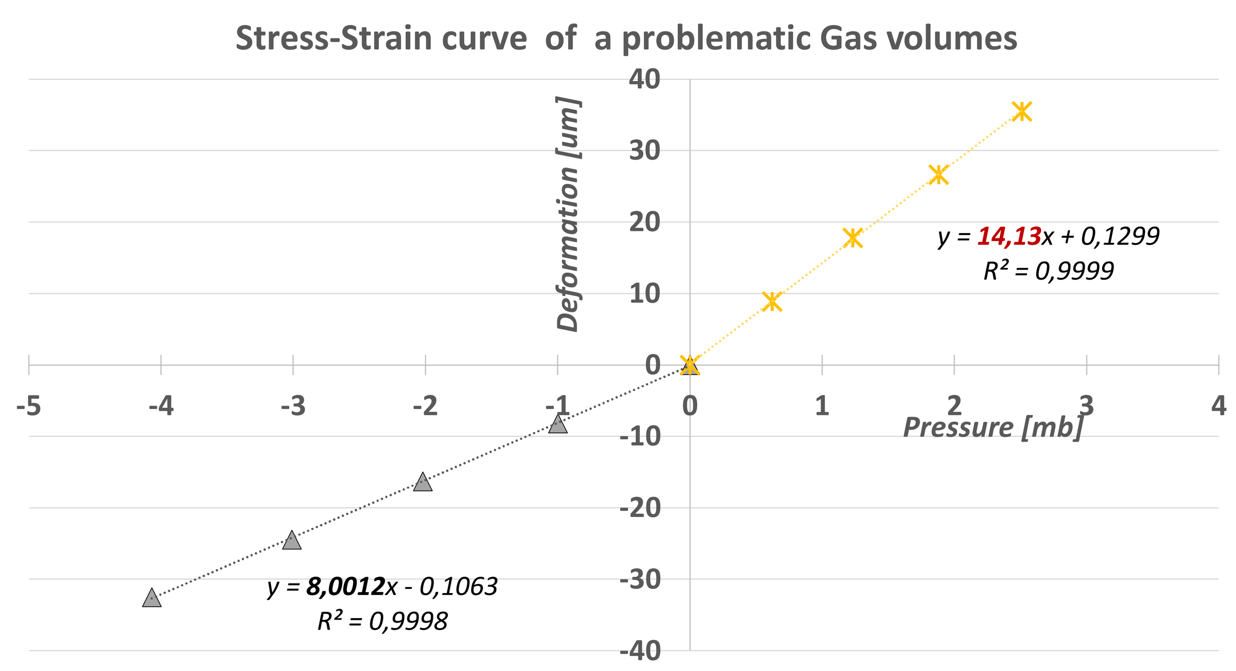
Valid only for small deformation : $< d > \neq < \frac{1}{d} >^{-1}$

n.b. due to the nature of RPCs resistive electrodes a Capacitance Meter could fail to measure accurately the Gas Gap Capacitance.

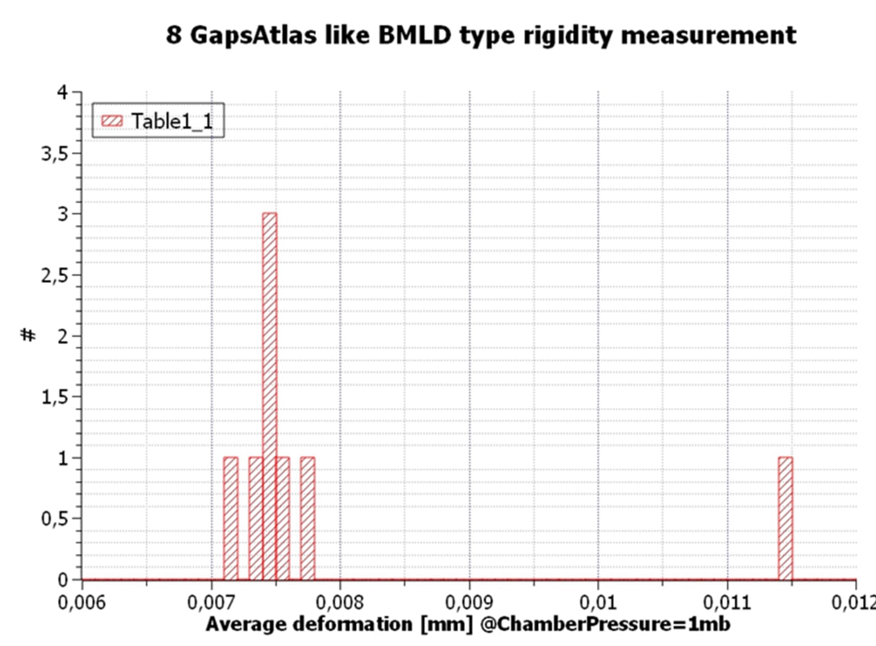
First measurement: Gas volumes Atlas like S= 14280 cm^2, Vol= 2958.4 cc, Gas gap size=2 mm, Cgas=6.32 nF



A linear relation between pressure and deformation (Hook low) has been obtained with both methods. The slope of the curve gives the deformation per mb of Chamber pressure

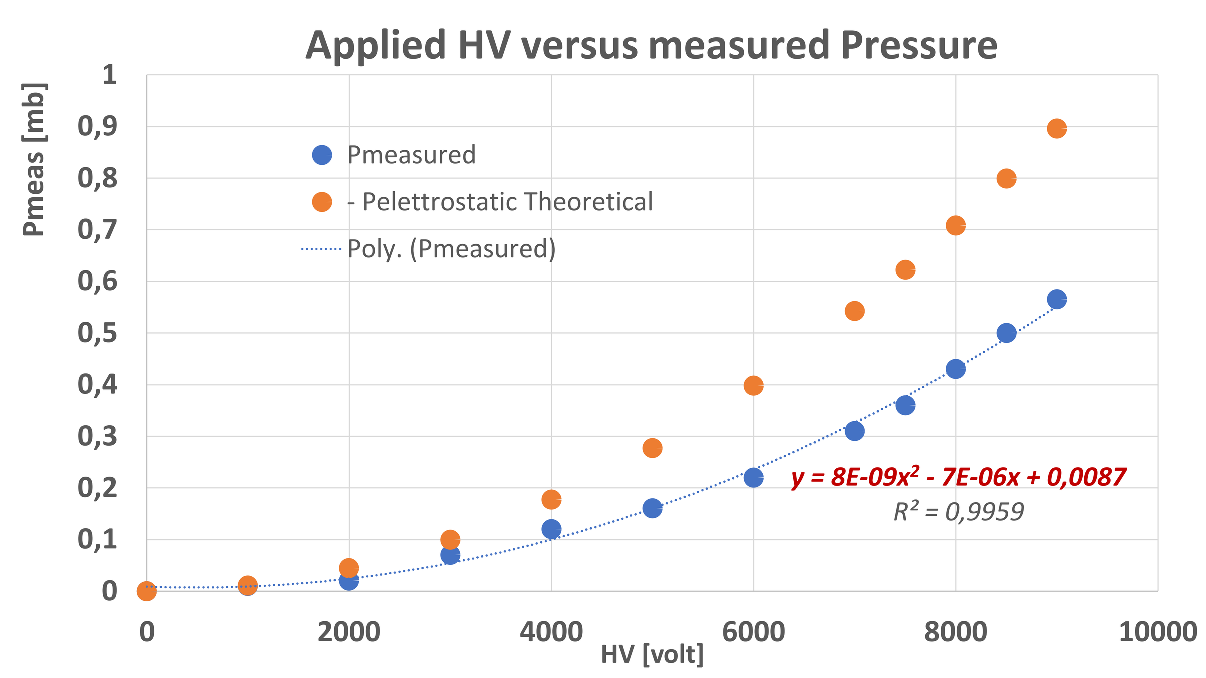


A defective Gas Volume with unglued spacers shows two different slopes for positive and negative Chamber pressure



Measurements distribution of 8 equal Gas Gap. The bin on the right is a defective Gas Volume.

Chamber Pressure vs applied High Voltage

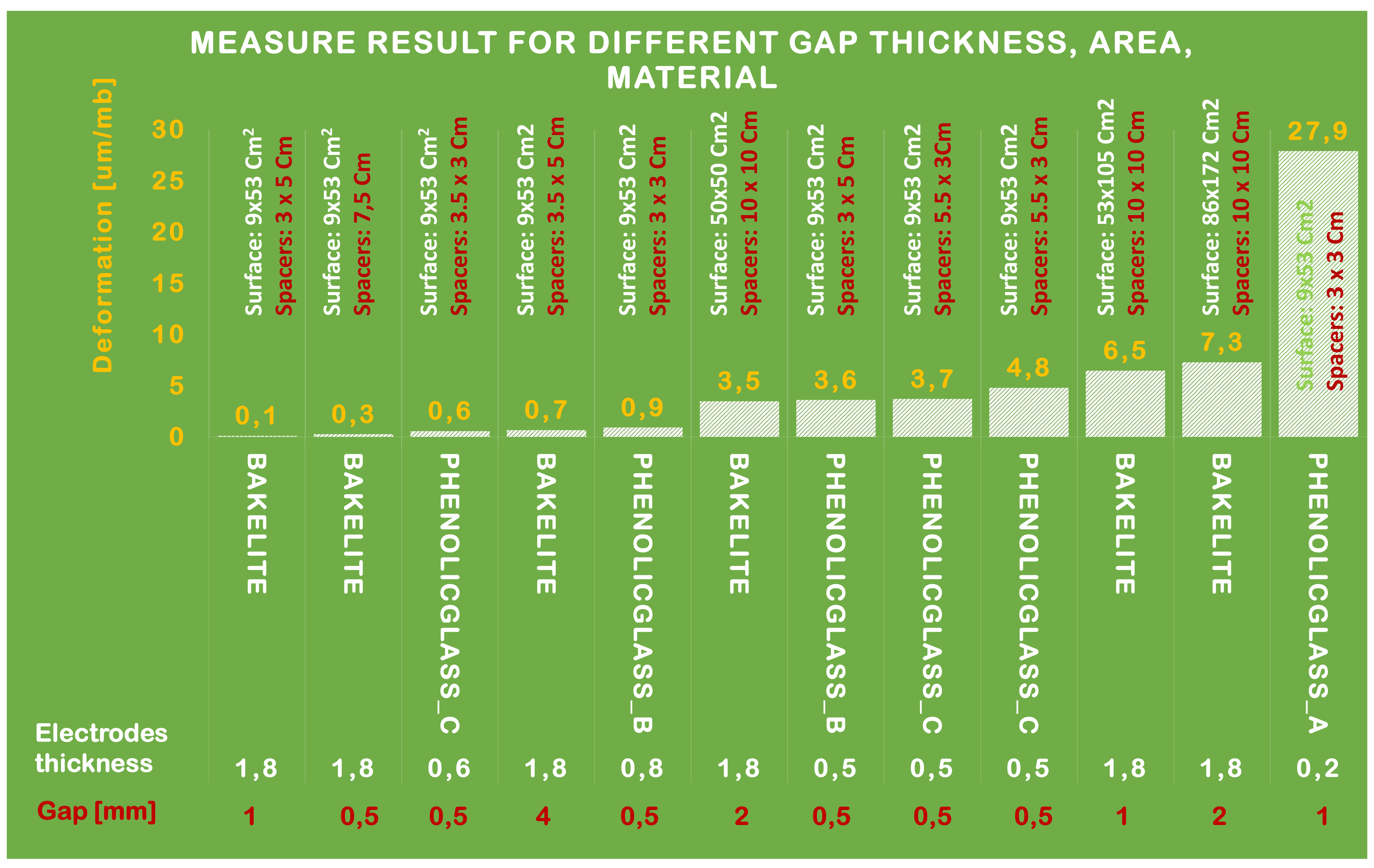


Applying an electrostatic field on a sealed Gas Volume a resulting force is experienced by the electrode plates. The Chamber Pressure is measured as a function of the applied Gas Gap Voltage.

The resulting electrostatic pressure is $P = \frac{1}{2} C \frac{(HV)^2}{d} \frac{1}{S}$;

Since the chamber is not rigid, the electrostatic force squeezes the RPC plates and the internal pressure rise. The experimental measured points are well fitted by a quadratic relation.

Measure result for different gas gap thickness, area, material



Non dimensional coefficient

The method could be generalized to different volumes shape considering the following parameter obtained by injecting in a known volume Vessel a fixed quantity of gas and measuring the resulting pressure.

$$\rho(isot) = 1 - \frac{\Delta V}{v} = \frac{V_0}{v}\frac{\Delta p}{p_0}$$

The defined parameter **ρ will range from 0 (soap ball) to 1 (perfect stiffness)**

Conclusion

The proposed method for deformation measurement could be used both as Quality Control in large Gas Volumes production and for single gap functionality control. Comparing two pressure measurements, after injecting or sucking the same quantity of gas into the RPC, can discriminate the failure of glued spacers. Moreover, the proposed method could be effectively used as prototype test validation for new materials, electrodes thickness and stiffness, and spacers distribution.