Q7: The filling pressure of equipment with natural-origin gases is often above 1 MPa. Is there any experience or an estimate on the long-term leakage or other lifetime limiting mechanisms, including mechanical damage, deformation of internal parts, e.g., vacuum interrupters at 0 MPa?

For medium voltage switchgear filled with air at 0.25 MPa abs, we need to take into consideration 3 aspects:

- Tightness of tank,
- mechanicals withstand of tank
- operating in case of abnormal leakage down to atmospheric pressure (0 MPa rel).

Regarding "normal leakage" of gas during life of equipment, there are 2 physical phenomena:

- Permeation through gaskets,

$$V = \frac{A \times d \times \Delta P}{t} \times Pe$$

With:

V: volume of air permeating through gasket
t: thickness of gasket
A: area
d: duration
ΔP*:* partial pressure difference of the considered gas between inside and outside of tank
(Pe): permeability coefficient of material

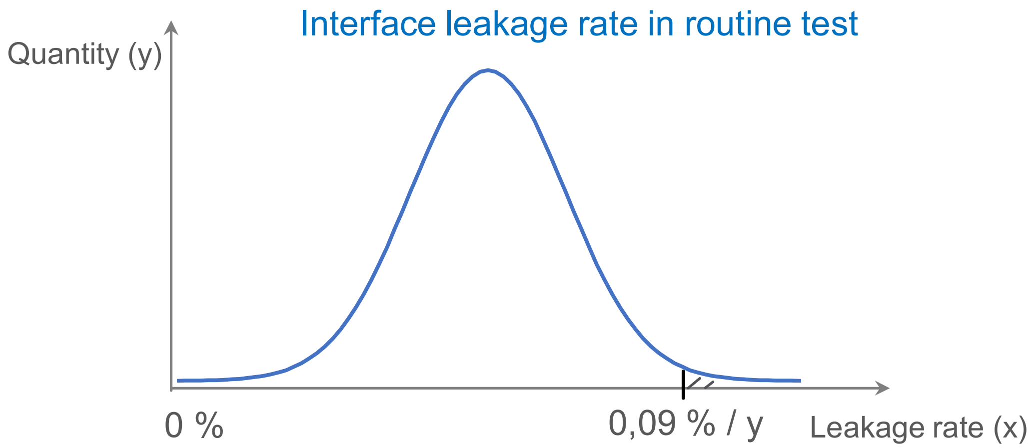
- Leakage at interface

$$Q_{l,air} = \frac{{P_{air,in}}^2 - {P_{atm}}^2}{{P_{He\ test,in}}^2 - {P_{He\ test,out}}^2} \times \frac{\eta_{He}}{\eta_{air}} \times Q_{l,He}$$

With :

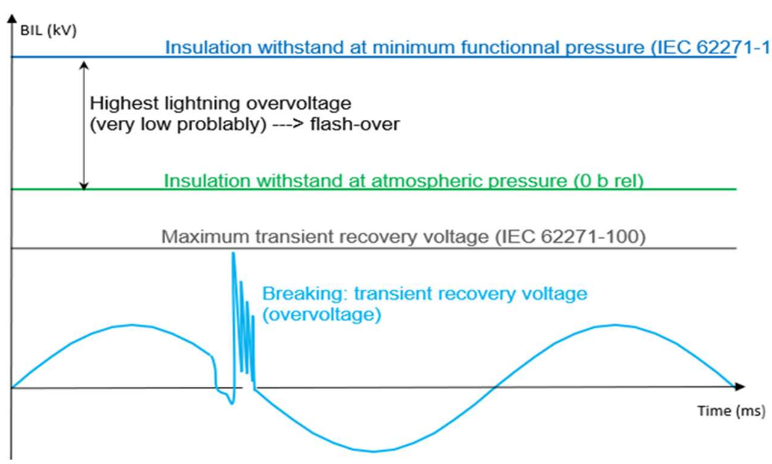
Q: leakage rate
η: dynamic viscosity
P: pressure inside or outside the tank

Suitable gasket material (Chlorobutyle) enables very low level of permeation: 0.004%/year at 20°C. Leakage at interfaces are measured as routine test with He in manufacturing plant and air leakage is determined with Poiseuille's equation (here above). Careful design of switchgear enables to ensure leakage at interface < 0.09%/year at 20°C. Total leakage rate <0.1%/year at 20°C is then insured and expecting life is over 40 years.



Regarding mechanical withstand of tank, the use of well-known austenitic stainless steel is recommended. The return of experience on this type of steel is huge (more than 1 800 000 tanks only for 1 range of GIS of Schneider-Electric).
GIS tanks are type tested up to pressure relief membrane opening without any rupture (according to IEC 62271-200) and switchboard are successful tested with internal arc fault. It is then useful to remind that tank does not burst in case of internal arc fault …
Fatigue tests of 20 000 pressure cycles representing more than the service life over 40 years are performed to validate the design of the tank.
Finally, individual routine pressure test (+30 % of design pressure) and tightness tests performed on all products in manufacturing line ensure the quality.
To sum-up on the mechanical withstand of the medium voltage tanks, we can say that the use of a proven technology, a good design and relevant tests ensure expecting life over 40 years and protection of people in case of internal arc fault.

In an unlikely event of air leakage down to atmospheric pressure (0 bar rel), switchgear can still be operated until leakage reparation or switchgear replacement. Indeed, the current breaking capacity is still maintained thanks to vacuum interruption and the insulation voltage withstand at 0 bar relative is higher than the maximum overvoltage during the breaking (maximum transient recovery voltage of breaking according to IEC 62271-100).



Moreover, there is no partial discharge at the rated voltage. Therefore, the insulation level at 0 bar allows to operate the switchboard under normal conditions (without highest lightning overvoltage) and the service continuity can be maintained until appropriated action to recover normal pressure.
We can notice that with SF6 GIS or other F-gas, in case of leakage down to atmospheric pressure, air is entering inside the tank and mixture ratio of SF6/F-gas and air is not known. There could be a complete loss of SF6/F-gas and then insulation withstand and breaking capacity are strongly reduced with risk of internal arc at service voltage. That is why it is recommended to not operate switchgear filled with SF6 in case of leakage down to atmospheric pressure.