Recuperation systems for fluorinated gases at the CERN LHC Experiments

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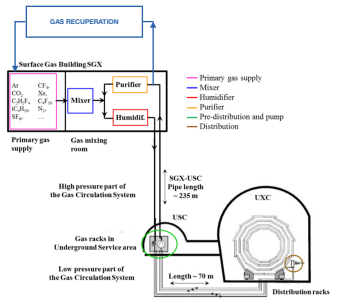
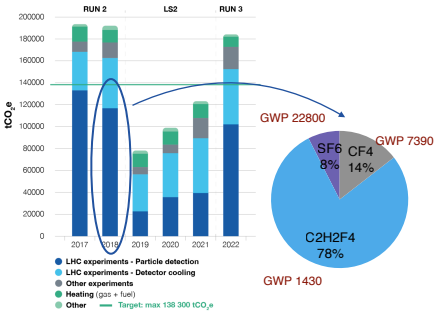
CERN Greenhouse gas emissions in particle detectors

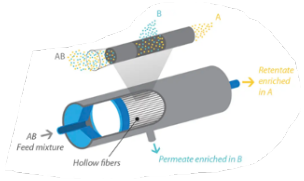
- The LHC experiments have different gaseous detectors that use a wide range of gas mixtures
- Some of these gaseous detectors employ **fluorinated gases** (F-gases) which have a high global warming potential (GWP)
  - $C_2H_2F_4$, SF_6, CF_4, C_4F_{10}
  - These gases are because they guarantee optimal detector performance and long term operation
- **Recirculation systems** are always employed in presence of GHGs
  - Not always possible to recirculate 100% of the gas mixture
- **Gas Recuperation** plants are added to recirculation system when it is not possible to recirculate 100%
  - GHG is extracted, stored and re-used





Gas separation techniques

Membrane separation



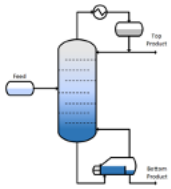
- **Difference** in **thermodynamic activities** existing across the membrane and **interacting forces** working between **membrane material** and permeating **molecules**
- Separation process driven by several factors
  - Permeability, Solubility, Diffusivity

Pressure and thermal swing adsorption

Crystalline metal aluminosilicates having a three-dimensional interconnecting network of silica and alumina tetrahedra

- Separation of gases according to the species **molecular characteristics** and affinity with an **absorbent material** (Molecular Sieve)
- **PSA**: the target gas absorbed in the MS is extracted by vacuum regeneration of the material
- **TSA**: the target gas absorbed in the MS is extracted by heating the material

Distillation

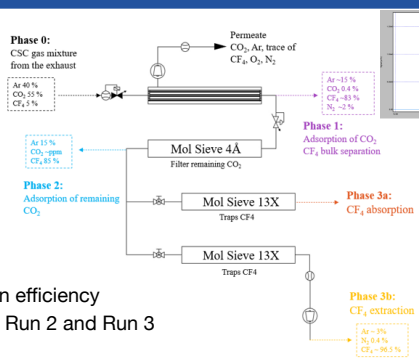


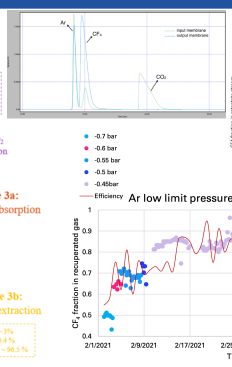
- Purification method to separate 2 or more compounds based on **differences in boiling points** or **volatility**
- Simple distillation
- **Fractional** distillation
  - Subsequent vaporization-condensation event
- Difficult in case of **azeotropic** gas mixture

CF_4 Recuperation system

The CMS Cathode Strip Chamber (CSC) case

- CMS CSC gas mixture: 50% CO_2, 40% Ar, 10% CF_4
- 90 m³ gas volume, 90% recirculation fraction, ~800 l/h at the exhaust
- Recuperation of CF_4 with warm separation
  - Membrane separation and PSA
  - 3 phases needed and several parameters affect recuperation efficiency
  - Use of membranes to remove the majority of CO_2
  - Use of MS to remove CO_2 and trap CF_4
- Several parameters affect gas quality and recuperation efficiency
- CSC detectors operated with recuperated CF_4 in LHC Run 2 and Run 3
- Recuperation efficiency: 60-70%

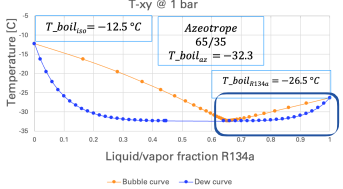




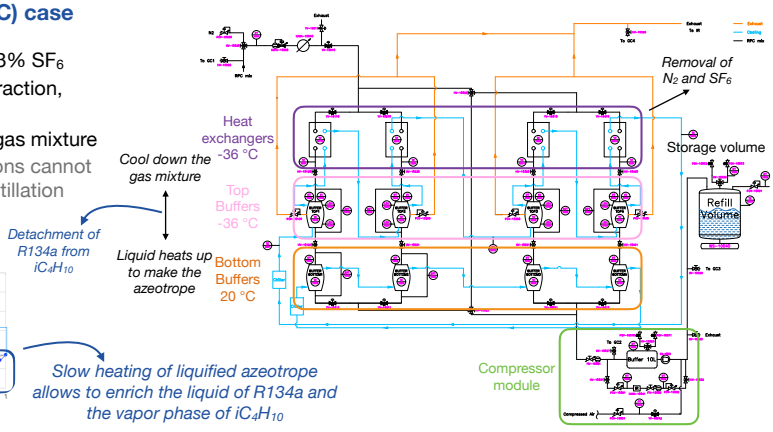
$C_2H_2F_4$ Recuperation system

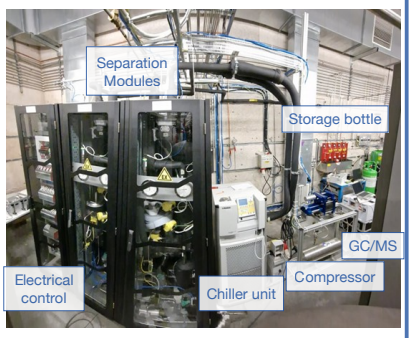
The Resistive Plate Chamber (RPC) case

- RPC gas mixture: ~95% $C_2H_2F_4$ (R134a), ~5% iC_4H_{10}, 0.3% SF_6
- 15 m³ gas volume, 90% recirculation fraction, ~600 l/h at the exhaust
- R134a and iC_4H_{10} form an azeotropic gas mixture
  - A mixture of liquids whose proportions cannot be altered or changed by simple distillation
- Distillation process
- Recuperation efficiency: 80%



Slow heating of liquified azeotrope allows to enrich the liquid of R134a and the vapor phase of iC_4H_{10}





Conclusions

Recirculation systems are fundamental to reduce as much as possible GHG emissions in particle detectors when high GWP gases are used. Sometimes is necessary to add gas recuperation systems, that allow to further reduce the emissions by extracting the GHG from the exhaust gas mixture and to re-use it. Gas recuperation systems for particle detectors are custom-made and use different separation techniques depending on the gas mixture. At CERN several recuperation systems have been developed in the last years using different techniques. They provide very good efficiency and they allow to recuperate and re-use greenhouse gases lowering emissions, operational costs and mitigating issues in case of shortage for the operation of the LHC experiments.