

validation of the C_2F_6 gas-radiator system

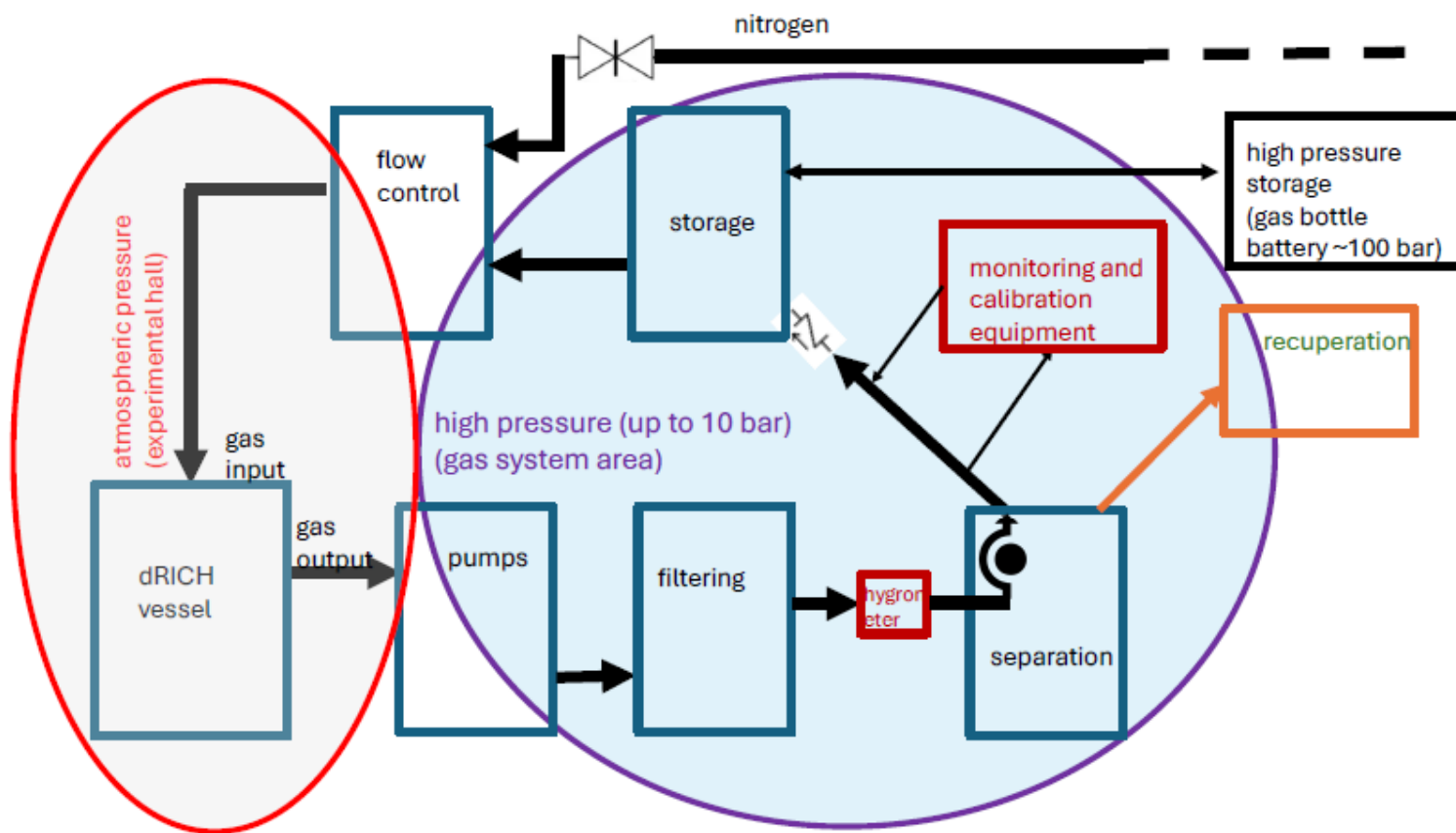


ePIC TIC Meeting

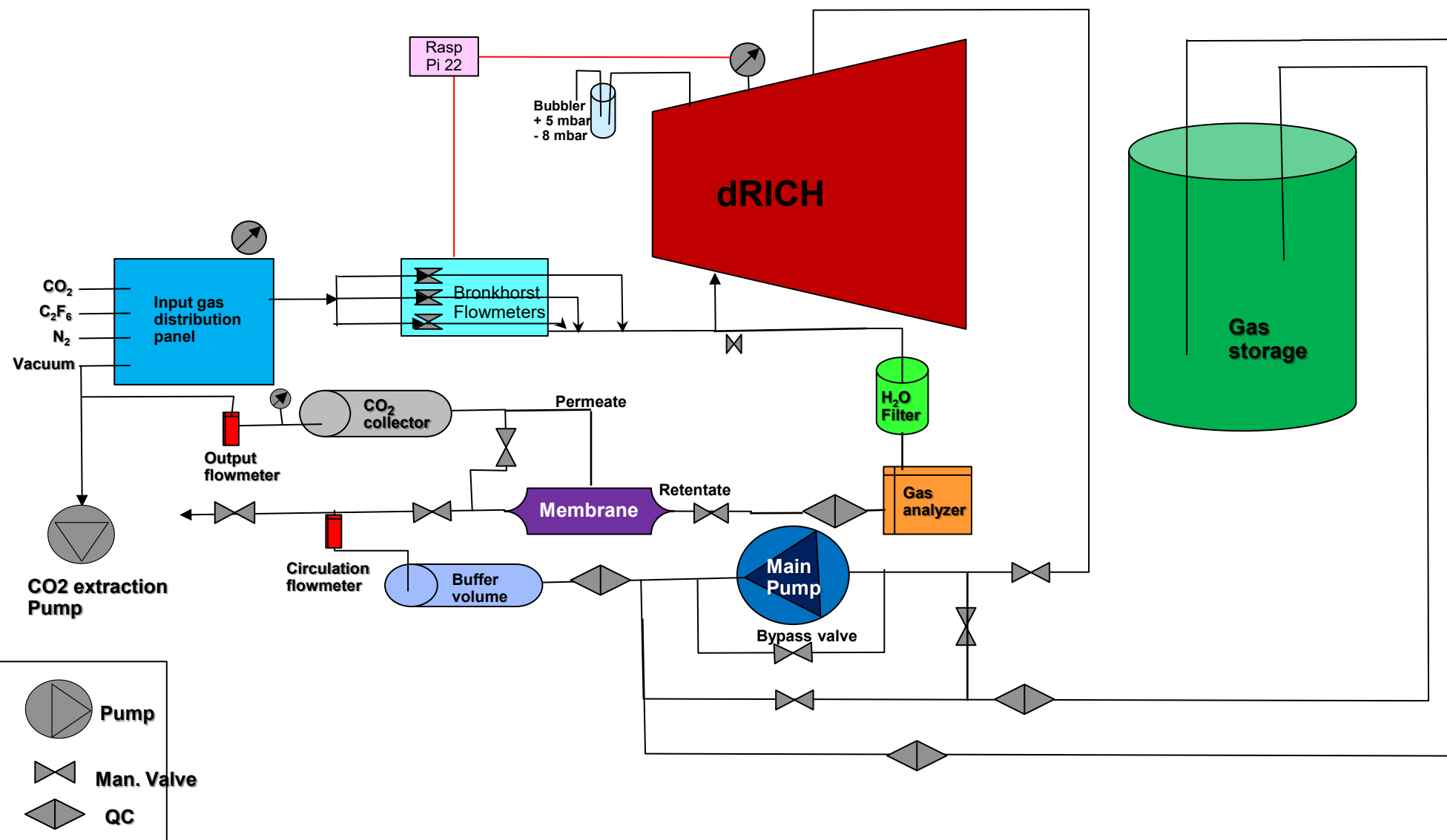
preliminary result of the dRICH testbeam

October 12th, 2026

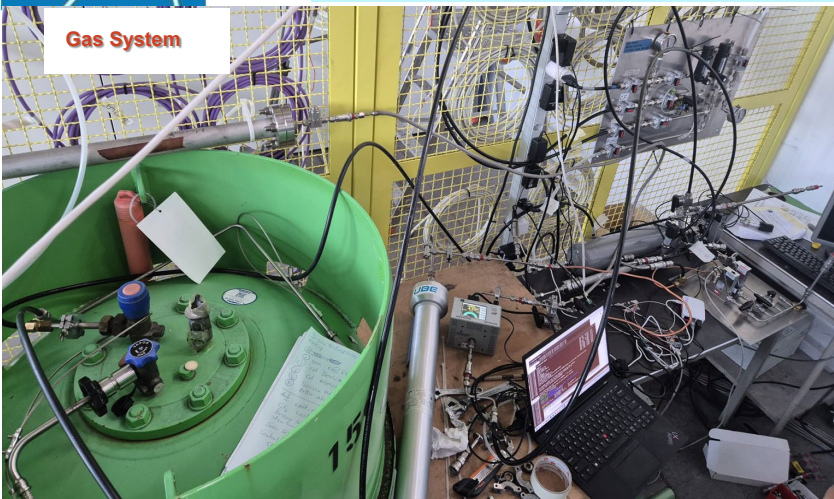
Fulvio Tassarotto, Silvia Dalla Torre, Chandradoy Chatterjee



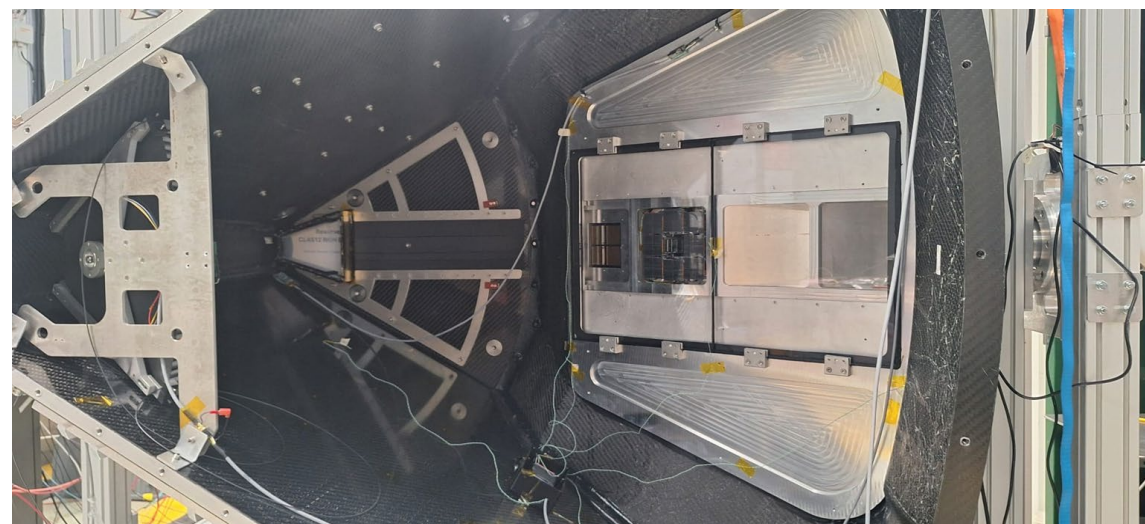
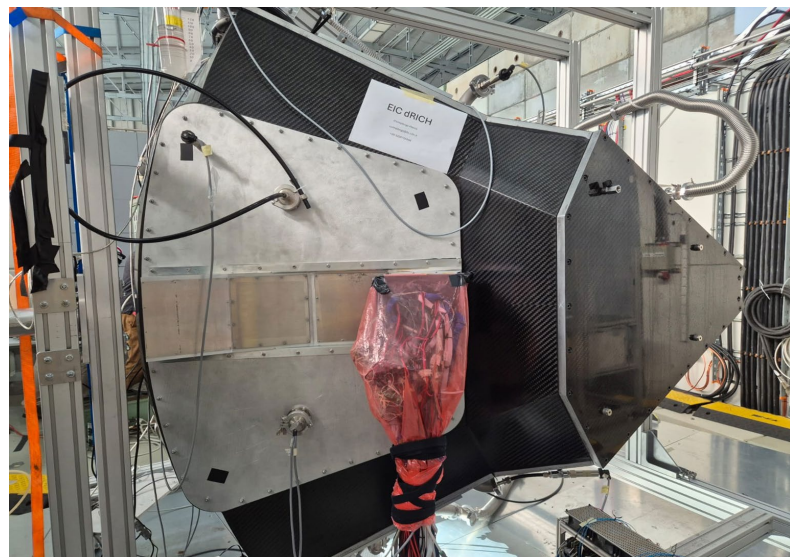
The design and prototyping of the gas system is ongoing in collaboration with the CERN Gas group

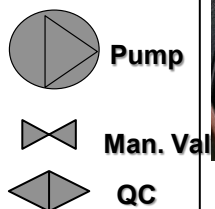
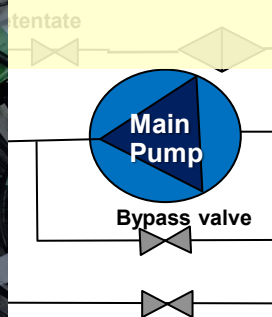
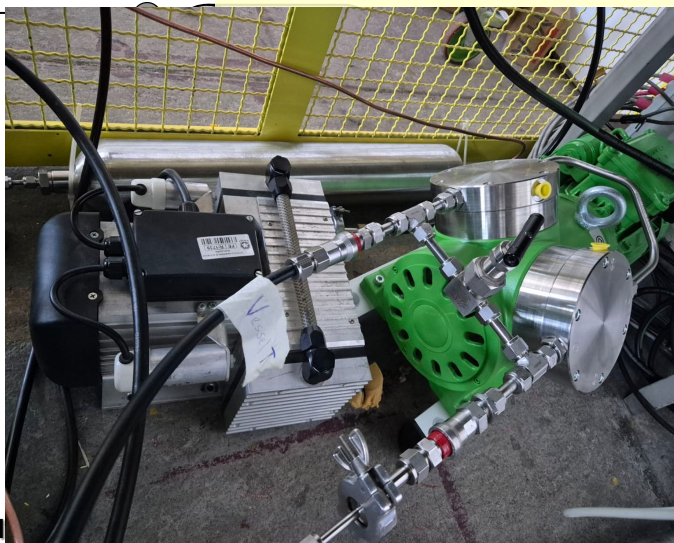
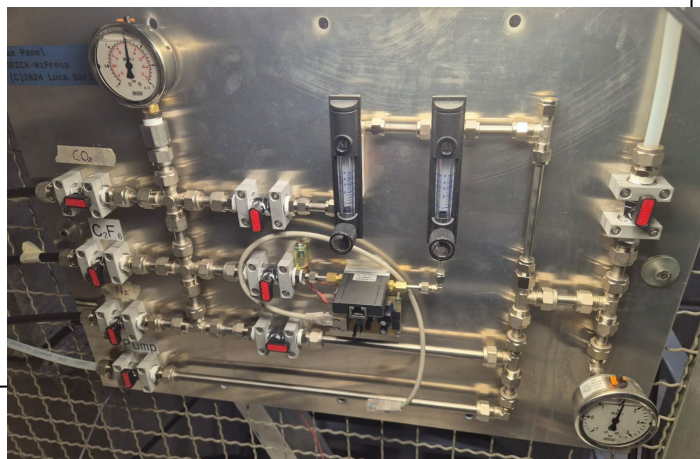
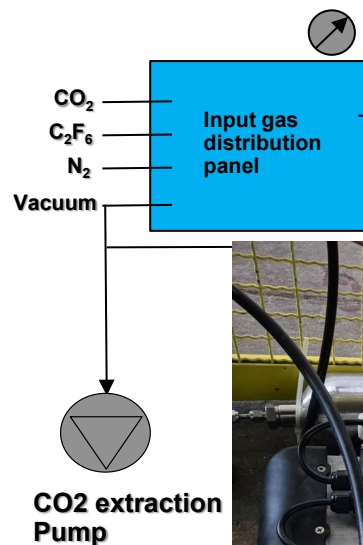


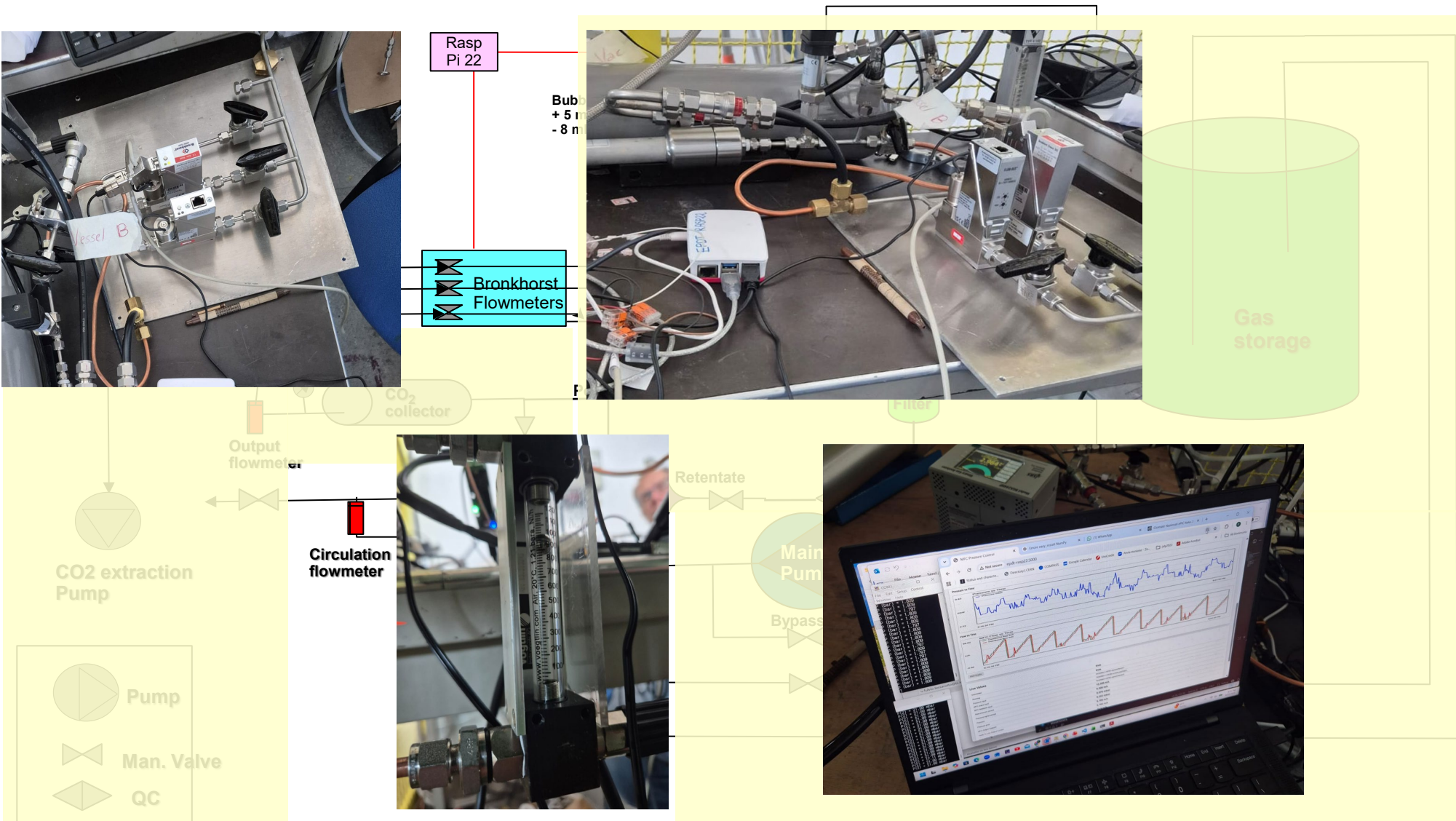
Vessel and gas system overview

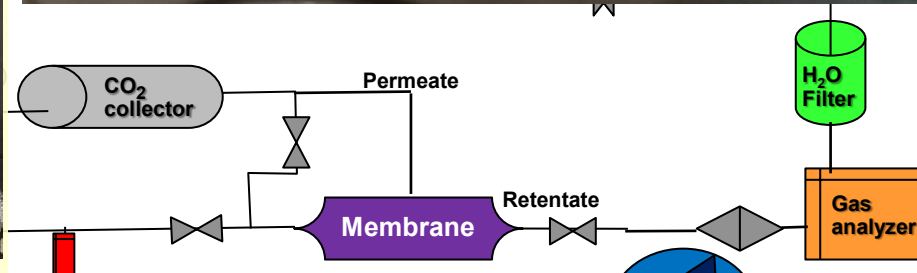


Final CO₂ Contamination in C₂F₆ for a delta-P ~ 4 bar



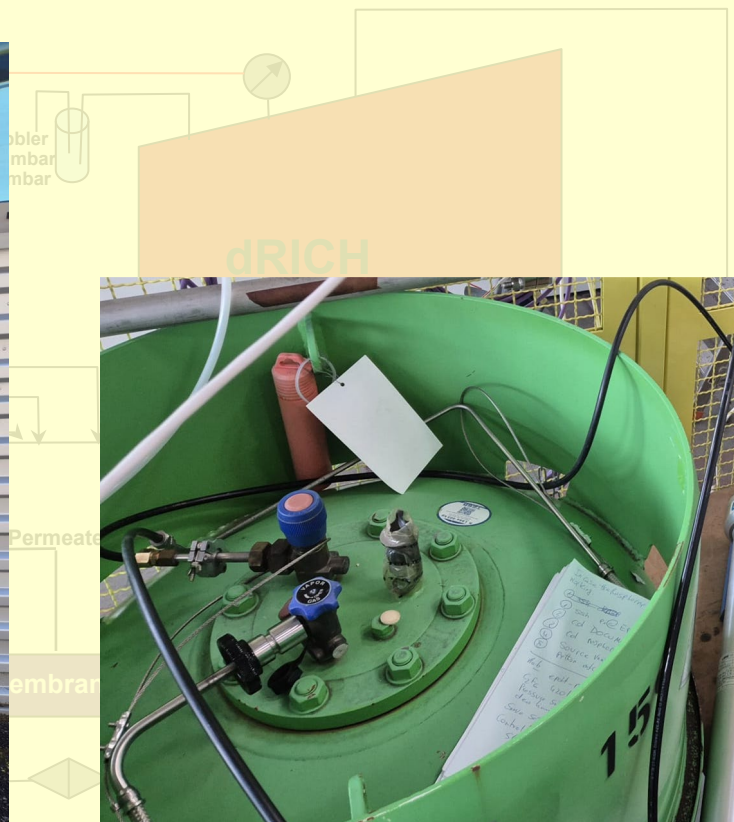




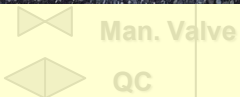
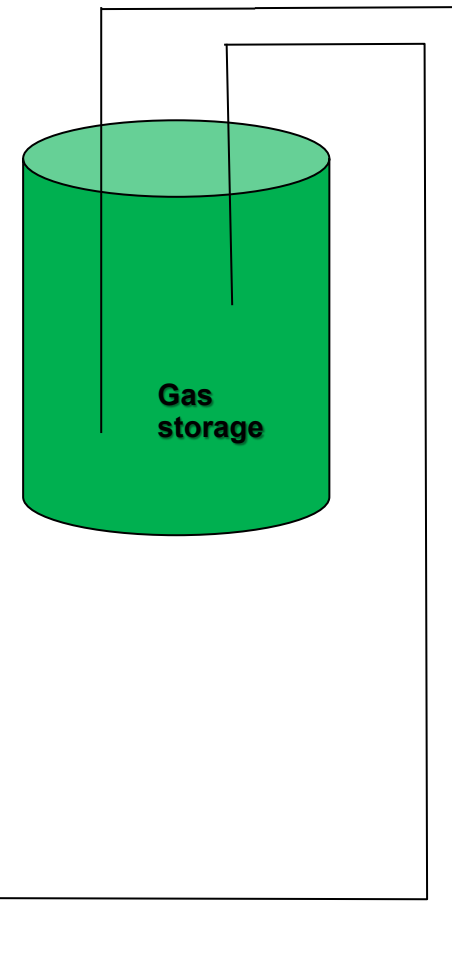




380 l recovery drum (50 bar max)



Drum top and bottom connections



Cleaning and filling:

- Air to N_2 : open circuit
- N_2 to CO_2 : open circuit
- CO_2 to C_2F_6 : recirculation, membrane separation

Normal operation with C_2F_6 :

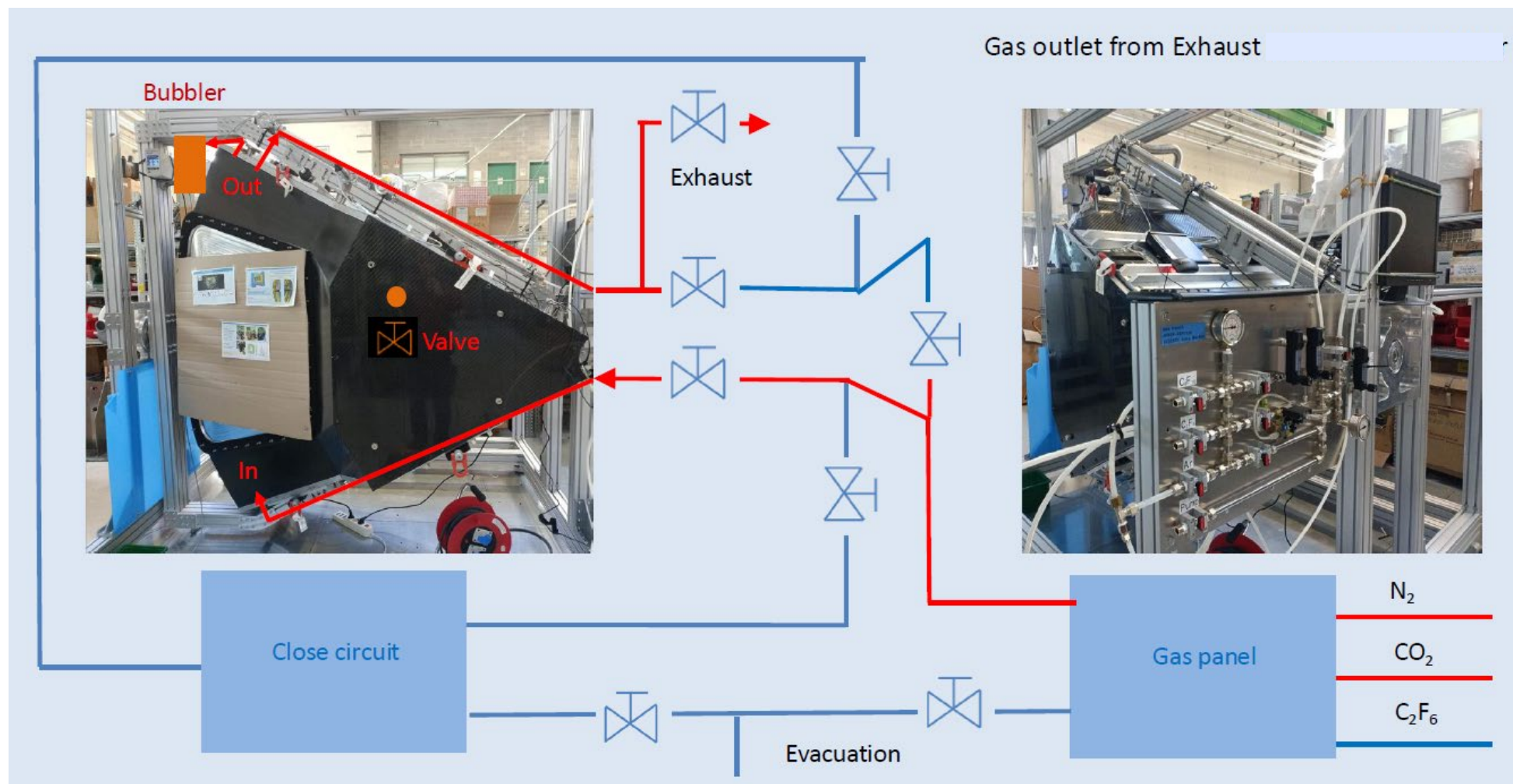
recirculation on, filtering on, membrane separation on
 C_2F_6 input compensates p,T variations, residual CO_2 purge, and leaks (~ 1 l/h)

Stand-by operation with C_2F_6 :

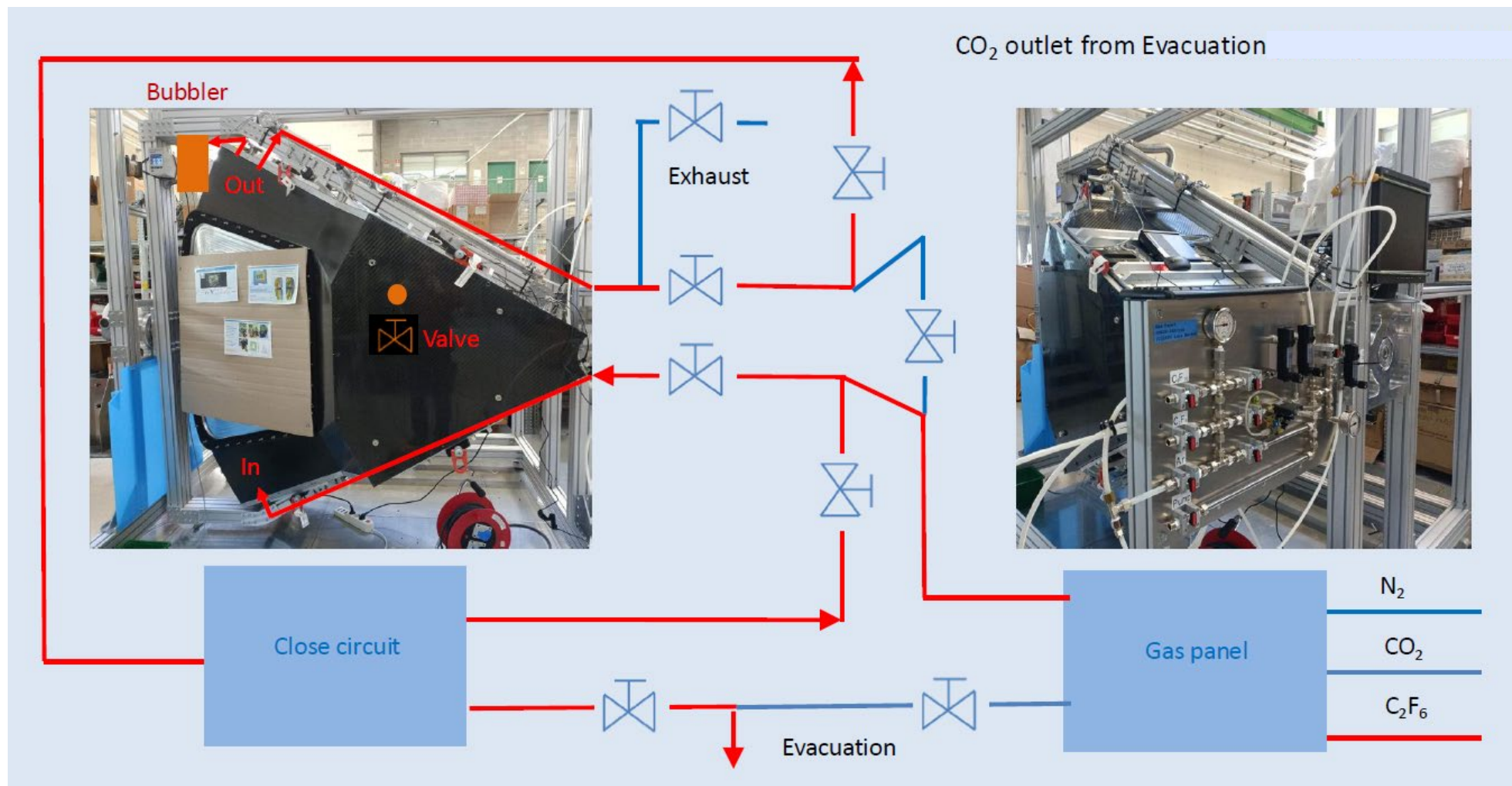
no C_2F_6 recirculation, pressure stability by allowing small input flow
 problems: contamination level increases, overpressure not compensated

C_2F_6 Recovery:

- C_2F_6 to CO_2 : circulation, membrane separation at high flow and high pressure
- CO_2 to N_2 or directly to air

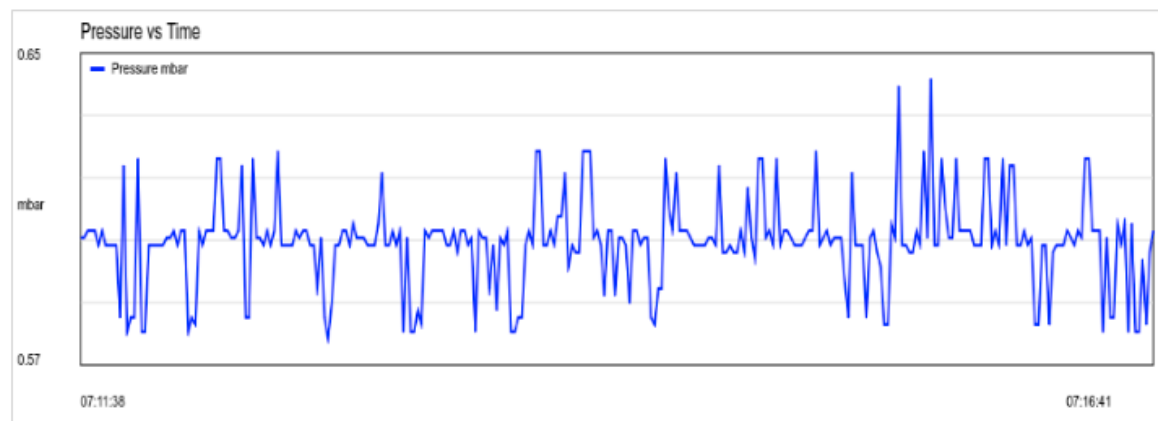


Air to N_2 and N_2 to CO_2 : open circuit

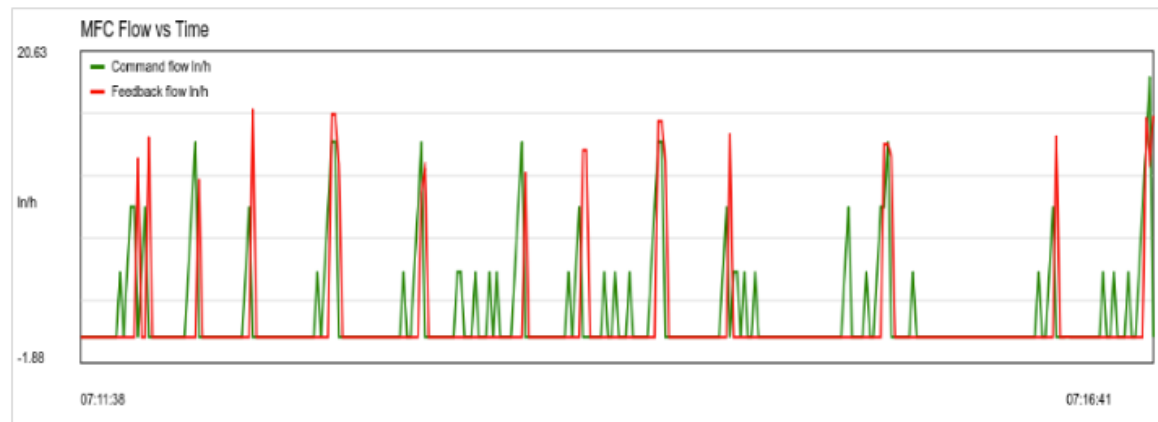


CO₂ to C₂F₆: recirculation and membrane separation

Pressure vs Time

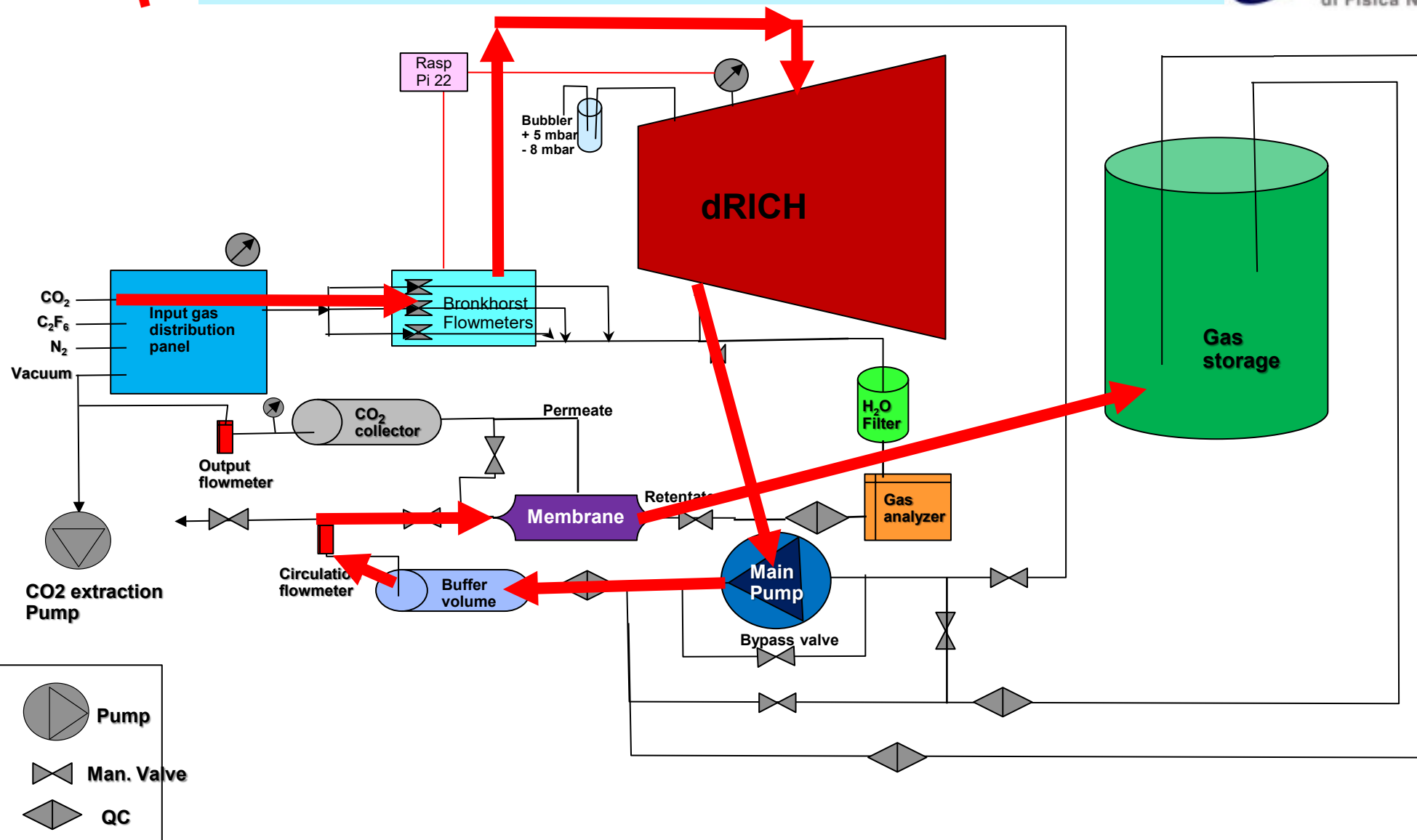


Flow vs Time



During data taking operation: C_2F_6 input compensates leaks and p,T evolution

delicate C_2F_6 recovery operation



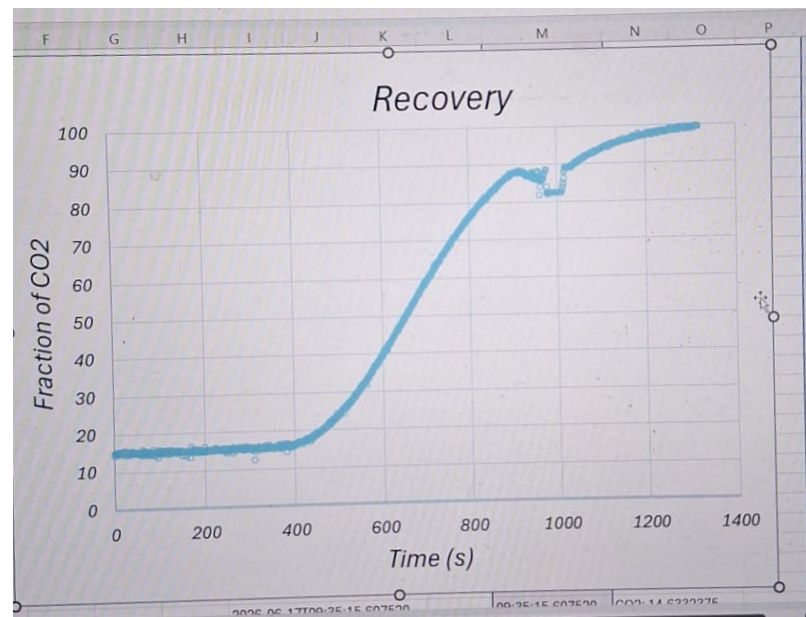
First filling: severe leaks with C_2F_6
after CO_2 operation with small leak

Fast intervention: external "sealing"
Data taking at SPS could be performed

Recovery in the Storage Drum
→ C_2F_6 successfully reused at PS

Opening and fixing leaks.
 C_2F_6 normal operation (~ 1 l/h)

Filling/Recovery performed three times



C_2F_6 to CO_2 transition in ~ 1.5 h

Filling: CO_2 extracted from the top, C_2F_6 injected from the bottom,
 CO_2 filtered by membrane, C_2F_6 from tank to prototype

Recovery: C_2F_6 extracted from the bottom, CO_2 injected from the top
 C_2F_6 passing the membrane (retentate), only CO_2 permeate purged

Essential role of p sensors
(4 on vessel, 4 on gas system)

Many temperature sensors helped
understanding the status and the
transitions

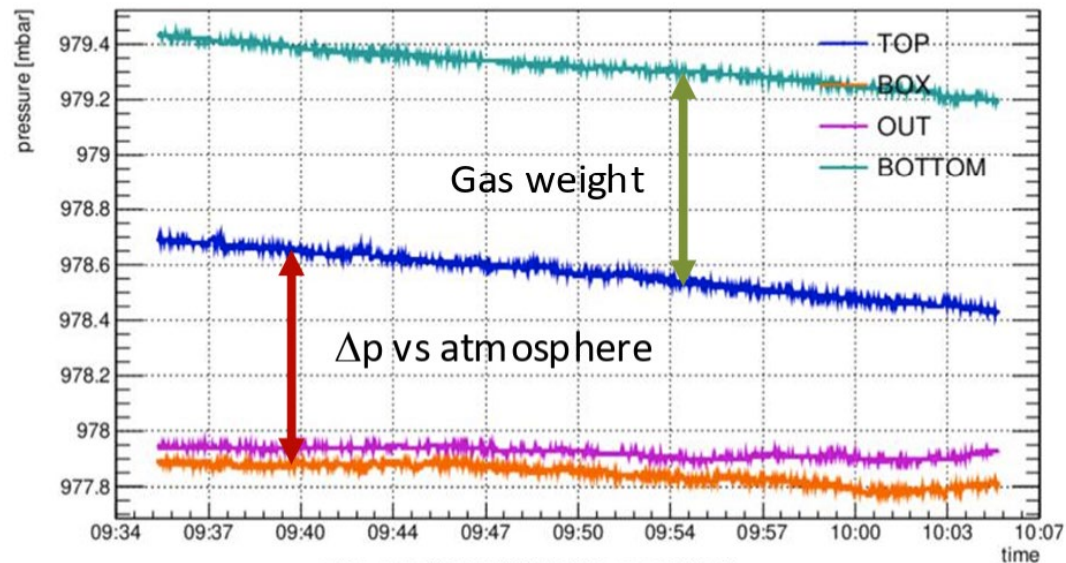
Important moisture measurement
and CO₂ measuring device

Six flow meters and rotameters

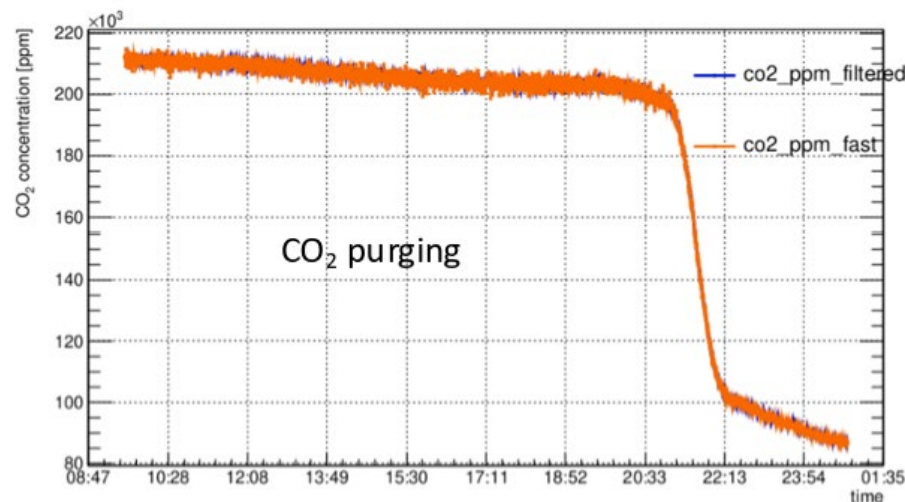
Speed of sound (binary gas analyzer)

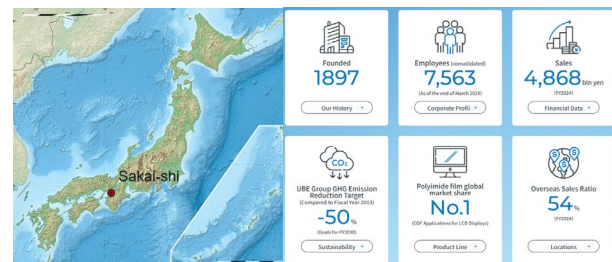
Control and recording

TPG pressures - start: 2026-06-23 09:35:42 - now: 10:05:44



CO₂ - start: 2026-06-22 09:33:02 - now: 00:49:44





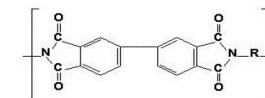
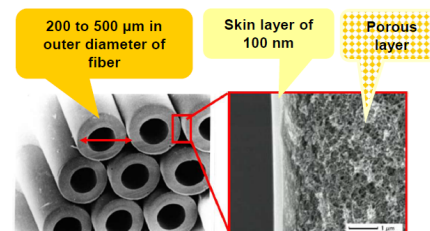
History of UBE's Membrane Business

- 1978 Started R&D Work
- 1981 Jointed MITI's C1 Project (National Project)
- 1983 First Membrane for H₂
Field Tests at Ammonia Plant for H₂ Recovery
Organized Membrane Dept.
- 1985 Supply First H₂ Recovery Unit
- 1989 First Membranes for CO₂ & Dryer
- 1989 First Membrane for Dehydration
- 1992 First Membrane for N₂/O₂ Separation
- Improving Membranes and Modules
- 2007 2nd Hollow Fiber Line in Ube City facility
Module Assembly Line in Sakai.
- 2008 3rd Hollow Fiber Line in Ube.
- 2025 4th Hollow Fiber Line in Ube.
Expansion in the Module Assembly facility in Sakai.



CS-001E_REV.K_250717
As a reference

Polyimide Hollow Fiber Membranes



BPDA-based polyimide

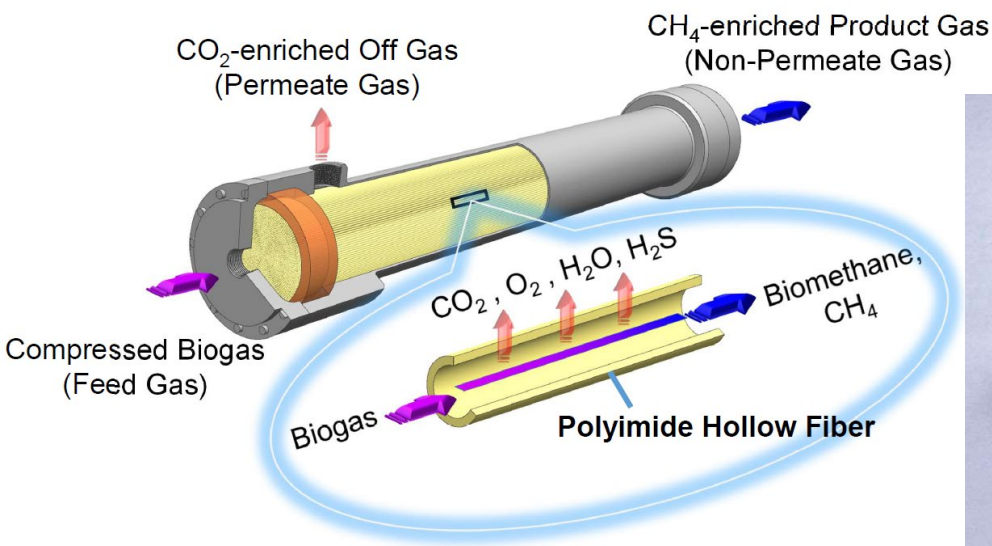
Permeation rate to gases in polyimide membrane

High permeation	H ₂ O
	H ₂ He
dependent on solubility and molecule size	CO ₂ H ₂ S
	O ₂
Equilibrium + Kinetic Separ.	CO Ar
Low	N ₂ CH ₄ C ₂ H ₅ OH
	C ₂ H ₆
	C ₃ + Hydrocarbons

Benefits of BPDA-based polyimide as material for hollow fiber membrane

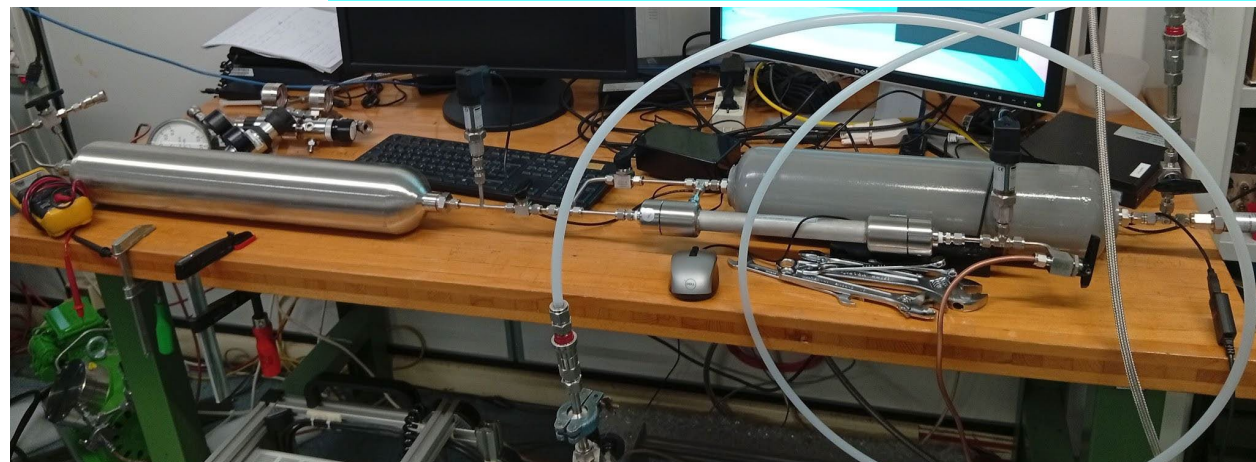
- 1) Good balance for permeability and selectivity
- 2) Good mechanical property
- 3) Excellent heat resistance
- 4) Good chemical resistance
- 5) Excellent lifetime
- 6) Easy to make fiber and thin skin layer

Module Structure - CO₂ Separator



Product Specification and Features

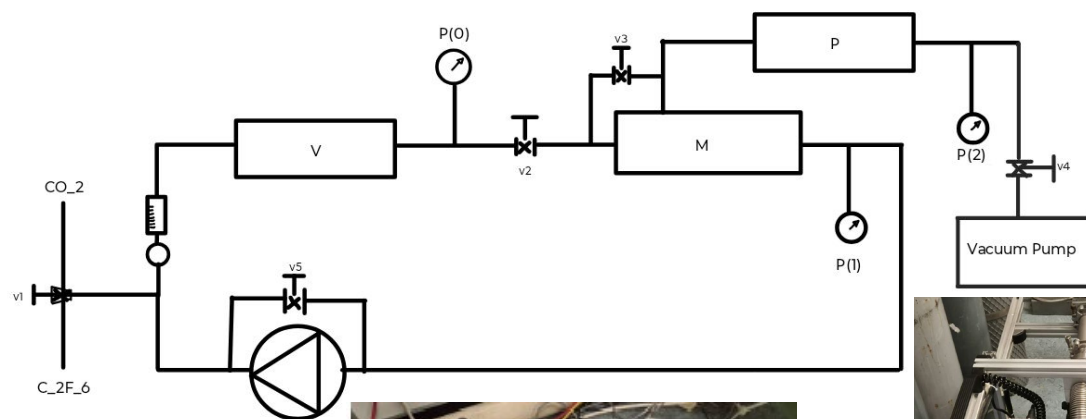
Hollow Fiber	Polyimide Resin
Housing	Aluminum
Operating Pressure	Housing type - Max. 1.4 MPaG Cartridge type - Max. 2.4 MPaG
Operation Temperature	up to 60°C
H ₂ S resistance	up to 3 vol %



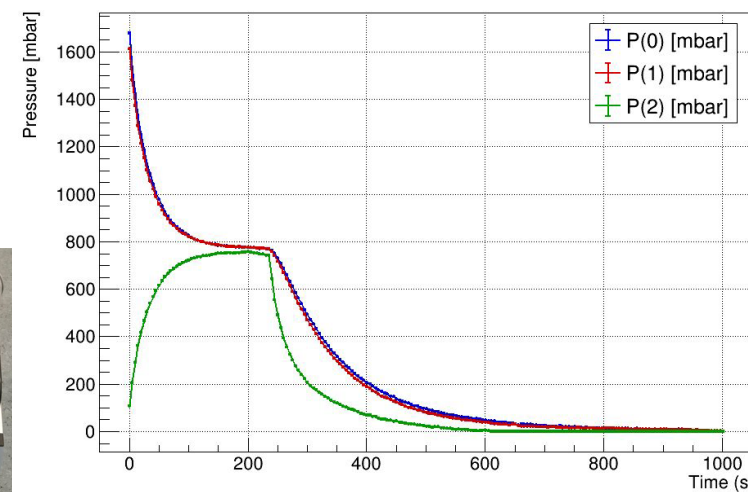
Permeability proportional to Δp .

For $\Delta p = 1$ bar we measured:

CO_2	200	l/h
C_2F_6	0.004	l/h
N_2	6	l/h
Ar	10	l/h



Pressure Plot

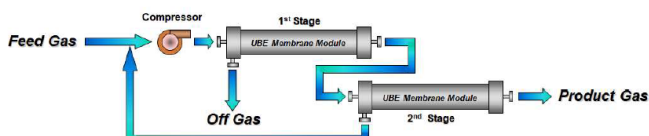


System Configuration of Membranes **

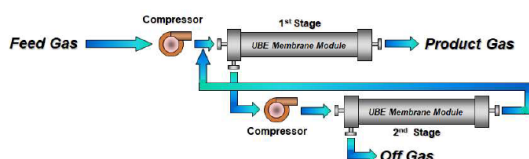
**UBE supplies membrane module/cartridge only.

UBE Corporation
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As a reference

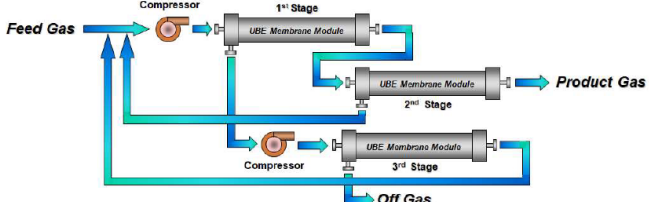
A. 2 Stages & 1 Compressor



B. 2 Stages & 2 Compressors



C. 3 Stages & 2 Compressors



New System Configuration of Membranes **

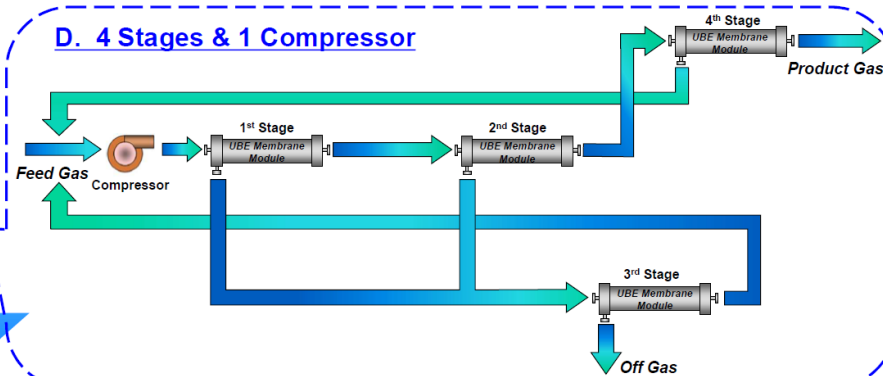
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Competitive Advantages

- 99.5 % recovery & 99.0 % purity CH₄, all in one go.
- Save energy with just one compressor.
- Big savings especially for small scale plants.

D. 4 Stages & 1 Compressor



Feed Gas Flow Rate : 600 Nm³/h (at 0 °C, 1013 mbara)
Feed Gas Composition : CO₂ 40 %, CH₄ 60 %
Product Gas Purity : CO₂ < 1 %

Operating Temperature : 25 °C (77 °F)*

*Maximum allowable temperature is 60 °C (140 °F).

