Conception of a gas recuperation system

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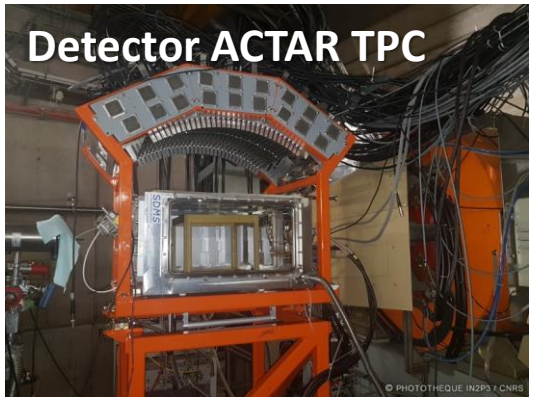
GANIL

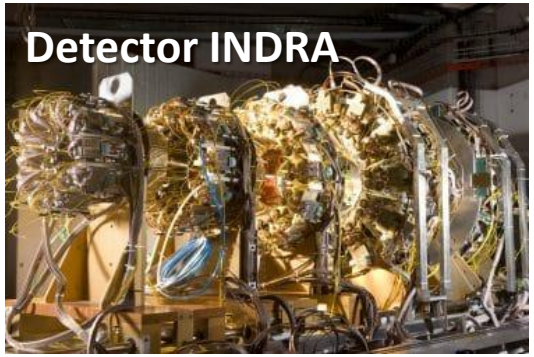
Instrumentation Days on gaseous detectors 2022

30–31 mars 2022
LPSC Grenoble

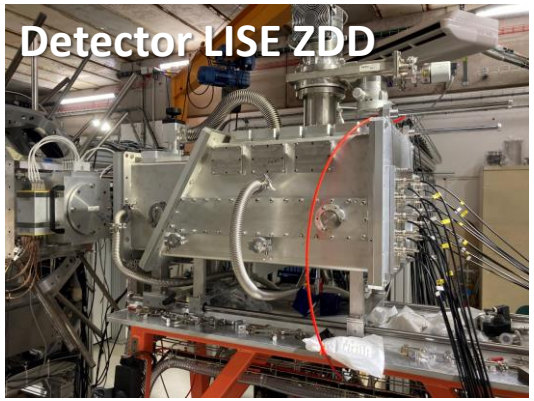
Gaseous detectors at GANIL that use fluorinated gas



CF4 gas
with pressure ~100 mbar



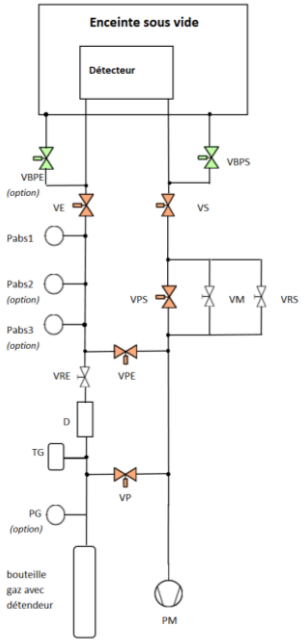
C3F8 gas
with pressure ~20-40 mbar

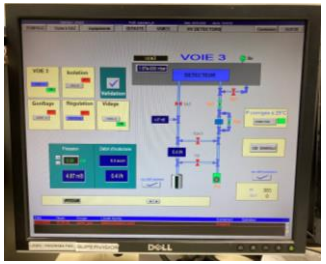


CF4 gas
as option 10%CF4+90%Ar
with pressure 100-500 mbar

Gas regulation stations

- Pressure range 5 - 50 mbar
- Gas flow rate 0.01 - 0.5 l/min

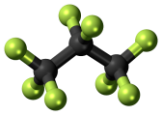




Fluorocarbons

How can we recuperate and reuse these gases ?

C3F8



Octafluoropropane

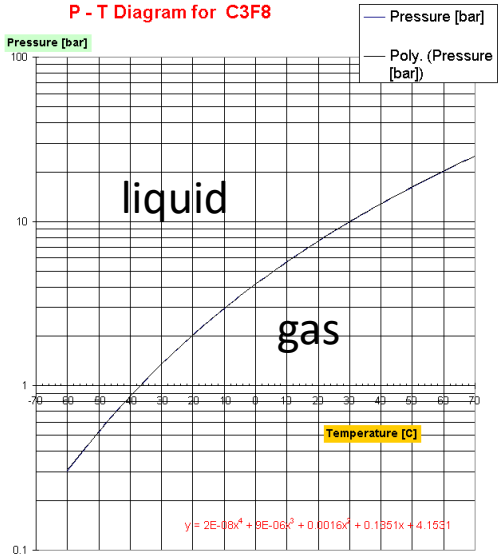
Synonymes

Perfluoropropane

R-218

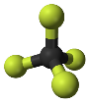
Gas effect: 24,000 times more that of CO2

Molar mass	188.02 g/mol
Appearance	Colorless gas with faintly sweet odor
Density	8.17 g/l, gas
Melting point	−147.6 °C (−233.7 °F; 125.5 K)
Boiling point	−36.7 °C (−34.1 °F; 236.5 K)



Can be liquidized at ~7,5 bar at room temperature

CF4



Tetrafluoromethane

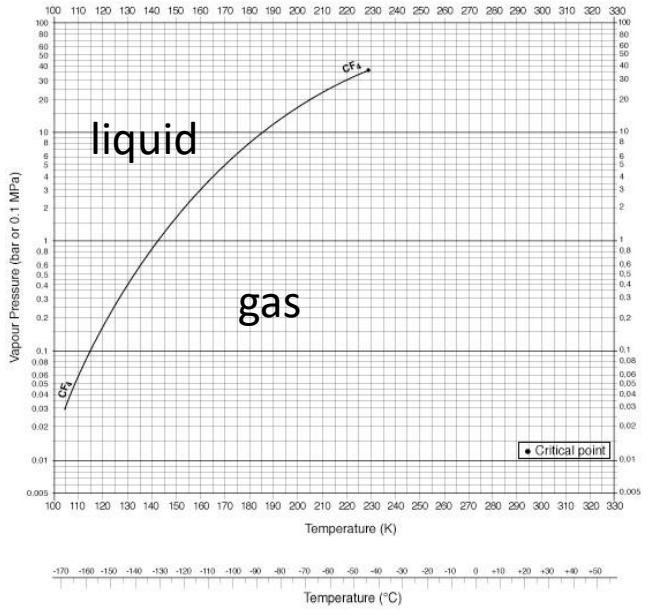
Synonymes :

Carbon tetrafluoride

R-14

Gas effect: 6,500 times more that of CO2

Molar mass	88.0043 g/mol
Appearance	Colorless gas without odor
Density	3.72 g/l, gas (15 °C)
Melting point	−183.6 °C (−298.5 °F; 89.5 K)
Boiling point	−127.8 °C (−198.0 °F; 145.3 K)



Gas recirculation system used at CERN

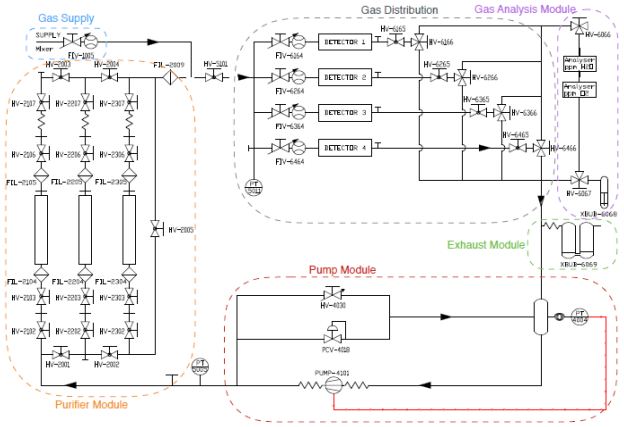
https://iopscience.iop.org/article/10.1088/1748-0221/12/10/T10002

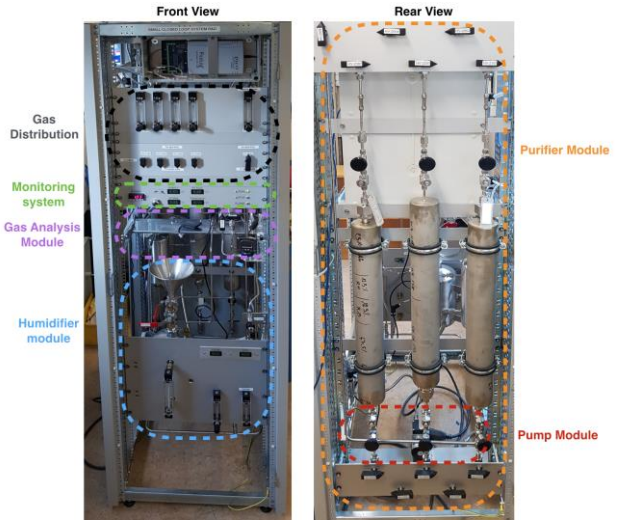
A portable gas recirculation unit for gaseous detectors

To cite this article: R. Guida and B. Mandelli 2017 *JINST* **12** T10002

Abstract

The use of greenhouse gases (usually $C_2H_2F_4$, CF_4 and SF_6) is sometimes necessary to achieve the required performance for some gaseous detectors. The consumption of these gases in the LHC systems is reduced by recycling the gas mixture thanks to a complex gas recirculation system. Beyond greenhouse gas consumption due to LHC systems, a considerable contribution is generated by setups used for LHC detector upgrade projects, R&D activities, detector quality assurance or longevity tests. In order to minimise this emission, a new flexible and portable gas recirculation unit has been developed. Thanks to its low price, flexibility and user-friendly operation it can be easily adapted for the different types of detector systems and set-ups.





Detectors operate at atmospheric pressure

Recuperation of fluorinated gases

The idea is to use compressor after pump outlet of gas regulation station, compress the gas and sent it to a bottle.

Searching at commercial available products

Main criterion: leakless and oil/dust free - no gas contamination

INFICON Vortex® Dual Refrigerant Recovery Machine

Type	Vortex Dual Refrigerant Recovery Machine
Compatible refrigerants	Recovers commonly used CFCs, HCFCs, and HFCs including blends such as R410A, R12, R22, R134a, R32, R404, R407C, R500, R502, and other Class III, IV and V refrigerants
Weight	29.75 lb. (13.5 kg)
Dimensions (L x W x H)	16.7 x 9.2 x 14.2 in. (42.4 x 23.3 x 36 cm)
Compressor	1 HP **oil-less,** dual valve, AC motor drive
High-pressure shut-off	550 psi (**37.92 bar**)
Power Source	115V, 60 Hz, 15A or 230V, 50/60 Hz, 10A (depending on model)

https://www.inficon.com/en/products/vortex-dual-refrigerant-recovery-machine

Choice of a vacuum pump

During the firsts tests with standard pump we were not able to liquidized C3F8 gas due to its contamination by air.

Two technoligies were chosen:

Membrane pump

https://knf.com/fr/fr/solutions/equipement-de-laboratoire/details/laboport-n-8423-ft18

Multistage roots pump

https://www.pfeiffer-vacuum.com/en/products/vacuum-generation/multi-stage-roots-pumps/light-duty-applications/air-cooled/sd-versions/12248/sd-versions-acp-15-acp-28-acp-40

Main criteries	**Membrane pump**	**Multistage roots pump**
Vacuum absolute better than 1mbar	+ −	+ +
Leakless	+ +	+
No gas contamination (oil and dust free)	+	+
Material should be resistive to fluorinated gas https://detector-cooling.web.cern.ch/data/Fluoro_Compatibility.htm	?	+

Material compatibility with fluorinated gases

COMPATIBILTY OF PF5060 / FC72 (C6F14) WITH MATERIALS

Communicated by Lionel Breuilly - 3M FRANCE

3M and various materials manufacturers have been contacted regarding their compatibility with Fluorinert:

GOOD

- Acrylic (Acrylite / Acrysteel / Aristech / Cyrolite / Diakon / Kamax) *possible
- Buna-N - Nitrile rubber (NBR=Acrylonitrile butadiene rubber - Perbunan-NT / Hycar / Butacril / Chemigum / Isr-N / Stansolv / Sol-Vex) *good
- Nalgene - Polyurethane (PU/PUR=Polyurethane rubber - Vulkollan / Adiprene) *possible
- Neoprene W (CR=Polychloroprene rubber - Baypren / Neox / Stanzoil) *prohibited
- Silicone (SIR=Silicone rubber - Silastic) *possible

BAD

- Nylon (PA=Polyamid - Stanyl / Capron / Ultramid / Maranyl / Zytel / Orgamid / Grilon / Rilsan / Reny / Vestamid) *possible
- Polypropylene (PP=Polypropylene - Celmar / Coprax / Giacogreen / Hostelen PP / Novolen / Appryl / Lacqtene / Propathene / Ektar FB / Fortilene / Marlex / Polyfine / Pro-Fax / Tenite) *possible
- PVC (PVC=Polyvinyl chloride - Betaglas / Darvic / Fiberlok / Trovidur / Hostalit / Vestolit / Tygon) *prohibited
- Teflon (PTFE=Polytetrafluoroethylene - Flubriflon / Fluon / Teflon TFE / Valflon F / Hostaflon TF / Furon / Gortex / Tfm / Rulon) *prohibited
- Tygon (PVC) *prohibited
- Viton (FKM=Fluoroelastomer - Fluorel) *prohibited
- (from our test) EPDM (Ethylene propylene rubber - Keltan / Nordel / Vistalon / Buna-AP / Pyrofil) *possible

*CERN IS 41 classification

CERN/P.BONNEAU/15/07/2003

https://detector-cooling.web.cern.ch/data/Fluoro_Compatibility.htm

Some standard materials used at vacuum engineering are not compatible with fluorinated gases

Choice of a vacuum pump

This pump will be a part of our gas system that we use for gas filled detectors. This system controls pressure and flow rate of gas passed through detectors placed in a vacuum chamber.
These detectors are operated with gas C3F8 at a **pressure range 5 - 50 mbar and flow rate 0.01 - 0.5 l/min.** The pump is installed at the end of the system and serves to provide circulation of the gas through the gas system and detectors.
We obliged to collect fluorocarbon gas after passing the gas system. For this case we want to use a compressor connected to pump outlet. After compressor gas will be sent in a bottle where it will be liquefied at a pressure about 10 bar. The compressor can provide a minimal pressure 0.3 bar at its entrance (the same pressure will be at pump outlet).
It is very important for us to keep purity of collected gas because we want to reuse it again. That is why we are looking for a **pump without gas ballast and with very low leakage rate**.
As we operate with small flow rate and gas volume of our detectors is also small (about few liters) we do not need a high output pump. It is more preferable for us to have a compact pump.

Kashiyama NeoDry 7E

Pfeiffer Vacuum ACP 15

Leybold ECODRY 40 plus

Choice of a vacuum pump

Pfeiffer Vacuum ACP 15 was choosen due to their leakage rate (< 1.10e-5 mbar.l/s) and price

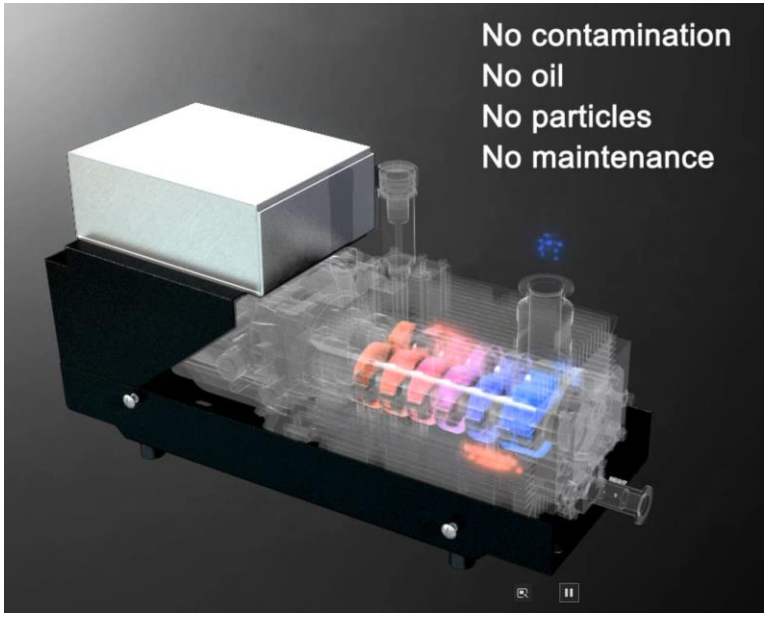
ACP 15

Product description

- Dry multi-stage Roots technology, SD versions, ACP pumps with a pumping speed of max. 15 m^3/h
- No particle contamination, thanks to frictionless design: no wearing parts in the pumped gases path
- No hydrocarbon vapors backstreaming: ACP series pumps are free of lubricant inside the pumping module
- Constant performances (Pumping speed, max. and ultimate pressure)
- High reliability: thanks to our expertise of dry multi-stage Roots pumps since 1988
- Low maintenance costs: no annual field service, complete overhaul only every 20000 hours for ACP 15
- Condensable vapor ability: with gas ballast ports and drainable silencer

Technical Data	ACP 15, standard, single phase, manual gas ballast
Ambient temperature	12-40 °C | 53.6-104 °F | 285-313 K
Connection flange (in)	DN 25 ISO-KF
Connection flange (out)	DN 16 ISO-KF
Continuous inlet pressure, max.	1,013 hPa | 759.75 Torr | 1,013 mbar
Cooling method	Air
Dimensions (L x W x H)	514 x 190 x 270 mm | 20.24 x 7.48 x 10.63 inch
Exhaust pressure, max.	1,200 hPa | 900 Torr | 1,200 mbar
Final pressure with gas ballast	$3 \cdot 10^{-1}$ hPa | $2.25 \cdot 10^{-1}$ Torr | $3 \cdot 10^{-1}$ mbar
Final pressure without gas ballast	$5 \cdot 10^{-2}$ hPa | $3.75 \cdot 10^{-2}$ Torr | $5 \cdot 10^{-2}$ mbar
Gas ballast	Yes
Gas ballast flow	0.5 m^3/h | 0.29 cfm | 8.33 l/min
Helium leakage rate, max.	$5 \cdot 10^{-8}$ hPa·l/s
Mains cable	No
Mains connection	110 – 230 V AC (±10%) 50/60 Hz
Max. pumping capacity of pure water vapor at 20°C	80 g/h
Power consumption at final pressure	450 W
Processes	Light Duty Applications
Pumping speed	14 m^3/h | 8.24 cfm | 233.33 l/min
Sound pressure level	63 dB(A)
Version	Standard
Weight	23 kg | 50.71 lb

Order number	
ACP 15, standard	V5SATSMGZF

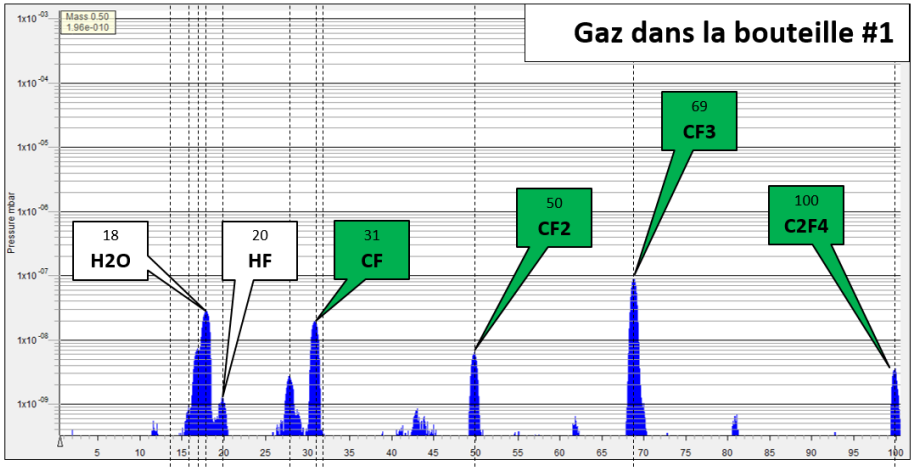


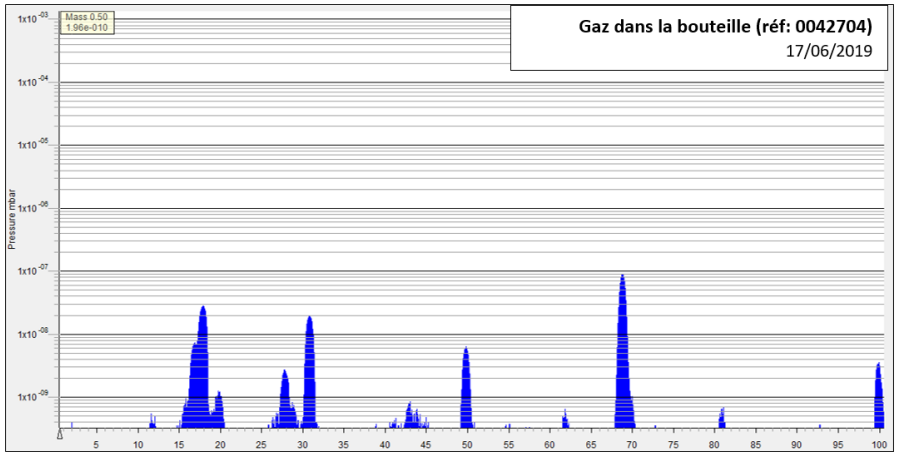
Analyse of gas composition after recuperation

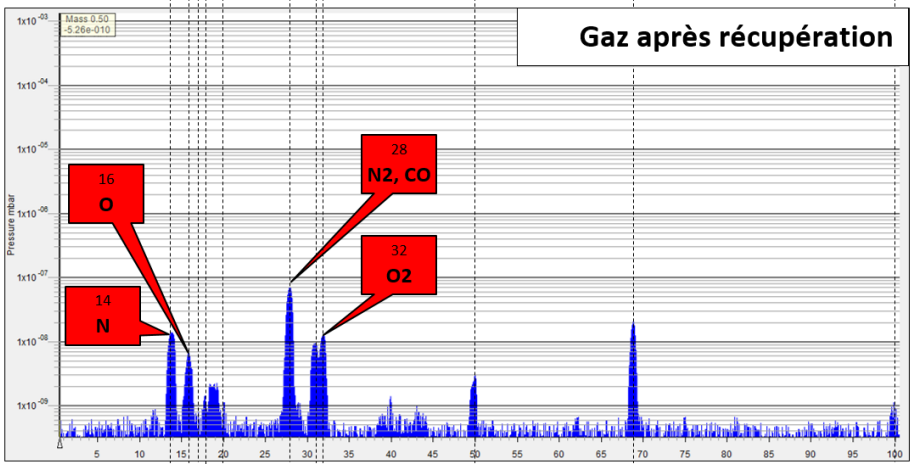
Test with gas C3F8 (R218)

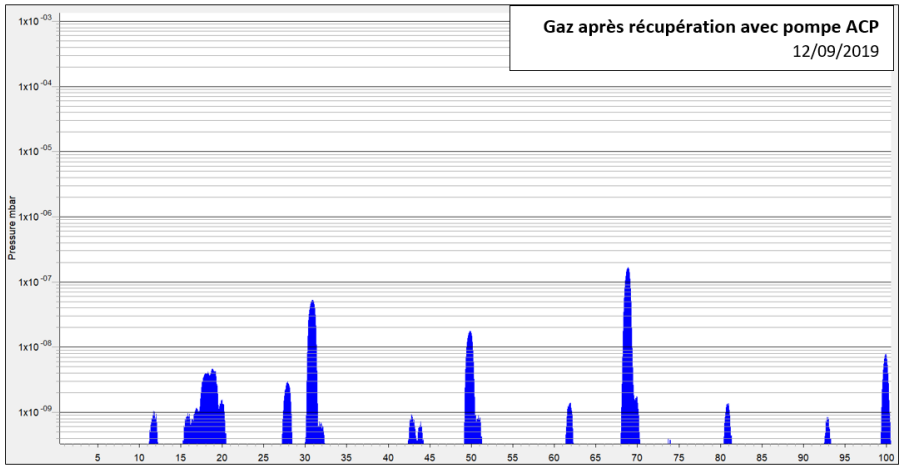
Standard vacuum pump

Multi roots vacuum pump

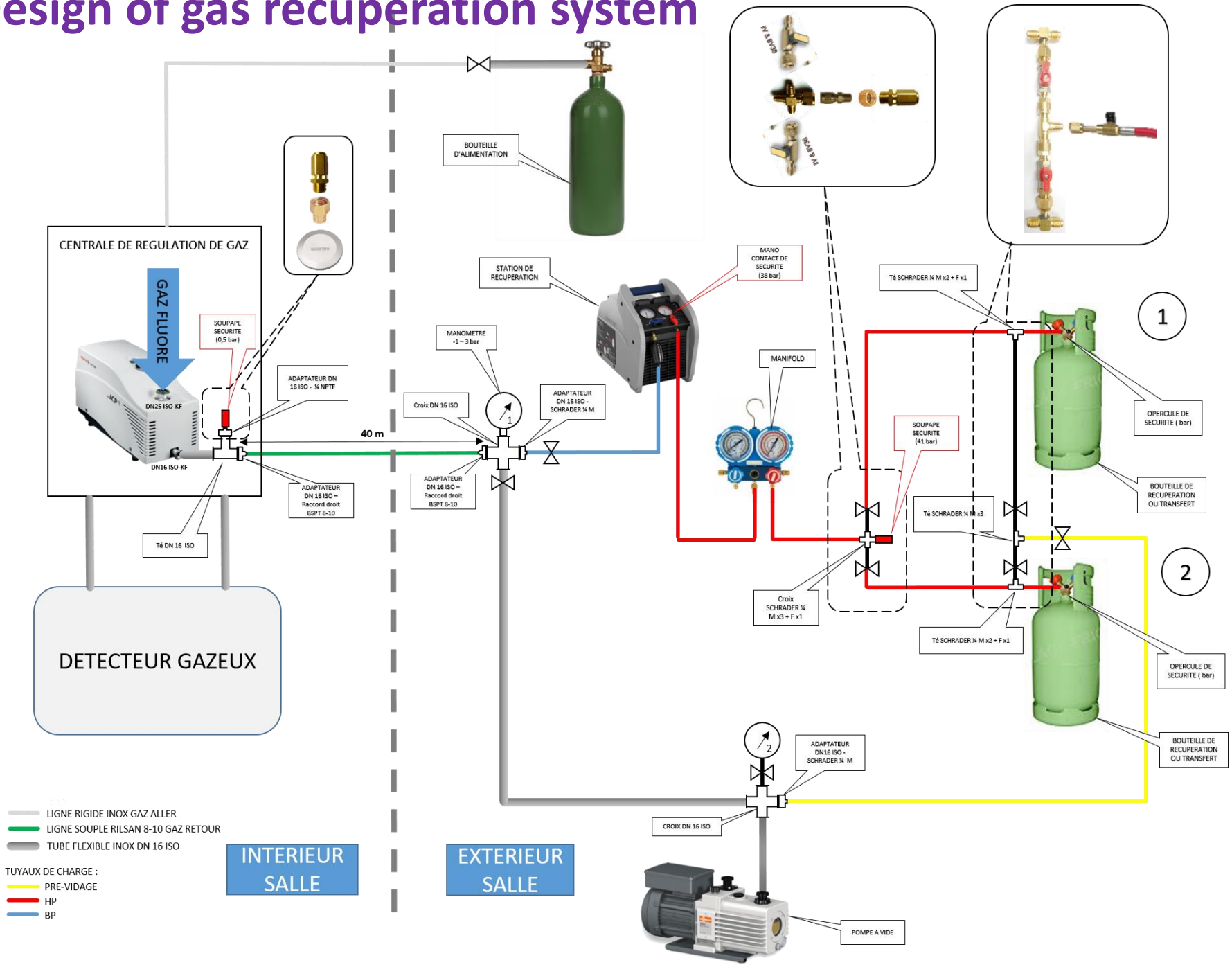




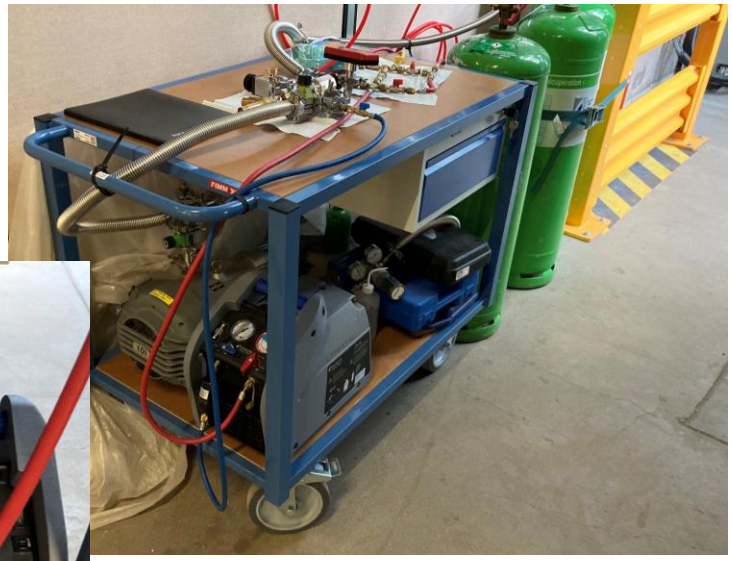


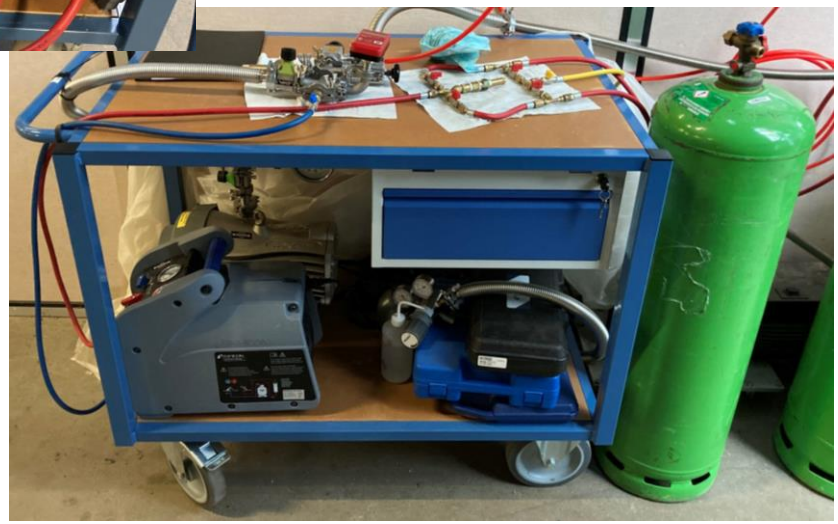


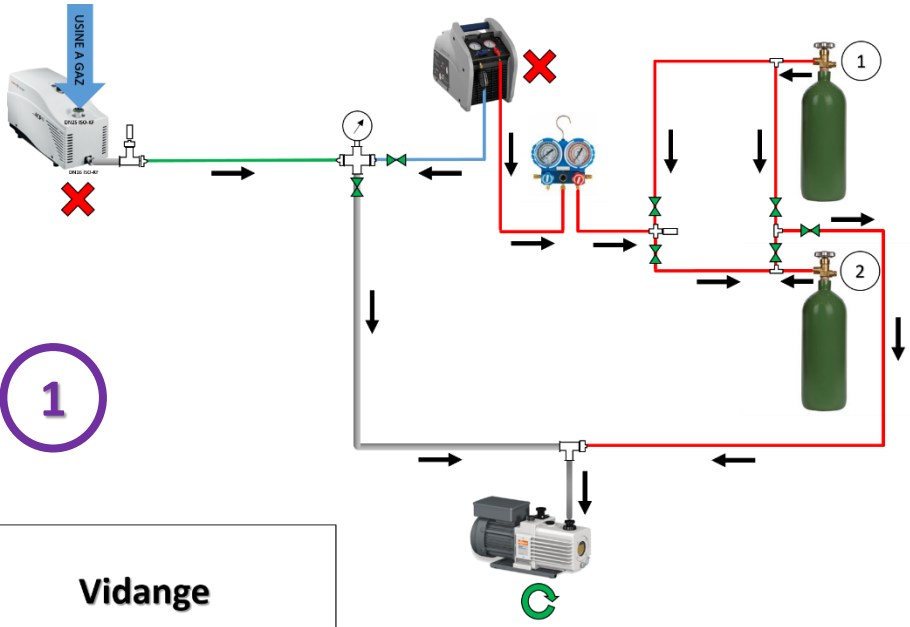
Design of gas recuperation system



Gas recuperation system at GANIL





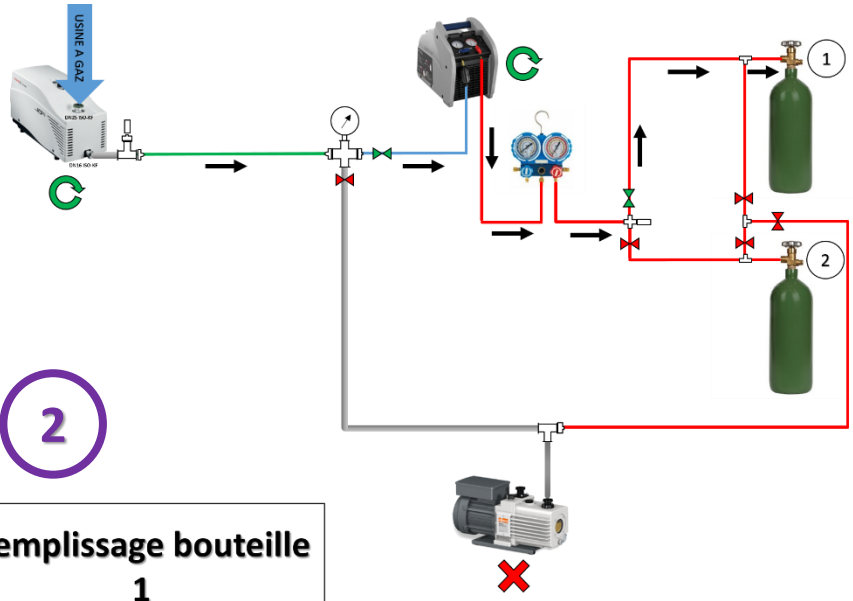


1

Vidange

Operation phases:

(1) – Vacuum pre-pumping of system
(2) – Gas recovery to bottle n°1
(3) – Gas recovery to bottle n°2 and vacuum pre-pumping of bottle n°3



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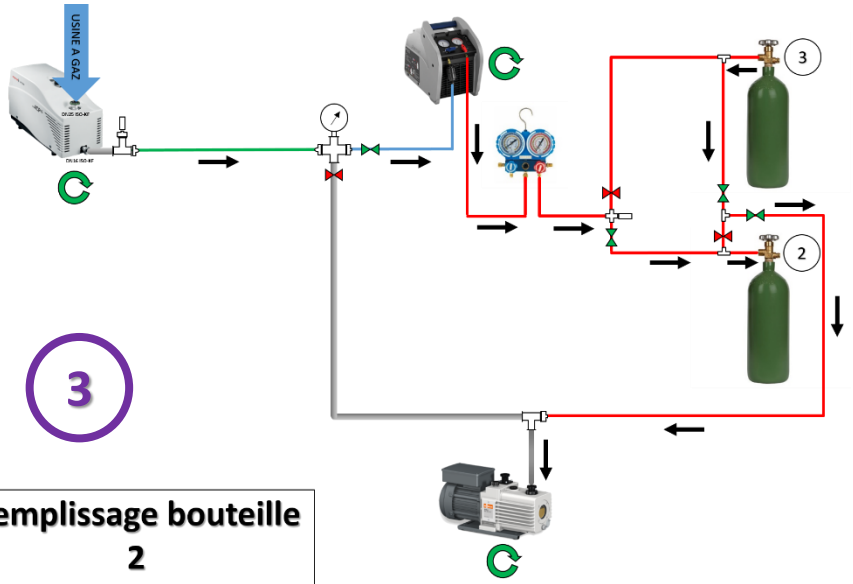
Remplissage bouteille 1



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Remplissage bouteille 2
Pre-vidange bouteille 3

Outlook

- Design of the system for gas recuperation was done using a commercial available products.
- First prototype of gas recuperation system was realized and tested. During laboratory test we were able to recovery and liquidize C3F8 gas using ACP15 pump.
- Gas recuperation system is in continuous operation during the last month.

Issues, questions and propositions:

- Problems with leakage of components (mainly at connections). Not so easy to detect them with gas detector due to a very low flow rate.
- No information about mechanical reliability of the compressor components for longterm usage. Searching solution for the compressor replacement by more reliable.
- Fabrication of a system with full automatic control.
- Analyse of recovered gas should be done to approve its possibility of reusing.

Thank you for your attention !