Considerations on the radiator gas system

COMPASS RICH-1 radiator gas system

Main elements and operation modes

The safety bubbler

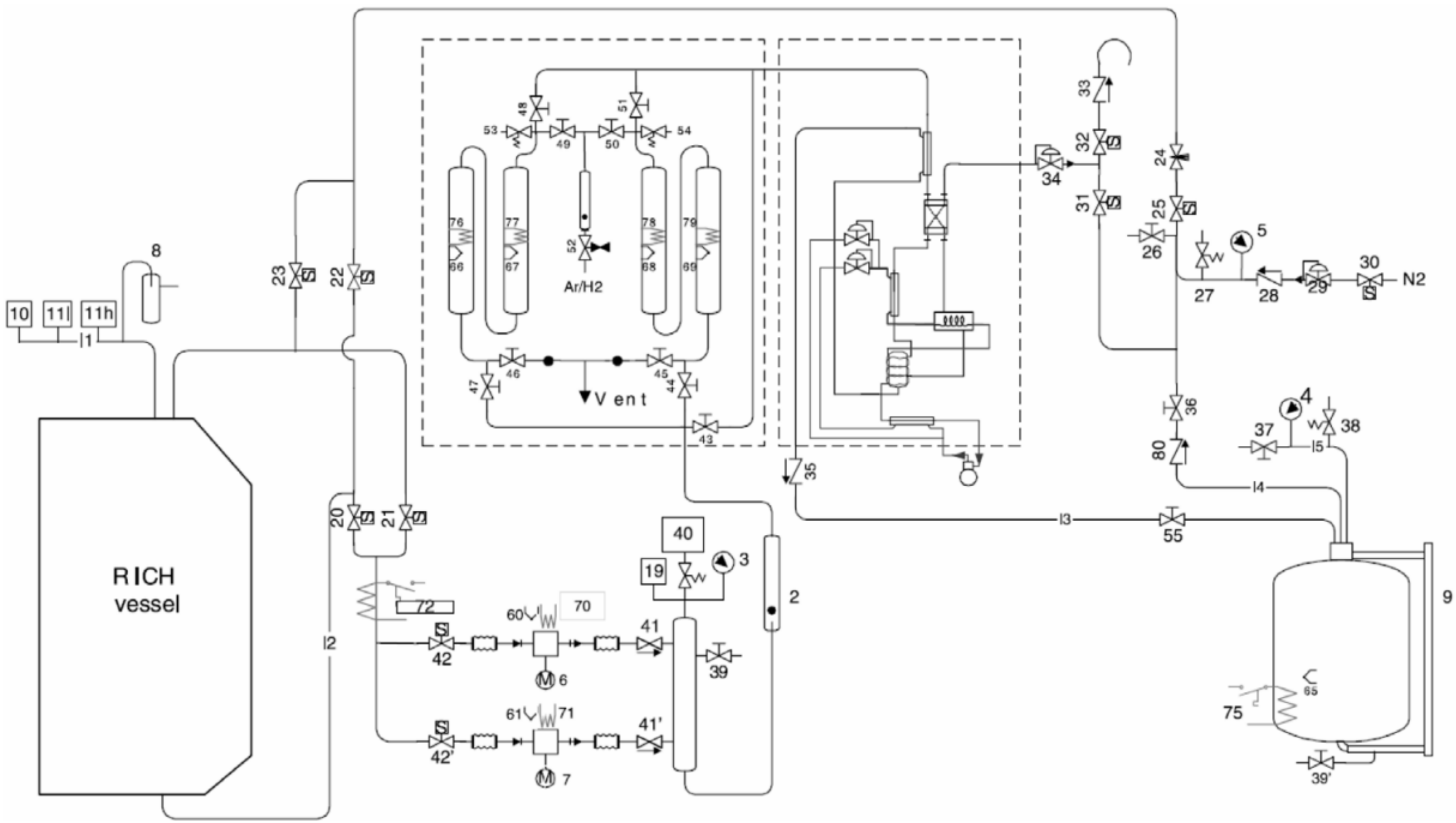
Problems with the COMPASS gas system

Fast circulation

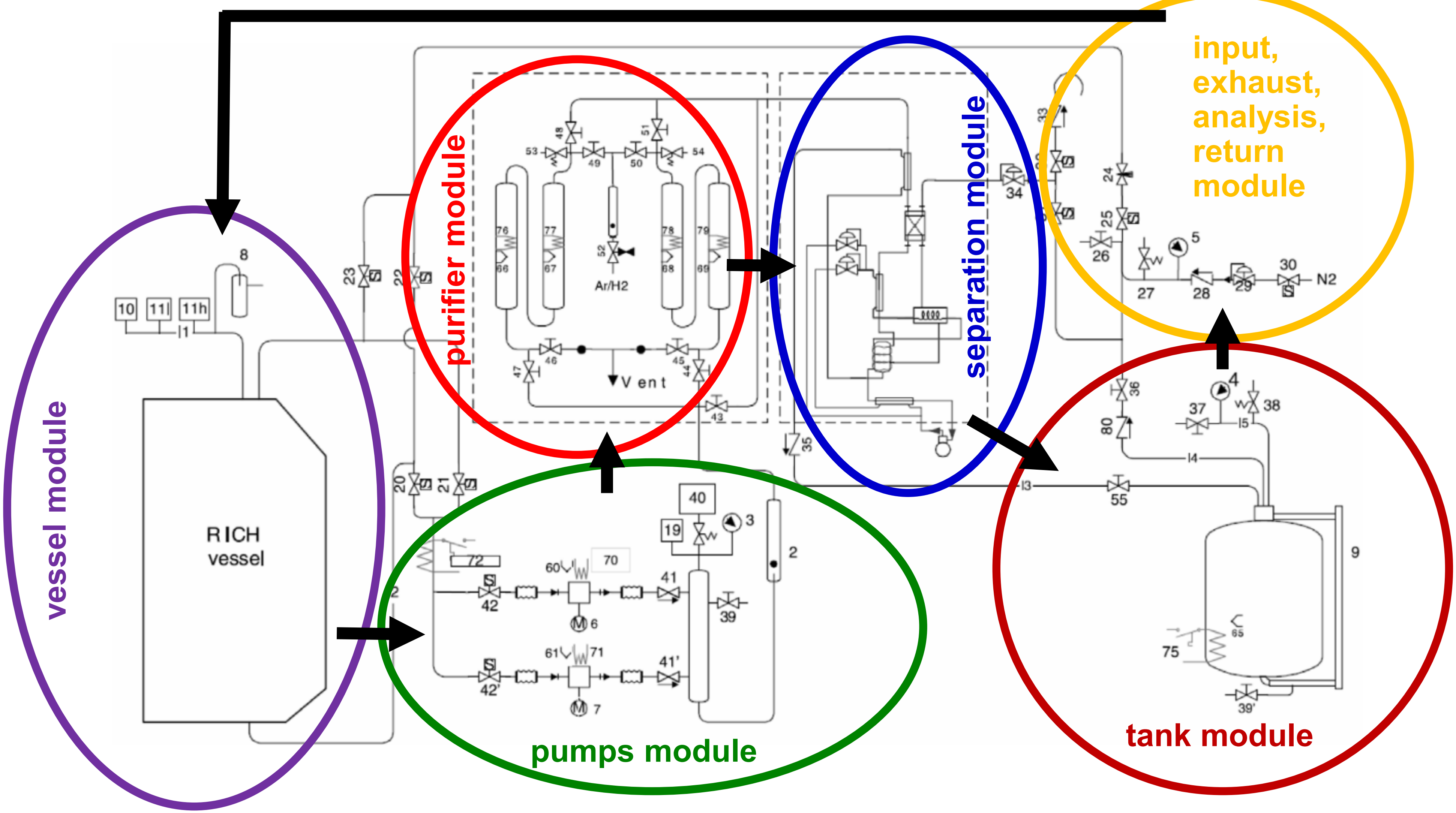
C2F6 separation

C2F6 transparency measurement

the COMPASS gas system



the COMPASS gas system



Main elements and operation modes

Main elements:

2 oil-free compressors Haug SOGX 50-D4 running in parallel (typically at 2.5 m^3/h), heated at 50°C

A pressure sensor on the RICH

A pneumatic valve regulated according to the pressure sensor

A PLC to control the system

A separation system

A storage tank

Main operation modes:

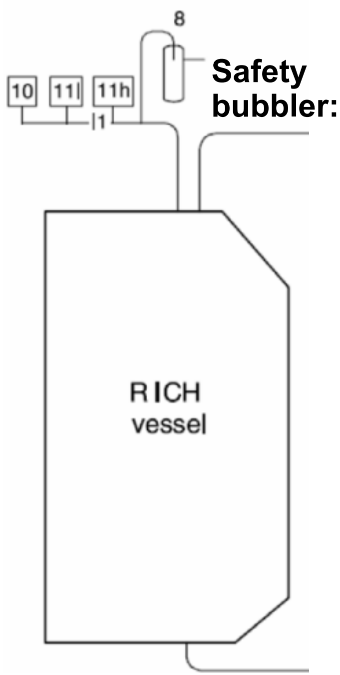
1) **Purge mode: flushing N_2**
2) **Filling mode: inserting C_4F_{10}, separating N_2 and C_4F_{10}, purging N_2 with residual C_4F_{10}**
3) **Run mode: circulating C_4F_{10}, no input, no purge**
4) **Recovery mode: inserting N_2, separating N_2 and C_4F_{10}, purging N_2 with residual C_4F_{10}**
5) **Stop mode (in case of emergency): compressors off, all electrovalves closed**

passive pressure safety system

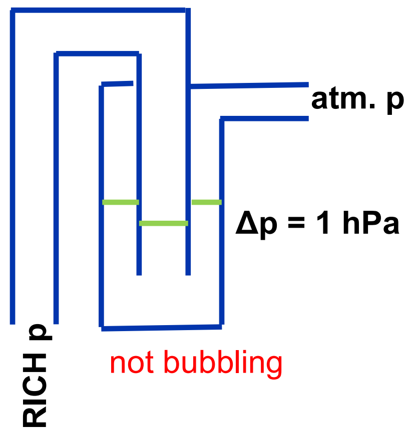
pressure gauges and hardware alarms

↓

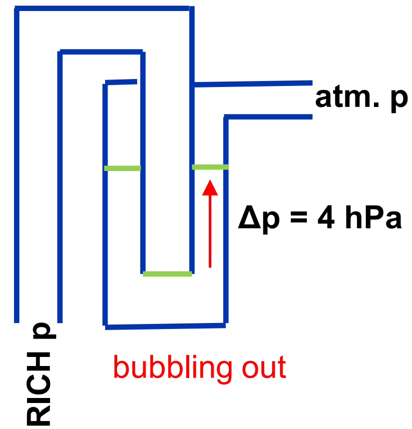
Problems from temperature + light + radiation → damage of alarm signal cables isolation → fake alarms



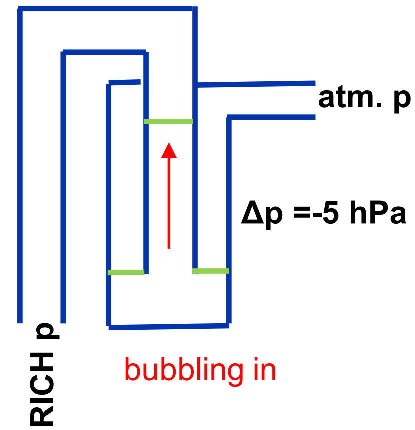
normal operation:



overpressure safety:



underpressure safety:



The safety Δp levels are defined by the inner/outer section surface ratio and the oil level

Large stainless-steel bubbler built for COMPASS RICH1 after choosing the safety levels

Pressure set at atmospheric pressure + 1.00 hPa at the top of RICH volume (

Feedback cycle tolerance < 0.1 mbar

High p alarms at + 2.0 hPa
Low p alarm at 0.0 hPa

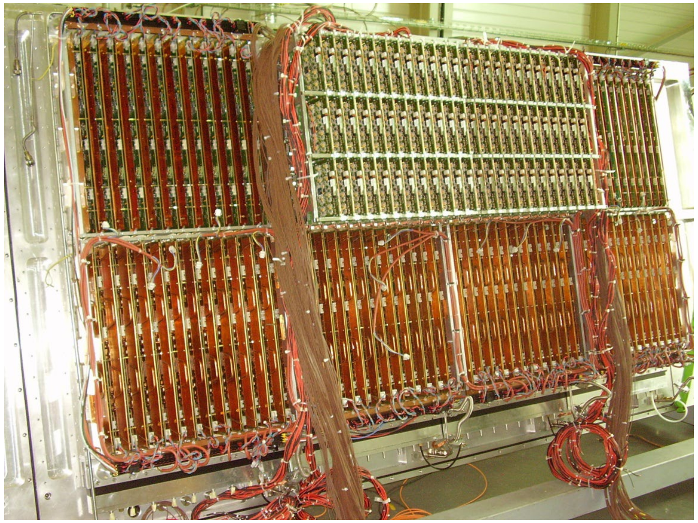
Protection of the fused silica windows, which are expected to be in danger for P > 30 hPa

$$t = l \cdot w \cdot \sqrt{\frac{P \cdot K \cdot SF}{2 \cdot M \cdot (l^2 + w^2)}}$$

t = 5 mm
$l = w$ = 500 mm
M = 52 MPa
SF = 4
K = 1.125

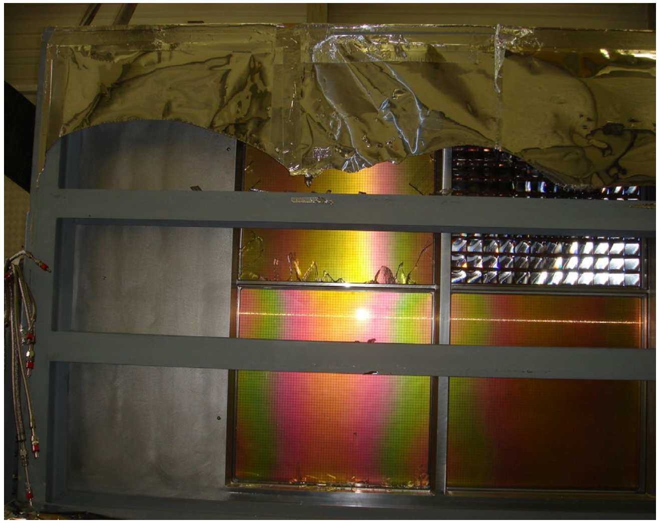
→ P = 30 hPa

"Δp accident" during transport 18.05.2006

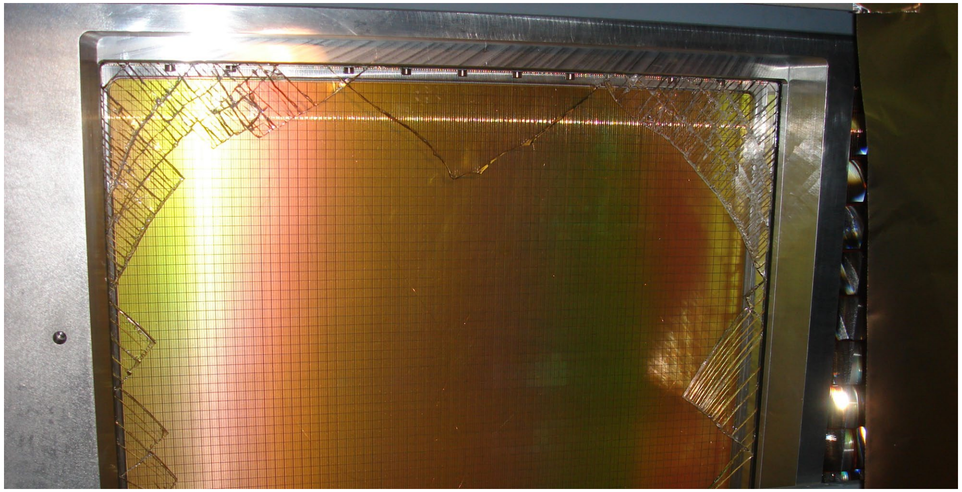


One COMPASS Photon Detector

Transport: gas lines connected in series



Δp Accident



The repair started on the same day

Spares of all pieces, including the large quartz windows were available

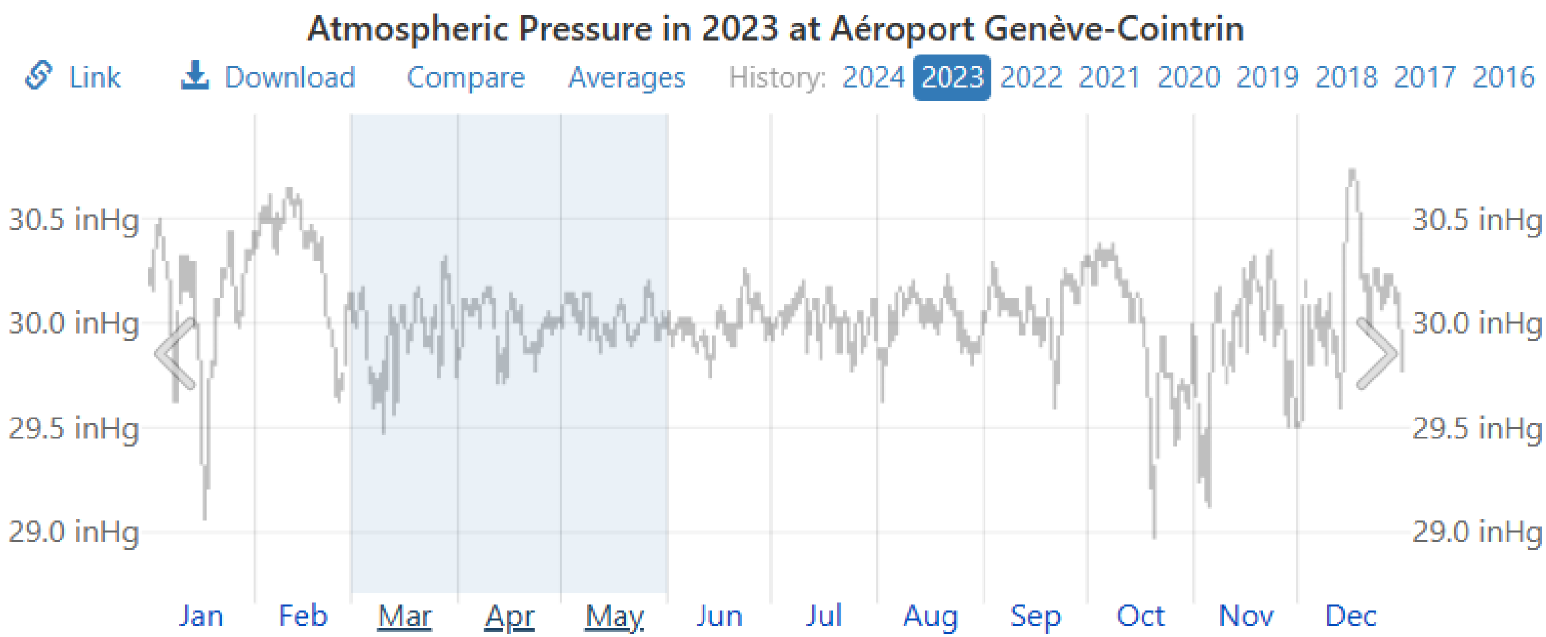
The accident was carefully studied and understood in detail

(under Δp > 20 hPa the central aluminum holder between fused silica windows collapsed)

One month later, in time for the start of the run, the repaired detector was installed

Atmospheric pressure variations

If the system follows the atmospheric pressure, the density of the radiator will vary accordingly.



The daily range of atmospheric pressure (gray bars), as measured by the altimeter setting reported in e.g. a METAR report.

External pressure variation in Geneva in 2023 (same as in previous years)

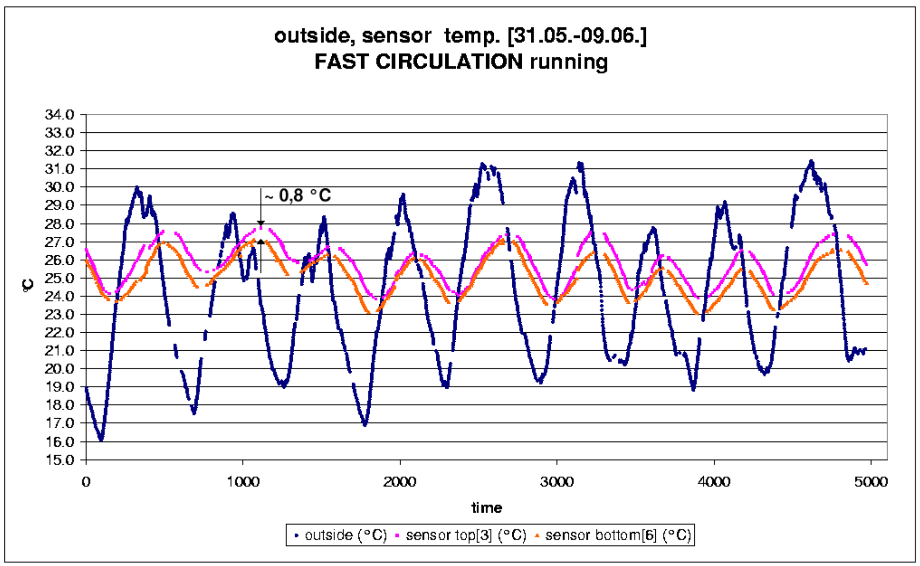
Min: 28.9 inHg = 978 hPa Max: 30.8 inHg = 1043 hPa Δp = 65 hPa

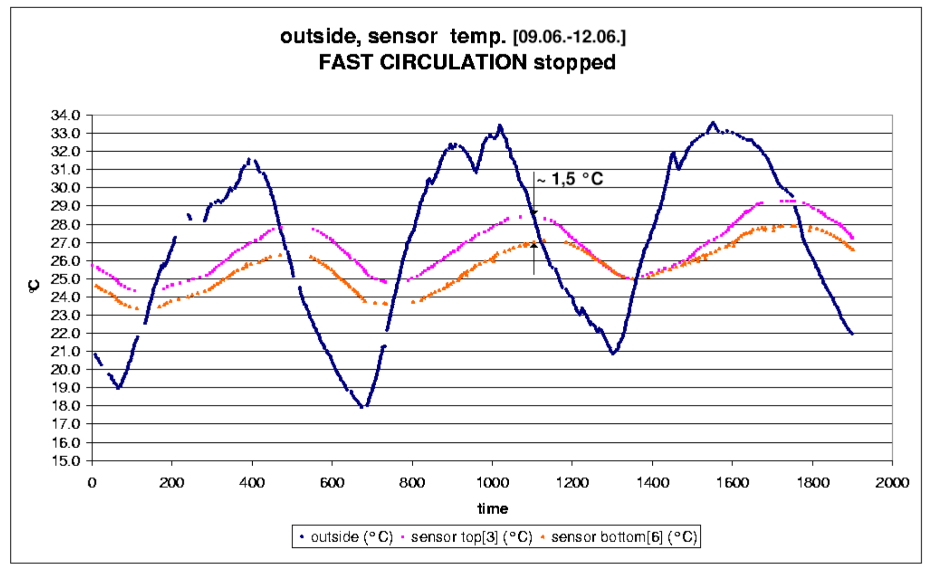
fast circulation

Thermalization of COMPASS RICH: proposal for a standalone RICH ("RICH tent") studied. Impossible to implement due to accumulation of other detectors around the RICH

Risk of thermal stratification studied by simulations: not fully conclusive but clearly suggesting a significant risk reduction in presence of a 10 times faster gas circulation.

→ Compressor ordered to HAUG and installed in 2003: flow = 20 m^3/h





Evidence for increase of thermal uniformity when the fast circulation is on.

Fast change in atmospheric pressure

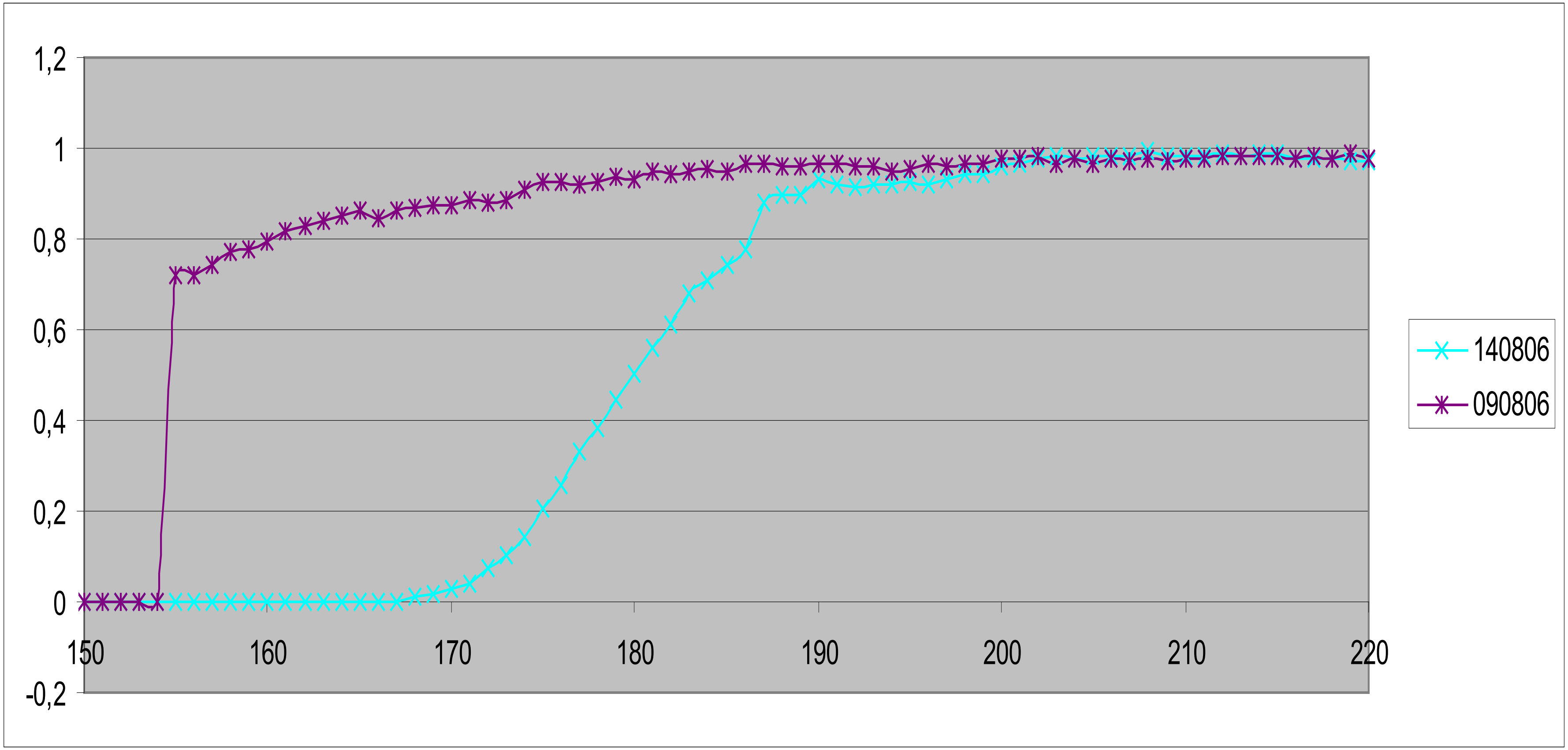
compressors in standard running conditions remove 0.7 l/s from the vessel, corresponding to 1 ‰ of the radiator gas content (80 l) in ~2 min.

In extreme cases (thunderstorms), Δp of several hPa can develop in < 1 min

→ overpressure alarm or (very rarely) even safety bubbler bubbling out.

Very fast increase of atmospheric pressure → underpressure alarm (compressors stopped) or even safety bubbler bubbling in. This happened in 2006

The most relevant gas accident



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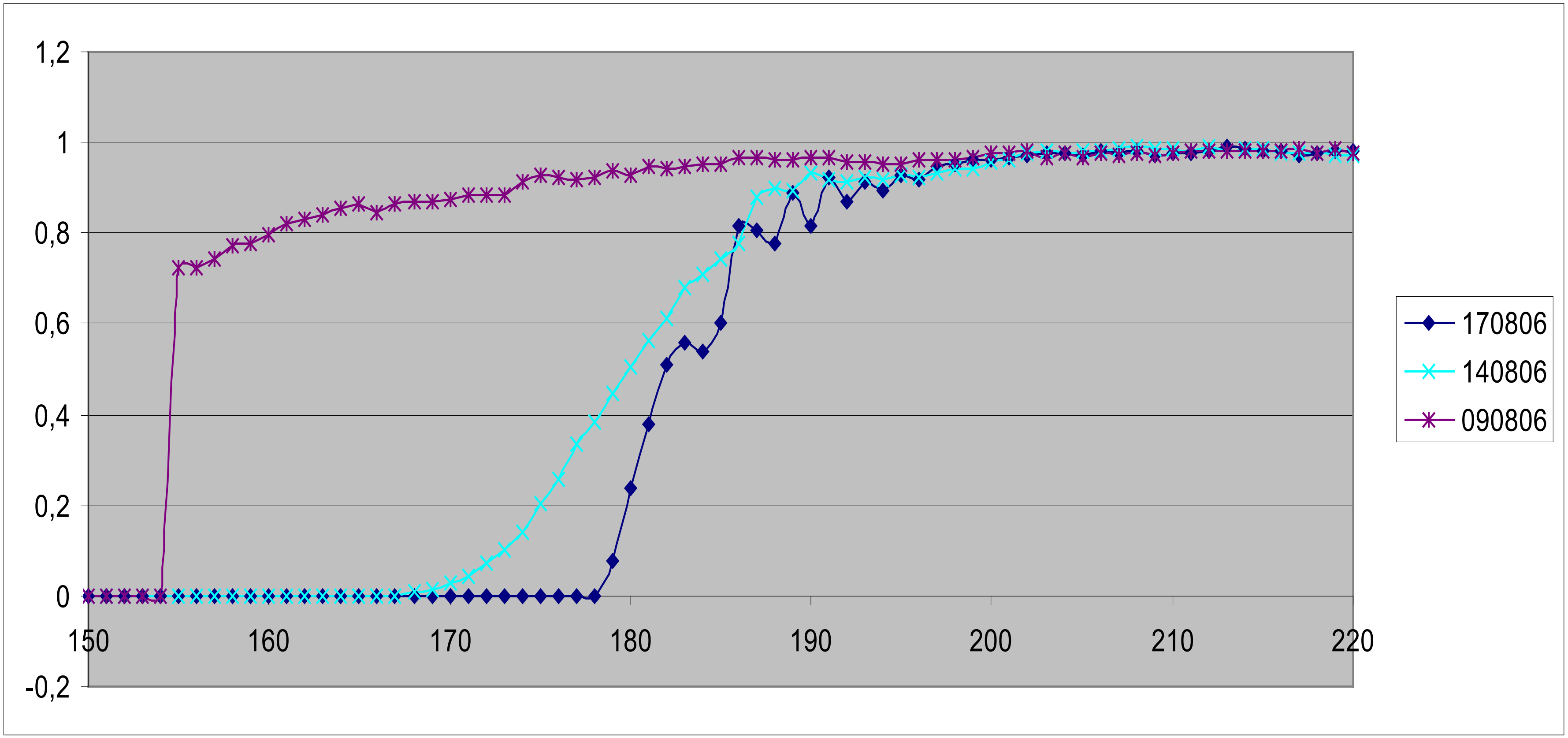

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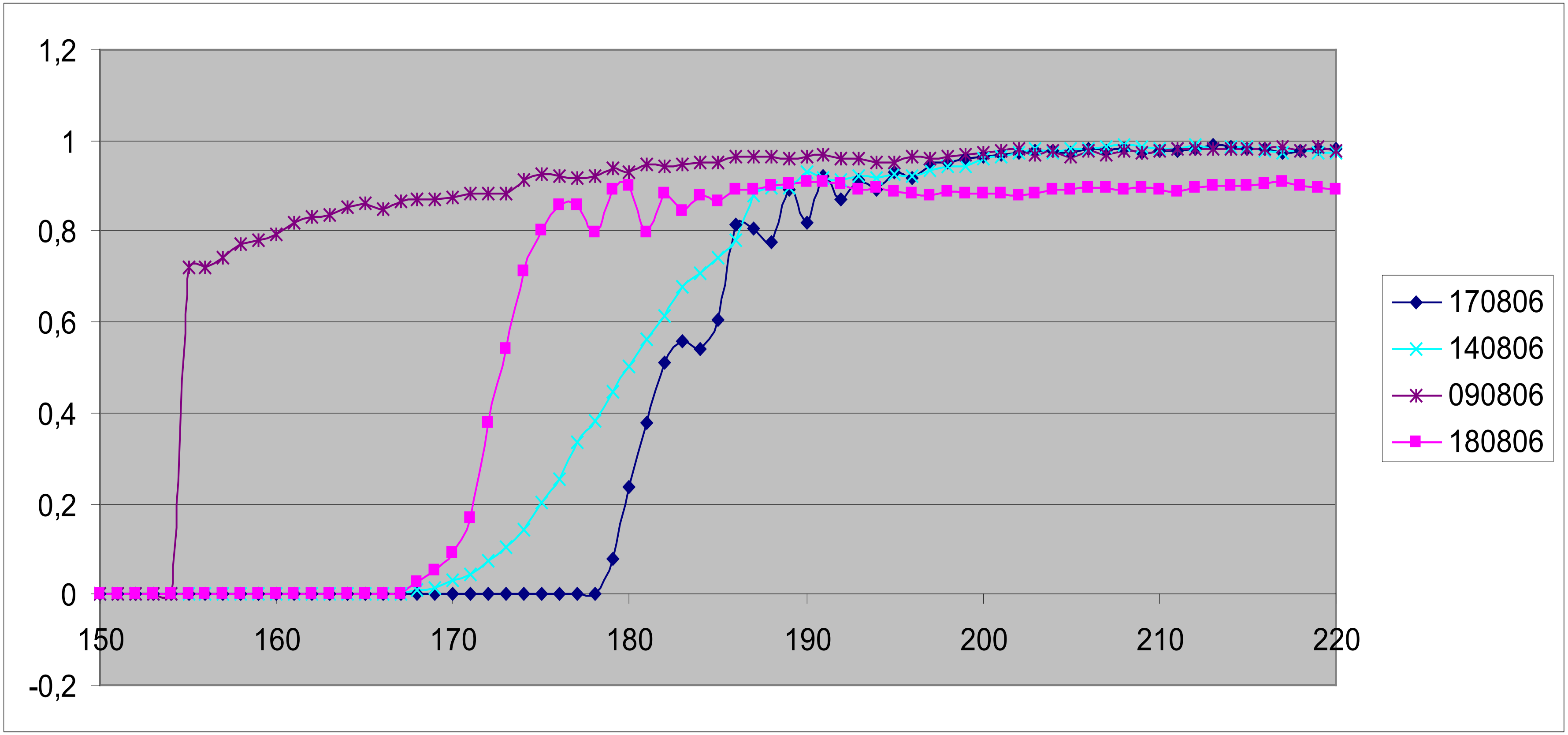
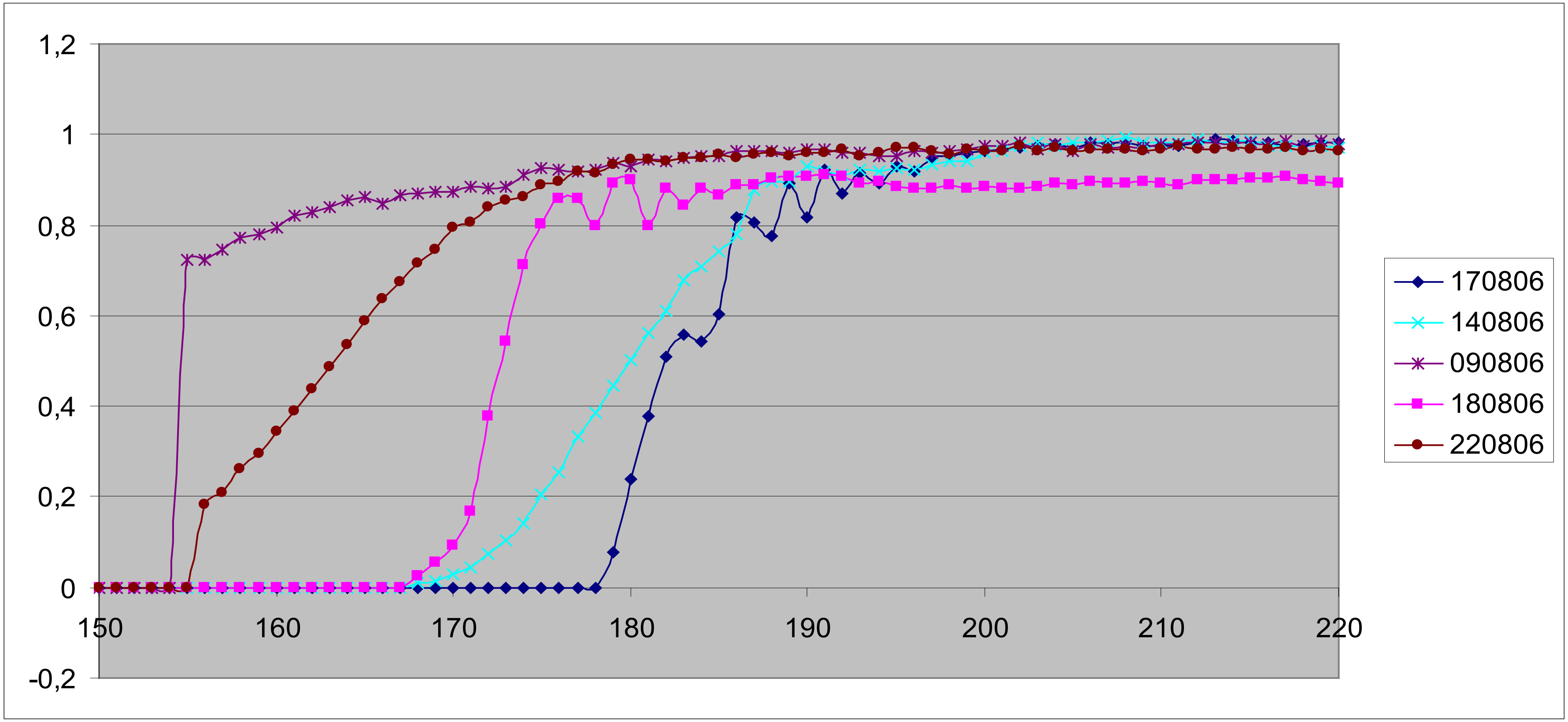
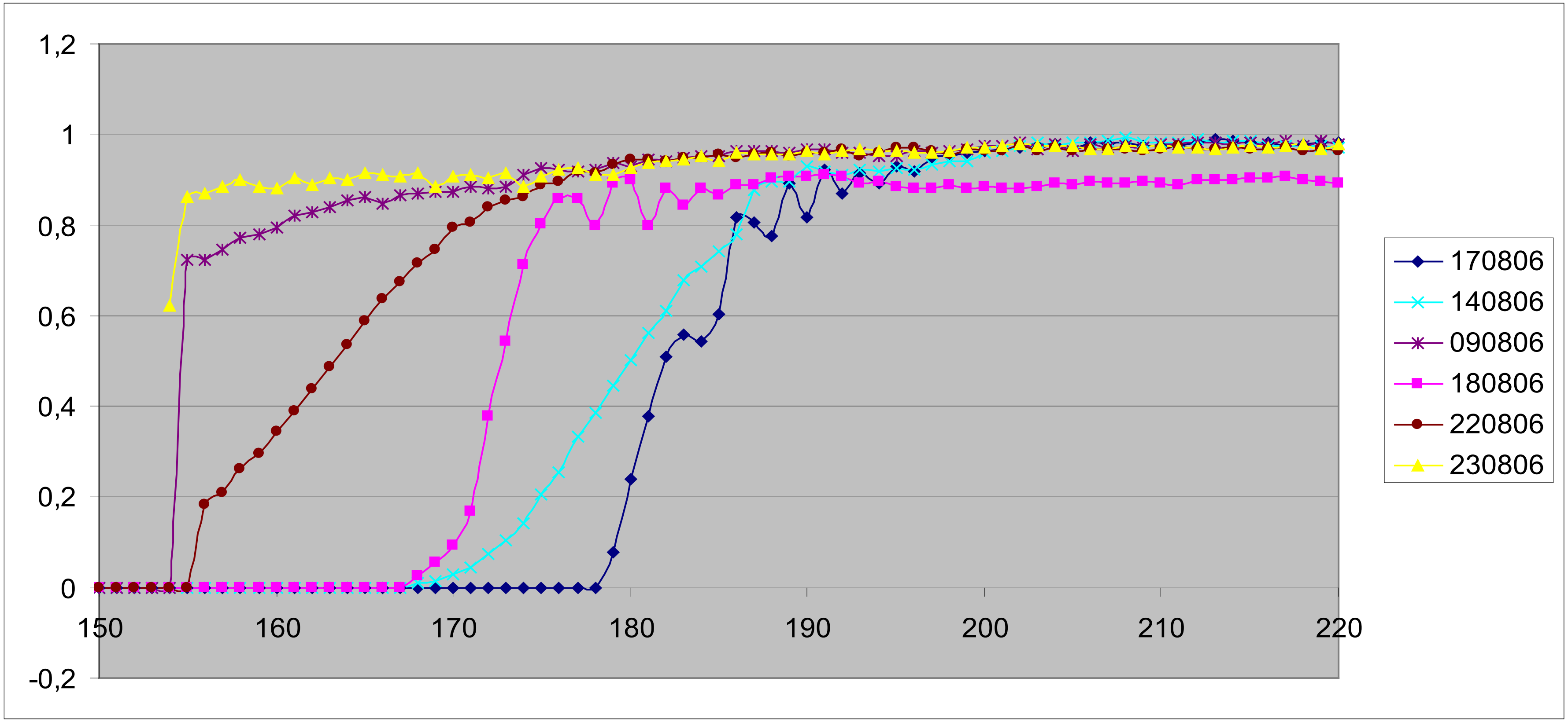


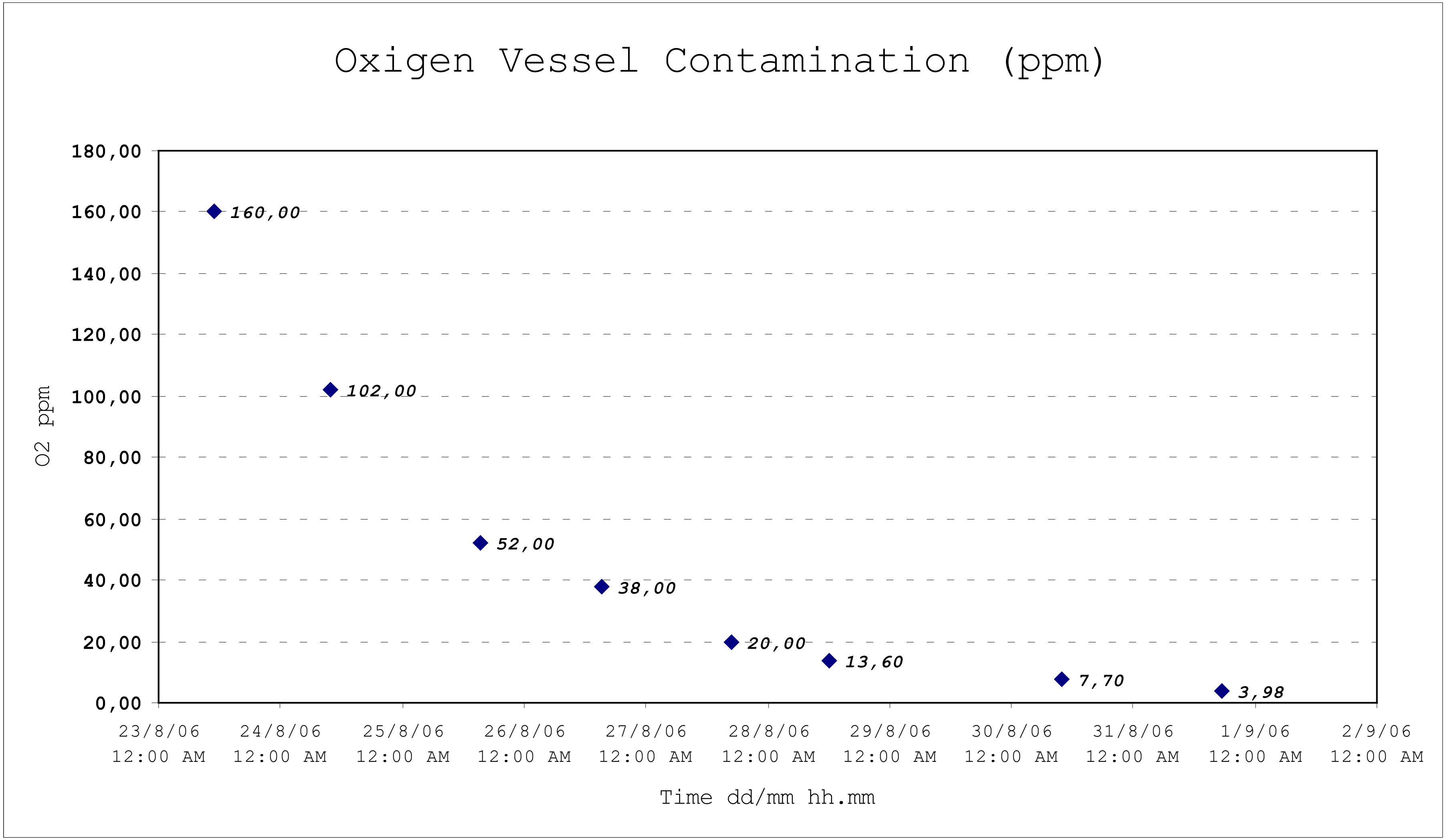
The most relevant gas accident



The most relevant gas accident



The recovery took almost 1 week



Problems with the radiator gas

Buying C_4F_{10} is non trivial (out of market for years)

It comes dirty (very dirty sometimes): pre-cleaning is a must (dedicated system, unavoidable losses, expert manpower)

Inserting it into the vessel (and recovering it) is delicate, losses ~ 2%, incomplete (97.5% maximum)

Critical circulation system with feedback to keep $\Delta p < 0.1$ mbar challenged by weather

C_4F_{10} leaks out (70 l/day): refill is needed

It integrates contaminants: some can be accepted (N_2, Ar), others need continuous filtering out (O_2, H_2O) ; the filters have limited capacitance (significant contaminations fill them quickly); regeneration takes several days

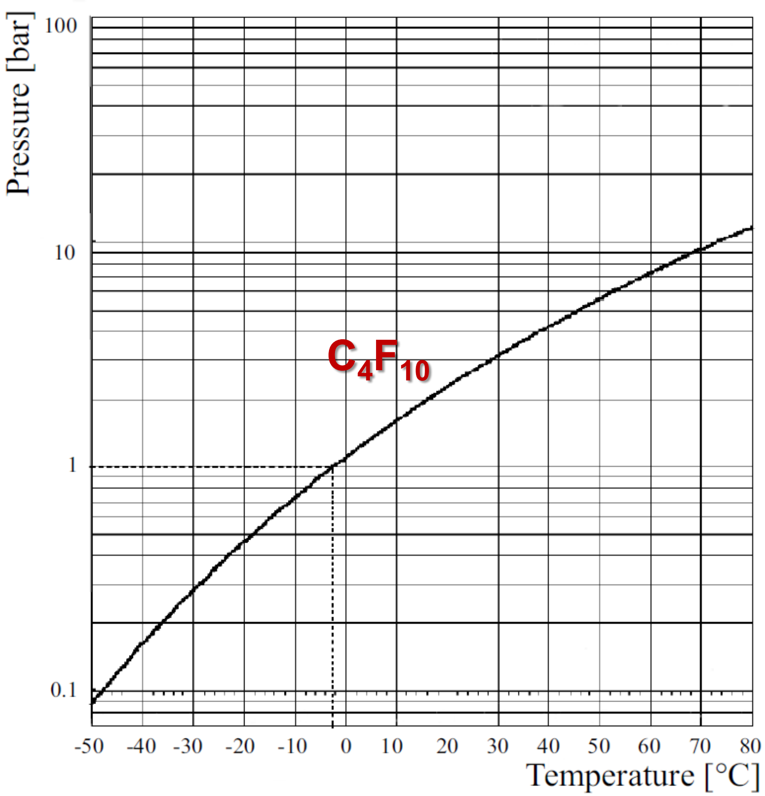
Monitoring the transparency is a must (dedicated system, expert manpower, significant gas consumption for each measurement)

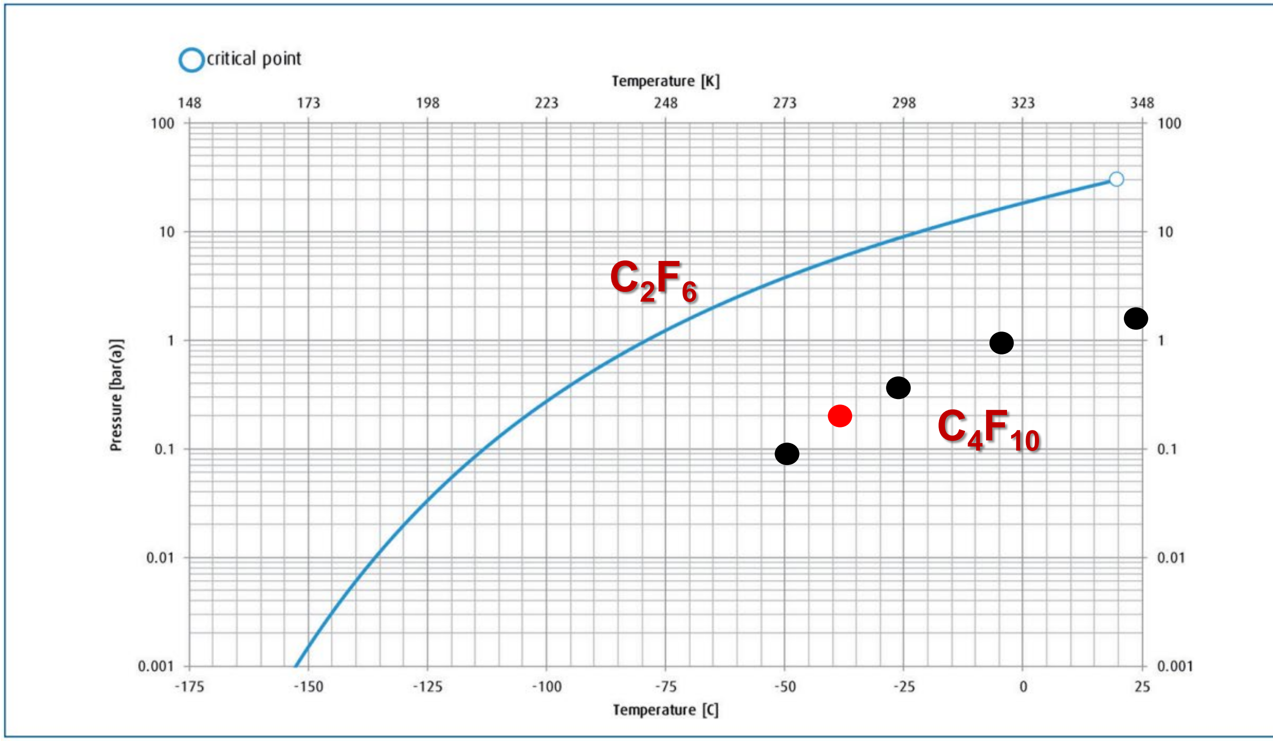
Thermal gradients problem: → new fast circulation (20 m^3/h) implemented in 2009

Accidents can become disasters; emergency intervention to be granted in short time: EXPERT ON CALL 24 h/day, 7 days/week for 7 months/year: heavy load on experts

C_2F_6 separation

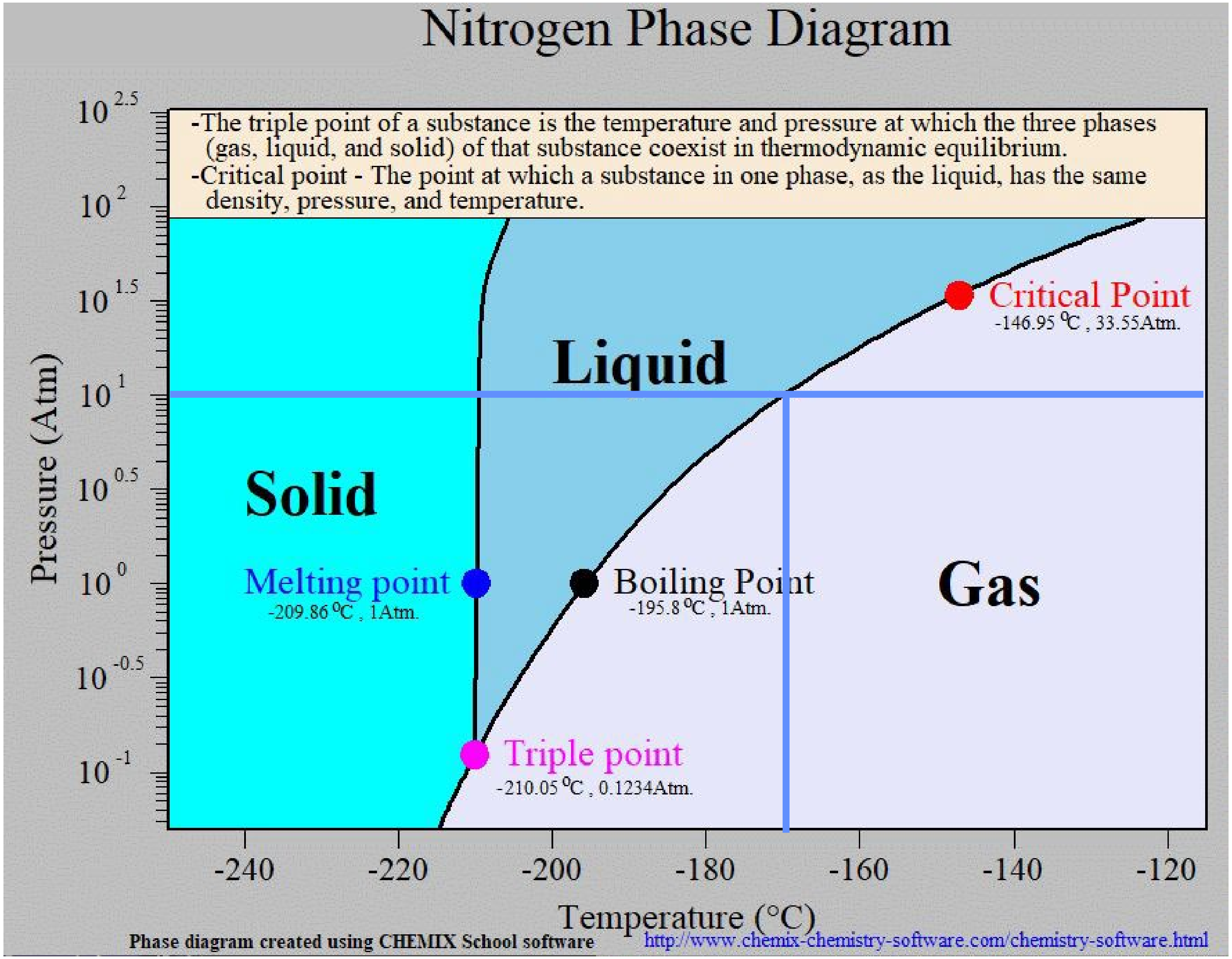
The partial pressures of C_2F_6 and C_4F_{10} are very different



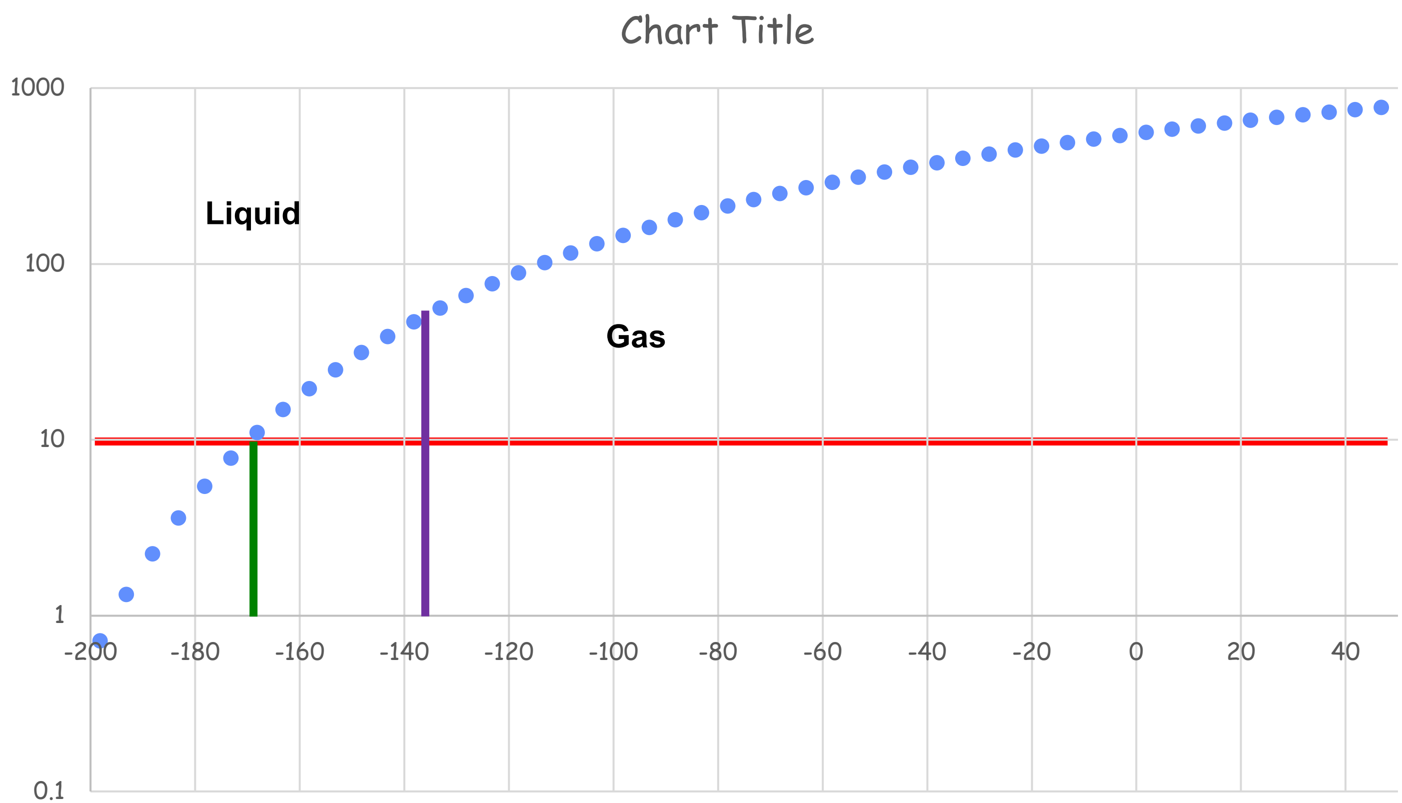


At - 36°C C_4F_{10} has 200 hPa vapor pressure. A separator working at 7 bars will purge 97% N_2 and 3% C_4F_{10}

N_2 Phase diagram

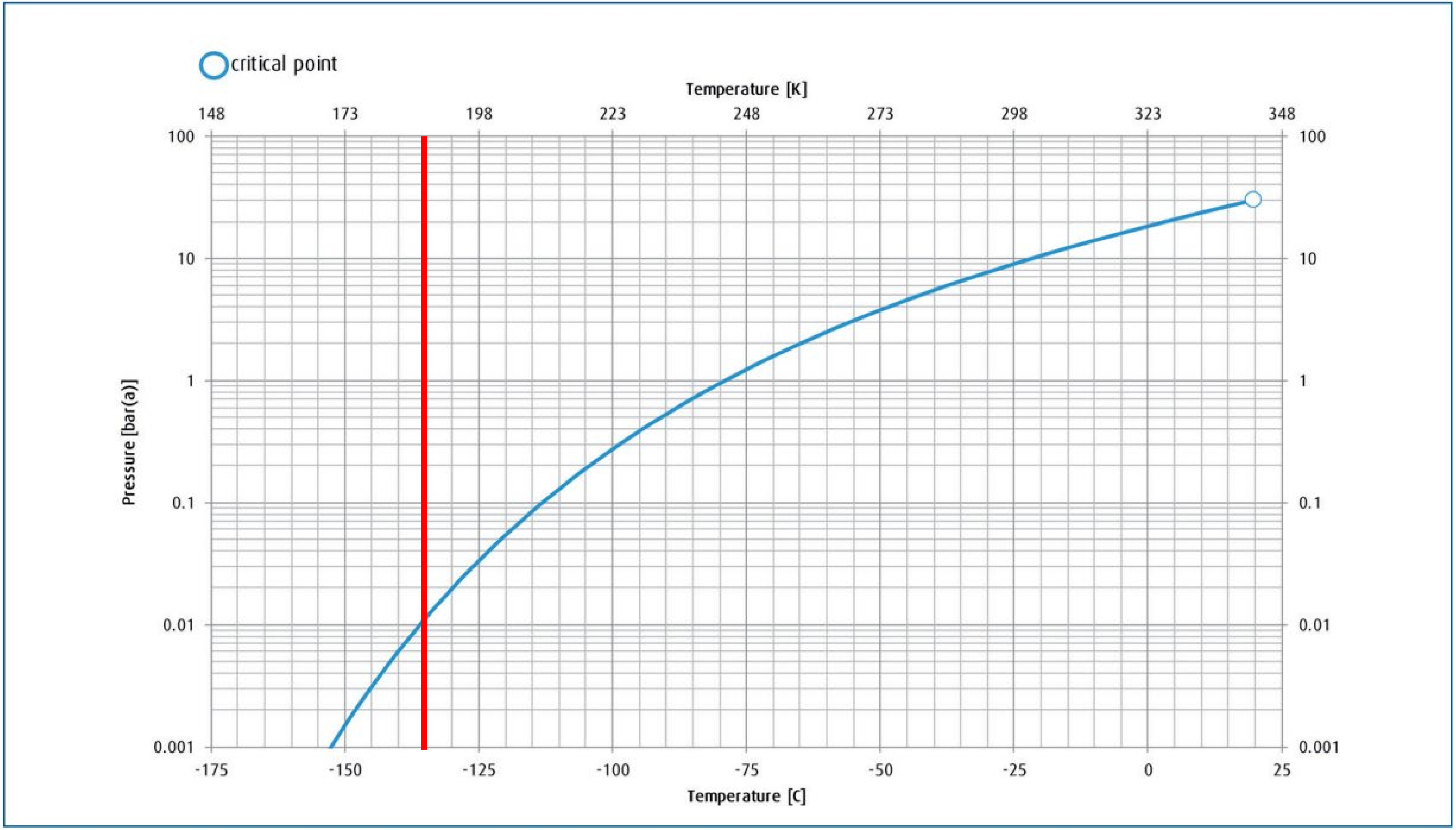


N_2 Partial pressure

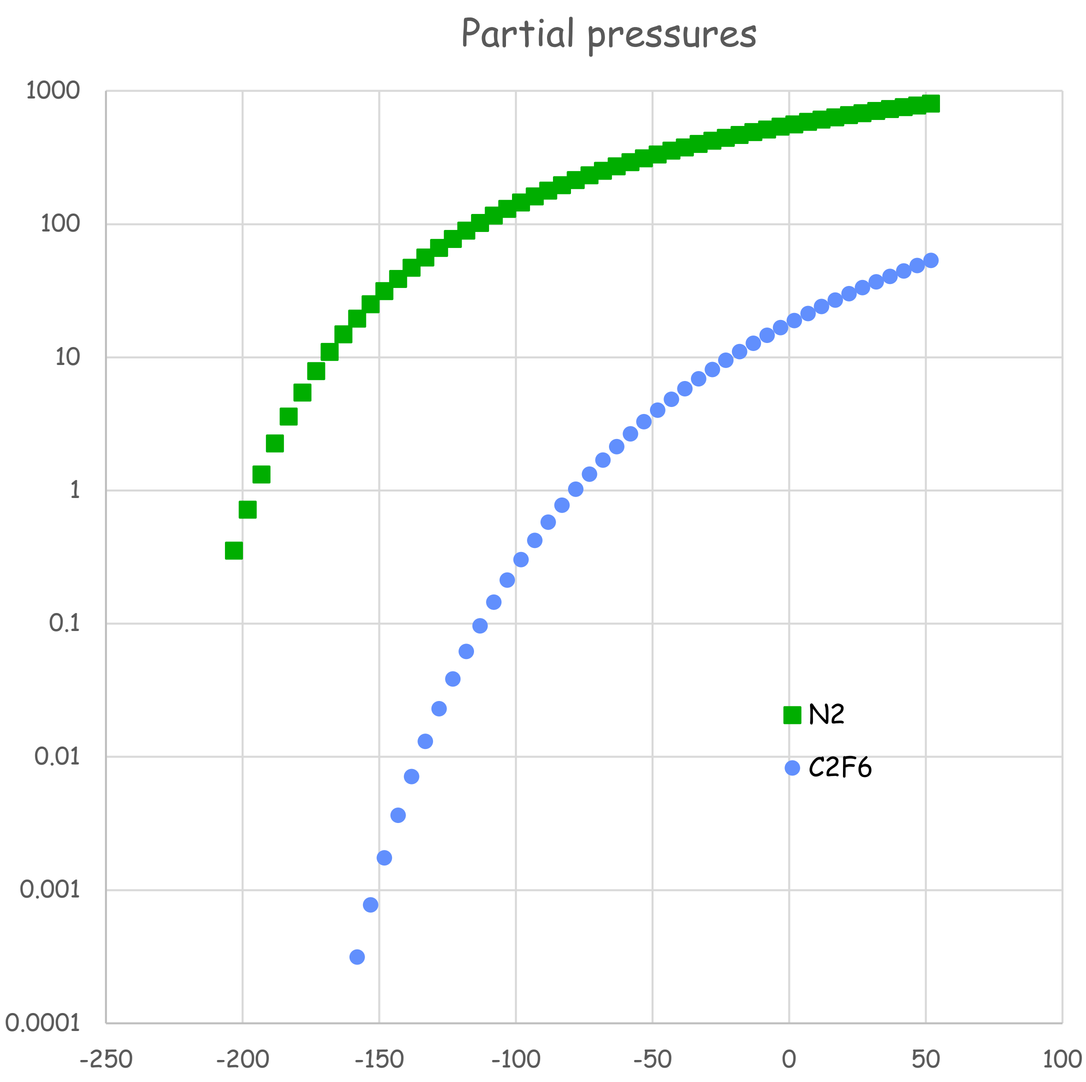


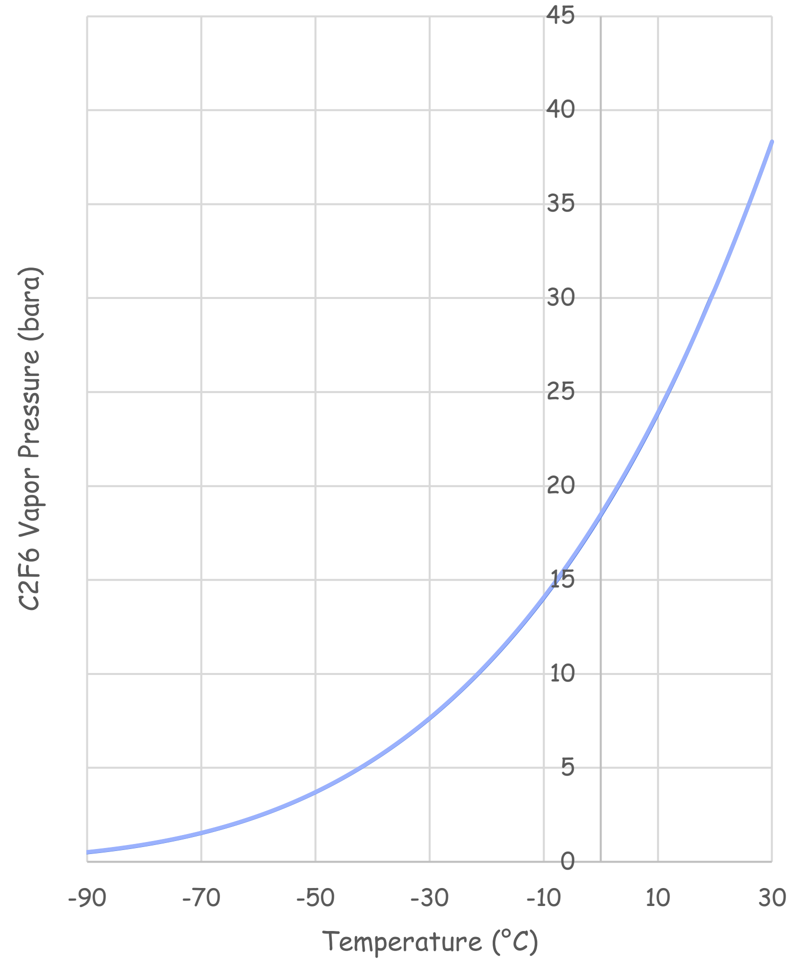
At 10 bar(a) N_2 an is in liquid phase for T > -170°C

C_2F_6 Partial pressure

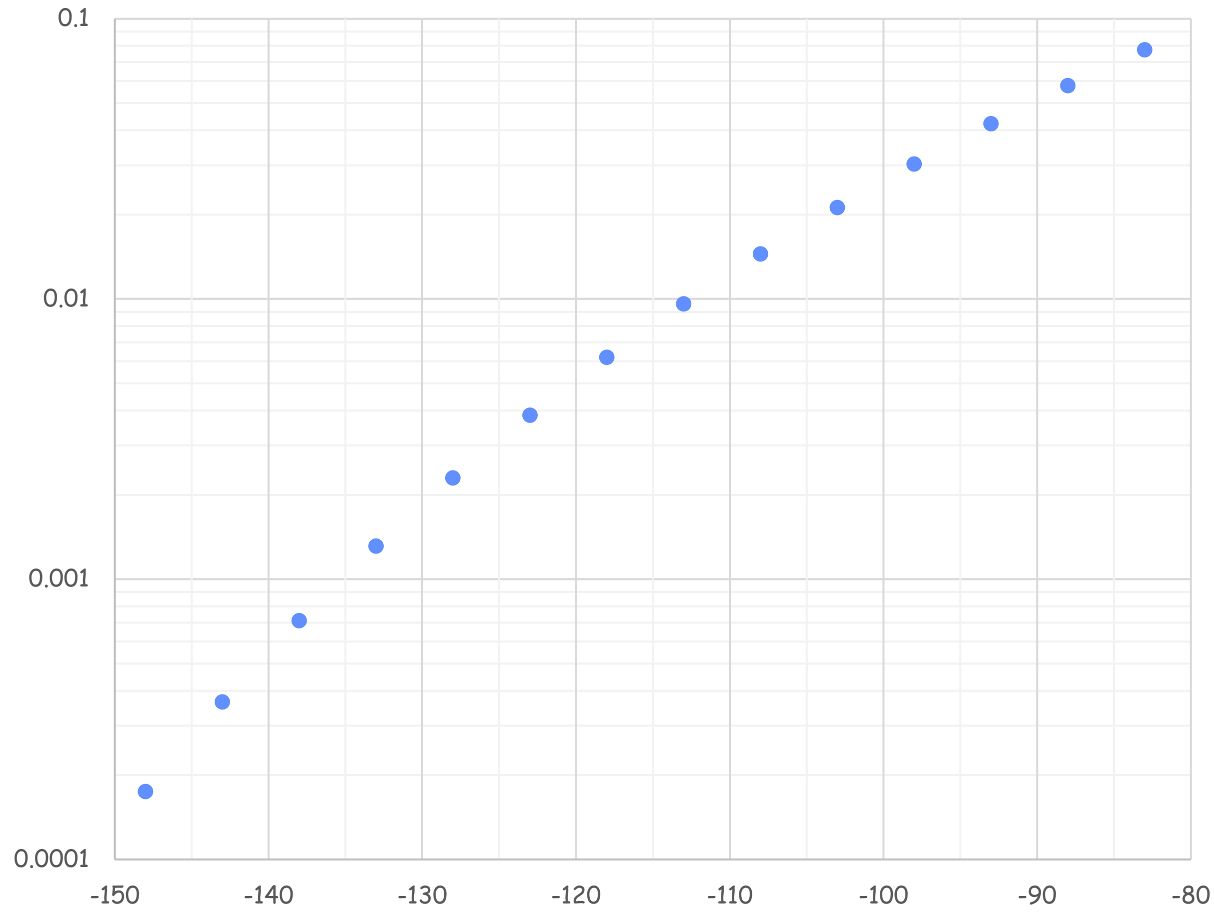


N_2 and C_2F_6 Partial pressure





C_2F_6 fraction in vented gas at 10 bars

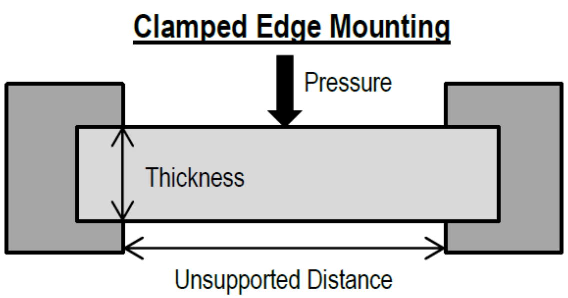


Discussion with Roberto Giuda at CERN to perform a test with a chiller at -98 °C and, possibly, -130 °C

C_2F_6 Transparency measurement

Can be safely performed at room temperature using sapphire windows

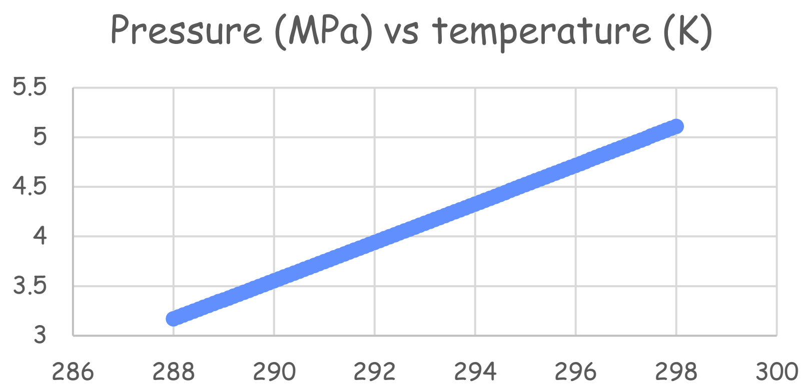
Sapphire	Mechanical Properties
Modulus of Rupture	65,000-100,000 psi ~ 448-689 MPa



$$t = r \cdot \sqrt{\frac{P \cdot K \cdot SF}{M}}$$

$$K = \begin{cases} 0.75 & \text{if mounted with clamped edge(s)} \\ 1.125 & \text{if mounted with unclamped edge(s)} \end{cases}$$

t	= window thickness	t = 5 mm
r	= unsupported window radius	r = 10 mm
M	= Modulus of Rupture,	M = 448 MPa
SF	= Safety Factor,	SF = 4
P	= pressure differential	P = 37 MPa



CONCLUSIONS

COMPASS gas system cannot be easily replicated for C_2F_6

Many lessons from its operation can be learned

It is possible to separate C_2F_6 from N_2 but not simple

A test of separation is being prepared

A measurement of transparency at CERN is being prepared too