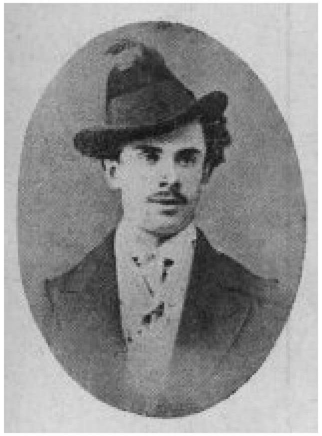
Storage and transfer of cryofluids

Christian Gianese

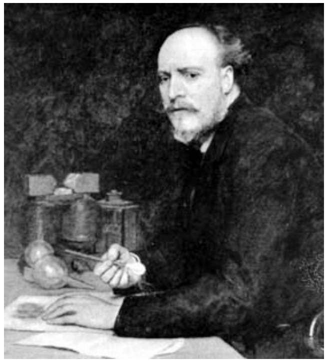
Guilty 1:
Arsène d'Arsonval
(1851 - 1940)

➢ He invented a glass container with double wall, the vacuum being done in the space between the outer and inner walls: the vase d'Arsonval.



About 1902, he collaborated with Georges Claude on the liquefaction of gases and inspires industries Air Liquid.

Guilty 2:
James Dewar
(1842 - 1923)



- He discovered a process to produce liquid oxygen in 1891 and liquid hydrogen in 1898, in industrial quantities.

- He developed an insulating bottle, the Dewar flask, still named after him, to study low temperature gas phenomena.
In fact, he improves the d'Arsonval vessel by depositing a layer of silver on the inside wall, to minimize the heat input by radiation.

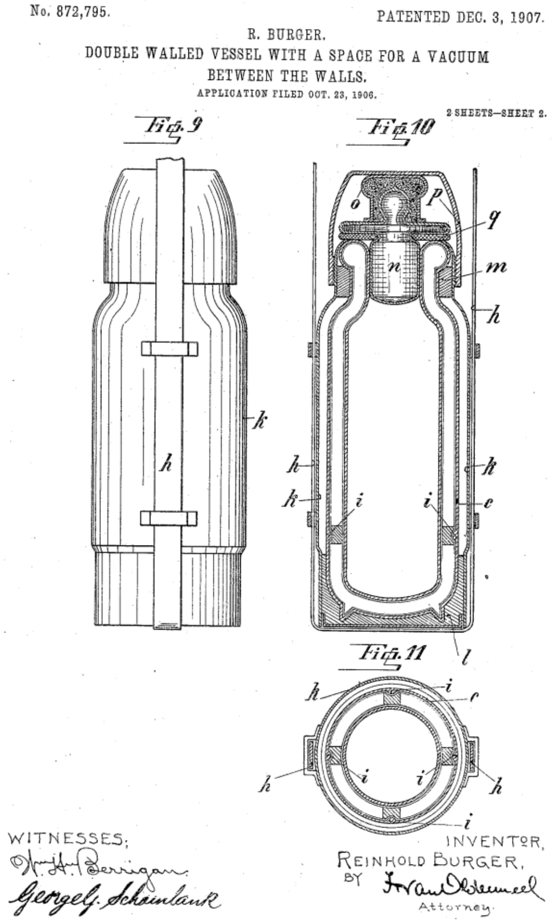
He also used this bottle to transport liquid gases such as hydrogen.

In 1905, he observed that cold charcoal could produce a vacuum.

Thermos

➢ The first vacuum flasks for commercial use were made in 1904 when a german company, Thermos GmbH, was formed.

Thermos, their tradename for their flasks, remains a registered trademark in some countries but was declared a genericized in the US in 1963 as it is colloquially synonymous with vacuum flasks in general; in fact it is far more common to speak of a domestic *thermos* than a *vacuum flask*.



STORAGE

The most important factors in storage systems

- Logistics
Volume of storage, dimensions, transport, etc

- Reliability, safety

- Economics

⚠ Rate of evaporation of cryogenic liquids (helium: 1 watt evaporates 1.4 L/H !!)

↓

Insulation

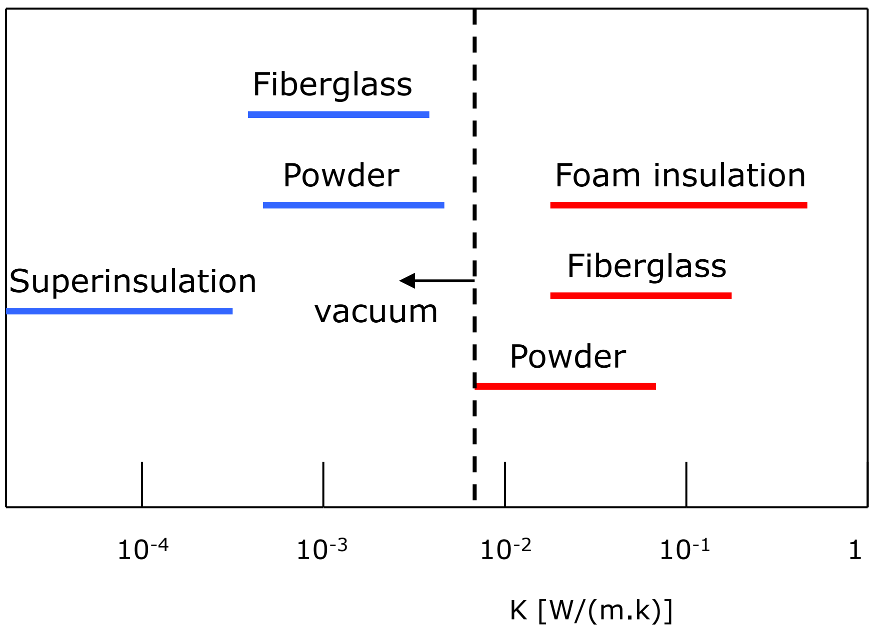
Insulation

Control of the mechanisms of heat transfer

↓

Cf: C.ENSS's course

Insulating materials



Foam insulation

Polystyrene foam: *(« Styrofoam »)*

Not used much for cryogenics (poor thermal properties and permeable in water)

Application: small LN2 tank (~10L)

Polyvinylic foam: *(« Klegecell »)*

One of the foam most used for cryogenics

Applications: insulation of the tanks of LPG tankers, insulation of cryogenics tank of the missile Ariane

Polyurethane foam

Easiness of implementation

Applications:transport by tank of natural gas, insulation of most refrigerators and freezers

Powder

- Good insulation when they are used under vacuum

⚠ Problems: heavy equipment, tendency to pack and to break

Less used

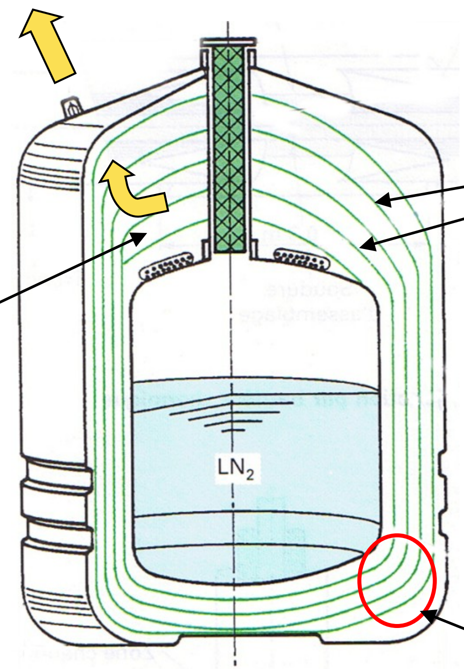
↓

Replaced by superinsulating material
Use, in most cases, in cryogenic work

Super Insulation

☑ and eliminate gaseous conduction

« eliminate pressure between walls »



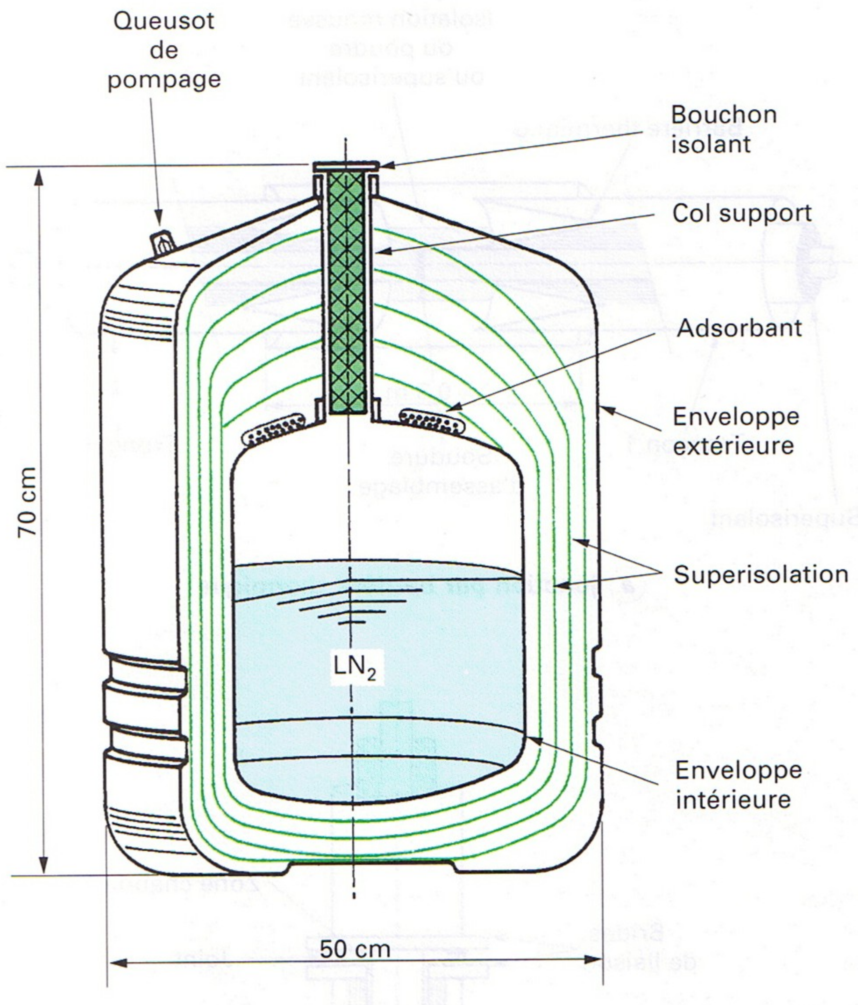
☑ Reduce exchanges of heat transfer by radiance

« interpose shields between the hot wall and the cold wall »

☑ without increasing exchanges by conduction solid

« minimize contacts between schields »

LN2 Storage



(a) **réservoir d'azote liquide à longue autonomie (60 L)**

LN2 Aluminium storage

Example:

Capacity: 2 L to 100 L

Weight full: 4.3 Kg for 2L
110 Kg for 100 L

Evaporation: ~0.6 L/day for 100 L

Price: ~ 550 € for 12 L
(Cryo Diffusion)

LN2 stainless steel storage

Example:

Capacity:	120 L to 600 L
Weight full:	190 Kg for 120 L 850 Kg for 600 L
Evaporation:	1.7 L/day for 120 L 1 L/day for 850 L
Price:	~ 4000 € for 200 L *(Cryo Diffusion)*

Chariot à roulettes pour le RBP 200 VLN
Réf. 9918272
Handling cart for RBP 200 VLN
Ref. 9918272

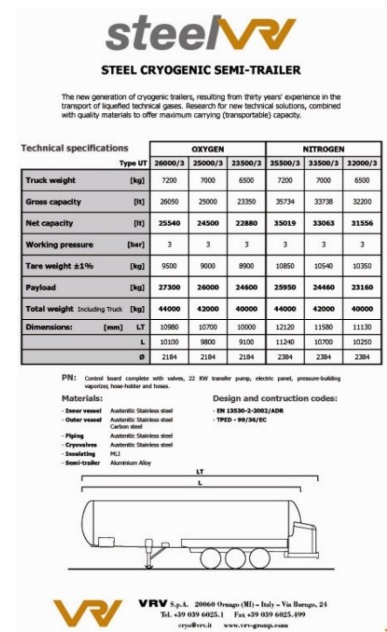
Large storage, transport

Generaly, these reservoirs are leasable

Ex: Institut Néel
(Messer)

3000 L: ~300 €/month
16 000 L: ~600 €/month

1000 liters, 3000 liters, ….,
30 000 liters and more …



steelVRV

STEEL CRYOGENIC SEMI-TRAILER

The new generation of cryogenic trailers, resulting from thirty years' experience in the transport of liquefied technical gases. Research for new technical solutions, combined with quality materials to offer maximum carrying (transportable) capacity.

Technical specifications

		OXYGEN			NITROGEN		
	Type UT	26000/3	25000/3	23500/3	35500/3	33500/3	32000/3
Truck weight	[kg]	7200	7000	6500	7200	7000	6500
Gross capacity	[lt]	26050	25000	23350	35734	33738	32200
Net capacity	[lt]	25540	24500	22880	35019	33063	31556
Working pressure	[bar]	3	3	3	3	3	3
Tare weight ±1%	[kg]	9500	9000	8900	10850	10540	10350
Payload	[kg]	27300	26000	24600	25950	24460	23160
Total weight Including Truck	[kg]	44000	42000	40000	44000	42000	40000
Dimensions: [mm]	LT	10980	10700	10000	12120	11580	11130
	L	10100	9800	9100	11240	10700	10250
	ø	2184	2184	2184	2384	2384	2384

PN: Control board complete with valves, 22 KW transfer pump, electric panel, pressure-building vaporizer, hose-holder and hoses.

Materials:

- Inner vessel: Austenitic Stainless steel
- Outer vessel: Austenitic Stainless steel, Carbon steel
- Piping: Austenitic Stainless steel
- Cryovalves: Austenitic Stainless steel
- Insulating: MLI
- Semi-trailer: Aluminium Alloy

Design and contruction codes:

- EN 13530-2-2002/ADR
- TPED - 99/36/EC

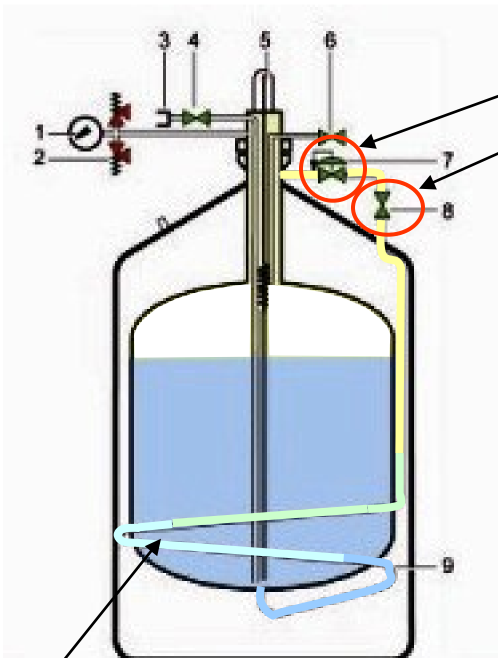
LT
L

VRV S.p.A. 20060 Ornago (MI) - Italy - Via Burago, 24
Tel. +39 039 6025.1 Fax +39 039 6025.499
cryo@vrv.it www.vrv-group.com

Pressure building system

Pressure regulator

Pressure building valve

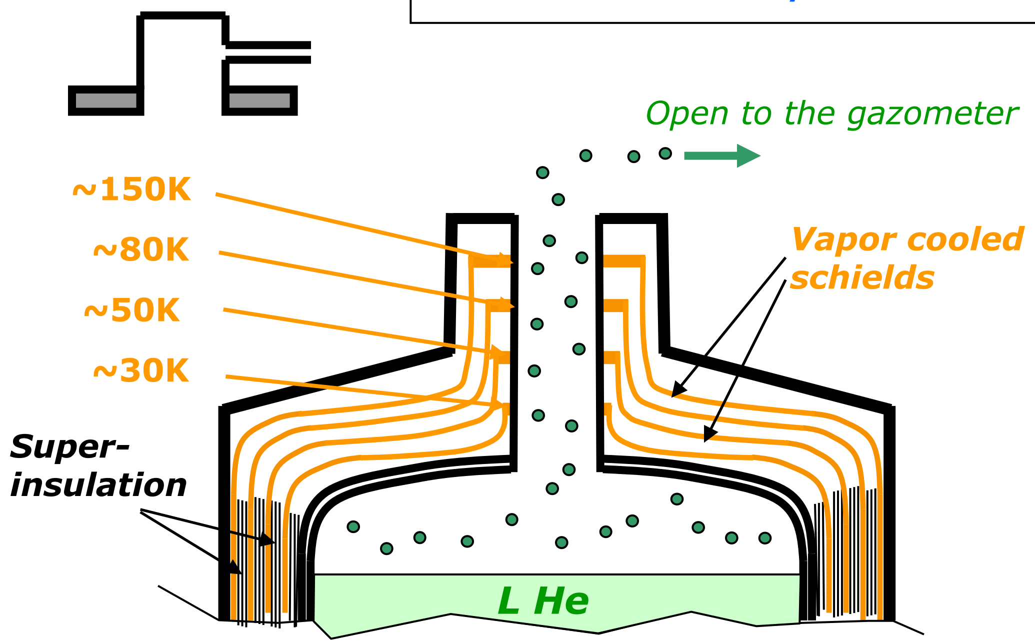


Pressure building heating coil

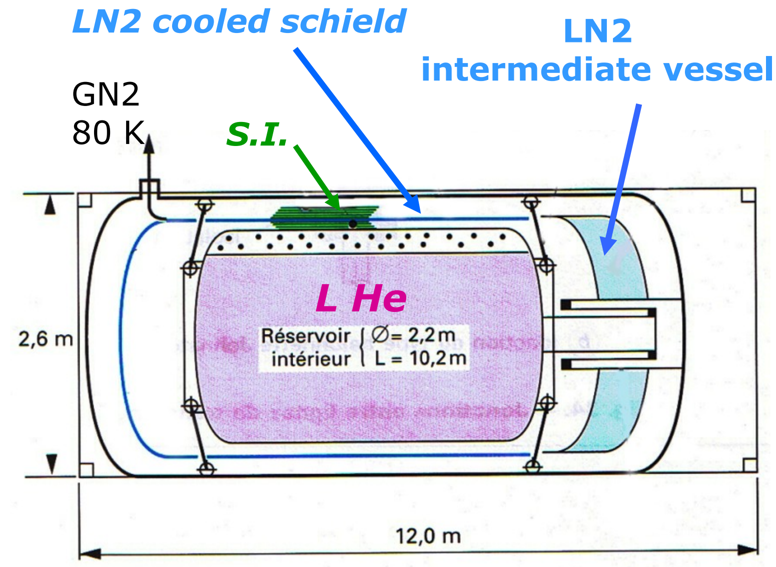
Helium or hydrogen storage

➤ The enthalpy of vaporization of helium (or hydrogen) is so weak that, even with the superinsulating material, the losses of gases would be considerable.

It is necessary to recover the enthalpy of gas.



« open » vessel



« closed » storage

Liquid helium containers

Aluminium série
~ 50L to 250L

NMH100: 4 742€
(Cry Diffusion)

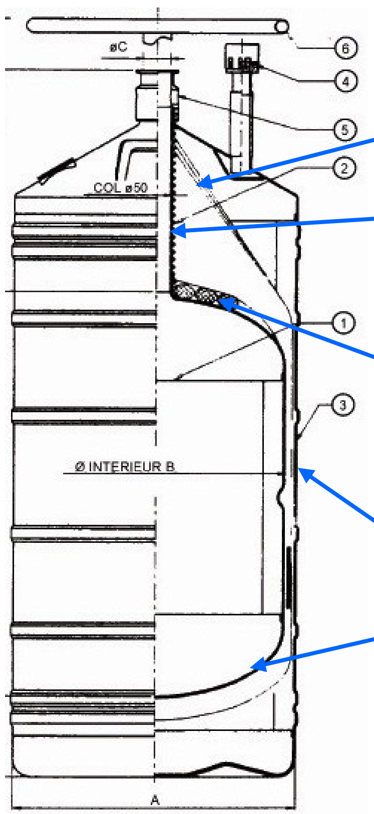
Stainlees steel série
~ 50L to ...

SPÉCIFICATIONS TECHNIQUES ***TECHNICAL SPECIFICATIONS***

	MSB 30	MSB 60	MSB 100	MSB 250	MSB 450	MSB 500	MS 1000	MS 2000	MS 3000	MS 5000
Capacité totale (l) *Total capacity (l)*	32,8	64,4	102,6	265	449	500	1106	2120	3300	5500
Poids à vide (kg) *Empty weight (kg)*	52	63	77	180	248	258	610	1100	1480	3050
Poids plein LHe (kg) *Full weight LHe (kg)*	56	71	89,7	212	305	320	735	1338	1855	3675
Raccordement tête mobile *Mobile head connection*	NW 50	NW 50	NW 50	NW 50 (1) bride/flange (2)	NW 50 (1) bride/flange (2)	NW 50 (1) bride/flange (2)	bride *flange*	bride *flange*	bride *flange*	bride *flange*
Pression max de service (bar) *Max working pressure (bar)*	0,5	0,5	0,5	0,5	0,5	0,5	0,9**	1**	1**	1**

Example:
Loss rate
(Cryo Diffusion) ⇨

Aluminium liquid helium containers

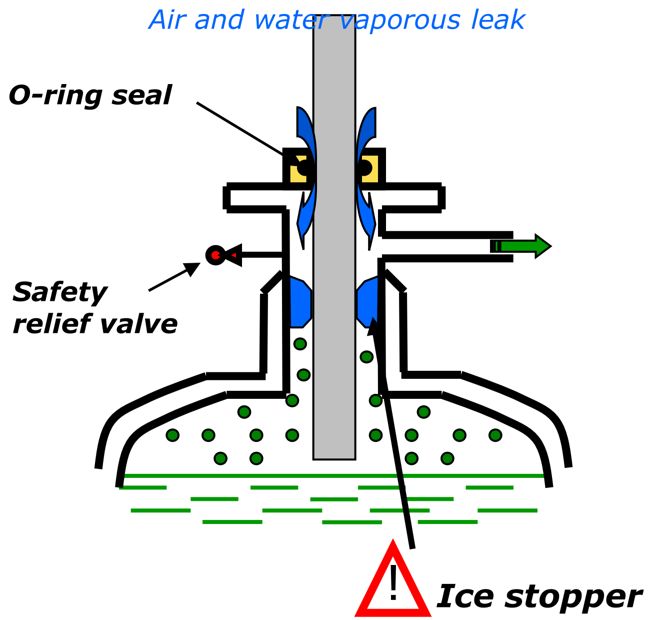


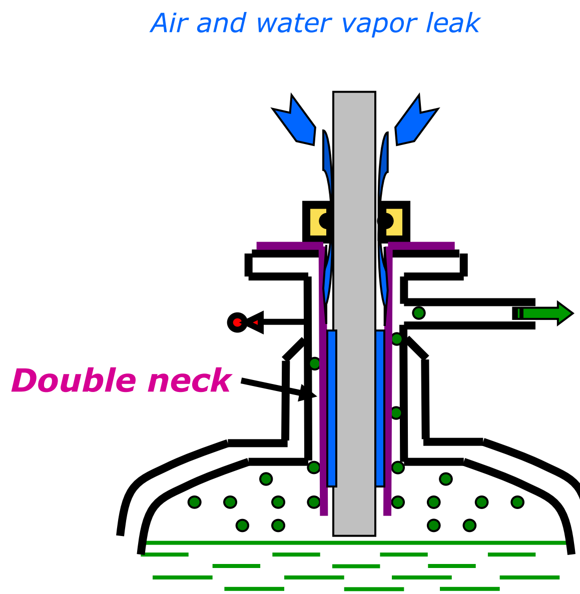
- Lihtweight, compact configuration,
- Low consumption

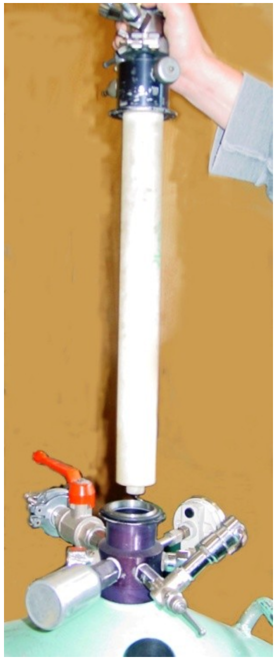
- **Non-magnetic**: this characteristic is particularly attarctive for applications using high magnetic fields

> ⚠ ***Keep this vessel at low temperature !***
>
> ***Fiber glass can be permeable to helium at room temperature***
>
> ***Connect the inner vessel to primary pump if you have to warm up***

Double neck


Air and water vaporous leak
O-ring seal
Safety
relief valve
Ice stopper


Air and water vapor leak
Double neck



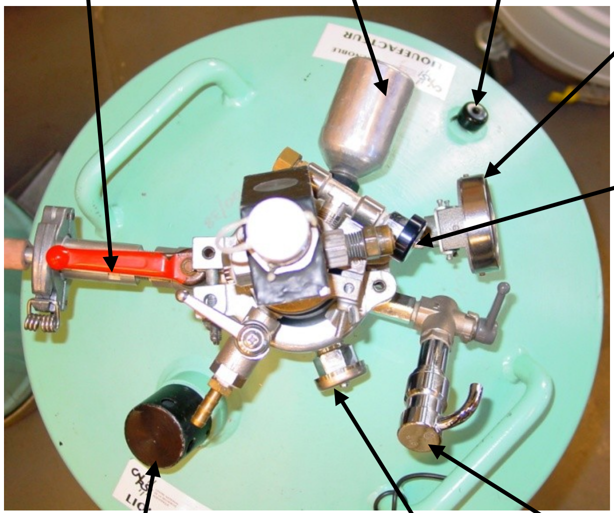
Safety

Taconis oscillation damper

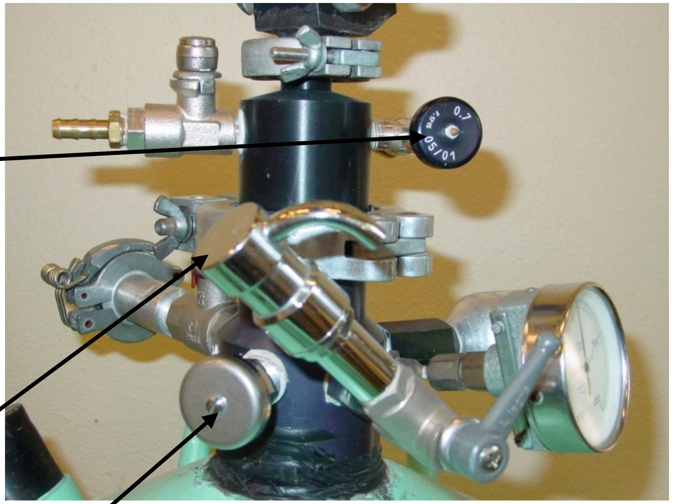
Vacuum pump valve

Vent valve

Pressure gauge



Safety relief valve
set to 0.7 bar
(on the double neck)



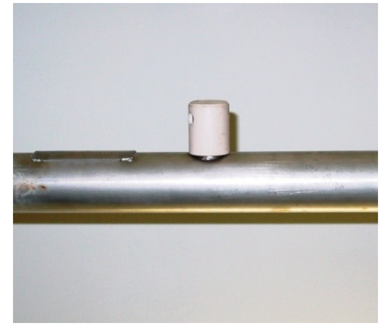
Transport
pressure relief
valve
set to 0.06 bar

Vacuum burst disc

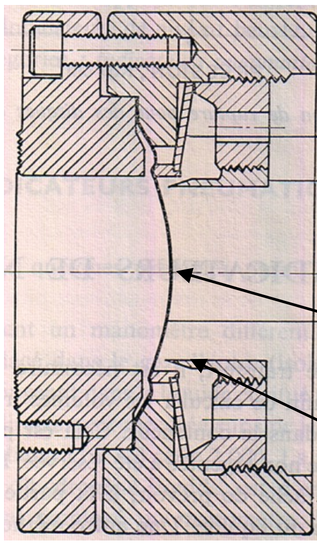
Safety relief valve
set to 0.7 bar

Safety

Burst disc



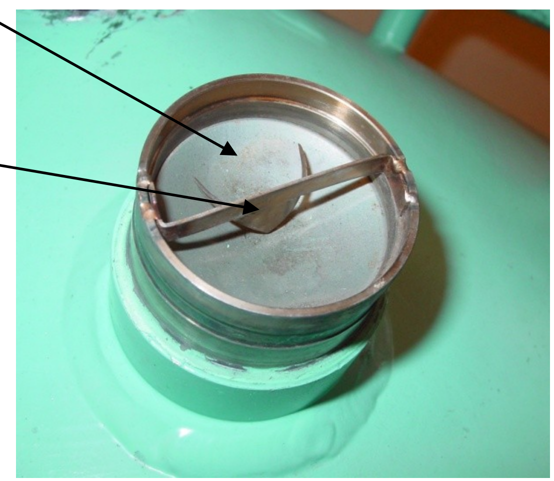
Safety on transfer line



burst disc

knife

Helium vessel



Transfer of liquefied gases

Important considerations when using cryogenic fluids

The choices depend on two main factors:

- Economic aspect
- Efficiency, performance

Examples:

For the common needs in liquid nitrogen of an experiment, a simple tube is enough, but, it is necessary to use a super-insolating line for liquid helium.

The losses depend on two factors:

- Insulation of the line
- Expansion of a part of transferred fluid

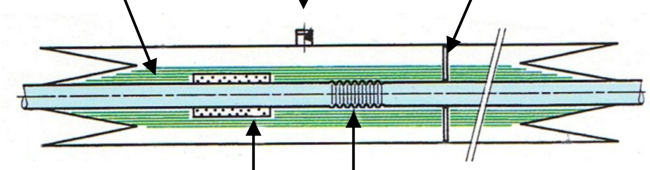
Uninsulated line

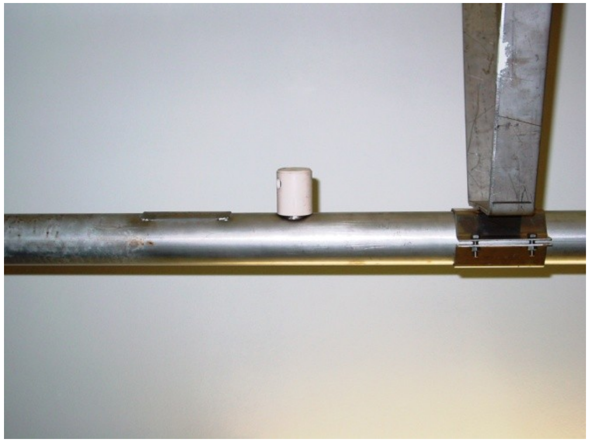
- Only with liquid nitrogen
- Short lenght
- Important icing
- Important losses (~a few liters/hour by linear meter)

Foam insulated line

- Only with liquid nitrogen
- Cheap
- Required performances (~30 to 50 watt/meter)

Superinsulated line





Superinsulated line

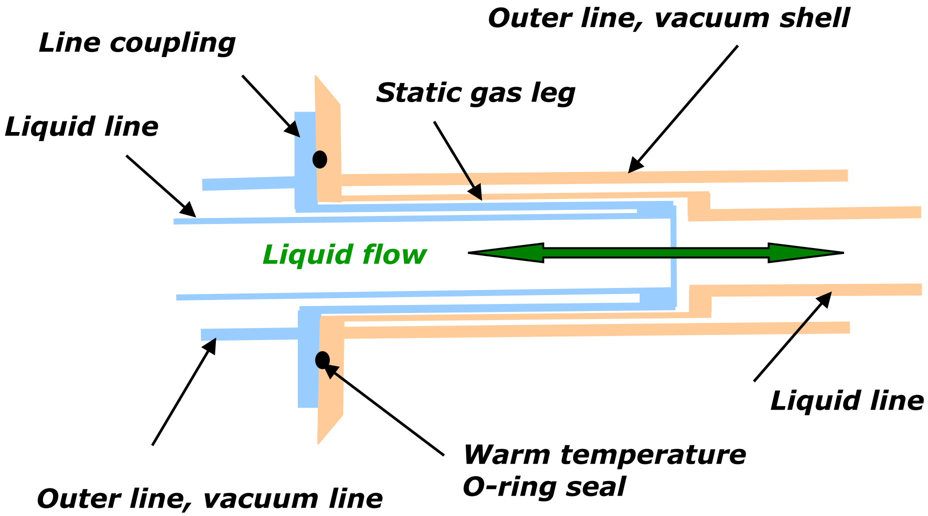
- Used with liquid nitrogen, hydrogen, helium, ….
- Very good performances (< 1 watt/meter)
- Weak thermal inertia
- Insulating material is suitable for the manufacture of flexible lines

Helium flexible vacuum-insulated transfer line

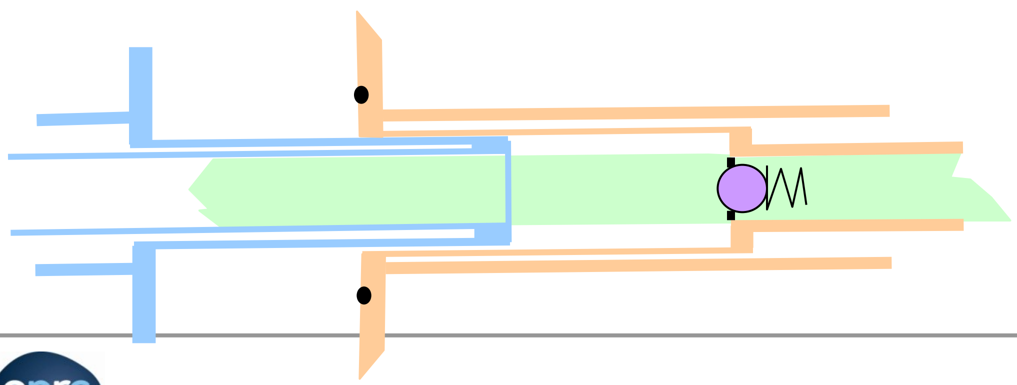
Helium vacuum-insulated transfer line

The 27 kms lines used to transfer 1.8K Helium LHC CERN

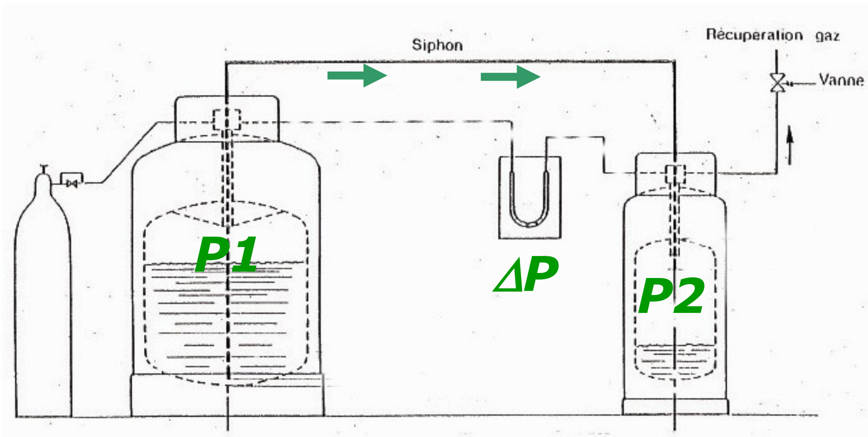
Bayonet joint



- Cool down ~1liter
- Losses ~0.5 watt (0.7 l/h)



Transfer losses by expansion



The transfer of a given quantity of liquid at pressure P1 to a pressure P2 evaporates a part of the fluid. Constant enthalpy process.

Important with helium

$$X\,(\%) = \frac{H_{Liq(P1)} - H_{Liq(P2)}}{H_{Vap(P1)} - H_{Vap(P2)}}$$

Transfer with ΔP weak ! (200 mbar maxi)

ΔP=500 mbar ⟹ 20% vaporised

ΔP=200 mbar ⟹ 7% vaporised