Cryogenic Safety – Fundamentals (en)

Training objectives

Be able to identify existing risks in their work area, applying safety measures to minimize risks, and react efficiently in case of malfunctioning.

Course content

1. Cryogenics at CERN

2. Introduction

3. Cryogenic Hazards

- Physiological risks
- Technical risks

4. Safety Practices and Instructions

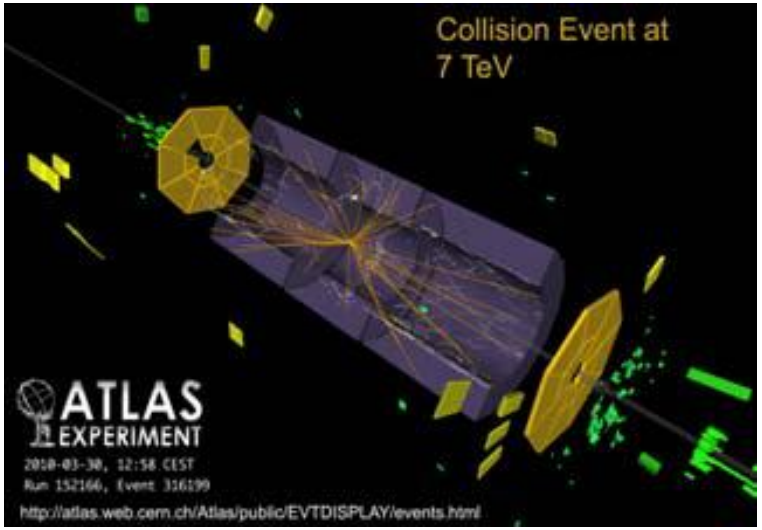
- Preventive and protective measures
- Good safety practices

5. Practical Demonstrations and Test

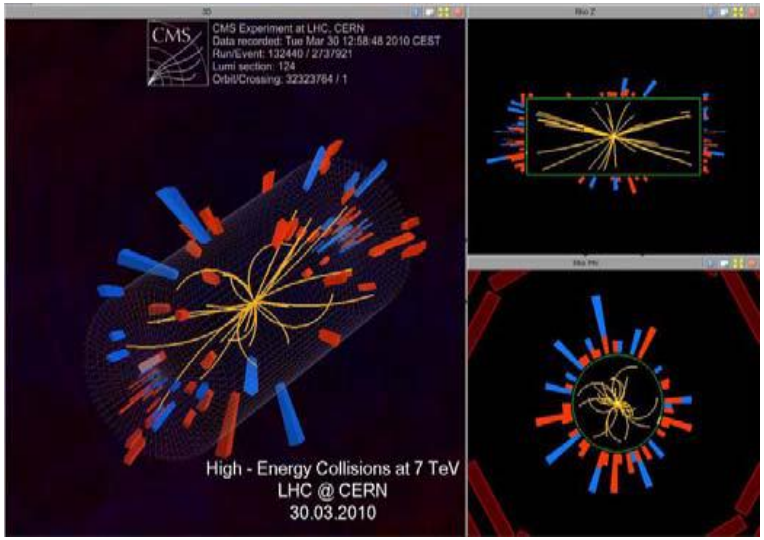
Cryogenics at CERN

Cryogenics at CERN

Main users – Physics detectors

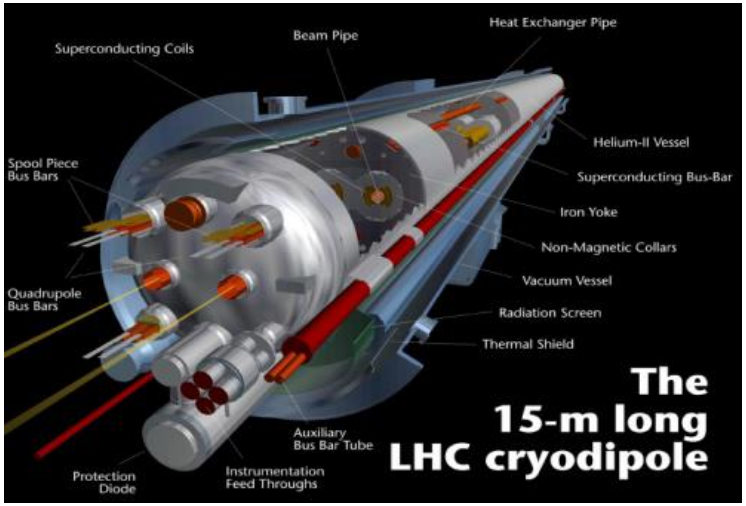


Superconducting coils of LHC detectors (ATLAS, CMS)



Different types of cryogens (Helium, Nitrogen and Argon)

Cryogenics at CERN
Main users – Physics detectors



Superconducting magnets of LHC accelerator

Helium at different operating temperatures (thermal shields, beam screens, distribution and magnets,…)

Cryogenics at CERN
Refrigeration plants/units and liquefiers

- Refrigeration plants (warm compressor stations and cold boxes – e.g., LHC, ATLAS, CMS)
- Refrigeration units (e.g., LHC cold compressor units)
- Liquefiers (Central Liqu., SM18, ISOLDE, CAST...)

Cryogenics at CERN
Storage and distribution

GHe 20 bar

QRL

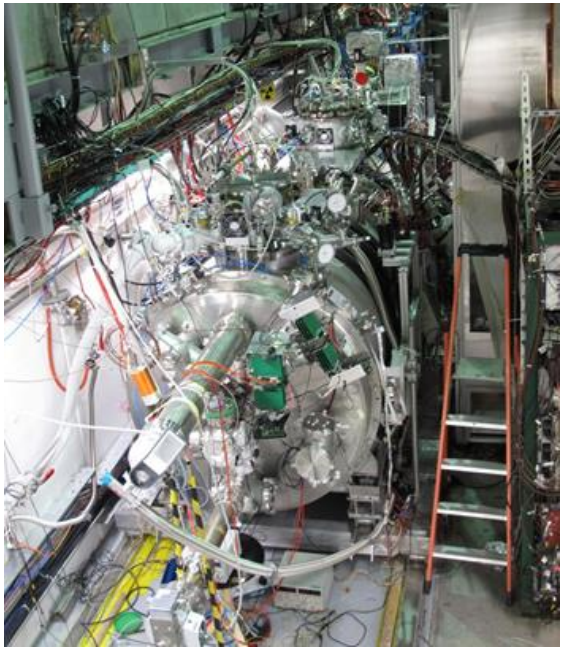
LN_2 at 80 K

LHe at 4.5 K

- Storage vessels: warm compressed gas or cryogenic
- Networks of distribution lines (warm and cryogenic)

Cryogenics at CERN
Other users – AD hall, Cryolab

AD complex experiments



***e.g. AEgIS* cryostat**

Cryolab

- Liquid nitrogen
- Liquid helium
- Superfluid helium

Introduction

Cryogenic Hazardous Events

Thermo-physical properties

Fluid	^4He	N_2	Ar	H_2	O_2	Kr	Ne	Air	*Water*
Boiling temperature (Tb) in (K) at 1.013 bar	4.2	77.3	87.3	20.3	90.2	119.8	27.1	78.8	*373*
Latent heat of evaporation at (Tb) in kJ/kg	21	199.1	163.2	448	213.1	107.7	87.2	205.2	*2260*
Ratio volume gas (273 K) /liquid	709	652	795	798	808	653	1356	685	…..
Specific mass of liquid (at Tb) in kg/m3	125	804	1400	71	1140	2413	1204	874	*960*

1 l of cryogenic fluid expands to about 700 l (0.7 m^3) of gas when warmed to ambient temperature (at constant pressure)

Demonstration: LN_2 properties: clear liquid, mist of moisture

Cryogenic Hazardous Events

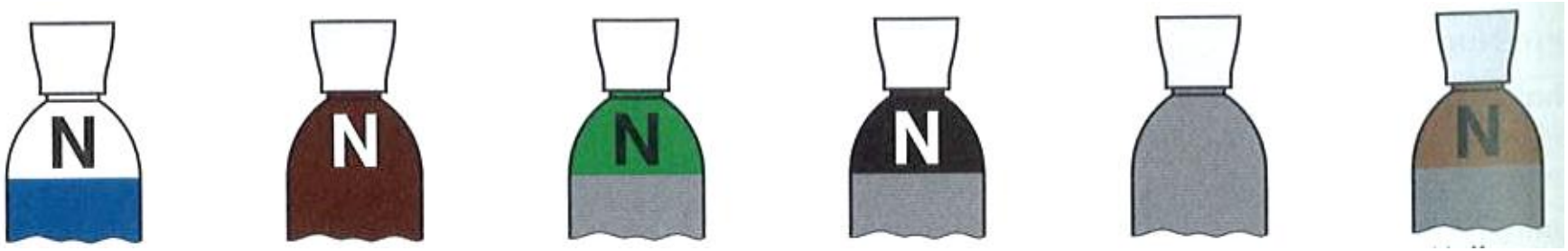
Cryogens - classification

		
Helium **He** Neon **Ne** Nitrogen **H_2** Argon **Ar** Krypton **Kr**	Hydrogen **H_2**	Oxygen **O_2**

Cryogenic Hazardous Events

Cryogens - classification

Colour codes of gas bottles

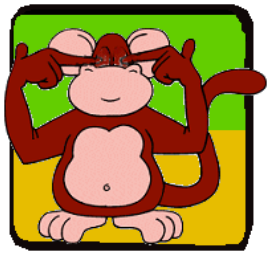


Oxygen **Acetylene** **Argon** **Nitrogen** **CO_2** **Helium**

Do not mix gases ! → blocking cryostat / Dewar necks etc.

Cryogenic Hazardous Events

Cryogens – Warning signs



Eyes

Ears

Nose

Liquid or gaseous cryogens are odourless and colourless.

Surface temperatures are not obvious

The human senses do not warn!

OFTEN ONLY secondary signs:

Ice, water, air condensation (!) → indicates cold surfaces

Fog → may indicate a leak of liquid or gazeous cryogens

Cryogenic Hazards

Physiological risks

Cryogenic Hazardous Events

Physiological – Contact burns/frost bite

Contact burns

Similar to hot burns

Frost bite → freezing of skin and body party:

Permanent damage and discoloration
Exposure time on the order of **seconds**, not minutes!

Inhalation

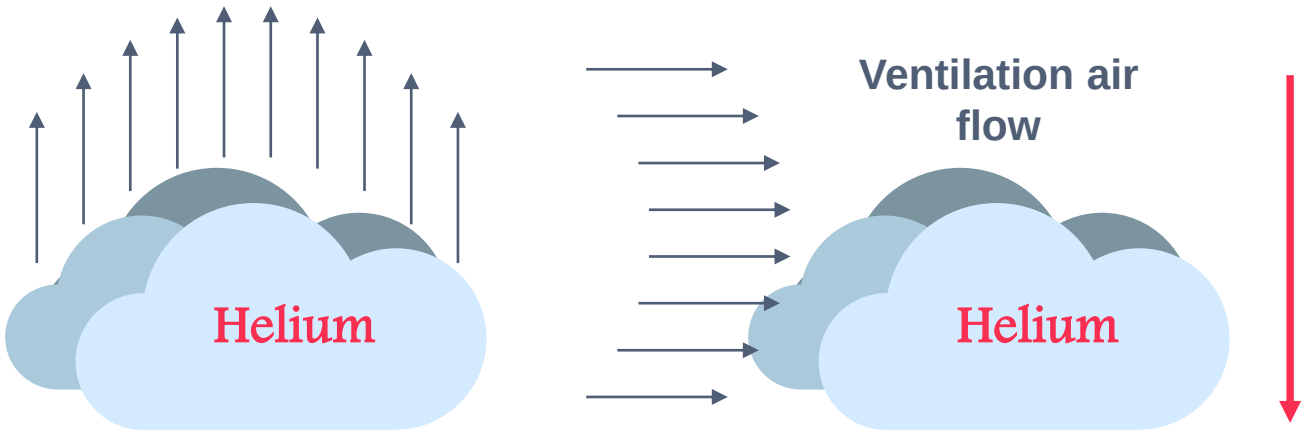
Inhalation of cold vapour can cause damage to the lungs and may trigger and asthma attack

Due to the low viscosity and surface tension of cryogens, it will flow through clothing much faster than water.

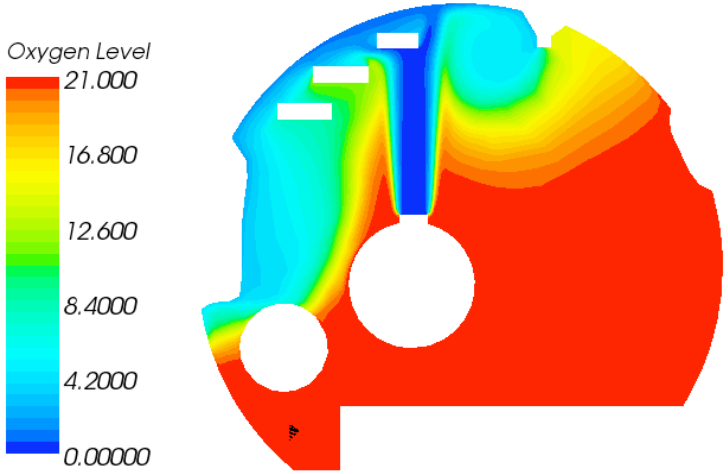
Demonstration: Leidenfrost effect fingers, cold surfaces, gummy bears

Cryogenic Hazardous Events

Cryogens - Discharge



Safer location at the floor

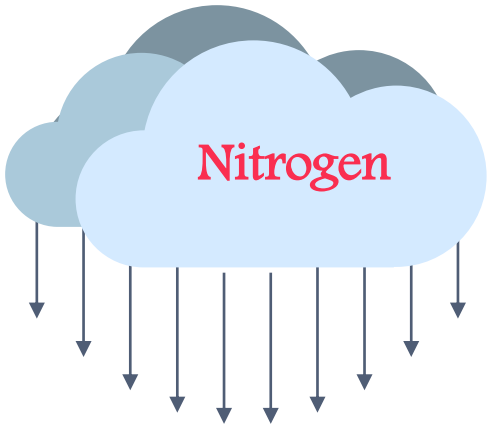


Simulated blow out in the LHC tunnel cross section

- Helium forms clouds while evaporating that move up, mixing rapidly with air
- Helium gas accumulates on the top T>40 K
- **Displacement of Oxygen!**

Cryogenic Hazardous Events

Cryogens - discharge



Safer location at the top

- Argon and nitrogen fall downwards when discharged, forming clouds
- Avoid confined spaces in pits underground channels etc.

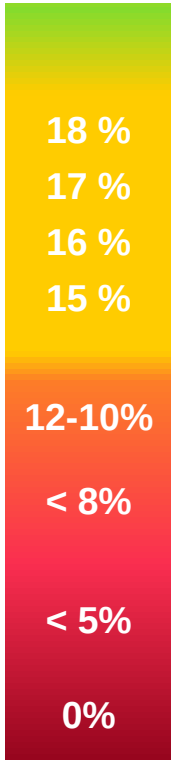
Demonstration: Balloons air and helium

Cryogenic Hazardous Events
Physiological - Asphyxiation

Gradual asphyxiation

Human behaviour depending on the oxygen level

LEVEL OF OXYGEN
IN THE ATMOSPHERE



21% O_2	Normal level of oxygen in the atmosphere (at sea level)
19% - 15% O_2	Oxygen deficiency alarm level
	Night vision reduced, Increased breathing volume, Accelerated heartbeat
	Dizziness, Reaction time for new tasks is doubled
	Poor judgment, Poor coordination, Loss of muscle control
15% - 0% O_2	Very faulty judgment, Very poor muscular coordination Loss of consciousness
	Nausea, Vomiting, Coma
	Permanent brain damage
0% O_2	Spasmodic breathing, Convulsive movements, Death in 5-8 minutes

Cryogenic Hazards

Technical risks

Cryogenic Hazardous Events
Technical risks

Build-up of pressure

- Pressure can be released when thermal loads are beyond normal operation dur to:
  - Fire
  - Loss of insulation vacuum
  - SC magnet resistive transition (quench)
  - Return line blocked

- Release of cryo-pumped gases during warm-up (air leaks)

Use pressure-relief devices to protect both the fluid volume **and** vacuum vessel against overpressure **is mandatory.**

Demonstration: Table tennis ball, film box

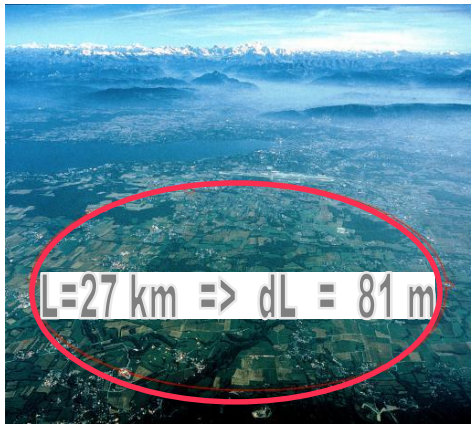
Cryogenic Hazardous Events
Technical risks

Embrittlement

- Some materials become brittle at low temperature and rupture when subjected to loads
- Protect surrounding equipment/structures from crogens discharge.

Thermal contraction (293 K to 80 K)

- Stainless steel: 3 mm/m
- Aluminium: 4 mm/m
- Polymers: 10 mm/m



Demonstration: Rubber tube

Cryogenic Hazardous Events
Technical risks

Combustion / Fire

- Use of flammable cryogens (e.g. Hydrogen).
- Liquid oxygen can cause spontaneous combustion. Adheres to clothing and presents an acute fire hazard.

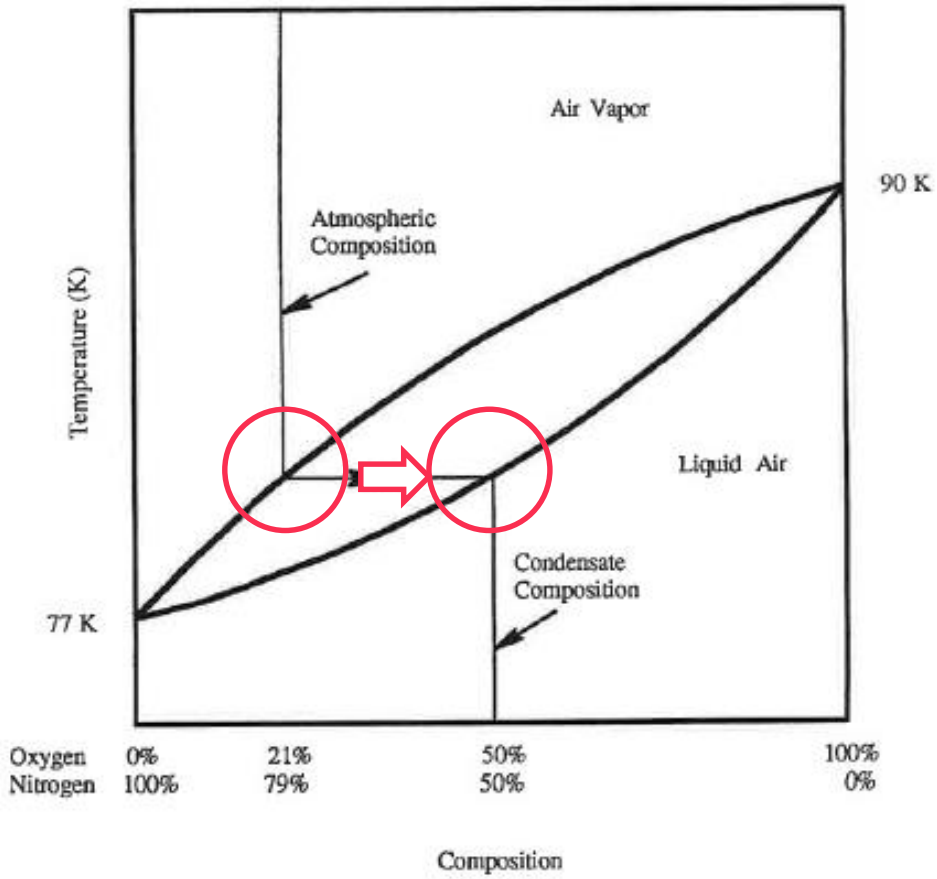
Condensation of atmospheric gases

- Innappropriate insulation or discharge of cryogens can lead to oxygen enrichment
- Mainly observed at tranfer lines and during filling operations

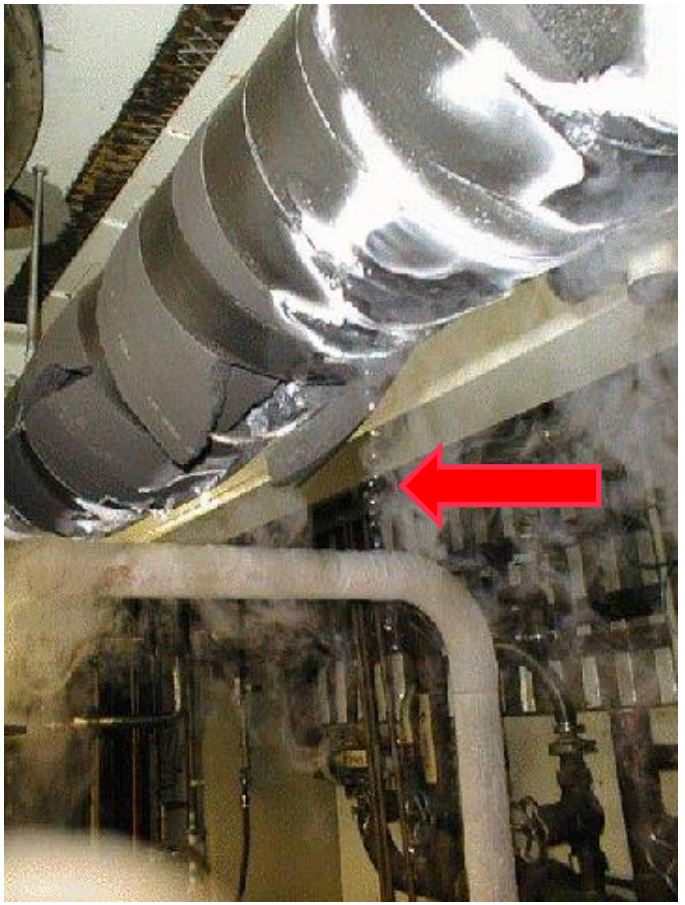
  (liquid air → **50% O_2** instead of 21% in atmospheric air)

Cryogenic Hazardous Events

Condensation of atmospheric gases – Oxygen enrichment



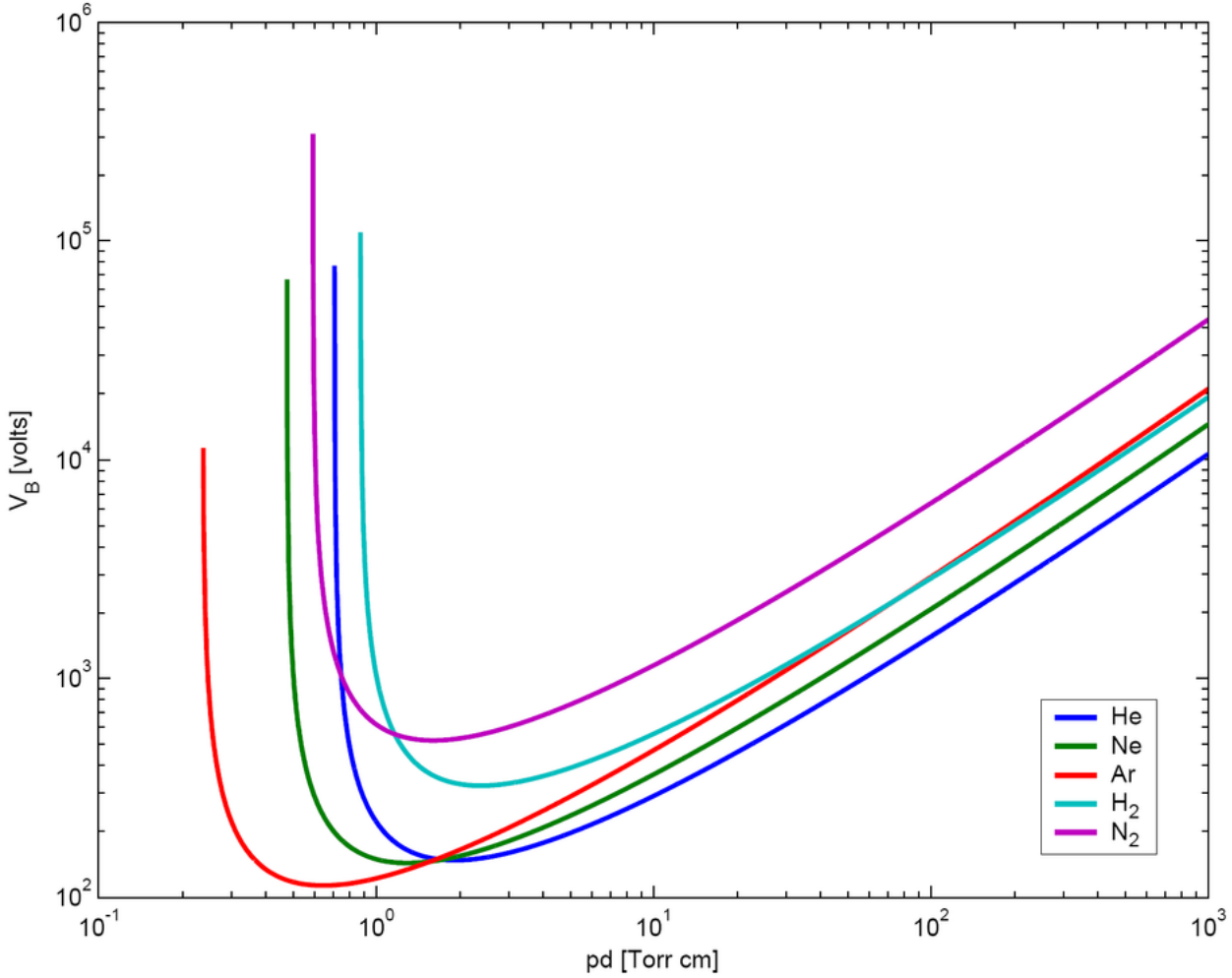
From: F. Edeskuty, Safety in the Handling of Cryogenic Fluids

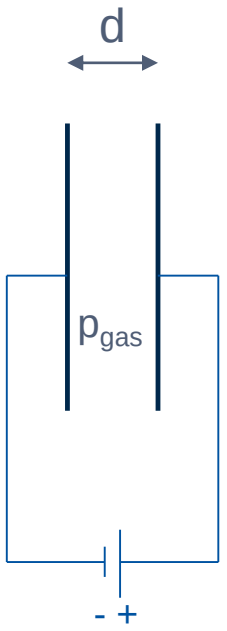


Demonstration: Oxygen enrichment at cone

Other Technical Hazards

Electric breakdown





Source Wikipedia

Safety Practices and Instructions

General Safety Practices
General practice

- Use only containers and systems specifically designed for these products!
- Transfer of cryo-liquids only in well ventilated areas => ODH!
- Materials must be compatible with the cryogen and the low temperatures.
- All cryogenic systems, including piping and vacuum space must be equipped with pressure-relief devices to prevent excessive overpressures.

Demonstration: Stainless steel Dewar example

General Safety Practices
General practice

Wear Personal Protective Equipment (PPE)

- Safety glasses (or face shield)
- Cryogenic gloves → loosely fitting
- Cryogenic apron
- Full length pants that extend over shoe tops
- Closed-toed shoes that are impermeable to liquids, such as leather, or covered with liquid proof shoe covers

PPE must be clean, free of oil and grease

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Demonstration: LN_2 through fabric

Cryogenic Hazardous Events
Oxygen Deficiency Hazard (ODH)

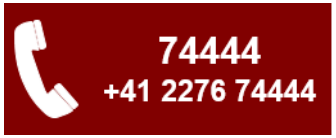
Actions

- Vent discharged cryogenic fluids to safe locations outdoors (use of relief lines)
- Equipment/system leak tightness
- Ventilation/extraction systems
- Oxygen deficiency hazard monitoring (ODH detectors)
- Emergency procedures & evacuation plan
- Use self-rescuing mask (PPE for long exposure to lack of oxygen – LHC tunnel) :
  Special HSE training required!

Keep evacuation paths free

Follow evacuation / exit panels

Keeping in mind the movement of cols gas clouds



Specific Safety Practices
Transport of cryogenic fluids

- Wear PPE
- The transport of open containers must be avoided only *π-marked* vessels for transport!
- Dewars must be secured to prevent tipping and damage.
- When not provided with transport wheels, a stable wheeled base with a braking mechanism must be used.
- Protection ring/collar on top of Dewar must not be used for lifting purposes.

- **It is forbidden to use elevators together with transport Dewar.**

- Do not transport LN_2 or other cryogenic fluids in a car

  → request transport service

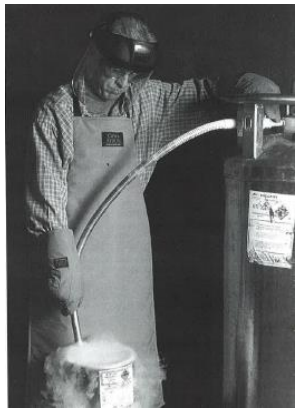
Not for lifting

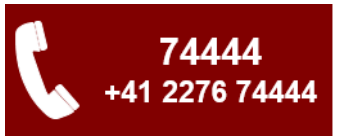
Specific Safety Practices

Transfer of LN_2

- Do not make modifications on pressure relief valves.
  => Report any leaks, damages, or improperly set relief valves.
- Do not work alone!
- An operation procedure for transfer must be available and training provided
- Make sure that there is good ventilation, open door or window in small rooms
- Remove watches, rings etc. on hands and wrists, wear proper PPE!
- Transfer of cryogenic fluids from open containers must occur below chest level of the person pouring liquid.
- Stay out of the vapor pathway during dispensing

- To perform a transfer of LHe additional training incl. safe handling of LHe Dewars and gas bottles is required.
  => Cryo-course “Helium transfer”.





Demonstration: Geyser

Accident Scenarios

Frozen or blocked Dewar

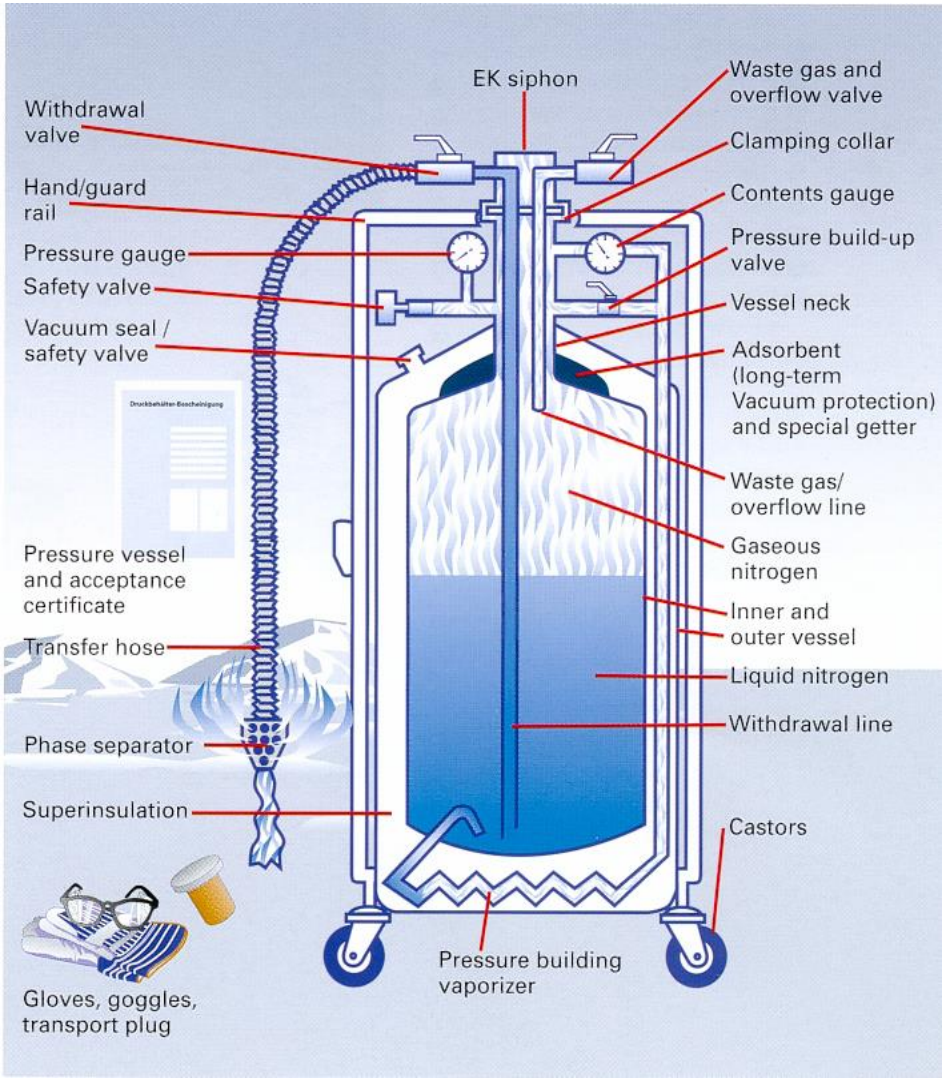
Risks:

- Pressure rise in the Dewar
- Bursting of outer or inner shell

In case of a blocked Dewar

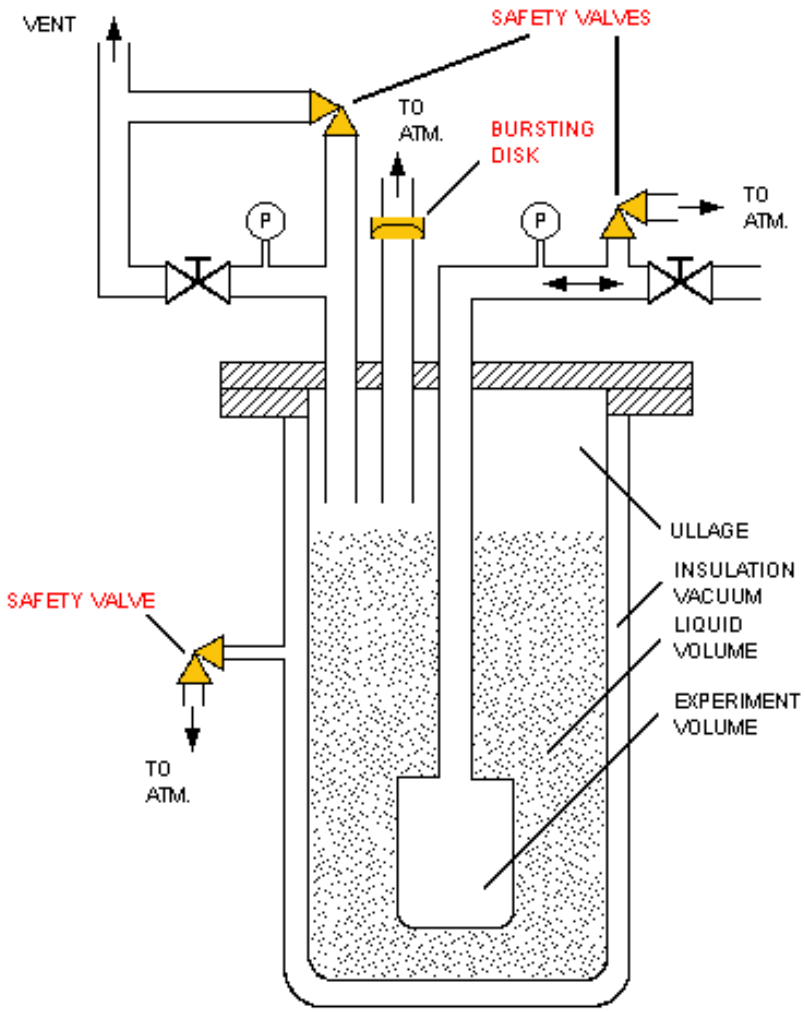
Evacuate the zone and contact:

- **CERN Fire brigade: (+41 2276) 74444**
- **Helium liqu. (Bldg. 165): 160041**



Check of Equipment
Control of experimental set-up

- Check safety equipment before cooldown! Respect Pressure Equipment Directive (PED) PS>0.5 barg.
- Check vacuum insulation space
  $p<10^{-3}$ mbar at warm conditions.
- **Nitrogen**: vent line with non return valve to ambient.
- **Helium**: vent line with non return valve to recovery line!
- Equipment should be kept clean and dry. Before cool-down the cryostat should be purged with the gas intended to be filled in.
- Check leak tightness during purge procedure



From: F. Edeskuty, Safety in the Handling of Cryogenic Fluids

Spills and Disposal

Minor release (V<1 liter):

- Allow liquid to evaporate, ensuring adequate ventilation

Major release (V>1 liter):

- Shut off all sources of ignition (whenever present)
- Evacuate area of all personnel
- Contact CERN fire brigade
- **DO NOT** return to the area until it has been declared safe by CERN fire brigade

Disposal:

DO NOT pour cryogenic liquids down the sink - they will crack waste pipes .
DO NOT store cryogenic fluids or allow them to vaporize in **enclosed areas**
→ including cars, sealed rooms and basements.

DO ensure that the area in which the cryogenic liquid is left to vaporize is well ventilated or that is located outdoors.

Emergency & First Aid

- Do not try to unblock frozen safety devices at a pressurized vessel.
  → contact **CERN Fire Brigade and central helium liquefier**.

- If a cryogenic spill occurs, immediately evacuate the area. If there is a risk of ODH contact the **CERN Fire Brigade.**

- If you experience symptoms such as **headache, dizziness or confusion**, immediately seek fresh air and contact **CERN Fire Brigade.**

- Do not provide aid to persons located in an ODH
  → contact **CERN Fire Brigade.**

- In the event that skin or eyes came into contact with cryogenic gases or liquid, do not apply dry heat or rub damaged areas, rinse with tepid water
  → contact **CERN Fire Brigade.**

- Removing of contaminated clothing can peel of skin!
  → contact **CERN Fire Brigade**.

Contacts / References

- Do not hesitate to contact your CSO in case you need help/advice.

Do not forget:

Every safety regulation is written with the blood of a colleague!

HSE Unit

- HSE Safety Training: safety-training@cern.ch
- ODH: Gunnar Lindell

Guidelines

- IS 47: Use of cryogenic fluids

=> https://espace.cern.ch/safety-rules-regulations/en/rules/byDomain/Pages/M.aspx

Nice try…

From lachschon.de

Thank you for your attention!

Questions ?

Test

Test

Q1 In case of a helium spill creating an Oxygen Deficiency Hazard, what is the safest location?

A1

- ☐ At the ground/floor
- ☐ At the ceiling/height
- ☐ It doesn't matter

Q2 What kind of personal protective equipment is needed for working with cryogens?

A2

- ☐ Gloves certified to withstand the low temperature of cryogenics
- ☐ Safety glasses/goggles
- ☐ Long pants covering closed shoes (e.g. leather safety working shoes)

Q3 Cryogenic liquids should only be stored in vented containers approved for storage of cryogenic liquids.

A3

- ☐ True
- ☐ False

Q4 Can I completely close a Dewar/cryostat containing cryogenic liquids?

A4

- ☐ Dewars/cryostats should be closed completely to avoid other gases in the vessel
- ☐ Never completely close a vessel, the build-up of pressure can lead to explosion
- ☐ Blocking safety equipment can help avoiding unwanted spill of cryogens.

Test

Q5 I only have 3 liter of liquid nitrogen. Why do I have to worry about being in an enclosed space?

A5

- ☐ The expansion ratio of liquid nitrogen to ambient temperature gas is about 1:650. This can rapidly fill a small space and cause a very dangerous situation.
- ☐ The evaporated gas can cause an Oxygen Deficiency Hazard.
- ☐ Such small amounts of cryogenic liquid are of no risk.

Q6 What do you need to do in case of a blocked/frozen Dewar?

A6

- ☐ Evacuate the zone from personal
- ☐ Stay close to the equipment and observe the pressure over time
- ☐ Contact CERN fire brigade and Piquet service from central liquefier

Q7 Can I work with cryogens or in cryogenic areas without assistance?

A7

- ☐ Yes, there is no additional risk.
- ☐ No, never work alone while handling cryogenic liquids


CERN