Handling of cold gases and fluids

Safety instruction for handling cryogenic mediums and components

DESY MKS (cryogenic group)
Hamburg, 10/9/2021

Cryogenics at DESY

Some examples








Objective of this presentation

At the end of this lesson you should remember the following hazards

Main dangers handling cryogens:

Hazards for people

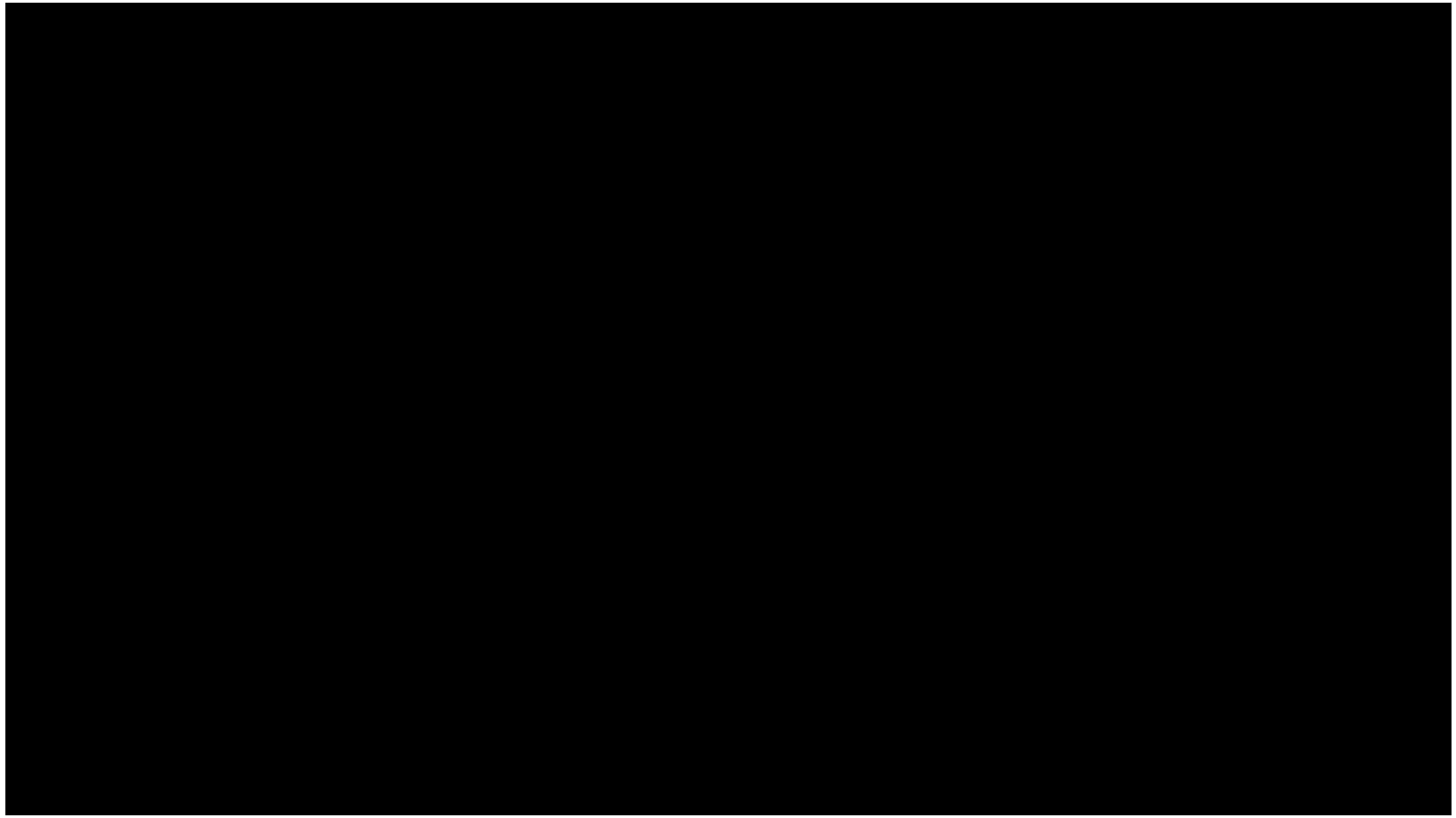
- Danger of cold burns
- Danger of suffocation

Technical risks

- Material-embrittlement
- Thermal stresses
- Pressure build-up by evaporation
- Hazards caused by condensation
- Fire danger

How dangerous are cold gasses and fluids?

Impressions from a venting test



Hazards for people

Cold burns

- **Direct contact** with **cryogenic liquids and gases** as well as **surfaces** at cryogenic temperatures can lead to

  massive damages to the skin and tissues

- The **danger** of cold burns is **higher** when handling **open cryogen containers** (typically liquid nitrogen)
- **Eyes** and **mucous membranes** are most at risk

George R.R. Martin

Cold burns

Protection and prevention

Prevention

Wear protective clothing:

- Eye protection (glasses)
- Gloves of insulating and non combustible material which can easily be removed
- High, tight fitting shoes
- Trousers without turn ups which overlap the shoes

First Aid

Same procedure as for burns:

- Small injuries: douching injury with water
- Sterile dressing
- Alert rescue service

Suffocation

Oxygen deficiency

- The **evaporation of cryogenic liquids** in closed or badly ventilated areas can lead to **oxygen deficiency**

- Most **cryogens** are **odorless and colorless**:
  - hazard can be detected ONLY with special equipment
  - the victim may not even become aware of the oxygen deficiency

- **Argon and cold nitrogen** are heavier than air and can therefore **collect near the floor or in pits**, **Helium** is lighter than air and **collects at the top**.

Soffocation

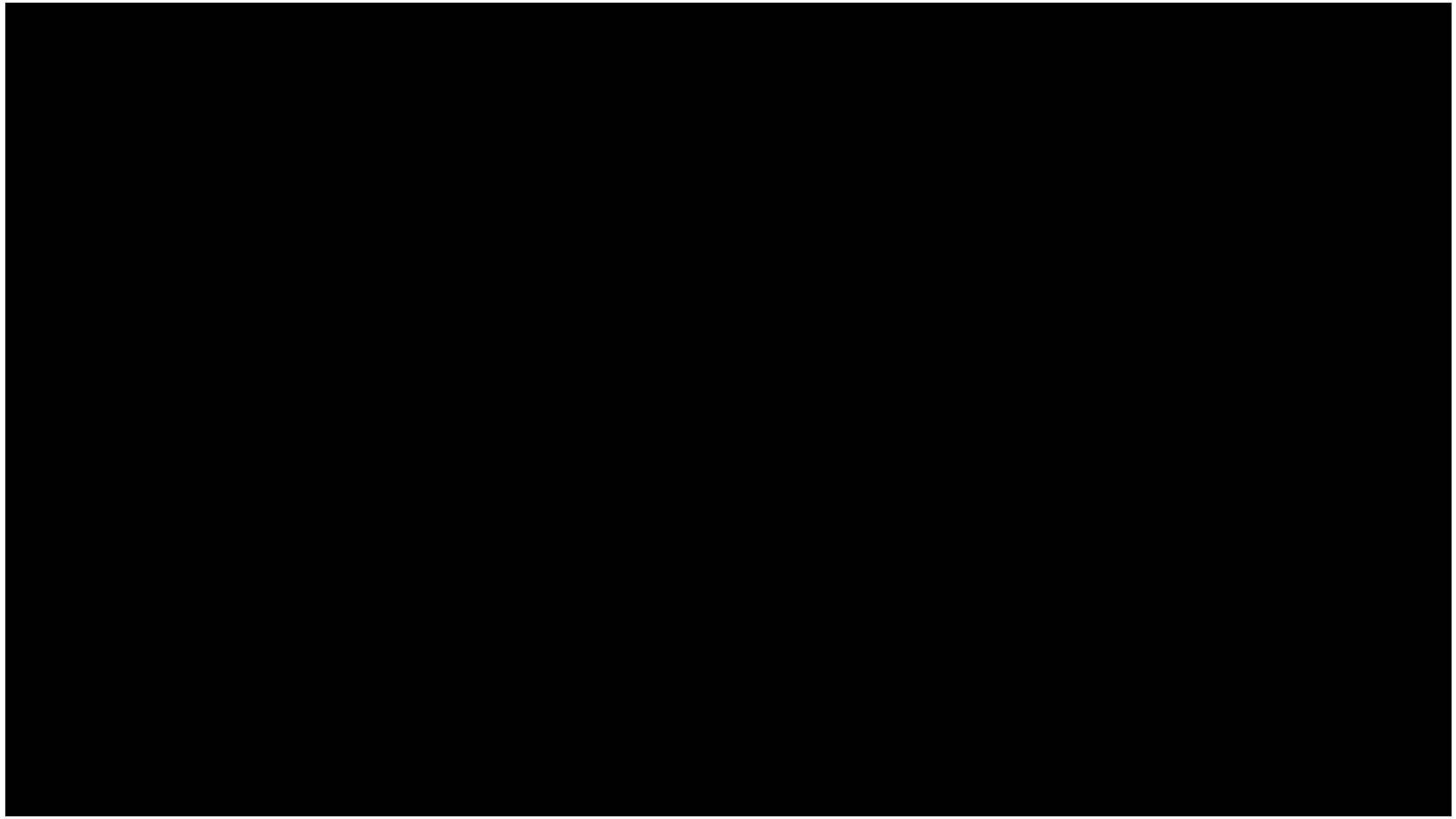
Some examples

- Example 1: discharge of Helium into the LHC-tunnel (fog formation within a few seconds)

Soffocation

Some examples

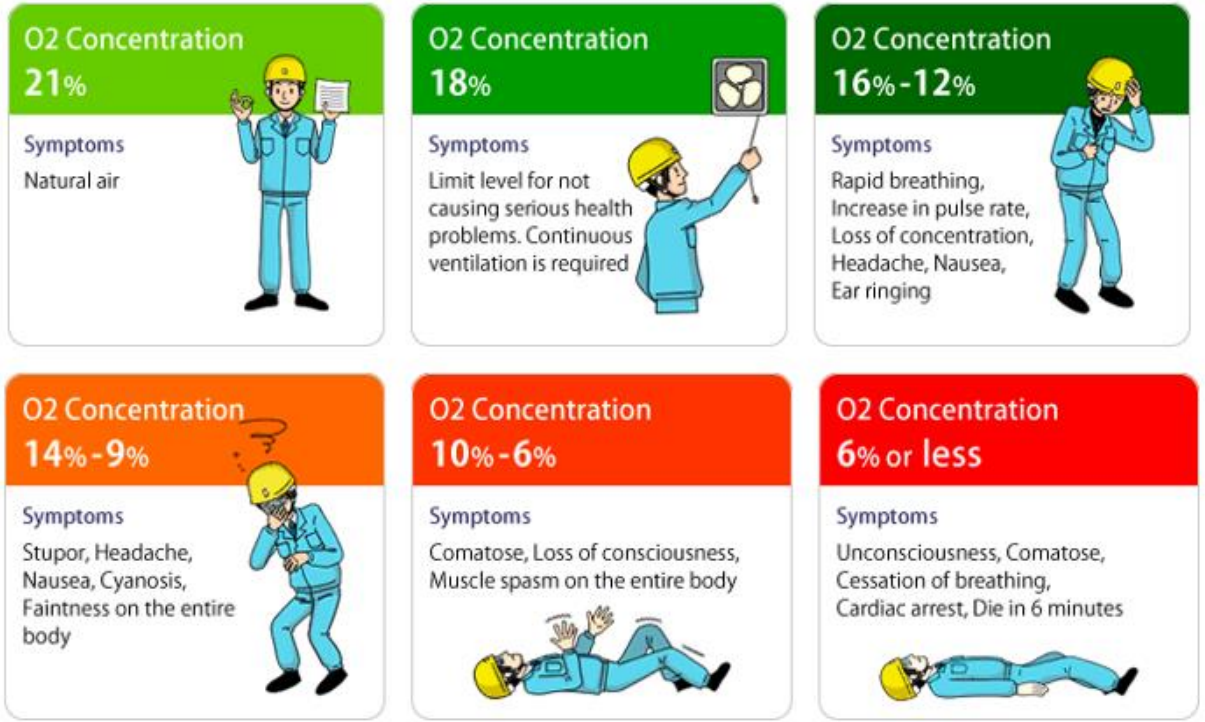
- Example 2: video of HERA test



Suffocation

Oxygen deficiency symptoms

Oxygen concentration in air: 20.9 %



Oxygen deficiency symptoms:

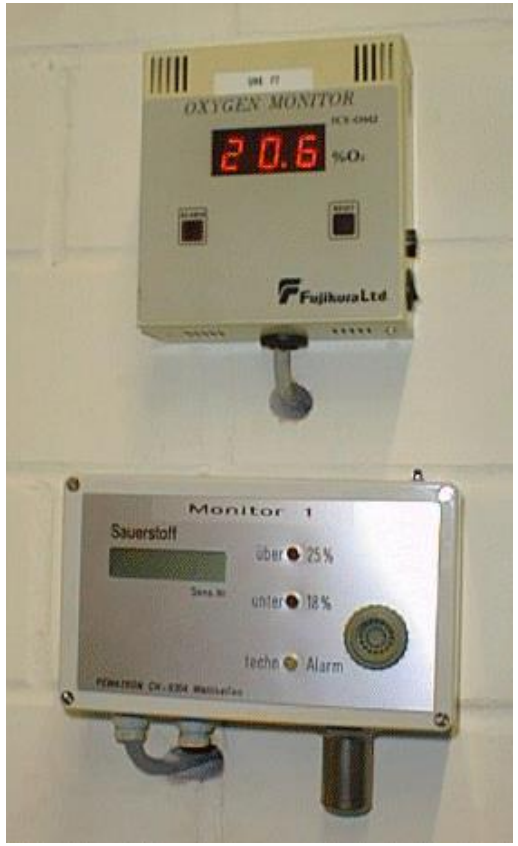
- 19% - 15% pronounced reduction of reaction speed
- 15% - 12% deep breaths, fast pulse, co-ordination difficulties
- 12% - 10% vertigo, misjudgments, lips slightly blue
- 10% - 8% nausea, vomiting, coma ← **life threatening below 10%**
- 8% - 6% death within 8 minutes, from 4-8 minutes brain damages
- 4% coma within 40 seconds, no breathing, death

Suffocation

Protection and prevention

Means of protection and preventive measures:

- sufficient ventilation of the working place
- feed exhaust pipes into a gas recovery system or chimney
- equip working place with oxygen monitors → in case of accident evacuate immediately
- enter confined areas, e.g. pits or tanks, only under supervision and only with portable oxygen monitors



Technical risks

Sources of Accidents and Failures

Pressure Build-up by Evaporation

- **Cryogen liquids expand** by a factor of 500 to 1500 when evaporated and warmed up to room temperature (300 K); Helium: 1liter 2K liquid → 900 liters 300K gas (factor 900)

→ **pressure build-up in a closed container**

1liter → 900 liters

- **Sources** of a quick temperature increase in a cryogenic system are:
  - Fire
  - Loss of insulating vacuum
  - Transition of superconducting components to the normal conducting state (quench) (instantly much higher heat loads)
  - Return line blocked
  - Release of cryo-pumped gases during warm-up (air leaks)

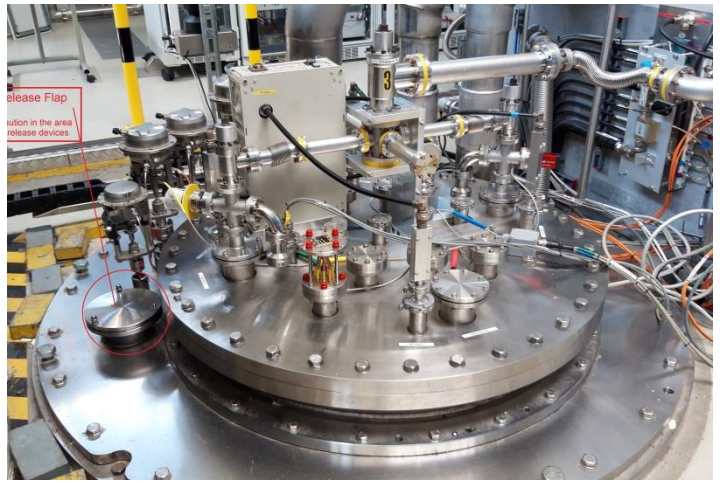
Sources of Accidents and Failures

Pressure build-up preventive measures

Preventive measures

- Safety devices are installed to avoid pressure build-up in closed environments
- Different type of safety devices are available: safety valves, release flaps, rupture disks, …
- Important recommendations while designing the safety system:
  - **Include redundancy:** double safety devices (more safety devices than required)
  - **Include diversity:** safety devices based on different mechanisms

Caution in the vicinity of release devices !



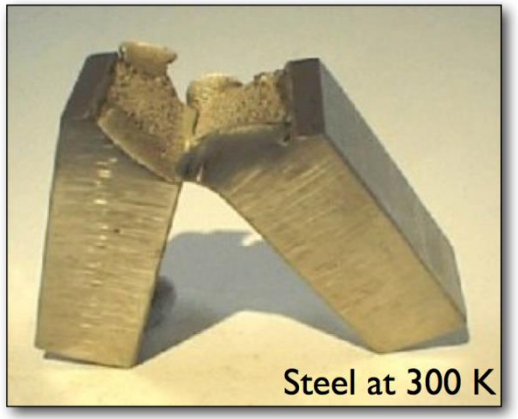
Sources of Accidents and Failures

Low temperature material embrittlement

- Some **ductile materials become brittle at low temperatures**: components can **fracture spontaneously** rather than accommodating the stress by plastic deformation
- Consequence: **only certain materials** are **allowed for cryogenic components**

Brittle Fracture

Ductile Fracture



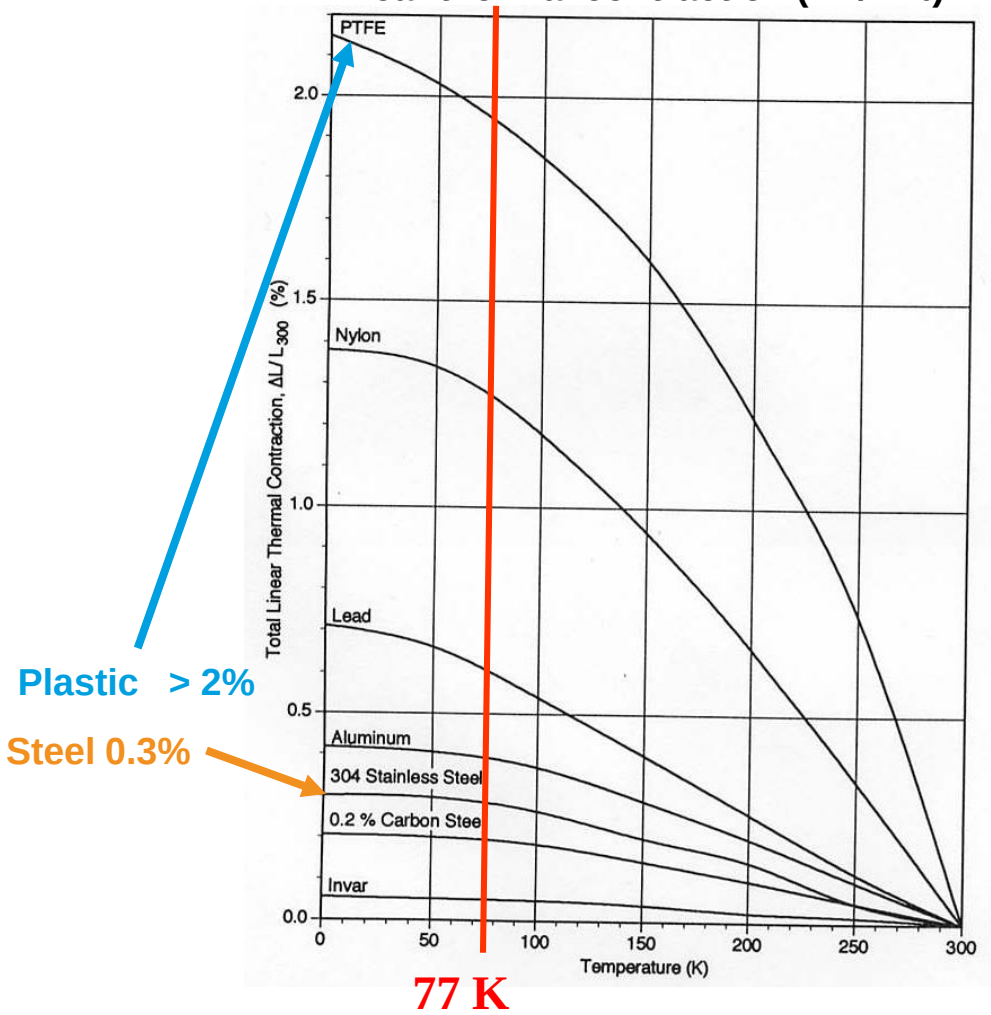
https://libatoms.github.io/QUIP/Tutorials/adaptive-qmmm-theory.html

Sources of Accidents and Failures

Thermal Stresses

- **Materials cooled** to cryogenic temperatures **contract** at different rates → can development **thermal stresses**
- The stresses (as transient or permanent load) can cause damage.
- The contraction strongly depends on the material type and takes place mainly above LN2 temperature (77K).
- The contraction has to be taken into account in the design of cryogenic components
- Examples:
  - **1 m long steel pipe** from 300 K to 4 K gets **3 mm shorter**
  - **1 m long plastic pipe** from 300 K to 4 K gets **2 cm shorter**

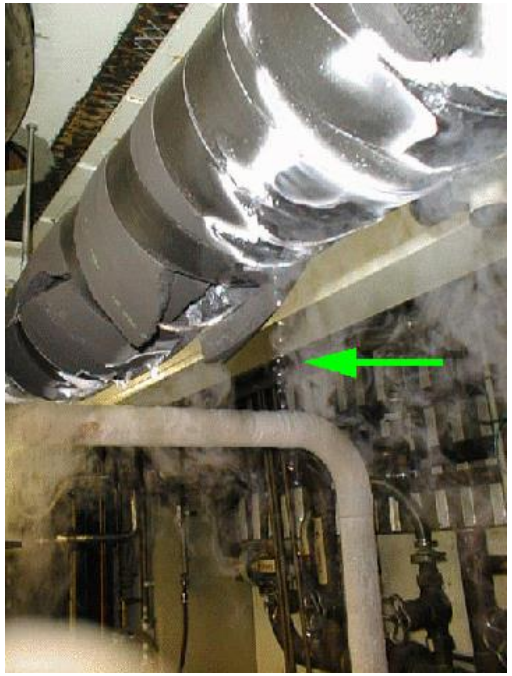
Linear thermal contraction (DL/L %)



Sources of Accidents and Failures

Condensation of Gases

- Condensation of gasses can be **useful:** cryo-pumps and cryo-traps
- Condensation of gasses can be **dangerous:**
  - frozen air / air moisture can plug exhaust pipes → **pressure build-up**
  - ice on components, dripping condensate, water condensate → **mechanical damages**
  - condensation of air or oxygen → **formation of explosive mixtures**



Preventive Measures

- Do not leave dewars open to atmosphere
- Equip exhaust lines to atmosphere with check valves (non-return)
- Perform a leak test before evacuating cryogen baths with emphasis on leaks that might allow air into the cold part of the apparatus

Sources of Accidents and Failures

Other

Other mechanisms that can lead to damages or failures are:

- **Boiling retardation**
  - In very clean environments (vessels) boiling may start at temperatures above the boiling point.
    In this case the boiling can be from violent to explosion like. Boiling retardation can be prevented by introducing porous material as boiling nuclei.
- **Stratification**
  - If the cryogen in a large tank is not disturbed for some time, a temperature stratification may occur. The stratification causes a larger pressure rise than expected due to the elevated temperature in the liquid surface layer.
- **Combustion and Explosion Hazard** can be caused by:
  - Presence of liquid or gaseous oxygen (promote combustion processes, reduce the ignition temperature, accumulate in combustible materials (especially in clothes) which will (explosively) burn when ignited
  - Presence of ozone in systems which contain oxygen and which are exposed to gamma or neutron radiation; an explosive amount of ozone can already be created from the oxygen impurities in a liquid nitrogen dewar

Summary

What you really need to take home with you:

1. Cryogenic liquids, gases and equipment at cryogenic temperatures can be seriously dangerous
2. Cryogens are odorless and colorless, surface temperatures are not obvious -> do not trust your senses
3. Avoid contact with cryogenic components / gases / liquids / materials
4. Stay away from safety devices, they can quickly become noisy and cold
5. If you hear any alarm or suspicious sound and / or if you see fog formations leave the area immediately

Thank you