



Cryogen Safety

**Created by C.L. Dennis, Metallurgy
Division, MSEL, July 2009**

Adapted for use at the NCNR by J. Scherschligt



Cryogen Background

Cryogenics are safe if properly used.

Like many other dangerous chemicals and gases, cryogenics are safe if properly stored and used.



However, if misused or used/stored improperly, cryogenics can seriously harm or even kill you.



LN2 powered rockets



Spilled LN2 = Embrittled Robots



Cryogen Background

What is a cryogen?

For our purposes, a cryogenic liquid is defined as any liquid with a normal boiling point below -150°C (123K).

At the NCNR,

by far the most commonly used cryogens are nitrogen and helium

Gas (abbreviation)	Boiling Point (K)	Expansion Ratio
Nitrogen (LN ₂)	77.4	694
Helium (LHe)	4.22	748

The expansion tells us that when a cryogen boils, its volume increases by a factor of about 700. **This can result in high pressures that may cause explosions.** Thus It is crucial to learn proper handling techniques!



Cryogen Hazards



Typical use of cryogenics at the NCNR create three lethal hazards:

- 1) The cold can cause cold burns - even frostbite – and hypothermia.
- 2) The boil-off can displace oxygen in the room, leading to asphyxiation.
- 3) The boil-off can build up pressure in a sealed container, leading to an explosion.

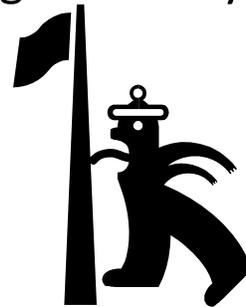
Cryogen Hazards

Ways to expose yourself to frostbite or hypothermia:

- 1) Directly by touching the liquid with your skin

The low viscosity of cryogenic liquids means that they will penetrate woven or other porous clothing materials much faster than, for example, water.

- 2) Indirectly by touching something cooled by the cryogenic liquid like a metal transfer line



- 3) Indirectly by exposure of skin or eyes to the cold gas coming out of a the pressure relief valve at the end of the transfer line.

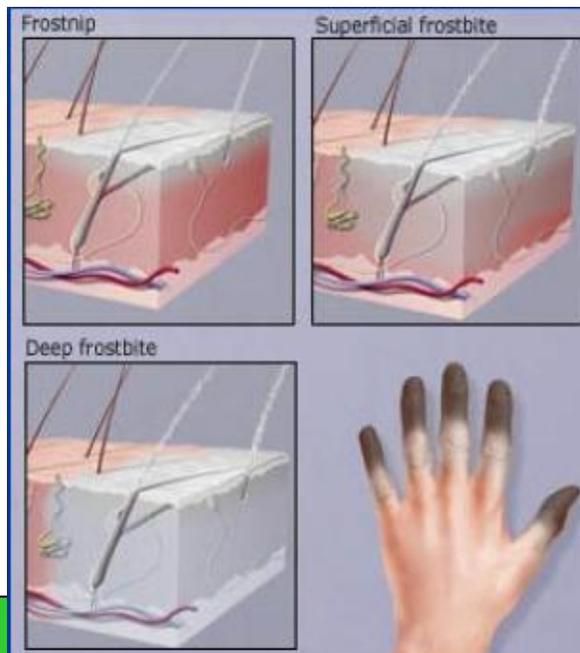


Cryogen Hazards: frostbite

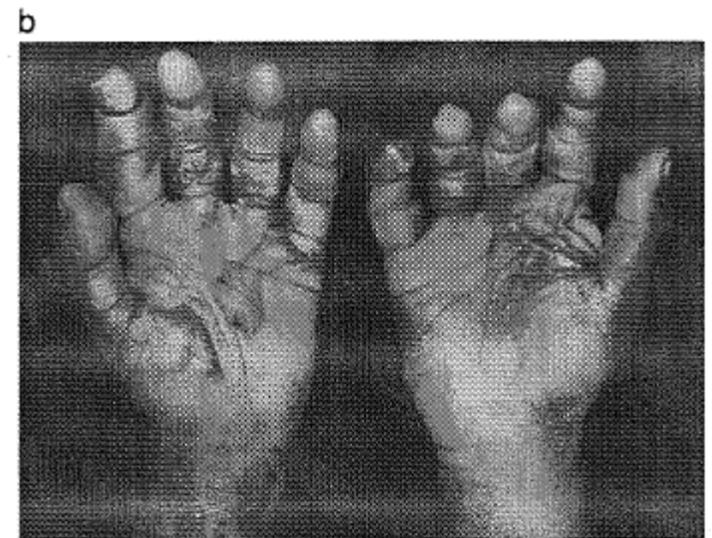
Frostbite

Symptoms:

- Frostbite changes color of the skin to gray or white, possibly followed by blistering.
- Deep tissue freezing generally indicated by a waxy and possibly a yellow appearance to the skin.



P. Kumar and P.T. Chirayil, "Helium Vapor Injury: A Case Report", Burns 25 (1999) 265



Photograph of hands two days after exposure to LHe by spilling in gloves (a) dorsal and (b) palmar view.

Note the blister formation especially around the wrists

Ways to expose yourself to asphyxiation:

1)By working in a room without a properly working ventilation system. Unless specifically granted permission to do otherwise, you must use cryogenics only in the Guide Hall or C100.

1)By standing in or around the white “fog cloud” that is emitted from the pressure relief valve end of a transfer line, or above a spill.

Cryogen Hazards: asphyxiation

Physical symptoms of oxygen content in air (by volume)

<i>% Oxygen (by volume)</i>	<i>Physical Symptoms</i>
14-19.5%	Increasing pulse rate, tiredness, but may have no noticeable symptoms
11-14%	Reduction in physical and intellectual performance, often without the individual realizing it.
8-11%	Possibility of headaches and fainting after a short time, often without prior warning.
6-8%	Fainting within a few minutes. Resuscitation possible if immediate.
0-6%	Fainting almost immediate. Death within minutes. Brain damage likely even if resuscitated.

Cryogen Hazards: explosions

Ways to cause an explosion:

By sealing any pressure relief valves on a cryogenic system or dewar.

By leaving a LHe or LH2 dewar transfer valve open such that as the initial boil-off decreases, air can get into the dewar and freeze solid, resulting in a plug inside the dewar. This prevents the pressure relief valves from working, resulting in a slow build-up of pressure!



The dewar on the right is what the dewar on the left looked like, prior to having its pressure relief valves sealed. This was after the dewar went through the floor above at Texas A&M University.

Cryogen Hazards: explosions

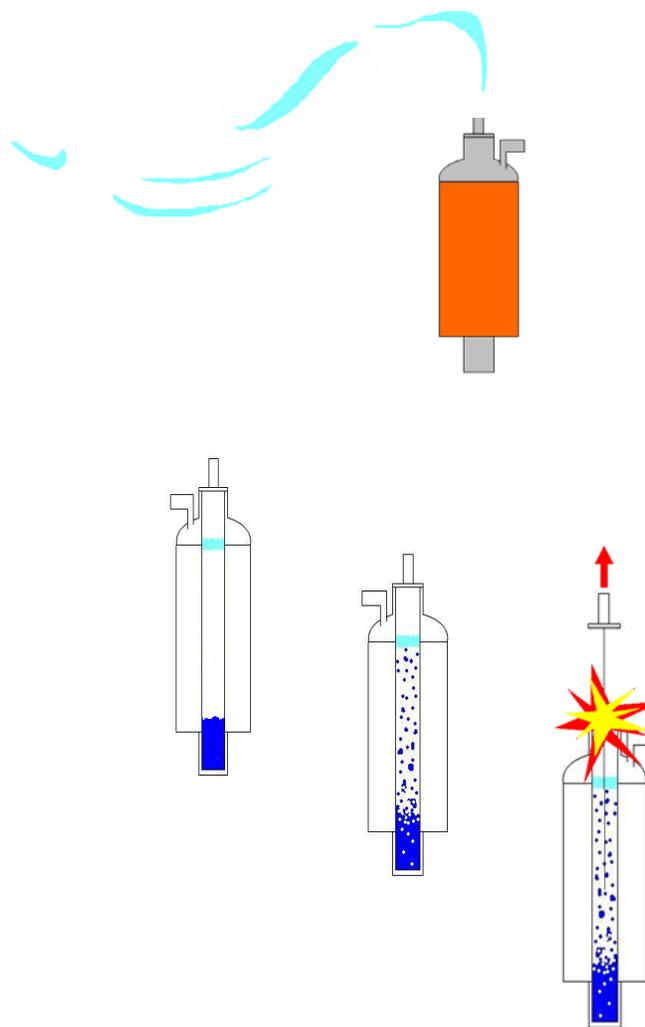
More on Ice Blockages

You must take all precautions to prevent air having any chance to get inside a cryostat or Dewar.

Water in the air can freeze and form a block inside the neck at a point where the temperature is 0°C , trapping liquified air below it.

When this liquified air boils, pressure builds (remember our expansion ratio of $\sim 700?$) it can cause the stick to be forcefully ejected, or in extreme cases can cause the dewar or cryostat to explode.

You must NEVER allow any part of your body to be directly over the sample stick in any kind of cryostat.



Cryogen Hazards: explosions

More on Ice Blockages

They can kill you.





Cryogen Safety



Control Measures to Mitigate Hazards Associated with Cryogenics

Engineering Controls

- Pressure Relief Valves
- Insulation
- Ventilation

Administrative Controls

- Training
- PPE (safety glasses, closed-toe shoes)

Note on PPE...

Insulated gloves are optional, but it is highly recommended that you have them within easy grabbing distance. When you do discover that you need gloves, you need them NOW.

Cryogen Safety

Transferring

Nitrogen

Do:

- use a metal line
- wear safety glasses

Don't:

- use a latex line
- Wear open-toe shoes

Helium

Do:

- open relief valve when finished, close other valves.
- wear safety glasses and proper shoes.
- vent dewar and cryostat before transferring
- Pressurize with dry He gas.

Don't:

- forget to tighten fill port on cryostat when done
- mistreat delicate transfer lines
- Pressurize more than 8 psi
- Stand in vapor cloud.

See video on Sample Environment website for more instruction
"How to refill Liquid Helium."

<http://www.ncnr.nist.gov/equipment/ancequip.html>

Warning signs of a damaged dewar or cryostat:

- Continuous venting from a vent valve is not normal. It could mean there is dirt in the vent valve or it is damaged.
- Sweat or Frost at the bottom or sides of a dewar or cryostat is an indication of a faulty or damaged vacuum jacket.

If you discover a dewar or cryostat in this state, contact sample environment.

Your responsibility:

Be Knowledgeable

- Be sure that you have all the necessary training to work with a specific piece of equipment
- If you are unsure, DO NOT assume that you know what you are doing! Do NOT use the equipment!

Be Aware

- Be aware of when cryogenics are being transferred
- Be aware of where potential locations/objects/body parts are with which the cryogenic liquid may come in contact

Your Responsibility

What to do in case of a suspected injury

- If the suspected injury occurs during the normal business hours, the staff member shall contact the health unit where they shall provide treatment or a referral to an appropriate medical professional.

Gaithersburg

Health Unit

Telephone Number: x5131

Location: Administration Bldg (101), Room C-33

Hours: Monday-Friday, 8:30 A.M. to 5:00 P.M

EMERGENCY TELEPHONE NUMBER: x2222

- Imperative that the staff member seek medical attention within 48 hours of the suspected injury
- The staff member must notify (or have someone notify) his/her Group Leader, Division Chief, and Division Safety Representative (DSR), even if the individual considers the injury to be insignificant and not likely to interfere with his/her work.

What to do in the event of: Suspected Asphyxiation

Symptoms:

The effect of oxygen deficiency resulting from simple asphyxiant (e.g. nitrogen or helium gas) may include:

- rapid or gasping breathing,
- fatigue,
- diminished mental alertness,
- impaired muscular coordination,
- faulty judgment,
- and depression of all sensations.

As asphyxiation progresses, symptoms include:

- nausea,
- vomiting,
- prostration,
- loss of consciousness may result, eventually leading to:
- convulsions,
- coma,
- and death.

What to do in the event of: Suspected Asphyxiation

Asphyxiation: (generally caused by rapid evaporation of liquid)

- Rescue:
 - If possible (oxygen monitors register >19.5% O₂ content in room), remove worker to air with known oxygen content of 20.9%, but do NOT enter the area alone!
 - If oxygen monitors register <19.5% O₂ content, contact emergency services to initiate rescue with self-contained breathing apparatus.
- Contact emergency services for immediate medical attention.
- If not breathing, give CPR (if qualified).
- A physician should see the patient promptly as supplemental oxygen may be required (especially if breathing is difficult).

What to do in the event of: Frostbite

Frostbite to EYES: (generally caused by rapidly evaporating liquid)

- Remove worker from the source.
- Contact emergency services and seek immediate medical treatment.
- Open eyelids wide to allow the liquid to evaporate.
- Flush affected area with copious quantities of cold/lukewarm (unheated!) water for 15 minutes.

What to do in the event of: Frostbite

Frostbite to SKIN: (generally caused by contact with liquid or metal refrigerated by LHe or LN2. In the latter case, the skin can stick to the metal and can tear when pulled away.)

- Contact emergency services for immediate medical attention if contact with the fluid has resulted in blistering or deep tissue freezing or a reduction in body temperature.
- Remove contaminated clothing. (This must be done carefully to prevent salvageable skin from being pulled off.)
- Remove clothing that may interfere with circulation of blood to affected area.
- Flush affected area with copious quantities of lukewarm (unheated!) water for 15 minutes.
- DO NOT USE HOT WATER!
- DO NOT USE DRY HEAT!
- DO NOT RUB (to prevent further damage to skin)!
- DO NOT APPLY ANY OINTMENTS!
- Once area has thawed, cover with dry sterile bandages and a large bulky protective covering until paramedics arrive. (This will help prevent further damage to area and infection.)
- If a large area has been exposed (such that the body temperature is reduced), then wrap worker in blankets and wait for paramedics arrive.

What to do in the event of: Ice Blockage

Contact Sample Environment

What to do in the event of: Explosion

**If you are still alive, vacate the building
and call emergency services.**

Cryogen Safety

It only takes a moment ...

The photograph above shows a liquid nitrogen dewar that exploded at Texas A&M University in early 2006. The dewar had a history of venting gas nitrogen through the pressure relief valve for the interior (bath) space, so someone **replaced the pressure relief valve with a metal plug**, defeating the safety feature. Pressure rise inside of the dewar (most likely caused by a breach of the exterior jacket, which allowed heat to flow into the liquid nitrogen) estimated at **1000-1200 psig caused the bottom of the dewar to blow out**, and the estimated 250,000 pounds of thrust propelled the dewar upwards through the concrete ceiling above (note the crushed ring and valve jungle). The floor below the dewar was extensively damaged as well. Fortunately, this occurred at approximately 3:00 am and there were no injuries, although building damage was extensive



Cryogen Safety

It only takes a moment ...

A man who was installing an M.R.I. machine at New York-Presbyterian Hospital was killed yesterday, apparently after **nitrogen** he was using leaked from its tank, officials said. Six other people were injured in the incident. The worker, Paul Ambrose, 25, of England, died about 11:25 a.m., apparently from asphyxiation, while working in a **poorly ventilated** trailer alongside the hospital on 70th Street and York Avenue, said Mayor Rudolph W. Giuliani, who arrived at the hospital shortly after the incident occurred. Two other workers, after learning that Mr. Ambrose had not left the trailer, **went back inside** and found him unconscious, the authorities said. The two workers and four other people in the vicinity complained of varying degrees of lightheadedness. They were treated at the hospital and released.

Attempting to rescue the asphyxiated victim can lead to death of the rescuers if they do not have proper PPE!

Lack of ventilation, even in a large space, significantly increases the risk of a fatality!

21 September 2000; *NY Times* by Eun Lee Koh

Cryogen Safety

It only takes a moment ...

Clinical and morphological aspects of death due to liquid nitrogen

International Journal of Legal Medicine **111**, 191-195 (1998)

A 24-year-old student died while filling flasks with liquid nitrogen....The student had **worked alone** **without a working ventilation system**. While filling the third flask he lost consciousness. ... The liquid nitrogen which was still escaping spread over the floor and vaporized. The student died from asphyxia due to oxygen deficiency in an atmosphere of nitrogen.

No back-up in the event of an emergency!

Lack of ventilation, even in a large space, significantly increases the risk of a fatality!



In Conclusion,

Cryogenics are dangerous...

- * they can freeze you*
- * they can suffocate you*
- * they can cause explosions*

...BE SAFE

and if you have questions or need help,
contact sample environment.

