Safe handling of cryogenic materials

1. Contents

1. Contents ... 1
2. Introduction ... 1
3. Definitions ... 1
   - Cryogenic liquid ... 1
   - Dewar ... 1
   - Dry Shippers ... 2
   - Dry Ice ... 2
4. Hazards from cryogenics materials ... 2
   a) Effects of lowered oxygen levels ... 2
   b) Effects of CO2 enrichment ... 3
5. Training requirements ... 3
6. Storage of bulk quantities and safety precautions ... 3
   a) Liquid nitrogen ... 3
   b) Dry ice ... 4
7. Emergency Procedures ... 4
8. References ... 5

2. Introduction

This guidance document provides information and advice on the hazards that may arise and suitable precautions that may be necessary when using, storing, and transporting low temperature liquefied or solidified gases (commonly referred to as cryogenics). The risks from use of cryogenics are considerable and have led to deaths in laboratory situations from asphyxiation due to oxygen displacement.

3. Definitions

- Cryogenic liquid

A liquid produced from a gas that can be liquefied, and in some cases solidified, by the application of pressure and cooling within the temperature range -75oC to -270oC. Examples of materials likely to be encountered within a research environment, with associated boiling points at atmospheric pressure, are Nitrogen (-196oC), Oxygen (-183oC), Helium (-269oC) and Carbon Dioxide (sublimes at -78.5oC).

- Dewar

A vacuum insulated container for storing very low temperature liquid gases. Sometimes dewars are considered to only include small open (non-pressurised) vessels but in most laboratory situations portable closed pressure vessels with pressure bleed/relief to allow escape of evaporating gas are also called dewars. Larger fixed bulk pressure storage vessels are normally termed 'tanks'.

- Dry Shippers

Dry shippers contain a cryo-absorbent material in the inner wall which soaks up the liquid nitrogen so there is no free liquid present and holds samples in a vapour phase environment at cryogenic temperatures. This means no spillage of liquid nitrogen will occur during transport and shipping.

- Dry Ice

Solid carbon dioxide (CO2) also known as 'cardice'. This is a solid cryogen rather than a cryogenic liquid and sublimes at -78.5oC.

Properties and Hazards of Dry Ice

In its solid form, carbon dioxide is very cold; measuring -78O C. It is normally supplied as pellets or blocks and does not pass through the liquid state as it melts, rather, it sublimes from its solid state into a colourless gas which is odourless at low concentrations but has a characteristic smell at higher concentrations. It is naturally present as a component of air at a concentration of 0.03% and it is not flammable, in fact it is used in fire extinguishers to supress fire.

4. Hazards from cryogenics materials

The hazards associated with low temperature liquefied or solidified gases mainly arise from their physical properties. They are:

- **Asphyxiation** - Rapidly evaporating gases can reduce the oxygen concentration of air by displacement so that it reaches dangerous levels (see table below). Areas with oxygen concentrations below 18% must never be entered. It is recommended that oxygen alarms are set to alarm at 19%.

- **Cold burns, frostbite and hypothermia** from contact with liquefied/solid materials, cold surfaces or gases.
- **Over pressurisation** if the large volume expansion caused by the liquid becoming a gas is confined or trapped.

- **Fire** from oxygen enriched atmospheres generated by the condensation of oxygen onto surfaces

- **Materials becoming brittle** from the effects of extreme cold and could result in catastrophic failure.

- **Manual handling** risks from delivering/transporting of cryogenic materials and their containers around site may create manual handling hazards.

a) Effects of lowered oxygen levels

Oxygen content of air	**Signs and symptoms of asphyxia**
18% - 19%	May affect physical and intellectual performance without person's knowledge.
15% - 18%	Decreased ability to work strenuously. May impair co-ordination and induce symptoms in persons with coronary, pulmonary or circulatory problems.
12% - 15%	Respiration deeper, increased pulse rate and impaired co-ordination, perception and judgement.
10% - 12%	Further increase in rate and depth of respiration, further increase in pulse rate, performance failure, giddiness, poor judgement, cyanosis (blue lips).
8% - 10%	Mental failure, nausea, vomiting, fainting, ashen face, cyanosis.
6% - 8%	Loss of consciousness within a few minutes, resuscitation possible if carried out immediately.

0% - 6%	Loss of consciousness almost immediate, death ensues, brain damage even if rescued.

b) Effects of CO2 enrichment

CO2 poses an intoxication risk which is actually more serious than asphyxiation and occurs at lower displacement levels. CO2 has been assigned a Workplace Exposure Limit (WEL) of 0.5% (5000 ppm) averaged over an 8 hour working period of 1.5% (15,000 ppm) averaged over a 15 minute short term exposure.

Dangerous conditions with elevated CO2 levels cannot be detected by a low oxygen alarm alone. CO2 forms a key part of the biochemical mechanism involved in the breathing reflex and high levels act as an intoxicant or narcotic which depresses and eventually suppresses breathing. Inhaling levels above 10% CO2 will rapidly lead to death, which will occur even if there is an adequate level of oxygen to support life.

CO2 in air	Signs and symptoms of narcosis
1% (10,000 ppm)	Slight symptoms; possible increase in breathing rate
2% (20,000 ppm)	Breathing becomes deeper – 50% above normal
3% (30,000 ppm)	Laboured breathing – 100% above normal, increased pulse rate, reduced hearing, headaches
4% – 5% (40,000 ppm – 50,000 ppm)	As for 3%, but after 30 minutes exposure signs of poisoning evident with a choking sensation

5. Training requirements

All users of the cryobank must have attended the Safe Use of Cryogenics[1] safety training course provided by the Safety Office.

They must also have read and understood the associated risk assessment: NDCN FM RA002 Use of cryogenics.

6. Storage of bulk quantities and safety precautions

NDCN Facilities team arrange the supply of both liquid nitrogen and dry ice – both of which are located on Level 5 of the West Wing.

a) Liquid nitrogen

Liquid nitrogen is stored in pressure vessels which are subject to an annual written scheme of examination which affirms the integrity of the pressure vessel and assess the need for preventative maintenance. There are 2 x 240L dewars holding liquid nitrogen, one feeding a vapour phase cryobank where research material are stored, whilst the other allows dispensing of liquid nitrogen and also acts as a back-up should the cryobank dewar became empty.

- Oxygen sensors will alarm if oxygen level fall below 19%, users must leave immediately the area if the alarm sounds.
- Uses are advised to work in pairs whilst accessing the cryobank and dispensing liquid nitrogen.
- Users must wear a face shield, closed shoes, labcoats and cryogloves whilst accessing the cryobank.
- Individuals dispensing liquid nitrogen must wear an apron in addition to the Personal Protective Equipment identified above.
- Liquid nitrogen must never be stored in an air-tight container, always use a container designed specifically for the holding of liquid nitrogen.

- Handle cryogenics samples with care in containers compatible with ultra-low temperature to prevent container shattering.

b) Dry ice

Dry ice stored in a specifically designed insulated chests which can reduce sublimation to 1-2% per day depending on how full the chest is.

Non-insulated, dry ice will sublimate at the rate of 14% - **hence user must not travel in a lift with non-insulated bulk dry ice** (in case the lift breakdown user would suffer severe CO2 poisoning).

Note that typical delivery of biological material on dry ice are stored in polystyrene containers, which have been found to limit sublimation rate between 1-2%, therefore user can travel with up to 20Kg of dry ice whilst in a lift.

- When collecting dry ice from the chest care the user must take care not to place their head inside the chest or breathe its internal atmosphere as it will be contain high levels of CO2, even if it is nominally empty.

- Do not handle with bare hands – use cryogenic gloves.

- Dry ice must be stored in a container that allow release of gas – never use an air-tight container as this will explode upon the build-up of gas.

- Do not store dry ice in a working refrigerator or freezer – it will sublimate at a faster rate than in an insulated storage container and the extremely cold temperature may cause the thermostat to cut out. Build-up of gas could also cause damage to the refrigerating unit.

- Dry ice must not be carried in a personal vehicle, taxi or a public transport unless a suitable insurance is in place.

- Use suitable storage containers (there are commercially available insulated containers with vented seals specifically designed for storing dry ice).

- Dispose of unwanted dry ice by allowing it to evaporate in a well ventilated area – it will sublime leaving no residue.

- Ensure that all users of dry ice are familiar with the hazards and necessary precautions.

7. Emergency Procedures

Cold burn:

- Contact a first aider.
- If clothing is frozen onto the skin, do not remove.
- Place the entire affected area under running tepid water.
- Flush affected are for at least 15minutes.
- If eyes are affected, cover both eyes using eye bandages provided in the first aid boxes and take the casualty to the eye hospital for assessment.
- Skin burns must be assessed, seek out medical attention.

Inhalation:

- If you suspect someone is suffering from asphyxia, do not enter the area, you must call for help.
- Only if it is absolutely safe to do so, you can access the area and remove the individual to fresh air.

All incidents and near missed must be reported immediately using the online reporting system[2].

8. References

[1]Safe Use of Cryogenics safety training course provided by the Safety Office:
https://cosy.ox.ac.uk/accessplan/LMSPortal/UI/Page/Courses/book.aspx?courseid=SAFE00013

[2]Incident Reporting and Investigation System:
https://oxforduni-remoteforms.info-exchange.com/Incident