HEALTH & SAFETY
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Cryogenic Liquids Policy Arrangements

HSA-10133

Contents

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1. Scope

These policy arrangements outline the hazards associated with the use of cryogenic liquids (excluding cryogenic flammable fluids) and provide a framework for assessment and management of the risk at the University.

2. Introduction

A cryogenic liquid is defined as a liquid with a normal boiling point below -90°C. Some common cryogenic liquids in use at Universities, and their properties are listed below:

	Oxygen	Nitrogen	Argon	Helium
Colour of gas	None	None	None	None
Colour of liquid	Light blue	None	None	None
Normal boiling point	-183°C	-196°C	-186°C	-269°C
Expansion Ratio*	1:842	1:682	1:822	1:738
Relative density to air	1.105	0.967	1.38	0.138

The expansion ratio is the volume of a given amount of a cryogenic substance in liquid form compared to the volume of the same amount of substance in gaseous form at room temperature and normal atmospheric pressure.

2.1 Hazards associated with cryogenic gases

Asphyxiation

Cryogenic liquids expand on warming to produce over 680 times its volume of gas. The resulting displacement of oxygen from the atmosphere may be sufficient to cause asphyxiation (oxygen depletion in the body). There is no visible warning of an oxygen deficient atmosphere caused by the addition of inert gases such as nitrogen, argon or helium. The physiological efforts of the inhalation of reduced oxygen atmosphere are:

21% oxygen - normal concentration in the atmosphere
18-21% oxygen - no discernible symptoms can be detected by the individual
14-18% oxygen - depth of breathing is increased and pulse rate accelerated. The ability to maintain attention and think clearly is diminished. Muscular co-ordination is disturbed
10-14% oxygen – judgement becomes faulty. Severe injuries may cause little pain. Muscular efforts lead to rapid fatigue. Excessive irritation and anger are easily aroused
6-10% oxygen – rate of breathing is double the normal. Nausea and vomiting may occur. Victim loses ability to perform any vigorous muscular movements or even to move at all and may be wholly unaware that anything is wrong. Legs may give way. Resuscitation may be possible if carried out immediately but permanent damage to the brain may result

<6% oxygen- respiration consists of gasps, fainting may occur almost immediately and convulsive movement may occur. Breathing stops but heart may continue to beat for a few minutes

An oxygen depleted atmosphere may occur during the normal boil-off of cryogenic gases during storage, during use, when leaning over vessels when retrieving samples or in the event of a leak or spillage.

Cold burns and frostbite

Skin contact with cryogenic liquids may cause severe cold burns and unprotected skin may freeze onto surfaces cooled by the liquid, causing severe damage on removal. Eyes are particularly susceptible and small splashes or exposure to cold vapour may cause freezing of eye tissues and permanent damage. Prolonged skin exposure to cold may result in frostbite, while prolonged inhalation of cold vapour or gas may cause serious lung damage.

Explosions due to trapped, expanding gas

If cryogenic liquids are trapped inside a sealed container, the expansion on warming may cause an explosion, giving rise to danger from contamination by the vessel's contents as well as injury from fragments of the vessel itself.

Condensation of liquid oxygen and oxygen enriched atmospheres

Oxygen may condense into liquid oxygen in the vicinity of containers of colder cryogenic liquids. The unsuspected presence of liquid oxygen may give rise to explosions caused by increased pressure if the vessels are subsequently sealed and allowed to warm up. Liquid oxygen may also react explosively in the presence of oxidisable material and local enrichment of oxygen (>23% oxygen) can cause combustible materials to be more susceptible to ignition and burn with added violence.

Effects on materials

Many materials become brittle when cooled by cryogenic liquids and may be irreparably damaged and other materials (e.g. glass Dewar's) may fail due to temperature stresses. Care should be taken when selecting materials to ensure compatibility.

3. Responsibilities

In addition to the roles and responsibilities set out in the Health and Safety Policy, the following tasks will be required to manage in accordance with these arrangements.

3.1 Head of College/ PSU

In order to manage the risks from cryogenic liquids in their areas, Heads of College/ Directors of PSUs must ensure:

- There are systems in place for the risk assessment of activities involving cryogenic liquids.
- Users and risk assessors have received appropriate training.
- The necessary equipment and personal protective equipment (PPE) is provided
- Safe storage facilities for cryogenic materials are provided and maintained.
- A self-inspection programme covering the use and storage of cryogenic materials is implemented.
- There are written procedures for the use and handling of cryogenic materials.
- There are written emergency protocols.
- There are systems in place for maintenance and written scheme of examination.
- Sufficient resources are allocated to cover the above items.

3.2 Line Managers/ Academic Supervisors

Managers who oversee activities involving cryogenic liquids must ensure that:

- Suitable and sufficient risk assessment of the use of cryogenic materials in their area are conducted by competent individuals.
- There is provision of appropriate PPE.
- Their staff and students have completed the appropriate training and receive the necessary supervision.
- Training records are maintained for each individual.

3.3 Staff and Students

Users of cryogenic liquids must:

- Take reasonable care of themselves and others affected by their actions.
- Comply with the control measures specified in risk assessments, or complete new risk assessments for their activities.
- Wear the PPE provided when handling cryogenic materials.
- Attend appropriate training.
- Follow instructions on handling cryogenic materials as described during training.

3.4 Tenants

Tenants who use cryogenic liquids in University buildings must share the significant findings of their risk assessments e.g. areas where there is a risk of asphyxiation. Tenants should ensure there are appropriate controls in place.

4. Risk assessment

Risk assessments must be in pace wherever cryogenic liquids are used, stored or transported, detailing the control measures needed to reduce all relevant risks as low as reasonably possible.

Whilst generic College or Department based risk assessments could adequately cover the risks of cold burns and explosions, they are unlikely to consider the asphyxiation risk for individual areas in sufficient detail.

4.1 Managing the risk from oxygen depletion (asphyxiation)

The risk of asphyxiation must be assessed wherever cryogenic liquids are used or stored, taking into account the volume present in relation to the room volume and appropriate control measures put in place.

Control measures for managing the risk of asphyxiation may include the following:

- Consider storing vessels in an external secure area with good natural ventilation.
- Where storage and use in internal rooms cannot be avoided, the rooms should be sufficiently large to ensure that the oxygen concentration does not fall below:
    - 18% due to the total loss of contents of the largest capacity Dewar in the area (e.g. total venting of a pressurised Dewar or spillage of the largest non-pressurised Dewar in the area
    - 19.5% due to the normal evaporation losses from ***all*** liquid nitrogen containers in the room or when filling the largest vessel

If there is the potential for oxygen levels to fall below 19.5% during normal operations, or 18% in an emergency situation then consideration should be given to reduce the volumes stored or changing locations so that so that this potential is removed.

If this cannot be achieved the risk assessment should investigate ventilation and oxygen depletion monitors as control measures. Where there is a serious risk to life e.g. potential for levels to fall below 18% the control measures must be robust and have a level of redundancy in the event of a system failure.

The worst case scenario (1) would be the total evaporation of the entire contents of the largest vessel in the room over a short period of time. The following calculation should be used to model the volume of oxygen remaining in the room:

$$Vol\ of\ 0_2 = 0.21\ x\ [\,Vol\ of\ Room\ in\ m^3 - (Vol\ of\ Liquid\ in\ L\ x\ Expansion\ Ratio)]$$

This can then be converted into the % of oxygen in the room using the following equation:

$$\%\ Oxygen = \frac{100\ x\ Vol\ of\ Oxygen}{Vol\ of\ Room\ m^3}$$

An excel spreadsheet calculator is available on the H&S website to assist with these calculations.

To calculate the reduction in the % of Oxygen in the air due to normal evaporation of Dewar's the following calculation should be used: $$= \frac{Room\ volume\ in\ m^3\ x\ 0.21\ x\ air\ changes\ per\ hr}{(2\ x\ Gas\ evaporation\ rate\ m^3\ per\ hr)\ + (Room\ volume\ m^3\ x\ air\ changes\ per\ hr)}$$ Gas evaporation rate will vary dependent on Dewar – seek advice from manufacturer. A factor of two has been included in the calculation to allow for increased evaporation due to loss of performance of insulation in Dewar's. Where multiple Dewar's are stored the total quantity of gas evaporated per hour should be used. In most rooms, natural ventilation will generally provide around one air change per hour. For basement rooms, cold rooms, or where there are well-sealed windows, less than half an air change per hour will be achieved. Because they are tightly sealed, cold rooms are particularly unsuitable as storage areas for liquid nitrogen and they must not be used for this purpose.
Oxygen displacement during filling of Dewar's: First calculate the volume of oxygen remaining in the room – based on the volume of the largest Dewar to be filled $$= 0.21\ x\ [\ Vol\ of\ Room\ in\ m^3 - \left[\frac{0.1\ x\ Size\ of\ dewar\ in\ L\ x\ Expansion\ Ration}{1000}\right]]$$ This can then be converted into the % of oxygen in the room using the following equation: $$\%\ Oxygen = \frac{100\ x\ Vol\ of\ Oxygen}{Vol\ of\ Room\ m^3}$$

- Identify any areas at particular risk because of the density of gas for example cold liquid nitrogen gas accumulates at low level, so basement rooms, rooms with ventilation openings only at high level, or rooms with floor ducts or pits may pose particular danger in the event of a spill.

- Where there is a risk of oxygen levels falling below 19.5% then consideration should be given to improving the ventilation of the area.
- Where natural ventilation is provided for internal stores, the vents should be at both high and low level, situated diagonally opposite each other and should have a total area of around 1% of the ground area of the room.
- Where mechanical ventilation is provided, then consideration should be given to the properties of the gas in use, for example with liquid nitrogen air should be extracted from low level and supplied at high level.
- It is important to remember that mechanical ventilation can fail, and when it does it "fails to danger" – where ventilation has been identified as a control measure there should be a system e.g. alarms and lights to clearly warn people entering the area that the ventilation system has failed.

- Where ventilation is insufficient to control the risk from oxygen depletion, or when leaks or spills would reduce the oxygen content to below 19.5 %, then fixed oxygen monitoring equipment must be used.
- Care should be taken in siting the oxygen sensors in order to avoid persistent false alarms caused by nuisance triggering (e.g. by direct exposure to gas issuing from containers as they are being filled).
- As a minimum the monitors should have an alarm level set at <19.5%. Consideration should be given to an additional alarm level of 18% which would enable a two-stage response to an alarm.
- Alarms must be easily visible and/or audible both inside and outside of the area monitored, in order to give adequate warning of oxygen depletion.

Note Where bulk tanks are used to supply cryogenic liquids or gases, the risk assessment should consider the risk within the building and oxygen depletion must be linked to an automatic valve that cuts off the supply from the bulk tank in the event of the alarm being set off. This link must operate in a fail-safe mode and be capable of operating in the event of mains power failure.

Where the risk assessment has identified a risk of oxygen depletion (before control measures are put in place), the entrance to the room should display the following signage.

Similar principles of prevention (reduction in quantity, ventilation and detectors) should be applied where there is a risk of an oxygen enriched atmosphere (>23%) occurring.

4.2 Managing the risk from explosions

Cryogenic liquids expand when they warm up and convert to gaseous form – the increase in volume and hence pressure represents an explosion risk in sealed vessels. The correct selection and maintenance of any equipment used with cryogenic liquids is key to controlling these risks.

Types of cryogenic vessels that may be used include:

Small Dewars - non-pressurised, vacuum-walled containers used for storage or transport of small amounts of liquid.

These are equipped either with a loose-fitting cap or pressure relief valves to avoid the build-up of pressure which would happen in a sealed vessel.

Domestic or sealable vacuum flasks must not be used for cryogenic liquids because of the risk of embrittlement, lack of pressure-relief devices and potential for seepage of liquid through joints representing an explosion risk.

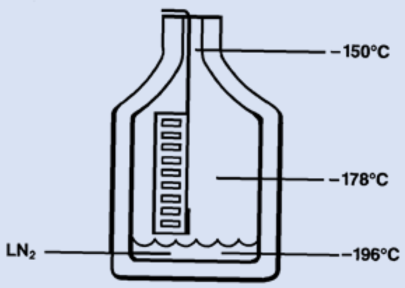
Non-pressurised Dewar's and storage vessels - quantities of up to about 50 litres of cryogenic liquids are often stored and transported in simple insulated storage vessels designed to operate at atmospheric pressure.

Pressurised Dewar's - larger quantities (up to 500 litres) are generally held in transportable pressurised cylinders. They are fitted with safety devices to allow them to vent excess pressure.

These vessels fall under the Pressure Systems Safety Regulations 2000 [which apply to all systems containing liquefied gas operating at a pressure greater than 0.5 bar (approx. 7 psi) above atmospheric pressure]. These Regulations require users to ensure that systems are properly maintained, periodically tested and examined, and are operated within established safe operating limits.

Bulk-supply tanks - are pressurised vessels which can contain upward of 500L of cryogenic liquids. These may be used to supply gas or liquid to a building or process. Because of the risk posed by these quantities special care must be taken in the design and operation of such systems.

Storage of samples in liquid nitrogen



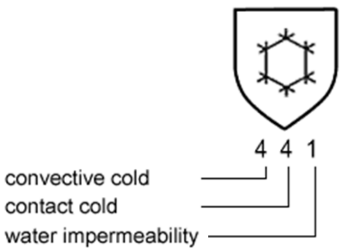
Sample tubes have been known to explode when removed from liquid nitrogen storage due to seepage of liquid nitrogen into the tube which expands rapidly on warming. This not only represents a significant risk injury but potentially also an infection risk (depending on the contents of the tube).

To reduce the likelihood of this occurring samples should be stored in appropriate vials (cryotubes with O-rings) in the vapour phase in the storage and Dewar.

If vials are stored in the liquid phase, on removal they should be placed in secondary containment e.g. a plastic sandwich box, or behind a shield in a safety cabinet, until they reach room temperature. During removal, the operator should wear a face shield.

4.3 Managing the risk from cold-burns and frost bite

Care should be taken to prevent the contact of skin with cryogenic liquids and materials cooled by them by using insulated equipment, remote handling devices (tongs etc.) and the following personal protective equipment:

Face protection	A full-face shield, or safety glasses with cheek and brow guards.
Gloves	Non-absorbent, insulated gloves with ribbed cuffs, made from a suitable material such as leather. The gloves should be loose fit for easy removal. Sleeves should cover the ends of the gloves. Gloves used for protection against convective and contact cold should be CE marked, comply with EN511 and display the following symbol.  Resistance to cold is given on a scale of 0-4 (where 4 is the best). Water permeability is on a scale of 0-1 where 0 is a fail (after 5 minutes) NB Gauntlet gloves are not recommended for decanting because liquid can drip into them. Gloves are not made to permit the hands to be immersed in a cryogenic liquid. They will only provide short-term protection from accidental contact with the liquid.
Body protection	When working with, decanting or transporting cryogenic liquids users should wear normal clothing consisting of long sleeved shirts and trousers without cuffs or turn-ups, with a laboratory coat over. Trousers should be worn over the shoes/boots.
Foot protection	Safety shoes or boots (not Wellingtons) should be worn when decanting or transporting cryogenic liquids in order that the liquid cannot enter them in the event of a spill i.e. no lace holes through to the inside of the shoe.

Consideration should be given to providing local mandatory PPE signage and storage hooks immediately adjacent to areas where cryogenic gases are decanted or used.

5. Information, instruction and training

All University staff and students working with cryogenic liquids and gases must receive appropriate information, instruction and training to enable them to understand the dangers associated with their use. Training should include:

- Completion of the mandatory on-line Decanting of Cryogenic Liquids training module (unless used as part of a taught practical class with direct supervision).
- College based practical demonstration of decanting from Dewar(s).
- Reading the relevant risk assessments.
- Practical demonstration of laboratory techniques using cryogenic gases by line manager/academic supervisor or appointed individual.

Users must demonstrate competency and be authorised before being allowed to use cryogenic liquids. All training must be recorded.

Where third-parties (e.g. tenants or visitors) request to use University facilities for cryogenic liquids, the person responsible for the equipment to be used is required to check that they have had appropriate training.

6. Lone working

Because of the significant risks involved the University prohibits lone working with cryogenic liquids. Should use be required outside of normal working hours e.g. to top up storage vessels over holiday-periods, then at least two people must be present to carry out these activities.

7. Transportation and manual handling

Lifting and carrying Dewar's should be regarded as hazardous and will require a risk assessment and lifting procedure to be laid down. Transportable Dewar's should be handled with care and trolleys used for transport must be suitably designed and in good condition to avoid accidents resulting in the Dewar's tipping over.

The following precautions must be adopted:

- Moving large Dewar's is always a two person operation.
- Appropriate PPE should be worn (lab coat, safety shoes, and safety glasses).
- Before transport check wheels are in good working condition.
- Keep unit upright at all times and handle it carefully.
- Do not "walk", roll or drag Dewars across a floor. Large units are heavy enough to cause personal injury or damage to equipment if proper lifting and handling techniques are not used.
- Ensure that the route to be followed is even and does not have features such as gratings or cobbles that could cause the Dewar to tip over or excessive slope – as this may affect the integrity of the neck and seal of pressure vessels
- Always ensure that the pressure inside the vessel is 50% or less of the relief valve level before moving a vessel.

7.1 Transportation of cryogenic liquids in lifts

There is a risk that a pressure vessel or Dewar may vent off or spill its contents whilst being transported in a lift and so place any accompanying handler at risk.

Therefore when use of a lift to move cryogenic liquids within a building cannot be avoided a risk assessment and standard operating procedure must be completed, following the guide lines below:

- Small volumes of cryogenic gases (less than 500 ml) can be accompanied in a lift (based on worst case scenario calculation for a lift of 3 m^3).
- Larger volumes should not be accompanies in a lift.
- Where possible use a key controlled goods lift which can prevent non-key holders from opening the doors and entering the lift during the transport procedures.
- If a key controlled lift is not available a goods lift should be used with extra barriers and visible warning notices to prevent entry to the lift during the transfer. Barriers must either be present immediately inside the lift or at lift doors on each floor.
- Where a good-lift is not available a passenger lift with extra barriers and warning notices may be used – consideration should be given to the time of day transport is carried out (to avoid peak periods of lift-use) and additional personnel may be required to prevent entry.
- Place a personal oxygen monitor in the lift with the vessel/Dewar to alert the receiver of a dangerous condition in the lift if the vessel/Dewar leaks during transport.

- One person should send the lift and the second should be waiting to receive the vessel/Dewar at the floor destination.
- Before placing in the list cryogenic pressure vessels should be vented off to atmosphere in a safe well ventilated area, until the pressure falls below 50% of the relief valve set pressure. This is to reduce the likelihood of the vessel over pressurising and venting during the transport procedure. Close all valves and check that the liquid has stabilised (monitor the pressure gauge) before placing in the lift.
- Non-pressurised Dewar's should only be filled to 90% of the net capacity to reduce the risk of spillage. Check open Dewars for excessive boil off. Allow to stand until there is no visible boil off. Then ensure that the correct neck plug is fitted.
- Care should be taken when removing a Dewar from the lift – any changes in level/alignment reported to E&FM.
- In the event of any persons discovered to have travelled in a lift – report as adverse event, review of risk assessment.

7.2 Use of stairs

Stairs present an increase tripping hazard which may lead to a spillage. Where possible, avoid carrying Dewars up stairs or steps. If movement of Dewars is unavoidable:

- Consider the installation of a stair lift where practical.
- Two people are recommended for carrying the Dewar.
- Ensure that access to the stairway is restricted the operators during the operation (in case of a spillage).

7.3 Transport in road vehicles

Transport of cryogenic liquids in vehicles is a hazardous activity because of the evaporation of gas into the passenger compartment of the vehicle which could cause asphyxiation.

Where practicable, cryogenic liquids should be delivered by the suppliers to the point of use. If this cannot be achieved the following practices must be followed to minimise risk:

- Consider use of dry ice (solid carbon dioxide) for the transport activity.
- Transport to smallest volume possible to complete the task required.
- The Dewar must not be in the same compartment as the driver and passengers (i.e. hatchbacks, minibuses and most vans are not normally suitable unless very small volumes are used).
- There must always be two members of staff in the vehicle.
- The container must be labelled appropriately.
- The container must secured to prevent movement during travel.
- There must be a constant airflow into the passenger compartment of the vehicle and a personal oxygen depletion alarm should be in the passenger compartment.
    - All occupants of the vehicle must be made aware of the hazards associated with the cryogenic gases and must have written information containing details of what to do in the event of an incident (e.g. spillage) and who to contact.

Note: Where cryogenic liquids are used to transport biological specimens, the Dewar must meet Biological hazard packaging requirements.

8. Emergency Procedures

8.1 Spillage

Each area using cryogenic liquids should have plans for dealing with reasonably foreseeable spillage events. The plans should take into account:

- Who may be affected by the spill.
- The means of raising an alarm.
- Possible escape routes.
- The means of isolating the supply of liquid nitrogen, especially if supplied from a bulk tank.
- The means of preventing access to the area until the oxygen content returns to normal.
- Possibility of liquid nitrogen affecting other areas (e.g. by penetrating floors, or by accumulating in ducts).
- Means of improving ventilation.
- What to, and what not to do, if someone has collapsed in an area of low oxygen concentration.

Attempts at rescue by poorly equipped and untrained rescuers are likely to lead to more casualties. Rescue should not be attempted if this is likely to put the rescuers in danger.

An example of decision making in the event of a spillage, or an oxygen depletion alarm sounding can be found in the diagram below.

8.2 First Aid

Skin contact

Contact between cryogenic liquids and eyes or skin should be treated immediately by flooding the affected area with large quantities of cold water, followed by the application of cold compresses. Never use dry heat. If the skin is blistered or the eyes are affected, medical attention must be obtained as soon as possible.

Remove any clothing that may constrict the blood circulation to the frozen area. Clothing which has stuck to frozen tissue must not be removed until completely thawed.

Eye contact

Flush the eye with running water for at least 15 minutes and ensure the casualty is taken to the hospital for assessment.

Inhalation of Inert Gases

Dizziness or loss of consciousness while working with cryogenic liquids must be treated by moving the affected person immediately to a well ventilated area (if it is safe to do so). Artificial respiration and treatment for shock should be given as necessary.

Precautions against shock must be taken following any accident involving cryogenic liquids.

9. Maintenance and testing of control measures

Pressurised storage vessels must have a written scheme of examination and be examined once every 12 months. Burst valves must be replaced at least once every 7 years. Any modification to the storage tank requires it to be re-examined. Pressurised vessels not used for more than 12 months should be examined before re-use.

All the above must be completed by a competent person, for University owned equipment this is organised via Estates & Facilities Management whilst leased equipment is usually maintained by the supplier. The College/PSU should retain records of examinations.

The majority of mechanical ventilation systems at the University are on a reactive maintenance schedule, defects must be reported via the Estates Help Desk. Where mechanical ventilation is used as a control measure to maintain oxygen levels above 18% it should be subject to programmed proactive maintenance regimen. The person responsible for the cryogenic liquid system in the area is responsible for notifying Estates of this need.

All oxygen monitoring equipment must be serviced, calibrated and sensors replaced in line with the manufacturer’s instructions.

Trolleys and wheels on Dewars should be checked prior to each use, any defects should be reported and remedial action undertaken prior to use.

10. Relevant legislation

- Control of Substances Hazardous to Health 2002
- Pressure Systems Safety Regulations 2000
- Confined Spaces Regulations 1997

11. Further information

- BCGA CP30 The safe use of liquid nitrogen Dewars up to 50 litres. Revision 2: 2013
- BCGA CP36 Cryogenic liquid storage at users' premises. Revision 2: 2013
- BGCA GN11 The management of risk when using gases in enclosed workplaces. Revision 4: 2018
- BCGA GN19 Cryogenic sample storage systems (Biostores) - Guidance on design and operation. 2012
- **https://www.boconline.co.uk/en/health-and-safety/gas-safety/gas-risks/cryogenic-gas-risks/index.html**