Summary

This guidance is intended to provide information on the hazards and risks associated with the use of liquid nitrogen and the control measures which can be used. The contents of this guidance should be brought to the attention of all users of liquid nitrogen. In many cases additional local information will be required to cover the particular circumstances in which liquid nitrogen is being used within laboratories. This information should be supplemented by appropriate training and demonstration where specific tasks are undertaken.

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1. Relevant Legislation

The *Management of Health and Safety at Work Regulations 1999* require every employer to make a suitable and sufficient risk assessment of the risks to health and safety of his employees to which they are exposed while at work. The Regulations also stipulate a requirement for the provision of adequate information, instruction and training and for procedures for dealing with serious and imminent danger. The *Personal Protective Equipment at Work Regulations 1992* require employers to provide suitable protective equipment where risk cannot be adequately controlled by other means which are equally or more effective.

The *Confined Space Regulations 1997* may also apply where unventilated or poorly ventilated areas are concerned.

In addition to the above, the *Pressure Systems Safety Regulations 2000* apply to all systems containing liquefied gas operating at a pressure greater than 0.5 bar (approx. 7 psi) above atmospheric. These Regulations require users to ensure that systems are properly maintained, periodically examined (and adequate records of examination kept) and are operated within established safe operating limits.

Note: the *Control of Substances Hazardous to Health (COSHH) Regulations* do not apply to the use of liquid nitrogen as it is not classified as a substance hazardous to health but as an asphyxiant.

2. Risk Assessment

It is particularly important that a risk assessment is completed for areas storing quantities of liquid nitrogen that present a significant risk of asphyxiation e.g. in the event of a spillage or the release of cylinder contents in the event of a valve failure. **Contact the technical services office (rm. 246 504775 or 507532)** for assistance if required.

The process for completing a risk assessment for the handling and use of liquid nitrogen follows the same general rules for all risk assessments.

1. Identify hazards
2. Decide who might be harmed and how
3. Evaluate the risks and decide whether existing precautions are adequate or whether more needs to be done
4. Record your findings
5. Review and revise your assessment as appropriate.

The remaining sections below will help you to identify the hazards and determine the relevant control measures needed.

3. Properties and Hazards

Liquid nitrogen is a colourless, odourless liquid with a boiling point of -196^{0}C. At low temperatures the gas / vapour is heavier than air. Small amounts of liquid vaporise rapidly to produce large volumes of gas (1 litre of liquid nitrogen will produce 0.7m^3 of gas). Nitrogen gas is invisible - the cloudy vapour which appears when liquid nitrogen is exposed to air is condensed moisture, not the gas itself.

Asphyxiation

One of the main dangers associated with liquid nitrogen is the risk of asphyxiation when used or stored in poorly ventilated areas. Liquid nitrogen evolves nitrogen gas which is inert and non-toxic but there is a risk of asphyxiation in situations where high concentrations may accumulate and subsequently displace air from the room.

Short exposures to cold gas vapour leads to discomfort in breathing whilst prolonged inhalation can produce serious affects on the lungs and could possibly provoke an asthma attack.

Methods for calculating the potential for oxygen depletion are given in Appendix 1.

Cryogenic burns

Liquid nitrogen can cause cryogenic burns if the substance itself, or surfaces which are or have been in contact with the substance (e.g. metal transfer hoses), come into contact with the skin. Local pain may be felt as the skin cools, though intense pain can occur when cold burns thaw and, if the area affected is large enough, the person may go into shock.

Frostbite

Continued exposure of unprotected flesh to cold atmospheres can result in frostbite. There is usually sufficient warning by local pain whilst the freezing action is taking place.

Hypothermia

Low air temperatures arising from the proximity of liquefied gases can cause hypothermia. Susceptibility is dependent upon temperature, exposure time and the individual concerned (older people are more likely to succumb).

4. First Aid

Where inhalation has occurred, the victim (who may be unconscious) should be removed to a well ventilated area. **Rescuers should not put themselves at risk - a contaminated area should not be entered unless considered safe. Breathing apparatus may be required but should only be used by trained personnel.** The person should be kept warm and rested whilst medical attention is obtained. If breathing has stopped then resuscitation should be commenced by a trained first aider.

Where contact has occurred, the aim should be to slowly raise the temperature of the affected area back to normal. For minor injuries, clothing should be loosened and the person made comfortable. Clothing should not be pulled away from burned or frozen skin. The affected area should be doused with copious quantities of tepid water (40^{o}C) for at least 15 minutes and a sterile burn dressing applied to protect the injury until the person can be taken to receive hospital treatment. Do not:

- use a direct source of heat such as a radiator
- permit smoking or alcohol consumption
- give analgesics (e.g. Paracetamol, aspirin)

For major injuries apply first aid as far as is practicable and arrange for the victim to receive medical attention.

5. Personal Protective Equipment (PPE)

This should be appropriate to the task in hand and readily available.

Hands - non-absorbent insulated gloves must always be worn when handling anything that is or has been in recent contact with liquid nitrogen. Cryogenic gloves are designed to be used in the vapour phase only and **should not be immersed into liquid nitrogen under any circumstances**. They should be a loose fit to facilitate easy removal. Gauntlet style gloves are not recommended for some liquid handling uses as liquid can drip into them and become trapped against the skin - sleeves should cover the ends of gloves or alternatively, a ribbed cuff style may be used.

There are a range of commercially available gloves suitable for use at cold temperatures, some of which meet the requirements of BS EN 420: 1994 'General requirements for gloves'.

Face - a full face visor should be used to protect the eyes and face where splashing or spraying may occur and, in particular, where operations are carried out at eye level e.g. when topping up reservoirs on electron microscopes.

Body - a laboratory coat or overalls should be worn at all times. Non-absorbent cryogenic aprons are also commercially available. Open pockets and turn-ups where liquid could collect should be avoided. Trouser bottoms should overlap boots or shoes for the same reason.

Feet - sturdy shoes with a re-enforced toecap are recommended for handling liquid nitrogen vessels. Open toed shoes should not be worn under any circumstances.

When not in use, all PPE should be stored in an appropriate manner (e.g. visors on wall mounted hooks) to ensure that it does not become damaged or contaminated.

6. Emergency Procedures

In the event of a large spillage or accidental release, the following procedures should be followed:

- Evacuate the area. Deploy warning signs if necessary.
- Ventilate the area. Open doors and windows or activate forced ventilation to allow any spilt liquid to evaporate and the resultant gas to disperse.
- Try to stop the release if at all possible e.g. turn off valves, but only if it is safe to do so - always wear protective clothing.
- Do not re-enter area unless it is proved safe to do so. The presence of oxygen deficiency monitors will indicate the oxygen levels in the vicinity.
- Prevent liquid nitrogen from entering drains, basements, pits or any confined space where accumulation may be dangerous.

7. Storage & Use

Ventilation is again a key issue. Large scale vacuum insulated tanks are normally stored outside buildings because of the quantities of stored liquid. Where smaller pressurised containers and non-pressurised dewars are stored within buildings, the following points should be considered:

- store below 50°C in well ventilated place
- ensure appropriate hazard warning signs are displayed (yellow triangle with exclamation symbol and text: 'Liquid nitrogen')
- use only properly specified equipment for storing liquid nitrogen

Working with liquid nitrogen in Cold Rooms.
This is permissible providing that risk assessment determines that it is acceptable. The following points should be considered:

- ventilation - is it adequate? Most cold rooms do not have any air supply or extract system and so there is little or no air change. Can the door be left open to allow gas to dissipate when vessels are being filled?
- do people spend significant periods working in the cold room (on unrelated tasks)?
- is the room fitted with an oxygen deficiency monitor / alarm?
- is the door fitted with a viewing panel?
- is there a 'panic button' within the room?

With regard to general use:

- do not leave vessels unattended when filling
- use only proper transfer equipment.

- do not overfill vessels.
- with non -pressurised containers, do not plug the entrance with any device that would interfere with the venting of gas. Use only the loose fitting neck tube core or an approved accessory.
- do not use brittle plastics which may shatter on contact with the cold liquid.
- do not use hollow dipsticks - use solid metal or wood. If a warm hollow tube is inserted into liquid nitrogen, liquid will spout from the tube due to rapid expansion of liquid inside the tube and gasification.

Any instructions given to staff should detail not only what they are required to do but also what they should not do. Departmental management have a responsibility to monitor all procedures to ensure that local rules are being complied with.

8. Maintenance

All static and transportable pressurised vessels must be maintained and tested in accordance with the *Pressure Systems Safety Regulations 2000*. Completion of a written scheme of examination and the periodic examination itself is usually carried out by trained engineers appointed by the insurance company responsible for insuring the vessel. The maintenance of transportable vessels is a School responsibility and all records of inspections should be filed and readily accessible to present to the enforcing authorities if requested.
Any obvious damage sustained by vessels (either static or transportable) must be reported immediately to the laboratory supervisor and if necessary, the vessel should be taken out of use until inspected by a competent person.

Forced ventilation systems and oxygen deficiency alarms should be maintained in good working order. (Details see Appendix 2)

9. Training

All liquid nitrogen users must be made aware of the properties and hazards and be fully trained in the local departmental procedures for usage, storage and transportation before they engage in handling the substance.

10. Local rules for decanting liquid nitrogen from BOC storage tank.

- All users must be trained and authorised to dispense liquid nitrogen from this storage vessel
- Liquid nitrogen may only be dispensed into containers designed for liquid nitrogen use of the narrow neck style.
- Liquid must **not** be dispensed into small volume (< 50 litres) even where designed for liquid nitrogen use.
- Wear PPE provided (gloves and eye/face protection) at all times during the dispensing process
- If raining ensure people are warned of possible slippery surface
- If liquid leaking from delivery hose or joints. Stop filling and report the problem.
- Out of normal working hours (weekdays 08:00 to 18:00hrs) liquid nitrogen must not be decanted out of the pressurised storage vessel.
- If there is an absolute necessity for liquid nitrogen from the pressurised storage dewar out of hours, this procedure must be carried out by two trained members of staff working together to allow for the alarm to be raised if there is an incident/accident.

Reports to P. McDonald, Rm 246

11. Transportation of Vessels within the Department

If vessels must be manoeuvred between locations and there is a risk or possible risk of injury then an assessment must be carried out.

Pressurised vessels and non-pressurised dewars are used in the School - a full 180 litre pressurised vessel can weigh in excess of 300 kg and manual handling injuries can be sustained. In the case of the larger pressurised cylinders, it is highly likely that the assessment will indicate that the movement of these vessels should be a two person operation, particularly if there is a requirement to move between differing levels using a lift (see below). The school has invested in a master mover for movement of large pressurised dewar vessels and can only be used by trained operators.

Before moving transportable containers, the route should be assessed to consider:

- rest stops
- movement through populated work areas
- possible obstructions and clutter
- lifts (see below)
- floor surfaces (are they sound and even?)
- kerbs
- stairs (hazardous due to potential for slips and trips which could result in spillages from small hand held dewars)
- whether the destination for the gas is ready to accept it

Only purpose designed handling equipment should be used. All transportable Dewar vessels are fitted with wheel and/or undercarriages. A two wheeled handling trolley is available for transporting the 25 litre un-pressurised storage containers and must be used for transporting these containers.

Transport in lifts

'Vessels should only be transported in lifts when covered by a safe system of work which takes account of the hazards, including that due to oxygen deficiency when a lift is stopped for a period between floors'.

Transportable Vacuum Insulated Containers of not more than 1000 Litres Volume - BCGA Code of Practice CP27

In practice, this means that pressurised vessels (and dewars) should not be accompanied in lifts. If a goods lift or passenger lift is used then it should be closed to all passengers. The vessel should be manoeuvred into the lift and the lift sent to the destination floor to be met by an assistant.

Appendix 1

Assessment of Ventilation Requirements

Nitrogen is the main component of air and is present at approximately 78% by volume (oxygen is approximately 21% and argon 1%). Any alterations in the concentrations of these gases, especially oxygen, have an effect on life. In the case of liquid nitrogen, there is a risk of asphyxiation where ventilation is inadequate and the nitrogen gas evolved can build up and displace oxygen from the local atmosphere. An atmosphere containing less than 18% oxygen is potentially hazardous and entry into atmospheres containing less than 20% should be avoided.

The general effects of reduced oxygen content in the atmosphere are given in the table below:

Oxygen content (vol. %)	Effects and symptoms
11 -14	Physical and intellectual performance diminishes without the person being aware.
8 - 11	Possibility of fainting without prior warning.
6 - 8	Fainting within a few minutes - resuscitation possible if carried out immediately.
0 - 6	Fainting almost immediate, death ensues, brain damage even if resuscitated.

In typical situations the concentration of nitrogen gas which may accumulate in a room over a period of time (assuming a certain evaporation rate from vessels and / or pipework) may be calculated using the following equation:

$$C = \frac{L}{Vn} \quad \text{approximately}$$

Where: C = gas concentration
L = gas release (m^3 / h)
V = room volume (m^3)
n = air changes per hour

For rooms at or above ground level, natural ventilation will typically provide 1 air change per hour. However, this is not the case with rooms which are windowless or have windows which are tightly sealed, in which case the number of air changes will be less than 1 per hour. For underground rooms with small windows, 0.4 changes per hour could be considered a typical value.

Example

A room (H = 2.8m, W = 3.0m, D = 4.0m) houses 6 x 25 litre capacity non-pressurised liquid nitrogen vessels. The rate of evaporation from the vessels is 0.5 litres / 24 hours (this information should be obtainable from the manufacturers and is typically 1 - 2% of the liquid capacity of the vessel per 24 hours). The figure is also multiplied x 2 to allow for deterioration in the vacuum insulation with time. The room is above ground but has no windows and is estimated to have 0.5 air changes per hour by natural ventilation. The gas expansion factor for nitrogen is 683.

$$L = \frac{(6 \times 0.5) \times 2 \times 683}{24 \times 1000} = 0.171\ m^3 / h$$

$$V = 2.8 \times 3.0 \times 4.0 = 33.6\ m^3$$

$$n = 0.5$$

therefore:

$$C = \frac{0.171}{33.6 \times 0.5} = 0.010\ (\times 100) = 1.0\%$$

The nitrogen concentration of the room is increased by 1.0%. The normal oxygen content of the atmosphere is approximately 21%, therefore:

$$21 \times \frac{100}{100 + 1.0} = 20.8\%$$

Under these circumstances the evaporation from the vessels only reduces the atmospheric oxygen content from 21% to 20.8% - negligible and well within the safe working limit. It should be noted however, that the nitrogen evolution will be greater during filling operations when the lids of the vessels are open and liquid nitrogen is being transferred. In most cases, this is a relatively short term operation.

Alternatively, oxygen deficiency resulting from a large spillage of liquid nitrogen or sudden rapid release of nitrogen gas from a pressurised vessel may be calculated as follows - this is the 'worst case scenario':

Resulting oxygen concentration (%)

$$\%O_2 = 100 \times \frac{Vo}{Vr}$$

Where, for nitrogen:

Vo = 0.2095 (Vr - Vg)

Vr = room volume (m^3)

Vg = maximum gas release, which is the liquid volume capacity of the vessel V x gas expansion factor.

Example

A pressurised liquid nitrogen vessel of 100 litre capacity located in a room 2.8 m x 5.0m x 10.0 m loses vacuum suddenly and vents it's contents to atmosphere in a very short space of time:

$$Vr = 2.8 \times 5.0 \times 10.0 = 140\ m^3$$

$$Vg = 100 \times 683 = 68300 \text{ litres} = 68.3 m^3$$

$$Vo = 0.2095\ (140 - 68.3) = 15.02$$

$$\%O2 = 100 \times \frac{15.02}{140} = 10.7\%$$

The oxygen content of the room is halved to 10.7%.

If the calculation suggests an oxygen content of less than 18% then the following should be considered:

- site the vessel outside the building and pipe liquid nitrogen to the point of use.
- or pipe the pressure release valve and bursting disc to vent the gas to the outside of the building.
- and / or fit a permanent oxygen depletion monitor and fit a forced ventilation system.

Appendix 2

Oxygen deficiency monitors.

Oxygen deficiency monitors are installed labs 14 and 14F

Where Oxygen deficiency monitors are not present it is recommended a portable oxygen monitor is used.

For details of use and suppliers please contact Technical Services Office, room 246.