DEEP CRYOGENICS INTERNATIONAL	**Standard Operating Procedure – Liquid Nitrogen – Storage, Use and Transportation Guidance and Code of Practice**

Summary

This guidance is intended to provide information on the hazards and risks associated with the use of liquid nitrogen and the safety 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 DCI's treatment area, laboratory and operations. This information should be supplemented by appropriate training and demonstration where specific tasks are undertaken.

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1. Relevant Legislation

The Canada Labour Code requires 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 Hazard Prevention Program Regulations of the Federal Code require employers to provide suitable protective equipment where risk cannot be adequately controlled by other means which are effective.

The Hazard Prevention Guide may also apply where unventilated or poorly ventilated areas are concerned. Additional guidance may be found in Praxair's Safety Data Sheet E-4630 governing safe handling and operation of equipment utilizing liquid nitrogen. 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, the release of cylinder contents in the event of a valve failure or interrupted tank operation).

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

- Identify hazards
- Decide who might be harmed and how
- Evaluate the risks and decide whether existing precautions are adequate or whether more needs to be done
- Record your findings
- 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°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 — a 645 times expansion from liquid state to ambient gas temperature). 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 creates 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. **NO ONE MAY ENTER THE SHOP AREA WITHOUT THE PRESENCE OF A COMPANY EMPLOYEE WHO IS WEARING A CALIBRATED OXYGEN DEFICIENCY MONITOR AND WHO HAS RECEIVED ADEQUATE TRAINING.**

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

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 while 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.

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 while medical attention is obtained. If breathing has stopped, then resuscitation should commence 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.,Tylenol, 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 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.

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 - goggles or 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 removing parts or coupons from a tank during an active DCT run.

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. Pants 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.
- Ventilate the area. Open doors and windows or activate forced ventilation to allow any spilled 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 and Use

Ventilation is a key issue. DCI uses pressurized 230-litre containers supplied by Praxair. They are stored within the building on the basement level (shop area). 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

Any instructions given to DCI staff should detail not only what they are required to do but also what they should not do.

8. Maintenance

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 monitors should be maintained in good working order.

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. Transportation of Vessels

If full liquid nitrogen vessels must be maneuvered within the shop, assess the risk of danger to employees and apply appropriate precautions.

Before moving containers, the route should be assessed to consider that all dewar vessels are fitted with wheels.

11. 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 can build up and displace oxygen. An atmosphere containing less than 18% oxygen is potentially hazardous and entry into atmosphere 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.

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

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 $\% O_2 = 100 \times Vo\ Vr$

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 gas expansion factor.

Example

A pressurized 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 its contents to atmosphere in a very short space of time:

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

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

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

$\%O2 = 100 \times 15.02 = 10.7\%$

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
- Pipe the pressure release valve and bursting disc to vent the gas to the outside of the building
- Install a permanent oxygen deficiency monitor and a forced ventilation system

12. Oxygen Deficiency Monitors

Oxygen deficiency monitors are required by all employees entering the shop/DCT area.
No visitor may enter the shop/DCT area unless accompanied by an employee wearing a calibrated and operational oxygen monitor with not less than one month of life remaining on the monitor.