RISK ASSESSMENT FOR STORAGE AND USE OF LIQUID NITROGEN

I. Properties of liquid nitrogen

Liquid nitrogen is a cryogenic liquid with a density of 0.807 g/ml at its boiling point of -196°C. The vapour released from liquid nitrogen dewar also remain very cold and it condenses the moisture in the air and creates a highly visible fog.

II. Liquid nitrogen containers

Liquid nitrogen is transported and stored in dewars, cryogenic liquid cylinders and cryogenic storage tanks. These containers are double-walled, vacuum vessels with multilayer insulation. Dewars are open , non-pressurized vessels with a free venting protective cap that hold liquid nitrogen. Cryogenic liquid cylinders and storage tanks are pressurized vessels. Center of Laboratory Supplies provides high-pressure liquid nitrogen tank (230 psig) and low-pressure liquid nitrogen tank (22 psig). High-pressure tank is used for the delivery of liquid and gas and low-pressure tanks are used only for the delivery of liquid.

III. Example of Use of liquid nitrogen in HKUST

- As a backup supply of nitrogen gas for laboratory equipment
- To store cells at low temperatures
- Maintain a low temperature around the primary liquid helium cooling system of high-field superconducting magnets
- Maintain a temperature sufficient to achieve superconductivity of high-temperature superconductors
- Maintain a temperature of cold trap for experiments involving vacuum lines
- Maintain a temperature for imaged cryogenically fixed sample on a CryoSEM
- Prepare frozen tissues for histology
- Use for scientific demonstrations such as making ultra-smooth ice cream, changing in the elasticity of materials and thermal expansion/compression of metals

IV. Risk Assessment

It is essential to conduct a risk assessment to identify hazards of handling liquid nitrogen and take appropriate safety measures to reduce the risk of particular hazards to acceptable levels prior to storing and using liquid nitrogen.

Hazards of Liquid Nitrogen	Hazard Controls of Liquid Nitrogen
Asphyxiation Hazard When liquid nitrogen is used, it is potentially hazardous due to its significant volume expansion when changing into the gaseous phase. It will undergo 696 times increase in volume when warming up at 21^{o}C to become gaseous nitrogen. Oxygen concentration below 19.5% is considered an oxygen-deficient environment. The resulting displacement of oxygen from the atmosphere may be sufficient to cause dizziness, nausea or asphyxiation without warning	• Liaise with HSEO and FMO-LS to conduct a laboratory ventilation risk assessment • The quantities of liquid nitrogen allow to be stored and used in a laboratory is based on the result of laboratory ventilation risk assessment • Do not over-stock liquid nitrogen dewars • Work in a well-ventilated area to ensure that the oxygen concentration does not fall below 19.5 vol % due to the routine conditions of use • Handle the liquid nitrogen slowly to minimize boiling and splashing • Use tongs to withdraw objects immersed in liquid nitrogen, as boiling and splashing always occur when charging or filling a warm container with liquid nitrogen or when inserting objects into the dewar • Do not store liquid nitrogen dewar in a cold room which has no fresh air change • Install an oxygen monitor with an audible alarm if needed • Ensure all parts of dewars are in proper functioning condition • Use a suitable insulated transfer line/hose to reduce the evaporation of liquid nitrogen and elimination of frost and condensation during transfers • Transfer liquid nitrogen in a well-ventilated area
Cryogenic Hazard The cryogenic properties of liquid nitrogen and its boil-off vapour can cause frostbite and prolonged breathing of extremely cold air may damage the lungs	• Do not overfill liquid nitrogen dewars • Use of liquid withdrawal devices fitted with pressure relief devices rather than pouring liquid nitrogen directly from the dewar • Avoid contact with both liquid and vapour of liquid nitrogen • Do not touch uninsulated piping of liquid nitrogen • Wear loose-fitting cryogen gloves, goggles, apron, face shield and closed shoes • If skin contacts liquid nitrogen, thaw burned area slowly in cold water. Do not rub

Fire and Explosion Hazard Liquid nitrogen (boiling point of -196°C) is able to condense oxygen (boiling point -183°C) from the atmosphere and liquefied oxygen (pale blue in colour) is a strong oxidizer which contains 4,000 times more oxygen by volume than normal air. Violent reactions such as rapid combustion or explosion may occur if liquid oxygen comes into contact with flammable materials such as organic solvent or grease	• Follow the standard operating procedure for the operation of a vacuum line system • Properly insulated tubing of liquid nitrogen to avoid condensation of liquid oxygen • Store away of combustible and flammable materials
Explosion Due to Rapid Expansion Improper storage of liquid nitrogen in a closed system without pressure-relief devices such as relief valves and rupture disks may pose a risk of boiling liquid expanding vapour explosion (BLEVE) Storage or immersion of sample vials in the liquid phase of liquid nitrogen may pose a risk of explosion. Liquid nitrogen may seep into the sample vials and rapidly expand when it warms up and explode	• Cryogenic containers shall be equipped with pressure-relief devices and rupture disks to protect the cylinders from pressure build-up • Use transfer lines designed for use with liquid nitrogen • Equip properly rated pressure relief devices on any transfer line between any two shut-off valves in the filling system to prevent trapping liquid nitrogen or vaporized nitrogen gas which can cause pressure to build up • Domestic thermo flasks are not appropriate for handling small volumes of liquid nitrogen for use in the laboratory, as they are not intended to be free-venting and can result in pressure build-up and a subsequent explosion • Store sample vials in the vapour phase of liquid nitrogen • Use of sample vials which certified by the manufacturer as appropriate for use with liquid nitrogen • Sample vials should have a silicone or rubber o-rings for a secure seal • Wear proper personal protective equipment such as cryogenic gloves, lab coats and face shield during retrieval and thawing of the samples.

<u>**Laboratory Ventilation Risk Assessment for**</u>

<u>**Storage and Use of Liquid Nitrogen**</u>

The laboratory ventilation risk assessment should take into account of the following factors

- The volume of the laboratory
- The quantity of liquid nitrogen
- The air change rate of the laboratory and
- Situations of loss of liquid nitrogen such as (1) normal evaporative losses, (2) filling losses and (3) spillage of the vessel's entire contents

The quantity of liquid nitrogen allowed to be stored in a laboratory depends on the volume and ventilation of the laboratory. Laboratory with proper mechanical ventilation and sufficient fresh air change rate is preferable for storing and using liquid nitrogen because evaporative losses and spills are less likely to cause an oxygen-deficient atmosphere.

Risk Assessment 1: **To evaluate oxygen level in a laboratory for nitrogen evaporation due to normal evaporation losses**

Room volume m^3	The volume of liquid nitrogen, litres										
	5	10	25	50	75	100	200	250	300	400	500
15	20.9	20.8	20.5	19.9	19.4	18.8	16.7	15.6	14.5	12.4	10.2
30	20.9	20.9	20.7	20.5	20.2	19.9	18.8	18.3	17.8	16.7	15.6
50	21.0	20.9	20.8	20.7	20.5	20.4	19.7	19.4	19.1	18.4	17.8
75	21.0	21.0	20.9	20.8	20.7	20.6	20.1	19.9	19.7	19.3	18.8
100	21.0	21.0	20.9	20.8	20.8	20.7	20.4	20.2	20.0	19.7	19.4
150	21.0	21.0	20.9	20.9	20.8	20.8	20.6	20.5	20.4	20.1	19.9
200	21.0	21.0	21.0	20.9	20.9	20.8	20.7	20.6	20.5	20.4	20.2
300	21.0	21.0	21.0	20.9	20.9	20.9	20.8	20.7	20.7	20.6	20.5
400	21.0	21.0	21.0	21.0	20.9	20.9	20.8	20.8	20.8	20.7	20.6
500	21.0	21.0	21.0	21.0	21.0	20.9	20.9	20.8	20.8	20.7	20.7

Table 1: Assume 2.2% of the volume of gas produced by evaporating liquid nitrogen and <u>no air change rate</u> in the laboratory.

Room volume m^3	The volume of liquid nitrogen, litres										
	5	10	25	50	75	100	200	250	300	400	500
15	21.0	21.0	21.0	20.9	20.9	20.8	20.6	20.5	20.5	20.3	**20.1**
30	21.0	21.0	21.0	21.0	20.9	20.9	20.8	20.8	20.7	20.6	20.5
50	21.0	21.0	21.0	21.0	21.0	20.9	20.9	20.9	20.8	20.8	20.7
75	21.0	21.0	21.0	21.0	21.0	21.0	20.9	20.9	20.9	20.9	20.8
100	21.0	21.0	21.0	21.0	21.0	21.0	20.9	20.9	20.9	20.9	20.9
150	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	20.9	20.9	20.9
200	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	20.9	20.9
300	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
400	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
500	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0

Table 2: Assume 2.2% of the volume of gas produced by evaporating liquid nitrogen and 1 air change rate in the laboratory.

- The lowest oxygen concentration in a laboratory with 1 air change per hour after normal evaporative loss is 20.1%. The risk of asphyxiation is insignificant.

Risk Assessment 2: To evaluate of oxygen level in a laboratory for nitrogen evaporation due to tank to tank liquid transfer

Room volume (m^3)	The volume of liquid nitrogen, litres						
	5	10	25	50	75	100	200
15	20.5	20.0	18.6	16.1	13.7	11.2	1.4
30	20.8	20.5	19.8	18.6	17.3	16.1	11.2
50	20.9	20.7	20.3	19.5	18.8	18.1	15.1
75	20.9	20.8	20.5	20.0	19.5	19.0	17.1
100	20.9	20.9	20.6	20.3	19.9	19.5	18.1
150	21.0	20.9	20.8	20.5	20.3	20.0	19.0
200	21.0	20.9	20.8	20.6	20.4	20.3	19.5
300	21.0	21.0	20.9	20.8	20.6	20.5	20.0
400	21.0	21.0	20.9	20.8	20.7	20.6	20.3
500	21.0	21.0	20.9	20.9	20.8	20.7	20.4

Table 3: Assume 10% loss of one dewar during liquid nitrogen transfer and no air change in the laboratory

Room volume (m^3)	The volume of liquid nitrogen, litres						
	5	10	25	50	75	100	200
15	21.0	21.0	20.9	20.9	20.8	20.8	20.6
30	21.0	21.0	21.0	20.9	20.9	20.9	20.8
50	21.0	21.0	21.0	21.0	21.0	20.9	20.9
75	21.0	21.0	21.0	21.0	21.0	21.0	20.9
100	21.0	21.0	21.0	21.0	21.0	21.0	20.9
150	21.0	21.0	21.0	21.0	21.0	21.0	21.0
200	21.0	21.0	21.0	21.0	21.0	21.0	21.0
300	21.0	21.0	21.0	21.0	21.0	21.0	21.0
400	21.0	21.0	21.0	21.0	21.0	21.0	21.0
500	21.0	21.0	21.0	21.0	21.0	21.0	21.0

Table 4: Assume 10% loss of one dewar in the laboratory during liquid nitrogen transfer and 4 air changes in the laboratory

- The above calculation proved that a laboratory with a ventilation rate of 4 air changes rate significantly reduces the risk of asphyxiation.

Risk Assessment 3: To evaluate of oxygen level in a laboratory for nitrogen evaporation due to 100% spillage of the entire content of dewar in the laboratory. For this calculation, the effect of ventilation was ignored and it assumes that liquid nitrogen vaporizes immediately and the released nitrogen gas mixes with the air.

Room volume (m^3)	The volume of liquid nitrogen, litres						
	1	5	10	25	50	75	100
10	19.5	13.7	6.3	0	0	0	0
15	20.0	16.1	11.2	0	0	0	0
30	20.5	18.6	16.1	8.8	0	0	0
50	20.7	19.5	18.1	13.7	6.3	0	0
75	20.8	20.0	19.0	16.1	11.2	6.3	1.4
100	20.9	20.3	19.5	17.3	13.7	10.0	6.3
150	20.9	20.5	20.0	18.6	16.1	13.7	11.2
200	21.0	20.6	20.3	19.2	17.3	15.5	13.7
300	21.0	20.8	20.5	19.8	18.6	17.3	16.1
400	21.0	20.8	20.6	20.1	19.2	18.2	17.3
500	21.0	20.9	20.7	20.3	19.5	18.8	18.1

Table 5: Assume 100% spillage of the entire content of a dewar in the laboratory

- The above calculation shows that in the worst-case scenario, the air will be displayed by the nitrogen leading to an oxygen-deficient atmosphere. Safety control measures specified in Section IV should be implemented to avoid the risk of asphyxiation.

References:

1. Code of Practice 30: The Safety Use of Liquid Nitrogen Dewars; British Compressed Gases Association (2019)
2. User Manual and Safety Information for Industrial Liquid Gas Containers; Hong Kong Oxygen & Acetylene Co. Ltd.
3. Code of Practice on Safe Use of Liquid Nitrogen; Royal Free Hampstead NHS Trust & Royal Free & University College Medical School (Royal Free Campus) (2014)
4. Policy number S4/03: Liquid Nitrogen; University of Oxford