Health & Safety Directorate

Safe Management of Cryogenic Liquids and Solids - Health and Safety Policy, Arrangements and Guidance for QMUL

(Ref: QMUL_HS_103)

QMUL_HS_103_Safe Management of Cryogenic Liquids – Policy Arrangements Guidance for QMUL
Status: Live - Issued 15 Dec 2016
Author: Mark Ariyanayagam
Approved by: Health & Safety Advisory Group 14 Nov 2016

Table of Contents   Page

1. Executive Summary

This Health and Safety Policy establishes the framework for the effective risk assessment, health & safety risk controls and measures to be adopted and implemented for the safe handling of **cryogenic liquids and solids** (e.g. liquid nitrogen, solid carbon dioxide and similar substances) by Queen Mary University of London (QMUL) staff and students; and also for others who may be affected by QMUL activities. The objective of the Policy is to eliminate, and where not reasonably practicable to reduce the arising risks to a negligible level, and to ensure compliance with the Regulations governing work with hazardous substances, which includes cryogenic liquids and solids.

The Policy defines the safe management and working requirements for cryogenic liquids and solids in the context of QMUL's activities; identifies the roles and responsibilities for Heads / Managers / Supervisors of Schools / Institutes / Directorates conducting the work and for QMUL staff, students and others who may be affected by the work, and notes the key legal and compliance requirements specified in the relevant health and safety legislation and supporting guidance.

Guidance on practical measures (including installation of cryogenic facilities, safe working procedures, dealing with accidents and emergencies, inspections, training, supervision and competency) for QMUL and resources for the risk assessment of work involving cryogenic liquids and solids are provided. The Policy has been issued following QMUL wide consultation and approval by the QMUL Health & Safety Advisory Group on 14 Nov 2016.

2. Queen Mary University of London – Policy Objective and Statement on the Safe Management and Use of Cryogenic Liquids and Solids

The **Policy Objective** of Queen Mary University of London (QMUL) is to ensure that the risks arising from working with cryogenic liquids and solids (e.g. liquid nitrogen and solid carbon dioxide) are eliminated or reduced to a negligible level, so far as is reasonably practicable. The policy aim is therefore to ensure the continued health, safety and welfare of employees (staff), students and others who may be affected by the work, and to ensure compliance with the regulations governing work with hazardous substances, which includes cryogenic liquids and solids.

It is the QMUL **Statement of Policy** that risk assessment/s are conducted ***before*** commencing the work and / or for the installation of cryogenic facilities and related infrastructure, and are continuously reviewed and updated in line with work and technology changes, upon incidents and other significant variables. The appropriate risk control and health & safety management measures identified shall be implemented and maintained throughout the duration of the work, and throughout the lifespan of the cryogenic facility and related infrastructure until safe decommissioning, to ensure arising risks to QMUL staff, students and others are minimised to a negligible level.

3. Definitions and Glossary

Cryogenic liquids: Gases liquefied by deep refrigeration. Typically, the following are used at QMUL laboratories for research purposes and operation of analytical equipment, for transport of laboratory samples and use in cryostorage facilities: liquid nitrogen, liquid oxygen, liquid helium and argon.

Cryogenic solids: Gases solidified by deep refrigeration. Typically, the use of solid carbon dioxide (‘dry ice’, ‘cardice’) is widespread in QMUL laboratories and in conjunction with the transport of laboratory samples.

Sublimation: Transition of a substance directly from the solid to the gas phase without passing through the intermediate liquid phase. A typical example that undergoes this process is solid carbon dioxide.

Evaporation: The type of vaporisation of a liquid that occurs from the surface of a liquid into a gaseous phase that is *not* saturated with the evaporating substance (i.e. that is *not* boiling evaporation). Most cryogenic liquids will have this property at normal atmosphere and at room temperature.

Gas expansion ratio: Liquid or solid to gas volume expansion conversion – volume of gas generated from 1 volume of liquid.

Gas density: Mass per unit volume for a gas at specified temperature and pressure.

Oxygen depletion (deficiency): Where the level of oxygen is **reduced** below the normal concentration in air i.e. below 21 %.

Oxygen enrichment: Where the level of oxygen is **increased** above the normal concentration in air.

Confined space: Any place* in which, by virtue of its enclosed nature, there arises a reasonably foreseeable specified risk. It is a place which is substantially, (though not always entirely) enclosed. There will be a reasonably foreseeable risk of serious harm and / or injury from; flammable or toxic atmospheres, oxygen deficient or enriched oxygen atmospheres.

**including room, chamber, tank, vat, silo, pit, trench, pipe, sewer, flue, well, or other similar space.*

Asphyxiation: The state or process of being deprived of oxygen, which can result in unconsciousness or death. Cryogenic liquids and solids via the evaporation or sublimation process can deplete oxygen in a confined space rapidly.

Cold burns: A cold burn (or ‘frostbite’) is the medical condition in which localized damage is caused to skin and other tissues due to freezing and /or contact with very cold substances. When handling cryogenic liquids or solids, cold burns can be caused in exposed or unprotected areas of the body by spillages and contact with cold metal or other types of surfaces. Skin tears can occur when it sticks to very cold surfaces.

Hypothermia: Hypothermia is a potentially dangerous drop in body temperature where the body loses heat faster than it can supply, and which is usually caused by prolonged exposure to cold temperatures. Hypothermia occurs when a person's body temperature drops below 35°C and can quickly become life threatening. (Normal body temperature is around 37°C).

4. Legislation

This QMUL Policy sets out the framework in the following sections to achieve compliance with, and effective health and safety management of work with cryogenic liquids and solids as required by the Control of Substances Hazardous to Health Regulations (2002) (COSHH) and where transport on public highways (air, sea or road) is involved, the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009.

The general 'duty of care' and applicable specific requirements of the Health and Safety at Work Act 1974 and the Management of Health and Safety at Work Regulations 1999 will also apply to work with cryogenic liquids and solids. Where explosive and / or flammability risks can be created, the requirements of the Regulatory Reform (Fire Safety) Order 2005 and the Dangerous Substances and Explosive Atmospheres Regulations 2013 (DSEAR) will apply. The Pressure Systems Safety Regulations 2000 (PSSR) cover the safe design and use of pressure systems and will apply where pressurised cryogenic liquid vessels are used.

5. Scope and Application of the Policy

This Policy applies to all QMUL staff, postgraduate and undergraduate students and others (e.g. contractors, suppliers, academic visitors) who are to conduct activities at QMUL with cryogenic liquids and solids, and to all others who may be affected by QMUL activities involving such substances.

Full weblinks are provided in section 18 below

This policy does *not* specifically address the safe management of compressed and toxic gases (i.e. gases that are *not* generated from work with cryogenic liquids and solids). A separate QMUL policy and guidance documents for safe management of compressed and toxic gases are available *here*.

This policy does *not* specifically address the hazards and risks of other hazardous substances that can be present *in conjunction* with the use of cryogenic liquids and solids (e.g. hazardous biological agents, hazardous clinical samples, radio-isotopes). Separate QMUL policy and guidance documents for safe management of other hazardous substances are available *here and here*.

Other relevant topics for safe handling of cryogenic liquids and solids:
Expanded policy and arrangements for QMUL with detailed guidance on fire / explosion hazards and risks can be found *here*, on lone working *here*, local exhaust ventilation *here*, personal protective equipment *here* and pressure vessels *here*.

6. QMUL Roles and Responsibilities - Head of School or Directorate / Director of Institute - Centre Lead

It is the responsibility** of the Head of School / Directorate or Institute Director and/or Centre Lead to ensure that;

1. Staff (e.g. facility manager, local safety officer, lab manager with health & safety responsibilities) with supervisory and allocated health & safety responsibilities are appointed, trained and are competent for the work involving cryogenic liquids and solids.
2. A framework for the School / Directorate / Institute – Centre is in place for the drafting, dissemination, implementation and review of risk assessment/s and local procedures ('safe systems of work') for handling cryogenic liquids and solids and for the facilities / infrastructure, in line with QMUL policy, arrangements and guidance.
3. Appropriate resources are provided for cryogenic facilities, related infrastructure and consumables for the work in order to minimise risks to staff, students and others to a negligible level.
   QMUL planning systems already in place should be utilised for planning – e.g. the QMUL Planning and Accountability Review process.
4. A framework for the training of all users of cryogenic liquids and solids is in place (including training needs assessment, initial and refresher training and with training recorded).
   QMUL systems for training already in place should be utilised – QMUL staff probation or the PhD student training system / staff appraisal for training needs assessments; training record templates issued by the Health & Safety Directorate; training courses or on the job training provided locally by an authorised trainer and/or the Health & Safety Directorate.
5. All accidents and incidents involving cryogenic liquids and solids are reported as per the QMUL Accident & Incident Policy, local hazard warning systems are installed (e.g. gas detection and monitoring alarms) and local emergency response procedures are established.
6. Cooperation with QMUL Estates & Facilities and the Insurance Manager occurs for insurance inspections where required (e.g. for pressurised vessels / systems under the Pressure Systems Safety Regulations 2000, PSSR) and details of such systems are notified to the Insurance Manager (or their nominee) to be added to the QMUL Insurance register.
7. Relevant planned preventative maintenance schemes are in place for hazard warning systems, cryogenic pressure vessels and piped cryogenic liquid systems.
8. Where piped liquid cryogenic systems are *installed* by an Academic School or Institute - Centre (outside the management of an Estates & Facilities (EAF) Capital Project), the School / Institute - Centre complies with *all* of the responsibilities listed for Estates & Facilities - Capital Projects. If *maintained* by an Academic School or Institute – Centre, the School / Institute - Centre complies with *all* of the responsibilities listed for Estates & Facilities - Infrastructure Maintenance below.
9. Where a QMUL School / Institute – Centre occupies 'embedded space' within another organisation's premises, to ensure that risks arising from cryogenic liquid and solid storage and use are communicated to partner organisations in a suitable format, and actions are completed to minimise the identified risks.
10. Where users of QMUL cryogenic facilities employed by third parties (e.g. staff of partner organisations such as Barts Health NHS Trust) use QMUL cryogenic facilities, to ensure that written agreements and/or procedures exist with regard

to the scope of the work permitted and that the conditions of such agreements and/or procedures are clearly communicated to all concerned and that any such agreements and/or procedures are periodically reviewed to ensure that they remain current.

***Responsibility cannot be delegated, although tasks associated with the responsibility can be delegated to a competent person.*

7. QMUL Roles and Responsibilities – Managers / Supervisors

It is the responsibility** of a Manager / Supervisor*** to ensure that:

1. Appropriate risk assessment/s for any work with cryogenic liquids and solids are made and recorded, and kept up to date by periodic review.
   Use the COSHH chemical risk assessment template or the template/s in attached appendices.
2. Following training needs assessment, all managed or supervised users of cryogenic liquids and solids receive appropriate training (see 6.4 above).
   Health & Safety Directorate provided training is detailed at http://hsd.qmul.ac.uk/Training/index.html - cryogenic safety is included within COSHH based training courses (chemical safety and biosafety). Practical on-the-job or local training is generally available at the School / Institute level – contact local safety coordinator for details.
3. Working practices throughout the duration of the work comply with applicable health & safety legislation requirements (e.g. COSHH), QMUL and local written laboratory / facility rules, and manufacturer's operating instructions.
4. All risk control measures identified in the risk assessment/s and protocols are correctly installed, maintained and tested (where stipulated, via planned preventative maintenance / insurance testing) and that these control measures are locally checked and inspected periodically for effectiveness. These include related equipment such as vessel trolleys, hoses and Personal Protective Equipment (PPE).
   Use the inspection checklist in Appendix 4.
5. Where statutory planned preventative management plans are required for cryogenic systems within their remit, to ensure they are conducted within specified timescales, and records are available for QMUL and Regulatory Authority audits and inspections.
6. All accidents and incidents involving cryogenic liquids and solids are reported as per the QMUL Accident & Incident Policy
7. Local emergency and assistance procedures (e.g. appropriate first aid personnel and procedures, spill procedures, rescue procedures) are in place and that these are tested by a simulated exercise periodically for effectiveness.
8. Ensure that all users are fully aware of applicable hazard warning systems (e.g. gas monitor alarms) and know how to respond safely in an emergency.
9. Maintain operating instructions and other documentation relating to vessels, piped systems and detectors where it can be readily accessed (electronically or hardcopy).
10. Where a defect / failure is identified with equipment or procedures, to identify remedial or corrective actions and implement without delay. Where remedial action for a safety measure is not in their control, to report defects / failure to the appropriate QMUL department or in the case of embedded space, to the

host organisation contact person as soon as possible for action (e.g. at QMUL, EAF help desk where the infrastructure maintenance role for the system is with EAF; Barts Health Trust Facilities help desk for facilities in Barts Health Trust embedded space).

11. Do not use condemned or failed cryogenic vessels or systems until full repair and safety checks have been satisfactorily made and that no unsolicited modifications are carried out to vessels or piped cryogenic systems that are likely to render them unsafe. Any modifications must be planned in consultation with cryogenics specialists and EAF. For health and safety issues, advice should be sought as needed from the Health & Safety Directorate.
12. Have a Permit to Work system in place to ensure service engineer / examiner safety during testing / servicing and to ensure return of the system in a safe condition. See details of QMUL permit to work systems here

***Responsibility cannot be delegated, although tasks associated with the responsibility can be delegated to a competent person.*
******IMPORTANT NOTE:** if an individual instructs or issues tasks to another individual or group of individuals, then whether a designated line manager/ supervisor or not, they become responsible for the health and safety of those they have instructed.*

8. QMUL Roles and Responsibilities – Cryogenic Liquid / Solid Users

It is the responsibility of all cryogenic liquid / solid users to ensure that they

1. Take reasonable care of their own health and safety, and that of others who may be affected by their work. This is achieved by following the local safety rules & instructions, understanding the risk assessment findings, attending mandatory and other appropriate training for the work, in line with QMUL Policy and arrangements. (See 7.2 above for training details, and Appendix 3).
2. To use all safety and protective equipment (equipment and/or personal protective) appropriately in line with manufacturer's information and local risk assessment / instructions.
3. Know and understand the limitations for health and safety when working with cryogenic liquids and solids, and know and understand safety critical features of equipment, personal protection and hazard warning alarms and emergency procedures.
4. Report all accidents and incidents involving cryogenic liquids and solids as per the QMUL Accident & Incident Policy
5. Report any defects with equipment or deficiencies in work practices to their Manager / Supervisor as soon as possible for remedial action.
6. Do not use failed or condemned cryogenic vessels or systems until they are repaired and fully fit for use.
7. Do not ignore or misuse anything provided for user health and safety during the work (e.g. not to mute hazard warning alarms and then continue to handle cryogenic liquids).

9. QMUL Roles and Responsibilities: Estates & Facilities – Capital Projects and Infrastructure Maintenance

A. It is the responsibility** of the Assistant Director of Estates & Facilities for **Capital Projects** to ensure that they

1. Select and employ competent contractors for the work in line with QMUL policies for contractors (also see sections 10 and 11 below).
2. Ensure that any piped liquid nitrogen system fitted as part of a Capital Project is installed in accordance with all relevant health and safety regulations and appropriate industry standards****.
   A summary of different types of typical cryogenic liquid or solids installations at QMUL are noted in below along with key health and safety specifications for each type.
3. Ensure that all design features of laboratories and associated areas where cryogenic liquids and solids is to be stored, moved or used, adhere to the health and safety requirements detailed below.
4. For cryogenic liquid piped systems, ensure that suitable commissioning of the system is carried out and that the relevant handover documentation is provided to the facility manager or responsible person.
5. Ensure that the handover documentation is forwarded to Estates Infrastructure Maintenance and the facility responsible person, and that details of any newly installed pressure systems (if applicable) are entered on the QMUL insurance register.
6. For gas detection and monitoring alarm systems, ensure that suitable commissioning is carried out and that the relevant handover documentation is provided.
7. Ensure that users receive appropriate training in the operation of relevant parts of the new cryogenic system and hazard warning systems.

***Responsibility cannot be delegated, although tasks associated with the responsibility can be delegated to a competent person.*

B. It is the responsibility** of the Assistant Director of Estates & Facilities for **Infrastructure Maintenance** to ensure that they

1. Select and employ competent contractors for the work in line with QMUL policies for contractors (also see section 10 and 11 below).

2. Ensure that any cryogenic system under their remit is maintained in accordance with all relevant health and safety regulations and appropriate industry standards****.
   A summary of different types of typical cryogenic liquid or solids installations at QMUL are noted in below along with key health and safety maintenance specifications for each type.

3. Have planned preventative management plans in place for cryogenic systems within their remit for local inspections and checks, statutory testing and where required, servicing and repairs. That they are conducted within specified timescales, and records are available for QMUL and Regulatory Authority audits and inspections.

4. Have a Permit to Work system in place to ensure service engineer / examiner safety during testing / servicing and to ensure return of the system in a safe condition. See details of QMUL permit to work systems are here.

5. Maintain operating instructions and other documentation relating to vessels, piped systems and detectors within their remit where it can be readily accessed (electronically or hardcopy).

***Responsibility cannot be delegated, although tasks associated with the responsibility can be delegated to a competent person.*

**** e.g. British Compressed Gas Association (BCGA)

10. Roles and Responsibilities: Cryogenic systems suppliers and designers

It is the responsibility of cryogenic system suppliers and designers to ensure that they:

1. Know and understand their roles and responsibilities and are competent and qualified to design and/or supply the required cryogenic system. Evidence for competency should be provided to the QMUL client via a portfolio containing industry accreditations, training qualifications and competency, including those for health & safety, history of design and supply of similar facilities (see Appendix 3).
2. Liaise effectively with the QMUL client and installer / commissioner.
3. Understand the QMUL client's requirements and provide the most effective system for safety, location, use, and checks and maintenance.
4. Fully brief the QMUL client on the system limitations.
5. Provide in full to the QMUL client, the **system specifications** and **documentation / information** for the system.
6. Provide to the QMUL client, the specification for **in-use performance checks**.

11. Cryogenic system Installers and Commissioners

In many cases, an installer and commissioner may be the same competent person. They should ensure that they

1. Know and understand their roles and responsibilities, and are competent and qualified to provide the installation and/or commissioning of the cryogenic system. Evidence for competency should be provided to the QMUL client via a portfolio containing industry accreditations, training qualifications and competency, including those for health & safety, history of installation / commissioning of similar facilities (see Appendix 3).
2. Liaise effectively with the named QMUL client (Estates & Facilities and/or Academic School / Institute) and cryogenic system supplier / designer.
3. Install and commission according to the statutory requirements, and the design and supply specification.
4. Know and understand if needed, how to modify the system design in line with the specification and statutory limitations to improve safety.
5. Provide **installation, commissioning records** and **system information** (e.g. system manual, user manual, log book, benchmark criteria for future performance (in use and life span), including decontamination and final disposal) to the named QMUL Client.

12. Cryogenic Service Providers

(Without prejudice to any commercial service contracts with QMUL)

1. Know and understand their roles and responsibilities, and are competent and qualified to provide the service for the cryogenic system. Evidence for competency should be provided to the QMUL client via a portfolio containing industry accreditations, training qualifications and competency, including those for health & safety (see Appendix 3).
2. Cryogenic service providers shall cooperate with QMUL to ensure that all deliveries and movements are conducted in a safe manner. All cryogenic delivery drivers shall comply with any entry / exit and road traffic procedures that may be in place on QMUL premises.
3. Delivery drivers shall report any safety related incidents to QMUL by the best practicable means (by contacting the local Safety Coordinator, responsible cryogenic facility or lab manager, QMUL Security and/or the Health & Safety Directorate).
4. As per the terms of a service contract with QMUL, cryogenic delivery drivers shall undertake pre-fill checks and annual planned preventative maintenance checks on vessels or systems provided for filling.
5. Cryogenic service providers retain the right to refuse to fill any vessels or system if they deem it unsafe to do so. If and when such cases arise, the service provider shall make it clear by a written communication to the responsible person, the reasons for not undertaking a filling procedure.
6. In the event of safety critical faults being discovered, the service provider shall disable the vessel or system to ensure safety, and report the matter by a written communication to the responsible person for the facility / item immediately for action.
7. For significant planned or emergency on-site maintenance works, the appropriate permit to work shall be obtained from the responsible person for the cryogenic facility or system and followed.

13. QMUL Roles and Responsibilities: Health & Safety Directorate

1. Provide QMUL with Health & Safety Policy and Guidance, tools and templates for the risk assessment, safe handling, use and transport of cryogenic liquids and solids, and related systems.

2. Provide competent safety advice to Heads of Schools or Directorates / Director of Institutes and their nominated duty holders, on the H&S and Fire Safety Legislative requirements and Best Practice.

3. Audit, inspect and monitor QMUL cryogenic liquid and solids systems and H&S procedures in line with the Topic and H&S / Fire Safety Audit and Inspection Policy, and provide recommendations to improve health and safety performance.

4. Facilitate and/or provide training for the safe use of cryogenic liquids and solids by QMUL staff and students.

5. Liaise with the QMUL Estates & Facilities, and other duty holders with regard to provide competent advice on health and safety legislation and standards for cryogenic facility planning, design, installation, commissioning, maintenance and decommissioning.

6. Liaise with the QMUL Estates & Facilities, Finance Procurement Department, Insurance Manager and other Contract duty holders with regard to provide competent advice on health and safety issues in contracts for cryogenic installations, servicing, inspections, maintenance and decommissioning.

7. Keep their own competency, training, knowledge and experience up to date on cryogenic liquids / solids and health and safety / fire safety management systems (see Appendix 3).

14. Health Surveillance / Monitoring for work with cryogenic liquids and solids

1. Routine health surveillance is unlikely at QMUL for work with cryogenic liquids or solids.
2. Where individual sensitivity to hazardous substances, significant medical conditions or specific change in circumstances arise (e.g. during pregnancy), a health monitoring check may be required.
3. In those cases, individuals and/or their line manager or supervisor should seek advice from Occupational Health via the health surveillance referral system.

15. Cryogenic Liquids and Solids Risk Assessment – Key Principles and Requirements

All aspects of work involving cryogenic liquids and solids must be subject to the risk assessment process. Guidance below is provided to assist with the completion of a risk assessment.

A. The risk assessment for an activity involving cryogenic liquids and/or solids:

The process follows the familiar 5 steps for risk assessment issued by the Health & Safety Executive:

1. Identify the hazards associated with the cryogenic liquid or solid (considering the intrinsic hazardous properties) and also the general hazards arising from pressurised vessels, hazardous materials stored within cryogenic liquids or solids, manual handling hazards, electrical hazards, slip trip and fall hazards.
2. Identify who may be harmed and how (identify the hazardous events or activities – e.g. filling of a dewar with liquid nitrogen, placing or withdrawing biological samples from liquid nitrogen tank, preparing a transport box for samples in dry ice).
3. (i) Evaluate the level of initial risk* (likelihood x severity / consequence) and (ii) Decide upon suitable precautions or control measures to manage the risk (to a residual risk* level of low to negligible). (* see Table 1 below).

   The preferred hierarchy for risk controls should be to:

   i. Eliminate the need for cryogenic liquids or solids.
   ii. Prevent or minimise the risk of a cryogenic liquid or solid release at source.
   iii. Disperse or dilute the resultant cryogenic gas before it reaches a critical level (e.g. using local exhaust / emergency ventilation systems).
   iv. Have warning systems (facility, personal) and emergency procedures in place, and training of users how to handle cryogenic liquids and solids safely and how to respond in an emergency.
   v. Wearing / donning of effective personal protective equipment to protect against the identified risks.

   ***Risk Controls** are detailed in section 16 below*.

4. Document the risk assessment.
5. Review it periodically e.g. if the work, facility or procedures change (or immediately in the case of an accident, near miss or other adverse incident).

However, as with all control measures, a combination of precautions is usually the case in practice, with the more reliable options taking precedence.

		LIKELIHOOD OF HAZARD			
		High	**Medium**	**Low**	**Negligible**
SEVERITY / CONSEQUENCE OF HAZARD	**High**	High	High	Medium	Effectively Zero
	Medium	High	Medium	Medium / Low	Effectively Zero
	Low	Medium / Low	Low	Low	Effectively Zero
	Negligible	Effectively Zero	Effectively Zero	Effectively Zero	Effectively Zero

Table 1 - Risk Level evaluation table

B. Properties and Hazards of Liquid Nitrogen

Properties

1. Nitrogen is colourless, odourless and tasteless. It constitutes around 78% of normal atmospheric air. It is non-toxic and does not support life or combustion.
2. Nitrogen gas is slightly heavier than air with a density of 1.19 kg / m^3 (at 1.103 bara & 25°C, standard atmospheric conditions).
3. Nitrogen liquid is immensely cold at standard atmospheric pressure, at -196°C.
4. Nitrogen has an expansion ratio of 683 from liquid to gaseous state at standard atmospheric conditions. (I.e. One litre of liquid expands into 683 litres of gas).

Hazards to health

1. **Asphyxiation:** Nitrogen can produce oxygen-depleted or deficient atmospheres in enclosed spaces (confined or semi-confined) and in areas with little or no air movement. Asphyxia due to oxygen depletion or deficiency is often **rapid** and with **no prior warning** to the victim. Enclosed spaces at QMUL where liquid nitrogen is handled or transported through can be laboratories, corridors, cryostorage or freezer rooms or lifts.

   A summary table of effects and symptoms where they generally have been observed previously is in Table 2 below. However, it must be stressed that reactions of any individual can be very different from shown below, and **all** oxygen depleted environments **must** be considered dangerous. In many previous documented cases, depletion of oxygen and the worst case effects happen **without** the person's knowledge and **without** prior warning.

Oxygen Content (% volume falling)	**Effects and Symptoms** (at atmospheric pressure)
21 - 14	Increasing pulse rate, tiredness
14 - 11	Physical movement and intellectual performance / judgment becomes difficult
11 – 8	Headaches, dizziness, fainting after a very short period

	of time
8 - 6	Nausea / vomiting, asphyxia / fainting can be immediate, brain damage
6 – 0	Breathing in heavy gasps leading to rapid respiratory failure, sudden asphyxia / unconsciousness, severe brain damage, death

Table 2 – Effects and Symptoms of Oxygen Depletion

2. **Cold (cryogenic) burns, including frostbite:** severe damage to skin (body, face, eyes etc) can be caused by contact with liquid or cold gaseous nitrogen, even within a very short period of contact time. This can occur from contact with cold equipment, from spills / splashes of cold liquids during handling, or release of cold gas during evaporation (see glossary in section 3 for further information).
3. **Effect of cold on lungs:** Transient and short exposure produces discomfort in breathing, prolonged inhalation of cold vapour can produce serious damage to lungs and severely affect breathing.
4. **Hypothermia:** a dangerous drop in body temperature due to exposure to cold liquid / gas (see glossary in section 3 for further information).

Physical and other hazards when using liquid nitrogen and associated equipment

1. **Manual handling hazard:** many liquid nitrogen vessels are heavy, bulky and therefore need appropriate roller bases or tipping trolleys to facilitate movement. In addition to harm caused by spillage of very cold liquids and depletion of oxygen, crush and other injuries can be sustained if a vessel topples onto a person. Transport routes can also be steep, uneven and bumpy which can result in vessels toppling over, resulting in crush and other injuries to persons in the vicinity.
2. **Electrical shock:** many liquid nitrogen storage tanks now have associated electrically powered monitoring systems attached with electrical cables and supplies in the vicinity. Splashes of cold liquid nitrogen onto cables, insulation and sockets can cause brittleness and degradation, leading to exposed electrical wires or sockets. Contact with exposed live wires or sockets can result in electrical shock, and in worst cases, fatality. In addition, formation of liquid (water) around tanks can increase electrical conductivity.
3. **Slip, trip and fall hazards:** Floor surfaces around vessels can become brittle and degrade when liquid nitrogen is repeatedly spilt onto it, leading to a trip and fall hazard for users. During handling, formation of liquid (water) from ice around vessels can occur leading to a slip and fall hazard.
4. **Lone Working / Out of Hours hazards**: Lone working both during normal working hours and out of hours with significant quantities of liquid nitrogen is prohibited at QMUL. Due consideration must be given to the fact that the consequences of an incident involving liquid nitrogen whilst lone working or out of hours can be catastrophic, as immediate help and assistance by others is limited by virtue of these situations.
5. **Oxygen enrichment, fire and explosion**: During filling operations of liquid nitrogen tanks, enrichment of oxygen can occur locally around hoses and filling points, due to oxygen condensing out of the air surrounding non-insulated parts. If ignition source/s are present, this can lead to fire and explosion.
6. **Pressure increases and explosion**: the formation of ice plugs or other blockages in the necks and other openings (e.g. safety valve) of liquid nitrogen

dewars is possible, leading to pressure build up and explosion, with release of contents present in the dewar (cold liquid, stored material which may be infectious or have chemical hazard properties, cold ice) onto persons in the vicinity.

7. **Property / equipment damage**: Floor surfaces and other equipment around liquid nitrogen vessels can become brittle and degrade when liquid nitrogen is repeatedly spilt onto it.

C. Properties and Hazards of other Cryogenic Liquids used at QMUL

i. Liquid Oxygen

Properties

1. Oxygen is colourless, odourless (light blue in liquid form) and tasteless. It constitutes around 21 % of normal atmospheric air. It is non-toxic and supports life. However, it is a potent oxidiser, reacts readily with many chemical compounds and vigorously supports combustion, fire and explosion (particularly in enriched conditions).
2. Oxygen gas is slightly denser than air with a density of 1.105 kg / m^3 (at 1.103 bara & 25°C, standard atmospheric conditions).
3. Oxygen liquid is immensely cold at standard atmospheric pressure, at -183°C.
4. Oxygen has an expansion ratio of 842 from liquid to gaseous state at standard atmospheric conditions. (I.e. One litre of liquid expands into 842 litres of gas).

Hazards to health

As described above for liquid nitrogen, exposure to cold liquid oxygen can also cause cold burns including frostbite, hypothermia, and damage to lungs.

Physical and other hazards when using liquid oxygen and associated equipment

As described above for liquid nitrogen, liquid oxygen containing equipment and facilities can also present the same hazards of manual handling, electrical shock, slip trip and fall hazards, lone and out of hours hazards, pressure increase and explosion and property / equipment damage.

In particular, oxygen enriched conditions can occur during filling operations and if spillages occur. Where the local atmosphere contains greater than 21% oxygen, the risk of fire and explosion is increased.

ii. Liquid Argon and Helium

Properties

1. Inert gases such as Argon and Helium are colourless, odourless and tasteless. They constitute small or trace amounts in normal atmospheric air. They are non-toxic but do not support life.

2. Helium gas is much lighter than air with a relative density to air of 0.138 (at 1.103 bara & 0°C). Argon gas is denser than air (relative to air: 1.38).
3. Both in liquid form are immensely cold at standard atmospheric pressure, at -186°C (Argon) and -269°C (Helium).
4. Argon has an expansion ratio of 822 from liquid to gaseous state at standard atmospheric conditions.
5. Helium has an expansion ratio of 738 from liquid to gaseous state at standard atmospheric conditions.

Health Hazards

By displacement of oxygen by expanded inert gas, asphyxiation hazard can occur in enclosed spaces or where there is little or no air movement. Exposure to cold inert liquid can also cause cold burns including frostbite, hypothermia, and damage to lungs. By displacement of oxygen by expanded inert gas, asphyxiation hazard can occur in enclosed spaces or where there is little or no air movement.

Physical and other hazards

As described above for liquid nitrogen, liquid Helium or Argon containing equipment and facilities can also present the same hazards of manual handling, electrical shock, slip trip and fall hazards, lone and out of hours hazards, pressure increase and explosion and property / equipment damage.

D. Properties and Hazards of Solid Carbon Dioxide

Properties

A. Carbon dioxide is colourless with a pungent odour at higher concentrations. It constitutes around 0.4 % of normal atmospheric air. It is mildly toxic with a Workplace Exposure Limit (WEL) of 5000 ppm. It does not support life in enriched conditions or combustion.
B. Carbon dioxide gas is denser than air, with a density of 1.48 kg / m^3 (at 1.103 bara & 25°C, standard atmospheric conditions).
C. Carbon dioxide solid is cold at standard atmospheric pressure, at -78.5°C.
D. Carbon dioxide solid sublimates in a ratio of 1:845 from solid to gaseous state at standard atmospheric conditions.

Health Hazards

By displacement of oxygen by sublimated gas, asphyxiation hazard can occur in enclosed spaces or where there is little or no air movement.

The following table indicates the asphyxiation effects and where it has been observed previously, symptoms. However, it must be stressed that reactions of any individual can be very different from shown below, and **all** carbon dioxide enriched environments **must** be considered dangerous. In many previous documented exposure cases, the worst case effects happen without the person's knowledge and without prior warning.

Carbon dioxide content in air	**Effects and Symptoms** (at atmospheric pressure)

(% volume rising)	
1	Increase in breathing rate
2	Breathing rate up to 50 % above normal, exhaustion, headache
3	Breathing laboured and can be twice the normal rate, increase in blood pressure and pulse rate
4-5	Intoxication and choking feeling may be felt to prolonged exposure
5-10	Pungent odour of carbon dioxide may be noticeable; exhaustion, confused state leading to loss of consciousness within minutes
10-100	Rapid loss of consciousness, death from respiratory failure (> 12% carbon dioxide).

Carbon dioxide gas is also mildly toxic upon exposure. Exposure to cold solid carbon dioxide can cause cold burns including frostbite, hypothermia, and damage to lungs by inhaling cold vapour.

Physical and other hazards

Lone and out of hours working hazards, pressure increase and explosion if container openings are blocked, and property / equipment damage can occur due to brittleness upon repeated cold exposure.

E. Key risks that can be encountered in facilities / areas handling cryogenic liquids or solids

Facility type	**Key Risks**
Biostores / Cryostores (supplied with Liquid Nitrogen or other cryogenic liquids from an external static vessel)	Asphyxiation – potential for large releases of cold gas and liquid into room. Cryogenic burns – particularly where manual filling procedures are In place.
Internal areas in which pressurised vessels are used or stored	As for above facilities plus manual handling of transportable vessels.
Internal areas containing non-pressurised vessels	Cryogenic burns from manual filling. Low rate of boil-off and relatively small quantities of cryogen usually reduce risk of asphyxiation unless room ventilation is particularly compromised or significant spillages are possible.
Spectroscopy or Analytical Facilities involving the use of liquid nitrogen or other cryogenic liquids	Asphyxiation from quenching and cryogenic burns from manual transfer operations.
External storage for transportable liquid nitrogen or other cryogenic liquids vessels	Manual handling of vessels and cryogenic burns from spillage in transit.
Internally stored solid carbon dioxide containers	Asphyxiation if room / area enclosed or ventilation compromised, cryogenic burns from spillage
Externally stored solid carbon dioxide containers	Manual handling of containers / bags and cryogenic burns from spillage in

	transit

16. Risk Controls for Cryogenic Liquids and Solids

A. Ventilation

1. Good ventilation is a key element of cryogenic liquid and solid safety. If a gas release cannot be avoided in the first place, good ventilation will help to disperse the gas and minimise the extent to which it accumulates.

2. All areas where cryogenic liquids and solids are stored and used must be adequately ventilated, whether by natural or mechanical means.

3. A room shall be sufficiently ventilated for the two normal conditions of evaporation and filling losses (i) **not** to cause a reduction in oxygen concentration **below 19.5 %**, and (ii) where the complete spillage or release of the contents of the largest dewar can cause the oxygen concentration to fall **below 18%.**

4. External locations such as cages or storage areas with large expanses of louvered panels (particularly when arranged to permit an airflow across the area) may not require additional mechanical ventilation, as these can be considered to be virtually the equivalent of storage in the open air.

5. Internal locations which only benefit from natural ventilation are more problematic to assess. Factors such as the size of the room; whether it has windows or is an enclosed room; whether it has door grilles and the quantity of liquid nitrogen stored to be stored will all need to be taken into consideration.

6. In determining what is considered to be adequate ventilation with regard to mechanically ventilated areas, 6 air changes per hour (ACH) should be taken as a minimum and this is sector standard for new laboratories.

7. If gas detection is provided, consideration shall be given to need to link this to the ventilation so that the extract ramps up (typically to around 12-20 ACH) in the event that the detector triggers (see: Gas Monitoring and Detection below).

8. All cryogenic vessels experience a natural loss of gas over time and pressurised vessels have a pressure relief valve that will temporarily lift if the pressure within the container exceeds the set value. This can be considered to be part of normal operation. For these reasons, ventilation provided within a room must be continuous so as to remove any nitrogen that may accumulate as time passes.

9. The ventilation system shall be designed so as to ensure adequate airflow around the normal operating area to prevent an asphyxiating atmosphere developing. Given that the cold nitrogen and many other cryogenic gases are heavier than air, there must be low level ventilation in addition to extract at any other points within the room. Where liquid helium is also present, there must be high level extract in addition.

10. Where mechanical ventilation is required, the low level extract shall be located with the lowest part of the exhaust grille positioned no more than 10 cm off the ground. Room users shall ensure that the extract points remain unobstructed.

11. Sufficient make-up air shall be provided to any room which has mechanical ventilation.

12. Air from within the room shall be extracted to a suitable external location where cryogenic gas cannot further accumulate. As nitrogen and most other cryogenic gases are non-toxic, this does not necessarily need to be at roof level and may be to any well ventilated space outside the building. Where oxygen enriched conditions may arise, fire retardant properties of the extract duct and damper position needs to be considered.

13. Where mechanical ventilation is required, there shall be a means for the room users to easily determine that the ventilation is functional. This can be achieved by installing indicating devices such as warning lights / audible alarms. (Whilst other subjective indicators such as the sound of the ventilation system humming or the temperature within the room may provide clues to whether the extract is functioning, they are not considered an adequate means of determining this to be the case).

14. Access to any plant relating to ventilation systems must be adequately controlled to prevent inadvertent or malicious tampering and all controls shall be identified with suitable signage indicating clearly the ‘on‘ and ‘off‘ positions and warning that the equipment is critical to safety.

15. All ventilation systems shall be subject to suitable maintenance regimes as described below.

B. Gas Detection Monitoring and Warning Alarms

Fixed Gas monitors and alarms

1. Prevention of an uncontrolled release is the first priority in the gas control hierarchy followed by the availability of good ventilation to disperse the gas in the event that the release cannot be prevented. Only when these points have received attention should the issue of gas monitoring and detection be considered.

2. There is often a temptation to readily install gas monitors and detectors without due consideration of what is involved. There are drawbacks: initial installation can be expensive, ongoing maintenance can be expensive, they can fall into neglect, neglect and lack of maintenance can cause faults to develop. As a result, they may not function when they need to and may also develop ‘nuisance’ triggering when no oxygen depletion is taking place.

3. If users have little understanding of why they are present or little confidence that they function correctly, they will be ignored. Their presence is therefore rendered useless.

4. To determine whether oxygen depletion monitoring is necessary, the risk assessment should consider the following -

Monitoring must be in place:

5. In all instances where liquid nitrogen or other cryogenic gas is piped from an external static storage vessel to the point of use. In such situations, there is clearly the potential for large quantities of liquid or gas to be discharged into the room in the event of something going wrong (uncontrolled release, blockage of flow, dispersal of gas before fault is evident).

6. For pressurised vessels - where an uncontrolled release from the largest vessel present within the area would give rise to an oxygen deficient atmosphere of below 18% (the 'worst case scenario' calculation).

7. For non-pressurised vessels - where the maximum foreseeable spillage would give rise to an oxygen deficient atmosphere of below 18%. This is most relevant where manual tipping operations are carried out from the likes of 'onion' dewars and dropping the dewar is a foreseeable risk.

8. Where the natural evaporation from rate from non-pressurised vessels may give rise to an oxygen deficient atmosphere of below 18% (the cumulative rate if several are present). This is very unlikely in practice **unless** there are a large number of vessels in a small room with poor ventilation - in which case, the first option must be to find a more suitable location.

Where the risk assessment determines that monitoring is necessary, then:

9. The detector must be of the correct type, fitted with an oxygen sensor(s). Where significant amounts of solid carbon dioxide are stored in a less ventilated area, a carbon dioxide sensor must also be considered.

10. The sensor(s) must be positioned where they will readily detect a nitrogen (or other cryogenic gas) release - (i) in proximity to the potential source of release but not close enough to cause continual 'nuisance' triggering (ii) at a height recommended by the manufacturer but typically no more than 1m above floor level i.e. below the breathing zone of the average person. Where liquid helium is also present, there will need to be detection at high level in addition. (iii) Above the location of any low level extract grilles. This will drastically reduce the likelihood of 'nuisance' triggering. (iv) unobstructed by equipment or other items (including temporarily located items) (v) in a position where they can be accessed for maintenance without too much difficulty.

11. The detector must be suitably calibrated and the set-points programmed at a level appropriate to detecting oxygen depletion.

12. A two stage alarm is recommended by industry guidance, the **first stage** alarm should be set at **19.5%** oxygen and the **second stage** alarm at **18%**.

13. Periodic testing of alarms must be carried out using a suitable test gas and the results of the test recorded (by trained personnel, referring to manufacturer's guidance).

14. Alarms—audible and / or visual—must be of the fixed type and must be present both **within** the laboratory (so that occupants can leave) and also **outside** the laboratory (so that others do not enter). This requirement dictates that detectors will normally need to be mains powered rather than battery powered unless there is a means of installing battery powered detectors in a way that satisfies this requirement.

15. Alarms must be assessed to determine whether any additional functionality is required e.g. whether the alarm needs to be linked to a solenoid valve that automatically shuts of the gas supply when it is triggered.

16. Alternatively, alarms can be linked to mechanical ventilation to enable the extract to be ramped up in the event of it triggering. These features are usual for piped installations.

17. Alarm panels should be located outside the area of the potential gas release. If necessary, they can then be interrogated from a position of relative safety.

18. The system must be subject to a maintenance regime. Some sensors require replacement or re-calibration as frequently as every six months.

19. All users of the area must receive local training so that they are aware of what the alarms mean and what to do in the event of them sounding. This information should be recorded in local protocols.

Portable personal monitors

20. Portable personal monitors may be considered in addition to, but **not** as an alternative to, fixed detection systems. The following points should be borne in mind:

    a. They may also require maintenance to keep them functioning (though fixed lifetime 'No Maintenance' models may be available).
    b. They will only provide a warning if the user remembers to wear it.
    c. They will only provide an appropriate level of warning once the gas enters the vicinity of the monitor (rather than at the source of the leak if this happens some distance away).

C. Storage of cryogenic liquids and solids

External storage

1. External storage commonly takes two forms: fixed static installations consisting of bulk storage tanks (often over 1000L capacity) and locations where transportable vessels (either pressurised or non-pressurised) are situated whilst awaiting refilling.

2. Static installations shall comply with the requirements of BCGA CP36.

3. Requirements are described in detail in the above Code of Practice, however the salient points are as follows:

a) Safety distances shall be in accordance with Appendix 3 of BCGA CP 36.
b) Storage installation should be situated in the open air in a well ventilated position where there is no risk from passing vehicles.
c) Vents, including safety relief devices shall vent to a safe place in the open so as not to impinge on personnel, occupied buildings and structural steelwork.
d) The liquid transfer area shall be designated a 'No Parking' area.
e) The area must be secure so as to prevent access by unauthorised personnel.
f) Hazard and Danger / Warning signage shall be clearly displayed (see Appendix 5).

4. Locations where transportable vessels are held shall comply with the requirements of BCGA CP27. These requirements broadly mirror those referred to above.
5. Solid carbon dioxide storage containers are to be placed outside buildings in well ventilated areas.

Storage within buildings (cryostores, laboratories and associated areas)

Where transportable pressurised containers and non-pressurised dewars are stored within buildings, the following points must be adhered to:

a) Store below 50°C in a well-ventilated place.
b) Avoid storing vessels in corridors or stairwells.
c) Ensure appropriate hazard warning signs are displayed (yellow triangle with snowflake symbol and text: ‘Liquid nitrogen’). *See Appendix 5.*
d) Use only properly specified equipment for storing liquid nitrogen.
e) Storage within cold rooms is prohibited unless it can be demonstrated that natural evaporation and worst case scenario release would not deplete oxygen below 19.5%. Most cold rooms are well sealed and do not have any air supply or extract system, so there is little or no air change, and therefore storage must be avoided.
f) Solid carbon dioxide storage containers must **not** be located inside buildings where ventilation is inadequate, and bags of solid carbon dioxide must **not** be stored inside freezers / fridges.

D. Use of cryogenic liquids and solids

In addition to the duties noted in section 8, users of cryogenic liquids must

a) Not leave vessels unattended when filling.
b) Never travel with cryogenic liquid (or solid) containers in lifts.
c) Always obey the oxygen depletion (or carbon dioxide) alarm by evacuating the area to a place of safety.
d) Not consider vessel filling to be a lone activity - always ensure other staff are on hand at a safe distance to raise the alarm and assist in the event of an emergency.
e) Not tamper with or adjust the safety relief valves of vessels.
f) Use only transfer equipment that is designed for the purpose.
g) Not handle cryogenic liquids out of hours (under any foreseeable circumstance where oxygen would be depleted below 18%).
h) Not overfill vessels.
i) (With non-pressurised containers) not plug the entrance with any device that would interfere with the venting of gas. Use only the loose fitting necktube core or an approved accessory.
j) Not use brittle plastics which may shatter on contact with the cold liquid.
k) 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.

Local rules and instructions given to staff and students should detail not only what they are required to do but also what they should not do. Research group leaders along with laboratory / facility managers have a responsibility to monitor all procedures to ensure that local rules are being complied with.

A local rules summary for users for the safe use of liquid nitrogen is here.

Detail on transport and personal protective equipment is in sections below.

The BCGA Code CP30 'The Safe Use of Liquid Nitrogen Dewars up to 50 litres' provides specifications for small vessels, and expands on user safety guidance.

E. Transport of vessels

1. If vessels must be manoeuvred between locations and there is a risk or possible risk of injury then an assessment must be carried out under the Manual Handling Operations Regulations.

2. This should be carried out with advice and assistance from a trained Manual Handling Assessor or other suitably qualified individual.

3. Most cryogenic vessels at QMUL will be filled either at point of use (if safe to do so), or at a designated external filling point by trained personnel of the cryogenic service provider.

4. Pressurised vessels and non-pressurised dewars are extensively used throughout QMUL - a full 250 litre pressurised vessel can weigh up to 400 kg and manual handling injuries can be sustained by staff / students.

5. Further advice on manual handling assessment and a manual handling checklist is available here

6. 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).

7. 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, pavements and road surfaces (damaged surfaces should be reported to Estates & Facilities Helpdesk), awareness of scheduled and non-scheduled traffic movements, stairs (hazardous due to potential for slips and trips which could result in spillages from small hand held dewars) and whether the destination for the vessel is ready to accept it.

8. Only purpose designed handling equipment should be used. A wide range of trolleys are commercially available for transportation of both pressurised and non-pressurised tanks, including roller base-tipping trolleys for the latter, which enable both transportation and safe pouring (but only if the receiving vessel is at an appropriate height). Other accessories are also available such as withdrawal devices which can be fitted to non-pressurised dewars to facilitate withdrawal without the need for tipping and pouring.

9. The transportation of cryogenic vessels off site is not a mainstream activity for QMUL staff. If cryogenic vessels are to be transported off site, this must be carried out in compliance with all regulations relating to the transport of dangerous goods. These regulations are complex and your local safety coordinator and the Health & Safety Directorate must be consulted in all cases.

10. **Lifts**: cryogenic liquid vessels, dewars and stocks of solid carbon dioxide must **not be accompanied in lifts** - measures must be taken to close the lift to all passengers. This applies to **ALL** QMUL staff, students, visitors and contractors (including cryogenic service providers).

11. The vessel should be manoeuvred into the lift, and the lift sent to its destination floor to be met by an assistant. It must not be a one-person operation that involves this person hurrying up or down the stairs to meet the vessel at its destination floor.

12. A system should be employed to ensure that no passenger enters the lift at intermediate floors. If the lift has a key mechanism which permits the operator to take control then this is the preferred option, though in reality this may not be possible due to the lift design. If this is the case, then a barrier (chain / tensa etc.) together with an appropriate warning sign *('Do not enter - liquid nitrogen in transit'*) must be deployed within the lift to prevent persons entering. A sign alone is not sufficient in the absence of a physical barrier.

13. Goods lifts must be used in preference to passenger lifts. Where a goods lift does not exist, a passenger lift may be used as an alternative as long as this is agreed by Estates & Facilities and is equipped in the same way as a goods lift - either with key control or fitted with a tensa barrier.

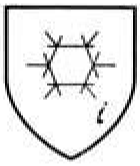
14. If, for any reason the floor of the lift does not finish flush with the floor outside the lift (i.e. there is a small step up or down), then this should be reported immediately so that the lift engineers can work to correct the fault. Under these circumstances extra care should be observed whilst manoeuvring the vessel in and out - one person should be charged with ensuring that the lift doors are held open during this process.

F. Personal Protective Equipment

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

1. **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 must **not** be immersed into liquid nitrogen under any circumstance. If gauntlet style gloves are chosen, lab coat sleeves should cover the ends of gloves to ensure that liquid cannot get between the glove and the hand or the gauntlet must be tight enough around the forearm so as to prevent any liquid from entering. Alternatively, a ribbed cuff style may be used. There are a range of commercially available gloves suitable for use at cold temperatures - gloves that are used with liquid nitrogen should meet the requirements of BS EN 511: 2006 'Protective gloves against cold' (see summary in Table 3 below). The Standard, pictogram and rating must be labelled on the glove to identify the protection level offered to the user.

Table 3 – *BS EN Standard Summary - Protective gloves against cold*

STANDARD	PICTOGRAM	DESCRIPTION	RATING (higher the number, greater the protection)
BS EN 511		Protection from Cold a) Resistance to convective cold b) Resistance to contact cold c) Permeability to water	 0-4 0-4 0-1

2. **Face** - a full face visor with cheek and brow guards 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.

   A face visor should provide adequate protection for the tasks with cryogenic liquids. BS EN Standard 166 identifies ratings that identify the level of mechanical strength, field of use (hazardous task), and optical performance. The following ratings are recommended for cryogenic liquid tasks:
   B (frame & lens) - Medium-energy impact (120m/s);
   3 (frame only) - Resistant to liquid droplets or splashes
   And where applicable -
   N - Anti-mist/resistant to fogging.
   Face PPE constructed of polycarbonate provides good impact and chemical resistance.

3. **Body** - a laboratory coat or overalls should be worn at all times to cover clothing and open skin. 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.

4. **Feet** - sturdy closed shoes or boots (*not* wellington boots) are recommended for handling cryogenic liquids / vessels or cryogenic solids. For cryogenic liquid filling / decanting – shoes should not allow liquefied gas to enter them in the event of a spill i.e. no lace holes through to the inside of the shoe. Open toed shoes or sandals must **not** be worn under any circumstance.

5. **General** - No metal jewellery, rings or watches should be worn on hands or wrists while transferring or handling cryogenic liquids.

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. Cleaning stations or materials must be available in the facility to clean dirty re-usable PPE.

G. Information, Instruction, Supervision and Training

All users of compressed gases must receive adequate information, instruction, supervision and training. This takes several forms:

1. **Provision of information:** Users must be able to access Safety Data Sheets and risk assessments / standard operating procedures (SOPs) for the activity. They must understand the hazards associated with the liquids, solids and gases they are using and the controls necessary to maintain safety. Where possible, they should be actively involved in the risk assessment process from the outset.

2. **Training.** QMUL offers a number of health & safety training courses which include the safe use of cryogenic liquids, solids and gases. See http://hsd.qmul.ac.uk/Training/index.html for further details.

   Practical and advanced training courses provided by external competent training providers may be attended upon training needs assessment by the line manager of the person concerned. For further information, consult your local safety coordinator and/or the Health & Safety Directorate. All training must be recorded – use personal and group/dept training record templates provided within the QMUL Training Policy if departmental recording system / templates do not exist.

   On-the-job training: This includes practical instruction (and necessary supervision) on the use of specific apparatus in the area where the individual is expected to work. This must include instruction on routine observation of controls such as alarms, indicators that ventilation is working, local lone working procedures and emergency procedures. All training must be recorded. – use personal and group/dept training record templates provided within the QMUL Training Policy if departmental recording system / templates do not exist.

F. Maintenance and disposal of cryogenic vessels

1. All static and transportable pressurised vessels must be subject to a Planned Preventative Maintenance (PPM) scheme.

2. The responsibility for ensuring that cryogenic vessels are suitably examined and maintained rests with the School / Institute or Directorate that owns or rents the vessel.

3. Pressure vessels having a pressure / volume product *exceeding* 250 bar litres must also be examined in accordance with a Written Scheme of Examination (WSE) under the Pressure Systems Safety Regulations 2000.

4. Completion of a written scheme of examination and the periodic examination itself is usually carried out by a trained engineer appointed by the QMUL insurers (currently Zurich Insurance).

5. Alternatively, if the vessel is rented, this may be arranged by the owners of the vessel. The end user must ensure that the owner conducts the necessary PPM and / or WSE based examination.

6. Though details of the examination are primarily the concern of the insurance inspector, guidelines pertaining to Written Schemes of Examination (WSE) for cryogenic liquid storage systems are given in Appendix 2 of BCGA CP23 *(under revision, 2016).*

7. Non-pressurised vessels should be subject to routine visual examination by the users to ensure that they are damage free and fit for purpose.

8. Trolleys and wheels, though not always an integral part of the vessel, must also be subject to visual examination and repair where necessary. Damaged parts must be reported and repaired or replaced.

9. All transportable pressure vessels *must* bear the following labels / markings:
   i. Data plate (engraved).
   ii. Valve labels (metal disks indicating the functions of the valves.
   iii. Decommissioning tag (metal disk stating the date of decommission). The decommission tag does not necessarily indicate the end of the lifetime of the vessel, but it must not be used beyond this date without repair or replacement of the relief valve.
   iv. Product label (hazard label /transport information) – see Appendix 5.
   v. PPM label (often a sticky label indicating the maintenance and inspection history
   vi. Vessel ID tag (usually a laminated tag with cryogenic service provider account number, identifying the owner).
   vii. QMUL asset registration label that identifies the vessel on a central database

10. All records of examination and maintenance must held by the School / Institute – Centre / Directorate in a format accessible to present to the enforcing authorities if requested or for internal audits and inspections.
11. Any obvious damage sustained by vessels (either static or transportable) must be reported immediately to the Facility / Laboratory Manager and if necessary, the vessel should be taken out of use until inspected by a competent person.

DISPOSAL OF CRYOGENIC VESSELS

12. Sample Storage Vessels

i. Ensure that the vessel is empty of liquid nitrogen (transfer and / or allow to convert to gas naturally in a well-ventilated area).
ii. Remove sample racks and samples. Check for loose specimen tubes (particularly under baseplate) and remove for appropriate disposal.
iii. Thoroughly clean all accessible surfaces (including racks) with suitably validated disinfectant.
iv. Append decontamination certificate and dispose via an appropriate route e.g. as equipment waste via Estates & Facilities.
v. Ensure that details of any disposed vessels are removed from inspection registers.

12. Pressurised Vessels

i. Empty vessel by transferring liquid. Once bulk of liquid has been removed, open relevant valve to enable remainder of gas to escape in a safe, well-ventilated area e.g. outdoors.
ii. Append a decontamination certificate and dispose via an appropriate route e.g. as equipment waste via Estates & Facilities.
iii. There should be no particular measures to take with regard to decontamination, though the certificate will still be required and this fact can be recorded on the certificate.

G. Lone and Out of Hours Working

1. All QMUL Schools / institutes / Directorates handling cryogenic liquids and solids must establish lone and out of hours working procedures in line with the QMUL Lone and Out of Hours Working Policy.

2. Due consideration must be given to the fact that the consequences of an incident involving liquid nitrogen whilst lone working and/or out of hours can be catastrophic.

3. Lone and out of hours working with significant quantities of cryogenic liquids or solids is **prohibited** at QMUL and must be avoided by planning such work to be done during normal working hours and with adequate assistance. Measures must be in place to ensure that assistance is always at hand by employing buddy systems, CCTV, man down alarms etc where appropriate.

H. Emergency Procedures

The following emergency procedures are generic responses. Emergency procedures must be in the risk assessment / local rules and communicated to all involved, including others who may be part of the response process or first on the scene e.g. Security.

Uncontrolled or significant release of cryogenic liquids

1. If no casualties are present

i. Evacuate the area and call for required assistance (from a safe place, telephone QMUL Emergency Number 0207 882 **3333**). Deploy warning signs or cordon off area.
ii. Ventilate the area. Open doors and windows or activate forced ventilation **only** if safe to do so, to allow any spilt liquid to evaporate and the resultant gas to disperse.
iii. Try to stop the release if possible e.g. activate emergency stops or turn off valves, but **only** if it is safe to do so.
iv. **Only** if safe to do so, prevent liquid nitrogen from entering drains, basements, pits or any confined space where accumulation may be dangerous
v. Do **not** re-enter area without self-contained breathing apparatus (BA) unless it is proved safe to do so (see below with regard to use of BA). The presence of oxygen deficiency monitors will indicate the oxygen levels in the vicinity.

2. Liquid nitrogen is used in many locations throughout QMUL. In most cases, it is not practicable to have breathing apparatus available. There are a number of reasons for this: the cost of purchasing the apparatus, the cost of maintaining the apparatus, a good maintenance regime is essential, BA must only be used by trained personnel, Training must be kept up-to-date, and there is a need to select individuals who are medically fit to wear BA.

3. The emphasis must therefore focus upon **not** entering the room until the atmosphere is known to have returned to normal. The extent and location of the release will determine whether it is necessary to evacuate only the immediate area or to evacuate a wider area such as the whole building. This will need to be decided on a case -by-case basis and judgement will be required.

4. If an alarm is found to be sounding, it must be assumed that there is potentially an oxygen deficient atmosphere present. **Do not automatically assume that there has been a sensor failure and enter the room without taking any precautions.**

If casualties are present

1. If no alarm is sounding or if there is no visual evidence that the casualty has been overcome by an oxygen deficient / rising carbon dioxide atmosphere, enter with caution and treat as a medical emergency.

2. If alarms are sounding or there is evidence of a liquid nitrogen or other cryogenic liquid release, **do not enter the room**.

3. In the event of an unconscious casualty, telephone the QMUL Emergency Number 0207 882 **3333** and ask for immediate response by the emergency services– both medical and the Fire Brigade (who will be equipped with BA). In such a situation, time will be crucial – and there will quite likely, not be enough time. It is therefore important that all the proactive measures described in this Policy are taken so as to reduce the likelihood of an unconscious casualty to a negligible level.

4. Only if safe to do so, then follow the same advice for ‘no casualties’ (1) above.

First Aid

1. Where inhalation has occurred, the victim (who may be unconscious) should be removed to a well-ventilated area. **Rescuers must 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.

2. 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.

3. 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°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.

4. Do **not** use a direct source of heat such as a radiator, permit smoking or alcohol consumption or give analgesics (e.g. paracetamol, aspirin).

5. For major injuries apply first aid as far as is practicable and arrange for the injured person to receive medical attention. On arrival at hospital, medical staff should be provided with a copy of BOC Gases Guidance Note G4968 'Treatment by medical practitioner or hospital' (see Appendix 6).

Fire

1. Nitrogen and other cryogenic gases are non-flammable gas but any vessels under pressure may explode when exposed to fire, irrespective of the type of gas contained within. There can also be oxygen enriched atmospheres around hoses or filling tanks which support combustion.

   There are certain general actions that should be taken:

2. Activate the fire alarm call point and evacuate the building / area.
3. QMUL staff should not attempt to fight fires involving (or near) vessels unless it is small enough to be dealt with very quickly.
4. Where piped systems are concerned, if possible, isolate the liquid nitrogen supply to the area affected but do not take any risks. Keep emergency response team appraised of any actions taken with regard to isolations - either successful or unsuccessful.
5. As with any fire, do not re-enter the building until clearance has been given. Vessels that have been heated can remain dangerous even after the fire has been extinguished.

Accident and Incident Reporting

1. Any incident involving cryogenic liquids / solids, vessels or associated pipework (irrespective of whether any injury or exposure occurred) **must** be reported via the QMUL Accident & Incident Reporting system by the responsible person for the area / facility.

2. Examples include - dropped or toppled vessels, significant release of liquid or gas either from direct spillage or failed components, visibly damaged components including hoses, wheels and trolley parts.

17. Static and Piped Installations

The design and installation of such facilities should be in accordance with BCGA Code of Practice CP36 (Cryogenic liquid storage at users' premises) and BCGA Guidance Note GN19 (Cryogenic sample storage systems (Biostores) – Guidance on design and operation).

In addition to these Codes of Practice, the following design features relate to laboratories which receive piped supplies:

1. Manually operated emergency stop buttons must be included. These will be used to isolate the liquid nitrogen flow via a solenoid valve in the event of an emergency. These must be located within the room close to the exit door and external to the room just outside the door, thus enabling users to quickly get clear of the danger zone and safely isolate the flow in the event of an abnormal situation arising.

2. Despite all precautions, drips and small spillages are likely to occur. Vinyl flooring will eventually crack and lift, presenting both a contamination and a trip hazard. The area (or at least the area immediately beneath the tap) must therefore be fitted with a suitably resistant flooring material - epoxy resin, aluminium, stainless steel or high density polyethylene (HDPE). Judgement will need to be used regarding the extent of the area to be covered though it should be borne in mind that even a small spillage will spread a considerable distance. Epoxy flooring provides a highly resistant, easily cleanable and aesthetically pleasing surface for whole room coverage.

3. Vessels shall be arranged in a manner that permits good accessibility and movement around them.

4. Manual filling points (if present) shall be located away from doors and in a position where the users can easily retreat to safety in the event of a problem developing.

5. Devices such as ‘dead man’s handles’ (or pedals) can be considered for manual filling points. This will ensure that the hose will only deliver liquid nitrogen when an operator the lever or button (or pedal) and will cut the supply in the event of the lever, button or pedal being released.

6. Sections of laboratory benching should be provided for sample sorting.

7. Doors must be fitted with vision panels that permit viewing of all parts of the room.
8. Mirrors may be employed to aid viewing of areas that are not within the direct sight line of the vision panels. Vision panels must remain unobstructed.

9. Door thresholds must be free of ridges to permit easy movement of transportable vessels in and out of the facility.

10. If the size and configuration of the room is such that escape in the event of an emergency could be difficult, an additional door(s) to the facility must be provided.

11. CCTV cameras or webcams should be considered. Where cameras are installed, consideration must also be given as to who will monitor them.

12. A suitable location for storage of PPE must be provided, ideally just before the exit.

13. Where biological and chemical hazardous samples are stored, a hand wash sink operable not by hand, with hot and cold water, and means to dry hands should be provided.

18. Further Resources and weblinks

QMUL Health & Safety Directorate – Topic Pages http://hsd.qmul.ac.uk/A-Z/index.html (Includes Policy, Arrangements and Guidance for QMUL)
Cryogenic Liquids and Solids http://hsd.qmul.ac.uk/A-Z/index.html
Lone Working http://hsd.qmul.ac.uk/A-Z/Lone%20Working/index.html
Chemical Safety http://hsd.qmul.ac.uk/A-Z/chemical%20safety%20and%20substances%20hazardous%20to%20health/index.html
Biological Safety http://hsd.qmul.ac.uk/Lab%20Safety/Biological/index.html
Fire Safety http://hsd.qmul.ac.uk/A-Z/Fire%20Safety/index.html
First Aid http://hsd.qmul.ac.uk/A-Z/First%20Aid/index.html
Manual Handling http://hsd.qmul.ac.uk/A-Z/Manual%20Handling/index.html
Local Exhaust Ventilation http://hsd.qmul.ac.uk/A-Z/Local%20Exhaust%20Ventialation/index.html

Regulator

Health & Safety Executive COSHH http://www.hse.gov.uk/coshh/index.htm

Industry / Sector

British Compressed Gas Association (BCGA) Publications
http://www.bcga.co.uk/pages/index.cfm?page_id=6&title=publications

BCGA Code CP36 Bulk Cryogenic Liquid Storage at Users' Premises
BCGA Code CP27 Transportable Vacuum Insulated Containers of not more than 1000 litres volume
BCGA Code CP23 Application of the Pressure Systems Safety Regulations 2000 to Industrial and Medical Pressure Systems Installed at User Premises *(under revision 2016)*
BCGA Code CP30 The Safe Use of Liquid Nitrogen Dewars up to 50 litres
BCGA Code CP34 The application of the Pressure Equipment Regulations to customer sites
BCGA Code CP38 Revalidation of cryogenic tankers and containers
BCGA Guidance GN19 Cryogenic sample storage systems (Biostores) – Guidance on design and operation
BCGA Guidance GN11 Reduced oxygen atmospheres. The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace
BCGA Guidance GN17 BCGA policy and guidance for the safe filling of third-party owned and/or maintained tanks
BCGA Technical TIS7 Guidelines for the safe transportation, storage, use and disposal of dry ice products
BCGA Leaflet L11 Safety checks for vacuum insulated cryogenic tanks

European Industrial Gases Association (EIGA) https://www.eiga.eu/

Commercial Cryogenic Service Providers
(For health and safety purposes, QMUL does not endorse any specific commercial service provider)

Safety data sheets and technical / safety information are available from the websites

BOC - Gas and Cryogenic Safety http://www.boconline.co.uk/en/sheq/gas-safety/index.html
Cryoservice (Air Products) - http://www.cryoservice.co.uk/downloads.aspx?FP
Air Liquide http://encyclopedia.airliquide.com/encyclopedia.asp

Appendix 1: Assessment of Oxygen Depletion

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 storage or handling rooms, 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 dangerous, and entry into atmospheres containing **less than 19.5% oxygen** must be avoided. It should be recognised that the response to oxygen deficient atmospheres can vary significantly between individuals. Sudden asphyxiation, such as inhalation of pure nitrogen, is likely to cause instant unconsciousness. Even in the case of gradual asphyxia due to a gradual reduction of the oxygen in the atmosphere, the victim may have little warning.

There are three common scenarios for which calculations can be performed to ascertain oxygen depletion levels. It should however, be recognised that this is not an exact science and circumstances may dictate that the actual situation may vary due to factors such as stratification i.e. where nitrogen may accumulate at low level and distribution may not be uniform throughout a room.

Example 1: Natural evaporation scenario - amount of gas evolved from vessels in their normal state

In typical situations the concentration of nitrogen gas that 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:

$C = L / Vn$

Where: C = gas concentration, L = gas evaporation rate (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 – 0.5 air changes per hour could be considered a typical value.

Example

Room volume (H=2.8m, W=3.0m, D=4m) [m^3]: 33.6
Number of non-pressurised liquid nitrogen vessels stored in room: 6
Capacity of each vessel [litres]: 25
Natural rate of evaporation (obtainable from the manufacturer's specification - typically 1 or 2% of the liquid capacity in a 24 hour period [litres]: 0.5
Factor to be multiplied to account for deterioration in the vacuum insulation over time: 2
Estimated air changes per hour by natural ventilation: 0.5
Gas expansion factor for liquid nitrogen: 683

$L = (6 \times 0.5) \times 2 \times 683 / (24 \times 1000) = 0.171\ m^3 / h$
$V = 33.6\ m^3$
$n = 0.5$

Therefore:

C = 0.171 / (33.6 x 0.5) = 0.010 (x 100) = 1.0%

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

Oxygen content after a timed period of evaporation = 21 x (100 / (100 + 1)) = 20.79%

Under these circumstances the evaporation from the vessels only reduces the atmospheric oxygen content from 21% to 20.79% - negligible change and remains within the safe working limit.

Example 2: Losses associated with filling operations

During filling operations, when the lids of the vessels are open and liquid nitrogen is being transferred, there will be an increase in the amount of gas generated. In most cases, this is a relatively short term operation and the increase may not be significant, as the following example demonstrates.

Example

The room in example 1 contains three 25 litre vessels which are topped-up one at a time every three days. We have estimated that the vessel loses 1.0 L by evaporation in 24 hours (0.5 L doubled to account for deterioration in vacuum). Therefore, 3.0 L will be lost in 72 hours and will need to be replaced. We can assume that 10% (0.3 L) of this will go to atmosphere during the topping-up process. Using the formula in example 1

L = 0.3 x 683 = 205 litres = 0.205 m^3
C = 0.205 / 33.6 (room volume) = 0.6% nitrogen added to atmosphere
Oxygen content after filling operation = 21 x (100 / (100 + 0.6)) = 20.87%

The oxygen in the atmosphere during the topping up process is therefore not reduced to a dangerous level and remains within the safe working limit.

Example 3: Worst case scenario - instant and uniform release of the entire contents of a vessel

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 x (Vo / Vr)

Where, for nitrogen:
Vo = 0.2095 (Vr - Vg)
Vr = room volume (m3)
Vg = maximum gas release, which is the liquid volume capacity of the vessel V x gas expansion factor.

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

Vr = 2.8 x 5.0 x 10.0 = 140 m^3
Vg = 100 x 683 = 68300 litres = 68.3m^3
Vo = 0.2095 (140 - 68.3) = 15.02

%O_2 = 100 x (15.02 / 140) = 10.7%

The oxygen content of the room is halved to 10.7%. This is a seriously dangerous condition.

Appendix 2: Risk Assessment Template

Model risk assessment for storage and use of liquid nitrogen tanks and dewars.

Source: BCGA Technical Information Sheet TIS No 27: 2012

(Further templates are included within this freely downloadable PDF publication for other tasks – for moving dewars, decanting liquid nitrogen etc)

i. The risk assessment should be carried out by persons who have been trained in the use of liquid nitrogen tanks / dewars and understand the concept of risk assessment

ii. Based on a comparison of the existing control measures in place against the suggested control measures stated carry out risk rating for each situation / activity by entering a rating of **Negligible, Low, Medium or High** for both the **Severity** and the **Likelihood**

Likelihood / Severity Matrix

Likelihood: *Based on the precautions / controls in place to prevent an incident occurring*.

High: Where no precautions are put in place and the person can only avoid an incident by following verbally communicated procedures - which typically are only short term. No physical barriers or controls in place.
Medium: Limited physical barriers or controls in place. The person can only avoid an incident by working carefully, following training, work instructions and safety procedures
Low: Physical barriers or engineering controls such as local exhaust / extraction systems in place to minimise the likelihood.
Negligible: probability is effectively zero.

Severity: *The degree of injury or harm to the affected person/s.*

High: Death or disabling injury / harm
Medium: Serious injuries requiring medical treatment and time off from work.
Low: Minor injuries.
Negligible: effectively zero injury or harm.

		LIKELIHOOD OF HAZARD			
		High	**Medium**	**Low**	**Negligible**
SEVERITY / CONSEQUENCE OF HAZARD	**High**	High	High	Medium	Effectively Zero
	Medium	High	Medium	Medium / Low	Effectively Zero
	Low	Medium / Low	Low	Low	Effectively Zero
	Negligible	Effectively Zero	Effectively Zero	Effectively Zero	Effectively Zero

iii. Risk Rating (H-M-L) and Result (M-A-N)

Effectively Zero, Result is likely to be **A**dequately Controlled.
Low Risk (LR), Result is likely to be **A**dequately Controlled or **M**inor Residual Risk.
Medium Risk (MR), Result is likely to be **M**inor Residual Risk or **N**ot Adequately Controlled.
High Risk (HR)), Result is likely to be **N**ot Adequately Controlled.

Model Risk Assessment: Storage of liquid nitrogen dewars

Assessment Date

Location

Workplace / Premises Description

Assessed by

Reviewed by

Review Date

No.	Situation / Activity	Hazard	Persons Affected		Recommended Control Measures	Existing Control Measures	Likelihood L-M-H	Severity L-M-H	Risk Rating	*Result M-A-N	Remedial Action Plan
1	Storage of dewars containing liquid nitrogen.	Storage of liquid nitrogen dewars in a room / building could result in oxygen depletion / asphyxiation under product vent, use or leak conditions.	Persons within the storage area or other areas nearby.	1.1	Store dewars in a sheltered but well ventilated location, ideally outdoors under a canopy.						
				1.2	Store away from excessive sources of heat. Storge area should be located away from workplace transport traffic and site drains.						
				1.3	Dewers shall be kept clean and free from oil and grease at all times.						
				1.4	In order to prevent the formation of ice plugs ensure that protective caps are in place and in good condition.						
				1.5	If outdoor storage is not possible the storage area shall be sufficiently ventilated to ensure oxygen concentration is maintained above 19.5 %, taking into account normal evaporation of all dewars within the room and above 18 % taking into account the complete spillage of the largest dewar. Consider forced ventilation. See Annex 3,4,5 of **BCGA CP 30** (7) for calculation guidance.						
				1.6	Pressurised dewars and those fitted with liquid withdrawal devices shall be fitted with a pressure relief device. Monitor pressure levels and vent in a safe location as required. Consider piping relief devices to a safe location outdoors.						
				1.7	For indoor storage areas use a fixed oxygen monitor linked to audible and visual alarm to detect oxygen depletion below 19.5 %.						
				1.8	Consider possible product release or spillage situations. Cold nitrogen gas is heavier than air and will accumulate at low level. Extra precautions are required for basement rooms, rooms with ventilation at high level and rooms with pits, ducts or trenches in the floor.						
				1.9	All relevant staff shall be trained in proper gas safety awareness and in particular specific hazards related to oxygen depletion. Refer: **BCGA GN 11** (10).						
				1.10	Use personal oxygen monitors to detect oxygen depletion below 19.5 % when operating liquid dewars.						
		Access to liquid nitrogen dewars by unauthorised personnel could result in release of product leading to oxygen depletion / asphyxiation or cold burns.		1.11	Dewars should be stored in a secure lockable enclosure that prevents access to unauthorised persons. Enclosure should be designed and constructed from appropriate, robust, materials suitable for the location and posiible risks e.g. palisade to prevent theft or access by unauthorised persons such as children. Refer: **BCGA GN 2** (8).						
				1.12	Display warning notices at access points to the storage area (in accordance with Safety Signs and Signals Regulations 1996 (1)) e.g. product warning, use of PPE, "*No naked flames*", "*No smoking*" and "*No Access for Unauthorised Persons*" Refer: **BCGA GN 2** (8), **BCGA CP 27** (6) & **HSE L 64** (4).						
		External fire or heat impacting on dewars in storage could cause catastrophic failure of the dewars or boil off of contents .		1.13	Dewar storage area to be designed fit for purpose and maintained in good order, i.e. use of non-combustible materials; not used to store flammable materials such as packaging; alarmed fire / smoke detector; use of fire breaks. Refer: **BCGA GN 2** (8).						

2	Manual handling of liquid dewars.	Manual handling injury or damage to property if liquid dewars are handled incorrectly.	Persons or equipment in close proximity to the dewars.	2.1	Design storage such that liquid supply is permenantly piped in with supply line for remote tanker filling and delivery line for dewar filling. Refer **BCGA CP 27** (6).						
				2.2	Dewars are heavy and need to be handled with care. Dewars over 25 litres are generally equipped with permanently installed wheels or trolley. If no wheels are fitted use purpose designed trolley, handcart or overhead hoist. Do not walk, roll or "trundle" by hand. Refer **BCGA GN 3** (9).						
				2.3	Storage floor should be flat level surface. Any gradients used for access or drainage shall be very shallow and drain covers / grating shall be avoided where dewars are to be manoeuvred.						
				2.4	All relevant staff shall be trained in proper handling and use of PPE with dewars.						
				2.5	Dewars fitted with wheels shall be secured by integral wheel brakes, chain or other device.						
				2.6	They shall be kept as near to their correct orientation as possible during transportation and when in use.						
3	Mechanical handling of liquid cylinders.	Mechanical impact or droping of liquid cylinder results in injury to persons or damage to property.	Persons or property in the vicinity of the liquid cylinders.	3.1	Mechanical lifting devices such as FLT's or hoists shall only be used to lift / move dewars that are either designed for purpose or properly secured in a purpose designed lifting / transport device such as a pallet. Some dewars have lifting lugs or slots for FLT forks.						
4	Management of empty liquid cylinders intended for routine transport.	Unintended realease of gas or liquid resulting in oxygen depletion or cold burns.	Persons or property in the vicinity of the gas cylinders.	4.1	Ensure the dewar is completely empty and warmed to ambient temperature before storage. Close any valves and ensure caps are in place, mark as empty and store in designated storage area until ready to return to vendor. Always return empty cylinders to the gas supplier, or agent, as soon as is reasonably practicable.						
				4.2	Dewars should never be considered as completely empty as they may contain residual gas. Hence the safety precautions applied to full dewars should also be applied to empty dewars.						
5	Maintain an inventory of liquid cylinders.	Injury to Fire and Rescue Service personnel due a lack of knowledge of what cylinders are present in the fire zone.	Fire and Rescue Personnel in the fire zone.	5.1	Users must always maintain an up to date inventory of cylinders stored on site (location and quantity). This information may be requested by the emergency services in the event of an incident. Refer: **HSE L64** (4).						
6	Emergency conditions.	Uncontrolled escape of product resulting in oxyen depletion, cold burns, fire / explosion.	Fire and Rescue Personnel in the vicinity. Property in the vicinity.	6.1	Emergency procedures must be in place e.g. the isolation of gas, shut down of all ignition sources, evacuation of area. Employee training of the emergency procedures. Information made available for visitors.						
		Fire / excessive heat could cause damage to product and the uncontrolled release of product.	Fire and Rescue Personnel in the vicinity. Property in the vicinity.	6.2	Emergency prepardness for dewers to be vented in an emergency - this could be achieved through the use of try-cock / vent exhaust, the product should be piped away to a fixed safe external location.						
		Product liquid spillage to site drainage causing damage to drain.	Damage remote from release.	6.3	Storage of dewers should be kept away from site drains.						
Key to Result:	M = Minor Residual Risk (monitor)	A = Adequately Controlled	N = Not adequately Controlled (stop work and improve controls)								

BCGA TIS 27: 2012

Page 8 of 13

Appendix 3 - Competency for the safe use or management of cryogenic systems

The Management of Health and Safety at Work Regulations 1999 (as amended) and the Control of Substances Hazardous to Health (COSHH) 2002 (as amended), requires adequate competency of those that select, design, supply, manage, use, examine, service or test systems for hazardous substances. Competency means having the appropriate knowledge, capabilities and experience for the task, allocated role and responsibility.

The following routes/methods are recommended to obtain adequate competency in the following roles:

Head of School or Directorate / Director of Institute

Understanding the QMUL H&S Policy for the Safe Management of Cryogenic Liquids and Solids.

Briefing by research group leader / project or maintenance manager on proposed project remit / work task and requirements for cryogenic systems (e.g. in Planning Round, Project Working Group).

Briefing by internal and/or external competent advisers on cryogenic liquids or solids system/s within the School / Directorate / Institute's remit.

Laboratory or Facility Manager or Supervisor / Maintenance Manager / Project Manager

Understanding the QMUL H&S Policy for the Safe Management of Cryogenic Liquids and Solids.

Where identified by training needs analysis, specific technical / safety training for the management of cryogenic liquids or solids (internal or external).

Experience of operating cryogenic systems.

Briefing by internal and/or external competent advisers on cryogenic liquids or solids system/s within the School / Directorate / Institute's remit.

Attendance and completion of QMUL safety training courses (taught, online) that cover cryogenic system operations.

Briefings from authorised users (e.g. research group leaders) on the research project / work task remit and requirements.

Consulting HSE and relevant Industry cryogenic safety guidance

Health and Safety Advisers

Full awareness and understanding of H&S legal requirements for cryogenic systems and QMUL H&S Policy and Guidance.

Full awareness and understanding of HSE guidance on cryogenic safety and consulting relevant Industry guidance.

Where identified by training needs analysis, specific cryogenics technical / safety training (internal and/or external).

Where applicable, experience of operating cryogenic systems and to maintain / update their ability to advise on their safe use.

Obtaining briefings from authorised users (e.g. research group leaders, maintenance manager) on the research project / work task.

Cryogenic system users

Attendance and completion of QMUL safety training courses (taught, online) that cover cryogenic safety.

Local training from competent persons (e.g. facility manager, safety coordinator)

Understanding and adhering to local safety operating rules.

Supplier and designers, installers, commissioners, examiners / service engineers

Obtaining suitable industry qualifications applicable to the role (via trade organisations such as BCGA, UKAS, CIBSE; other appropriate fire safety, technical and engineering qualifications)

Demonstration of competency via recorded portfolio of cryogenic system knowledge, experience and application (e.g. by Continual Professional Development).

Appendix 4 – Cryogenic Safety Inspection Checklist (small scale use)

This is expanded from the QMUL laboratory peer review inspection checklist. Use BCGA or other authoritative inspection checklists for bulk and piped facilities.

Date of Inspection:	**Laboratory / Area:**		**Location:**
Responsible Person and position:	**Inspected by, name and position:**		
Liquid Nitrogen / Cryogenic Liquids	**Yes**	**No**	**Comments**
Suitable dewars, tanks or containers of cryogenic liquids used for storage of samples			
Dewars, tanks or containers and transport mechanisms are robust, without significant damage			
Pressurised vessel regulators are within date and have been tested and contain required hazard labels and product markings			
Pressurised vessels above 250 bar have a current Written Scheme of Examination (WSE)			
Method of ventilation for storage area: Passive Fresh Air input Forced Fresh Air input Forced Extraction	State method/s:		
Cryogenic storage area adequately ventilated by above method/s to ensure oxygen levels are not depleted to unsafe levels (not below 19.5 %)			
Are modifications to the ventilation system needed to improve fresh air input and/or air extraction?			
If oxygen levels are likely to be depleted to an unsafe level, suitable oxygen monitoring and warning alarm system in place, tested and operating correctly?			
Emergency procedures specific to liquid nitrogen/cryogenic liquid spills/release in place?			
Cryogenic liquids transported in suitable dewars (e.g. transport dewar has robust (5-star) base and wheels, constructed for the dewar)			
Risk Assessment, safety data sheets and safe procedures for use and transport of cryogenic liquids in place			
Lone working and out of hours working assessed, and restricted according to QMUL Policy			
Suitable thermal gloves and eye/face protection available and worn for handling; PPE cleaned and in good condition; storage hooks / area for PPE available			
Local training on handling cryogenic liquids safely provided and recorded			

Appendix 5 – Hazard and Danger / Warning Signage

From left to right:

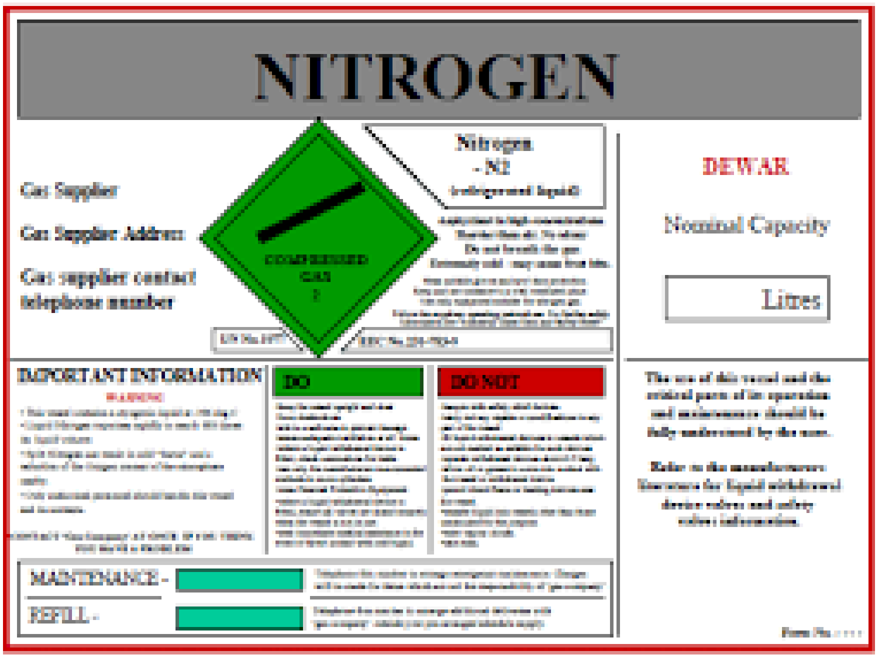
Hazard warning (liquid nitrogen and risk of asphyxiation), access control signage (amber) with supplementary 'no lone working' and contact information for those staff responsible for the area.

Include QMUL Emergency Number 0207 882 **3333**

The strip at the top provides instructions in relation to warning systems if present - other examples would be 'Do not enter if alarm is sounding' and 'If alarm sounds leave the room immediately'.

Hazard / Warning signage can be obtained from HSD as per procedure at http://hsd.qmul.ac.uk/A-Z/Safety%20Signage/index.html

Liquid Nitrogen Product Hazard Label



Appendix 6 – First Aid and Medical Treatment

BOC Gases Guidance Note G4968 'Treatment by medical practitioner or hospital'

BOC GASES

TREATMENT OF CRYOGENIC BURNS AND FROSTBITE

Cold burns or frostbite should receive medical attention as quickly as possible. However, such injuries are not an everyday occurrence and doctors, hospital staff or first aid personnel may not be aware of the basic methods of treatment. The following procedures for first aid treatment and for further treatments to be given by a medical practitioner or a hospital are recommended.

First aid treatment
The aim of treatment is to raise the temperature of the affected part SLOWLY back to normal.

MINOR INJURIES

1. Move victim to comfortable room if possible.
2. Ensure that clothing is loose to provide unrestricted circulation. Do not remove clothing that is stuck to the body until thawed thoroughly.
3. Place affected part in TEPID WATER or run TEPID WATER over for half an hour until skin changes from pale yellow through blue to pink or red. Do not use hot water or any other form of direct heat.
4. Cover affected part with bulky dry sterile dressing.
5. Send victim to hospital casualty department.

MAJOR INJURIES

1. Send for ambulance.
2. Follow minor injury procedure as much as possible.

NEVER GIVE ALCOHOL OR ALLOW SMOKING

Treatment by medical practitioner or hospital

1. Remove any clothing that may restrict circulation to the affected area.
2. Immediately place the part of the body affected in a water bath with a temperature of, ideally, not less than 40°C (104°F) but certainly not more than 42°C (108°F). **Note: 1. Never use hot water or dry heat. 2. Temperatures in excess of 45°C will superimpose a burn on the frozen tissue.**
3. If there has been extensive body exposure to cryogenic temperatures such that the general body temperature is depressed the patient must be re-warmed without delay. The patient should be placed in a bath of warm water at a temperature of 40°–42°C (104°–108°F). It is important that the temperature of the bath is maintained at a level of not less than 40°C to maximise the rate of re-warming.
4. In the absence of facilities for this treatment the patient should be taken to a warm atmosphere, preferably at a temperature of 22°C, kept at rest and lightly covered with one or two blankets until recovery is complete.
5. Shock may occur during the re-warming process.
6. Frozen tissues are often painless and appear waxy with a pallid, yellowish colour. Thawing after disruptive deep burns results in vasodilatation, increased capillary permeability and oedema. The tissues become painful, swollen and prone to infection when thawed. Thawing may take from 15–60 minutes and should be continued until the pale colour of the skin turns to pink or red. The thawing process may require major analgesia. Symptomatic treatment and the prevention of infection is indicated.
7. If the frozen part of the body is thawed by the time medical attention has been obtained, do not rewarm. Cover the area with dry sterile dressings with a large bulky protective covering.

SFT/004968/APUK/0803/5M

Document Control

Version 1 – Ref: QMUL/H&S/103

Author:	Dr Mark Ariyanayagam
Position:	QMUL Biological Safety Adviser and H&S Manager (SMD)
Checked by:	Mrs Zarah Laing
Position:	Director of Health and Safety, QMUL
Consultation :	QMUL Faculty / PS H&S Management Groups, EAF Managers
Date:	Oct - Nov 2016
Approved by:	QMUL Health & Safety Advisory Group
Date:	14 Nov 2016
Status:	Live
Date of Issue:	15 Dec 2016
Date of next scheduled review: 15 Dec 2019	

Version No.	Date of alteration and re-issue	Details of changes	Changes made by
QMUL/H&S/059 QMUL Guidance document for liquid nitrogen	First issued 30/9/2006, author Dr John Robinson, Director H&S Dept)	**Superseded** by this Policy document	Mark Ariyanayagam