CODE OF PRACTICE 30

THE SAFE USE OF LIQUID NITROGEN DEWARS UP TO 50 LITRES

Revision 2: 2013

British Compressed Gases Association

CODE OF PRACTICE 30

THE SAFE USE OF LIQUID NITROGEN DEWARS UP TO 50 LITRES

Revision 2: 2013

Copyright © 2013 by British Compressed Gases Association. First printed 2000. All rights reserved. No part of this publication may be reproduced or transmitted in any form or by any means, electronic or mechanical, including photocopy, without permission from the publisher:

BRITISH COMPRESSED GASES ASSOCIATION
Registered office: 4a Mallard Way, Pride Park, Derby, UK. DE24 8GX
Company Number: 71798, England

Website: www.bcga.co.uk

ISSN 0260 - 4809

PREFACE

The British Compressed Gases Association (BCGA) was established in l971, formed out of the British Acetylene Association, which existed since l901. BCGA members include gas producers, suppliers of gas handling equipment and users operating in the compressed gas field.

The main objectives of the Association are to further technology, to enhance safe practice, and to prioritise environmental protection in the supply and use of industrial gases, and we produce a host of publications to this end. BCGA also provides advice and makes representations on behalf of its Members to regulatory bodies, including the UK Government.

Policy is determined by a Council elected from Member Companies, with detailed technical studies being undertaken by a Technical Committee and its specialist Sub-Committees appointed for this purpose.

BCGA makes strenuous efforts to ensure the accuracy and current relevance of its publications, which are intended for use by technically competent persons. However this does not remove the need for technical and managerial judgement in practical situations. Nor do they confer any immunity or exemption from relevant legal requirements, including by-laws.

For the assistance of users, references are given, either in the text or Appendices, to publications such as British, European and International Standards and Codes of Practice, and current legislation that may be applicable but no representation or warranty can be given that these references are complete or current.

BCGA publications are reviewed, and revised if necessary, at five-yearly intervals, or sooner where the need is recognised. Readers are advised to check the Association's website to ensure that the copy in their possession is the current version.

This document has been prepared by BCGA Technical Sub-Committee 6. This document replaces BCGA CP 30, Revision 1, 2008. It was approved for publication at BCGA Technical Committee 147. This document was first published on 13/11/2013. For comments on this document contact the Association via the website www.bcga.co.uk.

CONTENTS

Appendixes:

* Throughout this publication the numbers in brackets refer to references in Section 14. Documents referenced are the edition current at the time of publication, unless otherwise stated.

TERMINOLOGY AND DEFINITIONS

Bulk supply vessel	The storage container from which the liquid nitrogen is transferred into the dewar.
Dewar	For the purposes of this Code of Practice the term dewar shall mean a vacuum insulated vessel operating at less than 0.5 bar(g).
Inner vessel	The vessel containing the liquid nitrogen.
May	Indicates an option available to the user of this Code of Practice.
Outer vessel	The insulation container.
Shall	Indicates a mandatory requirement for compliance with this Code of Practice.
Should	Indicates a preferred requirement but is not mandatory for compliance with this Code of Practice.
Transportable supply vessel	The storage container from which the liquid nitrogen is transferred into the dewar, where it is a transportable vacuum insulated container of not more than 1000 litres volume.

CODE OF PRACTICE 30

THE SAFE USE OF LIQUID NITROGEN DEWARS UP TO 50 LITRES

1. INTRODUCTION

This Code of Practice is intended for the guidance of users of liquid nitrogen dewars in the UK. It is recommended that any individual involved in the storage, filling, use or maintenance of dewars shall have a knowledge of and comply with the requirements of this Code of Practice.

The objective of this Code of Practice is to promote the safe use of liquid nitrogen. The Code of Practice makes reference to the UK legislation affecting liquid nitrogen dewar use, at the time of publishing. The Code of Practice also makes reference to other publications and training material, which are currently available.

The supplier of the product shall provide the users with full information on the properties of the product being used, and the user of the container shall ensure that all staff are fully conversant with the properties of that product.

2. SCOPE

This document is specifically addressing the use of liquid nitrogen in open dewars and dewars fitted with liquid withdrawal attachments operating at less than 0.5 bar(g). The maximum size of dewar covered by this Code of Practice (CP) is 50 litres. It also includes the safe transport of such dewars.

Customers wishing to use dewars in oxygen, helium or other product service should consult their gas supply company for additional advice.

WARNING: Liquid nitrogen dewars must **not** be used for liquid oxygen.

3. PROPERTIES AND HAZARDS OF NITROGEN

3.1 Properties

Nitrogen is colourless, odourless and tasteless. It constitutes around 78 % of normal, atmospheric air. It is classified as non-toxic and does not support life or combustion. Its physical properties are detailed in Table 1.

Gas density at standard atmospheric conditions (1.013 bar(a) & 15 °C)	1.19 kg/m^3
Liquid temperature at standard atmospheric pressure (1.013 bar(a))	-196 °C
Liquid density at standard atmospheric pressure (1.013 bar(a))	0.8 kg/litre
Expansion ratio from liquid state to gaseous state (1.013 bar(a) and 15 °C)	683

Table 1: Nitrogen. Physical properties.

3.2 Asphyxiation

Nitrogen can produce local oxygen-deficient atmospheres, which will cause asphyxia if breathed. This is especially true in confined spaces and areas of little or no air movement. In this case a risk assessment in accordance with the Confined Spaces Regulations (2) will be required.

As a minimum the oxygen concentration in the workplace should be maintained above 19.5 %.

Atmospheres containing less than 18 % oxygen are potentially dangerous and entry into such areas must be prohibited unless appropriate safety controls are adopted.

Asphyxia due to oxygen deficiency is often rapid with no prior warning to the victim. A general indication of what is liable to happen is given in Appendix 1, but it should be appreciated that the reactions of some individuals can be very different from those shown.

For first aid treatment for asphyxia due to oxygen deficiency, refer to Appendix 1.

Attempts to rescue persons from oxygen deficient atmospheres should only be made by trained persons using breathing apparatus.

3.3 Cold (cryogenic) burns

Severe damage to skin may be caused by prolonged contact with liquid or cold gaseous nitrogen. For this reason protective clothing should always be worn. Section 6 gives recommendations on personal protective equipment.

For first aid treatment for very cold or liquefied gases, refer to Appendix 2.

3.4 Effect of cold on lungs

Whilst transient and short exposure produces discomfort in breathing, prolonged inhalation of vapour or cold gas can produce serious effects on the lungs.

4. DEWARS

4.1 Types of dewar

There are basically two types of dewar. The first type are dewars which are used for the storage and transport of liquid. These dewars are typically narrow necked to facilitate pouring (refer to Figure 1). If suitable they can be fitted with a liquid withdrawal device, as described in Section 4.3, to allow the liquid to be removed without tipping. The second type of dewar is used for cooling items inserted into it. These are wider necked and sometimes come with storage racks or compartments, which can be removed (refer to Figure 2).

Figure 1: Pouring dewars.

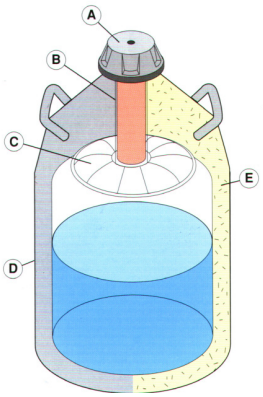
Figure 2: Sample storage dewars.

4.2 Dewar construction

All dewars shall be suitably constructed for use with liquid nitrogen. The relevant legislation is the Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations (6). These regulations implement the European Agreement Concerning the International Carriage of Dangerous Goods by Road (ADR) (7), which details the requirements for the packaging and labelling of dangerous goods.

Dewars shall conform to the relevant requirements for open cryogenic receptacles given in ADR (7), P203 and Section 4.1.6.

Dewars should be checked for cleanliness when first purchased. Section 12 covers the cleaning of dewars.



A	Dust / moisture cap	**D**	Outer vessel
B	Neck tube	**E**	Insulation
C	Inner vessel		

NOTE: A vacuum is formed between the inner and outer vessel.

Figure 3: Typical dewar construction.

The inner vessel is typically constructed from aluminium with an epoxy glass fibre neck or stainless steel with a stainless steel neck. Selecting stainless steel over aluminium

gains increased durability and resistance to impact damage. However, the penalty is increased weight.

The outer vessel is typically aluminium, carbon steel or stainless steel. Again the carbon steel gives increased impact resistance. The penalties are increased weight and decreased corrosion resistance if the paintwork is damaged. Stainless steel gives increased corrosion resistance over carbon steel.

4.3 Liquid withdrawal devices

Figure 4 shows a diagram of a liquid withdrawal device. Because the dewar is sealed, the gas which boils off due to atmospheric warming raises the pressure in the dewar above atmospheric. These devices shall be fitted with a pressure relief device that will prevent the internal pressure exceeding the design limit of the dewar, which shall in any case be below 0.5 bar(g). As the pressure in the dewar is greater than atmospheric pressure the gas at the top of the dewar pushes the liquid out via the dip tube. Only a very small amount of pressure is required, 0.1 bar(g) (1.5 psig), will lift the liquid 1 m high.

Liquid withdrawal devices are normally attached to the dewar via a clamping device. The device shall have a secondary retaining measure, e.g. a retaining wire, to restrain travel in the case of clamp failure.

WARNING: Only fit liquid withdrawal devices to dewars that are designed for these devices and are marked as being compatible and suitable for such devices. Only fit devices which have been designed and built by a manufacturer of proven competence.

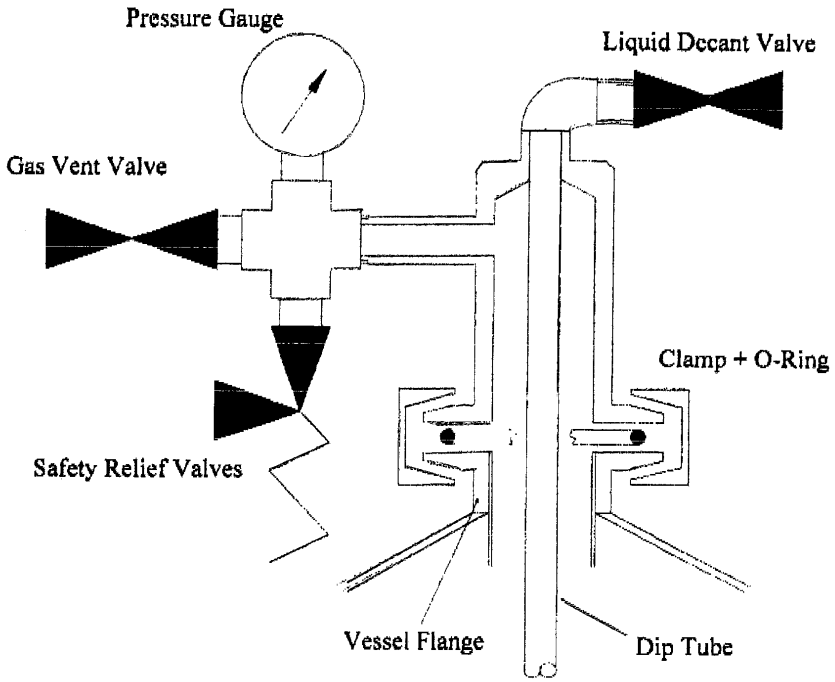


Figure 4: Liquid withdrawal device.

5. LABELLING

Liquid nitrogen dewars shall be clearly and adequately labelled. Figure 5 shows a typical label. The label includes:

- Basic safety information.
- Transport labelling information.
- Gas supplier contacts.

As a minimum the label shall include the statutory labelling requirements of ADR (7), Chapter 5.2, and basic safety information for users.

ADR (7) requires the label to include:

- Product UN number, i.e. UN 1977.
- Product proper shipping name, i.e. NITROGEN, REFRIGERATED LIQUID.
- Product hazard label, i.e. Class 2.2, non-flammable, non-toxic gas, a green diamond with a cylinder symbol and the figure 2 at the bottom.

Product hazard labels shall have a side length of at least 100 mm unless the size and/or shape of the dewar make this impractical. In this instance it shall be as large as possible.

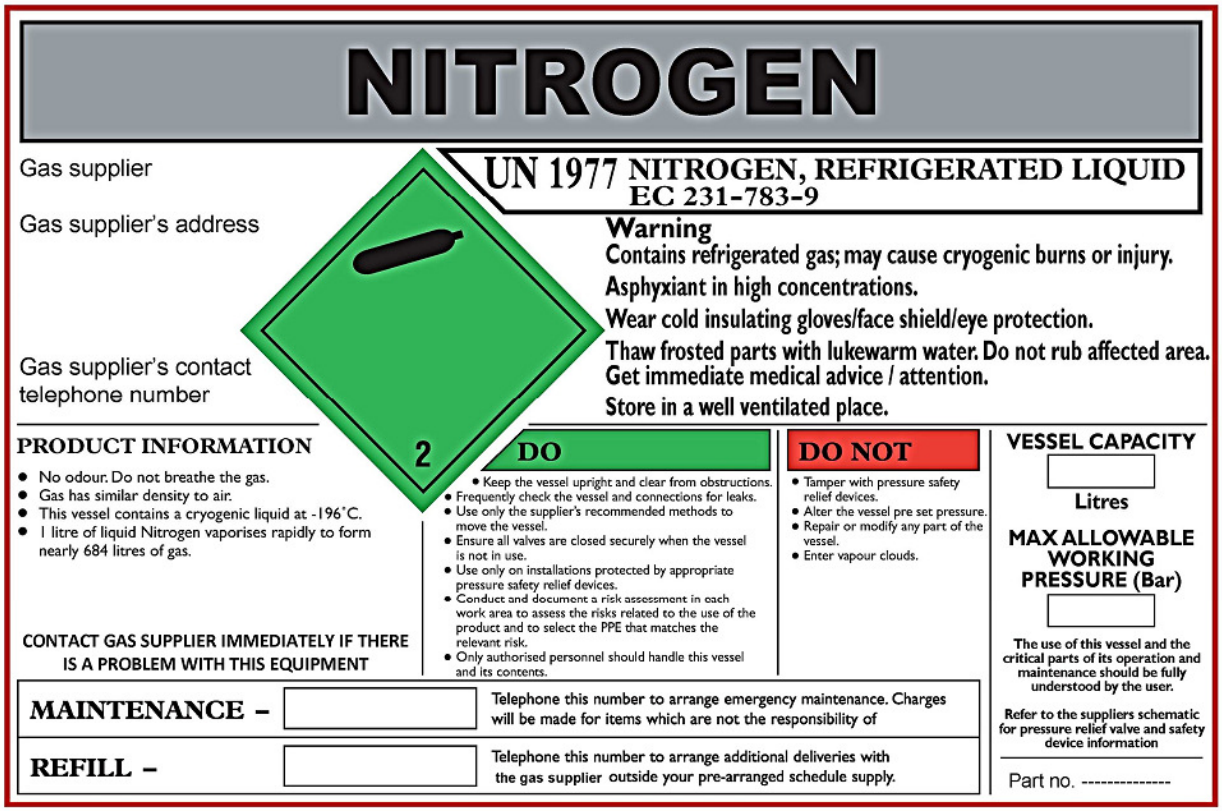


Figure 5: Typical labelling (not to scale)

6. HANDLING

6.1 Manual handling

Keep the vessel upright at all times, except when pouring liquid from dewars specifically designed for that purpose.

Handle with care at all times as rough handling can cause serious damage to the dewar and spillage. Do not 'walk', roll or drag dewars. Always protect the vessel from severe jolting and impact. Do not allow the dewar to come into contact with chemicals or other substances which could promote corrosion.

Be careful to avoid spillage during handling. This could lead to cold burns or oxygen depletion. Even small spills will damage labelling.

The Manual Handling Operations Regulations (1) apply to the handling of liquid nitrogen dewars. Irrespective of the size or type of dewar, users shall carry out a manual handling assessment on the activities operators are required to perform. The Manual Handling Operations Regulations (1) do not cover injury due to liquid spill. It is recommended that users include this in their risk assessments. Under the Management of Health and Safety at Work Regulations (3) employers are required to make a suitable and sufficient assessment of the risks to the health and safety of their employees while at work.

NOTE: Health and Safety Executive (HSE) guidance recommends that female workers should not lift loads greater than 16 kg.

Do not attempt to lift or move large, heavy vessels without assistance. Roller bases and tipping trolleys should be considered and are recommended for dewars of 25 litres and above. However the use of tipping trolleys with dewars of above 35 litres can introduce risks of instability, which should be checked as part of the risk assessment.

BCGA publishes Guidance Note (GN) 3 (12), *Safe cylinder handling and the application of the manual handling operations regulations to gas cylinders*, and Technical Information Sheet (TIS) 17 (15), *Model risk assessment for manual handling activities in the industrial gas industry*, to provide guidance and assistance with risk assessment on manual handling activities. Additional guidance is published by HSE in Leaflet 23 (8), *Manual handling. Guidance on regulations*, and INDG 143 (9), *Getting to grips with manual handling. A short guide for employers*. Further advice is available from The Ergonomics Society (see Section 14).

6.2 Personal Protective Equipment

Personal Protective Equipment (PPE) is to be provided as required by the Personal Protective Equipment at Work Regulations (4). PPE may only be considered as a control to achieve an acceptable level of residual risk after other levels of control have been addressed. The risk assessment will determine the requirement for the use of PPE. Where PPE is required a PPE Assessment is to be carried out. Due regard is to be given to the requirements of the Control of Substances Hazardous to Health (COSHH) Regulations (5), any relevant equipment publications, manufacturers information and the product Safety Data Sheet. The PPE selected is for a particular task and location and must be appropriate and chosen to reduce the overall risk effectively. Thus there are different PPE requirements for differing products and different tasks. The following

protective equipment, manufactured to an approved standard, shall be worn when handling, filling or using dewars:

Eye protection	Goggles or glasses with cheek and brow guards. Glasses will give added impact protection over goggles but cheek and brow guards are essential. Face visors can be used, though may allow splashes to come under the visor and damage the eye unless other eye protection is also worn.
Hand protection	Non-absorbent, insulated gloves, made from a suitable material such as leather. The gloves should be loose fit for easy removal. Sleeves should cover the ends of the gloves. Gauntlet gloves are not recommended because liquid can drip into them.
Protective shoes	Safety shoes with reinforced toe protection are recommended.
Body protection	Overalls or a similar type of clothing should be worn. They should be made preferably without open pockets or turn-ups where liquid could collect. Trousers should be worn outside boots for the same reason. Where dewars are being carried over uneven ground or on stairs at chest height, the user should consider additional splash protection. A splash resistant apron may be appropriate, however care is to be taken not to allow liquid to become trapped between the apron and the body.

7. FILLING

7.1 Equipment and location

If the supply vessel is a bulk storage vessel it shall be sited in accordance with BCGA CP 36 (11) *Cryogenic liquid storage at users' premises.* If the supply vessel is a transportable container it shall be sited in accordance with BCGA CP 27 (10), *Transportable vacuum insulated containers of not more than 1000 litres volume.*

In all cases the dewar fill location shall be suitably ventilated to prevent oxygen depletion; ideally this will be a covered external location.

The supply vessel shall be fitted with appropriate decanting equipment. This shall include a device for venting excess gas before it reaches the dewar. Where the bulk storage vessel operates at above 1.5 bar(g), the decant-valve on the vessel should be a slow opening type, e.g. a globe-valve, not a ball-valve.

7.2 Fill procedure

Dewar filling shall be carried out by properly trained personnel wearing appropriate PPE. The filling procedure shall include the essential elements listed in Sections 7.2.1 and 7.2.2.

When filling dewars that are for sample storage, there is a risk of cross-contamination of the samples via the fill hose. If this is a possibility, the user should include in the procedure a method for preventing cross-contamination. BCGA GN 19 (14), *Cryogenic sample storage systems (Biostores). Guidance on design and operation*, provides additional guidance.

Further advice on maintaining and operating liquid gas storage tanks is available in BCGA Leaflet 12 (18), *Liquid gas storage tanks. Your responsibilities.*

7.2.1 Pre-fill checks

(i) Check that the supply vessel is in an appropriate location and at the correct operating pressure. If the pressure is too high ensure that someone trained to do so vents the tank.

(ii) Check that the dewar is labelled for liquid nitrogen service. Do not fill a dewar which is labelled for another product.

(iii) Check that the filling equipment is clean and free from damage. Do not attempt to use blocked or damaged filling equipment.

(iv) Ensure that the dewar is not fitted with a liquid withdrawal device. Initiating the fill with the device in place may lead to over filling or over pressurisation of the dewar. Excessive pressure may result in the device detaching from the dewar at high speed. Before removing the device ensure that the dewar is vented to atmospheric pressure by opening the vent-valve fully and ensuring that the pressure gauge is reading zero.

(v) Check that the dewar is in good condition. Ensure that there is no neck damage or twisting. Ensure that the insulating bung under the protective cap has not detached. If it has, fit a new cap before filling. If the bung has fallen into the dewar then it must be removed. (Refer to the maintenance procedures in Section 12). Do not fill a dewar which is damaged or has the bung inside.

(vi) Do not fill the dewar if:

- There is water inside.
- There is ice inside.
- There is excessive frosting around the neck.

7.2.2 Filling

(i) Purge the hose to clear any excess atmospheric moisture or dust. This can be done by securing the hose and cracking the decant valve slightly for a short period. Close the valve as soon as frosting appears.

(ii) Insert the fill hose into the dewar and ensure it is secure.

(iii) Initiate the fill slowly by cracking open the fill-valve. If the dewar has warmed the liquid will boil and turn to gas immediately on contact.

(iv) When the dewar has cooled the fill-valve can be opened to establish a steady flow of liquid. If liquid is spitting back out of the dewar then the flow should be reduced.

(v) For dewars with neck tubes, stop the fill when the liquid reaches the bottom of the neck. The 'sound' of the fill will change, indicating that it has happened. Do not fill past the bottom of the neck.

(vi) For dewars that do not have neck tubes, stop the fill when the liquid reaches the required level, which shall be a level below that which the insulating bung will reach when placed onto the dewar after filling.

WARNING: Never overfill a dewar.

(vii) When the dewar is full, replace the protective cap. If the cap rattles, this is evidence that the dewar is over filled and liquid is boiling at a greater rate than is normal. Leave the dewar in the open air until there is no excessive boiling.

(viii) If fitting a liquid withdrawal device, fit it immediately after the fill, ensuring that the dewar has not been overfilled. (Rapid gas boiling is an indication of overfilling). Check the pressure indicator on the device to ensure the pressure rise has stabilised at 0.1 to 0.2 bar(g) (2 to 3 psi(g)). If the pressure is rising towards 0.5 bar(g), open the vent-valve on the device and reduce the pressure. Check the pressure indicator again and repeat the venting cycle as many times as is necessary to obtain a steady pressure reading. Inability to achieve a steady pressure reading is an indication of loss of vacuum from the insulating jacket. Test that the liquid line is clear of ice blockage by operating the liquid valve momentarily, allowing liquid to issue out.

(ix) Check that the labelling has not been damaged by liquid spills during the fill. Replace if necessary.

8. USE

8.1 Outdoor use

When using dewars outdoors there is an increased risk of ice plugs forming in the neck due to condensation of atmospheric moisture or rain freezing on the neck. It is essential that, except when pouring or handling the storage racks, the cap is kept on the dewar. It

is also essential that the cap be in good condition with the insulating bung in place. If possible the dewar should be sited in a sheltered but well ventilated location, e.g. under a canopy. Further advice on avoiding ice plugs is given in Section 8.2.3.

When moving a dewar around premises, it shall never be transported in a closed vehicle, e.g. a car or van. Flat-backed vehicles or trailers are recommended. Section 10 gives more advice on transportation.

8.2 Indoor use

When using dewars indoors there is an increased risk of creating an asphyxiation hazard. The following paragraphs give appropriate precautions for typical hazardous situations.

8.2.1 The use of lifts when transporting dewars

Transporting dewars containing liquid nitrogen in an occupied lift is hazardous and should be avoided whenever possible. The main hazards are the operation of the safety relief device on the liquid withdrawal unit, liquid splashing or boiling liquid vaporising into the lift, creating an oxygen-deficient atmosphere. The majority of lifts have small internal volume and therefore the effects of oxygen deficiency could overcome a person in the lift in a relatively short time.

Spillage of liquid nitrogen can cause embrittlement and subsequent failure of certain materials, e.g. carbon steel. If liquid nitrogen is spilled onto a lift floor, the lift should subsequently be checked for mechanical damage.

When it is necessary to move a dewar to another floor in a building using a lift a detailed risk assessment must be carried out to establish the potential hazards that may occur and to identify the risk mitigating procedures to ensure the safety of the operator or the any other person who potentially could use the lift.

The preferred method of transporting a dewar in a lift is to use a key operated lift that permits the dewar to be carried unaccompanied in the lift and prevents any other person from getting into the lift with the dewar. Dewars should be transported unaccompanied in key operated lifts.

Where this is not possible to use a key operated lift, a detailed risk assessment in accordance with the Management of Health and Safety at Work Regulations (3) and the Confined Spaces Regulations (2) shall be carried out and suitable procedures established.

The risk assessment should take into consideration how other personnel could enter the lift, the type of dewar being moved and the potential for liquid nitrogen being spilt. Refer to BCGA TIS 27 (16), *Model risk assessment for the safe use of liquid nitrogen dewars*.

Where the use of lifts cannot be avoided, one or more of the following (in order of preference) shall be adopted:

(i) Dewars shall only be filled to 90 % of the net capacity to reduce the risk of spillage.

(ii) Dewars fitted with liquid withdrawal devices shall be vented to less than half the relief-valve set pressure.

(iii) Only an operator who has received suitable training shall be allowed in the lift during the transportation of dewars containing product.

(iv) The operator should have a fully functional oxygen depletion monitor that will warn him when the oxygen level has depleted to 19.5 %, allowing immediate evacuation from the lift before a dangerous level is reached.

(v) The operator shall have control of the lift to enable immediate evacuation at the next available floor, in the event of an escape of product.

(vi) The lift shall be fitted with an emergency alarm /t elephone.

(vii) If the lift is equipped with an extraction fan it should be switched on before the operator takes the dewar into the lift.

In addition to the above, the following rules should be rigorously applied:

(viii) Do not transport in a lift a dewar that is venting gas; this especially applies to dewars that have just previously been filled.

(ix) Do not vent dewars whilst in a lift.

(x) Do not transport a leaking or defective dewar in a lift.

(xi) Do not transport in a lift a dewar that has ice forming on the outside.

(xii) Do not transport an overfilled dewar in a lift.

The transportation of dewars in lifts containing product should be supervised / monitored outside the lift by a competent person who is aware of the potential hazards and of the action to take in an emergency.

8.2.2 Stairs and doorways

Stairs present an increased tripping hazard, which may lead to a nitrogen spillage. Where possible, avoid carrying dewars up stairs or steps. If the negotiation of stairs is unavoidable:

(i) Two people are recommended for carrying the dewar.

(ii) Consider the installation of a stair lift where practical.

(iii) Ensure that access to the stairway is restricted, other than to the operator.

(iv) Consider additional body protection against spills, e.g. a carrying apron.

Extra caution is required when transporting dewars through doorways.

8.2.3 Ice plugs

Always wear protective clothing when handling dewars. If ice plugs form they may be ejected at high velocity due to pressure build up. This can result in serious injury. In the worst case, ice plugs can build up sufficient pressure in the dewar to cause catastrophic failure of the dewar, which could result in serious injury, even fatalities.

In order to prevent ice plugs forming:

(i) Always ensure that a dewar is fully emptied after use.

(ii) Always fit protective caps and ensure the caps are in good condition.

For procedures on how to deal with an ice plug refer to Section 13.2.

8.2.4 Sample storage containers

Some liquid nitrogen dewars are used for decanting liquid into larger sample storage containers. Some of these containers can have lids in excess of 1 m diameter. When the lids are removed from containers the atmosphere above the container will be oxygen deficient. The user shall ensure that operators cannot lean over this area in such a way that loss of consciousness would result in collapse into or over the container opening, which would result in asphyxiation.

8.2.5 Ventilation

The paragraphs below deal with the general ventilation of rooms containing nitrogen dewars. However, cold nitrogen gas is heavier than air and will accumulate at low level. Users should, therefore, take extra precautions in basement rooms, rooms with ventilation at high level and rooms with pits, ducts or trenches in the floor where nitrogen can be trapped. Consideration shall be given to the use of oxygen monitors where ventilation is poor. Where possible, the use of such rooms should be avoided.

A room shall be sufficiently ventilated for the two, normal conditions not to cause a reduction in oxygen concentration below 19.5 %:

(i) The normal evaporation of all dewars and liquid nitrogen containers within the room.

(ii) The filling losses from filling the largest dewar from a warm condition.

Additionally, the complete spillage of the contents of the largest dewar shall not cause the oxygen concentration to fall below 18 %.

Appendix 3, guidance for assessment of ventilation requirements, gives a means of calculating whether any additional ventilation is required for the normal evaporation from the dewars. It is recommended that when performing the calculation the evaporation is taken as twice the manufacturers stated evaporation rate as new, to allow for vacuum deterioration with time.

Appendix 4, method of calculating the potential oxygen depletion in a room due to liquid nitrogen filling and spilling, gives a means of calculating the effect of spilling the dewar contents and of filling a dewar from the warm condition.

Appendix 5, oxygen depletion example, is a worked example for calculating ventilation for normal losses and the effects of spillage and filling.

Reference should be made to BCGA GN 11 (13), *Reduced oxygen atmospheres. The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace*, for additional guidance on atmospheric monitoring and ventilation requirements.

9. STORAGE

9.1 Storage of full or part-full dewars

Full or part full dewars should be stored in designated areas that meet the same criteria as dewars in use. There shall be adequate ventilation. Dewars should be stored in a dry area, sheltered from rain. The caps shall always be fitted in storage. Dewars shall be securely stored to prevent access by unauthorised personnel.

If storage rooms have forced ventilation an alarm to indicate its failure is recommended. If storage rooms have reduced ventilation when unoccupied then an alarm to indicate oxygen deficiency is recommended. Alarms should be situated outside the room so that operators are aware of the hazard before entering the room. Refer to BCGA GN 11 (13).

9.2 Storage of empty dewars

Always ensure that a dewar is completely empty before putting it into storage. Dewars shall be emptied in a safe, well-ventilated area. If possible allow the dewar to warm to ambient temperature. Always store the dewar with the dust cap in place. Store dewars in dry areas.

Handle empty dewars as full. It may be that they still have some residual content.

10. TRANSPORTATION OF DEWARS

10.1 Recommendations for transporting dewars

Dewars must always be fitted with caps to prevent the ingress of moisture, whether full or empty. Only caps designed for use with the dewar type shall be used. Caps shall not be secured down unless securing methods are integral to the manufacturer's design of the cap. Some caps may come loose during road transportation. Consideration should be given to the addition of a retaining device if the dewars are to be transported. This device should be a chain or wire which will keep the cap in place but not seal the cap as the dewar must be free to vent.

Dewars should be checked for damage before transportation. Do not transport a full damaged dewar or a full dewar that has lost vacuum.

Dewars must be transported separately from the driver or passengers. Flat-back vehicles, vehicles with a separating bulkhead that gas cannot leak through or trailers should be considered. Dewars shall not be transported in cars.

Dewars shall be adequately secure during transportation to prevent spillage or mechanical damage.

Dewars shall be checked for adequate labelling (see Section 5) before being transported by road.

Drivers shall be adequately trained in the handling of dewars and the properties of liquid nitrogen.

10.2 Regulatory requirements

Dewars filled on site and used at work shall be labelled as given in Section 5 and users shall be in possession of the Safety Data Sheet for the product, which is available from the gas supplier.

Dewars transported by road shall comply with the Carriage of Dangerous Goods and the Use of Transportable Pressure Equipment Regulations (6). These regulations implement (ADR) (7), which allows dangerous goods to be carried internationally in road vehicles subject to compliance with standards for the packaging and labelling of the dangerous goods, and appropriate construction and operating standards for the vehicles and crew. Gases are classified as Class 2 dangerous goods.

The driver shall carry a 'transport document' that includes the following information:

(i) Product UN number, i.e. UN 1977.

(ii) Product proper shipping name, i.e. NITROGEN, REFRIGERATED LIQUID.

(iii) Product classification code, i.e. Class 2.2.

(iv) The volume of each dewar and the number of dewars.

(v) The consignor's name and address.

(vi) The address of the consignee (if known).

If the total quantity of liquid nitrogen being transported is in excess of 1000 kg, ADR (7) is applicable in full. As it is unusual for users to transport such volumes, these requirements are not covered by this document.

Additional general advice for transporting Class 2 dangerous goods is available in BCGA Leaflet 1 (17), *Guidance for the carriage of gas cylinders on vehicles*.

NOTE: The transport of dewars by rail is not covered by this document.

11. SUMMARY OF RECOMMENDATIONS

Employers responsible for the filling, handling, use or transportation of liquid nitrogen dewars shall (where it is within the scope of their operators activities):

(i) Carry out a risk-assessment in accordance with the Management of Health & Safety at Work Regulations (3) and, where necessary, the Confined Spaces Regulations (2).

(ii) Ensure that all employees are adequately trained in the handling of dewars and are aware of the hazards of liquid nitrogen and that proper operating procedures are in place.

(iii) Ensure that adequate ventilation is provided in areas where dewars are used or stored.

(iv) Ensure that adequate procedures are in place for the transportation of dewars within the premises particularly in respect to the use of lifts and stairs.

(v) Ensure that manual handling assessments have been carried out on all activities involving dewars.

(vi) Ensure that labelling meets all regulatory requirements.

(vii) Ensure that dewars are adequately maintained and that they are in good condition.

(viii) Ensure that adequate emergency procedures are in place in event of a liquid spillage.

(ix) Ensure that a sufficient number of personnel are trained in the treatment of asphyxia and cold burns.

(x) Carry out actions resulting from risk assessments.

All personnel involved in the filling, handling, use or transportation of liquid nitrogen dewars shall:

(xi) Be aware of, and trained in, the hazards of liquid nitrogen.

(xii) Wear appropriate hand, eye, feet and body protection when handling full or empty dewars.

(xiii) Not fill, use or transport any dewar with a damaged neck, wall, trunnion support, base support or wheels.

(xiv) Ensure that dewars are correctly and clearly labelled for nitrogen service before filling.

(xv) Only use dewars which are correctly and clearly labelled.

(xvi) Only transport dewars which are correctly labelled for transport.

(xvii) Be adequately trained in the handling of liquid nitrogen dewars.

(xviii) Avoid ice plugs by ensuring that protective caps are always used and that dewars are fully emptied before being taken out of use or put into storage.

(xix) Know what actions to take in the event of a liquid spillage.

(xx) Know what actions to take if an incident results in a cold burn or asphyxia casualty.

Only accompany a dewar in a lift when:

(xxi) Wearing an oxygen monitor.

(xxii) You have control of the lift.

(xxiii) An emergency alarm / telephone is available.

(xxiv) The operation is being supervised / monitored by a competent person.

(xxv) A key controlled lift is not available.

12. MAINTENANCE

In addition to the checks carried out before filling and before transportation the following should be carried out on a regular basis, or at least at intervals not exceeding six months.

(i) Empty the dewar in a safe area and allow it to warm naturally to atmospheric temperature.

(ii) Check that the cap is in good condition and, if not, replace it.

(iii) Check the neck for twisting or damage. If the neck is in any way damaged the dewar should not be used.

(iv) Check the dewar for mechanical damage. Do not use the dewar if damage is found to the support trunnion for the tipping trolley, the dewar stand, the dewar wheels or the dewar wall. (Minor dents and scratches are acceptable, but excessive corrosion or dents that are severe enough to have caused damage to the inner wall are not).

(v) Ensure that the dewar is free of dirt and contaminants, including any insulating bungs which may have detached from the caps and fallen into the dewar.

(vi) If the dewar is contaminated, wash the dewar out with warm water. If a detergent is used, ensure that the dewar is thoroughly rinsed. Ensure that the dewar is completely dried.

(vii) Check that the liquid withdrawal device is in good condition. If the retaining wire, securing collar or valves are damaged, then replace the device.

(viii) For dewars fitted with liquid withdrawal devices, the relief device should be replaced at a suitable frequency, not exceeding ten years.

If a repair is carried out on a dewar it shall be done to the original manufacturing standard.

Further advice on maintaining and operating liquid gas storage tanks is available in BCGA Leaflet 12 (18), *Liquid gas storage tanks. Your responsibilities.*

13. ACTION IN EVENT OF:

13.1 Spillage

(i) Evacuate all personnel from the area likely to be affected by the liquid and the evolved nitrogen gas.

(ii) Pay particular attention to pits, basements, cellars and stairwells because the cold gas will collect in those areas. Try to prevent the gas flowing along the ground into such areas by closing doors.

(iii) Take appropriate action to ensure that the ventilation system does not spread the nitrogen to other areas.

(iv) Open exterior doors and windows to encourage evaporation of the liquid and safe dispersal of the nitrogen gas.

(v) Allow the liquid to evaporate naturally.

(vi) The evolved gas will be very cold and will create a cloud of condensed water vapour restricting visibility. Do not allow anyone to enter this cloud.

(vii) Do not allow anyone to enter the area until you are sure that the nitrogen gas has all dispersed and that the air is safe to breathe. If in doubt, use an oxygen monitor to check oxygen levels

13.2 An ice plug forming

If an ice plug forms there is a danger that:

(i) It will detach at high velocity when the dewar pressure rises.

(ii) It will cause sufficient pressure build up in the dewar to cause it to rupture.

Extreme caution shall be exercised if an ice plug is found. All personnel, except the minimum number required to deal with the incident, should be evacuated from the area.

The recommended method of dealing with the plug is to insert a copper tube into the neck and blow warm nitrogen gas onto the blockage. Compressed air is not recommended as it contains moisture.

Ensure that the dewar is completely sandbagged before approaching it. Extreme caution should be taken when inserting the copper tube. Insert the tube into the neck without making contact with the ice blockage. The gas supply should be set up so that the defrosting process can be initiated in a remote or protected position. Once the defrost has been initiated the operator can retire to a safe place whilst the blockage is being cleared.

The pressure build up may have damaged the inner wall of the dewar. Ensure that the dewar is examined by a competent person before returning it to service.

For advice in dealing with an ice blockage, contact your gas supplier or dewar manufacturer.

13.3 Burns due to liquid nitrogen

In the case of contact with liquid or cold gas, injury can result. Appendix 2 describes the nature of such injuries and gives information about first-aid treatment appropriate in such cases.

14. REFERENCES *

1.	SI 1992 No. 2793	The Manual Handling Operations Regulations 1992. (as amended).
2.	SI 1997 No. 1713	The Confined Spaces Regulations 1997.
3.	SI 1999 No. 3242	The Management of Health and Safety at Work Regulations 1999.
4.	SI 2002 No 1144	The Personal Protective Equipment at Work Regulations 2002.
5.	SI 2002 No 2677	Control of Substances Hazardous to Health Regulations 2002 (COSHH)
6.	SI 2009 No. 1348	The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009 (as amended).
7.	ECE/TRANS/215	European Agreement concerning the international carriage of dangerous goods by road (ADR).
8.	HSE Leaflet 23	Manual Handling Operations Regulations 1992. Guidance on Regulations.
9.	HSE INDG 143	Manual handling at work. A brief guide.
10.	BCGA Code of Practice 27	Transportable vacuum insulated containers of not more than 1000 litres volume.
11.	BCGA Code of Practice 36	Cryogenic liquid storage at users' premises
12.	BCGA Guidance Note 3	Safe cylinder handling and the application of the manual handling operations regulations to gas cylinders.
13.	BCGA Guidance Note 11	Reduced oxygen atmospheres. The management of risk associated with reduced oxygen atmospheres resulting from the use of gases in the workplace.
14.	BCGA Guidance Note 19	Cryogenic sample storage systems (Biostores). Guidance on design and operation.
15.	BCGA Technical Information Sheet 17	Model risk assessment for manual handling activities in the industrial gas industry.
16.	BCGA Technical Information Sheet 27	Model risk assessment for the safe use of liquid nitrogen dewars.
17.	BCGA Leaflet 1	Guidance for the carriage of gas cylinders on vehicles.

18.	BCGA Leaflet 12	Liquid gas storage tanks. Your responsibilities.
19.	British Cryoengineering Society	Cryogenic Safety Manual. *Available through the British Cryogenics Council*

Further information can be obtained from:

Health and Safety Executive	www.hse.gov.uk
UK Legislation	www.legislation.gov.uk
British Standards Institute (BSI)	www.bsigroup.co.uk
European Industrial Gases Association (EIGA)	www.eiga.eu
British Compressed Gases Association (BCGA)	www.bcga.co.uk
The British Cryogenics Council	http://bcryo.org.uk
The Ergonomics Society	www.ergonomics.org.uk

PHYSIOLOGICAL EFFECTS AND RECOMMENDED EXPOSURE LIMITS OF NITROGEN

Asphyxia due to oxygen deficiency is often rapid with no prior warning to the victim. A general indication of what is liable to happen is given below but it should be appreciated that the reactions of some individuals can be very different from those shown.

Sudden Asphyxia
In sudden and acute asphyxia, such as from inhalation of pure nitrogen, unconsciousness is almost immediate (seconds). A person will fall as if struck down by a blow on the head and may die in a few minutes.

Gradual Asphyxia
When asphyxia develops slowly by gradual reduction of the oxygen content in the air, the victim has little warning.

Oxygen reduced from 21 % to 14 % by volume
The first perceptible signs of anoxaemia develop. The depth of breathing increases and the pulse rate is accelerated. The ability to maintain attention and think clearly is diminished. Muscular co-ordination is disturbed.

Oxygen reduced to between 14 % and 10 % by volume
Consciousness continues, but judgement becomes faulty. Severe injuries may cause little pain. Muscular efforts lead to rapid fatigue. Emotions are disturbed – excessive irritation and anger are easily aroused.

Oxygen reduced to between 10 % and 6 % by volume
Rate of breathing is double the normal. Nausea and vomiting may appear. Victim loses ability to perform any vigorous muscular movements or even to move at all, and may be wholly unaware that anything is wrong. Legs give way, leaving him unable to stand, walk or even crawl. This is often the first and only warning, and it comes too late. He may realise that he is dying, but he does not greatly care. It is quite painless! Even if resuscitation is possible, permanent damage to the brain may result.

Oxygen reduced below 6 %
Respiration consists of gasps, separated by periods of increasing duration. Convulsive movement may occur. Breathing then stops, but the heart may continue to beat for a few minutes.

First aid
The victim may well not be aware of the asphyxia. If any of the following symptoms appear in situations where asphyxia is possible, immediately remove the affected person to the open air, following up with artificial respiration if necessary:

(i) Rapid and gasping breathing.

(ii) Rapid fatigue.

(iii) Nausea.

(iv) Vomiting.

(v) Collapse or incapacity to move.

(vi) Unusual behaviour.

If medical attention is not immediately available, arrange for the casualty to be transported to a hospital without delay. Ensure that the ambulance crew and the hospital are advised of details of the accident and of the first aid treatment already administered.

Recommended exposure limits
Taking account of the effects of reduced oxygen levels on personnel it is recommended that no work should be allowed where the oxygen concentration is not above 19.5 %.

Additionally any oxygen level below 18 % should lead immediately to evacuation of the area. Investigation of the cause of the problem will only be possible by the use of self-contained breathing apparatus.

HAZARDS FROM VERY COLD OR LIQUEFIED GASES

Below is a summary, reproduced with permission of the British Cryoengineering Society, from the Cryogenics Safety Manual (19) of the hazards which can arise when handling cryogenic liquids, very cold gas or equipment at very low temperatures. The hazards arise when using any cryogenic product and thus apply to this document, which addresses the handling of liquid nitrogen.

Cryogenic burns and frostbite

Exposure of the skin to low temperature can produce effects on the skin similar to a burn. These will vary in severity with temperature and the time of exposure.

Naked, or insufficiently protected, parts of the body coming into contact with very cold, un-insulated pipes or vessels may stick fast by virtue of the freezing of available moisture and the flesh may be torn on removal. Special care is needed when wearing wet gloves.

Prolonged exposure to cold can result in frostbite. There may well be insufficient warning through localised pain while the freezing action is taking place. All cold burns should be checked by a first-aider or, in extreme circumstances, by a medical expert to confirm the extent of damage.

Prolonged inhalation of cold vapour or gas can damage the lungs. Cryogenic liquids and vapour can damage the eyes.

The low viscosity of cryogenic liquids means that they will penetrate woven or other porous clothing materials much faster than, for example, water.

Precautions

Protective clothing for handling low-temperature, liquefied gases serves mainly to protect against cold burns.

Non-absorbent gloves (PVC or leather) should always be worn when handling anything that is, or may have been, in contact with cold liquids or vapours. Gloves should be a loose fit so that they may be readily removed should liquid splash on to them or into them.

If severe spraying or splashing is likely to occur, eyes should be protected with a face shield or goggles.

Trousers should be worn outside boots and have no pockets or turn-ups.

First aid (cryogenic burns)

Flush the affected areas of skin with copious quantities of tepid water, but do not apply any form of direct heat, e.g. hot water, room heaters, etc. Move the casualty to a warm place (about 22 ^{o}C / 295 K). If medical attention is not immediately available, arrange for the casualty to be transported to hospital without delay.

While waiting for transport:

(i) Loosen any restrictive clothing.

(ii) Place the affected part in **tepid** water, or run **tepid** water over, until the skin changes from pale yellow through blue to pink or red.

(iii) Protect frozen parts with bulky, dry, sterile dressings. Do not apply too tightly so as to cause restriction of blood circulation.

(iv) Keep the patient warm and at rest.

(v) Ensure that the ambulance crew or the hospital is advised of details of the accident and first aid treatment already administered.

(vi) Smoking and alcoholic beverages reduce the blood supply to the affected part and should be avoided.

GUIDANCE FOR ASSESSMENT OF VENTILATION REQUIREMENTS

The type of ventilation depends on a multitude of factors such as type of location, gas type, possible leaks, etc.

Ventilation can be natural or provided by forced ventilation. The design criterion is the number of air changes per hour.

In locations above ground level with no special ventilation openings, natural ventilation provides typically 1 change per hour. This is not the case in buildings with windows sealed with tight seals. For underground rooms with small windows 0.4 changes per hour can be considered as an average value.

For handling (storing, filling, withdrawal, etc). transportable cryogenic vessels with non-flammable, non-toxic contents in locations above ground level, natural ventilation is generally sufficient, provided that the room is large enough and that the outdoor area is not enclosed by walls etc.

An indoor location should have ventilation openings with a total area of 1 % of the ground area. The openings should be positioned diagonally across the room. The density of the gas should also be taken into consideration (the main opening at the highest point of the location for gases lighter than air, or at ground level for gases heavier than air).

For more than 2 changes per hour a forced ventilation system is necessary. Different situations may require a specific number of air changes per hour e.g. 5, 10, 20, etc.

In typical situations the number of air changes can be calculated, assuming a certain leakage rate from the vessel and a homogenous distribution of gas, using the following formula:

$$C_t = 0.21 + \left[\frac{0.21n}{\left(\frac{L}{Vr} + n \right)} - 0.21 \right] \left[1 - e^{-t/m} \right]$$

and for long periods (t tending to infinity):

$$C_\infty = \frac{Vr \times 0.21 \times n}{L + (Vr \times n)} \quad \text{approximately}$$

Where:

C_t = Oxygen concentration after defined time

C_∞ = Oxygen concentration after long periods (days)

L = Gas release rate, m^3/h

V_r = The volume of free air in the workplace, m^3

n = The number of workplace air changes per hour

t = Time, hours

e = 2.72

$$m = \frac{Vr}{L + n\,Vr}$$

A worked example of this is in Appendix 5, showing how to assess whether natural ventilation rates can be adequate for real situations.

METHOD OF CALCULATING THE POTENTIAL OXYGEN DEPLETION IN A ROOM DUE TO LIQUID NITROGEN FILLING AND SPILLING

Appendix 4 considers three scenarios, filling losses which always occur when a dewar is being filled, spillage of the contents of the dewar and the 'worst case' scenario where the entire contents of the vessel are lost to the room immediately after the dewar is filled.

The resulting oxygen concentration in the free space in a room may be calculated from the following formula for each of the scenarios:

$$C_{OX} = \frac{100 \times V_O}{V_R}$$

Where:

C_{OX} = Resulting oxygen concentration %

V_O = Volume of oxygen, m^3

V_R = Volume of the room, m^3

V_O is calculated for the following scenarios:

Filling

A value of 10 % of the volume of the product in the dewar is used to estimate the losses to atmosphere during filling.

$$V_O = 0.21\left[V_R - \left[\frac{0.1 \times V_D \times f_g}{1000}\right]\right]$$

Where:

V_R = Volume of the room, m^3

V_D = Dewar capacity, litres

fg = Gas factor. This is 683 for nitrogen. (Nitrogen gas takes up 683 times the volume of nitrogen liquid, i.e. one litre of liquid nitrogen creates 683 litres of gaseous nitrogen).

0.21 = The normal concentration of oxygen in air, 21 %

0.1 = 10 5 volume loss during filing

Spillage
For the spillage of the entire contents of a nitrogen dewar:

$$V_O = 0.21\left[V_R - \left[\frac{V_D \times f_g}{1000}\right]\right]$$

Where:

V_R = Volume of the room, m^3

V_D = Dewar capacity, litres

fg = Gas factor. This is 683 for nitrogen. (Nitrogen gas takes up 683 times the volume of nitrogen liquid, i.e. one litre of liquid nitrogen creates 683 litres of gaseous nitrogen).

0.21 = The normal concentration of oxygen in air, 21 %

Filling and spillage together
The 'worst case' scenario, where the entire contents of a dewar are lost to the room immediately after filling, equivalent to 110 % of vessel contents to allow for the 10 % filling losses prior to spillage:

$$V_O = 0.21\left[V_R - \left[\frac{1.1 \times V_D \times f_g}{1000}\right]\right]$$

Where:

V_R = Volume of the room, m^3

V_D = Dewar capacity, litres

fg = Gas factor. This is 683 for nitrogen. (Nitrogen gas takes up 683 times the volume of nitrogen liquid, i.e. one litre of liquid nitrogen creates 683 litres of gaseous nitrogen).

0.21 = The normal concentration of oxygen in air, 21 %

1.1 = 110 % volume loss during filling and spillage

Note: Risk assessment must assume the worst case scenario of spillage after filling.

Worked examples of this are shown in Appendix 5.

OXYGEN DEPLETION - EXAMPLE

Example:
A basement room contains two 25 litre and three 10 litre dewars.
Room dimension: 7 x 8 x 2.5 metres = 140 m^3
25 litre dewar: loses 0.2 litres per day through evaporation
10 litre dewar: loses 0.15 litres per day through evaporation
(Dewar manufacturers' quoted evaporation rates).

Normal evaporation losses
Evaporation is a continuous process, hence the oxygen concentration in the air (C_∞) can be calculated over a long period using:

$$C_\infty = \frac{V_R \times 0.21 \times n}{L + (V_R \times n)} \qquad \text{approximately}$$

Where:

V_R = Volume of the room, m^3

n = The number of air changes per hour

L = Gas evaporation rate, m^3/h

Whilst manufacturers will quote the evaporation rate for their dewar, it is prudent to double it when calculating the rate of nitrogen release, L. This allows for a deterioration in the insulation performance over the life of the dewar. The nitrogen gas factor of 683 has to be used to calculate the volume of gaseous nitrogen released through evaporation, as the dewar manufacturer's figures relate to the volume of liquid nitrogen lost.

Thus:

$$L = \frac{2 \times 683 \times (2 \times 0.2 + 3 \times 0.15)}{24 \times 1000}$$

$L = 0.048\ m^3/hr$

Assume there is an average of 0.4 air changes per hour in the room. The oxygen concentration is, therefore:

$$C_\infty = \frac{140 \times 0.21 \times 0.4}{0.048 + 140 \times 0.4}$$

$C_\infty = 0.2098 = 20.98\ \%$

Thus, in this case, evaporation from the five dewars in the circumstances described would reduce the oxygen concentration by some 0.02 %.

In this example, normal nitrogen evaporation from the dewars has only a small effect in increasing the nitrogen concentration, and thus reducing the oxygen concentration, in the room. If, however, far more dewars were stored in the same room used in the above example, or if a much smaller room was used for the five dewars mentioned, then the nitrogen concentration would increase by a much higher larger factor. If C_∞ in such a case was calculated to be 0.20 (i.e. 20 %), then forced ventilation would be recommended, since this would reduce the oxygen concentration in the room by 1 %, which is at the level where the safety margin has been virtually used up.

Losses due to filling (refer to Appendix 4)

First calculate the volume of oxygen in the room, V_O.

Using:

$$V_O = 0.21\left[V_R - \left[\frac{0.1 \times V_D \times f_g}{1000}\right]\right]$$

Where:

V_R = Volume of the room, m^3

V_D = Capacity of largest dewar, litres

fg = Gas factor. This is 683 for nitrogen. (Nitrogen gas takes up 683 times the volume of nitrogen liquid, i.e. one litre of liquid nitrogen creates 683 litres of gaseous nitrogen).

0.21 = The normal concentration of oxygen in air, 21 %

0.1 = 10 5 volume loss during filing

The same dewars and room size are used (140 m^3), but here the largest nitrogen release is during the filling of the largest (25 litre) dewar and again the nitrogen factor of 683 must be used to convert liquid to gaseous nitrogen.

Thus:

$$V_O = 0.21\left[140 - \left[\frac{0.1 \times 25 \times 683}{1000}\right]\right]$$

V_O = 29.04 m^3

The resulting oxygen concentration in the room (C_{ox}) can then be calculated:

Using:

$$C_{OX} = \frac{100 \times V_O}{V_R}$$

$$C_{OX} = \frac{100 \times 29.04}{140}$$

$$C_{ox} = 20.7\ \%$$

Clearly, this is no problem. As a guide it is recommended that the combined effect of normal evaporation and filling processes should give rise to alarm if the oxygen level falls to 19.5 %.

Losses due to filling and spillage (refer to Appendix 4)

Following the same process as above, calculate the volume of oxygen in the room (V_0) as a result of the spillage of the entire contents following filling. Appendix 4 shows that the factor of 1.1 is used to allow for filling losses, plus the total loss from spillage.

Using:

$$V_O = 0.21\left[V_R - \left[\frac{1.1 \times V_D \times f_g}{1000}\right]\right]$$

Where:

V_R = Volume of the room, m^3 = 140 m^3

V_D = Dewar capacity, litres = 25 litres

fg = Gas factor. This is 683 for nitrogen. (Nitrogen gas takes up 683 times the volume of nitrogen liquid, i.e. one litre of liquid nitrogen creates 683 litres of gaseous nitrogen).

0.21 = The normal concentration of oxygen in air, 21 %

1.1 = 110 % volume loss during filling and spillage

Again we have a 140 m^3 room and again the largest release is from the 25 litre dewar.

Thus:

$$V_O = 0.21\left[140 - \left[\frac{1.1 \times 25 \times 683}{1000}\right]\right]$$

$$V_O = 25.5\ m^3$$

Then calculate the resulting room oxygen concentration (C_{ox}) after the spillage:

Using:

$$C_{OX} = \frac{100 \times V_O}{V_R}$$

$$C_{OX} = \frac{100 \times 25.5}{140}$$

$$C_{ox} = 18.2\ \%$$

This is just above the level (set at 18 %) at which we recommend the oxygen monitor should give an emergency alarm, leading to immediate evacuation.

In this example, we would recommend an oxygen monitor be fitted with two levels of alarm:

- 19.5 % should lead to urgent investigation and corrective action.
- 18.0 % should cause immediate evacuation – assuming that this level results from spillage, follow the action list in Section 13.1 of this document.

British Compressed Gases Association

www.bcga.co.uk