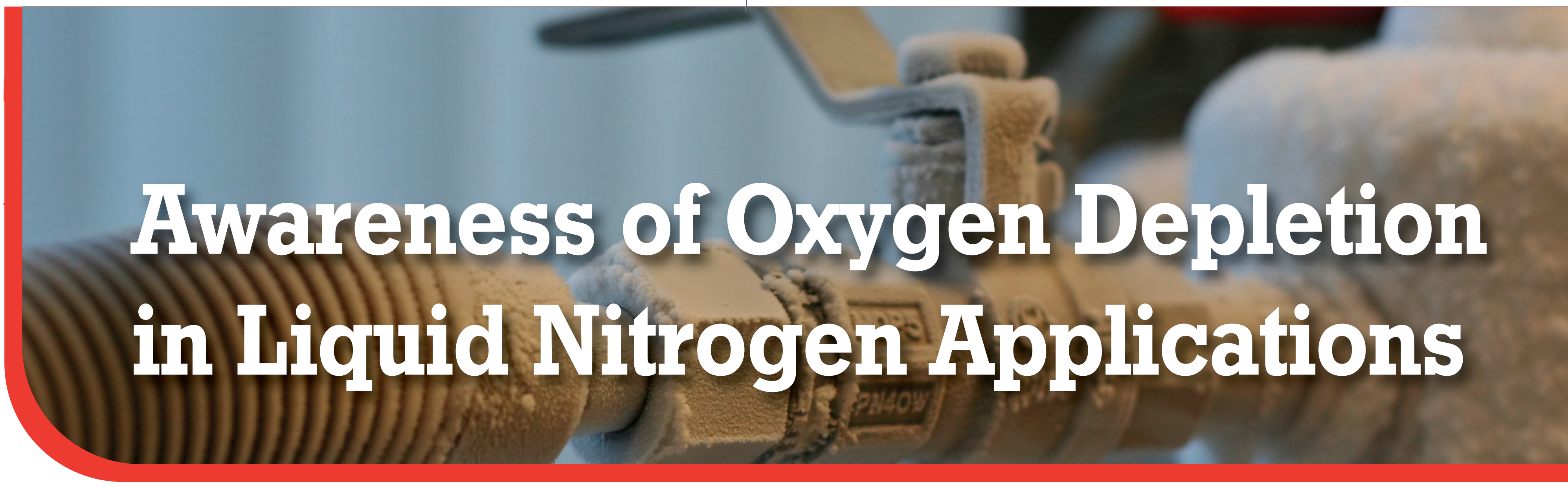


Awareness of Oxygen Depletion in Liquid Nitrogen Applications

All I Need is the Air that I Breathe….
Like most living organisms, humans have a few basic requirements for sustaining life – and sadly beer and curry are actually not on that list! However oxygen is essential for life and our requirements are actually quite specific and relate to the atmosphere that we as a species have developed in.

Any depletion of the oxygen level in air must be treated with concern, and as a minimum the concentration in the workplace should be maintained above 19.5%. Crucially, atmospheres containing less than 18% oxygen are potentially dangerous and suitable protection methods should be adopted (e.g. the use of breathing apparatus).

Asphyxiation as a result of oxygen depletion can take place on a gradual or sudden basis, depending upon the extent of the depletion. It is a little known fact that inhalation of a gas containing virtually no oxygen can result in immediate unconsciousness and rapid death.

The symptoms associated with oxygen depleted atmospheres are detailed in *Table 1*.

Liquid Nitrogen – the Great Cryogen

Liquid nitrogen is used in extensively across the world, particularly for its excellent cryogenic properties. Produced from the liquefaction of air, it is colourless, odourless and exists at temperature of -196°C at atmospheric pressure. Liquid nitrogen is the preferred method of cryogenic storage, for example in the preservation of biological samples, as unlike electrical freezers it relatively cheap to purchase, does not rely on electricity (and is not susceptible to electrical outages) and has low running costs. It is supplied via specialised road tanker into insulated storage vessels, ranging from non-pressurised dewars and desks flasks to pressurised tanks for mobile or static storage.

Typical small mobile liquid nitrogen vessels

Liquid nitrogen is also very safe under normal usage and many people associate the extreme cold temperature as the main source of risk. However, when liquid nitrogen evaporates (e.g. through spillage) it undergoes a large volume expansion as it returns to the gaseous form – one litre of liquid nitrogen produces approximately 680 litres of nitrogen gas! This expansion ratio will quickly displace the atmosphere within a confined space and can cause oxygen depletion if control measures are not in place.

Providing Early Warning

Whilst fully-integrated "cryorooms" are discussed later, one of the most critical aspects of safety awareness and enhancement in these applications is the correct use of gas detection equipment, in the form of oxygen depletion monitoring.

A typical oxygen depletion monitor consists of an electrochemical sensor which generates a small electrical signal in proportion to the concentration of oxygen present. This sensor signal is then amplified to display the oxygen level on either a portable or fixed-point instrument.

Oxygen sensors are typically calibrated in air (having first been zeroed using 100% nitrogen) so that 20.9% volume oxygen is displayed in clean-air environments. Oxygen depletion alarms are usually set at 19% and 17% volume.

Personal oxygen monitor

Portable instruments are typically worn on breast pockets (ie within the vicinity of the breathing zone) to provide protection to personnel. Staff working within an area where an oxygen depletion risk exists are trained to evacuate immediately in the event of their portable monitor producing a low oxygen alarm.

Fixed-point oxygen monitoring systems utilise one or more oxygen sensors installed in the vicinity of potential nitrogen leak sources (ie near vessels, flanges, valves etc), which are connected to a control panel. The sensors permanently monitor the area, and the control panel displays the gas levels and provides alarms in the event of a sensor reporting a reduced concentration of oxygen. Control panels can also be used to take executive actions such as closing solenoid valves to prevent further nitrogen releases. Fixed systems provide the significant advantage of warning of a reduced level of oxygen before personnel enter an area.

Table 1 - Asphyxia Symptoms for Low Oxygen Levels

Oxygen Content of Air	Signs and Symptoms of Asphyxia
18% - 19.5%	May affect physical and intellectual performance without person's knowledge.
15% - 18%	Decreased ability to work strenuously. May impair co-ordination and may induce symptoms in persons with coronary, pulmonary, or circulatory problems.
12% - 15%	Respiration deeper, increased pulse rate, and impaired co-ordination, perception and judgment.
10% - 12%	Further increase in rate and depth of respiration, further increase in pulse rate, performance failure, giddiness, poor judgment, blue lips.
8% - 10%	Mental failure, nausea, vomiting, fainting, ashen face, blue lips.
6% - 8%	Loss of consciousness within a few minutes, resuscitation possible if carried out immediately.
0% - 6%	Loss of consciousness almost immediate, death ensues, brain damage even if rescued.

Case Study –

"Workers at one of the UK's Largest Vacuum Test Chambers kept safe by Gas Detection System"

To protect workers from the danger of depleted oxygen levels, the Rutherford Appleton Laboratory has recently installed a gas detection system with four remote oxygen detectors. The control panel displays oxygen levels in all the testing cleanrooms simultaneously on a large, LCD display, allowing full system status checks at a glance.

The remote oxygen detectors are installed in the Assembly Integration and Verification (AIV) Facility's suite of cleanrooms, where spacecraft and satellite components are subjected to extreme temperature and vacuum conditions. The facility has a number of vacuum chambers and other testing laboratories. The largest vacuum chamber – one of the biggest in the UK – is highly versatile and can simulate near-space conditions with temperatures from -196°C to + 150°C.

The chambers are returned to atmospheric pressure by introducing nitrogen gas. It can take up to four hours to return the largest chamber to atmospheric pressure, and if nitrogen leaked out during this time, it could result in rapid oxygen depletion in the laboratory. The oxygen sensors ensure that should this happen, the control panel will instantly inform controllers which detector has been activated with a visual signal such as "Vacuum chamber 1", as well as activating audible/visual alarm devices.

"Our air conditioning system changes the air up to six times an hour so if there ever was a nitrogen leak, the aircon would normally take care of it," commented technician Dave Rippington. "The gas detection system is really in place as part of a 'belt and braces' approach, ensuring our workers are safe in the highly unlikely event that there was both a nitrogen leak and the air-con system failed."

Best Practise Control Measures

The main application considered here is biological sample storage within typical research, academic and hospital environments, and there are effectively two infrastructures in which this product is used.

The first is the purpose-designed "cryoroom", a dedicated facility for the storage of preserved samples and the supply of liquid nitrogen to them. These have generally undergone extensive design and feature

Liquid nitrogen is widely used and tanks are normally filled on site

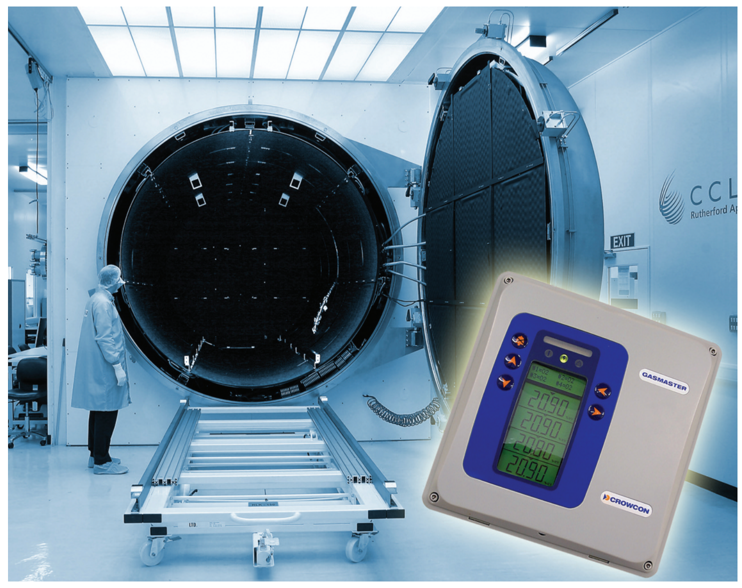
best practise in risk management. Typical features of a dedicated cryoroom are:

- External storage of liquid nitrogen.
- A transfer pipeline for liquid nitrogen into the cryoroom – this is often referred to as Super Insulated Vacuum Line (SIVL) as it is highly insulated to prevent liquid nitrogen boil-off.
- The use of large cryogenic freezers, generally storing samples in vapour phase (reduces the amount of liquid nitrogen contained) with automated temperature control and auto-fill systems. The latter means that personnel do not have to be present when the freezers are being filled; and systems can operate on a time or level basis.
- An integrated fixed gas detection system, often with multiple sensors and alarms linked to a Business Management System and a safety shut off solenoid for the SIVL line to cut-off the liquid nitrogen supply in the event of an oxygen depletion alarm.
- A ventilation system linked to the gas detection equipment, providing increased throughput on low oxygen levels.
- A door interlock system that allows escape but prevent access in emergency conditions.
- Specialised flooring and lifting equipment.
- An extensive maintenance routine covering all aspects of the system.

The second type is where liquid nitrogen is used in individual laboratories from small wheeled tanks or from unpressurised dewars. Liquid Nitrogen is generally manually decanted using a hose or transfer device into small aluminium freezers with liquid phase storage.

Whilst this arrangement is not as desirable as the purpose-built cryoroom, building infrastructure issues or funding often means that it is the most pragmatic way to operate. Safety can be maximised in these situations by considering the following:

A typical cryoroom facility at John Radcliffe Hospital



Rutherford Appleton Laboratory facility

- Minimise the storage of samples in a laboratory. Many facilities retain samples for archiving purposes that will rarely if ever be used in daily operation. Several private off-site repositories have opened in the UK specifically to assist with this problem.
- Minimise the amount of liquid nitrogen stored in your laboratory. Can the vessels be stored in a suitable outside area, where product can be transferred into a non-pressurised dewar for topping up freezers periodically?
- The use of a phase separator (a small sintered device) on liquid nitrogen transfer hoses to minimise splashing and resultant evaporation.
- The use of gas detection to allow early warning of oxygen depletion. Consider the fitment of a "repeater" or external alarm that is visible outside the laboratory to prevent people entering in emergency conditions. Fixed monitors are preferable to personal monitors as they protect everyone in an area.
- Ensuring adequate ventilation, through LEV or similar. Remember that cold nitrogen gas is heavier than air and will accumulate in low areas such as pits or gulleys.

Further reading

The British Compressed Gases Association represents the UK's industrial gas sector. It provides guidance notes and codes of practise that are recognised and utilised throughout the industry. Guidance Note GN11 "The Management of Risks Associated with Reduced Oxygen Atmospheres" has extensive additional information on this topic and is available via the BCGA website www.bcga.co.uk

CoGDEM (the Council of Gas Detection and Environmental Monitoring) is the trade association representing manufacturers and service providers who are active in the field of gas detection instrumentation and environmental monitoring apparatus.

It was formed in the 1970s and has been the guiding organisation behind many industry-specific standards and guidelines. Specific data about gas detection equipment, standards and applications can be found on its website www.cogdem.org.uk .

CoGDEM
The Council of Gas Detection and Environmental Monitoring

AUTHOR DETAILS

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Andy Avenell
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New Range of Infrared Gas Sensors

In order to meet the demand for smaller and lower cost gas sensors **Edinburgh Instruments** (UK) are launching the 'IRgaskiT' - a new range of infrared gas sensor products, based on a common, compact electronics platform, with interchangeable optical 'heads', permitting high performance continuous detection and measurement of target gases. Initially, the IRgaskiT will be available with options to detect and measure a wide range of CO_2 concentrations. IRgaskiT also supports certified explosion proof miniature gas sensor modules offered by other manufacturers. Furthermore, we plan to introduce new IRgaskiT sensor models for detecting additional gases. The compact design of the IRgaskiT, with the added option of mounting the optical assembly remotely from the support electronics, is ideal for applications where space on control panels (or within customer's own instrument enclosure) is limited.

The potential to separate the optical assembly and processing electronics will also be of particular interest where gases have to be measured in 'hostile' environments (eg. elevated temperature and / or humidity). Edinburgh Instruments Ltd has been designing and manufacturing gas sensors and gas monitors for the process control market for almost twenty years. We have an extensive range of products, based on the increasingly popular principle of non-dispersive infrared absorbtion (NDIR).Within the product range offered by Edinburgh Instruments are gas sensors and gas monitors capable of measuring carbon dioxide (CO_2), carbon monoxide (CO), nitrous oxide (N_2O), pentane (C_5H_{12}), methane (CH_4), ammonia (NH_4) and other refrigerants.

Reader Reply Card no 47

Real-Time Detection And Identification of Chemical Warfare Agents, Toxic Industrial Gases And Explosives with the Hand-Held, Multi-Sensor Gda2

AIRSENSE Analytics (Germany) has designed in cooperation with First Response teams a portable hazardous Gas Detector Array (GDA2) for the detection and the identification of CWA's like Nerve, Blister, Blood and Choking agents and a broad range of TIC's (ETW, AEGL, ERPG, ITF-25 list, etc.). Furthermore the GDA2 is able to detect some Explosives.

By using 4 different sensor-technologies like a Photo Ionization Detector (PID), an Ion Mobility Spectrometer (IMS), two semiconductor gas sensors and an electrochemical cell, simultaneously the GDA2 reduces false positives and achieves greatly extended far-superior coverage of hazardous volatiles with more accuracy than single-detection technology. The released gases and CWA's can be detected within seconds with detection limits from low ppb to high ppm concentration. The GDA2 holds up to 3 different libraries each are customized and comprising up to 256 compounds. The first target of the GDA2 is safety: The user is warned when compounds are present – although compounds may not contain in the library that is currently active.

NEW: In real situations users encounter situations where the toxic gases might reach extremely high concentrations, such as explosion levels (in the %-range). Therefore Airsense has designed new procedures for the self protection of the detectors and an ex-proof design. The GDA2 is the most enhanced chemical detector currently available. It is used by various first responder teams in chemical plants, semiconductor industry, fire brigades, military, Airports and Police worldwide.

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