Appendix 3. Calculations of Oxygen Levels Following Sudden Release and Normal Evaporation of Nitrogen

The asphyxiation risk level can be calculated by assuming the immediate and uniform introduction of gas from the vessel of largest storage capacity within the workplace.

$$\text{Oxygen Concentration} = \frac{Vox}{Vw} \times 100\%$$

Where:

Vox = volume of oxygen (m^3)
Vw = volume of available air (m^3)

Vox = 0.21 x {Vw — (Vt x 696)}

Where:

Vt = net storage tank capacity (m^3)
696 = expansion ratio of nitrogen (liquid to gas)

Vw = Vr-Vi

Where:

Vr = volume of workplace (obtained from room/area dimensions: length, width and height). If the height is greater than 2m, then the height should be taken as 2m for the purpose of the calculation since this is a little greater than a 'typical' person's height.

Vi = volume of objects/items/equipment within the workplace (e.g. sample storage vessels).

If the calculation shows the oxygen concentration in the workplace will be less than 19.5%, then an action plan will need to be developed to formulate suitable preventative and risk control measures.

Worked Example

This is the standard example used for this type of calculation. A Dewar containing 100 litres of liquid nitrogen in a room 10m by 10m by 3m. Calculate the resulting oxygen concentration if all the nitrogen was released into the room immediately and uniformly.

To calculate Vw, we will use 2m instead of 3m as the maximum height. We will also assume that the equipment will occupy 10% of the residual space in the room.

Thus, Vw = (200 - 20) = 180 m^3

Vox = 0.21 x {180 - (0.1 x 696)} = 23.18

(Where 100 litres = 0.1 m^3)

$$\text{Oxygen Concentration} = \frac{23.18}{180} \times 100\% = 12.9\%$$

This would indicate that if a sudden release was to occur, there would be a serious potential for major / fatal injury to persons within the room and further precautions would be required. The principal control measures to be considered would be to increase ventilation rates.

If we also consider a more typical situation where the storage and use of liquid cryogens, e.g. liquid nitrogen, are used in a laboratory, the potential for oxygen depletion can be estimated. There will be a continual evaporation of the nitrogen and the concentration of this gas may accumulate in a room over a period of time (assuming a certain evaporation rate from vessels, Dewars and / or pipework) may be calculated using the following equation:

$$\text{Gas Concentration, } C = \frac{L}{Vn}$$

L = gas release (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, if the rooms are windowless or have windows which are tightly sealed, the number of air changes will be less than 1 per hour. For underground rooms with small windows, 0.4 changes per hour maybe a typical value.

Worked Example

Consider a room 10m by 10m by 3m that houses 6 x 25 litre capacity non-pressurised liquid nitrogen vessels (for liquid nitrogen use 2m instead of 3m as the maximum height). The rate of evaporation from the vessels is 0.625 litres / 24 hours. This information should be provided by the manufacturer of the vessel when purchased. It is typically around 2.5% of the liquid capacity of the vessel per 24 hours for a new vessel. Since there will be a deterioration in the vacuum insulation with time we will assume that the rate of evaporation is double the stated value. The room is above ground but has no windows and is estimated to have 0.5 air changes per hour by natural ventilation. The gas expansion factor for nitrogen is 696.

$$\text{Gas released, } L = \frac{\text{Number of Dewars x Volume released per Dewar x Expansion Ratio}}{\text{Time Period x } 1000^{\dagger}}$$

(†The factor of 1000 should only be used if the volume of release is expressed in litres.)

$$L = \frac{6 \text{ x } (0.625 \text{ x}2) \text{ x } 696}{24 \text{ x } 1000} = 0.2175 \text{ m}^3 / \text{h}$$

V = 2.0 x 10.0 x 10.0 = 200 m^3
n = 0.5

We will assume that 10% of the room is occupied by items e.g. furniture etc.

Vw = Vr – Vi = 200 – 30 = 180m3

Thus:

$$C = \frac{0.2175}{180 \text{ x } 0.5} \text{ x } 100\% = 0.242\%$$

i.e. the nitrogen concentration of this room is increased by 0.242%. Since the normal oxygen content is approximately 21%, the reduction in oxygen after this gradual release over time is calculated as:

$$\text{Oxygen Concentration} = \frac{21 \times 100}{(100 + 0.242)} = 20.95\%$$

The reduction in oxygen content is negligible for a room of this size storing 6 x 25 litre Dewars. Obviously while the liquid nitrogen is being transferred there will be a small increase in the about of gas evolved but this should be a short term operation and have no significant effect.