

Chemical Safety Guidance

February 2020

Compressed Gas User Guidance

**Occupational Health and Safety Service
HSD032C (rev 6)**



**UNIVERSITY OF
CAMBRIDGE**

Scope

This code of practice describes the hazards, the risks and the control measures required for the safe use of compressed gas cylinders. It deals with the risks from the point of delivery until the container is exhausted and returned to the supplier. It does not specifically address 'house gases' derived from bulk cryogenic liquid supplies (nitrogen, carbon dioxide etc), although many of the hazards, risks and control measures would be applicable to them and would form part of the risk assessment for their use. It should also be noted that 'house gases' need consideration under the Pressure Systems Safety Regulations (PSSSR) see HSD046P.

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1 Gas Cylinders and Associated Equipment

1.1 Identification of the Gas and its Pressure

The primary means of identification of the contents of a gas cylinder is the label on the shoulder of the cylinder *.

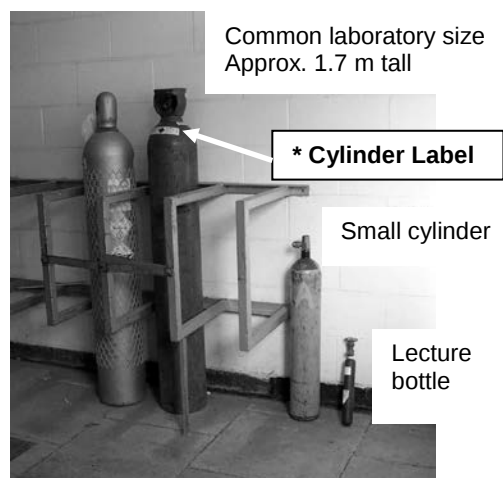
The label also shows the maximum fill pressure: which depends on the gas, the size of the cylinder and the supplier.

Cylinders are also painted in distinctive colours to aid identification. However, cylinder colour codes are not universal, nor does each gas have a unique colour!

The label should always be checked before connecting the cylinder.

If the label is unreadable or at variance with the colour code, the cylinder should be returned to the supplier unused.

Figure 1: Common cylinder sizes



Note: Fill pressures for larger cylinders have risen, from around 170 bar 50 years ago, to 300 bar on some cylinders today. In some cases the 300 bar fill pressure may be reduced to a lower delivery pressure (i.e. 200 bar) by an 'in- built' pre-set regulator on the cylinder.

NB: For a given gas and cylinder size, the higher the fill pressure the more gas it contains, which could have safety implications and requires the risk assessment to be reviewed.

1.2 The Pressure Vessel

Note: The cylinder that contains the gas is a pressure vessel and requires periodic checks and tests in accordance with the legislation governing the use of pressure equipment.

Normally, the University pays rental on the cylinder, but buys the gas that is inside.

This means that for these 'rented cylinders' legal ownership of the cylinder remains with the supplier, who is then responsible for ensuring that the periodic checks and tests are carried out. Cylinders generally have a colour and shape-coded collar at the neck, which is used by the supplier to identify those pressure vessels whose test is due.

It is important to identify if there are any cylinders that are 'wholly owned' by the Department, since the requirements for inspection and testing will be the Department's and there must be a recorded system to ensure they are carried out in accordance with the regulations.

It is recommended that any 'wholly owned' cylinders are recorded and clearly marked to show that they are 'Owned by the Department'. In most Departments, only lecture bottles are likely to be 'wholly-owned' by the Department, and whilst these are well below the 250 bar litre threshold of PSSSR, their age and condition should be subject to scrutiny.

Disposable single-use cylinders, for small-scale use, should be discarded when they are empty, either by returning them to the supplier or via the University's chemical waste disposal service and NOT in the general waste skips.

Under no circumstances should refilling of a single-use cylinder be attempted.

Since gas supplied in small quantities is inevitably expensive, it may be more economical to rent a 'larger' cylinder and return it to the supplier when no longer needed, even if it is not 'empty', saving the substantial disposal costs of lecture bottles (£100 to £500 each).

NB: It is to the Department's advantage to keep its inventory of gas to a minimum in both the size and number of cylinders, this minimises the costs and reduces the potential risks.

Cylinders should be returned to the supplier ASAP after the intended use is complete.

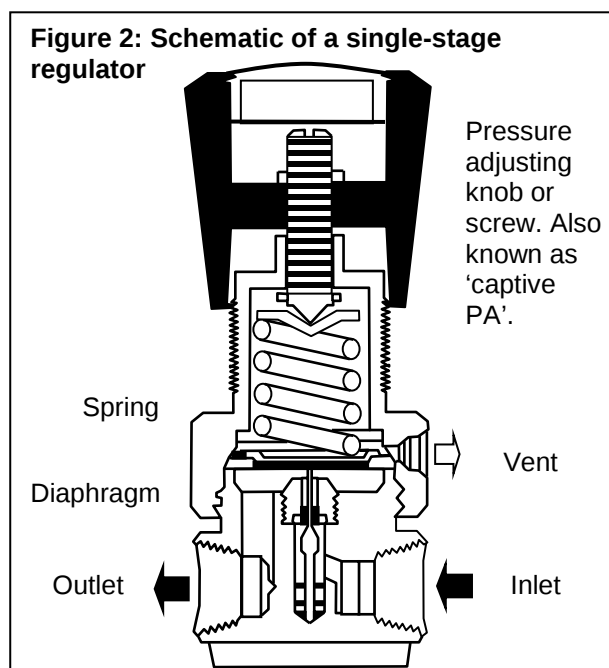
1.3 Regulators

In most cases regulators must be fitted to the cylinders to reduce the gas pressure from the cylinder pressure to the working pressure of the equipment (Appendix A).

In a small number of cases cylinders may be used without any equipment to regulate the pressure or flow, examples are the withdrawal of vapour or liquid from low pressure liquefied gases such as ammonia, sulphur dioxide and for liquid carbon dioxide (which has a different type of cylinder to CO₂ gas!)

It is essential to select regulators that are rated at or above the fill or max delivery pressure of the cylinder. Using a regulator or other equipment not rated for the pressure of the contents of the cylinder can result in catastrophic failure and a fatal accident is possible.

Figure 2: Schematic of a single-stage regulator



Regulators must be made to an approved standard (BS EN ISO 2503, 2009 or equivalent) and designed for the gas being used, buying from a reputable supplier should ensure this. Note: Using a nitrogen regulator on a helium cylinder may result in the regulator leaking, but using the wrong regulator with acetylene could result in an explosion!

Ensure the regulator to be used can deliver the outlet pressure required.

There are two common types of regulator, the single-stage and the two-stage. The diagram above shows a single stage regulator in cross section. Single stage regulators are cheaper to buy, but it is often difficult to maintain a steady outlet pressure over time – **it tends to rise as the cylinder empties** because there is less gas pressure exerted on the valve stem. Two-stage regulators are effectively two single-stage regulators in series.

The principle of both types is that high pressure gas enters the regulator through the inlet into the high pressure chamber. The pressure adjusting knob or screw, when turned clockwise, compresses the spring and this exerts a force against the diaphragm. This pushes the valve stem open, releasing gas into the low pressure chamber. Equilibrium is reached when the spring force on the diaphragm is equal to the opposing force of the gas in the low pressure chamber. In the two stage regulator the first stage reduces the inlet pressure to a preset intermediate pressure – typically 25 to 35 bar, and then by adjusting the pressure adjusting knob or screw the second stage reduces the intermediate pressure to the desired delivery pressure.

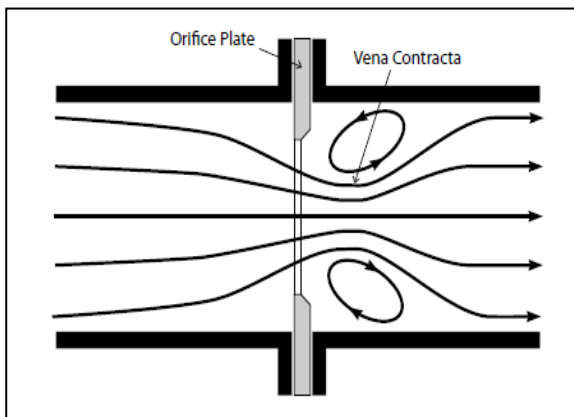
For special gases such as silane, borane, fluorine or chlorine etc, seek the advice of the supplier both as to the type of regulator that should be used, the materials of manufacture and the replacement interval. NB: Oxygen requires equipment to be scrupulously clean. If an oxygen regulator has been inadvertently used for another gas, then it should be down-rated, clearly labelled, and must not be used for oxygen again, or preferably replaced.

Regulators are primarily designed to control the pressure, whilst valves will control the flow. You must consider the intended gas flow rate and consider consulting the manufacturer, supplier or experienced user if you are using a 'low flow rate'. However what constitutes a 'low flow rate' may vary with the gas and the regulator design; **so advice should always be sought.** It may be that single stage regulators are more

suitable for controlling the pressure at 'low flow rates', with needle valves to control the flow rate.

Figure 2A: Schematic of an in-line orifice plate

The flow can also be controlled / limited by the use of an 'orifice plate'. The orifice plate or grid installed before the regulator will limit the flow potentially giving 'better' control at low flow rates. It could also limit the maximum potential flow in a given time in the event of a system or regulator failure, thus reducing the amount of gas 'released' in a that time.



In addition, purgeable regulators will allow you to clear (purge) toxic gas from the regulator using an 'inert' gas (i.e. argon), without releasing it into the laboratory.

1.4 Additional Safety Equipment

1.4.1 Gas cabinets

Gas cylinder storage cabinets are steel enclosures which have in-built forced ventilation and exhaust. They are often used for the more toxic, flammable or dangerous gases when the cylinder needs to be inside a building, although they can also be used externally.

Fire resisting cabinets manufactured to BS EN 14470-2 are also available and will significantly reduce the risk of cylinders overheating and exploding in a fire.

Where Extremely Flammable, Very Toxic or Pyrophoric gas cylinders are used inside a building ninety minute fire resisting cabinets to BS EN 14470-2 are recommended (aka 'Type 90' cabinets).

1.4.2 Flashback or flame arrestors

In applications such as gas welding, there is a risk of 'flashback', where a backfire in the blowtorch can propagate a flame back into the hose and it is possible for it to continue back towards the regulator. If it were to reach an acetylene or propane cylinder it might internally ignite it, and the cylinder could explode.

A flashback arrestor contains an element that rapidly quenches a flame. These devices also frequently incorporate a pressure or temperature actuated cut-off valve in order to cut off the gas supply. The arrestor should comply with BS EN 730, 2002 or equivalent.

For any application such as welding, preheating or cutting, where a flammable gas is used with oxygen, a flashback arrestor is required, with a cut-off valve is fitted to the pressure regulator outlet of the flammable gas, or to the outlet from a flammable gas distribution system. It is possible to fit the flashback arrestor at the blowpipe inlet, but it should be borne in mind that this leaves the hose unprotected in the case of a leak that is inadvertently ignited. For long hoses (in excess of 3 m), it is recommended that a flashback arrestor with cut-off valve be fitted at the regulator outlet and a second at the blowpipe (although it is acceptable to have a non-return valve only at the blowpipe).

For any other application where a pressurised oxidant is used in the same system as a pressurised flammable or pyrophoric gas, flashback arrestors are essential.

Figure 3: Flashback arrestor



Flashback arrestors MUST always be used with acetylene.

Where the flammable or pyrophoric gas, or oxidant is used **alone**, flashback arrestors give added protection but are not obligatory.

Flashback arrestors are subject to the same stringent replacement cycles that apply to regulators, that is they should be replaced every five years unless the manufacturer stipulates a different, usually shorter, interval

1.4.3 Non-return valves

Non-return valves are useful for preventing gas from one line flowing back into another when the pressures become unbalanced. These are highly recommended for welding applications, where it is strongly recommended that non-return valves be fitted to both the gas lines at the blowpipe inlet to reduce the risk of oxygen flowing into the fuel line and vice versa. Older style devices, known as 'hose check valves' or 'hose protectors' rely on a floating plate to stop the flow, are ineffective at low pressures and should be discarded. Non-return valves complying with BS EN 730, 2002, or equivalent should be used.

1.4.4 Regulator outlet threads

As a precaution against connection of the wrong regulator, the threads on the outlets of flammable gas regulators are left handed, whereas oxygen and inert gas regulators have a right handed thread. While the outlets are left or right hand thread to prevent connecting the wrong regulator, the user must still check the contents, to ensure that the regulator is suited to the purpose, i.e. a low-pressure regulator suited to propane is not compatible with a hydrogen cylinder.

It is potentially very dangerous to make / use an adaptor to connect a left hand thread regulator to a right hand thread cylinder, or vice versa, without very good reason and WRITTEN authorisation from a supplier(s). The reasons for justifying this to be carried out are very very limited and very very exceptional.

1.4.5 Pressure release devices

To guard against the effects of over-pressure, which may lead to the cylinder bursting, some gas cylinders, carbon dioxide is an example, may have a pressure relief device. These come in three main types:

- Relief valves, which re-seal when the pressure falls to normal
- Bursting discs, which release the entire contents of the cylinder
- Fused plugs, which operate on temperature rise releasing the entire contents.

Depending on type, these safety devices may dump the entire contents of the bottle into the laboratory. Pressure relief devices can also be useful to prevent the over-pressurisation of pipework, equipment / rigs etc which could result in explosion and/or gas release.

1.5 Gas monitoring equipment

Single-use analytical tubes may have a limited use for doing 'spot' checks of gas concentrations. These tubes are available for a range of gases, with a range of sensitivities. They can be useful for checking that a gas is beneath its Workplace Exposure Limit (WEL). The disadvantage of these is that they only take a measurement at a single point in time, and the tubes tend to have a short shelf life.

An alternative is a continuous reading gas monitor. These are available for a limited number of gases, e.g. volatile organic chemicals (VOCs), flammables, oxygen (depletion and enrichment), carbon monoxide, carbon dioxide, hydrogen sulphide and other 'common industrial gases'. Some are wall-mounted sensors, sending their readouts to a remote control panel, and others are simple stand-alone 'personal' monitors. As a general rule mains operated monitors, that alarm inside and outside the area, with a battery back-up facility where necessary, are preferred to portable hand held units (dependent on use and risk assessment). They usually alarm where the readings have gone outside a pre-

determined range. These are more expensive than the single-use monitors, but provide continuous cover. They require regular maintenance in accordance with the manufacturer's recommendations (preferably be under a maintenance contract). Monitors should be checked by the users before each use. Training should be given to ensure users know how to use the monitors and what action to take when the monitor goes into an alarm condition. Without this knowledge and training, the monitor may not be an effective control device. Records of maintenance and operation checks should be kept by the Department and the users.

The location of gas monitors should be considered carefully, paying attention to the nature of the work, the location of potential release and the density of the gas (see 2.3.1) and Appendix D

2 Assessment of the Risks

2.1 Scope of the Assessment(s)

Any gas under pressure is considered a 'dangerous substance' under the Dangerous Substances and Explosive Atmospheres Regulations (DSEAR) and must be risk assessed as such.

The risk assessment(s) should take account of the risk of injury or ill health due to the use of the gas, from delivery right through to its disposal. It should include the process in which it is used, taking account of any reasonably foreseeable fault conditions (such as the cylinder falling over, using the wrong regulator, failure of hose connections, reactions getting out of control) and any implications of release. The effect of a gas release in terms of the potential concentration of the gas in a room of known size can be estimated using the calculator on the Safety Office website: (<http://www.safety.admin.cam.ac.uk/>). Consideration of these points, in conjunction with the properties of the gas, should identify what control methods / systems, training and emergency / contingency plans are required.

The more hazardous the gas, the greater is the detail that needs to be included in the risk assessment. For a single cylinder of a commonly used low hazard gases in a reasonable sized room, taking note of the guidelines in this document may be sufficient. However, at the other extreme, with a gas such as silane or borane, a full assessment of the consequences of the malfunction of every part of the system, and the extent to which it can be made to fail to safety will be needed. It may be necessary to consult with an expert in the field.

While the risk assessment(s) should cover the entire life cycle of the cylinder and gas, it will often be more convenient to separate the risk assessment into the elements of the lifecycle. One risk assessment could therefore cover the delivery and storage of all the gas cylinders on the site, and another the storage and return of the empties. However, **the user themselves should always undertake the risk assessment of the actual use of the gas, and the reasonably foreseeable faults that can occur in that phase.**

2.2 Chemical Hazards Presented by Stored Gases

Gases may have chemical properties that need to be taken into account in the risk assessment process. Harm can arise to humans exposed to gases by inhalation or by contact with the eyes and other parts of the skin. Some gases are highly flammable or can form flammable / explosive mixtures in air. Therefore, both the requirements of the Control of Substances Hazardous to Health (COSHH) Regulations and the Dangerous Substances and Explosive Atmospheres (DSEAR) Regulations will need to be met.

Remember ANY gas under pressure is classified as a dangerous substance and therefore requires a DSEAR risk assessment.

The Safety Data Sheet (SDS) for the gas indicates the intrinsic hazards presented by it, which will include hazards to health, statutory exposure limits, reactivity, density compared to air and flammability (including the lower and upper flammability limits).

The main categories of harm are as follows:

Toxic gases are a direct threat to life and health. There may be a Workplace Exposure Limit (WEL), see the SDS and the HSE publication EH40 2005 (as amended). Examples of toxic gases include sulphur dioxide and carbon monoxide. Whilst the former has good 'warning' properties – you 'should' be able to smell it, but the latter has no smell, and consideration of these factors may increase the need to use a monitor. However it is potentially dangerous to place any reliance on an individual's sense of smell.

Corrosive gases may not only harm human beings, but may also damage equipment in the room. An assessment needs to be made of the effect of the gas on electrical insulation, metallic contacts, etc. The products of corrosion may include other gases such as hydrogen. Examples of corrosive gases are fluorine, hydrogen fluoride & sulphur dioxide.

Carcinogenic, Mutagenic, Toxic to Reproduction. A small number of gases have one or more of these properties, and this should be indicated on the MSDS and on the label. An example of a gas toxic to reproduction is carbon monoxide.

Flammable, Highly Flammable. Many gases are flammable, and the MSDS should indicate the limits of flammability. While the gas should not be flammable below its lower limit, or above its upper limit, it is always much safer to ensure that the concentration remains below the lower flammable limit, than to attempt to keep it above the higher flammability limit. The data for flammability ranges is not always accurate, and should be given a wide safety margin. Mixtures of flammable gases in air within the flammability range are potentially explosive. If there are areas where explosive atmospheres are likely to occur during normal operation they may need to be zoned in accordance with BS EN 60079, in order to define the type of electrical equipment that is safe to use in that area.

Note: Hydrogen can spontaneously ignite if it is released suddenly under high pressure as a result of the reverse 'Joule-Thomson' heating effect !

Pyrophoric gases may ignite spontaneously and burn in air or other oxidants. However, ignition is not a certain event and pyrophoric gases may have the potential to form an explosive atmosphere. Examples are silane, diborane and phosphine.

Oxidants will react with flammable gases and other combustible materials in a similar fashion to oxygen. Organic materials such as greases and oils may react explosively with oxidants, depending on the pressure and temperature. Examples of oxidants are oxygen, nitrous oxide and fluorine.

In addition to its own properties, if the gas is to take part in a reaction, the properties of the products must also be taken into account and assessed. It is particularly important to take account of the potential for runaway conditions to arise.

2.3 Physical Properties

2.3.1 Density

In theory, when a gas is released it should sink if its density is greater than that of air, or rise if it is less dense. Decisions on the location of gas monitoring equipment may

therefore depend on the density of the gas relative to air. However the density of a gas below the 'room temperature' will be higher than the same gas at room temperature and vice versa which can effect whether a gas rises or falls in air, again dependent upon what the air temperature is at the time of release.

You cannot guarantee that a gas will stratify according to its density: gases that are released very rapidly are liable to set up turbulent air movements in the room which will help the gas to be mixed thoroughly with the air. Conversely, gas that does stratify could form a toxic, asphyxiant or flammable atmosphere in that stratification irrespective of its potential 'overall' concentration if it were to be mixed homogeneously in the room. Gases can and may disperse through the room with time, 'mixing' with air.

Note: Gases that are released rapidly at elevated pressure may travel 'horizontally' before mixing, rising or falling dependent upon their relative density. This clearly has the potential for acute exposure to occur locally to the release (Appendix D).

Density is usually listed in the manufacturer's Safety Data Sheet (SDS) but if this information is not readily available, an estimate which is sufficiently accurate for the purpose of assessing safety may be made by using the fact that a mole of any gas (i.e. the relative molecular mass of the gas expressed in grams) occupies 24 litres at room temperature and pressure. Since the mean relative molecular mass of air is very approximately 29, the density of any gas may be calculated relative to air by taking the ratio of its relative **molecular** mass to 29. For example, chlorine has a relative **molecular** mass of 71, so using this model it is expected to be approximately 2.4 times as dense as air and would be expected to sink. Comparison with the MSDS reveals that the manufacturer states it has a relative density of 2.49.

The relative densities of most pure gases are available on-line.

2.3.2 Pressure release

The valve can be broken off a cylinder if it is dropped and this can cause the gas cylinder to become 'jet-propelled', since the gas is released very rapidly through the opening. The stem of a regulator is easily broken if a gas cylinder is knocked over, leading to a similar accident. The gas suppliers estimate that a full cylinder can accelerate to 34 mph in around 0.1 s and, coupled with a possible weight of over 70 kg, its destructive power is anticipated to be high. Cylinders can even become air borne and punch through solid walls if the valve is broken off. Therefore always use valve guards when transporting cylinders. The sudden release of pressure from a cylinder can also occur in a fire if the cylinder over heats and ruptures, this can cause large-scale destruction.

If a regulator fails, gas can be released suddenly with possible fatal consequences. Fortunately failures of regulators are rare where they have been manufactured to a proper standard, are within their current inspection period, and have been selected correctly for the application. However recent experience in the University has shown that regulators can fail if used at an inappropriately low flow rate. Under these conditions the diaphragm can audibly 'chatter' as it flexes and struggles to control the outlet pressure. If this audible 'chattering' is ignored the diaphragm may fail and cause the regulator to leak dramatically.

Opening the valve to a cylinder, where a regulator has not been fitted, causes gas to be ejected at the full cylinder pressure, and there is a risk to the hearing. There is a risk of injection of gas into the bloodstream if any part of the body is exposed to the gas stream, which can be fatal. The eyes are particularly vulnerable, even to a deflected gas jet.

2.3.3 Manual handling injuries

Cylinders are heavy and unstable. If a cylinder is dropped it can cause serious leg and foot injuries. The hands can be injured from the man-handling of the cylinders. Attempts to lift cylinders, or to prevent them from dropping out of control can lead to serious back and other bodily injuries.

2.4 Maintaining an Atmosphere that Supports Life

2.4.1 Composition of the air

Air has a composition of approximately 79% nitrogen and 21% oxygen, with traces of other gases such as argon and carbon dioxide. The release of large quantities of any gas other than oxygen can lead to asphyxiation due to the displacement of oxygen. Thus the overall concentration of oxygen in the area must be assessed if a large release of any gas is reasonably foreseeable. The potential for oxygen depletion from a gas release can be calculated on the Safety Office website (<http://www.safety.admin.cam.ac.uk/>). Evidence shows that it is possible to collapse and die without experiencing any warning symptoms. National and international accident reports show that, on average **for every person who has died in a space where the atmosphere did not support life, more than one additional person died in a failed attempt to rescue them.**

No-one should enter an atmosphere where the oxygen concentration is below 18%. To give a margin of safety, oxygen monitors generally have a factory set point of 19.5% for the low oxygen alarm.

NB: Under no circumstances should respirators that only filter the air be used to enter rooms where it is suspected that there is an oxygen deficient atmosphere.

Conversely, increasing the concentration of oxygen leads to an increased fire risk, which can render fire almost impossible to extinguish if the oxygen level were to be maintained. Increased oxygen levels also make things more readily combustible with lower initiation energies and may lead to materials that are not normally combustible becoming so. At very high concentrations spontaneous ignition can occur, depending on the substance exposed.

2.4.2 Sources of asphyxiant gases: resulting in oxygen depletion

Almost all gases are potential asphyxiants, the only exceptions are oxygen, air and non-toxic gas mixtures containing levels of oxygen at or above 21%. The release of the quantity of gas in the average gas bottle of non-toxic, gas may not normally pose an asphyxiant threat in a laboratory of a 'reasonable size. However, this calculation should **always be carried out as part of the risk assessment** in order to confirm, see above.

Example: A 'K' size cylinder contains approximately 10 m³ gas. If this was rapidly discharged into a room of volume 70 m³, then assuming 'perfect mixing,' it could potentially displace sufficient air for the overall oxygen concentration to fall to 18%. The risk of asphyxiation is small in this case. However the working room volume should be reduced if the gas has a density different to air. Less dense gases will clearly fill the room from the ceiling down and more dense gases from the floor upward. Allowance must also be made as to whether the people in the room will be sitting, standing or potentially both.

If your calculations reveal that a risk of asphyxiation does exist, measures will need to be taken to reduce the probability of a leak or mitigate its effects and gas monitoring may be required to ensure that the atmosphere is always safe to breathe. Simple measures to reduce the risk include, using a smaller cylinder with less gas, doing the work in a larger room or providing additional ventilation. Ventilation may be either passive air vents or mechanical ventilation, the latter having the potential to be connected to a gas monitor which would trigger activation if the level of gas reaches a critical concentration.

2.5 Hazardous Area Classification

When using flammable gases (e.g. acetylene, propane, hydrogen) there may be a requirement to classify the area into zones, depending on the potential for an flammable explosive gas atmosphere to be present. The requirement for zones arises from the Dangerous Substances and Explosive Atmosphere Regulations (DSEAR) and is described in BS EN 20079, the standard on hazardous area classification. The resulting zone designations determine the standards to which electrical apparatus in the particular zones must conform (also see HSD073C \ HSD080C).

It is anticipated that some indoor classified areas will exist in the University, since they represent areas where flammable explosive atmospheres are liable to be present. The probability that this could occur should have been designed out where possible by the use of restricted quantities of dangerous substances, high-integrity joints and/or ventilated enclosures. However, any valves or other fittings in the open laboratory are potential sources of release and can give rise to zoned areas.

2.6 Choice of Control Measures

While the gas is safely confined in its cylinder, whatever its properties, it is of only moderate risk, but the risk rises if the gas is released. Some gases will be especially high risk, either because their presence may go undetected or because they have particularly hazardous properties, or both.

Where the risk assessment identifies a gas as having a particular hazard to health – e.g. carcinogen, toxic to reproduction, users should consider substitution by a less hazardous gas where feasible.

If a toxic gas is used, then the first priority is to site the cylinder outside of the building wherever reasonably practicable. Failing that, the use of a ventilated cabinet located inside the building may be considered. If this is not feasible, then monitoring and emergency ventilation is necessary, preferably directly connecting the monitoring to the emergency ventilation system.

The next item in the hierarchy of controls is to ensure that connections and pipes are of high integrity so as to minimise the risk of escape. Waste gas from the process will need to be vented safely to the atmosphere, or in extreme circumstances chemically treated.

It is essential to purchase the correct types of gas regulator and safety devices for the gas. The properties of the gas will often determine the type of regulator that should be purchased – it is advised that the gas supplier is asked to make a recommendation. Where you are using a toxic gas and it is neither outside of the building nor in a ventilated cabinet, nor in a fume hood, then a purgeable regulator must be used, so that you can purge the system with an inert gas.

The properties of the gas may also place some restrictions on the materials that can be used for the pipework – for instance copper; certain copper alloys and silver-containing materials (such as certain solders) must not be used with acetylene.

Finally, where the gas has poor warning properties (i.e. you cannot smell it at all, or you can only smell it if it is above the exposure limit) and it is highly toxic or flammable, a monitor should be fitted to warn of escapes. Examples of such gases are carbon monoxide and hydrogen (hydrogen sulphide is also a special case).

There are only a very few cases where the use of breathing apparatus would be appropriate e.g. when changing a gas cylinder containing a highly toxic or pyrophoric gas.

3 Safe Systems of Work with Compressed Gases

3.1 Purchasing

In deciding what size gas container to purchase, the risk of having the larger quantity of the gas should be balanced against the risk of frequent cylinder changes. It is possible that despite the dangerous properties of a particular gas, the larger quantity of gas, which minimises the number of cylinder changes, is the safer option.

However, in general, the smallest quantity practicable should be purchased. It should be borne in mind that at the end of the experiment the cylinder will need to be disposed of. Gases that are purchased in rented cylinders are easy to dispose of – the partially full or empty cylinder goes back to the supplier. Lecture bottles are purchased outright, and these can cost in the order of £300 EACH to dispose of as hazardous waste. Therefore rented cylinders could be the cheaper option in the long run. In some cases methods of generating the gas 'in situ' may be worth consideration i.e. nitrogen generators.

Refilling gas cylinders is a specialised job and should normally only be done by the supplier; refilling cylinders at the University would be a very exceptional circumstance.

For high delivery rates, or high capacity, a number of cylinders can be purchased on a single manifold. The pipe and connectors are subjected to full cylinder pressure, so it is essential that they are made from materials completely compatible with the gas, and are tested before use. Where they are purchased in this form, the gas supplier will have ensured that this is the case.

Remember: Manifolds that are designed and fabricated by the University are the property of the University, who must arrange for testing and periodic inspection by a competent person, since they are defined as pressure equipment.

3.2 Delivery

The gas supplier should be instructed to deliver the gas to a safe point close to the store area. The driver will usually unload the cylinders from the lorry, and may also transfer them to the Department store. It is essential that cylinders are placed in a safe place as quickly as possible, since free-standing cylinders are extremely unstable and dangerous.

People and traffic should be kept away from the delivery vehicle, to reduce the risk of road traffic accident, or risk of an employee or other from coming into contact with the cylinders. University employees should not go onto the delivery vehicle.

3.3 Storage

The **gas store** is for cylinders that are not in current use, and is distinguished from the **gas supply point**, where gases are attached to gas lines for 'day-to-day' use.

It is desirable to have a special store set aside for gas cylinders, and a dedicated area for the return of empties. The area for the 'empties' can be inside the cylinder store or located elsewhere. Adequate access should be available for both the gas supplier's delivery transport and the user's distribution transport.

Gas bottle stores should be 'out-of-door's and constructed from fire resistant materials. The floor should be clean, even and well-drained. Provision should be made to segregate flammable gases (particularly LPG) from others either by distance, or using fire-resistant walls (see publication GN2 for segregation distances). Ventilation should be provided top and bottom so that it is effective both for gases that are lighter than air, and those that are heavier than air. There should be no sump or pit in which heavy gas can accumulate – LPG can drift and accumulate in drains, causing an explosive hazard. A suitable store is illustrated in Figure 4.

Figure 4: Gas store area



If gases are stored in the open, cylinders should be protected against direct sunlight to avoid excessive heating and rain etc. Roofing should be of lightweight construction, to provide protection against rain. All materials used to construct the shelter must be non-combustible.

Any electrical fitting within the immediate vicinity of a gas store that contains flammable gases such as methane, hydrogen, propane or acetylene should be of flame-proof construction, to avoid ignition of any accidental escape of gas. This will be Zone 1, according to BS EN 60079 part 10. For the same reason, no smoking should be allowed in or near the store. There should be a prominent sign to remind people of this prohibition.

Cylinders must be secured vertically in racks. These should be clearly marked to indicate gas type and whether full or empty, where there is scope for confusion.

Only if absolutely necessary gas cylinders (other than those for acetylene and propane), can be stacked horizontally, but the 'horizontal-stack' should not be more than 4 cylinders deep, with the large cylinders at the bottom, and they must be safely wedged.

Acetylene and propane must always be stored and used in the vertical position.

Other materials must not be left in the cylinder store, especially oils, petrol, paints and corrosive liquids. Necessary housekeeping standards can best be achieved by appointing a responsible person, who can also be trained on the actions that should be taken in the event of an emergency. A permanent notice outside the store should indicate the hazards of the gas cylinders within, and the name and location of the responsible person.

When not in use the cylinders should be protected to prevent damage to the valves. Some cylinder designs have a screw-on cap or 'valve guard', others have a shield permanently secured to the cylinder. To keep dirt out of the connection, caps or shrink fit plastic seals are usually fitted to outlets.

3.4 Moving Compressed Gases to the Point of Use

Gas cylinders must be treated with care and not subjected to mechanical damage or falls. If cylinders have to be handled by means of a crane they should be secured in a special carrier, and on no account should an ordinary chain sling, rope or fabric sling, or a magnetic lifting device be employed.

Where cylinders are moved with a fork-lift truck, they must be secured so as to avoid rolling off the forks. The valves, too, will be exposed to risk of damage if narrow doorways have to be negotiated, and special care should be taken in such circumstances.

It is recommended that cylinders are fitted with valve protection devices such as caps or 'valve guards' before being transported to reduce the risk of damaging the valve. Cylinders lacking such valve protection devices should only be transported with extreme care in multi-wheel trolleys.

Cylinders must not be lifted by the valve or valve protection cap or guard unless it has been specifically designed for that purpose. To do so may result in the cylinder falling to the ground, where the valve may shear off leading to a serious accident.

Figure 5 Three-wheeled trolley



When travelling along corridors, etc, to avoid damage to the cylinder, or injury or strain to the person moving them, a gas cylinder trolley must be used.

Cylinders should NOT be transported even over the shortest distances with the regulator attached, unless they are secure in a very stable multi-wheel cylinder trolley, and in this case only with extreme care, over short distances and the valve MUST be shut. This procedure is 'unusual' and would require a risk assessment specific to this operation.

Multi-wheeled trolleys, three or 4 wheels (see Figure 5), are a much better design than the older style two-wheeled trolleys, and should be purchased/used wherever possible.

Where portable cutting or welding equipment is required the oxygen and fuel gas cylinders are often in a dedicated trolley, which should never be allowed to rest horizontally.

For extremely short distances, cylinders may be moved by hand, but the regulator must be removed first. Cylinders must not be dragged or rolled along the ground. When handling the gas cylinders, protective footwear and industrial gloves should be worn. Loose clothing, especially loose sleeves which can catch on the cylinder valve, should be avoided. 'milk churning' cylinders is permissible, but it requires training and practice, it should not be used for distances greater than a few metres or on uneven ground. Users should never attempt to 'milk-churn' more than one cylinder at a time.

Users should never try to catch a cylinder that is toppling – they should be trained to let it fall. There is guidance for the avoidance of manual handling injuries issued by the British Compressed Gases Association (Guidance Note GN3).

3.5 Choice of the Location of the Point of Use

The point of use of a gas cylinder is the place where a gas cylinder that is currently attached to the apparatus is located.

The choice of this location will depend on the properties of the gas. The more hazardous gases should either be located out of doors and the gas piped in, or they should be kept in purpose-built ventilated fire resistant gas cabinets in compliance with BS14470-2. Any gas cylinder represents a serious hazard in a fire and wherever reasonably practicable they should be located outside of the building, preferably where, if necessary, they can be kept cool by the application of water by the fire service.

There is a flow chart in Appendix B, giving advice on where gas cylinders should be located.

3.6 Connection and Use of Gases

3.6.1 Preliminaries

The cylinder should be properly secured at the correct height, either to an immovable object, see Appendix C. In the case of oxy-acetylene kit, in its dedicated trolley. It should not be too close to any source of heat, such as a furnace.

Toxic gases should either be installed outdoors, with the gas piped into the laboratory, or inside a gas cabinet ventilated to a safe place outside.

If the cylinder has a valve cap/guard this may need to be removed first. A chain wrench or constrictor device should be used. Never insert a screwdriver or other inappropriate device through the holes in cap/guard.

Figure 6: A Valve Cap/Guard



Do not use a screwdriver to undo the valve cap/guard.

Use a strap or chain wrench and never apply any force to the valve

Use a suitable 'in-date' regulator, of the correct type for the gas. Check the labels and the inlet and outlet gauges, to be sure that it is suitable for the pressure of the cylinder. Before the regulator is fitted, the threads and the seats of the cylinder and the regulator should be inspected. If either is damaged, then it may be difficult to obtain a leak-tight seal. If there appears to be dirt or foreign material in the threads, do not use it, but contact the manufacturer for service or replacement.

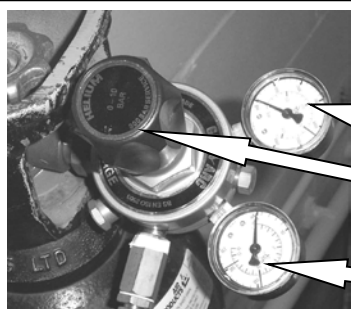


Figure 7: Checking the Regulator

Check the age and rating of the regulator. It is usually written on the body, but could be on the pressure adjusting knob or the high pressure gauge.

Check that the regulator is rated to a higher pressure than the maximum fill pressure of the

If the outlet of the cylinder is contaminated by hydrocarbons such as oil or grease, then the cylinder must be quarantined, marked as hazardous and returned to the supplier. It is not safe to attempt to remove hydrocarbon contamination yourself. In particular, all equipment for service with oxygen or other oxidisers must be scrupulously clean. Any oil or grease in contact with pure oxygen can potentially lead to serious (even fatal) accident.

3.6.2 Connection

The outlet to the cylinder must be undamaged, clean and dry. Attach the regulator and tighten the inlet nut securely with the appropriate gas cylinder spanner. If it does not seal properly when first connected, then it should be dismantled, the threads and seat carefully cleaned and tried again. NEVER use tape or other means to make a seal. If the regulator does not screw in easily, then do not force it - it is probably the wrong type. Never try to connect a regulator that is left hand thread to a right hand threaded cylinder, or vice versa.

For some gases, such as chlorine, the regulator has a gasket. **Each time the regulator is changed a fresh gasket should be used.**

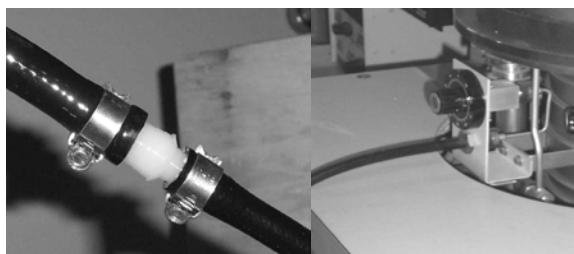
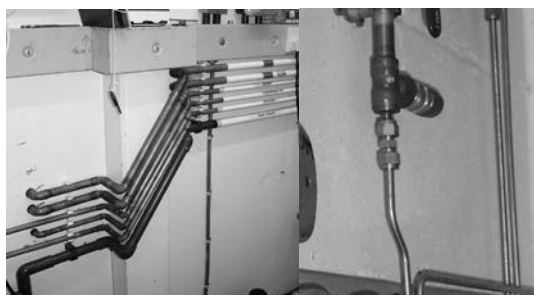
Checks that should be carried out on regulators, before use:

Check that...

- It is suitable for the gas and the inlet and outlet pressure. Reject if not
- It is still 'in-date', usually 5 years from manufacture* Check for expiry date markings on the regulator body (or any documentation). Reject if not 'in-date'.
*Note: Some regulators for toxic or corrosive gases may have shorter 'lives'
- It carries BS or BS EN numbers. Reject if uncertain of its standard.
- The inlet is clean and undamaged – reject if not.
- The gauges are 'original', in good condition, lenses attached and the gauges read zero before use. Reject if not.
- There are no signs of jointing compound or tape sticking to the inlet or outlet threads – reject if present.
- There are no signs of heat or mechanical damage. Reject if present.
- The pressure adjusting screw turns freely – reject if it does not.
- Only use the correct spanner for tightening up the inlet connection – do not use excessive torque or a hammer. Do not use an adjustable spanner.
- The pressure control knob is screwed fully anticlockwise before opening the cylinder valve.
- There are no leaks – only use the correct gas leak detection fluid /agent.

Unions, nuts and connectors should be inspected before use. Faulty seats are liable to lead to leaks and should be discarded. Valves and fittings for all purposes should be kept scrupulously clean, and care should be taken to make certain that no grit or other foreign matter is allowed to remain on them. Attention to this point will save problems arising from leaks. Care should be taken to avoid leaving any swarf when assembling the system. The assembled equipment should be checked for leaks with a leak-detecting fluid / agent.

Figure 8: Pipework integrity



Brazed pipes and couplings are good practice, the former being of higher integrity than the latter

Pressure testing pipework with air or an inert gas may be necessary to check its integrity before using it for a toxic gas.

Tapered connections with jubilee clips, or a simple push fit of the hose over the connector are both very low integrity joins **and are not acceptable** if the resulting gas release can be a threat to life, whether by asphyxiation, poisoning or generating a flammable atmosphere.

Pay attention to the integrity of the pipework. High integrity can be obtained by brazing or soldering pipes. A slightly lower degree of integrity can be obtained by the use of good quality demountable joints, and the lowest degree of integrity is provided by hose pushed onto straight or tapered fittings and (perhaps!) fastened with bits of wire, jubilee clips, etc. The latter will almost certainly fail at some time, probably when it is extremely inconvenient or even dangerous. If the risk assessment has shown the release of gas to be particularly dangerous, great care should be taken in the choice of gas fittings.

3.6.3 Safety devices

Fit flashback arrestors, where risk assessment has identified the need. It is normal and necessary to fit these to the cylinder end of hoses for both oxygen and acetylene (or other fuel gas) for welding. Non-return valves are also required. Users of pyrophoric gases should also identify where non-return valves and flashback arrestors are required.

3.6.4 Sniffing or cracking

It was common practice to 'sniff' or 'crack' cylinders to clean the outlet, but this is neither good practice nor is it recommended. This practice consists of briefly opening the main valve of the cylinder, and quickly closing it again. It is a potentially extremely dangerous practice, since the gas is emerging at very high speeds. On no account should a hand or other part of the body be placed in the gas stream. The gas stream can permanently damage the eyes, and gas injected into the body can lead to fatal conditions. **Eye protection and gloves must be worn**, and care should be taken that there is no source of heat or ignition nearby.

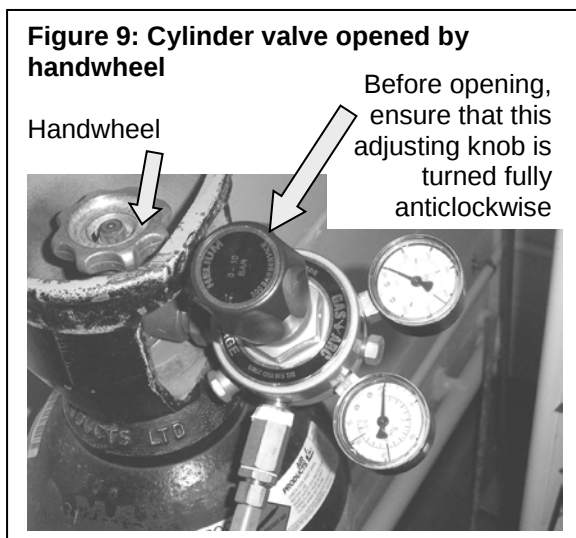
Never sniff hydrogen, since the emerging gas may ignite spontaneously.

Never sniff toxic or pyrophoric gases.

It is therefore recommended that sniffing is not used, but that the outlet is cleaned by wiping and/or by the use of a low pressure compressed air jet.

3.6.5 Opening the cylinder and adjusting the pressure on the regulator

Wear goggles. Wind the pressure adjusting knob or screw fully anti-clockwise. Then place both hands on the cylinder valve and slowly open it (anti-clockwise), using the hand wheel or a spindle key, depending on the type. Allow the pressure to rise gradually in the regulator, and stand so that the cylinder is between you and the regulator.



Make sure that, if the valve is key operated, you have a key for each cylinder.

You should not open a valve by more than about one full turn. Do not leave a valve fully open in case it gets stuck on the back-stop and cannot then be closed. In particular, an acetylene valve should never be opened by more than three turns.

Check the diaphragm for creep, which is diagnosed by looking for gas leaking from the high pressure side to the low pressure side when the adjusting knob is fully anticlockwise. The regulator should be taken out of service if it creeps.

The pressure is adjusted by turning the adjusting knob clockwise to establish the pressure you require, by referring to the reading on the low pressure gauge. Always make sure that the valve is accessible at all times when the cylinder is in use.

Should a valve, regulator, or any other piece of equipment become frozen in use (e.g. due to high flow rates), it should be thawed out by means of hot (but not boiling) water; no other method should be employed to thaw equipment.

Whenever gas delivery is not required, close the main valve. If the gas is not needed for a significant period of time return the cylinder to a safe storage area outside the building.

In the most unusual situation, where the risk assessment has prescribed the use of breathing apparatus (BA) for the connection of the regulator, the operation must be

carried out by two people, both should be fully trained in the use of BA, and both of whom should be wearing the equipment. The equipment should be serviced regularly by a competent person.

3.7 Hazardous Areas

Any hazardous areas should have signs to indicate the prohibitions that exist as a result. For instance, a gas store containing flammable gas maybe Zone 2 or Zone 1, requiring intrinsically safe electrical equipment, including any lighting if required and there must be no smoking in the vicinity. Ensure that no-one brings any electrical apparatus into a Zoned region unless the apparatus meets the specification for the zone.

3.8 Public Displays

Gases are occasionally used during public displays, for instance when filling balloons with helium. Care must be taken to ensure that the helium gas contains 20% oxygen and cylinders are secured so that they cannot fall over, and it is an advantage if they can be placed where children cannot gain access to the regulator.

Those in charge of the display should be trained, should understand the natural curiosity of children and should set an impeccably good example. They should also understand that attempts to inhale gas directly from the outlet of the low pressure side of the regulator can lead to fatal injury since the lungs can only withstand a very small over-pressure.

They must not do this, nor indeed be allowed to inhale any laboratory gas.

3.9 Disconnection After Use

Close the cylinder valve. Vent the gas in the regulator and/or system. Alternatively isolate the system and vent the regulator. The regulator should be vented by turning the adjusting knob fully clockwise so that no pressure is trapped inside the regulator. This is particularly important for two-stage regulators, which can trap high pressure gas inside the first stage. This trapped gas can vent spontaneously at any time. If the gas inside is flammable, pyrophoric, corrosive, toxic or an oxidant, then take suitable measures when venting – if it can be vented via the apparatus this is advantageous.

Close the regulator by turning the adjusting knob fully anticlockwise once more. Disconnect the low pressure side. Disconnect the regulator from the cylinder, and put it somewhere where it will not be damaged or get dirty.

Replace the cylinder outlet seal and valve cap, if it had one.

3.10 Inspection and Maintenance

When inspecting the laboratories check that cylinders are fixed / tethered securely, that regulators are of the correct type and that hoses and connections are in good order.

Flashback arrestors regulators and hoses should be replaced every five years, or as per manufacturers instruction. Pipework should be examined annually. Records of inspection, replacements and repairs should be kept.

(Check the records of regular (monthly) maintenance of any Breathing Apparatus used).

3.11 Training of Users

Gas users need to know how to:

- Identify the contents of the cylinder – the gas and the fill pressure,
- Identify its key properties using the MSDS and other information where relevant.

- Undertake a risk assessment, or how to interpret the requirements of the risk assessment that has already been carried out.
- Handle a gas cylinder and tether it securely
- Choose a suitable regulator and connect it correctly
- Open the gas and adjust the pressure
- Leak test
- Remove the regulator and return the cylinder to stores
- Deal with reasonably foreseeable emergencies.

There is a booklet for users published by Health and Safety Division (HSD121C)

3.12 Disposal of the 'Empties'

Modern cylinders usually have a pressure sensitive cut off valve which closes as the cylinder approaches 'empty' to retain some gas and prevent contamination problems when refilling the cylinder, therefore as they will still contain some gas they are not truly 'empty'. They are however regarded as being 'empty' from a practical perspective.

'Empty' cylinders should be taken to Stores for return to the gas supplier. DO NOT dispose of a cylinder any other way unless it is absolutely certain that it is the property of the University.

Remember, rent is paid for cylinders, so do not keep a cylinder longer than needed, especially if it is a common gas.

Lecture bottles, which are owned by the 'purchaser', will have to be disposed of by the Department / Institution. If they contain hazardous gases they are hazardous waste, and they may cost £300 to 500 each to dispose of. NB: The 'purchaser' will be responsible for this cost, **not** the University's hazardous waste disposal service.

3.13 Transport of Gases in Vehicles

Transportation of any compressed gas cylinder in a vehicle, is governed by the Carriage of Dangerous Goods by Road Regulations. It should be avoided as far as possible. However BOC have very useful guidance on this subject. Private vehicles should not be used and will NOT be insured for this purpose.

3.14 Security

Because oxyacetylene equipment is readily portable, it is attractive to thieves and vandals and adequate security measures should be taken. However, sets should never be locked in unventilated storerooms or cupboards overnight because any gas leak carries an extremely serious risk of fire. Any electrical equipment in the storeroom is unlikely to be suitable for flammable atmospheres and the emergency services will be unable to gain access to the equipment in the event of a fire breaking out elsewhere in the building.

Cylinders should be locked away when sited outside the building, so that the valves and regulators cannot be tampered with by anyone. Remember; members of the public, including children may tamper with cylinders that are accessible.

3.15 Emergencies

3.15.1 Fire

Cylinders involved in fire in buildings can explode, therefore, if fire breaks out where cylinders are present the Fire Brigade should be alerted to the presence of gas cylinders. This may result in evacuating the area up to 300 m or more away from the building.

The contents of cylinders of flammable gases could present a serious fire hazard if they escape. For example, a serious fire was once caused by an employee at a yard in London dragging an LPG cylinder along the ground in the open air – the sparks from the abrasion of the steel against the concrete ignited a cloud of flammable vapour.

If it is possible, **without taking any personal risk**, cylinders not immediately involved in the area of the fire, could be removed to a safe place away from the building.

Gas burning from a leak in a gas hose should not be extinguished unless the gas flow itself can be cut off immediately. In some cases it may be safer to leave a flammable gas burning than to risk building up an explosive mixture, if the gas supply can't be isolated.

Cylinders that have been involved in a fire must be cooled, **this is a job for the Fire Brigade**. They will then need to be removed to a safe place and the supplier notified so that they may be disposed of safely.

Should an acetylene cylinder become heated accidentally, or become hot as a result of excessive or severe backfire from the use of faulty equipment, the gas manufacturers recommend that it be dealt with promptly as follows:

Instructions for dealing with acetylene cylinders that have become hot:

Evacuate the area (to 200m) and call the Fire Brigade. Tell them the type, number and location of your cylinders, otherwise they cannot enter the premises to deal with the situation. An inventory of all gas cylinders in the premises is essential!

The fire Brigade will then cool the cylinder according to their own guidelines. Once they say it is 'safe', the cylinder will need cooling by the Fire Brigade for a further 24 hours. Advise suppliers immediately, quoting cylinder number, where known – it will need to be collected and sent back via a suitable and safe route.

3.15.2 Leaking cylinders

The valve on a cylinder must NEVER be removed or tampered with at any time.

If there is a leak around the valve spindle take the cylinder outdoors, provided it is safe to do so, and contact the gas supplier. Mark the cylinder to show that it is faulty and make arrangements to return it to the manufacturer.

If it is not safe to remove it, consider evacuating the building in the following circumstances:

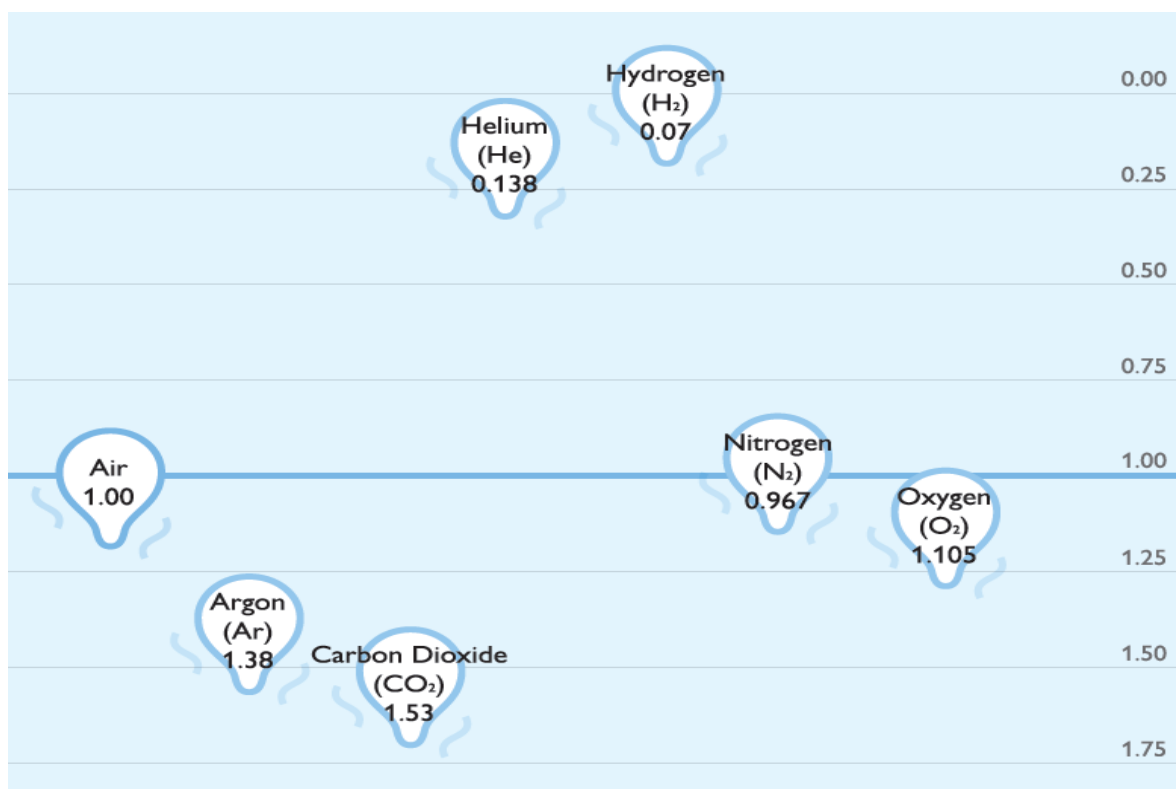
- The gas is toxic and poses a threat to life
- The gas is highly flammable and poses an explosion risk

How the evacuation should be carried out depends on the gas properties. The area that will be affected should be assessed – this maybe one room, or many. If its presence is very obvious by smell, and people are unlikely to enter a dangerous atmosphere then it may be permissible to consider using the fire evacuation procedure. However, it is more likely that an evacuation using a sweep of the building or the surrounding rooms will be needed, to prevent people from entering the gas cloud or an area of danger.

It is strongly recommended that the procedure to be followed when handling a leak should be assessed and formalised as a part of the risk assessment.

Remember that gases have different densities at room temperature and can travel from the source of the leak.

Figure 10. A few simple examples of gas densities relative to air at room temperature.



Note: If the gas temperature itself is above or below room temperature this will affect the density, for example cold nitrogen gas from liquid nitrogen will be denser than air and 'sink' to the floor, however upon warming it will slowly rise. However, carbon dioxide from dry ice will always be denser than room air.

4 References

Note: British Standards can sometimes be obtained from Technical Indices, with whom the University has an account.

Control of Substances Hazardous to Health Regulations, 2002, SI 2677

The Dangerous Substances and Explosive Atmospheres Regulations, 2002, SI 2776

HSD002C: Hazardous Substances Policy, University of Cambridge

HSD121C: Compressed gases – a User's Survival Guide, University of Cambridge.

HSD018C: Disposal of Chemical Waste: Policy and Guidance, University of Cambridge.

HSD009C: The Selection and Use of Respiratory Protective Equipment, University of Cambridge.

BS EN ISO 2503, 1998: Gas welding equipment: pressure regulators for gas cylinders used in welding, cutting and allied processes up to 300 bar.

BS EN 60079 part 10, 2003: Electrical apparatus for explosive gas atmospheres – classification of hazardous areas.

BS EN 60079 part 14, Electrical apparatus for explosive gas atmospheres – electrical installations in hazardous areas (other than mines).

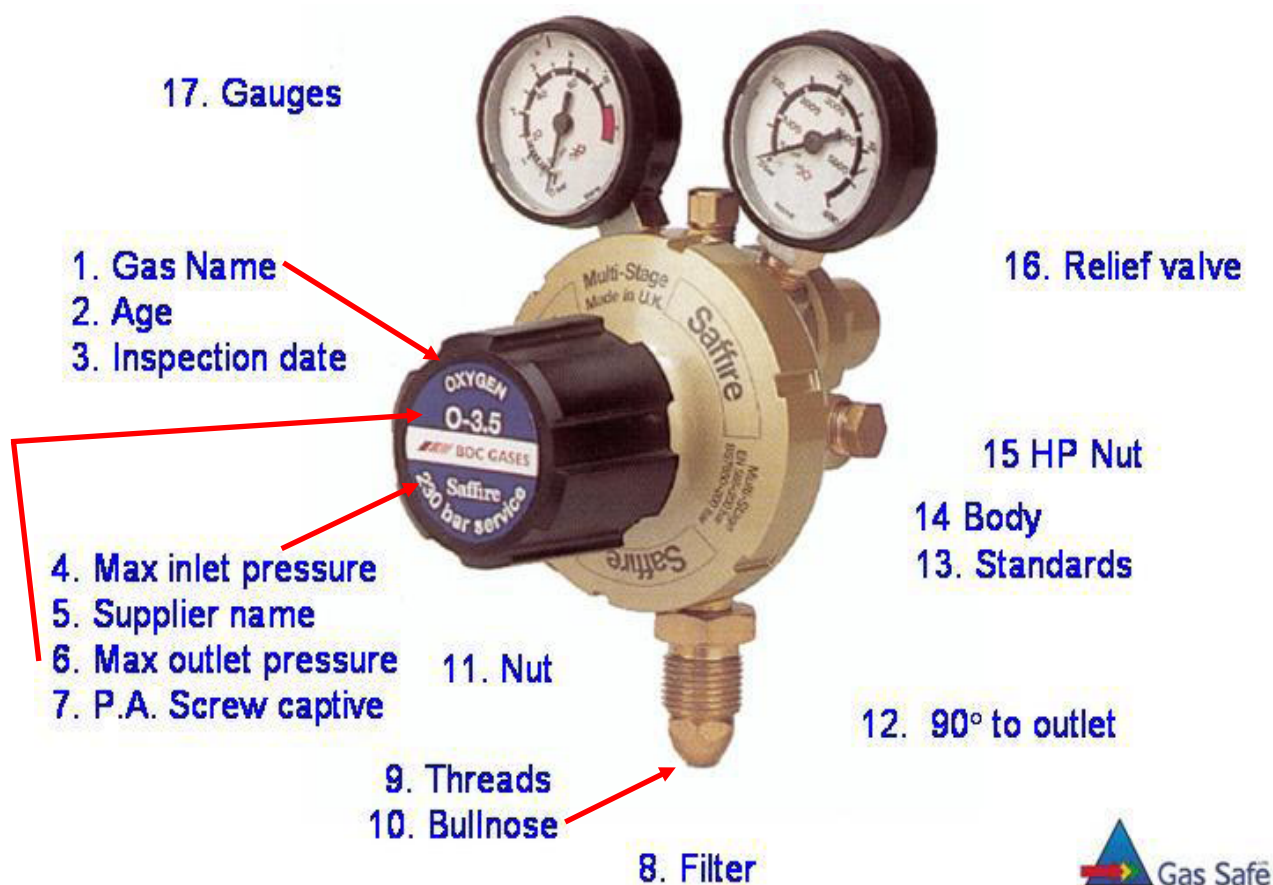
BS EN 730 part 1, 2002: Gas welding equipment, safety devices incorporating a flame (flashback) arrestor.

GN2 Guidance for the storage of transportable gas cylinders for industrial use, published by the British Compressed Gases Association.

GN3 Application of the manual handling operations regulations to gas cylinders, published by the British Compressed Gases Association.

Appendix A: Regulator Nomenclature:

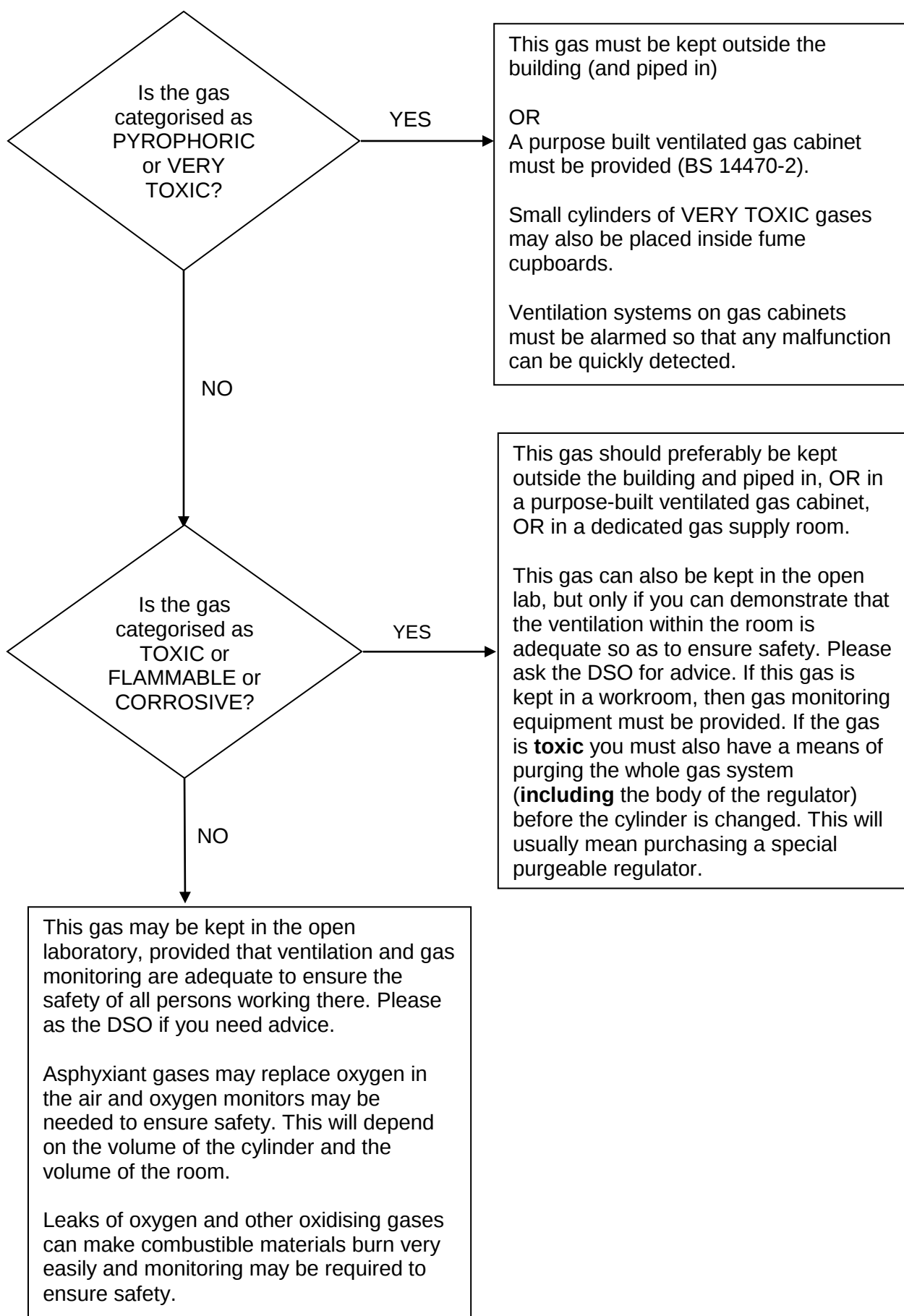
An example of an oxygen regulator with a max inlet pressure of 230 bar (aka bar service) and an outlet pressure range from 0 to 3.5 bar is shown below:



Information commonly found on the case of a regulator:



Appendix B: Flow Chart for Choosing the Gas Supply Point



Appendix C: Securing Gas Cylinders in Storage and in Use

Gas cylinders should always be appropriately secured in storage, transport or use.

Gas cylinders should NEVER be left unsupported and unattended aka 'free standing' for even the shortest of times.

Cylinders should be individually secured and NOT secured in pairs or groups by one strap or chain.

Securing Options Include:

1. Individually, strapping or chaining the cylinder to a secure robust fixture (a secure bench or solid wall) at a height **above 1/2 and below 2/3 of the cylinder height to prevent possible toppling**. For tall cylinders, in 'high traffic' areas a **second fixture** at 1/3 the height of the cylinder should be considered, especially if the traffic includes trolleys.
2. Floor based stands that prevent toppling whilst not creating a significant trip hazard.
3. Bench supports that are properly maintained (fully tightened onto a robust bench).
4. Strapped or chained to an appropriate cylinder trolley during transport.
5. (Other unique devices that adequately secure and support the cylinders and present no other hazard).

Consideration should be given to the robustness of the fixture point and of the securing device itself, in both the short and long term. Light weight plastic fixtures and Velcro straps should only be considered for short term use with small/short cylinders and are unlikely to be suitable for many of the larger/taller cylinders used in laboratories. Fixings should not be mounted on plaster board/cavity walls unless it is directly into a solid timber bearer or brickwork in the wall.

Every time a cylinder is moved/secured a quick visual/physical check should be carried out on the integrity of the securing device.

Unacceptable situations include:

1. Missing or inappropriate restraining strap/chain
2. Loose wall mounting or fixing point
3. Gang strapping (strapping one cylinder to another)
4. Strapping of more than one cylinder with a single strap (pair, cluster or group strapping).
5. Strapping to an unsecured object or fixture such as a loose table, drawer unit or chair!
6. Frayed, broken, torn or damaged, restraining straps
7. Bungee cords, string, binder twine, plastic chain, cable tidy, tape or any other material that is not capable of restraining the cylinder properly.
8. Any other condition which results in the cylinder being at risk of toppling

NEVER try to secure a cylinder to a sub-standard securing device.

Examples of Securing Devices



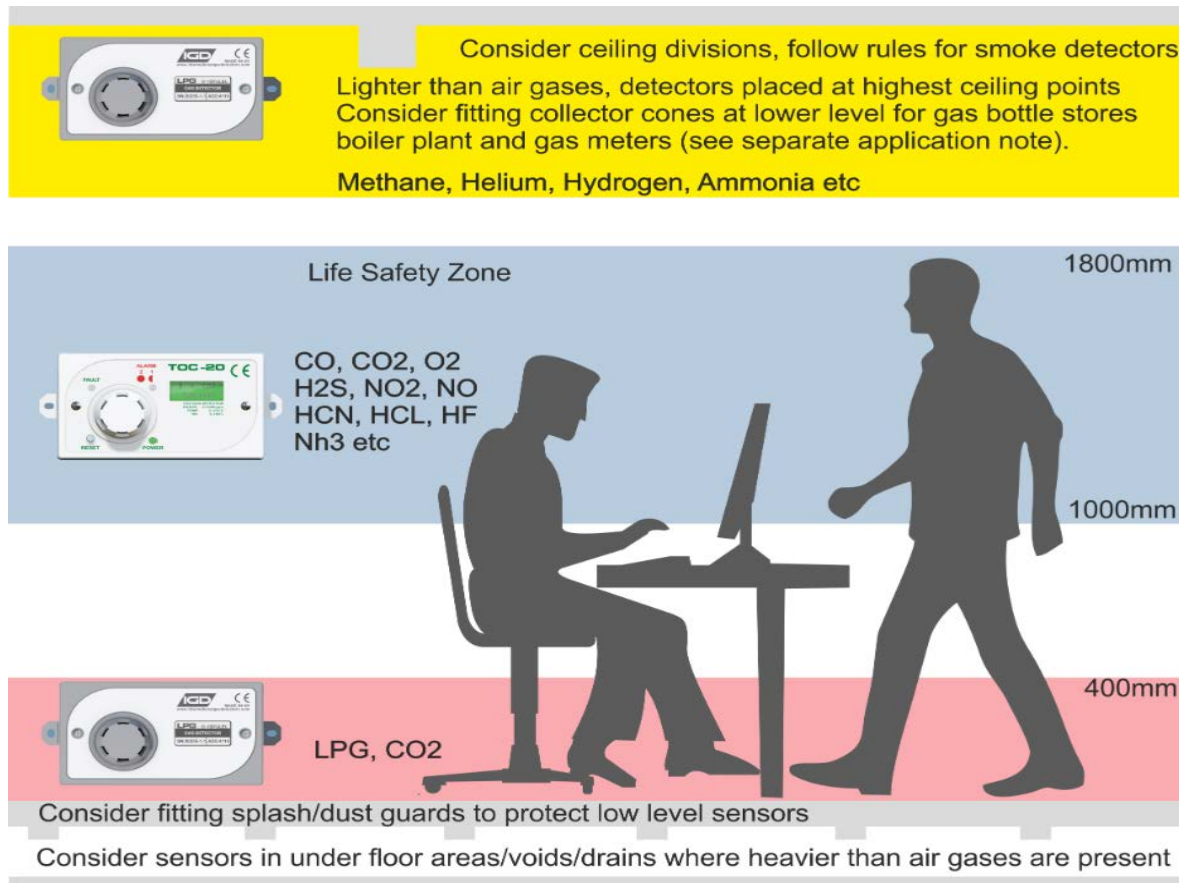
Example of cylinders secured at the 'correct height'



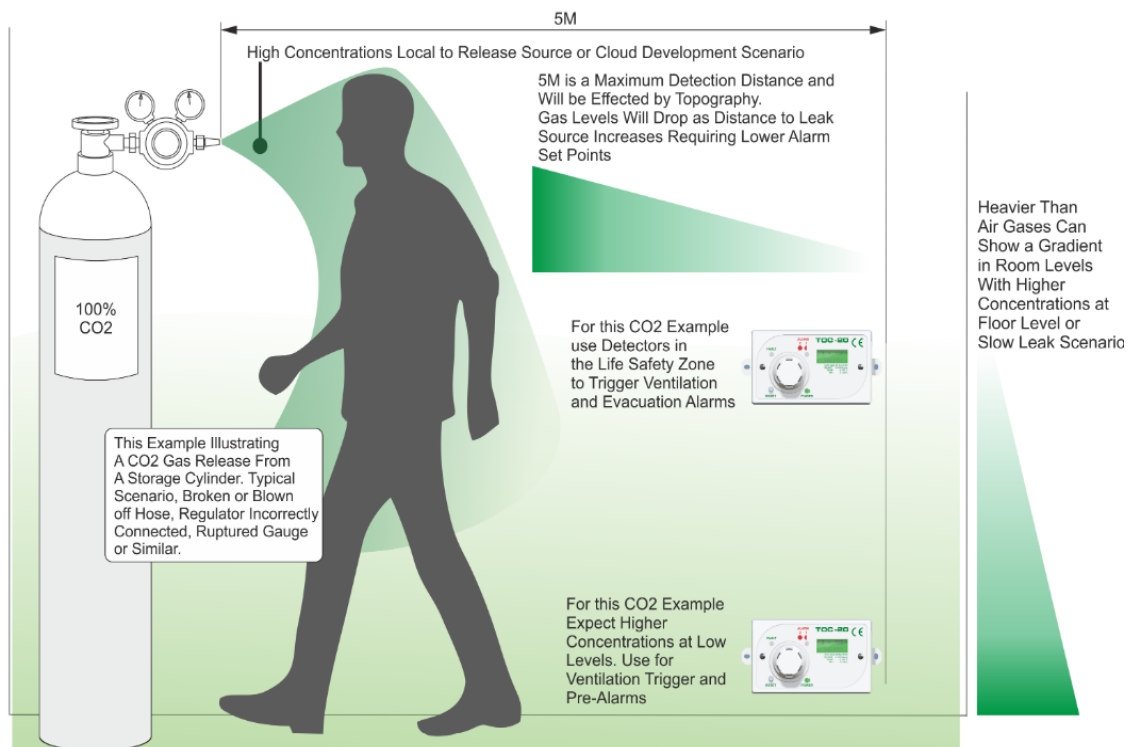
APPENDIX D:

Potential Monitor Locations:

Courtesy of International Gas Detectors Ltd www.internationalgasdetectors.com



Release of a heavier than air gas, such as Carbon Dioxide:



Publication History:

2006: First published

2011: (Rev1) Reviewed and revised

2014: (Rev2) Reviewed and revised

2015: (Rev3) Reviewed and revised

2016: (Rev4) Reviewed and revised

2018: (Rev5) Reviewed and revised, with text changes and several additions; including gas flow reduction orifices, reference to 'house gas' liquid gas supply systems and a gas monitor location guidance in appendix (C).

Reviewed and revised with an extra appendix 2020



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