

DISCIPLINE INFORMATION NOTE			
Other Gases			
DIN No	CD5/057	Issue Date	May 2004
Open Government Status	Fully Open	Review Date	May 2008

To: Process Safety Inspectors HID and FOD.

REVIEW OF DEVELOPMENTS IN THE USE OF OXYGEN BY MARGARET GREGSON

CONTENTS

Introduction, Oxygen Use in the Home, Oxygen Piping – Plastic Tubes, Oxygen Bars, Oxygen Generators, Oxygen Use in Water Treatment Processes, On-site Air Separation Plants, Modified Atmosphere Packaging

INTRODUCTION

1. The aim of this note is to provide a brief summary of recent developments in the use of oxygen. It will also report any identified problems and reference any relevant guidance and advice. Much of the technology is not new but it is being more widely applied because of economic and environmental factors. For example, oxygen is increasingly used in combustion processes, giving greater efficiencies in fuel consumption and a reduction in pollution products such as NO_x.
2. Similarly, oxygen has long been used in hospitals for the treatment of respiratory problems but is now used more and more in the home. In addition, it is being promoted amongst the general public as a means of reducing stress, improving energy and alertness and as a cure for headaches and hangovers. It is also increasingly used in food processing and water treatment.
3. At sites where the demand for oxygen is high, it is frequently supplied and stored as liquid oxygen (LOX). Many hospitals have two LOX tanks and a backup gaseous stock to ensure reliability of supply. High demand and reliability of supply is also an issue at refineries and steelworks. In these cases it can become economical to install air separation plants on-site.
4. The hazards associated with oxygen are well known and documented. However, the introduction of oxygen to a process, to an industry or to a location where it has not been used before can create some additional risk, particularly if there is a lack of understanding and training.

OXYGEN USE IN THE HOME (DOMICILIARY OXYGEN)

Background

1. Medical oxygen is being used increasingly in the home, as a prescribed medicine. It can be supplied in gas cylinders or liquid oxygen containers or from oxygen generators. All pieces of equipment used in the supply of medical oxygen are classed as medical devices. The Medical and Healthcare Products Regulatory Agency (MHRA) is the Competent Authority for medical devices and the Licensing Authority for medicines.
2. HSE has some interest in domiciliary oxygen as work activities can be involved – for example, installation and maintenance of the equipment, attendance by carers and nurses. Also, similar equipment and procedures could be used in care homes, hospitals and industry where HSE has a greater involvement. (Note: There is no mention of oxygen in HSG220 Health and Safety in Care Homes.)
3. The use of oxygen in the home carries a fire risk, mainly because many of the users are heavy smokers. Fires involving smoking and oxygen equipment are not uncommon and can be serious. Most of these fires affect only the patient/smoker but they could spread and involve others.
4. MHRA has adopted, as the basis of its own guidelines, the EIGA (European Industrial Gases Association) document:

IGC doc 89/02. Safe use of medical oxygen systems for supply to patients with respiratory disease.

Issues

5. MHRA has set up a domiciliary oxygen group involving the industrial gas companies, equipment suppliers, fire authorities and HSE. The purpose of this group is to regularly review the use of oxygen in the home, discuss problems and identify solutions. A task group was set up to carry out a formal risk assessment. This has raised a number of concerns including:
 - The actions to be taken if the installer (usually the gas company) considers that the home/user is unable to use the oxygen equipment safely. For example, there may be a previous history of fires - users may be unable to stop smoking;
 - The risks associated with the use of plastic tubing for transporting oxygen from the supply to the patient. This tubing can go from one room to another and can be several metres in length. Flames can backtrack along the tubing spreading the fire. (See section below on plastic tubing.);
 - The use of portable oxygen systems in the home and outside. These are small cylinders carried by the patient and can be taken anywhere - on public transport, into public places and to places of work. The use of portable systems containing liquid oxygen (LOX) is increasing as these can provide 6-8 hours breathing oxygen;

- The handling of LOX in the home. LOX is supplied in transportable minitanks delivered to the home. Respiratory equipment can be connected to the minitank or LOX can be decanted from the minitank into a smaller portable container (described above). Several hundred of these systems are in use in the UK and they are well established in the USA. The gas companies consider that the design of the equipment eliminates the possibility of spillage almost completely. LOX can leak from the relief valve if the tank is deliberately turned on its side or dropped. This would result in an increased risk of fire because of oxygen enrichment but spontaneous ignition is considered improbable. The main risk is cryogenic burns.

References

- European Industrial Gases Association IGC doc 89/02. Safe use of medical oxygen systems for supply to patients with respiratory disease.
- European Industrial Gases Association IGC doc 98/03/E. Safe supply of transportable medical liquid oxygen systems by healthcare service providers.
- Compressed Gas Association CGA P-2.7. Guide for the safe storage, handling, and use of portable liquid oxygen systems in healthcare facilities Edition 2.
- Domiciliary oxygen therapy services, Clinical guidelines and advice for prescribers. Report of a working party of the Royal College of Physicians 1999.

OXYGEN PIPING – PLASTIC TUBES

Background

1. Plastic tubing is used in the home to supply medical oxygen from cylinders, LOX tanks and generators to patients. HSE has received enquiries about using similar arrangements in working environments - for example in a veterinary surgery.

Information

2. The Medical and Healthcare Products Regulatory Agency (MHRA) approve medical equipment for use in homes. The installation of plastic tubing in homes is regarded as a temporary measure (even though it could be in position for months or years.) Currently, there are no standards or specifications for the tubing. Reliance is placed on the supplier to provide tubing which is suitable for the purpose.
3. MHRA is aware of incidents where fire has backtracked along the plastic tubing and there is the possibility that fire could spread in this way. Experiments are being conducted with 'fire breaks' and fire retardant PVC tubing. Fire breaks in this context are inserts in the pipe to stop any fire backtracking along the plastic tube.
4. MHRA has adopted the following guidance document, published by the European Industrial Gases Association (EIGA), as the basis for its own guidelines:

IGC doc 89/02. Safe use of medical oxygen systems for supply to patients with respiratory disease.

This gives the following advice on plastic tubing:

'In order to ensure that the medical oxygen flow rate remains satisfactory and to avoid any water condensing in the tube from restricting the flow of gas, the tube between the medical oxygen equipment and the patient shall be kept to less than 15m long. In addition, care is needed to prevent kinking of the tube to prevent restrictions in the flow. The main purpose of this limit is to maintain pressure and avoid blockage by water condensation.'

5. The British Compressed Gases Association (BCGA) has not produced any guidance on medical gases. The most relevant publication in terms of advice on tubing for oxygen supply is:

BCGA GN5 The safe application of oxygen enriched atmospheres when packaging food.

It makes the following recommendations for pipe bores of 12mm or less:

- reinforced PVC hose may be used subject to a pressure limit of 7 barg, unless oxygen compatibility testing shows it to be suitable for pressures up to 10 bar.

- attention should be paid to the service temperature since hoses can lose considerable strength with rising temperature.
- hoses carrying oxygen enriched gas could rapidly transmit fire through a building and so, their length should be restricted to a maximum of 3m.

Recommendations

6. The following is strongly recommended: for working environments, fixed metal pipework should be used wherever practicable and the use of flexible plastic piping should be minimised.
7. If plastic tubing is being proposed, the advice in BCGA GN5 (summarised in paragraph 5 above) should be considered. A risk assessment should be carried out addressing the following factors:
 - whether the installation is to be permanent or temporary;
 - the gas pressure in the tube;
 - the length of the tube and its diameter;
 - the probability of damage to the tubing – heat, mechanical, deliberate, vehicular, chemical;
 - whether the tube passes close to electrical equipment and other sources of ignition;
 - whether, in the event of fire, the tubing will spread the fire to other parts of the building.

References

- British Compressed Gases Association BCGA GN5. The safe application of oxygen enriched atmospheres when packaging food.
- European Industrial Gases Association IGC doc 89/02. Safe use of medical oxygen systems for supply to patients with respiratory disease.
- European Industrial Gases Association IGC doc 98/03/E. Safe supply of transportable medical liquid oxygen systems by healthcare service providers.

OXYGEN BARS

Background

1. Breathing oxygen is reported to produce a mild 'feel good' effect and it is now being supplied in bars for 'recreational use'. It is alleged to reduce stress, increase energy and alertness, and reduce the effects of hangovers and headaches.
2. The oxygen can be supplied in the following ways:
 - in cans - purchased over the counter or from coin machines. The appearance is like an aerosol, the lid becomes a basic breathing mask;
 - at breathing stations - customers are supplied with disposable nasal tubes, which are connected to the oxygen supply. The oxygen can be bubbled through bottles containing aromatic solutions. The oxygen is supplied from oxygen generators/concentrators or from cylinders. The oxygen from generators is low pressure (<10 bar), the concentration is usually above 90% but could be less;
 - in cylinders – as breathing oxygen. Medical oxygen is only available on prescription but diving or aviation oxygen can be purchased (pressures up to 250 bar).

Oxygenated water, sports drinks and skin sprays are also reported to be available.

3. Oxygen bars are reported to be particularly popular in USA and Japan. This does not appear to be the case in the UK, as yet. Only six examples were found on the Internet. One of these reportedly ran at a loss and is no longer operating. Another was advised by the local fire service to ban smoking but smoking proved more popular and again the oxygen bar closed. However, oxygen bars can be set up relatively easily as temporary attractions. They have been used as special features at trade shows, exhibitions, parties, special events etc.

Hazards

4. The main hazards associated with the comparatively unsupervised use of oxygen in this way are:
 - oxygen enrichment of the user's clothes and hair;
 - oxygen enrichment of the atmosphere of the room. Breathing oxygen en masse could lead to oxygen enrichment, particularly if the venue is poorly ventilated;
 - poor control of ignition sources – smoking is common in the pub/club environment;
 - use of 'aromatic flavourings' and the possibility of contamination of cylinder supplies;

- use of high pressure oxygen by untrained personnel.

Recommendations

5. The following recommendations should be considered:
 - the room where the oxygen bar is operating should be a designated no smoking area;
 - there should be clear instructions and warnings for customers – in particular ‘no smoking’;
 - the room should be adequately ventilated - there should be no possibility that oxygen could accumulate. In many cases, additional ventilation will not be required;
 - low pressure oxygen generators should be used rather than high pressure cylinder supplies;
 - the equipment should be designed and constructed for use with oxygen. Only oxygen compatible materials should be used. This is particularly important if high pressure oxygen is used;
 - all staff involved in operating oxygen equipment should be properly trained. Written procedures should be provided. Again, this is particularly important if high pressure oxygen is used;
 - the fire service should be informed if oxygen is used and stored on the premises.

Conclusions

6. The introduction of oxygen into premises where it has not been used before creates some additional risks but they are risks which have been controlled effectively in other environments. Particular care may be needed to prevent misuse by members of the public.
7. There is no real evidence that oxygen bars are gaining popularity in this country. However, they are available for hire and can be set up (and removed) quickly and easily.
8. The Fire Services and Local Authorities have not expressed undue concern.
9. There is no internal HSE guidance or any external publications.
10. There may be some related safety issues associated with the filling of cans with oxygen and the oxygenation of drinks. However, the food industry routinely uses oxygen without any particular problems. The drinks industry is familiar with compressed gases such as nitrogen and carbon dioxide but will need to take further safety measures to cope with the additional hazards of oxygen.

OXYGEN GENERATORS

Background

1. The technology of oxygen generation can be based on either membrane diffusion or adsorption or chemical reaction.
2. Generators based on membrane or adsorption technologies are often referred to as oxygen concentrators.

Adsorption

3. For oxygen generation by an adsorption process, air is passed through a molecular sieve designed specifically to separate oxygen from nitrogen and other gases in air, by adsorbing the nitrogen molecules, while allowing the oxygen molecules to pass through to a collection vessel. When the sieve bed is saturated with nitrogen, it is regenerated to allow the process to continue. The impure nitrogen combined with any water and carbon dioxide is vented to atmosphere.
4. There are two types of adsorption processes - pressure swing adsorption and vacuum swing adsorption. In pressure swing adsorption (PSA), the air is purified, dried and then compressed to about 10 bar. The vacuum swing adsorption (VSA) process produces oxygen at lower pressure (1.5 barg) and totally regenerates the sieve in a mild vacuum (0.5 barg). A VSA generator does not require an air compressor and uses less energy.

Membrane Diffusion

5. The process of membrane diffusion is based on the varying permeation rates of different gases through membranes. The air is first filtered, then compressed to the required pressure, dried and passed through membranes.

Comments

6. The advantage of oxygen generation by adsorption or diffusion from a safety perspective is that the oxygen is produced and used at low pressure, eliminating many of the hazards associated with high pressure oxygen (typically, cylinder pressures are in the range 100 to 250 bar). The purity of the oxygen produced depends on the design of the equipment but is normally in the range 90-95% which is sufficient for many applications.

Chemical Oxygen Generators

7. Chemical oxygen generators are devices which upon activation release oxygen as a product of chemical reaction. They are often used for emergency breathing systems such as on aircraft and are sometimes called oxygen candles. The chemicals contained in chemical oxygen generators are oxidising salts such as chlorates and perchlorates of lithium, sodium and potassium, which evolve oxygen when heated. These salts are mixed with a fuel, such as iron powder. Reaction is initiated by a percussion device, friction device or electric wire. Once the reaction begins, oxygen is released from the hot salt by thermal decomposition. A portion of

the oxygen reacts with the fuel to produce more heat, which produces more oxygen, and so on. These are single use devices.

Comments

8. The main hazard with chemical oxygen generators is unintentional activation in transport or in storage. This generates a lot of heat that can be sufficient to activate adjacent generators or ignite packaging and similarly combustible material. In 1997 unintentional activation of oxygen candles caused a fire in the hold of an aircraft in the USA, which subsequently crashed. As a consequence it is now a requirement for chemical oxygen to be fitted with two devices to prevent unintentional activation.

References

- Compressed Gas Association P-8.1. Safe Installation and Operation of Pressure Swing Adsorption (PSA) and Membrane Oxygen and Nitrogen Generators 1995.
- BS 7634:1993, ISO 10083:1992. Specification for oxygen concentrators for use with medical gas pipeline systems.
- BS EN ISO 8359:1997, BS 5724-2.23:1997. Medical electrical equipment. Oxygen concentrators for medical use. Safety requirements.
- There are no British or European standards for chemical oxygen generators. Requirements for packaging and transport are given in ADR 2003 and the associated carriage of dangerous goods regulations.

OXYGEN USE IN WATER TREATMENT PROCESSES

Waste water treatment processes

1. Biological treatment of waste water and (domestic) sewage water is used to lower the organic load of soluted organic compounds. There are two main categories of treatment:

- Aerobic treatment
- Anaerobic treatment

Aerobic treatment of waste is the natural biological degradation and purification process in which bacteria that thrive in oxygen-rich environments break down and digest the waste. In aerobic systems the oxygen levels must be maintained. This is commonly done by aeration but the use of oxygen gas offers much higher rates of oxygen transfer and destruction of waste material than conventionally aerated systems.

2. Oxygen treatment is also reported to provide a reduction in odours, surface foaming, aerosols and VOCs, as well as improved sludge settling and dewatering.

Oxygenation of waterways

3. Dissolved Oxygen (DO) shortage can cause catastrophes in natural waters. If the water is chemically or biologically contaminated the oxygen uptake rate can be high and DO can fall to zero levels. At such times, higher aquatic life dies, odours can cause nuisance, and waste water discharges can exceed consent levels.
4. One way of dealing with the oxygen shortfall is to introduce oxygen directly into the waterway. This can be done using jet mixing equipment or bubble diffusers. These can be placed at a waterside location or on a barge. Such systems have been used on the River Thames. Permanent installations can also be built to pump oxygen into still water such as at Salford.

Issues

5. The oxygen supply system depends on the quantity of oxygen required and whether the system is to be fixed or portable. The supply can be gaseous oxygen from cylinders, liquid oxygen from fixed tanks or oxygen generators. Portable systems such as those used on barges are usually oxygen generators.
6. Water treatment processes involve large quantities of oxygen being pumped into the system over long periods of time. One safety issue which should be considered is the possibility of oxygen accumulating in confined spaces such as underground inspection chambers. A fatality occurred at a water treatment works when operators were carrying out maintenance work in a confined space. They checked for oxygen depletion but not oxygen

enrichment. The oxygen enriched clothing of one operator was ignited by sparks from an angle grinder.

References

7. No published information or guidance is available on the use of oxygen specifically for water treatment. General guidance is available such as:
 - HSE 8 (rev 2). Take Care with Oxygen - Fire and explosions hazards in the use of oxygen (leaflet).
 - British Compressed Gases Association Code of Practice CP 19. Bulk Liquid Oxygen Storage at users' premises. Rev 3: 2002.
 - European Industrial Gases Association IGC 04/00. Fire hazards of oxygen and oxygen enriched atmospheres.
 - European Industrial Gases Association IGC33/97. Cleaning Equipment for oxygen service.

ON-SITE AIR SEPARATION PLANTS

Background

1. Using oxygen instead of air in combustion processes (glass furnaces and blast furnaces) results in higher temperatures, increased efficiency and economy in fuel consumption and a reduction in the volume of fumes produced (reducing nitrogen, reduces NO_x).
2. Steelworks consume oxygen on a massive scale. A modern plant can use hundreds of tonnes a day. As well as using oxygen for the combustion process, efficiencies can be boosted by blowing the molten metal with oxygen to remove impurities. Oxygen is also used in a huge range of steel-working operations including cutting billets, welding and forming.
3. Oil refineries use oxygen to boost the capacity of cat-cracking units and sulphur recovery plants, both of which operate at high temperatures and are essential for the conversion of crude oil to gasoline.
4. Another process which uses high levels of oxygen is the Gas-to-Liquid (GTL) process. This is being used increasingly to convert natural gas into petroleum products. The main advantage is that the product is environmentally clean and virtually sulphur free. GTL is also considered a way of enabling gas reserves in remote places to be utilised. Converting this 'stranded' gas into liquid makes its transfer and transport a much more economical proposition. There are currently many GTL projects, worldwide.
5. Large scale gasification processes also require massive quantities of oxygen. Coal gasification is considered environmentally superior to direct combustion, reducing SO_x and NO_x emissions and allowing low cost capture of carbon dioxide. It is regarded as an economical option in countries with large coal reserves such as China. The economics can be further improved if a market for the by-product carbon dioxide can be identified such as for enhanced oil recovery (EOR).
6. Where there is a huge demand for oxygen, such as for the processes identified above, it becomes more economic to built air separation plants at the site. These plants are designed for reliability of supply and often produce a surplus. This can be stored as a buffer or sold. Potentially, this could reduce the price of LOX worldwide and the use of oxygen could escalate.

Air separation plants and refinery sites

7. In the air separation process, compressed air is cooled down to cryogenic temperatures and fed into a distillation column system. The air is distilled to produce liquid oxygen and liquid nitrogen. Returning product streams are used to cool the incoming compressed air feed.
8. The problem with cryogenic air separation plants on refinery sites is that the air can be contaminated with hydrocarbon and other materials. Most of the problem contaminants will boil/condense at temperatures above oxygen and will tend to concentrate in the oxygen product. (Oxygen has a higher boiling point than nitrogen or argon.) The fire at an air separation

plant on a refinery in Malaysia in 1997 was attributed to an accumulation of contaminants in the reboiler.

9. Pre-treatment of the air feed reduces the possibility of organic contaminants getting into the separation plant. Pre-treatment stages include cooling to remove water and carbon dioxide, desiccants, molecular sieves and PSA absorbers. Even so, this does not totally eliminate the lighter hydrocarbons such as methane and ethane which tend to go forward to the separation unit. Therefore, the reboiler must be carefully designed and operated to ensure contaminants do not build up. Monitoring the liquid oxygen product for hydrocarbons can give an indication of problems.
10. EIGA (European Industrial Gases Association) published guidance on the safe operation of reboiler/condensers in air separation units following the incident in Malaysia.

References

- European Industrial Gases Association IGC Doc 65/99/E. Safe Operation of reboiler/condensers in air separation units.
- Compressed Gas Association. Safe Practices guide for air separation plants PG-8 Edition 3 Published 01/01/1989. Reaffirmed 12/12/02.
- Safe design and operation of a cryogenic air separation unit. Process Safety Progress (Vol 20 No 4 Dec 2001).
- Investigation of an air separation unit explosion. Journal of Loss Prevention in the Process Industries 14 (2001) 167-180.
- Fire and explosion in an air separation unit – a chemical detection exercise. Institution of Chemical Engineers Loss Prevention Bulletin 166 2002.

MODIFIED ATMOSPHERE PACKAGING

Introduction

1. As soon as food comes into contact with air, it can suffer from physical, enzymatic, microbiological, and biochemical deterioration. Modified Atmosphere Packaging (MAP) is a process for packaging foodstuffs with a gas or a gas mixture containing protective and reactive properties. Gases are used to replace the air inside the package and so eliminate or reduce any deterioration of the product.
2. 3.5 billion retail packs using MAP were produced in 2002. This is expected to grow by 30% in the next 5 years.
3. The use of oxygen as a MAP gas is expected to increase. Oxygen has long been used for packaging red meat as this maintains the red colour of the meat for longer. Packs containing 80% oxygen or higher are now being produced to reduce food borne pathogens in fresh chicken, other meat products and fish. This reduces the need for artificial preservatives and refrigeration.
4. Trials of high oxygen packaging are also being conducted for other food products such as fruit and vegetables, bread, sandwiches, pizza and part-baked dough.

Issues

5. Modified atmosphere packaging is a well established technology. There have been no reports of incidents involving MAP packing processes or packages in the UK or elsewhere. There is no reason to suppose that the introduction of modified atmosphere packaging into new product areas will cause additional problems.
6. Currently, oxygen, carbon dioxide and argon are the main gases used in MAP. Trials are being conducted using more exotic gas mixes including ethylene oxide, ozone, and carbon monoxide. Again, there is no reason to suppose that this will create new safety concerns for the user or the supplier.

References

- The British Compressed Gases Association (BCGA) published GN5 - The safe use of oxygen enriched atmospheres when packaging food in 1998. This was reviewed in 2002 but has not yet been reissued.
- BCGA is currently drafting GN14, a guide to good practice for the supply of food gases. This is linked to the requirements of the Food Standards Agency rather than safety.
- EIGA is producing a code of practice for food gases.