COVID-19 (nCorona) Virus Outbreak Control and Prevention State Cell

Health & Family Welfare Department

Government of Kerala

PREVENTION OF CHEMICAL ACCIDENTS INVOLVING MEDICAL OXYGEN IN HEALTH CARE SETTINGS

No.25/31/F2/H&FWD 9th May 2021

During the pandemic of COVID-19 there has been reports of chemical accidents in health care settings involving medical oxygen and other flammable substances that had led to the tragic loss of life of patients and health care workers. The major risk factors are medical oxygen enriched atmospheres, use of ethanol-based and organic solvents in oxygen rich atmospheres, leaks in oxygen delivery systems like pipes, hoses, valves, improper handling or storage, improper electrification, improper operation of equipment etc.

"In an oxygen-enriched environment, materials become easier to ignite and fires will burn hotter and more fiercely than in normal air. There is also a potentially heightened risk of using ethanol-based and organic solvents as cleaning agents in oxygen rich atmospheres. Ignition can come from gas velocity, friction, adiabatic heat, and contamination, and can be generated by the oxygen devices themselves (through improper handling or design) but also by the external environment"[1].

The aim of this advisory is to reduce all possible incidents and accidents related to flammable or explosive substances.

The Annexure attached is a detailed Guideline Module. It may be thoroughly read and Bio Medical Engineer with the help of technical agency conduct technical audit with a fixed periodicity to ensure safety of Hospital and ICUs.

The broad steps that need to be undertaken in the health care settings are as follows (list not exhaustive):

1. **Identification of hazards**
    a. Identify the high-risk settings like ICUs, wards with oxygen supply, storage and transport mechanisms of oxygen and other flammable or explosive substances.
    b. Identify faulty systems, inappropriate storage, handling of equipment and inappropriate storage of hazardous substances.
    c. Inspect the electrical system including earthing
    d. Inspect the equipment and other machines for faults and complaints
    e. Sensitization and training for staff on how to respond

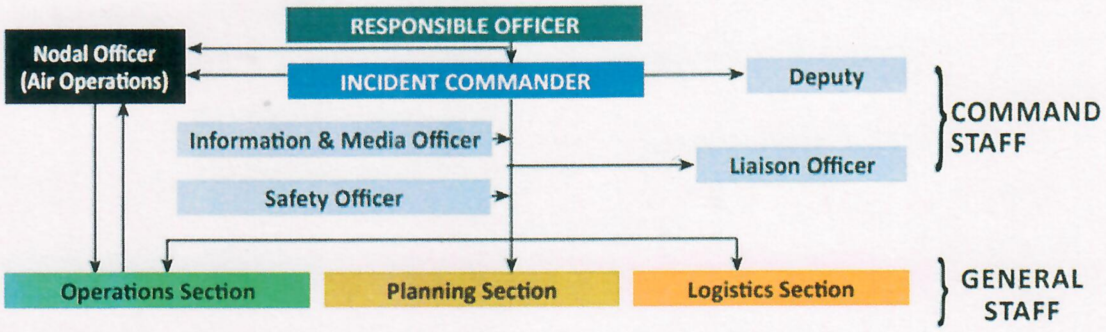
2. **Prepare and implement control measures:**
    a. Incident Response System
    b. Plan of evacuation
    c. Instillation of basic fire safety equipment
    d. Increase air exchange in closed settings like ICUs, by frequent cross ventilation, mechanical ventilation etc.
    e. Use of fire-retardant materials as far as possible (eg curtains)

3. **Investigate incidents**
    a. By the fire and safety committee and identify the gaps in prevention and take adequate measures

The following measures are to be undertaken by all the superintendents/ hospital administrations where COVID-19 patients are being treated (Government and Private).

Administrative measures:

1. Constitute Incident Response System (reporting system and chain of command), the details of which should be shared with the **District Control Room** by **10th May 2021.**



Schema of Incident Response System. National Disaster Management Guidelines[2]

2. Constitution of Institutional Fire and safety committee by **10th May 2021.** (Superintendent, Nursing officer, Engineering wing, Housekeeping department, Security etc, others may be co-opted according to the setting).
3. Develop organizational plan for fire emergencies (evacuation plans, exit pathways, communication protocol etc).
4. Develop Systems for fire prevention & control.
5. Prohibition of smoking in the facility, Indoor heating or cooking near patient care areas
6. Conduct mock drills.
7. Development of Maintenance and Inspection protocols for fire safety installations.
8. Investigation of incidents by the institutional fire and safety committee.
9. Training of staff.
10. Health education for the patients and bystanders.

In case of surgeries planned to be performed inside ICUs, the guidance of the Institutional fire and safety committee should be sought with regard to use of cautery or other spark generating equipment in order to ensure safe conduct of such surgeries.

Engineering measures

1. Installation and maintenance of fire safety equipment.
2. Provision for storage of flammable and explosive materials (chloroform, ethyl alcohol, spirit etc).
3. Periodic Inspection of all electrical equipment.
4. Measures for adequate ventilation and installation of smoke detection alarms.

Principal Secretary

References:

1. https://minerva.jrc.ec.europa.eu/en/shorturl/minerva/llb_2_covidoxygenv2pdf?campaign_id=7&emc=edit_mbae_20210426&instance_id=29730&nl=morning-briefing%3A-asia-edition&regi_id=97668788&segment_id=56362&te=1&user_id=ffd0af58df69999a10bef194e20f5446
2. https://ndma.gov.in/sites/default/files/PDF/Guidelines/incidentresponsesystemjuly.pdf
3. https://www.nabh.co/Images/PDF/Fire_Safety_NABH.pdf
4. https://sdma.kerala.gov.in

ANNEURE

1. Introduction

Medical oxygen is used by patients in healthcare facilities for life support and for medical treatment. It is vital to ensure that the medical oxygen supply system provides a safe and reliable supply of oxygen to healthcare facilities and patients as end user. Past experience indicated that the consequence of system failure could be very serious. It is therefore important that both gas supplier and healthcare facilities management understand the requirements on the design and installation of medical oxygen supply and pipeline distribution system. This is particularly common in Asia where the gas supplier is responsible for the design and installation of medical supply but may or may not be involved in the pipeline distribution system.

2. Definitions

Manifold: A device for connecting the outlet(s) of one or more cylinders or cylinder bundles of the same medical gas

Portable liquid cylinder: A vacuum insulated cryogenic container used for the storage of liquefied gases having a maximum allowable working pressure of greater than 0.5 bar and the capacity normally not exceeding 500 litres.

Primary source of supply: That portion of the supply system which supplies the pipeline distribution system

Reserve source of supply: That portion of the supply system which supplies the complete, or a portion(s), of the pipeline distribution system in the event of failure or exhaustion of both the primary and secondary sources of supply

Secondary source of supply: That portion of the supply system which supplies the pipeline distribution system in the event of exhaustion or failure of the primary supply

3. Sources of supply

The Medical supply system shall comprise of:

- Primary supply
- Secondary supply
- In some cases, Reserve supply can be installed as per the national

Each supply system can be a combination of the following:

a) gas in cylinders or cylinder bundles;

b) cylinders connected to a manifold;

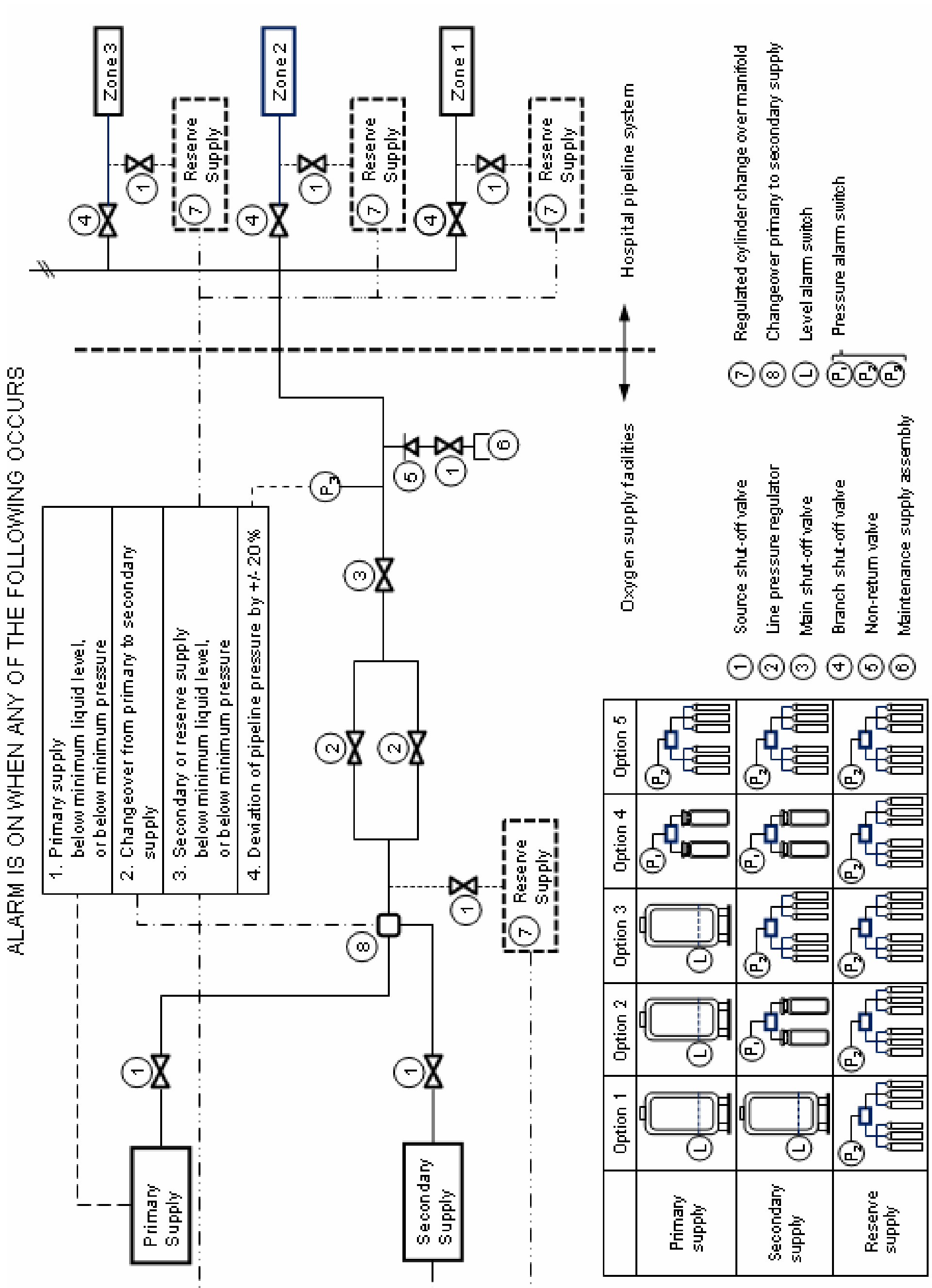
c) portable liquid cylinder;

d) cryogenic liquid in stationary vessels;

Remarks:

- Only cylinders dedicated to medical grade oxygen are to be used.
- The connection of portable liquid cylinder should follow the requirements of AIGA 019 ‘Connections for portable liquid cylinders’, and AIGA 016 ‘Safety Features of Portable Cryogenic Liquid Containers for Industrial and Medical Gases’.
- The connection of cryogenic liquid in stationary vessel should follow the requirements of AIGA 024/ ‘Connections for Transportable and Static Bulk Storage Tanks’.
- Pressure relief valve must be installed in liquid oxygen supply system where liquid can be trapped between two closed valves. Refer to Training Package AIGA TP 05 ‘Prevention of over- pressurization’.

Figure 1 (see page 3) show how the above can be combined as acceptable sources of supply. It also shows the different sources of supply and key system components including alarms. This schematic is not a design drawing. A competent person should design the supply system after selecting a suitable source of supply.



Primary supply

The primary source of supply shall be permanently connected and shall be the main source of supply to the medical oxygen supply system.

As a minimum, the primary supply should have usable quantity of product to meet expected usage between scheduled product deliveries.

Secondary supply

The secondary source of supply shall be permanently connected, automatically supply the pipeline, and capable of providing the total oxygen flow requirement in the event of a primary supply failure.

As a minimum, the secondary supply should have usable quantity of product to meet expected usage between a request for product delivery and the delivery of the product.

Reserve supply

The reserve supply is the final source of supply to specific sections of the pipeline, capable of meeting the required demand in the event of failure of the primary and secondary supplies, or failure of the upstream distribution pipe work.

As a minimum, the reserve supply should have usable quantity of product to meet critical patient care between a request for product delivery and the delivery of the product.

Under most conditions, compressed gas cylinders are the most appropriate method of providing a secondary and/or reserve source of supply. The reserve supply system should include the need for installation of independent reserve supplies to zones on the medical gas pipeline supplying critical care areas or wards or departments that are remote or vulnerable to interruption. The positioning of these manifolds is very important to ensure that the critical supply and high-dependency areas defined in the risk management process have adequate stocks of medical oxygen available in the event of a medical oxygen supply system failure.

Storage requirements

- The selection of location should comply with national regulations.
- Avoid installing liquid storage vessel in indoor environment or near drains or pits.
- The control equipment should be protected from the weather and the area fenced.
- Oxygen cylinder storage should be separated from vacuum and medical air compressor plant to avoid possible oil contamination.
- Appropriate undercover storage facilities for cylinders should be provided to ensure that the cylinders are maintained in a safe, secure and clean

condition.

Capacity requirements

The capacity of any supply system shall be based on the estimated usage and frequency of delivery. The location and the capacity of the primary, secondary and reserve sources of supply, of all supply systems and the number of full cylinders held in storage, as defined by the management of the health care facility in consultation with the gas supplier, using risk management principles, shall be taken into account by the system manufacturer.

Refer to ISO 7396 -1 for the recommended risk management procedure and typical risk assessment checklist used to identify the associated risks with the medical oxygen supply system

Alarm requirements

The following alarm signals should be fitted:

- Liquid level in any cryogenic vessel below the minimum specified by the management of the healthcare facility in consultation with the gas supplier
- Changeover from primary to secondary supplies
- Secondary or reserve supply below minimum pressure
- Deviation of pipeline pressure by more than ± 20 % from the nominal distribution pressure

- Both visual and audible alarm are required .
- If an audible alarm can be silenced by the operator, the silencing shall not prevent the audible alarm from being activated by a new alarm condition.
- Alarm system shall be tested periodically as recommended by equipment manufacturer.
- Master alarm shall be located in an area where 24 hours attendance is provided

4. System components

Pressure reducing station

- The healthcare facility supply pipeline pressure reducing station which reduces supply pressure to the healthcare facility pipeline pressure must consist of a dual parallel regulator system.
- Both regulators must be online and ALL isolation valves and regulators must be in the open position.
- The design based on a single pressure regulator with a by-pass is not accepted.
- The nominal distribution pressure should be within the range of 400 kPa to 500 kPa.

Pressure relief valve

Medical oxygen pipeline system should be provided with a pressure relief device downstream of the line pressure regulator connected by means of a three-way valve so that the safety device can be exchanged for a certified replacement in accordance with the frequency required by the Regulations.

The Manifold has been configured for 2 x 12 nos. of Oxygen Cylinders and is suitable to withstand a pressure of 145 Kg/cm2, along with high-pressure copper annealed tail pipes with end Brass adapter suitable for Oxygen Cylinders and manifold.

Top frame comprising of high pressure copper pipes of size 1/2" NB x 15swg with high pressure brass fittings made of high tensile brass and connections through non-return valves; high pressure copper tail pipes, made of high pressure copper pipe of size 1/4" NB x 15 swg. The design of middle and bottom frames has been provided to fit both round and flat bottom cylinders safely. The manifold has been tested (hydraulically) at 3500 psig and necessary test certificates accompany along with the supply.

Automatic Oxygen Control Panel with changeover Alarm

The Oxygen Control Panel shall be of microprocessor based and preferably Digital Display Type. Pressure reduction shall be in two stages. Panel shall be integrated with pressure gauges inside panel on downstream of pressure regulator. Panel shall be fitted with standby line regulator. Line regulators shall have pressure relief mechanism for testing and servicing purpose.

Panel shall be Fully Automatic and shall switch over from "Bank in Use" to 'Reserve

Bank' without fluctuation in delivery line pressure and without the need of external electrical power. After the switch–over, the "Reserve Bank" shall become the "Bank in Use" and the "Bank in Use" shall become the "Reserve Bank". The Control Panel will be powered by a microprocessor. The unit shall be compact and enclosed in NEMA 3 enclosure.

A Microprocessor circuit board assembly shall provide a relay output to give indication when or just before the manifold switches from one bank of cylinders to another. The switch over shall be mechanically controlled, not electrically.

MEDICAL GAS MANIFOLD SYSTEM

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To avoid excess pressure being supplied to the distribution system, a pneumatically relief valve for the line regulator shall be incorporated. An intermediate pressure

relief valve shall be installed between the high-pressure regulators and the line delivery regulators.

The control panel incorporates six coloured LED's, three for the Left Bank and three for the Right Bank: Green for Bank in use, Amber for Bank ready and Red for Bank empty. Both the Left and Right bank pressures and the main line pressure should be displayed on the front door of the cabinet by means of LED's. All pressure transducers, micro switches, and display LED's shall be pre-wired to an internal microprocessor circuit board.

All components inside the Control Panel like Pressure Regulators, piping and control switching equipment shall be cleaned for Oxygen Service and installed inside the cabinet to minimize tampering with the regulators or switch settings.

The Control Panel should be made to provide Heavy Duty with a Flow Capacity of over 1500 lpm at 60 psig.

Emergency Oxygen system has been configured with 4-cylinder oxygen manifold along with a High Pressure Regulator which will be mounted on the Emergency Manifold System for reducing the cylinder pressure suitable to the line pressure.

Note- To reduce the risk of medical oxygen system from contamination due to ignition of fluorinated polymer materials, only Non Halogenated Polymer materials has been used in the Non Return Valves and high pressure side of the pressure regulator of the manifold system.

GAS OUTLET POINTS

Double Lock Outlet

Outlets have been manufactured with a 165 mm length, Copper inlet pipe stub which is silver brazed to the outlet body. Body has been of one piece brass construction. For positive pressure gas services, the outlet has been equipped with a primary and secondary check valve and the secondary check valve has been rated at minimum 200 psi in the event the primary check valve is removed for maintenance.

The outlet assembly has separate colour coding for each service and accepts only corresponding gas specific adapters.

All outlets has been cleaned and de-greased for medical gas service, factory assembled and tested.

The medical gas outlets have been of quick connecting and wall mounted modular type.

6.0 COPPER PIPE

Solid drawn, seamless, de-oxidized, non-arsenical, half-hard, tempered and de-greased copper pipe conforming to BS : 6017, 1981, Table 2 (Cu - DHP) and manufactured as per BS : 2871, 1971 Part I, Table X (or as per BSEN 1057). All medical graded copper pipes are de-greased & delivered capped at both ends. The pipes are accompanied with manufacturers test

certificate for the physical properties & chemical composition. Copper pipe also has third party inspection certificate from Lloyds' Register Services.

The Pipe Sizes used are from among as under :

Pipe OD (in mm)	**Thickness (in mm)**
12	0.7
15	0.9
22	0.9
28	0.9
42	1.2
54	1.2
76.1	2

Copper fittings has been made of copper and suitable for a steam working Pressure of 17 bar and especially made for brazed socket type connections. All copper fittings are conform to BS 864/EN 1254.

INSTALLATION & TESTING

Installation of piping is carried out with utmost cleanliness. Only pipes, fittings and valves which has been degreased and brought in polythene sealed bags has been used at site. Pipe fixing clamps has been of non ferrous or non- deteriorating plastic suitable for the diameter of the pipe.

All pipe joints have been made using fluxless brazing method. All joints of copper to copper and are brazed by silver brazing filler material without flux.

Adequate supports have been provided while laying pipelines to ensure that the pipes do not sag. The spacing of supports not exceed 1.5 meter for any size of pipe. Suitable sleeves has been provided wherever pipes cross through walls / slabs. All pipe clamps has been non-reactive to copper.

After erection, the pipes has been flushed with dry nitrogen gas and then pressure tested with dry nitrogen / Medical Air at a pressure equal to twice the working pressure for a period of not less than 24 hours. All leaks and joints revealed during testing has been rectified and re-tested till the pressure in pipes stands for at least 24 hours.

All the piping system has been tested in the presence of the engineer or his authorized representative.

PAINTING

All exposed pipes is has been painted with two coats of synthetic enamel paint and colour codification is has been as per IS : 2379 of 1963.

7.0 ISOLATION VALVES

The isolation valves are Non Lubricated Ball type, suitable for oxygen service. All valves has been pneumatically tested for twice the working pressure and factory de-greased for medical gas service before supply.

Valve Box Assembly :

Valve Box are made of Powder Coated M.S. Material.

Valve Box Assembly consist of the following :

- Lever operated quarter turn valve (i.e. 90 degree shut off ball valve- has been manufactured by ISO 9001 company and factory degreased) with brass body and chrome plated brass ball.

- Brass fittings (Nut, Nipples and extruded brass Adapter) KE Type Seat Brass Block for pressure gauge
- 2" Dial gauges (0 - 10 kg/cm2, 0 - 760mm Hg)
- Nylon Bush for copper pipes holding with the valve box
- Beeding for box lead
- Lockable cover with breakable glass so that during normal operation access has been by key. But during emergency operation, access by breaking the glass panel.

ALARM SYSTEM

The Master Alarm

Area line pressure alarms

should be as per required locations.

The main alarm and area line pressure alarm (Digital) are micro-processor based which monitor the pressures of medical gases like oxygen, nitrous oxide, compressed air and vacuum levels at a specific area of piped gas system in any hospital. The electronic circuitry has been such that if the pressure / vacuum in the gas pipeline drops below the present limit, the equipment is give an audio- visual alarm. Visual alarm remains active even after pressing of “Mute” button. But it comes to normal condition when gas pressure / vacuum return to normal level.

The equipment has following features:

- Four Channel Microprocessor Controlled Alarm for Pneumatic & Vacuum Services has the following features:
- Digital Display of Line Pressure for all the services with factory calibrated pressure sensors.
- Color coded LED Display of Line pressure status (High – Caution – Normal – Caution– Low)
- Audible Alarm for High & Low pressure condition.
- Test and Alarm Acknowledge (Mute) facility. (Alarm acknowledge(Mute) time span is programmable from 1 to 60 min).
- Programming facility of alarm limits from front panel (Password protected, preferably to has been done through supplier's engineer).
- Facility to connect to remote alarm box by potential free contacts provided in the alarm box.
- Small and compact design. Light Weight (3 kg)
- Imported highly sensitive gas pressure sensors & CE marked power supply.
- Mounted on a powder coated MS box.
- Nut & Nipples are provided for connection with Pneumatic supply line.
- Low voltage internal operation with input power supply of 220V AC.
- Wall mounting facility.
- Low voltage operation for safety
- High / Low indication
- Test facility
- Mute / silence facility

LIQUID OXYGEN

Oxygen is the second largest component of the atmosphere, comprising 20.8% by volume. Liquid oxygen is pale blue and extremely cold. Although nonflammable, oxygen is a strong oxidizer. Oxygen is necessary to support life.

Oxygen will react with nearly all organic materials and metals, usually forming an oxide. Materials that burn in air will burn more vigorously in oxygen. Equipment used in oxygen service must meet stringent cleaning requirements, and systems must be constructed of materials that have high ignition temperatures and that are nonreactive with oxygen under the service conditions. Vessels should be manufactured to American Society of Mechanical Engineers (ASME) codes and designed to withstand the process temperatures and pressures.

Liquid oxygen is a cryogenic liquid. Cryogenic liquids are liquefied gases that have a normal boiling point below –130°F (–90°C). Liquid oxygen has a boiling point of –297°F (–183°C).

Because the temperature difference between the product and the surrounding environment is substantial—even in the winter—keeping liquid oxygen insulated from the surrounding heat is essential. The product also requires special equipment for handling and storage.

Oxygen is often stored as a liquid, although it is used primarily as a gas. Liquid storage is less bulky and less costly than the equivalent capacity of high-pressure gaseous storage. A typical storage system consists of a cryogenic storage tank, one or more vaporizers and a pressure control system. The cryogenic tank is constructed, in principle, like a vacuum bottle. There is an inner vessel surrounded by an outer vessel. Between the vessels is an annular space that contains an insulating medium from which all the air has been removed. This space keeps heat away from the liquid oxygen held in the inner vessel. Vaporizers convert the liquid oxygen into a gaseous state. A pressure control manifold then controls the gas pressure that is fed to the process or application.

Vessels used in liquid oxygen service should be designed for the pressure and temperatures involved. Piping design should follow similar design and conform to national standards and codes.

Oxygen is produced by an air separation unit (ASU) through liquefaction of atmospheric air and separation of the oxygen by continuous cryogenic distil- lation. The oxygen is then removed and stored as a cryogenic liquid. Oxygen can also be produced noncryogenically using selective adsorption processes to produce gaseous product.

The ASU manufacturing process begins with a main air compressor and ends at the output of the product storage tanks. Air is compressed and sent through a cleanup system where moisture, carbon dioxide, and hydrocarbons are removed. The air then passes through heat exchangers where it is cooled to cryogenic temperature. Next, the air enters a high pressure distillation column where it is physically separated into a vaporous form of nitrogen at the top of the column and a liquid form of “crude” oxygen (~90% O2) at the bottom.

This crude oxygen liquid is with- drawn from the column and sent to a low-pressure column, where it is distilled until it meets commercial specifications. The liquid oxygen is sent to a cryogenic storage tank.

Uses

Oxygen is generally liquefied so that it can be more effectively transported and stored in large volumes. However, most applications use oxygen after it is vaporized to the gaseous form. The primary uses of oxygen relate to its strong oxidizing and life-sustaining properties. Oxygen is commonly relied upon in health and medical applica tions. Liquid oxygen is used as an oxi- dant for liquid fuels in the propellant systems of missiles and rockets.

Oxygen is widely applied in the metal industries in conjunction with acety- lene and other fuel gases for metal cutting, welding, scarfing, hardening, cleaning and melting. Steel and iron manufacturers also extensively use oxygen or oxygen-enriched air to affect chemical refining and heating associated with carbon removal and other oxidation reactions. Benefits such as fuel and energy savings plus lower total emission volumes are often achieved when air is enriched or replaced with higher-purity oxygen.

In the chemical and petroleum industries, oxygen is used as a feed component to react with hydrocarbon building blocks to produce chemicals such as alcohols and aldehydes. In many processes, the oxygen for reac- tion can be obtained from the use of air. However, direct use of oxygen, or enrichment of the air with oxygen, is necessary for some processes. There are several major petrochemical inter- mediates that are presently manufac- tured with high-purity oxygen, includ- ing ethylene and propylene oxide (antifreeze), vinyl chloride (for PVC), and caprolactam (for nylon).

The pulp and paper industry uses oxygen as a bleaching and oxidizing agent. A variety of process (liquor) streams show enhanced physical properties after treatment with oxygen; plant operating costs also improve.

Similarly, oxygen enhances the combustion process in industries that manufacture glass, aluminum, copper, gold, lead, and cement, or that are involved in waste incineration or remediation. There are corresponding productivity, energy, maintenance, and emissions benefits end users may realize.

Wastewater treatment plants suc- cessfully employ oxygen to enhance their chemical process efficiency.

Aquaculturists such as fish farmers also see benefits in the health or size of their livestock when the host envi- ronment is oxygenated.

Table 1: Liquid Oxygen Physical and Chemical Properties

Molecular Formula	O_2
Molecular Weight	31.999
Boiling Point @ 1 atm	–297.4°F (–183.0°C)
Freezing Point @ 1 atm	–361.9°F (–218.8°C)
Critical Temperature	–181.8°F (–118.4°C)
Critical Pressure	729.1 psia (49.6 atm)
Density, Liquid @ BP, 1 atm	71.23 lb/scf (1141 kg/m³)
Density, Gas @ 68°F (20°C), 1 atm	0.0831 lb/scf (1.33 kg/m³) Specific Gravity, Gas (air=1) @ 68°F
(20°C), 1 atm	1.11
Specific Gravity, Liquid (water=1) @ 68°F (20°C), 1 atm	1.14
Specific Volume @ 68°F (20°C), 1 atm	12.08 scf/lb (0.754 m³/Kg)
Latent Heat of Vaporization at BP	91.7 Btu/lb (213 Kj/Kg) Expansion Ratio, Liquid to Gas, BP to 68°F
(20°C)	1 to 860
Solubility in Water @ 77°F (25°C), 1 atm	3.16% by volume

Health effects

Normally, air contains 21% oxygen, and oxygen is essentially nontoxic. No health effects have been observed in people exposed to concentrations up to 50% at 1 atmosphere for 24 hours or longer.

The inhalation at 1 atmosphere of 80% oxygen for more than 12 hours can cause irritation of the respiratory tract, progressive decrease in vital capacity, coughing, nasal stuffiness, sore throat, and chest pain, followed by tracheobronchitis and later by pul- monary congestion and/or edema.

Inhalation of pure oxygen at atmo- spheric pressure or less can cause pulmonary irritation and edema after 24 hours.

Respiratory symptoms can occur in two to six hours at pressures above 1 atmosphere. One of the earliest

responses of the lung is accumulation of water in its interstitial spaces and within the pulmonary cells. This can cause reduced lung function, which is the earliest measurable sign of toxic- ity. Other symptoms include fever and sinus and eye irritation.

When pure oxygen is inhaled at pressures greater than 2 or 3 atmo- spheres, a characteristic neurological syndrome can be observed. Signs and symptoms include nausea, dizziness, vomiting, tiredness, light-headedness, mood changes, euphoria, confusion, incoordination, muscular twitching, burning/tingling sensations (par- ticularly of the fingers and toes), and loss of consciousness. Characteristic epileptic-like convulsions, which may be preceded by visual disturbances such as loss of peripheral vision, also occur. Continued exposure can cause severe convulsions that can lead to death. The effects are reversible after reduction of oxygen pressure.

Premature infants placed in incuba- tors to breathe oxygen in concentra- tions greater than in air can develop irreversible eye damage. Within six hours after an infant is placed in a high-oxygen atmosphere, vasocon- striction of the immature vessels of the retina occurs, which is reversible if the child is immediately returned to air, but irreversible if oxygen-rich therapy is continued. Fully developed blood vessels are not sensitive to oxygen toxicity.

Extensive tissue damage or cryogenic burns can result from exposure to liquid oxygen or cold oxygen vapors.

Containers

Liquid oxygen is stored, shipped, and handled in several types of containers, depending upon the quantity required by the user. The types of containersin use include the dewar, cryogenic liquid cylinder, and cryogenic storage tank. Storage quantities vary from a few liters to many thousands of gal- lons. Since heat leak is always present, vaporization takes place continuously. Rates of vaporization vary, depending on the design of the container and the volume of stored product.

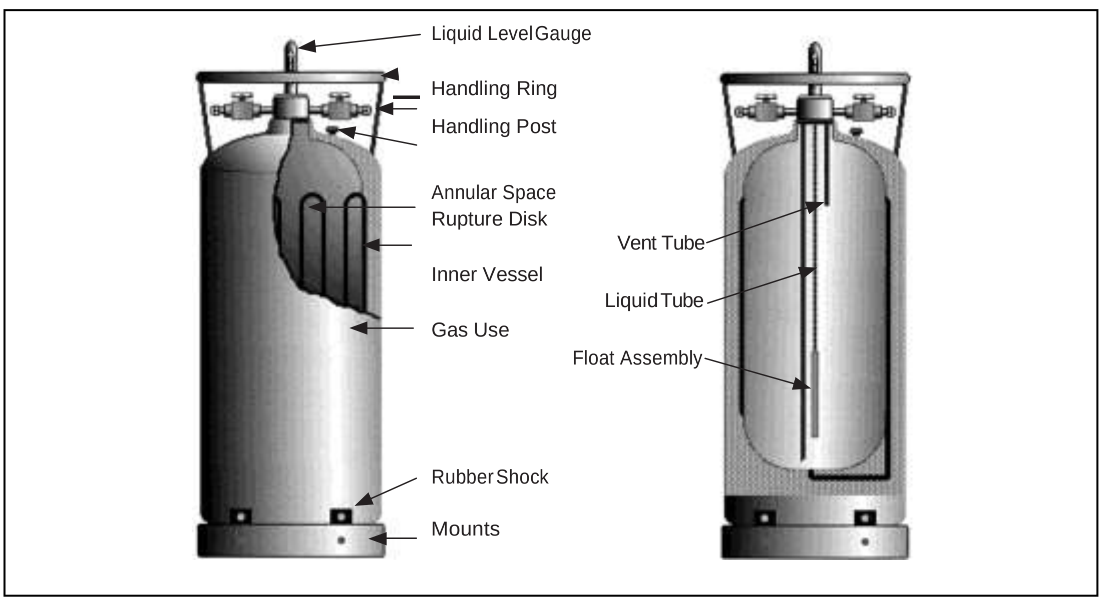
Containers are designed and manu- factured according to the applicable codes and specifications for the tem- peratures and pressures involved.

Dewars

Figure 1 illustrates a typical vacuum- jacketed dewar. A loose-fitting dust cap over the outlet of the neck tubes prevents atmospheric moisture from plugging the neck and allows gas produced from vaporized liquid to escape. This type of container is non-pressurized. The most common unit of measure for the capacity of a dewar is the liter. Five- to 200-liter dewars are available. Product may be removed from small dewars by pouring, while larger sizes will require a transfer tube. Cryogenic liquid cylinders that are pressurized vessels are sometimes incorrectly referred to as dewars

Figure 1: Typical Dewar

Figure 2a: Typical Cryogenic Liquid Cylinder, side view



Cryogenic liquid cylinders

A typical cryogenic liquid cylinder is depicted in Figure 2. This is an insulat- ed, vacuum-jacketed pressure vessel.

valves and rupture disks to protect the cylinders from pressure buildup. They are equipped with pressure relief Liquid containers operate at pres- sures up to 350 psig (24 atm) and have capacities between 80 and 450 liters of liquid. Oxygen may be withdrawn as a gas by passing liquid through an internal vaporizer or as a liquid under its own vapor pressure. For more datails on the construction and op- eration of cryogenic liquid cylinders, consult Air Products' Safetygram #27,

"Cryogenic Liquid Containers."

Cryogenic storage tanks

Customer installations generally include a tank, vaporizer, and pressure control manifold (see Figure 3). Tanks may be spherical or cylindrical in shape and are mounted in fixed locations as stationary vessels or on railcar or truck chassis for easy transportation. Sizes range from 500 to 420,000 gallons (1,893 – 1,589,873 Liters). All tanks are powder- and vacuum-insulated in the annular space and equipped with various circuits to control product fill, pressure buildup, pressure-relief, product withdrawal, and tank vacu- um. Tanks are designed to national specifications for the pressures and temperatures involved.

Transfer lines

A liquid transfer line is used to safely remove liquid product from dewars or cryogenic liquid cylinders. A typical transfer line for dewars is connected to a bayonet that provides a means of using product vapor pressure buildup or an external pressure source to remove the liquid. For cryogenic liquid cylinders, the transfer line is connect- ed to the cylinder's liquid withdrawal valve.

Liquid product is typically removed through insulated withdrawal lines to minimize the loss of liquid product to gas. Insulated flexible or rigid lines are used to withdraw product from stor- age tanks. Connections on the lines and tanks vary by manufacturer.

NOTE: Liquid cylinders designed to dispense gaseous oxygen have valves equipped with standard Compressed Gas Association (CGA) outlets. Suitable pressure-regulating equipment may be attached. Valves provided for the withdrawal of liquid product are also equipped with stan- dard CGA outlets but differ from con- nections used for gaseous withdrawal. This prevents cross connections between processes using the liquid or gaseous product.

Shipment of liquid oxygen

All shipments of liquid oxygen must comply with transportation regula- tions (DOT in U.S.). This applies to motor freight, rail, air, and water ship- ments. For air shipments, all packages must also comply with International Air Transport Association/ International Civil Air Organization (IATA/ICAO)

Dangerous Goods regulations: Water vessel shipments must also be prepared in accordance with the International Maritime Organization (IMO) regulations. In the U.S., all pack- aging used to transport oxygen must be either "UN/DOT Specification" or "UN/DOT Authorized" and in proper condition for transport.

Containers used for transporting liquid oxygen at less than 25 psig (40 psia) pressure are UN/DOT Authorized containers. These are containers built to other than DOT specifications, but ones authorized by DOT for use in the transport of ap- proved products. Containers used for transporting liquid oxygen at pres- sures greater than 25 psig (40 psia) need to be designed, manufactured, and tested to DOT specifications. DOT Code of Federal Regulations, Title 49 specifies these labeling and identifica- tion requirements:

Safety considerations

The hazards associated with liquid oxygen are exposure to cold tempera- tures that can cause severe burns; overpressurization due to expansion of small amounts of liquid into large volumes of gas in inadequately vented equipment; oxygen enrichment of the surrounding atmosphere; and the possibility of a combustion reaction if the oxygen is permitted to contact a noncompatible material.

The low temperature of liquid oxygen and the vapors it releases not only pose a serious burn hazard to hu- man tissue, but can also cause many materials of construction to lose their strength and become brittle enough to shatter.

It is important to note that fire chemistry starts to change when the concentration of oxygen increases. Materials easily ignited in air not only become more susceptible to ignition but also burn with added violence in the presence of oxygen. These materi- als include clothing and hair, which have air spaces that readily trap the oxygen. Elevated oxygen levels can be reached very quickly, and all personnel must be aware of the hazard.

Any clothing that has been splashed or soaked with liquid oxygen or ex- posed to high oxygen concentrations should be removed immediately and aired for at least an hour. Personnel should stay in a well-ventilated area and avoid any source of ignition until their clothing is completely free of any excess oxygen. Clothing saturated with oxygen is readily ignitable and will burn vigorously.

Do not permit smoking or open flames in any areas where liquid oxy- gen is stored or handled. Do not per- mit liquid oxygen or oxygen-enriched air to come in contact with organic materials or flammable or combus- tible substances of any kind. Some of the organic materials that can react violently with oxygen when ignited by a spark or even a mechanical shock are oil, grease, asphalt, kerosene, cloth, tar, and dirt that may contain oil or grease. If liquid oxygen spills on as- phalt or other surfaces contaminated with combustibles, do not walk on or roll equipment over the area of the spill. Keep sources of ignition away for 30 minutes after all frost or fog has disappeared.

Systems used in oxygen service must meet stringent cleaning require- ments to eliminate any incompatible contaminants. The CGA's Pamphlet G-4.1, "Cleaning Equipment for Oxygen Service," describes cleaning methods for equipment used in oxygen service. CGA's Pamphlet O2-DIR, "Directory of Cleaning Agents for Oxygen Service," provides comparative information on cleaning agents used to clean oxygen equipment.

Also, review the Material Safety Data Sheet (MSDS) and follow all recommendations.

Buildings

Because of the large expansion ratio of liquid-to-gas, it is very important to provide adequate ventilation in areas where liquid oxygen is in use. A mini- mum of six air changes per hour is suggested. U.S. OSHA has established the definition of an oxygen-enriched atmosphere as one containing more than 23.5% oxygen.

Storage

- Store and use liquid containers with adequate ventilation. Do not store containers in a confined area or in area unprotected from the extremes of weather.
- Cryogenic containers are equipped with pressure relief devices de- signed to control the internal pressure. Under normal conditions these containers will periodically vent product. Do not plug, remove or tamper with any pressure relief device.
- Oxygen must be separated from flammables and combustibles by at least 20 feet or a half-hour fire wall. Post “No Smoking” and “No Open Flames” signs.
- Customer storage sites having a ca- pacity of more than 20,000 scf must be installed in accordance with the National Fire Protection Association (NFPA) Standard 55.
- Liquid containers should not be left open to the atmosphere for extend- ed periods. Keep all valves closed and outlet caps in place when not in use. If restriction results from freezing moisture or foreign mate- rial present in openings and vents, contact the vendor for instructions. Restrictions and blockages may result in dangerous over-pressuriza- tion. Do not attempt to remove the restriction without proper instruc- tions. If possible, move the cylinder to a remote location.

Handling

- Cryogenic containers must be stored, handled and transported in the upright position. When moving, never tip, slide or roll containers on their side. Use a suitable hand truck for moving smaller containers. Move larger containers by pushing, not pulling. Avoid mechanical and thermal shock.
- Never allow any unprotected part of the body to come in contact with uninsulated pipes or equipment containing cryogenic product. The extreme cold will cause flesh to stick fast and potentially tear on withdrawal.
- Use only oxygen-compatible materi- als and lubricants.
- If there is any difficulty in operat- ing the container valve or container connections, discontinue use and contact the vendor. Do not remove or interchange connections. Use only the properly assigned connections.

Do not use adapters.

- Use only transfer lines and equip- ment designed for use with cryo- genic liquids. Some elastomers and metals, such as carbon steel, may become brittle at extremely low temperatures and may easily fracture. These materials must be avoided in cryogenic service.
- It is recommended that all vents be piped to the exterior of the building.
- On gas withdrawal systems, use check valves or other protective apparatus to prevent reverse flow into the container.
- On liquid systems, pressure relief devices must be used in lines where there is the potential to trap liquid between valves.

For additional information on the storage and handling of cryogenic liquids, refer to Air Products' Safetygram-16, "Safe Handling of Cryogenic Liquids," and CGA Pamphlet P-12, "The Safe Handling of Cryogenic Liquids."

Personal protective equipment (PPE)

Personnel must be thoroughly familiar with properties and safety considerations before being allowed to handle liquid oxygen and its associ- ated equipment.

The eyes are the most susceptible to the extreme cold of the liquid and vapors of liquid oxygen. The recom- mended PPE is a full faceshield over safety goggles; clean, loose-fitting thermal-insulated or leather gloves; long-sleeved shirts; and pants without cuffs. Wear this PPE when handling or using liquid oxygen, or whenever the possibility of exposure due to a spill exists. In addition, safety shoes are recommended for those involved with the handling of containers.

In emergency situations, self- contained breathing apparatus (SCBA) must be used. Clothing that is fire- resistant in air may be readily ignit- able in oxygen-enriched atmospheres. Only trained and certified emergency responders should respond to emer- gency situations.

First aid

For skin contact with liquid oxygen, remove any clothing that may restrict circulation to the frozen area. Do not rub frozen parts, as tissue damage may result. As soon as practical, place the affected area in a warm water bath with a temperature not exceed- ing 105°F (40°C). Never use dry heat.

Call a physician as soon as possible. Frozen tissue is painless and appears waxy with a possible yellow color.

It will become swollen, painful, and prone to infection when thawed. If the frozen part of the body has been thawed, cover the area with a dry sterile dressing with a large bulky protective covering, pending medical care. In case of massive exposure, remove clothing while showering the victim with warm water. Call a physician immediately.

If the eyes are exposed to the extreme cold of the liquid or vapors, immediately warm the frostbite area with warm water not exceeding 105°F (40°C) and seek medical attention.

Fighting fires

Since oxygen is nonflammable but supports combustion, fire-fighting ac- tions require shutting off the source of oxygen, if possible, then fighting the fire according to the material involved.

Compressed Gases Inspection Checklist

	Yes	No	N/A	Comments
1. Are storage rooms for cylinders dry, cool, and well-ventilated? (Note: The storage rooms should be fire-resistant and thestorage should not be in subsurface locations.)	☐	☐	☐	
2. Are cylinders stored away from incompatibles, excessiveheat, continuous dampness, salt or other corrosive chemicals, and any areas that may subject them to damage?	☐	☐	☐	
3. Are cylinders maintained at temperatures below 125degrees Fahrenheit?	☐	☐	☐	
4. Is the storage area permanently posted with the names of the gases stored in the cylinders?	☐	☐	☐	

5. Are oxygen and fuel gas cylinders separated by a minimumof 20 feet when in storage? (Note: A fire-resistant partition between the cylinders can also be used.)	☐	☐	☐	
6. Are cylinders stored in upright positions and immobilized bychains or other means to prevent them from falling?	☐	☐	☐	
7. Are cylinders stored away from electrical connections,sources of ignition, combustible waste material?	☐	☐	☐	
8. Is the bottom of the cylinder protected from the ground toprevent rusting?	☐	☐	☐	
9. Are charged or full cylinders labeled and stored away fromempty cylinders?	☐	☐	☐	
10. Are all compressed gas cylinders stored so they do notinterfere with exit paths?	☐	☐	☐	
11. Do all compressed gas cylinders have safety pressure reliefvalves?	☐	☐	☐	
12. Are cylinder valves closed at all times, except when thevalve is in use?	☐	☐	☐	
13. Are all compressed gas cylinder valve covers in place whencylinders are not in use?	☐	☐	☐	
14. Is using wrenches or other tools for opening and closingvalves prohibited? (Note: Hammering on valve wheels to open them should bestrictly prohibited. For hard-to-open valves, contact the supplier for instruction.)	☐	☐	☐	
15. Do all compressed gas cylinders have the contents andprecautionary labeling clearly marked on the exteriors?	☐	☐	☐	
16. Is painting cylinders without authorization by the owner prohibited?	☐	☐	☐	
17. Are all compressed gas cylinders subjected to periodichydrostatic testing and interior inspection by suppliers?	☐	☐	☐	
18. Are safety relief devices in the valve or on the cylinder free from any indication of tampering?	☐	☐	☐	
19. Are all compressed gas cylinders regularly inspected for corrosion, pitting, cuts, gouges, digs, bulges, neck defects and general distortion?	☐	☐	☐	
20. Is repair or alteration to the cylinder, valve, or safety reliefdevices prohibited? (Note: All alterations and repairs to the cylinder and valve must be made by the compressed gas vendor. Modificationof safety relief devices beyond the tank or regulator should only be made by a competent person appointed by management.)	☐	☐	☐	
21. Are compressed gas cylinders always moved, even shortdistances, by a suitable hand truck? (Note: They must never be dragged across the floor.)	☐	☐	☐	

22. Are suitable pressure-regulating devices in use whenever the gas is emitted to systems with pressure-rated limitationslower than the cylinder pressure?	☐	☐	☐	
23. Are all compressed gas cylinder connections (pressureregulators, manifolds, hoses, gauges, and relief valves) checked for integrity and tightness?	☐	☐	☐	
24. Are all compressed gas cylinders regularly subjected toleak detection using an approved leak detecting liquid?(Note: Leak detection liquids are available from commercial welding supply houses.)	☐	☐	☐	
25. Is an approved leak-detection liquid used to detectflammable gas leaks? (Note: A flame should never be used.)	☐	☐	☐	
26. Are procedures established when a compressed gas cylinder leak cannot be remedied by simply tightening thevalve? The procedures should include: (a) Attach tag to the cylinder stating it is unserviceable. (b) Remove cylinder to a well-ventilated outdoor location. (c) Place an appropriate sign on a flammable or toxic gascylinder warning of these hazards. (d) Notify the gas supplier and follow his/her instructionsregarding the return of the cylinder.	☐	☐	☐	
27. Are students/employees prohibited from using compressedgases (air) to clean clothing or work surfaces?	☐	☐	☐	
28. Are compressed gases handled only by experienced andproperly trained people?	☐	☐	☐	

1 Scope

These guidelines apply to all workers and others who store and handle gas cylinders

2 Definitions

Asphyxiation	Breathing difficulties (suffocation), loss of consciousness and eventual death caused by an inadequate supply of oxygen to the body.
Flammable gas	A gas that can be ignited in air.
Inert or Noble gas	Any of the six gases helium, neon, argon, krypton, xenon, and radon. These gases are un-reactive except under certain special conditions.
Non-flammable gas	A gas that is neither flammable nor poisonous but can still cause asphyxia and death.

Oxidizing gas	A gas that initiates or promotes combustion of materials through release of oxygen. These gases can also spontaneously combust/explode.
Short Term Exposure Limit (STEL)	Maximum concentration of a gas that a person can be exposed to for a 15 minute period. Only 4 such exposure periods can occur within an 8 hour day and 1 hour break is required between exposure intervals.
Time Weighted Exposure Limit (TWA)	Maximum concentration of a gas that a person can be exposed to for 8 hours per day over a 5 day working week.
Toxic gas	A gas that is poisonous or capable of causing injury or death, especially by chemical means.
Upper and Lower Explosive Limits (UEL and LEL)	Upper and lower concentration (in %) limits for which a particular gas is explosive in air.

3 Types of Gases

There are three types of gases commonly supplied and used:

1. Compressed Gases – Nitrogen, Oxygen, Air, Carbon Dioxide, Helium
2. Liquefied Gases – LPG, Liquefied Nitrous Oxide
3. Dissolved Gases – Acetylene

4 Types of Gas Cylinders

In general, there are three types of gas cylinders:

1. High Pressure Cylinders – High pressure cylinders come in a variety of sizes, see Figure 1. Some examples of gases supplied in High pressure cylinders include Nitrogen, Helium, Hydrogen, Oxygen and Carbon Dioxide.
2. Low Pressure Cylinders – Low pressure cylinders come in a variety of sizes, see Figure 2. Some examples of gases supplied in low pressure cylinder are LPG and refrigerant gases.
3. Acetylene Cylinders – aggregate filled and acetylene is dissolved in acetone to get sufficient product into the cylinder. See Figure 3.

Acetylene is in a class of its own as the cylinder is filled with an aggregate material and dissolved in a liquid medium (acetone).

Figure

5 Classes of Gases

The following table shows the four main classes of gases. Gases can also have corrosive properties, eg Ammonia. The class of gas defines its physical properties and transport requirements. However, it is also important for considering storage and handling/usage requirements.

Dangerous Goods Diamond	Class	Examples
	Class 2.1 Flammable gas	LPG, hydrogen, acetylene
	Class 2.2 Non-flammable, non-toxic gases	Compressed air, nitrogen, argon, carbon dioxide, helium.
	Class 2.2, Sub-risk 5.1 Oxidizing gas	Oxygen, nitrous oxide, Entonox (50% oxygen, 50% nitrous oxide).
	Class 2.3 Toxic Gas	Methyl bromide, anhydrous ammonia, chlorine.

6 Identification and Labelling

Gas cylinders are required to be labelled with the following:

- Class label and any subsidiary risk labels
- The proper shipping name
- A four digit United Nations number
- Manufacturer/importer’s name

Cylinder sizes are denoted by a letter code. The gas content of cylinders is measured in cubic metres, litres or kilograms. If volume unit is given, it refers to standard temperature and pressure of 15°C (101.3 kPa).

Protect the markings on cylinders that identify the contents, and mark the full/empty status on cylinders. Manufacturers paint gas cylinders using a colour coded system that is useful for identification. You should consult the manufacturer’s product catalogues for colour charts with this information.

NEVER alter markings, labelling or colour coding of gas cylinders supplied. They are a rented item and should be treated as such. The integrity and compliance of the gas cylinder is the supplier’s responsibility.

NOTE: All gas cylinders are also fitted with a barcode by the supplier for tracking purposes. The barcode should not be tampered with or removed. The barcode is scanned by the supplier on supply of the cylinder and also again upon return and identifies who has used the cylinder, the time period it has been used for and the rental charges to be paid by the user. If the barcode is removed or can’t be scanned on return to the supplier additional rental charges could be incurred and these could be substantial. Furthermore, if the supplier has no record of the cylinder been returned this could be considered as theft.

7 Cylinder Valves and Regulators

Cylinder Valves

The gas cylinder valve is the primary safety mechanism on a gas cylinder and shall not be tampered with. It is a device used to contain the contents of the cylinder that is under pressure. Cylinder valves are fitted with pressure relief valves of different types (depending on the cylinder) to protect against catastrophic failure of the cylinder valve. Figure 5 & Figure 6 show different types of cylinder valves and pressure relief devices respectively.

Figure 5 Examples of Typical Gas Cylinder Valves

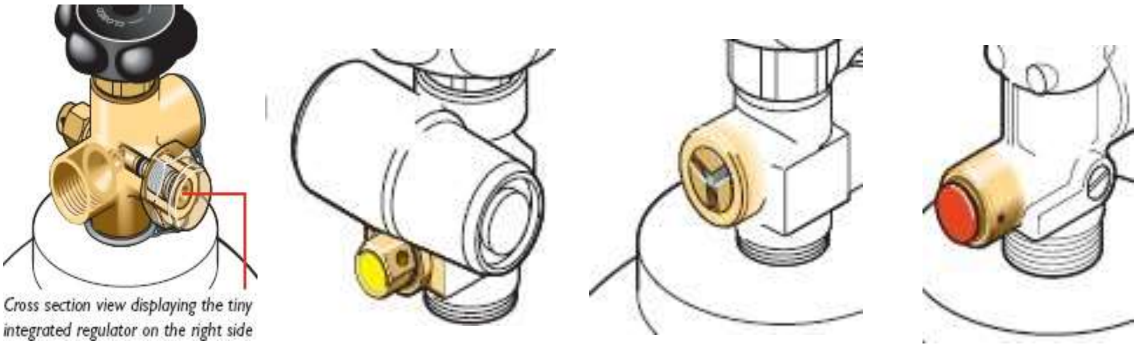


Figure 6 Typical pressure relief devices fitted to cylinder valves. Top Left - Integrated regulator type for 300 atms cylinders, Burst disc type, Fusible plug type, STD pressure relief valve.

NOTE:

Cylinder valves on flammable gases have a left hand thread to attach the regulator. This is to distinguish them from non-flammable gases.

The thread size of an Air or Nitrogen cylinder valve differs from Oxygen so that they cannot be mistaken in medical applications.

Cylinder valves open in an anticlockwise direction and close in a clockwise direction. Valves shall never be opened without a regulator attached. Always open cylinder valves slowly. Figure 7 shows the operation of the cylinder valve.

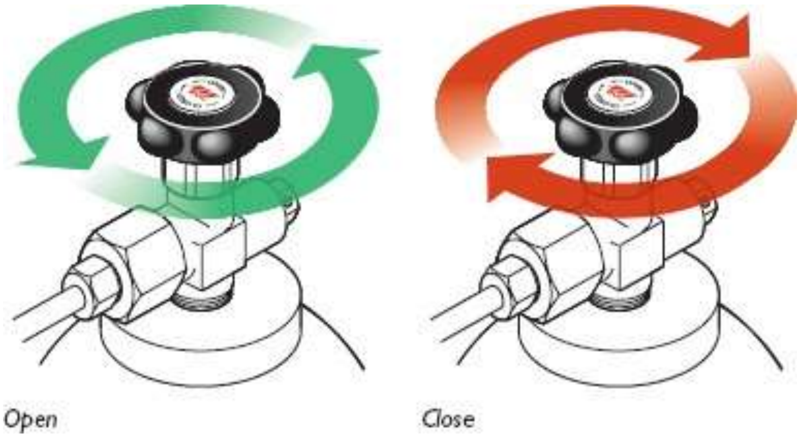


Figure 7 Correct operation of gas cylinder head valve tap

Reg ulat ors

The regulator is the next most important safety device to be fitted to a gas cylinder before operation/use. It allows for the high pressure of the cylinder contents to be brought down to a usable working pressure. Regulators come as single stage for short term applications and two stages for long term applications. Regulators are also constructed from different materials, mainly brass or stainless steel.

The application will define the required regulator. If you are unsure of which kind of regulator to use, consult your gas supplier.

Regulators are designed to be fitted directly to the cylinder valve. No other fittings, connections or lubricants shall be used to connect a regulator to a gas cylinder valve.

Regulators for flammable gases are left hand threaded and have a notch cut out of faces on the securing nut to distinguish them from non-flammable gas regulators.

8 Risks and Hazards from Gas Cylinders

Gas cylinders can be hazardous due to both their physical (size and weight) and chemical characteristics. Hazards from gases are also subject to the chemical properties of each gas. These may be one or more of the following:

- Fire or explosion from the release of flammable gases near ignition sources (e.g. acetylene or LPG). Refer to SDS for Upper and Lower Explosive Limits (UEL and LEL)
- Spontaneous combustion from oxidizing gases (e.g. oxygen or nitrous oxide)
- Exposure limits for all gases, especially toxic or corrosive gases (e.g. anhydrous ammonia); refer to SDS for Time Weighted Exposure Limit (TWA) and Short Term Exposure Limit (STEL)
- Asphyxiation from non-toxic, non-flammable gases by displacement of oxygen (e.g. nitrogen, carbon dioxide or argon)
- Incorrect storage
- Leaks
- Faulty equipment/connections

- Physical risks
- Manual handling
- Sudden release of gas if cylinder is damaged (torpedo effect).
- Pressure – compressed gas cylinders are filled to a pressure of 200-300 atmospheres
- Gas Density

Read, understand, and follow the markings on the cylinder, the label(s) on the cylinder, and the safety data sheet (SDS) to avoid misuse. The SDS must be read to identify:

- Chemical and physical hazards for each gas cylinder
- Appropriate safe storage and handling practices
- The need for additional control measures
- First aid measures
- Fire-fighting and emergency information
- Density of the gas
- Exposure limits
- Flammability/explosiveness
- Transport requirements

Each compressed gas cylinder has unique hazards based on its contents. Some are filled with inert gases – especially those used in arc welding. Many gases are flammable, explosive, toxic, or a combination.

NOTE: When gases are released and expand, a drop in temperature occurs. In some cases (e.g. carbon dioxide) the rapid release and expansion of gas can cause a cold hazard (e.g.

frostbite) to exposed persons.

9 Hazard Management

The below information outlines controls to be implemented for pre-identified hazards relating to gas cylinders. If further hazards are identified (e.g. local hazards) then a risk assessment must be carried out and recorded to identify hazards and the need for any additional control measures. Safe Work Procedures shall be developed for tasks that routinely involve the use and handling of gases from pressurised cylinders.

Anyone working with gas cylinders needs to be given information, training and effective supervision regarding the hazards from gas cylinders, safe storage and handling information and what to do in an emergency.

Storing Cylinders

Bulk Cylinder Storage

Gas stores should be located outdoors, preferably in a secure, cage protected from sunlight. Storage indoors is not recommended unless the building has been designed for that purpose with appropriate fire rated walls and ventilation. Where gases are stored indoors, additional safety considerations and control measures need to be given consideration.

It is recommended that if you store significant quantities of gas in cylinders that you consult *AS 4332 - The Storage and Handling of Gases in Cylinders* for guidance, or consider the services of a dangerous goods consultant.

Figure 8 Example of a bulk storage location for cylinders at UOW Wollongong Campus

Laboratory Specific Storage Requirements – Cylinders in Use

Store cylinders in an upright position[1]. If cylinders have been lying on their side, place the cylinder in the upright position and wait 60 minutes before using. If Acetylene has been laid on its side, then it is recommended that the cylinder is not used for 12-24 hours.

Secure cylinders using a purpose built non-abrasive coated chain, strap or cable that will not scratch the cylinder markings and paint work or a racking system. Refer Figure 9.

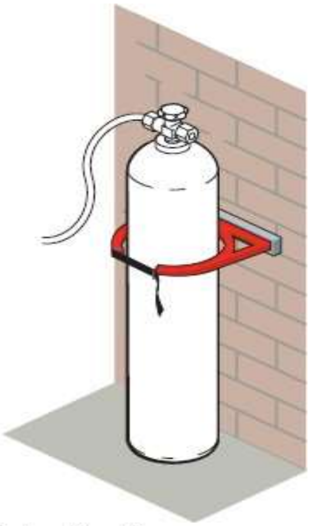


Figure 9 Cylinder secured by wall brackets

Completely close the valves, and keep the valve protection devices, such as caps or guards, securely in place when cylinder is not in use.

- Store cylinders in a dry, well-ventilated area.
- Place them in a location where they will not be subject to mechanical or physical damage, heat, or electrical circuits to prevent possible explosion or fire. Keep cylinders away from pedestrian traffic.
- Full and empty cylinders should be stored separately in clearly marked areas.
- Objects should not be stored on top of gas cylinders.

[1] Some cylinders are designed to be stored on their side. Consult the SDS or contact the supplier for additional information.

- Gases denser than air need to be stored with caution to avoid storage where these gases can collect in low lying areas.
- Gas cylinders should not be located where they may block stairs, exits, ladders or walk ways.
- Ensure an up to date and accurate inventory is kept. Keep inventory quantities as low as possible.
- Avoid storing cylinders below 0°C. Some mixtures may separate below this.
- Laboratory storage locations should be positioned as close to the usage point as possible.

Segregate Incompatible Gases and Dangerous Goods

Corrosive liquids can damage gas cylinders on contact. Flammable liquids can spread a fire across a workplace floor and allow flames to come into contact with gas cylinders. Other dangerous goods may also be adversely affected by gas cylinders in an emergency. For this reason, gas cylinders are kept separately from other dangerous goods and combustible liquids by at least 5m or by using appropriate fire rated barriers. Segregation of incompatible goods also allows fire fighters to safely use appropriate fire-fighting media for each type of goods present.

Gas cylinders must also be segregated from other incompatible gases by at least 3 m. The following is recommended:

- Class 2.3 “Toxic gas” and corrosive gases (subsidiary risk of Class 8 “Corrosive”) are stored away from all other gas cylinders.
- Class 2.1 “Flammable gas” shall not be stored with subsidiary risk class 5.1 gases or oxygen.
- Keep oxygen cylinders five metres away from other dangerous goods (e.g. Class 3, 4, 5, 6.1, 7, 8 or 9, etc) and combustible liquids (e.g. diesel fuel, acetylene), or separate them with a non-combustible barrier (such as a wall) at least one metre higher than the tallest cylinder with a fire-resistance rating of at least half an hour.
- Ensure gas cylinders are stored at least three metres away from combustible materials and debris (e.g. timber, card board, packaging materials) to prevent flame impingement on gas cylinders in a fire.

Mutually compatible gases (e.g. Class 2.2, without subsidiary risk) may be placed between incompatible gases.

Heat and Ignition Sources

Heating of the cylinder (e.g. from fire) or impact to the pressure vessel wall may result in explosion and shrapnel hazard to exposed persons.

- DO NOT use oil or grease on the valve of a cylinders or regulators/gauges, particularly those containing oxygen or oxidising agents, to avoid fire or explosion.
- Store cylinders in cool areas away from sources of radiant heat (e.g. boilers, hot surfaces, and internal combustion engines). Where possible, store cylinders in the shade to avoid exposing cylinders to direct sunlight.
- Cylinders containing flammable gas should not be stored near sources of ignition such as naked lights / flames, cigarette smokers, etc.
- For flammable gas storage, appropriate signs stating “No Smoking”, “No Naked Lights” should be erected to preclude ignition sources from these areas.

All gas cylinders should be fitted with a test tag that is heat sensitive. **DO NOT** use a cylinder if the test tag is missing or shows evidence of heat exposure.

Figure 10 Normal and heat effected test tags

Safe Handling Practices

Most accidents or injuries involving cylinders happen when moving or handling the gas cylinders. Large gas cylinders (e.g. G or F sized cylinders) can be bulky, heavy, and awkward to handle, they require special care and equipment in handling and securing so they don’t fall or tip over and cause injury.

Anyone involved in the handling of gas cylinders should undertake some basic induction training or have read the Safe Work Procedures relating to the transport, storage and use of Gas Cylinders. Wear protective footwear, safety glasses. Gloves are also recommended.

Securely install the valve protection devices when the cylinder is not in use, such as caps or guards. **EXEMPTION: G size cylinders will not have a protective cap or guard fitted.**

When moving cylinders, **DO NOT** roll or drag them. Ensure that an appropriate mechanical handling device is used (Figure 11). Secure cylinders upright to a proper hand truck or cylinder cart with a restraining strap designed for the purpose. Cylinder size E and greater shall be handled using mechanical assistance.

Figure 11 Mechanical handling devices

Contact your gas supplier if more sophisticated handling of cylinders is required.

DO NOT lift by the protective cap. If a cylinder does not have a handle then use mechanical assistance to move it.

DO NOT restrain cylinders around their necks or valve – restrain them around the main cylinder body at a height that will prevent them from falling over, i.e. 1/2 to 2/3 the height of the cylinder.
Avoid dropping or knocking cylinders about. Prevent damage to cylinders from impact from other objects (e.g. crashing into other cylinders). Some cylinders (e.g. acetylene) may react violently after being excessively shaken, heated, or knocked.

Cylinders should **NEVER** be used as rollers to move other objects.

Using Gas Cylinders

- Always use gas cylinders in well ventilated areas. **DO NOT** use gas cylinders in confined spaces unless qualified to do so and the appropriate PPE is used.
- Know the gas you are using and possible reaction products. Additional mechanical ventilation may be required. Seek expert assistance in designing and installing mechanical ventilation systems.
- Ensure the correct regulator is used for the purpose.
- Ensure there is a suitable emergency response procedure in place.
- Wear appropriate PPE for the gas been used, refer to SDS.
- Ensure connections, fittings and lines are leak tight and suitable for use.
- Ensure that flammable and oxidising gases are not used near ignition sources.
- Disconnect empty cylinders from equipment to avoid backflow issues
- Always close the cylinder valve when not in use.
- **DO NOT** use an empty cylinder as a waste receptacle.
- Fit non-return valves in line if required
- **DO NOT** use a gas cylinder that shows evidence of damage or corrosion. The gas cylinder is a rented item; its integrity is the responsibility of the gas supplier.
- If the cylinder contents cannot be clearly identified, **DO NOT** use it. Return it to the supplier.

NOTE: If a cylinder shows frosting around the valve than the flow through the system is too high or there is a significant leak in the system. If a high flow rate option is required, consult your gas supplier for the best solution. For information on handling leaks refer to section 12.2.

Manifest of Hazardous Chemicals

Requirements for management of placarding and manifest quantities of hazardous chemicals (including gas cylinders) is outlined in the Dangerous Goods Storage and Handling Guidelines. This includes a list of storage areas (including contents and quantities), site plan, emergency plan for Fire & Rescue NSW, and notification to SafeWork NSW.

10 Transporting Gas Cylinders

Transport within Buildings

Cylinders shall be transported within buildings according to section 10.2.

Transporting cylinders between floors of a building shall be done in the lift alone. No person is to travel in the lift with the gas cylinder. The cylinder trolley shall be secured to the lift hand rail to prevent it from falling over. Ideally a sign should be used across the entrance of the lift to prevent others entering the lift while the cylinder is in transit.

Secure the cylinder immediately once arriving at the usage location.

Transport with Vehicles

Gas cylinders used in the field may require the use of a vehicle to get them to the field site. Where possible, have your gas supplier deliver the cylinders directly to the field site. If a vehicle is required to transport cylinders, then it shall be done as follows:

Gas cylinders shall only be transported on an open back utility OR in a utility back canopy that is separate from the main body of the vehicle.

Ideally cylinders should be transported standing up and firmly secured. Flammable and Liquid withdrawal cylinders should always be transported in upright position.

If cylinders are transported lying down than suitable support devices are required to prevent the cylinders from rolling. Also settling time will be required for the cylinder before use, refer to section 10.1.2.

Remove the gas cylinder(s) from the vehicle immediately on arrival to destination and secure them appropriately.

DO NOT carry gas cylinders of any kind in the passenger compartment of a vehicle.

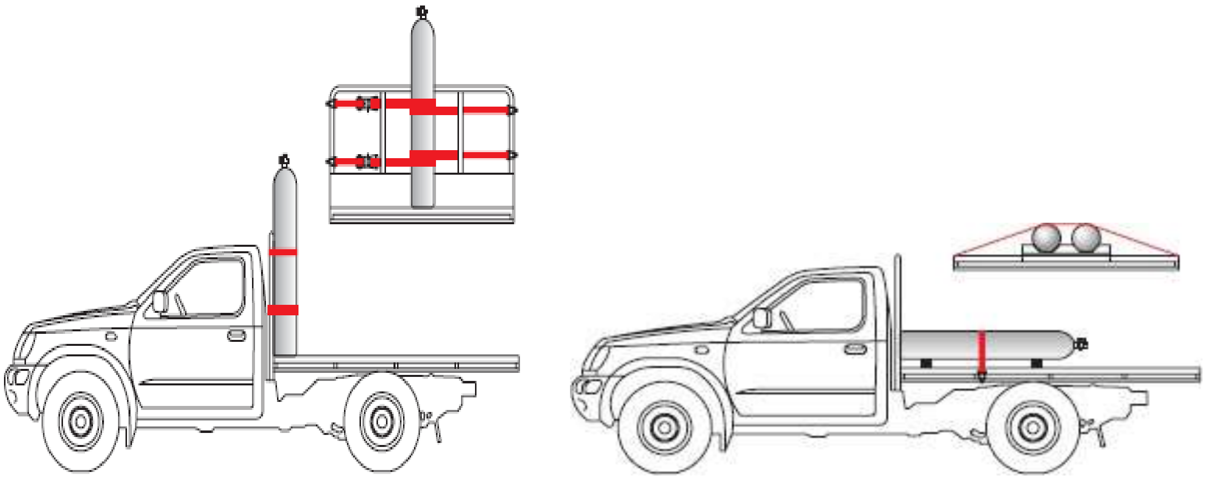


Figure 12 Correct transport requirements for transporting gas cylinders on the back of a utility

11 Troubleshooting

Cylinders in a Fire

If a cylinder has caught on fire OR is in close proximity to a fire than the following actions shall be taken:

- Evacuate the area 100m around the fire
- Inform those within 100-300m from the fire that a gas cylinder is involved in the fire
- Call the fire brigade and inform them of the fires location and gas(es) involved.
- Inform your gas supplier of the incident as the cylinder integrity will have been compromised.
- **DO NOT** attempt to fight the fire under any circumstances. Leave it to the professionals.

Leaks

Leaks from gas cylinders are potentially very dangerous, depending on the properties of the gas. If a gas cylinder is found to be leaking than appropriate measures should be put in place to limit risk.

If a flammable gas is found to be leaking then it should be treated as if the cylinder were on fire, Refer 12.1.

Non-flammable, non-toxic gases found to be leaking from a cylinder should be removed to a well ventilated outdoor location to degas.

Leaking toxic gases are extremely dangerous. Immediately evacuate the area and follow the normal school/faculty emergency response procedures. The fire brigade shall be called and informed of the type of leaking gas. **DO NOT** re-enter the area until it is deemed safe to do so by professionals.

NOTE: Where toxic gases are used suitable gas detection devices should be installed and a gas mask rated to the gas in question available. Gas detection devices are also recommended when storage and use of gas cylinders in poorly ventilated areas is unavoidable.

Test for leaks with a squeeze bottle of soapy water. Bubbles form at the point of gas escape. Leak detection devices are also available for determining the location of a leak.

12 Cylinder Safety

Below is a summary of the **DO's/DON'Ts** when working with gas cylinders

DO	DON'T
Ensure a regulator is fitted before use	Repaint a cylinder
Ensure cylinder is firmly secured	Change the markings on a cylinder
Ensure connections are tight and suitable	Use oil or lubricants on cylinder valve
Ensure cylinders are stored and used away from ignition sources	Tamper with the gas cylinder test tag
Store full and empty cylinders separately	Tamper with or remove the barcode from a gas cylinder
Ensure valve guards or caps are fitted when cylinders are not in use	Roll cylinders along the ground
Use mechanical assistance when handling cylinders	Attempt to fight a fire involving a gas cylinder
Ensure adequate ventilation is available for the gas in question	Transport gas cylinders in the passenger compartment of a vehicle

Ensure exposure limits are not exceeded	Use a cylinder that shows evidence of damage or corrosion
Read the SDS	Fill cylinders with any material at all
Follow appropriate SWP	
Have gas detection devices installed if required	

Oxygen therapy at home and low

resource setting for COVID-19

Contents:

Indications

1. SpO_2 <94% (ensure that the pulse oximeter probe is correctly positioned, the limb where probeis applied should be static, and proper waveform is visible on pulse oximeter for atleast 1 minute on pulse oximeter when the reading is noted)
2. Fall in SpO_2 by 4% from baseline after a 6-minute walk test (or 3 minutes if 6 minutes notpossible)
3. Visibly cyanosed (observed by Health care professional)
4. Tachypnea (RR> 24/min or age appropriate in children) and increased work of breathing –discuss need for oxygen with healthcare provider (HCP) if SpO_2 >94%
5. Altered mental status, confusion, inability to arouse - discuss need for oxygen with HCP ifSpO_2 >94%

*Control fever with Paracetamol 15 mg/kg (Maximum 650 mg); preferable to take saturation readingwhen fever has decreased; cold peripheries may show falsely low SpO_2

Oxygen concentrators

Oxygen concentrator extracts and separates oxygen from room air and runs on electricity. Does not need refilling and can be moved easily. The maximum flow rates vary in different models: from 5 L to10 L

Setting up

1. Place it atleast 6 inches away from walls or other objects to ensure good airflow in and out
2. Avoid using extension cords and plugging other devices to the same electrical wall outlet
3. An alarm is heard as it is turned on for approximately 5 seconds
4. A similar alarm during use may suggest malfunction
5. Look for any leaks at the connections
6. Ensure back up in case of electrical failure
7. Fill distilled/ clean water in the humidifier bottle not exceeding maximum mark

Oxygen concentrator ***Flowmeter*** ***Humidifier bottle*** ***Water trap***

Delivering oxygen using an oxygen concentrator:

1. Start by using nasal prongs interface at flow rates 1-2 L/min (in the flow meter- ball should be at the middle of the line to the set flow rate); or may use simple face mask starting at flow of 4L/min
2. Titrate by increasing flow by 1 L/min every 10 minutes to a maximum of 4-5 L/min targeting SpO_2 92-96% (88-92% in COPD) when using nasal prongs. For face mask, may increase in steps on 1L/ min to the maximum flow rate available with the model being used
3. Arrange oxygen cylinder if higher flow requirement (> maximum flow rate available with the model being used) to meet target SpO_2
4. Humidifier to be used if available for higher flows. A water trap may be required betweentubing and nasal cannula.
5. Maximum of 60% FiO_2 can be delivered at 10 L/min using oxygen concentrator
6. Arrange for transfer to a centre with HFNC, Non-invasive and invasive ventilation if the saturations are not maintained/ deteriorate
7. With oxygen concentrator, non-rebreathing mask cannot be used as the minimum flow requiredis 10 L/min

*Ensure nose is clear and free of crusting while using nasal cannula

*If tolerated, a surgical mask worn over nasal cannula may improve oxygen delivery

*Try awake proning at every step – use one pillow below neck, one or two below the chest through upper thighs, two below shin, change to left lateral, right lateral and sitting up 60-90° every 30-120 minutes (Refer to guidelines for proning: https://www.mohfw.gov.in/pdf/COVID19ProningforSelfcare3.pdf)

*Deep breathing exercises if possible

Cleaning

- Follow manufacturer's instructions
- Unplug the unit and wipe down the concentrator with a damp cloth
- Remove the filter out of the back of concentrator. Rinse with warm, soapy water and remove excess water with a soft absorbent towel. A clean filter will prevent the concentrator from over-heating.
- Wash out humidifier bottle with warm, soapy water and refill it with clean/ sterile distilledwater.

Portable oxygen cylinders

Oxygen cylinders contain oxygen under high pressure and need refilling as they empty. They come in different sizes which determine their weight when full and made of aluminium or steel and to be handled carefully. They are used with regulator conserving device and require cylinder wrench or key toopen and close the flow of oxygen

Setting up

1. The oxygen cylinder is firmly secured
2. Bull nose is fitted with Oxygen valve by the nut using a two in one spanner. Teflon tape is used to avoid any leakage from the threading.
3. Controlling knob shall be in tight position when gas is released from the cylinder. Using cylinder Key or a Spanner, the spindle of the cylinder is rotated in anti clockwise direction torelease the oxygen gas. Check the reading in pressure gauge; a full cylinder will show a pressure of around 2000 psi (140 kg/cm^2).
4. Humidifier is filled with water up to optimum level between the maximum and minimum levelsmarked on the bottle
5. Oxygen set pipe is attached at the outlet of the Humidifier bottle. FA valve knob shall berotated in anti clock wise direction to give oxygen to patients.
6. The medical oxygen flow meter can be adjusted using knob from 0.5-10 L/min (15 L/min is some models) to the patient.

Portable oxygen cylinder with regulator, flowmeter and humidifier

Regulator & Humidifier

- Oxygen Cylinders come with fine adjustment valve flow meter or oxygen valve regulator which regulates the supply of oxygen to the patient from the cylinder
- The main parts of the oxygen regulator kit are the bull nose, nut, medical oxygen gauge, flowmeter, Threading type humidifier, controlling knob, and connecting joint.
- Gauge ranges from 0-250 Kg per cm^2 and the flow meter range is 0-10 liters per minute.
- As the gas passes through the FA valve the pressure reading rises up to 140-150 Kg per cm^2/2000 psi
- As oxygen is used up, the pressure will drop depending on the flow rate
- When the pressure gauge reads low, approximately 50 Kg per cm^2 (the needle in the red area),it is time to refill
- The regulator provides oxygen at a continuous flow and does not require any batteries for use

Most common sizes of cylinders available

B cylinder

- 10 L volume
- Oxygen capacity: 1500 L
- Portable unit/ trolley

D cylinder

- 47 L volume
- Oxygen capacity: 7000 L
- Typically used in a bedside setting

Based on the available oxygen volume as mentioned above and the flow rate, one can calculate how long a cylinder may last. E.g., if the flow rate is 2 L/min, i.e. 120 L/hr, the B type cylinder will last for about 12 hours and a D type cylinder for about 58 hours. However, the actual time may be lower due toleaks, etc.

Delivering oxygen using an oxygen cylinder:

1. After connecting the reservoir and opening the cylinder, adjust the flow in flowmeter
2. Start by using nasal prongs interface at flow rates 1-2 L/min (in the flow meter- ball should be at themiddle of the line to the set flow rate); or may use simple face mask at flow of 4 L/min
3. Titrate by increasing flow by 1 L/min every 10 minutes to a maximum of 4-6 L/min targeting SpO_2 92-96% (88-92% in COPD) when using nasal prongs; for face mask, may increase to 8- 10 L/min
4. If poor response: Use a non-rebreathing mask at 12-15L/min (reservoir should be fully inflated withno twist or kink) with target SpO_2 92-96% (88-92% in COPD).
5. Fill the water in the humidifier not exceeding maximum mark
6. Arrange for transfer to a centre with HFNC, Non-invasive and invasive ventilation if the saturations are not maintained/ deteriorate

*Ensure nose is clear and free of crusting while using nasal cannula

*If tolerated, a surgical mask worn over nasal cannula may improve oxygen delivery

*Try awake proning at every step – use one pillow below neck, one or two below the chest through upper thighs, two below shin, change to left lateral, right lateral and sitting up 60-90° every 30-120 minutes. (Refer to guidelines for proning: https://www.mohfw.gov.in/pdf/COVID19ProningforSelfcare3.pdf).

*Deep breathing exercises if possible

Oxygen delivery interfaces

Nasal prongs

- The 2 prongs are placed into the nostrilscurved downward
- Slide the tubing over and behind each ear
- Adjust the tubing to fitcomfortably under thechin by sliding the adjustor upward.
- Regularly check the ears and nose for pressure areas and sores
- Usual Flow rate 0.5- 2 L/min

Simple face mask

Place oxygen mask over nose and mouth

- Slide the loose elastic strap over your head andposition it above your ears
- Ensure adequate seal byadjusting the nose clip and the straps
- Usual Flow rate 4-6 L/min

Non rebreathing mask

Place oxygen mask over nose and mouth

- Slide the loose elasticstrap over your head and position it above your ears
- Ensure adequate sealby adjusting the nose clip and the straps
- Reservoir should be fully inflated with no twist or kink
- Usual Flow rate 10-15 L/min; the flow rate should not be reducedbelow 10 L/min

Oxygen Safety Guidelines

Oxygen supports combustion so any material that is already burning will burn much faster and hotter inan oxygen-enriched atmosphere. These precautions are to be followed

1. No smoking in the room containing oxygen concentrator or cylinders.
2. Keep the oxygen source at least five feet away electrical boards, burning candles, open flames, gas stoves, electrical appliances, any item or that may spark
3. Do not use aerosols near oxygen equipment.
4. Do not use oil or lubricants on oxygen equipment.
5. Turn your oxygen off when not in use. Ensure that there are no leaks
6. Do not store oxygen cylinders in heat or direct sunlight.
7. Secure oxygen cylinders in upright position properly in appropriate stands to prevent tipping or place them on their side on the floor. Be careful to not trip on oxygen tubing.
8. Always store oxygen concentrator and tanks in a well-ventilated area.
9. Oxygen tanks should not be left in vehicles or garages during extreme heat.
10. When driving, secure the oxygen unit so it will not tip over. Leave a window open slightly for ventilation so the oxygen will not accumulate in the car.