Medical Gas Supplies

Liverpool Heart and Chest Hospital NHS
NHS Foundation Trust

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Health Education England

e-LfH
e-Learning for Healthcare

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Learning Objectives

- Explain how to safely use medical gas pipelines and cylinders on an anaesthetic machine
- Accurately describe the capacity and usage of common oxygen cylinder sizes
- Explain how to prevent pipeline and cylinder misconnections
- Describe the steps involved in changing an oxygen gas cylinder

Introduction

The gases used in anaesthesia are primarily oxygen, air and nitrous oxide.

An understanding of how to use them is an essential part of being a safe anaesthetist.

There are many safeguards built into modern anaesthetic machines to reduce the chances of accidents from medical gases occurring. Despite these, it is still possible to deliver gases of dangerous composition and pressures to patients.

Pressure Units

The variety of pressure units used both on devices and in texts can be confusing. The SI unit of pressure is the pascal (Pa) and is equivalent to a force of 1 newton applied over an area of 1 m^2.

For medical gases, pressures are usually expressed as kPa equivalent to 1000 Pa.

1 atmosphere equates to (approximately):

1 bar

15 pounds per square inch (psi)

100 kPa

1033.23 cmH_2O

Liquid Oxygen Storage

In most hospitals oxygen is stored as a liquid in a large vacuum flask, i.e. a Vacuum Insulated Evaporator or VIE (Fig 1).

The oxygen is liquefied by cooling it to -150°C and is kept at a pressure of 1000 kPa (10 atmospheres).

Before being supplied for use in the hospital the oxygen is allowed to warm up to room temperature.

Question: Why do you think this is done?

Answer: The oxygen is allowed to warm up to room temperature so that it turns back into a gas and the pressure is regulated to a pressure of 440 kPa.

This process allows large amounts of oxygen to be stored in a relatively small container.

A backup supply is maintained by a second smaller VIE or a bank of large steel cylinders.

Vacuum Insulated Evaporator

Insulated Evaporator

The final pipeline pressure for delivery into the hospital is regulated to 440 kPa.

In the past the contents of the evaporator were determined by placing it on a large set of weighing scales.

Modern VIEs measure the pressure difference between the top and the bottom of the liquid oxygen chamber, from which the remaining contents can be calculated.

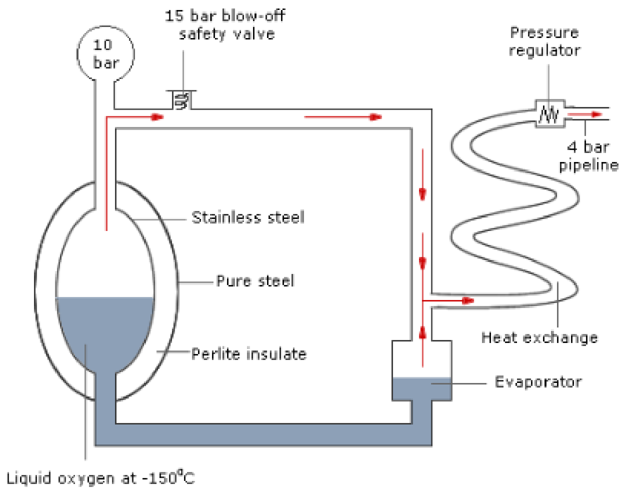


Fig 1 Vacuum Insulated Evaporator

Information

Nitrous oxide is stored in large banks of cylinders known as cylinder manifolds, and is delivered to gas outlets at 440 kPa (Fig 1).

Fig 1 Nitrous oxide bank or manifold

Medical air is usually supplied from a compressed air plant that includes high-quality drying and filtration (Fig 2). Blending oxygen and nitrogen on-site can also provide medical air. Where such systems are installed to provide both oxygen and medical air, nitrogen can be used for the power source for surgical tools. It is delivered to gas outlets at 440 kPa (MA4).

Fig 2 Medical air compressor

Learning Objectives

Medical air can also be supplied at the higher pressure of 700 kPa (MA7) for powering surgical tools, this may be supplied from special cylinders (Fig 3).

Fig 3 MA7 Cylinder which is used for powering surgical tools

Suction is generated by a large vacuum plant within the hospital. Care is taken that fluids and other waste materials are not drawn into the system (Fig 4).

Fig 4 Suction is generated by a large vacuum plant within the hospital

Oxide

In a cylinder of nitrous oxide there is a mixture of liquid and gas exactly like a butane lighter. As gas is removed so more of the liquid evaporates and the cylinder cools.

Because there is a mixture of liquid and gas the pressure in the cylinder does not reflect the amount of nitrous oxide left but is instead the saturated vapour pressure. To measure the amount of nitrous oxide left the cylinder needs to be weighed.

In practice, it is now very unusual to use nitrous oxide from machine mounted cylinders.

Nitrous oxide cylinders

Medical Gases Entonox

Entonox is a 50:50 mixture of nitrous oxide and oxygen that was introduced in the 1970s. It is very widely used as an analgesic in obstetrics, trauma and for minor procedures. It is usually delivered through a demand valve enabling the patient to have some control and to reduce the risk of producing excessive sedation.

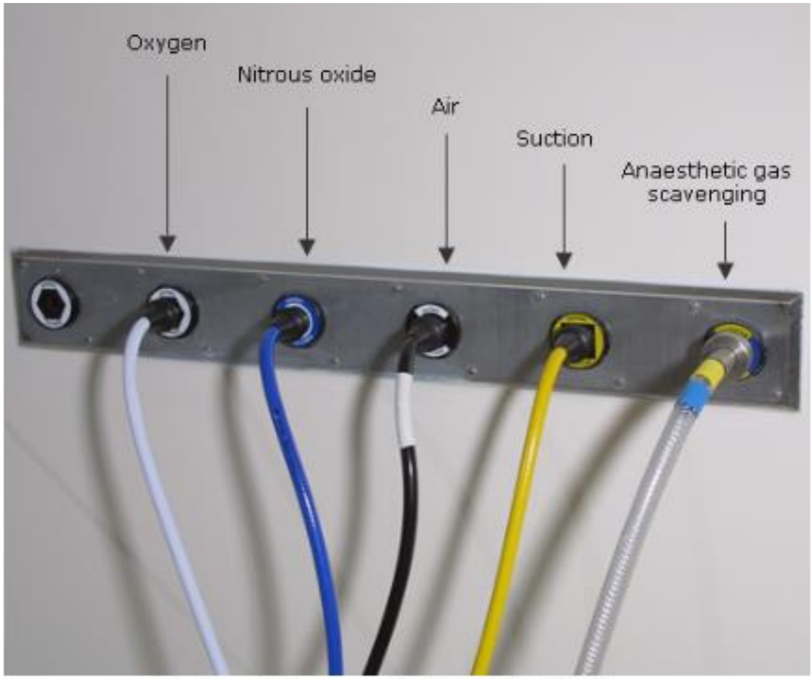
Unlike nitrous oxide, Entonox ® is in gas form in the cylinder and is produced using the Poynting effect where there is dissolution of gaseous oxygen when bubbled through liquid nitrous oxide, with vaporization of the liquid to form a gaseous oxygen/nitrous oxide mixture.

Entonox ® is stored in white or blue cylinders with blue and white shoulders. It is supplied in cylinders at a pressure of 137 bar and must be stored above its pseudocritical temperature of -6°c. Below this temperature the nitrous oxide liquefies in a process called lamination.

Entonox® cylinder

Medical Gas Pipelines
Pipelines and Outlets

- It is essential that the correct pipelines are inserted into the correct outlets.
- Pipelines and outlets are coloured to aid identification:
- White - Oxygen
- Blue - Nitrous oxide
- Black - Air
- Yellow - Suction
- Clear - Anaesthetic gas scavenging



Colours are used for the pipelines and outlets to aid identification

Medical Gas Pipelines
Probe and Socket System

As well as having pipelines and outlets that are coloured, a non-interchangeable probe and socket system is employed to ensure the correct connections are always used.

A non-interchangeable probe

A non-interchangeable socket

Medical Gas Pipelines
Probe and Socket System

Medical gases use a standard Schrader tapered probe; this makes a gas tight connection into a female tapered socket (Fig 1).

The probe is held in place by two metal bars which grip a groove cut into the probe (Fig 2).

The probe is made non-interchangeable by the addition of a diameter indexed collar (Fig 3).

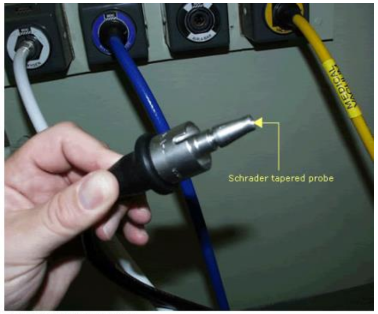


Fig 1 Schrader tapered probe

Fig 2 Groove in probe

Fig 3 Diameter indexed collar

Medical Gas Pipelines
Probe and Socket System

Both the internal and external diameter of the collar are fixed. The notch cut into the collar prevents the probe rotating in the socket (Fig 4).

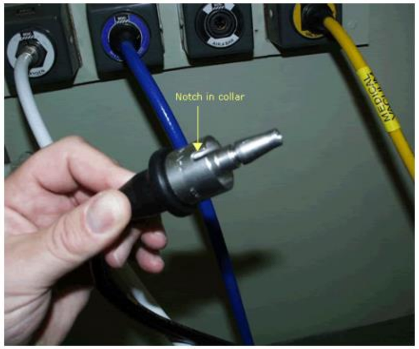


Fig 4 Notch in collar

At the outlet the indexing is provided by a ring which has a fixed internal and external diameter (Fig 5).

Fig 5 MA4 outlet showing fixed internal diameter

Both are required so as to prevent a probe with a small collar being inserted into a large diameter outlet (Fig 6).

Fig 6 MA4 outlet showing fixed external diameter

Connector

It is also essential that the pipelines are correctly connected at the anaesthetic machine end. This is achieved using a series of non-interchangeable screw threads (NIST).

Fig 1 shows a white oxygen pipeline attached to the back of an anaesthetic machine using a NIST connector.

These connections are not disturbed in normal practice.

Any loose connections, damaged hoses or gas leaks must be reported immediately.

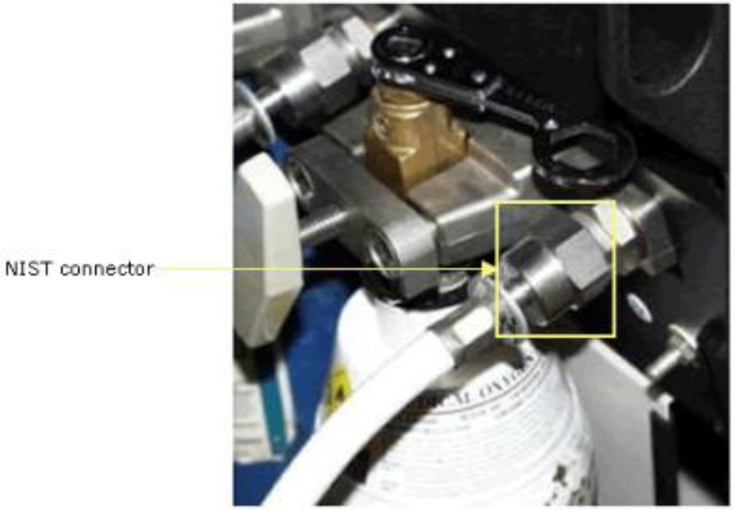


Fig 1 A white oxygen pipeline attached by a NIST connector

Medical Gas Cylinders
Gas Used

Modern anaesthetic machine cylinders are now only used as an emergency backup supply. Although air, nitrous oxide and carbon dioxide can all be supplied from cylinders attached to the anaesthetic machine, it is really only essential to have a backup supply of oxygen.

Cylinders contain gas at very high pressure. These high and variable pressures are reduced to the far lower and constant working pressure of the machine, similar to the pipeline value of 440 kPa:

Gas	kPa (full cylinder)	Bar
Oxygen	13 700 kPa	(137 bar)
Nitrous oxide	4400 kPa	(44 bar)
Air	13 700 kPa	(137 bar)

Fig 1 Oxygen cylinder

Medical Gas Cylinders
Cylinder Fittings

The high pressure involved means that cylinder fittings must be strongly constructed.

Fig 1 shows a standard oxygen cylinder fitting called a yoke, which is constructed from a solid block of stainless steel. The yoke supports the full weight of the cylinder here and is called a hanging yoke.

Modern yokes are designed so that they cannot be fully opened under pressure.

The cylinder valve must be fully closed before the yoke is opened, as release of gas at high pressure can be very dangerous.

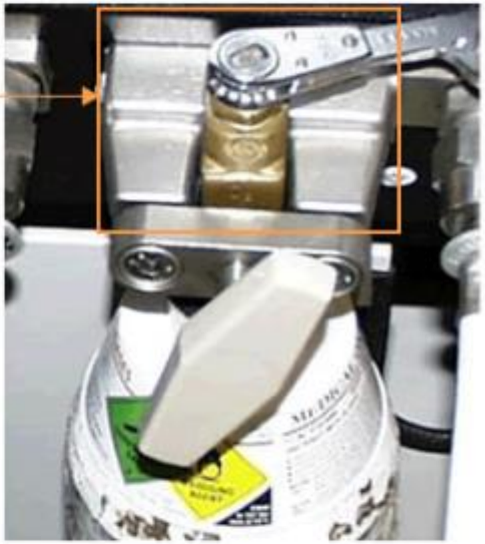


Fig 1 Oxygen cylinder yoke

A gas-tight seal is made between the cylinder and the yoke using a specialized washer called a Bodok seal (sometimes spelt Bodock).

A Bodok seal is a deceptively clever piece of equipment and comprises a neoprene washer surrounded by an aluminium ring.

A plastic washer alone would not withstand the high pressures involved. As the pressure builds up in the centre of the washer it tries to expand outwards but cannot do so because of the aluminium ring, so it becomes fatter instead making an even better seal.

It is essential that only one seal is used between the cylinder and the yoke.

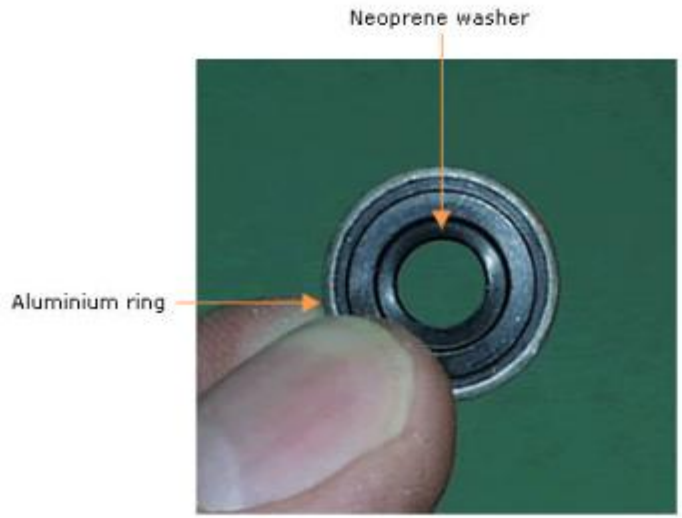


Fig 1 Bodok seal

Gas Cylinders

It is also necessary to ensure that the correct cylinder is attached to the correct yoke; this is achieved using a pin indexing system (Fig 1).

Fig 1 The yoke side of the system

Pin indexed cylinders have holes drilled in them to match the pins in the yoke; in positions specific for each gas (Fig 2).

Fig 2 Holes in cylinder which match pins in the yoke

Medical Gas Cylinders
Cylinder Pin Indexing

There are six possible pin positions and the pins must be correctly engaged before tightening the yoke (Fig 3). Two pin positions are used for all gases except entonox ® .

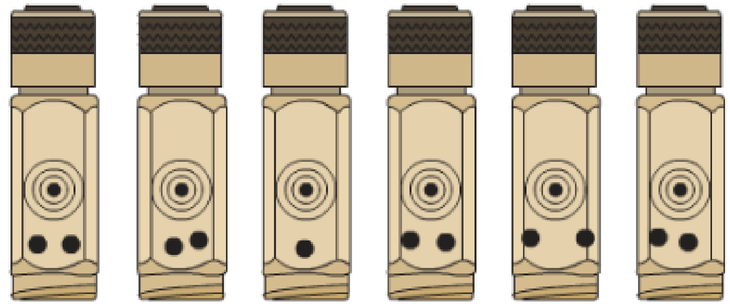


Fig 3 Cylinder pin indexing system

Table 1 gives a summary of medical gas cylinders, including their pin index.

	Physical state in cylinder	Colour (International)	Formula	Pin index
Oxygen	Gas	White	O_2	2-5
Nitrous oxide	Gas (liquid below 98ºF)	Blue	N_2O	3-5
Air	Gas	Black/white	-	1-5
Carbon dioxide	Gas (liquid below 88ºF)	Grey	CO_2	1-6
Entonox ®	Gas	Blue/white	-	7
Nitrogen	Gas	Black	N_2	1-4
Helium	Gas	Brown	He	No pin

Table 1 Summary of medical gas cylinders

Medical Gas Cylinders
Bull Nose Cylinder

The other type of cylinder fitting is called a bull nose. This is typically used on larger cylinders (F and G) found on the wards.

The fitting is **not** gas specific and an air regulator can be fitted to an oxygen cylinder.

The threads are cut so that it is very difficult to undo when under pressure.

They often leak when old and the cylinder should be turned off when not in use.

Fig 1 Bull nosed oxygen cylinder

Changing an Oxygen Cylinder

You should be able to change an oxygen cylinder quickly and safely:

The steps are:

- Turn the old cylinder fully off
- Vent through the anaesthetic machine using oxygen flush
- Open the yoke and remove the old cylinder
- Check the Bodok seal is in place
- Fit the new cylinder to the yoke
- Close and tighten the yoke clamp
- Open the new cylinder
- Check for leaks and cylinder pressure

Oxygen Cylinder Sizes

Oxygen cylinders come in a range of different sizes but only a small selection are commonly used in anaesthesia.

E size Cylinder: holds 680 L when full and is used on most
machines

D size cylinder: holds 340 L when full and is used for transport

Oxygen Cylinder Sizes

G size cylinder: holds 3400 L when full. It is usually supplied with a bull nose fitting rather than a pin index one and is used on the wards

Kevlar wrapped aluminium cylinder: holds 460 L when full and is filled to a pressure of approximately 20 000 kPa (200 bar). It is a lightweight cylinder with an integral reducing valve used for transport