Medical gases, their storage and delivery

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Abstract

Medical gas production, storage and delivery is a complex process. Design of such a system must ensure that gas delivery is safe, convenient and cost-effective. This article reviews the production, storage and delivery of commonly used anaesthetic gases, following the gases from production to delivery.

Keywords Cylinders; manifolds; medical gases; medical gas pipeline systems; vacuum-insulated evaporators

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Learning objectives

After reading this article, you should be able to describe:

- methods of production, storage and delivery of commonly used anaesthetic gases
- safety issues pertinent to the handling of medical gases
- how a vacuum-insulated evaporator functions
- definitions required for the FRCA examination

Oxygen

Oxygen production

Oxygen is commercially manufactured in large volumes by two mechanisms: fractional distillation of liquid air and oxygen concentrators which pass air through molecular sieves of zeolite.

Fractional distillation of air involves cooling and compressing air into a liquid and separating it into its main component gases; oxygen, nitrogen and argon. Air is first filtered, removing impurities and then cooled to −200°C. Carbon dioxide freezes at −79°C and is discarded at this point, but oxygen only liquefies at −183°C.

At −200°C the liquid air (now free of carbon dioxide) is passed into the bottom of a fractioning column which is warmer at the bottom (−185°C) than it is at the top (−195°C). Liquefied nitrogen (nitrogen liquefies at −195°C) boils and returns to its gaseous form and exits via the top of the column leaving liquid oxygen and argon. Both have similar boiling points and, therefore, require another fractioning column in order to produce pure oxygen.[1]

Oxygen concentrators are devices for extracting oxygen from atmospheric air. They range in size, from small portable units to large ones capable of supplying entire hospitals. Typically oxygen concentrators are useful in the community where lower flows of 2–4 litres/minute oxygen are required. However, modern oxygen concentrator units can achieve flows as high as 10 litres/minute.

Air is passed through a column of zeolite at high pressure (138 kPa), which acts as a molecular sieve, trapping nitrogen and water vapour leaving behind almost pure oxygen. There are two zeolite columns. Once the first zeolite cylinder becomes saturated (within seconds), the compressed air is fed to the second cylinder, whilst the first is vented to atmospheric pressure allowing the nitrogen to escape. Once the second cylinder becomes saturated, the compressor switches back to the now-available first, and the cycle repeats once again.

Oxygen storage

Medical oxygen can either be stored in cylinders or in vacuum-insulated evaporators (VIE).

Oxygen cylinders have a black body and white shoulders and contain gaseous oxygen at a pressure of 13,700 kPa at room temperature. Oxygen cylinders may be made of a variety of materials, but typically molybdenum steel is used to allow for higher filling pressures although it is heavy and less portable. Aluminium cylinders are 25–40% lighter and suitable for use in MRI scanners.

Cylinders are hydraulic and endoscopically tested on a regular basis (10 years for steel cylinders) with the date of the next test indicated by a plastic ring around the neck of the cylinder.[2]

Oxygen storage in a VIE is discussed later.

Nitrous oxide

Nitrous oxide production

Nitrous oxide is manufactured by carefully heating ammonium nitrate to 250°C to produce nitrous oxide and water vapour.

Nitrous oxide storage

Nitrous oxide is stored in blue cylinders at a gauge pressure of 4400 kPa in both liquid and vapour forms. As the cylinder empties, a constant pressure of 4400 kPa is maintained by evaporation of liquid until it is all depleted. The pressure will then fall rapidly with further emptying until supplies are exhausted; a similar process to propellant in a spray can.

A completely filled liquid cylinder can rapidly expand with increasing temperatures. Liquid cannot be compressed and there is a risk of explosion. In order to remove this risk, manufacturers only partially fill cylinders allowing for a layer of vapour to form above the liquid. As the temperature increases and the liquid expand, the vapour is compressed and condenses avoiding excessive changes in pressure within the cylinder. The term ‘filling ratio’ is used to describe how much liquid is added to each cylinder.

The filling ratio is the mass of gas in a cylinder divided by the mass of water required to fill the cylinder. As 1 litre of water weighs 1 kg, the filling ratio of a cylinder is the mass of nitrous oxide in kilograms divided by the internal volume of the cylinder in litres.[3]

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Volumes and filling pressures of commonly used cylinders

Size	C	CD/DD	D	E	F	HX	G	J	ZX
Volume (litres)	170	460	340	680	1360	2300	3400	6800	3970
Filling pressure oxygen bar	137	230	137	137	137	230	137	137	300

Table 1

A filling ratio of 0.75 is adopted in temperate climates whereas a filling ratio of 0.69 is adopted in hotter climates.

Entonox

Entonox production

Entonox is a mixture of 50% oxygen and 50% nitrous oxide and manufactured by mixing these two separate components together utilizing the 'Poynting effect'.

The Poynting effect describes the passing of gaseous oxygen through liquid nitrous oxide. Vaporization of the liquid occurs, forming a 50:50 mixture of oxygen and nitrous oxide.[3]

Entonox storage

Entonox is stored in cylinders with a blue body and blue/white quarter shoulders, at 13,700 kPa in its gaseous form.[2] Careful storage of Entonox is essential because of the risk of separation of the nitrous oxide and oxygen below its pseudocritical temperature.

Pseudocritical temperature refers to the temperature at which a mixture of gases will separate out into its constituent parts.

Entonox separates into nitrous oxide and oxygen at −5.5°C at 117 bar, −7°C at 137 bar (cylinder pressure) and −30°C at 4 bar (pipeline pressure). If the pseudocritical temperature is reached, there is a danger of an initial 100% oxygen delivery followed by a 100% nitrous oxide — a hypoxic gas. To avoid this, cylinders must be stored well above its pseudocritical temperature so if cylinders have been in a colder environment, it is recommended that they are first warmed to a temperature above 10°C and then agitated. Hospitals normally use size D cylinders which must be stored horizontally.

Cylinder colours

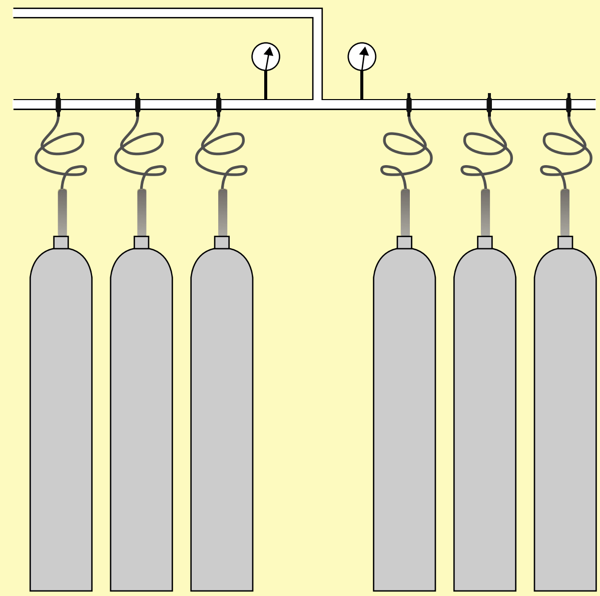
Body colour	Shoulder colour	Cylinder contents	Pin index
Black	White	Oxygen	2&5
Blue	Blue	Nitrous oxide	3&5
Grey	Grey	Carbon dioxide	1&6
Grey	White/black quarters	Air	1&5
Blue	White/blue shoulders	Entonox	
Black	White/brown quarters	Heliox	

Table 2

Medical air

Gaseous medical air is stored in grey cylinders with white/black quarter shoulders at 13,700 kPa or via pipeline air supplied at 400 kPa.

Cylinder manifold



- Two banks of cylinders
- Manifold automatically changes over between each bank of cylinders in the primary supply system
- Secondary system present in the same room provides 4 hours of oxygen supply during damage or repair

Figure 1 Cylinder manifold showing two banks of cylinders.

