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anesthesia

Lecture of anesthesia equipment

Teaching by

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Uses of Physical Principles in Anesthetic Practice:

PRESSURE:

Knowledge of pressure is very important to anesthetist.Understanding the various concept of pressure is a necessity.

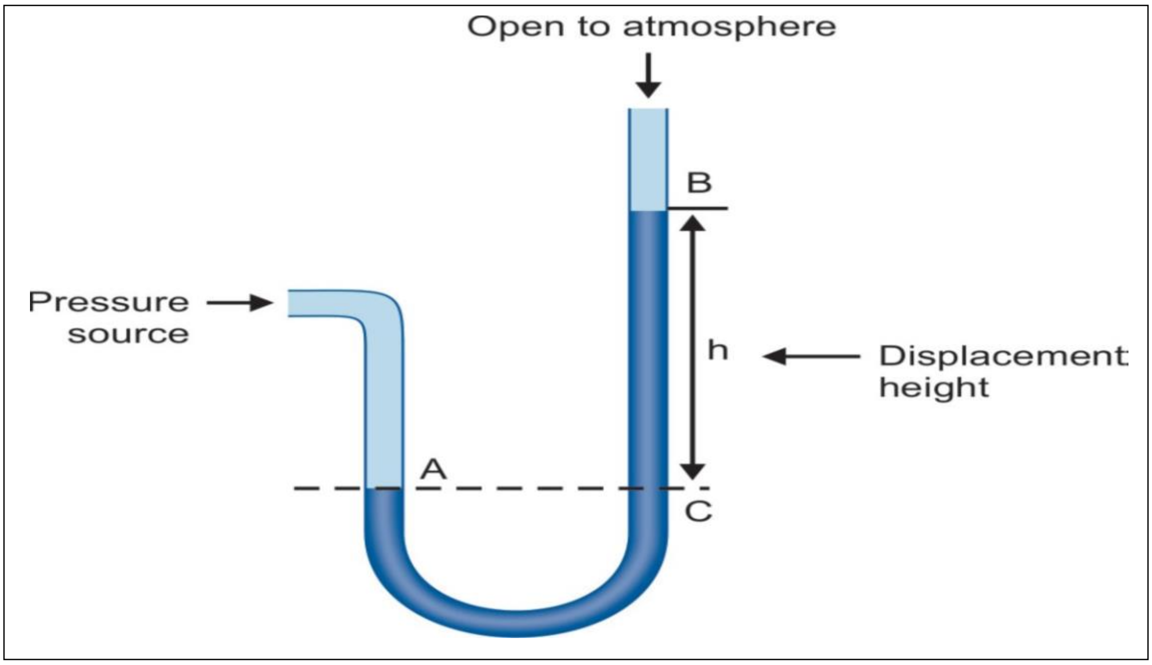
Vacuum is a space where there is zero pressure. We do not find vacuum routinely. At sea level, the pressure of air surrounding us is 1 atm. Pressure is defined as force acting per unit area (P = f/a). Pressure is measured in various units. In SI system, pressure is measured in Pascal (Pa) where 1 Pa is a pressure of 1 N acting over an area of 1 m2. Since 1 Pa represents a tiny pressure, it is more commonly represented as kilopascal (kPa). There are several units used to measure pressure depending upon which type of pressure is being measured.

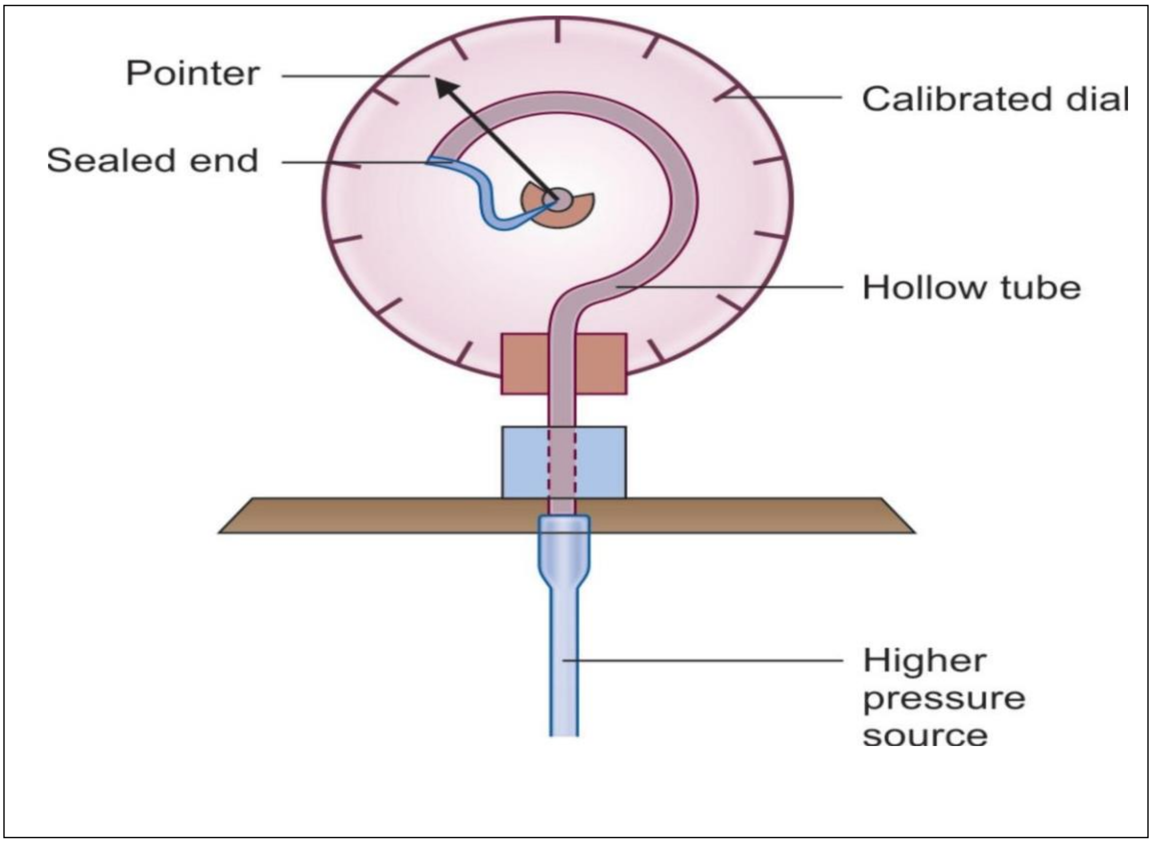
	atm	kg/cm^2	bar	psi	kPa	cm H_2O	mm Hg
atm	1	1.033	1.013	14.7	101.325	1,034	760
kg/cm^2	0.968	1	0.980	14.22	98.067	1,001	735.6
bar	0.987	1.02	1	14.504	100	1,021	750.1
psi	0.068	0.070	0.068	1	6.895	70.38	51.715
kPa	0.009	0.010	0.01	0.145	1	10.207	7.5
cm H_2O	0.0009	0.001	0.0009	0.014	0.098	1	0.735
mm Hg	0.001	0.001	0.001	0.019	0.133	1.36	1

Pressure Measuring Devices At sea level, all objects are subjected to 1 atm. All pressure measurements are done keeping this (1 atm) as a zero point, and hence they are called relative pressures (also known as gauge pressure).

Manometer:

This is a simplest way of measuring pressure. The pressure is simply measured by vertical displacement of the liquid in the manometer tube. The measuring pressure source is applied at one end and the other end is kept open to atmosphere. The displacement is also dependent on the density of the liquid. Such manometer is routinely used to measure blood pressure (where mercury is used as a liquid) and also while measuring central venous pressure (where saline is used as a liquid).





The gas laws:

The gas laws help us predict behavior of gases whenever there is achange in temperature and pressure. So lets define gas first. A gas is a substance that is in gaseous phase above its critical temperature. Critical temperature is the temperature above which a gas cannot be liquefied no matter how high the pressure. A vapor in contrast is a substance in the gaseous phase, but is below its critical temperature.

"Boyle's law":

states that at constant temperature, the volume of a given mass of gas varies inversely with the absolute pressure **(at constant T, P&1/V)** ,**(p1v1=p2v2),** e.g. if a gas is forced in smaller cylinder from larger cylinder, pressure inside the smaller cylinder will be much higher than larger cylinder.

"Charles' law":

states that at constant pressure, the volume of a given mass of gas varies directly with the absolute temperature **(at constant P, V & T)**,**(V1/T1=V2/T2)** e.g. gases expand when they are heated and become less dense, thus hot air rises.

"The third perfect gas law (Gay-Lussac's law)":

states that at constant volume, the absolute pressure of a given mass of gas varies directly with the absolute temperature **(at constant V, P& T).** For this reason, gas cylinders should be filled keeping in mind ambient temperature of storage. If temperature in storage place is high, the pressure inside the cylinder will increase leading to explosion.

The Combined Gas law:

P1V1/T1=P2V2/T2

Avogadro's law:

(N&V), (N= number of molecule), (V=volume), **(V1/N1=V2/N2)**, eg: balloon.

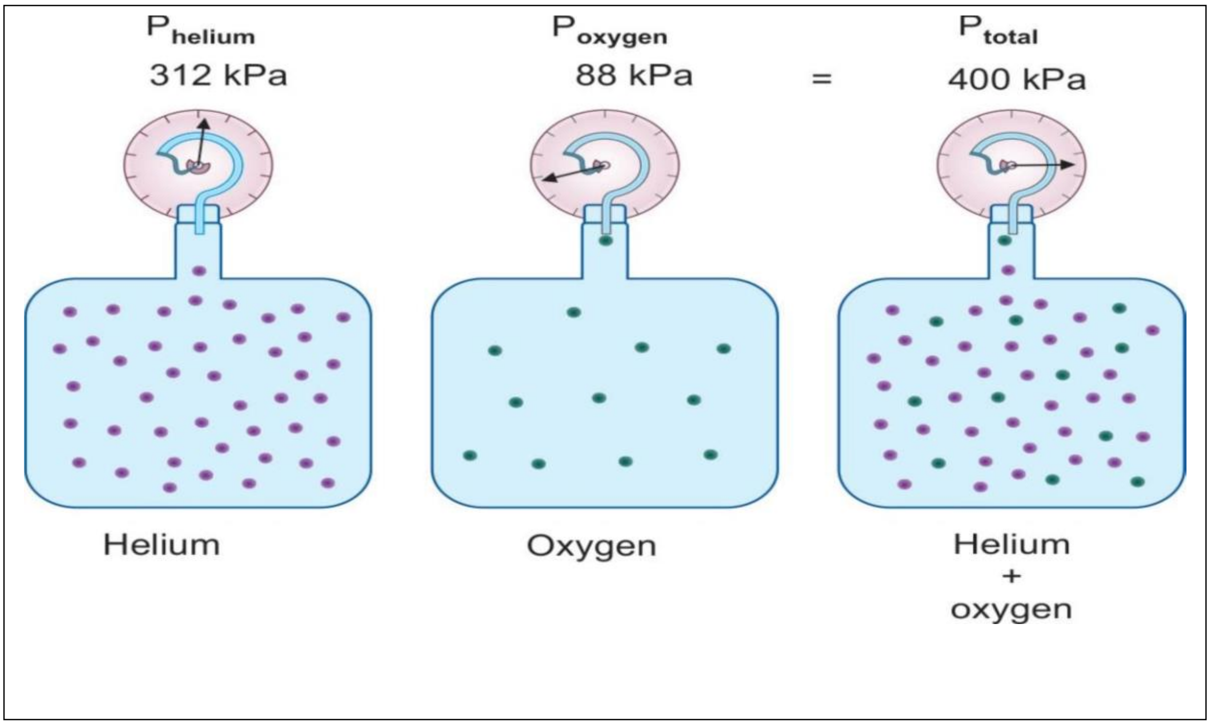
"Avogadro's law" states that equal volume of gases, at the same temperature and pressure, contain the same number of molecules.

If Avogadro's law is applied to combined gas law, it gives "universal" gas law. **(PV = nRT)**

The practical application of this law is the use of pressure gauges to assess the contents of a cylinder. If the volume, temperature and gas constant remain the same then pressure is proportional to n, the number of moles.

<u>"Dalton's law of partial pressures":</u>

states that in a mixture of gases, the pressure exerted by each gas is the same as that which it would exert if it alone occupied the container. That means the total pressure in a gas mixture is the sum of the partial pressure of each individual gas,**(PTOT=P1+P2+P3).**



So if a cylinder of gas mixture at 400 kPa contains 21% oxygen and 79% helium, then if the oxygen existed on its own it would exert a partial pressure of 21% of 400 kPa = 88 kPa. The helium, therefore, exerts a partial pressure of 400 – 88 = 312 kPa.

Medical Gas Supply, Storage, and Safety....

Gases used in anesthesia as well as medical practice are either provided in the form of cylinders or medical gas piping system. It is very important for anesthesiologists to understand the complexity of these systems, The medical gases commonly used in operating rooms are oxygen, nitrous oxide, air, and nitrogen. Although technically not a gas, vacuum exhaust for waste anesthetic gas disposal (WAGD or scavenging) and surgical suction must also be provided and is considered an integral part of the medical gas system.

The anesthesiologist must understand both these elements to prevent and detect medical gas depletion or supply line misconnection. Estimates of a particular hospital's peak demand determine the type of medical gassupply system required.

Cylinders/Parts of cylinder:

• Body • Valve • Port • Stem • Pressure relief devices.

1. Cylinders are made of thin walled seamless **molybdenum** steel in which gases and vapors are stored under pressure. They are designed to withstand considerable internal pressure.

2. The top end of the cylinder is called the neck, and this ends in a tapered screw thread into which the valve is fitted. The thread is sealed with a material that melts if the cylinder is exposed to intense heat. This allows the gas to escape so reducing the risk of an explosion.

3. There is a plastic disc around the neck of the cylinder. The year when the cylinder was last examined can be identified from the shape and colour of the disc.

4. Cylinders are manufactured in different sizes (A to J). Sizes A and H are not used for medical gases. Cylinders attached to the anaesthetic machine are usually size E, while size J cylinders are commonly used for cylinder manifolds. Size E oxygen cylinders contain 680 L, whereas size E nitrous oxide cylinders can release 1800 L. The smallest sized cylinder, size C, can hold 1.2 L of water, and size E can hold 4.7 L while the larger size J can hold 47.2 L of water.

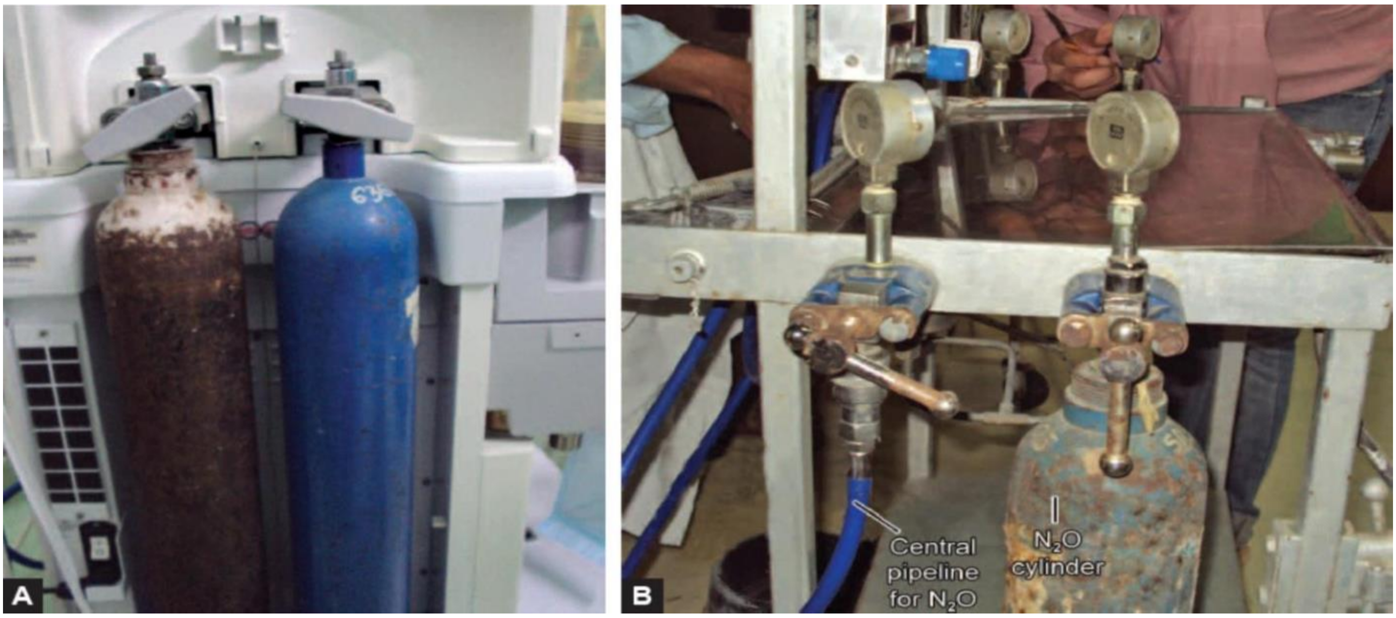
5. Lightweight cylinders can be made from aluminium. These can be used to provide oxygen at home, during transport or in magnetic resonance scanners. They have a flat base to help in storage and handling.

6. Oxygen is stored as a gas at a pressure of 13 700 kPa whereas nitrous oxide is stored in a liquid phase with its vapor on top at a pressure of 4400 kPa. As the liquid is less compressible than the gas, this means that the cylinder should only be partially filled. The amount of filling is calledthe filling ratio. Partially filling the cylinders with liquid minimizes the risk of dangerous increases in pressure with any increase in the ambient temperature that can lead to an explosion. In the UK, the filling ratio for nitrous oxide and carbon dioxide is 0.75. In hotter climates, the filling ratio is reduced to 0.67.

The filling ratio is the weight of the fluid in the cylinder divided by the weight of water required to fill the cylinder.

Gas	Color	Pin index	Size	Gas capacity (L)	Water capacity (L)	Service pressure
O_2	Black body, white shoulder	2:5	C	170	1.2	1987 psi/137 bar
			D	340	2.32	
			E	680	4.68	
N_2O	Blue body, blue shoulder	3:5	C	450	1.2	750 psi/51 bar
			D	900	2.32	
			E	1,800	4.68	
CO_2	Grey body, grey shoulder	1:6	C	450	1.2	725 psi/50 bar
			D	900	2.32	
			E	1,800	4.68	

Service pressure is the maximum pressure at 70°F to which the cylinder is ordinarily filled. Pressure in a filled cylinder at 70°F may not exceed the service pressure marked on the cylinder.



Cylinder on anesthesia machine as a reserve stock

Labels and markings on the cylinder body

Important note (1) : A typical size E full oxygen cylinder delivering 4 L per minute will last for 2 hours and 50 minutes but will last only 45 minutes when delivering 15 L/min.

Important note (2): At constant temperature, a gas-containing cylinder shows a linear and proportional reduction in cylinder pressure as it empties. For a cylinder that contains liquid and vapor, initially the pressure remains constant as more vapor is produced to replace that used. Once all the liquid has been evaporated, the pressure in the cylinder decreases. The temperature in such a cylinder can decrease because of the loss of the latent heat of vaporization leading to the formation of ice on the outside of the cylinder.

Problems in practice and safety features:

1. The gases and vapours should be free of water vapour when stored in cylinders. Water vapour freezes and blocks the exit port when the temperature of the cylinder decreases on opening.

2. The outlet valve uses the pin-index system to make it almost impossible to connect a cylinder to the wrong yoke.

3. Cylinders are colour-coded to reduce accidental use of the wrong gas or vapour. In the UK, the colour-coding is a two-part colour, shoulder and body.

4. Cylinders should be checked regularly while in use to ensure that they have sufficient content and that leaks do not occur.

5. Cylinders should be stored in a purpose built, dry, wellventilated and fireproof room, preferably inside and not subjected to extremes of heat. They should not be stored near flammable materials such as oil or grease or near any source of heat. They should not be exposed to continuous dampness, corrosive chemicals or fumes. This can lead to corrosion of cylinders and their valves.

6. To avoid accidents, full cylinders should be stored separately from empty ones. F, G and J size cylinders are stored upright to avoid damage to the valves. C, D and E size cylinders can be stored horizontally on shelves made of a material that does not damage the surface of the cylinders.

7. Overpressurized cylinders are hazardous and should be reported to the manufacturer.

Cylinders in use are checked and tested by manufacturers at regular intervals, usually 5 years. Test details are recorded on the plastic disc between the valve and the neck of the cylinder. They are also engraved on the cylinder:

1. Internal endoscopic examination.
2. Flattening, bend and impact tests are carried out on at least one cylinder in every 100.
3. Pressure test: the cylinder is subjected to high pressures of about 22 000 kPa, which is more than 50% above their normal working pressure.
4. Tensile test where strips of the cylinder are cut and stretched. This test is carried out on at least one cylinder in every 100.

The marks engraved on the cylinders are:

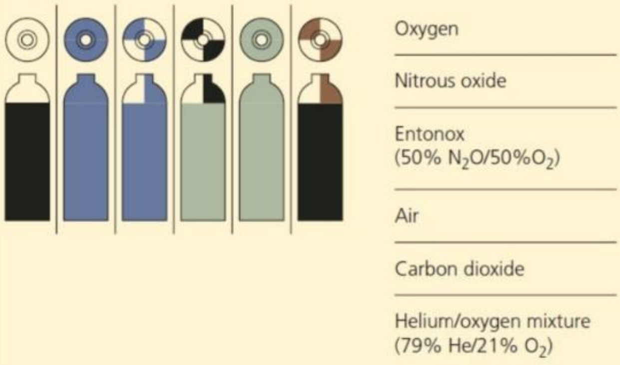
1. Test pressure.
2. Dates of test performed.
3. Chemical formula of the cylinder's content.
4. Tare weight (weight of nitrous oxide cylinder when empty).

Labelling

The cylinder label includes the following details:

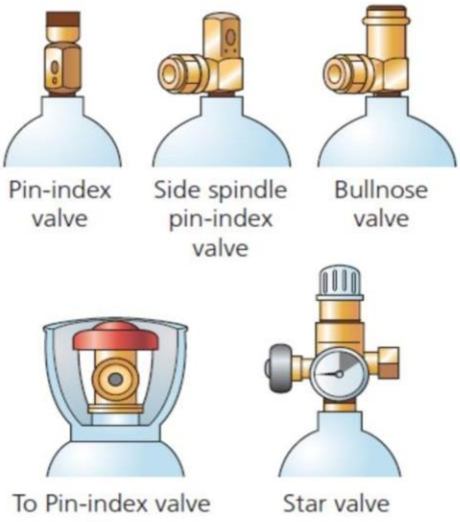
- Name, chemical symbol, pharmaceutical form, specification of the product, its licence number and the proportion of the constituent gases in a gas mixture.
- Substance identification number and batch number.
- Hazard warnings and safety instructions.
- Cylinder size code.
- Nominal cylinder contents (litres).
- Maximum cylinder pressure (bars).
- Filling date, shelf life and expiry date.
- Directions for use.
- Storage and handling precautions.

	Body colour	Shoulder colour	Pressure, kPa (at room temperature)	Physical state in cylinder
Oxygen	Black (green in USA)	White	13700	Gas
Nitrous oxide	Blue	Blue	4400	Liquid/vapour
Carbon dioxide	Grey	Grey	5000	Liquid/vapour
Air	Grey (yellow in USA)	White/black quarters	13700	Gas
Entonox	Blue	White/blue quarters	13700	Gas
Oxygen/helium (Heliox)	Black	White/brown quarters	13700	Gas

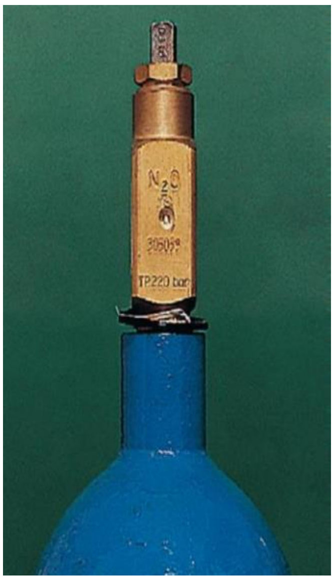


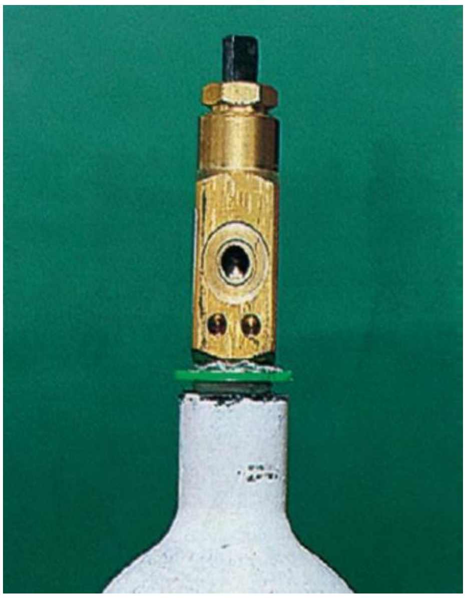
Cylinder valves:

These valves seal the cylinder contents. The chemical formula of the particular gas is engraved on the valve. Other types of valves, the bull nose, the hand wheel and the star, are used under special circumstances.



Valve types

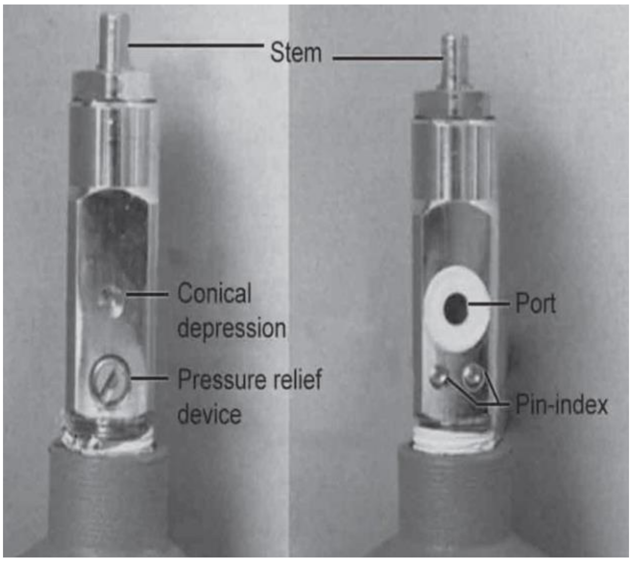


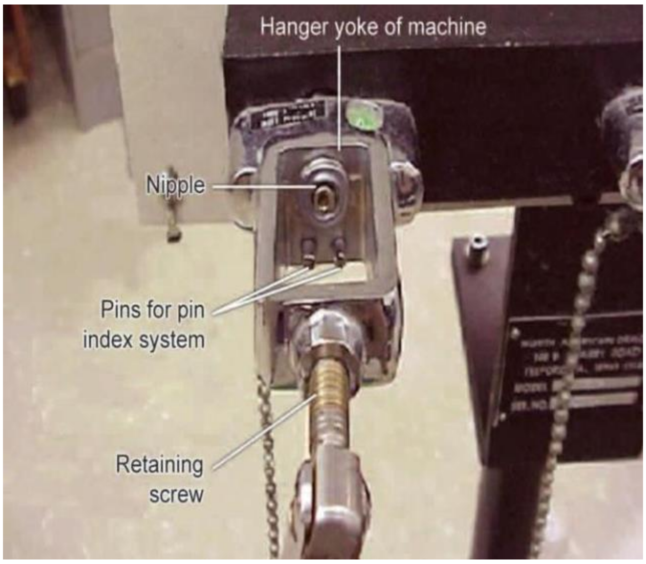


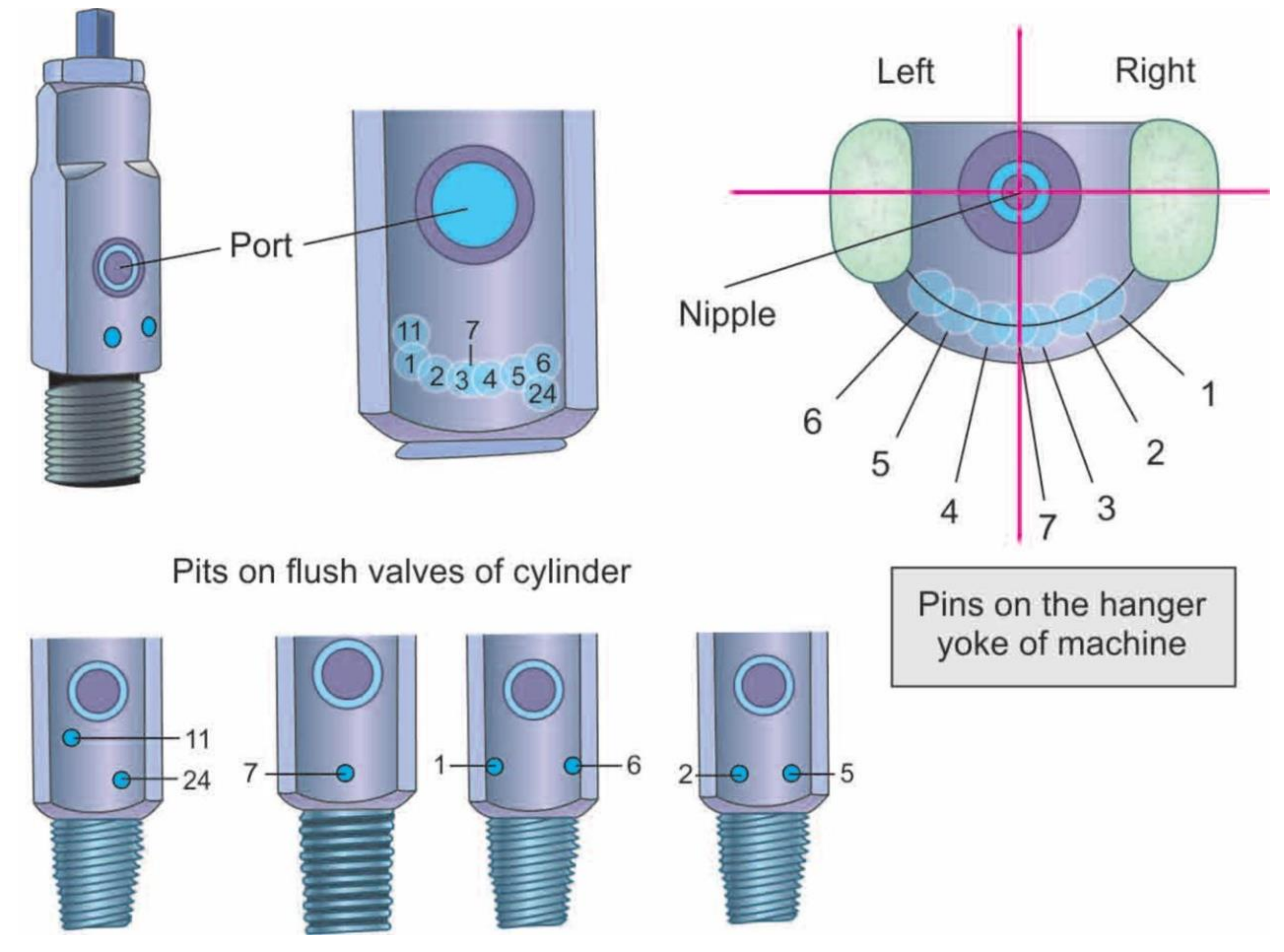
1. The valve is mounted on the top of the cylinder, screwed into the neck via a threaded connection. It is made of brass and sometimes chromium plated.
2. An on/off spindle is used to open and close the valve by opposing a plastic facing against the valve seating.
3. The exit port for supplying gas to the apparatus (e.g. anaesthetic machine).
4. A safety relief device allows the discharge of cylinder contents to the atmosphere if the cylinder is overpressurized.

5. The non-interchangeable safety system (pin-index system) is used on cylinders of size E or smaller as well as on F- and G-size Entonox cylinders. A specific pin configuration exists for each medical gas on the yoke of the anaesthetic machine. The matching configuration of holes on the valve block allows only the correct gas cylinder to be fitted in the yoke. The gas exit port will not seal against the washer of the yoke unless the pins and holes are aligned.

6. A more recent modification is where the external part of the valve is designed to allow manual turning on and off of the cylinder without the need for a key.







SAFETY FEATURES OF CYLINDERS:

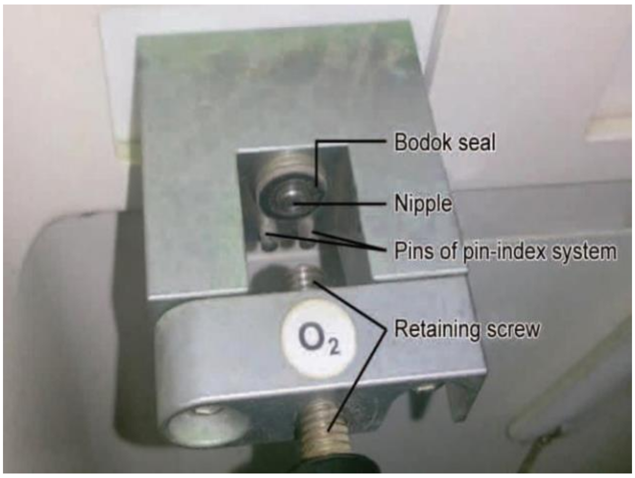
• **Molybdenum** steel alloy construction. This is stronger and lighter than its carbon steel predecessor

• **Color-coding for each gas or vapor**

• **Pin-index system:** This prevents the accidental connection of a cylinder/yoke block of one gas to the hanger yoke of another gas on the anesthesia machine or work station

• **Bodok seals (bonded disk):** These are noncombustible small metal and neoprene seal (neoprene washers with aluminum edges) to ensure a gas-tight fit between the cylinder and anesthetic machine yoke

• **Cylinder pressure indicator (gauge):** Bourdon pressure gauges are fitted adjacent to each yoke and pipeline connection on the machine. These are calibrated, labeled and color-coded for each gas.

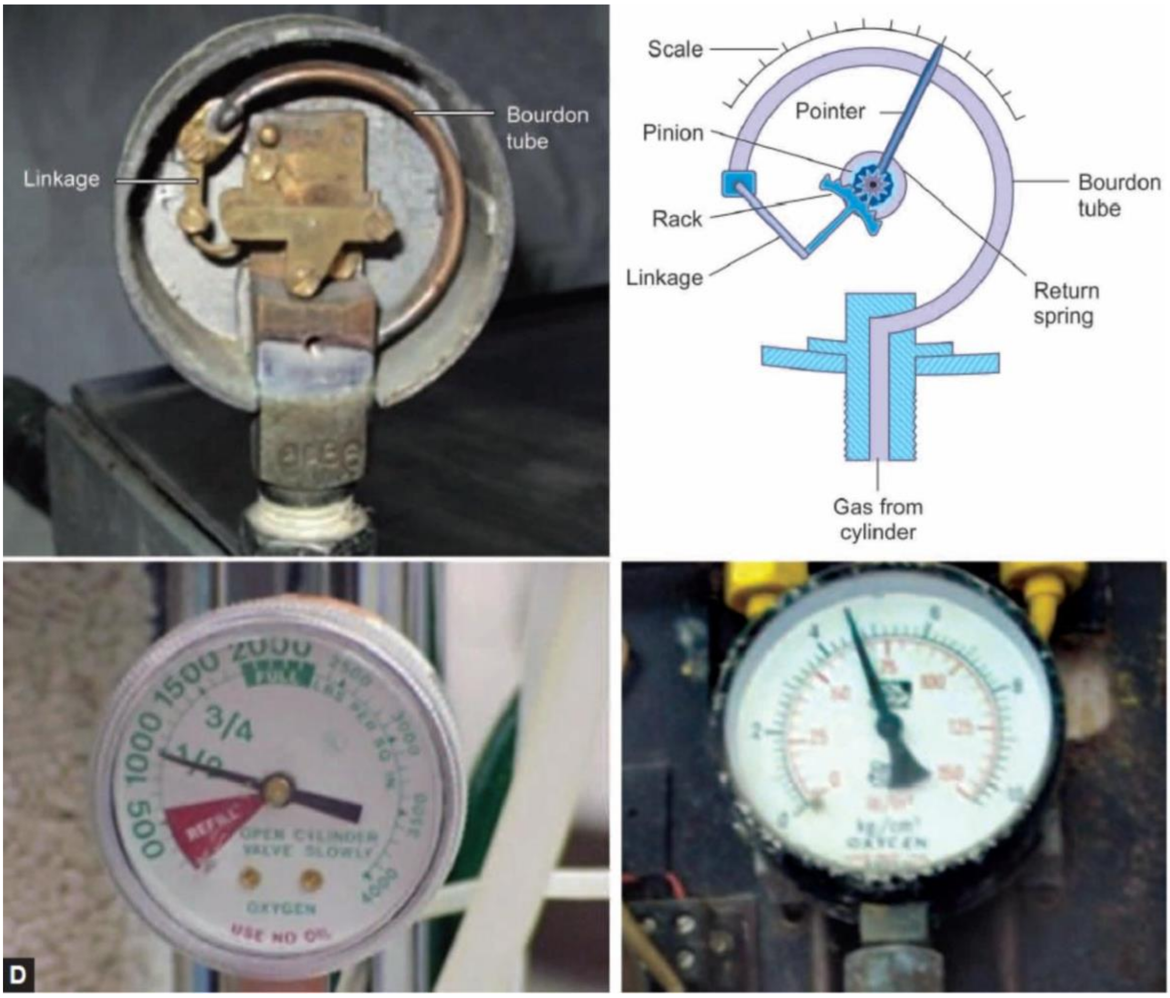


<u>Cylinder Pressure Indicator (Gauge)</u>

The anesthesia workstation standard requires that there be a pressure indicator to displays the cylinder pressure for each gas supplied by cylinders. The indicator may be located near the cylinders or on a panel on the front of the machine.

Many indicators are of the Bourdon tube (Bourdon spring, elastic element) .

A hollow metal tube is bent into a curve. One end is sealed and linked toa clocklike mechanism. The other end which is open is connected to the gas source. An increase in gas pressure inside the tube makes the curved tube to straighten out depending on the change in pressure. As the pressure falls, the tube resumes its curved shape. The open end is fixed and the sealed end moves. Movement of the sealed end is transmitted to the indicator, which moves over a calibrated scale. Cylinder pressure gauges are calibrated in kg/ cm2, pounds/inch2 or kilo Pascals (kPa).



Bourdon Tube Gauge When higher pressures are required to be measured like pressures in gas cylinder, simple manometer cannot be used. These higher pressures can be measured using a Bourdon tube gauge.

Important note:

As the cylinder content gets empty, the pressure in the cylinder falls proportionately if the cylinder contents are in gaseous form. If half of the content is over, the pressure drops to half of the original and so on. The same is not true for the gases in the liquid form. The pressure in the cylinder containing gases in liquid form remains as "full cylinder pressure" until the last drop of liquid form of gas vaporizes. This is because the pressure gauge reads the saturated vapor pressure of the liquid gas. Once all the liquid has evaporated, the pressure drops much faster till all the gaseous contents are over.

Pressure Relief Devices

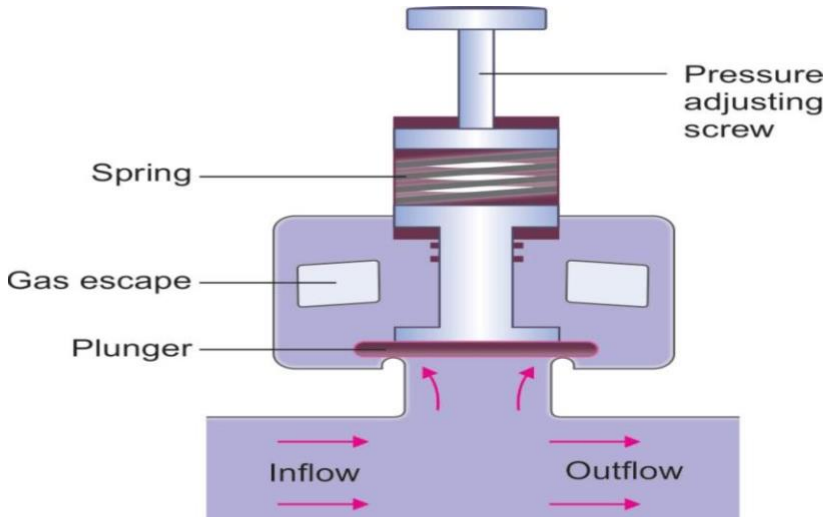
Every cylinder is fitted with pressure relief (safety relief/safety) device. The whole purpose of this device is to vent the cylinder's content to atmosphere rather than the cylinder bursting if the pressure of enclosed gas increases to dangerous level.

Types

1. Rupture disk: When predetermined pressure is reached, the disk ruptures and allows the cylinder content to be discharged. It is a non-reclosing device held against an orifice. It protects against excess pressure as a result of high temperature or overfilling.

2. Fusible plug

3. Spring-loaded pressure relief valve: It is a reclosing device. When the set pressure is exceeded, the pressure in the cylinder forces the spring to open the channel for letting out gases and gas flows around the safety valve seat to the discharge channel till the excess pressure is relieved.



Cylinder Key (Handle) or Handwheel:

A cylinder key (handle) or hand wheel is used to open or close a cylinder valve. It is turned counterclockwise to open the valve and clockwise to close it. This causes the stem to turn. A cylinder key (handle) is used to open a small cylinder valve. They come in a variety of shapes.

Hazards

• Incorrect cylinder contents

• Incorrect valve

• Incorrect color, labeling

• Inoperable valve, damaged valve

• Suffocation, fires, explosion, and thermal injury

• Contamination of contents • Overfilling.

Rules for Safe Use of Cylinders

• To be handled only by trained staff

• Store cylinders in a cool, clean room with adequate ventilation

• Do not drape cylinders with any material during storage

• Cylinders are best stored upright in a cylinder stand

•Should be grouped by contents or sizes

•Good segregation between empty and full cylinders

•To be kept away from oils, rubber and other combustible Substances

•Never to expose cylinders to heat or higher temperatures

•Never interchange parts of cylinder used for one gas with other

• Take care to avoid obstructions to discharge ports

•Keep the valve closed when not in use

•Identify contents by label

•Remove wrappings (protective cover) before using

•Remove dust and foreign bodies before connecting

• A sealing washer in good condition should be used

•Flow control valve should be closed before the cylinder valve is opened

•Quick opening to be avoided as it can generate heat leading to flame

•Valve should be fully opened when in use

•Valve should be closed before removing from a regulator or yoke

• Lower part of the tag removed when cylinder is empty.