

Maintaining the components of a medical gas system

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- troubleshooting
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 - replacing components
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13.4.3 Maintain the components of a medical gas system

Unit B 13.4 Maintaining Utility Systems and Medical Gas Systems

Module 279 18 B Medical Instrumentation I

Medical gas components: principles of operation

What is a medical gas used for ?

The clinical use of bottled (pressurized) gases can range from anaesthesia machines to spectroscopy (e.g. blood gas analysis).

What kinds of medical gas are used ?

The most common bottled gas is oxygen (O₂).

Anaesthesia gases (Nitrous Oxide/N₂O, Xenon), dry air and carbon dioxide are all seen occasionally.

Medical gas components: principles of operation

Medical Air is supplied by a special air compressor using clean outside air.

Pressures are maintained around 380 kPa (55 psi). Main use is:

- to drive ventilators and incubators, where it provides uncontaminated and controlled air flow to help reduce/dilute high concentration of oxygen exposure
- as a carrier gas for anaesthetic agents
- as a power source for driving surgical tools in the operating theatre

Oxygen may be used for patients requiring supplemental oxygen via a mask. Usually accomplished by a large storage system of **liquid oxygen** at the hospital which is evaporated into a concentrated oxygen supply, pressures are usually around 380 kPa (55 psi). In small medical centres with a low patient capacity, oxygen is usually supplied by multiple standard cylinders or **oxygen concentrators**.

Nitrous Oxide (N₂O, laughing gas) is supplied to various surgical suites for its **anaesthetic functions** during pre-operative procedures. Delivered to the hospital in standard tanks and supplied through the Medical Gas system. System pressures around 345 kPa (50 psi)

Medical gas components: principles of operation

The gas is either forced (**compressed**) into the cylinder and held under a high pressure or it is pumped into the cylinder as a **liquid** and a high pressure is developed by vaporisation of the liquid gas. In either case, the cylinder is under great strain. Cylinders must be handled with care as they are dangerous

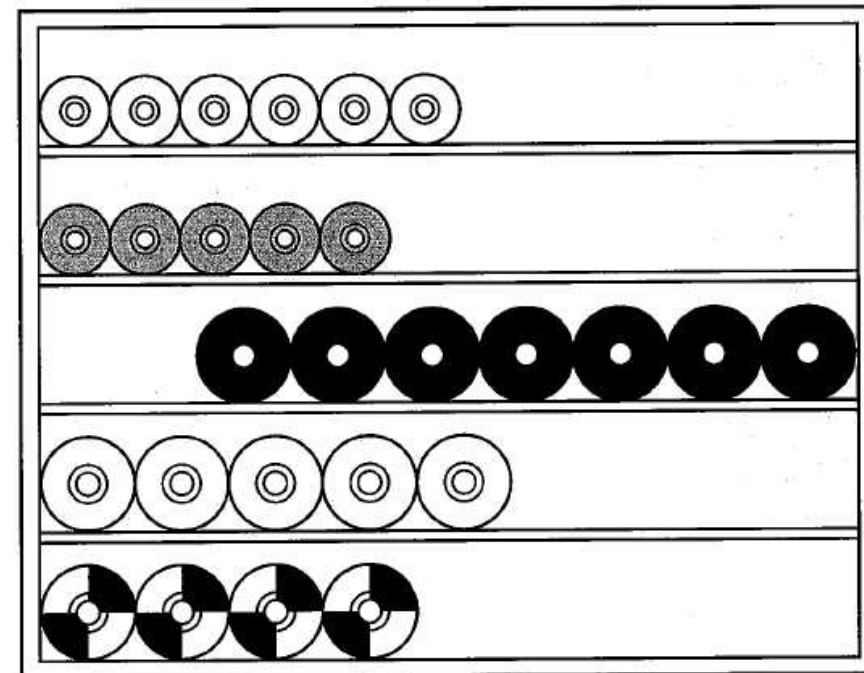
Unlike liquids, gases can be compressed. Their density increases under pressure. That is why a gas cylinder of **50** litres volume under pressure can contain gas that expands to **10 000** litres of volume when released to normal atmospheric pressure.

Safe storage of cylinders >>>

Larger cylinders stored in upright position



E-size cylinders and smaller can be laid on their sides



Carbon dioxide

Cyclopropane

Nitrous oxide

Oxygen

Air

Medical gas components: Construction



cylinder



manifold



regulator



gauge



flow splitter



flow meter



air compressor



vacuum generator

Medical gas components: Construction

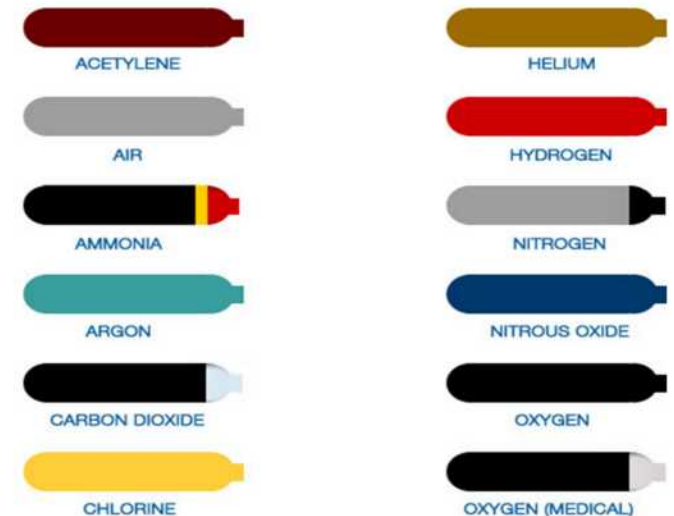


gas cylinders

There are several types and sizes of cylinders, any cylinder can be used with any or all of the gases.

It is normal to have two safety precautions on cylinders that are for medical gases.

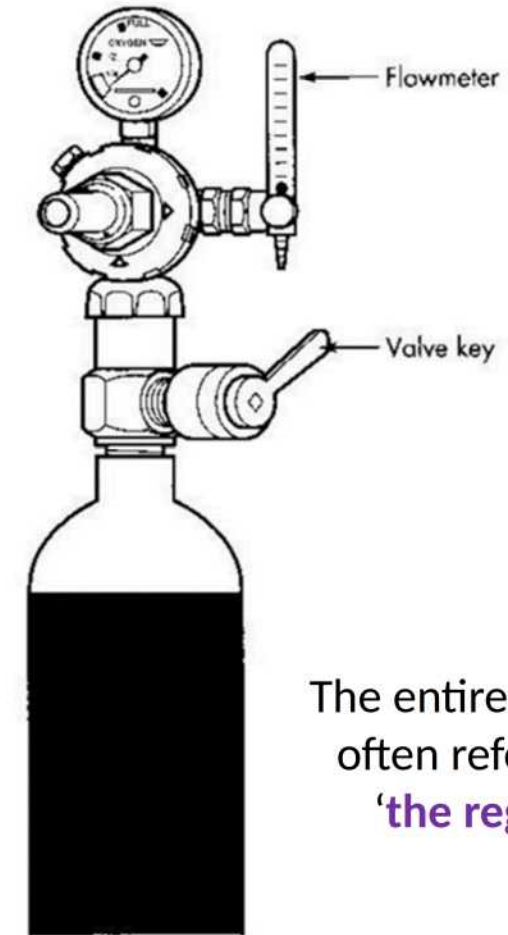
- The first precaution is a **colour code** for the specific gas. Oxygen for example, has green colour code.
- The second precaution is a **standard threading** on the cylinder outlet for the specific gas (Oxygen for example has a fine threading and Nitrous Oxide has a rough threading).



Medical gas components: Construction

Bottled gas has a few components:

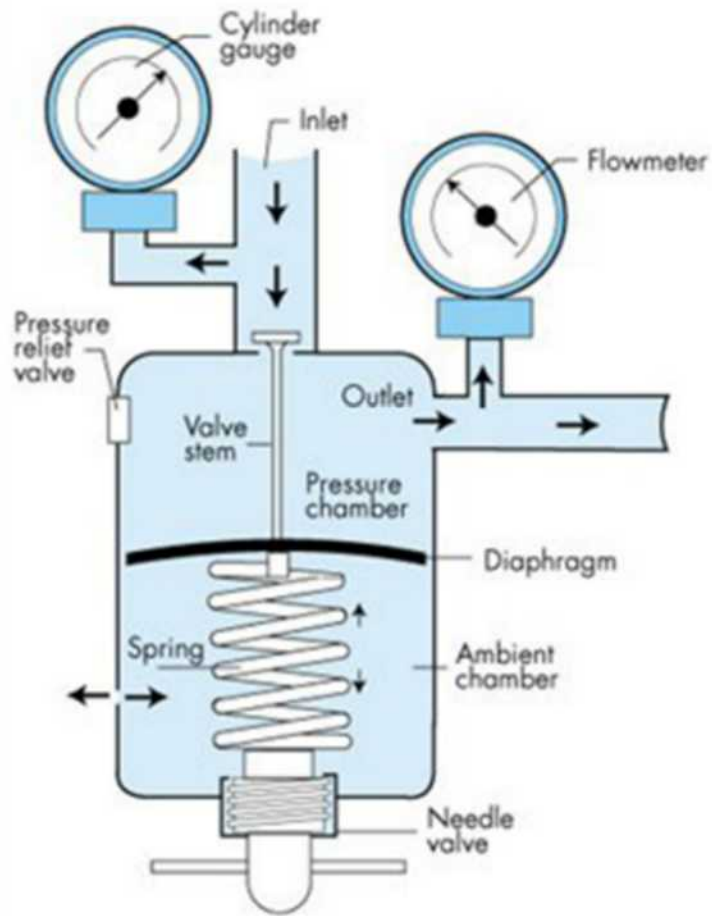
- the **cylinder** with the main **cylinder valve**,
- the **cylinder pressure gauge** (the gauge closest to the cylinder), showing the cylinder pressure, which corresponds to the amount of gas in the cylinder (with compressed gas).
- a **pressure regulator** for reducing the pressure. It reduces the high cylinder pressure to a low, usable pressure for clinical applications. The pressure regulator usually has an adjustment control. This control may have a large knob, or it may require a crescent wrench to adjust the outlet pressure. Furthermore, this outlet pressure is regulated and kept stable regardless of the filling level of the cylinder and how much gas (flow) is demanded.
- the **gas outlet pressure gauge**
- a **gas outlet flow control valve** and **flowmeter**



The entire assembly is often referred to as **'the regulator'**.

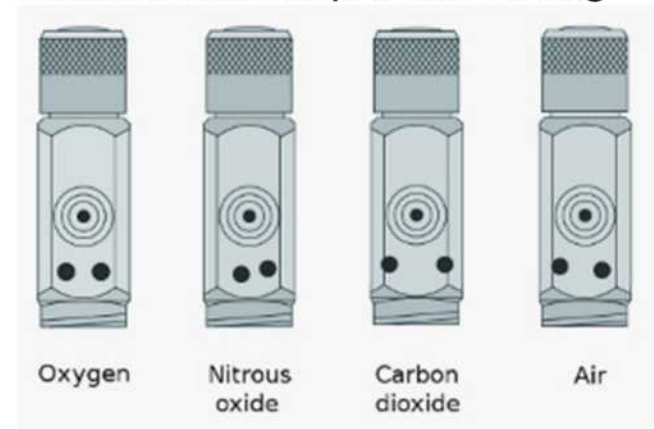
13 a. Bull-nose regulator and cylinder combination

Medical gas components: Regulator Construction

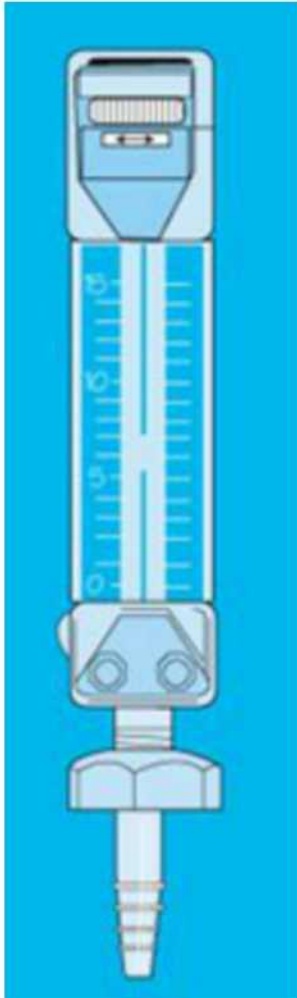


When medical gas is to be administered directly to a patient, the high pressure of the cylinder (~ 2900 psi, 200 bar) must be reduced to a level that the rest of the system is capable of handling (~ 50 psi). This is done with a regulator mounted to the neck of the cylinder. **Do not use a medical gas cylinder without its appropriate regulator.** Regulators are designed to fit on appropriate cylinders. This is for safety reasons. A regulator will not fit on a wrong cylinder.

Smaller cylinders (E or smaller) use a **pin index system** where holes in the cylinder must fit into pin in the regulator for them to connect correctly. If the wrong regulator and the wrong cylinder are put together, they should not fit together. These are standard safety requirements, and must be complied to by both the manufacturers and followed by the users.

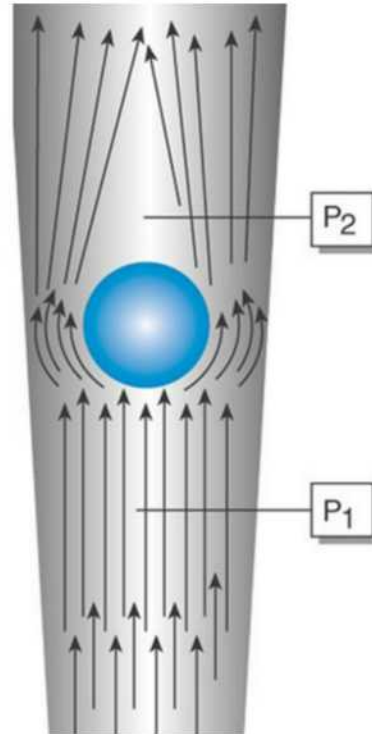


Medical gas components: Rotameter to measure flow



A **rotameter** is an instrument used to directly measure the flow rate of a gas in medical instruments. It consists of a connection to a gas source, a **needle valve** opened and closed by turning an attached dial for control of flow rate, a **float** resting in a clear tapered tube, and an outlet port.

Rotameters are designed for use only on systems not supplying more than 50 psi (about 3 bar).



When a driving pressure is applied to the inlet of a rotameter, the floater rises in the tapered tube until the flow rate creates an applied pressure on the floater equal to its weight. The tube's shape, that of a **slender cone**, decreases the pressure behind the float as it rises. A cylindrical tube would not permit driving pressure to decrease with flow rate, resulting in the floater rising to the top of the tube, and allowing for no variance in readings. The flow rate of a specific gas necessary to cause the floater to rise to a given height is pre-calculated in order to calibrate a tube.

The floater can have multiple shapes and is often made of anodized aluminium or ceramic. It often is diagonally grooved and coloured so that it visibly **rotates** when gas flows by. This indicates that the floater can move freely (and is not stuck to the wall of the tube.)

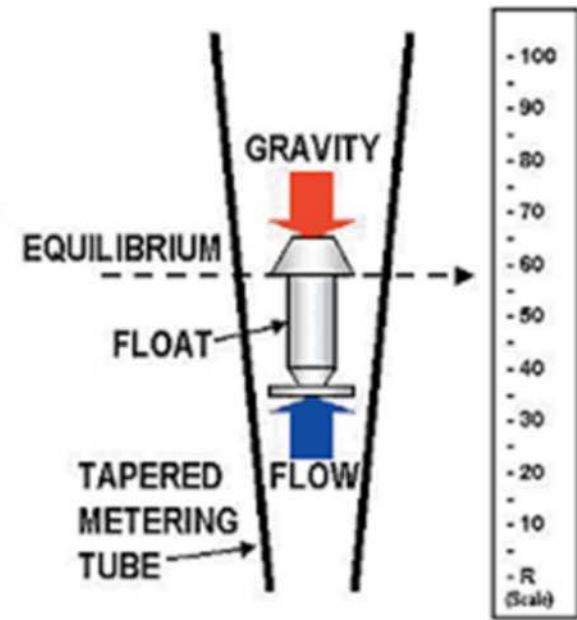
Rotameter: the full explanation

Rotameters are based on the variable area principle. They provide a simple, precise and economical means of indicating flow rates in fluid/gas systems. This variable area principle consists of three basic elements:

- a uniformly tapered flow tube,
- a float, and a measurement scale.
- a control valve may be added if flow control is also desired.

In operation, the rotameter is positioned vertically in the fluid system with the smallest diameter end of the tapered flow tube at the bottom. This is the fluid inlet. The float, typically spherical, is located inside the flow tube, and is engineered so that its diameter is nearly identical to the flow tube's inlet diameter.

When fluid is introduced into the tube, the float is lifted from its initial position at the inlet, allowing the fluid to pass between it and the tube wall. As the float rises, more and more fluid flows by the float because the tapered tube's diameter is increasing. Ultimately, a point is reached where the flow area is large enough to allow the entire volume of the fluid to flow past the float. The float is now stationary at that level within the tube, as its weight is being supported by the fluid forces which caused it to rise. This position corresponds to a point on the tube's measurement scale and provides an indication of the fluid's flow rate. A typical flow regulator allows adjustment of the flow between 1 and 5 l/min.



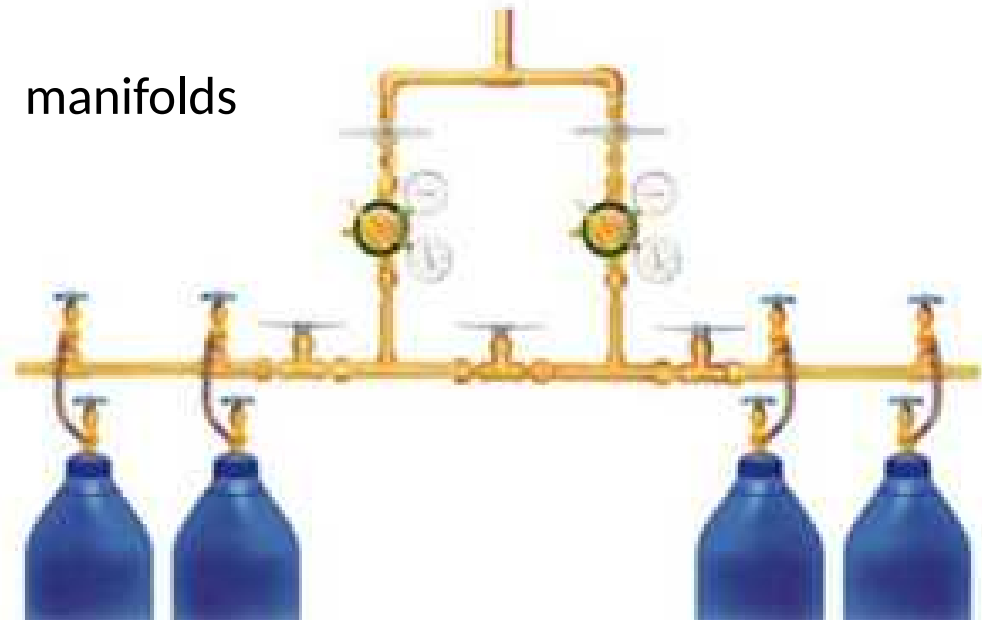
Medical gas components: Construction



(Oxygen) Manifold. This is a cylinder bank hooked together to supply a piped system in a hospital.

It may have 4-14 cylinders yoked together with a change-over mechanism from one set of cylinders to another when one set runs dry.

manifolds



Flow Splitter:

proportioned output to different uses

Medical gas components: Preventive maintenance

Gas cylinders are intrinsically simple devices that need very little calibration. The only apparatus that should be checked are the **pressure gauges** and the **piping**.

- Pressure gauges can be checked by attaching a **second gauge** (that is known to be accurate) in series with the first and assuring that both gauges give the same reading.
- If this is not possible, the outlet gas may be connected directly to a **mercury manometer** which will allow pressure checks at relatively low pressures, ranging from 0 – 300 mmHg typically (up to 40 kPa).
- Leaks may be checked by passing dilute soapy water over piping connections and looking for bubble formations.
- If the outlet gas is at the correct pressure and there are no leaks, the cylinder is ready for use.



Medical gas components: Trouble shooting

The most common problem is a **missing or broken regulator**, followed by a **hosing set** which does not match the standards of the regulator. Mismatched hosing sets need to be adapted with whatever parts and tools are available. This type of patching can only be accomplished after the pressure regulator (on the low pressure side). Clearly label the outlet of the hose after adaptation.

If the regulator is broken, it may be impossible to repair.



The pressure gauges are removable, by simply unscrewing them. Replacements can often be found. Use a Teflon pipe thread tape when replacing the gauges, as it will seal much better than the metal-to-metal seal required without the tape. The outlet flow control valve is not typically very important, and can be replaced with any valve which can be made to fit into the system.



Medical gas components: Trouble shooting

If you must work on the cylinder, **do not empty it entirely** (by leaving the cylinder valve open). This may allow ambient air to enter the cylinder and cause moisture to build up in the cylinder. The moisture can ruin the cylinder and contaminate the next filling.

Pipes and tubing leaks are common. Rub some soapy water over the pipe to check for bubbles and locate the leak. Try to cut out the leaky section of tubing and shorten the tube, if the leak is near the beginning or end of a long run. Otherwise, epoxy can serve as a temporary fix for a leaky pipe.

When you are placing the cylinder back on line, do not simply connect the regulator and open the cylinder valve. This can place unnecessary stress on the pressure regulator, can introduce contamination, and can stress the downstream system. The typical reconnection sequence is to first **“crack”** the main cylinder valve. Cracking the valve means **quickly opening and closing the cylinder valve a very small amount** to briefly allow the passage of a very small amount of gas. The gas will be high pressure and velocity. So, stay clear of the gas stream. This cracking clears debris in the valve outlet. Next connect the regulator to the system. Now crack the main cylinder valve again. This will pressure the regulator, but not stress it excessively. Finally, open the cylinder valve again to begin using the system.

Medical gas components: Safety considerations

If you must move a cylinder in order to repair it, or the regulator, place the **cap** on the cylinder before beginning.

Moving a gas cylinder is dangerous and difficult. Always ask for help. Before moving the cylinder, check the cap again to insure that it is secure. The best way to move a cylinder is to **slowly roll it on its bottom**, with the cylinder **tilted a few degrees**.

Highly experienced staff may move cylinders at high speed this way with seeming ease. However, if you are not very experienced at moving cylinders, you can easily lose control of the cylinder. Have a friend stabilize the cylinder while you tilt it and roll it.

Check the cap frequently while moving the cylinder.

make sure the cylinders cannot fall over



Medical gas components: Safety considerations

Butane, Propane and **Acetylene** are highly flammable gases which are not used in medicine. However, they are often seen at the hospital. Butane and propane are liquids under high pressure and are used for cooking and heating, including **clinical laboratory heating**.

Carbon dioxide (CO₂) is a non-flammable gas. However, take care to ensure proper ventilation when using carbon dioxide as any leaks may be hazardous. A concentration of CO₂ as low as 10% can cause **unconsciousness**.

Nitrous Oxide is sometimes used for anaesthesia, though its use is rare in the developing world. Any cylinders containing such a mixture must be stored above 10° C or the nitrous oxide will separate out. Warm and shake any such mixture before use. **When mixed with oxygen, nitrous oxide can be explosive**.

When not in use, gas cylinders should have a **cap** that screws onto the top of the cylinder to protect the gas cylinder valve from being cracked off, should the cylinder be dropped. This cap should always be used when the gas cylinder is being transported.



END

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