15. CHECKING THE EQUIPMENT

It is the responsibility of the anaesthetist to check all anaesthetic equipment and drugs before giving an anaesthetic.

There must always be alternative equipment to ventilate the patient's lungs if the anaesthetic machine or oxygen supply fails. A self-inflating resuscitation bag does not need a source of oxygen. It should be available whenever an anaesthetic is given.

Airway Equipment

An alternative method of ventilating the patient must always be available.

Ideally the anaesthetist would have at least two laryngoscopes of different sizes. The light should be checked. Oropharyngeal (and nasopharyngeal) airways should be available in different sizes. A flexible stylet and gum elastic bougies are excellent aids for intubation. The anaesthetist should have several different sized masks and an appropriate sized endotracheal tube (plus one size smaller and one bigger) available. A laryngeal mask may be used as the airway or as an excellent alternative airway if endotracheal intubation is difficult (secondary plan). Emergency airway equipment (e.g. laryngeal masks, intubating laryngeal masks, percutaneous tracheostomy, fibreoptic laryngoscopes) should be kept together in a labelled container in a central area.

Suctioning

Suction equipment should be available. It consists of a pump to generate a vacuum, a reservoir and tubing. The reservoir must be large enough to hold the aspirated fluid but not too large. (The larger the reservoir the longer it will take to achieve a vacuum). The minimal flow rate should be 35 l/min of air and generate at least 600 mmHg (80 kPa) negative pressure.
Suction may be powered by electricity, compressed gas or by hand/foot.

Continuous Flow Anaesthetic Machine (Boyle's machine)

The anaesthetic machine can be considered in thee parts: **high pressure** (pipeline, cylinders, pressure gauges and regulators), **low pressure** (oxygen failure alarm, antihypoxic device, flowmeters, vaporisers, pressure release valve, and common gas outlet) and the **breathing system**.

Cylinders and Pipelines

Cylinder and pipeline gases are too highly pressurised (5,000 kPa to 14,000 kPa) for safe flow regulation. Regulators are used to decrease the pressure to a safe level. Pressurised gases must never be connected directly to the breathing system.
(1 atmosphere = 760 mmHG = 98 kPa = 14 psi. 1 psi =6.9 kPa).

Cylinders should be checked regularly for faults. Full and empty cylinders should be kept separately. Cylinders must be handled carefully. They are heavy and oxygen cylinders are a fire risk.
Different gases are supplied at different pressures. Oxygen is stored at 14,000 kPa. A standard D cylinder contains 400 litres, an E cylinder 680 litre and an F cylinder 1400 litres. The gauge pressure on an oxygen cylinder will decrease at a rate proportional to the amount of oxygen used. When half the contents of a cylinder are used, the gauge pressure will be half of the original pressure.

A second oxygen cylinder must always be available and checked.
Oxygen is available as "industrial" or "medical" grade. The same process is used to produce both grades of oxygen and it is safe to use "industrial" grade oxygen if "medical" grade oxygen is unavailable.

Nitrous oxide cylinders are filled with liquid nitrous oxide. The gauge pressure of a nitrous oxide cylinder will not change as the nitrous oxide is used until all the liquid is depleted. Once the gauge pressure of a nitrous oxide cylinder starts to fall the cylinder is nearly empty. A full C cylinder of nitrous oxide contains 450 litres, a D cylinder 900 litres, an E cylinder 1800 litres and an F cylinder 3600 litres.

In order to ensure that the correct cylinder is attached to the yoke of the anaesthetic machine a series of pins on the machine yoke is made to fit an identical pattern of indentations on the cylinder. This is a **pin-index system**.

Flow Meters

Gases from the cylinders and pipeline pass though **flow meters**. The flow meters are made for a specific gas. They are not interchangeable. Flow meters have a spindle valve in the base to control flow and a bobbin or a ball in a vertical tube. The bobbin should spin. After the gases pass though the flow meters the different gases are joined together. Oxygen is added last to reduce the chance of giving a hypoxic mixture. New anaesthetic machines link the flow of nitrous oxide to the flow of oxygen to prevent less than 25% oxygen being given (**anti-hypoxic device**). Anaesthetic machines without an anti-hypoxic device should have an **oxygen analyser**.

Oxygen Failure Alarm

The anaesthetic machine should have an oxygen failure warning device. An anaesthetist should not use an anaesthetic machine that does not have an oxygen failure warning device or a broken device. If there is no alternative the anaesthetist must check the oxygen gauge pressure every 5 minutes. The cylinder must be changed when the cylinder pressure is less than quarter full.
There are a variety of alarms. Older models depend on batteries to power a red light and nitrous oxide to power a whistle (Bosun oxygen failure alarm). The anaesthetist must check that the batteries are working. Other devices do not rely on batteries and will shut off the nitrous oxide. Some have a reserve supply of oxygen.

Vaporisers

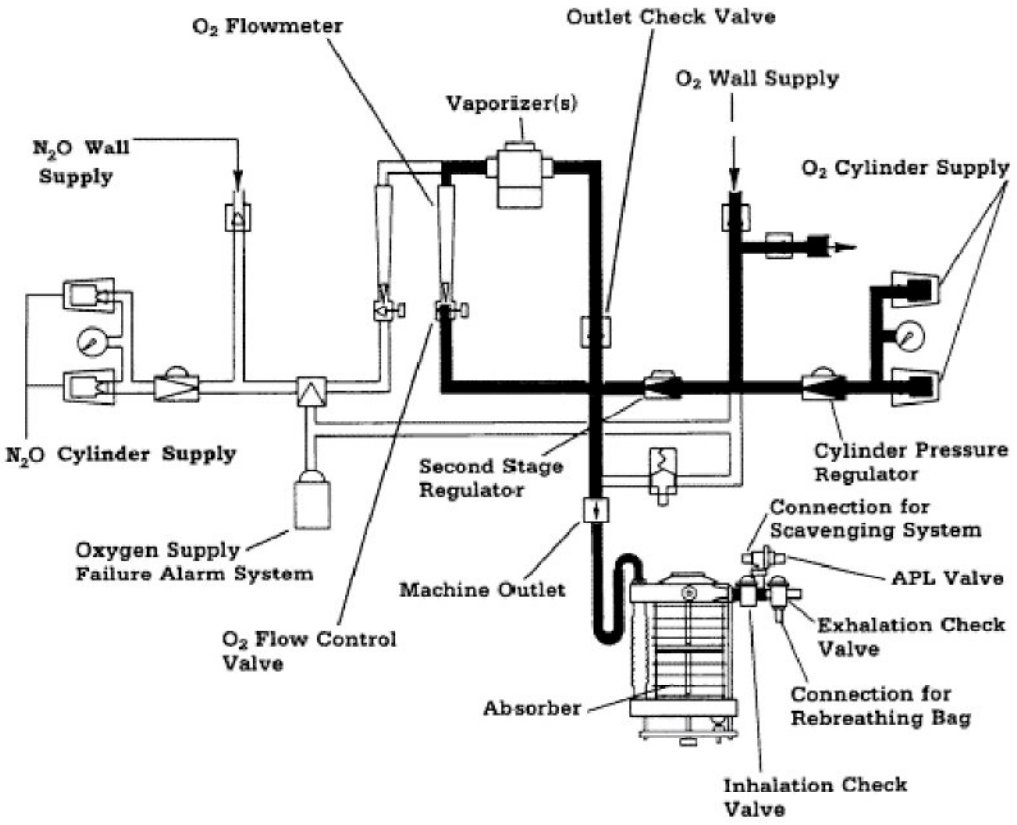
A horizontal pipe (**back bar**) on the anaesthetic machine connects the flow meters to a **common gas outlet**. The breathing systems are connected to the common gas outlet. **Vaporisers** are usually mounted on the back bar. Some older vaporisers may be free-standing and are connected to the common gas outlet. The anaesthetist must check that the vaporisers are connected in the correct direction.
Vaporisers are made for a specific volatile anaesthetic agent. Filling a vaporiser with the incorrect volatile anaesthetic agent will produce the wrong concentration. Some vaporisers have a special filling system to ensure that they are filled with the correct agent. If a vaporiser does become contaminated with the incorrect agent it should be emptied, washed out several times with the correct agent and then blown though with oxygen or air until all smell has been eliminated.

On some anaesthetic machines it is possible to connect more than one vaporiser to the back bar. Newer anaesthetic machines have a mechanism to prevent more than one vaporiser being turned on at the same time. Turning more than one vaporiser on at the same time will produce dangerous concentrations of volatile anaesthetic gases.
The vaporisers made for the back bar are for use with compressed gas. They have a high internal resistance. They must not be used for drawover anaesthesia.

The anaesthetist must check that the vaporiser is filled with the correct agent, correctly fitted to the back bar and that it easily turns on and off. The vaporiser should be left in the off position. (A Boyle's bottle should have both the lever and the plunger pulled up. Check that filling ports are closed). Vaporisers must never be tilted or turned upside down. This will produce dangerous concentrations of the agent when it is turned on.

Oxygen Flush/Pressure Relief Valve

At the end of the back bar there may be an emergency oxygen flow button (**oxygen flush**) and a **pressure relief valve**. Anaesthetic machines should have an emergency high flow rate (20 to 35 litres/min) supply of oxygen that bypasses the flow meters and the vaporisers. The anaesthetist should check the oxygen flush by pressing the spring-loaded button. The pressure relief valve is located downstream from the flow meters and the vaporiser. It protects the anaesthetic machine and vaporisers from high pressures. It does not protect the patient.



Oxygen and N_2O flow from cylinders and or wall outlet though flowmeters, along the backbar, though calibrated vaporiser and then via the machine common gas outlet to the breathing system. (Reproduced by permission of Datex·Ohmeda).

Checking the Anaesthetic Machine

Always have an alternative resuscitation device (e.g. self-inflating bag).

Check that cylinders are full and attached to the anaesthetic machine. There must always be a reserve supply of oxygen. Never use a machine if there is no reserve supply of oxygen.

Turn off all cylinders.

Turn on all flow meters. There should be no flow. Check the flow meters for cracks.

Turn on the oxygen cylinder. There should only be flow in the oxygen flow meter. The bobbin should spin. Repeat with each oxygen cylinder. Set the oxygen flow to 4 litres/min.

Turn on the nitrous oxide cylinder. Check that there is flow in the nitrous oxide flow meter (the bobbin should spin) and that the oxygen flow meter is still at 4 litres/min.

Turn off the oxygen supply and push the oxygen flush button.
The oxygen failure alarm should sound.

Turn on the oxygen cylinder again. The oxygen failure alarm should go off.

Check that all vaporisers are full and correctly fitted. The controls should operate thoughout their full range without sticking. Turn off the vaporisers.

If the anaesthetic machine is fitted with a pressure relief valve it should be tested by occluding the common gas outlet whilst gas is flowing. (Never do this test if a pressure relief valve is not fitted).

Attach the breathing system. Check that it has been correctly assembled. Close the APL valve, occlude the end and fill with gas. Squeeze the reservoir bag to ensure there are no leaks. Open the valve and ensure the breathing system empties.

Check all airway equipment, suction equipment and drugs.

16. BREATHING SYSTEMS

An ideal breathing system should be safe and simple. It should be able to be used for spontaneous and controlled ventilation. The system would be lightweight, not bulky or complicated and efficient. It should protect the patient against barotrauma.
Breathing systems include the **circle system** (with carbon dioxide reabsorption) and "**Mapleson"** systems.

Respiratory Physiology

The volume of air inspired during normal breathing is called the **tidal volume** (6 to 10 ml/kg). The **minute ventilation** (MV) is the tidal volume (TV) times the respiratory rate (RR). The normal adult minute ventilation is 80 ml/kg/min. Some of the tidal volume air does not enter the alveoli (where it gives up oxygen and takes up carbon dioxide). It remains in the oropharynx, trachea and larger airways. This volume of air is called the anatomical **dead space** (DS). The normal dead space is about 30% of the tidal volume. The **alveolar ventilation** (AV) is the amount of air that is involved in gas exchange each minute. It is equal to the (TV – DS) x RR.

Expired air contains 5% carbon dioxide and reduced oxygen (16%). If the patient breathes in his expired air (**re-breathing**) he will be breathing high concentrations of carbon dioxide and low concentrations of oxygen.

Circle System

Circle systems use less gas and volatile agent, conserve heat and moisture and are suitable for spontaneous ventilation and intermittent positive pressure ventilation (controlled ventilation or IPPV).
They can be used a with very low fresh gas flow (FGF) of less than 1 litre/minute. They must only be used with a very low fresh gas flow if the anaesthetist can check the inspired oxygen concentration, there is a carbon dioxide absorber and the inspired oxygen concentration is greater than 40%.

A circle system is larger, more complex (10 connections) and requires a carbon dioxide absorber.
The circle system consists of seven parts: the fresh gas flow, inspiratory and expiratory valves, inspiratory and expiratory tubing, a Y piece connector, reservoir bag, overflow or airway pressure limiting (APL) valve and the carbon dioxide absorbent container. There are several different ways of arranging the parts. To prevent rebreathing, the fresh gas flow must not enter between the expiratory valve and the patient, the overflow valve must not be located between the patient and the inspiratory valve, and the inspiratory and expiratory valves must be located between the patient and the reservoir bag on both the inspiratory and expiratory limbs of the circuit.
The fresh gas flow enters the inspiratory limb of the circle and passes though the inspiratory valve to the patient. Exhaled gas passes along the expiratory limb though the expiratory valve to a carbon dioxide absorber and back to the patient.

There are several common carbon dioxide absorbents (e.g. soda lime). In general, they contain a hydroxide that reacts with carbon dioxide. Heat and water are produced as by-products. They contain a chemical indicator which changes colour when the soda lime is

exhausted. The anaesthetist must know which chemical indicator is used. Different chemical indicators change to different colours.
A circle system can be used without soda lime but re-breathing and carbon dioxide retention can occur. The risk of re-breathing depends on the arrangement of the parts, the fresh gas flow and the ventilation. To prevent re-breathing the fresh gas flow should be 60 ml/kg/min and ventilate at thee times normal minute ventilation, or set the fresh gas flow to alveolar ventilation and ventilate at thee times normal minute ventilation.

Vaporisers can be placed in their usual position on the back bar (vaporiser out of circuit VOC) or can rarely be placed in the circle breathing system (vaporiser in circuit VIC). Vaporisers made to work with compressed gas (plenum) or drawover vaporisers must never be placed in the circuit. Gas expired from the patient will contain some volatile anaesthetic agent. If this is allowed to recirculate though the vaporiser it will continue to increase the volatile concentration above the concentration which has been selected on the vaporiser. Vaporisers should only be placed in circuit if they are made to be used in a circle breathing system and agent concentration monitoring is available.

Trichloroethylene must not be used with carbon dioxide absorbers due to production of toxic products.

Mapleson Breathing Systems

The **Mapleson breathing systems** have no valves to direct gases to and from the patient. There is no carbon dioxide absorber. The fresh gas flow must wash out the expired carbon dioxide in the breathing system. The parts of a Mapleson breathing system are a reservoir bag, tubing, fresh gas flow, APL valve and patient connector. The Mapleson breathing systems are simple and inexpensive. They require high fresh gas flow to prevent re-breathing and the fresh gas flow rate may need to be altered when changing from spontaneous to controlled ventilation. They do not conserve heat or moisture. The Mapleson A, B and C breathing systems have the APL valve close to the patient where it may be difficult to access. The Mapleson E and F breathing systems are difficult to scavenge. If there is a fall in fresh gas flow with the Mapleson breathing systems there is a risk of re-breathing.

There are different ways of arranging the parts.

The Mapleson **A** (Magill) breathing system is efficient for spontaneous ventilation. Fresh gas flow should equal minute ventilation. It is inefficient for controlled ventilation. Fresh gas flow must be 2 to 3 times minute ventilation to prevent re-breathing.

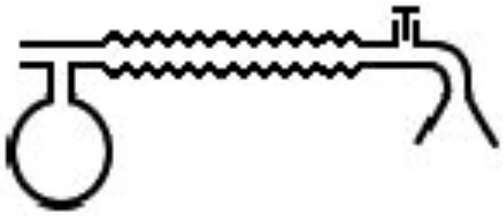
The Mapleson **B** and **C** breathing systems are rarely used for anaesthesia. They are used for resuscitation. Fresh gas flow for controlled ventilation should be 2 to 2.5 times minute ventilation.

The Mapleson **D** breathing system is inefficient for spontaneous ventilation. The flow rate should be 150 to 250 ml/kg/min. It is efficient for controlled ventilation. Fresh gas flow should be 70 ml/kg/min.

The Mapleson **E** (Ayres T piece) breathing system is used in children because it has a very low resistance and minimal dead space. The reservoir limb should be larger than the tidal volume and fresh gas flow should be 2 to 3 times minute ventilation.

The Mapleson **F** (Jackson Rees modification of the Ayres T piece) breathing system is a Mapleson E breathing system with an open bag attached to the expiratory limb. The bag allows easy controlled ventilation and visual assessment of spontaneous ventilation. Fresh gas flow should be 2 to 3 times minute ventilation.

MAPLESON A



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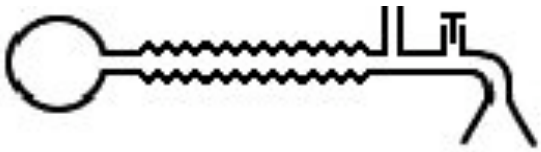
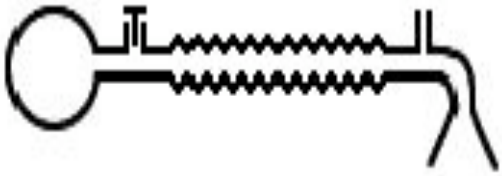
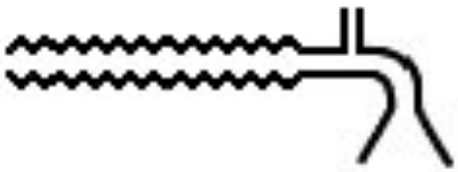


MAPLESON C

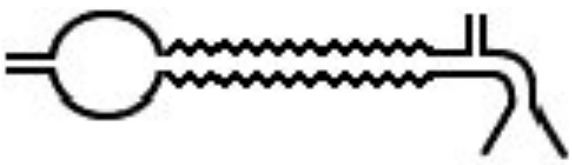
MAPLESON D

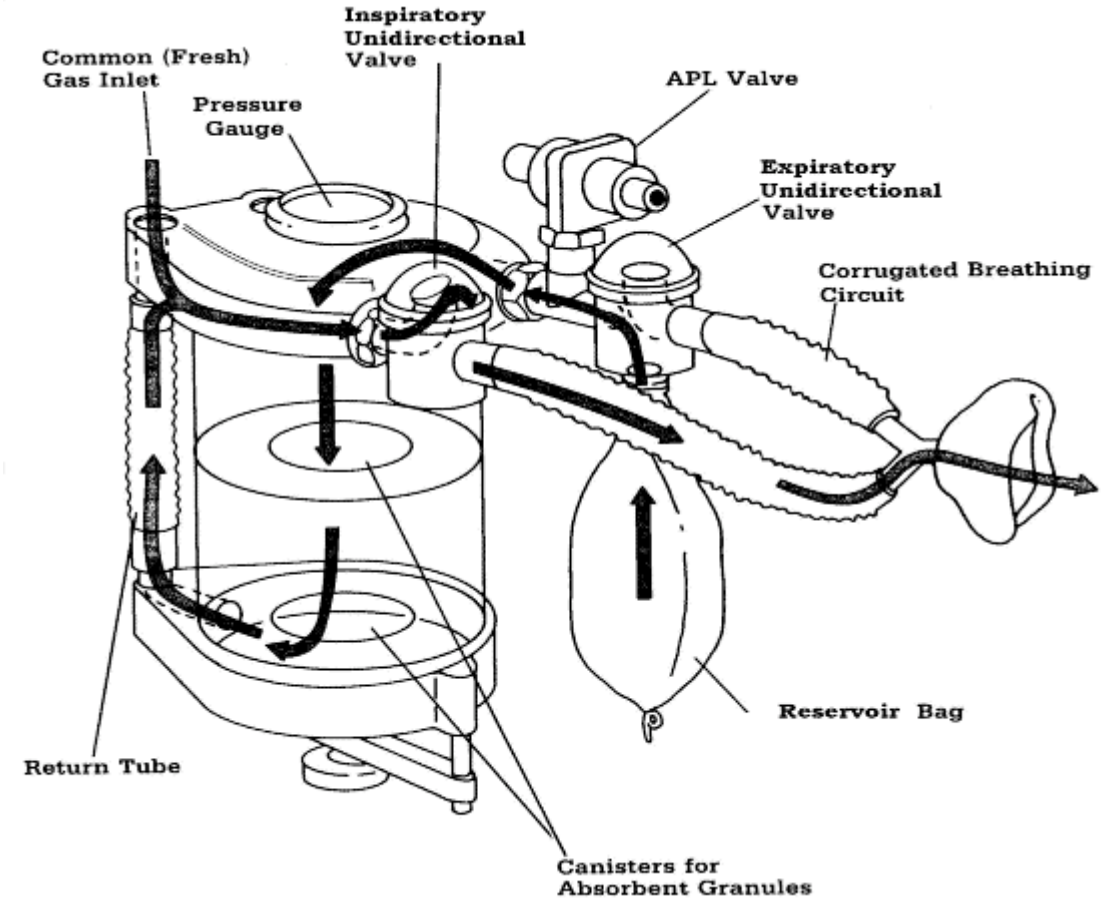


MAPLESON E



MAPLESON F





Basic circle breathing system.
(Reproduced by permission of Datex·Ohmeda, Madison, Wisconsin).

17. DRAWOVER ANAESTHESIA

Drawover anaesthesia is simple. The equipment is robust, versatile, easily maintained, relatively inexpensive, portable and does not need a pressurised gas supply, regulators or flow meters. In many parts of the world a regular supply of compressed gas is not available. The drawover vaporisers are less complex and have basic temperature compensation.

Drawover equipment is designed to provide anaesthesia without requiring a supply of compressed gas. In drawover systems the carrier gas (air or air/oxygen) is drawn though the vaporiser (adding the vapour from the liquid) either by the patient's own respiratory efforts or by a self-inflating bag or manual bellows with a one-way valve placed downstream from the vaporiser. (Supplemental oxygen is administered via a T-piece connection mounted on the intake port of the vaporiser). Drawover systems operate at less than, or at ambient pressure, and flow though the system is **"intermittent"**, varying with different phases of inspiration and ceasing in expiration. A one-way valve prevents reverse flow in the circuit.

This is different to **plenum** anaesthesia in which a carrier gas (compressed gas) is pushed though the vaporiser at a constant rate (**continuous flow**). In plenum systems the carrier gas and vapour is then collected in a breathing system with a reservoir bag or bellows. Plenum systems are more technically complex and need a well-regulated, constant, positive pressure gas supply. If the compressed gas supply ends, so does the anaesthetic. They require a more sophisticated anaesthetic machine (e.g. Boyles machine).

Supplemental Oxygen

The 21% oxygen in air is diluted by the addition of vapour in the vaporiser, allowing a potentially "hypoxic mixture" to be delivered to the patient. This is a theoretical problem rather than a practical one, as the vapour concentration is small, and it is unlikely that the inspired oxygen concentration would fall below 18%.
It is important to consider the respiratory physiological effects of general anaesthesia that tend to reduce ventilation and increase shunting of blood within the lung (V/Q mismatch). Therefore hypoxia becomes a clinical problem with inhalation agents that decrease ventilation (e.g. halothane, isoflurane, enflurane) with spontaneous ventilation (SV) in air and supplemental oxygen is required. The problem is reduced, but not abolished when applying intermittent positive pressure ventilation (IPPV). Ether can be used in air (without supplemental oxygen), though for IPPV when used without oxygen in air with spontaneous respiration, some patients may become hypoxic.

In drawover systems supplemental oxygen is administered via a T-piece connection mounted on the intake port of the vaporiser. To maximise the inspired oxygen concentration a "reservoir tube" is attached to the T-piece. A one metre length of tubing with an internal volume of 415 ml allows an inspired oxygen concentration of at least 30% with a flow rate of 1.0 l/min, and 60% at 4 l/min, at normal adult ventilation. With higher respiratory rates and/or tidal volumes, the inspired oxygen concentration falls due to increased air dilution.

Breathing System

The drawover vaporiser is connected by 22 mm tubing to a self-inflating bag or bellows. This is then connected by tubing to the patient's airway device. The breathing system must contain at least two valves to make the gas flow in the correct direction. There

should be one valve at the patient end to ensure that expired gas passes to the atmosphere. Another valve is needed to prevent gas flowing back up into the vaporiser rather than down to the patient. The PAC vaporiser has a built in valve and the self-inflating bag is mounted on a T-piece limb.

Drawover Vaporisers

The volume of carrier gas passing though the vaporiser is determined by the patient's tidal volume and respiratory rate. A proportion of the carrier gas is allowed to enter the vaporiser chamber and the remainder flows though a bypass channel. The gas flows then combine. The ratio of the flows and the saturated vapour pressure of the inhalation agent will determine the final concentration. Increasing the area of the vaporising chamber by inserting wicks will improve vaporisation but also increase airflow resistance. The ideal drawover vaporiser needs to have low internal resistance to gas flow to allow easy spontaneous ventilation, while the vapour output should be constant for a given dial setting over a wide range of minute volumes and ambient temperatures.

Plenum vaporisers have a constant driving pressure and predictable flow rates. They will operate effectively with increased internal complexity and resistance. Modern plenum vaporisers still have performance limitations at extremes of flow rate and temperature, but they are generally more accurate than drawover vaporisers.

Temperature Compensation

As vapour is liberated, the temperature of the liquid volatile agent falls due to the latent heat of vaporisation. This causes a fall in the saturated vapour pressure and lowers the output of the vaporiser. Temperature compensation is managed in two basic ways. The first is to provide a large heat-sink of conductive material (water bath or mass of metal), the dimensions of which are limited by size and portability. Heat is conducted from the heat-sink to the volatile liquid to minimise the fall in temperature. The second method is to vary the vapour chamber output with temperature, so that more carrier gas is allowed to pass though the vapour chamber as the temperature falls, and less as it rises. This is achieved by bimetallic strips and/or ether filled bellows in plenum vaporisers, but they cause an increase in the internal resistance. Some drawover vaporisers have basic thermo-compensation devices (EMO, PAC).

Drawover vaporisers theoretically should not be used as a plenum vaporiser, as the output may not be the same as the setting. Most plenum vaporisers cannot be used for drawover anaesthesia because their internal resistance is too high.

If a drawover vaporiser needs filling during an anaesthetic, the vaporiser must be turned to the zero position before opening the filling port. If the vaporiser is left "on" and the filling port opened, air will be drawn into the vaporising chamber and a dangerously high concentration of inhalation agent can be delivered to the patient.

EMO

EMO (Epstein Macintosh Oxford) is designed for use with ether and must not be used with halothane.
The temperature compensation device of the EMO vaporiser is a sealed canister containing liquid ether attached to a spindle, automated by opposing springs. The

thermo-compensation valve is automatic and can be seen though a small window on top of the vaporiser. When the temperature of the vaporiser is within its working range (10 to 30 ºC) a black ring is visible in the window. If the vaporiser overheats a red ring also appears. If the vaporiser is too cold the black ring disappears and only the aluminium disc is visible. The metal disc will also be visible if the thermo-compensation device breaks. The vaporiser should not be used if it is too hot or cold.
The splitting system comprises two concentric brass cylinders with holes, one of which rotates with the dial setter, thus altering the overall ratio between vapour chamber and bypass flow. The pointer may stick after prolonged use due to a build-up of sticky deposits around the brass cylinders. These can be removed and cleaned. A setting gauge is available from Penlon to position the splitting device correctly. Alternatively a 0.1 inch (2.6 mm, 8 French gauge, 12 Stubs needle gauge) wire can be used. To calibrate the dial properly, the central screw should be loosened and the dial placed in the 6% position. The setting gauge is placed in the aperture, though the temperature compensator portal, and the screw is tightened until the gauge is lightly gripped.
The vaporising chamber sits in a water bath that acts as a heat sink. (New vaporisers will have an empty water bath and must be filled before use). The chamber can be emptied for transport.
In plenum mode the EMO only begins to perform reasonably accurately with flow rates around 10 l/min.

OMV

The **OMV** (Oxford Miniature Vaporiser) is the most portable and versatile drawover vaporiser, but its size does create performance limitations. The original model contained only 20 ml of volatile agent. Newer models contain 50 ml but this can empty rapidly when in use.
It is suitable for a number of agents. A different dial is attached to the OMV for each agent. A pointer that is moved over the scale controls the concentration of the agent. A build-up of thymol (the preservative in halothane) can cause the pointer to stick. A temporary repair is to fill the OMV with some ether and move the pointer until it is free. The OMV must be emptied of ether and blown dry before adding another agent.
The OMV has basic thermal compensation made up of a reservoir of glycol within a metal heat-sink.
Metal mesh wicks increase the output without significantly increasing internal resistance. It suffers a reduction in vapour pressure at lower temperatures, with a maximum output varying from 2 to 4% with halothane between 0 and 30 degrees Celsius.
It is common to use 2 OMVs in series to increase the output, as is standard in the Triservice apparatus, which was originally used with trichloroethylene in one vaporiser and halothane in the other.
The OMV can operate as a plenum vaporiser. Output reflects the dial setting at 25 ºC, in either continuous or drawover use, but falls dramatically at 15 ºC and rises steeply when above 35 ºC.
It is reasonably accurate over a wide range of flow rates and tidal volumes and, in particular, performs well at small tidal volumes. With continuous flow it is best to keep the fresh gas flow above 4 l/min.
The OMV should not be used in a circle system. It is efficient and can produce very high concentrations.

PAC

The **PAC** (Portable Anaesthesia Complete. Now called TEC) was originally released as a series of individual vaporisers designed for specific volatile agents. A multi-agent version, the Ohmeda Universal PAC is now also available. It may be used with halothane, isoflurane, enflurane and ether. The PAC vaporisers have automatic bimetallic strip thermo-compensation. Unfortunately the output is less accurate at small tidal volumes, or when used as a plenum vaporiser with gas flows below 2 to 4 l/min. Therefore it is not as useful for paediatric anaesthesia.

Self-Inflating Bag/Bellows

Self-inflating bag/bellows allow controlled ventilation. The Oxford inflating bellows (OIB) comes with the EMO system. The bellows sit vertically with a residual internal volume maintained by a spring. This allows movement of the bellows during spontaneous respiration providing a useful indicator of breathing.
All self-inflating bags have a one-way valve upstream of the bag to prevent gas flowing back to the vaporiser. The OIB also has a one-way valve located downstream from the bellows. The OIB was originally designed for use with a simple spring-loaded valve (e.g. Heidbrink valve). This arrangement works well for spontaneous ventilation, but is less satisfactory for IPPV as the Heidbrink valve must be constantly re-adjusted. Because the Heidbrink valve has no mechanism to prevent the patient's expired gas from flowing backwards the OIB has the valve downstream.
Non-rebreathing valves (e.g. Laerdal, Ambu) can be used effectively at the patient end of the drawover circuit to facilitate IPPV, and are equally suitable for SV. These non-rebreathing valves will prevent expired gas flowing backwards.
The anaesthetist must be careful with this adaptation of the OIB because unless the downstream valve on the OIB is disabled with the magnet provided, the OIB is prone to jam. When the OIB jams the patient cannot exhale as an air lock develops between the non-rebreathing valve and the OIB valve. The patient must be disconnected to allow exhalation. The problem is more common with IPPV, but may occur with SV. When in use the magnet holds the distal OIB flap valve in the open position and stops the air lock developing. Some anaesthetists remove the downstream valve to prevent this problem. A simpler, single flap valve bellows called the Penlon Bellows Unit has been developed to prevent this problem and avoid confusion concerning when the magnet should and should not be used. Remember, when using <u>modern</u> valves use the <u>magnet</u>.

The tap on the side of the OIB is intended for connection to supplemental oxygen when using the bellows for resuscitation. However, during anaesthesia it is preferable to leave this closed and supply oxygen upstream of the vaporiser. Adding oxygen at the bellows dilutes the anaesthetic vapour.

With IPPV the OIB is operated by a rocking motion rather than direct up and down. This creates less fatigue and produces less variability in tidal volume. The bellows should not be lifted to its maximum capacity. This would produce a tidal volume of 2 litres. If the bellows is pushed down too hard a clip will engage and lock the bellows.

[The majority of this section has been reproduced from the excellent article in World Anaesthesia, Update in Anaesthesia Issue 15 (200) article 6 by Dr Scott Simpson and Dr Iain Wilson.]