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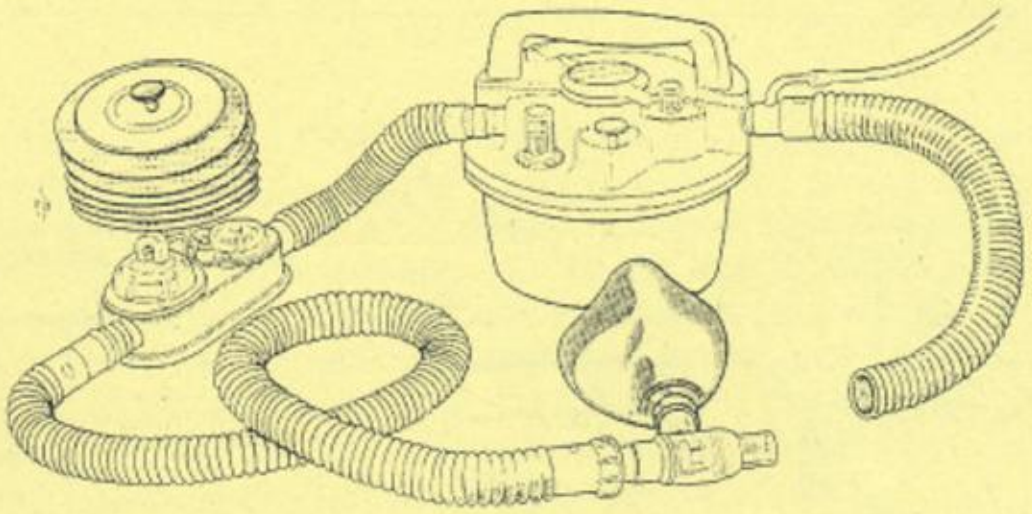
Healthcare Technology: Anaesthetic Inhalation Equipment

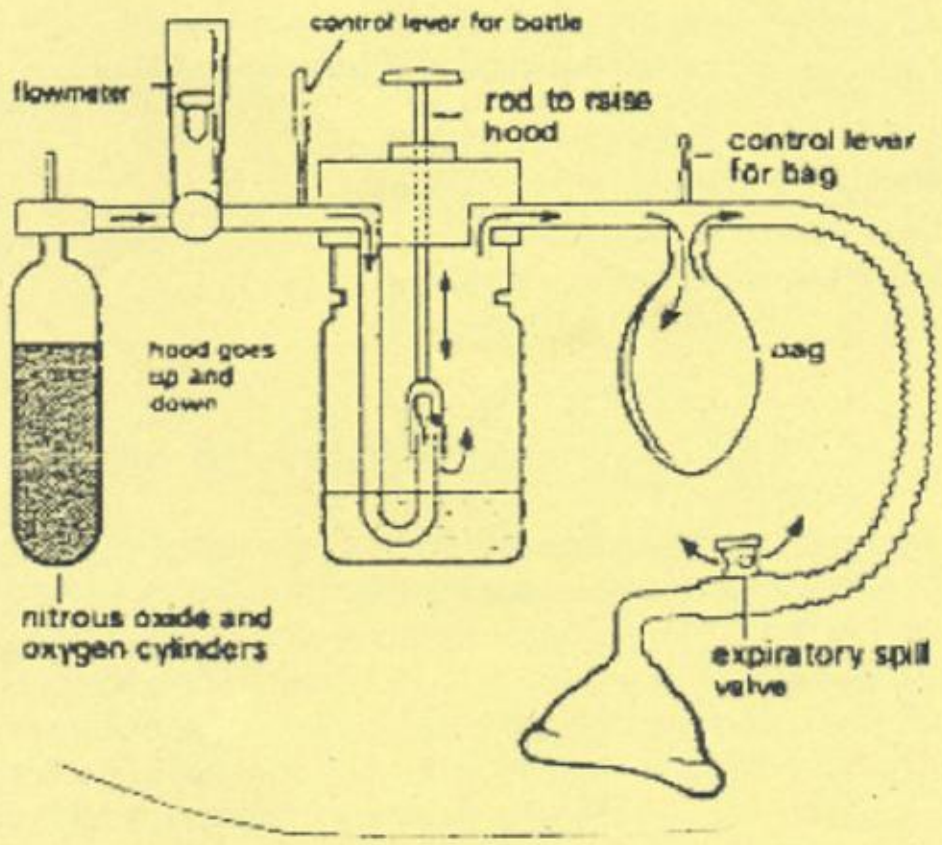
1. Technologies and Equipment Used

1.1. Draw-over system

Draw-over inhalation anaesthesia essentially requires two pieces of equipment: A vaporiser for the volatile anaesthetic and a self-inflating bag or bellow (SIB) to pump gas into the patient's lungs if he is not breathing spontaneously. These are connected through a breathing system with one or more one-way valves to the patient. Inspiration and expiration is done through either face mask or an endotracheal tube inserted into the patient's trachea.



1.2. Continuous-flow or Boyle's Machine



Continuous-flow machines rely on a supply of compressed medical gas. Usually this is oxygen taken from cylinders or a compressor fed from an oxygen concentrator. The apparatus operates at gas pressures between 3.5 and 5 bar, thus requiring reducing valves when the gas is taken from cylinders. Nitrous oxide can be added to the oxygen for pain suppression (analgesia) but in developing countries this gas is rare and expensive. In many cases it will be substituted by other analgesic agents.

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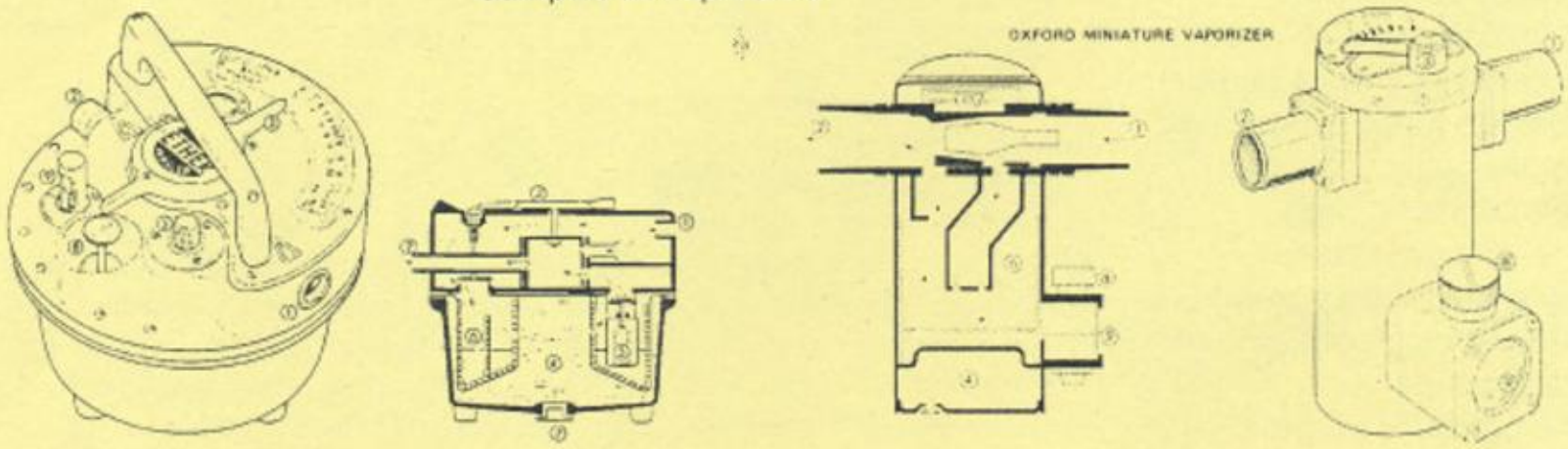
1.3. Essential component: Vaporiser

Vaporisers are devices designed to deliver a defined concentration of anaesthetic agent to the breathing gas lead through them. Ether and halothane are the predominant anaesthetic agents. Vaporisers used in draw-over systems need low inner resistance since the patient breathes through them, where as continuous-flow system's vaporiser of higher inner resistance do not allow breathing through them.

Vaporisers	Draw-over systems	Continuous-flow systems
EMO (Epstein MacIntosh Oxford)	works	works
OMV (Oxford Minature Vaporizer)	works	works
Tec-Series	unsuited	works
Boyle's Bottle	unsuited	works
Afya - Dräger	works	unsuited
PAC -Ohmeda	works	works

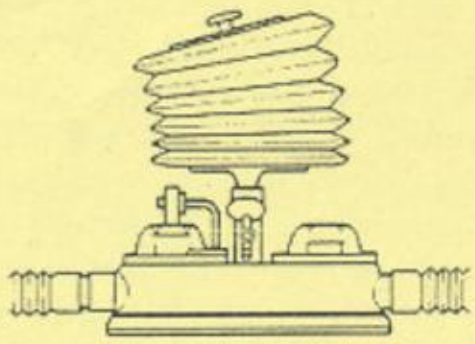
Samples of Vaporizers



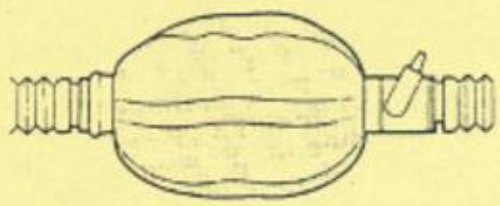
1.4. Essential component: SIBs

Self-inflating bags or bellows are a kind of air pump used to ventilate patients during anaesthesia. Spring-loaded, they are compressed to deliver air through the breathing system (hoses and valves) into the patient's lung.

Samples of SIBs



Oxford Inflating Bellows

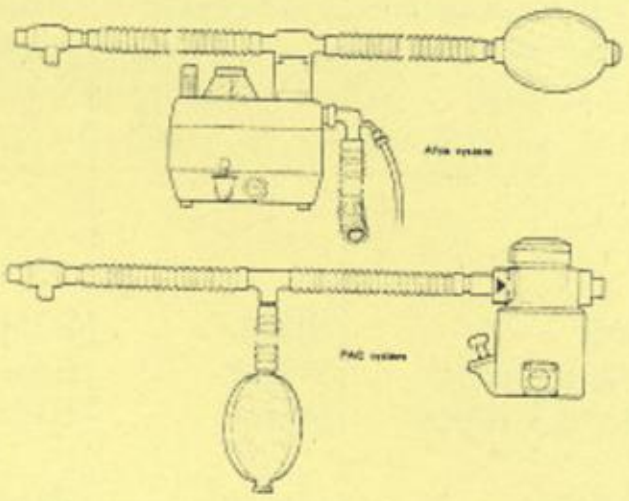


Self-Inflating Bag

1.5. Essential component: Breathing Systems

Breathing systems contain the set-up of SIBs, vaporisers. tubes and valves directing the gas flow.

Samples of Breathing Systems



1.6. Circular Patient Systems

In all above mentioned cases the gas exhaled by the patient is not re-used but expired into the theatre environment. This is one hand uneconomic use of medical gas and anaesthetic agents, and on the other hand theatre staff is constantly exposed to high anaesthesia concentration bearing health risks for them. In order to recuperate desired gas components from exhalation gas the carbon dioxide produced in patient's organism is absorbed in a lime tank. Consequently only has to add only the actually consumed gas components into the breathing circuit. The closer such a system is the more thoroughly patient's vital functions and gas concentrations have to be monitored with suitable equipment.

Type:	Description
open system	Anaesthetic agent vaporised on Schimmelbush mask placed over patients nose and mouth. No tubes or valves required.
half-open system	draw-over or continuous-flow systems All gas expired from the patients leaves the system , only fresh gas is used for aspiration, some 10 - 12 lt./min are needed
half-closed system	One part of the expiration gas is lead through a carbon dioxide absorber (lime) and then mixed with fresh-gas for aspiration (Fresh gas required of 2 - 4 lt./min)
closed system	No expiration gas is directly lead outside the system. All is passed through the absorber and reused with only small fresh gas requirement of 0.5 - 1 lt./min

1.7. Manley Multivent Ventilator

Some years ago a gas powered, electronically controlled ventilator for anaesthesia has been developed, suited for all electrical supplies world-wide. It can be driven by various sources such as oxygen from cylinders, compressed air (e.g. from accessory electric compressor), or in combination with a special adapted DeVilbiss Oxyvent Concentrator, engineered to supply oxygen for patient circuit while powering the ventilator. Internal batteries cover for times of power outage. Two models are available: Standard "O" not to be used with ether or any other flammable anaesthetic agent. Model "E" for ether and other flammable agents.

2.1. Important Gases in Anaesthesia

The following important gases are used in inhalation anaesthesia. They often come in pressurised steel cylinders or can be produced in small decentralised plant:

Gas	Air (medical)	Oxygen	Nitrous oxide	Remarks
Symbol	AIR	O_2	N_2O	
Colour codes for cylinders "International Standard" Cylinder Body Shoulder / Valve End Control Knob in USA in Germany	 Grey White + Black White + Black Yellow Yellow	 Black White White Green Blue	 Blue Blue Blue Blue Grey	Always double-check with local experts!
Physical state in cylinder	Gas	Gas	Liquid	
Type of cylinder valve	Hand Wheel	Pin Index Hand Wheel Bull Nose	Pin Index Hand Wheel	
Flammability	Supports combustion	Supports combustion Keep free from oil and grease!	None	
Availability	Frequent, medical air compressors	Frequent, technical O_2 can be used	Rare and expensive	
Cylinder Pressure when full (15°C) Normal working pressure	 3.5 – 5 bar	135 bar 3.5 – 5 bar	43.5 bar 3.5 – 5 bar	

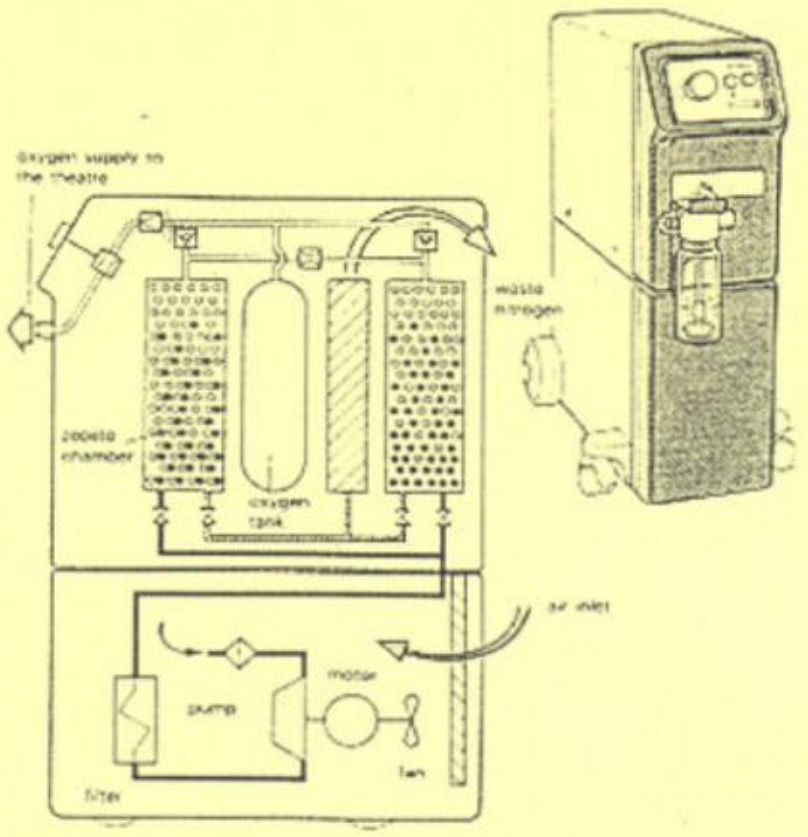
2.2. Characteristics of important anaesthetic agents

In many cases a combination of anaesthetic will be used since none of the agents has all desired qualities. E.g. Vaporisers for Halothane and Trichloroethylene are connected in series to supplement their respective characteristics.

Name	Characteristics	Fire Hazard or Remark
Ether (Diethyl ether) $CH_3CH_2OCH_2CH_3$	Colourless liquid with strong, irritant smell. Boiling point at 35°C. Concentration for anaesthesia 2 - 20 %	Flammable when mixed with air; explosive when mixed with oxygen or nitrous oxygen.
Halothane $CF_3CHClBr$	Liquid with sweetish, non-irritant smell. Boiling point at 50°C. Concentration for anaesthesia 0.2 - 3 %.	Neither explosive nor flammable in clinical conditions. To be used in a calibrated vaporiser only.
Trichloroethylene $CHCl.CCl_2$	Blue-dyed liquid with sweet smell. Boiling point at 87°C. Concentration for anaesthesia 0.35 - 1 %.	Neither explosive nor flammable in clinical conditions. To be used in a calibrated vaporiser only.

3. Oxygen Concentrator

Oxygen concentrators utilise the oxygen content (21Vol.%) in ambient air to produce oxygen (around 90Vol.%) in an electrically driven compressor and absorber system: Air is compressed and filtered and passed to one of two chambers filled with crystalised zeolites. The nitrogen is absorbed, after which the oxygen is passed to a storage tank. The nitrogen absorbed on the zeolite is then discharged ad the first chamber is regenerated and, while air is being compressed in to the second chamber. Since oxygen is delivered without considerable pressure it can be directly used in draw-over systems or has to be compressed for us in continuous-flow systems in special compressors.



4. Recommended literature

Primary Anaesthesia, edited by Maurice H. King, Oxford University Press, GTZ - 1986
ISBN 0 19 4424472

Anaesthesia at the district hospital, Michael B. Dobson, WHO 1988 - reprinted 1997
ISBN 92 4 154228 4

Anaesthesia Notebook for medical Auxiliaries, Georg Kamm, Peter Witton, Hatib Lweno,
Verlag Peter Lang - 1989, ISBN 3 8204 9977 6

5. Specification for Tender

The anaesthetic equipment listed below represents the minimum that a district hospital should be equipped with:

Anaesthetic face masks	2 of each size, infant to large adult; total 14
Oropharyngeal Airways	2 of each size 00 to 5: total 12
Laryngoscopes	2 handles + 3 pair of blades, or 4 plastic laryngoscopes (2 adult + 2 paediatric) 12 spare bulbs + 30 batteries (or 8 rechargeable batteries + charger)
Endotracheal tubes	sizes 2.5 – 10mm (internal diameter) in 0.5mm steps, Oxford or magill or similar, with cuffs only on sizes > 6mm
Urethral bougies	for use as intubating stylets
Magill's intubating foreceps	in an emergency, ovum forceps can be used instead
Endotracheal tube connection	15 mm plastic (can be connected directly to the breathing valve), 3 for each tube size
Catheter mounts	antistatic rubber, 4
Breathing hose and connector	2 length of 1 metre antistatic tubing
	4 length of 30 cm tubing for connection of vaporisers
	T-piece for oxygen enrichment
Breathing valves	universal non-rebreathing valves (6 adult + 2 paediatric)
Breathing systems (for continuous-flow anaesthesia)	Ayre's T-piece system Magill breathing system
Self-inflating bellows or bag (SIB)	1 for adults + 1 for children
Anaesthetic vaporisers (draw-type)	for ether, halothane, and trichloroethylene
Equipment for intravenous use	needles and cannulas, including paediatric sizes and an umbilical vein catheder, infusion sets
Spinal needles	range of sizes, 18-gauge to 25-gauge
Suction apparatus	

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6. Check-list for draw-over anaesthetic apparatus (Michael B. Dobson)

Keep a copy of this list by your anaesthetic apparatus.
You must fully check all apparatus before beginning anaesthesia.

Oxygen cylinder and flow meter
Turn on supply of gas from cylinder, and check pressure and flow. Also check spare cylinder.

Oxygen reservoir
Check for proper assembly of T-piece, and make sure that air inlet is unobstructed.

Vaporizer
Check that the vaporizer is filled (using only stocks of anaesthetic in their original containers).
Check that connections fit, and set dials to zero.

Self-inflating bag / bellows
Check connections and, if applicable, position of magnet on bellows.

Breathing and connecting hoses
Check connections and correct assembly of breathing system.

Breathing valve
Test the valve yourself and check it visually; the bobbin or valve leaflets should move during breathing.

Check for leaks
Squeeze the bag or bellows while using your hand to block the connector that joins the breathing valve to the patient. No air should escape.

Make sure that you have:

- 9 face mask of suitable size
- oropharyngeal airway of suitable size
- 9 tested laryngoscope and spare
- 9 endotracheal tube of suitable size (test cuff by inflating)
- tested suction apparatus
- table or trolley that can be tilted head-down
- all drugs you may need.

NEVER INDUCE ANAESTHESIA UNLESS AN ASSISTANT IS PRESENT.

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7. Check-list for continuous-flow (Boyle's) apparatus (Michael B. Dobson)

Keep a copy of this list by your anaesthetic apparatus.
You must fully check all apparatus before beginning anaesthesia.

Emergency equipment
You must have a suitable resuscitation device, for example a self-inflating bag or bellows, to ventilate the lungs of the patient in case your gas supply fails.

Oxygen supplies
For machines fitted with cylinder-only supply
Turn on the oxygen supply from the cylinder in use and check the pressure. Turn on the supply from the reserve cylinder, check the pressure, and turn it off again. Check that you have a third cylinder available to replace the cylinder in use when it is exhausted.
For machines fitted with a piped gas supply
Check the source of your piped gas supply. Check that you have a full cylinder of oxygen fitted to your machine in case the piped supply fails.
All machines
Turn off all gas supplies except one oxygen cylinder or piped supply. Open all rotameters. Oxygen should flow through only one rotameter tube (the oxygen one!). If this does not happen, do not use the machine.
If *your machine has an oxygen-failure warning device, test it as follows:*

- Turn on the gas supply from one oxygen cylinder (pipeline disconnected if fitted) and one nitrous oxide cylinder (if fitted).
- Open rotameter taps to give a flow of oxygen (and nitrous oxide also if fitted) of 5 litres/min.
- Turn off the oxygen supply at the cylinder. If a functioning warning device is fitted, an alarm should sound as the oxygen rotameter bobbin starts to fall (this may take a few seconds). On some machines, oxygen failure automatically cuts off the nitrous oxide supply also.
- After the test remember to open the oxygen cylinder valve again.

Avoid using a machine that does not have a functioning oxygen-failure alarm. If you have no alternative, you must record the oxygen,cylinder pressure every 5 min throughout anaesthesia and change cylinders when the cylinder pressure drops below 1500 kPa (15 atmospheres, 220 p. s. i.).
You must never begin anaesthesia with a machine that has only a single source of oxygen, i.e., only one cylinder or one pipeline.

Nitrous oxide
Check the pressure in the nitrous oxide cylinder in use and in the reserve cylinder. If the pressure in a nitrous oxide cylinder at room temperature is less than 5200 kPa (51 atmospheres, 750 p.s.i.), the cylinder is less than 15% full.

Rotameters
Inspect visually for cracks. Make sure that the bobbins do not stick in the tubes.

Emergency oxygen
Locate and turn on the emergency oxygen (bypass) button or tap. A high flow of oxygen should be delivered from the gas outlet. Note that this supply does not pass through the oxygen rotameter.

Vaporizers
Check that all vaporizers are firmly connected and filled with the correct anaesthetic agent (from stocks of anaesthetic in their original containers). Check that all filling ports are firmly closed, and that concentration dials are set to zero. A Boyle's bottle should have both the lever and the plunger pulled up.

Leaks
Check your machine once a month for leaks (or immediately, if you suspect one) by "painting" suspect areas with soapy water and watching for bubbles.

Breathing system
Check for correct assembly.

Make sure that you have.,

- face mask of suitable size
- oropharyngeal airway of suitable size
- tested laryngoscope and spare
- endotracheal tube of suitable size (test cuff by inflating)
- tested suction apparatus
- table or trolley that can be tilted head-down
- all drugs you may need.

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