

Ministry of Higher Education and Scientific Research
College of Health and Medical Technology
Anesthesia Techniques Department
Subject: Anesthesia Equipment, 4rd stage
2025-2026

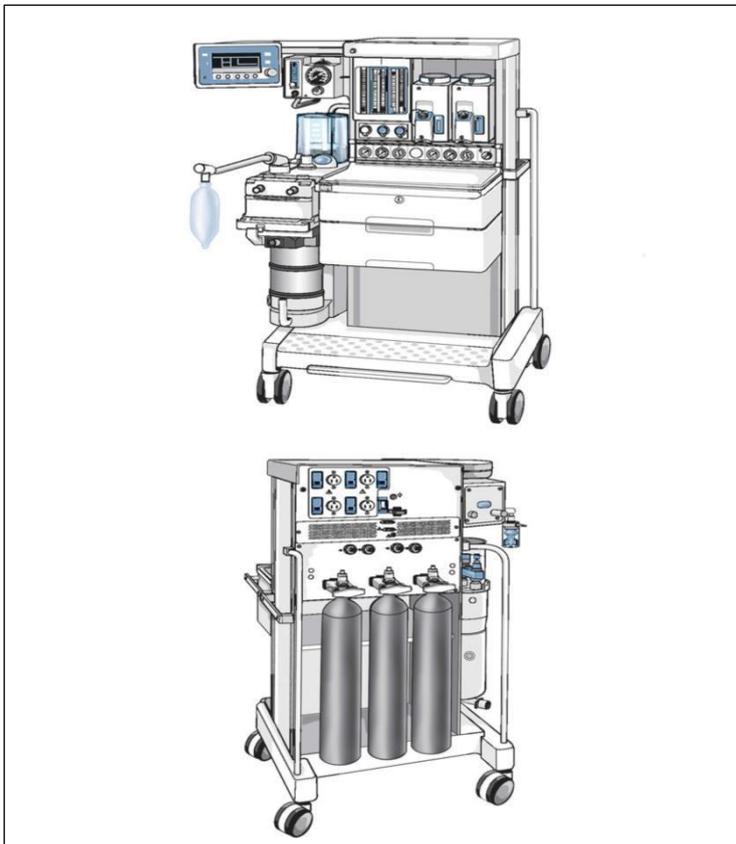
Anesthesia machine and anesthesia delivery

The anesthetic machine receives medical gases (oxygen, nitrous oxide, and air) under pressure and accurately controls the flow of each gas individually.

Old machine



Modern machine

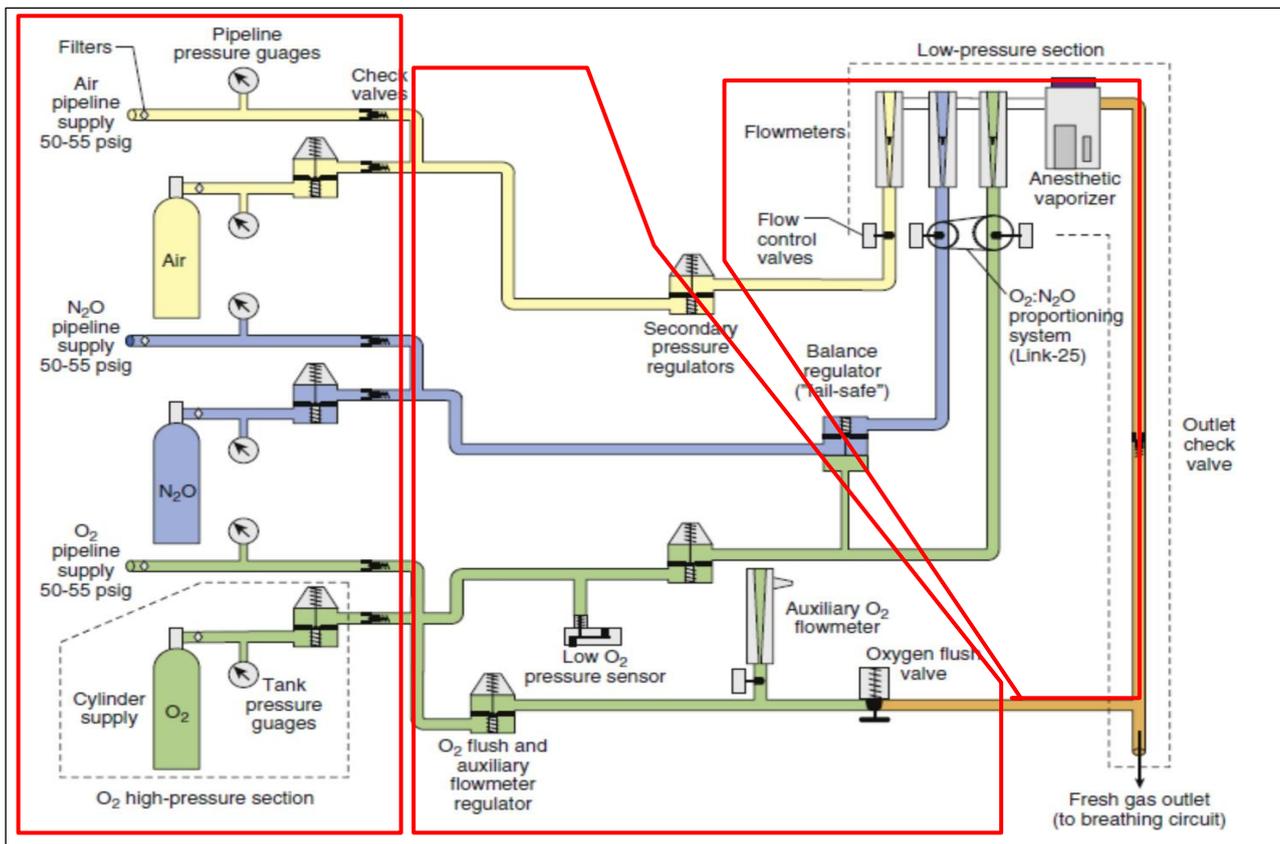


DThe Datex-Ohmeda Aestiva S/5 anaesthetic

The following components are likely to be encountered in sequence:

1. Source of gas supply
2. Yoke assembly
3. Pressure gauge
4. Pressure regulators
5. Oxygen (O₂) pressure failure safety/warning devices
6. Oxygen ratio control devices
7. Flowmeters
8. Vaporizers
9. Common gas outlet
10. Breathing systems.

Anatomy of an anesthesia machine:



The high-pressure system extends from the gas cylinders to the high-pressure regulators (dashed lines around O₂ high-pressure sections). The intermediate-pressure section extends from the high-pressure regulators to the flow control valves and also includes the tubing and components originating from the pipeline inlets. The low-pressure section (dashed lines) extends from the flow control valves to the breathing circuit.

High-Pressure Section:

- Cylinder P.G. & reg.
- Pipeline inlet & reg.
- Fail-safe.
- Flowmeter valve.
- O₂ flush.

Low-Pressure Section:

- Flowmeter.
- Vaporizer.
- Common gas outlet.

Important note: The high-pressure regulators are adjusted to provide gas from the E-cylinders at a pressure of approximately 45 psig (but it can be as low as 35 psig). Although this specific value may vary among machines, the principle is to keep the high-pressure regulator output pressure lower than the normal pipeline supply pressures. This approach ensures that the hospital's central gas supply will serve as the main supply of gas to the machine if a cylinder is open, as long as the hospital supply line pressure remains higher than the regulator output pressure. In other words, the E-cylinders, even when open, will not provide gas to the anesthesia machine if the hospital supply line pressure is within or higher than the normal range.

Pressure gauge

This measures the pressure in the cylinder or pipeline. The pressure gauges for oxygen, nitrous oxide, and medical air are mounted in a front-facing panel on the anesthetic machine.



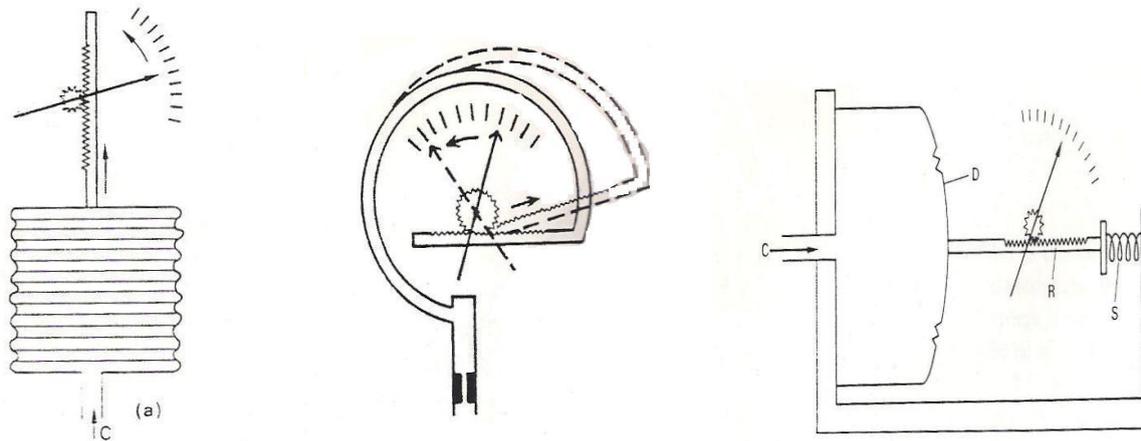
Components

1. A robust, flexible, and coiled tube that is oval in cross-section. It should be able to withstand the sudden high pressure when the cylinder is switched on.
2. The tube is sealed at its inner end and connected to a needle pointer, which moves over a dial.
3. The other end of the tube is exposed to the gas supply.



Mechanism of action

1. The high-pressure gas causes the tube to uncoil (Bourdon gauge).
2. The movement of the tube causes the needle pointer to move on the calibrated dial, indicating the pressure.



Problems in practice and safety features:

1. Each pressure gauge is color-coded and calibrated for a particular gas or vapor. The pressure measured indicates the contents available in an oxygen cylinder. Oxygen is stored as a gas and obeys Boyle's gas law (pressure X volume = constant). This is not the case in a nitrous oxide cylinder since it is stored as a liquid and a vapor.

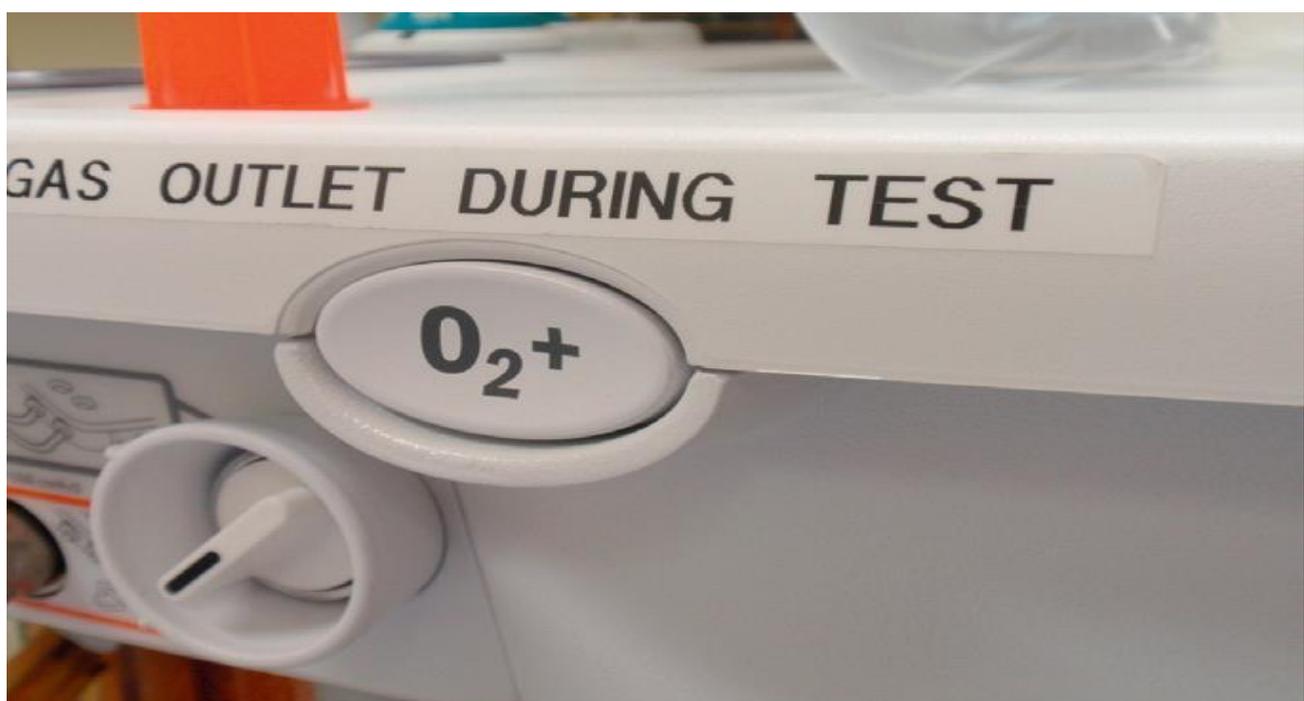
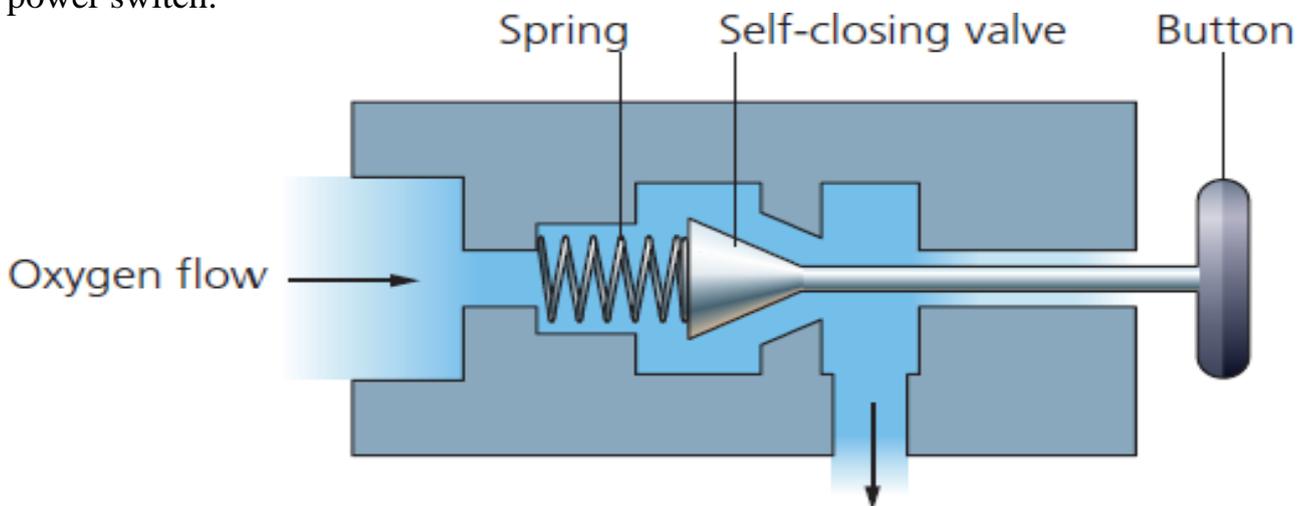


2. A pressure gauge designed for pipelines should not be used to measure cylinder pressure and vice versa. This leads to inaccuracies and /or damage to the pressure gauge.

3. Should the tube rupture, the gas vents from the back of the pressure gauge casing. The face of the pressure gauge is made of heavy glass as an additional safety feature.

Oxygen Flush Valve (O₂ bypass valve):

The oxygen flush valve is probably one of the oldest safety features on the machine, and it remains a machine standard today. The valve provides manual delivery of a high flow rate of 100% oxygen directly to the patient's breathing circuit. Flow from the oxygen flush valve bypasses the anesthetic vaporizer. The O₂ flush remains closed until the operator opens it. The feature is usually available even when the machine is not turned on because the valve is usually located upstream from the machine's pneumatic power switch.



Bypass the low-pressure section and deliver from the high-pressure section

- Name coded.
- Color coded with +.
- Easy to push, located in front of the anesthesia machine.
- The button is recessed in a housing to prevent accidental depression.

A flow of 35-75 L/min at about 400 kPa is expected.

35 L/60 time = 500 mL/second, so it can deliver a single tidal volume in one second, and it's very dangerous because it can lead to barotrauma; we use it **only** in an emergency.

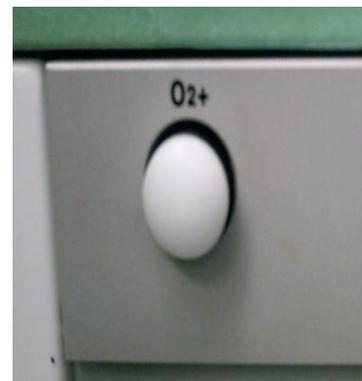
It should not be activated while ventilating a patient using a minute volume divider ventilator.

It's still activated when the machine turns off.

When the emergency oxygen flush is used inappropriately, it leads to dilution of the anesthetic gases and possible awareness.

The perfect uses are mentioned in the point below

1. Suddenly, in malignant hyperthermia, we can remove the CO₂-absorbed canister, vaporizer, and breathing circuit and clean the common gas outlet from anesthetic gas by pushing O₂ flush for a few minutes.
2. Use of O₂ flush during the test of the anesthesia machine every morning checklist.



Oxygen supply failure alarm

There are many designs available. But the characteristics of the ideal warning device are:



1. Activation depends on the pressure of oxygen itself (falls to 200 kPa).
2. It requires no batteries or mains power.
3. It gives an audible signal of a special character and of sufficient duration and volume to attract attention.
4. It should have pressure-linked controls that interrupt the flow of all other gases when they come into operation.
5. An alarm that cannot be switched off or reset until the oxygen supply is restored.

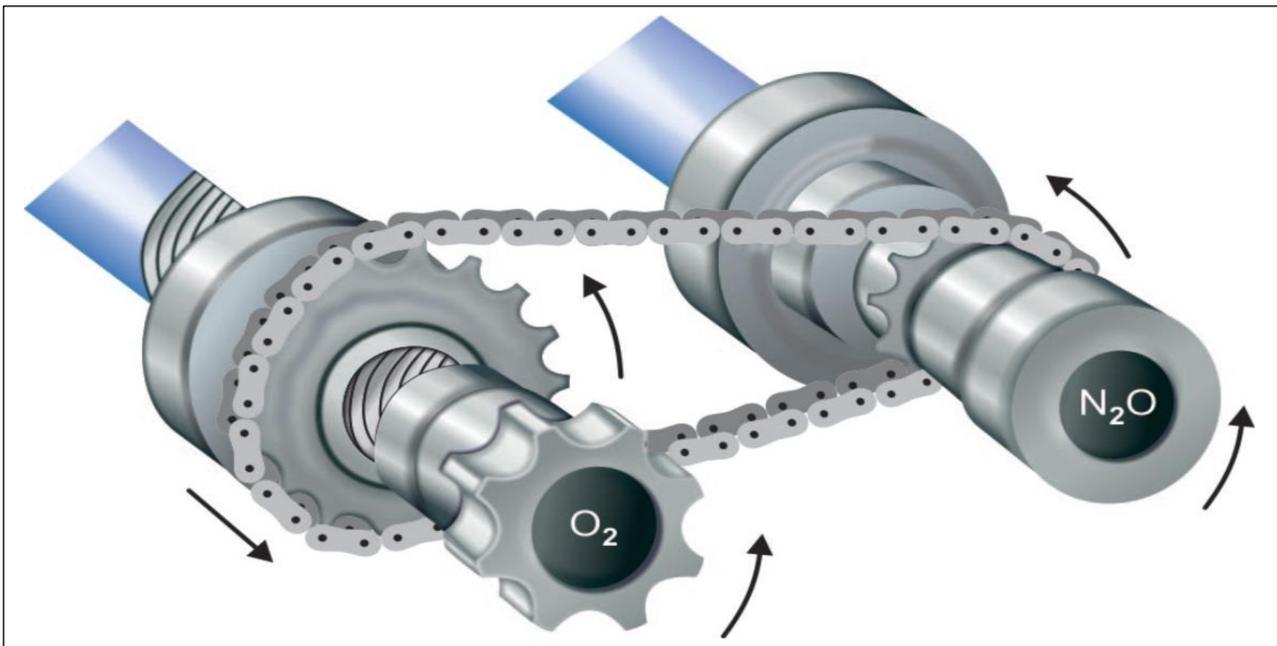
Important note: If there is any possibility that the workstation or the breathing circuit is a potential cause of difficulty with ventilation or oxygenation, switching to a self-inflating resuscitation bag is an appropriate decision. Ventilate and oxygenate first; troubleshoot later.

Important note: The most important part of the pre-use anesthesia workstation checkout procedure is verifying the presence of a self-inflating resuscitation bag.

Important note: If the hospital pipeline becomes crossed or contaminated, two actions must be taken. The backup oxygen cylinder valve must be opened, and the wall supply sources must be disconnected. Otherwise, hospital pipeline gas will continue to flow to the patient.

Link-25 Control System:

Conventional Datex-Ohmeda machines use the Link 25 system. The heart of the system is the mechanical integration of nitrous oxide and oxygen flow control valves. It allows independent adjustment of either valve. Yet it automatically intercedes to maintain a minimum 25% oxygen concentration with a maximum nitrous oxide-oxygen flow ratio of 3:1; the link-25 automatically increases oxygen flow to prevent delivery of a hypoxic mixture.

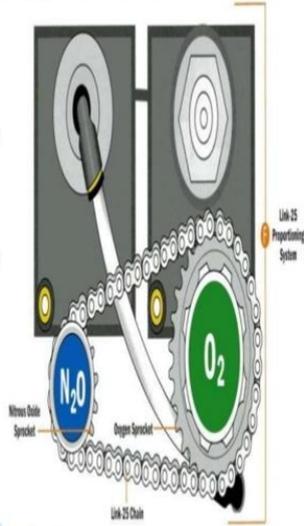
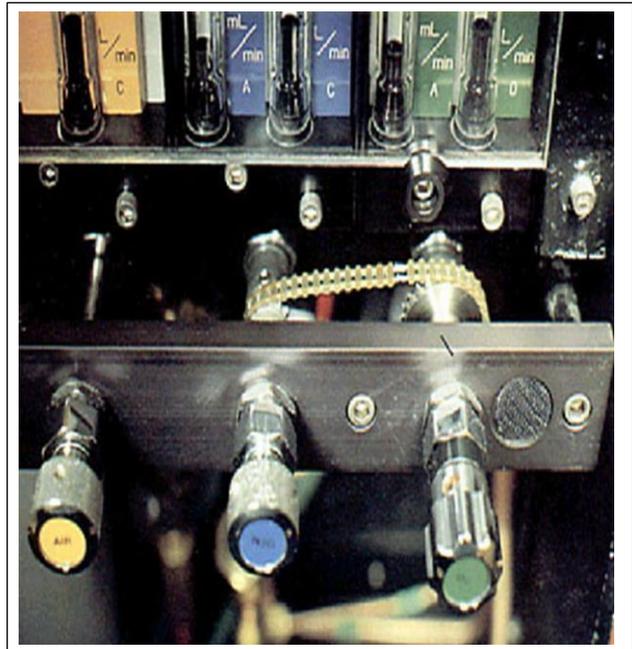


The nitrous oxide and oxygen flow control valves are identical. A 14-tooth sprocket is attached to the N₂O flow control valve and a 28-tooth sprocket to the oxygen flow control valve. A chain physically links sprockets. When nitrous oxide flow control is turned through two revolutions, the flow control valve will revolve once because of the 2:1 gear ratio. The final 3:1 ratio results because the N₂O flow control valve is supplied at approximately 26 psig, whereas the oxygen flow control valve is supplied at 14 psig. Thus, the combination of mechanical and pneumatic aspects of the system yields the final oxygen concentration.

The disadvantage of this system is in the mechanical linkage. If the spindle and the gear are not properly aligned, or if the threads in the spindle undergo wear and tear, the link system is likely to malfunction. Secondly, the proportioning devices can link only O₂ and N₂O. If a third gas, like air, is included in the flowmeter assembly, then it no longer assures a 25% O₂ delivery in the mixture. Most of the modern machines allow an air flowmeter in the flowmeter block.

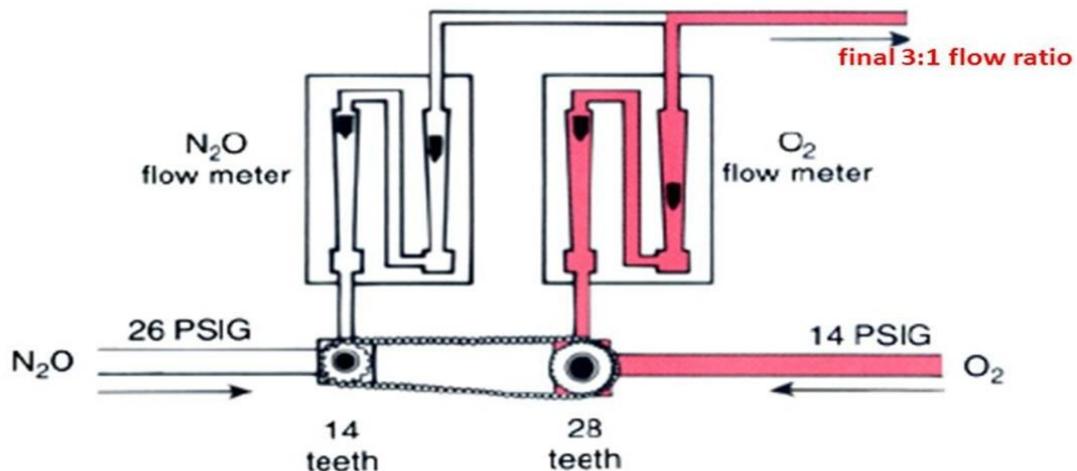
Ohmeda Link – 25 Proportioning System:-

- ▶ A 14-tooth sprocket is attached to the N₂O flow control valve, and a 28-tooth sprocket is attached to the O₂ flow control valve. A chain mechanically links the sprockets.
- ▶ For every 2 revolutions of the N₂O flow control spindle, an O₂ flow control, set to the lowest O₂ flow, rotates once because of the 14:28 ratio of the gear teeth.

Datex-Ohmeda Link-25 Proportion Limiting Control (Proportioning) System

A system that ↑O₂ flow when necessary to prevent delivery of a fresh gas mixture with an O₂ concentration of <25%



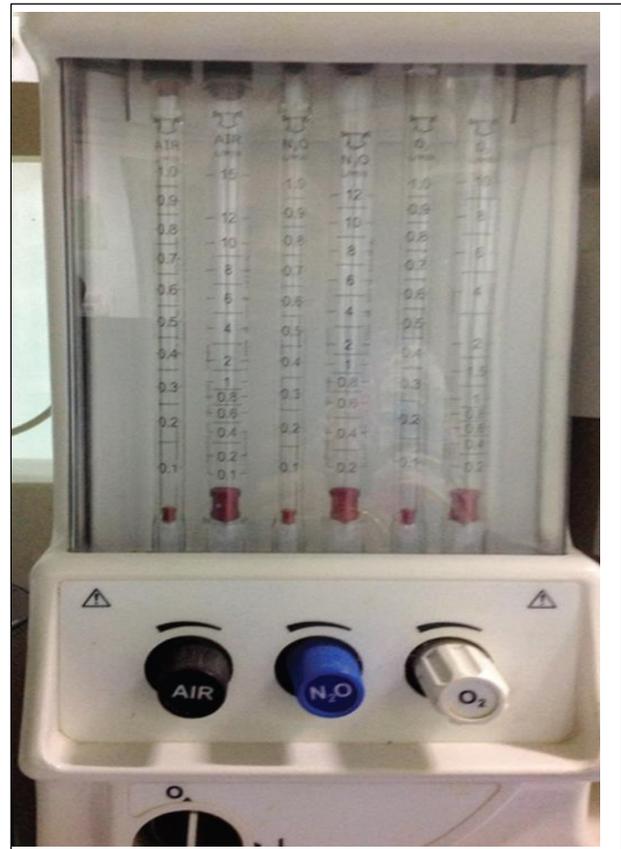
The combination of the mechanical and pneumatic aspects of the system yields the final oxygen concentration

Flowmeter

A **flowmeter** is a device that measures the flow rate of liquid or gas in a closed tube. It is used to control the rate of flow of gas and adjust the proportion of gas delivered. The flow rate of gas through a tube will depend on the pattern of flow, whether laminar or turbulent.

Flowmeters used in anesthesia machines help deliver anesthetic gases to the patient. Flowmeters form the low-pressure component of the anesthesia machines and are known as rotameters, as the “float” rotates with the flow of gases. A rotameter is a variable orifice, constant-pressure flowmeter.

“**Flow**” is defined as the quantity of gas (or fluid) passing a point in unit time. The units of flow are in mL/minute, L/minute, mL/hour, or L/hour. In anesthesia, we talk of the flow of gases in mL/minute or L/minute. Depending on the velocity of the flow, the flow can be laminar (at lower velocity) or turbulent (at higher velocity).

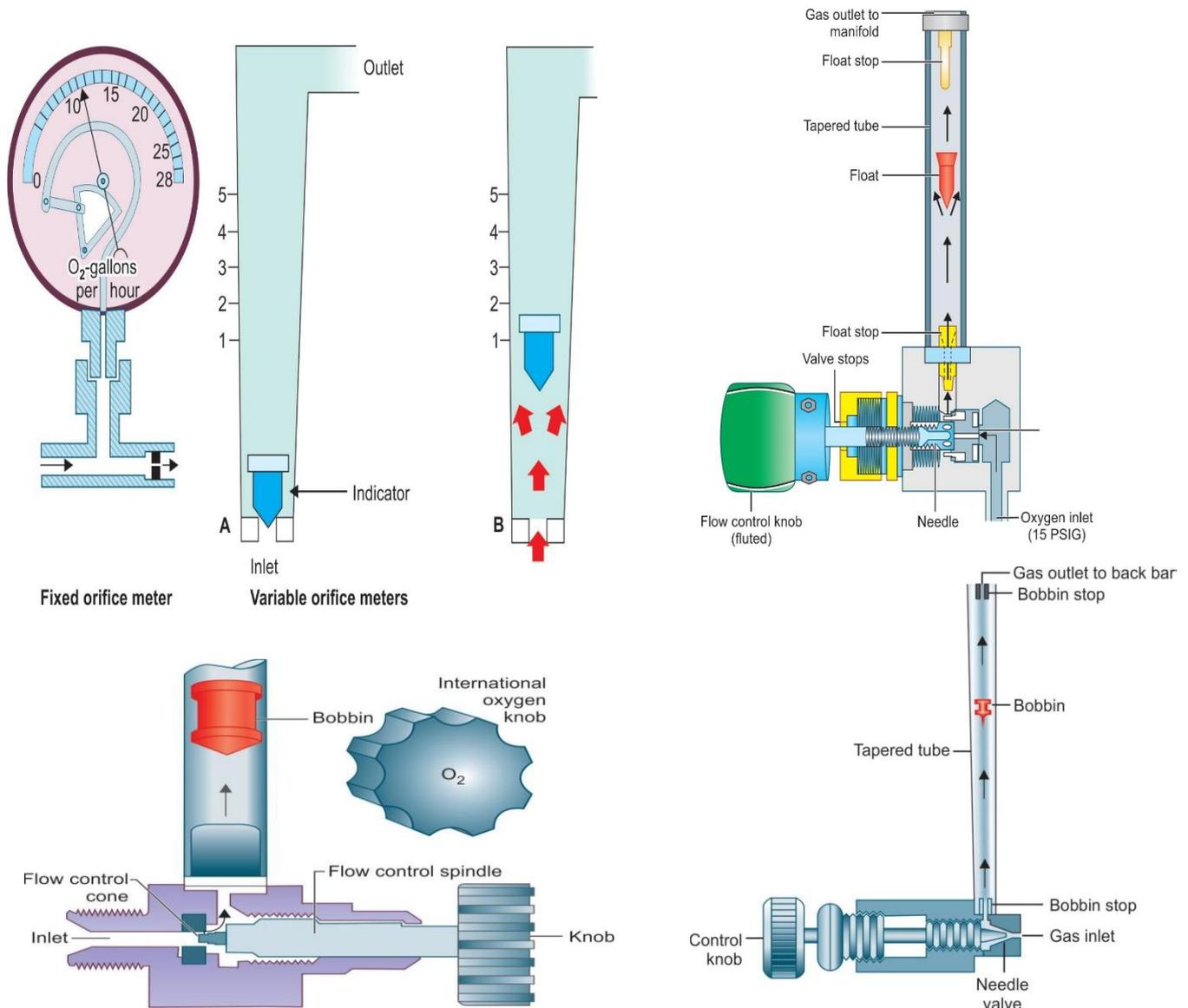


The two main types of anesthetic flow meters

Variable orifice meters: In these flowmeters, the pressure of the gas on either side of the bobbin remains constant, but the total area of the orifice progressively increases as the flow increases, e.g., a rotameter.

Fixed orifice meters: In these flowmeters, the dimension of the orifice through which the gas flows remains constant, but the pressure of the gas on either side of the orifice is varied, e.g., a Bourdon pressure gauge meter.

Note: the most commonly used flowmeters in anesthesia machines are the variable area type.

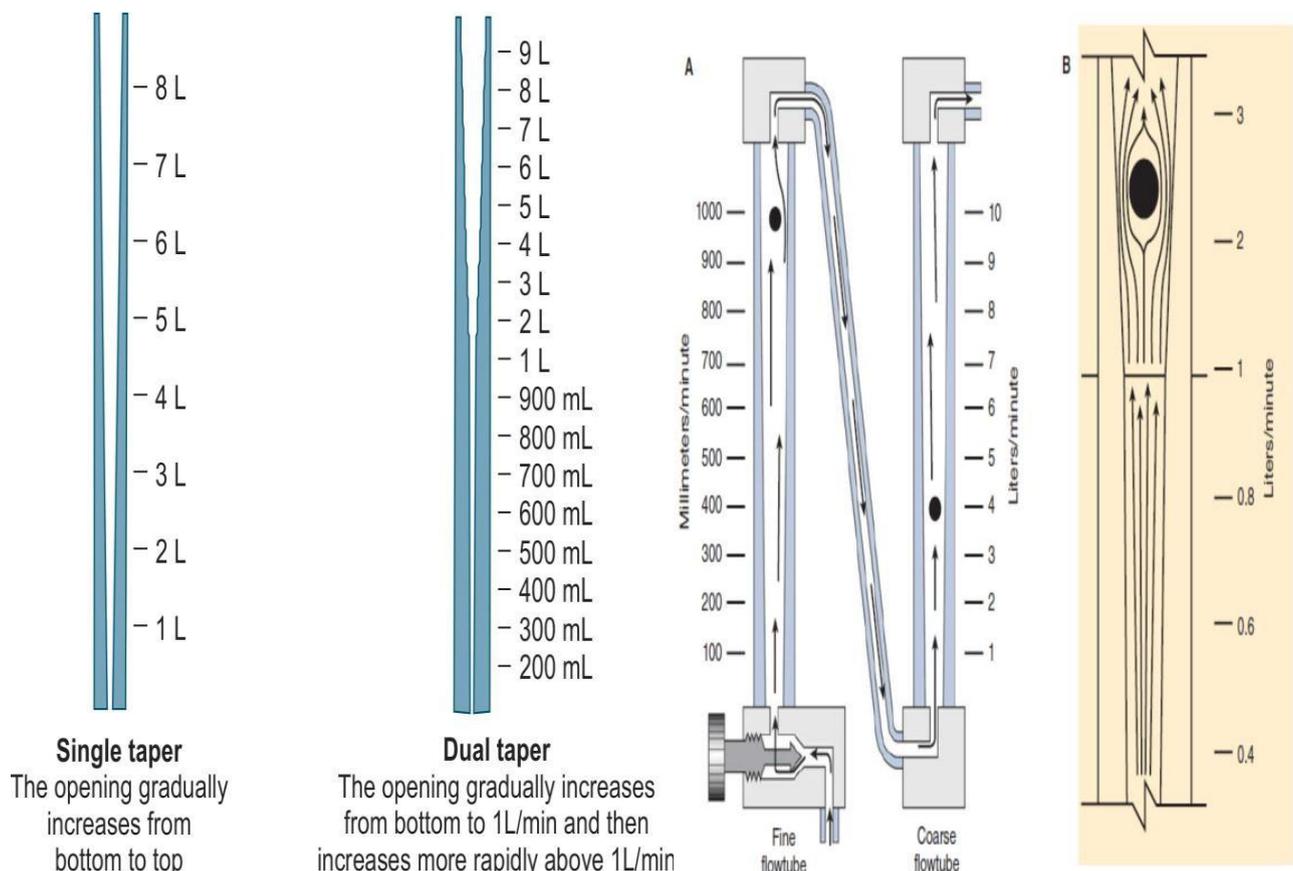


Flowmeter = Rotameter (general principle):

- Variable orifice, constant pressure.
- Agent specific.

Components		
	Flowmeter valve (FCV)	Flowmeter subunit
Valve	Control flow	Measure flow
Components	Flow control knob Needle valve Valve set valve stops	Tapered tube Floats Float stop Scale
Safety feature	Touch coded Color coded Name coded Protected Single for two tubes	Gas specific Color coded Inseparable unit Proportional syst arrangement Minimal O2 flow

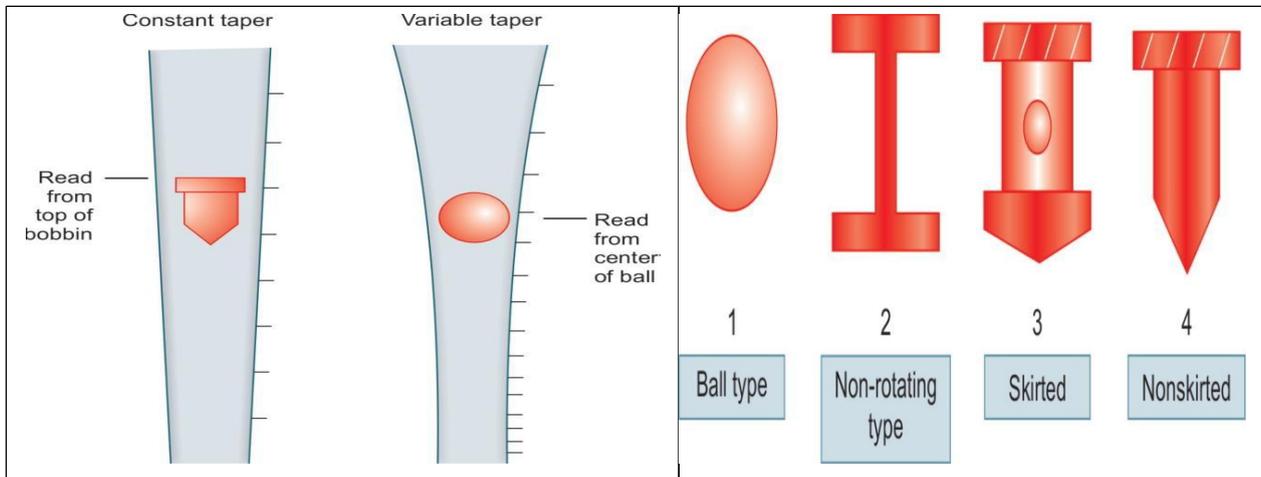
The tube is calibrated for a particular gas that covers flow rates from a few hundred mL/min to more than 10 L/min.



Indicator (Float or Bobbin):

Reading is taken at the upper rim.

Ball float: readings are taken at the center of the ball

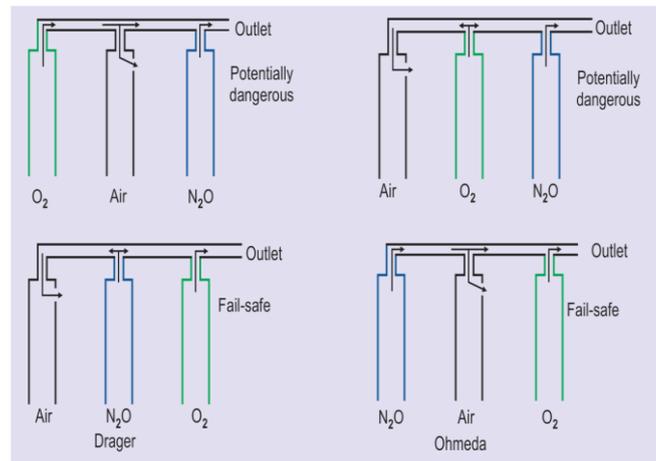
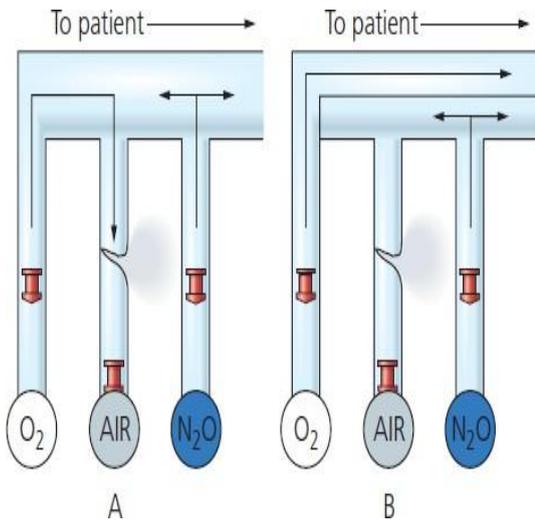
**TEMPERATURE AND PRESSURE EFFECTS:**

Flowmeters are calibrated at atmospheric pressure (760 torr) and room temperature (20°C). Hence, changes in temperature and pressure (by affecting density and viscosity) of gas affect flowmeter accuracy. In a hyperbaric chamber, a flowmeter will deliver less gas than indicated, and with decreased barometric pressure (high altitude), the actual flow rate will be greater than that indicated.

They have an accuracy of about $\pm 2.5\%$.

SEQUENCE OF FLOWMETER TUBES:

It is important to prevent delivery of a hypoxic gas mixture to the patient if any leak occurs in any of the flowmeter tubes. Therefore, it is safe to keep the oxygen flowmeter downstream of all the gases; otherwise, in case of leaks, oxygen will be selectively lost out from the leak if it is upstream of any of the flowmeter tubes.



A. Minimum Oxygen Flow

The oxygen flow valves are usually designed to deliver a minimum flow of 150 mL/min when the anesthesia machine is turned on. One method involves the use of a minimum flow resistor. This safety feature helps ensure that some oxygen enters the breathing circuit even if the operator forgets to turn on the oxygen flow.

Some machines are designed to deliver minimum flow or low-flow anesthesia (<1 L/min) and have minimum oxygen flows as low as 50 mL/min.

Type of Flowmeter

Type	Control	Display
Traditional	Mechanical valve	Glass tube
Transitional (hybrid)	Mechanical valve	Electronic
Electronic	Electronic	Electronic

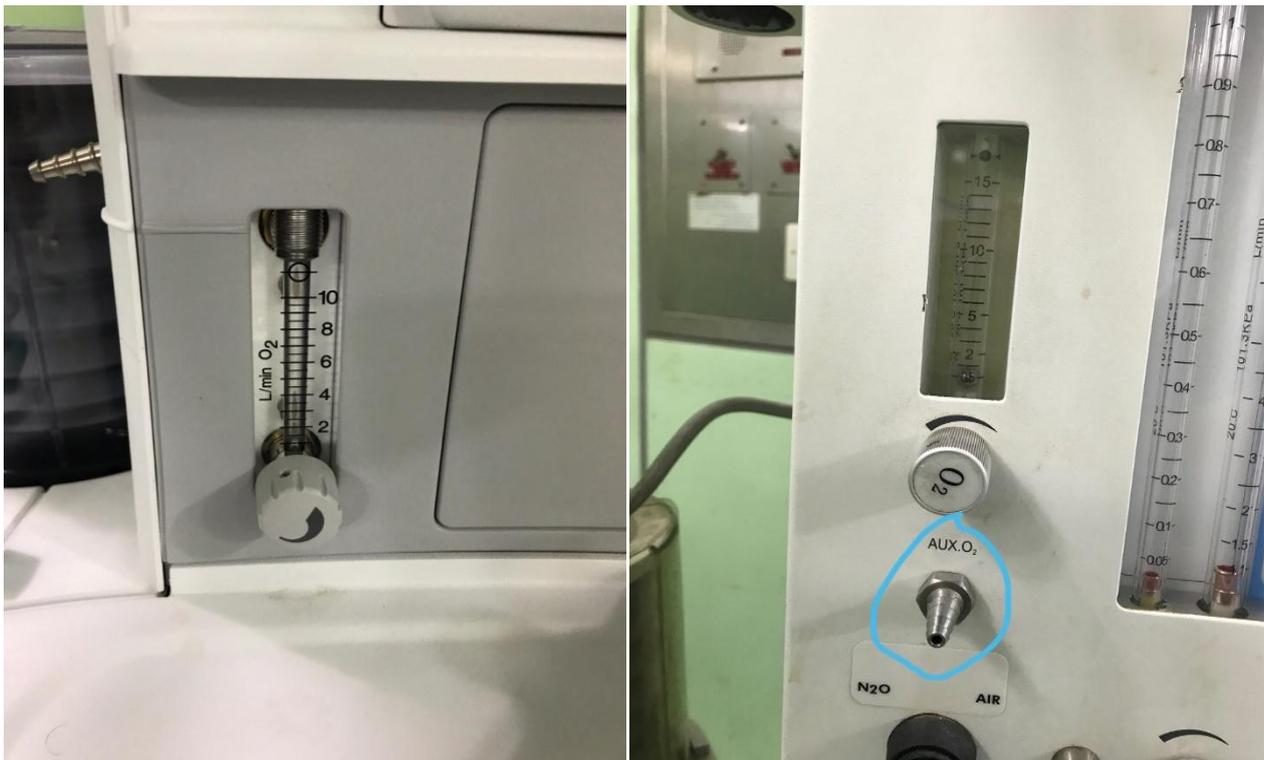


Alternate O2 supply. Activates in case of electronic failure

AUXILIARY OXYGEN FLOWMETER:

Auxiliary oxygen flowmeters are separate from the back bar flowmeters and the common gas outlet. It is an optional accessory seen on many models of anesthesia machines.

A nasal cannula or other oxygen delivery device can be attached for the delivery of supplemental oxygen



VAPORIZER MOUNTING SYSTEMS (Back Bar):

Can be permanent or detachable.

Permanent Mounting

Permanent mounting systems require tools to remove or install a vaporizer on the anesthesia machine. There is less physical damage to vaporizers and fewer leaks. The problems with permanent mounting are an inadequate number of mounting locations to accommodate all the vaporizers that are likely to be needed. If there is a malfunction and the vaporizer needs to be exchanged, it cannot be easily removed.

Detachable Mounting

The vaporizers can be mounted or removed without using tools. They are standard on most new anesthesia machines. The Select-a-tec system consists of a pair of port valves for each vaporizer position. The port valve has O-rings. If missing or misaligned, these are common sites of vaporizer leaks.

**Before mounting a vaporizer, the locking lever should be unlocked; the control dial must be turned off. The adjacent vaporizer must be turned off. The vaporizer is placed onto the mounting system and locked in position. After a vaporizer has been mounted:

. Look at the tops of the vaporizers; they should be at the same height and level with each other

- Try to lift the vaporizer. If it can be moved without unlocking, it is improperly positioned
- It should be possible to turn on only one vaporizer at a time
- The anesthesia machine must be checked for leaks with each vaporizer in both the “ON” and “OFF” positions.

When the vaporizer is turned on, the two plungers move downward and open the port valves, allowing fresh gas to enter the vaporizer. When the vaporizer is turned off, the port valves remain closed, and the FGF passes through the back bar without entering the vaporizer.

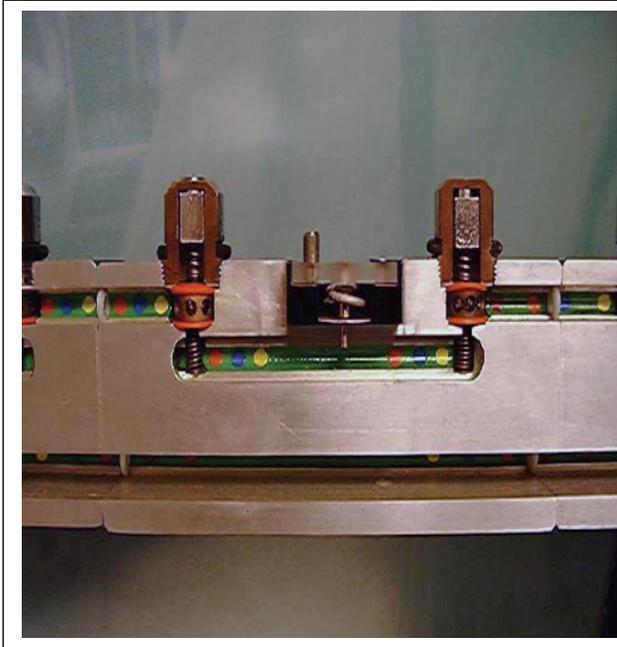
To remove the vaporizer from the machine, the vaporizer is turned off, and the locking lever is unlocked. The vaporizer is lifted off the manifold.

Advantages

- A more compact anesthesia machine with fewer mounting locations. Replacement is possible during a case
- If malignant hyperthermia is a potential problem, the vaporizers can be removed altogether.

Disadvantages

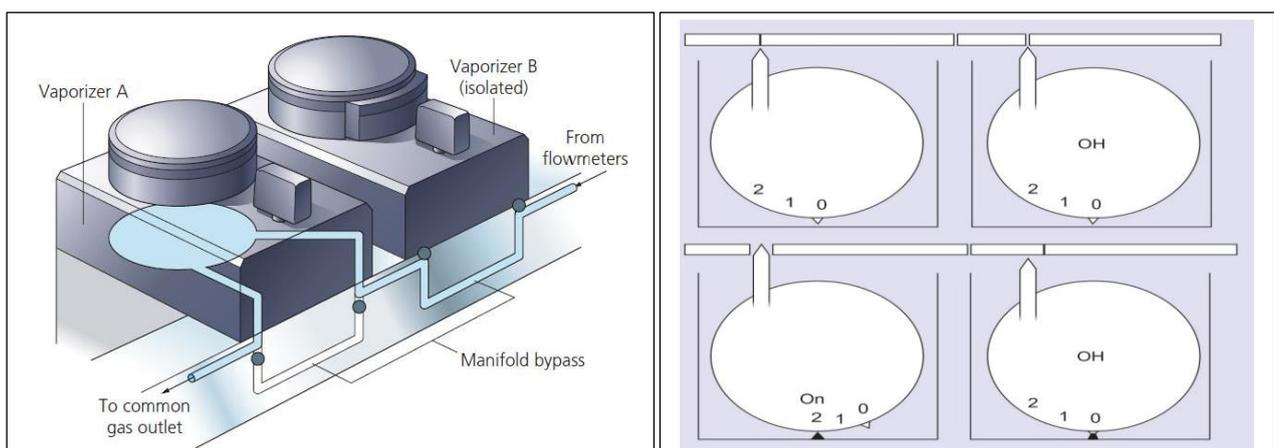
- Partial or complete obstruction to gas flow can occur due to misalignment
- Potential for leaks is high; a common leak source is an absent or damaged O-ring, or if the locking lever is unlocked.
- Awareness can occur if there is a failure to deliver agent vapor to the fresh gas due to problems with the mounting system.
- If something is pushed under the vaporizer enough so that it slightly lifts off the O-ring, a leak may result when the vaporizer is turned “ON.”
- Miscellaneous instruments placed on the vaporizer syringes for cuff inflation—may interfere with the locking and concentration dials and cause leaks or render the vaporizer non-functional
- Differences among vaporizers and interlocks from different manufacturers may be incompatible.



INTERLOCK DEVICES:

These are vaporizer exclusion systems that prevent more than one vaporizer from being turned on at the same time. These should be checked with the anesthesia apparatus checkout procedure.

When the dial release on the Datex-Ohmeda/GE vaporizers is unlocked and the dial is moved, a pin moves two extension rods that project out, and the concentration control dials of the neighboring vaporizers become operational.



HAZARDS

1. Misfilling

The vaporizer should be drained and flushed until no agent is detected at the outlet.

2. Tipping

A more likely outcome is an overdose, as 1 mL of liquid produces 200 mL of vapor. If tilted, a vaporizer should be flushed with oxygen at 5 L/minute for 5 minutes.

3. Leaks,

4. Overfilling,

5. No Output

6. Reversal of Flow:

7. **Projectile:** In the magnetic resonance imaging (MRI) suite, vaporizers should be firmly secured to the back bar. Very few vaporizers contain ferromagnetic material and are generally safe to use in this setting. However, if ferromagnetic material is present, the vaporizer may act as a projectile.

8. Trans filling (cross-filling)

Combined Systems (The Humphrey ADE breathing system)

This is a very versatile breathing system that combines the advantages of the Mapleson A, D, and E systems. It can therefore be used efficiently for spontaneous and controlled ventilation in both adults and children. The mode of use is determined by the position of one lever, which is mounted on the Humphrey block. Both parallel and coaxial versions exist with similar efficiency. The parallel version will be considered here.



Components:

1. Two lengths of 15 mm smooth-bore tubing (corrugated tubing is not recommended). One delivers the fresh gas, and the other carries away the exhaled gas. Distally, they are connected to a Y-connection leading to the patient. Proximally, they are connected to the Humphrey block.

2. The Humphrey block is at the machine end and consists of:
 - A. An APL valve featuring a visible indicator of valve performance.
 - B. A 2-liter reservoir bag.
 - C. A lever to select either spontaneous or controlled ventilation.
 - D. A port to which a ventilator can be connected, e.g., Penlon Nuffield 200.
 - E. A safety pressure relief valve that opens at pressures in excess of 60 cmH₂O.

Mechanism of action:

1. With the lever up in the spontaneous mode, the reservoir bag and APL valve are connected to the breathing system as in the Magill system.
2. With the lever down in the ventilator mode, the reservoir bag and the APL valve are isolated from the breathing system as in the Mapleson E system. The expiratory tubing channels the exhaled gas via the ventilator port. Scavenging occurs at the ventilator's expiratory valve.
3. The system is suitable for pediatric and adult use. The tubing is rather narrow, with a low internal volume. Due to its smooth bore, there is no significant increase in resistance to flow compared to 22 mm corrugated tubing used in other systems. Small tidal volumes are possible during controlled ventilation, and less energy is needed to overcome the inertia of gases during spontaneous ventilation.
4. The presence of an APL valve in the breathing system offers a physiological advantage during pediatric anesthesia since it is designed to offer a small amount of PEEP (1 cm H₂O).

During spontaneous ventilation:

- A. A fresh gas flow of about 50-60 ml/kg/min is needed in adults.
- B. The recommended initial fresh gas flow for children weighing less than 25 kg is 3 liters/min. This offers a considerable margin of safety.

During controlled ventilation:

- A. A fresh gas flow of 70 ml/kg is needed in adults.

B. The recommended initial fresh gas flow for children weighing less than 25 kg body weight is 3 liters/min. However, adjustment may be necessary to maintain normocarbida.

The essential components of the circle system are

A CO₂ absorbent canister: A vertically positioned canister containing soda lime, para lime, and ambo sorb. The canister has two ports, one to deliver inspired gases to the patient and the other to receive exhaled gases from the patient.

Soda lime consists of 94% calcium hydroxide and 5% sodium hydroxide with a small amount of potassium hydroxide (less than 0.1%). It has a pH of 13.5 and a moisture content of 14–19%. Some modern types of soda lime have no potassium hydroxide. Soda lime granules are prone to powder formation, especially during transport. Disintegrated granules increase resistance to breathing. Because of this, silica (0.2%) is added to harden the absorbents and reduce powder formation. A dye or colour indicator is added to change the granules' colour when the soda lime is exhausted. Colour changes can be from white to violet/purple (ethyl violet dye), from pink to white (titan yellow dye), or from green to violet. Colour changes occur when the pH is less than 10.

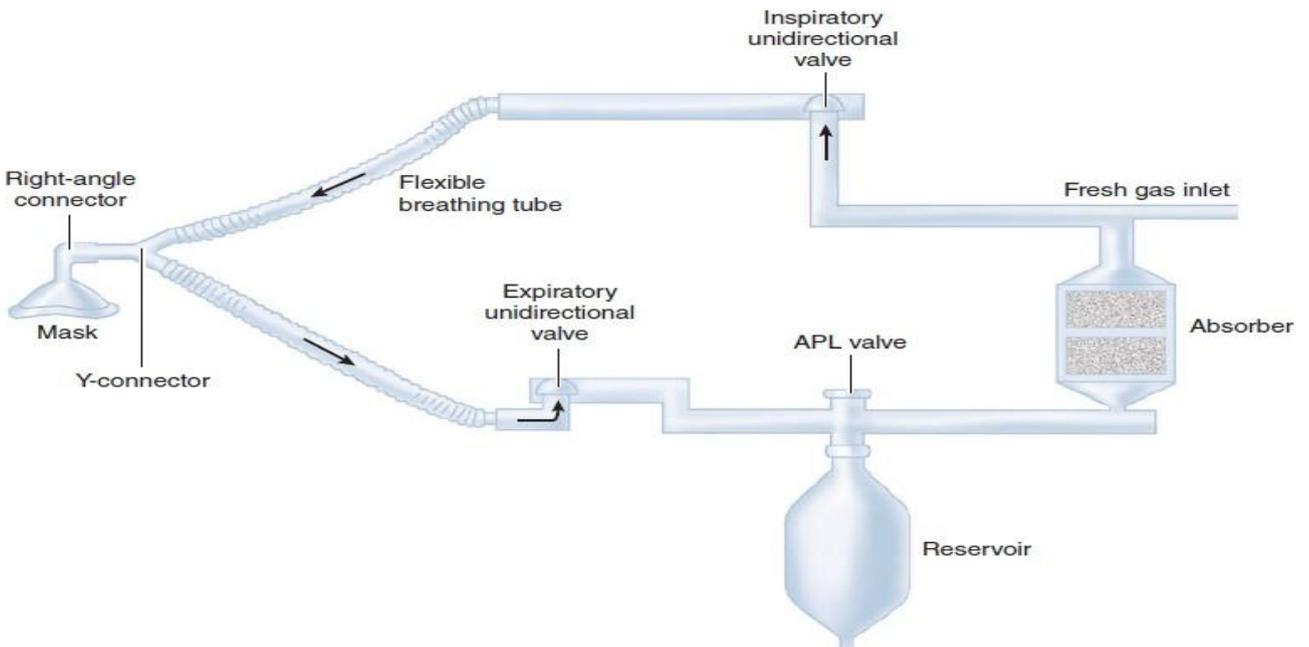
1 kg can absorb more than 120 L of CO₂.

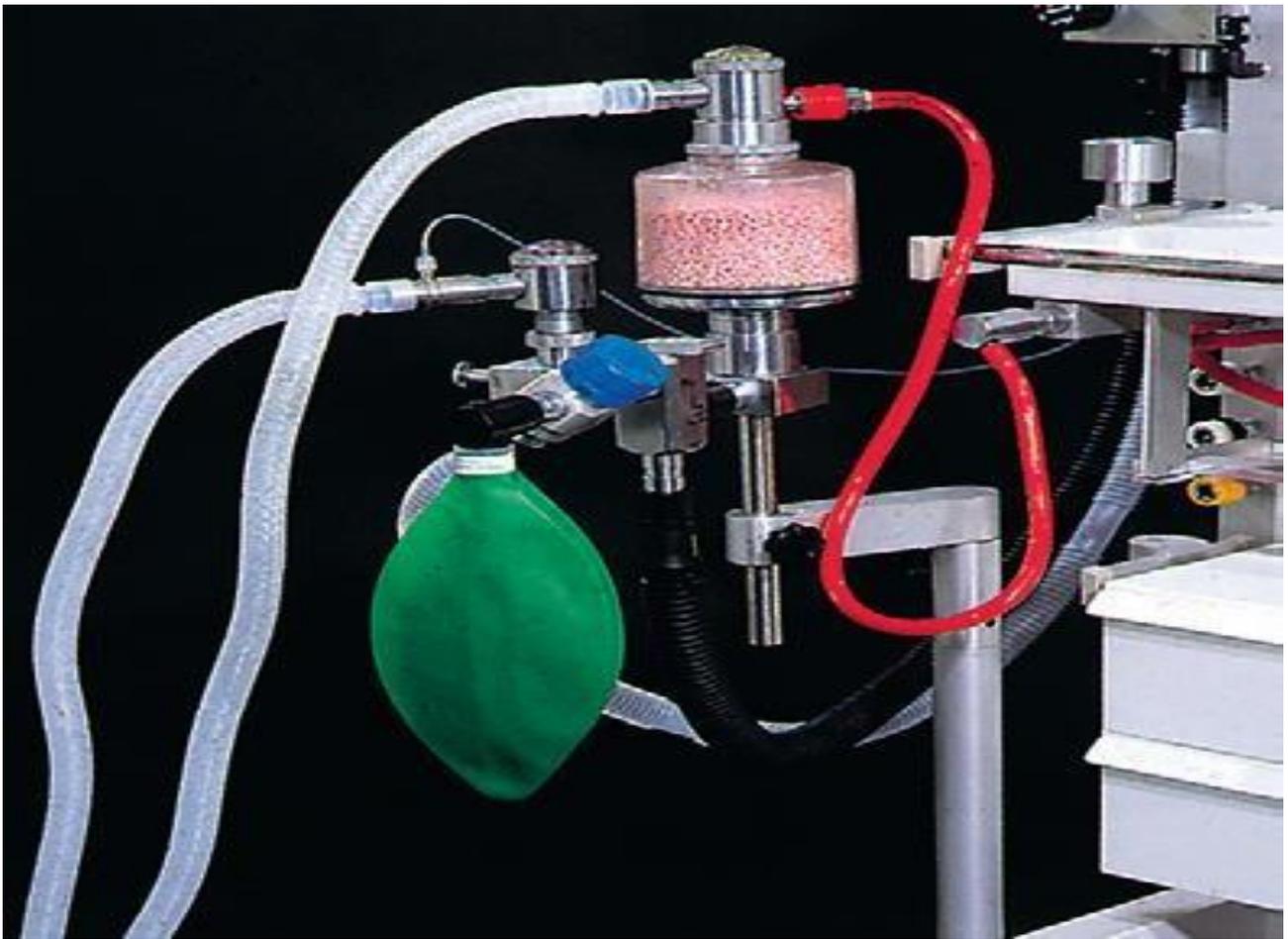
CO ₂ absorbents			
	Soda lime	baralyme	Amsorb
Composition	Ca (OH) ₂ (94%) Na OH (5%) K OH (1%) Silica (0.2%)	Ca (OH) ₂ (80%) Ba (OH) ₂ (20%) No Silica	Ca (OH) ₂ (83%) Ca Cl ₂ Ca sulfate
Absorption capacity	14-24 (20) L CO ₂ / 100Gg	9-18 (15) L CO ₂ / 100Gg	6-12 L CO ₂ / 100Gg

- Fresh gas flow source
- Insp. & exp. unidirectional valves
- Insp. & exp. corrugated tubes
- Y-piece to connect to the patient
- Bag/vent switch
- Adjustable pressure limited (APL) valve
- Low-resistance interconnecting tubing.

Note: A pH indicator dye (eg, ethyl violet) changes color From white to purple as a consequence of increasing Hydrogen ion concentration and absorbent exhaustion.

Absorbent should be replaced When 50% to 70% has changed color.







Over 80% of the anesthetic gases are wasted when FGF of 5.0 L/min is used. Typically, the reduction of FGF from 3.0 L/min to 1.0 L/min results in a saving of about 50% of the total consumption of any volatile anesthetic agent. In this breathing system, soda lime is used to absorb the patient's exhaled carbon dioxide.

Advantages of the circle system:

- **Economy:** The FGF could be reduced to as low as 500–1000 mL.
- **Humidification:** In the low-flow system, once the equilibrium has been established, the inspired gas will be fully saturated with water vapor.
- **Reduction in atmospheric pollution:** The loss from the system will equal the FGF minus the CO₂ that is absorbed; hence, the reduction in atmospheric pollution.

Disadvantages of the circle system:

- Bulky & complex system, liable for leakage and disconnection
- Real danger of hypercapnia may result from
- An inactive absorber
- Incompetent unidirectional valves and
- Incorrect use of absorber bypass necessitating EtCO₂ monitoring as mandatory.

Classified the FGF used in anesthetic practice into the following:

Categories:

Metabolic flow: About 250 mL/min. Minimal flow: 250–500 mL/min.

Low flow: 500–1000 mL/min. Medium flow: 1–2 L/min.

Techniques In Anesthesia Yesterday – Today

Type of <u>anesthesia</u>		Fresh gas flow	
High flow <u>anesthesia</u>	Yesterday	> 2 L/min	O ₂ + N ₂ O
Low flow <u>anesthesia</u>		= 1 L/min	
Minimal flow <u>anesthesia</u>	Today	= 0,5 L/min	O ₂ + AIR
Metabolic flow <u>anesthesia</u>		=0,35 L/min	

For most practical considerations, utilization of a fresh gas flow less than 2 L/min may be considered as low-flow anesthesia.

Clinical practice of using low-flow anesthesia (LFA)

- Pre-oxygenation and induction of sleep are performed according to the usual practice.

O₂ + Air + volatile anesthetic

➤ **Concerning adjustment of FGF, anesthesia can be divided into 3 phases:**

1. Initial high flow.
2. Low flow.
3. Recovery.

Initial High flow

- Sufficient denitrogenation.
- Establishing the wanted concentration of the volatile anesthetic.
- After the high-flow phase preset time, or when the target gas concentrations has been achieved, FGF can be reduced at the desired low flow level.
- Take time during induction and recovery.

Relative Contraindication of low-Flow Anesthesia

1. A hepatic disease patient expired with acetone
2. Heavy-smoking patients
3. Alcoholic patients
4. Uncontrolled diabetes
5. Prolonged sevoflurane anesthesia

Absolute contra-indication

1. Inhalational injury
2. Septicemia
3. Old machine

Equipment for safe use of the circle system

The minimum requirement for the conduct of low-flow anesthesia is a circle system with an efficient CO₂ absorber and a leak not exceeding 200 mL.

Monitoring inspired O₂ concentration should be monitored at all times if N₂O is used

in more than 65% concentration as one of the adjuvant gases. EtCO₂ monitoring seems to be necessary to ensure proper functioning of the absorber. If monitoring of end-tidal anesthetic concentration is available, the administration of low-flow anesthesia becomes very easy.

- Pulse oximeter
- Agent-specific monitor
- Measure circle
- Volume of circle
- Leak-free system
- Absorbent leakage
- Flowmeter check

For low-flow anesthesia

1. Experienced anesthetist
2. Calibration of the flowmeter down to 50 mL/min
3. Circuit no leaks—compliance
4. Gas monitoring
5. Efficient CO₂ absorbent

Risk of low-flow anesthesia

- Increased risk hypoxia and hypercapnia
- Increase risk of over/under dose of inhalational anesthetic
- Increase risk of accumulation of trace gas (N₂, methane, and acetone).

Important note: mixing CO₂ absorbents with volatile agents can produce different compounds.

Anesthetic agent with granules

Sevoflurane compound An effect on the kidney in rats (fluoromethyl-2-1-triflouromythyl)

High concentration of sevoflurane

Halothane compound BCDEF (BROMO CHLORO DI FLUORO ETHAN)

Isoflurane }
Desflurane } Carbonmonoxide with soda lime and para lime
Enflurane }

Important note: Amsorb has no effect on anesthetic agents.

Ventilators

Ventilators are used to provide controlled ventilation (IPPV). Some have the facilities to provide other ventilator modes. They can be used in the operating theater, intensive care unit, during transport of critically ill patients, and also at home (e.g., for patients requiring nocturnal respiratory assistance).

There are many ways of classifying ventilators: method of cycling, method of operation, source of power, suitability for use in theater and/or intensive care, and suitability for pediatric practice.

The ideal ventilator should include the following features:

1. Simple, portable, robust, and economical to purchase and use.
2. Versatility: tidal volumes up to 1500 ml with a respiratory rate up to 60/min and variable I/E ratio. It can be used with different breathing systems. It can deliver any gas or vapor mixture. The addition of PEEP should be possible.
3. Monitors the airway pressure, inspired and exhaled minute and tidal volume, respiratory rate, and inspired oxygen concentration.
4. Facilities to provide humidification. During, it can be nebulized through it.
5. Disconnection, high airway pressure, and power failure alarms should be present.
6. Has the facility to provide other ventilator modes, e.g., SIMV, CPAP, and pressure support.
7. Easy to clean and sterilize.

Some of the commonly used ventilators are described below.

Bag in bottle ventilator

Modern anesthetic machines often incorporate a bag-in-bottle ventilator.

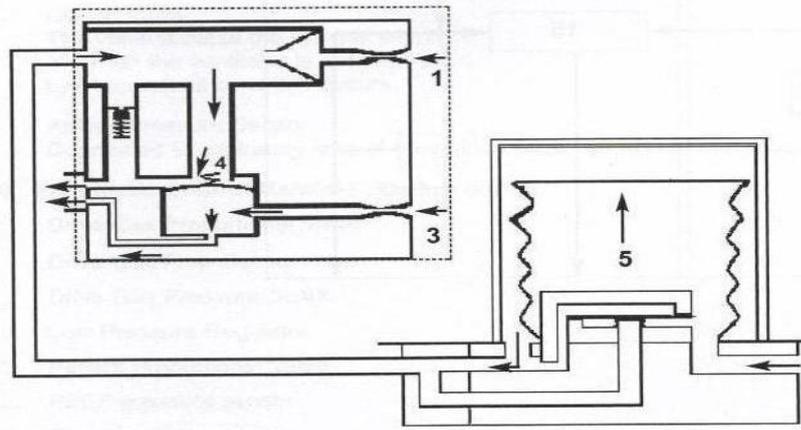


Components:

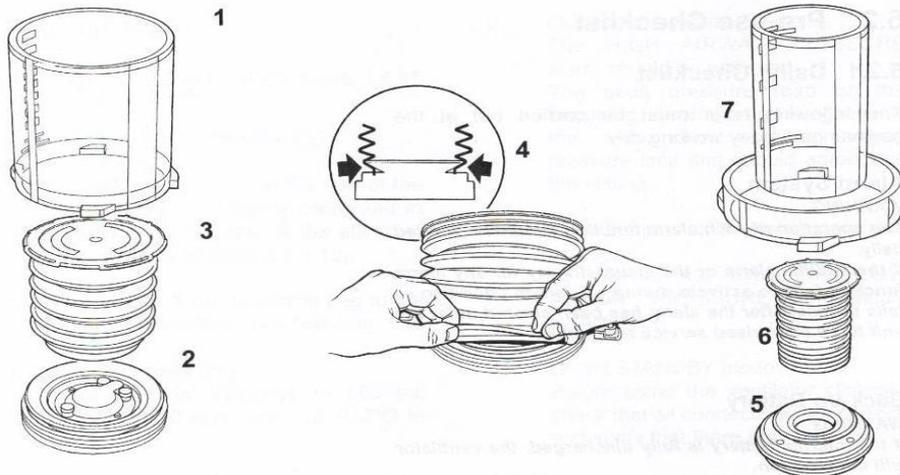
1. A driving unit consisting of:
 - a. A chamber with a tidal volume range of 0-1500 ml (a pediatric version with a range of 0-400 ml exists).
 - b. An ascending bellows accommodating the fresh gas flow.
2. A control unit with a variety of controls, displays, and alarms: the tidal volume, respiratory rate (6-40/min), I/E ratio, airway pressure, and power supply.

Mechanism of action:

1. It is a time-cycled ventilator.
2. Compressed air is used as the driving gas. On entering the chamber, the compressed air forces the bellows down, delivering the fresh gas to the patient (the fresh gas is accommodated in the bellows).



3. The driving gas and the fresh gas remain separate.
4. The volume of the driving gas reaching the chamber is equal to the tidal volume.
5. Some designs feature a descending bellows instead.



Problems in practice and safety features:

1. Positive pressure in the standing bellows causes a PEEP of 2-4cm H₂O.
2. The ascending bellows collapses to an empty position and remains stationary in cases of disconnection or leak.
3. The descending bellows hangs down to case of disconnection and may continue to move almost normally in cases of leak.

Seimens servo 900C ventilator

This is a versatile electronic ventilator used mainly in the intensive care unit and occasionally in theatre. It is time-cycled. It can also cycle in response to patient respiratory effort (triggering).



Components

1. Concertina bag bellows pressurized by a spring.
2. Electronically controlled inspiratory and expiratory valves.
3. Inspiratory and expiratory flow and pressure transducers.
4. A variety of controls, displays, and alarms: inspired and expired minute and tidal volume, respiratory rate, FiO₂, different modes of ventilator support, and high and low airway pressures.

Mechanism of action

1. Its electronic circuits, which modify its basic mechanical properties, allow the control of various aspects of IPPV.
2. It is powered by electricity but needs an inflating gas to operate. The bellows can accept gas flow from two sources:
 - a. Low-pressure gas inlet from flowmeters.
 - b. High-pressure gas inlet direct from pipelines.
3. The inflating gas(es) fills the bellows against a pressure supplied by a spring. This pressure is regulated by the preset working pressure control and displayed by the working pressure gauge (a range of 10-100 cm H₂O).

4. Inspiration starts with the flow of gas to the patient with the inspiratory valve open and the expiratory valve closed. The inspiratory flow and pressure transducers measure and display the volume and pressure of the gas flow. The waveform selection switch controls the performance of the inspiratory valve.
5. The ventilator cycles to the expiratory phase at the end of a period dictated by the settings of inspiratory time % and breaths per minute.
6. The expiratory flow transducer measures the expiratory flow rate and displays it as the expired minute volume.

Problems in practice and safety features

1. A comprehensive alarm system is featured.
2. Nebulization of drugs is not possible.

Servo-i ventilator (ICU ventilator)

The Servo-i is a versatile intensive care ventilator, capable of being used for pediatric and adult patients. It is fully transportable, utilizing 12 V battery power when mains electricity is not available.

It is not intended for use with inhalational anesthetics; it can be used with intravenous anesthetics in the theater setting if required. It can be used to ‘noninvasively’ ventilate patients with a tight-fitting nasal mask or face mask instead of an endotracheal tube or tracheostomy. Facilities to deliver Heliox also exist. The most modern versions have advanced tools to safely perform lung recruitment utilizing software that regulates PEEP and aims to maintain lung compliance.

Neurally Adjusted Ventilatory Assist (NAVA) uses a specially adapted nasogastric tube that detects the phrenic nerve impulses to the diaphragm. This enhances the ability of the ventilator to match the respiratory efforts of the patient by timing its assisted breaths.



Components:

1. 'Patient unit' where gases are mixed and administered.
2. 'Graphical user interface' where settings are made and ventilation monitored.

Mechanism of action

1. Gas flow from the oxygen and air inlets is regulated by their respective gas modules.
2. Oxygen concentration is measured by an oxygen cell.
3. The pressure of the delivered gas mixture is measured by the inspiratory pressure transducer.
4. The patient's expiratory gas flow is measured by ultrasonic transducers, and the pressure is measured by the expiratory pressure transducer.
5. PEEP in the patient's system is regulated by the expiratory valve.

VENTURI INJECTOR DEVICE

A manually controlled venturi ventilation device used during rigid bronchoscopy. The anesthetist and the operator share the airway. General anesthesia is maintained intravenously.

This should be avoided in children due to the risk of barotrauma. Attach the assembly to a 50 psi oxygen source (wall/machine) with an adjustable regulator so that pressure can be titrated to the lowest effective pressure required to deliver desired TV.

The gas flow through a 14-G catheter at 50 psi is 1,600 mL/second, and adequate TV is delivered in less than 1 second for a normally compliant lung. Keep a longer time for expiration. Since expiration will occur through the upper airway, it is important to ensure that the upper airway is patent before doing ventilation to avoid barotrauma. Avoid ventilation where upper airway patency is in doubt and in children below 5 years. In these cases, prefer the bag connector assembly for ventilation.

Components:

1. A high-pressure oxygen source at about 400 kPa (from the anesthetic machine or direct from a pipeline).
2. An on/off trigger.
3. Connection tubing that can withstand high pressures.
4. A needle of suitable gauge, which allows good air entrainment without creating excessive airway pressures.



Mechanism of action:

1. The high-pressure oxygen is injected intermittently through the needle placed at the proximal end of the bronchoscope.
2. This creates a venturi effect, entraining atmospheric air and inflating the lungs with oxygen-enriched air.
3. Oxygenation and carbon dioxide elimination are achieved with an airway pressure of 25-30 cm H₂O.

**Problems in practice and safety features:**

1. Barotrauma is possible. Airway pressure monitoring is not available.
2. Gastric distension can occur should ventilation commence before the distal end of the bronchoscope is beyond the larynx.

Checkout and maintenance of the anesthesia machine and equipment

Importance:

1. A checkout procedure is prepared to determine whether the equipment is present, functioning properly, and ready to use.
2. Properly checking equipment can reduce equipment-related morbidity and mortality
3. Failure to check equipment properly is a factor in many critical incidents
4. User manuals that are provided by anesthesia machine manufacturers have detailed directions for checking. These should be read carefully.

Electronic checking:

General considerations:

1. Many of the newer anesthesia machines provide an electronic checking procedure. When the machine is turned ON, it reminds the user to start the checkout before the electronic checkout is performed
2. All the components that are to be used for the anesthetic should be in place. The breathing tubing must be extended to the desired length before beginning the checkout
3. During the checking procedure, the machine may prompt the anesthesia provider to make certain adjustments, such as opening or closing the APL valve, occluding the Y piece, or adjusting the gas flows.
4. These electronic checking procedures test the electronic as well as some mechanical components of the anesthesia machine; in addition, they may gather information about breathing system resistance and compliance and leaks
5. Most machines have a mechanism to limit or skip the electronic checkout. This is meant for emergencies.

Daily checks before beginning anesthesia

1. Emergency ventilation equipment

a. Resuscitation bag:

- Sometimes the anesthesia machine problem cannot be diagnosed or quickly corrected; in this situation, a manual resuscitator will allow the user to provide positive pressure ventilation while the problem is corrected or the machine is replaced.
- The pt. port should be occluded, and the bag squeezed. Pressure should be built up rapidly to a point at which the bag can no longer be compressed
- The resuscitator should be inspected for signs of wear such as cracks or tears
- A reservoir bag should be placed over the pt. port on the resuscitation bag should cause the reservoir bag to inflate. After the reservoir bag is fully inflated and the resuscitation bag has been released, the bag should deflate easily. This tests both the input. And exhalation paths for patency
- To check the bag refill valve opens, the bag should be squeezed, then the pt. port occluded, then the bag is released. The bag should re-expand rapidly.

b. Oxygen source: A source of oxygen to connect to the resuscitation bag should be available. An oxygen flowmeter attached to the pipeline outlet or the courtesy flowmeter on the anesthetic machine will provide a source of oxygen.

c. Difficult airway equipment: if there is any indication that the pt. If airway or tracheal intubation will be difficult, the difficult airway cart should be in the room

d. Suction: The adequacy of suction can be checked by placing the end of the suction tubing on the underside of the thumb. With the hand at waist height, the tubing should stay attached without support. A rigid suction catheter should be immediately available.

2. Gas supply

a. Cylinder pressure

- The oxygen cylinder should be checked for correct mounting. If there is a date-expired label on a cylinder, it should be checked.

- All flow control valves should be closed by turning them completely clockwise; excessive torque should be avoided. Opening a cylinder or connecting a pipeline hose when a flow control valve is open may cause the indicator to shoot up to the top of the tube and be damaged, stuck at the top, or not noticed
 - The pressure in an oxygen cylinder is checked by turning the valve slowly counterclockwise while observing the related pressure gauge and hissing sound.
 - Anesthesia machine cylinders are frequently checked and replaced by anesthesia technicians or other operating personnel.
- a. Pipeline pressure: Some disconnect the pipeline hose from the machine at night to allow the anesthesia machine to be moved for cleaning and reduce gas loss from leaks. If this is the case, the hoses need to be reconnected to the pipeline system. The fitting should hold firmly, there should be no audible noise, and the hose should be arranged to prevent occlusion. The pipeline pressure should read 345-380 kPa.
 - b. Vaporizer: checking the liquid levels in each vaporizer, adding more if needed, filler cap and drain valve should be tight, and the vaporizer should be checked to make certain that they are not tilted, and cannot be lifted from their mounting

3. Turn the machine master switch and all other necessary equipment on

To continue the checkout, the machine master switch needs to be turned on to enable the pneumatic and electronic systems. The machine should be allowed to complete its own diagnostic checks and any automated procedures. Any electrical equipment to be used during the anesthetic should be turned on at this time.

4. Flowmeters

- a. Each flowmeter should be examined with the flow control valve closed to make certain the indicator is at the zero position (or at minimum flow)
- b. Each flow control valve should be slowly opened and closed while observing the indicator. The float should move smoothly and respond to small flow control valve adjustments.
- c. If the indicator is a rotameter or ball, it should rotate freely. An indicator that moves erratically or fails to return to zero may be displaying an erroneous flow rate

- d. An attempt should be made to create a hypoxic mixture by adjusting the nitrous up, or the O₂ flow down
- e. If the machine has a nitrous oxide: O₂ ratio alarm, it should be activated

5. Adjustable pressure limiting valve and scavenging system.

- a. The APL and scavenging system are checked by closing the APL valve, occluding the Pt. port, and filling the system by using the O₂ flush so that the breathing system pressure gauge reads 50 cmH₂O. The APL is then opened
- b. The scavenging system is checked when its closed system by the air intake valve (**negative pressure relief**) with minimal flow from the anesthetic machine. The APL valve should be fully opened, and the pt. port occluded. Scavenging suction should be turned on. If there is a bag at the scavenging system interface, it should collapse, and the pressure gauge should indicate a pressure of 0 to -2 cm H₂O and can be checked by **positive pressure relief**. The APL valve is fully opened and the breathing system pt. port occluded. The O₂ flush is activated the breathing system pressure indicator should read less than 10 cm H₂O.

6. Breathing system:

a. O₂ monitor calibration

- If daily calibration is required, the sensor should be removed from the breathing system and moved well away from sources of gas that might change the ambient O₂ concentration. It should be calibrated to 21%.
- The sensor should then be placed securely in its mount in the breathing system, and the breathing system should be flushed with O₂. This should result in a reading of over 90%

b. Initial breathing system status.

- The breathing system should be inspected to determine that no parts are damaged or missing and that all the accessory equipment (e.g. Humidifier, filter, PEEP valve) for the proposed anesthetic are in place.
- All connections should be made secure by (push and twist)

- If a diverting gas monitor is to be used, the sampling line should be checked for kinks or occlusion and connected to the breathing system. But the monitor should not be turned on at this time.
- Transparent breathing tubes should be checked for foreign bodies
- The bag -ventilator selector switch should be in the bag position
- The pressure gauge should read zero
- The absorbent color should be noted if there are any color changes.

c. Leaks in the circle and in a Mapleson breathing system.

- To initiate the breathing system leak test, all gas flows should be at zero. The APL valve should be closed and the pt. port occluded. The breathing system should be pressurized to 30 cm H₂O by using an O₂ flush. If there is no leak, the pressure will remain near this level for at least 10 sec. The APL valve is then opened the pressure should decrease.

d. Leaks in the Bain and Lack system

- Inspection: the circuit should be inspected to determine if the center tube is properly connected to the absorber end of the tube. The inner tube must also be connected near the pt. end. Any retraction or disconnection from either end should cause the system to be rejected.
- To perform the test, a 2L/min flow is set on one of the flowmeters. The plunger from a small syringe or a finger is inserted into the pt. At the end of the outer tube, occluding the inner tube, the flowmeter indicator should fall.
- Smell test: sometimes the anesthesia provider smells the gas from the patient port with a 3 L/min flow of O₂ set on flowmeters. No odor indicates that a vaporizer is not leaking or left on.

7. Manual and automatic ventilation systems

- A second reservoir bag should be placed on the pt. The port and O₂ flowmeter should be set at 300 ml/min
- The bag ventilator selector switch should be in the bag position

- As the reservoir bag on the bag mount in the breathing system is squeezed, the bag on the pt. The port should inflate. The bag on the pt. The port should then be squeezed the reservoir bag on the bag mount should inflate
- System resistance and compliance should be evaluated during this test. This is useful to detect inadvertent PEEP or an obstruction in the system
- Ventilator parameters appropriate for the pt. should be set and the bag –ventilator selector switch placed in the ventilator mode.
- The O₂ flowmeter should be set at the minimum flow or 300 ml/min. the bellow and reservoir bag on the pt. port should be filled by using the O₂ flush and the ventilator turned on
- The bag on pt. port should inflate and deflate. The appropriate tidal volume should be delivered and bellow fill completely during expiration
- If use of the PEEP valve is anticipated, it should be adjusted to different values, and the breathing system pressure gauge should be observed to verify correct performance
- The bag should be removed from the pt. The port and the ventilator are allowed to continue cycling. The low airway pressure and tidal volume or minute volume alarms should annunciate after an appropriate delay. Then pt. Port occlude and bellow filled using O₂ flush, the high-pressure alarm should sound.

8. Unidirectional valve tests.

Unidirectional valves may be checked by several methods includes:

- a. Breathing method: With the APL valve closed, the inspiratory limb of the breathing system is detached and occluded. Wearing a mask, the tester tries to breathe through the Y-piece. It should be possible to exhale freely but not inhale. Next, the exhalation tube is detached and occluded. The tester should be able to inhale but not exhale.
- b. Valve tester: this method utilizes a device consisting of a bulb with a 22-mm connector fitting that can be attached to the inspiratory and exhalation ports. To test the inspiratory valve, the compressed bulb is attached to the inspiratory port. It

should immediately reinflate. When the bulb is compressed, it should meet firm resistance. To check the expiratory valve, the tester is attached with the bulb inflated. It should be possible to squeeze the bulb, and it should remain deflated.

- c. Pressure decline method: to check the valves by this method, an extra reservoir is placed on the inlet. Port the other bag to the bag mount. The FGF is set to a minimum, and the APL valve is closed. The system is pressurized to 30 cm H₂O by using the O₂ flush. If the bag on the bag mount remains inflated, the exp. Valve is competent. Next, the APL valve is opened. If the reservoir bag is on the inspection. Port does not deflate, the insp. Valve is competent.

9. Final configuration and obstruction check

- At this point, breathing system accessory equipment (e.g., PEEP valve, heated humidifier) should be in place and turned ON.
- Obstruction in the breathing can be detected by having the pt. breathing 100% O₂ through a mask, provided a tight mask fit is achieved. This can also be done by the anesthesia provider wearing a mask. The reservoir bag should inflate and deflate, and the breathing system pressure indicator should show no PEEP. Negative pressure will reveal an obstruction in the insp. Limb. Positive pressure will reveal obstruction in the exp. Limb. While this is being done the capnogram should be checked to make certain that a normal waveform appears.
- All monitor should be turned on. Alarm should be tested, and appropriate limits should be set.
- The final status of all controls should be checked before the machine is put in use. This includes having all flow control valves closed, all flowmeters indicating zero, all vaporizers turned off, and the APL valve open. The breathing system should be ready to use with all components connected by using a push-and-twist motion. The scavenging system vacuum should be on.

10. Subsequent checks on the same machine on the same day

- If a thorough check is performed before the first case of the day, a less complete procedure can be used before subsequent cases.

- The tests so marked may not be repeated or may be abbreviated if the machine is used by the same anesthesia provider for successive cases on the same day
- It is important for the breathing system to be checked before the next case begins.

11. Procedure at the end of the case:

At the end of the case, flowmeters, vaporizers, and suction should be turned OFF. Monitors that would need recalibration if turned OFF should be left ON or put in a standby mode. The absorbent should be checked for signs of exhaustion and changed if indicated.

12. Procedures at the end of the day:

- 1) Following the last case, the pipeline hoses should be disconnected at the wall or ceiling and coiled over the machine
- 2) The cylinder valve should be closed. Each flow control valve should be opened until the cylinder and pipeline pressure gauge read zero, then closed.
- 3) Vaporizers should be filled at the conclusion of the day, after most operating room personnel have vacated the room.