Anaesthesia machine and breathing circuit

Introduction

- The Anesthesia gas machine is a device which delivers a precisely known but variable gas mixture, including anesthetizing and life sustaining gases.

Objective

- ✓Become familiar with the basic design of an anesthetic machine
- ✓ Become familiar with the design and functioning of anesthetic vaporizers.
- ✓Become familiar with the design and functioning of the more commonly used breathing circuits

History

before the invention of anaesthesia…
surgery was an agony…a nightmare….

October 16,1846

W.T.G.MORTON

Inventor and revealer of anaesthetic inhalation by whom, pain in surgery was arrested and annulled… before whom , in all time, surgery was agony…. since whom, science has control of pain

Desenho que reproduz a primeira cirurgia com anestesia geral, descoberta por Thomas Green Morton.
No detalhe, o aparelho para inalação de éter sulfúrico, criado pelo dentista americano em 1846.

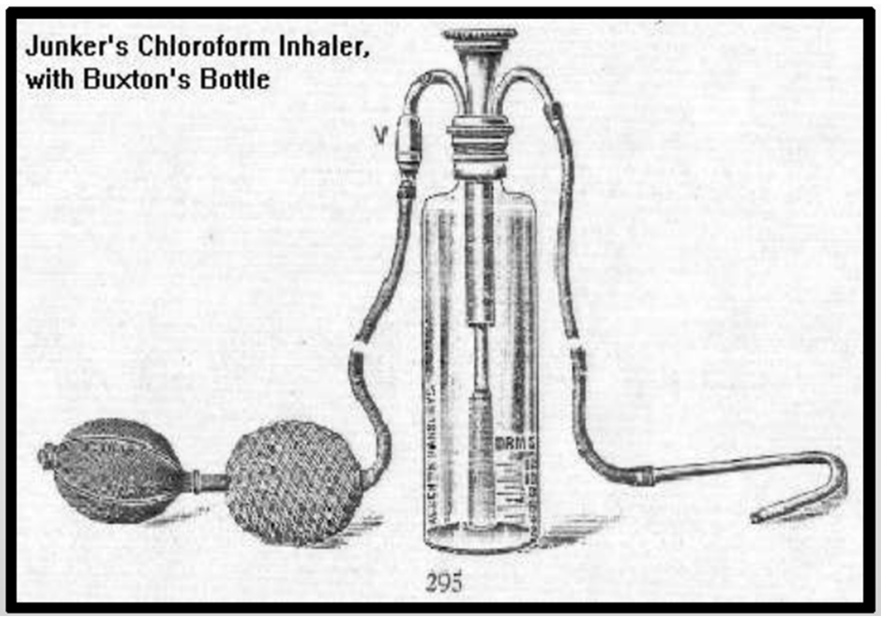
Cotton ball soaked in sulfuric ether..
a mouth piece and an exhalation port
housed in a glass bottle

Clover ether apparatus

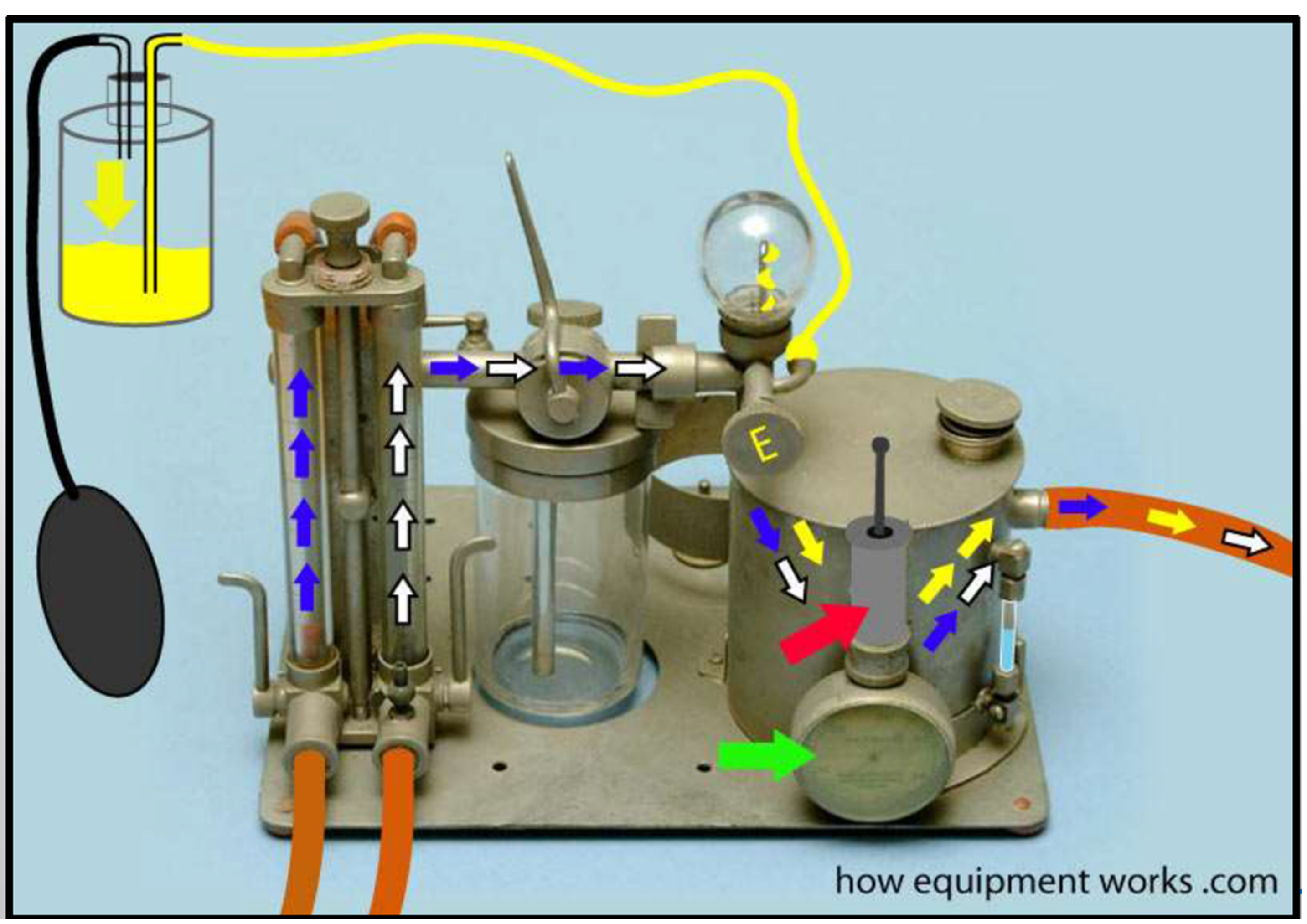
Mask designed to administer ether

HEWITT'S APPARATUS

A well-made antique anesthesia nitrous oxide gas and ether inhaler as introduced, in the early 1900s, by Sir Frederick Hewitt (1857-1916), anesthetist to King Edward VII. The Hewitt's improved large bore inhaler is a modification of Clover's portable regulating inhaler.



JUNKER'S CHLOROFORM BOTTLE



MAGILL'S ANAESTHETIC APPARATUS -1920

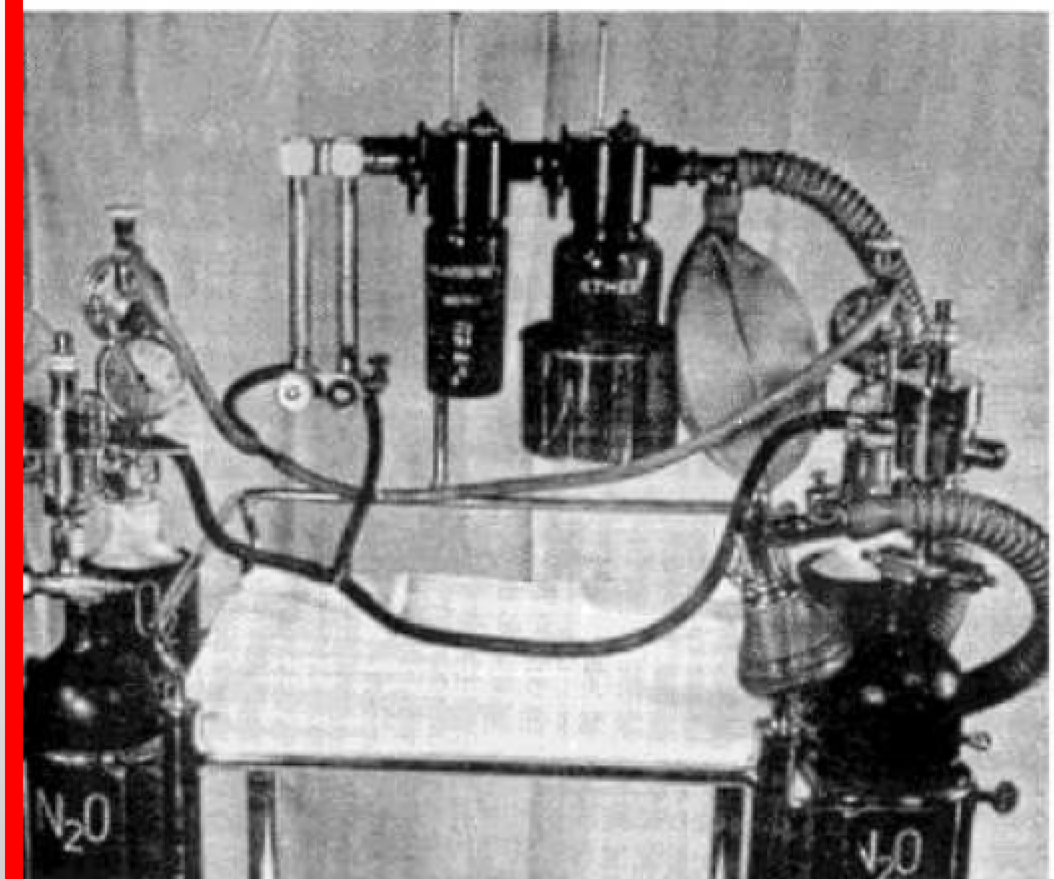
CONNELL 1936 MODEL

Dr. Karl Connell (1878-1941) introduced a line of closed circuit, multiple-gas anesthesia machines in the 1930s. These were among the first to have a built-in carbon dioxide absorber. This series of machines also had ball-bearing gauges, called flow meters, to accurately display the rate of gases flowing to the patient. Incorporating the suggestions of several leading anesthesiologists of that era, the machine's safety features included glass domes to make the action of the valves controlling the flow of air and gas visible, and conducting wires inside the rubber breathing tubes to reduce the possibility of explosion. These machines also introduced solid stainless steel cabinetry. This model could deliver carbon dioxide, oxygen, ethylene, nitrous oxide and cyclopropane. Ether and helium could also be added.

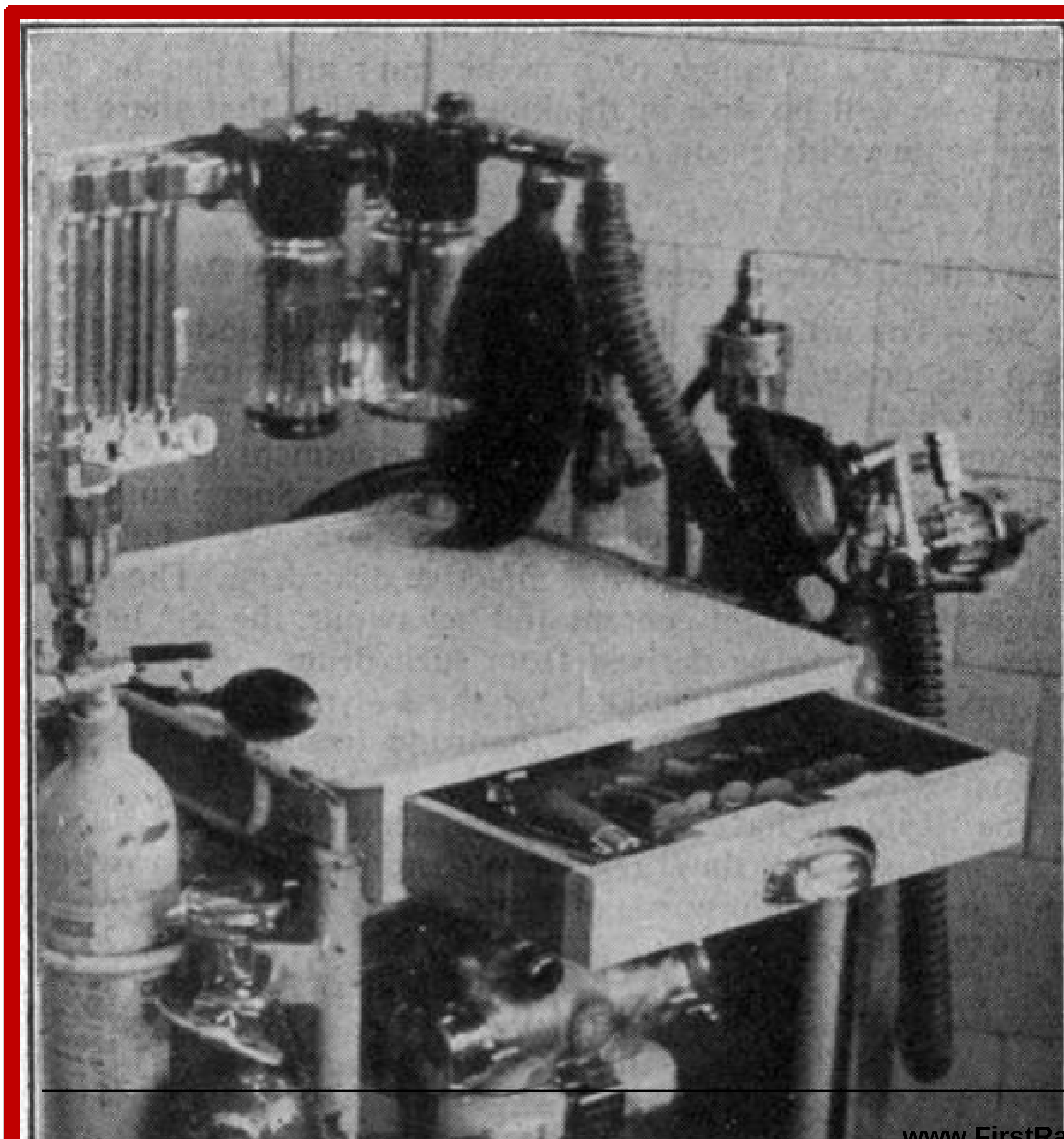
evolution of Boyle's apparatus

It is a misunderstanding that Boyle actually invented the Anaesthetic machine, this is incorrect. On a visit to New York he was persuaded by James. T Gwathmey who was a reservist American Army officer, to try his machine for delivering gases. It did provide an airtight mask with a pressure escape valve. After persuading the board of Governors at St Bart's, he imported two machines.

He was to eventually to modify the machine to make it more gas tight. It was given the name ***"Boyles Nitrous oxide Ether outfit"*** since then the elders of the anaesthetic environment will still refer to this machine as a ***"Boyles Machine"***



BOYLE'S MACHINE -1940



Boyles apparatus -1970

CO_2 flow meter
Trilene and Ether bottles

BOYLES APPARATUS -1975

- Halothane vaporiser
- Metal soda lime canister
- Cyclopropane flow meter
- Attached B.P apparatus

BOYLE'S BOTTLES -1980

- ETHER AND TRILENE BOTTLES
- PLUNGER
- ' U' TUBE
- COPPER TUBE IN ETHER
- CHROME PLATED TUBE IN TRILENE
- TRILENE LOCK

Boyle's Apparatus- 2000s

Modern anaesthesia workstation

Types of Anaesthesia Machine

- INTERMITTENT - Gas flow only during inspiration
  - Entonox appartus, Mackessons
- CONTINUOUS - Gas flows both during inspiration and expiration
  - Boyle machine , forregar , dragger

Components of anaesthesia machine

- Comprise of three different pressure systems-
- High pressure system: from cylinder to pressure reducing valves
- Intermediate pressure system: from pressure reducing valves to flowmeters
- Low pressure system: from flow meters to the common gas outlet on machine

Components of pressure systems

High Pressure System

1. Hanger Yoke Assembly
2. Cylinder Pressure Indicator (Bourdon Guage)
3. Pressure Reducing Device (Regulator)

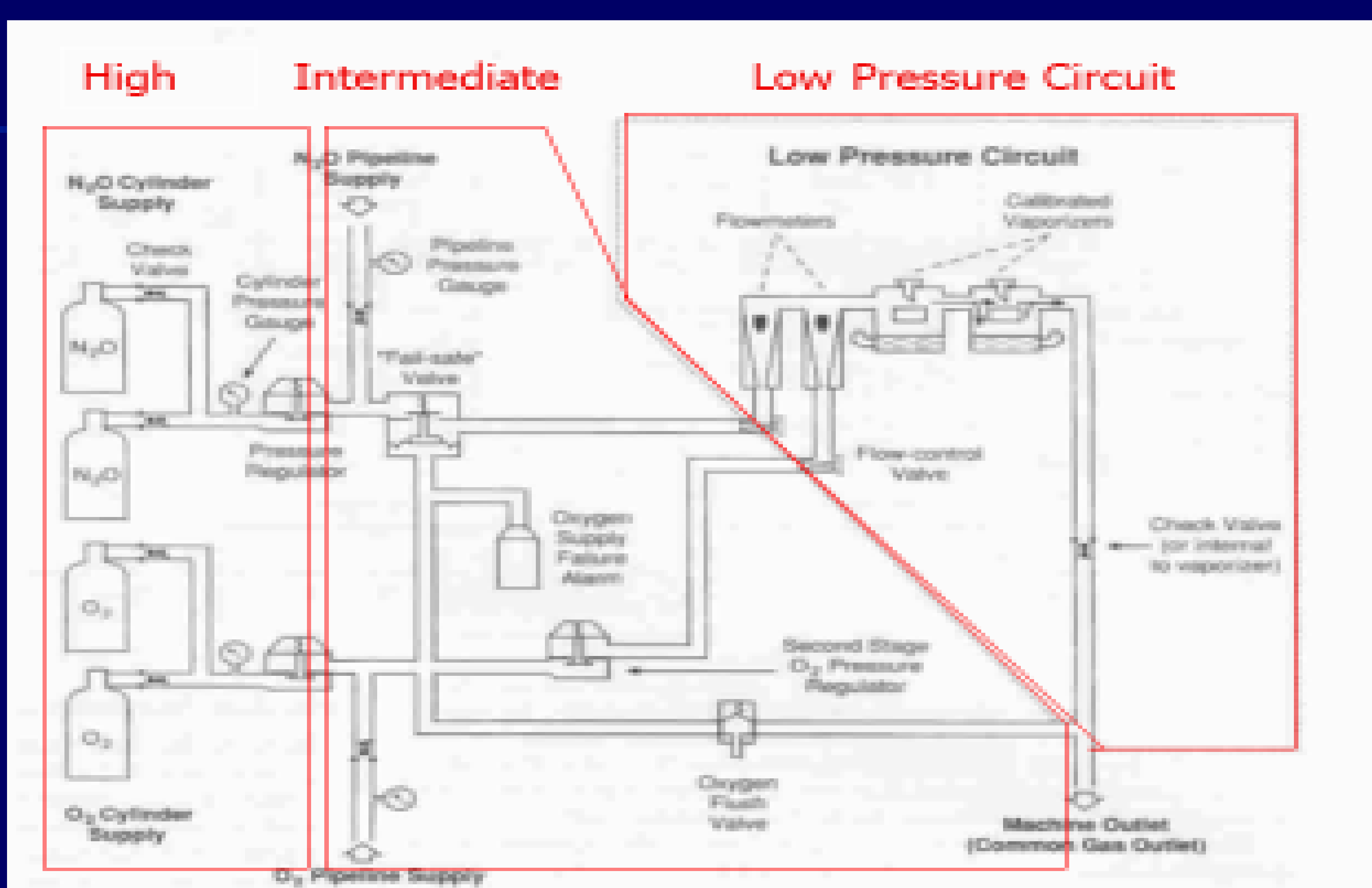
Intermediate Pressure System

1. Pipeline Inlet Connections
2. Pipeline Pressure Indicators (Gauge)
3. Piping
4. Gas Power Outlet
5. Master Switch
6. Oxygen Pressure Failure Devices
7. Oxygen Flush Valve
8. Second Stage Reducing Device
9. Flow Control Valves

Low Pressure System

1. Flow Indicators
2. Unidirectional Check valve
3. Pressure Relief Device
4. Vaporizer Mounting Devices
5. Common Fresh Gas Outlet

The Anesthesia Machine



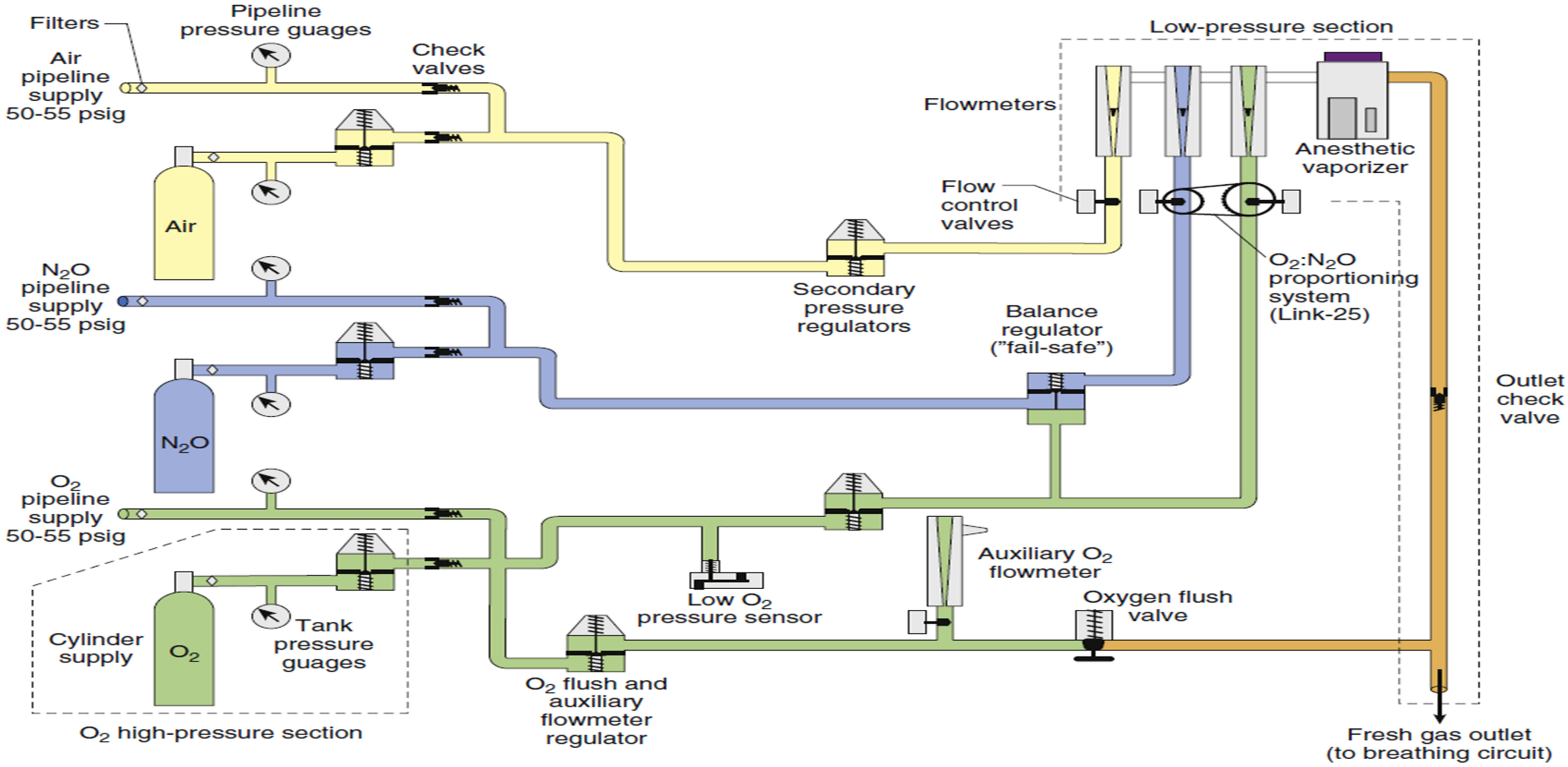
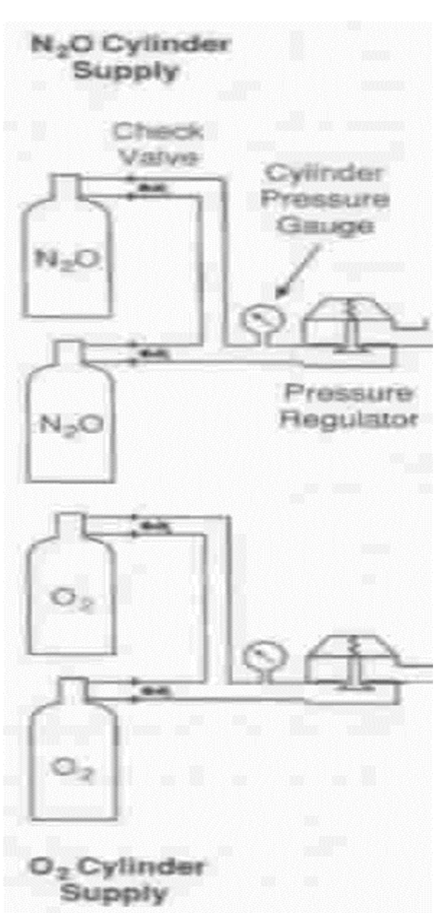


Figure 29-1. Anesthesia workstation gas supply system represented by the GE Healthcare Aespire anesthesia workstation. The high-pressure system extends from the gas cylinders to the high-pressure regulators (*dashed lines* around O_2 high-pressure section). The intermediate-pressure section extends from 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. See text for additional details. *(From Datex-Ohmeda: S/5 Aespire anesthesia machine: technical reference manual, Madison, Wis., 2004, Datex-Ohmeda.)*

High pressure system

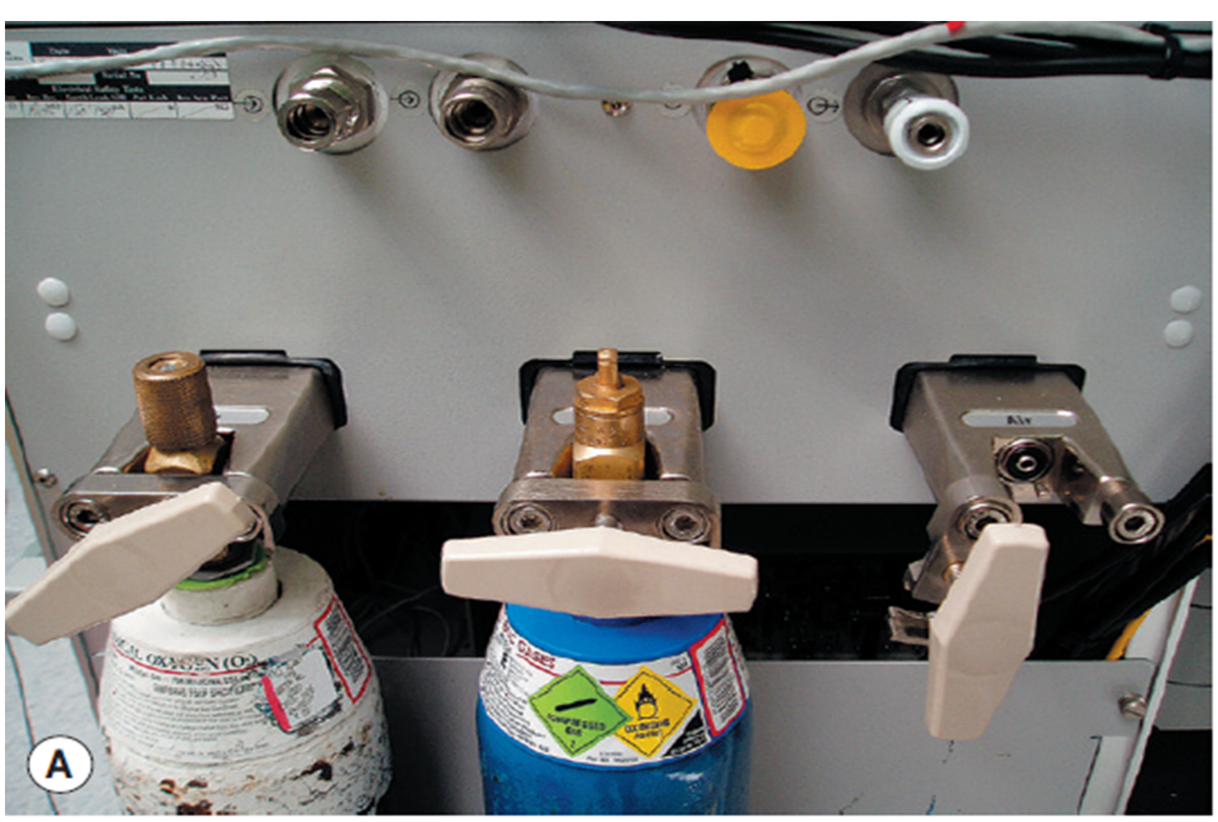


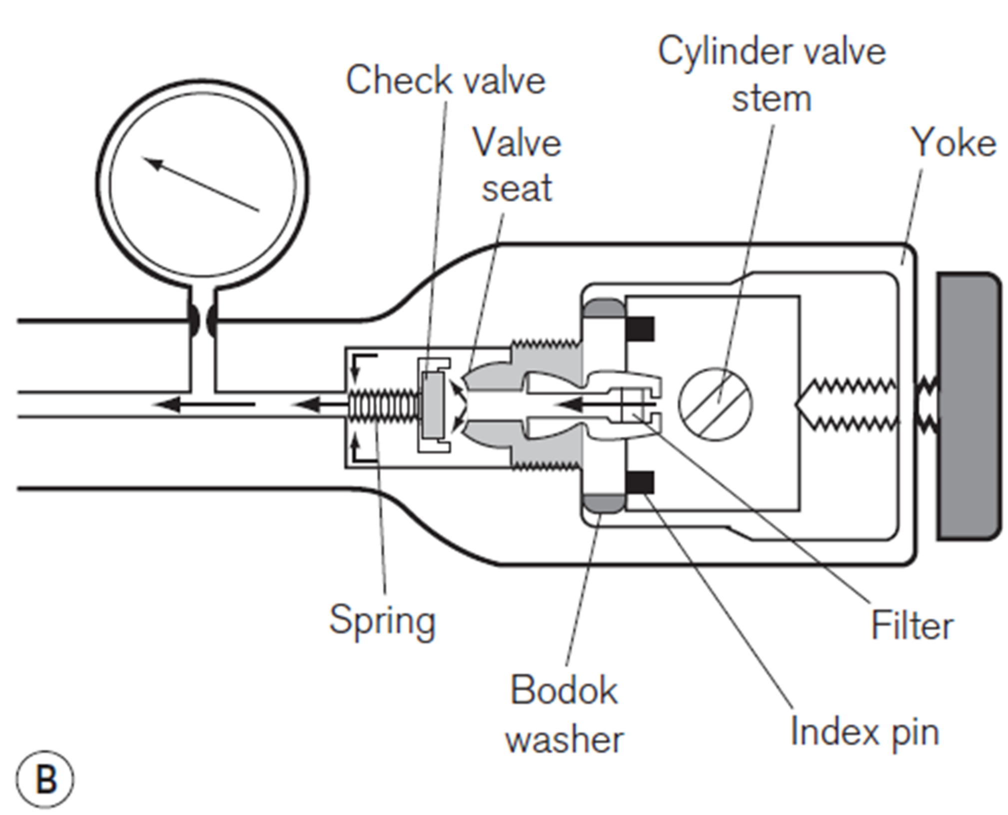
- Receives gasses from the high pressure E cylinders attached to the back of the anesthesia machine (2200 psig for O2, 745 psig for N2O)
- Consists of:
  - Hanger Yolk (reserve gas cylinder holder)
  - Check valve (prevent reverse flow of gas)
  - Cylinder Pressure Indicator (Gauge)
  - Pressure Reducing Device (Regulator)
- Usually not used, unless pipeline gas supply is off

Components of high pressure system

- Hanger yoke: orients and supports cylinder, provides a gas tight seal, ensures unidirectional gas flow. Parts of hanger yoke assembly are:
- Body: principal framework of yoke, attached to body of machine
- Retaining screw: its threaded into distal end of yoke, fits into conical depression of cylinder valve and yoke
- Nipple: gas enters machine through nipple
- Index pin: are below the nipple
- Washer/Bodok seal: Placed around nipple to produce seal between cylinder valve and yoke.
- Filter: filters 100µm particulates
- Check valve assembly: allows gas from cylinder to enter machine but not vice versa

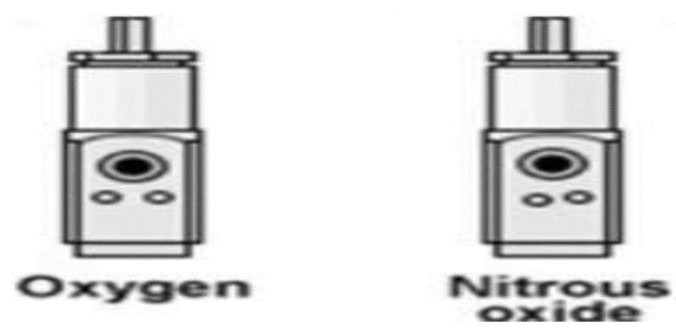
A. Cylinder yokes. The empty right-hand yoke shows a Bodok seal and the pins of the pin index system.
B. Diagram of cylinder yoke assembly

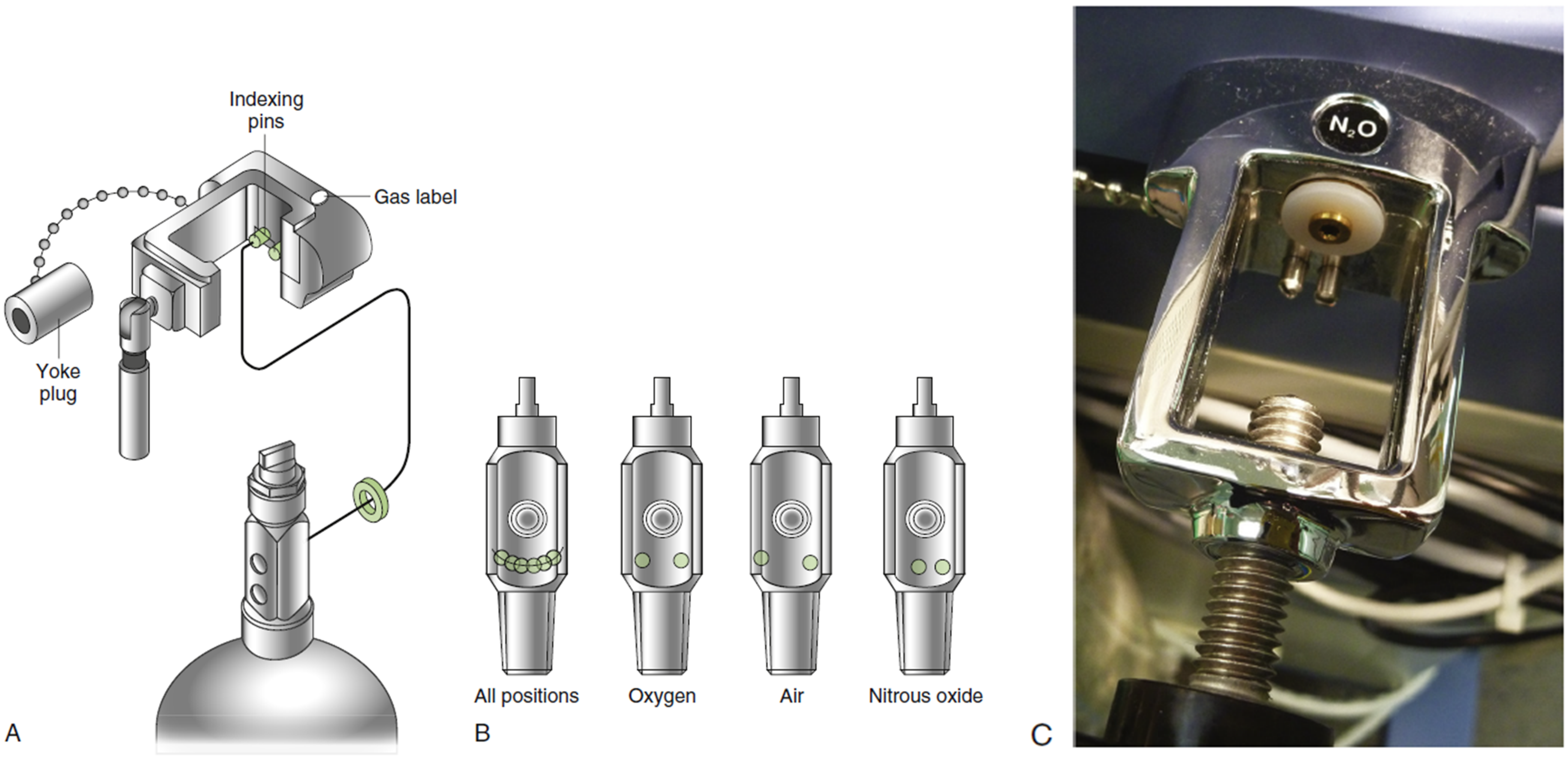


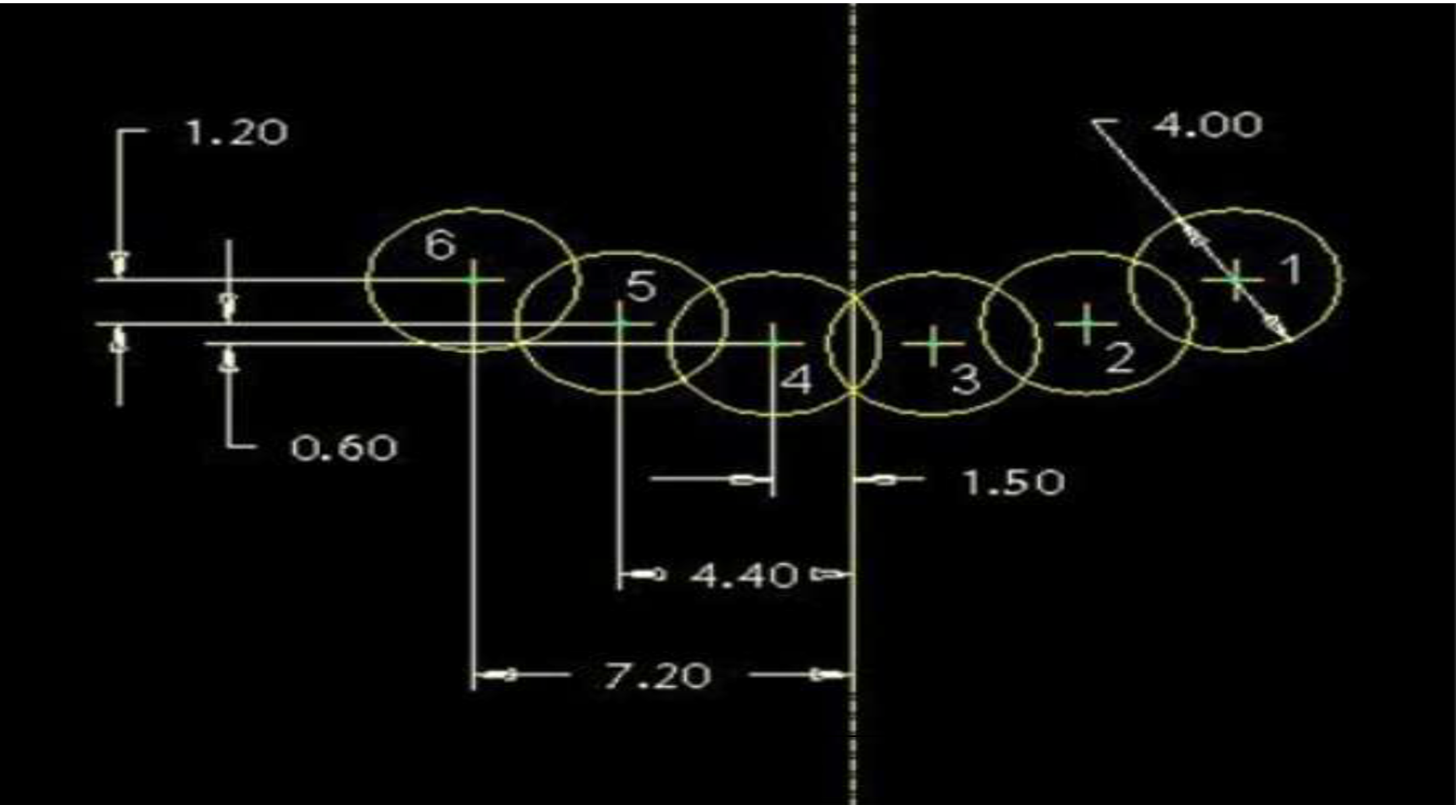


Pin-Index safety system-1952

- Safety mechanism so that one cylinder can not be fitted at the other's position
- It consists of holes on the cylinder valve and two pins on the yoke positioned to fit into the holes
- Pins are 4 mm in diameter and 6 mm long (except pin-7)
- The 7 hole positions are on the circumference of a circle of 9/16 inch radius centred on the port.
- Six pin positions are located at an interval of 12 degree, with pin 7 located between 3 and 4.




Indexing pins
Gas label
Yoke plug
A
All positions
Oxygen
Air
Nitrous oxide
B
C
N_2O


1.20
4.00
6
5
4
3
2
1
0.60
1.50
4.40
7.20

Pin-index system

Gas	Index pins
Oxygen	2,5
Nitrous oxide	3,5
Cyclopropane	3,6
O2-CO2(CO2<7.5%)	2,6
O2-CO2(CO2>7.5%)	1,6
O2-He(He>80.5%)	4,6
O2-He(He<80.5%)	2,4
Air	1,5
Nitrogen	1,4
N2O-O	7

Bourdon Pressure Gauge

- Must be clearly marked with: Name or chemical symbol of gas color assigned to gas
- Each hanger yoke or group of interconnected yokes should be supplied with pressure indicator to display pressure of cylinder supplied gas.
- If indicator is circular , the lowest pressure indication should be between 6 o' clock and 9 o' clock position on clock face.
- Scale must be 33% more than maximum filling pressures.

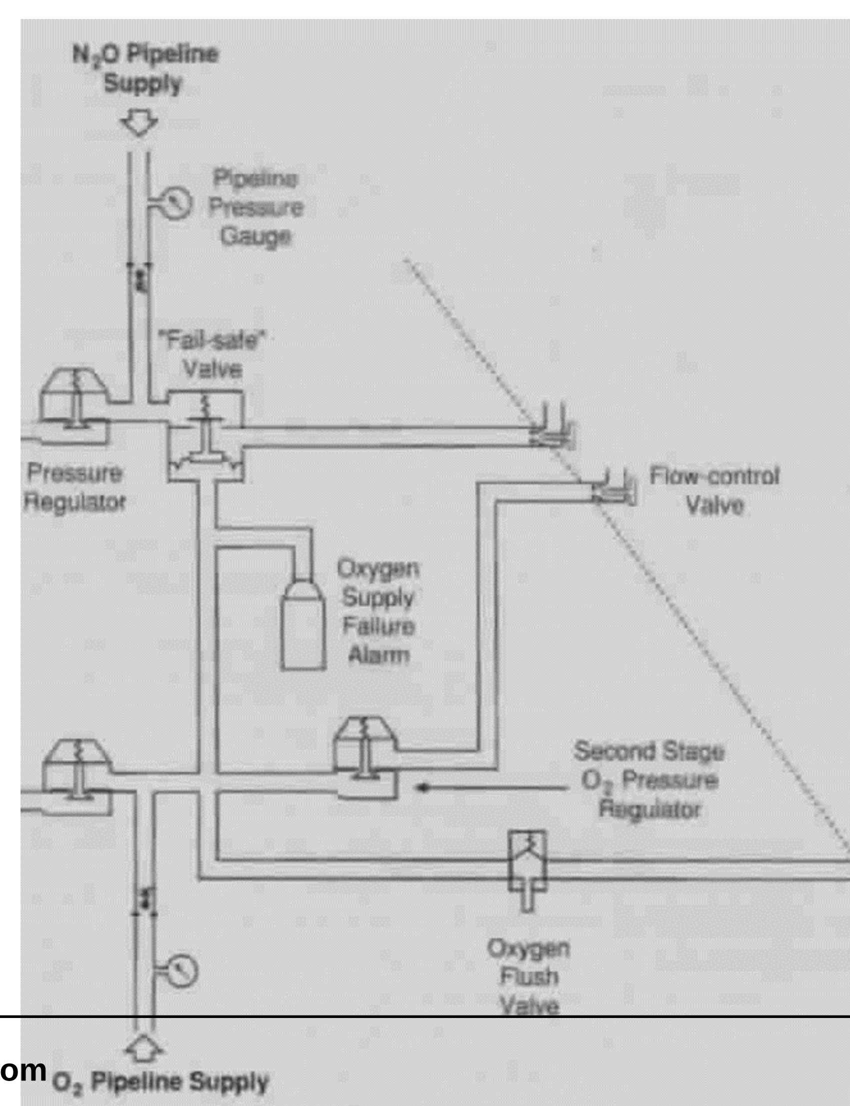
Pressure reducing devices

- Pressure in cylinder varies to maintain constant flow, with changing supply pressure regulators are provided

- Reduces high and variable pressure found in cylinder to a lower and more constant pressure found in the anaesthesia machine (40-45 psig)

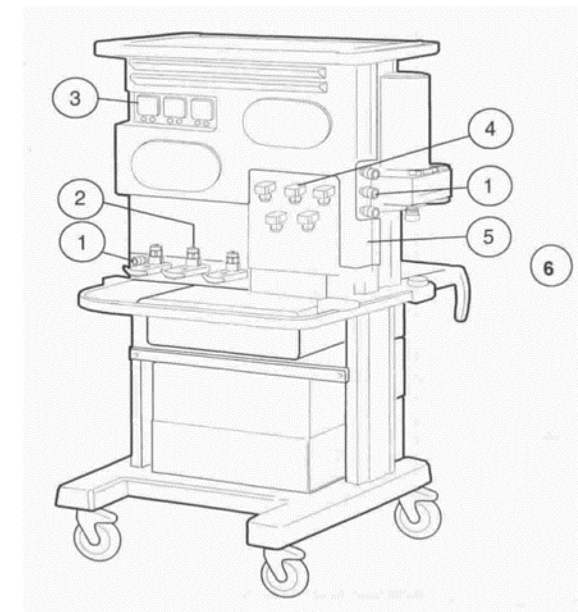
Intermediate Pressure System

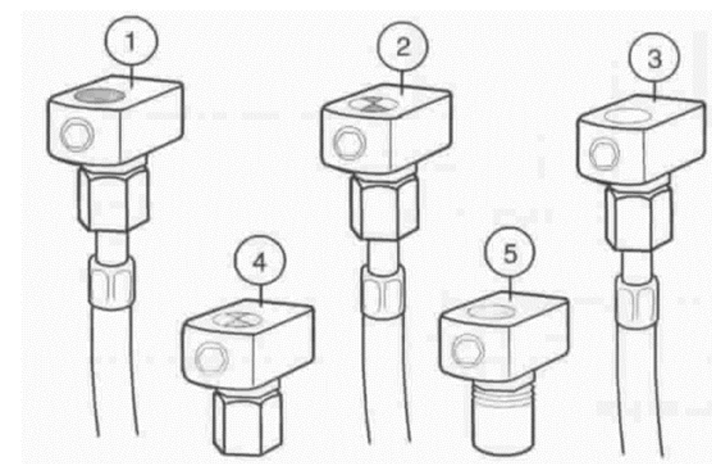
❑ Receives gasses from the regulator or the hospital pipeline at pressures of 40-55 psig
❑ Consists of:
✓Pipeline inlet connections
✓Pipeline pressure indicators
✓Piping
✓Gas power outlet
✓Master switch
✓Oxygen pressure failure devices
✓Oxygen flush
✓Additional reducing devices
✓Flow control valves



Pipeline Inlet Connections

- Mandatory N2O and O2, usually have air and suction too
- Inlets are non-interchangeable due to specific threading as per the Diameter Index Safety System (DISS)
- Each inlet must contain a check valve to prevent reverse flow (similar to the cylinder yoke)





DISS

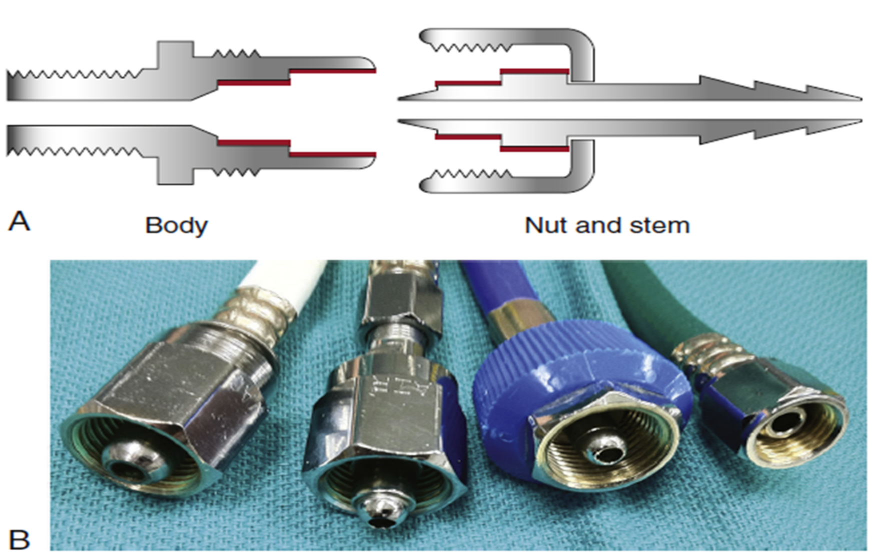
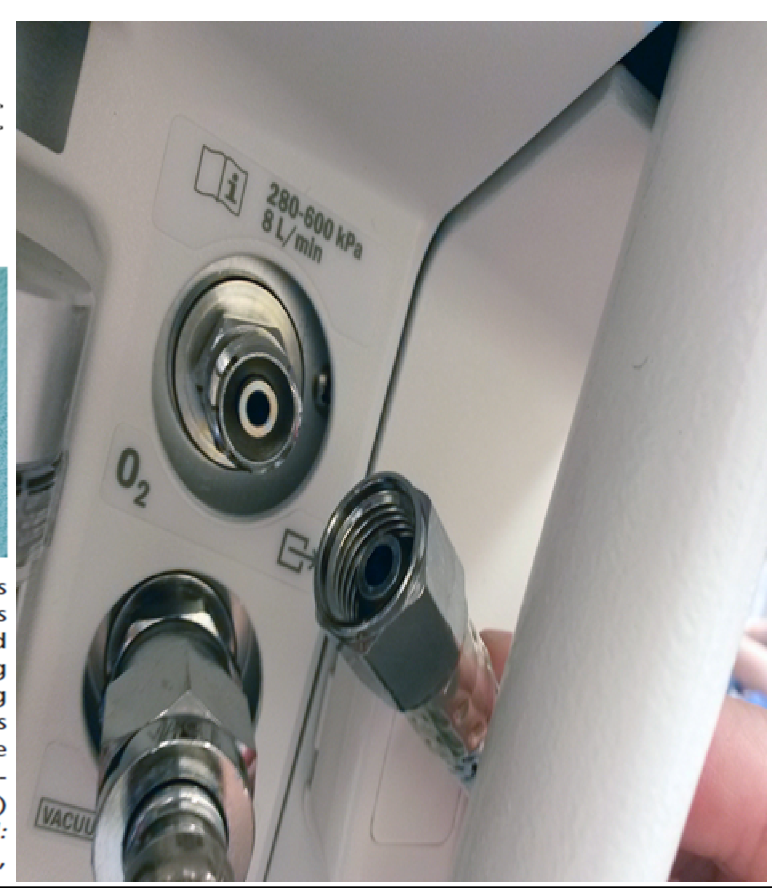
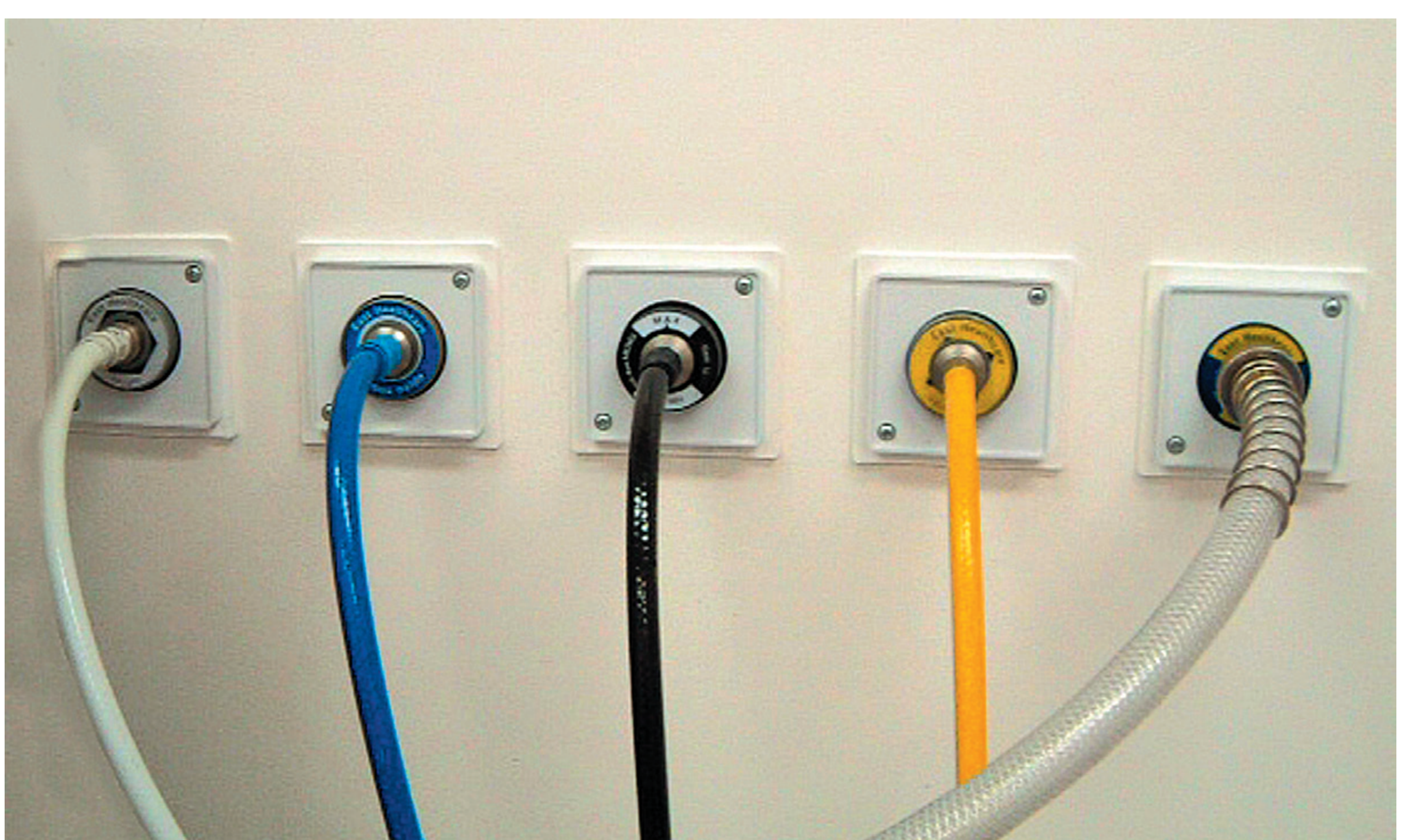


Figure 29-4. Diameter Index Safety System (DISS). DISS connectors are used for noninterchangeable, removable medical gas connections at pressures less than 200 psig. They are also used for suction and waste gas connections. Indexing is accomplished through differing diameters of the connection components, resulting in keylike fitting when matched connectors come together. The oxygen connector is additionally distinguished from the other gas connectors by a unique threaded fitting diameter and a unique thread count. **A,** DISS connector cross section. **B,** Nut and stem connectors for (*left* to *right*) vacuum, air, nitrous oxide, and oxygen. (*A, Modified from Yoder M: Gas supply systems. In* Understanding modern anesthesia systems, *Telford, Pa., 2009, Dräger Medical.*)



Terminal outlets. Note the different diameter recesses (collar indexing system) that match the collar on
the relevant probe

Flexible hose probes. Note the difference in size of the indexing collar



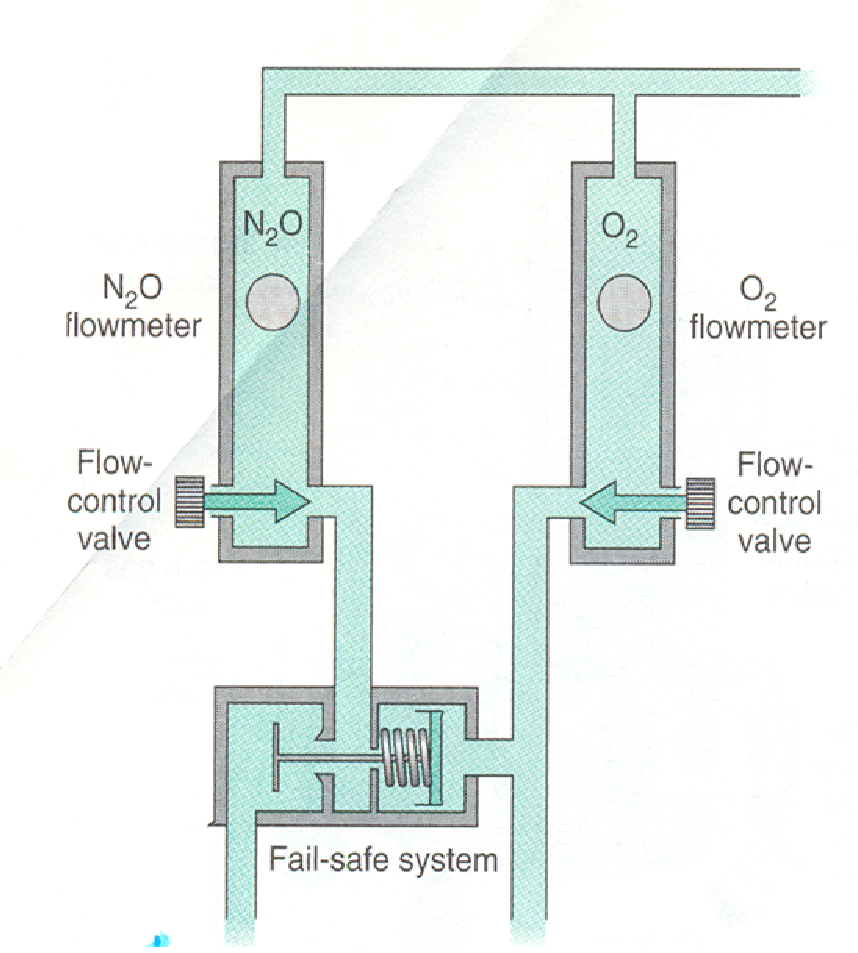
Colour-coded hoses.

Oxygen Pressure Failure Devices

- The oxygen concentration at the common gas outlet does not fall below 19%.

- A Fail-Safe valve is present in the gas line supplying each of the flowmeters (except O 2)
- This valve is controlled by the O2 supply pressure and shuts off or proportionately decreases the supply pressure of all other gasses as the O2 supply pressure decreases

- Historically there are 2 kinds of fail-safe valves
- Pressure sensor shut-off valve (Ohmeda)
- Oxygen failure protection device (Drager)



Oxygen Supply Failure Alarm

- The machine standard specifies that whenever the oxygen supply pressure falls below a manufacturer-specified threshold (usually 30 psig) a medium priority alarm shall blow within 5 seconds.

- Electronic alarms: A pressure operated electric switch operates this alarm\
- Ohmeda: 28 psig
- Drager: 30-37 psig

- Pneumatic alarms (Bowman's Whistle): Uses a pressurized canister that is filled with oxygen when the anesthesia machine is turned on. When the oxygen pressure falls below a certain value, the alarm directs a stream of oxygen through a whistle

Oxygen Flush Valve (O2+)

- Receives O2 from pipeline inlet or cylinder reducing device and directs high, unmetered flow directly to the common gas outlet (downstream of the vaporizer)
- Machine standard requires that the flow be between 35 and 75 L/min
- The ability to provide jet ventilation via the O2 flush valve is presence of a check valve between the vaporizer and the O2 flush valve (otherwise some flow would be wasted retrograde)

❑Hazards:

✓May cause barotrauma

✓Dilution of inhaled anesthetic

- Flush valves for gases other than oxygen are not permitted.

- Oxygen flush can be activated regardless of whether machine is turned ON or OFF.
- Protective rim is present which prevents unintentional activation

Master switch

- Turning the master switch to the ‘on’ position
- activates both pneumatic and electrical
- functions of the machine as well as certain
- alarms and safety devices.

Second-Stage Reducing Device

- Located just upstream of the flow control valves
- Receives gas from the pipeline inlet or the cylinder reducing device and reduces it further to 26 psig for N_2O and 14 psig for O_2
- Purpose is to eliminate fluctuations in pressure supplied to the flow indicators caused by fluctuations in pipeline pressure

Flow/ Control valves (Needle Valves/ Pin Valves/ Fine Adjustment Valves/ Flow adjustment controls

- Controls rate of flow of gas through its associated flow indicator by manual adjustment of a variable orifice.
- Current standard requires that there be only one flow control valve for each gas. It must be adjusted or identifiable with it's flow indicator

Components

- Body.

  -Screwed to the base of flow indicator

- Stem and Seat.

- Control knob.

Control Knob

- Touch coded.
- Color coded.
- Joined to stem.
- It should be large enough so that it can be turned easily.

Flow control knobs. Note the colour-coding and the distinctive-shape oxygen control knob

A flowmeter panel.

- Flow control knob for O2 must have fluted profile and be as large as or larger than for any other gas and all other flow control knobs must be rounded.
- Close proximity of flow control valves contributes to risk of errors. They need to be far enough to prevent inadvertent changes in position

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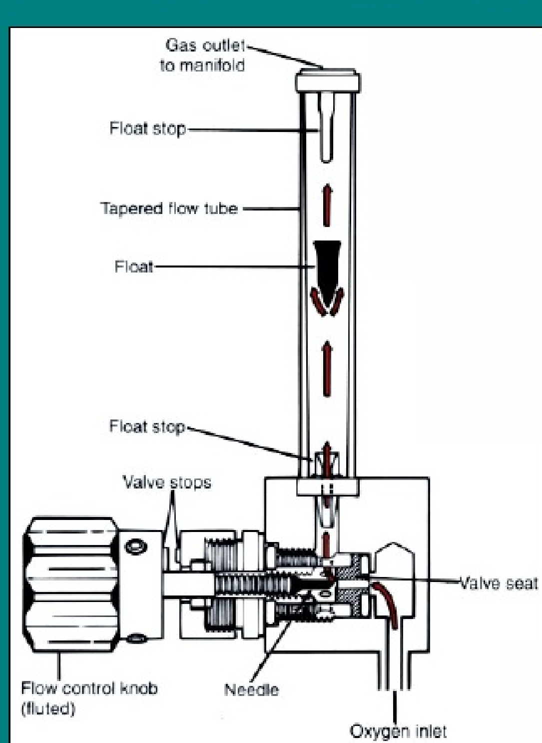
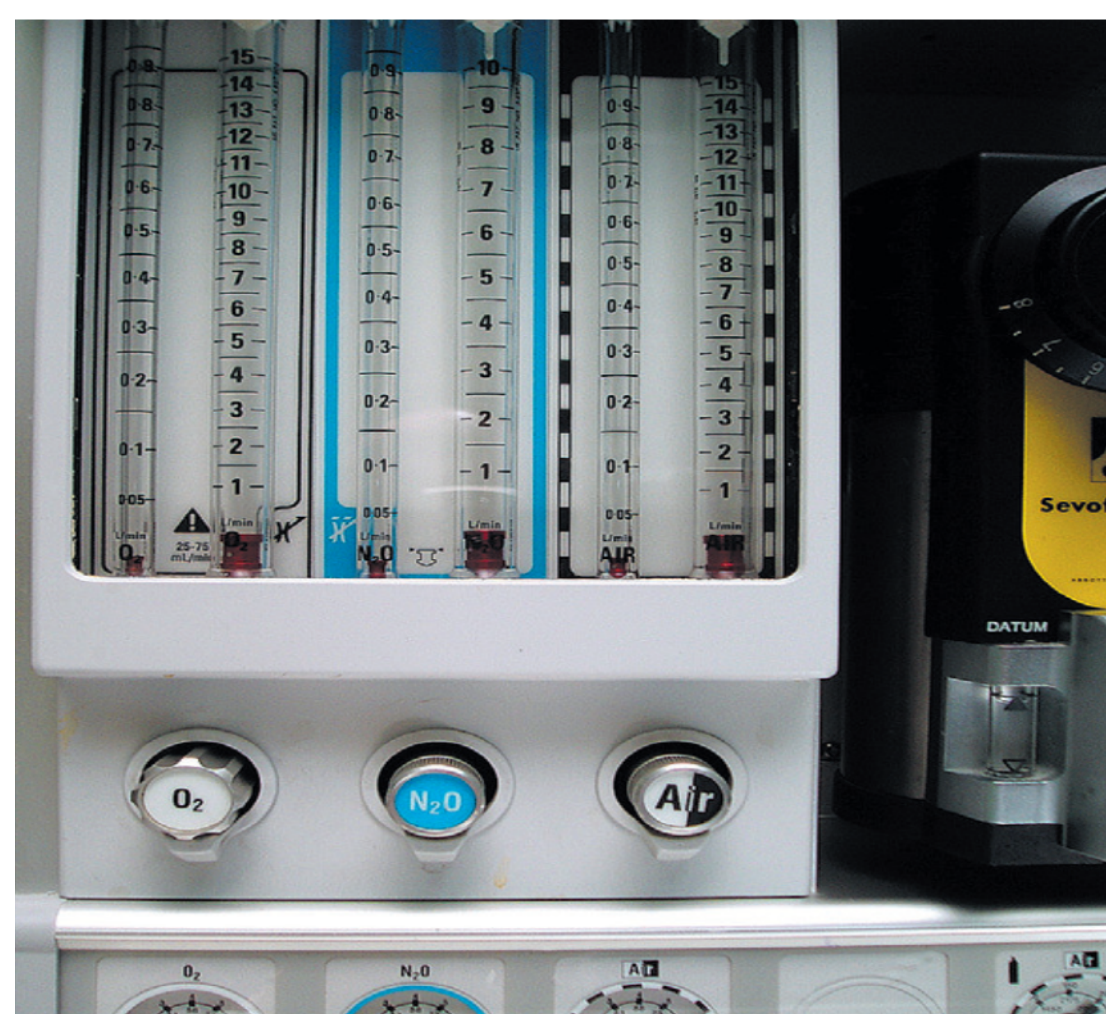
Flow Meter Assemblies





Low Pressure System

- Extends from the flow control valves to the common gas outlet
- Pressure is only slightly above atmospheric pressure.
- Consists of:
- Flow meters
- Vaporizer mounting device
- Check valve
- Back pressure safety devices (Pressure relief device)
- Common gas outlet

Flowmeter tubes

- Measures and indicates RATE OF FLOW of gas .
- TYPES:
- Constant-pressure variable-orifice type
- Electronic flowmeter

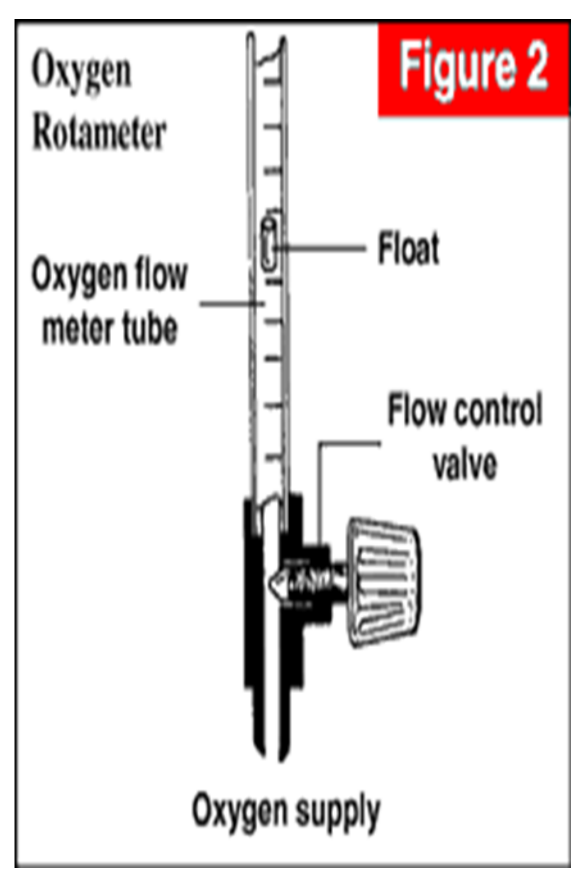
Constant-pressure variable orifice flowmeter

- Measures drop in pressure that occurs when gas passes through resistance

- Correlates this pressure –drop to flow

Flowmeter assembly

- When the flow control valve is opened the gas enters at the bottom and flows up the tube elevating the indicator
- The indicator floats freely at a point where the downward force on it (gravity) equals the upward force caused by gas molecules hitting the bottom of the float
- Because the tube is tapered the annular opening around the indicator increases with height and more gas flows around the float



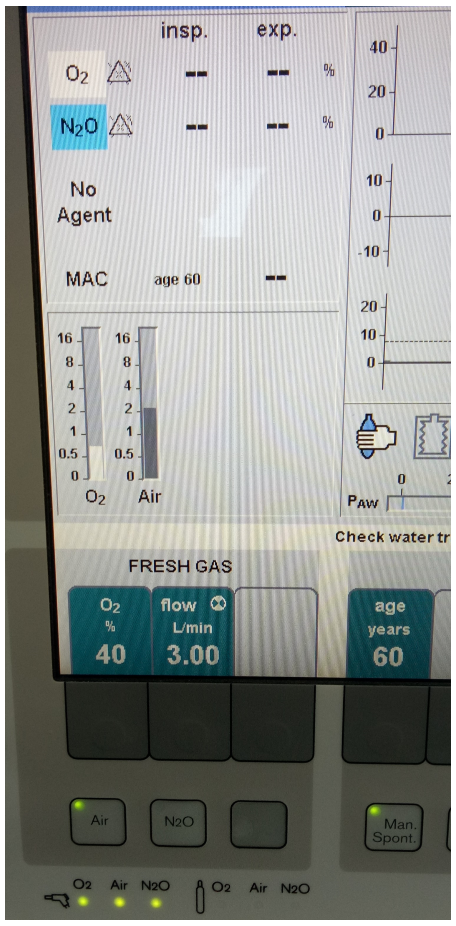
Parts of flowmeter assembly

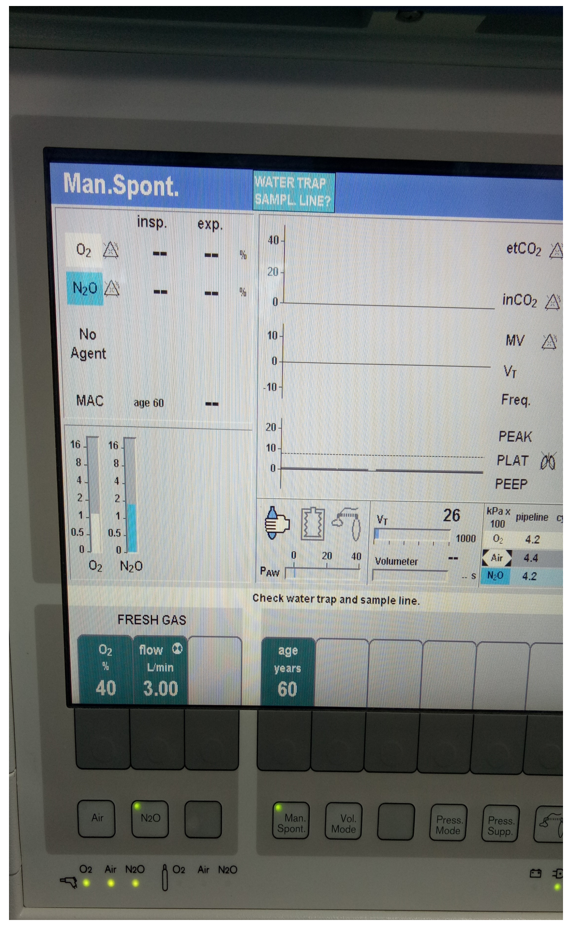
- Tube
- Float/Bobbin
- Stop at top of tube
- Scale
- Plastic shields
- Lights
- Each flowmeter assembly should be permanently identified with:
- Color of gas
- Chemical symbol / Name of gas

Tube

- Made of glass
- Gas passes between bobbin and inner wall of tube
- Tapered
- Flow increases from below upward
- Also known as 'Thorpe' tube

Electronic flowmeter





Prefer digital system

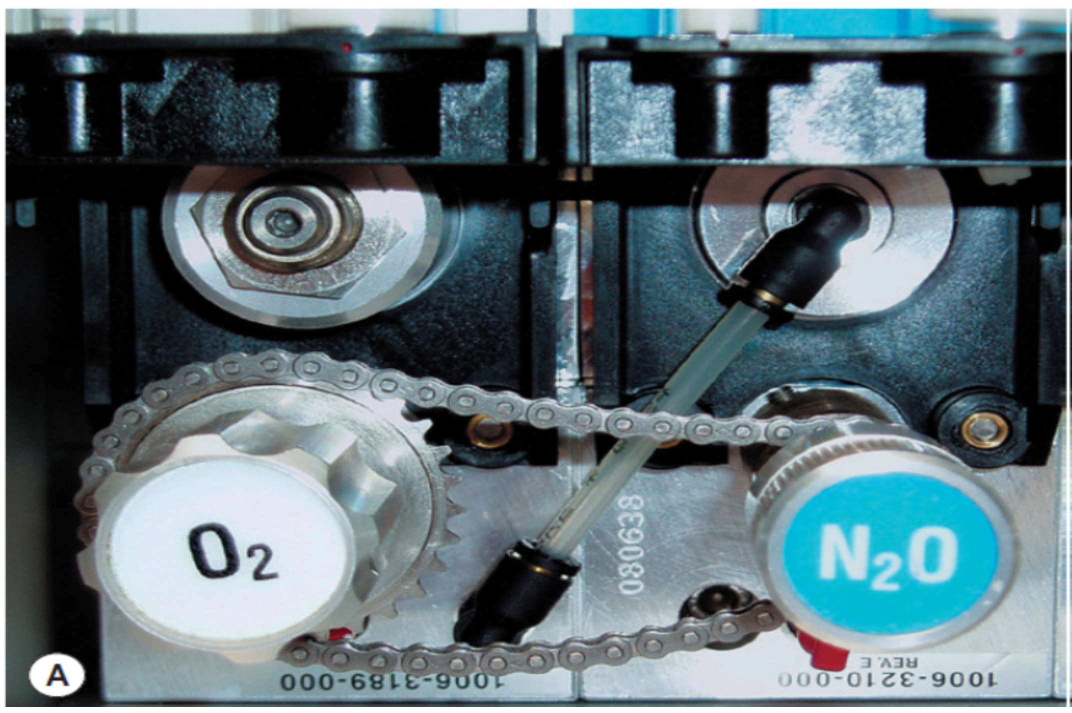
- Solenoid valves
- Control flow on or of valves
- Computer controlled

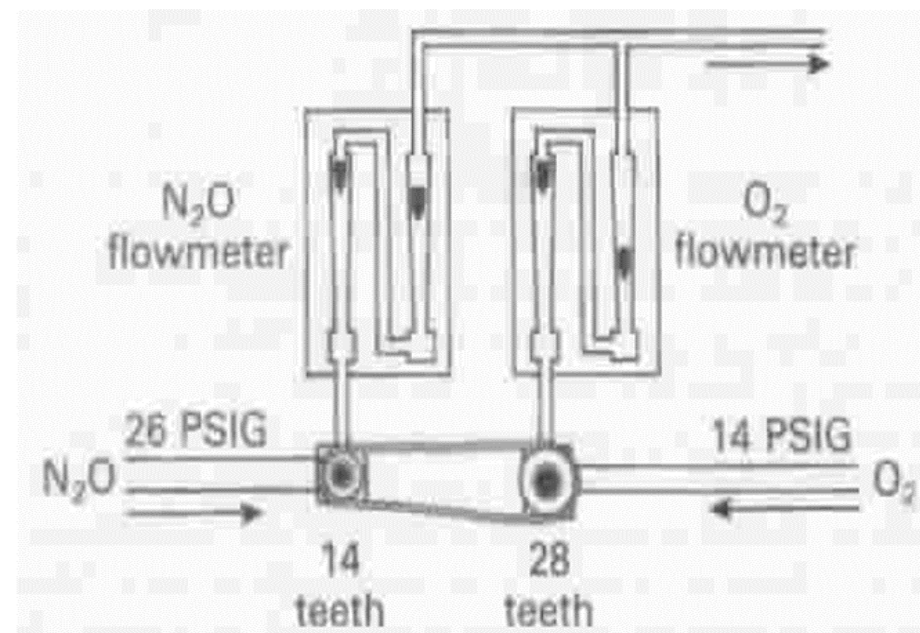
Auxiliary oxygen flowmeter

- Self contained flowmeter with its own flow control valve,flow indicator,& outlet
- Short tube with maximum flow of 10L/min
- Usually on the left side of the machine
- Can be used to supply O_2 to patient without turning ON the machine
- Older machines – works on pipeline supply,in newer ,works on cylinder & pipeline supply both.

Anti-hypoxia devices

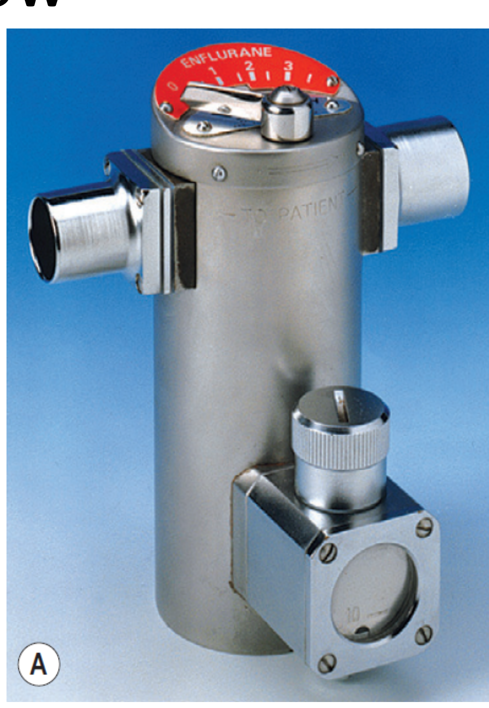
- Mechanical devices- “Link-25 system”
- Pneumatic device- “ratio-mixer valve”
- Electronically controlled device- “penlon ltd”





Vaporizers

- A vaporizer is an instrument designed to change a liquid anesthetic agent into its vapor and add a controlled amount of this vapor to the fresh gas flow



Common gas outlet

- Receives all gases and vapors from machine.
- Most machine outlets have 15mm female connection with coaxial 22mm male connection.

- Miscellaneous : Antistatic wheels

- This list is by no means exhaustive and newer anaesthesia machines have incorporated a lots of new features to enhance the safety.

Breathing system

- A breathing system is defined as an assembly of components which connects the patient's airway to the anaesthetic machine creating an artificial atmosphere, from and into which the patient breathes

- Purpose
- To deliver anesthetic gases and oxygen
- Offer a means to deliver anesthesia without significant increase in airway resistance
- To offer a convenient and safe method of delivering inhaled anesthetic agents

- Components
- A fresh gas entry port / delivery tube
- A port to connect it to the patient's airway;
- A reservoir for gas, in the form of a bag
- An expiratory port / valve
- A carbon dioxide absorber if total rebreathing is to be allowed
- Corrugated tubes for connecting these components.
- Flow directing valves may or may not be used.

- Requirements of a Breathing System
- Essential:
- The breathing system must deliver the gases from the machine to the alveoli in the same concentration as set and in the shortest possible time;
- Effectively eliminate carbon-dioxide;
- Have minimal apparatus dead space; and
- Have low resistance.

❖Requirements of a Breathing System

- Economy of fresh gas;
- Conservation of heat;
- Adequate humidification of inspired gas;
- Light weight;
- Convenience during use;
- Efficiency during spontaneous as well as controlled ventilation adaptability for adults, children and mechanical ventilators;
- Provision to reduce theatre pollution

Table 1. Classification of breathing systems

Classification Of Breathing Systems

BREATHING SYSTEMS WITHOUT CO_2 ABSORPTION.	BREATHING SYSTEMS WITH CO_2 ABSORPTION.
Unidirectional flow: a) Non rebreathing systems. B) Circle systems.	**Unidirectional flow** Circle system with absorber.
Bi-directional flow: a) Afferent reservoir systems. Mapleson A Mapleson B Mapleson C Lack's system. B) Enclosed afferent reservoir systems Miller's (1988) c) Efferent reservoir systems Mapleson D Mapleson E Mapleson F Bain's system d) Combined systems Humphrey ADE	**Bi-directional flow** To and Fro system.

Mapleson D

- 3 phases of respiration

1) Inspiration
2) Expiration
3) End-expiratory pause

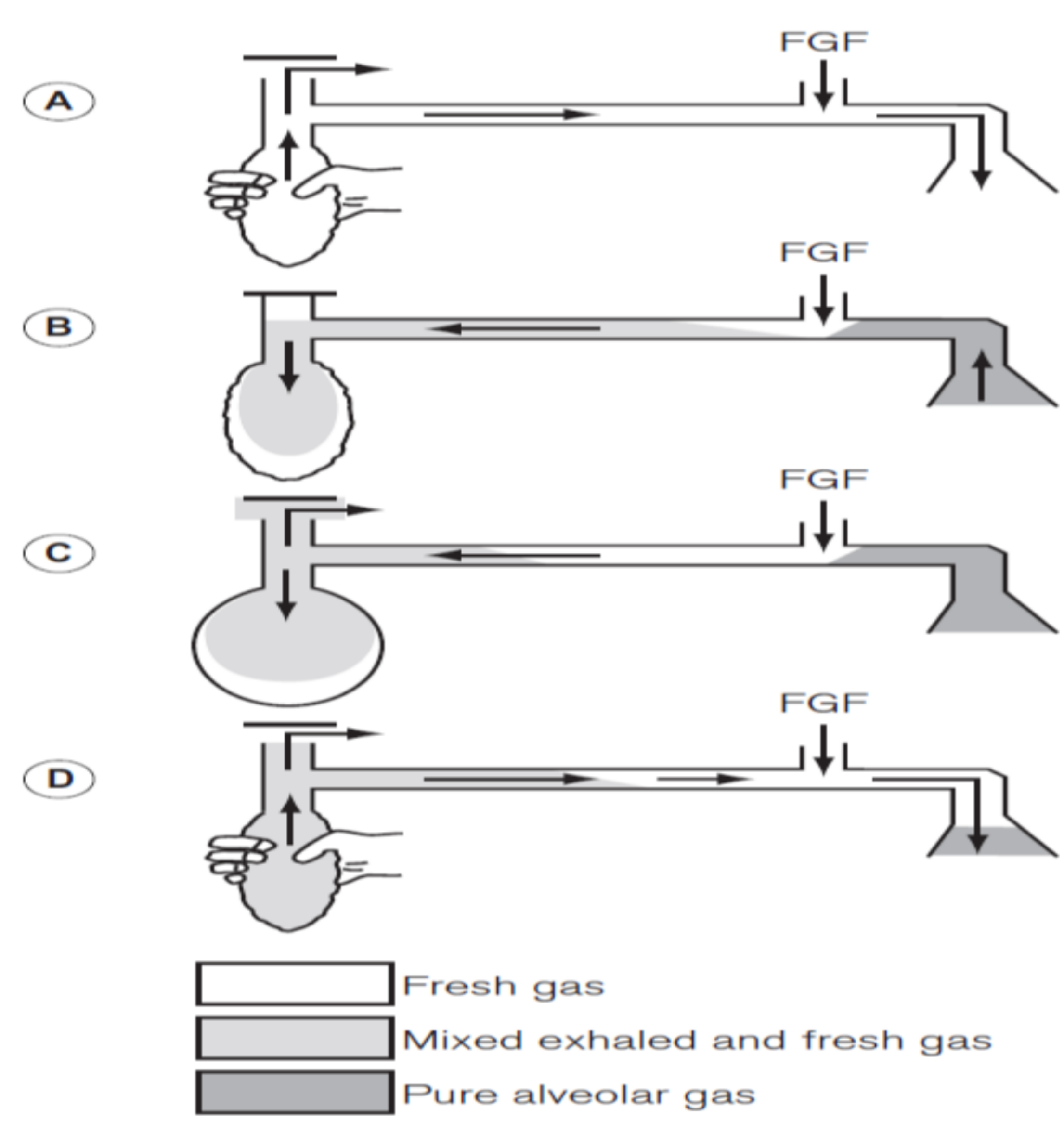


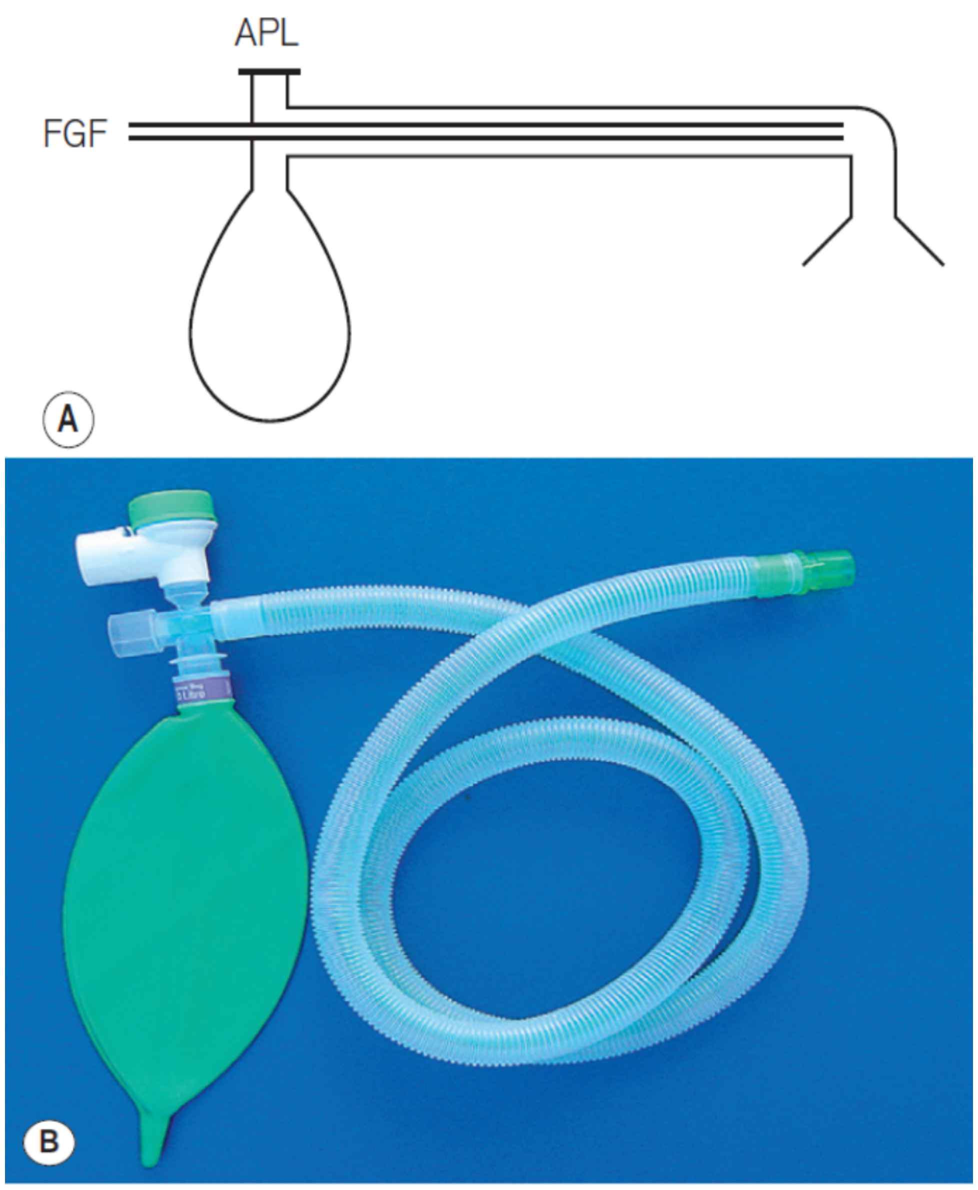
Figure 5.9 Mapleson D system with manual ventilation. **A.** The first inspiration; note that the APL valve is forced open. **B.** Early exhalation; the APL valve is closed and the partially collapsed reservoir bag is filling. **C.** Late exhalation/expiratory pause; mixed gas is vented from the system. **D.** Subsequent inspiration.

Bain's system

- Coaxial (tube within a tube) version of Mapleson D
- Fresh gas enters through narrow inner tube
- Exhaled gas exits through corrugated outer tube
- FGF required to prevent rebreathing:

  -200-300ml/kg/min with spontaneous breathing (2 times V E)

  -70ml/kg/min with controlled ventilation

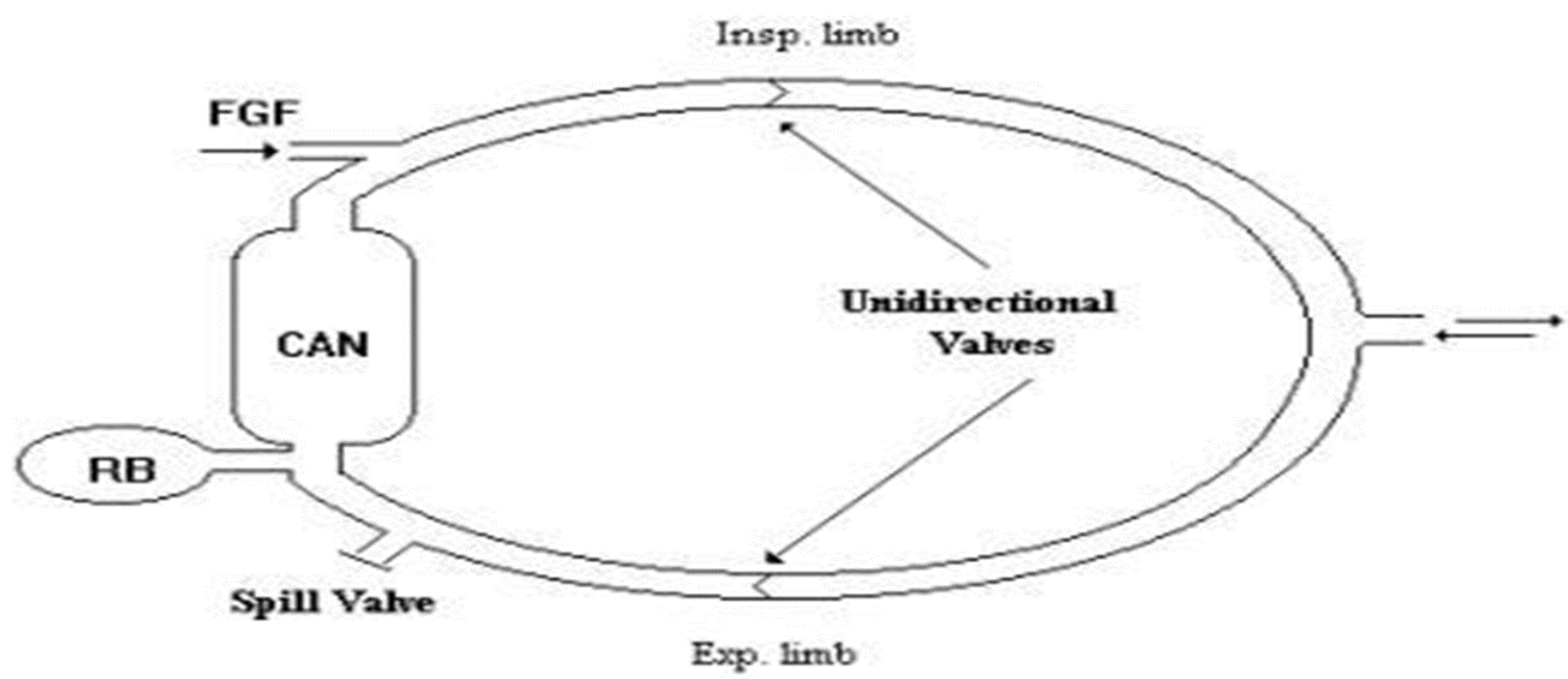


Circle system

❖ Breathing Systems with CO2 Absorption

- Sodalime canister,
- Two unidirectional valves,
- Fresh gas entry, Y-piece to connect to the patient,
- Reservoir bag a relief valve and
- Low resistance interconnecting tubing.

Circle system



Circle system

❖ 3 Essential Factors

- There should be two unidirectional valves on either side of the reservoir bag and the canister ,
- Relief valve should be positioned in the expiratory limb only,
- The FGF should enter the system proximal to the inspiratory unidirectional valve

Circle system

❖Optimization of Circle Design

❑ Unidirectional Valves

✓Placed in close proximity to patient to prevent backflow into inspiratory limb if circuit leak develops.

❑Fresh Gas Inlet

✓Placed between absorber & inspiratory valve. If placed downstream from inspiratory valve, it would allow FG to bypass patient during exhalation and be wasted. If FG were placed between expiration valve and absorber, FG would be diluted by recirculating gas

Circle system

❖Optimization of Circle Design

❑APL valve

- Placed immediately before absorber to conserve absorption capacity and to minimize venting of FG

❑Breathing Bag

- Placed in expiratory limb to decrease resistance to exhalation. Bag compression during controlled ventilation will vent alveolar gas thru APL valve, conserving absorbent

Circle system

- Circle system can be:

  # closed (FGF= patient uptake, complete rebreathing after CO_2 absorbed, and pop-off closed)

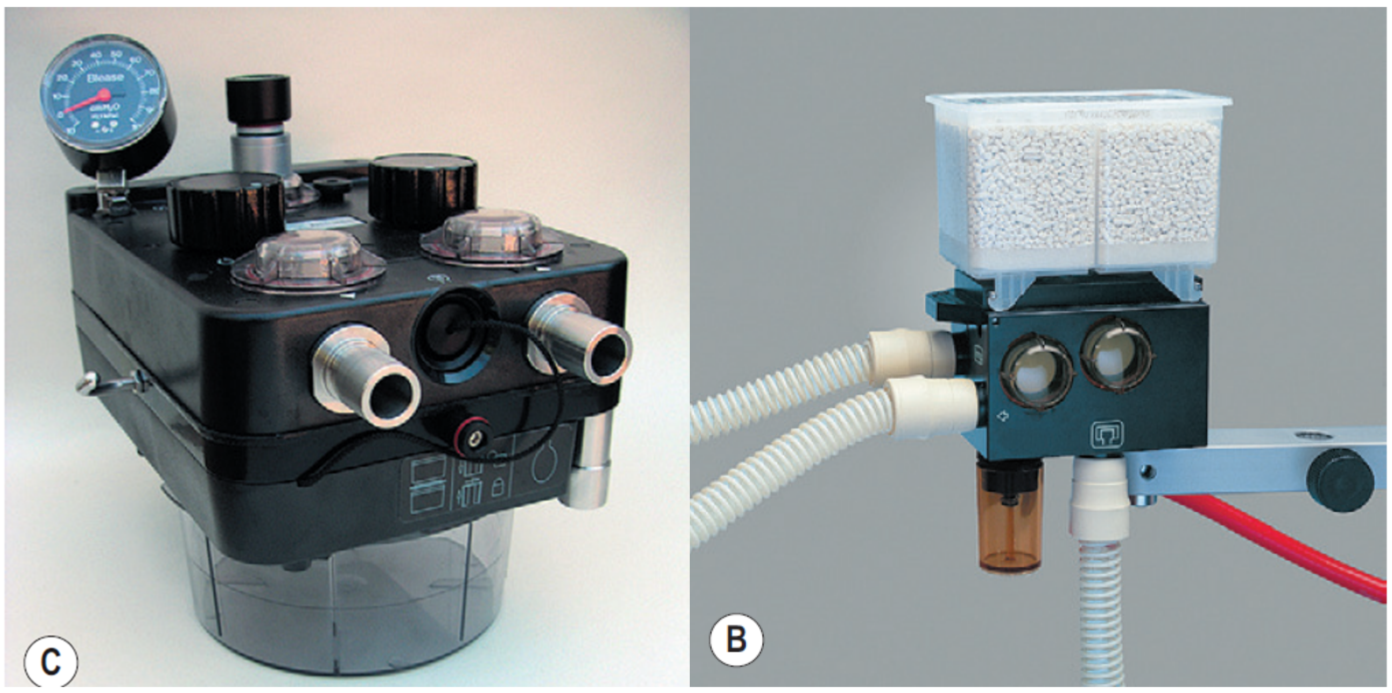
  # semi-closed (some rebreathing occurs, FGF and pop-off settings at intermediate values), or

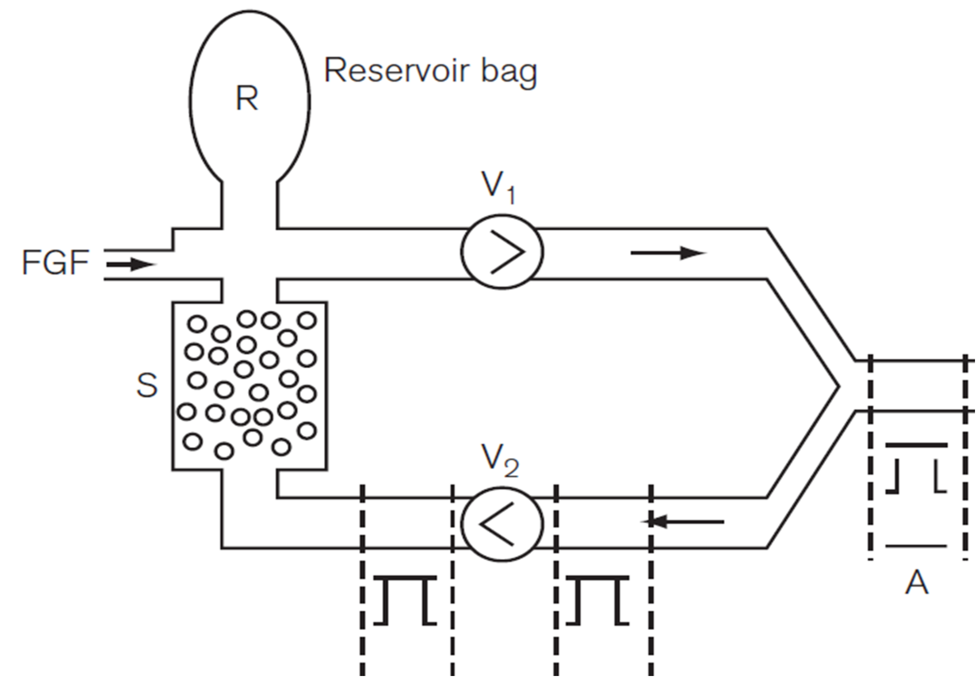
  # semi-open (no rebreathing, high fresh gas flow)

Circle system

- Most commonly used
- Adult and child appropriate sizes
- Can be semi open, semi closed, or closed dependent solely on fresh gas flow (FGF)
- Uses chemical neutralization of CO_2
- Conservation of moisture and body heat
- Low FGF's saves money

Circle system

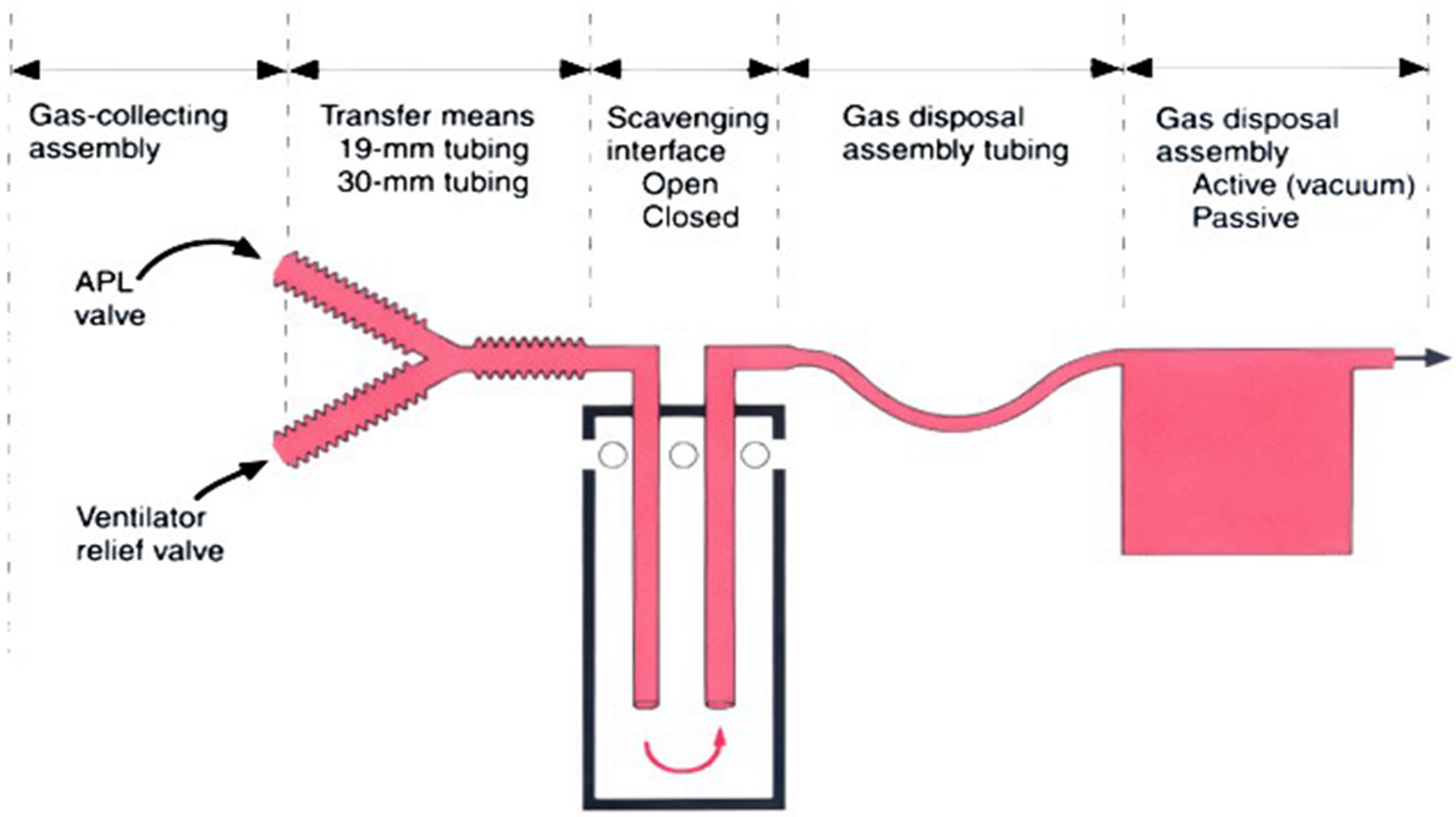




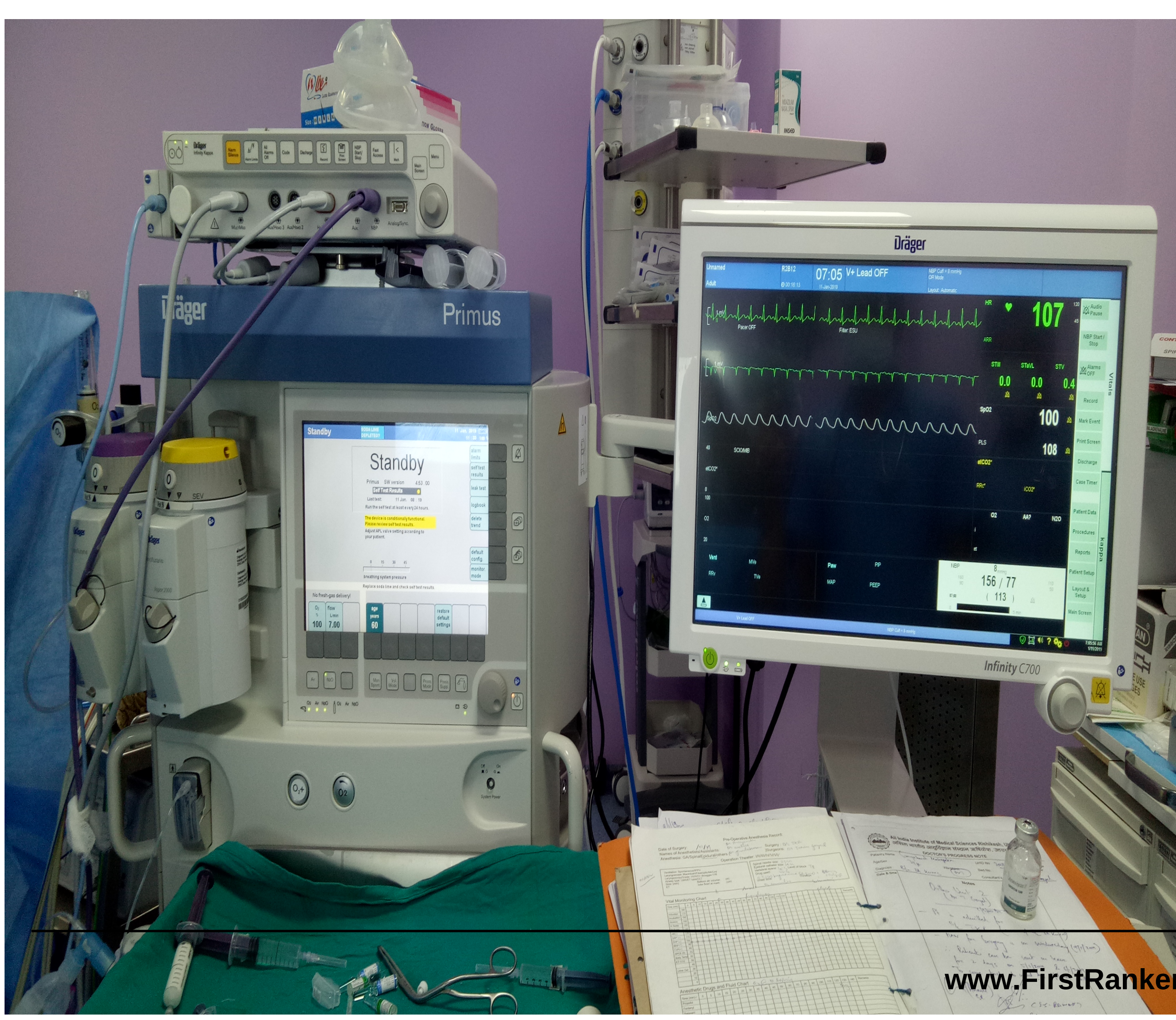
Scavenging system

- The collection and the subsequent removal of vented gases from the operating room
- Components
  - (1) the gas-collecting assembly
  - (2) the transfer means
  - (3) the scavenging interface
  - (4) the gas-disposal assembly tubing
  - (5) an active or passive gas-disposal assembly

Components of a scavenging system- APL valve, adjustable pressure limiting valve



Our institute…



Summary…

- The gases that are required are Oxygen, Nitrous Oxide and Air.
- The gases enter the machine at high pressures which are then reduced by pressure reducing valves.
- Controller knob on each rotameter causes gas to flow and lift the bobbin
- The vaporizer is fitted with a dial so that the concentration of the volatile agent can be varied
- The gas mixture is then delivered to the anaesthetic circuit.