Ventilators

Fig. 8.1 The Blease Manley MP3 with ventilator alarm (right).

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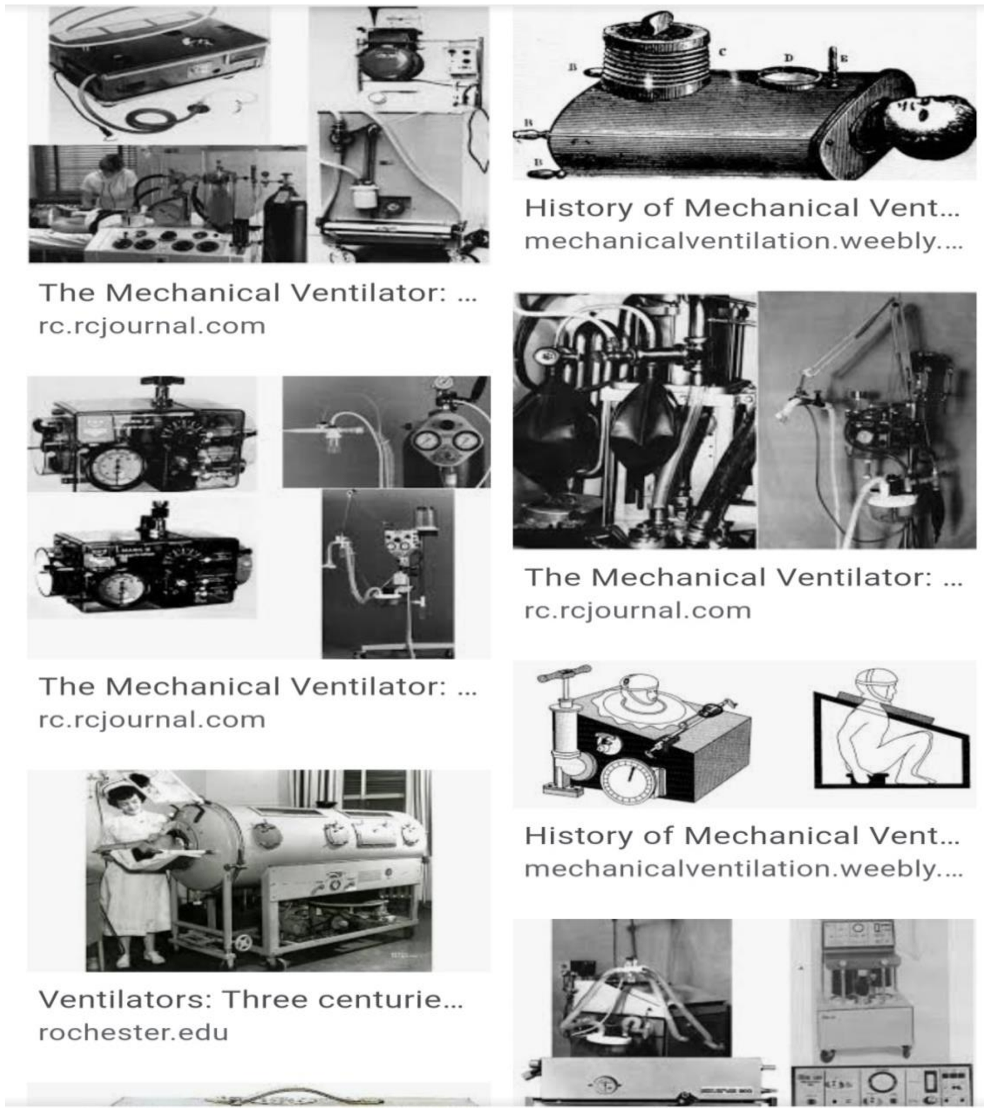
March 2023

Old Fashion ventilators



Introduction

-Provide controlled ventilation in different modes:

-IPPV(mainly) , INPV(Iron Lung) =Old fashion

-Other modes : (VC , PC , IMV , SIMV , PSV , ,PRVG ,CPAP ,BIPAP. Etc.)

-Used in :

OT ,ICU , Transport of critically ill patients

Home (Nocturnal respiratory assistance)

Iron Lung in treating Polio victims 1930-1950

Classification of ventilators

1- Method of cycling.

2-Inspiratory phase gas control.

3-Source of power.

4-Suitability for use.

5-Suitability for pediatric care.

6-Method of operation(pattern of gas flow during inspiration).

7- Sophistication.

8-Function.

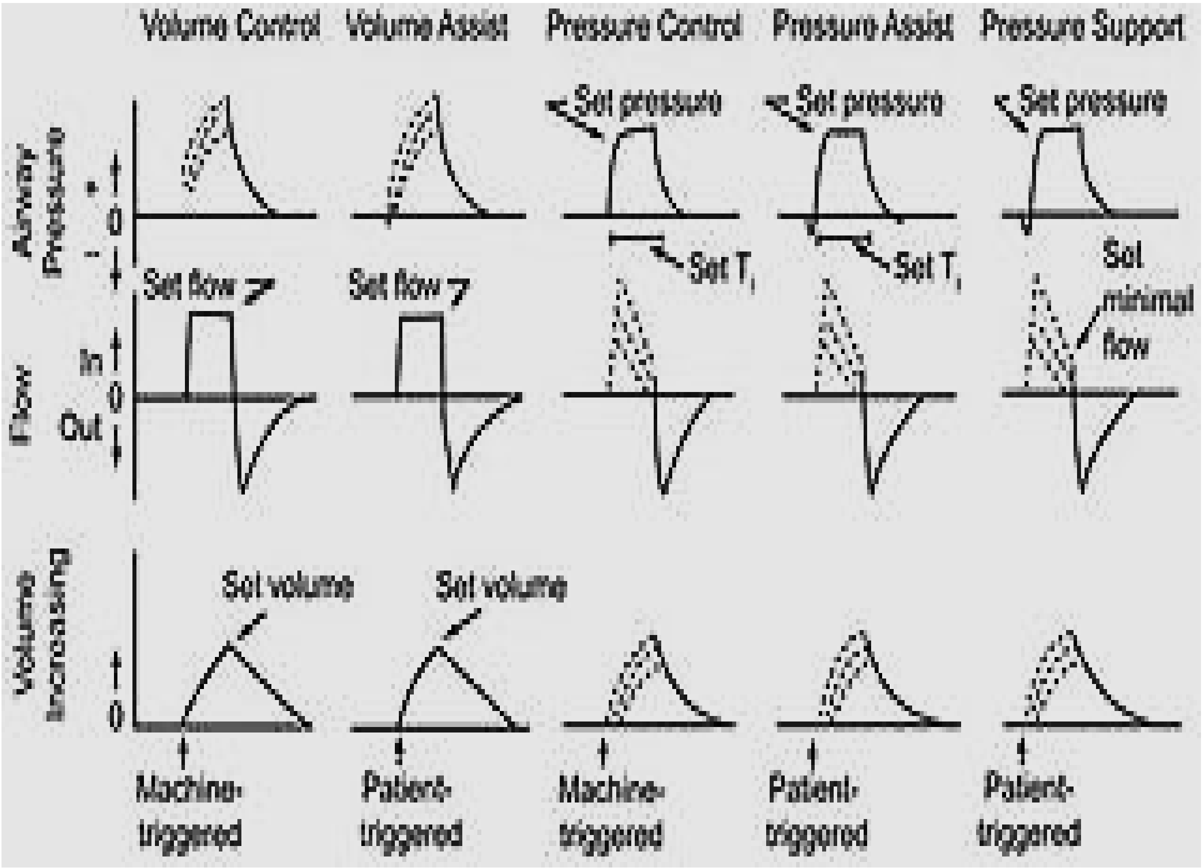
1-Method of cycling from inspiration-expiration-inspiration

a-Pressure cycling.
(Lung compliance affects V_T)

b-Flow cycling.
(Old ventilators)

c-Volume cycling.

d-Time cycling.
(most commonly used, cycling is not affected by lung compliance).



2-Inspiratory phase gas control

a- A preset volume is delivered.

b-A preset pressure is not exceeded.

While Expiration is passive

3- Source of power:

*(**Electrical or Pneumatic**)*

4-Suitability for use:

*(in **theatre ,ICU** or **Both**)*

*5-Suitability for **pediatric** use:*

(in addition to adult use)

*(**Yes** or **No**)*

6- Method of operation:

a- Pressure generator ,inspiration is produced by delivering a constant or pre-determined pressure. (inspiratory flow changes with compliance). It can not compensate for changes in the lung compliance.

b- Flow generator insp. Is produced by delivering a constant or pre-determined flow via a piston , a heavy weight or compressed air. This type have a high internal resistance to protect the patients lungs. It can not compensate for leaks.

7- Sophistication

Modern Ventilators can function in many of the previously discussed Modes e.g.

VCV(Volume Controlled Ventilation).

PCV(Pressure Controlled Ventilation).

IMV (Intermittent Mandatory Ventilation)

SIMV(Synchronized Intermittent Mandatory Ventilation)

CPAP (Continuous Positive Airway Pressure).

PSV (Pressure Support Ventilation).

PRVG or PRVC

(Pressure Regulated Volume Guarantee or Control)

8- Function

a- Minute Volume Divider:

FGF powers the ventilator .

MV equals the FGF and is divided by a preset V_T thus determining the Frequency or resp. rate.

b- Bag squeezers: need an external source of power, replaces the hand ventilation of Mapleson D or circle system.

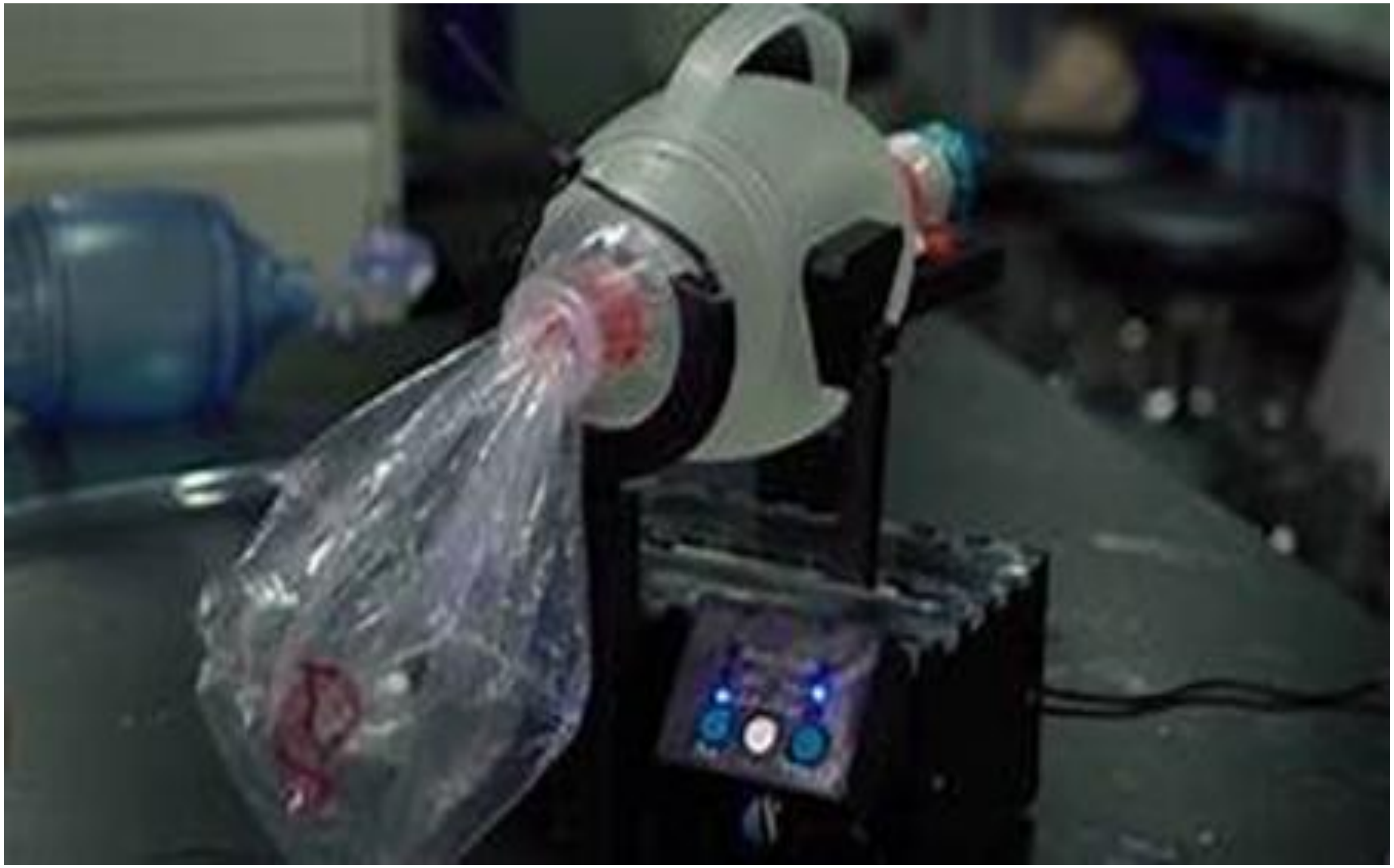
C-Light weight Portable : powered by compressed air (control unit and patient valve)

Minute volume Divider Manley ventilator

Manley Ventilator

- Minute Volume divider
- Vt set by operator. Rate=FGF/Vt
- Driving Force = Fresh Gas Pressure

Bag squeezers



Lightweight Portable ventilators

Characteristics of the ideal ventilator

1-Should be:

-Simple , Portable ,

-Robust & economical

-Ventilators using compressed gas ,a significant wastage is expected.

-Use of Venturi to drive the bellow, reduces the use of compressed oxygen.

Characteristics of the ideal ventilator

2-Should be versatile ,having (pediatric and adult) modes:

-V_T up to 1500 ml.

-Respiratory rate up to 60/min.

-I:E ratio e.g.(1:2 , 1:3 , 2:1 , 3:2)

-Can used with different breathing systems , and deliver any gas or vapour mixture.

-PEEP (Positive End Expiratory Pressure) can be added.

Characteristics of the ideal ventilator

3- should monitor:

-MVi , MVe , V_Ti , V_Te ,

-FiO_2 (inspired Fraction of O_2)

-Respiratory rate.(f)

-Inspiratory Pressure (P_{insp})

-Inspired and Expired concentration of vapors and gases e.g. N_2O

Characteristics of the ideal ventilator

-Should monitor & alarm for

Airway pressure :

High P_{aw} indicates obstruction.

Low P_{aw} indicates leak or disconnection.

Characteristics of the ideal ventilator

4- should have facilities for :

- Humidification.

-Drug Nebulization.

5-Should contain different modes of Ventilation e.g. (SIMV ,CPAP, PS)

6-should be easy to clean & sterilize.

Examples of Ventilators

1-Manley MP3 Blease Brompton Ventilator.

2-Penlon Anesthesia Nuffield Ventilator.

3-Bag in Bottle Ventilator.

4-Servo-I Ventilators.

5-High frequency Jet Ventilators.

(ICU +/- anesthesia)

6-VentiPAC Ventilators(e.g. Pneupac VR1 Ventilator) Light weight portable.

7-Venturi injector Device.

8-Self-inflating Bag and mask.

Manley MP3
Blease

-Min. Vol. Divider (all the FGF is delivered to the patient and divided into preset V_T.

-Time cycled.

-Pressure generator.

Manley MP3 Blease Brompton Ventilators

Components:

1-Rubber tubing.

2-Two sets of Bellows(small& big).

3-Three unidirectional valves.

4-APL.

5-Pressure gauge(up to 100cm H_20).

6-Two knobs (to change the mode of ventilation between:

Controlled or IPPV& Manual or spontaneous).

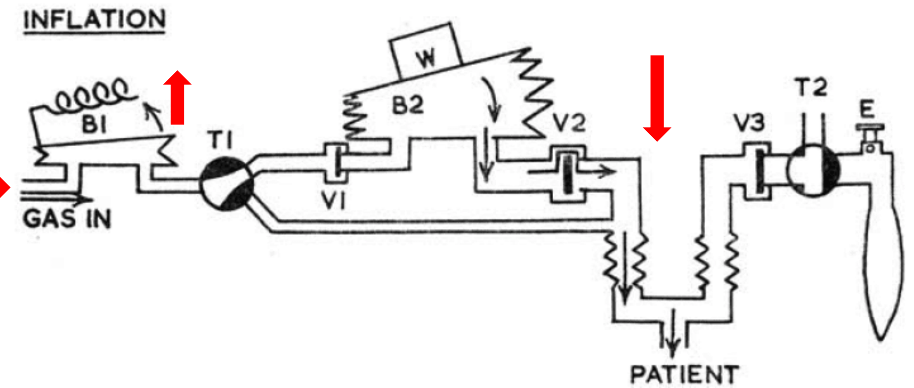
7-Inspiratory time knob

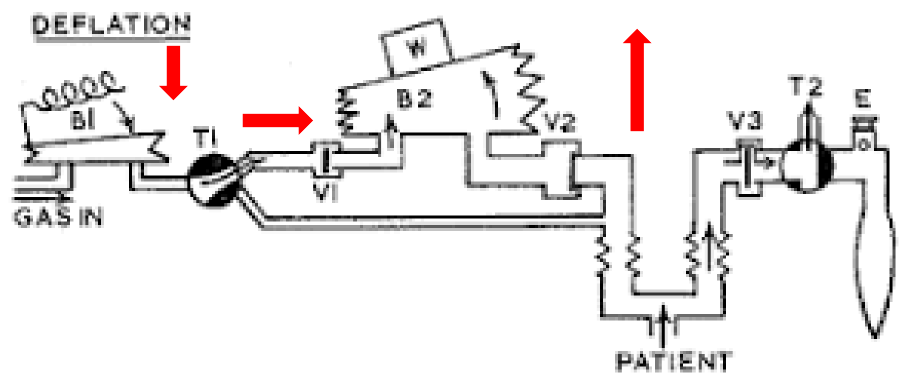
8-Sliding Weight on a rail to adjust (inflation pressure)

9-Expiratory block (autoclavable).

Mechanism of Action

1- FGF drives the ventilator.
2-During inspiration:
-Smaller bellows receives FGF. according to the inspiratory time.
-Main bellows delivers contents to the patient.
3-During expiration: smaller bellows empties into the main bellows.
4-Using spontaneous (manual mode) changes the system to Mapleson-D.





Mechanism of Action

Mapleson-A breathing system (Magill's system)

Penlon Anesthesia Nuffield Ventilator Series 200

-Intermittent Blower Vent.

-Small ,compact ,versatile.

(easy to use with different ages, sizes &breathing systems).

-In adult use:

Vol. preset , time cycled Flow generator.

-In paediatric use:

Press. Preset , time cycled Flow generator.

Components:

1-Control module consists of:

-On-Off switch.

-Airway press. Gauge (cm water)

-Insp. & Exp. Time Dials (sec.).

-Insp. Flow rate dial(L. per sec.)

-Connections for driving gas supply & valve block.

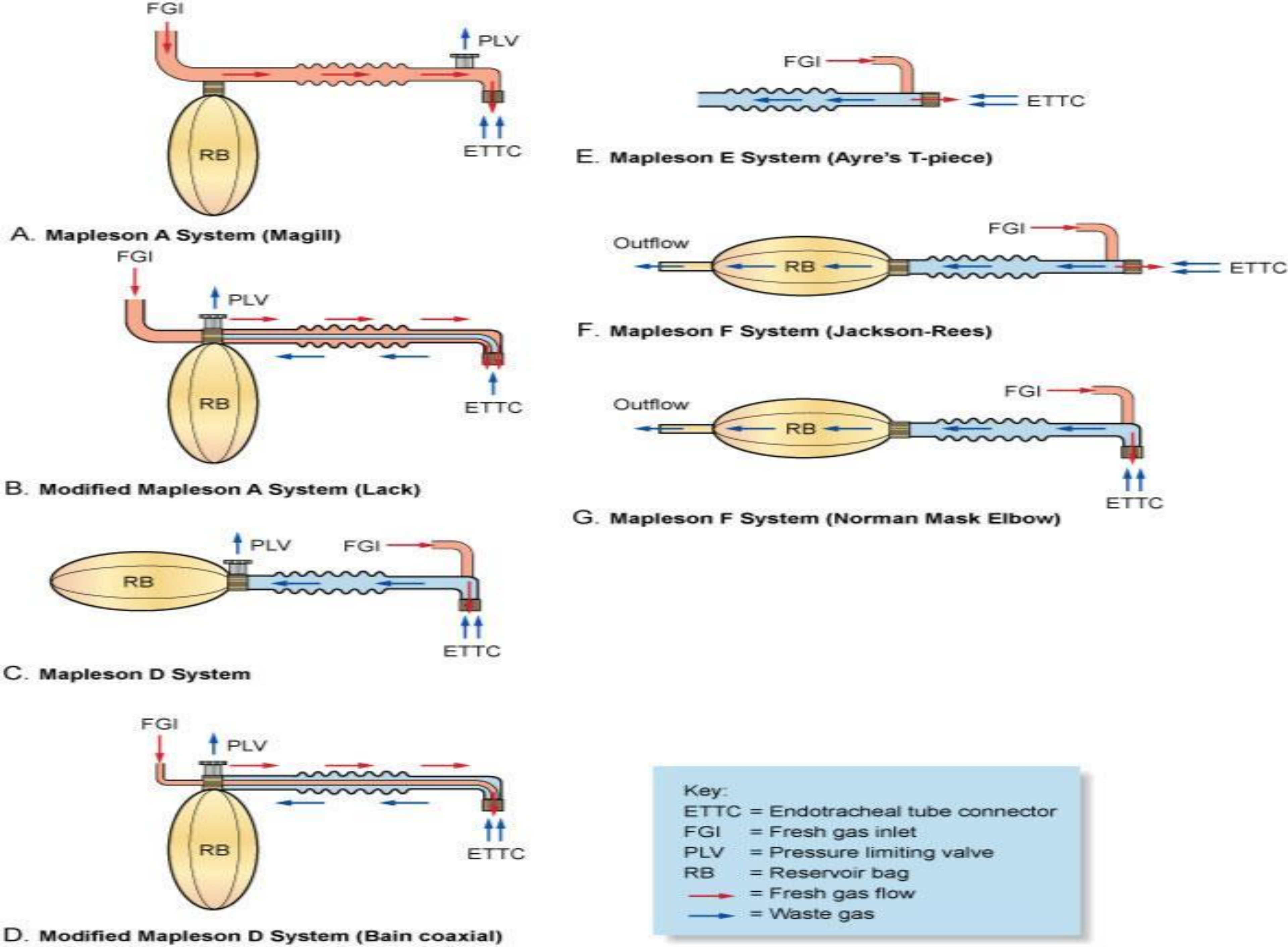
Valve block

2-Valve block :It can be changed to pediatric (Newton) valve. It has 3 ports:

a) A port for connection to breathing system reservoir bag mount.

b) A port exhaust ,can be connected to scavenging system.

c) A pressure relief valve opens at 60 cm H2O.


FGI
PLV
RB
ETTC
A. Mapleson A System (Magill)
FGI
PLV
RB
ETTC
B. Modified Mapleson A System (Lack)
PLV
FGI
RB
ETTC
C. Mapleson D System
FGI
PLV
RB
ETTC
D. Modified Mapleson D System (Bain coaxial)
FGI
ETTC
E. Mapleson E System (Ayre's T-piece)
FGI
Outflow
RB
ETTC
F. Mapleson F System (Jackson-Rees)
FGI
Outflow
RB
ETTC
G. Mapleson F System (Norman Mask Elbow)
Key:
ETTC = Endotracheal tube connector
FGI = Fresh gas inlet
PLV = Pressure limiting valve
RB = Reservoir bag
= Fresh gas flow
= Waste gas

Characteristics

-Driving gas is independent from FGF.

-Used with different breathing systems :

(Bain system , Humphery ADE system ,

T- Piece , Circle system).

In the Bain & circle system:

a-the reservoir bag is replaced by a tubing delivering the driving gas from the ventilator.

b- APL valve must be fully closed during ventilation.

Mechanism of action

-I:E ratio is adjusted by insp. & Exp. Times.

-V_T is adjusted by insp. Time & insp. Flow rate controls.

-Inflation press. Is adjusted by insp. Flow rate control.

-Standard valve (time cycled flow generator)

Minimum V_T= 50 ml.

Newton valve (time cycled press. Gen.)

V_T=(10-300) ml for premature & neonates.

i.e. for children less than 20 kg.

Problems

-Cycles despite disconnection.

-Requires high flows of driving gas.

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 V_T range of (0-1500) ml (pediatric version(0-400)ml.

b-an ascending (or descending) bellows accommodating the FGF.

2-A control unit with:

Controls, displays and alarms: V_T , resp. rate(6-40), I:E ratio, airway pressure & power supply.

Bag in bottle ventilator

Mechanism of action

1- it is a time-cycled ventilator.

2-compressed air (outside the bag) is used as the driving gas, entering the chamber thus forcing the bellows down (up in descending) ,delivering the FG (inside the bag) to the patient.

Driving gas(compressed air) ,outside the bag, should never mix with (FGF)inside the bag, delivered to the patient.

Problems in practice and safety features

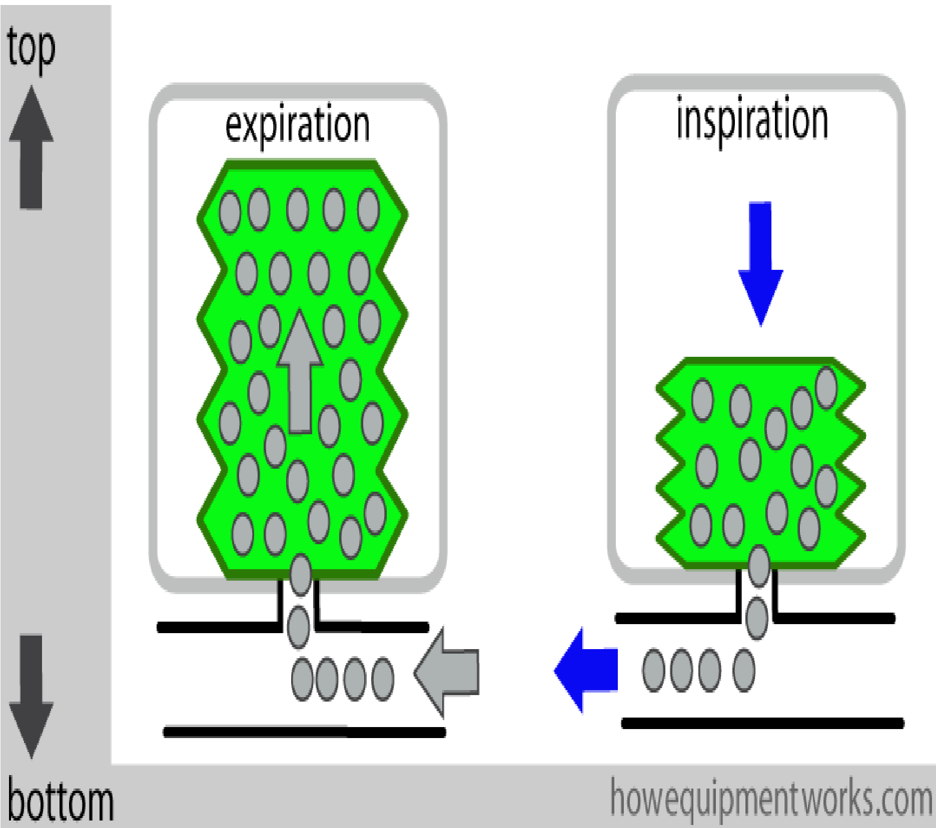
1-A positive press. Inside the descending bellows causes a PEEP of (2-4)cm H_2O.

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 fully expanded position in cases of disconnection and may continue to move almost normally even in case of leakage.

Problems in practice and safety features

Ascending bellows ***Descending bellows***



Servo- i Ventilator

-Versatile ICU ventilator(pediatric & adult).

-Fully transportable(utilizes 12V battery).

-Not used with inhalational but used i.v. anesthetics.

-Used for non-invasive ventilation (nasal or face mask).

-Facilitates Heliox.

-Modern version regulates PEEP to maintain lung compliance via a software.

-Neurally Adjusted Ventilatory Assist (NAVA).

Components

1-Patient unit:

(gases mixed and delivered).

2-Graphical user interface

(setting & monitoring).

Servo ventilator (900C)

Servo-i ventilator

Mechanism of action

1- Air and O_2 flow are regulated by modules.

2-O_2 % is measured by O_2 cell or O_2 sensor.

3-Inspiratory Pressure Transducer measures the delivered gas pressure.

4-An ultrasonic transducer measures expiratory gas flow.

5-PEEP is regulated by the expiratory valve.

Modes of Ventilation

I ***-SIMV (Synchronized Intermittent Mandatory Ventilation) .***

The ventilator delivers mandatory breaths at intervals synchronized with patients insp. efforts(if present) according to the selected setting.

-Usually 0ne of the following settings:

(A) PRVC or PRVG

Pressure Regulated Vol. Control or (Guarantee)

-A preset V_T is delivered.

- 5 cm H_2O lower than the set upper press. limit .

-Automatically limits barotrauma.

-Insp. Flow is decelerating.

-The patient can trigger extra breaths.

(B)VCV (Volume Control Ventilation)

-A preset V_T & Resp. rate are selected.

-insp. Flow is constant during a preset time.

-A constant V_T is delivered whatever the lung compliance is or whatever airway pressure is.

-Barotrauma (by excessive press.)can be avoided by setting the upper press. Limit to a suitable level.

(C) PCV (Press. Control Ventilation)

-A pressure level above PEEP is selected.

-V_T depends on Lung compliance & Airway resistance .

-Its selected when there's a leak (un-cuffed tube)or barotrauma is to be avoided(ALI).

-Needs continuous monitoring of pressure control setting to be reduced when the resistance and compliance improves quickly because of the risk of excessive V_T

(volu-trauma).

II-*Supported ventilation modes*

Once the patient has the ability to trigger the ventilator, usually one of the following modes is selected in addition to the PEEP setting

(A)VS(volume support)

-A preset V_T is assured once the required pressure support setting (supplied by the ventilator) is reached by the patient.

-It allows weaning from ventilatory support as the lung Compliance & insp. muscle strength improves, (shown by gradual reduction in airway resistance on the ventilator).

-Once support is minimal ,extubation can be considered.

(B) PS(Pressure support)

-The patient's breath is supported with a set constant pressure above PEEP.

-Gives a flexible V_T according to lung compliance & insp. muscle strength.

-Needs regular press. Support adjustment to allow weaning.

Problems in practice & safety features

1-A comprehensive Alarm system is available.

2-A main stream CO_2 analyzer (insp.& exp.)

3-Batteries (1-6) offer 30 min to extended use, At least 2 batteries are recommended.

4- (20kg)heavier than transport ventilators.

High frequency jet ventilator

-Reduces the extent of the side effects of conventional IPPV.

-Lower peak Airway pressure.

-Better maintenance of cardiac output.

-Less ADH production and fluid retention .

-Better tolerated by alert patient.

Components

1- A venturi injector is connected to a :

-Canuula in the tracheal tube.

-Cannula in the trachea via cricothyroid memb .

-Modified tracheal tube with two small additional lumens open distally. 2-solenoid valves to deliver jet gas.

3-Dials and displays for driving pressure , frequency and insp. time.

4-Built-in peristaltic pump for nebulizing drugs or distilled water for humidification of jet gas.

5-High-flow air/O2 or N2O/O2 blender.

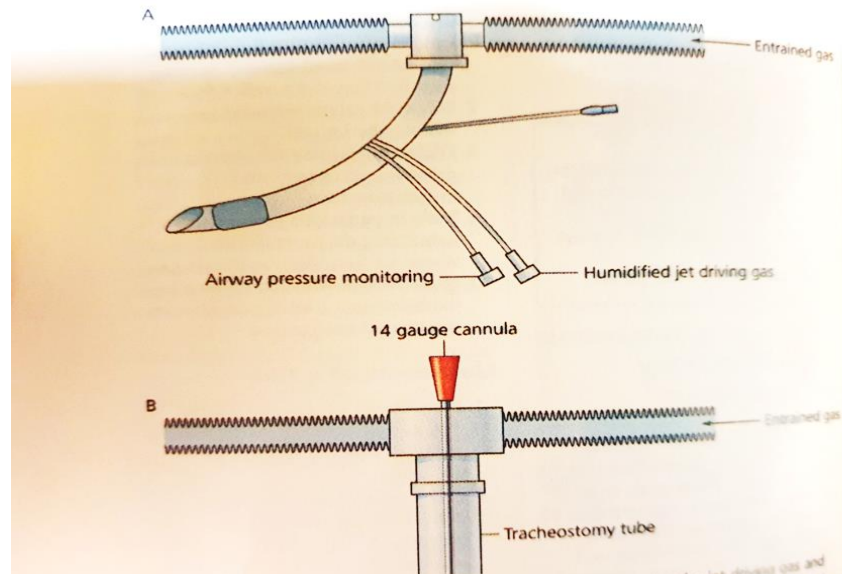
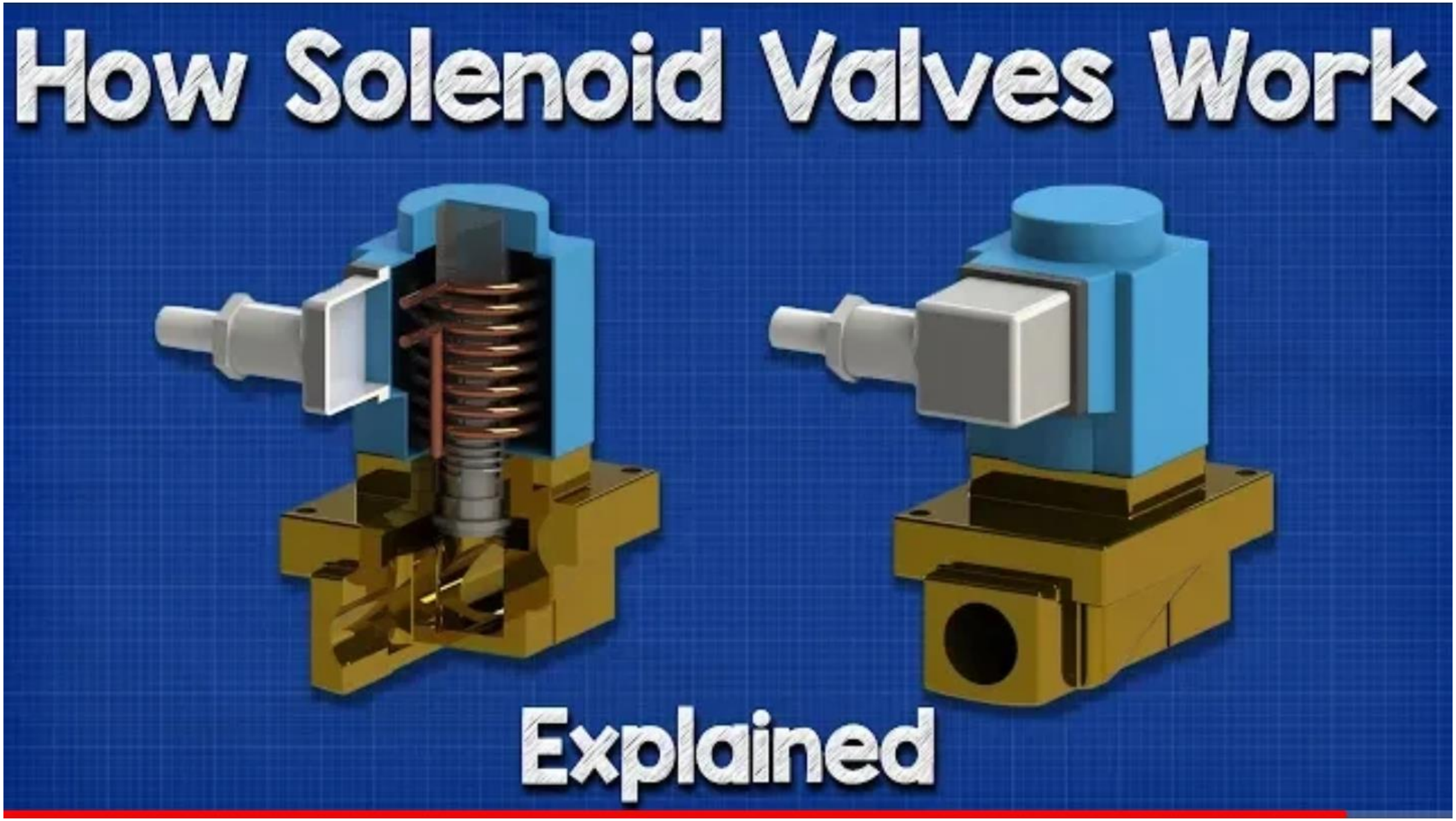


Fig. 8.8 (A) A jet tracheal tube with two additional lumens for the jet driving gas and airway pressure monitoring. (B) A 14-gauge cannula positioned within a tracheostomy tube, through which the jet driving gas can be administered.

Solenoid valve



Mechanism of action

1-Frequency is 20-500 cycle/min.

2-MV is (5-60) L/min.

3-Time cycled, gas is delivered in small jets pulsations.

Insp. Time adjusted (20%-50%).

4- V_T & FiO_2 are uncertain since the amount of entrained air via narrow injector of FGF is uncertain.

Jet ventilation using Venturi

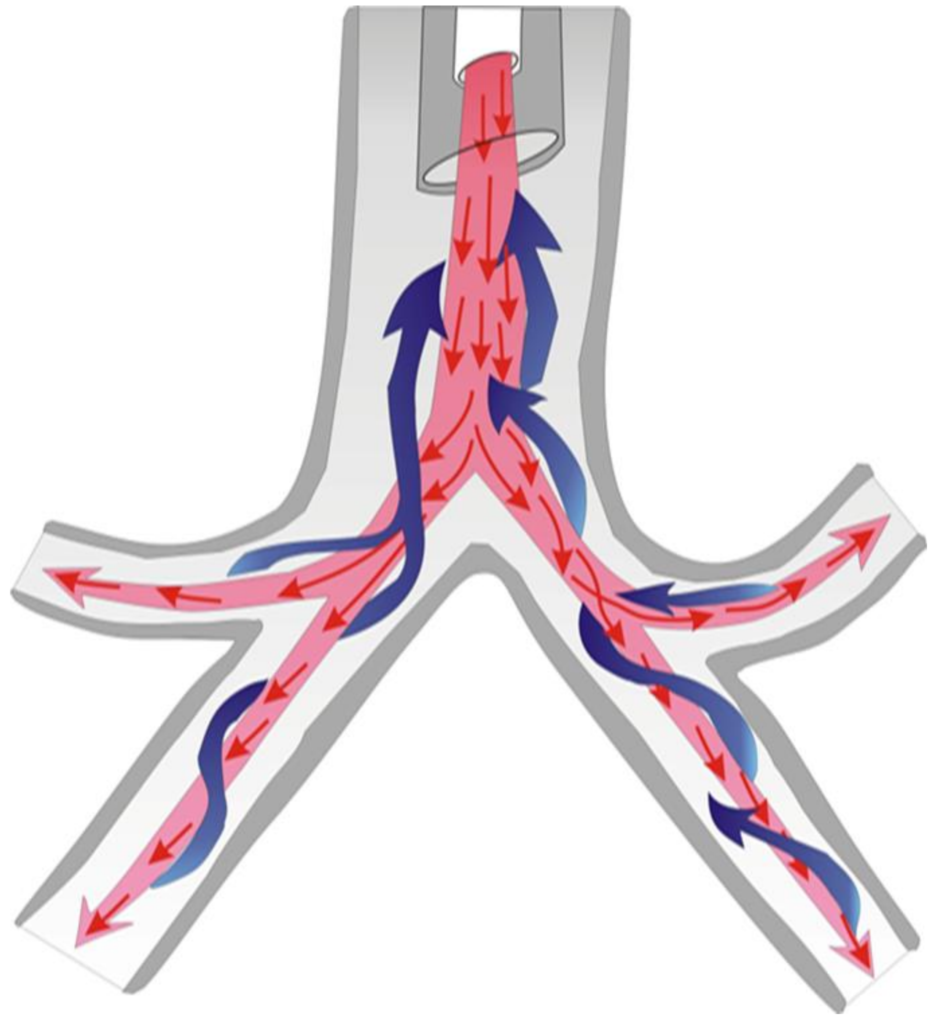
4-The jet and entrained air push the much larger immobile gases forwards.

5-Exp. is passive.

6-Resp. rate above 100/min.

automatically causes PEEP .

Additional PEEP by adding PEEP valve can be added.



Problems in practice and safety features

1- Barotrauma can still occur as exp. Is dependent on recoil of the lung and chest wall.

2-High press. (35-40) cm H_2O and system malfunction alarms are available.

VentiPac

-Portable ventilator .

for transport of critically ill patient.

-Flow generated.

-Time cycled.

-Volume preset.

-Press. Limited.

-Pressure generator.
-Below 0.25L/sec. flow in Air mix setting.

ParaPac ventilator

-Synchronizes ventilation
with External Cardiac Massage during CPR.

-A neonatal /pediatric version is available.

Components

1- Airway control includes:

a-insp. Flow (6-60)L/min.

b-insp. time (0.5-3.0) sec.

c-exp. time (0.5-6.0) sec.

d- adjustable insp. Press. relief + audible alarm (20-80) cm H_2O.

e- air mix/no air mix control.

f- a demand and CMV/demand control.

2- Inflation press.(Airway press.) monitor.

3-polyester or silicone tubing with one-way valve to deliver gases to the patient.

4-Tubing to deliver oxygen to the ventilator.

Mechanism of Action

***1-Source of power** is dry oil-free pressurized air (270-600) kPa ,using **Air mix** mode reduces **Oxygen consumption** by the ventilator by 70%.*

2-frequency** is adjusted by setting **insp.** And **exp. Times.

***3-V_T** is adjusted by setting **flow & Insp. time**.*

4-choice of FiO2= 100% (no air mix).

= 45% (air mix).

Mechanism of Action

5- demand mode provides 100% O_2 to spontaneously breathing. A visual indicator flashes when spont. breathing is detected.

6-CMV/demand mode provides CMV.

If spont. Breathig is detected, the ventilator shifts to SMMV(Synchronized Minimum Mandatory Ventilation).

7-Optional PEEP valve (up to 20 cm H_2O).

Problems in practice and safety features

1-press. Relief valve protects against barotrauma.

2-Audible and visual alarms for

High airway press.=(Obstruction) and Low airway press.=(disconnection).

3- Gas failure Alarm.

4-MRI compatible.

Pneupac VR1 emergency ventilator

- *-Light weight , hand-held.*
- *-Gas powered flow generator.*
- *-Time cycled.*
- *-Designed for emergency and transport.*
- *-MRI compatible up to 3 Tesla*

Components

1-V_T / frequency control.

2- Auto/manual control with manual trigger and push button.

3-Air mix switch allowing the delivery of oxygen at 100% or 50%.

4- patient valve connecting to catheter mount/filter or face mask.

5- gas supply inlet.

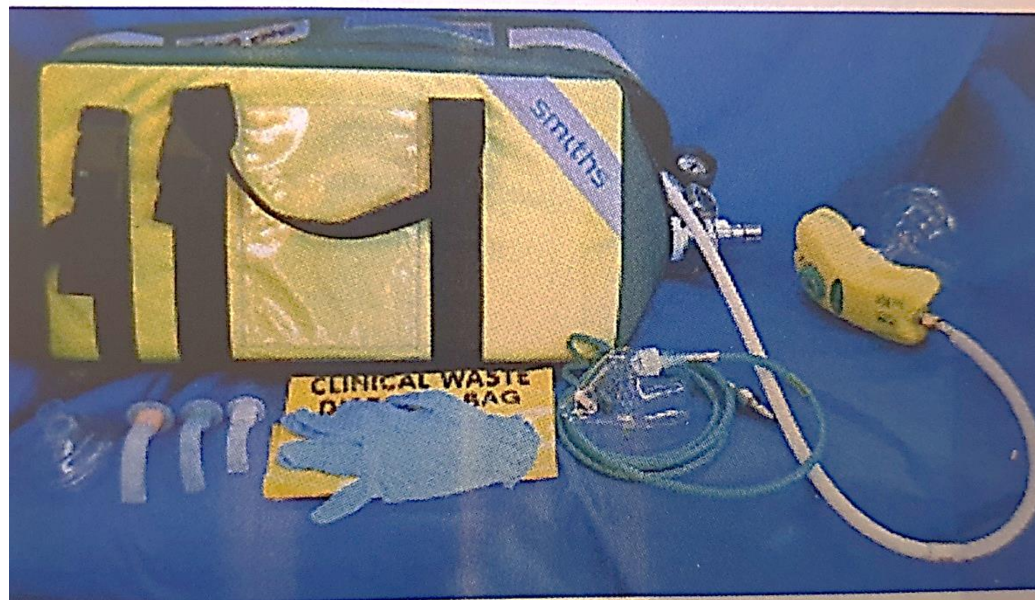


Fig. 8.11 Pneupac VR1 Emergency Ventilator.

Mechanism of action

1- Powered by pressurized oxygen(280-1034) kPa ,air mix prolongs duration of O2 cylinder.

2-Constant I:E ratio (1:2)

Flow rates (11-320) L/min.

3-Optinal patient demand facility incorporated to synchronize between patient and ventilator.

4- A linked manual control allows triggering of a single controlled ventilation ,thus used in CPR.

5- Used in adults &children above (10)kg .

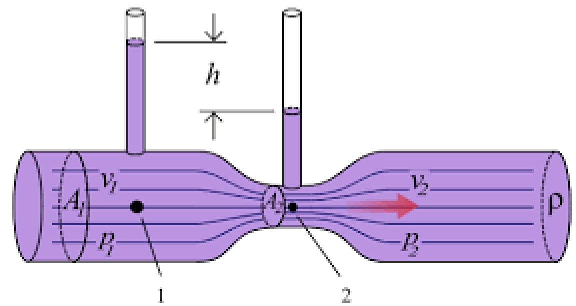
Problems in practice and safety features

1- Pressure relief valve operates at 40 cm H_2O.

2-Single manual ventilation triggered by equals to the volume of ventilation delivered in automatic ventilation. Thus its much safer to the patient.

Venturi

-Manually controlled ventilation device is used during bronchoscopy where the operator and the anesthetist share the airway.



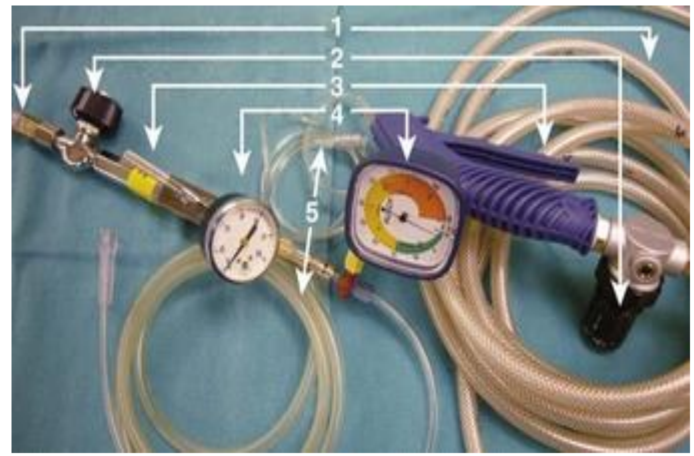
-GA is maintained intravenously.

Components

1-A high pressure O2 source (400kPa) from

-Anesthetic machine.

-Pipeline directly.



2- On/Off trigger.

3-High pressure connection tubing.

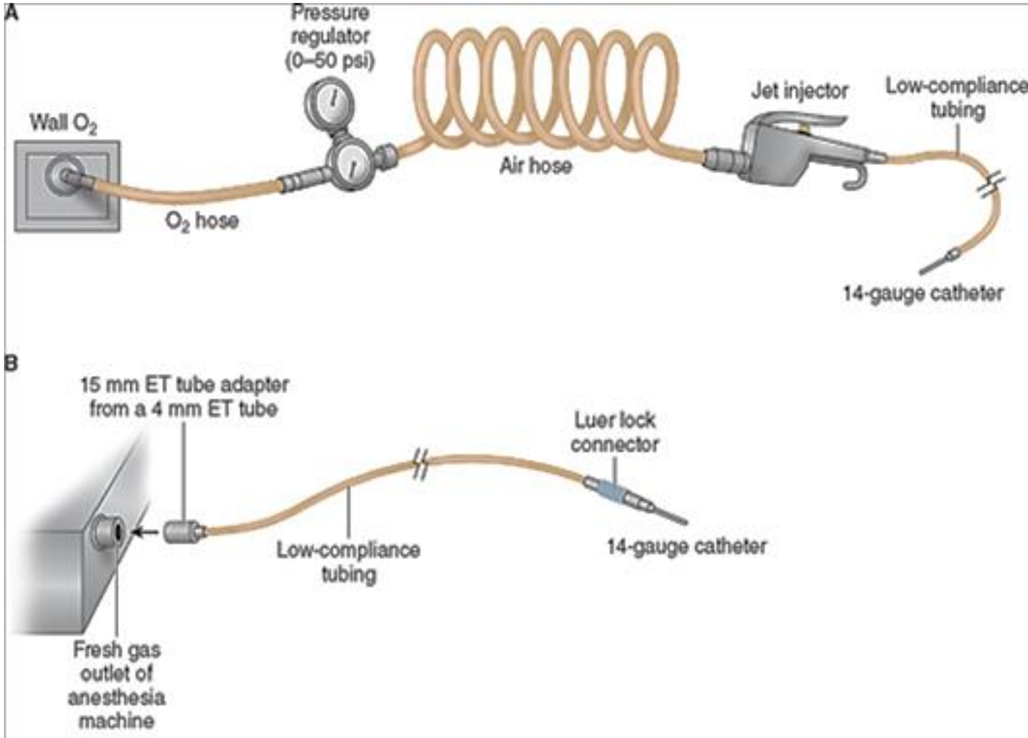
4-A suitable gauge needle to allow air entrainment without excessive airway pressure.

Mechanism of action

1-High pressure O_2 is injected intermittently via a needle at the proximal end of the bronchoscope.

2-this creates aVenturi effect entraining atmospheric air inflating the lungs with O_2 enriched air.

3- oxygenation and CO_2 elimination is achieved at airway pressure of (25-30) cm water.



Source: Butterworth JF, Mackey DC, Wasnick JD: *Morgan & Mikhail's Clinical Anesthesiology*, 5th Edition: www.accessmedicine.com

Problems in practice and safety features

-Barotrauma is possible (no pressure monitor).

-Gastric distention if ventilation starts before the distal end of the bronchoscope passes cricoid cartilage.

Self-inflating bag and mask

-This is a mean of providing manual IPPV.

-Portable , used during resuscitation, short-term ventilation &transport.

Components

1- self-inflating bag & connection of added O_2.

2-A one way valve with 3 ports:

a- Insp. Inlet for entry of FGF during inspiration.

b- Exp. Outlet for exhaled gas exit.

c- Connection to the face mask or Endotracheal tube and marked (Patient).

3- A reservoir for O_2 to increase FiO_2 to the patient.

Mechanism of action

1- The non-rebreathing valve (Ambu-valve).
Contains a silicone rubber membrane .
It has a small dead space and low resistance to flow.

- ***At flow of 25L/min. :***
  Insp. resistance of 0.4 cm water &
  Exp. resistance of 0.6 cm water are achieved.
- ***It can easily be dismantled for cleaning and sterilization.***

2- The valve acts as a spill over valve to push excess insp. Gas directly to the exp. Outlet bypassing the patients port.
3-The valve is suitable for IPPV and spontaneous ventilation.
4-The shape of the self-inflating bag is restored after compression, this allows FG to be pulled from the reservoir bag.
5- A pediatric version with a smaller bag and relief valve is available.
6- Disposable adult and pediatric versions exist.

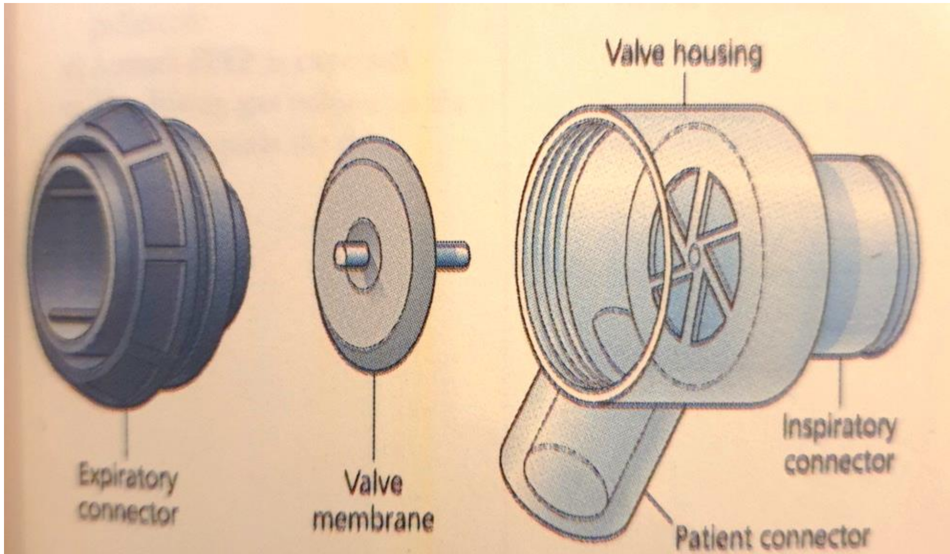


Fig. 8.14 An Ambu valve disassembled. (Reproduced with permission from AMBU International (UK) Ltd.)

PEEP valve

-It is used during IPPV to increase FRC

(Functional Residual Capacity) to improve patients oxygenation.

-It's a spring-loaded unidirectional valve positioned on the exp. Side of the ventilator breathing system.

-Provide a PEEP (0-20) cm water by adjusting the valve knob.

Fig. 8.15 The Ambu PEEP valve.