Anesthesia Workstation & Delivery Systems for Inhaled Anesthetics

R1 WANLAPA /LT.COL. NATTHAPHONG

Outline

- Gas supply system
- Vaporizers
- Anesthetic breathing circuit
- CO_2 absorber
- Anesthesia ventilators
- Scavenging system

Gas supply system

1

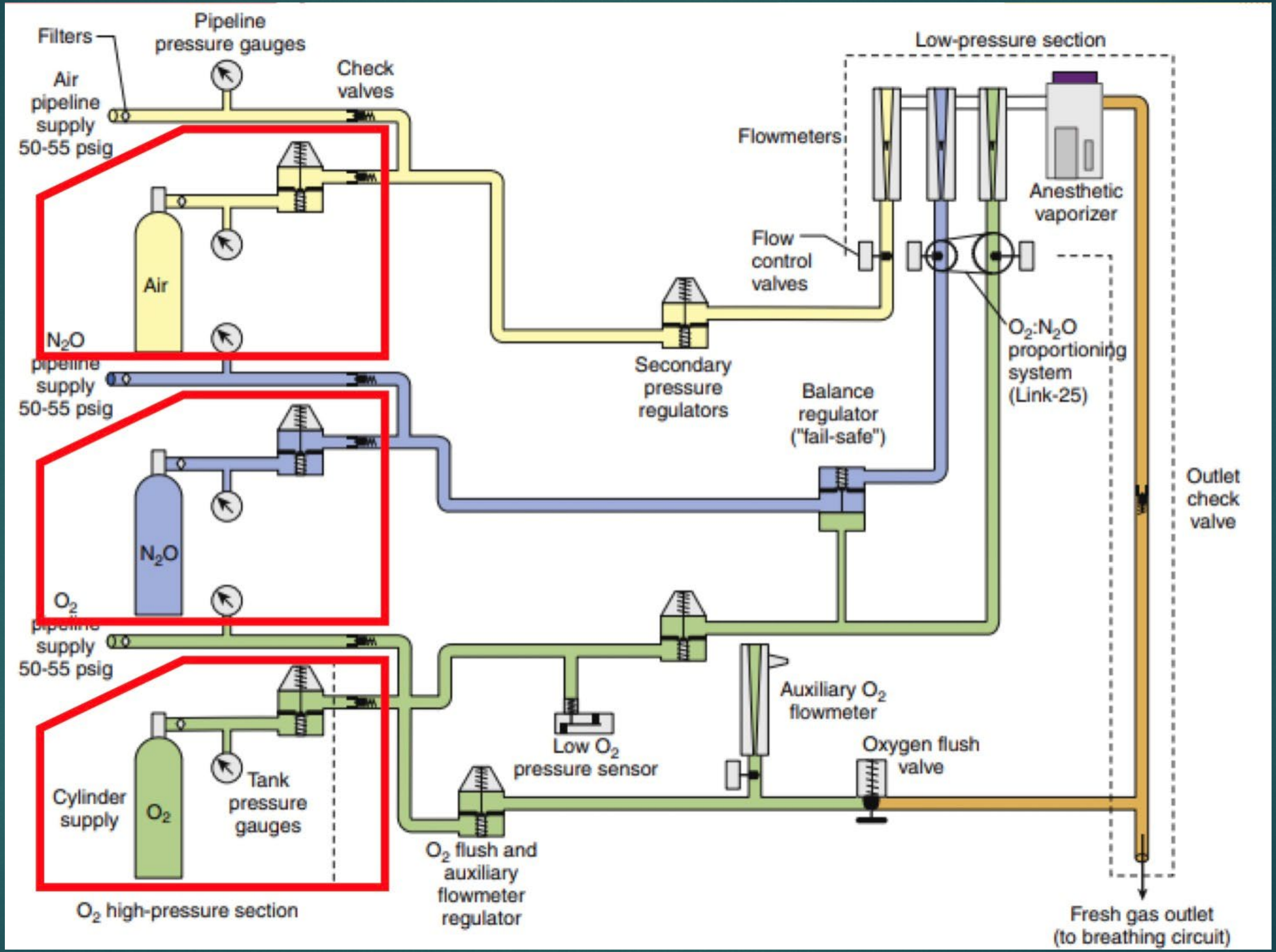
High-pressure section

2

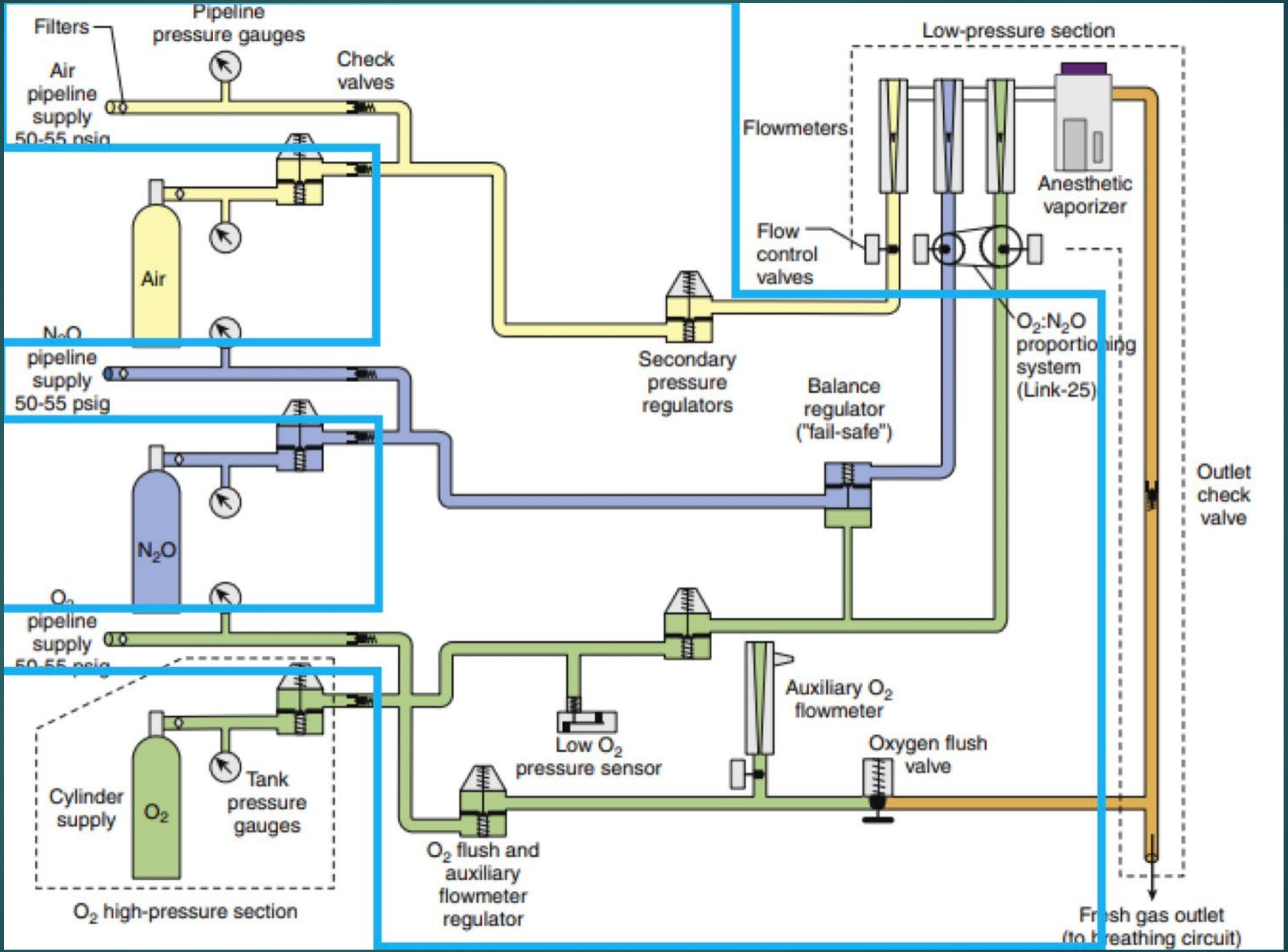
Intermediate-pressure section

3

Low-pressure section



Filters
Pipeline pressure gauges
Check valves
Air pipeline supply 50-55 psig
Air
N2O pipeline supply 50-55 psig
N2O
O2 pipeline supply 50-55 psig
Cylinder supply
O2
Tank pressure gauges
O2 high-pressure section
Low-pressure section
Flowmeters
Anesthetic vaporizer
Flow control valves
O2:N2O proportioning system (Link-25)
Secondary pressure regulators
Balance regulator ("fail-safe")
Outlet check valve
Auxiliary O2 flowmeter
Low O2 pressure sensor
Oxygen flush valve
O2 flush and auxiliary flowmeter regulator
Fresh gas outlet (to breathing circuit)



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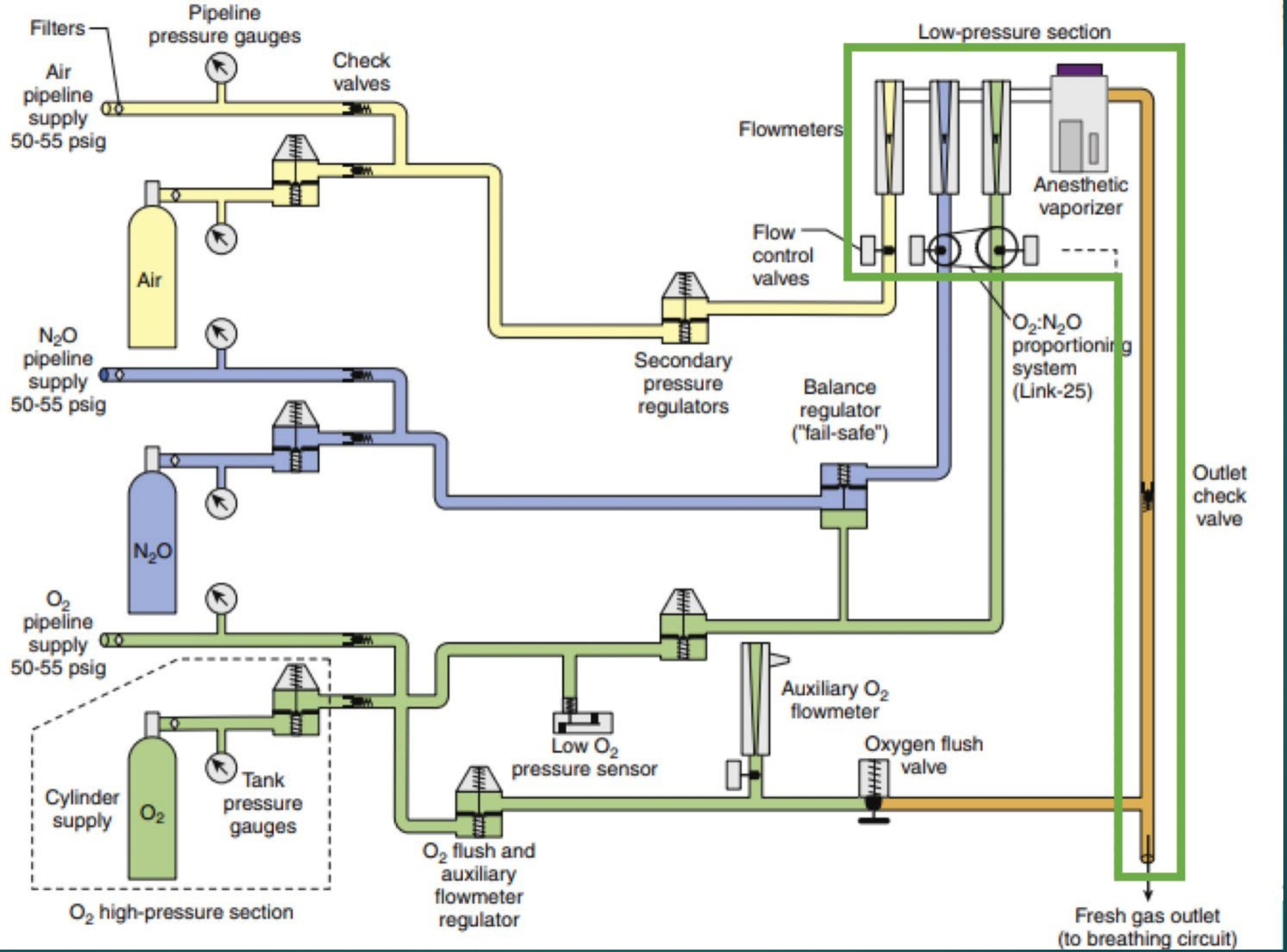

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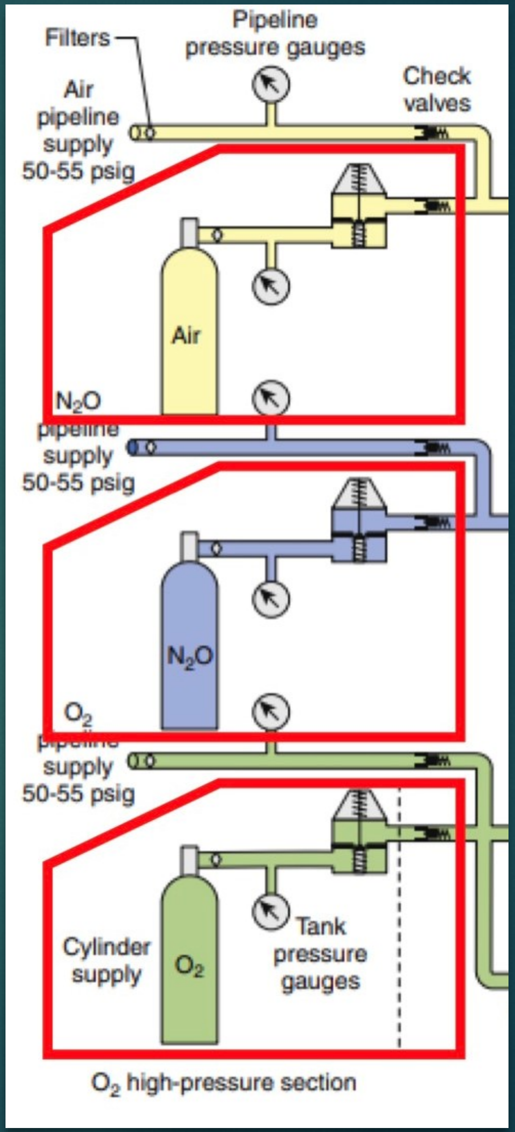
Outlet check valve
Fresh gas outlet (to breathing circuit)

High-Pressure Section

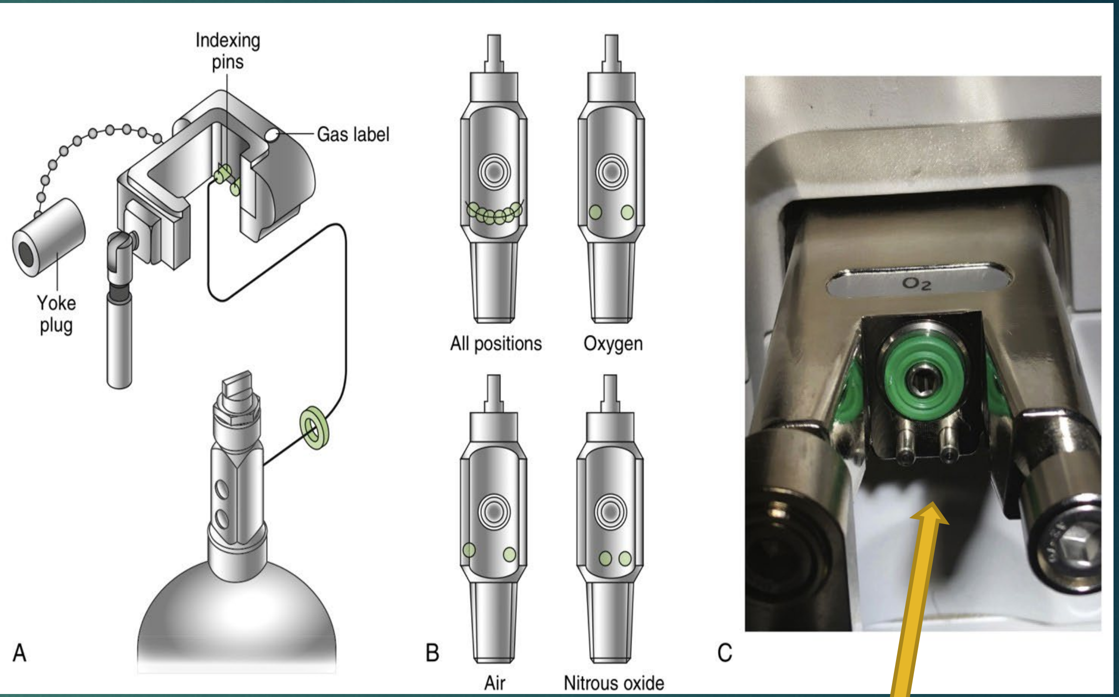
High-Pressure Section

- Receive gas from the high pressure E cylinder attached to the back of anesthetic machine
  - 2000 psig for Air and O_2
  - 745 psig for N_2O
- Consist of
  - E-cylinders
  - Hanger yolk
  - Tank pressure gauges
  - High pressure regulators
  - Check valves
- Usually not used, unless pipeline gas supply is off



E-cylinder Hanger Yoke

- Hanger yoke orients &support the cylinder
- Provide a gas-tight seal
- a unidirectional gas flow into the machine
- Pin Index Safety System(PISS)
    - Reduced the risk of a medical gas error
- Color coding

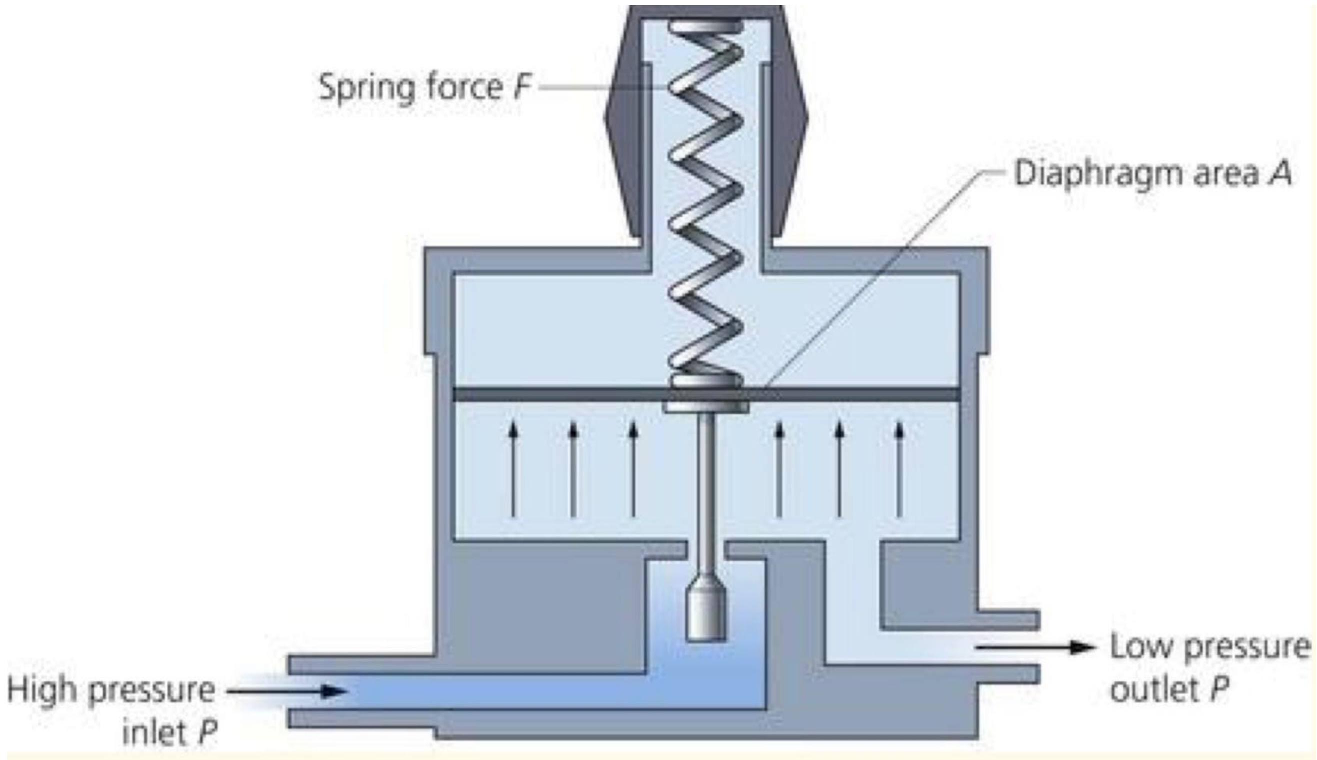


PISS

Tank Pressure Gauges

- must be displayed on the front of the anesthetic machine
- Accurate only when the tank is open

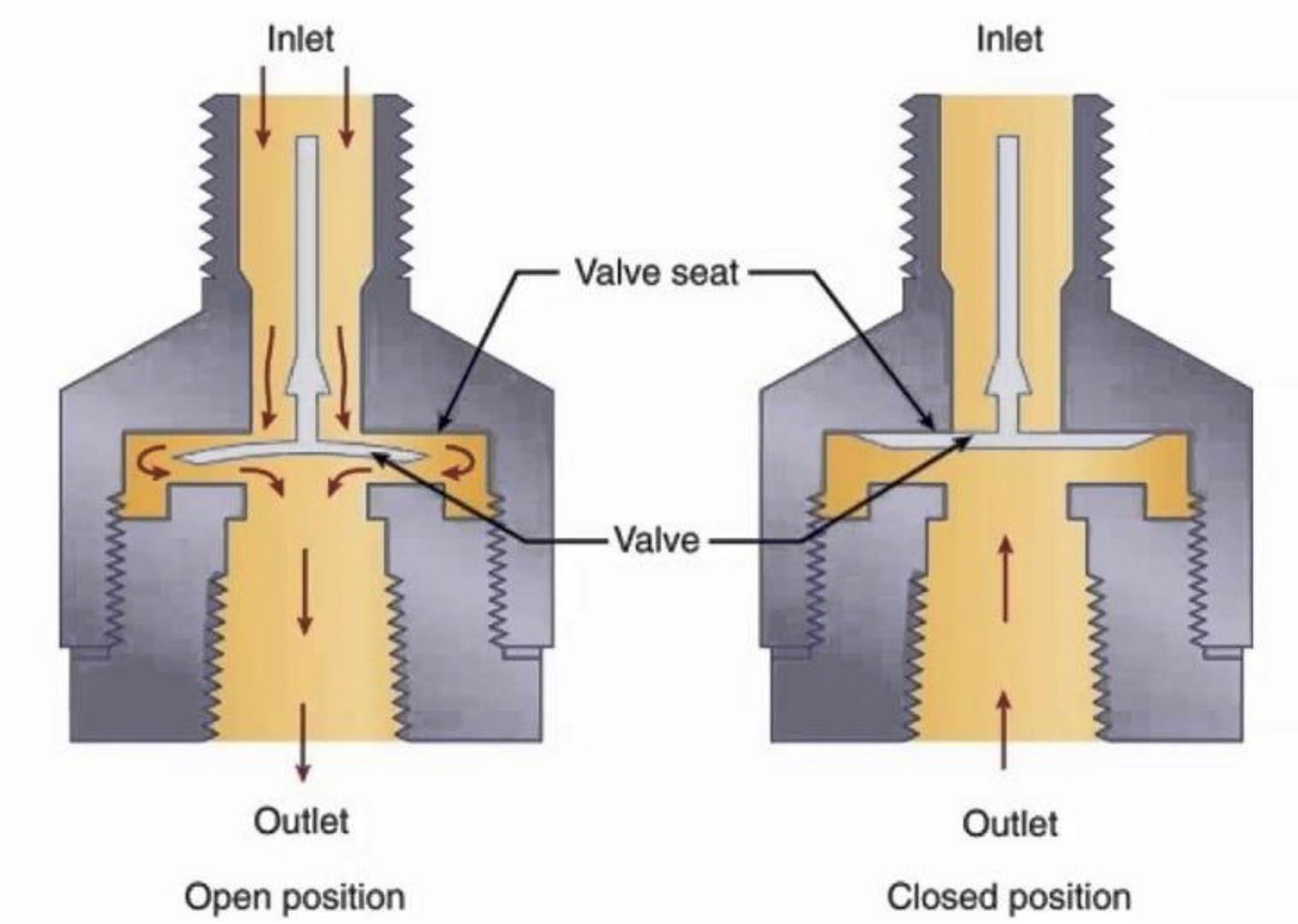
High pressure regulators



- Reduces the variable high pressure in the E-cylinder to a constant pressure slightly lower than the normal pipeline supply pressure
- approximately 40-45 psig

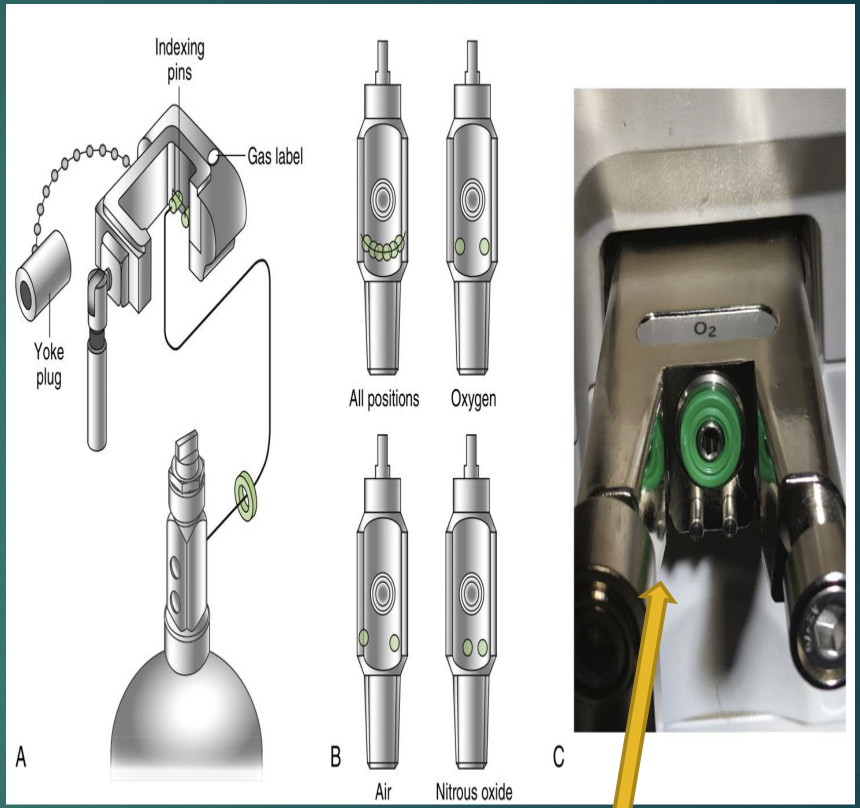
Check valves

- A one-way valve
- prevent any black flow of machine gas out through and empty yoke or back into a nearly empty cylinder



Safety Feature

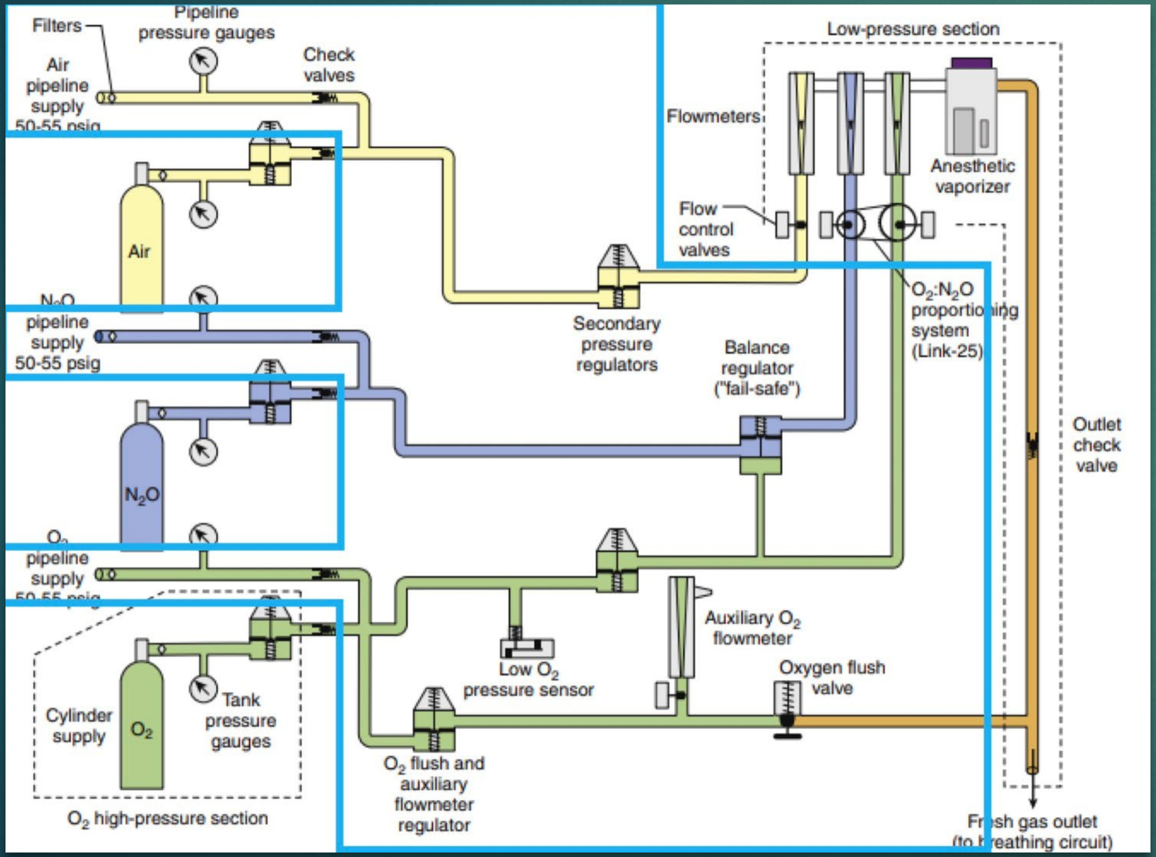
- E-Cylinder hanger yoke
  - Pin Index Safety System(PISS)
    - Reduced the risk of a medical gas error



PISS

Intermediate-Pressure Section

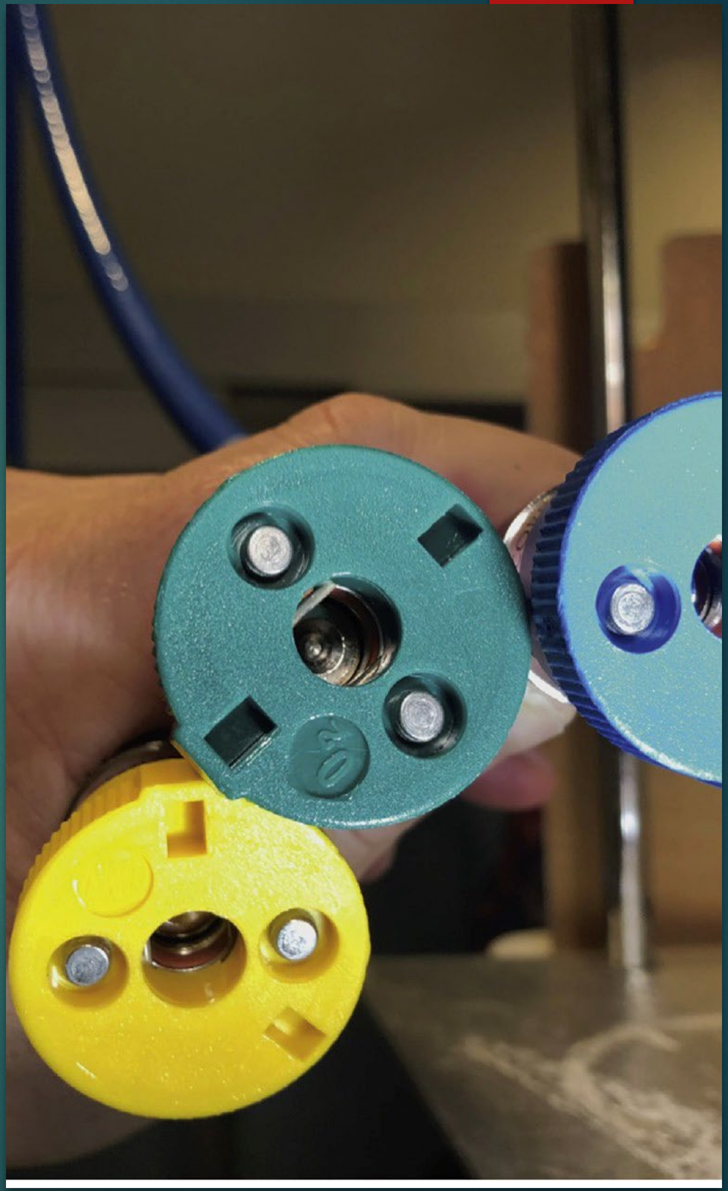
Intermediate-Pressure Section



- **Receives gasses from hospital pipeline to flow meters**
- Main sources of gases for anesthetic machine
- Consist of :
  - Pipeline
  - Pipeline pressure gauges
  - Low oxygen pressure sensors
  - Oxygen pressure failure device
  - Oxygen flush valve
  - Secondary-stage pressure regulators
  - Auxiliary oxygen flowmeter

Pipeline

- Received gases from hospital main supply to anesthetic machine
- Each inlet must contain a check valve to prevent reverse flow from anesthetic machine
- Diameter Index Safety System(DISS)

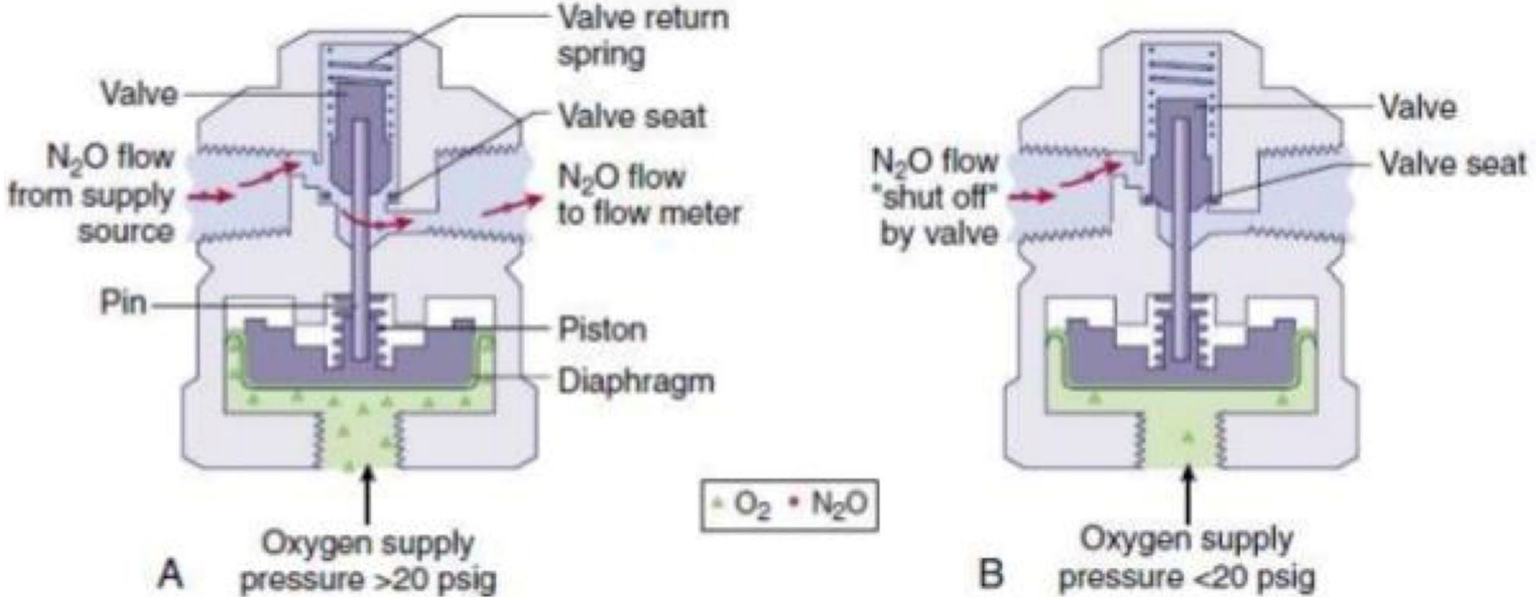


Pipeline Pressure Guages

PIPELINE PRESSURE USUALLY 50-55 PSIG

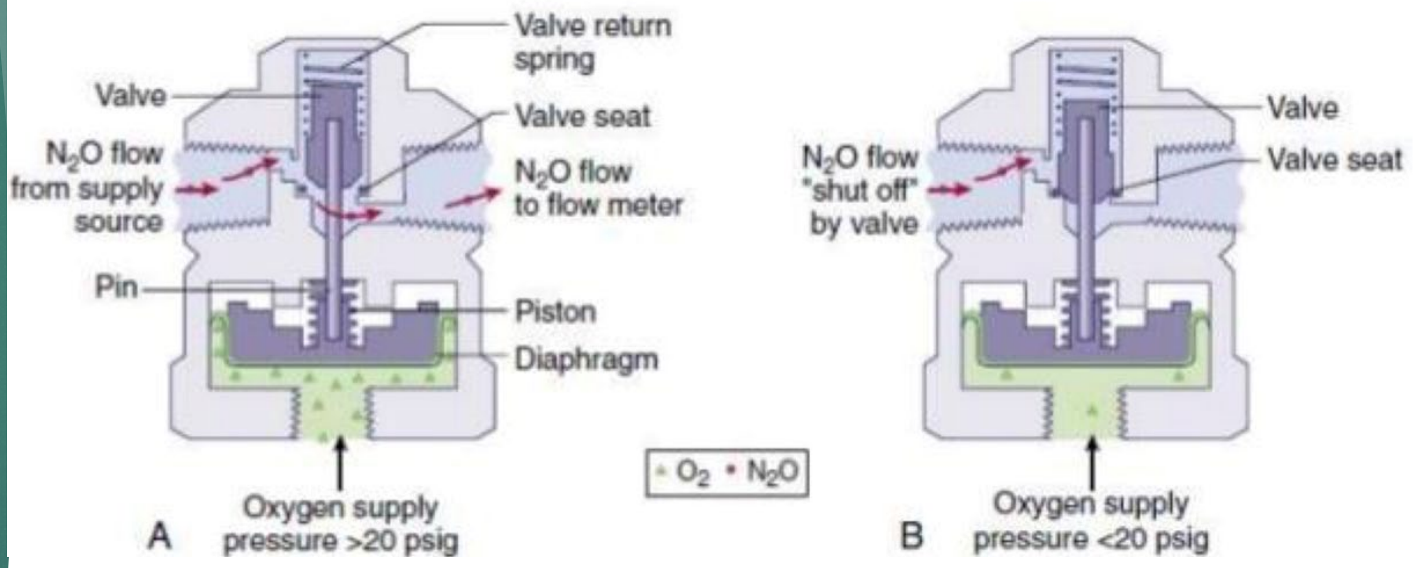
Low Oxygen Pressure Sensors

- Known as “Oxygen supply failure alarm”
- Triggered by a loss of or significant decrease in pipeline pressure, or a nearly empty oxygen tank
- The minimum threshold pressure usually 30 psig (differ amongmanufacturers)



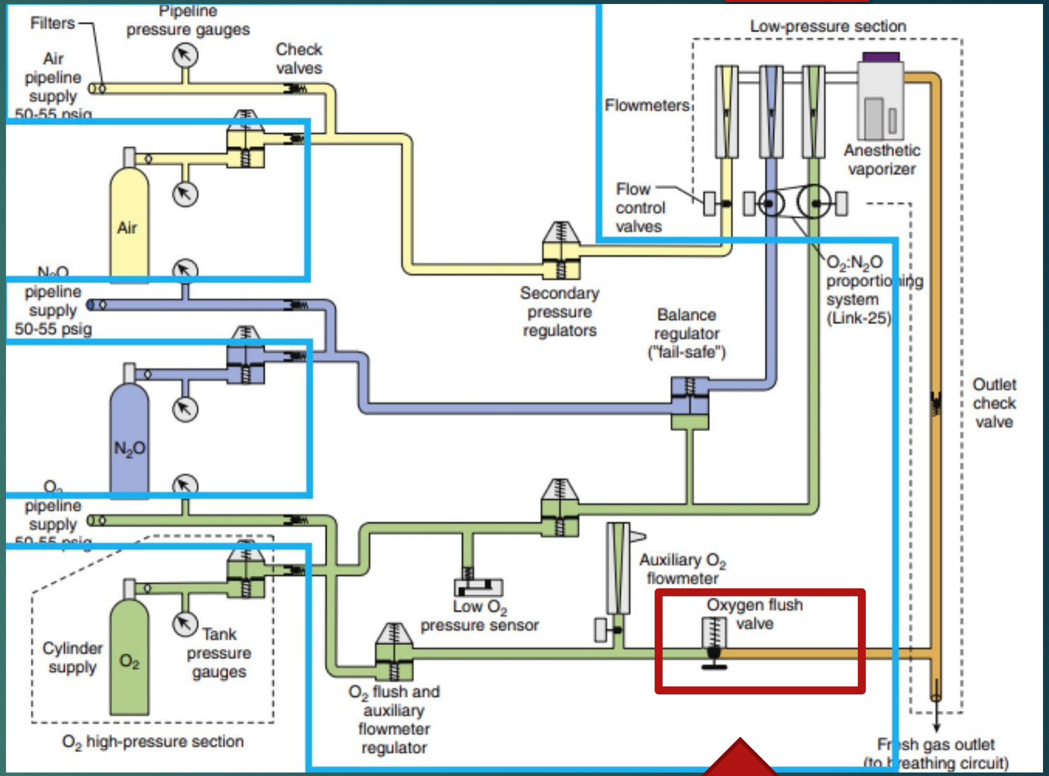
Oxygen Pressure Failure Device

- Known as "Fail-safe valves"
- Prevent a hypoxic mixture
- In response to low oxygen pressure valve close or reduces the flow of other gases e.g., N_2O or air to flow control valve



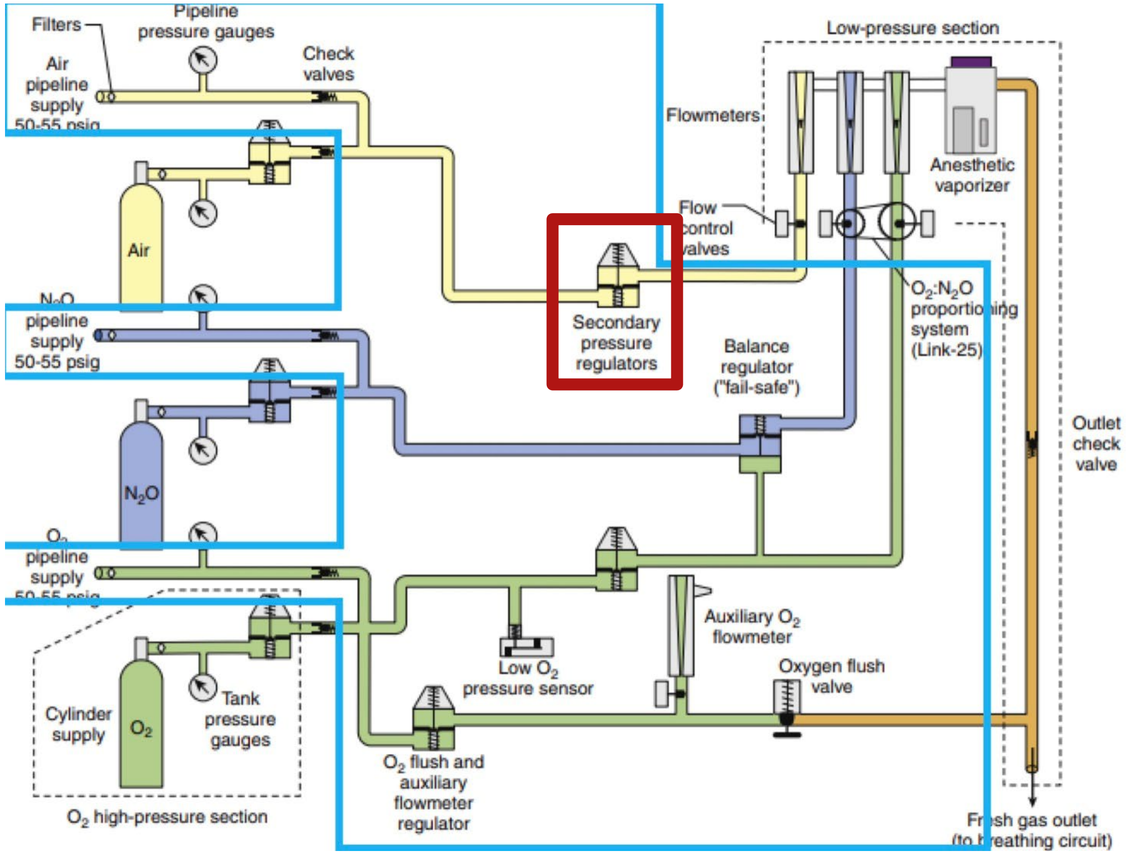
Oxygen Flush Valve

- high flow rate of 100% oxygen directly to the patient's breathing circuit
- to overcome circuit leaks or to rapidly inhaled oxygen concentration
- Flow rate between 35-75L/min
- Hazards
  - Barotrauma
  - Dilution of inhaled anesthetic



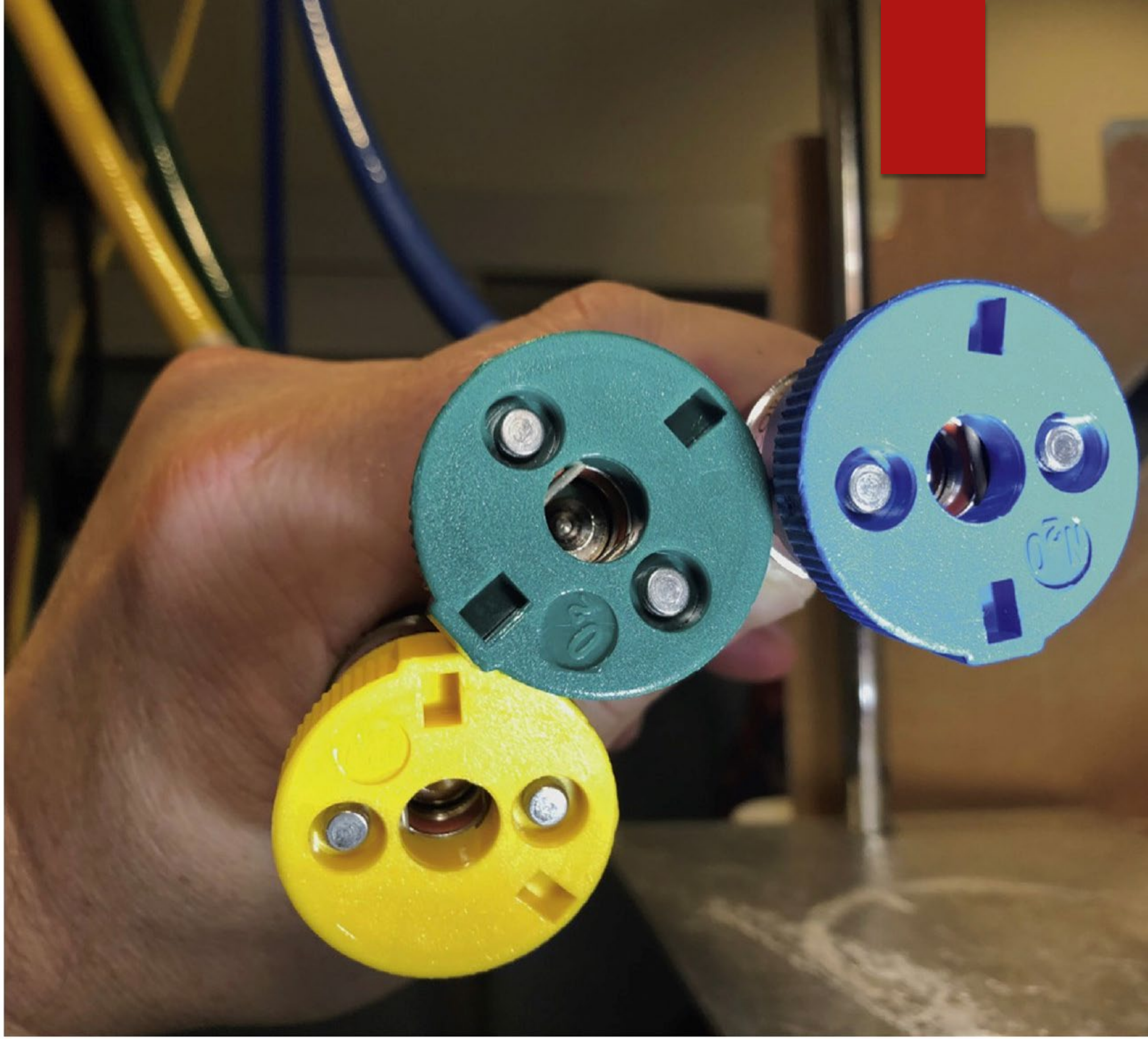
Secondary-Stage Pressure Regulators

- Supply constants pressure to the flow control valves and the proportioning system regardless of potential fluctuations in hospital pipeline pressures
- Adjusted to low pressure levels than pipeline supply
  - 26 psig for N_2O
  - 14 psig for O_2



Safety Features

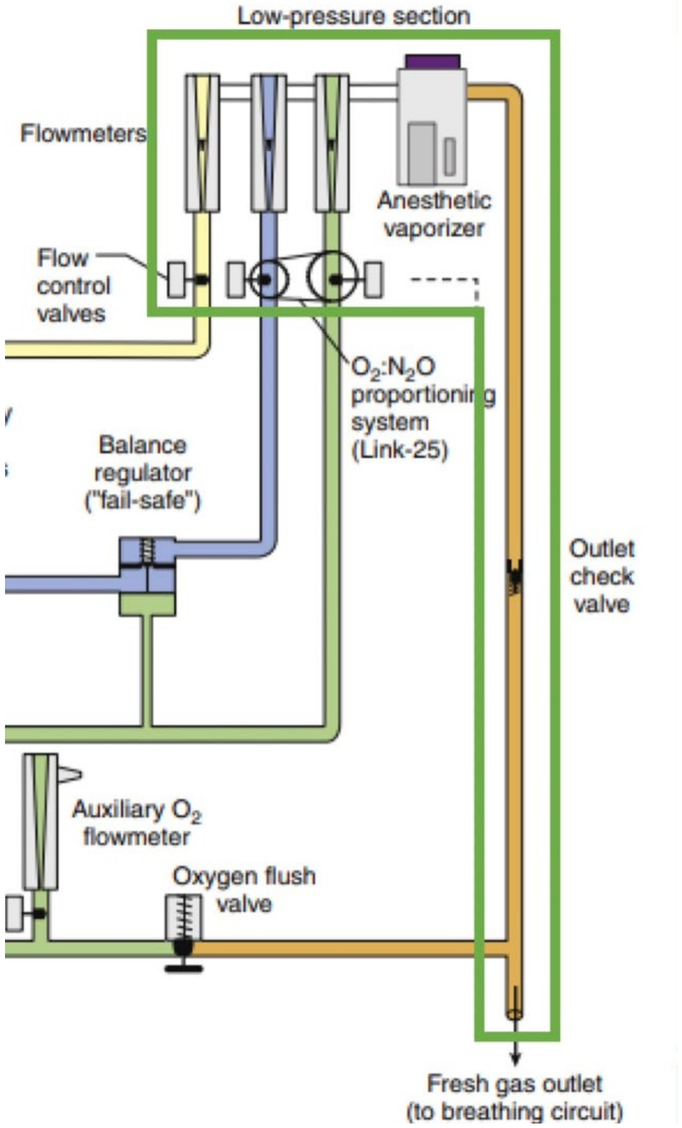
- Pipeline : DISS
- Low oxygen pressure sensor : alarm
- Oxygen pressure failure: Prevent a hypoxic mixture
- Secondary stage pressure regulars : Adjusted to low pressure level



Low-Pressure Section

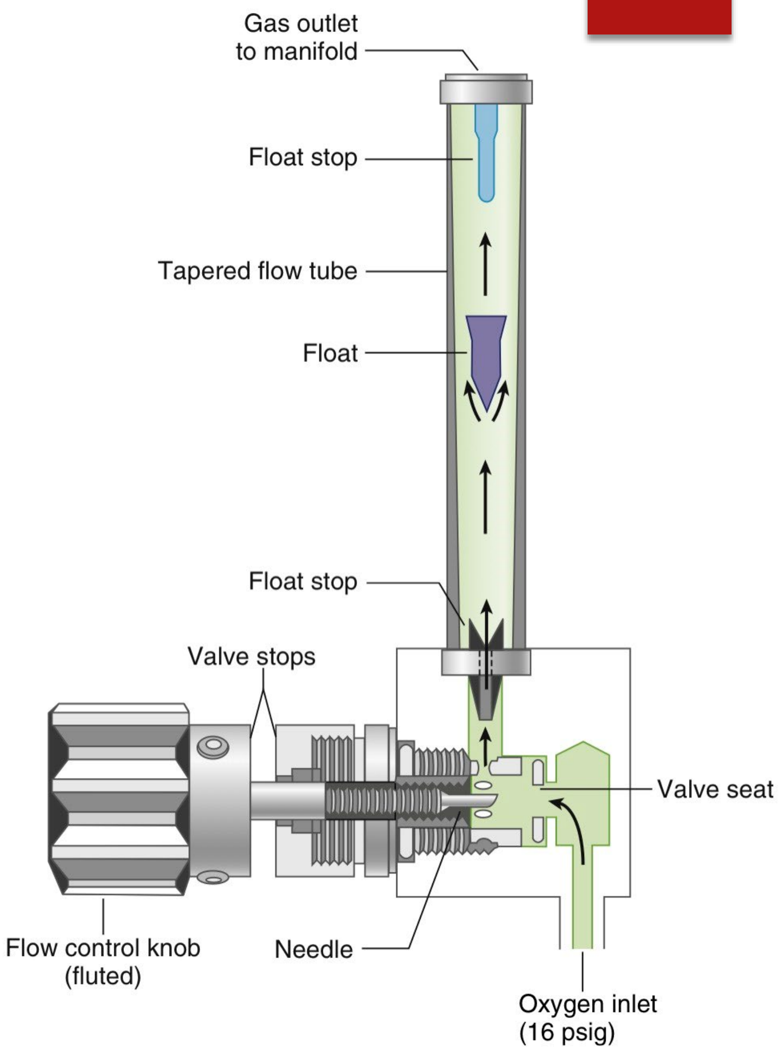
Low-Pressure Section

- Extends from the flow control valves to the common gas outlet
- Consists of :
  - Flow meters
  - Proportioning systems
  - Anesthetic vaporizer
  - Check valve
  - Common gas outlet

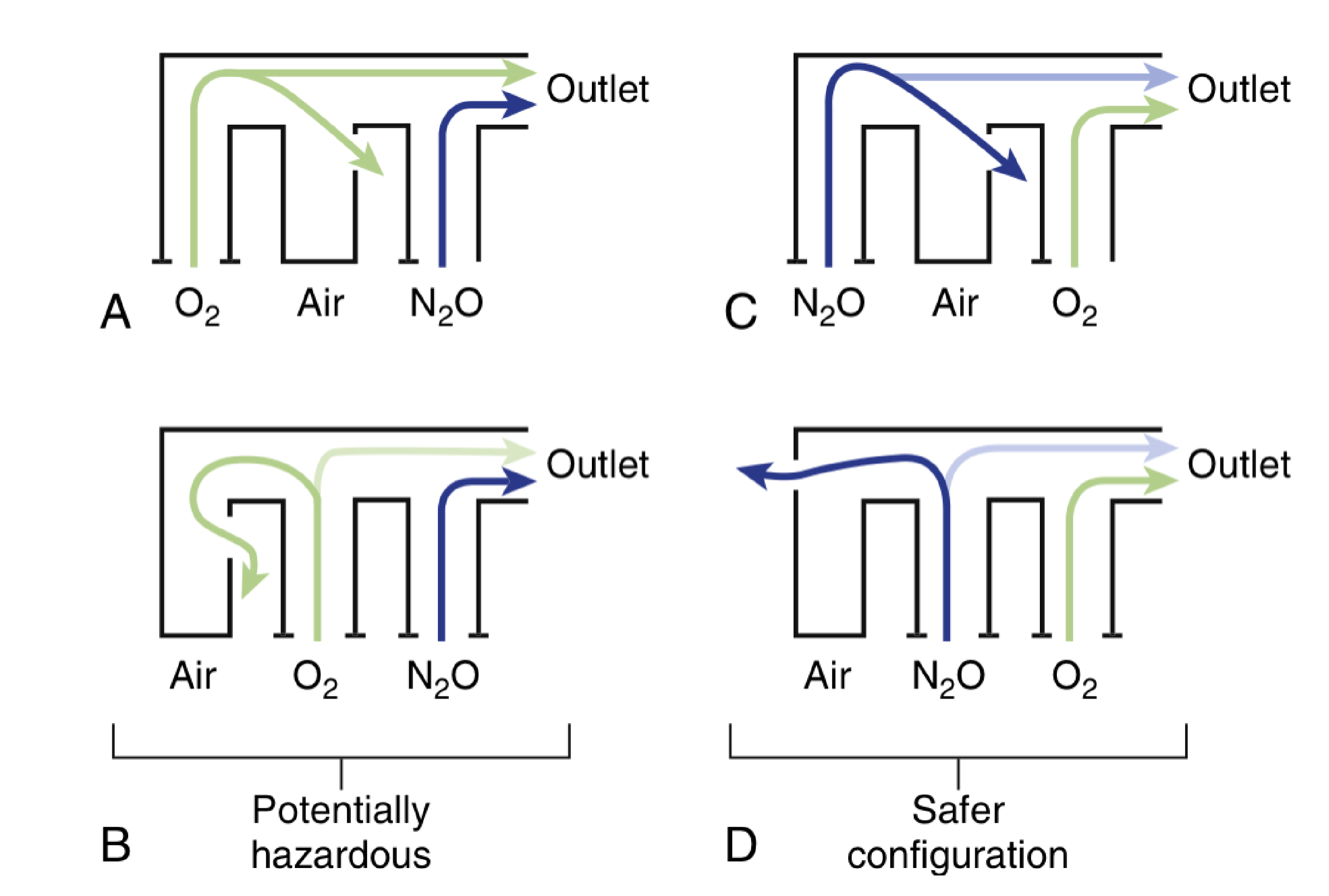


Flow meter

- Gas flow increases when the flow control valve is turned counterclockwise , and it decreases when the valve is turned clockwise
- All knobs are color coded for the appropriated gas
- Problems
  - Leak, Inaccuracy and Ambiguous scale



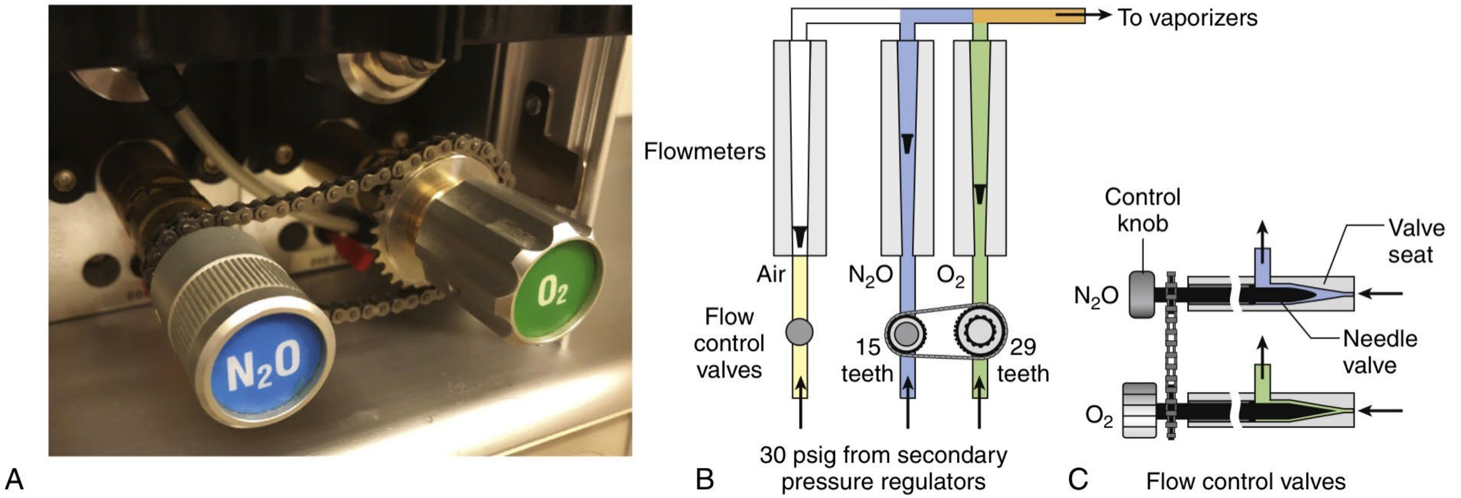
Flow meter



Outlet
A
O2
Air
N2O
Outlet
C
N2O
Air
O2
Outlet
Air
O2
N2O
Outlet
Air
N2O
O2
B
Potentially
hazardous
D
Safer
configuration

Proportioning Systems

- Prevent hypoxic mixture for delivery to the fresh gas outlet
- Maintain a minimum 25% concentration of oxygen with a maximum N_2O : O_2 ratio of 3: 1
- Limitations
  - Wrong supply gas
  - Defective pneumatics or mechanics
  - Leak downsteam
  - Inert gas administration



Anesthetic Vaporizers

Anesthetic Vaporizers

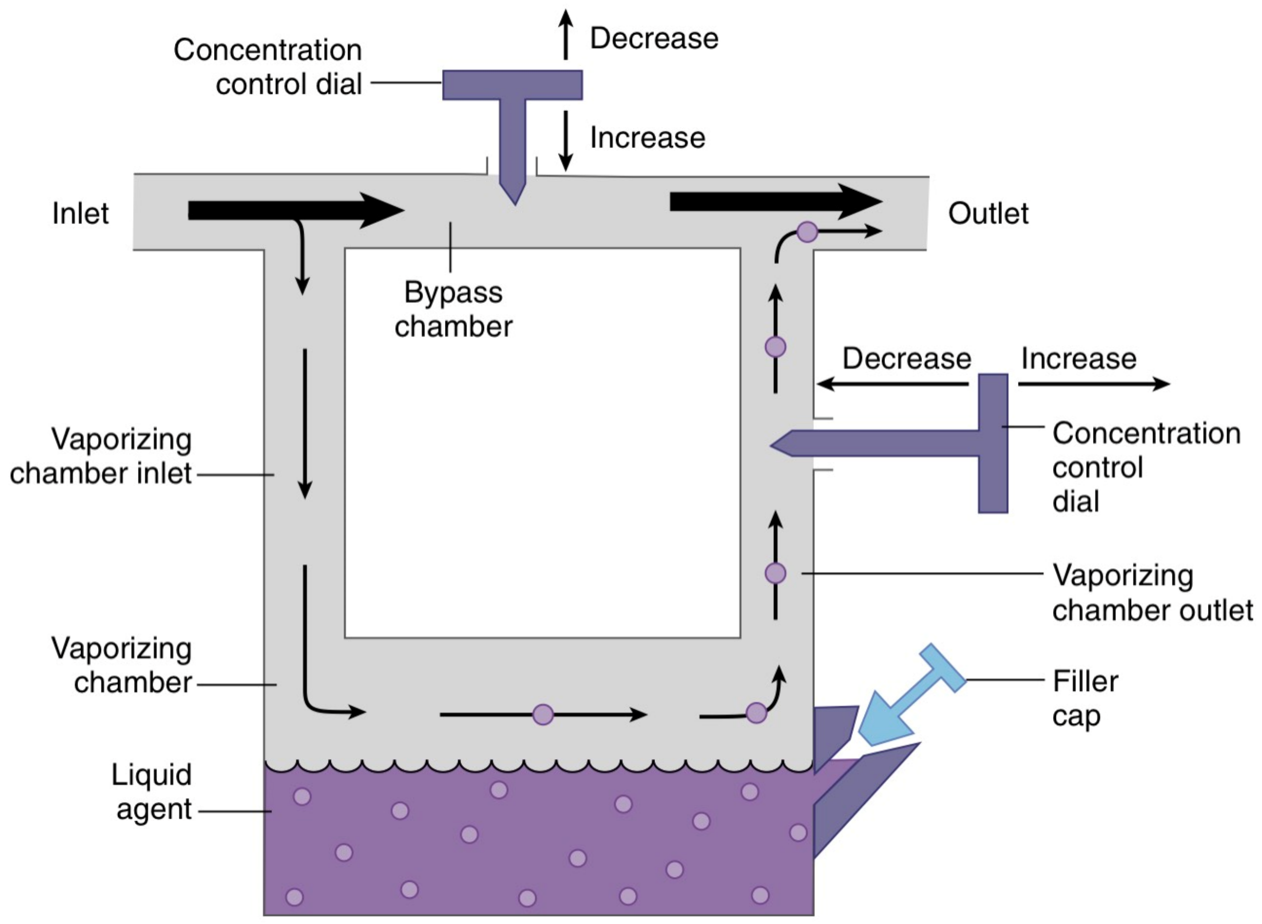
- Anesthetic vaporizer is a device that change the anesthetic liquid to the anesthetic gas

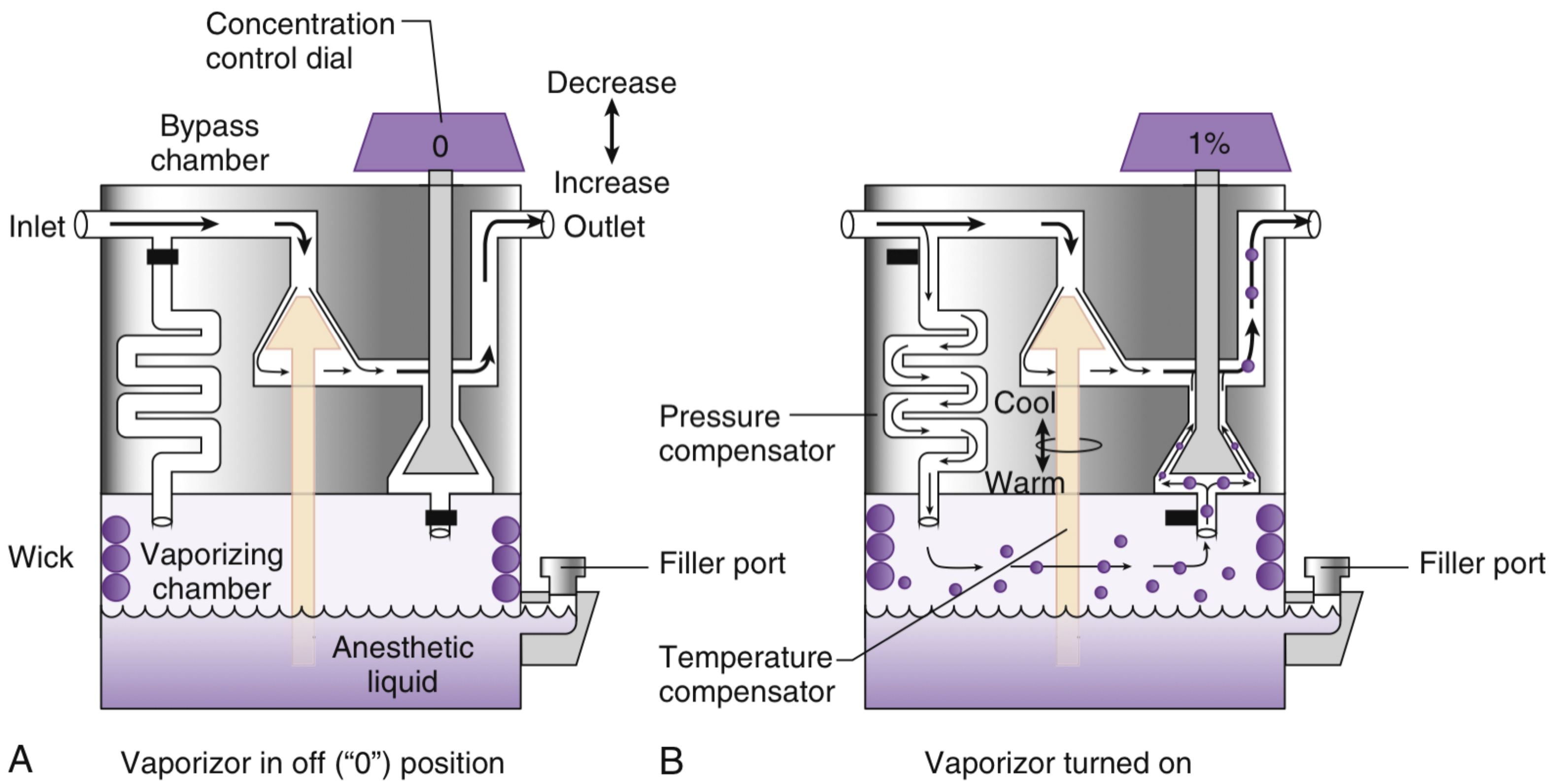
Anesthetic Vaporizers :Type

Method	Type
Vaporization	Flow over with wick
	Flow-over without wick
	Bubble-through
Regulating output concentration	Measured flow vaporizer e.g. copper kettle vaporizer
	Variable bypass vaporizer e.g. Tec 6,Tec Z vaporizer
	Direct injection of volatile anesthetic(DIVA) vaporizer e.g. Aladin 2 cassette vaporizer
Temperature	Variable temperature
	Fix temperature(heat supply vaporizer) e.g. Desflurane vaporizer

Variable bypass vaporizers

- diluting gas fully saturated with anesthetic agent with a more voluminous flow of gas

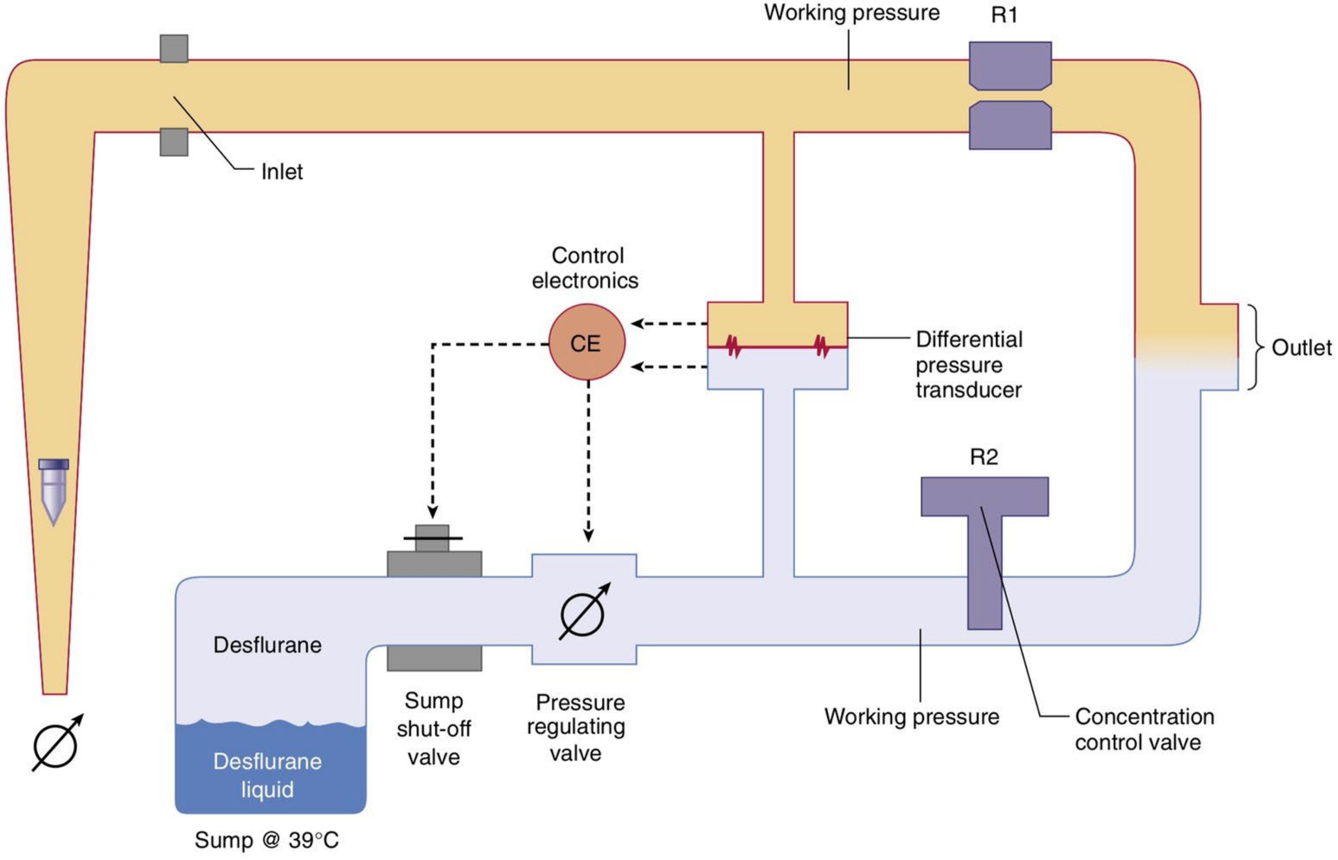




Variable Bypass Vaporizers

Desflurane Vaporizer

- Desflurane is more likely to boil : boiling point 22 °C at 1 atm
- dual-gas blender
- Desflurane sump
  - electrically heated to 39°C at ~2 atm
- Pressure-regulating valve
  - regulates the pressure to the pressure of the background gas
  - controls the output of desflurane by adjusting the concentration control valve, which is a variable restrictor



The Datex-Ohmeda Tec 6 vaporizer

Desflurane Vaporizer

- "SAF-T-FILL" adapter intended to prevent use with traditional vaporizers

Factor that influence vaporizer output

- Impact of carrier gas composition
  - Change in carrier gas from 100% oxygen to 100%N_2O result in decreasing volatile output

Impact of Tipping/overfilling

- Excessive tipping can allow the liquid agent to enter bypass chamber and cause an extremely high output

Factor that influence vaporizer output

- Impact of gas flow rate

- At low flow rates (<250 ml/min) : slightly less than the dial setting
- At high flow rates(such as 15 L/min) : slightly less than the dial setting

Anesthetic Breathing Circuit

Anesthetic Breathing Circuit

- Interposed between the anesthetic machine to the patient
- Function "Deliver oxygen and other gases to the patient and to eliminate CO_2"
- Classification
  - Open/Closed circuit
    - Open
    - Semiopen
    - Closed
    - Semiclosed
  - CO2 Absorber
    - CO_2 absorber : circle system
    - Non-CO_2 absorber : Mapleson System

Breathing Systems

Mode	Reservoir	Rebreathing	Venting waste gas	Example
Open	No	No	more	Ether or chloroform
Semi-open	Yes	No	more	Nonrebreathing circuit or circle at high FGF(>VE)
Semi-closed	Yes	Yes, partial	some	Circle at low FGF(<VE)
Closed	Yes	Yes, complete	No	Circle(if APL valve closed)

Open System

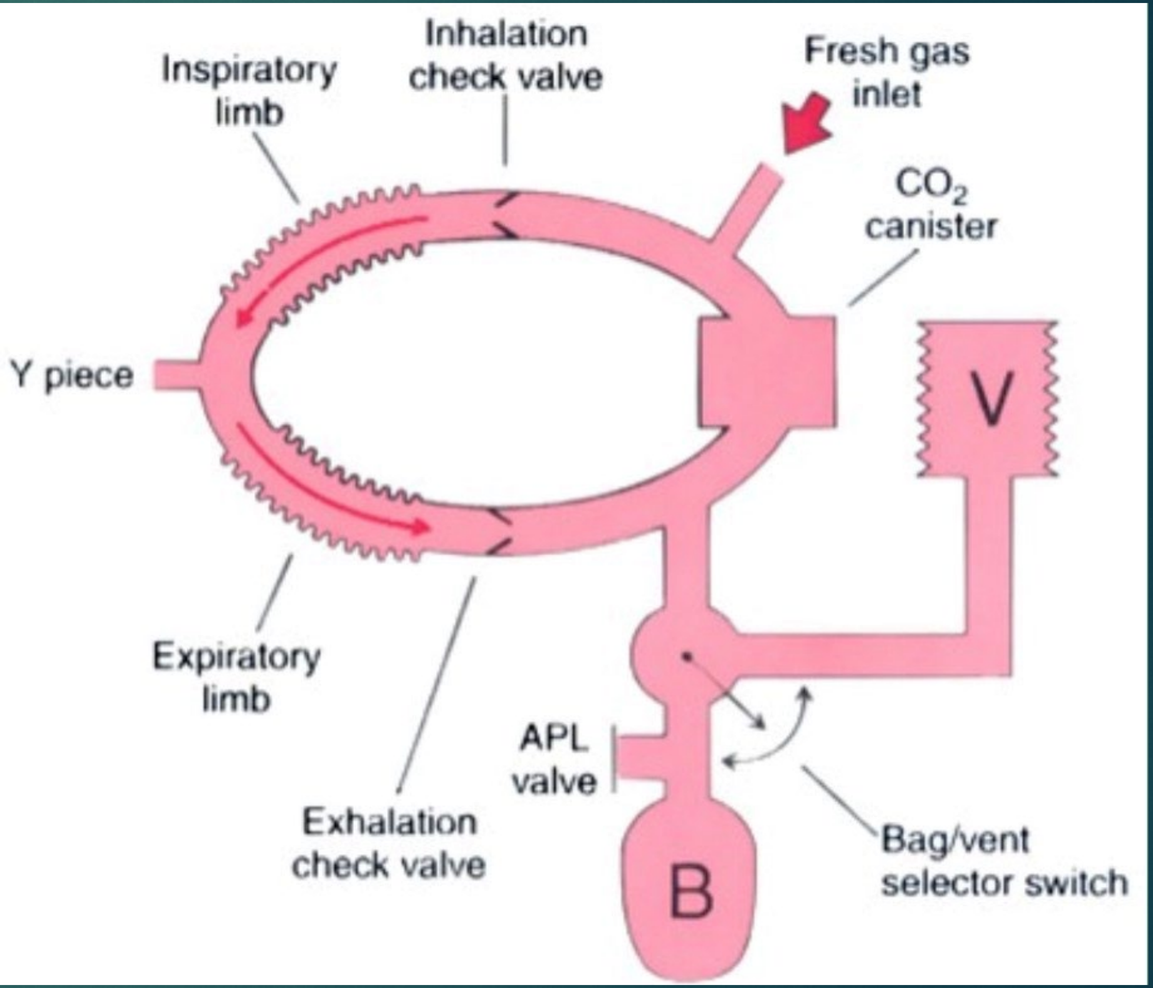
- Open Drop : Ether or Chloroform
- No reservoir
- No rebreathing

Semiopen System

- Reservoir bag
- High fresh gas flow rate
- No rebreathing
- More venting waste gas
- A Mapleson circuit or a circle at high fresh gas flow (FGF)

Semiclosed System

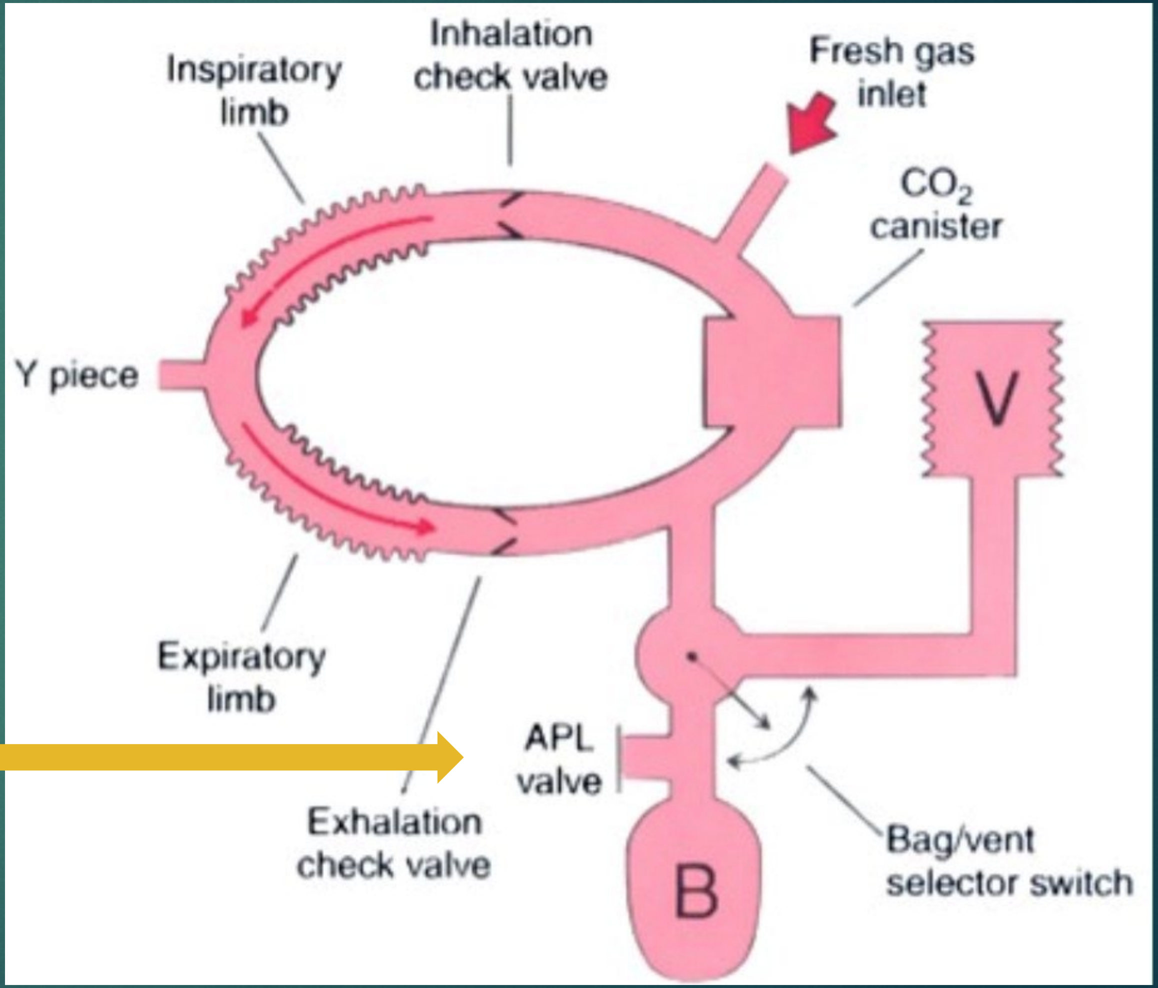
- Contemporary circle system
- Some rebreathing occur
- Some waste flow is vented
- Low-flow anesthesia
- FGF < minute ventilation



Closed System

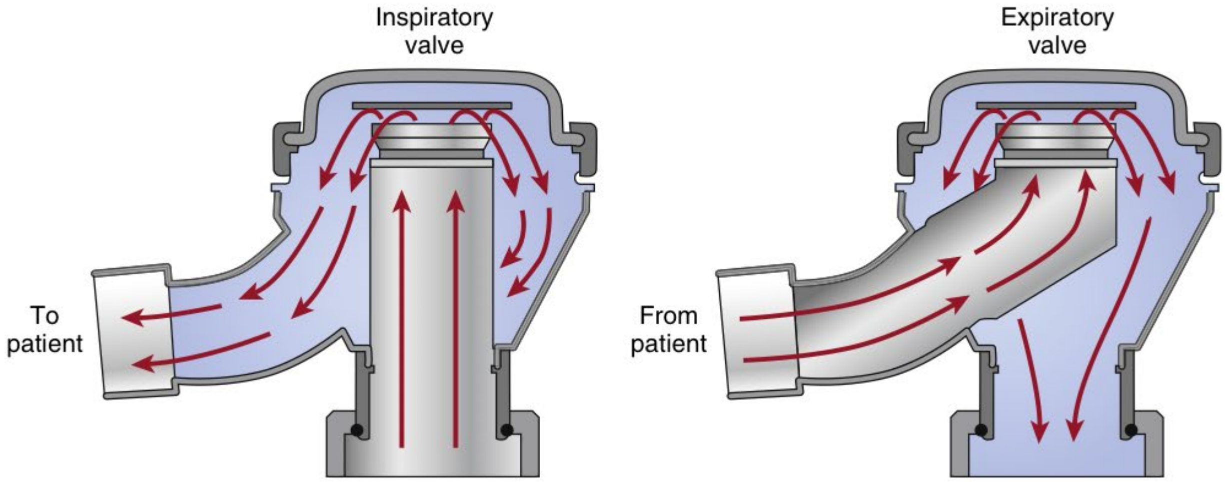
- Oxygen inflow = metabolic demand
- Rebreathing is complete
- No waste gas is vented
- Pop-off (APLvalve) closed

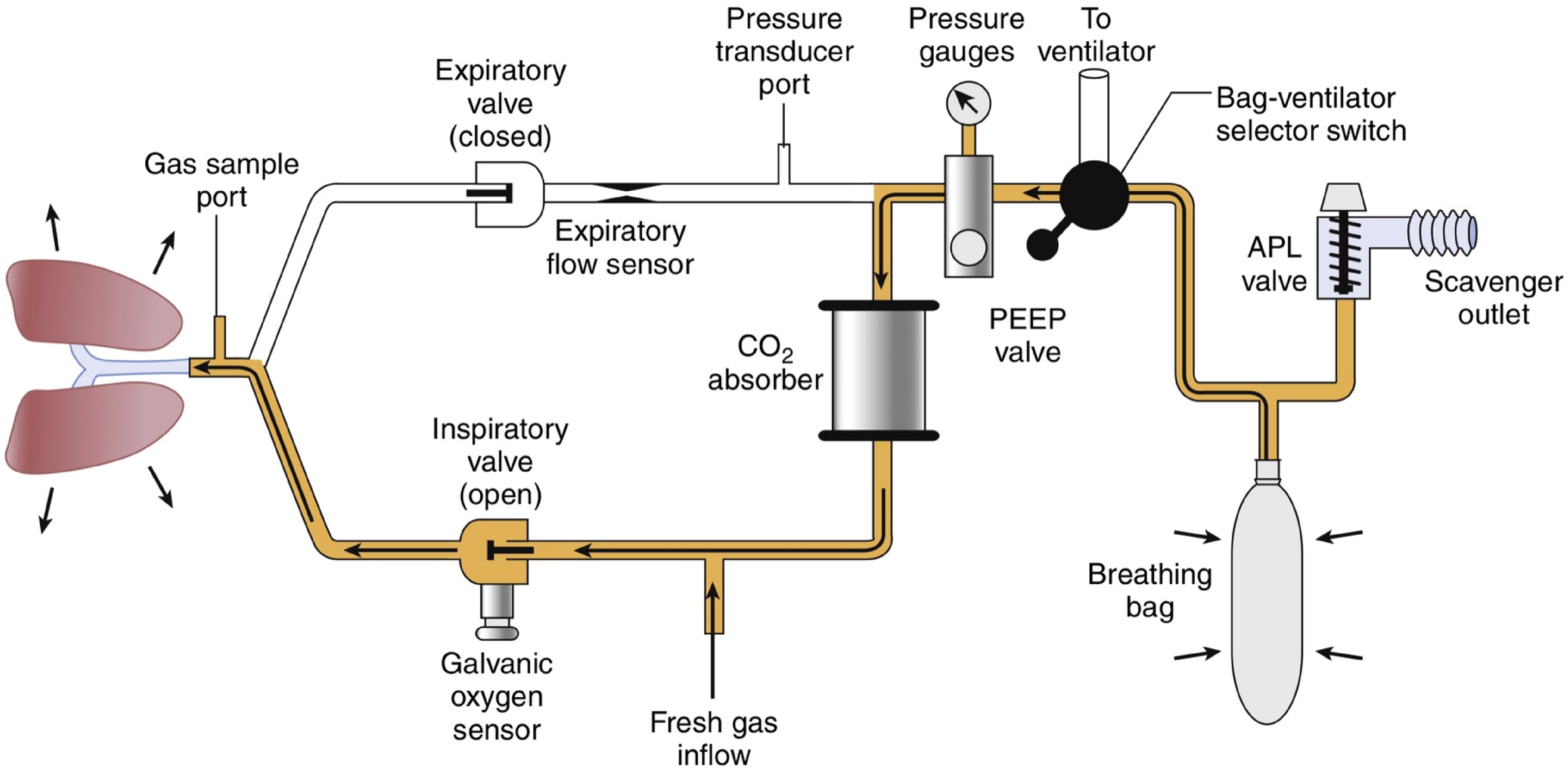
APL valve
Closed



Circle Breathing Systems

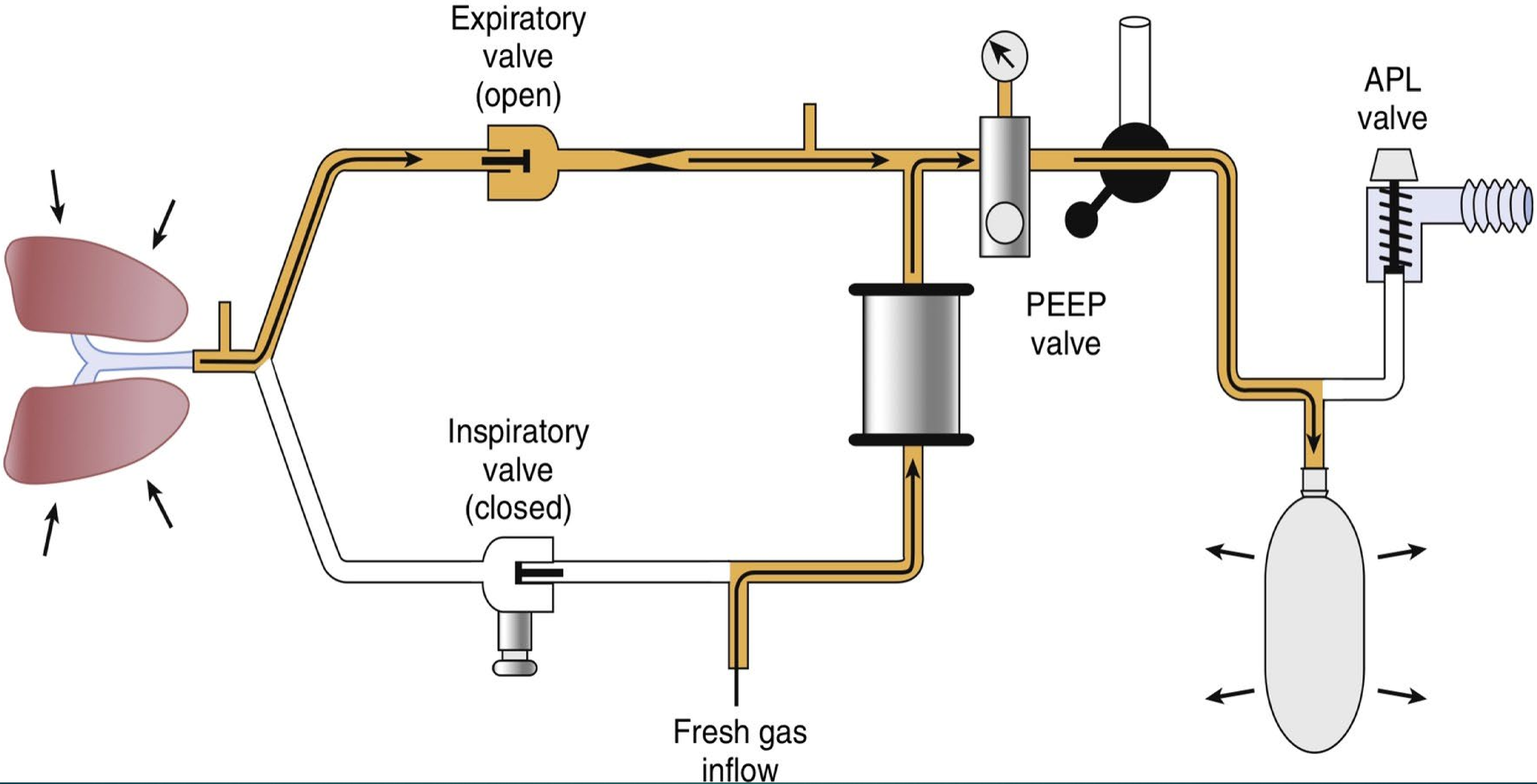
- Circular and unidirectional flow of gas facilitated by one-way valves





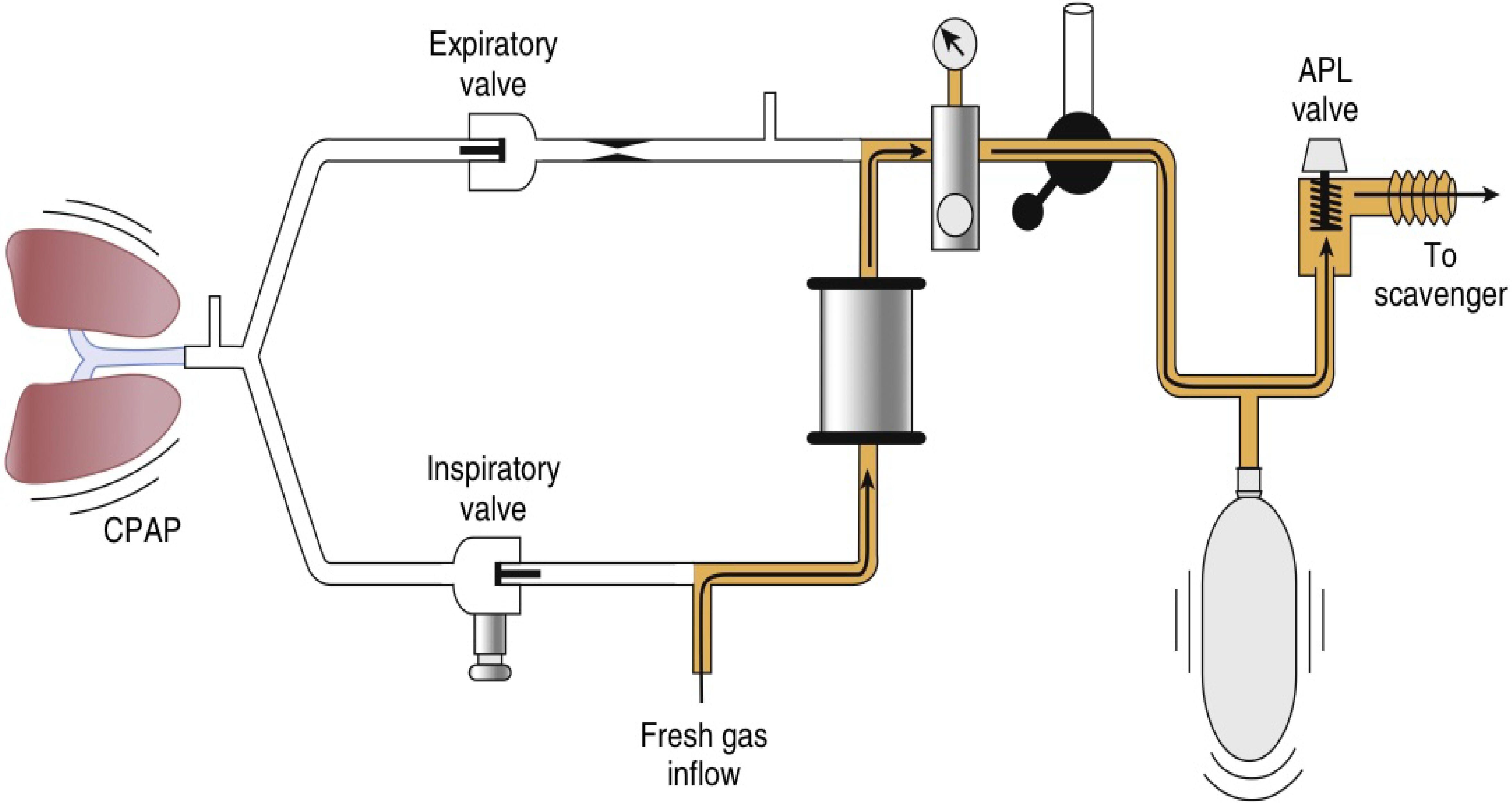
Circle Breathing Systems

Spontaneous breathing : early inspiratory phase



Circle Breathing Systems

Spontaneous breathing : early-expiratory phase



Circle Breathing Systems

Spontaneous breathing : end-expiratory phase with continuous positive airway pressure(CPAP)

Circle Breathing Systems

Advantages	Disadvantages
Stable inspired gas concentration	Complex design
Conserve respiratory heat and moisture	Risk misconnection ,disconnection, obstructions, and leaks
Elimination CO_2	Anesthetic degradation
Prevention of OR pollution	

CO_2 Absorber

CO_2 Absorber

- CO_2 removal from the exhaled gases
- Avoid rebreathing and hypercapnia
- Ideal CO_2 absorbent
  - Lack of reactivity with common anesthetic
  - Absence of toxicity, low cost, minimal dust production
  - Low resistance to airflow
  - Container easy to remove and replace

Absorber Canister

- Visible to the operator
- Transparent to monitor for absorbent presence color
- Single or two clear plastic canister
- Modern (single canister, allow replaced during anesthesia)

Chemistry of Absorbents

- Soda lime (most commonly used)
  - Contain : 80% [Ca(OH)2] " *slaked lime*", water and strong base

TABLE 22.8 Carbon Dioxide Absorber Comparisons

Absorbent (Reference)	$Ca(OH)_2$ (%)	LiOH (%)	H_2O (%)	NaOH (%)	KOH (%)	Other (%)
Classic soda lime (165)	80	0	16	3	2	–
Baralyme (164)*	73	0	11-16	0.0	5	11 $Ba(OH)_2$
Sodasorb (161)*	76.5	0	18.9	2.25	2.25	–
Dragersorb 800 Plus (162, 166)*	82	0	16	2	0.003	–
Medisorb (166)*	81	0	18	1-2	0.003	–
New soda lime*	73	0	<19	<4	0	–
Sodasorb LF (163)	>80	0	15-17	<1	0	–
Dragersorb Free (161, 164)	74-82	0	14-18	0.5-2	0	3-5 $CaCl_2$
Sofnolime*	>75	0	12-19	<3	0	–
Amsorb Plus (161, 165)	>75	0	14.5	0	0	<1 $CaCl_2$ and $CaSO_4$
Litholyme*	>75	0	12-19	0	0	<3 LiCl
SpiraLith*	0	≈95	0†	0	0	≤5 PE

Sodalime

Carbon Dioxide Reaction With Soda Lime

Net Reaction

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O + heat$$

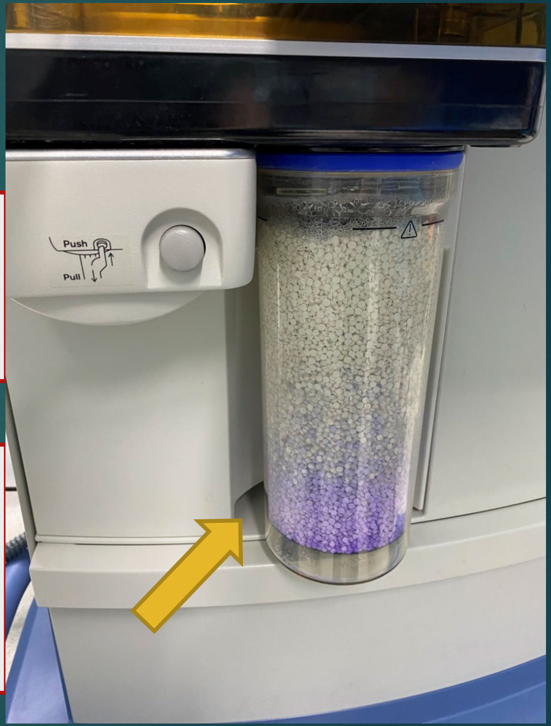
Sequential Reactions

1. $CO_{2\ (gas)} + H_2O_{\ (liquid)} \rightleftharpoons H_2CO_{3\ (aqueous)}$
2. $H_2CO_3 + 2NaOH$ (or KOH) $\rightarrow Na_2CO_3$ (or K_2CO_3) + $2H_2O$ + heat
3. Na_2CO_3 (or K_2CO_3) + $Ca(OH)_2 \rightarrow CaCO_3 + 2NaOH$* (or KOH*) + heat

Indicators

Conventional absorbent >> indicator dye "*ethyl violet*"

- Fresh absorbent : PH > 10.3 dye is colorless
- Exhausted : PH < 10.3 dye become purple



Ethyl violet may not always reliable

- Prolong exposure of fluorescent light : photo deactivate dye
- Purple back to white [strongly alkaline of NaOH]
- Back to white on Monday morning

Interaction with Inhaled Anesthetic

- Formation : harmful degradation product
- Volatile agents interact with strong base [KOH & NaOH]
- *Today main degradation product concern*
  - *Compound A with sevoflurane*
  - *CO with desflurane, enflurane, and isoflurane*

Compound A

- Nephrotoxic to rats
- Transient albuminuria and glucosuria
- Should not exceed 2 MAC-hours at flow rate between 1-2 L/min (flow < 1L/min are not recommended)
- Several factors may predispose to higher concentration of compound A
  - Low-flow or closed-circuit
  - Higher concentrations of sevoflurane
  - Type of absorbent (KOH or NaOH-containing)
  - Higher absorbent temperatures
  - Fresh absorbent

Compound A

- Strong base cause degradation product (KOH > NaOH)
  - Classic soda lime and Baralyme (withdrawn from market)

Absorbent (Reference)	$Ca(OH)_2$ (%)	LiOH (%)	H_2O (%)	NaOH (%)	KOH (%)	Other (%)
Classic soda lime (165)	80	0	16	3	2	–
Baralyme (164)*	73	0	11-16	0.0	5	11 $Ba(OH)_2$

- LiOH and newer Ca(OH)2 [Free of KOH and NaOH]
  - Generate zero of compound A

Amsorb Plus (161, 165)	>75	0	14.5	0	0	<1 $CaCl_2$ and $CaSO_4$
Litholyme*	>75	0	12-19	0	0	<3 LiCl
SpiraLith*	0	≈95	0†	0	0	≤5 PE

Carbon monoxide

- Factors that increase production CO and risk of carboxyhemoglobinemia
  - Inhaled anesthetic *(D > E > I)*
  - Degree of desiccation of the absorbent
  - Type of absorbent [KOH or NaOH-containing]
  - Higher temperature
  - Higher concentrations of anesthetic
  - Low fresh gas flow rate

Anesthesia Ventilator

Classification

- **Type of reservoir**
  - Bellows, piston or volume reflector
- **The drive mechanism of the reservoir**
  - Pneumatic or mechanical

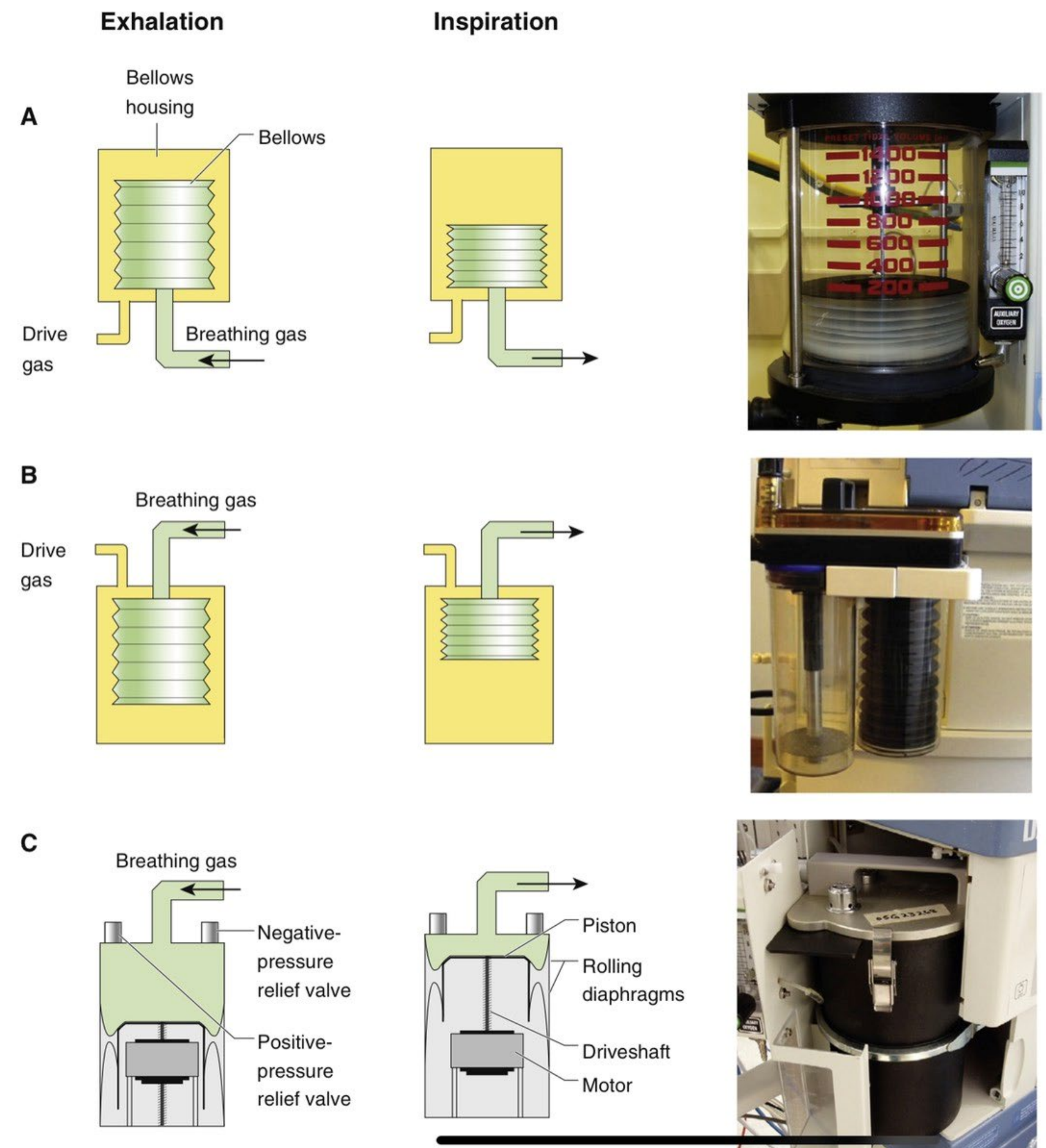
Classification

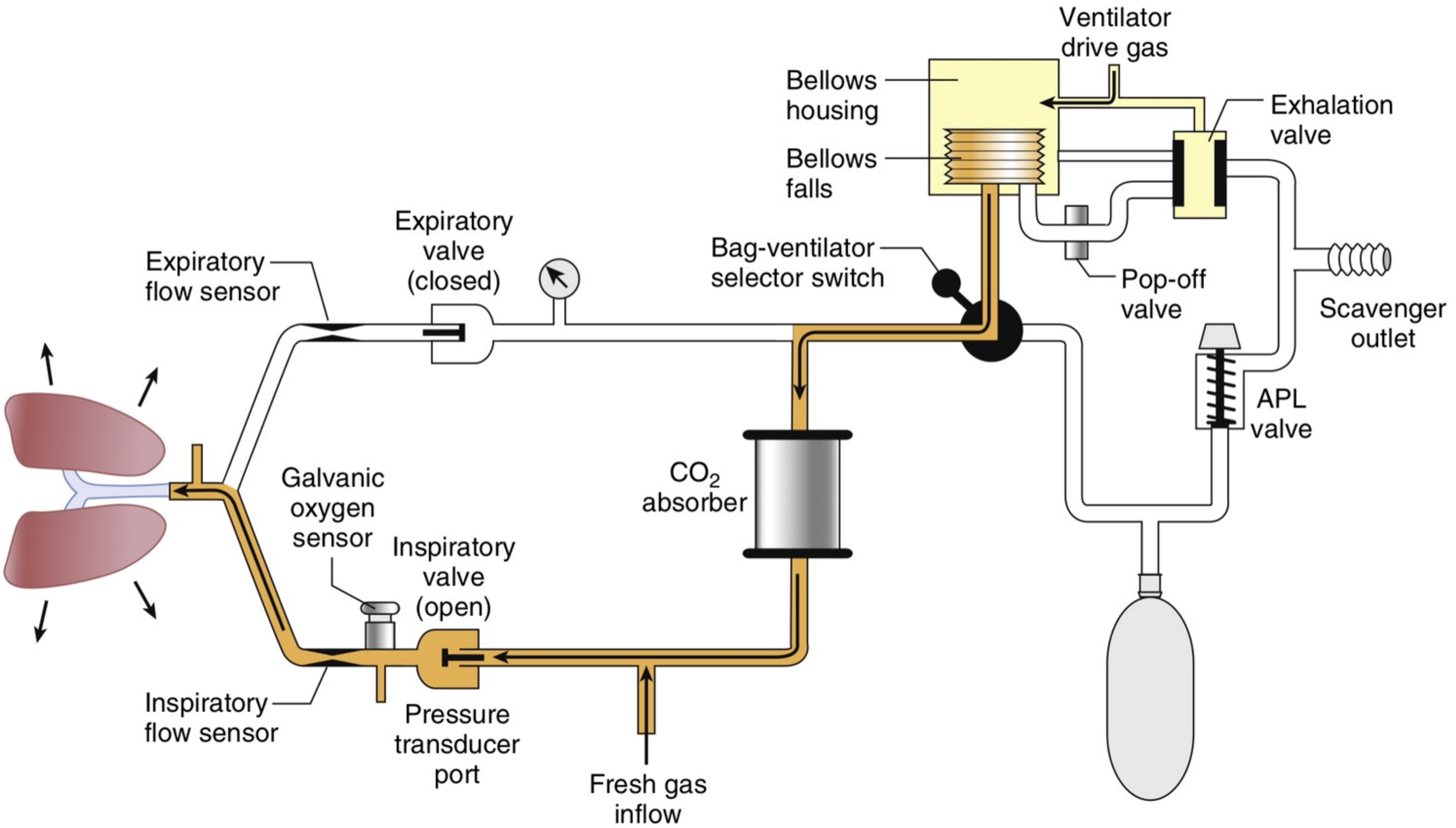
- Bellows-type
  - pneumatically driven
- Piston-type
  - Mechanically driven

Descending Bellow

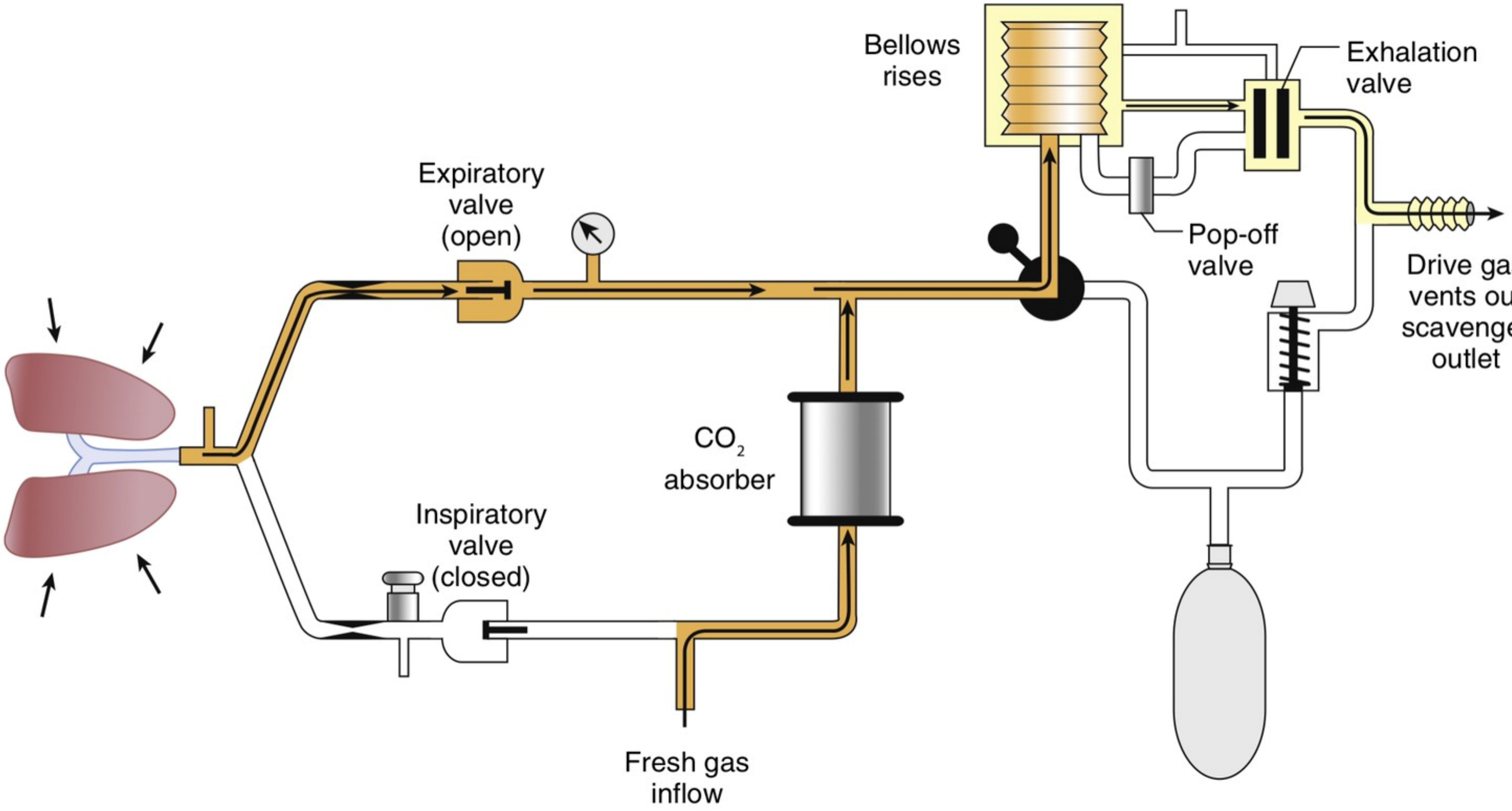
Ascending Bellow

Piston





Inspiratory phases of ventilation with an ascending bellows ventilator represented by GE Aisys anesthesia workstation

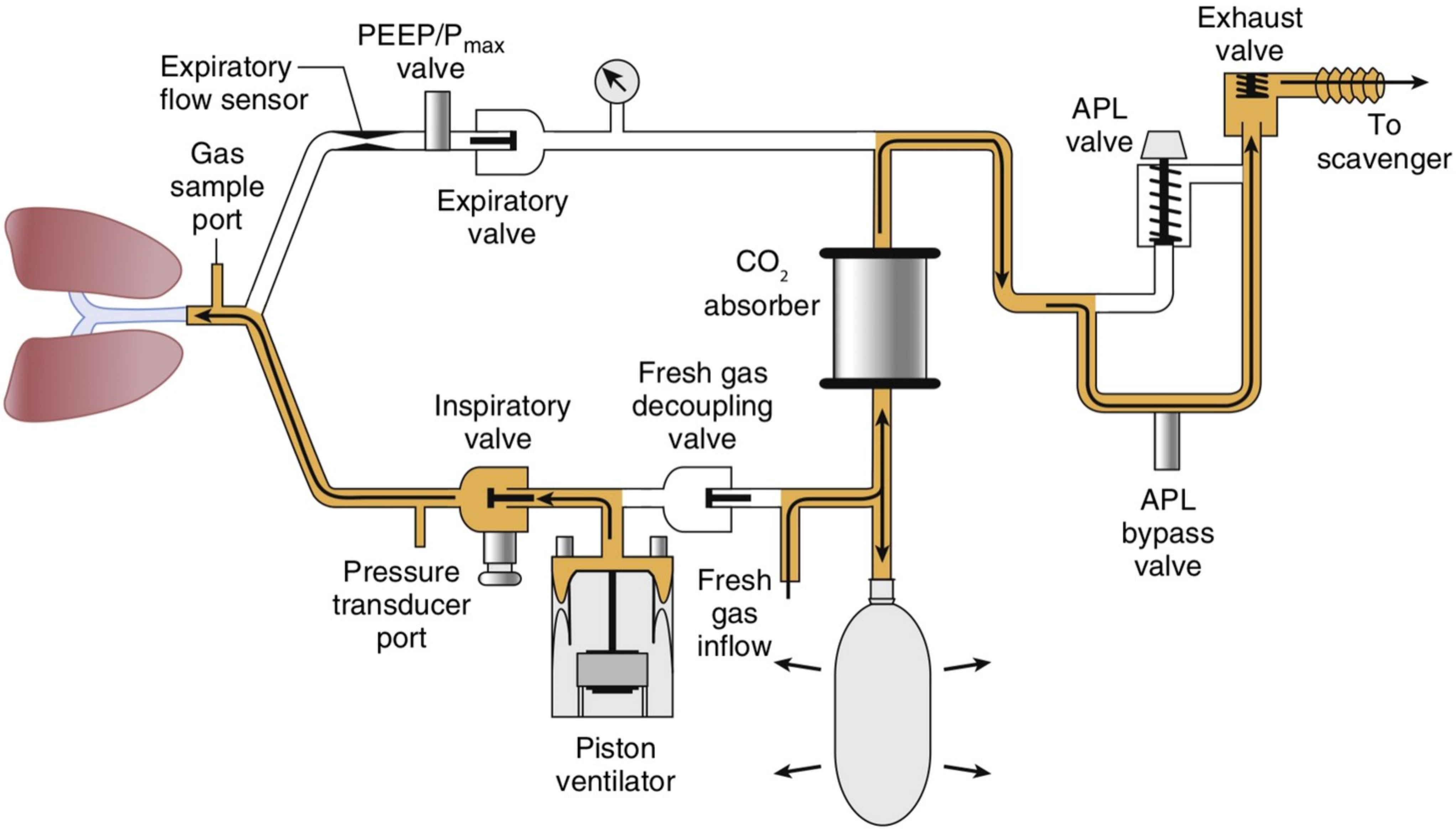


Expiratory phases of ventilation with an ascending bellows ventilator represented by GE Aisys anesthesia workstation

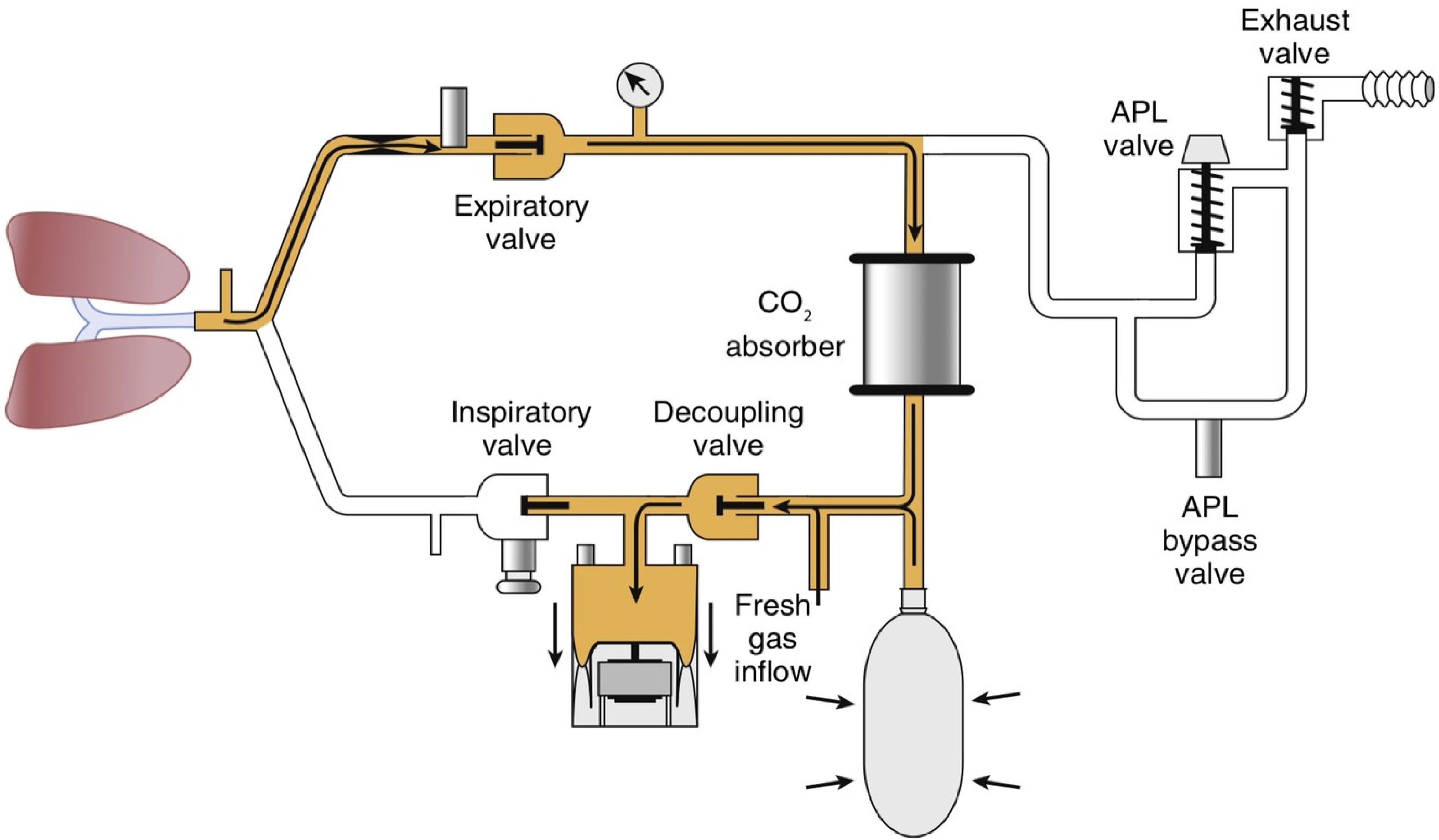
Ascending VS Descending Bellows

- The ascending bellows is safer
  - Will not fill it total disconnection occurs, or it may only partially fill a circuit leak exceeds the fresh gas flow rate
  - Important visual cue for a circuit disconnect or leak

- The descending bellows will continue its regular upward and downward movement despite patient disconnection
  - Go unrecognized



Inspiratory phases of ventilation with a piston ventilator represented by Drager Fabius anesthesia workstation



Expiratory phases of ventilation with an piston ventilator represented by Drager Fabius anesthesia workstation

Advantages of Piston Ventilators

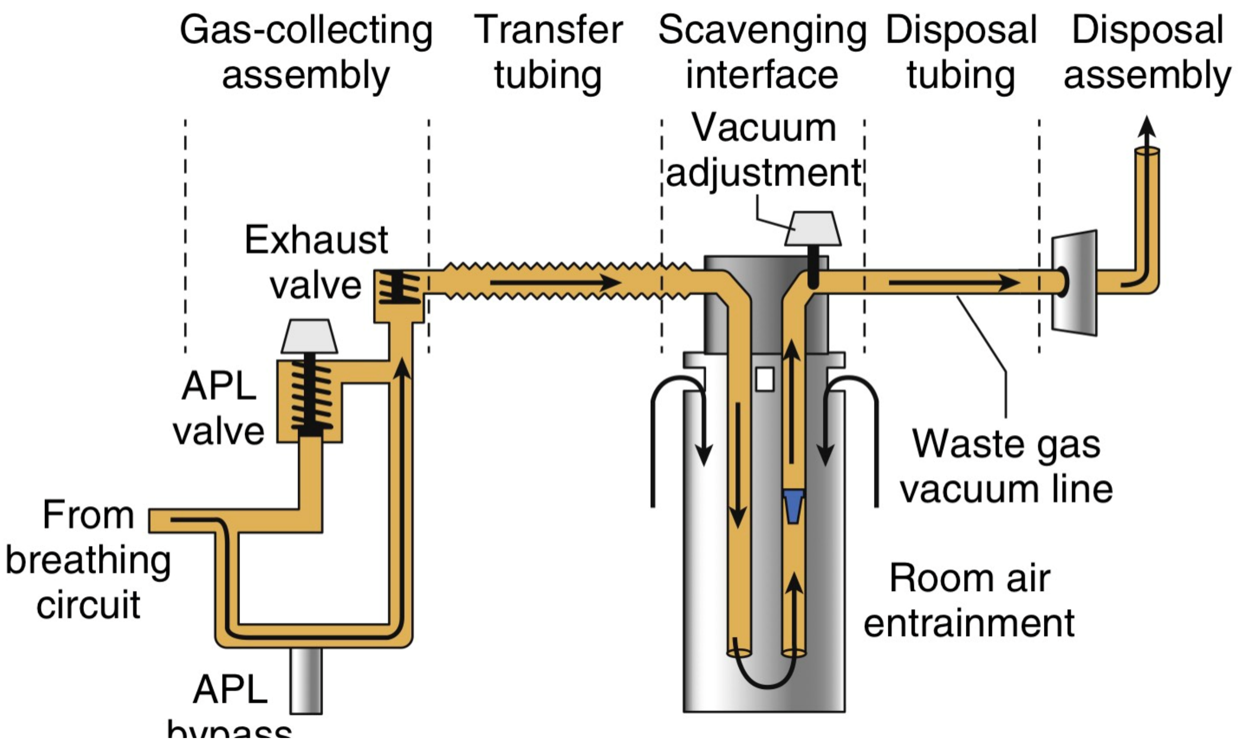
- Greater precision of tidal volume delivery due to rigid piston design, decreased compliance losses
- Greater precision of pressure control with use of pressure sensors
- Electrical control instead of pneumatic control
- No intrinsic PEEP
- Quiet

Scavenging System

Classification

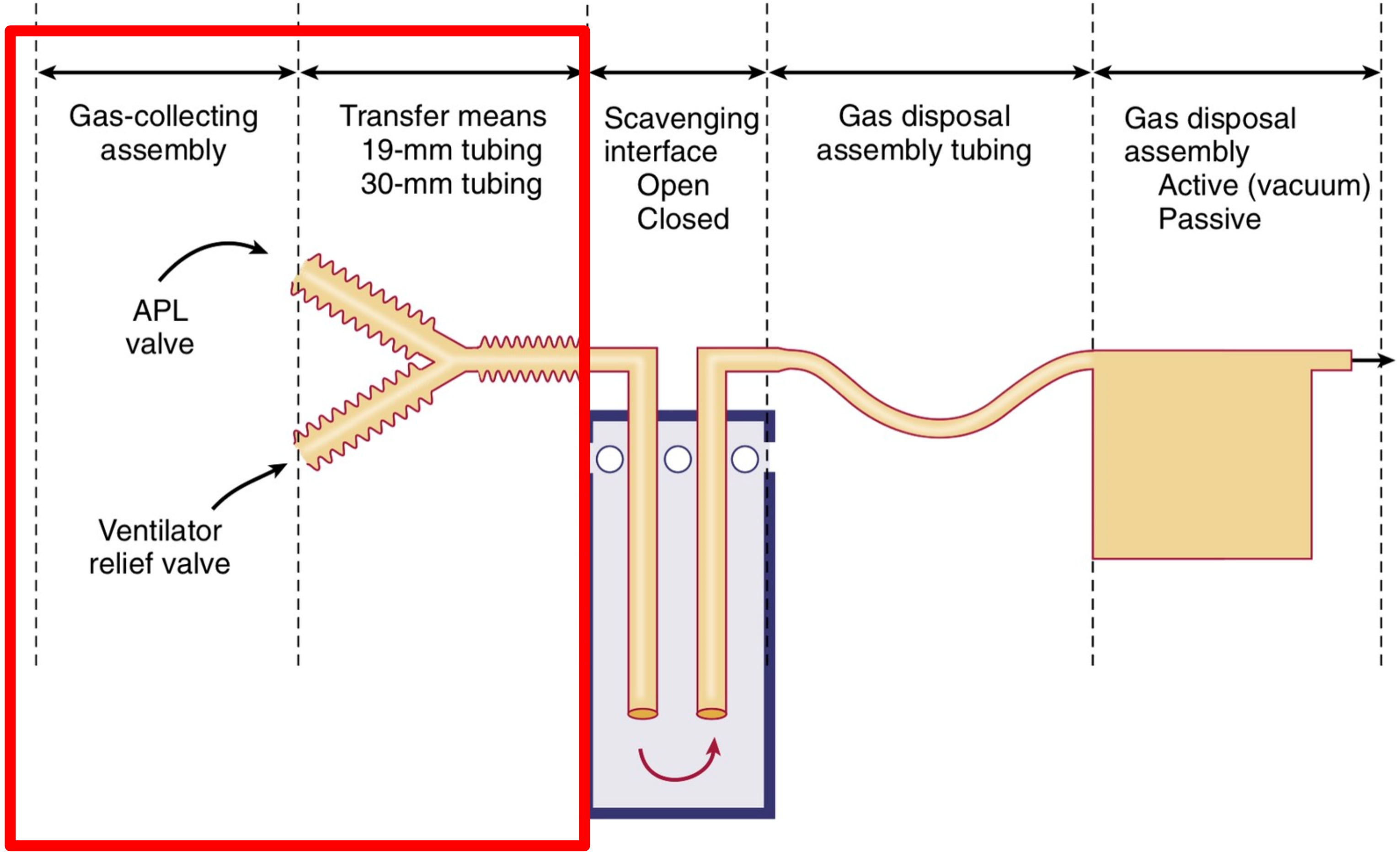
Active systems	• Connected to a vacuum source : hospital suction system
Passive systems	• Simply vent the waste gas into a heating, ventilation and air conditioning (HVAC) system or through a hose to the building through a wall or ceiling

Components


Gas-collecting assembly
Transfer tubing
Scavenging interface
Disposal tubing
Disposal assembly
Vacuum adjustment
Exhaust valve
APL valve
From breathing circuit
APL
Waste gas vacuum line
Room air entrainment

Gas-collecting Assembly + transfer Tubing

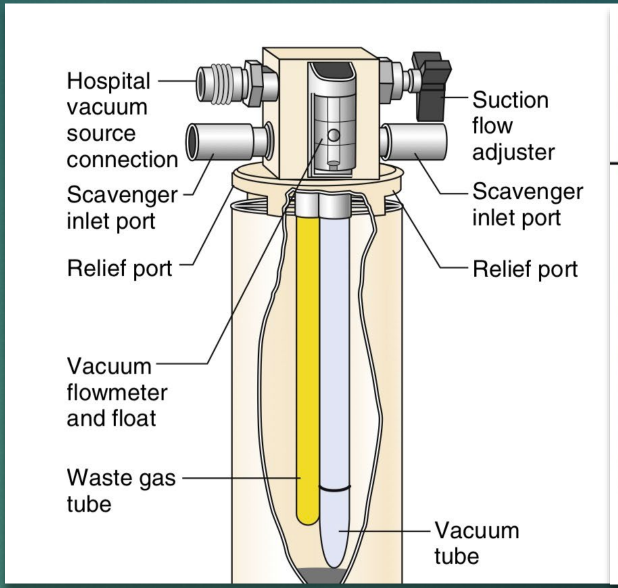
- Gas exit from breathing circuit Through APL valve and ventilator relief valve
- 19 or 30 mm
- Short, rigid enough
- Not touch the floor
- Look different from breathing system tubing(22mm)
  - Some manufacturers color-code

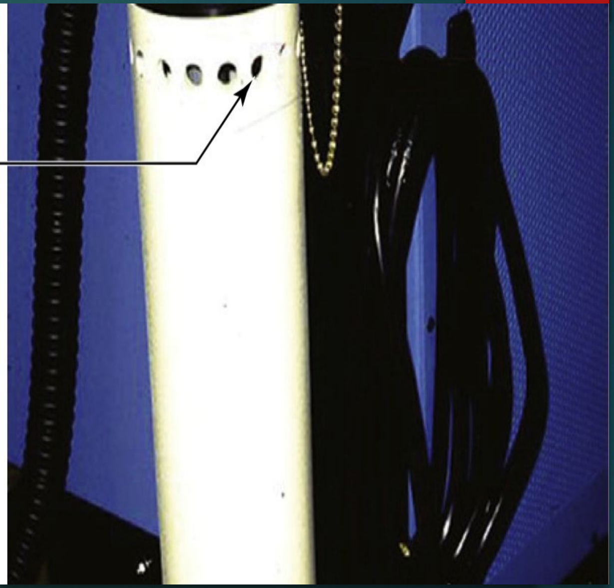


Scavenging Interfaces

- Protect the breathing circuit or ventilator from excess positive or negative pressure
- Classification
  - Open scavenging interfaces
  - Closed scavenging interfaces

Open Scavenging Interfaces

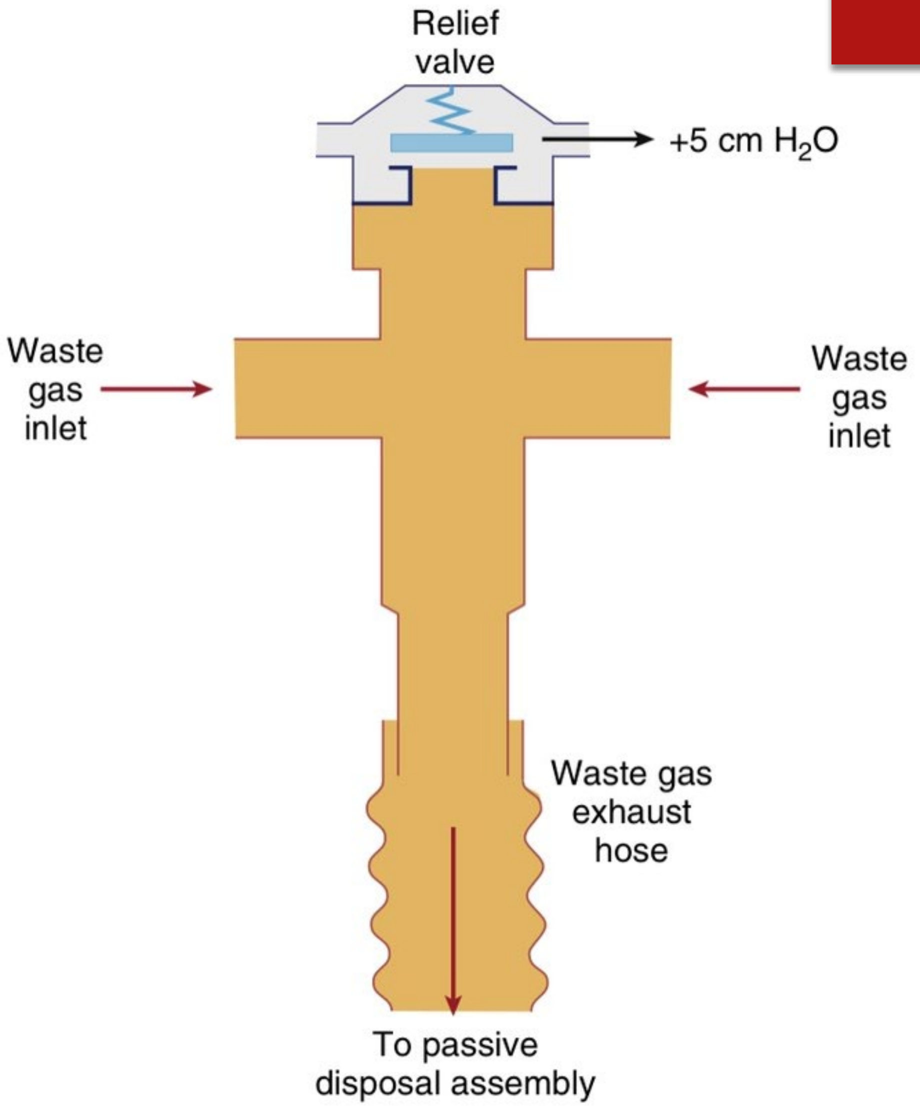




- Require active disposal system
- Require a reservoir canister
- Open to the room
- Balance gas in and out (keep bobbing position)
- No positive or negative-pressure relief valves because the canister is open to the atmosphere
- Relief port provide positive and negative pressure relief

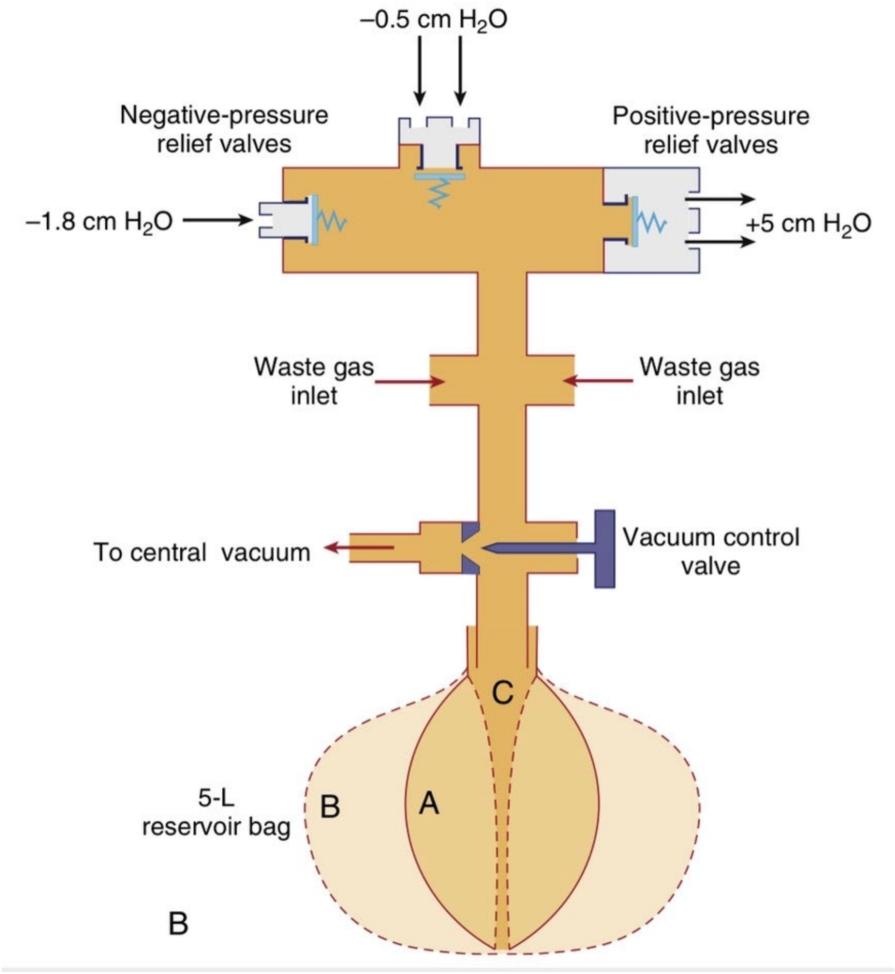
Closed Scavenging Interfaces

- Interface used with a passive disposal system
  - A hose the divert out of the room
  - Positive pressure relief valve
  - Rigid enough(10kg/cm^2)
  - Large diameter
  - Reservoir bag is optional



Closed Scavenging Interface

- Interface used with an active system
  - Adjustment knob and reservoir bag(5L size)
  - Positive pressure relief valve (5 cmH_2O)
  - Negative pressure relief valve (-0.5 to -1.8 cmH_2O)



Hazards of Scavenging

- Excessive vacuum : undesirable negative pressure within the breathing system
- Obstruction : excessive positive pressure in the breathing circuit
- Inadequate vacuum : venting of waste gas into OR

Take Home Message

Pin	Pin Index Safety System(PISS) : prevent incorrect gas cylinder connection
Prevent	Diameter Index safety system(DISS) : prevent misconnection gas supply pipeline
Lead	Oxygen flush valve : improper use can lead to barotrauma or patient awareness
Toxic	Compund A with sevoflurane , CO with desflurane
Ventilate and oxygenate	When in doubt, ventilate and oxygenate the patient first via another method – troubleshoot later

References

Miller's Anesthesia, Ninth Edition, Manuel C.Pardo, Jr.,Ronald D.Miller

Clinical Anesthesia, Eight Edition, Paul G Barash

Thank you