Anesthetic breathing circuits

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Outline

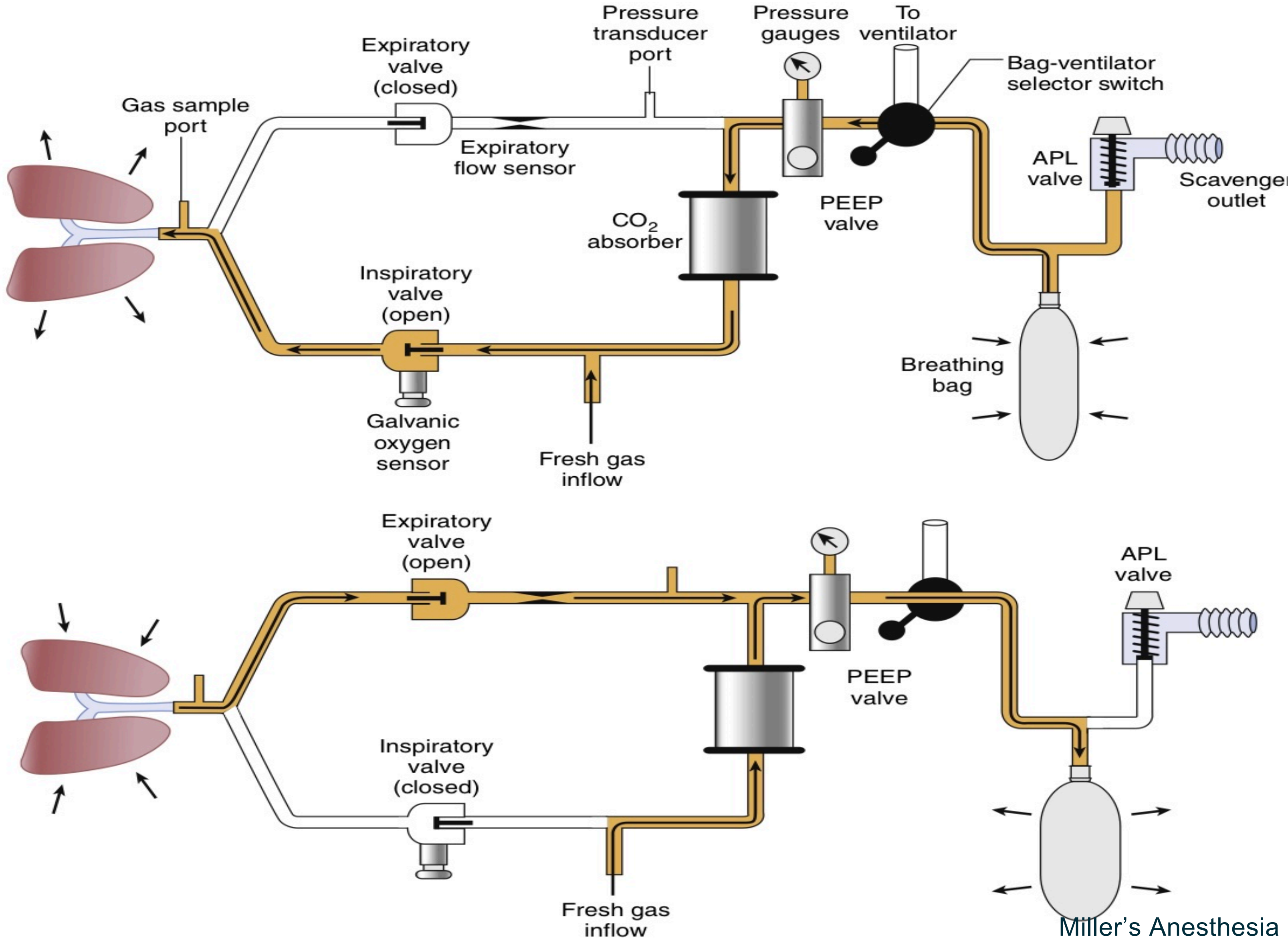
- Circle systems
- CO_2 absorber
- Degradation product
- Mapleson systems

Anesthetic breathing circuits

- Function >> *Deliver oxygen and other gases* to the patient and to *eliminate* CO_2
- Categorize [use an absorber]
  - Circle systems
  - Mapleson systems
- Leak & obstruction [two most important hazard]

Circle systems component

1. Fresh gas inflow source
2. Inspiratory and expiratory unidirectional valves
3. Inspiratory and expiratory corrugated tubes
4. Y-piece that connect to the patient
5. Overflow or APL or “pop-off” valve
6. Reservoir or breathing bag
7. CO_2 absorbent



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Add to enhance patient safety

- Circuit pressure sensor
- Pressure gauge
- Expiratory flow sensor
- Inspired oxygen concentration sensor

Circle Breathing Systems

- Circular and unidirectional flow of gas

Advantages	Disadvantages
1. Stable inspired gas concentration 2. Conserve respiratory heat and moisture 3. Elimination CO_2 4. Prevention of OR pollution	1. Complex design 2. Risk misconnection, disconnection, obstructions, and leaks 3. Anesthetic degradation

Mechanical component of the circle breathing circuit

Unidirectional Valves

- One-way valve
- Resist the humidity accumulate
- Occasionally fail during use
  - Expire > Inspire : greater moisture expose

If expire valve stick in malposition

Open position	Closed position
• Rebreathing CO_2	• Barotrauma

Unidirectional valves

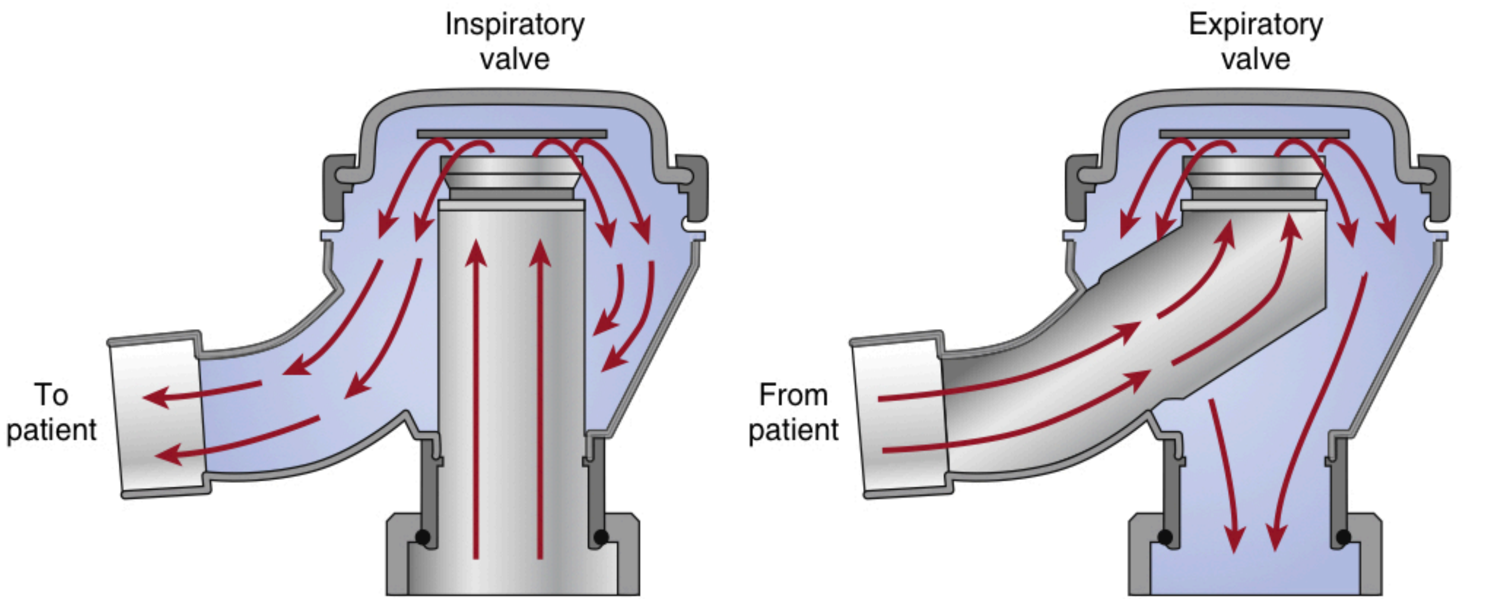


Fig. 22.35 Circle breathing system unidirectional valves. (Modified from Yoder M. Absorbers and breathing systems. In: *Understanding Modern Anesthesia Systems*. Telford, PA: Dräger Medical; 2009:83–126.)

- Part of the anesthesia workstation pre-use check out

Adjustable Pressure-Limiting Valve

- APL valve ,pop off valve or pressure relief valve
- Vent excess breathing circuit gas to scavenging system
- Control breathing system pressure [manual mode]
- Two basic type
  - Variable-orifice [flow control valve]
  - *Pressure-regulation type [modern]*

Pressure-regulation type

- Adjustable internal spring
- External scale [approximate opening pressure]
- When pressure > spring tension >> disk open and gas is vented
- Maintain stable circuit pressure even FGF increase

Pressure-regulation type

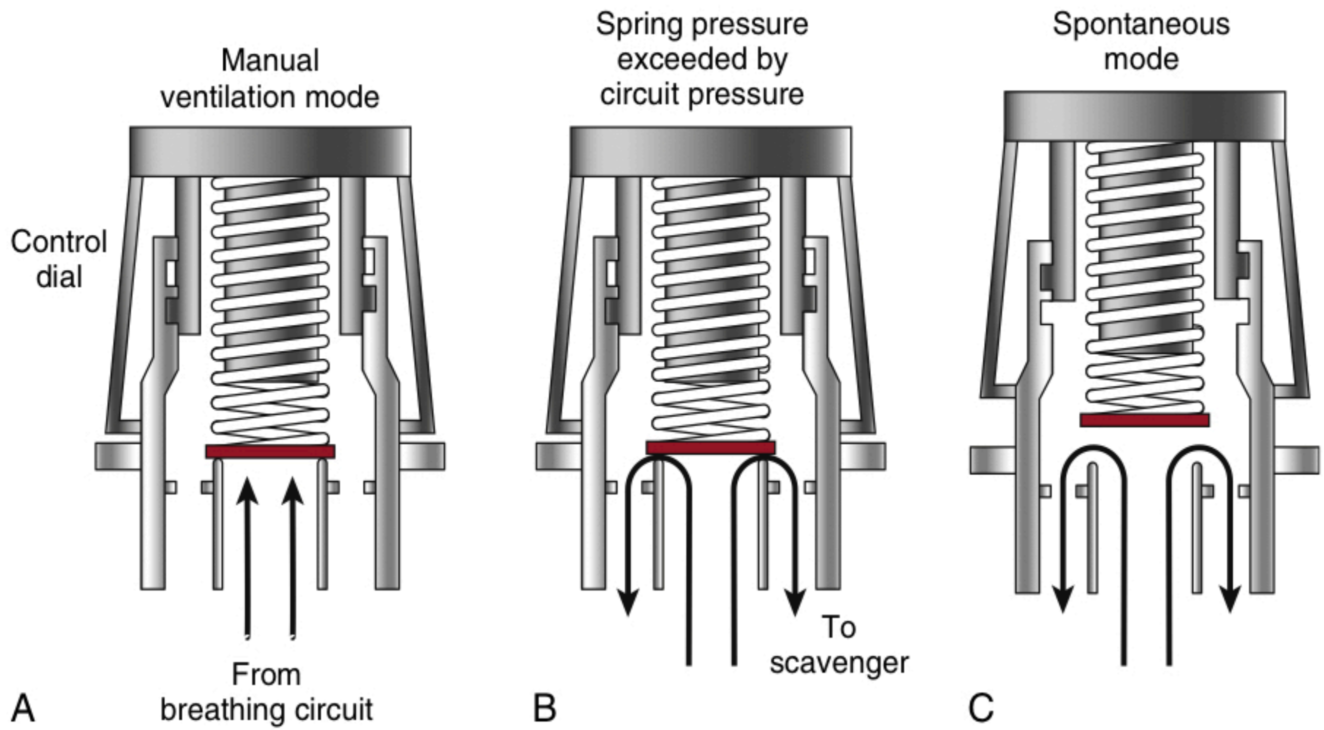


Fig. 22.37 Adjustable pressure-limiting valve: pressure-regulating type. (A) In the "manual" setting, the operator adjusts spring tension, thereby adjusting valve opening pressure. In this image the breathing circuit pressure has not yet exceeded spring tension. (B) Breathing circuit pressure has exceeded the set pressure (spring tension), and gas is vented to the scavenger. With the pressure regulating type of adjustable pressure-limiting valve, circuit pressure is independent of the fresh gas flow rate. (C) When the valve is placed in the spontaneous mode, the disk is lifted off the valve seat, and gas flows freely to the scavenger. A check valve downstream prevents waste gas from returning to the breathing circuit.

Anesthesia Reservoir Bag

- "Breathing Bag" function
  1. Reservoir for exhaled gas & excess fresh gas
  2. Deliver manual ventilation
  3. Visual or tactile [patient spontaneous ventilation]
  4. Partially protecting patient from excessive positive pressure in the circuit

Anesthesia Reservoir Bag

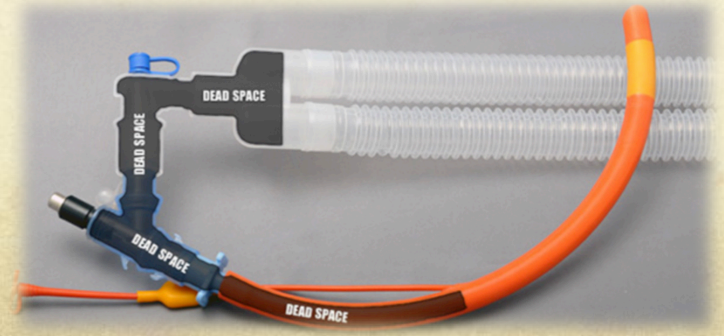
- Most compliant part of breathing system
- Standard adult breathing bag 3 L
- Pediatric bags available 0.5 L
- Standard mandate pressure
  - Minimum 30 cmH_2O
  - Maximum 60 cmH_2O [filled 4 x capacity]

Corrugated Breathing Circuit Tubing

- Most of volume within the circle system

Y-piece

- Y-piece is distal [nearest the patient]
  - Merge the inspiratory and expiratory limbs
  - 15-mm inner diameter to connect to ETT or elbow joint
  - 22-mm outer diameter to connect to face mask
- *Dead space in the circle system [Y-piece to patient]*



Filters and Heat and Moisture Exchangers

- HMEs >> replace the normal warming and humidifying function of the upper airway *[bypass by artificial airway]*
- Filters >> prevent transmission microbes from patient to machine
- Hydrophobic membrane filter
- Filter should be place between EET – Y-piece

SafeStar® Family

CareStar® Family

HumidStar® Family

TwinStar® Family

CombiStar Family

FILTERS AND HMES

									
Product name	**Filter/HME TwinStar® 90**	**Filter/HME TwinStar® 55**	**Filter/HME TwinStar® 65A**	**Filter/HME TwinStar® 25**	**Filter/HME TwinStar® 8**	**Filter/HME TwinStar® 10A**	**Filter/HME TwinStar® HEPA**	**Filter SafeStar® 80**	**Filter SafeStar® 55**
Part no.	MP01800	MP01805	MP01810	MP01815	MP01820	MP01825	MP01801	MP01785	MP01790
Deadspace (ml)	90	55	65	25	8	10	55	80	55
Recommended patient	adult	adult	adult	pediatric	pediatric/ neonatal	pediatric/ neonatal	adult	adult	adult
Recommended tidal volume (ml)	300 – 1.500	300 – 1500	300 – 1.500	75 – 500	30 – 200	30 – 200	300 – 1.500	300 – 1.500	300 – 1.500
Bacterial retention[1]	≥ 99.999%	≥ 99.999%	≥ 99.999%	≥ 99.999%	≥ 99.9%	≥ 99.9%	≥ 99.9999%	≥ 99.9999%	≥ 99.9999%
Viral retention[1]	≥ 99.999%	≥ 99.99%	≥ 99.99%	≥ 99.99%	≥ 99.9%	≥ 99.9%	≥ 99.9999%	≥ 99.9999%	≥ 99.9999%
Filtration method	electrostatic	electrostatic	electrostatic	electrostatic	electrostatic	electrostatic	mechanical (HEPA[2])	mechanical	mechanical
Fluid breakthrough at (mbar)	–	–	–	–	–	–	151	87.5	96
Moisture loss[3] (mg H_2O/l air)	4.7 (@ Vt 500 ml)	7.2 (@ Vt 500 ml)	6.9 (@ Vt 500 ml)	5.8 (@ Vt 250 ml)	6.1 (@ Vt 50 ml)	6.4 (@ Vt 50 ml)	9.8 (@ Vt 500 ml)	–	–
Moisture output (mg H_2O/l air)	39.3	36.8	37.1	38.2	37.9	37.6	34.2	–	–
Resistance (mbar)	1.0 at 30 l/min 2.2 at 60 l/min 3.6 at 90 l/min	0.9 at 30 l/min 2.0 at 60 l/min 3.5 at 90 l/min	1.1 at 30 l/min 2.4 at 60 l/min 4.2 at 90 l/min	1.3 at 15 l/min 1.8 at 20 l/min 2.8 at 30 l/min	0.6 at 5 l/min 1.6 at 10 l/min 3.0 at 15 l/min	0.4 at 5 l/min 1.0 at 10 l/min 1.6 at 15 l/min	1.3 at 30 l/min 2.7 at 60 l/min 4.3 at 90 l/min	1.4 at 30 l/min 3.2 at 60 l/min 5.5 at 90 l/min	1.3 at 30 l/min 2.9 at 60 l/min 4.6 at 90 l/min
Maximum duration of use	24h	24h	24h	24h	24h	24h	24h	24h	24h
Housing material	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent	Polypropylene transparent
Housing height (mm)	81.6	78.5	89.9	72.0	50.5	58.2	85.1	81.6	81.5
Housing diameter (mm)	80.0	68.5	68.5	48.1	36.8	36.8	68.5	80.0	68.5
Product	PVC free Latex free	PVC free Latex free	PVC free Latex free	PVC free Latex free	PVC free Latex free	PVC free Latex free	PVC free Latex free	PVC free Latex free	PVC free Latex free
Weight (g)	37	28	30	18	9	9	40	47	39
Sampling port	Luer lock	Luer lock	Luer lock	Luer lock	Luer lock	Luer lock	Luer lock	Luer lock	Luer lock
Cap of sampling port	tethered	tethered	tethered	tethered	tethered	tethered	tethered	tethered	tethered
Connector patient side	22M/15F	22M/15F	22M/15F	22M/15F	22M/15F	22M/15F	22M/15F	22M/15F	22M/15F
Connector machine side	22F/15M	22F/15M	22F/15M	22F/15M	15M/8.5M	15M	22F/15M	22F/15M	22F/15M
Shelf life	3 years	3 years	3 years	3 years	3 years	3 years	5 years	5 years	5 years
Colour code	Blue	Blue	Blue	Blue	–	–	Blue	Red	Red
Units/package (pcs.)	50	50	50	50	50	50	50	50	50

[1] According to Nelson Laboratories, Inc., Salt Lake City, USA
[2] According to EN 1822-1:2009
[3] According to EN ISO 9360-1 (2009)

Filtration Efficiency

	Bacterial retention*	Viral retention**	NaCl retention***
CareStar® 45 (MP01755)	≥ 99.9999%	≥ 99.9999%	≥ 98.5%
CareStar® 40A (MP01765)	≥ 99.9999%	≥ 99.9999%	≥ 98.1%
CareStar® 30 (MP01770)	≥ 99.99%	≥ 99.99%	≥ 95.3%
SafeStar® 80 (MP01785)	≥ 99.9999%	≥ 99.9999%	≥ 99.99%
SafeStar® 55 (MP01790)	≥ 99.9999%	≥ 99.9999%	≥ 99.97%
SafeStar® 60A (MP01795)	≥ 99.9999%	≥ 99.9999%	≥ 99.98%
TwinStar® 90 (MP01800)	≥ 99.999%	≥ 99.999%	≥ 97.8%
TwinStar® HEPA**** (MP01801)	≥ 99.999%	≥ 99.9999%	≥ 99.8%
TwinStar® 55 (MP01805)	≥ 99.999%	≥ 99.99%	≥ 95.1%
TwinStar® 65A (MP01810)	≥ 99.999%	≥ 99.99%	≥ 97.3%
TwinStar® 25 (MP01815)	≥ 99.999%	≥ 99.99%	≥ 98.0%
TwinStar® 8 (MP01820)	≥ 99.9%	≥ 99.9%	≥ 79.1%
TwinStar® 10A (MP01825)	≥ 99.9%	≥ 99.9%	≥ 79.1%
Infinity ID Expiratory Filter**** (MP01780)	≥ 99.9999%	≥ 99.9999%	-
Expiratory Filter**** (MP01781)	≥ 99.9999%	≥ 99.9999%	-

* BFE

According to Nelson Laboratories, Inc. Salt Lake City, USA. The mean particle size (MPS) of the challenge aerosol must be maintained at 3.0 ± 0.3 µm. The average percent bacterial filtration efficiency (%BFE) for the reference material must be within the upper and lower control limits established for the BFE test.

** VFE

According to Nelson Laboratories, Inc. Salt Lake City, USA. The mean particle size (MPS) of the challenge aerosol must be maintained at 3.0 ± 0.3 µm. The average percent virus filtration efficiency (%VFE) for the reference material must be within the upper and lower control limits established for the VFE test.

*** NaCl

According to Nelson Laboratories, Inc. Salt Lake City, USA. The filter tester produces a particle size distribution with a count median diameter of 0.075 ± 0.02 µm and a standard geometric deviation not exceeding 1.86 µm as determined with a scanning mobility particle sizer (SMPS).

**** HEPA

HEPA filter class H13 according to DIN EN 1822-1:1998 / DIN EN 1822-1:2011 at 0.1 µm. Our SafeStar® filter are designed with the same filtration medium as our TwinStar® HEPA.

TB and COVID-19

- TB particle size 1-5 micron
- COVID-19 particle size 0.06-0.14 micron
- *ASA recommend use filter in TB patient >> efficiency rating > 95% for particle size > 0.3 micron*
- Clinical use at PMK hospital
  - HEPA [HME] >> between tube and corrugate

  - HEPA filter >> expiratory valve

Respiratory transmission

- Droplet >> particle size large than 5-10 micron
- Aerosol >> particle size smaller than 5 micron

- Filter capture particle > 1 micron >> inertial impact
- Filter capture particle < 1 micron >> diffusion


HAMILTON-G5

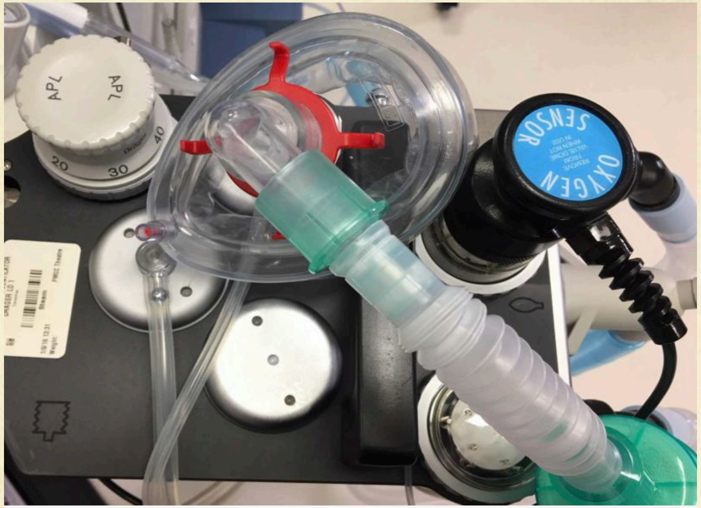
Sensors [patient safety]

- Inspired Oxygen Concentration Monitor
- Flow Sensors
- Breathing Circuit Pressure Sensors

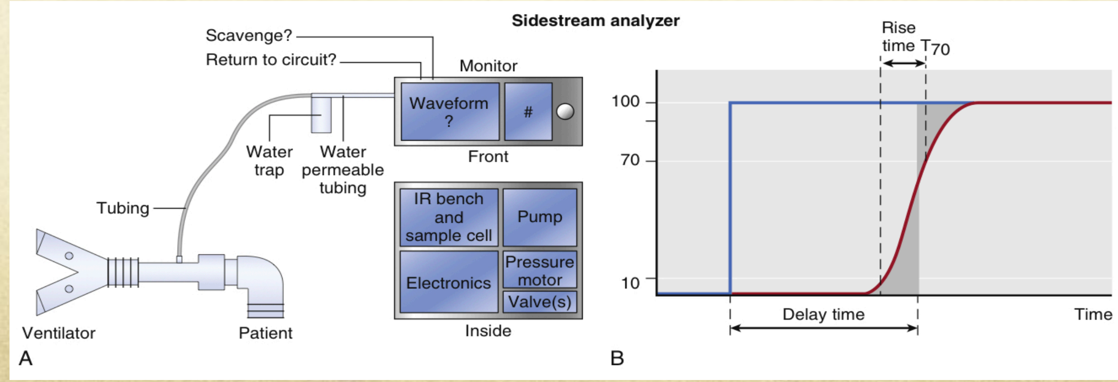
Inspired Oxygen Concentration Monitor

- Monitor oxygen concentration
  [inspiratory limb or at Y-piece]
- Low oxygen concentration alarm must sound within 30 sec
  >> if FiO_2 drop below limit [cannot less than 18%]
- Defense patient receiving a hypoxemic gas mixture

"Galvanic cell oxygen analyzers" [inspiratory valve]



Modern use side-stream multigas analyzers [Y-piece]



Flow Sensors

- Measure tidal volume
- Monitor patient exhaled tidal volume and minute ventilation
- Display flow waveforms / flow volume loops

Breathing Circuit Pressure sensors

- Measure airway pressure
- *Critical patient safety*
  - Continue display pressure in breathing circuit
  - Alarm >> high pressure [CPAP 15 sec or longer]
  - Alarm >> negative pressure < -10 cmH_2O more than 1 sec
  - Alarm >> breathing pressure fall below a preset more than 20 sec [disconnection alarm]

Circle system function

- Semiclosed system
- Semiopen system
- Closed system

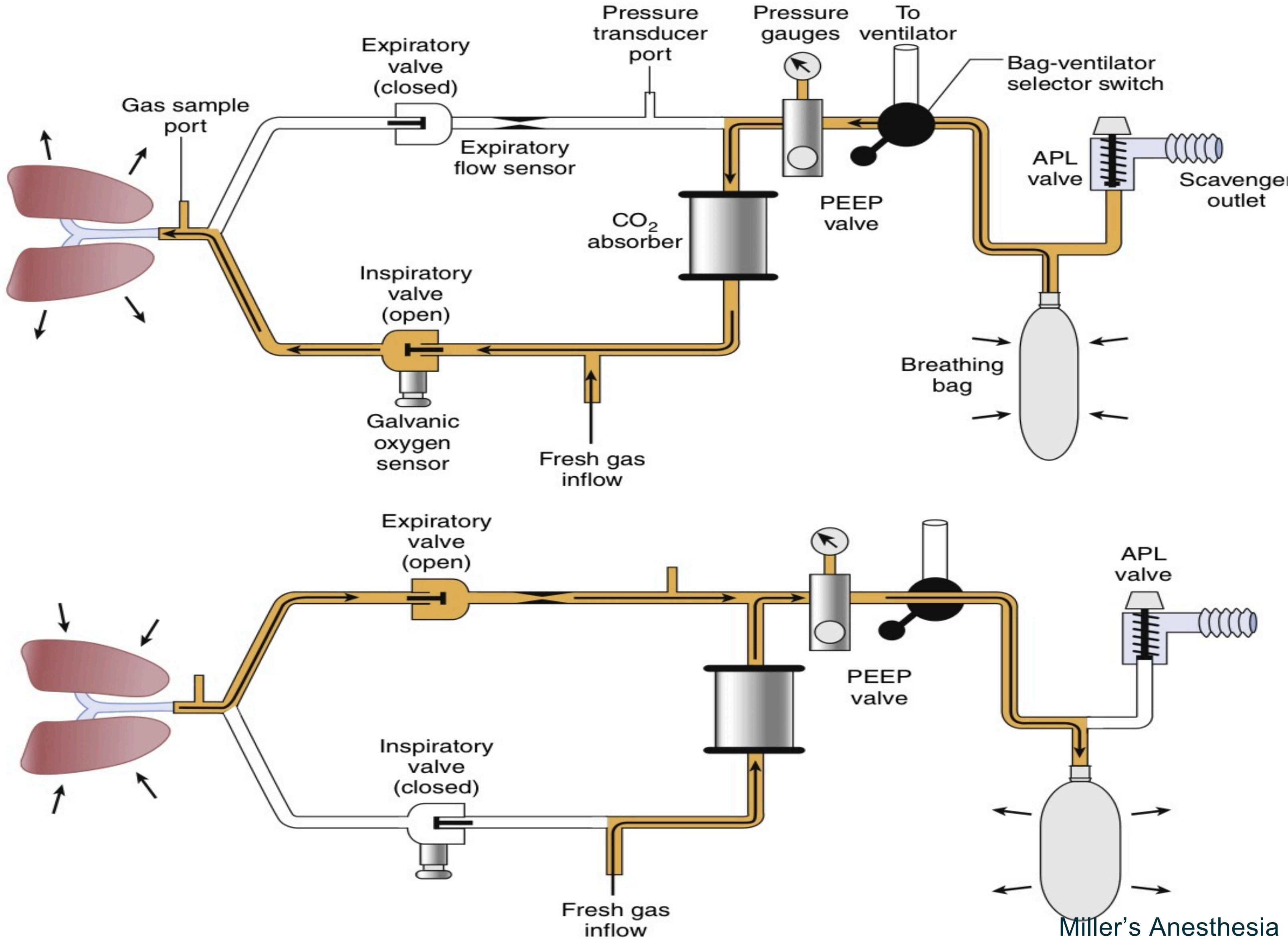
Semiclosed system

- *Modern circle system*
- Some rebreathing occur
- Some waste flow is vented
- Low-flow anesthesia with circle system exmplify“semiclosed”
  - *Low-flow >> FGF < minute ventilation and at least 50% of expired gas is rebreathed after* CO_2 *removal*

Low-flow anesthesia with circle system

- Exemplify "semiclosed system"
- *Low-flow >> FGF < minute ventilation and at least 50% of expired gas is rebreathed after CO_2 removal*

Advantages	Disadvantages
1. Conducting low-flow or minimal-flow decrease use volatile 2. Improved temp & humidity control 3. Reduce environment pollution	1. Difficult adjust anesthetic depth 2. Accumulating unwanted exhaled gas [CO, acetone, methane] or degradation product



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Semiopen system

- High fresh gas flow rate
- Minimal rebreathing
- More venting waste gas

Closed system

- Oxygen inflow = metabolic demand
- Rebreathing is complete
- No waste gas is vented

Table 15-3 Classification of Anesthetic Breathing Systems

System	Gas Reservoir Bag	Rebreathing of Exhaled Gases	Chemical Neutralization of Carbon Dioxide	Unidirectional Valves	Fresh Gas Inflow Rate*
Open					
Insufflation	No	No	No	None	Unknown
Open drop	No	No	No	None	Unknown
Semiopen					
Mapleson A, B, C, D	Yes	No†	No	One	High
Bain	Yes	No†	No	One	High
Mapleson E	No	No†	No	None	High
Mapleson F (Jackson-Rees)	Yes	No†	No	One	High
Semiclosed Circle	Yes	Partial	Yes	Three	Moderate
Closed Circle	Yes	Total	Yes	Three	Low

*High, greater than 6 L/min; moderate, 3 to 6 L/min; low, 0.3 to 0.5 L/min.

†No rebreathing of exhaled gases only when fresh gas inflow is adequate.

Potential circle system problems

- Leak and disconnections >> critical incident
  - Disposable tubing and component
  - Point of connection
  - Partial disconnect [during anesthesia]
- Small leak >> increase FGF to compensate lost Tidal volume
- Several monitor can assist for detect leak

Methods of detect leak

TABLE 22.7 Methods of Detecting Leaks and Disconnections During the Course of Anesthesia

Method	Leak Indications
Breathing circuit pressure sensors	*Threshold pressure alarm** Pressure waveform evaluation Trend of peak pressures
Workstation tidal volume sensors	Low minute ventilation or low tidal volume alarm Failure to deliver set tidal volume Disparity between inhaled and exhaled tidal volumes Decreasing trend of tidal volume and minute ventilation
Exhaled gas analysis	Exhaled carbon dioxide automated monitoring Abnormal appearance and trend of capnography tracing
Physiologic sensors (e.g., SpO_2, HR, BP)	*Late detection* of significant leaks and disconnections because the patient is already decompensating
A vigilant practitioner	Assesses breath sounds and chest wall excursion Pays close attention to alarms and responds promptly Observes workstation and physiologic monitors Notes that ventilator bellows is not refilling completely and tidal volumes are decreasing Notes that flow rate requirements are increasing to refill an ascending bellows Senses that breathing bag motion and feel are not normal Detects the odor of anesthetic gas Follows his or her instinct that something is not right

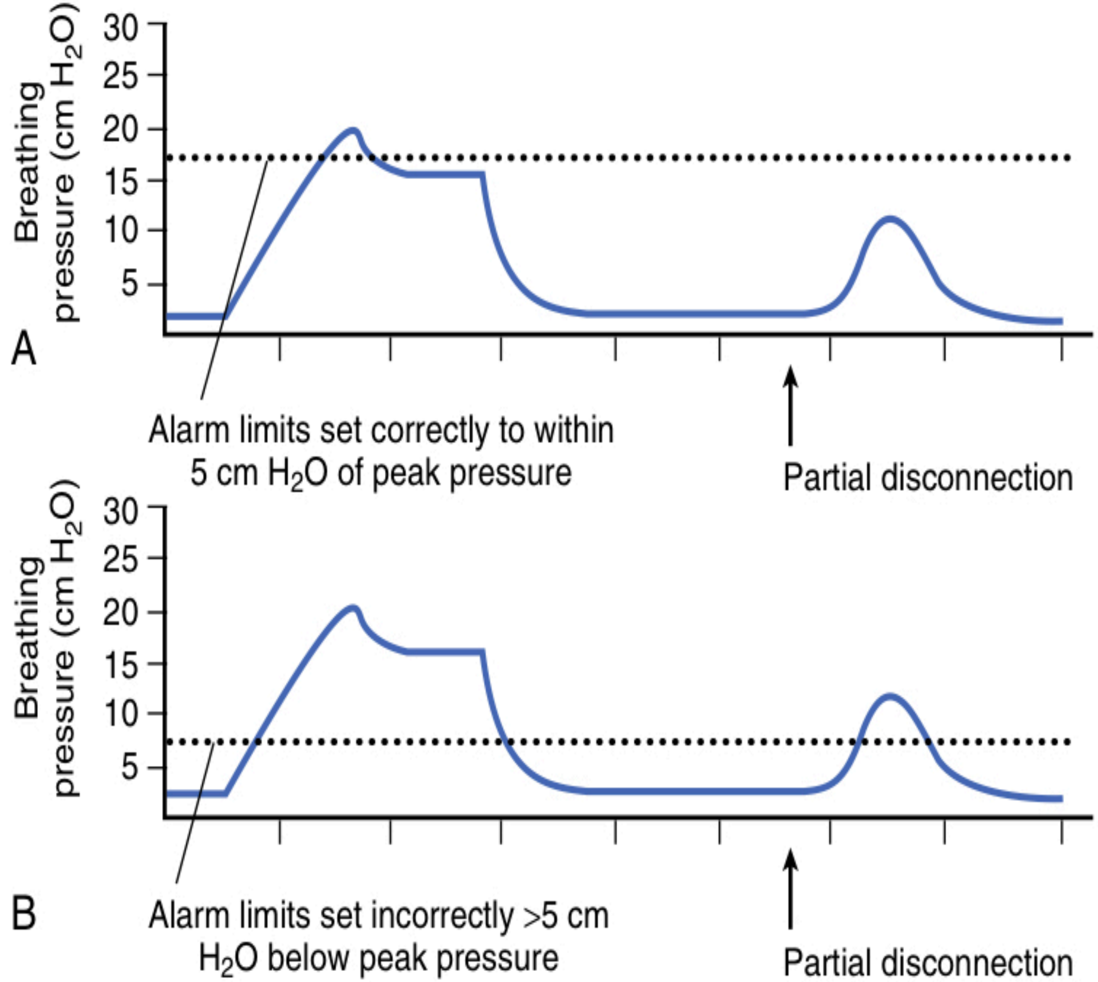


Fig. 22.39 Threshold pressure alarm limit. (A) The threshold pressure alarm limit *(dotted line)* has been set appropriately. An alarm is actuated when partial disconnection occurs *(arrow)* because the threshold pressure alarm limit is not exceeded by the breathing circuit pressure. (B) Partial disconnection is unrecognized by the pressure monitor because the threshold pressure alarm limit has been set too low. (Redrawn from North American Dräger. *Baromed Breathing Pressure Monitor: Operator's Instruction Manual.* Telford, PA: North American Dräger; 1986.)

Potential circle system problems

- Misconnection
  - Standard different diameter to various circuit connection
- Obstruction [occlusion]
  - Tracheal tube kink, secretion obstruction
  - Breathing circuit valve malfunction
  - Hoses of breathing circuit [internal & external obstruction]
- *If can't ventilate >> do not delay to switch to self-inflating bag*

Carbon Dioxide Absorbers

- 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

Absorbers 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

- CO_2 is removed from circuit by chemical in canister
- CO_2 is transformed into water, heat, and other product
- Most absorbents : Calcium hydroxide [$Ca(OH)_2$]
  - CO_2 not react quickly with [$Ca(OH)_2$] need strong base catalyst
  - Potassium hydroxide [KOH], Sodium hydroxide [NaOH]
  - Humectant [calcium chloride]

Chemistry of Absorbents

- Newer absorbent : Lithium hydroxide [LiOH]
  - Strong base not require any addition catalyst
  - Liquid water not required to generate H_2CO_3

Soda lime

- 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

BOX 22.2 **Carbon Dioxide Absorber Reactions (Net and Sequential)**

Carbon Dioxide Reaction With Soda Lime

Net Reaction

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

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

Carbon Dioxide Reaction With Lithium Hydroxide Monohydrate

$$2\ LiOH{\bullet}H_2O + CO_2 + \text{heat} \rightarrow Li_2CO_3 + 3H_2O$$

Interaction with inhaled anesthetic

- Formation > harmful degradation product
- Volatile agents interact with strong base [KOH & NaOH]
- Historical : trichloroethylene volatile in 1940 [neurotoxic]
  - Dichloroacetylene base catalyst in prior soda lime
- *Today main degradation product concern*
  - *Compound A with sevoflurane*
  - CO *with desflurane, enflurane, and isoflurane*

Compound A

- Sevoflurane base catalyst >> trifluoromethyl vinyl ether "*Compound A*"
- Nephrotoxic to rats , transient albuminuria and glucosuria
- Data show no relationship between sevoflurane use and postoperative renal dysfunction in humans
  - Sevoflurane package >> patient exposure should not exceed 2 MAC-hours at flow rate between 1-2 L/min [flow < 1L/min are not recommend]

Compound A

- Factor >> higher concentration of compound A
  - Low-flow or closed-circuit
  - Higher concentrations of sevoflurane
  - Type of absorbent [KOH or NaOH-containing]
  - Higher absorbent temperatures

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

- Strong base are extremely dry >> degrade inhale anesthetic to clinical significant concentration of CO
- Can produce blood carboxyhemoglobin level 35% or greater in an exposed patient
- *Typical scenario : dangerous* CO *exposure [first case on a Monday morning]*

Carbon monoxide

- Factor >> increase production CO and risk of carboxyhemoglobinemia
  - Inhaled anesthetic *[D > E > I >> H = S]*
  - Degree of desiccation of the absorbent
  - Type of absorbent [KOH or NaOH-containing]
  - Higher temperature
  - Higher concentrations of anesthetic
  - Low fresh gas flow rate , Smaller patient size

Absorbent heat production

- Extremely rare but life-threatening
- Extreme exothermic reaction >> fire and explosions
  - Desiccated strong base [particularly Baralyme]
  - Desiccated Baralyme 200°C and fire was note in some breathing circuit [formaldehyde, methanol, and formic acid]
- *Avoid to use sevoflurane with baralyme [desiccated]*

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 >> photodeactivate dye
  - Purple back to white [strongly alkaline of NaOH]
- *Absorbent desiccated is impossible to detect by visual*

Carbon dioxide removal capacity

- Main factor to remove CO_2
  1. Amount of absorbent surface expose to exhaled gas
  2. Intrinsic capacity of absorbent to remove CO_2
  3. Amount of nonexhausted absorbent remaining
- $Ca(OH)_2$ 1 pound can absorb CO_2 0.59 pound
- LiOH 1 pound can absorb CO_2 0.91 pound

Recommend ASA

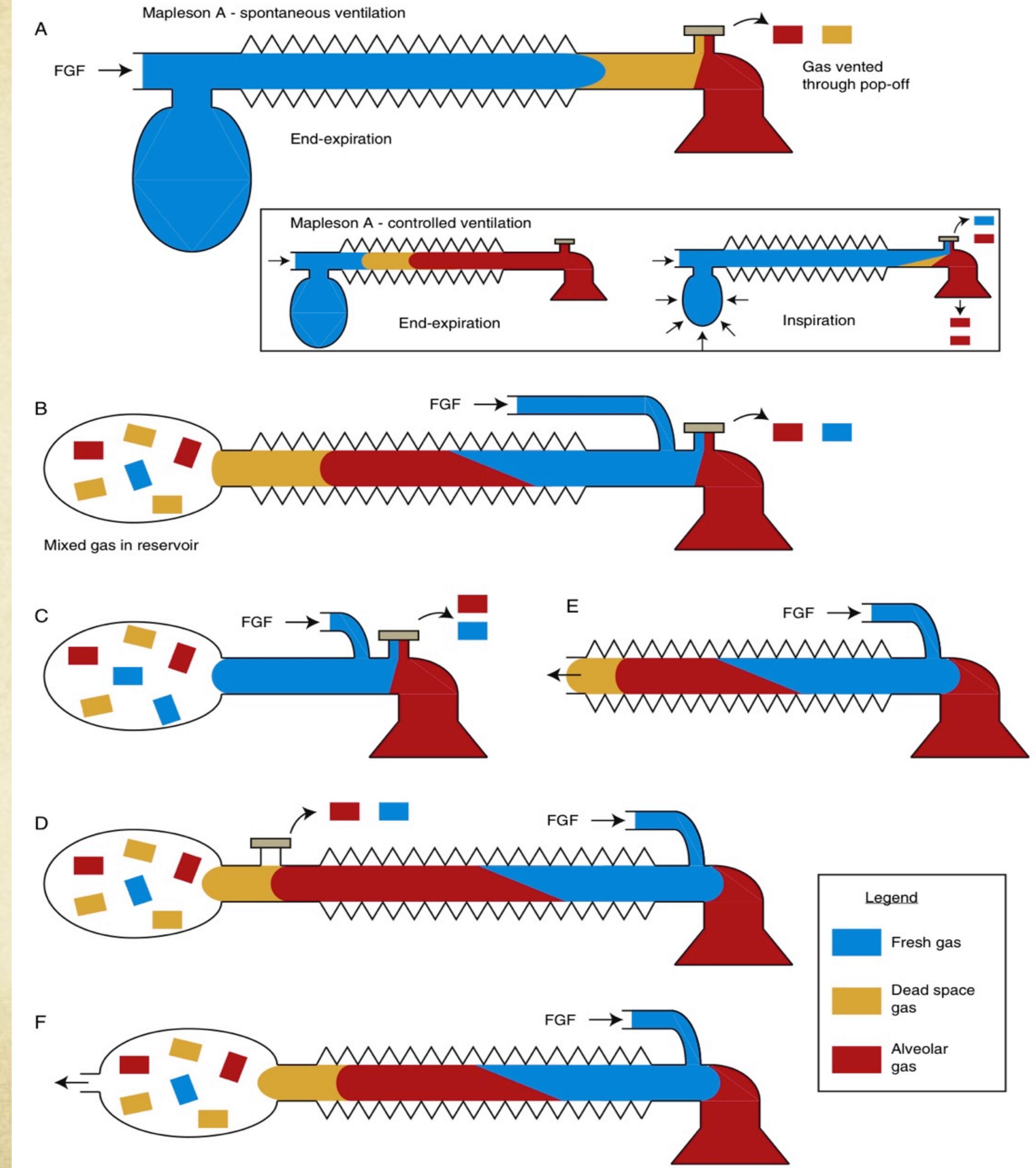
- Reduce risk of volatile degradation by *desiccated* CO_2 *absorbent*
  - Turn off all gas flow when the machine is not in use
  - Change the absorbent regular
  - Change the absorbent if color change indicates exhaustion
  - Change all absorbent [not just one canister in a two canister]
  - Change the absorbent when uncertain about the state of hydration

Mapleson breathing systems

- In 1954 >> Mapleson breathing systems A-E
- In 1975 >> Willis and coauthor breathing system F
- Accept FGF >> supply the patient with gas from reservoir to *meet inspiratory flow* and *volume requirement* and *eliminate* CO_2
- Differ from circle systems
  - Bidirectional gas flow
  - Lack of absorber

Mapleson system

Advantages	Disadvantages
1. Low resistance to gas flow 2. Small and contain few part 3. Volatile no chance of degradation	1. Need higher FGF to prevent rebreathing 2. Not economical volatile gas 3. Less conservative heat and humidity


Mapleson A - spontaneous ventilation
A
FGF
Gas vented through pop-off
End-expiration
Mapleson A - controlled ventilation
End-expiration
Inspiration
B
FGF
Mixed gas in reservoir
C
FGF
E
FGF
D
FGF
F
FGF
Legend
Fresh gas
Dead space gas
Alveolar gas

Mapleson breathing systems

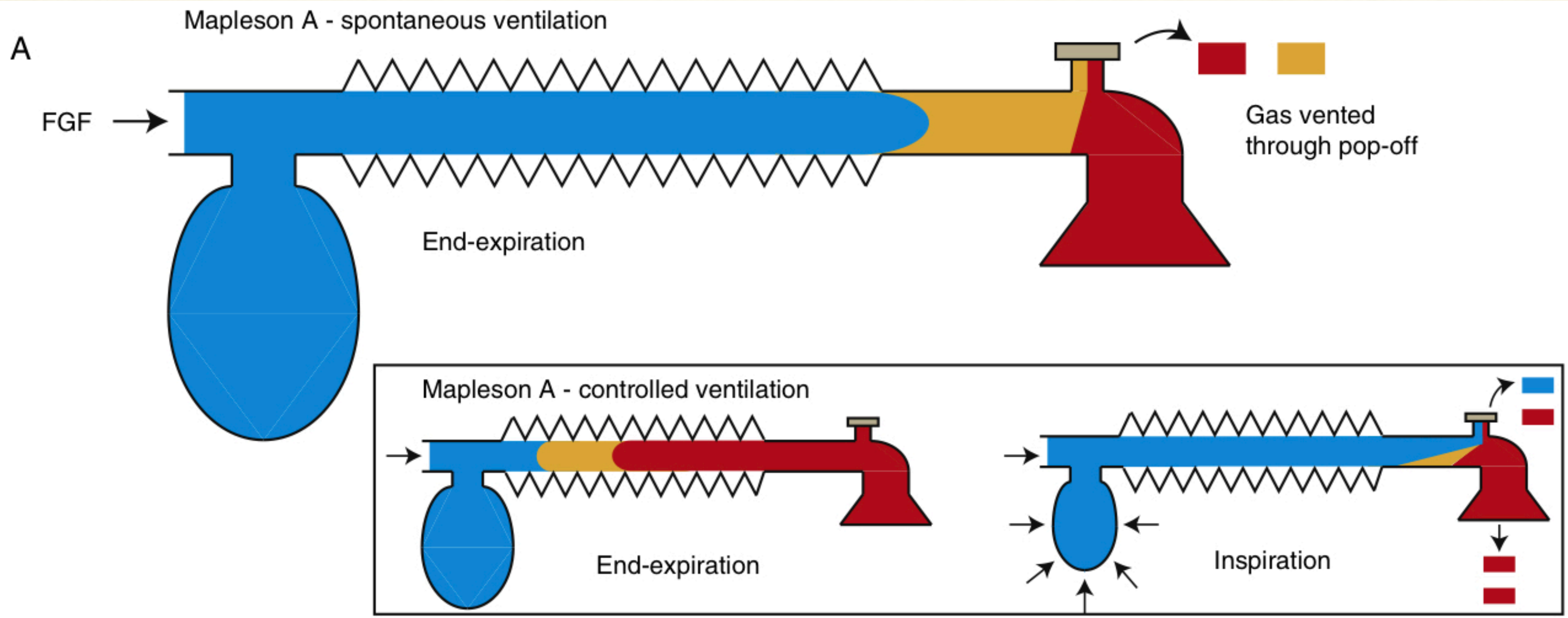
- Mapleson A, B and C systems are rarely used today
- Mapleson D, E and F systems are common used
- Most popular
  - Bain circuit [modified D]
  - Jackson-Rees circuit [F]
- Three distinct functional group [A, BC, DEF]

Factor CO_2 rebreathing in Mapleson system

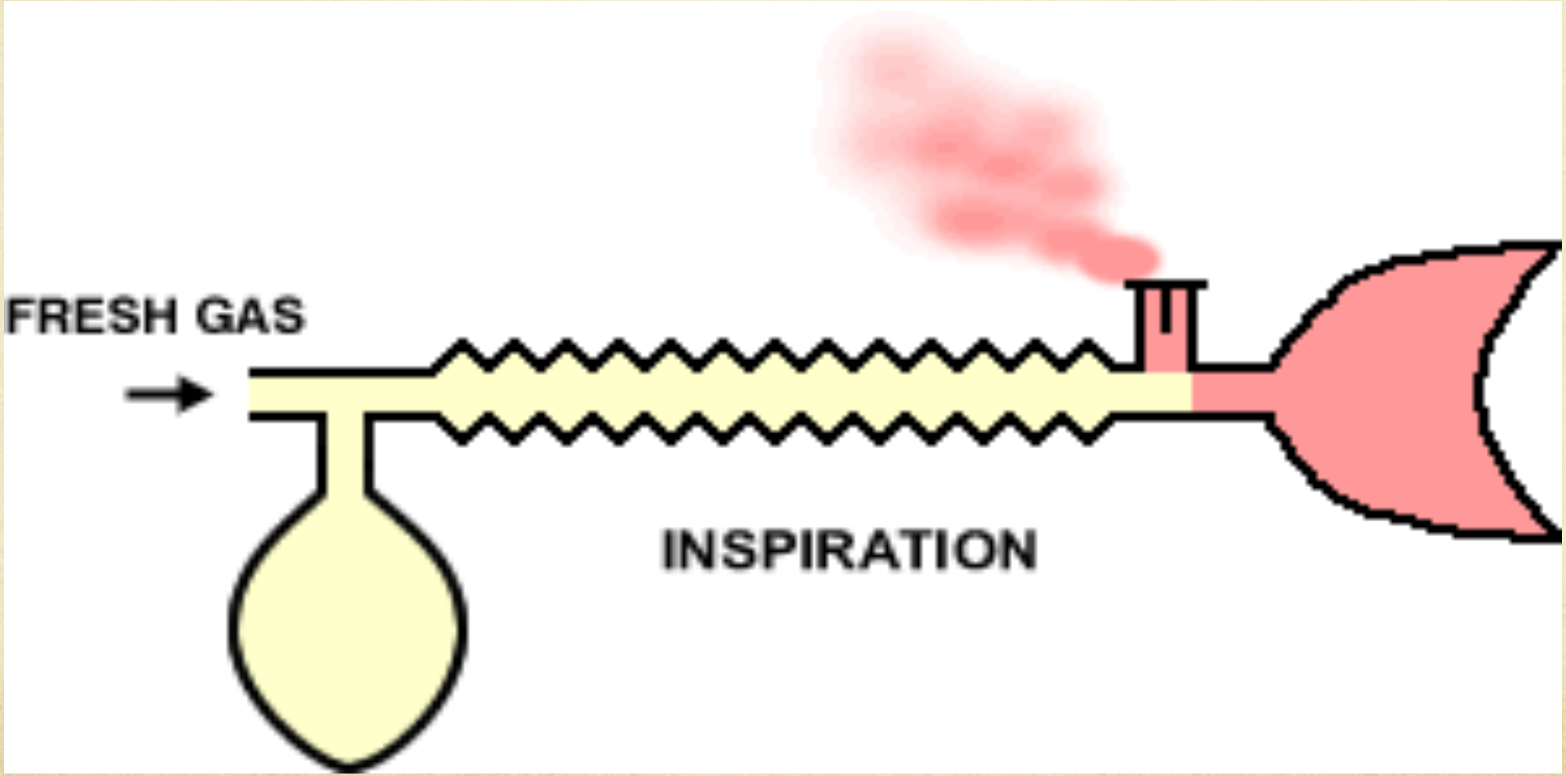
- Fresh gas inflow rate
- Minute ventilation
- Ventilation mode
- Tidal volume
- Respiratory rate
- I:E ratio
- Duration of expire pause
- Peak inspiratory flow rate
- Volume of reservoir tubing
- Volume of breathing bag
- Airway device [mask,ETT]
- CO_2 sampling site

Mapleson A “Magill circuit”

- Pop-off valve near the face mask
- Different performance [Spontaneous VS Control ventilation]



Mapleson A "spontaneous"



Mapleson A “Magill’s circuit”

- Key factor [timing when pop-off valve open]
  - During expiration for spontaneous ventilation
  - During inspiration for controlled ventilation

- FGF to prevent rebreathing of CO_2
  - Spontaneous ventilation : 1 x MV
  - Control ventilation : >3 x MV

- *Due to FGF near patient in other mapleson do not differ as markedly between spontaneous VS control ventilation*

Bain circuit "modified D"

- FGF through a narrow inner tube in corrugate hose
- Central fresh gas tube enter near reservoir bag
- Exhale gas pass corrugate around central tubing >> vented through pop-off valve [add warm to inspired fresh gas]
- Main hazard use Bain circuit
  - Unrecognized disconnection or kinking of inner gas hose
  - Outer corrugate tube should be transparent

Bain circuit "modified D"

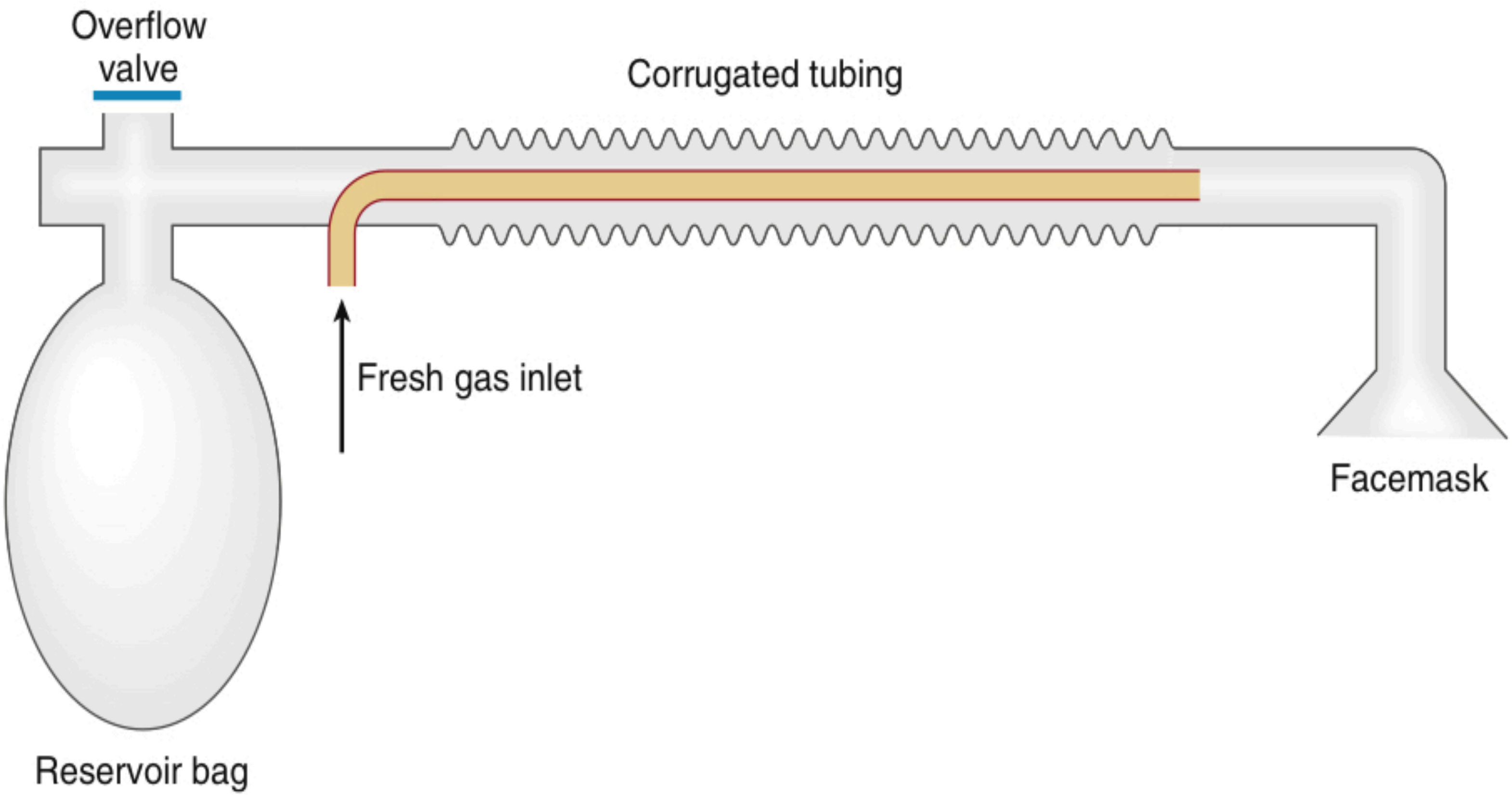
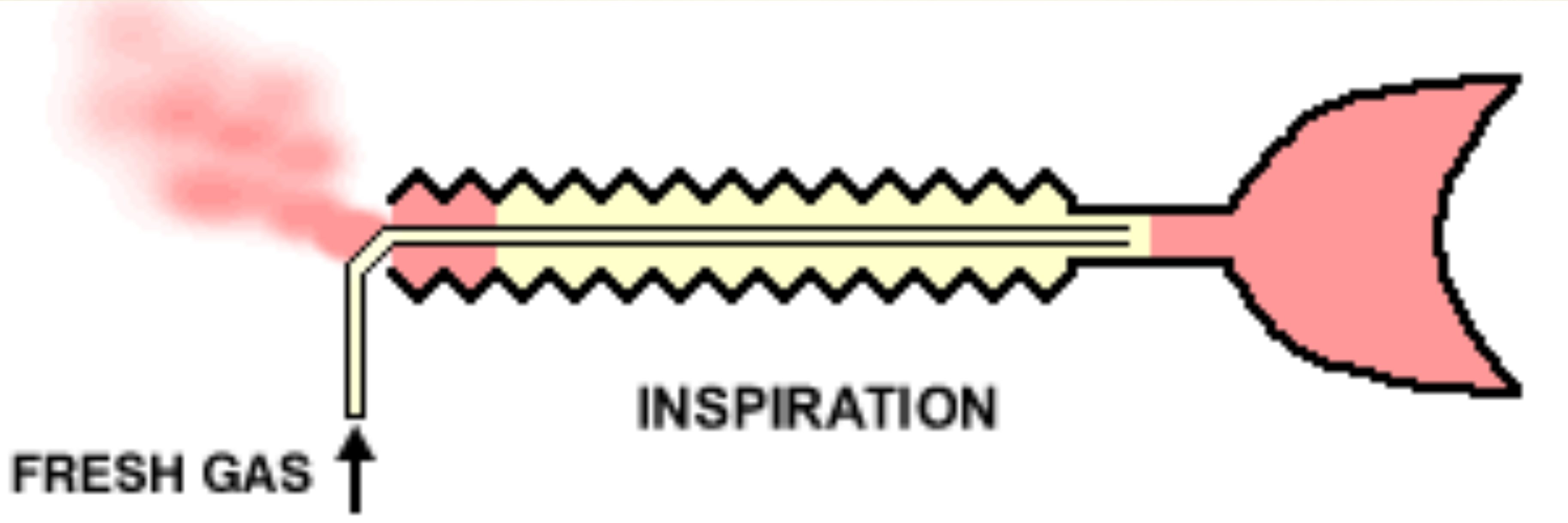


Fig. 22.41 The Bain circuit. (Redrawn from Bain JA, Spoerel WE. A streamlined anaesthetic system. *Can Anaesth Soc J*. 1972;19:426.)

Bain circuit “modified D”

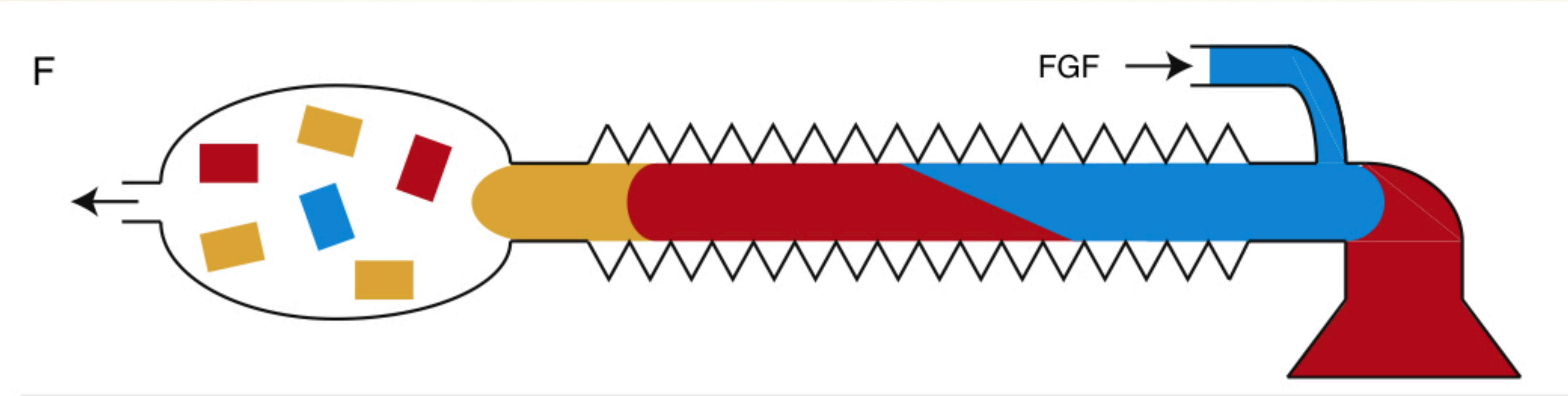


Jackson-Rees circuit

- Mapleson F >> hole in the end of reservoir bag
- Convenient for
  - Patient transport
  - Preoxygenation during ICU or out-of-the OR procedure
- Circuit may use for spontaneous [venting hole open] or assisted/controlled [venting hole partial or total occluded]

Jackson-Rees circuit

- Fresh gas flow require
  - 2.5-3 x MV for spontaneous ventilation
  - 1.5-2 x MV for control ventilation



Relative efficiency

- Mapleson systems prevent rebreathing [spontaneous]
  - A > DFE > CB
  - *A Dog Can Bite*
- Mapleson systems prevent rebreathing [control ventilation]
  - DFE > BC > A
  - *Death Body Can Ate*

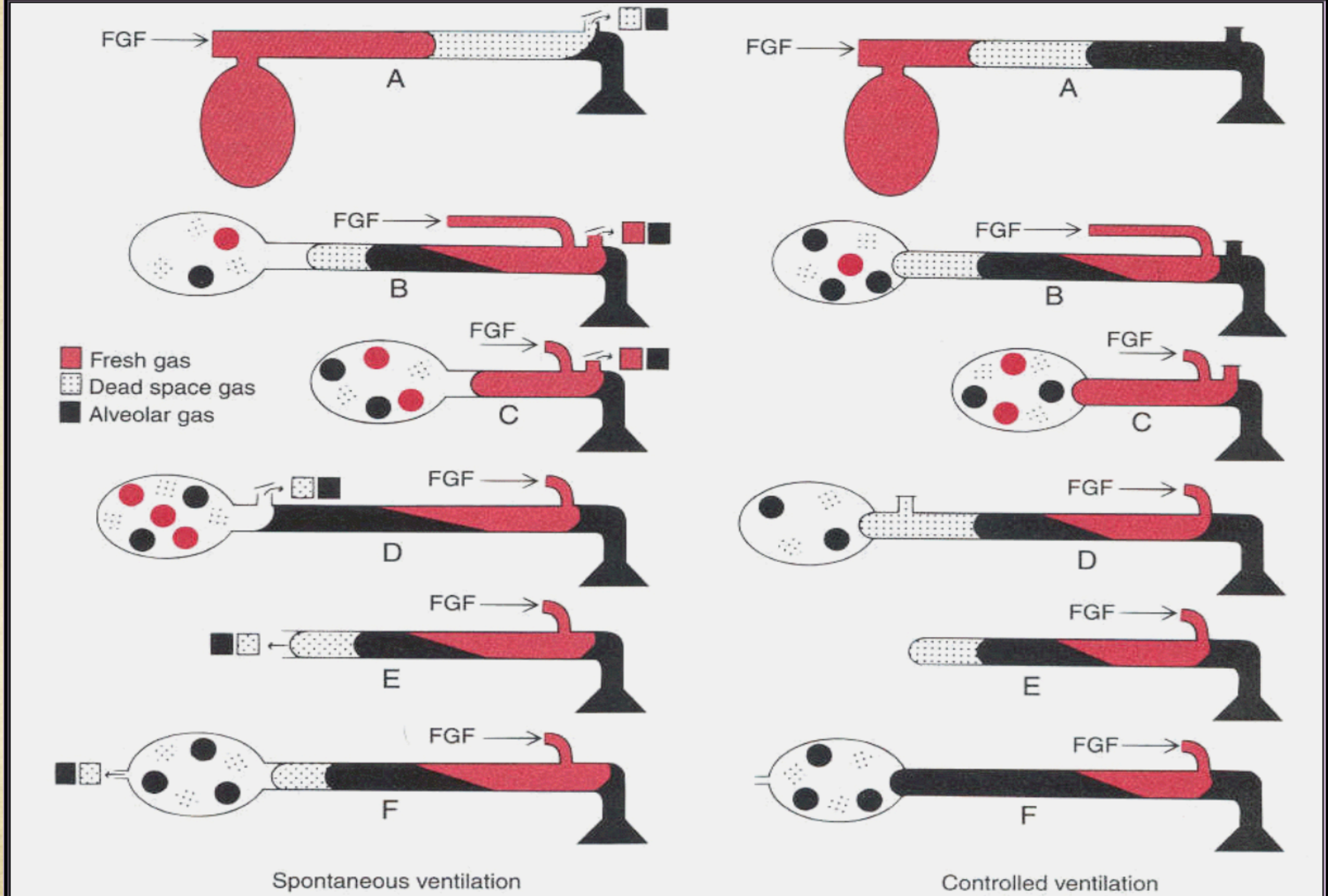
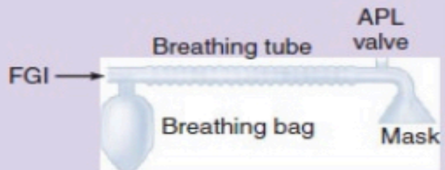
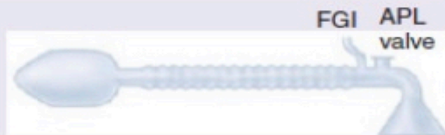
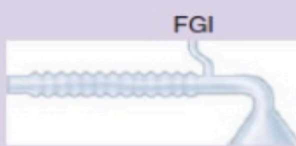

FGF
A
B
C
D
E
F
Fresh gas
Dead space gas
Alveolar gas
Spontaneous ventilation
Controlled ventilation

TABLE 3–2 Classification and characteristics of Mapleson circuits.

Mapleson Class	Other Names	Configuration[1]	Required Fresh Gas Flows: Spontaneous	Required Fresh Gas Flows: Controlled	Comments
A	Magill attachment		Equal to minute ventilation (≈80 mL/kg/min)	Very high and difficult to predict	Poor choice during cotrolled ventilaton. Enclosed Magill system is a modification that improves efficiency. Coaxial Mapleson A (Lack breathing system) provides waste gas scavenging.
B			2 × minute ventilation	2–2½ × minute ventilation	
C	Waters' to-and-fro		2 × minute ventilation	2–2½ × minute ventilation	
D	Bain circuit		2–3 × minute ventilation	1–2 × minute ventilation	Bain coaxial modification: fresh gas tube inside breathing tube (see Figure 3–7).
E	Ayre's T-piece		2–3 × minute ventilation	3 × minute ventilation (I:E-1:2)	Exhalation tubing should provide a larger volume than tidal volume to prevent rebreathing. Scavenging is difficult.
F	Jackson-Rees' modification		2–3 × minute ventilation	2 × minute ventilation	A Mapleson E with a breathing bag connected to the end of the breathing tube to allow controlled ventilation and scavenging.

[1]FGI, fresh gas inlet; APL, adjustable pressure-limiting (value).

Self inflating manual resuscitator

- Ambu bag, Laerdal resuscitator, or simply bag-valve-mask device
- Key feature : compressible reservoir, automatically expands upon release
- Use for
  - patient transport
  - cardiopulmonary resuscitation
  - emergency back-up [ventilator or oxygen supply fail]

Self inflating manual resuscitator

1. T-shape nonrebreathing valve
2. Inlet valve permit refill bag >> reservoir gas or roomair
3. Pop-off valve [limit PIP] >> ISO limit PIP to 45 cmH_2O

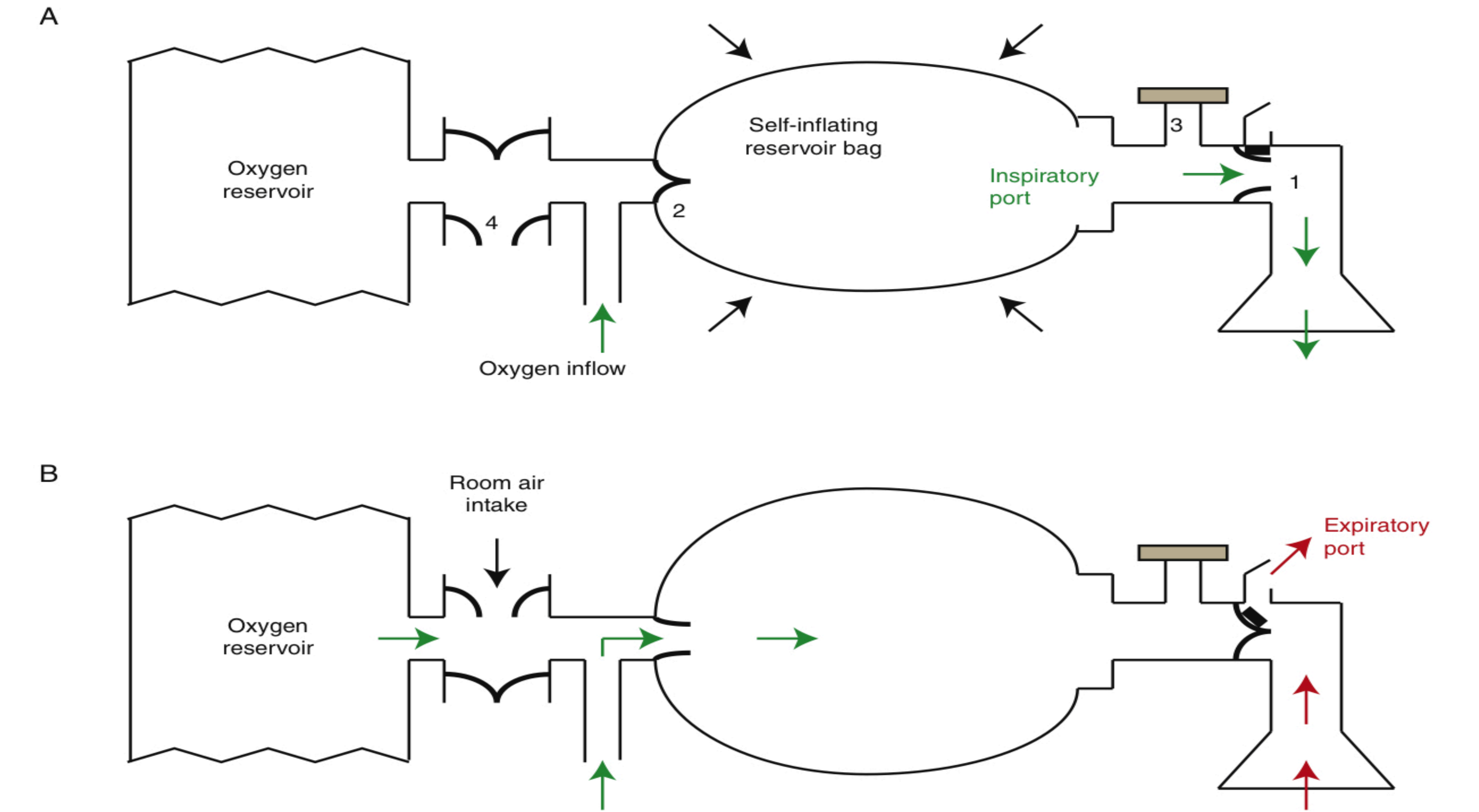


Fig. 22.42 Self-inflating manual resuscitator. (A) Flow of gas during inspiration. (1) Nonrebreathing valve, (2) bag inlet valve, (3) pop-off or pressure limiting valve (standard for pediatric and infant devices), and (4) outflow or excess-oxygen venting valve. (B) Flow of gas during expiration. See text for details. (Redrawn after Dorsch JA, Dorsch SE. The anesthesia machine. In Dorsch JA, Dorsch SE, eds. *Understanding Anesthesia Equipment*. 5th ed. Baltimore: Williams & Wilkins; 2008:83, Chapter 10 Manual Resuscitators; and Lien S, Verreault DJ, Alston TA. Sustained airway pressure after transient occlusion of a valve venting a self-inflating manual resuscitator. *J Clin Anesth*. 2013;25[5]:424–425.)

THANK YOU