FYS 4250

Lecture 9



John Hopkins Medicine

Case 9



http://2.bp.blogspot.com/-Waqweh2ytJg/UfFvD2R8FZI/AAAAAAAAB2Y/dMx7qn3hg2w/s1600/surgeon.jpg

- A 69-year-old man is undergoing surgery because of a liver tumor. The surgery is uneventful in all ways, except for a minor rhythm disturbance after approximately 35 minutes of anesthesia.

Case 9

- The patient’s weight is 72 kg when hospitalized, blood pressure is 135/80 mmHg, the heart rate is 65 bpm, no drug abuse, and the HIV assay is negative. Anesthesia introduction is prolonged due to a defect vaporizer, but no problem is observed in the start of the procedure. After approximately 40 minutes, muscle shivering is observed, and the blood pressure rises. The muscle relaxant dosage is increased, and the shivering dissipates, the blood pressure is restored at the original level. After the surgery is accomplished, they start cessation of medication in order to wake up the patient slowly. However, after several hours at the ICU, there are no signs of awakening.

What has happened?

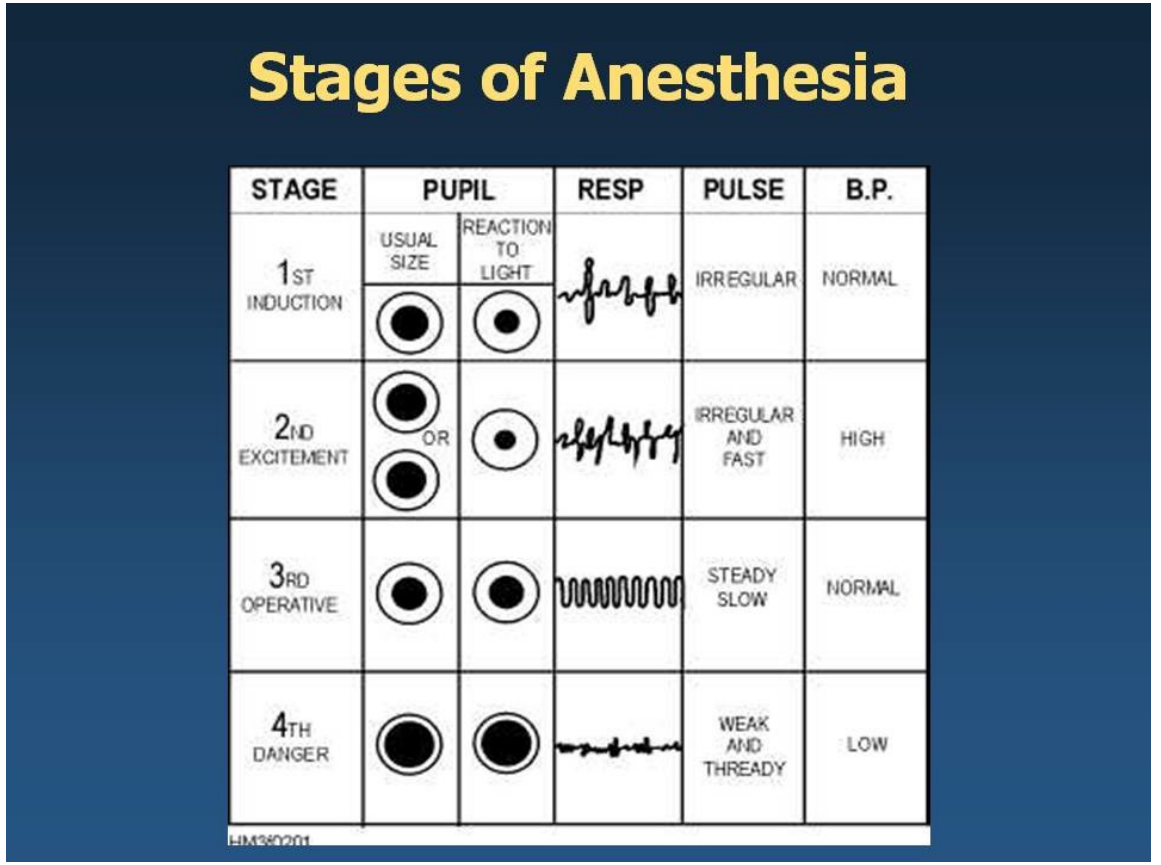
Anesthesia

- Anesthesia is defined as abolition of sensation
- Analgesia is defined as abolition of pain
- The “triad” of anesthesia is:
  - Unconsciousness of the patient
  - Analgesia of the patient
  - Muscle relaxation

Challenge:

- What is consciousness? How to measure it?
- A delicate balance: too little sedation and the patient can feel the pain, too much and the patient dies

Stages of Anesthesia



http://telemedicine.orbis.org/data/1/rec_imgs/13830_Slide19.JPG

The short history of anesthesia



The effect of anesthesia

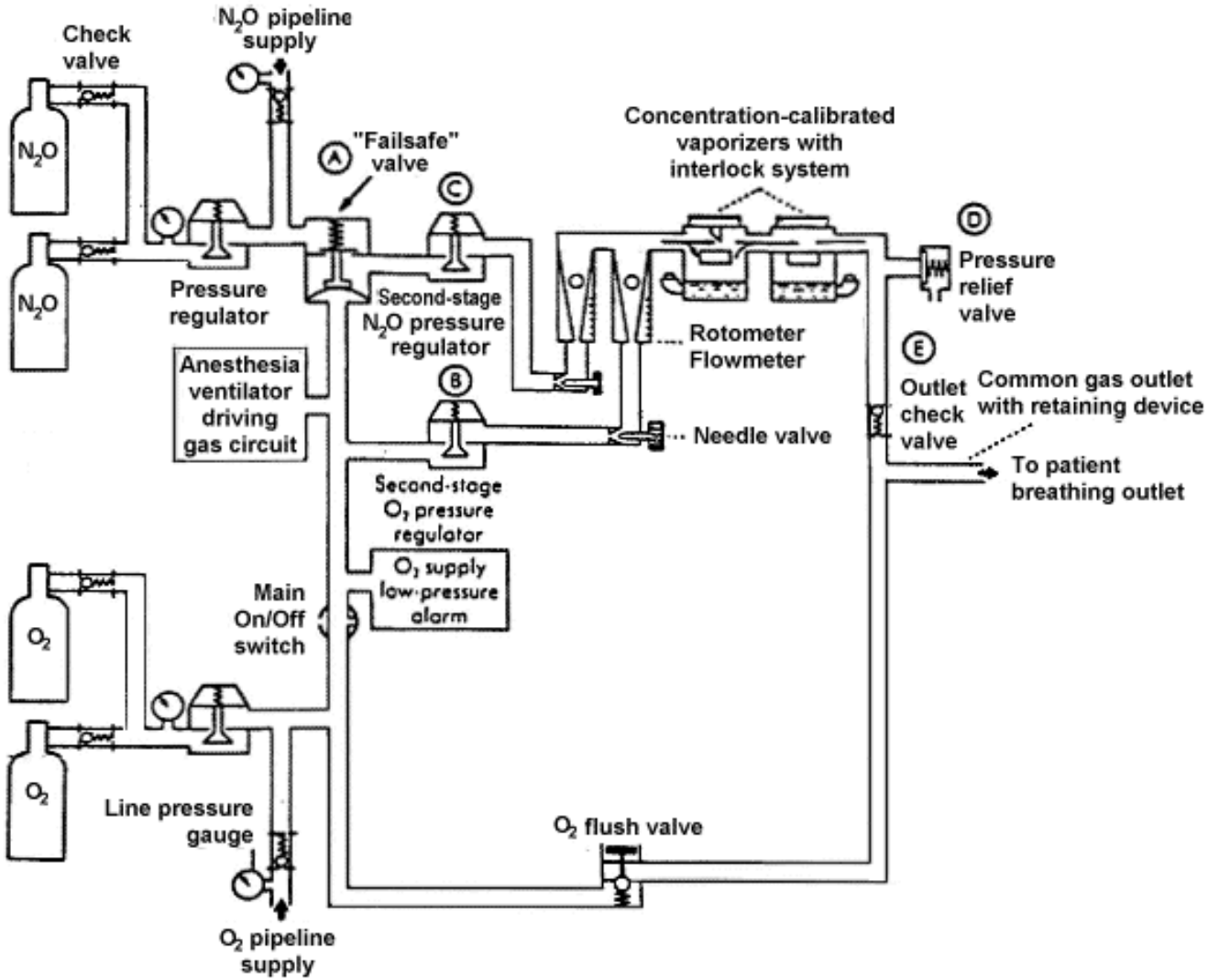


The Anesthesia Workstation



www.medicalexpo.com

Anesthesia machine, overview



The Anesthesia Workstation

Main functions:

a. Provide anesthetic drugs in correct concentration
b. Take care of the waste
c. Ventilate the patient
d. Monitor the vital signs during anesthesia



Main concerns:

1. Wrong gas concentrations
2. High pressure
3. Rebreathing
4. Leakages

www.medicalexpo.com

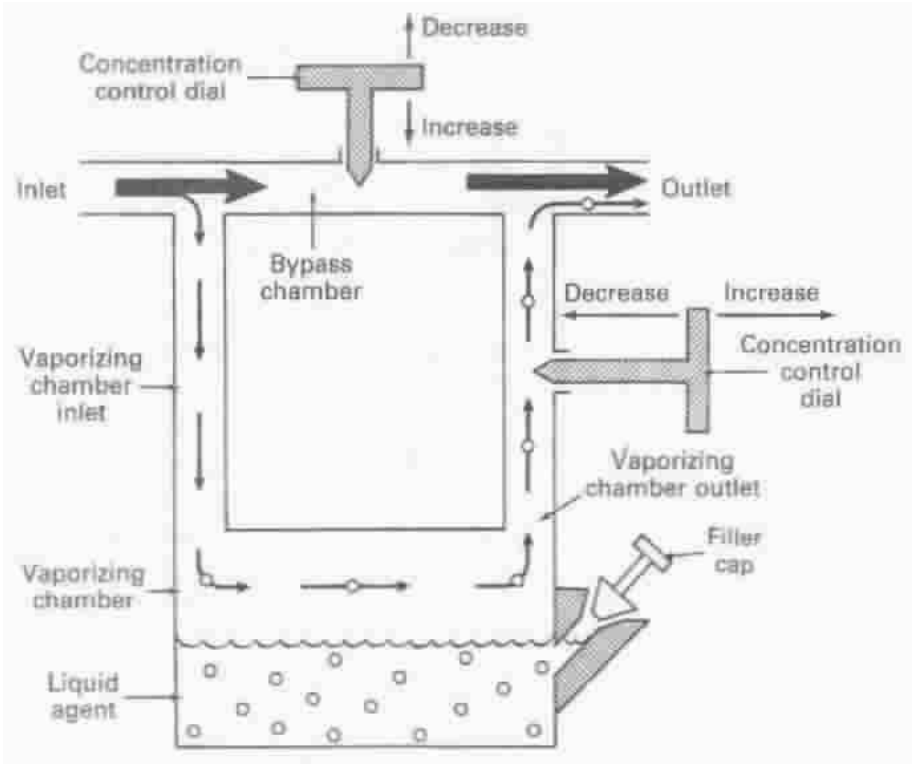
a. Provide anesthetic drugs in right concentration





The vaporizer

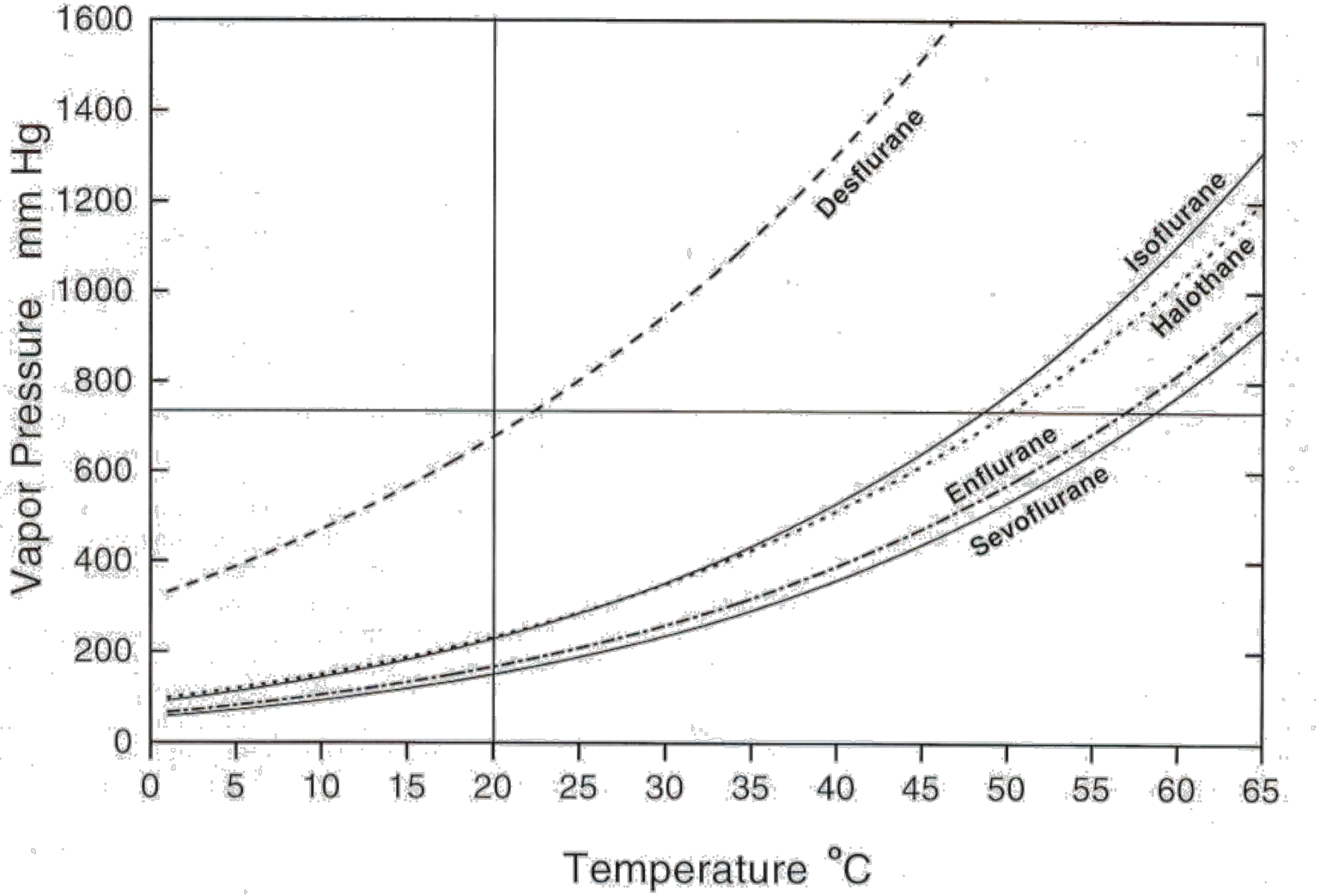
A vaporizer will change the liquid anesthetic agent into a vapor and insert a certain amount of this vapor into the fresh gas flow

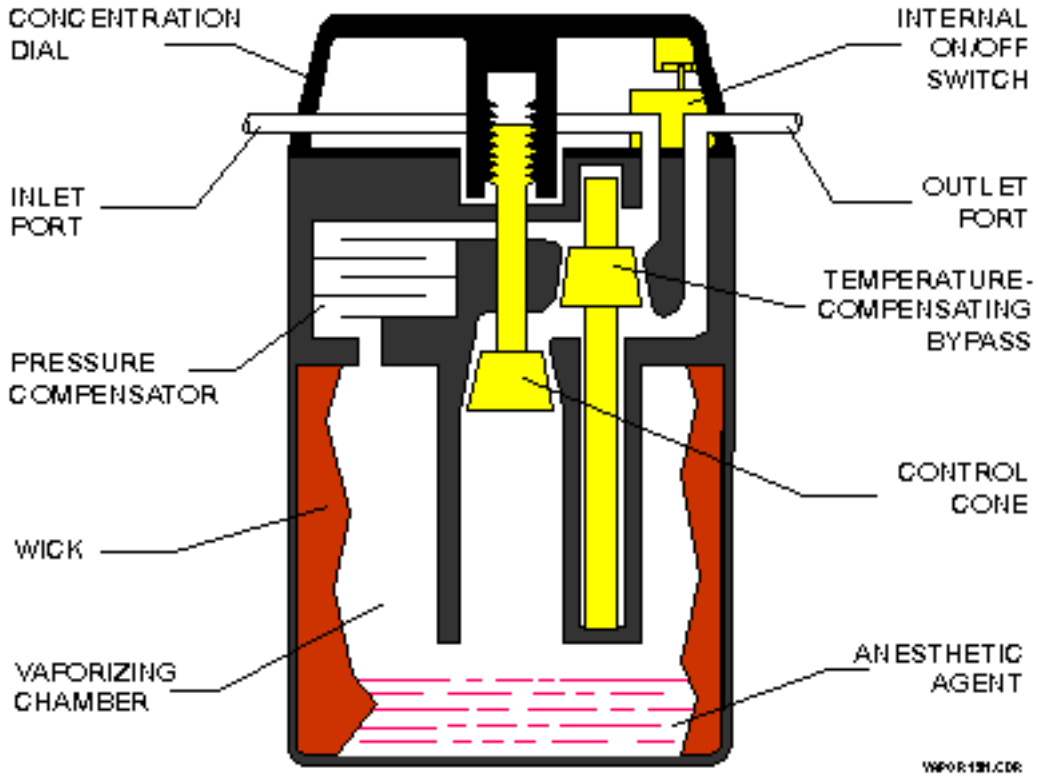


http://www.vajira.ac.th

Main source of error?

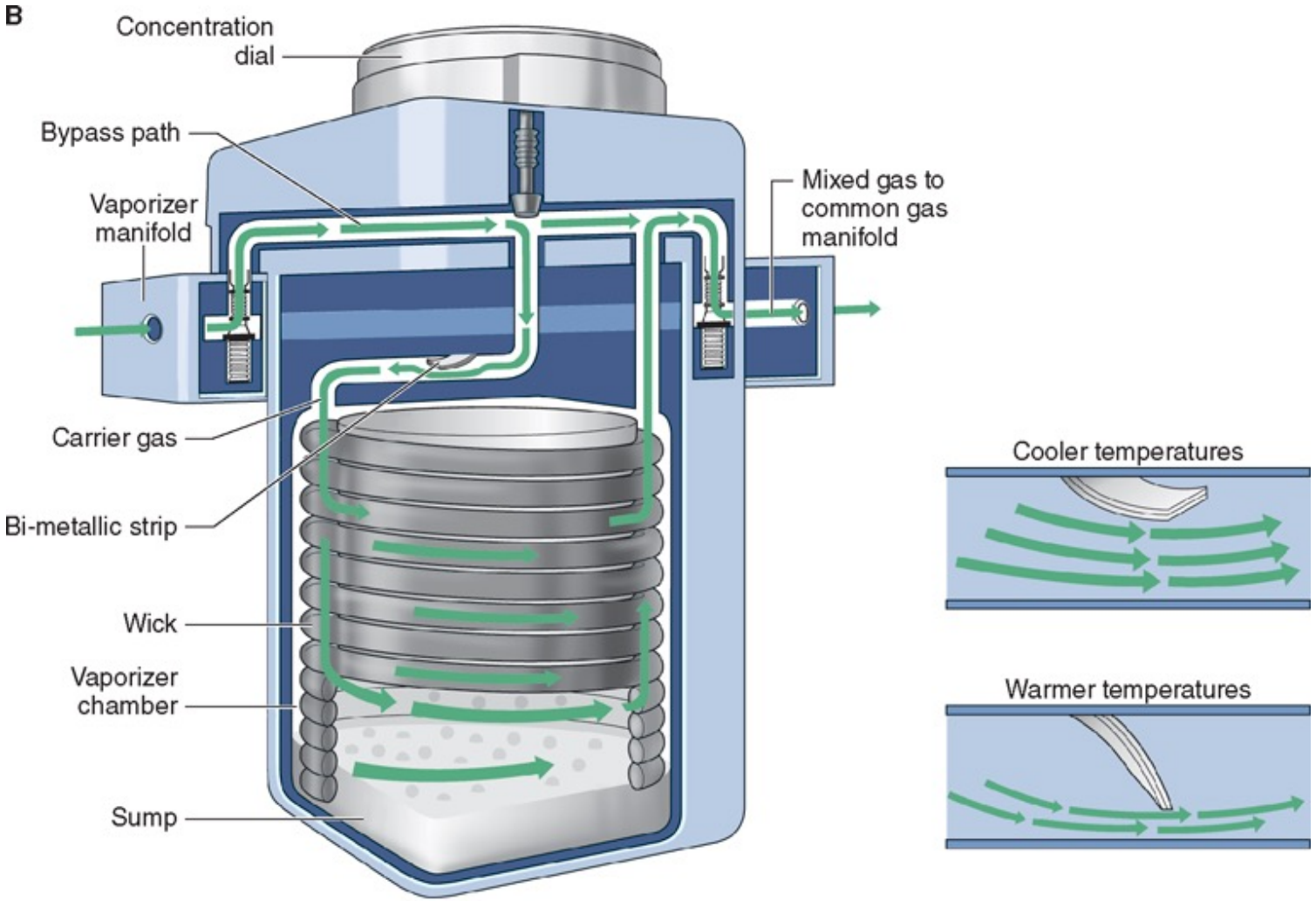
Temperature compensation





http://www.anesthesia2000.com/physics/Chemistry_Physics/physics17.htm

Vaporizer with temperature compensation

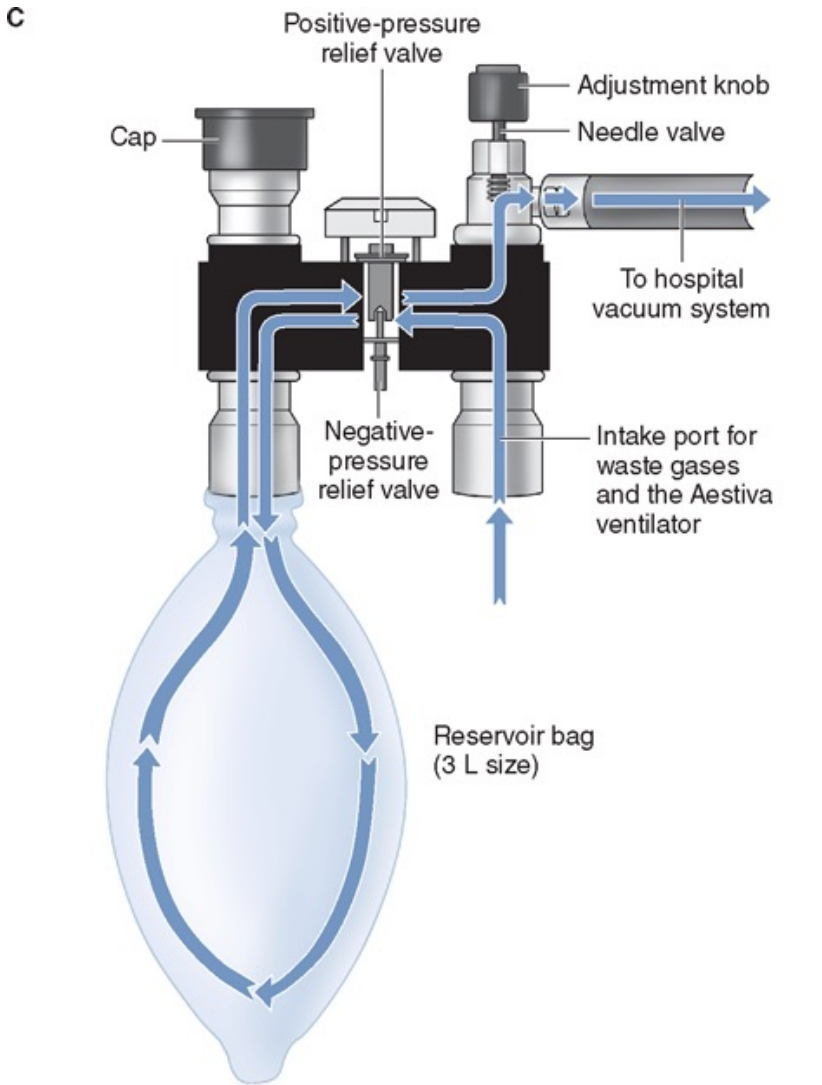


Source: Butterworth JF, Mackey DC, Wasnick JD: *Morgan & Mikhail's Clinical Anesthesiology*, 5th Edition: www.accessmedicine.com

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b. Scavenging system

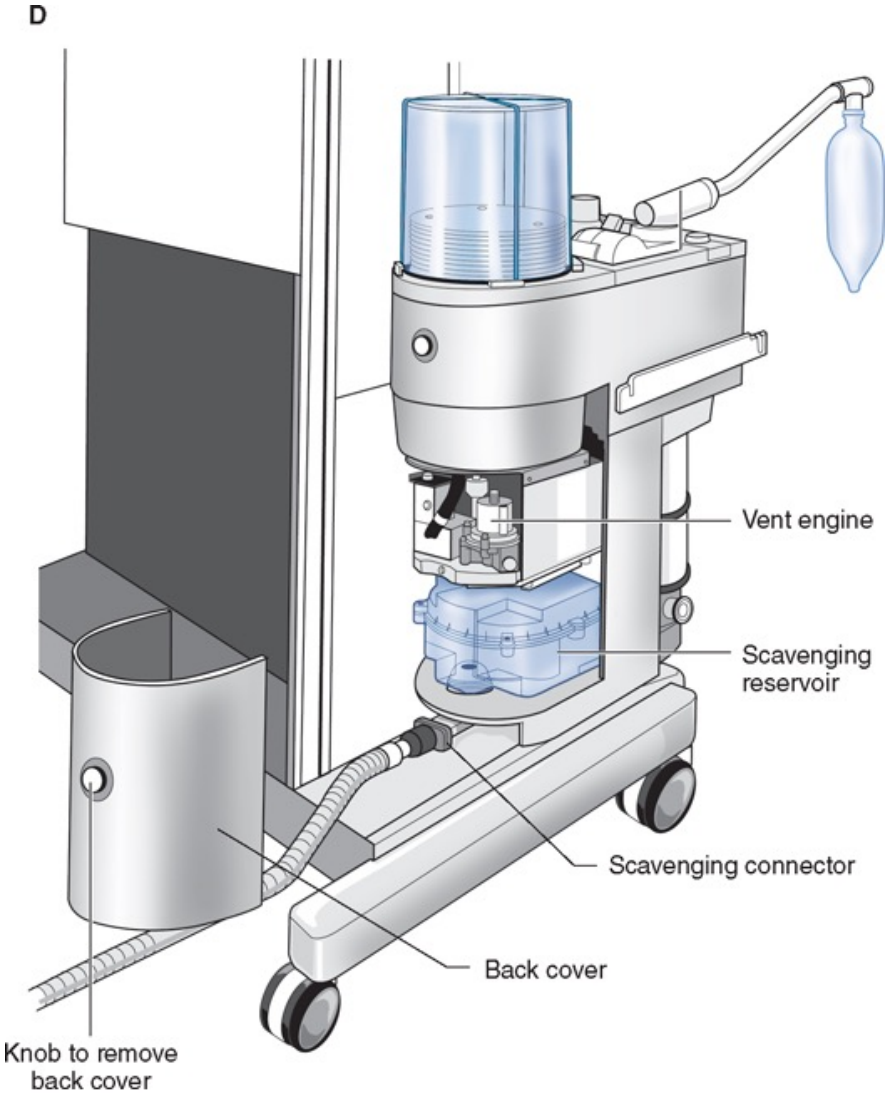
Scavenging system



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

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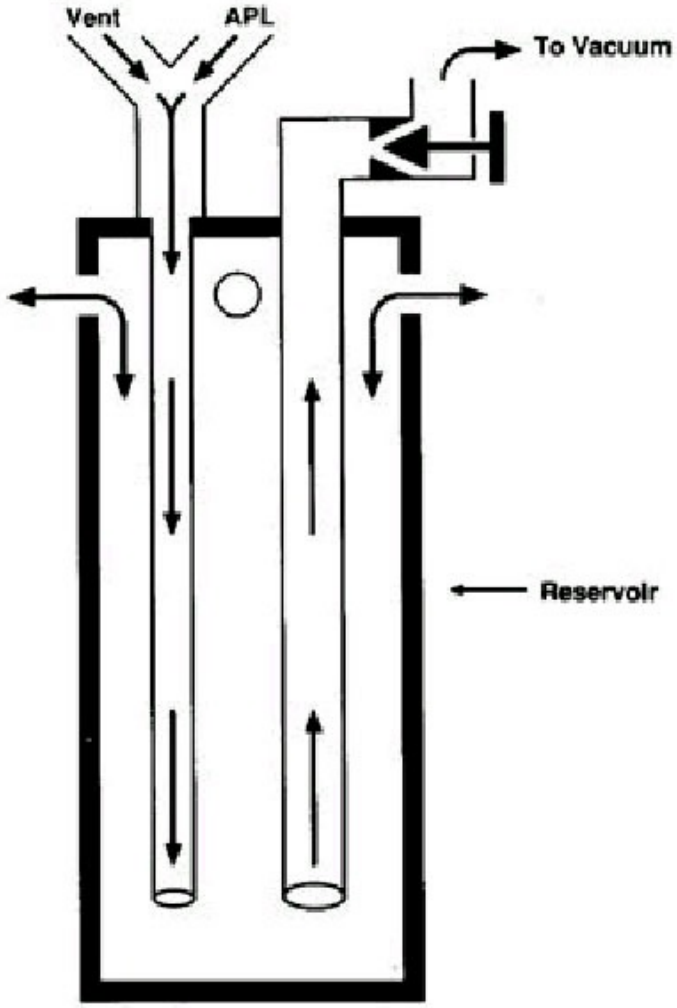
Scavenging system



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

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Scavenging system





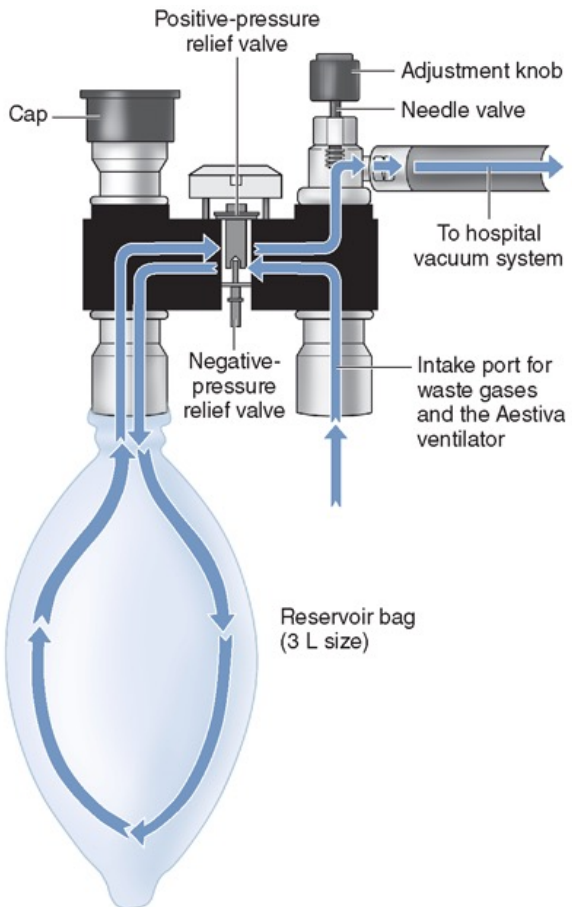
Dräger open scavenging interface

Exercise

Form groups of 2 or 3 students, and discuss:

a. What could happen if the positive pressure relief valve from the scavenging system does not work properly?

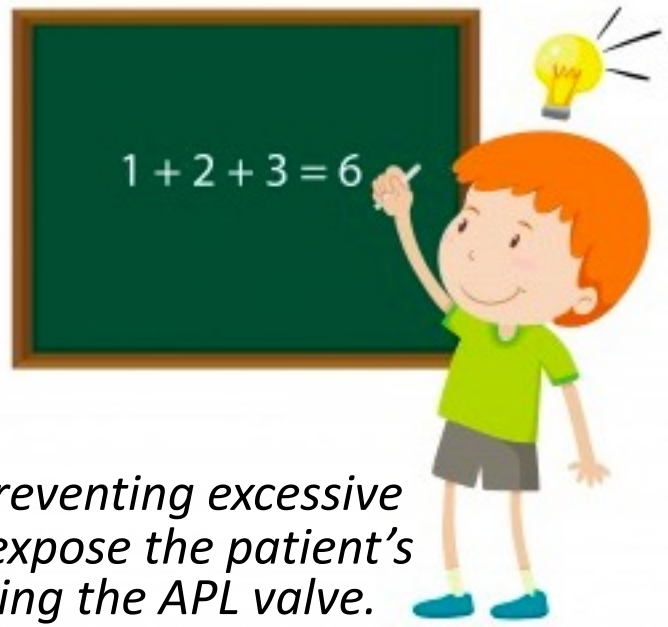
b. What could happen if the negative pressure relief valve from the scavenging system does not work properly?





http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

Answers



a. *The positive pressure relief valve is made for preventing excessive pressures in the circle which would otherwise expose the patient's lungs to dangerous pressures indirectly by closing the APL valve. (Remember that the scavenging system is a part of the patient circle)*

b. *The negative pressure relief valve will be activated when the scavenging system is adjusted to remove more gas than the anesthesia workstation can provide. Otherwise, a negative pressure can collapse the bag and eventually the lungs*

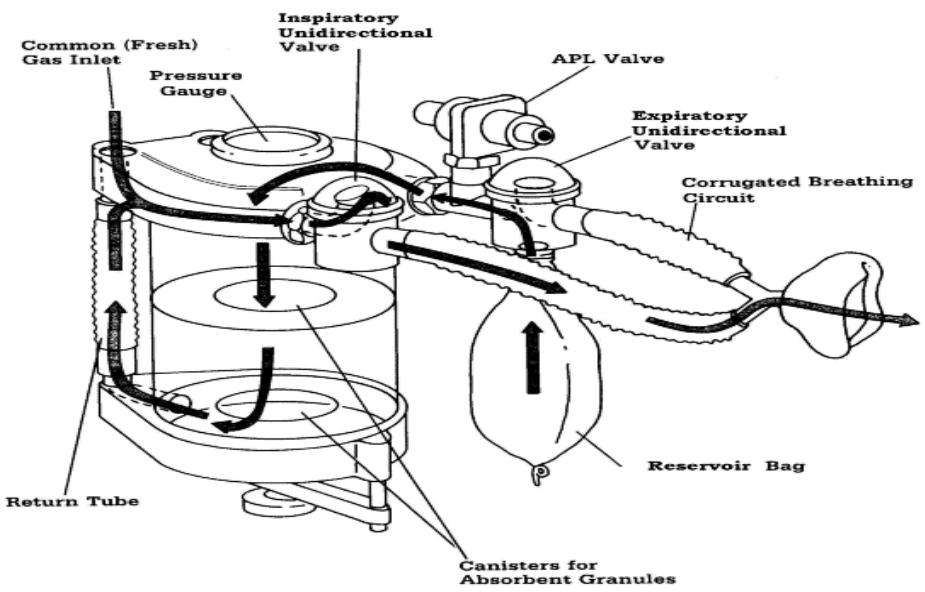
c. Ventilate the patient

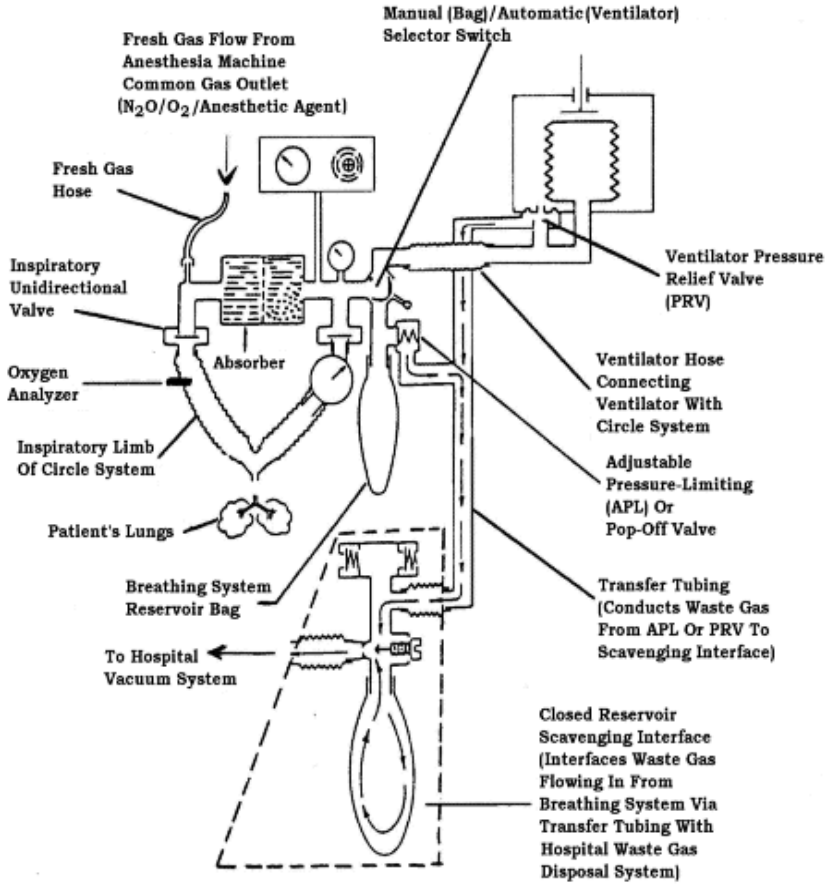




Breathing Systems

Will protect the breathing circuit from excessive pressures



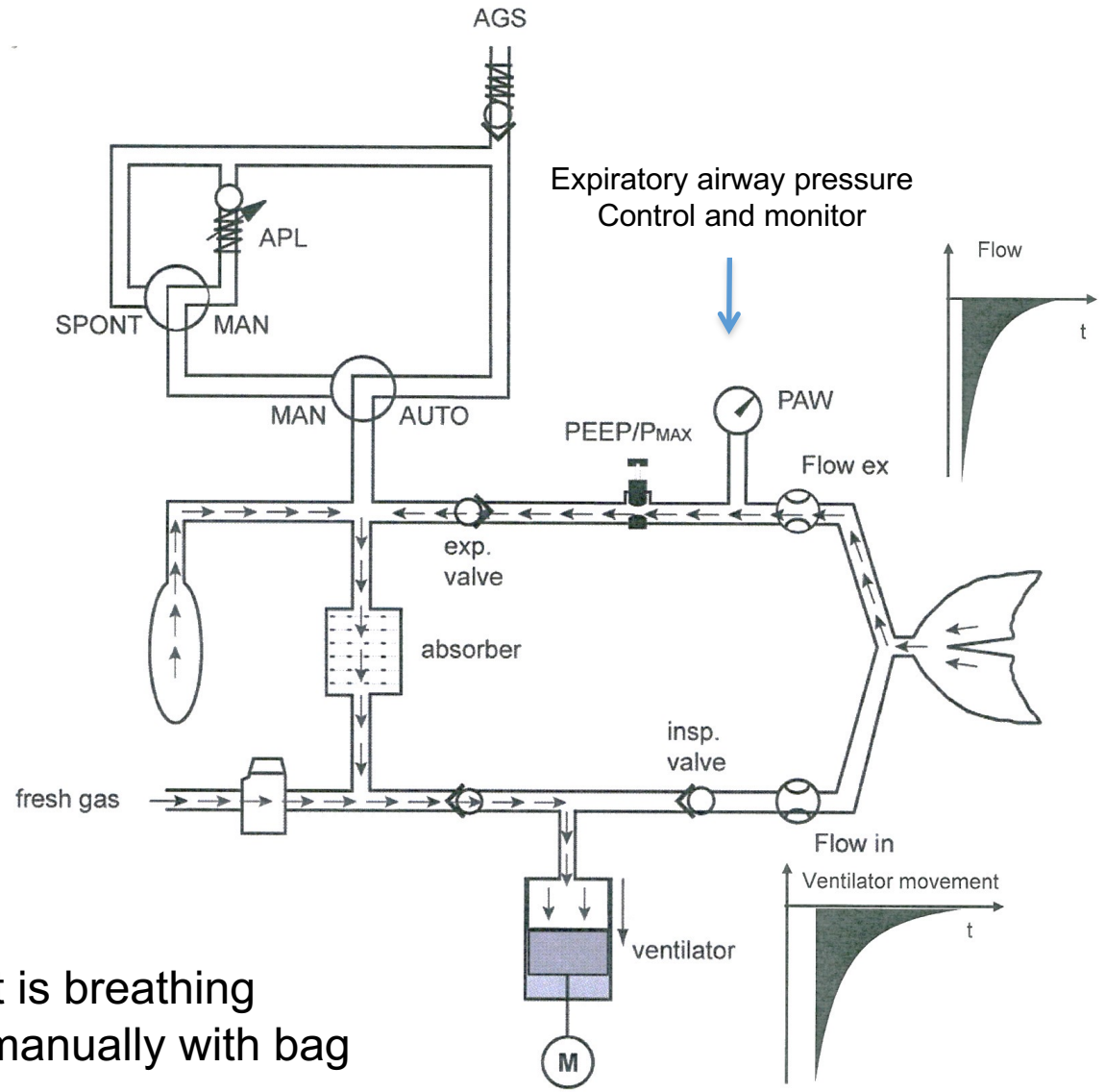


http://www.vajira.ac.th

Anesthetic gas scavenging system

Adjustable pressure limiting valve provide control of the pressure in the breathing circle

The patient circle

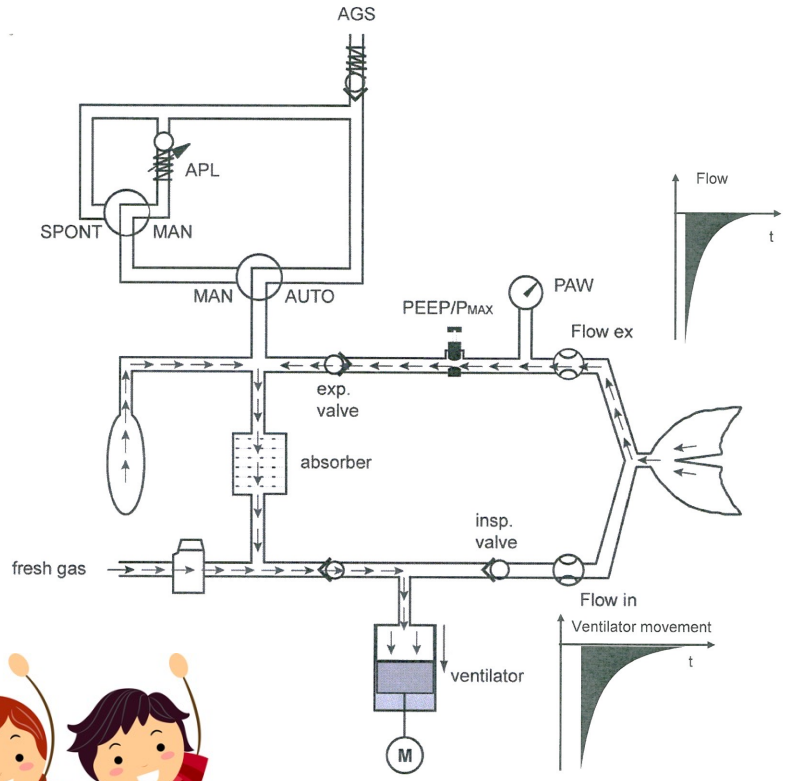


Three modi:
Spontanous – Patient is breathing
Manual - Ventilating manually with bag
Auto - Ventilator

Exercise

Form groups of 2 or 3 students, and discuss:

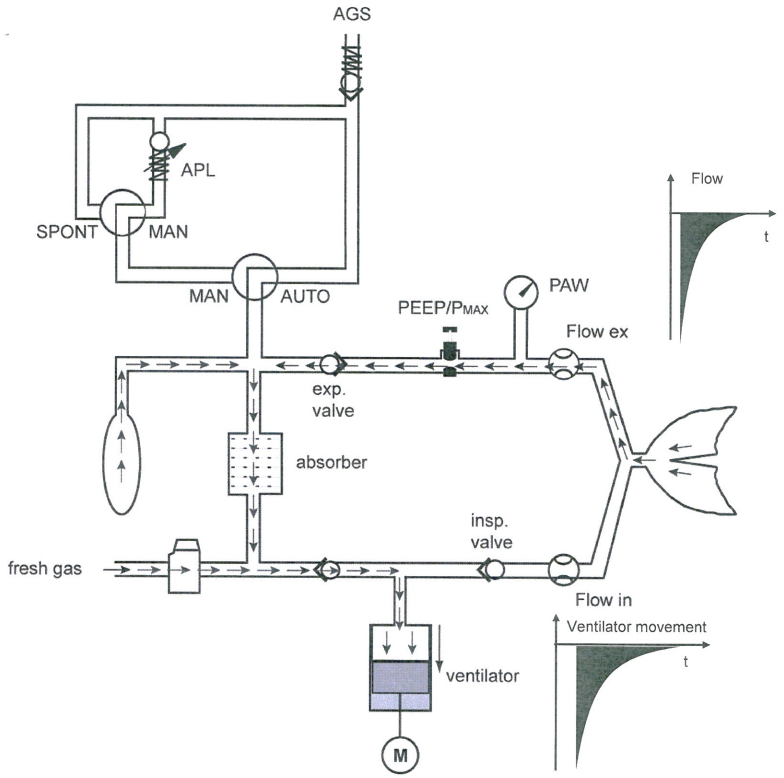
a. Why is the APL-valve bypassed in automatic ventilation?

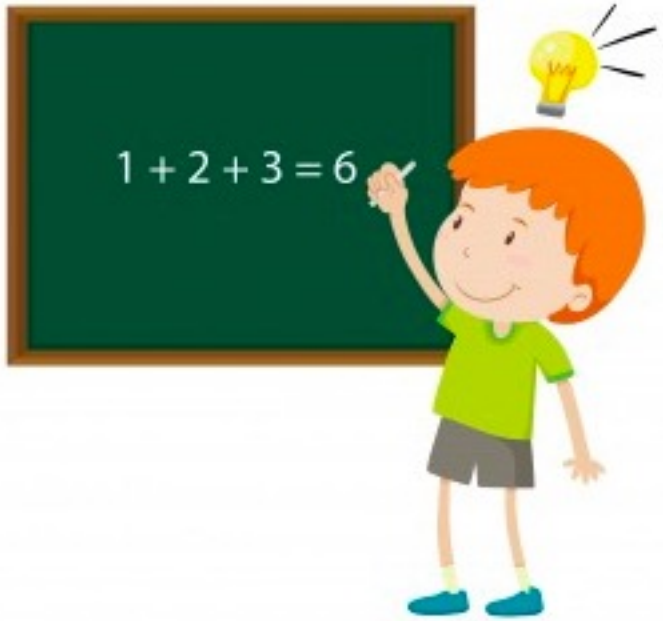




http://integrativeosteopathy.com.au/wp-content/uploads/2015/08/Exercise.jpg

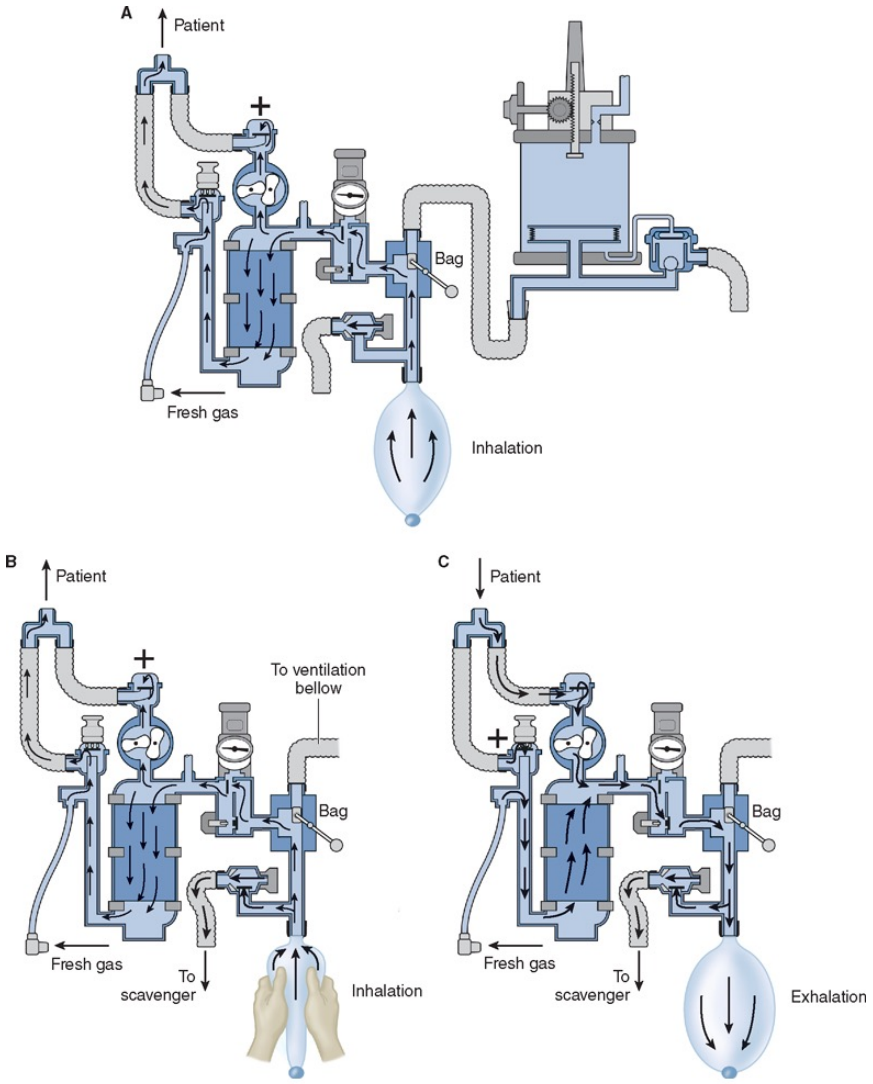
Answers





a. *The APL-valve is active for manual ventilation only because the automatic ventilation is so precise and well-monitored that excessive pressure is most unlikely in this mode. The spontaneous mode is semi-automatic (the patient is breathing with help from the machine)*

Inhalation/exhalation with bag (Manual ventilation)



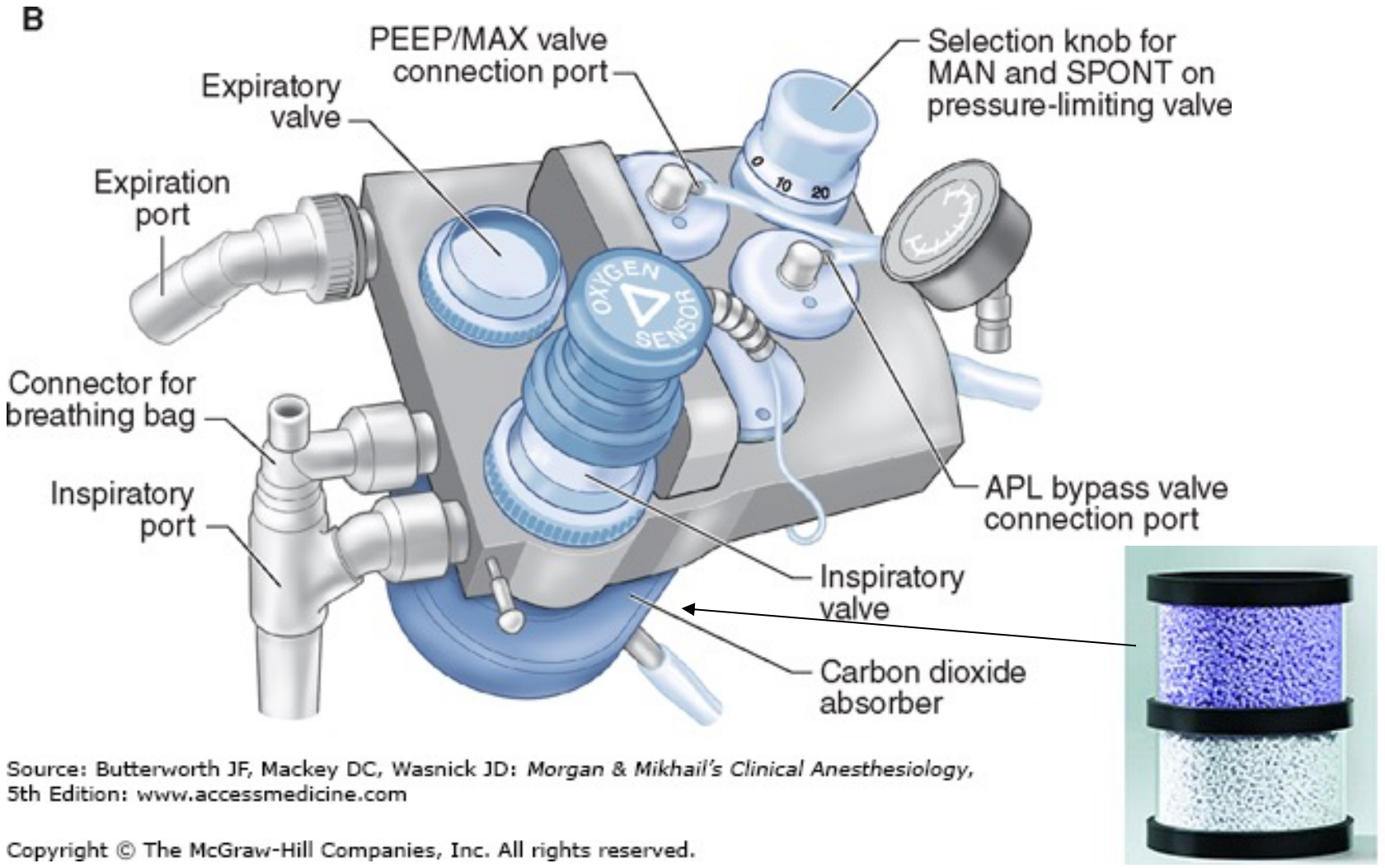
Source: Butterworth JF, Mackey DC, Wasnick JD: *Morgan & Mikhail's Clinical Anesthesiology*, 5th Edition: www.accessmedicine.com

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Exhalation
Air from the patient together with fresh gas is filling the bag, the excess is evacuated through the APL-valve

Inhalation
The bag is squeezed and the air is pushed through the calc absorber (soda lime) into the patient. The exhalation valve makes sure that there is no backflow of air (Rebreathing)

Patient casette



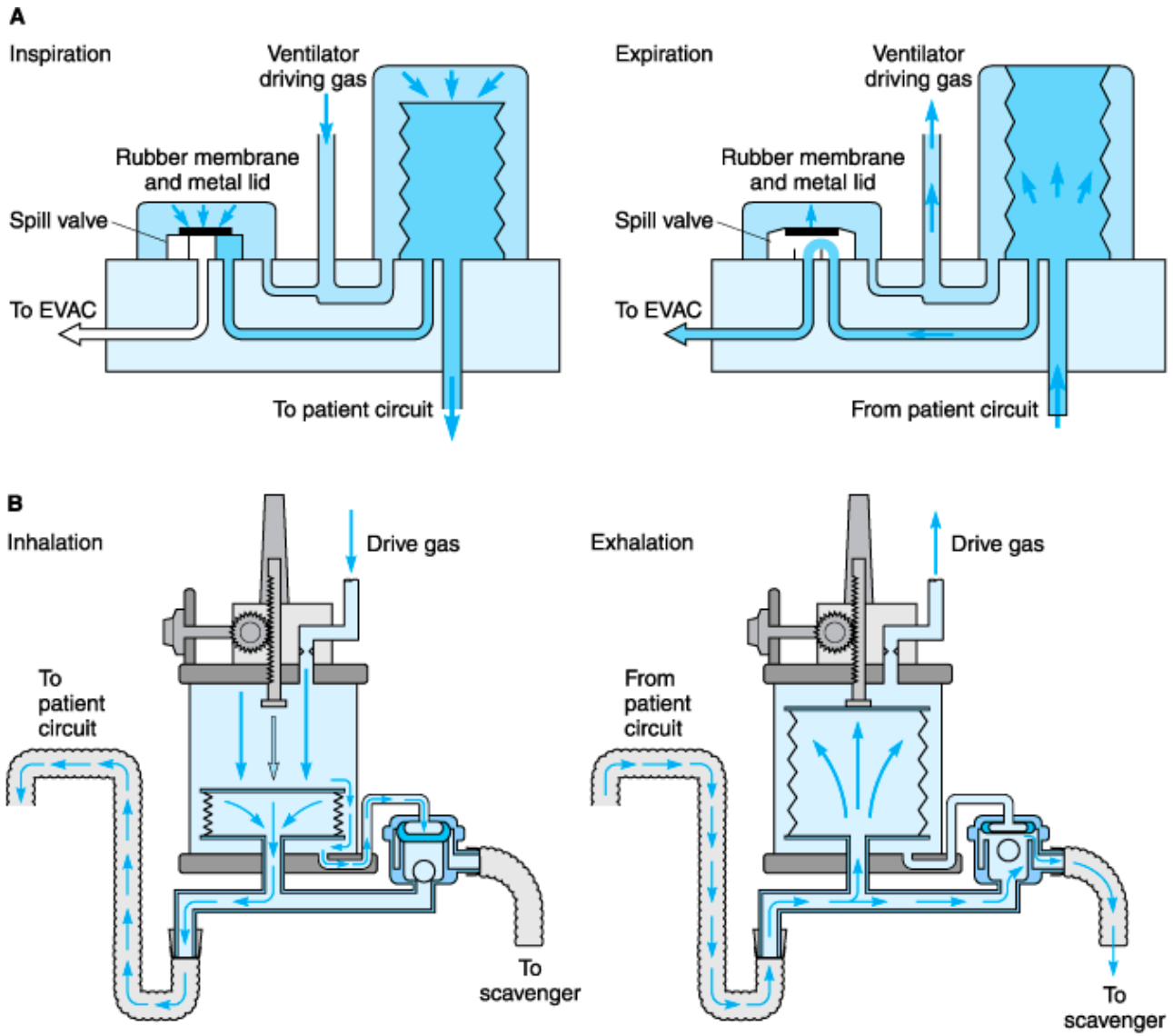
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Source: AccessAnesthesiology McGrawHill medical

https://www.osha.gov/dts/osta/anestheticgases/

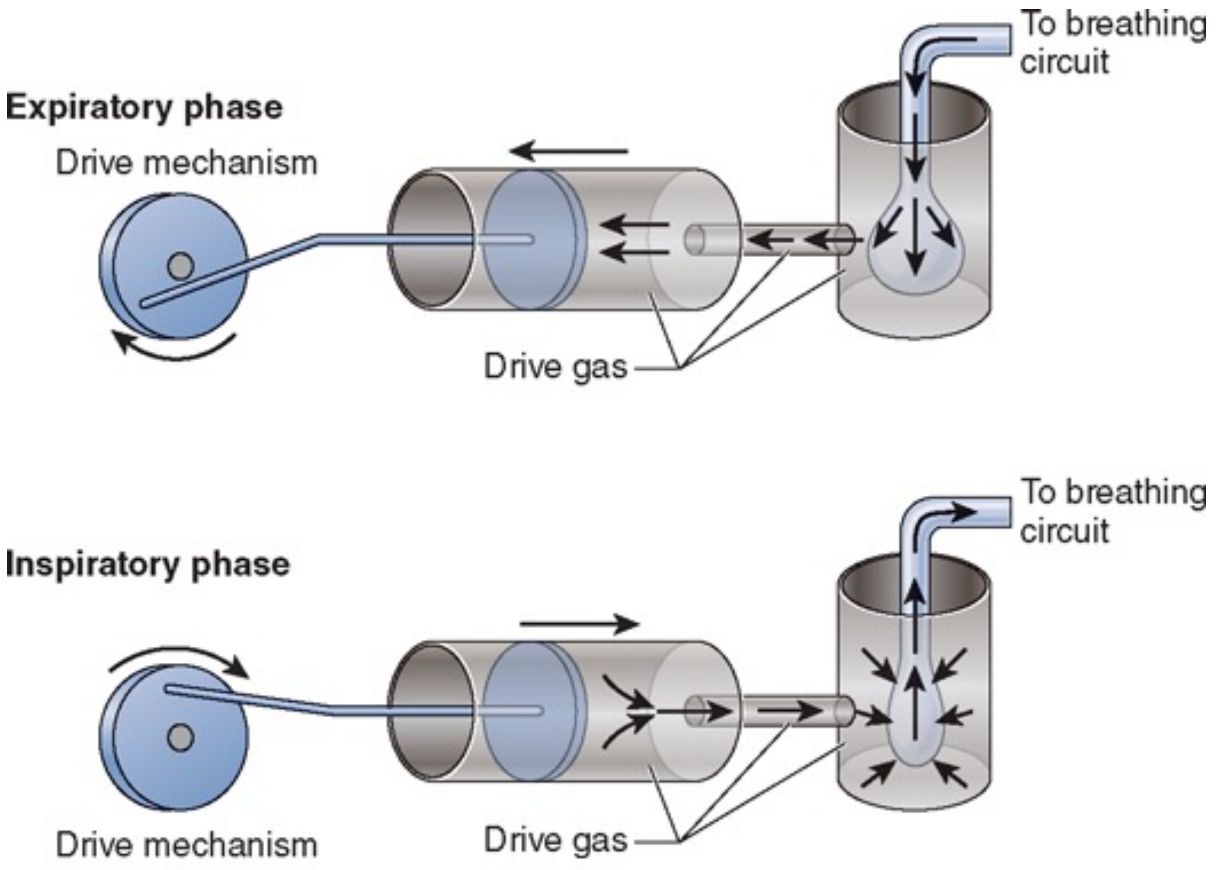
Bag in bottle



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Piston air supply

- Only low flow rates
- Precise gas mixture
- Control with minute volume
- Cannot compensate for leakages
- Better gas economy
- Quieter operation



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

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Turbine flow

- *Higher flow rates can be generated, up to 240 L/min*
- *Can compensate for leakages (in masks e.g.)*
- *Does not need compressed air supply*
- *Short delay, fast response*
- *Less moving parts*
- *Less precise gas mixture*

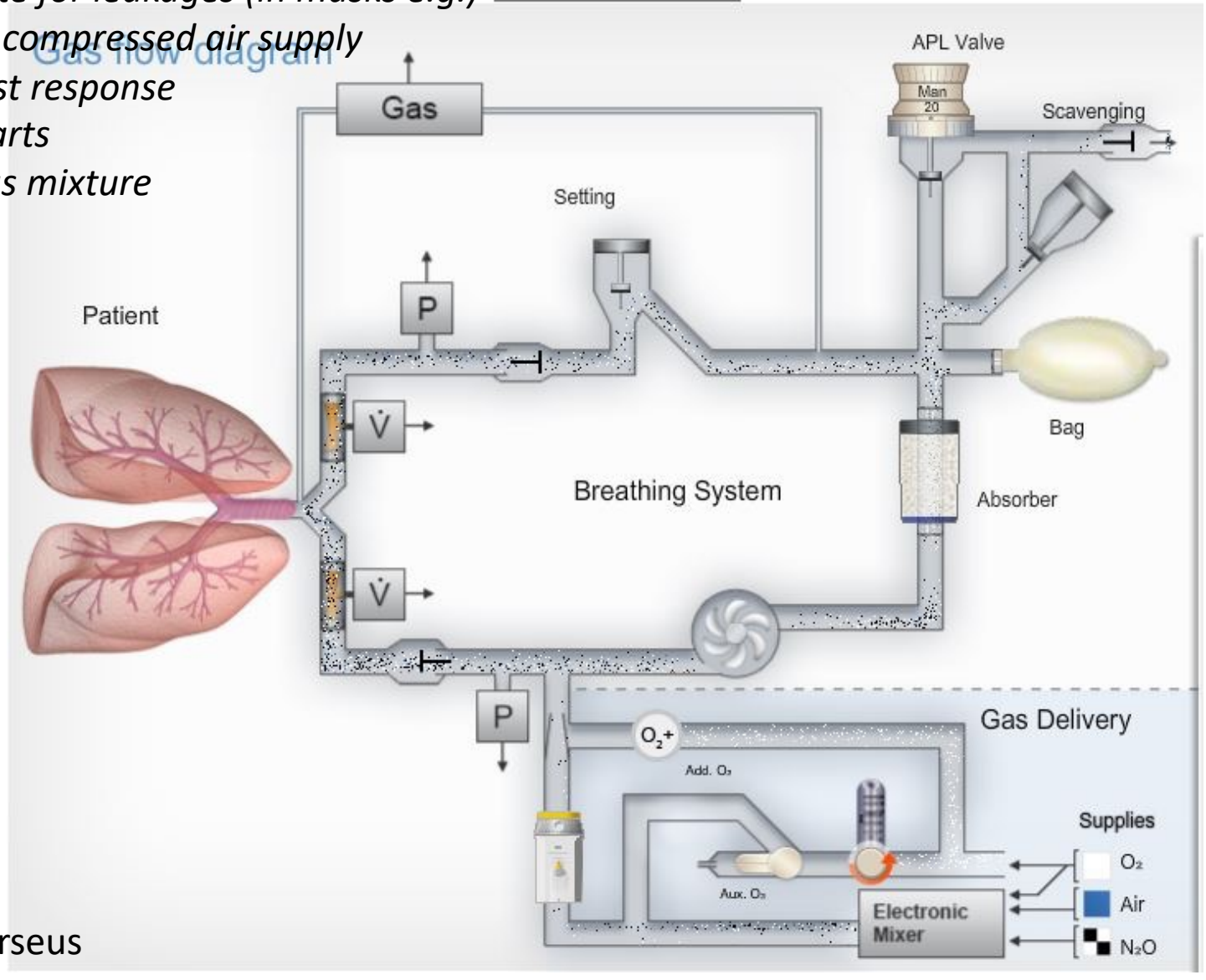
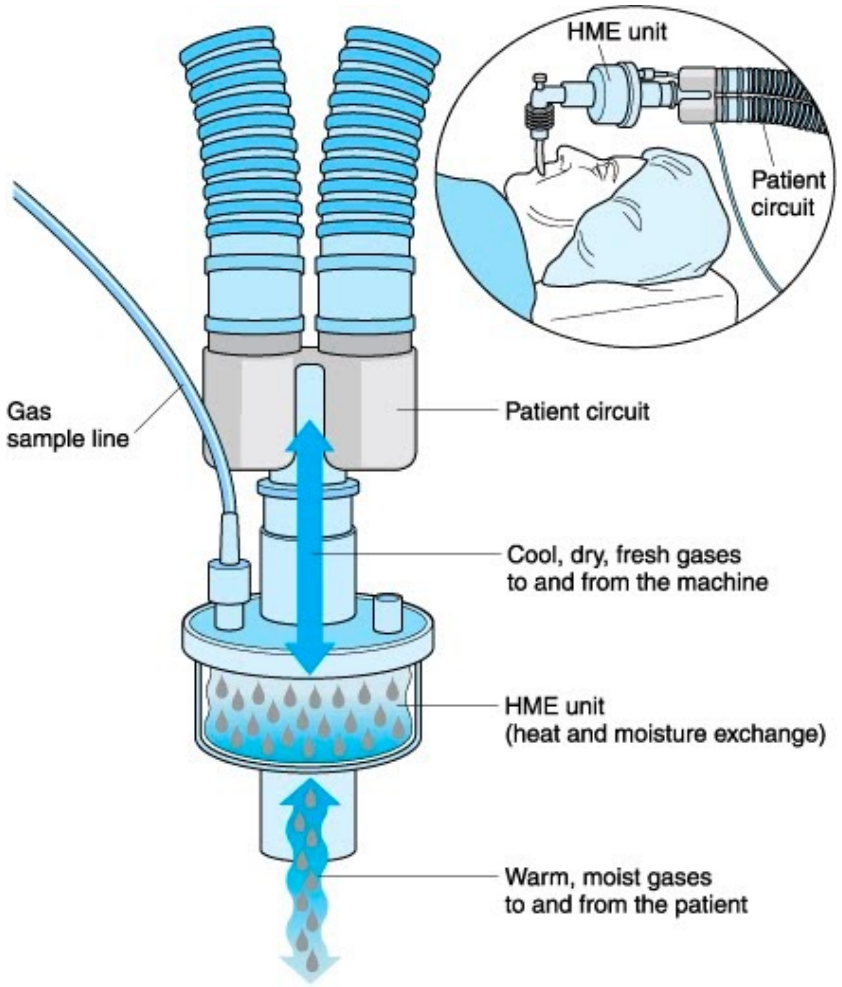


Image: Dräger Perseus

Patient tubing and HME unit

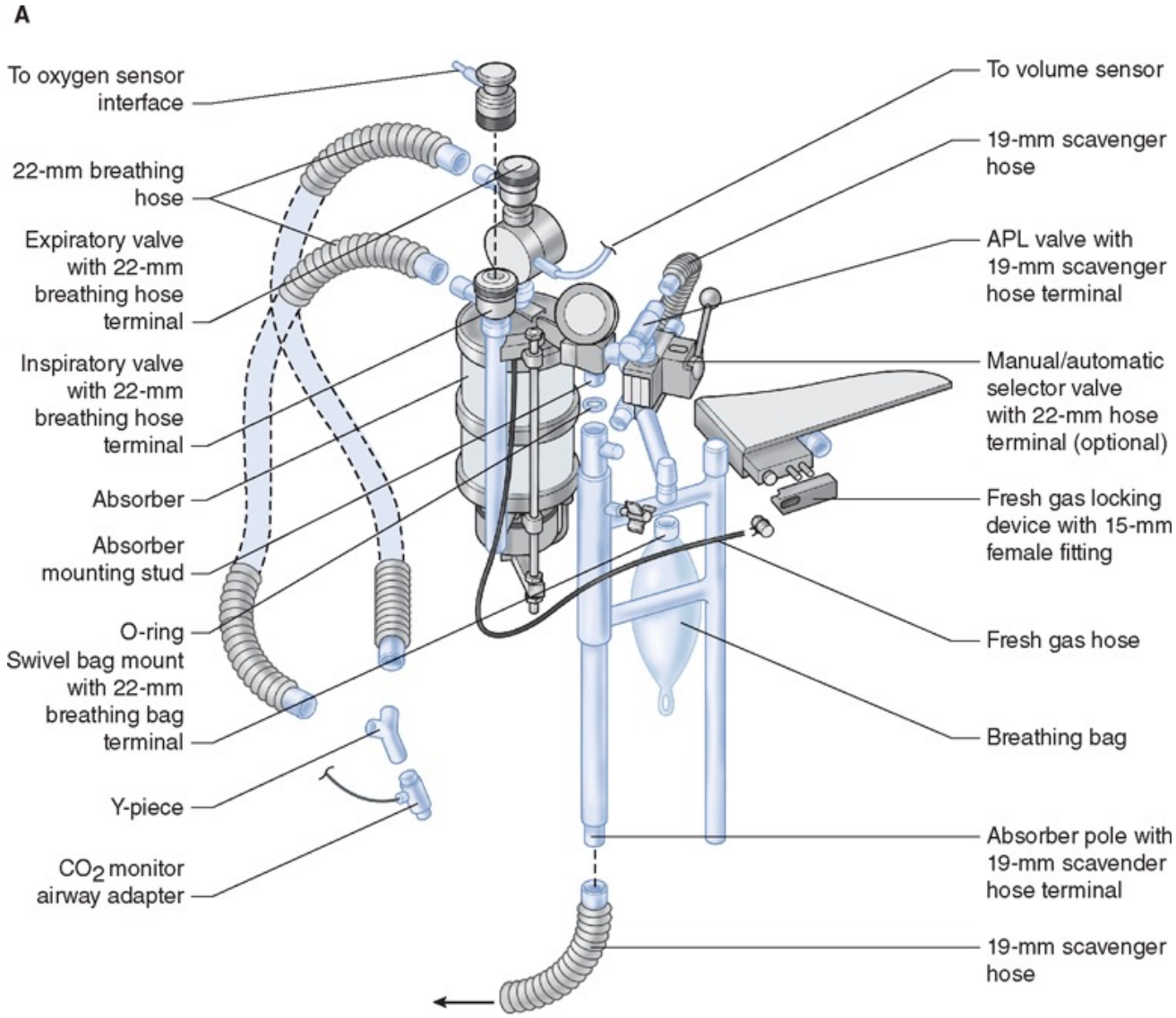
Gas sampling line is used for sidestream multigas measurement. What is the most common gas measured?



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HME unit, a filter which is exchanging heat and moisture between inhalation gas and exhalation gas. Introducing increased resistance in the circle

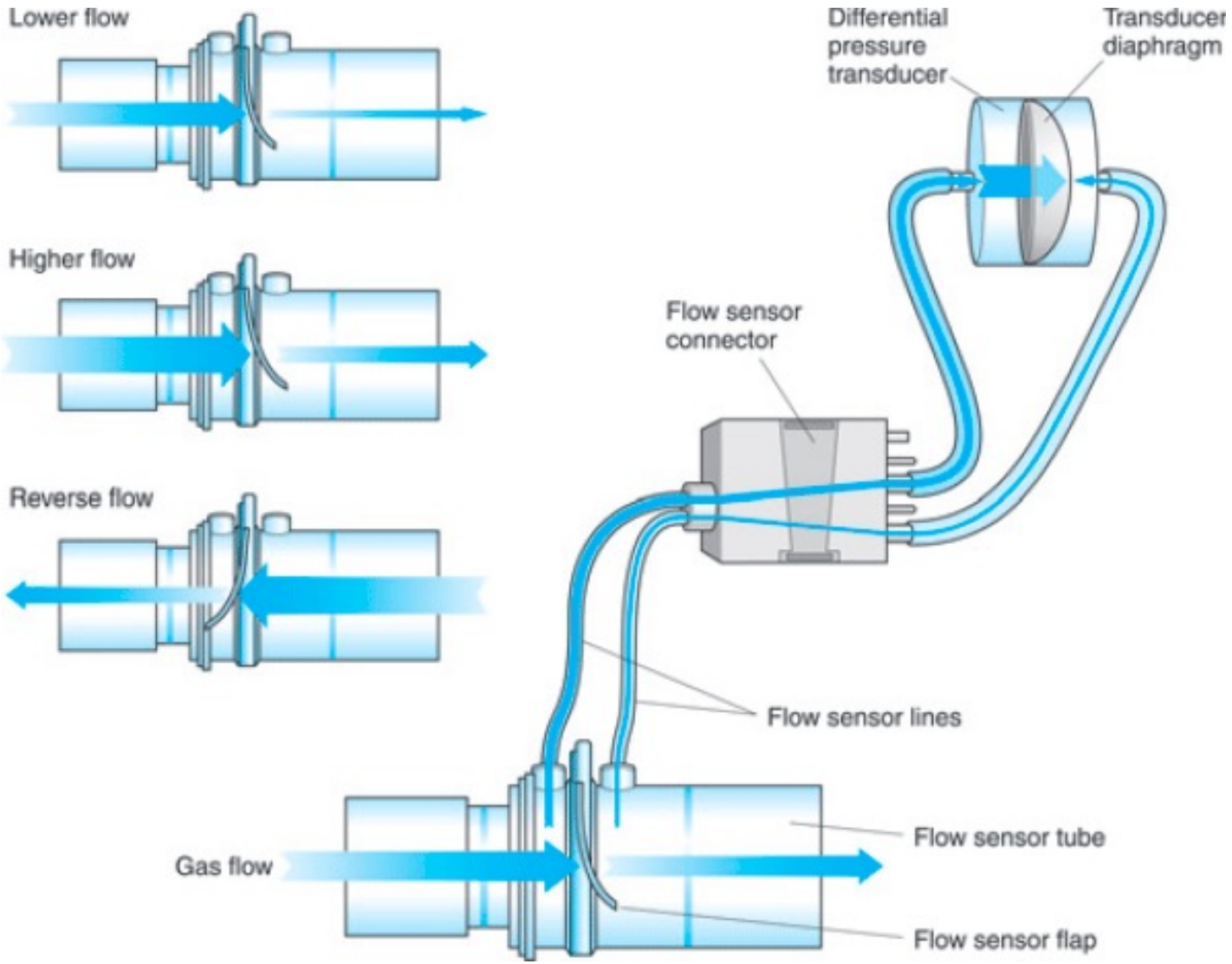
Patient tubing and connections



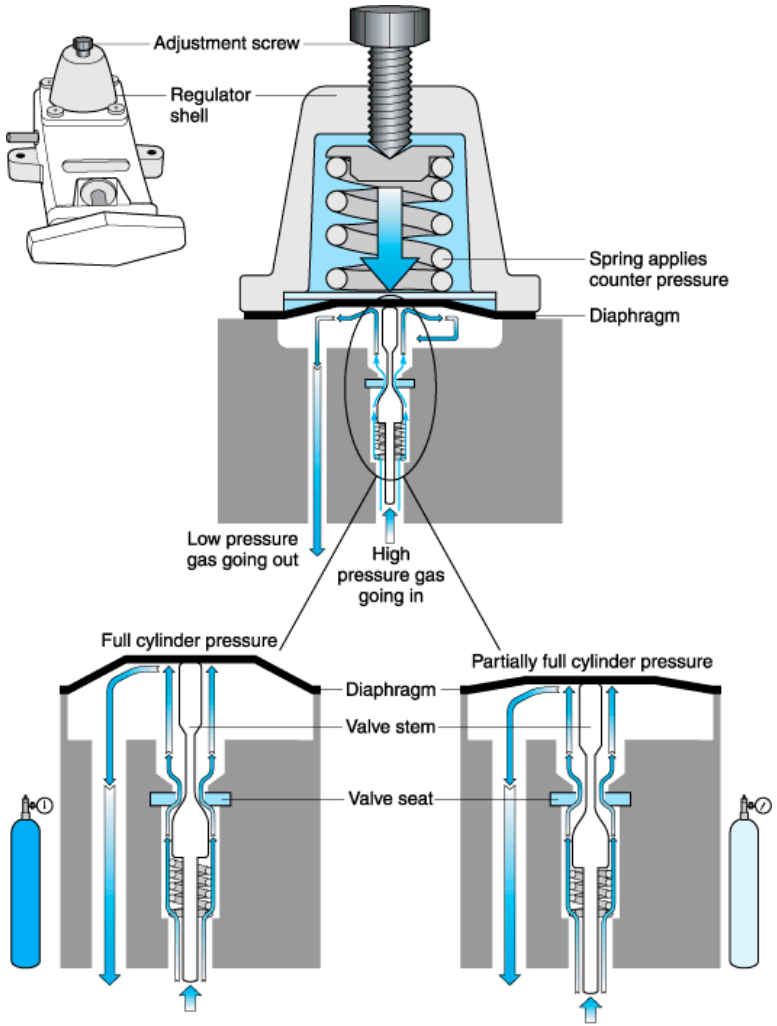
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Flow sensors, vane flow and differential flow



Pressure regulator



Source: Morgan GE, Mikhail MS, Murray MJ: *Clinical Anesthesiology*, 4th Edition: http://www.accessmedicine.com

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d. Monitor vital signs



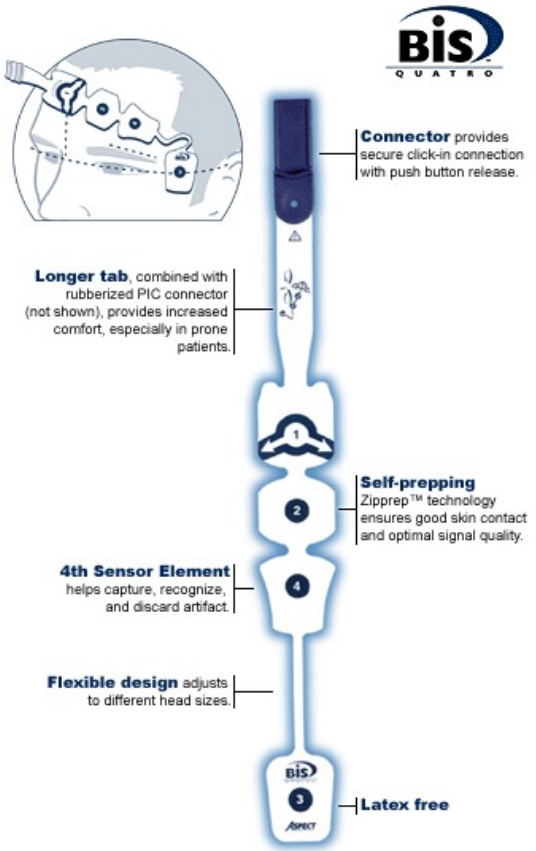
Anesthetic monitoring

- Connecting it all together, what is necessary?
  - ECG
  - Blood pressure
  - End tidal CO_2
  - Sleep depth
  - Other?

Sleep depth: Bispectral index score (BIS)



http://bcrt.ca/wp-content/uploads/2009/07/bis.jpg



http://www.firesa.co.za/medical/1f65e210.gif

Bispectral index score (BIS)

- Based on EEG-measurements. A sensor placed on the forehead registers raw EEG-signals, transmits to a monitor which filters and digitalizes the EEG signal. Advanced pattern recognition calculate a value (BIS-score) from 0 (Isoelectric EEG) to 100 (completely awake)

http://bcrt.ca/wp-content/uploads/2009/07/bis.jpg

http://www.firesa.co.za/medical/1f65e210.gif

BIS Sources of error

- Hypothermia: Decrease in BIS value
- Sleep: Decrease in BIS value
- Cerebral ischemia: Decrease in BIS value
- Neurological states: Decrease in BIS values
- Encephalopathic states: Decrease in BIS values
- Interference from medical devices: Increase in BIS values
- Low $PaCO_2$: Decrease in BIS values
- And what about the electrodes??

http://bcrt.ca/wp-content/uploads/2009/07/bis.jpg

http://www.firesa.co.za/medical/1f65e210.gif

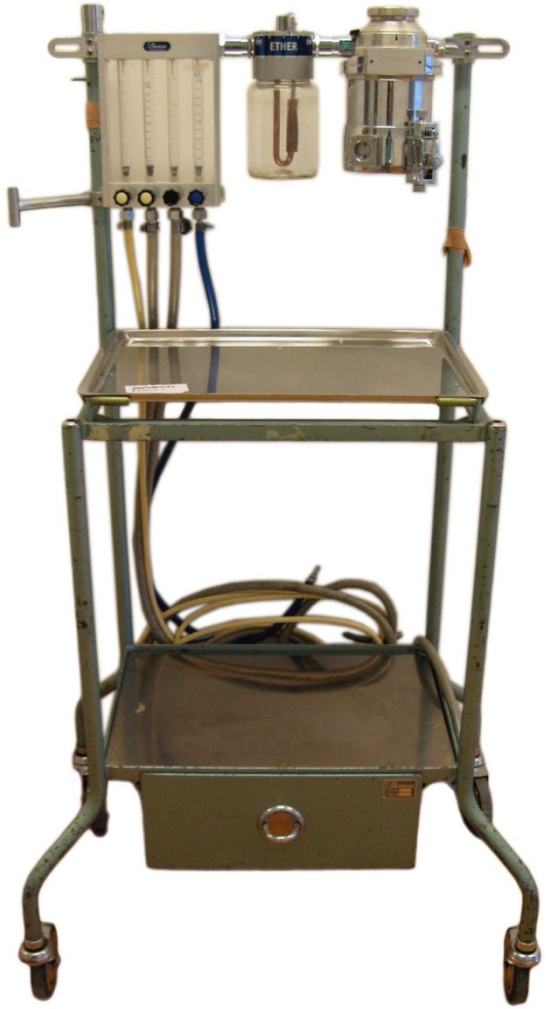
Inside the Anesthesia machine



To understand the inside of the Anesthesia workstation, let’s start with the historical beginning and look at some patient accidents and the safety features that came out of those experiences

1. Wrong gas concentrations

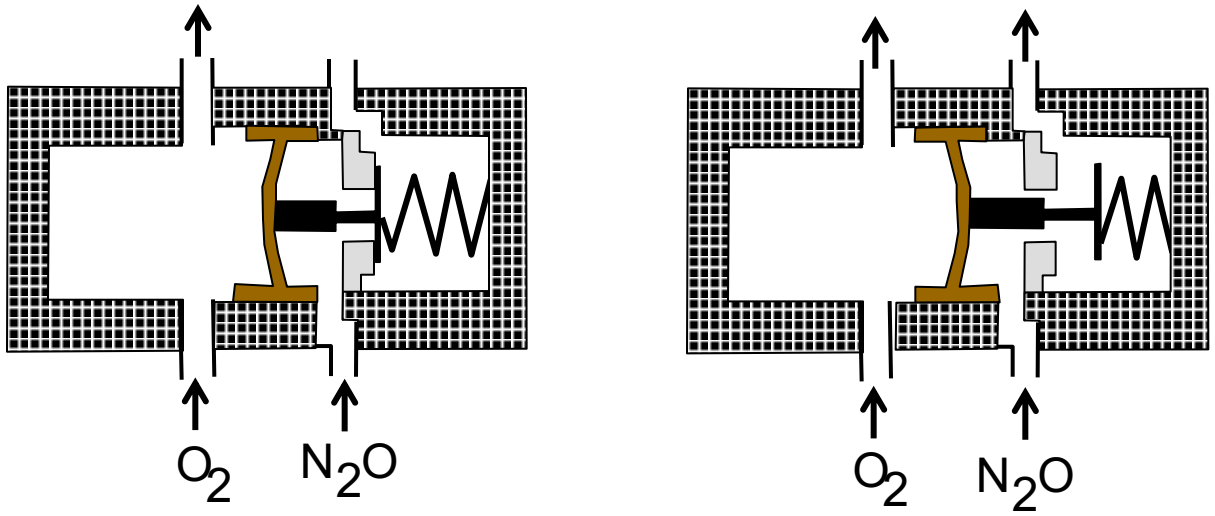
Error: Wrong gas concentrations



Accident: patient did not get adequate oxygen levels

Wrong gas concentrations

Accident: Leakage from O_2 to N_2O



2-room slave regulator

Wrong gas concentrations

Accident: No O2 flow

Berge Grimnes: Gassteknisk medisinsk utstyr Del 2

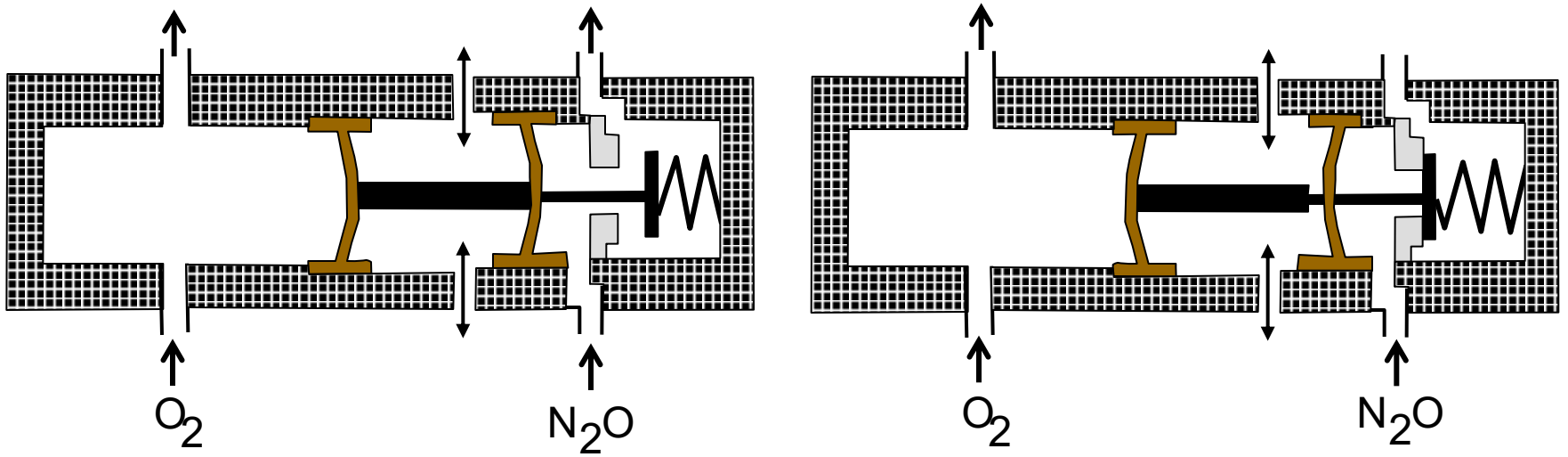
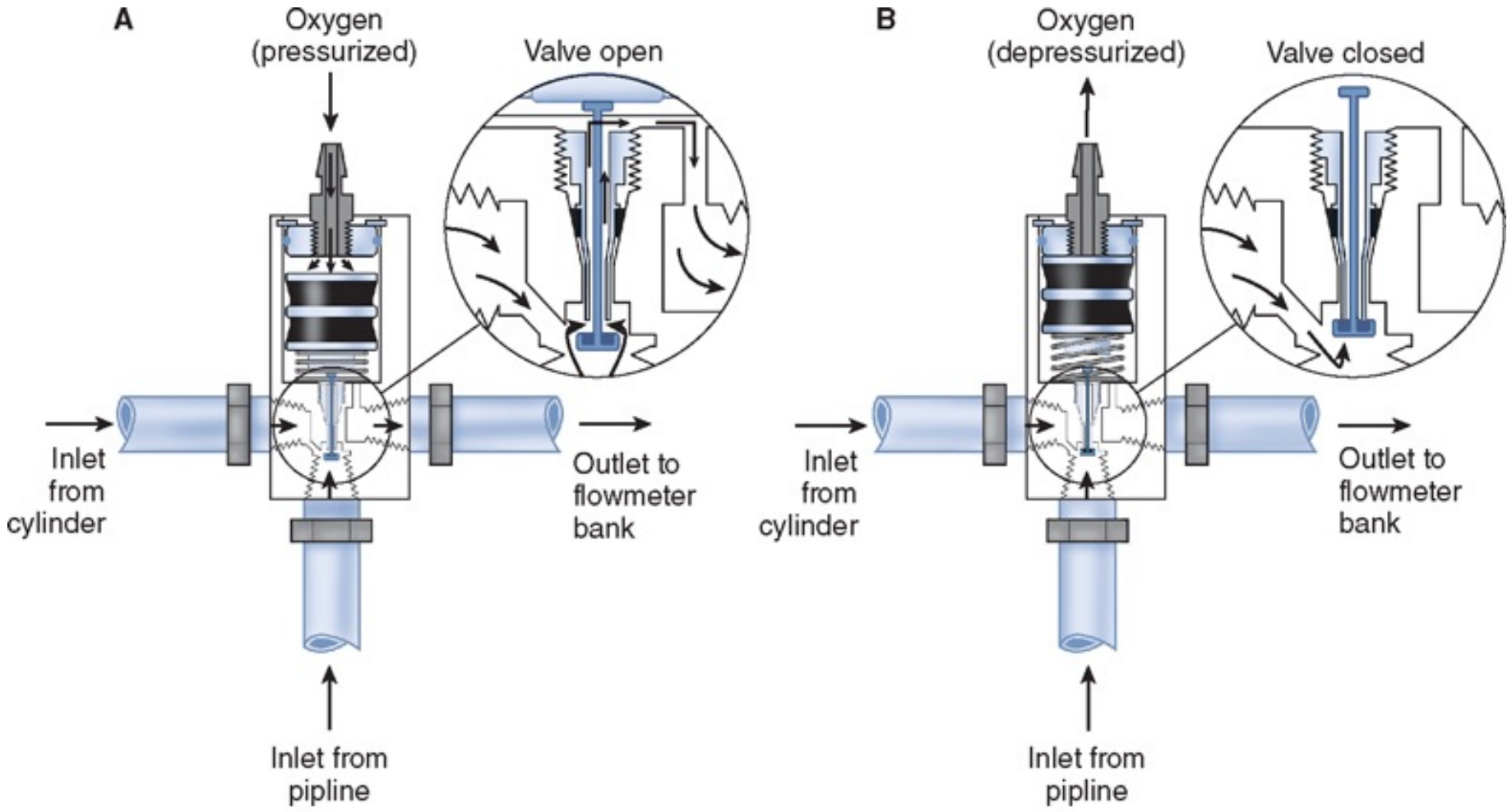


Fig. 2.F. 3-room slave regulator

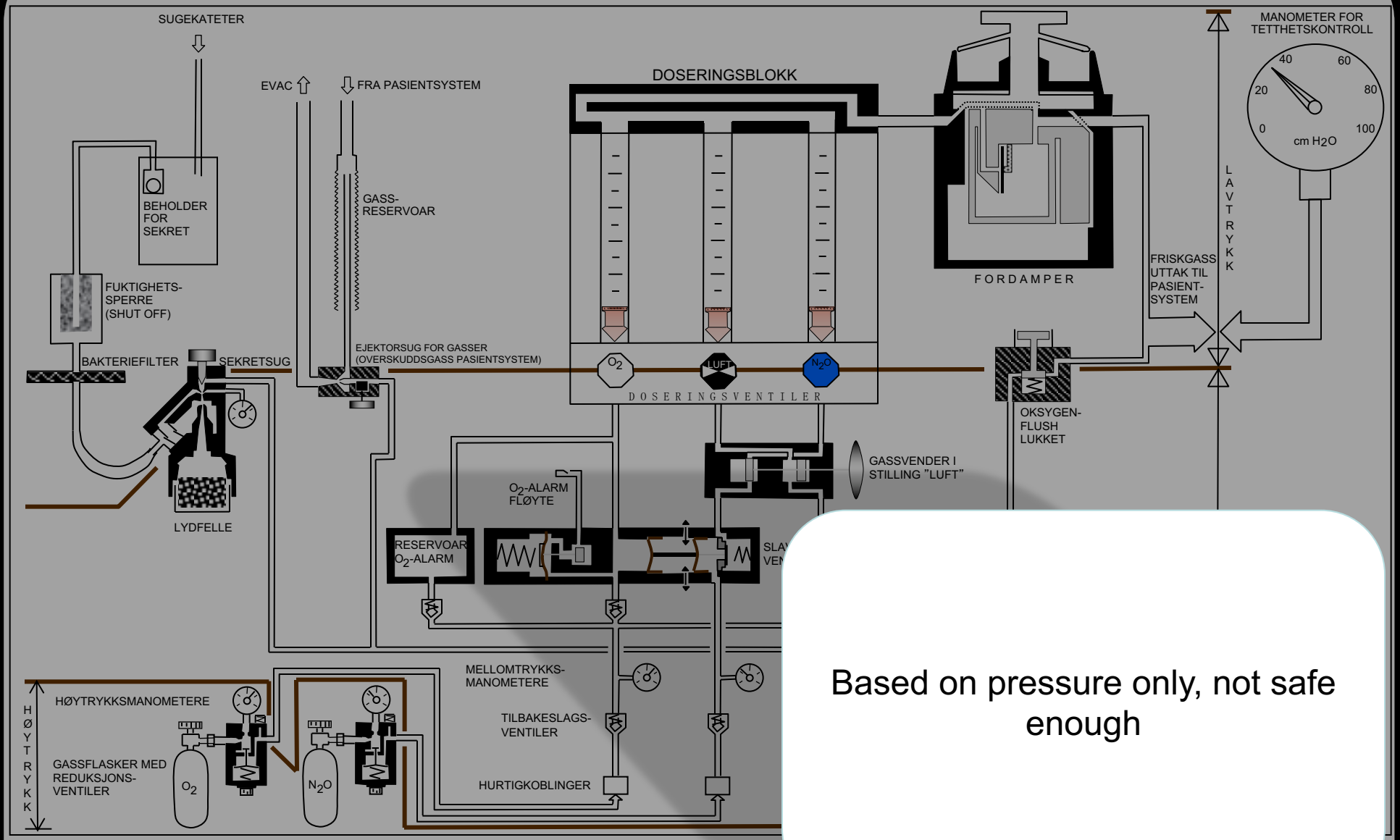
Slave regulator, pressure controled



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

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Berge, Grimnes: Gassteknisk medisinsk utstyr Del 2



Based on pressure only, not safe enough

Fig 2A, side 11

Redigert 2006
av TM.

Mechanical connection

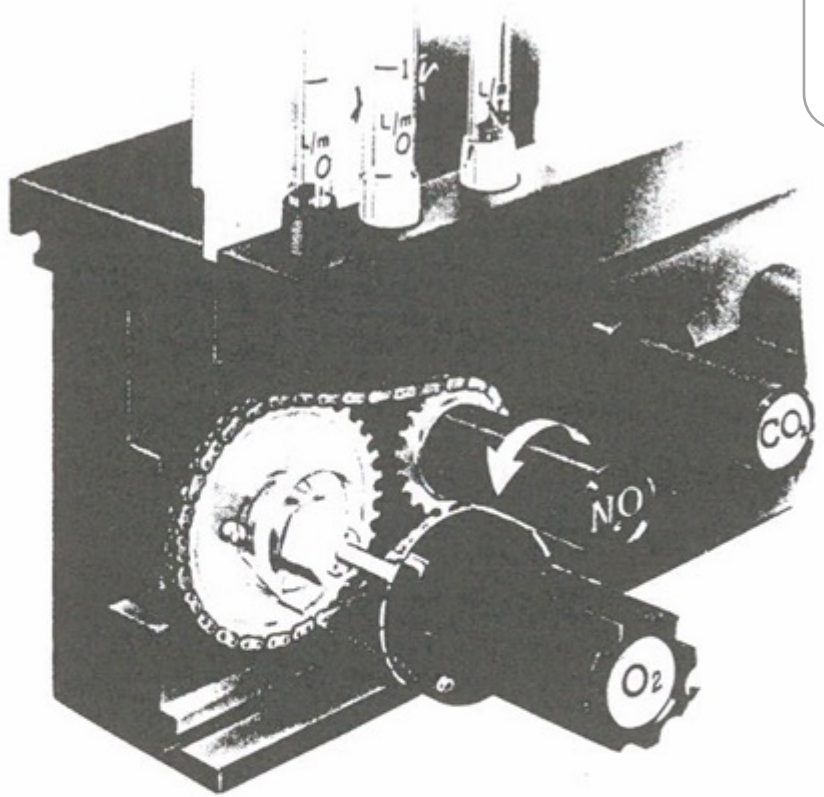


Fig. 2.V. Ohmeda narkoseapparat

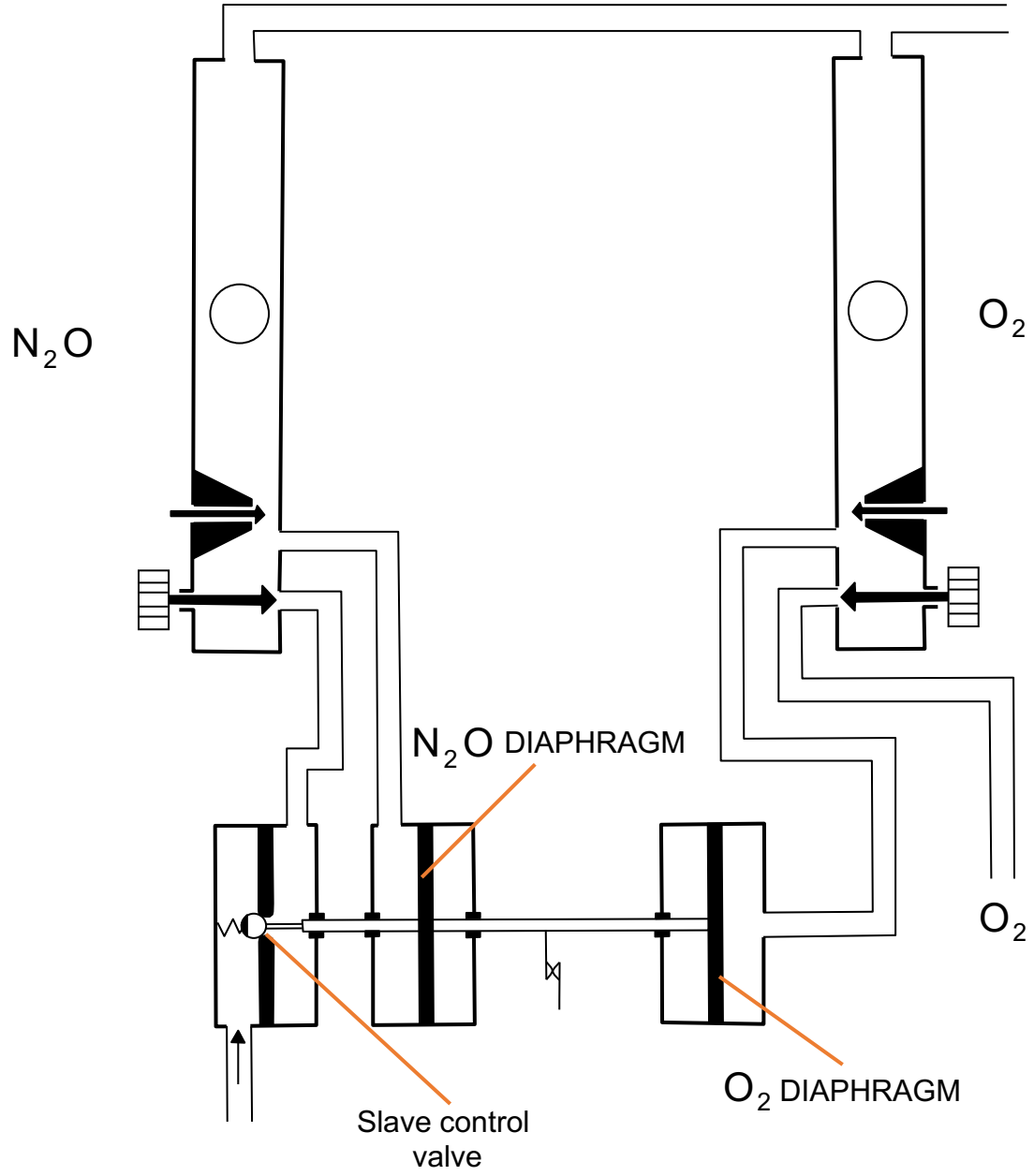
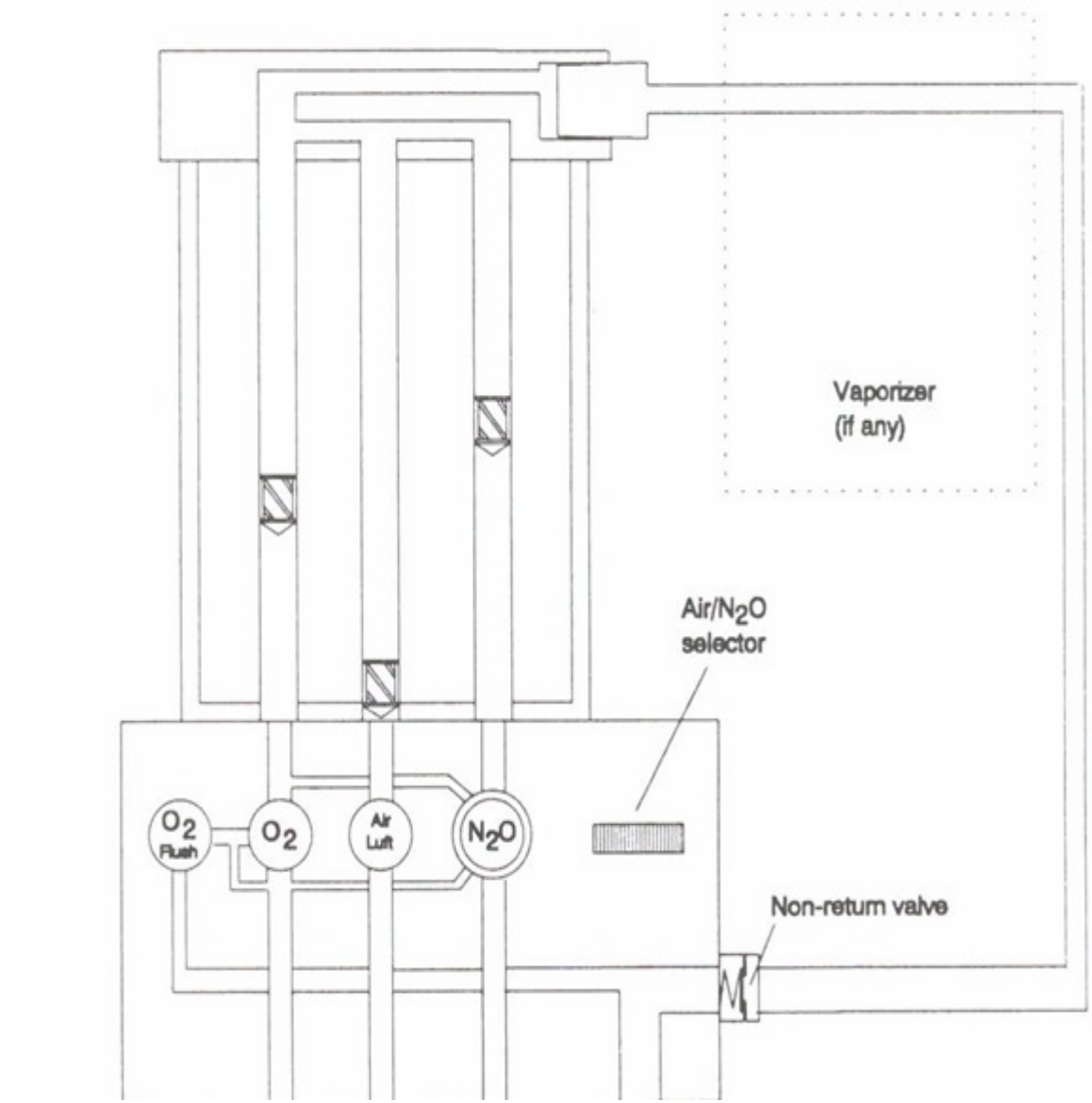
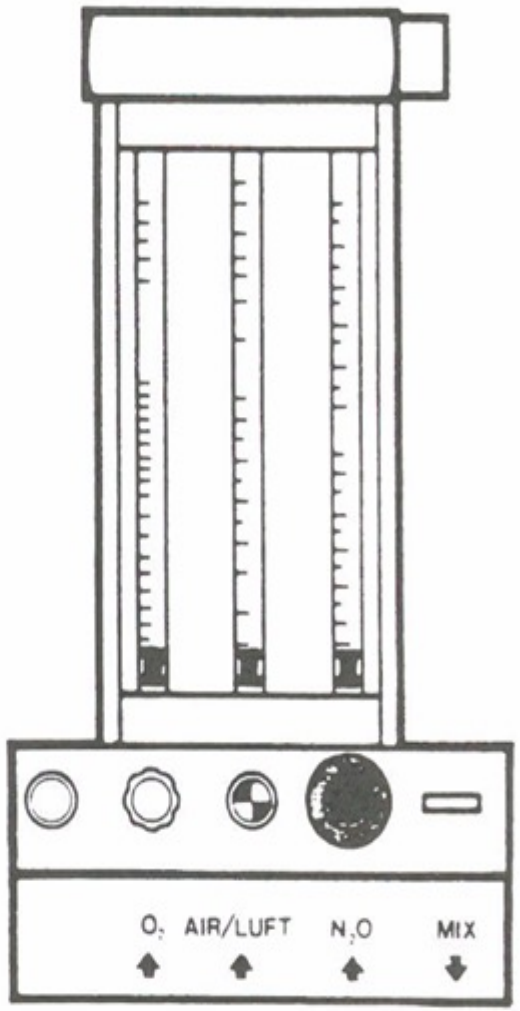


Fig. 2.X.1 Dameca Minioxyguard

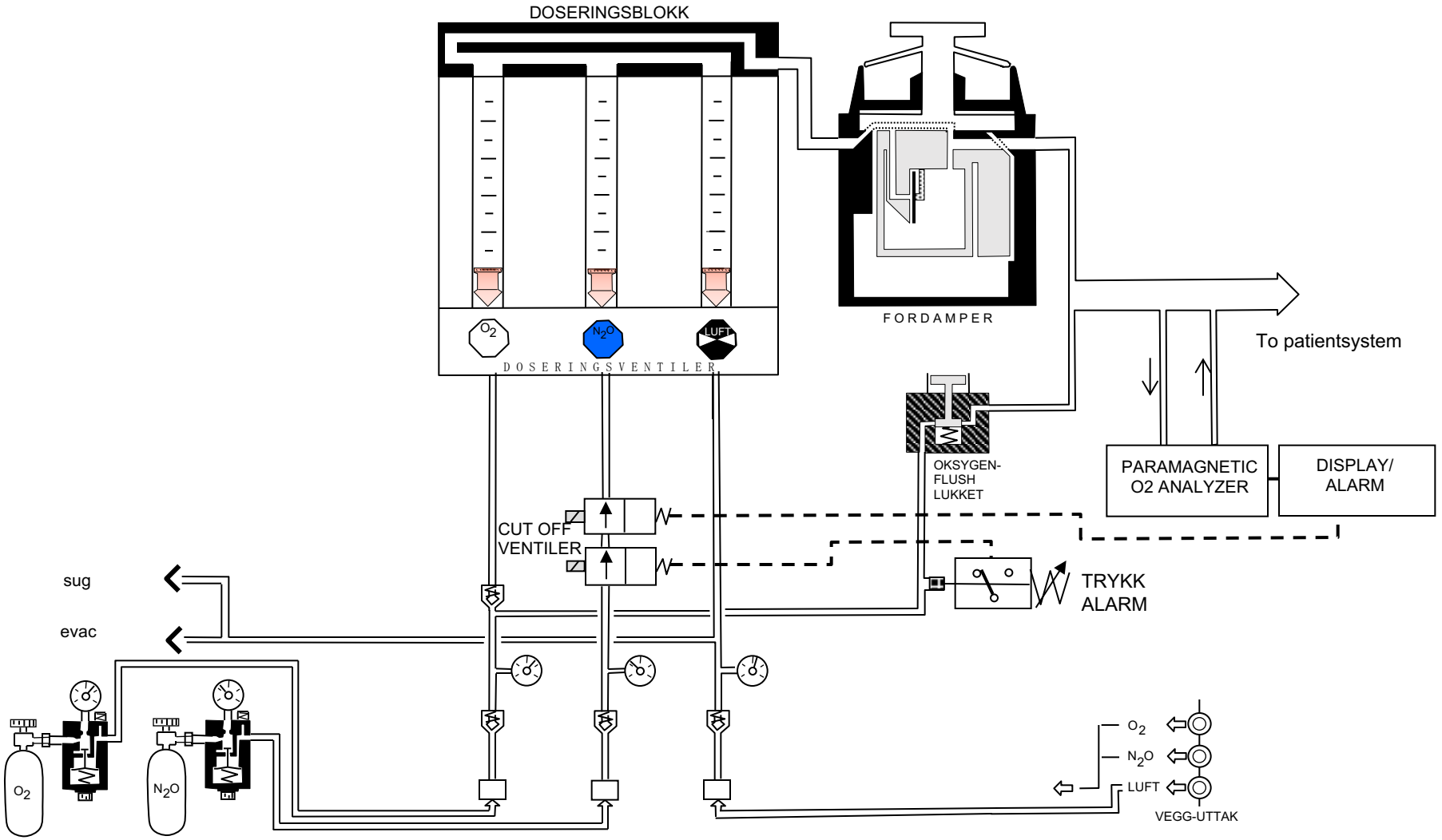
Wrong gas concentration

Wrong gas concentration





Wrong gas concentration



Wrong gas concentrations

Accident: Reflux of gas

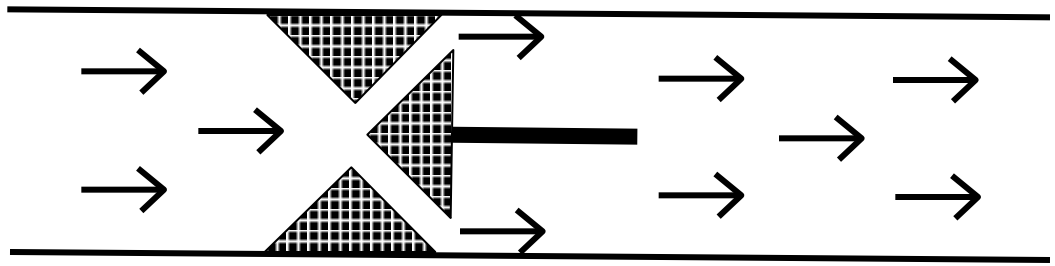
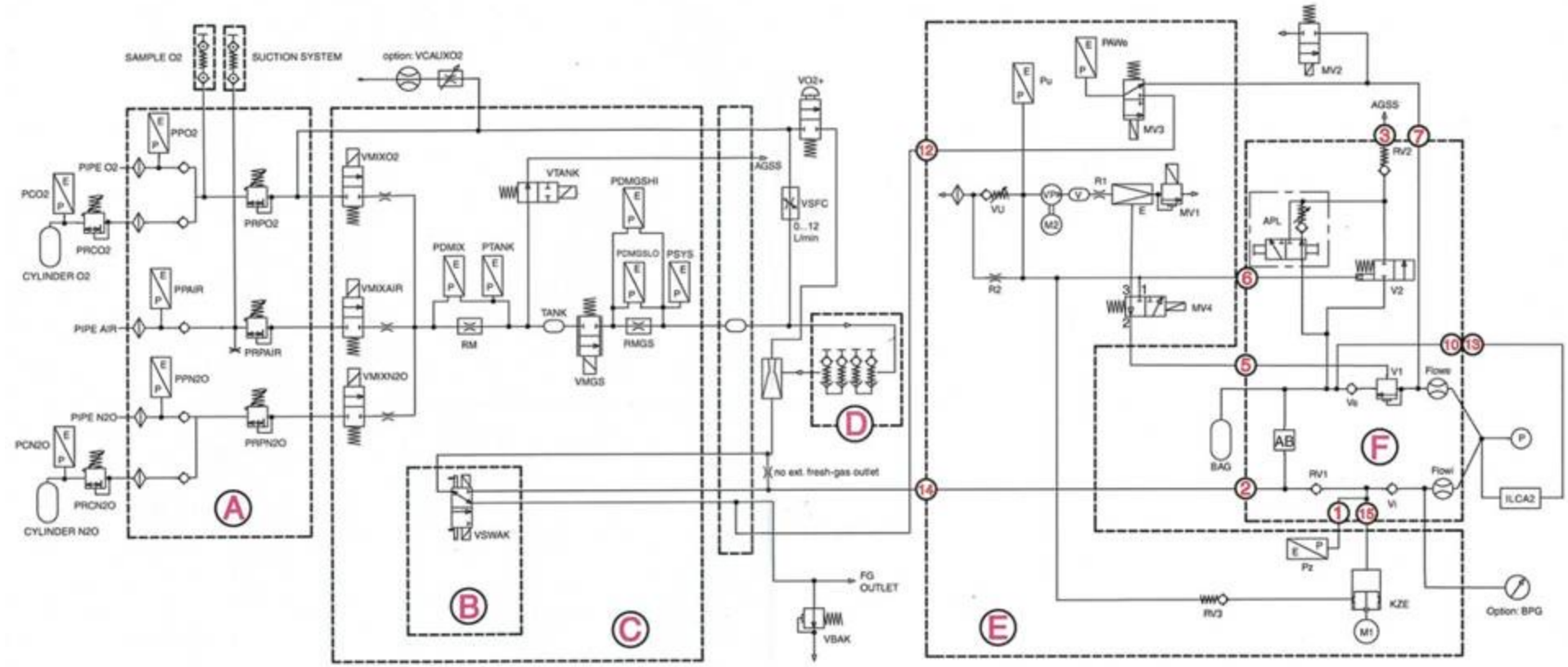


Fig 2B Simple valve

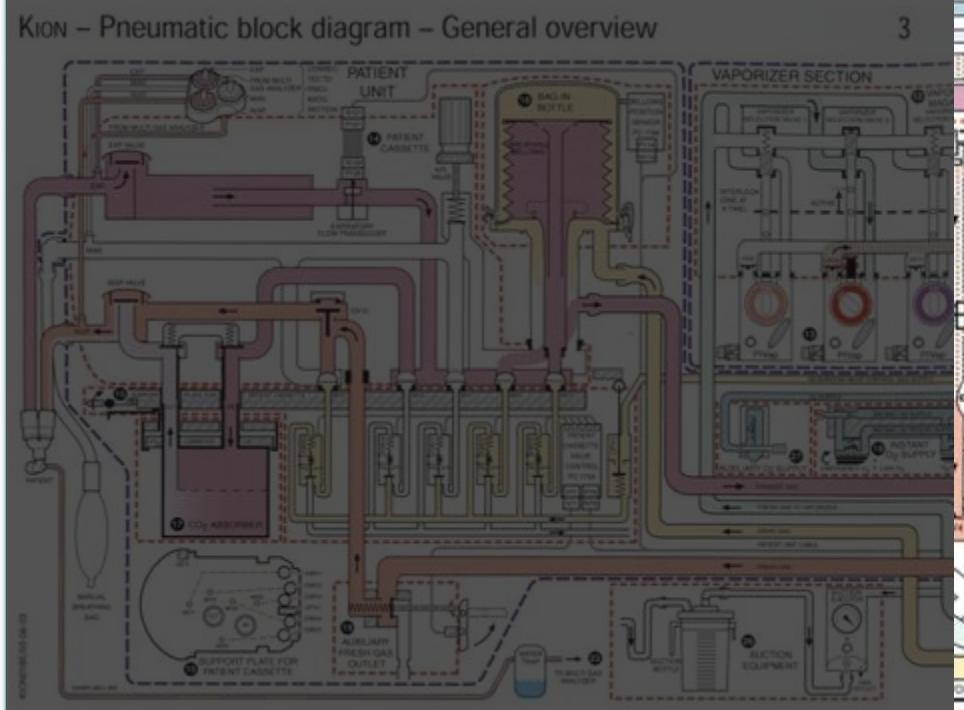
Today’s anaesthesia workstations

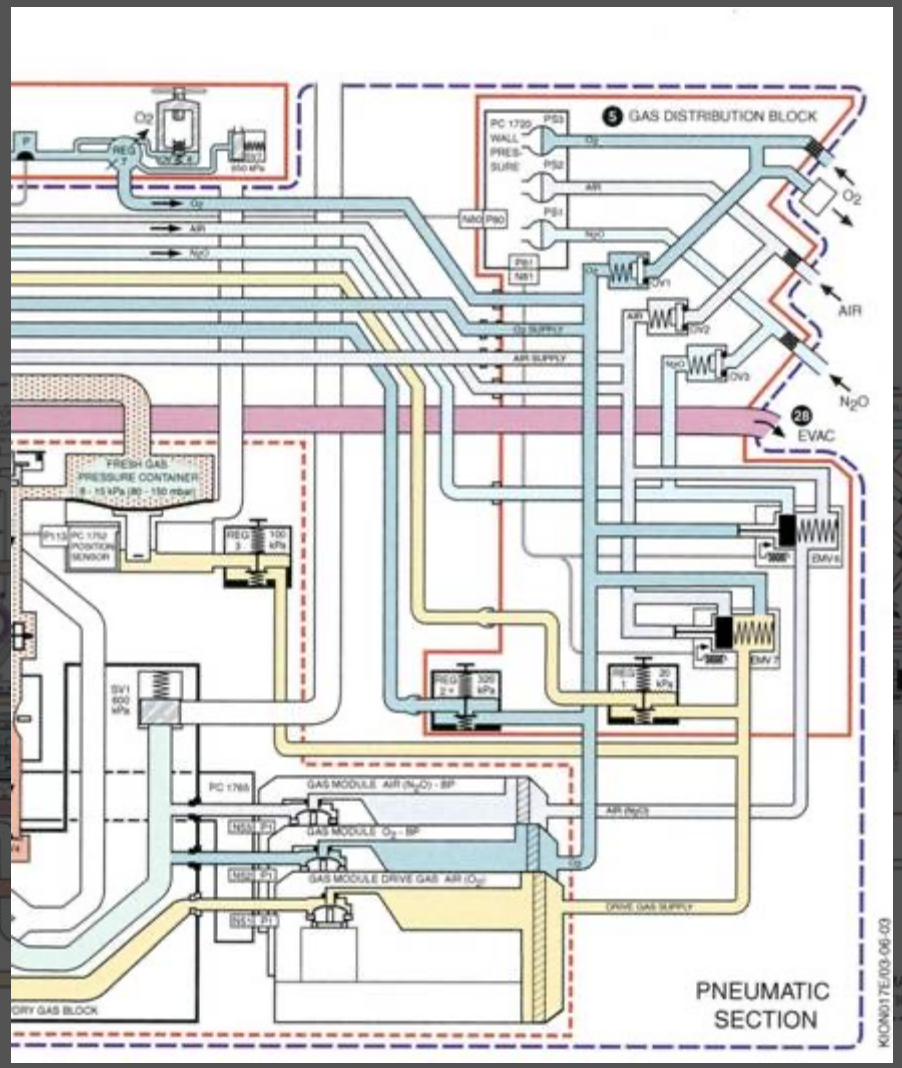


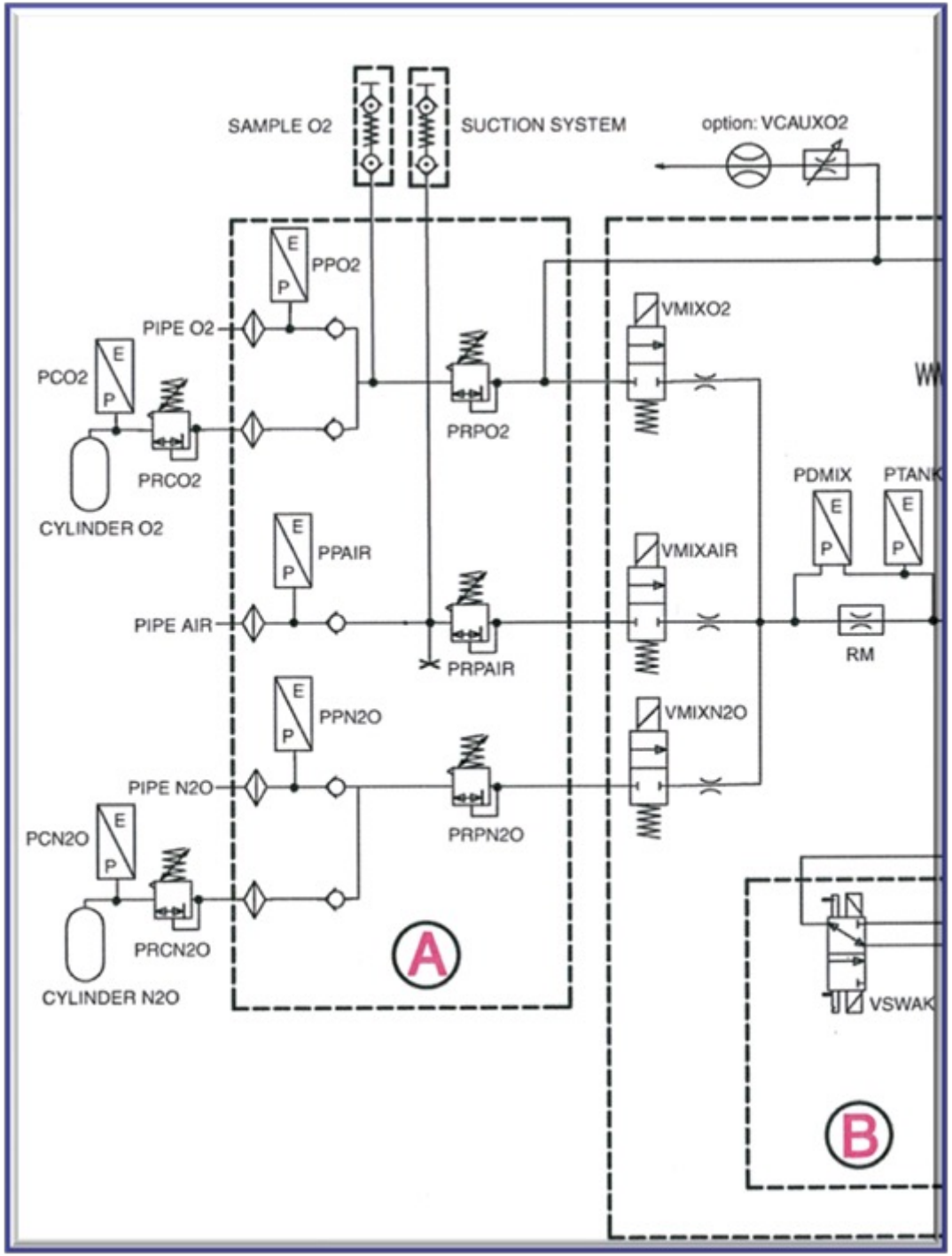


Today’s anaesthesia workstations











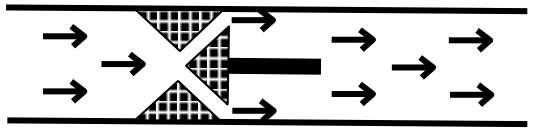


Fig 2B Simple valve

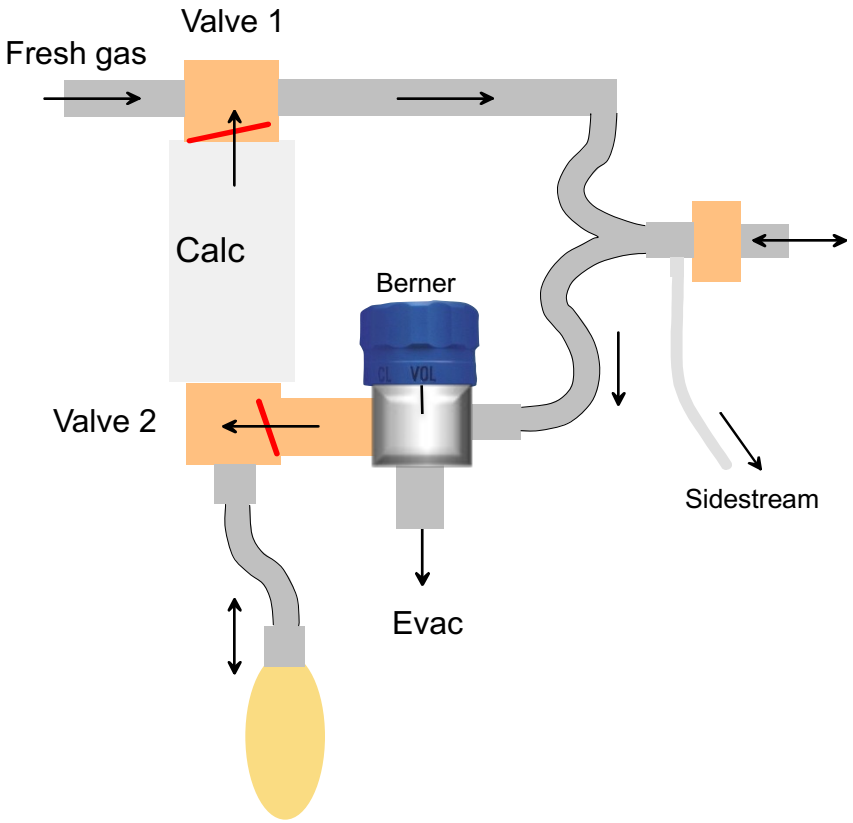
Wrong gas concentrations

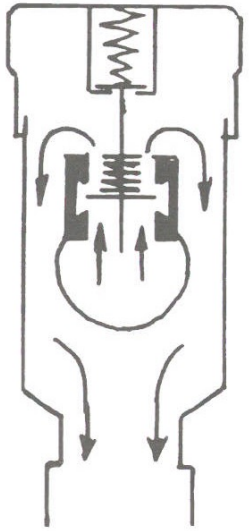
Accident: Two vapourizers simultanously



2. Excessive pressures

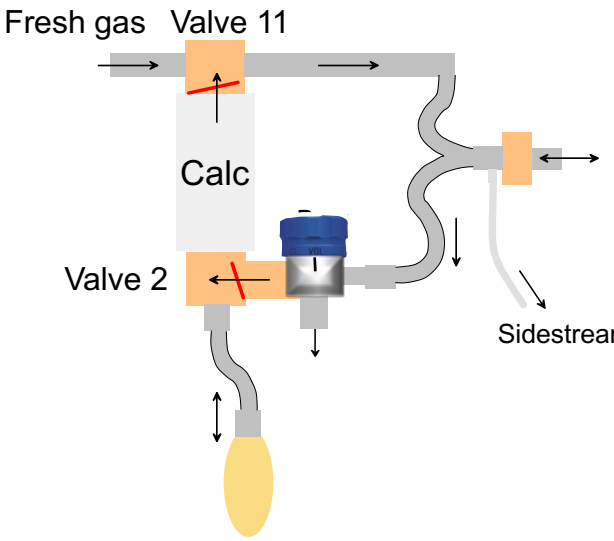
Too high pressure	Accident: valve is locked

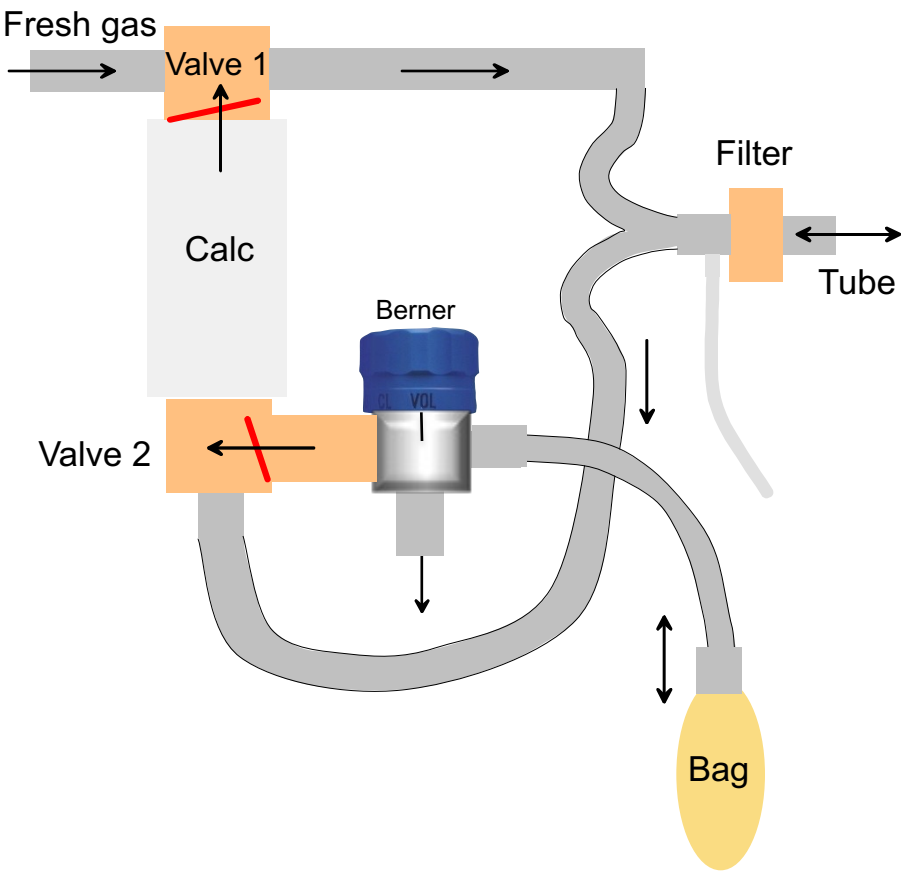




Too high pressure

Accident: wrong connection, no outlet for gas = pneumathorax





The 7-stage test of the Anesthesia workstation

- How to make sure your device is safe and ready to use

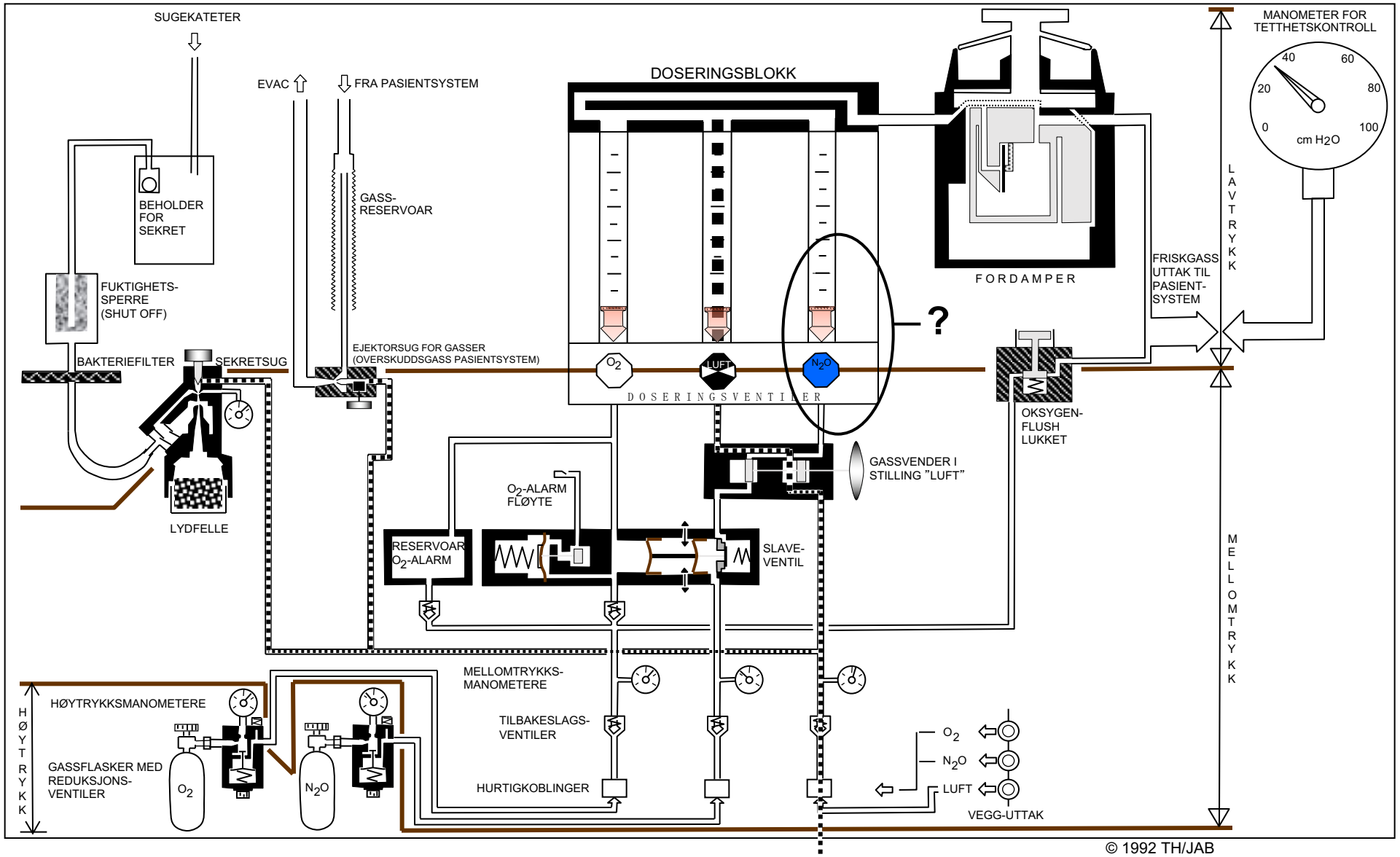
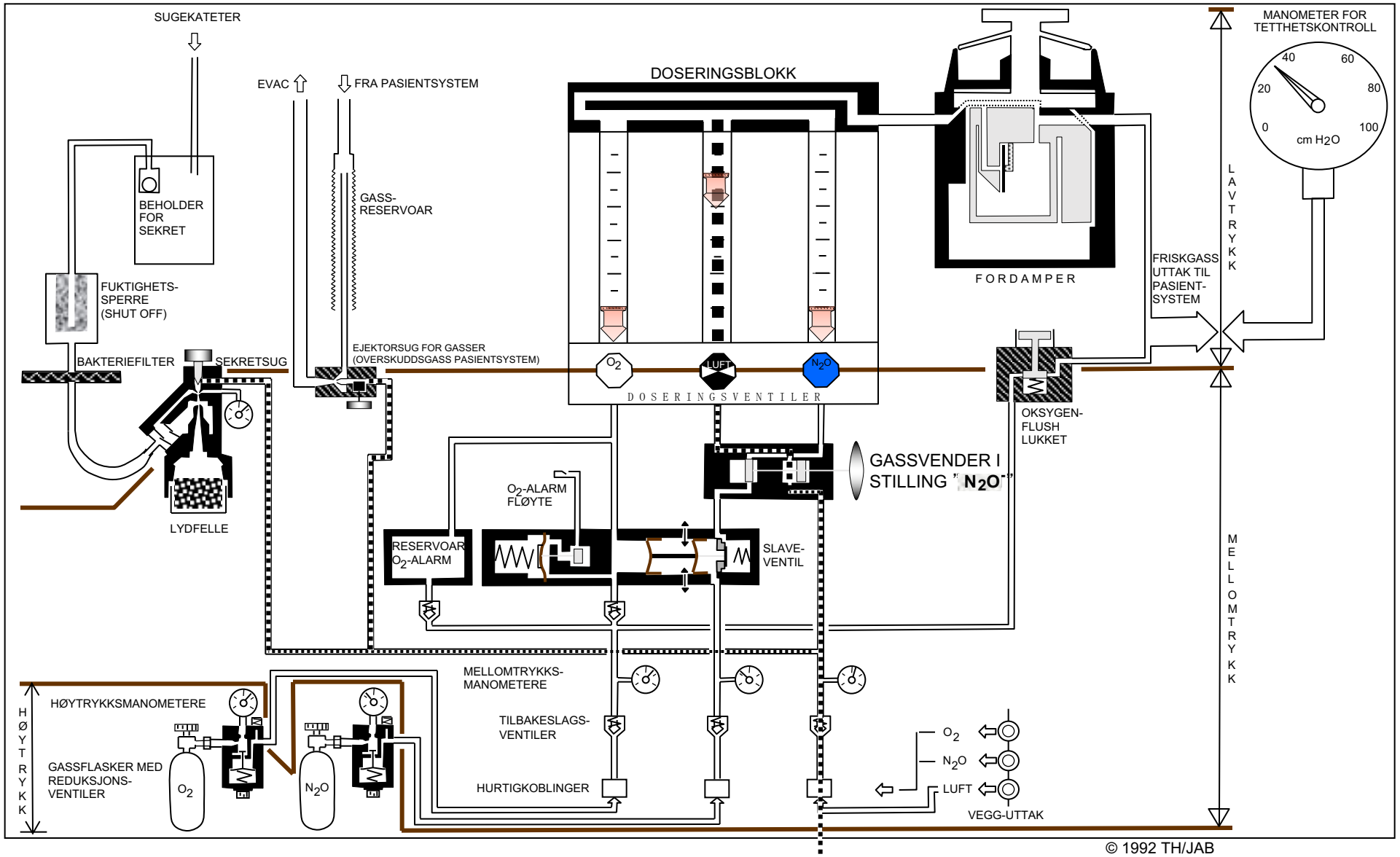


Fig 2A, side 11

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Fig 2A, side 11

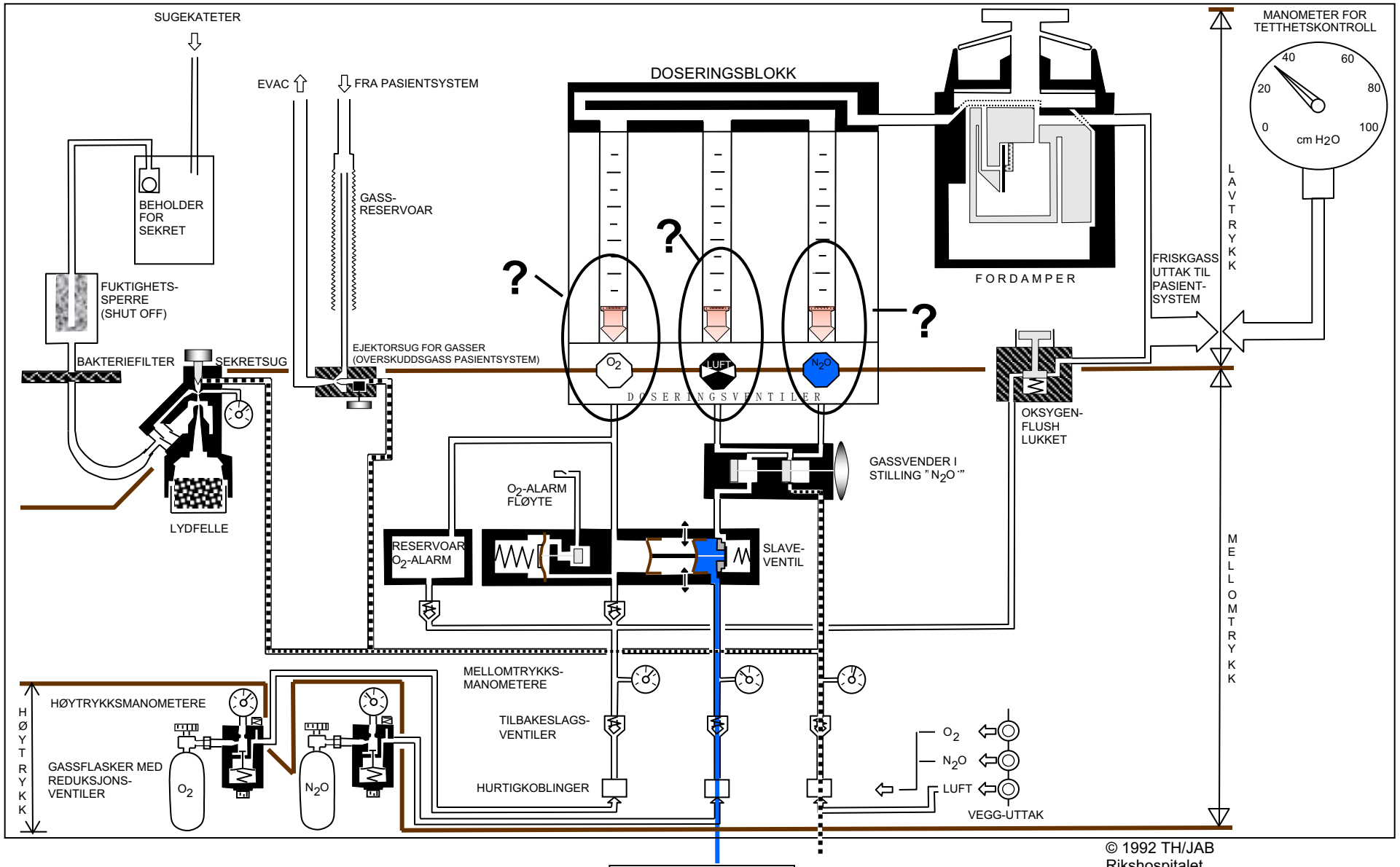


Fig 2A, side 11

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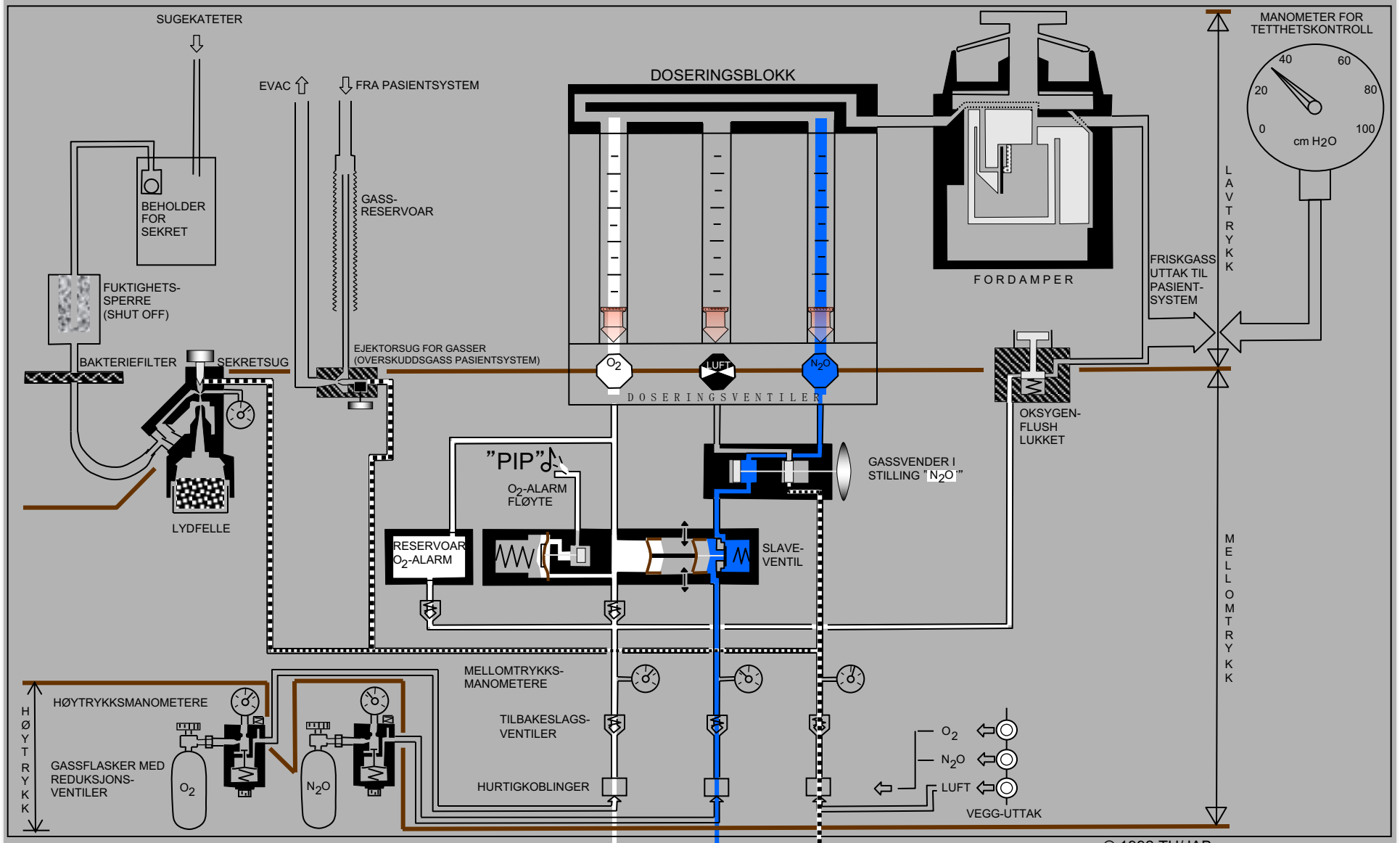


Fig 2A, side 11

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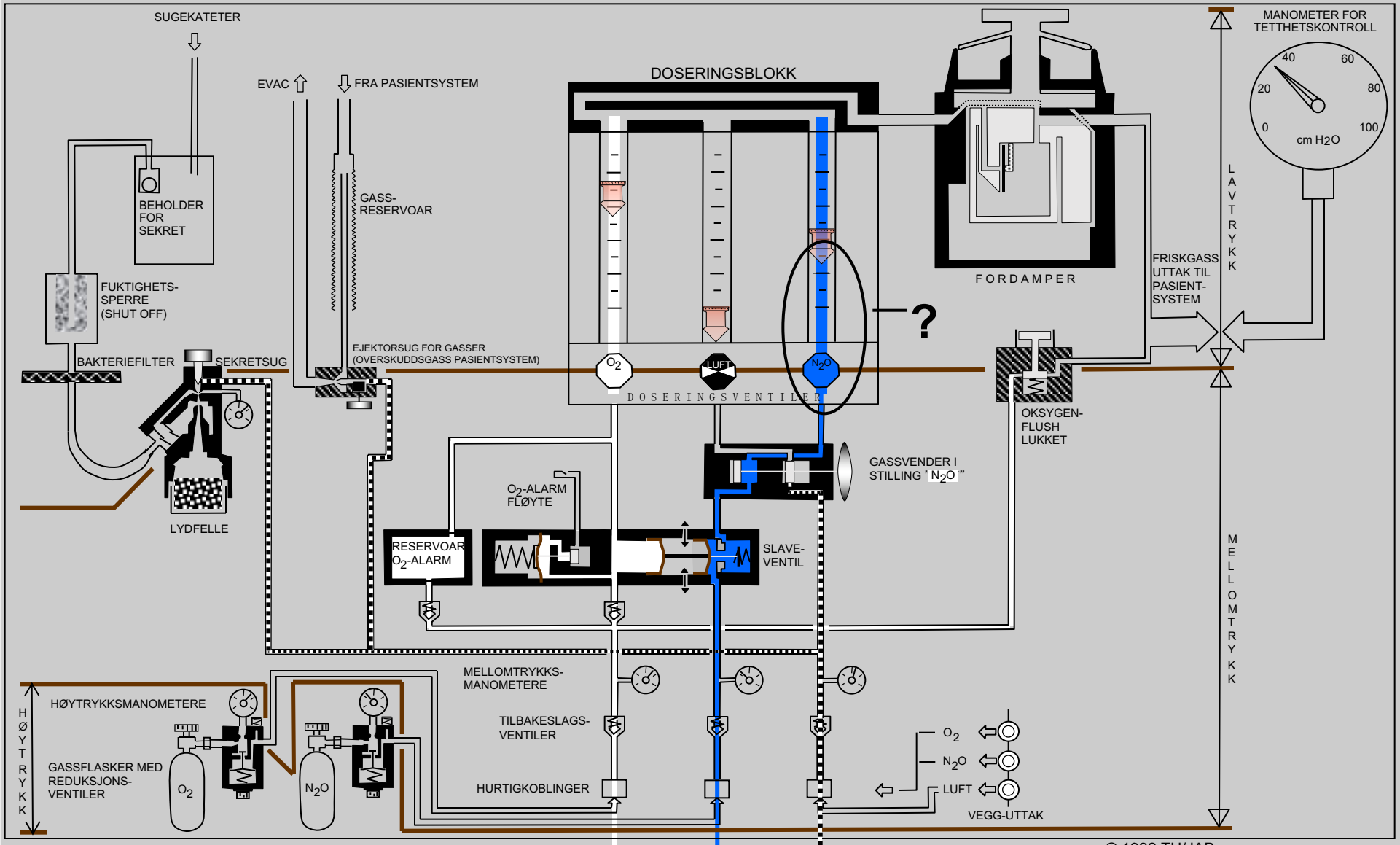


Fig 2A, side 11

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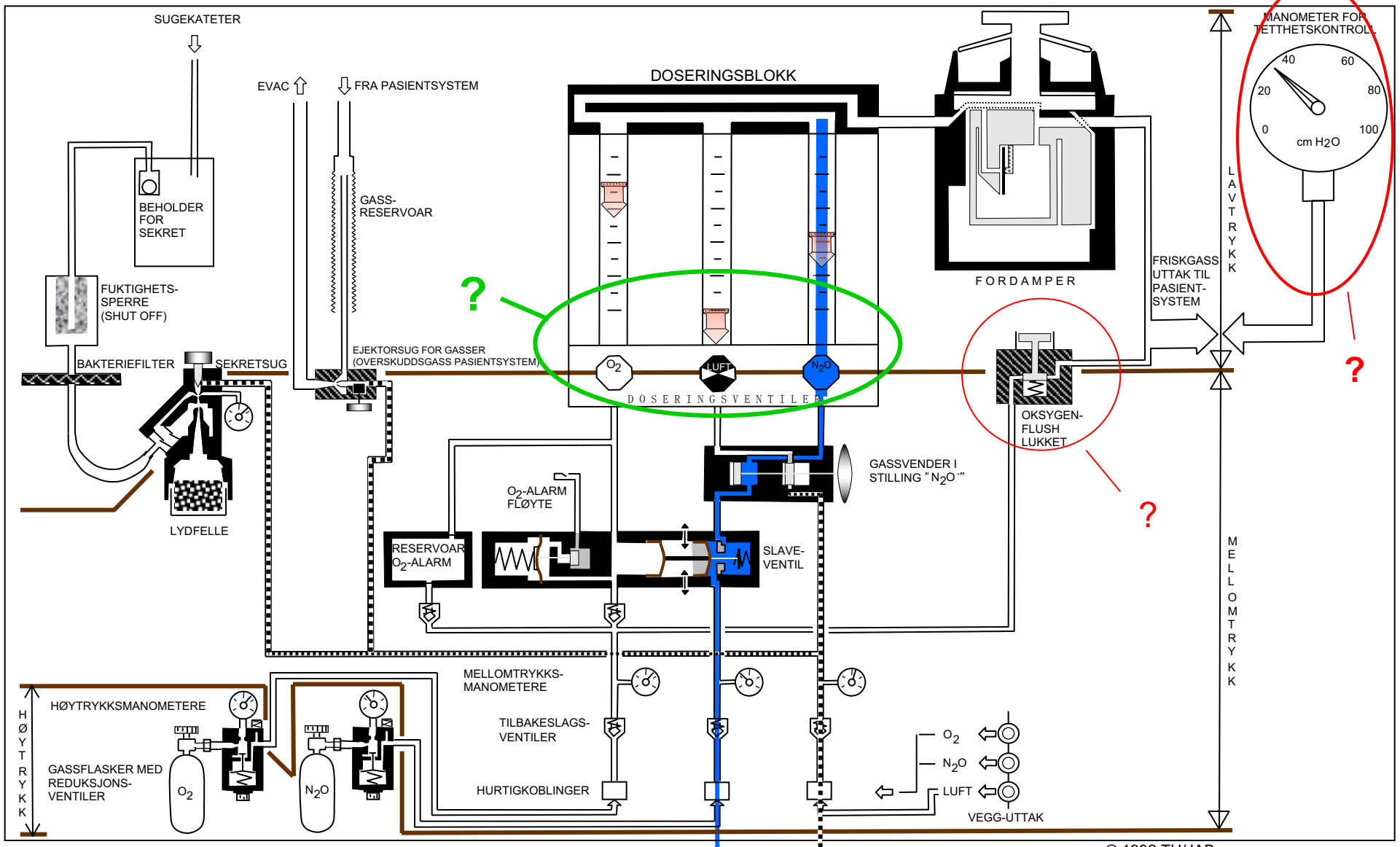


Fig 2A, side 11

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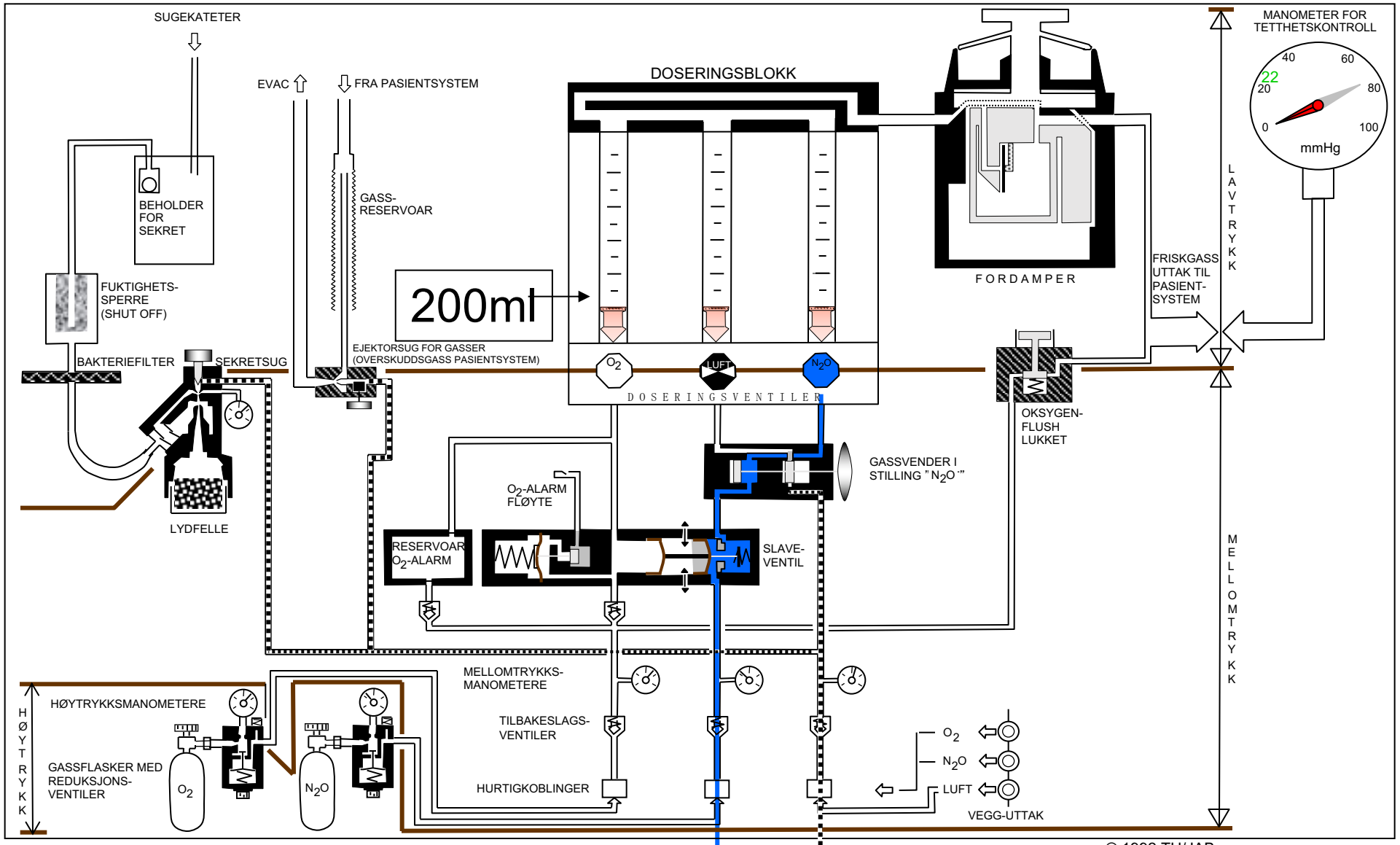
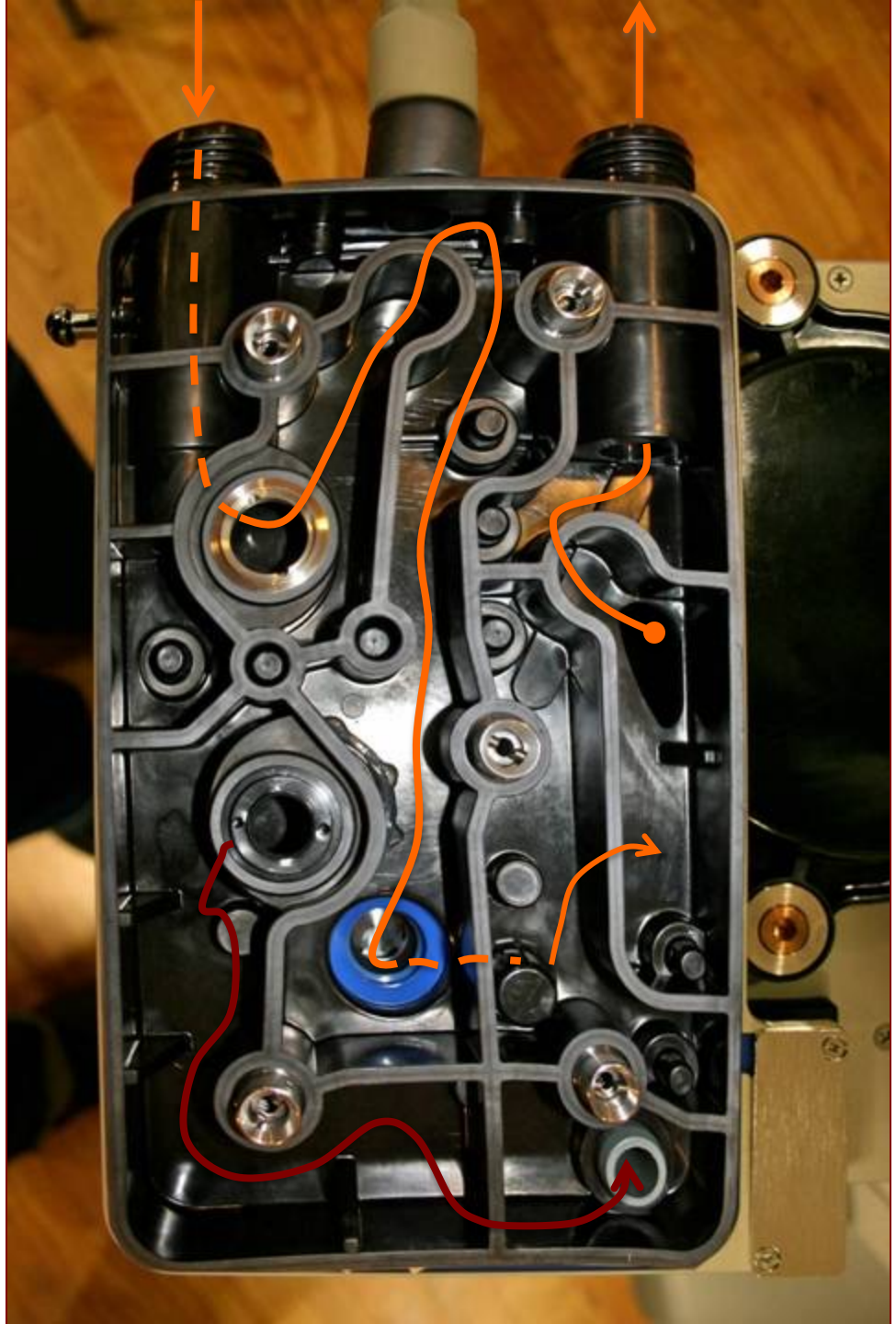
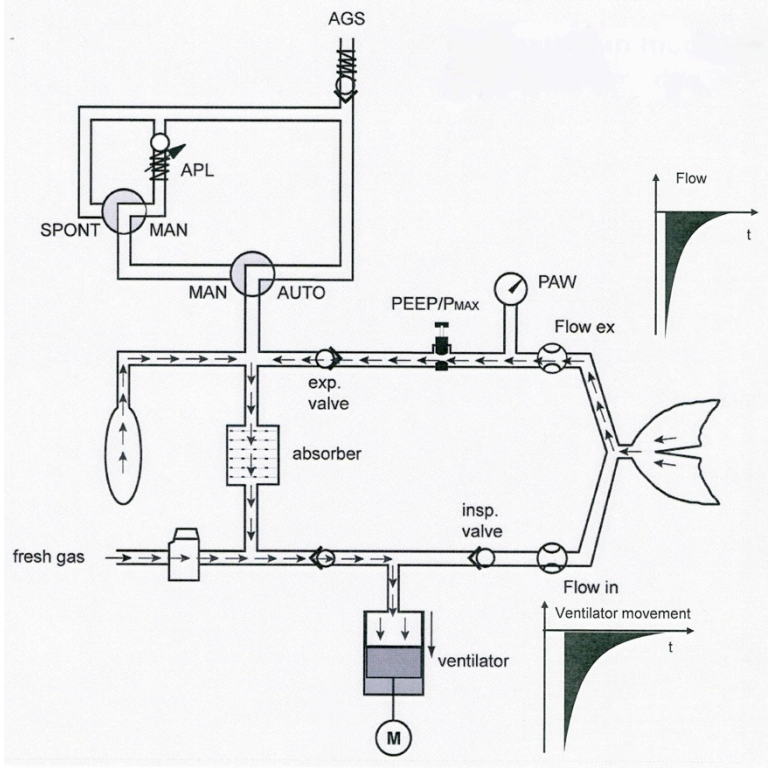
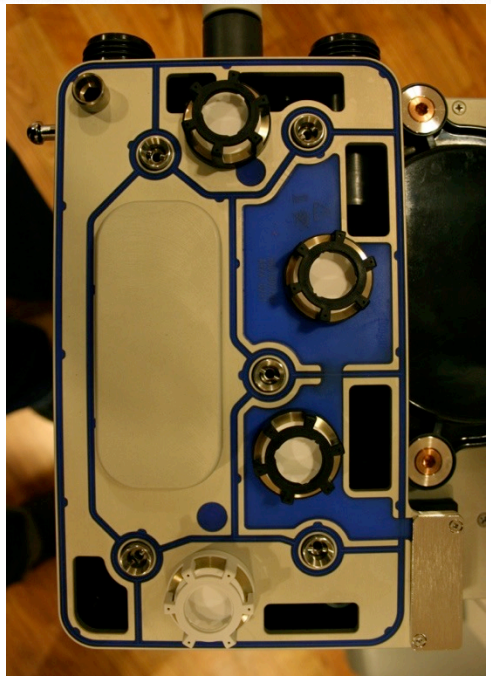


Fig 2A, side 11

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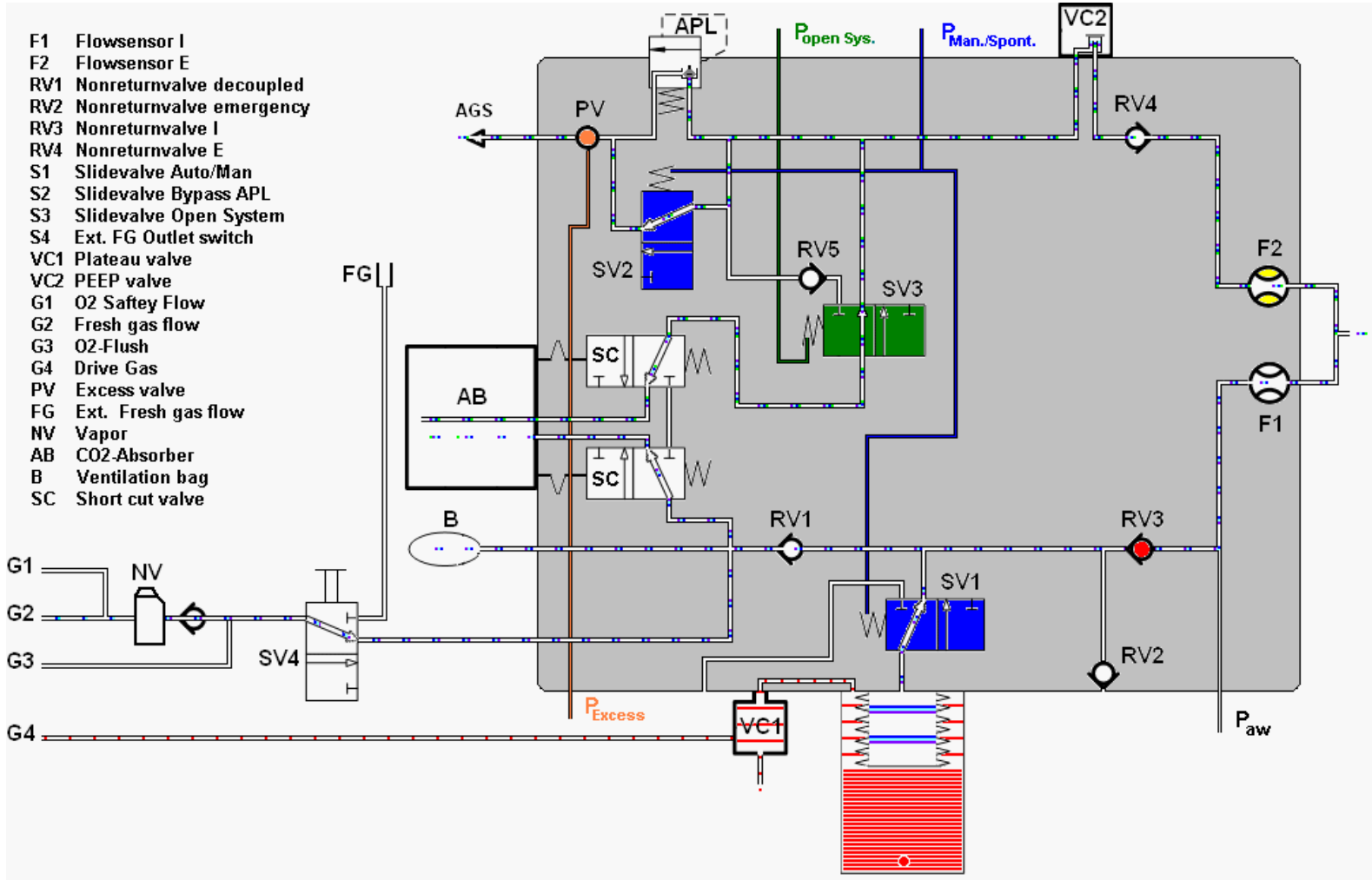



AGS
APL
SPONT
MAN
MAN
AUTO
PEEP/PMAX
PAW
Flow
t
Flow ex
exp.
valve
absorber
insp.
valve
fresh gas
Flow in
Ventilator movement
t
ventilator
M




Flow meter
ventilator
bellow
vaporizer
Corrugated tube
APL valve
Soda lime
Scavenging system

Block diagram



The future?

- Closed loop system
  - Control system, fully automated
  - Sensors for all vital processes



Sedasys Inc

Case 9

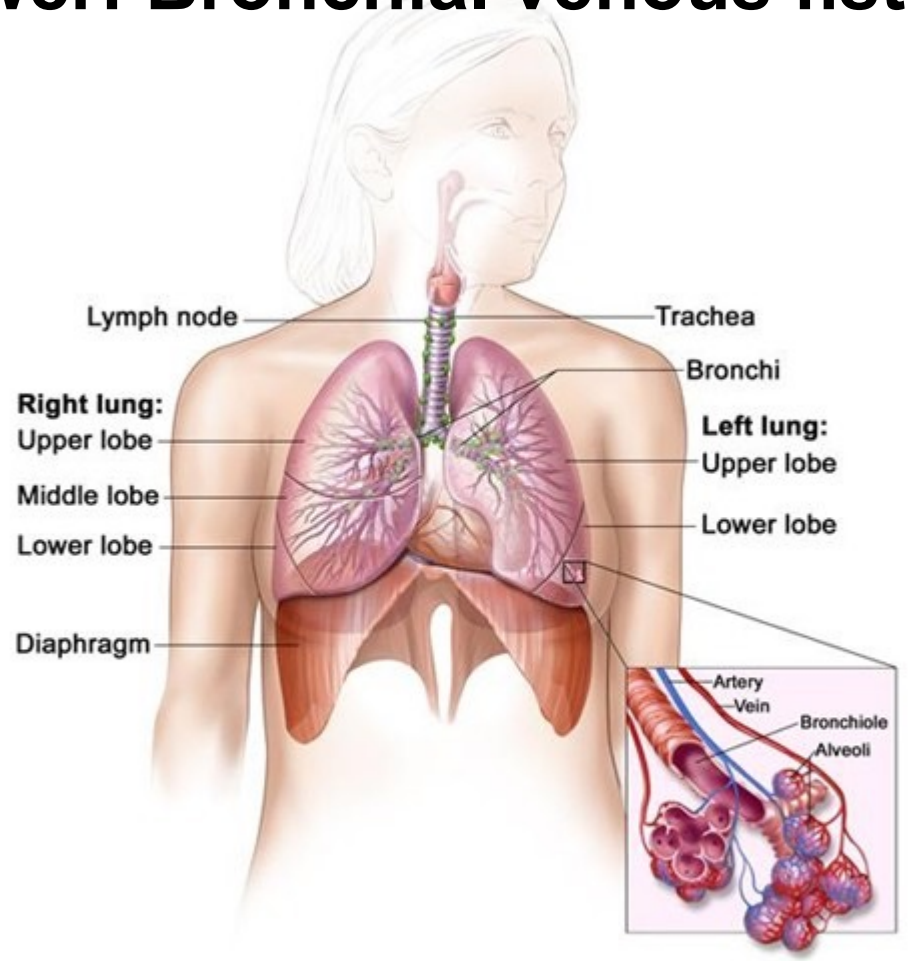
- Weaning of the ventilator is also a problem, and a CT-caput is finally scheduled. The CT-images show several air embolies in the left side of the brain. There were also blood in the endotracheal tube used during anesthesia



http://www.ajnr.org/content/33/3/E40/F2.small.gif

What has happened?

Answer: Bronchial venous fistula



Patient is ventilated with relatively high pressure, the fistula breaks and air is pushed into the venous system. Too much air will pass through the lungs and into the heart/brain depending on the position of the patient. Both cases may be fatal. In this case, the patient died after short time