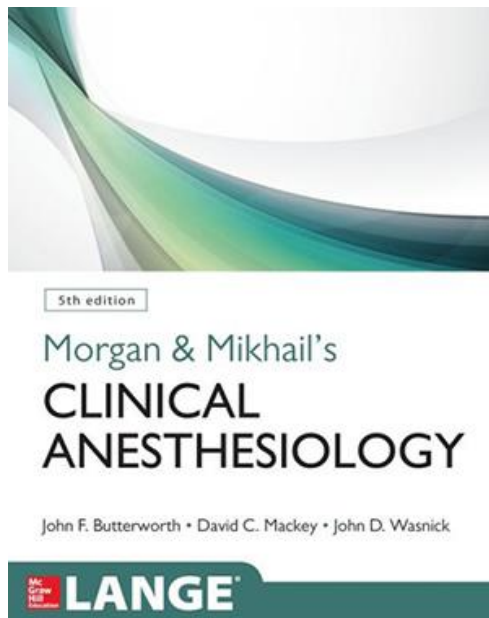




DESIGN PRINCIPLES: ANESTHESIA MACHINE

Recommended Textbook

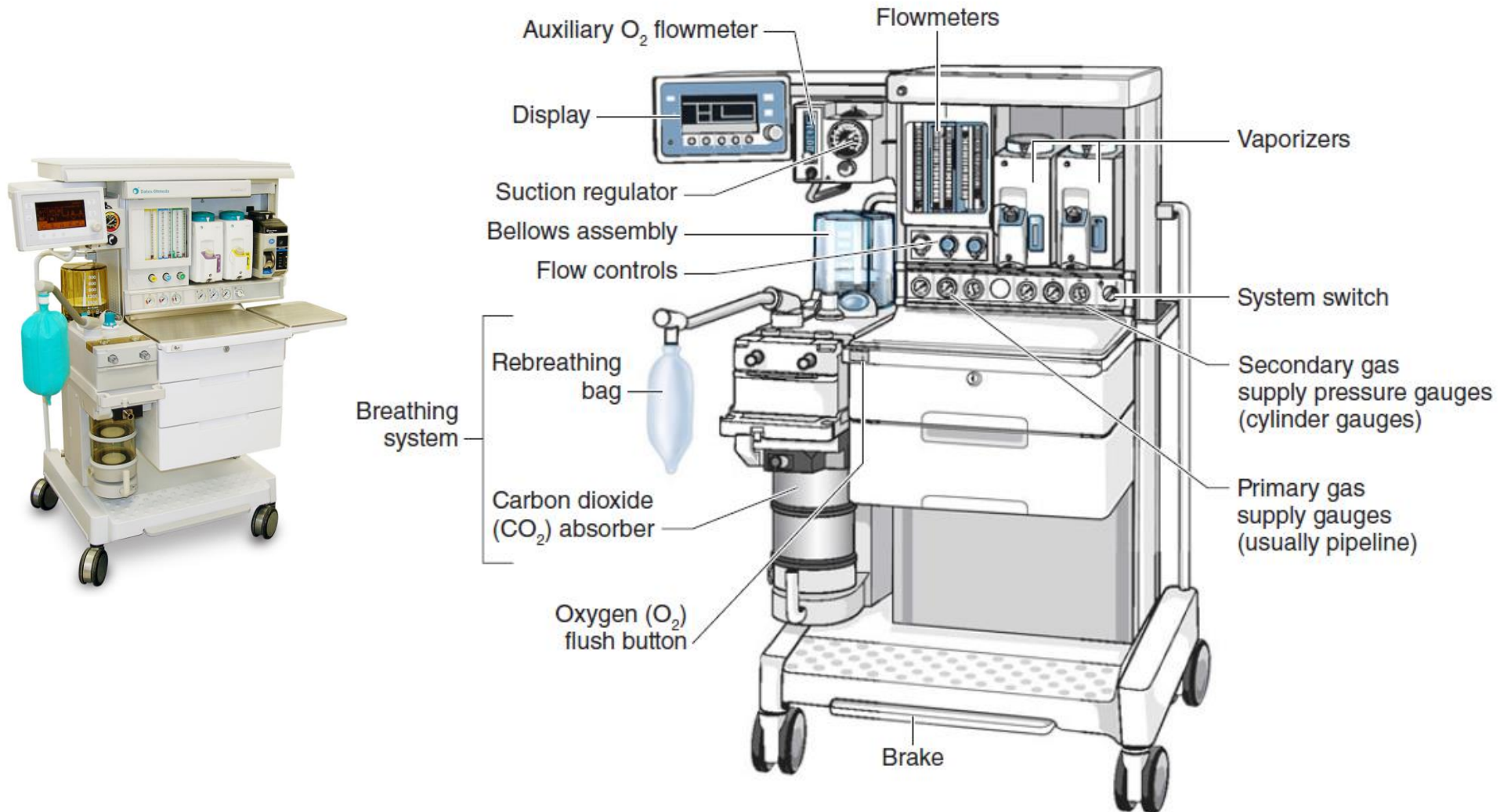
- John F. Butterworth IV, David C. Mackey and John D. Wasnick, *Morgan & Mikhail's Clinical Anesthesiology*, 5th Ed., McGraw-Hill Education, New York, 2013. (ISBN: 978-0-07-171405-1)
- Rüdiger Kramme, Klaus-Peter Hoffmann, Robert S. Pozos (Eds.), *Springer Handbook of Medical Technology*, Springer-Verlag, Berlin, 2011. (ISBN: 978-3-540-74657-7)



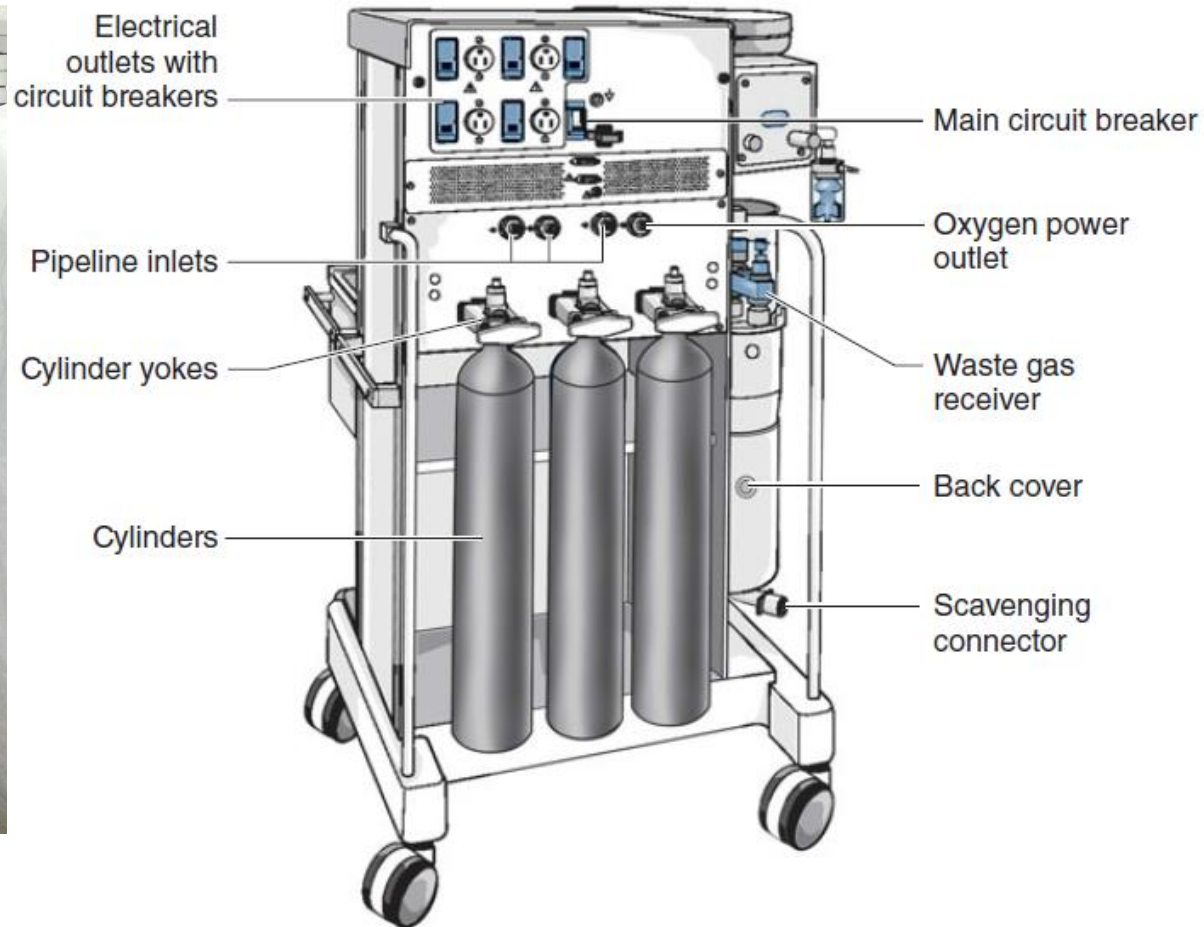
Definition

- Anesthesia devices are used in operating rooms in hospitals by medical staff to ensure that operative and diagnostic procedures can be performed on a patient without pain in an unconscious and relaxed state
- On the most basic level, anesthesiologist uses anesthesia machine to control patient's ventilation and oxygen delivery and to administer inhalation anesthetics

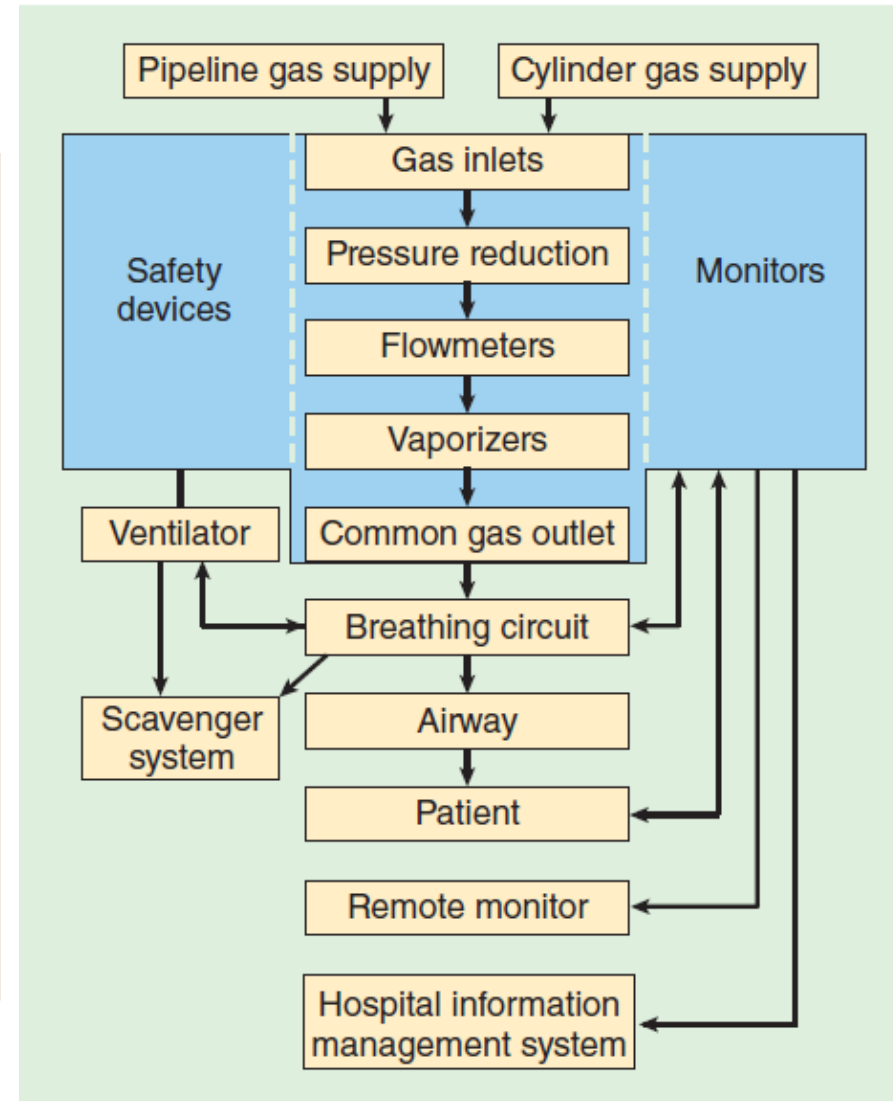
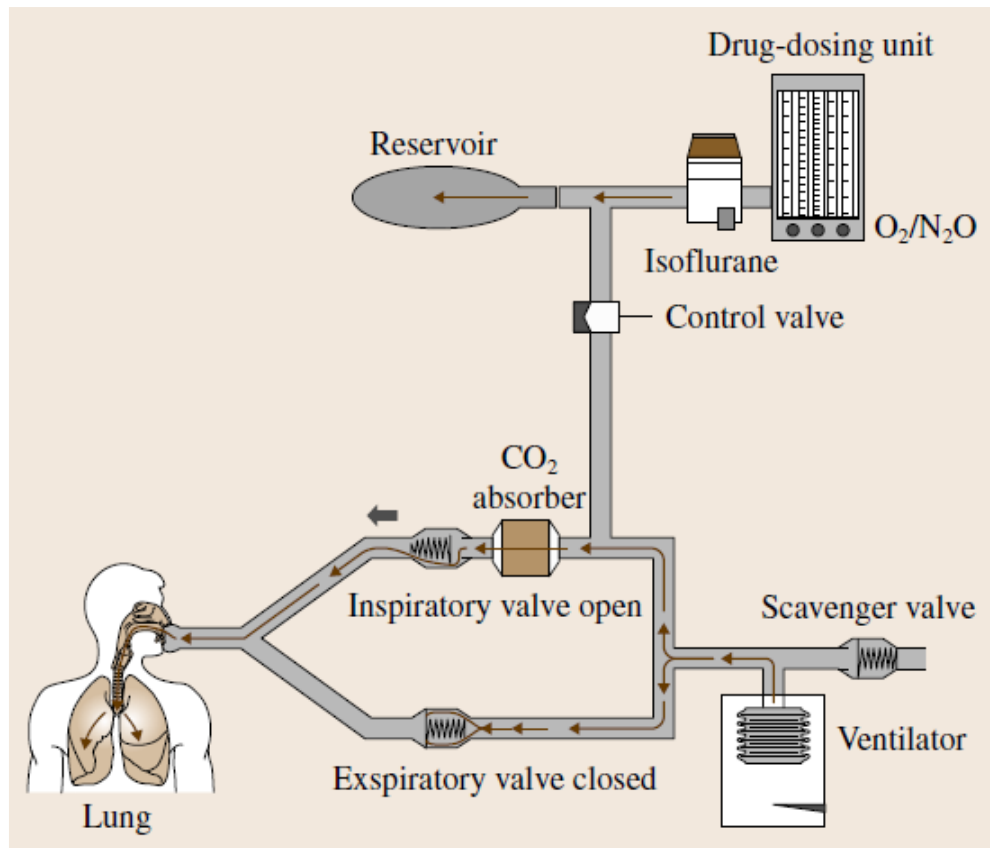
Modern Anesthesia Machine - Front



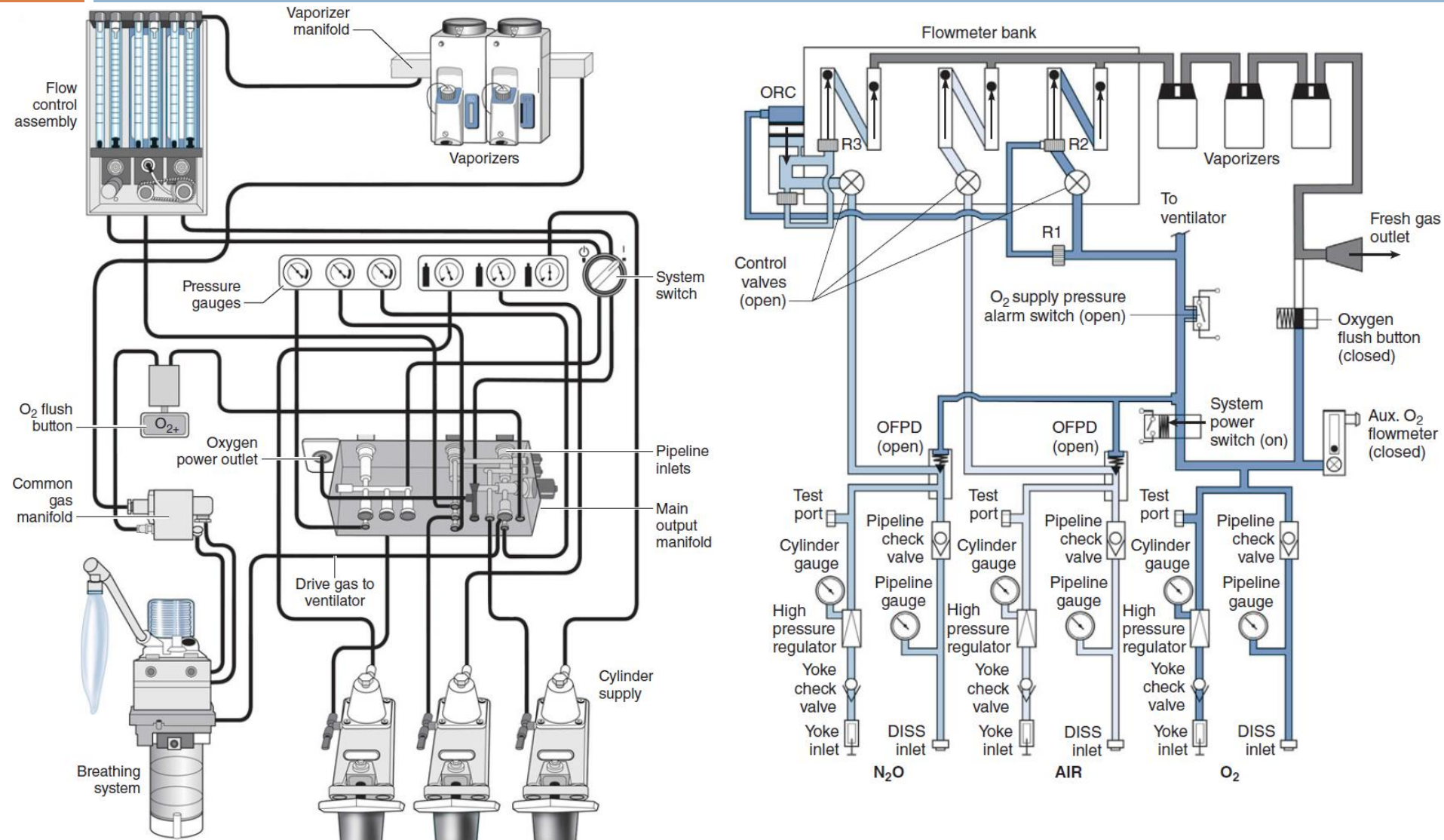
Modern Anesthesia Machine - Back



Functional Schematic



Internal Schematic Examples

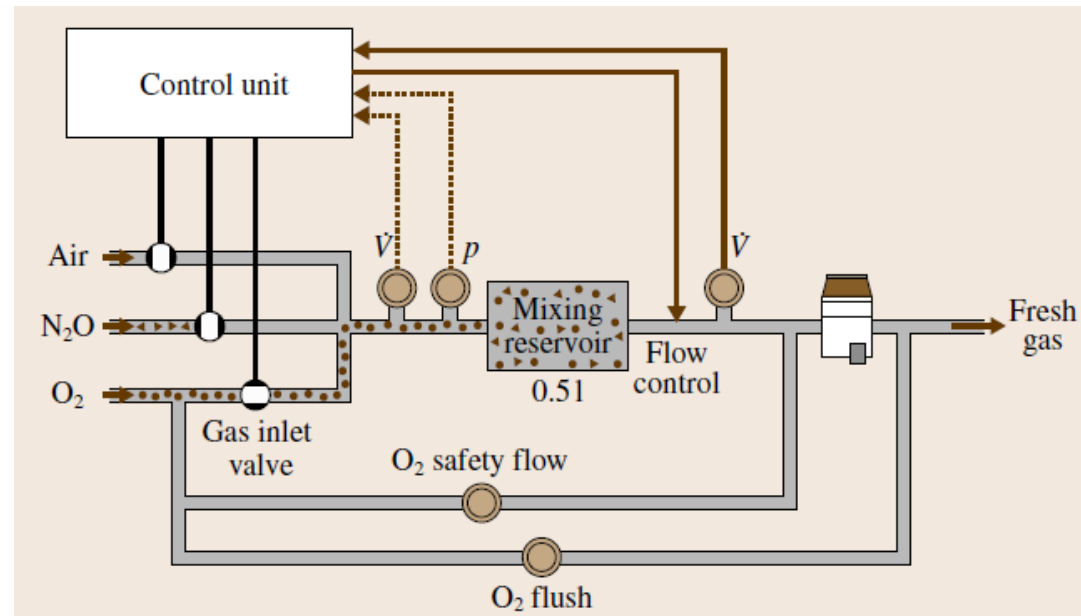
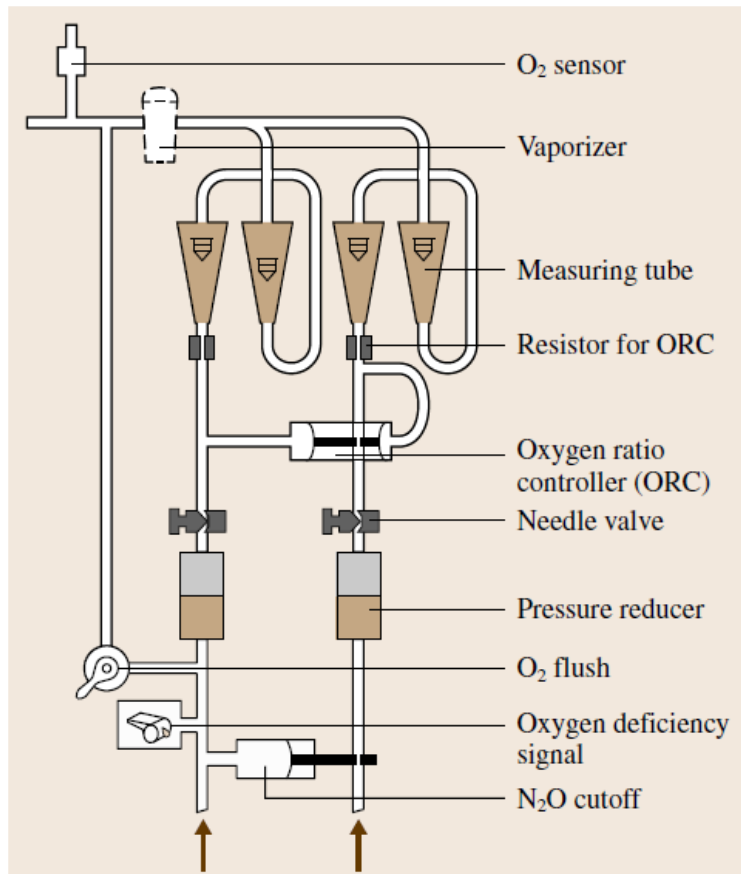


Components of Anesthesia Machine

- Anesthesia device consists of following components, according to its intended medical purpose:
 - ▣ Drug dosing unit
 - ▣ Ventilator with breathing system
 - ▣ Monitoring unit consisting of 3 subunits:
 - One monitors drug dosing and the ventilator called device monitoring
 - One monitors the patient called patient monitoring
 - One monitors the *depth of anesthesia* called anesthesia effect monitoring

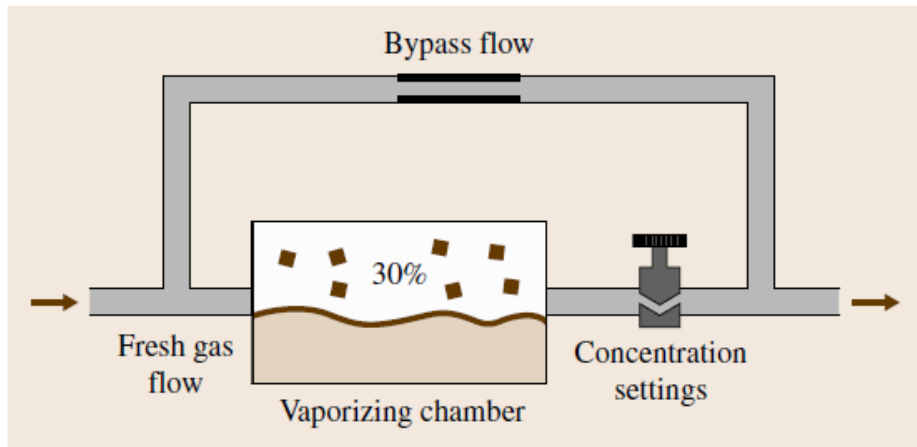
Drug Dosing

- Two principles are used for delivering O_2 , air, and N_2O , namely mechanical metering valves and electronic mixers

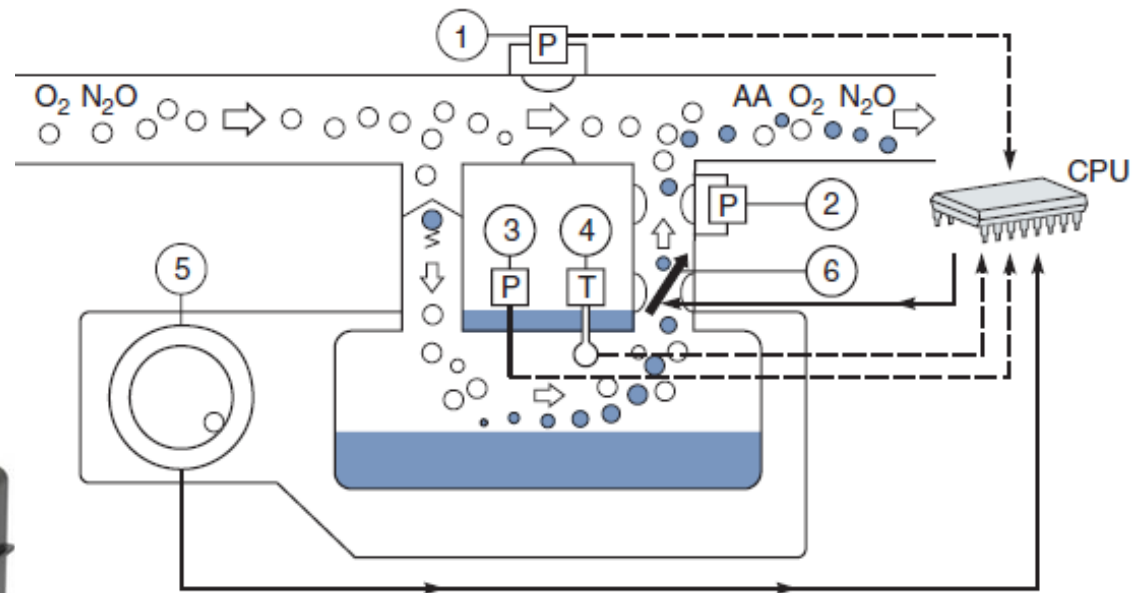


Anesthetic Agent Vaporizers

- Volatile anesthetic agents are used to achieve unconsciousness
 - ▣ Exhalable and evaporate quickly (e.g., isoflurane and sevoflurane)
- Anesthetic agent vaporizer converts anesthetic agent from liquid to vapor and mix it with fresh gas at preset concentration
- Concentration of saturated agent vapor is much higher (20 fold) than therapeutically necessary
 - ▣ Vaporizer is primarily designed to reduce high saturation concentration of, e.g., 30% to concentration required during anesthesia, e.g., 2%



Electronic Vaporizer Example



Measurement part

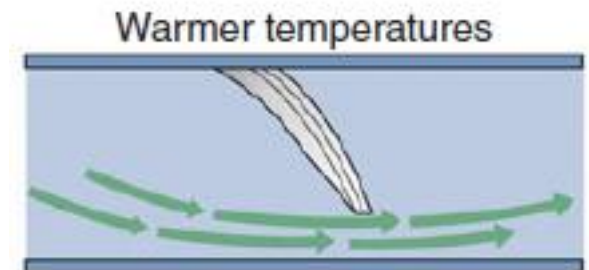
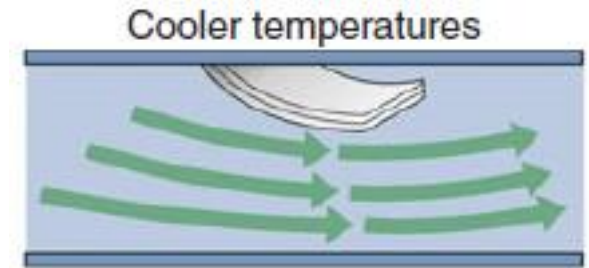
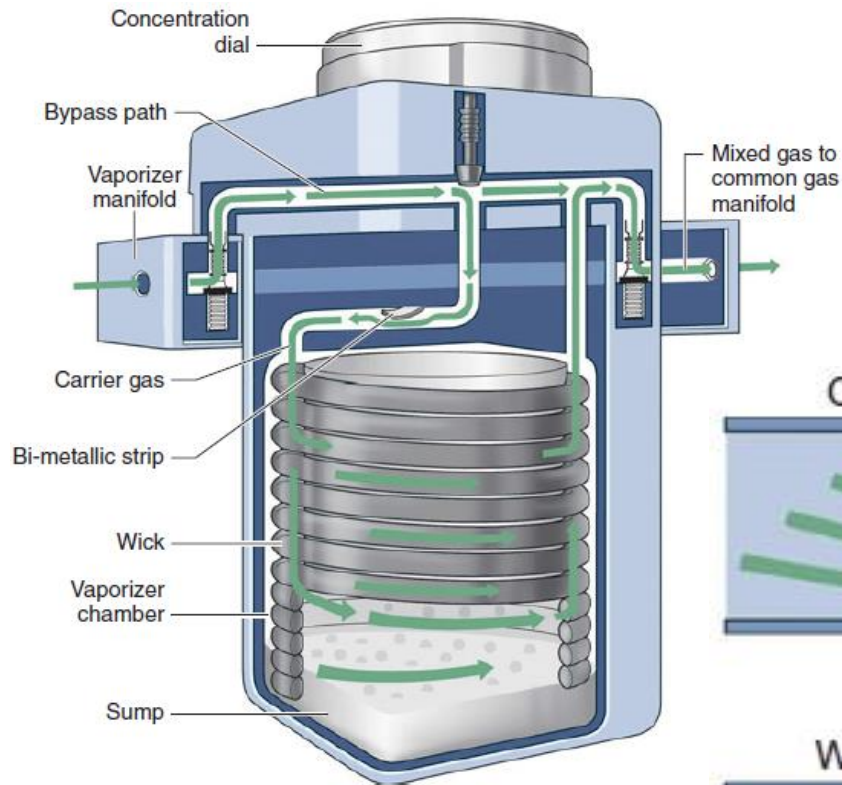
- (1) Bypass flow
- (2) Flow through the cassette
- (3) Cassette pressure
- (4) Cassette temperature

Agent control

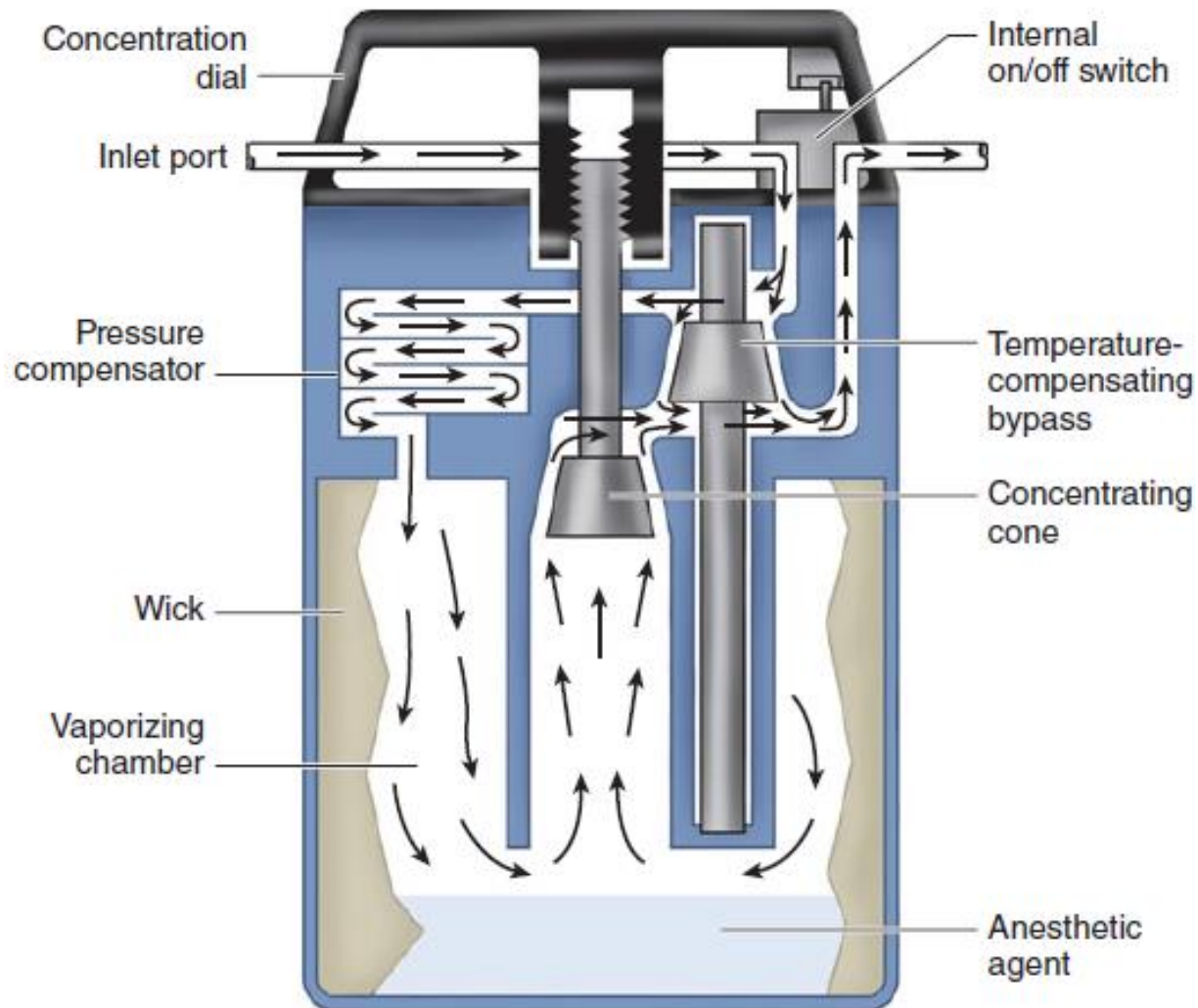
- (5) Agent setting
- (6) Control valve



Mechanical Vaporizer Example



Mechanical Vaporizer Example

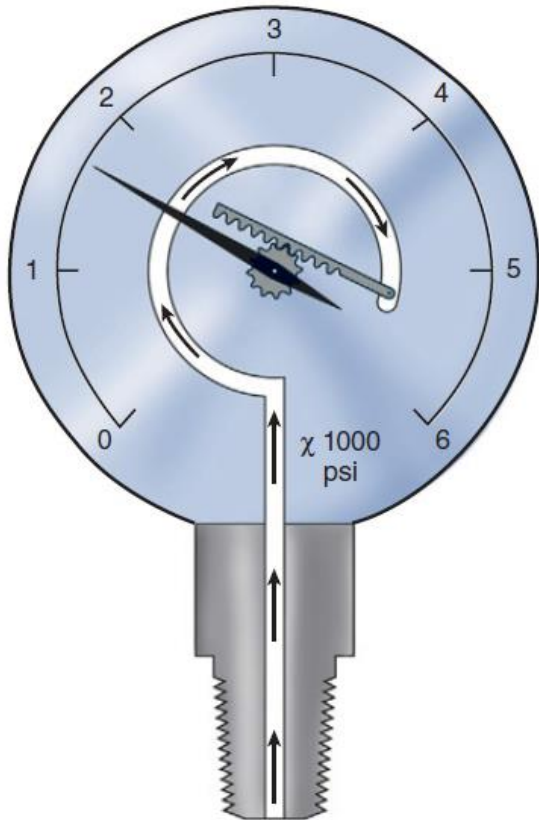


Monitoring in Anesthesia

- Generally, anesthesia devices are equipped with nine sensors
- Five device monitoring sensors for drug dosing and ventilation
 - ▣ Oxygen
 - ▣ Pressure
 - ▣ Volume
 - ▣ Carbon dioxide (CO₂)
 - ▣ Anesthetic agent
- Four patient monitoring sensors for monitoring patient health during uncomplicated operations
 - ▣ Electrocardiogram (ECG)
 - ▣ Noninvasive blood pressure (NIBP)
 - ▣ Oxygen saturation (SpO₂), and
 - ▣ Body temperature.

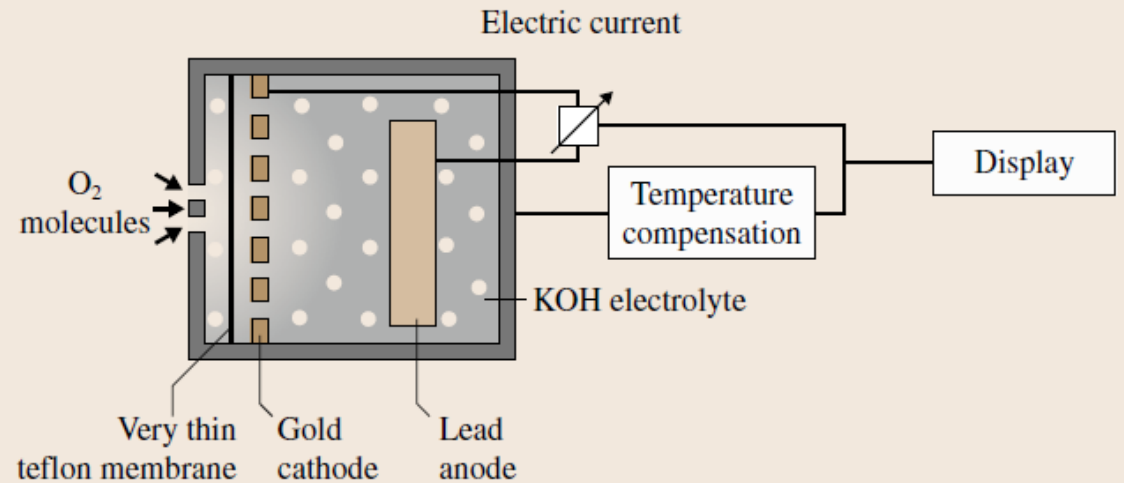
Bourdon Pressure Gauge

- Cylinder pressure is measured by Bourdon pressure gauge
 - ▣ A flexible tube within this gauge straightens when exposed to gas pressure, causing a gear mechanism to move a needle pointer

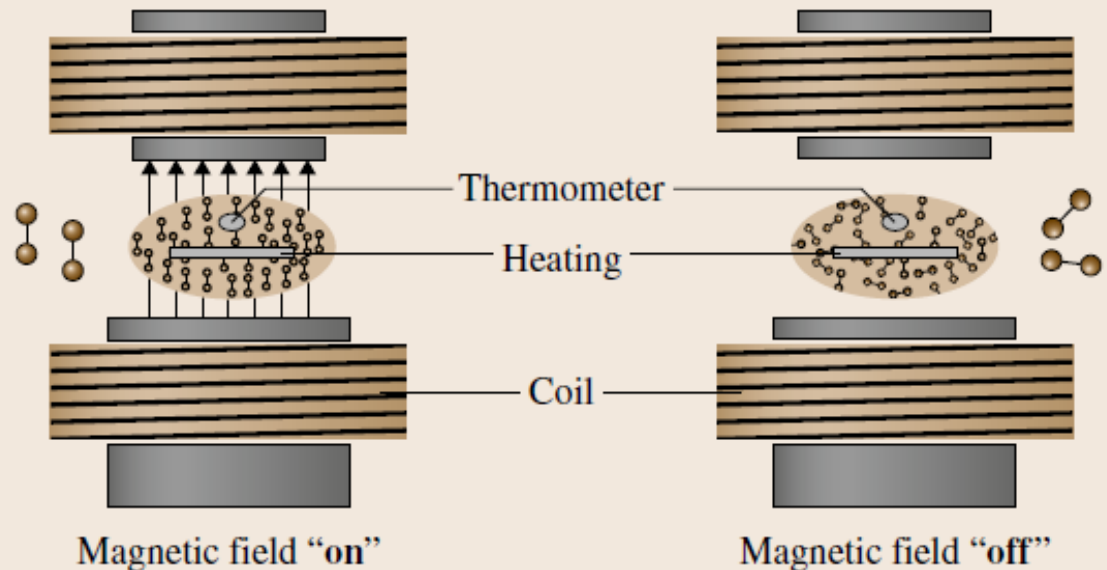


Oxygen Sensor

□ Fuel Cell type



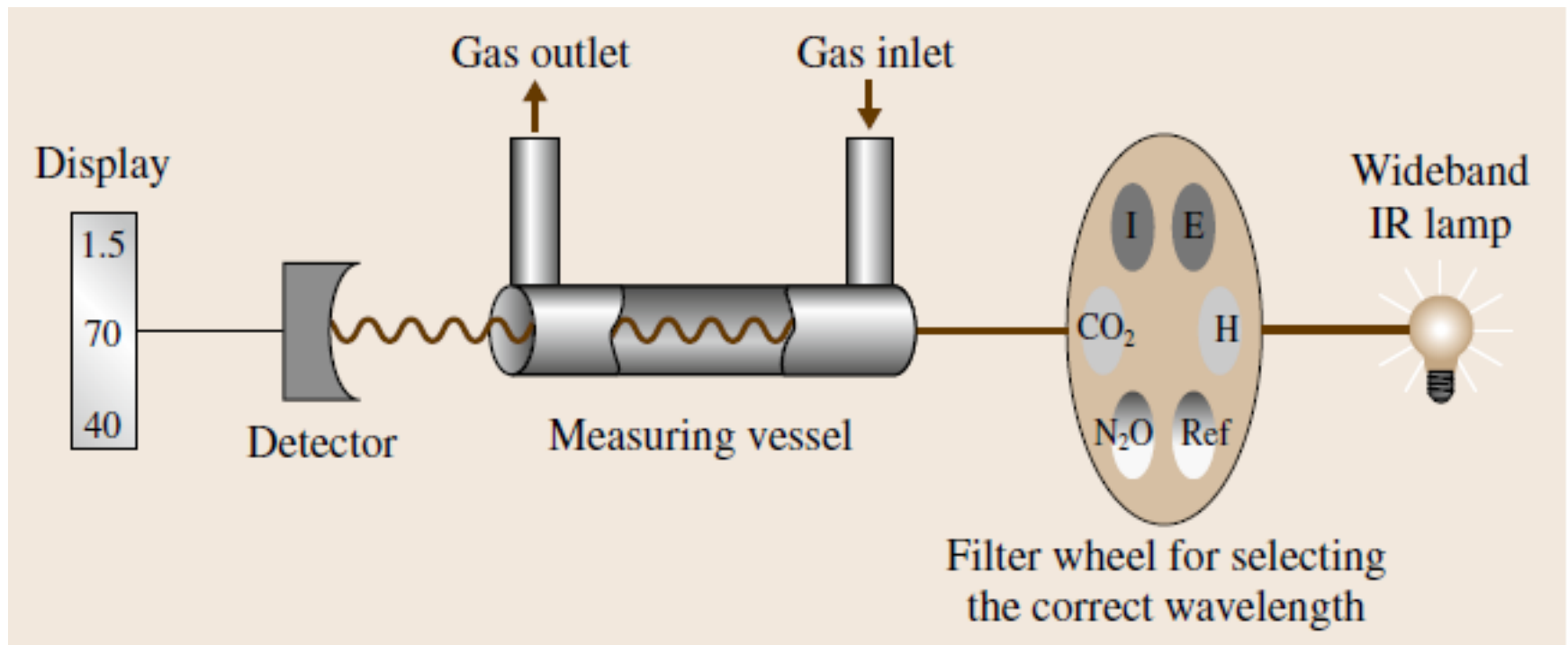
□ Paramagnetic type



CO₂, N₂O, and Anesthetic Agent Sensors

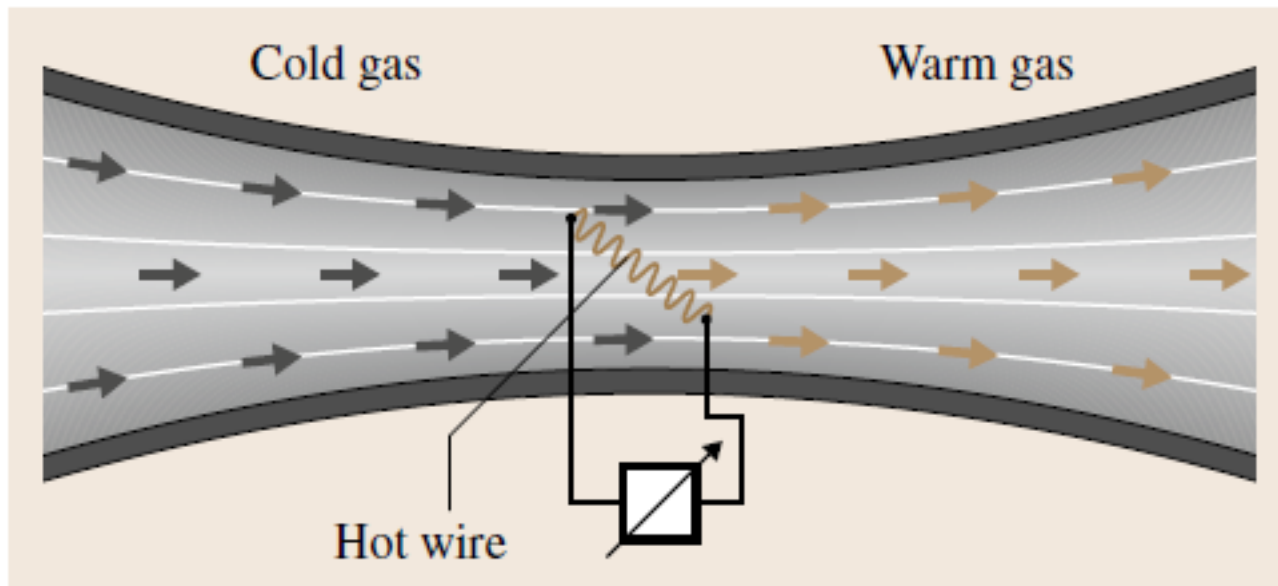
□ Infrared absorption spectroscopy

- ▣ Based on physical principle that polyatomic gases absorb infrared radiation at characteristic frequencies
- ▣ Level of absorption depends on concentration of molecules according to Lambert–Beer law: $\text{Concentration} = \text{Absorption constant} \times \ln(I_0/I)$



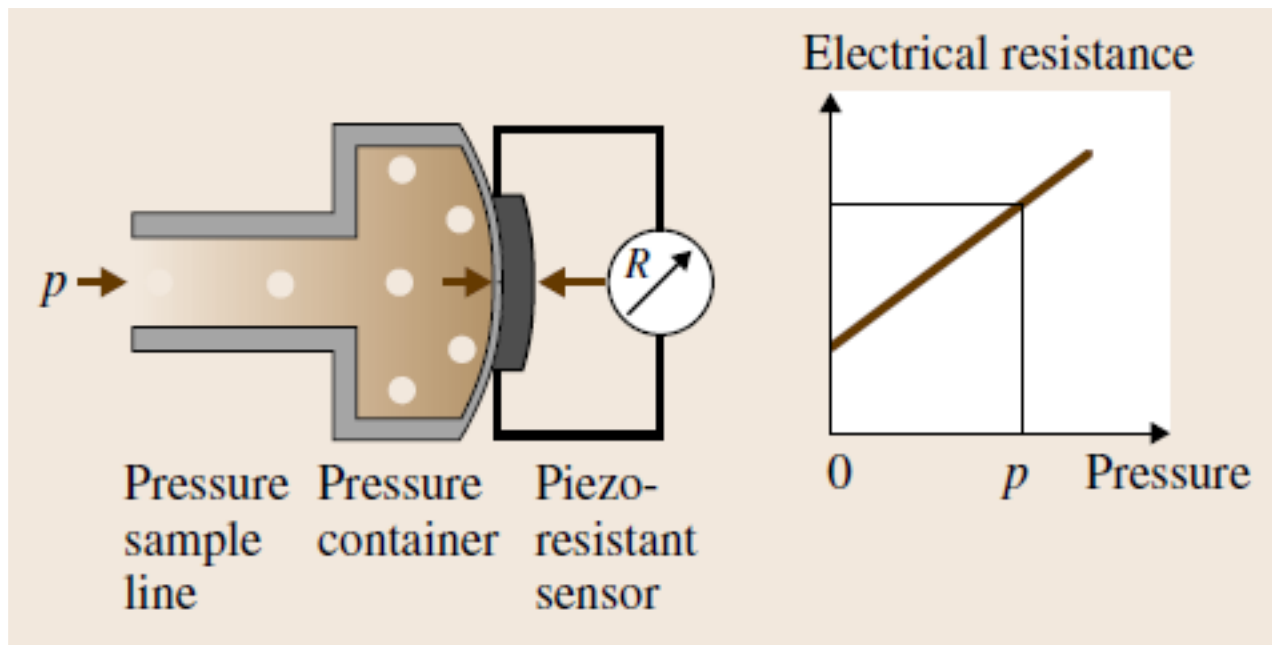
Volume and Flow Sensor

- Hot-Wire Anemometer method
 - ▣ Purely electrical method for volume measurement

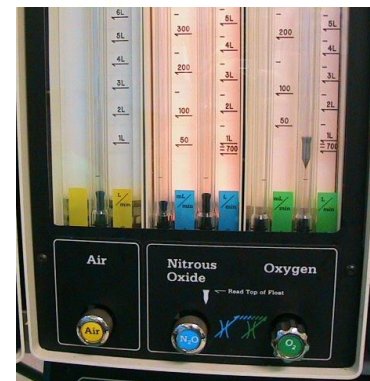
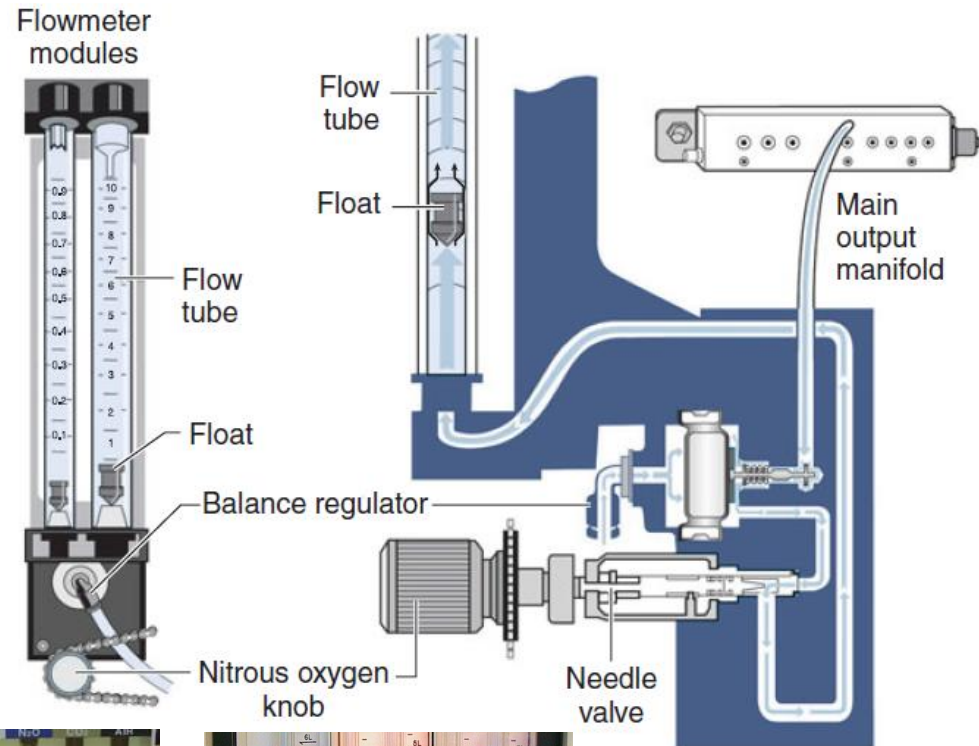
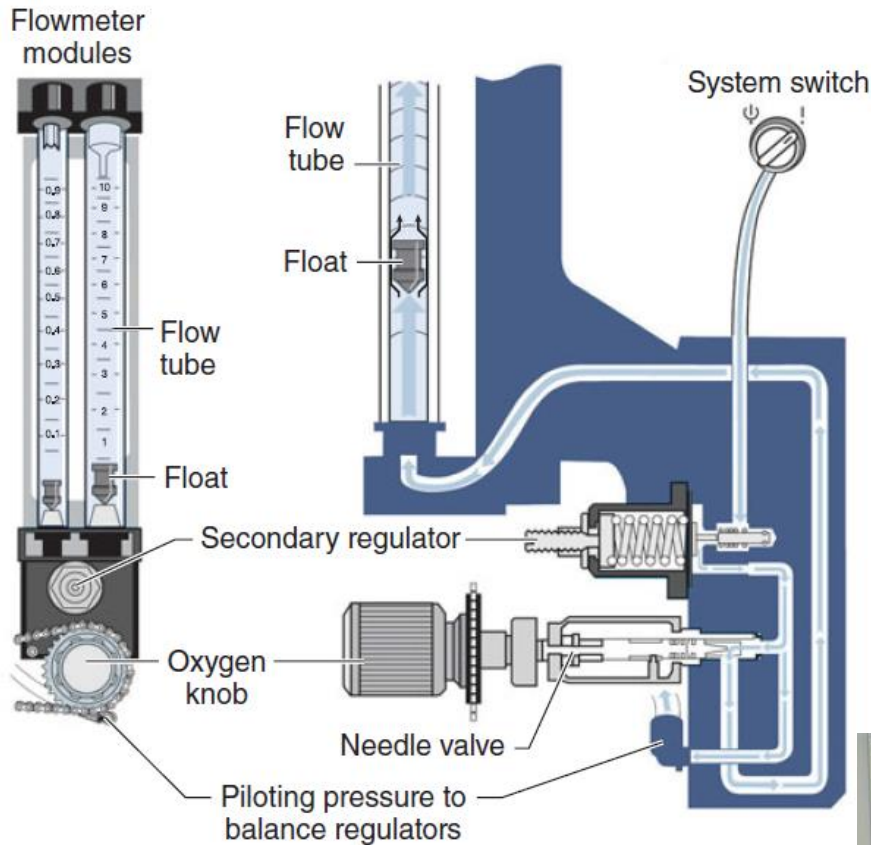


Pressure Sensor

- Piezoresistive Sensor
 - ▣ Solid-state device whose electrical resistance depends on elongation of membrane (and hence, pressure)

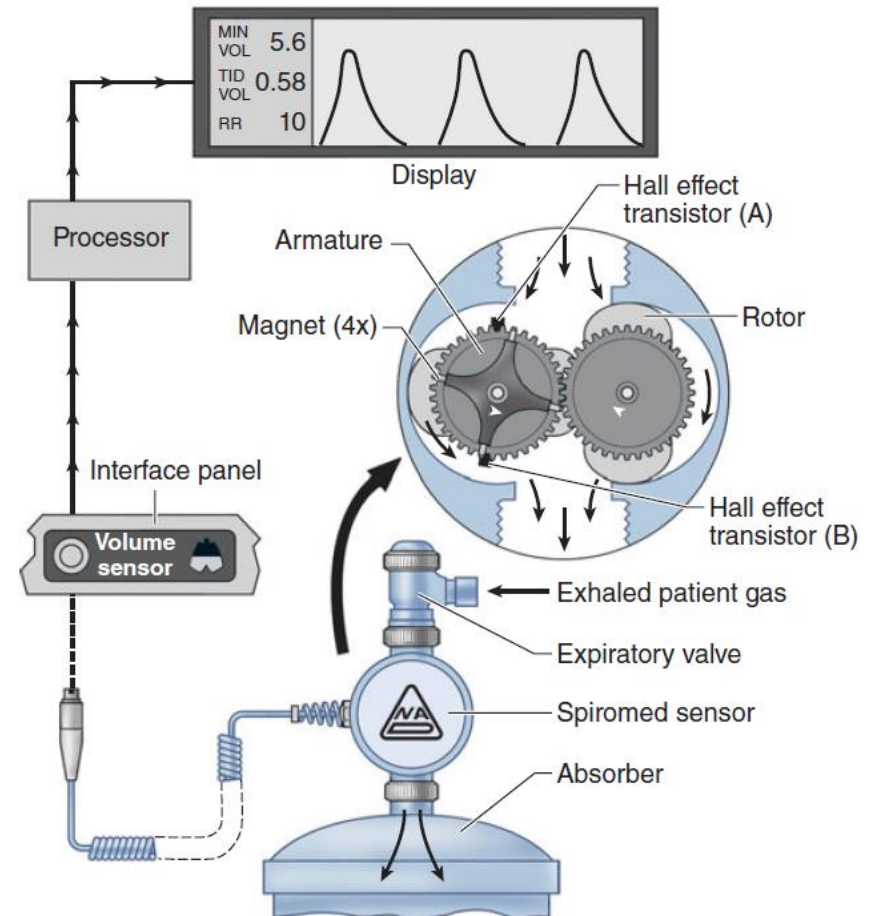
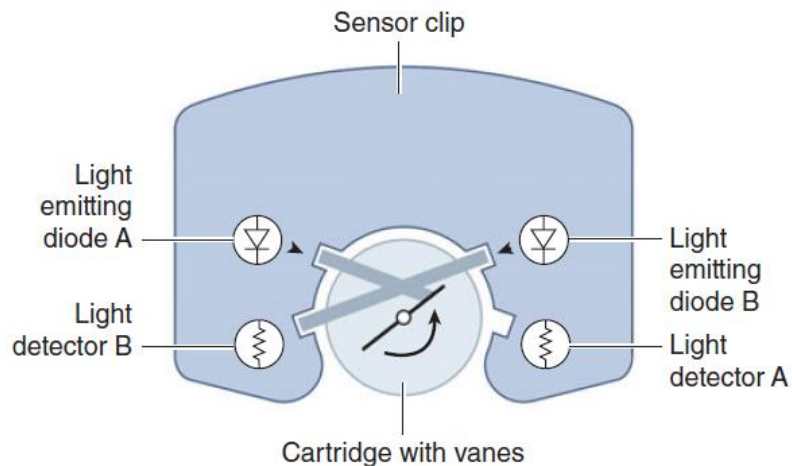
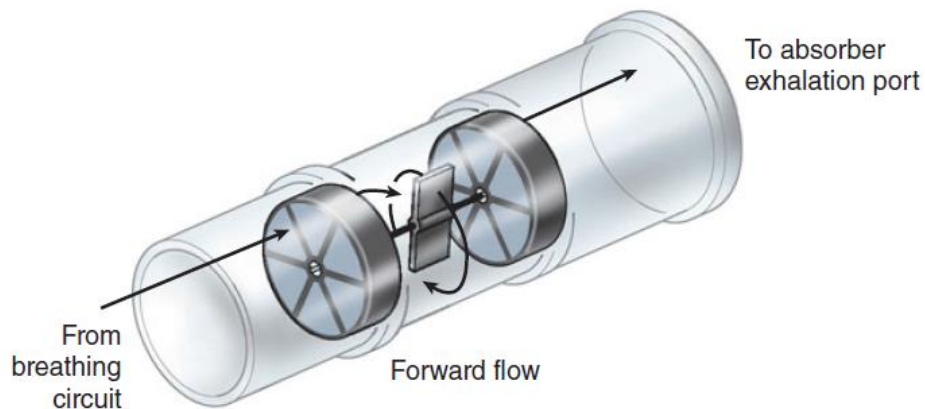


Flowmeters

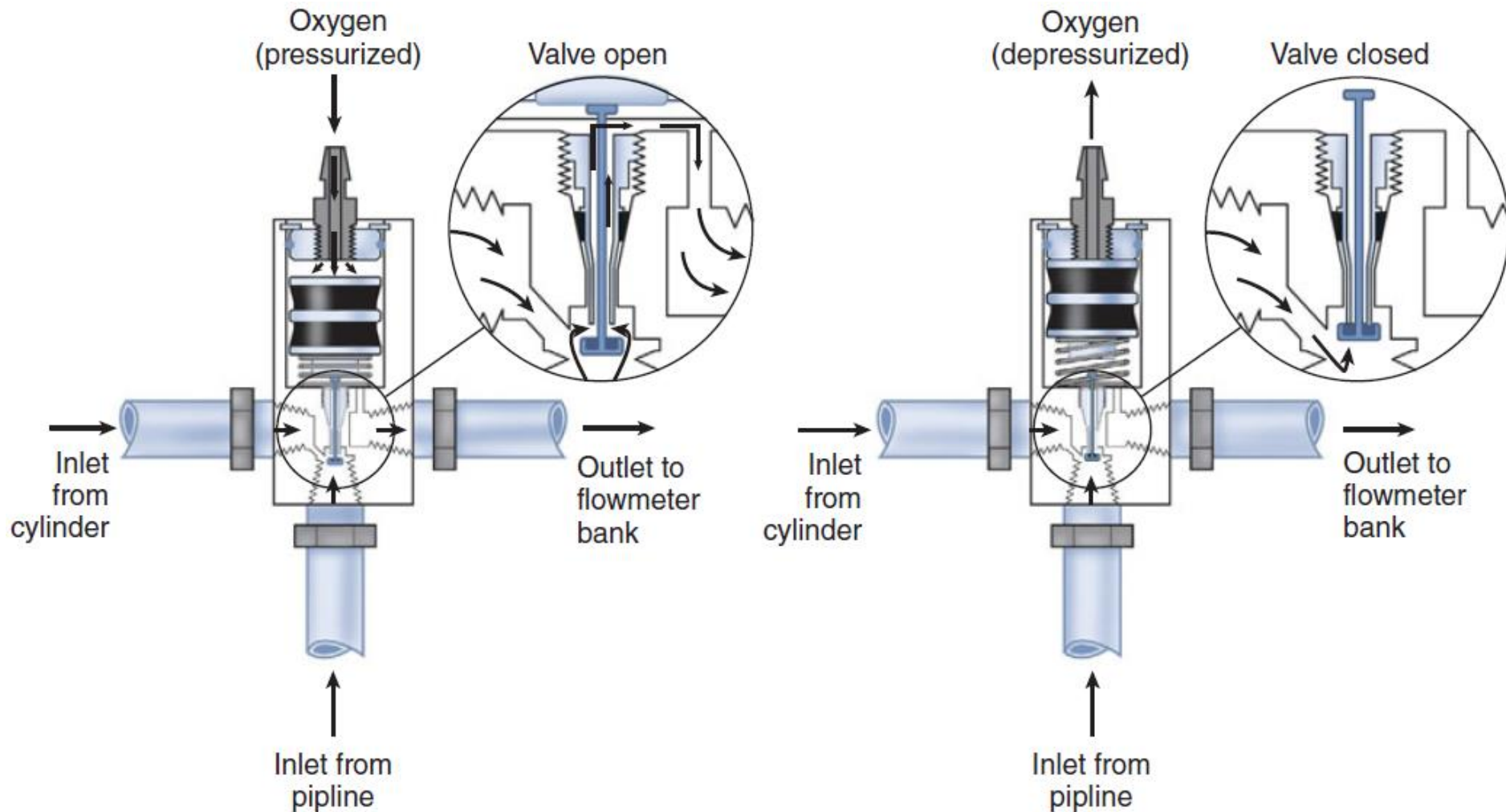


Spirometers

- Used to measure exhaled tidal volume in breathing circuit on all anesthesia machines, typically near exhalation valve



Oxygen Failure Protection



Suggested Readings and Assignments

- Chapter 4 of Recommended Reference #1
- Chapter 30 of Recommended Reference #2