DESIGN PRINCIPLES:
ANESTHESIA MACHINE
Recommended Textbook


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

- Auxiliary O₂ flowmeter
- Display
- Suction regulator
- Bellows assembly
- Flow controls
- Breathing system
- Reservoir bag
- Carbon dioxide (CO₂) absorber
- Oxygen (O₂) flush button
- Flowmeters
- Vaporizers
- System switch
- Secondary gas supply pressure gauges (cylinder gauges)
- Primary gas supply gauges (usually pipeline)
- Brake
Modern Anesthesia Machine - Back
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
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

- Concentration dial
- Inlet port
- Pressure compensator
- Internal on/off switch
- Temperature-compensating bypass
- Concentrating cone
- Wick
- Vaporizing chamber
- Anesthetic agent
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: Concentration = Absorption constant × \( \ln(I_0/I) \)
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)

![Diagram of pressure sensor](image-url)
Flowmeters
Spirometers

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

Diagram showing the flow of oxygen from a pressurized cylinder to an outlet flowmeter bank with a valve open and closed in both states.
Suggested Readings and Assignments

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