Anesthesia Equipment Lecture

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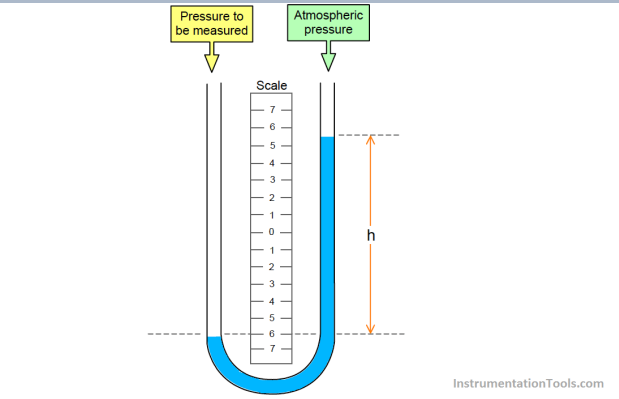
I. Introduction to Physical Principles in Anesthetic Practice

A. Pressure

- **Definition:** Force acting per unit area (P=f/a).
- **Vacuum:** A space with zero pressure, not routinely found.
- **Atmospheric Pressure:** At sea level, the pressure of air is 1 atm.
- **Units of Measurement:** Pressure is measured in various units. Like Bar, cmH2O, psi and KPa
    - **SI Unit:** Pascal (Pa), where 1 Pa is a pressure of 1 N acting over an area of 1 m2.
    - **Common Unit:** Kilopascal (kPa) is more common since 1 Pa is a tiny pressure.
- **Relative (Gauge) Pressure:** All pressure measurements are done using 1 atm as a zero point.

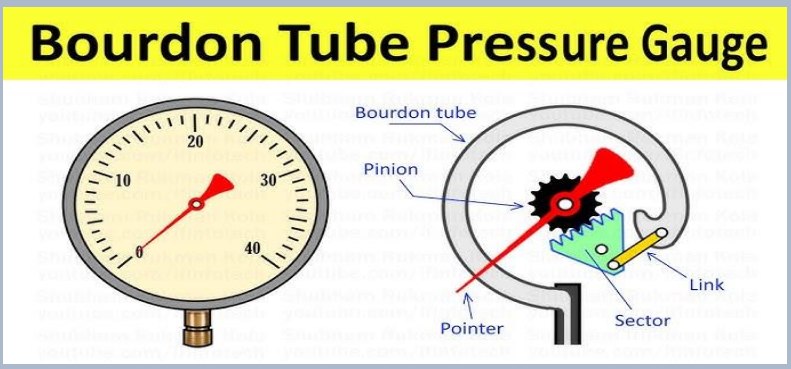
B. Pressure Measuring Devices

- **Manometer:** The simplest way to measure pressure, it works by the vertical displacement of a liquid in a tube.
    - One end is connected to the pressure source, and the other is open to the atmosphere.
    - The displacement depends on the density of the liquid.
    - Routinely used to measure



blood pressure (using mercury) and **central venous pressure** (using saline).

- **Bourdon Tube Gauge:** Used to measure higher pressures, such as those in gas cylinders, where a simple manometer cannot be used.
  - It consists of a hollow metal tube bent into a curve; one end is sealed and linked to a clocklike mechanism, and the open end is connected to the gas source.
  - An increase in pressure straightens the curved tube. The movement of the sealed end is transmitted to a pointer over a calibrated scale.



II. The Gas Laws These laws help predict the behavior of gases with changes in temperature and pressure.

- **Gas:** A substance in the gaseous phase above its **critical temperature**.
- **Critical Temperature:** The temperature above which a substance cannot be liquefied regardless of how high the pressure is.
- **Vapor:** A substance in the gaseous phase but is **below** its critical temperature.

Gas Laws and Practical Applications

Understanding the behavior of gases under varying conditions is crucial in anesthetic practice to prevent and detect medical gas depletion or supply line misconnection. Estimates of a particular hospital's peak demand determine the type of medical gas supply system required.

Gas Law	Definition	Clinical application
Boyle's Law	States that the at constant temperature the volume of a given mass of gas varies **inversely** with the absolute pressure	If a gas is forced into a smaller cylinder from a larger one, the pressure inside the smaller cylinder will be much higher. This principle is vital in understanding how high-pressure gases are stored.
Charles's Law	States that at constant pressure the volume of a given mass of gas varies **directly** with the absolute temperature	Gas expand when they are heated and become less dense thus hot air rises
Avogadro's Law	States that equal volumes of gases, at the same temperature and pressure, **contain the same number of molecules**.	uses of pressure gauges to assess the contents of a cylinder
third perfect gas law	states that at constant volume, the absolute pressure of a given mass of gas varies **directly** with the absolute temperature .	gas cylinders should be filled keeping in mind ambient temperature of storage If temperature in storage place is high, the pressure inside the cylinder will increase leading to explosion

III. Medical Gas Supply, Storage, and Safety

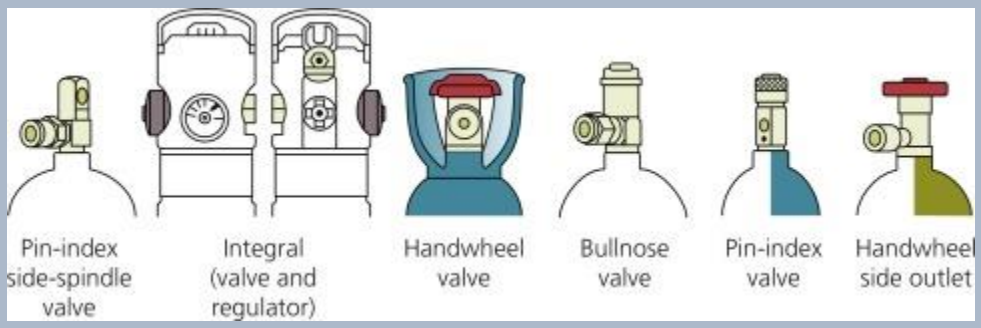
Medical gases are supplied in

cylinders or via a **medical gas piping system**. Common gases in operating rooms are oxygen, nitrous oxide, air, and nitrogen.

A. Cylinders and Components

- **Parts:** Body, valve, port, stem, and pressure relief devices.
- **Construction:** Made of thin-walled, seamless **molybdenum steel** (stronger and lighter than carbon steel) to withstand high internal pressure.

- Lightweight cylinders can be made from aluminum. These can be used to provide oxygen at home, during transport or in magnetic resonance scanners. They have a flat base to help in storage and handling.
- **Valve and Neck:** The valve is fitted into a tapered screw thread at the top end (the neck). The thread is sealed with a material that melts in high heat, allowing gas to escape to prevent an explosion.
    - **Valves:** Seal the cylinder contents and are typically made of brass, sometimes chromium plated.
    - Types include the pin-index valve, side spindle pin-index valve, bullnose valve, hand wheel, and star valve.



- **Size and Capacity:** Cylinders come in sizes A to J; sizes E and J are common in anesthesia. Size E oxygen holds 680 L, and size E nitrous oxide holds 1800 L.

Size	Capacity (liters)	
	Oxygen	Nitrous oxide
E	680	1800
J	6800	18000

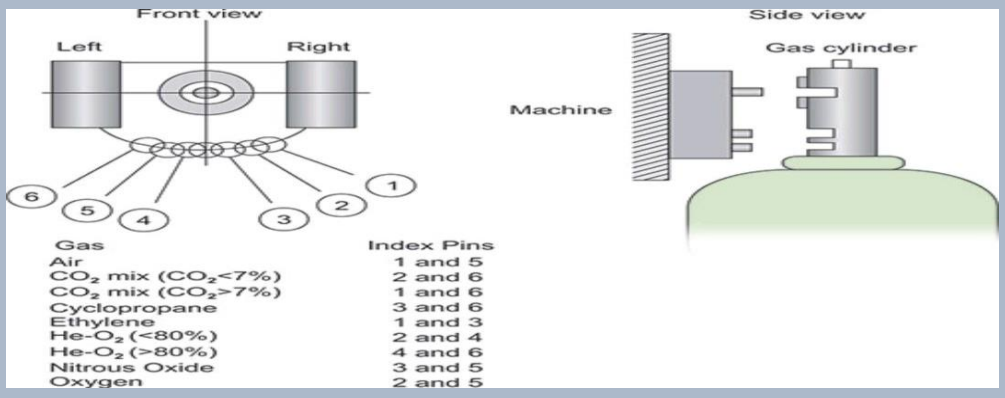
- **Storage State and Pressure:**
  - **Oxygen** (O_2) is stored as a **gas** at 13,700 kPa.
  - **Nitrous Oxide** (N_2O) and **Carbon Dioxide** (CO_2) are stored in a **liquid phase** with vapor on top.

    N_2O pressure is 4,400 kPa, and CO_2 is 5,000 kPa (at room temperature).

- **Filling Ratio (for liquid gases):** Since liquid is less compressible, cylinders must be partially filled to minimize explosion risk from pressure increases due to temperature changes.
  - **Formula:** (Weight of fluid in cylinder) / (Weight of water required to fill the cylinder).

B. Safety Features of Cylinders

- **Color-Coding:** Cylinders are color-coded (body and shoulder) to prevent accidental use of the wrong gas.
  - **Oxygen:** Black body, white shoulder (Green body in USA).
  - **Nitrous Oxide:** Blue body, blue shoulder.
  - **Carbon Dioxide:** Grey body, grey shoulder.
- **Pin-Index System:** A non-interchangeable safety system used on size E and smaller cylinders, as well as F- and G-size Entonox cylinders.
  - A specific pin configuration on the anesthesia machine's yoke matches a configuration of holes on the cylinder's valve block, ensuring only the correct cylinder can be fitted.
  - O_2 pin index is **2:5**; N_2O is **3:5**; CO_2 is **1:6**.



- **Bodok Seals:** Noncombustible neoprene washers with aluminum edges that ensure a gas-tight fit between the cylinder and the anesthetic machine yoke.

- **Pressure Relief Devices:** Fitted to every cylinder to vent contents to the atmosphere if the pressure increases to a dangerous level, preventing bursting

    - **Rupture disk:** A non-reclosing device that ruptures when a predetermined pressure is reached.
    - **Fusible plug**.
    - **Spring-loaded pressure relief valve:** A reclosing device that opens to let out gas until the excess pressure is relieved.
- **Cylinder Key (Handle) or Hand wheel:** Used to open (counterclockwise) or close (clockwise) the cylinder valve.

C. Cylinder Pressure and Contents Estimation

- **Gaseous Contents (O2, Air):** The pressure in the cylinder falls **proportionately** as the content empties. If half the content is used, the pressure drops to half.
- **Liquid/Vapor Contents (N2O, CO2):** The pressure remains **constant** ("full cylinder pressure") until the liquid has completely evaporated.
    - This is because the gauge reads the saturated vapor pressure of the liquid gas.
    - Once all the liquid is gone, the pressure then drops much faster.

- The vaporization of the liquid can cause the cylinder's temperature to decrease due to the loss of latent heat of vaporization, potentially forming ice on the outside.

D. Cylinder Testing and Marking

- Cylinders are checked and tested by manufacturers at regular intervals, usually every **5 years**.
- Tests include: Internal endoscopic examination, flattening/bend/impact tests (on

  1/100 cylinders), pressure test (subjected to ~22,000 kPa), and tensile tests (on 1/100 cylinders).

- **Engraved Marks:** Test pressure, dates of test performed, chemical formula of contents, and tare weight (weight of empty N2O cylinder).
- **Labels:** Include details like name/chemical symbol of the product, hazard warnings, cylinder size code,

nominal contents (liters), maximum pressure (bars), filling date/expiry date, and storage precautions.

E. Rules for Safe Use

- Handle only by trained staff.
- Store in a

  cool, clean, dry, well-ventilated, and fireproof room.

- Do not store near

  heat sources, flammable materials (oil, grease), or corrosive chemicals.

- **Separate full and empty cylinders**.
- Store F, G, and J sizes **upright**; C, D, and E sizes can be stored

  horizontally on shelves.

- Keep the valve

  closed when not in use and always fully open when in use.

- Use a sealing washer in good condition.
- Identify contents by label.
- Report over-pressurized cylinders to the manufacturer.


ANESTHESIA GAS SUPPLY SYSTEM
Port
6
5
4
3
2
1
Oxygen (2,5)
Nitrous oxide (3,5)
Air (1,5)
Carbon dioxide (1,6)
Entonox (7)
Pin Index safety system
Valve
Body
Stem
Port
Pin index
Neck
Shoulder
Body
Base
Color code
Locking groove
Hose
socket
Index collar
Diameter Index safety system

Thank you