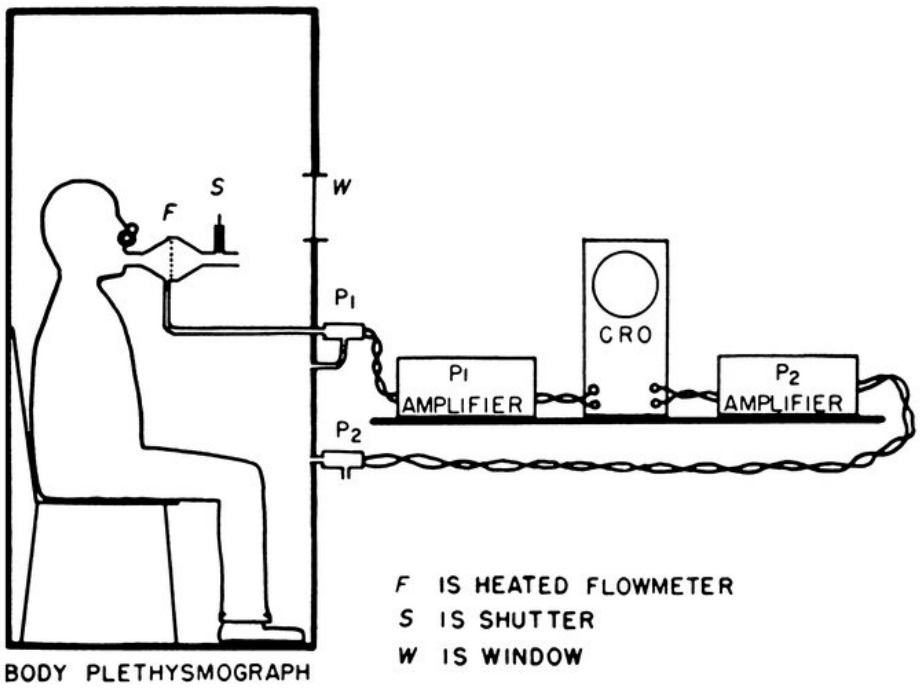
4.4 Whole body Plethysmograph

- A whole-body plethysmograph is a specialized device used to measure **lung volumes and airway resistance**, providing a comprehensive assessment of respiratory function.
- The test is commonly used in clinical settings to diagnose and monitor respiratory conditions such as **asthma, chronic obstructive pulmonary disease (COPD)**, and other lung disorders.
- The **volume-constant whole-body plethysmograph** is a chamber resembling a glass-walled telephone box in shape and volume (about 700 to1000L).
- During measurement the **box is closed** with an airtight seal, except for a small controlled leak that is used to stabilize the internal pressure by allowing for equilibration of slow pressure changes, e.g. due to warming-up.
- One **pressure transducer** serves to measure the pressure inside the box relative to ambient pressure, **another one is placed close to the mouth** for recording mouth pressure during a shutter maneuver.
- The shutter mechanism can be used to deliberately block the airflow by transient occlusion.
- Moreover, respiratory flow rate is recorded by conventional equipment, such as pneumotachograph, anemometer, or ultrasound measurement, all of which is calibrated via syringes delivering a defined volume.
- The principle of measurement of the commonly used plethysmographs relies on detecting changes in box pressure in combination with either changes of mouth pressure or with flow rate under defined breathing conditions.
- These signals are evaluated in order to determine static lung volumes and airflow resistance.



- The principle of operation of the plethysmograph depends on the **Boyle's law** which states that at a given kelvin temperature, the pressure of a given mass of gas is inversely proportional to its volume.

Step-by-Step Procedure for Measuring Total Lung Capacity (TLC) via Plethysmography:

Components:

- **Body Plethysmograph Box:** This is the enclosed chamber where the subject sits. It's airtight except for the mouthpiece and a small opening for the flowmeter.
- **Heated Flowmeter (F):** This measures the volume of air flowing in and out of the lungs. The heating element ensures accurate measurements by preventing condensation.
- **Shutter (S):** This can be closed to create an airtight seal within the box.
- **Pressure Transducer (P1):** This measures the pressure inside the box.
- **Pressure Transducer (P2):** This measures the pressure in the mouthpiece.
- **Amplifiers:** These amplify the signals from the pressure transducers.

- **CRO (Cathode Ray Oscilloscope):** This displays the pressure signals, allowing for visual analysis of the respiratory cycle.

Working:

1. **Subject Preparation:** The subject sits inside the box and breathes through a mouthpiece connected to the flowmeter and pressure transducer P2.
2. **Measurement:**
    - **Inhalation:** The subject inhales, drawing air from the box. This reduces the pressure inside the box (measured by P1) and increases the flow of air into the lungs (measured by F).
    - **Exhalation:** The subject exhales, expelling air into the box. This increases the pressure inside the box (measured by P1) and increases the flow of air out of the lungs (measured by F).
3. **Data Analysis:** The pressure and flow signals are recorded and analyzed using the CRO and other data processing techniques. This allows for the calculation of lung volumes (such as total lung capacity, vital capacity, and residual volume) and respiratory mechanics (such as airway resistance and lung compliance).
4. **Calculate Total Lung Capacity (TLC)**:
    - After measuring FRC, the patient is instructed to take a deep breath to their maximum lung capacity.
    - Using the FRC measurement as a baseline, TLC can be calculated with the following formula:
    - TLC=FRC+ Inspiratory Capacity (IC)
    - Inspiratory Capacity (IC) is measured separately by having the patient inhale maximally from a relaxed end-expiratory position (starting from FRC).

5. Derive Residual Volume (RV):

- ❒ Another important component of TLC is the Residual Volume (RV), which is the volume of air remaining in the lungs after maximal exhalation.
- ❒ RV can be derived from TLC using the formula:
- ❒ RV=TLC−Vital Capacity (VC)
- ❒ Vital Capacity (VC) is measured separately, typically by having the patient inhale to their maximum lung volume and then exhale fully.

$$TLC = VOL_c \left[\frac{dP_C}{dP_T}\right]$$

$$P_T = Thorax\ pressure$$
$$P_C = Chamber\ pressure$$
$$VOL_c = Chamber\ volume$$

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