UNIT II

BIO CHEMICAL NON MECHANICAL PARAMETER MEASUREMENT

P^H, PO_2, PCO_2, colorimeter, Autoanalyzer, Blood flowmeter, cardiac output, respiratory measurement, temperature, pulse, Blood cell counters, Bloodpressure.

2.1 INTRODUCTION:

Chemical electrodes to determine used to measure P^H, Po_2 of blood. They used to determine the oxygen and carbon di oxide tension in the blood. Tension or partial pressure of any gas is proportional to the quality of the gas in the blood.

Different types of chemical electrode.

2.2CHEMICAL ELECTRODE

2.2.1P^H Electrode:

Chemical balance of the human body in identified by the measurement of p^H content of blood and other body fluids. P^H is defined as the logarithmic of reciprocal of H^+ ion concentrations.

$$P^H = \log_{10} 1 /[H^+]$$
$$= - \log_{10} [H^{+}]$$

Neutral solution has a p^H value of 7. If $p^H < 7$, it is acidic, $p^H > 7$ it is basic.

Human blood is slightly basic such that p^H value of venous blood 7.35 and for arterial blood 7.40. Glass electrode is normally used as p^H electrode. Glass electrode consists of spherical bulb 0.5 cm in a diameter which provide thin glass membrane which permit the passage of only hydrogen ions in the term of H_3O^+.

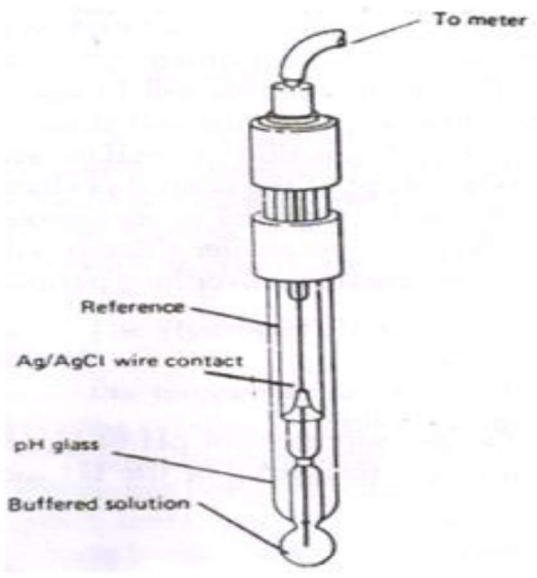


Fig 2.2.1 : P^H Electrode

Inside the glass bulb silver / silver chloride non polarized electrode is immersed in chloride buffer solution usually of $p^H = 1$. Other side of glass bulb is exposed to the solution of unknown p^H. The connection to the potential measuring circuit and solution being tested completed through a potassium chloride salt bridge and a calomel reference electrode.

Glass electrode advantages (over hydrogen electrode):

It is independent of oxidation – reduction potential. It is not necessary to pass the gas through the solution i.e equilibrium condition is reached rapidly. It can be used in coloured or turbid solution. It gives small error when we measure the p^H for highly acidic p^H =0 alkaline solution p^H =9.

2.2.2 PO_2 Electrode:

The oxygen electrode is a piece of platinum wire embedded in an insulating glass holder with the end of the wire exposed to the electrolyte solution into which oxygen is allowed to diffuse through the membrane The bottom of the vessel containing electrolyte consists of a membrane permeable to oxygen and the top of vessel is sealed.

Ag - Agcl electrode is used A voltage of 0.7V is applied between the platinum wire and the reference electrode using a battery. The negative of the battery is connected to the platinum wire through an ammeter. Reduction of oxygen takes place at platinum wire.Hence an oxidation-reduction current is developed and is proportional to the partial pressure of oxygen.

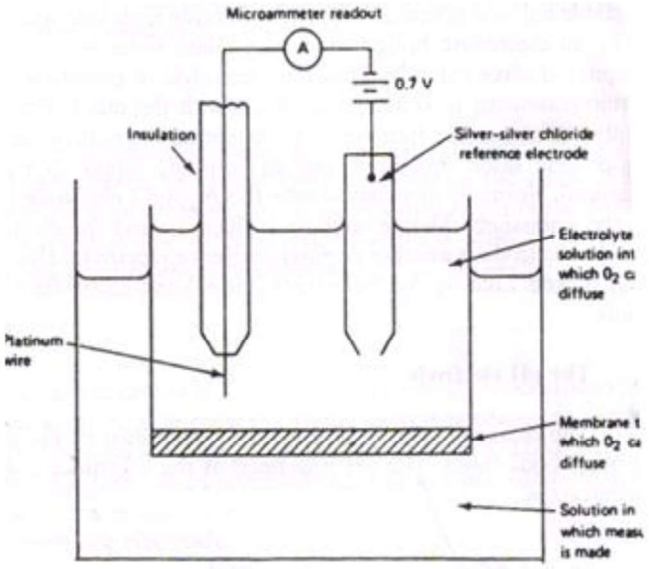


Fig 2.2.2 : PO_2 Electrode

Advantages

- The oxygen electrode is also used to monitor the partial pressure of oxygen in biological fluids.
- It is available in integrated version consisting of platinum electrode and reference electrode in the same enclosure called Clark electrode.

2.2.3 PCO2 Electrode:

It consists of a standard glass P^H electrode covered with rubber membrane permeable to CO_2.Between the glass surface and membrane there is a thin film of water. The solution under test contains dissolved CO_2 is presented to the outer surface of rubber membrane. After equilibrium P^H of aqueous film is measured by glass electrode and interpreted interms of PCO_2.

2.3 PHOTOMETERS AND COLORIMETERS

They are used to measure the transmitted and absorbed light as it passes through a simple. The colorimeters uses light absorption to determine blood proteins and iron levels. The basic principle behind colorimeter is that many chemical compounds in solution appear coloured with saturation of colour depending on the concentration of compound. By analyzing the transmitted light through the sample or emitted light by the sample, the concentration of the substance can be determined.

$$\text{Transmittance } T = \frac{I_1}{I_0}$$

Where $I_1 \rightarrow$ Transmitted light intensity

$I_0 \rightarrow$ Incident light intensity

$$\text{Absorbance or optical density } A = -\log \frac{I_1}{I_0} = \log \left(\frac{I}{T}\right)$$

$$\text{Thus } A = \alpha C L$$

Where $\alpha \rightarrow$ Absorbtivity which depends on the absorbing substance and optical wavelength at which measurement is performed.

$C \rightarrow$ Concentration of absorbing substance

$L \rightarrow$ Path length of cuvette

By measuring optical density or absorbance 'A' the concentration of given substance in the sample can be determined. Colorimeters can be in the fitter photometer or spectrophotometer. When an interference filter is used to select a given wavelength it is called filter photometer. When a diffraction grating or prism is used as a monochromator to get different spectral components or wavelengths is the colorimeter, and then it is called spectrophotometer.

Fluorescence is an optical phenomenon in which the light of shorter wavelength is incident on a sample and he sample absorbs and remits light of longer wavelength the

concentration of such chemicals can be determined by fluorometers. There are filter fluorometer and spectrofluoremeters depending on whether filters or monochromators are used to select the emission wavelength.

2.3.1 Filter Photometer (Colorimeter)

It is used to measure transmittance. Light from a halogen lamp is incident on a filter F. The divergent transmitted light is converted into two parallel beams by an optical arrangement.

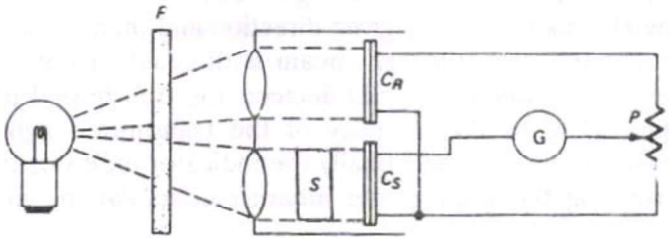


Fig 2.3.1: Filter Photometer

One beam falls on a reference selenium photoelectric cell C_R and other beam falls on a sample selenium photoelectric cell Cs after passing through sample in the cuvette. Without the sample, outputs from photoelectric cells are the same. When the sample is placed in the light path, output is reduced and hence the potentiometer is adjusted such that both cells C_R & C_S give the same output which is indicated by null deflection in Galvanometer 'G'. Since the potentiometer is calibrated in terms of transmittance, the concentration of the give substance in the sample can be determined.

2.3.2 Spectrometer:

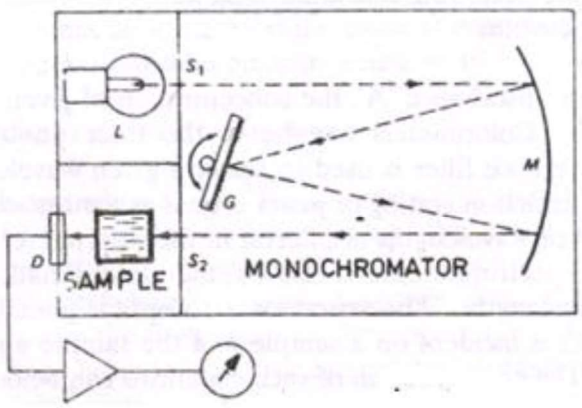


Fig 2.3.2 : Spectrometer

Light from a halogen lamp is passed through an entrance slit s1 and incident on a concave reflector which focuses the light on a diffraction grating 'G' to disperse light. The dispersed light is allowed to incident on the reflector. Then the light beam is directed to the sample through a narrow exit slit s2.

A sensitive photodetector D detects the transmitted light and gives an electrical output corresponding to the intensity of transmitted light. The amplifier amplifies the output from the detector and finally the indicator indicates the concentration of substance. By rotating the grating measurements can be made at different wavelengths.

2.3.3 Flame Photometer:

A flame photometer is used to analyze urine or blood in order to determine the concentration of K, Na, Ca, and Li. Lithium is used as a calibration substance in analysis of other three substances. A known amount of lithium is added to the sample and the emitted light intensity is measured relative to that of lithium.

By this way, any error due to varying flame temperature is eliminated. Using an atomizer, liquid sample is sprayed into fine droplets by passing oxygen or air to it. A combustible gas like acetylene is also added with air. The sample air mixture is burnt out and the light emitted in the flame is passed through a narrow slit and then to diffraction grating. The diffracted colours are incident on various photodiodes.

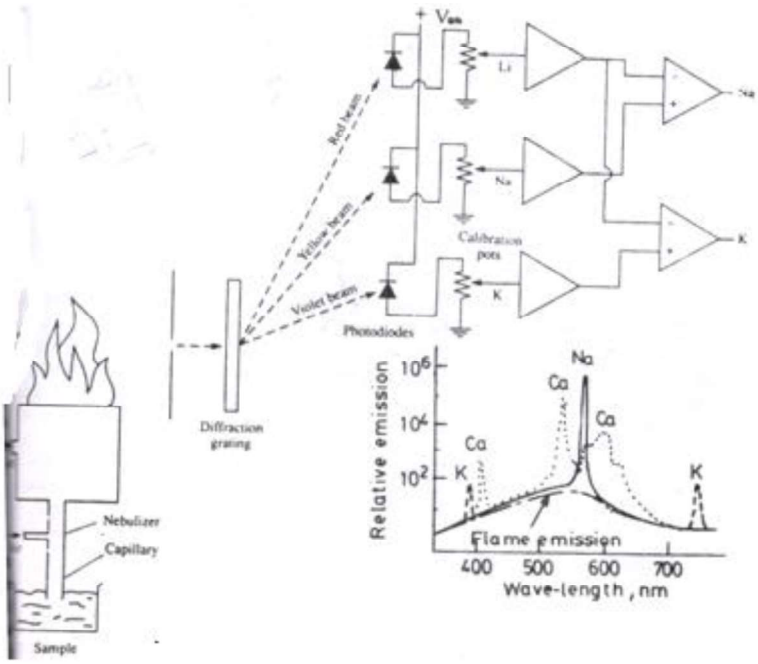


Fig 2.3.3 : Flame Photometer

The variations in the intensity of light are eliminated by proper electronic monitoring circuit. The concentration of potassium ions is detected by observing the peak height of spectral line corresponding to it.

K : 4047 A^0, Na : 5890 A^0, Li : 6703 A^0

Separate photo detector is used for each channel. The photodetctor circuit consists of a reverse biased diode in which current flow increases as the intensity of light increases. Flame photometer has many advantages such as fast response, high accuracy and lesser cost of equipment. But its sensitivity is smaller than fluorometer.

2.4.4 Filter Fluorometer:

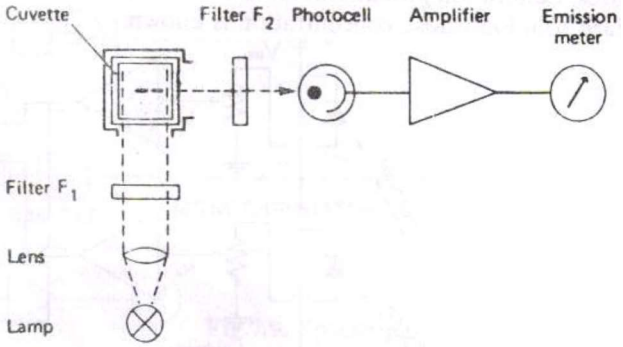


Fig 2.3.4 : Filter Fluorometer

Flurometer is carried out by illuminating the sample with a lower wavelength light, normally UV light and then measuring the fluorescent light intensity which is at higher wavelength. It is used only when the substances are available in lower concentration (eg) certain hormones and vitamins. Light from a light source is made parallel by a convex lens and passed through a filter F1. Filter allows the wavelength which is highly absorbed by the sample in the cuvette. F2 allows the selected fluorescent peak wavelength to incident on the photocell. The output of this detector is amplified and the concentration of substance is indicated by emission meter.

2.4.5 Chromatography:

Chromatography is a technique used for separating closely related chemical substances. It is based on differences in the migration velocity of the substances between a stationary phase and a mobile phase. The difference is due to a difference in solubility in two phases. Depending upon the nature of mobile phase, there are

- → Liquid chromatography which uses liquid mobile phase
- → Gas chromatography which uses gas mobile phase.

Liquid chromatography is used to analyse amino acids and composition of drugs.

Gas Chromatography is used to anayse steroids and aromatic acids.

The sample is added with the mobile phase gas or liquid flow.The components in the sample travel with different velocities depending on their solubility in the stationary phase.If the solubility of a component is lower, then it will travel faster

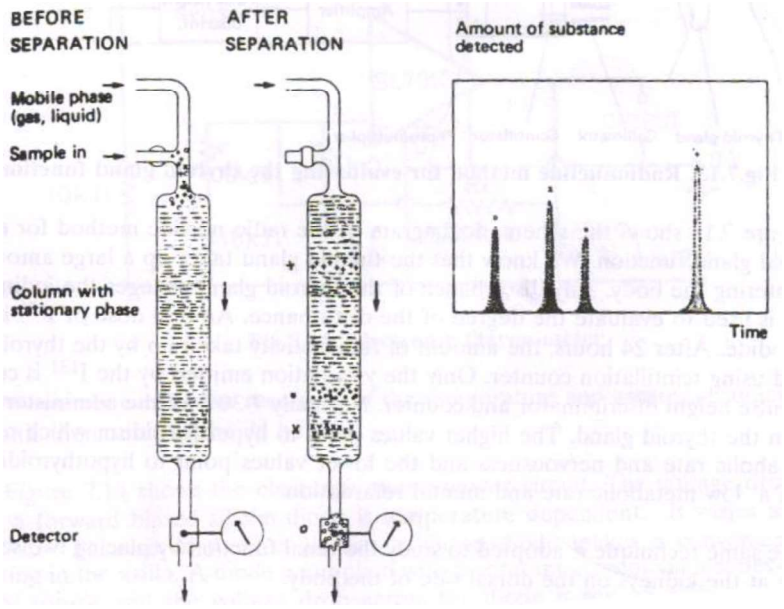


Fig. 2.3.5 :basic principle of chromatography.

Thus the different components in the sample are separated as a result of their different migration velocities.The detector in the outflow detects and displays the various components arriving at different timer.

2.4 AUTOANALYZER (AUTOMATION OF CHEMICAL TESTS)

Most chemical tests consist of simple steps like pipetting, diluting and incubating. These are time consuming and require skilled technicians to avoid the errors. To replace the technicians by an automatic device, the first automatic analyse was found and still used at most hospitals. In auto analyzer the mixing, reaction and colorimetric determination takes place in a continuous stream and not in an individual test tube for each sample.

The sample feeds the sample into the analyzer in time sequence .A peristaltic pump is used to meter the sample and reagent .The pump works simultaneously on a number of tubes .Mixing is achieved by injecting air bubbles. The mixture is flowing through heated coils.

The air bubbles are removed and the solution finally flows to a colorimeter or a flame photometer An electronic ratio recorder compares the output of reference and sample photocells. The recording shows the individual samples as peaks of a continuous absorbance or transmittance recording. The principle of auto analyzer is shown in fig.

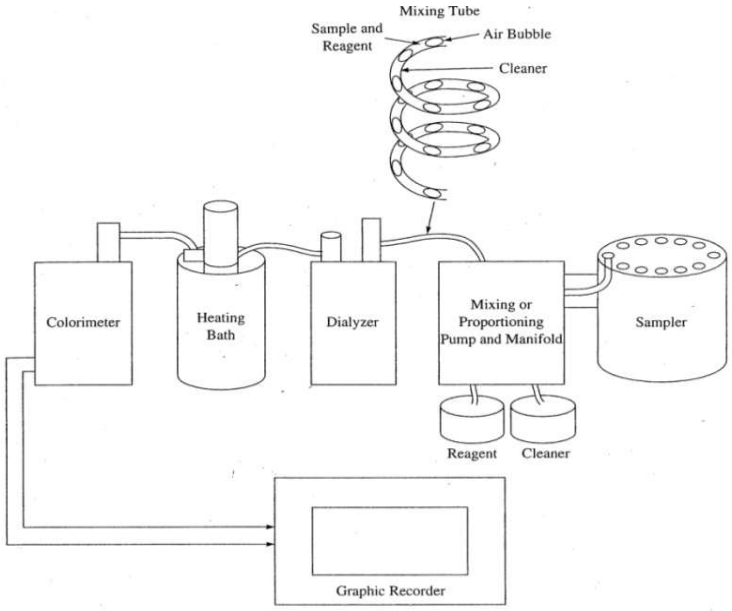


Fig 2.4: continuous flow analyzer

The concentration of samples is determined by comparing the peaks of the samples with the peaks of standards. In this way, the errors are eliminated because they affect standards and samples in the same way.

2.5 BLOOD FLOW METERS

Blood flow meters are used to monitor the blood flow in various blood vessels and to measure the cardiac output .Electromagnetic flow meters, Ultrasonic flow meters and laser base blood flow meters are widely used to measure the blood flow rate. Flow rates are expressed in lit/min or ml/min (cm3/min)

All blood flow meters are based on one of the following physical principle.

(1) Electromagnetic induction
(2) Ultrasound transmission or reflection
(3) Thermal convection
(4) Radiographic principles
(5) Indicator (dye or thermal) dilution

2.5.1) Magnetic Blood Flow Meter:

They are based on the principle of magnetic induction. When an electrical conductor is moved through a magnetic field, a voltage is induced in the conductor proportional to the velocity of its motion. The Principle applies when the moving conductor is not a wire but a conductive fluid that flows through a tube located in magnetic field.

Working Principle:

A permanent magnet or electromagnet positioned around the blood vessel generates a magnetic field perpendicular to the direction of blood flow. The voltage inducted in the moving blood column is measured with stationary electrodes located on opposite sides of blood vessel and perpendicular to direction of magnetic field.

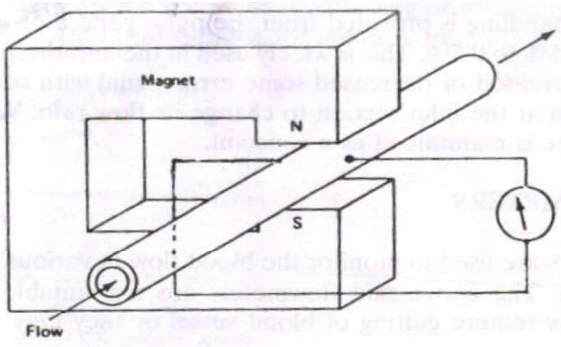


Fig 2.5.1(a): Magnetic blood flow meter principle

Block Diagram

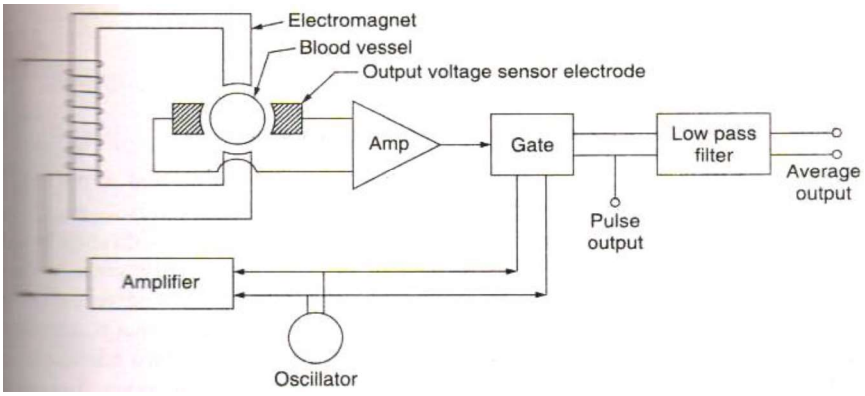


Fig 2.5.1 (b):Block Diagram of Magnetic blood flow meter

The oscillator drives the magnet and provides a control signal for the gate, operates at a frequency between 60 & 400Hz.The gated detector makes the polarity of output signal reverse when the flow direction reverses. The frequency response is usually high enough to allow the recording of flow pulses while the mean or average flow can be derived by use of a low pass filter.

2.6.2 Ultrasonic Blood flow meters:

In this, a beam of ultrasonic energy is used to measure the velocity of flowing blood. The two different ways are:

(i) Transit time ultrasonic flow meter

(ii) Doppler type

2.5.2.1Transit Time Ultrasonic flow meter:

A pulsed beam is directed through a blood vessel at a shallow angle and its transit time is measured. When the blood flows in the direction of energy transmission the transit time is shortened. If it flows in the opposite direction, the transit time is lengthened.

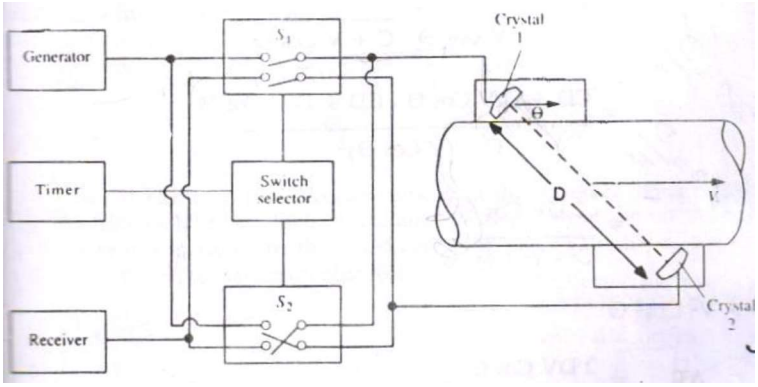


Fig 2.5.2.1: Transit Time Ultrasonic flow meter

A piezoelectric crystal emits a pulse of ultrasound which propagates diagonally across the blood vessel . If the flow is in same direction as the pulse then the pulse reaches a receiving crystal situated on the opposite side wall of the blood vessel. Electronics circuit convert change in transit time to velocity.

D- Distance travelled by sound waves (or) Distance between transmitter and receiver ultrasonic waves.

T_D- Down stream transit time, V-velocity of blood flow, C-ultrasound velocity

Ultrasonic velocity in down stream $C+V\cos\Theta = D/T_D$

Ultrasonic velocity in up stream $C - V\cos\Theta = D/T_U$

Difference in transit time $\Delta T = T_U - T_D$

$$= \frac{2DV\cos\Theta}{C^2 - V^2\cos^2\Theta} \quad , \quad C^2 >> V^2\cos^2\Theta$$

$$\Delta T = \frac{2DV\cos\Theta}{C^2}$$

$$V = \Delta T\, C^2 / 2D\cos\Theta$$

Thus blood flow velocity determining difference between upstream and down stream transist time

2.5.2.2 Doppler type Ultrasonic Blood flow meter:

Ultrasonic flow meters are based on the Doppler principle. An oscillator operating at a frequency of MH_Z excites a piezoelectric transducer. This transducer is coupled to the wall of exposed blood vessel and sends an ultrasonic beam with frequency F into flowing blood. A small part of transmitted energy is scattered back and is received by a second transducer arranged opposite to first one. Scattering occurs as a result of moving blood cells but the reflected signal has a different frequency due to Doppler Effect. The frequency is either $F+F_D$ or $F-F_D$ depending on the direction of flow. The Doppler component FD is directly proportional to the velocity of flowing blood.

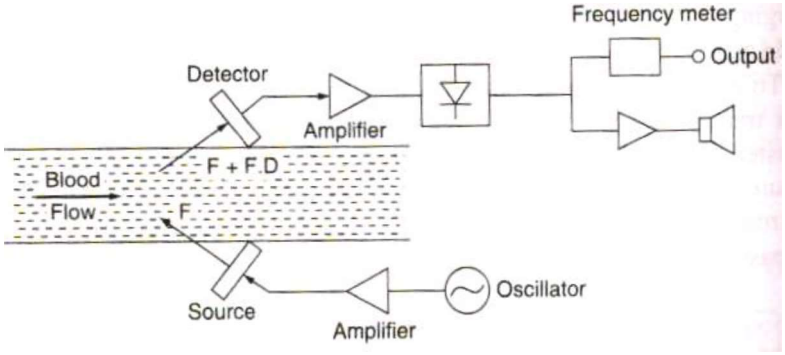


Fig 2.5.2.2: Doppler type Ultrasonic Blood flow meter

Doppler frequency can be obtained at the output of deleted as the difference between the direct and scattered signal components .Doppler signal is in low audio frequency range and hence it is in the form of narrow band noise. By using a frequency meter, Doppler frequency ban be calibrated directly in flow-rate units.

2.5.3 Thermal Convection method

A hot object in a colder flowing medium is cooled by thermal convection. This principle is applied in this method . Here the rate of cooling is proportional to the rate of flow of the medium. A thermistor placed on the blood stream is kept at a constant temperature by a servo system. The rate of flow can be determined by the electrical energy required to maintain the constant temperature of the thermistor. The blood velocity can be determined by the difference between the upstream and downstream temperature indicated by the sensor. Since it is oldest method of blood flow determination it is replaced by the radiographic technique.

2.5.4 Radiographic Method

In radiographic method radio isotopes are injected in to the blood circulation which helps in the detection of vascular obstruction. The nuclear radiation can be analysed with the help of imaging device like scanner or cameras. The vascular obstructions can also be detected by measuring the difference in the skin temperature due to improper and reduced circulation of blood.

2.5.5 Indicator dilution method

The indicator dilution method helps in the determination of rate of blood flow and not the velocity of blood.

There are two types of measurements involved in this method

(i)open circulation method

(ii) closed circulation method

(i)open circulation method

In this method the measurements is made under the assumption that the blood is not recirculated. The indicator is injected in to the blood flow continuously at the beginning time with a constant infusion rate of Igrams per minute. A detector measures the concentration of the downstream from the injection point.

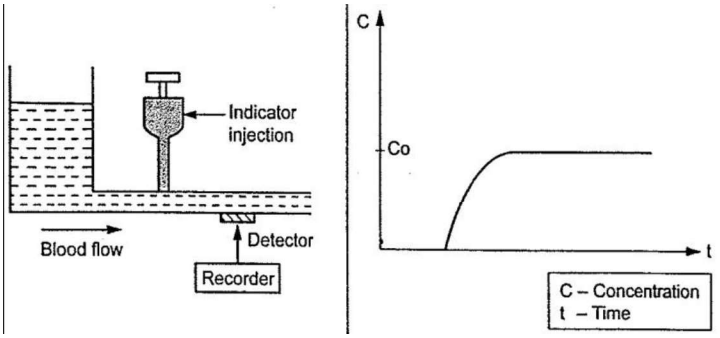


Fig: open circulation method

The output of the detector is connected to the recorder and here at a certain time after injection the concentration of the indicator increases and finally reaches a constant value C_0 miiligrams per litre. The flow can be determined with the help of injection rate I and measured concentration Co

Rate of flow(litres per minute)= I(milligrams per minute)/Co(milligrams per litre)

ii) closed circulation method

This method states that when a dye or isotope is used as an indicatior the concentration does not assume a steady state instead increases in steps whenever the recirculated indicator again passes the detector. This method is based on the assumption that the blood is being recirculated.

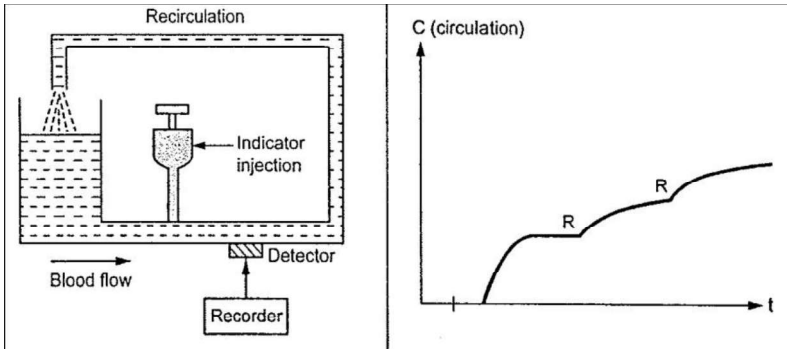


Fig:closed circulation method

2.6 CARDIAC OUTPUT MEASUREMENT

Cardiac Output is the amount of blood delivered by the heart to the aorta per minute. In adults, during each beat the amount of blood pumped ranges from 70 to 100ml and hence the cardiac output is 4-6 lit/min. A decrease in cardiac output may be due to low blood pressure, shock and poor renal function. The direct method is not adopted practically since it involves surgery. Indirect methods are adopted in routine applications. They are,

2.6.1 Fick's Method:

This is based on the determination of cardiac output by the analysis of gas-keeping of the organism. The cardiac output is calculated by continuously infusing oxygen into the blood or removing it from the blood and measuring the amount of oxygen in blood before and after its passage.

Let I be the amount of infused or removed oxygen per unit time.

I is equal to the difference between amount in blood arriving at and departing from it.

$$I = C_A Q - C_V Q$$

$$\therefore Q = \frac{I}{C_A - C_V}$$

Where I → Volume of Oxygen
Q → Cardiac Output
C_A, C_V → Concentration of oxygen in arterial (outgoing) Blood and venous (incoming) blood.

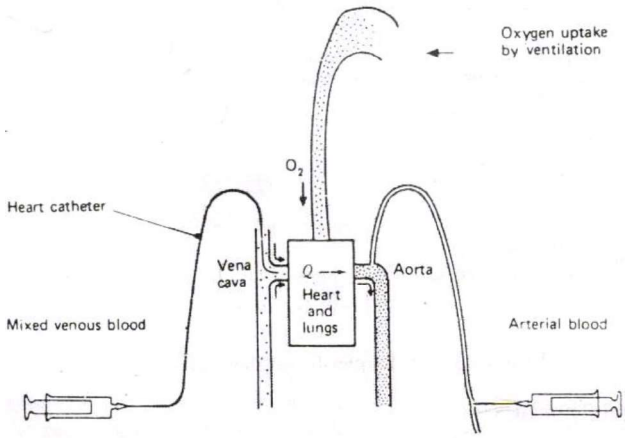


Fig:2.6.1 Fick's Method

2.6.2 Indicator Dilution Method:

This is based on the principle that if we introduce an indicator in the blood circulation and then measuring the concentration of indicator with respect to time. We can estimate the volume flow of blood. Let M mg of an indicator is injected into the right heart.

After passing through the right heart, lungs and left heart, the indicator appears in arterial circulation. The presence of the indicator in peripheral artery is detected by a detector. The output of the detector is directly proportional to the concentration of indicator. The detector is displayed on a chart recorder with respect to time. Let an increment in volume dv passes the sampling site in time dt. Let the mass of indicator in dv = dm

$$\therefore \text{Concentration of indicator} \quad c = \frac{dM}{dV}$$

Now $$\frac{dM}{dt} = C \frac{dV}{dt}$$

But $\frac{dV}{dt}$ = Q, the cardiac output

$$\therefore \frac{dM}{dt} = Q\,c \Rightarrow dM = Q\,C\,dt$$

Integrating it,

$$M = {}_o\int^t QC\,dt$$

Consider the flow to be constant

$$M = Q\,{}_o\int^t C\,dt$$

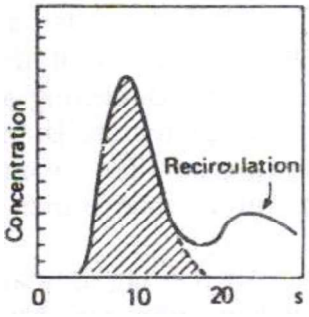
(or) $$Q = \frac{M}{{}_o\int^t c\,dt}$$

'c' is a function of time

By drawing a curve between concentration and time, area of the curve gives the value of ${}_o\int^t c\,dt$.

$$\therefore Q = \frac{M}{area\,of\,curve}$$

Fig. shows the dilution curve.



During the first circulation period, the indicator would mix up with the blood in a small quantity. After that there is a rapid change of concentration.

This is shows by rising portion of dilution curve. After reaching maximum, the concentration of indicator decreased exponentially.

A second peak would then appear. When the indicator is completely mixed up with blood, the curve becomes parallel with time axis. Extrapolation is made as dotted list in the curve.

The disadvantages in these methods are that the accumulation of foreign substance in the body may create some problems in the body.

Thermo Dilution Method.

Now-a-days thermo dilution method is adapted to measure cardiac output. A bolus of about 10ml of 5% dextrose in water at room temperature is injected as a thermal indicator into right artrium.

After mixing, it is detected in the pulmonary artery by means of a thermistor mounted at the tip of a miniature catheter probe.

The temperature difference between the injected temperature and the circulating blood temperature in the pulmonary artery is measured.

The reduction in temperature is integrated with respect to time and the meter reads the cardiac output.

Assume that the thermo indicator mixes thoroughly with the blood and negligible heat flow across the blood vessel wall.

The heat injected is equal to heat conducted.

$$\text{(ie)}\quad V\rho_i S_i (T_i - T_b) = Q\,\rho_b S_b \int \Delta T\, dt$$

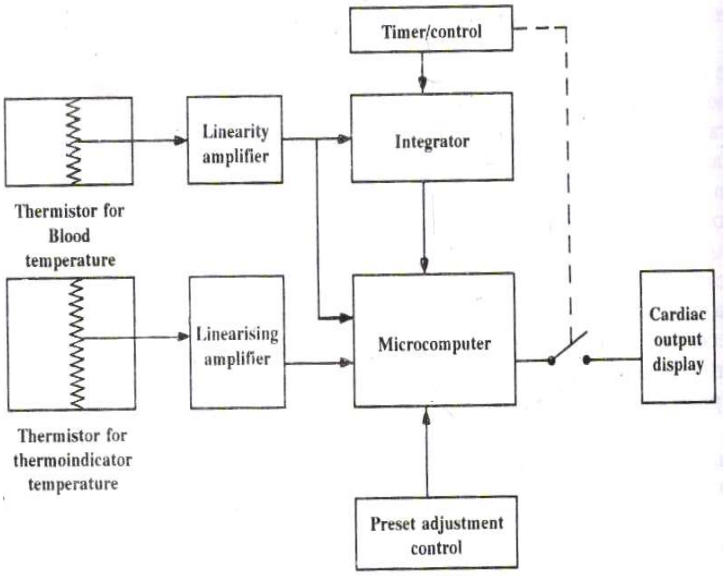
$$\text{(or)}\qquad Q = \frac{V(Ti - Tb).\rho_i S_i}{\int \nabla T dt.\rho_b S_b}$$

Where
- Q → Cardiac output per second
- V →Volume of thermal indicator injected into the blood
- ρ → density
- S → Specific heat
- T → Temperature (°C)

$\int \nabla T$ dt → Integral of blood temperature change (or)
Area of thermo dilution curve.

- ❖ Subscribe i & b denotes the inject ate and blood.

Fig. shows the block diagram of thermo dilution system.



A linear relation between temperature and resistance of the thermistor can be obtained by connected a parallel resistor with it. Then the line arising amplifier works. Integrator delivers the value of integral of blood temperature change over a given time. By feeding data about p, s, Q and thermal indicator, the computer can deliver the cardiac output in lit/min.

2.6.3 Measurement of cardiac output by impedance change.

By the impedance method, the cardiac output can be determined electronically. 4 probes method is adopted here.

The electrode pair 1 & 4 is used as current electrodes.

The electrode pair 2 & 3 is used to pick up the voltage across the thorax.

Let ρ →resistivity of patient's haematocrit

A → cross-sectional area of thorax

L → Separation between the potential electrodes 2 & 3.

The resistance of thorax is given by

$$R = \frac{\rho L}{A} = \frac{\rho L^2}{AL} = \frac{\rho L^2}{V}$$

$$\therefore V = \frac{\rho L^2}{R}$$

Where V → Volume of thorax

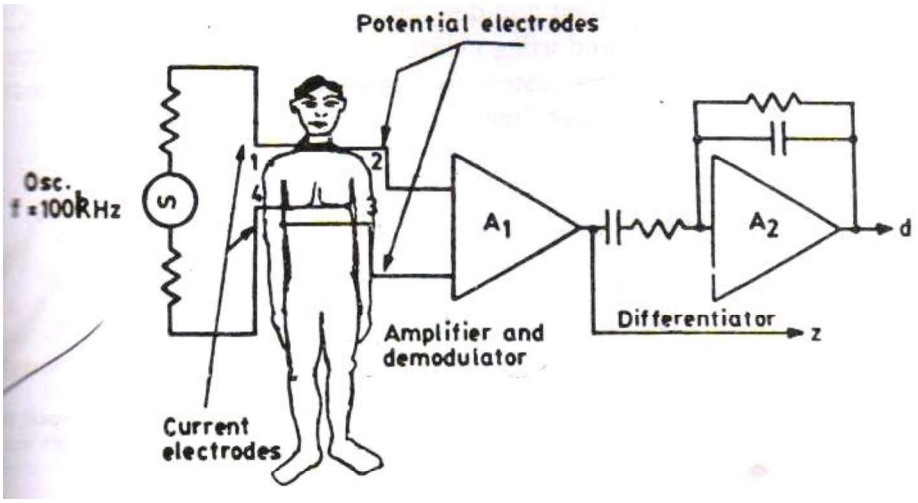


Fig 2.6.3: Measurement of cardiac output by impedance change

During objection of stroke volume, change in volume is dv and corresponding decrease in resistance is dR.

Differentiating V we get,

$$Dv = -\rho \frac{L^2}{R^2} dR$$

Since a.c current is used, R should be replaced by impedance Z.

$$Dv = -\rho \frac{L^2}{Z^2} dZ$$

Take $dZ = t\left[\frac{dZ}{dt}\right]_{max}$

Where $\left[\frac{dZ}{dt}\right]_{max}$ corresponds to peak negative value of $\frac{dZ}{dt}$

And t is the interval between $\frac{dZ}{dt}$ =0 & second heart sound.

$$\therefore dv = -\rho \frac{L^2}{Z^2} t\left[\frac{dZ}{dt}\right]_{max}$$

When a consistent current at 100 khz is applied between 1 & 4, the impedance is 25 and this diminishes to with each systole. The voltage signals due to changes in impedance is

amplified and demodulated to obtain Z. The value of $\frac{dZ}{dt}$ is calculated using a differentiator and it output is recorded on the recorder. From the recorded output $\left[\frac{dZ}{dt}\right]_{max}$ can be noted. By determining dv, the cardiac output can be measured by multiplying dv with heart beat rate per min.

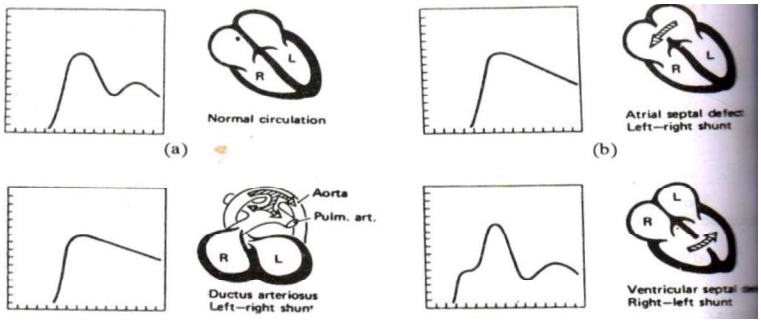
Advantages of Cardiac Output Measurements.

Indicator dilution is more useful when there is no severe heart defects. Here the diagnostic information can be obtained from the changes in the shape of dilution curve.
Fig. (a) shows the normal curve corresponding to normal circulation of blood.

Fig (b) shows article output defect where blood flows internally from left atrium to right atrium.

Fig (c) shows ductus arterisus. Here blood flows from aorta to pulmonary artery.

Fig (d) shows ventricular septal defect. Here blood flows from right ventricle to lift ventricle. It is called right left shunt.



Impedance method is a non-invasive on where one can monitor the cardiac output during each stroke volume.

2.7 PULMONARY FUNCTION ANALYSIS (RESPIRATORY MEASUREMENT)

They are used to evaluate the state of lungs or respiratory process. The three basic types of measurement are ventilation, distribution and diffusion.

Ventilation:

Ventilation deals with the determination of the ability of body to displace air volume quantitatively and the speed with which it moves the air. Spirometers are used in the ventilation measurement.

Distribution:

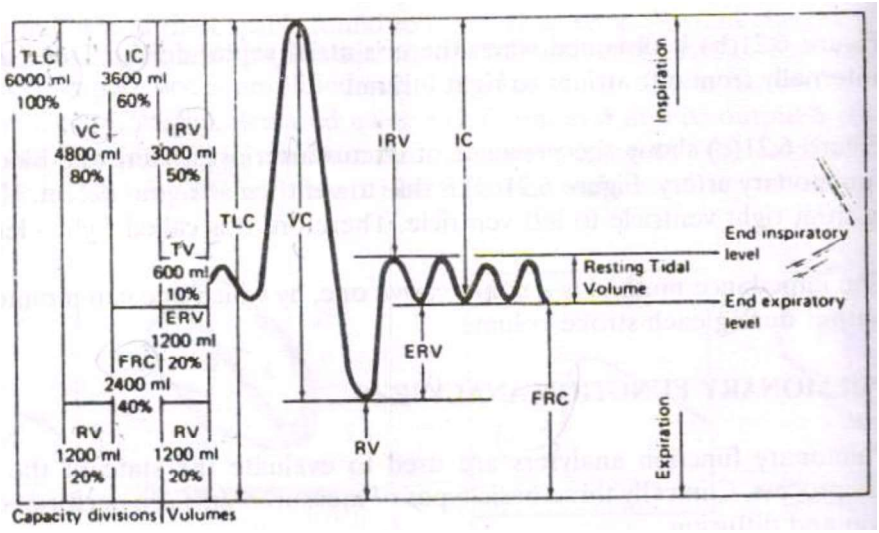
It indicate the degree of lung obstructions for the flow of air and also determine the residual volume of air that cannot be removed from the lungs. Pneumotachometers are used to measure the instantaneous rate of volume flow of respired gases.

Diffusion.

It indicate the lung ability to exchange gas with the circulatory system or the rate at which gas is exchanged with the blood stream. Gas analysers are used in the diffusion measurements.

2.8.1Lung volumes and capacities

Pulmonary function analysers are used to determine the lung volumes and capacities. These parameters depend on individuals physical characteristics and condition of breathing mechanism.



Lung volumes are indicated by '%' and capacities by 'ml'

TLC – Total Lung Capacity. TLC is the amount of gas contained in the lungs at the end of a maximal inspiration.

TLC is the sum of vital capacity (VC) and residual volume (RV). During inspiration, the lung volume is increased. During expiration, the lung volume is decreased. VC is the maximum volume of gas that can be expelled from the lungs after a maximal inspiration.

TV Tidal Volume is the volume of gas inspired or expired during each normal, quiet and respiration cycle. RV is the volume of gas remaining in the lungs at the end of a maximal expiration. IRV→Inspiratory Reverse Volume,ERV → Expiratory Reverse Volume. IRV is the extra volume of gas that can be inspired with maximal effort after reaching the normal end of inspiratorylevel. ERV is the extra volume of gas that can be expired with maximal effort beyond reaching the normal end of expiratory level.

IC→ Inspiratory Capacity. It is the volume of gas remaining in the lungs at the end of expiratory level. FRC→ Functional Residual Capacity. FVC and FEV are some of the forced breathing tests used to assess the muscle power.

FVC → Forced Vital Capacity
FEV → Forced Expiratory Volume

FVC is the total amount of air that can forcibly be expired as quickly as possible after taking the deepest possible breath. FEV is the maximum amount of gas that can be expelled at the given time.

2.7.2 Spirometer:

It is used to measure the respiratory volume measurements. It is used to determine all lung volumes and capacities by measuring the gas inspired or expired during a given time involved.

Fig. shows an electrical spirometer.

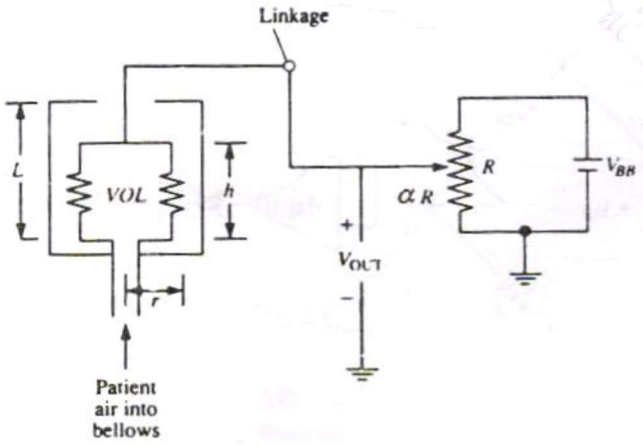


Fig 2.7.2 : Spirometer

It consists of light weight bellows.Due to light weight, there is no airway resistance error. The bellows are articulated to a biased potentiometer such that the wiper arm voltage is proportional to volume VOL of bellows. The maximum volume of bellows is given by

$$VOL_{max} = L\pi r^2$$

Proportionality constant α is

$$\alpha = \frac{V_{out}}{V_{BB}} = \frac{VOL}{VOL_{max}}$$

$$\therefore VOL = \frac{V_{out}}{V_{BB}} VOL_{max}$$

Better linearity can be obtained provided the voltmeter should have better linearity over desired volume.

2.7.3 Pneumotachograph using strain gauge:

Pneumotachograph is an instrument to measure the patient's air flow rate during respiration and vital air capacity of lung. Now-a-days strain gauge transducer is used to sense line air flow to get better accuracy. The airflow changes the resistance of strain gauge. Straingauge is attached to a wheatstone bridge & it forms one arm of bridge. A dummy strain gauge is fixed in the opposite arm to eliminate error from changing arbient temperature. The other two arms have resistance of strain gauge R. Due to air flow, resistance is changed to R+ΔR. Hence the balance of bridge is upset and an output voltage V_{AB} is developed and amplified by a differential amplifier A_P. Integrator integrates the output from A_D and gives the output.

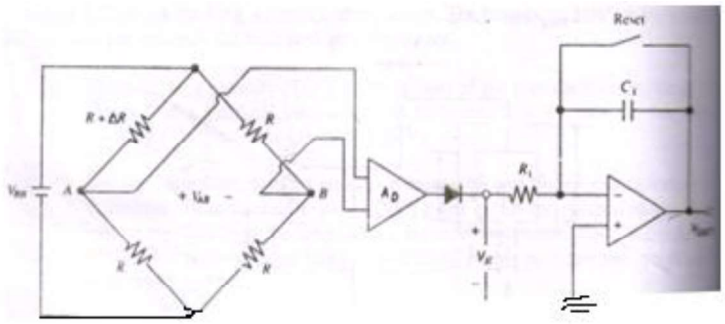


Fig 2.7.3 Pneumotachograph using strain gauge

Procedure:

1. The volume of air exhaled by a patient is measured by first closing and then opening the reset switch. This set the initial charges on C1 to Zero and fixed Vout at Zero.
2. The patient is then asked to exhale through pneumotach mouthpiece. Hence resistance change R in strain gauge is proportional to airflow F.

   Thus airflow F = KΔR

   Where K →Pneumotach coefficient (lit/sl)

   The unbalanced voltage from the bridge

$$V_{AB} = \left[\frac{R}{R+\nabla R+R} - \frac{R}{2R}\right] V_{BB}$$

$$= \frac{2R^2 - R(2R \div \nabla R)}{2R(2R+\nabla R)} V_{BB}$$

$$V_{AB} = \frac{-R\nabla R}{4R^2 + 2R\nabla R)} V_{BB}$$

Since R>>ΔR,

$$V_{AB} = \frac{-\nabla R}{4R} V_{BB}$$

- The differential amplifier output

$$V_F = -A_D\left[\frac{\nabla R}{4R}\right] V_{BB} \quad \therefore V_F = A_D V_{AB}$$

$$V_F = -A_D \frac{F}{K.4R} V_{BB} \quad \therefore F = K\Delta R$$

$$\therefore V_F = \frac{-ADV_{BB}}{4KR}.F$$

- ❖ F is directly proportional to output voltage V_F.

3. VF is a function of time. V_F is given to the integrator and V_{out} is proportional to volume of air expired from time o to‘t’ seconds.
4. After the patient has stopped exhaling V_{out} remains constant in proportion to the total volume of air expired until the most switches is closed.
5. When the reset switch is set and then opened, the output voltage from the integrator is

$$V_{out} = \frac{-1}{R_1C_1}\int_o^t V_F dt$$

$$= \frac{A_D V_{BB}}{4KRR_1C_1}\int_o^t F dt$$

- ❖ The total volume of air expired

$$VOL = \int_o^t F dt$$

$$\therefore V_{out} = \frac{A_D V_{BB}}{4RR_1C_1K} VOL$$

- ❖ The air flow can be drawn by giving VF to strip chart recorder.

2.7.4 Plethysmograph:

Pneumotachograph cannot be used to measure TLC. To measure TLC, pletheysmograph is used. Plethysmography is used to measure the volume changes in any part of body that result from pulsations of blood occurring with each heart beat. These measurements are useful in

- → Diagnosis of artenal obstructions.
- → Pulse ware velocity measurement

It consists of a rigid cup or chamber placed over the body. The cup is tightly sealed to member and charged in volume reflect the pressue changes of air inside the chamber. Useful measurements can be done by measuring pressure change at constant volume condition or measuring volume change at constant pressure condition.

Depending on the nature of sensor, it can be called capacitance plethysmograph, mercury strain gauge plethysmograph, photoelectric plethysmograph and impedance plethsmograph. The principle of plethysmograph depends on Boyle’s low which states that “At

a give Kelvin temperature, the pressure of a given mass of gas is inversely proportional to its volume".

(i.e) $P \times VOL = K_1 T$

Where $K \rightarrow$ Constant

Incase of TLC measurement, the patient sits inside an airtight chamber whose temperature remains constant

$\therefore$ P x VOL = Constant

Partially differentiating the above equation

$$D(PVOL) = \frac{\partial(PVOL)}{\partial P} dp + \frac{\partial(PVOL)}{\partial VOL} dVOL = 0$$

(or) VOL dp + P dVOL = 0 dp=-P dVOL

$$\frac{dP}{dVOL} = -\frac{P}{VOL}$$

Now the door of air tight chamber is sealed and valve on the mouthpiece is closed.

The patient cannot breathe hence the air pressure on mothpiece is equal to lung pressure P_T.

$$\therefore \frac{dTLC}{dP_T} = -\frac{TLC}{P_T}$$

Where TLC $\rightarrow$ Thorax Volume

P^T $\rightarrow$ Thorax Pressure

In the chamber

$$\frac{dVOL_C}{dP_C} = -\frac{VOL_C}{P_C}$$

Where VOL_C is the chamber volume

P_C is the chamber pressure

Since the chamber is closed any increase in thoracic volume causes a decrease in chamber volumes of air.

(i.e) $d(VOL_O) = -d(TLC)$

$$\therefore \frac{TLC}{P_T} dP_T = \frac{-VOL_C}{P_C} dP_C$$

During measurement $P_C = P_T$

$$\therefore TLC \approx - VOL_C \frac{dP_C}{dP_T}$$

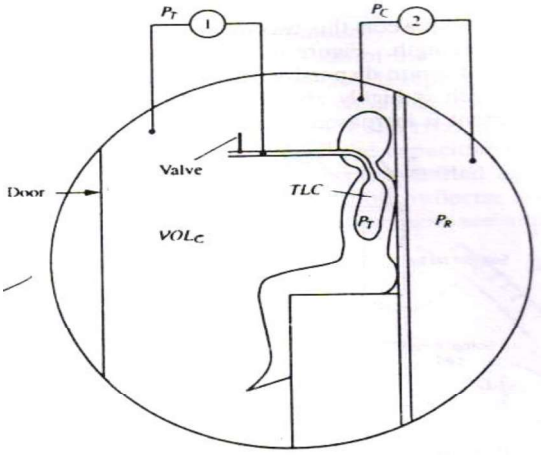


Fig 2.7.4: Plethysmograph

Procedure:

(1) First mothpiece valve is closed when the patient is sitting inside he sealed chamber.
(2) Now the patient is asked to make breathing motions.
(3) Note down he change in pressure reading in pressure gauge 1 which gives dP_T.
(4) Note down the change in pressure reading in pressure gauge 2 which gives dP_C.

By knowing the value of VOL_C, TLC can be calculated using the formula.

$$TLC = VOL_C \left[\frac{dP_c}{dP_T} \right]$$

2.7.5 Gas Analyser :

Determine composition of inspired & expired gas and to access lung function.

Infrared gas analyser:

CO_2 concentration can be evaluated by its infrared absorption. One is filled with non absorbing gas such as nitrogen, other with sample.

The difference in optical absorption detected between the 2 cells is a measure of absorption of sample at a particular wave length. Infrared CO_2 analyser which makes use of a non dispersive infrared analysis technique.

In this technique selective wavelength which is highly absorbed by gas in used accuracy of measurement.

Infrared source operates at a temperature of about 815^0C and it can deliver to a mirror .If the mirror have two beam with same intensity.There is a high speed rotating chopping disc which includes each beam twice per motion.

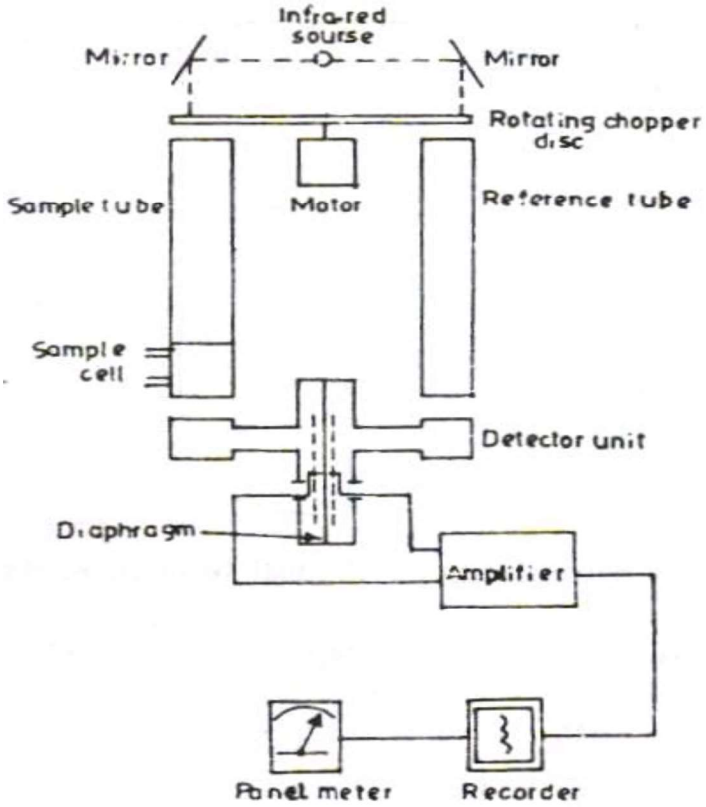


Fig 2.7.5 Gas Analyser

The chopped lights are passing through the reference and samples tubes.

The detecter consists of two identical chambers fitted with infrared transparent windows and seperated by means of a thin flexible metal diaphragm.

Each chamber is filled with infrared CO_2 which is to be analysed with the same pressure.

Assuming that there is a significant absorption in the sample cell by the component of interest then he sample beam falling on the decetor .

Thus the heating of the gas in the detecter situated in the reference beam side will cause some rise in pressure in it.

Thus the diaphragm vibrates at the chopping frequency. The diaphragm is arranged to form one half of a capacitor.

The capacitor is supplied with a constant charge and the resulting periodic voltage changes at the chopping frequency are amplified and demodulated and the output is displayed on a meter.

2.8 PULSE RATE MEASUREMENT

Each time the heart muscle contracts blood is ejected from ventricles and a pulse of pressure is transmitted through the circulatory system.

This pressure pulse can be felt by placing the finger tips over the radial artery in the wrist or some other location where an artery seems just below the skin. The timing and ware shape of pressure pulse provide valuable diagnostic information.

The pulse pressure and waveforms are indicators for blood pressure and flow. Instruments used to detect the artinal pulse and pulse pressure waveforms in the extremities are called plethysmographs.

Plethysmograph techniques respond to a change in the volume of blood as a measure of blood pressure. The pulse gives a measure of pulse wave velocity and can be recorded and compared with ECG signal.

The pulse wave travels at 5 to 15 m/s depending on the size and rigidity of the arterial walls. The larger and more rigid the artery walls, the greater the velocity. The velocity is 10-15 times faster than blood flow.

2.8.1Photoelectric Method:

It is the most commonly used method to measure the pulsatile blood volume changes. Two commonly used methods are,

i) Reflectance Method
ii) Transmittance Method

2.8.1(a)Transmittance Method:

A light emitting diode (LED) and photo resistor are mounted in an enclosure that fits over the tip of patient's finger. Light is transmitted through finger tip and resistance of photo resistor is determined by the amount of light reaching it.

With each contraction of heart, blood is forced to the extremities and the amount of blood in finger increases. This reduces the light transmission through the finger and increases the resistance of photo resistor.

The photo resistor produces a voltage that follows the pressure pulse and its wave shape can be displayed on an oscilloscope or recorded on a strip-chart recorder.

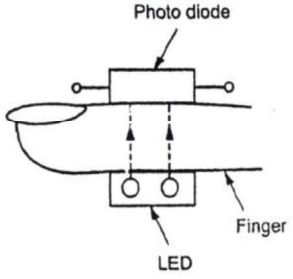


Fig 2.8.1(a)Transmittance Method

2.8.1(b) Reflectance Method:

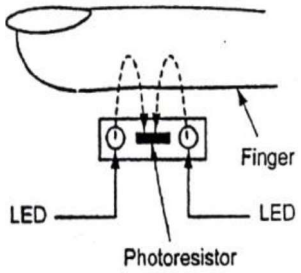


Fig 2.8.1(b) Reflectance Method

The photoresistor is placed adjacent to exciter lamp. Part of light rays emitted y LED is reflected and scattered from the skin & tissues and falls on photoresistor. The quantity of light reflected is determined by the blood saturation of capillaries. The voltage drop across the photoresistor will vary in proportion to the volume changes of blood vessels.

2.9 TEMPERATURE MEASUREMENT:

Two types of temperature measurement can be obtained from the body. Systematic, surface temperature.

Systematic temperature:

Temperature of the internal regions of the body. Usually heat is generated by the active tissues of the body & heat is lost by the body to the environment, between temperatures of body is maintained carefully. Normal mouth temperature 37^0C, normal under temperature 1^0C lower than above temperature. Systematic temperature is measured accurately at tympanic membrane of ear, brain contain temperature control centre for the body.

Systematic Body Temperature Measurement:

Mercury thermometer is used for temperature measurement. It is inexpensive to use. When continuous temperature recording thermocouple or thermister used.

Thermocouple:

A junction of 2 dissimilar metal produce an o/p voltage. This is proportional to temperature at that junction.

Thermistor:

It is a temperature sensing device. Its resistance varies with temperature. This is mostly proffered in the biomedical field compared with thermocouple. Thermister can be manufactured in various shapes. In this relationship between resistance change & temperature in non – linear. Resistance of thermister is given by

$$R_t = R_r e^{+\beta(1/\tau_1 - 1/\tau_0)}$$

R_t = resistance at temperature T_t

R_r = resistance at temperature to (ref temperature)
T_1 = Temperature at which measurement is taken
T_0 = Ref temperature
β = Temperature coefficient (range 3000 -4000)

Sp^1 circuit are used to overcome nonlinear characteristics of thermister Sp^1 circuit consists of 2 matched thermister.

Problem in thermister:

Self heating this problem overcome by limiting current used in measure power dissipation of thermister is maintained mV range to overcome this problem. Thermister problem is should be chosen based on resistance change sensitivity.

Skin temperature measurement:

Skin temperature is not constant through out body varied from 30^0C- 35^0C.

Various factors affect skin temperature

How fat covers over capillary area.
How skin portion is exposed to ambient temperature.
Blood circulation pattern beneath skin

Probes used – small, flat thermister probe is used.

Infrared thermometer – Device used to measure skin temperature. It is used to identity spots in which blood circulation is poor

2.10 BLOOD CELL COUNTER

The blood cells have important functions in our body. The red blood cell is used for transport of oxygen and carbon-di-oxide.

The white blood cells are part of the body's defenses against infections and foreign substances. The platelets are involved in the clotting of blood.

The red blood cells in the blood consist of haemoglobin. When the haemoglobin in the blood decreses, anemia is produced. The amount of haemoglobin is normally 130-170 g/l for men and 120-160 g/l for women.

To determine retain proportion of blood cells in a given volume of blood, hematocrit or packed cell volume is used. The packed cell volume is the ratio between the height of the packed cells and height of blood in the tube.

Normal range of packed cell volume for men is 42-54% and for women is 37-47%. The number of red blood cells can be counted using a microscope, but the microscopic counting is time consuming. Now-a-days automatic red blood cell counters are used.

2.10.1Automatic Red Blood Cell Counter:

This method us based on the fact that red cells have a higher electrical resistivity than the saline solution in which they are suspended. Fig (1) shows the automatic blood cell counter using electronic circuitry.

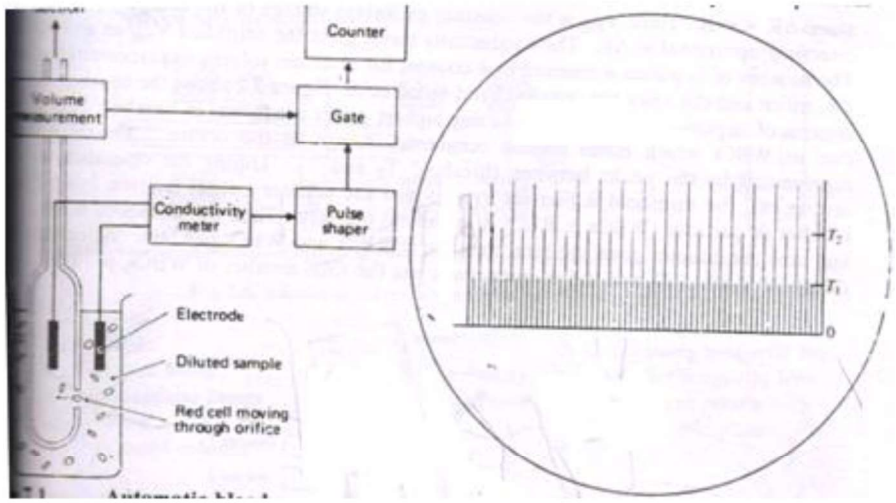


Fig 2.10.1 : Automatic Red Blood Cell Counter

A diluted blood sample is drawn through a small orifice by means of a section pump. The electrodes are placed such that one in the surrounding sample chamber and other in the suctioned blood.

The electrodes are attached with the conductivity bridge such that their resistance forms one arm of bridge. Before suctioning, the resistance of the electrode arm is equal to R. Increase in resistance equal to (R+ΔR) or Rout. Assume equal resistance R is placed in other arms. Bridge Output Voltage $V_{out} = \left[\frac{R_{out}}{R_{out}+R} - \frac{1}{2}\right] V_{BB}$

$$= \frac{\nabla R}{4R + 2\nabla R} V_{BB}$$

$$V_{out} = \frac{\nabla R}{4R} V_{BB} \text{ since } \Delta RR << R$$

$V_{BB} \rightarrow$ Constant excitation voltage of bridge.

V_{out} is directly proportional to ΔR.

The conductivity meter gives the amplified V_{out} as an impulse. The number of impulseis counted by a counter and this gives the density of red blood cells. WBC_s are represented by the impulses having highest peaks. RBC_S are represented by the peaks between threshold T_2 & T_1

Operation

The threshold is first set to zero and the counter output is given by the total number of particles (WBC_s + RBC_S + platelets) per litre. Then the threshold is set to T_1 and the counter gives the total number RBC_S and WBC_S per litre. After that the threshold is set to T_2 and the counter reads the total number of WBC_S per litre.

2.10.2 Laser Blood Cell Counter:

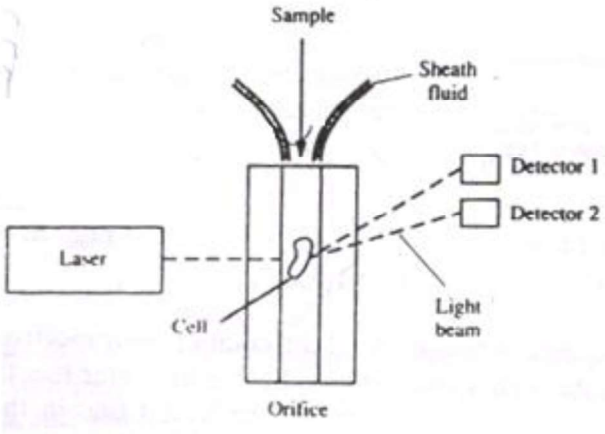


Fig 2.10.2 : Laser Blood Cell Counter

This is a modern technique which gives the number of RBCs, WBCs and Platelets , hematocrit and concentration of haemoglobin. The basic Principle is that the angle of scattered light intensity is different for different sized particles.

The sample blood is heavily diluted to reduce the number of particles counted to one at a time. A sheath fluid is directed around the blood stream to confine it to the center of aperature through which a laser beam is passed.

Thus the blood cells are illuminated by the laser light and they scatter light. The scattered light from platelets and red blood cells are directed into two photo detectors. The output of the photodetector is given to a digital voltmeter which gives the density of red blood cells or platelets.

To separates WBCs from RBCs, we can destroy the RBCs by a lying agent. This frees the haemoglobin from the blood and its concentration can be measured. Once again the measurements are made by which the concentration of WBCs can be measured.

2.11 BLOOD PRESSURE MEASUREMENT.

Pressure is defined as force per unit area p = F / A

P = pressure in pascal,F= force, A=Area

Pressure is increased by increasing the applied force or by decreasing the area.

Hydrostatic pressure :.If the force in a system under pressure is not varied then pressure is known as Hydrostatic pressure

Hydrodynamic pressure :If the force in a system under pressure is varied then pressure is known as Hydrodynamic pressure

Methods :

1. Indirect method using sphygmomanometer
2. Direct method

2.11.1 Indirect method using sphygmomanometer:

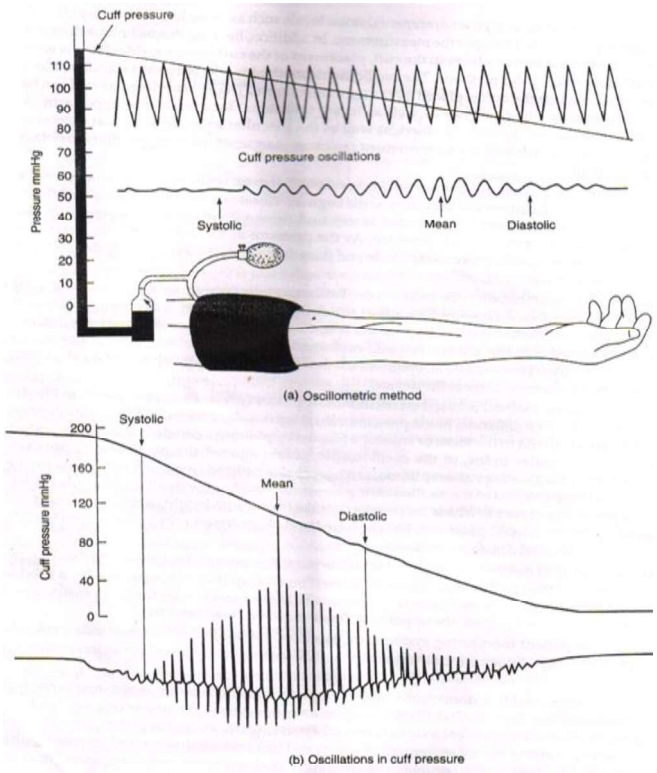


Fig 2.11.1 Indirect method using sphygmomanometer

In this method Sphygmomanometer is used to measure blood pressure indirectly. It consists of inflatable rubber bladder which is known as cuff, rubber squeeze ball pump & valve assembly. Pressure is measured using manometer with mercury column.

Procedure to use Sphygmomanometer: Cuff is wrapped around the patient's upper arm at a point midway between elbow & shoulder. Stethoscope is placed over as artery distal to the off, because at this place, brachial artery comen close to surface.

The cuff is inflated so the pressure inside the inflated bladder is increase to a point greater than the anticipated systolic pressure. This pressure compresses the artery against the underlying bone so blood flow is stopped in the vessel.

Then doctor slowly reduces the pressure in the cuff & he watch the mercury column when the systolic pressure exceeds the cuff pressure. Then doctor can hear some crashing, snapping sound through stethoscope. This sound is known as korotkoff sound.

Korotkoff sound is vanished when the pressure drops below the diastolic pressure. Pressure reading in the mercury column during onset of korotkoff sound is noted as systolic pressure usually 120 mmHg. Pressure reading in the mercury column at which korotkoff sound is disappeared is noted as diastolic pressure usually 80 mmHg for normal persons. Korotkoff sound is disappeared at some point. That is known as muffling. The use of korotkoff sound as

the in direct indicator for blood pressure measurement is known as asculation. (It means use of hearings)

Advantages

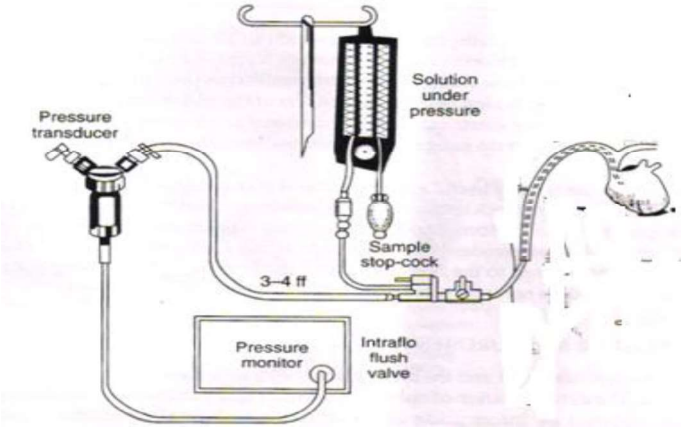
- ❖ Method is very simple
- ❖ Painless techniques
- ❖ There is no hazardous surgical procedure involved.

Disadvantages

Effective result depend on the fact how accurately doctor read pressure values when koratkoff sound is heard.

2.11.2 Direct method

Direct method of blood pressure is used when accurate blood pressure reading. If we want to know blood pressure in deep region indirect method is not useful.so direct method is used.



Probe used in Direct blood pressure measurement:

Catheter tip probe sensor mounted at the tip of the probe. Pressure exerted on the tip is converted to the corresponding electrical signal.In fluid filled catheter type. Pressure exerted on the fluid filled column is transmitted to external transducer. This transducer converts pressure in to electrical signal.

Direct method of blood pressure measurement:

Here fluid filled catheter is used.Before inserting catheter into blood vessel, fluid filled system should be completely flushed out. Usually sterile saline is used for this purpose. Because blood clotting is avoided.

Working:

Blood taken from vessel using catheter tip probe.Pressure exerted is transmitted to the pressure transducer. The output of transducer is given to pressure monitor.Because transducer converted into electrical signal. Strain gauge pressure transducer is used. The change in pressureis given to the amplifier circuit. Two indicators, systolie, diastole display. If output of

the amplifier is positive going pulse then D_3 will be ON. In C_3 charging up to peak value. R_3 & C_3 combination is used to set some time constant value.

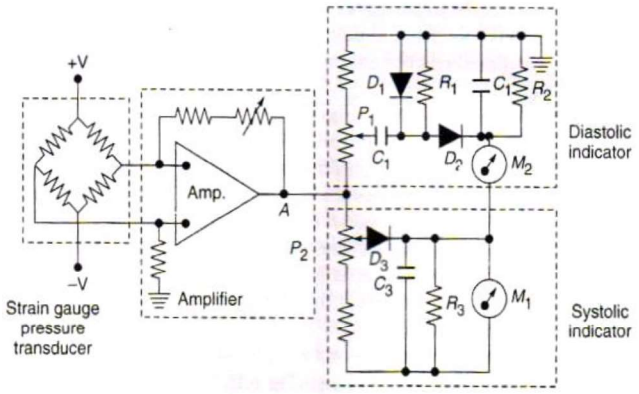


Fig 2.11.2(b) Circuit diagram for measurement of systolic and diastolic blood pressure

Which is used to stable display. Clamping circuit is available C_1 & D_1 used to develop voltage is equal to peak to peak value of the pressure pulse. This Voltage appeared across R_1 resistance. D_2 diode is ON so C_2 charged up to the peak value. Diastolic pressure is displayed using the indicator M_2

M_2 reading = peak systolic value - peak to peak pressure value.

TWO MARKS

1) What are the typical values of blood pressure and pulse rate of an adult?

Systolic (maximum) blood pressure in the normal adult is in the range of 95 to145 mm Hg, with 120 mm Hg being average. Diastolic (lowest pressure between beats) blood pressure ranges from60 to 90 mm Hg, 80 mm Hg being average.

2) What are systolic and diastolic pressures?

The heart's pumping cycle is divided into two major parts systole and diastole. Systole is defined as the period of contraction of the heart muscles specifically the ventricular muscle at which time blood is pumped into the pulmonary artery and the aorta. Systolic pressure is 120 mm Hg(average value). Diastole is the period of dilation of the heart cavities as they fill with blood. Diastolic pressure is 80 mm Hg (average value).

3) What is the reason for decrease of cardiac output?

The reason for decrease of cardiac output may be due to low blood pressure, reduced tissue oxygenation, poor renal function, shock and acidosis.