2.2 BLOOD FLOW METER

Blood flow meters are used to monitor the blood flow in various blood vessels and tomeasure cardiac output.

Types

- Electromagnetic blood flow meters
- Ultrasonic blood flow meters
- Laser based blood flow meters

ELECTROMAGNETIC FLOWMETERS

- Electromagnetic blood flow meters measure blood flow in blood vessels
- Consists of a probe connected to a flow sensor box. The bellow Figure 1 shows the Blod flow meter.

Figure 1 Blod flow meter

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

An Electromagnetic Flow Meter is a device capable of measuring the mass flow of a fluid. Unlike the common flow meter you can find on the market it has no moving parts, and for this reason it can be made to withstand any pressure (without leakage) and any fluid (corrosive and non corrosive). This kind of flow meter use a magnet and two electrodes to peek the voltage that appears across the fluid moving in the magnetic field.

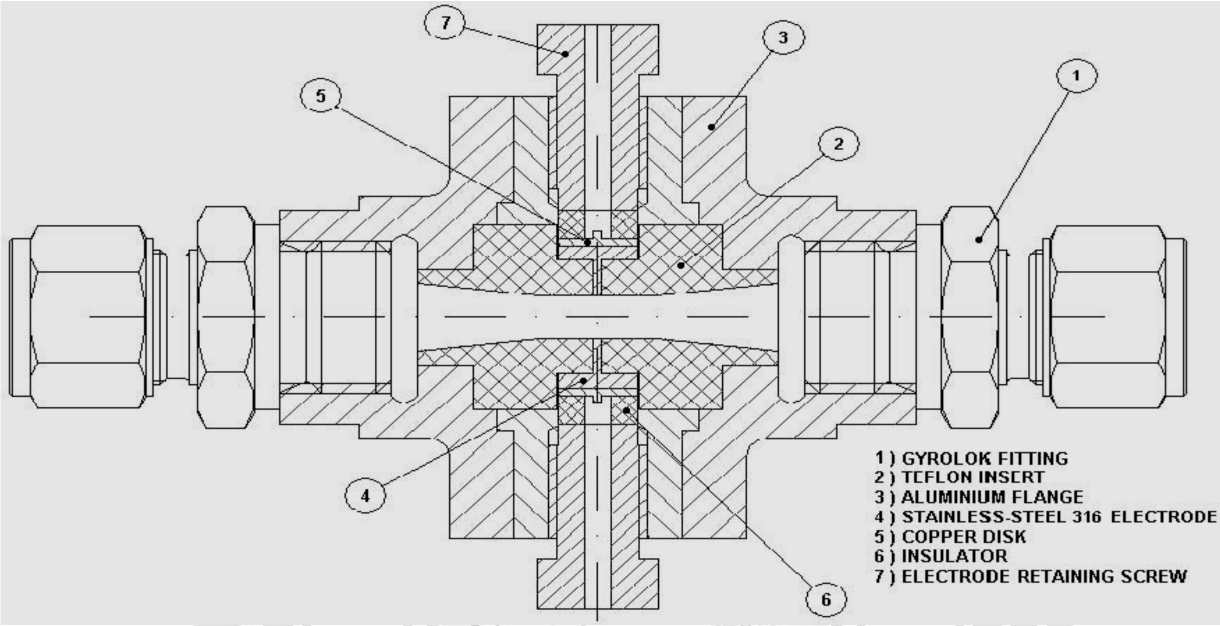


Figure 2 Electromagnetic Flow meter.

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The above Figure 2 shows the Electromagnetic Flow Meter

The Neumann Law (or Lenz Law) states that if a conductive wire is moving at right angle through a magnetic field, a voltage ***E*** [Volts] will appear at the end of the conductor .

E=B*L*V

Where

B = Magnetic Induction[Weber/m2]

L = Length of the portion of the wire 'wetted' by the magnetic field [m]

V = Velocity of the wire [m/sec]

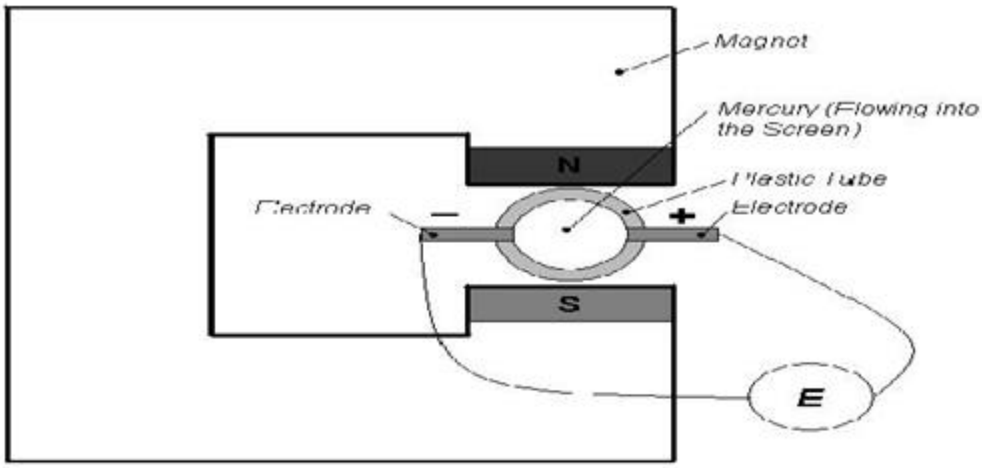


Figure 3 Magnetic Blood flowmeter principle

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The above fugure 3 represents the principles of Magnetic Blood flow meter. Now imagine you have a plastic tube with two electrodes on the diameter and Mercury flowing into it (fig above). A voltage will appear on the electrodes and it will be

E=B*L*V

As in the previous example (***L*** in this case is the inner diameter of the tube).Mercury as tiny conductive wires next to each other: each wire, moving in the tube, will touch the two electrodes ,and thus you can measure their voltage.

An interesting fact is that if you reverse the flow, you still get a voltage but with reverse polarity (Fig.1). Till now we have talked about a conductive fluid, Mercury, but this stuff will also work with non conductive fluid, provided that you use an alternating magnetic field. Two physicists, Middleman and Cushing, in an unpublished work, stated that when using a non conductive fluid, if the frequency of the alternating magnetic field is ***v*** the voltage at the electrodes will be attenuated by a factor ***a*** so that:

Measuring the flow A perfect axisimmetric construction cannot be achieved and thus some magnetic flux lines will 'wet' the connecting wires to the electrodes. The alternating magnetic field will create an offset voltage in this wire and even if the fluid is not moving, the measured voltage will not be zero.

ULTRASONIC FLOWMETERS

The blood cells in the fluid scatter the Doppler signal diffusively.In the recent years ultrasound contrast agents have been used in order to increase the echoes.The ultrasound beam is focused by a suitable transducer geometry and a lens.

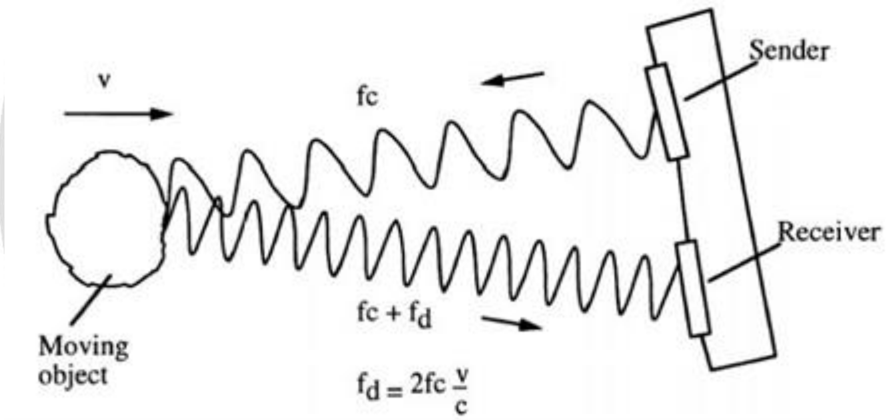


Figure 4 Ultrasonic flowmeters

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

$f_d = 2f_c v/c$

$f = 2\text{- }10\ MHz$

$c = 1500 - 1600$ m/s (1540 m/s)

$f = 1{,}3 – 13\ kHz$

In order to know where along the beam the blood flow data is colledted, a pulsed Doppler must be used. The flow velocity is obtained from the spectral estimation of the received Doppler signal.The ultrasound Doppler device can be either *a continuous wave* or *a pulsed Doppler*

A Continuous Wave

No minimum range

Simpler hardware

Range Ambiguity

Low flow cannot be detected

A Pulsed Doppler

Accuracy

No minimum flow

Minimum range

(Maximum flow) x (range)= limited the power decays exponentially because of the heating of the tissue. The absorption coefficient ~ proportional to frequency the far field operation shouldbe avoided due to beam divergence.

$$D_{nf} = D^2/4\lambda$$

D = Transducer diameter (e.g. 1 – 5 mm) the backscattered power is proportional to *f* .The resolution and SNR are related to the pulse duration. Improving either one of the parameters always affects inversely to the other.

LASER DOPPLER FLOWMETRY

The principle of measurement is the same as with ultrasound Doppler.The laser parameter may have the following properties:5 mWHe-Ne-laser 632,8 nm wavelength.

The moving red blood cells cause Doppler frequency 30 – 12 000 Hz.The method is used for capillary (microvascular) blood flow measurements

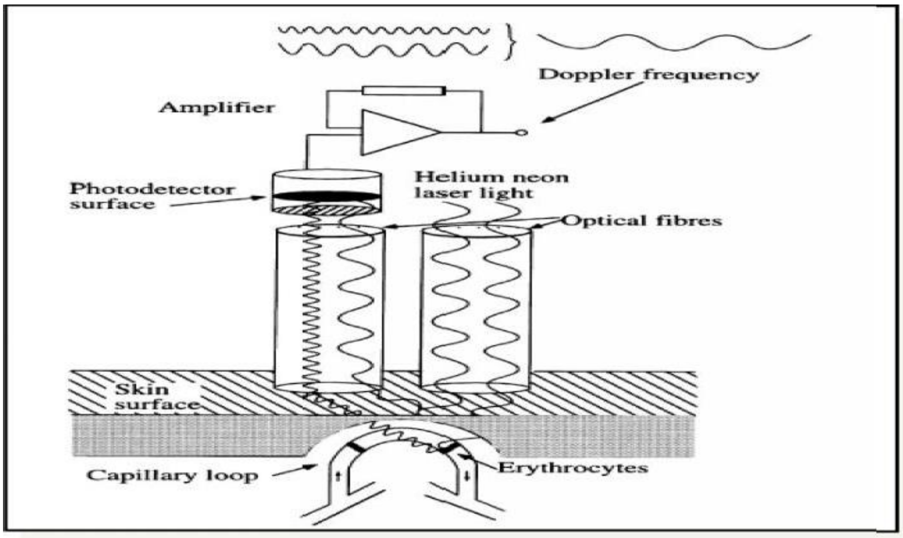


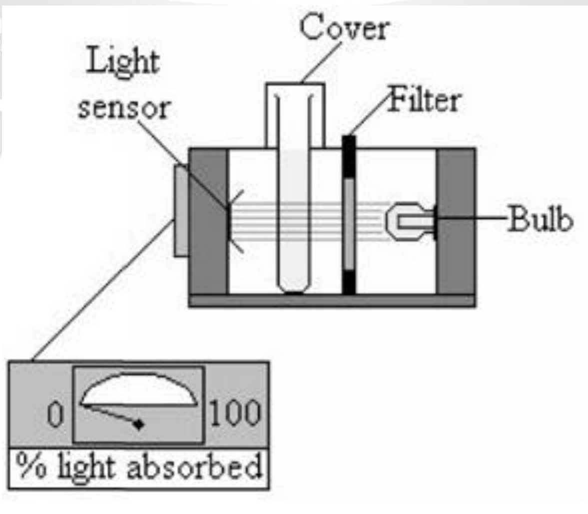
Figure 5 Laser Doppler flowmeter

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Indicator Dilution Methods

Dye Dilution Method

A bolus of indicator, a colored dye *(indocyanine green),* is rapidly injected in to the vessel. The concentration is measured in the downstream The blood is drawn through a colorimetric cuvette and the concentration is measured using the principle of absorption photometry



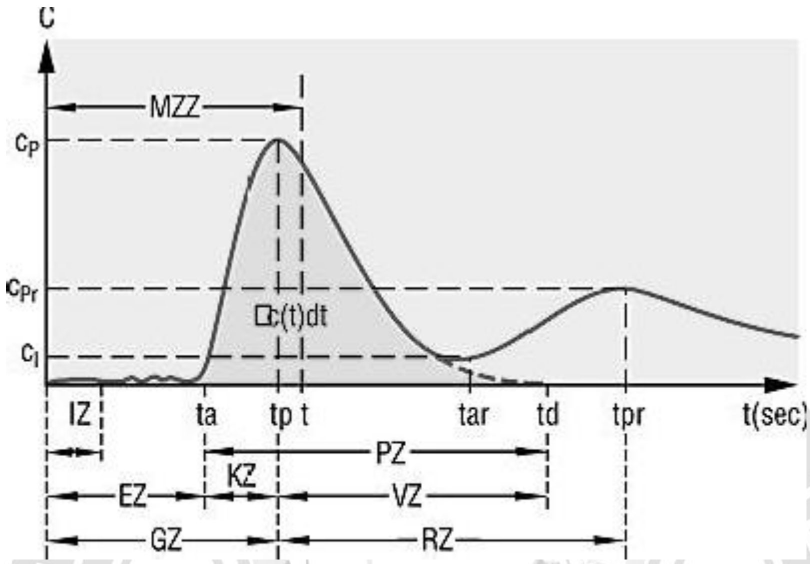


Figure 6 Dye Dilution Method

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Thermal Dilution Method

A bolus of chilled saline solution is injected into the blood circulation system (right atrium). This causes decrease in the pulmonary artery temperature. An artery puncture is not needed in this technique.Several measurements can be done in relatively short time .A standard technique for measuring cardiac output in critically ill patients

Photoelectric Method

A beam of IR-light is directed to the part of the tissue which is to be measured for bloodflow (e.g. a finger or ear lobe)

The blood flow modulates the attenuated / reflected light which is recorded.The light thatis transmitted / reflected is collected with a photodetector

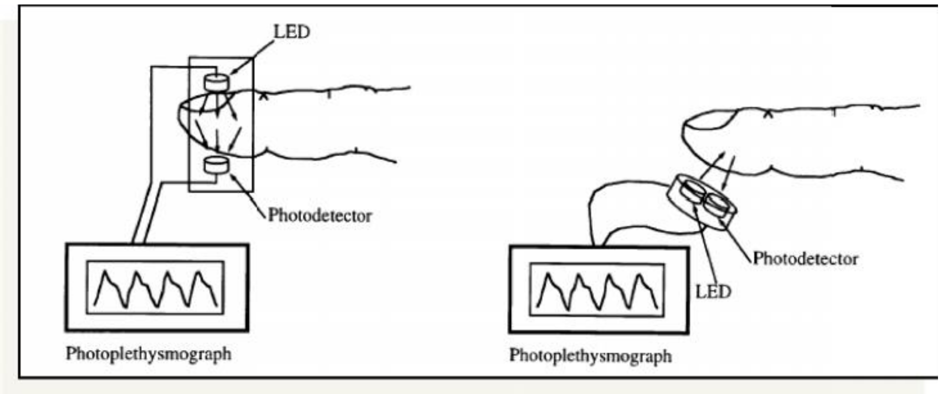


Figure 7 Photoelectric Method

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

Radioisotopes

A rapidly diffusing, inert radioisotope of lipid-soluble gas (Xe or Kr) is injected into the tissue or passively diffused

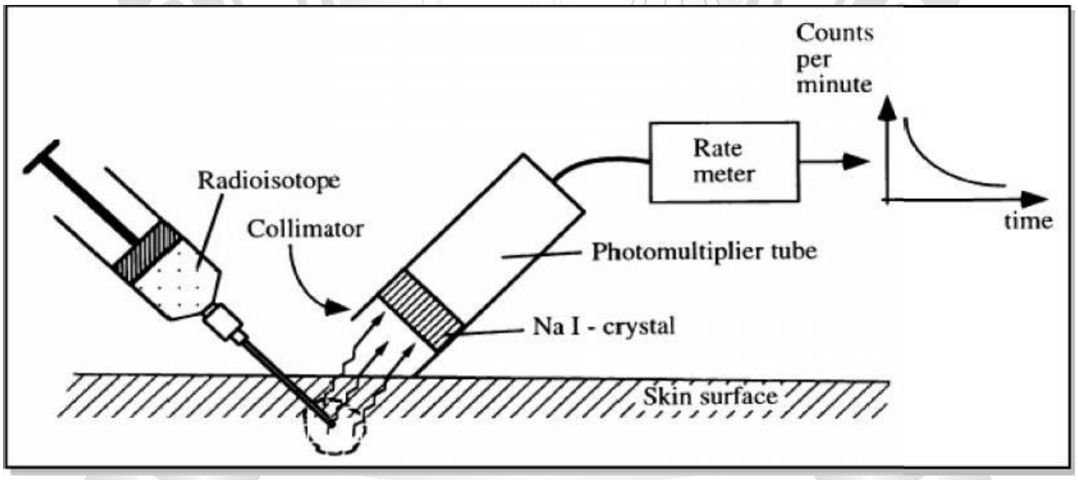


Figure 8 Radioisotopes

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]

The elimination of the radioisotope from microcirculatory bed is related to the blood flow.

Thermal Convection Probe

- This is one of the earliest techniques for blood flow measurements

- The rate of heat removal from the tissue under probe is measured
- The concentric rings are isolated thermally & electrically from each other
- The central disk is heated 1 – 2 C over the temperature of tissue.
- A temperature difference of 2- 3 C is established between the disks.The method is not very common due extreme nonlinear properties and difficulties in practical use (e.g. variable thermal characteristics of skin)

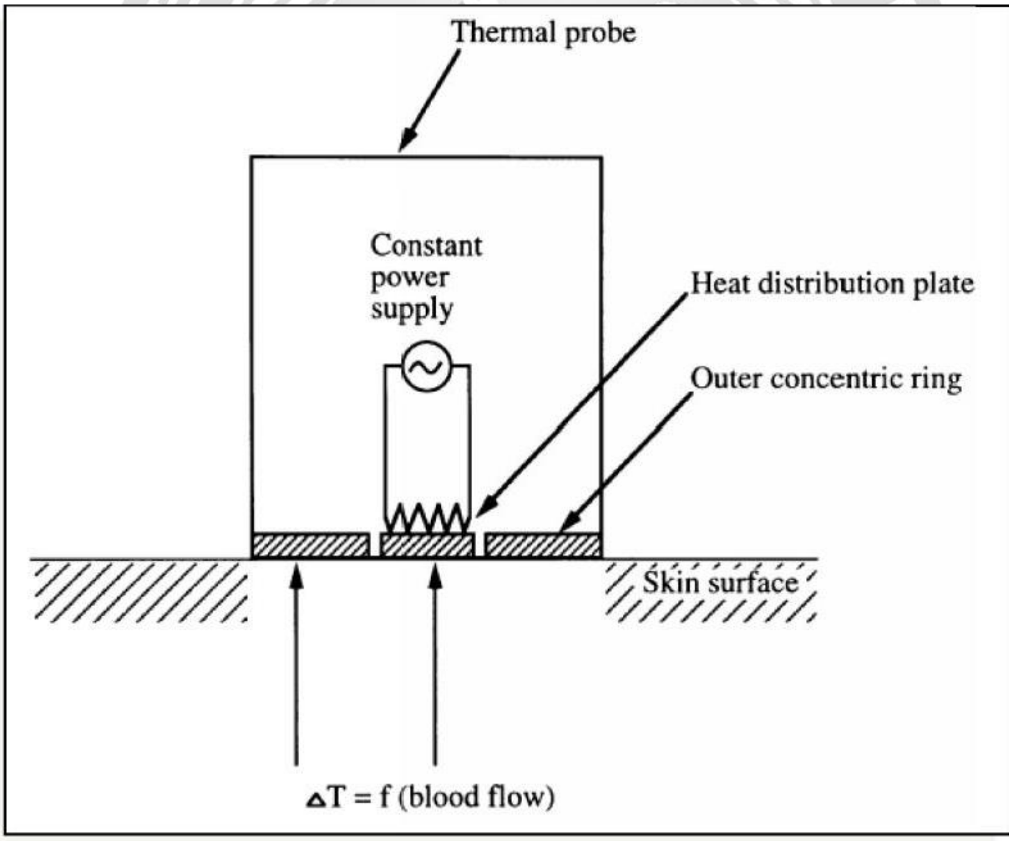


Figure 9 Thermal Convection Probe

[Source : Leslie Cromwell, — "Biomedical Instrumentation and Measurement"]