FLOW METERS

A flow meter is an instrument used to measure linear, nonlinear, mass or volumetric flow rate of a liquid (blood) or a gas.

Electromagnetic flow meters

These are commonly used to measure blood flow. The two factors that determine the flow of blood through blood vessels are the pressure gradient between two points in the blood vessels and the resistance because of friction.

Noninvasive electromagnetic flow meter was introduced by Fabre where as Kolin and Wetterer found the invasive measurement.

Blood can be measured in intact blood vessels without cannulation but the blood vessel should be exposed so that flow head/measuring probe can be put across it.

Electromagnetic blood can measure a cardiac output of 4l/min to 25l/min with a frequency range of dc to 20 Hz

Principle

The operation principle behind the electromagnetic blood flow meters is Faraday's law of electromagnetic induction which states that if electrical current carrying conductor moves at right angle through a magnetic field, an electromotive force is induced in the conductor.

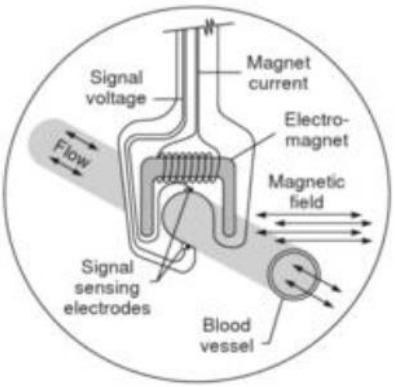
In the case of electromagnetic blood flow meters, while the blood flows between forces of magnetic field, which are provided by the electromagnetic blood flow meters, voltage is induced in the blood stream. The induced voltage is perpendicular to the magnetic field and the direction

of the flow of blood. Then this voltage is picked up by the blood flow transducer probes placed 90 degree to the direction of the blood flow.

Working

A circular probe with a gap to fit the vessel is fitted around the vessel. This probe applies an alternating magnetic field across the vessel and detects the voltage induced by the flow via small electrodes in contact with the vessel.

The magnitude of the voltage is proportional to the strength of the magnetic files,diameter of blood vessel and velocity of blood flow.



Alternating magnetic fields (typically at 400 Hz) are used since the induced voltages are in the microvolt region and d.c. electrode potentials may cause significant errors with unchanging magnetic fields.

$$e = CHVd$$

where e = induced voltage

C = constant

H = strength of magnetic field

V = velocity of the blood flow

d = diameter of the blood flow

Since H and d are constants, e is directly proportional to V.

$$e = C_1 V \ (C_1 = CHd)$$

Flow rate Q = VA ; V = Q/A A = area of c.s of tube

$$e = C_1 \times Q/A$$

$$= C_2 Q \ (C2 = C_1/A)$$

Therefore the induced voltage is proportional to the flow rate through blood vessel.

The tube is made of a non magnetic conducting material and is insulated.

The electrodes are made of Stainless steel or Platinum.

A number of probes are required to fit the various diameters of blood vessel. The size varies between 1-24 mm.

An alternative design carries the sensing device on the tip of a special catheter which passes inside the vessel and generates a magnetic field in the space around it and has the electrodes on its surface.

Average flow velocity in arteries = 20-25 cm/s and veins = 10-12 cm/s.

Types

A flowmeter consists of a generator of AC, a robe assembly, series of capacitance coupled amplifiers, demodulator, a dc amplifier and a recording device.

Sine wave electromagnetic blood flow meters

The sine wave electromagnetic blood flow meter uses wave alternating current to generate the required magnetic field. The induced voltage is also sinusoidal.

The main drawback of the sine wave electromagnetic blood flow meter is the induction of transformer voltage. The blood vessel and the blood that flows through it act as the secondary winding of the transformer which in turn generates the transformer voltage. Hence it requires complex circuitry but has a good signal to noise ratio.

Square wave electromagnetic blood flow meters

In the square wave electromagnetic blood flow meter, the excitation is square wave alternating current, and the induced voltage is square wave too.

In the square wave electromagnetic blood flow meter, the transformer voltage appears as a spike at the beginning of the square wave induced voltage which can be easily removed by using gated amplifier.

Applications

The electromagnetic blood flowmeter is sometimes used during vascular surgery to measure the quantity of blood passing through a vessel or graft, before during or after surgery.

Ultrasonic Blood flow meters

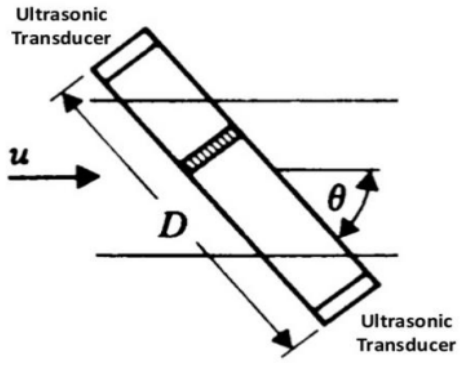
An ultrasonic blood flow meter is a type of flow meter that measures the velocity of a blood with ultrasound to calculate volume flow.

There are two types of US flow meters- Transit time velocity meter and Doppler shift meter.

Transit time velocity meters

It measures the difference in travel time between pulses transmitted in the direction of, and against, the flow. This type of meter is also called time of flight and time of travel.

A cuff is placed around an artery, and it incorporates 2 crystals diagonally placed on either sides of the vessel. Both the crystals act as transmitter and receiver. Transit time is measured by starting a ramp voltage rising with each burst emitted and which is stopped by the reception of the pulse.



The transit time is shortened when the blood flows in the same direction as the transmitted energy.

t = distance / conduction velocity

$t = D / c +\_ u \cos \theta$

where t – transit time

D – distance between the transducers

c – sound velocity

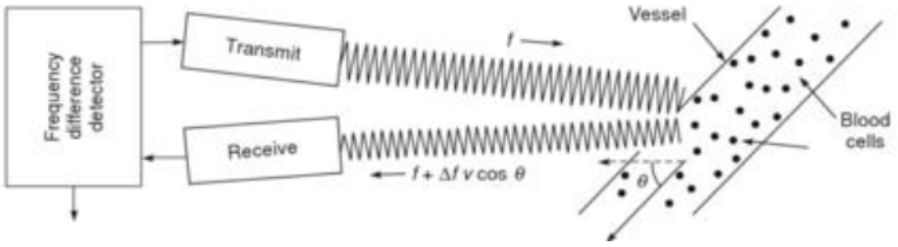
u – blood flow velocity

Doppler shift US flowmeters

These are used for routine clinical measurements. They are used for the measurement of blood velocity, volume flow, flow direction and flow profile.

The apparent difference between the frequency at which sound or light waves leave a source and that at which they reach an observer, caused by relative motion of the observer and the wave source.

It is a measure of the size and direction of flow velocity.



Principle

Incident US is scattered by blood cells and the scattered wave is received by the receiver.

The frequency shift due to the scattering is proportional to the velocity of the scatterer. There is a change in frequency as the US arrives at the receiver after it is scattered by the blood cells.

$$f_d = \frac{2f_0 u \cos\theta}{c}$$

Where,

fd = Doppler frequency shift

fo = source frequency

u = target velocity / velocity of blood cells

c = velocity of sound in blood

This forms the basis of measuring blood velocity. Velocity is directly proportional to difference in frequency.