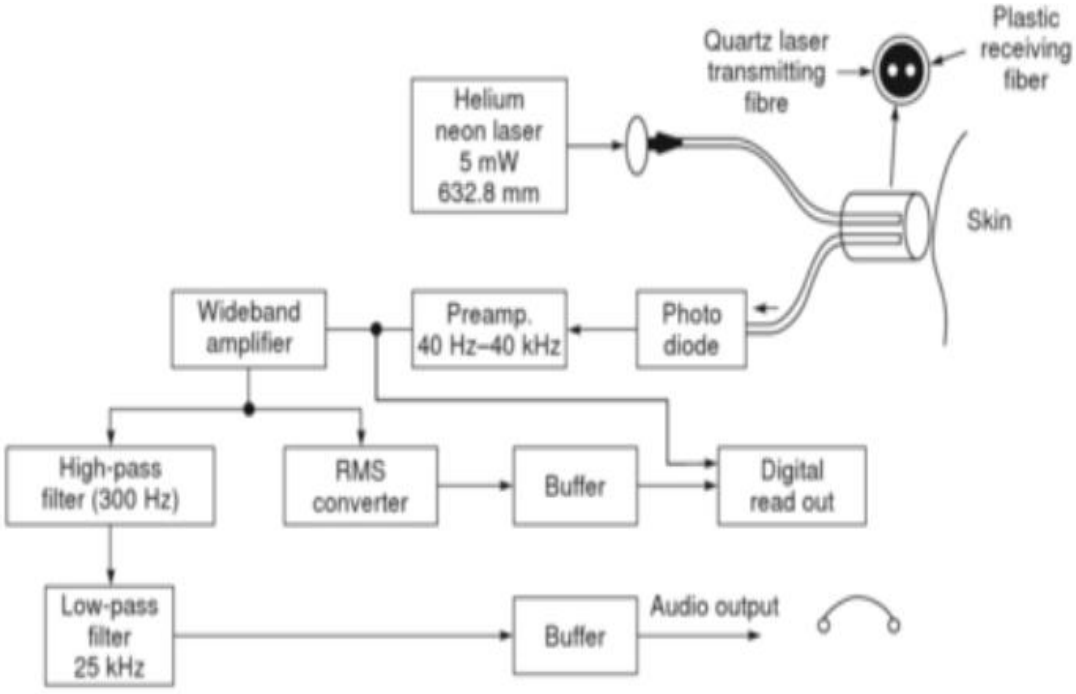
Laser Doppler Blood flow meters

Laser Doppler is a standard technique for the non-invasive blood flow monitoring and measurement of blood flow in the microcirculation.

Principle

The laser Doppler technique measures blood flow in the very small blood vessels of the microvasculature, such as the low-speed flows associated with nutritional blood flow in capillaries close to the skin surface and flow in the underlying arterioles and venules involved in regulation of skin temperature.

The technique depends on the Doppler principle whereby low power light from a monochromatic stable laser (a), e.g. a Helium Neon gas laser at a power of 5mW and 632.8nm or a single mode laser diode, incident on tissue is scattered by moving red blood cells and as a consequence is frequency broadened (b). The frequency broadened light, together with laser light scattered from static tissue, is photo detected and the resulting photocurrent processed to provide a blood flow measurement.



Laser light can be directed to the tissue surface either via an optic fibre or as a light beam. In some cases optic fibre terminates in an optic probe which can be attached to the tissue surface. One or more light collecting fibres also terminate in the probe head and these fibres transmit a proportion of the scattered light to a photodetector and the signal processing electronics.

Lasers scattered by moving blood particles undergo change in frequency (Doppler Shift) and these beams are received by a plastic fibre at the skin and are transmitted to photo diode.

Heterodyned optical signal is proportional to the Doppler shift frequency and signal is amplified.

The RMS value of output signal is calculated and the total zero light noise is filtered from it.

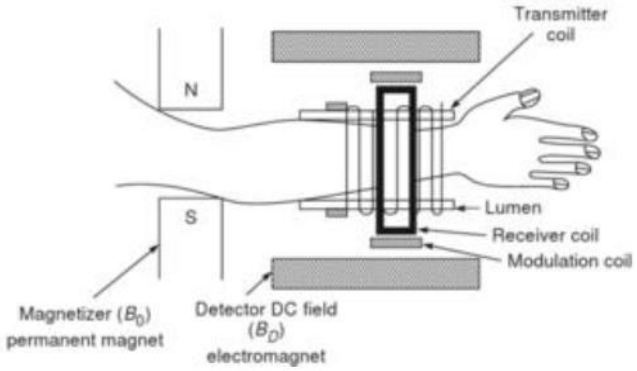
The output voltage gives the output flow velocity on a display device.

An audio output can also be added to hear the flow pattern.

NMR Blood flow meters.

A non invasive method for measurement of peripheral blood flow or blood flow in organs.

The principle behind NMR is that many nuclei have spin and all nuclei are electrically charged. If an external magnetic field is applied, an energy transfer is possible between the base energy to a higher energy level . The energy transfer takes place at a wavelength that corresponds to radio frequencies and when the spin returns to its base level, energy is emitted at the same frequency. The signal that matches this transfer is measured in many ways and processed in order to yield an NMR spectrum for the nucleus concerned.



The NMR signals help in the detection of presence of hydrogen atoms in blood and hence magnitude of magnetization is found. The magnitude of magnetization can be related to the flow rate or flow velocity.

Cardiac Output Measurement

Cardiac output is the volume of blood pumped by the heart per minute (mL blood/min).

Cardiac output is a function of heart rate and stroke volume. The heart rate is simply the number of heart beats per minute. The stroke volume is the volume of blood, in milliliters (mL), pumped out of the heart with each beat. Increasing either heart rate or stroke volume increases cardiac output.

Cardiac Output in mL/min = heart rate (beats/min) X stroke volume (mL/beat)

An average person has a resting heart rate of 70 beats/minute and a resting stroke volume of 70 mL/beat.

The cardiac output for this person at rest is:

Cardiac Output = 70 (beats/min) X 70 (mL/beat) = 4900 mL/minute.

The total volume of blood in the circulatory system of an average person is about 5 liters (5000 mL).

There are 3 measurement techniques. They are

Indicator Dilution method,

Dye dilution method,

Thermal dilution method

Indicator Dilution method

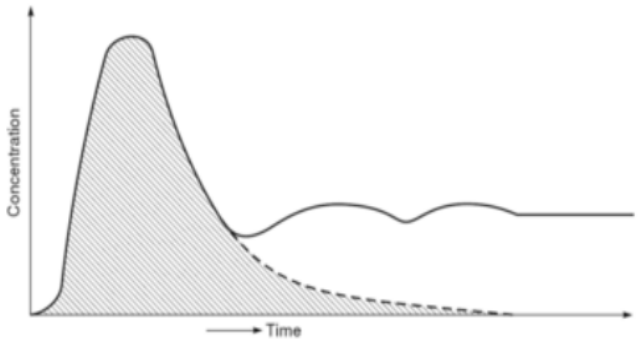
The principle behind the method states that the volume flow of blood from the heart can be estimated by introducing a known amount of indicator and measuring the concentration difference upstream and downstream of the injection site.

An indicator is a substance that permits observations of some element of volume of the fluid under study. The indicator shows the position of the element of volume in space and with respect to time, and distinguishes the indicated element from all other elements of volume.

In the method, a known quantity of indicator is introduced into a fluid flowing at unknown rate through a system of unknown volume. Fluid is sampled or monitored at one or more points downstream from the plane of introduction and the concentration of indicator, diluted by the parent fluid, is measured as a function of time.

Indicator may be introduced at a constant rate in the form of injections or as a bolus.

The presence of an indicator is detected by a photoelectric transducer and is displayed on the chart recorder and the dilution curve is obtained.



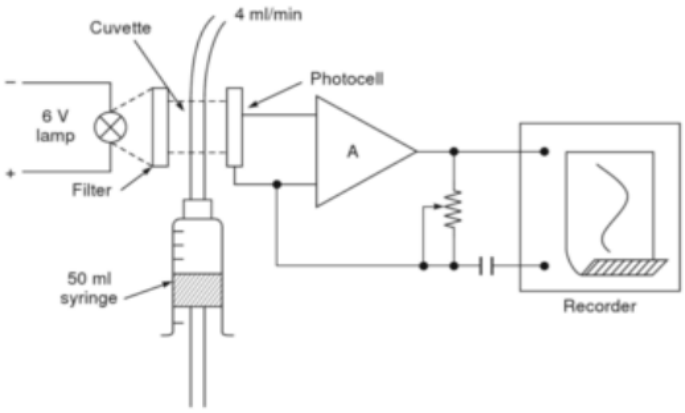
Amplitude of curve depends on the quantity of injected indicator and total quantity of circulating blood.

Dye dilution method

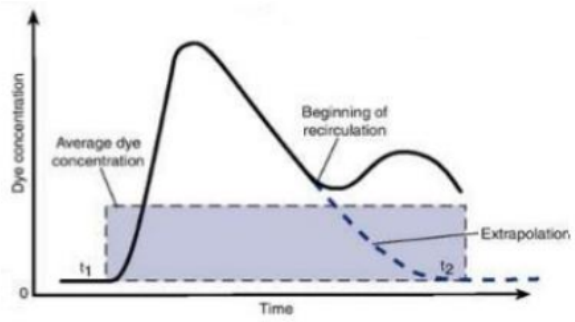
The Dye dilution method is based on the measuring of the light absorbance of the dye injected into the blood.

A known quantity of a dye is rapidly injected into one site of the circulatory system, and withdrawing blood at a distal site for determination of a concentration curve of the dye.

The dye (Indo-Cyanine Green) is injected by special pulmonary catheter. Dyed blood is continuously sucked into the absorption photometer or IR photo cell transducer. Its absorption is maximum in the infrared part of the spectrum (at 805 μm) – where oxyhaemoglobin and reduced haemoglobin transmit light equally.



Cardiac output = Quantity of dye injected x 60 / Avg. conc of dye in each ml of blood for the duration of the curve x duration of curve in Sec.



After output is measured, saline is injected to flush the dye out of the circulating blood.

Thermal dilution method

Thermodilution is an indicator-dilution method of measuring blood flow. This method is based on the fact that when an indicator substance is added to circulating blood, the rate of blood flow is inversely proportional to the change in concentration of the indicator over time.

The indicator substance can be a dye (dye-dilution method) or a fluid with a different temperature than blood (thermodilution method).

A 5% dextrose or saline solution that is colder than blood is injected through the proximal port of the catheter in the right atrium. The cold fluid mixes with blood in the right heart chambers, and the cooled blood is ejected into the pulmonary artery and flows past the thermistor on the distal end of the catheter. The thermistor records the change in blood temperature with time and sends this information to an electronic instrument that records and displays a temperature-time curve. The area under this curve is inversely proportional to the rate of blood flow in the pulmonary artery. In the absence of intracardiac shunts, this flow rate is equivalent to the (average) cardiac output.

Blood temperature is measured over a range of 30-40°C.

Cardiac Output = constant x (blood temp-injectate temp) / area under dilution curve