Flow Measurement

Hot Wire Anemometer

Definition: The Hot Wire Anemometer is a device used for measuring the velocity and direction of the fluid. This can be done by measuring the heat loss of the wire which is placed in the fluid stream. The wire is heated by electrical current.

The hot wire when placed in the stream of the fluid, in that case, the heat is transferred from wire to fluid, and hence the temperature of wire reduces. The resistance of wire measures the flow rate of the fluid. The hot wire anemometer is used as a research tool in fluid mechanics. It works on the principle of transfer of heat from high temperature to low temperature.

Construction of Hot Wire Anemometer

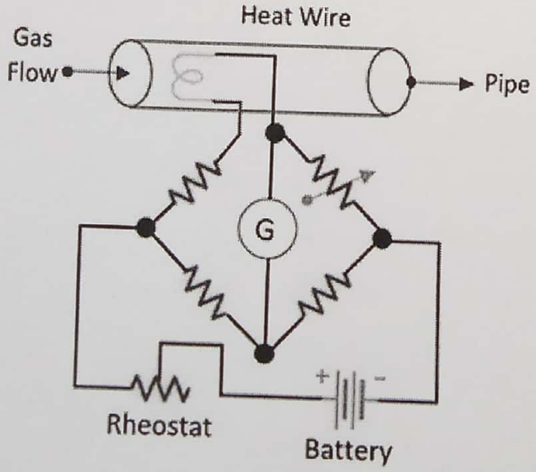
The hot wire anemometer consists two main parts.

1. Conducting wire
2. Wheat stone bridge.

The conducting wire is housed inside the ceramic body. The wires are taking out from the ceramic body and connecting to the Wheatstone bridge. The wheat stone bridge measures the variation of resistance.

Constant Current Method

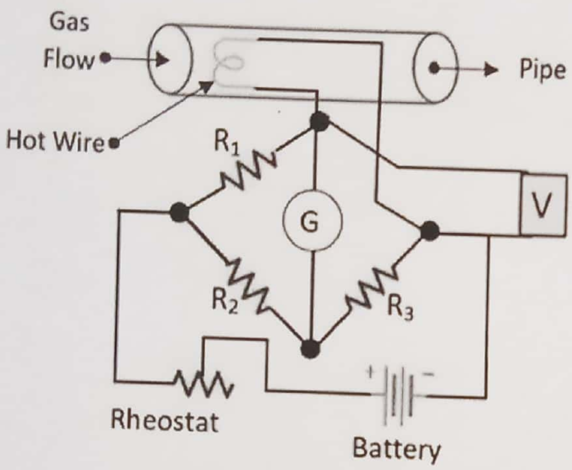
In the constant current method, the anemometer is placed in the stream of the fluid whose flow rate needs to be measured. The current of constant magnitude is passed through the wire. The Wheatstone bridge is also kept on the constant voltage.



When the wire is kept in the stream of liquid, in that case, the heat is transferred from the wire to the fluid. The heat is directly proportional to the resistance of the wire. If heat reduces, that means the resistance of wire also reduces. The Wheatstone bridge measures the variation in resistance which is equal to the flow rate of the liquid.

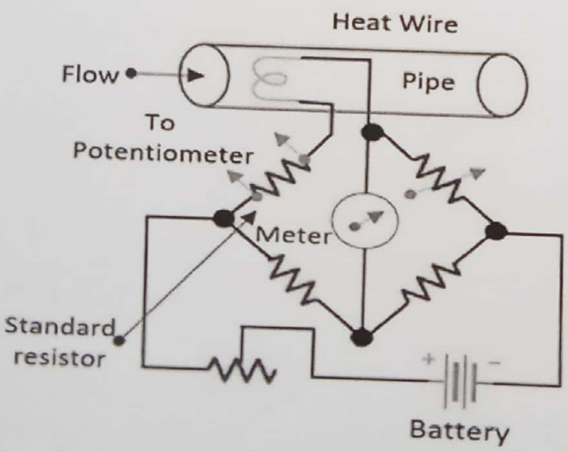
Constant Temperature Method

In this arrangement, the wire is heated by the electric current. The hot wire when placed in the fluid stream, the heat transfer from wire to the fluid. Thus, the temperature of the wire changes which also changes their resistance. It works on the principle that the temperature of the wire remains constant. The total current requires to bring the wire in the initial condition is equal to the flow rate of the gas.



Measurement of the rate of a fluid using a Hot Wire Instrument

In hot wire anemometer, the heat transferred electrically to the wire which is placed in the fluid stream. The Wheatstone bridge is used for measuring the temperature of wire regarding their resistance. The temperature of the wire remains constant for measuring the heating current. Thus, the bridge remains balanced.



The standard resistor is connected in series with the heating wire. The current across the wire is determined by knowing the voltage drop across the resistor. And the value of voltage drop is determined by the potentiometer.

The equation determines the heat loss from the heated wire

$$= a(vp + b)^{1/2} J/s$$

Where, v – velocity of heat flow,
ρ – the density of fluid,

Where a and b are the constants. Their value depends on the dimension and the physical properties of the fluid and wire.

Suppose I, is the current of the wire and the R is their resistance. In equilibrium condition,

Heat generated = Heat Lost

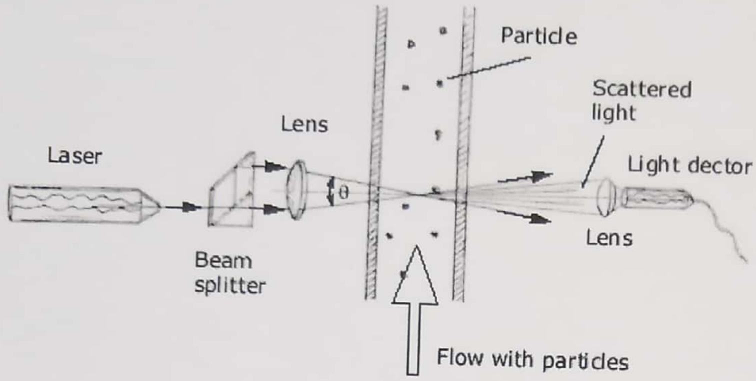
$$I^2R = a(vp + b)^{1/2}$$

$$v = \frac{\left(I^2R/_{a^2} - b\right)}{\rho}$$

The resistance and temperature of the instrument are kept constant for measuring the rate of the fluid by measuring the current I.

LDV - Laser Doppler Velocimetry

Laser Doppler Velocimetery (LDV) is a technique used to measure the instantaneous velocity of a flow field. This technique is non-intrusive and can measure all the three velocity components. The laser Doppler velocimeter sends a monochromatic laser beam toward the target and collects the reflected radiation. According to the Doppler Effect, the change in wavelength of the reflected radiation is a function of the targeted object's relative velocity. Thus, the velocity of the object can be obtained by measuring the change in wavelength of the reflected laser light, which is done by forming an interference fringe pattern (i.e. superimpose the original and reflected signals).This is the basis for LDV. A flow is seeded with small, neutrally buoyant particles that scatter light. The particles are illuminated by a known frequency of laser light. The scattered light is detected by a photomultiplier tube (PMT), an instrument that generates a current in proportion to absorbed photon energy, and then amplifies that current. The difference between the incident and scattered light frequencies is called the Doppler shift. By analyzing the Doppler-equivalent frequency of the laser light scattered (intensity modulations within the crossed-beam probe volume) by the seeded particles within the flow, the local velocity of the fluid can be determined.



Laser Doppler Optical System

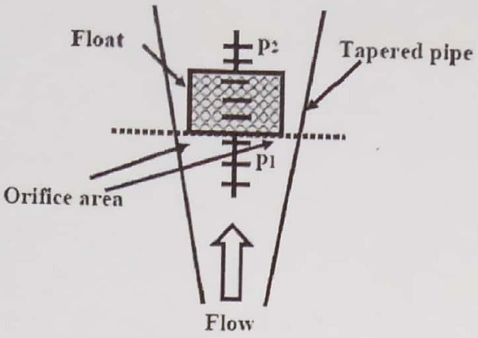
Basic one-component LDV Equipments:

Laser system (Continuous-Wave-CW, single colour for single channel), transmission optics (e.g. Bragg cell, lenses, beam expanders, beam splitter, mirrors, prisms, fiber cable link with laser beam manipulator), receiving optics (e.g. lenses, pinhole, interference filter, photomultiplier), signal processor units (e.g.. fringe-counting, spectral analysis, photon-correlation), traversing mechanism (manual or automated) for transmitting and receiving optics, oscilloscope, seeding generation (solid or liquid vapour) and computer (large capacity hard disk) with a data acquisition board and data handling software. The more compact and easy to handle type of LDV system has fiber transmission and receiving optics.

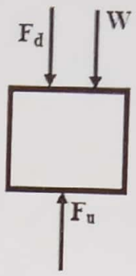
→ Rotameter —

Rotameter works as a constant pressure drop variable area meter. It can be only be used in a vertical pipeline. Its accuracy is also less (2%) compared to other types of flow meters. But the major advantages of rotameter are, it is simple in construction, ready to install and the flow rate can be directly seen on a calibrated scale, without the help of any other device, e.g. differential pressure sensor etc. Moreover, it is useful for a wide range of variation of flow rates (10:1).

The basic construction of a rotameter is shown in figure. It consists of a vertical pipe, tapered downward. The flow passes from the bottom to the top. There is cylindrical type metallic float inside the tube. The fluid f lows upward through the gap between the tube and the float. As the float moves up or down there is a change in the gap, as a result changing the area of the orifice. In fact, the float settles down at a position, where the pressure drop across the orifice will create an upward thrust that will balance the downward force due to the gravity. The position of the float is calibrated with the flow rate.



[redacted] Rotameter



[redacted] Force acting on float

γ_1= Specific weight of the float

γ_2= specific weight of the fluid

v= volume of the float

A_f= Area of the float.

A_t= Area of the tube at equilibrium (corresponding to the dotted line)

$$Q = \frac{C_d A_2}{\sqrt{1-(\frac{A_2}{A_1})^2}} \sqrt{\frac{2g}{\gamma_2}(p_1 - p_2)}$$

F_d = Downward thrust on the float

F_u = Upward thrust on the float

The major source of error in rotameter is due to the variation of density of the fluid. Besides, the presence of viscous force may also provide an additional force to the float.

Applications

- Can be used to measure flow rates of corrosive fluids
- Particularly useful to measure low flow rates

Advantages

- Flow conditions are visible
- Flow rate is a linear function(uniform flow scales)
- Can be used to measure flow rates of liquids, gases and vapour
- By changing the float, tapered tube or both, the capacity of the rotameter can be changed.

Limitations

- They should be installed vertically
- They cannot be used for measurements in moving objects
- The float will not be visible when coloured fluids are used, that is, when opaque fluid are used.
- For high pressure and temperature fluid flow measurements, they are expensive
- They cannot be used for fluids containing high percentage of solids in suspension.