MVPS's Rajarshi Shahu Maharaj Polytechnic, Nashik

Mechanical Engineering Department

Mechanical Engineering Measurement (22443)

Class: ME4I

Unit 04: Flow Measurement

Subject Teacher : Mr. M. S. Gaidhani

Course Outcome:
Students should able to use relevant instruments for measurement of flow.

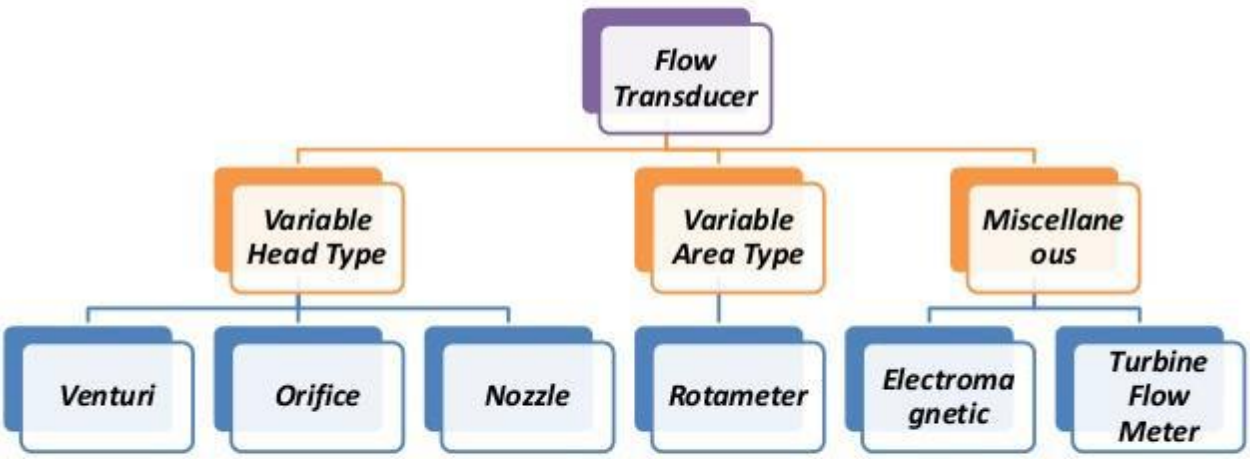
Unit Outcome:
Students should able to

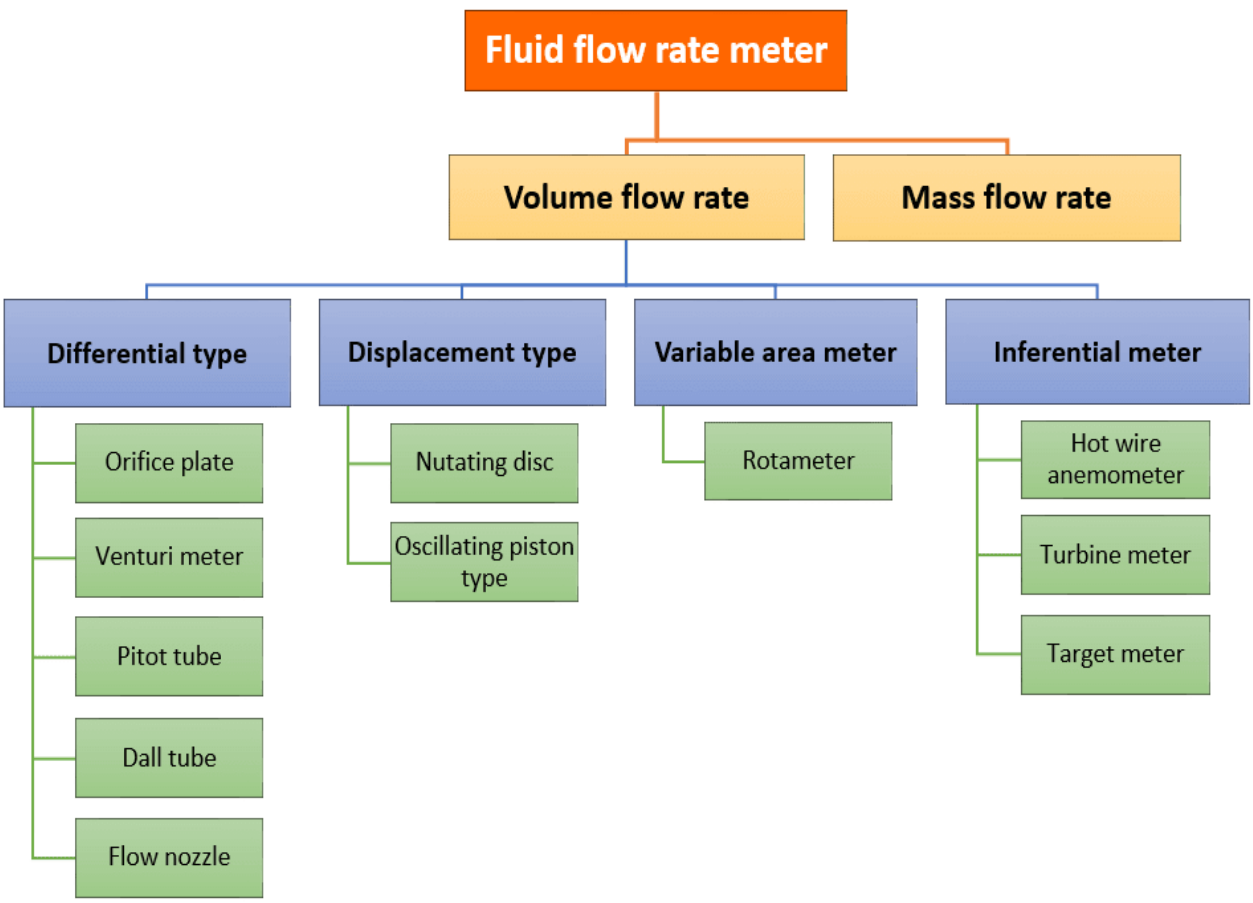
4a. Identify flow meter for given situation with justification mentioning silent features.

4b. Select relevant flowmeter to measure flow in the given system with justification.

4c. Describe with sketches the procedure for measurement of using ultrasonic flow meter.

Methods of Flow Measurement





- **List out flow measuring devices with applications**

1. **Rotameter** : Measure Liquid or Gas Flows in refrigeration system
2. **Hot wire anemometer**: widely used in research application to study varying flow conditions.
3. **Electromagnetic Flow meter:** Obstruction less flow meter used in chemical process plant.
4. **Ultrasonic flow meter**: Obstruction less flow meter used where high flow rate is to be measured R & D work.
5. **Turbine Flow Meter**: Used in Petroleum Industry.
6. **Vortex Flow Meter**: Used For measurement of flow of liquid and gas.

- **With a neat sketch, explain working of variable area flow meter.**

Working Principle: "The pressure differential across the orifice is proportional to the square of its flow area and square of the flow rate."
For measurement float must be dynamically stable

(Buoyancy force+ drag force= Weight of float)
Range- Rotameter can directly measure flows as high as 920LPH.

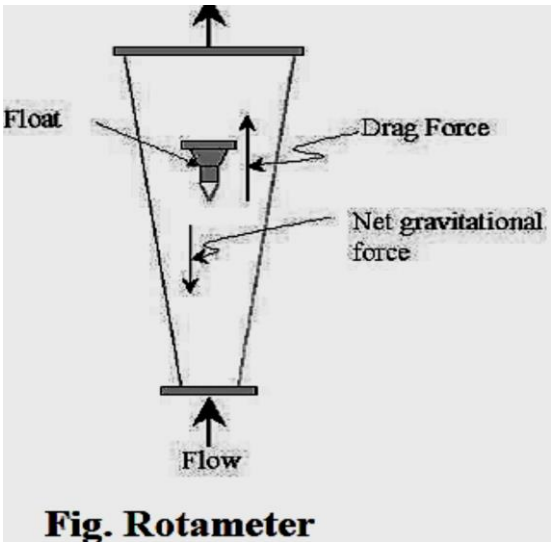
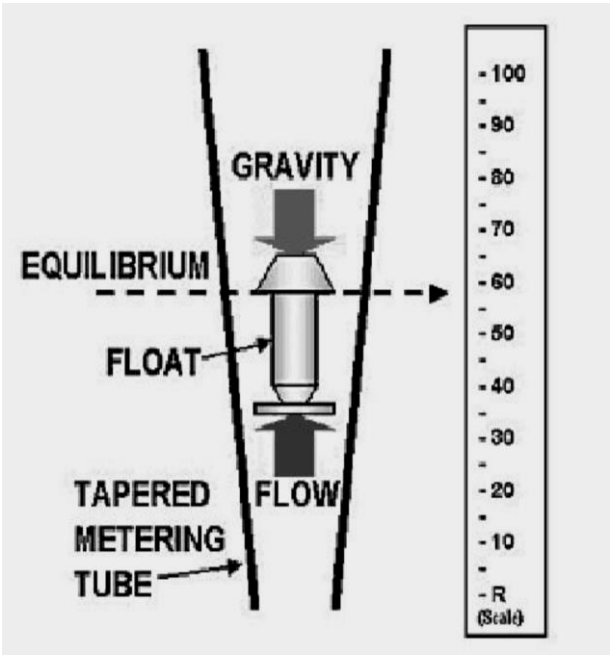


Fig. Rotameter



Construction:
The rotameter (variable area flow meter) consists of three basic elements:
1) A uniformly tapered flow tube,
2) A float
3) A measurement scale.
- A control valve may be added if flow control is also desired.
- In operation, the rotameter is positioned vertically in the fluid system with the smallest diameter end of the tapered flow tube at the bottom.
- This is the fluid inlet. The float, typically spherical, is located inside the flow tube, and is engineered so that its diameter is nearly identical to the flow tube's inlet diameter.

Working
- When fluid like gas or liquid is introduced into the tube, the float is lifted from its initial position at the inlet, allowing the fluid to pass between it and the tube wall.

- As the float rises, more and more fluid flows by the float because the tapered tube's diameter is increasing.
- Ultimately, a point is reached where the drag force exerted by the fluid is balance by weight of float and gravitational force.
- The float is now stationary at that level within the tube as its weight is being supported by the fluid forces which caused it to rise.
- This position corresponds to a point on the tube's measurement scale and provides an indication of the fluid's flow rate.

Advantages (Rotameter)

1) Pressure loss is nearly constant and small.
2) It can handle any corrosive fluid.
3) Good accuracy at low flow rate.
4) Provide linear scale.
5) Low cost
6) Condition of flow is easily visible.
7) It can use for some light slurry services.

Disadvantages (Rotameter)

1) It must install in vertical position.
2) Expensive for high pressure and temperature condition.
3) When opaque fluid is used, float may not be visible.
4) It is not rugged as venturi meter and orifice meter.
5) Not good in pulsing service
6) It requires in line mounting

Applications (Rotameter)

1) It is used for measurement of flow of liquid and gases.

- **Explain with neat sketch Turbine Flow meter.**

Working Principles: "The turbine flow meter works on basic principle of turbine."

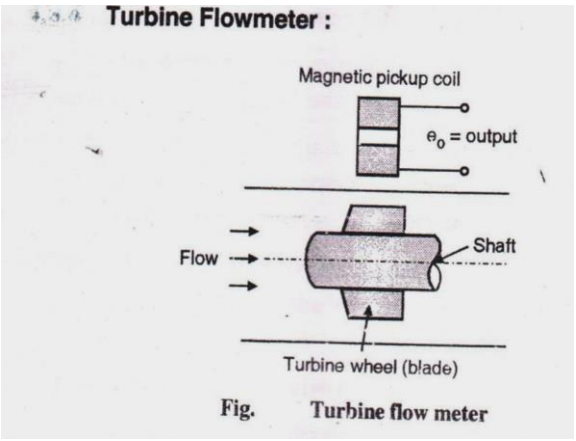
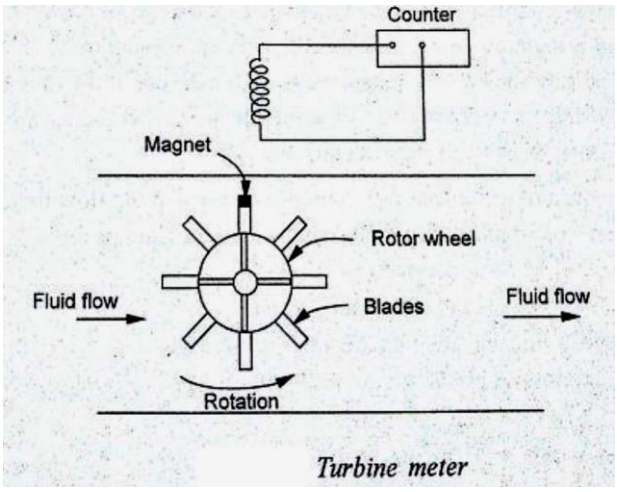


Fig. Turbine flow meter

OR



Construction:

- The turbine flow meter consists of a multi blade rotator which is placed at right angle to the axis of flowing fluid.

- The rotor is supported by ball bearing on a shaft.
- This is free to rotate about its axis.
- A magnetic pickup coil is placed near the table. It is used to measure the speed of blade.
- If is losses are kept minimum, the turbine speed varies linearly with flow rate i.e. flow rate can be measured by measuring the speed of the turbine.
- When blade passes by pickup coil it interrupts magnetic field and produces a pulse. The rate of pulse gives flow and total number of pulses gives a measures of the flow.

Working

- Flowing fluid impinging on turbine blade imparts a force on blade surfaces and set the rotor in motion with angular speed which is proportional to the fluid velocity.
- The rotor speed is measured with mechanical counter or with an electro –magnetic pick up.
- As each rotor blade passes the magnetic pick-up, it generates a voltage pulse which is a measuring of flow rate and the total number of pulses given measure of the total flow.
- The electric voltage pulses can be totalled, subtracted and manipulated by digital techniques.
- The no of pulses generated per Gallen of flow is given as,

K=(Tk*F/Q)
Where,
K=Pulses per volume unit.
Tk= Time constant in minute.
F= Frequency in Hz.
Q=Volumetric flow rate in GPM

Advantages

1) Good accuracy 2) Excellent repeatability and rangeability.
3) Allow low pressure drop. 4) Easy to install and maintain
5) Good temperature and pressure range
6) It can be compensated for viscosity variations.

Disadvantages

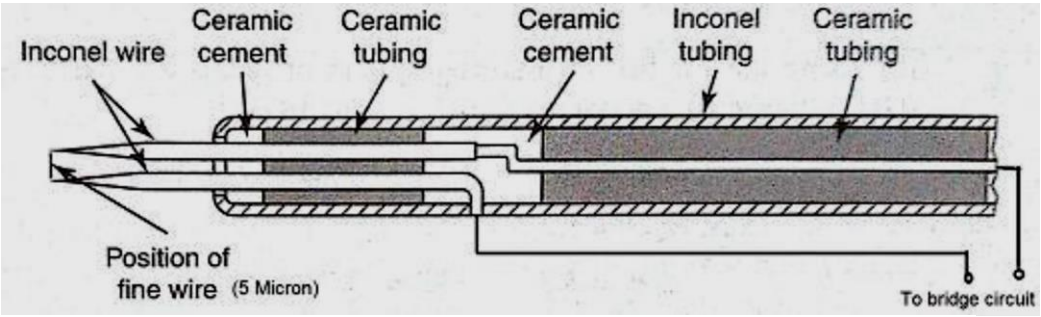
1) High cost 2) Limited for slurry application

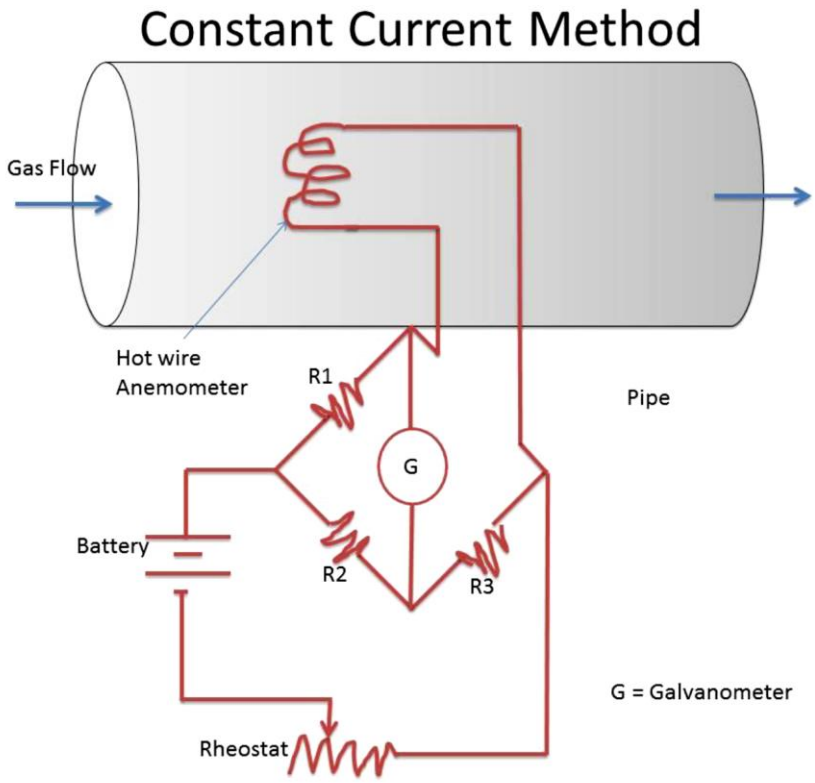
Applications

1) It is used for measurement of liquid, gas and very low flow rates.
2) To measure wind speed/velocity.
3) In petroleum industry.

- **Explain Hot wire anemometer with neat sketch.**

Working Principle: "When fluid flow over a heated surface, heat is transfer from the surface and therefore its surface temperature reduces. The rate of reduction of temperature is related to flow rate".





 It is thermal method of flow measurement.

Construction and Working

 A filament of 5-micron diameter platinum tungsten wire welded between two prongs of the probe and heated electrically to form part of Wheatstone circuit.

 When the probe is introduced into the flowing fluid, it tends to be cooled by the velocity and there is decrease in its resistance.

The rate of cooling of wire depends upon the

1.Dimension and physical properties of the wire

2. Difference of the temperature between the wire and fluid There are two methods of measuring fluid flow. (Anyone method may be considered)

Constant –current mode

 In constant current type, the heating current i.e. voltage across the bridge maintained constant.

 Initially circuit is adjusted such that the galvanometer reads zero when probe wire lies on stationary air.

 When air flows, the hot wire cools and changes its resistance.

- Hence deflects galvanometer which is already calibrated to get flow velocity.

Constant-temperature mode

- In this, operating resistance of wire hence the temperature of the wire is maintained constant.
- The hot wire will be cooled when it comes in contact with moving air; the external voltage is applied to keep temperature constant.
- The bridge voltage is varied to bring the galvanometer reading to zero.
- The reading of volt meter is recorded and co- related with fluid velocity.

Advantages

1) Accurate measurement.
2) It can use for calibration purpose.
3) Micro measurement is possible.
4) It can handle dynamic conditions.

Disadvantages

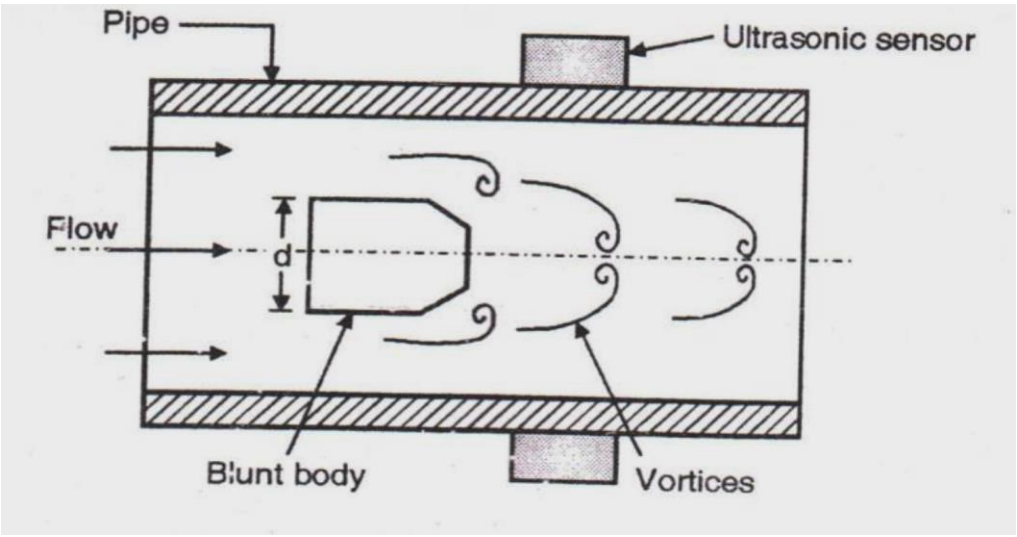
1) Fine wire is required.
2) Wheatstone bridge is required.
3) Primary source needed.

Applications

1) Hot wire anemometer is used for measurement of flow rate of fluctuating and unsteady flow.
2) It can you for research purpose.

- **Explain the working of Vortex Shedding Flow Meter with a neat sketch**

Working Principle: "It is based upon phenomenon vortex shedding which occurs when a gas or liquid flows around a non-stream lined object known as sluff body."



vortex shedding flow meter

Construction and working

- The principle of operation of vertex shedding flow meter is based on a phenomenon known as vertex shedding.
- When a blunt or bluff body or obstacle is placed in a flow path , vortices are formed alternately around and downstream of an object.
- The frequency at which the vortices are formed is directly proportional to the fluid velocity.
- The frequency is called as vortex shedding frequency .
- The frequency can be measured by ultrasonic transducer placed in pipe.

It is given by
$F \alpha (V / D)$
Where
F= Frequency
V=Velocity
D=Diameter

Advantages

1. A wide variety of fluids may be measured
2. It has linearity within + 0.5 % and rangeability up to 200:1 is possible
3. It has no moving parts
4. It is more acceptable in the market
5. Speed of response is good.

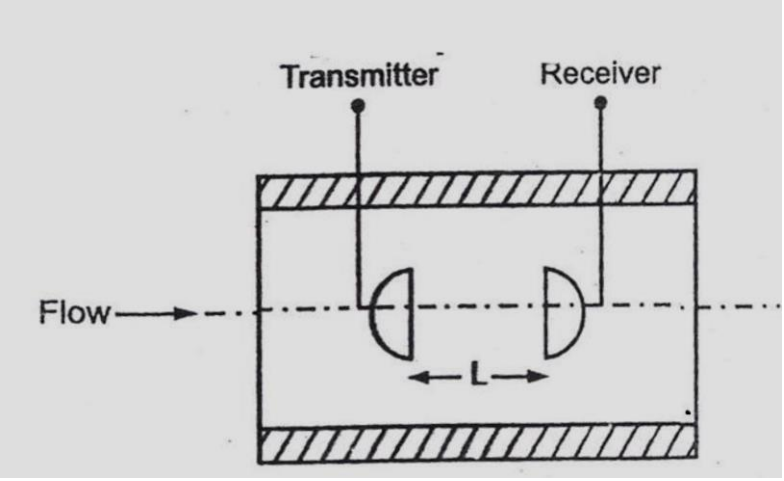
Disadvantages

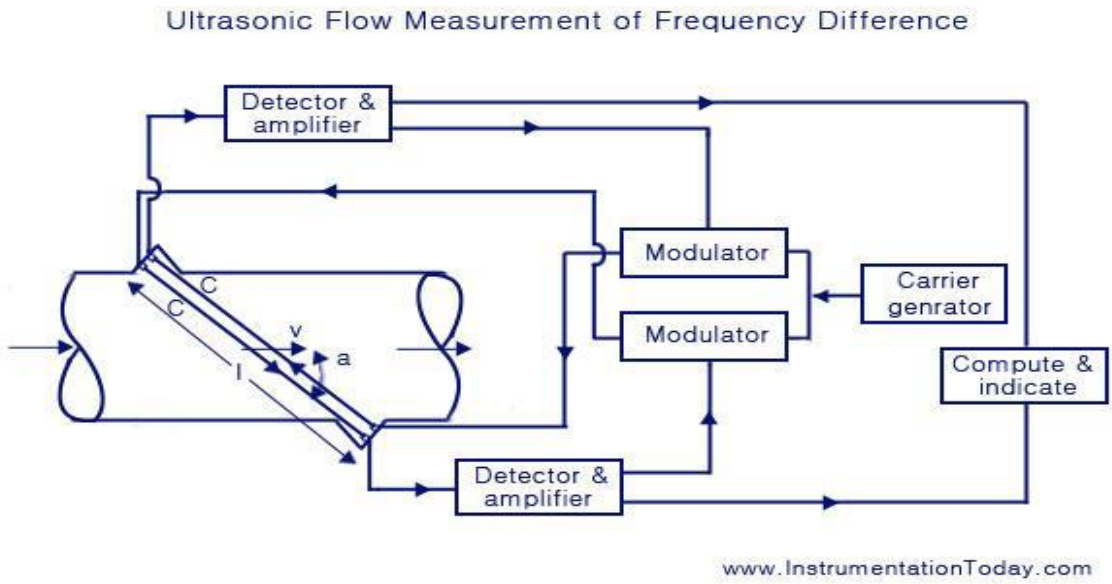
1) High cost
2) Not available over 200mm size.
3) Upper temp limit is 204°C.
4) In-line mounting is required.

Applications

1) It used to measure liquid and gas.

- **Explain the construction and working of Ultrasonic Flow measurement**





Working Principle: "The difference in transmit times of ultrasonic pulses is linearly proportional to flow velocity."

Construction and working

- Ultrasonic flow meters measure the difference of the transit time of ultrasonic pulses propagating in and against flow direction.
- This time difference is a measure for the average velocity of the fluid along the path of the ultrasonic beam.
- By using the absolute transit times both the averaged fluid velocity and the speed of sound can be calculated.
- Using the two transit times and the distance between receiving and transmitting transducers.
- An ultrasonic flow meter is a type of that measures the velocity of a fluid with ultrasonic flow meter to calculate volume flow.
- Using ultrasonic transducers, the flow meter can measure the average velocity along the path of an emitted beam of ultrasound, by averaging the difference in measured transit time between the pulses of ultrasound propagating into and against the direction of the flow or by measuring the frequency shift from the Doppler effect.
- Ultrasonic flow meters are affected by the acoustic properties of the fluid and can be impacted by temperature, density, viscosity and suspended particulates depending on the exact flow meter.

Advantages

1) No moving parts. 2) Excellent dynamic response.
3) No flow obstruction

Disadvantages

1) High cost 2) Complex circuit

Applications

1) For the flowing liquids.

- **Explain the construction and working of Ultrasonic Flow measurement (Doppler Effect)**

Doppler shift flow meters

- Another method in ultrasonic flow metering is the use of the Doppler shift.
- This results from the reflection of an ultrasonic beam on sonically reflective materials, such as solid particles or entrained air bubbles in a flowing fluid, or the turbulence of the fluid itself, if the liquid is clean.
- Doppler flow meters are used for slurries, liquids with bubbles, gases with sound-reflecting particles.

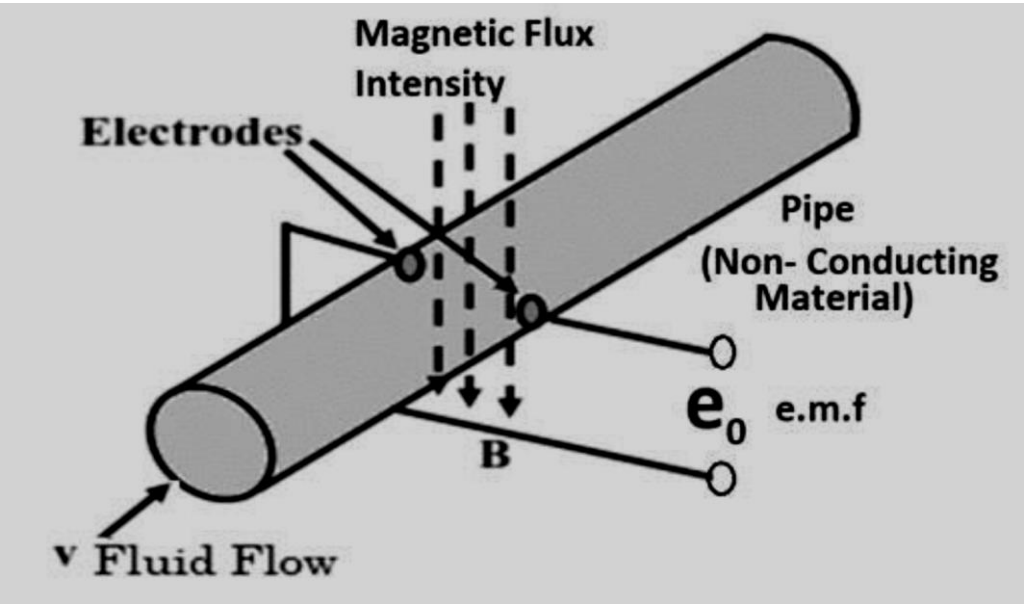
This type of flow meter can also be used to measure the rate of blood flow, by passing an ultrasonic beam through the tissues.

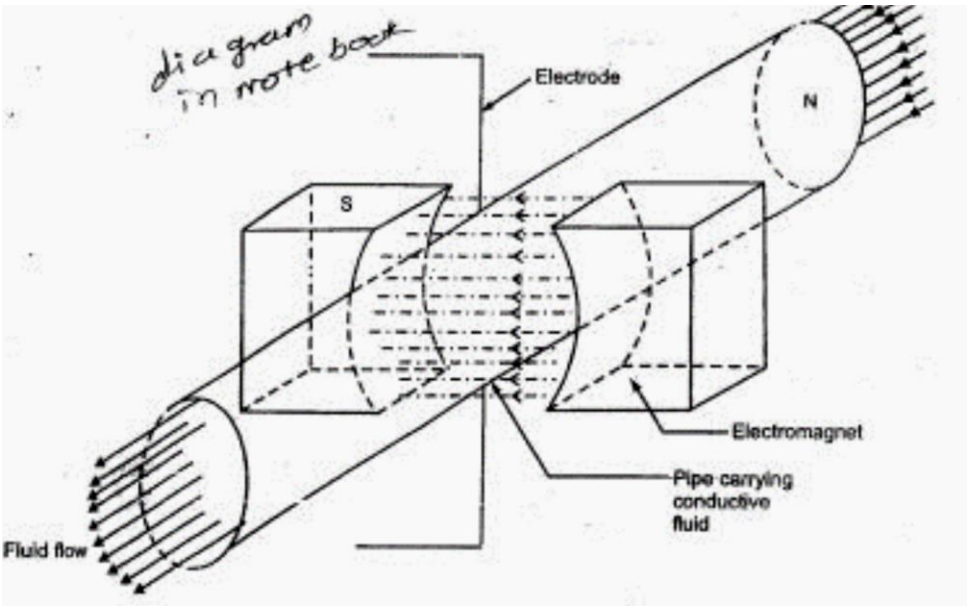
Advantages and Disadvantages are same as above type (Transit type)

- **Explain flow measurement using electromagnetic flow meter with neat sketch.?**

Working Principle:

"Electromagnetic Induction i.e. when a conductor moves along a magnetic field perpendicular to the direction of flow, a voltage would be induced perpendicular to the direction of movement as also to the magnetic field."





 Electromagnetic flow meter is a kind of inductional instrument designed by Faraday‟s law of electromagnetic induction to measure flow of conductive media in the tube.

 Electromagnetic flow meter can realize local indication and output electrical current signal of 4-20mA which can be used to record, adjust and control. The diagram is as shown as follows, V3=V1+V2

Construction

- It consists of a permanent magnet or electromagnet.
- Either alternating current (if the liquid medium is water or any other polarizable liquid) or direct current supplied to a non-conducting pipe.
- Two electrodes placed at right angles to the magnetic field for picking up the induced emf.
- Fluid flow in the pipe which is right angles to plane of magnetic field and induced emf direction.
- The magnet, pipe for conducting liquid and electrodes are mutually perpendicular to each other.

Working

- The flowing liquid acts like a conductor.
- External magnetic field is applied perpendicular to the direction of the flow and two electrodes are flushed on the wall of the pipeline as shown
- Conducting liquids cuts the magnetic flux lines and hence emf is induced in it.
- The expression for the voltage induced is given by:

$$eo = B\,l\,v$$

where,

eo = Induced e. m. f. B = Magnetic Flux Density

l = Length of conductor (diameter of Pipe) v = velocity of conducting fluid

- The e. m. f. induced is picked up by two electrodes.
- This induced e. m. f. is directly proportional to the velocity of fluid as B = Magnetic Flux Density and l = Length of conductor (diameter of Pipe) is constant.
- The e. m. f. induced is calibrated to give the value of fluid flow rate.

Advantages

1) No obstruction is created to flow.
2) Ability to measure reverse flow.
3) No drop-in fluid pressures.
4) Provide wide linear scale.
5) Speed of response is high.
6) It can handle slurries and greasy materials.
7) It can handle corrosive fluids.
8) It has very low pressure drop.

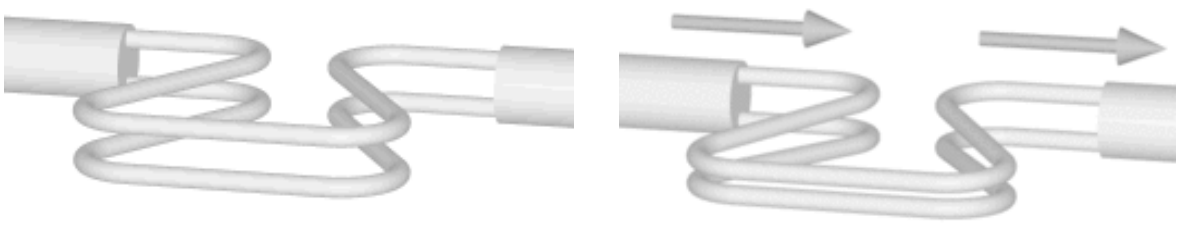
9) It is totally obstruction less. 10) Available in several construction materials.
11) Available in large pipe size and capacities.
12) Measurement unaffected by change in density, pressure, temperature etc.
13) Capable of handling extremely low flow rates or very high flow rates.
14) Voltage o/p is proportional to average velocity and does not depend on whether flow is laminar or turbulent.

Disadvantages

1) Cost high for slurry. 2) Not suitable for low velocities.

Applications
1) Measurement of slurries, sludge and any electrically conducting liquid.

- **Coriolis Flow Meter:**
- Fluid is being pumped through the mass flow meter.
- When there is mass flow, the tube twists slightly.
- The arm through which fluid flows away from the axis of rotation must exert a force on the fluid, to increase its angular momentum, so it bends backwards.
- The arm through which fluid is pushed back to the axis of rotation must exert a force on the fluid to decrease the fluid's angular momentum again, hence that arm will bend forward.
- In other words, the inlet arm (containing an outwards directed flow), is lagging behind the overall rotation, the part which in rest is parallel to the axis is now skewed, and the outlet arm (containing an inwards directed flow) leads the overall rotation.
- The inlet arm and the outlet arm vibrate with the same frequency as the overall vibration,
- but when there is mass flow the two vibrations are out of sync: the inlet arm is behind, the outlet arm is ahead.
- The two vibrations are shifted in phase with respect to each other, and the degree of phase-shift is a measure for the amount of mass that is flowing through the tubes.



- **Oscillating Piston Flow Meter:**

- Oscillating piston meters use a precision-machined chamber containing a cylindrical piston that oscillates as liquid flows.
- The piston's central shaft is constrained to run in a circular groove in the chamber, resulting in an off-center rotating motion as the liquid sequentially enters and exits compartments machined into the underside of the piston.
- Since the volume of the compartments are known, the amount of liquid metered per revolution can be calculated accurately.
- Liquid enters a precision-machined chamber containing an oscillating (rotating) piston.
- The position of the piston divides the chamber into compartments containing an exact volume.
- Liquid pressure drives the piston to oscillate and rotate on its center hub.
- The movements of the hub are sensed through the flowmeter wall by a follower magnet.
- Each revolution of the piston hub is equivalent to a fixed volume of fluid, which is indicated as flow by an indicator/totalizer.
- Close clearances between the piston and the chamber ensure minimum liquid slip for highly accurate and repeatable flow measurement of each volume cycle.

Advantages:

- High accuracy and repeatability.
- Only one moving part to cause wear.
- Can be made of materials to ensure sanitary needs of food and beverage processing.

Disadvantages:

- Can only be used with relatively clean liquids.
- Moving Parts are subjected to wear
- Available in small sizes.