EIPC
NEE-403
Unit-2
Flow measurement

Types of Flow Measurement Technologies

- Variable Area (rotameters)
- Rotating Vane (paddle & turbine)
- Positive Displacement
- Differential Pressure
- Vortex Shedding
- Thermal Dispersion
- Magnetic Magnetic
- Thermal Mass
- Coriolis Mass
- Ultrasonic

Variable Area (Rota Meter) Flow Meter

Electromagnetic Flowmeters

- *Magnetic flowmeters* have been widely used in industry for many years.
- Unlike many other types of flowmeters, they offer true noninvasive measurements.
- They are easy to install and use to the extent that existing pipes in a process can be turned into meters simply by adding external electrodes and suitable magnets.
- They can measure reverse flows and are insensitive to viscosity, density, and flow disturbances.

Electromagnetic flowmeters can rapidly respond to flow changes and they are linear devices for a wide range of measurements.

As in the case of many electric devices, the underlying principle of the electromagnetic flowmeter is Faraday's law of electromagnetic induction.

The induced voltages in an electromagnetic flowmeter are linearly proportional to the mean velocity of liquids or to the volumetric flow rates.

- As is the case in many applications, if the pipe walls are made from nonconducting elements, then the induced voltage is independent of the properties of the fluid.

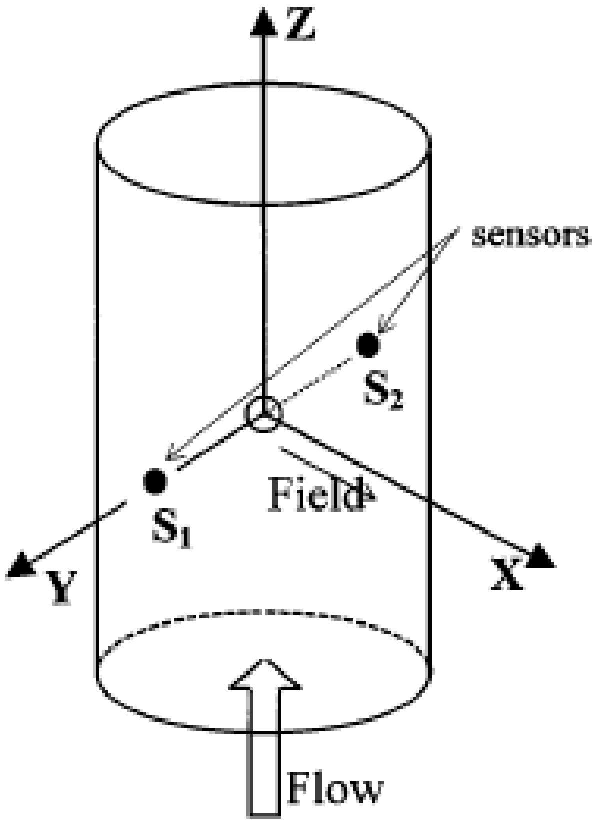
- The accuracy of these meters can be as low as 0.25% and, in most applications, an accuracy of 1% is used.

- At worst, 5% accuracy is obtained in some difficult applications where impurities of liquids and the contact resistances of the electrodes are inferior as in the case of low-purity sodium liquid solutions.

Faraday's Law of Induction

This law states that if a conductor of length *l* (m) is moving with a velocity *v* (m/s^{-1}), perpendicular to a magnetic field of flux density *B* (Tesla), then the induced voltage *e* across the ends of conductor can be expressed by:

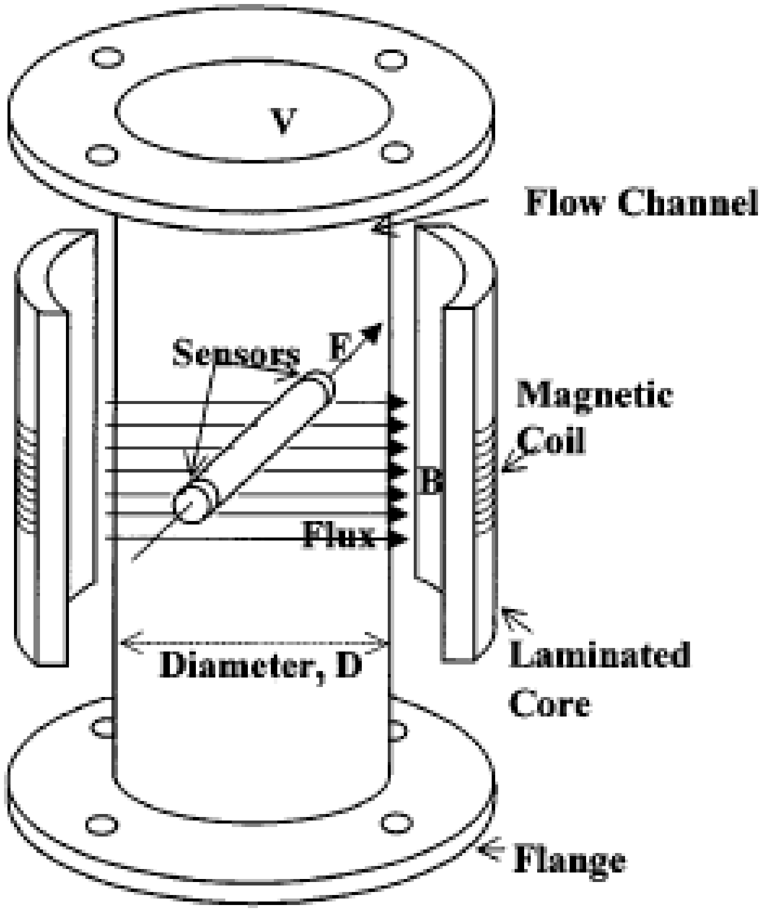
$$e = Blv$$



The velocity of the conductor is proportional to the mean flow velocity of the liquid.

Hence, the induced voltage becomes:

$$e = BDv$$



$$e = BDv$$

$$Q = Av = \frac{\pi}{4} D^2 v$$

$$e = \frac{4BQ}{\pi D}$$

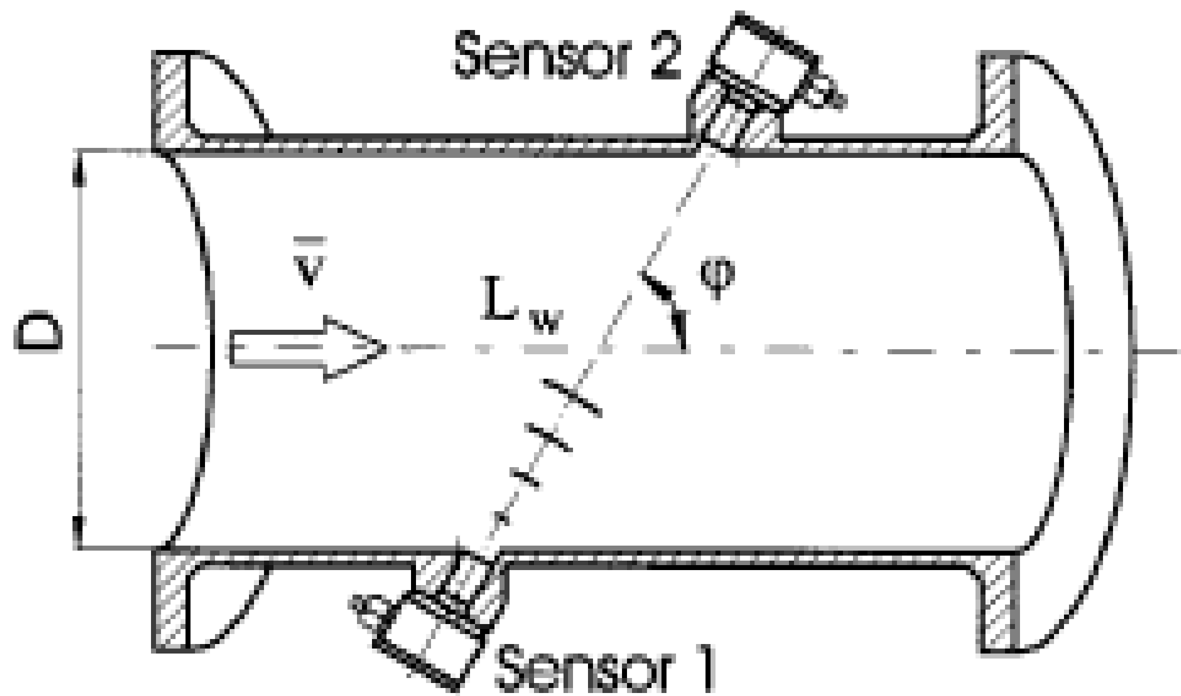
Ultrasonic Flowmeters

- There are various types of ultrasonic flowmeters in use for discharge measurement:
- (1) *Transit time:* This is today's state-of-the-art technology and most widely used type.
- This type of ultrasonic flowmeter makes use of the difference in the time for a sonic pulse to travel a fixed distance.
- First against the flow and then in the direction of flow.
- Transmit time flowmeters are sensitive to suspended solids or air bubbles in the fluid.

(2) *Doppler:* This type is more popular and less expensive, but is not considered as accurate as the transit time flowmeter.

It makes use of the Doppler frequency shift caused by sound reflected or scattered from suspensions in the flow path and is therefore more complementary than competitive to transit time flowmeters.

Principle of transit time flowmeters.



Transit Time Flowmeter

- **Principle of Operation**
- The acoustic method of discharge measurement is based on the fact that the propagation velocity of an acoustic wave and the flow velocity are summed vectorially.
- This type of flowmeter measures the difference in transit times between two ultrasonic pulses transmitted upstream t_{21} and downstream t_{12} across the flow.
- If there are no transverse flow components in the conduit, these two transmit times of acoustic pulses are given by:

$$t_{12} = \frac{L_w}{c + v_a \cos\varphi} \qquad t_{21} = \frac{L_w}{c - v_a \cos\varphi}$$

where L_w = Distance in the fluid between the two transducers

c = Speed of sound at the operating conditions

ϕ = Angle between the axis of the conduit and the acoustic path

$\bar{v}_a$ = Axial low velocity averaged along the distance L_w

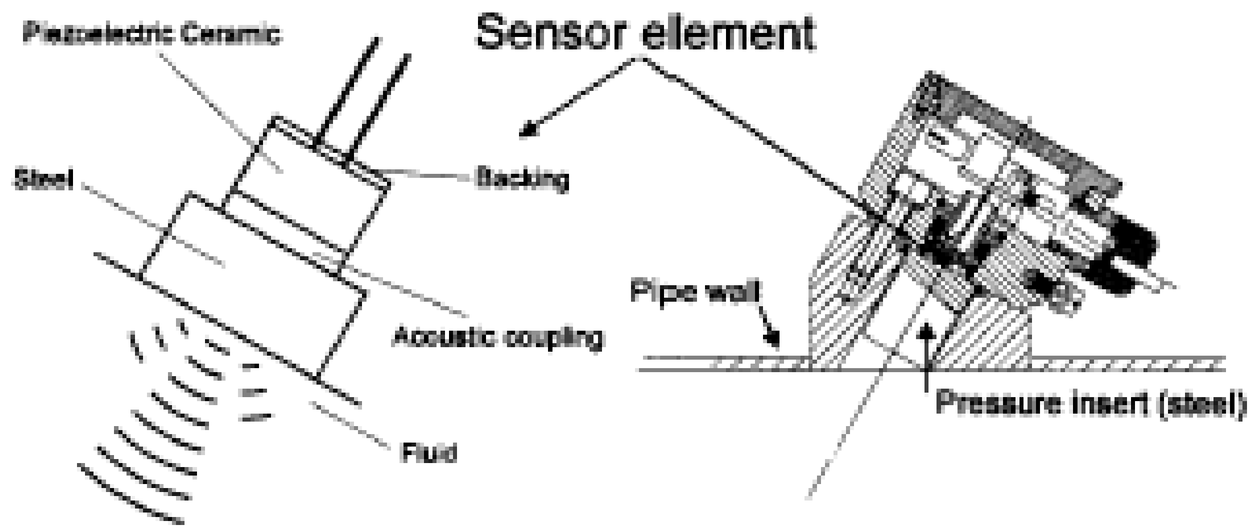
Since the transducers are generally used both as transmitters and receivers, the difference in travel time can be determined with the same pair of transducers. Thus, the mean axial velocity along the path is given by:

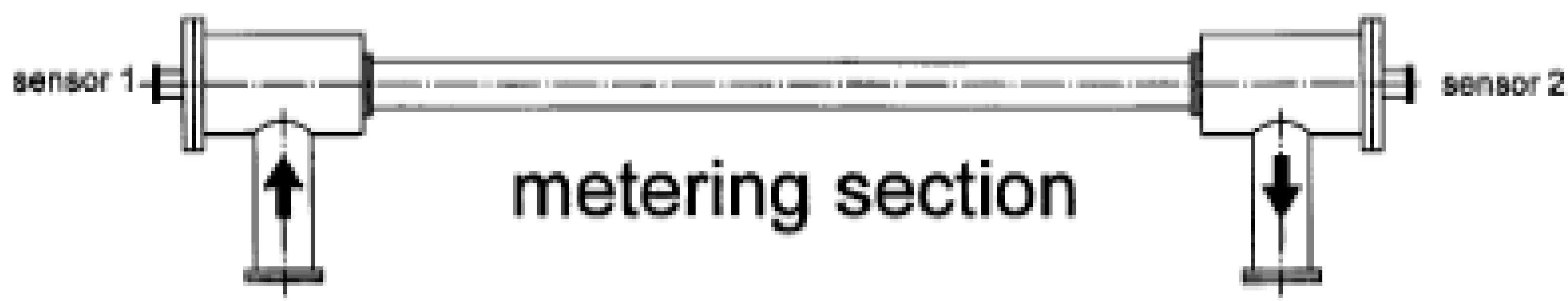
$$\bar{v}_a = \frac{L_w}{2\cos\varphi}\left(\frac{1}{t_{21}} - \frac{1}{t_{12}}\right) = \frac{D}{2\cos\varphi\sin\varphi}\left(\frac{1}{t_{21}} - \frac{1}{t_{12}}\right)$$

Example

- The following example shows the demands on the time measurement technique:
- Assume a closed conduit with diameter D = 150 mm, angle ϕ = 60°, flow velocity = 1 m/s, and water temperature =20°C.
- This results in transmit times of about 116 s and a time difference
- $\Delta t = t_{12} - t_{21}$ on the order of 78 ns.

- To achieve an accuracy of 1% of the corresponding full-scale range, Δt has to be measured with a resolution of at least 100 ps ($1X10^{-10}$s).
- Standard time measurement techniques are not able to meet such requirements so that special techniques must be applied.
- Digital timers with the state-of-the –art Micro computers will make it possible to measure these time difference.


Piezoelectric Ceramic
Sensor element
Steel
Backing
Acoustic coupling
Fluid
Pipe wall
Pressure insert (steel)


sensor 1
sensor 2
metering section

Point Velocity Measurement

- Pitot Probe Anemometry : Potential Flow Theory & Bernoulli's Theory .
- Thermal Anemometry : Newton's Law of Cooling.
- Laser Anemometry: Doppler Theory.

Thank You