FLOW SENSORS

Flow sensors are devices that measure the rate of fluid (liquid or gas) flow in a system.

They are widely used in various industries for process control, safety, and efficiency optimization.

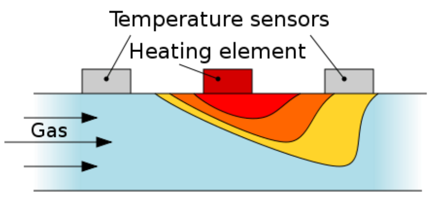
Flow sensors, also known as flow meters, are devices used to measure the rate of flow or quantity of a fluid (liquid or gas) moving through a system. These sensors play a critical role in industries ranging from water treatment and automotive to biomedical, HVAC, and industrial automation.

Flow sensors can measure:

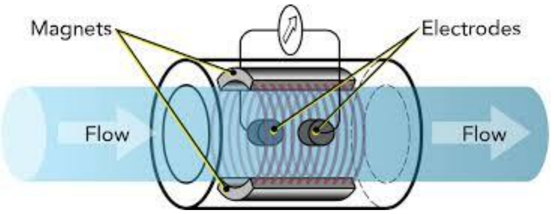
- **Volumetric flow rate (e.g., liters per minute)**
- **Mass flow rate (e.g., kg per hour)**
- **Velocity of flow (e.g., meters per second**

Types of Flow Sensors

1.Thermal Flow Sensors

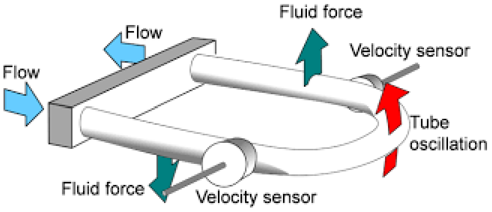


2. Electromagnetic Flow Sensors



3. Ultrasonic Flow Sensors

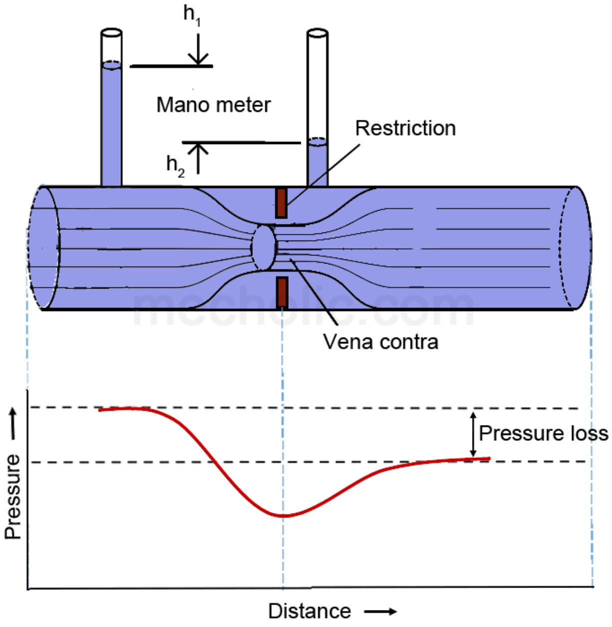
4. Mass Flow Sensors



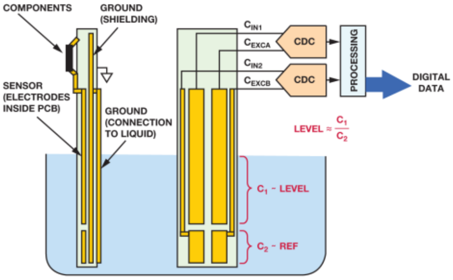
FLOW SENSORS

5. Turbine Flow Sensors

7. Differential Pressure Flow Sensors



6. Capacitive Flow Sensors



Working Principle

The working principle of a flow sensor depends on its design and technology. Generally, it detects movement or changes in pressure, temperature, or velocity of a fluid, and converts that into an electrical signal proportional to the flow.

For example:

•In mechanical flow sensors, a rotor or turbine moves with the fluid, and the rate of rotation corresponds to flow.

•In thermal flow sensors, heat dissipation is used to estimate flow velocity.

Applications

•It is used for monitoring and checking flows in HVAC systems, and exhaust systems.

•It measures the instantaneous velocity of the fluid.

•It is also part of the automotive industry for monitoring air use of engine

•It also measures airflow, humidity, and temperature on electronic components.

•In the pharmaceutical industry, used for monitoring airflow in biosafety cabins, chemical fume, and laminar flow hoods

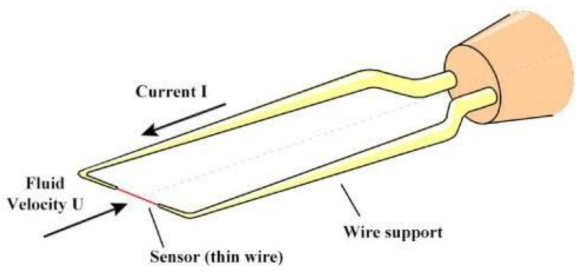
FLOW SENSORS

Hot Wire Anemometer

Definition:
The Hot Wire Anemometer is a device used for measuring
i) the velocity of the fluid
ii) 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.



Working Principle

A thin wire (typically platinum or tungsten) is electrically heated to a constant temperature.

When air or gas flows over the wire:

✅ **Higher airflow → More cooling → Resistance decreases**

✅ **Lower airflow → Less cooling → Resistance increases**

By measuring the change in resistance or electrical current, the velocity of the air can be determined.

- ❑ **It operates based on the principle of heat loss due to convection from a heated wire exposed to a flowing fluid.**
- ❑ **This type of anemometer is extremely sensitive and capable of detecting even very low air velocities, making it an essential tool in aerodynamics, turbulence studies, and experimental fluid mechanics**

FLOW SENSORS

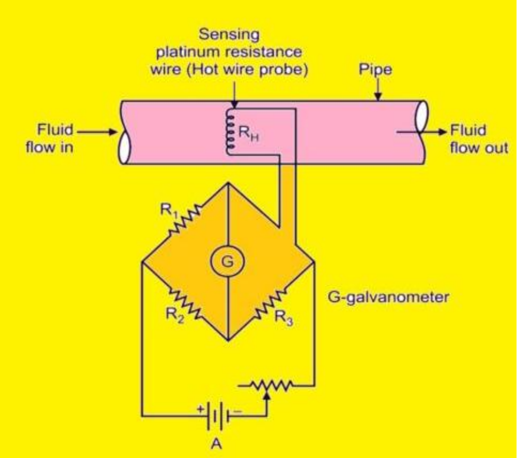
Hot Wire Anemometer

Construction of Hot Wire Anemometer

The hot wire anemometer consists two main parts.

1.Conducting wire

2. Wheat stone bridge.



The heater wire is housed inside the Ceramic tube

The wires are taken out from ceramic tube and connected to the Wheatstone bridge circuit

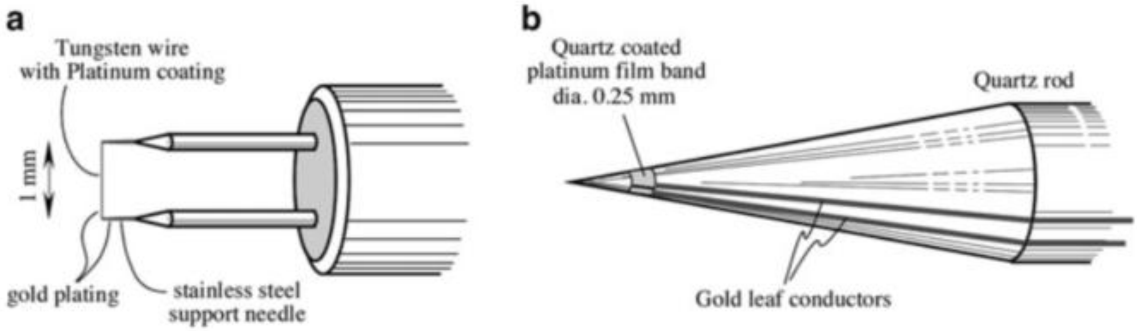


Fig. 11.6 Hot-wire probe (**a**) and a conical hot-film probe (**b**)

Types of Hot Wire Anemometers:

Constant Current Anemometer (CCA)

Uses a fixed current, and voltage changes with airflow.

Constant Temperature Anemometer (CTA)

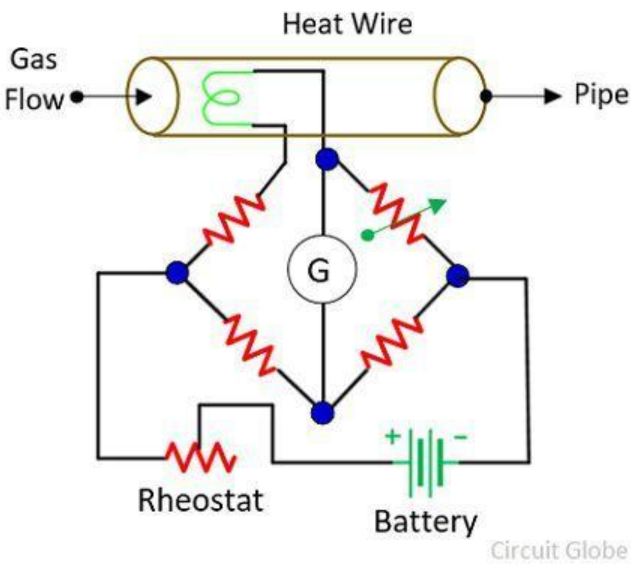
Keeps the wire at a fixed temperature, and the required current is measured.

Based on the type of Wires used

1. **Single-wire (1D):** Measures velocity in one direction
2. **X-wire (2D):** Two wires at an angle to measure flow components in two dimensions.
3. **Triple-wire (3D):** Three wires for full 3D velocity vector analysis

FLOW SENSORS

1) 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.
- ❑ Wheatstone bridge measures the variation in resistance which is equal to the flow rate of the liquid.

Key Characteristics:

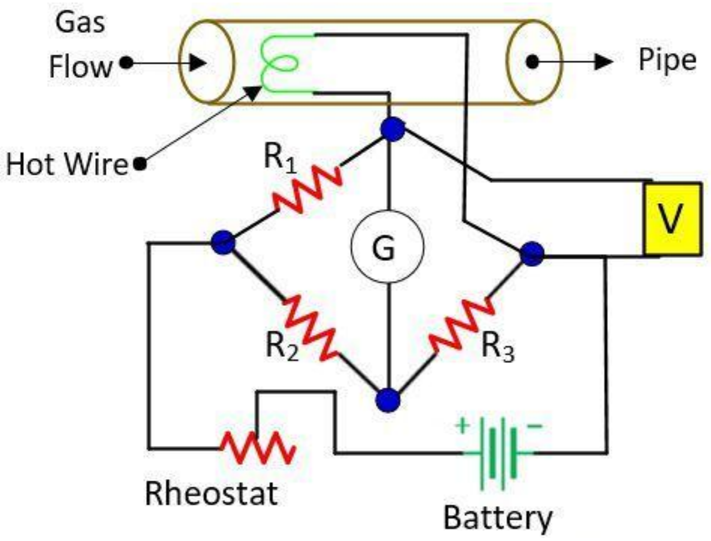
- ❑ Simple circuit design
- ❑ Slower response time compared to CTA
- ❑ Good for low-speed flow measurements
- ❑ Less expensive, suitable for educational and basic industrial uses

What You Measure?

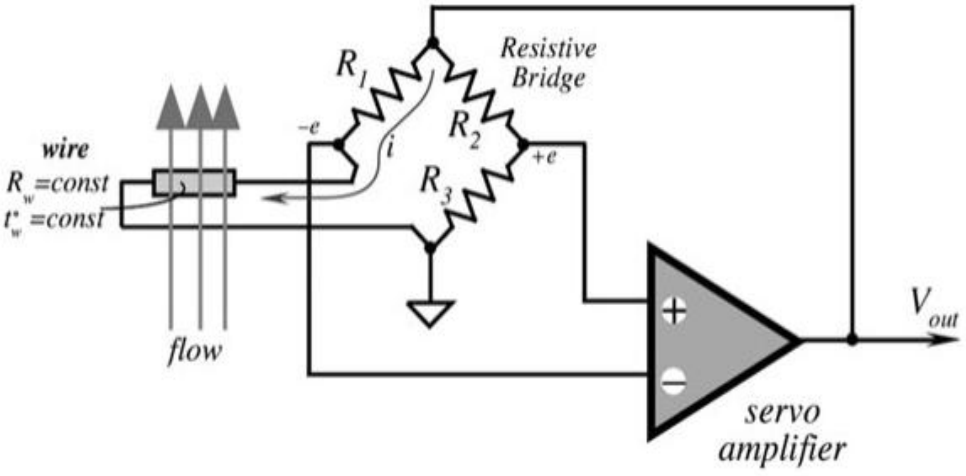
Change in voltage due to resistance change

FLOW SENSORS

2) 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.



- The wire is heated and kept at a constant elevated temperature using a feedback control circuit.
- As air flows and cools the wire, the control circuit increases current to maintain the same temperature (and resistance).
- The amount of current required to maintain this temperature is directly related to the airflow velocity.

FLOW SENSORS

Hot Wire Anemometer

Under a steady flow rate,

the electric power Q_e supplied to the wire is balanced by the out-flowing thermal power Q_T carried by the flowing media due to a convective heat transfer.

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

Heat Generated = Heat Loss

$$Q_e = Q_T$$

Considering
the heating current i,
the wire temperature t_w,
temperature of the fluid t_f,
the wire surface area Aw,
and the heat transfer coefficient h,

$$I^2R_w = hA_w(t_w - t_f)$$

$$h = a + bv_f^c,$$

This equation is known as King's law
heat transfer coefficient h,
- **a, b= Empirical constants (depends on wire material & setup)**
- **V = Flow velocity (m/s)**
- **c = Constant (typically between 0.4 and 0.5 for turbulent flow)**

$$a + bv_f^c = \frac{i^2R_w}{A_w\left(t_w - t_f\right)}.$$

Considering that $V_{out} = i(R_w + R_l)$,
Solving this equation for the output voltage as function of the fluid velocity:

$$V_{out} = (R_w + R_l)\sqrt{\frac{A_w(a + b\sqrt{v})(t_w - t_f)}{R_w}}.$$

FLOW SENSORS

Hot Wire Anemometer

1) Constant Current Method	2) Constant Temperature Method
Change in voltage due to resistance change	Current (or power) needed to maintain wire temperature
Key Characteristics:	**Key Characteristics:**
❑ Simple circuit design ❑ Slower response time compared to CTA ❑ Good for low-speed flow measurements ❑ Less expensive, suitable for basic industrial uses	❑ Very fast response time ❑ Highly sensitive, especially for turbulent or rapidly changing flows ❑ More complex and expensive, often used in research and wind tunnel testing ❑ More stable operation, even in fluctuating environmental conditions

Advantages

- It was used due to low cost and accurate results.
- It is sensitive.
- The spatial resolution of the hot wire anemometer is good.
- It has a high-frequency response higher than 10 kHz.
- It operates on high temperature.

Disadvantages

- It is fragile and used in clean glass fluids.
- Its turbulence intensity is high.
- Probes of instruments can break.
- It has heat transfer problems between the probe and the surface.
- It also faces pointer deflection problems due to changes in atmospheric temperature.