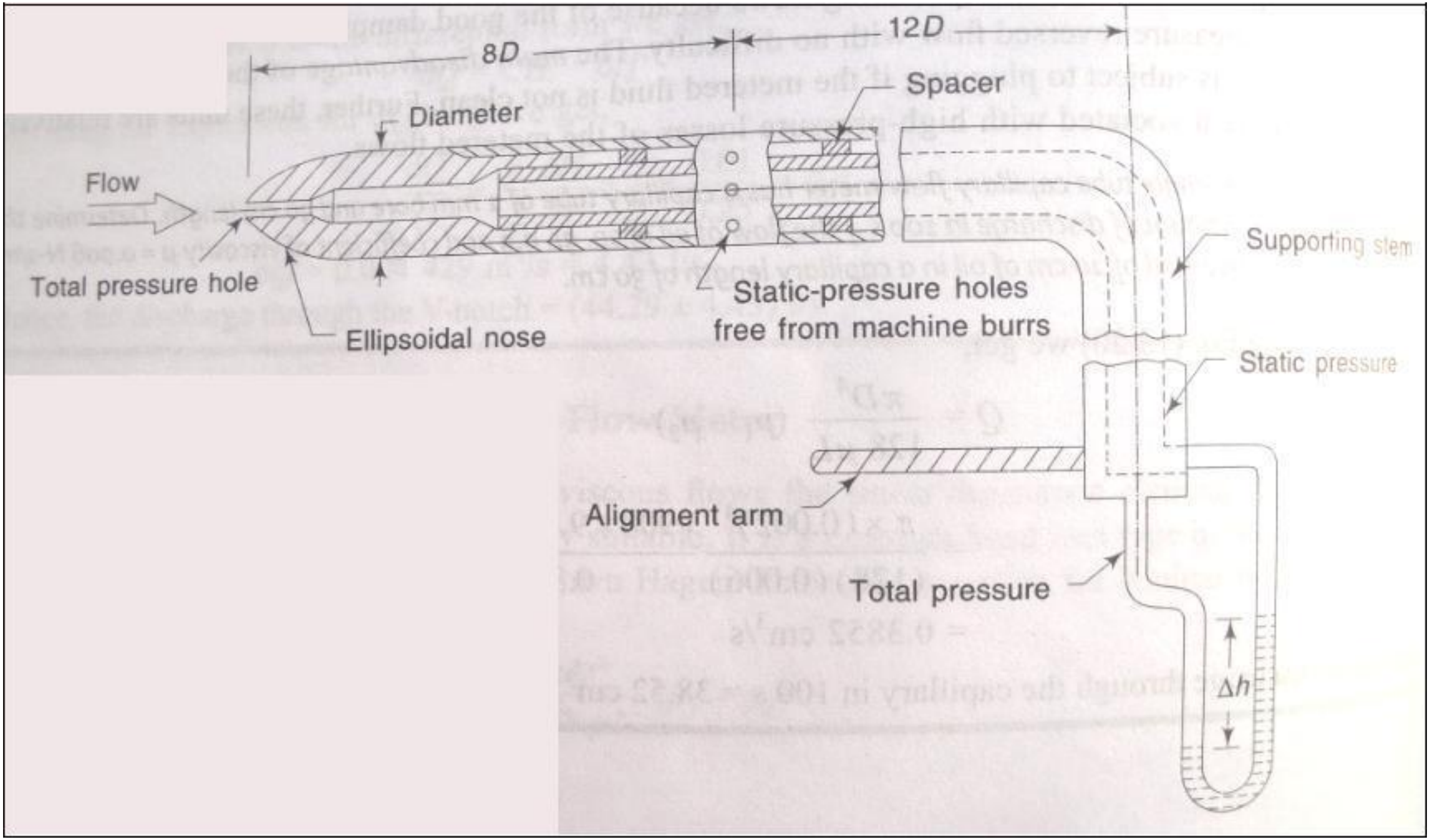
Pitot-Static Tube Meter



Assuming a steady, one-dimensional flow of an incompressible, frictionless fluid, we can derive the expression for free stream velocity by applying Bernoulli's equation between a point in the free stream and another point at the tip of the stagnation tube. Thus

$$\frac{p_{stat}}{\rho} + \frac{V^2}{2} = \frac{p_{stag}}{\rho}$$

which gives

$$V = \sqrt{\frac{2(p_{stag} - p_{stat})}{\rho}}$$

where V is the flow velocity
ρ is the density of the fluid
p_{stag} is the stagnation or total pressure of the free stream given by the stagnation tube
p_{stat} is the free stream static pressure given by static tube.

The pitot tube has the following advantages:

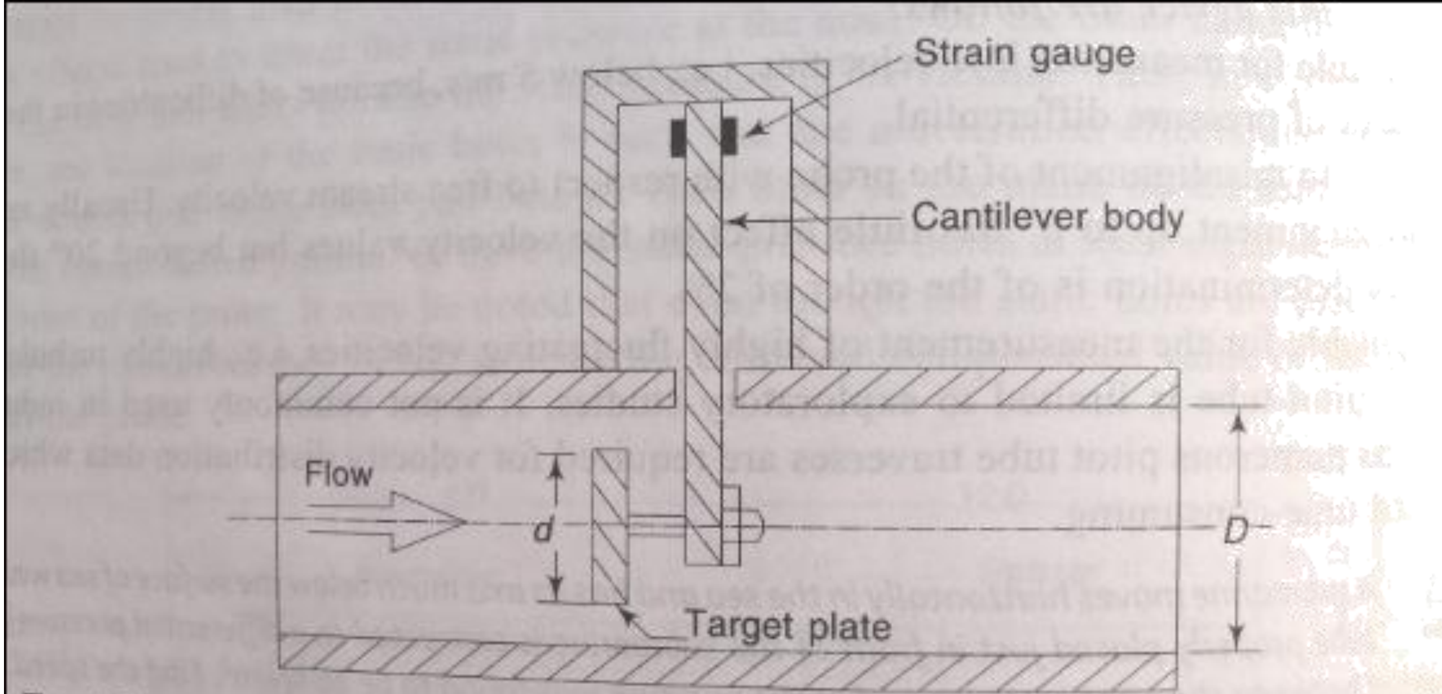
1. It is a simple and low-cost device,
2. It produces no appreciable pressure loss in the flow system,
3. It can be easily inserted through a small hole into the pipe or duct, and
4. It is very useful for checking the mean velocities of the flows in venturi, nozzle, orifice plate or any other complex flow field.

Target or Drag Force Flow Meter

- The drag force F_d acting on body immersed in a flowing fluid becomes measure of flow rate, which is given by following equation.

$$F_d = \frac{1}{2} C_d \rho g V^2 A$$

where C_d is the coefficient of drag
A is area of cross-section (in m^2)
ρ is the fluid density (in kg/m^3)
V is the fluid velocity (in m/s).



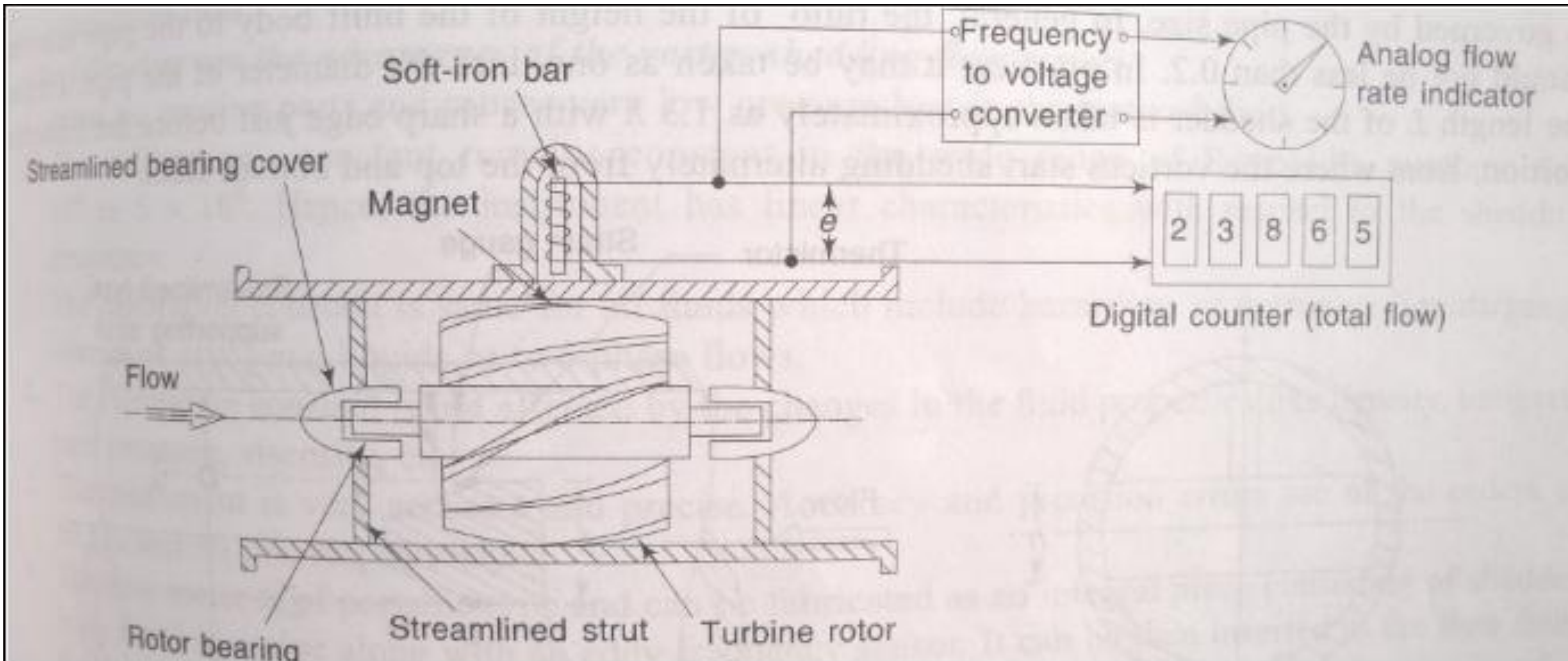
Target flow meter

- Good dynamic response
- Accuracy is ± 0.5%
- Common examples of flows are highly viscous flows of hot asphalt, tar, oils or slurries at high pressures of the order of 100 bars.

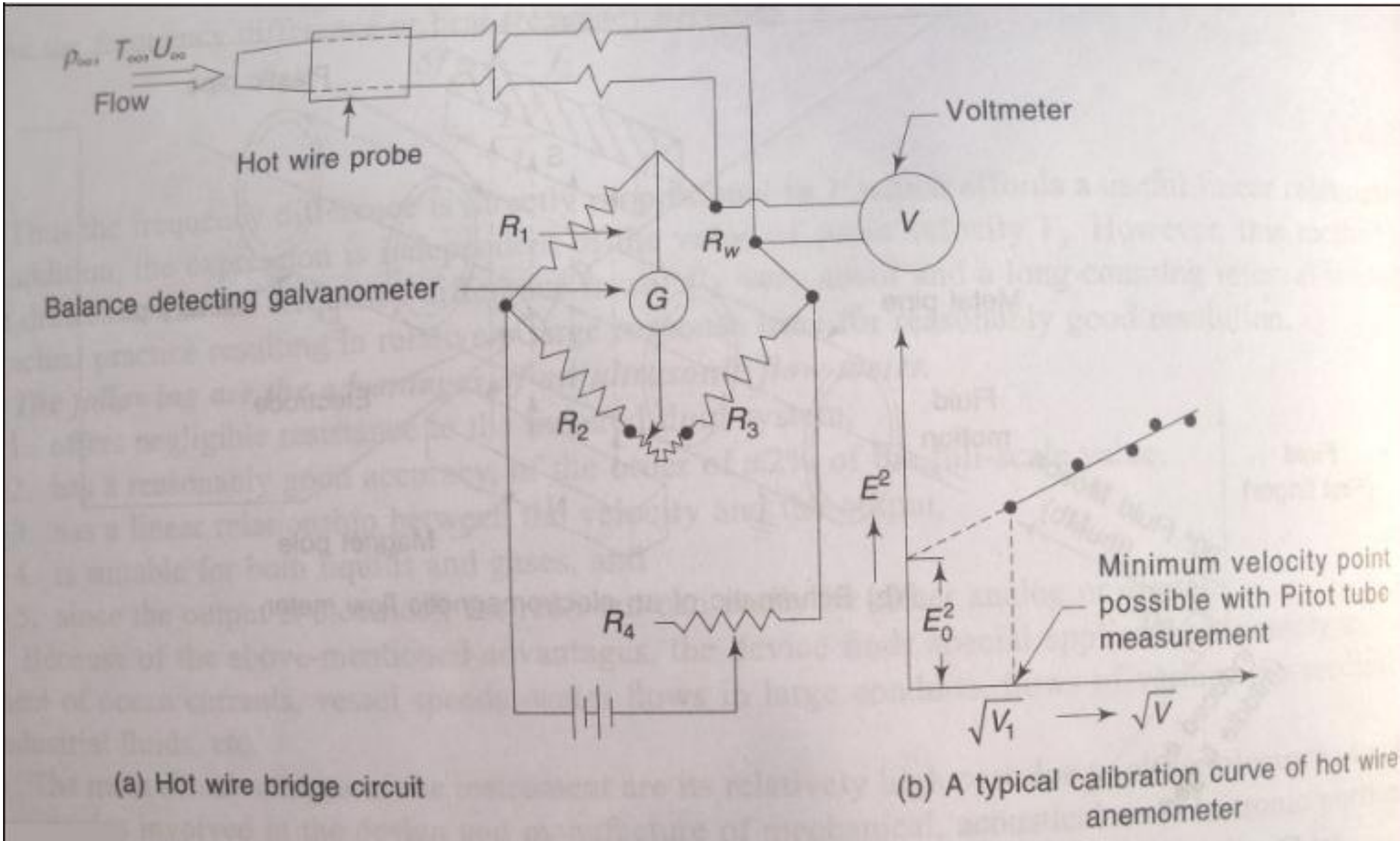
Turbine Flow Meter

- If the frictional torque is small, then the number of turns of the rotor per unit time gives a measure of the volumetric rate of flow over a wide range of flow rates.
- Q = k n where Q is the volume flow rate, n is rotor angular velocity (rad/s) and

  k is constant of flow meter.
- Range is 0.5 to 150000 Lit/min for liquids & 5 to 100000 Lit/min for air.
- Accuracy $\pm$ 1 %



Hot-Wire Anemometer



Schematic diagram of hot wire operation

Hot-Wire Anemometer

- Wire material – platinum, nickel, tungsten or platinum-rhodium. Advantages:
- Electrical output
- Excellent dynamic characteristics with time constant of the order of 10^{-4} to 10^{-6} s.
- Excellent accuracy $\pm$ 0.1 %
- Range from very slow velocity to supersonic velocity.
- Low pressure loss.
- Suitable for both gases and liquids. Hot film probe is used for liquids. Disadvantages:
- Doesn’t sense direction of flow
- Dirt/dust changes its sensitivity
- Wire is very fragile, can break easily with dirt.
- Expensive circuitry and need skilled operations.

The basic governing equation of the hot wire operation is based on the well-known King's law for the convective heat transfer from the heated wire, which is

$$\frac{hD}{k} = 0.30 + 0.5\left(\frac{\rho VD}{\mu}\right)^{1/2} \tag{13.38}$$

for $\dfrac{\rho VD}{\mu} > 10^2$

where h is convective film coefficient of heat transfer
k is the thermal conductivity of the hot wire
ρ is the density of the fluid.
V is the velocity of the fluid stream
μ is the coefficient of viscosity of the fluid
D is the diameter of the hot wire.

Since the flow properties and material parameters like diameter and k are fixed for a particular wire being used, therefore, we can simplify Eq. (13.38) as follows:

$$h = c_1 + c_2\sqrt{V} \tag{13.39}$$

For equilibrium condition in a hot wire, the electrical energy input is equal to the convective heat transfer in the flow. Therefore, writing the energy balance equation we get,

$$I^2R_w = K_c hA\,[T_w - T_f] \tag{14.40}$$

where I is the current flowing in the hot wire

R_w the resistance of the wire

K_c the conversion factor from electrical to thermal power

A the heat transfer area

T_w the hot wire temperature

T_f the temperature of flowing fluid

Substituting the value of h from Eq. (13.39) in (13.40) and simplifying we get,

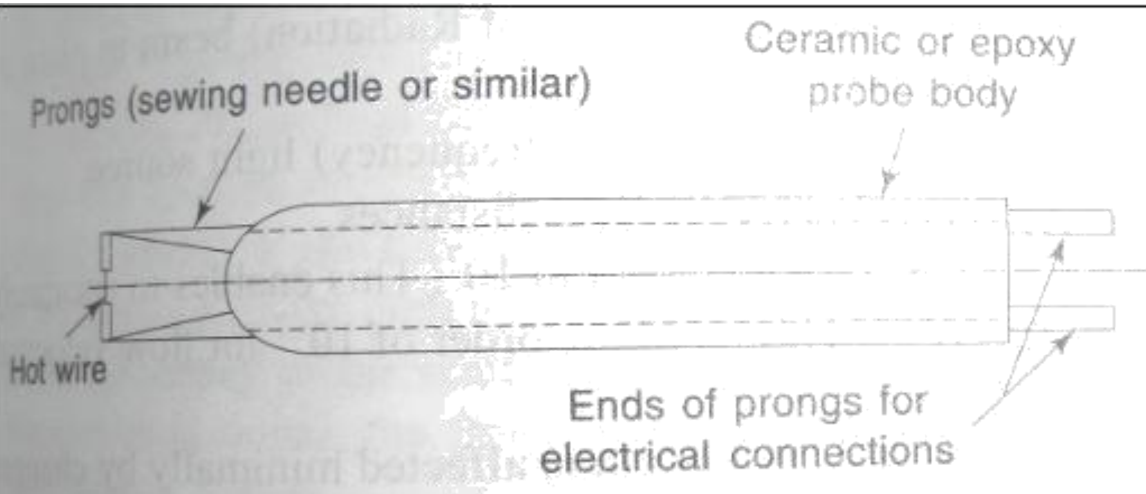
$$I^2R_w = K_c A\,(T_w - T_f)\,(C_1 + C_2\sqrt{V}) \tag{13.41}$$

The change in resistance from temperature of fluid T_f to hot wire temperature T_w is directly proportional to the temperature difference for the platinum–tungsten material. Therefore,

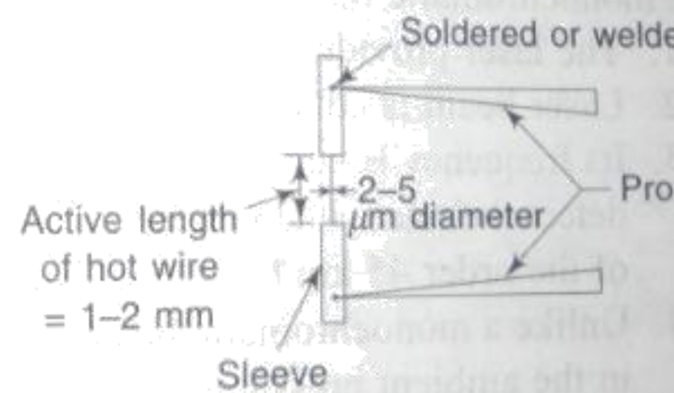
$$R_w - R_f = C_3\,(T_w - T_f) \tag{13.42}$$

Equation (13.42) now becomes

$$\frac{I^2 R_w C_3}{K_c A(R_w - R_f)} = C_1 + C_2\sqrt{V} \tag{13.43}$$



(a) A typical hot wire probe



(b) Constructional details of the wire of the probe