Streamflow Measurement

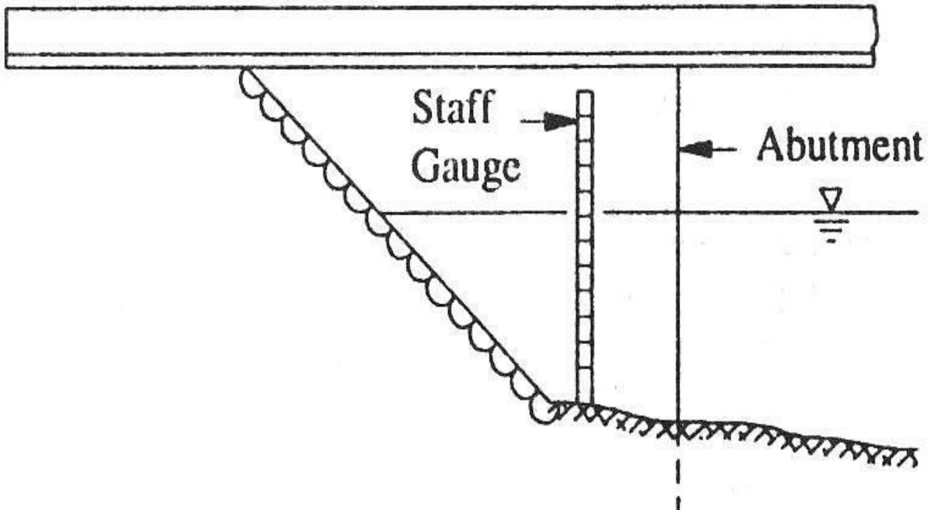
Streamflow measurement techniques can be broadly classified into two categories as (i) direct determination and (ii) indirect determination.

1. Direct determination of stream discharge:
   (a) Area-velocity methods,
   (b) dilution techniques,
   (c) electromagnetic method, and
   (d) ultrasonic method.

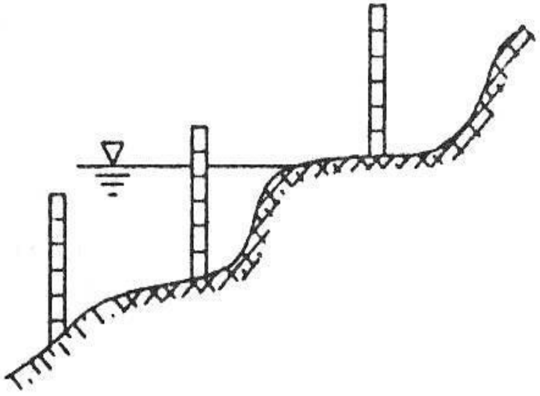
2. Indirect determination of stream flow:
   (a) Hydraulic structures, such as weirs, flumes and gated structures and
   (b) Slope area method

Measurement of Stage

(a) Staff Gauge



(a) Vertical Staff Gauge



(b) Sectional Staff gauge

Fig. 4.1 Staff gauge

(b) Wire Gauge

(c) Automatic Stage Recorders

Two typical automatic recorders are below

(i) Float-Gauge Recorder

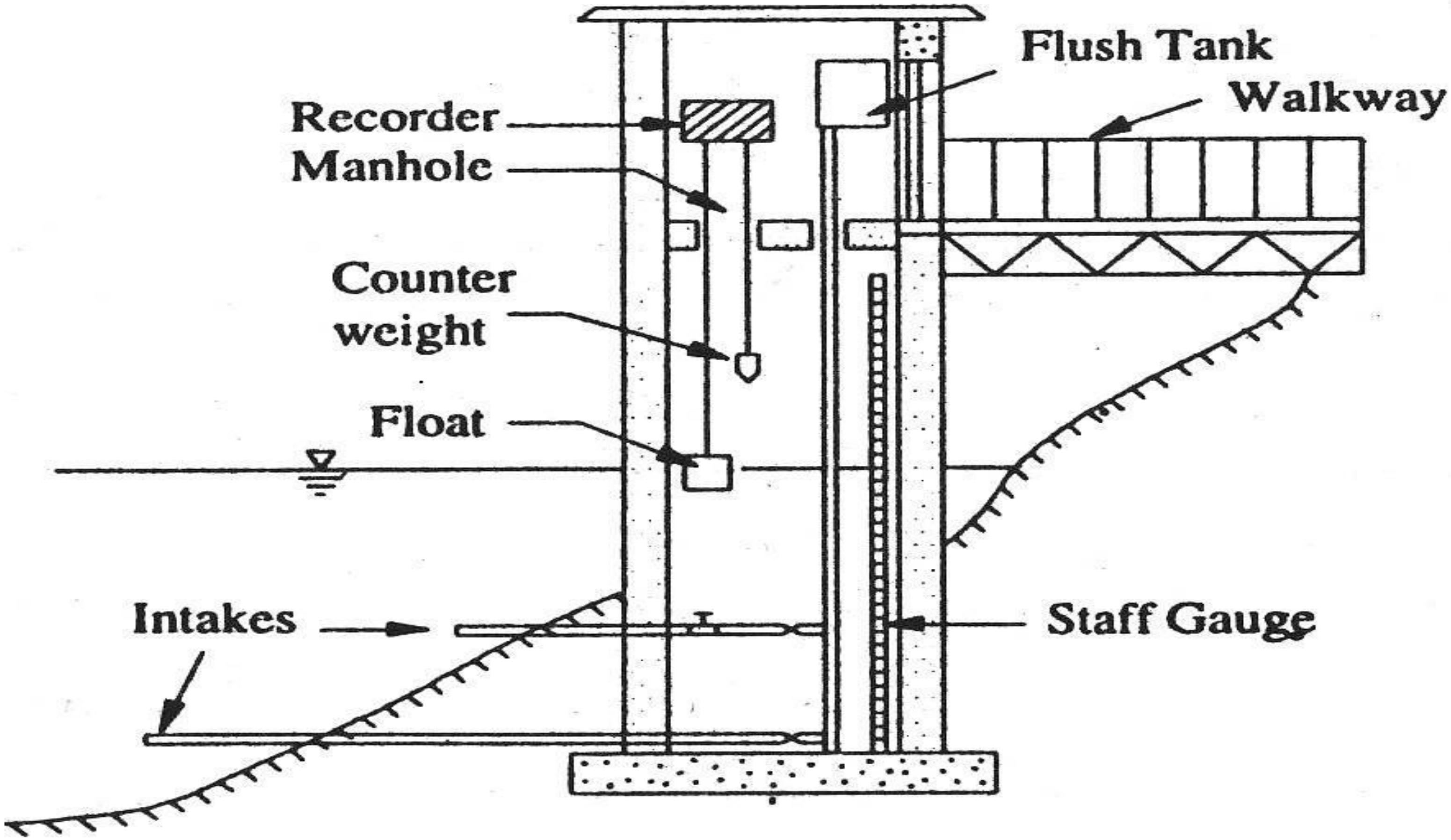


Fig. 4.2 Stilling well installation

(ii) Bubble Gauge

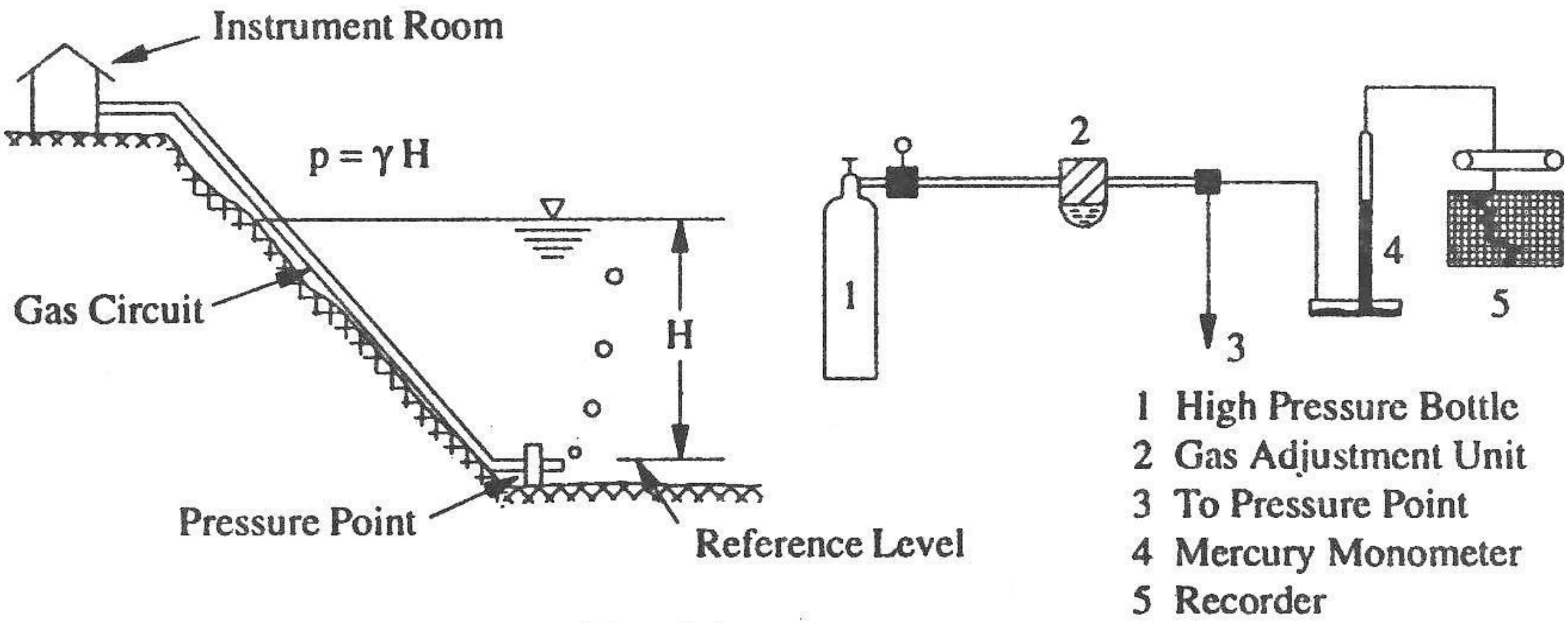


Fig. 4.4 Bubble guage

The bubble gauge has certain specific advantages over a float operated water stage recorder and these can be listed as under:

1. There is no need for costly stilling wells;
2. a large change in the stage, as much as 30 m, can be measured;
3. the recorder assembly can be quite far away from the sensing point; and
4. due to constant bleeding action there is less likelihood of the inlet getting blocked or choked.

Measurement of Velocity

The measurement of velocity is an important aspect of many direct stream flow measurement techniques. A mechanical device, called current meter.

Current Meters

There are two main types of current meter

1. Vertical – axis meters, and
2. Horizontal – axis meters

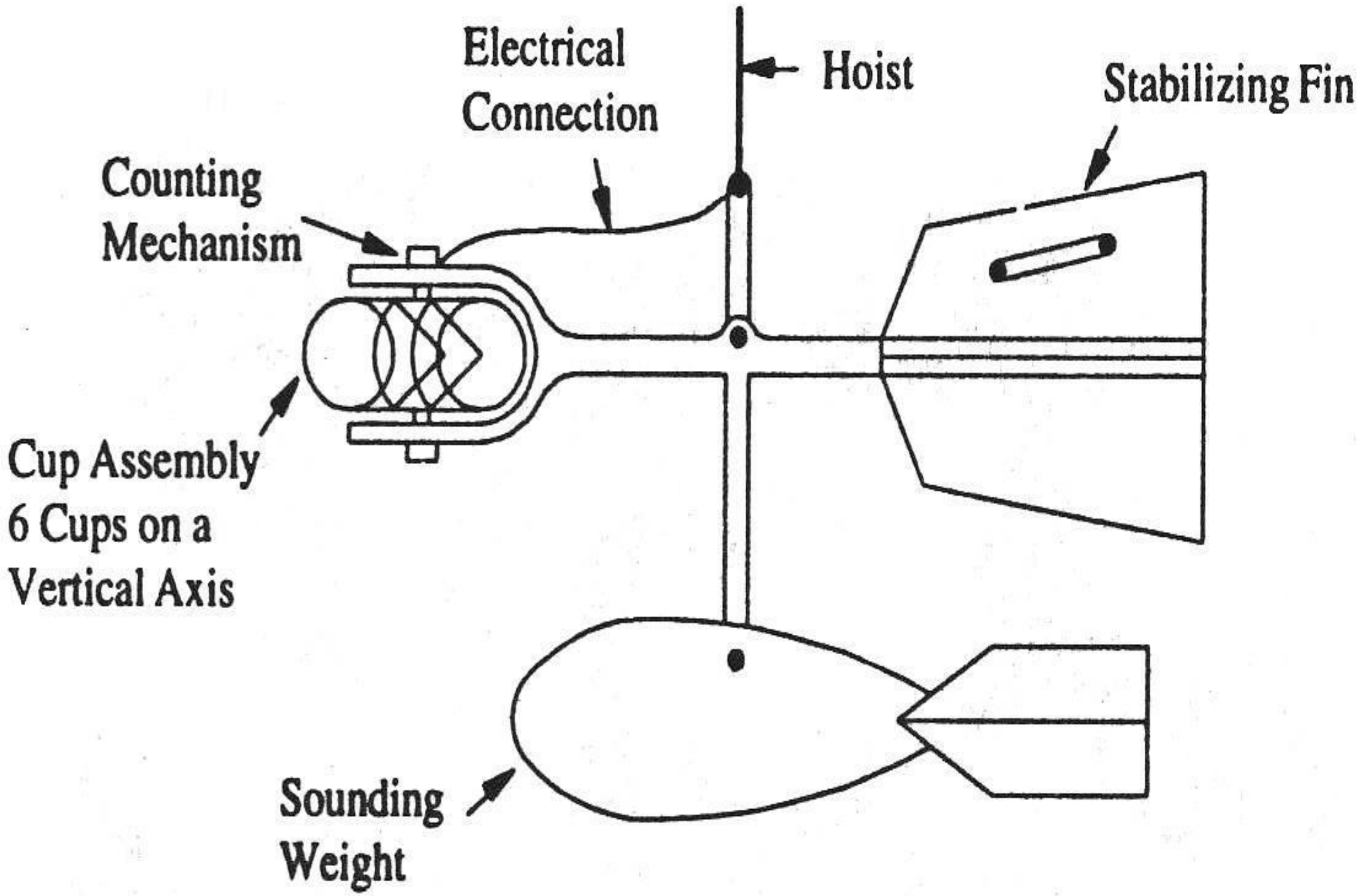


Fig. 4.8 Vertical-axis current meter

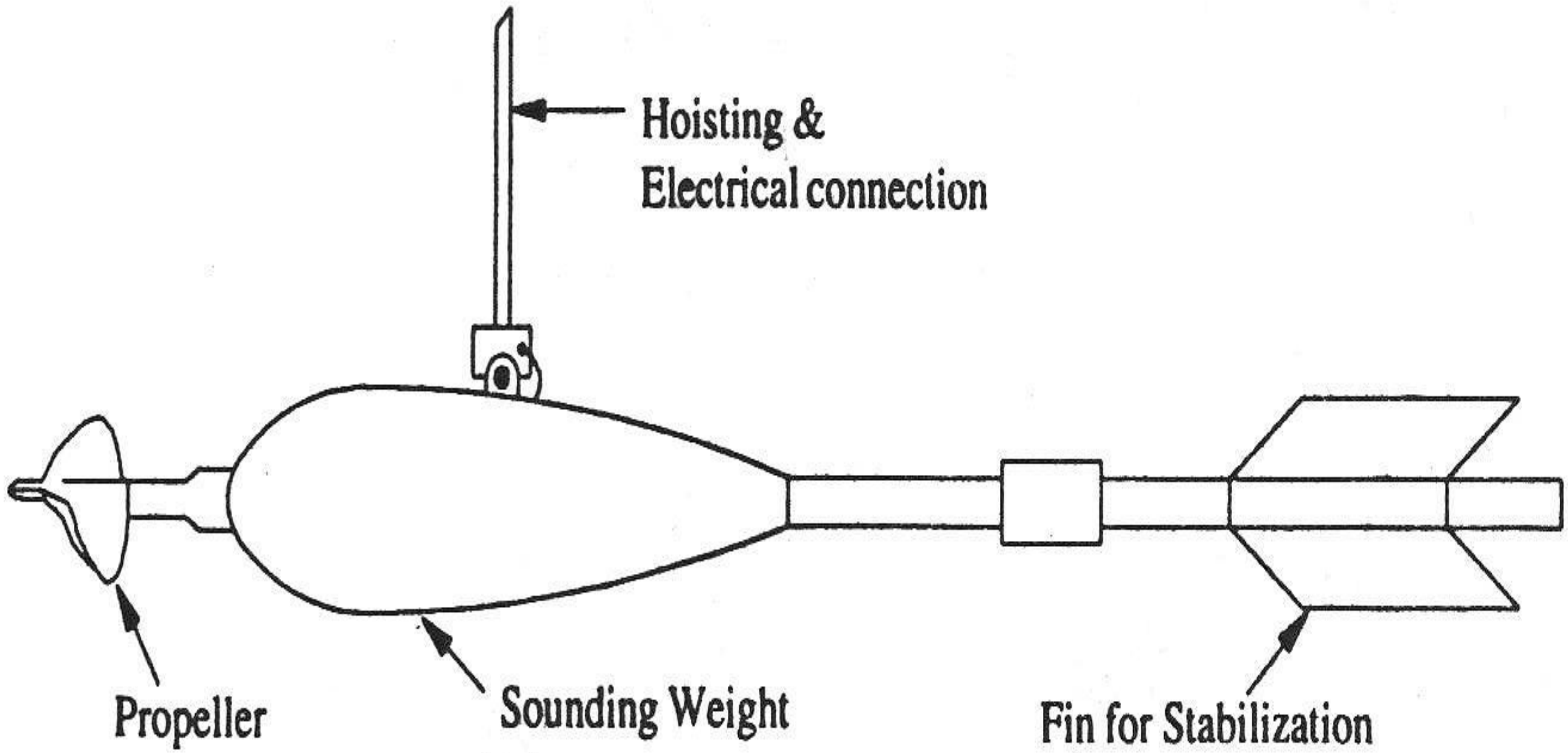


Fig. 4.11 Horizontal-axis current meter

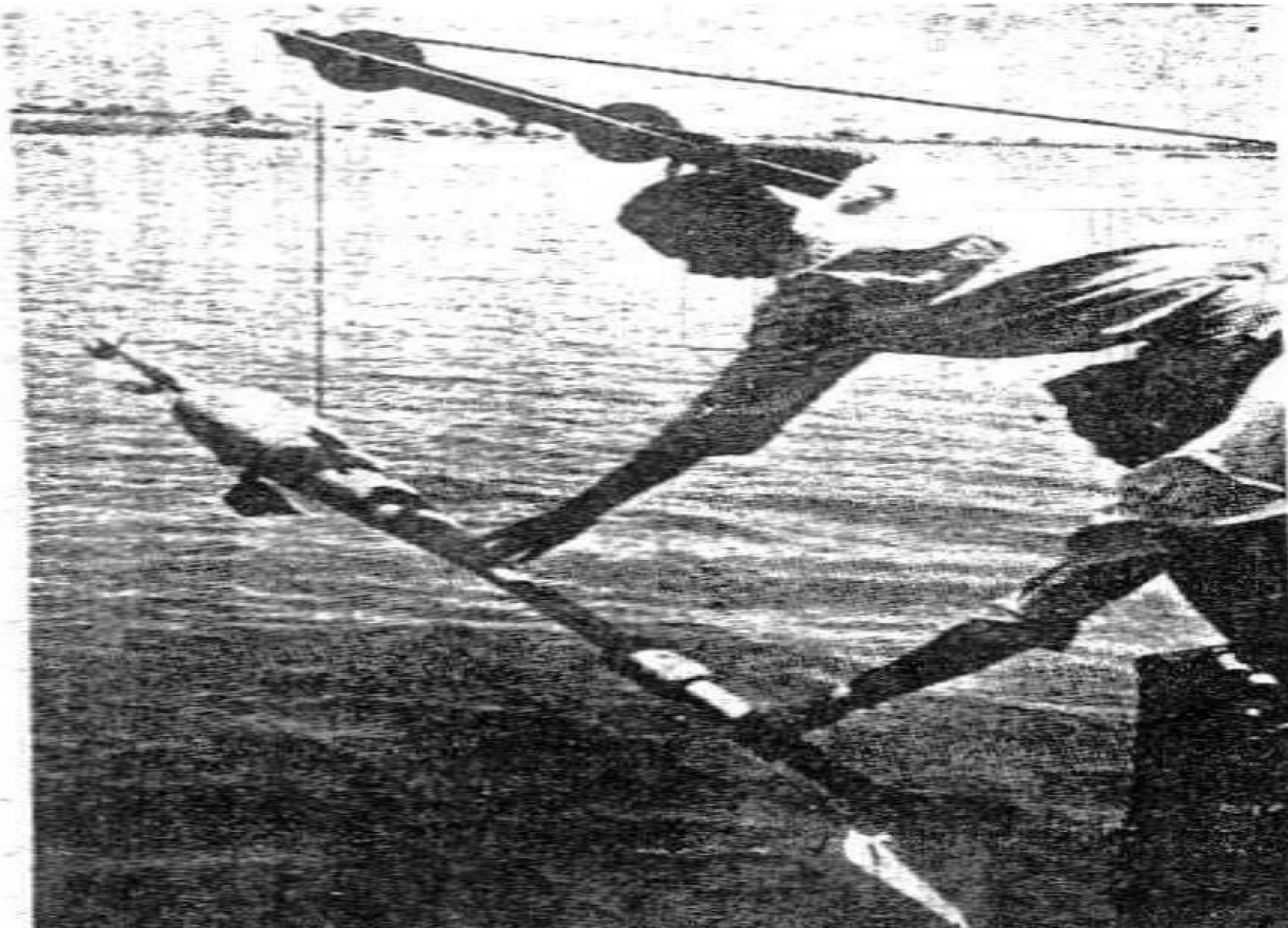


Fig. 4.10 Propeller-type current meter — Neyrtec type with sounding weight

A current meter is so designed that its rotation speed varies linearly with the stream velocity v at the location of the instrument. A typical relationship is

$$V = a\,N_s + b$$

Where v = stream velocity at the instrument location in m/s

Ns = revolutions per second of the meter and

a, b = constants of the meter

Sounding Weights

Current meter are weighted down by lead weights called sounding weights

$$W = 50\,v\,d$$

Where w = minimum weight in N

v = average stream velocity in the vertical in m/s

d = depth of flow at the vertical in m

Velocity Measurement by Floats

A floating object on the surface of a stream when timed can yield the surface velocity by the relation

$$v_s = \frac{S}{t}$$

Where S = distance travelled in time t.

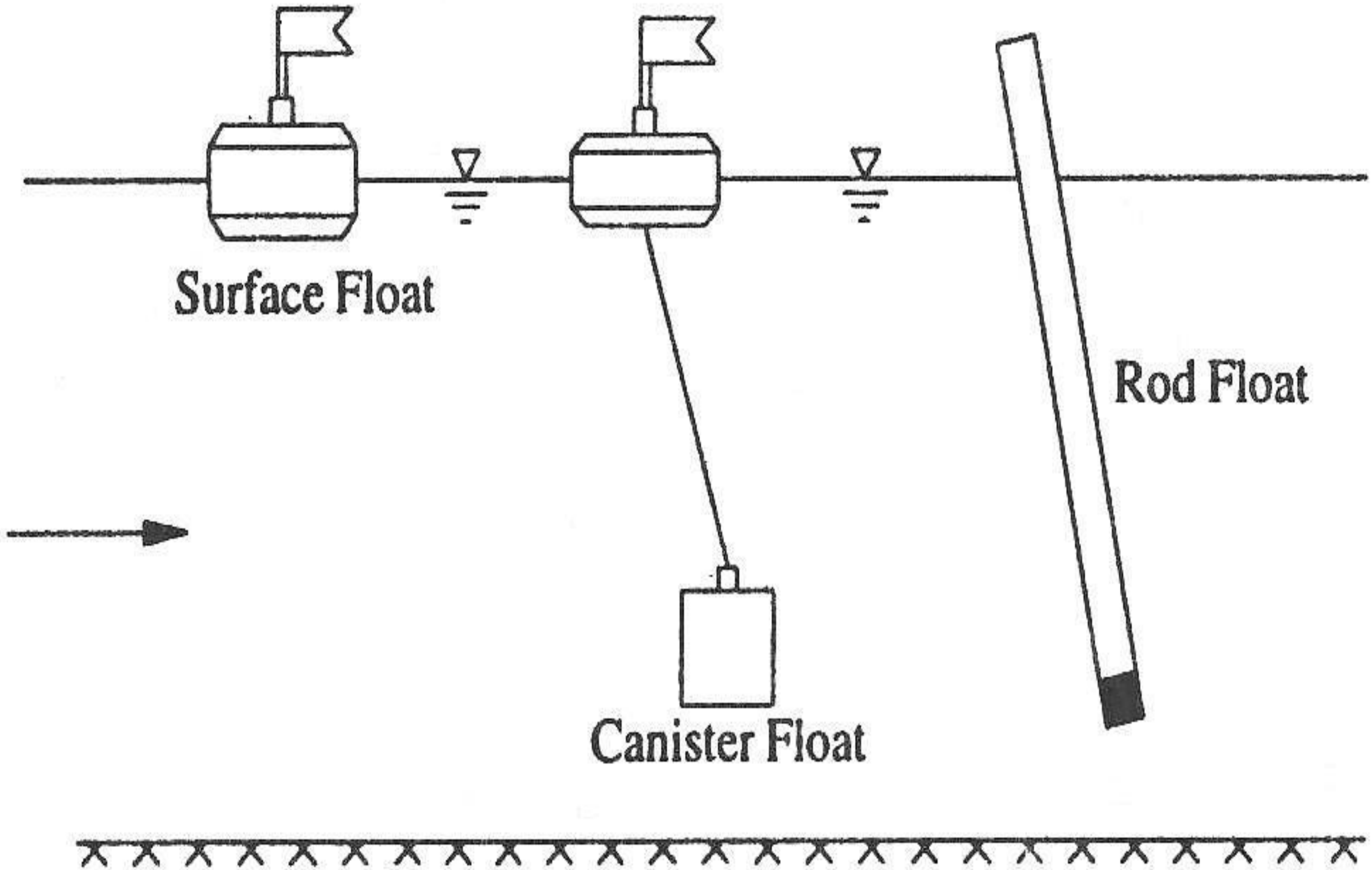


Fig. 4.13 Floats

Area – Velocity Method

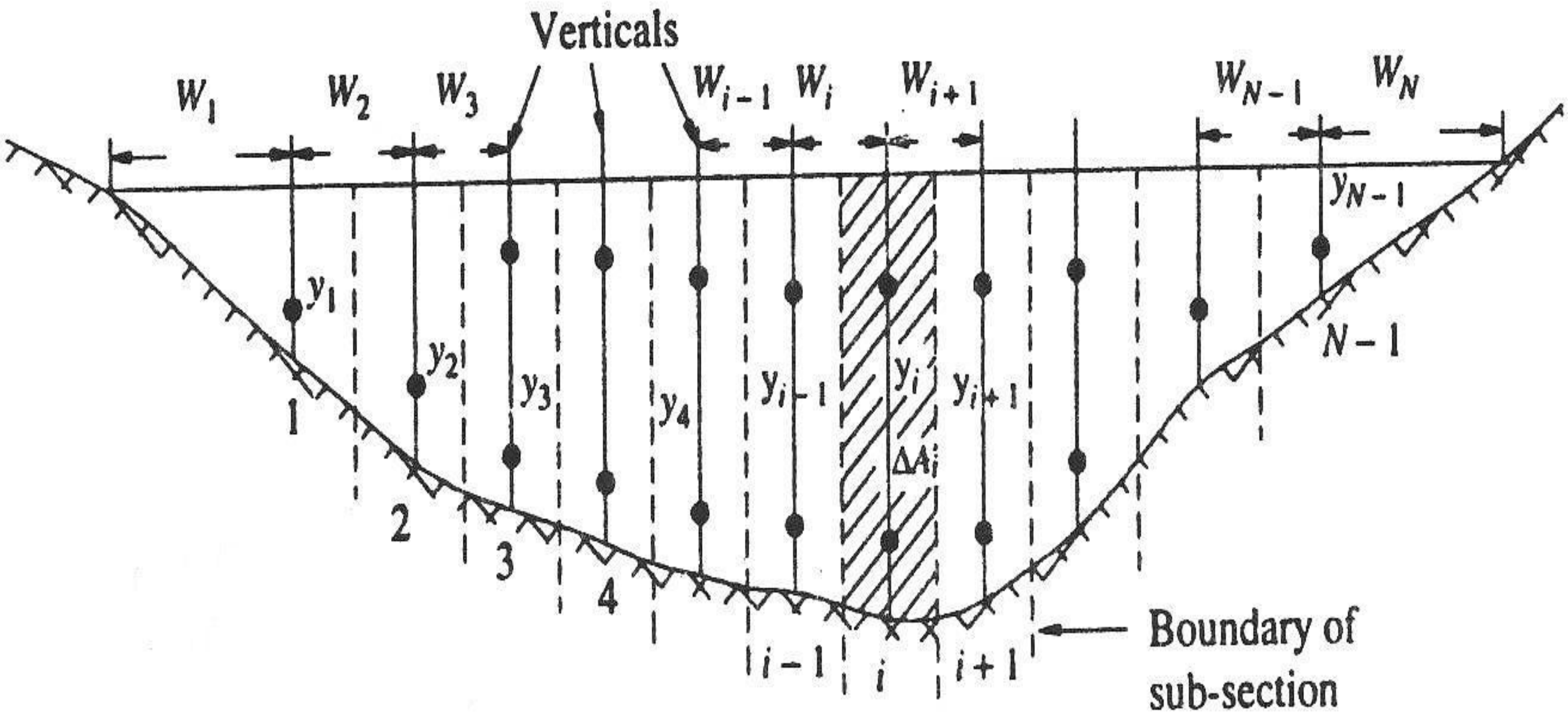


Fig. 4.14 Stream section for area-velocity method

Calculation of Discharge

Figure (4.14) shows the cross section of a river in which N–1 verticals are drawn. The velocity averaged over the vertical at each section is known. Considering the total area to be divided into N–1 segments, the total discharge is calculated by the *method of mid-sections* as follows:

$$Q = \sum_{i=1}^{N-1} \Delta Q_i$$

where ΔQ_i = discharge in the i th segment

= (depth at the ith segment) × ($\frac{1}{2}$ width to the left

+ $\frac{1}{2}$ width to right) × (average velocity at the ith vertical)

$$\Delta Q_i = y_i \times \left(\frac{W_i}{2} + \frac{W_{i+1}}{2} \right) \times v_i \qquad \text{for } i = 2 \text{ to } (N-2)$$

For the first and last sections, the segments are taken to have triangular areas and area calculated as

$$\Delta A_1 = \overline{W}_1 \, y_1$$

where $$\overline{W}_1 = \frac{\left(W_1 + \frac{W_2}{2}\right)^2}{2\,W_1}$$

and $$\Delta A_N = \overline{W}_{N-1}\, y_{N-1}$$

where $$\overline{W}_{N-1} = \frac{\left(W_N + \frac{W_{N-1}}{2}\right)^2}{2\,W_N}$$

to get

$$\Delta Q_1 = \bar{v}_1 \,.\, \Delta A_1 \quad \text{and} \quad \Delta Q_{N-1} = \bar{v}_{N-1}\, \Delta A_{N-1}$$

EXAMPLE 4.1 *The data pertaining to a stream-gauging operation at a gauging site are given below.*
The rating equation of the current meter is $v = 0.51\,N_s + 0.03$ m/s
Calculate the discharge in the stream.

Distance from left water edge (m)	0	1.0	3.0	5.0	7.0	9.0	11.0	12.0
Depth (m)	0	1.1	2.0	2.5	2.0	1.7	1.0	0
Revolutions of a current meter kept at 0.6 depth	0	39	58	112	90	45	30	0
Duration of observation (s)	0	100	100	150	100	100	100	0

SOLUTION : The calculations are performed in a tabular form.
For the first and last sections,

Average width, $$\overline{W} = \frac{\left(1+\frac{2}{2}\right)^2}{2\times 1} = 2.0 \text{ m}$$

For the rest of the segments,
$$\overline{W} = \left(\frac{2}{2}+\frac{2}{2}\right) = 2.0 \text{ m}$$

Since the velocity is measured at 0.6 depth, the measured velocity is the average velocity at that vertical ($\bar{v}$).

The calculation of discharge by the mid-section method is shown in tabular form below:

Distance from left water edge (m)	Average width $\overline{W}$ (m)	Depth y (m)	Velocity $\bar{v}$ (m/s)	Segmental discharge ΔQ_i (m^3/s)
0	0	0	—	—
1	2.00	1.1	0.229	0.504
3	2.00	2.0	0.326	1.304
5	2.00	2.5	0.411	2.055
7	2.00	2.0	0.336	1.344
9	2.00	1.7	0.260	0.884
11	2.00	1.0	0.183	0.366
12	0	0		—
			$\Sigma \Delta Q_i =$	6.457

Total discharge $Q = 6.457\ m^3/s$

$$v_b = v_R \cos\theta \qquad \text{and} \qquad v_f = v_R \sin\theta$$

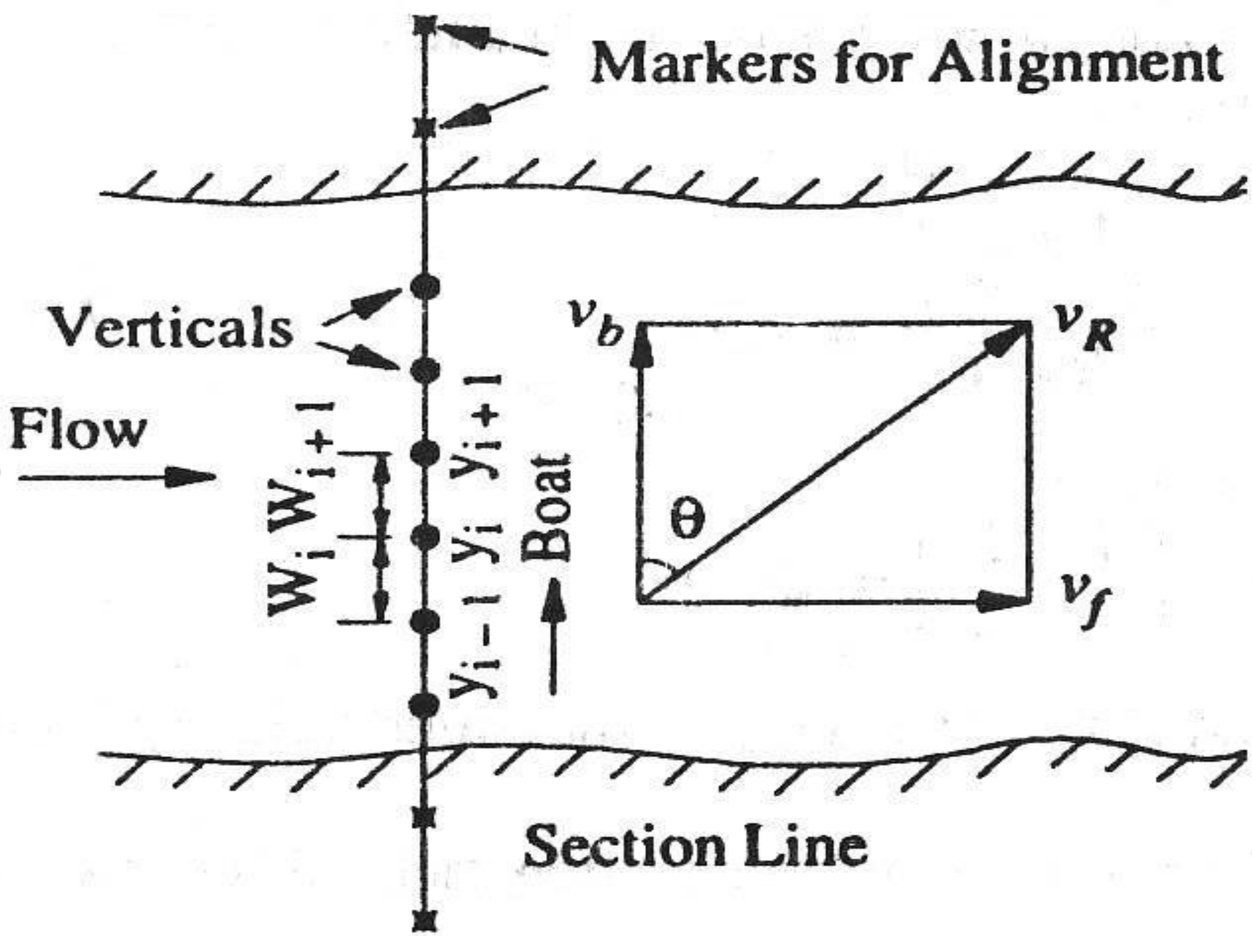


Fig. 4.15 Moving-boat method

If the time of transit between two verticals is Δt, then the width between the two verticals (Figure 4.15) is

$$W = v_b \, \Delta t$$

The flow in the sub-area between two verticals i and $i+1$ where the depths are y_i and y_{i+1} respectively, by assuming the current meter to measure the average velocity in the vertical, is

$$\Delta Q_i = \left(\frac{y_i + y_{i+1}}{2} \right) W_{i+1} \, v_f$$

i.e.

$$\Delta Q_i = \left(\frac{y_i + y_{i+1}}{2} \right) v_R^2 \sin\theta \cdot \cos\theta \cdot \Delta t$$

Thus by measuring the depths y_i, velocity v_R and θ in a reach and the time taken to cross the reach Δt, the discharge in the sub-area can be determined. The summation of the partial discharges ΔQ_i over the whole width of the stream gives the stream discharge

$$Q = \Sigma \, \Delta Q_i$$

Dilution Technique of Streamflow Measurement

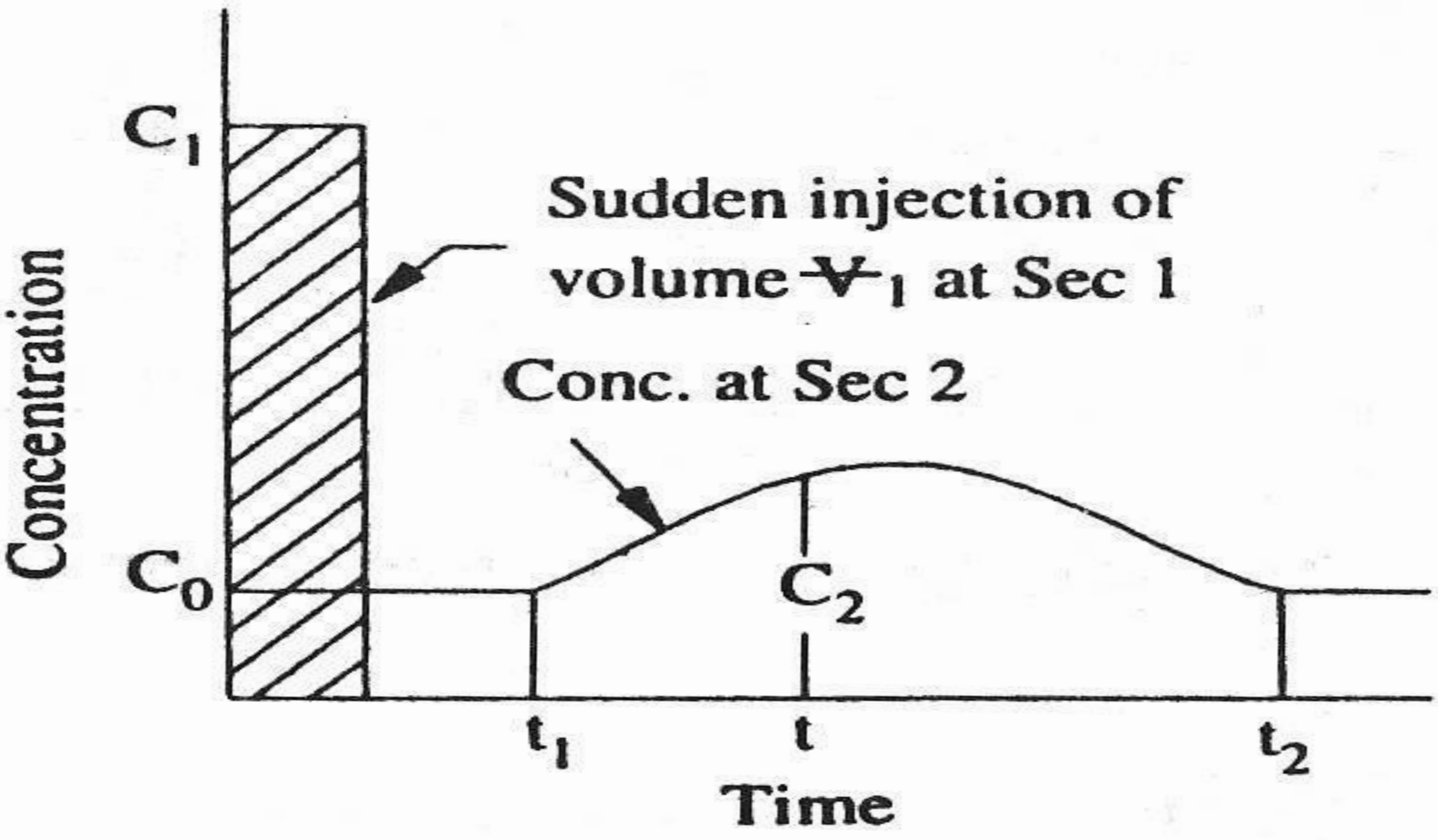


Fig. 4.16 Sudden-injection method

$$M_1 = \text{mass of tracer added at section } 1 = \forall_1 C_1$$

$$= \int_{t_1}^{t_2} Q\,(C_2 - C_0)\,dt + \frac{\forall_1}{t_2 - t_1} \int_{t_1}^{t_2} (C_2 - C_0)\,dt$$

Neglecting the second term on the right-hand side as insignificantly small,

$$Q = \frac{\forall_1 C_1}{\int_{t_1}^{t_2} (C_2 - C_0)\,dt}$$

Another way of using the dilution principle is to inject the tracer of concentration C_1 at a constant rate Q_t at section 1. At section 2, the concentration gradually rises from the background value of C_0 at time t_1 to a constant value C_2 (Fig. 4.17). At the stready state, the continuity equation for the tracer is

$$Q_t C_1 + Q C_0 = (Q + Q_t) C_2$$

i.e.

$$Q = \frac{Q_t (C_1 - C_2)}{(C_2 - C_0)}$$

This technique in which Q is estimated by knowing C_1, C_2, C_0 and Q_t is known as *constant rate injection method* or *plateau gauging*.

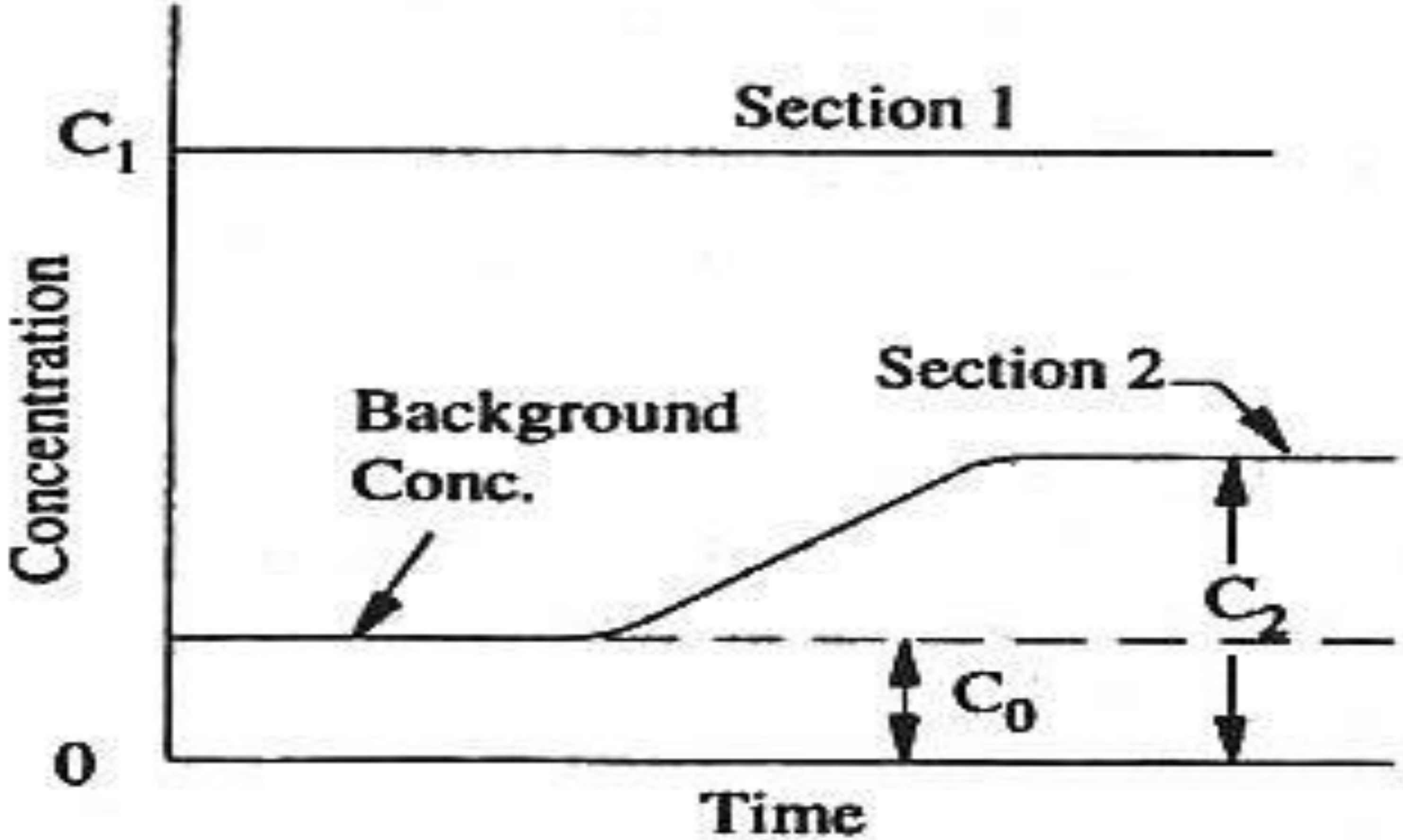


Fig. 4.17 Constant rate injection method