FLOW MEASUREMENT:

STREAM GAUGING: DEPTH AND VELOCITY MEASUREMENTS

Introduction

The water which constitutes the flow in the surface stream is called *streamflow or channel flow*. Streamflow forms the most important data for engineers and hydrologists since they are concerned mainly with estimating rates, volumes and quality of the streamflow to be used in the design of water resources and environmental projects, or the changes in these values resulting from the man-made causes.

In evaluating the capacity of a surface water resource to multipurpose activities, it is important to estimate the volume, quality, and reliability of the water supply. Methods for determining flow in open channels range from very detailed and precise to "quick and dirty."

The flow of water in an open channel is expressed in units of volume per time. Common units are gallons per minute (gpm), cubic feet per second (cfs), liters per second (l/s), or cubic meters per second (m^3/s). In flow measurement, flow is often estimated by determining the velocity at which water flows through a given cross-sectional area. Using the conservation of mass (continuity equation), the discharge can be determined as,

$$\text{Flow or Discharge} = \text{velocity X cross-sectional area or simply } Q = VxA \quad \ldots\ldots\ldots\ldots(1)$$

Alternately, the flow can be routed through a measurement device and measured directly, or it may be determined indirectly through use of appropriate measurements and mathematical models.

To apply continuity equation, one has to determine the velocity and cross sectional area of the stream. The following sections would deal with the same to arrive at the quantity of water flowing in the stream.

Some of the important Definitions:

Depth: It is the depth of water in the channel measured from the bottom of the channel
Stage: It is the height of water surface above a fixed datum. The datum could be bottom of the channel or Mean Sea Level or any other standard identity.
Rating: This is the relationship existing between stream stage and discharge in the stream.

Measurement of water depth

The river stage has been defined as the height of the water surface in the river at a given section above any arbitrary datum. It is usually expressed in meters. In many cases, the datum is taken as the mean sea level. Sometimes the datum may be selected at or slightly below the lowest point on the river bed.

Stage can be very easily measured by installing Non-recording (manual) or Recording(automatic) stream gauge stations. The various methods adopted can be listed as;

Non recording stream gauge :
  a. Point and Hook Gauge
  b. Staff
  c. Wire(String)
  d. Crest staff

Recording stream gauge :
  a. Float type
  b. Digital gage

a. Point & Hook Gauges

These are the simple and common methods adopted to determine the depth of flow in small channels. For instance, the measurement of depth of water in the in the laboratory channels would commonly adopt this technique.

These consists of a graduated bar attached to a hook or pointer. The bar can slide up or down over a fixed mounting. The Fig. 1 shows the typical view of the two systems.

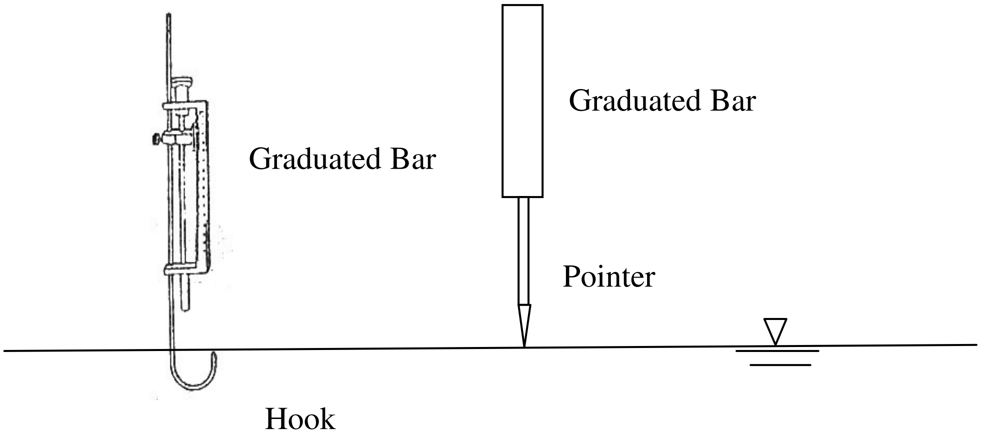


Fig. 1. Point and Hook gauges

The depth of water is measured by operating the system by bringing the pointer or hook to close to the water surface. Then with the help of finer adjustment screw the sharp point of the pointer or hook is made to just touch the surface of water. At this moment it is ready for measurement of the depth by reading on the graduated bar. Provision of vernier is also made for accurate reading.

b. Staff Gauge

The vertical staff gauge which is nothing but a graduated scale (about 15cm wide) such that a portion of it is always in water at all times. It can be conveniently attached to a bridge pier or any or existing structure. It is read manually by noting level of water surface in contact with it. The vertical height should cover the highest and lowest water levels in that section. Figure .2 shows the arrangement of vertical staff to measure the depth of water.

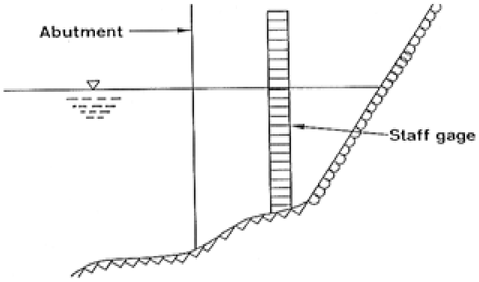


Fig. 2 Vertical Staff Gauge arrangement

When flow in stream is subjected to large variations resulting in correspondingly large fluctuations in stage, it may be beyond the range of a single vertical staff gauge to record entire rise or fall in the water surface. In such situations it may be convenient to use a series of vertical staff gauges as shown in Fig.3 covering entire range, graduations of all gauges being reduced to same datum. There should be a minimum overlap of.0.5 m between any two successive staff gauges. This arrangement is known as **Section Staff Gauges**.

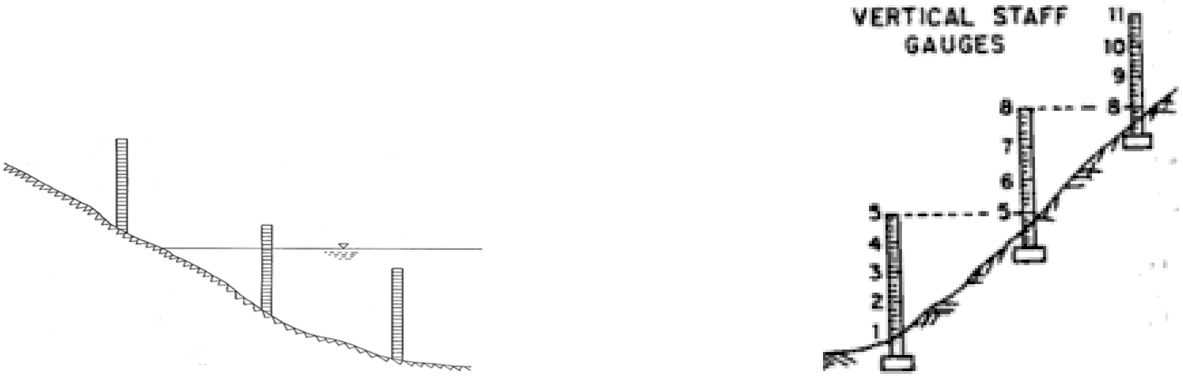


Fig. 3. Section Staff Gauge arrangement

Sometimes gauge may be placed in an inclined position up the stream bank shown in Fig 4. This arrangement would be more accurate for the streams which have low stages. It must be properly anchored to slope of natural bank of river channel. It is calibrated in site by precise leveling and graduated accordingly. **Inclined gauges** may be constructed on one continuous slope or on more slopes. A flight of steps constructed alongside inclined gauge proves to be convenient and facilitates taking of observations easily.

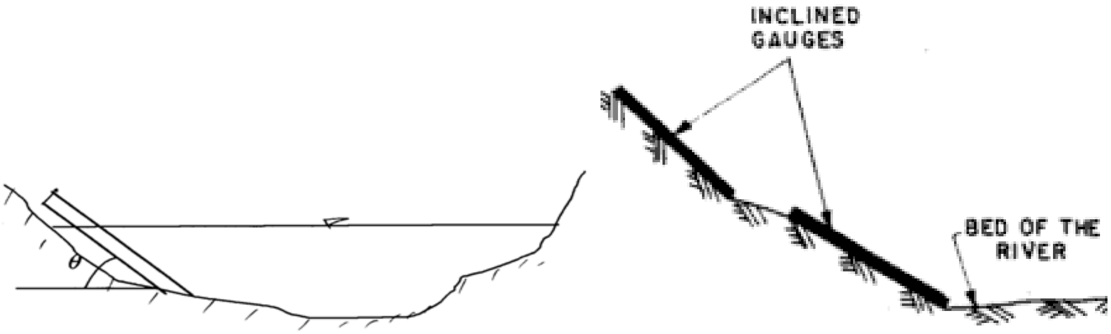


Fig. 4. Inclined Staff Gauge arrangement

Proper care must be taken while installing staff gauges to protect m from damage by boats, ice, or flood transported debris and to ensure that flow disturbances across scale are at a minimum.

c. Weight Gauge

The river stage can also be measured manually by using another type of device called ***suspended weight gauge***. In this method a weight(electrically connected) attached to a rope is lowered from a fixed reference point on a bridge or other overhead structure till it touches the water surface. By subtracting the length of the rope lowered from the reduced level of the fixed reference point the stage is obtained (Fig.5).

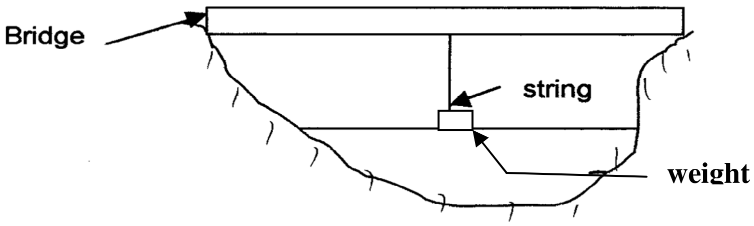
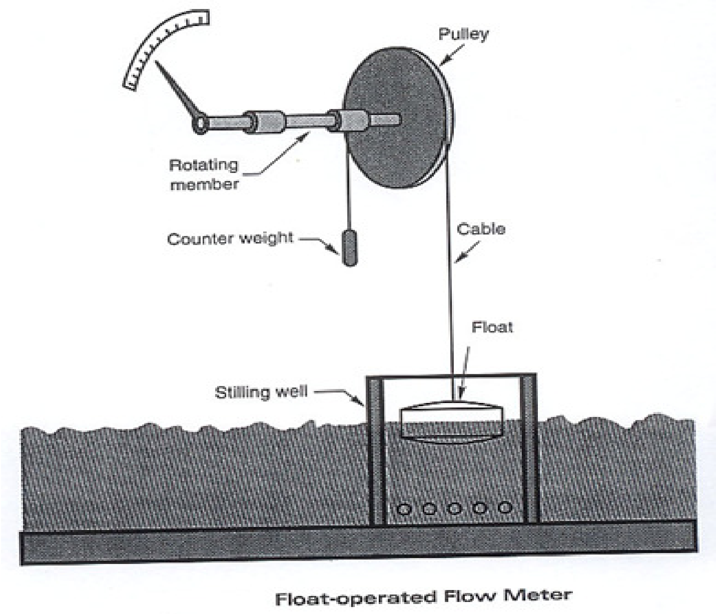


Fig.5. Suspended Weight Gauge arrangement

d. Float Gauge

The stage can also be measured by the arrangement of float and pulley attached to a pointer which moves over the graduated scale in accordance with the water surface in the stream. Figure.6 shows one such arrangement.



Float-operated Flow Meter

Fig. 6. Float Gauge arrangement

Rules Guiding Location of Gauges

- Gauges should not be located in rivers with scouring characteristics.
- The locations should not be on river bends because the water surface is inclined and there is turbulence making the stage measurement inconsistent.
- The upstream of a natural control eg. a rapid should be used, not downstream (Fig. 7)

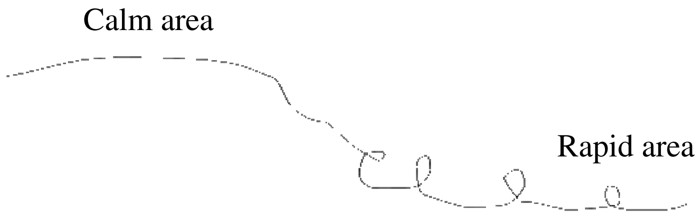


Fig. 7. Areas associated with natural control

- A uniform channel helps good stage measurement. Irregular cross sections should be avoided(Fig. 8)

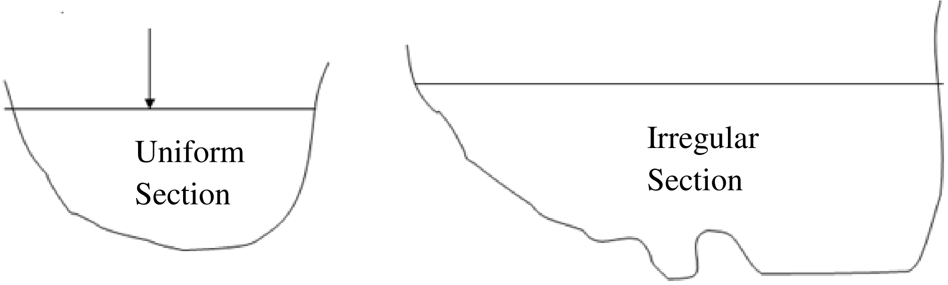


Fig. 8. Channel cross sections

Recording Gauges

Though the manual gauges described above are simple and inexpensive, they must be read frequently to get a continuous curve of the streamflow, especially when, the stage is, changing rapidly. Also, it is likely that the peak stage may be missed when it occurs in between the observations. *Recording type gauges* may be installed to overcome these difficulties.

Recording type gauge used to measure the stage continuously with time is also known as an *automatic stage recorder*. It usually consists of a float tied to one end of a cable running over a pulley. To the other end of the cable a counterweight is attached. The float would be resting on the water surface and the counterweight always keeps the cable in tension. Any change in water surface makes the float either to raise or lower and this in turn makes the pulley rotate. The movement of the pulley would actuate a pen arm which rests on a clock-driven drum wrapped with a chart. The circumference of the drum represents the time axis while the height of the drum represents the stage. So, either sufficient height of the drum or some scaling mechanism is provided to cover the expected range of the stage. The clock and the drum may be so designed that the chart runs for a specified period of time (like a day or a week or a month) unattended.

A float type automatic stage recorder requires a shelter in the form of a stilling well as shown is Fig.9a,b. This stilling well gives protection to the float and counterweight from floating debris and with proper design of intake pipes it suppresses the fluctuations resulting from surface waves in the river, Generally two or more intake pipes are placed to allow the water from the river into the well so that at least one will admit water at all the times. As the stilling well is likely to get filled with sediment, it is necessary to make provision for the removal of silt from time to time. It is customary to install staff gauges inside and outside the well. These staff gauges serve to check the performance of the recorder and these are read each time the station is visited.

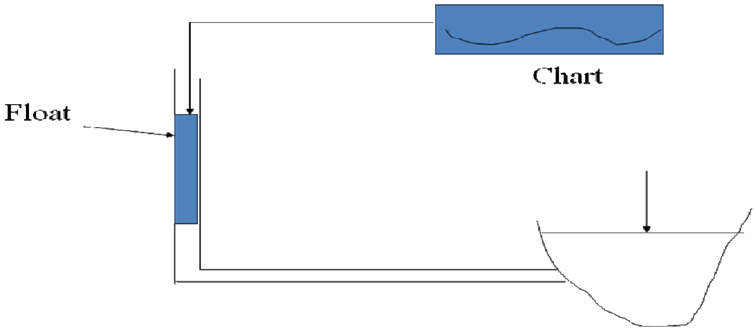


Fig. 9a. Concept of Float Gauge

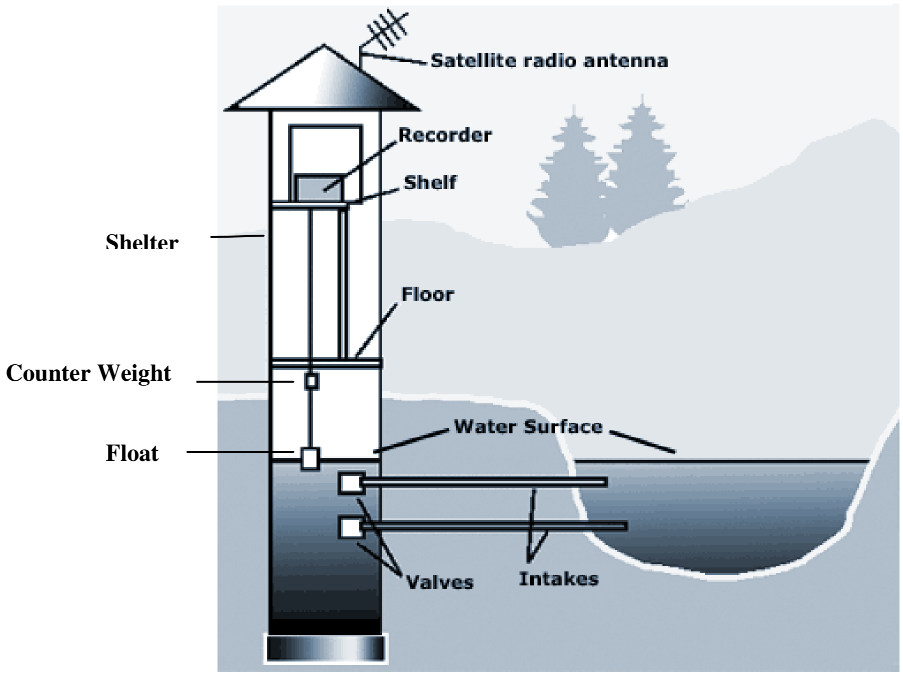


Fig. 9b. Schematic Representation of Float Gauge arrangement

Crest Gauge

When the finances do not permit the installation of recording gauge, a *crest gauge* may be installed along with the manual gauge so that the peak stage is not missed. A crest gauge may consist of a cylindrical tube sealed below with only a few holes to allow the water to enter the tube. A smal1 float(ground cork) fixed in the tube floats up and is held by surface tension when stage increases. It stays at maximum stage until the reading is taken and let loose (Fig. 7).

A water soluble paint applied to a bridge pier and protected from rain may also be used as a crest gauge. The portion of the paint coming in contact with water is washed out indicating the peak stage attained during a flood. The data from the crest gauges are valuable in the establishment of flood profiles and in determining the slope for the investigation of the flood formulae.

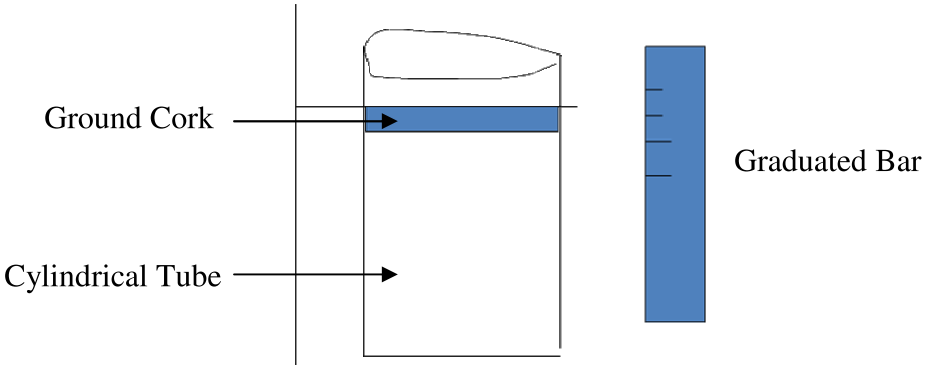


Fig. 7. Crest Gauge

Measurement of Velocity

The rate of flow or discharge flowing in the river can be determined using principle of conservation of mass, known as continuity equation. As indicated earlier, the flow using the concept of conservation of mass is given by Eq.(1), i.e.,

$$Q = A \times V$$

Where A is the cross sectional area of the stream and V is the mean(average) velocity of flow in it. By using the sectional staff or any other method of determining the depth, the cross sectional area of the stream can be established. To measure the flow rate in the stream, it necessary to determine the mean velocity of the flow. The velocity of the stream or a river can be determined by the following method.

- Current-meter
- Floats
- Tracer-dilution technique
- Ultrasonic method
- Electromagnetic method

Among the above methods, most popular methods are using current meters and floats. These two methods are discussed in the present case.

Current Meters

It has a propeller/cup which is rotated when water hits it and is connected to magnets which actuates recorders when the propeller/cup rotates. The velocity of water increases the propeller/cup rotation.

There are mainly two types of current meters which are in common use, namely, **cup type** current meter (also known as the *price and pigmy* current meter) and the *propeller type* current meter.

The principle involved in both the meters is that the water flowing past the rotating clement of the meter makes it revolve due to the unbalanced drag force acting on it and the speed of the rotating clement is directly proportional to the velocity of water.

The cup type current meter consists of a wheel of six conical cups rotating about a vertical axis as shown in Fig.8. The tail vanes (also known as the *fins)* will always align the meter along the direction of flow.

The USGS Type AA current meter is commonly known as the Price- type current meter. This is suspended in the water using a cable with sounding weight (counter weight) or wading rod. It accurately measures streamflow velocities from 0.1 to 25 feet per second (0.03 to 7.6 meters per second).

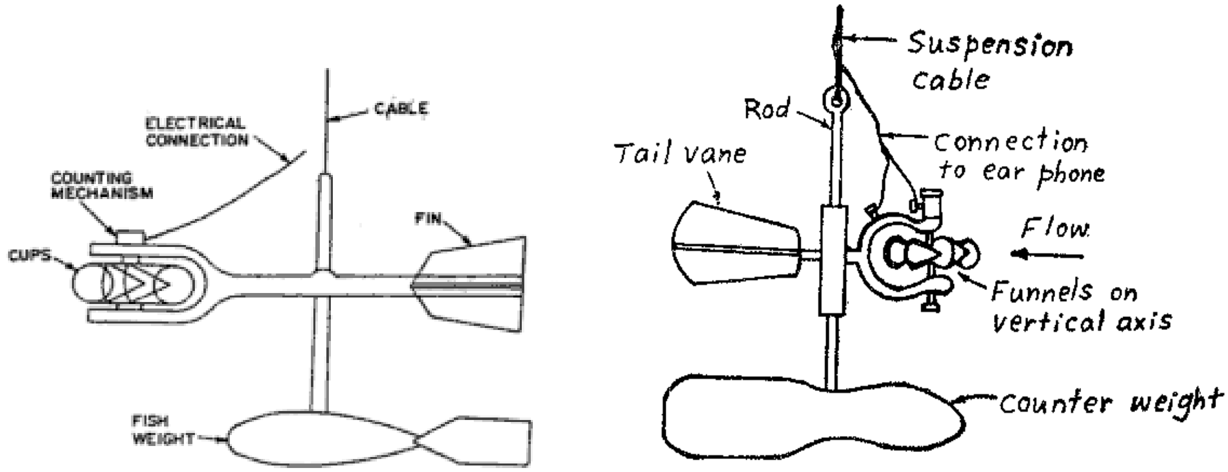


Fig. 8. Cup Type Current Meter

Pygmy type current meter is scaled two-fifths the size of the standard Type AA current meter.

The propeller type current meter is shown in Fig. 9

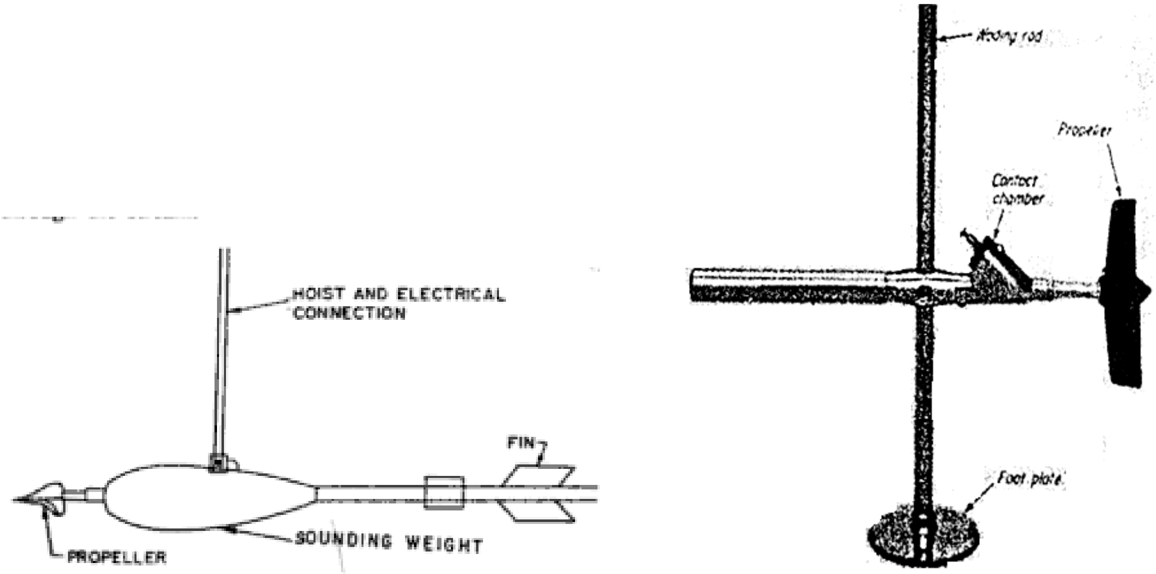


Fig.9. Propeller type current meter.

Rating of Current Meter

The rating of current meter refers to the calibration of the unit with respect to the varation of the velocity with depth. It is found from the experimentation that this variation follows a straight line as shown in the Fig. 10. The equation representing this variation is known as **Rating Equation,** mathematically it can be written as,

$$v = a + bN \quad \text{...(2)}$$

Where v is the velocity (m/s), N is the rotation of the cup or propeller in revs/sec, a and b are the constants of the equation which are determined through the calibration as shown in the figure.

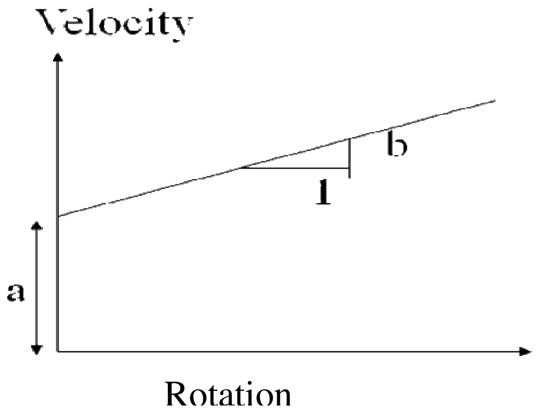


Fig. 10. Typical Rating of Current Meter

Average Velocity along a Vertical:

The velocity in an open channel at any vertical varies from zero at the bottom to a maximum value at or slightly below the free surface as shown in Fig 11. Considering the velocity profile with depth, average value along the vertical can be showed to occur at a distance of 0.368 d-0.393 d from the bottom. Therefore the general practice is to take the velocity measured at a distance of 0.4 d from the bottom (or at a depth of 0.6 d from the free surface) as equal to the average velocity of the vertical. It can also be shown that the arithmetic average of the velocities at 0.2 d and 0.8 d is almost equal to the average velocity of the vertical.

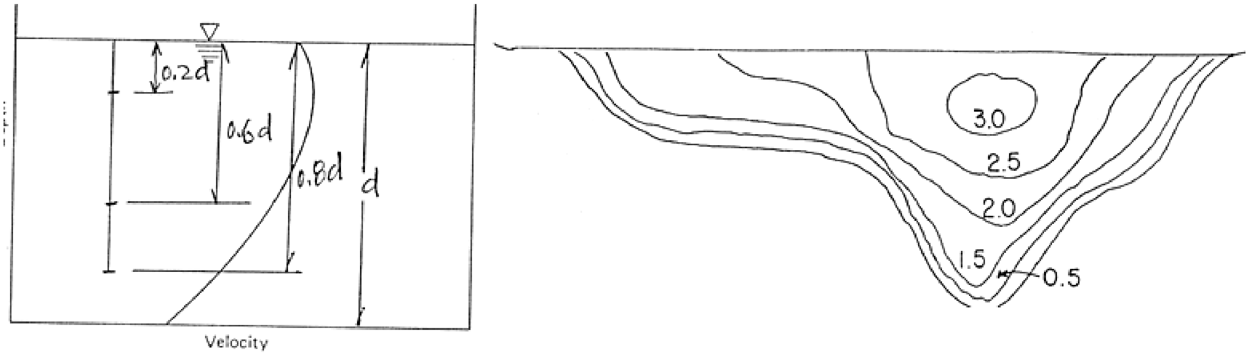


Fig. 11 Velocity distribution at a vertical

The method, considering the values at 0.2 d and 0.8 d, is more accurate but in a shallow cross-section, the velocity at 0.2 d may be difficult to measure so use a single value at 0.6 d.

In general, following thumb rule can be applied:

$V_{av} = V_{0.6}$ for shallow stream ; depth < 0.6 m ....(3)

$V_{av} = (V_{0.8} + V_{0.2})/2$ for moderate stream, $0.6 < d < 2m$ ....(4)

$V_{av} = (V_{0.8} + 2V_{0.6} + V_{0.2})/4$ for depth, d>2m ……………………………………(5)

$Vav = C\,V_{0.5}$ for deep stream –flood flow . ……………………………………(6)

Mean Flow Velocity Estimation by Floats

Any floatable substance eg. a tennis ball is placed at a point and the time(t) it takes it to move a known distance(d) is noted. d/t gives the *average surface velocity* of the water. The surface velocity(Vs) is equal to 1.2(average Velocity, V) ie.,

$$Vs = 1.2V \text{ and } V = 0.8\ Vs. \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(7)$$

The following figure(Fig. 12) gives some information about the application of this method.

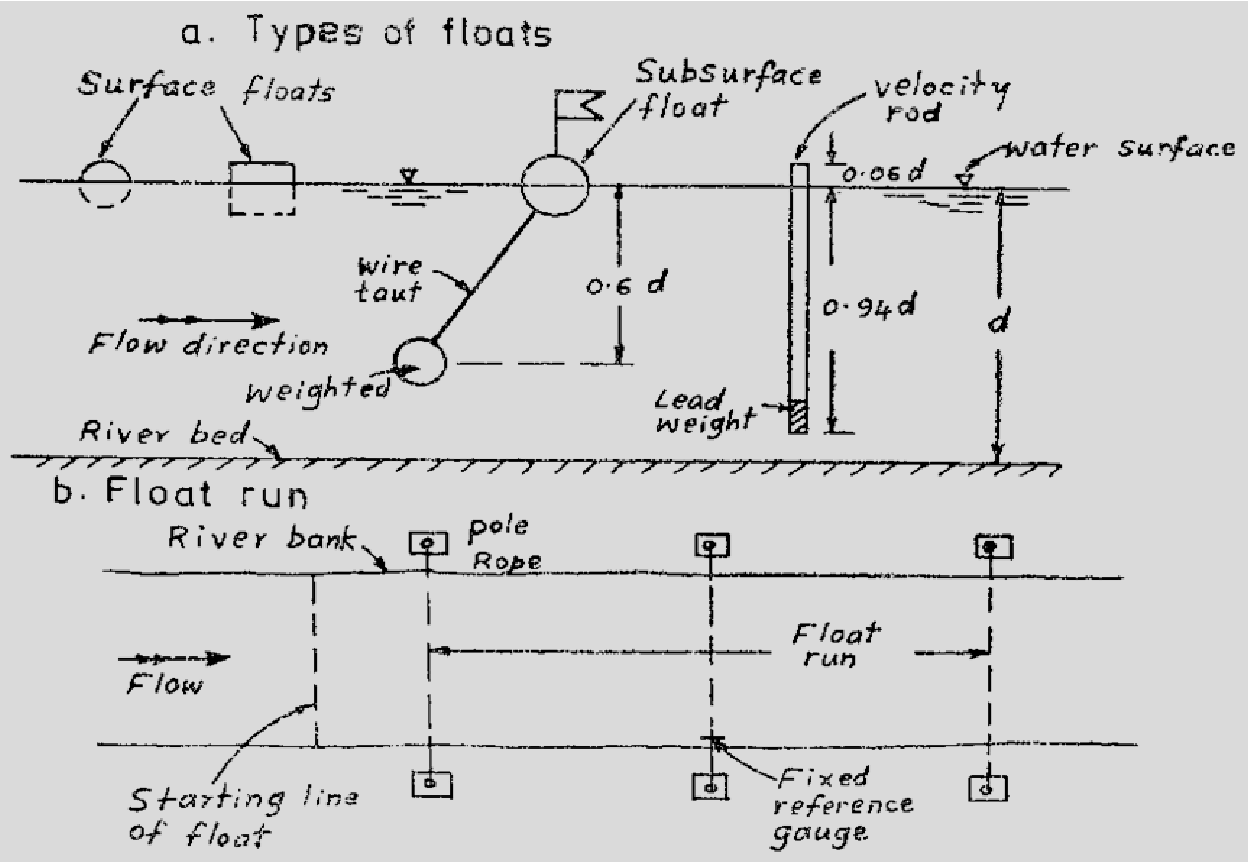


Fig. 12. Measurement of Flow Velocity by Floats

Measurement of Discharges: Area –Velocity (A-V) Method

Divide the cross-section of the stream into vertical sections such that no section carries more than 10 % of the total flow as shown in Fig. 13. Take soundings to determine various depths.

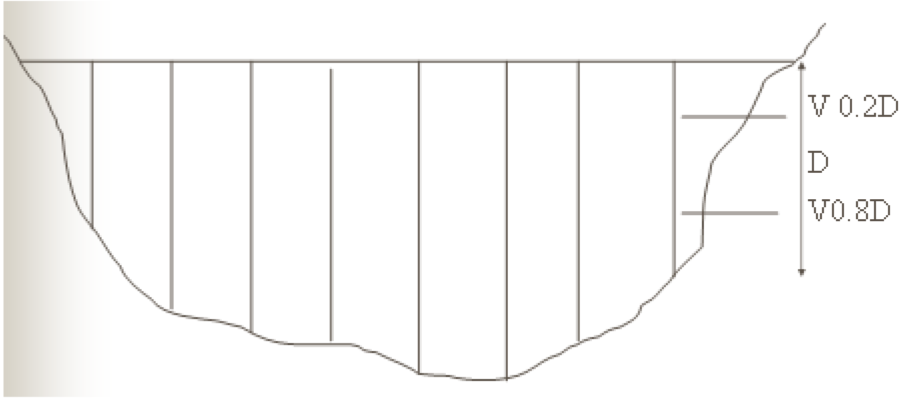


Fig. 13. Division of Cross section to vertical sections

The discharge through the cross section is determined by the concept of continuity equation as explained earlier (Eq. 1), Q= AxV. In Area-Velocity method, the same principle is applied. The discharge through each segment is estimated by determining the each strip area and mean velocity through the strip. Area of each segment can be calculated using the trapezoidal formula. The mean velocities are calculated by noting the velocities along the 0.2 D and 0.8 D **OR** 0.6 D alone.The total discharge thorough the cross section is equal to the sum of segmental discharge, i.e,

Flow in one segment,

q = average velocity (v_i)x area of segment(a_i). .... (8)

Total discharge, Q is equal to: (average velocity x area of segments)

$$Q = \Sigma q_i = \Sigma v_i a_i \qquad \text{..................(9)}$$

Measurement of discharge is determine by two methods:

1. Mean Section Method
2. Mid SectionMethod

1. Mean Section Method:

Divide the cross section into number of segments as per above said condition (Fig. 14). The distance of each strip is indicated from the shore as, b_1, b_2, etc. The two point velocities on the vertical (which are at 0.2 d and 0.8 d) are averaged to get the mean velocity for the strip. The area of the strip is obtained as the averaging measured depth of flow at the each vertical (for eg., between 3 and 4th verticals) multiplied by the width (between 3 and 4th vertical, b_3 - b_2). Incremental discharges are estimated by multiplying segmental area and averaging the averaged velocities on each vertical, viz., 3 and 4.

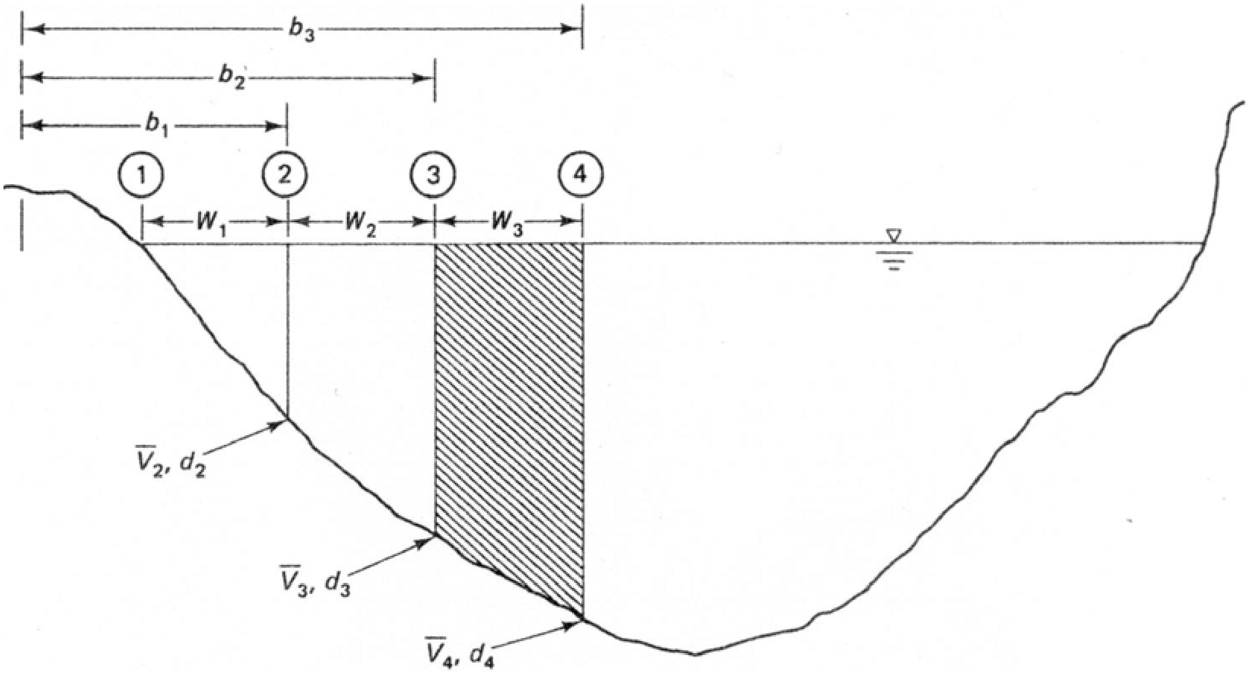


Fig. 14. Mean Section Method

The segmental discharge can be expressed mathematically as,

$$q_x = \left(\frac{\overline{V}_x + \overline{V}_{x+1}}{2}\right)\left(\frac{d_x + d_{x+1}}{2}\right)W_x \qquad \text{................................(10)}$$

For eg., Between strip 3 and 4,

$$q_{3-4} = \left(\frac{\overline{V}_3 + \overline{V}_4}{2}\right)\left(\frac{d_3 + d_4}{2}\right)W_{3-4} \qquad \text{................................(11)}$$

3. Mid Section Method

Divide the cross section into number of segments as per above said condition (Fig. 15). The distance of each strip is indicated from the shore as, b_1, b_2, etc. The two point velocities on the vertical (which are at 0.2 d and 0.8 d) are averaged to get the mean velocity for the strip. The area of the strip is obtained as the measured depth of flow at the each vertical (for eg., vertical no. 3) multiplied by the average width, which is halfway to the adjacent verticals on either side of vertical 3. Incremental discharges are estimated by multiplying segmental area and the average velocity along vertical, viz., 3.

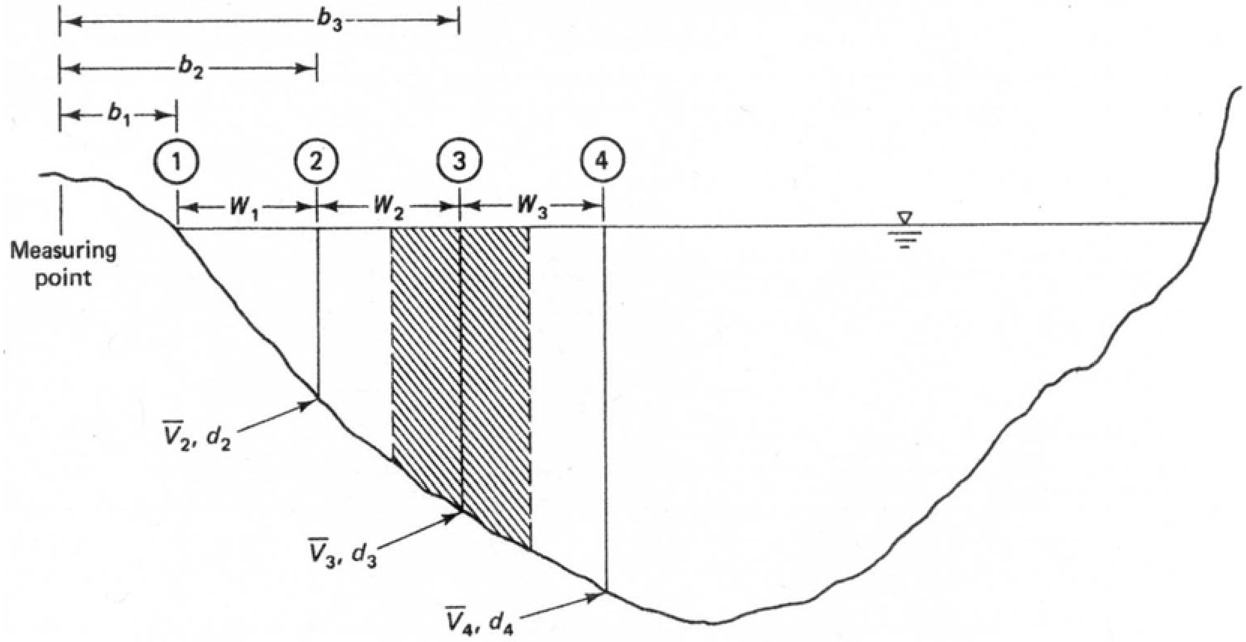


Fig. 15. Mid Section Method

The segmental discharge can be expressed mathematically as,

$$q_x = \overline{V}_x \left(\frac{W_{x-1} + W_{x+1}}{2} \right) d_x \qquad \text{..................................(12)}$$

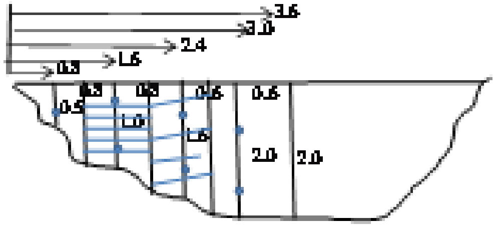
For eg., along strip 3,

$$q_3 = \overline{V}_3 \left(\frac{W_2 + W_4}{2} \right) d_3 \qquad \text{................................(13)}$$

Example:

The current meter observations taken during the gauging of a stream are given in Col. (1) to Col. (5) in the Table. The current meter rating may be taken as v = 0.04 + 0.35 N, where v is in m/s and N is in rev/s. Compute the discharge in the stream.

Distance from bank, m	Depth of flow, m	Meter depth, m	No of revolutions	Time, sec
0.8	0.5	0.3	12	48
1.6	1.0	0.8	23	52
		0.2	36	51
2.4	1.6	1.28	27	54
		0.32	41	60
3.0	2.0	1.60	33	58
		0.40	45	62
3.6	2.0	1.60	32	58
		0.40	44	60
4.2	1.8	1.44	28	53
		0.36	42	58
5.0	1.2	0.96	24	50
		0.24	35	50
5.8	0.6	0.36	14	45
6.6	0.0	-	-	-



Solution:

Distance from bank, m	Depth of flow, m	Meter depth, m	No of revolutions	Time, sec	**N, revs/sec**	**Velocity, v, m/s**	**Mean velocity V, m/s**	**Area of strip, m^2**	**Incremental discharge, m^3/sec**
0.8	0.5	0.3	12	48	**0.250**	**0.128**	**0.128**	**0.40**	**0.0512**
1.6	1.0	0.8	23	52	**0.442**	**0.195**	**0.241**	**0.80**	**0.1928**
		0.2	36	51	**0.706**	**0.287**			
2.4	1.6	1.28	27	54	**0.500**	**0.215**	**0.247**	**1.12**	**0.27664**
		0.32	41	60	**0.683**	**0.279**			
3.0	2.0	1.60	33	58	**0.569**	**0.239**	**0.2665**	**1.20**	**0.3198**
		0.40	45	62	**0.726**	**0.294**			
3.6	2.0	1.60	32	58	**0.552**	**0.233**	**0.265**	**1.20**	**0.318**

		0.40	44	60	**0.733**	**0.297**			
4.2	1.8	1.44	28	53	**0.528**	**0.225**	**0.259**	**1.26**	**0.32634**
		0.36	42	58	**0.724**	**0.293**			
5.0	1.2	0.96	24	50	**0.480**	**0.208**	**0.2465**	**0.96**	**0.23664**
		0.24	35	50	**0.700**	**0.285**			
5.8	0.6	0.36	14	45	**0.311**	**0.149**	**0.149**	**0.48**	**0.07152**
6.6	0.0	-	-	-	**-**	**-**	**-**	**-**	**-**

N= Col 4/col 5
Velocity by Rating Eqn., $v = 0.04 + 0.35\ N$, $v_{0.8} = .04+0.35*0.25 = 0.128$ m/s

Avg. Velocity
$= (v_{0.2d} + v_{0.8d})/2$; $V_{1.6} =(0.195+ 0.287)/2 = 0.241$ m/s

Segmental Area calculation by **Mid Section Method**
For ex. At Sec-2,
D= 1.0m,
a= 1.0 ((0.8+0.8)/2)
= 0.8 sq.m
Sec-3, D= 1.6m
a= 1.6 ((0.8+0.6)/2)
= 1.12 sq.m

Incremental discharge = col 8 x col 9

Total discharge= sum col 10.

Total Discharge = summation of incremental discharges in the each strip = 1.793 m^3/sec

It is rather difficult to measure the discharge of flow in the natural streams directly. But it is very easy to make a direct and continuous measurement of *stage* in the river which is nothing but the height of the water surface in the river above some arbitrary datum. Obviously the higher the stage in the river, the higher is the discharge. The general practice in the streamflow measurement is, therefore, to record the river stage and to convert the data on stage into the discharge data. This is accomplished through the *stage- discharge relationship* which is first established by actual measurement *of* discharge in the river at different stages. Once a stable stage-discharge relationship is established at a gauging site, the discharge measurement is discontinued and only the stage is recorded continuously

Stage- Discharge Relationship- Rating Curve

It is rather difficult to measure the discharge of flow in the natural streams directly as it is done in the case of flow in pipes or laboratory flume' using the flow meters such as venturimeter, venturiflume, notches etc. But it is very easy to make a direct and continuous measurement of stage in the river which is nothing but the height of the water surface in the river above some arbitrary datum. Obviously the higher the stage in the river, the higher is the discharge. The general practice in the streamflow measurement is, therefore, to record the river stage and to convert the data on stage into the discharge data. This is accomplished through the *stage-discharge relationship* which is first established by actual measurement *of* discharge in the river at different stages. Once a stable stage-discharge relationship is established at a gauging site, the discharge measurement is discontinued and only the stage is recorded continuously.

After a sufficient number of discharge measurements have been made at a gauging station along with simultaneous stage observations, the results are plotted on an ordinary graph. It is customary to take the discharge as abscissa and the stage as the ordinate. Such a plot between the discharge and stage is known as the ***stage-discharge relation*** or the ***rating curve*** of the gauging station. Once a stable stage-discharge relation is established, it is only a matter-of recording the stage continuously which can be readily converted into the discharge through the above relation. For most of the gauging stations a simple plot of stage vs. discharge is satisfactory. Such a curve is approximately parabolic as shown in Fig16. It may show some irregularities if the cross-section is irregular. In most of the cases the discharge measurements are made within a, rather, limited range around the average stage in the river. Both at very low stages and at very high stages during floods there may be no measurements. It is, therefore, necessary to extend the curve downward for the low stages and upward for the high stages. The stage-discharge curve has its greatest curvature in too low stages.

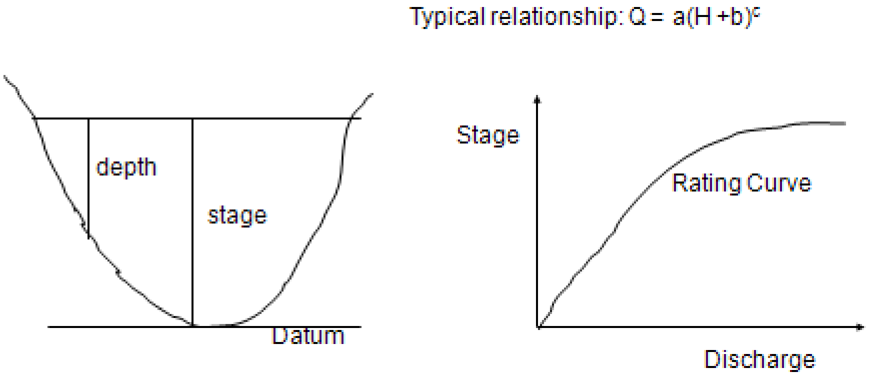


Fig. 16. Typical Rating Curve

PITOT TUBE

It is one of the means of measuring of the local velocity in a flowing fluid

Pitot tube named after Henri Pitot who used a bent glass tube in 1730 to measure velocity in the river Seine.

Used for measurement of velocity using either an inclined manometer or other type of manometer.

In a simple form, it is made up of a glass tube in which the lower end bent at right angles

Arrangement shown is for measuring velocity in free flow- Open Channel flows

The Liquid level in the tube (h) depends on velocity of stream. The term, H, is depth of tube from the free surface

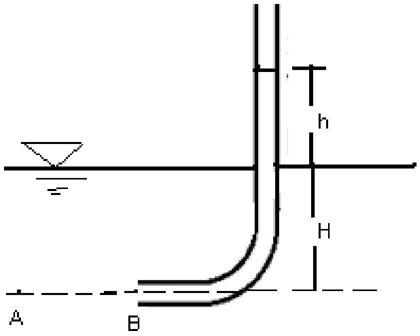


Fig. 15 Pitot tube

The points A and B are at the same level as that of H

The point A is just u/s of Pitot tube entry point and point B is at tube inlet point. The inlet of the pitot tube acts as an obstruction to flow, where in KE of flowing fluid converts to PE. Hence at the point of inlet, i.e., at B, the velocity of flow become zero. This point is called as stagnation point.

Let v be the velocity at A. The Pressure head, H, at A is given by,

$$\frac{P_a}{w} = H \qquad \text{--(20)}$$

Where, w is the specific weight of the liquid.

Pressure at B: There is no velocity at B. It is a stagnation point, which means that the KE flowing fluid converts in to potential energy. i.e., pressure head, h above liquid surface. Pressure head at B is expressed as,

$$\frac{P_b}{w} = H + h \qquad \text{--(21)}$$

,

Now applying Bernoulli's Equation between A and B,

$$\frac{P_a}{w} + \frac{v^2}{2g} = \frac{P_b}{w} \qquad \text{--(22)}$$

i.e.,

$$H + \frac{v^2}{2g} = H + h \qquad \text{-----------------------------------(23)}$$

the converted energy head,h, can be represented by,

$$h = \frac{v^2}{2g} \qquad \text{----------------(24)}$$

From the above equation the theoretical velocity ,v, can be calculated as,

$$v = \sqrt{2gh} \qquad \text{----------------(25)}$$

The above expression would give the theoretical velocity because in the above analysis the energy losses occurring in the system is not considered. The actual velocity can be determined by introducing a coefficient, C_v, which is the ratio of Actual Velocity to Theoretical Velocity. Hence the actual velocity is given by,

$$v = \boldsymbol{C_v}\sqrt{2gh} \qquad \text{----------------(26)}$$

Where C_v is the coeffcient of tube.

After obtaining the localvelocity, the discharge can be calculated by continuity equation as,

Discharge = Ax v

Discharge Measurements in Pipes

The cylindrical probe (pitot tube) is inserted into fluid as show in Fig. 16. The Velocity head converted into impact pressure. Since this point indicates the position of zero velocity, it is also called as Stagnation pressure. As in the case of free flow, the pressure just u/s to the tube is also measured here also. Since the pipe flow is a pressure flow, the pressure is measured by providing a peizometer as sown in Fig. 16. This pressure is known as static pressure.

The difference between static pressure & impact pressure is proportional to rate of flow in the pipe.

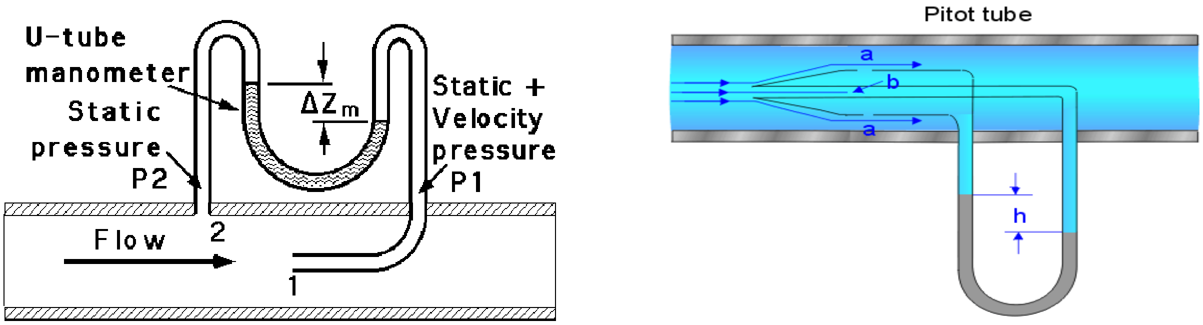


Fig. 16 Discharge Measurement in Pipe

The pressure,P_1 is a ***Static pressure:*** It is measured by a device (static tube) that causes no velocity change to the flow. This is usually accomplished by drilling a small hole normal to a wall along which the fluid is flowing.

The presuure, P_2 is a ***Stagnation pressure:*** It is the pressure measured by an open-ended tube facing the flow direction. Such a device is called a Pitot

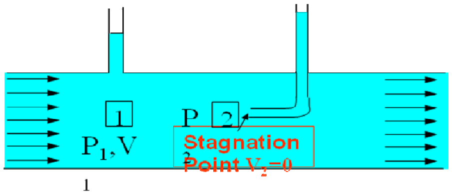


Fig. 17 Pressure Measurement in Pipe

Now, applying Bernoulli equation between 1 and 2:

$$\frac{(P_2 - P_1)}{\rho} + \frac{(V_2^2 - V_1^2)}{2} = 0 \qquad \text{----------------(27)}$$

- ❖ Stagnation Pressure is higher than Static Pressure

$$\boxed{P_2 = P_1 + \frac{1}{2}\rho V_1^2} \quad \text{OR} \quad \frac{P_2}{w} = \frac{P_1}{w} + \frac{v_1^2}{2g} \qquad \text{----------------(28)}$$

Where, ρ and w are the mass density and weight density of the lowing fluid respectively. From the above equation velocity of flow at section 1 can be obtained as,

$$\boxed{V_1 = \left[\frac{2(P_2 - P_1)}{\rho}\right]^{1/2}} \quad \text{OR} \quad \boxed{V_1 = \left[\frac{2g(P_2 - P_1)}{w}\right]^{1/2}} \qquad \text{----------------(29)}$$

The velocity, V_1, in the above expression gives the theoretical velocity of flow as the energy losses are not considered in the analysis. The difference of pressure between the two points can be measured using a differential manometer. If 'h', represents the difference of pressure head in terms of flowing fluid then,

$$v_1 = \sqrt{2gh} \qquad \text{----------------(30)}$$

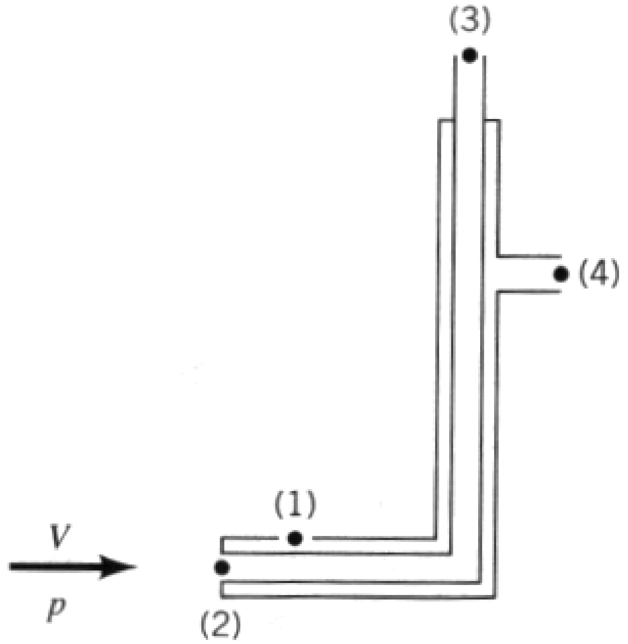
The actual velocity can be determined by introducing a coefficient, C_v, which is the ratio of Actual Velocity to Theoretical Velocity. Hence the actual velocity is given by,

$$v_1 = C_v\sqrt{2gh} \qquad \text{----------------(31)}$$

Where C_v is the coeffcient of tube.
The discharge in the pipe is determined using the principle of continuity equation.
Therefore, $Q= A_1 x\ V_1$
Where, A_a is the area of cross section of pipe at section 1.

Pitot-Static Tube

The static and Pitot tube are often combined into the one-piece . This arrangement is known asPitot-static tube. The Fig. 18 shows the salient features of this instrument.



(1) Static pressure measurement hole
(2) Stagnation pressure measurement port
(3) and (4) to the manometer connection to measure the difference in pressure.

Fig. 18 Pitot- Static Tube

Determination of differential Pressure Head

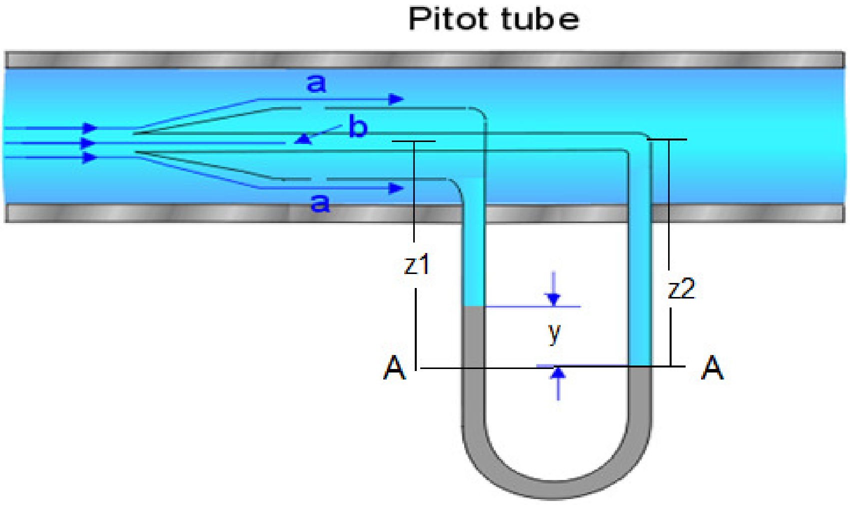


Fig 19. Differential Pressure Measurement

The differential pressure head between the stagnation and static pressure can be determined by using the principle ofmanometry.
Applying manometric equation along A-A,
It can be shown that as in the venturi and orifice meters,

$$h = y(\frac{S_m}{S} - 1) \quad \text{----------------(32)}$$

Where, S_m is the RD of Manometric liquid and S is the RD of flowing fluid

Advatages

Pitot tubes are simple, reliable, inexpensive, and suited for a variety of environmental conditions, including extremely high temperatures and a wide range of pressures.

PROBLEM 1

A pitot-static tube is used to measure the velocity of water in a pipe. The stagnation pressure head is 6m and the static pressure head is 5 m. calculate the velocity of flow assuming the coefficient of the tube equal to 0.98.

solution

Given:
Stagnation pressure head = 6 m
Static pressure head = 5m
Hence, h= 6-5 = 1m
$C_v = 0.98$

$$v = C_v\sqrt{2gh}$$

Substituting in the equation, v= 0.98 $(2x9.81x1)^{0.5}$
= **4.34 m/s**

PROBLEM 2

A pitot tube is used to measure the flow of turpentine in a pipe line. The two tappings of the pitot tube are connected to a differentia U-tube manometer. If the manometric liuid is mercury and the differential mercury level is 12 cm, what is the velocity? Take RD of turpentine = 0.86. The coefficient of the pitot tube is 0.975.

Solution

Given:
Y = 12 cm of mercury
$C_v = 0.975$
S_m is the RD of Manometric liquid = 13.6
S is the RD of flowing fluid = 0.86

$$v = C_v\sqrt{2gh}$$

$$h = y(\frac{S_m}{S} - 1)$$

h = 0.12((13.6/0.86)-1) = **1.772 m**
v= 0.975 $(2x9.81x1.772)^{0.5}$
v= 5.75 m/s