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Streamflow Measurement

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Basic references - "Discharge Measurements at Gaging Station", Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter A 8 1969.

"Calibration and Maintenance of Vertical-Axis Type Current Meters, Techniques of Water Resources Investigations of the United States Geological Survey, Book 8, Chapter B 2 1968.

Both publications available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

Streamflow, or discharge, is defined as the volume rate of flow of the water including any sediment or other solids that may be dissolved or mixed with it. Dimensions are usually expressed in cubic feet per second. Other common units are million gallons per day, acre-feet per day and in Montana, miners inches, (40 Mont. statutory miner's inches = 1 cfs).

The most common methods of determining discharge in open channels are by means of:

1. Current meters
2. Weirs
3. Parshall flumes
4. Tracer methods
5. Volumetric methods
6. Floats
7. Indirect measurements based on surveys of channel dimensions and water-surface slope

The current meter, float, some of the tracer, and some of the indirect measurement methods of determining discharge require separate determinations of velocity and area. In others, discharge is obtained without determing either velocity or area directly.

Current-Meter Measurements

Most discharge measurements of streamflow and of flow in large artificial channels are made by the current-meter method because it is adaptable to a wide range of velocities and is practically unlimited as to the total discharge which can be measured. Essentially, the method consists of: (1) measuring the velocity of flow in and the

area of each of several parts of a cross section, (2) computing the discharge in each part as the product of the velocity and area, and (3) summing the partial discharges to obtain the total. The method is referred to as the Mid-section method of computing discharge measurements and is used commonly by the U.S. Geological Survey.

Equipment

To make a discharge measurement by wading a stream the following items would be needed:

1. Current meter (Price type - AA or pygmy meter)
2. Wading rod
3. Tag line (tape for measuring width of stream)
4. Stop watch
5. Note pad & measurement forms
6. Head set.
7. Hip boots or waders.

Current-Meter Measurement Procedure

The first step in making a current-meter measurement is the selection of the cross section to be used. The reach of stream containing the selected cross section should have the following characteristics:

1. The reach should be straight and the threads of velocity parallel to each other.
2. Stable streambed free of large rocks, weeds, and protruding obstructions such as piers, which would create turbulence.
3. The profile of the streambed in the reach should be flat to eliminate any vertical component of velocity.

It is usually not possible to satisfy all of these conditions, but the best possible site using these criteria should be selected.

After the cross section has been selected, the next step is to determine the width of the stream. This is done by stringing a tag line or measuring tape across the stream. The line should be strung at right angles to the direction of flow to avoid horizontal angles in the cross section.

When the total width is known, the spacing of the verticals can be determined. Normally, about 25 to 30 partial sections are used, but with a smooth cross section and velocity distribution fewer sections may be used. The partial sections should be so spaced that

no partial section has more than 10 percent of the total discharge in it. The ideal measurement is one inwhich no partial section has more than 5 percent of the total discharge in it, but this is very seldom accomplished when 25 partial sections are used. Equal widths of partial sections across the entire cross section are not recommended unless the discharge is well distributed. The width of the partial sections should be less where depths and velocities are greater.

The hydrographer should stand in a position that least affects the velocity of the water passing the current meter, which is: With the meter rod at the tag line and facing the bank with the water flowing against the side of his leg, the hydrographer should stand from 1 to 3 inches downstream from the tag line and 18 inches or more from the meter rod. Care should be exercised in making wading measurements of narrow streams or those where the feet and legs of the hydrographer standing in the water occupy a considerable percentage of the cross section. In small streams where the width will permit, the hydrographer should stand on a plank or other support rather than in the water. The above recommendations for the proper position of the hydrographer for wading measurements were made by the Hydraulic Laboratory Committee of the Geological Survey in their report dated May 1941. These recommendations were made after extensive laboratory and field tests to determine the proper position of the hydrographer, and the report of the Committee should be read and studied by all hydrographers.

Care should be taken to keep the wading rod in a vertical position and the meter parallel to the direction of flow while the velocity is being observed. If the flow is not a right angles to the tag line, the angle coefficient should be measured carefully.

Care should be exercised in measuring streams with shifting beds, that the scoured depressions left by the hydrographer's feet do not affect sounding or velocities. Generally, the hydrographer had best measure ahead of and upstream from the direction he faces in crossing the section.

The observations made during a discharge measurement are recorded on discharge measurement note sheets. At the top of each discharge measurement note sheet, the following information should be recorded:

1. Name of stream referenced to a nearby community, if an established gaging station, or name of stream and exact location of site.
2. Date.
3. Type of meter suspension
4. Time measurement was started (military time is used).
5. Meter number.
6. Which side of stream was the starting point.

Item 6 is usually symbolized by either LEW or REW, which stand for left edge of water and right edge of water respectively. Determining left from right is done with the hydrographer facing downstream. When the measurement is completed, the time and the side of the stream the hydrographer finished on should be recorded on the note sheet.

After the equipment and the note sheet have been readied, the measurement is begun. The hydrographer indicates on his note sheet the distance from the initial point to the edge of the water. If there is depth at the edge of the water, he measures the depth of water and records it. The depth is measured by using a graduated rod.

After determining the depth, the hydrographer decides what method of velocity measurement he will use based on the depth (see table 1). Table 1 is designed so that no velocity observations will be made with the meter closer than 0.5 foot to the water surface for in the zone from the water surface to a depth of 0.5 foot, the current meter is known to give erratic results. Normally the two-point method or the 0.6 depth method is used. The setting of the meter for the particular method to be used is computed and the meter is placed at that depth. After the current meter is placed at the proper depth in the vertical it should be permitted to become adjusted to the current before the observation of velocity is started. The time required for such adjustment is usually only a few seconds if the velocities are greater than 1 foot per second, but for lower velocities, a longer period of adjustment is needed. After the meter has become adjusted to the current, the number of revolutions made by the rotor of the current meter is observed for a period of 40 to 70 seconds. Observation of time to the nearest second is sufficient. The number of revolutions and the time interval is then recorded in the notes. If the velocity is to be observed at more than one point in the vertical the meter setting is determined for the additional observation and the revolutions are timed and the data recorded. The hydrographer then moves to the next vertical and repeats this procedure recording the distance from initial point, depth, revolutions, and time interval, and then on to the next vertical until the entire cross section has been traversed.

If the direction of flow is not at right angles to the cross section, the angle that the flow makes with a flow line that would be at right angles to the tag line must be measured. The horizontal angle as it is called, is measured by holding the note sheet in a horizontal position with the point of origin (⊙) on the left edge of the note sheet over the tag line, bridge rail, or any other feature parallel to the cross section; with the long side of the note sheet parallel to the direction of flow, the tag line or bridge rail will intersect the value of the cosine of the angle on the top, bottom, or right edge of the note sheet. The cosine of the angle is then multiplied by the measured velocity to determine the velocity component normal to the measuring section.

Table 1. - Current-meter and velocity-measurement method for various depths.

Depth (feet)	Meter	Velocity Method
2.5 and above	Type AA	0.2 and 0.8
1.5 - 2.5	do	.6
.3 - 1.5	Pygmy[1]	.6

1 Used when velocities are less than 2.5 fps.

The air temperature and water temperature should be determined and recorded on the note sheet for each current meter measurement. The air temperature should be determined in the shade and the water temperature should be read while the thermometer is still in the water. The air temperature should be determined first to be certain that a dry thermometer is used.

Current Meters

A current meter is an instrument used to measure the velocity of flowing water. The principle of operation is based on the proportionality between the velocity of the water that strikes it and the rate of rotation of the rotor of the meter. By placing a current meter at a point in a stream and counting the number of revolutions of the rotor in a known interval of time, the velocity of water at that point can be determined from the calibration of the meter.

The number of revolutions of the rotor of the meter is obtained by counting the number of clicks in an earphone or by observing the number of contacts on an electric counter. The earphone or counter is in an electrical circuit which is closed twice each revolution, once each revolution, or once each fifth revolution of the rotor by contact points in the meter head. Each closure produces a click in the earphone or registers a count on the electric counter.

The time interval during which the revolutions are being counted is determined by use of a stop watch.

Care and rating of current meters

The hydrographer should examine the current meter before and after each discharge measurement with regard to the following details to make sure it is in good condition:

1. The vanes or cups of the rotor should be inspected for damage.
2. The pivot and bearing should be inspected for wear or damage.

3. The shaft should be straight. By spinning the rotor slowly, and watching the metal frame to which the cups or vanes are fastened, eccentricity in the rotor and hub assembly may be readily detected. The shaft may be bent by (1) a sharp blow, (2) raising the rotor too forcibly, and (3) by unscrewing the contact chamber cap when the rotor and hub assembly are in the raised position.

The following items should be checked before a discharge measurement is begun:

1. When supported by the hanger screw the meter should balance freely and come to rest in a horizontal position.

2. When supported on a rod the axis of the rotor should be parallel to the rod.

3. The conductor wire attached to the binding post should not interfere with the balancing of the meter or the spinning of the rotor.

Current meters should be cleaned and oiled at least daily when in use. When measurements are made in silty water it is desirable to clean and oil the meter after each measurement.

The price current meter has the following bearing surfaces which need cleaning and oiling each time the meter is used (see fig.1):

1. The pivot bearing.
2. The bearing surfaces between the penta gear and the acme threads on the shaft.
3. The cylindrical bearing of the small shaft of the penta gear.
4. The cylindrical bearing of the shaft within the bearing lug.
5. The thrust bearing between the shaft and the cap.

The pivot is the part of the meter that needs replacement most often. After being used, the pivot should be examined with a magnifying glass to see whether the point is fractured, rough, or worn flat at the apex. See table 2 for the procedure to follow for the adjustment of pivots.

Table 2 -- Adjustment of current meter pivots

(Numbers shown in this table refer to those in figure 1)

Sequence	Operation
1.	Make sure that the meter has been properly oiled, then hold meter in inverted position with pivot uppermost.
2.	Release keeper screw (19) for pivot adjusting nut (18), and unscrew the nut a few turns.
3.	Release set screw (7) and advance pivot until all vertical play of the hub assembly is eliminated.
4.	Tighten set screw (7) temporarily, and advance pivot adjusting nut (18) until it touches the yoke.
5.	Release set screw (7) (not too far because the pivot should not revolve), and advance the pivot adjusting nut one-fourth turn. Then tighten keeper screw (19).
6.	Push the pivot inward as far as it will go, and tighten set screw (7).

Note: The adjustment of the pivot for the vane type meter is identical to the above procedure except that in step 5 the pivot adjusting nut is advanced one-sixth turn rather than one-fourth turn. Also the pivots for the vane meter do not have a keeper screw in the pivot adjusting nut- instead a lock nut is used to replace parts (18) and (19).

No current meter should be transported with the pivot bearing resting on the pivot. The pivot and pivot bearing should be separated by the raising nut if provided. For pygmy meters the pivot should be removed and replaced by a brass plug when the meter is not in use.

SPIN TESTS

The spin test is an easy method of determing the condition of the current meter. In making this test, the meter should be so placed that the shaft is in a vertical position and the rotor protected from air currents. The rotor is then given a quick turn by hand to start it spinning, and the duration of its "spin" is timed with a stop watch. As the rotating rotor nears the stopping point, its motion should be carefully observed to see whether the stop is abrupt or gradual.

Regardless of the duration of the"spin", if the rotor comes to an abrupt stop, the cause of such behavior should be found and corrected before the meter is used. In such instances, a lack of oil, the maladjustment of the penta gear, and a misalinement of the yoke are possible sources of trouble that should be checked.

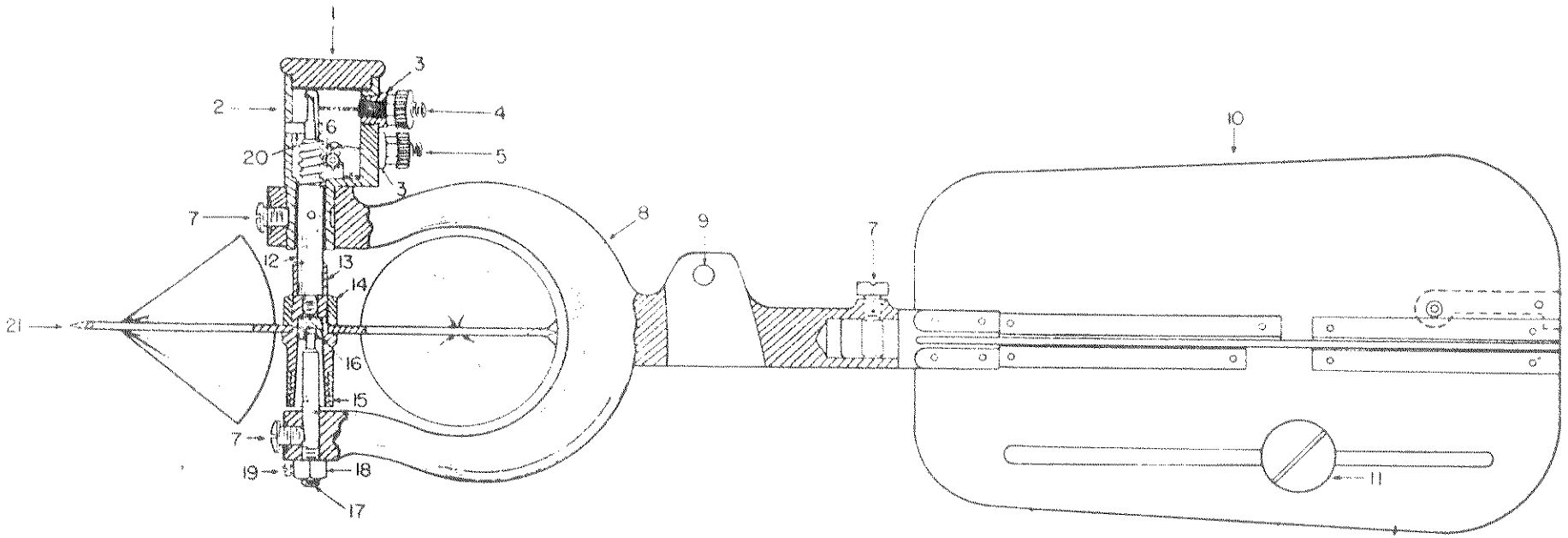
Table 3 shows the duration of spin that may be expected of various types of meters.

Table 3 -- Duration of spin tests

Type of Meter	Normal "Spin" of New (or Newly Reconditioned) Meters	*Minimum Permissable Value in Field Operations
Type A Type AA (General Duty Meters)	4 Minutes	1 1/2 Minutes
Pygmy meters	1 1/2 Minutes	1/2 Minute

*The "minimum permissible value" shown in this table applies only if the rotor comes to a smooth, gradual stop.

FIGURE 1.-- TYPE-AA SMALL PRICE CURRENT METER



Sheet 7

EXPLANATION

1 Cap for contact chamber
2 Contact chamber
3 Insulating bushing for contact binding post
4 Single-contact binding post
5 Penta-contact binding post
6 Penta gear
7 Set screws
8 Yoke
9 Hole for hanger screw
10 Tailpiece
11 Balance weight
12 Shaft
13 Bucket-wheel hub
14 Bucket-wheel hub nut
15 Raising nut
16 Pivot bearing
17 Pivot
18 Pivot adjusting nut
19 Keeper screw for pivot adjusting nut
20 Bearing lug
21 Bucket wheel