Designation: D 3858 – 95 (Reapproved 1999)

Standard Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method[1]

This standard is issued under the fixed designation D 3858; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This test method covers the measurement of the volume rate of flow of water in open channels by determining the flow velocity and cross-sectional area and computing the discharge therefrom (Refs **(1-7)**).[2]

1.2 The procedures described in this test method are widely used by those responsible for the collection of streamflow data, for example, the U.S. Geological Survey, Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Department of Agriculture, Water Survey Canada, and many state and provincial agencies. The procedures are generally from internal documents of the above listed agencies, which have become the defacto standards as used in North America.

1.3 This test method covers the use of current meters to measure flow velocities. Discharge measurements may be made to establish isolated single values, or may be made in sets or in a series at various stages or water-level elevations to establish a stage-discharge relation at a site. In either case, the same test method is followed for obtaining field data and computation of discharge.

1.4 Measurements for the purpose of determining the discharge in efficiency tests of hydraulic turbines are specified in International Electrotechnical Commission Publication 41[3] for the field acceptance tests of hydraulic turbines, and are not included in this test method.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 1129 Terminology Relating to Water[4]
D 2777 Practice for Determination of Precision and Bias of Applicable Methods of Committee D-19 on Water[4]
D 4409 Test Method for Velocity Measurements of Water in Open Channels with Rotating Element Current Meters[4]
D 5089 Test Method for Velocity Measurements of Water in Open Channels with Electromagnetic Current Meters[4]

2.2 *ISO Standard:*

ISO 3455 (1976) Calibration of Rotating-Element Current Meters in Straight Open Tanks[5]

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *current meter*—an instrument used to measure, at a point, velocity of flowing water.

3.1.2 *discharge*—the volume of flow of water through a cross section in a unit of time, including any sediment or other solids that may be dissolved in or mixed with the water.

3.1.3 *float*—a buoyant article capable of staying suspended in or resting on the surface of a fluid; often used to mark the thread or trace of a flow line in a stream and to measure the magnitude of the flow velocity along that line.

3.1.4 *stage*—the height of a water surface above an established (or arbitrary) datum plane; also termed *gage height*.

3.2 *Definitions*—For definitions of terms used in this test method, refer to Terminology D 1129.

4. Summary of Test Method

4.1 The principal of this test method consists in effectively and accurately measuring the flow velocity and cross-sectional area of an open channel or stream. The total flow or discharge measurement is the summation of the products of partial areas of the flow cross section and their respective average velocities. The equation representing the computation is:

$$Q = \Sigma (av)$$

where:
Q = total discharge,
a = individual partial cross-sectional area, and
v = corresponding mean velocity of the flow normal (perpendicular) to the partial area.

4.2 Because computation of total flow is a summation or integration process, the overall accuracy of the measurement is

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[1] This test method is under the jurisdiction of ASTM Committee D-19 on Water and is the direct responsibility of Subcommittee D19.07 on Sediments, Geomorphology, and Open-Channel Flow.

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[2] The boldface numbers in parentheses refer to the references listed at the end of this test method.

[3] For availability of this publication, contact the International Electrotechnical Commission, 3 rue de Varembe, CH 1211, Geneva 20, Switzerland.

[4] *Annual Book of ASTM Standards*, Vol 11.01.

[5] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

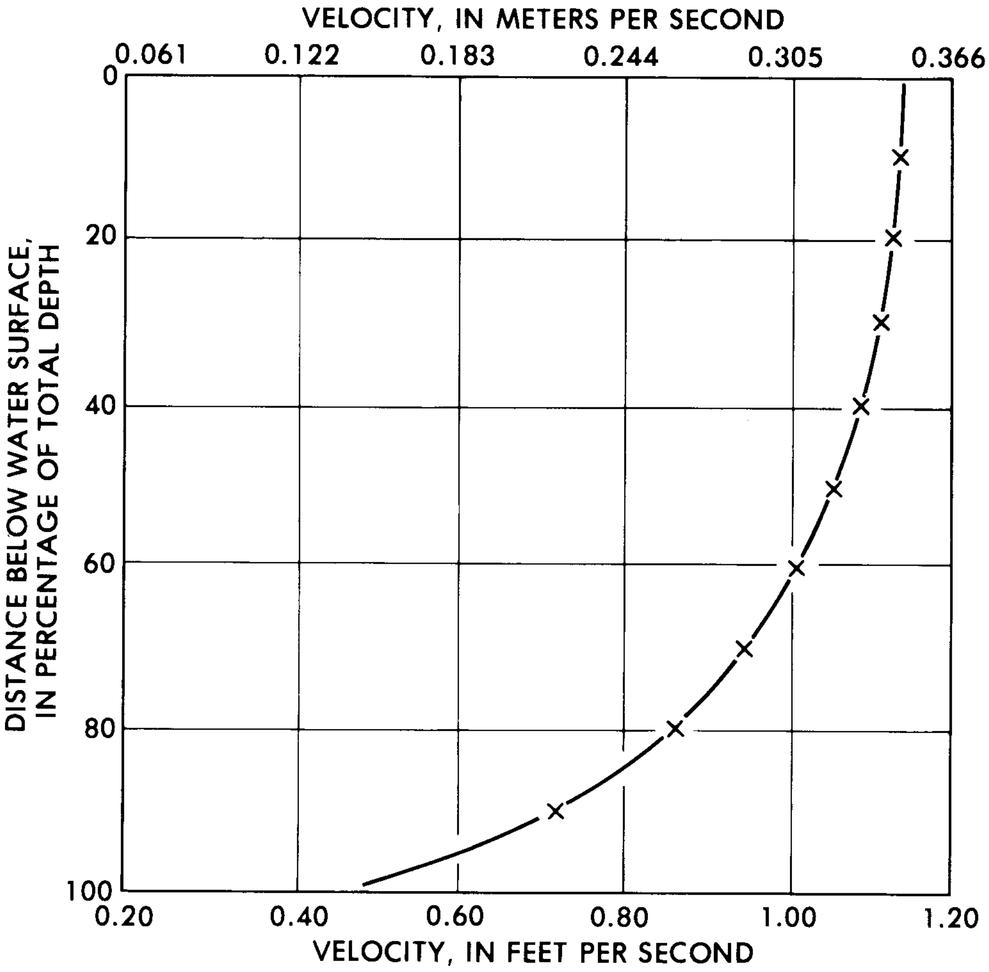

FIG. 1 Typical Open-Channel Vertical-Velocity Curve (Modified from Buchanan and Somers) [7]

generally increased by increasing the number of partial cross sections. Generally 25 to 30 partial cross sections, even for extremely large channels, are adequate depending on the variability and complexity of the flow and the cross section. With a smooth cross section and uniform velocity distribution, fewer sections may be used. The partial sections should be chosen so that each contains no more than about 5 % of the total discharge. No partial section shall contain more than 10 % of the total discharge.

NOTE 1—There is no universal "rule of thumb" that can be applied to fix the number of partial sections relative to the magnitude of flow, channel width, and channel depth because of the extreme variations in channel shape, size, roughness, and velocity distribution. Where a rating table or other estimate of total flow is available, this flow divided by 25 can serve as an estimate of the appropriate flow magnitude for each partial section.

4.3 Determination of the mean velocity in a given partial cross section is really a sampling process throughout the vertical extent of that section. The mean can be closely and satisfactorily approximated by making a few selected velocity observations and substituting these values in a known mathematical expression. The various recognized methods for determining mean velocity entail velocity observations at selected distances below the water surface. The depth selections may include choice of (1) enough points to define a vertical-velocity curve (see Fig. 1), [6] (2) two points (0.2 and 0.8 depth below water surface), (3) one point (0.6 depth), (4) one point (0.2 depth), (5) three points (0.2, 0.6, and 0.8 depth), and (6) subsurface (that is, just below the water surface) (see 10.9 for further description of each method.)

5. Significance and Use

5.1 This test method is used to measure the volume rate of flow of water moving in rivers and streams and moving over or through large man-made structures. It can also be used to calibrate such measuring structures as dams and flumes. Measurements may be made from bridges, cableways, or boats; by wading; or through holes cut in an ice cover.

5.2 This test method is used in conjunction with determinations of physical, chemical, and biological quality and sediment loadings where the flow rate is a required parameter.

6. Apparatus

6.1 Many and varied pieces of equipment and instruments are needed in making a conventional discharge measurement.

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[6] Buchanan, T. J., and Somers, W. P., "Discharge Measurements at Gaging Stations," *U.S. Geological Survey Techniques of Water-Resources Investigations*, Book 3, Chapter A8.

The magnitude of the velocity and discharge, location of the cross section, weather conditions, whether suspended, floating, or particulate matter are present in the water, and vegetative growth in the cross sections are all factors determining equipment needs. Instruments and equipment used normally include current-meters, width-measuring equipment, depth-sounding equipment, timers, angle-measuring devices, and counting equipment. The apparatus is further described in the following paragraphs.

6.1.1 *Current Meter*— Current meters used to measure open-channel flow are usually of the rotating-element (see Note 2) or electromagnetic types. Refer to Test Methods D 4409 and D 5089 for more specific information. However, the equipment sections of this test method emphasize the rotating-element meters mainly because of their present widespread availability and use. The operation of these meters is based on proportionality between the velocity of the water and the resulting angular velocity of the meter rotor. Hence, by placing this instrument at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined. Rotating-element meters can generally be classified into two main types: those having vertical-axis rotors, and those having horizontal-axis rotors. The principal comparative characteristics of the two types may be summarized as follows: (*1*) the vertical-axis rotor with cups and vanes operates in lower velocities than does the horizontal-axis rotor, has bearings that are well protected from silty water, is repairable in the field without adversely affecting the meter rating, and works effectively over a wide range of velocities; (*2*) the horizontal-axis rotor with vanes disturbs the flow less than does the vertical-axis rotor because of axial symmetry with flow direction, and is less likely to be fouled by debris. Also, the rotor can be changed for different velocity ranges and meters of this type are more difficult to service and adjust in the field.

NOTE 2—Vertical-axis current meters commonly used are of the Price type and are available in two sizes, the large Price AA and the smaller Pygmy meter. The rotor assembly of the type AA is 5 in. (127 mm) and the Pygmy is 2 in. (51 mm) in diameter. The rotor assemblies of both meters are formed with 6 hollow metal or solid plastic cone-shaped cups.

The small Price pygmy meter is generally used when the average depth in a stream cross section is less than 1.5 ft (0.5 m) and velocity is below 2.5 ft/s (0.8 m/s). The large Price type meter should be used when average depths are greater than 1.5 ft (0.5 m). For high velocities, the large meter may be used for shallower depths. Do not change the meter if a few partial sections are outside these limits. In any case, meters should not be used closer to the streambed than 1.5 rotor or probe diameters.

Current meters used in the measurement of open-channel flow are exposed to damage and fouling by debris, ice, particulate matter, sediment, moss, and extreme temperature variations, and should be selected accordingly. Meters must be checked frequently during a discharge measurement to ensure that they have not been damaged or fouled.

6.1.2 *Counting Equipment*—The number of revolutions of a rotor in a rotating-element type current meter is obtained by an electrical circuit through a contact chamber in the meter. Contact points in the chamber are designed to complete an electrical circuit at selected frequencies of revolution. Contacts can be selected that will complete the circuit once every five revolutions, once per revolution, or twice per revolution of the rotor. The electrical impulse produces an audible click in a headphone or registers a unit on a counting device. The count rate is usually measured manually with a stopwatch, or automatically with a timing device built into the counter.

6.1.3 *Width-Measuring Equipment*—The horizontal distance to any point in a cross section is measured from an initial point on the stream bank. Cableways, highway bridges, or foot bridges used regularly in making discharge measurements are commonly marked with paint marks at the desired distance intervals. Steel tapes, metallic tapes, or premarked taglines are used for discharge measurements made from boats or unmarked bridges, or by wading. Where the stream channel or cross section is extremely wide, where no cableways or suitable bridges are available, or where it is impractical to string a tape or tagline, the distance from the initial point on the bank can be determined by optical or electrical distance meters, by stadia, or by triangulation to a boat or man located on the cross-section line.

6.1.4 *Depth-Sounding Equipment*—The depth of the stream below any water surface point in a cross section, and the relative depth position of the current meter in the vertical at that point, are usually measured by a rigid rod or by a sounding weight suspended on a cable. The selection of the proper weight is essential for the determination of the correct depth. A light weight will be carried downstream and incorrectly yield depth observations that are too large. A "rule of thumb" for the selection of proper sized weights is to use a weight slightly heavier in pounds than the product of depth (feet) times velocity (feet per second) (no direct metric conversion is available). The sounding cable is controlled from above the water surface either by a reel or by a handline. The depth-sounding equipment also serves as the position fixing and supporting mechanism for the current meter during velocity measurements. Sonic depth sounders are available but are usually not used in conjunction with a reel and sounding weight.

6.1.5 *Angle-Measuring Devices*—When the direction of flow is not at right angles to the cross section, the velocity vector normal to the cross section is needed for the correct determination of discharge. The velocity as measured by the current meter, multiplied by the cosine of the horizontal angle between the flow direction and a line perpendicular to the cross section, will give the velocity component normal to the measuring cross section. A series of horizontal angles and corresponding cosine values are usually indicated as a series of marked points on the measurement note form (standard form) or on a clipboard. The appropriate cosine value is then read directly by orienting the note form or clipboard with the direction of the cross section and the direction of flow. When measuring in deep swift streams, it is possible to sound the depth but the force of the current moves the weight and meter into positions downstream from the cross section; hence, the depths measured are too large (see Fig. 2).[6] Measurement of the vertical angle (between the displaced direction of the sounding line and the true vertical to the water surface) is necessary for computation of both air-line and wet-line corrections to the measured depth. A protractor for measuring vertical angles is considered to be special equipment which is available. Tables of air-line and wet-line corrections are also

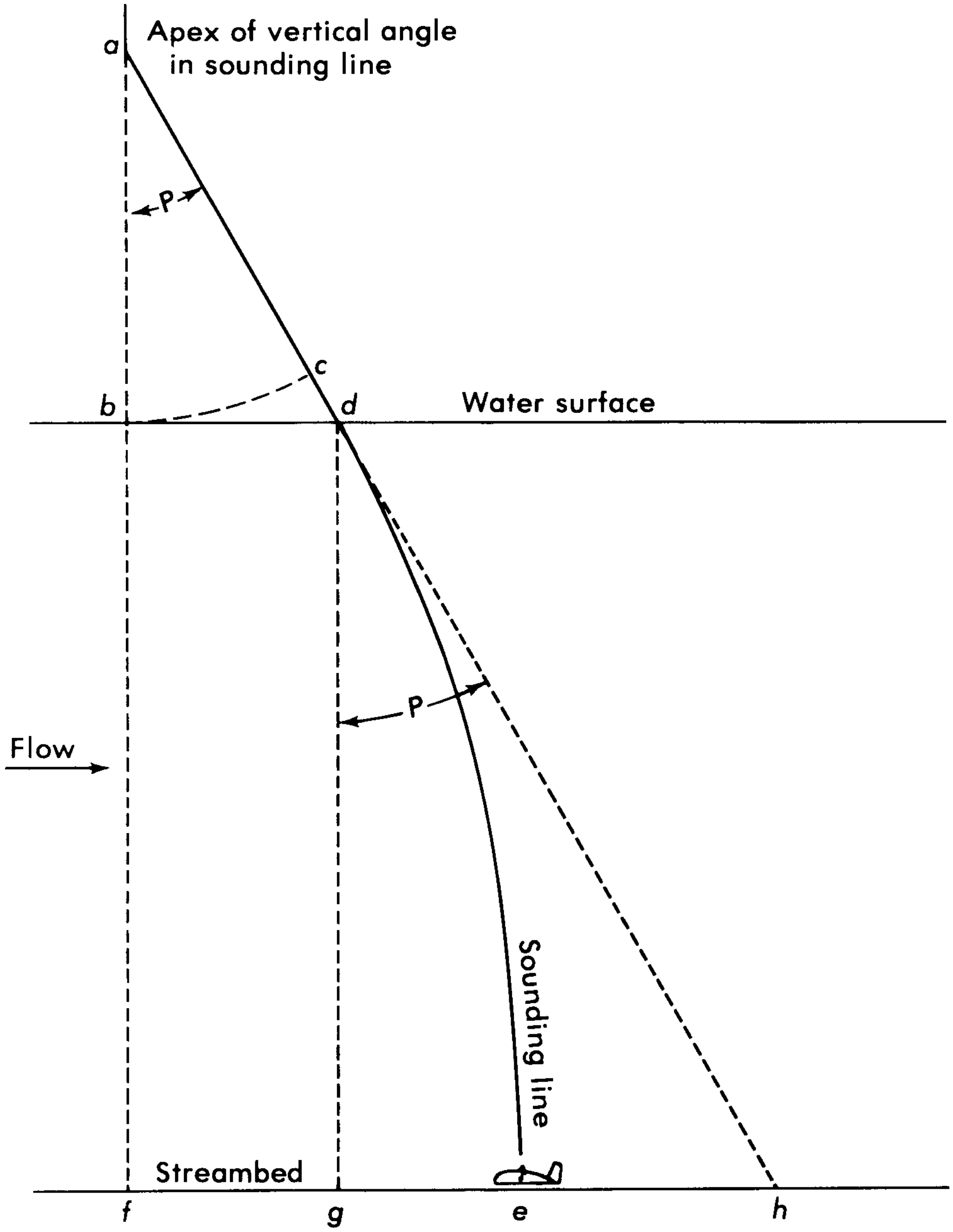


FIG. 2 Position of Sounding Weight and Line in Deep, Swift Water (from Buchanan and Somers) [7]

available. Tags or colored streamers placed on the sounding line at known distances above the center of the meter facilitate the measurement of depth, may eliminate the need for air-line corrections, and facilitate setting the meter at the proper depth.

6.1.6 *Miscellaneous Equipment*—The type and size of the equipment necessary to make a velocity-area discharge measurement are extremely variable, depending on the magnitude of the discharge to be measured. Items such as sounding reels, streamlined sounding weights that range in size from 15 to 300 lb (6.8 to 136 kg), wading rods, handlines, taglines, etc., are available to measure discharges, velocities, and cross-sectional dimensions of almost any magnitude normally found in open-channel or stream settings.

7. Sampling

7.1 Sampling as defined in Terminology D 1129 is not applicable in this test method.

7.2 Make spatial sampling of velocity and flow in accordance with procedures and principles set forth in 4.2, 4.3, and 10.9

8. Calibration

8.1 To meet stipulated accuracy standards, it is necessary that rigid controls be established and observed in the manufacturing, care, and maintenance of current meters.

8.1.1 For all practical purposes, virtually all vertical-axis rotating-element meters of a specific type and manufacturer are identical. Some of the large organizations using these meters obtain rigid controls by supplying the production dies and fixtures and detailed specifications to manufacturers, so that identical properties are assured for each unit produced.The rating equations for the meters are nearly identical and a standard meter-rating table can be developed for each group of meters received from a common supply source.

8.2 Current-meter rating facilities have been constructed for the purpose of developing quality control and uniformity in the whole current-meter rating procedure (see ISO 3455). At these rating facilities a current meter is "rated" by towing it through a long tank of still water. The meter is rigidly suspended from an electrically driven car that rides on rails precisely anchored along the top edges of the tank. The car is driven at precisely controlled speeds, for a large number of independent runs, to simulate a range of velocities representing those normally encountered in streamflow measurement.

9. Procedure

9.1 *Site Selection*— The selection of a suitable site for making a discharge measurement will greatly affect the accuracy of that measurement. The stream should be straight above and below the measuring section with the main thread of flow parallel to the banks. As a rule, the stream should be straight for at least three channel widths above and below the selected section. The streambed should be free of large rocks, piers, weeds, or other obstructions that will cause turbulence or create a vertical component in measured velocity. Water velocities and depths at the selected section must be consistent with capabilities of the equipment available for making the measurement.

9.2 *Current Meter Measurement by Wading*—Wading measurements usually are preferred if stream depth and velocity conditions permit. When the selection of a site is not dependent on an overhead structure this allows a wider range in choice of possible cross-section locations. Because the field person is in the water near his measuring equipment, he is in a position to note changes in channel geometry, flow angles, or obstructions which might effect flow patterns. In a wading measurement, the current meter is mounted on a wading rod in such a way that when the rod is held in a true vertical position, the meter is parallel to flow. The technician must stand in a position, usually to the side and slightly downstream from the rod, so that his body will not obstruct flow past the meter. As a "rule of thumb," wading measurements are unsafe when the product of water velocity (feet per second) times depth (feet) exceeds 10 (metres per second times depth in metres exceeds 1).

9.3 *Current Meter Measurement from Bridges*—Bridges are frequently used as a platform for making discharge measurements. Measurements from bridges are made by suspending the current meter on a handline or on a line attached to a sounding reel mounted on a bridge crane or bridge board. A sounding weight is suspended below the meter to hold it in position and as a method of obtaining the water depth. Measurements can be made from either the upstream or downstream sides of a bridge. The upstream side is generally preferred because the hydraulic characteristics of the bridge structure are less likely to affect the flow, streambed scour is less, and the presence of approaching drift in the stream is more visible. Advantages of the downstream side are that the need for horizontal-angle corrections to the flow vector may be minimized by the effects of the bridge-support structure. In situations where a bridge has a pedestrian walkway, that may offer a safer working environment. Older bridge alignments were generally perpendicular to riverbanks to minimize the clear span; modern bridge alignments may cross streams at skewed angles or even on curves. Such bridges are difficult to work from because of constantly changing horizontal-angle corrections.

9.4 *Current Meter Measurements from Cableways*—At sites where the frequency of discharge measurements is high, for example, as at a gaging station, a cableway may be erected to serve as a platform for measuring equipment and personnel. The advantage of a cableway is that it can be located at the most suitable hydraulic features on a stream. The meter and sounding weight are suspended by cable from a sounding reel in the same manner as from a bridge. Most cableways are built to accommodate hand-powered cablecars, to carry the field person across the stream. A few larger installations are equipped with gasoline-powered cablecars.

9.5 *Current Meter Measurements from Boats*—Small, lightweight boats, usually powered by outboard motors, are frequently used as a platform for making discharge measurements. Measurement sites can be selected on the basis of favorable hydraulic characteristics. Heavy taglines are usually attached to both streambanks to hold the boat in a cross section oriented perpendicular to the flow. Meter and sounding weight are suspended by cable attached to a boom extending over the bow of the boat, and data-collection procedures are similar to those used on bridges and cableways.

9.6 *Current Meter Measurements Under Ice Cover*—In regions where rivers freeze over during the winter, measurement of discharge through holes cut or drilled in the ice is common. Positioning of the current meter and the determination of water depth are most commonly obtained with a wading rod. For deep-swift-moving streams, cable suspension equipment is required. Sounding reels are mounted on specially designed sleds or stands and specially designed sounding weight hangers have been developed to pass through ice holes as small as 8 in. (200 mm) in diameter.

9.6.1 The presence of an ice sheet on top of the water surface changes the way the water depth is computed. When an ice cover exists, it is necessary to compute the effective depth, that is, the depth of water beneath the ice cover. At holes cut with an ice chisel, chain saw, or ice drill, the total depth is measured from the water surface in the hole to the streambed. Then the distance from the water surface to the bottom of the ice layer is measured using an ice rod, L-shaped scale, or similar device. The effective depth is computed by subtracting the latter value from the total depth. In those cases where a thick slush layer exists below the ice cover, its thickness is determined by lowering the meter through it until it turns freely, then raising the meter until the rotor stops. The distance thus determined is then subtracted from the overall depth of water. The partial section area computation is made by multiplying the effective depth times the width, which is obtained in the same manner as is an open-water wading measurement.

9.6.2 The presence of ice cover can have the effect of added channel roughness and resistance to flow. Therefore, the shape of the vertical-velocity profile is altered. When velocity is obtained by either the 0.2 and 0.8 depth method or by measuring the vertical-velocity profile, the observations are used as in an open-water measurement. However, if the 0.6 depth method is used, a coefficient of 0.92 is applied to the velocity observations to adjust for the added resistance of the ice sheet. An acceptable alternate procedure is to obtain a velocity observation at 0.5 depth and apply a coefficient of 0.88.

10. Calculation

10.1 In the velocity-area method of making a discharge measurement it is assumed that the velocity sample for each partial cross section represents the mean velocity in that section. The lateral extent of a given partial cross-section spans half the distance toward the preceding meter location and half the distance toward the next meter location. The vertical extent is from the streambed to the water surface at the vertical in which the meter is located. Observations of velocity are normally made along with measurements of the sounded depth.

10.2 The total flow cross section (see Fig. 3) is defined by depths at locations 1, 2, 3, 4, 5, ... *n*. At each of these locations the mean of the vertical distribution of velocity is approximated to the desired accuracy through a selected sampling technique of current-meter measurements. The discharge for the partial cross section at location x is then computed as:

$$q_x = v_x\left[\frac{b_x - b_{(x-1)}}{2}\right] + \left[\frac{b_{(x+1)} - b_x}{2}\right] d_x = v_x\left[\frac{b_{(x+1)} - b_{(x-1)}}{2}\right] d_x$$

where:

q_x = discharge through partial section *x*,
v_x = mean velocity at location *x*,
b_x = distance from initial point to location *x*,
$b_{(x+1)}$ = distance from initial point to center of next partial section, and
d_x = water depth at location *x*.

Hence, the partial stream discharge through partial 4 (heavily outlined in Fig. 3) is computed as:

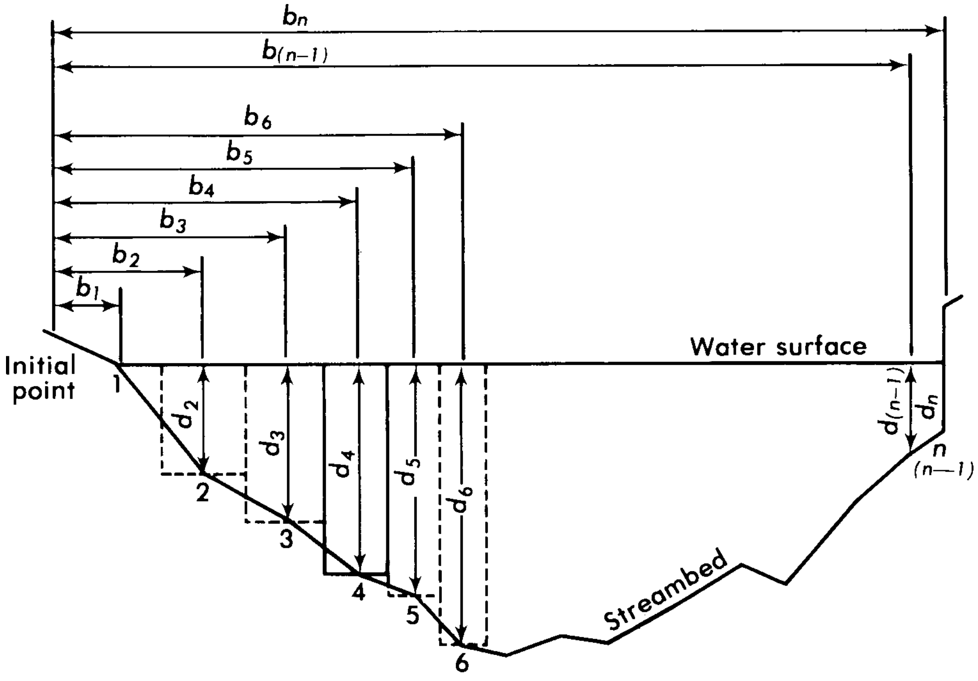
$$q_4 = v_4\left[\frac{b_5 - b_3}{2}\right] d_4$$

10.3 Discharge computations at the end sections shown in Fig. 4 differ slightly in that there is no "preceding location" at location 1 and no "next location" at location *n*. Therefore,

$$q_1 = v_1\left[\frac{b_2 - b_1}{2}\right] d_1$$

$$q_n = v_n\left[\frac{b_n - b_{(n-1)}}{2}\right] d_n$$

However, d_1 is zero in the example and therefore q_1 must also be zero. The depth at location *n* is shown as a finite vertical distance, which could occur at canal walls or at bridge piers



EXPLANATION

1,2,3...............n	Observation points
b_1, b_2, b_3..........b_n	Distance, in feet, from the initial point to the observation point
d_1, d_2, d_3..........d_n	Depth of water, in feet, at the observation point
Dashed lines	Boundary of partial sections; one heavily outlined discussed in text

FIG. 3 Definition Sketch of Midsection Method of Computing Cross-Section Area for Discharge Measurements (from Buchanan and Somers) [7]

and abutments. Because it is impossible to obtain a current-meter velocity measurement exactly at location *n*, the velocity is usually estimated as a percentage of the velocity measured at the preceding section. A "rule of thumb" for selection of this correction is 85 to 95 %, depending on the roughness of the structure and the observed effect on the flowlines. End sections should therefore be chosen to have small widths.

10.4 In case of narrow streams, the horizontal spacing of partial sections is partially dependent on the width of the current meter. Normal minimum section spacing for Type AA Price meters is 0.5 ft (150 mm) and for the Pygmy meter 0.2 ft (60 mm). For exceptionally small measuring sections, where the total channel width is about 2 ft (0.6 m) or less, section spacing as close as 0.1 ft (30 mm) improves the accuracy of the measurement.

10.5 The summation of the discharges for all of the partial sections is the total discharge of the stream.

10.6 In order to determine the velocity at a point with a current meter, it is necessary to immerse the meter at that point for a measured interval of time, usually 40 to 70 s. Do not begin timing until disturbances caused by inserting the meter have subsided. It is then necessary for the measurement process to span a period of time that is long enough to smooth and average out transient velocity fluctuations. When the timing interval is completed, the velocity value is found from a meter-rating table for the particular meter. Refer to Test Method D 4409 for guidelines on checking performance of rotating element current meters.

10.7 Periodically remove the current meter from the water for examination during the measurement, usually when moving from one vertical location to another.

10.8 Take care to ensure that the current-meter velocity observations are not affected by upstream obstructions in the channel, random surface waves, and wind.

10.9 As stated in 4.3, there are various recognized methods of measuring the mean velocity in a vertical. Each method has its merits depending on the time available to make the measurement, the width of the stream cross section and depth of water, the streambed roughness, whether the stage is changing, whether the flow is steady or unsteady, and type of current-meter suspension. Some of the relative merits and uses of the various methods are as follows:

10.9.1 The vertical-velocity curve method for determining a mean velocity value (see Fig. 1) normally requires averaging velocity readings taken at 0.1 depth increments over the interval between 0.1 to 0.9 of the depth. This method is valuable in determining coefficients for application to results of other methods. Generally, however, it is not used for routine discharge measurements because of the large amount of time required to collect nine velocity readings in each vertical in order to compute each mean velocity.

10.9.2 The two-point depth method (0.2 and 0.8 depth below the water surface) averages the velocities observed at these two depths in a vertical and this average is used as the mean velocity for that vertical. A rough test of whether or not the velocities at the 0.2 and 0.8 depths are sufficient for determining the mean vertical velocity is given in the following criterion: the 0.2-depth velocity should be greater than the 0.8-depth velocity but no more than twice as great. If this test is not met then the 3-point depth method should be used. Experience has shown that this method gives more consistent and accurate results than any of the other methods except the vertical-velocity curve method. The two-point depth method generally is not used at depths less than 2.5 ft (0.76 m) because the settings for a large rotating element meter or 1.5 ft (0.46 m) for the pygmy meter would be too close to the water surface and streambed for dependable results.

10.9.3 The six-tenths depth method (0.6 depth below water surface) uses the observed velocity at this depth as the mean velocity in the vertical. This method gives reliable results whenever the water depth is too shallow for application of the two-point depth method, whenever large amounts of slush ice or debris prevent observation of the 0.2 depth velocity for the two-point depth method, or whenever the stage or flow is changing rapidly and a measurement must be made quickly.

10.9.4 The two-tenths depth method (0.2 depth below water surface) uses the observed velocity at this depth, multiplied by a coefficient, to obtain a value for the mean in the vertical. This method is used mainly during periods of extremely high flow when the velocities are great, making it impossible to obtain reliable velocity measurements at the 0.8 or 0.6 depth. A general knowledge of the cross section, the relative depths with stage, and the vertical-velocity curve at the location are needed if it is impossible to obtain reliable depth soundings. A coefficient of about 0.87 is typically used as the multiplier for the velocity readings. A sizeable error in the assumed 0.2 depth is not critical to accuracy because the vertical-velocity curve at this point is usually nearly vertical. Normally, the two-point and six-tenths depth methods are preferred to this method because of their greater accuracy.

10.9.5 The three-point depth method consists of measuring the velocity at 0.2, 0.6, and 0.8 of the depth, thereby combining the two-point and six-tenths depth methods. The mean velocity is obtained by averaging the 0.2 and 0.8 depth observations and then averaging this result with the 0.6 depth measurement. This method is used when the velocities in the vertical are abnormally distributed. The depths must exceed 2.5 ft (0.86 m) before this method is used, if the measurements are being made with large rotating-element current meters.

10.9.6 The subsurface method of velocity determination observes the velocity at some small distance below the water surface and converts this velocity determination to a mean velocity in the vertical through the use of a coefficient of 0.86. The observation of velocity should be far enough below the water surface to avoid the effect of surface disturbances. This method is used when it is impossible to obtain reliable depth soundings.

10.9.7 The surface method has limited use but is appropriate in such events as major floods. Floating debris or ice is simply timed over a known or estimated distance. In these circumstances, a knowledge of the vertical-velocity curve at the location and a reliable estimate of an applicable coefficient is needed to convert a surface velocity to a mean velocity in the vertical. A coefficient of about 0.85 is commonly used. The surface or float method is appropriate when it is impossible to use a current meter because of excessive velocities and depths, or where velocities and depths are too low for a current-meter measurement.

11. Precision and Bias

11.1 Determination of the precision and bias for this test method is not possible, both at the multiple and single operator level, due to the high degree of instability of open channel flow. Both temporal and spatial variability of the boundary and flow conditions do not allow for a consent standard to be used for representative sampling. A minimum bias, measured under ideal conditions, is directly related to the bias of the equipment used and is listed in the following sections. A maximum precision and bias cannot be estimated due to the variability of the sources of potential errors listed in 11.3 and the temporal and spatial variability of open channel flow. Any estimate of these errors could be very misleading to the user.

11.2 In accordance with 1.6 of Practice D 2777, an exemption to the precision and bias statement required by Practice D 2777 was recommended by the results advisor and concurred with by the Technical Operations Section of the Committee D-19 Executive Subcommittee on June 7, 1989.

11.3 The accuracy of a flow measurement by the velocity-area method is directly related to the following:

11.3.1 The accuracy in the total and section width measurements. Where the measurement of the width between verticals is normally based on distance measurements from a reference point on the back, the error is usually negligible. Normally, width measurements are made and recorded to 1 ft (300 mm) units, except when partial section widths are less than 1 ft (300 mm) in which case measurements to 0.1 ft (30 mm) units are used. Where the measurements are by optical means, the errors will depend on the distance magnitudes and equipment used.

11.3.2 The errors in measuring the depths relate to both individual soundings and readings of the water level. These errors can be extremely variable depending on the depth and roughness of the channel, velocity of flow, stability of the bed materials, roughness of the water surface, distance of observer above the water surface, and adequacy of sounding weights. When discharge measurements are made by cable suspension from bridges or cableways, depth observations are generally recorded to 0.1 ft (30 mm). For wading measurements, where the depths are small and the technician is close to the equipment, depth readings to 0.02 ft (6 mm) to 0.05 ft (15 mm) are possible.

11.3.3 The errors in determining point velocities in a vertical will depend on the accuracy of the measuring equipment (current meter), the method used for velocity measurement (see 10.9), the accuracy in placement of the current meter, the duration of the velocity sampling period, closeness to boundaries, and the irregularity of the velocity distribution in time and space. Meters should not be used to sense velocities outside their calibration limits. Velocity observations are generally recorded to two decimal places, in feet per second (5.28 ft/s or 1.61 m/s), except at extremely low flow, where three-decimal accuracy may be used (0.233 ft/s or 0.068 m/s).

11.3.4 The overall errors in determining stream discharge by the velocity area method relate particularly to the choice of the number of verticals and to the number of measurement points in each vertical. Errors will also depend on the width of channel, the ratio of width to depth, the method of computation used, and the irregularity of stream velocity in time and space. Measured discharge is generally calculated to three-significant figure accuracy. [7]

11.3.5 It has been shown that discharge measurements having 30 partial sections and using the two-point depth method of observation, with a 45-s period of observation, will have a standard error of 2.2 %. This means that two thirds of the measurements made using this procedure would be in error by 2.2 % or less. It has also been shown that the standard error is 4.2 % for a 25-s period of observation, using the 0.6 depth method of velocity observations, with depth and velocity observed at 16 partial sections. The error caused by using the latter shortcut method is generally less than the error that can be expected by shifting of flow patterns during periods of rapidly changing stage.

12. Keywords

12.1 discharge measurement; open channel flow; water discharge

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[7] Carter, R. W., and Anderson, I. E., “Accuracy of Current-Meter Measurements,” *Journal of the Hydraulics Division—Proceedings of the American Society of Civil Engineers*, Vol 89, No. HY 4, July 1963, American Society of Civil Engineers, pp. 105–115.

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REFERENCES

(**1**) Carter, R. W., and Davidian, Jr., "General Procedures for Gaging Streams," U.S. Geological Survey, *Techniques of Water Resources Investigations*, Book 3, Chapter A-6, 1968.

(**2**) Buchanan, T. J., and Somers, W. P., "Discharge Measurements at Gaging Stations," U.S. Geological Survey, *Techniques of Water Resources Investigations*, Book 3, Chapter A-8, 1969.

(**3**) Smoot, G. E., and Novak, C. E., "Calibration and Maintenance of Vertical Axis Type Current Meters," U.S. Geological Survey, *Techniques of Water Resources Investigations*, Book 8, Chapter B-2, 1968.

(**4**) U.S. Bureau of Reclamation, *Water Measurement Manual*, Second Edition Revised Reprint 1974, U.S. Government Printing Office, 1974.

(**5**) Rantz, S. E., "Measurement and Computation of Streamflow," *Measurement of Stage and Discharge*, Vol I, Water Supply Paper 2175, 1982.

(**6**) *ISO Standard 748-1979E*—Measurement of Liquid Flow in Open Channels, International Standards Organization, 1979.

(**7**) *National Handbook of Recommended Methods for Water Data Aquisition*, U.S. Geological Survey, 1977.

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