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

[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.

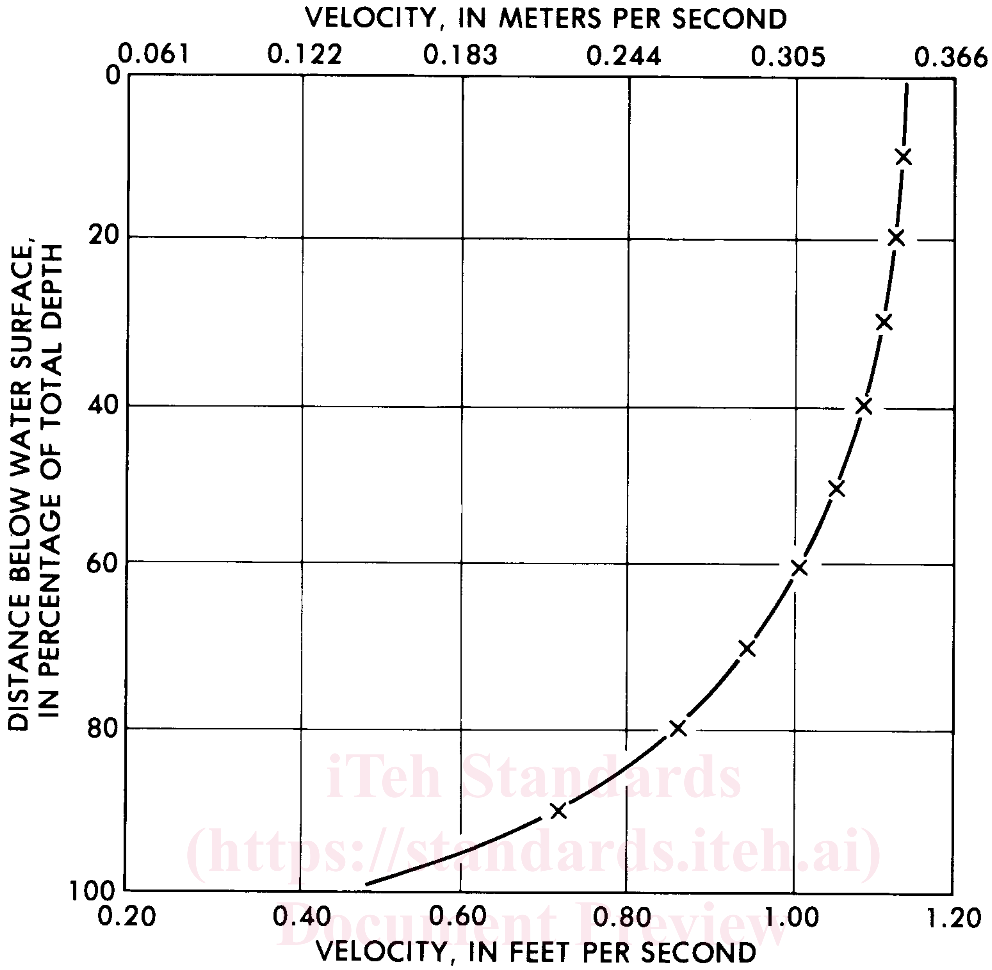

FIG. 1 Typical Open-Channel Vertical-Velocity Curve (Modified from Buchanan and Somers) [7]

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.

[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

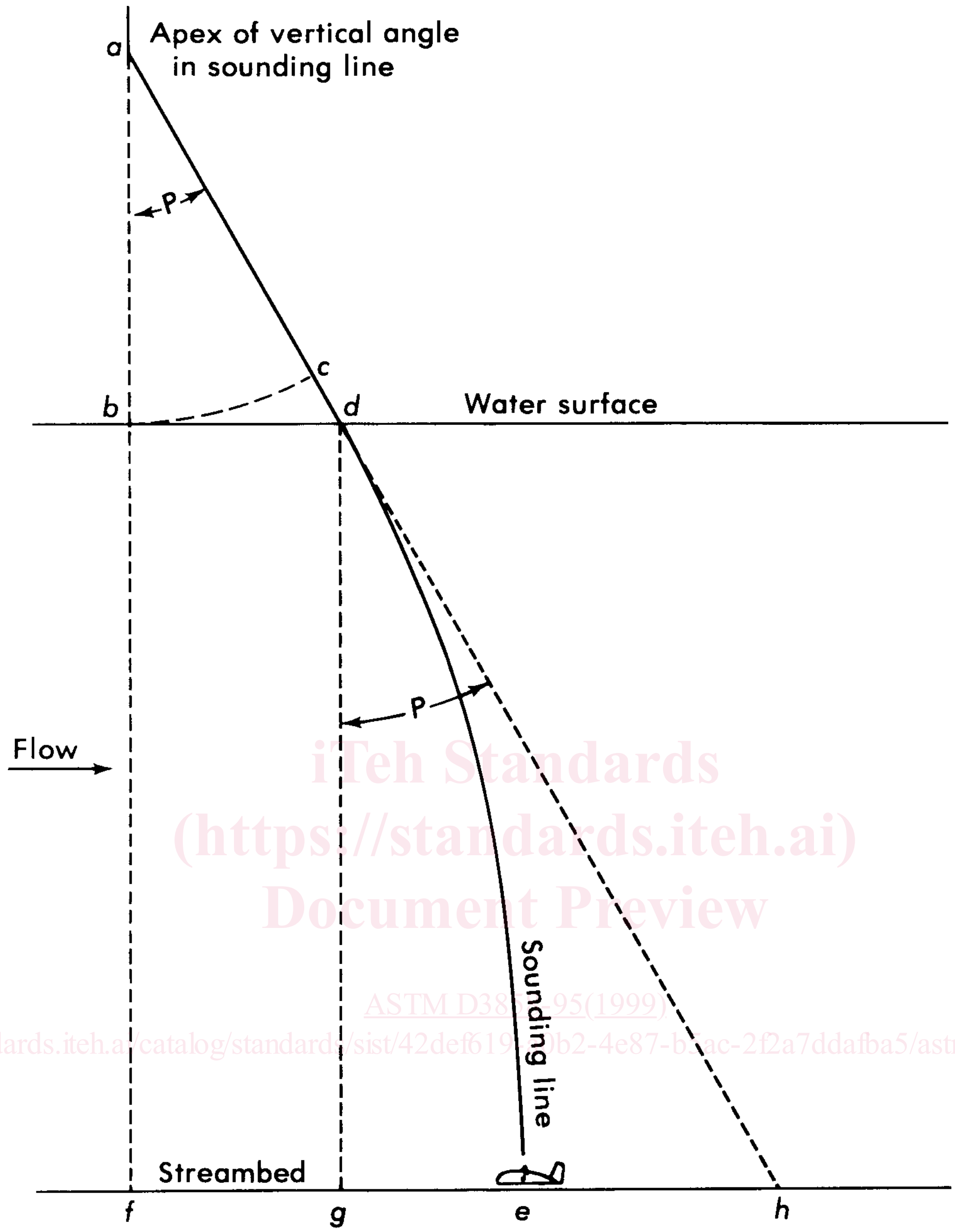

FIG. 2 Position of Sounding Weight and Line in Deep, Swift Water (from Buchanan and Somers) [7]

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