Designation: D5614 – 94 (Reapproved 2014)

Standard Test Method for Open Channel Flow Measurement of Water with Broad-Crested Weirs[1]

This standard is issued under the fixed designation D5614; 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 measurement of the volumetric flow rate of water in open channels with two types of horizontal broad-crested weirs: those having a square (sharp) upstream corner and those having a well-rounded upstream corner.

1.2 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.3 *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:*[2]

D1129 Terminology Relating to Water

D2777 Practice for Determination of Precision and Bias of Applicable Test Methods of Committee D19 on Water

D3858 Test Method for Open-Channel Flow Measurement of Water by Velocity-Area Method

2.2 *ISO Standards:*[3]

ISO 555-1973 Liquid Flow Measurement in Open Channels—Dilution Methods for Measurement of Steady Flow—Constant Rate Injection Method

ISO 3846-1989 Liquid Flow Measurement in Open Channels by Weirs and Flumes—Rectangular Broad-Crested Weirs

ISO 4373-1979 Measurement of Liquid Flow in Open Channels—Water Level Measuring Devices

ISO 4374-1990 Liquid Flow Measurement in Open Channels by Weirs and Flumes—Round-Nose Horizontal Crest Weirs

3. Terminology

3.1 *Definitions*—For definitions of terms used in this test method, refer to Terminology D1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *boundary layer displacement thickness*— the boundary layer is a layer of fluid flow adjacent to a solid surface (in this case, the weir crest and sidewalls) in which, due to viscous friction, the velocity increases from zero at the stationary surface to an essentially frictionless-flow value at the edge of the layer. The displacement thickness is a distance normal to the solid surface that the flow streamlines can be considered to have been displaced by virtue of the boundary-layer information.

3.2.2 *crest*—the horizontal plane surface of the weir.

3.2.3 *critical flow*—open channel flow in which the energy, expressed in terms of depth plus velocity head, is a minimum for a given flow rate and channel. The Froude number is unity at critical flow.

3.2.4 *Froude number*—a dimensionless number expressing the ratio of inertial to gravity forces in free surface flow. It is equal to the average velocity divided by the square root of the product of the average depth and the acceleration due to gravity.

3.2.5 *head—in this test method* , the depth of water above a specified elevation. The measuring head is the depth of flow above the weir crest measured at an appropriate location upstream of the weir; the downstream head is referenced similarly to the crest elevation and measured downstream of the weir. The head plus the corresponding velocity head is often termed the total head or total energy head.

3.2.6 *hydraulic jump*—an abrupt transition from supercritical flow to subcritical or tranquil flow, accompanied by considerable turbulence or gravity waves, or both.

3.2.7 *nappe*—the curved sheet or jet of water overfalling the downstream end of the weir.

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

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

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3.2.8 *primary device*—the device (in this case, the weir) that creates a hydrodynamic condition that can be sensed by the secondary instrument.

3.2.9 *Reynolds number*—a dimensionless number expressing the ratio of inertial to viscous forces in a flow. The pertinent Reynolds number on the weir crest is equal to the (critical) velocity multiplied by the crest length and divided by the kinematic viscosity of the water.

3.2.10 *secondary instrument— in this case*, a device that measures the depth of flow (referenced to the crest elevation) at an appropriate location upstream of the weir. The secondary instrument may also convert this measured head to an indicated flow rate or could totalize flow rate.

3.2.11 *stilling well*—a small free-surface reservoir connected through a restricted passage to the head-measurement location upstream of the weir so that a head measurement can be made under quiescent conditions.

3.2.12 *subcritical flow*—open channel flow that is deeper and at lower velocity than critical flow for the same flow rate; sometimes called tranquil flow. A Froude number less than one exists.

3.2.13 *submergence*—a condition in which the water level on the downstream side of the weir is high enough to affect the flow over the weir and hence alter the head-discharge relation. It is usually expressed as a ratio or percentage of downstream to upstream head or downstream to upstream total head.

3.2.14 *supercritical flow*—open channel flow that is shallower and at higher velocity than critical flow for the same flow rate. A Froude number greater than one exists.

3.2.15 *tailwater*—the water elevation immediately downstream of the weir.

3.2.16 *tranquil flow*—see *subcritical flow*.

3.2.17 *velocity head*—the square of the average velocity divided by twice the acceleration due to gravity.

4. Summary of Test Method

4.1 In broad-crested weirs, the length of the horizontal crest in the direction of flow is large enough relative to the upstream head for essentially rectilinear critical flow to occur at some point along the crest. This ideally permits the flow rate to be obtained from a single measurement of the upstream head; a corrective coefficient must be applied in practice. This coefficient has been evaluated experimentally for square-edge weirs and can be determined analytically for rounded weirs.

5. Significance and Use

5.1 Broad-crested weirs can be used for accurate measurements of a wide range of flow rates, but their structural simplicity and sturdiness make them particularly useful for measuring large flows under field conditions.

5.2 Because they require vertical sidewalls, broad-crested weirs are particularly adaptable to rectangular artificial channels or to natural and artificial channels that can readily be lined with vertical sidewalls in the immediate vicinity of the weir.

6. Interferences

6.1 Broad-crested weirs are not suitable for use in sediment-laden streams that are carrying heavy bed loads. However, floating debris is readily passed, particularly by the rounded weir (see 7.2.1).

6.2 Broad-crested weirs cannot be used beyond submergence limits because insufficient data exist to document their performance. It is therefore necessary to adhere to the tailwater-level limitations described in this test method.

7. Apparatus

7.1 A broad-crested weir measuring system consists of the weir itself and its immediate channel (the primary) and a head measuring device (the secondary). The secondary device can range from a simple staff gage for visual readings to an instrument that senses the depth continuously, converts it to a flow rate, and displays or transmits a readout or record of the instantaneous flow rate or totalized flow, or both.

7.2 *Square-Edge (Rectangular) Broad-Crested Weir:*

7.2.1 *Configuration*—The square-edge broad-crested weir as shown in Fig. 1 is rectangular in longitudinal profile and provides a plane horizontal crest that has finite length in the direction of flow and extends the full width of the channel between vertical sidewalls. A contracted section must be constructed as shown (see also 7.4.1.2) if the channel does not have vertical sidewalls or is wider than the desired crest. The vertical sidewalls must extend downstream of the downstream face of the weir a distance of at least twice the maximum head. Recommended limits on dimensions and geometric ratios are given in 7.2.5. The upstream and downstream faces must be vertical and perpendicular to the channel surfaces, and it is important that the upstream corner be square and sharp.

NOTE 1—High flow rates combined with floating debris may damage the sharp edge; rounded-edge weirs should be considered for such applications.

7.2.2 *Construction Requirements:*

7.2.2.1 The structure must be sturdy enough to withstand the maximum flow rate and must be watertight so that no measurable leakage can bypass it.

7.2.2.2 *Finish*—Large weirs constructed in the field should have a finish equivalent to that of smooth concrete. Smaller weirs, such as those in a laboratory environment, should have a smoothness equivalent to that of rolled sheet metal.

7.2.2.3 *Level*—The crest must not deviate from a level plane by more than 0.01 ft (2 mm) at any point or exceed a slope of 0.01 anywhere.

7.2.3 *Head Measurement Location*—Make the head measurement at a distance of 3 h to 4 h_{max} upstream of the upstream face of the weir, where h_{max} is the anticipated maximum head.

7.2.4 *Head-Discharge Relations:*

7.2.4.1 *Basic Equations*—The basic relation for the flow rate, Q, over a broad-crested weir is, in compatible units,

$$Q = (2/3)^{3/2} g^{1/2} C_v C_d B h^{3/2} \quad (1)$$

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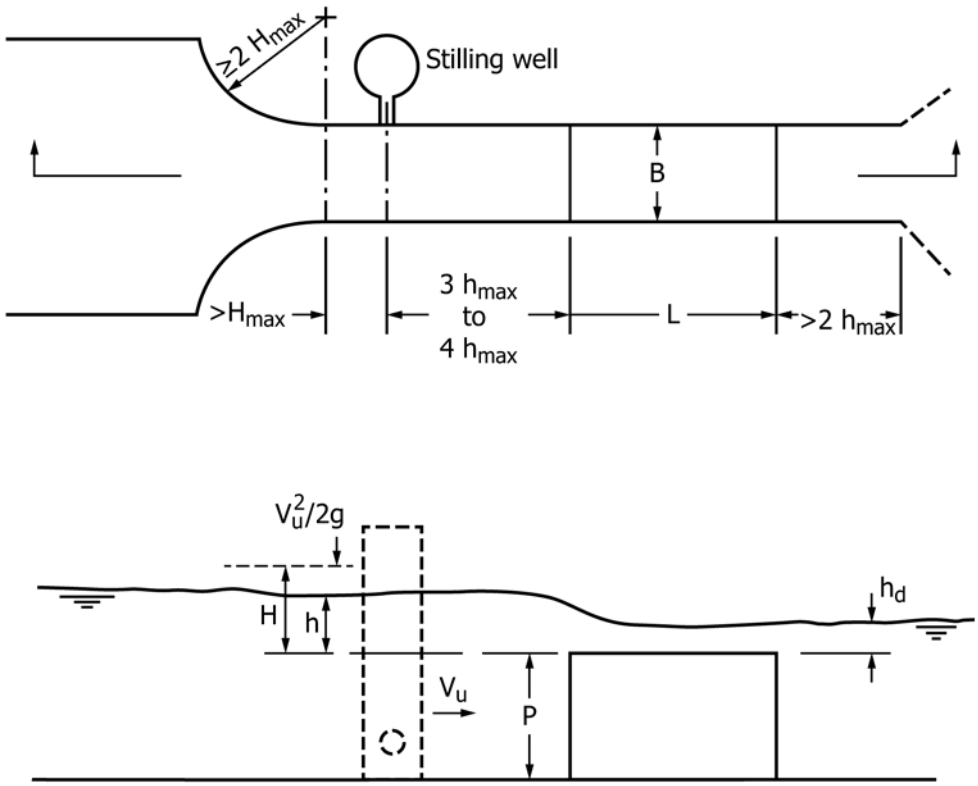

FIG. 1 Square-Edge Broad-Crested Weir

where:

h = measured upstream head referenced to the crest elevation,
B = width of the weir between the vertical side-walls,
g = acceleration due to gravity,
C_d = discharge coefficient that accounts for departures from ideal conditions, and
C_v = velocity-of-approach coefficient that permits the flow rate to be related to the measured head rather than the total head, H. Then,

$$C_v = (H/h)^{3/2} = [(h + \alpha V^2{}_u/2g)/h]^{3/2} \quad (2)$$

where:

V_u = average velocity at the head-measurement location, and
α = coefficient that accounts for any increase in the kinetic energy term caused by a nonuniform velocity distribution. However, in this test method, the approach velocity is considered sufficiently close to uniform (see 7.4.1) for α to be essentially unity.

7.2.4.2 In the case of square-edge weirs, both C_d and C_v are affected by the head-to-weir height ratio, h/P, so it is convenient to combine them into a single coefficient, C; then,

$$Q = (2/3)^{3/2} g^{1/2} CBh^{3/2} \quad (3)$$

7.2.4.3 *Discharge Coefficient, C:*

(1) The discharge coefficient is given as a function of h/L and h/P in Fig. 2, which has been adapted from ISO 3846-1989.

(2) The discharge coefficient for $h/L \leq 0.3$ is constant at 0.850, provided that $h/P < 0.15$. (For $h/L > 0.4$, the weir is no longer truly broad crested in accordance with 4.1, since the flow over the crest is curvilinear throughout.)

7.2.5 *Limiting Conditions*—The flow conditions and dimensions of the square-edge weir are subject to the following limits:

(1) $h > 0.2$ ft (0.06 m), or 0.1 L, whichever is larger;
(2) $B > 1$ ft (0.3 m);
(3) $P > 0.5$ ft (0.15 m);
(4) $0.1 < h/L < 1.6$;
(5) $h/P < 1.6$; and
(6) $0.1 < L/P < 4$.

The minimum h is recommended in order to minimize the effects of surface tension, viscosity, and surface roughness and to avoid small heads that may be difficult to measure accurately. The minimum h/L prevents frictional effects from causing the point of critical flow to shift away from the upstream end of the crest. The limitation on maximum h/P is intended to reduce the likelihood of upstream disturbances, and the remaining limitations are recommended mainly to conform to the experiments from which the coefficients were obtained. Limiting values of tailwater depth to avoid submergence are given in 7.4.2.2.

7.3 *Rounded Broad-Crested Weir:*

7.3.1 *Configuration:*

7.3.1.1 The rounded broad-crested weir is shown in Fig. 3. As in the square-edge weir, a plane level crest of finite

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