Designation: D5390 – 21

Standard Test Method for Open-Channel Flow Measurement of Water with Palmer-Bowlus Flumes[1]

This standard is issued under the fixed designation D5390; 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 and wastewater in sewers and other open channels with Palmer-Bowlus flumes.

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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D1129 Terminology Relating to Water

D1941 Test Method for Open Channel Flow Measurement of Water with the Parshall Flume

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

D5242 Test Method for Open-Channel Flow Measurement of Water with Thin-Plate Weirs

2.2 *ISO Standards:*[3]

ISO 4359 Liquid Flow Measurement in Open Channels—Rectangular, Trapezoidal and U-Shaped Flumes

ISO 555 Liquid Flow Measurements in Open Channels—Dilution Methods for Measurement of Steady Flow—Constant Rate Injection Method[3]

2.3 *ASME Standard:*[4]

Fluid Meters Their Theory and Application

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this standard, refer to Terminology D1129.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *boundary layer displacement thickness, n*—a layer of fluid flow adjacent to a solid surface (in this case, the flume throat) in which, owing 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 surface and flow streamlines can be considered to have been displaced by virtue of the boundary-layer formation.

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

3.2.3 *Froude number, n*—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.

3.2.4 *head, n*—the depth of flow referenced to the floor of the throat measured at an appropriate location upstream of the flume; this depth plus the velocity head is often termed the total head or total energy head.

[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.

[4] Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Three Park Ave., New York, NY 10016-5990, http://www.asme.org.

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

3.2.6 *long-throated flume, n*—a flume in which the prismatic throat is long enough relative to the head for essentially critical flow to develop on the crest.

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

3.2.8 *Reynolds number, n*—a dimensionless number expressing the ratio of inertial to viscous forces in a flow. In a flume throat the pertinent Reynolds number is equal to the (critical) throat velocity multiplied by the throat length and divided by the kinematic viscosity of the water.

3.2.9 *scow float, n*—an in-stream float for depth sensing, usually mounted on a hinged cantilever.

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

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

3.2.12 *subcritical flow, n*—open channel flow that is deeper and at lower velocity than critical flow for the same flow rate; sometimes called tranquil flow.

3.2.13 *submergence, n*—a condition where the depth of flow immediately downstream of the flume is large enough to affect the flow through the flume so that the flow rate can no longer be related to a single upstream head.

3.2.14 *supercritical flow, n*—open channel flow that is shallower and at higher velocity than critical flow for the same flow rate.

3.2.15 *tailwater, n*—the water elevation immediately downstream of the flume.

3.2.16 *throat, n*—the constricted portion of the flume.

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

4. Summary of Test Method

4.1 In Palmer-Bowlus flumes, critical free-surface flow is developed in a prismatic throat so that the flow rate is a unique function of a single measured upstream head for a given throat shape and upstream channel geometry. This function can be obtained theoretically for ideal (frictionless) flows and adjustments for non-ideal conditions can be obtained experimentally or estimated from fluid-mechanics considerations.

5. Significance and Use

5.1 Although Palmer-Bowlus flumes can be used in many types of open channels, they are particularly adaptable for permanent or temporary installation in circular sewers. Commercial flumes are available for use in sewers from 4 in. to 6 ft (0.1 to 1.8 m) in diameter.

5.2 A properly designed and operated Palmer-Bowlus is capable of providing accurate flow measurements while introducing a relatively small head loss and exhibiting good sediment and debris-passing characteristics.

6. Interferences

6.1 Flumes are applicable only to open-channel flow and become inoperative under full-pipe flow conditions.

6.2 The flume becomes inoperative if downstream conditions cause submergence (see 7.3.2).

7. Apparatus

7.1 A Palmer-Bowlus flume measuring system consists of the flume itself (the primary), with its immediate upstream and downstream channels, and a depth or head measuring device (the secondary). The secondary device can range from a simple scale or gauge for manual readings to an instrument that continuously senses the head, converts it to a flow rate, and displays or transmits a readout or record of the instantaneous flow rate or the totalized flow, or both.

7.2 *The Palmer-Bowlus Flume:*

7.2.1 *General Configuration:*

7.2.1.1 The Palmer-Bowlus flume is a class of long-throated flume in which critical flow is developed in a throat that is formed by constricted sidewalls or a bottom rise, or both. Sloped ramps form gradual transitions between the throat and the upstream and downstream sections. See Fig. 1. The flume was developed primarily for use in sewers[5] but it is adaptable to other open channels as well. There is no standardized shape for Palmer-Bowlus flumes and, as long-throated flumes, they can be designed to fit specific hydraulic situations using the theory outlined in 7.2.3.

7.2.1.2 *Prefabricated Flumes*—Prefabricated flumes with trapezoidal or rectangular throats and with circular or U-shaped outside forms are commercially available for use in sewers. Although there is no fixed shape for Palmer-Bowlus flumes, many manufacturers of trapezoidal-throated flumes use the proportions shown in Fig. 2. These prefabricated flumes are also available in several configurations depending on how they are to be installed, for example, whether they will be placed in the channel at the base of an existing manhole, inserted into the pipe immediately downstream of the manhole, or incorporated into new construction. The size of these prefabricated flumes is

[5] Palmer, H. K., and Bowlus, F. D., "Adaptation of Venturi Flumes to Flow Measurements in Conduits," *Trans. ASCE*, Vol 101, 1936, pp. 1195–1216.

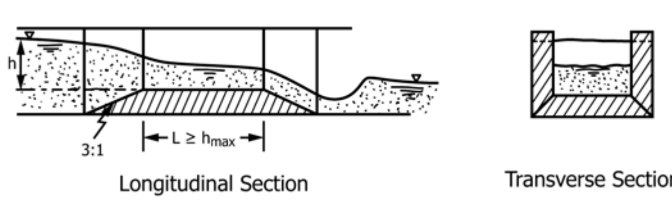

FIG. 1 Generalized Palmer-Bowlus (Long-Throated) Flume in a Rectangular Channel