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Standard Guide for
Methods for Measuring Well Discharge[1]

This standard is issued under the fixed designation D 5737; 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 guide covers an overview of methods to measure well discharge. This guide is an integral part of a series of standards prepared on the in-situ determination of hydraulic properties of aquifer systems by single- or multiple-well tests. Measurement of well discharge is a common requirement to the determination of aquifer and well hydraulic properties.

1.2 This guide does not establish a fixed procedure for any method described. Rather, it describes different methods for measuring discharge from a pumping or flowing well. A pumping well is one type of control well. A control well can also be an injection well or a well in which slug tests are conducted.

1.3 This guide does not address borehole flow meters that are designed for measuring vertical or horizontal flow within a borehole.

1.4 The values stated in SI units are to be regarded as standard.

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.* Furthermore, it is the user's responsibility to properly dispose of water discharged.

1.6 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*

D 653 Terminology Relating to Soil, Rock, and Contained Fluids[2]

D 1941 Test Method for Open Channel Flow Measurement of Water with the Parshall Flume[3]

D 4043 Guide for Selection of Aquifer-Test Method in Determining Hydraulic Properties by Well Techniques[4]

D 5242 Test Method for Open-Channel Flow Measurement of Water Indirectly at Culverts[3]

D 5390 Test Method for Open Channel Flow Measurement with Palmer-Bowlus Flumes[5]

D 5716 Test Method to Measure the Rate of Well Discharge by Circular Orifice Weir

2.2 *ISO Standard:*

Recommendation R541 Measurement of Fluid Flow by Means of Orifice Plates and Nozzles[6]

2.3 *ANSI Standard:*

Standard 1042 Part 1 Methods for the Measurement of Fluid Flow in Pipes, 1, Orifice Plates, Nozzles and Venturi Tubes[6]

2.4 *ASME Standard:*

Standard MFC-3M-1989 Measurement of Fluid Flow in Pipes Using Orifice, Nozzle, and Venturi[7]

3. Terminology

3.1 *Definitions:*

3.1.1 *conceptual model*—an interpretation or description of the characteristics, interactions, and dynamics of a physical system.

3.1.2 *control well*—a well by which the head and flow in the aquifer is changed, by pumping, injection, or imposing a change of head.

3.1.3 *discharge*—or rate of flow, is the volume of water that passes a particular reference section in a unit of time.

3.1.4 *totalizing flow meter*—a flow meter that indicates the cumulative flow displayed as a volume. The flow rate is calculated based on the time between two readings.

3.2 For definitions of other terms used in this guide, see Terminology D 653.

[1] This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

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[2] *Annual Book of ASTM Standards*, Vol 04.03.

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

[4] *Annual Book of ASTM Standards*, Vol 04.08.

[5] *Annual Book of ASTM Standards*, Vol 11.02.

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

[7] Available from American Society of Mechanical Engineers, 345 E. 47th Street, New York, NY 10017.

4. Significance and Use

4.1 This guide is limited to the description of test methods typical for measurement of ground-water discharge from a control well.

4.1.1 Controlled field tests are the primary means of determining aquifer properties. Most mathematical equations developed for analyzing field tests require measurement of control well discharge.

4.1.2 Discharge may be needed for evaluation of well design and efficiency.

4.1.3 For aquifer tests, a conceptual model should be prepared to evaluate the proper test method and physical test requirements, such as well placement and design (see Guide D 4043). Review the site data for consistency with the conceptual model. Revise the conceptual model as appropriate and consider the implications on the planned activities.

4.1.4 For aquifer tests, the discharge rate should be sufficient to cause significant stress of the aquifer without violating test assumptions. Conditions that may violate test assumptions include conversion of the aquifer from confined to unconfined conditions, lowering the water level in the control well to below the top of the well screen, causing a well screen entrance velocity that promotes well development during the test, or decreasing the filter pack permeability characteristics.

4.1.5 Some test methods described here are not applicable to injection well tests.

4.2 This guide does not apply to test methods used in measurement of flow of other fluids used in industrial operations, such as waste water, sludge, oil, and chemicals.

5. Test Methods

5.1 *Selection of a Well Discharge Rate Measurement Method*—Select a well discharge measurement method based on the desired discharge rate or rates, the desired pumping method, the required accuracy and frequency of measurement, the type of pump discharge and the water conveyance method.

5.2 *Principal Well Discharge Rate Measurement Methods*—A summary of principal methods is given below for typical hydrogeologic testing. Additional information may be found in a publication of the National Institute of Standards and Technology (NIST) **(1)**[8], the American Society of Mechanical Engineers (ASME) **(2)** or in a comprehensive book on the subject of flow meter engineering **(3)**. Discharge methods can be classified as open channel flow and closed conduit flow. Open channel flow is limited to calibrated control structures, such as weirs and flumes. Closed conduit flow includes methods such as turbine meters and magnetic meters. Also included are methods that measure the discharge of water from the closed conduit to the air, such as the orifice tube.

5.3 *Open Channel Flow Methods*:

5.3.1 *Weirs*—A weir is a vertical obstruction that restricts the total flow of water in channel. Weirs fall into three general classifications, sharp crested, broad crested, and suppressed. Sharp crested weirs use a flat plate that is configured in a triangular "V" or rectangular shape; they are described in 5.3.1.1. See Test Method D 5242. Broad crested weirs are wide rectangular restrictions that are usually only used as spillways in dams. They are not described here. More information on broad crested weirs may be found in Ref **(4)**. A third classification of weirs, called suppressed weirs, are more commonly known as flumes. Flumes are discussed in 5.3.2.

5.3.1.1 *Sharp Crested Weirs*—The weir is placed flush against the flowing stream, and the notch is made as sharp as possible using a flat piece of metal with sharp edges forming the weir notch. The relation between the head and the discharge of a weir varies according to the shape of the weir notch. A weir is inexpensive to construct, easy to install and highly accurate when installed and used properly.

5.3.2 *Flume*—A flume is a device that restricts flow in the channel which causes the water to accelerate, producing a corresponding change in the water level. The head can then be related to discharge. Several types of flumes have been developed; the most common flume for measuring well discharge is the Parshall flume, originally designed by R. L. Parshall of the U.S. Soil Conservation Service **(5)**. See Test Methods D 1941 and D 5390.

5.3.2.1 Flumes have several advantages over weirs. The most important of these is the self-cleaning capacity of flumes compared with sharp-edged weirs. Head losses through a flume are also much less than for a weir, so when the available head is limited, flumes are more desirable. Flumes can function over a wide range of discharges and still require only a single upstream head measurement. However, flumes require more time to set up than weirs.

5.4 *Closed Conduit Methods*:

5.4.1 *Invasive Methods*:

5.4.1.1 *Turbine-Type (Propeller) Flow Meters*—A totalizing flow meter is a device used in measuring water in most domestic and commercial potable water uses. This flow meter consists of a flow tube in which a rotor blade is mounted together with either a means of generating an electrical signal proportional to the angular velocity of the rotor or a mechanical system of gears that rotates proportional to the flow volume. The meter is installed as a section of the water line between the pump and the point of discharge. Turbine-type flow meters have a limited operating range. The meter must be calibrated and the pipe must be full. Mechanical turbine meters typically only totalize flow.

5.4.2 *Noninvasive Methods*:

5.4.2.1 *Magnetic Flow Meters*—The magnetic flow meter operates on the same general principle as an electric generator **(2)**. The pipe is placed such that the fluid path is normal to the magnetic field. The motion of the fluid through the magnetic field induces an electromotive force across the fluid. By placing insulated electrodes in the pipe in a plane normal to the magnetic field the strength of the field can be measured using a special voltmeter. An electromotive force is induced in the flowing water (that is, the conductor) across a pair of electrodes. Advantages are that there is no added head loss. Disadvantages include their relatively high cost and potential errors due to scaling.

5.4.2.2 *Venturi Meters*—The venturi meter uses the relationship between pressure and flow velocity across a throat.

[8] The boldface numbers given in parentheses refer to a list of references at the end of the text.

Advantages include less head loss relative to orifice meters and less required maintenance. More information may be gained from British Standard 1042.

5.4.2.3 *Acoustic Meters*—The acoustic meter, also called the sonic meter or doppler flow meter, uses sound waves in conjunction with knowledge of pipe wall thickness to allow estimation of flow rate. Many acoustic meters require suspended material or entrapped air to obtain a quality reading. An advantage of acoustic meters over other types is their limited mechanical parts and thus longer equipment life. A disadvantage is sensitivity to pipe encrustation.

5.4.3 *Discharge to Air Methods*:

5.4.3.1 *Bucket and Stop Watch*—The bucket and stop watch method is simply the collection of discharged water in a container of known volume for a measured period of time. The volume collected divided by the time the water is collected is the discharge rate over that time period. Alternately, the volume can be determined by measuring the weight and using a density conversion. The rate is measured periodically over the course of the test. Advantages include its ease to set up and the simplicity of taking readings. Disadvantages include its manual operation and inability to obtain continuous measurements.

5.4.3.2 *Orifice Bucket*—The orifice bucket is a container with precisely cut holes in the bottom and a calibrated piezometer tube on the side. The well discharge is directed into the top of the bucket where water then accumulates as it is delayed in flowing out the holes located in the base of the container. The accumulated head can be read on the piezometer tube. The discharge is read from a chart relating discharge to head. The device is especially useful in measuring rates of production of reciprocating and airlift pumps where the flow is not at a uniform rate. An orifice bucket 30.5 cm (12 in.) in diameter can be constructed to measure discharge rates from 8 to 151 L/min (2 to 40 gal/min). An orifice bucket 61.0 cm (24 in.) in diameter can be constructed to measure discharge rates from 38 to 680 L/min (10 to 180 gal/min). Advantages include its ease in setup and use and its ability to be configured with a float water level recorder. The orifice bucket was described by the Illinois State Water Survey **(5)**.

5.4.3.3 *Circular Orifice Weir*—Also called the orifice tube and orifice meter, the circular orifice weir is the device often used to measure the discharge rate from a high-capacity pump. The orifice meter is a circular restriction in a pipe that causes back pressure that can be measured in a piezometer tube. The water level in the piezometer tube is the pressure head in the approach pipe when water is being pumped through the orifice. For any size of orifice diameter and approach pipe diameter, the rate of flow through the orifice varies with the pressure head in the piezometer tube. For example, a discharge of 208 L/min (55 gal/min) will cause 12.7 cm (5 in.) of head due to a 6.35-cm (2½-in.) orifice and a 10.16-cm (4-in.) approach pipe. Similarly, a discharge of 20 100 L/min (5 310 gal/min) will cause 177.8 cm (70 in.) of head due to a 30.48-cm (12-in.) orifice and a 40.64 cm (16-in.) approach pipe. Advantages are the low cost and relatively high accuracy of measurement. Disadvantages include the relatively low range of measurement, high head loss, and physical constraints, for example, the orifice meter must be level and must always run full. For more information see I.S.O. Recommendation R541 and Layne Western Company, Inc. **(6)** and Test Method D 5716.

5.4.3.4 *Trajectory Method*—The flow rate can be determined from measurement of the trajectory of a horizontal pipe discharge to the air. Curves were prepared from Purdue University experiments in 1948 on pipes from 5.08 to 15.24 cm (2 to 6 in.) in diameter **(1)**. Tabularized data also exist for discharge from vertical pipes.

5.5 *Procedures Specific to Measurement of Well Discharge for Aquifer Test Analysis*:

5.5.1 Certain aquifer tests require variation of the discharge rate over the course of the test. Therefore, select a test method that is capable of accurate measurement over the required discharge rate range.

5.5.2 Methods that allow continuous measurement of discharge are desirable to establish any change or trend. Most test methods for analysis of aquifers properties include an assumption that the discharge is constant. Some variation is acceptable. The specific aquifer test analysis method should be considered in determining acceptable variation in discharge.

6. Report

6.1 Prepare a report presenting the purposes of discharge measurement and the criteria used in selecting a particular method. Discuss the frequency of discharge measurements required and the anticipated accuracy of the measurement method.

7. Keywords

7.1 aquifer; aquifer test methods; discharge rate; flume; ground water; weir

REFERENCES

(**1**) National Institute of Standards and Technology Special Publication 421, *A Guide to Methods and Standards for the Measurement of Water Flow*, Kulin, G. and Compton, P. R., Institute for Basic Standards, NIST, Washington, D.C. 20234, May 1975.

(**2**) *Fluid Meters, Their Theory and Application, A Report of ASME Research Committee on Fluid Meters*, Sixth Edition, edited by H. S. Bean, American Society of Mechanical Engineers, 345 East 47th Street, New York, NY 10017, 1971.

(**3**) Spink, L. K., *Principles and Practice of Flow Meter Engineering*, Ninth Edition, The Foxboro Co. Foxboro, MA, 1967.

(**4**) *Water Measurement Manual*, Bureau of Reclamation, U.S. Dept. of the Interior, U.S. Government Printing Office, 1984.

(**5**) Parshall, R. L., *Measuring Water in Irrigation Channels with Parshall Flumes and Small Weirs*, Soil Conservation Circular No. 843, U.S. Department of Agriculture, May, 1950.

(**6**) *Measurement of Water Flow Through Pipe Orifice With Free Discharge*, Bulletin 501, Published by Layne & Bowler, Inc., Memphis, TN, available from Layne Western Company, Inc. 5800 Foxridge Dr., Mission, KS 66202, 1958.