Standard Test Method for Measuring the Rate of Well Discharge by Circular Orifice Weir[1]

This standard is issued under the fixed designation D 5716; 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 construction and operation of a circular orifice weir for measuring the discharge from a well. This test method is a part of a series of standards prepared on the in situ determination of hydraulic properties of aquifer systems by single- or multiple-well tests. Selection of a well discharge measurement test method is described in Guide D 5737.

1.2 This test method is common to a number of aquifer test methods and to evaluation of well and pump performance.

1.3 *Limitations*—This test method is limited to the description of a method common to hydraulic engineering for the purpose of ground water discharge measurement in temporary or test conditions.

1.4 Much of the information presented in this test method is based on work performed by the Civil Engineering Department of Purdue University during the late 1940s. The essentials of that work have been presented in a pamphlet prepared by Layne-Bowler, Inc.[2] and updated by Layne Western Company, Inc.[3]

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information only.

1.6 *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 653 Terminology Relating to Soil, Rock, and Contained Fluids[4]

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

D 5737 Guide for Methods for Measuring Well Discharge

3. Terminology

3.1 *Definitions:*

3.1.1 *circular orifice weir*—a circular restriction in a pipe that causes back pressure that can be measured in a piezometer tube. Also called *orifice tube* and *orifice meter*.

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.

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

3.3 *Symbols:Symbols and Dimensions:*

3.3.1 *A*—orifice plate open area [L^2].

3.3.2 *C*—coefficient of discharge for the orifice [*nd*].

3.3.3 *g*—acceleration due to gravity [LT^{-2}].

3.3.4 *h*—head in manometer [*L*].

3.3.5 *Q*—control well discharge [L^3T^{-1}].

3.3.6 *o*—orifice diameter [*L*].

3.3.7 *d*—pipe inside diameter [*L*].

4. Summary of Test Method

4.1 This test method involves pumping a control well at a constant or variable rate for a given period of time. Discharge is through an orifice weir that allows determination of the discharge rate.

4.2 This test method provides design information for construction of an orifice weir. It also describes setup, operation, inspection, calculation of discharge, and reporting.

5. Significance and Use

5.1 Many mathematical equations for determining aquifer properties based on controlled field tests utilizing a single or multiple-pumping wells include a dependent variable, termed discharge, and generally designated as *Q*. Equations have been developed for constant and variable discharge. Those for variable discharge may specify regularly increasing, or regularly decreasing, or randomly varying discharge rate.

5.2 Aquifer testing has been conducted for the purposes of production and pressure relief well design and water resource assessment. Production wells are used for public and industrial

[1] This test method 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] *Measurement of Water Flow Through Pipe Orifice With Free Discharge*, Bulletin 501, Layne-Bowler, Inc., Mission, KS, 1958.

[3] *Measurement of Water Flow Through Pipe Orifice With Free Discharge*, Layne-Western Company, Inc., Mission, KS, 1988.

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

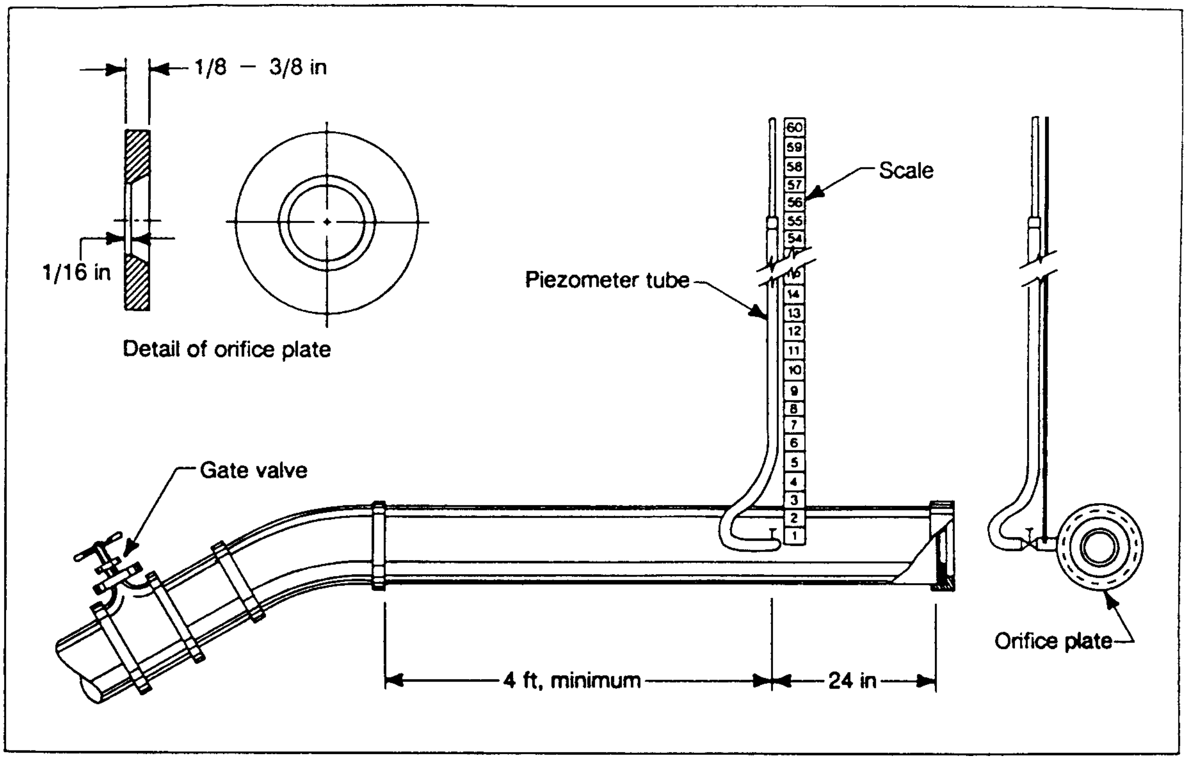

FIG. 1 Construction of a Circular Orifice Weir[5]

water supplies, hydraulic controls, and ground water capture. Pressure relief wells are for hydraulic controls. Test wells are for the purpose of water resource assessment.

5.3 Discharge must also be known for certain methods to evaluate well and pump performance.

6. Apparatus

6.1 *Construction of a Circular Orifice Weir*—A construction diagram of a circular orifice weir is presented in Fig. 1.[5] The circular orifice is a hole located in the center of a plate attached to a straight horizontal length of discharge pipe. The pipe is at least 6 ft (1.8 m) in length. Twenty-four inches (609 mm) from the end plate and at least 4 ft (1.2 m) from the other end of the discharge pipe, a manometer is attached to the discharge pipe so that the head in the discharge pipe can be measured.

6.1.1 *Orifice Plate*—The orifice is a round hole with clean, square edges in the center of a circular steel plate. The plate must be a minimum of 1⁄16 in. (1.59 mm) thick around the circumference of the hole. The remaining thickness of the orifice should be chamfered to 45° and with the chamfered edge down stream.

6.1.2 *Discharge Pipe*—The discharge pipe must be straight and level for a distance of at least 6 ft (1.8 m) before the water reaches the orifice plate. This approach channel should be longer if possible. The end of the pipe must be cut squarely so the plate will be vertical. The bore of the pipe should be smooth and free of any obstruction that might cause abnormal turbulence.

6.1.3 *Manometer*—The discharge pipe wall is tapped midway between the top and bottom with a 1⁄8-in. (3.17 mm) or 1⁄4-in. (6.35 mm) hole exactly 24 in. (609 mm) from the orifice plate. The manometer should be a distance of at least ten discharge pipe diameters from the gate valve used to control pipe flow. Any burrs inside the pipe resulting from the drilling or tapping of the hole should be filed off. A nipple is screwed into the tapped hole. The nipple must not protrude inside the discharge pipe. A clear plastic tube 4 or 5 ft (1.2 or 1.5 mm) long is connected at one end to the nipple. A scale is fastened to a support so that the vertical distance from the center of the discharge pipe up to the water level in the manometer can be measured. Alternately, a u-tube manometer or pressure transducer may be used. During a test the manometer must be free of air bubbles.

6.2 The water level in the manometer indicates the pressure head in the approach pipe when water is being pumped through the orifice. For any given size of orifice discharge pipe, the rate of flow through the orifice varies with the pressure head as measured in this manner. Table 1 presents the flow in gallons per minute (gpm) for various combinations of orifice and pipe diameters.

6.3 The diameter of the orifice should be less than 80 % of the inside diameter of the approach channel pipe.

7. Procedure

7.1 Set up the apparatus as shown in Fig. 1 and Fig. 2. The apparatus should be set up so that the orifice pipe is horizontal and the discharge is unimpeded. Use a combination of pipe and orifice diameter so that the anticipated head will be at least three times the diameter of the orifice. The orifice plate must be vertical and centered in the discharge pipe.

[5] Driscoll, F. G., *Ground Water and Wells*, Johnson Division, St. Paul, MN, 1986, pp. 537–541.

TABLE 1 Flow Rates Through Circular Orifice Weirs[5,A]

NOTE 1—Flow rates indicated below the line are more exact than those above the line because the head developed in the piezometer tube for particular pipe and orifice diameters is large enough to ensure the accuracy of results obtained from Eq 5.

Head of Water in.	4-in. Pipe		6-in. Pipe		8-in. Pipe			10-in. Pipe			12-in. Pipe		16-in. Pipe		
	2½-in. Orifice gpm	3-in. Orifice gpm	3-in. Orifice gpm	4-in. Orifice gpm	4-in. Orifice gpm	5-in. Orifice gpm	6-in. Orifice gpm	6-in. Orifice gpm	7-in. Orifice gpm	8-in. Orifice gpm	6-in. Orifice gpm	8-in. Orifice gpm	8-in. Orifice gpm	10-in. Orifice gpm	12-in. Orifice gpm
5	55	89	76	145	131	220	355	310	460	680	300	580	530	880	1420
6	60	97	82	158	144	240	390	340	500	740	325	640	580	960	1560
7	65	105	88	171	156	260	420	370	540	830	350	690	620	1040	1680
8	69	112	94	182	166	275	450	395	580	880	375	730	670	1110	1800
9	73	119	100	193	176	295	475	420	610	940	400	780	710	1180	1910
10	77	126	106	204	186	310	500	440	640	990	420	820	750	1240	2010
12	85	138	115	223	205	340	550	480	700	1080	460	900	820	1360	2200
14	92	149	125	241	220	365	595	520	760	1170	500	970	880	1470	2380
16	98	159	132	258	235	390	635	555	810	1250	530	1040	940	1570	2540
18	104	168	140	273	250	415	675	590	860	1330	560	1100	1000	1670	2690
20	110	178	150	288	265	440	710	620	910	1400	590	1160	1050	1760	2840
22	115	186	158	302	275	460	745	650	950	1470	620	1220	1110	1840	2980
25	122	198	168	322	295	490	795	690	1020	1560	660	1300	1180	1960	3180
30	134	217	182	353	325	540	870	760	1120	1710	730	1420	1290	2150	3480
35	145	235	198	380	355	580	940	820	1210	1850	790	1530	1400	2320	3760
40	155	251	210	405	370	620	1000	880	1290	1980	840	1640	1490	2480	4020
45	164	267	223	430	395	660	1060	930	1370	2030	890	1740	1580	2630	4260
50	173	280	235	455	415	690	1120	980	1440	2140	940	1830	1670	2780	4490
60	190	310	260	500	455	760	1230	1080	1580	2340	1030	2010	1830	3040	4920
70	205	350	280	525	490	810	1280	1140	1710	2530	1110	2170	1970	3280	5310

[A] Values in mm are obtained by multiplying 25.38 mm/in. Values in Lpm are obtained by multiplying 3.785 L/gal.

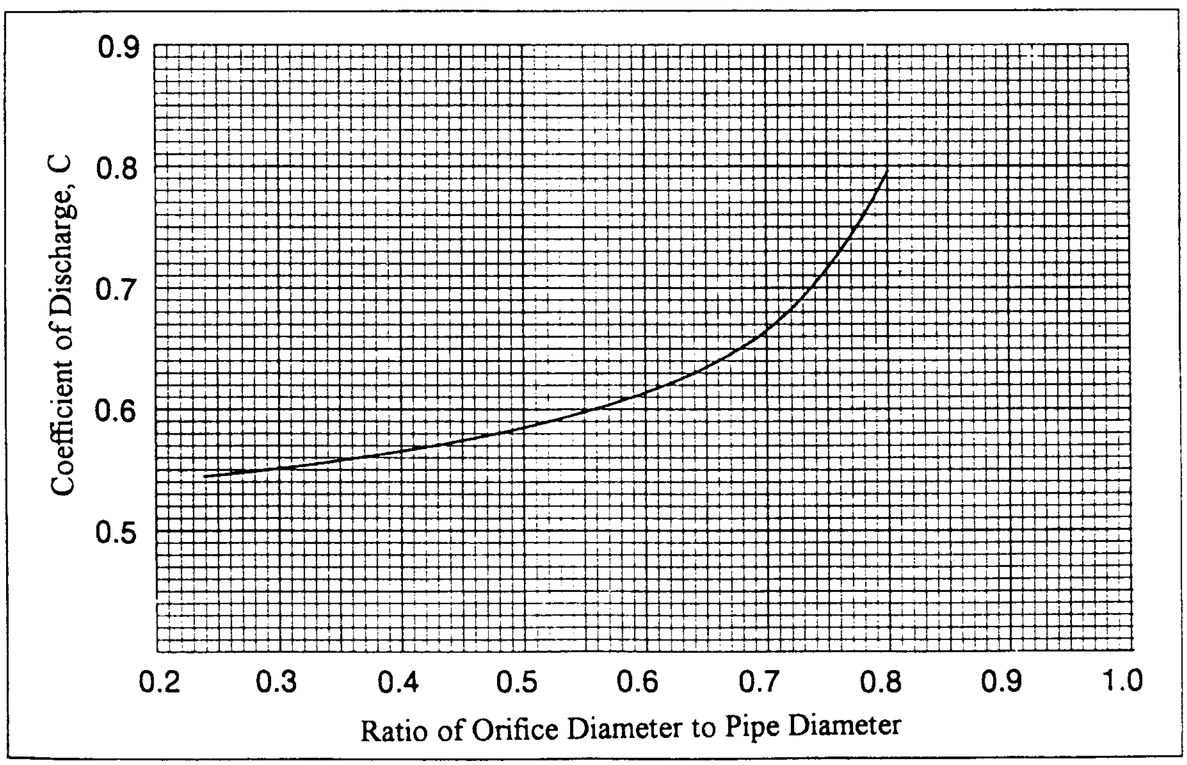

FIG. 2 The Coefficient of Discharge, *C*, in the Orifice-Weir Equation[5]

7.2 Equipment should be inspected to minimize the potential of wear, damage or misuse causing increased head loss that will bias results.

7.3 Initiate flow through the discharge pipe. Check that the manometer is free of air bubbles. Record the manometer level. Using Table 1 for the appropriate pipe and orifice size, read the discharge.

8. Calculation

8.1 Calculate the flow through the orifice using the basic equation:

$$Q = AVC \quad (1)$$

where:

Q = the flow per unit time,
A = the area of the orifice,
V = the velocity of flow through the orifice, and
C = the coefficient of discharge for the orifice.

The velocity of the water at the orifice consists of its velocity in the approach channel plus the additional velocity head created by the pressure drop that occurs between the connection for the manometer and the orifice. Because the water discharges at atmospheric pressure, the pressure head indicated by the manometer can be converted to the velocity if friction in the pipe is neglected.

8.2 Relate the velocity to the head in the manometer by the equation:

$$V = \sqrt{2gh} \tag{2}$$

where:
V = velocity,
g = acceleration due to gravity, and
h = the height of water in the manometer.

To compute the actual velocity through the orifice, the value of V from Eq 2 must be added to the velocity in the discharge pipe approach, and the sum of these must be corrected by two factors. One correction is for the contraction of the jet stream just outside of the orifice, and the other is for the sudden change in cross-sectional area of flow which is controlled by the size of the orifice relative to the size of the approach channel. The approach velocity and the two correction factors are combined into a single factor, C, whose value varies with the ratio of the orifice inside diameter to the approach-pipe inside diameter as presented in Fig. 2.

8.3 The equation for flow through the orifice is:

$$Q = CA\sqrt{2gh} = 8.025CA\sqrt{h} \tag{3}$$

Values of C may be obtained from Fig. 2, and Eq 3 may be used to calculate the pumping rate for any combination of orifice diameter, approach-pipe diameter, and water height in the piezometer tube. The pumping rate, Q, will be in the units of gallons (litres) per minute when the orifice area, A, is in square inches (millimetres) and the water level in the manometer, h, is in inches (millimetres). The value of C from Fig. 2 is only valid for use with this combination of units.

8.4 A discharge of 55 gpm (208 Lpm) will cause 5 in. (127 mm) of head due to a 2½-in. (63.5 mm) orifice and a 4-in. (102 mm) approach pipe. Similarly, a discharge of 5 310 gal (20.100 L) per minute will cause 70 in. (1.780 mm) of head due to a 12-in. (305 mm) orifice and a 16-in. (406 mm) approach pipe.

8.5 Extensive calibrations of circular orifice weirs indicated that they will measure the flow through the orifice within 3 % of the true value when properly constructed and used.[2,3]

9. Report

9.1 Record pertinent information, including orifice and pipe sizes and manometer reading, time of reading, and well discharge rate.

9.2 Describe the physical features of the apparatus and any unusual aspect of the measurements.

10. Precision and Bias

10.1 *Precision*—Due to the nature of this test method it is either not feasible or too costly at this time to develop a valid precision statement. Subcommittee D18.21 welcomes proposals that would allow for development of a valid precision statement.

10.2 *Bias*—There is no accepted reference value for this test method, therefore, bias cannot be determined.

11. Keywords

11.1 aquifers; aquifer test methods; discharge rate; ground water; orifice weir