INTERNATIONAL

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Standard Test Method for (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of a Confined Nonleaky or Leaky Aquifer by Constant Drawdown Method in a Flowing Well[1]

This standard is issued under the fixed designation D 5855; 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 an analytical solution for determining transmissivity and storage coefficient of a leaky or nonleaky confined aquifer. It is used to analyze data on the flow rate from a control well while a constant head is maintained in the well.

1.2 This analytical procedure is used in conjunction with the field procedure in Practice D 5786.

1.3 *Limitations*—The limitations of this technique for the determination of hydraulic properties of aquifers are primarily related to the correspondence between field situation and the simplifying assumption of the solution.

1.4 *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[2]

D 4043 Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques[2]

D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)[2]

D 5786 Practice (Field Procedure) for Constant Drawdown Tests in Flowing Wells for Determining Hydraulic Properties of Aquifer Systems[3]

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms used in this test method see Terminology D 653.

3.2 *Symbols:Symbols and Dimensions:*

3.2.1 T—transmissivity [L^2T^{-1}].

3.2.2 K_1— modified Bessel function of the second kind, first order [*nd*].

3.2.3 K_2— modified Bessel function of the second kind, zero order [*nd*].

3.2.4 J_0— Bessel function of the first kind, zero order [*nd*].

3.2.5 Y_0— Bessel function of the second kind, zero order [*nd*].

3.2.6 $W(u)$—w (well) function of u [*nd*].

3.2.7 u—variable of integration [*nd*].

3.2.8 t—elapsed time test [T].

3.2.9 Q—discharge rate [L^3T^{-1}].

3.2.10 s_W—constant drawdown in control well [L].

3.2.11 S—storage coefficient [*nd*].

3.2.12 r_W—radius of control well.

4. Summary of Test Method

4.1 This test method describes the analytical procedure for analyzing data collected during a constant drawdown aquifer test. This test method is usually performed on a flowing well. After the well has been shut-in for a period of time, the well is opened and the discharge rate is measured over a period of time after allowing the well to flow. The water level in the control well while the well is flowing is the elevation of the opening of the control well through which the water is allowed to flow. Data are analyzed by plotting the discharge rate versus time.

NOTE 1—This test method involves the withdrawal of water from a control well that is fully screened through the confined aquifer. The withdrawal rate is varied to cause the water level within the well to remain constant. The field procedure involved in conducting a constant drawdown test is given in Practice D 5786. Methods used to develop a conceptual model of the site and for initially selecting an analytical procedure are described in Guide D 4043.

4.2 *Leaky Aquifer Solution*—The solution is given by Hantush.[4] Transmissivity is calculated as follows:

[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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This practice is presently under development in Section D18.21.04 and may be obtained by contacting the Committee D-18 Staff Manager.

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

[3] *Annual Book of ASTM Standards*, Vol 04.09.

[4] Hantush, M. S., "Nonsteady Flow to Flowing Wells in Leaky Aquifer," *Journal of Geophysical Research*, Vol 64, No. 8, 1959, pp. 1043–1052.

NOTE 2—These are Eq (93) through (97) of Lohman.[5]

$$T = \frac{Q}{2\pi s_W\, G\,(\alpha, r_W/B)}\,[L^2T^{-1}] \quad (1)$$

where:

$$\alpha = \frac{Tt}{S r_W^{\,2}}\,[nd] \quad (2)$$

$$r_W/B = r_W[T/(K'/b')]^{-0.5}\,[L^2] \quad (3)$$

and:

$$G\left[\frac{r_W}{B}\right] = \left[\frac{r_W}{B}\right]\left[\frac{K_1(r_w/b)}{K_0(r_W/b)}\right] + \frac{r}{\pi^2}\exp\left[-\alpha\left(\frac{r_W}{B}\right)^2\right]. \quad (4)$$

$$\int_o^\infty \frac{u\,exp(-\alpha u^2)}{J_0^{\,2}(u) + Y_0^{\,2}(u)} \cdot \frac{du}{u^2 + (r_W/B)^2}\,[nd]$$

4.2.1 Storage coefficient is given by:

$$S = \frac{Tt}{r_W^{\,2}\alpha}\,[nd] \quad (5)$$

4.3 *Non-Leaky Aquifer*:

4.3.1 *Log-Log*—The solution is given by Lohman.[5]

NOTE 3—These equations are Eq (66) through (69) of Lohman.[5]

4.3.1.1 Transmissivity is calculated as follows:

$$T = \frac{Q}{2\pi G(\alpha) s_W}\,[L^2T^{-1}] \quad (6)$$

where:

$$\alpha = \frac{Tt}{S r_W^{\,2}}\,[nd] \quad (7)$$

and:

$$G(a) = \frac{4\alpha}{\pi}\int_o^\infty x e^{-\alpha x^2}\left[\frac{\pi}{2} + \tan^{-1}\left(\frac{Y_o(x)}{J_o(x)}\right)\right]dx\,[nd] \quad (8)$$

4.3.1.2 Storage coefficient is given by:

$$S = \frac{Tt}{\alpha r_W^{\,2}}\,[nd] \quad (9)$$

4.3.2 *Semi-Log*—The solution is given by Jacob and Lohman.[6]

NOTE 4—Jacob and Lohman[6] showed that for all but extremely small values of t, the function of $G(a)$ shown above can be approximated very closely by $2/\,W(u)$. For sufficiently small values of u, $W(u)$ are further approximated by $2.30\,log_{10}\,2.25Tt/r_W^{\,2}S$. The use of this semi-logarithmic method will produce values of transmissivity that are slightly elevated. Examples of this error are shown below:

u	W (u)	Estimated Error, %
0.25000	1.044283	25
0.00625	4.504198	10
0.000833	6.513694	5
1.25E-05	10.71258	2

4.3.2.1 Transmissivity is calculated as follows:

NOTE 5—These equations are Eqs (71) and (73) of Lohman.[5]

$$T = \frac{2.30}{4\pi\Delta(s_W/Q)/\Delta\log_{10}(t/r_W^{\,2})}\,[L^2T^{-1}] \quad (10)$$

by extrapolating the straight line to $s_W/Q = 0$ (the point of zero drawdown), storage coefficient is given by:

$$S = 2.25\,T\frac{t}{r_W^{\,2}}\,[nd] \quad (11)$$

NOTE 6—In (Eq 10) and (Eq 11), Q is in cubic feet per day, t is in days.

5. Significance and Use

5.1 *Assumptions—Leaky Aquifer*:

5.1.1 Drawdown (s_W) in the control well is constant,

5.1.2 Well is infinitesimal diameter and fully penetrates aquifer,

5.1.3 The aquifer is homogeneous, isotropic, and areally extensive, and

5.1.4 The control well is 100 % efficient.

5.2 *Assumptions—Nonleaky Aquifer*:

5.2.1 Drawdown (s_W) in the control well is constant,

5.2.2 Well is infinitesimal diameter and fully penetrates aquifer,

5.2.3 The aquifer is homogeneous, isotropic, and areally extensive,

5.2.4 Discharge from the well is derived exclusively from storage in the nonleaky aquifer, and

5.2.5 The control well is 100 % efficient.

5.3 *Implications of Assumptions*:

5.3.1 The assumptions are applicable to confined aquifers and fully penetrating control wells. However, this test method may be applied to partially penetrating wells where the method may provide an estimate of hydraulic conductivity for the aquifer adjacent to the open interval of the well if the horizontal hydraulic conductivity is significantly greater than the vertical hydraulic conductivity.

5.3.2 Values obtained for storage coefficient are less reliable than the values calculated for transmissivity. Storage coefficient values calculated from control well data are not reliable.

6. Apparatus

6.1 Analysis of data from the field procedure (see Practice D 5786) by the methods specified in this procedure requires that the control well and observation wells meet the specifications given in the apparatus section of Practice D 5786.

7. Procedure

7.1 *Data Collection*—Procedures to collect the field data used by the analytical procedures described in this test method are given in Practice D 5786.

7.2 *Data Calculation and Interpretation*—Perform the procedures for calculation and interpretation of test data as given in Section 8.

7.3 *Report*—Prepare a report as given in Section 9.

8. Calculation and Interpretation of Results

8.1 *Leaky Aquifer Solution*:

8.1.1 (Eq 4) cannot be integrated directly but has been evaluated numerically and the values are given in Table 1 of Hantush.[4]

[5] Lohman, S. W., "Ground-Water Hydraulics," *Professional Paper 708, U.S. Geological Survey*, 1972.

[6] Jacob, C. E. and Lohman, S. W., "Nonsteady Flow to a Well of Constant Drawdown in an Extensive Aquifer," *American Geophysical Union Transactions*, Vol 33, No. 4, 1952, pp. 552–569.