Designation: D 5472 – 93 (Reapproved 1999)$^{\epsilon 1}$

Standard Test Method for Determining Specific Capacity and Estimating Transmissivity at the Control Well[1]

This standard is issued under the fixed designation D 5472; 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.

ϵ^1 NOTE—Section 10.2.1 was corrected editorially in August 1999.

1. Scope

1.1 This test describes a procedure for conducting a specific capacity test, computing the specific capacity of a control well, and estimating the transmissivity in the vicinity of the control well. Specific capacity is the well yield per unit drawdown at an identified time after pumping started.

1.2 This test method is used in conjunction with Test Method D 4050 for conducting withdrawal and injection well tests.

1.3 The method of determining transmissivity from specific capacity is a variation of the nonequilibrium method of Theis **(1)** for determining transmissivity and storage coefficient of an aquifer. The Theis nonequilibrium method is given in Test Method D 4106.

1.4 *Limitations*—The limitations of the technique for determining transmissivity are primarily related to the correspondence between the field situation and the simplifying assumptions of the Theis method.

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

1.6 This standard may involve hazardous materials, operations, and equipment. This standard does not address safety problems 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 4050 Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems[2]

D 4106 Test Method for Analytical Procedure for Determining Transmissivity and Storativity of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method[2]

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

3. Terminology

3.1 *Definitions:*

3.1.1 *aquifer, confined*—an aquifer bounded above and below by confining beds and in which the static head is above the top of the aquifer.

3.1.2 *aquifer, unconfined*—an aquifer that has a water table.

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

3.1.4 *head, static*—the height above a standard datum of the surface of a column of water that can be supported by the static pressure at a given point.

3.1.5 *hydraulic conductivity*—(field aquifer test) the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit area measured at right angles to the direction of flow.

3.1.6 *observation well*—a well open to all or part of an aquifer, and used to make measurements.

3.1.7 *specific capacity*—well yield per unit drawdown at an identified time after pumping started.

3.1.8 *storage coefficient*—the volume of water an aquifer releases from or takes into storage per unit surface area of the aquifer per unit change in head.

3.1.9 *transmissivity*—the volume of water at the existing kinematic viscosity that will move in a unit time under a unit hydraulic gradient through a unit width of the aquifer.

3.1.10 For definitions of other terms used in this method see Terminology, D 653.

3.2 *Symbols:*Symbols and Dimensions:

3.2.1 *K*—hydraulic conductivity $[LT^{-1}]$

3.2.2 *m*—saturated thickness [L]

3.2.3 *Q*—discharge $[L^3T^{-1}]$

3.2.4 *Q/s*—specific capacity $[(L^3T^{-1})L^{-1}]$

3.2.5 *r*—well radius [L]

3.2.6 *s*—drawdown [L]

3.2.7 *S*—storage coefficient [dimensionless]

3.2.8 *T*—transmissivity $[L^2T^{-1}]$

3.2.9 *T′*—provisional value of transmissivity $[L^2T^{-1}]$

3.2.10 *t*—elapsed time of pumping [T]

---

[1] This test method is under the jurisdiction of ASTM Committee D-18 on Soil and Rock and is the direct responsibility of Subcommittee D18.21 on Ground Water and Vadose Zone Investigations.

Current edition approved Nov. 15, 1993. Published January 1994.

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

3.2.11 u—$r^2S/4Tt$ [dimensionless]

3.2.12 $W(u)$—well function of “u” [dimensionless]

3.2.13 c_1— $[W(u)/4\pi]$

4. Significance and Use

4.1 Assumptions of the Theis **(1)** equation affect specific capacity and transmissivity estimated from specific capacity. These assumptions are given below:

4.1.1 Aquifer is homogeneous and isotropic.

4.1.2 Aquifer is horizontal, of uniform thickness, and infinite in areal extent.

4.1.3 Aquifer is confined by impermeable strata on its upper and lower boundaries.

4.1.4 Density gradient in the flowing fluid must be negligible and the viscous resistance to flow must obey Darcy’s Law.

4.1.5 Control well penetrates and receives water equally from the entire thickness of the aquifer.

4.1.6 Control well has an infinitesimal diameter.

4.1.7 Control well discharges at a constant rate.

4.1.8 Control well operates at 100 percent efficiency.

4.1.9 Aquifer remains saturated throughout the duration of pumping.

4.2 *Implications of Assumptions and Limitations of Method*.

4.2.1 The simplifying assumptions necessary for solution of the Theis equation and application of the method are never fully met in a field test situation. The satisfactory use of the method may depend upon the application of one or more empirical correction factors being applied to the field data.

4.2.2 Generally the values of transmissivity derived from specific capacity vary from those values determined from aquifer tests utilizing observation wells. These differences may reflect 1) that specific-capacity represents the response of a small part of the aquifer near the well and may be greatly influenced by conditions near the well such as a gravel pack or graded material resulting from well development, and 2) effects of well efficiency and partial penetration.

4.2.3 The values of transmissivity estimated from specific capacity data are considered less accurate than values obtained from analysis of drawdowns that are observed some distance from the pumped well.

5. Apparatus

5.1 Apparatus required for specific capacity testing includes control well, control well pump, discharge measuring equipment and water-level measuring equipment. The description and function requirements of this equipment is given in Test Method D 4050.

6. Conditioning Procedures

6.1 Conditioning procedures are conducted before the test to ensure that the control well is properly equipped and that the well discharge and water-level measuring equipment is operational.

6.1.1 Equip the control well with a calibrated accumulating water meter or another type of calibrated well yield measuring device.

6.1.2 Provide the control well with a system for maintaining a constant discharge.

6.1.3 Equip control well for measuring the pretest water level (prepumping water level) and pumping water levels during the specific capacity test.

6.1.4 Measure static water level immediately before starting the pump.

6.1.5 Start pump and simultaneously measure elapsed time with a stop watch or data recorder. After 3 to 5 minutes well yield and drawdown should be measured and recorded.

6.1.6 If all the equipment is working properly, drawdown measurements can be obtained, and constant discharge maintained, the equipment check can be ended.

6.1.7 Cease pumping and allow the water level to recover to its prepumping level before the specific capacity test procedure (Section 5) is initiated.

7. Test Procedure

7.1 Initiate well discharge.

7.2 Measure the well yield and pumping water level in the control well at predetermined time intervals, for example, 2-, 5-, 10-, 20-, 30-, minutes after discharge is initiated. Adjust the discharge rate during the test to maintain discharge within 5 % of the rate planned.

7.3 While test continues make the following calculations:

7.3.1 Adjust drawdown for effects of desaturation of the aquifer, if applicable (see Section 8).

7.3.2 Determine the specific capacity (see Section 10) and estimate transmissivity (see Section 11). If well bore storage effects are negligible (see Section 9), compare the new value of T' to the value used to calculate c_1, if the value is within 10 %, the test can be terminated.

7.3.3 If control well is not screened through the entire thickness of the aquifer, estimate the transmissivity of the aquifer following procedure in Sections 11 and 12.

8. Correction of Drawdown in an Unconfined Aquifer

8.1 The Theis equation is directly applicable to confined aquifers and is suitable for use with limitations in unconfined aquifers. If the aquifer is unconfined and drawdown is less than 10 percent of the prepumping saturated thickness, little error will be introduced. If drawdown exceeds 25 percent of the prepumping saturated thickness, this test should not be used to estimate transmissivity. For unconfined aquifers with drawdown equal to 10 to 25 percent of the original saturated thickness, correct the drawdown for the effects of reduced saturated thickness by the following formula given by Jacob **(2)**:

$$s' = s - \frac{(s^2)}{2m} \tag{1}$$

where:

s = measured drawdown in the control well,

s' = corrected drawdown, and

m = saturated thickness of the aquifer prior to pumping.

9. Well Bore Storage Effects

9.1 Evaluate the time criterion to determine if well-bore storage affects drawdown at the current duration of the test. Weeks **(3)** gives a time criterion modified after Papadopulos and Cooper **(4)** of $t > 25\, r^2/T$ after which drawdown in the control well is not affected by well-bore storage. For example, a well with a radius of 1 foot and a T of 1000 ft^2/day has a time criterion of $t > 25\ r^2/T = t > 25\ (1)^2/1000 = t > 0.025$ days $= t > 36$ min.

10. Computation of Specific Capacity

10.1 Record the drawdown and the time since pumping started.

10.2 Compute the specific capacity of the control well from the average well yield (Q) and the drawdown (s):

$$\text{Specific Capacity} = Q/s[(L^3T^{-1})L^{-1}] \quad (2)$$

10.2.1 An example of specific capacity where discharge is given in American Standard Units (1000 gallons per minute) and drawdown in feet (50):

Specific Capacity =
[1000 gpm (1440 min/day/7.48 gal/ft^3)]/50 ft =
3850 [(ft^3/day)]ft

11. Estimate Transmissivity from Specific Capacity

11.1 A modification of the Theis **(1)** nonequilibrium equation is used to evaluate transmissivity data derived from specific capacity as follows:

$$T = [W(u)/4\pi]Q/s \quad (3)$$

11.1.1 A general form of the equation is:

$$T' = c_1Q/s \quad (4)$$

where:
$c_1 = W(u)/4\pi$.

11.1.2 Calculate the value of c_1 from a provisional value of transmissivity, T', estimated storage coefficient, S, well radius, r, and duration of the test, t. An example of the computation of c_1 using field values of discharge in American units is as follows:

where:
T' = 11 000 ft^2/day,
S = 2×10^{-5}
r = 0.67 ft (16-in. diameter pipe),
t = 0.50 days

$$C_1 = W(u)/4\pi$$
$$W(u) = (-0.5772 - \mathrm{L}n[u])$$

where:
$u = (r^2S)/(4Tt) = 4.0809 \times 10^{-10}$
$C_1 = (-0.5772 - \mathrm{L}\ n[4.0809 \times 10^{-10})/4\pi]$
$C_1 = (-0.5772 - \mathrm{L}n[4.0809 \times 10^{-10}])/12.5664$
$C_1 = (-0.5772 - [-21.6195])/12.5664$
$C_1 = 21.0423/12.5664 = 1.6745$

11.1.3 Calculate transmissivity from Eq 4;

$T = c_1Q/s$,
Assume Q/s = 3850 [(ft^3/day)/ft]
$T = 1.6745 \times 3850 = 6450$ ft^2/day (rounded)

11.1.4 If transmissivity calculated in 11.1.3 is not within 10 % of the provisional transmissivity, T', recalculate c_1 from the new value of transmissivity and recalculate transmissivity by formula. In the example, because 6450 ft^2/day is 59 percent of the initial T' value of the 11 000 ft^2/day, a more accurate c_1 can be computed to match the new T' value.

T' = 6450 ft^2/day
$S = 2 \times 10^{-5}$
$c_1 = W(u)/4\pi$
$W(u) = (-0.5772 - \mathrm{L}n[u])$

where:
$u = (r^2S)/(4Tt) = 8.9780 \times 10^{-6} = 6.9597 \times 10^{-10}$
$C_1 = (-0.5772 - \mathrm{L}n\ 6.9597 \times 10^{-10})/4\pi$
$C_1 = (-0.5772 - \mathrm{L}\ n\ 6.9597 \times 10^{-10})/12.5664$
$C_1 = (-0.5772 - (-21.0857)/12.5664$
$C_1 = 20.5085/12.5664 = 1.6320$

thus:
$T' = C_1(Q/s) = 1.6320 \times 3850 = 6300$ ft^2/day (rounded). The new value of transmissivity is within 10 % of the value used to compute transmissivity.

11.1.5 To obtain SI units, multiply American units by 9.290×10^{-2} for m^2/day.

NOTE 1—The initial estimates of transmissivity can be based on values of transmissivity and storage of the aquifer determined at other locations or from a general knowledge of the aquifer properties. The transmissivity could be estimated from driller's logs using methods described by Gutentag and others **(5)**. The storage coefficient can be estimated for unconfined aquifer as 0.2 and for confined aquifers as $b \times 10^{-6}$, where b is the thickness of the aquifer in feet. In areas where aquifer properties are not known and drillers log data are lacking, the following values, modified from Harlan, Kolm, and Gutentag **(6)** can be used as initial estimates of c_1:

Confined aquifers	1.6
Unconfined aquifers	0.8

12. Correction of Transmissivity for Partially Penetrating Well

12.1 If the full aquifer thickness is not screened, the value of T' represents the transmissivity of the screened section of the aquifer. To estimate the transmissivity of the full thickness of the aquifer, divide estimated transmissivity by the length of the screened interval to compute the hydraulic conductivity (K). After computing (K) the hydraulic conductivity value is multiplied by the entire thickness of the saturated thickness (m) of the aquifer to compute an estimate of transmissivity as: $T = Km$.

13. Report

13.1 Prepare a report containing all data, including a description of the field site, well construction, plots of pumping water level and well discharge with time.

13.2 Present analysis of data, using iteration techniques for c, when results differ from initial input values of T and S.

13.3 Compare estimated test conditions with the test method assumptions listed in 4.1.

14. Precision and Bias

14.1 It is not practicable to specify the precision of this procedure because the response of aquifer systems during aquifer tests is dependent upon ambient system stresses. No statement can be made about bias because no true reference values exist.

15. Keywords

15.1 aquifers; aquifer tests; control wells; hydraulic conductivity; observation wells; specific capacity; storage coefficient; transmissivity; unconfined aquifers

REFERENCES

(**1**) Theis, C. V., 1935, The Relation Between the Lowering of Duration of Discharge of a Well Using Ground-Water Storage: *American Geophysical Union Transactions*, v. 16. pt. 2, p. 519–524.

(**2**) Jacob, C. E., "Determining the Permeability of Water-Table Aquifers," in Bentall, Ray, Compiler, "Methods of Determining Permeability, Transmissibility, and Drawdown," U.S. Geological Survey Water-Supply Paper 1536-I, 1963, pp. 245–271.

(**3**) Weeks, E. P., 1978, Aquifer Tests—the State of the Art in Hydrology: in Proceedings Invitational Well-Testing Symposium, October 19–21, 1977, Lawrence Berkeley Laboratory, University of California, LBL-7027, UC-66, TID 4500-R66, p. 14–26.

(**4**) Papadopulos, I. S., and Cooper, H. H., Jr., 1967, Drawdown in a Well of Large Diameter: Water Resources Research, v. 3, no. 1, p. 241–244.

(**5**) Gutentag, E. D., Heimes, F. J., Krothe, N. C., Luckey, R. R., and Weeks, J. B., 1984, Geohydrology of the High Plains Aquifer in parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma, South Dakota, Texas, and Wyoming: U.S. Geological Survey Professional Paper 1400-B, 63 p.

(**6**) Harlan, R. L., Kolm, K. E., and Gutentag, E. D., 1989, Water-Well Design and Construction: Elsevier, Amsterdam, 205, p.