Designation: D4104 – 96 (Reapproved 2004)

Standard Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)[1]

This standard is issued under the fixed designation D4104; 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 the determination of transmissivity from the measurement of force-free (overdamped) response of a well-aquifer system to a sudden change of water level in a well. Force-free response of water level in a well to a sudden change in water level is characterized by recovery to initial water level in an approximate exponential manner with negligible inertial effects.

1.2 The analytical procedure in this test method is used in conjunction with the field procedure in Test Method D4044 for collection of test data.

1.3 *Limitations*—Slug tests are considered to provide an estimate of transmissivity. Although the assumptions of this test method prescribe a fully penetrating well (a well open through the full thickness of the aquifer), the slug test method is commonly conducted using a partially penetrating well. Such a practice may be acceptable for application under conditions in which the aquifer is stratified and horizontal hydraulic conductivity is much greater than vertical hydraulic conductivity. In such a case the test would be considered to be representative of the average hydraulic conductivity of the portion of the aquifer adjacent to the open interval of the well.

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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D653 Terminology Relating to Soil, Rock, and Contained Fluids
D4043 Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques
D4044 Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers
D4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)
D5912 Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug)

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 *confining bed*—a hydrogeologic unit of less permeable material bounding one or more aquifers.

3.1.3 *control well*—well by which the aquifer is stressed, for example, by pumping, injection, or change of head.

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

3.1.5 *hydraulic conductivity*—*(field aquifer tests)*, 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.

3.1.7 *overdamped-well response*—characterized by the water level returning to the static level in an approximately exponential manner following a sudden change in water level. (See for comparison *underdamped-well response*.)

3.1.8 *slug*—a volume of water or solid object used to induce a sudden change of head in a well.

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[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] 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.

3.1.9 *specific storage*—the volume of water released from or taken into storage per unit volume of the porous medium per unit change in head.

3.1.10 *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. For a confined aquifer, the storage coefficient is equal to the product of specific storage and aquifer thickness. For an unconfined aquifer, the storage coefficient is approximately equal to the specific yield.

3.1.11 *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.

3.1.12 *underdamped-well response*—response characterized by the water level oscillating about the static water level following a sudden change in water level. (See for comparison *overdamped-well response*.)

3.1.13 For definitions of other terms used in this test method, see Terminology D653.

3.2 *Symbols:*

3.2.1 J_0 [nd]—zero-order Bessel function of the first kind.

3.2.2 J_1 [nd]—first-order Bessel function of the first kind.

3.2.3 K [LT^{-1}]—hydraulic conductivity.

3.2.4 T [L^2T^{-1}]—transmissivity.

3.2.5 S [nd]—storage coefficient.

3.2.6 Y_0 [nd]—zero order Bessel function of the second kind.

3.2.7 Y_1 [nd]—first order Bessel function of the second kind.

3.2.8 r_c *[L]*—radius of control-well casing or open hole in interval where water level changes.

3.2.9 r_w [L]—radius of control well screen or open hole adjacent to water bearing unit.

3.2.10 u—variable of integration.

3.2.11 H *[L]*—change in head in control well.

3.2.12 H_o *[L]*—initial head rise (or decline) in control well.

3.2.13 t—time.

3.2.14 β—Tt/r_c^2.

3.2.15 α—r_w^2S/r_c^2.

4. Summary of Test Method

4.1 This test method describes the analytical procedure for analyzing data collected during an instantaneous head (slug) test using an overdamped well. The field procedures in conducting a slug test are given in Test Method D4044. The analytical procedure consists of analyzing the recovery of water level in the well following the change in water level induced in the well.

4.2 *Solution*—The solution given by Cooper et al (**1**)[3] is as follows:

$$H = \frac{2H_o}{\pi}\int_0^\infty [[\exp(-\beta u^2/\alpha)[J_0(ur/r_w) [uY_0(u) - 2\alpha Y_1(u)] - Y_0(ur/r_w) [uJ_0(u) - 2\alpha J_1(u)]]/\Delta(u)]]du \quad (1)$$

where:

$$\alpha = r_w^2S/r_c^2,$$

$$\beta = Tt/r_c^2,$$

and:

$$\Delta(u) = [uJ_0(u) - 2\alpha J_1(u)]^2 + [uY_0(u) - 2\alpha Y_1(u)]^2$$

NOTE 1—See D5912 and Hvorslev (**2**) Bouwer and Rice (**3**), and Bouwer (**4**).

5. Significance and Use

5.1 *Assumptions of Solution of Cooper et al* (**1**):

5.1.1 The head change in the control well is instantaneous at time $t = 0$.

5.1.2 Well is of finite diameter and fully penetrates the aquifer.

5.1.3 Flow in the nonleaky aquifer is radial.

5.2 *Implications of Assumptions*:

5.2.1 The mathematical equations applied ignore inertial effects and assume the water level returns the static level in an approximate exponential manner. The geometric configuration of the well and aquifer are shown in Fig. 1.

5.2.2 Assumptions are applicable to artesian or confined conditions and fully penetrating wells. However, this test method is commonly applied to partially penetrating wells and in unconfined aquifers where it may provide estimates of hydraulic conductivity for the aquifer interval adjacent to the open interval of the well if the horizontal hydraulic conductivity is significantly greater than the vertical hydraulic conductivity.

5.2.3 As pointed out by Cooper et al (**1**) the determination of storage coefficient by this test method has questionable reliability because of the similar shape of the curves, whereas, the determination of transmissivity is not as sensitive to choosing the correct curve. However, the curve selected should not imply a storage coefficient unrealistically large or small.

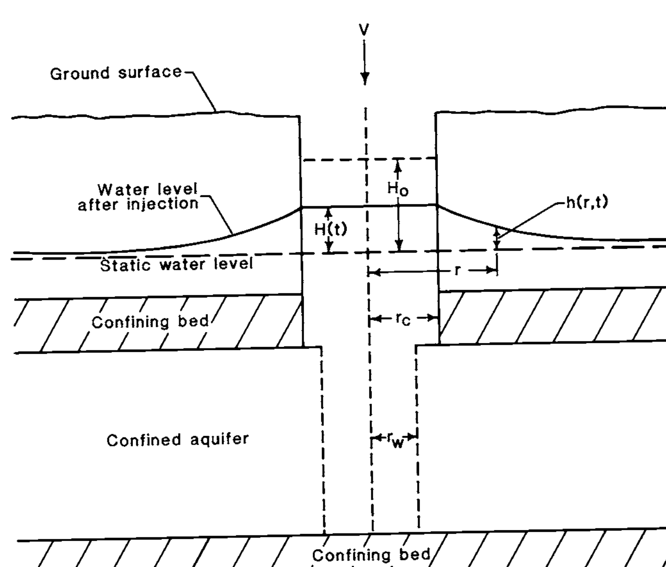

FIG. 1 Cross Section Through a Well in Which a Slug of Water is Suddenly Injected

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