Designation: D4044/D4044M – 15

Standard Test Method for (Field Procedure) for Instantaneous Change in Head (Slug) Tests for Determining Hydraulic Properties of Aquifers[1]

This standard is issued under the fixed designation D4044/D4044M; 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 field procedure for performing an in situ instantaneous change in head (slug) test.

1.2 This test method is used in conjunction with an analytical procedure such as Test Method D4104 to data analysis and to determine aquifer properties.

1.3 *Units*—The values stated in either SI Units or inch-pound units are to be regarded separately as standard. The values in each system may not be exact equivalents; therefore each system shall be used independently of the other. Combining values from the two systems may result in nonconformance with the standard. Reporting of test results in units other than SI shall not be regarded as nonconformance with this test method.

1.4 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D6026.

1.4.1 The procedures used to specify how data are collected/recorded and calculated in the standard are regarded as the industry standard. In addition, they are representative of the significant digits that generally should be retained. The procedures used do not consider material variation, purpose for obtaining the data, special purpose studies, or any considerations for the user's objectives; and it is common practice to increase or reduce significant digits of reported data to be commensurate with these considerations. It is beyond the scope of these test methods to consider significant digits used in analysis methods for engineering data.

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

D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D4043 Guide for Selection of Aquifer Test Method in Determining Hydraulic Properties by Well Techniques

D4104 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Tests)

D5785 Test Method for (Analytical Procedure) for Determining Transmissivity of Confined Nonleaky Aquifers by Underdamped Well Response to Instantaneous Change in Head (Slug Test)

D5881 Test Method for (Analytical Procedure) Determining Transmissivity of Confined Nonleaky Aquifers by Critically Damped Well Response to Instantaneous Change in Head (Slug)

D5912 Test Method for (Analytical Procedure) Determining Hydraulic Conductivity of an Unconfined Aquifer by Overdamped Well Response to Instantaneous Change in Head (Slug) (Withdrawn 2013)[3]

D6026 Practice for Using Significant Digits in Geotechnical Data

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of common technical terms used in this standard, refer to Terminology D653.

4. Summary of Test Method

4.1 This test method describes the field procedures involved in conducting an instantaneous head (slug) test. The slug test

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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] The last approved version of this historical standard is referenced on www.astm.org.

***A Summary of Changes section appears at the end of this standard**

method involves causing a sudden change in head in a control well and measuring the water level response within that control well. Head change may be induced by suddenly injecting or removing a known quantity or "slug" of water into the well, rapid removal of a mechanical "slug" from below the water level, increasing or decreasing the air pressure in the well casing, or emplacement of a mechanical slug into the water column.

4.2 The water-level response in the well is a function of the mass of water in the well and the transmissivity and coefficient of storage of the aquifer. One method of analysis of the data from this field practice is described in Test Method D4104.

5. Significance and Use

5.1 This slug test field procedure is used in conjunction with a slug test analytical procedure, such as Test Method D4104 to provide quick and relatively inexpensive estimates of transmissivity.

5.2 The slug test provides an advantage over pumping tests in that it does not require the disposal of the large quantities of water that may be produced. This is of special importance when testing a potentially contaminated aquifer. However, slug tests reflect conditions near the well, therefore are influenced by near-well conditions, such as gravel pack, poor well development, and skin effects, as a result, slug test results should be viewed as semi-quantitative in comparison to pumping test results.

5.3 Slug tests may be made in aquifer materials of lower hydraulic conductivity than generally considered suitable for hydraulic testing with pumping tests.

5.4 The method of data analysis (analytical procedure) should be known prior to the field testing to ensure that all appropriate dimensions and measurements are properly recorded. Selection of the analytical procedure can be aided by using Guide D4043, Test Method D5785, Test Method D5881, and Test Method D5912.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

6. Apparatus

6.1 *Slug-Inducing Equipment*—This test method describes the types of equipment that can be used. Because of the infinite variety of testing conditions and because similar results can be achieved with different apparatus, engineering specifications for apparatus are not appropriate. This test method specifies the results to be achieved by the equipment to satisfy the requirements of this practice.

6.2 *Water-Level Measurement Equipment*—The method of water level measurement may be dependent on the method selected for injection or withdrawal of water, and the nature of the response of the well. For an open-well test, that is, where access to the water level is open to the surface, measure water levels manually, by an automatic recording device linked to a float, or with a pressure transducer linked to a data logger or display device. A pressure transducer linked to a data logger will be necessary for a test in a closed well in which water-level changes are induced by vacuum or pressure on the control well and where manual measurements do not provide measurements of adequate frequency (see 10.3).

6.3 *Barometric Pressure*—Barometric pressures should be determined and routinely logged.

7. Conditioning

7.1 *Pre-Test Procedure:*

7.1.1 *Measuring Pre-Test Water Levels*—Measure the water level in the control well before beginning the test for a period longer than the duration of the test to determine the pre-test water level fluctuations and to establish the statis pre-test water-level trend and to determine a pre-test reference water level.

7.1.2 *Well Development*—Prior to slug testing the well must be adequately developed (or re-developed) to provide the most representative test results. Failure to perform adequate development may result in low-biased determinations of formation hydraulic conductivity and transmissivity exceeding an order of magnitude. If a well has been inactive for several months or years since its original installation and development a re-development may be required. Development may consist of surging and purging the well with one of several methods. Purging with a bailer may be adequate in some wells where sufficient energy can be injected into the surrounding aquifer to remove fines and damage caused due to well installation and construction activities. Use of an inertial pump may also be effective, especially if a surge block is applied alternately. Over pumping the well may be more effective in larger wells with a high yield. In low permeability formations (for example, sand to silty clay) these development methods may not be appropriate and could lead to a clogged filter pack or well screen.

7.1.3 *Verify Development*—It is possible to verify adequate development of well in permeable formations by performing repeat slug tests using the same initial head. Usually three to five repeat tests can be conducted in less than an hour in permeable formations. Often visual inspection/comparison of the test response curve in the field can be used to assess well performance. Significant changes in the magnitude of the response curve or shape of the response curve between repeat tests indicates that further development or redevelopment is required.

8. Procedure

8.1 Cause a change in water level, either a rise or decline, by one of the following methods:

8.1.1 *Water Slug*—Inject or withdraw water of a known quantity into or from the control well.

8.1.2 *Mechanical Slug*—Inject a mechanical slug to below the water level in the well, or withdraw the mechanical slug below the water level in the well. The water within the control well will then rise or decline an amount equal to the volume of the mechanical slug.

8.1.3 *Release Vacuum or Pressure*—A method of simulating the injection or withdrawal of a slug of water is by the release of a vacuum or pressure on a tightly capped (shut-in) control well. Before the release, the vacuum or pressure is held constant.

NOTE 2—There is no fixed requirement for the magnitude of the change in water level. Similar results can be achieved with a wide range in induced head change. Some considerations include a magnitude of change that can be readily measured with the apparatus selected, for example the head change should be such that the method of measurement should be accurate to 1 % of the maximum head change. Generally, an induced head change of from one-third to one metre [1 to 3 feet] is adequate. Although the induced head change should be sufficient to allow the response curve to be defined, excessive head change should be avoided to reduce the possibility of introducing large frictional losses in well bore and to avoid mechanically damaging the aquifer material.

8.1.4 The addition of any water to a well should be fully evaluated prior to the test. The addition of water may change the chemistry of the well for subsequent monitoring, and the rapid injection may damage the well pack and surrounding natural soils. The injection of water into a well may be ineffective and should not be permitted for wells screened across the water table as the resulting data cannot be effectively evaluated unless the screened interval is long relative to the change in head. In other cases, pouring water into the control well will allow water to run along the well casing wall and can result in non-instantaneous test initiation. The withdrawal of water from a well may be problematic by the generation of contaminated water that will have to be handled and disposed of in accordance with applicable regulations.

8.1.5 The mechanical model for the test assumes the head change is induced instantaneously. Practically, a finite time is required to effect a head change. Selection of time zero can be selected experimentally. Refer to the method of analysis (such as Test Method D4104) to determine time zero and to evaluate the suitability of the change effected in the well.

8.2 Measure and record the water-level response to the change in water level. The frequency of water-level measurement during the test is dependent upon the hydraulic conductivity of the material being tested. During the early portions of the test, measure water levels at closely-spaced intervals. Measurements of water level made manually with a tape should be made as frequently as possible until the water level has recovered about 60 to 80 %. Increase the length of time between measurements with increasing duration of the test. Since most methods of data analysis are curve-fitting techniques, it is essential that water levels are measured frequently enough to define the water-level response curve (see Guide D4043, Test Methods D4104 and D5785).

8.2.1 In aquifer-well systems where water-level changes are rapid, it may be necessary to use a pressure transducer linked to an electronic data logger to measure and record the water levels frequently enough to adequately define the waterlevel response. The use of transducers and data loggers generally provides a greater than adequate frequency of measurements, ranging from several measurements per second in the early part of the test to a specified frequency in the later portions of a test. With such equipment, the test analysis may use a reduced data set of measurements to calculate the hydraulic properties (see Guide D4043, Test Methods D4104 and D5785 for analysis of water level data).

NOTE 3—There is a potential for damage or entanglement of the wires when using transducers and mechanical slugs. Entanglement of the wires may cause the quality of the data to be unknown.

8.3 *Post-Test Procedure*—Make preliminary analysis of data before leaving the field and evaluate the test regarding the criteria given in this test method and the method of analysis, such as Test Method D4104 to determine if the test should be rerun.

NOTE 4—Dependent on the properties of the well, the confidence in the results may be increased by performing multiple tests (rising and falling head) over a period of days or when the static level has returned to the original level.

9. Calculation and Interpretation of Test Data

9.1 Plot the water-level response in the well to the sudden change in head, Calculation and plotting information is contained in D5785 with supporting information in D4104 and D4043.

10. Report: Test Data Sheet(s)/Form(s)

10.1 The methodology used to specify how data are recorded on the test data sheet(s)/form(s), as given below, is covered in 1.4 and in Practice D6026.

10.2 Record as a minimum the following:

10.2.1 Date, time, and well identification,

10.2.2 Method of slug withdrawal or injection, as well as whether the test is a falling head (injection) or a rising head (withdrawal) test,

10.2.3 Inside diameter of well screen and well casing above screen,

10.2.4 Depth of well,

10.2.5 Length and depth setting of screen,

10.2.6 Pretest well conditions, and description and results of any well conditioning or redevelopment.

10.2.7 Barometric pressures logged during trend monitoring and testing. Water levels on open wells should be corrected for barometric pressure changes.

10.2.8 Volume of mechanical slug or pressure change imposed on water level, and

10.2.9 Pre-testing water-level trend.

10.3 Establish and record the measurement point from which all measurements of water level are made. Record date, time, and depth to water level below measurement point of all water levels.

10.4 Water levels measured during the test should be recorded with information on date, clock time, and time since test started. If the water levels are measured with a pressure transducer and recorded with an electronic data logger, record the name of the data file on the data logger. Barometric pressures should be logged with the other data.

10.5 Plots of the conditioning/re-development tests.

10.6 Plots of the multiple individual tests performed on the well over a period of days should be included.

11. Precision and Bias

11.1 *Precision*—Test data on precision is not presented due to the nature of the materials tested by this test method. It is either not feasible or too costly at this time to have ten or more agencies participate in an in situ testing program at a given site. Subcommittee D18.21 is seeking any data from the users of this test method that might be used to make a limited statement on precision.

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

12. Keywords

12.1 aquifer tests; aquifers; groundwater; hydraulic conductivity; hydraulic properties; instantaneous head test; slug tests; storage coefficient; transmissivity

SUMMARY OF CHANGES

In accordance with Committee D18 policy, this section identifies the location of changes to this standard since the last edition (96 (Reapproved 2008)) that may impact the use of this standard. (September 1, 2015)

(1) Removed references to D4750, which has been withdrawn.
(2) Added D3740 to Referenced Documents and Significance and Use sections.
(3) Added D6026 to Referenced Documents section and in the text body.
(4) Corrected cross-references in 6.2.
(5) Removed terminology definitions that are already in D653.
(6) Added Notes 1,3 and 5,
(7) Revised Note 2 for clarification of information.
(8) Added subsections on pre-conditioning and redevelopment of wells prior to testing.
(9) Added editorials changes and references on the recording and use of data appropriate to a test method.
(10) Expanded the Report section.