



Designation: D 2922 – 01

## Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth)<sup>1</sup>

This standard is issued under the fixed designation D 2922; 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 ( $\epsilon$ ) indicates an editorial change since the last revision or reapproval.

*This standard has been approved for use by agencies of the Department of Defense.*

### 1. Scope

1.1 These test methods cover the determination of the total or wet density of soil and soil-rock mixtures by the attenuation of gamma radiation where the source and detector(s) remain on the surface (Backscatter Method) or the source or detector is placed at a known depth up to 300 mm (12 in.) while the detector(s) or source remains on the surface (Direct Transmission Method).

1.2 The density in mass per unit volume of the material under test is determined by comparing the detected rate of gamma radiation with previously established calibration data.

1.3 The values tested in SI units are to be regarded as the standard. The inch-pound equivalents may be approximate.

1.4 It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and a unit of force (lbf). This implicitly combines two separate systems of units; that is, the absolute system and the gravitational system. It is scientifically undesirable to combine the use of two separate sets of inch-pound units within a single standard. These test methods have been written using the gravitational system of units when dealing with the inch-pound system. In this system the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm), or the recording of density in lbm/ft<sup>3</sup> should not be regarded as nonconformance with these test methods.

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.* For specific Hazard statements, see Section 6.

### 2. Referenced Documents

#### 2.1 ASTM Standards:

**D 698** Test Methods for Laboratory Compaction Charac-

teristics of Soil Using Standard Effort (12,400 ft-lbf/ft<sup>3</sup> (600 kN-m/m<sup>3</sup>))<sup>2</sup>

**D 1557** Test Methods for Laboratory Compaction Characteristics of Soil Using Modified Effort (56,000 ft-lbf/ft<sup>3</sup> (2,700 kN-m/m<sup>3</sup>))<sup>2</sup>

**D 2216** Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass<sup>2</sup>

**D 3017** Test Method for Water Content of Soil and Rock In-Place by Nuclear Methods (Shallow Depth)<sup>2</sup>

**D 4253** Test Method for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table<sup>2</sup>

**D 4643** Test Method for Determination of Water Content by the Microwave Oven Heating<sup>2</sup>

**D 4718** Practice for Correction of Unit Weight and Water Content for Soils Containing Oversize Particles<sup>2</sup>

**D 4944** Test Method for Field Determination of Water (Moisture) Content of Soil by the Calcium Carbide Gas Pressure Tester Method<sup>2</sup>

**D 4959** Test Method for Determination of Water (Moisture) Content by Direct Heating<sup>2</sup>

### 3. Significance and Use

3.1 The test methods described are useful as rapid, nondestructive techniques for the in-place determination of density of soil and rock.

3.2 The test methods are suitable for quality control and acceptance testing for construction and for research and development applications.

3.3 The nondestructive nature of the tests allow repetitive measurements to be made at a single test location.

### 4. Interferences

4.1 The chemical composition of the sample may affect the measurement, and adjustments may be necessary.

4.2 The test methods exhibit spatial bias in that the instrument is more sensitive to the density of the material in close proximity to the surface (Backscatter Method only).

NOTE 1—The nuclear gauge density measurements are somewhat biased to the surface layers of the soil being tested. This bias has largely

<sup>1</sup> These test methods are under the jurisdiction of ASTM Committee D18 on Soil and Rock and are the direct responsibility of Subcommittee D18.08 on Special and Construction Control Tests.

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<sup>2</sup> Annual Book of ASTM Standards, Vol 04.08.

been corrected out of the direct transmission method and any remaining bias is insignificant. The backscatter method is still more sensitive to the material within the first several inches from the surface.

4.3 Oversize rocks or large voids in the source-detector path may cause higher or lower density determination. Where lack of uniformity in the soil due to layering, rock or voids is suspected, the test volume site should be dug up and visually examined to determine if the test material is representative of the full material in general and if rock correction (see 9.6) is required.

4.4 The sample volume is approximately 0.0028 m<sup>3</sup> (0.10 ft<sup>3</sup>) for the Backscatter Method and 0.0057 m<sup>3</sup> (0.20 ft<sup>3</sup>) for the Direct Transmission Method when the test depth is 15 cm (6 in.). The actual sample volume is indeterminate and varies with the apparatus and the density of the material. In general, the higher the density the smaller the volume.

## 5. Apparatus

5.1 *Nuclear Gage*—An electronic counting instrument, capable of being seated on the surface of the material under test, and which contains:

5.1.1 A sealed source of high energy gamma radiation such as cesium or radium.

5.1.2 *Gamma Detector*—Any type of gamma detector such as a Geiger-Mueller tube(s).

5.2 *Reference Standard*—A block of material used for checking instrument operation and to establish conditions for a reproducible reference count rate.

5.3 *Site Preparation Device*—A plate, straightedge, or other suitable leveling tool which may be used for planning the test site to the required smoothness, and in the Direct Transmission Method, guiding the drive pin to prepare a perpendicular hole.

5.4 *Drive Pin*—A pin of slightly larger diameter than the rod in the Direct Transmission Instrument, used to prepare a hole in the material under test for inserting the rod.

5.5 *Drive Pin Extractor*—A tool that may be used to remove the drive pin in a vertical direction so that the pin will not distort the hole in the extraction process.

5.5.1 A slide hammer, with a drive pin attached, may also be used both to prepare a hole in the material to be tested and to extract the pin without distortion to the hole.

## 6. Hazards

6.1 This equipment utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of this equipment must become familiar with applicable safety procedures and government regulations.

6.2 Effective user instructions together with routine safety procedures, such as source leak tests, recording and evaluation of film badge data, and so forth, are a recommended part of the operation and storage of this instrument.

## 7. Calibration

7.1 Calibration of the instrument will be in accordance with Annex A1.

## 8. Standardization and Reference Check

8.1 Nuclear gages are subject to long-term aging of the radioactive source, detectors, and electronic systems, which

may change the relationship between count rate and material density. To offset this aging, the gage may be calibrated as the ratio of the measured count rate to a count rate made on a reference standard or to an air-gap count (for the backscatter air-gap technique, see 9.5.1.3). The reference count rate should be of the same order of magnitude as the measured count rate over the useful density range of the instrument.

8.2 Standardization of the gage shall be performed at the start of each day's work, and a permanent record of these data shall be retained. Perform the standardization with the gage located at least 8 m (25 ft) away from other sources of radioactive material, and clear of large masses or other items which may affect the reference count rate.

8.2.1 If recommended by the instrument manufacturer to provide more stable and consistent results: (1) turn on the gauge prior to use to allow it to stabilize, (2) leave the power on during the use of the gage for that day.

8.2.2 Using the reference standard, take at least four repetitive readings at the normal measurement period and determine the mean. If available on the gage, one measurement period of four or more times the normal period is acceptable. This constitutes one standardization check.

8.2.3 If the value obtained above is within the limits stated below, the gage is considered to be in satisfactory condition, and the value may be used to determine the count ratios for the day of use. If the value is outside these limits, allow additional time for the gage to stabilize, make sure the area is clear of sources of interference, and then conduct another standardization check. If the second standardization check is within the limits, the gage may be used, but if it also fails the test, the gage shall be adjusted or repaired as recommended by the manufacturer. The limits are as follows:

$$|N_s - N_o| \leq 2.0 \sqrt{N_o F} \quad (1)$$

where:

$N_s$  = value of current standardization count,

$N_o$  = average of the past four values of  $N_s$  taken for prior usage, and

$F$  = value of prescale. [The prescale value ( $F$ ) is a divisor which reduces the actual value for the purpose of display. The manufacturer will supply this value if other than 1.0.] Some instruments may have provisions to compute and display these values.

8.2.3.1 If the instrument standardization has not been checked within the previous three months, perform at least four new standardization checks, and use the mean as the value for  $N_o$ .

8.3 Use the value of  $N_s$  to determine the count ratios for the current day's use of the instrument. If for any reason the measured density becomes suspect during the day's use, perform another standardization check.

## 9. Procedure for Field Use

9.1 Standardize the gage. (See Section 8.)

9.2 Select a test location. If the gage will be closer than 250 mm (10 in.) to any vertical mass that might influence the result, such as in a trench or alongside a pipe, follow the manufacturer's correction procedure.

9.3 Remove all loose and disturbed material. Remove additional material as necessary to reach the material that represents a valid sample of the zone or stratum to be tested. Surface drying and spatial bias should be considered in determining the depth of material to be removed.

9.4 Plane or scrape a smooth horizontal surface so as to obtain maximum contact between the gage and the material being tested. The placement of the gage on the surface of the material to be tested is always important, but is especially critical to the successful determination of density when using the backscatter method. The optimum condition in all cases, is total contact between the bottom surface of the gauge and the surface of the material being tested. To correct for surface irregularities, use of native fines or fine sand as a filler may be necessary. The depth of the filler should not exceed approximately 3 mm ( $\frac{1}{8}$  in.) and the total area filled should not exceed 10 % of the bottom area of the instrument. The maximum depth of any void beneath the gage that can be tolerated without filling shall not exceed approximately 3 mm ( $\frac{1}{8}$  in.). Several trial seatings may be required to achieve these conditions.

9.5 Proceed with the test in the following manner:

9.5.1 *Backscatter Procedure:*

9.5.1.1 Seat the gage firmly on the prepared test site.

9.5.1.2 Keep all other radioactive sources away from the gauge to avoid affecting the measurement so as not to affect the readings.

9.5.1.3 Secure and record one or more readings for the normal measurement period in the backscatter position.

NOTE 2—When using the backscatter air-gap procedure, follow the instrument manufacturers instructions regarding apparatus set up. Take the same number of readings for the normal measurement period in the air-gap position as in the standard backscatter position. Determine the air-gap ratio by dividing counts per minute obtained in the air-gap position by counts per minute obtained in standard backscatter position.

9.5.1.4 Determine the ratio of the reading to the standard count or to the air gap count. From this count ratio and the appropriate calibration and adjustment data, determine the in-place wet density.

9.5.2 *Direct Transmission Procedure:*

9.5.2.1 Make a hole perpendicular to the prepared surface using the guide and the hole-forming device (5.4), or by drilling if necessary. The hole shall be of such depth and alignment that insertion of the probe will not cause the gage to tilt from the plane of the prepared area. The depth of the hole must be deeper than the depth to which the probe will be placed. The guide shall be the same size as the base of the gauge, with the hole in the same location on the guide as the probe on the gauge. The corners of the guide are marked by scoring the surface of the soil. The guide plate is then removed and any necessary repairs are made to the prepared surface.

9.5.2.2 Proceed with testing in the following manner:

9.5.2.3 Set the gage on the soil surface, carefully aligning it with the marks on the soil so that the probe will be directly over the pre-formed hole.

9.5.2.4 Insert the probe in the hole.

9.5.2.5 Seat the gage firmly by rotating it about the probe with a back and forth motion.

9.5.2.6 Pull gently on the gage in the direction that will bring the side of the probe against the side of the hole that is closest to the detector (or source) location in the gauge housing.

9.5.2.7 Keep all other radioactive sources away from the gauge to avoid affecting the measurement.

9.5.2.8 Secure and record one or more readings for the normal measurement period.

9.5.2.9 Determine the ratio of the reading to the standard count. From this count ratio and the appropriate calibration and adjustment data, determine the in-place wet density.

NOTE 3—Some instruments have built-in provisions to compute the ratio, wet density, and to enter an adjustment bias. Additionally some instruments may have provisions to measure and compute moisture content, and dry density.

9.6 If the volume tested as defined in 4.4 has excess oversize material with respect to the limitations in the appropriate Test Methods D 698, D 1557 or D 4253D 698D 1557D 4253, then a correction for wet density (unit weight) and water content must be applied. This correction will be done in accordance with Practice D 4718D 4718. This test method requires sampling from the actual test volume.

9.6.1 If samples of the measure material are to be taken for purposes of correlation with other test methods or rock correction, the volume measured can be approximated by a 200 mm (8 in.) diameter cylinder located directly under the center line of the radioactive source and detector(s). The height of the cylinder to be excavated will be the depth setting of the source rod when using the Direct Transmission method or approximately 75 mm (3 in.) when using the Backscatter Method.

9.6.2 An alternative to the correction for oversize particles, that can be used with mass density methods or minimal oversize situations, involves multiple tests. Tests may be taken at adjacent locations and the results averaged to get a representative value. Comparisons need to be made to evaluate whether the presence of a single large rock or void in the soil is producing unrepresentative values of density. Whenever values obtained are questionable, the test volume site should be dug up and visually examined.

## 10. Calculation of Results

10.1 The in-place wet density is determined as outlined in 9.5. If dry density is required, the in-place water content shall be determined using either gravimetric samples and laboratory determination of water content (Test Methods D 2216, D 4643, D 4959, D 4944D 2216D 4643D 4959D 4944), or an instrument which determines water content by neutron thermalization (Test Method D 3017D 3017).

10.1.1 If the water content is determined by nuclear methods, Test Method D 3017D 3017, subtract the  $\text{kg/m}^3$  ( $\text{lb/ft}^3$ ) of moisture from the  $\text{kg/m}^3$  ( $\text{lb/ft}^3$ ) of wet density, and obtain dry density in  $\text{kg/m}^3$  ( $\text{lb/ft}^3$ ).

10.1.2 If the water content is determined by other methods, and is in the form of percent, proceed as follows:

$$\rho_d = \frac{100\rho_m}{100 + W} \quad (2)$$

where: