Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and AASHTO Provisional Standards, 41st Edition (HM-41)

March 2022

Dear Customer:

AASHTO has issued an erratum, which includes technical revisions, for the *Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and AASHTO Provisional Standards*, 41st Edition (HM-41). A description/list follows on the reverse.

Additional copies of the erratum can be downloaded from the following link:

https://downloads.transportation.org/HM-41-Errata.pdf

AASHTO staff sincerely apologizes for any inconvenience.

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List of Errata for *Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and AASHTO Provisional Standards,* 41st Edition (HM-41)

Page	Standard Number	Incorrect Content	Corrected Content
xxiv	List of Technical Changes—Part 2	Reclassified as a practice, R 99; revised rod dimensions in Table 1.	Reclassified as a practice, R 100; revised rod dimensions in Table 1.
lxxiv		Revised and renumbered as R 99	Revised and renumbered as R 100
T 99-8	T 99	In Section 5.3.1, the variable for wet density is W_1.	Section 5.3.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.
T 99-9		In Section 5.5, the variable for wet density is W_1.	Section 5.5's last sentence now reads: When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil (Note 7) perform one more determination such that there is a minimum of two determinations over optimum moisture.
T 99-10		In Section 7.1, the variable for wet density is W_1.	Section 7.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.
		In Section 9.3.1, the variable for wet density is W_1.	Section 9.3.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.
T 99-11		In Section 9.5, the variable for wet unit mass is W_1.	Section 9.5's last sentence now reads: When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil perform one more determination such that there is a minimum of two determinations over optimum moisture.
		In Section 11.1, the variable for wet density is W_1.	Section 11.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.

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Page	Standard Number	Incorrect Content	Corrected Content
T 99-11 (cont'd.)	T 99 (cont'd.)	In Section 12.1, the variable for wet density is W_1.	Section 12.1 now begins: Wet density (ρ_t) shall be determined… Equation 1 now reads: $$\rho_t = (A - B)/V \qquad (1)$$ and its equation legend now reads in part: ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil
T 99-12		In Section 12.2, the variables for dry and wet density are W and W_1, respectively.	Equation 2 now reads: $$\rho_d = \frac{\rho_t}{w+100} \times 100 \qquad (2)$$ and its equation legend now reads in part: ρ_d = dry density, in kg/m^3 (lb/ft^3) of compacted soil, ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil,
T 180-8	T 180	In Section 5.3.1, the variable for wet density is W_1.	Section 5.3.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.
T 180-9		In Section 5.5, the variable for wet density is W_1.	Section 5.5's last sentence now reads: When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil (Note 7) perform one more determination such that there is a minimum of two determinations over optimum moisture.
T 180-10		In Section 7.1, the variable for wet density is W_1.	Section 7.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.
		In Section 9.3.1, the variable for wet density is W_1.	Section 9.3.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.

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Page	Standard Number	Incorrect Content	Corrected Content
T 180-11	T 180 (cont'd.)	In Section 9.5, the variable for wet unit mass is W_1.	Section 9.5's last sentence now reads: When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil perform one more determination such that there is a minimum of two determinations over optimum moisture.
		In Section 11.1, the variable for wet density is W_1.	Section 11.1's last sentence now reads: Calculate the wet density, ρ_t, as described in Section 12.1.
T 180-11		In Section 12.1, the variable for wet density is W_1.	Section 12.1 now begins: Wet density (ρ_t) shall be determined… Equation 1 now reads: $$\rho_t = (A - B)/V \qquad (1)$$ and its equation legend now reads in part: ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil
T 180-12		In Section 12.2, the variables for dry and wet density are W and W_1, respectively.	Equation 2 now reads: $$\rho_d = \frac{\rho_t}{w+100} \times 100 \qquad (2)$$ and its equation legend now reads in part: ρ_d = dry density, in kg/m^3 (lb/ft^3) of compacted soil, ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil, and
T 310-2	T 310	In Section 2.1, R 18 is missing from the list of AASHTO standards. Note: Pagination is affected through p. T 310-10.	The first standard listed in Section 2.1 is as follows: R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories

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List of Errata for *Standard Specifications for Transportation Materials and Methods of Sampling and Testing, and AASHTO Provisional Standards,* 41st Edition (HM-41)

Page	Standard Number	Incorrect Content	Corrected Content
T 310-7	T 310 (cont'd.)	In Section 10.1.2, Equation 2 is incorrect and the two density variables in the equation legend are notated as *d* and *m*.	Equation 2 now reads: $$\rho_d = \frac{\rho_t}{w+100} \times 100 \qquad (2)$$ and its equation legend now reads in part: ρ_d = dry density in kg/m^3 (lbm/ft^3), ρ_t = wet density in kg/m^3 (lbm/ft^3), and
T 310-11 and -12		In Section A2.4.2, the variable for wet density is ρ.	Equation A2.1 now reads: $$M_m = \frac{\rho_t \times w}{w+100} \qquad (A2.1)$$ and its equation legend reads in part: ρ_t = wet (total) density, kg/m^3 or lbm/ft^3, and

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Errata to HM-41: March 2022 (HM-41-E1)

Designation Number	Title	Technical Subcommittee Number	Balloted Revisions
R 62-13 (2021)	Developing Dynamic Modulus Master Curves for Asphalt Mixtures	2d	Reconfirmed for 2021 publication.
R 63-13 (2021)	Solid Wall High-Density Polyethylene (HDPE) Conduit for Non-Pressure Applications Used for the Protection of Power and Telecommunications Cables	4b	Reconfirmed for 2021 publication.
R 64-17 (2021)	Sampling and Fabrication of 50-mm (2-in.) Cube Specimens Using Grout (Non-Shrink) or Mortar	3b	Reconfirmed for 2021 publication.
R 80-17 (2021)	Determining the Reactivity of Concrete Aggregates and Selecting Appropriate Measures for Preventing Deleterious Expansion in New Concrete Construction	3c	Reconfirmed for 2021 publication.
R 81-17 (2021)	Static Segregation of Hardened	3c	Reconfirmed for 2021 publication.
R 82-17 (2021)	Pipe Joint Selection for Highway Culvert and Storm Drains	4b	Reconfirmed for 2021 publication.
R 83-17 (2021)	Preparation of Cylindrical Performance Test Specimens Using the Superpave Gyratory Compactor (SGC)	2d	Reconfirmed for 2021 publication.
R 84-17 (2021)	Developing Dynamic Modulus Master Curves for Asphalt Mixtures Using the Asphalt Mixture Performance Tester (AMPT)	2d	Reconfirmed for 2021 publication.
R 99-21	Troubleshooting Asphalt Specimen Volumetric Differences between Superpave Gyratory Compactors (SCGs) Used in the Design and the Field Management of Superpave Mixtures	2d	Adopted AASHTO Provisional practice PP 76 as a full standard practice, R 99; no revisions made.
R 100-21	Making and Curing Concrete Test Specimens in the Field	3b	Reclassified T 23 as a practice, R 100; revised rod dimensions in Table 1.

Errata to HM-41: March 2022 (HM-41-E1)

LIST OF TECHNICAL CHANGES—PART 2

   The balloted technical changes listed below are also indicated in the specifications by a change bar in the left. Unballoted editorial changes do not receive the change bar; however, the subheader line below the designation number will indicate if the standard has been editorially revised.

Release: July 2021

Designation Number	Title	Technical Subcommittee Number	Balloted Revisions
All tests and provisional tests			Editorially revised to include the following statement in Section 1: "The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors."
T 23-18	Making and Curing Concrete Test Specimens in the Field	3b	Reclassified as a practice, **R 100**; revised rod dimensions in Table 1.
T 30-21	Mechanical Analysis of Extracted Aggregate	2c	Revised Table A2.1 as follows: • Removed sieves with opening sizes larger than 2 in. and related rows • Removed 350 by 350 mm and 372 x 580 mm sieves and related columns • Added U.S. customary equivalencies for remaining sieve sizes and sieving area
T 59-16 (2021)	Emulsified Asphalts	2a	Reconfirmed for 2021 publication.
T 71-08 (2021)	Effect of Organic Impurities in Fine Aggregate on Strength of Mortar	1c	Reconfirmed for 2021 publication.
T 84-13 (2021)	Specific Gravity and Absorption of Fine Aggregate	1c	Reconfirmed for 2021 publication.

Errata to HM-41: March 2022 (HM-41-E1)

Standard Number	Original Title	Current/Final Title	Year Adopted	Status	Year Discontinued	Reason Discontinued (If Known)	Other Notes
T 4	Abrasion of Gravel	Abrasion of Gravel by Use of the Deval Machine	1924	Discontinued	1983	Lack of use	
T 5	Toughness of Rock	Toughness of Rock	1924	Discontinued	1961		
T 6	Toughness of Gravel	Toughness of Gravel	1924	Discontinued	1942		
T 7	Determining Quality of Glacial Gravels by Lithological Count of Particles	Determining Quality of Glacial Gravels by Lithological Count of Particles	1924	Discontinued	1942		
T 8	Quantity of Soft Pebbles in Gravel	Quantity of Soft Pebbles in Gravel	1924	Discontinued	1942		
T 9	Soundness of Coarse Aggregate	Soundness of Coarse Aggregate	1924	Discontinued	1935		
T 10	Percentage of Shale in Aggregate	Percentage of Shale in Aggregate	1924	Discontinued	1950	"Replaced by [unspecified] other [test] methods."	This statement probably refers to T 149 and T 150
T 11	Quantity of Clay and Silt in Gravel	Materials Finer Than 75-µm (No. 200) Sieve in Mineral Aggregates by Washing	1924	Active			
T 12	Decantation Test for Sand and Other Fine Aggregates	Decantation Test for Sand and Other Fine Aggregates	1924	Discontinued	1935		
T 13	Apparent Specific Gravity of Sand, Stone, and Slag Screenings, and Other Fine Nonbituminous Highway Materials	Apparent Specific Gravity of Sand, Stone, and Slag Screenings, and Other Fine Nonbituminous Highway Materials	1924	Discontinued	1935		
T 14	Apparent Specific Gravity and Absorption of Stone and Other Coarse Materials	Apparent Specific Gravity and Absorption of Stone and Other Coarse Materials	1924	Discontinued	1935		
T 15	Apparent Specific Gravity and Absorption of Sand, Gravel, or Other Fine Nonbituminous Highway Materials	Apparent Specific Gravity and Absorption of Sand, Gravel, or Other Fine Nonbituminous Highway Materials	1924	Discontinued	1935		
T 16	Approximate Apparent Specific Gravity of Fine Aggregate	Approximate Apparent Specific Gravity of Fine Aggregate	1924	Discontinued	1935		
T 17	Approximate Percentage of Voids in Inundated Fine Aggregate	Approximate Percentage of Voids in Inundated Fine Aggregate	1924	Discontinued	1935		
T 18	Surface Moisture in Fine Aggregate	Surface Moisture in Fine Aggregate	1924	Discontinued	1935		
T 19	Unit Weight of Aggregate for Concrete	Unit Weight and Voids in Aggregate	1924	Converted	1991	Replaced by dual-unit standard T 19M/T 19	
T 19M/ T 19	Unit Weight and Voids in Aggregate	Bulk Density ("Unit Weight") and Voids in Aggregate	1991	Active			

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Errata to HM-41: March 2022 (HM-41-E1)

Standard Number	Original Title	Current/Final Title	Year Adopted	Status	Year Discontinued	Reason Discontinued (If Known)	Other Notes
T 20	Determination of Voids in Fine Aggregate for Concrete	Voids in Aggregate in Concrete	1928	Discontinued	1980	Incorporated into T 19	
T 21	Organic Impurities in Sands for Concrete	Organic Impurities in Fine Aggregates for Concrete	1924	Active			
T 22M/ T 22	Methods of Making Compression Tests of Concrete	Compressive Strength of Cylindrical Concrete Specimens	1924	Active			Changed to dual units in 2020
T 23	Method of Making and Storing Compression Test Specimens of Concrete in the Field	Making and Curing Concrete Test Specimens in the Field	1924	Renumbered	2021	Revised and renumbered as **R 100**	
T 24	Methods of Securing Specimens of Hardened Concrete from the Structure	Securing Specimens of Hardened Concrete from the Structure	1924	Converted	2007	Replaced by dual-unit standard T 24M/T 24	
T 24M/ T 24	Obtaining and Testing Drilled Cores and Sawed Beams of Concrete	Obtaining and Testing Drilled Cores and Sawed Beams of Concrete	2007	Active			
T 25	Method of Test for Absorption of Concrete	Test for Absorption of Concrete	1924	Discontinued	1947		
T 26	Quality of Water to be Used in Concrete	Quality of Water to be Used in Concrete	1924	Discontinued	2014	Lack of use	
T 27	Sieve Analysis of Aggregates for Concrete	Sieve Analysis of Fine and Coarse Aggregates	1924	Discontinued			
T 28	Method of Mechanical Analysis of Sand or Other Fine Highway Material	Method of Mechanical Analysis of Sand or Other Fine Highway Material	1924	Discontinued	1935		
T 29	Method of Mechanical Analysis of Coarse Aggregates	Method of Mechanical Analysis of Coarse Aggregates	1924	Discontinued	1935		
T 30	Method of Mechanical Analysis of Extracted Aggregates	Mechanical Analysis of Extracted Aggregate	1924	Discontinued			
T 31	Paving Brick	Sampling and Testing Paving Brick	1924	Discontinued	1971		
T 32	Testing Brick (Compression, Flexure, Absorption)	Sampling and Testing Brick	1924	Discontinued	2011	Replaced by ASTM C67	
T 33	Methods of Testing Culvert Pipe	Testing Culvert Pipe	1935	Discontinued	1984	Lack of use	
T 34	Drain Tile	Sampling and Testing Drain Tile	1924	Discontinued	1938		
T 35	Methods of Making Compression and Tension Tests of Fine Aggregate for Concrete	Methods of Making Compression and Tension Tests of Fine Aggregate for Concrete	1924	Discontinued	1942		
T 36	Method of Sampling Mineral Filler	Sampling Mineral Filler	1924	Discontinued	1947		
T 37	Determination of Fineness of Mineral Filler	Sieve Analysis of Mineral Filler for Hot Mix Asphalt	1924	Active			

by the previous blow. A more detailed calibration procedure for laboratory mechanical-rammer soil compactors can be found in ASTM D2168.

3.2.3.   *Rammer Face*—The circular face rammer shall be used, but a sector face may be used as an alternative, provided the report shall indicate type of face used other than the 50.8-mm (2-in.) circular face, and it shall have an area equal to that of the circular face rammer. The in-service area of sector face rammers shall be standardized and yield a surface area within 1.5 percent of the area of the 50.8-mm (2-in.) circular face rammer.

3.3.   *Sample Extruder (for Solid-Walled Molds Only)*—A jack, lever, frame, or other device adopted for the purpose of extruding compacted specimens from the mold.

3.4.   *Balances and Scales*—A balance or scale conforming to the requirements of M 231, Class G 5. Also, a balance conforming to the requirements of M 231, Class G 2.

      Note 3—The capacity of the metric balance or scale should be approximately 11.5 kg (25 lb) when used to determine the mass of the 152-mm (6-in.) mold and compacted, moist soil; however, when the 102-mm (4-in.) mold is used, a balance or scale of lesser capacity than 11.5 kg may be used, if the sensitivity and readability are 1 g.

3.5.   *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of $110 \pm 5°C$ ($230 \pm 9°F$) for drying moisture samples.

3.6.   *Straightedge*—A hardened-steel straightedge at least 250 mm (10 in.) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.250 mm per 250 mm (0.01 in. per 10 in.) (0.1 percent) of length within the portion used for trimming the soil (Note 4).

      Note 4—The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.250 mm per 250 mm (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil with the cutting edge will cause a concave soil surface.

3.7.   *Sieves*—19.0-mm ($^3/_4$-in.), and 4.75-mm (No. 4) sieves conforming to the requirements of ASTM E11.

3.8.   *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

3.9.   *Containers*—Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

METHOD A

4.   SAMPLE

4.1.   Obtain a representative sample. This sample must be large enough that when the oversized (retained on the 4.75-mm [No. 4] sieve) particles are removed 3 kg (7 lb) or more of the sample remains.
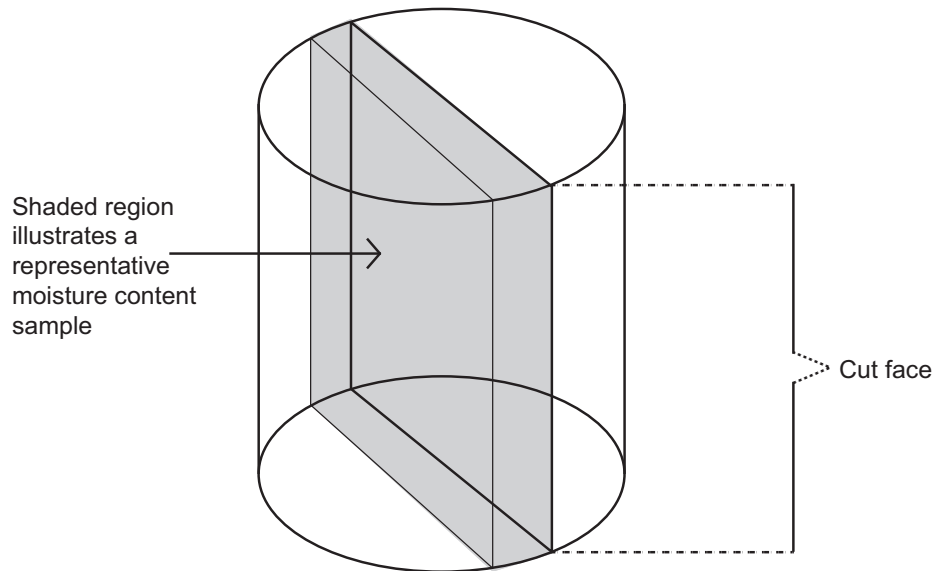
4.2.   Dry the sample until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

4.3.   Sieve the soil over the 4.75-mm (No. 4) sieve. When the sample has oversized particles, particles retained on the 4.75-mm (No. 4) sieve, refer to the Annex A1.

4.4.   Reduce the sample, to a mass of 3 kg (7 lb) or more in accordance with R 76.

5.   PROCEDURE

5.1.   Determine the mass of the mold and base plate to the nearest 1 g (0.005 lb).

5.2.   Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four to eight percentage points below optimum moisture content.

     Note 7—When developing a compaction curve for free-draining soils, such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture content sample from the mixing bowl may be preferred to determine the amount of moisture available for compaction.

5.3.   Form a specimen by compacting the prepared soil in the 101.60-mm (4-in.) mold assembly (in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Prior to compaction, place the loose soil into the mold assembly and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or a similar device having a face diameter of approximately 50 mm (2 in.). Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device and evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 305 mm (12 in.) above the elevation of the soil when a sleeve-type rammer is used, or from 305 mm above the approximate elevation of compacted soil when a stationary mounted type of rammer is used. During compaction, the mold assembly shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process (Note 6).

     Note 6—Each of the following has been found to be a satisfactory base on which to rest the mold assembly during compaction of the soil: a block of concrete, with a mass not less than 90 kg (200 lb), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as are found in concrete box culverts, bridges, and pavements.

5.3.1.   Following compaction, remove the collar; carefully trim the compacted soil even with the top of the mold by means of the straightedge, and determine the mass of the mold, base plate, and moist soil in kilograms to the nearest 1 g (0.005 lb). Calculate the wet density, ρ_t, as described in Section 12.1.

5.4.   Detach the base plate and remove the material from the mold using the extruder when necessary. Obtain a representative sample of the material by slicing vertically through the center of the molded material and removing one of the cut faces (Figure 3) or from the center of the pile if the material falls apart. Weigh the sample immediately. Determine the moisture content in accordance with T 265 and record the results.

Shaded region illustrates a representative moisture content sample

Cut face

Figure 3—Representative Moisture Content Sample Selection

5.5.	Thoroughly break up the remaining portion of the molded specimen until it will pass through a 4.75-mm (No. 4) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil 1 to 2 percentage points (water content increments should not exceed 2.5 percent except when heavy clay soils or organic soils exhibiting flat elongated curves are encountered; the water content increments may be increased to a maximum of 4 percent) and repeat the above procedure for each increment of water added. When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil (Note 7) perform one more determination such that there is a minimum of two determinations over optimum moisture.
5.5.1.	One additional determination over optimum moisture is sufficient for non-cohesive, drainable soils.
5.5.2.	In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample shall be used in each compaction test. **Note 7**—In some cases where the soil is a heavy-textured clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture points selected shall bracket the optimum moisture content, thus providing samples that, when compacted, will increase in mass to the maximum density and then decrease in mass. The samples of soil–water mixtures shall be placed in covered containers and allowed to stand for not less than 12 h before making the moisture–density test.

METHOD B

6.   SAMPLE

6.1.	Obtain a representative sample in accordance with Section 4, except that the sample shall have a minimum mass of 7 kg (16 lb).

7.	**PROCEDURE**

7.1. Follow the same procedure as described for Method A in Section 5, except for the following: Form a specimen by compacting the prepared soil in the 152.4-mm (6-in.) mold assembly in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.), each layer being compacted by 56 uniformly distributed blows from the rammer. Calculate the wet density, ρ_t, as described in Section 12.1.

METHOD C

8.	**SAMPLE**

8.1. Obtain a representative sample. This sample must be large enough that when the oversized (retained on the 19.0-mm [$^3/_4$-in.] sieve) particles are removed 5 kg (11 lb) or more of the sample remains.

8.2. Dry the sample until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

8.3. Sieve soil over the 19.0-mm ($^3/_4$-in.) sieve. When the sample has oversized particles, see Annex A1.

8.4. Reduce the sample to a mass of 5 kg (11 lb) or more in accordance with R 76.

9.	**PROCEDURE**

9.1. Determine the mass of the mold and base plate to the nearest 1 g (0.005 lb).

9.2. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four to eight percentage points below optimum moisture content (Note 5).

9.3. Form a specimen by compacting the prepared soil in the 101.60-mm (4-in.) mold assembly in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Prior to compaction, place the loose soil into the mold assembly and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or a similar device having a face diameter of approximately 50 mm (2 in.). Following compaction of each of the first two layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device and evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 305 mm (12 in.) above the elevation of the soil when a sleeve-type rammer is used, or from 305 mm (12 in.) above the approximate elevation of each finely compacted layer when a stationary mounted-type rammer is used. During compaction, the mold assembly shall rest firmly on a dense, uniform, rigid, and stable foundation (Note 6).

9.3.1. Following compaction, remove the collar; carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller-sized material. Determine the mass of the mold, base plate, and moist soil in kilograms to the nearest 1 g (0.005 lb). Calculate the wet density, ρ_t, as described in Section 12.1.

9.4. Detach the base plate and remove the material from the mold using the extruder when necessary. Obtain a representative sample of the material by slicing vertically through the center of the molded material and removing one of the cut faces (Figure 3) or from the center of the pile if the material falls apart. Weigh the sample immediately. Determine the moisture content in accordance with T 265 and record the results.

9.5. Thoroughly break up the remainder of the material until it will pass through a 19.0-mm (0.75-in.) sieve and 90 percent of the soil aggregations will pass a 4.75-mm (No. 4) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added (Note 7). When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil perform one more determination such that there is a minimum of two determinations over optimum moisture.

9.5.1. One additional determination over optimum moisture is sufficient for non-cohesive, drainable soils.

METHOD D

10. SAMPLE

10.1. Obtain a representative sample in accordance with Section 8 except that it shall have a mass of approximately 11 kg (25 lb).

11. PROCEDURE

11.1. Follow the same procedure as described for Method C in Section 9, except for the following: Form a specimen by compacting the prepared soil in the 152.4-mm (6-in.) mold assembly in three approximately equal layers to give a total compacted depth of about 125 mm (5 in.), each layer being compacted by 56 uniformly distributed blows from the rammer. Calculate the wet density, ρ_t, as described in Section 12.1.

CALCULATIONS AND REPORT

12. CALCULATIONS

12.1. Wet density (W_1) shall be determined using the mold volume. For masses recorded in kilograms, the unit of wet density is kilograms per cubic meter of compacted soil. For masses recorded in pounds, the unit of wet density is pounds per cubic foot of compacted soil.

$$\rho_t = (A - B)/V \tag{1}$$

where:

ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil,

A = mass of the mold, base plate, and wet soil,

B = mass of the mold, base plate,

V = mold volume as determined in Section 3.1.1 for Methods A and C, or Section 3.1.2 for Methods B and D.

12.2. The dry density is related to the wet density as follows:

$$\rho_d = \frac{\rho_t}{w+100} \times 100 \qquad\qquad (2)$$

where:

ρ_d = dry density, in kg/m^3 (lb/ft^3) of compacted soil,

ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil,

w = moisture content (percent) of the specimen.

13. MOISTURE–DENSITY RELATIONSHIP

13.1. The calculations in Section 12 shall be made to determine the wet density (unit mass) and oven-dry density (unit mass) in kilograms per cubic meter or pounds per cubic foot of the compacted samples. The oven-dry densities of the soil shall be plotted as ordinates, and the corresponding moisture content as abscissas.

13.2. *Optimum Moisture Content*—When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in Section 13.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture content" of the soil under the above compaction.

13.3. *Maximum Dry Density*—The oven-dry density in kilograms per cubic meter or pounds per cubic foot of the soil at optimum moisture content shall be termed "maximum dry density" under the above compaction.

14. REPORT

14.1. *The report shall include the following*:

14.1.1. The method used (Method A, B, C, or D).

14.1.2. The optimum moisture content to the nearest 0.1 percent.

14.1.3. The maximum density to the nearest 1 kg/m^3 (0.1 lb/ft^3).

14.1.4. Type of face if other than 50.8 mm (2 in.) circular.

14.1.5. Oversized particle correction.

14.1.5.1. The adjusted maximum dry density to the nearest 1 kg/m^3 (0.1 lb/ft^3).

14.1.5.2. The corrected optimum moisture content to the nearest 0.1 percent.

14.1.5.3. The oversized particles to the nearest 0.1 percent of the original dry mass of the sample.

14.1.5.4. G_{sb} of oversized particles to the nearest 0.001.

15. PRECISION STATEMENT

15.1. *Repeatability (Single Operator)*—Two results obtained by the same operation on the same sample in the same laboratory using the same apparatus and on different days should be considered

3.2.3.   *Rammer Face*—The circular face rammer shall be used but a sector face rammer may be used as an alternative provided that the report shall indicate type of face used other than the 50.8-mm (2-in.) circular face, and that the sector face rammer shall have an area equal to that of the circular face rammer. The in-service area of sector face rammers shall be standardized and yield a surface area within 1.5 percent of the area of the 50.8-mm (2-in.) circular face rammer.

3.3.   *Sample Extruder (for Solid-Walled Molds Only)*—A jack, lever, frame, or other device adapted for the purpose of extruding compacted specimen from the mold.

3.4.   *Balances and Scales*—A balance or scale conforming to the requirements of M 231, Class G 5. Also, a balance conforming to the requirements of M 231, Class G 2.

    Note 3—The capacity of the metric balance or scale should be approximately 11.5 kg (25 lb) when used to determine the mass of the 152-mm (6-in.) mold and compacted, moist soil; however, when the 102-mm (4-in.) mold is used, a balance or scale of lesser capacity than 11.5 kg may be used, if the sensitivity and readability are 1 g.

3.5.   *Drying Oven*—A thermostatically controlled drying oven capable of maintaining a temperature of $110 \pm 5°C$ ($230 \pm 9°F$) for drying moisture samples.

3.6.   *Straightedge*—A hardened steel straightedge at least 250 mm (10 in.) in length. It shall have one beveled edge, and at least one longitudinal surface (used for final trimming) shall be plane within 0.1 percent of the length within the portion used for trimming the soil (Note 4).

    Note 4—The beveled edge may be used for final trimming if the edge is true within a tolerance of 0.25 mm per 250 mm (0.1 percent) of length; however, with continued use, the cutting edge may become excessively worn and not suitable for trimming the soil to the level of the mold. The straightedge should not be so flexible that trimming the soil surface with the cutting edge will cause a concave soil surface.

3.7.   *Sieves*—19.0-mm (0.75-in.), and 4.75-mm (No. 4) sieves conforming to the requirements of ASTM E11.

3.8.   *Mixing Tools*—Miscellaneous tools such as mixing pan, spoon, trowel, spatula, etc., or a suitable mechanical device for thoroughly mixing the sample of soil with increments of water.

3.9.   *Containers*—Suitable containers made of material resistant to corrosion and not subject to change in mass or disintegration on repeated heating and cooling. Containers shall have close-fitting lids to prevent loss of moisture from samples before initial mass determination and to prevent absorption of moisture from the atmosphere following drying and before final mass determination. One container is needed for each moisture content determination.

METHOD A

4.   SAMPLE

4.1.   Obtain a representative sample. This sample must be large enough that when the oversized (retained on the 4.75-mm (No. 4) sieve) particles are removed 3 kg (7 lb) or more of the sample remains.

4.2.   Dry the sample until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up the aggregation in such a manner as to avoid reducing the natural size of individual particles.
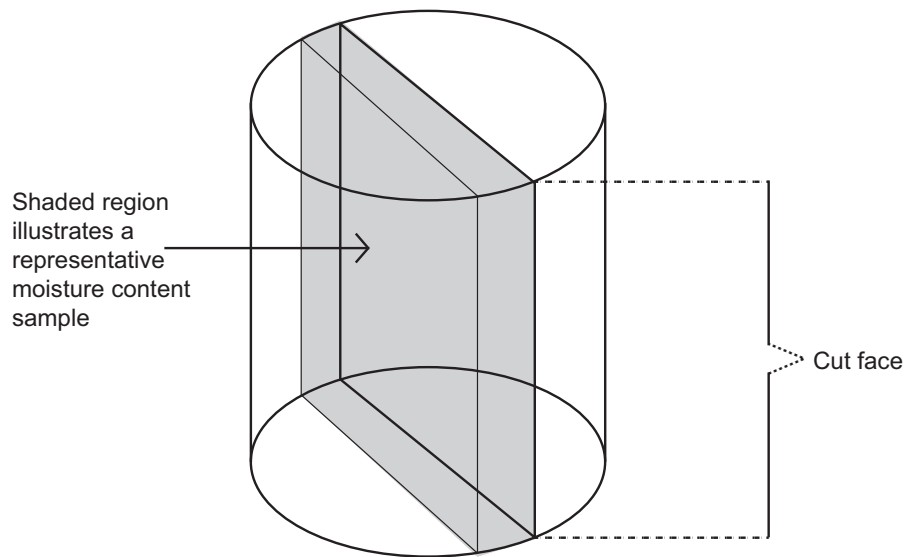
4.3.   Sieve the soil over the 4.75-mm (No. 4) sieve. When the sample has oversized particles, particles retained on the 4.75-mm (No. 4) sieve, refer to the Annex A1. Reduce the sample, to a mass of 3 kg (7 lb) or more in accordance with R 76.

5.   PROCEDURE

5.1.   Determine the mass of the mold and base plate to the nearest 1 g (0.005 lb).

5.2.   Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four to eight percentage points below optimum moisture content.

Note 5—When developing a compaction curve for free-draining soils, such as uniform sands and gravels, where seepage occurs at the bottom of the mold and base plate, taking a representative moisture content sample from the mixing bowl may be preferred to determine the amount of moisture available for compaction.

5.3.   Form a specimen by compacting the prepared soil in the 101.60-mm (4-in.) mold assembly in five approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Prior to compaction, place the loose soil into the mold assembly and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 50 mm (2 in.). Following compaction of each of the first four layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device, and be evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from the rammer dropping free from a height of 457 mm (18 in.) above the elevation of the soil when a sleeve-type rammer is used, or from 457 mm (18 in.) above the approximate elevation of the soil as compacted by the previous blow when a stationary mounted type of rammer is used. During compaction, the mold assembly shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process (Note 6).

Note 6—Each of the following has been found to be a satisfactory base on which to rest the mold assembly during compaction of the soil: a block of concrete, with a mass of not less than 90 kg (200 lb), supported by a relatively stable foundation; a sound concrete floor; and for field application, such surfaces as are found in concrete box culverts, bridges, and pavements.

5.3.1.   Following compaction, remove the collar; carefully trim the compacted soil even with the top of the mold by means of the straightedge, and determine the mass of the mold, base plate and moist soil in kilograms to the nearest 1 g (0.005 lb). Calculate the wet density, ρ_t, as described in Section 12.

5.4.   Detach the base plate and remove the material from the mold using the extruder when necessary. Obtain a representative sample of the material by slicing vertically through the center of the molded material and removing one of the cut faces (Figure 3) or from the center of the pile if the material falls apart. Weigh the sample immediately. Determine the moisture content in accordance with T 265, and record the results.

Figure 3—Representative Moisture Content Sample Selection

5.5.   Thoroughly break up the remaining portion of the molded specimen until it will pass a 4.75-mm (No. 4) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amount to increase the moisture content of the soil by approximately 1 to 2 percentage points (water content increments should not exceed 2.5 percent, except when heavy clay soils or organic soils exhibiting flat elongated curves are encountered; then the water content increments may be increased to a maximum of 4 percent), and repeat the above procedure for each increment of water added. When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil (Note 7) perform one more determination such that there is a minimum of two determinations over optimum moisture.

5.5.1.   One additional determination over optimum moisture is sufficient for non-cohesive, drainable soils.

5.5.2.   In instances where the soil material is fragile in character and will be reduced significantly in grain size by repeated compaction, a separate and new sample shall be used in each compaction test.

Note 7—In some cases where the soil is heavy-textured, clayey material into which it is difficult to incorporate water, a separate and new sample shall be used in each compaction test. In these cases, separate samples shall be thoroughly mixed with amounts of water sufficient to cause the moisture contents of the samples to vary by approximately two percentage points. The moisture contents selected shall bracket the optimum moisture content, thus providing samples which, when compacted, will increase in mass to the maximum density and then decrease in mass. The samples of soil–water mixtures shall be placed in covered containers and allowed to stand for not less than 12 h before making the moisture–density test.

METHOD B

6.   SAMPLE

6.1.   Obtain a representative sample in accordance with Section 4 except that the sample shall have a mass of approximately 7 kg (16 lb).

7. PROCEDURE

7.1. Follow the same procedure as described for Method A in Section 5, except for the following: Form a specimen by compacting the prepared soil in the 152.40-mm (6-in.) mold assembly in five approximately equal layers to give a total compacted depth of about 125 mm (5 in.), each layer being compacted by 56 uniformly distributed blows from the rammer. Calculate the wet density, ρ_t, as described in Section 12.

METHOD C

8. SAMPLE

8.1. Obtain a representative sample. This sample must be large enough that when the oversized (retained on the 19.0-mm ($^3/_4$-in.) sieve) particles are removed 5 kg (11 lb) or more of the sample remains.

8.2. Dry the sample until it becomes friable under a trowel. Drying may be in air or by use of a drying apparatus that is maintained at a temperature not exceeding 60°C (140°F). Thoroughly break up the aggregations in such a manner as to avoid reducing the natural size of individual particles.

8.3. Sieve soil over the 19.0-mm ($^3/_4$-in.) sieve. When the sample has oversized particles, see Annex A1.

8.4. Reduce the sample to a mass of 5 kg (11 lb) or more in accordance with R 76.

9. PROCEDURE

9.1. Determine the mass of the mold and base plate to the nearest 1 g (0.005 lb).

9.2. Thoroughly mix the selected representative sample with sufficient water to dampen it to approximately four to eight percentage points below optimum moisture content.

9.3. Form a specimen by compacting the prepared soil in the 101.60-mm (4-in.) mold assembly in five approximately equal layers to give a total compacted depth of about 125 mm (5 in.). Prior to compaction, place the loose soil into the mold assembly and spread into a layer of uniform thickness. Lightly tamp the soil prior to compaction until it is not in a loose or fluffy state, using either the manual compaction rammer or similar device having a face diameter of approximately 50 mm (2 in.). Following compaction of each of the first four layers, any soil adjacent to the mold walls that has not been compacted or extends above the compacted surface shall be trimmed using a knife or other suitable device, and be evenly distributed on top of the layer. Compact each layer by 25 uniformly distributed blows from a rammer dropping free from a height of 457 mm (18 in.) above the elevation of the soil when a sleeve-type rammer is used, or from 457 mm (18 in.) above the approximate elevation of each finely compacted layer when a stationary mounted type of rammer is used. During compaction, the mold assembly shall rest firmly on a dense, uniform, rigid, and stable foundation or base. This base shall remain stationary during the compaction process (Note 6).

9.3.1. Following compaction, remove the collar; carefully trim the compacted soil even with the top of the mold by means of the straightedge. Holes developed in the surface by removal of coarse material shall be patched with smaller-sized material. Determine the mass of the mold, base plate, and moist soil in kilograms to the nearest 1 g (0.005 lb). Calculate the wet density, ρ_t, as described in Section 12.

9.4.   Detach the base plate and remove the material from the mold using the extruder when necessary. Obtain a representative sample of the material by slicing vertically through the center of the molded material and removing one of the cut faces (Figure 3) or from the center of the pile if the molded material falls apart. Weigh the sample immediately. Determine the moisture content in accordance with T 265 and record the results.

9.5.   Thoroughly break up the remainder of the material until it will pass a 19.0-mm (0.75-in.) sieve and 90 percent of the soil aggregations will pass a 4.75-mm (No. 4) sieve as judged by eye, and add to the remaining portion of the sample being tested. Add water in sufficient amounts to increase the moisture content of the soil sample by one or two percentage points, and repeat the above procedure for each increment of water added (Note 7). When the series of determinations indicate a decrease or no change in the wet unit mass per cubic meter (cubic foot), ρ_t, of the compacted soil perform one more determination such that there is a minimum of two determinations over optimum moisture.

9.5.1.   One additional determination over optimum moisture is sufficient for non-cohesive, drainable soils.

METHOD D

10.   SAMPLE

10.1.   Obtain a representative sample in accordance with Section 8, except that it shall have a mass of approximately 11 kg (25 lb).

11.   PROCEDURE

11.1.   Follow the same procedure as described for Method C in Section 9, except for the following: Form a specimen by compacting the prepared soil in the 152.40-mm (6-in.) mold assembly in five approximately equal layers to give a total compacted depth of about 127 mm (5 in.), each layer being compacted by 56 uniformly distributed blows from the rammer. Calculate the wet density, ρ_t, as described in Section 1.

CALCULATIONS AND REPORT

12.   CALCULATIONS

12.1.   Wet density (ρ_t) shall be determined using the mold volume. For masses recorded in kilograms, the unit of wet density is kilograms per cubic meter of compacted soil. For masses recorded in pounds, the unit of wet density is pounds per cubic foot of compacted soil.

$$\rho_t = (A - B)/V \qquad\qquad (1)$$

where:
ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil,
A = mass of the mold, base plate, and wet soil,
B = mass of the mold, base plate,
V = mold volume as determined in Section 3.1.1 for Methods A and C, or Section 3.1.2 for Methods B and D.

12.2.   The dry density is related to the wet density as follows:

$$\rho_d = \frac{\rho_t}{w + 100} \times 100 \qquad\qquad (2)$$

where:

ρ_d = dry density, in in kg/m^3 (lb/ft^3) of compacted soil,

ρ_t = wet density in kg/m^3 (lb/ft^3) of compacted soil, and

w = moisture content (percent) of the specimen.

13. MOISTURE–DENSITY RELATIONSHIP

13.1. The calculations in Section 12 shall be made to determine wet density (unit mass) and oven-dry density (unit mass) in kilograms per cubic meter or pounds per cubic foot for each of the compacted samples. The oven-dry densities of the soil shall be plotted as ordinates and corresponding moisture contents as abscissae.

13.2. *Optimum Moisture Content*—When the densities and corresponding moisture contents for the soil have been determined and plotted as indicated in Section 13.1, it will be found that by connecting the plotted points with a smooth line, a curve is produced. The moisture content corresponding to the peak of the curve shall be termed the "optimum moisture content" of the soil under the above compaction.

13.3. *Maximum Dry Density*—The oven-dry density in kilograms per cubic meter or pounds per cubic foot of the soil at optimum moisture content shall be termed "maximum density" under the above compaction.

14. PRECISION STATEMENT

14.1. Repeatability (Single Operator)—Two results obtained by the same operator on the same sample in the same laboratory using the same apparatus and on different days should be considered suspect if they differ by more than 0.8 percent for optimum moisture content and 29 kg/m^3 (1.8 lb/ft^3) for maximum density.

14.2. Reproducibility (Multilaboratory)—Two results obtained by different operators in different laboratories should be considered suspect if they differ by more than 1.4 percent for optimum moisture and 62 kg/m^3 (3.9 lb/ft^3) for maximum density.

14.3. Annex A, Oversized Particle Correction—Since the correction for coarse particles involves no testing but instead utilizes the results of other tests and mathematically combines the results, determination of the precision and accuracy is not applicable.

Note 8—Data used to develop the precision statement is from AASHTO re:source proficiency samples including results from over 300 laboratories. The average density varied from 135 to 142 lb/ft^3 and the optimum moisture content varied from 5.75 to 6.95 percent.

15. REPORT

15.1. *The report shall include the following*:

15.1.1. The method used (Method A, B, C, or D);

15.1.2. The optimum moisture content to the nearest 0.1 percent;

Standard Method of Test for

In-Place Density and Moisture Content of Soil and Soil–Aggregate by Nuclear Methods (Shallow Depth)

AASHTO Designation: T 310-19

AASHTO

Technically Revised: 2019

Technical Subcommittee: 1b, Geotechnical Exploration, Instrumentation, Stabilization, and Field Testing

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1.	**SCOPE**
1.1.	This test method describes the procedure for determining the in-place density and moisture of soil and soil–aggregate by use of nuclear gauge. The density of the material may be determined by either Direct Transmission, Backscatter, or Backscatter/Air-Gap Ratio Method. The moisture of the material is determined only from measurements taken at the surface of the soil (i.e., backscatter).
1.2.	*Density*—The total or wet density of soil and soil-rock mixtures is determined by the attenuation of gamma radiation where 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) or the source and detector(s) remain on the surface (Backscatter Method).
1.2.1.	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.	*Moisture*—The moisture content of the soil and soil-rock mixtures is determined by thermalization or slowing of fast neutrons where the neutron source and the thermal neutron detector both remain at the surface.
1.3.1.	The water content in mass per unit volume of the material under test is determined by comparing the detection rate of thermalized or slow neutrons with previously established calibration data.
1.4.	*SI Units*—The values stated in SI units are to be regarded as the standard. The inch-pound equivalents may be approximate. It is common practice in the engineering profession to concurrently use pounds to represent both a unit of mass (lbm) and of force (lbf). This implicitly combines two systems of units, that is, the absolute system and the gravitational system.
1.4.1.	This standard has been written using the absolute system for water content (kilograms per cubic meter) in SI units. Conversion to the gravitational system of unit weight in lbf/ft^3 may be made. The recording of water content in pound-force per cubic foot should not be regarded as nonconformance with this standard, although the use is scientifically incorrect.
1.4.2.	In the U.S. Customary units system, the pound (lbf) represents a unit of force (weight). However, the use of balances or scales recording pounds of mass (lbm) or recording of density (lbm/ft^3) should not be regarded as nonconformance with this 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.* See Section 6, Hazards.

1.6. *The quality of the results produced by this standard are dependent on the competence of the personnel performing the procedure and the capability, calibration, and maintenance of the equipment used. Agencies that meet the criteria of R 18 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with R 18 alone does not completely assure reliable results. Reliable results depend on many factors; following the suggestions of R 18 or some similar acceptable guideline provides a means of evaluating and controlling some of those factors.*

2. REFERENCED DOCUMENTS

2.1. *AASHTO Standards*:
- **R 18, Establishing and Implementing a Quality Management System for Construction Materials Testing Laboratories**
- T 99, Moisture–Density Relations of Soils Using a 2.5-kg (5.5-lb) Rammer and a 305-mm (12-in.) Drop
- T 180, Moisture–Density Relations of Soils Using a 4.54-kg (10-lb) Rammer and a 457-mm (18-in.) Drop
- T 191, Density of Soil In-Place by the Sand-Cone Method
- T 265, Laboratory Determination of Moisture Content of Soils
- T 272, One-Point Method for Determining Maximum Dry Density and Optimum Moisture

2.2. *ASTM Standards*:
- D4253, Standard Test Methods for Maximum Index Density and Unit Weight of Soils Using a Vibratory Table
- D4254, Standard Test Methods for Minimum Index Density and Unit Weight of Soils and Calculation of Relative Density
- D7013/D7013M, Standard Guide for Calibration Facility Setup for Nuclear Surface Gauges

3. SIGNIFICANCE

3.1. The test method described is useful as a rapid, nondestructive technique for the in-place determination of the wet density and water content of soil and soil–aggregate.

3.2. The test method is used for quality control and acceptance testing of compacted soil and rock for construction and for research and development. The nondestructive nature allows for repetitive measurements at a single test location and statistical analysis of the results.

3.3. *Density*—The fundamental assumptions inherent in the methods are that Compton scattering is the dominant interaction and that the material under test is homogeneous.

3.4. *Moisture*—The fundamental assumptions inherent in the test method are that the hydrogen present is in the form of water as defined by T 265 and that the material under test is homogeneous.

3.5. Test results may be affected by chemical composition, sample heterogeneity, and to a lesser degree, material density and the surface texture of the material being tested. The technique also

exhibits spatial bias in that the gauge is more sensitive to water contained in the material in close proximity to the surface and less sensitive to water at deeper levels.

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4. INTERFERENCES

4.1. *In-Place Density Interferences*:

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

4.1.2. The gauge is more sensitive to the density of the material in close proximity to the surface in the Backscatter Method.

Note 1—The nuclear gauge density measurements are somewhat biased to the surface layers of the soil being tested. This bias has largely 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. Density measurements with direct transmission is the preferred method.

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

4.1.4. The sample volume is approximately 0.0028 m^3 (0.10 ft^3) for the Backscatter Method and 0.0057 m^3 (0.20 ft^3) for the Direct Transmission Method when the test depth is 150 mm (6 in.). The actual sample volume is indeterminate and varies with the gauge and the density of the material. In general, the higher the density, the smaller the volume.

4.1.5. Other radioactive sources must not be within 10 m (30 ft) of the gauge in operation.

4.2. *In-Place Moisture Content Interferences*:

4.2.1. The chemical composition of the sample may dramatically affect the measurement and adjustments may be necessary. Hydrogen in forms other than water will cause measurements in excess of the true value. Some chemical elements, such as boron, chlorine, and minute quantities of cadmium, will cause measurements lower than the true value.

4.2.2. The water content determined by this test method is not necessarily the average water within the volume of the sample involved in the measurement. The measurement is heavily influenced by the water content of the material closest to the surface. The volume of soil and rock represented in the measurement is indeterminate and will vary with the water content of the material. In general, the greater the water content of the material, the smaller the volume involved in the measurement. At 160 kg/m^3 (10 lb/ft^3), approximately 50 percent of the typical measurement results from the water content of the upper 50 to 75 mm (2 to 3 in.).

4.2.3. Other neutron sources must not be within 10 m (30 ft) of the gauge in operation.

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5. APPARATUS

5.1. *Nuclear Density/Moisture Gauge*—Although exact details of construction of the gauge may vary, the system shall consist of:

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

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

5.3.   *Fast Neutron Source*—A sealed mixture of a radioactive material, such as americium, radium, or californium-252, and a target material such as beryllium.

5.4.   *Slow Neutron Detector*—Any type of slow neutron detector, such as boron trifluoride or helium-3 proportional counter.

5.5.   *Reference Standard*—A block of material used for checking gauge operation, correction of source decay, and to establish conditions for a reproducible reference count rate.

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

5.7.   *Drive Pin*—A pin not to exceed the diameter of the rod in the Direct Transmission gauge by more than 6 mm ($^1/_4$ in.), or as recommended by the gauge manufacturer, used to prepare a hole in the material under test for inserting the rod.

5.7.1.   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.

5.8.   *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.

6.   HAZARDS

6.1.   The gauge utilizes radioactive materials that may be hazardous to the health of the users unless proper precautions are taken. Users of the gauge 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, etc., are a recommended part of the operation and storage of this gauge.

7.   CALIBRATION

7.1.   Calibration of the gauge will be in accordance with Annexes A1 and A2. (See also ASTM D7013/D7013M.)

8.   STANDARDIZATION

8.1.   All nuclear density/moisture gauges are subject to long-term aging of the radioactive sources, detectors, and electronic systems, which may change the relationship between count rates and the material density and water content. To offset this aging, gauges are calibrated as a ratio of the measurement count rate to a count rate made on a reference standard or to an air-gap count (for the backscatter/air-gap ratio method). The reference count rate should be in the same or higher order of magnitude than the range of measurement count rates over the useful range of the gauge.

8.2.   Standardization of the gauge on the reference standard is required at the start of each day's use and a permanent record of these data shall be retained. The standardization shall be performed with the gauge at least 10 m (30 ft) away from other nuclear density/moisture gauges and clear of large

masses of water or other items that may affect the reference count rates. Standard counts should be taken in the same environment as the actual measurement counts.

8.2.1. Turn on the gauge and allow for stabilization according to the manufacturer's recommendations. If the gauge is to be used either continuously or intermittently during the day, it is best to leave it in the "power on" condition to prevent having to repeat the stabilization (refer to the manufacturer's recommendations). This will provide more stable, consistent results.

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

Use the procedure recommended by the gauge manufacturer for determining compliance with the gauge calibration curves. Without specific recommendations for the gauge manufacturer, use the procedure in Section 8.2.3.

8.2.3. If the mean of the four repetitive readings is outside the limits set by Equation 1, repeat the standardization check. If the second standardization check satisfies Equation 1, the gauge is considered in satisfactory operating condition. If the second standardization check does not satisfy Equation 1, the gauge should be checked and verified according to Annexes A1 and A2, Sections A1.8 and A2.5. If the verification shows that there is no significant change in the calibration curve, a new reference standard count, N_o, should be established. If the verification check shows that there is a significant difference in the calibration curve, repair and recalibrate the gauge.

$$N_s = N_o \pm 1.96\sqrt{(N_o/F)} \qquad\qquad (1)$$

where:

N_s = value of current standardization count;

N_o = average of the past four values of Ns taken for prior usage; and

F = factory prescale factor (contact gauge manufacturer for the factor).

9. PROCEDURE

9.1. Select a test location where the gauge will be at least 150 mm (6 in.) away from any vertical mass. If closer than 600 mm (24 in.) to a vertical mass, such as in a trench, follow the gauge manufacturer's correction procedures.

9.2. *Prepare the test site in the following manner*:

9.2.1. Remove all loose and disturbed material and additional material, as necessary, to expose the top of the material to be tested.

Note 2—The spatial bias should be considered in determining the depth at which the gauge is to be seated.

9.2.2. Prepare a horizontal area sufficient in size to accommodate the gauge by planing the area to a smooth condition so as to obtain maximum contact between the gauge and material being tested.

9.2.3. The maximum void beneath the gauge shall not exceed 3 mm ($^1/_8$ in.). Use native fines or fine sand to fill the voids and smooth the surface with a rigid plate or other suitable tool. The depth of the filler should not exceed approximately 3 mm ($^1/_8$ in.).

Note 3—The placement of the gauge on the surface of the material to be tested is critical to the successful determination of density. The optimum condition is total contact between the bottom surface of the gauge and the surface of the material being tested. When optimal conditions are not present, correct surface irregularities by the use of sand or similar filler material. The total area

filled should not exceed 10 percent of the bottom area of the gauge. Several trial seatings may be required to achieve these conditions.

9.3.   Turn on and allow the gauge to stabilize (warm up) according to the manufacturer's recommendations (see Section 8.2.1).

9.4.   *Backscatter or Backscatter/Air-Gap Ratio Method of In-Place Nuclear Density and Moisture Content*:

9.4.1.   Seat the gauge firmly.

9.4.2.   Keep all other radioactive sources at least 10 m (30 ft) away from the gauge to avoid affecting the measurement.

9.4.3.   Set the gauge into the Backscatter (BS) position (see Note 4).

9.4.4.   Secure and record one or more 1-min readings (see Note 5). When using the backscatter/air-gap ratio method, follow the manufacturer's instructions regarding gauge setup. 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 the counts per minute obtained in the air-gap position by the counts per minute obtained in the standard position. Many gauges have built-in provisions for automatically calculating the air-gap ratio and wet density.

9.4.5.   Determine the in-place wet density by use of the calibration curve previously established or read the gauge directly if so equipped.

9.5.   *Direct Transmission Method of In-Place Nuclear Density and Moisture Content:*

9.5.1.   Select a test location where the gauge in test position will be at least 150 mm (6 in.) away from any vertical projection.

9.5.2.   Make a hole perpendicular to the prepared surface using the guide and the hole-forming device (Section 5). The hole shall be a minimum of 50 mm (2 in.) deeper than the desired measurement depth and of an alignment that insertion of the probe will not cause the gauge to tilt from the plane of the prepared area.

9.5.3.   Mark the test area to allow the placement of the gauge over the test site and to allow the alignment of the source rod to the hole. Follow manufacturer recommendations, if applicable.

9.5.4.   Remove the hole-forming device carefully to prevent the distortion of the hole, damage to the surface, or loose material to fall into the hole.

9.5.5.   Place the gauge on the material to be tested, making sure of maximum surface contact as described above.

9.5.6.   Lower the source rod into the hole to the desired test depth. Pull gently on the gauge in the direction that will bring the side of the probe to face the center of the gauge so that the probe is in intimate contact with the side of the hole in the gamma measurement path.

         Note 4—As a safety precaution, do not extend a rod containing radioactive sources out of its shielded position prior to placing on the test site. Always align the gauge so as to allow placing the rod directly into the test hole from the shielded position.

9.5.7.   Keep all other radioactive sources at least 10 m (30 ft) away from the gauge to avoid affecting the measurement.

9.5.8.   If the gauge is so equipped, set the depth selector to the same depth as the probe before recording the automated (gauge computed densities, moisture contents, and weights) values.

9.5.9.   Secure and record one or more 1-min readings (see Note 5).

9.5.10.   Determine the in-place wet density by use of the calibration curve previously established or read the gauge directly; if so equipped.

Note 5—The gauge may be rotated about the axis of the probe to obtain additional readings.

9.6.   If representative samples of material are to be taken for purposes of water content and/or density determination, the sample shall be taken from directly underneath the gauge. For the Backscatter Method, remove the material to a depth of approximately 75 mm (3 in.). For the Direct Transmission Method, remove the material to the approximate depth of the measurement of the gauge.

10.   CALCULATION OF RESULTS

10.1.   If dry density is required, the in-place water content may be determined by using the nuclear methods described herein, gravimetric samples and laboratory determination, or other approved instrumentation.

10.1.1.   If the water content is determined by nuclear methods, use the gauge readings directly, or subtract the kg/m^3 (lbm/ft^3) of moisture from the kg/m^3 (lbm/ft^3) of wet density, and obtain dry density in kg/m^3 (lbm/ft^3).

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

$$\rho_d = \frac{\rho_t}{w+100} \times 100 \qquad (2)$$

where:

ρ_d =   dry density in kg/m^3 (lbm/ft^3),

ρ_t =   wet density in kg/m^3 (lbm/ft^3), and

w =   water as a percent of dry mass.

10.2.   *Percent Density:*

10.2.1.   It may be desired to express the in-place density as a percentage of some other reference density, for example, the laboratory densities determined in accordance with T 99, T 180, or T 272. This relation can be determined by dividing the in-place density by the laboratory reference density and multiplying by 100. Calculations for determining relative density are provided in ASTM D4253 or D4254. Corrections for oversize material, if required, should be performed.

11.   REPORT

11.1.   *The report shall include the following*:

11.1.1.   Standardization and adjustment data for the date of the tests;

11.1.2.   Make, model, and serial number of the test gauge;

11.1.3.   Name of the operator(s);

11.1.4.   Test site identification;

11.1.5.   Visual description of material tested;

11.1.6.   Test mode (backscatter or direct transmission) and test depth (if applicable);

11.1.7.   Wet and dry densities in kg/m^3 or unit weights in lb/ft^3;

11.1.8.   Water content in percent of dry mass or dry unit weight; and

11.1.9.   Any adjustments made in the reported values and reasons for adjustments (i.e., offset, oversize particles).

12.   PRECISION AND BIAS

12.1.   *Precision*:

12.1.1.   *Wet Density*—Criteria for judging the acceptability of wet density test results obtained by this test method are given in Table 1. The figure in Column 3 represents the standard deviations that have been found to be appropriate for the materials tested in Column 1. The figures given in Column 4 are the limits that should not be exceeded by the difference between the results of two properly conducted tests. The figures given are based on an interlaboratory study in which five test sites containing soils, with wet densities as shown in Column 2, were tested by eight different devices and operators. The wet density of each test site was determined three times by each device.

Table 1—Results of Statistical Analysis (Wet Density)[a]

	Soil Type (Column 1)	Average, lb/ft^3 (kg/m^3) (Column 2)	Standard Deviation (Column 3)	Acceptable Range of Two Results,[b] lb/ft^3 (kg/m^3) (Column 4)
Single-Operator Precision				
Direct Transmission:				
	CL	114.7 (1837.3)	0.34 (5.45)	0.94 (15.06)
	SP	120.9 (1936.6)	0.27 (4.32)	0.74 (11.85)
	ML	130.1 (2084.0)	0.46 (7.37)	1.28 (20.50)
Backscatter:				
	ML	124.6 (1995.9)	1.21 (19.38)	3.39 (54.30)
Multilaboratory Precision				
Direct Transmission:				
	CL	114.7 (1837.3)	0.66 (10.57)	1.86 (29.79)
	SP	120.9 (1936.6)	0.68 (10.89)	1.91 (30.59)
	ML	130.1 (2084.0)	0.77 (12.23)	2.15 (34.44)
Backscatter:				
	ML	124.6 (1995.9)	2.38 (38.12)	6.67 (106.84)

[a]   The data used to establish the density and moisture content precision statements are contained in ASTM Research Report RR:D18-1004. Similar soil types using other classification systems should reflect similar precision values.

[b]   Two separate readings at a singular site with constant gate orientation and settings.

12.1.2.   *Moisture Content*—Criteria for judging the acceptability of the moisture content results obtained by this test method are given in Table 2. The value in Column 2 is in the units actually measured by the nuclear gauge. The figures in Column 3 represent the standard deviations that have been found to be appropriate for the materials tests in Column 1. The figures given in Column 4 are the limits that should not be exceeded by the difference between the results of two properly conducted

tests. The figures given are based on an interlaboratory study in which five test sites containing soils, with moisture content as shown in Column 2, were tested by eight different devices and operators. The moisture content of each test site was determined three times by each device.

Table 2—Results of Statistical Analysis (Moisture Content)

Soil Type (Column 1)	Average, lb/ft^3 (kg/m^3) (Column 2)	Standard Deviation (Column 3)	Acceptable Range of Two Results,[a] lb/ft^3 (kg/m^3) (Column 4)
Single-Operator Precision			
CL	12.1 (193.8)	0.35 (5.6)	0.97 (15.5)
SP	18.7 (299.5)	0.46 (7.4)	1.29 (20.7)
ML	19.6 (314.0)	0.35 (5.6)	0.99 (15.8)
Multilaboratory Precision			
CL	12.1 (193.8)	0.52 (8.3)	1.44 (23.1)
SP	18.7 (299.5)	0.75 (12.0)	2.10 (33.6)
ML	19.6 (314.0)	0.58 (9.3)	1.63 (26.1)

[a] Two separate readings at a singular site with constant gauge orientation and settings.

12.2. *Bias*:

12.2.1. There are no accepted reference values for these test methods; therefore, bias cannot be determined.

13. KEYWORDS

13.1. Compaction test; construction control; density; moisture content; nuclear methods; quality control; water content.

ANNEXES

(Mandatory Information)

A1. WET DENSITY CALIBRATION AND VERIFICATION

A1.1. *Calibration*—Newly acquired gauges shall be calibrated initially. Existing gauges shall be calibrated after repairs that may affect the gauge geometry. Existing gauges shall be calibrated to reestablish calibration curves, tables, or equivalent coefficients if the gauge does not meet the specified tolerances in the verification process. If the owner does not establish a verification procedure, the gauge shall be calibrated at a minimum frequency of 24 months.

A1.2. *Verification*—Existing gauges shall be verified at a minimum frequency of 12 months. The verification process and resultant tolerances obtained over the depths that the gauge shall be formally recorded and documented. If the verification process indicates a variance beyond the specified tolerances, the gauge shall be calibrated.

A1.3. The calibration response of the gauge shall be within ±16 kg/m^3 (±1.0 lb/ft^3) on the blocks on which the gauge was calibrated. This calibration may be done by the manufacturer, the user, or an independent vendor. Nuclear gauge response is influenced by the chemical composition of measured materials. This response must be taken into account in establishing the assigned standard block density. The blocks used for calibration shall be capable of generating a general

and reliable curve covering the entire density range of materials tested in the field. The density of these standard blocks shall be determined to an accuracy of ±0.2 percent.

A1.3.1. Calibrate the density of the blocks used to verify the gauge calibrations any time the blocks are damaged, structurally altered in any way, and at a period not to exceed 5 years. The density of blocks composed of natural materials such as soil or rock shall be verified annually.

Note A1—Unless calibration blocks are damaged during transportation from one facility to another, they do not need to be re-verified for density. However, changes in the size and set up of the calibration bays, or environmental conditions such as temperature changes and different background radiation levels, may affect the blocks and the gauge response on the calibration blocks. To determine the effect of the changes, it is recommended that the gauge response be checked by one or more gauges recently calibrated at the original location.

A1.4. Sufficient data shall be taken on each density standard block to ensure a gauge count precision (see Annex A3) of at least one half of the gauge count precision required for field use, assuming field use measurement of 1-min duration and 4-min duration used for calibration, or an equivalent relationship. The data may be presented in the form of a graph, table, equation coefficients, or stored in the gauge, to allow converting the count rate data to density.

A1.5. The method and test procedures used in establishing the calibration count rate data shall be the same as those used for obtaining the field count rate data.

A1.6. The material type, actual density, or assigned standard block density of each calibration standard used to establish or verify the gauge calibration shall be stated as part of the calibration data for each measurement depth.

A1.7. The standards should be sufficient in size to not change the count rate if enlarged in any dimension.

Note A2—Minimum surface dimensions of approximately 610 mm by 430 mm (24 by 17 in.) have proven satisfactory. For the Backscatter Method, a minimum depth of 230 mm (9 in.) is adequate, whereas for the Direct Transmission Method the depth should be at least 50 mm (2 in.) deeper than the deepest rod penetration depth. A larger surface area should be considered for the backscatter air-gap method. For blocks with width and length smaller than the sizes specified, follow the block manufacturers' recommendations for proper installation and use.

A1.8. The most successful standards that have been established for calibration have been made of magnesium, aluminum, aluminum/magnesium, granite, and limestone. These standards have been used in combination with each other, with historical curve information, and with other prepared block(s) to produce accurate and reliable calibration.

A1.8.1. Standards of soil, rock, and concrete that have stable characteristics for reproducibility and uniformity are difficult to prepare. These standards may be of use for specialty verification or field calibration where local site material chemistry or background situation require special adaptation.

A1.9. Verify an existing calibration by taking a sufficient number of counts at each measurement depth on one or more blocks of established density to ensure the accuracy of the existing calibration within ±32 kg/m^3 (±2.0 lb/ft^3) at each measurement depth.

A1.9.1. Sufficient data shall be taken to ensure a gauge count precision of at least one half of the gauge count precision required for field use assuming field use measurement of 1-min duration and 4-min duration used for calibration, or an equivalent relationship.

A1.9.2. Calibration blocks, which are used for calibration of the gauge, or prepared block(s), which are capable of generating a general and reliable curve covering the range of densities of the materials to be tested in the field, can be used to verify the gauge calibration.

A1.9.2.1.   Blocks prepared of soil, rock, concrete, asphalt, and engineered blocks that have characteristics of reproducible uniformity may be used, but care must be taken to minimize changes in density and water content over time.

A1.9.2.2.   Density values of prepared blocks shall be determined to an accuracy of ±0.5 percent at each measurement depth.

A1.9.3.   The assigned block density for each calibration depth used to verify the gauge calibration shall be stated as part of the verification data.

A2.   WATER CONTENT CALIBRATION AND VERIFICATION

A2.1.   *Calibration*—Newly acquired gauges shall be calibrated initially. Existing gauges shall be calibrated after repairs that may affect the gauge geometry. Existing gauges shall be calibrated to reestablish calibration curves, tables, or equivalent coefficients if the gauge does not meet the specified tolerances in the verification process. If the owner does not establish a verification procedure, the gauge shall be calibrated at a minimum frequency of 24 months.

A2.2.   *Verification*—Existing gauges shall be verified at a minimum frequency of 12 months. The verification process and resultant tolerances obtained over the depths the gauge shall be formally recorded and documented. If the verification process indicates a variance beyond the specified tolerances, the gauge shall be calibrated.

A2.3.   The calibration response of the gauge shall be within ±16 kg/m^3 (±1.0 lb/ft^3) on the blocks on which the gauge was calibrated. This calibration may be done by the manufacturer, the user, or an independent vendor. The blocks used for calibration should be capable of generating a general curve covering the entire water content range of the materials to be tested in the field. The calibration curve can be established using counts and water contents of standard blocks, previous factory curve information, or historical data. Due to the effect of chemical composition, the calibration supplied by the manufacturer with the gauge will not be applicable to all materials. It shall be accurate for silica and water; therefore, the calibration must be verified and adjusted, if necessary, in accordance to Section A2.5.

A2.4.   Calibration standards may be established using any of the following methods. Prepared containers or standards must be large enough to not change the observed count rate if made larger in any dimension.

Note A3—Dimensions of approximately 610 mm long by 460 mm wide by 360 mm deep (approximately 24 in. by 18 in. by 14 in.) have proven satisfactory. For blocks with width and length smaller than the sizes specified, follow block manufacturers' recommendations for proper installation and use.

A2.4.1.   Prepare a homogeneous standard of hydrogenous materials having an equivalent water content determined by comparison (using a nuclear gauge) with a saturated silica sand standard prepared in accordance with Section A.2.4. Metallic blocks used for wet density calibration, such as magnesium or aluminum, are a convenient zero water content standard.

A2.4.2.   Prepare containers of compacted material with a percent water content determined by oven-dry (T 265) and a wet density calculated from the mass of the material and the inside dimensions of the container. The water content may be calculated as follows:

$$M_m = \frac{\boldsymbol{\rho_t} \times w}{100 + w} \qquad\qquad (A2.1)$$

where:

M_m =   water content, kg/m^3 or lbm/ft^3;

ρ_t = wet (total) density, kg/m^3 or lbm/ft^3; and

w = water content, percent of dry mass.

A2.4.3. Where neither of the previous calibration standards are available, the gauge may be calibrated by using a minimum of four selected test sites in an area of a compaction project where material has been placed at several different water contents. The test sites shall represent the range of water contents over which the calibration is to be used. At least four replicate nuclear measurements shall be made at each test site. The density at each site shall be measured by making four closely spaced determinations with calibrated equipment in accordance with T 191. The water content of each of the density tests shall be determined by T 265. Use the mean value of the replicate readings as the calibration point value for each site.

A2.5. *Calibration Adjustments*:

A2.5.1. The calibration of newly acquired or repaired gauges shall be verified and adjusted prior to use. Calibration curves shall be checked prior to performing tests on materials that are distinctly different from material types previously used in obtaining or adjusting the calibration. Sample materials may be selected by either Section A2.5.1.1 or Section A2.5.1.2. The amount of water shall be within ±2 percent of the water content established as optimum for compaction. Determine the water content in kg/m^3 or lb/ft^3 by Equation A2.1. A microwave oven or direct heater may be utilized for drying materials that are not sensitive to temperature, in addition to the methods listed in Section A2.4.3. A minimum of four comparisons is required and the mean of the observed differences used as the correction factor.

A2.5.1.1. Container(s) of compacted material taken from the test site may be prepared in accordance with Section A2.4.2.

A2.5.1.2. Test site(s) or the compacted material may be selected in accordance with Section A2.4.3.

A2.5.2. The method and test procedures used in obtaining the count rate to establish the error must be the same as those used for measuring the water content of the material to be tested.

A2.5.3. The mean value of the difference between the moisture content of the test samples as determined in Section A2.5.1.1 or Section A2.5.1.2 and the values measured with the gauge shall be used as a correction to measurements made in the field. Some gauges utilizing a microprocessor may have provision to input a correction factor that is established by the relative values of water content as a percentage of dry density, thus eliminating the need to determine the difference in mass units of water.

A2.6. Verify an existing calibration by taking sufficient number of counts on one or more blocks of established water content to ensure the accuracy of the existing calibration within ±16 kg/m^3 (±1 lb/ft^3). The water content block(s) should be prepared in accordance with Sections A2.4.1 and A2.4.2.

A2.6.1. Sufficient data shall be taken to ensure a gauge count precision (see Annex A3) of at least one half of the gauge count precision required for field use, assuming field use measurement of 1-min duration and 4-min duration used for calibration, or an equivalent relationship.

A2.6.2. Calibration blocks used to establish calibration parameters and prepared block(s) that are capable of generating a general and reliable curve covering the range of densities of the materials that are to be tested in the field can be used to verify calibration.

A2.6.3. Prepared block(s) that have characteristics of reproducible uniformity may be used, but care must be taken to minimize changes in density and water content over time.