Test Procedure for

FIELD METHOD FOR DETERMINING IN-PLACE DENSITY OF SOILS AND BASE MATERIALS

TxDOT Designation: Tex-115-E

Effective Date: August 1999

1. SCOPE

1.1 This method determines the density of untreated and treated soil and granular material compacted in the roadway or in the natural state, as exists in a cut section and borrow source prior to excavation.

1.2 The principal use of the in-place density is to determine the degree of compaction or percentage of the density obtained by the method outlined in Tex-113-E and Tex-114-E.

1.3 The term "soils" used in this procedure includes all base materials, as well as fine grain soils.

1.4 The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

2. TEST RECORD FORMS

2.1 Tx115.xlsm, "Nuclear Density and Moisture Determination: Tex-115-E"

PART I—NUCLEAR GAUGE METHOD

3. APPARATUS

3.1 *Nuclear testing gauge,* capable of making density and moisture determinations.

3.2 *Portable reference standard.*

3.3 *Calibration curves*, for the nuclear gauge.

3.4 *Scraper plate and drill rod guide*.

3.5 *Drill rod and driver or hammer*.

3.6 *Shovel, sieve, trowel, or straightedge and miscellaneous hand tools*.

3.7 *Gauge logbook.*

4. STANDARDIZING EQUIPMENT

4.1 Standardize equipment to a reference standard at the start of each day's use and when test measurements are suspect.

4.1.1 Set the standardizing block 1.5 m (5 ft.) from any object and 7.62 m (25 ft.) from any other nuclear gauge.

4.1.2 Place the gauge on the standardizing block in the closed (safe) mode and take four one-minute density counts.

4.1.3 Repeat the four one-minute counts for moisture in the backscatter position.

4.1.4 Record in the gauge logbook.

4.1.5 When the nuclear gauge is equipped with electronic circuitry capable of automatically averaging four one-minute density and moisture standard counts simultaneously, place the gauge on the standardizing block in the closed (safe) mode and take the averages on the field form and in the gauge logbook.

Note 1—Any field form suitable for use with the gauge is acceptable. For additional gauge operation information not covered in this paragraph, follow instructions given in the manufacturer's manual.

Note 2—Each individual count (taken using the appropriate time base) must be within the statistical tolerance of:

$$\pm 1.96 \times (average\ count\ rate)^{1/2}$$

4.1.6 Since some gauges display one or two digits less than the gauge is actually counting, multiply the count on those gauges by either 10 or 100 before calculating the tolerance. Then divide this tolerance by 10 or 100 to determine the statistical tolerance.

Table 1—Example of Individual Count and Its Statistical Tolerance

Count/Time Base	Tolerance
23500	± 300
2350(0)	± 30
235(00)	± 3

5. PROCEDURE

5.1 Prepare the test area by creating a surface plane free of loose material and deformations that extends laterally not less than 152 mm (6 in.) beyond the gauge housing.

5.2 Fill in minor depressions with sand or native fines. Proper test site preparation is closely related to testing accuracy. Make every effort to smooth the site as much as possible.

5.3 Make a hole using the pin and guide plate.

5.4 Extract the pin by hand or with a pin puller or pipe wrench. The depth of hole should be 51 mm (2 in.) greater than the transmission depth being used. This hole must be as close as possible to 90° from the plane of the testing surface. If the plate is rotated slightly around the pin and the plate does not make contact with the ground, or if it appears that the hole is crooked, make a new hole.

5.5 Place the nuclear gauge on the prepared surface so that the bottom of the gauge seats firmly, in full contact with the soil or base material.

5.6 Insert the rod into the hole to the predetermined depth.

5.7 Adjust the gauge so that the rod is firmly against the side of the hole that is nearest to the source or detector tubes.

5.8 After seating the probe, record the number of readings required for the particular instrument being used.

5.9 Rotate the gauge 90° and repeat. (Rotating gauge 90° is optional.)

6. CALCULATIONS

6.1 Determine the wet density and moisture by dividing the field counts by the standard counts and use the appropriate calibration curves.

6.2 On programmable models, read the density and moisture directly.

7. REPORTING TEST RESULTS

7.1 Report dry density to the nearest 1 kg/m^3 (0.1 lb./ft.^{3}) and moisture to the nearest 0.1%.

Note 3—This procedure is intended to be a general guide method.

Note 4—Follow the instruction manual furnished with a particular gauge for specific operation of that gauge. This is essential, because several different models and different brands are in standard use by the Department.

Note 5—Check nuclear density gauges for density at regular time intervals by taking readings using the limestone and granite blocks located in each district. Variation in readings will indicate a possible problem with the gauge. The test position of the gauge on the block and the location of the blocks should be as near the same as practical each time.

Note 6—If moisture results obtained by the nuclear gauge are suspect, use Tex-103-E to determine the correct moisture content of the soil.

Note 7—Use of these gauges must be according to all applicable State and Federal rules and regulations, and the terms of the radioactive materials license issued to the Department.

Note 8—Chemical composition of the materials tested may affect the test results of the gauge.

Note 9—Where the material contains chemically bound water (i.e., gypsum) and other hydrogen atoms, such as in asphalt, iron ore, coal, mica and vegetation, use of nuclear gauges may not provide accurate results.

Note 10—When used for trench measurements or near obstructions such as abutments, follow the instructions provided in the gauge manual carefully.

PART II—SAND-CONE METHOD

8. SCOPE

8.1 This method is applicable for soils without appreciable amounts of rock or coarse materials in excess of 38 mm (1.5 in.) in diameter, natural soil deposits, aggregates, soil mixtures, and other similar material, and for undisturbed (or in-situ) soils, provided natural void or pore openings in the soil are small enough to prevent sand used in the test from entering the voids.

8.2 Use this test method to determine the density of compacted soils placed during construction of earth embankments, road fill, and structural backfill. It is often used as a basis of acceptance for soils compacted to a specified density or percentage of a maximum density determined by Tex-113-E and Tex-114-E.

8.3 The soil or other materials being tested should have sufficient cohesion or particle attraction to maintain stable sides on a small hole or excavation, and be firm enough to withstand the minor pressures exerted in digging the hole and placing the apparatus over it, without deforming or sloughing.

Note 11—This test method is not suitable for:

- organic, saturated, or highly plastic soils that would deform or compress during the excavation of the test hole,
- soils consisting of unbound granular materials that will not maintain stable sides in the test hole, or
- granular soils having high void ratios.

8.4 The use of this method is generally limited to soils in an unsaturated condition.

8.4.1 It is not recommended for soils that are soft or friable (crumble easily) or in a moisture condition such that water seeps into the hand excavated hole.

8.4.2 The accuracy of this test may be affected for soils that deform easily or that undergo a volume change in the excavated hole from vibration, or from standing or walking near hole during test.

Note 12—When testing in soft conditions or in soils near saturation, volume changes may occur in the excavated hole.

9. APPARATUS

9.1 *Attachable jar*, or other sand container having a volume capacity in excess of that required to fill the test hole and apparatus during the test.

9.2 *Metal base plate or template*, with a flange, center hole cast or machined to receive the large funnel (cone) of the appliance described above.

9.2.1 The base plate may be larger than the funnel (sand-cone).

9.2.2 The plate will be flat on the bottom and have sufficient thickness or stiffness to be rigid.

9.2.3 Plates with raised edges, ridges, ribs, or other stiffeners or approximately 10–13 mm (0.375–0.5 in.) high may be used.

9.3 *Detachable appliance*, consisting of a cylindrical valve with an orifice approximately 13 mm (0.5 in.) in diameter, attached to a metal funnel and sand container on one end, and a large metal funnel and sand container on the other end.

9.3.1 The valve will have stops to prevent rotating past the completely open or completely closed position.

9.3.2 The appliance should be constructed of metal sufficiently rigid to prevent distortion or volume changes in the cone.

9.3.3 The walls of the cone will form an angle of approximately 60° with the base to allow uniform filling with sand.

9.4 *Balance*, Class G5 in accordance with Tex-901-K with a minimum capacity of 20 kg (50 lb.)

9.5 *Drying equipment*, as specified in Tex-103-E.

9.6 *Calibration container*, of known volume, approximately the same size and allowing sand to fall approximately the same distance as the hole excavated during a field test.

9.7 *Miscellaneous equipment*, including:

- knife
- small pick
- chisel
- small trowel
- screwdriver or spoons
- large nails or spike
- metal straightedge about 51 mm (2 in.) wide and 1.5 times the length of the calibration container
- buckets with lids

- plastic-lined cloth sacks, or other suitable containers
- small paint brush
- calculator
- notebook or test forms, etc.

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10. MATERIALS

10.1 *Sand*, clean, dry, and uniform in density and grading, un-cemented, durable, and free flowing.

10.1.1 Use any gradation that has a coefficient of uniformity ($C_U = D_{60} / D_{10}$) less than 2.0, a maximum particle size passing the 2.00 mm (No. 10) sieve and less than 3% by mass passing the 250 µm (No. 60) sieve.

10.1.2 Use uniformly graded sand to prevent segregation during handling, storage, and use.

10.1.3 Sand free of fines and fine sand particles is required to prevent significant bulk-density changes with normal daily changes in atmospheric humidity.

10.1.4 Sand comprised of durable, natural sub-rounded, or rounded particles may not be free flowing, a condition that can cause bridging resulting in inaccurate density determinations.

10.2 In selecting sand from a potential source, make a gradation and five separate bulk-density determinations according to the procedure in Section 12 on each container or bag of sand.

10.2.1 The bulk-density variation between any one determination must not be greater than 1% of the average.

10.2.2 Before using sand in density determinations, it should be dried and then allowed to reach an air-dried state in the general location of use.

10.3 Do not re-use sand without removing contaminants.

Note 13—As a general rule, reclaiming sand after testing is not desirable.

10.4 Make bulk-density tests of the sand at least every 14 days, after any significant changes in atmospheric conditions, before reusing, and before use of a new batch from a previously proven supplier.

Note 14—Most sands have a tendency to absorb moisture from the atmosphere. A very small amount of absorbed moisture can make a substantial difference in bulk-density. In areas of high humidity, or where the humidity changes frequently, the bulk-density may need to be determined more often than the 14-day maximum interval indicated. The need for more frequent checks can be determined by comparing the results of different bulk-density tests on the same sand made in the same conditions of use over a period.

Note 15—Some manufactured (crushed) sands, such as blasting sand, have been successfully used with good reproducibility. Check the reproducibility of test results using singular sand under laboratory-controlled testing situations before selecting an angular sand.

Note 16—Many organizations have found it beneficial to store sands in moisture-resistant containers. Sand should be stored in dry areas protected from weather. The use of a lighted bulb or other heat source in or adjacent to the storage containers is also beneficial in areas of high humidity.

11. CALIBRATING SAND-CONE APPARATUS

11.1 *Method A:*

11.1.1 Since the mass of the sand contained in the apparatus funnel and base plate is dependent on the bulk density of the sand, if using Method A, it must be repeated whenever the bulk-density of the sand changes.

11.1.2 Fill the apparatus with sand that is dried and conditioned to the state anticipated during use in testing.

11.1.3 Determine the mass of the apparatus filled with sand, kg (lb.)

11.1.4 Place the base plate on a clean, level, plane surface.

11.1.5 Invert the container/apparatus and seat the funnel in the flange center hole in the base plate.

11.1.6 Mark and identify the apparatus and base plate so that the same apparatus and plate can be matched and reseated in the same position during testing.

11.1.7 Open the valve fully until the sand flow stops, making sure the apparatus, base plate, or plane surface is not jarred or vibrated before the valve is closed.

11.1.8 Close the valve sharply, remove the apparatus, and determine the mass of the apparatus and remaining sand.

11.1.9 Calculate the mass of sand used to fill the funnel and base plate as the difference between initial and final mass.

11.1.10 Repeat the procedure a minimum of three times. The maximum variation between any one determination and the average may not exceed 1%.

11.1.11 Use the average of the three determinations for this value in the test calculations.

11.2 *Method B*—(optional):

11.2.1 Determine the mass of sand required to fill the apparatus funnel and base plate according to Sections 11.1.2–11.1.7 of Method A.

11.2.2 Calculate the volume of the funnel and base plate by dividing the bulk-density of the sand (as determined in Section 12) by the mass of sand found in Section 11.1 7 of Method A.

11.2.3 Perform a minimum of three determinations and calculate an average value.

11.2.4 The maximum volume variation between any one determination and the average may not exceed 1%.

11.2.5 Use the average of the values when performing test calculations.

12. CALIBRATING DENSITY SAND APPARATUS

12.1 *Method A:*

12.1.1 Fill the apparatus with sand conditioned to the same state anticipated during use.

12.1.2 Determine and record the mass of the calibration container when empty.

12.1.3 When calibration container has the same diameter as the flange hole in the base plate, invert and center the sand filled apparatus and base plate on the calibration container.

12.1.4 Fully open the valve and allow the sand to fill the container. When the sand flow stops, close the valve.

12.1.5 Determine the mass of the apparatus and remaining sand. Calculate the net mass of sand in the calibration container by subtracting the mass of sand contained in the cone and base plate (as determined in Section 11) and record.

12.2 *Method B:*

12.2.1 Fill the apparatus with sand conditioned to the same state anticipated during use.

12.2.2 Determine and record the mass of the calibration container when empty.

12.2.3 Invert and support the apparatus over the calibration container so that the sand falls approximately the same distance and location as in a field test, and fully open valve.

12.2.4 Fill the container until it just overflows and close the valve.

12.2.5 Clean any sand from outside of the container.

12.2.6 Determine the mass of container and sand.

12.2.7 Record the net mass of the sand by subtracting the mass of the empty container.

12.2.8 Perform at least three bulk-density determinations. Any one determination and the average will not exceed 1% in difference.

12.2.9 Repeated determinations not meeting these requirements indicate non-uniform sand density, and the sand source should be reevaluated for suitability.

12.2.10 Use the average value obtained in the test calculations.

13. CALCULATIONS

13.1 Calculate the bulk-density of the sand:

$$\rho_1 = M_5 / V_1$$

Where:

M_5 = mass of the sand to fill the calibration container, kg (lb.)

V_1 = volume of the calibration container, m^3 ($ft.^3$)

14. PROCEDURE

14.1 Select a location and elevation that is representative of the area to be tested.

14.2 Inspect cone apparatus for damage, free rotation of valve, and properly matched baseplate.

14.3 Fill the cone container with conditioned sand for which the bulk-density has been determined in accordance with Section 12.

14.4 Determine the total mass, M_2 as shown under Section 15.

14.5 Prepare the surface of the location to be tested so that it is a level plane.

14.6 Use the base plate as a tool for striking off the surface to a smooth level plane.

14.7 Seat the base plate on the plane surface, making sure there is contact with the ground surface around the edge of the flange center hole.

14.8 In soils where leveling is not successful or surface voids remain, determine the volume horizontally bounded by the funnel, plate, and ground surface by a preliminary test.

14.9 Fill the space with sand from the apparatus.

14.10 Determine the mass of sand used to fill the space.

14.11 Refill the apparatus.

14.12 Determine a new initial mass of apparatus and sand before proceeding with the test.

14.13 After this measurement is completed, carefully brush the sand from the prepared surface.

14.14 Dig the test hole through the center hole in the base plate, being careful to avoid disturbing or deforming the soil that will bound the hole.

14.15 Test hole volumes are to be as large as practical to minimize errors and will in no case be smaller than the volumes indicated in Table 2 for the maximum size of soil particle removed from the test hole.

14.16 The sides of the hole should slope slightly inward and the bottom should be reasonably flat or concave.

14.17 Keep the hole as free as possible of pockets, overhangs, and sharp obtrusions, since these affect the accuracy of the test.

14.18 Soils that are essentially granular require extreme care and may require digging a conical shaped test hole.

14.19 Place all excavated soil, and any soil loosened during digging, in a moisture tight container that is marked to identify the test number.

14.20 Take care to avoid losing any materials.

14.21 Protect this material from any loss of moisture until determining the mass and obtaining a specimen for a water content determination.

14.22 Clean flange of base plate hole, invert sand-cone apparatus, and seat sand-cone funnel into flange hole at the same position as marked during calibration. (See Section 11.)

14.23 Eliminate or minimize vibrations in test area by personnel or equipment.

14.24 Open valve and allow sand to fill hole, funnel, and base plate.

14.25 Take care to avoid jarring or vibrating apparatus while sand is running.

14.26 When sand stops flowing, close the valve.

14.27 Determine mass of apparatus with remaining sand, record, and calculate mass of sand used.

14.28 Determine and record the mass of the moist material removed from the test hole.

14.29 When oversized material corrections are required, determine the mass of the oversized material on the appropriate sieve and record, taking care to avoid moisture losses.

14.30 Mix the material thoroughly, and obtain a representative specimen for determining water content or use the entire sample.

14.31 Determine the water content in accordance with Tex-103-E, Section 7.

Note 17—Select water content specimens to represent all material obtained from the test hole, and their minimum mass must provide water content values accurate to 1.0%.

Table 2—Minimum Test Hole Volumes and Minimum Moisture Content Samples Based on Maximum Size of Particle

Maximum Particle Size	Minimum Test Hole Volume, m^3	Minimum Test Hole Volume, $ft.^3$	Minimum Moisture Content Sample, g
No. 4 Sieve (4.75 mm)	0.0007	0.025	100
1/2 in. (12.5 mm)	0.0014	0.050	300
1 in. (25 mm)	0.0021	0.075	500
2 in. (50 mm)	0.0028	0.100	1000

15. CALCULATIONS

15.1 Calculate the volume of the test hole (V):

$$V = (M_1 - M_2) / \rho_1, m^3 (ft^3)$$

Where:

M_1 = mass of the sand used to fill the test hole, funnel and base plate, kg (lb.)

M_2 = mass of the sand used to fill the funnel and base plate (from calibration of sand-cone apparatus), kg (lb.)

ρ_1 = bulk density of the sand, kg/m^3 (lb./$ft.^3$)

15.2 Calculate the dry mass of the material (M_4) removed from the test hole:

$$M_4 = 10[M_3 / (w + 100)], kg\ (lb.)$$

Where:

w = water content of the material removed from the test hole, %

M_3 = moist mass of the material removed from the test hole, kg (lb.)

15.3 Calculate the in-place wet density (ρ_m) of the tested material removed from the hole:

$$\rho_m = M_3 / V, kg / m^3 (lb / ft^3)$$

15.4 Calculate the in-place dry density (ρ_D) of the tested material removed from the hole:

$$\rho_D = M_4 / V, kg / m^3 (lb / ft^3)$$

15.5 It may be desired to express the in-place density as a percentage of some other density, for example, the laboratory densities. Determine this relationship by dividing the in-place density by the laboratory density and multiplying by 100.

16. REPORTING TEST RESULTS

16.1 Report density to nearest 1 kg/m^3 (0.1 lb./ft.^{3}) and moisture content to the nearest 0.1%.

PART III—VOLUMETER METHOD

17. APPARATUS

17.1 *Volumeter,* a calibrated metal chamber mounted between a top and bottom assembly.

17.1.1 The base plate has an opening designed to accept a rubber membrane, which fits over the base insert.

17.1.2 The base is fastened to the bottom assembly by means of thumbscrews.

17.1.3 A pump provides pressure to fill the rubber membrane or vacuum to remove the water.

17.1.4 A four-way valve controls these operations.

17.1.5 The compound gauge indicates the kilopascals (pounds) of pressure (or inches of mercury) applied.

17.1.6 A transparent gauge tube and graduated metal tape connected through the upper and lower base assembly measures the quantity of water used, which is the volume of the material removed.

17.1.7 A level is attached to the upper assembly.

17.2 *Equipment,* for digging holes, such as post hole auger, soil auger, density-in-place digging tools.

17.3 *Buckets,* 4 L (1 gal.), with lids, or plastic bags,

17.4 *Drying pans,*

17.5 *Drying oven,* with temperature maintained at 110 ± 5°C (230 ± 2°F),

17.6 *Balance,* Class G2 in accordance with Tex-901-K, with a minimum capacity of 15 kg (33 lb.)

18. PREPARING THE VOLUMETER

Use the operating manual furnished with each volumeter for complete description of parts, how to disassemble and reassemble the device, and general information about the care and use of the instrument.

18.1 Depress the pump handle into “hold” position to interlock the control valve and to prevent the water from entering the pump or escaping from the volumeter.

18.2 Invert volumeter and set on top six legs.

18.3 Loosen thumbscrews and remove base plate.

18.4 Carefully center base insert.

18.5 Use clean tap or deionized water and fill the metal chamber to within 6.5 mm (0.25 in.) of the top of the inverted lower base.

18.6 Remove the protective talc from a rubber membrane and fold the open end inside itself to obtain a length approximately 25 mm (1 in.) longer than the depth of hole to measure.

18.7 Examine base quad ring for twists and check surfaces of base and base plate for grit.

18.8 Place base on volumeter with flat side out; align holes and finger tighten all thumbscrews.

18.9 Invert and tilt volumeter so the pump cylinder is on top of the water chamber.

18.10 Lift pump handle from interlock and shift control valve to vacuum position.

18.11 Use short and slow strokes of pump handle to apply vacuum, while using the other hand to assist the rubber membrane to retract and flatten out over base insert.

18.12 Place control valve in “hold” position and lower pump handle into curved notch.

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19. PROCEDURE

19.1 Select a density test location that is reasonably smooth and free from loose soil or pebbles.

19.2 Place matching tray flat side down on test site.

19.3 Fasten to surface of compacted soil with spikes through boss holes.

19.4 Zero the volumeter tape before excavating the test hole. This compensates for any irregularity in surface of test site, the temperature of water, the volume of the rubber membrane and the tray thickness.

19.5 Place the volumeter upright on the tray between the three bosses.

19.6 Rotate entire volumeter until the bubble level centers.

19.7 Open memory valve at the bottom of the gauge tube.

19.8 Lift the pump handle, turn the control valve to “open” for a few seconds and then shift to “pressure.”

19.9 Place one knee on center of the top of volumeter, hold volumeter firmly down against tray, and apply 20.7 kPa (3 psi) pressure.

19.10 While maintaining this pressure, reach down and close memory valve.

19.11 Retract membrane by turning valve to "vacuum."

19.12 Pump with short, slow strokes of handle until 25 mm (1 in.) of vacuum registers on gauge.

19.13 Turn control valve to hold position and depress knob on pump handle into curved notch.

19.14 Remove knee.

19.15 Rotate the upper or lower tape spool until the 76.2 lineal mm (0.4 lineal ft.) mark coincides with the top of the meniscus of the water in the adjacent gauge tube. This will automatically compensate for the 0.00113 m^3 (0.04 $ft.^3$) in the bulged upper chamber of the 220 model volumeter.

19.16 While holding lower tape spool, securely tighten tape lock nut. Set volumeter aside in upright position.

19.17 Use the various tools available and excavate the soil inside the limit of the hole in center of tray.

19.18 To ensure accuracy of the density determination, dig the hole as large as possible but be sure not to exceed the capacity of the volumeter.

19.18.1 The walls should be as smooth as possible and round into the bottom surface.

19.18.2 Use caution in digging holes in freshly compacted materials so as not to enlarge the hole due to excessive effort applied with digging tools.

19.18.3 Avoid having cavities so deep that the membrane might not fill them, or cave-ins directly under the tray, or considerable variation in diameter of the hole.

19.19 Recover all of the material removed from the hole and seal in a gallon bucket or plastic bag to prevent loss of moisture.

19.20 Measure the volume of the test hole by repeating the operations outlined in Sections 19.4 through 19.17, and record as V under Section 20.

19.21 Weigh the material excavated from the test hole to determine the wet mass.

19.22 Dry the soil at 110°C (230°F), obtain the dry mass, and record as W_D, under Section 20.

20. CALCULATIONS

20.1 Calculate moisture content in accordance with Tex-103-E.

20.2 Calculate the mass of the water (W_W):

$$W_W = W_1 - W_2$$

20.3 Calculate the mass of the solid particles (W_S):

$$W_S = W_2 - W_C$$

20.4 Calculate the water content (%) (WC):

$$WC = (100 \bullet W_W \;/\; W_S)$$

Where:
W_C = mass of container and lid, g
W_1 = mass of container, lid, and moist specimen, g
W_2 = mass of container, lid, and oven-dried specimen, g.

20.5 Calculate in-place density:

$$In\ Place\ Density = W_D \;/\; V$$

Where:
W_D = mass of oven-dried soil, kg (lb.)
V = volume of test hole, kg/m^3 (lb./ft.^{3})

Note 18—Carefully read operating manual for the volumeter.

Note 19—Use only clean, pure water in volumeter and change often to prevent corrosion. Add only antifreeze selected from manufacturer's recommended list.

Note 20—When retracting the rubber membrane with the volumeter in a tilted position, always have the cylinder of the pump on top of the metal chamber.

Note 21—To obtain accuracy in measuring the volume of the hole, the volumeter must be held solidly against the tray and not be allowed to rise when pressure is applied to rubber membrane.

Note 22—Other methods of in-place density tests that correlate satisfactorily with this method for the soil material in question will be satisfactory for use.

21. TEST REPORT

21.1 Report density to the nearest 1 kg/m^3 (0.1 lb./ft.^{3}) and moisture to the nearest 0.1%.