Introduction

After placement and compaction of the embankment material by the contractor, the inspector then conducts a field density test and a field moisture content test on the lift. The results of these field tests are compared to the target values (see Chapter 5) to determine if the contractor has met specifications for density and moisture content of that lift.

Section 303.04(h) and 305.03(a) of 2007 Road and Bridge Specifications stipulates that field density determination are to be performed in accordance with the following AASHTO tests:

- T191- Density of Soil in Place by the Sand Cone Method
- T324- Density of Soil in Place by the Nuclear Gauge

![Soil Density Testing Flowchart](image)
FIELD DENSITY & MOISTURE CONTENT
WITH THE NUCLEAR TESTING GAUGE

The Nuclear Moisture Density device is specifically designed to measure the moisture and density of soils, aggregates, cement, and lime treated materials, and to measure the density of asphalt concrete. It offers the Inspector and Contractor a method of obtaining fast, accurate and in-place measurement of densities and moisture. With suitable calibrations, the device gives results which are comparable to those given by the Sand Cone or Volume Meter Test.

The device uses a small radioactive source which sends radiation through the material being tested, giving data which can be correlated to density and/or moisture. While no radiation hazard is imposed on the operator when following the normal procedures of use, a potential hazard does exist if improperly used. Three ways to limit exposure to radiation are time, distance, and shielding.

Before operating a nuclear gauge a person must pass a Nuclear Safety course and be issued a TLD (Thermoluminescent dosimeter) badge. The badge measures exposure to radiation and is to be worn whenever operating a nuclear gauge. The TLD is to be stored at least 10 feet from the gauge. Two gauges should not be operated within 33 feet of one another. In case of an accident, maintain a 20 foot radius around the accident site.

COMPONENTS OF THE NUCLEAR GAUGE

A small radioactive source is located in the tip of the stainless steel rod which is primarily used for density testing, whereas another source is located inside the device which is used specifically for taking moisture determinations simultaneously. The probe rod is capable of being moved to the various desired depths, as shown on the following pages. The positions are stamped on the guide rod for easy determination of the proper depths.

The 3440 gauge provides three different count times to be used for taking readings. The 15 second setting is recommended to be used only in the roller pattern test method (Backscatter method). The one minute setting is used for all embankment and subgrade materials. The four minute setting is generally used for calibration.
3440 Handle Positions

SAFE POSITION
(Use For Storage and Standard Counts)

BACKSCATTER POSITION

50 mm
(2 In.)

100 mm
(4 In.)

150 mm
(6 In.)

200 mm
(8 In.)

DIRECT TRANSMISSION POSITIONS

3440 Display Screen
THEORY OF OPERATIONS

The nuclear moisture density gauge is specifically designed to measure the moisture content and density of soils, aggregates, cement and lime treated materials, and to measure the density of Bituminous Concrete. It offers the inspector a method of obtaining fast, accurate, in-place measurement of density and moisture. With suitable laboratory calibrations, and proper field operation of the gauge, the device gives results which are comparable to those given by the sand cone or volume meter tests.

The tip of the source rod contains a small radioactive source (cesium-137) which emits gamma rays. Detectors in the base of the gauge measure this radiation and calculate the density of the material. The gauge has two modes to measure density: the direct transmission mode and backscatter mode.

In the direct transmission mode, the source rod is inserted into the material to be tested to the desired depth of test. The 6 inch depth is the most recommended depth for testing densities and moisture content simultaneously in soils used in backfills, embankments and subgrade. The 4 inch depth is used for backfilling around pipe and abutments where hand tamping and pneumatic tamping is used. The 8 inch depth is only used when specified on the contract.

In the backscatter mode the gauge is placed on the material to be tested and the source rod is locked in the first position below the SAFE position. Since the rod is flush with the bottom of the gauge and no hole is required for the rod, the backscatter mode is used only in conjunction with the roller pattern/control strip method for testing densities on asphalt concrete and all aggregate material such as base, subbase and select materials.

The gauge has an internal radioactive source (Americium-241:Beryllium) that emits neutrons which measure the hydrogen to determine moisture content. Any position below the SAFE position can be used to determine moisture content.

Problems may arise when testing materials containing mica, boron, cadmium and chlorine or when testing heavy clays and organic material. It is permissible to use the Speedy Moisture Tester to verify nuclear results.
Like the conventional test, the operator must compare the results from the nuclear gauge to the one point proctor or laboratory proctor. The nuclear density is compared to the maximum dry density to calculate the percent density and the moisture content from the nuclear gauge is compared to the optimum moisture limits.

**PRETEST WARM-UP PROCEDURES FOR THE 3440 GAUGE**

The standard count should be taken daily before any testing is done to check gauge operation and allow the gauge to compensate for natural source decay. The 3440 gauge should be turned on and allowed to go through the self-test (RAM TEST) before beginning. (NOTE: It is very important that the RAM TEST display has ended before proceeding. During the test, the screen will display a count down from 300 seconds and then display READY on the screen.) Place the reference block on a flat surface with a minimum density of 100 lb/ft³ at least 10 feet from any structure and 33 feet from any other radioactive source, in the same manner as when using any other model gauge. Place the gauge on the reference block, making sure that it is seated flat and within the raised edges, with the right side of the gauge pushed firmly against the metal plate on the block. Press STANDARD on the finger keypad for the display:

- Standard Count
  - DS=
  - MS=
  - Take new count?

Press YES for the display:

- Is the gauge STD. Block & Source rod in SAFE pos?

Press YES for the display:

- Taking Standard Count - - seconds remaining.

After the countdown, the display is:

- MS= - - - - %P
- DS= - - - - %p
- Do you want to use the new STD?

Press yes to enter the new counts into memory. NOTE: If the screen displays an F instead of a %P, first look to see if you are too close to any structure or another gauge. Then press NO and take a new set of counts. If the second set fails, press YES and take 3 new standard counts. Refer to the gauge manual for more detailed instructions.
Nuclear Gauge Equipment Needed
For Soil Testing

- Gauge
- Reference Block
- Scraper Plate/Drill Rod Guide
- Extraction Tool
- AC Charger
- Drill Rod
- Hammer
- Operators Manual
- Bill of Lading and Proctor Results
- TLD
NUCLEAR TESTING PROCEDURES
FOR EMBANKMENTS

A construction project presents various situations in which compaction data is required. Depending upon the material to be tested, there are different testing methods that can be used to obtain the data. One method is used for testing embankment and subgrades; while another method is used for aggregate base, subbase, and select material and asphalt concrete.

When performing a test, some preliminary test information must be obtained by conducting a One-Point Proctor Test. This test establishes the maximum obtainable density and optimum moisture content. This test should be run while the contractor is compacting the soil layer to be tested.

If an appreciable amount of + 4 material (rock fragment, gravel, shale, etc.) is noticed in the soil layer, refer to VTM-1 and 12, for proper instruction. Contact the District Materials Engineer’s Office for the specific gravity of + 4 material when encountered.

RECOMMENDED NUCLEAR TEST PROCEDURES FOR DETERMINING DENSITY AND MOISTURE ON EMBANKMENT AND SUBGRADES

1. First, the test site must be properly selected and prepared. Choose a test site on the compacted layer of soil or soil mixture represented by the One-Point Proctor Test. Standard Counts should have been taken in the morning and are good for that day’s use.

2. Turn the gauge on to allow the device to warm up before testing is to begin. This should be done while the test site is being prepared for testing.

3. To obtain accurate results, the nuclear device must be seated flush on the compacted layer of soil. Level an area to place the device, either with a shovel or the scraper plate. If significant voids remain in the area where the device is to be placed, the voids should be filled with small amounts of soil common to the site, and lightly tamped in place with the scraper plate and excess material removed.

4. To take a Direct Transmission Density Test and a Moisture Test follow the procedure listed below.
   a. Place the drill rod guide on the test site and insert the drill rod into the guide sleeve. Place one foot
on the drill rod guide to keep it in position. Drive the rod 2 inches deeper than the depth of test.

b. Carefully remove the rod and drill rod guide. Place the gauge over the hole and extend the source rod into the hole to the required test depth. This should be done in a manner which prevents the source rod from disturbing the sides of the hole.

c. Make sure that the gauge is resting flush on the surface and that the source rod is in the locked position. Gently pull on the gauge housing so that the extended source rod will be tight against the hole.

d. Confirm that the gauge is on and depress “TIME” on the keypad and select one minute. The display panel will read COUNT TIME 1 min. and will return to “READY”. Depressing “SHIFT 8” on the keypad will allow you to select the Soils Mode and the display will read “READY”.

e. To begin the test press “START/ENTER”. After the gauge completes its count the display will show %PR (Percent Compaction), DD (Dry Density), WD (Wet Density), M (Moisture) and %M (Moisture Content). Record these figures on the TL-124.
Now that the direct transmission and moisture tests are completed, gently retract handle to the safe position, turn the power switch off, return the device to the field carrying case, and complete Form TL-124.

**Taking tests in the Backscatter Position** (Asphalt and Aggregate Only)

5. If for any reason a backscatter-density and moisture test is required by the Materials Engineer or representative of the Materials Division, follow the procedure listed below.

   a. Place the device on the prepared test site and lower the handle to the BACKSCATTER position.
   
   b. With the “TIME” set on 1 minute depress “START/ENTER” button.
   
   c. When the display appears record the results on the TL-124.

**Only use this method of test when instructed by District Materials Technicians.**

**NOTE:** When making density tests in close places, such as trenches and sidewalls, background effects will be encountered that will give incorrect density moisture counts. If this occurs, see instruction for background calculations on page 36 of this chapter.

**Filling out the TL - 124**

1. Fill in Line E (Maximum Dry Density) which is transferred from Line G of the One-Point Proctor (Form TL-125).

   Fill in Line F (Optimum Moisture) which is transferred from Line H of the One-Point Proctor (Form TL-125).

2. Fill in Lines A through D and Line J using the information on the 3440 Display Screen.

3. Fill in Line K (Percent Minimum Density Required). Density Requirements are located in Appendix C.

   **Lines G, H & I are only used when +4 material has been encountered.** When 10% or more +4 material is encountered the dry density (Line C) is divided by the Corrected Maximum Dry Density (Line H) and multiplied by 100 to obtained the percent compaction. (See Line J.)

   Also when 10% or more +4 material is encountered it is necessary to do a moisture correction which will be entered on Line I. This will be discussed in Chapter 7.
<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>585 + 00</td>
</tr>
<tr>
<td>Ref. to center line ft. (m)</td>
<td>At C/L</td>
</tr>
<tr>
<td>Test Elevation</td>
<td>+8 / -4</td>
</tr>
<tr>
<td>Compacted Depth of Lift in. (mm)</td>
<td>6&quot;</td>
</tr>
<tr>
<td>Method of Compaction</td>
<td>Sheepsfoot</td>
</tr>
</tbody>
</table>

A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)
B. Moisture Unit Mass (lbs/ft³), Moisture Unit Mass (kg/m³)
C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A - B)
D. Moisture Content (B + C) x 100
E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)
   Lab Proctor or One Point Proctor
   **124.2**
F. Percent Optimum Moisture from Lab or One Point Proctor
   **10.7**
   **8.6 – 12.8**
G. Percent of plus #4, (plus 4.75mm)
H. Corrected Maximum Dry Density (lbs/ft³) Dry Unit Mass (kg/m³)
I. Corrected Optimum Moisture
J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)
   \((C + E) \times 100 \text{ or } (C + H) \times 100\)
K. Percent Minimum Density Required

**Remarks:**

**CC:** District Materials Engineer

**By:**

**Title:**

---

1. From One-Point Proctor Results
   
   **(TL-125 Line G)**
   
   **Moisture and Range**
   
   **(TL-125 Line H)**
2. From 3440 Display Screen

\[
\begin{align*}
\% \text{ PR} & = 97.0 \\
\text{DD} & = 120.5 \\
\text{WD} & = 133.3 \\
M & = 12.8 \\
\%M & = 10.6
\end{align*}
\]

Lines G, H & I used only for +4 corrections

3. Density Requirements located in Appendix C
The actual density specification will vary with the vertical location of the material in the embankment and with the amount of plus No. 4 material within the fill (see below).
### Correcting Density Tests for High Moisture with the Speedy Moisture Tester

<table>
<thead>
<tr>
<th>Test No.</th>
<th>2E</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>Station ft. (m)</td>
</tr>
<tr>
<td>of</td>
<td>Ref. to center line ft. (m)</td>
</tr>
<tr>
<td>Test</td>
<td>Elevation</td>
</tr>
<tr>
<td></td>
<td>Compacted Depth of Lift in. (mm)</td>
</tr>
<tr>
<td>Method of Compaction</td>
<td>Sheepsfoot</td>
</tr>
<tr>
<td>A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)</td>
<td>139.0</td>
</tr>
<tr>
<td>B. Moisture Unit Mass (lbs/ft³), Moisture Unit Mass (kg/m³)</td>
<td>18.1</td>
</tr>
<tr>
<td>C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A - B)</td>
<td>120.9</td>
</tr>
<tr>
<td>D. Moisture Content (B ÷ C) x 100</td>
<td>15.0</td>
</tr>
<tr>
<td>E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor</td>
<td>129.3</td>
</tr>
<tr>
<td>F. Percent Optimum Moisture from Lab or One Point Proctor</td>
<td>9.2</td>
</tr>
<tr>
<td></td>
<td>7.4 – 11.0</td>
</tr>
<tr>
<td>G. Percent of plus #4, (plus 4.75mm)</td>
<td></td>
</tr>
<tr>
<td>H. Corrected Maximum Dry Density (lbs/ft³) Dry Unit Mass (kg/m³)</td>
<td></td>
</tr>
<tr>
<td>I. Corrected Optimum Moisture</td>
<td></td>
</tr>
<tr>
<td>J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)</td>
<td>93.5</td>
</tr>
<tr>
<td>(C ÷ E) x 100 or (C ÷ H) x 100</td>
<td></td>
</tr>
<tr>
<td>K. Percent Minimum Density Required</td>
<td>95.0</td>
</tr>
</tbody>
</table>

### Moisture Content from Nuclear gauge is suspected to be incorrect
### Correcting Density Tests for High Moisture with the Speedy Moisture Tester

**Test No. 2E**

<table>
<thead>
<tr>
<th>Location of Test</th>
<th>Station ft. (m)</th>
<th>Ref. to center line ft. (m)</th>
<th>Compacted Depth of Lift in. (mm)</th>
</tr>
</thead>
</table>

**Method of Compaction**

- A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)
- B. Moisture Unit Mass (lbs/ft³), Moisture Unit Mass (kg/m³)
- C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A - B)
- D. Moisture Content (B ÷ C) x 100
- E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor
- F. Percent Optimum Moisture from Lab or One Point Proctor
- G. Percent of plus #4, (plus 4.75mm)
- H. Corrected Maximum Dry Density (lbs/ft³) Dry Unit Mass (kg/m³)
- I. Corrected Optimum Moisture
- J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100
- K. Percent Minimum Density Required

<table>
<thead>
<tr>
<th>Method</th>
<th>Sheepsfoot</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>585 + 00 At C/L</td>
<td></td>
<td></td>
</tr>
<tr>
<td>+6 / -5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**1. Moisture Content using Speedy Moisture Tester**

<table>
<thead>
<tr>
<th>Wet Density (as a decimal)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>139.0 / 1.098</td>
<td></td>
</tr>
</tbody>
</table>

**2. Calculate Dry Density**

\[
\text{Wet Density} - \text{Dry Density} = \text{Moisture Unit Weight}
\]

\[
139.0 - 126.6 = 12.4 \text{ lb/ft}^3
\]

**3. Calculate Moisture Unit Weight**

\[
\frac{\text{Wet Density}}{1 + \% \text{ Moisture (as a decimal)}}
\]

\[
\frac{139.0}{1.098}
\]

**Remarks:**

- Speedy Moisture Used Due to Micaceous Soil
- Dial Reading 8.9

**By:** ________________________

**Title:** ______________________

**Date:** ______________________

**County:** Campbell
BACKGROUND CALCULATIONS FOR TRENCH AND SIDEWALL MOISTURE TESTING

When a 3440 Nuclear Gauge is operated within 24 inches of a vertical structure the density and moisture counts will be affected due to gamma photons and neutrons echoing off the walls of the structure. It is necessary to perform a trench offset when testing backfill material around pipe culverts, abutments, near a building, etc. This correction should be performed each day and when trench wall conditions (distance from wall, moisture content, material composition, etc.) vary.

The procedure to determine the background effect and apply the necessary correction is as follows:

1. Take the daily standard count with the gauge on the Standard Block outside the trench and record the density and moisture values.

2. Place the gauge on the Standard Block inside the trench in the testing area and press “OFFSET” on the display panel and select No. 3 “TRENCH OFF”. The gauge will show Trench Offset Disabled and ask if you want to use Trench Offset. Press “YES”. The gauge will show trench offset for moisture and density and ask if you want to change. Press “YES” to perform a new offset and “NO” to use the existing offset constants. If you selected yes, the gauge will prompt you to press “START” for 1 minute Standard Counts in trench. Make sure to take counts the same distance from the wall as the anticipated test readings. The density and moisture trench offset constants will be calculated and stored. When the gauge is not to be used for trench measurements disable the offset.
SELF REGULATIONS & THE VDOT LICENSE

VDOT has a Materials License issued by the Virginia Department of Health (VDH). The VDH is responsible for ensuring the safety of people who work with radioactive by-product materials and the security of such materials. To control the risks associated with the use of nuclear by-product materials, the VDH sets strict health and safety standards for nuclear equipment, defines allowable limits for radiation exposure and frequently conducts inspections of nuclear products and facilities. The VDH enforces the Code of Federal Regulations and all applicable state requirements governing the use of radioactive by-product materials. The codes are Federal and state law and they are binding upon licensees to uphold.

In addition to the Codes of Federal Regulation (CFR), licensee are governed by the provisions outlined in the license authorizing the possession of by-product material. The possession of a license obligates the Department to scrupulously perform the actions it stated it would perform to comply with the requirements of its license. This commitment is the condition under which the Department is able to receive and then retain the license. Failure to comply could mean a severe fine, loss of license, or both, together with the adverse publicity. The provisions of the license are just as compelling as the C.F.R. govern nuclear safety.

Possession of a VDH license requires the licensee to adhere to safe practices and act as self-regulator in the enforcement of regulations. This Agency is compelled to report its own infraction of rules to the VDH. To enforce these safety regulations periodic checks on the program to see that VDOT’s employees are following Department’s instructions and radiation safety rules are an essential part of safe operations of nuclear gauges. VDOT has established a system of records covering the receipt and transfer of nuclear gauges. We must maintain records of radiation exposure of persons working in the program and surveys are conducted to evaluate the effectiveness of radiation safety programs.
STORAGE REQUIREMENTS

1. “Radioactive Material” signs shall be posted in the storage unit on the inside of the door in accordance with Virginia Department of Health Radiation Protection Regulations.

2. The Form “Notice to Employees,” shall be posted on the project bulletin board where the nuclear gauge is assigned, in accordance with Virginia Department of Health Radiation Protection Regulations.

3. The radioactive source when not in use and when left unattended shall be stored and secured (locked, bolted, etc.) at all times against unauthorized removal from the storage place, in accordance with Virginia Department of Health Radiation Protection Regulations. The magenta and yellow "FEDERAL OFFENSE" sign shall be posted on the locked blue carrying case while the nuclear gauge is being stored. The intent of this sign is to discourage the theft of the gauge.

4. VDOT requires that an outside storage facility be used and that it be at least 10 feet from personnel’s permanent workstation (desk). See Road and Bridge Specification Section 514.02 (c).

5. The nuclear gauge and TLD’s (Film Badge) stored shall be at least 10 feet apart. Badges shall be stored in designated area inside project trailer.

6. The required records of transfer shall be completed when the nuclear gauge is in transit on the project site by using log sheet located in the storage facility on the project site, or moved from one assigned area to another or when transferred to another license.
NUCLEAR GAUGE CALIBRATIONS

The source decays at a rate of 2.2% per year and the electronics have a minor amount of drift from aging parts. Therefore, gauges are calibrated in the laboratory at least yearly under controlled conditions using the same methods of testing as in the field. The gauges are calibrated on a series of blocks of known density and moisture contents.

This is for your information--do not proceed with gauge maintenance unless you have had the proper safety training.

NUCLEAR GAUGE MAINTENANCE

Cleaning

The source rod in the 3400 Series is supported in linear bearings packed with Magnalube-G grease. The grease is retained within the bearings and soil kept out by a system of wipers and seals at the top and bottom of the center post of the gauge. These bearings will require little or no service, unless the gauge is overhauled. Do not lubricate.

On the bottom surface of the gauge is a removable plate with a brass scraper ring mounted in it. This ring will remove most of the soil from the source rod. However, under some soil conditions, small amounts will be carried into the sliding shield assembly. If allowed to build up, this soil can cause wear in the shield cavity and can ultimately be forced into the bearings and ruin them.

Cleaning the cavity is relatively simple. Place the gauge on its side on a bench with the base away from the operator. The source rod should be latched in the SAFE position. Using a Phillips screwdriver, remove the four screws holding the bottom plate assembly in position and pry out the assembly using a flat blade screwdriver. Using the same tool, remove the sliding block and spring.

Using a rag, stiff brush and compressed air, if available, remove all soil and wipe clean the cavity, sliding block and bottom plate assembly. Inspect all items for excessive wear and replace if required. Check the scraper ring to insure that it is free to move in its groove. If the ring is damaged it may be replaced or replace the assembly. The cleaning time will take no longer than five minutes.
Stand gauge on the end and stand behind the gauge to work. Remove screws from the bottom plate.

Remove the bottom plate and the tungsten sliding block that shields the source rod.
Clean the area around the tungsten block and clean and polish the face of the block to remove all rough surface. Do not get hands near the source rod.

Replace the block and plate. Clean the gauge when difficulty is encountered when lowering and raising the source rod.
Battery Charging for Model 3440

A fully charged battery will last approximately 8 weeks under normal working conditions (8 hr. day). The 3440 display panel will give you the hours remaining on the current charge, and when it is running low, the screen will display BATTERIES LOW! You still have a few hours left when this display occurs in order to finish the current test. At the completion of the days testing, the gauge needs to be plugged in overnight to fully recharge. IMPORTANT: Only recharge when the gauge indicates that it is low. Needless recharging will shorten the battery life.

Alkaline Battery Use

Alkaline batteries may be used when recharging is not an option. The gauge has a separate battery case for this purpose. Refer to manual for further instructions.

CAUTION: Never mix alkaline and rechargeable batteries in the gauge. They may explode when charging!!!
INSTRUCTIONS TO FOLLOW IN THE EVENT OF AN ACCIDENT
DO NOT DISCUSS INCIDENT WITH ANYONE EXCEPT POLICE, STATE MATERIALS PERSONNEL, AND YOUR IMMEDIATE SUPERVISOR.
The District Public Relations Specialist must address all news media questions.

1. Stop and detain all equipment or vehicles involved until the assessment can be made to determine if there is any contamination. If a vehicle is involved, notify the local and state police. Let them know that radioactive materials are involved. Segregate and detain all persons involved.

2. Assess and treat life-threatening injuries immediately. Do not delay advanced life support if victims cannot be moved. Move victims away from the radiation hazard area if possible, using proper patient transfer techniques to prevent further injury. Stay within the controlled area if contamination is suspected.

3. Prohibit eating, drinking, or smoking by persons while at the accident scene.

4. Locate the gauge and or source, see attached check list.

5. Immediately cordon off at least a 20 feet radius surrounding the gauge and parts, if any. Keep on-lookers and all unnecessary personnel at a safe distance, while caring for or rescuing any persons who are injured.

6. Notify the nearest Radiation Safety Officer of the license holder to come and monitor the device to determine if there is possible leakage. (Give good directions as to location of accident.)

7. Never let anyone remove the gauge, equipment or any articles that are involved in the accident until the area has been cleared by a monitoring team.

8. Complete the Nuclear Accident Checklist located in the Bill of Lading after the RSO or monitoring team has arrived and assessed the situation. The Emergency Notification List is also in the Bill of Lading.
Nuclear Testing Flowchart

Pretest and Warm Up Procedures
1. Clean Gauge (if needed)
2. Warm Up Gauge (300 sec.)
3. Standard Counts
   (daily calibration)
4. Charge if Needed
   (16 hour minimum except in emergency such as roller pattern)

Equipment Needed

For Soils Testing
1. Film Badge
2. Bill of Lading
3. Plate
4. Pin
5. Hammer
6. Proctor Results
7. Speedy Moisture
   (if testing micaceous soils or other Material with high hydrogen content)
8. Proper Form (VDOT TL-124A)

For Base and Subbase
1. Film Badge
2. Bill of Lading
3. Control Strip Target Densities
4. Proper Forms
   TL-53A for Roller Pattern
   TL-54A for Control Strip
   TL-55A for Acceptance Testing

Test Site Preparation

For Soils Testing
1. Construction Plans (as an aid in choosing test sites in proposed fills)
2. Blade off area (fill in voids with -4 material)

For Base and Subbase
1. Choose representative site
   (not an area with only coarse or only fine material)
2. DO NOT fall into a routine
   (randomize testing pattern and frequency)

Testing

Soils
1. Set time control (1 min. for all testing except roller patterns)
2. Pull gauge back
3. Push start button
4. STEP BACK - at least two paces
5. Direct Transmission Position for soils

Base and Subbase
1. Set time control (1 min. for all testing except roller patterns)
2. Push start button
3. STEP BACK - at least two paces
4. Backscatter Position for base and subbase material
Record Counts

1. TL-124A for Direct Transmission
2. TL-53A for Roller Pattern
3. TL-54A for Control Strip
4. TL-55A for Acceptance Tests
   (on all forms moisture counts are taken on soil and
   aggregate only)

Accept Test Results

All tests are accepted based on their comparison to
known TARGET densities and moisture.

Soil test are compared to PROCTOR Results:
Moisture range for Acceptance is +/- 20% of
optimum moisture. Density range is 95% for
embankment and pipe backfill and 100% for
subgrade. (See Appendix C.)

Base and subbase material is compared to
control strip test results: Density range is a
minimum of 95% for each individual reading
and 98% for an average of the same 5 readings.
(Note: 5 readings equal one test.)
# Troubleshooting Guide for the Nuclear Moisture/Density Gauge

<table>
<thead>
<tr>
<th>Problem</th>
<th>Probable Cause</th>
<th>Solution</th>
</tr>
</thead>
</table>
| Gauge turns off after it is turned on or will not turn on | 1. Gauge may be wet. DO NOT turn gauge on until it has dried.  
2. Batteries are low | 1. Wait until gauge dries off.  
2. Recharge batteries minimum of 16 hours (short and frequent charge drains battery life). If charge doesn’t hold call District Materials Section. |
| Short battery life | 1. Bad outlet.  
2. Batteries are reaching end of cycle or charge isn’t working. | 1. Check outlet.  
2. Call the District Materials Section. |
| Questionable Standard Counts | 1. Gauge needs more warm-up time or isn’t properly seated on the standard block.  
2. Handle isn’t in the safe position.  
3. Background interference. | 1. Check to see that the gauge isn’t on the standard block backwards. Clean all dirt, gravel, etc. from the gauge standard or test block. Make sure these counts are taken exactly as all prior tests.  
2. Check handle position  
3. Move away from any large structures. |
| Questionable moisture Counts | 1. Mica, asbestos or other hydrogen rich material is in soil.  
2. Background interference from large structure or trench wall if below ground level.  
3. Internal tube failure  
4. Handle not locked in testing position notch | 1. Run a Speedy Moisture test.  
2. Move test site away from structures or run background count if testing in a trench.  
3. Run new standard count to check gauge.  
4. Check handle position |
| Questionable density Counts | 1. Presence of +4 material.  
2. Test isn’t taken on soil represented by Proctor test result.  
3. Internal tube failure  
4. Handle isn’t locked into testing position | 1. Check for +4 material and take corrective action that applies to your District  
2. Run a Proctor test.  
3. Run new standard counts.  
4. Check handle position |
CHAPTER 6
Nuclear Field Density Testing of Soil
Study Questions

1. Batteries should be charged______________________________

2. True or False. The nuclear gauge should be warmed-up first thing in the morning before using it.

3. True or False. The only maintenance performed in the field is cleaning the nuclear gauge and charging the batteries.

4. When taking a standard count, the nuclear gauge should be a minimum of _____ ft. from any structure and _____ ft. from any other radioactive source.

5. True or False. Cesium-137 is located in the tip of the stainless steel rod which is used in taking moisture determinations and Americium-241:Beryllium is located inside the nuclear gauge and is used for density testing.

6. When taking Standard Counts the Reference Standard should be placed on what type of surface?

7. Three ways to limit exposure to radiation are__________________________

8. If the soil material fails a nuclear test because of excessive moisture, the first step taken is__________________________

9. A testing method for testing densities whereby the source rod is inserted into the material to be tested to a depth of either 4, 6 or 8 inches is______________.

10. If, during construction, the density results either change suddenly, or simply don’t make sense to you, you should__________________________

11. If the moisture results from the Nuclear test appear high, the_____________ could be used to check the moisture.

12. When a nuclear gauge is operated within 24 inches of a vertical structure, the_____ and _________________ are influenced by the structure.
CHAPTER 6
Practice Problems
Nuclear Field Density Testing of Soil
Nuclear Method

Complete the TL-124 using the information below and determine if tests pass.

PRACTICE PROBLEM 5

PROCTOR DATA
Maximum Dry Density 114.6 lb/ft³
Optimum Moisture: 14.1%

3440 DISPLAY SCREEN
%PR 99.7
DD = 114.2
WD = 133.3
M = 19.1 %M = 16.7

PRACTICE PROBLEM 6

PROCTOR DATA
Maximum Dry Density 106.9 lb/ft³
Optimum Moisture: 17.6%

3440 DISPLAY SCREEN
%PR 98.9
DD = 105.7
WD = 123.6
M = 17.9 %M = 16.9

PRACTICE PROBLEM 7

PROCTOR DATA
Maximum Dry Density 112.1 lb/ft³
Optimum Moisture: 15.2%

3440 DISPLAY SCREEN
%PR 97.8
DD = 109.6
WD = 128.2
M = 18.6 %M = 17.0
## STANDARD COUNT

<table>
<thead>
<tr>
<th>DENSITY</th>
<th>MOISTURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>2844</td>
<td>701</td>
</tr>
</tbody>
</table>

### Problem 5  
### Problem 6  
### Problem 7

<table>
<thead>
<tr>
<th>Test No.</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>305+00</td>
<td>305+60</td>
<td>306+20</td>
</tr>
<tr>
<td>of</td>
<td>@ C/L</td>
<td>10' Lt.</td>
<td>7' Lt.</td>
</tr>
<tr>
<td>Test</td>
<td>+10/-7</td>
<td>+3/-10</td>
<td>+3/-3</td>
</tr>
<tr>
<td>Compacted Depth of Lift in. (mm)</td>
<td>6&quot;</td>
<td>6&quot;</td>
<td>6&quot;</td>
</tr>
<tr>
<td>Method of Compaction</td>
<td>Sheepsfoot</td>
<td>Sheepsfoot</td>
<td>Sheepsfoot</td>
</tr>
</tbody>
</table>

### Calculations

A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³) =

B. Moisture Unit Mass (lbs/ft³), Moisture Unit Mass (kg/m³) =

C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A - B) =

D. Moisture Content (B / C) x 100 =

E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor =

F. Percent Optimum Moisture From Lab or One Point Proctor =

G. Percent of plus #4, (plus 4.75mm) =

H. Corrected Maximum Dry Density (lbs/ft³) Dry Unit Mass (kg/m³) =

I. Corrected Optimum Moisture =

J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C + E) x 100 or (C + H) x 100 =

K. Percent Minimum Density Required =

### Remarks:

### CC:
- District Materials Engineer
- Project File
- By: ____________________________
- Title: ____________________________
CHAPTER 6
Practice Problem
Nuclear Field Density Testing of Soil
Correcting for False High Moisture Content

PRACTICE PROBLEM 8

The nuclear density test reported on the TL-124 on the following page shows a false high moisture content, assumed to be caused by micaceous soil. Correct the test results using a Speedy Moisture Meter and record results in the second column of the TL-124.

Speedy Dial Reading = 9.6
**VIRGINIA DEPARTMENT OF TRANSPORTATION**  
**MATERIALS DIVISION**  
**REPORT OF NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)**

---

**English**  
**Metric**

---

**Report No.:** _________________  
**Date:** _________________  
**Sheet No.:** __1 of __1__

---

**Route No.:** 17  
**County:** Campbell

---

**Project No.:** 0017-015-104,C503  
**F.H.W.A. No.:** None  
**Test For:** Embankment

---

**Nuclear Gauge Model No.:** 3440  
**Serial No.:** 23456  
**Calibration Date:** ____________

---

### STANDARD COUNT

**DENSITY**  
**2830**

**MOISTURE**  
**701**

---

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Location of Ref. to center line ft. (m) Test Elevation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

**Compacted Depth of Lift in. (mm):** 6"

---

**Method of Compaction:** Sheepsfoot

---

**A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³) =** 141.0

---

**B. Moisture Unit Mass (lbs/ft³), Moisture Unit Mass (kg/m³) =** 23.1

---

**C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A - B) =** 117.9

---

**D. Moisture Content (B ÷ C) x 100 =** 19.6

---

**E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor =** 132.4

---

**F. Percent Optimum Moisture from Lab or One Point Proctor =** 9.2  
**7.4 - 11.0**

---

**G. Percent of plus #4, (plus 4.75mm) =**

---

**H. Corrected Maximum Dry Density (lbs/ft³) Dry Unit Mass (kg/m³) =**

---

**I. Corrected Optimum Moisture =**

---

**J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100 =** 89.0

---

**K. Percent Minimum Density Required =** 95.0

---

**Remarks:**

---

**CC:** District Materials Engineer  
**By:** ____________________________

---

**Project File:** ____________________________  
**Title:** ____________________________

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