FIELD MOISTURE AND DENSITY TESTING WITH THE NUCLEAR GAUGE

LEARNING OUTCOMES

- Understand the components of the nuclear gauge and how it is used to measure moisture and density
- Understand the procedures for evaluating moisture and density using the direct transmission method
- Understand the basic regulations that govern the storage, transport, and use of the nuclear gauge
- Understand basic maintenance techniques and procedures for emergency response

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 determinations are to be performed in accordance with the following AASHTO tests:

- T191- Density of Soil in Place by the Sand Cone Method
- T310- Density of Soil in Place by the Nuclear Gauge

SOIL DENSITY TESTING FLOW CHART
TROXLER 3440 NUCLEAR GAUGE (FOR SOILS AND AGGREGATE MATERIAL)
DETERMINING FIELD DENSITY & MOISTURE CONTENT WITH THE NUCLEAR GAUGE

The Nuclear Moisture Density device (or Nuclear Gauge) 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 thermoluminescent dosimeter (TLD) 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 Nuclear 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.
TROXLER 3440 NUCLEAR GAUGE (HANDLE POSITIONS)

SAFE POSITION
(Use For Storage and Standard Counts)

BACKSCATTER POSITION

USE ANY POSITION
FOR MOISTURE

50 mm
(2 In.)

100 mm
(4 In.)

150 mm
(6 In.)

200 mm
(8 In.)

TROXLER 3440 NUCLEAR GAUGE (BASE AND DISPLAY SCREEN)
NUCLEAR GAUGE - THEORY OF OPERATIONS

The Nuclear 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 NUCLEAR 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 lbs/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”

- **Is the Gauge STD. Block & Source in SAFE Pos?**

Press “YES”

- **Taking Standard Count**
  - ---- seconds remaining.

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 three (3) new standard counts. Refer to the gauge manual for more detailed instructions.
Nuclear Gauge Equipment Needed
For Soil Testing

- Gauge
- Reference Block
- Extraction Tool
- Drill Rod
- Hammer
- Operators Manual
- AC Charger
- Scraper Plate/Drill Rod Guide
- 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. This test establishes the maximum obtainable Dry Density and Optimum Moisture Content for particular embankment material. 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 VTM 12, for proper testing instructions. Contact the Quarry or the District Materials Division for the specific gravity of the +4 material when encountered.

Embankment/Subgrade Testing Procedures (Direct Transmission Method)

1) 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 entire 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 against 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 then press “TIME” on the keypad and select one minute. The display panel will read “COUNT TIME 1 min.” and then return to “READY”. Pressing “SHIFT8” 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 Form TL-124 (Report on Nuclear Embankment Densities).

f) 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 finish completing the Form TL-124 (Report on Nuclear Embankment Densities).

**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, press the “START/ENTER” button.
   
   c) When the display appears record the results on the Form 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 readings. If this occurs, see instructions for background calculations on Page 6-18 of this chapter.

**Filling out the Form TL-124:**

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

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

3) Fill in Lines A through D and Line J using the information on the 3440 Nuclear Gauge Display Screen.

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

5) Calculate the Percent Density (Line J) by dividing the Dry Density (Line C) by the Maximum Dry Density (Line E) and then multiplying by 100.

   **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 then 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.
**VIRGINIA DEPARTMENT OF TRANSPORTATION**  
**MATERIALS DIVISION**  
**REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)**

```
Report No. 1-21A-1          Date 06/22/2015          Sheet No. 1 of 1
Route No. 17              County Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440            Serial No. 23456          Calibration Date 02/10/2015
```

### STANDARD COUNT DATA

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</tr>
<tr>
<td>B. Moisture Unit Mass (lbs/ft³ or kg/m³)</td>
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<tr>
<td>C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>D. Moisture Content (B ÷ C) x 100</td>
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<td>E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor</td>
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<td>F. Percent Optimum Moisture from Lab or One Point Proctor</td>
<td>= 10.7</td>
<td>8.6 – 12.8</td>
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<td>H. Corrected Max. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)</td>
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</tr>
<tr>
<td>J. Percent Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (C ÷ E) x 100 or (C ÷ H) x 100</td>
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<td></td>
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<tr>
<td>K. Percent Minimum Density Required</td>
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**One-Point Proctor Results**  
Max. Dry Density (TL-125 Line G)  
Optimum Moisture (TL-125 Line H)

**Comments:**

BY: ____________________________  
TITLE: __________________________

2016v1.0  
Chapter 6 | 11
### STANDARD COUNT DATA

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<th>Density</th>
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<tr>
<td>Elevation</td>
<td>+8 / -4</td>
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</table>

**Compaction Depth of Lift in. (mm)**
- 6”

**Method of Compaction**
- Sheepfoot

**A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)**
- = 133.3

**B. Moisture Unit Mass (lbs/ft³ or kg/m³)**
- = 12.8

**C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)**
- = 120.5

**D. Moisture Content (B ÷ C) x 100**
- = 10.6

**E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)**
- Lab Proctor or One Point Proctor
- = 124.2

**F. Percent Uncompacted Moisture from Lab or One Point Proctor**
- = 10.7
- 8.6 – 12.8

**G. Percent of PR Provided by Gauge (%PR = 97.0%)**
- =

**H. Corrected Moisture (lbs/ft³ or kg/m³)**
- =

**I. Corrected Optimum Moisture (lbs/ft³ or kg/m³)**
- =

**J. Percent Dry Density (Line C ÷ (Line E) × 100)**
- (120.5 + 124.2) x 100 = 97.0%
- =

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

**Comments:**

BY: __________________________
TITLE: ________________________
Does the Material meet specification?

The actual density specification will vary with the vertical location of the material in the embankment and with the amount of +4 Material within the fill (see below).
CORRECTING FOR HIGH MOISTURE READINGS

As stated previously, the Nuclear Gauge is specifically designed to measure the moisture content and density of soils, aggregates, cement and lime treated materials. The gauge has an internal radioactive source (Americium–241: Beryllium) and it uses this source to determine moisture by releasing “fast” neutrons into the compacted material. These “fast” neutrons are then slowed down, or thermalized, when they interact with the nucleus of hydrogen, a key ingredient of the water molecule. However, some soils (i.e. micaceous soils) contain high-levels of naturally bound hydrogen, which increases the “thermalization” process. The gauge misinterprets this naturally bound hydrogen as “excessive” moisture content. Such errors in measurement can lead to a false Dry Density reading, which in turn may result in a false low or failing Percent Density value. When this situation arises, it is up to the technician to “correct” the moisture and density reading using the following process and standard calculations.

Example Problem:

A nuclear test conducted on a hydrogen-rich soil has produced false Moisture (M = 18.1, M% = 15.0) and Dry Density (DD = 120.9) readings. These false readings in turn have prompted a failing Percent Density value (%PR = 93.5%).

Maximum Dry Density = 129.3 lbs/ft³
Optimum Moisture Content = 9.2%
Optimum Moisture Range (± 20%) = 7.4 – 11.0%
Minimum Density Required = 95.0%
Speedy Dial Reading = 8.9

Procedural Steps for Correcting the Moisture and Dry Density Readings (Form TL-124)

1) Conduct a Speedy Moisture Test to determine the correct Moisture Content (M%).

2) Adjust the Dry Density (Line C) by the dividing the original Wet Density (Line A) by the corrected Moisture Content (M%) plus 1. [DD = WD / (1 + M%)]

3) Adjust the Moisture Unit Mass (Line B) by subtracting the corrected Dry Density value from the original Wet Density value (Line A). [MM = WD – DD]

4) Adjust the Percent Density (Line J) by dividing the corrected Dry Density value by the Maximum Dry Density value (Line E) and then multiplying by 100. [%PR = (DD ÷ Max. DD) x 100]
**CORRECTING FOR HIGH MOISTURE READINGS USING THE SPEEDY MOISTURE DEVICE**

- **Report No.**: 1-21A-1  
- **Date**: 06/22/2015  
- **Page**: 1 of 1

**STANDARD COUNT DATA**

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<td>+8 / -4</td>
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<td>Compaction Depth of Lift in. (mm)</td>
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<td>Method of Compaction</td>
<td>Sheepfoot</td>
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<td>A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)</td>
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<tr>
<td>E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³)</td>
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<td></td>
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<tr>
<td>G. Percent of Plus #4, (plus 4.75 mm)</td>
<td>7.4 - 11.0</td>
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<tr>
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<tr>
<td>I. Corrected Optimum Moisture</td>
<td>95.0</td>
<td></td>
<td></td>
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<td>J. Percent Dry Density (lbs/ft³)</td>
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<td>K. Percent Minimum Density Required</td>
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</table>

**Comments:**

- **BY:**
- **TITLE:**

---

**Nuclear Gauge Display Panel**

- **% PR = 93.5%**
- **DD = 120.9**
- **WD = 139.0**
- **M = 18.1**
- **M% = 15.0**

---

**Moisture Content is suspected to be incorrect due to soil properties or conditions**

**Failing Percent Density is suspected to be incorrect due to false high moisture readings**

---

**CORRECTING FOR HIGH MOISTURE READINGS USING THE SPEEDY MOISTURE DEVICE**
CORRECTING FOR HIGH MOISTURE READINGS USING THE SPEEDY MOISTURE DEVICE

Report No. 1-21A-1 Date 06/22/2015 Sheet No. 1 of 1
Route No. 17 County Campbell
Project No. 0017-015-104, C503
FHWA No. None
Testing for Embankment
Model No. 3440 Serial No. 23456 Calibration Date 02/10/2015

STANDARD COUNT DATA

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<tr>
<th>Density</th>
<th>2830</th>
<th>Moisture</th>
<th>701</th>
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</table>

| Location of Test | 585+00 ft. (m) | 6" |
| Elevation        | +8 / -4 ft. (m) | at. C/L |
| Location ft. (m) | 585+00          |
| Moisture Unit Mass (lbs/ft³) | 139.0 |
| Dry Density (lbs/ft³) | 139.0 – 126.6 |
| Moisture Content (lbs/ft³) | 12.4 |
| Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) | 129.3 |
| Lab Proctor or One Point Proctor |
| Percent Optimum Moisture | 9.2 |
| Percent of Plus #4 | 7.4 – 11.0 |
| Corrected Max. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) | |
| Corrected Optimum Moisture | |
| Percent Dry Density (lbs/ft³) | 93.5 |
| Percent Minimum Density | 95.0 |

Comments:

BY: ________________________________
TITLE: ________________________________

Step 1 – Conduct a Speedy Moisture Test to correct Moisture Content

Step 2 – Adjust Dry Density

DD = WD ÷ (1 + M%)
DD = 139.0 ÷ (1 + 0.098)
DD = 120.9
126.6

Step 3 – Adjust Moisture Mass

MM = WD - DD
MM = 139.0 – 126.6
MM = 12.4 lbs/ft³

Step 4 – Correct Percent Density

%PR = (DD ÷ Max. DD) x 100
%PR = (126.6 ÷ 129.3) x 100
%PR = 97.9%
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 the 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 byproduct 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 (CFR) and all applicable state requirements governing the use of radioactive byproduct materials. The codes are Federal and state law and they are binding upon licensees to uphold.

In addition to the CFR, licensees are governed by the provisions outlined in the license authorizing the possession of byproduct 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 it 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 potential consequences of bad publicity. The provisions of the license are just as compelling as the CFR and 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 the Department’s instructions and radiation safety rules are an essential part of nuclear gauge safety and effective program management. 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.
NUCLEAR GAUGE 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 Specifications, 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.
NUCLEAR GAUGE MAINTENANCE

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 the 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 (5) minutes.

Nuclear Gauge Cleaning Procedures

1) Standing behind the gauge with the source rod pointing away from you, place the gauge on its end and remove the screws from the bottom plate.
2) Remove the bottom plate and the tungsten sliding block that shields the source rod.

3) Clean the area around the tungsten sliding block. Then, clean and polish the face of the block to remove all rough surfaces. Do not get hands near the source rod.
4) Replace the block and plate. Clean the gauge anytime that difficulty is encountered when trying to lower and/or raise the source rod.

**Battery Charging for Model 3440**

A fully charged battery will last approximately 8 weeks under normal working conditions (8 hours/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 testing. At the completion of the days testing however, 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 onlookers 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 GAUGE TESTING FLOWCHART

Pretest and Warm Up Procedures
1) Clean Gauge (if Needed)
2) Warm Up Gauge (300 seconds)
3) Perform Standard Count
   (Must be performed daily)
4) Charge Batteries (if needed)
   (16 hour minimum except in emergency, such as Roller Pattern)

Soil Testing Equipment
1) Film Badge
2) Bill of Lading
3) Scraper Plate
4) Drill Rod
5) Extraction Tool
6) Hammer
7) Proctor Data
8) Proper Form (i.e. TL-124)

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

Soil Testing Procedures
1) Set time control (1 minute for all testing except Roller Patterns)
2) Pull gauge back
3) Push “Start” button
4) Step back from gauge (at least two paces)
5) Direct Transmission method for all soil material

Record Data and Accept Test Results
All test results are accepted based on their comparison to known TARGET densities and moistures

Soil tests are compared to proctor results:
Moisture range for acceptance is ± 20% of optimum moisture. Density range is 95% for embankment material and pipe backfill and 100% for subgrade material

Aggregate Testing Equipment
1) Film Badge
2) Bill of Lading
3) Scraper Plate
4) Drill Rod
5) Extraction Tool
6) Hammer
7) Proctor/Target Density Data
8) Proper Forms (i.e. TL-53, etc.)

Aggregates Testing Site Preparation
1) Choose representative site (not an area with only coarse or only fine material)
2) Do not fall into a set testing routine (randomize testing patterns and frequency)

Aggregate Testing Procedures
1) Set time control (1 minute for all testing except Roller Patterns)
2) Push “Start” button
3) Step back from gauge (at least two paces)
4) Backscatter method for all aggregate material
5) Direct Transmission method is only used when validating Control Strip

Aggregate material is compared to Control Strip test results: Moisture range is ± 2 percentage points of optimum moisture. Density range is a minimum of 95% for each individual reading and 98% for an average of the same 5 readings
# TROUBLESHOOTING GUIDE FOR THE NUCLEAR 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 at all | 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 the 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 the handle position. |
CHAPTER 6 – 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 ____________, ____________, and ____________.

8) If the soil material fails a nuclear test because of excessive moisture, the first step taken is to ________________.

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

10) If, during construction, the density results either change suddenly, or simply don’t make sense, 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” of a vertical structure, the ________________ and ________________ are influenced by the structure.
CHAPTER 6 – PRACTICE PROBLEMS

Nuclear Gauge Testing of Soil Material (Density and Moisture)

Transfer the information from each Practice Problem below to the Form TL-124 and then determine whether each test passes.

Practice Problem 1
Proctor Data
Maximum Dry Density = 114.6 lbs/ft³
Optimum Moisture = 14.1%

Nuclear Gauge Display Panel
% PR = ______%
DD = 114.2
WD = 133.3
M = 19.1   M% = 16.7

Practice Problem 2
Proctor Data
Maximum Dry Density = 106.9 lbs/ft³
Optimum Moisture = 17.6%

Nuclear Gauge Display Panel
% PR = ______%
DD = 105.7
WD = 123.6
M = 17.9   M% = 16.9

Practice Problem 3
Proctor Data
Maximum Dry Density = 112.1 lbs/ft³
Optimum Moisture = 15.2%

Nuclear Gauge Display Panel
% PR = 97.8%
DD = 109.6
WD = 128.2
M = 18.6   M% = 17.0
### STANDARD COUNT DATA

<table>
<thead>
<tr>
<th>Test No.</th>
<th>Density</th>
<th>Moisture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2844</td>
<td>701</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Test of</th>
<th>Compaction Depth of Lift in. (mm)</th>
<th>Method of Compaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>6&quot;</td>
<td>Sheepsfoot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6&quot;</td>
<td>Sheepsfoot</td>
</tr>
<tr>
<td></td>
<td></td>
<td>6&quot;</td>
<td>Sheepsfoot</td>
</tr>
</tbody>
</table>

| A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³) | = |
| B. Moisture Unit Mass (lbs/ft³ or 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 4.75 mm) | = |
| H. Corrected Max. 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 | = |

**Comments:**

BY: ____________________________

TITLE: __________________________

VIRGINIA DEPARTMENT OF TRANSPORTATION
MATERIALS DIVISION
REPORT ON NUCLEAR EMBANKMENT DENSITIES (UNIT MASSES)

Report No. 45
Date 06/22/2015
Sheet No. 1 of 1

Route No. 252
County Augusta

Project No. 0252-132-101, C501

FHWA No. None

Testing for Embankment

Model No. 3440
Serial No. 23456
Calibration Date 02/10/2015

Density 2844
Moisture 701
CHAPTER 6 – PRACTICE PROBLEMS

Nuclear Gauge Testing of Soil Material (Correcting for High Moisture)

Practice Problem 4

The nuclear density test reported on the Form 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 the results in the second column of the Form TL-124.

Speedy Dial Reading = 9.6
### STANDARD COUNT DATA

<table>
<thead>
<tr>
<th>Density</th>
<th>2830</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>701</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Station ft. (m)</th>
<th>85+00</th>
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</thead>
<tbody>
<tr>
<td>of</td>
<td>Ref. to center line ft. (m)</td>
<td>at. C/L</td>
</tr>
<tr>
<td>Test</td>
<td>Elevation</td>
<td>+9 / -3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Compaction Depth of Lift in. (mm)</th>
<th>6”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method of Compaction</td>
<td>Sheepsfoot</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>A. Wet Density (lbs/ft³), Wet Unit Mass (kg/m³)</th>
<th>= 141.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>B. Moisture Unit Mass (lbs/ft³ or kg/m³)</td>
<td>= 23.1</td>
</tr>
<tr>
<td>C. Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) (A-B)</td>
<td>= 117.9</td>
</tr>
<tr>
<td>D. Moisture Content (B ÷ C) x 100</td>
<td>= 19.6</td>
</tr>
<tr>
<td>E. Maximum Dry Density (lbs/ft³), Dry Unit Mass (kg/m³) Lab Proctor or One Point Proctor</td>
<td>= 132.4</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 4.75 mm)</td>
<td>=</td>
</tr>
<tr>
<td>H. Corrected Max. 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) (C ÷ E) x 100 or (C ÷ H) x 100</td>
<td>= 89.0</td>
</tr>
<tr>
<td>K. Percent Minimum Density Required</td>
<td>= 95.0</td>
</tr>
</tbody>
</table>

### Comments:

BY: ____________________________

TITLE: __________________________

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2016v1.0