Lesson 4

DENSITY OF SOILS AND BITUMINOUS CONCRETE MIXTURES IN PLACE BY THE NUCLEAR METHOD
FM 1 T-238
Learning Outcomes

- Describe the Nuclear Density Test theory and its' use
- Determine Daily Standard Counts compliance
- Perform a Nuclear Density Test
- Calculate Dry Density and Percent Maximum Dry Density
Purpose

- Determines the in-place density
- Proven, Rapid, accurate test
- Results determine if required percent of maximum density has been achieved
What is the “Density” we are measuring?

Can the “Density” be more than 100% of the Maximum Dry Density reported in the Proctor Test?
Typically the gauges use Cesium-137 as their nuclear source, which is in the source rod. When the source rod is lowered, gamma radiation emission occurs in the form of “photons”, which is an electromagnetic radiation particle composed of light and other electromagnetic radiation. Geiger Mueller tubes in the gauge serve as the detectors for detecting “counts” from the source.

**A “count” is 1 photon.**

As the gamma photons collide with the electrons present in the soil, the number of photons reaching the detector is reduced. The more dense the material, the less photons or “counts” get through to the detectors. Therefore, the lower the “counts” the denser the material.

There are two methods of gauge operation, those being:

**DIRECT TRANSMISSION:** In this method, the rod containing the Cesium-137 source is lowered to the desired depth. The photons must pass through the full distance of the material being tested to the detectors. This is the method used on soils and limerock base and/or stabilized subbase.

**BACKSCATTER:** The gamma photons must be scattered (or reflected) at least once to reach the detectors in the gauge. This is achieved by leaving the source rod in a retracted position in the gauge. This is the method used for asphalt.
Nuclear Density Gauge - Manufacturers include Troxler, Humbolt, CPN

Standard Block - this is the block the gauge is placed on when obtaining daily standard counts. Should be the block that came with gauge and have matching serial number.

Scrapper Plate/Drill Rod Guide - this plate is used to smooth and prepare the site for testing and the align the drill rod.

Drill Rod - this is used to create the hole for the gauge’s source rod to be inserted into.

Extraction Tool - this is used for removing the drill rod after driving.
We will review the Nuclear Density Test in its' entirety, starting with Calibration requirements through the performance of the test.
Gauge Calibration

Why calibrate the gauge?

The gauge is calibrated, meaning a “baseline” of performance established and documented, in the form of “counts”, prior to leaving the factory. Routine re-calibration is the manner in which this performance level is checked.
**Gauge Calibration**

- Must be performed by qualified personnel
- Calibrated annually (FDOT requirement) or
- Calibrate when needed

The calibration is **NOT** conducted by You, the Inspector, but it is your responsibility to ensure that the calibration is current.

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3. **CALIBRATION**

3.1 Gauges are required to be calibrated yearly or at any time the operator determines there is a need for recalibration if confirmed by DRSO or his designee.

**Spec. 120 Excavation and Embankment**

120-10.1.1 Initial Equipment Comparison: ...Calibrate all Quality Control gauges annually.

Consultant must follow yearly calibration requirements as in Chapter 9, FDOT Employed Consultants, of the Radiation Safety Manual.

The annual calibration is an FDOT requirement.
Standard Counts

Why take Standard Counts?

Standard counts, taken with the source rod in the safe position, measure the counts inside the gauge, with virtually no outside interference. The gauge came with a calibrated Standard Count, therefore, the daily standard count should be very close to the calibration standard. By doing this daily, we can detect inconsistencies early enough to make a difference.

Why take Counts?
4.0 Daily Standard Count

4.1 The gauge calibration data has been ratioed to standard density counts at the factory or SMO on the reference standard supplied with the gauge. New reference counts must be made in the field to compensate for component aging and drift within the instrument.

The standard block which came with the nuclear gauge is the one that should be used. Do not use a standard block from a different gauge.

If not on the block, put the serial number of the gauge on the block for positive identification.
4.1 Daily Standard Count (continued)

A set of standard counts shall be taken and recorded in the gauge’s diary every day the gauge is used. If on a given day the gauge is not used, “idle” should be entered for that day in the diary. Diary entries are not necessary on weekends and holidays if the gauge is not in use. It is recommended that this data be taken twice a day when the gauge is first received (new gauge) in order to detect any shift during daily use, per manufacturer’s instructions.

In the case of a new gauge or repaired gauge, you should take the Standard Counts twice a day, for a day or so, which helps build up a record.
5. General Procedure for Daily Standard Count

5.2 Place the reference standard on compacted soil (100 PCF or more), asphalt or concrete paving, at least ten (10) feet from any large object and at least thirty (30) feet from another gauge.

- More than 10 ft. from large objects
- More than 30 ft. from other nuclear sources
- Standard block placed on asphalt, concrete or >100 pcf material
- Standard block level & stable

Material of 100 pcf, Asphalt or Concrete
5. General Procedure for Daily Standard Count (continued)

5.3 Prepare the gauge to achieve a set of standard counts as described in the gauge’s instructions or operator’s manual.

5.4 Insure that the gauge is properly positioned on the reference standard and that the source rod is in the proper position.

5.5 Turn power on and allow gauge to stabilize for the period of time recommended by the manufacturer in the instruction or operator’s manual.
### Standard Counts

- Obtain counts for density & moisture
- Record in the gauge diary
- Retain counts in gauge memory, if applicable

### 5. General Procedure for Daily Standard Count (continued)

5.6 Obtain a density standard count and moisture standard count, and record them in the gauge’s diary. Moisture content is not required for gauges, which are not approved for moisture content determination. If the gauge has a memory, retain standard counts in the gauge memory per manufacturer’s instructions.

5.7 Return reference standard to compartment provided in the FDOT Transporting and Storage Container, or to the proper storage position in the vehicle being utilized to transport and store the gauge.
4. Daily Standard Count

4.2 If the day-to-day shift in the density standard count is greater than 1 percent or the moisture standard count is greater than 2 percent when compared to the average of the previous four sets of counts, there is a possibility of gauge malfunction or operator error in placing the gauge on the standard, or in the count taking process. Additional attempts to obtain a usable standard count are recommended.

TOLERANCES STANDARD COUNTS

Density Counts: 1% or less when compared to the Avg. of Prev. 4 counts

Moisture Counts: 2% or less when compared to the Avg. of Prev. 4 counts

STEPS TO DETERMINE

1. Determine the average of previous 4 standard counts
2. Determine the numerical difference between the average of previous 4 and Today's standard count
3. Divide the Difference by the Average of the previous 4
4. Multiply the result by 100 to move decimal
# Standard Counts

- Day-to-day shift is compared to Average of Previous 4 counts
  - Density – shift of 1% or less
  - Moisture – shift of 2% or less

<table>
<thead>
<tr>
<th>Determine Avg. &amp; %</th>
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<tbody>
<tr>
<td>Our Moisture Std. Count = 657</td>
</tr>
<tr>
<td>Average of last 4 Moisture Standard Counts:</td>
</tr>
<tr>
<td>637</td>
</tr>
<tr>
<td>640</td>
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<tr>
<td>631</td>
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<td>644</td>
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</table>
**Standard Counts**

**WHAT IF THE GAUGE FAILS?**
- Record the Counts
- Run the Standards again
- Compare to the new Average
- Repeat the procedure per manufacturer’s recommendation
- Save and record the results each time

**WHAT IF THE GAUGE FAILS ROUTINELY?**
- Check for human error
- Contact ECI II
- Perform stat test / drift test, and/or
- Inform the DRSO or RSO

**FAILING STANDARD** – Remember, a count represents the number of photons reaching a detector and because the standards are run on the same reference block each time, approximately the same number of photons should register on the detector each time a standard count is run. Standards falling outside the tolerances are Failing Standards.

**STAT AND DRIFT TEST** – Stat test is a series of 20 one-minute tests that tells you how far you are off on the numbers. If the Stat test fails, then perform a Drift test which is a series of five Stat tests. It is not specified as a requirement, but is an operator’s test for performance of the equipment.

Follow DRSO / RSO instructions concerning these tests.

Remember, Standard Counts are required to be run daily by FDOT for correct results and you are required to keep a record (the gauge diary) to insure that counts are within proper ranges.
### Standard Counts

#### TROUBLESHOOTING OUT-OF-TOLERANCE COUNTS

- Are the batteries low?
- Is the reference block on proper material?
- Is the gauge properly seated on the reference block?
- Is the source rod in the proper position?
- Has proper maintenance routinely been performed on the gauge?
- Has the gauge been subject to rain or extreme moisture?

The causes for counts being out-of-tolerance can be attributed to a variety of items, such as:

- Operator error - gauge not seated properly on reference block; reference block not firmly positioned, etc.
- Environmental effects - too close to large objects or other gauges; wall, trenches, etc.
- Transporting effects - aggressive handling, bouncing around, dropped repeatedly, etc.
- Mechanical changes - the base can warp, parts wear down, etc.
- Moisture - moisture in the gauge from being left in the rain, immersed in water, etc.
<table>
<thead>
<tr>
<th>Learning Outcomes</th>
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<tbody>
<tr>
<td>What is the tolerance of difference permitted for Density Standard Counts?</td>
</tr>
<tr>
<td>What is the tolerance of difference permitted for Moisture Standard Counts?</td>
</tr>
<tr>
<td>Learning Outcomes</td>
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<tr>
<td>Standard counts are generally taken how often?</td>
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</table>
### Learning Outcomes

Today’s Standard Density Count = 2733  
Previous 4 are: 2721, 2726, 2738, 2731  

Today’s Standard Moisture Count = 651  
Previous 4 are: 632, 647, 642, 639  

Using the above, is this gauge within the allowable tolerance?
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>How far from large objects should your gauge be when taking standard counts?</td>
</tr>
<tr>
<td>How far from other gauges should your gauge be when taking standard counts?</td>
</tr>
</tbody>
</table>
Test Location

In selecting and preparing the site for performing the nuclear density test, it is important that:

- The location is selected using the Random Number Generator being used for the project.
- Site is level

SITE SELECTION

- Test locations will be determined using a Random Number generator, including Stations and Offsets.
- Look for wet or yielding areas and report to proper personnel. The Department’s Engineer may chose to perform additional Independent Verification testing.
6. Procedure

6.1 Select a smooth test site free of surface irregularities where the gauge in test position will be at least (6) six inches away from any vertical projection.

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

6.3 Smooth the test surface sufficiently in size to accommodate the gauge. The maximum void beneath the gauge shall not exceed approximately 1/8 inch. Use native fines or fine sands to fill these voids. Using the scraper plate, lightly tamp an area equal to the bottom of the gauge.
6. Procedure

6.3 When the test site is below ground elevation, if at all possible, the plane of the surface to be tested shall extend approximately six (6) inches beyond the edges of the gauge on all sides.
6. **Procedure**

6.4 *Place the scraper plate with the drill rod guide on the test site.*

6.5 *Place the drill rod into the drill rod guide and drive a hole at least two (2) inches deeper than the desired test depth. The hole must be perpendicular to the prepared surface of the test site.*

6.6 *Remove the drill rod by rotating and pulling straight up. The drill rod extraction tool may be used to facilitate the procedure. DO NOT loosen the drill rod by tapping with a hammer.*
The purpose of driving the drill rod into the ground and at least 2” beyond the anticipated test depth is to provide a neat, clean hole to lower the source rod into. If the hole is not deep enough, then the source rod can’t reach the test depth. Also, with the source rod resting on the bottom of the pre-drilled hole, the gauge may be elevated off the ground surface, thereby creating a space beneath the gauge. This leads to inaccurate test results.

If the hole is not symmetrically round, due to banging on drill rod with hammer or pulling side to side, the source rod is unable to make good contact, thereby, putting the data in question.
Learning Outcomes

How far beyond the test depth is the drill rod to be driven?

How far is the gauge to be from vertical projections?
Learning Outcomes

When preparing the test surface, voids exceeding what depth are to be filled?

These voids may be filled with “concrete sand”.

True or False
When performing the test, it is important to:

- Not damage your prepared site
- Not collapse or damage the hole you prepared
- Extend the rod to the correct depth
- Gently pull the gauge back to place the rod in contact with the side of the hole
6. **Procedure**

6.7 *Extend and place the source rod in the hole to the desired depth of measurement.*

6.8 *Seat the gauge firmly by rotating it about the source rod while pulling gently on the gauge in the direction that will bring the side of the source rod in firm contact with the side of the hole nearest the scaler.*
Gauge Operation & Testing

- Obtain the Wet Density per gauge instructions
- Record on Earthwork Density Report
- Recording Accuracy: nearest 0.1 pcf

6. Procedure

6.9 Follow the manufacturer’s instructions to obtain the WET DENSITY.

6.10 Record all required information applicable to the gauge used on the Density Log Sheet. The WET DENSITY should be recorded as applicable to the gauge used.
## Procedure

6. If the gauge and material are approved, follow the manufacturer’s instructions to obtain the percent moisture. Record to the nearest 0.1 percent.

- Determine and record and dry density. Record to the nearest 0.1 PCF whether obtained from the gauge by direct reading or obtained by manual calculation.

The FDOT maintains a list of those gauges, by manufacturer and model number, that are approved for use to obtain moisture contents, on limerock, cemented coquina & shell-rock base material only, on FDOT projects.
If the gauge and/or material HAS NOT been approved for moisture determination by nuclear method, then:

- Take a representative sample of the material from the test site and determine the moisture content in accordance with Section 10.22 (Speedy Moisture Tester)
- Record the MOISTURE CONTENT to the nearest 0.1 percent.

### 6. Procedure

6.14 Take a representative sample of the material from the test site and place in a suitable moisture-proof container.

6.15 The material shall be thoroughly mixed and a moisture determination made in accordance with Section 10.22.

6.16 Record the MOISTURE CONTENT to the nearest 0.1 percent.
### Gauge Operation & Testing

If the gauge and/or material **HAS NOT** ... (Cont.)

Determine the **DRY DENSITY** to the nearest 0.1 PCF by dividing the **WET DENSITY** by the **PERCENT MOISTURE plus 100** and multiplying the results by 100.

**EXAMPLE**
- Wet Density = 112.0 pcf
- Speedy = 8.0 %

To Determine Dry Density

\[
\text{Dry Density} = \frac{\text{Wet Density (from gauge)}}{\text{100 + % Moisture (from corrected speedy or gauge)}} \times 100
\]

### WORK AREA FOR SAMPLE MATH PROBLEMS
If the gauge and/or material HAS NOT ... (Cont.)

Determine the percent MAXIMUM DENSITY to the nearest whole percent by dividing the DRY DENSITY by the REQUIRED MAXIMUM DENSITY and multiplying the result by 100.

To Determine Percent Max. Density

\[
\text{Dry Density (from your calc.)} \times 100 \div \text{Required Maximum Density (from Proctor)}
\]

**EXAMPLE**

Dry Density = 103.0 \text{pcf}
Proctor = 105.0 \text{pcf}
<table>
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<tbody>
<tr>
<td>What is the recording accuracy required for Wet Density?</td>
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<tr>
<td>What is the recording accuracy required for Moisture Content?</td>
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<tr>
<td>Learning Outcomes</td>
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<tr>
<td>What is required in order to permit the use of the moisture content from the nuclear density gauge?</td>
</tr>
<tr>
<td>What is the recording accuracy required for % Maximum Density Content?</td>
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### Learning Outcomes

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<tbody>
<tr>
<td>Wet Density = 124.8 pcf</td>
</tr>
<tr>
<td>Moisture Content = 9.7%</td>
</tr>
<tr>
<td>Proctor = 112 pcf at 10% moisture</td>
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Using the above, what is the Dry Density and % Maximum Density?
Gauge Maintenance
Gauge Maintenance
The preceding video was shown to provide you general information concerning the maintenance of the nuclear density gauge. It was not intended to illustrate or demonstrate all of the various gauges on the market in use today, nor their respective instructions or guidance for maintenance of their particular gauge.

It is your responsibility to ascertain your firm’s corporate policy concerning maintenance on the gauges and your responsibilities and duties therein. It is your responsibility to adhere to your corporate policy for radiation safety, gauge operation and maintenance.

It is your responsibility to obtain and utilize the manufacturer’s instructions for maintenance of your particular gauge.
Any Questions