I. **DAILY STANDARD COUNT**

It is important that a current and valid standard count be performed and retained in the gauge's memory in order for measurement results to be reliable.

A. **10 MINUTE WARM-UP:**

Turn the gauge on 10 minutes before taking a standard count to allow the systems to stabilize.

B. **SET-UP FOR STANDARD COUNT:**

With the gauge in the safe or shielded position and firmly seated on the standard block, follow these precautions:

- At least 100 pcf material (1600 kg/m³) under standard block.
- No large vertical objects (walls, heavy equipment, etc.) within 10 ft. (3m).
- No other nuclear sources within 30 ft. (10m).
- The keypad end of the gauge is against the metal butt plate. (For 4640, place gauge on air gap spacer with 2 posts at the handle end of the gauge. The gauge and spacer are seated on the reference plate with the plate handle toward the operator.)
- After beginning the standard count take a small step away from the gauge (approx. 1 meter) to reduce exposure and to not influence the count.

C. **TAKE A STANDARD COUNT:**

1) **Model 3401:** Set the power/time switch to the slow (4-minute) count time and press the `<Start>` button.

2) **Model 3411-B:** Set the power/time switch to the slow (4-minute) count time and press `<Shift>` & `<std/measure>` keys.

3) **Model 3430:** Press the `<STD>` key, then the `<Yes>` key. Press `<Start>`.

4) **Model 3440:** Press the `<STANDARD>` key, and then the `<Yes>` key twice.

5) **Model 3450:** Press the `<STANDARD>` key, and then press `<1>`. Check the gauge position and press `<Enter>`.

6) **Model 3440 Plus:** Press the `<STD>` key. Choose `<Yes>`. Be sure gauge is placed properly on the standard block. Press `<Start>`.

7) **Model 4640:** Press the `<STD>` key, and then press `<Yes>`.

Check gauge position then press `<Enter>`. 
D. CHECK AND RECORD STANDARD COUNT:

(The 3401, 3411 and 3430 require a standard count log to be kept by the operator. Before 4 standard counts have been taken, the factory supplied DS, MS, DS1, & DS2 can be used.)

1) **Model 3401**: The “err” symbol will disappear. Set the display switch on density to view the DS and on moisture to view the MS. Record these counts in the standard count log. The DS should be within 1% and MS within 2% of the average of the previous 4 standards. The new standards can also be compared to the factory calibration standard counts. They should be within 2% of the density standard count and within 4% of the moisture standard count on the factory calibration data sheet.

2) **Model 3411-B**: The “err” symbol will disappear and the moisture and density counts can be displayed by pressing MS and DS respectively. Record these counts in the standard count log; they will only remain in memory until the gauge is turned off. The DS should be within 1% and the MS within 2% of the average of the previous 4 standards.

3) **Model 3440 / 3440 Plus**: After count completion, the gauge will display the MS (moisture standard) and the DS (density standard). The P or F displayed following these numbers indicates whether or not the counts fall within the acceptable limits. The DS should be within 1% and the MS within 2% of the average of the previous 4 standard counts.

4) **Model 3430**: After the count is complete the gauge displays DS (density standard) and MS (moisture standard). Record these counts in the standard count log. Compare these standard counts to the average of the previous 4 counts. The DS should be within 1% and the MS within 2% of the average of the previous 4 standard counts.

5) **Model 3450**: After count completion the gauge will display the MS (moisture standard) and the DS1 and DS2 (density standards for systems 1 and 2) along with a P or F indicating if the counts fell within the acceptable limits. These counts are compared to the average of the previous 4 counts. The tolerance is based on a 1% variance for the DS and a 2% variance for the MS. After accepting the standard count the gauge will ask you to calibrate the depth strip by placing the rod in backscatter and pressing enter.

6) **Model 4640**: After the count is complete the DS1 and DS2 (density standard for system 1 and 2) counts are displayed along with a P or F indicating if the standard count fell within the acceptable limits. These counts are compared to the average of the previous 4 standard counts. The tolerance is based on a 1% variance for system 1 and a 1.2% variance for system 2 counts.
II. TAKING MEASUREMENTS ON SOILS – DIRECT TRANSMISSION

A. SITE PREPARATION:

Using the scraper plate, smooth out the test surface and place the scraper plate on the prepared test surface. Put the drill rod through the extractor tool, then through the scraper plate guide. Securing the scraper plate with one foot, use a hammer to drive the drill rod into ground to the appropriate depth (note the marks on the rod at 2” intervals). Use the extractor tool to remove the rod from the ground with your foot remaining on the plate. Mark around the corners of the plate with the drill rod. Remove the scraper plate. Position the gauge within the outline of the scraper plate. Release the trigger in the handle and lower the source rod to the desired testing depth. Pull the gauge in the direction of the keypad to insure that the source rod is snug against the wall of the hole. This procedure reduces any exposure to the source rod by placing it directly in the hole.

NOTE: Backscatter mode may be used on soil materials also if the lift thickness is approximately 4” or if the material cannot be drilled with the drill rod.

B. MEASUREMENT:

1) Model 3401: Set the power/time switch to the norm, or one minute count time. Press the start button. After one minute, calculate your moisture and density count ratios by dividing the counts just taken by the standard counts taken in part 1. Look up the moisture and density values (for the count ratios just calculated) on the gauge’s calibration chart according to the depth of the measurement.

2) Model 3411-B: Set the power/time switch to norm, or one-minute count time. Set the depth switch to the same depth as the source rod. To set the target density value, hold the shift key and press the set/M key. The value of 124.8 pcf (2000kg/m3) will display until it is changed. Set the +/- switch to the appropriate symbol (+ to go up, and - to go down) and press both shift & set. When shift is released, the number will change. Remember that this target number should be changed as the material being tested changes. To begin the test, press the std/meas key. After one minute, obtain density and moisture values by pressing the WD (wet density), DD (dry density), M (moisture), %M (percent moisture), and the %PR. %PR compares the gauge read DD to the proctor value, or target DD derived from the laboratory, which is placed in gauge memory before the test is taken.

3) Model 3430: Press the time key and scroll up or down to choose the desired length of the test (recommend 1 min.). Press the depth key. To select the desired depth of the test being taken use the up or down arrows. Press the MA/PR key and scroll to select PR to indicate the use of soils mode or MA to indicate the use of asphalt mode. Yes allows you to enter the proctor value using the arrow keys. Press enter. Lower the source rod and press the start key. After the count time has elapsed, the measurement results will be displayed. Use the up or down arrows to view the remaining results.

4) Model 3440: Press the shift and mode keys and follow the display to select the soil mode. Press the time key to set the desired count time (recommend 1 min.). If desired enter the target dry density (Proctor) by pressing the proctor/marshall key and follow the display instructions. Lower the source rod and press the start/enter key. If the automatic depth function is enabled, the correct depth of the source rod will be displayed. Otherwise the
6) **Model 3440Plus:** Press the mode key and choose 2 for the soil mode. Press the Setup key and choose 1 to choose the count time, then press 2 to select the recommended 1 min time. If desired, set the Proctor target density by pressing the target key and choosing 2 for Proctor. Enter either a stored value (press 1-4) or a new laboratory derived value (press 5). Lower the source rod and press the start key. The depth of the source rod will automatically be displayed if it is in automatic mode, but will need to be entered if in manual mode. After the count time the measurement results will display.

7) **Model 4640:** This model is not used on soil materials; it does not have a moisture source.

**C. DEPTH OF MEASUREMENT:**

The density depth of measurement is simply the depth at which the source rod is placed; with the exception of backscatter mode (this is approximately 4”) and thin-layer mode (this depth is determined by the operator). The moisture depth of measurement is determined by the moisture (or Hydrogen) content of the material being tested. This depth can be determined by the following formula:

\[
\text{Moisture Depth of Measurement (in inches) = 11 – [0.17 (M)]; (in mm) =280 – [0.27 x (M)]}
\]

(where M = the gauge moisture reading in pcf or kg/m3, not %M)

**D. MOISTURE CORRECTION:**

In soils with considerable hydrogen other than water and/or significant concentrations of neutron absorbing elements, gauge moisture readings must be compared to oven dried samples to establish a correction factor. (Those hydrogenous materials include; gypsum, lime, mica, organics, cement, fly ash, coal, phosphates, etc. and neutron absorbers include; boron, cadmium, lithium, salt, iron oxide, etc.) Take four or more gauge/oven-dry sample pairs as follows; perform and record a 1 min. gauge measurement, then collect a soil sample from the same spot, keeping in mind the gauge’s depth of measurement. Repeat four or more times in locations with similar moisture content. Seal the soil sample as to not lose any moisture. Find the true moisture content of the samples by oven drying. Average the values from all locations and perform the following calculations.

1. **Model 3401:** Calculate the moisture in PCF from the oven dry by:

   \[
   \frac{\%M \text{ oven dry} \times WD}{ WD} = \frac{\%M \text{ oven dry} + 100}{ WD} \quad \text{Where WD = wet density}
   \]

   Correction factor = M oven dry – M (perform this for each sample site)

   **NOTE:** Do not use the %M value for this calculation. This correction is best made and used near optimum moisture and compaction. Be sure to note the plus/minus sign.
2. **Model 3411-B:** Make sure the gauge Moisture Correction knobs are set at 00 when taking gauge reading/soil sample pairs. Calculate correction factor using averaged values above by:

\[
\text{Correction Factor (K)} = \frac{\%M \text{ oven dry} - \%M \text{ gauge}}{100 + \%M \text{ gauge}} \times 1000
\]

*Dial this number along with the sign on the gauge’s Moisture Correction knobs to correct from apparent to true moisture for a soil type regardless of DD, WD, and moisture content.*

3. **Model 3430:** Calculate the correction factor by using the averaged values and the formula:

\[
\text{Correction Factor (K)} = \left(\frac{\%M \text{ oven dry} - \%M \text{ gauge}}{100 + \%M \text{ gauge}}\right) \times 1000
\]

*Press the special key, and then press the down arrow 1 time to access the offset function. Press the down arrow 1 time to choose moisture and press enter. Press yes and enter the K factor.*

4. **Model 3440:** This gauge calculates the correction (K) factor as long as the %M oven-dry and %M gauge are entered. Press the offset key, then 2, then Yes. Press yes again and the 1 to be able to enter the %M true (oven-dry) and the %M gauge. Press 1 and input the %M oven-dry (true) averaged above. Press 2, then choose 2 and follow the instructions to take 4 measurements at the sites where samples were taken. After both values are entered, the calculation of K is done and this factor may be stored.

5. **Model 3450:** This gauge calculates the correction (K) factor as long as the %M oven-dry (true) and %M gauge are entered. Press the offset key and press 2, and then choose 3. The 3450 then allows you to choose a stored offset (already entered), a gauge derived offset (determined by taking readings), or a keypad entry offset (tests already taken are averaged, the K factor is calculated and entered manually). Choose 3 for keypad entry and enter the K factor derived from the formula:

\[
K = \left(\frac{\%M(\text{true}) - \%M \text{ (gauge)}}{100 + \%M \text{ (gauge)}}\right) \times 1000
\]

Choose 2 for gauge derived offset and press 1 to measure moisture. Follow the instructions to take readings on the soil requiring an offset. To enter true moisture later (after returning to lab) press 1; to enter true moisture, now press 2 and follow gauge instructions, when the true moisture is to be entered later. The K factor will then be displayed and may be stored.

6. **Model 3440 Plus:** This gauge calculates the correction (K) factor as long as the %M oven-dry (true) and %M gauge are entered (Manual entry). Press the offset key and press 2; then choose 5 for a new offset or select a previously stored offset if desired. The gauge then allows you to choose a manual entry offset (data has already been collected). Or a gauge derived offset (determined by taking readings and comparing to a known moisture value). Gauge derived is used if the true moisture can be determined quickly at the site (stove dry, Speedy, etc.) For manual entry, choose 1 and enter the data as prompted. This is generally done after the gauge readings are performed and recorded and a sample is taken to the lab and analyzed. After all data is known the K factor can be calculated by the gauge.
E. TRENCH CORRECTION:

All nuclear soils gauges are sensitive to any moisture (hydrogen) in the neighborhood of the
gauge. Therefore it is necessary to compensate for the effect on gauge moisture readings any
time the gauge is used in a trench, next to a retaining wall, by the wall of a building, or near any
large vertical obstacle. In every case, this compensation involves taking a moisture count (not a
standard count) with the gauge placed on the standard block at the “trench test site” and
comparing the count obtained to the standard count taken earlier that day.

1. **Model 3401:** Subtract the daily moisture standard count (MS) from the moisture count (MC)
taken with the gauge on the standard block in the trench. Subtract this difference from the
gauge moisture count taken in trench measurements.

2. **Model 3411:** Take the measurement in the trench on the standard block and subtract the
MS from the MC. Now dial this difference into the gauge by setting it on the moisture
correction knobs. While holding down the shift key, press MC; the difference should appear
on the LCD screen. This value will then be subtracted from the moisture count until either a)
the gauge is turned off or b) the trench correction is zeroed by setting the moisture
correction knobs to 00 and pressing shift, MC; the gauge will display all zero’s to indicate
that the trench correction factor has been removed from gauge memory.

3. **Model 3430:** After taking a daily standard count, take a 4 min. test in the trench with the
gauge on the standard block.
   - Subtract the daily standard counts from the trench counts.
   - Trench Density Count (Dens. Const.) = (DC trench – DS)
   - Trench Moisture Count (Moist. Const.) = (MC trench – MS)
   - Press the special key, choose the offset option by pressing the down arrow 1 time, and
     choose trench.
   - The gauge will then request the Dens. Const. And the Moist. Const. To scroll through the
     numerals, press the up and down arrows.

4. **Model 3440:** Press offset and choose #3. Press yes 2 times to perform a new offset. Place
the gauge on the block in the trench and begin the 1 minute count by pressing start. The
Density and Moisture Trench Offset constants will be calculated, enabled and stored.

5. **Model 3450 & 3440 Plus:** Press the offset key and then choose 3. Press 3 to change the
offset. Place the gauge on the block in the trench where measurements will be performed
and press the start key to begin the count. Press yes to enable the new trench offset that has
been calculated.

6. **Model 4640:** This gauge does not have a moisture source, no trench offset is needed.
F. DENSITY CORRECTION:

A density correction factor may be used when the material being tested varies in density from the normal range of soils (90 to 170 PCF/1450 to 2720 kg/m³) or if the material composition varies from average soil/asphalt on which the factory calibration is based. A comparison may be made between an accurately controlled sand cone and nuclear testing. Also cores drilled from compacted asphalt can be correlated to nuclear density readings. The average difference of at least 4 tests should be used in the calculations.

1. Model 3401 and 3411-B: The correction factor obtained should be applied by the operator as a plus or minus figure to the measure wet density.
   i. Model 3430: Press special and press the down arrow 1 time, then enter. Press yes. Input the average difference between the gauge and alternative wet density measurement result; to input a negative number press the down arrow first. Use the enter key to select the next digit or to exit.
   ii. Model 3440: Press the offset key and choose 1. Press yes 2 times to change the offset. Choose + or -, then enter the average difference between the gauge and alternative wet density measurement result.
   iii. Model 3450 & 3440 Plus: Press the offset key and choose 1. Press 3 to enter a new offset, and then enter the average difference between the gauge and alternative wet density measurement results (core or sand cone test for example).
   iv. Model 4640: Press shift and offset then 1 and yes to change the value. Choose + or -, then enter the average difference between the gauge and alternative wet density measurement result.

III. FIELD MEASUREMENTS ON ASPHALT OR CONCRETE – BACKSCATTER

A. SITE PREPARATION:

On coarse materials, you may sprinkle sand or native fines over the test surface and scrape with a straight edge to fill in large voids. Position the gauge so that it sits flat and does not rock. Carefully lower the source rod handle to the backscatter position, seating it in the first notch below “safe”. Do not pass the first notch or the rod will not be in the correct position. (It is possible to take direct transmission readings on asphalt by drilling a hole with the drill rod on soft asphalt or by other means on hardened asphalt. It is also possible to take soil density tests in the backscatter position when a small lift is being tested).
B. MEASUREMENT:

1. **Model 3401**: Set the On/Time switch to the norm (1 minute) count time, lower the handle and press start button. After 1 minute, calculate your density count ratio by dividing the density measure count just taken by the density standard count taken that day. Look up the density value (for the count ratio just calculated) on the Backscatter section of that gauge’s calibration chart.

2. **Model 3411-B**: Set the On/Time switch to the norm (1 minute) count time and the depth switch to BS. If percent compaction readings are desired, enter the Marshall value using the shift/set keys as described in Section 2, B, #2. Lower the handle and press the Meas. key. After one minute, obtain density and percent compaction values by pressing the WD (wet density) and shift/%mar (percent of Marshall Compaction).

3. **Model 3430**: Set the time to one minute and the depth to Backscatter (0 in.). Select asphalt mode using the MA/PR key. Enter or accept Marshall Value. Lower the handle and press enter to start the count. The test results will be displayed after one minute. The up and down arrow keys are used to view the information.

4. **Model 3440**: Press the shift and mode keys and follow the display to select the asphalt mode. Press the time and then 2 to select the one-minute count time. If desired, enter a target wet density, or Marshall Value by pressing the Proctor/Marshall key. Follow the display instructions to key in the Marshall Value for that material. Lower the handle and press the start/enter key. After one minute, the density and percent compaction will be displayed. The results can be stored along with notes by pressing store, if a project number was entered.

5. **Model 3450**: Press the mode key, select asphalt and press the enter key. Press the target key, choose 2. MA, 3. Voidless, or 4. Voidless/MA Pair, then choose either a stored or new value. To set the count time, press the time key and choose “2” for a one minute count time. Lower the handle and press the start key to begin the test. The test results will be displayed after one minute. These results, along with notes, can be stored under the project name that has been enabled prior to testing by pressing the store key and following the prompts.

6. **Model 3440Plus**: Press the mode key and choose 1 for the asphalt mode. Press the Setup key and choose 1 to choose the count time, and then press 2 to select the recommended 1 min time. If desired, set the Gmb (Marshall) and/or Gmm (Voidless) target density by pressing the target key and choosing 1 for Gmb or 3 for Gmm. Enter either a stored value (press 1-4) or a new laboratory derived value (press 5). Lower the source rod and press the start key. The depth of the source rod will automatically be displayed if it is in automatic mode, but will need to be entered if in manual mode. After the count time the measurement results will display.

7. **Model 4640**: Press the thick key and dial in the thickness of the material to be tested (4 inches for backscatter). To input the target density values(s) press the MA/Voidless key, choose yes to change, and dial in the correct target Marshall and/or Voidless values for the material. Press time to change the count time and choose yes to change. Choose 2 for a one minute count time. Lower the handle and press start to begin the test. The results will be displayed after one minute. These numbers along with notes can be stored by pressing store if a project number was entered.
C. THIN-LAYER MEASUREMENTS FOR MODELS 3401, 3411-B, AND 3430:

The following method (formula) has been developed to allow thin lift measurements with gauges that do not have a thin-lift measurement system. Asphalt and concrete layers from 1 to 3 inches (2.5 to 7.5 cm) thick can be measured using this method, though not as accurately as with a true thin layer gauge. This method relies on the assumption that the bottom layer density is known and that it does not vary.

\[
DT = \frac{DG - [DB \cdot (K)]}{1 - K}
\]

Where:
- \( DT \) = Overlay density
- \( DG \) = Density read by gauge
- \( DB \) = Bottom layer density
- \( K \) = Effect of top layer thickness on the gauge

To use the above method of overlay measurement, follow the steps below:

- Measure density of existing (bottom layer) material with gauge in backscatter position (DB).
- Apply thin lift overlay and compact.
- Determine thickness of overlay. Select corresponding (K) value from table 1.
- Measure density of newly placed asphalt with gauge in backscatter position (DG).
- Enter all values into above equations and calculate overlay density (DT).

D. THIN-LAYER MEASUREMENT FOR MODEL 3440 AND 3440 PLUS:

This model gauge offers a nomograph mode to measure thin layer overlay densities on concrete and asphalt layers 1 to 3 inches (2.5 to 7.5 cm) thick. This method is not as accurate as a true thin layer gauge and assumes that the bottom density is known and does not change. Follow the steps below to access the nomograph mode:

**3440:**
- Press shift and special then yes 2 times.
- Option 7. Nomograph should be chosen then press 1 to enable nomograph.
- Choose option 3. Chg/view data to change the thickness and bottom density values.
- Enter the overlay thickness and press enter. The bottom density can be either keyed in or measured by the gauge. Follow the prompts after choosing 1. Bottom dens.
- After the nomograph on screen appears take overlay readings.

**3440 Plus:**
- Press Setup and choose 6 for Nomograph.
- Press 3. To enter new Nomograph data.
- Press Yes to change data shown and select the method of data entry (1 for keypad and 2 for measurement).
- For keypad entry, enter the top layer thickness in the units shown, press enter then enter the underlying layer wet density.
- For gauge measurement entry, choose the number of measurements to take on the bottom layer material and press enter. Position gauge, lower handle and press start to begin reading. Continue at different locations until measurements are complete. Average is then shown by pressing enter to enable the nomograph.
E. THIN LAYER MEASUREMENT FOR MODELS 3450 AND 4640:

1. **Model 3450**: This gauge offers a thin layer mode to measure the density of asphalt and concrete layers 1 to 4 inches (2.5 to 10 cm) thick which is accessed by pressing the mode key and choosing option 3. Thin Layer Mode. This is a true thin layer gauge and does not require the input of the bottom density due to the fact that the bottom density does not influence the reading. When the thin layer mode is selected the gauge will prompt you for the overlay thickness. The thickness of the overlay measurement is changed by pressing the thickness key. Enter the thickness of the asphalt or concrete layer that is being measured, or the minimum layer thickness of the asphalt or concrete layer that is being measured, or the minimum layer thickness of the layer if it will vary. The test is then performed in the same way a backscatter on asphalt would be done.

2. **Model 4640**: This gauge is the first true thin layer gauge and is a asphalt only gauge due to the that does not have a moisture source. A test is taken in the same way a backscatter asphalt measurement is taken except that the thickness is dialed in for the overlay that is to be tested. Press the thick key and enter the overlay thickness (1 to 4 inches or 25 to 100 mm) and press enter. Enter the thickness of the asphalt or concrete layer that is being measured, or the minimum thickness of the layer is will vary.

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