COVER PAGE

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ATT-11/22, DENSITY, In-Place Nuclear Method

1.0 SCOPE

This test method is a rapid, non-destructive technique for determining the in-place density of soil and rock. The non-destructive nature of this test allows for repeated measurements to be made at a single test location.

The Nuclear Moisture/Density Gauge is used for the monitoring of soil and asphalt compaction in road construction. The gauge operates by producing small doses of backscattered gamma waves. The radiation reflected from the soil is detected at the base of the gauge and converted to soil density when the gauge is calibrated to the specific soil. The gauge also has a neutron source to determine the moisture content by detecting the hydrogen in a soil sphere around the gauge.

This test method describes the procedures for using nuclear moisture-density gauges to determine:

a) if the standard count percent drift is within limits, which accounts for the gauge's long-term aging of the radioactive source, detectors, and electronic systems

b) the wet density, dry density, and moisture content of soil, asphalt and rock in-place with the gauge in the backscatter or direct transmission mode.

2.0 EQUIPMENT

Nuclear Moisture-Density Gauge

Gauge Accessories:
- Operators Manual,
- Quick Reference Card,
- Plastic Reference Block,
- Scraper Plate/Drill Rod Guide,
- Drill Rod,
- Drill Rod Extraction Tool,
- Source Certificate,
- AC & DC Charger/Adapter,
- Utilization Log Book,
- Extra battery packs,
- Handle Lock and Keys.

The gauge shall also be supplied with a sturdy lockable transport case capable of storing all the accessories furnished with the gauge.

1,250 µm sieve (for producing native fines to fill any open voids)

Data Sheets:
Nuclear Density Test, such as MAT 6-34, or
Daily ACP Nuclear Density Report, such as MAT 6-6

2.1 Gauge Basics

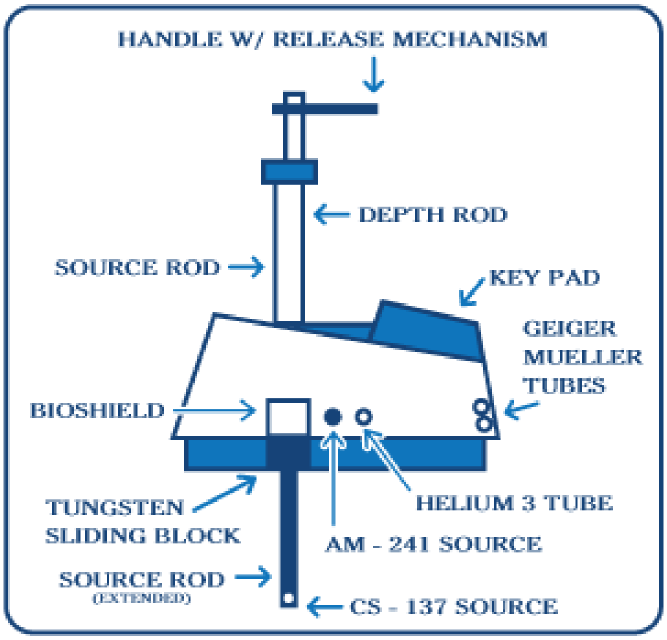
There are several gauge manufacturers; CPN, Humboldt, InstroTek, Seaman and Troxler, which collectively have more than 20 different gauge models that measure soil, asphalt and concrete density and soil moisture content. Mechanically, all soils and asphalt moisture density gauges work the same. The gauges have a source rod that lowers into the ground to measure wet density and another stationary source contained in the base of the gauge that measures moisture.

The radioactive source that measures density is located at the base of the source rod. The actual radioactive material is fused into a dry pellet about the size of a pebble. The pellet is encapsulated in two laser fused metal cells that in essence create a solid piece of material that is virtually impenetrable. This double encapsulated cell is secured in another metal capsule that forms the bottom of the source rod. Geiger Mueller tubes embedded in the base at the other end of the gauge detect the gamma radiation that is emitted from the radioactive pellet and passes through the material under the gauge.

In its normal retracted position inside the gauge base, the source rod is shielded by a spring loaded tungsten sliding block. Tungsten is a denser and heavier metal that provides far more shielding and fire protection than lead.

It is only when the trigger at the top of the source rod is recessed that the source rod is released from the gauge housing. When released, the source rod gives off just enough radiation to measure density.

Remember that **radiation is <u>always</u> being emitted from the gauge.**



Classification: Public

3.0 HAZARDS

The radioactive sources in a nuclear moisture-density gauge produce four types of radiation:

- Alpha Particles
- Beta Particles
- Photons (Gamma Rays)
- Neutrons

The alpha and beta particles are stopped by the source capsule. Only the photons and neutrons contribute to any occupational radiation exposure.

The gauge is always emitting radiation. The power switch only controls the electronic readouts.

Completing a hands-on radiation safety training course in the safety, operation and proper care of a nuclear gauge, before a new technologist operates a gauge, is a requirement by the CNSC, which should be provided by your company's Radiation Safety Officer (RSO). Other effective training tools for the technologist are the manufacturers "Manual of Operation and Instruction", the consultants' manual for use of Nuclear Density Gauges, and gauge training manuals available at most manufacturer websites.

4.0 PROCEDURE

4.1 Daily Inspection

The gauge should be inspected daily, before use, to ensure the proper operation of all its safety features. This should be explained in the manufacturer's manual of operation.

- From the **SAFE** (shielded) position, push the source rod down into the backscatter position, and then back to the **SAFE** position. Ensure that the movement is smooth and that there is no binding during this operation.
- The source rod opening in the bottom of the gauge is equipped with a spring-loaded tungsten sliding block that shuts when the source rod is in the **SAFE** position. Turn the gauge over and verify that the sliding block is completely shut. If the sliding block is not completely closed, do not attempt to use or transport the gauge, put the gauge in an area away any other personnel, then contact your Radiation Safety Officer and inform them of the situation immediately.
- Check the gauge case to ensure that it has not been damaged.

4.2 Turning the Gauge On

Before attempting to use any nuclear gauge, read the manufacturer's instructional manual provided for the particular brand and model being used. This will explain the warm up time required before use.

If a low battery charge is indicated, charge the rechargeable battery pack overnight. The alkaline battery backups will provide temporary testing ability till the rechargeable batteries can be recharged. Rechargeable battery packs are fully protected against overcharge and over-discharge. **Do not re-charge alkaline batteries.** When alkaline batteries are discharged, have them replaced by a qualified technician who is allowed to open the gauge cover plate.

4.3 Gauge Parameter Setup

There are several gauge display parameters that can be initialized. These parameters do not usually require changing once they have been input once; these include the measurement units, count time, and depth of measurement.

4.3.1 Setting the Measurement Units

The gauge display allows measurement results to be displayed in either metric or imperial. Alberta Transportation utilizes metric (SI) measurement, so set the “Units” to kg/m^3.

4.3.2 Setting the Count Time

The count time display defines how long the gauge takes to take a reading. Longer count times result in more accurate measurement precision. One minute count times are recommended for most sample measurements.

4.3.3 Setting the Depth of Measurement

The handle of the source rod controls the position of the radioactive source. Pressing the trigger releases the handle allowing the source rod to be repositioned in a depth notch. The “Depth of Measurement” display can be set to “Backscatter”, or to “Direct Transmission” depths in Metric units (50, 100, 150, 200, 250, or 300 mm) or Imperial units (2, 4, 6, 8, 10, or 12 inches).

Ensure that you check to see that you set the gauge handle position to the same depth that is set on the gauge display (either Backscatter, or if metric then 50-300mm)

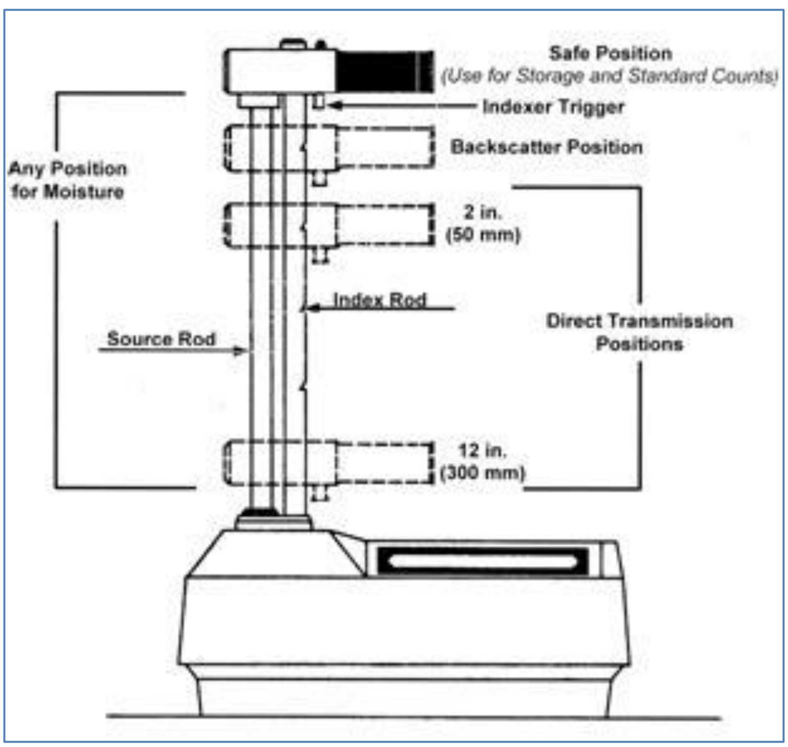


FIGURE 1

4.3.4 Selecting the Mode (Marshall or Proctor)

The gauges can be used on many construction materials (soils, gravel, sand, asphalt, concrete, and so on). To select the "Soil" mode, enter or activate a Proctor value. To select the "Asphalt" mode, enter or activate a Marshall value.

4.4 Standard Counts

Most gauges use a cesium and an americium:beryllium source for taking measurements. These radioactive sources undergo a natural decay process which results in a gradual loss in the intensity of their radiation.

To compensate for this source decay and to check the proper operation of the gauge, a daily reference "standard count" should be performed. When this is done, the previous standard count is replaced and the gauge uses the new standard to calculate the new density / moisture counts to compensate for any source decay and environmental influence.

Each gauge is equipped with a reference standard block for taking the standard count. **These reference blocks are not interchangeable, and are designed to be used for one particular gauge only (same serial number as the gauge).**

If recommended by the manufacturer to provide stable and consistent results,

- After turning on the gauge, allow at least 10 minutes for the gauge to warm up and stabilize, prior to use.
- Leave the power on all day while the gauge is being used.

Ensure that the bottom of the reference standard and the nuclear gauge are both clean. Ensure that the gauge handle is positioned in the SAFE position.

Place the reference standard block on a dry, flat surface at least 3 meters (10 ft.) from any large vertical surface and at least ten meters (33 ft.) from any other radioactive source. The surface under the reference block should be compacted material at least 10 cm (4 in.) thick and with a density of at least 1600 kg/m^3. An asphalt or concrete surface is ideal.

The technologist will keep a **daily log of the moisture and density standard counts** in the log book equipped with each gauge. **To verify the gauge stability**, the technologist will compare the percentage difference between the current standard count and the average of the last 4 standard counts taken, as explained in the operator's manual.

Acceptable standard count limits: *±1% each day for DS (density standard)*
±2% each day for MS (moisture standard).

If the standard counts obtained are within the acceptable standard count limits, the gauge is considered to be in satisfactory condition, and ready for use. If the gauge standard counts are outside these limits, allow additional time for the gauge to stabilize, ensure that the area is clear of any sources of interference, then conduct another standard count. If the second standard count is within the limits, the gauge may be used, but if the second count also fails the limit test, the gauge should be adjusted or taken in for repair as recommended by the manufacturer.

If for any reason the measured densities or moisture contents become suspect during the days testing, perform another standard count.

4.5 Site Preparation

Proper site preparation is the most important step in the in-place nuclear density test procedure. The presence of excess surface voids seriously affects the obtained values. Surface voids must be reduced to a minimum, and the gauge should sit solidly on the prepared site without rocking. A minimum of amount of native fines should be used to fill surface voids. The use of excess fines does not compensate for poor site preparation and gives poor results.

1. Once the test site has been chosen, obtain and record the station, location and depth below grade or lift of the test site in the heading section of the data sheet corresponding to the vertical column to be used to record the test data.

2. If the gauge will be closer than 250 mm (10 in.) to any large vertical mass, such as in a trench or alongside a pipe, that might influence the result, follow the manufacturer's correction procedure.

3. Prepare the test site as directed in either of the following sections, depending on the type of material on which the test is to be performed.

4.5.1 Subgrade

1. Test the subgrade as soon after compaction as possible to avoid any surface drying. If the surface has dried out, use a flat nose shovel, or other scraping tool, to remove the top 50 mm of soil, or until a consistent moisture condition is reached. The excavated area must be slightly larger than the base of the gauge.

2. Selecting a location that is representative of the material being testing is paramount. If the test is to follow a pass with a pneumatic, sheepsfoot, static, or vibratory steel roller, a grader blade may be used to plane the top of the surface so that the gauge will rest on a flat level surface.

3. Use the scraper plate to level the surface. Avoid tearing out pieces of the soil and creating voids. Remove all loose stones or loose soil.

4. Use a flat part of the scraper plate/drill rod guide to lightly tamp the prepared site. This removes any slight roughness and provides a good base for the gauge.

5. If excess surface voids are still evident after the trimming and leveling process, shake some locally obtained "fines" through a 1250 µm sieve onto the prepared surface. Ensure the fines are at the same moisture content as the site surface.

6. Slide the scraper plate around as required to move the fines and fill any visible surface voids.

   NOTE: Use the minimum amount of fines. Fines are not to be used as a substitute for poor site preparation.

7. Place the gauge on the prepared site and test the seating of the gauge. The gauge must sit solidly on the prepared site, without rocking.

4.5.2 Cement Stabilized Base Course

1. If the mat is a flat, freshly laid sand base cement stabilized base course, very little surface preparation is required, other than levelling the site.

2. If the mat is rutted, rippled, or uneven, prepare the surface as done for the subgrade, ensuring all loose stones are removed, the surface voids are filled with - 1250 µm native fines and the gauge sits level.

4.5.3 Granular Base Course

1. Remove any dried or loose soil and stones to form a level surface for the gauge.

2. Fill the surface voids with native fines. The native fines should be at the same moisture content as the site surface.

3. For testing GBC, Backscatter testing is normally used, as per ATT-58.

3. If the topsize of the aggregate is 25 000 µm or less and the base course layer is thicker than 100 mm, the direct transmission method may be used on this material. However, avoid overly disturbing the aggregate when punching the access hole.

4.5.4 Asphalt Concrete Pavement

1. Select test locations away from excessively voided or rough surface areas.

2. If required, fill the surface voids with – 1 250 µm native fines.

4.5.5 Seating Quality Experiment

This experiment is used to determine the effort required to obtain good seating:

1. Before preparing the site, take a backscatter density reading.

2. Perform a minimum of surface work, and then take another reading.

3. Perform more work, such as clearing, smoothing, etc., and take another reading.

4. The density readings will increase when the gauge is seated better and better. When readings cease to change, the gauge is properly seated. This is then an index of the work required, in order to obtain good gauge seating.

4.6 Moisture Detection

The moisture measurement is non-destructive test, with the neutron source and detector located inside the gauge just above the surface of the test material.

When the nuclear moisture-density gauge is set to read "moisture", it actually picks off the hydrogen content of the material. As water and asphalt contain hydrogen, the actual moisture content obtained in any material containing both of those elements is increased by the percentage of asphalt in it. On the other hand, if the amount of water in an asphalt mix is negligible, the gauge would pick off the approximate asphalt content of the mix when in the "Moisture" mode. In conclusion, the gauge may be used for moisture measurements on all construction materials with the exception of asphalt bound soils or aggregate.

The gauge can usually determine the level of moisture under the gauge to a depth of 4-8 inches. This depth is controlled by the level of moisture. The higher the moisture content becomes, the shallower the depth of measurement will be.

4.7 Density Detection

There are **two basic modes of determining the density of soils, aggregate or asphalt.** These are **Direct Transmission and Backscatter**.

1. The Direct Transmission method is most commonly used to test cohesive soils. Direct Transmission would be used more extensively on all materials, but drilling a hole into granular material is difficult. To perform a Direct Transmission measurement the source rod is lowered below the test material surface into a predrilled hole to measure a layer of compacted material, for a depth of up to 300 mm (12 inches), and counts the amount of gamma rays that are able to pass through the material to the detector tubes. The denser the material becomes under the gauge, the lesser amount of radiation there is to be detected. You can track this densification by taking measurements after each pass of the compaction roller(s).

   The Direct Transmission method helps reduce errors in nuclear gauge readings caused by poor surface conditions or from unforeseen conditions below the gauge. Instead of just scattering gamma photons back to the gauge as is done with the backscatter method, a considerable number of photons travel from the source rod through the material being tested and directly to the detector tubes. Surface roughness errors are reduced and the measurement of density and/or moisture is more reliable.

2. Backscatter Density measurement is very similar to the direct transmission method, except that the rod is only lowered to the first notch position, also known as the Backscatter position. The backscatter notch positions the bottom of the source rod just above the surface. This is a non-destructive test, since no hole is needed to be made in the test material. This method is used to test aggregate and asphalt materials.

   When a gauge is set to read density, it actually reads wet density. Only wet densities must be recorded on asphalt bound materials because the density of asphalt bound materials includes the weight of the asphalt.

4.7.1 Direct Transmission Measurements

The Direct Transmission method is used to test subgrade as follows:

1. After the surface measurements have been taken (if required), place the guide plate on the prepared site, ensuring the hole in the plate is at the point where the source was placed during the surface measurements.

2. Insert the drill rod through the extraction tool and then through the guide hole in the guide plate. Place one foot on the guide plate and hammer the drill rod to punch an access hole at least 50mm (2 in.) deeper than the desired test depth. Safety goggles and steel-toed footwear should be worn while driving the drill rod. The drill rod increments include the additional depth.

3. Remove the drill rod, while standing on the guide plate to ensure an undisturbed hole, by pulling **straight** up and slightly twisting the extraction tool. Avoid disturbing the access hole.

4. <u>Do not loosen the drill rod by tapping</u> <u>the side of the rod with a hammer</u> as this will distort the hole, or cause loose material to fall into the hole.

5. In heavy clay, lightly rotate the extraction tool to loosen the drill rod as it is being pulled upward. Make sure the area surrounding the hole is not disturbed excessively. Do not use the guide plate as a retraction device, as this will damage the top of the guide hole on the guide plate.

   For heavy clays, a Campbell hammer, or similar type of tool, may also be used. This weighted hammer is used to both drive, and extract, the pin while the operator stands on the guide plate.

6. Carefully pick up and remove the scraper/guide plate. Position the gauge on the prepared site and align the source rod with the hole. This can be accomplished by tilting the front of the gauge up slightly and pushing the index handle down until the source rod begins to exit through the bottom of the gauge.

7. Align the source rod of the gauge with the hole as follows:
   a) With the left hand hold the gauge by the source rod handle and bring the gauge closer to the hole.

   b) With your body safely above the gauge, brace the right elbow on the right knee and use the right hand to lift the lip located on the front of the bottom casting, as shown in Figure 2.

   c) Lower the source rod until it is between 50 and 100 mm through the bottom of the gauge.

   d) Let go of the source rod handle and grasp the guide tube above the handle (take a quick peek over the front end of the gauge).

   e) Slowly lower the gauge and source rod into the formed hole. **Use care when inserting the source rod, trying not to disturb the soil around the hole.**

8. Set the source rod handle to the desired testing depth. Increments of 50 mm (2") are clearly marked on the detent rod at 50, 100, 150, 200, 250 and 300 mm (2", 4", 6", 8”, 10, and 12").

9. Gently slide the gauge horizontally towards the detector end of the gauge housing until the source rod makes contact with the side of the hole. Ensure the gauge is seated firmly on the surface to be tested.

10. Using the gauge keypad, the operator now sets the count time. The *count time* defines how long the gauge reads. Longer count times produce better measurement precision. A count time of 1 minute is recommended for most sample measurements.

FIGURE 2

11. Using the gauge keypad, the operator now sets the *depth of measurement*, to match the depth that the source rod has been lowered to. If the depth set in the keypad doesn’t match the depth that the rod is at, then the measurement number will be erroneous.

12. Using the gauge keypad, the operator now presses the Start key to take a measurement of the Moisture Content and the Dry Density. After the count time has elapsed, the gauge displays the measurement results.

13. Record the test results on the data sheet.

4.7.2 Backscatter Measurements

In the Backscatter mode, the gauge is used to produce a rapid non-destructive surface measurement, measuring from the surface to a depth of approximately 10 cm (4 inches). This method is normally used when determining the density of granular materials. Generally, the Backscatter mode is not used on soils except when the soil is very loose and granular.

Prepare a test site on the compacted material (GBC or asphalt). The site should be as smooth as possible so that no large voids are present under the gauge base. Place the gauge on the test site, then lower the handle to the first notch (backscatter position).

Whenever backscatter is used, the bottom surface of the gauge is required to be clean.

To take a measurement, set the measurement depth and count time, then press the START key. Record the dry density and moisture content readings.

FIGURE 3

Alberta Transportation

MAT 6-34/13

NUCLEAR DENSITY TEST

see ATT-11, DENSITY, In-Place Nuclear Method

PROJECT NO. :	Hwy 96:04	DATE :	24-Jan-2013
FROM :	S. of Nowhere	TO :	N. of Someplace
PROJECT MANAGER :	J. Jones	CONTRACTOR :	R. Roads
GAUGE NO. :	3333	GAUGE TYPE :	Troxler (Model 3430)

SITE:			1	2	3	4	5
STATION			10+970				
LOCATION			0.5m Lt cl				
DEPTH BELOW GRADE			0.00-0.15				
DATE TESTED			24-Jan-2013				
VISUAL DESCRIPTION							
MATERIAL TYPE			Cl				
ESTIMATED MOISTURE CONTENT			opt.				
ESTIMATED PERCENT COMPACTION			100+				
MOISTURE							
A	MOISTURE STANDARD COUNT		730				
	MOISTURE CONTENT	READING NO. 1	20.6				
	MOISTURE CONTENT	READING NO. 2	20.8				
B	AVERAGE MOISTURE CONTENT	%	20.7				
C	MOISTURE CORRECTION FACTOR (see ATT-48)		-0.9				
D	CORRECTED MOISTURE CONTEN	B + C %	19.8				
DENSITY							
E	MODE (BS or DT 50, 100, 150, 200, 250, 300 mm)		DT 150				
F	DENSITY STANDARD COUNT		2404				
	WET DENSITY	READING NO. 1	2025				
	WET DENSITY	READING NO. 2	2030				
G	AVERAGE WET DENSITY	kg/m^3	2028				
H	DENSITY CORRECTION FACTOR (see ATT-48)		-13				
I	CORRECTED WET DENSITY	G + H kg/m^3	2015				
J	DRY DENSITY	100 I / (100+D) kg/m^3	1682				
CORRELATION							
K	PROCTOR NUMBER		4				
L	OPTIMUM MOISTURE CONTENT	%	19.4				
M	MAXIMUM DRY DENSITY	kg/m^3	1685				
N	ROCK CORRECTION FACTOR		N/A				
O	CORRECTED MAXIMUM DRY DENSITY		1685				
	FIELD MOISTURE CONTENT	D %	19.8				
P	MOISTURE DIFF. FROM OPT.	D - L %	0.4				
	FIELD DRY DENSITY	J kg/m^3	1682				
Q	PERCENT COMPACTION	100 J / O %	99.8				

REMARKS

Site 1. Material hauled from Borrow Pit #3

Site 2.

Site 3.

Site 4.

Site 5.

Compaction Equipment: 2 - RAY GO STEEL WHEEL PACKERS 4 - WOBBLY TIRED ROLLERS

Construction Equipment: 2 - GRADERS

TECHNOLOGIST(S) : M. KEEN

4.8 Percent Compaction

4.8.1 Subgrade

Identify the soil type as follows.

1. Use a garden trowel to excavate the soil located at the test site, from the source rod hole to where the detector tube sat, to the depth that the source rod was lowered.

2. Identify the soil as directed in ATT-29, SOILS IDENTIFICATION, Hand Method.

3. In the Remarks section, of form MAT 6-34, Nuclear Density Test, on the numbered line corresponding to the vertical test column number being used, record the following:

   a) results of the Soil Identification by Hand Method test,

   b) a description of the soil in common terms, e.g., dark brown sandy clay with some small white pebbles,

   c) a description of the origin of the soil, e.g., common excavation at station 21+090.

   d) any evidence of stratification of any kind, e.g., moisture content, soil type, or density, and

   e) any problems encountered in the test, e.g., equipment problems, rocks in hole, etc.

4. In the Visual Description section of the form, on the numbered line corresponding to the vertical test column number, enter the following:

   a) The unified soil classification on the Material Type line, based on the Hand Method test results, e.g. CL.

   b) Estimate the moisture content of the in-place soil and express it as a relationship between the field moisture content and the estimated optimum moisture content based on the plastic limit test,
   e.g., 1% above opt, 2% below opt, optimum (opt), etc.

      Enter the results on the Estimated Moisture Content line.

   c) Estimate the percent compaction of the in-place soil and record the value on the Estimated Percent Compaction line, knowing the relative moisture content of the soil.

To determine the actual degree of compaction of a soil in which a nuclear density gauge was used to establish the dry density, the following rock correction must be performed. The reason for the rock correction is that rocks are heavier than soil, so the more rocks present in a soil then the higher the corrected maximum dry density will be.

Determine the Rock Correction as follows:

1. Establish the percent of rock in the density zone as follows:

   a) Weigh the collected soil (minimum 7,000 g), and record the weight on line A of the Rock Correction" form.

   b) Separate the +20,000 µm rock from the soil.

   c) Weigh the +20,000 µm rock and record the weight on line B.

   d) Calculate the percent of +20,000 µm rock using the formula:

   $$\%\ +20{,}000\ \mu m = \frac{Wt.\ +20{,}000\ \mu m\ Rock}{Wt.\ of\ Soil\ Sample + Rock} \times 100$$

   Record this value on line C.

   e) If there is more than 30% of +20,000 µm material, disregard the density test results.

   f) <u>If there is less than 10% of the +20,000 µm material, a rock correction is not necessary</u>.

   g) If there is between 10% and 30% of +20,000 µm material, a rock correction is required, as follows.

If the amount of +20,000 µm rock is between 10% and 30%, adjust the proctor maximum dry density (MDD) established in test method ATT-20 as follows:

2. Calculate the % of -20 000 µm rock using the formula: line D = 100 – line C

   $$\%\ -20{,}000\ \mu m = 100 - (\%\ of\ -20{,}000\ \mu m)$$

3. The density of rock is assumed to be 2.6 (line E).

4. Calculate the Aggregate Adjustment (line F) using the table showing the % +20,000 µm aggregate and the corresponding Aggregate Adjustment.

5. Calculate the "+20 000 µm Ratio", line G, using the formula:

   $$+20\ 000 \mu m\ Ratio = \frac{\%\ +20\ 000 \mu m\ aggregate}{2.6 \times Aggregate\ Adjustment}$$

6. Use test method ATT-20, MOISTURE DENSITY RELATION, One Point, to establish the Maximum Dry Density and Optimum Moisture Content Of the -20,000 µm soil. Enter this value on line "H" of the Rock Correction form.

   If a rock correction is not required, record the Optimum Moisture Content on Line "L" and the Maximum Dry Density on Line "M" of data sheet MAT 6-34.

7. Calculate the "-20,000 µm Ratio", line I, using the formula:

$$\text{-20 000 µm Ratio} = 1000 \left(\frac{\text{\% -20 000 µm aggregate}}{\text{Maximum Dry Density of -20 000 µm aggregate}} \right)$$

8. Calculate the "Rock Correction Factor", line J, using the formula:

$$\text{Rock Correction Factor} = (\text{+20 000 µm Ratio}) + (\text{-20 000 µm Ratio})$$

9. Calculate the "Corrected Max. Dry Density (MDD), using the formula:

$$\text{Corrected Max. Dry Density} = \frac{100{,}000}{\text{Rock Correction Factor}}$$

MAXIMUM DRY DENSITY CORRECTED FOR ROCK				
A.	Wt. of Soil Sample + Rock		g.	7100
B.	Wt. of +20,000µm Rock		g.	800
C.	% +20,000µm	(B / A) x 100	%	11.3
D.	% -20,000µm	100-C	%	88.7
E.	Density of +20,000µm Rock		g/cm³	2.600
F.	Aggregate Adjustment	from Table		1.00
G.	+20,000µm Ratio	C / 2.600 x F		4.33
H.	Max. Dry Density of -20,000µm		kg/cm³	1682
I.	-20,000µm Ratio	1000 (D / H)		52.8
J.	Correction Factor	G + I		57.1
K.	Corrected Max. Dry Density	100,000 / J	kg/cm³	1752

F. AGG. ADJUSTMENT	
% +20,000	**Adjustment**
0% - 9%	no corr. needed
10% - 20%	1.00
21% - 25%	0.99
26% - 30%	0.98
31%+	discard sample

FIGURE 4

Transfer the Rock Correction Factor and Corrected Maximum Dry Density from the "Maximum Density Corrected for Rock" data sheet to line "N" and "O" on form MAT 6-34.

Determine the Correlation as follows:

1. Subtract the Proctor "Optimum Moisture Content" (line "L") from the "Field Moisture Content" (line "D"). Record this difference as the "Moisture Difference from Optimum" (line "P").

2. Calculate the "Percent Compaction" (line "Q") as follows:

$$\%\ Compaction = \frac{Field\ Dry\ Density\ (line\ "J")}{Maximum\ Dry\ Density\ (line\ "O")}\ x\ 100$$

Use the Corrected Maximum Dry Density (line "O"), if the MDD value has a rock correction.

4.8.2 Granular and Asphalt Stabilized Base Courses

Refer to ATT-58, DENSITY, GBC, Control Strip Method for further testing of granular base course materials.

ATT-66, DENSITY, ASBC, Control Strip Method, describes the procedure for testing asphalt stabilized base courses.

4.8.3 Asphalt Concrete Pavement - Quality Control Testing

If cores are not being obtained, nuclear wet densities may be used for quality control of ACP contracts. This procedure must be followed to satisfy the Specifications' Quality Control Testing Requirements. If this procedure is not followed, cause for an appeal may not be allowed.

The percent compaction obtained using this procedure may be allowed as "Cause for an Appeal" of quality assurance test results if, **prior to an appeal,** the contractor submits to the Project Manager the following documentation:

1. A copy of the most recent gauge calibration data using calibration blocks, the date of the calibration and the name of the company which performed the calibration.

2. A copy of the nuclear gauge log book showing the field daily standard counts percent drift to verify the gauge stability.

3. A copy of the applicable density correction factor data sheet (MAT 6-54), as outlined in ATT-48.

A copy of each Stratified Random Test Sites data sheet (MAT 6-82) completed for the lot must be submitted with the appeal request.

A copy of each density correction factor performed for the project must be submitted to the Project Manager as obtained.

When quality control and quality assurance percent compaction differ, and an appeal is being considered, the contractor may be required to confirm the nuclear density data with core densities before the appeal process is allowed.

When taking moisture readings, nuclear moisture-density gauges pick off the hydrogen content of materials and do not differentiate between the hydrogen in water or asphalt.

Therefore, when a nuclear gauge is used to test asphalt concrete pavements, only the wet density is used, not the dry density. However, the pavement surface must be dry at the time of testing. Also, no tests should be taken within 24 hours of rain fall, as surface and absorbed water affect the readings.

4.8.3.1 Quality Control Nuclear Densities on ACP

Each segment is divided into three areas or Sub-Segments. A nuclear backscatter wet density is taken for each Sub-Segment at a random station and a random location, as directed in ATT-56, Part II.

The lift thickness and the surface texture of each density site must be similar to that of the test sites used to establish the correction factor determined in ATT-48.

The average corrected segment nuclear backscatter wet density may then be used to replace the segment core dry density. The procedure is as follows:

1. Use form MAT 6-82, Stratified Random Test Sites and test method ATT-56, Part II, to calculate the station (line "H") and location (line "K") of each of the three sub-segment test sites.

2. Transfer to form MAT 6-6, Daily ACP Nuclear Density Report, the calculated stations (column "A") and locations (column "B") as shown in Figure 5.

3. Take a “Density Standard Count” at the road. Record the count in line "E".

4. For each test site of each segment:

    a) Prepare the site by filling the surface voids with a minimum amount of native fines.

    b) Take two backscatter wet density readings on each site. Record the readings as Wet Density Reading (line "C").

5. For each segment 1-5, calculate the average of the six backscatter density readings and record as Average Wet Density (line "D").

6. Plot the segment's nuclear wet density on the horizontal x-axis of the ACP Density Correction Factor Graph (ATT-48), as shown in Figure 6.

7. Proceed vertically to where the Nuclear Wet Density intercepts the trendline.

8. Proceed horizontally and pick off, on the vertical axis, the corresponding “Core Dry Density”. Record this number as the segment's “Corrected Nuclear Wet Density” (line "H").

FIGURE 5

Alberta Transportation MAT 6-6/13	DAILY ACP NUCLEAR DENSITY REPORT ATT-11, DENSITY, In-Place Nuclear Method			
	PROJECT NO.:	Hwy 43:16	CONTRACT NO.:	12345
	GAUGE TYPE:	Troxler (Model 3430)	LOT NUMBER:	5
	GAUGE SERIAL NO.:	3333	DATE:	24-Jan-2013

E. DENSITY STANDARD COUNT	2404	F. DENSITY CORRECTION FACTOR (ATT-48)	N/A	kg/m^3	G. LOT AVERAGE MARSHALL DRY DENSITY	2343	kg/m^3

BACKSCATTER DENSITY READINGS

SITE NO.	SEGMENT NUMBER 1			SEGMENT NUMBER 2			SEGMENT NUMBER 3			SEGMENT NUMBER 4			SEGMENT NUMBER 5		
	STATION	LOCATION	WET DENSITY	STATION	LOCATION	WET DENSITY	STATION	LOCATION	WET DENSITY	STATION	LOCATION	WET DENSITY	STATION	LOCATION	WET DENSITY
	A. (1)	B. (1)	C. (1)	A. (2)	B. (2)	C. (2)	A. (3)	B. (3)	C. (3)	A. (4)	B. (4)	C. (4)	A. (5)	B. (5)	C. (5)
1	26+017	-1.6	2255	26+799	-5.2	2210	26+017	-1.6	2255	26+017	-1.6	2245	26+017	-1.6	2235
			2250			2208			2258			2240			2230
2	26+307	-5.7	2255	26+927	-3.7	2200	26+307	-5.7	2262	26+307	-5.7	2235	26+307	-5.7	2236
			2252			2205			2255			2240			2232
3	26+601	-2.3	2260	27+298	-5.4	2211	26+601	-2.3	2251	26+601	-2.3	2241	26+601	-2.3	2231
			2255			2202			2248			2237			2235
D.	AVG. WET DENSITY		*2255*			*2206*			*2255*			*2240*			*2233*

SEGMENT PERCENT COMPACTION

		Segment 1	Segment 2	Segment 3	Segment 4	Segment 5
H. CORRECTED NUCLEAR WET DENSITY (kg/m^3)		2295	2239	2295	2278	2270
I. SEGMENT % COMPACTION	100 H/G	97.9	95.6	97.9	97.2	96.9

J.	LOT AVERAGE CORRECTED NUCLEAR WET DENSITY	AVE. "H"	kg/m^3	2275
K.	LOT AVERAGE PERCENT COMPACTION	100 J/G	%	97.1

REMARKS : CORRECTED NUCLEAR WET DENSITIES PICKED OFF FROM ACP EPS NUCLEAR DENSITY CORRECTION FACTOR GRAPH.
Line "H" = "Corrected Nuclear WD" using trendline equation from ACP EPS Nuclear Density Corr. Factor Graph = 1.1434 * W.D. - 283.23

TECHNOLOGIST: R. JONES

9. Instead of manually picking off the Core Dry Density from the graph, as shown in steps 6-8, you can use the trendline equation printed on the excel graph for the corresponding Correction Factor Graph, to calculate the Core Dry Densities.

   Example: If the average nuclear wet density = 2255
   If the trend line equation = (1.1434 * Wet Density) – 283.23
   Corrected Wet Density = (1.1434 * 2255) – 283.23 = 2295 kg/m^3

10. Repeat steps 6 to 9 for the remaining four segments.

11. Record in line "G" the “Lot Average Marshall Dry Density” as established by the Quality Assurance testing program.

12. Calculate the Segment % Compaction (line "I") using the formula:

$$= \frac{\textit{Corected Nuclear Backscatter Wet Density}}{\textit{Lot Average Marshall Dry Density}} \times 100$$

ACP EPS NUCLEAR GAUGE DENSITY CORRECTION FACTOR GRAPH

NUCLEAR WET DENSITY vs CORE DRY DENSITY

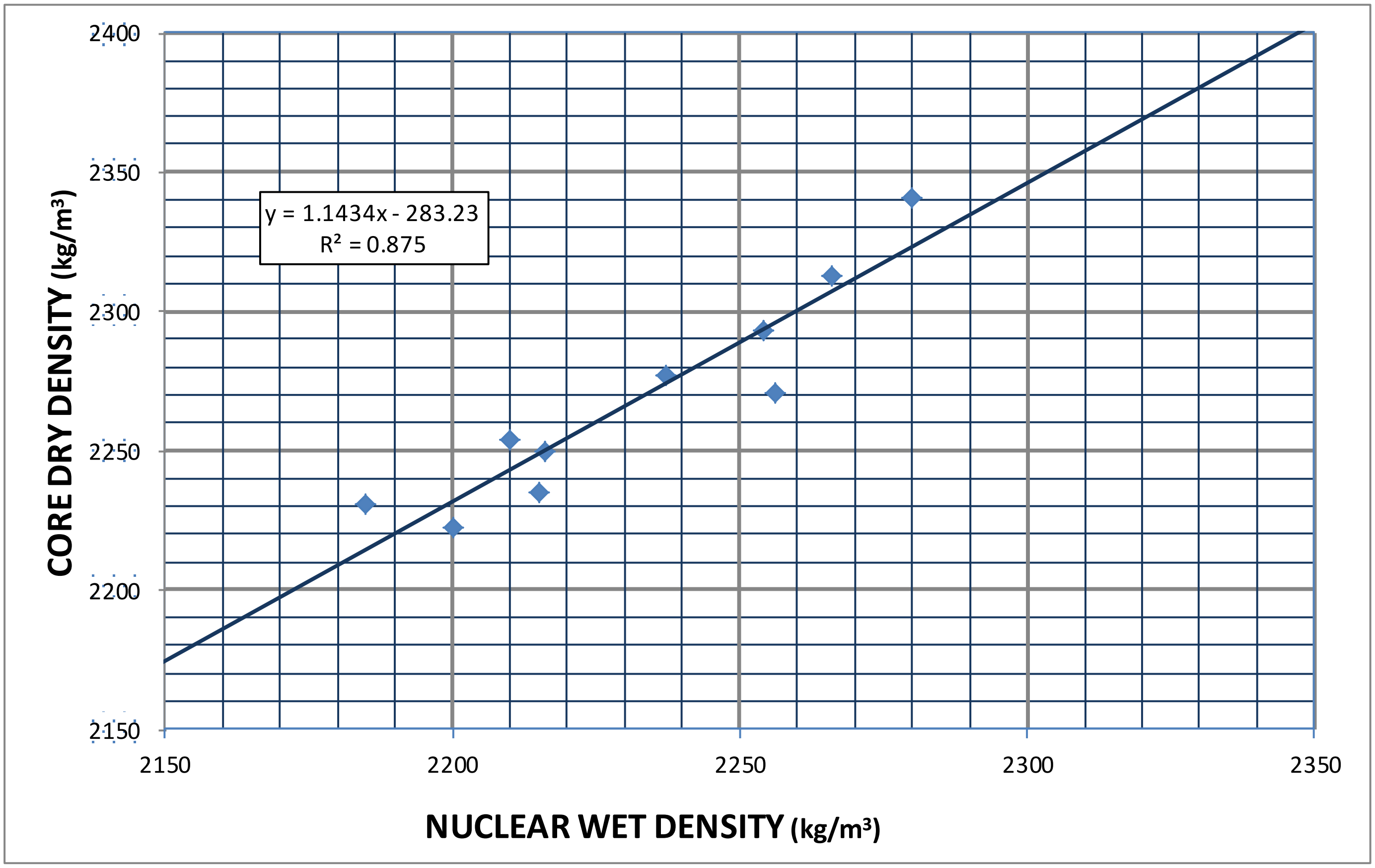


FIGURE 6

13. Calculate the Lot Average Corrected Nuclear Wet Density (line "J") by averaging the "Corrected Nuclear Wet Densities" for Segments 1-5 and entering this average on Line "J".

14. Calculate the Lot Average Percent Compaction (line "K") as follows:

$$= \frac{\textit{Lot Average Corected Nuclear Wet Density}}{\textit{QA Lot Average Marshall Dry Density}} \times 100$$

5.0 HINTS AND PRECAUTIONS

1. Operators must be trained in the safety, operation and proper care of nuclear moisture-density gauges. The training requirements are outlined under the Canadian Nuclear Safety Commission (CNSC) licensing requirements.

2. **Correction factors (ATT-48) must be determined and used for each significant construction material to be tested**.

3. Poor site preparation will affect all density and moisture measurements, especially for readings obtained using the Backscatter operating mode, as this is strongly influenced by surface density.

4. **Any material, or layers of non-representative moisture**, such as a chunk of mud or dry crust must be removed before starting the test, because it **will affect moisture measurements**.

5. Ensure that the index handle is locked securely in the proper depth detent before taking the measurements. Push the handle down to the desired depth then pull upwards slightly and push down until a definite click is heard. Improper positioning of the rod will give incorrect readings and erroneous decisions may be made based on these results.

6. Care is required when positioning the index handle to prevent pinching the hand, especially when raising the handle to the SAFE position. Wear the proper PPE (Safety goggles and steel-toed footwear should be worn while driving the drill rod).

7. When using the direct transmission method, be certain that the depth selected for the test does not exceed the thickness of the lift on which the density is desired.

8. Where maximum accuracy is not required, take 2 or 3 minute readings to speed up the test procedure; for example, take 3 minute readings for rolling pattern measurements on hot asphalt test strips.

9. The gauge can be placed on a hot asphalt pavement. Surface temperatures are generally low enough for the nuclear gauge not to experience excessive temperature rise. Do not leave the gauge on a hot mat for a long period of time. If the gauge becomes uncomfortably hot to the bare hand, allow a cooling period between readings.

10. **DO NOT – Let your gauge get wet. This will affect the gauge electronics.**

11. **DO NOT – Leave your gauge unattended during field use**. Always keep your eyes on the gauge while it is in operation, and ensure that equipment operators in the area know that you are there.

12. Always practice good ALARA by maintaining your distance from the gauge during the test. Individuals must be made aware that **radiation is always travelling undetected in all directions around the gauge**. This is why you should maintain a safe distance outside this radiation zone (10' should be sufficient).

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