1. **SCOPE**

This procedure determines the density of asphalt concrete in place by using the backscatter position (the gamma radiation source remains on the surface).

2. **APPARATUS AND MATERIALS**

2.1. **Equipment Required**

An electronic nuclear moisture-density gauge equipped with gamma and neutron sources, detector tube, standard reference block for obtaining a standard count, calibration tables and instruction manual. The gauge must be constructed in such a manner as to be licensable in accordance with applicable federal and provincial regulations.

A guide plate complete with a drill rod, hammer and an extractor for making holes.

Miscellaneous tools such as a spade, banister brush and straight edge for levelling sand.

2.2. **Materials Required**

A fine graded sand passing the 400 µm sieve to be used to fill the open voids, if the asphalt concrete is coarse textured.

2.3. **Sample To Be Tested**

Select the designated section, of the asphalt concrete, where the Marshall characteristics are known (tests have been performed on the material as produced from the asphalt plant). If there are no available data, select the site at random in accordance with STP 107.
2.4. **Data Required**

Marshall characteristics information is required to calculate percent compaction on material to be tested.

3. **Hazards**

This equipment utilizes radioactive materials. Only authorized personnel, who have received the appropriate training and carrying a valid training certificate, are to operate or handle nuclear gauges. Users of this equipment must be familiar with current safety procedures and regulations. Refer to section 7 of this procedure for more information on the proper safety, care and handling of the equipment.

4. **PROCEDURE**

4.1. **Equipment Preparation**

4.1.1. **Gauge Operation**

Before attempting to use any nuclear gauge, read the instruction manual provided for the particular model being used. This will explain warm up times and time modes for the various models being used.

4.1.2. **Characteristics of Nuclear Gauges**

Handle Positions for density measurement

a) Backscatter Position: The source rod is approximately 1 mm up from the base of unit.

b) Direct Transmission: The gamma source rod is extended to various depths 50.8 mm, 101.6 mm, 152.4 mm and 203.2 mm, from the base of unit.
4.1.3. Standard Counts

Standard counts provide a reference check from day to day on gauge operation and are an opportunity for the operator to observe the performance of the gauge.

On a new project site the initial standard count readings may be erratic due to environmental or background interference. Initially, take as many standard count readings as necessary until the gauge is stabilized.

After the gauge is stabilized, take standard counts once per day on the reference standard block provided with each gauge as explained in the applicable instruction manual. This is also a requirement of the Atomic Energy Control Board.

Details such as warm up periods and proper placement should be closely followed. Source rods must be in the safe position and gauges should be at least 10 meters away from other gauges when standard counts are taken.

The standard reference block must be clean and does not have soil or other material in the seating area.

Turn gauge’s power on and wait at least 10 minutes to allow stabilization of the regulators and detectors. Place the TIME switch on SLOW and press STD.

After 4 minutes, read the standard moisture and read the standard density counts.

If the day to day shift in the standard count is greater than 2% for moisture or 1% for density, there is a possibility of gauge malfunction. To confirm the accuracy of the unit, perform the statistical standard count described in section 4.1.4. below.

Record and keep this data as it provides a valuable long-term record of the performance of the gauge. A Standard Count Use Log sheet is provided with each unit.
4.1.4. Statistical Standard Count

The statistical standard count is a stability test that is performed to validate the normal operation of the gauge. The unit automatically records a series of readings, 16 to 20 readings, and determines the standard deviation of those readings. If the recorded standard deviation is within a predicted value, the unit is functioning properly.

Statistical standard counts must be taken if the day to day shift in the standard count is greater than 2% for moisture or 1% for density. Compare the statistical count readings obtained in the field to the statistical count readings obtained by Testing Services during the calibration process. The two readings must not vary by more than 2% for moisture or 1% for density.

If the statistical count fails, check if there are any gauges near by, if the gauge is seated correctly on the reference block and/or if the gauge base and block surfaces are clean. Take a second test. If the second test also fails, contact Testing Services as the gauge may require repair and/or recalibration.

If the statistical count passes, repeat the standard count to confirm that the gauge is functioning properly.

To perform the statistical count on the Troxler 3400 series:

Ensure the source rod is in the safe position.
From the Special Function menu choose STAT TEST and press Start.
The unit automatically calculates the average statistical count for both density and moisture. The unit will also indicate if the count is a pass or a fail.

Record the readings and compare them to the readings provided by Testing Services.

To perform the statistical count on the Humboldt 5001:

Ensure the source rod is in the safe position.
Press SHIFT/STAT.
Record the readings and compare them to the readings provided by Testing Services.

Refer to the respective instruction manual for the exact steps on conducting the test.
4.2. **Site Preparation**

Maximum contact between the base of the instrument and the surface of the material under test is critical. The test site should be flat and smooth and fairly free of surface voids. If the texture of the mat has sufficient surface voids to affect the readings, a fine sand, passing the 400 µm sieve, should be used to fill them. The special sand may be obtained from the pit used for bituminous mixing or native fines can be used from the roadway. After application, this sand must be levelled with the guide plate to provide an even distribution on the surface. It is important that the sand only fills the voids and does not provide a cushion for the gauge as too much sand will affect the readings. Sand can be scraped off with a straight edge instead of guide plate.

4.3. **Test Procedure**

Place the handle in the backscatter position. Take three one minute readings of the wet (bulk) density. The dry density is not taken into consideration since the nuclear gauge readings are compared to that of the Marshall density which is also a wet (bulk) density.

For establishing rolling patterns, 15 or 30 second readings can be used in lieu of one minute readings. The expected error for backscatter is between ± 8 kg/m³ to ± 16 kg/m³ when the 15 or 30 second times are used. This is acceptable when rapid readings are required; however, one minute counts should be used for actual density control.

If the lift thickness under test is less than 50 mm a correction factor may be required. Refer to section 6.2. below for more details on corrections to thin lifts.

5. **RESULTS AND CALCULATIONS**

Perform all calculations as described in test procedure and report all data Form MR-14 and Form MR-70. In addition report all standard counts on the Standard Count Use Log sheet.

6. **CALIBRATIONS, CORRECTIONS, REPEATABILITY**

6.1. **Calibration**

Once a year, all gauges are calibrated by Testing Services on a series of certified blocks with varying densities. New calibration charts will be issued if required.
The best method of checking for changes in your gauge is by observing your daily standard and the periodic statistical counts. Any sudden change in the counts indicates a possible malfunction in the gauge.

Each gauge also has a selector switch that provides an internal check of electrical circuit operations. These numbers for the various models are available in the instruction manual. If the gauge does not read these numbers then there is a problem with circuits and the gauge must be repaired and recalibrated.

6.2. Corrections to thin lifts

Corrections to the density of thin lifts is required if the overlay thickness is less than 50 mm and if the density of the underlying material has a substantially lower or higher density than the lift being assessed. Examples are overlay lifts on top of subgrade or on top of portland cement concrete. Failure to make these corrections can result in errors of 16 to 48 kg/m³.

The gauges use the nomograph principle to adjust the overlay density of thin lifts. The density of the underlying material has to be known from prior measurement. The thickness of the top layer is also required. Both pieces of data, once determined for a specific section of the roadway, have to be entered and stored in the unit. Care must be taken as both the density of underlying material and the thickness of the top layer may vary from section to section. If such variations occur, the new data must be re-determined and re-entered into the unit so that the proper correction factor can be calculated. A typical construction project will require more than one correction factor.

Corrections to thin lifts vary with different models. Refer to owner's manual for specific details.

If the density result obtained by applying a correction factor is not reliable, determine the density using the coring method in accordance with STP 204-5 and STP 204-21.

6.3. Repeatability

Initial as well as periodic checks will be made between nuclear machine and conventional methods to recognize discrepancies. Consistent differences should be corrected in accordance with STP 204-26.

Repeatability is influenced by many factors including consistency of aggregate, asphalt content, site preparation and proper use of correction factors.
6.4. **Sources of Error**

There are many potential sources of error in nuclear density measurements. If all procedures, including the performance of daily standard count and the periodic statistical count, are followed carefully, the errors can be minimized.

The most critical source of error is due to site preparation and surface voids.

When using a nuclear gauge, care must be taken to ensure that the source rod is locked exactly in the position desired. Any slight change in the elevation of the source rod will radically affect the readings. The indexing device, located on the handle, must always be disengaged before changing positions on the index rod. Wear of the indexing mechanism should be checked regularly because slight wear can affect the test results. Keeping the gauge clean will also reduce the sources of error.

7. **ADDED INFORMATION**

7.1. **General**

Because of the speed with which tests can be done, these gauges can be very useful in establishing rolling patterns. Sometimes density is destroyed by over compaction and over rolling. The gauge can be used to determine when the density peaks and no further compaction is necessary.

The field percent compaction is based on the standard Marshall compaction completed at the field laboratory. Field densities using the nuclear gauges will be taken where the material is placed. If the Marshall densities are fairly uniform, they may be averaged and thus allowing more actual field densities based on the averaged Marshall test.

7.3. **Transportation, Safety and Care of Department Gauge**

Testing Services of Engineering Services Branch has overall responsibility and authority for safety regulations of nuclear gauges. This includes updating licenses.

The Directors Engineering Projects or designate has responsibility and authority for ensuring that these regulations are followed for gauges used on their projects.

Only authorized personnel are to operate or handle nuclear gauges.
The vehicle containing the gauge has to be either driven by the person who has charge, management and control of the instrument or that person accompanies the instrument during transportation.

Radiation hazard markings on the gauge and carrying case are to be kept clean and visible at all times.

Vehicles used for the transportation of a single gauge shall carry a package on the front seat containing:

a) a document showing pertinent information required by the permit.
b) a copy of the permit.
c) a copy of a valid Atomic Energy Board license.
d) a placard resistant to fire, water and embossed with the radioactive symbol.
e) a standard count use log.

Always carry the gauge in the trunk or truck box. Special holders may be required when carried in trucks.

The gauges must be packaged in the container provided and labelled in accordance with the provincial regulations.

Vehicles used for the transportation of more than one gauge will be clearly marked on the front, rear and sides using four magnetic signs. These signs will be removed from the vehicle when the gauges are elsewhere.

When not in use, gauges are to be padlocked and if the period is longer than one day, the gauge should be padlocked and placed inside the locked carrying case.

For storage or during the charging of the batteries keep the gauge in an isolated area marked with radiation hazard signs.

The gauge is not to be dismantled or opened for any reason. At no time should the source rod be removed from the gauge.

Radiation leak tests will be conducted once a year by the Testing Services in Regina.

The gauge is always on, as far as radiation is concerned. The switch only controls the electronic readout. Exposure depends on time; therefore complete your work as quickly as possible.
There is no need for the operator to hover over the gauge during the test. The greater the distance from the radioactive source, the lesser the intensity of radiation. Doubling the distance from the radiation source decreases the radiation by a factor of four.

7.4. Emergency Procedure for Damage to Gauges

If the nuclear gauge is damaged in a construction accident, vehicle accident or a fire, proceed as follows according to the severity of the damage listed below.

7.4.1. Minor Damage

If case did not sustain an open breakage and the source rod can be placed in its retracted position, place the gauge in its shipping case, store as usual and phone Testing Services, Radiation Safety Officer in Regina at (306) 787-4914 or (306) 787-0385 for further instructions.

7.4.2. Medium Damage

If case sustained an open breakage and the source rod is bent and cannot be retracted into safe position, examine the gauge with care at ARM's length. Touching only the upper gauge parts, lift or roll back the gauge to expose the source rod for examination.

If the rod containing the radioactive source is not mechanically damaged, place the gauge in its shipping case the best way possible and transport to its usual overnight storage area.

Keep everyone at least 3 m from the gauge and do not handle the source rod. If it is necessary to pick up any damaged parts of the gauge use gloves and place any damaged parts in a container, preferably plastic container such as a bag or a bottle. Keep hands at least 15 cm from the source. After handling parts, place the gloves in container and seal it. If you must leave the area, have someone guard the area in order to discourage entry.

Call Testing Services, Radiation Safety Officer at (306)-787-4914, (306) 787-0385 or the 24-hour Emergency Spill Control at 1-800-667-7525 for further instruction. Testing Services will contact the Canadian Nuclear Safety Commission. This must be done within 24 hours of the accident.
7.4.3. Major Damage

If the gauge sustained an open breakage or the source rod is mechanically damaged, broken off, cracked open or source rod itself is exposed, do not move the gauge or walk in the area.

Rope off the area for 3 m around the gauge. Stop all vehicles which could have collided with the gauge and which could have radiation contamination on tires, cleats or tracks. Call Testing Services, Radiation Safety Officer at (306)-787-4914, (306) 787-0385 or the 24-hour Emergency Spill Control at 1-800-667-7525. Also notify the local RCMP for further instructions.

The Radiation Safety Officer will check the area for radioactive contamination. The likelihood of damage to the source is extremely remote but the operator cannot determine this possible damage without a field survey meter. Testing Services will contact the Canadian Nuclear Safety Commission within 24 hours.

7.4.4. Lost or Stolen Gauge

Notify Testing Services, Radiation Safety Officer at (306) 787-4914 or (306) 787-0385 and the local RCMP.

7.5. Specific Gauge Information

7.5.1. Charging of Batteries

The life of the Nicad batteries can be greatly improved by proper charging procedure. Some of these procedures to follow are:

a) Do not charge gauges using contractors power source, use normal domestic power.

b) Do not charge batteries when the ambient temperature exceeds 38° C or below 5° C. Allow the temperature of the gauge to stabilize to room temperature before charging.
c) The Troxler 3400 series will operate for several weeks on fully charged batteries. When charging is required the "Bat Alarm" will be displayed.

Recharging overnight will fully restore the charge. To obtain a temporary charge the gauge may also be plugged into a car cigarette lighter outlet for 30 minutes.

d) The Troxler 3440 displays battery life in hours remaining and should be charged overnight when gauge indicates "Batteries Low".

7.5.2. Periodic Maintenance

The gauge has been designed for rugged field use and will withstand normal wear and tear. Simple precautions will greatly reduce damage and extend the time between major repairs.

When operating nuclear gauges, display buttons should be operated by fingertips rather than sharp objects since they can cause the circuit boards to short.

Maintenance, repairs and calibration will be performed by Testing Services. Do not attempt to repair the unit in the field.

8. References

ASTM D2950
ASTM D3017