TROXLER®
The Leader in Construction Testing Equipment

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Application Brief

TROXLER MODEL 3450

Roadreader™ Plus
Nuclear Moisture Density & Thin Layer Gauge

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Introduction

The Troxler Model 3450, Roadreader Plus™, nuclear moisture / density gauge offers the unprecedented combination of a surface moisture and density gauge with a thin layer density gauge in a single instrument. This gauge allows the user to measure the moisture and density of soil materials, the density of full depth asphalt and concrete and the density of asphalt and concrete thin layer overlays. In addition, the Model 3450 provides a host of technical advancements to ensure easier operation, greater reliability and improved performance. The ASTM standard numbers D 6938 (replaced D 2922 and D 3017 as of November 2006), D 2950, and C 1040 are met or exceeded by this gauge. This application brief will describe the operation, application and features of the Model 3450.

Traditional Methods

Until the introduction of the Model 3450 Roadreader Plus™ users who performed quality control testing on both soil and asphalt had to use both the Model 3440 and Model 4640 nuclear gauges in order to fulfill all of their testing requirements. Rather than purchase both gauges, many users compromised by purchasing a standard surface moisture / density gauge with the nomograph capability (a way to calculate top layer density using the backscatter density, the bottom layer density and the top layer thickness). The nomograph function will, in theory, provide a reasonable estimate of the top layer density, however the results are highly dependant on the bottom layer density and the thickness of the top layer, both of which must be known before performing the measurement. Since the bottom layer is covered at the time that the top layer is being measured it is difficult to know the exact bottom density; as a result an average density or estimated density is usually used. If this estimated bottom layer density is not correct erroneous top layer density readings could result.

The Model 4640 Thin Layer Density Gauge is the predecessor to the Roadreader Plus™. This gauge is strictly an asphalt or concrete gauge and can measure the density of lifts with

thicknesses from 1 to 4 inches (2.5 to 10 cm) without influence of the density of the underlying layer. This gauge cannot be used for direct transmission measurements or moisture measurements, and therefore cannot be used on soil materials. The Model 4640 is useful for the contractor who simply works with asphalt or concrete and never has the need to measure the density of subgrade soils or base aggregates.

Troxler Technology

Traditional nuclear gauges use the interaction of gamma photons with matter to measure density. One means of performing this measurement is through direct transmission, when the source is inserted into a predrilled hole and positioned below the surface of the test material. In this position the photons from the source travel through the material to reach the photon detectors in the gauge base where they are counted. This density count is then related to a density that was determined during the gauge calibration. The resulting density is an average density of the material between the source and the detectors. The second means of performing a density measurement is in the backscatter position. In this position the source rod is lowered to the first “notch” below the “safe” position. At this level the source is on the same plane as the photon detectors. The photons from the source travel into the test material where many collide with electrons and are scattered (or reflected). Many of those that are scattered toward the gauge base are counted by the detectors. This type of density reading measures approximately the top 4 inches (10 cm) of the test material under the gauge base.

The thin-layer density technology also determines density through the backscatter of photons. In fact the thin layer system is essentially two backscatter systems working together to differentiate between the density of the upper portion of the measured material and the lower portion of the measured material. One set of photon detectors (system 1) is positioned closer to the source so that it can primarily measure the density of the shallower material. The other set of photon detectors (system 2) is positioned similarly to the standard surface density gauge, near the end of the gauge base, to measure the density of the measured material more deeply. Using this technology, the thin layer system of the Model 3450 gauge can measure the density of asphalt layers with thicknesses from 1 to 4 inches (2.5 to 10 cm) without influence from the density of the underlying material.

The Roadreader Plus™ has the capability to measure density in all three modes mentioned above; direct transmission, backscatter and thin layer. In addition, the Model 3450 gauge also has the ability to measure moisture content for the testing of soil materials. This measurement is based on the principle of neutron thermalization. Fast neutrons are emitted by the moisture source, Americium- 241: beryllium, and pass through the test material. The hydrogen present in the test material thermalizes, or slows, the neutrons. These thermalized neutrons are detected and counted by the detector in the gauge base. This count is then converted to a moisture content that has been determined by the gauge calibration.

Gauge Operation

Modes of Operation

The Model 3450 offers three modes of operation: Soil, Asphalt and Thin Layer. All three modes perform density measurements, however the information is used and presented in different ways for each mode.

Soil mode is designed for measuring the moisture and density of soil, sand, aggregate and other materials where both moisture and density are of interest. In this mode the target density is a dry density value, therefore the dry density measurement result will be compared to the target density value entered by the operator (Proctor Value). The backscatter test mode and direct transmission test mode can be used when the gauge is used in Soil Mode. Direct transmission is the recommended test method because it typically offers a better precision, however it is not always possible. The information provided by the gauge when measuring in the soil mode includes; percent proctor, dry density, wet density, moisture content, percent moisture, density counts and moisture count.

Asphalt mode is used for the measurement of asphalt and concrete layers that are 4 inches (10 cm) or more in thickness. In this mode the target density is a wet density value. Because moisture content does not play a role in the compaction of these materials the wet density value will be compared to the target density that is entered by the operator (Marshall value or voidless density). Again, the backscatter or direct transmission modes may be used. Typically the backscatter mode is used on asphalt and concrete materials because they are too hard to be drilled for a direct transmission measurement. The information provided by the gauge when measuring in the asphalt mode includes: percent Marshall, wet density, percent voids and density counts.

Thin Layer mode is used on asphalt or concrete materials with a layer thickness of 1 to 4 inches (2.5 to 10 cm). Similar to the asphalt mode, in the thin layer mode the target density is a wet density value due to the fact that moisture does not play a role in the compaction process. Only the backscatter mode may be used for thin layer measurements. The information provided by the gauge when measuring in the thin layer mode includes: percent Marshall, wet density, percent voids and density counts.

Data Storage and Output

The Model 3450 has the most advanced storage capability of any Troxler nuclear density gauge. This gauge can store up to 1000 readings and project notes under a project name that has been enabled. Up to 620 readings can be stored per project. Project names can be 20 characters long with letters and / or numbers included. In addition to storing the test data and simple project notes the operator has the option to use the Full Store feature. This feature allows the operator to enter project data that is typically required on FHWA projects such as station number, relative position, lane direction, elevation, compaction method, lift number, lift thickness, etc.

The operator can easily retrieve, print and download stored project data in the field or in the office with just a few keystrokes. The serial port, for downloading data, is located on the outside of the gauge for quick, simple field or lab use. For downloading data in the home or office a second serial port is present on the side of the gauge control panel so that the sources can be left in the safety of a storage area. To download data directly from the control panel it first must be removed from the gauge. In order to do this, take the gauge to a secure storage area, loosen the four screws at the corners of the gauge face, remove the two screws that hold the cable (connecting the gauge to the control panel) in place on the control panel and disconnect this cable. Then simply connect the control panel to your computer or printer and follow the download instructions in the gauge manual.

Features

The Roadreader Plus™ is the first nuclear moisture / density gauge with soil, asphalt and thin layer measurement capabilities. This gauge is also the first to offer the options of a backlit display screen, adjustable “beeper” levels and a serial port on the control panel for downloading of data without nuclear sources nearby. These functions are designed to cover the full range of construction material testing situations.

The Model 3450 gauge offers the conveniences of the typical Troxler density gauge in that the user can: enter and store a target density for calculation of percent compaction; set the units to either pounds per cubic foot (pcf), kilograms per cubic meter (kg/m^3) or grams per cubic centimeter (g/cc); set the count time to either 15 seconds, 1 minute or 4 minutes and set the depth indicator to automatic or manual reading of the source rod depth. This gauge, as do most Troxler gauges, stores the last 4 standard counts performed and compares the newest standard count to the average of those in memory. Another convenient option that is available to the operator of the Model 3450 is the *QA Sampling* feature which generates random test locations to ensure fair and representative quality assurance sampling. In thin layer mode the gauge also offers a *Number Averages* function which allows for averaging of one to nine readings from a test location.

It is sometimes necessary to offset gauge readings due to the presence of materials not covered by the factory calibration or due to environmental influences present. Three types of offsets are provided by the Model 3450. A *wet density offset* may be used in any test mode and may be necessary if the test material is not representative of a “typical” soil or asphalt material in its composition or texture. A *moisture offset* may be used when testing in the soil mode and is necessary if the test material contains hydrogen in forms other than water, such as cement, gypsum, coal, lime or mica, or if the test material contains neutron absorbers, such as boron, cadmium or chlorine. The third offset is a *trench offset,* which can be used in all test modes and adjusts the gauge measurements when testing in a trench or close to a vertical structure. The *Special Calibration* function is another option available for adjusting gauge readings in soil and thin layer modes. This function allows the user to recalibrate the gauge for material densities, compositions and / or texture that is not covered by the factory calibration.

Correct gauge operation can be assured through a number of diagnostic functions that are provided by the Roadreader Plus™. The stability *(Stat) test* is performed by the user if the gauge readings are “suspect”. This test consists of twenty 1 minute test counts from which the gauge calculates the standard deviation. If the stat test passes and the user wishes to examine the gauge further a *Drift test* is performed to check the long-term drift of the gauge. It consists of five 4 minute test counts. In addition, a check of the gauge’s stability is included in the daily standard count procedure. This count is performed every working day and a sudden change in the counts, resulting in failing standard counts, can indicate a problem with the gauge. If any of these tests fail or an error message is displayed the operator should refer to the operation manual for instruction or contact the nearest Troxler service center for assistance.

Keypad

The Roadreader Plus™ has a keypad that was designed to provide full access to gauge functions with a minimum of submenus while not overwhelming the user with too many keys. There are ten major function keys, a numeric keypad and a few special function keys such as the up and down arrows, escape, light, shift and the on / off keys. The up and down arrow keys allow the user to view more menu options, as well as the moisture and density counts after a measurement is performed, which cannot all be displayed on one screen. The Escape (*Esc*) key will always abort the menu or command that is displayed and return the display screen to the “Ready” message so a new function can be performed. Pressing the *Light* key activates the backlight function, illuminating the display screen for better visibility on night paving jobs. The *Shift* key is provided to allow access to the letter keys. This permits full alphanumeric entry of notes and project names.

In addition to a very comprehensive and user friendly keypad the Model 3450 has a 4 line by 20 character liquid crystal display (LCD) screen located above the keypad. This large screen allows for more descriptive menus, aiding the user in accessing functions. The display screen backlight, described above, is a new feature on this gauge and aids the gauge operator when using the gauge at night. The user can easily adjust when the backlight comes on (e.g. after a keypress) as well as how long it remains lit.

Use of this gauge is also made easier with the option of adjusting the volume of the “beeper”. This can be set to provide a tone at the conclusion of a measurement at a level of soft, loud or extra loud. In addition, an external speaker is provided to boost the volume of the tone when working near loud equipment; simply open or close the speaker to raise or reduce the volume.

Batteries and Power Consumption

The Model 3450 operates from either a quick charge Ni-Cad battery pack or 6 AA alkaline batteries. This combination provides up to 6 months of service life without charge. The gauge can operate on fully charged Ni-Cad batteries for up to a month and on new alkaline batteries for up to 5 months. Of course, actual battery life depends on how much the gauge is used and whether high current devices, such as the backlight and the external beeper, are

used. Two sets of batteries are used to provide the user with the recharging capability of the Ni-Cad batteries combined with the long life and easy availability of alkaline batteries.

To provide maximum battery life, the 3450 applies the *Display Time Out* (or sleep mode) which is a power saving feature. After a user selected period of inactivity the gauge turns off the display and most of the electronics. A blinking LED next to the display screen alerts the user that the gauge is still in operation. Pressing any key returns the gauge to the fully "on" state and all previous data in use is retained.

Should the Ni-Cad batteries run low in the field the user may operate the gauge using the alkaline batteries until the gauge can be recharged. Charging the Ni-Cad batteries takes no longer than 4 hours to obtain a full charge. A 20 minute charge time will provide enough power to operate for 8 hours. Overcharging of the Ni-Cad batteries is not possible because the gauge turns the current off when the batteries have been fully charged. This improves the typical life of the Ni-Cad batteries to approximately 400 charge cycles. Both the Ni-Cad batteries and the alkaline batteries are easily changed by the gauge user by removing the control unit from the top of the gauge.

Summary

In addition to combining a thin layer density gauge with a standard surface moisture / density gauge, the Model 3450 offers a variety of technological innovations including low power operation, long battery life with quick recharge, easy to follow menus and a user friendly keypad. Field use is made more convenient with a backlit display, a loud external "beeper" and a blinking LED to indicate that the gauge is in low power mode. These new features, combined with the standard Troxler nuclear density gauge features, result in an instrument that is the most advanced as well as the most versatile gauge on the market.

The Troxler Roadreader Plus™ Model 3450 is the top of the line nuclear gauge for the measurement of moisture and density of aggregates and soils, and the density of full depth asphalt and concrete as well as thin layer asphalt and concrete. This is the only gauge that can truly cover all of your construction material density testing needs in the field. The 3450 is designed to meet the demanding needs of the testing lab, DOT, municipality, county or contractor who works with a wide variety of construction materials.

Comparison of Measurement Precision
Model 3450

Soil and Asphalt Modes

Density @ 2000 kg/m^3 (125 pcf)

	15 sec.	1 min.	4 min.
Direct Transmission 150mm (6")			
Precision	5.2 (0.32 pcf)	2.6 (0.15 pcf)	1.3 (0.08 pcf)
Composition error	8.0 (0.50 pcf)	8.0 (0.50 pcf)	8.0 (0.50 pcf)
Surface error 1.25 mm (0.05"), 100% void	-18 (-1.1 pcf)	-18 (-1.1 pcf)	-18 (-1.1 pcf)
Backscatter			
Precision	16 (1.0 pcf)	8.0 (0.50 pcf)	4.0 (0.25 pcf)
Composition error	14.0 (0.87 pcf)	14.0 (0.87 pcf)	14.0 (0.87 pcf)
Surface error 1.25 mm (0.05"), 100% void	-80 (-5.0 pcf)	-80 (-5.0 pcf)	-80 (-5.0 pcf)
Moisture @ 249 kg/m^3 (15 pcf)			
Precision	11 (0.69 pcf)	5.5 (0.34 pcf)	2.8 (0.17 pcf)
Surface error 1.25 mm (0.05"), 100% void	-19 (-1.2 pcf)	-19 (-1.2 pcf)	-19 (-1.2 pcf)

Depth of measurement = 215 mm (8.5")

Thin Layer mode

Precision @ 2240 kg/m^3 (140 pcf)

Time	Thickness	kg/m^3	pcf
1.0 min	2.5 cm (1.0")	+/- 16	+/- 1.0
	5.0 cm (2.0")	+/- 10	+/- 0.6
	6.3 cm (2.5")	+/- 8	+/- 0.5
	10.0 cm (4")	+/- 8	+/- 0.5
4.0 min	2.5 cm (1.0")	+/- 8	+/- 0.5
	5.0 cm (2.0")	+/- 5	+/- 0.3
	6.3 cm (2.5")	+/- 4	+/- 0.25
	10.0 cm (4")	+/- 4	+/- 0.25