C-200 Operator's Manual

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C-200 Operator's Manual

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Table of Contents

Notes:

Foreword

Owner responsibilities

The possession, use, and transportation on public highways of Seaman Nuclear Corporation Density Moisture meters is controlled by governing authorities. In the United States these authorities are the United States Nuclear Regulatory Commission, Agreement States, and the United States Department of Transportation.

As the meter owner, you are solely responsible for complying with the rules of these regulatory bodies. Seaman Nuclear Corporation's seminars, operator's manuals, and other instructional materials are provided to assist the owner in meeting their responsibilities. Purchase of 49 CFR for transportation and other regulations, if they are not provided by your licensing authority, is encouraged.

Safety

The following is a helpful quotation on safety from the United States Nuclear Regulatory Commission: "Nuclear gauges are tools like a power saw or a welding torch that may be hazardous unless proper safety precautions are taken. But because the potential harm from radiation is not as obvious as the dangers from a sharp blade or a flame, the safety precautions are not as obvious either. By following a few simple rules you can be assured that working with or around nuclear gauges will pose no threat to your health and safety."

Operator's manual

Study of this manual by each meter operator is recommended to assist in compliance with regulations, safe handling, and proper operation of Seaman Nuclear Corporation meters.

Notes

Model C-200 Equipment List

One Model C-200 or C-200 BP Seaman Nuclear Density Moisture Meter includes the following:

Quantity	Description
1	Molded polyethylene shipping container with polyurethane packaging meeting all I.A.T.A. and U.S.D.O.T. Type A requirements
1	Standard count reference
1	Battery charger
1	Spare 6 volt rechargeable battery
1	Lock with keys
1	Surface preparation plate

Data pack containing:

- Operator's Manual
- Warranty Certificate
- Registration Card
- Calibration Certificate
- Leak Test Certificate
- Special Form Certificates (Americium/Cesium sources only)
- Packaging Evaluation Certificate
- Hazmat training information
- "Caution Radioactive Materials" Sign
- Shipping instructions and materials

Options:

Plastic Concrete Float

220 volt converter for overseas use

Cart

Notes:

1 Description & Capabilities

This chapter describes the meter, its capabilities and theory of operation.

The meter

The Series 200 Density Moisture Meter is a portable surface meter designed to make rapid nondestructive determinations of density and moisture in soils, embankments, sub-base, base, asphaltic concrete, and other construction materials with a density range of 70-170 pounds per cubic foot (PCF), or 1120-2720 kg/m^3, and a moisture range of 0-45 PCF or 0-720 kg/m^3. The three American Society of Testing Materials (ASTM) specifications covering this method are D2922, D2950, and D3017.

Radioactive source and detectors

The radioactive materials used in the Series 200 meter are doubly encapsulated in sealed source capsule(s), and mounted in a shielding mechanism in the bottom center of the meter. The two standard source configurations are described in the table below. To determine the configuration of your meter, check the isotope(s) on your meter serial label.

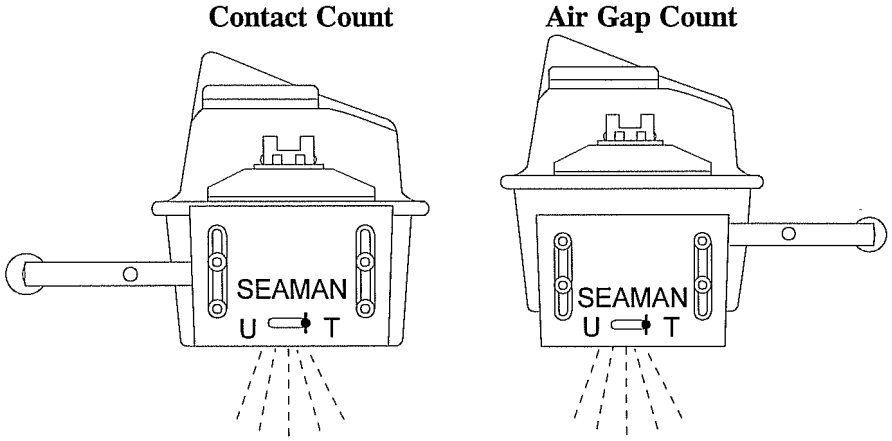
Model C-200 source configuration			
Configuration	**Isotope**	**Quantity**	**Output**
Byproduct	Cs 137	8 mCi	gamma
	Am 241:Be	40 mCi	neutron
or			
NARM	Ra 226:Be	4.5 mCi	gamma & neutron

See the chapter on radiological instructions for information on the licensing requirements in your locale and the definition of terms used in the above table.

A gamma detecting density tube is mounted to the base of the meter on the left side under the battery well (when viewed from the front of the meter). See the figure on the next page and the source shielding diagram in the Appendix. A thermal neutron detecting moisture tube is mounted to the base on the right side.

Air gap ratio density determinations

The Series 200 meters use the air gap backscatter method of density measurement; that is, the density is determined by the ratio of the air gap count to the contact count. The contact count is taken with the base of the meter resting on the surface of the test material, or in the Untouchable mode, approximately ¼"(6 mm) above of the test surface. The air gap count is taken over the same spot with the meter raised 1¾" (45 mm) above the surface.



A brief explanation of the air gap ratio method

CPM is Counts Per Minute. All counts regardless of duration, are expressed in CPM.

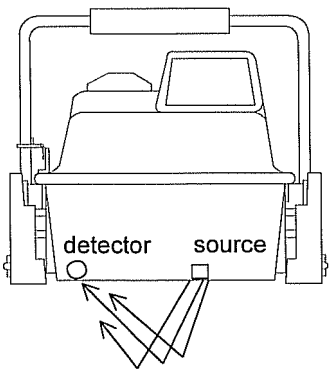
Contact count - the meter reading (CPM) is a function of the material density and it's chemical content.

Air gap count - the meter reading (CPM) is primarily a function of the chemical content of the material. Materials that are of the same chemical type will have similar air gap readings regardless of density.

By dividing the air gap reading by the contact reading, the chemical effect mathematically cancels. The resulting ratio is a function of only material density (see below for more details).

Air gap backscatter theory and background

The meter is placed on the test surface and the material under test is exposed to gamma radiation from the radioactive source.



The Geiger Mueller detector inside the meter measures the amount of gamma radiation reflected, or "scattered back", from the material in terms of counts per minute (CPM).

The greater the density, the greater the absorption of radiation and therefore, the lower the meter reading in CPM.

For testing one particular material, a simple calibration curve for CPM vs. density could be constructed. However, as different types of materials are encountered, this approach presents some difficulties. The reason for this is that certain chemical elements found in soils and aggregates affect the rate that radiation is absorbed or reflected. Therefore, the meter reading is a function of both soil density and the chemical content of the material. Some combinations of elements vary widely in their absorption causing significant testing error.

To overcome this shortcoming of the pure backscatter method of testing, the "Air Gap Ratio" method of calibration was developed.

By dividing the air gap reading by the contact reading, the chemical effect mathematically cancels. The ratio of these two readings produces a single density calibration curve regardless of material type. Therefore, AGR is a function of density only.

$$\text{Air Gap Ratio} = \frac{\text{Air Gap Count}}{\text{Contact Count}} = \frac{\cancel{\text{Chemical Effect}}}{\text{Density} \times \cancel{\text{Chemical Effect}}}$$

Using this method, correlations with conventional tests (sand cone, balloon, and core samples) are improved across a wide range of materials. One factory supplied calibration for density will work for all construction materials from 70-170 PCF (1120-2720 kg/m^3).

Note: All ASTM approved methods for nuclear density testing employ some type of count ratio method to reduce the testing error associated with the nuclear method. A ratio may be developed between a contact density count and a count on a reference standard. This standard count ratio reduces error related to changes in background radiation from that present at calibration, as well as error due to the aging of the detector and source.

Additional benefits of the air gap method

Besides correcting for the chemical composition differences between materials, the air gap method automates the correction of various sources of error that would otherwise result in poor correlation with conventional methods.

Because the air gap reading is taken at each testing location, it can cancel site specific problems not addressed by "count ratio only" methods.

Site specific corrections with air gap ratio (AGR)

Check density directly behind the asphalt paver.

Heat - When testing asphalt, surface temperatures can vary tremendously depending on where measurements are made. The characteristics of the detectors and electronics are affected by these temperature extremes, significantly impairing calibration accuracy. However, using the air gap ratio method, the "heat effect" is the same for the air gap and contact counts and is therefore canceled. AGR is the only test method that provides accurate tests results from directly behind the paver to areas where the asphalt has cooled.

The air gap method simplifies testing because it reduces the number of variables that contribute to test error.

Side effect - since a small amount of radiation is being emitted from the meter on all sides, nearby objects reflect radiation back toward the meter affecting the meter's calibration. With AGR, tests can be taken next to equipment or trench side walls without impairing the meter's density calibration. For a discussion on moisture correction, see trench density in the chapter on meter operation.

Changes in background radiation - In areas of changing radiation levels, such as those involving compaction of uranium mine tailings, the level may change from one test spot to another. AGR provides test spot to test spot correction.

Application of the air gap count

Customers report that on jobs where different materials were used that were not easy to visually identify, the air gap count was monitored to identify which material was being tested and therefore, which Proctor values to use for comparison.

If the shortest possible test time is desired (e.g., between passes of a compactor), the air gap count need not be taken for each density test. If testing conditions are not changing, the corrective function of the air gap count is not required. The best way to determine if test conditions are not changing is to observe the following precautions: First, do not present the meter to varying test conditions (e.g., changes in heat, testing next to a large object, etc.). Second, monitor the air gap count. It should remain within a normal range of variation (about 50 CPM) due to the randomness of the source output. Larger air gap count variations indicate that the air gap counts should continue to be taken at each test.

When air gap counts are skipped, it is good practice to take an air gap reading every 5 tests or so, to insure that it is still within 50 CPM of recent counts.

Moisture measurement

Moisture determinations are based on the neutron moderation principle to detect the amount of hydrogen present. When testing construction materials, it is assumed the hydrogen detected is in the form of free water (H_2O). The radioactive source in the meter emits high speed neutrons. The neutrons have the same atomic weight as a hydrogen atom. When the high speed neutrons encounter hydrogen atoms in the test material (hydrogen being the element that most effectively slows neutrons), the resulting collisions reduce the speed of the neutrons. The neutrons are now called slow speed, or thermal, neutrons. The moisture detector in the meter is sensitive only to slow speed neutrons. Therefore, the greater the moisture count recorded, the greater the amount of moisture (hydrogen) present.

Touchable and Untouchable test modes

In order to provide the best accuracy under varying surface conditions, the Series C-200 meters have two different operating modes:

1) Touchable and 2) Untouchable.

Touchable mode

In the Touchable mode, the contact reading is taken with the meter in direct contact with the surface of the test material. The Touchable mode provides maximum precision or repeatability. It is also known as the "fail-safe" mode because any operator error will always result in too low a density reading. The Touchable mode is normally used for most soil-aggregate mixtures and smooth pavement surfaces.

Untouchable mode

In the Untouchable mode, the "contact" reading is taken with the meter separated from the surface of the test material by a small (approximately ¼ in or 6mm) gap. The Untouchable mode greatly reduces surface preparation requirements on open graded and slightly uneven surfaces. The Untouchable mode is not a "fail-safe" mode of operation since there is one circumstance which can lead to a higher indicated density. This can occur when the test surface is slightly convex. Convex surfaces can easily be identified, see the chapter on surface preparation for more information.

Accudepth

This is a special function that allows accurate density determinations of thin lifts of asphaltic concrete. Accudepth is able to measure lifts as thin as ¾ in (19 mm). This microprocessor-based function has achieved excellent correlation with cores and was awarded a Patent by the U.S. Government.

Accudepth may also be applied to thin layers of concrete, common to bridge deck overlays.

Temperature measurement

The Series C-200 meters are equipped with a probe to measure the temperature of hot asphalt material. The probe can be used to measure temperatures from 32 to 400°F (0 to 204°C) +/- 0.5°F. It contains a thermistor at the tip of a 3/16 in. diameter by 4 in long rugged stainless steel tube. The probe is furnished with a 10 ft cord that plugs into a socket on the front of the C-200.

Insert the tip of the probe into the center of the lift for accurate evaluations.

Experience has shown that conventional infrared surface temperature measurements are adversely affected by various factors such as surface texture or wind and does not provide accurate data regarding test material temperature. For this reason, the C-200 probe is designed to be inserted into the material. In cases where difficulty is encountered with insertion, use the awl supplied with the meter to form a pilot hole into which the probe may be inserted.

Depth of measure

The depth of measurement with nuclear meters of this type, including the C-200, varies with the density of the material and other factors. Density information is obtained from the top 6 inches of material. The material nearest the surface, the upper 3-4 inches, has the greatest influence on the count. Greater densities and higher moisture contents reduce the depth of measure somewhat. Reference ASTM D2922-81 appendix note X 1.4.

Accuracy

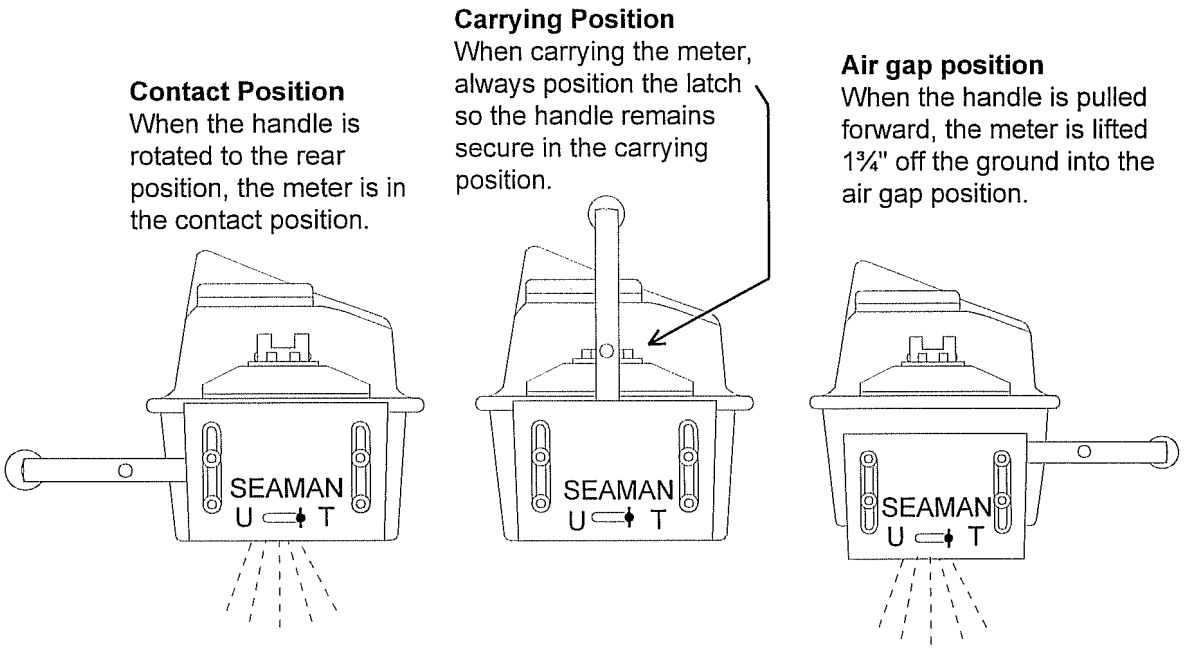
Nuclear methods of density measurement have gained the reputation for a high degree of accuracy. Accuracy, however, depends on which method is being compared to the nuclear. Correlation with the sand cone test in soils should be within 3 PCF; with asphaltic concrete cores, it should be within 2 PCF. Bear in mind that the sand cone test is considered to have a precision (repeatability) of 3 PCF at best. When nuclear methods are compared with conventional coring techniques in asphalt, the correlations are closer since the core test is more precise (repeatable) than the sand cone test.

2 Meter Operation

This chapter explains how to operate the Model C-200 density moisture meter and activate its functions.

Carrying handle

The carrying handle on the C-200 meter controls the radioactive shielding and the test position. When the handle is in the vertical or carrying position, the source is shielded and can be locked for storage or shipment. In both the air gap and contact positions, the source is in the operate position, pointing straight down into the test material.



Safe operation of meter

The following operating precautions should be applied to the use and transportation of nuclear meters. Additionally, all users should study the chapter on Radiological Instructions, particularly, the section "How to minimize your exposure".

In the carrying position

In the carrying position, the source is surrounded by shielding. The radiation level on all sides of the meter, including the bottom, is low. Always shield the source for cleaning, maintenance, storage, or transportation of the meter.

In the operate position

To operate, the source is moved to a position where it is shielded on all sides, except the bottom where the radiation can pass through the cast aluminum base into the test material. Therefore, the radiation level at the bottom of the meter is relatively high, while the radiation level at the sides and top remains low. Keep hands, fingers, and other body parts away from the bottom of the meter when in the operate position.

Maintain a 3 foot distance

When you are not using or carrying the meter stay 3 feet (1 meter) away. Get in the habit of taking a step back from the meter while waiting for a test to finish. When transporting, keep the meter in the rear of the vehicle. If the vehicle is open (e.g., pickup truck), secure the meter with tie downs or other means. Remember, the meter is always emitting some radiation, even when the electronics are not operating.

Never leave your meter unattended.

Never leave the meter unattended at a job site or anywhere else without first locking the source in the shielded position and placing it in a secured area. Unattended meters are the major reason for accidental runovers and theft.

Accident procedures

Familiarize yourself with the "In the event of an accident" procedure in the chapter on radiological instructions.

Keyboard operation & display

The C-200 control panel consists of two pushbutton power control switches, 21 touch key controls, and a liquid crystal display. For reference, a listing of all keys and their definitions called the "Model C-200 Key Function Index" is located at the end of this chapter. An explanation of general keyboard operation follows:

The 2nd F key

Remember:
Black = 1st function,
Green = 2nd function.

Most of the keys on the keyboard have two functions. The prime or first function corresponds to the legends printed in black. Examples are all numbers, "Bulk", and "Start Test". The second or alternate function corresponds to the legends printed in green. Examples are "Enter Lab Density", "% Moisture" and "Top Lift".

The "2nd F" key converts keys to their alternate (green) function. When the "2nd F" key is pressed, an "F" appears in the display, indicating the alternate function mode is activated.

Keys revert to their first function (black letters) after the execution of a second function or after the "Clear" key is pressed.

The Clear key

The "Clear" key is used to clear incorrect entries in the display or end a test cycle in progress. During a test cycle, pressing any other key will have no effect. After pressing the "Clear" key, a small "r" for "ready" will appear in the display, meaning the instrument is now ready to accept instructions. No previously stored data is lost by pressing this key.

Operator Entries and Selections

There are five user entries: time/test, lab density, moisture standard count, base density, and lift thickness. There are three user selections: Touchable/Untouchable mode, english/metric units, and temperature.

Number Entries

Numerical entries, such as "Time/Test" or "Lab Density", are accomplished by:

1. Enter the desired number
2. Depress the "2nd F" key, followed by the appropriate enter key.

Note: If an "enter" function is made without being preceded by a numeric entry, 0 will be entered. For example, the key press sequence "2nd F", "Enter Base Density" will result in a base density of 0.

For example, to enter a lab density of 150, press the numbers 1, 5 and 0 in sequence, then press "2nd F" and "Enter Lab Density" (which is the same key as the numeral 4). The entry may be confirmed by pressing "2nd F" followed by "Display Lab Density" (same key as numeral 5).

Time/test entries should be in whole numbers of seconds. Other numerical entries may be 1 to 4 digits with the decimal placed anywhere.

Power up initialization

When the meter is turned on, it is placed in the following condition:

Time/Test ..... 60 Seconds
Lab Density 0
Base Density (Accudepth) 0
Depth (Accudepth) 0
Contact Count 0
Air Gap Count 0
Moisture Count 0
Units ..... english (metric optional)
Mode ..... Touchable
Moisture Standard Count ..... Factory Preset Count
Density Standard Count ..... Factory Preset Count

Display messages

The C-200 display provides a variety of information to the user regarding instrument status, as well as acknowledging user input. The following is a list of these messages and their meanings:

C-200 Display Messages				
Message	**Meaning**		**Message**	**Meaning**
Sn Axxx	Serial Number Axxx		**no**	An attempt was made to start a test when the source is not in the operate position.
F	Second function operation (green function)			
C	Contact count in progress.		**T**	The acknowledgment for "Touchable" mode entry.
A	Air gap count in progress.			
CF	Contact count finished.		**U**	The acknowledgment for "Untouchable" mode entry.
AF	Air Gap count finished.			
U	Untouchable count in progress.		**P**	The acknowledgment for english units.
UF	Untouchable count finished.		**d**	The acknowledgment for metric units.
Hi	Requested data is greater than the display range (9999).		**r**	Ready symbol. Meter is ready for key entries.
E	Error. This message can result from math errors. For example, a request for % bulk density when no lab density has been entered causes a divide by zero error.		**Lo**	Low battery. This is a high priority message that overwrites all of the above except "C" and "A" (it does overwrite "CF" and "AF").

Units entry: english or metric

The C-200 will accept and display values in either english or metric units. Upon start-up, the meter is initialized in the english mode (metric start-up optional).

To enter the metric mode, press the "2nd F" key and then the "Metric" key. To change to the english mode, press the "2nd F" key twice.

Units			
	Density	**Depth**	**Temperature**
English	Pounds Per Cubic Foot (PCF)	inches	°F
Metric	Kilograms Per Cubic Meter (kg/m^3)	cm	°C

Note: 1 PCF = 16 kg/m^3

Note: The entries of "Lab Density", "Base Density", and "Top Lift Depth" must be in the same system of units for which the meter is currently set.

When in the metric mode, the density can be converted to specific gravity (g/cc) by simply dividing it by 1000.

Test time

For nuclear instrumentation, the random emission of radiation from the source causes some variation in test results even when the meter is not moved. The repeatability of the test, or precision, is improved by increasing the time of the test.

Precision is a function of the square root of the time; that is, to reduce the variation of readings by 1/2, the test time must be increased 4 times. For instance, 4 minute readings vary 1/2 as much as do 1 minute readings and 15 second readings vary twice as much as 1 minute readings.

The meter wakes up with the time of test set to 60 seconds. If another test time is desired, use the following procedure:

1. **Enter the test time in seconds** (whole numbers only). Any time from 1 to 9999 seconds may be entered.
2. **Press the "2nd F" key**. An "F" will appear in the display.
3. **Press the "Enter Time/Test" key** and the number in the display will be stored in memory. An "r" will appear, indicating the microprocessor is ready for other key entries.
4. Verify the test time by pressing the "2nd F" key and then the "Display Time/Test" key.

Standard count reference

Each C-200 meter is supplied with a matched, serial numbered standard count reference. It consists of a solid block of Benelex or polyethylene and a lead plate mounted in a metal frame on 6 inch legs. Benelex and polyethylene are rich in hydrogen and serve as known and unchanging standards for moisture. The lead serves the same purpose for density.

The standard count reference is used to: (a) check meter functioning, and (b) adjust the moisture calibration to compensate for aging of the detector and moisture side effect when testing in trenches.

Daily test

Daily standard counts are recommended to check meter functioning and adjust moisture calibration. (Asphalt-only users may substitute with tests at their density reference spot.)

For a daily test, center the meter on the standard count reference. Take a four minute reading, or a series of (4) one minute readings (average the 4 readings). Maintain a log of standard count tests. Compare the contact and moisture counts to the factory set density and moisture standard counts permanently stored in the microprocessor's memory. The daily average moisture count should be noted and entered into the moisture standard count memory.

Location of test

The tests should be performed with the meter and standard count reference on a concrete floor, or on ground, with a minimum density of 120 PCF, at least 4 feet (1.5 m) from any wall or other large objects, and 30 ft (10 m) from any other nuclear meters.

Standard count test procedure

1. **Center the meter on the standard count reference**.
2. **Turn the meter on**. The serial number will appear in the display.
3. **Rotate the handle to the rear position** and **press the "Start Test" key**. A "C" will appear in the display, indicating that a 60 second contact count is in progress. A "CF" will appear when the test is finished.
4. **Press the "Contact Count" key to display measurement on standard count reference.** Record this for later use.
5. **Compare the contact count measured with the density standard count stored in memory**. To display the density standard count:
   A. Press the "2nd F" key. An "F" will appear in the display.
   B. Press the "Density Standard Count" key. A factory set density count value will appear in the display.
   C. The contact count from Step 4 should be the same as the **density standard count +/- 300 CPM**.
6. **Press the "Moisture Count" key to display the measurement on the standard count reference. Record this count for later use.**
7. **Compare the moisture count measured with the moisture standard count**. To display the moisture standard count:
   A. Press the "2nd F" key. An "F" will appear in the display.
   B. Press the "Moisture Standard Count" key. A factory set moisture count value will appear in the display.
   C. The moisture count from Step 6 should be the same as the **moisture standard count +/- 40 CPM**.
8. **Enter the daily count obtained from the reference standard in the moisture standard count memory**. The count entered should be the result of at least (1) four minute test or the average of (4) one minute tests.
   A. Enter moisture count in the display by pressing the numbers on the keyboard.
   B. Press the "2nd F" key. An "F" will appear in the display.
   C. Press the "Enter Moisture STD Count" key. The number in the display will be stored in memory. An "r" will then appear in the display.
   D. To verify the entry, press the "2nd F" key and then the "Display Moisture STD Count" key.
9. **If the meter is turned off and used later in the day, reenter the moisture standard count as done in step 8.**

D. To verify the entry, press the "2nd F" key and then the "Display Moisture STD Count" key.

9. **If the meter is turned off and used later in the day, reenter the moisture standard count as done in step 8.**

When results are outside of tolerances

Sudden changes

If the moisture standard counts become erratic or change suddenly by 20%, see the chapter on maintenance and troubleshooting.

Density standard count

There is no provision or need to alter the density standard count. If the density standard counts are outside of the tolerance, see the section "Density/moisture reference spot" in the chapter on maintenance and troubleshooting.

Temperature measurement

To display the temperature:

1. **Insert the plug** at the end of the probe cable into the socket on the front of the C-200.
2. **Press the "2nd F" key and then the "Temperature" key.**
3. **To exit the temperature mode, press the "Clear" key.**

The temperature of the material is displayed in either °F or °C depending on whether the system is set to english or metric display mode.

Test mode entry: Touchable & Untouchable

The meter is initialized in the Touchable mode upon start-up. To set the meter in the Untouchable mode:

1. **Set the side plates to Untouchable** by rotating the carrying handle forward into the air gap position and moving the black slide lever knob on each side plate to the "U" position.
2. **Set the keyboard to Untouchable** by pressing the "2nd F" key and then the "Untouchable" key.

If the slide levers and mode are not synchronized, the resulting density readings will be in error by as much as 15-25 PCF.

Upon completion of these two steps, the meter is in the Untouchable mode. Tests may be performed in the normal manner (e.g., with air gap and contact counts).

When testing in the Untouchable mode, the display will indicate "CU" and "AU" for contact and air gap counts respectively.

Asphalt density test procedure

1. **Turn the meter on**. The serial number will appear in the display.
2. **Position the meter on a flat part of the surface to be tested, without large surface voids**. Press opposite corners to verify that the meter is properly seated. Even a slight rocking may lead to low density results. On soft material, for instance, directly behind the paver, position the meter carefully in the air gap mode so the end plates do not sink in.
3. **Check the side plates to verify that the black knobs are in the desired mode**. The knobs may be moved easily when the carrying handle is rotated forward into the air gap position.
4. **If a test time other than 60 seconds is desired, enter the test length in seconds into the memory**. (See Test Time for details)
5. **If display of density as % Marshall is desired, enter the Marshall value into the lab density memory**.
   A. Enter the lab density in PCF in the display by pressing the numbers on the keyboard in sequence.
   B. Press the "2nd F" key. An "F" will appear in the display.
   C. Press the "Enter Lab Density" key. The number in the display will be stored in memory. An "r" will then appear in the display.
   D. To verify the lab density entry, press the "2nd F" key and then the "Display Lab Density" key.
6. **Rotate the handle to the rear position press the "Start Test" key**. A "C" will appear in the display indicating a contact test in progress. A "CF" will appear when the test is finished.
7. **Rotate the handle to the forward position press the "Start Test" key**. An "A" will appear in the display, indicating an air gap test in progress. An "AF" will appear when the test is finished. Both air gap and contact count memories now contain the test data necessary to obtain results.
8. **To display density in PCF, press the "Bulk Density" key**.
9. **To display density as a % of Marshall, press the "% Bulk Density" key** for the actual density as a percent of Marshall. If the display shows "E", no lab density was entered, see step 5 above.

Percent air void determination

The Seaman Nuclear C-200 can also be used to determine the percent air voids in asphaltic concrete, provided that the zero air void density is known. (This is not the same as Marshall density.)

For asphaltic concrete, the zero air void density can be determined using ASTM D2041, "Theoretical Maximum Specific Gravity of

Bituminous Paving Mixtures". This specification includes a short version of the test called the Rice Method.

Test procedure

To determine the percent air voids of the material under test, use the following procedure:

1. **Enter the zero air void density into the "Lab Density"** just as with Proctor or Marshall densities.
2. **Conduct a density test** by taking contact and air gap counts.
3. **Press "% Bulk"** to display the measured density as a percent of Lab Density.
4. **Subtract this number from 100% to find the % air voids**. EXAMPLE: % Bulk gives a display of 94.0%. The % air void will then be 100% – 94% = 6%.

Entering lab density as specific gravity

In some districts the lab density (Marshall) of bituminous paving mixtures is given in terms of specific gravity (density of mixture / density of water). The C-200 can convert specific gravity to PCF. The metric density units of the C-200 (Kg/M^3) are 1000 times the specific gravity.

Conversion procedure

1. Place the C-200 in the metric mode.
2. Mentally multiply the lab density value (e.g., 2.423 by 1000, giving 2423).
3. Enter this value (2423) as lab density.
4. Place the C-200 in the english mode.
5. To observe the lab density, now converted to english units, press "2nd F" and "Lab Density Display". This example shows 151.2 PCF.

Top lift asphalt density test

To measure top lift density, it is necessary to first determine the density of the underlying base material and the thickness of the top lift. The base can be either soil, asphalt or concrete.

Determine base density

Measure the bulk density of the base by conducting a density test. Identify the location of the test area. For best results, this should be an average of several readings representative of the test area.

If it is impractical to measure the base density prior to placing the top lift, use the specified density of the base (Marshall or wet density).

Determine top lift thickness

After a section of the top lift has been laid and compacted, determine the lift thickness to the closest 0.1 in (3 mm). The awl provided with the meter will facilitate the thickness measurement. For a badly grooved base, the top lift thickness will be greater in the wheel tracks.

Procedure

1. **Turn the meter on**. The serial number will appear in the display.
2. **Place the C-200 in position for the test. Check flatness of surface (meter should not rock)**.
3. **Enter the density of the base material** in PCF (kg/m^3) into the base density memory.
   A. Enter previously determined base density into the display by pressing the numbers on the keyboard in sequence.
   B. Press the "2nd F" key. An "F" will appear in the display.
   C. Press the "Enter Base Density" key. The numbers in the display will be stored memory. An "r" will appear in the display, indicating the microprocessor is ready for other key entries.
   D. To verify the base density entry, press the "2nd F" key and then the "Display Base Density" key.
4. **Enter the top lift thickness** measured in decimal inches (cm) into the memory. For instance, enter 1¾ in as 1.75 in.
   A. Enter the desired top lift thickness into the display.
   B. Press the "2nd F" key and then the "Enter Depth" key.
   C. To verify the top lift thickness entry, press the "2nd F" key and then the "Display Depth" key.
5. **If a test time other than 60 seconds is desired, enter the test length in seconds into the memory**. (See Test Time for details)
6. **If a comparison is to be made with Marshall or test strip density, enter this value into the lab density memory**.
   A. Enter the desired lab density into the display.
   B. Press the "2nd F" key and then the "Enter Lab Density" key.
   C. To verify the lab density entry, press the "2nd F" key and then the "Display Lab Density" key.
7. **Rotate the handle to the rear position and press the "Start Test" key**. A "C" will appear in the display, indicating a contact

test in progress. A "CF" will appear in the display when the test is finished.

8. **Rotate the handle to the forward position and press the "Start Test" key**. An "A" will appear in the display, indicating an air gap test in progress. An "AF" will appear when the test is finished. All memories now contain the test data necessary to obtain results.
9. **To display the bulk density in PCF, press the "Bulk Density" key**.
10. **To display the top lift density in PCF, press the "Top Lift Density" key**.
11. **To display density as a % of Marshall, press the "% Top Lift Density" key** for the actual density as a percent of Marshall. If the display shows "E", lab density was not entered, see step 6 above.

When should Accudepth be used?

The use of Accudepth in measuring asphalt density will make a significant correction when the difference between base and top lift density is more than 10 PCF (160 kg/m^3) and when the thickness of the top lift is less than 2 in (5 cm).

In other circumstances, top lift density can be compared to the standard full depth bulk density to observe the amount of correction provided by Accudepth. One can never go wrong using Accudepth. The worst that can happen is that the amount of this correction will be very small.

Soil density test procedure

1. **Turn the meter on**. The serial number will appear in the display.
2. **Prepare a flat, smooth test surface for the meter**. Surface voids may be filled with native fine material (see Chapter 3: Filler Material). Place the meter on the test surface. Press on opposite corners to assure that the meter is properly seated, not rocking.
3. **Check the side plates to verify that the black knobs are in the desired mode**. The knobs may be moved easily when the carrying handle is rotated forward into the air gap position.
4. **If a test time other than 60 seconds is desired**, enter the test length in seconds into the memory. (See Test Time for details)
5. **If display of density as % Proctor is desired, enter the Proctor value into the lab density memory**.
   A. Enter the lab density in PCF into the display by pressing the numbers on the keyboard in sequence.
   B. Press the "2nd F" key. An "F" will appear in the display.

C. Press the "Enter Lab Density" key and the number in the display will be stored in memory. An "r" will then appear in the display.

D. To verify the lab density entry, press the "2nd "F" key and then the "Display Lab Density" key.

6. **Rotate the handle to the rear position and press the "Start Test" key**. A "C" will appear in the display, indicating a contact test in progress. A "CF" will appear when the test is finished.

7. **Move the handle to the forward position and press the "Start Test" key**. An "A" will appear in the display, indicating an air gap test in progress. An "AF" will appear when the test is finished. Both air gap and contact count memories now contain the test data necessary to obtain results.

8. **To display bulk density in PCF, press the "Bulk Density" key**.

9. **To display the moisture (water) content in PCF**, press the "Moisture" key.

10. **To display the dry density of the soil** (bulk density - moisture density) in PCF, press the "2nd F" key and then the "Dry Density" key.

11. **To display the moisture as a % of the dry density**, press the "2nd F" key and then the "% Moisture" key.

12. **To display density as a % of Proctor , press the "% Dry Density" key** for the actual density as a percent of Proctor. If the display shows "E", lab density was not entered, see step 5 above.

Trench density (moisture side effect) procedure

To minimize the effect of the trench side wall, place the meter so the moisture detector, which is located on the right side of the meter, is furthest from the side wall.

To determine if the side wall is affecting the moisture calibration, and to correct for this condition, do the following:

1. **Turn the meter on**. The serial number will appear in the display.

2. The meter "wakes up" with a factory installed moisture standard count in the memory. The operator should note this count using the following steps:

   A. Press the "2nd F" key. An "F" will appear in the display.

   B. Press the "Display Moisture Standard Count" key. The moisture standard count is used by the microprocessor for all routine testing. If there is a moisture influence from a trench

side wall or a nearby (18 in. or less) building wall, a new moisture standard count must be used.

3. **Place the meter squarely on the standard count reference** in the trench where a density moisture measurement is needed. The trench must be at least 18 in. deep.
4. **Rotate the handle to the rear position and press the "Start Test" key**. A "C" will appear in the display, indicating a contact test in progress. A "CF" will appear when the test is finished.
5. **Press the "Moisture Count" key and note the counts per minute (CPM) displayed.** The value will be higher than the factory installed moisture standard count normally obtained on the standard count reference due to the influence of moisture in the side wall.
6. **Enter the new moisture count into the moisture standard count memory**.
   A. Enter the new moisture count in the display by pressing the numbers on the keyboard in sequence.
   B. Press the "2nd F" key. An "F" will appear in the display.
   C. Press the "Enter Moisture Standard Count" key. The number in the display will be stored in memory and used by the microprocessor when determining moisture until the meter is turned off or the operator changes the value. An "r" will appear in the display.
   D. To verify the entry of the new moisture standard count, press the "2nd F" key and then the "Display Moisture Standard Count" key.

   Note: The new moisture standard count is valid only at the distance from the side wall at which the meter was placed on the standard count reference. New moisture standard counts must be obtained and used for other distances between the meter and the side wall.
7. **Remove the standard count reference and place the meter on a properly prepared test surface. Proceed with a routine (air gap and contact) test.** All test results will now show accurate density/moisture information of the test area below the meter.
8. **For normal testing, reenter the factory installed moisture standard count** noted in Step 2 by following Step 6. Alternately, the meter may be turned off and on. The factory installed moisture standard count should be used routinely unless there is side wall moisture influence.

Another method to determine moisture side effect is to note the difference between the nuclear moisture and a conventional oven dried

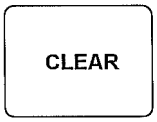
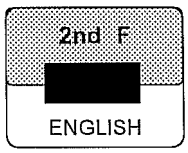
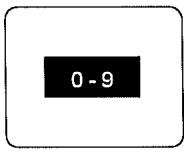
moisture test. Then correct the nuclear readings accordingly. Wet (bulk) density is unaffected by trench side effect since any error is canceled out by the Air Gap Ratio method.

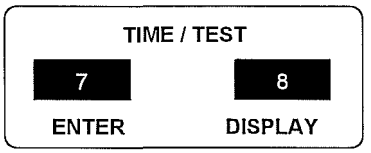
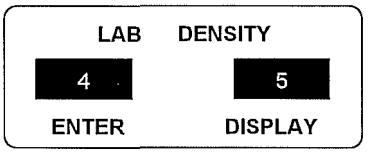
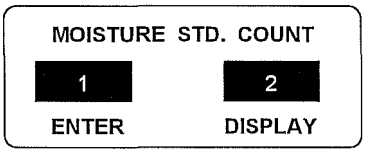
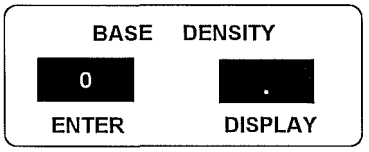
Model C-200 Key Function Index

The key function index provides a brief description of each key's function on the C-200 keyboard with a cross reference to other parts of the manual for further information.

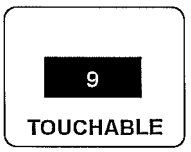
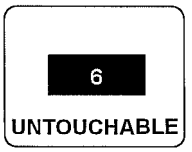
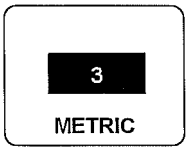
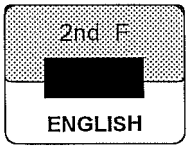
Please note the **2nd F**unction key. It selects the alternate function of a key shown in ***green*** letters on the keys with this feature. For instance, to select a function described in green on a key, first depress the "2nd F" key and then the desired key. Its function is similar to the second function key on a calculator.

The description refers to the function of a key(s) and comments refer to the key(s) usage.

Keys	Description	Comment / Use
	• Stops test in progress. • Clears display.	• Eliminates incorrect entries into the display.
	• 2nd function key. • Activates the alternate function mode.	• Selects the alternate function printed in green lettering on the touch key panel.
	• There are ten, numeric, first function keys (0-9) and a decimal point key (all shown on the next page). • Displays a number for entry into memory.	• For number entries.

First Column Keys	Description	Comment / Use
2nd F + 	• Enters or displays the duration of the test period in seconds.	• To change the test time from the standard 60 seconds.
2nd F + 	• Enters or displays the lab density value in memory.	• % bulk, & dry , and % top lift calculations.
2nd F + 	• Enters or displays the moisture standard count. • Note: If an operator-entered number differs from the factory supplied value, the moisture calibration will be changed.	• Standard count tests. • Trench tests. • Adjust moisture calibration.
2nd F + 	• Enters or displays the base density.	• Top lift density tests.

Second Column Keys

2nd F + 	• Returns the meter's operation to the touchable mode. • Note: Slide levers on side plates must be in "T" position.	• Touchable mode tests.
2nd F + 	• Changes the meter's operation to the untouchable mode. • Note: Slide levers on side plates must be in "U" position.	• Untouchable mode tests. • See "Test mode entry" in the chapter on meter operation.
2nd F + 	• Changes the meter's mode of operation to the Metric system. • Renders density and moisture in kg/m^3, depth in centimeters, and temperature in degrees C.	• To obtain specific gravity.
2nd F + 	• Changes the meter's mode of operation to the english system. • Renders density and moisture in lbs/ft^3, depth in inches, and temperature in degrees F.	• Key is pressed twice to activate.

	Third Column Keys	Description	Comment / Use
	CONTACT **COUNT** AIR GAP	• Displays the density count obtained in the contact position after test is finished.	• Standard count tests.
2nd F +	CONTACT **COUNT** **AIR GAP**	• Displays the density count obtained in the air gap position after test is finished.	• Illustrates the magnitude of the chemical effect. • Assists in identifying when the Proctor lab density has changed.
	MOISTURE **COUNT** DENSITY STD.	• Displays the moisture count obtained in the contact position after test is finished.	• Standard count tests. • Trench density test.
2nd F +	MOISTURE **COUNT** **DENSITY STD.**	• Displays the factory-programmed density standard count.	• Standard count tests.
	MOISTURE [■] % MOIST.	• Calculates and displays moisture in lbs/ft^3 or kg/m^3. • Note: Test count must first be obtained in the contact position.	• Soil density/moisture test.
2nd F +	MOISTURE [■] **% MOIST.**	• Calculates and displays moisture as a percentage of dry density. • Note: Test counts must first be obtained in the contact and air gap positions.	• Soil density/moisture test. $\%\ \text{Moisture} = \frac{\text{Moisture}}{\text{Dry Density}} \times 100$
	DISPLAY **DEPTH** ENTER	• Displays user entered top lift thickness in memory.	• For top lift and % top lift calculations. • To determine lop lift density (Accudepth).
2nd F +	DISPLAY **DEPTH** **ENTER**	• Puts user's lift thickness into memory. • Note: Thickness in inches or centimeters must first be entered from the keyboard.	• To determine top lift density (Accudepth).

Fourth Column Keys	Description	Comment / Use
START TEST / TEMP.	• Begins test counts for density and moisture in air gap or contact position.	• Asphalt and soil tests.
2nd F + START TEST / TEMP.	• Displays temperature measured by the temperature probe in °F or °C.	• Asphalt temperature measurement.
BULK / DENSITY / DRY	• Calculates and displays wet density in lbs/ft^3 or kg/m^3. • Note: Test counts must first be obtained in the contact and air gap positions.	• Density tests.
2nd F + BULK / DENSITY / DRY	• Calculates and displays dry density in lbs/ft^3 or kg/m^3. • Note: Test counts must first be obtained in the contact and air gap positions.	• Density tests.
% BULK / DENSITY / % DRY	• Calculates and displays bulk density as a percentage of lab density. • Lab density must be entered. • Note: Test counts must first be obtained in the contact and air gap positions.	• Density and moisture tests. $\%\ \text{Bulk Density} = \frac{\text{Bulk Density}}{\text{Lab Density}} \times 100$
2nd F + % BULK / DENSITY / % DRY	• Calculates and displays dry density as a percentage of lab density. • Lab density must be entered. • Note: Test counts must first be obtained in the contact and air gap positions.	• Soil density/moisture test. $\%\ \text{Dry Density} = \frac{\text{Dry Density}}{\text{Lab Density}} \times 100$
TOP LIFT / DENSITY / % TOP LIFT	• Calculates and displays top lift density in lbs/ft^3 or kg/m^3. • Base density & depth must be entered. • Note: Test counts must first be obtained in the contact and air gap positions.	• Top lift density test.
2nd F + TOP LIFT / DENSITY / % TOP LIFT	• Calculates and displays top lift as a percentage of lab density. • Base density & depth must be entered. • Note: Test counts must first be obtained in the contact and air gap positions.	• Top lift density test. $\%\ \text{Top Lift} = \frac{\text{Top Lift Density}}{\text{Lab Density}} \times 100$

3 Surface Preparation

It is the operator's responsibility to present a representative sample for the meter to test. To obtain consistent and accurate readings, intimate contact between the bottom of the meter and the test material is important. If any air gap exists below the meter, radiation may "short-circuit" from the source to the detector tube, resulting in too low a density reading. The meter operates in the fail-safe mode; that is, any operator error in surface preparation will result in too low a density reading. Inadequate surface preparation will result in obviously low (by 6-10 PCF) density readings. Surface preparation errors never result in small density variations of 1-2 PCF. Factory calibration does compensate for slight surface irregularities. It is good initial experience to note the various degrees of surface roughness that cause the meter to read too low a density.

Always remember that the calibration of the meter in the Touchable mode is such that it cannot read too high a density. Operator error always manifests itself in too low a density reading. Improper seating, not presenting a representative sample, not cutting in deep enough, and too much or not enough filler material are all conditions resulting in too low a density reading.

Surfaces that have air dried or developed shrinkage cracks and other voids are not acceptable for testing. Extra surface preparation of the material is necessary if accurate and consistent readings are to be taken on surfaces with cracks and voids. Therefore, two important points to remember are:

1. Test during or immediately after the compaction process.
2. Attempt to conduct tests while representative moisture is present in the test material.

It is impossible to obtain reliable readings when testing concave surfaces. Even if the meter does not rock (all four corners of the meter sitting solidly on the test surface), an air gap may exist at the sensitive (center) area. Any tools (flat nosed shovel, tamping plate, etc.) that are used to prepare the surface must be used in a manner that will avoid concaveness. Convex surfaces, however, may be tested by locating the sensitive area of the meter directly over the mound. The sensitive area is that between the source (center) and the left side of the meter. To test surfaces compacted with pneumatic rubber tired rollers: test on the ridges, avoid the wheel tracks.

Touchable and Untouchable

New meter operators should be trained in using only the Touchable mode. The Touchable mode is fail-safe; that is, any surface preparation errors will result in too low a density reading. This mode is self teaching as to the proper amount and type of surface preparation required at a given test site. If surface preparation is inadequate for a given situation, the operator should notice that the meter will produce density readings that are low by 6-10 PCF or more. Only Seaman Nuclear meters operate in such a manner that the meter reading is either right on the expected density reading or it is low by an obvious amount.

When the operator masters the Touchable mode, it will be obvious that the test surface must also be flat when testing in the optional Untouchable mode. Concave or convex surfaces will alter the 1/4 in. air gap between the base of the meter and the test surface, producing an erroneously high or low density reading. In the Untouchable mode, the test surface must be representative and flat, but does not have to be smooth. Surfaces with air voids are acceptable and filler material is generally not necessary. As a result, the Untouchable mode may be 2 to 3 times quicker per test than the Touchable mode. The Untouchable mode may be particularly useful when testing open-graded surfaces or wet concrete overlays.

Surface preparation hand tools

When performing tests with the meter on soils, little or no surface preparation is necessary if testing is done during or immediately after compaction. If testing is not done at this time or if tests are to be conducted on sheep footed material, the operator must cut into the material to reach a representative test sample. The preferred method for cutting to reach a representative sample is to scrape off the overlying material with a dozer or blade. If a dozer is not available for this purpose, surface preparation with various hand tools is required.

Typical surface preparation hand tools are the flat nosed shovel, tamping plate, and draw knife. Each tool must be used in the proper manner as described in the following paragraphs.

Flat nosed shovels are not flat. They often leave a concave surface in the test material and should only be used to rough in the surface. It is essential that the shovel be used in one direction and, then, perpendicular to the former direction to avoid concaveness. The prepared surface area should be at least two feet square to allow for selection of the best test surface spot and to avoid side effects.

After shoveling, the tamping plate is used to remove any surface concaveness and to compact any loose surface material. Careless use of

the tamping plate can cause concave surfaces. Cut in only one direction. Do not use the plate in a fore and aft motion, as this may produce a concave surface.

The last action with the plate should be a hard, vertical tamping to knock down any loose material rolled up by soil shearing. To avoid developing a concave surface from tamping, first tamp at the perimeter of the test site, followed by tamping at the middle of the test site.

A plain carpenter's draw knife can often be used in plastic materials in lieu of a shovel. Cut in one direction and then perpendicular to that direction. Finish with vertical tamping with the plate.

Native filler material

When testing open graded or air dried surfaces, native filler material may be required to fill in surface voids. Radiation leakage between the source and the density detector tube is thus eliminated. Only use native filler material, or fines, of the same material that is being tested. Native fines must be used or the air gap (chemical) reading will be defeated.

Fines should be added to the test surface in the form of a wet slurry. Use only enough fines to fill surface voids. Do not make a complete bed of fines for the meter. If it is not evident how many fines are required, a series of density tests must be run. First, take a density reading with no fines added. Then, add a little of the fine material, tamping or spinning (with a circular motion of the tamping plate) the slurry mix into place. Take a second density reading. Continue this process until the density readings peak and then drop. The highest density reading is obtained when the proper amount of fines have been added. The trial and error technique is required only until the new operator gains some experience.

The tamping plate should always be used to pack the fines in place. The force exerted when tamping the fines in place will not increase the density of the underlying material. In some materials, such as binder or open-graded bituminous mixes, spinning the plate on the surface will "glaze" the fines in place, making a perfect test surface. Native fines for asphalt may be obtained from the asphalt plant in the form of mineral filler.

The use of water

Through experience, water has proven to be a valuable aid in surface preparation. Water may be added to the test surface to fill in shrinkage cracks due to surface air drying or when testing on coarse granular materials. The use of water is only an intermediate step in surface preparation, immediately preceding the use of native filler material. The addition of water to the surface will not significantly change the

density or moisture at the test site. Reported moisture increases are 1/2 to 1 PCF. Regardless of the reported moisture increased, the dry density remains unchanged.

The addition of water is canceled out for dry density results. If the actual moisture content is required, take a moisture reading prior to the addition of water to the surface and use this moisture with the dry density for calculating percent moisture.

If very precise moisture and dry density values are desired, take a moisture reading in PCF before adding any water to the test surface. Then, add a couple of cups of water and take a bulk density test. To obtain the dry density, subtract the moisture value obtained above from the bulk density reading.

Side effect

Side effect occurs because the meter is not only radiating through the bottom but also through the sides. An erroneous reading is generated because the meter calibration assumes no radiation is coming back through the sides of the unit. Side wall influences will affect only the moisture reading, not the bulk density reading.

Accurate moisture and dry density readings are possible if the meter is six inches away from the side wall, bridge abutment, etc. The six inch figure is not absolute, however, because it depends on the differential in density and soil chemistry between the side wall and the test material. If the difference between the two materials is large, the distance must be increased.

In determining how far the meter should be away from the side wall, remember that any side effect will increase the moisture reading and lower the dry density reading. A series of contact tests must be performed. Place the meter next to the side wall and take a dry density reading. Next, move the meter one inch away from the side wall and take another dry density reading. Continue moving the meter away from the side wall, taking dry density readings at each location. When the highest dry density reading is obtained, side effect is nonexistent.

Test procedures for various materials

Listed below are suggested procedures for performing nuclear tests on various types of materials. Through experience, the procedures listed below have been found to be feasible, accurate, and fast.

Plastic materials

On plastic material such as clay, sheepsfoot or segmented rollers are often used. With these types of impact rollers, the highest density appears below the foot or pad. Therefore, to reach a representative test

sample, it is necessary to cut in at least one inch below the deepest penetration of the sheepsfoot on the last pass. If the cut is not deep enough, "pock" marks (the size of the sheepsfoot) will be evident and a deeper cut will be necessary.

Watch for transverse stretch cracks from blading. These cracks occur because the moldboard blade is rolled backward instead of forward when cutting into the test material. When stretch cracks are encountered, position the meter transverse to the stretch cracks; that is, position the meter so that the handle (and therefore the line between the source and detector) is perpendicular to the cracks. If the meter is positioned parallel to the cracks, radiation will short-circuit down the channel of the crack without penetrating the soil.

Sandy materials

As materials (such as sands) approach lower and lower optimum moistures, surface air drying problems increase. Therefore, it is important to test sandy materials immediately after the compaction process and before surface air drying occurs. If surface air drying is evident, pour a couple of cups of water on the test surface prior to testing.

Because vibratory compactors are often used on sandy materials, one important characteristic of this combination should be noted. While most compactors will produce a positive density gradient (higher density at the top than at the bottom of the lift) in most materials, vibratory compactors may produce a negative density gradient in sandy materials. To determine whether or not a negative density gradient exists, apply the trial and error procedure explained earlier, remembering that the meter cannot read too high a density. Take an initial density reading at the surface. Take further tests digging deeper into the lift until the highest density reading is obtained. This will be the representative sample that will correlate with the conventional test taken from the top.

Granular materials

Special care must be exercised when testing aggregate base materials. Dense graded aggregates and ungraded aggregates have low optimum moisture contents (as low as 4%). Surface air drying occurs rapidly. Normally, there is no problem if the test is made during or immediately after the compaction process. This is the ideal time to test because no additional surface preparation is necessary. The surface moisture is still present and construction traffic has not eroded away the surface fines.

If testing cannot be performed during or immediately after the compaction process, a "too low" density reading may be indicated by the meter. This occurs because the top one inch (or more) has air dried and the surface fines have been eroded away, leaving a surface of pointed stones with air voids. Surface cracking may also be present. In normal soils, the technique to obtain a representative sample would be to cut in an inch or two until a darker color, evidence of moisture, is apparent. Unfortunately, in base aggregates, any attempt to cut in unravels the underlying material, making it difficult to get a representative sample for wet density.

The base material may be tested without any surface disturbance as follows:

1. Use the tamping plate to flatten the test surface and to drive any protruding stones into the base. The surface does not have to be smooth, but it does have to be flat. Check with the edge of the tamping plate for flatness in two directions. Avoid concave surfaces.
2. To test in the Touchable mode, use fines to fill the surface voids. The fines (minus No.8) should be of the material being tested. If the surface is very dry, apply 3-4 cups of water to the surface before the use of fines. Wet the fines with more water to make a slurry and the tamp/spin into place with the tamping plate.
3. Testing in the Untouchable mode is generally recommended. In this mode, the meter is suspended 1/4 in. above the test material and averages out any variances such as protruding stones or voids up to 1/4 in. In most cases, the use of native fines is eliminated. Add 3-4 cups of water to the test surface immediately before testing.

Bituminous concrete

Generally, no surface preparation is required if the operator is selective in choosing a test site. Again, test during or immediately after compaction if at all possible. On binder and open graded surfaces, use the Untouchable mode. On fine surface courses, the Touchable mode may be used. Both pneumatic rollers and some pavers can produce longitudinal ridges that can allow an air gap to exist beneath the meter. Every effort should be made to test the ridged area and not the concave area between. A 12 in. straight edge is an effective tool for locating ridges.

Trench compaction

Generally, any trench 24 in or more wide will produce accurate results for both density and moisture. Trenches as narrow as 18 in wide can be tested provided the side effect is compensated for. Take a two minute contact test on the standard count reference in the trench. Enter the

average moisture count from these tests as the new moisture standard count. Side wall effect is thus eliminated. Proceed with any necessary surface preparation and testing. See Chapter on Meter Operation.

High / low density moisture readings

There are a number of conditions that may cause the meter to indicate a density or moisture reading that is too high or too low. Each situation is discussed below, with references to a more detailed surface preparation discussion found elsewhere in the manual.

Radiation always travels along the path of least resistance. Therefore, if air gaps exist between the base of the meter and the ground surface, the radiation emitted from the meter will "short-circuit" across the air gap and be counted by the detector rather than penetrating the test material. The meter density reading produced under this condition will be too low. Here are some of these conditions:

Surface Air Voids

These may occur where there is material gradation or when surface air drying and shrinkage cracks develop. To minimize the effect due to shrinkage or "stretch" cracks, make sure to position the meter with the handle perpendicular to the cracks. Native filler material or water may be used in various situations to solve the problem.

Surface Not Flat

Additional surface preparation with various tools is necessary in this situation. A flat nosed shovel, draw knife, and tamping plate may be used. Refer to the section in this manual entitled "Surface Preparation" for more detailed information on the proper use of hand tools. In heavy, cohesive subgrade material, a road grader or dozer might be used to make a flat cut.

Surface air drying

If testing is not done during or immediately following the compaction process, representative moisture may not be present in the test material. Therefore, it is necessary to dig down to reach a sample in the test material that has representative moisture. Generally, these materials will be darker in color when representative moisture is present.

Side effect

When testing near side walls, care must be exercised so as to eliminate the side wall effect on moisture readings, which will also affect the dry density. To correct, use the standard count reference and corrected Moisture Standard Count. See Chapter on Meter Operation.

Filler material

Native filler material can be used to fill in surface voids, thereby increasing the operating range of the meter. Caution must be exercised, however, to use the proper amount of filler. Too much or too little filler material can lead to low density readings. Filler material must be used in the form of a wet slurry. Dry fines are not adequate. Refer to the "Surface Preparation" section in the manual for further information.

Always remember that the calibration of the meter is such that any operator error will result in too low a density (except when improperly used in the Untouchable mode). To prevent penalties resulting from under compaction, it is preferable that any errors be on the low side.

Moisture correction

The moisture calibration is the result of years of correlation with known moisture standards and conventional test results, and will provide accurate results for the majority of materials encountered. For operation in unusual conditions however, adjustments to this calibration may be made when conventional tests show it is needed. For example, the presence of iron oxide, boron or salt will cause low moisture readings, and organic material will cause a high moisture reading.

The factory set moisture standard count may be altered to compensate for this condition. One oven-dried test sample must be run first to determine the true % moisture of the test material. Convert the % moisture value to a moisture value expressed in PCF (refer to the "% Moisture" key in the Key Function Index for the calculation). Then, place the meter on the material on site and take a moisture reading in PCF. If the reading is too high, enter a higher moisture standard count into the memory (and vice versa). Then re-check the moisture reading. Continue changing the moisture standard count, and hence, the moisture reading, until the moisture reading from the meter equals the value obtained from the oven-dried sample.

Note: Once the moisture standard count is changed, the factory calibration value is no longer available from the front panel. To restore operation to the factory calibration value, either turn the instrument off and then back on or manually enter the original factory number. It may be a good idea to make a note of this number to permit entry without having to turn the meter off and then on.

Moisture reading errors

A moisture reading that is too low may be indicated by the meter when the soil under test has a high iron or carbon (or, rarely, lead) content. Negative moisture readings may also occur when a reading is taken on materials where the moisture content is extremely low. An example of this is the metal floor of a trailer.

The meter may indicate an erroneously high moisture (water) reading when the soil under test contains sources of hydrogen other than water. Organic material, asphalt chips, or any hydrocarbons all contain hydrogen. Because the meter detects moisture by counting slow speed neutrons, which have the same atomic weight as hydrogen, extra sources of hydrogen are a cause of the high moisture reading. Light elements, such as lithium, which are close to hydrogen in atomic weight, may also be detected as hydrogen, resulting in too high a moisture reading.

Notes:

4 Maintenance & Troubleshooting

Precautions

The C-200 meter should not be disassembled for service or inspection of any kind without direction from the factory. Specific instructions are available to allow the user to safely replace the keyboard, circuit boards or perform other minor diagnostic procedures. In any event, the license conditions under which these meters are distributed do not permit users to service or disassemble the source/shielding assembly.

Maintenance should only be performed by individuals that have completed the radiological safety training and are familiar with the operation of the source shielding mechanism. All maintenance procedures must be performed with the source in the shielded position.

Regular maintenance and inspection

Routine inspection and cleaning is needed for proper operation of the C-200 meter and compliance with license conditions.

Keep the base of the meter clean

The base of the meter and side plates should be checked and cleaned as necessary. Any accumulation of asphalt, cement, or dirt, will create an unwanted air gap beneath the meter, resulting in density readings that are too low. To clean, place the source in the shielded position, turn the meter on it's side and remove material. Solvent may be used as required. Always keep fingers, hands, etc., away from the bottom of the meter when the source is in the operate position.

Side plates

When the meter is in the contact position in the Touchable mode, check that the side plates can be easily raised off the surface.

The two side plates raise and lower the meter and set the Untouchable mode. Proper instrument operation requires the side plate slots and bushings, and the bottom of the side plates to be free of dirt, sand, asphalt, etc. A silicone based dry lubricant should be used to lubricate the slots and bushings. Occasionally check for loose screws, especially the four cap screws in the vertical slots in each side plate. When properly adjusted, the side plates will have a small amount of side-to-side play.

Display

To protect the LCD display from impacts, there is a Lexan plastic lens. Use gentle methods when cleaning to avoid scratching.

Sealed source leak testing

Leak tests are required every 6 months. For more information refer to the chapter on radiological instructions. The leak test kit contains directions for this test procedure.

Source shielding mechanism check

The source shielding assembly is very rugged and it is unlikely that any difficulty in its operation will occur. If there is any question about the proper functioning of the source shielding mechanism, use the following evaluation procedure: Rotate the carrying handle from the vertical carrying position to the horizontal contact test position. The movement of the handle must be smooth. Detents will be felt when moving the handle from the carrying position and again at the contact and air gap test positions. This is normal. If firm stops are felt in either direction, the mechanism is functioning correctly.

If the meter has been damaged and the handle will not rotate from the operate position, keep hands, fingers, and other body parts away from the bottom of the meter. Call the factory for further instruction.

Density / moisture reference spot

This is a user-selected location to test the meter. This is the best means for the user to verify that the meter's calibration has not changed and to check its general operation.

Selecting the location

Upon receipt of your meter, find a smooth, flat spot on a concrete floor in your building that is kept dry and that is at least 3 ft (1 m) from any walls and file cabinets. Use a 2 ft straightedge to insure that the spot is flat. Mark this spot permanently with an outline of the meter on the floor so the meter will be in the same position, facing the same way each time. Take a series of ten contact and air gap readings, recording and averaging the density and moisture results. These averages should be retained for future reference. Establish other reference spots when operating at a distance from the original reference location.

When and how used

Regular weekly or daily checks are recommended before testing at the job site. A log of test results from this spot is helpful in identifying problems.

If the meter's performance is in question

If the meter has been damaged or the calibration is in question, check both density and moisture results on the reference spot. Readings taken periodically should repeat within +/-2 PCF or a malfunction may exist. Moisture readings will indicate significant moisture content even though the floor is dry. This is normal and is due to water of hydration that is chemically bound within concrete.

The reference spot should also be used when the standard counts on the standard count reference are out of tolerance. Changes in background or atmospheric radiation can cause readings on the reference to shift out of tolerance. This does not necessarily mean the meter is out of calibration, but is responding to extraneous sources of radiation.

Battery

The Series C-200 meters are designed for operation from a 6 volt battery. Standard equipment is a 6v, 6 ampere hour, gelled electrolyte, sealed lead acid battery. This is the only standard power source for the meter. Consult the Seaman Nuclear Corporation concerning the availability of, or modification for, any other power sources that may be used.

Low battery indication

The C-200 meter is designed to provide normal operation for battery voltages above 5.5v. At a battery voltage of approximately 5.8v, a message indicating low battery voltage ("Lo") will appear on the display. When the battery voltage drops below 5.5v, an automatic cutoff circuit is activated and the meter will then turn off. The reason for this is: (1) to prevent the possibility of testing at too low a battery voltage, which may lead to erroneous test results, and (2) to prevent deep discharge of the battery. When the battery is below 5.5v, the meter may be turned on by holding the On switch down, but upon releasing it the meter will turn off. This is normal and does not indicate a faulty switch unless the Off switch is stuck down.

Battery capacity

The standard battery will provide a nominal capacity of 40-50 hours operating time (one week) during typical testing. Battery capacity is slightly less under cold conditions.

Recharging

When the meter is in storage, charge the battery every 60 days to avoid loss of capacity.

The battery charger supplied is designed to operate from a standard 115v ac, 60 Hz line outlet. With a fully discharged battery, a full charge is reached in 48 hours; approximately 70% of full charge is reached overnight. An automatic "float" charge engages when the

battery is fully charged to prevent overcharging. The battery may be left on charge for longer periods of time, up to one week.

Always keep the spare battery charged and with you at the job site.

Do not leave the battery plugged into the charger unless the charger has power applied to it, because the battery can slowly discharge back through the charger if this precaution is not observed. In an emergency, a 6v lantern battery may be used. Be careful to maintain the proper polarity. Reversed polarity will cause the fuse to blow.

Fuse

A single, one amp fuse is located inside the yellow top of the meter. The fuse protects the electronics from dangerously high amounts of current due to possible short circuits or wrong polarity on the battery. To replace, place the source in the shielded position, separate the yellow top from the green bottom (4 screws), and pry out the black plug marked "F", uncovering the fuse.

Troubleshooting poor test results or malfunction

Testing error has three primary sources:

1. Incorrect operation of meter.
2. Electronic malfunction or other damage to the meter that causes erratic or inaccurate results.
3. Failure to present a representative sample to test or improper application of the meter.

Step one

If poor test results occur, the goal is to determine which of the above sources of error is the culprit. The first step in this process should be to take a series of tests on the user-established density/ moisture reference spot. The results from these tests should be compared with the symptoms & suggested remedies section below.

Step two (for soils only)

Determine if the problem is related to the density or the moisture system. For instance, low dry density test results may result from either low wet density readings or high moisture readings. Knowing which system is the source of the problem will aid in determining a proper solution.

Symptoms & suggested remedies

Readings are consistently low by a few PCF: ♦ Generally, this is a result of dirt on the base of the meter, dirt in the side panel mechanism, or improper seating of the meter on the test surface. ♦ See surface preparation instructions. Recheck the density/moisture reference spot.

Readings are low by 8-12 PCF: ♦ See surface preparation instructions. ♦ Check the absolute density/moisture spot.

Readings in error by 15-25 PCF or more: ♦ The most probable cause is that the meter and the electronics are not in the same test mode. For example, the side plates may be in the Touchable mode while the microprocessor is in the Untouchable mode (or vice versa). ♦ Also, check that all units are consistent. For example, if metric operation is selected, base and lab density entries must be in metric units. In this case, the units would be kilograms per cubic meter.

Standard count readings suddenly change: This is indicative of a electronic malfunction. ♦ Check density moisture reference spot to determine if it significantly effects the meter calibration. If the meter is not erratic, a bias may be applied to the test results until the meter can be returned for service.

Moisture reads "E": ♦ A value of zero has been entered for the moisture standard count. Turn the meter off and back on. The factory set moisture standard count will now be in the memory.

Display shows "no": ♦ Carrying handle is not fully in the contact or air gap position. Gently depress the handle until a click is heard. ♦ Call the factory.

Display shows "E" when density key is depressed: ♦ Contact or air gap count has not been taken. Lab density or top lift value has not been entered into memory.

Display blank when meter turned on: ♦ Charge or replace the battery ♦ Check the battery connection and fuse. ♦ Check if the off switch is stuck. ♦ Moisture may be inside of meter. Call the factory for instructions on how to dry out the meter.

Meter shuts off immediately after turn on: ♦ Charge or replace the battery. ♦ Check if the off switch is stuck.

Battery does not charge: ♦ Replace the battery ♦ Check the battery charger (5.5 volts dc without load).

Display shows "Lo": ♦ Charge battery ♦ Check battery and charger connections.

Notes:

Radiation Safety & Regulations

If any questions arise regarding safety or compliance with regulations, call the Seaman Nuclear Corporation.

Radiation

The term "radiation" refers to the entire electromagnetic spectrum, including light and radio waves. As used in this manual it refers to ionizing radiation which causes molecules to become electrically charged, or ionized. The presence of these ions may disrupt normal biological function and present a health hazard. We are exposed to ionizing radiation from both natural sources (soil, rocks, cosmic rays) and man-made sources. Medical and dental diagnosis make up over 90% of the man-made dose contribution.

Radiation is emitted when an unstable atom undergoes a transformation, which we call decay, into a more stable atom. There are four main types of ionizing radiation:

Alpha radiation: Heavy, positively charged particles which are the nuclei of helium atoms. Alpha radiation can easily be stopped and cannot penetrate the skin or any other material. Therefore, alpha particles are contained within the gauge.

Beta radiation: Negatively charged electrons that are more penetrating than alpha, but can be stopped by thin sections of metal. Therefore, beta particles are contained by the gauge's shielding.

Gamma rays: A penetrating form of electromagnetic radiation, similar to X-rays. Gamma rays are attenuated (reduced) with the use of shielding materials of high density, such as lead, concrete, etc. Gamma sources are used in Seaman gauges to measure density.

Neutrons: Uncharged, heavy particles which penetrate dense materials and are attenuated (reduced) with the use of shielding materials that are hydrogen rich, such as water, polyethylene, paraffin, etc. Neutron sources are used in Seaman gauges to measure water content.

Radiological safety

The radioactive source in your gauge is small and well shielded. The dose received from a nuclear gauge can be less than the variation in natural background radiation levels in different parts of the U.S. For instance, you would increase your exposure more by moving from Louisiana to Colorado than by using a Seaman nuclear gauge. By following a few simple rules, one can be assured that working with the gauge will result in radiation doses well below limits.

Sealed source

In a Seaman gauge the radioactive material is contained in a welded stainless steel capsule contained in a second welded stainless capsule. Sealed sources contain the radioactive material and prevent its spread in case of an accident. The potential for contamination or leakage of radioactive material from this doubly encapsulated source is extremely low. In over 45 years of use in the field, including severe accidents, there has never been a leakage of radioactive material.

The sealed sources in your Seaman Nuclear gauge contain either a combination of cesium 137 (a gamma source) and americium 241/beryllium (a neutron source), or radium 226/beryllium (a gamma and neutron source). The type and amount of radioactive material is listed on the label on the gauge.

Limits of radiation exposure

Radiation exposure should be limited to As Low As Reasonably Achievable (ALARA). Regulatory agencies have set occupational exposure limits for radiation workers. For dose to the whole body, 5000 millirems (50 millisieverts) in a year. For persons younger than 18 years, the dose limit is 500 millirems in a year. For pregnant women, the dose limit during the 9 month term is 500 millirems. These levels are in excess of the average exposure of 100 millirems per year that might be anticipated by a user. Many medical x-ray procedures give a greater dose than would be received from using a Seaman gauge for an entire year.

How to minimize your exposure

Even though your anticipated exposure would be well below the occupational limits, it is a good practice under ALARA (As Low As is Reasonably Achievable) guidelines, to know and use all practical methods to minimize your exposure. These methods include shielding, time, and distance:

Shielding

Radiation attenuating material (shielding) placed between you and the source reduces the radiation reaching you. In a nuclear gauge the internal source housing shields the user. Always place the source in the shielded position by lifting the handle before carrying the gauge, or going near the gauge's bottom surface.

Time

The less time a person remains in the area of radiation, the lower the dose that person will receive. To minimize your exposure to radiation, work quickly to reduce the time.

Distance

A small increase in distance from a radioactive source gives a large drop in exposure. Due to an effect known as the Inverse Square Law, doubling the distance from a source reduces the exposure to one-quarter; tripling the distance reduces the exposure to one-ninth, etc. This is the most effective and readily available method of reducing your exposure.

Remember, radiation is always present around any gauge, whether or not it is operating.

Three feet (one meter) is the recommended minimum distance when working with a Seaman gauge. When making measurements, take a few steps back from the gauge while waiting for the test to finish. This will also improve the accuracy of the test, due to water in the operator's body affecting the moisture reading.

Licensing

A license to possess and use nuclear gauges is issued once an application has been approved that documents certain required procedures and your commitment to follow them. Regulatory authorities perform routine compliance inspections to insure that the licensee (you) are following these procedures.

The transportation of radioactive materials is also regulated. While there is no separate license required for transportation, your compliance with the necessary procedures is reviewed during compliance inspections. The requirements for the transportation of nuclear gauges are addressed in a separate chapter in this manual.

Which licensing authority has jurisdiction?

Regulation of nuclear gauges in the United States, is by the US NRC or a state that has entered into an agreement with the NRC, an agreement state.

Reciprocity

A NRC licensee may operate in any NRC controlled state. To operate in an agreement state, an NRC license must apply for reciprocity.

An agreement state licensee must apply for reciprocity to operate in another agreement state or in a NRC controlled state.

There is a 180 day limit in any one particular year. To operate longer, a license is normally obtained in that jurisdiction.

Radiation safety program

To apply for and operate under a license, you will need to establish a Radiation Safety Program, documenting how you will maintain control of your gauge and minimize dose to personnel. The elements of a radiation safety program are:

Training

Each operator must be familiar with the operation of the gauge, radiological safety principles, and regulations. This training is required as a condition of the user's license. The Seaman Nuclear Corporation conducts one day training seminars to help you meet this requirement.

Security

You must take steps to prevent unauthorized use or removal of the gauge whenever it is not under your direct surveillance. To accomplish this:

Regulations refer to this method of security as "two independent tangible barriers".

1. Lock the source mechanism in the shielded position.
2. Provide two physical barriers to prevent unauthorized removal of the gauge. Example: Place the gauge inside a locked vehicle or room. Then, lock the gauge case and lock the case to an immovable object.

Monitoring of personnel

Some licensing agencies require personnel monitoring. This is usually accomplished with a dosimeter (TLD or film badge) that provides a record of the actual radiation dose received by each user. The dosimetry reports for each employee are kept on file and available for review by the employee and for inspection. These reports should be reviewed with employees and kept until the licensing agency authorizes their disposal.

Since dosimeters are intended to measure occupational dose only, they should only be worn (usually at waist level) on the job, and at other times stored away from any sources of radioactivity. For example, do not wear your dosimeter when you might receive a dental x-ray. The control

dosimeter, which accompanies each batch of dosimeters from and to the dosimetry vendor, should also be stored in a low radiation area.

Leak testing

The leak test (wipe test) verifies the integrity of the gauge's sealed source(s) to insure that radioactive material is contained by the source capsule(s). It is performed by wiping the joints of the gauge following the instructions in the leak test kit. This sample is then returned to Seaman Nuclear for analysis. A source is considered leaking if an activity greater than 5 nanocuries (0.005 microcuries) is found on the sample. If this occurs, you will be notified immediately and in turn notify the licensing authority in accordance with license conditions. This test is to be performed at 6 month intervals or as specified by your licensing authority.

The leak test must be current in order to either use or transfer the gauge to another organization. A current leak test is not required during periods of long term storage.

Note that a measurable amount of radiation is always present around the gauge and can be detected in a radiation survey even when the source capsule is intact. This is normal, and does not indicate source leakage or contamination, although it is sometimes referred to incorrectly as "leaking".

Notice to employees

If provided by the licensing authority, a Notice to Employees must be posted in view of anyone who uses the gauge and/or enters the storage area. This notice lists the locations and telephone numbers of agency offices, and informs employees of their rights. Other postings, such as those in the storage area, are also required by regulations.

Transfer or disposal of the gauge

Transfer or disposal can only be made to another license holder authorized to possess this type of material, or to the Seaman Nuclear Corporation. A copy of the recipient's license must be maintained on file.

Record keeping requirements

These records must be maintained and available for inspection by regulatory personnel and your workers:

1. Your current radioactive material license.
2. Training records for operators.
3. Applicable regulations.
4. Leak test reports.
5. Transport package certification.

6. Personnel dosimetry reports (if required).
7. Source certificate, showing approval of source capsule design by a "Competent Authority". (Americium/Cesium sources only)
8. Utilization log showing where the gauge is stored, when and by whom it is taken and returned to storage or shipped to Seaman Nuclear.
9. Record of twice annual physical inventory of gauges.
10. Emergency procedures including telephone numbers of user's office, regulatory agency office and Seaman Nuclear.
11. Bills of lading used in transporting the gauge.
12. Annual self-audit.
13. Other records required by regulation or your license.

Storage of Gauge

1. Store the gauge in its locked shipping container.
2. Identify the owner on the shipping container. This will be important in case the gauge is lost, damaged, or stolen.
3. Lock the area where the gauge is stored. Follow the two-barrier rule described in the section on Security above.
4. Place a Caution Radioactive Materials sign (provided with your gauge) in the storage area or room when the gauge is present. A "notice to emergency responder" should be posted next to the radiation sign listing emergency phone numbers.
5. The storage area should be as far as possible and at least 20 ft from any work area occupied full-time. Shorter distances are possible with dose modeling. Contact Seaman for details.

Accident procedures

In the event of accident, fire, theft, or loss the U.S.D.O.T., NRC and States have procedural requirements that are described in the next section.

Audit

An annual self-audit of the radiation safety program is recommended and required by some regulators.

In the event of an accident

Whenever an accident or fire occurs which results in damage to a nuclear gauge, the following steps should be taken:

1. If a gauge has been involved in an accident, stop and detain any involved vehicles until the degree of damage is known. If the gauge has been damaged so that the integrity of the shielding is in question, establish a controlled zone having a radius of at least 15 ft (5 gauges) from the gauge until the condition of the source and shielding mechanism is known. Do not allow vehicular or foot traffic in this area unless necessary.
2. Inform your foreman, supervisor and RSO immediately and establish a plan of action. The RSO will notify Seaman. He may also need to notify regulatory authorities. The RSO will check regulations and determine what is necessary for the circumstances. If the RSO cannot be located, call Seaman immediately.

   Supervisor at work _____ at home _____

   RSO at work _____ at home _____

   Seaman Nuclear Corporation 414-762-5100
3. Have a leak test performed after any incident that may have resulted in source damage.
4. Do not use the unit until its operation and safety have been verified. Call Seaman Nuclear Corporation for further instructions on returning the gauge for repair.

Note in the transportation section "Emergency response information", in addition to the above, must be carried with the driver.

Glossary of radiological terms

Activity: Quantity of radioactive material. Two units of measure are commonly used: See Curie and Becquerel.

ALARA: As Low As Reasonably Achievable

Agreement state: A state that has signed an agreement with the U. S. Nuclear Regulatory Commission, allowing the State to regulate the use of radioactive materials.

Background radiation: Naturally occurring radiation to which we are exposed all the time.

Becquerel (Bq): the amount of radioactive material that undergoes one decay/sec., a unit of radioactivity, or quantity of radioactive material. The Becquerel is replacing another unit, the Curie.

Beryllium (Be): A non-radioactive material mixed with americium or radium to provide neutron emission for measurement of water content.

Byproduct: Radioactive material which is a by product of a nuclear reactor, such as cesium, americium, etc. Regulated and licensed by the NRC or agreement states. Congress amended the Atomic Energy Act of 1954 to include some types of NARM, including radium.

Compliance inspection: An inspection performed by the licensing or registering authority to ensure that leak tests have been performed and that license conditions are being followed.

Curie (Ci): the amount of radioactive material undergoing 37 billion decays per second, a unit of radioactivity, or quantity of radioactive material. The Curie is being replaced with another unit, the Becquerel.

Dose: The radiation absorbed by the body.

Dosimeter: A personnel measuring device used to monitor one's radiation exposure. Examples are film badge or TLD.

Exposure: Quantity of x-ray or gamma radiation. The level of radioactivity is usually expressed in Roentgen (R) or milliRoentgens (mR).

Half-life: Time for radioactivity to decay to one half of the original value. Some examples for some well known radioisotopes:

- radium: 1600 years
- cesium: 30 years
- radon: 3.8 days
- americium: 450 years
- uranium: 4,490,000,000 years

Hazmat: Hazardous materials.

Ionizing radiation: The result of the change of an unstable atom's nucleus changes to a more stable nucleus.

Leak tests: Tests performed on nuclear gauges to ensure the integrity of the source capsule.

Man-made radiation: The radioactive substances or sources of radiation created by man (e.g., medical x-rays, Byproduct materials).

NARM: Naturally occurring or Accelerator produced Radioactive Material, such as uranium, radium, etc.

Non-agreement state: A state in which an NRC license is required for possession of Byproduct material. A state license may or may not be required for NARM.

NRC: United States Nuclear Regulatory Commission, the regulatory body responsible for ensuring the safety and security of nuclear products and facilities subject to the Atomic Energy Act of 1954.

(Radio)activity: Quantity of radioactive material. Two units of measure: See Curie and Becquerel.

Radioisotope: A radioactive form of an element, either man-made or naturally-occurring.

Roentgen: A unit of measurement of exposure which is a quantity of x-ray or gamma radiation. The level of radiation is usually expressed in R/hr, or mR/hr.

RAD: (Radiation Absorbed Dose) Quantity of radiation received.

RBE: (Relative Biological Effectiveness) Used to determine the equivalent dose, in rem or sievert. It depends on type of radiation.

REM: (Radiation Equivalent Man) The traditional unit measuring the radiation dose equivalent, a term that includes the radiation dose and its biological effect on living tissue. The dose will depend on the type as well as the amount of radiation absorbed. This unit is used for protection and administration purposes. One rem is equal to 0.01 sievert. One millirem (1/1000 rem) is equal to 0.01 millisievert

RSO: Radiation Safety Officer

Sealed source: Radioactive material encased in a protective capsule.

Sievert: System International (SI) unit of radiation dose absorbed equivalent, equal to 100 rem.

Shipping papers: Information carried by the driver of a vehicle which identifies the nature and classification of a radioactive shipment.

Unrestricted area: An area to which access is not restricted for purposes of radiation protection and where warning signs are not required. The dose limits in Unrestricted Areas are such that an individual members of the public would not exceed 100 millirem (1 millisievert) in a year and 2 millirem (0.02 millisievert) in any one hour.

Notes:

6 Transportation

When transporting your gauge to, from, or within the United States, the Department of Transportation regulations contained in Title 49 of the Code of Federal Regulations (49 CFR) parts 100-185 pertaining to the transport of radioactive material must be followed. These regulations apply to your transportation of the gauge to and from the job site as well as by common carrier or air freight.

The USDOT also allows the use of IATA (International Air Transport Association) regulations for transportation within the USA. Some air carriers, for instance FedEx, may prefer the use of IATA regulations. IATA regulations are always used for international shipments.

As the shipper, you are responsible for insuring that your shipment complies with the requirements of the governing authorities. Be aware that fines for non-compliance can be imposed. As the device manufacturer, we will assist you with the information needed to meet these requirements. Since shipping requirements may change over time, Seaman provides current instructions with gauges shipped from the factory. If it has been longer than one year since you have received updated instructions, ask our shipping department if updated instructions are needed. These instructions are current as of February 2009.

For reference, USDOT regulations may be viewed on-line at http://hazmat.dot.gov. IATA regulations may be purchased at http://www.iata.org.

Employee transportation training

All employees who transport or prepare hazmat (hazardous materials), such as your gauge, for shipment must have had initial or recurrent hazmat training within the last 3 years for USDOT requirements and the last 2 years for IATA (international shipments only) requirements. This training may be conducted by the employer. Seaman training courses also provide the required hazmat training. 49 CFR 172 Subpart H. Also 49 CFR 173.1(b). IATA 1.5.

Inspection

Before transportation, you must ensure that:

- The gauge is transported in a Type A package. The case provided with your gauge has been tested and meets the requirements of a Type A package described in 173.410 and 412. See the Type A package certificate supplied with your gauge.
- Check that "the packaging is in unimpaired physical condition, except for superficial marks." 49 CFR 173.475(b). For example, the case should not be cracked. The case hinges, lock and latch mechanisms should be functional.
- The radiation level must be within the requirements for the Yellow-II label and Transport Index. This can be satisfied by insuring that your gauge's source is in the shielded position during shipment. For Seaman models C-300 and C-200, this is indicated by the carrying handle being in the vertical position. For the models C-75 and DOR, refer to the instructions on the device. The model R-50 does not have a shielded position and it is adequate for transport as is.
- Package marking and labels are legible and unobscured.
- The leak test certificate is current at the time of shipment. 49 CFR 173.475
- When offered to a carrier, the case must have a seal or padlock to show the package has not been tampered with. 49 CFR 173.412(a)
- Shipping documents appropriate for the method of transportation. See below.
- Place the appropriate records on file. See Record keeping.

Private transportation

When you transport your gauge on public roads the following are required:

1. The gauge must be in a Type A container. Your Seaman Nuclear shipping case is a Type A container.
2. We recommend that the gauge be transported in the rear of the vehicle, three feet (one meter) away from occupants. Before placing gauges in a vehicle closer than three feet to a person, or when transporting more than 10 gauges, consider the table below. The USDOT has specified minimum distances between a person and any point on a package containing a gauge when transporting. See the table below from 49 CFR 177.842. For example: Two C-300s with T.I. of 0.6 each have a total T.I. of 1.2. The nearest point on either package must be at least two feet from a person.

T.I. Transport Index can be found on the yellow label on the gauge case.

Total T.I. (Transport Index)	Feet
0.1 to 1.0	1
1.1 to 5.0	2
5.1 to 10.0	3
10.1 to 20.0	4
20.1 to 30.0	5
30.1 to 40.0	6
40.1 to 50.0	7

3. The transport case "must be secured to prevent shifting during normal transportation conditions." 49 CFR 173.448(a) and 177.834(a). Make sure it is secured and braced, especially when carried in an open area such as the bed of a pickup truck.
4. The case and gauge must be secured to prevent theft during transportation and storage. Take whatever measures are necessary in your circumstances to prevent loss of the gauge. At a minimum, regulatory agencies require use of "two independent tangible barriers" to secure the gauge whenever it is not under direct supervision. See examples of how to meet this requirement in the NRC's Regulatory Guide NUREG-1556, Vol. 1 or your equivalent State Guide.

Shipping Papers, classify and describe the radioactive materials in the gauge.

Emergency Response Information, provides instructions to emergency responders about the nature of the risk in accident conditions and appropriate actions. This information may be photocopied on the back of the Shipping Papers.

5. Ensure that the shipping paper is readily available to, and recognizable by, authorities in the event of accident or inspection. According to 49 CFR 172.200-203, the driver shall:
   A. Clearly distinguish the Shipping Paper, if it is carried with other papers, by either distinctively tabbing it or by having it appear first; and
   B. The shipping paper shall be: (1) Within immediate reach of the driver when restrained by the lap belt; and (2) either

readily visible to a person entering the driver's compartment or in a holder which is mounted to the inside of the door on the driver's side of the vehicle.

C. When the driver is not at the vehicle's controls, the shipping paper shall be: (A) In a holder which is mounted to the inside of the door on the driver's side of the vehicle; or (B) on the driver's seat in the vehicle.

6. Emergency Response Information must be immediately available 49 CFR 172.600 (c) (1). The supplied Shipping Papers have the Emergency Response Information on the back side.

Other items are also recommended:

- Gauge operating procedures (Operator's Manual).
- Accident procedures (in Operator's Manual).
- A copy of your radioactive materials license or registration.
- Radiation sign, in event the gauge needs to be stored apart from the vehicle.
- Applicable regulations.

Transportation by common carrier or air cargo

Acceptable carriers are cargo only aircraft and truck lines. Gauges cannot be shipped by UPS, Postal Service, or passenger bus lines.

The shipping documents are dependent on the type of transportation.

Air shipments

For transport by air, provide two copies of the "Shippers Declaration of Dangerous Goods" with the Air Bill. Gauges that contain cesium or americium sources require a copy(s) of the Certificate of Competent Authority for each material to accompany the shipment.

Truck shipments

For transport by commercial trucking, the document needed is a Bill of Lading that contains a description of the hazardous material. Vehicle placarding is not required for packages meeting Yellow-II requirements, such as Seaman gauges.

Marking and Labeling shipping cases

Packages must be marked (with permanent marker or decal) to indicate description of contents and the place origin or destination. There is a further requirement for warning and descriptive labels.

The "Type A" decal meets the marking requirement to indicate the package type and the proper shipping name. "RQ" (Reportable Quantity) is shown on the decal if the gauge contains an Americium source. 49 CFR 172.301, .304, .310, and .324(b).

Shipping case labels must be unobstructed and undamaged.

The "Yellow II" label is for all transportation. An additional "**Cargo Aircraft Only**" label is for air freight within the USA:

The "Yellow II" radiation label indicates the radioactive material, activity, and the transport index. The **Transport Index (T.I.)** is the maximum radiation level in mR (milliroentgen) per hour at 1 meter from the external surface of the package. The maximum T.I. for Yellow II is 1.0. Seaman gauges are within the Yellow II classification. 49 CFR 172.403.

Labels are shown at the end of this chapter.

The orange "Cargo Aircraft Only" label (The orange "Danger" label can be used until 2013.) must appear on any package offered for shipment by air with in the USA, and indicates that the package may not be loaded on passenger carrying aircraft. Note, loading on small, private aircraft is not prohibited, provided no paying passengers are being carried while the hazmat is present. 49 CFR 172.402(c).

Record keeping

A shipper must have certain records on file for at least 375 days after the latest shipment (except as noted).

1. **Hazmat (hazardous material) Training Records** - retain for three years.
2. **Leak test certificate current at time of shipment** - retain for the life of the gauge.
3. **Type A package testing results**. 49 CFR 173.415(a)
4. **For gauges containing cesium 137 and/or americium 241, a Certificate(s) of Competent Authority, also called Special Form Certificate is required for each material.** This document shows approval of source capsule design by a "competent authority". Check the expiration date before shipping and request a current one from Seaman if needed. 49 CFR 173.476(a)
5. Shipping Documents as applicable:

A. For shipment by common carrier (truckline) retain a copy of the **Bill of Lading** or

B. For shipment by air cargo carrier, retain a copy of the **Shipper's Declaration and Air Bill** or

C. For private transportation, retain a single copy of the **Shipping Papers and Emergency Response Information** on file and tracking the transportation activity with a Utilization Log for each gauge owned. The Log should show the date in/out, person transporting, and destination. 49 CFR 172.201 and 172.600-602.

6. **Emergency Response Information**: This is printed on the back of the provided Shipping Paper. It describes the degree of hazard and means to deal with it in the event of an accident during transportation. See sample. This must also be available at any facility where hazmat is received, stored, or handled during transportation. 49 CFR 172.600-602.

Accident reporting

Immediate notification to the USDOT, 800-424-8802 must be made when, "as a direct result of hazardous material", in the course of transportation, there is severe injury, physical damage over $50,000, or evacuation required. 49 CFR 171.15. Notification should also be made to the instructions of your licensing agency in your state.

Returning your gauge for service

When returning your gauge to the factory for service, be sure to include the standard count reference, battery(s), charger, and a note explaining the reason for service.

Shipping container labels

The CARGO AIRCRAFT ONLY label is only required for passenger air freight within the USA. 49 CFR 172.448(c)

The "Cargo Aircraft Only" label replaces the "Danger" label below, which can still be used until January 1, 2013.

49 CFR 172.448(c)

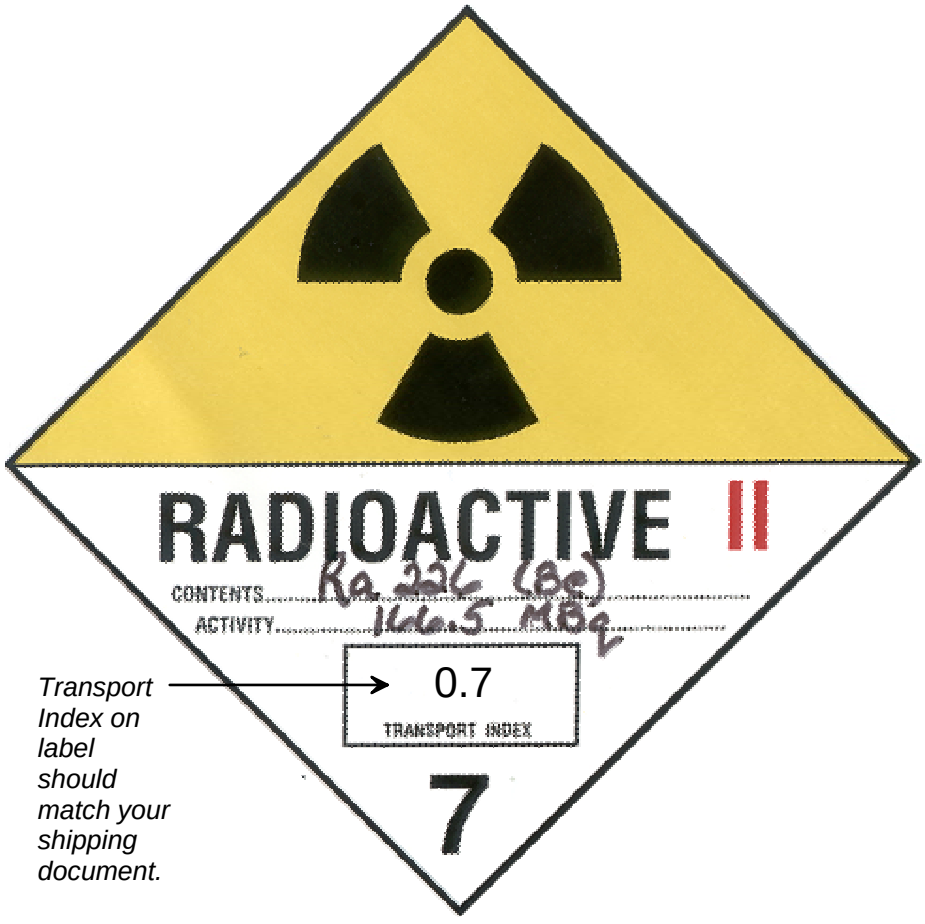
Labels for gauges containing radium

Radioactive Materials,

TYPE A

Package, UN2915,
USA DOT 7A

Seaman Nuclear Corporation Tel 414-762-5100
7315 South First Street, Oak Creek, WI 53154, USA



Transport Index on label should match your shipping document.

Labels for gauges containing americium-241 and cesium-137

RQ, Radioactive Materials,

TYPE A

Package, Special Form,
UN3332, USA DOT 7A

Seaman Nuclear Corporation Tel 414-762-5100
7315 South First Street, Oak Creek, WI 53154, USA

Transport Index on label should match your shipping document.

Appendix

C-200 source shielding diagram