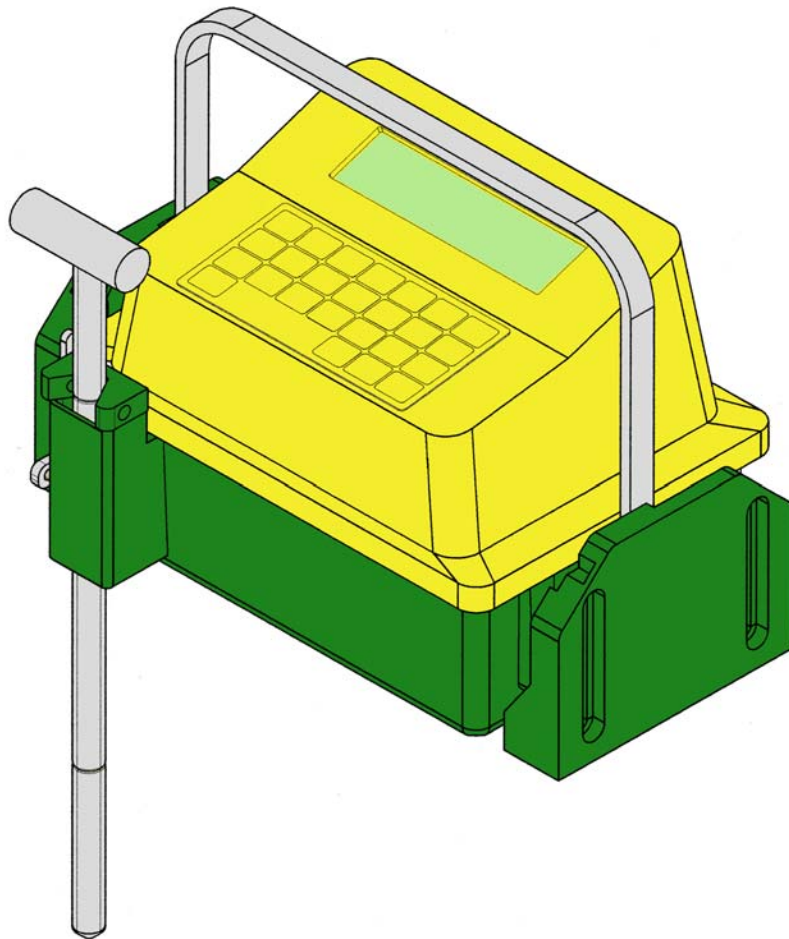


C-300 Operator's Manual



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Foreword

Owner responsibilities

The possession, use, and transportation 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 these requirements. Seaman Nuclear Corporation's seminars, operator's manuals, and other instructional materials are provided to assist you in meeting your responsibilities. Obtaining 49 CFR for transportation and other regulations is strongly encouraged.

Safety

"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." The source of this quote is a NRC publication "Working Safety with Nuclear Gauges" NUREG/BR-0133 Rev. 1, page 13.

Operator's manual

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

Notes

Model C-300 Equipment List

One model C-300 Seaman Nuclear density moisture gauge including:

- 1 Molded polyethylene shipping container with packaging.
Exceeds US DOT Type A and ICAO requirements.
- 1 Standard count reference.
- 1 Battery charger.
- 2 12 volt rechargeable batteries (1 in gauge, 1 as spare).
- 1 Lock with keys.
- 1 Surface preparation plate.
- 1 Loop back connector.
- 1 Data transfer cable.
- 1 Data pack containing:
 - Operator's manual.
 - Warranty certificate.
 - Registration card.
 - Calibration certificate.
 - Wire seal.
 - Leak test certificate.
 - Gauges containing cesium and americium will have Certificate of Competent Authority for each material.
 - Packaging evaluation certificate.
 - Hazmat training information.
 - "Caution Radioactive Materials" sign.
 - Notice to firefighters.
 - Shipping instructions.

Options:

220 volt converter for overseas use.

Cart.

Direct transmission system:

Pin.

Puller.

Probe.

Hammer.

Pin guide (attached to surface preparation plate).

Notes:

1

Description & Capabilities

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

The meter

The C-300 is a portable density moisture 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 1.12-2.72 kg/l, and a moisture range of 0-45 PCF or 0-0.72 kg/l. The American Society of Testing Materials (ASTM) specifications covering this method are D6938 and D2950.

Radioactive source and detectors

The radioactive materials used in the C-300 meter are doubly encapsulated in sealed source capsule(s), and mounted within the meter, 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-300 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 Radiation Safety and Regulations for information on the licensing requirements in your locale and the definition of terms used in the above table.

A gamma detecting (Geiger-Mueller) density tube is mounted to the base of the meter on the left side. A thermal neutron detecting (He-3) moisture tube is mounted to the base on the right side. See the figure on the next page and the general construction diagram at the end of the manual.

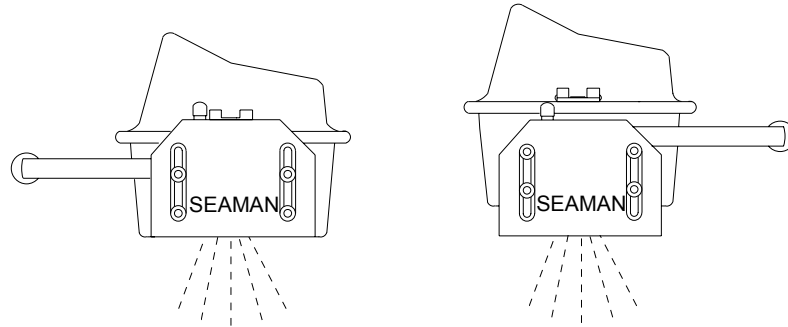
Air gap ratio density

The C-300 meter uses 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 1/4" (6 mm) above of the test surface. The air gap count is taken over the same spot with the meter raised 1 3/4" (45 mm) above the surface.

Contact Count

Air Gap Count



A brief explanation of the air gap ratio method

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

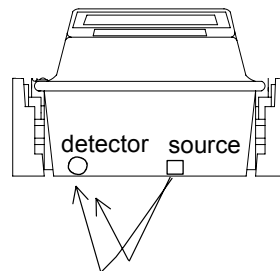
Contact count - the meter reading (CPM) is a function of the material density and it's chemical content.

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

To determine density 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. 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.

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

Using this method, correlations with conventional tests (sand cone, balloon, and core samples) are improved across a wide range of materials from 70-170 PCF (1.12-2.72 kg/l).

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 standard count ratio 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

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

where the asphalt has cooled.

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 only the correction needed at each test spot.

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 due to the randomness of the source output, about 50 CPM. 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 (H₂O). 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 C-300 meter has 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 $\frac{1}{4}$ 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 function allows accurate density determinations of thin lifts of asphaltic concrete. Accudepth is able to measure lifts as thin as $\frac{3}{4}$ 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.

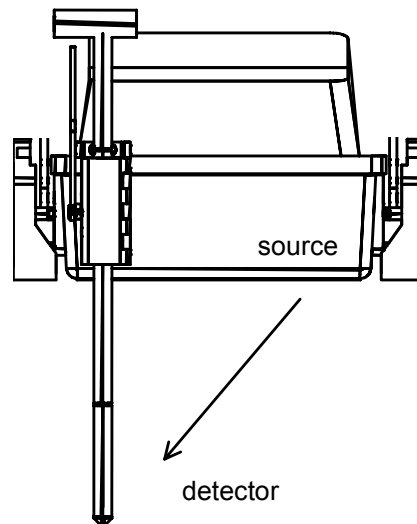
Direct transmission (optional)

The Seaman Nuclear C-300 moisture/density gauge can be equipped with a probe and accessories for direct transmission density measurements in addition to the Air Gap Ratio method which is standard on all Seaman Nuclear gauges. The standard probe allows 4 in to 8 in (10 cm to 20 cm) depths and a 4 in to 12 in (10 cm to 30 cm) is also available.

Principle of operation

The direct transmission method requires the user to create an access hole at the test site to allow a probe containing a gamma measuring detector to be inserted to the desired depth of measure. Radiation passes from the source through the test material to the detector in the probe. The radiation measured by the detector is inversely proportional to density. The test result provides an average density of the depth measured.

In the air gap ratio backscatter mode, the bulk density is computed as a function of the ratio of two gauge counts (cpm): air gap and contact. In the direct transmission mode, the standard count replaces the air gap



count and the probe count replaces the contact count.

The standard count is taken with the C-300 placed on the standard count reference resting on compacted soil, asphalt or concrete and with the external probe set at the "S" (standard count) depth position. The source is in the operate position.

The probe count is taken with the C-300 on a prepared test surface and the probe lowered to the desired depth (4, 6, or 8 inches) in the previously prepared hole.

When the density count is taken, with the probe inserted to the desired depth in the soil, the count will be higher with low density materials and lower with high density materials.

Moisture counts are always taken in the surface or backscatter mode, regardless of the density mode being used (air gap backscatter (surface) or direct transmission). In other words, the moisture is not measured with the probe.

Depth of measure

The depth of measurement using air gap backscatter 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.

The depth of measurement using the direct transmission system is controlled by the depth the rod is lowered into the hole.

Accuracy

Nuclear methods of density measurement have gained the reputation for a high degree of accuracy. Accuracy assessment, 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.

Notes:

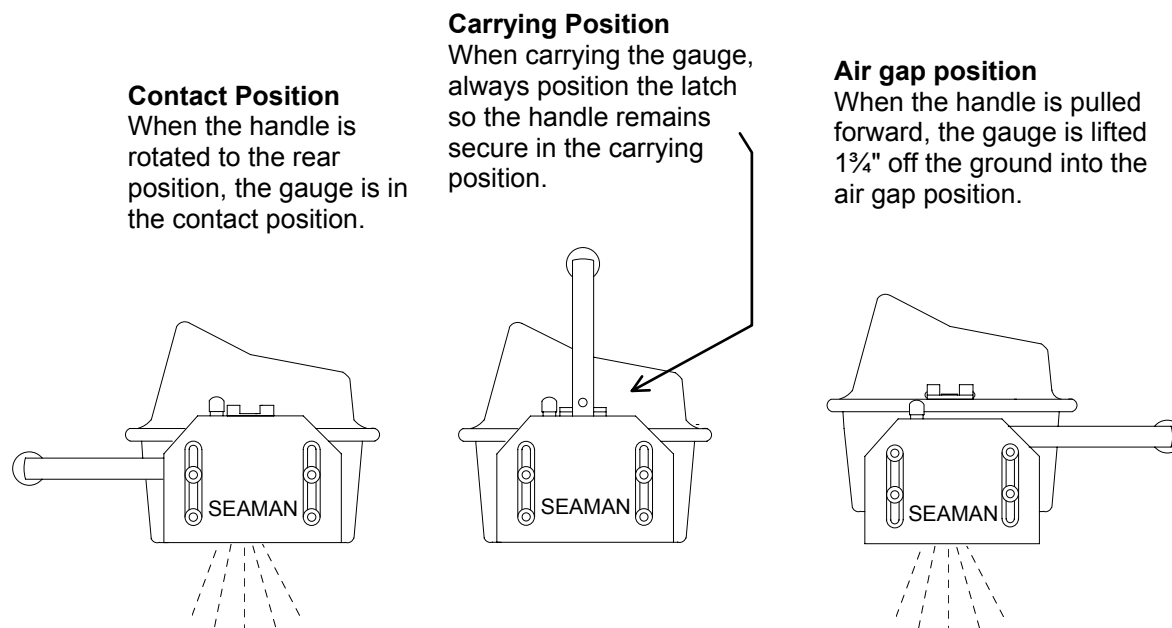
2

Gauge Operation

This chapter explains how to operate the Model C-300 density moisture gauge and activate its functions.

Carrying handle

The carrying handle on the C-300 gauge 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 gauge

The following operating precautions apply to the use and transportation of nuclear gauges. Additionally, all users should study the chapter on Radiation Safety and Regulations, particularly the section entitled "How to minimize your exposure".

In the carrying position

In the carrying position, the gamma source is surrounded by shielding. The gamma dose rate on all sides of the gauge, including the bottom, is low. Always place the source in the carry position for cleaning, maintenance, storage, or transportation of the gauge. The neutron source is in the bottom of the instrument. Contact with the bottom should be

avoided. Do not carry the gauge with the bottom facing you and do not place the gauge where you can be directly under it.

In the operate position

To operate, the gamma 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 gauge is relatively high, while the radiation level at sides and top remains low. Keep hands, fingers, and other body parts away from the bottom of the gauge when in the operate position.

Maintain a 3 foot distance

When you are not using or carrying the gauge stay 3 feet (1 meter) away. Step back from the gauge while waiting for a test to finish. This not only reduces operator's exposure, but prevents the moisture test from being affected by the water in the operator's body.

Remember, the gauge is always emitting some radiation, even when the electronics are not operating.

When transporting, keep the gauge in the rear of your vehicle, away from occupants. If the vehicle is open, (e.g. pickup truck), secure the gauge with tie downs or other means.

Never leave your gauge unattended.

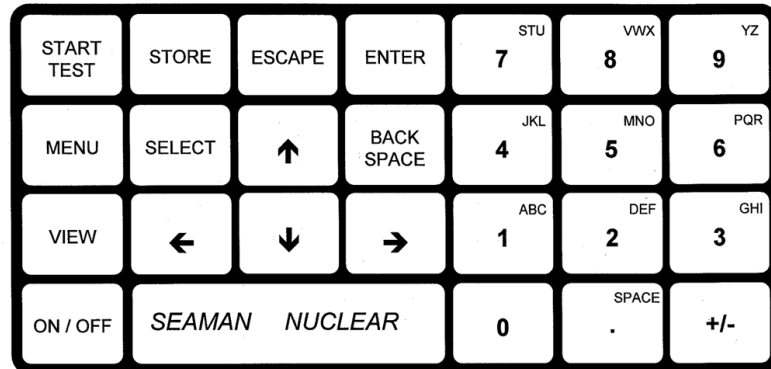
Never leave your gauge unattended at a job site or anywhere else without first locking the source in the shielded position and placing it in your vehicle or other secured area. Unattended gauges are the major reason for accidental runovers and theft.

Accident procedures

Familiarize yourself with the "What to do in the event of an accident" procedures in the radiological instructions.

Keyboard operation & display

The C-300 control panel consists of 25 touch keys and a 4 x 40 character display with a flashing cursor for selecting and editing.



Keys

ON/OFF Turns the gauge on or off. When turned on, a system check is performed to confirm proper operation.

ENTER Completes a keyboard entry of a number, letter, or choice from a menu of functions.

ESCAPE Cancels an operation without changing the entry or activating a function. ESCAPE also returns moves you up one level or returns you to the main menu, depending on what function was being accessed.

START TEST Starts a density/moisture test (count). A test can be started any time except when data is being entered.

VIEW Displays test data from the last test taken or from a test previously stored. See viewing test results in this chapter.

STORE Stores the data from the last test with a project. A project is a group of related tests. See viewing test results in this chapter.

MENU Displays a menu of functions. For instance, the time of test can be changed by choosing **Enter Test Time** from the menu.

ARROW KEYS ↑↓←→ Moves the cursor in the display.

↑↓ keys move the cursor to the desired menu item. ←→ keys move the cursor for changing entries.

BACKSPACE Deletes the character to the left of the cursor.

SELECT Selects or deselects projects for printing, transferring, and deleting.

NUMBER, DECIMAL, +/- KEYS Are used for numeric entries. Pressing number keys more than once when naming a project will enter letters A...Z and a...z. ↑↓ keys change the letter case. See Entering Numbers and Creating Projects in this chapter.

General operation

This section discusses activating functions and the entering of data.

Activating functions

Some functions are activated directly from the keyboard. Other functions are accessed by pressing the MENU key.

There are two ways of choosing function in menus or an item in a list:

1. **Press the number key** that corresponds to the item. For instance, pressing the number 3 key will activate Enter Test Time from the main menu.
2. **Press ↑↓ keys** to move the cursor onto the desired item **and Press the ENTER key** to choose the item.

Press ESCAPE to exit the function without choosing an item.

Guidelines for numeric entries

- The keys used to enter data are the number keys 0 through 9, the decimal point, the ± key, ESCAPE, ENTER, and the ←→ keys.
- To accept an existing number, press ESCAPE or ENTER.
- To accept a number just entered, press ENTER.
- To enter negative number press the ± key.
- To change a number before ENTER has been pressed, press BACKSPACE until the number is deleted, then re-enter the correct numbers. Press ENTER to accept the entry.
- To change a number after the ENTER has been pressed, return to that function and key-in the desired value.
- Some number fields place restrictions on the value to be entered. For instance, the time of test cannot be greater than 34 minutes, negative, or contain a decimal point.

Main menu

The main menu is accessed by pressing the MENU key. It contains seven functions displayed in a scrolling list:

| | |
|-----------|------------------------|
| MAIN MENU | 1. Set Test Mode |
| | 2. Enter Lab Density |
| | 3. Enter Test Time |
| | 4. Standard Count Test |

Press the ↑↓ keys to see all 7 items in the main menu. To select an item from the menu, press ENTER.

| | |
|-----------|-------------------|
| MAIN MENU | 5. Trench Test |
| | 6. Print Job Data |
| | 7. Utilities |

1. Set Test Mode Configures the display for Asphalt, Soils, or Top Lift testing. The cursor will be located on the currently active mode. Once a mode is set, the user will be prompted to set the type of percent lab density to display:

| Test Mode | Display Options |
|---------------------|---|
| Asphalt or Top Lift | None - displays density only. % Marshall - displays density and % of Marshall or theoretical maximum density % Zero Air Voids - displays density and %AV. Both - display all of the above. |
| Soils | None - displays density only. % Proctor - displays density and % Proctor. |

If the **Top Lift** mode is chosen, the user will be prompted to enter the Base Density and the Lift Thickness of the test material.

2. Enter Lab Density Displays and allows entry of Proctor, Marshall, and Zero Air Void densities. Proctor density is used for soils test mode, the other two are used for asphalt and top lift test modes.

3. Enter Test Time The current system time is displayed as MM:SS. To change, enter the time in minutes and seconds. Examples: 2, 0, 0, results in 2 minute test time. Entering 3, 0, results in 30 seconds.

4. Standard Count Test Checks the gauge and prevents moisture system errors. See standard count reference in this chapter.

5. Trench Test Used to correct moisture errors caused by the moisture present in the side wall of a trench. See the section in this chapter on the trench density procedure.

6. Print Job Data Used to send stored data to a printer or a computer. See Printing or transferring stored data in this chapter.

7. Utilities Accesses the utilities menu. See following section.

Utilities menu

The utilities menu is accessed from item 7 in the main menu. It contains eight functions displayed in a scrolling list. The $\uparrow\downarrow$ keys can be used to view the entire list. Each function in the menu is discussed below:

```
UTILITIES      1. Set Units
                2. Statistical Self Test
                3. Display Contrast
                4. Battery Check/Run Time
```

To see all 8 items in the Utilities menu, press the $\uparrow\downarrow$ keys. To select an item from the menu, press ENTER.

```
UTILITIES      5. Beep On/Off
                6. Set Bias
                7. Display Free Memory
                8. Special Functions
```

1. Set Units Allows selection of the English or Metric mode. The cursor will be located on the currently active mode.

| Units | | |
|--------------------|----------------------------|---------------------------|
| Data | English | Metric |
| Density / Moisture | PCF (pound per cubic foot) | KGL (kilograms per liter) |
| Depth / Thickness | in (inches) | cm (centimeters) |

2. Statistical Self Test Checks performance of detectors and electronics by taking 100 tests of 10 seconds each and comparing the actual standard deviation of this data set with the theoretical standard deviation. This calculation, a Q factor, is displayed for density and moisture, along with their pass or fail status.

A Q factor of 1.0 is ideal. Acceptable limits for passing are .76 to 1.16. If either Q factor is outside these limits, the test should be retaken. If the gauge continues to fail, it may require service.

You may desire to turn off the beeper before conducting a statistical self test.

Procedure

1. **Press MENU, 7, 2, to enter the statistical test function.**
2. **Place the gauge on the standard count reference** at least 15 feet (5 meters) from any other gauge or 4 feet (1 meter) from any wall. See statistical self-test in the Maintenance chapter.
3. **Place the handle in its carrying (shielded) position.**
4. **Press ENTER** to begin the test. Step back. Do not move the gauge. Results will be displayed in 16 minutes and 40 seconds.

3. Display Contrast When this function is selected, the contrast can be adjusted by pressing a number from 0 to 7, or by using the $\uparrow\downarrow$ keys. To accept the contrast change, press ENTER. To quit this function without accepting any change, press ESCAPE.

4. Battery Check/Run Time Displays battery voltage and the approximate running time remaining on the battery before recharge is necessary. Pressing any key will return the gauge to the utilities menu.

5. Beeper On/Off If enabled, the beeper will sound at the completion of a test.

6. Set Bias Allows enabling, disabling, and setting a bias offset for density and/or moisture. See Applying a Bias section in this chapter.

7. Display Free Memory Indicates the number of available projects and tests for use by the storage function.

8. Special Functions Allows access to less frequently used, or maintenance functions. See the following section for a complete description.

Special functions

Special function are accessed from item 8 in the Utilities menu. Inadvertant/unauthorized use of these functions could result in the loss of data. To select special functions, press MENU, 7, 8. Key in the code number for the desired function and press ENTER. Code numbers are provided separately to the gauge purchaser so they have the option of distributing them as needed.

Serial port settings

Allows matching the settings of C-300 serial port to those on a printer or computer. The current settings are shown in the left side of the display.

- There are four baud rate settings from 4,800 to 38,400 baud.
- Parity can be either none, even, or odd (usually none).
- Data length can be either seven or eight bits (usually 8).
- Stop bits can be either one or two (usually 1).

The C-300 is year 2000 compliant.

Once the desired changes have been made, press the ESCAPE key to exit the function. The serial port connector is located next to the battery.

Time/date settings

The time and date of tests are stored with test data. When this function is entered, the system time is displayed. To change the time, enter the desired time in 24 hour format. Entries must include numbers for hours, minutes, and seconds otherwise the change will not be accepted. To accept the new time entered, press the ENTER key. To cancel changes or keep the current time, press ESCAPE. When ENTER OR ESCAPE have been pressed, the system date is displayed. To change the system date, key in two digits each for the month, day, and year, and press ENTER. To cancel date changes or accept the current date, press ESCAPE.

Erasing storage memory

Erases projects from memory. The user can erase all projects or selected individual projects. See the section in this chapter on data storage for a complete description of this function.

Hardware testing

This function tests several subsystems of the C-300 to assist in problem identification. Gauge repair may be expedited by recording the test results and reporting any failure. The tests performed:

- The battery voltage is measured and displayed.
- The three high voltage power supply outputs are measured and displayed.
- The counters and timer are tested and the results displayed.
- The display is tested by being cycled through all valid display characters. While observing the display, problems such as a character row failure will be visible.
- An interactive keyboard test is initiated requiring the user to press each key, with the exception of the ON/OFF key. The gauge displays the key pressed. Pressing the ENTER key twice will exit the keyboard test.
- Checks the operation of the serial port. A loop back connector, supplied with the gauge, is required for this test. The gauge sends out a text string and compares it with the text string received back. The test is performed from 4,800 to 38,400 baud. If any problems are found, the gauge will display an error.

Data storage

Test results, time and date of tests, and gauge settings used may be stored for later viewing, printing, or transfer to a computer. This data can not be altered and will remain in memory until it is deleted. The types of data stored with each test is dependent on the test mode setting in MENU, 1. Regular printing or transfer of data is recommended to avoid the potential of data loss should a system failure occur.

Tests and projects

For easy management of data, tests are stored in groups called "projects". The maximum storage capacity is 1365 tests grouped in as many as 999 projects.

Creating projects

The storing of test results requires the creation of a project. Up to 12 alphanumeric characters may be used in naming a project. Pressing number keys more than once enters letters. The decimal key allows entry of a space. After each character is entered, press ENTER to accept it. To change characters use ←→ keys to move to the character and enter the desired letter. Pressing ENTER twice accepts the project name. Once a project name has been accepted it can not be changed.

Procedure:

1. **Press the STORE key.**
2. **Select Create New Project.**
 - A. If other projects exist when the STORE key is pressed, a menu is displayed with the choices being: Use Current Project, Select Another Project, and Create New Project.
 - B. The current project is shown on the bottom line of the display.
3. **Enter a project name.** A project name may consist of up to twelve numbers, letters, spaces, and +/- characters.
 - A. **To use letters, press a number key repeatedly** to step through the other characters available on that key. For example, pressing the "7" key 3 times displays a "T" and pressing it 2 more times displays "7" again.
 - B. **To change the letter case, press the ↓ key** to change a letter to lower case and the ↑ key to return it to upper case.
 - C. **To accept each character, press the ENTER key.** The cursor will move to the next position.
 - D. **To change characters use ←→ keys to move to the character and enter the desired letter and press ENTER.**
 - E. **To accept the completed project name, press ENTER.** The user will be prompted to enter the location of the last

To cancel, press ESCAPE at any time (prior to the last step) to exit without accepting a new entry.

test. To not save the last test with the project just created, press ESCAPE.

Storing tests

The last test taken may be stored in gauge memory by pressing the STORE key. If the memory is empty a prompt will appear to create a project name (see the preceding section). If one or more projects exist in memory, a menu is displayed with the choices being: Use Current Project, Select Another Project, and Create New Project. The last project chosen is the current project. It is shown at the bottom of the screen. When the gauge is set for English, the distance units are feet, when set to Metric, the distance units are meters.

To store tests:

1. **Press the STORE key** when a test has been completed.
2. **Select the project in which to store the test.**
 - A. **To store with the current project, press 1 or ENTER.**
 - B. **To Select Another Project, press 2.** A list of projects is displayed, with the date created and the number of tests stored in each. The cursor will be on the current project. **Locate the desired project by pressing the ↑↓ keys and press ENTER.**
 - C. **To create a new project, press 3.** For details, see Creating Projects above.
3. **Enter the Station No.** to indicate the longitudinal distance of the test location.
 - A. **In the English mode,** the length is in the form of XXXX+XX. The first four digits may be any number from 1 to 9999 and represent hundreds of feet. The last two digits after the "+" may be any number from 1 to 99 and represent the number of feet. Example: To enter a station number of 105 feet, press 1, ENTER, 5, ENTER.
 - B. **In the metric mode,** a single number of up to 8 digits is used. Example: To enter a station number of 2225 meters, press 2, 2, 2, 5, ENTER.
4. **Enter the Offset** from the centerline of the road in feet (meters).
5. **Select Right of Center or Left of Center** to indicate the direction from the road centerline. The test will be stored, and the display will show the number of projects and tests that can still be stored. This screen will disappear after about 5 seconds.

Note: When viewing stored tests, Right of Center is represented as " + " and Left of Center is represented as " - ".

Erasing projects

All projects can be erased at once, individually, or in batches with the Clear Storage Memory function. This feature requires the user to enter a separately provided code in order to prevent accidental erasure. To erase, do the following:

NOTE: Erased projects cannot be recovered. Press the **ESCAPE** key at any time to exit.

1. **Press the MENU key and 7** to enter utilities.
2. **Press 8** to enter special functions.
3. **Enter code.** The gauge will display a message warning that all marked data will be erased.
4. **Press the ENTER key** to select projects for erasure. The Clear menu appears with the option to erase Select Projects or All Stored Projects.
5. **To erase all stored projects, press 2.**
6. **To select specific projects, press 1.** A list of projects is displayed, with the date created and the number of tests stored in each. The cursor will be on the current project.
 - A. **Locate the desired project(s) by pressing the ↑↓ keys.**
 - B. **Press the SELECT key to mark each selection.** An X appears next to the selected project(s). To deselect a project, press the SELECT key again.
 - C. **When finished marking projects, press the ENTER key to delete these projects.**

A brief message will be displayed, after using either option, indicating that the projects have been erased. Pressing the ESCAPE key at any time will immediately exit to the utilities menu.

Viewing test results

Viewing the last test results

Press **VIEW, 1**. These results will be lost when the next test is taken. To store these results, press **STORE**.

Viewing stored tests

1. **Press VIEW, 2.** A list of projects will be displayed, with the cursor on the currently active project.
2. **Locate the desired project by pressing the ↑↓ keys and press ENTER.** A list of stored tests will be displayed.
3. **Locate the desired test by pressing the ↑↓ keys and press ENTER to display test results.**
4. To return to the test list to choose another test, press **ESCAPE**.
5. To choose another project, press **ESCAPE** (again).

Tip: In long lists such as in test storage, use the number keys in conjunction with the arrow keys. For instance, to move down 14 lines, key in 14, press the **ENTER** key and the ↓ key.

6. To return to the main menu, Press ESCAPE (again).

Printing or transferring stored test results to a PC

Stored test results may be printed by a printer connected to the C-300 as described below. Test results may also be transferred to a personal computer with a serial port and a commercially available communications software package such as Hyperterminal provided with Windows, or Procomm.

Similar types of tests are grouped together for printing or transfer. For instance, if a project contains both soil and asphalt tests, they will be grouped together by test type.

The connector on the C-300 is inside the battery compartment.

Printing

The C-300 can be connected to a serial or parallel port on a printer.

To connect to a printer with a serial port, attach a printer directly to the serial port of the C-300. Use a serial printer cable with a 9 pin female connector. This cable can be purchased from Seaman Nuclear. The data cable provide with the C-300 is only for connection to a PC and will not work as a printer cable.

To connect to a printer with a parallel port, a serial to parallel adapter and cable are needed. These items are available from Seaman Nuclear as a Parallel Printing Kit.

Transfer to a PC

Connect the C-300 to the 9 pin serial port on the PC (personnel computer), using the supplied data cable. It is not necessary to power down either unit when making this connection.

Set the modem communication program parameters to match the C-300 serial setup, e.g., 19200, 8, n, 1. Handshaking (flow control) may be set to hardware, software, or none. The connection setup should be set directly connected to COM 1 (assuming COM 1 is the serial port on the PC). To prepare to receive the data, set the program to capture text.

Transferring or printing procedure

The word "print" is used in the C-300 menu to imply a data transfer, whether to a printer or a computer. To print or transfer data:

1. **Press MENU, 6** to select Print Job Data in the main menu. All or just selected projects may be printed.
2. **To print every project, press 2.**

3. **To select specific projects, press 1.** A list of projects is displayed, with the date created and the number of tests stored in each. The cursor will be on the current project.
 - A. **Locate the desired project(s) by pressing the ↑↓ keys.**
 - B. **Press the SELECT key to mark each selection.** An X appears next to the selected project(s). To deselect a project, press the SELECT key again.
 - C. **When finished marking projects, press the ENTER key.**
4. **Select output format 1. Report or 2. Comma Delimited.** The Report format is suitable for printing or for import to a computer text file or word processor. Comma delimited format is not intended for sending directly to a printer. This format is better suited for import to a computer spreadsheet or data base.
5. **If report format is selected, Select 1. Standard or 2. Advanced format.** The standard report is 80 columns wide and will print the most important data fields only. The advanced report is 132 columns wide and prints all the test data fields, including raw counts, bias values, etc. If advanced is chosen, and a standard width 8.5 in (216 mm) printer is connected to the C-300, put the printer in compressed mode prior to printing.
6. **To interrupt the data transfer, press the ESCAPE key.** The message "Printing Interrupted by User" will be displayed along with a prompt to press the ENTER key to continue or the ESCAPE key to exit.

Test time

For nuclear instrumentation, the random nature of radiation from the source causes variation in test results, even when the gauge is not moved between tests. 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 half, the test time must be increased 4 times. For instance, 4 minute readings vary half as much as 1 minute readings, and 15 second readings vary twice as much as 1 minute readings.

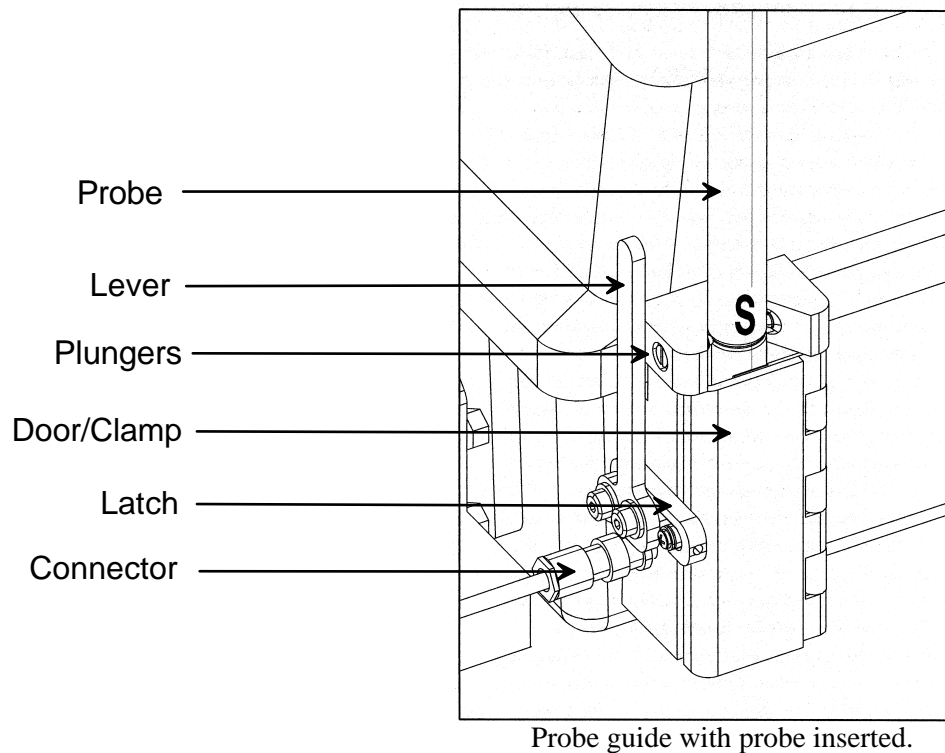
The gauge retains the last test time setting. If another test time is desired, use the following procedure:

1. **Press MENU, 3.**
2. **Key in test time in minutes and seconds.** Any time from 1 second to 34 minutes may be used. Examples: for 15 seconds, key in 1, 5. For 2 minutes, key in 2,0,0.
3. **To accept the new time, press ENTER.**

Direct transmission option

To insert the direct transmission probe in the guide:

1. Turn off the gauge if it is on.
2. Loosen the probe guide clamp by lowering its lever.
3. Insert the probe into the probe guide on the gauge. Lower the probe until the plungers are in the "S" groove. Rotate the probe handle so it is parallel to the front of the gauge and the depth "S" is visible, as shown below.
4. Tighten the probe clamp by raising the lever.
5. Remove the connector cover and connect the probe cable.



To remove the probe from the guide:

1. Turn off the gauge.
2. Disconnect the cable and replace the connector cover.
3. Loosen the probe guide clamp by lowering its lever.
4. Remove the probe.

To open the probe guide door:

1. Lower the lever and remove the probe.
2. With the lever lowered, push the hinge door closed.
3. Lift the latch and swing the door open.

Standard count reference

Note: The air gap backscatter density calibration is not effected by the standard count. Thus, if only air gap backscatter density tests (e.g. asphalt testing) will be performed and not moisture tests, a daily standard count is not needed for accurate operation.

Each C-300 gauge is supplied with a matched, serial numbered standard count reference. It consists of an aluminum frame, polyethylene, and lead. Polyethylene is rich in hydrogen and serves as a known and unchanging standard for moisture. The lead serves the same purpose for density. The purpose of the standard count reference is:

- Daily compensation for changes in background radiation, detector aging, radioactive decay and other factors that effect the moisture and direct transmission density calibration accuracy.
- To check gauge functioning (also see the maintenance chapter).
- To compensate for the side wall moisture effect when testing in trenches. See the procedure in this chapter on trench density.

Following ASTM and AASHTO procedures, a standard count test is the comparison of the current four minute count on the reference stand with the running average of the last 4 counts (16 minutes). The test passes if the current standard count, is within 2 standard deviations of the previous average (of the last 4 tests).

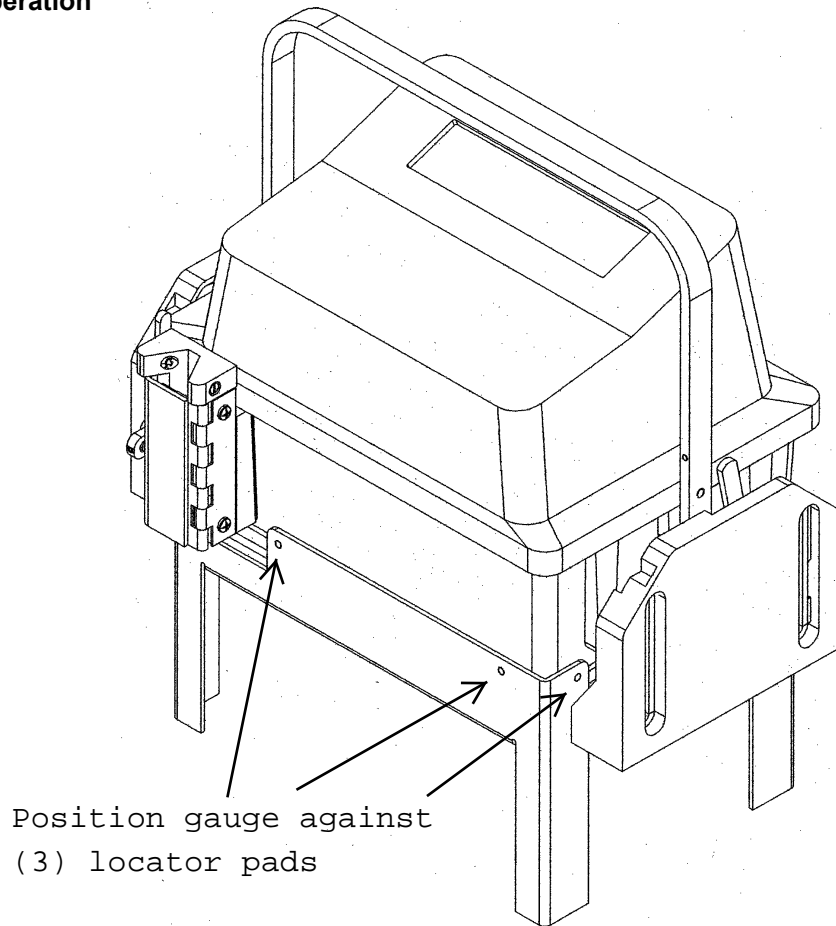
Daily test

Location for the Standard Count Test

The test location should be at least 4 feet (1.5 m) from any wall or other large objects and 30 ft (10 m) from any other nuclear gauges. The test surface can be concrete, asphalt, or soil with a minimum density of 100 PCF (1.6 Kg/l) and a minimum moisture of 5 PCF (0.08 Kg/l). If there is question if the surface meets these minimum requirements, perform a density moisture test in the soils mode using at least 15 second counts. Concrete and asphalt are usually acceptable surfaces even when dry, because they contain an amount of hydrogen equalivent to 5 PCF (0.08 Kg/l) of water. If the standard count test is performed on a surface that is below the minimum density and moisture requirements, the standard count test may indicate a fail, however, gauge accuracy will not be significantly effected. Bottom of gauge and top of reference must be clean.

Standard count test procedure

1. **For air gap backscatter density and moisture, the optional probe should not be present in its guide.**
2. **For direct transmission, with the power off, insert probe into probe guide and connect cable as described on page 26.**
3. **Turn the gauge on.** The main screen will appear on the display.
4. **Place the C-300 on the reference stand** according to the diagram on the next page to avoid standard count errors.



5. **Press MENU, 4.** Follow the instructions in the display.
6. **After the test is complete, the results are displayed. Record the counts and SDev (Standard Deviation) for future reference. To accept the new counts, press ENTER.** To ignore the results, press ESCAPE.
 - A. Pressing ENTER will add the test results to the moving average, replacing the oldest one.
 - B. If a fail occurs, check to make sure the requirements for the standard count test have been met and the gauge is positioned properly on the stand. If the requirements have not been met, press ESCAPE so that reading does not become part of the average. Repeat the standard count test.
 - C. A fail does not necessarily indicate a malfunction. It may be caused by previous tests taken under different conditions, e.g. differing background radiation. If this is the case, press Enter and begin taking measurements.

If an accuracy check is desired, press Enter. With the gauge on the Reference Stand, lower the probe to 4 inch (10 cm) depth and take a density measurement. If this reading is not close to past readings, contact Seaman Nuclear Corporation.

When results are outside of tolerances

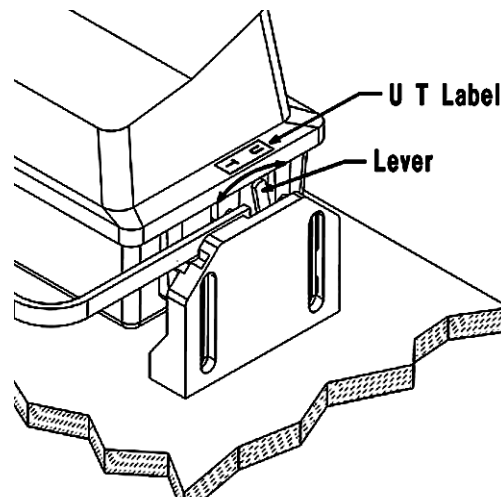
If the moisture standard counts become erratic or change suddenly by 20% or fail is indicated, see the chapter on maintenance and troubleshooting.

Test mode entry: Touchable & Untouchable

To place the gauge in the Touchable (T) or Untouchable (U) modes:

1. **Rotate the carrying handle forward to place the gauge in air gap position.**
2. **Move the levers on both side plates to the T (Touchable) or U (Untouchable) position.**

If the slide levers are not synchronized, the gauge will report an error when trying to start a test.

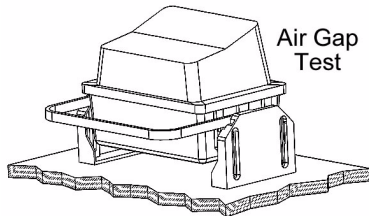
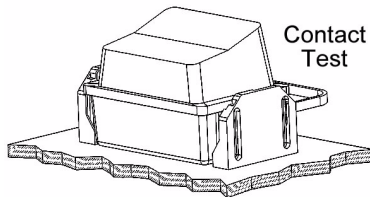


Applying a bias to density or moisture readings

Under certain circumstances, it may be necessary to apply a bias value to density or moisture readings. This bias is entered in either PCF or KGL depending on the current units setting. Density biasing is added to either the bulk value or the top lift value, depending on the mode. Moisture biasing is added to the moisture value. Entering a positive value for either bias will increase the readings, whereas entering a negative value will decrease the reading. To enter a bias:

1. **Press MENU, 7, 6** to enter the bias mode.
2. **Choose 1. Disable Bias, 2. Enable Density, 3. Enable Moisture, or 4. Enable Both.**
3. **If bias is enabled, the gauge will prompt for a bias value.**
 - A. **To keep the current bias, press ENTER or ESCAPE.**
 - B. **To enter a new bias, key-in the new value and press ENTER.** Bias values can be either a positive or negative.

Asphalt density test procedure



1. **Turn the gauge on.** The main screen will appear on the display.
2. **Set asphalt mode by pressing MENU, 1, 1. Then select asphalt display format.** Choose 1. None, 2. % Marshall, 3. % Air Voids, or 4. Both.
3. **Enter lab density by pressing MENU, 2.** If the lab density is correct, press ENTER or ESCAPE. Otherwise, enter the new lab density and press the ENTER key.
4. **Position the gauge on a flat test surface.** A straight edge can be helpful to check flatness of the test site. Press opposite corners to verify that the gauge is properly seated. Even a slight rocking may lead to low density results. For more information on surface preparation see that chapter.
5. **Select Touchable or Untouchable mode by placing the gauge in the air gap position and moving the both side plate levers.**
6. **Begin a contact count by rotating the handle to the rear position and pressing START TEST.** Step Back. The gauge will display the test description, test mode(s) and the time remaining.
7. **When the contact test is finished, begin an air gap test by rotating the handle to the forward position and pressing START TEST.** Step back. The gauge will display the test description, test mode(s) and the test time remaining. On soft material, like that found directly behind a paver, position the gauge carefully in the air gap mode so the end plates do not sink in. Note the order of the counts is not important; the contact or air count can be taken first.
8. **Test result will automatically display at the end of the count.** To display raw count data (cpm) and any bias values, press the ↓ key.
9. **To store the test, press STORE, and follow prompts for entry of project name and test location.** For more information on storing tests see the section titled "Data Storage" in this chapter.

Top lift (Accudepth) asphalt density

To measure top lift density, it is necessary to first determine the bulk 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 the best results, this should be an average of several readings representative of the test area.

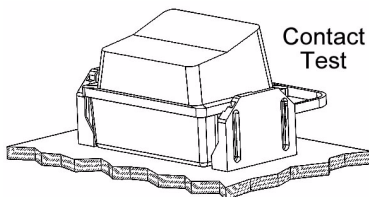
If it is impractical to measure the base density prior to placing the top lift, use the specified density of the base.

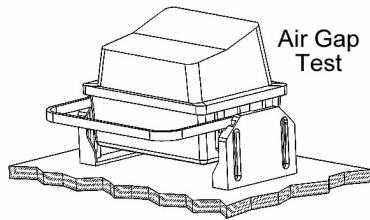
Determine top lift thickness

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 gauge will facilitate the thickness measurement. For a badly rutted base, the top lift thickness will be greater in the wheel tracks.

Procedure

1. **Turn the gauge on.** The main screen will appear on the display.
2. **Select top lift mode by pressing MENU, 1, 3.**
 - A. **Then select asphalt display format.** Choose 1. None, 2. % Marshall, 3. % Air Voids, or 4. Both.
 - B. **Enter the base density and press ENTER.**
 - C. **Enter the lift thickness and press ENTER.**
3. **Enter lab density by pressing MENU, 2.** If the lab density is correct, press ENTER or ESCAPE. Otherwise, enter the new lab density and press the ENTER key.
4. **Position the gauge on a flat test surface.** A straight edge can be helpful to check flatness of the test site. Press opposite corners to verify that the gauge is properly seated. Even a slight rocking may lead to low density results. For more information on surface preparation see that chapter.
5. **Select Touchable or Untouchable mode by placing the gauge in the air gap position and moving the both side plate levers.**
6. **Begin a contact count by rotating the handle to the rear position and pressing START TEST.** Step Back. The gauge will display the test description, test mode(s) and the time remaining.





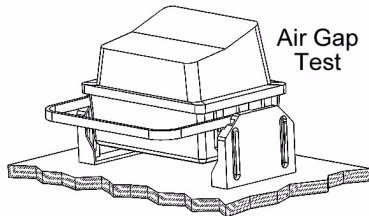
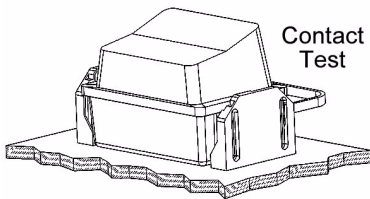
7. **When the contact test is finished, begin an air gap test by rotating the handle to the forward position and pressing START TEST.** Step back. The gauge will display the test description, test mode(s) and the test time remaining. On soft material, like that found directly behind a paver, position the gauge carefully in the air gap mode so the end plates do not sink in. Note the order of the counts is not important; the contact or air count can be taken first.
8. **Test result will automatically display at the end of the count.** To display raw count data (cpm) and any bias values, press the ↓ key.
9. **To store the test, press STORE, and follow prompts for entry of project name and test location.** For more information on storing tests see the section titled "Data Storage" in this chapter.

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 (0.16 kg/l) 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 using air gap backscatter



1. **Turn the gauge on.** The main screen will appear on the display.
2. **Set soils mode by pressing MENU, 1, 2. Then select soils display format.** Choose 1. None or 2. Proctor.
3. **Enter lab density by pressing MENU, 2.** If the lab density is correct, press ENTER or ESCAPE. Otherwise, enter the new lab density and press the ENTER key.
4. **Position the gauge on a flat test surface.** A straight edge can be helpful to check flatness of the test site. Press opposite corners to verify that the gauge is properly seated. Even a slight rocking may lead to low density results. For more information on surface preparation see that chapter.
5. **Select Touchable or Untouchable mode by placing the gauge in the air gap position and moving the both side plate levers.**
6. **Begin a contact count by rotating the handle to the rear position and pressing START TEST.** Step Back. The gauge will display the test description, test mode(s) and the time remaining.
7. **When the contact test is finished, begin an air gap test by rotating the handle to the forward position and pressing START TEST.** Step back. The gauge will display the test description, test mode(s) and the test time remaining. Note the order of the counts is not important; the contact or air count can be taken first.
8. **Test result will automatically display at the end of the count.** To display raw count data (cpm) and any bias values, press the ↓ key.
9. **To store the test, press STORE, and follow prompts for entry of project name and test location.** For more information on storing tests see the section titled "Data Storage" in this chapter.

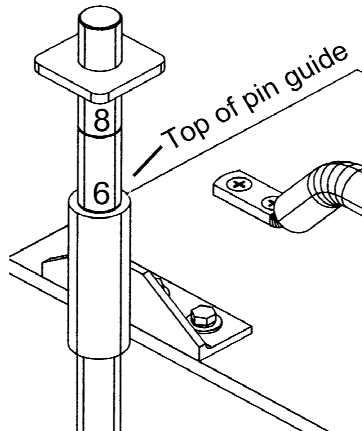
Soil density using direct transmission

There are three parts to performing direct transmission tests.

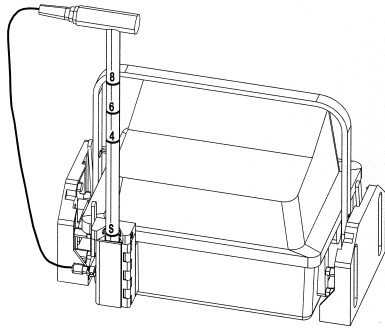
1. Perform a standard count on the reference stand once each day before taking measurements. (See pgs. 27-28)
2. Test site preparation. (See below)
3. Perform the density test at the prepared site. (See next page)

Site Preparation

The accuracy of the test depends on the care used in preparing a flat, smooth surface for the gauge. Procedure:



1. **If the surface is loose or not flat**, use the surface preparation plate to scrape and/or tamp an area slightly larger than the bottom of the C-300. Loose stones should be removed and replaced with native fines.
2. **Place the surface plate on the prepared area.**
3. **Place the pin in the pin guide of surface plate and hammer it to the desired depth. The depth indicators on the pin should line up with the top of the pin guide.** Note: the actual penetration is an additional 3 in (8 cm) beyond the depth indicated. This provides space for loose material that may drop to the bottom of the hole.
 - A. Use safety glasses.
 - B. Place one foot on the surface preparation plate while hammering the pin to insure that the hole is vertical.
4. **Remove the pin** with the puller (supplied):
 - A. Slide the puller over the pin.
 - B. Turn the puller so the pin fits in the notches. (See diagram)
 - C. Lift with a twisting motion.
 - D. Keep one foot on the plate so that the pin comes straight out and so the hole is not disturbed or enlarged.
 - E. Do not loosen the pin by striking it from the side.

Gauge operation for direct transmission testing.

C-300 with 8 inch (20 cm) probe

1. **Attach the probe to the gauge.**
 - A. Turn off the gauge if it is on.
 - B. Loosen the probe guide clamp by lowering its lever.
 - C. Insert the probe into the probe guide on the gauge. Lower the probe until the plungers are in the "S" groove. Rotate the probe handle so it is parallel to the front of the gauge. The depth indicator "S" should be visible.
 - D. Tighten the probe clamp by raising the lever.
 - E. Remove the connector cover and connect the probe cable.
2. **If the daily standard count test has not been performed, do this now.** The standard count test must be performed once each day, before density testing. (See pgs. 27-28)
3. **Place the C-300 on the prepared site with the probe over the hole.**
4. **Lower the probe into the test material.**
 - A. Loosen the probe guide clamp by lowering its lever.
 - B. **Lower the probe to the desired depth indicated (in inches) by the number above the groove. The plungers must drop into (engage) the groove in the probe to correctly set the depth. Incorrect depth will result in testing error. Rotate the probe handle so it is parallel to front of the gauge. The depth number should be visible.**
 - C. Tighten the probe clamp by raising the lever.
5. **Gently slide the gauge diagonally toward the #8 key on the keyboard,** so the probe makes contact with the side of the hole closest to the source.
6. **Enter lab density by pressing MENU, 2, 1.** If the lab density is correct, press ENTER or ESCAPE. Otherwise, enter the new lab density and press the ENTER key.
7. **Place the source in the operate position by rotating the carrying handle to the rear.**
8. **Press the START TEST key. Step back.** The gauge will display the test mode, depth setting, and time remaining.
9. **Test result will automatically display at the end of the count.** To display raw count data (cpm) and any bias values, press the ↓ key.
10. **To store the test, press STORE, and follow prompts for entry of project name and test location.** For more information on storing tests see the section titled "Data Storage" in this chapter.

Trench density (moisture side effect) procedure

To minimize the effect of the trench side wall, place the gauge so the moisture detector, which is located on the right side of the gauge, is furthest from side wall. Normally, 1 foot (25 cm) from a side wall is sufficient.

To determine if side wall is effecting the moisture calibration, and to correct for this condition, the gauge is placed in the trench on the reference stand at distance from the side wall that density/moisture tests will be taken. By taking a standard in the trench and comparing it to the standard count outside of the trench, the degree of correction, if any, can be determined. If no side effect is detected, then the trench mode is not required.

(from Menu section: Selecting this item will display the option Disable Trench Mode or Enable Trench Mode. The cursor will be on the currently active mode.

If the user enables the trench mode, the gauge will display the current trench mode count and display a list of three choices: 1. Use Existing Count, 2. Enter New Count (from the keyboard), or 3. Take New Test.)

1. **Enable the trench mode by pressing MENU, 5, 2.**
2. **Select desired count by:**
 - A. If the existing count is valid, press 1 to accept,
 - B. otherwise a new count can be entered from the keyboard by pressing 2,
 - C. or the gauge will take a new test by pressing 3.
3. **To take a new test, center gauge on the standard count reference** in the trench where a density moisture measurement is needed.
4. **Begin a contact count by rotating the handle to the rear position, press the ENTER key.** The gauge will take a one minute test.

Note: The new moisture standard count is valid only at the distance from the side wall at which the gauge was placed on the standard count reference. New moisture standard counts must be obtained and used for other distances between the gauge and the side wall and for other levels in the trench.
5. **Remove the standard count reference and place the gauge on a properly prepared test surface. Proceed with a routine (air gap and contact) test.** Step back. All test results will now show reflect the moisture side wall correction, until the trench mode is disabled.
6. **To disable the trench mode, press MENU, 5, 1.**

Do not take the test on the reference stand with the gauge handle in the shielded position.

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. See Applying a bias to density or moisture readings.

Notes:

3

Surface Preparation

The following instructions apply to air gap backscatter measurements in asphalt and soils. See chapter 2 for procedures relating to direct transmission testing.

It is the operator's responsibility to present a representative sample for the gauge to test. To obtain consistent and accurate readings, intimate contact between the bottom of the gauge and the test material is important. If any air gap exists below the gauge, radiation may "short-circuit" from the source to the detector tube, resulting in too low a density reading. The gauge 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 gauge to read too low a density.

Always remember that the calibration of the gauge 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 gauge does not rock (all four corners of the gauge 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 gauge directly over the mound. The sensitive area is

that between the source (center) and the left side of the gauge. To test surfaces compacted with pneumatic rubber tired rollers: test on the ridges, avoid the wheel tracks.

Touchable and Untouchable

New gauge 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 gauge will produce density readings that are low by 6-10 PCF or more. Only Seaman Nuclear gauges operate in such a manner that the gauge 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 gauge 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 gauge 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 gauge. 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 gauge is not only radiating through the bottom but also through the sides. An erroneous reading is generated because the gauge 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 gauge 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 gauge 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 gauge next to the side wall and take a dry density reading. Next, move the gauge one inch away from the side wall and take another dry density reading. Continue moving the gauge 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 gauge transverse to the stretch cracks; that is, position the gauge so that the handle (and therefore the line between the source and detector) is perpendicular to the cracks. If the gauge 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 gauge 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 gauge. 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 gauge 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 gauge. 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 the chapter on gauge operation.

High/low density moisture readings

There are a number of conditions that may cause the gauge 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 gauge and the ground surface, the radiation emitted from the gauge will "short-circuit" across the air gap and be counted by the detector rather than penetrating the test material. The gauge 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 gauge 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 chapter on 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 the adjusted moisture standard count. See the chapter on gauge operation.

Filler material

Native filler material can be used to fill in surface voids, thereby increasing the operating range of the gauge. 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 chapter on surface preparation for further information.

Always remember that the calibration of the gauge 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 gauge 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 gauge 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 gauge off and then on.

Moisture reading errors

A moisture reading that is too low may be indicated by the gauge 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 gauge 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 gauge 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-300 gauge 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 repair procedures.) In any event, the license conditions under which these gauges are distributed do not permit users to service or disassemble the source/shielding assembly. Regulations require observing the "Do Not Disassemble Beyond this Point" label.

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-300 gauge and compliance with license conditions.

Keep the base of the gauge clean

The base of the gauge 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 gauge, resulting in density readings that are too low. Check the base for flatness with a straight edge and by placing the gauge on a true, flat surface. To clean, place the source in the shielded position, turn the gauge on its side, and remove the material using a long handled scraper. Solvent may be used as required. Always keep fingers, hands, etc., away from the bottom of the gauge.

Side plates

The two side plates raise and lower the gauge 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. When properly adjusted, the side plates will have a small amount of side-to-side play.

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

Display

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

Sealed source leak testing

In most cases, leak tests are required every 6 months. For explanation of the leak test, refer to the chapter on Radiation Safety & Regulations. Directions for the procedure are provided with the leak test kit.

Source shielding mechanism check

The source shielding assembly is very rugged and it is unlikely that any difficulty in its operation will occur. To check 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 gauge 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 gauge. Call Seaman for further instruction.

Density/moisture reference spot

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

Selecting the location

Upon receipt of your gauge, 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 objects. Use a 2 ft straightedge to insure that the spot is flat. Mark this spot permanently with an outline of the gauge on the floor so the gauge 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. Step back for each test. These averages should be retained for future reference. Establish other reference spots when operating at a distance from the original reference location.

For Direct Transmission, test on Reference Stand with Probe set to 4 inch.

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 gauge's performance is in question

If the gauge 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 gauge is out of calibration, but is responding to extraneous sources of radiation.

Battery

The C-300 gauge is designed for operation from a 12 volt battery. Standard equipment is a 12 volt, 3.2 ampere hour, gelled electrolyte, sealed lead acid battery. This is the only standard power source for the gauge. Consult the Seaman Nuclear Corporation concerning the availability of, or modification for, any other power sources that may be used. The battery is located in a compartment in the rear of the gauge. To access the battery, twist the quarter turn fasteners and remove the cover.

Low battery indication

The C-300 gauge is designed to provide normal operation for battery voltages above 10.5 volts. At a battery voltage of approximately 11.5 volts, a message indicating low battery voltage will appear on the display. When the battery voltage drops below 10.5 volts, an automatic cutoff circuit is activated and the gauge 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.

Battery capacity

The standard battery will provide a nominal capacity of 90-100 hours operating time during typical testing. Battery capacity is slightly less under cold conditions.

Recharging

The battery charger supplied is designed to operate from a standard 115 vac, 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

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

Keep the spare battery charged and with you at the job site.

longer periods of time, up to one week.

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.

Fuse

A single, one amp 250 volt fuse is located inside the battery well of the gauge. The fuse protects the electronics from a short circuit or wrong polarity on the battery.

Direct transmission (optional)

Cleaning

The probe and probe guide, pin, and tamping plate with pin guide should be cleaned as necessary to allow proper functioning. No lubrication of these parts is required.

To open the probe guide door:

1. Lower the lever and remove the probe.
2. With the lever lowered, push the hinge door closed.
3. Lift the latch and swing the door open.

Adjustments

On an infrequent basis, such as once a year, it may be necessary to adjust the plungers so they provide positive engagement with the grooves in the probe for easy setting of the probe depth. Adjust each plunger equally until positive engagement is felt.

Also, on an infrequent basis, it may be necessary to adjust the clamping force provided by the probe guide to insure there is no play in the mechanism when a test is conducted. To check for play, place the probe in the S position, raise the lever, and grab the probe handle. If play is felt, adjustment is needed. To adjust, lower the lever and turn the set screw in the latch 1/4 turn. Raise the lever and recheck. Repeat as needed.

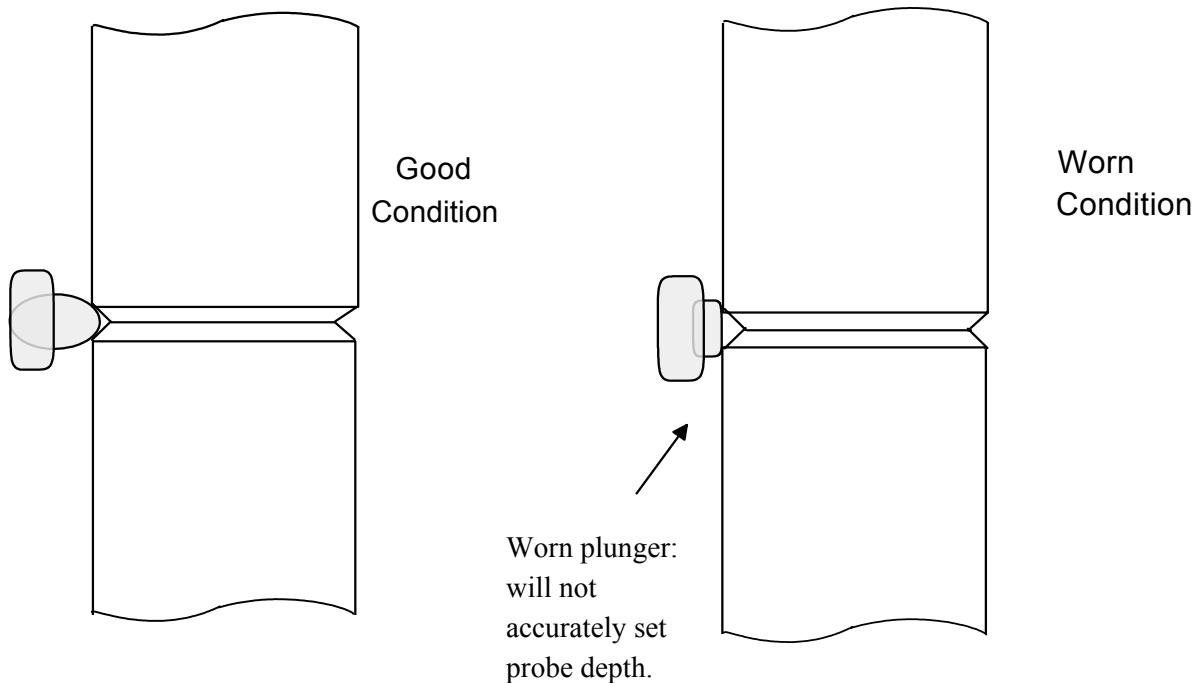
Locktight is applied to the set screw at the factory. During adjustment if the set screw is loose, remove the screw, applied a removable grade of locktight and readjust. If the screw is lost, replace only with a flat tip set screw.

Inspect plungers

The two drawings below show a close up of the direct transmission probe and depth locating plunger. The plunger fits into the V groove in the probe to positively set the test depth at 4, 6, or 8 inches. Poor density test results will occur if the pin becomes worn (as displayed in the lower drawing) or the operator is careless about locating the probe depth.

The Plunger is designed to wear, preventing damage to the probe. Replace the plunger when it wears flat and positive detent is no longer felt.

When replacing the plunger, adjust so the body of the new plunger is in the same depth as the one removed. Fine adjust to minimize friction of plunger against probe, while insuring positive detent (click) when plunger is in groove. Additional plungers, part number 763-6707 are available from the Seaman Nuclear Corporation at (414) 762-5100.



Troubleshooting poor test results or malfunction

Testing error has three primary sources:

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

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.

Step three

Run the diagnostic hardware testing described in the Special functions section of Chapter 2. Report any failure to Seaman Nuclear Corp. when sending the gauge in for service.

Symptoms & suggested remedies

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

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

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

Gauge will not start a test: ♦ 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 blank when gauge turned on: ♦ Charge or replace the battery ♦ Check the battery connection and fuse. ♦ Moisture may be inside of gauge. Call the factory for instructions on how to dry out the gauge.

Gauge shuts off immediately after turn on: ♦ Charge or replace the battery.

Battery does not charge: ♦ Replace the battery ♦ Check the battery charger (10.5 volts dc without load).

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:

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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

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

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.

| 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.
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

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.

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



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



C-300 Gauge Drawing

