CPN® MC-1DR-P PORTAPROBE®

Operating Manual

CPN International, Inc.

4057 Port Chicago Highway

Suite 100

Concord, CA 94553 USA

Tel: (925) 363-9770

Fax: (925) 363-9385

Website: www.cpn-intl.com

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WARRANTY

CPN products are guaranteed against defective material and workmanship for a period of eighteen (18) months from the date of receipt by customer, or a maximum of twenty-four (24) months from the date of manufacture, whichever comes first. Detector tubes are guaranteed for twelve (12) months from the date of shipment from CPN. Fuses and batteries are guaranteed for six (6) months from the date of shipment from CPN.

Upon their prepaid return, CPN will replace free of charge any part found to be defective within these warranty periods. CPN reserves the right to repair all defective parts at our factory, or authorized CPN service facility.

This warranty is void if inspection shows evidence of abuse, misuse, or unauthorized repair. This warranty covers only replacement of defective materials and workmanship. This warranty does not cover damage caused by exposure to excessive moisture.

If, for any reason, this unit must be returned to our factory for warranty service, please contact us for return authorization and shipping instructions. Include with the shipment: customer purchase order number, CPN Company invoice number and date, serial number of gauge and reason for return.

Using The MC1DR-P Bias Feature
Operator Manual Change Notice
Software Version 6.0

This MC1DR-P has been updated to include a Bias capability for both the density and moisture readings. This feature allows the user to enter in a correction (+/-) that will be stored into memory and applied to each test.

To use this feature press the **[MAX]** key. Within the **MAX** menu you can **[STEP]** between.

Proctor Test? **= 0.0**	*User enters Proctor value and %* *of Proctor is displayed after test.*
Marshall Test? **=0.0**	*User enters Marshall value and %* *of Marshall is displayed after test.*
Moisture Bias? **=0.0**	****User enters bias +/- in the appropriate units*** ***and the Moisture results are adjusted up or down.***
Density Bias? **=0.0**	****User enters bias in the appropriate units and*** ***the Wet Density results are adjusted up or down.***
Air Voids Test? **=0.0**	*User enters a Specific Gravity and %* *Air Voids is displayed after test.*

***When a bias is entered in either Density or Moisture the end result is preceded by the "#" symbol to remind the user that an adjustment has been applied.**

EXAMPLE: A laboratory oven dry reveals that the nuclear gauge is reading moisture contents 2.4 PCF higher than actual moisture for a certain material.

On the MC1DR press **[MAX]** then press **[STEP]** until the display reads
Moisture Bias?
= 0.0
Press **[ENTER]** then use the ▲▼to enter a **–2.4** bias then press **[ENTER].**

Your results will now have 2.4 PCF moisture subtracted from the measured moisture of each test until the bias is removed by resetting it 0.0.
All of the results that have a bias will be preceded by the "#" symbol.

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Section 1 - General Information

Product Description

The **CPN MC-1DR-P PORTAPROBE®** is a rugged, microprocessor-based instrument that measures the density and moisture of soil and construction materials. The **PORTAPROBE®** provides fast and accurate measurements, and displays the results on a liquid crystal display (LCD).

The **PORTAPROBE®** complies with the following ASTM standard test methods:

D 2922 - Density of Soil and Soil Aggregate in Place by the Nuclear Method
D 3017 - Moisture Content of Soil and Soil Aggregate by the Nuclear Method
D 2950 - Density of Bituminous Material in Place by the Nuclear Method

The **PORTAPROBE®**, depending upon the model, measures material density in 1 or 2 inch (25 or 50 mm) increments to depths up to 8 or 12 inches (200 or 300 mm). The keypad of the **PORTAPROBE®** allows the operator to enter target maximum density values. Moisture measurement averages 6 inches (150 mm) depth.

Proper use of the **PORTAPROBE®** will impose no radiation hazard on the operator. However, a potential danger does exist if the equipment is improperly used. Operators should read and understand the literature covering radiation safety, and attend a radiation safety and applications training course offered by the manufacturer or other competent instructor.

CPN MC-1DR-P PORTAPROBE® Features

- Direct readout of density and moisture test results on a large liquid crystal display:

  Total (wet) density
  Total Moisture
  Dry density
  % Water
  % Proctor
  % Marshall
  % Air voids
  Air voids ratio

- Large (3/8") display characters are easily to read in direct sunlight from a standing position.
- Battery pack of 6 D size cells is field replaceable in about 5 minutes.
- New batteries allow up to 25,000 tests, or 1 or 2 years of intensive use.
- Percent battery remaining and test position displayed at start of each test.
- Easy to use. Four keys only. No hands-on training required.
- Display of standard count statistics verifies proper performance daily.

Functional Description

The **CPN MC-1DR-P PORTAPROBE®** operates by emitting radiation from two safety-sealed radioactive sources:

- Cesium-137, a gamma emitter for density measurement
- Americium-241:Beryllium, a neutron emitter for moisture measurement.

To determine density, the Cesium-137 source emits gamma radiation into the test material. Some of the gamma radiation will pass through the material and be detected by the Geiger-Mueller detectors located within the **CPN MC-1DR-P**. A material of low density will give a high count per time of test. A material of high density will give a low count for the same period of time, as the high-density material absorbs more gamma radiation.

To determine moisture content, the Americium-241:Beryllium source emits neutron radiation into the test material. The high-energy neutrons are moderated by collision with hydrogen atoms in the moisture of the material. Only low-energy, moderated neutrons are detected by the Helium-3 detector. A material that is wet will give a high count per time of test. A material that is dry will give a low count for the same period of time.

Standard Equipment

Each **CPN MC-1DR-P** is provided with a durable plastic shipping case and the items shown in Figure 1-1. There are no special instructions for unpacking the **CPN MC-1DR-P PORTAPROBE®**. It comes fully assembled.

Item	Part Number
CPN MC-1DR-P PORTAPROBE®	114082
Reference Standard, 3"	701423
Handle Lock Key	400925
Guideplate	200050
Drill Pin	100035
Lubricant	704396
Operating Manual	704497
Leak Test Certificate	700762
Leak Test Kit	401197
Radiation Sign Kit	101085
Padlock and Keys	700472
Shipping Case	704467
Clipboard	703946
Phillips Screwdriver	700646
Allen Head (Hex Drive) Wrench	700760
Hex Ball Driver, 9/64 in	700764
Hex Ball Driver, 5/32 in.	700763
Cleaning Brush	702403

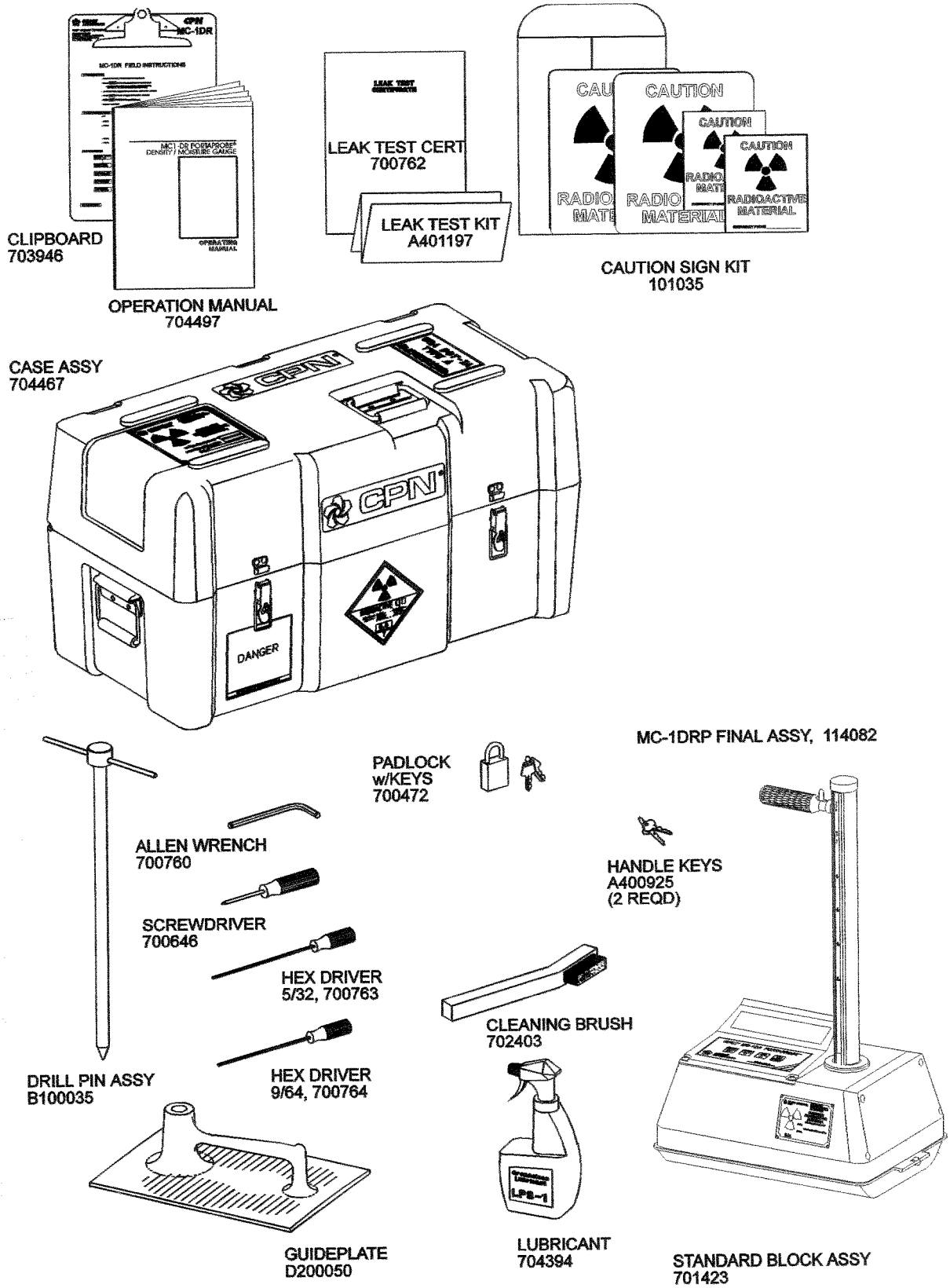


Figure 1-1. **CPN MC-1DR-P PORTAPROBE®** Standard Equipment

Specifications

Dimensions/Shipping Weights

Model	Weight	Length	Width	Height
CPN MC-1DR-P (gauge only)	31 lbs/14.3 kgs	14 in/356 mm	9 in/229 mm	22 in/559 mm
CPN MC-1DR-P (with shipping case)	77 lbs/35.5 kgs	25.6 in/650 mm	15.4 in/391 mm	16.1 in/409 mm

Performance

Functions — In-place density and moisture measurements.

Density Range — 70 to 170 pcf (1.12 to 2.73 g/cm^3)

Moisture Range — 0 to 40 pcf (0 to 0.64 g/cm^3)

Precision
[one minute test at 125 pcf (2.00 gm/cm^3) density; 10 pcf (0.24 g/cm^3) moisture]

Backscatter (BS)	±0.80 pcf (0.013 g/cm^3)
Asphalt-Concrete (AC)	±0.50 pcf (0.008 g/cm^3)
Transmission(6 in)	±0.25 pcf (0.004 g/cm^3)
Moisture	±0.25 pcf (0.004 g/cm^3)

BS Chemical Error — ±1.00 pcf (0.016 g/cm^3)

Transmission Chemical Error — ±0.75 pcf (0.012 g/cm^3)

Surface Roughness Error
[0.05 in (1.3 mm); 100% void]

Backscatter (BS)	-3.00 pcf (-0.048 g/cm^3)
Asphalt-Concrete (AC)	-6.0 pcf (-0.0096 g/cm^3)
Transmission(6 in)	-0.5 pcf (-0.008 g/cm^3)
Moisture	-0.7 pcf (-0.011 g/cm^3)

Depth of Measurement

Backscatter (BS)	3.0 in (7.6 cm).
Transmission	2 to 8 in (50 to 200 mm); optional 2 to 12 in (50 to 300 mm)
Moisture	6 in (15.2 cm)

Display — 2 line x 16 character dot matrix liquid crystal display (LCD)
Readable in direct sunlight.

Counting Time — 1 minute. Keystroke completes test early.

Specifications

Performance

Calibration	Factory calibration.
Units of Measurements	Factory preset: pcf or g/cm^3.

Electrical

Power Source	Internal battery pack of 6 D size alkaline cells.
Battery Life	Up to 25,000 1 minute tests.
Power Consumption	12 mA, average (based on 600+ 1 minute counts)

Environmental

Operating Temperature	Ambient: 32° to 150°F (0° to 66°C) Hot substrate Surface Temperature: Up to 350°F (177°C) for 15 min.
Storage Temperature	-4° to 140°F (-20° to 60°C)
Humidity (non-condensing)	95%

Radiological

Gamma Source	0.37 GBq (10 mCi) Cesium-137
Neutron Source	1.85 GBq (50 mCi) Americium-241:Beryllium
Encapsulation	Double-sealed capsule, CPN-131
Shipping Requirements	Radioactive Material, Special Form, N.O.S., UN2974, Transport Index 0.4, Yellow II Label, USA DOT 7A, Type A Package
Special Form Approval	GB/24/S and GB/281/S

An NRC or Agreement State license is required for domestic use. Contact Boart Longyear/CPN Company for assistance in obtaining training for a license.

Definitions

CHEMICAL COMPOSITION ERROR:

The error due to the variation in photon scattering and absorption coefficients for limestone and granite. Most natural soils and aggregates are between these limits.

SURFACE ROUGHNESS ERROR:

The error due to surface voids, determined by measuring the density or moisture content of a smooth surfaced standard and repeating the measurement with the instrument baseelevated 0.05 inch above the standard.

DEPTH OF MEASUREMENT:

The depth through which 95% of the counted photons and thermal neutrons pass before reaching the detectors.

PRECISION (Pr):

The statistical precision of the gauge computed at the 68.3% confidence level (± 1 standard deviation). It states that the repeatability of the gauge is such that 68.3% of repeated measurements on the same site will fall within the average ± precision value.

$$\text{Precision (Pr)} = \frac{\sqrt{\text{actual accumulated counts}}}{\text{slope of the calibration curve}}$$

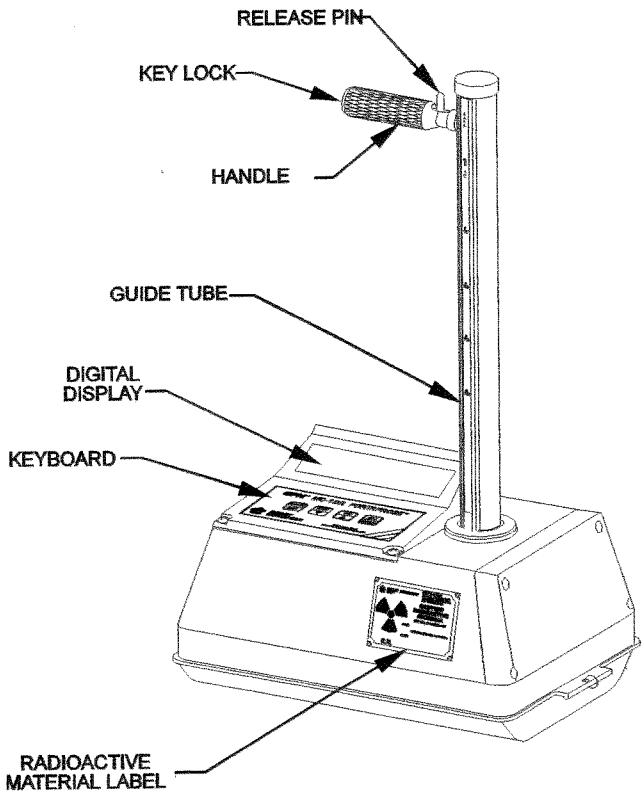
Boart Longyear/CPN reserves the right to change equipment specifications and/or design to meet industry requirements or improve product performance.

CPN MC-1DR-P PORTAPROBE® Inspection

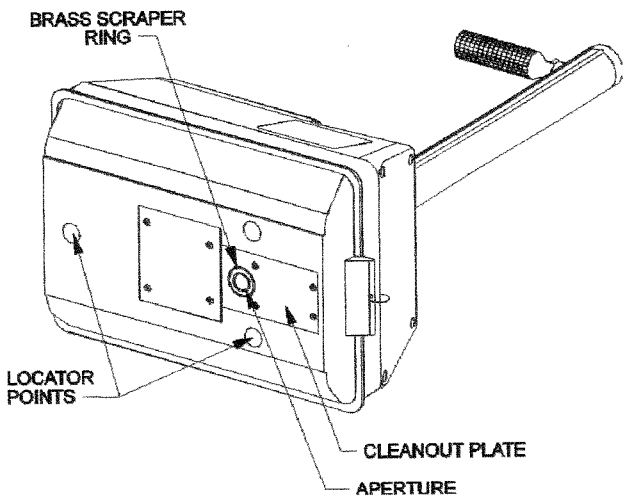
To familiarize yourself with the **CPN MC-1DR-P PORTAPROBE®**, perform the following review.

1. Remove **PORTAPROBE®** from shipping case and place on solid flat surface, such as a concrete floor.

2. Examine the keyboard, display screen, handle, and guidetube.



3. Examine the bottom of the unit. Behind the aperture in the cleanout plate is a carbide shutter block which is spring-mounted and automatically opens and closes when the source rod is lowered and retracted. A brass scraper ring around the opening cleans the source rod as it is retracted.



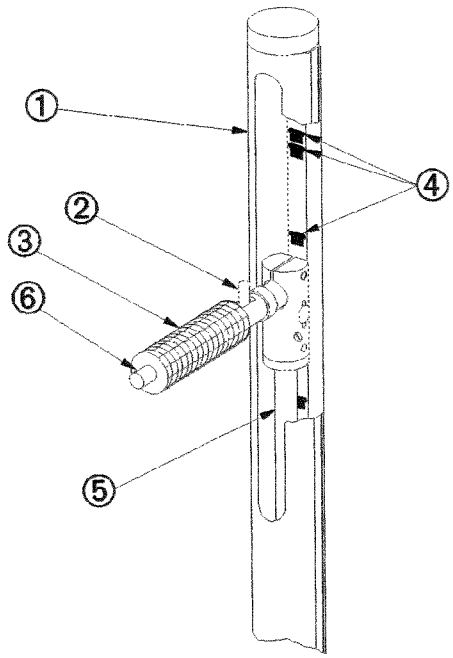
NOTE

A radioactive source is located in the source rod behind the shutter block. Do not touch the source rod or place yourself in front of unshielded source rod.

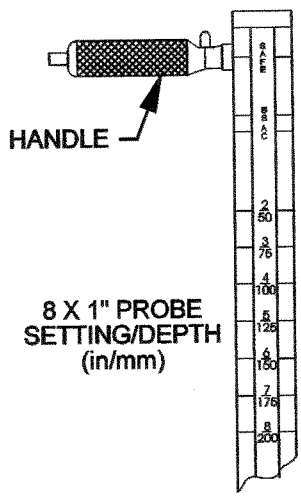
CPN MC-1DR-P PORTAPROBE® Inspection

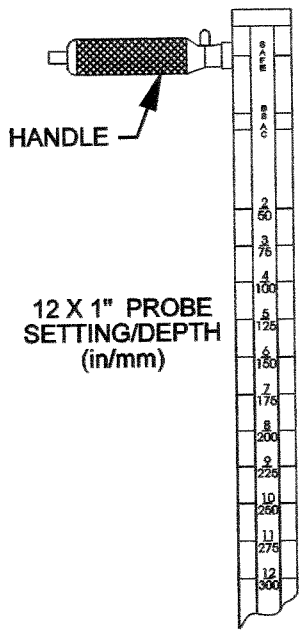
4. Examine the guide tube assembly.

    1. Guide Tube.
    2. Release or Thumb Pin.
    3. Probe Handle.
    4. Locking Recesses.
    5. Source Rod (gamma source at bottom).
    6. Button Key Lock.



The **CPN MC-1DR-P** has 8 in (200 mm) or 12 in (300 mm) maximun depths of measurements in 1 in (25 mm) or 2 in (50 mm) increments.





Keyboard Functions

The keyboard of the **MC-1DR-P PORTAPROBE®** is shown below.

Key	Function
START / EXIT	Starts a test. Completes a test in progress. The EXIT function is enabled when the MAX key is pressed.
STEP / ▼	Displays most recent test results. Steps to next display. Steps to the next test mode when the MAX key has been pressed and also decrements the selected maximum value.
STD / ▲	STD and then START, starts a new standard count. Increments the selected maximum value when the MAX key is pressed twice.
MAX / ENTER	Enables the lower functions of the keys. Starts selection of the test mode (Proctor, Marshall, or Air voids). When pressed again selects the test mode displayed. The ENTER function stores the value displayed.

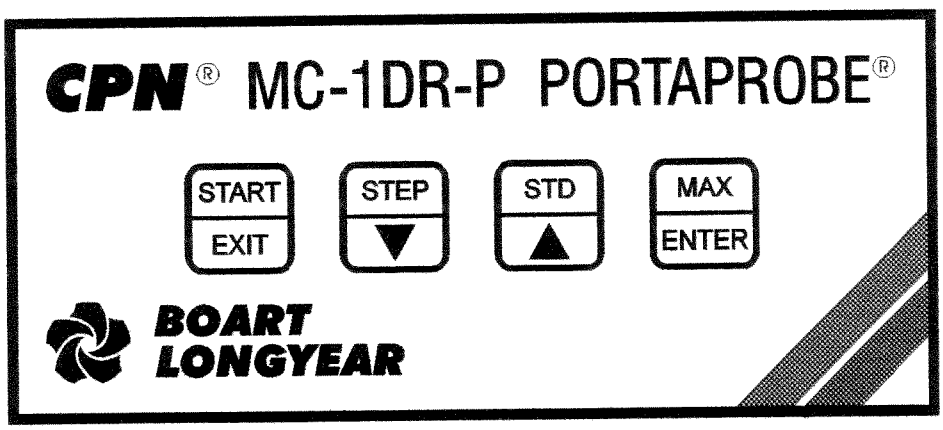


Figure 2.1. **MC-1DR-P PORTAPROBE®** keyboard.

Special Functions

If required, several special functions can be set on an internal switch panel.

1. Remove the 4 screws securing the keypad/display module.

2. Lift out the module and turn upside down, leaving the cables connected.

3. A switch panel is located between the keypad/display module and the PC board.

4. Set the switch selections as desired. Factory settings are to the OFF position unless otherwise specified.

Switch Number	Function	
	ON	**OFF**
1	4 minutes counting time. Overrides switch 4.	No function.
2	Counts only	Density and counts.
3	Spanish labels.	English labels.
4	¼ min. test in BS/AC	1 minute test.
5	g/cm^3 units	pcf units.

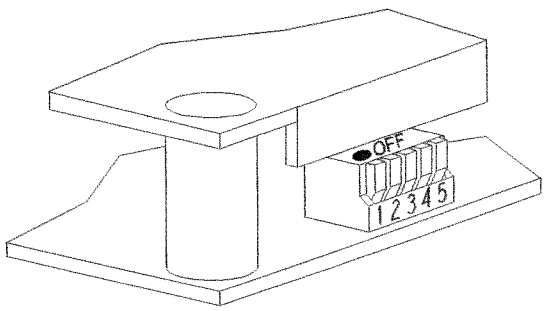


Figure 2.2. Internal Switch Functions.

Configuring the PORTAPROBE® for Measurements

The **CPN MC-1DR-P PORTAPROBE®** displays the following direct measurements after all tests.

1. TotDen: Wet or total density (pcf or g/cm^3).
2. TotWater: Total moisture (pcf or g/cm^3).
3. DryDen: TotDen - TotWater (pcf or g/cm^3).
4. %Water: (TotWater / DryDen) x 100.
5. Dcount: Density counts (cpm).
6. Mcount: Moisture counts (cpm).

The operator may enter target maximum values determined by standard laboratory tests (ASTM or comparable) before or after a test is taken.

Pressing the **MAX/ENTER** key allows selection of one of three possible target density vakues: Proctor Test, Air void Test, or Marshall Test. The first time that the **MAX/ENTER** key is pressed, the measurement test in use is displayed. Pressing the **STEP/▼** key will switch to the other tests. To accept another test, press the **MAX/ENTER** key again, or press this key if the maximum value corresponding to the test in use needs to be changed.

Following are the keypads operations for the three relative measurement options:

Case 1:

The **MAX/ENTER** key was pressed, and the MC-1DR-P displays that the test in use is the Marshall Test.

Marshall Test?

Pressing the **MAX/ENTER** key will accept this test mode. The Maximum Wet Density value (commonly called the Marshall value) is displayed, and the other three keys become active. The **START/EXIT** key allows to exit without making any change to the maximum value, and also left the selected test active. The **STEP/▼** and **STD/▲** keys allows the operator to change the maximum value. Pressing and holding any of these keys it will change the value. When the desired value is displayed, press the **MAX/ENTER** key to accept it.

Max Wet Density 148.0

When the Marshall Test mode has been selected, at the completion of any test the gauge will display, besides the direct measurements, the percent Marshall and the percent Water.

%Marshall	98.5
%Water	12.7

Configuring the PORTAPROBE® for Measurements

Case 2:

The **MAX/ENTER** key was pressed. The MC-1DR-P displays that the test in use is the Proctor Test.

Proctor Test?

Pressing the **MAX/ENTER** key will accept this test mode. The Maximum Dry Density value is displayed, and the other three keys become active. Press the **START/EXIT** key to exit without making any change to the maximum value, or **STEP/▼** and **STD/▲** keys to change the maximum value. When the desired value is displayed, press the **MAX/ENTER** key to accept it.

Max Dry Density 132.0

When the Proctor Test mode has been selected, at the completion of any test the gauge will display (besides the direct measurements) the percent Prooctor and the percent Water.

%Proctor 98.5 %Water 12.7

Case 3:

In this case the MC-1DR-P displays that the test in use is the Air Void Test Test.

Air Void Test?

Pressing the **MAX/ENTER** key will accept this test mode. The Theoretical Maximum Density is displayed. Change the maximum value using the other three keys, and press **MAX/ENTER** to accept it.

Theoret Max Den 120.0

In this test mode the gauge will show the percent Air Voids and the percent Water.

%AirVoid 12.55 %Water 12.7

Configuring the PORTAPROBE® for Measurements

The following parameters can be configured for the **CPN MC-1DR-P PORTAPROBE®** to meet your needs.

Parameter	Factory Configuration	Range/Options
Units	pcf	- pcf - g/cm^3.
Test Mode	Proctor Test	- Proctor Test - Marshall Test - Air Void Test
Maximum Wet Density	150.0	0.0 to 250.0 pcf (0.0 to 4.00 g/cm^3)
Maximum Dry Density	150.0	0.0 to 250.0 pcf (0.0 to 4.00 g/cm^3)
Theoretical Maximum Density	150.0	0.0 to 250.0 pcf (0.0 to 4.00 g/cm^3)

The **CPN MC-1DR-P PORTAPROBE®** will calculate and display the relative (%) compactions using the following equations.

$$\%Proctor = \frac{Dry\ Density}{Maximum\ Dry\ Density} \times 100$$

$$\%AirVoids = \left(1 - \frac{Total\ Density}{Theoretical\ Maximum\ Density}\right) \times 100$$

$$\%Marshall = \frac{Total\ Density}{Maximum\ Wet\ Density} \times 100$$

Taking a Test

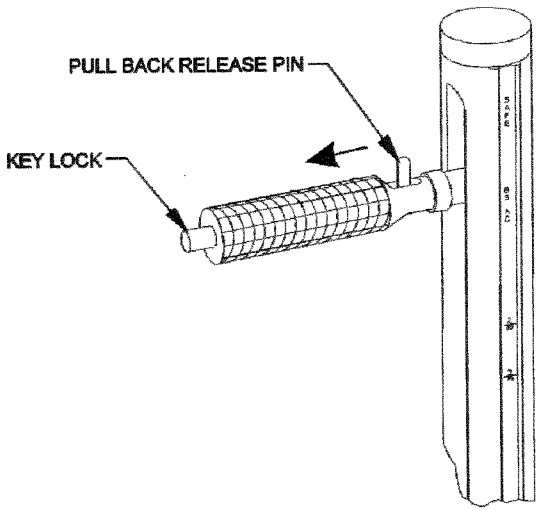
To take a field test, perform the following:

Action

1. Prepare the site to be tested (see section 3, Field use) and position the gauge and handle. Use key to unlock handle. Pull back release pin and set handle to depth position desired.

   Press **START** to begin a test.

Result



The MC-1DR-P displays the % battery remaining and the position (depth) of the density test for 5 seconds.

Battery 75 % Depth 6

Then the gauge displays the test countdown, beginning at 60 seconds.

Countdown 60 seconds

Note: Pressing **START** during countdown will complete the test early.

At the completion of the test the gauge displays the total density (Wet Density) and the total moisture (TotWater).

TotDen	128.5
TotWater	12.7

Press **STEP** to display the dry density (DryDen) and the percent of water (% Water).

Dry Den	115.8
% Water	10.97

Press **STEP** again to display the density and moisture counts (Dcount and Mcount).

Dcount	26717
Mcount	5301

The next screens will depend on the test mode selected as follows:

Case 1: Proctor test selected.

Press **STEP** to display the percent Proctor and the percent Water (% Water).

%Proctor	90.8
% Water	10.97

Case 2: Air Void Test selected.

Press **STEP** to display the percent Air Voids and the percent Water.

%AirVoid	12.26
%Water	10.97

Case 3: Marshall Test selected.

Press **STEP** to display the percent Marshall and percent Water.

%Marshall	90.8
%Water	10.97

In any case, after 30 seconds, the display goes blank to conserve power. Press the **STEP** key to display most recent test results.

Standard Counts

Because the radioactive sources in the **PORTAPROBE®** decay slowly over time, the user must periodically take a standard count on the reference standard provided. When this is done, the previous standard count is replaced and the **CPN MC-1DR-P** program uses the new standard to calculate the field count/standard count ratio to compensate for source decay. It is recommended that a new standard be taken daily to verify the performance of the **PORTAPROBE®.**

"Xi" is displayed and signifies the chi-squared distribution of the counts. This is the ratio of the actual distribution of the counts compared to the expected distribution. Xi ratios between 0.75 and 1.25 indicate that the **CPN MC-1DR-P** is working properly. If the Xi value is outside of expected limits, repeat the standard count. If the statistics are again poor, call the Boart Longyear/CPN factory for service.

The change between the present and previous standard counts should be smaller than 2 times the square root of the average count. ASTM Standard Test Methods D2922, D3017 and D2950 contain a section on standardization and reference checks on nuclear instrumentation.

Standard Count Procedure

Action	Result
1. Set the **PORTAPROBE®** on the standard count block on a solid, flat surface (i.e. compacted soil, asphalt, etc.). Three metal pins on the standard block match up with three indentations on the bottom of the gauge. Handle is in **SAFE** position.	

NOTE
Locate the **PORTAPROBE®** at least 15 ft. (4.5 m) from any other nuclear gauge and at least 5 ft. (1.5 m) from other objects.

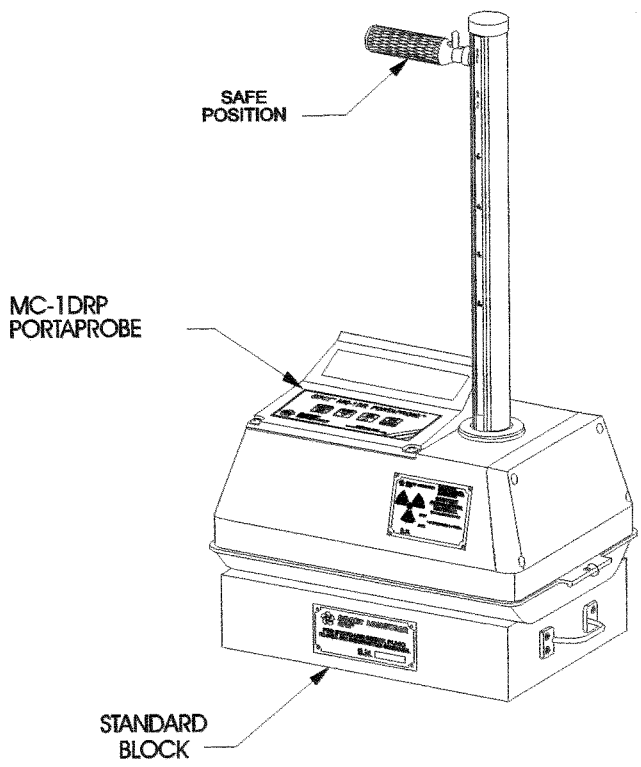


Figure 2-3. Standard Count Procedure

Action	Result
Press **STD** to display the current density and moisture standards counts (Dstd and Mstd).	Dstd 26304 Mstd 21394
Press **START**.	
The gauge displays the % battery remaining and the position (**SAFE**) of the handle for 5 seconds.	Battery 75% Depth safe
Then the gauge displays the test countdown, beginning at 240 seconds.	Countdown 240 seconds
At the completion of the count the gauge displays the density and moisture standards counts (Mstd and Dstd).	Dstd 26233 Mstd 21445
Press **STEP** to display the density and moisture Chi-square ratios (Dxi and Mxi).	Dxi 0.97 Mxi 1.03
The new standard counts are now in memory, replacing the previous values.	

Calibration

Each **CPN MC-1DR-P** is calibrated at the Boart Longyear/CPN factory on standards traceable to the National Bureau of Standards. A computer calibration printout, similar to the example below, is in the shipping container. This information is permanently burned into Eeprom and cannot be accidentally erased. It is recommended that the **CPN MC-1DR-P** be recalibrated by the Boart Longyear/CPN factory or authorized Service Center every 1 to 2 years.

Boart Longyear/CPN CALIBRATION

SERIAL NO: 2103 MODEL: MC-1DR-P

DENSITY STANDARD COUNT: 36310 DATE: 940712
CALIBRATION DATE: 940712

DEPTH	-----COUNT AT----- 1.717	2.14	2.632	--- A ---	--- B ---	--- C ---
	----- Mg/m^3 -----					
BS	24868	18698	13812	2.41224	1.18436	.11896
AC	49236	37044	26900	4.44034	1.36054	.09914
50	120314	87758	60185	11.61835	1.43689	-.20318
100	109341	74293	47628	14.69058	1.07225	.04968
150	82174	51398	29800	15.24046	.89976	.00285
200	53821	30680	16683	16.58982	.69386	.08571
250	32612	17447	9188	14.59902	.59712	.07516
300	19205	10033	5507	11.8642	.52773	.07068

$$\text{WHERE: DENSITY IN Mg/m^3} = B * \text{Ln}\left(\frac{A}{R - C}\right)$$

$$R = \text{RATIO} = \frac{\text{COUNT}}{\text{STD CNT}}$$

MOISTURE STANDARD COUNT: 10610 DATE: 940712
CALIBRATION DATE: 940712

---COUNT AT--- 0.0	.53	--- A ---	--- B ---
--- Mg/m^3 ---			
494	6634	.91615	.04265

WHERE: MOISTURE IN Mg/m^3 = (A * R) - B

Figure 2.4. Computer calibration printout.

Take a field Test

- Prepare the site, position the gauge and handle.
- Press **START**. Gauge counts down from 60 seconds.
- Press **START** during countdown to complete a test of less than 1 minute.
- At the end of the test, gauge displays TotDen and TotWater. Record.
- Press **STEP** to display DryDen and % Water. Record.
- Press **STEP** to display Dcount and Mcount. Record if desired.
- If Proctor Test Selected:
    - Press **STEP** to display %Proctor and %Water. Record.
- If Air Voids Test Selected:
    - Press **STEP** to display %AirVoid and %Water. Record.
- If Marshall Test Selected:
    - Press **STEP** to display %Marshall and %Water. Record.

Change Test Mode

- Press **MAX.** Gauge display test mode in use.
- Press **STEP** to roll over test modes, or **EXIT** to quit.
- Press **ENTER** to accept test mode displayed. Lower functions of the keys are enabled.
- Gauge display actual value of corresponding maximum.
- Use ▼ and ▲ keys to change the maximum value or **EXIT** to quit and leave the value unchanged.
- Press **ENTER** to store the displayed value.

Take a Standard Count

- Set gauge on standard block on compacted surface, handle in **SAFE** position.
- Press **STD** then **START.** Gauge counts down from 240 seconds.
- At the end of the count, gauge displays Dstd and Mstd. Record.
- Press **STEP** to display Dxi and Mxi. Record.

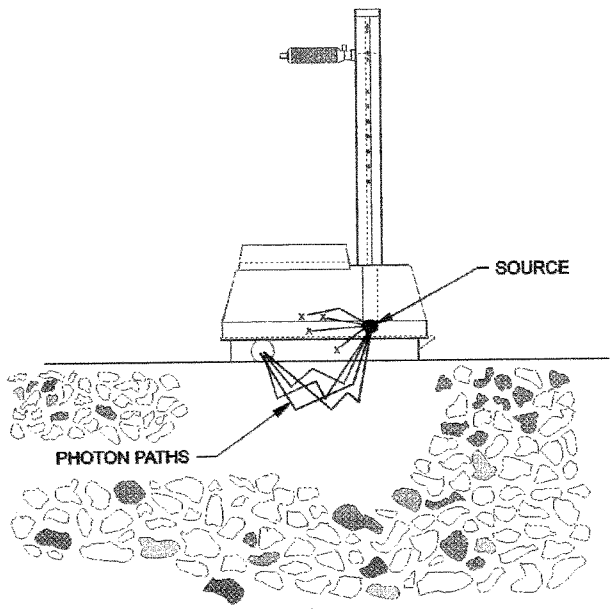
Section 3 - Field Use

Asphalt Pavement

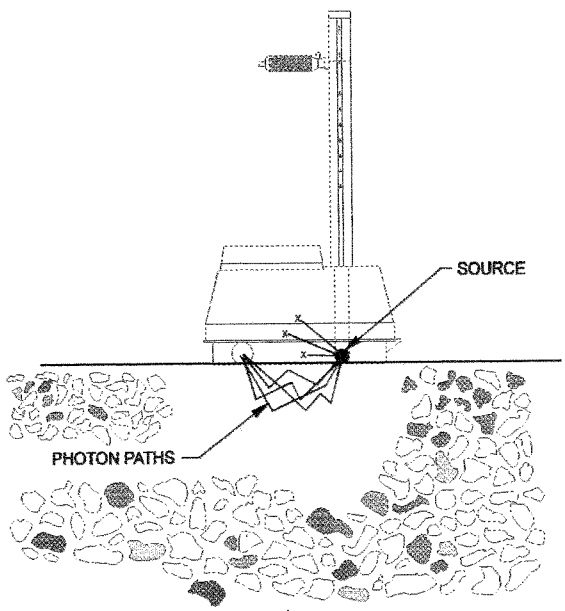
Backscatter Measurements

The **CPN MC-1DR-P PORTAPROBE®** has two density modes of operation: (1) backscatter (BS and AC surface settings) and (2) transmission (depth settings). The backscatter settings provide non-destructive tests and are most often used for asphalt and concrete pavements where drilling a transmission hole is not feasible.

CPN MC-1DR-P handle set to BS (backscatter) position. Raised or collimated source position blocks shallow photon path to provide effective deeper readings and minimize surface roughness effect. Measures density to a depth of 2.8 in (71 mm). Typically used on pavements thicker than 3.0 in (76 mm).



CPN MC-1DR-P handle set to AC (asphaltic concrete) position. Source flush wth surface. Measures density to a depth of 2.0 in (51 mm). Typically used on thin pavement overlays.



NOTE

If the density of the underlying material and the thickness of the overlay are known, use the Thin Lift Overlay test procedure.

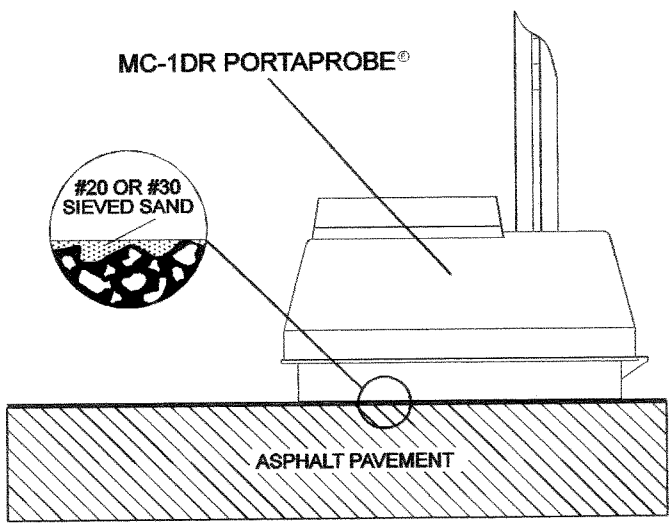
Backscatter Measurements

Density measurements are performed to determine the compaction of asphalt pavements. This type of measurement is made with the **CPN MC-1DR-P** set in either the AC or BS position, depending on the thickness of the asphalt (see table below).

Probe Position	Type Asphalt Application	Maximum Measurement Depth (95% return)
AC	thin lift overlays; surface or wearing course	2.0 in (51 mm)
BS	asphalt base or final mat if 3.0 in (76 mm) or greater thickness.	2.8 in (71 mm)

To obtain accurate measurements, the asphalt surface must be flat and, if it contains voids, must first be prepared with a filler of #20 or #30 sieved sand. The seived sand should be used to fill the depressions on the surface only. Use the edge of the guideplate to remove all excess sand and produce a level condition. Make sure the **CPN MC-1DR-P** does not rock or wobble before taking a test. With these precautions, the effect of surface voids will be minimized.

Do not use a sand filler on smooth (voidless) surfaces as this may raise the gauge off the surface enough to cause lower density readings in error.

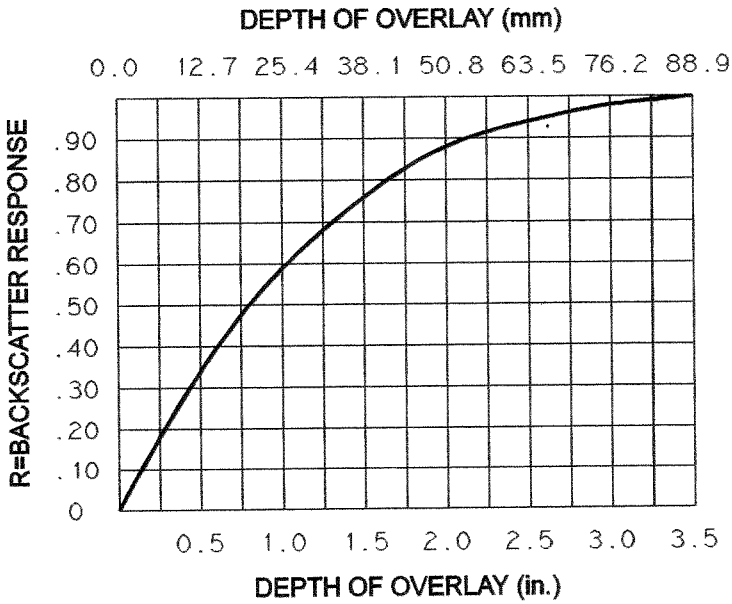


Asphalt Pavement

Thin Lift Overlays

The following graph shows the relative influence of the upper layer of an asphalt pavement on the backscatter (BS) density test of the **CPN MC-1DR-P**.

Use the graph curve and the formula below to determine the density of upper layers of asphalt pavement overlaying a base material. The density of the base material and the depth of the compacted overlay must be known.



1. Find the thickness of the overlay on the horizontal axis.

2. Proceed vertically to the curve on the graph, then horizontally to find the correction factor (CF).

3. To determine the density of the upper layer, use the relationship:

$$TotDen,\ upper\ layer = \frac{TotDen - TotDen,\ lower}{CF} + TotDen,\ lower$$

where:

TotDen, upper is the density of the upper layer

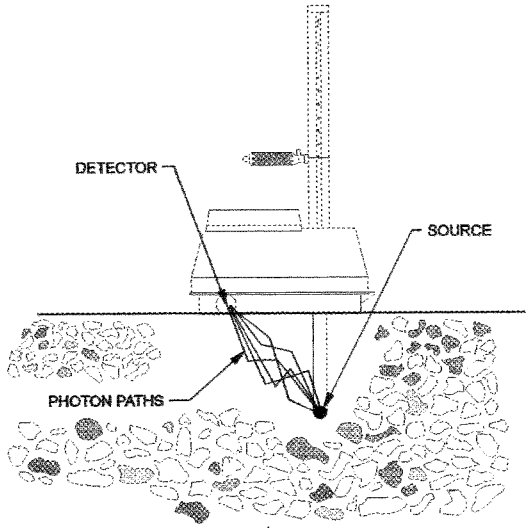
TotDen is the density reading of the MC-1DR-P

TotDen, lower is the density of the lower or base material

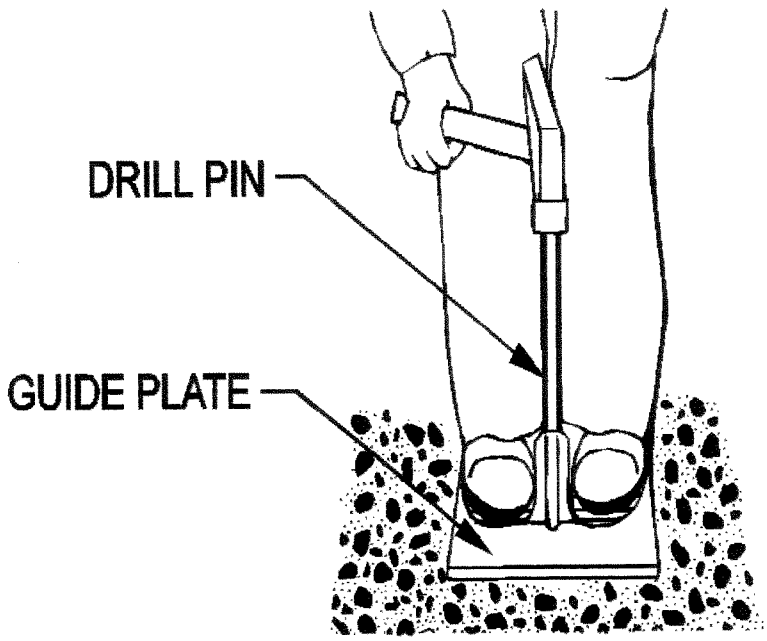
CF is the correction factor from Step 2.

Transmission Measurements

The transmission mode of the **PORTAPROBE®** measures density of soils and aggregates to depths of 2 to 8 in (50 to 200 mm). Optional models measure to depths of 12 in (300 mm).



Density measurements are made with the **CPN MC-1DR-P PORTAPROBE®** set to one of the transmision mode depths. Measurements performed on soils require no special preparation other than preparing a surface that is level and relatively smooth, and drilling a hole for inserting the source rod.



The guideplate can be used to smooth loose soil on an uneven surface. For soft soils, the hole can be drilled with the drill pin and a hammer or mallet, using the guideplate as a template. Extract the pin while standing on the guideplate to ensure an undisturbed hole. Do not use the guideplate as a tool to remove the drill pin.

Soils/Aggregates

Transmission Measuremens

For hard soils, a Campbell hammer (optional accessory) may be required, as shown in Figure 3-2. The weighted hammer is used to both drive and extract the pin while the operator stands on the guideplate. Drill the hole a minimum of 2 in (50 mm) deeper than the intended depth of measurement.

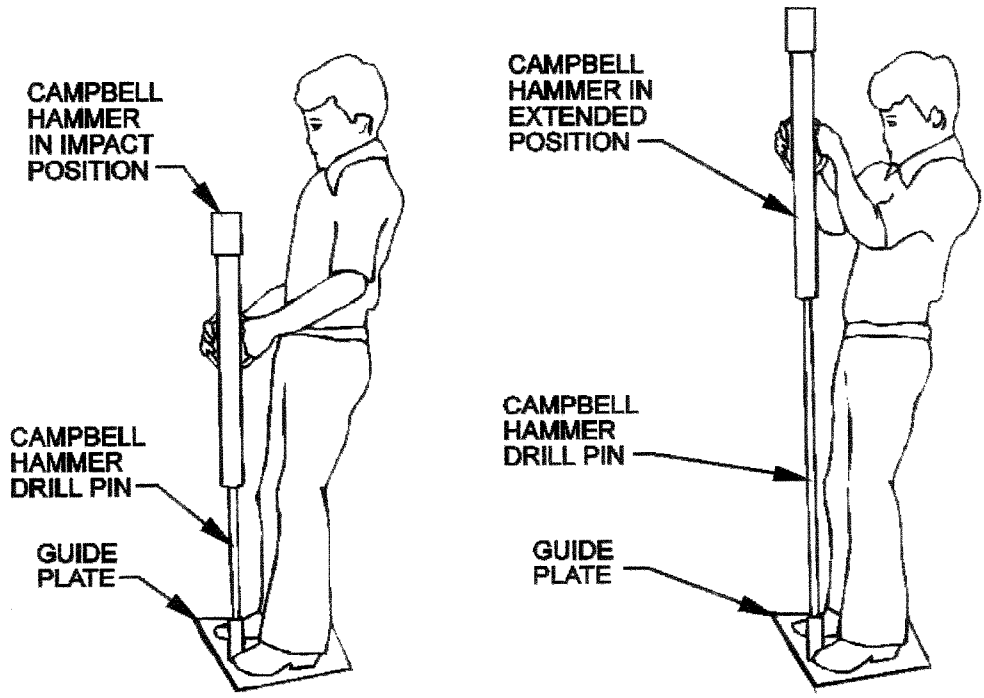


Figure 3-2. Using the Campbell Hammer

After drilling the transmission hole:

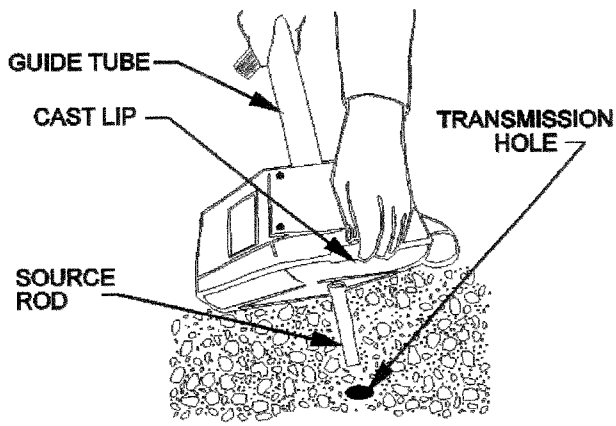
1. Tilt the **PORTAPROBE®** slightly using the cast lip on the front of the bottom casting.

2. Lower the source rod until the handle is between 2 and 4 in (50 and 100 mm).

3. Grasp the guide tube above the handle and raise the **CPN MC-1DR-P** until the source rod is visibly going into the hole. (Look over the front end of the gauge.)

4. Lower the **CPN MC-1DR-P** and source rod into the hole.

5. Set the handle to depth position desired and start test.



Moisture Measurements

Moisture measurements are taken simultaneously with density measurements by the **CPN MC-1DRP PORTAPROBE®**. Depth of measurement is a function of the moisture content and decreases with an increase in moisture. Depth of measurement averages 6 in (15 cm) of a soil at 15 pcf (0.240 g/cm3) moisture. The **CPN MC-1DRP** moisture mode measures all hydrogen in the material. In most soils and aggregates this hydrogen is in free water. Serpentine soils, clays, organic matter, and lime-treated soils, which contain bound hydrogen, produce higher moisture readings on the **PORTAPROBE®**.

To establish the correct bias in such a soil, use the following procedure, condensed from ASTM D 3017:

1. On a compacted soil having a uniform moisture content, determine the total density (TotDen) and moisture (TotWater) using the **CPN MC-1DRP PORTAPROBE®**.
2. Obtain one or more soil samples (150 to 200 g) from the site of the nuclear gauge test.
3. Weigh each sample, oven dry to a constant weight at 110° C, and weigh each dry sample. Compute the average moisture content as follows:

$$\frac{Weight\ of\ water\ lost\ x\ 100}{Weight\ of\ dry\ soil\ sample} = MC,\ \%\ moisture,\ dry\ weight\ basis$$

4. Determine the actual moisture in pounds per cubic foot follows:

$$M = \frac{MC\ x\ TotDen}{MC\ +\ 100}$$

where: M = moisture, pcf
MC = moisture content, % of dry weight (step 3)
TotDen = total density, pcf (from step 1)

5. Determine the correction factor to be applied to MC-1DRP moisture readings:

$$M\ BIAS = M,\ oven\ dry\ -\ TotWater,\ nuclear\ gauge$$

6. This value can be used for all field testing of the same soil type.

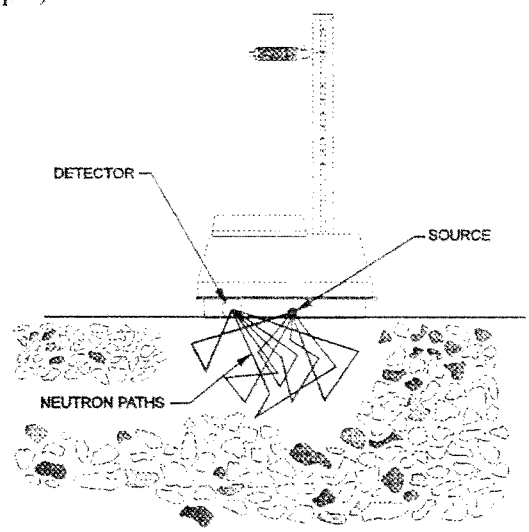
Example:

CPN MC-1DRP test results: TotDen = 130.0 pcf
TotWater = 12.5 pcf

Oven dry MC = 9.0%

$$\text{Then, M} = \frac{9.0 \times 130.0}{9.0 + 100} = 10.73 \text{ pcf}$$

$$\text{M BIAS} = 10.73 - 12.50 = -1.77 \text{ pcf}$$



Over-sized Rock Correction

Often rocky, natural soils are tested for density. The **CPN MC-1DRP** will measure the total density of the material under test, including rocks. For this reason, a series of random tests on this material will show a greater deviation around the average than on an area of processed uniform material. A number of separate soil volumes can be tested at one prepared site by rotating the gauge 90 or 180 degrees around the transmission hole and recording the average density value. This procedure should be used whenever the material requires a rock correction in the laboratory test of moisture-density relationships, whenever 10 to 30 percent of the material is retained on the ¾ inch sieve.

Soils/Aggregates

Trench Testing

For tests performed in trench excavations that are at least 30 in (762 mm) wide, the **PORTAPROBE®** should be centered in the bottom of the trench to avoid reflection errors from the trench walls.

When testing in confined excavations, such as trenches less than 30 in (762 mm) wide, the following procedure corrects the moisture test (TotWater) for the background influence of neutrons reflected from nearby trench walls. The density test (TotDen) is not influenced by nearby trench walls.

Trench Wall Correction

1. Take a 1 minute backscatter (BS) test with the gauge on the polyethylene standard block, flat surface. Record the total moisture (TotWater).

2. Take a 1 minute backscatter (BS) test with the gauge on the standard block on the site of the backfill test. Record the total moisture (TotWater).

3. The increase in total moisture from step 1 to step 2, if any, is caused by reflected neutrons from the trench walls and is the correction value.

4. Remove the standard block and take a normal test in the same location. (Typically a transmission density test of the backfill material in the trench). Record the test results.

5. Calculate the correct total moisture by subtracting the correction value (step 3) from the normal test result (step 4).

Example:

1. Total moisture (TotWater) on standard block on solid, flat surface.	52.9 pcf (.847 g/cm^3)
2. Total moisture (TotWater) on standard block in trench at backfill test site.	56.0 pcf (.897 g/cm^3)
3. Calculate correction value.	56.0 - 52.9 = 3.1 pcf (.897 - .847 = .05 g/cm^3)
4. Total moisture (TotWater), normal test of backfill material in trench.	15.8 pcf (.253 g/cm^3)
5. Calculate correct total moisture.	15.8 - 3.1 = 12.7 pcf (.253 - .05 = .203 g/cm^3)

Section 4 - Other Test Methods

Because of the increase in the rate of placement of earthworks and pavements in highway construction, state highway departments and other agencies have adopted procedures that simplify and speed density control testing with nuclear gauges. They are discussed in general terms below.

Statistical Control

A statistical approach to compaction control consists of taking several in-place density tests in an area designated by the engineer and based on the uniformity of materials to be tested. The acceptance or rejection is based on the average relative compaction and the percentage falling below the required relative compaction value. For example, a test specification might require that the average of 10 tests on an area must be above 95% relative compaction with no individual test below 90%.

Core Correlation

A common test method compares a series of **CPN MC-1DR-P** density tests with laboratory determined core sample densities taken from directly beneath the site of the nuclear tests. A correction factor can now be established to program into D BIAS for all further testing on the same material. ASTM Standard Test Method D 2950 discusses these procedures in more detail. Historical data indicates D BIAS's of 1-2 pcf (0.016-0.032g/cm^3) in BS and 3-4 pcf (0.048-0.064 g/cm^3) in the AC position. For example, a series of 10 total density (Dw) readings on a 300-ft. test strip average 144 pcf and the 10 core determinations at the same locations average 145.5 pcf. The D BIAS is then 145.5 - 144.0 or +1.5 pcf.

Concrete Testing

The **CPN MC-1DR-P** can be used to determine the density of concrete pavements or structures. Density measurements may be performed in either the transmission or the backscatter mode. It is best to prepare a transmission hole when the concrete is still setting. Before the concrete has initially begun to set, drill a transmission hole. After the concrete has set up, transmission tests can be taken. The **PORTAPROBE®** can be used on portland cement concrete, roller-compacted concrete, and soil-concrete mixtures.

Control Test Strip

The **CPN MC-1DR-P** can be used to establish the maximum obtainable density of both embankments and asphalt pavements. An initial section of material under construction is used as a control strip. Nuclear density tests are taken after each successive pass of the roller until no further increase in density is achieved (see Figure 4-1). At this point, a number of **CPN MC-1DR-P** tests are taken to accurately determine the maximum obtainable density.

The completed control strip becomes a part of the construction and specifications for the remainder of the project are established as a percent of the control strip density. A new control strip is required when a change in materials occurs. For example, a test method may require:

1. A 300-ft.-long by one lane control strip. After completion, the average of 10 **CPN MC-1DR-P** total density tests (TotDen) is the maximum obtainable density.

2. 2000-ft. by one lane or 100-ft. by two lane test sections. The average of 10 **CPN MC-1DR-P** total density tests must be at least 98% of the maximum obtainable density (on the control strip), with no individual test below 95%.

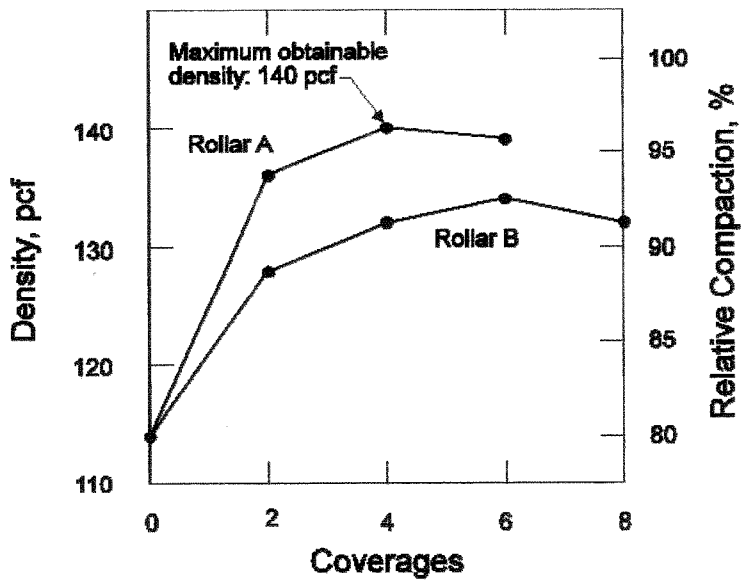


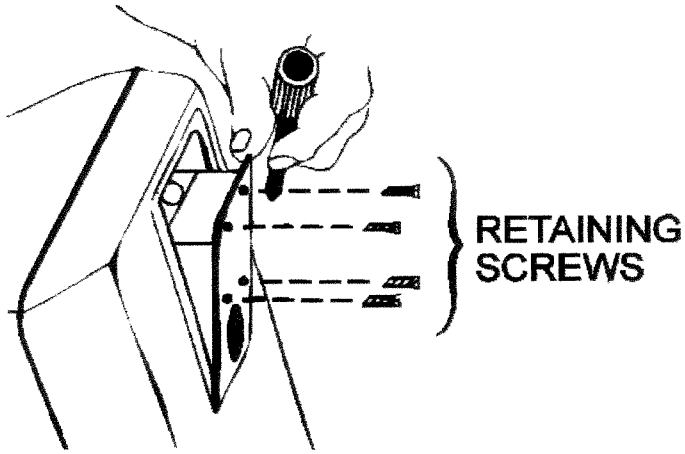
Figure 4-1. Test Strip Roller Pass Pattern

Roller Compaction Evaluation

The **CPN MC-1DR-P** can be used to evaluate the capabilities of compactive rollers, allowing the most efficient use of time and equipment for a given project.

Clean and Lubricate Shutter Mechanism

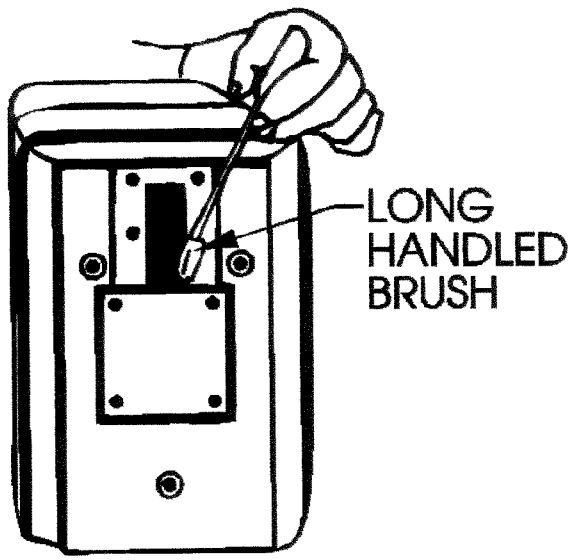
The shutter should be cleaned and lubricated weekly during use, or whenever the source rod becomes dirty and begins to stick.



1. Remove the four screws securing shutter plate block assembly.

2. Remove shutter assembly.

CAUTION
Radioactive source is located in base cavity. Do not touch the source rod tip and do not place yourself in front of the opening after the shutter block is removed.



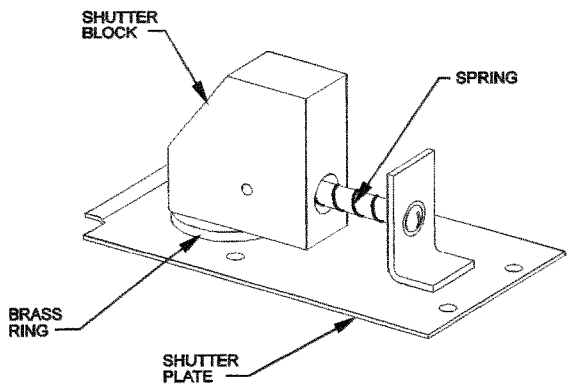
3. Stand behind the gauge and use a long-handled brush or compressed air to clean exposed area inside the **CPN MC-1DR-P**.

4. Clean entire shutter assembly and spray with the greaseless silicone lubricant provided.

5. Allow assembly to dry, then reinstall shutter block and plate.

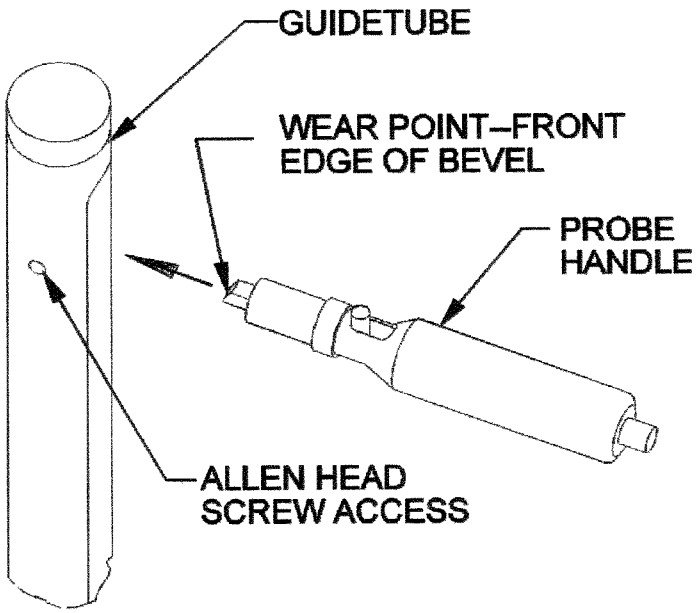
6. Check the **CPN MC-1DR-P** handle to ensure it slides freely in guidetube.

Cleaning and lubrication completed.



Handle Assembly Inspection

Inspect the handle assembly monthly for wear.

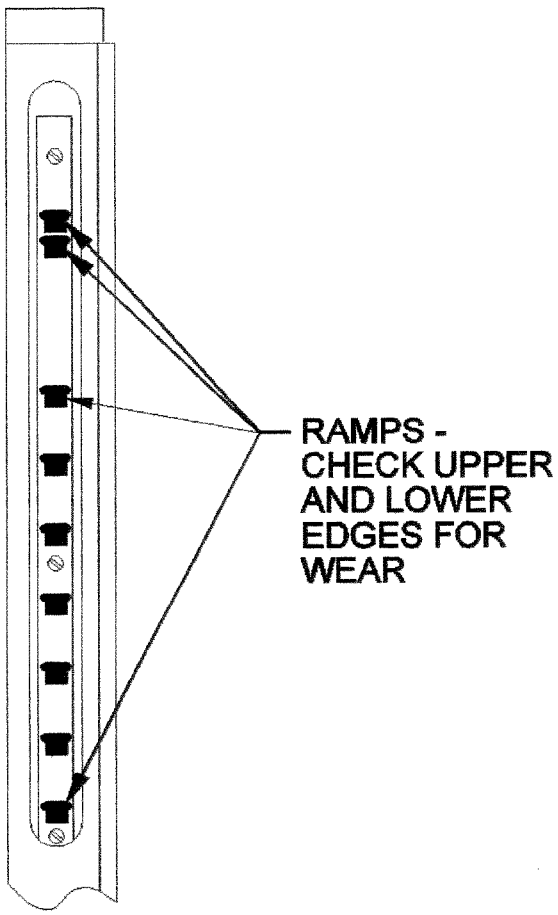


1. Set handle in BS position.
2. Loosen 5/32 in Allen head hex screw on side of guide tube ONLY until handle is free. Do not remove screw.
3. Pull handle away from guide tube.
4. Check beveled front edge of handle latch for excessive wear.
5. Check notches inside guide tube for excessive wear.

NOTE

If wear on the notches or latch appears to be excessive, contact your Boart Longyear/CPN service representative for assistance.

6. Reassemble handle to guide tube assembly and tighten Allen screw.

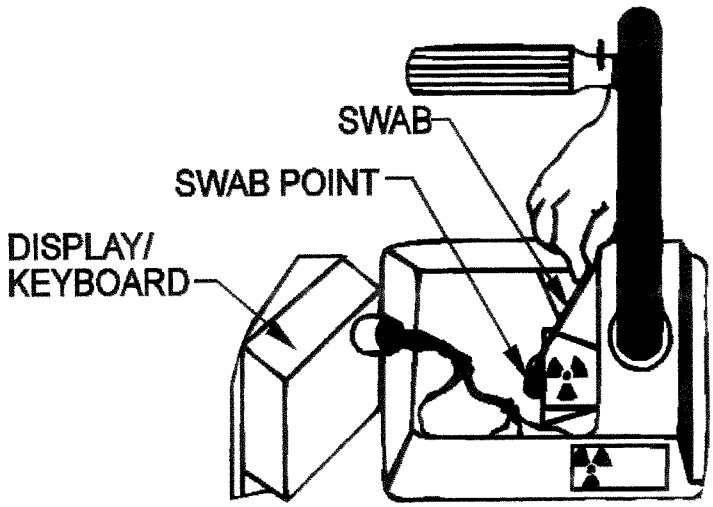


Leak Test

The leak test is required every six months or yearly. (Check your Radioactive Materials license for the time interval.)

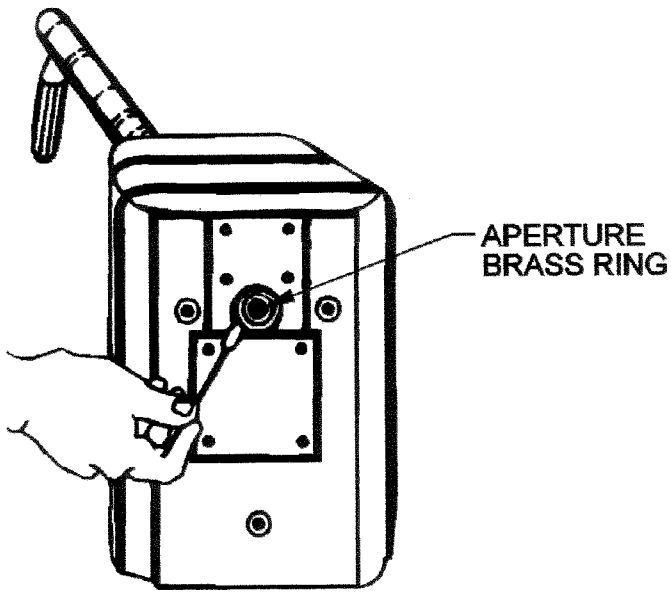
1. Use the CPN TD-11 LTK Leak Test Kit to perform this required test for leakage of the source material from its capsule. Set handle to SAFE position.

2. Remove four screws securing display/keyboard panel to **CPN MC-1DR-P**. Set keyboard/display panel aside, leaving cables connected.



3. Use the cotton swab in the kit and swab the source holder inside the **CPN MC-1DR-P**. This will pick up any removable traces of the Am-241:Be source material.

4. Reattach display/keyboard to **CPN MC-1DR-P** with four screws that were removed in step 2.



5. Use the cotton swab in the kit to swab around cleanout plate ring on the aperture. This will pick up any removable traces of the Cs-137 source material.

6. Break swab stick in half and place in plastic envelope. Complete form and staple envelope to it; mail to address on the kit. Within approximately six weeks you will receive notification of results.

Replacing Battery Pack

A battery pack of 6 D size alkaline cells is located beneath the keyboard/display electronics moduke.

At the start of each test, the % battery remaining is displayed (e.g. Battery 85%). When this value becomes zero, the display will read "Replace Batteries". Call Boart Longyear/CPN Service Department or an authorized service center and order a replacement battery pack (Part #703750).

1. Set **PORTAPROBE®** handle to **SAFE** position.

2. Remove the 4 screws securing the keypad/display module.

3. Lift out the module and turn upside down, leaving the cables connected.

4. Remove the 4 screws from the aluminumplate holding the battery pack in position.

5. Disconnect the used battery pack and replaced it with the new one.

6. Reinstall the electronics module.

Battery pack replacement complete.

The **CPN MC-1DR-P** can also be operated from a standard 9 volt alkaline battery using the 9 volt strap assembly (Part #703923) supplied. Over 500 1 minute tests can be taken with a new 9 volt alkaline battery.

Cleaning and Storage

Follow these recommendations to keep the **CPN MC-1DR-P** always fully operable:

- Clean the gauge with soap and water if it becomes unusually dirty.
- Always dry the unit promptly after getting it wet.
- Remove asphalt with a mineral solvent.
- Do not scratch the display window with abrasive cleaners.
- Store gauge in the shipping container when not in use.

Troubleshooting guide

Problem	Action
Display remains blank, no response to keypad commands.	Batteries are dead and require replacement.
Bad counters.	Call Boart Longyear/CPN Service Department.
Bad EEprom.	Call Boart Longyear/CPN Service Department.

Display Messages and Prompts

Message	Meaning
Battery xxx% Depth xxx	Field test or standard count in progress.
Countdown xxx seconds	
Bad depth, set rod, try again	Handle not in safe position for standard or handle not in desigmated test position at START of test.
Replace batteries	Battery capacity depleted. Replace batteries.
Bad Counts call factory	Call Boart Longyear/CPN factory or nearest service center for assistance.
Bad Eeprom, call factory	Call Boart Longyear/CPN factory or nearest service center for assistance.

APPENDIX A

Conversion Factors

Multiply	By	To Obtain
inches (in)	25.4	millimeters*
millimeters (mm)	0.03937	inches
pounds per cubic foot (pcf)	16.01846	kilograms per cubic meter
kilograms per cubic meter (kg/m^3)	0.06243	pounds per cubic foot
pounds per cubic foot (pcf)	0.01601846	grams per cubic centimeter
grams per cubic centimeter (gr/cm^3)	62.428	pounds per cubic foot

* On the source rod depth settings of the **CPN MC-1DR-P** guidetube, 1 inch is equals to 25.0 millimeters.

GLOSSARY

ASTM: American Society of Testing and Materials. Publish standard test methods for all materials, including moisture and density determination of soil-aggregates and pavements.

COMPACTION (DENSITY) CONTROL: The testing of soil and aggegate mixtures during field construction to assure that specified compaction levels are obtained relative to laboratory-determined values. The following ASTM standard test methods are used to obtain the maximum values to be entered into the **CPN MC-1DR-P PORTAPROBE®** for relative (%) compaction determinations.

D 1557: Moisture-Density Relations of Soils and Soil-Aggregate Mixtures Using 10-lb (4.54 kg) Rammer and 18-in (457 mm) Drop.

D 1188: Bulk Specific Gravity of Compacted Bituminous Mixtures Using Paraffin-Coated Specimens.

D 2041: Theoretical Maximum Specific Gravity of Bituminous Paving Mixtures.

DRY DENSITY (DryDen): Mass of soil, after drying for 24 hours at 110° C, contained in a unit volume of undried soil, expressed in pcf or g/cm^3. Calculated by the **CPN MC-1DR-P** as follows: TotDen - TotWater = DryDen.

DRY DENSITY-MOISTURE CONTENT RELATIONSHIP: The relationship between dry density and moisture content of a soil under a given compactive effort. Commonly known as a Proctor Test after its originator, R.R. Proctor.

MAXIMUM BULK SPECIFIC GRAVITY (SG): the maximum bulk specific gravity of a paving mixture. Determined by laboratory test and programmable into the **CPN MC-1DR-P** for percent air void calculations (%AirVoid).

MAXIMUM DRY DENSTIY (Md): The dry density obtained using a specified amount of compaction at the optimum moisture content. Commonly known as the Proctor value and programmable into the **CPN MC-1DR-P**.

MAXIMUM WET DENSITY (Mw): The maximum density of a paving mixture. Determined by laboratory test and commonly known as Marshall value. Programmable into the **CPN MC-1DR-P** for relative compaction calculations (%Marshall).

MOISTURE CONTENT: (%Water): The mass of water in a soil expressed as a percent of the dry soil mass. Calculated by the **CPN MC-1DR-P** as:

TotWater/DryDen.

OPTIMUM MOISTURE CONTENT (OMC): The moisture content of a soil at which a specified amount of compaction will produce the maximum dry density, expressed as % moisture.

PERCENT AIR VOIDS (%Av): The volume of air voids in a soil or paving mixture expressed as a percentage of the total volume of the material. Calculated by the **CPN MC-1DR-P** as:

100 x (1 - (DryDen/SG) - TotWater).

RELATIVE or % COMPACTION, PAVEMENTS (%Mw): The percentage ratio between the total density of an in-place pavement (TotDen) and its maximum total density (Mw) as determined by a specified laboratory compaction test.

RELATIVE or % COMPACTION, SOILS (%Md or Av): The percentage ratio between the dry density of an in-place soil (TotDen) and its maximum dry density (Md), determined by a specified laboratory compaction test.

TOTAL MOISTURE (TotWater): The mass of water in a unit volume of soil, expressed in pcf or g/cm^3. A direct measurement of the **CPN MC-1DR-P**.

TOTAL or WET DENSITY (TotDen): Mass of bulk soil, including solids, water, and air, contained in a unit volume, expressed in pcf or g/cm^3. A direct measurement of the **CPN MC-1DR-P**.

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