CPN 501DR DEPTHPROBE

Operating Manual

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Section 1 - General Information

Product Description

The Model **CPN 501DR DEPTHPROBE®**, DEPTH DENSITY-MOISTURE PROBE, measures the sub-surface density and moisture in soil and other materials by use of a probe containing a gamma source and a GM detector for density and source of high energy neutrons and a slow (thermal) neutron detector for moisture. The probe is lowered into a pre-drilled and cased hole (1.5 or 2 inch diameter) to the depth of measurement.

The density and moisture data are displayed directly in units of interest on an above-surface electronic assembly which is integral to the source shield assembly. The data is also stored for later dowload to an off-line printer or computer.

This state-of-the-art instrument offers a simple to operate but superior alternative to other methods of soil density-moisture monitoring. The operator needs minimal instructions. Unlike other instruments, the **CPN 501DR** performs its own calculations and records test results automatically.

The gauge is supplied with a 12 foot cable and five adjustable cable stops. Additional stops and longer cable lengths are available.

Upon retraction of the probe into the shield, the probe locks automatically in place for transportation.

The complete assembly is supplied with a plastic shipping and carrying container which contains accessory items, cable, instruction manual, charger, and other materials which the operator may wish to carry.

CPN 501DR Features

The **CPN 501DR** Direct Readout Model provides:

- Integral microprocessor for simple function selection.
- Rapid, precise repetitive testing throughout construction.
- Light weight and portable.
- 13k locations for memory logging.
- Field service and component exchange with tools provided.
- Rechargeable, extended-use battery pack.
- Storage and recall selection of 16 calibrations.
- Operator selected time of test, logging format and units of measurements.
- Data transfer to a personal computer or printer via RS232C interface.

The **CPN 501DR DEPTHPROBE®** operates by emitting radiation from two encapsulated 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 soil. Some of the gamma radiation will pass through the soil and be detected by the Geiger -Mueller detectors located within the probe. A soil of low density will give a high count per time of test. A soil of high density will give a low count for the same period of time, as the high density soil absorbs more gamma radiation.

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

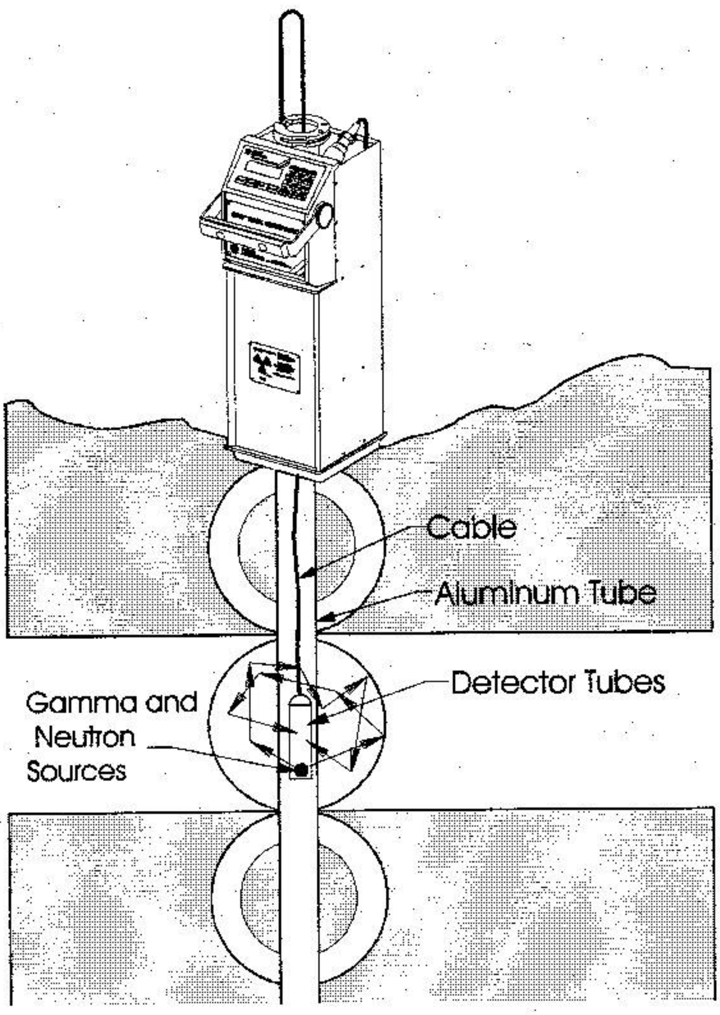


Figure 1.1. Operation of the 501DR **DEPTHPROBE®**

Standard Equipment

Each **CPN 501DR** is provided with a durable plastic shipping case and the items shown in Figure 1.2. There are no special instructions for unpacking the **CPN 501DR DEPTHPROBE®**. It comes fully assembled.

Item	Part Number
CPN 501DR DEPTHPROBE®	501548
Operating Manual	700483
Leak Test Certificate	700762
Leak Test Kit	401197
Padlock and Keys	700472
Radiation Sign Kit	101085
Shipping Case	501359
Phillips Screwdriver	700646
Screwdriver, 3/16 Flat	703552
Battery Charger	500406
Wrench, Probe	500267
Cable, 33 ft/10 meter	501341
Cable Clamp	501329
Cable Stops (5 each)	501122
Dummy probe (1.5 in)	501322
Access Collar (1.5 in)	500315
Video, Irrigation Water Management	704444, 704445

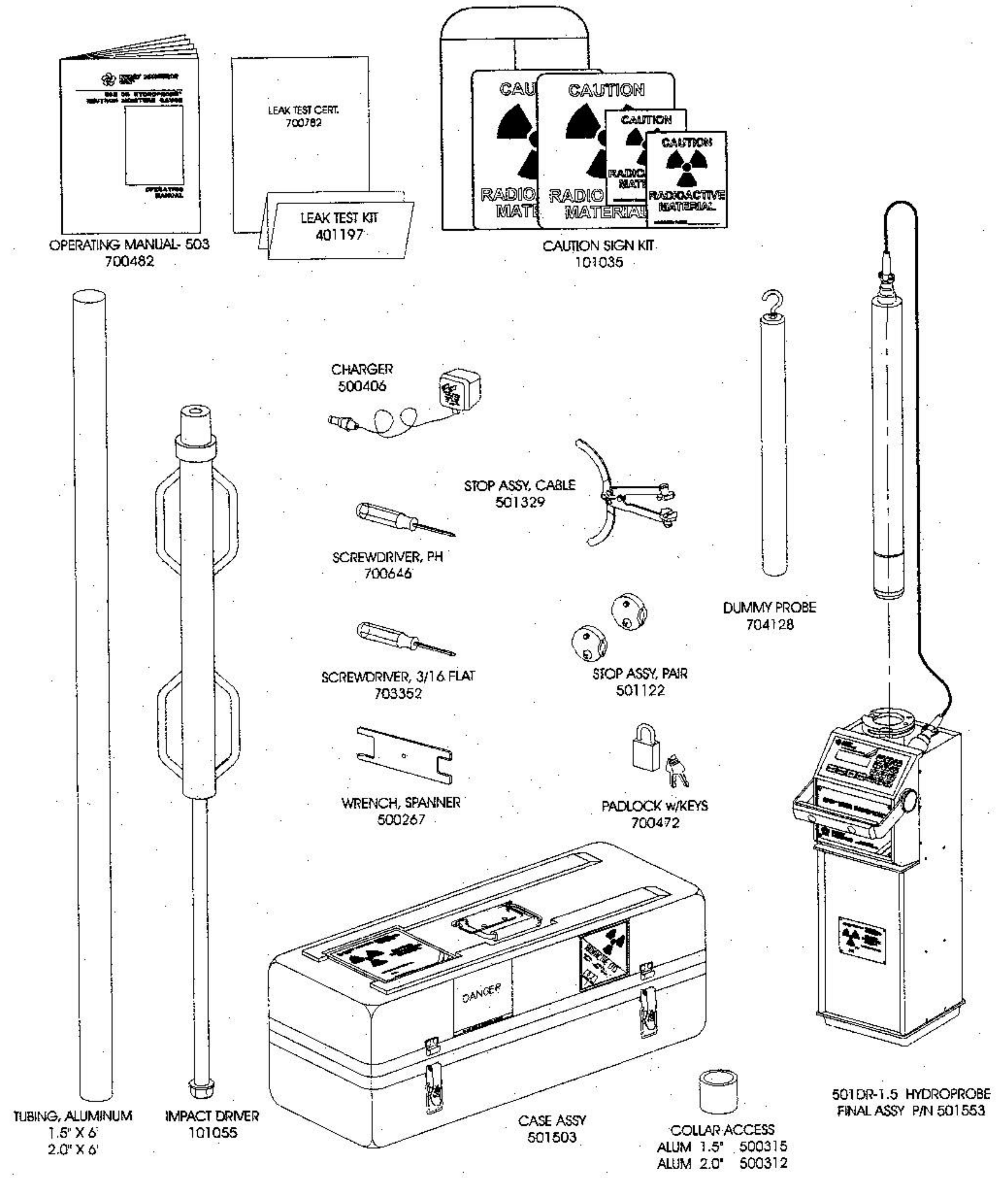


Figure 1.2. **CPN 501DR DEPTHPROBE®** Standard Equipment.

Specifications

Dimensions/Shipping Weights

Model	Weight	Length	Width	Height
CPN 501DR(gauge only)	41.1 lb/18.6 kg	7.0 in/178 mm	6.8 in/173 mm	22.2 in/564 mm
CPN 501DR(with carrying case)	80 lb/36.3 kg	14 in/350 mm	29 in/725 mm	16 in/406 mm

Probe	Weight	Length	Diameter
Model 2.0	8.0 lb/3.6 kg	22.7 in/577 mm	1.865 in/47.4 mm
Model 1.5	6.0 lb/2.7 kg	22.7 in/577 mm	1.5 in/38.1 mm

Performance

Function	Sub-surface density and moisture measurements.
Range	Density: 60 to 180 pcf (0.96 to 2.88 gcc) Moisture: 0 to 80% per volume, 0.65 gcc, 40 pcf, 9.6 in/ft.
Precision	Density: 0.6 pcf at 125 pcf at one minute (0.01 gcc at 2.002 gcc) Moisture: 0.24% at 24% per volume at one minute.
Count Time	1, 2, 4, 8, 16, 32, 64, 128 and 256 seconds.
Display	8 character alpha/numerical Liquid Crystal Display. Easily readable in direct sunlight.
Data Output	RS232C serial download to external printer or personal computer.
Calibration	16 user programmed (log for density, linear for moisture).
Units	User selectable: in/ft pcf, g/cc, % vol, cm/30cm,count and count ratio.
Construction	Aluminum with epoxy paint or hard-anodize finish. Stainless steel wear parts.

Specifications

Electrical

Power	AA NICAD battery pack (0.5 Ah) 8 cells.
Battery Life	500 - 1000 charge-discharge cycles.
Consumption	6.5 mA average (allows more than 3000 each 16 second counts).
Recharge	14 hours at C/10 via wall charger.

Environmental

Operating Temperature	Ambient: 32° to 150° F (0° to 66° C)
Storage Temperature	-4° to 140° F (-20° to 60° C)
Humidity (non-condensing)	95%

Radiological

Neutron Source	50 mCi Americium-241:Beryllium.
Gamma Source	10 mCi Cesium-137
Encapsulation	Double-sealed capsules CPN-131.
Shielding	Lead for gamma and Silicon Base Paraffin for moisture.
Shipping Requirements	Radioactive material, R.Q. Special form N.O.S. UN2974 Transport index 0.2 Yellow II label USA DOT 7A Type A Package
Special Form Approval	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.

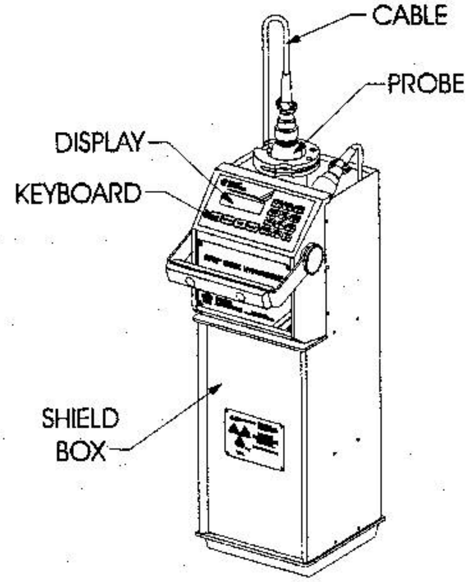
Boart Longyear/CPN reserves the right to change equipment specifications and/or design to meet industry requirements or improve product performance.

CPN 501DR DEPTHPROBE® Inspection

To familiarize yourself with the **CPN 501DR DEPTHPROBE®**, perform the following review.

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

2. Examine the keyboard, the display screen, the cable, the probe, and the shield box.



> **NOTE**
>
> The radioactive sources are located at the bottom part of the probe. **Do not touch** this part of the probe or place yourself in front of it.

Figure 1.3. **CPN 501DR DEPTHPROBE®**

3. Cable Stops

   The gauge is supplied with five each clamp-on cable stops. This will allow taking measurements at one foot increments in a root zone up to five feet deep. For a deeper root zone or for smaller increments, order more stops. Figure 1.4 shows a cross-section of the gauge. Use it to position the first stop so that the measurement point on the probe (as indicated by the band) is in the middle of the top foot of the root zone. Its actual location will depend upon how high the access tubes stick out of the soil. Install all tubes to the same height.

   For example, if the base of the gauge is 5.0 inches above the soils, and you want to take the first measurement at 12 inches, place the stop at 7.91 + 5.0 + 12.0 = 24.91 inches above the stop reference line.

4. Tube Adapter Ring

   The bottom of the gauge contains an oversize hole to allow inserting an adapter ring with a diameter to match the type of access tubing being used. The ring is secured by a screw through the front of the casting. Unless specified otherwise at the time of order, an adapter ring for aluminum tubing will be supplied. Adapter rings for other types (e.g. diameters) are available from Boart Longyear/CPN, or can be constructed locally.

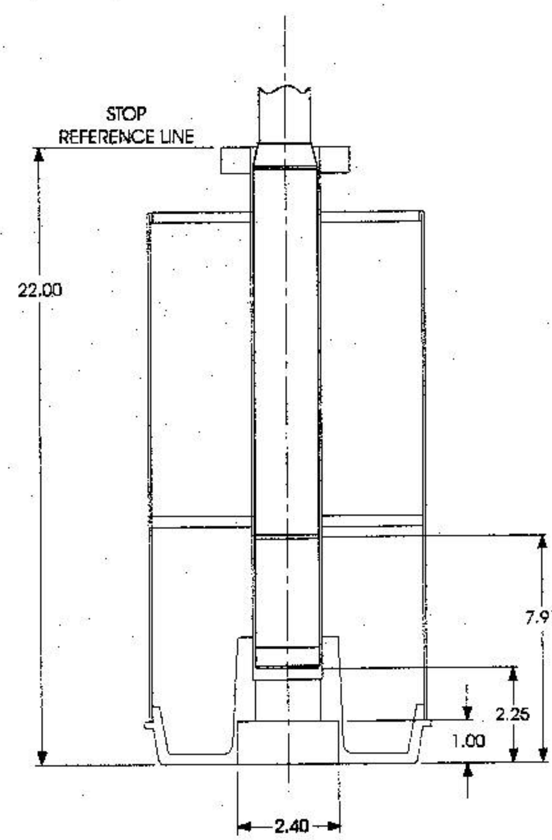


Figure 1.4. **501DR** Cross Section.

The stand-by power drain of the gauge is less than the self-discharge of the NICAD cells thus eliminating the need for a power switch. The **CPN 501DR** is always "ON", but has an internal function that automatically, after 30 seconds of no operation, switches it to stand-by mode (the display will be blank) to save battery power. To turn the **CPN 501DR** ON again, press any key and the display will show the last function that was executing before it went into the standby mode. When first received, it is recommended that the gauge be placed on charge overnight to insure starting with a full charge.

The operator has to set the gauge to a configuration to meet the field conditions. To assist in understanding the gauge initially, it is shipped from the factory in the following configuration:

DUNIT	Grams per cubic centimeter.
UNITS	Grams per cubic centimeter.
TIME	1 second.
DCALIB	CAL #1, Factory calibration in a low, mid and high concrete standard. Coefficient A (intercept) typical value 11.27, coefficient B (initial slope) typical value 5.583 gcc per count ratio and coefficient C(offset) typical value -5.617.
MCALIB	CAL #1, Factory calibration in saturated and dry sand. Coefficient A (slope) approx. 0.6986 gcc per count ratio and coefficient B (intercept) approx. -0.0031 gcc.
DSTD	Density standard count approx. 2000 to 4000.
MSTD	Moisture standard count approx. 7000 to 11000.
FMT	1 ID, 1 Keydata and 3 Depths allowing 180 records.

With the gauge sitting on the nameplate on the shipping case, press **START**. The gauge should take a one second count and display the equivalent wet density of the wax in the shield. It should be approximately 3.0 gcc. Press **WATER,** the gauge should display the equivaleny moisture in the wax shield, approximate 0.6 gcc. Press **D-DRY** , the gauge should display the equivalent dry density in the wax shield (DDRY = DWET - WATER), approximate 2.4 gcc. The **D-WET, D-DRY** and **WATER** keys may be used to view the last reading any time the gauge is in the **READY** state. The settings of the **UNITS**, and **CALIB** keys determine the units and calibration used to calculate the display.

CPN 501DR DEPTHPROBE® Getting Started

Most of the commands are **READ/STEP/WRITE**. That is, when first called up, you read the display to see the current value, step to a new value, and then write (enter) the new value into memory. Try this by using the following keystrokes to change the time from 1 to 16 seconds.

PRESS	DISPLAY
	READY
TIME	TIME 1 (Read the current value)
STEP	TIME 4
STEP	TIME 16 (Step to a new value)
ENTER	READY (Write it to memory)

Do the same for Units, changing from grams per cubic centimeter (gcc) to pounds per cubic foot (pcf) for the wet and dry density display and from gcc to % Volume for the moisture display.

PRESS	DISPLAY
	READY
UNITS	DUNIT
ENTER	DUNT GCC
STEP	DUNT CNT
STEP	DUNT RAT
STEP	DUNT PCF
ENTER	READY
	READY
UNITS	DUNIT
STEP	MUNIT
ENTER	MUNT GCC
STEP	MUNT CNT
STEP	MUNT%V
ENTER	READY

Take another count by pressing **START**. The measured result should be the same as above except that the count should take 16 seconds and the display should be approximately 190.0 pcf wet density, 6.25% water by volume and 186.0 pcf dry density. These are equivalent to the readings above, just in different units.

Controls and Display

Most functions are directly entered by pressing the appropriate key. Options are reviewed by **STEP**ing, and selected with **ENTER**.

Key	Function
D-WET	Display latest wet density reading.
D-DRY	Display latest dry density reading.
WATER	Display latest moisture reading.
UNITS	
D	Select measurement units (CNT, RAT, PCF,GCC)
M	Select measurement units (CNT, RAT, PCF, IPF, GCC, CPC, %V).
TIME	Select counting time (1, 2, 4, 8, 16, 32, 64, 128, 256) seconds.
CALIB	Select calibration (1..16) and optionally:
COEFF	Enter coefficients directly.
SLFCAL	Semi-automatic calibration.
LOG	Log a tube site record.
RCL	Recall a record for review.
PRINT	Dump records to external device:
PRINT CD	Dump to an active device (Computer Device).
PRINT LP	Dump to a passive device (Line Printer).
MENU	Select miscellaneous function:
SELFTEST	Self test of circuits (non-destructive RAM test).
BAUDRATE	Select baudrate (110, 300, 1200, 2400, 4800, 9600).
ATTRIB	Set attributes for the Print LP dump. 3 each Prefix, 3 each Suffix and a Top of Form.
SERNO	Display/Enter a four-digit serial number.
VERSION	Display software version.
STD	Display/update standard count summary.
FMT	Set record format, **CLEAR** records.
START	Take a reading.
CLEAR (NO)	**CLEAR**, abort, "NO".
STEP	Next, skip, toggle.
ENTER (YES)	Enter data, make selection, "YES"
STEP & CLEAR	Master Reset (Hold **STEP** down and press **CLEAR**)

Display	Function
"READY"	Gauge is ready for operation.
"READY LO"	Indicates Low Battery.

Keyboard Functions

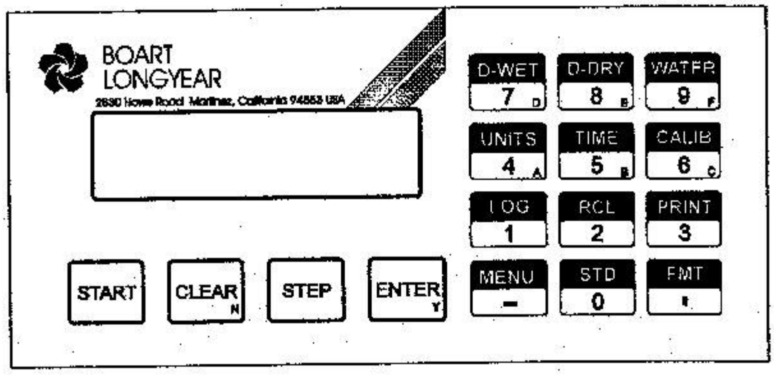


Figure 2.1. **CPN 501DR DEPTHPROBE®** Keyboard.

D-WET

Disp'ays wet density using currently selected calibration and units.

D-DRY

Displays dry density using currently selected calibration and units.

WATER

Displays the most recent moisture reading in current units using current calibration (e.g. "M 23.4"). If number to be displayed is undefined (e.g. exceeds the display size), then "M *.* " will be displayed.

UNITS

Display/Select measurement unit for density and moisture. When first entered, displays last units selected. Press **STEP** to toggle between "DUNIT" and MUNIT", press **ENTER** to select. The MC-1DR gauge will display the unit selected, e.g. "MUNT GCC". To select new unit, **STEP** to desired unit and press **ENTER**. If **CLEAR** or another selection key is pressed, unit remains unchanged.

Units	Description	Conversion	Channel
CNT	counts/unit-time (16 second display)	N/A	both
RAT	ratio (count/stdcount)	N/A	both
PCF	lbs of water/cubic foot of soil	62.428	both
GCC	gms of water/cubic cm of soil	1.0	both
IPF	inches of water/ft of soil	12.0	moisture only
CPC	cm of water/30 cm of soil	30.0	moisture only
%V	percent water by volume	100.0	moisture only

The conversion numbers are shown for reference only. The gauge performs the conversion internally depending upon your selection of units (e.g. a reading in gm/cc is divided by 1.0 and multiplied by 12 to get an equivalent reading in inches per foot.

CALIB

Display/Select calibration (1 through 16 and/or review/change its coefficients). When first entered displays last channel accessed. Press STEP to toggle between "DCALIB" (density calibration) or "MCALIB" (moisture calibration) and press ENTER

Before pressing **CALIB**, select the appropriate units and time via the **UNITS** and **TIME** keys. If counts (CNT) or ratio (RAT) is the selected unit, the gauge will display "SET UNIT". If SLFCAL is to be used to take a count, select a time of 256 seconds for maximum precision.

DENSITY CALIBRATION

To Select A Calibration

Active calibration is displayed on entry (e.g. "DCAL 4"). To select another calibration, **STEP** to the desired number and press **ENTER**. When the prompt "DCOEFF ?" appears, press **CLEAR** to return to "READY".

To Enter/Change Coefficients When The Coefficients Are Known

Select the calibration number as above. When "DCOEFF ?" is displayed, press **ENTER**.
The current coefficient "A" will be displayed. Press **ENTER** to accept it, or change it via the numeric keys and press **ENTER**. Repeat for "B" and "C". For "B" use values consistant with the units previously selected by **UNITS** key. "A" and "C" are dimensionless and so remain the same regardless of units. Returns to "READY" after last coefficient is entered.

To view coefficients without changing them, follow the above steps except press **ENTER** after each coefficient is viewed.

To Enter/Change Coefficients When The Counts Are Know Or To Be Determined

Select the calibration number as above. Press **STEP** until "DSLFCAL?" is displayed. Press **ENTER**.

The gauge will prompt for three each reference pairs (density/count - R3/C3, R2/C2, R1/C1).
Enter the pairs (low, middle, high) in any order. Thecounts may be entered direct from the keyboard, or automatically from the probe by pressing **START** when the count prompt appears.
After the last pair has been entered the gauge will prompt "DATA OK?". Press **STEP** to review/edit the pairs starting with R3/C3, press **ENTER** to begin calculating the coefficients. After the MC-1DR finish calculating the coefficients, returns to READY. To view the new coefficients, use "DCOEFF" as above.

Select the calibration number as above. Press **STEP** until "DSLFCAL?" is displayed. Press **ENTER**.

"R3 0.0"	Enter first reference density in the selected units.
"C3 0"	Enter associated count, or place the probe in the appropriate density standard and press **START** to take a count. During the count the gauge will display the mode e.g. "C3 COUNT". At the end of the count period the value will be displayed e.g. "C3 1234". Press **ENTER** to accept the count or **START** to retake. Pressing any key during the count will abort the count in progress and cause a reprompt for the same reference count.

"R2 0.0" Enter second pair as above.
"C2 0"

"R1 0.0" Enter third pair as above.
"C1 0"

"DATA OK? " Press **STEP** to review the pairs just loaded, ENTER to begin calculating the coefficient, CLEAR to exit to "READY".

"A", "B", and "C" are the coefficients from an expression of the form:

$$r = A \times e^{(-d/B)+C}$$

Reversing this to display density for a given count ratio:

$$d = -B \times Ln((r - C)/A)$$

Where r is the count ratio (count divided by the standard count).

MOISTURE CALIBRATION

To Select A Calibration

Active calibration is displayed on entry (e.g. "MCAL 4"). To select another calibration, **STEP** to the desired number and press **ENTER**. When the prompt "MCOEFF ?" appears, press **CLEAR** to return to "READY".

To Enter/Change Coefficients When The Coefficients Are Known

Select the calibration number as above. When "MCOEFF ?" is displayed, press **ENTER**. Coefficient "A" is the slope, "B" is the intercept in an expression of the form:

Display = A x (ratio) + B

Where ratio is count divided by standard count

Enter A and B using the same units as previously selected by the **UNITS** key.
The current "A" coefficient will be displayed. Press **ENTER** to accept it or change it via the numeral keys, and press **ENTER**. Same for "B". Returns to "READY" after last coefficient entered.

To Enter/Change Coefficients When The Counts Are Know Or To Be Determined

Select the calibration number as above. Press **STEP** until "MSLFCAL?" is displayed. Press **ENTER**.

"R2 0.0" Enter first moisture value in the selected units.
"C2 0" Enter associated count or press **START** to take a count. **ENTER** to accept, **START** to retake.
"R1 0.0" Enter second moisture value in the selected units.
"C1 0" Enter associated count or press **START** to take a count. **ENTER** to accept, **START** to retake.

Either the low or high data pair may be entered first. When taking a count, place the probe in the appropriate moisture standard before pressing **START**. After coefficients are computed and stored, display returns to "READY". To review the coefficients use "MCOEFFS?".

LOG

Arms the storage mechanism to log a tube site record. As defined previously by the **FMT** key, each RECORD consists of 1 each ID, 0 to 99 keypad entries, and 0 to 99 depths. ID number, keypad entries and depths start at the highest value and down count to 1. When LOG is first pressed, the current record number is displayed. Press ENTER to use it as the default ID number or key in a meaningful record number. The record number decrements from the maximum to 1, each time a new record is logged. The record number is thus an indicator of how many additional records may be logged.

Keypad fields are read/modify/write (i.e. it will first display what is stored in that location — normally blank for a new location). Key in a value and press **ENTER** to store the new value. Press **CLEAR** to abort a wrong key entry. A keypad field may be skipped by pressing **STEP**.

Following the keydatas, the gauge will prompt for the first depth to be loaded e.g. "DEPTH 3". Press **STEP** or **ENTER** to skip one or more depths, press **DWET, DDRY or WATER** to view the depths current measurements e.g. "W3 123.45", or press **START** to take a new reading. During the count, the gauge will display "COUNT n", and at the end of the count the updated value of the measurement last viewed(DWET, DDRY, WATER). To abort the count in progress, press **CLEAR** once and the gauge will reprompt for the depth as above. To retake a measurement stored at a current depth, press **START**. The measurement stored at a given depth is the last one taken when STEP or ENTER is pressed. To skip all , or the remaining depths, press **CLEAR** when the depth prompt is displayed e..g. "DEPTH 3" and the gauge will prompt with "DATA OK?".

After the depths, if the record has been formatted for one or more depths and the current moisture unit is in IN/Ft (IPF) or cm/30 cm (CPC), the gauge will display the record's total moisture in the current moisture unit e.g. "TM 100.12". Press STEP or ENTER to move on to "DATA OK?".

A record is not stored in the log until the prompt "DATA OK?" appears and **ENTER** is pressed. If at that time you press **STEP** instead, the display will step around to the beginning of the record, allowing it to be viewed and edited. To accept an existing keydata or moisture value, press **ENTER** or **STEP**. To change the data, write over the keydata field followed by **ENTER** or press **START** for a new count followed by **ENTER**. The corrected record is finally stored when you press **ENTER** while "DATA OK?" is displayed.

RCL

To review the record log. On entry, it displays ID number of last record logged. **STEP** back through the log to the ID number of desired record and press **ENTER**, or enter ID number directly (i.e. 1234 **ENTER**). If the keyed ID number does not exist, the gauge displays "NOT HERE". Press **STEP** to acknowledge and continue [**STEP**ing] from last real ID. When desired ID is displayed, press **ENTER**. Use the **STEP** key to move across the fields of the record (like a window moving across a tickertape).

Press **CLEAR** to step down the ID's. Press **ENTER** to return to the more detailed level. At the outer level you see the IDs only, at the inner level of the entire record.

Keyboard Functions

After a valid record ID is ENTERed, the records density calibration number will be displayed e.g. "DCAL 1". Press **STEP or ENTER** to view the moisture calibration number e.g. "MCAL 1", and continue likewise with the keydatas.

Depths initially display wet-density e.g. "W3 123.45". Press **DWET, DDRY or WATER** to view the corresponding measurements. The last pressed will be the initial display on subsequent depths and records until another is pressed. This feature allows the records log to be conveniently scanned over all the records and depths for a single measurements of interest.

After the depths, if the record has been formatted for one or more depths and the current moisture unit is in IN/Ft (IPF) or cm/30 cm (CPC), the gauge will display the record's total moisture in the current moisture unit e.g. "TM 100.12". Press STEP or ENTER to move on to the next record ID.

PRINT

Dumps record log to external device via the serial connector. For "PRINT CD", press **PRINT, ENTER**. For "PRINT LP", press **PRINT, STEP, ENTER**.

PRINT CD

Output formatted to upload record log to a computer directly or via modem. Includes a line count and with each data line, a checksum. Uses ACK, NACK software protocol to control transmission.

PRINT LP

Output formatted for a line printer. Contains same information as PRINT CD dump, without the line count and the checksums, and does not wait for a response.

MENU

Step down the menu choices and press ENTER to select a choice.

SELFTEST

Runs a comprehensive hardware check on the gauge consisting of RAM test, ROM test, Counter test, Timer test, Display test and Keyboard test. The RAM test is destructive. Do **NOT** run it if the LOG data is important. Selftest takes about 2 minutes. You must watch the display test to see that all segments are the same. The keyboard test echoes the key pad you touch. To complete the keyboard test, press **CLEAR** twice. A successful test will display "TST OK". If an error occurs, an error message will be displayed at the end of that test. To acknowledge it and continue the remaining tests, press ENTER. To abort any test, press **CLEAR** during the test.

BAUDRATE

Allows setting the baudrate for transmission on the serial connector. When first selected, displays the baudrate currently selected. Use the **STEP** key to step to a new rate, and press ENTER.

ATRIB

Allows setting attributes into the PRINT LP output for specific external equipment. Has provisions for three each characters at the beginning of transmission (prefix) and three each at the end (suffix). A typical prefix would be to transmit an ASCII decimal 15 to an EPSON printer to place it in the compressed mode. A typical suffix would be an ASCII decimal 26, which is recognized by a CP/M system as the end of transmission of a file of data.

A Top of Form character (TOF) is transmitted for each 60 lines of data.

"PX1 000"	1st prefix character
"PX2 000"	2nd prefix character
"PX3 000"	3rd prefix character
"SX1 000"	1st suffix character
"SX2 000"	2nd suffix character
"SX3 000"	3rd suffix character
"TOF 012"	Top of Form character

As shipped from the factory, the prefix and two of the suffix characters are nulls (0). One of the suffix characters is a control Z (ASCII 26 for end of file in CP/M programs), and the TOF is a control L (ASCII 12). The ASCII characters are entered as their decimal values (0...127) by keying them in and pressing ENTER.

SERNO

Displays the last four numbers of the probe serial number. Press **CLEAR** to return to the "READY" display. The serial number may be changed by keying in a new number, followed by ENTER. This is useful when moving a surface electronic assembly from one gauge shield/probe to another.

VERSION

Displays the gauge software version (useful for service purposes).

STD

Displays standard count information and/or take a new std count. Initially displays the current density standard count ("DS 12345"). Step through the five remaining attributes, or press **CLEAR** to return to **READY**. After the attributes have been STTEPed thru, the gauge will prompt to take a new standard count by displaying "NEW STD?". Press **ENTER** to take a new standard, **STEP or CLEAR** to return to **READY.**

To take a new standard count, after "NEW STD?" is shown press **ENTER,** the gauge will prompt for the channel whose counts are to be displayed during the counting "DISP DCT" for density or "DISP MCT" for moisture, STEP to the channel desired and press **ENTER**. The DR will take 32 each 8-second counts, with a 2 second warm-up delay between each count (4.27 minutes of counting). During each count period the previous count and channel selected are displayed (e.g. "32D1234" or "32M 12345"). When the last count is finished, a NEW standard count, based on the average of the 32 counts, is calculated and displayed (it is displayed as an equivalent 16-second count to be consistent with a normal count display, and so will be twice the previously displayed 8-second counts).

Use the **STEP** key to view the CURRENT standard count (identified as previous at this point) and NEW chi-square ratio (continuing to press **STEP** will cycle the display around the three pieces of standard count information). If the difference between the new and current standard counts and the value of the new chi-square ratio are acceptable, press ENTER to update the standard count information. If they are not acceptable, press **CLEAR** to abort and take another new standard count.

To abort a standard count in progress, press **CLEAR** several times until "READY" is displayed. The standard count information will remain unchanged.

FMT

Sets the record format, and clears the Logging space. On entry, displays the maximum number of possible records to be logged in the current format (e.g. "REC 279"). Press ENTER, then key in the desired number of keydata entries (0 through 15), press ENTER again. Do the same for depths (0 through 15). When the gauge displays "SET FMT?", be sure you want to do it, and then press ENTER. This **CLEAR**s the Log, sets the new record format, and starts the storage at the top of the Log area. Be sure you have dumped the previous information before **CLEAR**ing the memory, otherwise it will be erased. If you just want to view the current format, but not **CLEAR** it, press **CLEAR** to abort.

To display the maximum number of records under this new format, press **FMT** again. Press **CLEAR** to return the display to "READY" without changing or **CLEAR**ing the format.

Taking A Reading

To take a reading, lower the probe to the appropriate depth and press **START**. Before doing this you must select **UNITS, TIME** and **CALIBRATION**. If you select any units other than count (CNT), the gauge must have a valid standard count.

How to Select UNITS

The choice of display units will depend upon your use. It is the same data only differing by conversion factors. Counts and count ratio are used for downloading to a software program and are helpful for troubleshooting and calibration

Once the units have been selected, then each time a count is taken, the display will be in the units selected.

How to Select TIME

For a given counting rate, the counting time interval determines the precision of the measurement. The longer the time, the more counts, and thus the more precise the measurement. Correspondingly, the longer the counting time, the less measurements that can be made in a day.
Thus the time interval is normally selected as the minimum time that will not sacrifice precision.

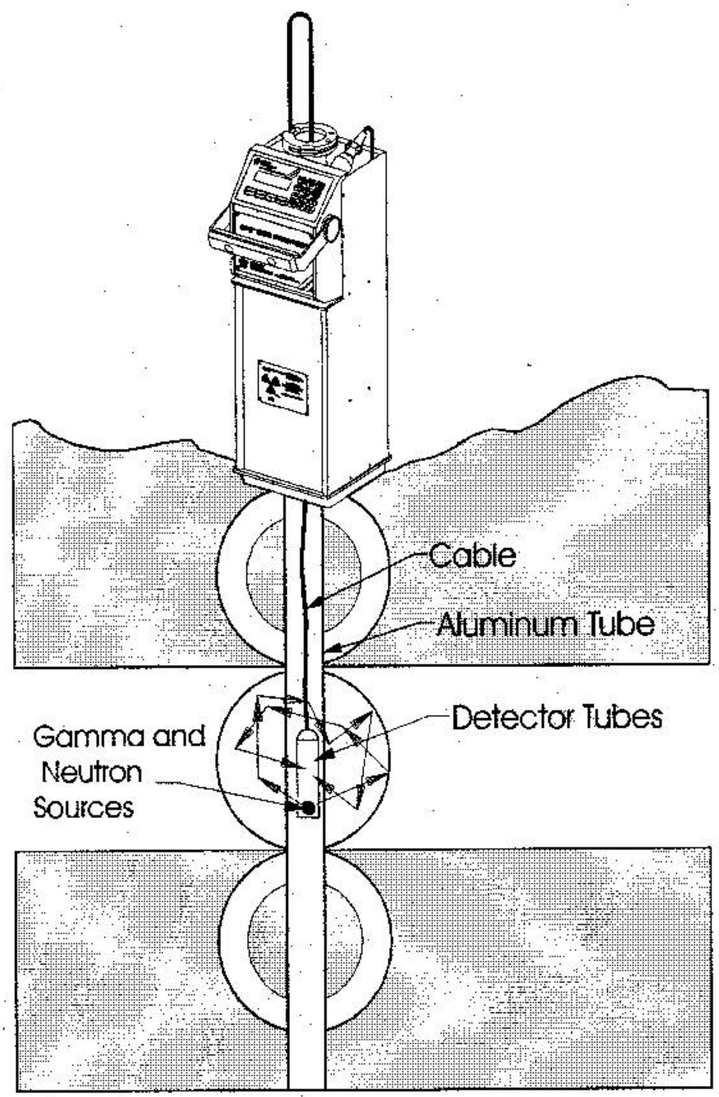


Figure 2.2. Taking a Reading.

Tipicallly a 64 second count time will be sufficient to achieve a precision of ± one pcf in density. Because of the higher counting rate a 16 second count time is sufficient for moisture measurements.

See the appendix section on Counting Statistics for a further discussion of precision.

How to Select CALIBRATION

The calibration will have been determined previously, and the coefficients in one of the sixteen calibrations. Select the one that is appropriate for the soil and type of access tube.

Operating Procedures

To Log Readings

Readings can be logged by the gauge as they are taken in the field. Each tube site represents a record of information. Prior to storing any readings, you must define the format of the tube site record. After readings have been logged, they can be recalled for display or dumped to an external device.

How to FORMAT The Records

Use the **FMT** key to format the data storage area to agree with the tube conditions. For each access tube at which one record of data is stored, the format will allow 0 to 99 keydata entries and/or 0 to 99 tube depths (counts per tube). The gauge always provides for an identifier number (ID) for each record and stores the selected calibration number (1-16).

FIELDS	BYTES
ID	2
CALIBRATION	1 (density and moisture)
KEYDATA	2
DEPTH (count)	4 (one density and one moisture)

Thus a typical site record format of one ID, one calibration number, one keydata, and three depths (counts), takes 17 bytes per record, and allows 180 records to be stored.

After the number of depths is entered, the gauge will display "SET FMT?". Press **ENTER** to set the new format or **CLEAR** to abort. Setting a new format clears all the data records. DO IT ONLY WHEN EACH TIME A NEW SET OF DATA IS TO BE STORED.

Press **FMT, ENTER, ENTER, ENTER, CLEAR** to view the number of records, keydatas and depths without clearing the data records.

How to TAKE/LOG Your Measurements

Set units, time, calibration and format. Then to log a record of information, place the gauge on the access tube and press **LOG**. The gauge will display the number of the current record into which data is to be logged. Since it down counts, it is also an indication of how many empty records remain.

You can use the gauge generated number as the ID number to be stored by pressing **ENTER,** to enter your own ID number for this record (access tube), key in any number from 1 to 65,535 followed by **ENTER**. It may be meaningful to treat this number as more than one number. i.e. consider the first two digits as a farm number (allowing from 1 to 65 farms), and the last two digits as a farm field number (allowing from 1 to 99 fields on any farm). Enter the middle digit as 0 or use it to indicate an operator number from 1 to 9.

After entering the ID number, the display will prompt for keydata entry (e.g. "K1 0" - if selected by the **FMT** key previously). Keydata entries allow you to use the gauge to key in auxiliary information such as temperature, rainfall, etc. This feature helps eliminate errors in translating readings to note pad, and then from the note pad to the computer. (It is recommended that all field data be hand recorded to prevent loss due to subsequent equipment failure.)

Enter the keydata as a number from 0 to 65,535 followed by **ENTER**. Again, it may be treated as more than one piece of information (i.e. first two digits for temperature in degrees Celsius and the last two digits for rainfall in inches). A keydata field does not have provisions for decimal points. They must be implied, not entered directly.

Use any scheme which fits your field conditions. Just be consistent from record to record. The **Probe** program (Crop Management And Irrigation Scheduling Software) from IRRICROP TECHNOLOGIES, available through Boart Longyear/CPN, provides for entering the date for a series of readings by setting the ID to "0", and the first keydata to the date (e.g. 412 for April the 12th). Press **ENTER** without taking counts to skip the depth readings for this special record. All records following until the next ID of "0" are then access tube readings. The **Probe** program expects that the farm number times 100 plus the field number will be stored in the ID, and the site number in the first keydata (e.g. for farm "1", field "2", and site "3", the ID would be 102 and the first keydata would be 3).

If you make an error in entering a number, press **CLEAR** and enter the correct number. If you press **CLEAR** more than once in succession, it will cancel the record storage without saving any of the record, and return to the "READY" display.

If the gauge does not accept the number (e.g. you try and enter a decimal point) it will give a multiple beep and re-prompt. If it does accept the number, it will prompt for the next keydata, or if all keydatas are entered, it will prompt for a moisture reading by displaying "DEPTH ##" ("##" is the number of the depth position and will down count from the maximum number set via FORMAT to 1).

Lower the probe to the correct depth and press **START.** When the count is completed, the gauge will display the value of the reading in the units selected (e.g. "D3 2.6538"). To view wet density, dry density or moisture press DWET, DDRY or WATER. The last display selected will be displayed initially for the next measurement and until changed by selecting another display. If the reading is acceptable, press **ENTER** to store it. If not acceptable, identify the reason and press **START** to take another. thus the gauge will only store a reading if you accept and enter it. The display will then prompt to take the next depth moisture reading. Move the probe and repeat the process by pressing **START**. Continue in this manner until all depths have been recorded.

Operating Procedures

If you want to skip a depth (e.g. the bottom depth is flooded), press **STEP** instead of **START/ENTER**. This is also useful if you have some tubes with five depths and some with only three. Format for five and skip two readings when on a tube with only three depths.

When the gauge displays "DATA OK?", press **ENTER** to log all the data for this record. The display will return to "READY". If the data is not correct, press **STEP** until the bad data is displayed (the display will start with the ID and skip across the record). Correct it by a keydata entry or taking and entering a new count. If you press **CLEAR** when "DATA OK?" is displayed, then the logging of that record will be aborted and all data for that record cleared.

If the units IPF or CPC have been selected, then after the last depth has been entered or stepped over, the gauge will totalize and display the record's total moisture in the root zone in inches or cm e.g. "TM 16.437".

Use the **ENTER** or **STEP** key to skip to the keydata you want to change or take a new count. When you again reach the end of the record and "DATA OK?" is displayed, press **ENTER** to log that record.

How to RECALL a Record

Normally the stored data will be downloaded to a printer or computer. It may also be recalled to the display by the **RCL** key. When first entered, it will point to the last ID stored. Either use the **STEP** key to step up the ID list (it steps back through the list and circles around at the beginning), or key in a specific ID and press **ENTER**. Use the **STEP** key to move across the record. If you continue pressing **STEP**, the display will advance up to the next record and then across, etc.

The standard count is a measurement of the neutrons which have lost significant energy by collision with the hydrogen in the wax in the shield. By taking the standard count in the same manner each time, it provides two means for checking the validity of the counting function.

1. By comparing it with the previous standard count to see that it has not changed more than an acceptable amount, it is an indication of acceptable drift of the electronics. Americium-241/Beryllium has a half-life of 458 years. It's decay rate is negligible over the life of the product.

2. By taking it as a series of short counts rather than one long count, and verifying that its statistical distribution is normal, it is a means of checking that noise is not influencing the count.

Previous Standard Count

When a new standard count is taken, the previous standard count is replaced and the **501DR** program uses the new standard to calculate the field count/standard count ratio.

"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. A ratio near 1.0 and small changes between previous an new counts, indicates that the **501DR** is working properly. It is recommended that a new standard be taken daily to check "Xi" and changes in counts. The Xi ratio should be between 0.75 and 1.25, and the change between the present and previous standard counts should be smaller than the square root of the average count (1 standard deviation). This will verify the performance of the 501DR every day of use. If the Xi value is outside of expected limits, repeat the standard count. If the statistics are again poor, consult the Troubleshooting Guide (Appendix B).

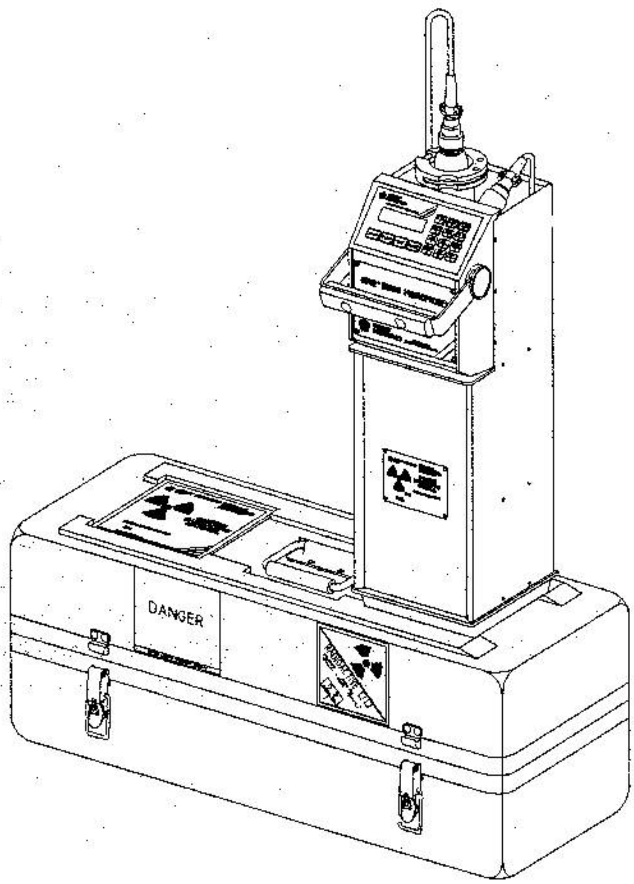


Figure 2.3. Standard Count Procedure.

Taking a Standard Count

With the case on the ground, place the gauge on the CPN nameplate depression on the top of the case. No other radioactive sources should be within 30 feet of the gauge, and no source of hydrogen should be within 10 feet after starting the reading.

To initiate a new standard count, press **STD** and then **START**.

The wax in the shield is not an infinite volume. Thus a standard count taken in this manner is subject to surrounding conditions. It is important that the standard count be taken in the same conditions as that used to establish the calibration, and that the conditions are the same each time.

Standard Count

A more stable method to take a standard count is in an access tube installed in a 30 gallon or larger water barrel. To use the factory calibration, but change to a new method of taking a standard count, modify the "A" calibration slope term by the ratio of the new standard count and the factory standard count (e.g. the original factory standard count was 11,000 with an "A" slope of 2.6, while the new water barrel standard is 33,000. The new "A" coefficient should be:

$$2.6 \times (33{,}000 / 11{,}000) = 7.8.$$

When a standard count is started, the gauge will take 32 each 8.0 second counts, turning the HV power supply to the probe on with each count. With each count, the display will show the count number (32, 31, 30 ....,1) followed by the actual 8-second count (e.g. "30 7200"). When the 32nd count is completed, the NEW standard count is displayed (e.g. "S 7405"). It is normalized to a 16-second count time, the same as a normal display count.

Press the **STEP** key to view the CURRENT standard count (e.g. "P 7385"). Press the **STEP** key again to view the Chi-Square Ratio of the NEW count (e.g. "CHI 0.95"). Continuing to press **STEP** will cycle the display through the three pieces of standard count information. To update the standard count, press **ENTER** while the display is in this loop. The current standard count will be stored as the previous standard count, and the new standard count will be stored as the current standard count. (Note that the previous standard count viewed above is actually the current standard count until you press **ENTER** to accept the new standard count.)

To exit STANDARD without updating the standard count, press **CLEAR**. To abort a standard count in process, press **CLEAR** several times until "READY" is displayed.

If the gauge is connected to a printer via the serial link, individual counts and summary information will be printed out.

503B-2.1 STANDARD COUNT FOR SN255
SAMPLE COUNTS ARE 8 SECONDS NORMALIZED TO 16

N	COUNT
32	7370
31	7370
30	7200
29	7370
28	7370
27	7812
26	7370
25	7370
24	7402
23	7370
22	7370
21	7370
20	7636
19	7370
18	7370
17	7566
16	7370
15	7370
14	7370
13	7368
12	7370
11	7368
10	7370
9	7730
8	7368
7	7370
6	7370
5	7370
4	7370
3	7370
2	7370
1	7370

AVERAGE 7405
PREVIOUS 7385
CHI-RATIO 0.95

Figure 2.3. Standard Count Printout.

Standard Count Statistics

Taking such a series of 32 counts will result in a distribution of counts around a central value. The standard deviation is a measure of the spread of these counts about that central value. For a random device, such as the decay of a radioactive source, the ideal standard deviation should be equal to the square-root of the central value.

If the gauge is working properly, then the measured standard deviation and the ideal standard deviation should be the same, and their ratio should be 1.00. The Chi-Squared test is used to determine how far the ratio can deviate from 1.00 and still be considered acceptable. This is similar to expecting heads and tails to come up equally when flipping an unbiased coin, but accepting other distributions when only flipping a small number of times.

For a sample of 32 counts, the ratio should be between 0.75 and 1.25 for 95% of the tests. Note that even a good gauge will fail 5 out of every 100 tests. If the ratio falls too consistently outside, it may mean that the counting electronics is adversely affecting the counts. Generally, the ratio will be high when the electronics is noisy. This might be due to breakdown in the high voltage circuits or a defective detector tube. The ratio will also be high if the detector tube counting efficiency or the electronics is drifting over the measurement period (i.e. the average of the first five counts is significantly different than the average of the last five counts).

It will be low when the electronics is picking up a periodic noise such as might occur due to failure of the high voltage supply filter. This should be accompanied by a significant increase in the standard count over its previous value.

Calibration

The neutron probe is a source of fast or high energy neutrons and a detector of slow or thermal neutrons. The fast neutrons are slowed down by collision with the nucleus of matter in the soil, and then absorbed by the soil matter. Since the mass of the nucleus of hydrogen is the same as that of a free neutron, the presence of hydrogen will result in a high field of thermal neutrons. Heavier elements will also slow down the neutrons, but not nearly so effectively. While it takes, on the average, only 18 collisions with hydrogen, it takes 200 with the next element normally found in agro soil.

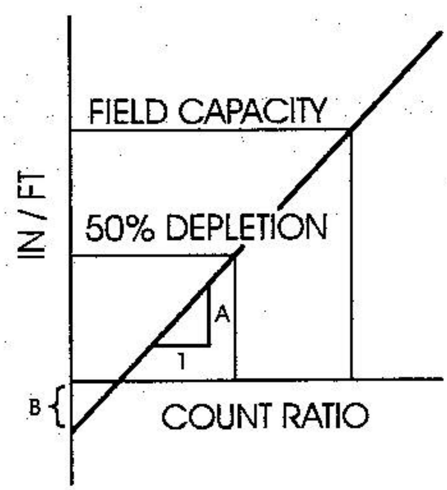
The thermal neutrons are continually being absorbed by the matter in the soil. Boron, for example, has a high affinity for thermal neutrons. The resulting thermal neutron flux will depend upon a number of factors, both creating and absorbing thermal neutrons, but most importantly will be how much hydrogen is present. The neutron probe may thus be used as a measuring device for moisture in the soil, but it may require calibration for local soil conditions.

Field Calibration

A field calibration requires the probe, a volume sampler, a scale and a drying oven. Install the access tube in a representative point in the soil. Take probe readings in the tube and volume samples in pairs around the tube. Take them at the same depth and within a foot or two of the tube.

Seal the volume samples in a sample can or plastic seal bag immediately after removing from the soil. Be careful not to compact the surrounding soil when taking the samples. Ideally (20) such measurement pairs should be taken over a range of moisture conditions.

An alternate method is to use a sampler of smaller diameter than the tube and take volume samples at each depth while making the hole to install the access tube. Then take probe readings at the same depths. This has the advantage that the calibration is performed on the tube to be used for scheduling.



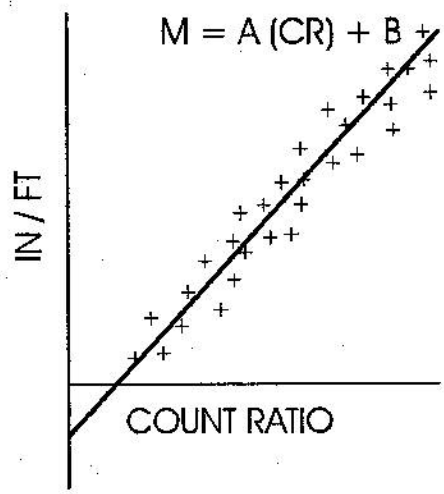
Another alternate, popular with irrigation schedulers, is to only take two measurement pairs, one pair at field capacity and a second at a soil moisture condition near 50% depletion.

Weigh the soil samples wet and dry (24 hrs at 105° C in a vented oven). Calculate the moisture by weight and the dry soil density, and then combine to determine the soil moisture content in inches per foot as follows:

$$\textit{inches per foot} = \frac{Ww - Wd\,(gm\ water)}{Wd(gm\ soil)} \times \frac{Wd\,(gm\ soil)}{V\,(cc\ soil)} \times \frac{1\,(cc\ water)}{(gm\ water)} \times 12$$

Using linear graph paper, plot the probe readings in count ratio versus the volume samples in inches per foot.

Fit the graph to a straight line. For a scatter diagram of 10 to 20 data pairs, do a linear regression on a hand calculator. For only two pairs, use the following equations to determine the slope and intercept.



$$slope = A = \frac{MH - ML}{RH - RL}$$

$$intercept = B = ML - A \times RL$$

$$then: \quad m = (A \times r) + B$$

where:

- m = moisture in inches per foot
- r = count ratio
- MH = high moisture value in inches per foot
- ML = low moisture value in inches per foot
- RH = probe count ratio at the high moisture value
- RL = probe count ratio at the low moisture value.

Example:

A field capacity of 3.8 in/ft gives a ratio of 1.500, while 50 percent depletion gives a ratio of 0.77

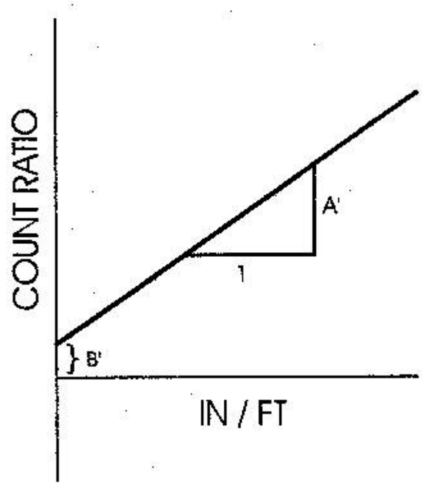
$$A = \frac{3.8 - 1.90}{1.5 - 0.77} = 2.603 \text{ in / ft / count ratio}$$

$$B = 1.9 - 2.603 \times 0.77 = -0.1043$$

or

$$m = 2.603 \times r - 0.1043$$

The DR defines the slope and intercept with water on the vertical axis and ratio on the horizontal axis. If your data has been plotted with the axis reversed as shown in the following Figure, it will be necessary to transpose the slope and intercept terms before entering in the DR.



$$A = \frac{1}{A'}$$

$$B = \frac{B'}{A'}$$

Calibration

Laboratory Calibration

For a laboratory calibration, two known calibration points are needed. A high calibration standard can be a barrel of sand saturated with water (typically 0.32 gm/cc. i.e. 0.32 grams of water per cubic centimeter of soil, or 32% water by volume, or 3.84 inches of water per foot of soil). A low standard of dry sand would be 0.0 gm/cc.

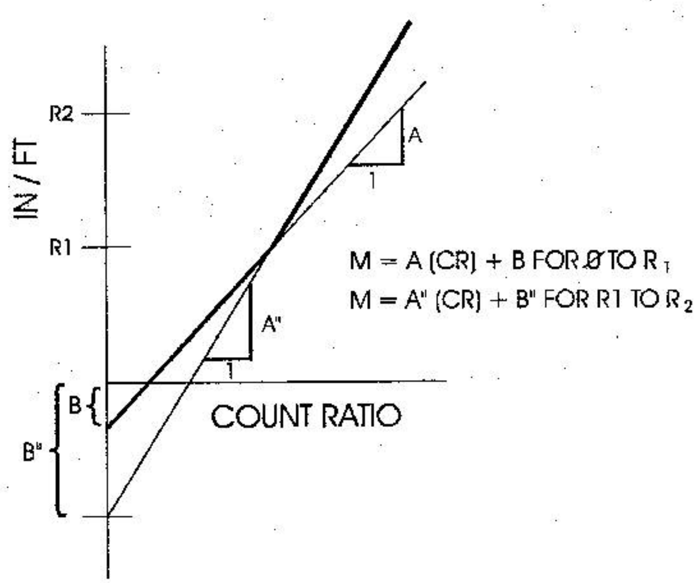
Set the gauge to the desired units and select a 256 second count time. Use the SLFCAL feature of the probe. Place the probe in one of the two know moisture standards. The display will prompt for the know moisture density of the standard. Enter it in the units selected, e.g. 3.88 **ENTER**. If count or ratio has been selected as the units, an error message will be displayed.

Pressing **START** will cause the gauge to take and store a 256 second reading. When the count is completed, move the probe to the second moisture standard. The display will prompt for the moisture density of that standard. Press **START** to take a 256 second reading in the second standard. When the count is completed, the gauge will calculate and store the slope and intercept coefficients for the calibration in the selected units. Use "COEFF ?" **ENTER** to view them. Record them in your note book for future reference.

This is how the factory calibration was determined. It will be applicable for sandy soils with no significant minerals or organics. It can also be used for relative measurements, e.g. measuring a field before and after a known irrigation, will allow determining how much was applied versus how much the probe measures before and after, thus calibrating the probe to that field.

Range

The linear calibration supplied with the DR is useful over the most commonly used moisture range, 0 to 40%. For use in moisture percentages higher than this, it is necessary to have a special calibration. The following Figure shows a high range calibration. If field data is not available, a count in a water barrel can be used.



Section 3 - Maintenance

General

This section supplies basic information to perform maintenance on a field level basis. The only required tools are the screwdriver and the spanner wrench which are supplied with the gauge. A voltmeter capable of reading to 15 vdc is recommended.

The model **CPN 501DR** consists of four major assemblies:

1) Surface Shield/Carrying Box
2) Surface Electronic Assembly (DR)
3) Cable
4) Probe Assembly

Using the following maintenance guide, isolate the problem to one of the major assemblies. If a second gauge is available, the parts can be interchanged to easily isolate the defective assembly.

The Surface Shield/Carrying Box is only a mechanical assembly. Other than the latch mechanism, which can be repaired by replacement parts, no service other than occasional cleaning is required.

If the cable is defective, it should be replaced. It is recommended that a spare cable be kept on hand to minimize down time.

If the Surface Electronic Assembly or the Probe Assembly are found to be defective for reasons other than battery cells, then they require test equipment including an oscilloscope, signal generator and a digital voltmeter. As such, they should be returned to the factory for repair. The Probe Electronic Assembly can be easily separated from the Source Tube Assembly, making it easy to ship the Probe Electronic Assembly by UPS or other convenient means, and leave the source in its shielded position.

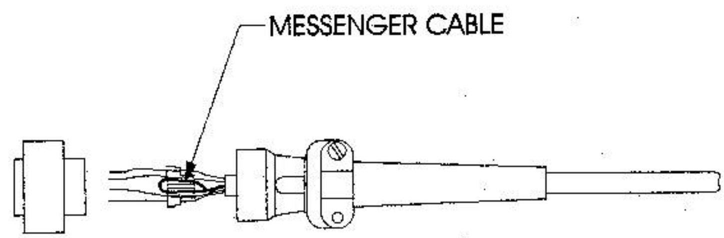
Exchange Policy

Boart Longyear/CPN Service Centers keep on hand an inventory of exchange parts. Where minimum down time is important, Boart Longyear/CPN will ship an exchange assembly, upon your request. The time and material cost to repair is generally less than the exchange cost, but with the exchange unit, the repair time and the one-way shipping time are eliminated. If the returned item is not in good condition or is not returned to the factory within 30 days, the customer will be billed for the full price.

Cable Maintenance

The cable is constructed using a central stainless steel messenger surrounded by four insulated stranded copper wires. The messenger is firmly clamped to the connector shell at each end to support the weight of the probe. The four copper conductors are wired point to point as shown in Figure 3.1.

Undue stress or extended usage may cause separation of the copper conductors. If the break is intermittent, it may be located by taking a count while flexing the cable and observing spurious or sporadic counts. Most often the break will occur at the end near the probe. The cable is made as a separate assembly so that is can be easily replaced. Breaks near the ends can be repaired by shortening the cable and resoldering the copper conductors. The inner chamber of the connector should be filled with RTV or an equivalent insulating compound to prevent moisture intrusion. The messenger should be pre-stressed to take the strain off the copper conductors.



Probe Assy	Color/Signal	Surface Assy
P1-A	Red / 10V	P2-A
P1-B	Brown / Not used	P2-B
P1-C	Black / Ground	P2-C
P1-D	Yellow / Moisture Pulse	P2-D

Figure 3.1. **CPN 501DR** Cable Assembly.

Surface Electronic Assembly Maintenance

The Surface Electronic Assembly consists of:

1) Surface PC-Assembly
2) Battery Cells (8)
3) Display PC-Assembly
4) Fuse Holder and Fuse
5) Cable Connector

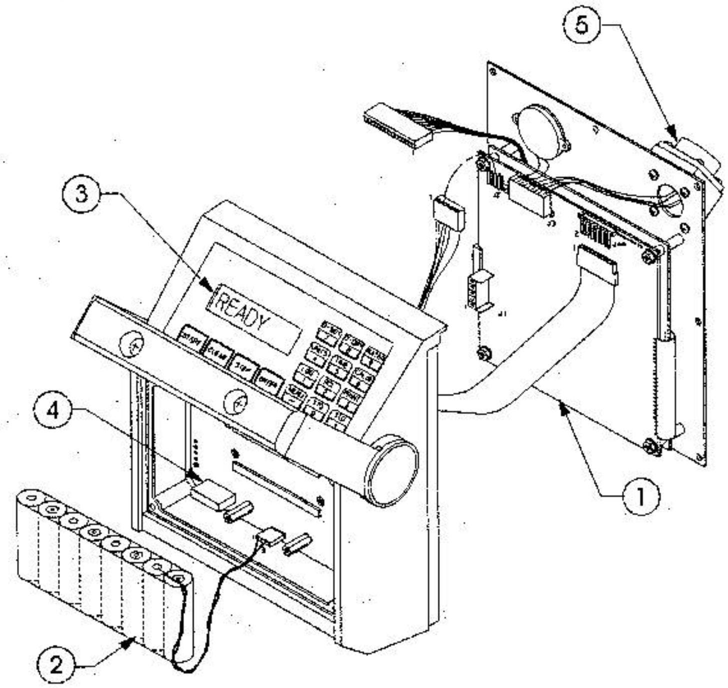


Figure 3.2. Surface Electronic Assembly

Field maintenance of this unit will normally be limited to replacing the battery cells or the fuse.

Removal

The Surface Electronic Assembly can easily be removed from the Surface Shield/Carrying Box for convenience or return to the factory for repair or exchange by removing the screws on each side of the assembly.

Battery Cells

The Model **CPN 501DR** is supplied with 500 milliampere-hour nickel-cadmium (NICAD) AA size rechargeable battery cells. The gauge draws approximately 5 milliamperes when on. Assuming 50% derating, this means a fully charged gauge can operate 50 hours, or make 3000 tests (one/half minute count with one/half minute display) before requiring charging.

Battery Recharging

The AA cells have a rated energy storage capacity of 500 milliampere-hours. The charger supplied with the gauge charges at a rate of 50 mA. Nominally this C/10 charge rate should take 10 hours to recharge the battery. However, if the individual cells were then examined some would be fully charged while some would be undercharged. The undercharged cells would limit the battery's capabilities. A technique to balance the cells state of charge is to deliberately overcharge them 140 to 160%. To fully recharge the cells, leave it on the charger 14 to 16 hours or overnight.

After charging, the cells should feel warm to the touch indicating that they have gone into the overcharged state.

Surface Electronic Assembly Maintenance

Battery Overcharging

Once a NICAD is fully charged, any additional energy supplied will be dissipated as heat. At the C/10 rate the cells can be overcharged for several weeks without it being a major cause of end of life. There is, however, a tendency to dry out the electrolyte, so it should not be done on a routine basis.

> **CAUTION**
> Overcharging with a charger that charges at a greater than C/10 rate may cause venting of the cells resulting in damage to the cells and surrounding circuitry.

Battery Replacement

A NICAD is rated for approximately 1000 deep charge-discharge cycles. Using your gauge during the week and then charging it overnight every week or two should result in approximately 5 years of cell service.

What is suspected as a bad cell is sometimes really a contact problem.

The gauge is equipped initially with industrial grade, 500mAh, rechargeable NICAD, AA size cells. Replacement cells of this type are available from Boart Longyear/CPN.

Storage

Fully charged NICAD's standing idle at 20° Celsius lose about 1% of their charge per day because of chemical self-discharge. Thus if a gauge is not used for a month or more, it will have lost 30% or more of its capacity and should be recharged before use. The self-discharge rate increases with ambient temperature.

The Probe Assembly consists of:

1) Source Tube Assembly
2) Probe Electronic Assembly

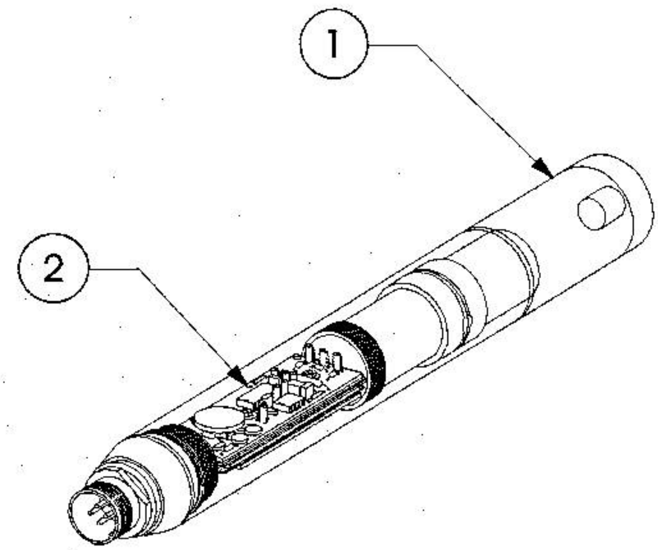


Figure 3.3. Probe Assembly.

Removal

The Probe Electronic Assembly is easily removed from the Source Tube Assembly. As shown in Figure 3.3, grasp the top of the Source Tube Assembly with the left hand and using the spanner wrench in the right hand, rotate the Probe Electronic Assembly counter-clockwise. After the threads are disengaged, pull the Probe Electronic Assembly out of the Source Tube Assembly.

> **WARNING**
> The radioactive source is mounted in the base of the Source Tube Assembly. Do not grasp the base with your hand. The Source Tube Assembly should be placed back in the Surface Mechanical Assembly during repair of the Probe Electronic Assembly.

The Probe Electronic Assembly consists of the connector, brass plug housing a ferrite transformer, an amplifier PC-Assembly, an HVPS PC-Assembly, both mounted on a tray and the detector tube itself. These items are shown in Figure 3.3.

Field repair of the probe electronic assembly will generally be limited to a physical examination for loose items. The connector pins at each end of the PC-Assemblies should be engaged and the brass rings on each end of the tray should be tight.

If moisture is observed inside the probe and no permanent damage has occurred it can be dried by placing in a household oven for one hour on warm (140° to 158° F, 60° to 70° C).

Probe Re-Installation

When re-installing the repaired or exchanged Probe Electronic Assembly in the Source Tube Assembly, insure that the threads are properly engaged. If the probe has been roughly handled in shipping, it may be necessary to bend the tray slightly to insure a correct fit. Thread together the assemblies almost all the way by hand and then apply a thin coating of silicon grease to the O-ring. Use the spanner wrench to compress the O-ring to insure a moisture seal.

Intentionally Blank

Appendix A

Error Messages

If an error occurs in the **CPN 501DR**, then the function that was being performed is aborted, and an error description or number is displayed (the gauge is actually in the **READY** mode). Errors that may occur in the normal operation of the gauge, will display a descriptive message. You should take corrective action as appropriate.

Operating Errors

NO STD	No moisture standard count. Take a new standard.
FULL	Record log full, PRINT-out record log, and clear via FORMAT.
NOT HERE	ID entered into RECALL does not exist. Enter correct ID.
EMPTY	Record log empty when RECALL pressed. Load record(s) via LOG.
NO DATA	Record log empty when PRINT pressed.
SET UNIT	Calibration coefficients undefined for CNT or RAT unit. Change UNIT.

Internal Check (hardware) Errors

RAM XXXX	Non-destructive ram test failure at address XXXX.
ROM XXXX	Program memory checksum error. XXXX is the non-zero sum.
EEP XXXX	EEPROM read after write failure at address XXXX.
CK X.XXXX	Timer clock test period error. $\lvert 1 - X.XXXX \rvert > 0.01$ seconds.
MCTR ERR	Moisture counter failure.

Appendix A

Program Error Codes

Equipment errors that should seldom occur will display a descriptive message or "ERR" followed by a number of 100 or above. If such an error number occurs, contact the factory or local service center.

Program Error

I DIV 0	Integer divide by zero.
DIV BY 0	Real divide by zero.
NEG ROOT	Square root of negative number.
PBUS ERR	Pcode buss error.
EEP XXXX	EEPROM read after write failure at address XXXX.
ERR 100	Computer bus error undefined restart.
ERR 102	Message number too big.
ERR 108	Real display roundup exponent underflow.
ERR 109	On clear pstack pointer greater than current pstack pointer.
ERR 110	On clear machine stack pointer greater than current machine stack pointer.
ERR 113	Undefined pcode.
ERR 116	Spurious timeout.
ERR 117	Pcode pointer underflow (machine stack running pcode).
ERR 120	On clear, stack underflow.
ERR 201	Depth index too big.
ERR 203	Record index too big.
ERR 204	Count too big to store in record.
ERR 217	Spurious initialization.

Appendix B

Troubleshooting Guide

CONDITION	POSSIBLE CAUSE
Chi ratio too high, no change in the average standard count.	Look for a drift in the counts over the measurement time. (e.g. the average of the first five counts is significantly different than the average of the last five counts).
Chi ratio too low with an increase in the average count over previous.	Periodic noise occurring. Possibly an open filter capacitor in the HV power supply.
Chi ratio too low, no change in the average count.	Procedure error. Possibly analyzing normalized counts. The standard deviation must be determined on direct counts.
Chi ratio OK but change in average count.	Change in gauge geometry. A change in counting efficiency will be normalized out by ratio technique. A change in gauge geometry must either be corrected or the gauge recalibrated.

Appendix B

Troubleshooting Guide

Problem	Reason
Power Circuit	
No display and no audible hum at top of probe.	Blown fuse. Open or dirty battery cell contact. Defective battery cell.
Gauge blows fuses.	Stack defective (shorted capacitor, IC etc.). Shorted cable
Low battery condition soon after a full charge.	Open or dirty cell contact. Battery cell defective. Charger defective. Excessive load in surface or probe electronics.
Counting	
Display reads "0", a 6 kHz hum can be heard.	Probe defective. Cable defective.
Same except no 6 kHz hum.	Probe defective. Cable defective.
Statistics test results in high ratio due to one or more wild counts.	HV supply noisy
Statistics test results in high ratio due to shift of mean during the test period.	HV supply drifting. Detector drifting
Statistics test results in low ratio with an increase in the standard count.	Periodic noise being counted, most likely due to open bypass capacitor in HV supply.
Performance	
Moisture reads high compared with other methods (2nd gauge, oven dry, etc.) while statistics test of standard count and all other functions are okay.	Gauge is reading both free water and bound water of hydration. Apply correct bias, Calibration not applicable to the soil type or to the access tube type.
Same except moisture reads low	Calibration not applicable to the soil type or to the access tube type.
Same except accompanied by a shift in standard count.	Probe geometry changed. Defective detector

Appendix C

Data Transfer

Using the logging feature, the gauge can record many records of site readings for recall later. It is extremely convenient if that data can be used in a program that can manipulate the data for the users needs. To get the data from the probe to the computer, you may use the PRINT CD feature which stands for PRINT Computer Dump. Computer to computer communication requires a matched standard means of data communication implemented on both ends of the transfer. The gauge is capable of serial communication in an RS232 ASCII format, which is standard for many computers and communication packages written to be used on them. One problem of serial communication is that it is not fool-proof, and some form of error checking must be performed on the data to insure that it is valid. The gauge uses a format where at the end of each line that is transmitted, the computed checksum of the ASCII values of each character in the line is sent as the last data field. The receiving program must compare this value with the value it computes as the data is being received and send back an appropriate response. This format of communication is styled after ACK and NACK types of communication. The response is either ACK — the line was received correctly and it is ACKnowledged, or the response is NACK — the line was not received correctly and it is Not ACKnowledged. The gauge receives the response and either transmit the line again or transmit the next line. The data records received are stored as a file on the current storage medium.

The program specifications that pertain to the gauge are:

- RS232 type serial communication (TXD, RXD, GND).
- 1 start bit, 8 data bits, no parity, and 2 stop bits.
- Baud rate; 110, 300, 1200, 2400, 4800, 9600, (programs in basic may not operate at speeds higher than 300 baud).
- ACK character ASCII value 6 decimal.
- NACK character ASCII value 21 decimal (any unrecognized character is treated as a NACK character).
- Checksum computed by ASCII values up to, and including, the comma before the checksum field.
- "p" is the ASCII character (value 112 decimal) that will remotely activate the PRINT feature of the gauge.
- CR is the ASCII character (value 13 decimal) that will remotely acknowledge the PRINT CD prompt.

Using the **PRINT** key outputs the contents of the record log to an external device (computer, CRT Terminal, modem, printer, etc.) via the RS232C serial interface connector.

Two forms are available:

PRINT CD - for dump to an active device such as a computer (or computer via modem). Each line of data includes a check sum, and requires a software response from the computer to insure proper transmission of data.

PRINT LP - for dump to a passive device such as a printer or CRT Terminal. Same as the Print CD except no checksum, and the next line of data is transmitted without waiting for a response from the receiving device. Also, the data is formatted for ease of readability and header information is included.

Appendix C

Data Transfer

PRINT CD

A simple software ACKNOWLEDGE/NEGATIVE-ACKNOWLEDGE handshaking scheme (ACK/control-F, NACK/control-U) allows the external device to control the dump: ACK echoed in response to a received line causes transmission of the next line, while NACK causes retransmission of the same line. NACK may be echoed as often as necessary to receive an error free line. Characters other than ACK, are by default NACK. If the DR does not receive a reply within 60 seconds after sending the carriage return and line feed (CRLF) at the end of each line, a default ACK is assumed, and the next line is transmitted. The computer should not echo the DR transmission.

It takes approximately 100 ms after an external device has transmitted an ACK or NACK, for the DR to respond and transmit another line of data.

Each dump line consists of a series of fields separated by commas, and terminated by CRLF. The fields are variable in number and width. The last field is a checksum determined by summing the ASCII decimal values of each of the characters in the line up to, and including the last comma.

A received line whose computed checksum agrees with the transmitted checksum is good and should be echoed by ACK, or else a loss of data is implied and NACK should be echoed.

As each line is being transmitted (or retransmitted), its line number is displayed on the DR. The line number counts down, giving an indication of the lines remaining (e.g. "LINE 123").

PRINT CD Format

A file image of a PRINT CD dump is shown. Note that all data fields are separated by commas allowing easy use of input statements in BASIC or spreadsheet or database programs.

The print program requires that the computer be up during the dump. This places a heavy drain on the battery. Charge the battery before dumping. If you believe the pack is up, but are not sure, connect the charger during the dump. If the cutout circuit turns on during the dump, the data is not lost. Charge the gauge for about an hour and then re-initiate the dump.

```
20,503B-2.1,255,PCF,4266,1,3,1497
19,1,23.2,.12,673
18,2,20.25,-1.23,819
17,3,15.36,.35,734
16,4,-0.0,0.0,660
15,5,0.0,*.*,603
14,6,0.0,*.*,603
13,7,*.*,*.*,591
12,8,-0.0,183.38,827
11,9,-0.0,0.0,660
10,10,*.*,0.0,642
9,11,*.*,*.*,591
8,12,0.0,0.0,615
7,13,184.36,*.*,769
6,14,*.*,*.*,591
5,15,0.0,0.0,615
4,16,-0.0,*.*,648
3,1023,3,1,16.08,16.08,*.*,1293
2,1022,3,2,*.*,*.*,16.08,1169
1,1021,3,3,16.09,16.08,16.08,1415
```

Figure C.1. CD Format Printout.

Appendix C

Data Transfer

PRINT LP

A dump to a printer or a terminal contains the same information as the **PRINT CD** dump except that there are no checksums, no line count and it is formatted for readability with a header and Top of Form command every 60 lines. Print LP also transmits three control characters at the beginning and three at the end of the transmission. These sign-on and sign-off characters may be used to set external devices, such as a printer to a desired configuration (e.g. compressed print). These attributes, along with the character recognized as the Top of Form (TOF), are set via ATTRIB, a sub-menu of MENU.

Lines of data are transmitted one after another without waiting for an ACK/NACK response. The receiving device should NOT echo the transmission.

While PRINT CD is preferred because of its handshaking, PRINT LP can be used to make a passive data transfer to a computer.

MODEL	SERIAL	UNIT	STD	KDATA	DEPTH
503B-2.3	255	PCF	4266	1	3

CAL	A	B
1	23.2	.12
2	20.25	-1.23
3	15.36	.35
4	-0.0	0.0
5	0.0	*.*
6	0.0	*.*
7	*.*	*.*
8	-0.0	183.38
9	-0.0	0.0
10	*.*	0.0
11	*.*	*.*
12	0.0	0.0
13	184.36	*.*
14	*.*	*.*
15	0.0	0.0
16	-0.0	*.*

ID	C	K1	M3	M2	M1
1023	3	1	16.08	16.08	*.*
1022	3	2	*.*	*.*	16.08
1021	3	3	16.09	16.08	16.08

Figure C.2. LP Format Printout.

Appendix C

Data Transfer

DR Dump Software

This is an optional software supplied by Boart Longyear/CPN on a 3½ in diskette (P/N 704506) or on a 5¼ diskette (P/N 704507). Two programs are included on this disk: **DRDUMP.EXE** and **123DUMP.EXE** and both are intended to be used with all versions of **CPN's 501DR/501DR** nuclear gauges.

Both programs perform the same basic function: they establish a link to the **CPN 501DR/501DR** gauge through one of the PC's COM ports, send commands to the gauge to retrieve stored records, and output the data to a file on the PC. The only difference between **DRDUMP.EXE** and **123DUMP.EXE** is in the format of the file produced.

The **CPN 501DR/510DR** directly outputs its data in one of two formats: the "PRINT LP" format (for Print to Line Printer), and the "PRINT CD" format (for Print to Computer Device). The DRDUMP and 123DUMP programs will only work with the PRINT CD format, then you must be sure that the option selected in the gauge is PRINT CD. You can verify the selection pressing the PRINT key in the gauge and then in the screen you must see "PRINT CD", if "PRINT LP" appears press STEP and ENTER to change the selection to PRINT CD.

The DRDUMP program will copy the data in the PRINT CD format to the DRDUMP.DAT file. The data as it appears in the output file is altered by the DRDUMP program only by deleting the checksum value for each line. The DRDUMP.DAT file will always be created and updated after each run. The data in the DRDUMP.DAT file will be copied to the user named file but without the line numbers, without the checksum in each line and without the date, as is required by the PROBE software.

The 123DUMP program reads the data from the 501DR/501DR in the native PRINT CD format, and then modifies the data quoting any non numeric data and deleting the checksum values for each line before outputting it to the user named file.

If you will be using a spreadsheet or database program such as Lotus 1-2-3, Borland Quattro Pro, Microsoft Excel, dBase, Paradox, or similar application, it is recommended that you use the 123DUMP program. This program formats the data in the output file named by the user to accommodate the File Import feature of most spreadsheet and database applications. When importing the output file into the application, it is sometimes necessary to specify to the application program that the data format is ASCII, with fields (columns) delimited by a comma, text delimited by quotes (""), and records (rows) terminated by a carriage return <CR>.

In Lotus 1-2-3, the keystrokes required to import a file are /FIN (mnemonic /File:Import:Numbers). If you use a program other than Lotus 1-2-3, refer to the program documentation to determine the exact procedure for importing a comma and quote delimited ASCII file.

But, if you will be using **The Probe** program (from Irricrop Technologies) it is recommended that you use the DRDUMP program. This program formats the data in the output file to be posted using the option 3 of the **PROBE** program, Post Readings.

Both MC3DUMP and LOTUSMC3 will work with either COM1 or COM2 on your computer.

> **NOTE**
>
> To use special upload options, contact Boart Longyear/CPN for assistance.

Appendix D

Counting Statistics

General

Radioactive decay is a random process. For Cesium-137, which has a half-life of 30 years, it can be expected that in 30 years one-half of the material will have decayed, but in the next minute exactly which atoms will decay and exactly how many will decay is only by chance. Repeated measurements with the gauge will thus most likely result in a different count for each measurement. A typical set of 32 such measurements is shown in Figure D.1.

Fig. D.2 shows the distribution of these counts. The two characteristics of interest are: 1) the average value (also called measure of central tendency or mean), and 2) how wide the counts spread around this average.

Mathematically the average value is defined as:

$$\bar{x} = \frac{\sum x}{n}$$

The width of the spread is defined by a term called standard deviation.

$$s = \sqrt{\frac{\sum (x - \bar{x})^2}{n - 1}}$$

Or an alternate form useful on calculators:

$$s = \sqrt{\frac{n(\sum x^2) - (\sum x)^2}{n(n - 1)}}$$

where:

s = standard deviation of the sample
x = count (value of each sample)
$\bar{x}$ = average of the sample
n = number of measurements in the sample.

The above describes the average value and the standard deviation of a sample from a population. They are in approximation to the true average value and true standard deviation of the population.

μ = average of the population
σ = standard deviation of the population

SAMPLE	COUNT
32	4370
31	4370
30	3742
29	4370
28	4370
27	3812
26	4370
25	4370
24	4402
23	4370
22	4370
21	4370
20	3636
19	4370
18	4370
17	3566
16	4370
15	4370
14	4370
13	4368
12	4370
11	4368
10	4370
9	3730
8	4368
7	4370
6	4370
5	4370
4	4370
3	4370
2	4370
1	4370

AVERAGE 4266
CHI-RATIO 0.95

Figure D.1.

The distribution from measurement samples of any process can be classified into expected shapes that have been previously observed. Three are applicable to radioactive decay; Binomial, Poisson and Normal (also called Gaussian).

Appendix D

Counting Statistics

The Binomial distribution applies when the measured event can take one of two states. Tossing a coin is an obvious case. It can also be applied to a given atom, either decaying or not, in a time period. It is difficult to deal with computationally.

Since the number of atoms is very large and the expected probability of a decay occurring is very low (source life in years and measurement time in minutes), we can use the Poisson distribution which is a special case of the binomial distribution for these conditions. A special property of the Poisson distribution is that the expected standard deviation is equal to the square-root of the average value.

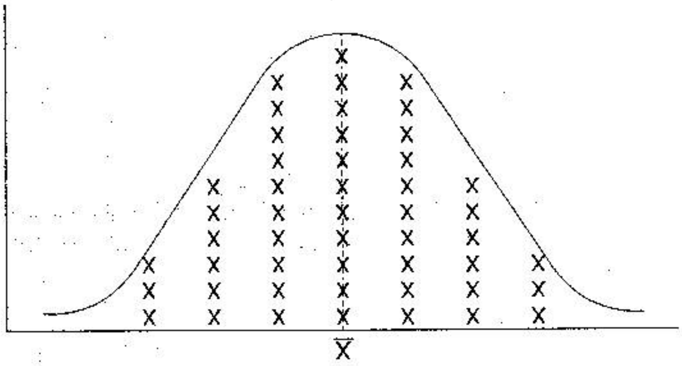


FIG. D-2

$$\sigma = \sqrt{\bar{x}}$$

If the sample is large enough, we can approximate for the standard deviation of the sample.

$$\delta = \sqrt{\mu}$$

This is an important relationship. It means that if repeated measurements are taken without moving the gauge and the detector electronics are working properly, then the spread of the counts will only be dependent upon the average count rate. This is in contrast to most measurements where the spread will depend upon the process. Figure D.3. shows the diameter of a part turned on a new lathe while Figure D.4 shows the same part turned on a old lathe. Both lathes produce a part with the same average diameter but a loose bearing caused the wider spread for parts manufactured on the older lathe.

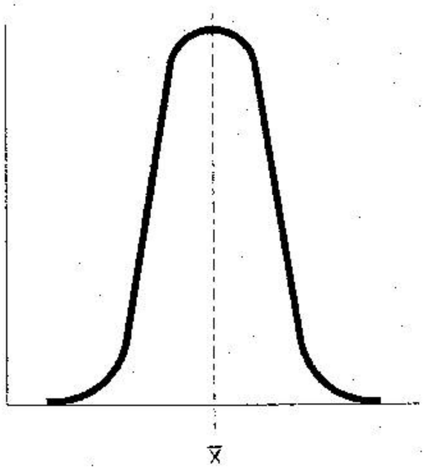


Figure D.3.

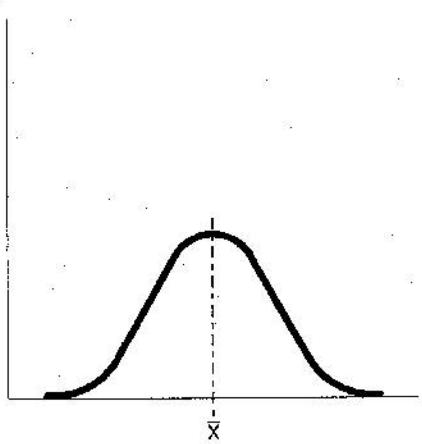


Figure D.4.

Counting Statistics

The Poisson distribution applies to discrete measurements, e.g. count or no count. Provided the average value is large enough (20 or greater), the Poisson distributions can be approximated by the Normal distribution.

Using the Normal distribution simplifies things even further. It is a continuous distribution. It is symmetrical about the average, and most important, it can be completely described by its average and standard deviation.

As shown in Figure D.5., for a normal distribution, 68.3% of all counts will be within one standard deviations, 95.5% of all counts will be within two standard deviations, and 99.7% of all counts will be within three standard deviations.

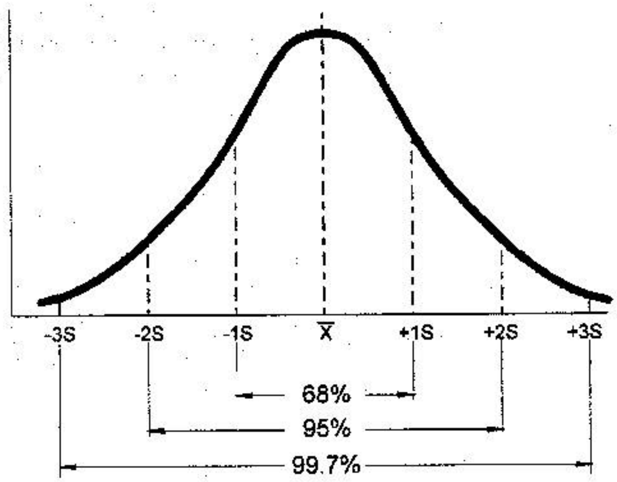


FIG. D-5

Thus, these three distribution models become identical for the case with a small individual success probability, but with a large number of trials, so that the expected average number of successes is large. this allows the use of the best features of each distribution for three statistical situations concerning the gauge:

1) Single measurement precision
2) Expected spread of measurements
3) Expected difference between two measurements

Appendix D

Counting Statistics

Single Measurement Precision

The expected variation for one standard deviation (68.3%) of a single count can be expressed as a percent error as follow:

$$\%ERROR = 100 \cdot \frac{\sqrt{x}}{x} = 100 \cdot \frac{1}{\sqrt{x}}$$

This expression reveals that the only way to improve the count precision (e.g. reduce the percent error) is to increase the size of x (e.g. the gauge manufacturer selects components for a higher count rate while gauge user counts for a longer period of time).

The following table demonstrates that a minimum of 10000 counts is required to achieve a count precision of 1.0 percent or better, 68.3% of the time.

COUNTS	SQUARE ROOT	COUNT PRECISION (68.3%)	COUNT PRECISION (95.5%)
1	1	100.0	
10	3.16	31.6	63.2
100	10	10.0	20.0
1000	31.62	3.16	6.32
10000	100	1.00	2.0
100000	316.22	.32	.63

The count precision improves with the square of the count. Thus taking four times the counts improves the count precision by a factor of two.

To provide a consistent frame of reference to the operator, the count displayed in the DR is always an equivalent 16-second count, regardless of the time base selected. It is necessary to correct a precision determination for other time base selections as follow:

$$\%ERROR = 100 \cdot \frac{1}{\sqrt{\frac{x \cdot t}{16}}}$$

Where t is the selected time in seconds.

Example:

A 64-second direct count is taken and displays 3000. The precision of the count is:

$$Precision = \frac{100}{\sqrt{\frac{3000 . 64}{16}}} = .913 \%.$$

The direct reading is 2.0 gm/cm^3. To determine the end measurement precision, it is necessary to multiply the count precision by the slope of the calibration curve. Assuming a slope of 0.0416 gm/cm^3 per percent, the 2.0 gm/cm^3 reading varies by +/- 0.038 gm/cm^3 (68% of the time representing one standard deviation).

If you take repeat measurements but move the gauge between readings, then the standard deviation of that set of readings will include both the source random variation and the variation due to re-positioning the gauge, and thus be larger.

Appendix D

Counting Statistics

Expected Spread of Measurements

An accepted quality control procedure for a random counting device is to record a series of 20 to 50 successive counts while keeping all conditions as constant as possible. By comparing the distribution of this sample of counts with the expected Normal distribution, abnormal amounts of fluctuation can be detected which could indicate malfunctioning of the gauge.

The "Chi-squared test" is a quantitative means to make this comparison. It can be used when a calculator is available to determine the standard deviation of the sample:

$$\chi^2 = \frac{(n - 1)\, s^2}{\sigma^2}$$

Where χ^2 is from the Chi-squared tables.

By substituting that the expected standard deviation is equal to the square-root of the average count ($\sigma = \sqrt{\bar{x}}$), re-arranging terms and taking the square-root of both sides:

$$\sqrt{\frac{x^2}{(n - 1)}} = \frac{s}{\sqrt{\bar{x}}}$$

Ideally the ratio on the right hand side of this expression should be 1.00. The degree to which this ratio departs from unity is indicator of the extent to which the measured standard deviation differs from the expected standard deviation.

On the left hand side of the expression, the degree to which x^2 differs from (n-1) is a corresponding allowance for the departure of the data from the predicted distribution (e.g. we flip a coin ten times and expect five heads and five tails, but accept other distributions for a given sample). Chi-squared distribution tables are found in texts on statistics. The table values depend upon the degrees of freedom (one less than the number of counts) and the probability that a sample of counts would have a larger value of x2 than in the table. The x2 values for 2.5% and 97.5% (a 95% probability range) and 31 degrees of freedom are 17.54 and 48.23. Substituting these values into the left hand side of the expression gives ratio limits between 0.75 and 1.25 for 32 samples and a 95% probability.

If the ratio on the right side is between these limits, then there is no reason to suspect the gauge is not performing properly. If the ratio is outside these limits, then the gauge is suspect and further tests are in order (even a properly working gauge will fall outside of the Chi-squared limits 5% of the time).

If a calculator is not available which can easily determine the standard deviation, a qualitative method to compare the observed standard deviation with the expected standard deviation is to take a series of 10 counts and determine their mean and the square-root of their mean (guess the square-root to 2 digits if not available on the simple calculator). If their distribution is normal, than 68.3% of the readings will be within the mean +/- the square-root of the mean (e.g. 7 out of 10).

Counting Statistics

Example:

9668
9797 H
9691
9562 L
9684
9783 H
9687
9585
9651
9599

96707 TOTAL

$$\frac{96707}{10} = 9671 \text{ AVG}$$

SQUARE ROOT = 98

AVG + SQRT = 9769

AVG - SQRT = 9573

This example has three counts outside the ± square root limits. Two are high and one is low. This is an acceptable distribution. There is no reason to suspect this gauge.

Since this test only involves a sample of 10 counts, it is not very predictable. Even a properly operating gauge will only pass this test one out of four times. If the test fails, repeat it to see if any adverse trends exist.

Appendix D

Counting Statistics

Expected difference between two readings

The standard count or some other reference count should be recorded on a regular basis to allow observing if it stays the same or if any adverse trends are present. If enough counts have been used to determine the average, and thus also the standard deviation of the population, then the Normal distribution may be used.

$$Z = \frac{\bar{x} - \mu}{\frac{\sigma}{\sqrt{n}}}$$

Expressing the $\bar{x}$ value in term of the μ value plus a factor of the deviation:

$$\bar{x} = \mu \pm k * \sigma$$

$$Z = \pm k * \sqrt{n}$$

From the Normal tables, for 95% confidence, the Z value is 1.96.

$$K = \pm \frac{Z}{\sqrt{n}} = \pm \frac{1.96}{\sqrt{1}} = \pm 1.96$$

Thus the new reading should be equal to the average of the old reading plus/minus 1.96 times the square-root of the old average.

This is true for the 16-second count which is direct. For another time base, the K term must be reduced by the square-root of the count pre-scaling (e.g. for a 64-second count which is 4 times as long as the direct 16-second count, the new reading should be plus/minus 0.98). A special case is the standard count which involves 32 each (n=32) 8-second counts. A new standard count should be equal to the old standard count plus/minus 0.49 times the square-root of the old standard count 95 percent of the time.

EXAMPLE:

The average of the daily standard count for the last month is 10,000. The square-root of this average is 100. A new standard count (32 each at 8 seconds, but displayed as 16 seconds) should be between 9,951 and 10,041 (95% probability).

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