Manual of Operation

CPN 503 TDR HydroProbe®
Moisture Gauge

FAST ACCURATE INNOVATIVE

InstroTek® Inc.

503TDR HYDROPROBE®

OPERATING MANUAL

CPN, Div. of InstroTek, Inc.

5052 Commercial Circle

Concord, CA 94520 USA

Tel: (925) 363-9770

Fax: (925) 363-9385

www.InstroTek.com

NOTE:

This Operating Manual applies only to CPN Model 503DR, software version 503TDR .6 and up.

Table of Contents

Section 1 – General Information

Production Description

The Model **CPN 503TDR HYDROPROBE®,** NEUTRON MOISTURE PROBE, measures the sub-surface moisture in soil and other materials by use of a probe containing a source of high energy neutrons and a slow (thermal) neutron detector. The probe is lowered into a pre-drilled and cased hole (1.5 or 2 inch diameter).

Hydrogen as present in the water in the soil slows the neutrons down for detections. The moisture data is displayed directly in units of interest on a surface electronic assembly which is integral to the source shield assembly.

This state-of-the-are instrument offers a simple to operate but superior alternative to other methods of soil moisture monitoring. The operator needs minimal instructions. The **CPN 503TDR** is formatted by the operator for test result storage by depth and numerical identifier.

The probe is supplied with an 8 foot cable and ten adjustable cable stops. Additional stops and longer cable lengths are available upon request.

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

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

CPN 503TDR Features

The **CPN 503TDR** Direct Readout Model Provides:

- Integral microprocessor for simple function selection.
- Rapid, precise repeatable soil moisture measurements.
- Light weight and portable.
- Field service and component exchange with tools provided.
- Storage and recall selection of linear calibrations for 16 soil or tubing types.
- Operator selected time of test, logging format and units of measurements.
- Data transfer to a computer or printer via RS232C interface or USB port using conversion cable.

Functional Description

The **CPN 503TDR HYDROPROBE®** operates by emitting radiation from an encapsulated radioactive source, Americium-241:Beryllium. 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 colliding with hydrogen atoms in the moisture of the soil. Only low-energy, moderated neutrons are detected by the Helium-3detector. 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.

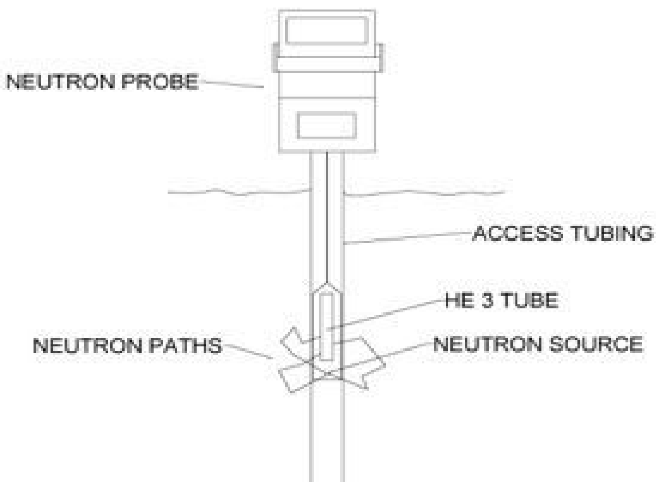


Figure 1.1 Operation of the 503TDR HYDROPROBE®

Standard Equipment

Each 503TDR is provided with a durable plastic shipping case and the items shown listed below. There are no special instructions for unpacking the 503TDR Hydroprobe ®. It comes fully assembled.

Item	**Part Number**
503TDR Hydroprobe ®	503515
Padlock with Keys	700472
Shipping Case	501359
8 ft. (2.44 meter) Cable	501144
10 Cable Stops	501122
Access Collar (1.5 in.)	500312
Battery Pack	704767
Operating Manual	N/A
Leak Test Certificate	N/A

Specifications

Dimensions/Shipping Weights

Model	Weight	Length	Width	Height
CPN 503DR (gauge only)	15.7 lb/7.12kg	7.0 in/178 mm	6.8 in/173 mm	14 in /356 mm
CPN 503DR (with carrying case)	36.5 lb/16.6 kg	13 in/330 mm	24 in/610 mm	10 in/254 mm

Probe	Weight	Length	Diameter
Model 2.0	2.3 lb/1.04 kg	12.7 in/323 mm	1.86 in/47.4 mm
Model 1.5	1.7 lb/0.77 kg	12.7 in/323 mm	1.5 in/38.1 mm

Performance

Function	Sub-surface moisture measurements.
Range	Linear calibration: 0 to 40% per volume, 0.40 g/cc, 25 pcf, 4.8 in/ft.
Precision	0.24% at 24% per volume at one minute.
Count Time	User selectable from 1 to 960 seconds.
Display	8 character alpha/numerical Liquid Crystal Display. Easily readable in direct sunlight.
Data Storage	24576 bytes of storage memory. Format operator programmable. From 0 – 99 key data and 0 – 99 counts per record.
Data Output	RS232C serial download to external printer or personal computer.
Calibration	16 user programmed (linear).
Units	User selectable: in/ft, pcf, g/cc, % vol, cm/30cm, count and count ratio. (cnt, rat, gcc, pcf, ipf, cpc, and %v)
Construction	Aluminum with epoxy paint or hard-anodize finish. Stainless steel wear parts.

Specifications

Electrical

Power	C Size Alkaline Battery Pack (7 Ah) 6 cells.
Battery Life	1 Year Approximately
Consumption	6.5 mA Average (allows more than 3000 each 16 second counts).

Environmental

Operating Temperature	Ambient: 32º to 150º F (0º to 66º C)
Storage Temperature	-4º to 140º F (-20º to 60º C)
Humidity (Non-Condensing)	95%

Radiological

Neutron Source	1.85 GBq (50 mCi) Americium-241:Beryllium
Encapsulation	Double-sealed capsule CPN-131
Shielding	Silicon-Based Paraffin.
Shipping Requirements	UN3332, Radioactive Material Type A Package, Special form 7 Transport index 0.2 Yellow II label, RQ
Special Form Approval	USA/0627/S or CZ/1009/S

An NRC or agreement state license is required for domestic use. Contact CPN - InstroTek for assistance in obtaining training for a license.

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

CPN 503TDR HYDROPROBE® Inspection

To familiarize yourself with the **CPN 503TDR HYDROPROBE®,** perform the following review.

1. Remove the **HYDROPROBE®** 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 shield box.

> **NOTE**
>
> The radioactive source is 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 503DR HYDROPROBE®**

3. Cable Stops

The gauge is supplied with ten 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 6 inches, place the stop at 5.35 + 5.0 + 6.0 =16.35 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 CPN –InstroTek, Inc. or can be constructed locally.

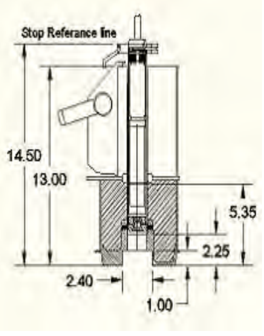


Figure 1.4. **503DR** Cross Section.

CPN 503TDR HYRROPROBE® Getting Started

The stand-by power drain of the gauge is less that the self-discharge of the alkaline cells thus eliminating the need for a power switch. The **CPN 503TDR** is always **"ON"**, but has an internal function that automatically, after 30 seconds of no operation, switched it to stand-by mode (the display will be blank) to save battery power. To turn the **CPN 503TDR** on again, press any key and the display will show the last function that was executing before it went into the standby mode.

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:

UNITS	Inches per foot.
TIME	1 second.
CALIB	CAL #0 Factory calibration in saturated and dry sand. Coefficient A (slope) approx. 2.5 in/ft per count ration and Coefficient B (intercept) approx. –0.06 in/ft.
STD	Standard count approx. 10000.
FMT	1 Keydata and 3 Depths.

With the gauge sitting on the top of the shipping case, press **START**. The gauge should take a one second count and display the equivalent moisture of the wax in the shield. It should be approximately 2.4 inches per foot.

Most of the commands are **READ/STEP/WRITE**. That is, when first called up, you read the display to see the current 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**
CLEAR	READY
TIME	TIME 1 (Read the current value)
16	TIME 16
ENTER	READY (Write it to memory)

Do the same for Units, changing from Inches per foot to % Volume.

PRESS	DISPLAY
CLEAR	READY
UNITS	UNIT ipf
STEP	UNIT cpc
STEP	UNIT %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 20.0% moisture by volume (which is equivalent to 2.4 inches per foot in the reading above).

Section 2 - Operation

Controls and Display

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

Key	Function
D-WET	Display latest wet density reading (501 only).
D-DRY	Display latest dry density reading (501 only).
WATER	Display latest moisture reading.
UNITS	Select display units (cnt, rat, gcc, pcf, ipf, cpc, %v)
TIME	Select counting time (1 to 960) seconds.
CALIB	Select calibration (0…15) and optionally:
MCOEFS	Enter coefficients directly.
MSLFCAL	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, with handshaking).
PRINT LP	Dump to a passive device (Line Printer).
PRINT NF	Dump to an active device (Computer Device, no handshaking).
MENU	Select miscellaneous function:
BAUDRATE	Select baud rate (11, 300, 1200, 2400, 4800, 9600).
SERIAL #	Display/Enter a four-digit serial number.
VERSION	Display software version.
CLOCK	Set the real time clock.
CYCLE	Put the gauge in cycling mode.
FACTOR	Selects counts/min. or counts per 16 seconds format
RECOVER	Recovers the data from memory
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"

Display	Function
"READY"	Gauge is ready for operation.
"BAT xx%"	Indicates Battery Life Remaining in %.

Keyboard Functions

Figure 2.1 CPN 503 TDR HydroProbe Keyboard

D-WET (CPN 501DR ONLY)

Displays wet density using currently selected calibration and units (On a **CPN 503DR** returns to "READY")

D-DRY (CPN 501DR ONLY)

Displays dry density using currently selected calibration and units (On a **CPN 503DR** returns to "READY")

WATER

Displays the most recent moisture reading in current units using current calibration (e.g. "M23.4").

UNITS

Display / Select display unit. Displays current unit (e.g. "UNIT 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
cnt	counts/unit-time (per 16 sec. Or per minute)	N/A
rat	ratio (count/stdcount)	N/A
pcf	lbs of water/cubic foot of soil	62.428
gcc	gms of water/cubic cm of soil	1.0
ipf	inches of water/ft of soil	12.0
cpc	cm of water/30 cm of soil	30.0
%v	percent water by volume	100.0

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.

Keyboard Functions

CALIB

Display/Select calibration (0 through 15 and/or review/change its coefficients).

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 SELFCAL** is to be used to take a count, select a time of 240 seconds for maximum precision.

To Select A Calibration

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

To Enter/Change Coefficients When The Coefficients Are Known

Select the calibration number as above. When **"COEFFS?"** is displayed, press **"ENTER"**. It will display the units that are selected and then it will show the date of the calibration (e.g. D021196 which is February 11, 1996). 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 "SELFCAL?" 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 **"COEFFS?"** and then press **ENTER.**

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**, the calibration number being used, the date and time of the logging, 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. Press **STEP** to switch to alpha mode and use characters from A to F for **ID**. 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.

Keyboard Functions

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.**

Moisture fields are stored the same, except that value is from a count initiated by pressing **START**. It may be retaken, but will only be stored and advanced to the next field when you press **ENTER.**

A record is not stored in the log until the prompt "**DATE 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 **key data** or moisture value, press **ENTER** or **STEP.** To change the data, write over the key data field followed by **ENTER**. Use the **STEP** key to move across the fields of the record (like a window moving across a tickertape).

RCL

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

To quit the current record and review another one or exit, press **CLEAR** once to return to **"REC xxxx"** and continue as above.

PRINT

Dumps record log to external device via the serial connector. Press **STEP** to select another print option.

PRINT CD

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.

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.

PRINT NF

Output formatted to upload record log to a computer directly or via modem. It has the same format as

PRINT CD but doesn't include the checksum for each line neither uses **ACK, NACK** software Protocol to control transmission.

Keyboard Functions

MENU

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

BAUDRATE

Allows setting the baud rate for transmission on the serial connector. When first selected, displays the baud rate currently selected. Use the **STEP** key to step to a new rate, and press **ENTER**. You must press ENTER to change or accept the new rate.

SERIAL#

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/probeto another.

VERSION

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

CLOCK

Allows setting the real time clock. The clock is 24 hours base. To set the date to 10/25/06 and the Time to 15:32 press **MENU, STEP, STEP, STEP** and **ENTER**. The month is first displayed, **MONTH** 10, key in the new month or press **ENTER** to accept, then displays the **DAY 25**, the **YEAR 06**, the **HOUR 15** and **MIN. 32.** Follow the same procedure as in the month to edit the new values. If the battery pack is replaced for any reason, the gauge will show "SET CLOCK" as the first screen indicating that the real time clock must be set.

CYCLE

This function has use only in factory, and allows to put the gauge in cycling mode for burn-in purposes.

FACTOR

This function selects either a counts per 16 second format for display (**FACTOR 16)** like the older 503-Drs, or a counts per minute format (**FCTR 60)**.

RECOVER

If for any reason the data in memory is lost, this function could be used to try to recover that data. Before is used, is necessary to **FORMAT** the gauge to the **KEYS** and **DEPTH** that had before the data was lost, then pressing **RECOVER** will ask for the number of records that were in memory "**REC**"___", if the exact value is not known, make a guess and then use the **RECALL** function to see the data.

Keyboard Functions

STD

Displays standard count information and/or take a new standard count. Initially displays the current moisture standard count (S). Pressing **ENTER** at this moment allows the **STD** value to be edited using the keyboard, key in the new **STD** value and then **ENTER** to accept it or press **STEP** to display previous moisture standard count (P). **STEP** again to display the chi-square ratio of the current standard (**CHI**).

To take a new standard count, press **ENTER** after "**NEW STD?"** is showed in the screen. The **DR** will take 240 seconds (4 minutes) count. When the count finishes, a **NEW** standard count is stored in memory.

To view the **CURRENT** standard count (identified as previous at this point) press **STD** again, **STEP** to see the previous and **STEP** again to see the **NEW** chi-square ratio. If the difference between the new and current standard counts and the value of the new chi-square ratio are not acceptable, take another **STD** count and repeat the process.

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 actual key data, key in the desired number of key data entries (0 through 99) and press **ENTER.** Do the same for depths (0 through 99). Then the gauge will show the maximum number of possible records to be logged in the current format (e.g. "**REC 279"**). Press **ENTER** and 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 downloaded 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.

Operating Procedures

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.

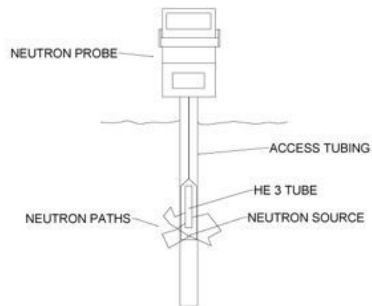


Figure 2.2 Taking a Measurement

How to Select UNITS

The choice of display units will depend upon your use. Researchers will normally prefer grams per cubic centimeter or percent volume, while irrigation schedulers use inches per foot or centimeter per 30 centimeters. Counts are used for downloading to a software program and are helpful for troubleshooting. It is the same data, only differing by the conversion factor.

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 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 specific precision.

For scheduling-type operation, a count time of 16 seconds will provide sufficient precision to project the next irrigation date.

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 slope (A) and intercept (B) coefficients stored 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 downloaded 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 key data entries and/or 0 to 99 tube depths (counts per tube). The gauge always provides for an identifier (**ID**) for each record, stores the selected calibration number (0-15), the date and the time of the logging.

The total memory space available is 24576 bytes. The number of bytes required in a recordfor each tube is as follows:

FIELDS	**BYTES**
ID	6
CALIBRATION	2
DATE	4
HOUR	2
KEYDATA	2
DEPTH (count)	2

Thus a typical site record format of one **ID**, one calibration number, the date, the hour, one keydata, and three depths (counts), takes 22 bytes per record, and allows 1117 records to be stored.

After the number of depths is entered, the gauge will display the maximum number of records with that configuration, then will show “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.

Operating Procedures

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 of 5 digits or press **STEP** and key in alphanumeric A to F or any combination e.g. "**ID A21B1**", press **ENTER** to accept it. 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 99 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.

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.

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 on the **"READY"** display.

After accepting the data the gauge will prompt for the next keydata, or if all keydata are entered, it will prompt for a moisture reading by displaying "**TAKE** ##" ("##" 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. "3M 2.6538"). 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.

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 record store. Either use the **STEP** key to step up the record list (it steps back through the list and circles around at the beginning), or key in a specific record number and press **ENTER**. Use the **STEP** key to move across the record.

Standard Count

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
2. acceptable amount, it is an indication of acceptable drift of the electronics. Americium-41/Beryllium has a half-life distribution is normal, it is a means of checking that noise is not influencing the count.
3. 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 **503DR** 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 **503DR** is working properly. It is recommended that a new standard be taken daily to check "Xi" and changes in counts. The Xi ration should be between 0.75 and standard counts should be smaller than the square root of the average count (1 standard deviation). This will verify the performance of the 503DR 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 a 240 seconds count. When the count is completed, the NEW standard count is displayed (e.g. "S 7405").

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").

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 printed via the serial link, individual counts and summary information will be printed out.

Standard Count Statistics

Taking such a series of 240 1-second 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 the 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 240 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 bsorbed 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 agricultural 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.

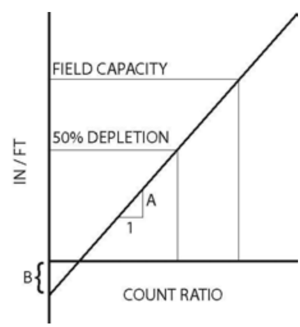
Field Calibration

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.



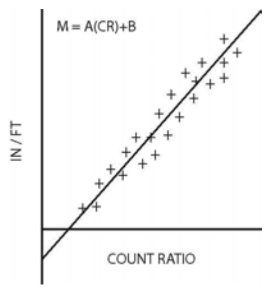
Weigh the soil samples wet and dry (24 hrs at 105º C in a vented oven). Calculate the moisture by weight and the dry soil density, and then combine to determine the soil moisture content in inches per foot as follows:

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

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

Calibration

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.



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

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

$$Then{:}\ m = (A \times r) + B$$

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 ration at the high moisture value
RL = probe count ration 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

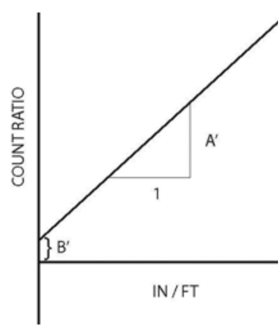
$$A = \frac{3.8 - 1.90}{1.5 - 0.77} = 2.603 \text{ in / ft / count ratio}$$

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

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. This is how the factory calibration is determined. It will be applicable for sandy soils with no significant organics.

Set the gauge to the desired units and select a 240 seconds (4 minutes) 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 content 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.

By pressing **START** the gauge will take and store a 240 seconds reading. When the count is completed, move the probe to the second moisture standard. The display will prompt for the moisture content of that standard. Press **START** to take a 240 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.

Range

The linear calibration supplied with the **DR** is useful over the most commonly used moisture range, 0 to 40%. For use in moisture contents higher than this, it is necessary to have a special calibration that covers the intended range of use.

Section 3 – Maintenance

General

This section supplies basic information to perform maintenance on a field level basic. 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 503TDR** 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.

Leak Testing

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

1. Use a Leak Test Kit to perform this required test for leakage of the source material from its capsule.
2. Tip the shielding box on its side, away from the operator. Leave the probe latched in the shielded position.
3. Use the cotton swab in the kit and swab the circular radioactive material label on the end of the probe for any removable traces of the Am-241:Be source material.
4. Break swab stick in half and place in plastic envelop. Complete form and staple envelope to it; mail to address on the kit. Within approximately two weeks you will receive notification of results.

Figure 3.1 Leak Test Procedure

Surface Electronic Assembly Maintenance

The Surface Electronic Assembly consists of:

1) Surface PC-Assembly
2) Battery Pack (6 C-type alkaline batteries)
3) Display PC-Assembly
4) Cable Connector

Field maintenance of this unit will normally be limited to replacing the battery pack.

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.

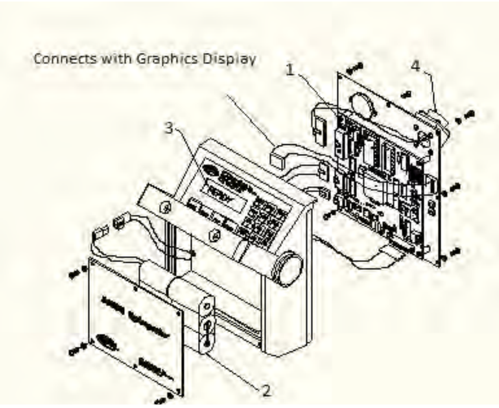


Figure 3.2 Surface Electronic Assembly

Probe Assembly Maintenance

The probe Assembly consists of:

1) Source Tube Assembly
2) Probe Electronic Assembly

Removal

The Probe Electronic Assembly is easily removed from the Source Tube Assembly. As shown in Figure 3.4, 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.

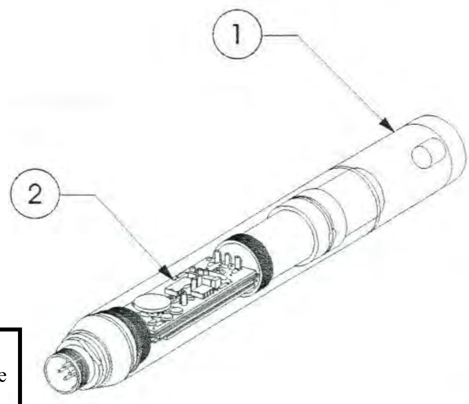


Figure 3.3. Probe Assembly

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 3.4.

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.

Appendix A

Operation Cautions

1. To protect the gauge against damage from water, check the access tube for water before lowering the probe.

2. Do not use sharp objects to actuate the keyboard. It consists of stainless steel snap domes covered by a polycarbonate overlay and can be damaged by sharp objects.

3. Use a dummy probe to verify tube clearance.

Error Messages

If an error occurs in the **CPN 503TDR,** 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.
REC FULL	Record log full, PRINT out record log, and clear via FORMAT.
NO DATA!	Record log empty when PRINT or RCL pressed.
CNT ZERO	There were no counts, probably due to bad detectors.
SET UNIT	Calibration coefficients undefined for CNT or RAT unit. Change UNIT.
CALC ERR	Gauge cannot calculate moisture, check the standard count value.
Batt Low	The batteries have been depleted. Change the battery pack.
SET CLCK	When a new battery pack is installed, this warning indicates to set the real time clock.

Appendix B

Troubleshooting Guide

Overall Operation

CONDITION	POSSIBLE CAUSE
Keypad does not respond	Press and release the RESET button on the lower front of the gauge. The battery pack may be dead.
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 calibrated.

Counting

CONDITION	POSSIBLE CAUSE
Display reads "CNT ZERO", with or without a 6 kHz hum can be heard	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

CONDITION	POSSIBLE CAUSE
Moisture reads high compared with other methods (2^{nd} 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 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, RSD, GND)
- I start bit, 8 data bits, no parity, and 2 stop bits.
- Baud rate: 110, 300, 1200, 2400, 4800, 960
- 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.

Using the PRINT key outputs the contents of the record log to an external device (computer, modem, printer, etc.) via the RS232C or USB interface connector. The RESET Pushbutton (to the left of the serial RS-232 connector on the 503-DR) can be used if the communications link with the computer gets hung up. You will hear 3 beeps when the Reset Pushbutton is pressed and then the display will show "READY" – the data will not be lost. All logged data resides in non-volatile EEPROM memory.

Three 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. 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.

PRINT NF – for dump to an active device such as a computer (or computer via modem). It is the same format as in PRINT CD but each line doesn't include the check sum, and doesn't require a software response from the computer to transmit the data.

PRINT CD

A simple software ACKNOWLEDGE/NEGATIVE-ACKNOWLEDGE handshaking scheme (ACK/ALT-6, NACK/ALT-21) 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 internal processor be up during the dump. This places a heavy drain on the battery; *therefore, only leave the serial cable plugged into the 503-DR when you are actually downloading data to the PC.*

```
20,503TDR,1,1234,gcc,12345,2,2,1745
19,0,10,05,95,0.372,0.004,1174
18,1,10,05,95,0.000,0.000,1158
17,2,10,06,95,2.320,0.120,1169
16,3,10,05,95,0.000,0.000,1158
15,4,10,05,95,0.000,0.000,1158
14,5,10,05,95,0.000,0.000,1158
13,6,10,05,95,0.000,0.000,1158
12,7,10,05,95,0.000,0.000,1158
11,8,10,05,95,0.000,0.000,1158
10,9,10,05,95,0.000,0.000,1158
9,10,10,05,95,0.000,0.000,1158
8,11,10,05,95,0.000,0.000,1158
7,12,10,05,95,0.000,0.000,1158
6,13,10,05,95,0.000,0.000,1158
5,14,10,05,95,0.000,0.000,1158
4,15,10,05,95,0.000,0.000,1158
3,1117,1117,0,10,05,95,15,53,1,2,1.001,0.004,2038
2,1116,AB123,0,10,05,95,15,54,3,4,1.007,1.007,2130
1,1115,CD789,0,10,05,95,15,54,7,8,1.007,0.004,2154
```

Figure C.1 CD Format Printout

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 the 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 and 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.

```
CPN –INSTROTEK    503DR Hydroprobe                Page 1
                  Moisture Depth Gauge

MODEL    SERIAL   STD    *KEYDATAS  #DEPTHS  UNITS
+-----------+-------------+--------+-----------------+--------------+--------
+
503TDR.1   1234   12345      2          2      gcc

  CAL     DATE      COEFF A     COEFF B
+-------+--------------+-----------------+---------------+
   15   10/05/05     0.000       0.000
   14   10/05/05     0.000       0.000
   13   10/05/05     0.000       0.000
   12   10/05/05     0.000       0.000
   11   10/05/05     0.000       0.000
   10   10/05/05     0.000       0.000
    9   10/05/05     0.000       0.000
    8   10/05/05     0.000       0.000
    7   10/05/05     0.000       0.000
    6   10/05/05     0.000       0.000
    5   10/05/05     0.000       0.000
    4   10/05/05     0.000       0.000
    3   10/05/05     0.000       0.000
    2   10/06/05     2.320       0.120
    1   10/05/05     0.000       0.000
    0   10/05/05     0.372       0.004

   REC    ID   CAL   DATE    HOUR  K1   K2   D2     D1
+------+----------+----+------------+-------+-----+-----+-------+--------+
  1117  1117    0  10/05/05  15:53  1    2  1.001  0.004
  1116  AB123   0  10/05/05  15:54  3    4  1.007  1.007
  1115  CD789   0  10/05/05  15:54  7    8  1.007  0.004
```

Figure C.2 LP Format Printout

PRINT NF

A dump to a printer or a terminal, contains the same information as the **PRINT CD** dump except that there are no checksums. A file image of a **PRINT NF** dump is shown. Note that all data fields are separated by commas and the alphanumeric data is quoted, allowing easy import of the file to a spreadsheet or database program.

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

White PRINT CD is preferred because of its handshaking and checking for transmission errors, PRINT NF can be used to make a passive data transfer to a computer and obtain the same data file to import to the spreadsheet program.

```
20,”503TDR,1”,1234,”gcc”,12345,2,2
19,0,10,05,95,0.372,0.004
18,1,10,05,95,0.000,0.000
17,2,10,06,95,2.320,0.120
16,3,10,05,95,0.000,0.000
15,4,10,05,95,0.000,0.000
14,5,10,05,95,0.000,0.000
13,6,10,05,95,0.000,0.000
12,7,10,05,95,0.000,0.000
11,8,10,05,95,0.000,0.000
10,9,10,05,95,0.000,0.000
9,10,10,05,95,0.000,0.000
8,11,10,05,95,0.000,0.000
7,12,10,05,95,0.000,0.000
6,13,10,05,95,0.000,0.000
5,14,10,05,95,0.000,0.000
4,15,10,05,95,0.000,0.000
3,1117,”1117”,0,10,05,95,15,53,1,2,1.001,0.004,
2,1116,”AB123”,0,10,05,95,15,54,3,4,1.007,1.007,
1,1115,”CD789”,0,10,05,95,15,54,7,8.1.007,0.004,
```

Figure C.3 NF Format Printout

DR Dump Software

This is optional software supplied by CPN -InstroTek on a CDROM and is sold separately. The Windows program is included on a disk and intended to be used with all versions of **CPN’s 503TDR/501DR** nuclear gauges. Instructions are included on the CD.

The program establishes a link to the **CPN 503TDR/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 **CPN 503DR/501DR** 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 program will only work with the PRINT CD format.

Appendix D

Remote Operation

The 503DR may be operated remotely via the RS232C serial connector. Set the 503DR and the external device to the same baud rate and the terminal in no echo mode. If the 503DR is in the command mode ("READY" is shown on the display) then the appropriate remote control from the following table will activate the DR.

Input Character	503DR key	Action
m	MENU	Activates MENU command
s	STD	Activates STD command
f	FMT	Activates FORMAT command
l	LOG	Activates LOG command
r	RCL	Activates RECAL command
p	PRINT	Activates PRINT command
u	UNITS	Activates UNIT command
t	TIME	Activates TIME command
c	CALIB	Activates CALIBRATION command
h	WATER	Activates WATER command
g	START	Activates START command
z	STEP	Activates STEP command
ESC	CLEAR	Activates CLEAR command
ENTER	ENTER	Activates ENTER command
Ctrl R		Enable terminal mode
Ctrl T		Disable terminal mode

These commands can be used to control the 503TDR from a CRT terminal or a special program can be written to control the TDR from a computer.

Control R is a special command that places the TDR in the remote terminal mode. While in the remote terminal mode all the information which appears on the TDR display will also be sent on the serial output mode line where it can be received by the control device. The TDR will stay in this mode for 60 seconds after the last command.

The remote terminal mode is disabled by pressing Control T, the Reset button or when the 503TDR goes to sleep.

Appendix E

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 E.1.

Fig. E.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:

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

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 = *true average of the population*
σ = *true 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

Figure E.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).

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.

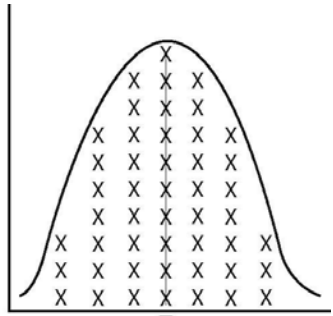


Figure E.2

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

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 E.3 shows the diameter of a part turned on a new lathe while Figure E.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.

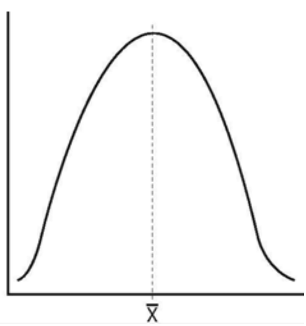


Figure E.3

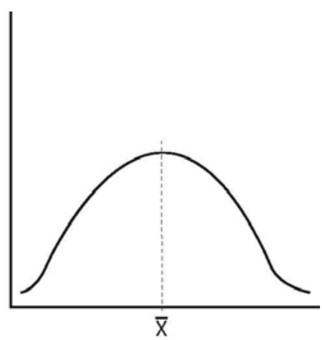


Figure E.4

The Poisson distribution to discrete measurements, e.g. count or not 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 E.5., for a normal distribution, 68.3% of all counts will be within one standard deviation, 95.5% of all counts will be within two standard deviations, and 99.7% of all counts will be within three standard deviations.

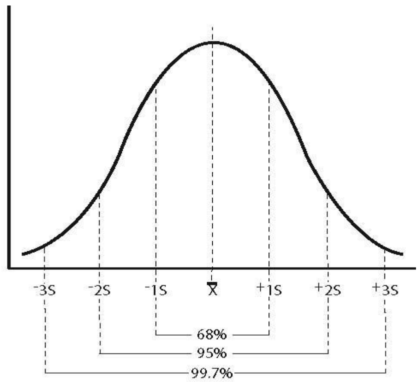


Figure E.5

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.

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:

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

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 rte while gauge user counts for a longer period of time).

The following table demonstrates that a minimum of 10000 counts of readings 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 to 60-seconds count or CPM (counts per minute), regardless of the time base selected. It is necessary to correct a precision determination for other time base selections as follow:

$$\%ERROR = 100 \bullet \frac{1}{\sqrt{\frac{x \bullet t}{60}}}$$

Where t is the selected time in seconds.

Example:

A 60-second direct count is taken and displays 3000. The precision of the count is:

$$Precision = \frac{100}{\sqrt{\frac{3000.60}{60}}} = 1.82\%$$

The direct reading is 2.0 gm/cm³. To determine the end measurement precision, it is a necessary to multiply the count precision by the slope of the calibration curve. Assuming a slope of 0.0416 gm/cm³ per percent, the 2.0 gm/cm³ reading varies by +/- 0.076 gm/cm³ (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.

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 distributions, 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 the expected standard deviation with the square-root of the average count $\left(\sigma = \sqrt{x}\right)$; re-arranging terms and taking the square-root of both sides, we obtain:

$$\sqrt{\frac{\chi^2}{n-1}} = \frac{s}{\sqrt{x}}$$

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 χ^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 χ^2 than in the table. The χ^2 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 ration 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, then 68.3% of the readings will be within the mean +/- the square-root of the mean (e.g. 7out of 10).

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 them 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.

$$K = \pm\frac{Z}{\sqrt{n}} = \pm\frac{.196}{\sqrt{1}} = \pm 1.96$$

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 60-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 240-second count which is 4 times as long as the direct 60-second count, the new reading should be plus/minus 0.98):

$$K = \pm\frac{Z}{\sqrt{n}} = \pm\frac{1.96}{\sqrt{4}} = \pm 0.98$$

This is the case when the standard count is taken which involves 240 each (n=240/60=4) 1-second counts. A new standard count should be equal to the old standard count plus/minus 0.98 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 (240 each at 1 seconds, but displayed as 60 seconds, CPM) should be between 9,902 and 10,098 with a 95% of probability.

Appendix F

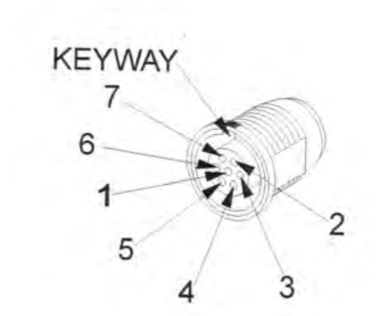
Connectors Pinouts

The pinout of the MOLEX connector in the rear panel of the gauge is as follows:

Pin number	Function
A	Power + 10Vdc
B	Not used
C	Ground
D	Detector Signal

The pinout of the LEMO connector in the lower from of the gauge is:

Pin number	Function
1	DSR
2	Ground
3	TXD
4	RXD
5	ENABLE
6	ENABLE GND
7	CTS



Index

SETTING NEW STANDARDS

At InstroTek, we specialize in the fusion of product innovation with exemplary service. Our customers are our first priority. That's why we work hard to identify and solve industry problems by creating new, exciting product solutions that are accurate, practical, and cost-effective for you. Contact our staff of highly qualified professionals today, and experience business the InstroTek way.

Our mission is to lead our industry through innovative instrumentation, exemplary customer service, and an infrastructure of proud, dedicated employees.

InstroTek®, Inc., 5908 Triangle Drive, Raleigh, NC 27617 • phone 919.875.8371 • fax: 919.875.8328
sales@instrotek.com • www.InstroTek.com

Headquarters/East Coast

5908 Triangle Drive, Raleigh, NC 27617

919.875.8371

Central US

4495 44th St. SE Suite A, Grand Rapids, MI 49512

616.726.5850

West Coast

Southern Area

6625 S. Valley View Blvd. Suite. 400, Las Vegas, NV 89118

702.270.3885

Northern Area

5052 Commercial Circle, Concord, CA 94520

925.363.9770