AN INSTROTEK® COMPANY

CPN 503 ELITE HYDROPROBE™

OPERATING MANUAL

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OPERATING MANUAL

w/ Expanded Keypad

CPN International
An InstroTek Company

www.InstroTek.com

NOTE:

This Operating Manual applies only to
CPN 503 Elite software.

Table of Contents

Section 1 – General Information

Congratulations on the purchase of your new CPN 503 Elite soil moisture gauge. The Model **CPN 503** Elite **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).

The source used in this gauge emits fast neutrons. Fast neutrons from the source interact with Hydrogen in water and thermalize (slow down) neutrons. The thermal or slow neutrons are then counted by the He3 tube. Increase in water content results in a proportional increase in thermal neutron counts detected by the tube. The moisture data is displayed directly in units of interest on the electronic assembly which is connected to the source shield assembly.

This state-of-the-art instrument offers a simple to operate but superior alternative to other methods of soil moisture monitoring. The operator needs minimal instructions.

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 latches automatically in place for transportation and may be locked with a pad lock if necessary.

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 503 Elite Features

The **CPN 503 Elite** 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 32 soil or tubing types.
- Operator selected time of test, logging format and units of measurements.
- Data transferred serially to a PC via a USB port using a USB 2.0 A-male to B-male cable.
- Data downloaded to a USB mass storage device (Thumb Drive).

Functional Description

The **CPN 503 Elite 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 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.

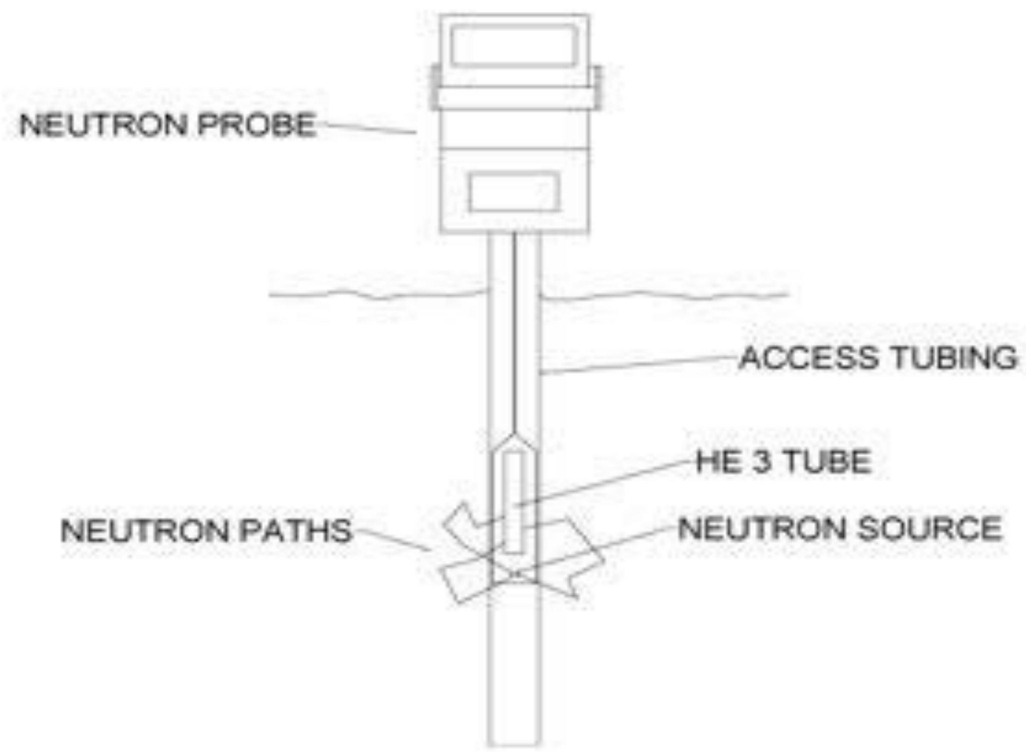


Figure 1.1 Operation of the 503 Elite HYDROPROBE®

Standard Equipment

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

503 Elite Hydroprobe ®
Padlock with Keys
Shipping Case
8 ft. (2.44 meter) Cable
10 Cable Stops
Access Collar (1.5")
Battery Pack (Installed)
Operating Manual
Leak Test Certificate

Figure 1.2 Standard Equipment

Specifications

Dimensions/Shipping Weights:

Model	Weight	Length	Width	Height
Gauge Only	15.7lbs (7.12kg)	7.0" (178mm)	6.8" (173mm)	14" (356mm)
Gauge & Carry Case	36.5lbs (16.6kg)	13.0" (330mm)	24.0" (610mm)	10.0" (254mm)

Probe	Weight	Length	Diameter
Model 2.0	2.3lbs (1.04kg)	12.7" (323mm)	1.86" (47.4mm)
Model 1.5	1.7lbs (0.77kg)	12.7" (323mm)	1.50" (38.1mm)

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

Count Pre scale………………………………..…………… 3.75 for 1 min, 15 for 4 min

Display... 4 lines x 20 character Liquid Crystal Display

Data

Storage .... 2 GB of storage

Format .... Operator programmable

Notes .... 0-99 notes of 19 characters each

Counts ....0-99 counts per record

Data Output ....USB A-B Male Cable download to personal computer

Calibration ....32 user programmed (linear)

Units .... in/ft, pcf, g/cc, %Moist, cm/30cm

Construction

Body:..Aluminum with epoxy paint & hard-anodize finish

Wear Parts:..Stainless Steel

Specifications

Electrical

Power

Lithium .... Li-Ion 7.4V 4400mAh Battery Pack

Battery Life .... Approximately 2 years

Consumption .... 6.5 mA Average

Environmental

Operating Temperature

Ambient .... 32° to 150° F (0° to 66° C)

Storage .... -4° to 140° F (-20° to 60° C)

Humidity (Non-Condensing) 95%

Radiological

Neutron Source .... Maximum 1.85 GBq (50 mCi) Americium-241:Beryllium

Encapsulation .... Double-sealed capsule CPN-131

Shielding .... Silicon-Based Paraffin

Shipping Requirements:

USA DOT 7A Type A
Radioactive Material
Type A Package
Special Form
UN 3332 RQ
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 503 Elite HYDROPROBE® Inspection

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

1. Remove the **HYDROPROBE®** from the shipping case and place it on a solid flat surface, such as a concrete floor.
2. Examine the keyboard, the display screen, the cable, probe, and shield box.

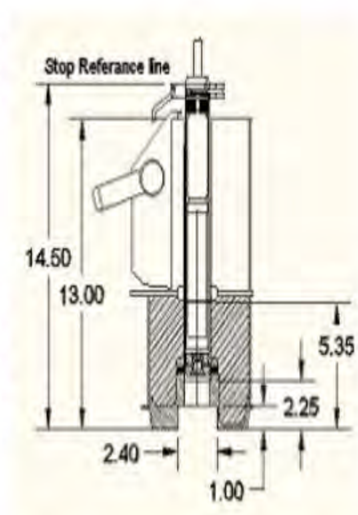
> **NOTE**
>
> The radioactive source is located at the bottom part of the probe.
> **Do not touch** this part of the probe or place yourself in front of it.

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 half 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

Section 2 – Getting Started

The **CPN 503** Elite includes an updated keypad interface with menu related function keys.

	Function
Start/Enter	Take a reading and select from drop down menu functions
On/Off	Power on/off function
No	Function key for software/menu requests
Yes	Function key for software/menu requests
Store	Store Data and settings to an internal SD card
Time	Enter count time for the length of a reading
Esc	Escape key used to return to main menu or previous screen
Yes	Function key for software/menu requests.
STD	Select Standard Count menu
Menu	14 Item gauge control functions
Arrow Keys	Navigate through the menus
Numeric Keys	Expanded Keypad aids in project and data entry

The operator must set the probe 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.

The initial setting may be accessed by pushing **MENU or (Front Panel Key)**

8-UNITS	**3**-Inches per foot.
(TIME)	15 second.
14CALIB	CAL #0 Factory calibration in saturated and dry sand.
	Coefficient A (slope) approx. 2.5 in/ft. and
	Coefficient B (intercept) approx. –0.06 in/ft.
(STD)	Standard count approx. 4000

With the gauge sitting on the top of the shipping case, **press STD** the gauge will prompt you to take a new Standard Count; press YES. The count lasts 256 seconds and should be taken once a day.

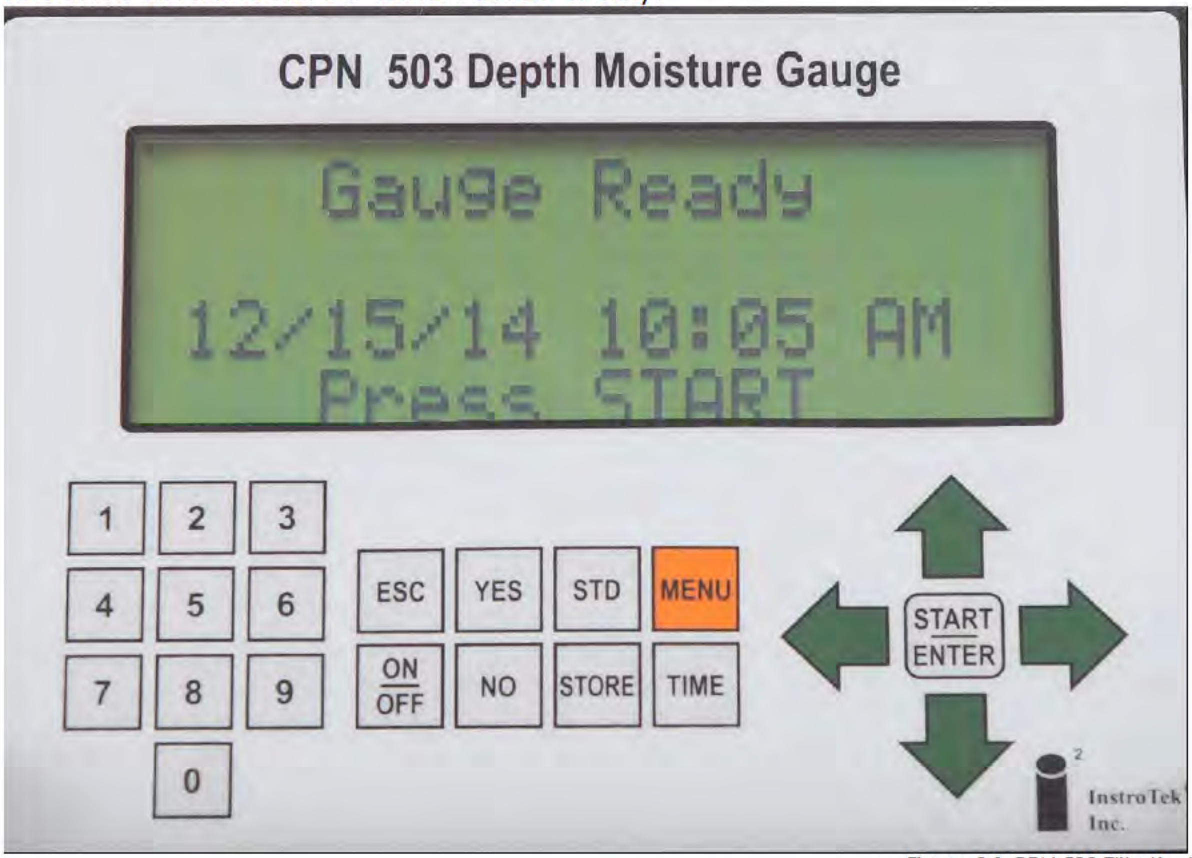


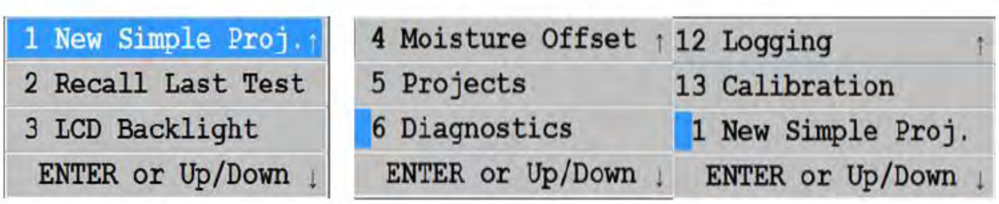
Figure 2.1 CPN 503 Elite Keyboard

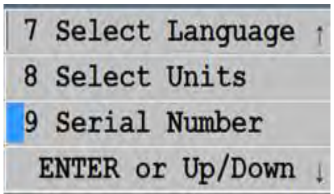
To change from Inches/foot to %Moisture:

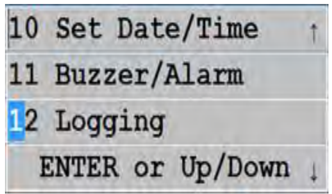
- PRESS MENU – use Arrow keys to navigate to Item 8- Select Units
- PRESS ENTER - use Arrow keys to navigate to Item 5- % Moist
- PRESS ENTER
- PRESS ESC

Take another count by pressing **START.** The measured result should be the same as above except that the count should take 15 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).

Keyboard MENU Controls and Display







Most functions are directly entered by pressing **MENU.** Options are chosen by the arrow keys and selected with **ENTER**. Test Results are viewed by using the **up/down arrows** after pushing **START**.

Menu	**Function**
MC	Moisture Count: Raw gauge counts/unit time
R	Ratio: MC/Standard Count= Ratio
Units (7)	Select Units
%Moist	Water content (vol. %) = a * count ratio + b
g/cc	grams of water/ cubic cm of soil
lb/cf	pounds of water/cubic foot of soil
in/ft	inches of water/ft of soil
cm/30cm	centimeters of water/30 cm of soil
TIME	Select counting time (1 to 960) seconds.
CALIB(13)	**(1)** Select calibration (0…32) **(2)** Enter/Change **(3)** View Calibration **(4)** Send to USB **(5)** Send to Serial **(6)** Load from USB
Project(5)	User defined measurement/site information. Contains Calibration, tube/count time information depths. Projects required to log readings outside of daily log
Logging(12)	Functions 1-6 Start, Change Log Time (1-999sec), Change # Logs (1-999), View, Send

Recall (2)	Recall Last Test
PRINT	Menu selection 12,13, Select 5 Send to Serial to Print
MENU	Select miscellaneous function:
STD	**1-4** Standard Count New, Review, Send USB or Serial
START	Take a reading.
NO	**CLEAR**, Abort, **No**
STORE	Store Reading in Daily Log or Project
ENTER	Enter data, make selection

Section 3 - Operation

Operating Procedures

Taking A Reading (Standard Count Required to Calculate Moisture)

To take a reading, lower the probe to the appropriate depth and press **START**. Before doing this you must select **UNITS**, **TIME** and **CALIBRATION or PROJECT**. *Note: The gauge must have a valid standard count to function correctly.*

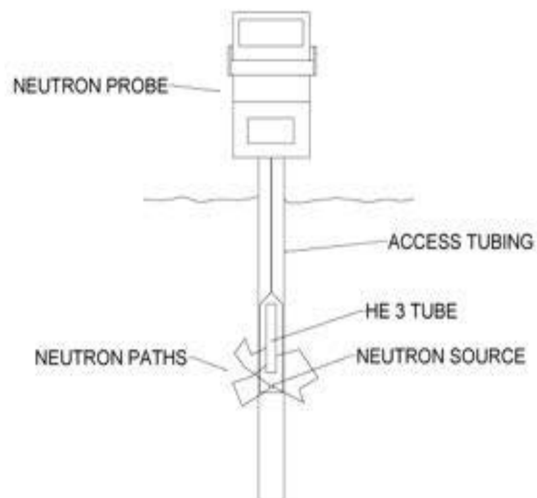


Figure 3.1 Operation of the 503 Elite HYDROPROBE®

How to Select UNITS (MENU item 8)

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 (Select from Front Panel 1-960 seconds)

For a given counting rate, the counting time interval determines the precision of the measurement. The longer the time selected, the more precise the measurement. Correspondingly, the longer the counting times the fewer measurements that can be made in a day. Thus the time interval is normally selected as the minimum time that will meet your specific precision.

For scheduling-type operation, a count time of 16 seconds will provide sufficient precision for irrigation scheduling.

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

How to Select CALIBRATION (MENU item 13 1-32)

The calibration will have been determined previously, and the slope (A) and intercept (B) coefficients stored in one of the 32 calibrations. Select the one that is appropriate for the soil and type of access tube.

```
1 Sel. Calibration↑
2 Enter/Edit Cal
3 View Calibration
 ENTER or Up/Down ↓
```

```
4 Send to USB     ↑
5 Send to Serial
6 Load From USB
 ENTER or Up/Down ↓
```

Operating Procedures

To Log Readings (Press STORE after completion of reading if not using Auto Store)

Readings can be logged by the gauge as they are taken in the field or pre-set with count time and number of readings/logs per location. 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 may be recalled for display or downloaded to an external device.

There are 4 ways to log data with the 503 Elite.

1. Daily log
2. Simple Project
3. Full Project
4. Continuous Logging

Each will be described in detail below.

Daily Log

The results are shown after taking a reading. Pressing STORE from this screen will prompt you with:

```
  No project is
selected, store
  in daily log?
    (YES/NO)
```

Pressing YES here will save the results in a log called 'Daily Log' under the date the log was taken.

Note: All projects must be deactivated to use the Daily Log.

Simple Project:

To start a simple project, From the Gauge ready screen:

- Press MENU

- Press "1" on the key pad or – Use Arrow keys to select '1. New Project'
- Press ENTER – Use Arrow keys to select 'New Simple Proj.'

```
1 New Simple Proj.↑
2 Recall Last Test
3 LCD Backlight
 ENTER or Up/Down ↓
```

- Press ENTER – Use Arrow and ENTER keys to enter Project ID. Press STORE.
- Use Left and Right Arrow to enter Counts/Tube. This will be the total counts for this project. Press STORE.

```
ABCDEFGHIJKLMNOPQR
STUVWXYZ.%+-/?_()←
 Enter Project ID
LP:
```

```
    0123456789←
    Counts/Tube
10
Press STORE to Save
```

- Press YES at the Accept Screen if the data is correct. Notice the A on the Gauge Ready Screen, it signifies that Auto Store is enabled. To disable Auto Store you must go throught the "5 New Project Menu"

```
    Simple 1
  Auto: ENABLED
  Counts/Tube=10
 Accept?(Yes/No)
```

```
 Gauge Ready  P:Yes
Project: Simple 1 A
 01/01/80 12:00 AM
    Press START
```

- Press START from this screen to take a test. You will be prompted to enter notes at the beginning of each tube. Press YES to enter any notes. Press NO and the test will begin.

Project: Simple 1
Enter Notes?
1/1
(YES/NO)

Project: Simple 1 A
1 of 9 A 13 Sec
Cal #0

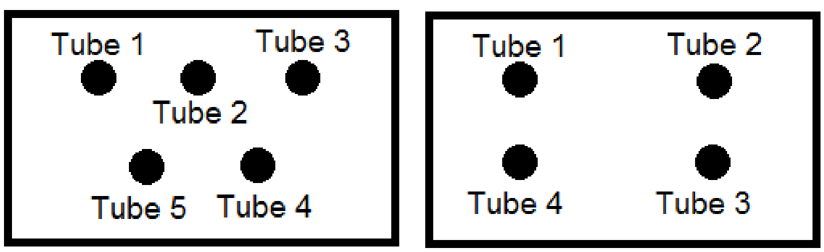
- After the test finishes the result screen is shown. Pressing START from here will run another test. Pressing STORE will save the results again.

Project:Simple 1 ↑
A 1 of 9
MC=0 R=0.0000
M=0.0000 g/cc ↓

M=0.0000 g/cc ↑
M=0.0000 lb/cf
M=0.0000 in/ft
M=0.0000 cm/30cm ↓

Full Project Template:

The Full project would be used in a situation where you have a static setup with 2 or more fields and a known number of tubes. This example contains 2 fields with different number of tubes, readings and calibration constants.



Field 1 Field 2

To setup a full Project you must first setup a template.
From the Gauge Ready screen:

- Press MENU – Use the Arrow keys to select '5. Projects'
- Press ENTER – Use Arrow keys to select '1. Act/Deact Project'

4 Moisture Offset ↑
5 Projects
6 Diagnostics
ENTER or Up/Down ↓

1 Act/Deact Projec↑
2 Auto Store
3 View Stored Proj.
ENTER or Up/Down ↓

- Press ENTER – Use Arrow keys to select '1. New Project'
- Press ENTER – Use Arrow keys to select 'New Template' Press ENTER

```
1 New Project       ↑
2 Activate Existing
3 Deactivate Proj
  ENTER or Up/Down  ↓
```

```
New Simple Proj.
New Full Project
New Template
  ENTER or Up/Down
```

- Use Arrow and ENTER keys to enter Template ID. Press STORE.
- Use Left and Right Arrow to enter the number of stations, 2 in this example.

```
abcdefghijklmnopqrst
uvwxyz 0123456789_?←
Enter Template Name:
Temp2Flds
```

```
   0123456789←
 Enter Number of
Stations:2
Press STORE to Save
```

- Use Arrow and ENTER keys to enter Station 1 ID. Press STORE.
- Use Left and Right Arrow to enter the number of tubes at this station, 5 in this example.

```
abcdefghijklmnopqrst
uvwxyz 0123456789_?←
 Enter Station 1 ID
Field 1
```

```
   0123456789←
 Number of Tubes at
Station 1:5
Press STORE to Save
```

- Use Arrow and ENTER keys to enter Tube 1 ID. Press STORE.
- Use Left and Right Arrow to enter the number of readings for this tube.

```
cdefghijklmnopqrst%.
wxyz 0123456789_?←-+
  Enter Tube 1 ID
Tube 1
```

```
   0123456789←
   Counts/Tube
10
Press STORE to Save
```

- Use UP/DOWN keys to select the calibration constant for this tube. Each tube can have a different calibration constant.

```
 Sel. Calibration
01: Alpha
02: Beta
03: Gamma
```

- Repeat from enter Tube ID for the remaining 4 tubes.
- Repeat from enter Station ID for the Field 2.

When you are finished you will be presented with the accept screen. Press YES if all the data is correct

```
 Template:Temp2Flds
Stations: 2
Tubes: 9
  Accept?(Yes/No)
```

Full Project:

Once the template has been created, you can select it for a new Full Project.

- Press MENU – Use Arrow keys to select '5. Projects'
- Press ENTER – Use Arrow keys to select '1. Act/Deact Project'

```
 4 Moisture Offset ↑
 5 Projects
 6 Diagnostics
  ENTER or Up/Down ↓
```

```
1 Act/Deact Projec↑
2 Auto Store
3 View Stored Proj.
 ENTER or Up/Down ↓
```

- Press ENTER – Use Arrow keys to select '1. New Project'
- Press ENTER – Use Arrow keys to select 'New Full Project.'

```
1 New Project ↑
2 Activate Existing
3 Deactivate Proj
 ENTER or Up/Down ↓
```

```
New Simple Proj.
New Full Project
New Template
  ENTER or Up/Down
```

- Use UP/DOWN keys to select the Template for this project.
- A summary of the Template will be displayed. Press YES to accept it.

1:Temp2Flds
2:Tmp1Field
3:Tmp4Field
ESC/Up/Down Select

Template:Temp2Flds
Stations: 2
Tubes: 9
Accept?(Yes/No)

- Use Arrow and ENTER keys to enter Project ID. Press STORE.
- Press No to leave Auto Store Enabled (The Results will be stored automatically in the project, no need to press STORE at the result page.) or Press Yes to Disable Auto Store (to save the results in the project you will have to press STORE at the result page). Pressing STORE at the results screen with Auto Store on will cause the result to be stored a second time.

abcdefghijklmnopqrst
uvwxyz 0123456789_?←
Enter Project ID:
Proj2Field

Auto Store
ENABLED
Disable Autostore?
(YES/NO)

- Once accepted, the gauge will show the Gauge Ready Screen.

Gauge Ready P:Yes
Proj: Proj2Field
01/01/80 12:00 AM
Press START

- Press START from this screen to take a test. You will be prompted to enter notes at the beginning of each tube. Press YES to enter any notes. Press NO and the test will begin.

Proj2Field Field 1
Enter Notes?
1/5 Tube 1
(YES/NO)

Proj2Field-Field 1
1 of 10 A 15 Sec
Tube 1-Alpha

- After the test finishes the result screen is shown. Pressing START from here will run another test. Pressing STORE will save the results again

```
Proj2Field-Field 1↑
  A Tube 1 1/10
 MC=0 R=0.0000 OE
  M=-0.0098 g/cc  ↓
```

```
 M=0.0000 g/cc    ↑
 M=0.0000 lb/cf
 M=0.0000 in/ft
M=0.0000 cm/30cm ↓
```

How to format Continuous Logging

Use the **MENU** key item **(12) Logging** 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 1 to 999 moisture readings per location/depth (counts per tube/depth). The gauge always provides for an identifier: example: L001 for each record, stores the selected ID number, the date and the time of the logging.

```
1 Start Logging
2 Change Log Time
3 Change Num Logs
 ENTER or Up/Down
```

```
4 View Log
5 Send to Serial
6 Send to USB
 ENTER or Up/Down
```

How to START and LOG Your Measurements

Ensure updated Standard count. Select Set units, time, calibration and format. Then to log a record of information, place the gauge on the access tube and press **START**. If no Project is selected the results may be stored in the Daily Log by pressing **STORE** on the keypad.

How to RECALL Last Test (MENU item 2)

Normally the stored data will be downloaded to a printer or computer. It may also be recalled to the display by pressing **MENU and Selecting 2-Recall Last Test**. When first entered, it will point to the last record store. Either use the **Arrow Up/Down** key to step up the record list (it steps back through the list and circles around at the beginning)

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 acceptable amount, it is an indication of

acceptable drift of the electronics. Americium-41/Beryllium has a half-life of 432.2 years.

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 average of the last four standard counts is used to evaluate pass or fail on the Standard Count Percent difference which must be less than 2.0%. This is calculated using the equation: (COUNT – AVERAGE) / AVERAGE * 100. Where COUNT = the last Standard Count taken and AVERAGE = the average of the past 4 Standard Counts.

The 503DR program uses the new standard to calculate the field count/standard count ratio.

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**, Display will show the last standard count and “Would you like to take a new STD Count” Select either (Yes/No).

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 4000 with an “A” slope of 2.6, while the new water barrel standard is 12,000. The new “A” coefficient should be:

2.6 x (12000 / 4000) = 7.8

When a standard count is started, the gauge will take a 256 second count. When the count is completed, the NEW standard count is displayed (e.g. “S 3857”).

Press the **STD** key (1-4) to take a New Standard Count, Review the Current standard count (e.g. “P 3857”).

To use the new Moisture STD (STANDARD) select **YES or NO** if standard fails

If the gauge is connected to a printed via the USB or serial link, individual counts and summary information will be stored printed out by Selecting item 3 or 4.

Standard Count Statistics

Taking such a series of 256 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.

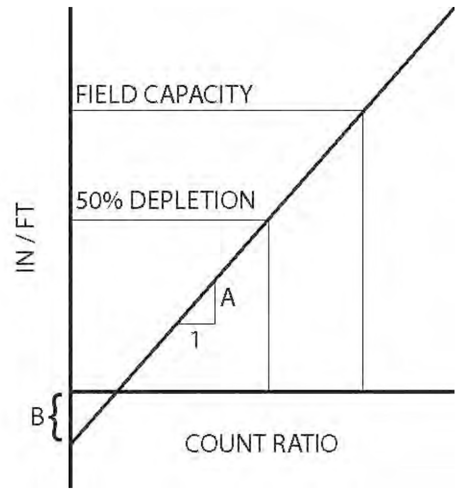
For a sample of 256 counts, the ratio should be between 0.75 and 1.25 for 95% of the tests. Note that even a good gauge will fail 5 out of every 100 tests. If the ratio falls too consistently outside, it may mean that the counting electronics is adversely affecting the counts. Generally, the ratio will 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 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.

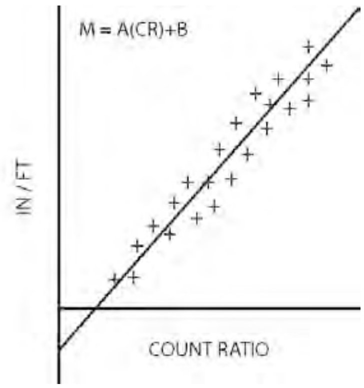
Another alternate, popular with irrigation schedulers, is to only take two measurement pairs, one pair at field capacity and a second at a soil moisture condition near 50% depletion.

Weigh the soil samples wet and dry (24 hrs at 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:

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

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

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

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

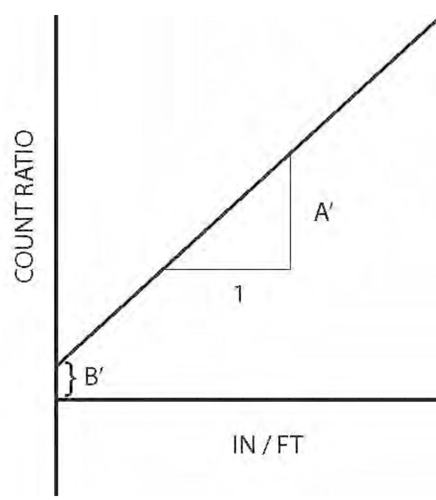
$$B = 1.9 - 2.603 \times 0.77 = -0.1043$$

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.

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



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

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.

Range

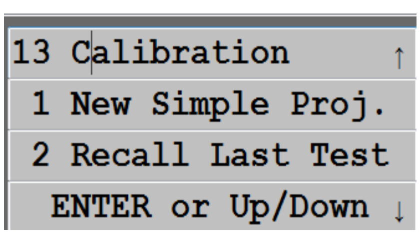
The linear calibration supplied with the **DR** is useful over the most commonly used moisture range, 0 to 40%. For use in moisture contents higher than this, it is necessary to have a special calibration that covers the intended range of use.

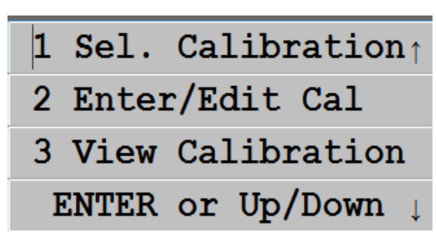
Entering Calibrations

Calibrations can be entered manually or by self-calibration.

Changing Existing Calibration:

- Press MENU – Use Arrow keys to select '13. Calibration'
- Press ENTER.
- Use Arrow keys to select '2. Enter/Edit Cal'. Press Enter.





- You will be prompted to enter the Password (3548). Enter it and press STORE.
- Use the Arrow keys to select '1. Enter New Cal'. Press ENTER.

```
ABCDEFGHIJKLMNOPQRST
UVWXYZ 0123456789_?←
Press STORE to Save
3548
```

```
1 Enter New Cal
2 Edit Calibration
3 Self Calibration
  ENTER or Up/Down
```

- Use the Arrow keys to select the calibration you wish to change. You will be asked if you really wish to change the calibration.
- Press YES.

```
  Sel. Calibration
01: Alpha
02: Beta
03: Gamma
```

```
   Cal 3: Gamma
  08/09/13 in/ft
A:1.59251 B:-0.2567
  Change? (YES/NO)
```

- Use Arrow and ENTER keys to enter Template ID. Press STORE.
- Use UP/DOWN Arrows to select the units of the calibration. Press STORE.

```
ABCDEFGHIJKLMNOPQRST
UVWXYZ 0123456789_?←
    Enter Cal ID
Gamma
```

```
  Select Cal Units
       in/ft
 Up/Down to Change
Press STORE to Save
```

- Use LEFT or RIGHT Arrows and ENTER to change the coefficients.
- Press STORE.

```
   0123456789.-←
    COEF A in/ft
1.592512
Press STORE to Save
```

```
   0123456789.-←
    COEF B in/ft
-0.256712
Press STORE to Save
```

- Review the information at the summary page and press YES to accept.

```
   Cal 3: Gamma
  01/01/80 in/ft
A:1.59251 B:-0.2567
  Save? (YES/NO)
```

An alternative method of updating the calibrations manually

- From the Gauge Ready Screen, press MENU – Use the Arrow keys to select '13. Calibrations'.
- Press Enter. Use the Arrow keys to select '4. Send to USB'. Insert a Thumb Drive, and press ENTER.
- After the data has been downloaded to the Thumb Drive, remove the Drive and insert it into your PC.
- The calibrations will have been saved in the folder \InstroTek\503 HydroProbe\CAL 01-01-80_12_00_AM.XML
- Open the file with EXCEL, make any changes you want and save it back to the Thumb Drive as \InstroTek\503 HydroProbe\LoadCal.XML
- Insert the Thumb Drive back into the gauge. Use the Arrow keys to select '6 Load From USB.
- Press Enter.

Self-Calibration

- From the Gauge Ready Screen, press MENU – Use the Arrow keys to select '13. Calibrations'.
- Press Enter. Use the Arrow keys to select '2. Enter/Edit Cal'. Press Enter. Enter the Password (3548).
- Use the Arrow keys to select '3 Self Calibration'. Use the Arrow keys to select '2 Gauge Derived'.
- Press Enter.

1 Enter New Cal
2 Edit Calibration
3 Self Calibration
ENTER or Up/Down

Self Calibration
1 Enter Manually
2 Guage Derived
ENTER or Up/Down

- Enter the first Moisture Reference value.
- Press ENTER. Place the probe into the first moisture Standard and Press START.

0123456789.-←
Enter Moist Ref 1
Press STORE to Save

Place Probe in
Moisture
Standard 1
Press START

- The gauge will run a 240 second test on the standard. After the test has completed you will be prompted to repeat the steps for the second standard. After the second test is completed the results are shown.

- Press YES to accept the calibration. Use the Arrow keys to select the calibration slot where you wish to store the new calibration. Press STORE.

```
R1=0.0000 C1=0
R2=0.0000 C2=0
A=0.0000 B=0.0000
  Accept?(Yes/No)
```

```
  Save Results in:
01: Alpha
02: Beta
03: Gamma
```

Manual Entry Calibration

- From the Gauge Ready Screen, press MENU – Use the Arrow keys to select '13. Calibrations'.
- Press Enter. Use the Arrow keys to select '2. Enter/Edit Cal'. Press Enter. Enter the Password (3548).
- Use the Arrow keys to select '3 Self Calibration'. Use the Arrow keys to select '2 Gauge Derived'.
- Press Enter.

```
1 Enter New Cal
2 Edit Calibration
3 Self Calibration
  ENTER or Up/Down
```

```
  Self Calibration
1 Enter Manually
2 Guage Derived
  ENTER or Up/Down
```

- Enter the first Moisture Reference value. Press ENTER. Enter the first count value.

```
   0123456789.-←
 Enter Moist Ref 1

Press STORE to Save
```

```
   0123456789←
   Enter Count 1
1532
Press STORE to Save
```

- Repeat for the second reference. At the results page press YES to accept.

Section 4 – 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 503** Elite consists of four major assemblies:

1) Surface Shield/Carrying Box
2) Electronic Assembly
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).

Figure 4.1 Leak Test Procedure

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.

Surface Electronic Assembly Maintenance

All this will change

The Surface Electronic Assembly consists of:

1) Surface PC-Assembly
2) Battery Pack (Li-Ion 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.

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.

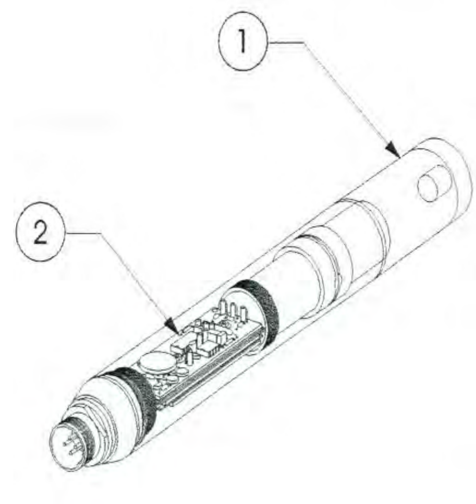


Figure 4.3. Probe Assembly

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 4.3.

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).

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.***

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 and make sure the probe electronics threads are no longer visible to ensure a good seal. 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 503** Elite**,** 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.
SD ERROR	Internal memory full, delete projects and directories.
LOG EMPTY!	Record log empty when PRINT or RCL pressed.
CNT ZERO	There were no counts, probably due to bad detectors.
MOIST=0	Gauge cannot calculate moisture, check the standard count value.
Batt Low	The batteries have been depleted. Charge the battery pack.

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
Drift 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 (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 access tube type.
Same except accompanied by a shift in standard count.	Probe geometry changed. Defective detector.

Appendix C

Print/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 user needs. To get the data from the probe to the computer

To download project data:
Press MENU – Use Arrow keys to select 5. Projects.
Press ENTER – Use Arrow keys to select 4. Save Projects
Press ENTER – Select:

1. Send Project to USB – Project will be saved on Thumb drive in .XLS format.
2. Send All to USB – All projects will be saved on Thumb drive in .XLS format.
3. Send Project Serial – Project will be sent to PC over a RS232 connection
4. Send All Serial – All projects will be sent to PC over a RS232 connection
5. Legacy Format – CPN DR Dump Software.

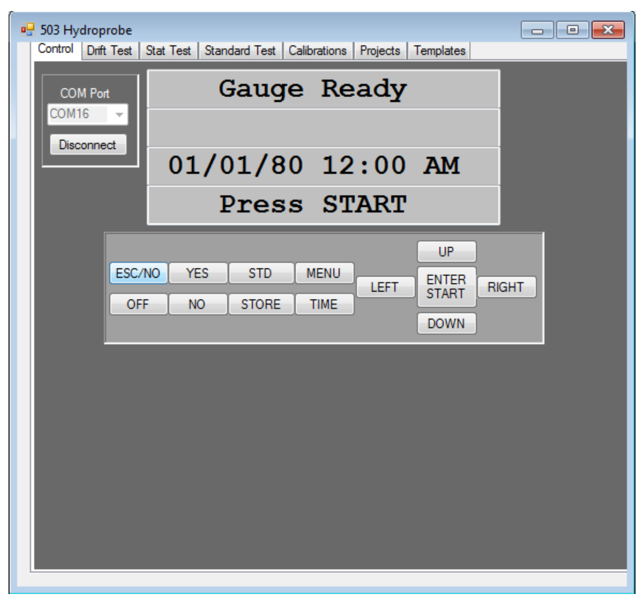
The program specifications that pertain to the gauge are:

- RS232 type serial communication (TXD, RSD, GND)
- I start bit, 8 data bits, no parity, and 1 stop bits.
- Baud rate: 115200

503 Hydroprobe Control Software for Windows 7 or earlier

The program connects to the 503 through a USB serial cable from the pc to the gauge. It permits the user to control the gauge from the pc, download data from the gauge, and upload calibrations and templates to the gauge. Download available at http://instrotek.com/downloads/#software

Downloaded data can be saved as XLS, CVS, or text file.



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:

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

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 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).
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.

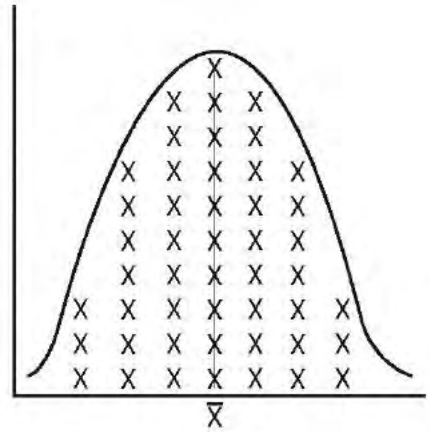


Figure D.2

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.

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

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 D.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.

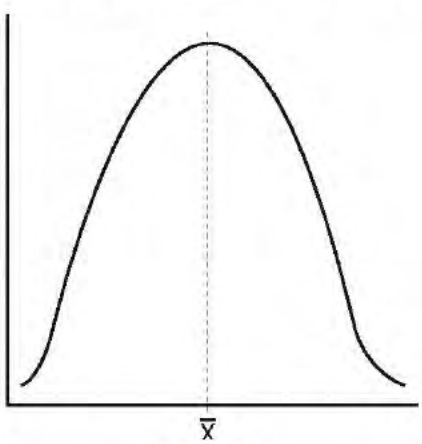


Figure D.3

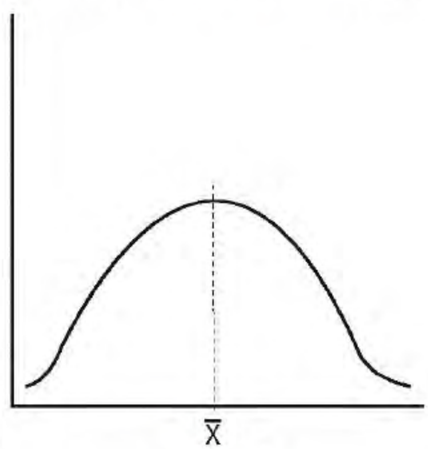


Figure D.4

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 D.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.

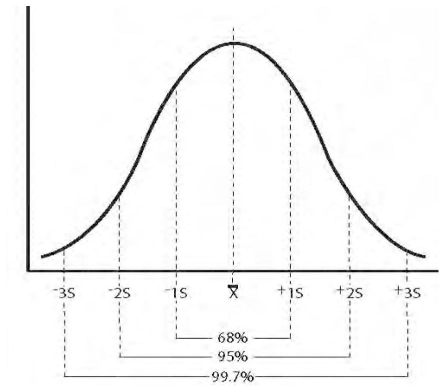


Figure D.5

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.

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 rate 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 (68.35)	Count Precision (95.5%)
1	1.00	100.00	
10	3.16	31.60	63.2
100	10.00	10.00	20.0
1000	31.62	3.16	6.32
10000	100.00	1.00	2.00
100000	316.22	0.32	0.63

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:

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

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 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 than in the table. The 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 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.

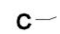
EXAMPLE:

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 E

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

Appendix F

Sample of Data downloaded via the thumb drive to an Excel spread sheet.

Appendix G

Access Tubing

Almost any tube type can be used as long as the probe is calibrated with the same type of tube that is used in the field. The ideal tubing has a minimum wall thickness and is strong enough to prevent damage and bending during installation. The tubing should be capped at the top and bottom if to prevent water from getting inside.

Aluminum 6061-T6

This tubing is ideal for minimal moisture sensitivity.
It can be installed easily in rocky soils.
Thicker walled versions (.125") won't dent easily and will last longer.

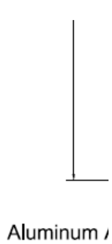
Steel: Carbon and Stainless

This is expensive but very durable in rocky soils.
Some larger wall thickness versions can be flush coupled and thread together.
Some measurement sensitivity.

PVC Schedule 125

This is inexpensive and readily available.
Sunlight may cause brittleness and cracking to exposed tubing.
The chloride content will reduce the response on the moisture measurement.

The factory calibrations determined on all new 503DR gauges are based on an aluminum tubing calibration. This calibration can be adjusted to represent the other tubing types listed here.



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