AN INSTROTEK® COMPANY

CPN 503 ELITE™
HYDROPROBE

OPERATING MANUAL

www.InstroTek.com

'This page may be removed from the manual to prevent the unauthorized access to the restricted menu functions of the InstroTek/CPN 503 Elite Hydroprobe.'

Restricted Menu Function

Access Code:

3548

Please note up to 2% of the mechanical components used in the gauge may be recycled material.

This page may be removed from the manual to prevent the unauthorized access to the restricted menu functions of the InstroTek/CPN 503 Elite Hydroprobe.

503 Elite Hydroprobe ™
Operation Manual Version 12

1. Table of Contents

****

1. INTRODUCTION	2
2. GAUGE FUNCTIONS	9
3. OPERATION	13
4. CALIBRATION	15
5. LOGGING AND PROJECTS	25
6. MENU ITEMS	37
7. MAINTENANCE	41
8. OPERATION PRECAUTIONS	45
9. TROUBLESHOOTING	46
10. PRINT DATA/TRANSFERS	48
11. STANDARD COUNT INFORMATION	50
12. COUNTING STATISTICS	53
13. CONNECTOR PINOUTS	62
14. EXCEL SPREADSHEET	64
15. APPENDICES	65
16. INDEX	73
17. WARRANTY	77

1. Introduction

Thank you for your purchase of the InstroTek/CPN Model 503 Elite Hydroprobe. 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 that's either 1.5 or 2 inches in 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 and must be locked during 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 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.

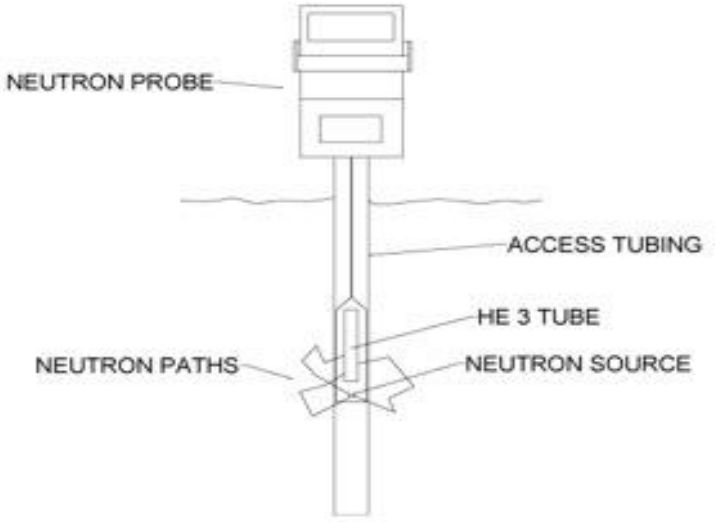


Fig 1.1 Operation of the 503 Elite HYDROPROBE®

Model 503 Elite Hydroprobe and Standard Accessories

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 503 Elite Hydroprobe ®. It comes fully assembled.

Fig 1.2 Standard Equipment

1. **503 Elite Hydroprobe®**
2. **Padlock with Keys – 2 Locks**
3. **Shipping Case**
4. **8 ft. (2.44 meter) Cable**
5. **10 Cable Stops**
6. **Access Collar (1.5")**
7. **Operating Manual**
8. **Spanner Wrench**
9. **AC Charger**
10. **Gauge Certificate**
11. **Leak Test Certificate**

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 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

Electrical:

Power

- **NiMH 7.5V 2500 mAh Battery Pack**

Battery Life - 100 hours of operation

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:

RQ, UN 3332, RADIOACTIVE MATERIAL, TYPE A PACKAGE, SPECIAL FORM, 7

Special Form Approval - 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 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.

Fig 1.3 CPN 503 Elite 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 soil, 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.

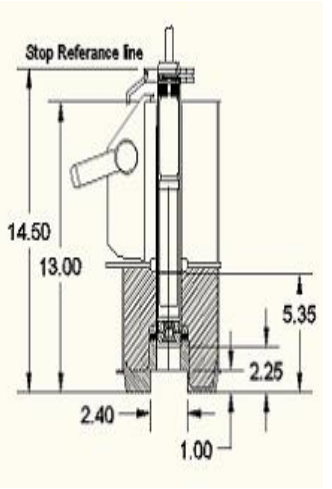
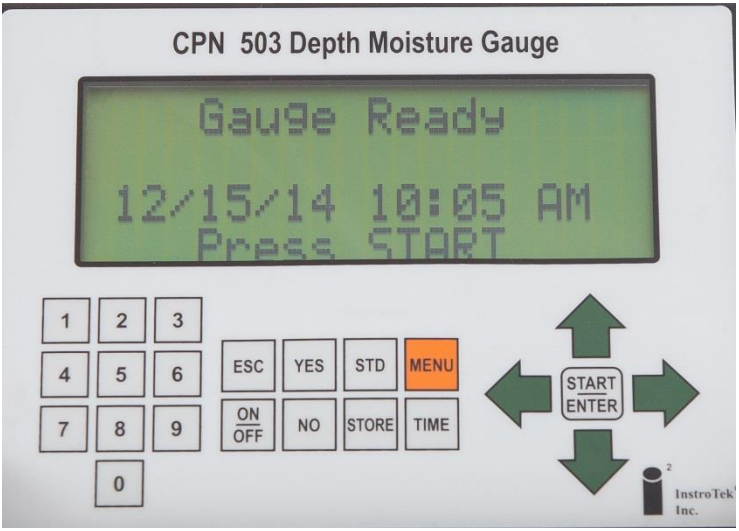


Fig 1.4 503 Cross Section

2. Gauge Functions

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
STD:	Select Standard Count menu

Menu:	14 Item gauge control functions (See Sect. 6 for details)
Arrow Keys:	Navigate through the menus
Numeric Keys:	Expanded keypad aids in project and data entry

Standard Count

Taking a Standard Count

Note: A new standard count should be taken at least once a day.

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**. The display will show the last standard count and asks you "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.

See section 11 for further discussion on standard count.

Select TIME

The counting time is selected by pressing the **TIME** button on the keypad.

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 15 seconds will provide sufficient precision for irrigation scheduling.

See section 11 on Standard Count for a further discussion of precision.

Select UNITS

Gauge units are under menu item **8**.

These are the different units the user can choose:

1. g/cc- grams of water/cubic cm of soil
2. lb/cf – pounds of water/cubic foot of soil
3. in/ft – inches of water/foot of soil
4. cm/30cm – centimeters of water/30 cm of soil
5. %moist – Water content (vol.%) = a* count ratio + b
6. Count – Raw gauge counts/unit time

The choice of display units will depend upon your use. Researchers will normally prefer grams per cubic centimeter (1) or percent volume (5), while irrigation schedulers use inches per foot (3) or centimeter per 30 centimeters (4).

Counts (6) 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 Reading is taken, the display will be in the units selected.

3. Operation

Operating Procedures

Taking A Reading (Standard Count Required to Calculate Moisture)

Before taking a reading, you must select **UNITS**, **TIME** and **CALIBRATION**, or **PROJECT**. After this, lower the probe to the appropriate depth and press **START**.

Note: The gauge must have a valid standard count to function correctly.

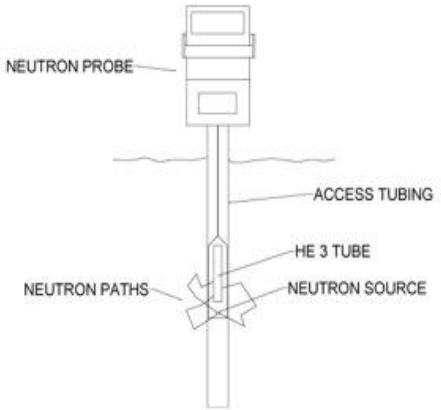


Fig 3.1 Operation of the 503 Elite HYDROPROBE®

After the count time, the gauge will display the results.

Project ORCHARD1
MC=1024 R=0.89

Test Results

MC	Moisture Count: Raw gauge counts/unit time
R	Ratio: MC/Standard Count
M	Moisture in selected units. (See page 12 for changing units.)

The moisture is calculated with the following formula:

$$M = R\ x\ A + B$$

A and B are from the selected calibration that is stored in the gauge.

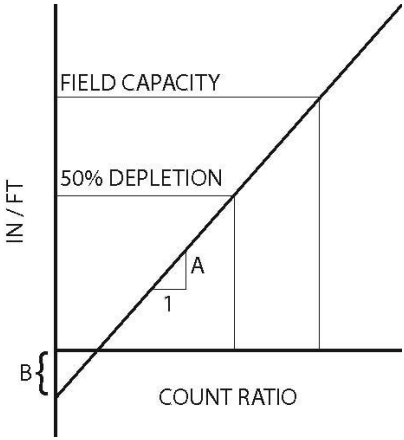
32 different calibrations can be stored in the gauge. (See Section 4, Calibration)

Charging the Batteries

The 503 contains a NiMh battery pack. The NiMh batteries are charged at the factory prior to calibration. Life of rechargeable batteries depends on the number of charge/discharge cycles. For longest battery life, only charge your batteries when the battery low warning is displayed. There will be a "Battery Low" message displayed when the battery is getting low. When the batteries are new, the gauge will operate for about 2 hours after the "Battery Low" message appears.

4. 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:

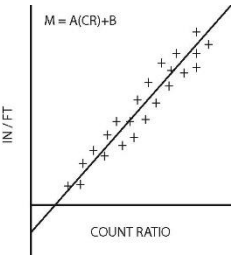
$$\frac{inches}{ft} = 12 \times (weight\ fraction\ of\ water\ dry\ basis) \times (dry\ density\ of\ soil)\left(\frac{1}{density\ of\ water}\right) = \left(\frac{W_w - W_d}{W_d}\right)(d_d)\left(\frac{1\times12}{d_W}\right)$$

Using linear graph paper, plot the probe readings in count ratio versus the volume samples in inches per foot. W_w is the weight of soil wet and W_d is the weight of soil dry.

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.

MH - ML
Slope: A = RH – RL
Intercept: B = ML – A x RL
Then: M = (A x r) + B



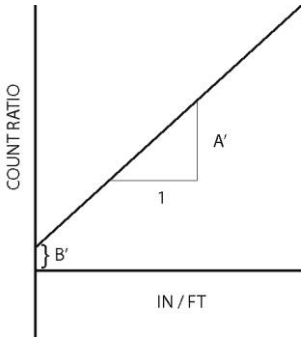
Where:
m = *moisture in inches per foot*
r = *count ratio*
MH = *high moisture value in inches per foot*
ML = *low moisture value in inches per foot*
RH = *probe count ration at the high moisture value*
RL = *probe count ration at the low moisture value*

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.

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

B = 1.9 - 2.603 x 0.77 = -0.1043 or
M = 2.603 x r - 0.1043

The 503 Elite 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.



$$\boldsymbol{r} = (\boldsymbol{A'} \times \boldsymbol{M}) + \boldsymbol{B'}$$

$$\boldsymbol{A'} = {}^{\mathbf{1}}/_{\boldsymbol{A}}, \boldsymbol{B'} = {}^{\boldsymbol{B}}/_{\boldsymbol{A}}$$

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

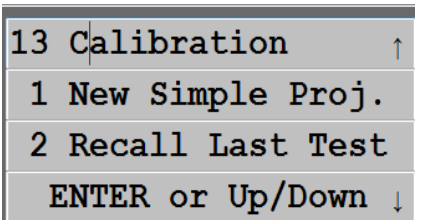
The linear calibration supplied with the 503 Elite is useful over the most commonly used moisture range, 0 to 40%. For use in moisture contents higher than this, it is necessary to have a special calibration that covers the intended range of use.

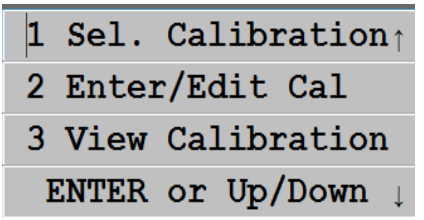
Entering Calibrations

Calibrations can be entered manually or by self-calibration.

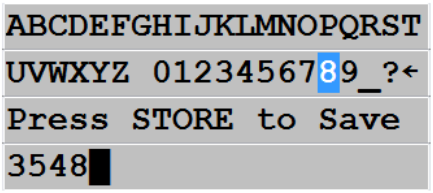
Changing Existing Calibration:

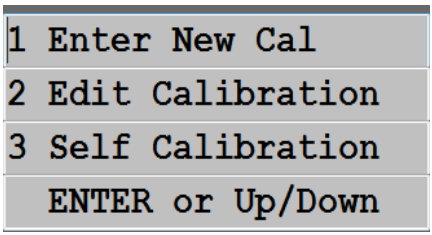
- Press **MENU** – Use Arrow keys to select '**13. Calibration**'
- Press **ENTER**.
- Use Arrow keys to select '**2. Enter/Edit Cal**'. Press **Enter**.



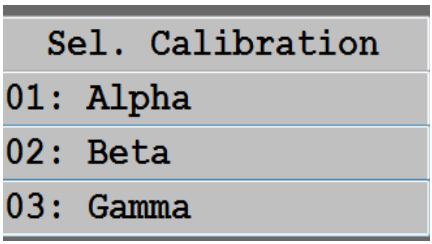


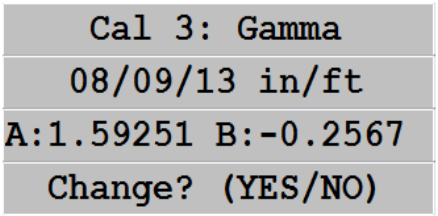
- You will be prompted to enter the **Password (3548)**. Enter it and press **STORE**.
- Use the Arrow keys to select '**1. Enter New Cal**'. Press **ENTER**.



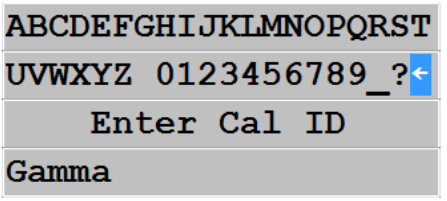


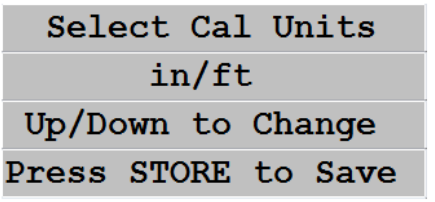
- Use the Arrow keys to select the calibration you wish to change. You will be asked if you really wish to change the calibration.
- Press **YES**.



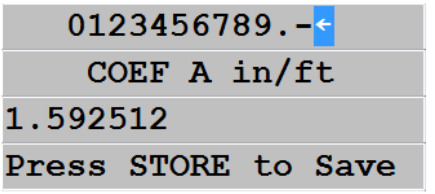


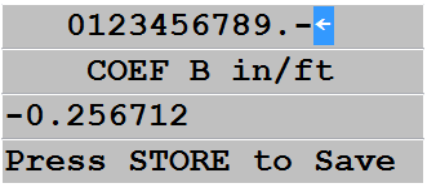
- Use Arrow and ENTER keys to **enter Template ID**. Press **STORE**.
- Use UP/DOWN Arrows to select the **units of the calibration**. Press **STORE**.



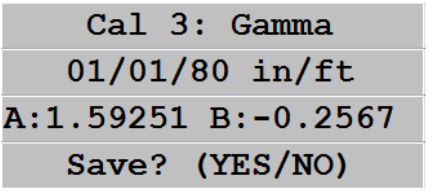


- Use LEFT or RIGHT Arrows and ENTER to **change the coefficients**.
- Press **STORE**.





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

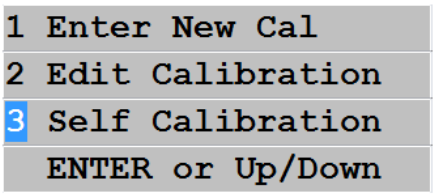


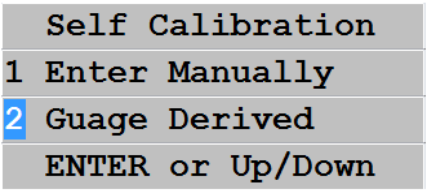
An alternative method of updating the calibrations manually

- 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**.

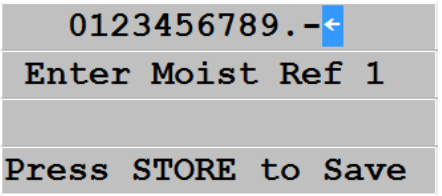
Self-Calibration

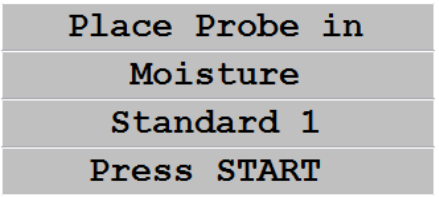
- From the Gauge Ready Screen, press **MENU** – Use the Arrow keys to select '**13. Calibrations'**.
- Press **Enter**. Use the Arrow keys to select '**2. Enter/Edit Cal**'. Press **Enter**. Enter the **Password** (**3548**).
- Use the Arrow keys to select '**3. Self-Calibration**'. Use the Arrow keys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



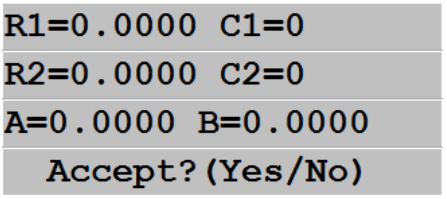


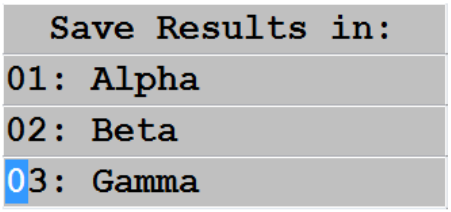
- Enter the first Moisture Reference value.
- Press **ENTER**. Place the probe into the first moisture Standard and Press **START**.





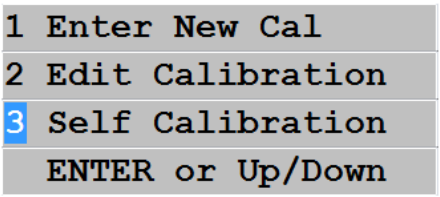
- The gauge will run a 240 second test on the standard. After the test has completed, you will be prompted to repeat the steps for the second standard. After the second test is completed the results are shown.
- Press **YES** to accept the calibration. Use the Arrow keys to select the calibration slot where you wish to store the new calibration. Press **STORE**.

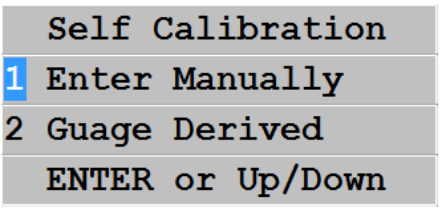




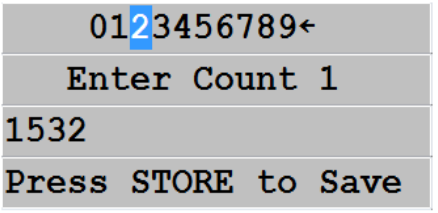
Manual Entry Calibration

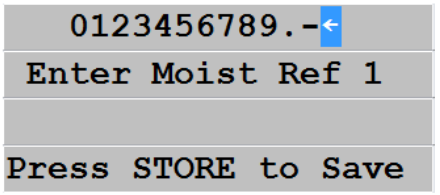
- From the Gauge Ready Screen, press **MENU** – Use the Arrow keys to select '**13. Calibrations**'.
- Press **Enter**. Use the Arrow keys to select '**2. Enter/Edit Cal**'. Press **Enter**. Enter the **Password (3548)**.
- Use the Arrow keys to select '**3. Self-Calibration**'. Use the Arrow keys to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





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





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

5. Logging and Projects

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.

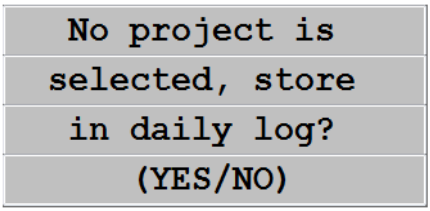
There are 4 ways to log data with the 503 Elite:

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:



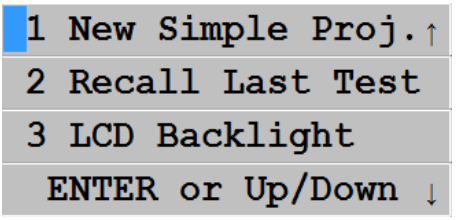
Pressing **YES** here will save the results in a log called 'Daily Log' under the date the log was taken.

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

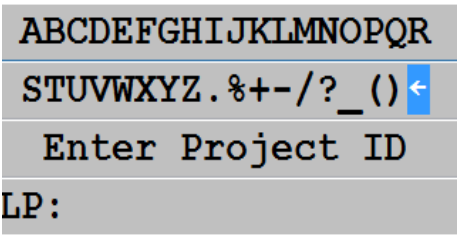
Simple Project:

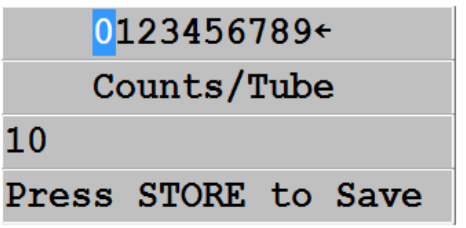
To start a simple project from the Gauge ready screen:

- 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.**'.

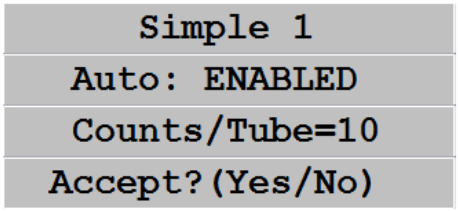


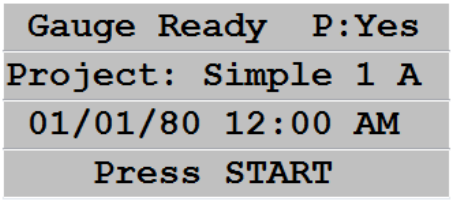
- Press **ENTER** – Use Arrow and ENTER keys to enter Project ID. Press **STORE**.
- Use Left and Right Arrow to enter Counts/Tube. This will be the total counts for this project. Press **STORE**.



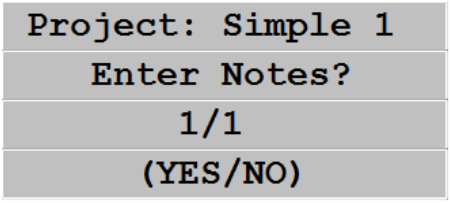


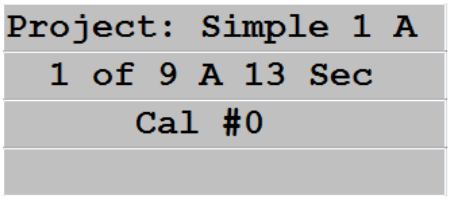
- Press **YES** at the Accept Screen if the data is correct. Notice the A on the Gauge Ready screen; it signifies that Auto Store is enabled. To disable Auto Store you must go through the "**5 New Project Menu**".



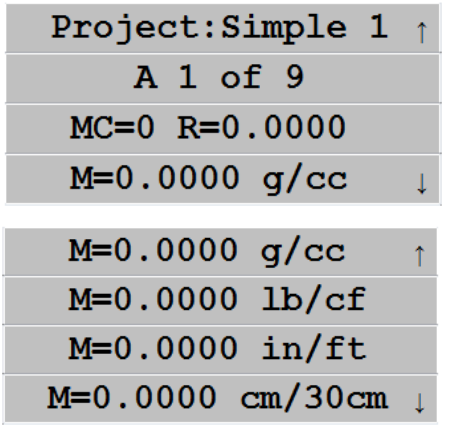


- Press **START** from this screen to take a test. You will be prompted to enter notes at the beginning of each tube. Press **YES** to enter any notes. Press **NO** and the test will begin.



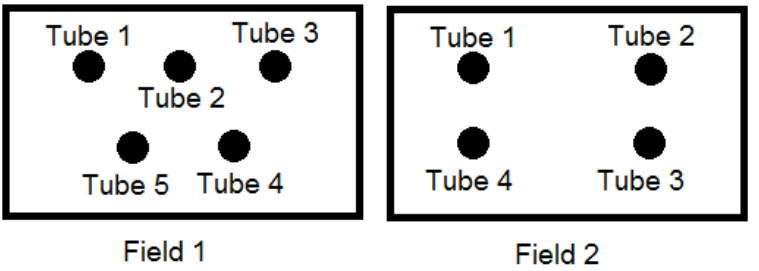


- After the test finishes the result screen is shown. Pressing **START** from here will run another test. Pressing **STORE** will save the results again.



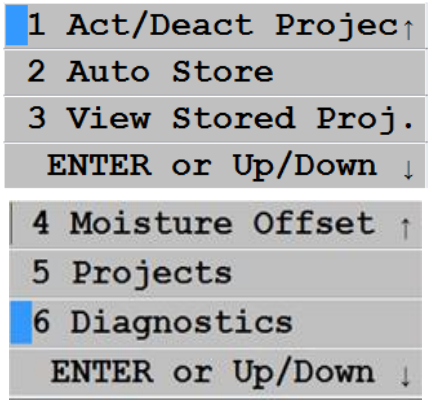
Full Project Template:

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.

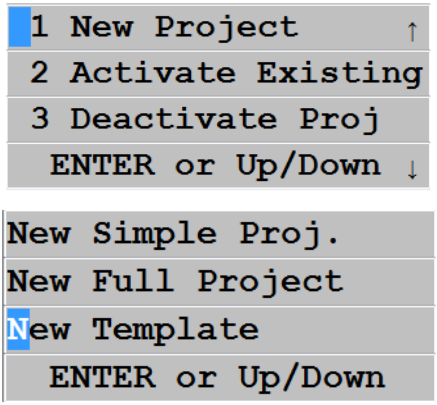


To setup a full Project you must first setup a template.
From the Gauge Ready screen:

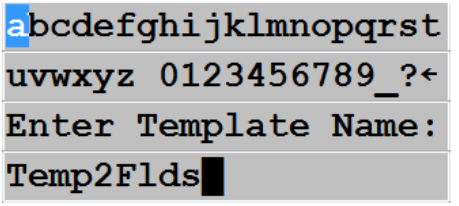
- Press **MENU** – Use the Arrow keys to select '**5. Projects**'.
- Press **ENTER** – Use Arrow keys to select '**1. Act/Deact Project**'.



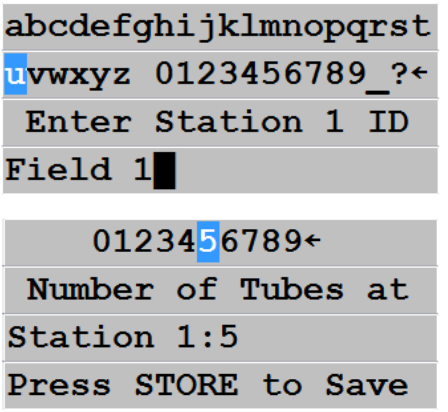
- Press **ENTER** – Use Arrow keys to select '**1. New Project**'.
- Press **ENTER** – Use Arrow keys to select '**New Template**'. Press **ENTER**.



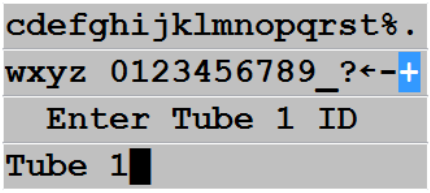
- Use Arrow and ENTER keys to enter Template ID. Press **STORE**.
- Use Left and Right Arrow to enter the number of stations, 2 in this example.

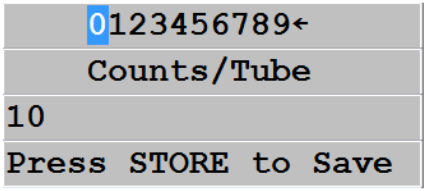


- Use Arrow and ENTER keys to enter Station 1 ID. Press **STORE**.
- Use Left and Right Arrow to enter the number of tubes at this station, 5 in this example.

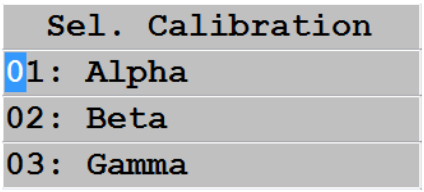


- Use Arrow and ENTER keys to enter Tube 1 ID. **Press STORE**.
- Use Left and Right Arrow to enter the number of readings for this tube.



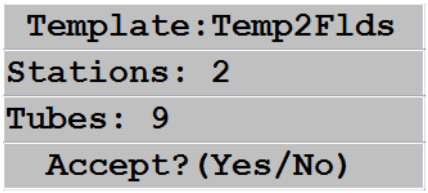


- Use UP/DOWN keys to select the calibration constant for this tube. Each tube can have a different calibration constant.



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

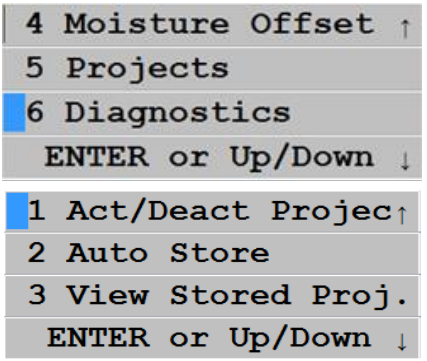
When you are finished you will be presented with the accept screen. Press **YES** if all the data is correct.



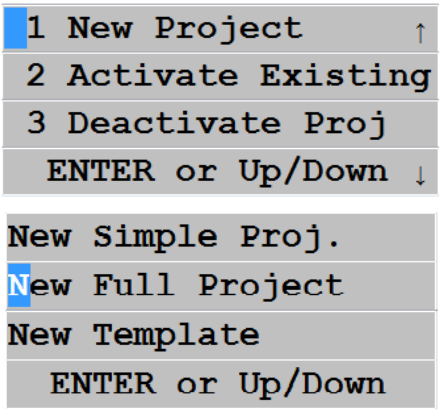
Full Project:

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

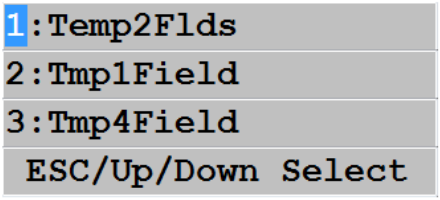
- Press **MENU** – Use Arrow keys to select '**5. Projects**'
- Press **ENTER** – Use Arrow keys to select '**1. Act/Deact Project**'

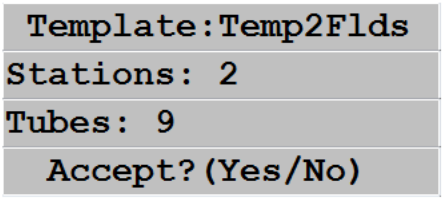


- Press **ENTER** – Use Arrow keys to select '**1. New Project**'
- Press **ENTER** – Use Arrow keys to select '**New Full Project.**'

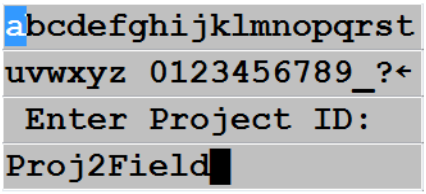


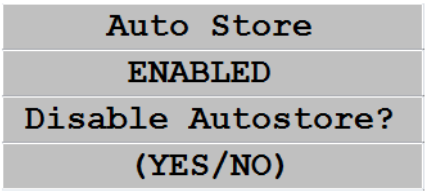
- Use **UP/DOWN** keys to select the Template for this project.
- A summary of the Template will be displayed. Press **YES** to accept it.



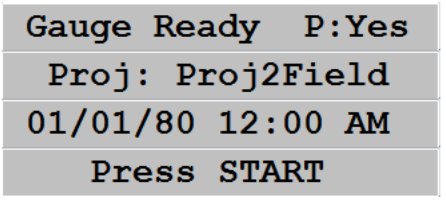


- Use Arrow and ENTER keys to enter Project ID. Press **STORE**.
- Press **NO** to leave Auto Store Enabled (The Results will be stored automatically in the project, no need to press STORE at the result page.) Press **Yes** to Disable Auto Store (to save the results in the project you will have to press 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.

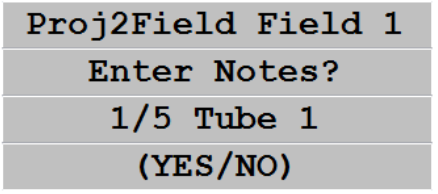


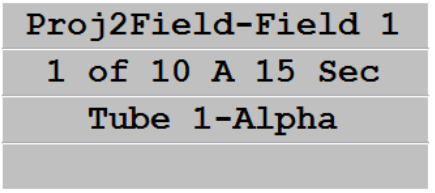


- Once accepted, the gauge will show the Gauge Ready Screen.

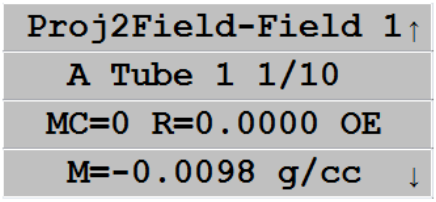


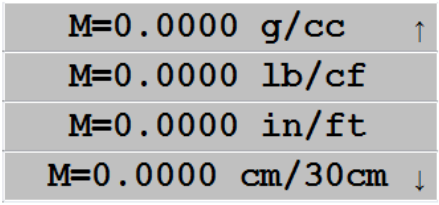
- Press **START** from this screen to take a test. You will be prompted to enter notes at the beginning of each tube. Press **YES** to enter any notes. Press **NO** and the test will begin.





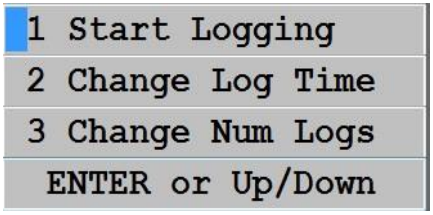
- After the test finishes the result screen is shown. Pressing START from here will run another test. Pressing STORE will save the results again.

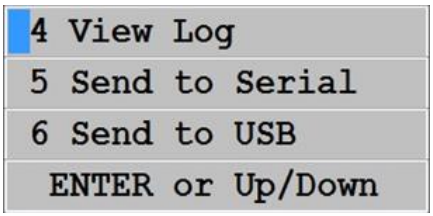




How to format Continuous Logging:

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.





How to START and LOG Your Measurements

Ensure there is an 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. Use the **Arrow Up/Down** key to step up the record list (it steps back through the list and circles around at the beginning).

6. Menu Items

1) **New Simple Proj** – Start a new simple project. Only name and Readings/Tube are required. A simple project allows you to enter a note or ID before the first count, which is then saved before the gauge takes the count. If you press no, the gauge will immediately take a count. (See page 26 for complete instructions on how to create a simple project).
2) **Recall Last Test** – Displays the last test results.
3) **LCD Backlight** – Turns on/off the LCD Backlight.
4) **Moisture Offset** – Enter the required Moisture Offset. This corrects the gauge moisture reading to oven or speedy dry moisture.
5) **Projects** - User defined measurement/site information. It contains calibration, tube/count time, and information depths. Projects are required to log readings outside of the daily log.
6) **Diagnostics** – Various Tests to aid in determining problems and prove the device is operating correctly
   a) Keypad Diag – Displays the key depressed
   b) Stat Test

      A Stat Test may be performed to validate the normal operation of the gauge electronics. A Stat Test consists of taking 20, one minute readings, and calculating the standard deviation between each reading and the average. If two out of three stat tests fail the limits set by the gauge, contact your CPN/InstroTek representative. Note: *Control the movement of other gauges during this test. Always keep other gauges a minimum of 10 meter (30 feet) away, while taking a Stat test.*

      i. New Stat Test - Performs a Stat Test consisting of 20 one minute readings.
      ii. Review Last Test – Displays the Results of the last Stat Test taken.
      iii. Send to USB – Saves the results of the last Stat Test to the USB thumb drive.

iv. Send to Serial – Sends the results of the last Stat Test out the RS232 port.

c) Drift Test

If there is a consistent drift in the standard counts from count to count or day to day, the electronics may have a drift problem. This test monitors the long-term drift of the gauge. The drift test consists of performing five 240-second counts. To obtain a meaningful drift result, first take a Stat Test (please refer to the Stat Test section) and wait 3-4 hours before starting a drift test. The average of the five drift counts is compared against the average of the 20 one minute Stat test averages. Passing limit on moisture is equal to 1.0% or less. Note: *Control the movement of other gauges during the test. Always keep other gauges a minimum of 10 meter (30 feet) away, while taking a Drift test.*

i. New Drift Test - Performs a Drift Test consisting of 5 four minute readings.
ii. Review Last Test – Displays the Results of the last Stat Test taken.
iii. Send to USB – Saves the results of the last Stat Test to the USB thumb drive.
iv. Send to Serial – Sends the results of the last Stat Test out the RS232 port.

d) Standard Test

i. Take new STD – Takes a new STD of 256 seconds. Functions the same as the Front panel key "STD"
ii. Review STD Counts – Shows the last 32 STDs taken. Only the last 4 are averaged for the STD used.
iii. Send to USB – Saves all 32 STDs to the USB thumb drive.
iv. Send to Serial – Sends all 32 STDs out the RS232 port.

e) Extended Chi-2 – Performs 10 Chi tests consisting of 32 256 second readings. (this is a 23 hour test)
f) HE3 Probe Diag – Starts the tube and pulse counter – displaying the counts received.
g) Battery Diag – Displays the battery voltage.
h) Backlight Diag – turns the backlight on and off.

i) SD Card Diag – Writes a string to the SD card and reads that string back.
j) USB Drive Diag – Writes a test file to the USB drive
k) Defaults – Puts all the gauge control data into their default states.

7) **Select Language**
   a) English
   b) Spanish
   c) German
   d) French
8) **Select Units**
   a) g/cc – grams of water / cubic cm of soil
   b) lb/cf - pounds of water / cubic foot of soil.
   c) in/ft – inches of water / foot of soil
   d) cm/30cm - centimeters of water / 30 cm of soil
   e) %moist – Water content (vol.%) = a * count ratio + b
   f) Count – Raw gauge counts / unit time
9) **Serial Number** – Displays and changes the serial number.
10) **Set Date/Time** – Sets the date and time
11) **Buzzer/Alarm** – turns the buzzer on and off
12) **Logging**
   a) Start Logging
   b) Change Log Time – Set the count time for the log (0 – 999 seconds).
   c) Change Number of logs – Set the number of counts to take (0 – 999).
   d) View Log – Displays the results of the last log.
   e) Send to Serial – Sends the results of the Logs out the RS232 port.
   f) Send to USB – Saves the results of the Logs to the USB thumb drive
13) **Calibration**
   a) Sel. Calibration – If using SIMPLE or DAILY projects, choose the necessary calibration.
   b) Enter/Edit Cal – Change the values of a particular calibration
   c) View Calibration – View the values of all 32 calibrations.
   d) Send to Serial – Sends all 32 calibrations out the RS232 port.

e) Send to USB – Saves the results of the last Stat Test to the USB thumb drive.
f) Load From USB – Loads the values for all 32 calibrations from a file on the thumb drive.

7. 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).

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.

Fig 7.1 Leak Test Procedure

Surface Electronic Assembly Maintenance
All this will change

The Surface Electronic Assembly consists of:

1) Surface PC-Assembly
2) Battery Pack
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

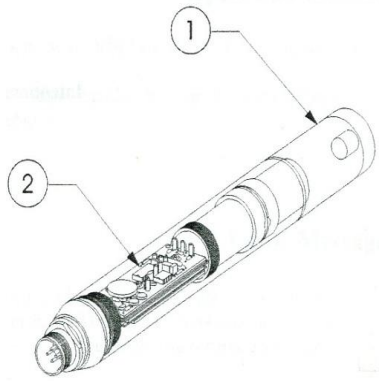


Fig 7.2 Probe Assembly

Removal

The Probe Electronic Assembly is easily removed from the Source Tube Assembly. As shown in Figure 7.2, 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.

The Probe Electronic Assembly consists of the connector, brass plug housing a ferrite transformer, an amplifier PC-Assembly, and

an HVPS PC-Assembly. Both of these are mounted on a tray and the detector tube itself. These items are shown in Figure 7.2.

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.

8. Operation Precautions

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.

9. Troubleshooting

Overall Operation

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

10. Print Data/Transfers

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 download project data and get it from probe to computer:

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 Dump Software.

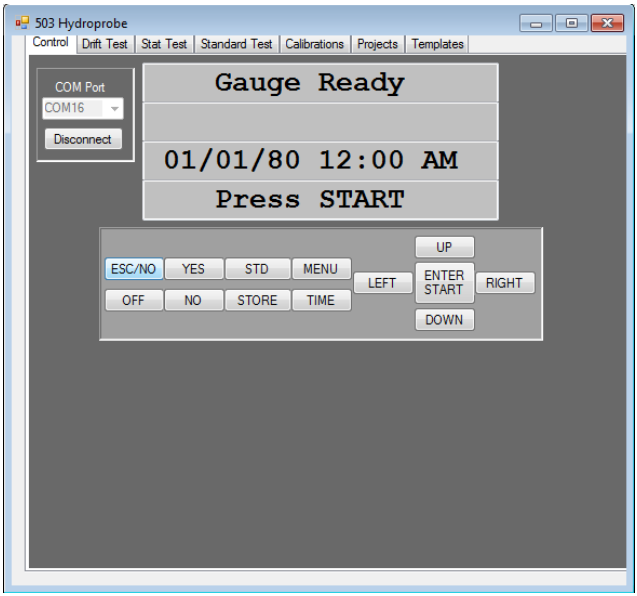
The program specifications that pertain to the gauge are:

- 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 XP, 7, 10, and Higher

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.



11. Standard Count Information

The standard count is a measurement of the neutrons which have lost significant energy by collision with the hydrogen in the wax 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. This must be less than 2.0%.

This is calculated using the equation:

(COUNT – AVERAGE) / AVERAGE * 100.

Where
COUNT = the daily or the last Standard Count taken

AVERAGE = the average of the previous 4 Standard Counts

The 503 Elite program uses the new standard to calculate moisture count in the field by using (measured count/standard count).

Note: When you first receive the gauge, take 4 standard counts and accept each standard to obtain a good Average.

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 and can be printed by selecting items 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 average 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 are 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.

12. 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.

Figure 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 calculations:

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

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*

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.

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

Fig D.1

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

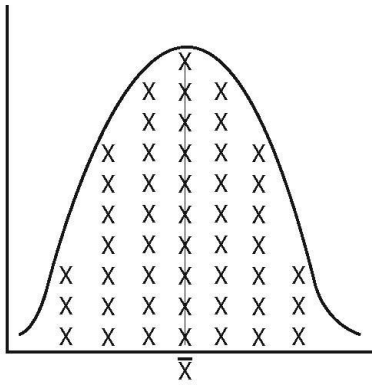


Fig D.2

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

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

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

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

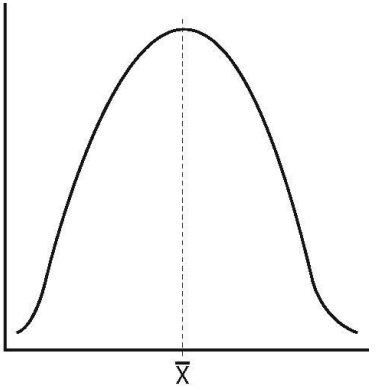


Fig D.3

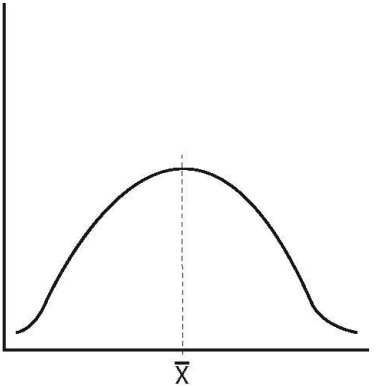


Fig D.4

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.

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

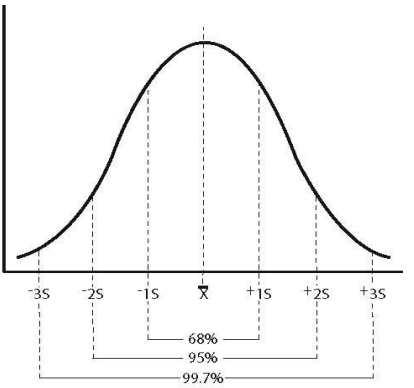


Fig D.5

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 503 Elite 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:

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

In this equation, ***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.

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

In this equation, χ^2 is from the Chi-squared tables.

By substituting the expected standard deviation with the square-root of the average count $\left(\sigma = \sqrt{\bar{x}}\right)$; 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 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 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.

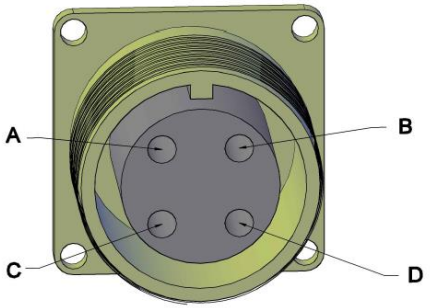
EXAMPLE:

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.

13. Connector 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



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.

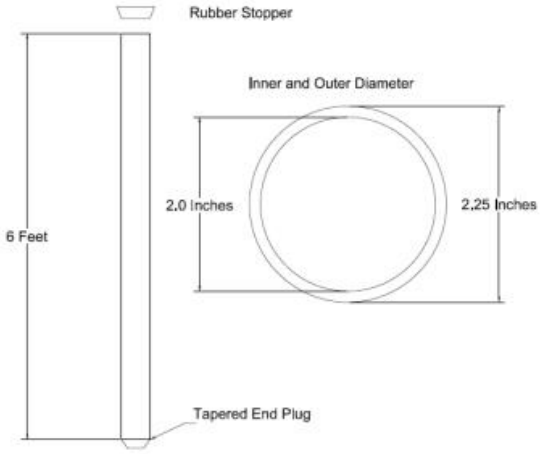
Steel: Carbon and Stainless

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

PVC Schedule 125

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

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



Aluminum Access Tube Assembly PN 704362

14. Excel Spreadsheet

InstroTek/CPN HydroProbe 503												
SN:000000	1/1/1980	12:00 AM										
Proj2Field												
Stations:	2											
Note:	This is a note Tube 1											
Note:	This is another											
Tube#	Tube ID	MC #	Cal #	Cal ID	A	B	Cal Units	STD	MC	Ratio	M%	M% Units
1	Tube 1	1	1	Alpha	1.3456	-0.0098	g/cc	1439	1529	1.062543	1.419958	g/cc
		2	1	Alpha	1.3456	-0.0098	g/cc	1439	1563	1.086171	1.451752	g/cc
		3	1	Alpha	1.3456	-0.0098	g/cc	1439	1526	1.060459	1.417153	g/cc
		4	1	Alpha	1.3456	-0.0098	g/cc	1439	1533	1.065323	1.423699	g/cc
		5	1	Alpha	1.3456	-0.0098	g/cc	1439	1523	1.058374	1.414348	g/cc
		6	1	Alpha	1.3456	-0.0098	g/cc	1439	1566	1.088256	1.454557	g/cc
		7	1	Alpha	1.3456	-0.0098	g/cc	1439	1501	1.043085	1.393776	g/cc
		8	1	Alpha	1.3456	-0.0098	g/cc	1439	1543	1.072272	1.43305	g/cc
		9	1	Alpha	1.3456	-0.0098	g/cc	1439	1511	1.050035	1.403127	g/cc
		10	1	Alpha	1.3456	-0.0098	g/cc	1439	1528	1.061849	1.419023	g/cc
Note:	Sunny today											
2	Tube 2	1	1	Alpha	1.3456	-0.0098	g/cc	1439	1551	1.077832	1.440531	g/cc
		2	1	Alpha	1.3456	-0.0098	g/cc	1439	1504	1.04517	1.396581	g/cc
		3	1	Alpha	1.3456	-0.0098	g/cc	1439	1567	1.088951	1.455492	g/cc
		4	1	Alpha	1.3456	-0.0098	g/cc	1439	1512	1.05073	1.404062	g/cc
		5	1	Alpha	1.3456	-0.0098	g/cc	1439	1511	1.050035	1.403127	g/cc
		6	1	Alpha	1.3456	-0.0098	g/cc	1439	1539	1.069493	1.429309	g/cc
		7	1	Alpha	1.3456	-0.0098	g/cc	1439	1545	1.073662	1.43492	g/cc
		8	1	Alpha	1.3456	-0.0098	g/cc	1439	1543	1.072272	1.43305	g/cc
		9	1	Alpha	1.3456	-0.0098	g/cc	1439	1520	1.056289	1.411543	g/cc
		10	1	Alpha	1.3456	-0.0098	g/cc	1439	1529	1.062543	1.419958	g/cc

15. Appendices

Appendix 1: Sample Bill of Lading

Bill of Lading

Shipper:
ABC Company, Inc.
1234 John Smith Rd
Raleigh, NC 27617

RQ, UN 3332, Radioactive Material, Special Form, NON FISSILE OR FISSILE
EXCEPTED, 7
Type "A" Package, Containing:

Am-241:Be, 1.85 GBq (50 mCi)

Radioactive Yellow II Label, TI=0.2

********EMERGENCY CONTACT********

1-800-535-5053

Shipper

_____

(Signature)

Appendix 2: Emergency Response Information

Nuclear Gauge Emergency Response Information for Transportation

Reference DOT ERG 2016 pg 266-267 Guide 164, and 49CFR

Potential Hazard

1) Proper Shipping Name

- UN3332 Radioactive Material Type A Package, special Form, 7, RQ

2) Health Hazards

- Radiation presents minimal risk to transport workers, emergency response personnel and the public during transportation accidents. Packaging durability increases as the potential hazard of radioactive content increases.
- Undamaged packages are safe; contents of damaged packages may cause external radiation exposure and much higher external exposure if contents (source capsules) are released.
- Contamination and internal radiation hazards are not expected, but not impossible.
- Packages (cartons, boxes, drums, articles, etc.) identified as "Type A" by marking on packages or by shipping papers contain non-life endangering amounts. Radioactive sources may be released if Type A packages are damaged in moderately severe accidents.
- Type B packages, and the rarely occurring Type C packages, (large and small, usually metal) contain the most hazardous amounts. They can be identified by package markings or by shipping papers. Life-threatening conditions may exist only if contents are released or package shielding fails. Because of design, evaluation, and testing of packages, life endangering releases are not expected in accidents except those of utmost severity.

- Radioactive White-I labels indicate radiation levels outside single, isolated, undamaged packages are very low (less than 0.005 mSv/h (0.5 mRem/hr)).
- Radioactive Yellow-II and Yellow-III labeled packages have higher radiation levels. The transport index (TI) on the label identifies the maximum radiation level in mRem/h one meter from a single, isolated, undamaged package.
- Radiation from the package contents, usually in durable metal capsules, can be detected by most radiation instruments.
- Water from cargo fire control is not expected to cause pollution.

3) Fire or Explosion

- Packaging can burn completely without risk of content loss from sealed source capsule.
- Radioactivity does not change flammability or other properties of materials.
- Radioactive source capsules and Type B packages are designed and evaluated to withstand total engulfment in flames at temperatures of 800°C (1475°F) for a period of 30 minutes.

Public Safety

- **CALL EMERGENCY REPSONSE Telephone number on Shipping Paper first. If Shipping Paper is not available or there is no answer, refer to the appropriate telephone number listed on the inside back cover of the DOT Emergency Response Guidebook.**

EMERGENCY RESPONSE PHONE #:1-800-535-5053 (US & Canada)
1-352-323-3500

- **Priorities for rescue, life-saving, first aid, fire control and other hazards are higher than the priority for measuring radiation levels.**
- Radiation Authority must be notified of accident conditions. Radiation Authority is usually responsible for decisions about radiological consequences and closure of emergencies.
- As an immediate precautionary measure, isolate spill or leak area for at least 25 meters (75 feet) in all directions.
- Stay upwind, uphill and/or upstream.
- Keep unauthorized personnel away.
- Delay final cleanup until instructions or advice is received from Radiation Authority.

4) Protective Clothing

- Positive pressure self-contained breathing apparatus (SCBA) and structural firefighters' protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.

5) Evacuation

Large Spill

- Consider initial downwind evacuation for at least 100 meters (330 feet)

Fire

- When a large quantity of this material is involved in a major fire, consider an initial evacuation distance of 300 meters (1000 feet) in all directions.

6) Fire

- Presence of radioactive material will not influence the fire control processes and should not influence selection of technique.
- Move containers from fire area if you can do it without risk.

- Do not move damaged packages; move undamaged packages out of fire zone.
- Small Fires:
  - Dry chemical, CO_2 water spray or regular foam.
- Large Fires:
  - Water spray, fog (flooding amounts)

7) Spill or Leak

- Do not touch damaged packages or spilled material.
- Damp surfaces on undamaged or slightly damaged packages are seldom an indication of packaging failure. Contents are seldom liquid. Content is usually a metal capsule, easily seen if released from package.
- If source is identified as being out of package, **DO NOT TOUCH.** Stay away and await advice from Radiation Authority.

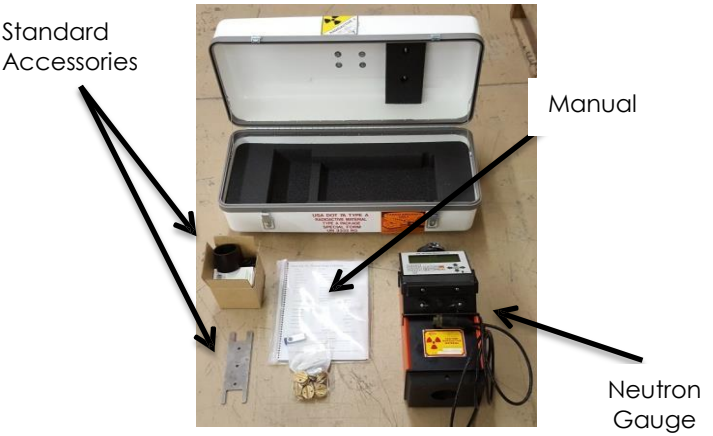
8) First Aid

- Ensure that medical personnel are aware of the material(s) involved, take precautions to protect themselves.
- Call 911 or emergency medical service.
- Medical problems take priority over radiological concerns.
- Use first aid treatment according to the nature of the injury.
- Do not delay care and transport of a seriously injured person.
- Persons exposed to special form sources are not likely to be contaminated with radioactive material.
- Give artificial respiration if victim is not breathing.
- Administer oxygen if breathing is difficult.
- Injured persons contaminated by contact with released material are not a serious hazard to health care personnel, equipment or facilities.

Appendix 3: Closure Instructions for 503 Elite

Note: These closure instructions are for both orange and white cases. This case is certified for all version of the 503 series gauges.

1. The contents of the 503 package are shown below.



The gauge is part of the Type A Package. The Am241:Be is permanently affixed inside the source probe which is housed inside the gauge during non-use and transportation.

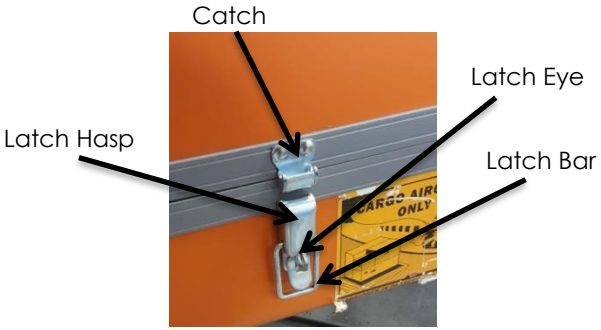
2. Placing the contents

The interior of the box has pre-formed sections for the placement of the gauge, standard accessories, and manual. The manual and other gauge related documents should be packed with the gauge by laying it over the neutron gauge arm.

3. Close the lid.

4. Fastening of the latches

A picture of the latch mechanism is shown below, note the three parts, the catch, the latch bar, and latch eye, and the latch hasp.



5. Place the latch bar into the catch as shown below. Make sure the latch bar is securely in the catch.

6. Push firmly down on the latch hasp until the latch eye is completely through the latch hasp.

7. In order to secure the latch, insert a wire tie or lock through the eye as shown below.

8. Secure the wire tie or lock as shown above. **You must make sure that the wire tie is of sufficient size that it will not slip through the slot in the latch hasp allowing the case to be opened.**

16. Index

A

Accessories 5

Americium 4, 5, 50

Appendices 65

B

Battery Life 5

Bill of Lading 65

C

Cable Stops 2, 5, 7

Calibration 15-17

Chi-squared 52, 59-60

Closure Instructions 70

Connector Pinouts 62

Control Software for Windows 49

Count Time 4, 9, 12-13, 39

Counting Statistics 53

D

Data Storage 35

Data Transfer 3

Dimensions 4

E

Emergency Response 66-67

Emergency Response Number 67
Encapsulation 5
Error Messages 45
Excel Spreadsheet 64

F

Features 3
Field Calibration 15
Full Project 25, 28, 32
Functional Description 4

G

Gauge Functions 9

H

Humidity 5

I

Inspection 7

L

Laboratory Calibration 17
Leak Testing 42
Logging and Projects 25
Logging Your Measurements 36

M

Maintenance 41
Manual Entry Calibration 23
Menu Items 37

N

Neutron Source 5

O

Operation 13

Operation Precautions..... 45

P

Performance 4, 47

Precision 4, 57-58

Print Data/Transfers 48

Probe Assembly 41, 43

R

Radiological 5, 68-69

Recall.....36-37

S

Self-Calibration 21

Simple Project 26, 37

Single Measurement Precision..... 57

Shielding..... 5

Shipping Requirements 6

Shipping Weights..... 4

Special Form Approval 6

Specifications..... 4, 48

Standard Count..... 9, 11

Standard Count Information..... 50

Storage.....3-5

Surface Electronic Assembly 41, 43

T

Taking a Reading 13, 25

Taking a Standard Count.....11, 51

Temperature 5

Operating 5

Storage..... 5

Transport Index.....67

Troubleshooting 12, 46

Tube Adapter Ring …….. 8

U

Units 5, 12, 14, 39

17. Warranty

InstroTek, Inc. extends a 2-year limited warranty on the Model MC 503 Elite Hydroprobe™ to the original purchaser of this equipment. This warranty covers defects in material, workmanship, and operation under the conditions of normal use and proper maintenance. This warranty includes all components except for the normal wear components including all accessories, shipping case, seals, batteries, scraper ring, and reference standard block.

InstroTek will replace, free of charge, any part found to be defective within the warranty period.

This warranty is void if inspection shows evidence of abuse, misuse, or unauthorized repair.

This warranty covers replacement of defective materials and workmanship only. It does not cover shipping charges, duties, or taxes in the transport to and from the factory or authorized service center.

InstroTek's liability is in all cases limited to the replacement price of its products. InstroTek shall not be liable for any other damages, whether consequential, indirect, or incidental arising from use of its product.

If return of the product is necessary, please include return shipping directions, contact name, phone & fax number and a description of the action needed.

Call InstroTek, Inc. for shipping details at (919) 875-8371.

Contact Information

Contact us for top quality, best value and superior service!

email: **sales@instrotek.com** ✦ visit: **InstroTek.com**

CALL A LOCATION NEAR YOU:

Headquarters: **Research Triangle Park, NC** phone: **919.875.8371**

Bensalem, PA phone: **215.645.1064** ✦ **Grand Rapids, MI** phone: **616.726.5850**

Denver, CO phone: **303.955.5740** ✦ **Austin, TX** phone: **512.452.8848**

Las Vegas, NV phone: **702.270.3885** ✦ **Concord, CA** phone: **925.363.9770**