product manual

# HS-5001NX

HS-5001NX_MAN_06.24


# Moisture-Density Gauge

## IMPORTANT NOTICE

The information contained herein is supplied without representation or warranty of any kind. Humboldt Scientific, Inc. therefore assumes no responsibility and shall have no liability, consequential or otherwise, of any kind arising from the use of the described equipment or radioactive materials and/or information contained in this manual.

Use of the supplied hammer and drill rod requires driving the rod into compacted soil or other hard materials and may cause damage to the user due to flying particles from the hammer, drill rod or the materials under test. Safety glasses must be utilized for this procedure.

See Section 9 for Equipment Warranty.

# Contents

# 1 GENERAL AND SPECIFICATIONS

## 1.1 Introduction

This Density/Moisture Gauge, the HS-5001NX, is specifically designed to measure the moisture content and density of construction materials.

The microprocessor-based unit automatically computes these parameters and makes corrections to the measurements.

It uses the attenuation of gamma radiation due to Compton scattering and photoelectric absorption. It is directly related to the electron density of materials as an indication of the mass density of specific materials having a chemical composition approximating the crust of the earth.

The standard factory supplied density calibration is based on a material consisting of 50% limestone and 50% granite as being very close to the average material encountered in engineering construction. This calibration may be altered by the user to best fit other materials, which may have a chemical composition vastly different from the supplied calibration.

The measurement of moisture content is based on the thermalization (slowing down) of fast neutron radiation. It is predominately a function of the hydrogen content of the materials, and to a lesser degree, by other low atomic number elements such as carbon and oxygen. The presence of chemical elements such as boron, which may absorb or capture thermal neutrons, will also have some effect on the accuracy. Hydrated minerals Gypsum or crystals such as mica may cause the largest single error. In general, a material containing hydrogen, which is not removed during an oven dry procedure, as outlined in ASTM D2216, will cause an error in the measurement.

The standard factory supplied moisture calibration is based on a water saturated silica sand standard, which is used to calibrate a working standard. The user, to correct for other materials, may alter the calibration.

**THIS INSTRUMENT CONTAINS RADIOACTIVE MATERIALS, WHICH MAY BE HAZARDOUS IF IMPROPERLY USED.**

HUMBOLDT recommends that users participate in a radiation safety and applications training program given by competent instructors. Where this is not possible or impractical, users should study the Radiation Safety Manual supplied with this instrument and carefully read this Instruction Manual to become familiar with the safe operation of the instrument.

A Radioactive or Byproduct Material License is required from an Agreement State or The US Nuclear Regulatory Commission for possession in the United States. The governments of other countries require a similar license.

Proper use of this equipment will have little effect on the total exposure of a typical operator to ionizing radiation. However, a potential danger does exist and any questions regarding this danger should be addressed to the Radiation Safety Officer within the owner's organization or other competent personnel.

Any theft or other loss and accidents to the equipment, which may involve the sealed sources of radioactive material, must be immediately reported to the Radiation Safety Officer.

## 1.2 Definitions

### 1.2.1 Precision

A statistical variation of repetitive measurements due to the binomial distribution of radioactive decay. The value used is the standard deviation of repetitive measurements. Sixty eight percent of repetitive measurements will fall within this limit and ninety five percent will fall within twice this limit. The value is changes with density and is stated at a density of 2000 kg/m³ (125 PCF).

Precision is not a percentage of the absolute density and thus cannot be converted directly to a precision at other densities. It can be computed at other densities by obtaining the absolute count rate and slope of the count rate at other densities (see 7.3).

Precision is a function of time and varies as the square root. Increasing the count time of the measurement by a factor of four will improve the precision by a factor of two.

### 1.2.2 Chemical Error

An error that is caused by the variations in the chemical composition of the material being tested. Gamma attenuation is a function of the electron density of materials and is thus related to both the mass and the ratio (A/Z) of the atomic mass (A) and the atomic number (Z).

The standard factory calibration is based on the average attenuation of a theoretical material consisting of half limestone and half granite. The chemical error is the spread ± of measurements made on these materials at a true density of 2000 Kg/m³ (125 PCF).

### 1.2.3 Surface Error

The error that is caused by surface voids. Per ASTM, the error is with the Gauge flush on a smooth surface and then repeating the measurement with the Gauge elevated 1.25mm (0.050 inch) over the surface. The difference in the two values is defined as "Surface error".

In actual field use, the streaming along the base of the Gauge could not take place since a portion of the Gauge base will always be resting on the material surface and the streaming will be broken up. As a result, even under extremely adverse conditions, the error would be less.

### 1.2.4 Depth of Measurement

The depth of measurement is defined as the depth above which 95% of measurement occurs. The balance of (5%) is determined by material below stated depth. This is an important parameter of a Backscatter type Gauge since a deeper depth of measurement reduces the error caused by surface voids.

### 1.2.5 Units of Measurement

Where "density" and "moisture content" are used in the SI system of measurement, the absolute units of kilograms per cubic meter are utilized. Conversions to the US Customary system have been made using pounds per cubic foot (pcf). This is a gravitational system of measurement by multiplying by 0.06243. Conversion to the SI gravitational system may be made by multiplying by 9.807 to obtain kilonewtons per cubic meter. It is common practice to refer to these units in the gravitational system as "unit weights" and to those units in the absolute system as "densities".

## 1.3 Specifications

### 1.3.1 Density Measurement

Backscatter Density at 2000 kg/m³ (125 pcf)

| | | SLOW 4 min | NORMAL 1 min | FAST 15 sec |
|---|---|---|---|---|
| Precision | kg/m³ (pcf) | ± 4 (0.25) | ± 8 (0.5) | ±16 (1.0) |
| Chemical Error | kg/m³ (pcf) | ±40 (2.5) | ±40 (2.5) | ±40 (2.5) |
| Surface Error | kg/m³ (pcf) | - 48 (3.0) | - 48 (3.0) | - 48 (3.0) |
| Depth | mm (inch) | 88 (3.5) | 88 (3.5) | 88 (3.5) |

Direct Transmission Density at 150 mm (6 inch)

| | | SLOW 4 min | NORMAL 1 min | FAST 15 sec |
|---|---|---|---|---|
| Precision | kg/m³ (pcf) | ± 2 (0.13) | ± 4 (0.25) | ± 8 (0.5) |
| Chemical Error | kg/m³ (pcf) | ±16 (1.0) | ±16 (1.0) | ±16 (1.0) |
| Surface Error | kg/m³ (pcf) | - 8 (0.5) | - 8 (0.5) | - 8 (0.5) |
| Depth | mm (inch) | 50 to 300 (2 to 12) | 50 to 300 (2 to 12) | 50 to 300 (2 to 12) |

### 1.3.2 Moisture Measurement at 160 kg/m³ (10 pcf)

| | | SLOW 4 min | NORMAL 1 min | FAST 15 sec |
|---|---|---|---|---|
| Precision (pcf) | kg/m³ | ± 2 (0.13) | ± 4 (0.25) | ± 8 (0.5) |
| Surface Error | kg/m³ (pcf) | - 4 (0.25) | - 4 (0.25) | - 4 (0.25) |
| Depth (inch) | mm | 100 to 200 (4 to 8) | 100 to 200 (4 to 8) | 100 to 200 (4 to 8) |

### 1.3.3 Calibration Method

The Gauges are calibrated in accordance with the method recommended by ASTM D6938, D7759, D2950 and AASHTO 310. Five density standards consisting of three metallic blocks of Magnesium, Magnesium/Aluminum and Aluminum and two mineral blocks of Granite and Limestone to cover the measurement range of 1100 to 2700 kgm³ (70-170 PCF). The density of these standards has been determined to an accuracy of better than ±0.1%. The working moisture standard has been calibrated against saturated silica sand with an accuracy of better than ±0.5 % to cover the measurement range of 0 to 640 kgm³ (0-40 PCF).

Four entirely different calibrations are available to the engineers or technicians controlling the use of the Gauge, but they are not accessible to the operator without the use of a password. Two of these are adjustments to the main calibrations to compensate for materials widely different from normal soils. No additional equipment is required for the adjustment other than a sample of the material at a known density. No additional equipment is required for an entirely new calibration other than a suitable set of standards.

Count rate data is converted to densities using USNIST gamma attenuation coefficients and the known density of the standards.

### 1.3.4 Field Data Conversion

| | | |
|---|---|---|
| Wet Density | and | % Compaction (Marshall) |
| Dry Density | and | % Compaction (Proctor) |
| Moisture Content | and | % Moisture |
| Void Ratio | and | % Air Voids |

### 1.3.5 Radiological

| | |
|---|---|
| Gamma Source | HSI 2200064 |
| Amount and Type of Material | 0.37GBq (10mCi) Cesium 137 |
| Special Form Registration | USA/0634/S-96, USA/0356/S |
| ISO / ANSI Classification | C66546 |

| | |
|---|---|
| Neutron Source | HSI 2200067 |
| Amount and Type of Material | 1.38GBq (40mCi)<br>Americium-241:be |
| Neutron Yield | 90 knps (nom) |
| Special Form Registration | CZ/1009/S-96 |
| ISO / ANSI Classification | ANSI 77C66545 |
| Surface Dose Rate | 18.7 mrem/hour maximum |
| Transit Case | DOT 7A, Type A, Yellow II Label,<br>0.2 TI |

A Radioactive or By Product Material License is required from an Agreement State or The US Nuclear Regulatory Commission for possession in the United States. The governments of other countries require a similar license

### 1.3.6 Electrical Specifications

| | | |
|---|---|---|
| Displays: | | TFT; Normal Color, Sunlight Readable |
| Timer Stability: | | 0.01% Power Supply |
| Stability: | | 0.10% |
| Power Source: | | NiMH Rechargeable 7 cells or (6) alkaline AA batteries |
| Power Consumption: | | Battery life is only an estimate, power settings and individual operation of the gauge will greatly affect the life of the batteries |
| Processor: | | |
| | Idle: | 1.7 mA @ 8 volts<br>13.6 milliwatts<br>1470 Hours Battery Life – AA<br>2650 Hours Battery Life – NiMH |
| | Active: | 32 mA @ 8 volts<br>255 milliwatts<br>78 Hours Battery Life – AA<br>140 Hours Battery Life – NiMH |
| | Backlight On: | 65mA @ 8 volts<br>520 milliwatts<br>38 Hours Battery Life – AA<br>70 Hours Battery Life – NiMH |

Power Protection: Resettable Fuse

Short Circuit Proof

Auto Alarm for low battery condition

Auto shutoff for dead battery condition

### 1.3.7 Mechanical Specifications

#### 1.3.7.1 Materials

| | |
|---|---|
| Source Rod: | 440C Stainless Steel, induction heat-treated to 55 Rockwell C. |
| Index Rod: | 7075 Aluminum, hard coated and PTFE impregnated. |
| Gauge Base: | Machined 6061-T6 Aluminum, hard coated and PTFE-impregnated. |
| Post and Frames: | Machined 6061-T6 Aluminum, anodized for anti-corrosion. |
| Top Shell: | Injection Molded Noryl. |
| Bearing: | Relieved bronze with neoprene seals. |
| Screws/fittings: | Stainless/brass, no steel. |
| Operating Temp.: | 10 to 70 °C, 175 °C Test Material Surface. |
| Storage Temperature | -55 to 85 °C |
| Humidity: | 98% without condensation, Rain proof construction. |
| Vibration: | 2.5 mm (0.1 in) at 12.5 Hz |
| Shock Unpadded: | Gauge meets USDOT 7A without transit case. |

#### 1.3.7.2 Gauge

| | |
|---|---|
| Size (excluding handle): | 400 x 220 x 140 mm (15.75 x 8.66 x 5.5 in) |
| Height (with handle): | 450 or 550 mm (18 or 21.6 in) |
| Weight: | 13.6 kg (30 lbs.) |

#### 1.3.7.3 Reference Standard

| | |
|---|---|
| Size: | 350 x 200 x 75 mm (25 x 7.8 x 3 in) |
| Weight: | 4.5 kg (10 lbs.) |

#### 1.3.7.4 HS-5001 Series Transit Case

| | |
|---|---|
| Size: | 600 x 495 x 356 mm (26 x 14 x 19.5 in) |
| Weight: | 11.8 kg (26 lbs.) |

### 1.3.7.5 Zippered Accessory Case (loaded)

Size: 500 X 250 X 125 mm (19.7 x 9.8 x 5 in)

Weight: 8.2 kg (18 lbs.)

### 1.3.7.6 Total Shipping

Weight: 41 kg (89 lbs.)

### 1.3.8 Accessories

Transit Case

Reference Standard

Operator's Manual

Radiation Safety Manual

Source and Case Certification

Wipe Test Materials

Zippered Accessory Case

Rod Guide/Scraper Plate

Drill Rod

Four Pound Hammer

Rod Extraction Tool

## 2 Equipment Description

Before using this equipment, the operator should be thoroughly familiar with the Radiation Safety Manual supplied with the instrument. If possible, a suitable course in the safe use and field application should be attended.

Users who desire knowledge regarding the theory of operation of the equipment should refer to Section 7.0. This information will be helpful in understanding, the limitations of the equipment and how to avoid or work around these limitations.

### 2.1 Zippered Accessory Case

Zippered Accessory Case Containing:

Rod Guide/Scraper Plate
Drill Rod
Four-Pound Hammer
Rod Extraction Tool

The accessories may be carried in the transit case or may be carried in a zippered canvas bag. It is convenient to carry and decreases the bulk and weight of the transit case, which contains the Gauge, Reference Standard and Manuals.

### 2.1.1 Scraper Plate / Rod Guide

When the Gauge is to be used on soil, the Scraper Plate is used to smooth the site to eliminate as many surface voids as possible. Two convenient handles are located so that it may be used to scrape away loose material.

The two handles are also used as a guide when driving the rod into soil or soil aggregates for a direct transmission density measurement. The operator or a helper can stand on the plate to prevent it from shifting while the rod is hammered.

The plate is the same size as the Gauge base, and if the rod is used to mark lines around it, then the Gauge can then be approximately located over the rod hole before attempting to lower source rod into the hole.

The plate may be used to lightly tamp soil or native fines that may have been used to fill the surface voids. It should not be used with the hammer to pack soil since it may distort the plate and cause erroneous measurements.

### 2.1.2 Drill Rod

The Drill Rod is a medium hardness tough steel and has a captive head to allow it to be driven into soil or soil aggregates so that the source can be placed into the material for a direct transmission density measurement. The rod is marked so that the depth can be controlled by reference to the top of the Scraper Plate handle.

Use of the rod in stiff clays may require the application of the extraction tool for removal. It must not be driven or moved sideways as this will enlarge the hole or modify the density of the material being tested.

The rod is expendable and must be replaced after extensive or severe use. Repeated hammering of the cap may cause metal chips to break away and the operator and others close by the test site must wear safety glasses

### 2.1.3 Four-Pound Hammer

The hammer is supplied to drive the rod into soils or soil aggregates, and it may be used with the extraction tool to help remove the rod from clay. It is sufficiently heavy for this purpose and a larger hammer is not needed since it could rapidly damage the Drill Rod.

### 2.1.4 Extraction Tool

This tool is used to assist the removal of the Drill Rod if it becomes stuck in clay or granular material. The usual problem is a vacuum, which can exist in the hole when attempting to pull the rod out.

It does not have to be put into place before driving the rod. A slot in the middle is placed on a square, which is cut in the Drill Rod head. The arms may then be used to rotate the rod and will make it easier to extract by supplying handles to pull up on the rod. If necessary, the hammer may be lightly topped on the underside of the tool to drive the rod up out of the hole.

## 2.2 HS-50001 Transit Case

Containing: Gauge
Reference Standard
Operator's Manual
Radiation Safety Manual

Both the Gauge and the Transit Case are supplied with locks and they should be secured when the instrument is not in use or attended. When stored, the equipment should be placed in a locked room or area, which is dry and maintained at a livable temperature. Storage below 20°C should be avoided and temperatures above 30°C for extended periods of time will deplete the batteries at a rapid rate and shorten their useful life.

### 2.2.1 Transit Case

The Transit Case is a rotational molded high strength, plastic case and is equipped with a lockable latch. The design and components follow the standard ATA case configuration that is in popular use for air shipment of delicate instruments. It has fitted compartments for the Gauge, Reference Standard and accessories along with a storage area for engineering note-books and manuals. It has been tested to US DOT 7A Type A requirements and has labels, which meet both International and US requirements, for surface and air cargo shipment.

### 2.2.2 Reference Standard

The Reference Standard is used to provide a standard count to account for aging of the calibration. Instruments, which use radiation to perform measurements, are subject to decay of the source (2.3% per year for Cs 137) drift of the detectors due to leakage and absorption of quench gas, and long-term drift of the electronics. To decrease the effect of these errors, the calibration is made as a ratio to a standard measurement. The moisture count is a ratio to a moisture count on the standard and the density count is a ratio to a density count on the standard. The hydrogen in the reference standard determines the moisture standard count. The density standard count is determined primarily by the shielding material in the base of the Gauge and only slightly by the Reference Standard. The Reference Standard is serialized to match the Gauge and they must not be interchanged between Gauges or moisture measurement errors may exist

### 2.2.3 Gauge HS-5001NX

The HS-5001NX -type Gauge utilizes an alphanumeric LCD touch screen, state of the art electronic circuits to generate the necessary timing circuit, and power supplies. The processor automatically compensates for the abnormal gamma attenuation coefficient for hydrogen as compared to the values of higher atomic numbered materials found in soils. Using the current standard count, it also compensates for the decay of the Cesium source. It also allows the operator to enter a correction factor (KVAL) to compensate for hydrogen found in construction materials, which is not represented by water.

The lettering is embedded in the plastic overlay and is not harmed by water or abrasion. Since there are many functions available, a description of the purpose for each key is necessary.

**NOTE:** When you first receive your new HS-5001**NX** the main power will be turned off for shipping. The motherboard will have a three-position switch located at the center top of the board. Sliding the switch to the bottom or top position will power up the base plane. The center position is the off position.

| | |
|---|---|
| | **TOP – NiMH Battery Pack** |
| **POWER SWITCH** | **MIDDLE – OFF** |
| | **BOTTOM – AA Batteries** |

**2.2.3.1 Auto Depth Indication**

The Gauge will indicate the position of the handle (source location). The method used is totally enclosed and not subject to wear by abrasive materials on a job site. It should be as reliable as any other part of the Gauge and not require periodic replacement. In case of failure, an alternate manual method of indicating the depth to the microprocessor is available.

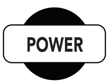
**2.2.3.2 Data Storage and Dumping**

The Gauge utilizes an 8GB micro-SD card. It will store complete field tests including date, time, project number, station, offset, and all the measurement data including standard and measurement counts, depths, soil / asphalt / nomograph and any corrections applied to factory calibrations. This data can be dumped to a USB, which provides a convenient way to capture test data and take it with you, as well as provide an easy way to upgrade the gauge's firmware. Firmware upgrades will be available via the internet from our website.

**2.2.3.3 Front Panel Touch Screenand Keypad**

All data entry, function selections, and other options are available via a 10 key membrane keypad at the front panel. Each time a key is pressed, a short beep indicates that the key press has been recognized. The key must be pressed and released for the action to take place.
Each key can have multiple actions, corresponding to the currently selected instrument function. The actual functions are all described in Section 3 Field Operation.


### On/Off (Power)




When the **POWER** key is pressed the Gauge powers up, and then runs through self-test routines. The battery test included in the self-test routines is also performed at various times in use (transparent to the operator) so that constant monitoring of battery condition is done. After this test, the Gauge condition at the time of the last use is loaded from memory. If it was turned off with an active measurement in the registers, the measurement is recalled.

### Backlight


When the **BACKLIGHT** key is pressed, the display panel lights up, for night viewing. Pressing the **BACKLIGHT** key again will toggle the light off.

**Note:** The **BACKLIGHT** key can be set to **STATIC** mode or **PERCENT** mode.
**STATIC** mode will toggle the backlight on and off.
**PERCENT** mode will cycle through five different brightness.

### Maximum Density


The **MAX "D"** key allows entry of information pertaining to characteristics of the material under test. MAX D is the target density for percent compaction. For soil, it is normally a value based on a laboratory Proctor test. For asphalt, it is a value based on a laboratory Marshall density or maximum theoretical density. The value set into this register must never be set to a value outside the range of normal soil or asphalt densities. Anything between 900 kg/m³ (56 PCF) and 3000 kg/m³ (200 PCF) will not cause processor errors. It must never be set to 0.0.

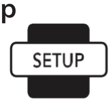
### Standard/Statistical


The STD / STAT key initiates a 4- or 16-minutes count of both the moisture and density channels when the handle is in the SAFE position.
It retains the values so that they can be used to ratio all the subsequent measurement counts.

### Measurement


This key initiates a measurement using a 4-minute, 1-minute or 0.25-minute periods as previously selected. The actual counts are displayed on the screen and the time remaining during the measurement. After completion of the measurement, the dry density (**DD**), wet density (**WD**), moisture (M), percent moisture (**%M**), percent proctor (**%PR**) are displayed, if the Gauge is in the soil mode. Wet density (**WD**) or total density, % Marshall (**%MA**) if in the asphalt mode. Any of the other parameters may be successively obtained by pressing the appropriate key.

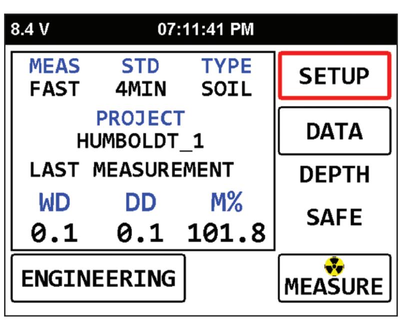
### Setup




This key has a customizable menu setting allowing the user to select which menu will display when the key is pressed. There are five selectable preset menus available to choose from. For example, if you are using the **MEASURE MODES** menu frequently, you could preset this menu to the **SETUP** key to jump to this menu quickly.

**NOTE:** This is referring to the **SETUP** key on the overlay and not the **SETUP** icon on the touchscreen.

Shown below is the **MAIN MENU**:




More details about the touchscreen menus will be described later in this manual.

## 3. Field Operation

This chapter will describe the proper use of the equipment during the process of making field measurements on soils, soil aggregates, treated bases, or asphaltic concrete. It is assumed that the user has read the previous chapter and understands the functions of the various keys. The operator should have had training in radiation safety or thoroughly read the **RADIATION SAFETY MANUAL** supplied with this instrument and understand the basic principles of minimizing his/her exposure.

### 3.1 Transportation of the Equipment

The Gauge and Reference Standard should be transported in its Transit Case, which is designed for this purpose. The Gauge lock and the Transit Case lock should be in place and secured. In case of an accident to the vehicle, the locks prevent unauthorized access to the radioactive material and the case will help protect the equipment from damage. The Zippered Accessory Case will prevent loss of its items and if an automobile is used, it will protect the trunk space.

If transport is made by automobile, the Transit Case and Gauge should be placed in the trunk to keep it as far away from passengers as possible. Van location should be toward the rear and the case secured to prevent shifting. In open trucks, means must be taken to prevent shifting and unauthorized removal.

### 3.2 Standardization of the Gauge

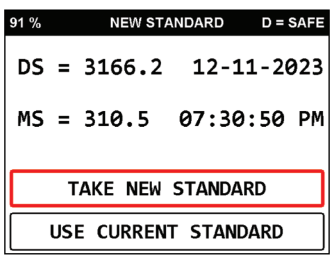
Prior to use of the Gauge, a set of **STANDARD COUNTS** must be taken and used for all of the measurements to be made on a particular day. These counts should be logged for verification of proper operation and provide a history for service if required, Remove the Gauge lock and make certain that the handle is latched in the "**SAFE**" position. It must be in the top position of the index rod.

***Important notice: The Reference Standard and bottom surface of the Gauge must be clear of any debris that would prevent the Gauge from seating firmly on the Reference Standard. Place the Reference Standard on compacted material, place the Gauge on the Reference Standard with the handle end of the Standard away from the operator. The Gauge must be seated inside the guide rails along the edges of the Standard, and the back of the Gauge up against the handle of the Reference Standard.***

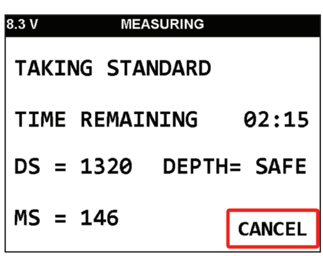
To begin the standard counts procedure from the main menu display, or from any other menus.

Press the **STD/STAT** to begin the standardization procedure.

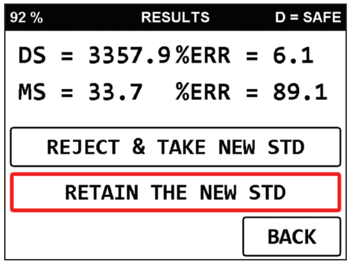
Where **DS** and **MS** are the values of the last density and moisture standard take on date **MM/DD/YYYY** and time **HH:MM:SS**.
Press **TAKE NEW STANDARD** to begin the 4-minute standard.



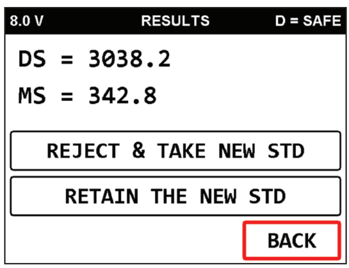

The display will show:



After the standard count has completed, the display will show the new standard with % error derived from the last four standard counts. If the errors are outside these limits refer to the important notice above. If the above conditions are normal, then press **RETAIN THE NEW ST**D and take a new standard as above in 3.2. Repeat taking new standard for a maximum of four times to reduce to within the limits.



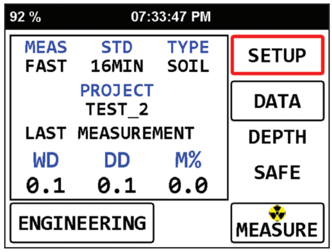

If the error is below 1% and 2% for DS & MS respectively then the display will show just the DS and MS counts as seen below:



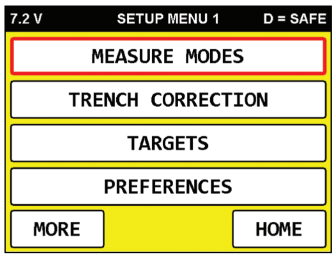

**NOTE:** It is important to **RETAIN THE NEW STANDARD** before running another 4-minute standard.

There are two methods of taking the Standard Reference Counts. The quickest is using the above procedure, which takes four minutes. The four minutes counter indicates the amount of time remaining before the end of the count. At the end of four minutes, the two count values are stored in the DS and MS registers. The second method is the statistical standard test. The Gauge will take 16 one-minute counts and store each 1-minute value. After 16 minutes, the averages of the 16 counts are stored in the DS and MS registers. A statistical test would then have been run on the 16 individual counts and an “R” value displayed for both DS and MS. These values should fall between 0.5 and 1.5. If they are only slightly out, another test may be made but if the value is greatly outside the 0.5 to 1.5 limits, service is needed. To run the statistical standard test:

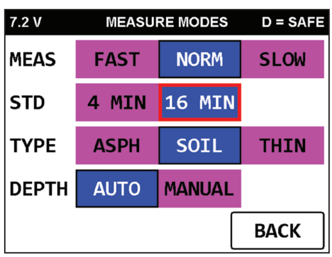
Press **SETUP** on the display to enter **SETUP MENU 1**



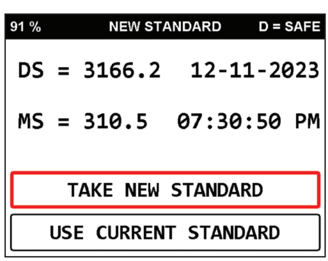

The display will show:



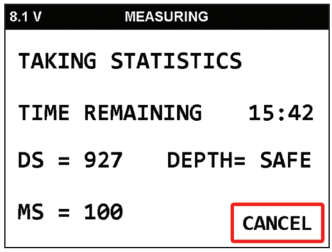

Press **MEASURE MODES** to enter **MEASURE MODES** menu.



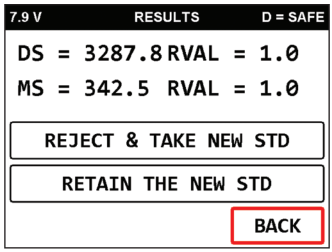

Press 16 MIN to change the **STANDARD** mode to **STATISTICAL** mode and press the **STD/STAT** button to jump to the **NEW STANDARD** menu as shown below:



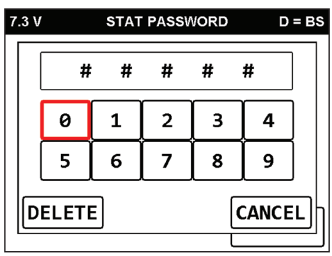

Press **TAKE NEW STANDARD** on the display




After the 16-minute Statistical is done measuring you should see the following on the display:



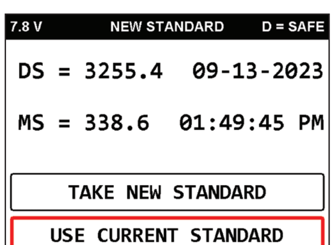

The 16-Minute **Statistical Standard** test can also be performed at different depths if required. Set the rod to the desired depth first and press **STD/STAT**, the following password screen will appear:




**The password is 33344.**

**Note:** Once the correct password has been entered, the menu will remain unlocked until the power has been cycled.

After the password has been entered the following screen will appear. Using the same methods as described previously, the new standard counts can now be taken.



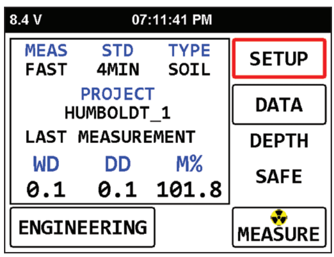
## 3.3 Entry of Pre-Test Data

While not required to make simple moisture and density measurements, certain parameters of the material must be entered to utilize the full potential of the **HS-5001NX** Gauge.

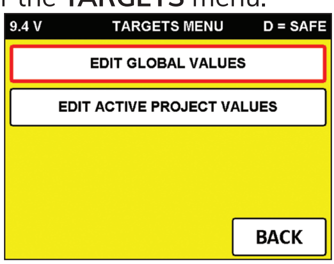
### 3.3.1 Maximum Density

For any type of material, the maximum density is required to calculate the percentage of compaction. For soils, this is normally a laboratory Proctor density and for asphaltic materials, the Marshall or a maximum density is used. The degree of compaction is based on a percentage of the proctor (**%PR**) and is a function of the measured dry density that is obtained from the result screen after a successful measurement. For asphaltic materials, the percentage of the Marshall (**%MA**) is a function of the wet density or total density.

Press **SETUP** on the display to advance to the **SETUP MENU 1**.




Press **TARGETS** to enter the **TARGETS** menu.




**NOTE:** Pressing the MAX D key from any screen will jump to the **TARGETS** menu.

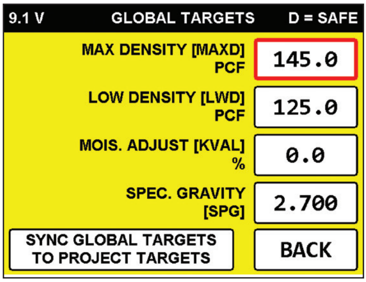
Press **EDIT GLOBAL VALUES** to enter the Global Values Menu

**NOTE:** There are two types of **TARGETS, GLOBAL TARGETS** and **PROJECT TARGETS**.

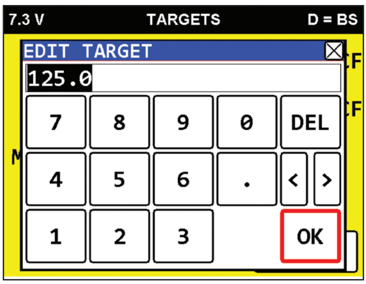
**GLOBAL TARGETS:** These target values will be used if no active project is selected.

**PROJECT TARGETS:** These target values can be used for specific projects and will only be used on that project.

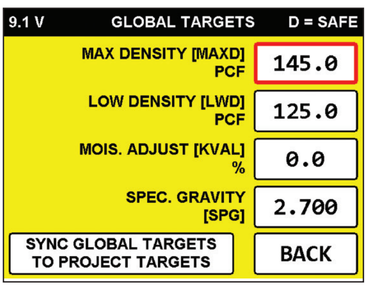
There are multiple ways to edit the target values. You can edit the targets directly in the project menu, or if you already created a project and want to edit the targets you can set the targets in the global targets menu and use the sync global target to project targets which will update only the active project.




To edit the **MAX DENSITY**, touch the value on the screen and the EDIT TARGET keypad will pop up as shown below:




Press **OK** on the screen when you have entered the desired target value.




Once the Target values are set be sure to press the **BACK** button to save any changes that you have made.

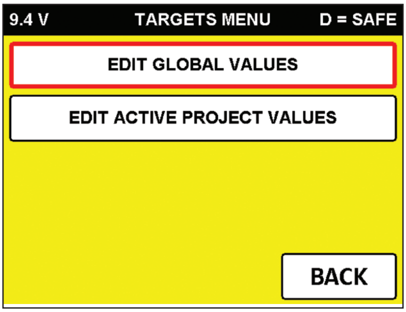
### 3.3.2 Moisture Correction Factor (%KVAL)

KVAL is a correction factor to be applied to the moisture measurement to account for hydrogen in the material that is not water, or water that was not removed by normal oven drying methods. A value of -1.00 would reduce the computed percent of water by roughly 1%. Typical values are between -1.00 and +2.00. If unknown, always set the value to 0.0.

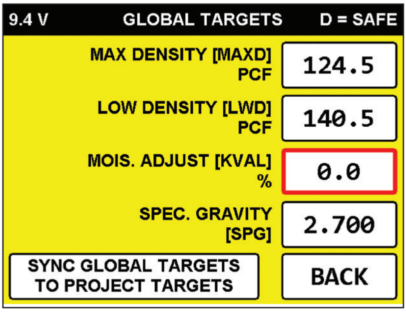
Press the 

key to jump to the **TARGETS** menu.

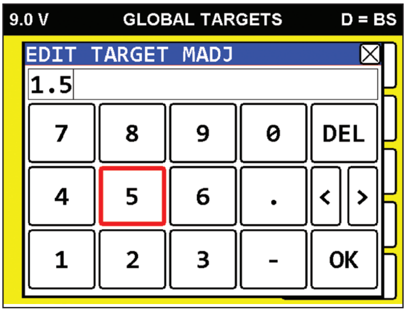
Press **EDIT GLOBAL VALUES** to enter the Global Values Menu




Press the **MOIS. ADJUST [KVAL]** value on the screen and the **EDIT TARGET** keypad will pop up as shown:




Press **OK** on the screen when you have entered the desired target value. Press the **BACK** button on the next screen to save the changes.




The value entered will affect the computed values of **MOISTURE CONTENT** (M), **DRY DENSITY** (DD), and **PERCENT MOISTURE** (%M).

There are three methods of determining the proper value of **KVAL** to be used:

(A) If tests can be run in the field with **KVAL** set on zero and samples of the material taken from under the Gauge. Laboratory oven dry can be used to compute the correct value of **KVAL**. An average of four or more samples is advisable to decrease statistical errors in the Gauge and oven dry errors due to mishandling of the material.

The equation is:

$$Kval = \frac{\%M\ (Oven) - \%M\ (Gauge)}{\%M\ (Gauge) + 100}$$

(B) If laboratory facilities are not available, the tests can be run using other methods of determining percent moisture. The same equation may be used or the value of **KVAL** can be determined by systematically changing the stored value of **KVAL** until the correct **PERCENT MOISTURE** is computed by the Gauge while retaining the same measurement data in memory.

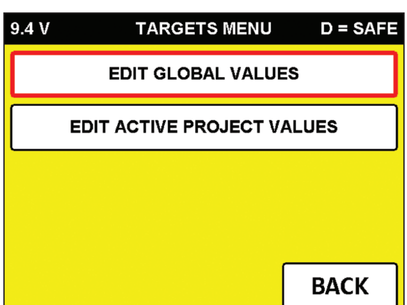
(C) If no other method is available to verify the Gauge moisture calibration, the **PERCENT AIR VOIDS** may be utilized to determine if major errors exist. Well-compacted soils should have **PERCENT AIR VOIDS** between 2.0% and 5.0% depending on gradation. If a result of the void content is negative, it is evident that the Gauge is measuring an excessive amount of water and a more negative value of **KVAL** should be used.

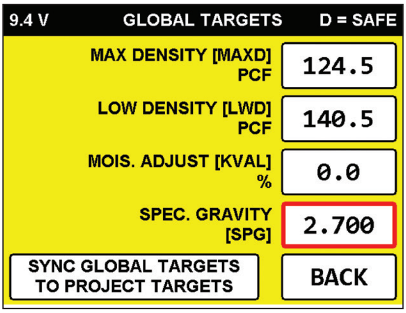
### 3.3.3 Specific Gravity (SPG)

**SPG** is the specific gravity of solids and is obtained by hydrometer, or other tests. The normal range for soils or aggregates will be between 2.6 and 2.75. If no accurate value is known, use 2.700. The specific gravity of the measured material solids is required to compute the **VOIDS RATIO** (VR) or **PERCENT AIR VOIDS**.

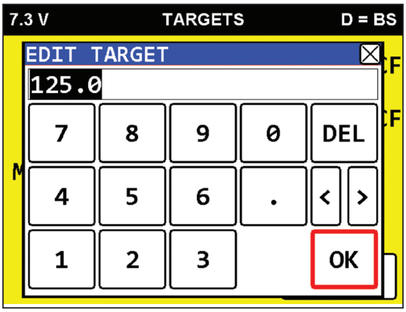
Press the MAX D key to jump to the **TARGETS** menu.

Press **EDIT GLOBAL VALUES** to enter the Global Values Menu






Press **SPEC. GRAVITY** [SPG] value on the screen and the **EDIT TARGET** keypad will pop up as shown below:




Press **OK** on the screen when you have entered the desired target value.

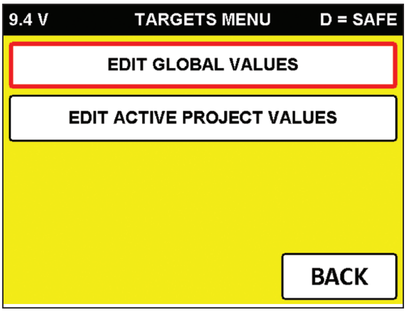
Press **BACK** on the next screen to save any changes.

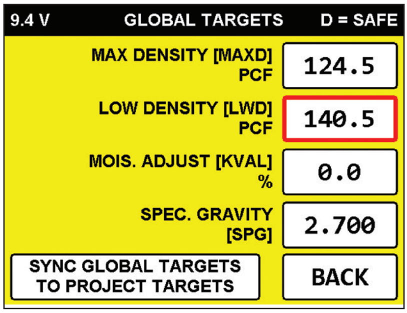
### 3.3.4 Density of Underlying Materials (LWD)

LWD is the density of the underlying material when the nomograph method (**THIN MODE**) is used to compute the density of thin layers. Any reasonable value may be entered.

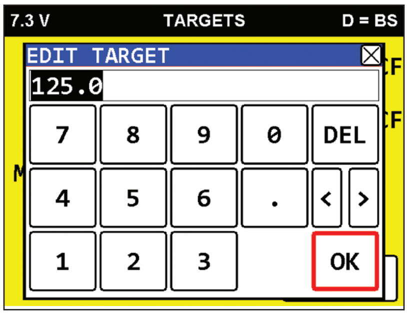
Press the  key to jump to the **TARGETS** menu.


Press **EDIT GLOBAL VALUES** to enter the Global Values Menu






Press **LOW DENSITY** [LWD] value on the screen and the **EDIT TARGET** keypad will pop up as shown below:




Press **OK** on the screen when you have entered the desired target value. Press the **BACK** button on the next screen to save any changes.

### 3.4 Site Selection

In general, all measurement should be made as soon as possible after the site has been compacted. This is particularly true for fills and embankments since evaporation may dry out the surface material and lower the average moisture measurement. Any rain prior to the measurements may increase these values unless sufficient time has elapsed to allow surface drying.

These conditions may be alleviated by removing surface materials to a depth necessary to eliminate non-homogeneous materials. For asphaltic concrete emplacements, the testing should ideally be made while the material is being compacted so that additional rolling can be accomplished before the material cools below acceptable compaction temperatures. The selection of a site to be measured is left to the judgement of the operator or may be defined by prescribed procedures or specifications. A random sampling method is recommended. An optionally selected site should not be chosen on obvious conditions which may either reject or pass the results It should be representative of the total area to be tested.

### 3.5 Site Preparation

Any site to be measured should be clear of all loose debris before attempting to seat the Gauge. After removing the loose material from soils, the area should be leveled using the Scraper Plate to provide a flat surface. Any large surface void areas should be filled with native fines even though a direct transmission measurement will be made.

If hard surfaced areas are involved which make the direct transmission method impractical or impossible, then a backscatter measurement will have to be made. In addition, the surface voids must be carefully leveled with mineral filler and lightly compacted with the Scraper Plate to minimize surface errors.

The Scraper Plate is used as a guide for the Drill Rod to facilitate making a vertical hole. Place the Scraper Plate over the desired site and while holding it in place with one foot, drive the rod to a depth at least 50 mm (2 inches) deeper than the measurement depth. The Drill Rod is marked in 50mm (2- inch) increments to aid in judging the depth. Safety Glasses must be worn to prevent eye damage while striking the rod with the hammer. If the Drill Rod cannot be easily removed from the hole, place the Extraction Tool around the rod and engage the flat surfaces at the bottom of the head.

Using the tool, rotate and pull on the Drill Rod to remove it. If the Drill Rod is still difficult to remove, lightly tap on the bottom surface of the Extraction Tool and drive it vertically out of the hole. If the line is used to make a light mark is drawn around the Scraper Plate while it is placed over the hole, it will be easier to locate the Gauge such that the source rod will extend into the hole without difficulty.

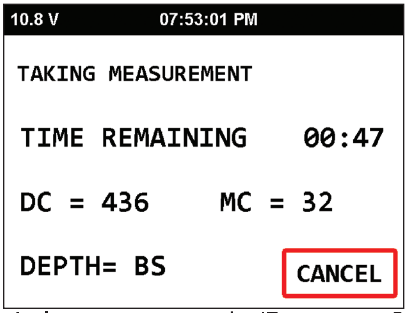
### 3.6 Positioning the Gauge

Carefully place the Gauge over the prepared site. If backscatter is used, seat the Gauge to make it as flush to the surface as possible. If a line was scribed around the site for direct transmission, then the base should be centered over the site to ease insertion of the source rod into the hole. Release the LATCH by pressing the trigger into the handle, push the handle down until the approximate correct position is obtained, the first notch for backscatter or the correct predetermined depth for direct transmission. At the correct depth, release the trigger, and lift the handle just above the notch then push the handle one more time until hearing the “click” as the INDEXER accurately position the source.

If a direct transmission is being used, pull the Gauge toward the control panel end to force the source rod against the side of the prepared hole. This is important since void could exist between the rod tip and the side of the hole.

## 3.7 Taking the Measurement Count

Press MEASURE from any menu and the screen will be shown as below:




**NOTE:** If the gauge is in low power mode (Power on Screen off) when pressing the **MEASURE** key, a warm up period of about 10 seconds will elapse to bring the electronics and detector tube signals up to a stable level before measurement can begin.

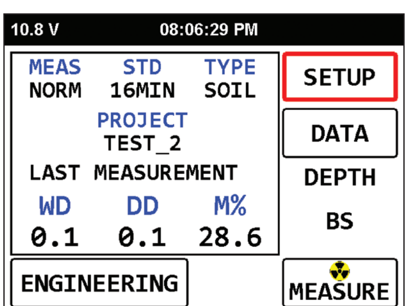
The measurement can be taken by simply pressing the **MEASURE** key. Most measurements will be made, by using the "**NORM**" in measure mode, which takes an exact one-minute count. It may be desirable to use the "**FAST**" or fifteen-Second measure mode if it is necessary to make a quick measurement to avoid conflict with compaction equipment. The measurement precision will be degraded by a factor of two.

Use of the "**SLOW**" four-minute measuring mode will enable the user to improve the precision by a factor of two. This will allow close examination of small density changes such as establishing a roller pattern or attempting to improve compaction efficiency.

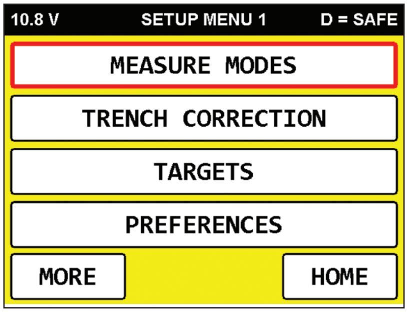
### 3.7.1 Measurement Depth Selection

The gauge is equipped with automatic depth detection. The depth mode can be changed to manual mode if necessary.

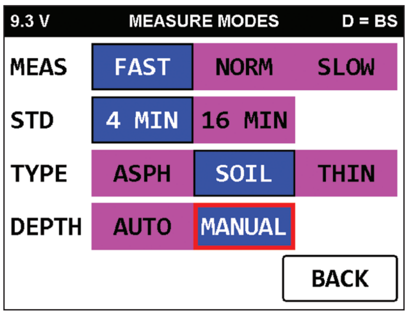
Press the **SETUP** button on the screen to enter **SETUP MENU 1**.



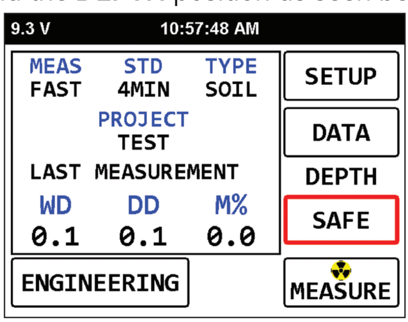
Press **MEASURE MODES** to enter the **MEASURE MODES MENU.**



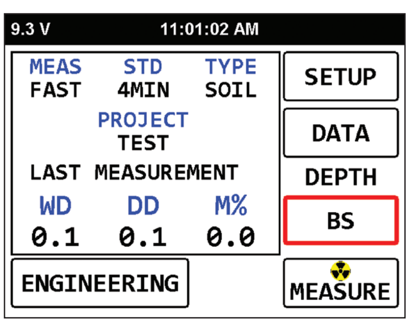

Press **AUTO**, or **MANUAL** to select the desired Depth type.




When the gauge is in Manual Mode the Main Screen will now show an outlined button around the **DEPTH** position as seen below:



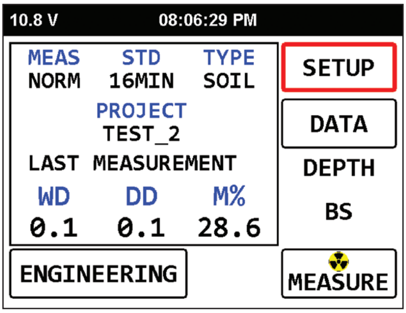

Press the **SAFE** key and the **DEPTH** will advance to Backscatter.



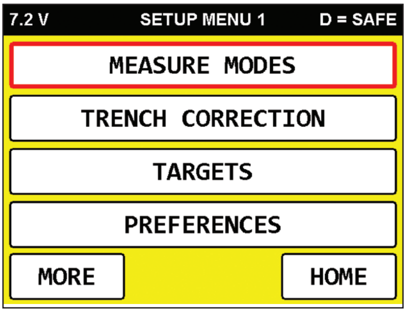

Now pressing the **BS** key will advance to **DEPTH 2** and so on.

### 3.7.2 Measurement Time Selection

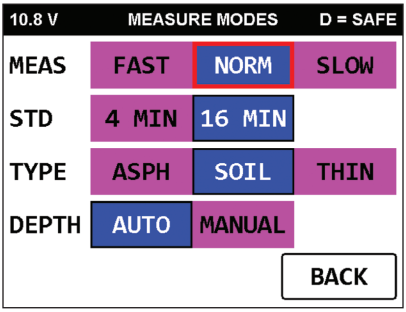
Press the **SETUP** button on the screen to enter **SETUP MENU 1**.




Press **MEASURE MODES** to enter the **MEASURE MODES MENU**.

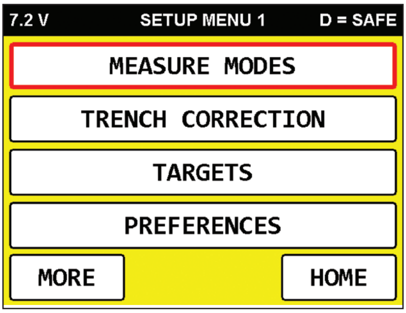



Press **FAST**, **NORM**, or **SLOW** to select the desired time measurement.

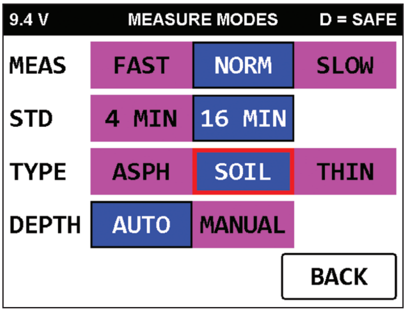


### 3.7.3 Measurement Type Selection

Before a measurement can be taken, the material under test must be selected i.e., (**ASPHALT / SOIL / THIN LAYER**).
Press **MEASURE MODES** to enter the **MEASURE MODES MENU.**



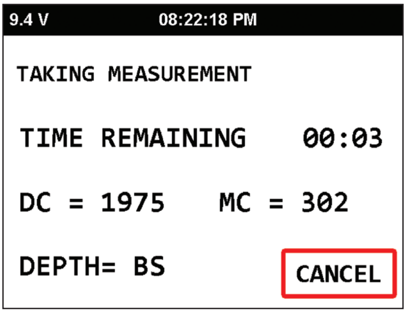

Press **ASPH**, **SOIL**, or **THIN** to select the desired measurement type.



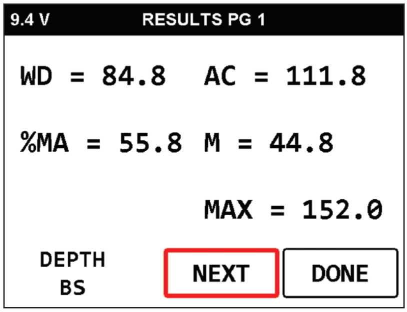

#### 3.7.3.1 Asphalt Measurements

Set the mode to Asphalt as described above. Set the rod depth to the desired depth and press the **MEASURE** key. **NOTE:** Both backscatter and direct transmission may be used for Asphalt. The latter is seldom used due to the destructive nature of making the direct transmission hole.

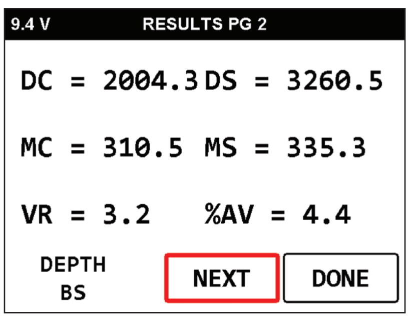
Press **MEASURE** on the display and the display will show as:



After the **TIME REMAINING** counter has elapsed. The Wet Density (WD) and Percent Marshall (%MA) will appear on the display. Since the moisture channel is measuring Hydrogen, the displayed results will approximate the Asphalt Content (AC) of the mix. The depth of measurement will be 100mm (4 inches) or even more depending on the actual asphalt content.




Press **NEXT** to advance to the next results page.




The Density Counts (DC), Density Standard (DS), Moisture Counts (MC), and Moisture Standard (MS) will indicate the counts used to determine the computed data. The Void Ratio (VR) and Percent Air Voids (%AV) are calculated along with the **DEPTH** at which the measurement was taken.

Move the handle back to the **SAFE** position and note that the display did not change. It is not necessary to leave the source in the measurement position (exposed) while calculations are made. So long as measurement data is present in the active registers the handle position in which the data was taken remains in the display.

#### 3.7.3.2 Asphalt Thin Layer Measurements

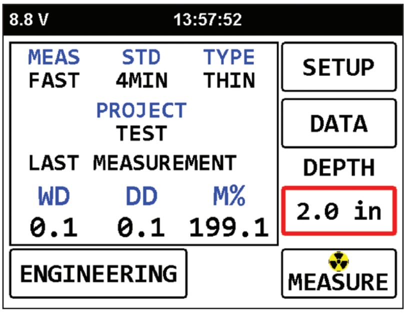
There are currently no available true Thin-Lift Gauges of the surface typ. They all make one or two measurements at depths greater than the desired thickness and calculate the apparent density of the top layer using the varying depth response of the Gauge in the backscatter mode. The major problem with them is that the resultant precision is so poor that the validity of the results is questionable.

The **HS-5001NX** uses the Nomograph principal where the density of the underlying material is known from prior measurement. The top layer density is then calculated.

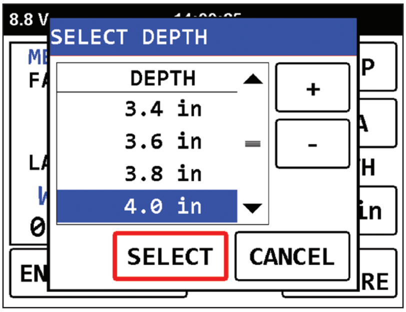
The density of the underlying material must be entered into the **LWD** register as described in section 3.3.4 Density of Underlying Materials.

Next the **MEASURE MODE** must be set to **THIN** as described in section 3.7.2 Measurement Type Selection.

The main screen will now show the thickness under **DEPTH** as shown below:



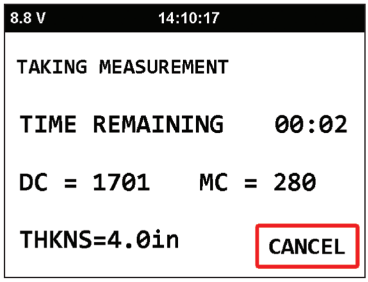

Press the value under **DEPTH** 2.0 in button on the screen to select the desired thickness for the material being measured.




Using the + or - Keys on the screen select the desired depth and press Select to accept.

The increments are 5mm (0.2 inches) and the maximum range is from 25mm (1.0 inch) to 160mm (6.4 inches). The latter value includes 100% of the maximum response of the Gauge to density in the backscatter mode. After the desired thickness has been entered. Set the index rod to the backscatter.

The results will now show the thickness in the instead of the depth in the results window.




Move the handle back to the **SAFE** position and note that the display did not change. It is not necessary to leave the source in the measurement position (exposed) while calculations are made. So long as measurement data is present in the active registers the handle position in which the data was taken remains in the display. Clear the data by pressing Discard or Save as in 3.7.2.3. The display will again correctly indicate **SAFE**. To view the results of the current measurement again from the main menu or a saved test see section 3.7.2.5.

This Gauge obtains its backscatter density measurement in a manner which is nonlinear with respect to the strata within the sample. The table below indicates the response at various depths:

**Thickness**

| mm | inch | Relative Response |
|---|---|---|
| 0 | 0.0 | 0.000 |
| 25 | 1.0 | 0.490 |
| 50 | 2.0 | 0.778 |
| 75 | 3.0 | 0.912 |
| 100 | 4.0 | 0.960 |
| 125 | 5.0 | 0.985 |
| 150 | 6.0 | 0.998 |
| 162 | 6.5 | 1.000 |

Below 100mm (4 inches) the Gauge is relatively unaffected by any change in density. In fact, a large change in density below 75mm (3 inches) has very little effect.
There is always a question of when to use the nomograph method. The table below presents some information as a guideline.

Since the best accuracy that one can expect for a backscatter density measurement, even assuming corrections for chemistry, is about 2.0% then attempting to correct for the bottom layer density when it causes less than a 2% error is futile. The conditions noted within an * are ones where the nomograph correction is recommended.

**Errors Due To Mat Thickness**

| Top Layer | | % Error with no correction for % difference in density | | | | | | |
|---|---|---|---|---|---|---|---|---|
| mm | inch | 2% | 4% | 6% | 8% | 10% | 15% | 20% |
| 25.0 | 1.0 | 1.0 | *2.1 | *3.1 | *4.1 | *5.2 | *7.8 | *10.4 |
| 37.5 | 1.5 | 0.7 | 1.4 | *2.1 | *2.8 | *3.5 | *5.3 | *7.0 |
| 50.0 | 2.0 | 0.5 | 0.9 | 1.4 | 1.8 | *2.3 | *3.4 | *4.6 |
| 62.5 | 2.5 | 0.3 | 0.6 | 0.8 | 1.1 | 1.4 | *2.1 | *2.8 |
| 75.0 | 3.0 | 0.2 | 0.3 | 0.5 | 0.7 | 0.8 | 1.2 | 1.6 |
| 87.5 | 3.5 | 0.1 | 0.2 | 0.3 | 0.4 | 0.5 | 0.7 | 0.9 |
| 100.0 | 4.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 | 0.6 |
| 112.5 | 4.5 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.5 |
| 125.0 | 5.0 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 |
| 137.5 | 5.5 | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.3 | 0.4 |
| 150.0 | 6.0 | 0.0 | 0.0 | 0.1 | 0.1 | 0.1 | 0.2 | 0.2 |
| 162.5 | 6.5 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

While the table may seem confusing it simply states that, for example, one should correct for a mat thickness of 37.5mm (1.5 inches) only when the difference between the top layer and bottom layer densities is 6% or more. If the mat is 50mm (2.0 inches) then use the nomograph when the density difference is 10% or more.

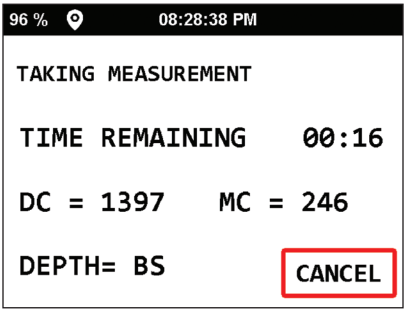
Since a density difference greater than 10% is seldom encountered, one need only be concerned when the mat thickness is 50mm (2.0 inches) or less.

If field procedures involve establishing a passing density using a test strip, then only relative densities are important, and no corrections are necessary.

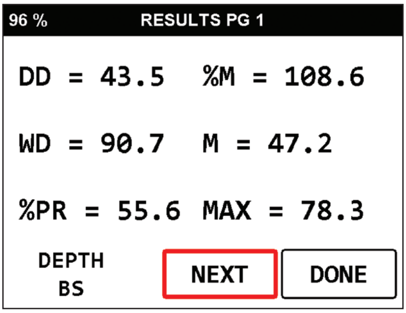
### 3.7.3.3 Soil Measurements

Set the measure mode to Soil as described above in 3.7.2 Measurement Type Selection.

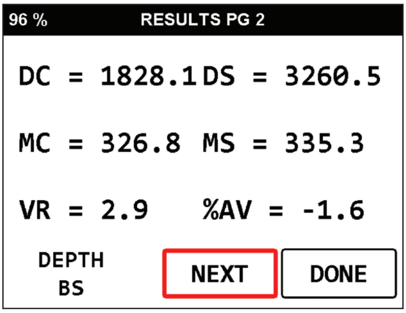
Press the **MEASURE** button on the screen and the display will be shown as below:




After the **TIME REMAINING** counter has elapsed. The Dry Density (DD), Wet Density (WD), Percent Moisture (%M), Wet Density (WD), Moisture Content (M), and Percent Proctor (%PR) will appear on the display.




Press **NEXT** to advance to the next data screen as shown below:




Pressing **NEXT** again will cycle through the data results menus again. The Density Counts (DC), Density Standard (DS), Moisture Standard (MS), and Moisture Counts (MC), will indicate the counts used to determine the computed data. The Void Ratio (VR) and Percent Air Voids (%AV) are calculated along with the DEPTH at which the measurement was taken.

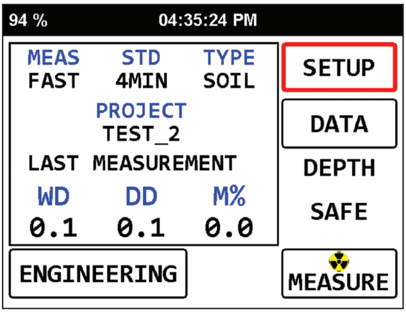
The latter is quite useful to assure that the moisture calibration including the **KVAL** used fits the chemistry of the soil. Well-compacted soil should have air voids between 3% and 5%. If the value is negative, comparative data must be run against oven dry or other acceptable methods to determine the correct KVAL.

Move the handle back to the **SAFE** position and note that the display did not change. It is not necessary to leave the source in the measurement position (exposed) while calculations are made. So long as measurement data is present in the active registers the handle position in which the data was taken remains in the display.

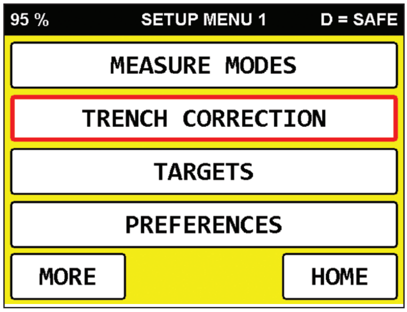
### 3.7.3.4 Soil Measurements in Trenches

Moisture measurements made in trenches are subject to error, due to water in the walls of the trench. Special software is included (Trench Correction) to compensate for this error. Making measurements in a trench requires some precautions. Extra shielding of detectors has minimized these effects on the 5001 model gauges if a few precautions are taken. The gauge should not be used in a trench where the distance between the walls is less than 600mm (24 inches). When the standard counts are made, they should be done in the trench. If the point to be measured is less, then 400mm (16 inches) and the reference standard should be placed in the approximate location (distance from the wall) that the measurement is to be made. The source end of the gauge should be facing the closest wall of the trench.
If the trench is more than 900mm (36 inches) and no measurement will be made at a distance less than 400mm (16inches) from the wall, then a normal standard count may be used.

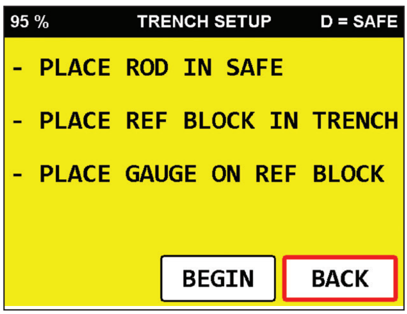
Set the measure mode to **SOIL** as described above in 3.7.2 Measurement Type Selection. First, place the Gauge on its Reference Standard in the same location in the trench where a measurement is to be made. With the Gauge handle in the **SAFE** position.
From the main menu press **SETUP** as shown below:



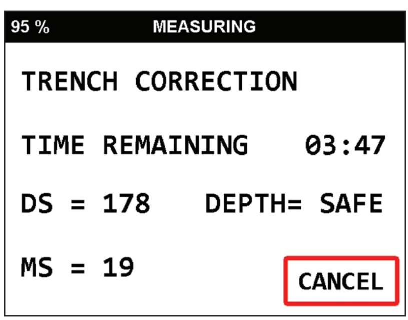
Next press **TRENCH CORRECTION** to begin.



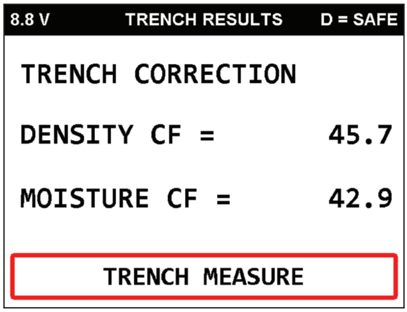

Press **BEGIN** to start the **TRENCH CORRECTION**.



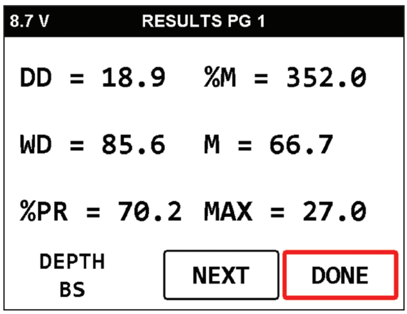

A four-minute count is started indicating that a correction is being determined to account for the water in the walls of the trench. Four minutes are used to produce a precision sufficient to determine the value otherwise the correction factor may produce an error larger than the trench error.




When the count is complete both the Density and Moisture Correction Factor will appear on the display, which is the difference between the Moisture Standard Count outside of the trench and the same standard inside the trench.




Press **TRENCH MEASURE** to take the measurement in the trench. After the measurement is completed, the gauge will display the results based off the trench correction factors.




The gauge will not stay in Trech Correction mode after the test is done. Every trench measurement will need to have an individual the Trech Correction prior to taking a measurement.

## 3.8 Processing The Results

The **WET DENSITY** is obtained using the following equation:

$$CR = Ae^{-BD} - C$$

Where: CR = Density Measurement Count (DC) divided by Density Standard Count (DS)

D = Wet Density of the material
@ depth X A, B, C = Calibration Constants @ depth X

In addition, the MOISTURE CONTENT
is obtained by simply using the following equation:

$$CR = E + FM$$

Where: CR = Moisture Measurement Count (MC) divided by Moisture Standard Count (MS)

M = Moisture Content
E, F = Calibration Constants

The **DRY DENSITY** is obtained by subtracting the **MOISTURE CONTENT** from the **WET DENSITY** and the P**ERCENT MOISTURE** is obtained by dividing the **MOISTURE CONTENT** by the **DRY DENSITY**.

The processor performs the functions, which produce the results without consulting tables, or transferring data to a handheld calculator. This decreases the potential for operator error. The processor also compensates for the attenuation coefficient of hydrogen, which is vastly different from soils.

If the measurement was made on asphaltic concrete only the **WET DENSITY** has any meaning however, the calculated **PERCENT MOISTURE** will closely approximate the asphalt content of the mix.

Before actually processing data, the display must indicate the actual depth at which the measurement was made. This is set by using the "**F4**" key in the manual depth mode or automatically set by the auto-indexing network. The display will only indicate calibrated depths and the value will be in millimeters or inches as preset in the instrument.

The **KVAL** should have previously been placed into the processor as explained in 3.3.2.

### 3.8.1 Compaction Control

Generally, it is desirable to obtain compaction as a percentage of a maximum density based on a laboratory Proctor density for soils, or as a percentage of the maximum density based on a laboratory Marshall density, or other requirements for asphaltic concrete.

If the desired maximum density has been placed in the register by using the “**MAX D**” key as described in 3.2.1, the **PERCENT COMPACTION** can be obtained.

% PR = Percentage of the dry density to the maximum soil density.
% MA = Percentage of the wet density to the maximum asphalt density.

### 3.8.2 Void Ratio

By definition, the void ratio (VR) is the ratio of the volume of the void to the volume of the solids. To make this calculation, it is necessary for the processor to know the specific gravity of the solids. There are standard laboratory tests to make this determination. If the true specific gravity is not known, the value of 2.70 may be used to yield approximate void ratios.

The specific gravity may be entered as described in 3.3.3. The “VR” will perform the necessary calculations and display the result in “VR = XXX.X”. No attempt is made to allow for rock corrections since the volume of larger rock is unknown.

Void ratio is an indication of the degree of compaction if the maximum density is not known.

### 3.8.3 Percent Air Voids

This term is defined as volume of air as a percentage of the total volume. The specific gravity of the solids must be known and have been entered as described in 3.3.3. If the calculation is made for asphaltic concrete, the normal PERCENT MOISTURE calculation for soils will have to be adjusted by using “KVAL” to agree with the asphalt content of the mix. The calculation is performed by “% AV” and the results will be displayed in “%AV = XX.XX”.

“% AV” is an indication of the degree of compaction and saturation of the compacted materials. It is also a good indication of the validity of the calibration, particularly moisture, for the specific materials being tested. A negative value for "% AV" indicates that the KVAL needs to be a more negative value. A positive value of more than 5.0% may be caused by incomplete compaction or the need to increase the KVAL in a positive direction (not necessarily a positive number but perhaps less negative one).

## 3.9 Repackaging the Equipment

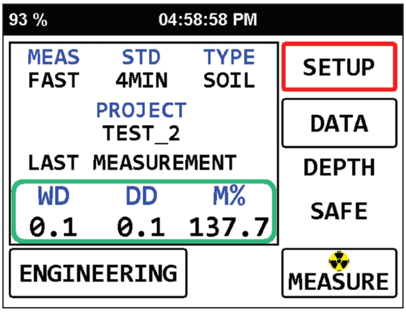
After use, secure the equipment: First, latch the handle in the "safe" position and install the padlock. After wiping the Gauge and Reference Standard to remove all soil and moisture, place them in the Transit Case and lock the case latch. This double security is provided to prevent unauthorized access to the Instrument and possible injury. Clean the accessories and place them in the Zippered Accessory Case to prevent loss.

# 4 Menus

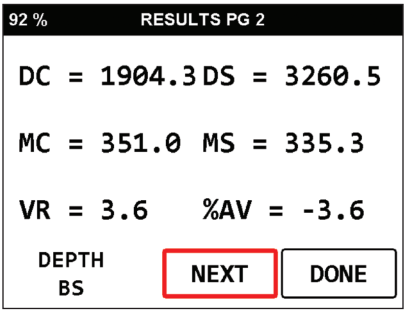
## 4.1 Data Menus

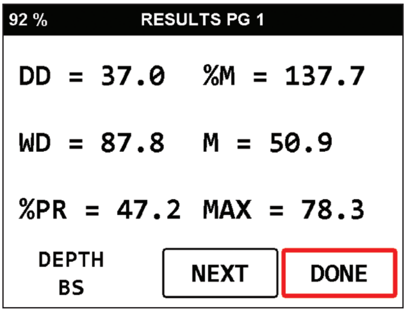
### 4.1.1 View Current Measurement

To View the current measurement simply press on the screen where it is outlined in **GREEN** shown below:




Below you will see the **RESULTS** pages.

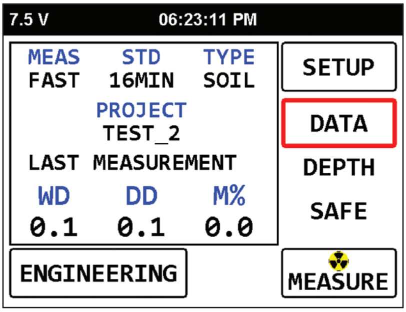


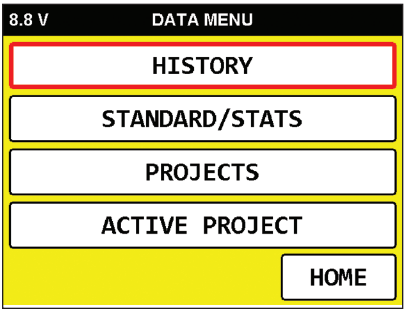

Pressing **NEXT** will cycle between the first and second page of the results. Press **DONE** to exit to the main menu.

### 4.1.2 View History Measurements

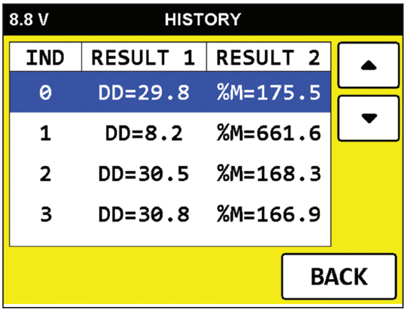
Press **DATA** to enter the data menu.




From the **DATA MENU** press **HISTORY** to view all measurements.

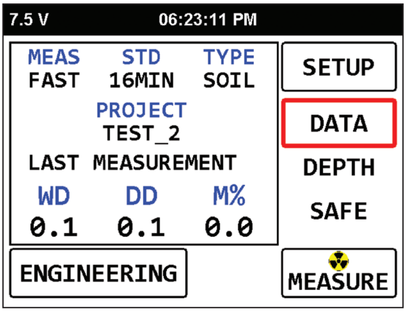



Shown below is the list of measurements. Index 0 will always be the last measurement that was taken.

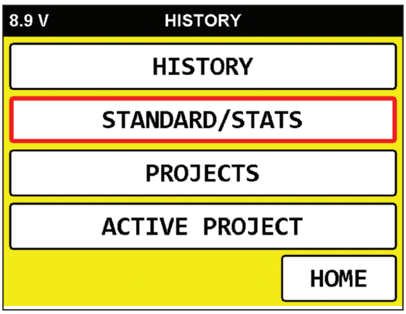


### 4.1.3 Current Standard / Statistical Count

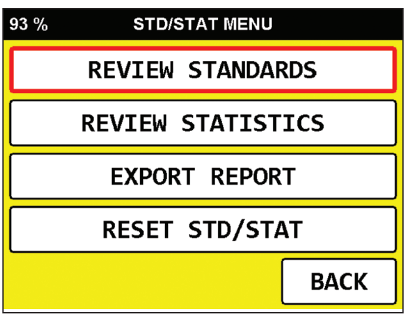
Press **DATA** to enter the data menu.



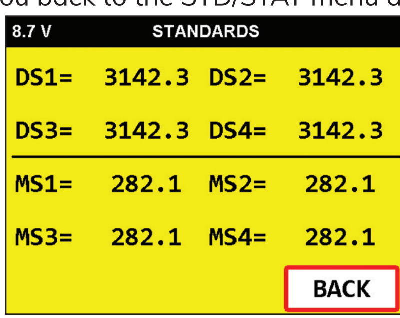

Press **STANDARD/STATS** to enter the **STD/STAT** menu.



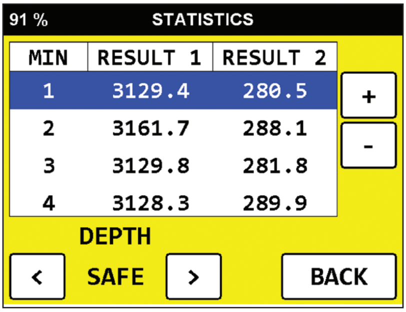

Press **REVIEW STANDARDS** to display the last four standards.




This menu will show you the last four density and moisture counts. Pressing **BACK** will take you back to the STD/STAT menu as seen here:



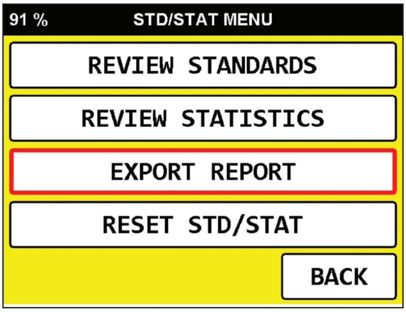
Pressing **REVIEW STATISTICS** will enter the Statistics as shown:



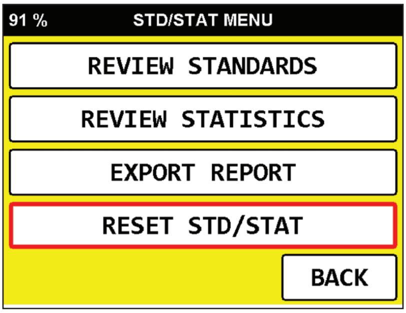

Pressing the + and - keys will navigate to the desired minute.

Pressing the < and > arrows will navigate to the desired depth.
RESULT 1 displays density counts per measurement.
RESULT 2 displays moisture counts per measurement.
Press BACK will take you to the STD/STAT menu.

Pressing EXPORT REPORT will export all the standard and statistical data to a USB drive in a .csv format.



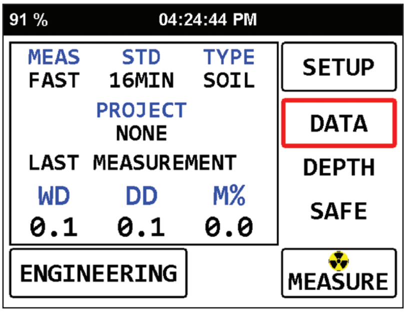

Pressing **RESET STD/STAT** will clear the registers of the current standards and reload the standards from the factory calibration.



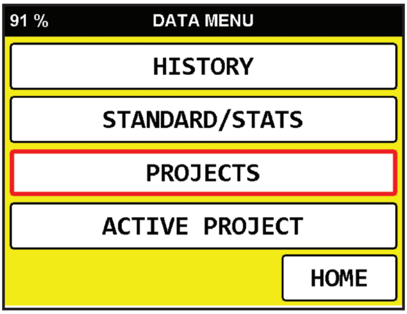
## 4.2 Projects Setup

This setup allows the entry of data pertaining to the project(s) on which the Gauge is being used.

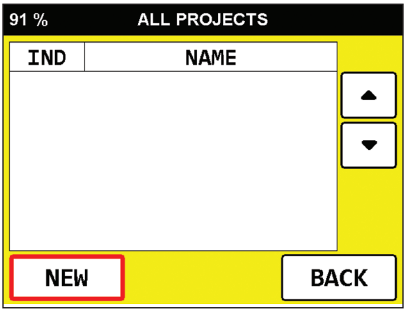
Press **DATA** from the main screen to enter the **DATA MENU**.



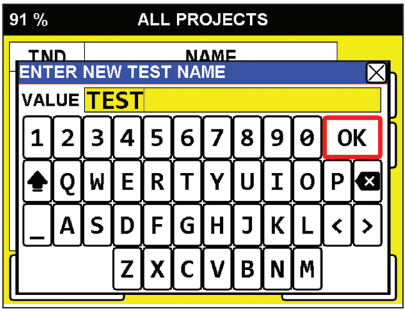

Press **PROJECTS** to enter the **PROJECTS MENU**.




To create a new project, press **NEW** and the alphanumeric will pop up to name the project as shown below:

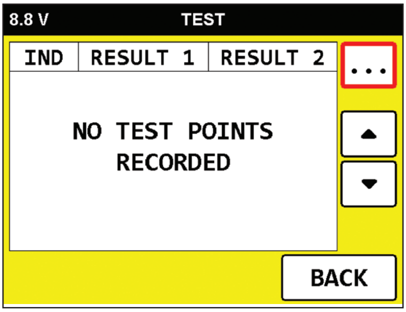


Name the project and press **OK** to continue.



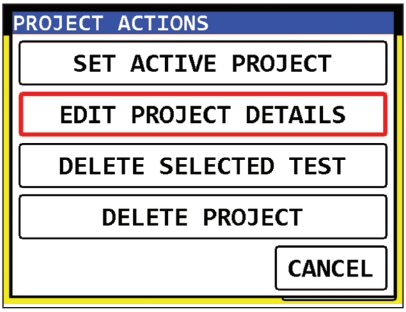

Now you will see the project name that you just created in the task bar at the top of the screen.

Press the ... in the top right corner of the screen to advance to the **PROJECT ACTIONS** menu.

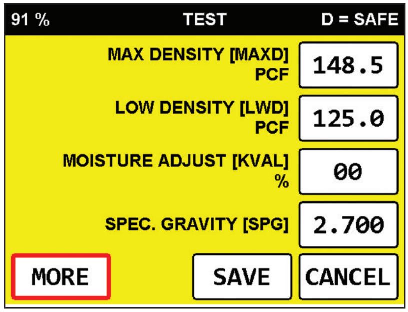



### 4.2.1 Edit Projects

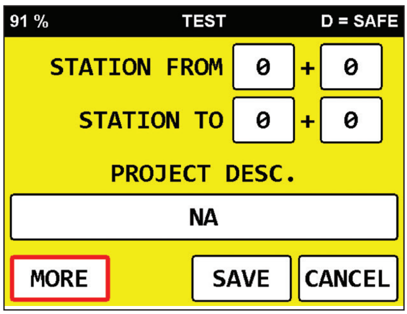
Press **EDIT PROJECT DETAILS** to set the project specific values for the material you will be working on.



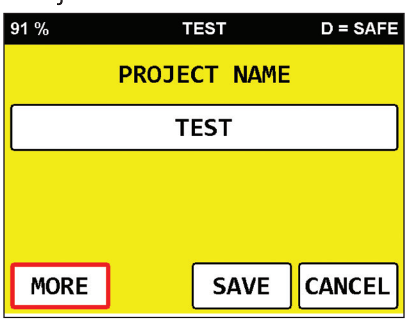
This screen will allow you to adjust the project specific targets.



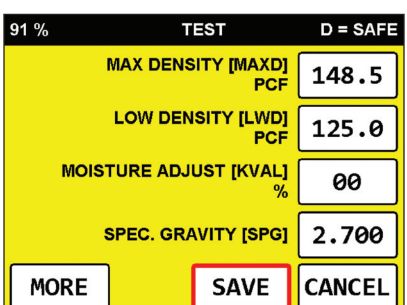

Press **MORE** to advance to the next project edit menu.
This screen will allow you to set the Station ID and Project Description.



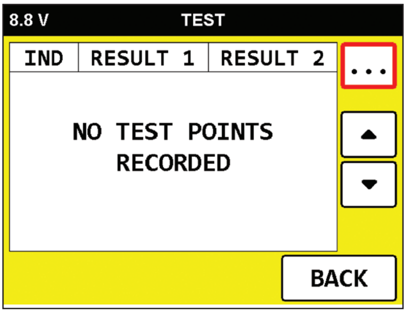

Press **MORE** to advance to the next project edit menu.
Here you can edit the Project Name if desired.



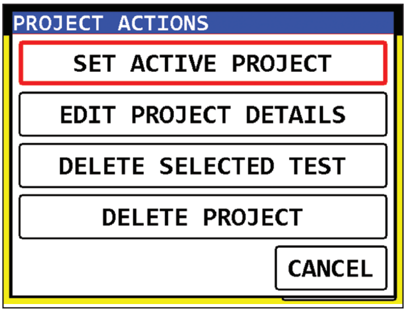

Pressing **MORE** again will bring you back to the Project Targets menu.



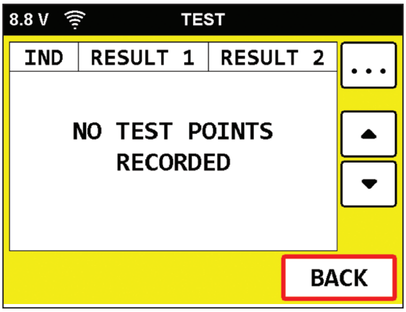
Press **SAVE** to store the changes and then the screen below will be shown.



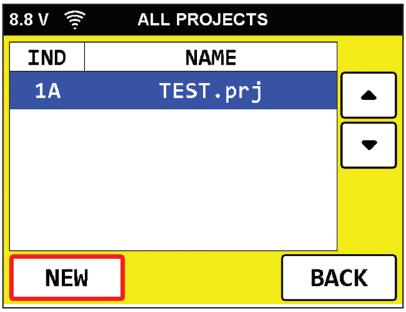

Press the ... in the top right corner of the screen to advance to the **PROJECT ACTIONS** menu.



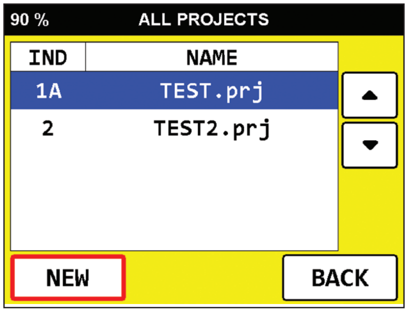

Press **SET ACTIVE PROJECT** to activate the project register to store measurement data in the project folder.




Press the **BACK** key to enter to enter the project folders as shown below:



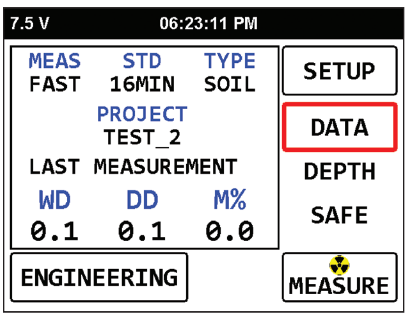
Note: The "**A**" next to the number in the index column indicates the project is active. **TEST** is the current active project as seen below.



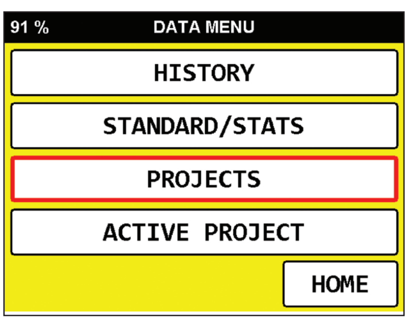

### 4.2.2 Export Data

Data can be exported to a USB drive or over a serial connection. The user can export the whole history list or individual project test history.
**NOTE:** The serial connection option is a factory installation only.
To export a project history.

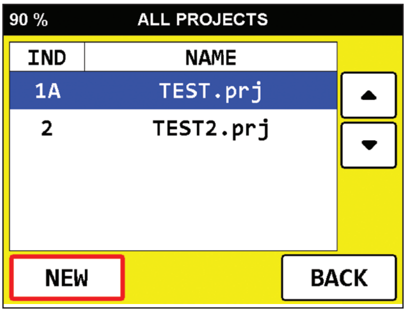
Press **DATA** from the main screen to enter the **DATA MENU**.



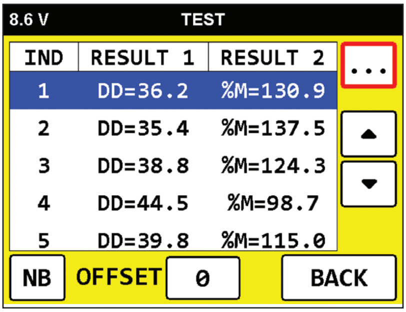

Press **PROJECTS** to enter the **PROJECTS MENU**.



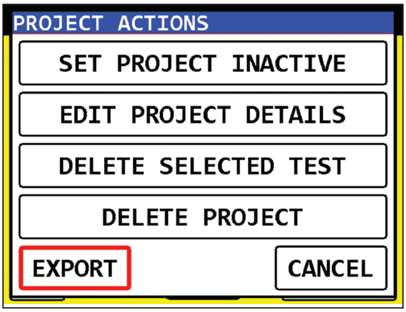
Press on the desired project folder.



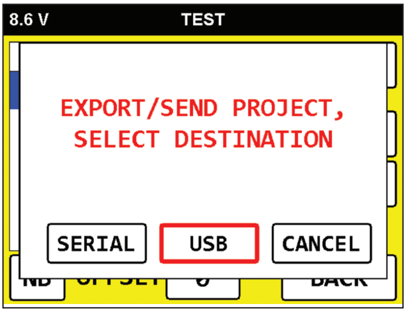

Press the ... in the top right corner of the screen to advance to the **PROJECT ACTIONS** menu.



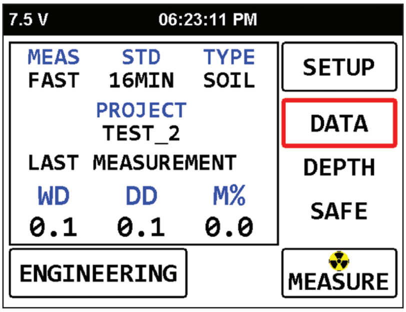

In the Project Actions menu press **EXPORT**.



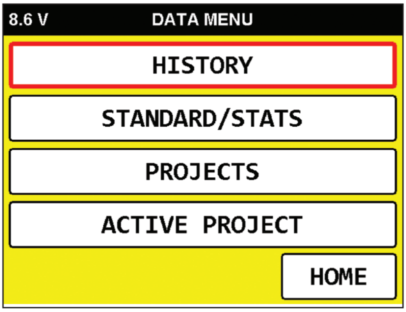

Press **USB** to export a .csv file of the project's history to be viewed in Excel.



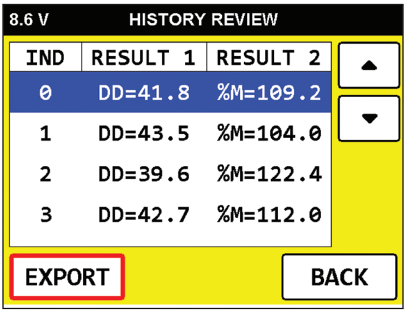
**To export all the History.**
Press **DATA** from the main screen to enter the **DATA MENU**.




Press **HISTORY** from the **DATA MENU**.



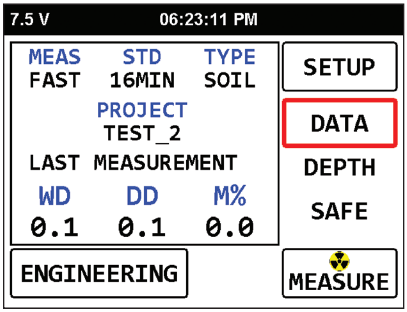

Press **EXPORT** in **HISTORY REVIEW**.



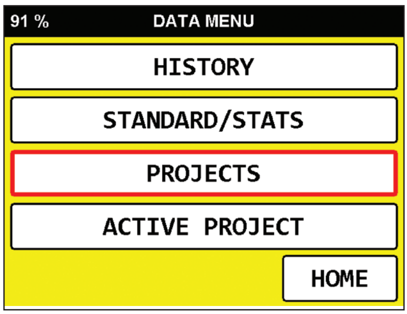

Press **USB** to export a .csv file of the project's history to be viewed in Excel.

### 4.2.3 Delete Project/Field Test

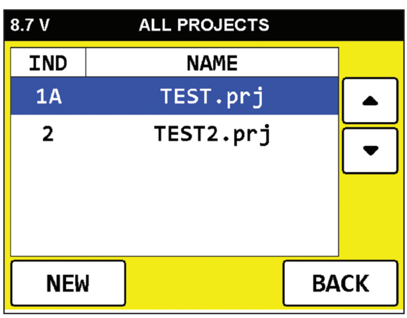
Press **DATA** from the home screen.



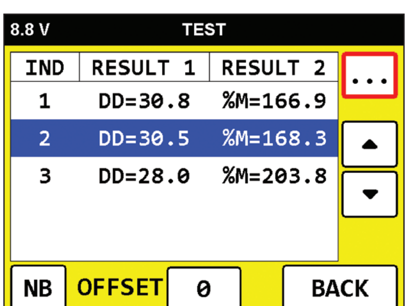

Press **PROJECTS** to enter the **PROJECTS MENU**.



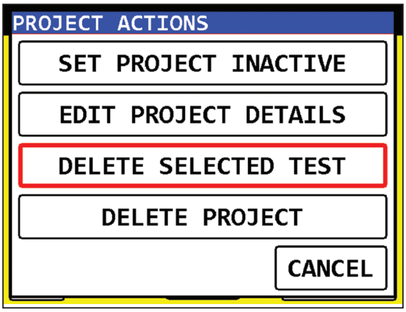

Select the project of the test you want to delete.



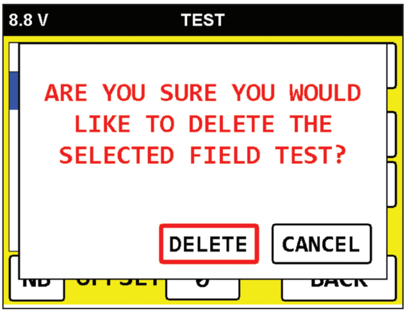

In this example we will delete field test 2 as highlighted below:
Select the test first and then press ... in the upper right corner.



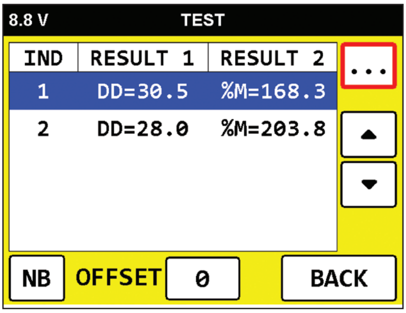
Next press **DELETE SELECTED TEST**.



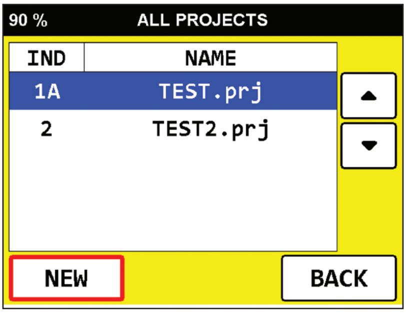

Press **DELETE** to delete the selected field test.



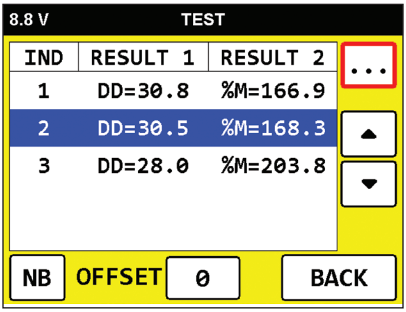

**Note:** Test number 2 is now deleted and test 3 in now in test 2 position.



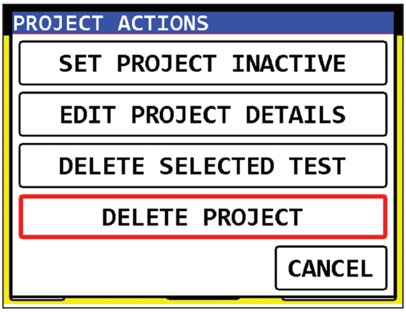

The next steps will show how to delete a whole project.
From the Projects menu select the project that you want to delete.



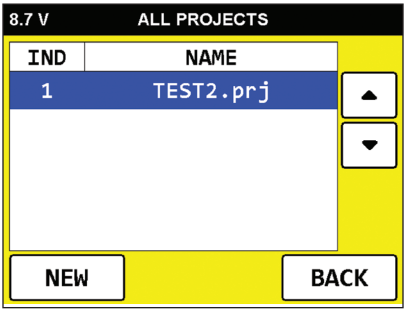
Press ... in the upper right corner.




Press **DELETE PROJECT**.




Press **DELETE** to confirm deletion of the selected project.

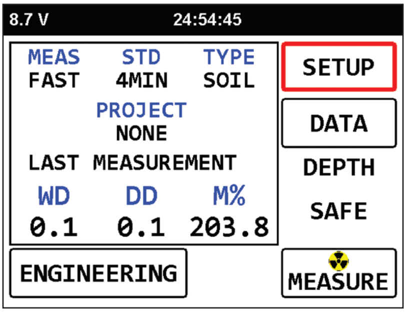




**Note:** The project that we deleted was active, so now there will not be any active projects until the user activates a project.

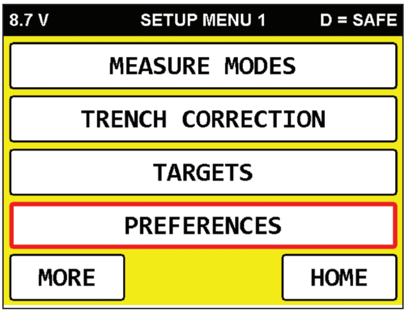
### 4.3 Setup Menus

The physical **SETUP** key on the overlay has a customizable menu setting allowing the user to select which menu will display when the key is pressed. There are five selectable preset menus available to choose from. For example, if you are using the **MEASURE MODES** menu frequently, you could preset this menu to the **SETUP** key to jump to this menu quickly.

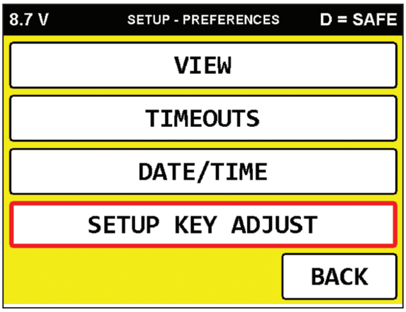
To change the **SETUP** key preset press SETUP from the home screen:



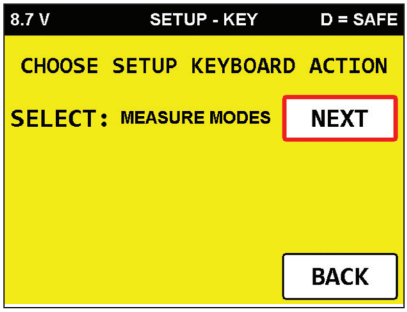

Press **PREFERENCES** on the screen.




Press **SETUP KEY ADJUST** to enter **SETUP KEY** menu.



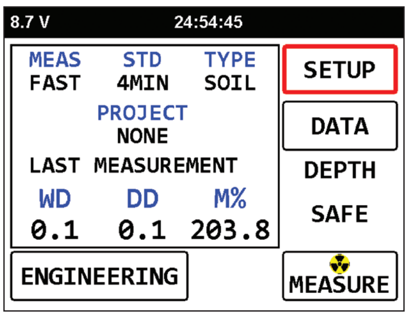
Press **NEXT** to cycle through the desired settings.



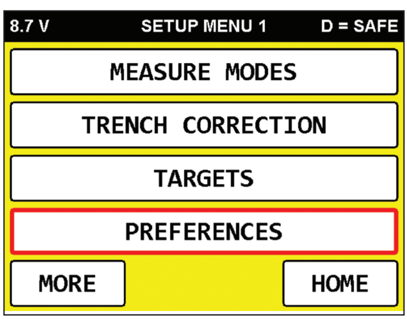

Now when you press the physical overlay **SETUP** button you will jump directly to the measure modes menu.

### 4.3.1 Time and Date Setup

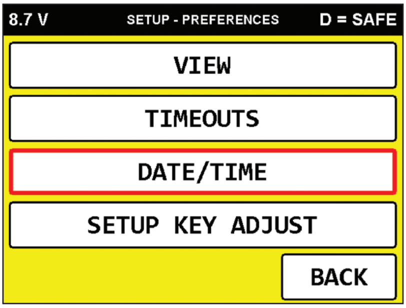
Press the **SETUP** button on the screen to enter the **SETUP** menu.



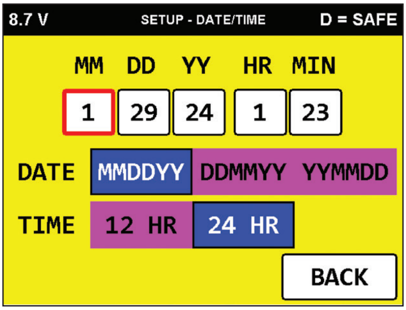

Press **PREFERENCES** to enter the preferences menu as shown:



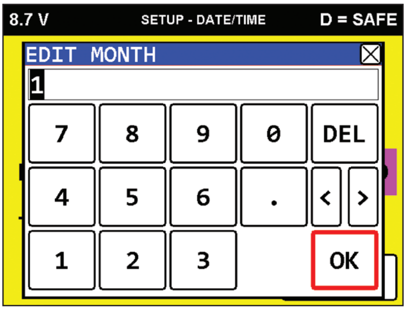
Press **DATE/TIME** to enter Date and Time setup menu.




Here you will be able to select which field of the date and time you need to adjust.



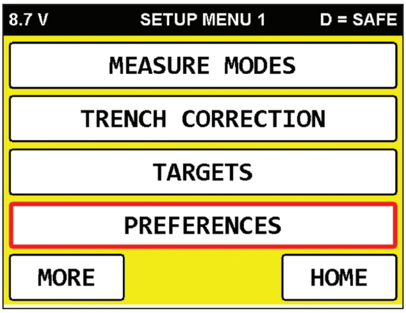

Press on the number field and a popup keypad will appear.



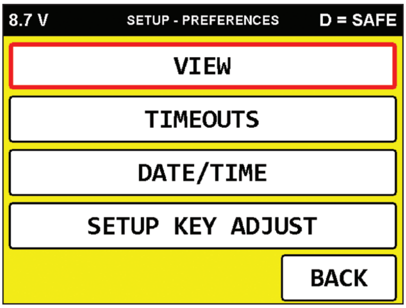

Press **OK** and the new value will automatically be stored.

### 4.3.2 Units Setup and Language

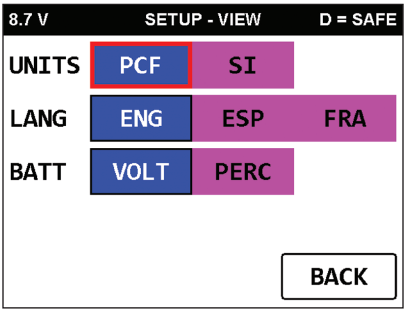
Press PREFERENCES to enter the preferences menu as shown:




Press VIEW to change the units and language settings.



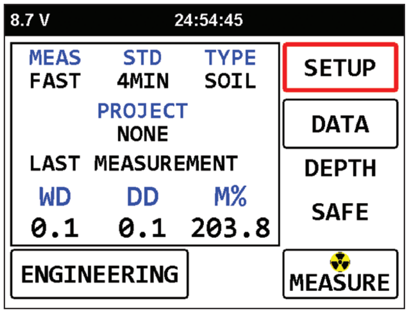

From this menu you can change the Units, Language, and Battery remaining in volts or percentage.



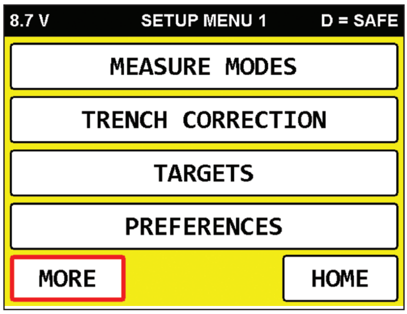

### 4.3.3 GPS

The first time the Gauge is powered on, a new location there will be a delay up to 10 minutes to locate satellites. The system requires a minimum of 4 satellites to acquire latitude, longitude, and altitude.

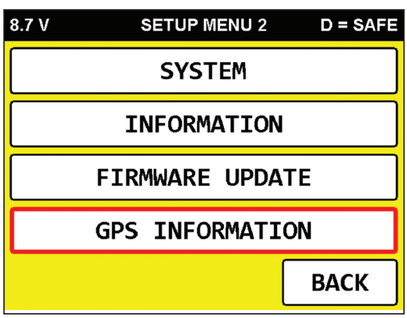
Press **SETUP** to enter Setup menu 1.



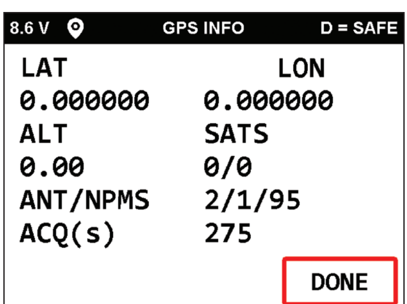

Press **MORE** to enter Setup menu 2.




Press **GPS INFORMATION** to enter the **GPS** Information menu.



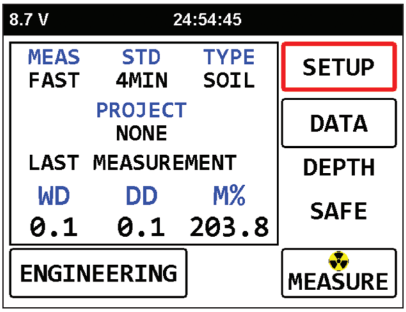

Here you can view the current **GPS** information.



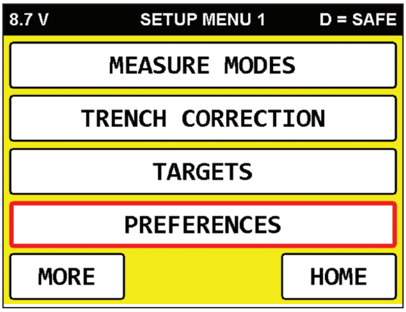
### 4.3.4 Timeouts Power Settings

The **TIMEOUTS** menu allows you to adjust the power settings to conserve battery life.

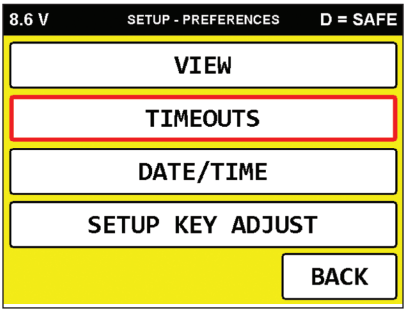
Press **SETUP** from the main menu.

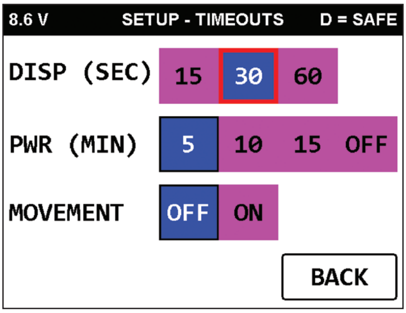



Press **PREFERENCES** to enter the preferences menu as shown:




Press **TIMEOUTS** to enter the menu to adjust the power settings.



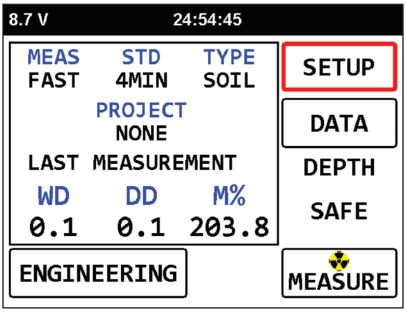



**DISP** (SEC) – This will set the timeout in seconds as to when the gauge will go into sleep mode. Pressing any key or touching the display will wake it back up.
**PWR** (MIM) – This will set the timeout in minuets as to when the gauge will power off.
**MOVEMENT** – When this setting is turned on the gauge will go into sleep mode when it senses that the gauge has been picked up and moved.

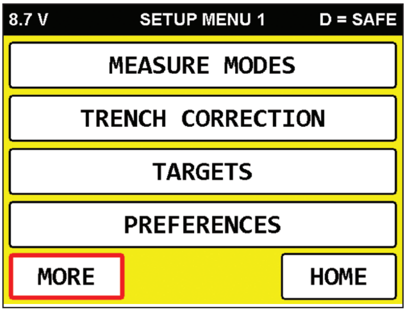
### 4.3.5 System Settings

The system setting allows the user to adjust the Beeper, Wireless connection, **GPS** power settings, **ALS** sensor, and Backlight control.

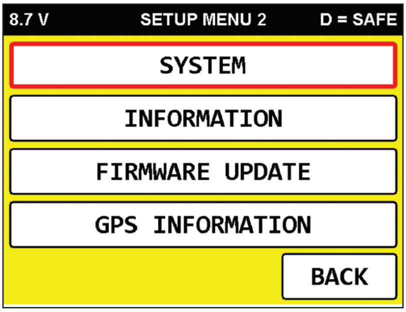
Press **SETUP** from the main menu.

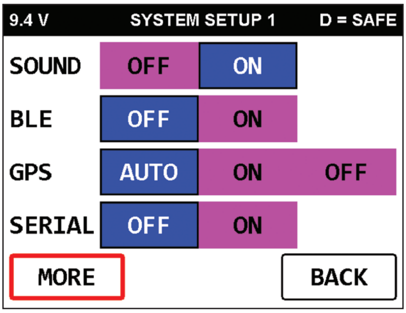



Press **MORE** in Setup Menu 1.




Press **SYSTEM** in Setup Menu 2.





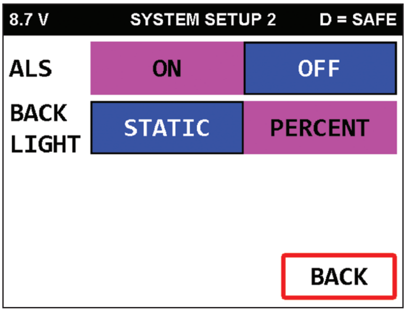

**SOUND** – Turns the key beep **ON** and **OFF**.

**BLE** – Turns the wireless connection **ON** and **OFF**.

**GPS** – Sets if you want the **GPS** to stay **ON** all the time or turn it **OFF**. When the **GPS** is in **AUTO** mode it will turn the **GPS** on as needed to conserve power.

**SERIAL** – This setting allows you to activate the export of data through serial communication if equipped with from factory.

Press **MORE** to advance to system setup 2 menu.



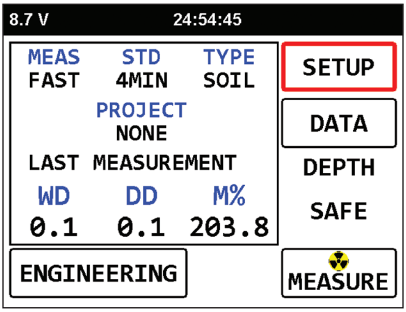

**ALS** – Turns the Automatic Light Sensor **ON** or **OFF**. When this function is on the Backlight button is disabled.

**BACKLIGHT:**
**STATIC -** will set the Backlight button to turn ON and OFF the backlight.
**PERCENT -** will set the Backlight button to cycle through 5 different brightness levels and then back off each time the key is pressed.

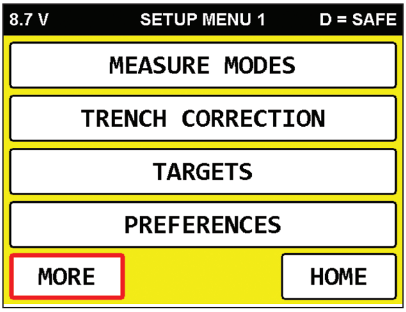
### 4.3.6 System Information

The System Information will allow the user to see contact information and export the system log for help in troubleshooting.

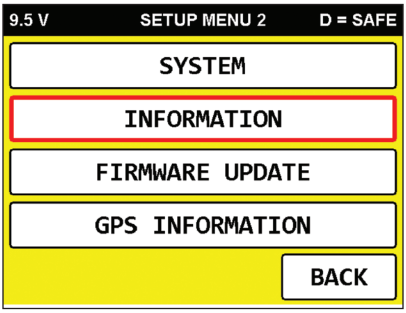
Press **SETUP** from the main menu.



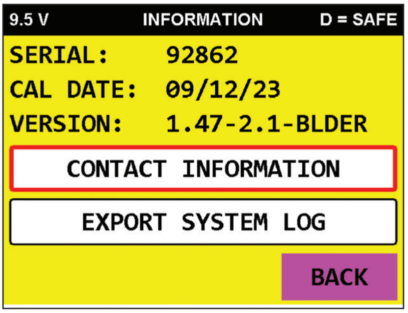

Press **MORE** in Setup Menu 1.



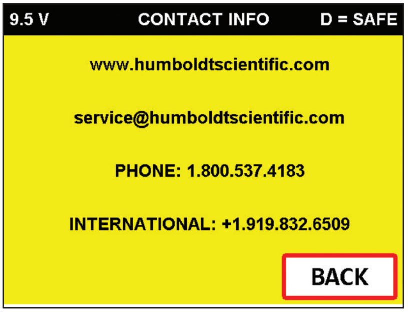

Press **INFORMATION** in Setup Menu 2.



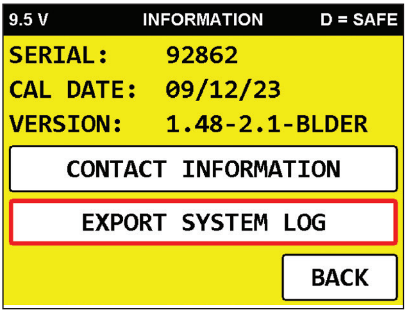
Press **CONTACT INFORMATION** to view Humboldt’s contact information.




Below you will see the screen for Humbolt’s contact information.




To Export the system log to email to Humboldt support. Place a USB drive in the **USB** port first and then:
From Setup Menu 2 press E**XPORT SYSTEM LOG**



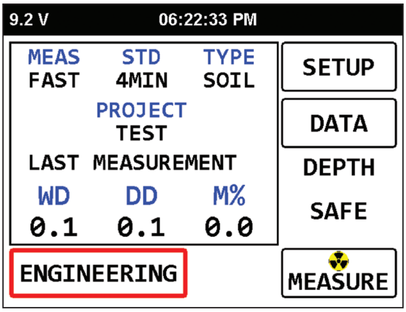

A system log will be created on the **USB** drive in a (.txt) format.

### 4.4 Engineering Menus

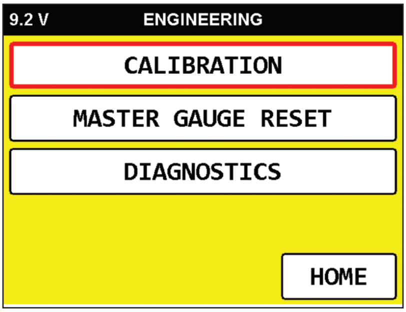
#### 4.4.1 Field Calibration

As with water content, nuclear Gauges can have density errors due to the chemical composition of material, but they are far less than those encountered in moisture measurements. Generally, very few materials other than industrial waste used as aggregates or soils with high iron content will require adjustment. Most of the time, no corrections are required in the direct transmission mode unless there are original calibration errors. In the backscatter mode, the surface roughness or surface air voids may require some small correction. Again, original calibration errors account for a large percentage of this error. The Gauge has a means of altering the factory calibration by a + / - percent value. There are nine sets (CAL1 through CAL9) available, and each set contains a separate adjustment value for backscatter and direct transmission densities.

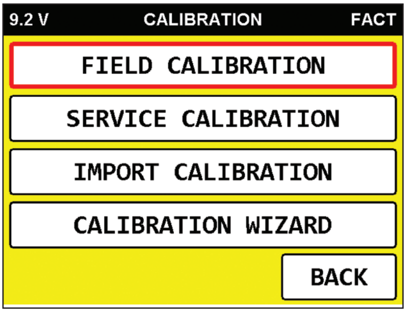
Press **ENGINEERING** from the main menu.



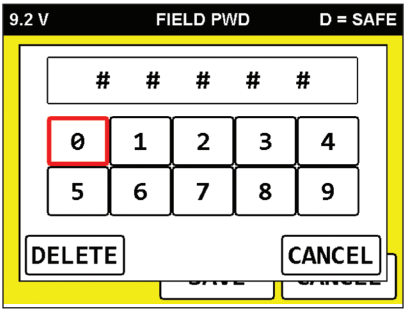

Press **CALIBRATION** from the Engineering menu.



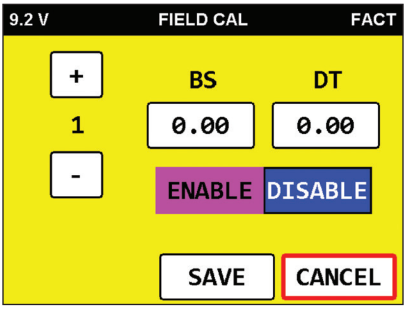

Press **FIELD CALIBRATION** from the Calibration menu.



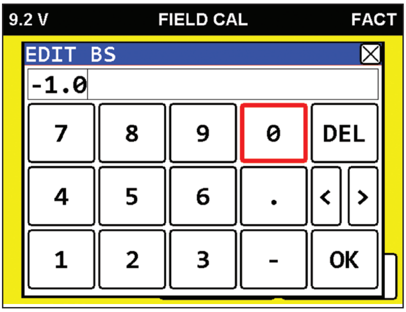
To enter the Field Calibration menu, you must enter the following password **1 1 1 2 3**.



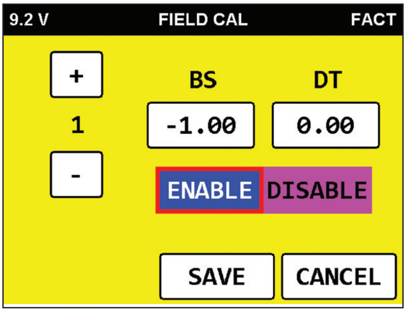

In this example we will set a Field Calibration for BS to -1.0% in position 1. Press the value box under BS and a popup keypad will appear.



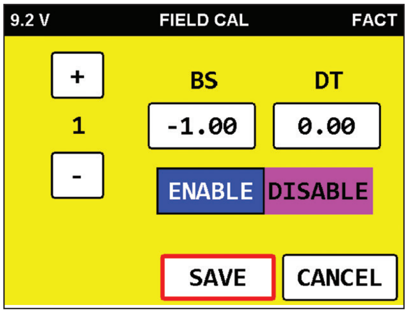

Enter in -1.0 and press **OK**.




Next press **ENABLE** to use this stored Field Calibration location.



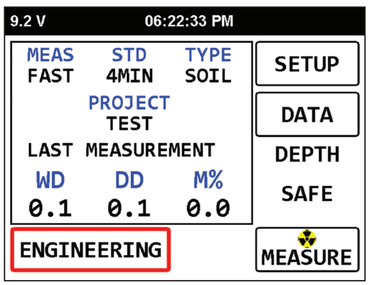

Press **SAVE** to store the Field Calibration.



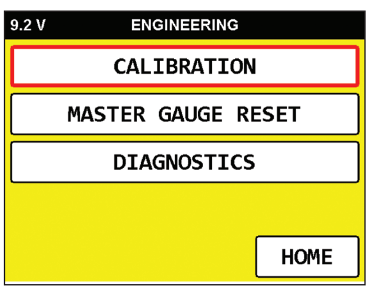

Now the Field Calibration is saved and enabled. Every measurement taken in Backscatter will now be reduced by 1 percent.

### 4.4.2 Service Calibration

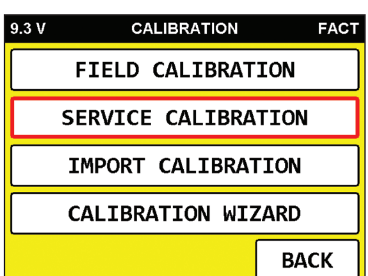
Press ENGINEERING from the main menu.



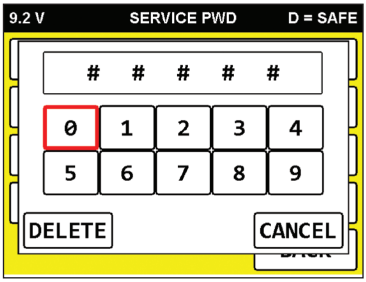

Press **CALIBRATION** from the Engineering menu.



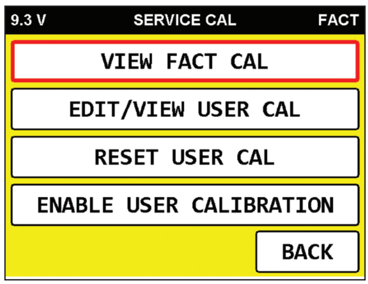

Press **SERVICE CALIBRATION** to enter the Service Calibration menu.



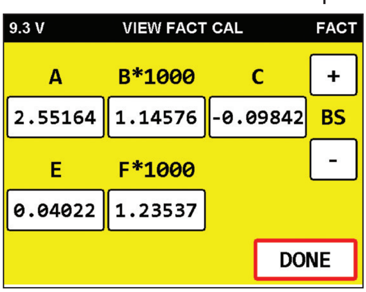
To enter the Service Calibration menu, you must enter the following password **2 2 2 3 4.**



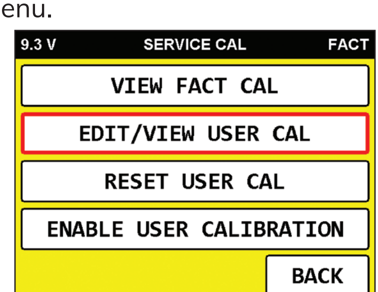

In the Service Calibration menu, you can view the factory calibration, edit, and view the user calibration, reset the user calibration to factory calibration, and enable or disable the user calibration.
Press **VIEW FACT CAL** to see the factory calibration constants.



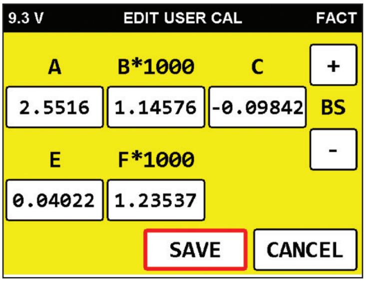

Here you can view the factory calibration constants for each depth. Press the + or – key to advance to the desired depth as seen below:



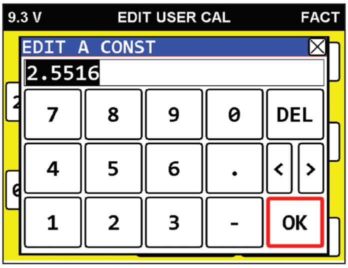

To Edit or View the user calibration press **EDIT/VIEW USER CAL** from the Service Calibration menu.



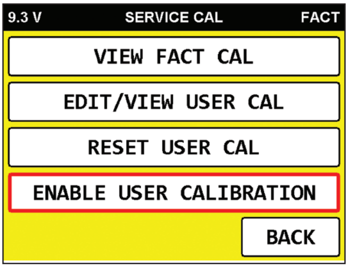
Press on the Value Box under the Constant that you want to edit, and a popup keypad will appear.



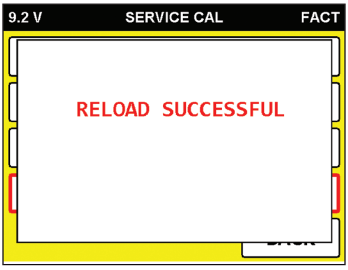

Enter the new value and press **OK**, next press **SAVE** when you are done changing the Constants for each Depth.



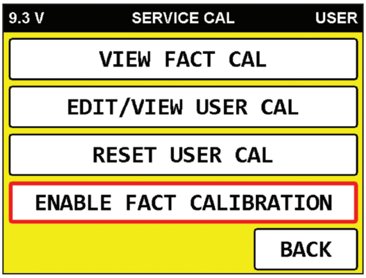

For the user Calibration to take effect you must enable the new User Calibration.
From the Service Calibration menu, press **ENABLE USER CALIBRATION**.



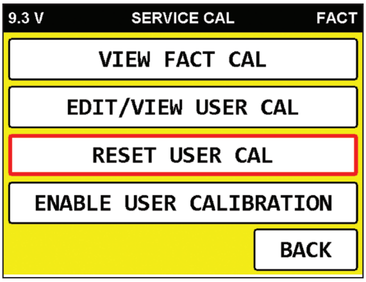

You will get a popup window if the reload is successful and seen here:



In the upper right corner of the display, you will see which calibration is active.




Pressing RESET USER CAL will reset the user calibration to match the Factory Calibration.




### 4.4.3 Factory Calibration

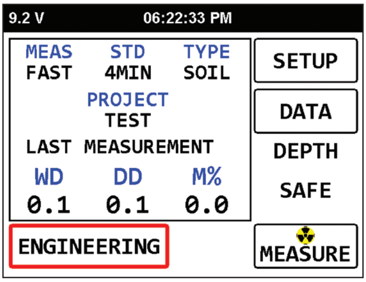
The Factory Calibration is to only be performed by Humboldt or an authorized service center.

### 4.4.4 Master Gauge Reset

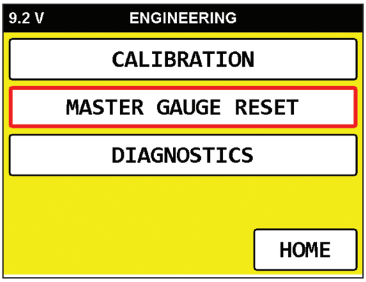
Performing the Master Gauge Reset will clear the working memory of the gauge. This will clear the statistical data to what was recorded at the last known factory calibration. All Global Targets will be cleared to defaults along with the Trench Correction factors. The User Calibration will be reloaded to the Factory Calibration.

**NOTE:** This does not clear the User Calibration Constants. All History, Project Data, and Project Targets will be retained as well.

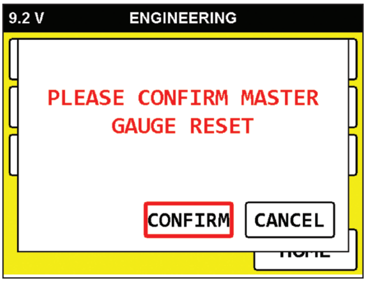
To perform a Master Gauge Reset press **ENGINEERING** from the main menu.



Press **MASTER GAUGE RESET** from the Engineering menu.

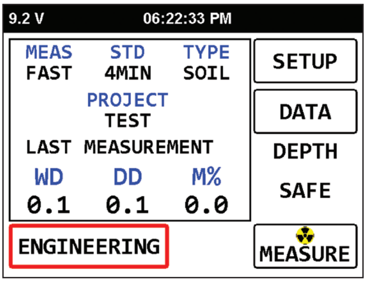



Press **CONFIRM** to continue with the reset.

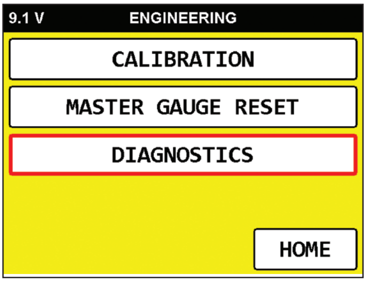



### 4.4.5 Diagnostics

The Diagnostics menu will help diagnose an electronic hardware issue with the gauge. Press **ENGINEERING** to enter the Engineering menu.




Press **DIAGNOSTICS** to enter the Diagnostics menu.

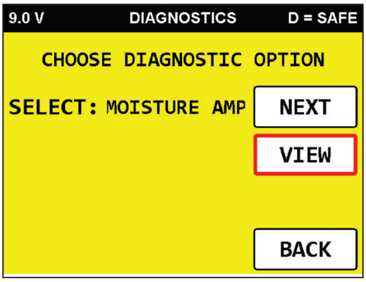



From the Diagnostics menu you can view Moisture, Density, High Voltage and Battery Voltages.

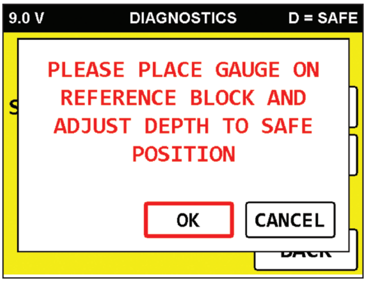
The Moisture, Density and High Voltage will give you a **PASS / FAIL** along with actual values to help determine root cause failure.

In this example we will look at the Moisture option.

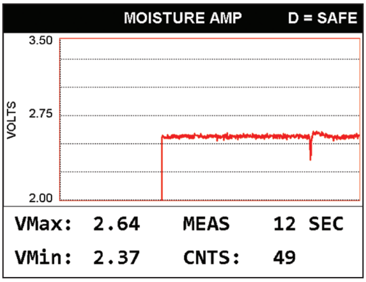
Press **VIEW** when Moisture Amp is selected.




It will prompt you to place the gauge on the reference block, which is important to take moisture readings.




The diagnostic screen will show you a voltage graph of the signal. It will do a 15 second sampling of the counts and display a pass or fail for three seconds and then repeat the process over until you press the screen or any key to exit the diagnostic menu.




This information will help you if you find that you are having an issue with the gauge. It will be most beneficial to call Humboldt support and a technician can review the data and determine if a part is needed to repair the gauge.

## 5 Preventive Maintenance

This equipment was designed for severe service and is a rugged instrument. If properly maintained it will require very little service other than routine maintenance.

### 5.1 Storage Environment

The instrument was designed to operate over an ambient temperature range of -10 to 70 °C. The storage temperature of the most critical components is -55 to 85 °C. There is not a likely chance that this range will ever be exceeded but storing it at room temperature will greatly extend its service life. The recommended range is 10 to 35 °C (50 to 95 °F).

The most damaging environment to electronic instruments is humidity. While it is possible to hermetically seal the instrument case, the cost would be prohibitive. It does have gaskets to seal out water from rain but the case must "breathe" and consequently water vapor moves in and out. If the combination of humidity and temperature causes condensation it will ultimately cause failure.

The interior parts are all non-corrosive or have protective coatings applied to slow down this process. The user can prevent condensation by limiting storage to a temperature range and humidity where condensation cannot occur and if it is likely remove the front panel during storage to allow moisture to evaporate and escape rather than be trapped inside.
If it is used during a rain or exposed to surface water, it should be dried off before being put away.

### 5.2 Exterior Cleaning

The Gauge is going to get soiled during use. While this causes no harm, removing loose material at the end of each working day will prolong the cosmetic appearance.

Occasionally it would help if the exterior were cleaned with an industrial grade detergent and water. Heavy scrubbing may damage the finish on labels but will not harm the other materials.

The Source Rod and Index Rod may be sprayed with silicon ok and the excess wiped off with a cloth. The Source Rod is 440C stainless steel and while no pitting can occur, surface rust may form initially due to iron molecules brought to the surface by heat-treating. Light rubbing with an abrasive will remove it and after several times, it will no longer occur. Cleaning the top seal around the Source Rod will aid in preventing soil from working into the bearing, which is located below the seal.

### 5.3 Sliding Shield Cavity

A Sliding Shield of tungsten covers the gamma source when it is retracted to the “SAFE” condition. After prolonged use, the small amount of soil carried into the cavity with each retraction will accumulate in this cavity. If not periodically cleaned, the abrasion from the soil will increase the force required to push the rod out and could cause jamming of the shield which will result in faulty **STANDARD COUNT** repeatability. Ultimately the soil will damage the seals between the cavity and the bearing.

The bottom plate, which contains a scraper ring to remove soil from the rod when it is retracted, can be removed by using a hex key to take out the two screws. Lay the Gauge on its side or end with the bottom pointed away from personnel and the rod in the "**SAFE**" position to prevent exposure from the source. Remove the screws and pull the plate away from the base. The sliding shield is held in place by a spring. Be careful not to let the spring fly off when removing the shield.

Clean the parts with a damp cloth and clean the cavity with a stiff brush. Finally, spray the parts and cavity with dry silicon spray.
The cavity and bottom plate are impregnated with Teflon and do not require extensive lubrication. If excessive wear has occurred to the bottom plate and scraper ring, they may need to be replaced.

Push the spring into the hole in the Sliding Shield and replace it in the cavity with the sloping side towards source and the spring compressed against the end of the cavity. If the sliding shield does not fully close it may be necessary to stretch / replace the spring. Replace the plate and screws being certain that they are tight and the heads of the screws do not extend above the surface of the plate.

### 5.4 Performing a Wipe Test

Regulations require that sealed capsules of radioactive materials be tested every six months to assure that they are not leaking. This is to prevent contamination of personnel and other equipment. Absorption of radioactive material into the body is the most severe accident that can occur in use of this equipment and there is little that can be done to remove it. Prevention of the absorption is the only solution.
The materials to perform this test have been supplied with the Gauge in kit (200177) and additional materials may be obtained from Humboldt Scientific, Inc. or other venders of these kits. Ethanol (ethyl alcohol) at 95% purity may be obtained from a local beverage store under the trade name "Everclear". It is preferred but water may be used.
Since the user does not have access to the actual surface of the capsule, the regulations allow the wipe to be made on a surface that is likely to be contaminated by a leaking capsule. There are **TWO** sources in this Gauge. The gamma source is mounted in the source rod and the most accessible location to wipe is the hole in the case through which the rod extends in normal use. The neutron source is mounted in a cylindrical holder inside the case just behind of the main circuit board.

Most processors of these wipes allow both of these sources to be wiped with the same filter paper since they are able to determine from which source any contamination came. First fill out the form including the Gauge model and serial number, the type of radioactive material (Cs-137 and

Am- 241:Be) and the Gauge serial number (some kits also list the sources serial numbers). Include the owner's name and the address to which the form is to be returned.

Wet the filter paper with the solvent. Remove the front panel and locate the label around the Am-241:Be source holder. Using the tongs, wipe the threads of the allen screw at the top of the holder with the wetted paper. Lay the Gauge on its side with the base away from personnel so that the case provides a shield. Using the tongs to hold the paper, wipe the rim of the hole thoroughly with the wet paper. After wiping a source, do not touch the paper with fingers. Treat it as potentially radioactive material. Place the Gauge in the upright position. Place the filter paper in the plastic envelope and seal it.

Place the plastic envelope and the properly completed form in another envelope and mail it to the processor. The owner and authorities will be notified if the testing indicates a removable activity in excess of 5 nCi (0.005 uCi) which is the legal maximum allowable. An activity in excess of 1.0 nCi will likely result in a request to re-wipe the sources.

**5.5 Statistical Stability Test**

This test is a simple method of testing the short-term stability of the detectors and electronic counting circuits. The basis for it is explained in section 7.3 covering radiation statistics.

Radioactive decay is a binary process (an atom decays or it does not). The average rate of decay determines the half life (the time for half of the material to disintegrate) of the material. For Cs 137 this is 30.17 years and for Am 241: Be, it is 433 years. The decrease in the average rate of decay for Cs 137 is 2.3% per year and for Am 241: Be is 0.16% per year. Calibrating the Gauge in forms of a ratio eliminates the effect of this change on the measurement.

The short-term fluctuation of binary decay is predictable. The predicted standard deviation is the square root of the average count rate (m):

$$\sigma = \sqrt{m}$$

The Gauge electronics divide the actual events counted in a one-minute period by a factor of 16 before using the number, so the above expression is actually:

$$\sigma = \frac{\sqrt{m}}{4}$$

This equation can be used to predict the standard deviation of the count rate for a series of measurements. By taking a series of 16 measurements and computing the actual standard deviation, the value obtained can be compared as a ratio to the predicted value thus:

$$R = 4 \sqrt{\left[\frac{\sum (n - m)^2}{m (N-1)}\right]}$$

Where: σ = Standard deviation of count rate
n = Individual measurement
N = Number of measurement
m = Mean of the measurement
R = Statistical ratio

" STAT" automatically runs this series of measurements and displays the R values for the density and moisture channels. See section 3.2.

For: R > 0.6 and < 1.4 Good R
< 0.5 or > 1.5 Bad
Others— Try Again

## 6 Field Service

The **HS-5001NX** is designed for reliability and field service is kept to a minimum. Little, if any, test equipment is required and the only tools necessary are:

| | | |
|---|---|---|
| Hex Key, | 1/16 | inch |
| Hex Key, | 1/8 | inch |
| Hex Key, | 9/64 | inch |
| Hex Key, | 3/16 | inch |

Phillips Screwdriver, #1 x 4 inch

Your Radioactive Material License must specifically allow removal of the Source Rod if the rod bearings and seals are to be removed, cleaned or replaced.

### 6.1 Mechanical Disassembly / Assembly

#### 6.1.1 Bottom Plate and Shield

The Bottom Plate Assembly (200666) is held in place by two Flat Head Hex Socket Screws (001010). Removing them will allow the plate to pull away and the Sliding Shield (200030) and Spring (000816) can be removed for cleaning. The Scraper Ring (000806) in the Plate (200665) can be replaced by removing the Retaining Ring (000811).

#### 6.1.2 Source Rod

Other than replacing a set of bearings, it is not necessary to remove the Source Rod. A suitable shield must be available. REQUIRES

**AUTHORIZATION FROM REGULATORY AGENCY ON USERS LICENSE.**
Drop the Source Rod to the backscatter position. Loosen the two Hex Setscrew (001007) at the top and unscrew the Lift Cap (200667) and the

Auto Lift Bumper (200278) to allow complete removal of the Source Rod and handle. Hold the rod by the handle with the tip as far as possible from the body and store it in a shielded container with a minimum 25 mm (1 inch) lead wall or in one of the calibration standards at least 3 m (10 ft) from personnel work areas. The rod must not be left unattended and should be replaced in the Gauge shield as soon as practical.

### 6.1.3 Indexer and Latch

This may be accomplished without removing the source rod from the Gauge. Remove the Lift Cap as described in 6.1.2. Raise the handle off of the Index Rod and rotate it 90º: Push the rod back into the shield. Remove the two Hex Setscrew (001034) at the end cap of the handle and slide the complete latch assembly and Index Pin (200660) out the rear of the handle. These parts are lubricated by the Teflon coating.

### 6.1.4 Index Rod

The Index Rod may be removed without removing the Source Rod. Remove the Lift Cap as described in 6.1.2, lift the handle off the Index Rod and rotate it out of the way. **MAY REQUIRE FACTORY RE-CALIBRATION**.

Loosen the Index Lock Nut (200052) and unscrew the Index Rod (200668, 669, 670 or 671) from the post. When replacing the Index Rod Latch the handle firmly in the backscatter position and screw the Index Rod until the tip of the Source Rod is flush to 0.05 mm (0.002 inch) recessed within the bottom of the Gauge. The rod must not protrude or backscatter measurements in the field could be in error. Tighten the Index Lock Nut (200052).

### 6.1.5 Top Cover

First remove the Processor Module (201016) by releasing the four Thumbscrews (001013). Lift the panel out and disconnect the Module Cable (H-4114.060) from the base frame assembly. Remove the six Socket Head Cap Screws (001008) and Washers (001030) around the edge of the cover. The cover can be totally removed from the Gauge by placing the handle partially between the backscatter and safe positions and working the cover over it. It will be easier if the Post Grommet (200109) is removed from the hole. If worn or damaged, the Bottom Gasket (200149) or Panel Gasket (200351) should be replaced.

### 6.1.6 Top Post and Seals

The seals and wipers will wear due to soil abrasion and soil working into them as the Source Rod is moved up and down. Keeping the bottom cavity clean and lightly lubricating the Source Rod with silicon grease will help prolong their life.

**Caution:** the owner's license must allow Source Rod removal before this service may be performed. With the Source Rod removed and safely stored as covered in 6.1.2 and the Top Cover removed: Remove the four Socket Head Cap Screws (001009) and Lock Washers (001031) from around the Post. The Post may be lifted up over the tungsten bio shield. The Wiper Plate (200031) and Wiper Ring (000803) may be removed from the inside of the post. When replacing them, the wiper goes into the top of the plate such that it cleans the Source Rod as it moves in an upward direction.

The Top Wiper Cap (200032) may be removed from the Post by removing the two Hex Socket Screws (001007) from the side of the Post. Pry up lightly on the Cap. The Wiper Ring (000803) in the Cap may be replaced by carefully prying it out of the top.

The two Bearing Seals (000805) may be removed by carefully prying them out of the center hole. The seals will be destroyed but be careful not to damage the Source Rod Bearing (200136). When replacing the seals, they must be pushed or lightly tapped in place with a wood or soft metal dowel to prevent damage. The bearing has recesses for soil to accumulate to prevent binding. Clean the bearing with a solvent and lubricate with silicon grease. Lightly coat all of the seals and wipers with the same grease before reassembling. Reassemble in reverse order.

### 6.1.7 Base Module

There are high voltage capacitors on the circuit board, which may be charged to 900 volts. **The current available is low but injury may occur due to the surprise of receiving a severe shock.** Discharge them by firstly sliding the circuit breaker at the top of the batteries pack to the off position and secondly pressing and holding the push-button switch at the top of the circuit board for about one second.

Remove the Top Cover as described in 6.1.5. Remove the seven Socket Head Cap Screws (001008) and Lock Washers (001029) around the edge of the module. Carefully lift the Base Module up out of the Gauge Base. The detectors may be replaced if necessary and the parts reassembled.

## 6.2 Batteries

The **HS-5001NX** is equipped with two sets of batteries. The primary battery is a pack of seven NiMH batteries. Fully charged batteries can power the Gauge for 140 hours continuously with the processor active. Depending on the number of tests per day, an average of 20 tests (1 minute) per day with a 4-minute standard translate to 82 days or 16 weeks for a single charge.
The second set of batteries is a pack of six alkaline batteries, which provide backup for the primary batteries in the event of complete discharge.

The NiMH battery pack is located underneath the Index Post. The switch on the charger PCB is only used to power the USB port for Humbolt's Find My Gauge tracker kits. It is not necessary to turn this switch on unless you want to power the USB port on the charger PCB.

To Charge the NiMH batteries plug the charger into the round jack. It is equipped with a charge indicator in line on the cord. The indicator is steady GREEN when the charger is unplugged, or the batteries are finished charging. The indicator will blink BLUE when the battery pack is charging, a full charge can take up to six hours to complete depending on how low the battery pack.

**It is not necessary to let the battery pack drain completely before recharging. It is best to periodically charge the pack to extend the life of the battery pack.**

The life cycle of the battery pack will be effected by many variables including use of the gauge, environmental conditions, storage conditions. Here are some best practices for maintaining and charging NiMH battery packs.

### Manage Partial Charges and Discharges

**Partial Cycles:** NiMH batteries perform well with partial discharges and recharges, which can be beneficial for their longevity compared to full discharge cycles.
**Deep Discharge:** Avoid letting NiMH batteries fully discharge before recharging. Complete discharges should be infrequent to avoid reducing the battery's lifespan.

### Conditioning

**Periodic Cycling:** Every six months, it can be helpful to fully discharge and then fully recharge NiMH batteries to "condition" them. This can help reverse any potential memory effect (though it's much less of an issue with NiMH than with older NiCd batteries) and equalize the cells in a battery pack.

### Storage

**Charge State for Storage:** If you plan to store NiMH batteries for an extended period(six months or longer), charge them to about 40-50% of their full capacity. This level is generally considered optimal for long-term storage.
**Regular Checks:** Periodically check and maintain the charge of stored batteries every 3-6 months to prevent them from deep discharging, which can be detrimental.

### 6.3 Electronic Modules Adjustment / Replacement

To improve reliability and maintain ease of service, the **HS-5001NX** electronics are divided into three modules, which may be individually replaced. Two of them have adjustments, which may need to be adjusted.

#### 6.3.1 Processor Module (201016)

This Front Panel Module contains two counting systems, a programmed microprocessor, and a display. Field service is impractical other than replacement. It is easily removed by means of four thumbscrews located in the corners. The cable is disconnected from the Base Plane Module by releasing the latches at each end of the connector. Note that the cable, when properly installed, has no twists in it, only a 180° turn.

The Factory or Authorized Service Facility may repair or replace the module. No re-calibration is necessary; however, the Gauge calibration is stored in a memory module that must stay with the same Gauge or re-calibration will be necessary.

**6.3.2 Base Plane Board (201012)**

This Board, into which all the small modules are plugged, has no active components, only interconnects between other components. The probability of failure is very low except for physical damage. Should it become necessary to replace it, some soldering is required so either the entire Base Frame must be replaced, or returned, or the entire Gauge returned. No re-calibration is required.

For protection a circuit breaker is above the battery holders which will open if the main power circuits become shorted. A red indicator is visible when the circuit breaker is closed and applies power to the board.

The Base Board also has a push-button switch in the upper center of the board which is used to discharge the high voltage before servicing any of these circuits. This button should be pushed and held for about one second before removing or replacing the High Voltage, Density, or Moisture Modules.

The entire frame, including the detectors, is removed by means of the seven screws around the edge of the frame. Do not remove the screws, which attach the Board to the frame.

**6.3.3 High Voltage Power Supply Module (200088.NX)**

This module supplies a highly regulated 900 vdc to the Density and Moisture Amplifier modules and in turn to the detectors. From unit to unit, the voltage may vary ±25 volts but once established, it is very stable.

**This voltage can cause a severe shock and before any replacement is attempted, the discharge push-button switch located in the center of the base circuit board must be pushed and held for about one second.**

The module is easily replaced by removing the screw located in the middle of the module. When plugging in another one, look at the pins closely. and orient the module pins to the circuit board sockets. If they are aligned the module can be inserted easily. Do not apply force as the pins may be bent or damaged.

The module is not repairable and must be replaced if defective. The replacement does not affect calibration.

### 6.3.4 Density Amplifier Module (200087)

This module is used to condition varying amplitude pulses from the two gamma detectors to logic level pulses for the counter in the Processor Module.

There are two adjustments, which control the amplitude of the pulses from each of the detectors. They should be set, using an oscilloscope, to produce average 500 millivolt negative pulses at test point **DTP** on the base circuit board. This pulse height is not very critical and if the adjustments are set at mid range, and the **STAT** test indicates stability, the setting is acceptable without the availability of the oscilloscope.

The high voltage can cause a severe shock. Before any replacement is attempted, the discharge push-button switch located in the center of the base circuit board must be pushed and held for about one second.
The module is easily replaced by removing the screw located in the middle of the module. When plugging in another one, look at the pins closely and orient the module pins to the circuit board sockets. If they are aligned, the module can be inserted easily. Do not apply force as the pins may be bent or damaged.

The module is not repairable, and must be replaced if defective.

### 6.3.5 Moisture Amplifier Module (200086)

This module is used to condition varying amplitude pulses from the thermal neutron detector to logic level pulses for the counter in the Front Panel Module.

There is one adjustment, which controls the amplitude of the pulses from the detector. It should be set, using an oscilloscope, to produce average 500 millivolt negative pulses at test point **MTP** on the base circuit board. This pulse height is not very critical and if the adjustment is set at mid range, and the **STAT** test indicates stability, the setting is acceptable without the availability of the oscilloscope.

**The high voltage can cause a severe shock. Before any replacement is attempted, the discharge push-button switch located in the center of the base circuit board must be pushed and held for about one second.**
The module is easily replaced by removing the screw located in the middle of the module. When plugging in another one, look at the pins closely and orient the module pins to the circuit board sockets. If they are aligned the module can be inserted easily. Do not apply force as the pins may be bent or damaged.

The module is not repairable, and must be replaced if defective.

## 6.4 Detector Replacement

If total failure of a detector occurs or if adjustments to correct instability problems are not possible, then the detectors require replacement. The procedure is quite simple.

Remove the Base Frame Module as instructed in 6.1.7 after **discharging the high voltage.** The Gamma Detector(s) (200035) may be removed by sliding them out of the side of the module. When replacing the Gamma Detectors, note that a leaf spring is in contact with the shell and needs to be compressed when sliding in the replacement.

The Moisture Amplifier must be removed in order to slide the Neutron Detector (200026) out of the frame. Slide the new detector in place and carefully install the amplifier so the module pins and the detector connector engage. **NOTE:** any replacement of the detectors will requires re-calibration.

## 6.5 Parts List

This list includes all parts, which may be field replaced.

| | |
|---|---|
| Tool Set | 200112 |
| Zippered Accessory Case | 200175 |
| Drill Rod | 200130 |
| Scraper Plate/Rod Guide | 200127 |
| Rod Extractor Tool | 200145 |
| Hammer | 000176 |
| Transit Case Assembly | 200681 |
| Reference Standard | 200122 |
| Gauge Padlock | 000177 |
| Instruction Manual, **HS-5001NX** | 201026 |
| Radiation Safety Manual | 200121 |
| Radioactive Source Certificate | 200173 |
| Wipe Test Materials (Kit) | 200177 |
| Leak Test Certificates | 200174 |
| Filter Paper | 000175 |
| Plastic Bags | 000178 |
| Forceps | 000181 |
| Lift Cap | 200667 |
| Hex Socket SS Set Screw, 6 32 x 3/16 (2) | 001061 |
| Lift Bumper | 200278 |
| Index Rods | |
| 8 X 1 | 200668 |
| 8 X 2 | 200669 |
| 12 X 1 | 200670 |
| 12 X 2 | 200671 |
| Index Lock Nut | 200052 |
| Handle Assembly | 200664 |
| Gauge Handle | 200661 |
| Lift Handle | 200662 |
| End Cap | 200663 |
| Index Pin | 200660 |
| Cs Source Label | 200091 |
| Roll pin, 0.125 x 0.375 | 001020 |
| Handle Repair Kit | 200659 |
| Top Cover Assembly | 200170 |
| Top Cover | 200133 |
| Post Grommet | 200109 |
| Bottom Gasket | 200149 |
| Panel Gasket | 200351 |
| Panel Nut, 8 32 (4) | 200163 |

| | |
|---|---|
| Washer, Internal Tooth ¼", SS (4) | 001037 |
| Radioactive Material Label | 200134 |
| Hex Socket Head SS Cap Screw, 8 32 x 1/2 (6) | 001008 |
| Flat SS Washer, #8 (6) | 001030 |
| Drive Screws #00 | 001023 |
| Front Panel Assembly | |
| Front Panel | 201016 |
| Captive Screw (4) | 001013 |
| Display Board | 201009_T |
| Post Module Assembly | 200031 |
| Post Assembly | 200154 |
| Bearing Post | 200028 |
| Source Rod Bearing | 200136 |
| Top Wiper Cap | 200032 |
| Wiper Ring | 000803 |
| Hex Socket SS Set Screw, 6-32 x 3/16 (2) | 001007 |
| Seal 5/8" (2) | 000805 |
| Shield Insert | 200156 |
| Hex Socket Head SS Cap Screw, 1/4-20 x 1 (4) | 001009 |
| Lock Washer, SS Split Spring, 1/4 (4) | 001031 |
| Gauge Base (No internal Parts) | 200027 |
| Bio Shield | 200029 |
| Bottom Plate Assembly | 200666 |
| Bottom Plate | 200665 |
| Scraper Ring | 000806 |
| Retainer Ring | 000811 |
| Flat Head Hex Socket SS Screw, 8-32 x 1/2 (2) | 001010 |
| Sliding Shield | 200030 |
| Shield Spring, SS | 000817 |
| Am:Be Source Label | 200092 |
| Hex Socket SS Set Screw, 5/8 18 x ½ | 001032 |
| Base Frame Assembly | 200201 |
| Hex Socket SS Cap Screw, 8 32 x 1/2 (7) | 001008 |
| Lock Washer, SS Internal Tooth, #8 (7) | 001029 |
| Base Circuit Board Assembly | 201012 |
| Phillips Head SS Screw, 6 32 x 1/2 (6) | 001005 |
| Lock Washer, SS Internal Tooth, #6 (6) | 001006 |
| High Voltage Power Supply Module | 200088.NX |
| Phillips Head SS Screw, 6 32 x 1 ¼ | 001042 |
| Lock Washer, SS internal Tooth, #6 | 001006 |
| Density Amplifier Module | 200087 |
| Phillips Head SS Screw, 6 32 x ¾ | 001004 |
| Moisture Amplifier Module | 001006 |
| Phillips Head SS Screw, 6 32 x ¾ | 200086 |
| Lock Washer, SS internal Tooth, #6 | 001004 |
| Ground Spring | 001006 |
| Phillips Head SS Screw, 4 40 x ¼ | 200162 |
| Lock Washer, SS Internal Tooth #4 | 001054 |
| Detector, Gamma (2) | 001018 |
| Detector, Neutron | 200035 |
| Seal and Wiper Set | 200179 |
| Silicon Grease, General Purpose | 200199 |

## 6.6 Calibration

The Calibration of this instrument will be valid for a minimum of one year and probably much longer if reasonable care is taken to prevent the application of heavy shock loads to the Gauge base.

Users are advised to establish a location on a laboratory floor or other reference and measure this location on receipt of the equipment. Periodic measurement of this location will provide a means of verifying the calibration over a long period of time.

Any discrepancy in this measurement or suspected errors in field data will indicate the need for calibration. If the owner does not have facilities to perform the Calibration as covered previously then the equipment should be returned to an Authorized Service Facility or the factory.

# 7 Theory of Operation

This instrument uses two types of radiation to measure the density and moisture content of materials. The interaction between the radiation and the materials is very different but most of the electronics are compatible with the two functions. Both measurements are indirect in the sense that another parameter of the material is actually measured and the parameter then stated in terms of density and moisture.

The differences between the measured parameters and the desired density and moisture is typically called "composition" or "chemical" error since it does involve the chemical elements or molecules which form the materials.

## 7.1 Density Measurement by Gamma Radiation

Gamma radiation is a form of electromagnetic radiation similar to the radio frequencies that carry television signals and rays of visible light. The only difference is one of frequency. At the frequency of gamma radiation, materials exposed to it are ionized and this creates a hazard to living tissue. Gamma and X radiation's are identical and are only differentiated by their origin. X radiation is emitted when electrons change energy states and gamma is emitted from the nucleus when some types of radioactive decay occur. While one normally thinks of electromagnetic radiation as occurring in continuous waves, at higher frequencies it is more usual to analyze the effects in quanta or points of energy (photons) having zero rest mass.

An isotope of Cesium-137 with a half life of 30.17 years is used in this Gauge to produce gamma radiation. The isotope decays with the emission of a beta particle having a maximum energy of 1.176 MeV and an average of 0.195 MeV. The Cesium-137 is transformed into Barium-137m which has excess energy and decays with a half life of 2.5 minutes to a ground state with the emission of gamma having an energy of 0.662 MeV.

The nominal amount of Cesium-137 used is 10 mCi with a rate of decay at $3.7 \times 10^8$ disintegration per second. The efficiency of gamma production is 85% so 3.2 x $10^8$ photons are produced per second. The beta particles are absorbed by the capsule wall.

When gammas of this energy pass through materials, either of two interactions may occur. At the original energy of 0.662 MeV, the primary effect is collision with the loosely bound electrons of the material with a scattering (change in direction) and transfer of energy. As scattering continues and the energy decreases, photoelectric absorption occurs in which the gamma transfers all of its energy to a more tightly bound electron and the electron leaves the atom which may result in some X radiation.

As evident from the above, the interaction is with the electrons in a material and not the nucleus which contains most of the mass. Consequently the Gauge actually measures the electron density of the material which is only approximately related to the mass density. The relationship is the ratio of the Z (atomic number or number of electrons per atom) and A (atomic mass of the atom). The term Z/A is used frequently.

The process is further complicated by the probability that the interaction will or will not occur. Atoms are mostly voids so many gammas will simply pass through with no interaction.

The probability is a function of both the atomic number and the energy of the gamma and is different for scattering and photoelectric absorption. We will combine the two and call the resultant probability as the "mass attenuation coefficient" or u/p.

The classic equation for the attenuation of gamma passing through material is:

$$\frac{-L*p*u/p}{I = Io * e}$$

Where:

I = resulting intensity

Io = Initial intensity

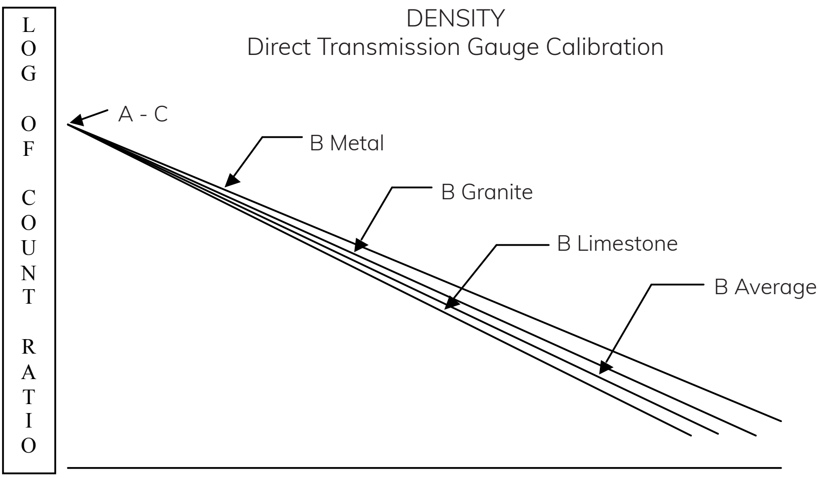
L = path length

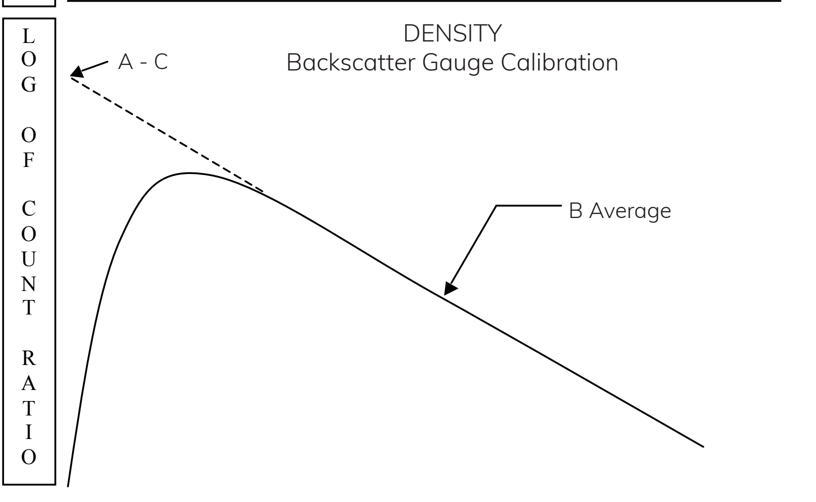
p = density of material

u/p = attenuation coefficient

The table below indicates the relative percentage for the most predominant elements in the crust of the earth along with their values of Z/A and u/p.

| Element | Percent | Z/A | u/p(0.662 MeV) |
|---|---|---|---|
| Oxygen | 44.6 | 0.500 | 0.0806 |
| Silicon | 27.7 | 0.498 | 0.0805 |
| Aluminum | 8.1 | 0.482 | 0.0777 |
| Iron | 5.0 | 0.466 | 0.0762 |
| Calcium | 3.6 | 0.499 | 0.0809 |
| Sodium | 2.8 | 0.478 | 0.0772 |
| Potassium | 2.6 | 0.486 | 0.0787 |
| Magnesium | 2.1 | 0.498 | 0.0796 |
| Hydrogen | – | 0.992 | 0.1600 |



Fortunately the most common materials in the surface layers are oxygen, silicon and calcium in the form of oxides or carbonates. If this were not the case, Gamma Density Gauges would not be practical for use. These materials all have a u/p between 0.0805 and 0.0809. Large amounts of hydrogen in surface water do require an adjustment in the measured density.

The equation indicated is not practical for use in a Gauge since the mass attenuation coefficient varies with energy which is changing as the gammas pass through materials and the detectors used are not linear with energy.

While many equations may be used to fit the data, the most common is:

$$\boldsymbol{CR = A * e^{-BD} - C}$$

Where:

CR = Count rate or Ratio at the detectors

D = Density of the material

A,B,C = Constants

Geiger Mueller detectors are used in the system along with a gamma filter to select the desired energy spectrum. The filter limits the low energy response and the detector design limits the upper energy, which can be detected. The available energy at the filter is a function of the initial energy of the gamma radiation from the source and the path length through the material.

The count rate at the detectors is ratioed to a standard set of conditions in order to eliminate drift of the system and the effect of aging of the radioactive material over long periods of time.

This table lists the mass attenuation coefficients for suggested calibration materials covering the possible range of photon energy. The values are calculated from data included in "Gamma Cross Sections, Attenuation Coefficients, and Energy Absorption Coefficients from 10 keV to 100 GeV" published by NIST.

**Mass Attenuation Coefficients ($cm^2/g$)**
**GAMMA ENERGY(MeV)**

| Material | 0.10 | 0.15 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 |
|---|---|---|---|---|---|---|---|
| Magnesium | 0.1610 | 0.1360 | 0.1220 | 0.1060 | 0.0944 | 0.0861 | 0.0796 |
| Magn./Alum | 0.1620 | 0.1350 | 0.1210 | 0.1040 | 0.0931 | 0.0849 | 0.0784 |
| Aluminum | 0.1620 | 0.1340 | 0.1200 | 0.1030 | 0.0922 | 0.0841 | 0.0777 |
| Limestone | 0.1920 | 0.1460 | 0.1280 | 0.1080 | 0.0960 | 0.0874 | 0.0808 |
| Granite | 0.1640 | 0.1370 | 0.1240 | 0.1070 | 0.0950 | 0.0867 | 0.0802 |
| Lime/Gran. | 0.1780 | 0.1415 | 0.1260 | 0.1075 | 0.0955 | 0.0870 | 0.0805 |
| Water | 0.1680 | 0.1490 | 0.1360 | 0.1180 | 0.1060 | 0.0967 | 0.0895 |

After using this data to correct the metallic materials, the experimental count rates will give an equation, which is still not applicable for construction materials. Assuming that most construction materials will have a composition between limestone and granite, the metallic values of A and C can be used to calculate a value of B which applies to these materials or other values of B can be determined for any material.

Experimental data must be used and not the values from the above table. The initial gamma energy is known to be 0.662 MeV but the average energy for the interactions would be impossible to determine. Gamma filters are used with the detectors to limit the lower energy in order to reduce the errors due to chemical composition.

Using energy discriminating detectors, the lowest possible chemical error for limestone and granite is ± 0.4%. With Geiger Mueller detectors and mechanical filters, the practical limits are about 2% for backscatter modes and 1.5% for direct transmission.

The direct transmission mode involves placing the source and detectors across the material (opposite sides) so that the gamma path is directly through the material. This is the most accurate method due to the higher average energy and the method produces true average densities.

The backscatter method involves placing the source and detectors on the same surface of the material. The gamma must be deflected back prior to measuring the attenuation by the material. As a result, the average energy is lower and the method does not produce a true average density since a larger portion of the gammas pass through the materials closest to the surface and less at deeper depths.

## 7.2 Moisture Measurement by Neutron Radiation

Neutron radiation is in the form of a particle having no electrical charge. The particle is emitted from the nucleus of an atom usually as the result of having absorbed a very high-energy gamma or an alpha particle. While very rare, a neutron may result from spontaneous fission. For industrial use, isotopic sources are available which consist of alpha radiation combined with beryllium metal. The reaction is:

$$Be^{9} \quad (\alpha, n) \quad C^{12}$$

When the beryllium nucleus reacts with the alpha particle it becomes an isotope of carbon. The C12 is left at an excess energy state and yields a 1 to 10 MeV neutron when it goes to the ground state.

In 5001NX, Americium 241 is used as the source of alpha. The 40 mCi source yields an average of 9 X 104 neutrons per second. The Americium-241 also yields low energy gammas, which are shielded out in the source holder.

The neutron interaction with matter is relatively complex. Having no charge, it passes through atoms quite readily and unless it collides with the nucleus of an atom little or no energy is lost. Only when the collision involves a Low Mass nucleus such as hydrogen is there a significant loss of the neutron energy, and that loss is dependent on the angle of the collision.

The neutrons from an Am-241:Be source starts with an average energy of 4.5 MeV. With each collision some energy is lost until the neutron reaches energy of about 0.025 eV. This value is called thermal since it equals the velocity of surrounding materials at room temperature which is 2200 m/s (7300 ft/s). The neutron may decay with a half-life of 11 minutes or, at thermal energy, may be captured by another atom. The elements in the earth’s crust, which may either thermalize or capture thermal neutrons, are listed on the next page.

| Element | Percent | Collisions | Absorption |
|---|---|---|---|
| Hydrogen | | 19 | 0.33 |
| Boron | <0.1 | 109 | 759.00 |
| Carbon | <0.1 | 121 | <0.01 |
| Oxygen | 44.6 | 159 | <0.01 |
| Sodium | 2.8 | 225 | 0.53 |
| Magnesium | 2.1 | 237 | 0.06 |
| Aluminum | 8.1 | 263 | 0.23 |
| Silicon | 27.7 | 273 | 0.16 |
| Chlorine | <0.1 | 343 | 33.00 |
| Potassium | 2.6 | 378 | 2.10 |
| Calcium | 3.6 | 387 | 0.43 |
| Manganese | <0.1 | 529 | 13.30 |
| Iron | 5.0 | 537 | 2.53 |
| Cadmium | <0.1 | 1075 | 2390.00 |
| Lead | <0.1 | 1976 | 0.17 |

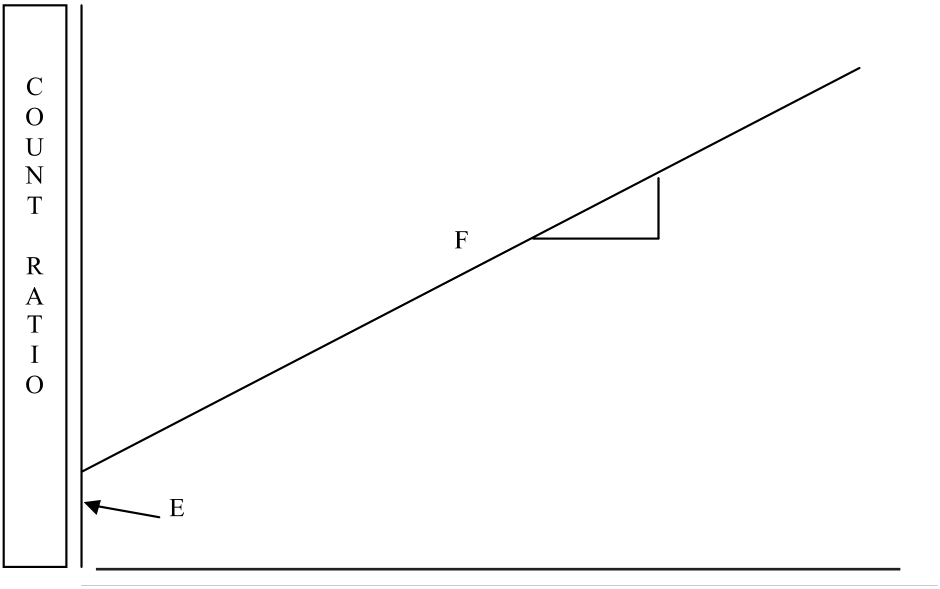
Note that the number of collisions required to produce thermal neutron increase rapidly above hydrogen and the only other significant elements that are present, oxygen and silicon require a much larger number of collisions. Oxygen of which there is a large amount is usually uniformly distributed with all elements in the form of oxides, including water.

For this reason, If a thermal neutron exists there is a very good probability that it was produced by collision with hydrogen. While most hydrogen in construction materials is in water, there may be hydrated minerals that contain large amounts of hydrogen and the error must be corrected.

The Absorption column lists the cross section (probability) of the material capturing a thermal neutron. Outside of some rare elements such as cadmium, only boron and to a lesser degree chlorine, manganese and iron have a cross section a great deal higher than hydrogen.

These elements seldom cause errors with the exception of a few areas, which have large amounts of boron, coastal areas, which may have significant sodium chloride in the soil, and a few locations where iron oxide may be present in large amounts.

Helium-3 is an isotope that has a very large capture cross-section for thermal neutrons and the detector in the 5001 is filled with this gas at a high pressure so that it is very efficient. If the source and detector are mounted very close together, the relationship between detected thermal neutrons and hydrogen (water) is linear over the normal range of soil moisture.




MOISTURE
Moisture Gauge Calibration

The count rate is ratioed to a standard count and a suitable equation is:

$$CR = E + F * M$$

Where:

CR = Count Ratio

M = Moisture content

E = CR at zero moisture content

F = Slope of the function

In order to determine the values of E and F, two moisture standards are required. One may be zero since it is easy to obtain and the other must have a known amount of water or contain hydrogen, which can be related to water.

The moisture measurement is sometimes called backscatter but once a neutron has been thermalized by multiple collisions with hydrogen, it obeys gas diffusion laws and drifts off in any direction. Some arrive at the detector and get counted.

## 7.3 Radiation Statistics

Radioactive decay is a binary process, any given atom may decay or it may not. For large quantities of atoms a Poisson distribution very accurately describes the process. This distribution has a standard deviation s, which is equal to the square root of the mean rate of decay. The predicted precession of the count rate is defined as ± one standard deviation.

The mean of a sample is:

$$m = \frac{\sum n}{N}$$

Where N number of samples:

The predicted precision of the sample is:

$$\sigma(n) = \sqrt{m}$$

The one standard deviation spread of a single sample is:

$$n = n \pm \sqrt{n}$$

From these equations it is evident that the predicted precision of the Gauge is directly related to the square root of the number of detector counts accumulated during a measurement. Further, the precision can be improved either by counting a longer time period or by averaging the count rate for a number of measurements and this improvement is the square root of the number of measurements made.

While the precision of the Gauge in count rate shows the trend, what is of interest is the precession of the density and moisture measurement. In order to obtain this information, it is necessary to know the change in the measured parameter in terms of a change in count rate. This is the slope of the calibration equation.

$$\boldsymbol{CR = A * e^{-BD} - C}$$

Or

$$\boldsymbol{n = DS * A * e^{-BD} - C}$$

Then the differential is:

$$\boldsymbol{S = \frac{dn}{dD} * A * e^{-BD} - C}$$

Which is the slope in terms of counts per minute per unit density. Combining this equation and the equation for precision and accounting for the pre scale value of 16 yields:

$$\boldsymbol{DP = \frac{\left(\sqrt{(DS * A * e^{-BD} - C)}\right)}{4DS * A * B * e^{-BD}}}$$

Where:

| | |
|---|---|
| DP= | Density precision at density D |
| D= | Density |
| DS = | Density standard count |
| A, B, C = | Calibration constants |
| S = | Slope |

This is for one standard deviation, a 68% confidence factor.

Applying the same procedure to the moisture equation results in an equation for the moisture precision:

$$\boldsymbol{MP = \frac{\left(\sqrt{(MS * (E + F * M))}\right)}{4MS * F}}$$

Where:

MP = Moisture precision

M = Moisture

MS = Moisture standard count

E, F = Calibration constants

Both of the above previsions are stated for the one minute (NORM) measurement period. The values would increase by a factor of two for 0.25 minutes (FAST) and decrease by a factor of two for the four minute (SLOW) measurement period.

These precisions are the theoretical values and the Gauge should yield these values if there are no instability problems. Measurement data can be used to test the Gauge.

If a series of measurements are made on the same location, the values of precision can be calculated by using:

$$\sqrt{\frac{\sum(n-m)^2}{(N-1)}}$$

Where:

P = Precision

n = Individual measurements

m = Average of measurements

N = Number of measurements

If the actual count rate precision obtained above is divided by the theoretical precision, a test can be made of the Gauge stability. The resultant value, R will indicate electronic noise in the circuits or an unstable detector. The equation for this test is indicated in 5.5, and the Gauge has this function included in the software.

## 8 Radiation Safety

The user of this equipment should study the Radiation Safety Manual, which is supplied with it. If available, a formal course on the subject is desirable. While the radioactive materials in the Gauge are very small amounts and only a major accident to the Gauge could cause an immediate hazard, care should be taken in its use in order to keep exposure as low as reasonably achievable.

Remember that short time and long distance are the most effective means of minimizing the user's exposure.

Refer to the Radiation Safety Manual for more complete details of safety procedures.

### 8.1 Licensing

Prior to receipt and use of this equipment, the user must obtain a Radioactive or By product Material License from the government agency responsible for the purchaser's area.

The licensee must have a Radiation Safety Officer who has received training in safety and applicable regulations. He will be responsible for the initiation and maintenance of a safety program for the users. All records and inventory controls must be available for inspection.

## 8.2 Dosimeter

Personnel using the equipment should wear personnel dosimeters in order to assure that proper care is being taken in storage, transport and use. Some regulations allow dispensing with this requirement after a period of monitoring.

All visitors in the area of use should be kept to a minimum. If long-term observance of the use of the equipment is needed then dosimeters should be supplied. The general rule is that any individual that is likely to receive 10% or more of the regulatory maximum is required to be monitored.

Any person whose age is less than 18 years must not be exposed to any dose which is likely to exceed 10% of the regulatory maximum for radiation workers.

## 8.3 Wipe Tests

There is a legal requirement that the sealed capsules containing the radioactive materials in this Gauge must be tested for integrity of the seals. This test is described in detail in 5.4. The record of this test must be retained for inspection by the regulatory agency. The user's license will specify who may make the wipe and process the material.

## 8.4 Transport

Any equipment given to a common carrier for shipment must have a current negative leak test. The shipper must have this record in his possession along with a certification that the capsule, and transport container meet the US Department of Transportation requirements as specified in Title 49 Parts 172 and 173 of the Code of Federal Regulations these certification must be on file for one year after the shipment. For international shipment the Regulations of the international Atomic Energy Agency apply and other countries have their own regulations for domestic shipment. The consignee of any shipment other than a freight forwarder or customs agent must be in possession of a license for the radioactive materials.

A shipping paper presented to the carrier along with the package certification must contain the following information:

RQ, Radioactive Material, TYPE A PACKAGE, Special Form, UN3332

| Name | Cesium-137 | Americium-241 |
|---|---|---|
| Activity | 0.37 GBq (10 mCi) | 1.48 GBq (40 mCi) |
| Category | YELLOW II | |
| Transport Index | 0.2 | |
| Type | A | |

A record of the shipment and copies of all the documentation including a copy of the consignee's license must be retained by the shipper.

## 8.5 Disposal

The owner must not dispose of this equipment except under the following conditions:

- Transfer to another licensee for possession and use as covered in their license.
- Transfer to another licensee for storage or disposal as covered in their license.

## 8.6 Reporting of Loss or Incidents

The loss of this equipment or incidents, which may cause exposures in excess of the recommended maximums, must be reported immediately to the Radiation Safety Officer and to the government agency responsible for administering the license.

Other events, which may represent a safety hazard, must also be reported.

## 8.7 Radiation Profile

The maximum surface and one meter exposure rates for this equipment are listed below in mRem/h.

The Transport Index for the Transit Case and Gauge is:

**Dose Rate in mRem/hr** 0.2

| Transit Case | Gamma | Neutron | Total |
|---|---|---|---|
| Maximum any surface | 10.50 | 1.50 | 12.00 |
| Maximum at one meter | 0.07 | 0.10 | 0.17 |
| **5001 Gauge** | **Gamma** | **Neutron** | **Total** |
| Rear Surface | 17.00 | 0.30 | 17.30 |
| Rear at one meter | 0.10 | 0.00 | 0.10 |
| Front Surface | 2.50 | 0.40 | 2.90 |
| Front at one meter | 0.10 | 0.00 | 0.10 |
| Bottom Surface | 8.50 | 1.50 | 10.00 |
| Bottom at one meter | 0.06 | 0.50 | 0.56 |
| Top Surface | 18.00 | 0.70 | 18.70 |
| Top at one meter | 0.06 | 0.00 | 0.06 |
| Side Surface | 11.00 | 0.80 | 11.80 |
| Side at one meter | 0.20 | 0.00 | 0.20 |
| Handle | 0.80 | 0.50 | 1.30 |
| Handle at one meter | 0.10 | 0.0 | 0.10 |

North Carolina Protection Section Measurement Dose Rates. Gamma dose rates were measured 08/05/88 using a Ludium Model 14C Survey Meter. Neutron does rates were measured 08/05/88 using an Eberline Model PNR-4 Neutron Rem Counter with a 22.9 cm sphere on the Gauge surface, centerline was approximately 11 cm from the surface. 0.0 indicates does rates same as background.

## 9 Warranty

The purchase of this equipment includes a limited 12 month warranty against defective material and workmanship. The owner may replace defective parts in the field by prepaid shipment for installation.

Equipment shipped prepaid to the factory will be repaired or replaced at the option of HUMBOLDT and returned prepaid to the customer. This warranty does not apply if the product as determined by HUMBOLDT, is defective because of normal wear or accident or misuse, or because of service or modification by other than an Authorized Service Facility.

THIS EQUIPMENT CONTAINS HAZARDOUS RADIOACTIVE MATERIALS AND THE PROPER USE OF THE EQUIPMENT AND PROTECTION OF FACILITIES AND PERSONNEL IS SOLELY THE RESPONSIBILITY OF THE PURCHASER. OWNERS AND USERS ACCEPT RESPONSIBILITY FOR COMPLIANCE WITH LOCAL AND NATIONAL LAWS COVERING THE POSSESSION, USE AND DISPOSAL OF THE MATERIALS.

THERE ARE NO WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WITHOUT LIMITATION ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS, WHICH EXTENDS BEYOND THIS DESCRIPTION. THIS EXPRESS WARRANTY EXCLUDES THE COVERAGE OF AND DOES NOT PROVIDE RELIEF FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES OF ANY KIND OR NATURE, INCLUDING BUT NOT LIMITED TO LOSS OF USE, LOSS OF SALES OR INCONVENIENCE. THE EXCLUSIVE REMEDY OF THE PURCHASER IS LIMITED TO REPAIR, RECALIBRATION OR REPLACEMENT OF THE EQUIPMENT AT HUMBOLDT'S OPTION.

Specifications and descriptions are as accurate as possible. HUMBOLDT reserves the right to make changes and improvements in accordance with the latest specifications and design improvements. Upgrading of older equipment to current specifications will be made, where possible, at the expense of the current owner except where HUMBOLDT may elect to make the upgrade at no cost to the owner.

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Testing Equipment for Construction Materials

HUMBOLDT

NUCLEAR GAUGES