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Section 1 - General Information

Product Description

The Model **CPN MCM-2 HYDROTECTOR®** is a non-destructive, moisture measurement gauge designed for rapid determination of water content in the thermal insulation of pipes and vessels. This gauge is ideal for petrochemical applications.

Hydrogen present in the water in the insulation, causes the neutrons to lose energy (neutron moderation) for detection. The moisture data is displayed directly in units of interest on a electronic display assembly and can be stored in memory for subsequent download or printout.

This state-of-the-art instrument offers a simple to operate but superior alternative to other methods of moisture monitoring. The operator needs minimal instructions. The **CPN MCM-2** is designed as a screening tool to rapidly locate areas of trapped moisture. It works well in conjunction with corrosion detection instruments to quickly detect areas where Corrosion Under Insulation (CUI) is highly probable.

The complete assembly is supplied in a sealed, dust proof, and water resistant enclosure. A padded shoulder bag offers additional protection and convenience. The detector assembly is enclosed in a strong, light weight aluminum housing.

CPN MCM-2 Features

The **CPN MCM-2** Direct Readout Model provides:

- Integral microprocessor for simple function selection.
- Precise repeatable moisture measurements.
- Light weight and portable.
- 24k bytes of memory logging for records.
- Storage and recall selection of 16 linear calibrations.
- Operator selected time of test, logging format and units of measurements.
- Data transfer to a personal computer or printer via RS232C interface.
- Testing at rates up to 10 feet per minute.

Functional Description

The **CPN MCM-2 HYDROTECTOR®** operates by emitting radiation from an encapsulated radioactive source, Americium-241:Beryllium. To determine the moisture content in the insulation, the Americium-241:Beryllium source emits neutron radiation into the pipes under test. The high-energy neutrons are moderated by collision with hydrogen atoms in the trapped moisture of the insulation. Only low-energy, moderated neutrons are detected by the Helium-3 detectors. An insulation with a high water content will give a high count per time of test. A dry insulation will give a low count for the same period of time.

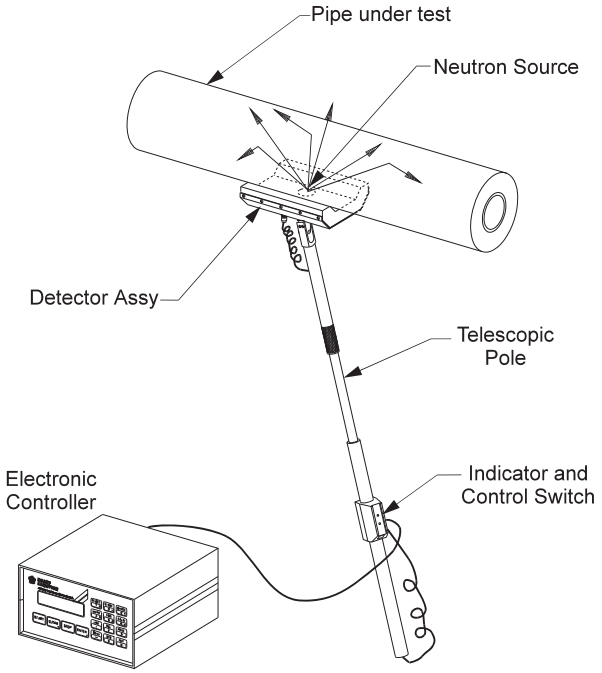


Figure 1.1. Operation of the **MCM-2 HYDROTECTOR®**

MCM-2 Hydrotector ®

Standard Equipment

Each MCM-2 Hydrotector ® is provided with the items listed below. There are no special instructions for unpacking. It comes fully assembled.

Item	**Part Number**
MCM-2 Hydrotector ®	117100
Shipping Case	704736
Shipping Tube for Extendable Pole	704651
Readout	704606
Case Pole	704669
Detector Assembly	704607
Cables	704674
Padlock & 2 Keys	700472
Shoulder Bag	704650
Battery Pack	704590
Operating Manual	
Leak Test Certificate	

Specifications

Dimensions/Shipping Weights

Model	Weight	Width	Depth	Height
Detector Assembly	7.0 lbs (3.17 Kg)	7.0 in (178 mm)	6.0 in (229 mm)	2.0 in (51 mm)
Detector Assembly in shipping container	24.0 lbs (10.88 Kg)	27.0 in (686 mm)	12.0 in (305 mm)	12.0 in (305 mm)
Adjustable Pole in shipping container	11.0 lbs (5.0 Kg)	5.5 in (140 mm)	5.5 in (140 mm)	5.5 ft (1670 mm)

Performance

Function	Insulator moisture measurements.
Range	Linear calibration: 0 to 40% per volume, 0.40 g/cc, 25 pcf, 4.8 in/ft.
Precision	0.24% at 24% per volume at one minute.
Count Time	User selectable from 1 to 960 seconds, in 1 second increment.
Display	8 character alpha/numerical Liquid Crystal Display. Easily readable in direct sunlight.
Data Storage	24576 bytes of storage memory. Format operator programmable. From 0 - 99 key data and 0 - 99 counts per record.
Data Output	RS232C serial download to external printer or personal computer.
Calibration	16 user programmed (linear).
Units	User selectable: in/ft pcf, gcc, % vol, and counts.
Construction	Aluminum

Electrical

Power	6 “C” cell size alkaline battery pack (7 Ah).
Battery Life	1 year aproximately.
Consumption	6.5 mA average (allows more than 3000 each 16 second counts).

Environmental

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

Radiological

Neutron Source	1.85 GBq (50 mCi) Americium-241:Beryllium.
Encapsulation	Double-sealed capsule CPN-131.
Shipping Requirements	Radioactive Material, R.Q. Special Form N.O.S. UN2974 Transport Index 0.3 Yellow II Label USA DOT 7A Type A Package
Special Form Approval	GB/281/S-85.

An NRC or agreement state license is required for domestic use. Contact Boart Longyear/CPN Company for assistance in obtaining training for a license.

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

CPN MCM-2 HYDROTECTOR® Inspection

To familiarize yourself with the **CPN MCM-2 HYDROTECTOR®**, perform the following review.

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

2. Examine the keyboard, the display screen, the cable, the telescopic pole, and the detector assembly.

CAUTION

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

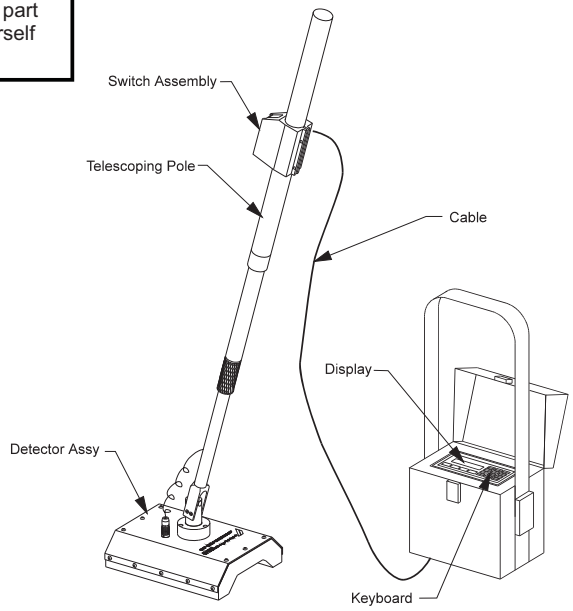


Figure 1.3. **CPN MCM-2 HYDROTECTOR®**

CPN MCM-2 HYDROTECTOR® Getting Started

The stand-by power drain of the gauge is less than the self-discharge of the alkaline cells thus eliminating the need for a power switch. The **CPN MCM-2** is always "ON", but has an internal function that automatically, after 30 seconds of no operation, switches it to stand-by mode (the display will be blank) to save battery power. To turn the **CPN MCM-2** ON again, press any key and the display will show the last function that was executing before it went into the standby mode.

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

UNITS	%Moisture by volume.
TIME	1 second increments; 4 second averages, or 1 second QuickTest .
CALIB	CAL #1, Factory calibration. Coefficient A (slope) approx. 20.8% per count ratio and coefficient B (intercept) approx. -0.5%.
STD	Standard count approximately 10000.
FMT	1 Keydata and 3 Sites.

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

PRESS	**DISPLAY**
CLEAR	**READY**
TIME	**TIME 1 (Read the current value)**
16	**TIME 16**
ENTER	**READY (Write it to memory)**

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

PRESS	DISPLAY
CLEAR	READY
UNITS	UNIT ipf
STEP	UNIT cpc
STEP	UNIT %V
ENTER	READY

Take another count by pressing **START**. The measured result should be the same as above except that the count should take 16 seconds and the display should be **approximately ____%** moisture by volume.

Section 2 - Operation

Controls and Display

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

Key	Function
START	Take a reading.
CLEAR (NO)	**CLEAR**, abort, "NO".
STEP	Next, skip, toggle.
ENTER (YES)	Enter data, make selection, "YES"
D-WET	Not used.
D-DRY	Not used.
WATER	Display latest moisture reading.
UNITS	Select display units (cnt, rat, pcf, gcc, ipf, cpc, %v).
TIME	Select counting time (1 to 960) seconds.
CALIB	Select calibration (1..16) and optionally:
MCOEFS	Enter coefficients directly.
MSLFCAL	Semi-automatic calibration.
LOG	Log a tube site record.
RCL	Recall a record for review.
PRINT	Dump records to external device:
PRINT CD	Dump to an active device (Computer Device, with handshaking).
PRINT LP	Dump to a passive device (Line Printer).
PRINT NF	Dump to an active device (Computer Device, no handshaking).
MENU	Select miscellaneous function:
QUIK TST	Counts continuously and compare counts with selected value, beeps and lights the alarm (red) LED if counts are higher than selected value.
BAUDRATE	Select baudrate (110, 300, 1200, 2400, 4800, 9600).
SERIAL#	Display/Enter a four-digit serial number.
VERSION	Display software version.
CLOCK	Set the real time clock.
CYCLE	Put the gauge in cycling mode.
RECOVER	Recovers the data from memory.
STD	Select display/update check count summary or standard count summary.
STD CNT	Display/update standard count summary.
CHK CNT	Display/update check count summary.
FMT	Set record format, **CLEAR** records.

Display	Function
"READY"	Gauge is ready for operation.
“READY LO”	Indicates low battery.

Keyboard Functions

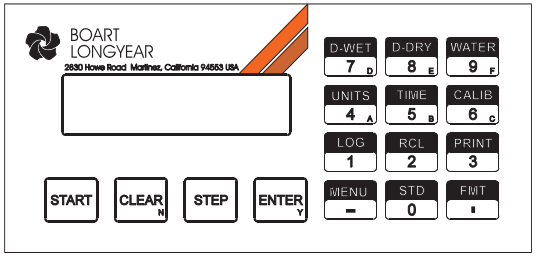


Figure 2.1. **CPN MCM-2 HYDROTECTOR®** Keyboard.

D-WET (Not Used)

Displays wet density using currently selected calibration and units (On a **CPN MCM-2** returns to "READY").

D-DRY (Not Used)

Displays dry density using currently selected calibration and units (On a **CPN MCM-2** returns to "READY").

WATER

Displays the most recent moisture reading in current units using current calibration (e.g. "M 23.4").

UNITS

Display/Select display unit. Displays current unit (e.g. "MUNT PCF"). To select new unit, **STEP** to desired unit and press **ENTER**. If **CLEAR** or another selection key is pressed, unit remains unchanged.

Units	Description	Conversion
cnt	counts/unit-time (16 second display)	N/A
rat	ratio (count/stdcount)	N/A
%v	percent water by volume	100.0

Keyboard Functions

CALIB (CALIBRATION)

Display/Select calibration (1 through 16 and/or review/change its coefficients).

Before pressing **CALIB**, select the appropriate units and time via the **UNITS** and **TIME** keys. If counts (CNT) or ratio (RAT) is the selected unit, the gauge will display "SET UNIT". If MSLFCAL is to be used to take a count, select a time of 240 seconds for maximum precision.

To Select A Calibration

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

To Enter/Change Coefficients When The Coefficients Are Known

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

Display = A · (ratio) + B

Where ratio is count divided by standard count

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

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

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

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

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

LOG (LOGGING)

Activates the storage mechanism to log a unique site record. As defined previously by the **FMT** key, each RECORD consists of 1 each ID, the calibration number in use , the date and time of the logging , 0 to 99 keypad entries, and 0 to 99 sites. ID number, keypad entries and sites start at the highest value and down count to 1. When **LOG** is first pressed, the current record number is displayed. Press **ENTER** to use it as the default ID number or key in a meaningful record number. Press **STEP** to switch to alpha mode and use characters from A to F for ID.The record number decrements from the maximum to 1, each time a new record is logged. The record number is thus an indicator of how many additional records may be logged.

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

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

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

RCL (RECALL)

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

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

PRINT

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

PRINT CD

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

PRINT LP

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

PRINT NF

Output formatted to upload record log to a computer directly or via modem. It has the same format as PRINT CD but doesn’t include the checksum for each line nor does it use ACK, NACK software protocol to control transmission.

MENU

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

QUIK TST

BAUDRATE

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

SERIAL

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

VERSION

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

CLOCK

Allows setting the real time clock. The clock is 24 hours base. To set the date to 10/25/95 and the time to 15:32 press **MENU, STEP, STEP, STEP** and **ENTER**. The month is first displayed, MONTH 10, keyin the new month or press **ENTER** to accept, then displays the DAY 25, the YEAR 95, the HOUR 15 and MIN 32. Follow the same procedure as in the month to edit the new values. If the battery pack is replaced for any reason, the gauge will show “SET CLOCK” as the first screen indicating that the real time clock must be set.

CYCLE

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

RECOVER

If for any reason the data in memory is lost or if you reformat the memory you can use the RECOVER function to recover the data. You need only to input the format (number of keydatas and number of sites) that were used for that data, and the number of records that were in memory in order for the gauge to find and recover the lost data. If you don’t remember the exact number of data records involved, input your best guess. If you guess too large a value, the gauge will recover the actual data and then also return non-real data for the excess records.

Keyboard Functions

STD

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

To take a new standard count, press **ENTER** after “NEW STD?” is showed in the screen. The MCM-2 will take 240 seconds (4 minutes) count. When the count is finished, a NEW standard count is stored in memory.

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

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

STD CNT

CHK CNT

FMT

Sets the record format, and clears the Logging space. On entry, displays the actual key datas, key in the desired number of keydata entries (0 through 99) and press ENTER. Do the same for sites (0 through 99). Then the gauge will show the maximum number of possible records to be logged in the current format (e.g. "REC 279"). Press ENTER and when the gauge displays "SET FMT?", be sure you want to do it, and then press ENTER. This **CLEAR**s the Log, sets the new record format, and starts the storage at the top of the Log area. Be sure you have downloaded the previous information before **CLEAR**ing the memory, otherwise it will be erased. If you just want to view the current format, but not **CLEAR** it, press **CLEAR** to abort.

Modes of Operation

RELATIVE MEASUREMENT MODE

In this mode, the operator takes several readings on a given **pipe configuration** and establishes a low base line count. Tests are compared to this baseline and areas which read higher are marked for follow-up inspection. Since the configuration should have the same insulation type, pipe diameter and jacketing material, changes in counts will be the result of increases or decreases in the moisture content of the insulation.

> **ADVANTAGE:** This mode of operation requires very little prior knowledge of the area being tested. It allows the operator to quickly establish an expected “dry” baseline which s used to compare the other tests.

DIRECT READOUT IN % MOISTURE BY VOLUME

This mode of operation requires a pre-established calibration sample be made for each pipe configuration being tested. For piping a length of 24” (600mm) of the pipe, insulation and jacketing should be used to establish the calibration. Taking readings on the dry sample, then wetting the insulation with a known amount off water and then taking readings, will serve as a calibration. The readout will allow entry of this data and it will generate a linear calibration which it can store into memory.

The readout can store up to sixteen of these calibrations, each corresponding to a different pipe configuration. Once established, the operator selects the appropriate calibration for the pipe being tested, and sets the readout units to “%”. Then the operator can move along, taking tests, looking for specific change in moisture %, which is much easier to interpret than a fluctuating number. This mode works well for establishing specifications for when to strip or when to inspect by some other means. *(For more information, refer to the calibration section of this manual.)*

> **ADVANTAGE:** Once the calibration work is done, it is very easy to train any user to test areas and flag locations which read above a pre-determined moisture percentage.

SETTING-UP THE UNIT FOR USE

The **MCM-2 HYDROTECTOR®** can be assembled in minutes if you follow these steps.

Connect the pole to the DETECTOR ASSEMBLY

> **CAUTION:** When connecting the pole ot the detector assembly and when using the gauge, always maintain a maximum distance from the source and detector assembly. The neutron source is **ALWAYS ON** and a maximum distance will keep the operator's exposure to a minimum. The operator should be careful to keep the detector away from others, as well.

Turn the pole so that the notch aligns with the key in the detector assembly connector. Then push the connectors into each other, and slide the sleeve over the connectors and tighten.

Connect the readout to the pole assembly by plugging the cable into the readout, then feeding the cable through the shoulder bag, and plugging the cable into the START/ENTER switch assembly, mounted on the pole assembly. Either end of the cable will fit the connectors.

Place the shoulder strap over your head and carry the pole with the detector farthest from your body.

Press any key on the readout, and the display will come on and display the last screen used. Pressing CLEAR will return the screen to "READY".

To conserve power, the unit will shut off the display after 20 seconds. No data or memory will be lost.

Push the detector assembly against the ground or some ffirm surface to adjust the position of the detector, so that the detector will conform to the surface you want to test. The detector will pivot and swivel in two directions. The swivel has a stop to prevent damage to the cable.

Taking A Reading

To take a reading, place the detector assembly against the insulation and press **START**. Before doing this you must select **UNITS**, **TIME** and **CALIBRATION**. If you select any units other than count (CNT), the gauge must have a valid standard count.

How to Select UNITS

The choice of display units will depend upon your use. Inspectors will normally prefer counts. Counts provide a rapid relative measurement. When an absolute value is required, a calibration will have to be established on the specific pipe configuration (refer to Appendix B for more information on this). Counts are used for downloading to a software program and are helpful for troubleshooting. It is the same data, only differing by the conversion factor.

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

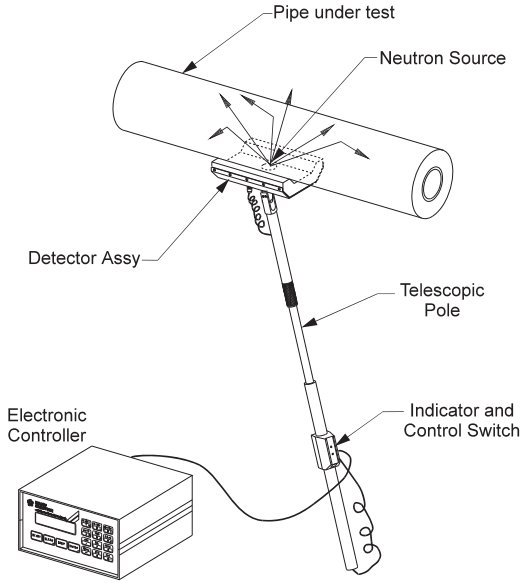


Figure 2.2. Taking a Reading.

How to Select TIME

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

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

How to Select CALIBRATION

The calibration will have been determined previously, and the slope (A) and intercept (B) coefficients stored in one of the sixteen calibrations. Select the one that is appropriate for the material you are testing.

To Log Readings

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

How to FORMAT The Records

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

The total memory space available is 24576 bytes. The number of bytes required in a record for each pipe section is as follows:

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

Thus a typical location record format of one ID, one calibration number, the date, the hour, one keydata, and three sites, takes 22 bytes per record, and allows 1117 records to be stored.

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

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

How to TAKE/LOG Your Measurements

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

You can use the gauge generated number as the ID number to be stored by pressing **ENTER,** to enter your own ID number for this record (access tube), key in any number of 5 digits or press STEP and key in alphanumeric A to F or any combination e.g. “ID A12B1”, press **ENTER** to accept it. It may be meaningful to treat this number as more than one number. i.e. consider the first two digits as a site number (allowing from 1 to 99 sites), and the last two digits as a location number (allowing from 1 to 99 locations on any jobsite). Enter the middle digit as 0 or use it to indicate an operator number from 1 to 9.

After entering the ID number, the display will prompt for keydata entry (e.g. "1K 0" - if selected by the **FMT** key previously). Keydata entries allow you to use the gauge to key in auxiliary information. This feature helps eliminate errors in translating readings to note pad, and then from the note pad to the computer.

Enter the keydata as a number from 0 to 65,535 followed by **ENTER**. Again, it may be treated as more than one piece of information. A keydata field does not have provisions for decimal points. They must be implied, not entered directly.

Use any scheme which fits your site conditions. Just be consistent from record to record.

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

After accepting the data the gauge will prompt for the next keydata, or if all keydatas are entered, it will prompt for a moisture reading by displaying "TAKE ##" ("##" is the number of the site position and will counts down from the maximum number set via FORMAT to 1).

Locate the detector assembly at the first site and press **START.** When the count is completed, the gauge will display the value of the reading in the units selected (e.g. "3M 12.43"). If the reading is acceptable, press **ENTER** to store it. If not acceptable, identify the reason and press **START** to take another. The gauge will only store a reading if you accept and enter it. The display will then prompt to take the next moisture reading. Move the detector and repeat the process by pressing **START**. Continue in this manner until testing is complete.

If you want to skip a site (e.g. it is not accesible), press **STEP** instead of **START**/**ENTER**.

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

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

How to RECALL a Record

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

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

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

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

Previous Standard Count

When a new standard count is taken, the previous standard count is replaced and the **MCM-2** program uses the new standard to calculate the field count/standard count ratio.

"Xi" is displayed and signifies the chi-squared distribution of the counts. This is the ratio of the actual distribution of the counts compared to the expected distribution. A ratio near 1.0 and small changes between previous an new counts, indicates that the **MCM-2** is working properly. It is recommended that a new standard be taken daily to check "Xi" and changes in counts. The Xi ratio should be between 0.75 and 1.25, and the change between the present and previous standard counts should be smaller than the square root of the average count (1 standard deviation). This will verify the performance of the gauge every day of use. If the Xi value is outside of expected limits, repeat the standard count. If the statistics are again poor, consult the Troubleshooting Guide (Appendix B).

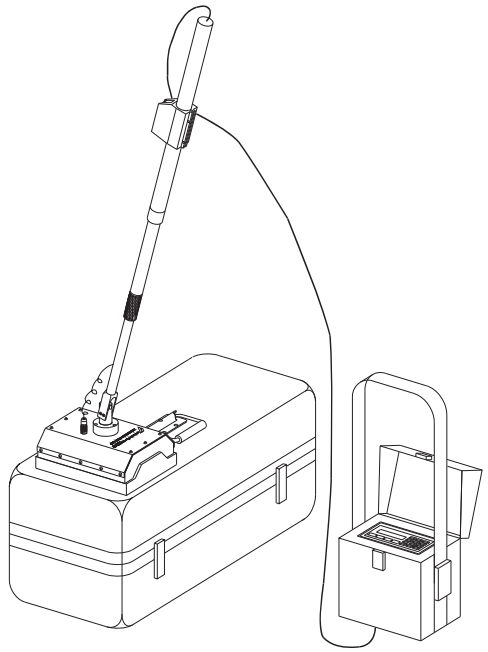


Figure 2.3. Standard Count Procedure.

Taking a Standard Count

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

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

Standard Count

When a standard count is started, the gauge will take a 240 second count. When the count is completed, the NEW standard count is displayed (e.g. "S 7405").

Press the **STEP** key to view the current standard count (e.g. "P 7385"). Press the **STEP** key again to view the Chi-Square Ratio of the NEW count (e.g. "CHI 0.95").

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

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

Standard Count Statistics

Taking such a series of 240 1-second counts will result in a distribution of counts around a central value. The standard deviation is a measure of the spread of these counts about that central value. For a random device, such as the decay of a radioactive source, the ideal standard deviation should be equal to the square-root of the central value.

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

For a sample of 240 counts, the ratio should be between 0.75 and 1.25 for 95% of the tests. Note that even a good gauge will fail 5 out of every 100 tests. If the ratio falls too consistently outside, it may mean that the counting electronics is adversely affecting the counts. Generally, the ratio will be high when the electronics is noisy. This might be due to breakdown in the high voltage circuits or a defective detector tube. The ratio will also be high if the detector tube counting efficiency or the electronics is drifting over the measurement period (i.e. the average of the first five counts is significantly different than the average of the last five counts).

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

The MCM-2 contains a source of fast or high energy neutrons and a detector of slow or thermal neutrons. The fast neutrons are slowed down by collision with the nucleus of matter in the insulation, and then absorbed by the moisture. Since the mass of the nucleus of hydrogen is the same as that of a free neutron, the presence of hydrogen will result in a high field of thermal neutrons. Heavier elements will also slow down the neutrons, but not nearly so effectively. The thermal neutrons are continually being absorbed by the material under test.

Site Calibration

A site calibration requires the gauge, dry and wet insulation samples, a scale and a drying oven. Install the access tube in a representative point in the soil. Take gauge readings on the insulation samples. Ideally such measurement pairs should be taken over a range of moisture conditions.

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

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

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

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

Laboratory Calibration

For a laboratory calibration, two known calibration points are needed. A high moisture calibration standard can be a section of saturated insulating material. A low moisture standard would be a section of dry insulating material.

Set the gauge to the desired units and select a 240 second (4 minutes) count time. Use the SLFCAL feature of the probe. Place the gauge in one of the two know moisture standards. The display will prompt for the know moisture content of the standard. Enter it in the units selected, e.g. 3.88 **ENTER**. If count or ratio has been selected as the units, an error message will be displayed.

By pressing **START** the gauge will take and store a 240 seconds reading. When the count is completed, move the probe to the second moisture standard. The display will prompt for the moisture content of that standard. Press **START** to take a 240 second reading in the second standard. When the count is completed, the gauge will calculate and store the slope and intercept coefficients for the calibration in the selected units. Use "COEFF ?" **ENTER** to view them. Record them in your note book for future reference.

Section 3 - Maintenance

General

This section supplies basic information to perform maintenance on a field level basis. The only required tool is the screwdriver which is supplied with the gauge. A voltmeter capable of reading to 15 VDC is recommended.

The model **CPN MCM-2** consists of three major assemblies:

1) The Electronic Controller
2) Detector Assembly
3) Telescopic Pole (Handle) with cable.

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

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

If the Electronic Controller is found to be defective for reasons other than battery cells, then it requires test equipment including an oscilloscope, signal generator and a digital voltmeter. As such, they should be returned to the factory for repair. The Electronic Controller can be disconnected and shipped by UPS or other convenient means to a CPN Service Center. **Do not attempt to remove the sealed source or its housing from the detector assembly.**

Exchange Policy

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

Leak Testing

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

1. Use the CPN TD-11 LTK Leak Test Kit to perform this required test for leakage of the source material from its capsule.

2. Use the cotton swab in the kit and swab the circular radioactive material label on the source housing on the detector assembly for any removable traces of the Am-241:Be source material.

3. Break swab stick in half and place in plastic envelop. Complete form and staple envelop to it; mail to address on the kit. Within approximately six weeks you will receive notification of results.

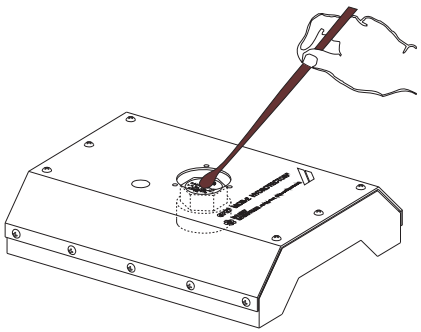


Figure 3.1. Leak Test Procedure.

Electronic Assembly Maintenance

The Electronic Controller consists of:

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

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

Removal

If the Electronic Controller is faulty, it can be returned to the factory for repair or exchange while leaving the source in the storage container.

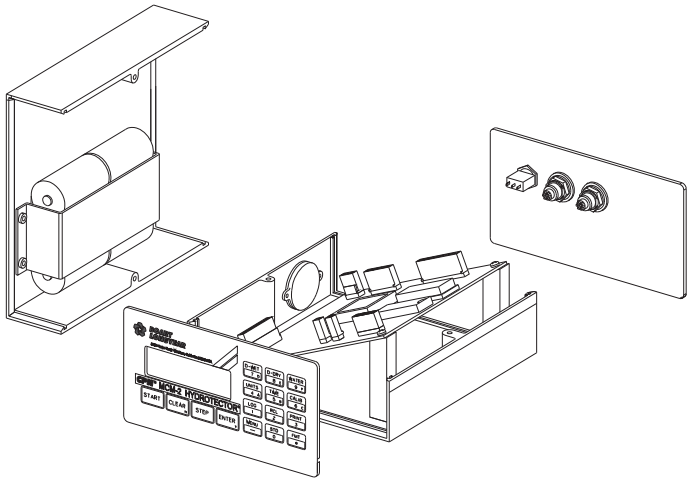


Figure 3.2. Electronic Controller

Detector Assembly Maintenance

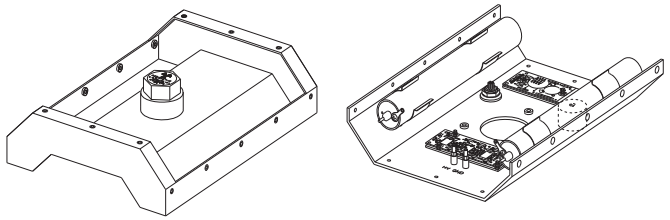


Figure 3.3. Detector Assembly.

WARNING
The radioactive source is mounted on the Detector Assembly. Do not grasp it with your hand.

The Detector Assembly consists of the connector, brass plug housing a ferrite transformer, an amplifier PC-Assembly, an HVPS PC-Assembly, both mounted on a tray and the detector tubes. These items are shown in Figure 3.4.

Appendix A

Operation Cautions

1. Do not expose either the detector assembly or controller electronics to standing water or to a water spray.

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

Error Messages

If an error occurs in the **CPN MCM-2,** then the function that was being performed is aborted, and an error description or number is displayed (the gauge is actually in the **READY** mode). Errors that may occur in the normal operation of the gauge, will display a descriptive message. You should take corrective action as appropriate.

Operating Errors

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

Appendix B

Troubleshooting Guide

CONDITION	POSSIBLE CAUSE
Keypad does not respond.	Press and release the RESET button on the back of the readout. The battery pack may be dead.
Chi ratio too high, no change in the average standard count.	Look for a drift in the counts over the measurement time. (e.g. the average of the first five counts is significantly different than the average of the last five counts).
Chi ratio too low with an increase in the average count over previous.	Periodic noise occurring. Possibly an open filter capacitor in the HV power supply.
Chi ratio too low, no change in the average count.	Procedure error. Possibly analyzing normalized counts. The standard deviation must be determined on direct counts.
Chi ratio OK but change in average count.	Change in gauge geometry. A change in counting efficiency will be normalized out by ratio technique. A change in gauge geometry must either be corrected or the gauge recalibrated.

Appendix B

Troubleshooting Guide

Counting

Display reads "CNT ZERO", a 6 kHz hum can be heard.	Detector Assembly defective. Cable defective.
Same except no 6 kHz hum.	Detector Assembly defective. Cable defective.
Statistics test results in high ratio due to one or more wild counts.	HV supply noisy
Statistics test results in high ratio due to shift of mean during the test period.	HV supply drifting. Detector drifting
Statistics test results in low ratio with an increase in the standard count.	Periodic noise being counted, most likely due to open bypass capacitor in HV supply.

Performance

Moisture reading higher than expected, while statistics test of standard count and all other functions are okay.	Gauge is reading hydrogen in both trapped moisture and the insulation itself. Adjust the calibration for this type of insulation.
Same except moisture reads low	Calibration requires adjustment.
Same except accompanied by a shift in standard count.	Probe geometry changed. Defective detector

Appendix C

Data Transfer

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

The program specifications that pertain to the gauge are:

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

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

Three forms are available:

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

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

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

Appendix C

Data Transfer

PRINT CD

A simple software ACKNOWLEDGE/NEGATIVE-ACKNOWLEDGE handshaking scheme (ACK/ALT-6, NACK/ALT-21) allows the external device to control the dump: ACK echoed in response to a received line causes transmission of the next line, while NACK causes retransmission of the same line. NACK may be echoed as often as necessary to receive an error free line. Characters other than ACK, are by default NACK. If the MCM-2 does not receive a reply within 60 seconds after sending the carriage return and line feed (CRLF) at the end of each line, a default ACK is assumed, and the next line is transmitted. The computer should not echo the MCM-2 transmission.

It takes approximately 100 ms after an external device has transmitted an ACK or NACK, for the MCM-2 to respond and transmit another line of data.

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

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

As each line is being transmitted (or retransmitted), its line number is displayed on the MCM-2. The line number counts down, giving an indication of the lines remaining (e.g. "LINE 123").

PRINT CD Format

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

The print program requires that the computer be up during the dump. This places a heavy drain on the battery. If the cutout circuit turns on during the dump, the data is not lost.

Figure C.1. CD Format Printout.

```
20,MCM-2.3,1234,gcc,12345,2,2,1745
19,0,10,05,95,0.372,0.004,1174
18,1,10,05,95,0.000,0.000,1158
17,2,10,06,95,2.320,0.120,1169
16,3,10,05,95,0.000,0.000,1158
15,4,10,05,95,0.000,0.000,1158
14,5,10,05,95,0.000,0.000,1158
13,6,10,05,95,0.000,0.000,1158
12,7,10,05,95,0.000,0.000,1158
11,8,10,05,95,0.000,0.000,1158
10,9,10,05,95,0.000,0.000,1158
9,10,10,05,95,0.000,0.000,1158
8,11,10,05,95,0.000,0.000,1158
7,12,10,05,95,0.000,0.000,1158
6,13,10,05,95,0.000,0.000,1158
5,14,10,05,95,0.000,0.000,1158
4,15,10,05,95,0.000,0.000,1158
3,1117,1117,0,10,05,95,15,53,1,2,1.001,0.004,2038

2,1116,AB123,0,10,05,95,15,54,3,4,1.007,1.007,2130

1,1115,CD789,0,10,05,95,15,54,7,8,1.007,0.004,215
4
```

PRINT LP

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

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

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

```
CPN COMPANY                MCM-2 HYDROTECTOR
Page 1
                           Moisture Gauge


  MODEL     SERIAL   STD     #KEYDATAS  #SITES  UNITS
 +-----------+-----------+---------+----------+----------+----------+
  MCM-2.3        1234    12345                 2           2     gcc

  CAL   DATE   COEFF A     COEFF B
 +-----+----------+-------------+-------------+
     15  10/05/95      0.000         0.000
     14  10/05/95      0.000         0.000
     13  10/05/95      0.000         0.000
     12  10/05/95      0.000         0.000
     11  10/05/95      0.000         0.000
     10  10/05/95      0.000         0.000
      9  10/05/95      0.000         0.000
      8  10/05/95      0.000         0.000
      7  10/05/95      0.000         0.000
      6  10/05/95      0.000         0.000
      5  10/05/95      0.000         0.000
      4  10/05/95      0.000         0.000
      3  10/05/95      0.000         0.000
      2  10/06/95      2.320         0.120
      1  10/05/95      0.000         0.000
      0  10/05/95      0.372         0.004

 REC    ID       CAL  DATE     HOUR    K2    K1     D2       D1
 -------+---------+------+----------+---------+------+------+--------+---------+
  1117   1117       0     10/05/95   15:53       1       2   1.001
0.004
  1116   AB123      0     10/05/95   15:54       3       4   1.007
1.007
  1115   CD789      0     10/05/95   15:54       7       8   1.007
0.004
```

Figure C.2. LP Format Printout.

Appendix C

Data Transfer

PRINT NF

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

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

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

```
 20,"MCM-2.3",1234,"gcc",12345,2,2
 19,0,10,05,95,0.372,0.004
 18,1,10,05,95,0.000,0.000
 17,2,10,06,95,2.320,0.120
 16,3,10,05,95,0.000,0.000
 15,4,10,05,95,0.000,0.000
 14,5,10,05,95,0.000,0.000
 13,6,10,05,95,0.000,0.000
 12,7,10,05,95,0.000,0.000
 11,8,10,05,95,0.000,0.000
 10,9,10,05,95,0.000,0.000
 9,10,10,05,95,0.000,0.000
 8,11,10,05,95,0.000,0.000
 7,12,10,05,95,0.000,0.000
 6,13,10,05,95,0.000,0.000
 5,14,10,05,95,0.000,0.000
 4,15,10,05,95,0.000,0.000

3,1117,"1117",0,10,05,95,15,53,1,2,1.001,0.004,

2,1116,"AB123",0,10,05,95,15,54,3,4,1.007,1.00
7,

1,1115,"CD789",0,10,05,95,15,54,7,8,1.007,0.00
4,
```

Figure C.3. NF Format Printout.

Appendix C

Data Transfer

MCM-2 Download Software

This is an optional software supplied by Boart Longyear/CPN on a 3½ in diskette (P/N 704506) or on a 5¼ diskette (P/N 704507). Two programs are included on this disk: **MCMDUMP.EXE** and **123MCM.EXE** and both are intended to be used with the MCM-2.

Both programs perform the same basic function: they establish a link to the **CPN MCM-2** gauge through one of the PC's COM ports, send commands to the gauge to retrieve stored records, and output the data to a file on the PC. The only difference between **MCMDUMP.EXE** and **123MCM.EXE** is in the format of the file produced.

The **CPN MCM-2** directly outputs its data in one of two formats: the "PRINT LP" format (for Print to Line Printer), and the "PRINT CD" format (for Print to Computer Device). The MCMDUMP and 123MCM programs will only work with the PRINT CD format, then you must be sure that the option selected in the gauge is PRINT CD. You can verify the selection pressing the PRINT key in the gauge and then in the screen you must see "PRINT CD", if "PRINT LP" appears press STEP and ENTER to change the selection to PRINT CD.

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

The 123MCM program reads the data from the MCM-2 in the native PRINT CD format, and then modifies the data quoting any non numeric data and deleting the checksum values for each line before outputting it to the user named file.

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

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

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

Both MCMDUMP and 123MCM programs will work with either COM1 or COM2 on your computer.

Appendix D

Remote Operation

The MCM-2 may be operated remotely via the RS232C serial connector. Set the MCM-2 and the external device to the same baudrate and the terminal in no echo mode. If the MCM-2 is in the command mode (“READY “ is shown on the display) then the appropiate remote control from the following table will activate the MCM-2.

Input Character	MCM-2 key	Action
m	MENU	Activates MENU command
s	STD	Activates STD command
f	FMT	Activates FORMAT command
l	LOG	Activates LOG command
r	RCL	Activates RECAL command
p	PRINT	Activates PRINT command
u	UNITS	Activates UNIT command
t	TIME	Activates TIME command
c	CALIB	Activates CALIBRATION command
h	WATER	Activates WATER command
g	START	Activates START command
z	STEP	Activates STEP command
ESC	CLEAR	Activates CLEAR command
ENTER	ENTER	Activates ENTER command
Ctrl R		Enable terminal mode
Ctrl T		Disable terminal mode

These commands can be used to control the MCM-2 from a CRT terminal or a special program can be written to control the MCM-2 from a computer.

Control R is a special command that places the MCM-2 in the remote terminal mode. While in the remote terminal mode all the information which appears on the MCM-2 display will also be sent on the serial output mode line where it can be received by the control device. The MCM-2 will stay in this mode for 60 seconds after the last command.

The remote terminal mode is disable pressing Control T, the Reset button or when the MCM-2 goes to sleep.

Counting Statistics

General

Radioactive decay is a random process. For Am-241/Be, which has a half-life of 458 years, it can be expected that in 458 years one-half of the material will have decayed, but in the next minute exactly which atoms will decay and exactly how many will decay is only by chance. Repeated measurements with the gauge will thus most likely result in a different count for each measurement. A typical set of 32 such measurements is shown in Figure E.1.

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

SAMPLE	COUNT
32	4370
31	4370
30	3742
29	4370
28	4370
27	3812
26	4370
25	4370
24	4402
23	4370
22	4370
21	4370
20	3636
19	4370
18	4370
17	3566
16	4370
15	4370
14	4370
13	4368
12	4370
11	4368
10	4370
9	3730
8	4368
7	4370
6	4370
5	4370
4	4370
3	4370
2	4370
1	4370
AVERAGE	4266
CHI-RATIO	0.95

Mathematically the average value is defined as:

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

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

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

Or an alternate form useful on calculators:

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

where:

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

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

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

Figure E.1.

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

Appendix E

Counting Statistics

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

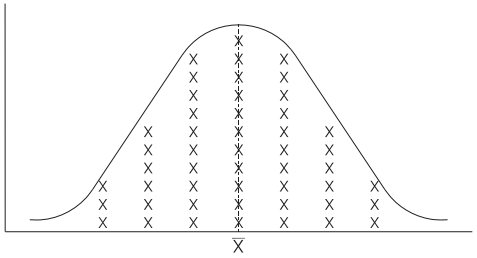


FIG. E-2

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

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

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

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

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

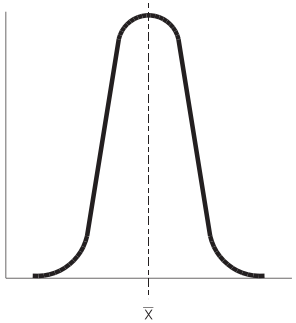


Figure E.3.

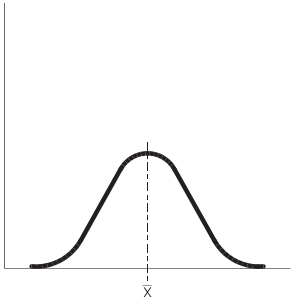


Figure E.4.

Counting Statistics

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

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

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

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

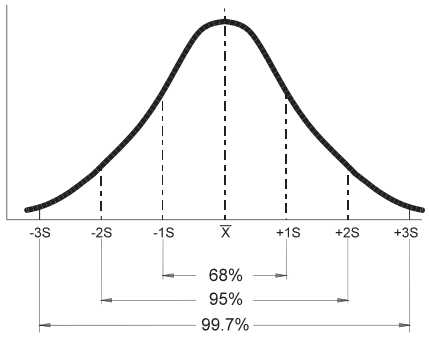


FIG. E-5

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

Single Measurement Precision

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

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

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

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

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

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

To provide a consistent frame of reference to the operator, the count displayed in the MCM-2 is always an equivalent to 60-seconds count or CPM (counts per minute), regardless of the time base selected. It is necessary to correct a precision determination for other time base selections as follow:

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

Where t is the selected time in seconds.

Counting Statistics

Example:

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

$$Precision = \frac{100}{\sqrt{\frac{3000 \, . \, 60}{60}}} = 1.82\ \%.$$

The direct reading is 2.0 g/cm^3. To determine the end measurement precision, it is necessary to multiply the count precision by the slope of the calibration curve. Assuming a slope of 0.0416 g/cm^3 per percent, the 2.0 g/cm^3 reading varies by +/- 0.076 g/cm^3 (68% of the time representing one standard deviation).

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

Appendix E

Counting Statistics

Expected Spread of Measurements

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

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

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

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

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

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

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

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

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

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

Appendix E

Counting Statistics

Expected difference between two readings

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

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

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

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

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

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

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

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

This is true for the 60-second count which is direct. For another time base, the K term must be reduced by the square-root of the count pre-scaling (e.g. for a 240-second count which is 4 times as long as the direct 60-second count, the new reading should be plus/minus 0.98):

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

This is the case when the standard count is taken which involves 240 each (n = 240/60 = 4) 1-second counts. A new standard count should be equal to the old standard count plus/minus 0.98 times the square-root of the old standard count 95 percent of the time.

EXAMPLE:

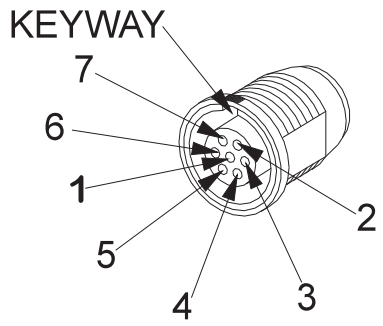
The average of the daily standard count for the last month is 10,000. The square-root of this average is 100. A new standard count (240 each at 1 seconds, but displayed as 60 seconds,CPM) should be between 9,902 and 10,098 with a 95% of probability.

Appendix F

Connectors Pinouts

The pinout of the LEMO connector for downloading is:

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



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Index

Nuclear Gauge Emergency Response Information for Transportation
Reference DOT p5800.5 ERG93, and 49CFR

Potential Hazard

1) Proper Shipping Name

- Radioactive Material Type A Package, special Form, Non-Fissile or Fissile-Excepted, 7, UN3332 RQ

2) Health Hazards

- Radiation presents minimal risk to lives of persons during transportation accidents.
- Undamaged packages are safe; damaged packages or materials released from packages can cause external radiation hazards. Contamination is not suspected.
- Packages (cartons, boxes, drums, articles, etc.) identified as “Type A” by marking on packages or by shipping papers contain non-Life endangering amounts. Radioactive sources may be released if packages are damaged in moderately sever accidents.
- Packages (large and small, usually metal) identified as “Type B” by marking on packages or by shipping papers contain potentially life endangering amounts. Because of design, evaluation. and testing of packages, life endangering releases are not expected in accidents except those of utmost severity.
- Commonly available instruments can detect most of these materials.
- Water from cargo fire control is not expected to cause pollution.

3) Fire or Explosion

- Packaging can be consumed without content loss from sealed source capsule.
- Radioactive source capsules and Type B packages are designed to withstand temperatures of 1475°F (800°C)

Emergency Action

4) Immediate Precautions

- Priority response actions can be performed before taking radiation measurements.
- Priorities are life saving, control of fire and other hazards, and first aid.
- Isolate hazard area and deny entry. Notify Radiation Authority of accident conditions.
- Delay final cleanup until instruction or advice of Radiation Authority.
- Positive pressure self-contained breathing apparatus (SCBA) and structural firefighter’s protective clothing will provide adequate protection against internal radiation exposure, but not external radiation exposure.
- Call the following numbers depending on the gauge model:
  - InstroTek, Inc. 1-800-424-9300

5) Fire

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

6) Spill or Leak

- Do not touch damaged packages or spilled material.
- Slightly damaged or damp outer surfaces seldom indicate failure of inner container.
- If source is identified as being out of package, stay away and await advice from Radiation Authority.

7) First Aid

- Use First aid treatment according to the nature of the injury.
- Persons expose to special form sources are not likely to be contaminated with radiation material.