INSTRUCTION MANUAL

CS725 Snow Water Equivalent Sensor

January 2017

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This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twenty-four (24) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

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Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

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CS725 Snow Water Equivalent Sensor

1. Introduction

The CS725 sensor measures Snow Water Equivalent (SWE) in a snow pack. SWE is measured by passively monitoring the attenuation of naturally existing electromagnetic radiation emitted from the soil or bedrock below the sensor. This radiation is due to the presence of Potassium-40 (^{40}K) and Thallium-208 (^{208}Tl).

As snow accumulates, the CS725 measures a decrease in the naturally-occuring radiation. The higher the water content of the snow pack, the higher the attenuation of the radiation.

A collimator (available option) is used when there are sources of ^{40}K and ^{208}Tl at the site that will not be covered by snow (ex: trees). The collimator acts to reduce this radiation from affecting the measurement.

Proper operation of the CS725 is dependent on suitable amounts of ^{40}K and ^{208}Tl being present in the ground. Since the radiation levels will vary from site to site, CS725 performance is site dependant.*

* No special licenses or precautions are required to install or operate the CS725 because it does not emit gamma energy.

Before using the CS725 please study:

- Section 2, Cautionary Statements
- Section 7.3, Wiring

1.1 Abbreviations/Syntax

K	Potassium
SWE	Snow Water Equivalent
Tl	Thallium
[ ]	Square brackets identify a typed command. The content inside the brackets is what is sent or typed; the brackets are excluded
< >	Denotes a special key. For example, <Enter> represents the Enter key.

2. Cautionary Statements

- If you are unable to determine that your structure or mounting method is suitable for the CS725 sensor, please contact Campbell Scientific for assistance in determining the structural mounting requirements.

- We recommend installing this CS725 before there is snow on the ground to establish a baseline SWE.

- Always ensure that when using a collimator, it is secured to the structure with the safety cable provided. Due to its weight, the collimator should be handled with caution.

- Do not disassemble the CS725 without consulting the factory. The CS725 contains a fine bead-like insulation material - Aerogel Nanogel (Cabot Corporation). Proper MSDS sheets and instructions should be obtained prior to opening the CS725.

- Never force the connector on to the CS725. If the connector does not easily fit into place, it is likely misaligned.

3. Initial Inspection

- Upon receipt of the CS725, inspect the packaging and contents for damage. File any damage claims with the shipping company. Immediately check package contents against the shipping documentation. Contact Campbell Scientific about any discrepancies.

- The model number and cable length are printed on a label at the connection end of the cable. Check this information against the shipping documents to ensure the expected product and cable length are received.

- The CS725 is shipped with a DB9F-TERM for communication, and a safety cable.

4. Overview

The CS725 sensor is a gamma radiation spectrometer that has been specifically designed to measure SWE. The CS725 utilizes a Thallium-doped Sodium Iodide crystal NaI(Tl) to detect gamma radiation.

Naturally-occuring terrestrial gamma radiation is produced by traces of radioactive elements in the earth. The most abundant of those elements are Potassium_40 (^{40}K) and Thallium_208 (^{208}Tl). ^{40}K emits gammas at 1.460 megaelectronvolts (MeV), and ^{208}Tl at 2.613 MeV. Gamma rays have a well defined "probability of interaction", based on the energy of the gamma and the nature of the material it is travelling through.

The net effect of gamma rays travelling through the snow pack, is that a fraction of the rays interact with the snow, while another fraction is either degraded in energy, or attenuated. Quantifying the attenuated gamma rays provides necessary information to calculate the SWE within the CS725. As such, the CS725 should be installed prior to snowfall to acquire a baseline

measurement and account for soil moisture, which serve as reference points throughout the season.

Each time a gamma ray is detected by the CS725, it is placed in its corresponding bin in the energy histogram (see Figure 4-1). This histogram is the basic data set required for the SWE calculation. Since it is statistical in nature, the accuracy of the SWE evaluation is proportional to the square root of the measurement time. The CS725 builds each histogram for a 24 h period in order to achieve the specified accuracy.

It should be noted that only the integrated counts from the ^{40}K and ^{208}Tl peaks are evaluated and used to determine SWE. Recall that SWE is evaluated by measuring attenuation by the snow pack. However, other isoptopes, such as bismuth produced by radon decay chains, and cosmic radiation are present above the snow pack and must be removed or accounted for when determining SWE.

The CS725 uses an algorithm to calculate SWE. The data is held internally until polled by a datalogger or sent to a RS-232 device. The CS725 can hold approximately 730 days of data.
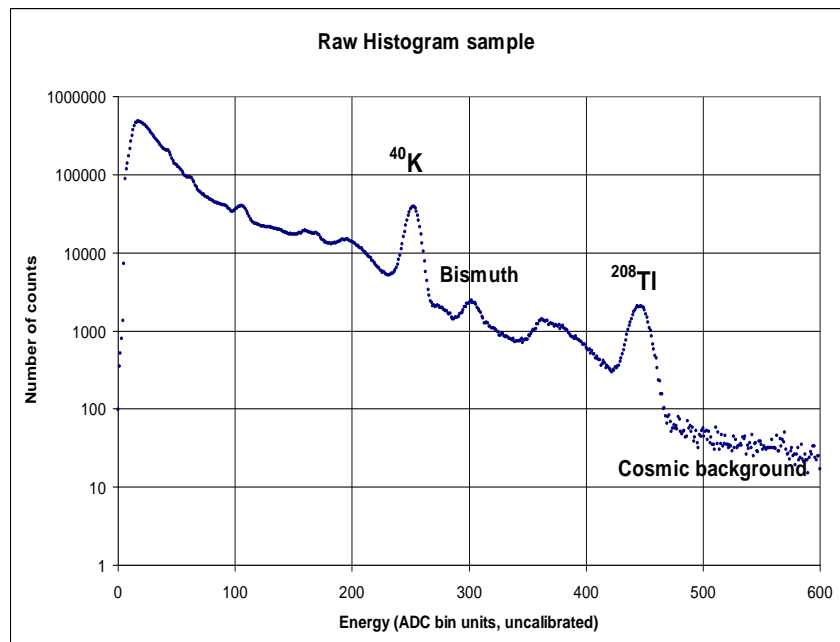
FIGURE 4—1. Gamma radiation histogram

5.   Specifications

Features:

**Compatible
Dataloggers:**   CR800/CR850
                            CR1000
                            CR3000

Power requirements:	11-15 Vdc
Power Consumption:	180 mA
Measurement Time:	Continuous; 24 hours/day
Output Format:	RS-232 (1200 to 115200 BAUD) Default is 9600
Measurement Range:	0 – 600 mm of water equivalent
Accuracy:	±15 mm from 0 to 300 mm ±15 % from 300 to 600 mm
Resolution:	1 mm
Coverage Angle:	60° (from center)
Operating Temperature:	-40°C to +40°C
Maximum Cable Length:	30 m (at 9600 BAUD or less)
Cable Type:	4 conductor 2-twisted pair 22 AWG Stantoprene jacket
Dimensions (w/o Collimator):	Length 62 cm Diameter 12.7 cm
Weight:	Main Body: 9.0 kg (20 lbs) Collimator (optional): 25 kg (55 lbs)

6. Installation

It is recommended to pre-configure and test the system before taking it to the field. Issues that are unresolved before placing instrumentation in the field will usually be more difficult to resolve.

The CS725 must be configured using a computer before deployment.

6.1 Siting

It is important to determine if the intended installation site of the CS725 will have appropriate sources of Potassium (K) and Thallium (Tl) to provide

sufficient counts for the expected SWE. It is also important to reduce the effects of background K and Tl sources that will adversely affect the SWE measurement.

Do not mount the CS725 in close proximity to buildings, wood material or trees. Wood material can contain potassium, which may be a source of gamma radiation that will interfere with the measurements. Potassium sources above the snow will emit gamma radiation that is not attenuated by the snow pack.

It is reasonable to have small amounts of wood material within the 6 m clearance radius. However, be aware that reducing the amount of material near the CS725 or increasing the distance will reduce its influence on the readings.

6.2   Mounting

Note	Please contact a Campbell Scientific representative if you are unsure of suitable mounting structures or methods for the CS725

• Always ensure that the collimator is secured to the structure with the long safety cable.

• Always install the collimator after the main CS725 body is mounted and secured to the structure.

Mount the CS725 above the snow pack. It is recommended to mount the CS725 approximately 3 m above ground or above the expected maximum snow height. If the CS725 is submersed in the snow, it may be damaged by water ingress. The CS725 can also be mounted lower than 3 m; however, this will reduce the effective measurement area.
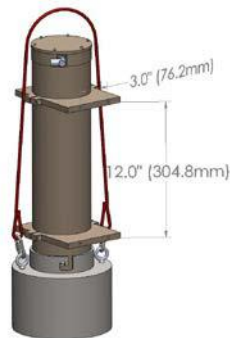
FIGURE 6—1. CS725 with collimator and safety cable

It is possible to rotate the CS725 Main Body with respect to the mounting plates. Figure 6-2 shows one of the four fasteners that need to be loosened in order to rotate the main body.

5
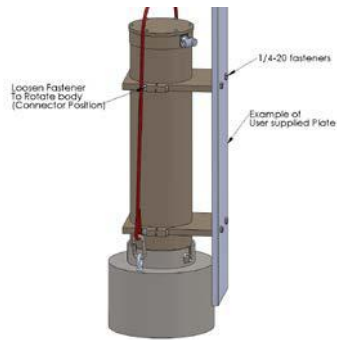
FIGURE 6—2. Plate Mounting
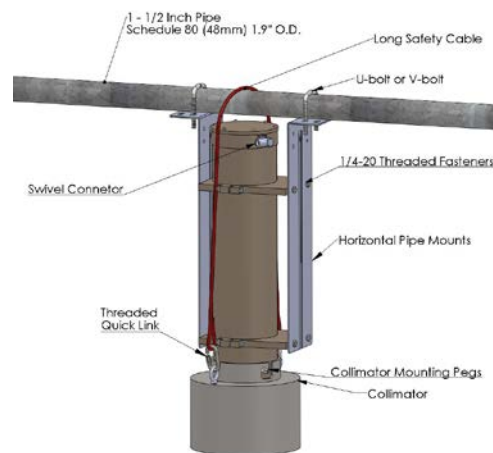
FIGURE 6—3. CS725 with C2470 Mounting Kit

6.2.1 C2476 Collimator

The collimator is optional. The collimator will help eliminate non-soil gamma radiation sources. Factors considered when determining whether or not to use a collimator include the presence of wooded vegetation and man-made structures, and the expected SWE for a given site.

Table 6-1 is a guideline for determining if the site can be used with or without a collimator.

TABLE 6-1. Collimator Guidelines			
Site Characteristics	**Max SWE < 300 mm**	**Max SWE 300 – 400 mm**	**Max SWE > 400 mm**
Very open with no proximity to trees, buildings or vegetation within 48 m (160 ft) radius	Optional	Optional	Optional
No trees, buildings or tall vegetation within a 24 m (80 ft) radius	Optional	Optional	Required
No trees, buildings or tall vegetation within a 12 m (40 ft) radius	Optional	Required	Required
Site with minimum clearance radius of 6 m (20 ft) radius	Required	Required	Required

6.2.2 Soil Moisture

Soil moisture can influence SWE by attenuating the signal. Avoid low lying areas where water pools or saturates the soil during the snow melt and bog type ground conditions due to the potentially high moisture content. It will be necessary to determine the soil moisture (aka: soil humidity) content of the site in % by weight. This value is entered into the CS725 setup parameters. See Appendix C *Gravimetric Soil Moisture Method* for detailed instructions on how to determine soil moisture content.

6.2.3 Initial Site Evaluation

As there is naturally-occuring variability in radiation levels from site to site, it is recommended to qualify the site prior to permanently installing the CS725.

Required equipment:

- CS725 with accessories
- Suitable +12 Vdc power supply to run the CS725 for several hours
- Mounting hardware to vertically suspend the CS725 over the ground at the qualifying site. Note: for qualifying purposes the suspension height is not critical (0.5-1 m is sufficient)
- Laptop with suitable terminal emulator program (e.g. HyperTerminal)

Overview of steps:

- Mount the CS725 as close as possible to desired permanent location
- Avoid placing items underneath the CS725 during testing
- For best results, mounting at 1 m or more above the ground
- Install the collimator if available

- Connect the CS725 to the laptop and power supply, as shown in the wiring section (7.3)
- Run the terminal emulator program you have chosen (see section 6.3) and follow the steps to set up a CS725
- Allow the CS725 to monitor gamma radiation for 1 hour
- Review number of counts of K and Tl and compare to Table 6-2 and 6-3 to determine if site has sufficient K and Tl present in the soil/bedrock
- If site is suitable, set CS725 parameters to determine the baseline (no snow) SWE measurement
- 24 h later, verify that the system is working properly

6.3   Terminal Set-up for RS-232 Communications

Following are settings required for the terminal program to communicate with the CS725. Typical programs include HyperTerminal or Procomm.

BAUD Rate:	9600 (Default)
Data Bits:	8
Parity:	None
Stop Bits:	1
Flow Control:	None
Local Echo:	Enabled
Terminal Mode:	ANSI
Send Line Ends with news feed:	Disabled

6.4   Communicating with the CS725

Upon power–up, the CS725 defaults to a baud rate parameter defined by "DefaultBaudRate". This is normally 9600 BAUD - the recommended setting.

The 'Esc' key resets the current command line being entered into the CS725. If you are communicating with the CS725 using another intelligent device, the commands must be preceded with the Esc character to ensure reliable operation.

All commands are terminated by the Enter key, or <CR> character.

6.4.1 Auto BAUD Rate Detection

Note   Any changes to the CS725 baud rate must be accounted for in the datalogger program

If the startup message is absent or garbled, or the terminal baud rate does not match the CS725 baud rate, synchronize the baud rates by typing

'UU' '.' <Enter>

This triggers the auto-baud system in the CS725.

6.5   Sensor Setup

1. Wire the sensor to the DB9F-TERM, a +12Vdc power supply, and a PC serial port (or USB) as shown in Table 7-1 Connection to Datalogger and DB9F-TERM (Section 7.3).

2. Start terminal program, connect to CS725, and set internal parameters

The following example uses HyperTerminal for the terminal software.

Open HyperTerminal > File > New Connection
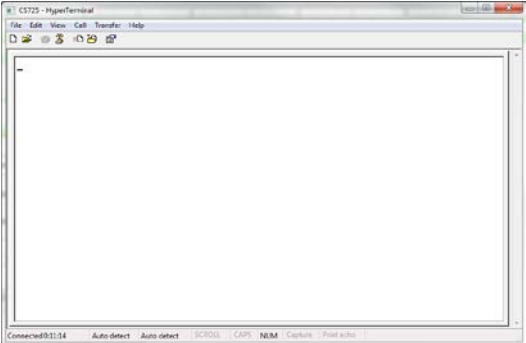
When the following appears, enter CS725 for the Name:
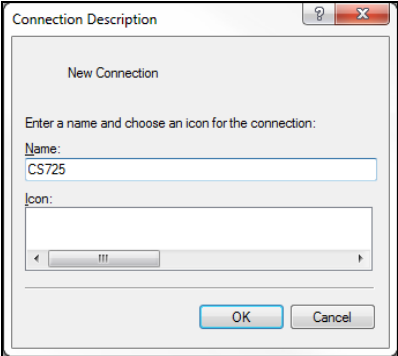
Click OK

The following screen will appear. Choose the correct COM port, which your computer is using. Click OK
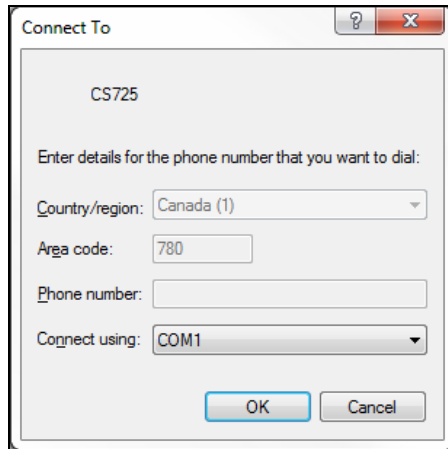
Change Port Settings as necessary to match the following screen:
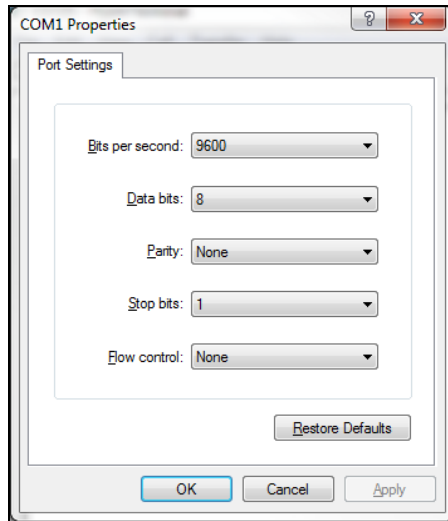
Click Apply > OK

Next, go to File > Properties

Click on the Settings tab
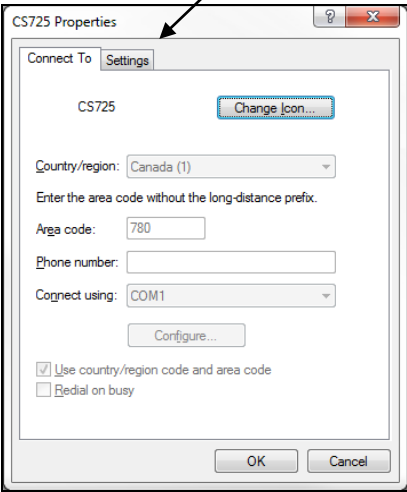
Set parameters according to the following screen shot:
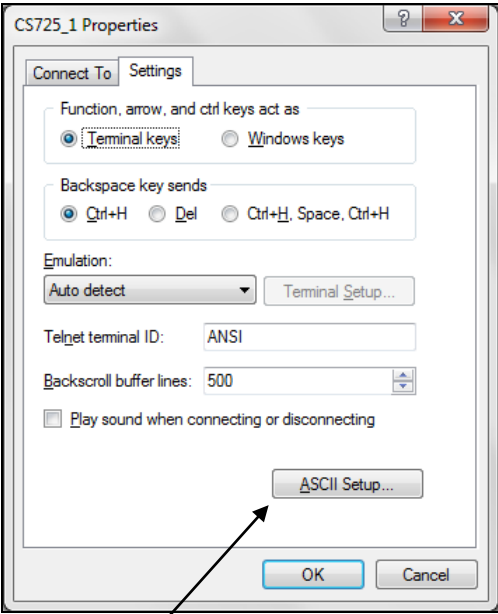
Click on ASCII Setup…
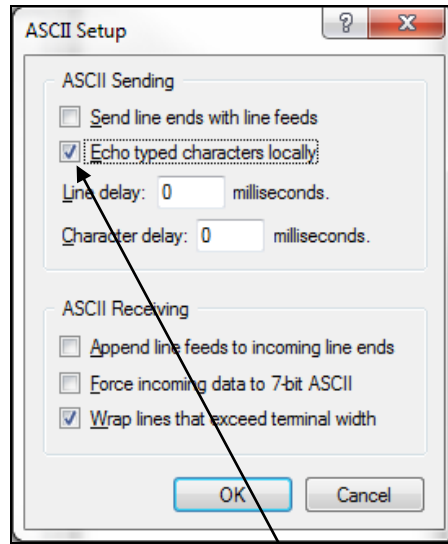
Check the box beside 'Echo typed characters locally'

Click OK and return to the main HyperTerminal screen.
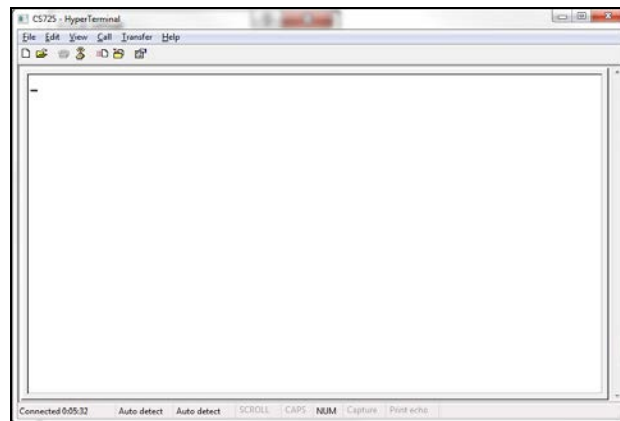
3. Apply +12Vdc power to the CS725. The sensor will power up and start communicating with your computer.

The following screen should appear:
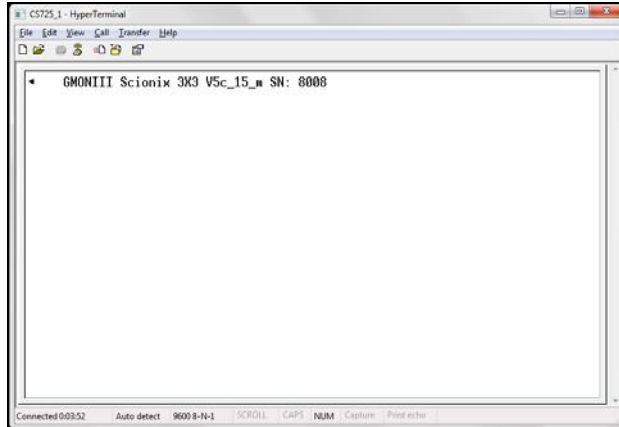
Where:

GMONIII:	Original sensor identifier (now known as model CS725)
Scionix 3x3:	Gamma detector type
V5c_15_m:	Firmware software revision
SN: 8008:	sensor serial number

6.5.1 Set Internal Parameters for Field Deployment

Internal parameters are accessed by menus. There are several menu options used for technical diagnoses and firmware upgrades; however, most are not required for standard applications.

See Appendix A for all menu options with detailed descriptions.

Words in brackets <   > are actions.

Ex: <Enter> means to hit the Enter key on your keyboard. <space> means to hit space bar on your keyboard.

To access the Main Menu, while connected with HyperTerminal, type
<Enter>
<Enter>
? <Enter>

The following menu will appear:

English menu:
[.l] Language (French or English)
[.h] Read the current live histogram
[.hp] Display the K and Tl positions from the live histogram
[.hl] Display the current histogram in log scale
[.hr] Display results after completion of a manual measurement
             (histogram, position and # counts K and Tl)
[a.] Special command: define start/stop time limits for one
             measurement (manual mode only)
[.t] Display temperature in °C

[.d] Display date and time
[.dd] Modify date and time
[.hd] Read back histograms from EPROM according to dates
[.f] Read back measurement results from EPROM according to dates
[.fl] Read back current day measurement results
[flla] Read back last calculated line result
[.fs] Read back last results calculated line result in short form ± (Time
        and EENs only)
[.p] Display parameter menu
[.s] Display status and current measurement information
[.0xps] Parameters save to file function
[.0xpr] Parameters recovery from file function
[%Rhard]/[%Rboot] Restart software processor/Reboot firmware
[UU] GMON/Terminal synchronizing sequence for rates other than
        9600 BAUDS

The menu will be used to:

- Set the language [.l]
- Check the internal clock [.d]
- Set current date and time [.dd]
- Display and set parameter setup menu [.p] this command includes a submenu with parameters that must be set. See section 7.1 for instruction
- Set start and stop times for measurement intervals [a.]
- Obtain current histogram results [h]
- Verify radiation counts in MANUAL mode [.hr]
- Display status and current measurement information [.s]
- Display current day readings [.fl]

Note   To select a menu option, type the character found in the square brackets followed by Enter. Ex: .d<Enter>

1. Start by setting the preferred language.
        .l<Enter>   *{The letter l as in Lima}*

        [0] Tapez 0 pour Français
        [1] Type 1 for English

        Type the required number followed by <Enter>.

        More menu items can be entered successively. Type ?<Enter> to view the menu list at any time.

2. View date and time.
        .d<Enter>

        Format example:
        02/24/2014   15:00:20
        dd/mm/year   HR:MIN:SEC

3. Set current date and time (if required)
        .dd<Enter>

Modify that date? :
[1] yyyy: 2014
[2]   mm: 02
[3]   dd: 24
[4]   hh: 15
[5]   mm: 00
[6]   ss: 20
[0]   Exit
[99] Accept selection

To Modify: [parameter number, space, new value, CR]

Ex: 5 <space>02<Enter>

This changes the clock to 02 minutes

Type 99<Enter> for the CS725 to accept the changes

4. Verify date and time

.d<Enter>

The CS725 does not perform any timezone or Daylight-Savings time correction.

5. Enter parameter setup menu
.p<Enter>

The following menu will appear:

[1] Station ID (Max 8 characters; ex: Gouin_21) .... : _SWESite1
[3] Time of start of measure (relative to GMON 00h RTC)..... : 00
[4] Delay after start of measure for data transmission (secs.)
              0=> No transmission).. : 0
[5] Frequency of data transmission: 0 => every 24 h
                 1 => every 6 h .. : 1
[6] GMON height above ground in centimeters................. : 300
[7] Observed position for the K line on the histogram....... : 245
[8] Collim (1: Collimator installed; 0: no collimator)...... : 1
[9] Nominal soil humidity in %weight,(min: 1, max: 150)..... : 25
[10] Estimated soil humidity in %weight (min: 1, max: 150)
                for HCalib mode.. : 27
[11] NoK.. : 230000
[12] NooK (residual K counting) Default:0 .... : 0
[13] N0Tl.. : 41000
[14] n00Tl (residual Tl counting).......................... : 0
[16] SN Threshold for the snow cover........................ : 0
[17] Baud rate for scheduled transmissions.................. : 9600
[18] Number of hours per partial histo (hours),(1,2,3,or 6) : 1
[19] Manual mode (1); Auto mode (0) ; HCalib mode (2);...... : 1
[0] Quit without saving the new parameters on EPROM
[99] Save parameters on EPROM
    To modify: [parameter number, space, new value,CR]
=>

6. Set Station ID
              1<space>*user defined*<Enter>
              Maximum 8 alphanumeric characters; no spaces.
              99 <Enter>   *this saves the parameter to the CS725*
              99<Enter>   *must be entered twice*

15

.p<Enter>   *this brings the parameter menu back to the screen*

Note: execute the .p command or ? to reinvoke the menus after a parameter is changed

7. Ensure [3] is: 0

8. Set Collimator Setting
        Type :
        8<space>0<Enter> {for no collimator}

        8<space>1<Enter> {for collimator}

        99<Enter>
        99<Enter>

9. Set the Nominal soil humidity (soil moisture) in %weight to:20
        9<space>20<Enter>

        99<Enter>
        99<Enter>

10. Set the Estimated soil humidity (soil moisture) in %weight
    for HCalib mode to 20.
        10<space>20<Enter>

        99<Enter>
        99<Enter>

11. Ensure [12] is: 0

12. Ensure [14] is :0

13. Set SN Threshold for the snow cover to: 0
        16<space>0<Enter>   *disregard the warning*
        99<Enter>
        99<Enter>

14. Ensure baud rate is set to: 9600

15. Set the Number of hours per partial histo to 1
        18<space>1<Enter>99<Enter>
        99<Enter>

16. Place CS725 in Manual mode
        19<space>1<Enter>

17. Save the parameters to the CS725
    99<Enter>
    99<Enter>

18. Return to the Main Menu by typing ?<Enter> and continue as follows.

        .a<Enter>   *This will set the start/stop times for a specified measurement
                             interval.*

Set a delay of 5 sec with a duration of 3600 sec (1 hour).

5<space>3600<*Enter*>

Wait >5 seconds
.h<Enter>

The screen will scroll with many numbers in the left column. If you see values >0, the sensor has begun reading gamma energy. If the values are all 0 (zeros), re-type .h<Enter>. If still all 0, verify parameters and retry .h<Enter>.

19. After 1 hour, re-connect to the CS725 to view the number of K and Tl counts generated during that time.

?<Enter>   *to activate Main Menu*

Choose [.hr] command

.hr<Enter>   *to view the results in detail*

Ex:
-Elapsed time,current histo : 00:59:59

Pos K =   246.8; Pos Tl =   437.3;
Cnt K = 010200.0; Cnt Tl = 001410.0;

20. Compare the counts to Tables 6-2 and 6-3. The CS725 uses only K or Tl to calculate SWE.

TABLE 6-2. Potassium Count (Cnt K) Guideline for SWE – 1 hour Reading		
With Collimator	**Without Collimator**	**Description**
0 to 4000	0 to 6000	Insufficient K at site
4000 to 7500	6000 to 11250	Usable Cnt K range. May experience larger errors for higher SWE values
7500 to 11000	11250 to 16500	Good Cnt K range. Should maintain specified operating characteristics
> 11000	> 16500	Excellent Cnt K range

TABLE 6-3. Thallium Count (Cnt Tl) Guideline for SWE – 1 hour Reading		
With Collimator	**Without Collimator**	**Description**
0 to 400	0 to 600	Insufficient Tl at site
400 to 1500	600 to 2250	Usable Cnt Tl range. May experience larger errors for higher SWE values

1500 to 2000	2250 to 3000	Good Cnt Tl range. Should maintain specified operating characteristics
> 2000	> 3000	Excellent Cnt Tl range

The sensor uses K or Tl to calculate SWE. If either of the counts are suitable, continue to Section 6.6.

If counts of both K and Tl are too low, move to another location and repeat test.

Note

For expected SWE values approaching 600 mm, a higher count will provide better results

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6.6   Final Parameter Setup

Once it has been determined that the K and/or Tl counts are suitable at the site, the true soil humidity (soil moisture) levels must be determined. This is entered as a % by weight which is typically determined by weighing a soil sample, drying it, then re-weighing. See Appendix C *Gravimetric Soil Moisture Method* for detailed instructions. This process must be done and the value entered every year before winter begins.

If, for any reason, the soil moisture values cannot be obtained, an estimate can be made, based on the following:

- Sandy soil – 15%
- Sand/Organic mixture – 30%
- Humus soil – 50%

Once the soil humidity is known:

1.   Go to the [.p] menu and set parameter [9] to the correct value.
   ?<Enter>
   .p<Enter>
   9<space>*moisture%*<Enter>   *where moisture% is an integer, typically ~20-40*
   99<Enter>
   99<Enter>

The same must be done for [10] Estimated soil humidity in % weight for HCalib mode.

The difference between parameter [9] and [10] is that [9] is a value typically entered well before freeze-up, whereas [10] is the value entered as close to freeze-up as possible.

For example, with a mid-summer installation, enter the same soil humidity value in [9] and [10]. If you are able to access the site again before freeze-up, enter the new value in [10]. The more accurate soil humidity readings, the better the SWE measurement. A gravimetric soil moisture calculation must be done every year before winter and entered into the CS725, so that it has an

accurate baseline from which all subsequent SWE measurements will be referenced.

2. Finally, return to [.p] menu and change parameter [19] to 2 (HCalib Mode). This mode allows the CS725 to determine the baseline SWE value before snowfall.

>   19<space>2<Enter>   *this will put CS725 in HCalib mode*
>   99<Enter>
>   99<Enter>   *save parameters in CS725*

3. Verify that all parameters as mentioned above are set properly. Parameters not discussed above do not need to be changed.

>   .p<Enter>

[1] Station ID (Max 8 characters) .... : SWESite1   *user given name*
[3] Time of start of measure (relative to GMON 00h RTC)..... : 00
[4] Delay after start of measure for data transmission (secs.)
>   0=> No transmission).. : 0
[5] Frequency of data transmission: 0 => every 24 h
>   1 => every 6 h .. : 1
[6] GMON height above ground in centimeters................. : 300   *no longer used*
[7] Observed position for the K line on the histogram....... : 245
[8] Collim (1: Collimator installed; 0: no collimator)...... : 1
[9] Nominal soil humidity in %weight,(min: 1, max: 150)..... : 25
[10] Estimated soil humidity in %weight (min: 1, max: 150)
>   for HCalib mode.. : 27
[11] NoK.. : 230000
[12] NooK (residual K counting) Default:0 .... : 0   Default *0*
[13] N0Tl.. : 41000
[14] n00Tl (residual Tl counting)......................... : 0   Default *0*
[16] SN Threshold for the snow cover........................ : 0   Default *0*
[17] Baud rate for scheduled transmissions.................. : 9600
[18] Number of hours per partial histo (hours),(1,2,3,or 6)   : 1   Default *1*
[19] Manual mode (1); Auto mode (0) ; HCalib mode (2);...... : 2   Default *2*
[0] Quit without saving the new parameters on EPROM
[99] Save parameters on EPROM

6.7   Final Setup Verification

The following morning after 6:00 am, verify sensor operation.

1. Verify that the CS725 automatically switched to Auto mode

>   .p<Enter>

View parameter [19], it should be as follows:

[19] Manual mode (1); Auto mode (0) ; HCalib mode (2);...... : 0

- Only set to HCalib mode once. The sensor automatically goes to Auto mode from HCalib mode.

- If it is not in Auto mode, verify that it was set to HCalib mode. A common error is to leave it in Manual mode.

    Reset to HCalib mode and let the sensor establish baseline at midnight. Re-check the sensor operation the next morning after 6 am.

- If in Auto mode, execute the [.fl] command.
  Ex: ?<Enter>
  .fl<Enter>

Sample output generated after 6:00am:

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
/2014	11:59:	SWESITE1	1065	57037	13168	6074	371	309	392	18	18	77	1	7	19	24	13	4.2	12.23

	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
/2014	17:59:	SWESITE1	1065	69645	13016	6415	371	360	375	18	18	27	1	2	8	24	12	3.2	12.23

The format is the date and time stamp followed by the following numbers:

1. Date
2. Time Stamp
3. Station ID (up to 8 alphanumeric characters)
4. CS725 Serial number
5. K counts total (uncorrected)
6. K counts total (corrected) - this value is used in the SWE calculations
7. Tl counts total (corrected) -this value is used in the SWE calculations
8. SWE value generated from ^{40}K
9. Ratio generated from K and Tl
10. SWE value generated from Tl
11. Soil Moisture values generated from K
12. Soil Moisture values generated from Tl
13. Soil Moisture values generated from K and Tl
14. Precipitation index: Flag indication recent snowfall or rain
15. Crystal temperature min
16. Crystal temperature max
17. Total number of histogram blocks used for the analysis
18. Displacement of the K peak from its nominal position (in bins)
19. Statistical significance of the SWE Tl measurement
20. Power input voltage at the CS725 (after protection diode drop)

Verify that there are K counts total (column 4) and that there are about 6 times the counts you measured the day before when evaluating the site, as the ouput is over a 6 h period instead of a 1 h period.

Verify that there are Tl counts total (column 6) and that there are about 6 times the counts you measured the day before when evaluating the site, as the ouput is over a 6 h period instead of a 1 h period.

SWE at (7) should be '0'

SWE at (9) should be '0'

7. Operation

7.1 Internal Makeup of CS725

To reduce drastic temperature gradients, the CS725 is filled with an advanced insulating material known as Nanogel. The manufacturer's (Cabot Corporation) MSDS sheet should be consulted prior to exposing the Nanogel insulation.
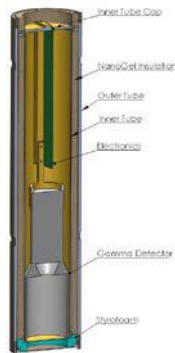
FIGURE 7—1. CS725 cross-section

7.2 Power System Requirements and Recommendations

It is recommended that the CS725 be operated from an uninterruptable power supply. For sites with AC power, batteries should have the capacity to supply

the system for a minimum of 48 h. Increase capacity where frequent power outages are expected.

7.2.1 Solar Powered Sites

The maximum power draw from the CS725 is 180 mA (4.32 Amp-hours) per day. It is recommended that solar powered systems be designed with a minimum reserve capacity of 260 Amp-hours. It is important to account for the power draw from other equipment that may operate from the power supply.

A large reserve capacity is required:

- As solar panels may become covered in ice and snow, charging may not be possible for extended periods of time.

- Battery capacity decreases in cold temperatures.

- Cold temperatures can significantly reduce battery ability to received a charge. Generally, very little charging occurs below -30°C.

Solar Panel Size:
Solar panels required to charge the CS725 should be sized according to the geographic location of installation and total maximum power draw.

7.3 Wiring

The wiring for the CS725 connector-cable assembly is:

<table>
<tr><td colspan="4" align="center">TABLE 7-1. CS725 Connection to Datalogger and DB9F-TERM</td></tr>
<tr><td>Colour</td><td>Connection to Datalogger</td><td>Connection to DB9F-TERM</td><td>Function</td></tr>
<tr><td>Black</td><td>G</td><td>No connection</td><td>Power Ground</td></tr>
<tr><td>Red</td><td>+12Vdc</td><td>No connection</td><td>Power Source</td></tr>
<tr><td>Green</td><td>Com Port – Rx</td><td>Pin 2</td><td>RS-232 Tx (sensor output)</td></tr>
<tr><td>White</td><td>Com Port - Tx</td><td>Pin 3</td><td>RS-232 Rx (sensor input)</td></tr>
<tr><td>Clear</td><td>⏚</td><td>No connection</td><td>Shield</td></tr>
<tr><td>Large Green</td><td>No connection</td><td>Battery G</td><td>Earth Ground</td></tr>
<tr><td>RS-232 Port</td><td>No connection</td><td>RS-232 of PC (DTE)</td><td>RS-232 Communication</td></tr>
</table>

7.4   Datalogger and Basic Programming

7.4.1 Extended data output [.flla] command

The following program example reads the data values using the [.flla] command.

This program obtains information reported SWE values, in addition to radiation counts and other diagnostic information.

```
'CR1000 Series Datalogger
'Program for CS725 Sensor

'Wiring CS725

'Red: +12VDC
'Black and Clear: G - Ground
'Green RS-232 TX: C2
'White RS-232 RX: C1

'Declare Public Variables
Public PTemp As Float,batt_volt As Float
Public Read_CS725_SWE_Flag As Boolean
Public CS725SerialIn As String * 120
Public CS725_COMMAND_String As String * 20
Public CS725_TIME_String As String * 17
Public CS725_Date_Time(5) As Float

Alias CS725_Date_Time(1) = CS725_Day
Alias CS725_Date_Time(2) = CS725_Month
Alias CS725_Date_Time(3) = CS725_Year
Alias CS725_Date_Time(4) = CS725_Hour
Alias CS725_Date_Time(5) = CS725_Min

Public CS725_StationID As String * 10
Public CS725_Values(17) As Float

Alias CS725_Values(1) = CS725_SerialNum
Alias CS725_Values(2) = CS725_K_Uncorrected
Alias CS725_Values(3) = CS725_K_Counts
Alias CS725_Values(4) = CS725_TL_Counts
Alias CS725_Values(5) = CS725_SWE_K
Alias CS725_Values(6) = CS725_K_TL_Ratio
Alias CS725_Values(7) = CS725_SWE_TL
Alias CS725_Values(8) = CS725_SM_K
Alias CS725_Values(9) = CS725_SM_TL
Alias CS725_Values(10) = CS725_SM_K_TL
Alias CS725_Values(11) = CS725_Precip_Index
Alias CS725_Values(12) = CS725_Crystal_TEMP_MIN
Alias CS725_Values(13) = CS725_Crystal_TEMP_MAX
Alias CS725_Values(14) = CS725_Hist_Blocks
Alias CS725_Values(15) = CS725_K_Disp
Alias CS725_Values(16) = CS725_Stats
Alias CS725_Values(17) = CS725_PWR_Volt

Public CS725SplitStr(20) As String * 16

Dim loopcount As Long

'Declare Constants
'Command to Read back last results in short data output form
'preceed .flla with an ESCAPE key CHR(27) and emd with an Enter CHR(13)
Const CS725_Command_get_output = CHR(27) + ".flla" + CHR(13)
```

```
'Define Data Tables
DataTable (Diagnostics,1,-1)
  DataInterval (0,1440,Min,10)
  Minimum (1,batt_volt,FP2,0,False)
  Maximum (1,batt_volt,FP2,0,False)
  Minimum (1,PTemp,FP2,0,False)
  Maximum (1,PTemp,FP2,0,False)
EndTable

DataTable (CS725_6Hour,1,-1)
  DataInterval (30,360,Min,10)
  Sample (1,CS725_TIME_String,String)
  Sample (1,CS725_StationID,String)
  Sample (1,CS725_SerialNum,IEEE4)
  Sample (1,CS725_K_Counts,IEEE4)
  Sample (1,CS725_TL_Counts,IEEE4)
  Sample (1,CS725_SWE_K,IEEE4)
  Sample (1,CS725_K_TL_Ratio,IEEE4)
  Sample (1,CS725_SWE_TL,IEEE4)
  Sample (1,CS725_Crystal_TEMP_MIN,IEEE4)
  Sample (1,CS725_Crystal_TEMP_MAX,IEEE4)
  Sample (1,CS725_Hist_Blocks,IEEE4)
 Sample (1,CS725_K_Disp,IEEE4)
  Sample (1,CS725_PWR_Volt,IEEE4)
EndTable

'Main Program
BeginProg
  'Prepare COM1 for the CS725
  SerialOpen (Com1,9600,3,0,1000)

  'Scan rate is dependent on application
  Scan (30,Sec,7,0)
    PanelTemp (PTemp,250)
    Battery (batt_volt)

    'Based on the Factory default settings of the CS725 will
    'calculate SWE on the Hour every 6 Hours.
    'The CS725 is read every 6 hour in this program.
    'The reading will take place 10 minutes After the period to ensure the CS725
    'is not processing calculations at the top of the hour when the measurement is
requested
    'flag is set 10 minutes into every 6 hour period
    If TimeIntoInterval (10,360,Min) Then Read_CS725_SWE_Flag = TRUE

    'If the flag is high obtain a measurement
    If Read_CS725_SWE_Flag = TRUE Then
      'Reset the Flag
      Read_CS725_SWE_Flag = False

      'Load the command into the string
      CS725_COMMAND_String = CS725_Command_get_output

      'Flush the serial buffer
      SerialFlush (Com1)

      'Send the command string out
      SerialOut (Com1,CS725_COMMAND_String,"",0,0)

      'Wait up to 2 seconds, a <CR> or 100 chars for the values to be returned.
      SerialIn (CS725SerialIn, Com1, 200,13, 100)

      'The string is in the following format
      '02/25/2014 12:59: 1234 23 637733 485431 24425 80 76 79 22 23 21 0 6 12 24 -1
1.3
      ' 12.05
      'Split out the string into smaller strings - use a space as the filter
```

```
        SplitStr (CS725SplitStr(1),CS725SerialIn," ",20,5)

        'first string contains 02/25/2014
        SplitStr (CS725_Date_Time(1),CS725SplitStr(1),"",3,0)

        'Next string contains HH:MM
        SplitStr (CS725_Date_Time(4),CS725SplitStr(2),"",2,0)

        'Next string contains the station identifier and is left as a string
        CS725_StationID = CS725SplitStr(3)

        'The next 17 strings are all numerical values
        For loopcount = 1 To 17 Step 1

          'Convert all strings to numbers
          'Values produced are as follows"
          'CS725_SerialNum *Suggest to Output to Final Storage*
          'CS725_K_Uncorrected
          'CS725_K_Counts *Suggest to Output to Final Storage*
          'CS725_TL_Counts *Suggest to Output to Final Storage*
          'CS725_SWE_K *Suggest to Output to Final Storage*
          'CS725_K_TL_Ratio *Suggest to Output to Final Storage*
          'CS725_SWE_TL *Suggest to Output to Final Storage*
          'CS725_SM_K
          'CS725_SM_TL
          'CS725_SM_K_TL
          'CS725_Precip_Index
          'CS725_Crystal_TEMP_MIN *Suggest to Output to Final Storage*
          'CS725_Crystal_TEMP_MAX *Suggest to Output to Final Storage*
          'CS725_Hist_Blocks *Suggest to Output to Final Storage*
          'CS725_K_Disp *Suggest to Output to Final Storage*
          'CS725_Stats
          'CS725_PWR_Volt *Suggest to Output to Final Storage*
          SplitStr (CS725_Values(loopcount),CS725SplitStr(loopcount + 3),"",1,0)

        Next
        'Prepare the output time string from when the CS725 produced the data
        'Format is YYYY-MM-DD HH:MM
        CS725_TIME_String = FormatFloat (CS725_Year,"%04.0f") + "-"
        CS725_TIME_String=CS725_TIME_String + FormatFloat(CS725_Month,"%02.0f") + "-"
        CS725_TIME_String= CS725_TIME_String + FormatFloat (CS725_Day,"%02.0f") + " "
        CS725_TIME_String=CS725_TIME_String + FormatFloat(CS725_Hour,"%02.0f") + ":"
        CS725_TIME_String=CS725_TIME_String + FormatFloat (CS725_Min,"%02.0f")

      EndIf

      'Call Output Tables.
      CallTable Diagnostics
      CallTable CS725_6Hour

    NextScan

EndProg
```

7.4.2 Short form data output [.fs] command

The following program example reads the SWE values by using the [.fs] command.

The format of the data output [.fs] command as follows:

```
DD/MM/YYYY HH:MM:SS SWE_K_SWE_TL
 01/10/2009    06:59:50    123   129
```

```
'CR1000 Series Datalogger
'Program for CS725 Sensor

'Wiring CS725

'Red -Power:                        +12VDC
'Black and Clear:                   G - Ground near +12V
'Green -RS-232 TX:                  C2
'White -RS-232 RX:                  C1


'Declare Public Variables
Public PTemp As Float,batt_volt As Float
Public Read_CS725_SWE_Flag As Boolean
Public CS725_RET_Values(8) As Float
Public CS725SerialIn As String * 100
Public CS725_COMMAND_String As String * 20

Alias CS725_RET_Values(7) = SWE_K
Alias CS725_RET_Values(8) = SWE_TL

'Declare Constants

'Command to Read back last results in short data output form
'preceed .fs with an ESCAPE key CHR(27) and emdcmd? with an Enter CHR(13)
'Change - Previously ".Fs", software version V5c_15_L and newer is ".fs" Lower case
F Const CS725_Command_get_output = CHR(27) + ".fs" + CHR(13)

'Define Data Tables
DataTable (Diagnostics,1,-1)
  DataInterval (0,1440,Min,10)
  Minimum (1,batt_volt,FP2,0,False)
  Maximum (1,batt_volt,FP2,0,False)
  Minimum (1,PTemp,FP2,0,False)
  Maximum (1,PTemp,FP2,0,False)
EndTable


'Define Data Tables
DataTable (CS725Hourly,1,-1)
  DataInterval (0,60,Min,10)
  Sample (8,CS725_RET_Values(1),IEEE4)
EndTable

'Main Program
BeginProg

  'Prepare COM1 for the CS725
  SerialOpen (Com1,9600,3,0,10000)

  'Scan rate is dependent on application
  Scan (30,Sec,7,0)
    PanelTemp (PTemp,250)
    Battery (batt_volt)

    'Based on the Factory default settings of the CS725 the CS725 will
    'calculate SWE on the hour every 6 hours.
    'We will simply read the CS725 every hour in this program.
    'The reading will take place 10 minutes after the hour to ensure the CS725
    'is not burdened with extra processing when the measurement is requested
    If TimeIntoInterval (10,60,Min) Then Read_CS725_SWE_Flag = TRUE

    If Read_CS725_SWE_Flag = TRUE Then
      'Reset the Flag
      Read_CS725_SWE_Flag = False

      'Load the command into the string
```

```
        CS725_COMMAND_String = CS725_Command_get_output

    'Flush the serial buffer
    SerialFlush (Com1)

    'Send the command string out
    SerialOut (Com1,CS725_COMMAND_String,"",0,0)

    'Wait up to 2 seconds, a <CR> or 100 chars for the values to be returned.
    SerialIn (CS725SerialIn, Com1, 200,13, 100)

    'The string is in the following format
    '23/09/2009    18:59:50  123 456
    'Split out the time stamp and values 8 numbers are returned
    SplitStr (CS725_RET_Values(),CS725SerialIn,"",8,0)
    'The contents of the array are as follows:
    'Day,Month,Year,Hour,Min,Second,SWE-from K, SWE-from TL
  EndIf

  'Call Output Tables.
  CallTable Diagnostics
  CallTable CS725Hourly

 NextScan
EndProg
```

8. Troubleshooting and Maintenance

8.1 Maintenance and Assembly

User maintenance is required for the CS725 every 7 years.

Do not disassemble the CS725 for any reason. The CS725 instrument is very complex and is intended to be repaired or maintained only by factory trained personnel.

It is recommended that the CS725 be calibrated every 7 years to ensure the gamma ray detector does not drift out of specification and to replace the internal lithium battery.

8.2 Firmware Update (using command .0xw)

Firmware can be updated using the RS-232 serial communication interface. See Section 6.3 for instructions.

A terminal communication program (e.g. HyperTerminal) is required to transfer the new firmware files to the CS725.

As the firmware update involves the transfer of a large file, the BAUD rate setting can be increased for the duration of the update procedure. The

maximum BAUD rate that can be used is a function of the cable length. See Table 8-1 for maximum BAUD rates for various cable lengths.

TABLE 8-1. Maximum BAUD Rates for Various Cable Lengths	
Cable Length m (ft)	**Max BAUD Rate**
0 to 7.6 (0 to 25)	57600
0 to 15.2 (25 to 50)	38400
0 to 30.5 (50 to 100)	9600

Terminal Settings should be as follows:

BAUD Rate:	See Table 8-1
Data Bits:	8
Parity:	None
Stop Bits:	1
Flow Control:	XON/XOFF
Local Echo:	Enabled
Terminal Mode:	ANSI
Send Line Ends with news feed	Disabled

Note that XON/XOFF flow control must be enabled. For all other normal communications the XON/XOFF flow control needs to be disabled.

Once the Terminal Program is setup, and the CS725 is connected to the computer using the DB9F-TERM, power can be supplied to the CS725.

If a BAUD rate other than 9600 was selected, the Auto BAUD rate synchronization can be invoked by typing the command "UU.<Enter> When the menu is displayed, the command ".0xw" can be entered for reprogramming the firmware.

The following will be displayed once "0xw" is entered:

Allocating memory buffer,,,,,,,,,

After the memory is allocated (within 1 min), the CS725 will prompt for the file transfer with the following message:

Launch the file transfer with the HyperTerminal

If using HyperTerminal, select "Send Text File…" from the *Transfer* menu.

The supplied programming file will need to be selected and sent to the CS725. This process takes approximately 5 min @ 57600 BAUD, and in excess of 30 min @ 9600 BAUD.

If the scrolling characters stop for a long duration, it is possible that an error in communication has occurred. In this case, shut down HyperTerminal, power down the CS725, and restart the process.

A single line of scrolling data will be displayed as the transfer takes place. Once the transfer is complete, the following text will be displayed:

Transfer completed; type w to overwrite the EPROM memory, type . to abort

Note

Do not interrupt this process or power down the CS725. If the process is interrupted, the CS725 may need to be sent back to the factory for reprogramming.

Type in the command "w<Enter>"

The terminal will then display that the programming has begun. Progress will be displayed as follows:

Begin EPROM programming
Erasing block 0x0
Writing EPROM from 0x0 to 0xffff

Upon completion, the CS725 will prompt to be reset. It is recommended to cycle power only after the following message is displayed:

Programming done..cycle power on the GMONIII, or do a Hard Reset

We recommend restarting HyperTerminal, return BAUD rate setting to 9600, and disable the XON/XOFF flow control to resume normal communications. Verify that the CS725 powers up properly and retained its Parameter settings.

Appendix A. Detailed Main Menu Command Information

1. **[.l]**

    The [.l] command is used to set the language setting to French or English.

    The following menu is activated once the [.l] command is received:

    [0] Tapez 0 pour Francais
    [1] Type 1 for English

    Type the number 0 for French or the number 1 for English followed by <Enter>.

2. **[.h]**

    Obtain the current histogram results. This information would normally be used for diagnostics or by a user who requires an analysis of the gamma radiation spectrum. The counts for 1024 bin values are returned in this command. The format is as follows:
    12<CR><LF>   *This line represents the counts for BIN#1*
    345<CR><LF> *This line represents the counts for BIN#2*
    333<CR><LF> *This line represents the counts for BIN#3*
    .
    .
    .
    30<CR><LF>   *This line represents the counts for BIN#1024*

3. **[.hp]**

    The [.hp] command is used to obtain the current bin positions for the Tl and ^{40}K peaks. In general the Tl peak should be near 438 and the ^{40}K peak should be near 245. It is important for the software to find the peaks properly in order to obtain proper SWE measurements.

    In most cases the sensor must be monitoring for at least 2 min to determine these bin positions. It may take as long as 1 h if the radiation counts are very low.

    Once the command is typed the following is immediately displayed:

    > This operation may take 1-2 min

    Once the calculation has been completed the values are displayed. Even under ideal conditions the values are allowed to vary from the target values. If the value does vary by more than 20 BINS then there may be issues with the sensor finding the proper peaks. The displayed values are formatted as follows:

    > Valid positions range: K: 225 - 265; Tl: 418 - 458
    > Measured positions   : K:245.3; Tl: 436.2

4. [.hl]

The [.hl] command is used to obtain a graphical representation of the current histogram results. This information would normally be used for diagnostics or by a user who requires an analysis of the gamma radiation spectrum. The command produces a log scale graph as follows:
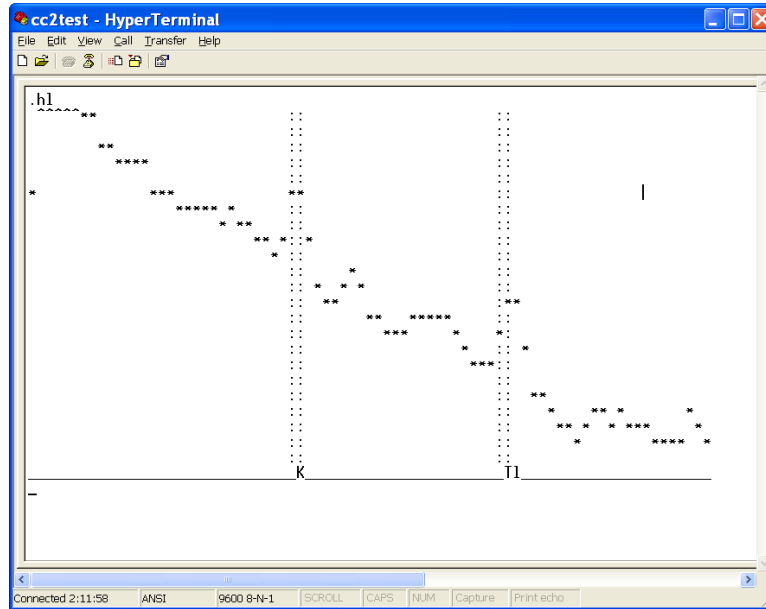
5. [.hr]

The [.hr] command is used to verify radiation counts in Manual mode. The [.hr] command would normally be used in the process of qualifying a site for adequate background radiation counts and is used in conjunction with the [.a] command (see the [.a] command for details).

Please note that the [.hr] command can take several minutes to complete. When the command is entered the [.hr] command will immediately report the duration of the current manual count time as follows:

> -Elapsed time,current histo : 00:03:59 (HH:MM:SS)
>   Wait for the calculation to complete.

There will then be a pause that can take several minutes. After the pause a histogram will be output followed by the radiation count summary. The summary will report 3 lines; the duration of the counting, the position of the ^{40}K peak and its processed count value, the position of the ^{208}Tl peak and its processed count value. The output format after the histogram is as follows:

> -Elapsed time,current histo : 00:03:59

> Pos K =   240.4; Pos Tl =   427.5;

> Cnt K = 003679.8; Cnt Tl = 000088.3;

6. **[.a]**

    The [.a] command is used to set the start and stop times for a specified measurement interval. This command could be used in the process to qualify a site for appropriate amounts of background radiation. This parameter is only made use of when the CS725 is in the Manual mode. The CS725 is placed in Manual mode by entering the Parameter Menu [.p] and set parameter 19 to 1 for Manual mode.

    Once the parameter is set (the setting will be saved automatically) use the .a command to specify the delay and duration in seconds. For qualifying a site it is recommend that the sensor be setup in the desired location and the delay of 5 sec be used with a duration of 3600 sec (1 h) as a minimum. The example below shows the syntax for the recommended delay and duration for the manual measurement:

        (Delay should be larger or equal to 5 seconds)
         Format: =>Delay Duration
             =>5<space>3600<*Enter*>

    After completion the [.hr] command can then be used to view the results in detail. If the CS725 is placed in Auto or HCalib mode, the following message will be printed:

            This function should be called in Manual mode only

7. **[.t]**

    For diagnostics purposes only, outputs internal temp of sensor
            Ex: temp. crystal: 21   temp. electronics: 26

8. **[.d]**

    The [.d] command is used to display the current date and time (used for internal data logging).

    Ex: .d <Enter>

    16/09/2013   15:00:20

    {dd/mm/year}   HR:MIN:SEC

    The CS725 does not perform Daylight-Savings time correction. This can be done in the datalogger.

9. **[.dd]**

    Set the current date and time.   Ex: .dd<Enter>
            Modify that date? :
            [1]   yyyy: 2013
            [2]   mm: 11
            [3]   dd: 24
            [4]   hh: 15
            [5]   mm: 01
            [6]   ss: 54

[0] Exit
[99] Accept selection

To modify: parameter number, space, new value <Enter>

Ex: 5<Space>02<Enter>

This changes the clock to 02 minutes

After new values are entered, the long format of the date/time will be
displayed once the 99 is entered to accept the selection.
                    99<Enter>

and the CS725 will print
          16/09/2009   15:02:54

The time should be set for the purpose of control and analysis of the data. It
can be local time, GMT, or any other. The CS725 does not perform any time
zone or Daylight-Savings time correction.

 Change the time and date by using the following command:

.dd*<space>*dd/mm/yyyy*<space>* hh:mm:ss*<Enter>*

Example:
.dd*<space>*05/11/2010*<space>*10:46:00*<Enter>*

Use the .d<Enter> command to confirm the time has been set properly.

10. [.hd]

 Output histogram data for a specific date.
  Ex: .hd<Enter>
          Histograms: Select first day to retrieve

            Modify that date? :
          [1] yyyy: 2011
          [2]   mm: 01
          [3]   dd: 16
          [0] Exit
          [99] Accept selection

          To Modify: [parameter number, space, new value,CR]

This is the first day that the historic histograms will be displayed from. Once
the start date is entered and accepted, the menu will prompt for an end date as
follows:

          Histograms: Select last day to retrieve

            Modify that date? :
          [1] yyyy: 2009
          [2]   mm: 09
          [3]   dd: 16
          [0]   Exit

[99] Accept selection

To Modify: [parameter number, space, new value,CR]

After the last day or end date is accepted the Histograms will be reported in the following format. For each day requested the date is placed first followed by the 1024 bin values.

22/09/2009   23:59:50
Time stamp of first requested day

29
This line represents the counts for BIN#1

52
This line represents the counts for BIN#2

7
This line represents the counts for BIN#1024

23/09/2009   23:59:50
Time stamp of second requested day

359
This line represents the counts for BIN#1 for the second day
.
No more histogram data available in this time window

11. [.f]

Display measurements according to selected dates

Four lines will be output for every day requested where monitoring occurred. See the section under [.fl] for output details.

The date selection procedure is the same as the [.hd] command.

12. [.fl]

Display only the readings of the current day which can be up to 4 detailed measurement results as follows:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
01/10/2014 23:59:	1	2	52913	11342	5716	393	343	411	18	18	64	0	9	24	24	13	4.2	12.98
01/10/2014 05:59:	1	2	57037	13168	6074	371	309	392	18	18	77	1	7	19	24	13	4.2	12.23
01/10/2014 11:59:	1	2	69645	13016	6415	371	360	375	18	18	27	1	2	8	24	12	3.2	12.23
01/10/2014 17:59:	1	2	58951	14218	6280	359	292	382	18	18	83	0	1	16	24	13	3.2	12.23

The format is the date and time stamp followed by the following numbers:

1. Date
2. Time Stamp
3. Station ID (up to 8 alphanumeric characters)
4. CS725 Serial number
5. K counts total (uncorrected)

A-5

6. K counts total (corrected)this value is used in the SWE calculations)
7. Tl counts total corrected (this value is used in the SWE calculations)
8. SWE value generated from ^{40}K
9. Ratio generated from K and Tl
10. SWE value generated from Tl
11. Soil Moisture values generated from K
12. Soil Moisture values generated from Tl
13. Soil Moisture values generated from K and Tl
14. Precipitation index: Flag indication recent snowfall or rain
15. Crystal temperature min
16. Crystal temperature max
17. Total number of histogram blocks used for the analysis
18. Displacement of the K peak from its nominal position (in bins)
19. Statistical significance of the SWE Tl measurement
20. Power input voltage at the CS725 (after protection diode drop)

14. [.flla]

Display last reading. The output is in the same format as [.fl] command above.

08/11/2010 11:59: 1234 1023 637733 485431 24425 0 -706 0 -47 68 -47 0 26 27 24 -1 1.3 12.05

15. [.fs]

Display last reading in short form. Output is date and time of the readings and the SWE values in millimeters as follows:

DD/MM/YYYY   HH:MM:SS SWE_K SWE_TL

01/10/2013   06:59:50 123 129

16. [.p]

Display the parameter setup menu as follows:

[1] Station ID (Max 8 characters; ex: Gouin_21) .... : GMON3_#1
[3] Time of start of measure (relative to GMON 00h RTC)..... : 00
[4] Delay after start of measure for data transmission (secs.)
                      0=> No transmission).. : 0
[5] Frequency of data transmission: 0 => every 24 h
                      1 => every 6 h .. : 1
[6] GMON height above ground in centimeters................. : 300
[7] Observed position for the K line on the histogram....... : 245
[8] Collim (1: Collimator installed; 0: no collimator)...... : 1
[9] Nominal soil humidity in %weight,(min: 1, max: 150)..... : 25
[10] Estimated soil humidity in %weight (min: 1, max: 150)
                      for HCalib mode.. : 27
[11] NoK... : 230000
[12] NooK (residual K counting) Default:0 .... : 0
[13] N0Tl... : 41000
[14] n00Tl (residual Tl counting)......................... : 0
[16] SN Threshold for the snow cover....................... : 5
[17] Baud rate for scheduled transmissions.................. : 9600

[18] Number of hours per partial histo (hours),(1,2,3,or 6) : 1
[19] Manual mode (1); Auto mode (0) ; HCalib mode (2);...... : 1
[0] Quit without saving the new parameters on EPROM
[99] Save parameters on EPROM
     To modify: [parameter number, space, new value,CR]
=>

[1] Station ID
A user selectable value that can be used to identify a CS725. The Station ID
is part of the output information for certain data formats. The value is a
string (maximum 8 alphanumeric characters). DO NOT use spaces in the
station ID.
    Ex: NoName<space>NewName
[1] Station ID (Max 8 characters; ex: Gouin_21) .... : CS725_#1

[3] Time of start of measure (relative to CS725 00h RTC)
This defines the hour at which a 24-hour period of measurements will begin.
This number is relative to the time set in the internal Real Time Clock (RTC)
by the user. The format is an integer, with values from 0 to 24. This also
defines the time a 24-hour measurement will end. This end time is 10 sec
before the start of measure.

[4] Delay after start of measure for data transmission (secs.)
[explain why this is needed]
This defines the time at which the calculated results from the previous 24-
hour period will be automatically transmitted from the serial port. It is
recommended to set the value to zero in order to disable the Automatic
transmission of data via the serial port.

This is in seconds after the start of the new 24-hour period. The minimum
value should be 300, in order to allow the calculations to complete. The
maximum value is 23h 55 min (86100 sec) in the case of one transmission
every 24 h, and 5 h 55 min (21,300 sec) in the case of one transmission every
6 h. This option is set with parameter [5] Frequency of data transmission.
There will be 4 transmissions spaced by 6 h.

[5]Frequency of data transmission: 0 => every 24 h 1 => every 6 h
This configures the Automatic Data output, and allows output every 24 h or
every 6 h.

This parameter is a flag to instruct the software to transmit the calculated data
once a day (value = 0), or once every 6 h (value = 1). All data output
configured with this parameter is relative to the "Time of start of measure"
parameter.

 It should be noted that the daily output transmission consists of four
averaged values from four overlapping 24-hour periods, which are offset by 6
h intervals.

When the every 6 h mode is selected, the same four periods will be
transmitted, one at the time, as they become available.

[6] CS725 height above ground in centimeters
Enter the actual installed height of the CS725 above the ground. Measured
from the bottom of the main body, not from the collimator. This is a

parameter used in the SWE calculation to account for the absorption of gamma rays in air.

[7] Observed position for the K line on the histogram
This is a parameter used by the peak finding and identifying algorithm, in order to properly frame the search window. It is the bin position at which the ^{40}K isotope peak is observed on the histogram. This is to allow for small shifts in the detector gain. The format is an integer with a value equal or close to 245.

[8] Collim (1: Collimator installed; 0: no collimator)
This parameter is used to indicate if the optional collimator is being used with the CS725. Be sure to select the appropriate configuration, as this does affect the function of the CS725.

[9] Nominal soil humidity in %weight (min: 1, max: 150)
The value (site specific) for the soil humidity is used to account for the amount of water in the soil. This quantity is defined for a unit volume of soil as:

$$100 \text{ (mass of water/mass of dry soil)}$$

Once the soil is frozen, this quantity is relatively constant. The format is an integer between 1 and 150.

See Appendix C *Gravimetric Soil Moisture Method* for detailed instructions on how to determine the soil humidity (moisture) content.

[10] Estimated soil humidity in %weight (min: 1, max: 150) for HCalib mode
This is a site specific parameter used for the auto-calibration of the CS725. The auto calibration mechanism calculates baseline values for the coefficients n0Ke and n0Tl. These coefficients correspond to the integrated rates of gamma rays seen by the detector for the K peak (n0Ke) and the Tl peak (n0Tl) with zero humidity. The HCalib parameter is normally the humidity measured by some other means at the time of the calibration in order to account for this humidity in the soil when the parameters n0Ke and n0Tl are evaluated. The format is an integer.

[11] N0K
This site specific parameter is used in the calculation of the SWE. It represents the integrated gamma ray count rate for the Potassium ^{40}K isotope peak, with no snow cover and dry soil. This number is dependent upon the level of natural radioactivity of the soil at the installation site. It can only be calculated on the site. The auto-calibration method is a tool to obtain the first estimate of that parameter. The format is an integer.

[12] N00K (residual K counting) Default:0
This is a parameter to account for the gamma rays coming from above the snow surface. This is typically a very small number (< 225), and affects the SWE evaluation only under very high SWE conditions (> 300 mm). This value is normally obtained after a full season of operation and can only be determined by comparing the CS725 data with Manual measurements.

Note: This value should not be altered above 225 unless extensive site data analysis has been completed and Campbell Scientific has been consulted.

[13] N0Tl
This site specific parameter is used in the calculation of SWE. It represents the integrated gamma ray count rate for the Thallium ^{208}Tl isotope peak, with no snow cover and dry soil. This number is of course dependent upon the level of natural radio-activity of the soil at the installation site. It can only be calculated on the site. The auto-calibration method is a tool to obtain the first estimate of that parameter. The format is an integer.

[14] n00Tl (residual Tl counting)
This is a parameter to account for the gamma rays coming from above the surface of the snow. It affects the SWE evaluation only under high SWE conditions (>300 mm.). This value is normally determined after the 1st year of operation. The value is typically 1900 or less.

[16] SN Threshold for the snow cover
This parameter is a threshold above which the normal calculation of the SWE will be performed. The threshold is applied to a calculation of the last five averaged SWE data based on the ratio of K/Tl, which is independent of the humidity of the soil, but less accurate than the SWE measured from the K and Tl information independently. When the averaged SWE calculated from the K/Tl ratio is higher than the threshold, it is assumed that there is a snow cover. The nominal humidity parameter is then used for the calculation. Otherwise, the snow cover is assumed to be zero, and the CS725 calculates the humidity of the soil. The default value is 5 mm.

[17] Baud rate for scheduled transmissions
This parameter defines the baud rate to be used for the automatic data transmissions. In interactive mode with a terminal, the CS725 can adjust to the terminal's baud rate by typing "UU<Enter>". However, for scheduled transmissions, the CS725 will use the baud rate specified by this parameter. This is for the cases when an interactive terminal used for the configuration of a site is disconnected and replaced by the normal communication device (modem, satellite, datalogger) with a different baud rate. This guarantees that the scheduled transmissions will be done at the proper baud rate for the communication device. The default rate is 9600 BAUD. Valid values for this parameter are:
1200, 2400, 4800, 9600, 19200, 38400, 57600, and 115200.

[18] Number of hours per partial histo (hours),(1,2,3,or 6)
It is highly recommended to leave this setting to **1 h**. It is recommended to contact Campbell Scientific technical support prior to using other values.

In normal operation 1 h histograms generate, 24 partial histograms per day. However, under very large snow packs (> 500 mm), the absorption of the gamma rays is such that the peaks do not stand up much above the cosmic radiation background after one hour of counting. In this case, the peak identifying mechanism may fail. To overcome this situation, it is possible to have histograms generated in periods of 2,3, or 6 hours.

[19] Manual mode (1); Auto mode (0) ; HCalib mode (2);
This parameter defines the operating mode of the CS725. In the Manual mode (code =1), the CS725 will accumulate a histogram from the initialization cycle until a manual command is sent to delete it. No calculations of SWE will be performed, and no results transmission will be scheduled. This mode is used when setting up the CS725 (i.e. verifying the peak positions, modifying parameters, setting the time, etc.).

The HCalib mode (code = 2) has been referred to in the parameter description for [10] HCalib. When this mode is set, the CS725 will acquire the data in a normal manner, and the results will be transmitted at the end of the period at the scheduled transmission time. However, instead of calculating the SWE, it will assume that the SWE is zero. Then, it will perform the inverse SWE calculation, and infer the values of the n0Ke and n0Tl from the measured integrals for the K and Tl isotope peaks, taking into account the humidity of the soil specified in the parameter HCalib. When this is done, the new values of n0Ke and n0Tl will be stored in the parameter block, and the operation mode will be changed internally by the CS725 to automatic (code =0).

The automatic mode (code =0) is the normal mode of operation. The CS725 will continuously cycle through 24-hour periods, calculating the SWE for the previous 24 h at 6 h intervals.

[0] Quit without saving the new parameters on EPROM
[99] Save parameters on EPROM

17. [.s]

The [.s] command is used to Display status and current measurement information:

System status:
 -Present time   : 05/11/2010   12:40:05
 -Firmware Version   : 5c
 -Software Version   : 15_L
 -V bat(Volts)   : 12.64
 -V HV (Volts)   : 380.02
 -V HV-DAC (code)   : 20472
 -Data acquisition start time : 05/11/2010   12:37:15
 -Data acquisition stop time : 06/02/2136   06:28:15
 -Next Results Xmission time   : 06/02/2136   06:28:15
 -Elapsed time,current histo   : 00:02:39
 -Mode   : MANUAL
 -Automatic heating   : disabled
 -TMax   : 24 0 0 0
 -Min   : 24 0 0 0

18. [.0xps]

[.0xps] Parameters save to file function

The [.0xps] command is used to save the parameters list from the CS725 in a text file. It is useful when a new CS725 has replaced an old CS725 at a site. The CS725 will prompt:

Enable the screen capture to a file with the HyperTerminal
To begin the transfer of parameters, type S (CR)

where CR is the Enter key. Before typing S, the file will be named using the HyperTerminal function.

19. [.0xpr]

[.0xpr] Parameters recovery from file function

The [.0xpr] command is used to recover the parameters list from a text file created with the [.0xps] command and send the list to the CS725 . It is useful when a new CS725 replaced an old CS725 at a site. The CS725 will prompt:

Allocating tempory buffer,,,,,,,,,
Launch the parameter file transfer with the HyperTerminal

The file to retrieve will then be selected using the HyperTerminal function.

20. **[%Rhard][%Rboot]**

 [%Rhard] restarts the software processor.

[%Rboot] restarts the firmware and it has the same effect as a power off /power on.

21. **[UU]**

[UU]   CS725/Terminal synchronizing sequence for rates other than 9600 bauds

The [UU] command synchronizes the baud rate of the CS725 to the terminal baud rate.

Appendix B. 24 hour K and Tl Counts used for Site Evaluation

TABLE B-1. Potassium Count (Cnt Tl) Guideline for SWE – 24 hour Reading

With Collimator	Without Collimator	Description
< 96000	144000	Insufficient K at site
96000 to 180000	144000 to 270000	Usable Cnt K range. May experience larger errors for higher SWE values
180000 to 264000	270000 to 396000	Good Cnt K range. Should maintain specified operating characteristics
> 264000	> 396000	Excellent Cnt K range

TABLE B-2. Thallium Count (Cnt Tl) Guideline for SWE – 24 hour Reading

With Collimator	Without Collimator	Description
< 9600	14400	Insufficient Tl at site
9600 to 36000	14400 to 54000	Usable Cnt Tl range. May experience larger errors for higher SWE values
36000 to 48000	54000 to 72000	Good Cnt Tl range. Should maintain specified operating characteristics
> 48000	> 72000	Excellent Cnt Tl range

Appendix C. Gravimetric Soil Moisture Method

C.1 Gravimetric Soil Moisture Method

Determining the amount of soil moisture is necessary to initiate data collection for Snow Water Equivalent (SWE) monitoring with a CS725. The prefered method to determine soil moisture is the Gravimetric Soil Moisture Method.

C.1.1 Equipment Required

- Airtight/sealable container (e.g. Ziploc bag)

- Small shovel

- Microwave safe plate (microwave); baking dish (conventional oven)

- Scale – accuracy to 1 gram

- Microwave or conventional oven

C.1.2 In-field Sampling

Sample a field at a minimum of three sample locations (preferably five). Choose sample locations that are representative of the area where the SWE is to be measured. Avoid sampling small areas of low spots or ridges that do not represent the majority of the area. The size of the soil sample should be the size of a large grapefruit.

The CS725 measures an area of 100 m^2. The five soil samples should be taken about 2 m apart in an 8 m transect underneath the sensor. If there seems to be large differences in moisture contents between samples, it would be advisable to sample an extra location or two.

Take the samples and store in the airtight container. This will prevent the loss of moisture to evaporation. The samples can be mixed together in a single container because the measurement is a spatial average.

C.1.3 Drying Samples

After soil samples have been taken and returned to the office, perform the following quickly and carefully.

1. Thoroughly mix the samples in the airtight container to ensure uniform distribution of the sample.

2. Weigh the microwave safe plate or baking dish before putting soil on it. This value will be needed for the calculation of soil moisture. Do not use plasticware in the microwave as it may melt.

3. Place approximately 25 grams of wet/moist soil on the paper plate and record the weight of soil and plate.

4. Drying the sample can be done in either a microwave oven or conventional oven. Be sure there is good ventilation with whichever drying device you use.

The appropriate steps for drying with a **microwave** oven are as follows:

a. Place sample (on microwave safe plate) into microwave and run for 10 minutes.

b. Weigh the sample and return to microwave oven for 5 minutes and reweigh. If the weight of the sample has changed, return to the microwave oven for 5 more minutes. Repeat the process until the weight does not change. Typical drying times for a wet sample is close to 20 minutes. Water is the first component of the soil to heat and evaporate. If the sample is dry and microwave drying continues, the soil temperature will increase and oxidize organic matter. This will bias your results.

5. If you are using a **conventional** oven, place samples on a baking sheet or similar at 105°C (220°F) for 24 hours.

6. After the moisture is determined, use the following equation to get the correct value:

%weight = 100 x (mass of water/mass of dry soil)

Input this value into the CS725 parameter **[9] Nominal soil humidity in %weight (min: 1, max: 150)**

Once the soil is frozen, this quantity is relatively constant. The format is an integer between 1 and 150. It can go above 100 in boggy-type of soils where the mass of water is greater than the mass of solids.

Appendix D. FAQ

D.1 What is the calculation of height versus sampling foot print if the sensor were to be mounted at 10 m?

This is of interest as the CS725 can easily sample a larger area than $3 - 5$ m² of snow pillow or snow scale.

Answer:

When the CS725 is installed with a collimator, 80% of the radiation is eliminated outside of the 60° angle from center. Using the effective measurement angle of 60°, the circular radius is Tan(60°)*H. Table D-3 shows the height versus effective measurement area.

TABLE D-3. Height versus Effective Measurement in Meters		
Sensor Height	**Circular Radius**	**Effective Measurement Area**
1 M	1.73 M	9.4 M²
2 M	3.46 M	38 M²
3 M	5.2 M	85 M²
4 M	6.93 M	151 M²
5 M	8.66 M	236 M²
6 M	10.39 M	339 M²
7 M	12.12 M	461 M²
8 M	13.86 M	603 M²
9 M	15.59 M	764 M²
10 M	17.32 M	942 M²

If a site is very open and has good uniformity, it is desirable to remove the collimator rather than raising the sensor height to increase the measurement angle. Removing the collimator substantially increases the counts that come from outside the 60° measurement angle. Typically, the total radiation counts for potassium are doubled when the collimator is removed. Theoretically, increasing the height of the sensor does not increase the counts, but simply increases the measurement area that is not attenuated by the collimator.

D.2 Does most of the gamma detection occur under the area of the CS725?

Answer:

Yes, the closer the distance, the more influence it has on the overall readings for a given area. The following table provides some theoretical calculations on the contribution to total counts versus angle from the center.

TABLE D-4. Contribution to Total Counts versus Angle from the Center				
Angle Range Outer Tadius @ 3M	**Total Count Contribution with Collimater**		**Total Count Contribution Without Collimator**	
		Sum from 0°		Sum from 0°
0-5° (0.26 M)	0.4%	0.4%	0.2%	0.2%
5-10° (0.26 M)	1.55%	2.05%	0.85%	1.05%
10-15° (0.80 M)	3.0%	5.05%	1.55%	2.6%
15-20° (1.09 M)	4.3%	9.35%	2.2%	4.8%
20-25° (1.40 M)	6.0%	15.35%	3.1%	7.9%
30-35° (2.1 M)	9.0%	32.15%	5.05%	17.0%
35-40° (2.52 M)	9.55%	41.7%	6.0%	23.0%
40-45° (3.00 M)	9.55%	51.25%	7.0%	30.0%
45-50° (3.58 M)	9.2%	60.45%	7.9%	37.9%
50-55° (4.28 M)	8.6%	69.05%	8.75%	46.65%
55-60° (5.20 M)	7.9%	76.95%	9.15%	55.8%
60-65° (6.43 M)	6.9%	83.85%	9.6%	65.4%
65-70° (8.24 M)	5.8%	89.65%	9.65%	75.05%
70-75° (11.20 M)	4.5%	94.15%	9.2%	92.4%
75-80° (17.01 M)	3.2%	97.35%	8.15%	92.4%
80-85° (34.3 M)	2.1%	99.45%	6.0%	98.4%
85-90°	.55%	100%	1.6%	100%

The table above shows that 23% of the radiation counts come from sources beyond the 60° beam angle when a collimator is installed versus 44% when the collimator is removed.