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USER'S TESTING SCHEDULE FOR THE WALLINGFORD PROBE SYSTEM

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ABSTRACT

The Wallingford Neutron Soil Moisture Meter is a field instrument that is very stable through varying field conditions. These tests aim to provide definite performance limits within which the probe assembly, when functioning correctly, should operate. They require little specialist knowledge or equipment and can be performed by the field operator of the probe.

The performance tests apply to the performance of the probe assembly, i.e. the Wallingford probe plus either scaler, ratescaler or ratemeter, as it is used in the field. They can be performed easily by the person who is in charge of the field operation of the probe and require no knowledge of electronics. The tests have been kept as simple as possible to minimise the need for ancillary testing equipment. They must be applied with care and the results must be considered with due appreciation of the probability laws of counting random pulses. In formulating the various performance limits the appropriate random counting errors have been allowed for to a 95% probability level (two standard deviations) except where otherwise stated.

PRECAUTIONS

When using or handling the radioactive source all statutory health physics precautions must be observed, and it is recommended that international and national codes of practice be consulted and followed.

EQUIPMENT

(1) A standard water moderator. This is a tank of water at least 60 cm deep and 50 cm diameter which effectively provides an infinite medium for the probe. It has an aluminium alloy access tube 1¾ in (44.5 mm) O.D. x 16 swg sealed at the bottom end mounted axially and extending from the bottom of the drum to about 10 cm above the water surface.

(2) An aluminium access tube as above but 2 in (50.8 mm) O.D.

(3) Expanded polystyrene wallpaper or similar lagging material.

(4) A cabinet large enough to accommodate the probe (not in its transport shield), fitted with air circulation fans, freezer, heater and thermostats such that it can maintain (±2°C) any temperature in the range -10°C to +40°C.

(5) A stabilised power supply, variable 10-15V at 0.25A. If a ratescaler is being used, a second power supply is necessary to produce the required +12/0/-12V supply.

(6) A water tank suitable for probe immersion to a depth of one metre.

RANDOM COUNTING ERROR

As the probe produces random pulses, the count rate has associated with it a standard deviation, σ_r and 95% of the count rate values should lie within $\pm 2\sigma_r$ of the true mean count rate. The method of determining σ_r varies with the type of instrument used and is given by :

<u>Ratescaler</u>

$$\sigma_r = \sqrt{(R/t)} \quad \ldots\ldots \text{(1a)}$$

where R is the count rate reading (counts per sec)
t is the preset time (sec)

Scaler

$$\sigma_r = \sqrt{(n)}/t \quad \ldots\ldots\ldots \quad (1b)$$

where n is the number of counts
t is the count time (sec)

Ratemeter

$$\sigma_r = \sqrt{(R/2\theta)} \quad \ldots\ldots\ldots \quad (1c)$$

where R is the count rate (c.p.s.)
θ is the time constant (sec)

If N individual readings of count rate R are obtained, then the standard deviation $\sigma_{\bar{r}}$ of the mean count rate $\bar{R}$ is given by :

$$\sigma_{\bar{r}} = \sigma_r /\sqrt{(N)} \quad \ldots\ldots\ldots \quad (1d)$$

PROCEDURE

Except where stated, all equipment is kept at constant temperature ($\pm 2^{\circ}C$) and under constant conditions. The treatment of the probe is the same no matter which meter or scaler is used but the manner of obtaining the count rate differs. The various procedures are given below :

Ratescaler

For tests 1, 2, and 3 the power supply is connected to the ratescaler in place of the nickel-cadmium cells in the power pack section and is kept constant at about +12/0/-12V. Except where otherwise stated, the mean count rate $\bar{R}$ is determined by taking 10 successive count rate readings R using the 64-sec preset time.

Scaler

Except for test 5 the power pack is connected to the probe and kept constant at about 12V.

i) If the scaler has a preset count facility, a 500,000 preset count should be used. The count rate R is given by :

$$R = n/t \qquad \ldots\ldots\ (2)$$

If necessary, the same precision can be achieved by meaning, for example, 5 counts with 100,000 preset.

ii) If the scaler has a preset time facility, a preset time of at least 10 min should be used, the same precision can be achieved by measuring at least, for example, 10 counts with 1 min preset.

Ratemeter

The 8-sec time constant is used throughout. The dial is read at all times with the meter in a horizontal position. For tests 1, 2 and 3 the power supply is connected in place of the ratemeter's own battery and kept constant at 12V. To determine the mean count rate $\bar{R}$ it is necessary first to determine the mean dial reading $\bar{D}$ and then to correct this for the counts lost due to the dead time T of the ratemeter. The true count rate is given by :

$$\bar{R} = \bar{D} + \bar{D}T\bar{R}$$

$$\therefore \bar{R} = \bar{D}/(1-\bar{D}T) \qquad \ldots\ldots\ (3)$$

(T ≈ 100μs for a Wallingford ratemeter, see test 8 for details).

The mean dial reading $\bar{D}$ (except where otherwise stated) is determined by meaning 40 readings taken at intervals of about 10 sec. The ratemeter needle fluctuates due to the random nature of the pulses produced by the probe and so, to avoid subjective reading errors, each reading is taken as the first scale division crossed by the needle after each 10 sec interval.

A pause of at least 5 times the time-constant (in this case 40 sec) must occur after switch-on before the first reading is taken.

If possible, the meter should be subjected to tests 8 and 9 before the other tests are performed as the validity of some of the other tests may be dependant upon these results.

Test 1 Count Rate in Air

The probe is suspended freely in air with its centre of sensitivity at least one metre from floor, walls, ceiling or any other object. The count rate R is determined in this position and must be less than 10 counts per second (c.p.s.). As the count rate is very low, the standard deviation σ_r is small and so the count rate need not be determined as rigorously as in other tests, i.e. using the probe with :

Ratescaler - Mean 2 readings with the 64-sec preset time

Scaler - Preset 1000 counts (or 100 sec)

Ratemeter - It is not possible to read the dial of the ratemeter accurately enough to determine a count rate of this order. The analogue voltage output can be measured, and must be less than 0.05V, or alternatively, a rough guide to satisfactory performance is given if the meter reads less than 10 c.p.s.

Test 2 Count Rate in Water

The probe is suspended in the access tube of the standard water moderator with the centre of sensitivity located midway between the water surface and the bottom. The mean count rate $\bar{R}$ is determined (as specified previously) and must be greater than 950 c.p.s.

Test 3

i) Count Rate Drift with Operating Time

ii) Random Counting Error

The probe is suspended in the access tube of the standard water moderator (as above, Test 2) and left entirely undisturbed for the duration of the test. Count rate determinations are made at approximately equal time intervals of about 4 min over a period of 6 to 8 hours until at least 100 readings have been made.

Count rate readings are made thus :

Ratescaler - one reading with the 64-sec preset time

Scaler - 50,000 counts (~60 sec)

Ratemeter - mean of 4 readings

The first reading is started at 5 sec after switch-on (40 sec with the ratemeter). The probe must not have been operated for at least 2 hr previously.

i) Count rate drift

The count rate drift, given by the linear regression of count rate on time, must not exceed 0.5 c.p.s. per hour meaned over the period of the test.

ii) Random counting error

Of the derived count rate values R

90% must be within $2\sigma_r$,

98% must be within $3\sigma_r$

and all must be within $4\sigma_r$ of the mean value of all the derived count rates.

Test 4 Temperature Stability

Probe

The probe is wrapped securely with a layer of thermal insulation such that the probe fits into the 2 in (50.8 mm) access tube with a radial clearance of 1 or 2 mm. The wrapping should have a smooth surface so that the probe can be inserted and removed easily. The probe is placed in the temperature controlled cabinet for at least 20 hr at the required temperature (to allow all the components of the probe to reach thermal equilibrium). It is then removed, quickly placed in the access tube of the standard water moderator (as for test 2 but substituting the 2 in O.D. access tube) connected to the meter (ratescaler, scaler or ratemeter) and switched on with as little delay as possible. After a pause of 5 sec (40 sec with the ratemeter) the mean count rate $\bar{R}$ is determined. The instrument is switched off and the probe returned to the cabinet for equilibration for 20 hr at the next temperature. This procedure is repeated so as to obtain the mean count rate $\bar{R}$ at each of the following temperatures :

$-10^\circ C$, $0^\circ C$, $+10^\circ C$, $+20^\circ C$, $+30^\circ C$ and $+40^\circ C$. The moderator is maintained at the same temperature ($\pm 2^\circ C$) on each occasion.

It is essential that the probe is transferred to the moderator and the count started as quickly as possible so that no significant change in the internal temperature of the probe occurs before the count rate is determined.

The six mean count rates thus determined must lie within ±5 c.p.s. of the overall mean count rate.

Ratescaler

For this test the ratescaler is used with its own battery pack which is maintained throughout the test at the same temperature as the ratescaler. The probe is suspended in the standard water moderator (as in Test 2) and connected to the ratescaler which is placed in the temperature controlled cabinet set at the required temperature. After a period of 20 hr the ratescaler is switched on and, after a 5 sec pause, the mean count rate $\bar{R}$ determined. This procedure is repeated, allowing a 20 hr 'soak' period in each case, at each of the following temperatures :

$-10^{\circ}C$, $0^{\circ}C$, $+10^{\circ}C$, $+20^{\circ}C$, $+30^{\circ}C$ and $+40^{\circ}C$. The ratescaler is left in the cabinet throughout the test, thus ensuring that no unrecognised temperature variations occur.

The six mean count rates thus determined must lie within ±5 c.p.s. of the overall mean count rate.

Ratemeter

The procedure is the same as that for the ratescaler, using the meter's own battery.

Test 5 Battery Voltage Working Range

With the probe suspended in the standard water moderator (as in Test 2) the mean count rates are determined at various applied stabilised voltages as specified below :

Ratescaler

With the variable voltage supplies connected in place of the ratescaler's own NiCa cells, the mean count rate $\bar{R}$ is determined at voltages of :

+11/0/-11	+12.5/0/-11	+14/0/-11
+11/0/-12.5	+12.5/0/-12.5	+14/0/-12.5
+11/0/-14	+12.5/0/-14	+14/0/-14

The 9 mean count rates thus determined must lie within ±5 c.p.s. of the overall mean count rate.

Scaler

With the voltage applied direct to the probe, the mean count rate $\bar{R}$ is determined at voltages of :

11, 12, 13 and 14V.

The linear regression of count rate on voltage must have a gradient of less than 1 c.p.s. per volt.

Ratemeter

With the voltage applied in place of the ratemeter's own NiCa cells, the mean count rate $\bar{R}$ is determined at voltages of :

11, 12, 13 and 14V.

The linear regression of count rate on voltage must have a gradient of less than 1 c.p.s. per volt.

Test 6 Watertightness

Probe

The probe, with its cable connected, is completely immersed to a depth of 1 metre for 24 hr. On removing and drying the probe, the mean count rate $\bar{R}$ in the standard water moderator must lie within the random counting limits of its value before immersion and the probe must perform normally in all ways. If the probe is removed from its housing, no visible signs of water ingress should be apparent.

Ratescaler and Ratemeter

The ratescaler and ratemeter are designed to operate in rainy conditions without ingress of water but are not, as is the probe, designed to withstand complete immersion. It is therefore not possible to specify a simple test. It is envisaged that the Mark III ratescaler at present under development will be able to withstand complete immersion.

Test 7 Ratemeter Time-Constant

This test applies only to the ratemeter.

The ratemeter is connected to the probe suspended in the standard water moderator and the mean dial reading determined at each of the time constant settings 8, 4 and 2. Using the :

8	sec	time	constant	40	readings	are	meaned
4	"	"	"	80	"	"	"
2	"	"	"	160	"	"	"

$\sigma_{\bar{r}}$ is then the same for each mean reading (≈1.2 c.p.s. for a count rate of 950 c.p.s.). The three mean dial readings thus obtained must lie within ±4 c.p.s. of the mean of the three.

Test 8 Ratemeter Dead Time

This test applies only to the ratemeter; it requires either a ratescaler or a scaler with a negligible (or accurately known) dead time.

With the ratemeter connected to the probe and the probe suspended in the standard water moderator (or other moderator) the mean dial reading $\bar{D}$ is determined. Similarly, with the ratescaler (or scaler) connected to the probe, the mean count rate $\bar{R}$ is determined. The dead time T is then given by :

$$T = (\bar{R}-\bar{D})/(\bar{D}\bar{R}) \qquad \text{(from equation 3)}$$

The dead time must be less than 110 microsec.

N.B. Although the dead time will remain constant for a given ratemeter/probe combination, it may be different if the ratemeter is used with a different probe.

Test 9 Linearity and Proportionality of Ratemeter Dial Reading and Analogue Output

This test applies only to the ratemeter.

If a pulse generator is available, a standard (2V 2 microsec negative) pulse can be fed into the probe socket of the ratemeter. The ratemeter dial should read the same as the pulse rate, and be linear over the whole range, but an error of ±5 c.p.s. is permissible. The analogue output voltage should be 5V at F.S.D.(≡1000 c.p.s.) and linearly proportional (±0.025V) over the whole range.

If no pulse generator is available, but a ratescaler or a scaler is, then the test can be performed as follows :

1. With the probe feeding into the ratemeter determine both the mean dial reading $\bar{D}$ and the analogue output voltage with the probe positioned in each of several moderators giving count rates of about 200, 400, 600, 800 and 1000 c.p.s. The analogue output voltages should be linearly proportional (±0.025V) to the dial readings. Correct the dial readings using the dead time correction (See equation 3 and Test 8 above).

2. With the probe feeding into the ratescaler or the scaler determine the mean count rate $\bar{R}$ in the standards.

3. Plot a graph of $(\bar{R}-D_c)$ against $\bar{R}$, where $\bar{R}$ is the actual (scaled) count rate and D_c is the corrected mean dial reading. The graph should not deviate from the zero line by more than ±10 c.p.s.

   An incorrect dead time will cause a progressive divergence with increasing count rate. In such a case the dead time should be checked and D_c values re-calculated if necessary (Test 8).

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