A PORTABLE INSTRUMENT FOR MEASURING SOIL MOISTURE[1])

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SUMMARY

A description is given of a portable measuring instrument for determining soil moisture. The most important features are small dimensions, light weight, low energy consumption and simple handling.

1 INTRODUCTION

The Physico-Technical Service for Agriculture has developed a new instrument for measuring soil moisture in the field (Fig. 1).

Miniature components and the semi-conductor device, the transistor, have been successfully used, so that the meter has small dimensions and is light in weight.

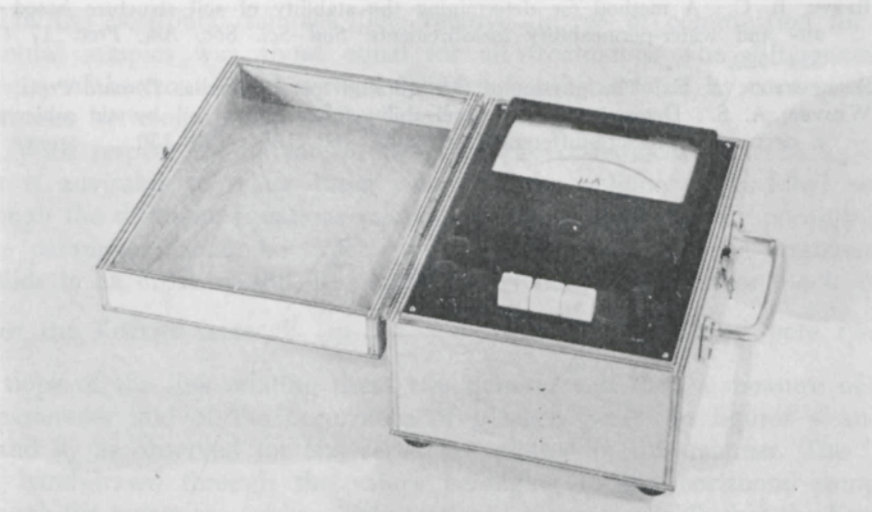

FIG. 1 RESISTANCE METER FOR DETERMING SOIL MOISTURE.

The current is supplied by two 4.5 V batteries which are very durable because in the first place the current could be kept very low on account of the use of transistors and the development of an economic circuit of a high efficiency, and in the second place the current is only consumed during the part of a measurement operation when one of the buttons is pushed in.

These features make the instrument extremely suitable for its purpose, viz. a portable instrument that can be easily taken into the field.

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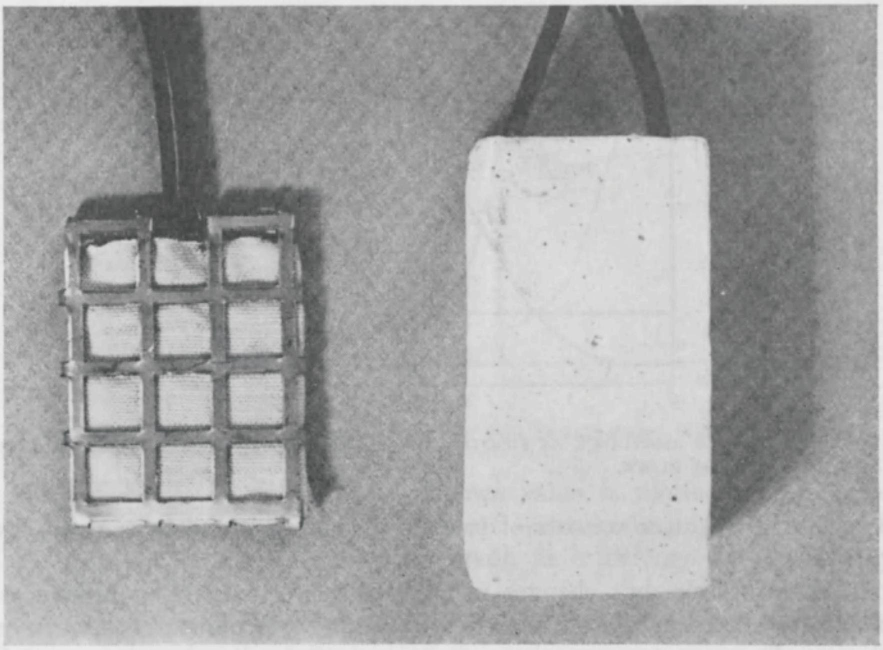

FIG. 2 LEFT, NYLON TRANSDUCER ; RIGHT, GYPSUM BLOCK.

Although there are three measuring ranges (the three white push buttons, Fig. 1) the instrument is very simple to use.

Gauging is done by turning the potentiometer knob (on the right in the photo) thereby obtaining at the same time a compensation for the ambient temperature and a correction for the battery voltage.

The circuit is so constructed that the instrument is not damaged either by pushing a button intended for another measuring range, or by the short-circuiting of the input terminals.

2 PROCEDURE FOR DETERMINING THE SOIL MOISTURE

A moisture transducer is introduced into the soil of which it is required to determine the soil moisture at regular intervals.

This transducer should remain in the ground so that the surroundings are not disturbed by each measurement. Only a flex with plugs for connection to the input terminals remains above ground.

The electric magnitude which changes according to the moisture condition of the transducer is its impedance (the alternating current resistance), this being determined by means of the instrument.

There are two types of transducers, viz. the oldest gypsum block type and now also the nylon transducer. The first type consists of a small block of gypsum in which two electrodes are inserted (Fig. 2, right). In this type the gypsum acts as a moisture-sensitive material. It is used at places where lower soil moistures are found. An advantage of the gypsum is that the alkaline medium acts as a buffer against the influence of soil salts on the measurements. A disadvantage is that the gypsum block is affected and disintegrates after a certain time depending on the type of soil.

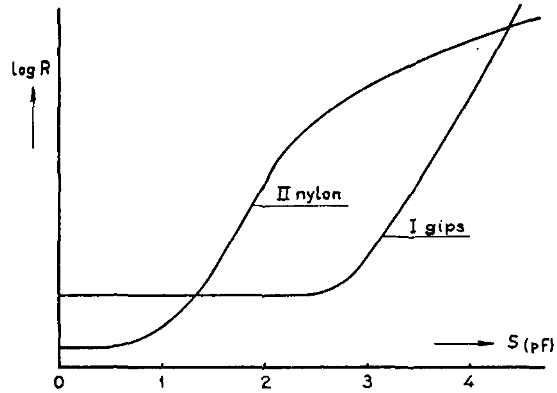

FIG. 3 TREND OF THE RESISTANCE AS FUNCTION OF THE pF VALUE S FOR A NYLON TRANSDUCER AND A GYPSUM BLOCK.

The nylon transducer consists of two electrodes separated by a nylon tissue (Fig. 2, left).

It is more durable, but changes in the soil salt concentration influence the measurement. It is used at places where higher soil moistures also have to be measured.

The graphs (Fig. 3) show the logarithm of the resistance value of a gypsum block (I) and a nylon transducer (II) as function of the pF-value S, viz. the logarithm of the moisture tension.

It can be seen from the steep gradient of the curve that a gypsum block can only be used above a value of pF = 2.5 and has a good sensitivity for higher pF values.

Nylon transducers can be used from pF = 1, above which value the moisture tension is significant. They can also be used for values above pF = 2.5, but are less accurate than gypsum blocks.

The graph in Fig. 4 is required in order to interpret the moisture content of the soil from the pF value; the graph shows this value as a function of the moisture content in percentages for two different kinds of soils.

This graph should be separately determined for each type of soil. A graph

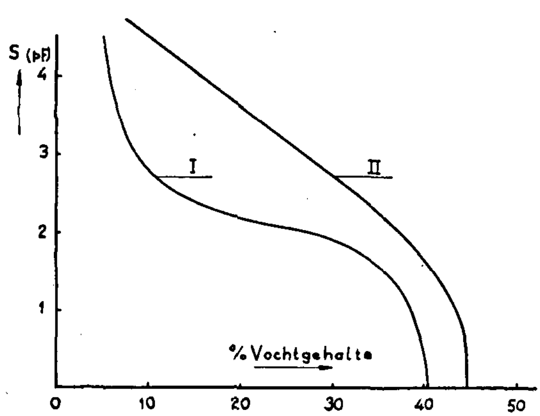

FIG. 4 TREND OF THE MOISTURE TENSION AS FUNCTION OF THE MOISTURE CONTENT FOR TWO DIFFERENT KINDS OF SOILS.

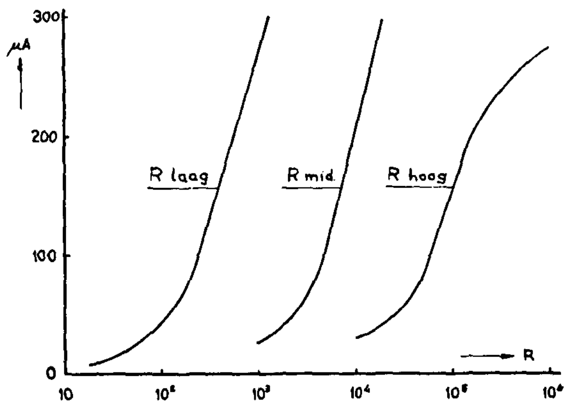

FIG. 5 GAUGE GRAPH OF AN INSTRUMENT FOR DETERMINING SOIL MOISTURES.

can also be drawn in which the resistance value is plotted directly against the moisture content. The moisture content is determined more rapidly with this method, but it is not a universal graph as it belongs to a special type of soil only.

It is easier to work out the relationship in a table if a correction is made at the same time for the influence of the soil temperature on the measured resistance value. The intersection of the measured resistance value and the measured soil temperature gives the pF value.

3 OPERATING PRINCIPLE OF THE INSTRUMENT

The instrument measures the alternating current resistance of a moisture transducer. The measurement is made with an alternating current in order to avoid polarization voltages which would result in an apparent increase in the resistance value.

There are three ranges, i.e. for high, medium and low-resistance values.

Within the range for high resistances the frequency of the alternating current is about 2000 cycles/sec, a minimum value which enables polarization errors to be sufficiently avoided.

The ranges for the medium and low resistances operate on a frequency of about 1000 cycles/sec in order to decrease the effect of wiring capacities, etc. which is relatively greater with lower resistances.

The meter reading is made in micro-ampères (μ A). For the transposition in the corresponding resistance value a gauge graph is given which is measured separately for every instrument and of which Fig. 5 gives an example. The chief reason for the separate gauging of every instrument is the variability of the properties of the transistors employed. The current value in μ A is plotted as a function of the resistance for the three measuring ranges R_{high} R_{medium} and R_{low}.

A simplified electric circuit is shown in the block scheme in Fig. 6. On the left of the scheme is the oscillator for transforming the direct current of the batteries into an alternating current used for the measurements.

Owing to the great variations in the properties of the oscillator transistors each oscillator is tested and adjusted separately. It is built into a small metal box which is in a socket for ready replacement in case of breakdown.

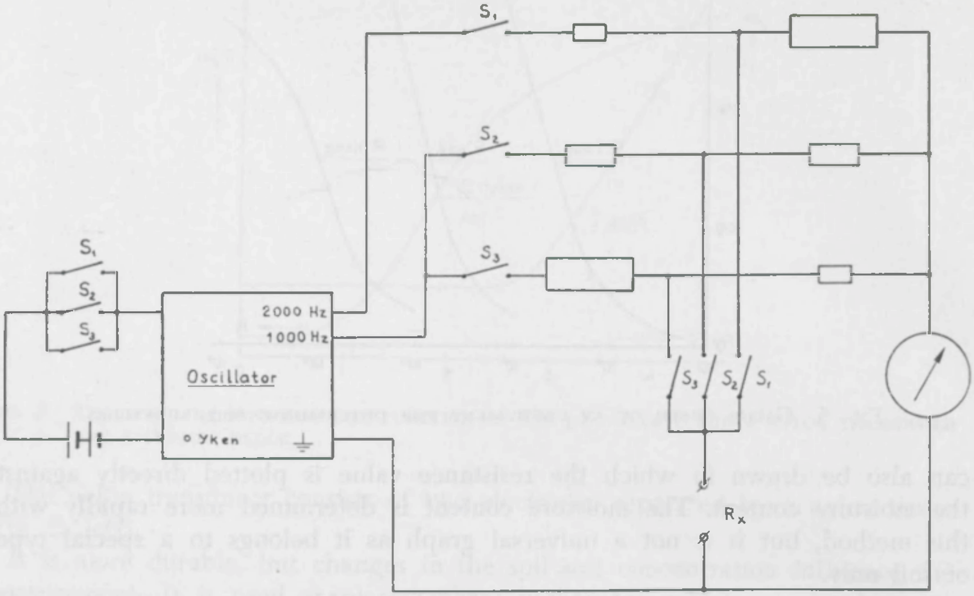

FIG. 6 SIMPLIFIED BLOCK SCHEME FOR OPERATING THE INSTRUMENT.

The range required is selected by means of one of the three push buttons. When these buttons are pushed down the input terminals are connected to the proper measuring circuit, this circuit is switched on, and the oscillator is started by connecting the battery voltage to it.

Fig. 7 is a photograph of the inside of the instrument. The batteries are

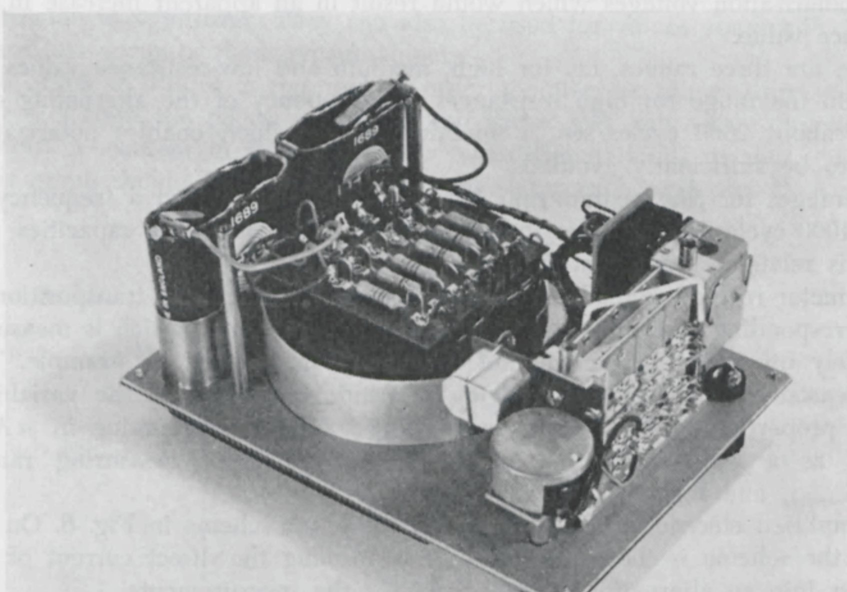

FIG. 7 THE CONSTRUCTION OF THE INSTRUMENT.

readily taken out of their holder when a replacement is needed. The connecting wires of the different circuit components are linked to wirebundles. In the foreground can be seen from left to right the gauge potentiometer, the three push button switches and the oscillator.

4 Direction for use

Before measurements can be taken with the instrument, it has to be gauged for the ambient temperature and the battery voltage. With open input terminals the push button bearing the legend "gauging" in pushed down and after some seconds the reading of the micro-ammeter is adjusted by turning the knob of the gauging potentiometer on the right till the result is exactly 300 μ A.

The instrument is now ready for use.

A moisture transducer is connected to the input terminals on the left, bearing the legend R_x . after which the push button for R_{high} is pushed down and the result can be read.

If the pointer remains in front of the red mark on the left the button for R_{medium} is pushed down, after which the reading can be taken. Should the pointer still remain in front of the red mark on the left the button for R_{low} is used.

Both the measuring range (high, medium or low) and the reading should be noted.

5 Technical data

Input impedance:	suitable for connecting gypsum blocks or nylon transdusers.
Measuring ranges:	R_{high} 1.000.000 – 10.000 ohm
	R_{medium} 10.000 – 1000 ohm
	R_{low} 1000 – 25 ohm.
Accuracy:	greater than 2%.
Adjustment time:	3 seconds.
Temperature compensation Battery voltage correction	with potentiometer.
Power supply:	two 4.5 V batteries.
Alternating current:	1000 and 2000 cycles/sec.
Gauge graph:	per instrument.
Dimensions:	(without handle) 200 × 150 × 110 mm.
Weight:	2100 grams.

References

1 Feinberg, R.: On the performance of the push-pull relaxation oscillator. *Phil. Mag.* 29 (1948) ser. 7, p. 268.

2 Richards, L. A. and R. B. Campbell: The effect of salinity on the electrical resistance of gypsum, nylon and fiber glass soil moisture units. *U.S.D.A. (Reg. Sal. Lab.) Res. Rep.* 42 (1950).

3 Aitchison, G. D. and P. F. Butler: Gypsum block moisture meters as instruments for the measurements of tension in soil water. *Austr. J. Appl. Sci.* 2 (1951) p. 257–266.

4 Baier, W.: Elektrische Methoden zur Messung der Bodenfeuchte. *Ber. Deutsch. Wetterd.* US. zone 32 (1952) p. 18–22.

5 Wind, G. P.: De waarde van gipsblokjes en tensimeters voor de bepaling van het watergehalte van de grond. *Versl. C.I.L.O.* (1952) (1953) p. 66–72.

6 EBERS, J. and J. MOLL: Large signal behaviour of junction transistors. *Proc. I.R.E.* 42 (1954) p. 1773.
7 WIND, G. P.: Nylon elementen als vochtmeters. *Landbouwk. Tijdschr.* 67 (1955) nr. 8, p. 541–551.
8 JACKETS, A. E.: Oscillator circuits using junction transistors. *Electronic Engng.* 28 (1956) p. *184.*
9 Four-pole analyses for transistors. *Electr. Engng.* (1958) oct., p. 592.