The measurement of ground temperatures using a modified portable potentiometer

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SUBJECT THE MEASUREMENT OF GROUND TEMPERATURES USING A MODIFIED PORTABLE POTENTIOMETER

Thermocouple installations are used extensively to obtain ground temperatures. The instrument frequently used to measure these temperatures is a portable potentiometer. This note describes one such potentiometer which has been used by the Division of Building Research of the National Research Council and which has been modified to permit its use when air temperatures are below 32°F. The note also outlines procedures to be followed in the use of this instrument to measure ground temperatures.

THERMOCOUPLES

Whenever two dissimilar metals are joined to form a complete electric circuit, a small electromotive force, varying with temperature, is induced. The electromotive force developed is dependent upon the difference in temperature between the two junctions and the metallurgical properties of the two wires. Temperatures on the Fahrenheit scale are obtained by measuring the difference in electromotive force between a junction of known temperature, i.e., a reference junction, and one of unknown temperature. In the usual thermocouple circuit the reference junction is a bath of water and finely crushed ice which when well mixed will maintain a constant temperature of 32°F.

Copper-constantan, 20-gauge, duplex thermocouple wire has generally been used for these ground temperature installations.

This wire has two conductors, one copper and one constantan, individually encased in polyvinyl with an over-all covering of polyvinyl. When ground temperatures are desired at different depths below the ground surface, all duplex wires are usually fastened together to form a cable which can be placed in a test pit, borehole, etc. For many installations where ground moisture can have an appreciable effect on the thermocouple performance the cable has been placed inside a protective tubing such as flexible polyethylene pipe which is filled with a special oil. To facilitate the measurement of temperatures at several points in the ground at one location the thermocouple wires are connected to a rotary selector switch usually placed in a weatherproof box having a pair of terminals (one copper, one constantan) to which the potentiometer can be connected.

POTENTIOMETER

A potentiometer is an instrument for measuring potential differences. A basic potentiometer circuit is shown in Fig. 1. The battery current, suitably adjusted, flows through the slidewire. Upon connection of the EMF to be measured a new position of the slidewire contactor must be found, so that there is no current flow as indicated by the galvanometer G.

The slidewire is arranged so that provided that the battery current through it has been adjusted to the proper initial valve, the EMF to be measured can be read directly on the slidewire contactor dial. The battery current must first be standardized in an initial operation which involves connecting a Standard cell which produces a standard, fixed EMF across an appropriate length of slidewire, and then adjusting the battery rheostat until the galvanometer shows no current flow.

The instrument found suitable by the Division of Building Research for their ground temperature work is a Rubicon portable precision potentiometer. It is self contained and includes calibrated resistors, an Eppley standard cell, 2-1½ volt dry batteries, two rheostats for fine and coarse adjustment of the potentiometer current and a "Pointerlite" galvanometer. A schematic circuit diagram is shown in Fig. 1. Several modifications have been made to this instrument, for field use, e.g. the millivolt scale has been replaced by a scale graduated to read temperature directly in °F when the appropriate cold junction and type of thermocouple wire are used.

The major modification, however, has been made to allow the instrument to be used under low air temperature conditions. The standard cell and the dry batteries are subject to damage or deterioration by freezing and therefore have been removed from the instrument and are carried in a vest worn under normal winter

clothing. They are connected to the potentiometer by a 6-point plug-type fitting which is easily connected and disconnected. In addition, the instrument case has been enlarged somewhat so that the thermos bottle holding the ice bath and a double throw switch are contained with the potentiometer. This results in a more compact unit and the double throw switch simplifies the operation when temperatures above and below the reference junction temperature (32°F) are to be read alternately. The external connections and equipment added are shown schematically in Fig. 2.

A specially fabricated thermocouple cable is used to connect the potentiometer to the switch box. The connector at the potentiometer end of the cable combines the thermocouple reference junction and the double throw switch and potentiometer connections in one unit. To prevent damage to the galvanometer suspension when the instrument is not in use or is being transported provision has been made to "short out" the galvanometer by means of a special connection on the "lamp" switch or on the two screw fasteners at the top of the galvanometer.

NOTE: The sensitivity of the portable precision potentiometer is greatly affected if the external resistance of the thermocouple circuit is greater than about 30 ohms. This factor becomes extremely important if the temperatures to be measured are at or close to the reference junction temperature of 32°F. The external resistance is dependent on the size of wire, increasing with a decrease in wire size, and therefore limits the length of wire which can be used, (e.g. approximately 50 ft of 20-gauge and 200 ft of 16-gauge copper-constantan). The resistance can also be increased by poor switching and connection details. This instrument must be used with care therefore, when installations having long lengths of wire are to be measured.

PROCEDURES FOR MEASURING GROUND TEMPERATURES

Storage

1. The potentiometer itself is not damaged by freezing temperatures. It should be stored and transported at outdoor temperatures to prevent the formation of condensation inside the instrument. If it must be brought indoors for any reason, place it in a plastic bag (well sealed) until the instrument has warmed up to room temperature (approximately 1 hour). These precautions do not apply during the summer.

2. The standard cell in the "battery vest" is easily damaged by freezing. When not in use, store the battery vest in an upright position (hang from a nail or hook) in a sheltered location which is always kept heated. BOTH THE POTENTIOMETER AND THE STANDARD CELL ARE FRAGILE PRECISION INSTRUMENTS, COSTLY AND DIFFICULT TO REPLACE. THEY SHOULD BE HANDLED CAREFULLY.

Preparations at the Office

3. During the winter or when the air temperatures are below freezing, fill the thermos bottle (reference ice bath) one quarter full with clean finely crushed ice, and fill the remaining volume with clean cool water. Check the ice-water mixture periodically (by shaking the thermos bottle) to be sure that it has not frozen solid. Any temperature readings taken with this mixture frozen solid (i.e. not at 32°F are of no value.

During the summer, or when air temperatures are above freezing, fill the thermos bottle three quarters full with clean finely crushed ice and fill the remaining volume with clean cool water. Check the ice-water mixture periodically (by shaking the thermos bottle) to be sure that all of the ice has not melted. Any temperature readings taken with only water in the thermos bottle (i.e. not at 32°F) are of no value.

NOTE: It is extremely important that great care be taken in preparing the ice bath so that it will produce a temperature of exactly 32°F. A deviation of a few tenths of a degree from 32° can affect the temperatures being measured by an equal amount. Even small errors may be serious when temperatures are being used to determine when the ground is frozen.

4. Put on the vest containing the standard cell, two #6 dry batteries and connecting cable, under normal outdoor clothes such as a sweater and parka. The connection cable may be carried in vest pocket or parka pocket, whichever is more convenient. Do not disconnect standard cell or dry battery connections except to replace units. Keep cable connector and plug clean.

Preparations at the Switch Box

5. Place the potentiometer so that it is firm and level close to the switch box.

6. Potentiometer and switch box terminals should be at the same temperature during the observation period. Both should be shielded from the sun's rays during this time.

7. Connect battery vest cable to potentiometer. The female plug connector will only fit in one way - the correct way. Do not force.

8. Connect the cable from the thermos bottle to the terminals on the switch box.

Preparations to the Potentiometer

9. Disconnect the wires which "short out" the galvanometer.

10. Turn on the switch for the potentiometer and also the switch for the lamp under the graduated glass scale.

11. Make "zero" correction to the galvanometer:
    (a) rough correction by bringing pointer on meter to zero by turning knurled knob under pointer.
    (b) final correction by moving the graduated glass scale slightly to either side so that the hairline on the spot of light coincides with the zero position of the graduated glass scale.

12. Standardize potentiometer current.
    (a) hold down button marked "SC" and bring illuminated hairline close to zero by adjustment of knob marked R1.
    (b) make final correction holding down SC button and bring illuminated hairline exactly to zero by adjustment of knob marked R2.
    (c) if this calibration cannot be carried out within the range of R1 and R2, replace the two #6 dry cells in the battery vest.

13. Release button marked SC. It is not used in any measurement but is merely for calibration.

To Take a Temperature Reading

14. Turn rotary switch pointer to first thermocouple point to be measured.

15. With potentiometer reversing switch to right or red position (for readings below 32°F - use red scale) press button marked "emf". Pointer and spot of light should deflect. Bring pointer and then spot of light with hairline to zero by adjustment of potentiometer dial knob. Read temperature directly from dial (using red scale) estimating reading to nearest 0.1°F. If it is not possible to zero the hairline put reversing switch to left or black position (for readings above 32°F - use black scale) and proceed as before using black scale.

16. Repeat step #15 for all switch points. Check

standardization current before each temperature reading as outlined in step #12.

17. After all the readings have been taken, repeat the first few. If the readings vary by more than 0.5°F repeat all the readings until they are consistent.

18. When all readings have been taken, disconnect the lead cable at the switch box.

19. When all readings have been taken, or when the potentiometer is being carried from one point to another, turn off the potentiometer switch and also the lamp switch. "Short" out the galvanometer.

TROUBLE SHOOTING

MALFUNCTIONING OF POTENTIOMETER

A. When "Zeroing" Galvanometer

(1) Lamp burned out - replace with spare bulb carried on frame under galvanometer.
(2) Movement of graduated glass scale restricted by screws holding shield over scale - loosen screws.
(3) Rough adjustment of galvanometer pointer by means of knurled knob not made.
(4) Dead or weak $1\frac{1}{2}$ volt cells in battery vest - replace both dry cells.
(5) Cable connections from battery vest to potentiometer not securely attached to dry cells, standard cell, or to potentiometer thereby not making a complete circuit.
(6) Galvanometer "shorted out" - release. On some instruments the galvanometer is shorted out when the "lamp" switch is off and released when the switch is on. On other instruments the galvanometer is shorted out by connecting two wires at the top of the galvanometer - to release, disconnect these wires.
(7) Potentiometer not level.
(8) Potentiometer not stable - subject to vibration which causes galvanometer needle to swing.

B. When Standardizing Potentiometer Current

(9) Potentiometer switch in "off" position - turn on.

(10) "emf" button not released.
(11) See (1), (4), (5), (6), and (8) above.
(12) Dead or dirty spot on rheostats - turn knob 1 and knob 2 backwards and forwards several times and restandardize instrument.

C. When Taking a Temperature Reading

(13) See (1), (4), (5), (6), (8), and (9) above
(14) Standardizing button (SC) not released.
(15) Potentiometer reversing switch in neutral position or in wrong position (i.e. in "above 32°" position when reading a temperature "below 32°" or vice versa).
(16) Broken wire in switch box lead cable at or in thermos bottle connector or at switch box connector.
(17) "Dead" switch point - that is, no thermocouple is connected to that switch point, or the thermocouple connected to that point has somehow become disconnected or "shorted out". Check this by turning to the next switch point. If a reading is obtained on this one then omit further readings on the "dead" point until it can be repaired.

D. ALWAYS MAKE SURE A PROPER ICE AND WATER MIXTURE IS USED FOR THE REFERENCE JUNCTION SO THAT ITS TEMPERATURE IS EXACTLY 32°F.

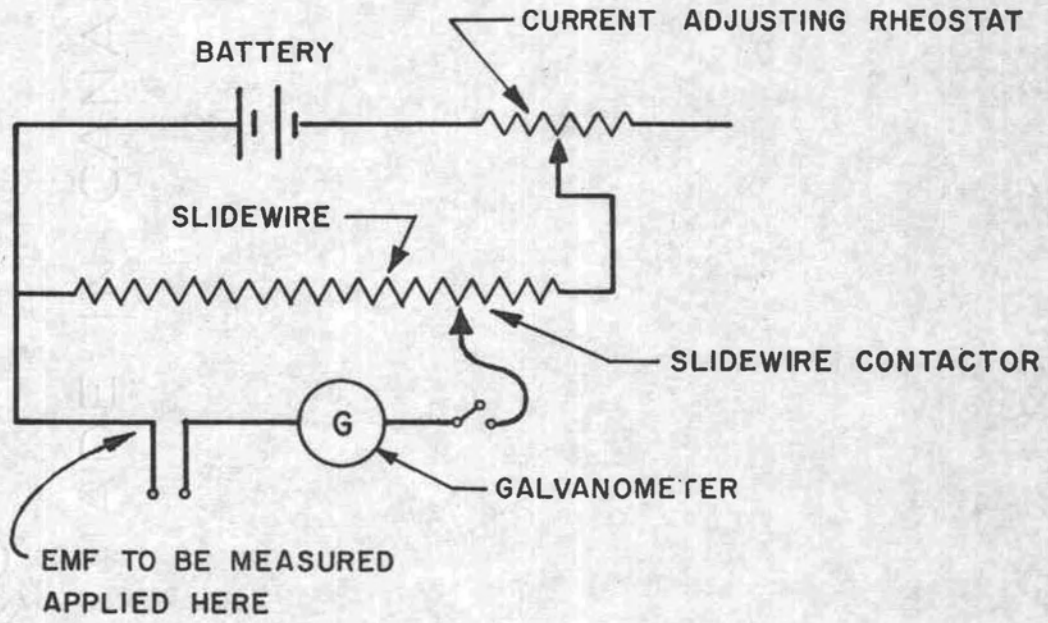

FIGURE 1
BASIC POTENTIOMETER CIRCUIT

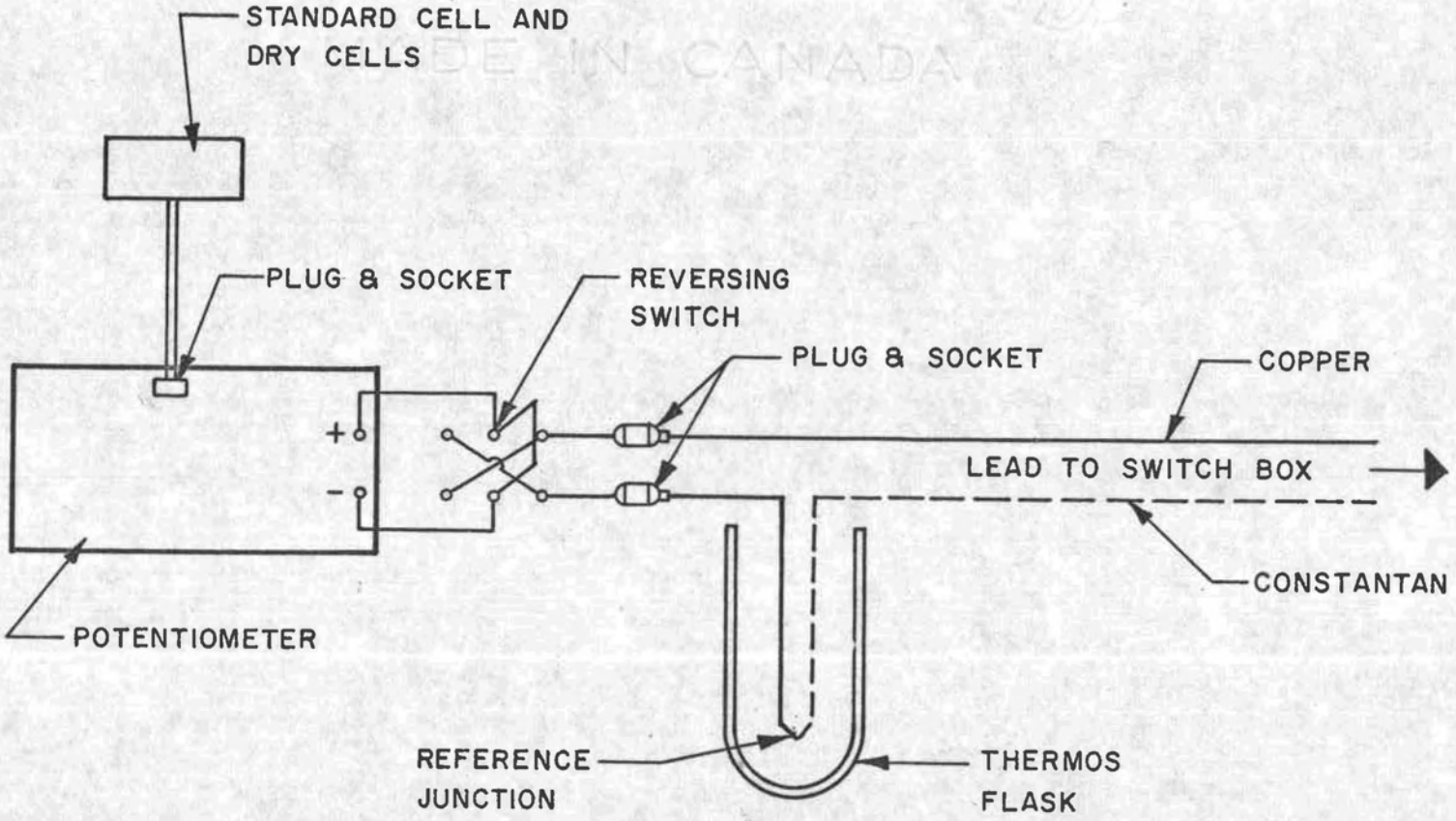

FIGURE 2
EXTERNAL POTENTIOMETER CONNECTIONS & EQUIPMENT