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A temperature difference recorder

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ABSTRACT. A simple and sensitive instrument for continuously recording difference of temperature between any two levels in the free atmosphere in connection with study of exchange processes in the lower atmosphere has been described. It operates over a temperature range of 0-50°C and has a sensitivity of the order of 0·02°C for temperature difference. Bead thermistors of 1·2 mm diameter are used as sensors after linearisation of their characteristics.

1. Introduction

In micrometeorological studies, in connection with boundary layer problems, detailed knowledge of the thermal structure of the lower layers of the atmosphere is required. Upward and downward heat flux can be known if wind data and temperature data are available for particular levels. Standard instruments are available to measure and record fluctuations of temperature at desired levels. From these records, it is however not possible to evaluate the difference of temperature between any two levels with sufficient degree of accuracy. It was, therefore, proposed to develop an instrument for measuring and recording the difference of temperature between two levels so that a continuous record of a temperature difference profile is obtained.

2. Principle of operation

The instrument is basically a Wheatstone bridge circuit as shown in Fig 1. R_3 and R_4 are two fixed resistances of the bridge and two thermistors Th_1 and Th_2, form other two resistances of the bridge. Two potentiometers R_1 and R_2 are connected in series with thermistors for balancing purpose. Zener controlled 15 V d.c. supply is used for the bridge. A switch S_2 is provided for selecting two different sensitivities. In position 1 (unit I) it provides a higher sensitivity whereas in position 2 (unit II) lower sensitivity is obtained by changing the resistances of arms. As the resistances of the two thermistors are equal when they are kept at same levels the bridge is balanced and the output is zero. If thermistors are kept at different levels having different temperature, an unbalanced voltage output is obtained depending upon the temperature difference. The null point of the bridge can be checked by inserting thermistor equivalent resistance of 3·9 K ohms by a switch S_1.

The out-of-unbalance voltage from the bridge is amplified by an operational amplifier (type 141-B FET; Analogue Devices). This amplifier needs two supplies of $\pm$ 15 V and has an open loop gain of 8×10^4. The desired gain is obtained by adjusting the feed-back resistances of either 470 K ohms or 270 K ohms by means of a switch S_3. 470 K resistance gives higher gain, called without attenuation whereas 270 K provides a gain called with attenuation reduced by a factor of about 1 : 0·5. The output of the operational amplifier is then fed to a 0-1 mA strip chart recorder. The switch S_2 in position 1 provides an output of 0·5 mA from centre zero of the recorder for a difference of 1°C in temperature; maximum temperature difference of 2·0°C can, therefore, be recorded in this position. The position 2 of the switch furnishes an output of 0·5 mA for a difference of 11·5°C and maximum temperature difference of 23°C can be recorded in this position.

3. Sensor

Small bead thermistors are used as temperature sensors having a mean diameter of 1·2 mm, dissipation constant of 0·1 mw/°C, and time constant of about 2 seconds. The thermistor is a nonlinear device which has negative temperature coefficient obeying an approximate relation of the type,

$$R = e^{B/T} \tag{1}$$

where, R — resistance of the thermistor,
B — a constant and
T — temperature in °C.

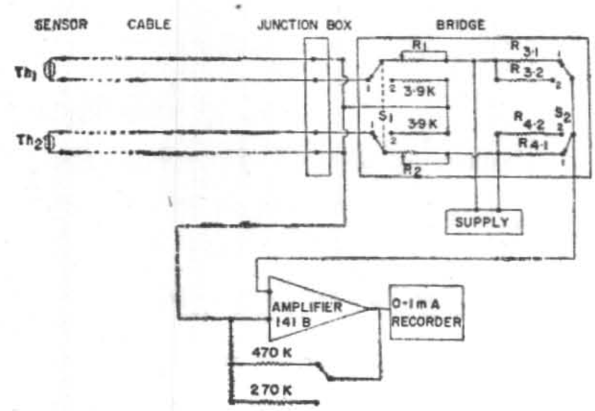

Fig. 1

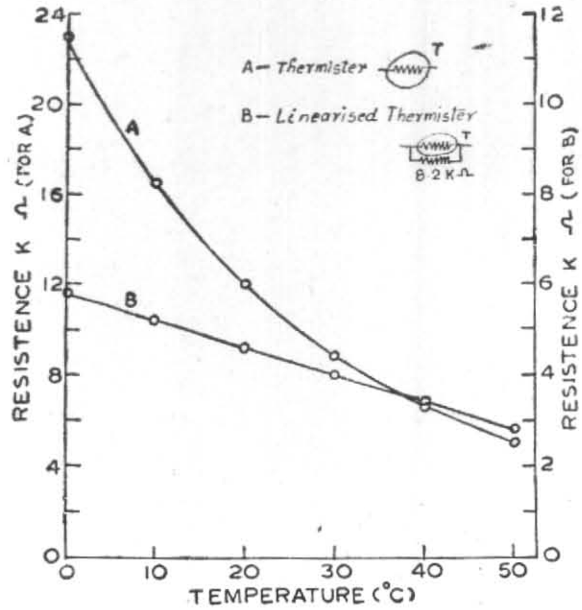

Fig. 2

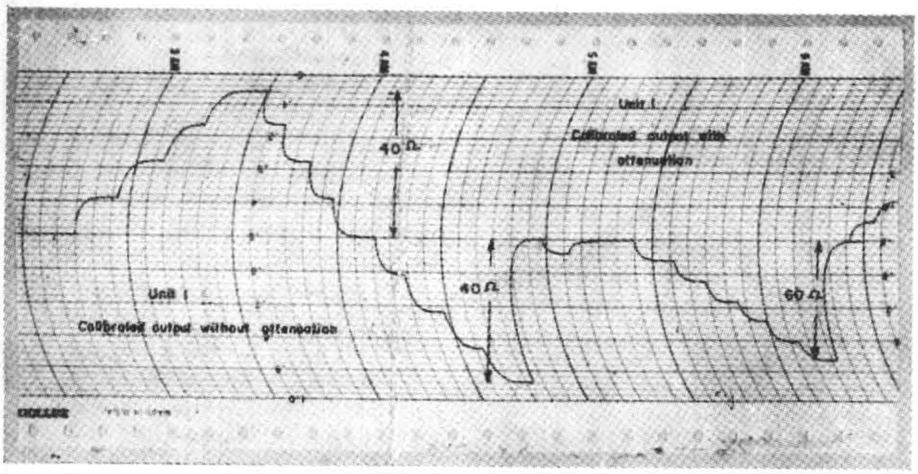

Fig. 3

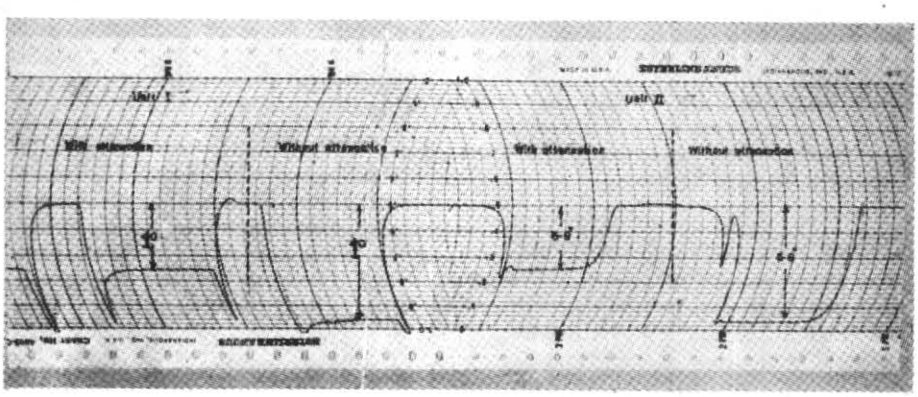

Fig. 4

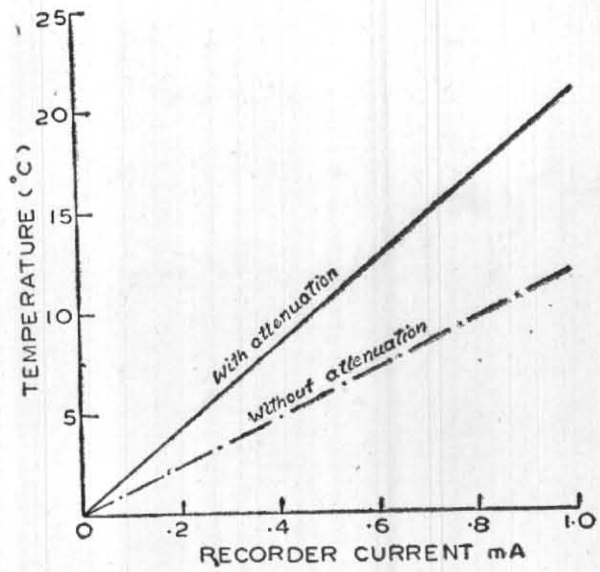

Fig. 5

As the above relation is exponential it is necessary to linearise the temperature resistance characteristic of the thermistor for this instrument. The resistance temperature relation of any thermistor can be linearised by connecting fixed resistance in parallel (Nordon and Bainbridge, 1962). This resistance should have a value equal to that of the thermistor corresponding to the mid point of temperature range over which linearity is required. If the relation for the temperature dependance of a parallel combination of thermistor and a resistor is expanded in Taylor's series and the terms involving second differential coefficients equated to zero, one obtains the value of the shunt resistance as —

$$r = R_T \frac{(B-2T)}{(B+2T)} \qquad (2)$$

where, T is the temperature of the middle point of the range considered. In this instrument, as the total temperature range was taken to be 0–50°C, T would be 25°C and R_T would be the resistance of the thermistor at this temperature. From a series of experiments the average value of B was found to be 2792 for the bead thermistors used. The calculated value of shunt resistance is found to be 8·1 K ohms. A metal film resistance of 8·1 K with ±50 PPM/°C temperature coefficient was used as a parallel resistance. A number of thermistors were selected from a lot having very nearly the same characteristics which were linearised with 8·1 K ohms as shunt resistance giving the same linear curve for each. Fig. 2 shows the linearised relation along with the original thermistor temperature resistance characteristic. An uniform variation of 42Ω/°C obtained within the operating temperature range. The scale of the recorder can be calibrated using this relation.

4. Calibration

To check the similarity of response on either side of centre zero of the recorder, known values of resistances were connected in place of thermistors alternately. The record obtained is shown in Fig. 3. The output may be seen to be linear and symmetrical. For calibration, the thermistors were next immersed in two mineral oil baths of fixed but different temperature. The temperatures of the baths were measured by thermocouples with an accuracy of 0·02°C. Fig. 4 shows the calibration record in terms of temperature difference with two different gain settings of the amplifier. Fig. 5 shows output of unit II (settings out-put calibrated for temperature difference in terms of recorder current).

The following table shows different sensitivities obtained from the instrument —

	Unit I		Unit II	
	without attenuation (°C)	with attenuation (°C)	without attenuation (°C)	with attenuation (°C)
Full Scale	2	4	12	23
Half Scale	±1	±2	±6	±11·5
Sensitivity	0·02	0·4	·12	·23

The overall accuracy of the instrument is estimated to one per cent.

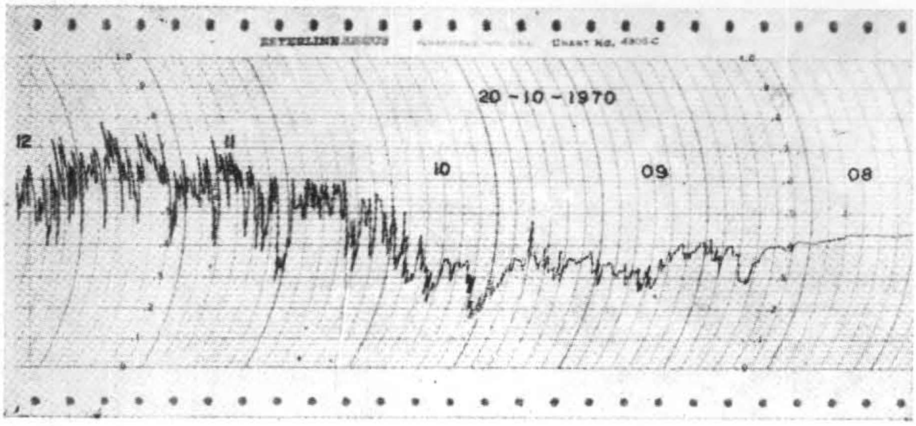

Fig. 6 (a)

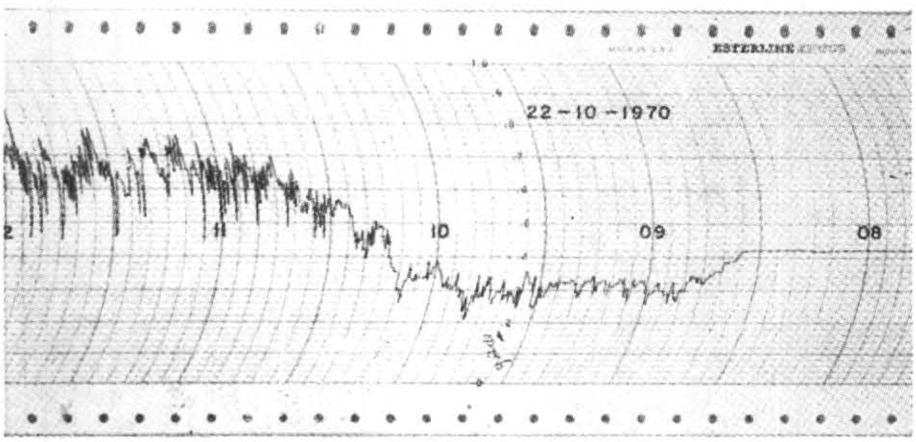

Fig. 6 (b)

Fig. 6 shows the sample records obtained with unit II with attenuation. These records were obtained by exposing thermistors on a tower with 8 metre distance between them, one of them being kept near the ground. It was observed that the temperature fluctuations start at about 8·30 P. M. and continue up to 5 P. M. During night there are no fluctuations.

5. Use

The instrument can be used for measuring temperature difference between two levels in the free atmosphere. With modification it can be used also as a recording psychrometer. Use as net radiometer and soil temperature difference recorder are other possibilities which are being explored. It can be utilized for measuring Bowen's ratio also.

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