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A platinum resistance thermometer system designed for microclimatic measurements

R. R. KELKAR and V. R. CHIVATE

Meteorological Office, Poona

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ABSTRACT. A platinum resistance thermometer system designed for continuous measurement of air temperature at two levels above ground is described. The resistance sensors are housed in aspirated radiation shields.

The system has high sensitivity and is able to record rapid fluctuations of air temperature not measurable by a conventional thermograph. Case studies of the diurnal temperature variation at 0·5 and 1·5 m above ground on clear and overcast days are presented.

1. Introduction

The measurement of temperature in an air layer just above the ground presents problems as the sensor needs to be shielded from radiation effects and, at the same time, has to be well-ventilated. The Assmann Psychrometer is a simple and compact instrument which satisfies both these requirements and is widely used in agro-meteorological observatories in India for spot measurements of temperature and humidity in crop environments. In recent years, the need to develop sophisticated methods for accurate and continuous recording of microclimatic temperatures has been increasingly felt. A direct application is in the estimation of evapotranspiration by indirect methods such as the aerodynamic profile approach (Gangopadhyaya *et al.* 1966). Electrical techniques for temperature measurement, besides being more sensitive compared to other methods, have an added advantage in that they allow for the remote location of sensors. Recent technological advances in platinum resistance thermometry have made it possible to use this technique for precision micrometeorological work (*e.g.*, Arai *et al.* 1973). Platinum resistance thermometers are superior to other electrical transducers in many respects, particularly in their high stability of calibration and reproducibility of measurement.

A platinum resistance thermometer system designed for continuous measurement of air temperature at more than one level above the ground surface is described in this paper. Initial results obtained with the system have been discussed.

2. Basic theory

A resistance thermometer consists of a metallic element whose resistance increases with a rise in the ambient temperature. Considering the resistance-temperature relationship to be linear within a narrow temperature range, the resistance at temperature t in that range is given by

$$R_t = R_0\,(1 + \alpha \triangle t) \qquad (1)$$

where R_0 is the resistance of the element at a reference temperature t_0 and $\triangle t = t - t_0$. The value of the coefficient α can be determined by measurement of resistance R_1, R_2 at two different temperatures t_1, t_2 respectively :

$$\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1} \qquad (2)$$

For temperatures above 0°C, the relationship between resistance and temperature can be expressed as

$$t = 100\,\frac{R_t - R_0}{R_{100} - R_0} + \delta \left(\frac{t}{100} - 1\right) \frac{t}{100} \qquad (3)$$

where R_t, R_0 and R_{100} are the resistance values at temperatures t, 0 and 100 (°C) respectively; $\alpha \simeq 0.00392$ and $\delta \simeq 1.49$ (Riddle *et al.* 1973). The second term of Eq. (3) is a correction introduced to compensate for the non-linear variation of resistance over a large temperature range. It, however, becomes insignificant (0.0015°C) in the range 0-60°C.

3. Practical details

3.1. *Construction of sensor* — A high degree of

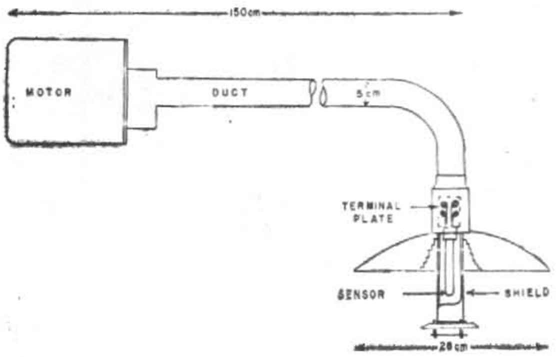

Fig. 1. Construction of aspirated radiation shield for platinum resistance sensor

reproducibility of the platinum resistance thermometer (PRT) calibration can be achieved only if the resistance coil can freely expand and contract with changes in temperature. This is relatively easy when the physical dimensions of the sensor are not of consequence. However, when a small sized bulb is desired, special design considerations have to be applied to make the resistance winding strain-free (Barber 1950). In the present work, spectrally pure platinum wire of 99.999 per cent purity having diameter 0.03 mm was coiled round a mica-cross framework in a bifilar manner to minimise induced e.m.f. effects. About 76 cm length of wire was required to obtain a resistance specification conforming to the BS 1904 standard, *viz.*, $R_0 =$ 1000 ohms, $R_{50} = 119.4$ ohms and $\alpha \simeq 0.00392$. The sensor wound on a mica-cross (Meyer's design) had a length of 5 cm and was enclosed in a thin stainless steel sheath of 6.5 mm outer diameter to prevent moisture deposition on the sensor. Gold leads, passing through a short stainless steel tube stem and ending on a terminal plate, were used to reduce lead resistance. Short leads of thicker platinum were used to connect the sensor to the gold leads. In view of the short stem of the thermometer, the values of R_0 and α measured experimentally were liable to be slightly different from those aimed at, depending upon the characteristics of the platinum wire used. A small compensating correction had, therefore, to be applied to the recorder calibration. The National Physical Laboratory, New Delhi, fabricated two sensors of the above design.

3.2. *Radiation shield* — Two aspirated radiation shields (Beckmann and Whitley) were used for setting up the platinum resistance sensors in the field. The construction of the shield is shown in Fig. 1. The sensor is housed in a vertical cylindrical enclosure made of thin stainless steel surrounded by another co-axial cylindrical shield of aluminium. Since the two materials have different absorption characteristics, re-radiation to the sensing element is significantly reduced. A third shield in the shape of a flattened dome further cuts down the heating effects of incident solar radiation. The sensor is supported by a terminal plate fixed in the upper neck of the shield assembly. Aspirated air flows at the rate of 3 m/sec between the walls of the shielding cylinders and over the sensing element. The aspirator consists of a small blower driven by a synchronous motor. The entire shield is mounted over a suitable support by means of U-bolts clamped around the duct assembly.

3.3. *Recorder* — The platinum resistance thermometers were connected to a six-channel point printing recorder (Cambridge Clearspan; P. 180). This recorder employs a d.c. resistance bridge circuit to measure the change in the resistance of the sensor. A transistorised amplifier detects any circuit imbalance and automatically brings the system to null position by directing the slide wire contact through a servo-motor. The recorder calibration corresponds to the BS 1904 standard specification and the temperature is directly readable in the 0-60°C range with an accuracy of 0.1°C.

4. Results and discussion

4.1. *Comparison with thermograph* — One PRT was initially installed near a Stevenson screen (1.2 m height) at the Central Agricultural Meteorological Observatory, Poona. A conventional thermograph with bimetallic element was placed within the Stevenson screen. Continuous records of temperature were obtained with both the instruments with a view to comparing their response under indentical environmental conditions. Fig. 2 shows the PRT temperature record for a day in February 1973 and also the thermogram for the same period. The two temperature curves show an almost identical diurnal trend and particularly during daytime the absolute values of temperature recorded by the two instruments agree very closely. However, the PRT record reveals a close succession of rapid and large temperature changes which are not reflected in the thermogram. These changes are very strongly evident during the night hours, some of them being of the order of ±3°C within an interval of a few minutes.

One reason for this apparent dissimilarity between the two temperature measurements could be that the thermograph being a mechanical device is unable to react to a steep rise or fall of temperature occurring in a very brief duration. Whereas, the PRT which operates on the principle of change in electrical resistance with temperature, may be expected to have high-sensitivity and high-fidelity response.

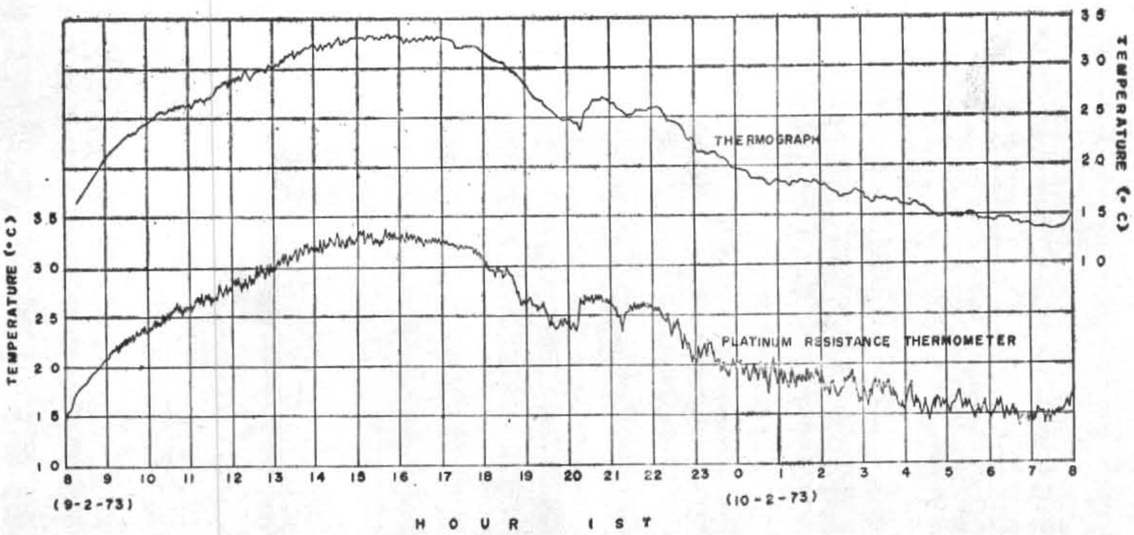

Fig. 2. Comparison of simultaneous temperature records made by the thermograph and platinum resistance thermometer at Stevenson screen level

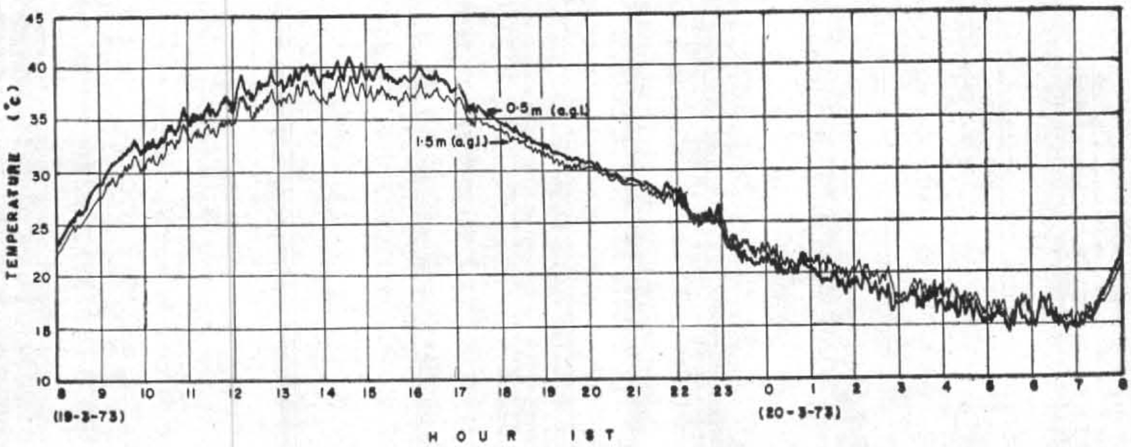

Fig. 3. Diurnal temperature variation on a clear day at 0·5 and 1·5 m above ground as recorded by two platinum resistance thermometers

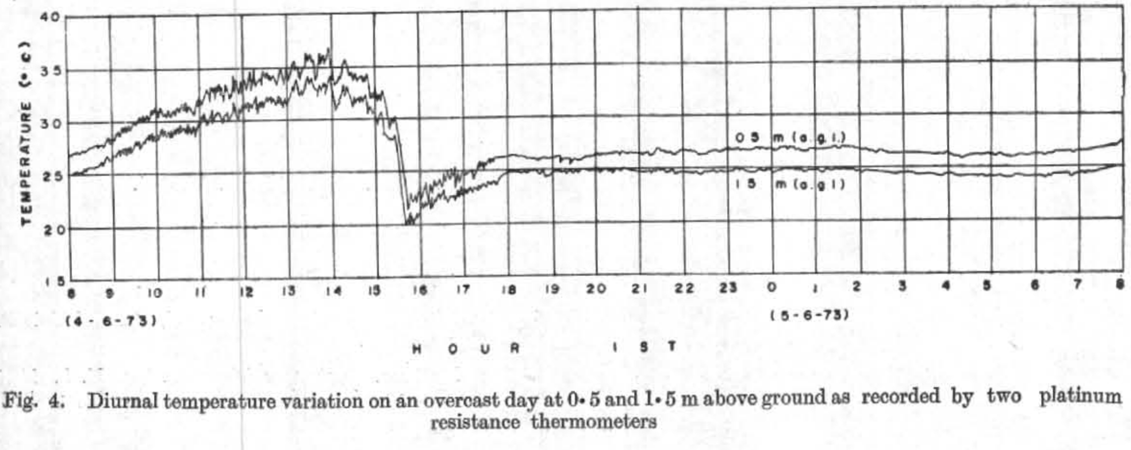

Fig. 4. Diurnal temperature variation on an overcast day at 0·5 and 1·5 m above ground as recorded by two platinum resistance thermometers

Another plausible explanation is that the thermograph was enclosed in a Stevenson screen while the PRT sensor was subjected to a current of air continually blown across it. In order to study the effect of aspiration, test measurements were made with the aspirator motor of the PRT assembly shut down. The zigzag nature of the temperature curve was found to persist even in the absence of aspiration, although to a lesser extent.

The nature and magnitude of the temperature perturbations recorded by the PRT varied from day to day, suggesting again that such variations actually occurred in the atmosphere.

The temperature perturbations of the type recorded by PRT have been observed by other workers also. Geiger (1965) has termed this effect as 'temperature instability' and has given several instances of such instability being noticed in the air layer close to the ground when highly sensitive measuring devices were used. He has explained it primarily as the effect of eddy diffusion and has shown that perturbations of this nature take place in the water vapour content also.

4.2. *Microclimatic observations* — After the preliminary experiments to compare the PRT and the thermograph, the two PRT sensors were set up in aspirated radiation shields one above the other at heights of 0.5 and 1.5 m above the ground. Simultaneous continuous recording of temperature at these two levels was in progress during the months of March to June 1973. Figs. 3 and 4 show the temperature records made on two typical occasions, one in March characterised by a clear sky and the other in early June with near overcast sky.

On the day chosen for clear sky (Fig. 3), the 0.5 m level temperature is seen to be consistently higher than the 1.5 m level temperature from 0800 to 2200 hours. The difference is highest, 2.5°C, around the time of occurrence of maximum temperature. After 2300 hours the trend is reversed, the 0·5 m level now being colder than the 1.5 m level by upto 2°C. After the minimum temperature epoch, the two curves again intersect and the diurnal cycle is completed.

Fig. 4 depicts the temperature variation on a day marked by a persistent cloud cover of 6-8 octas. There was also a pre-monsoon thundershower in the afternoon, followed by a squall. In contrast to Fig.3, the 0.5 m and 1.5 m level temperature curves run almost parallel to each other throughout the 24-hour period considered. The 0.5 m level remains warmer by 2 to 2.5°C during the day as well as night. Both the levels register a drop of 8°C at the commencement of the thundershower at 1530 hours.

5. Concluding remarks

(*i*) The PRT system described in this paper is sensitive enough to record rapid fluctuations in air temperature not measurable by conventional means.

(*ii*) Initial results obtained with the two-level PRT system suggest that the system can be used to quantify the microclimatic features known in a general qualitative sense.

(*iii*) It is proposed to set up the PRTs over cropped fields to study the temperature variations in crop environments.

(*iv*) The PRT system described herein readily gives the temperature to an accuracy of 0.1°C. The authors are working on a temperature-difference measurement system to improve the attainable accuracy.

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