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A dew point Hygrometer with thermo-electric cooling

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ABSTRACT. A dew point hygrometer which uses photo-electric detection and thermo-electric cooling is described. The instrument is especially useful in measuring very small values of moisture contained in the air at low temperatures and high altitudes, for which normal types of hygrometers are not quite suitable.

1. Introduction

The dew point hygrometer has marked advantages in practice over the common types of hygrometers in that it does not suffer from any defects such as large time lag, temperature dependence and hysteresis and is capable of measuring very small values of moisture contained in the air at low temperatures and high altitudes. Further, it gives direct measurements unlike other instruments, where the measurements are relative, requiring frequent comparison with reference to standard instruments.

Of the earlier investigators mention may be made of Thornthwaite and Owen (1940) who designed a dew point hygrometer making use of a photo-electric cell to detect the formation of dew. Using the same principles Barret and his collaborators (1951) constructed an electronic dew point hygrometer which was later modified and adopted for use in radiosondes (Suomi and Barret, 1952). More recently, balloon borne dew point hygrometers have been developed in U.S.A. (Mastenbrook and Dinger, 1961) and in Japan (Kobayashi and Toyama, 1962). All these instruments had limitations arising from the use of refrigerating liquids, gases and other cooling equipment.

2. Details of construction

The inconveniences present in these instruments have been overcome in the instrument described below by utilizing thermo-electric cooling and dispensing with the use of refrigerants. The thermo-electric cooling module used was developed at the Atomic Energy Establishment, Trombay using bismuth telluride.

Fig. 1 shows the photograph of the dew point hygrometer with its top cover removed, showing the various components of which (1) is the thermo-electric module type TM-78. It works on direct current of 10 to 20 amperes with an input voltage of 0·5 to 1 volt. When this current is applied to the module, it causes heat to be pumped from one face to the other, thus making one face of the module cooler and the other hotter. A finned aluminium block (2) is firmly fixed to the hot side of the module to serve as a heat sink and also as a mount for the module. To the cold face of the module is bonded a metallic mirror (3), made of copper sheet 3 mm thick and of diameter 20 mm, with its exposed face silvered and polished to receive the condensate.

It is essential to have perfect thermal contact between the faces of the module and those of the heat sink and the metallic mirror on either side. This has been accomplished by making all the contacting faces extremely flat and coating them with a thin layer of thermally conducting silicon grease before fixing them. Screws made of fibre material have been used for fixing, so as to prevent the conduction of heat from one side to the other. Similarly, strips of thermally non-conducting material have been used fixing the heat sink on to the instrument case.

A small hole is drilled at the top of the mirror into which a bead thermistor (4) is inserted for measuring the temperature of the mirror. The thermistor is connected through a bridge circuit to the micro-ammeter (5) and is calibrated to indicate temperatures from +40° to −40°C. A potentiometer (6) has also been introduced in the bridge circuit to correct for changes in the battery voltage.

The light source is seen at (7). It is a 3-volt torch bulb working on dry cells. The light focussing arrangement has been made simple by eliminating the use of condensing lenses and using only a torch light reflector. The light from this source, when switched on, falls on the mirror (3) and is reflected on to the photo-transistor (8) which has been fixed about an inch below the light source and on the same stand. The photo-transistor is connected through an electronic amplifying circuit to the micro-ammeter (9) where the photo-electric current is indicated. (10), (11), (12) and (13) are the switches for closing the various electric circuits, (10) and

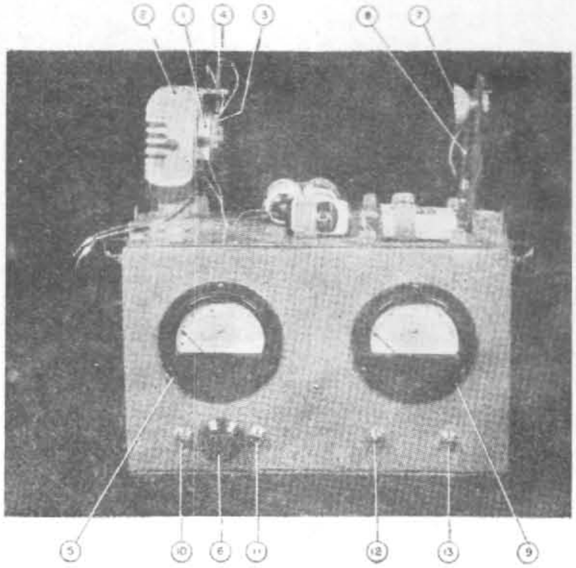

Fig. 1. Dew point Hygrometer (co ver removed)

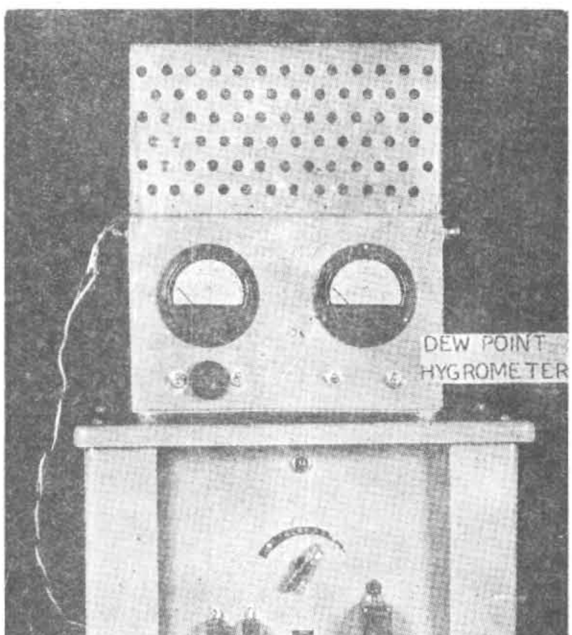

Fig. 2. Dew point Hygrometer with rectifier unit

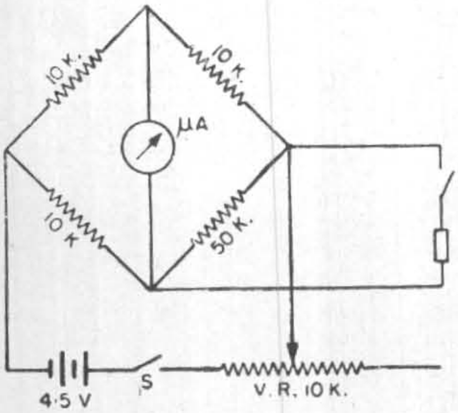

Fig. 3. Thermostat circuit

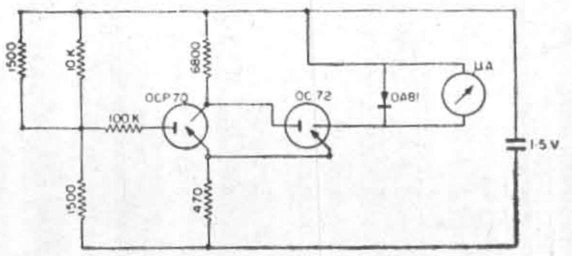

Fig. 4. Photo transistor circuits

(11) being used in the thermistor circuit, (12) in the light source circuit and (13) in the photo-transistor circuit.

The dry battery cells used in the different circuits are seen clamped on the case of the instrument. These require replacement only once in six months or a year depending on use.

The current for exciting the thermo-electric module is taken from an accumulator. A 6 volt car battery with arrangement for tapping 2 volts at a time and with a small resistance in the circuit, has been found to be very convenient for use in field observations. The battery requires recharging only about once a month when hourly observations are taken. For use in the laboratory, where mains supply is available, rectifier unit may be used, as this is more economical and convenient to use (Fig. 2). The rectifier unit gives about one volt d.c. and the current can be adjusted over a range of 10 to 20 amperes by means of a regulator.

The circuit diagram for the thermistor and the photo-transistor are shown in Figs. 3 and 4 respectively.

The instrument weighs 16 kg and measures $40\times33\times15$ cm. The rectifier unit weighs 17 kg and measures $38\times45\times31$ cm.

3. Method of operating

The instrument is simple to operate. First the thermistor bridge circuit is closed by moving the switch (10) to 'on' position. The micro-ammeter (5) now shows the initial set reading of 100 μA. If this reading is slightly out, it is corrected by means of the potentiometer (6). Then, the thermistor is brought into circuit by putting 'on' the switch (11) and the reading of the micro-ammeter (5) noted. This corresponds to the temperature of the ambient air which can be read off from the calibration graph. After this, the photo-electric circuit and the light circuit are switched on and the photo current noted in the indicator (9). Now direct current of the proper voltage and polarity is applied to the thermo-electric module from an accumulator or the rectifier unit. Immediately, the temperature of the mirror begins to fall as seen by the movement of the pointer in the temperature indicator (5). When the temperature of the mirror approaches the dew point temperature of its ambient air, dew begins to form on its surface and this causes the scattering of the beam of light falling on it. Therefore, the diffusion of the reflected beam caused by the dew leads to a decrease in the photo-electric current and the pointer in the indicator (9) begins moving down. At this moment, the reading of the micro-ammeter (5) is noted. This corresponds to the dew point temperature. Generally, the mean of the two temperatures, at which the dew just appears and that at which it just disappears, is taken as the dew point. The temperature at which the dew just disappears is obtained by switching off the current to the thermo-electric module and noting the reading of the ammeter (5) when the pointer in the photo-current indicator (9) just comes back to its original position.

4. Characteristics and measuring accuracy

It takes from 1 to 2 minutes for the mirror to cool down to the dew point. The thermo-electric module can lower the temperature of the mirror by about 30° to 35°C below the ambient temperature and this cooling range is quite sufficient for the determination of dew point under normal conditions. According to the data sheet supplied with the thermo-electric module, type TM-78, it is capable of cooling down by more than 60° C, provided a water bath heat exchanger is used with the hot face and its temperature is kept below 32°C.

The values of the dew point obtained with the instrument were compared with those calculated from the readings of a ventilated psychrometer under ordinary conditions. These values agreed to within $\pm 0 \cdot 5$°C and the calculated humidity values agreed to within $\pm$ 2 per cent.

Manual operation was decided upon for the instrument to make it simple and inexpensive and at the same time obtain accurate readings from it.

5. Acknowledgement

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