Development of the Remote-Reading and -Recording Thermometer with Sealed Carbon Filament

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Abstract

Improvements of the remote-reading and -recording thermometer with sealed carbon filament are described. As its application, a portable remote temperature indicator, a remote sea-depth and -temperature indicator and an automatic temperature regulator are reported.

1. Introduction

The present remote-reading and -recording thermometer is constructed from a solid mercury-in-glass thermometer, within the capillary of which two platinum terminals are fused and a fine carbon filament of high electric resistance is suspended between them (Fig. 1). As the ambient temperature changes, the mercury column rises or falls and a short-circuit is caused for the portion of the carbon filament immersed in the mercury. The measurement of temperature is thus effected directly or remotely by that of the electric resistance of the carbon filament.

The merits of the present thermometer compared with ordinary electric-resistance types (metal or thermistor) consist in its larger change of resistance in proportion to the original value, enabling the use of a less sensitive meter or recorder, and also in its lower price and easier production. The workmanship errors of the thermometer capillary and the carbon filament are standardized by inserting a series \( R_s \) in Fig. 2.

Fig. 1. Thermometer with sealed carbon filament.
and a parallel-resistor ($R_p$ in Fig. 2) into the measuring circuit which adjust the shift and slope of the temperature-resistance curve of the complete thermometer. The thermometer is then interchangeable for a given indicator or recorder. The indicator and recorder convenient for use are of the cross-coiled type, and also electronic recorders may be utilized if more power and linear scale are demanded.

All these features except the electronic recorder are already reported [1]. In the present paper the improvements and applications thenceforth will be briefly described in compliance to the frequent inquiries addressed to the writer.

2. Improvements of the thermometer design

Earlier models employed a comparatively thick (0.16 mm in diameter) carbon filament within a small capillary of ca. 0.30 mm in diameter. The narrow clearance between the filament and the capillary wall caused the following troubles:

1) The position of the mercury column is changed by slight shocks.
2) Rising and falling temperature cause different indications.
3) Mercury column is separated at times.
4) Indications are in certain conditions stepwise. A larger capillary of 0.35 mm in diameter, on the contrary, caused other troubles as follows:
5) Lag of thermometer becomes large owing to its large bulb.
6) Mercury flows back when the thermometer is inverted.

For these reasons a fine carbon filament of ca. 0.05 mm is now sealed within a capillary of about 0.2 mm in diameter. Further, nitrogen gas of 1 atm pressure is introduced within the capillary to prevent the mercury back flow. By these improvements all the above-mentioned troubles are perfectly eliminated at present.

3. Portable remote temperature indicator

The indicator employs four improved thermometers and thus remote measuring of temperatures at four locations is easily and comfortably carried out. The principle is given in Fig. 2, and the equipment is illustrated in Fig. 3.

The specifications are as follows:

1) Selector switch:
   Four points.
2) Measuring range:
   $-10.5^\circ\sim+38.5^\circ$C.
3) Divisions of scale:
   A common scale with sub-divisions, $-10.5^\circ\sim+6.5^\circ$C, $+5.5^\circ\sim+22.5^\circ$C and $+21.5^\circ\sim+38.5^\circ$C.

Fig. 2. Portable remote temperature indicator.
(Circuit diagram)
4. Remote sea-depth and -temperature indicator

A protected and a non-protected thermometer with sealed carbon filament are coupled with the portable remote temperature indicator mentioned above. The sea depth is given by the difference of the indications of the two thermometers, while the protected one gives the sea temperature. The equipment is illustrated in Fig. 4. The specifications are as follows:

1) Selector switch: Two points for the protected and the non-protected thermometer.
2) Measuring range: $-0.5^\circ \text{C} \sim +30.5^\circ \text{C}$. 

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Fig. 3. Portable remote temperature indicator.

Fig. 4. Remote sea-depth and -temperature indicator.
3) Divisions of scale: A common scale with sub-divisions, \(-0.5^\circ \sim +10.5^\circ\), \(+9.5^\circ \sim +20.5^\circ\) and \(+19.5^\circ \sim +30.5^\circ\).
4) Minimum reading of scale: same as Section 3.
5) Resistance change for temperature: \(30\Omega/^\circ\text{C}\).
6) Measuring distance: same as Section 3.
7) Accuracy: Within \(\pm 0.05^\circ\text{C}\) maximum under the lead influence.
8) Probable error and 9) Electric source: same as Section 3.
10) Pressure coefficient of the non-protected thermometer: \(0.364^\circ\text{C}/\text{atm}\).
11) Accuracy of sea-depth measurement: ca. \(\pm 1\text{ m}\).
12) Range of sea-depth measurement: \(0 \sim 300\text{ m}\).
13) Size: \(10 \times 20 \times 20\text{ cm}\).
14) Weight: \(3\text{ kg}\).

The indicator was tested in September, 1952 on the Tokyo Bay [2]. The results were satisfactory except for the difficulty of indicator reading on a rough sea owing to the oscillation of the indicator pointer. This difficulty will probably be remedied by the use of an electronic recorder.

5. Automatic temperature regulator

A handy and extremely sensitive automatic temperature regulator is devised, employing the present thermometer. The principle and the actual set are illustrated in Figs. 5 and 6. The thermometer with sealed carbon flament is placed in one of the branches of the electric bridge with A.C. As the thermometer temperature, i.e. its electric resistance deviates from that set by the variable resistance, the balance of the bridge is interrupted. The phase of the A.C. voltage in unbalanced state is reversed according as the temperature change is higher or lower than the balanced value. The unbalanced A.C. voltage is amplified and applied to the grid of a Thyatron. If an A.C. voltage of the same phase as that of the bridge A.C. is applied to the plate of the Thyatron, a current is passed and actuates the relay, only when the amplified signal and the plate A.C. are in phase. The relay opens or shuts the heater circuit until
the balance of the bridge is again restored.

The function of the regulator is as follows:

1) Range of regulation: $-26^\circ C \sim +66^\circ C$.
2) Accuracy of regulation: $\pm 0.02^\circ C$.
3) Sensitivity of regulation: Within $\pm 0.01^\circ C$, the thermometer and the heater lags are not included.

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References
