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Radiation and Lag Errors of the Chronometric type Radiosonde

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ABSTRACT. The radiation and lag errors of the temperature element of the C-type radiosonde were determined in the laboratory using a wind tunnel constructed for this purpose. The experimental arrangement and the results obtained are briefly discussed in this paper.

1. Introduction

It was found during the International Comparison of Radiosondes at Payerne in June 1956, that the temperatures recorded by the Chronometric type radiosonde were higher by 8° to 10° C at 20-km level and above, in comparison to the U.S.A. or West German instruments. It therefore, became necessary to determine the error attributable to the radiation shield used and also to find out the extent to which the error could be minimized by improving the shield.

The shield used for the C-type radiosonde at Payerne is shown in Fig. 1. This shield while effectively checking the solar radiations falling on the element directly, was itself heated appreciably by the absorption of solar radiation, which in turn heated the air passing through the narrow duct. Besides this, multiple reflections from the walls of the shield contributed to the rise in temperature of the element. The design of the shield was therefore altered to minimize these defects and the final form is shown in Fig. 2. The inner sides of the outer shield are blackened to a distance of 8·5 cm from the top with lamp black to absorb radiation falling on them and avoid multiple reflections. The distance between the inner and the outer walls has also been increased to remove the excess heat from the blackened surface.

2. Experimental details

These experiments are based on the "Theory of heat transfer by forced convection" developed by Scrase (1954). The factors affecting radiation erro.s have been dealt at great length by him. In simulating in laboratory the atmospheric conditions to which a radiosonde is subjected during its flight, there are obvious limitations. The various assumptions involving measurement of low wind speeds, intensity of radiation etc inside an experimental wind tunnel have been discussed by Hayashi *et al.* (1956). The laboratory set up for the investigations presented here is similar to their arrangement. A wind tunnel 10 ft long and 4 sq. ft in cross-section was constructed for this purpose (Fig. 3). With a powerful 3-phase exhaust fan and a set of variacs, steady wind flow in the range of 6 mps to 0·4 mps could be obtained, which corresponds to a ventilation from the ground level to a height of nearly 50-mb level. The wind velocity was measured by means of a sensitive air meter and checked with the help of a pitot tube. The radiosonde was mounted in the middle of the tunnel. A 500 watt condencing unit with a good reflector was employed as a source of radiation. The intensity of radiation was measured with the help of a sensitive Angstrom Pyrheliometer. The value of the intensity of radiation for a particular angle of incidence was multiplied by a suitable factor so as to correspond to solar radiation intensity. Individual readings of temperature increments were multiplied by the factor

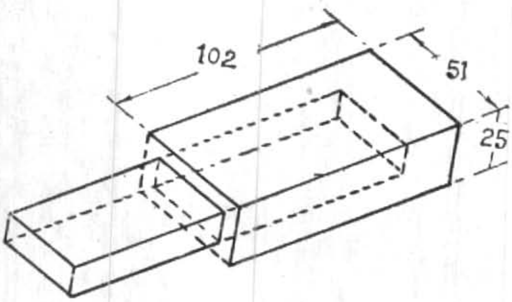

Fig. 1. Shield used in Payerne
All dimensions are in mm

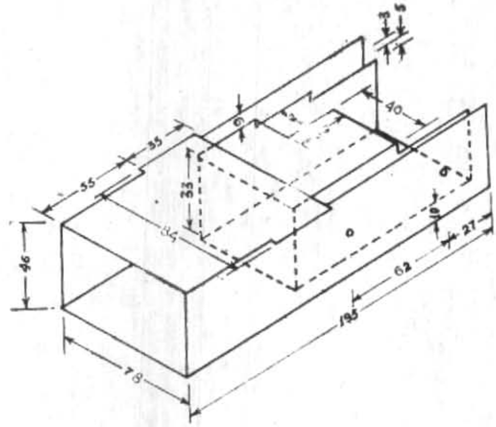

Fig. 2. Modified radiation shield
Dimensions in mm

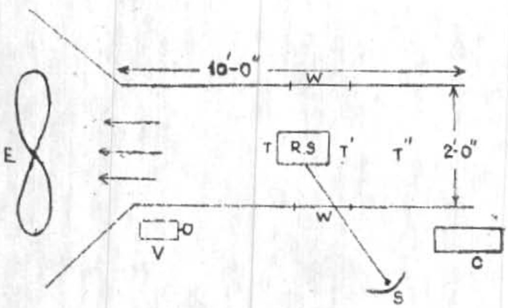

Fig. 3. Wind Tunnel

T T' T"	Thermocouple
W	Windows (Transparent)
S	Source of Radiation
R.S.	Radiosonde with Shield
C	Chronographic Recorder
V	Set of variacs
E	Exhaust fan

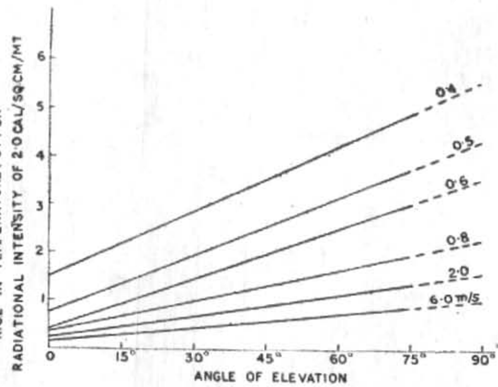

Fig. 4. Relationship between the angle of elevation and temperature rise

thus obtained for that particular set of observation. The increments in temperature were measured by means of copper-constantan thermocouple and vernier potentiometer. One of the thermocouples was placed near the element, the other at the entrance of the radiation shield, and the third one to measure the ambient temperature inside the tunnel. Keeping the angle of incidence constant, different sets of readings of temperature increments were taken for 6·0, 2·0, 1·0, 0·5 and 0·4 mps. Similar sets of observations were made for 0°, 15°, 30°, 45°, 60°, 75°, angles of incidence to the horizontal position of the radiosonde.

3. Results of the experiments

Temperature increments for a radiational intensity of 2·0 cal/sq. cm/min have been plotted against angles of incidence of radiation for the modified shield in Fig. 4. It shows that temperature increments are proportional to the angles of incidences for all speeds of ventilation. Figs. 5(a) and 5(b) show the temperature rise at different wind velocities for various angles of incidences for the Payerne and the modified shield respectively. These graphs show a sharp discontinuity at the point where the velocity is approximately 1·0 mps. The values of the temperature increments corresponding to ventilation velocity of 0·2 mps and lower can be extrapolated from these graphs. Figs. 6(a) and 6(b) show the value of the radiation errors at different pressure levels for different solar elevation angles, for the Payerne and the modified shield respectively. The conversion between the ventilation velocity and the altitude of radiosonde in flight is based on the International Standard values of density at different pressure levels. The conversions are made for an ascensional rate of 6 mps. For other rates of ascents the values of radiation errors will have to be found from the following formula—

$$E' = \frac{E(6)^{0.6}}{V}$$

where E' is the error at ventilation velocity V and E is the error at 6·0 mps rate of ascent.

4. The Lag error of the bimetal thermometer of the C-type radiosonde

Since the time of the earlier study of this problem by Mitra and Dutta (1954), (upto 200 mb only) the length of the bimetal the rmometer of the radiosonde has been altered to allow better exposure of the element. In its present form the bimetal consists of a steel-invar polished strip of thickness ·025″, width ·125″ and length 4·0″ fabricated in the form of a spiral coil of $2\frac{1}{2}$ turns. It was therefore, considered necessary to redetermine the lag errors in the wind tunnel. The present study is confined to 100-mb level.

The pen of the thermometer element rested in the experimental arrangement, lightly on a precalibrated set of contactors separated by insulators, and was connected to a chronographic recorder. The recorder received impulses every $\frac{1}{2}$ second from an electrically driven Master Contactor. The element after being heated to a pre-determined temperature was drawn into the wind tunnel and exposed at right angles to the wind flow, which was varied from 6·0 to 0·8 mps. The fall of temperature with time was recorded on the chronographic recorder.

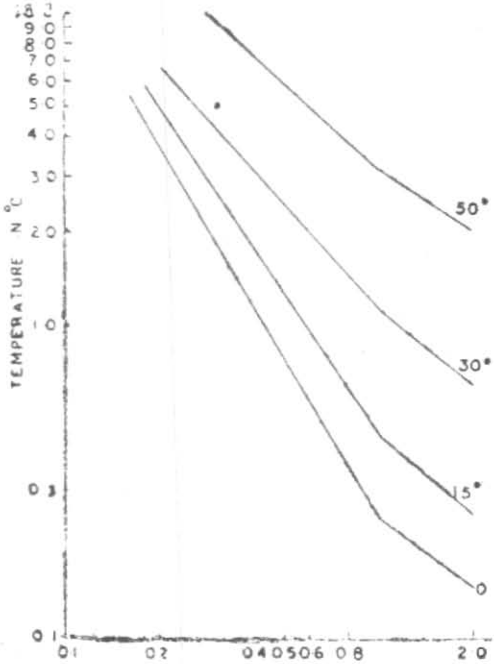

Fig. 5(a). For shield used at Payerne

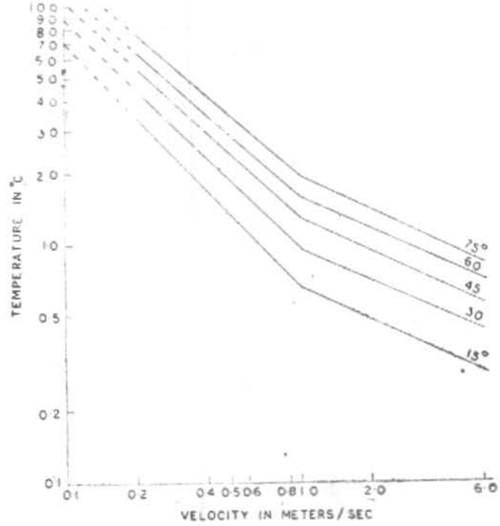

Fig. 5(b). For modified shield

Relationship between the wind velocity and the temperature rise

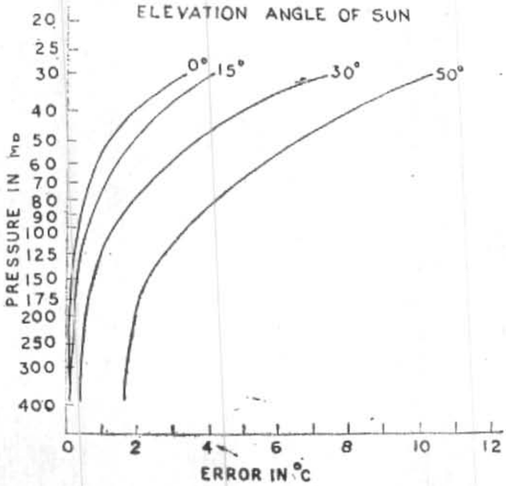

Fig. 6(a). Radiation error of Chronometric Radiosonde used at Payerne for rate of ascent of 6 mps

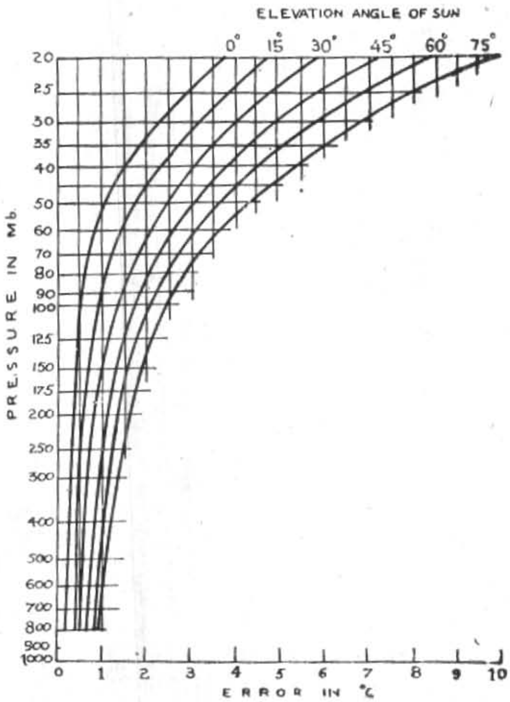

Fig. 6(b). Radiation error of M III Chronometric type radiosonde for rate of ascent of 6 mps

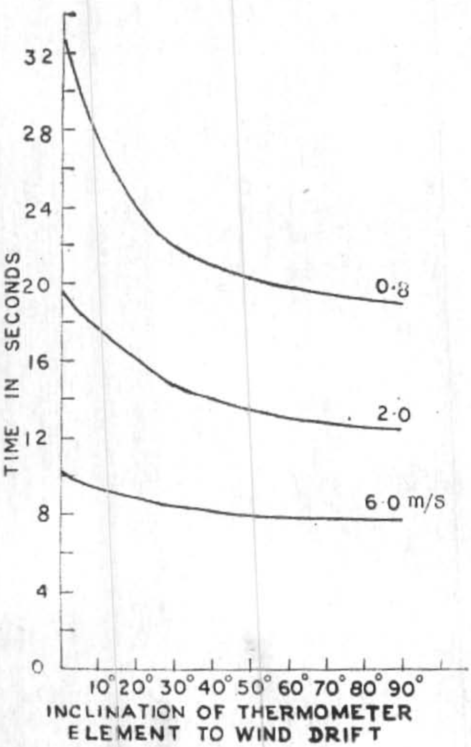

Fig. 7. Variation of lag coefficient with the inclination of the element

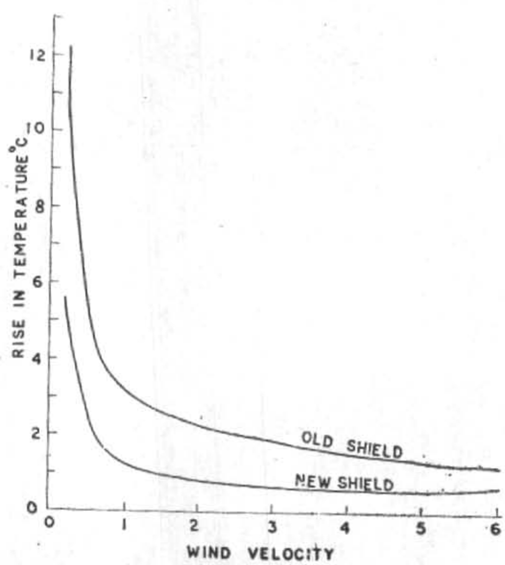

Fig. 8. Comparative errors of the modified shield with the shield used at Payerne (for angle of incidence 45°)

TABLE 1
Lag Error

Coil of the thermometer element normal to the directio 1 of ventilation

Levels (mb)	Lapse rate 10°C/km — Rates of ascents (mps)			Lapse rate 6·5°C/km — Rates of ascents (mps)		
	6	5	4	6	5	4
1000	0·49	0·46	0·40	0·32	0·30	0 26
900	0·52	0·48	0·42	0·33	0·31	0·27
800	0·55	0·50	0·43	0·35	0·33	0·28
700	0·58	0·52	0·44	0·37	0·34	0·29
600	0·61	0·54	0·46	0·39	0·35	0·30
500	0·64	0·56	0·48	0·42	0·36	0·31
400	0·67	0·59	0·50	0·44	0·38	0·33
300	0·71	0·63	0·60	0·46	0·41	0·37
200	0·89	0·82	0·72	0·58	0·53	0·47
100	1·30	1·18	1·10	0·82	0·76	0·71

The experiment was repeated with the plane of the coil inclined at 0°, 30°, 60° and 90° to the wind draft. Cooling curves were then drawn for different wind speeds and inclinations of the coil. The time for an initial difference in temperature between the thermometer element and the environment to be reduced in the ratio $1/e$ was calculated. In this way the lag coefficients were determined with different ventilation velocities at different orientations of the element to the wind draft (Fig. 7). The lag errors were then computed for the lapse rates of 10°C/km and 6·5°C/km for the ascensional rates of 6, 5 and 4 mps respectively. The results thus obtained are presented in Table 1.

5. Conclusions

1. The radiation error of the new modified shield is approximately 45 per cent of the shield used at Payerne, at an angle of elevation of 45° at 300-mb level and above (Fig. 8).

2. It is seen that the radiation error for an angle of elevation of 30° of the sun is 0·8°, 1·3°, 2·4° and 5·8°C at 200, 100, 50 and 20 mb respectively.

6. Acknowledgements

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