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A high level Chronometric Radiosonde

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ABSTRACT. The paper describes a modified chronometric type of radiosonde for obtaining meteorological data upto 100,000 ft. The instrument was used during Indo-US Balloon Flight Programme at Hyderabad in 1961.

1. Introduction

The India Meteorological Department participated in the Joint Indo-US Equatorial Balloon Flight Programme in which the Atmospheric Circulations Laboratory of the US Air Force collaborated with the Tata Institute of Fundamental Res arch, Bombay, for making high altitude ascents using large size plastic balloons at Hyderabad during January-April 1961. The I. M. D. chronometric radiosonde (Mathur 1948) was modified for use with these balloons. The main requirements were that it should (*i*) withstand the initial shock at launching, (*ii*) operate for the longer period of extended flights and (*iii*) furnish more accurate data, particularly at higher altitudes. No limitation was imposed on the weight of the instrument.

2. The Instrument

The radiosonde instrument (Figs. 1 and 2c) contains two pressure capsules P_1 and P_2 operating over the ranges 1000-5 and 150-5 mb respectively and a temperature element T having a range of +40°C to —80°C. D is the pen for fixed reference contact. Jewelled bearings are used for the axles to minimise friction. The tips of the pens move due to changes in meteorological element over the rotating contact cylinder S which is 3½ inches long and 3/8 inch in diameter. The cylinder is polished and provides a smooth surface so that friction to the movement of the pens is minimum. A fine conducting helix of 1/4″ pitch is embedded in the insulating cylinder. Specially designed clockwork (Fig. 3) ensures smooth rotation of the cylinder whose length has been increased to accommodate larger deflections of the pens. It, therefore, causes a heavier loading on the drive mechanism. A flexible coupling C is used for driving the cylinder. The useful running life of clockwork has been increased to 3 hours at —80°C. This modification was necessary as the large plastic balloons took much longer time to attain the ceiling and floated at that level for three to four hours. Temperature records under floating conditions at high altitudes were also obtained. The clockwork is lubricated by a special low temperature oil, processed in the departmental laboratory at New Delhi. It has a freezing temperature lower than —80°C and contains trichloroethylene, Shell Telpa oil No. 20 and Verilube oil in the proportion of 1 : 1 : 3.

The pressure elements P_1 and P_2 consist of two and four hermetically sealed berylium copper capsules respectively. P_2 engages its pen at the preadjusted pressure level of 150 mb. The total expansion of the aneroid P_1 for the pressure range of 1000-5 mb corresponds to 54 inches on the recorder. It thus provides a sensitivity of 30 mb/inch at higher (1000-200 mb) and 15 mb/inch at lower pressure levels (200-5 mb). The expansion of aneroid P_2 for the range 150-5 mb is 15″ on the chart, improving the sensitivity to 10 mb/inch. Because of the increased resolving power of aneroid P_2 due to the use of four capsules and the expanded scale, the accuracy of the pressure measurement on the record is increased to ±0·5 mb.

The temperature element T consists of an equiangular spiral made of steel-invar bimetal (Highflex 45, 0·01″ thick, 0·125″ wide and 1″ long). The temperature deflection characteristic per unit change of temperature for the thinner bimetal used in this instrument is greater, hence it is more sensitive. The error due to the lag in the response of the temperature element is also reduced due to the reduction in mass and size of the strip. The elements are annealed at a temperature of 100°C for 6 hours and then seasoned by subjecting them to 12 cycles of temperature change from +40°C to —60°C. A range of temperature from +40°C to — 80°C corresponds to 40″ on the recorder chart. This provides a sensitivity of 3·0°C per inch of record. The accuracy of the temperature measurement from the record is thus increased to ±0·15°C.

A double-walled aluminium shield (Fig. 2d) is used to minimise the effect of the direct radiation

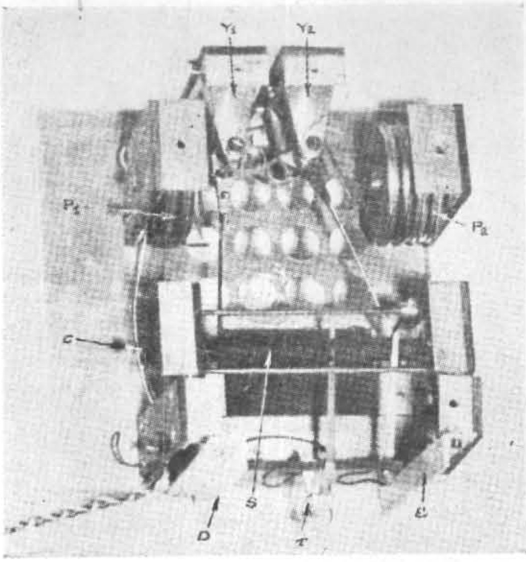


Fig. 1

TABLE 1

Upper air temperatures (in°C) at different standard levels at Begumpet during March and April 1961

Pressure levels (mb)	9 Mar 0843 IST	10 Mar 0820	11 Mar 0853	20 Mar 0749	29 Mar 0720	31 Mar 0720	4 Apr 0720	20 Apr 0825	21 Apr 0642	23 Apr 0726	25 Apr 0629 IST
Surface	26·0	26·0	26·2	27·7	22·0	22·7	26·2	31·0	27·8	32·0	27·4
850	23·2	19·8	24·1	23·0	20·8	25·2	20·5	25·5	27·1	24·9	24·8
700	14·7	11·1	12·5	11·0	10·9	13·4	8·3	15·7	12·5	16·2	13·2
500	2·0	—4·1	—3·9	—4·3	—3·4	—9·8	—11·2	—6·1	—5·2	—1·2	—4·0
300	—32·9	—31·2	—34·9	—30·9	—31·0	—38·5	—37·0	—29·5	—29·5	—27·3	—30·2
200	—54·0	—	—55·0	—45·9	—44·2	—52·5	—52·0	—49·6	—47·5	—46·2	—48·2
100	—70·5	—	—66·0	—63·2	—69·0	—70·4	—73·8	—74·5	—	—75·9	—70·0
50	—62·1	—	—64·8	—57·9	—49·0	—57·8	—61·5	—65·5	—	—61·2	—50·5
Ceiling*	—55·2 (36)	—	—46·3 (25)	—52·5 (14)	—31·9 (23)	—57·7 (41)	—15·3 (14·5)	—29·2 (7)	—71·3 (106)	—3·5 (10)	—33·7 (20)
Duration of ascent (mts)	71	40	72	68	109	108	181	121	56	129	139

*Ceiling level (in mb) for the particular day is indicated within brackets below the temperature value

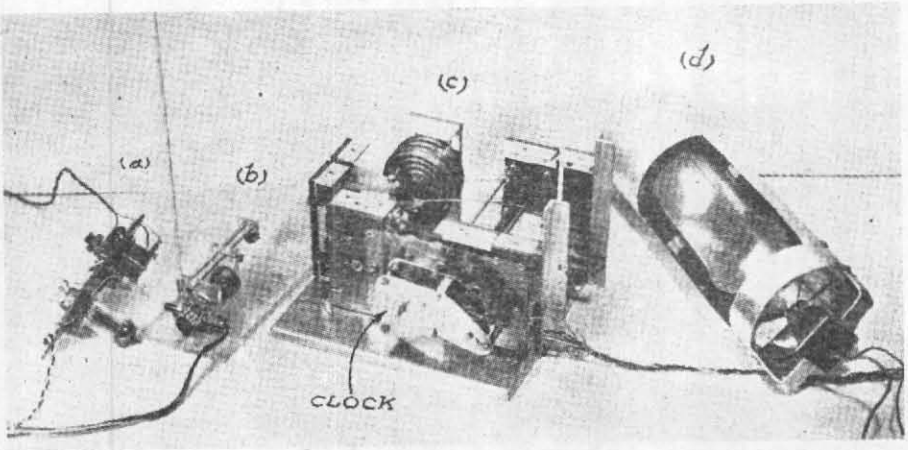
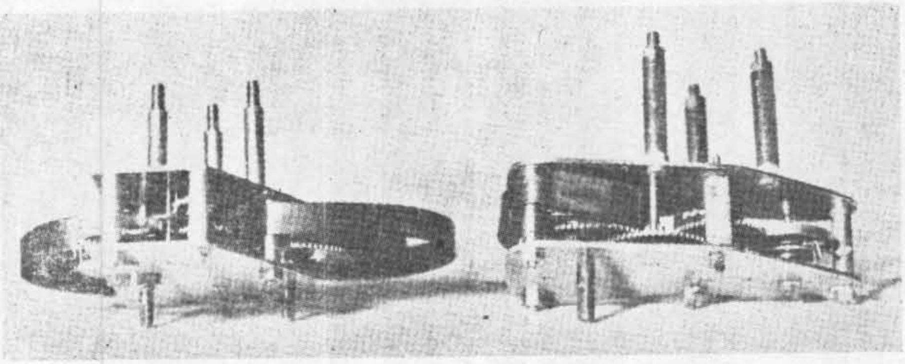


Fig. 2



Clock 1 Clock 2

Fig. 3

from the sun on the temperature element during the sounding. A suitable mounting stud with a collar is designed to ensure that the element remains in the centre of the shield. In later soundings artificial ventilation through the shield was provided by a specially designed fan operated by a 6 V D.C. motor (Fig. 2d). The fan was used as air exhaust so that it added to the natural flow of air from top to bottom during the ascent. This arrangement further reduces errors due to lag in the response of bimetal element and provides ventilation when balloon is floating at constant level.

3. Calibration

Each instrument was individually calibrated over the entire ranges of pressure and temperature it was likely to encounter during the sounding– 20 points for pressure and 6 points for temperature were recorded during the cycle in the chamber and the calibration curves for each instrument prepared from these readings.

4. Data obtained

4.1. The modified chronometric radiosonde was used in 12 soundings. The rate of ascent during these soundings was nearly constant and varied from 10-12 km/hr (US balloons) and 16-18 km/hr (TIFR balloons) in different flights. The distance between the instrument and the balloon in case of these cosmic ray soundings could not be increased because of other payloads. The temperature data obtained are given in Figs. 6-8 and Table 1. The balloons fabric was black in case of T.I.F.R. and white in case of US balloon.

4.2. Sample records of the ascents taken on 11 March and 23 April 1961 are shown in Figs. 4(a) and 4(b) respectively. The time-temperature curves for these ascents obtained from the above records are shown in Figs. 5(a) and 5(b). The ceilings were reached at points marked Y_1 in Figs. 4 and 5, after which the balloons floated at a constant level. Artificial ventilation was provided in the instrument used on 23 April but not in the one used on 11 March 1961. It is seen that the magnitude of fluctuations at floating level are very marked.

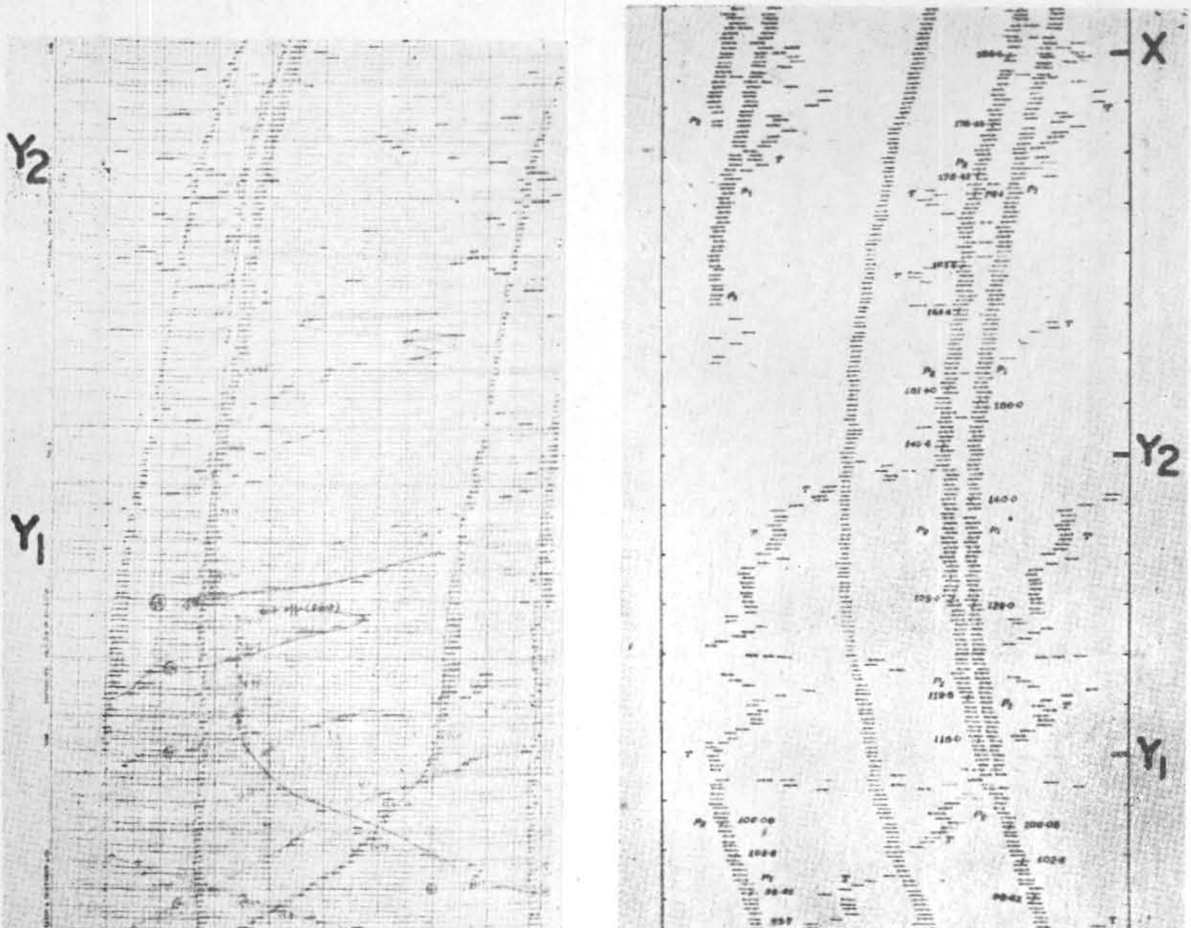


Fig. 4(a). 11 March 1961

Fig. 4(b). 23 April 1961

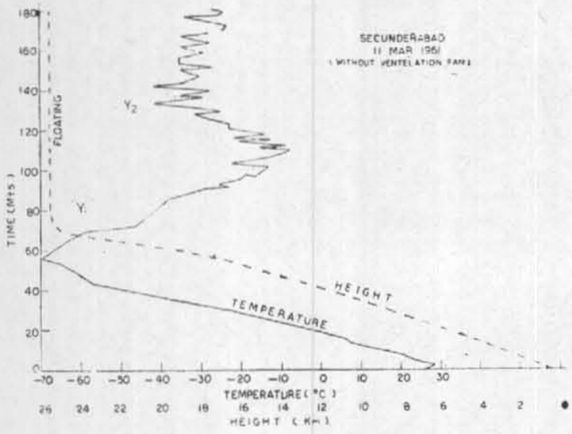


Fig. 5(a). Time-temperature and time-height curves for the ascent on 11 March 1961

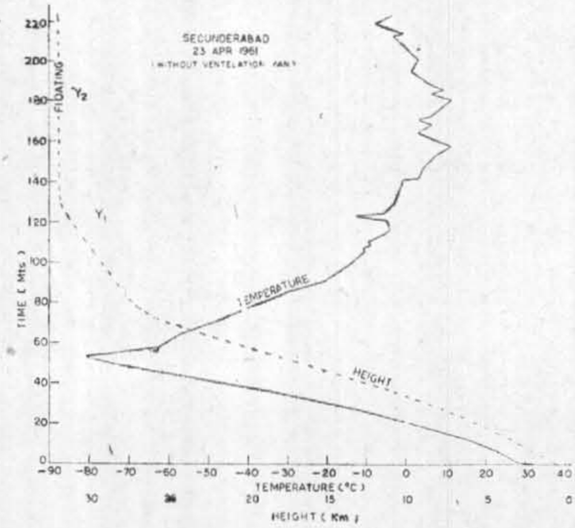


Fig. 5(b). Time-temperature and time-height curves for the ascent on 23 April 1961

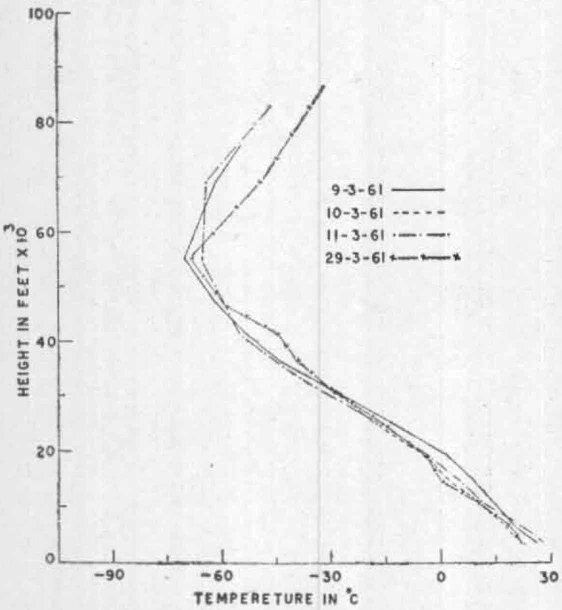


Fig. 6. Variation of temperature with height

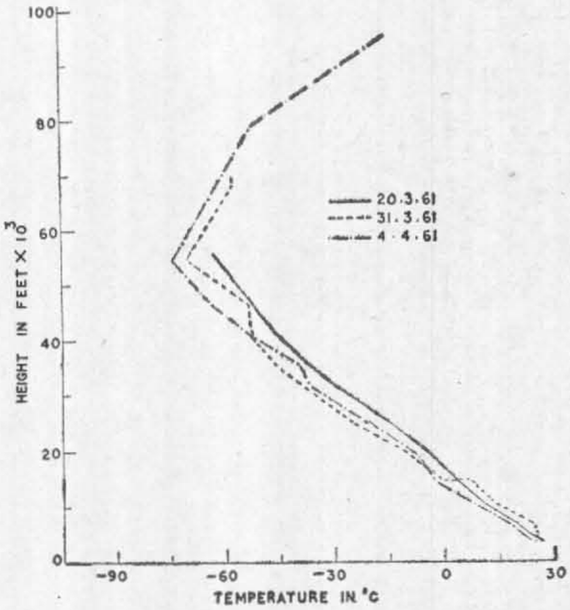


Fig. 7. Variation of temperature with height

They are over the range —8°C to —41°C during the sounding in which no artificial ventilation was provided and over the range —13°C to +11°C in the other case. This is due to the temperature reading being effected by the radiation from the balloon because of its proximity to the instrument. The fluctuations are caused by the swinging of the suspension line which results in the instrument moving in and out of the radiation shadow of the balloon. These fluctuations were smoothened out when artificial ventilation was used. The recording of high temperatures during the floating of the

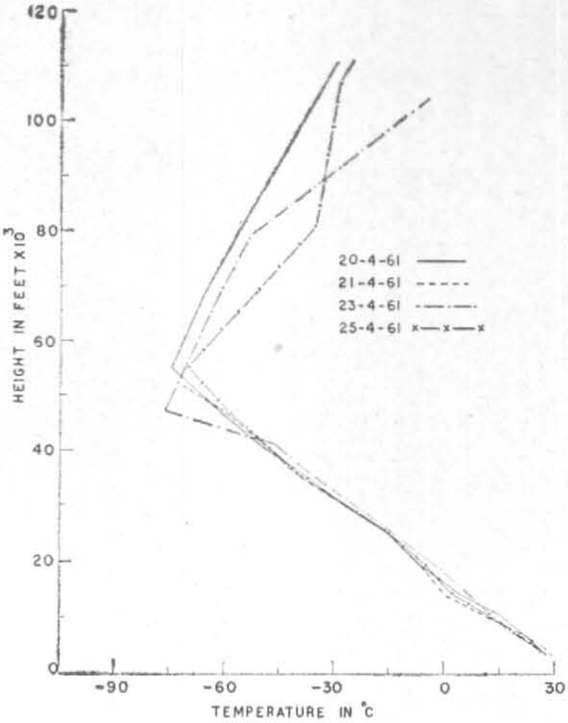


Fig. 8. Variation of temperature with height

Fig. 9

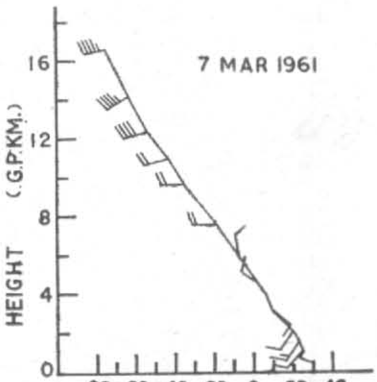


Fig. 10

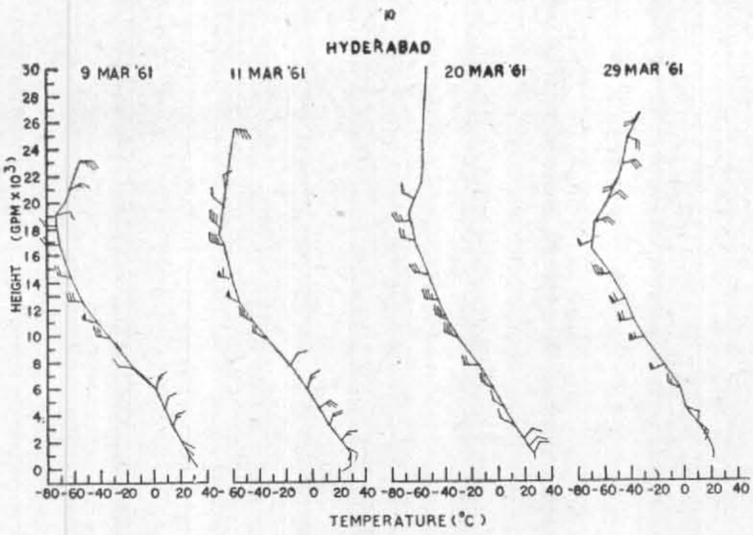


Fig. 11

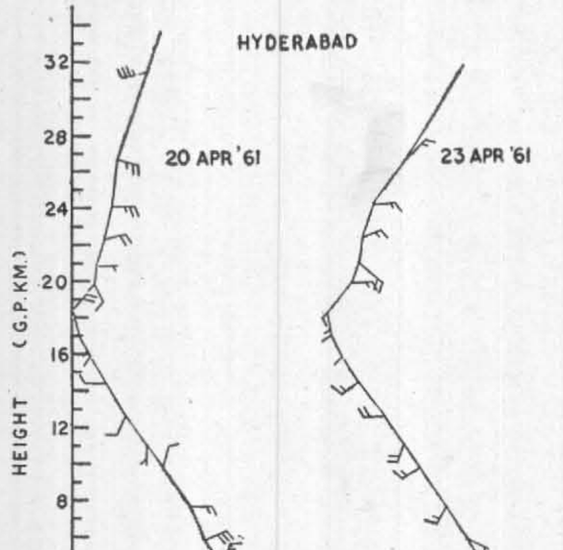


Fig. 12

Fig. 13

balloon was due to constant sucking by the fan, through the temperature element, air which was heated by radiation from the balloon.

The trend of temperature variations at floating level is the same in both the cases. The gradual steady increase in recorded temperature at the floating level (marked Y_1, Y_2 in Fig. 4), is partly due to the progressive heating of the element by the radiation from the balloon in the absence of proper ventilation and partly due to the increase in the angle of elevation of the sun.

The gradual decrease in temperature after 1100 IST (marked X) in the flight record of 23 April 1961 (Fig. 4b) is due to the shielding of the element from the direct radiation of the sun at this high elevation by the balloon. The diameter of this balloon was 60 ft and the instrument had to be tied to the line at a distance of only 6 ft from the balloon.

4.3. The instruments were used with a 400 Mc/s rawin transmitter (Figs. 2a and 2b) which was also utilised for tracking the balloon to obtain upper winds and help in recovery of the cosmic ray pay-load. Wind data obtained from these soundings are given in Figs. 9-13.

5. Conclusion

The instrument is capable of furnishing meteorological data upto 100,000 feet when used with plastic balloons not necessarily large. It would, however, be necessary to provide a long suspension line and to correct temperature data for radiation errors.

6. Acknowledgements

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