THE F-TYPE RADIO-METEOROGRAPH AS AN INSTRUMENT TO MEASURE VERTICAL CURRENTS IN THE ATMOSPHERE

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SUMMARY

The paper describes the chief features of the fan used in the Indian F-type radio-meteorograph and how it enables one to know from the radiosonde data whether the balloon is descending due to accumulation of snow or strong vertical currents. Instances when the balloon went up and down due to accumulation and melting of snow have been described. The decrease in the rate of ascent and even the descent of the balloon due to strong downward currents in a thunderstorm on the 26th April 1950, have been estimated. The paper also shows how the F-type radiosonde data can be used to identify regions of clear air turbulence.

THE F-type radio-meteorograph of the India Meteorological Department,[1] like the Vaisala or the British Meteorograph, employs a fan which rotates during the ascent of the balloon, but the design and mounting of the fan in the Indian instrument is very different from those in the others. The fan in the F-type meteorograph is made from a single sheet of paper; it is mounted in the instrument so as to rotate about a vertical axis when the balloon rises in the atmosphere (Fig. 1). In the Vaisala and British instruments, the fans are made of 3 or 4 cone cups mounted about a horizontal axis. In these instruments the cups can rotate both due to vertical ascent of the balloon and due to horizontal winds.

The chief feature of the fan in the F-type radio-meteorograph is that it rotates only when it moves relative to the air along the axis of rotation in the upward direction; horizontal winds at any level have very little effect. Moreover, during the ascent, the balloon moves horizontally with the speed of the wind and therefore the effect of the horizontal wind is unimportant.

As the fan in the F-type radio-meteorograph operates only during the upward motion along the axis of rotation, the rate of rotation of the fan serves as a very useful indication of the existence of vertical currents in the atmosphere. If the balloon develops a leak, the rate of ascent will first decrease, and later the balloon will descend. This will be reflected in the rate of rotation of the fan, which will first begin to slow, and later stop when the balloon begins to descend. On the other hand, if snow accumulates on the balloon, the rate of rotation will decrease gradually and the rotation will stop as soon as the accumulation is sufficiently large to exceed the free lift of the balloon, and the balloon descends. However, in this case, when the balloon descends below the freezing level, the accumulated snow will melt and the balloon will rise again, and the fan will restart working. Dr. Suryanarayana and Mr. Kachare[2] had occasion to observe this phenomenon on two days (6th October 1950 and 7th October 1950) when F-type radiosonde ascents were made during rain. Fig. 2 shows the pressure

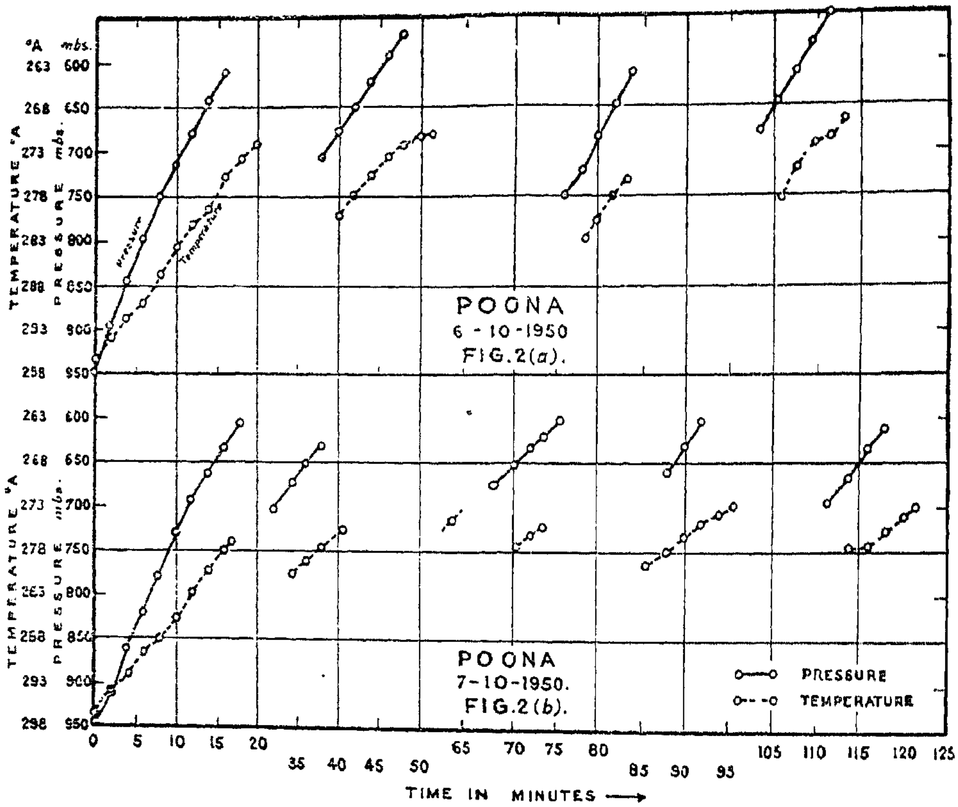
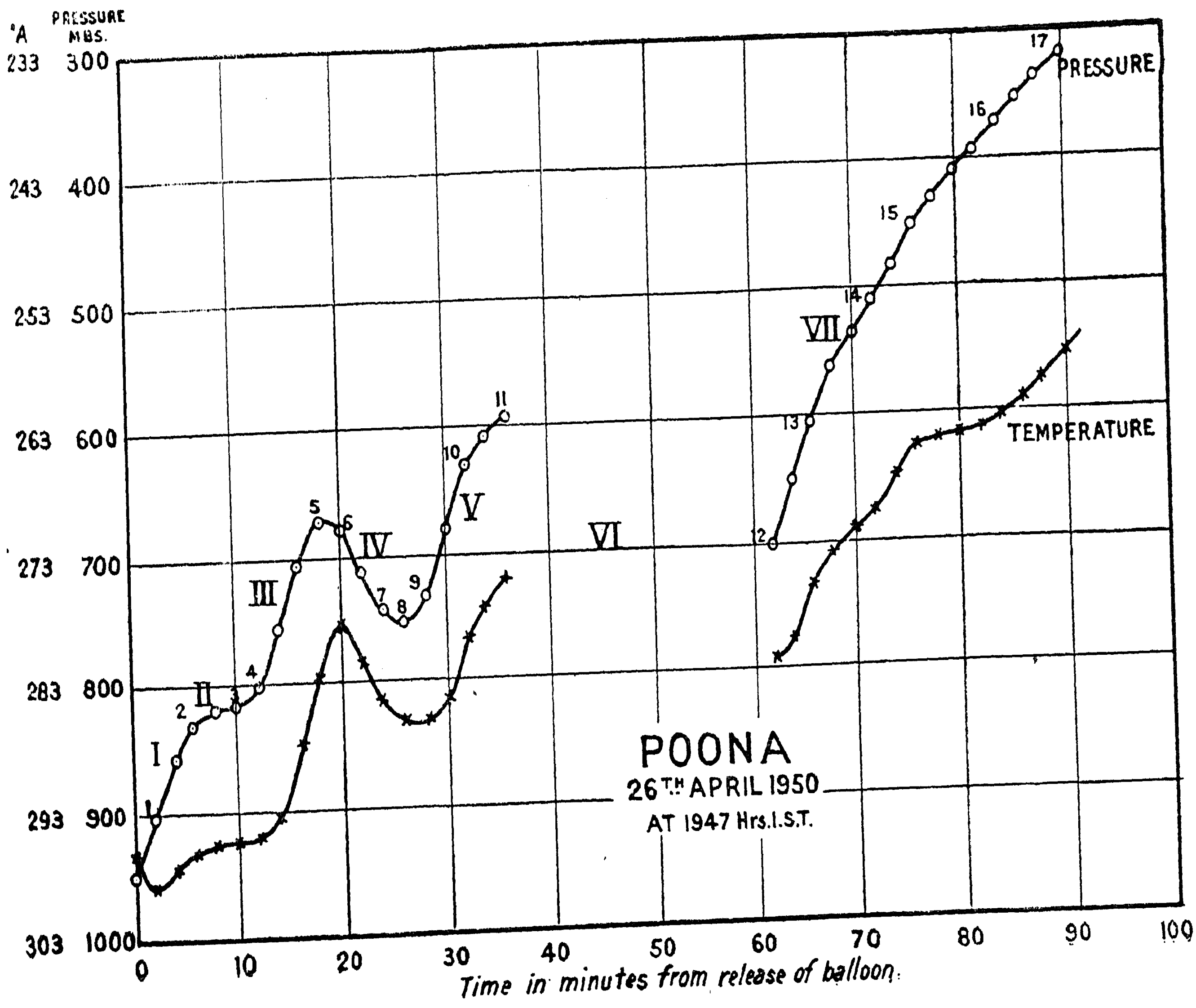


FIG. 2

and temperature distribution when the balloon went up and down due to the accumulation and melting of snow. It will be noticed that no signals were received every time the balloon descended due to the accumulation of snow, for, during this period, the fan was not rotating due to its motion in the reverse direction in the air.

In the case of all other types of radio-meteorographs, though one can observe the movement of the balloon up and down in the atmosphere from the pressure and temperature data, it cannot be said whether they are due to vertical currents of air or due to accumulation of snow. In the case of the F-type radiosonde, however, if the balloon descends due to a strong downward current of air, the fan will be continuously rotating, and the rate of descent due to this downward current can be estimated from the rate of increase of pressure and temperature. Venkiteshwaran and Tilakan[3] had occasion to analyse the movement of a radiosonde balloon in a thunder cloud on the 26th April 1950. During this ascent, the balloon was once forced down due to strong downward currents and also later due to the accumulation of snow. However, these various stages could be distinguished and even the rate of descent of the vertical current estimated as described below.

Fig. 3 gives the variation of pressure and temperature with time experienced by the radiosonde; Fig. 4 gives the rate of rotation of the fan operating the radio-meteorograph. This rate of rotation is measured by the length of paper tape per complete Olland cycle and is given by the distance between two consecutive signals from the fixed reference contacts in



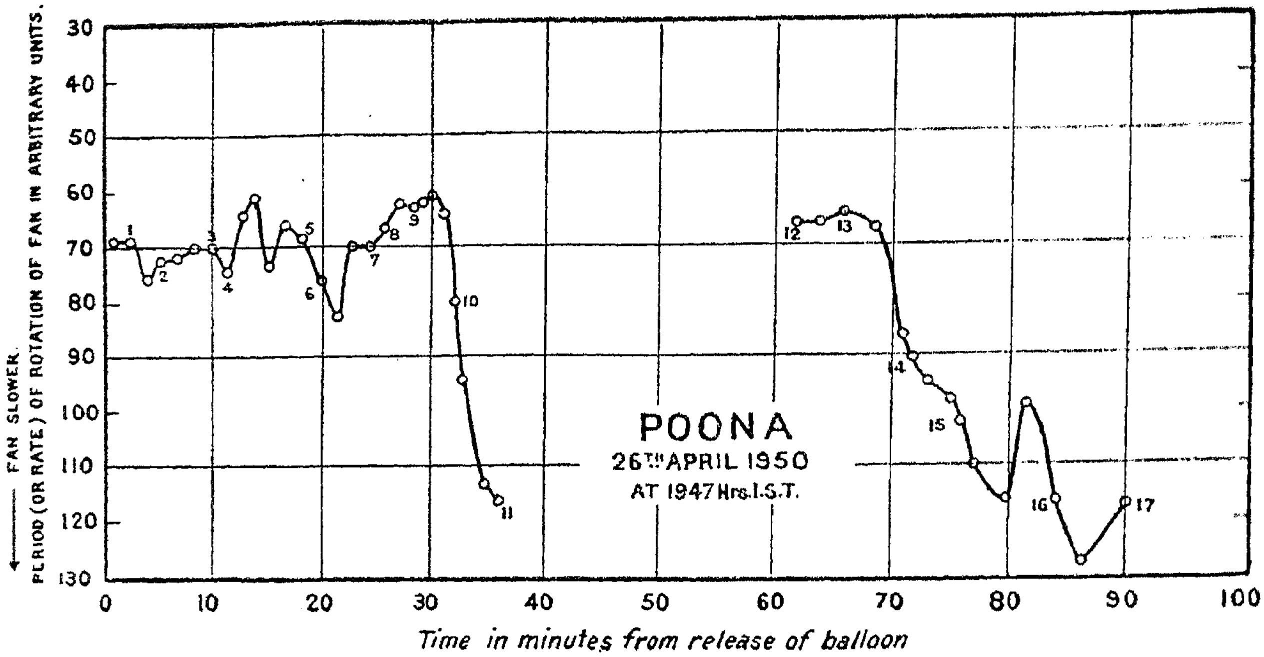


FIG. 4

the instrument. Fig. 5 gives the tephigram obtained from the ascent giving the distribution of dry bulb and wet bulb temperatures.

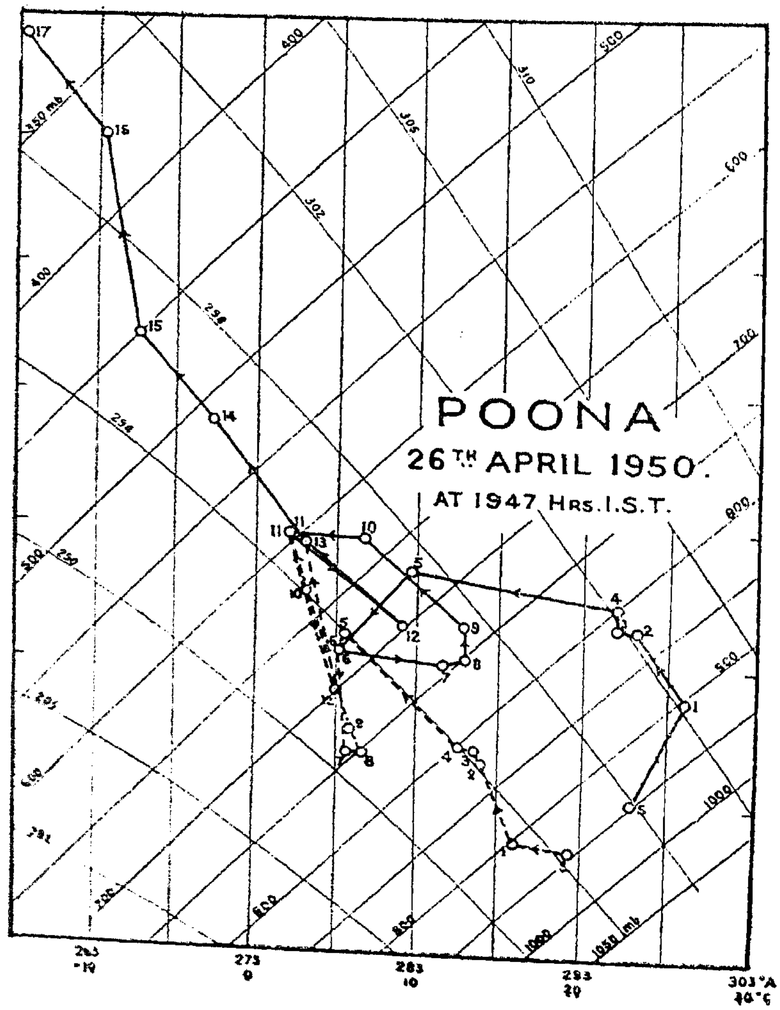


FIG. 5

It can be observed from Fig. 3 that in phase I, the balloon was rising uniformly for about 6 minutes till it reached the 827 mb. level when its rate of ascent was reduced for about 6 minutes. Later, it again rose uniformly for about 6 minutes more till it reached the 671 mb. level after which the balloon descended to the 750 mb. level in about 8 minutes. It again rose for about 10 minutes till it reached the 593 mb. level. After this no signals were received from the fan for about 24 minutes; later the signals were again received, but from a lower level, *viz.*, 700 mb. and continued thereafter till it reached 320 mb.

The approximate rates of ascent or descent of the balloon in the different phases are given below:

Phase	Characteristic points	Approximate rate of ascent (km.p.h)	Remarks
I	Upto 2	13	
II	2—4	3	
III	4—5	15	
IV	5—8	−7	Balloon descending; rate of descent about 11 m. p. h. between points 6 and 7
V	8—11	11	Rate of ascent about 18 m.p.h. between 9 and 10
VI	11—12	..	Balloon descended due to accumulation of snow
VII	12—17	13	

When the ascent curves in Figs. 3 and 4 are examined, it will be observed that during the phases II and IV, though the balloon was rising at an appreciably lower rate in phase II and even descending in phase IV, the fan in the meteorograph was rotating almost at the same rate as during the period immediately after release. As the fan can rotate only when there is an opposing wind, the balloon must have experienced strong downward currents in these two phases. Comparing the rate of ascent in the region corresponding to phase I with that at phase II, it is observed that the rate of ascent had decreased from about 13 km.p.h. to about 3 km.p.h. from which it can be inferred that the downward current was approximately 10 km.p.h. in phase II. Similarly, a rate of ascent of about 15 km.p.h. in phase III became a rate of descent of about 7 km.p.h. in phase IV, the maximum downward current experienced by the balloon then being not less than 22 km.p.h.

In phase VI, the balloon was descending and as the fan was not rotating, the descent must have been due to thick icing on the balloon. That this is so is confirmed by the fact that the temperature of the air at the level corresponding to the beginning of phase VI was about 2° C. As the rate of ascent began decreasing even from the 630 mb. level, it is possible that the snow had started falling and accumulating on the balloon even from this level.

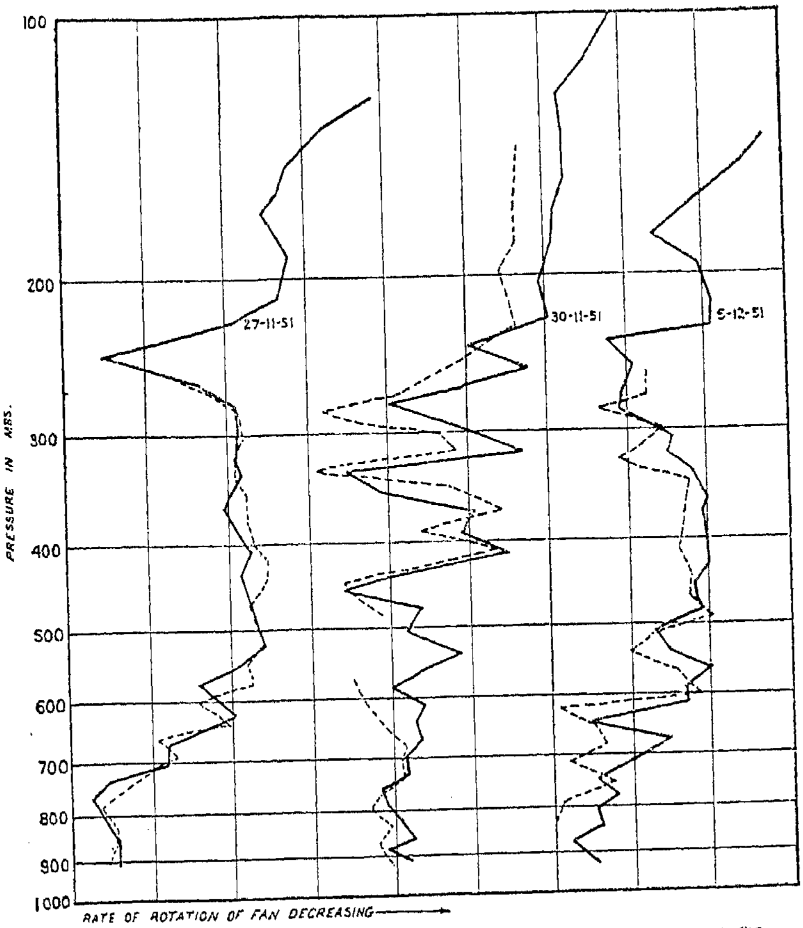
When the balloon descended, the ice should have melted and therefore the balloon began rising again as shown in phase VII. But the rate of ascent now was only 8 km.p.h., and this is probably because the balloon started rising before all the snow collected on it had melted, and even reached the freezing level again when further melting would not have been possible.

From the tephigram in Fig. 5 it will be observed that there was a ground inversion due to the rain cooled air. When the balloon reached the 671 mb. level, the dry bulb fell suddenly to that of the wet bulb indicating a very high super-adiabatic lapse rate. Simultaneously, the balloon was caught in the downward current which brought it down from the 671 mb. level to the 750 mb. level. During this descent, the rise of temperature was almost along the dry adiabatic.

Till the balloon reached the 671 mb. level after its release, the wet bulb temperature was changing along the saturation adiabatic. But during the descent of the balloon, though the dry bulb temperature changed along the dry adiabatic, the wet bulb temperature remained almost the same. The reduction in the wet bulb potential temperature is presumably due to the descending column entraining air from outside the cloud.

The details of the various phases have been described already in the previous paragraphs. It is, however, interesting to note that during the last phase VII, the lapse rate was almost equal to that of the saturation adiabatic upto about 450 mb. above which it decreased to about 1° C./km. till 372 mb., above which the lapse rate again increased. Probably, the anvil of the thunderstorm was in the region between 450 and 372 mb. *i.e.*, between 6·8 and 8·3 km. above sea-level.

It may also be mentioned in this connection that even in clear weather, the variations in the rate of rotation of the paper-fan are yielding valuable information about regions of turbulence in the atmosphere, whose existence cannot be known at present except from aircraft reports.[4] As the rate of rotation of the fan seems to indicate the vertical forces acting on it, it was decided to test whether the fluctuations in the rate of rotation of the fan are true indications of certain characteristic features in the atmosphere, and if so, to what extent. Fig. 6 shows the rate of rotation of the fans in two instruments let off simultaneously at Poona with two independent balloons. If the changes in the rate of rotation of the fan represents a characteristic property of the air mass, it should be indicated from two simultaneous ascents



COMPARISON OF RATE OF ROTATION OF FAN IN TWO INSTRUMENTS LET OFF SIMULTANEOUSLY WITH TWO INDEPENDENT BALLOONS AT POONA

FIG. 6

from different places. Fig. 7 shows the variation in the rate of rotation of the fan at Poona (18° 32′ N and 73° 51′ E) and Nagpur (21° 09′ N and 79° 07′ E). The ascents show a degree of agreement which confirms the view that the rate of rotation of the fan represents some specific property of the air mass. Fig. 8 shows a series of curves showing the variation of the rate of rotation of the fan at various levels over Poona from the 11th March 1951 to the 14th March 1951. It will be observed from these that in the region between 400 mb. and 300 mb. there were frequent and large increases in the rate of rotation of the fan. Its occurrence in a particular region, its persistence on a few days and absence later, are significant.

An increase in the rate of rotation of the fan can either be due to an increase in the rate of ascent of the balloon relative to the surrounding air or due to a downward current of air. These rapid increases or decreases in the rate of rotation of the fan can be attributed only to strong downward or upward currents due to turbulence occurring in these regions. As the

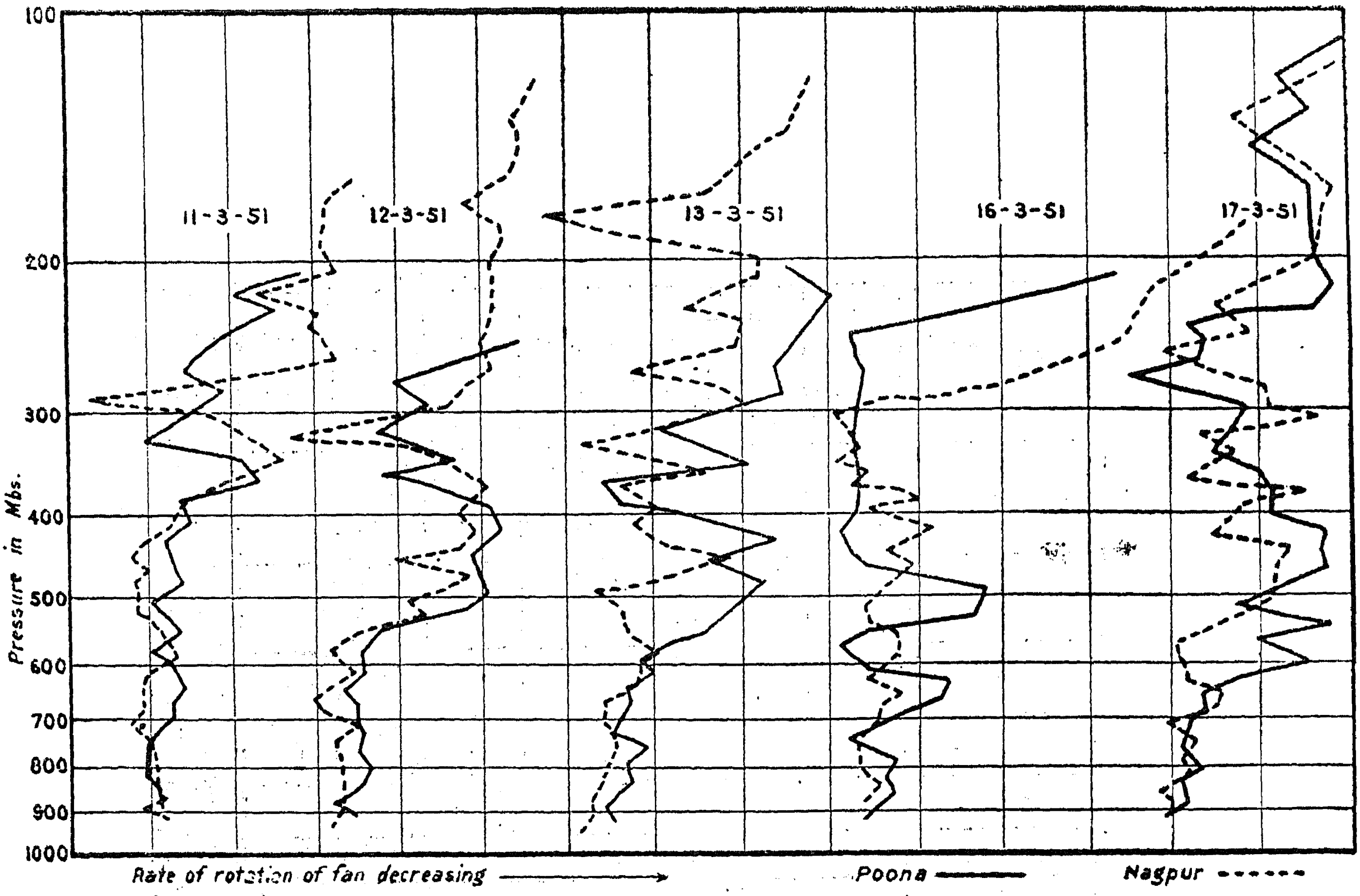


FIG. 7. Comparison of Rate of Rotation of Fan in Radiosondes Released at about 1500 hrs. G.M.T. at Poona and Nagpur.

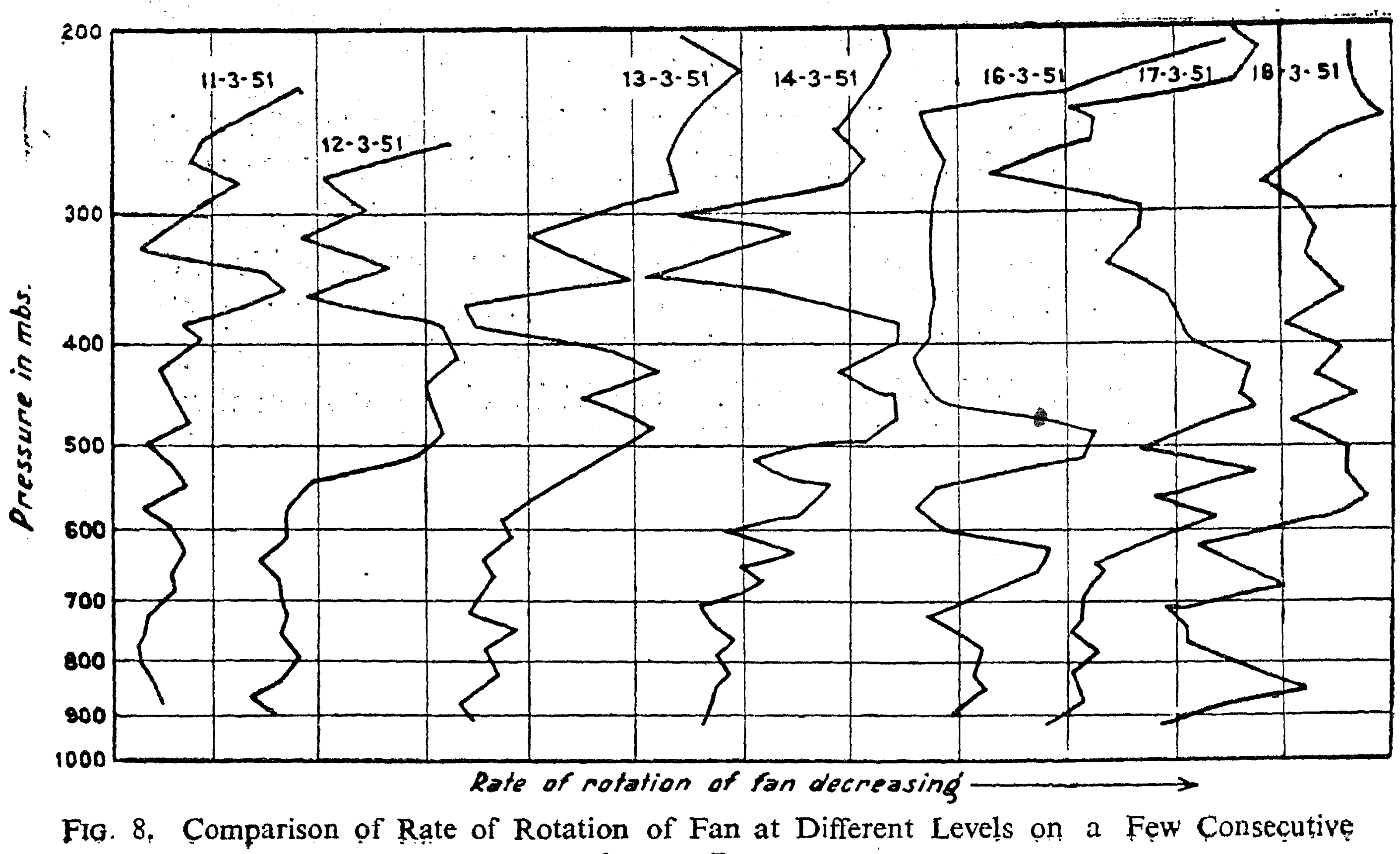
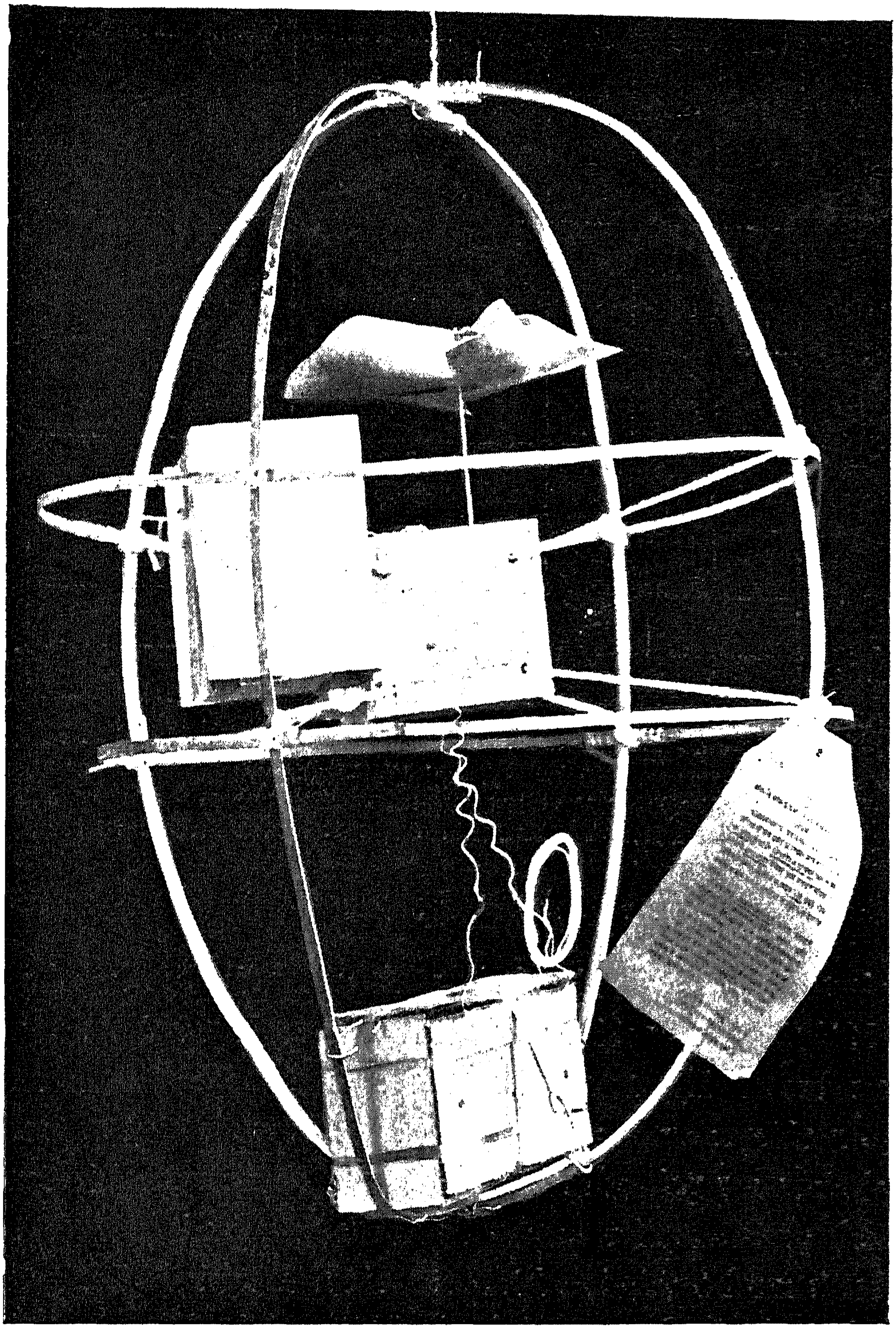


FIG. 8. Comparison of Rate of Rotation of Fan at Different Levels on a Few Consecutive days at Poona.



variations in the rate of rotation of the fan are of short durations and represent the effect of turbulence, they cannot be observed from the rate of ascent of the balloon computed from the observations of pressure signals received from the radio-meteorograph, nor by any of the methods of observations now available. With the increase in the frequency of high level flying, the phenomenon of clear air bumpiness has come to light. It appears from the above analysis of the F-type radiosonde records, that this simple instrument can be a tool for locating regions of turbulence at any height in the atmosphere. With standardised fans, it may be possible not only to locate such regions, but to compare the intensity of the turbulence from day to day. The F-type has certain unique features not available with any other type of radiosonde.

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