VERTICAL SOUNDINGS AT AHMEDABAD DURING PARTIAL SOLAR ECLIPSE ON 14th DECEMBER 1955

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ABSTRACT

The results of vertical ionospheric soundings at Ahmedabad during the partial (magnitude 47%) solar eclipse on 14th December 1955 are discussed. The critical frequency of the E layer on control days varied according to the law $f_0E = k \cos^n \chi$, k and n having the mean values 4·06 Mc./s. and 0·37 respectively. The variation of f_0E during eclipse period was roughly consistent with that of Chapman Layer with a recombination coefficient of about $0 \cdot 8 \times 10^{-8}$ cm.^{3} sec.$^{-1}$ The critical frequencies of E_1, E_2 and F_1 layers decreased during eclipse, though the variations were irregular. The percentage deviation of f_0F_2 on the eclipse day from the control day values showed a minimum at about the middle of the eclipse period. There were indications of the formation of $f_{1 \cdot 5}$ during the latter part of the eclipse. Semi-thickness of the F_2 layer had increased during the eclipse period. Sporadic E layer was not affected by the eclipse.

THE present article describes the results of vertical ionospheric soundings made at Ahmedabad during the partial solar eclipse of 14th December 1955.

The times of the various phases of the ground eclipse are given in Table I.

TABLE I

		Time 75° E.M.T.	Solar altitude
Commencement of the eclipse	..	1014 hours	37°
Maximum phase of the eclipse	..	1210 ,,	44°
End of the eclipse	..	1400 ,,	37°
Magnitude of the eclipse	..	47%	..

As the eclipse occurred almost at noon, there was very little difference in the time of the phases of the eclipse at ground and at ionospheric levels, and so no detailed calculations of these latter times were made. The portion (p) of the solar disc unobscured by the moon, the cosine of solar zenith angle ($\cos X$), and the product ($p \cdot \cos X$) during the eclipse are shown in Figs. 1 (*a*) and 1 (*b*). $p \cdot \cos X$ varied from 0·6 at the beginning and end of the eclipse to 0·37 at the maximum phase of the eclipse.

The British N.P.L. type ionospheric recorder of the Physical Research Laboratory was used for all the measurements. The equipment covered 0·65–15·4 Mc./s. in four minutes; the frequency range 15·4–25 Mc./s. was not used. On the control days, P′-f records were taken at intervals of fifteen minutes each day from 09 hr. to 15 hr. On the eclipse day, records were taken every five minutes from 10 hr. to 14 hr. The variation of critical fre-

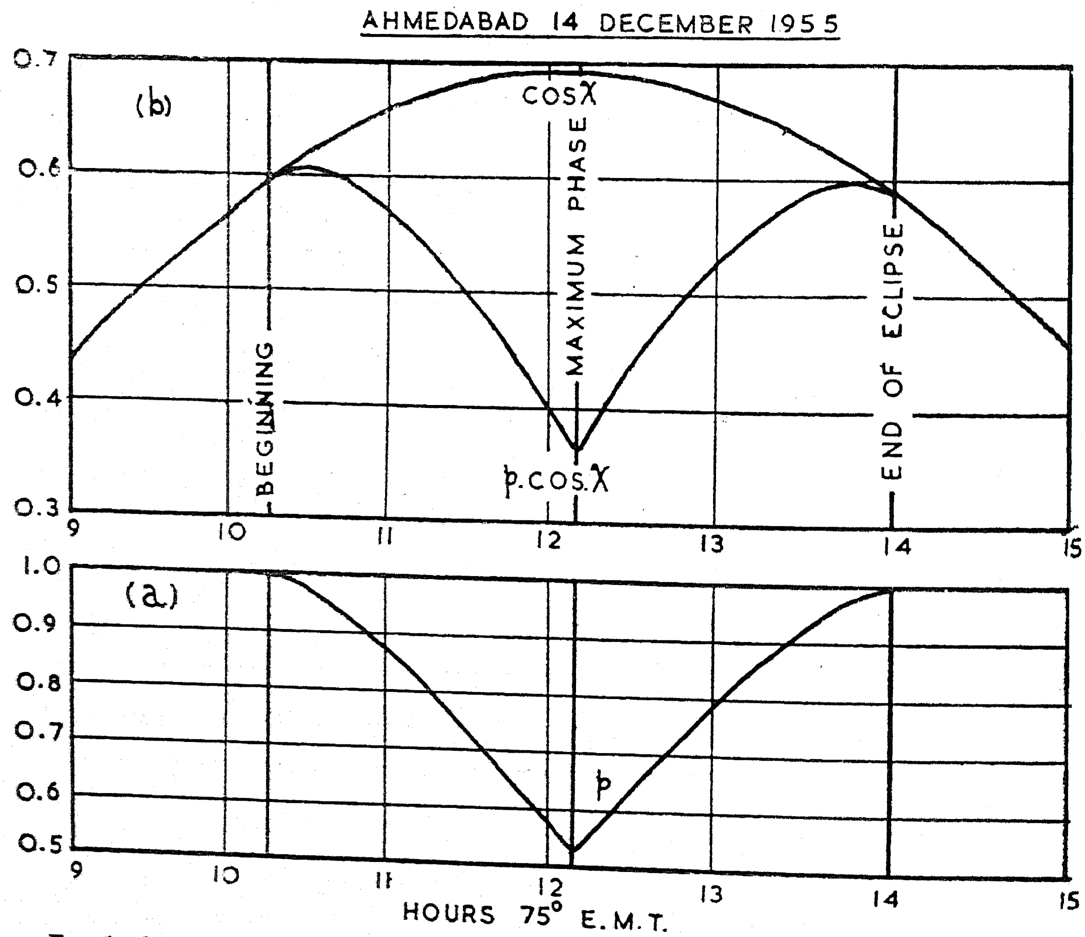

FIG. 1. (*a*) The variation of fraction (p) of the solar disc unobscured by the moon during the solar eclipse of 14th December 1955 at Ahmedabad. (*b*) The variation of the cosine of solar zenith angle ($\cos \chi$) and the product $p \cdot \cos \chi$ during the solar eclipse of 14th December 1955 at Ahmedabad.

quencies and the minimum virtual heights of E, E_1, E_2 and F_1 layers on control days and on the eclipse day are shown in Fig. 2. Figure 3 shows the critical frequencies (f_0F_2), the minimum virtual heights ($h'F_2$) and the virtual heights at $0{\cdot}83 \times f_0F_2$ (h_pF_2) on the eclipse day and on the control days.

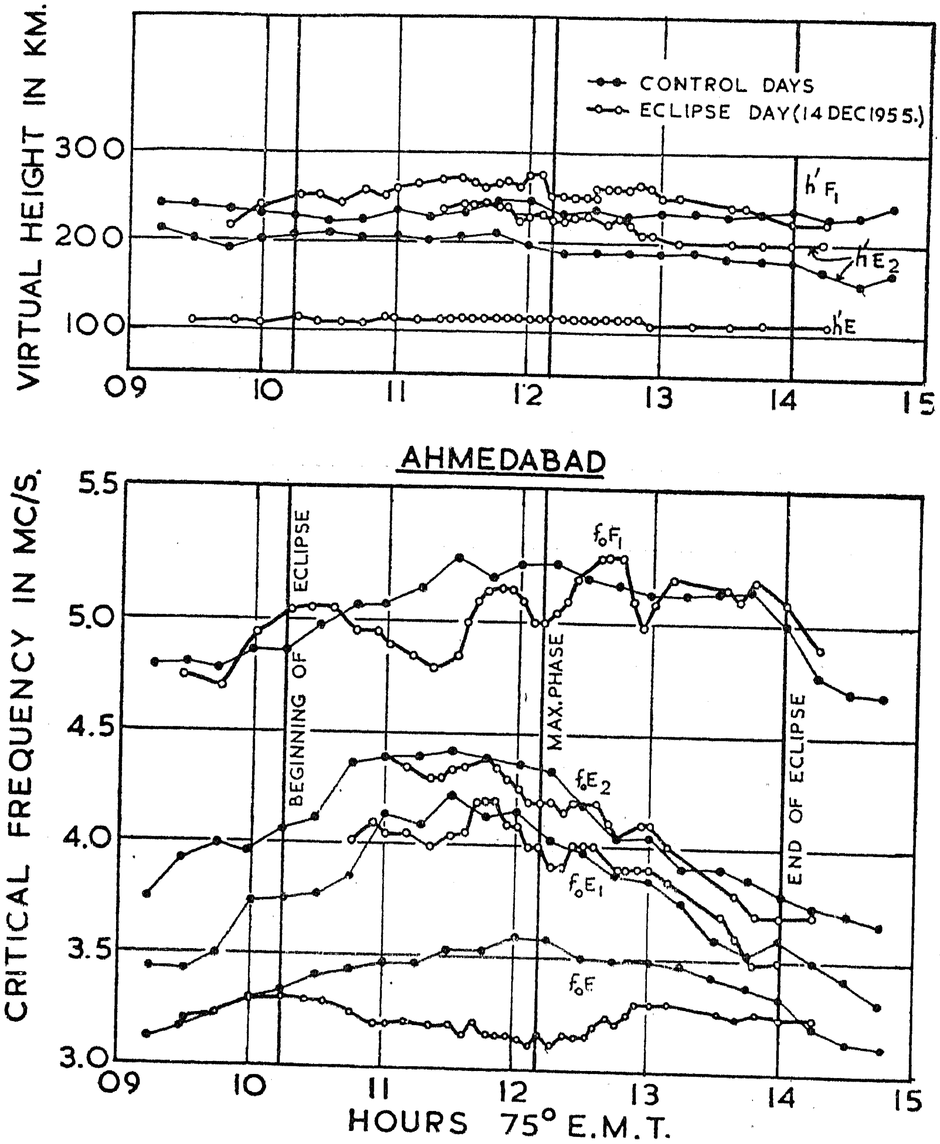

FIG. 2. The variation of critical frequencies and virtual heights of E, E_1, E_2 and F_1 layers on control days and on the eclipse day.

E layer.—As expected, the E layer critical frequencies decreased from the start of the eclipse and remained lower than the normal-day values during the entire period of the eclipse. The dip in f_0E during the eclipse was flat, as the eclipse occurred at noon and was only partial. The minimum virtual height of E did not show any change during the eclipse. The critical frequencies of the E layer on different control days are plotted against the corresponding values of $\cos \chi$ on double logarithmic paper in Fig. 4. The straight line nature of the curve joining the points indicated that f_0E varied with solar zenith distance according to the relation $f_0E = k \cos^n \chi$. The values of k and n on the control days are given in Table II.

TABLE II

December 1955	kE	nE
11	4·10	0·42
12	4·00	0·38
13	4·10	0·33
16	4·05	0·35
Mean ..	4·06	0·37

Ratcliffe (1956) has shown that during a solar eclipse

$$\frac{N_1^2}{N_0^2} = \frac{S_1 \cos \chi_1}{S_0 \cos \chi_0},$$

where N is the maximum electron density, S is the flux of ionising radiation, χ is the solar zenith angle and the subscripts 1 and 0 refer *to the times when the ionisation is not changing with time.* We find that for the E layer, N_1^2/N_0^2 was equal to 1·27 whereas $S_1 \cos \chi_1 / S_0 \cos \chi_0$ equalled 1·67.

Appleton (1953) has shown that the recombination coefficient in the E region can be determined from the time delay τ of the maximum of f_0E behind noon according to the equation

$$\tau = \frac{1}{2\alpha N}.$$

Using the above equation the value of α E was found to be $0 \cdot 78 \times 10^{-8}$ cm.^{3} sec.$^{-1}$ In Fig. 5 the variation of maximum electron density in E layer observed on control days and on the eclipse day are compared with the theoretical variations calculated for the period of the eclipse with assumed values of $\alpha = 0 \cdot 75 \times 10^{-8}$ and $0 \cdot 8 \times 10^{-8}$ cm.^{3} sec.$^{-1}$ Neither of the theoretical curves satisfied the observed points. The observed values were lower than the theoretical values during the first half of the eclipse, while they were higher during the latter half of the eclipse. Similar early falls of $_{f}$oE have been observed by other workers (Pierce, 1948; Minnis, 1955; Szendrei and McElhinny, 1956). This asymmetry has been attributed to the non-uniform distribution of the sources of ionising radiation on the solar disc.

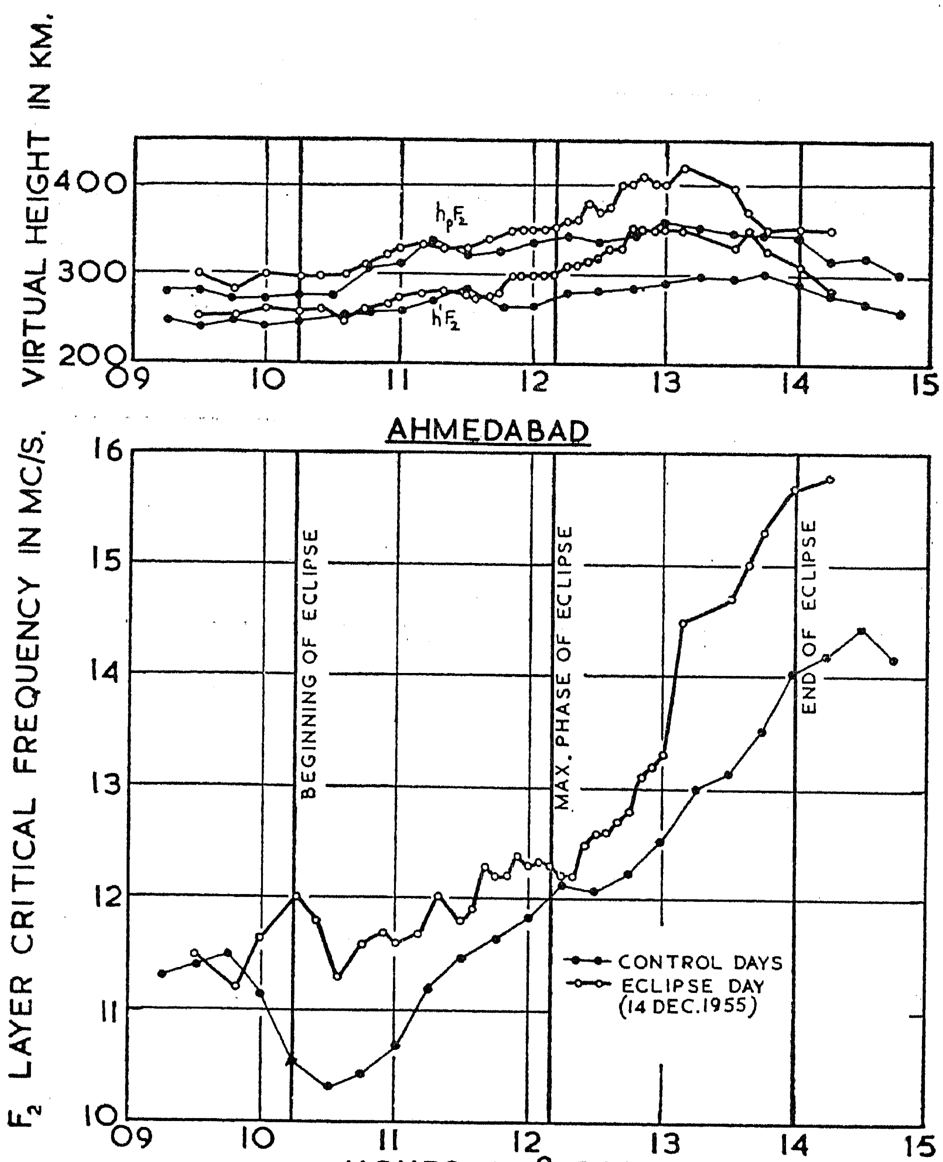

FIG. 3. The variation of critical frequency (f_oF_2), minimum virtual height ($h'F_2$) and virtual height at $0 \cdot 834 \times f_oF_2$ (h_pF_2) of the F_2 layer on control days and on the eclipse day.

E_1 and E_2 layers.—Besides the normal E layer two more intermediate layers, called E_1 and E_2, are regularly observed at Ahmedabad (Rastogi, 1954; 1956). The eclipse occurred at the time when E_1 and E_2 layers were being

formed out of the ledge in F_1 layer. The effect of the eclipse was not so clear on E_1 and E_2 as on E.*

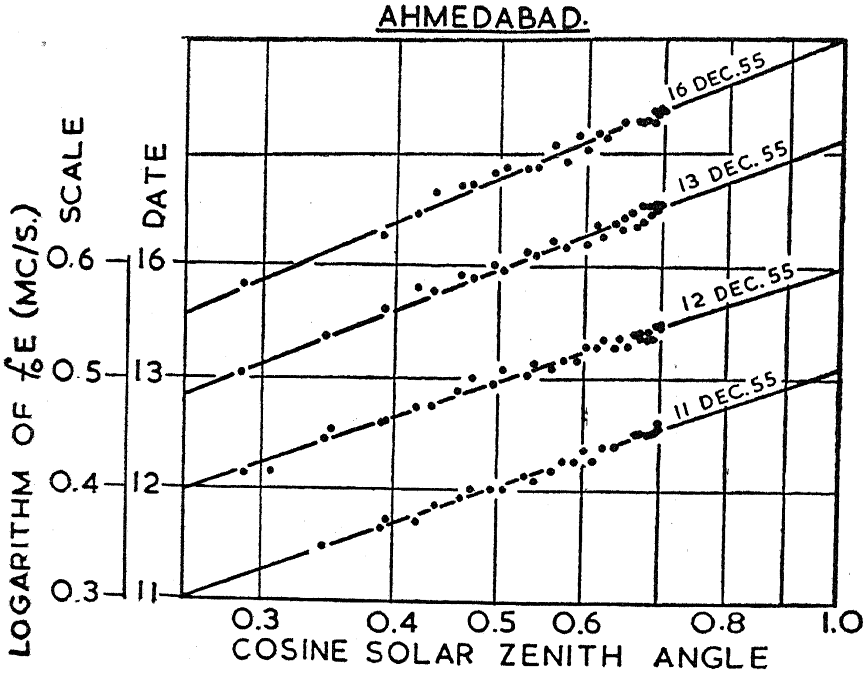

FIG. 4. The variation of the critical frequency of the E layer with the zenith angle of the sun.

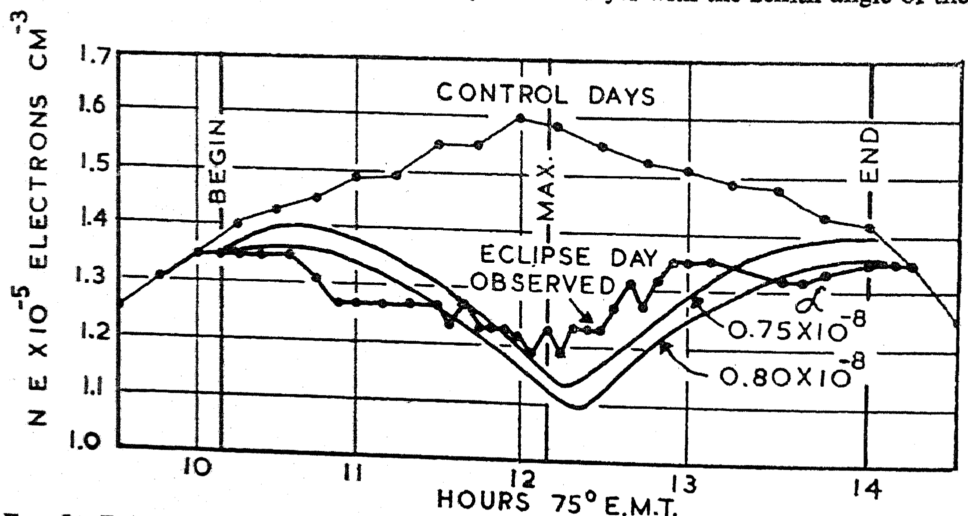

FIG. 5. Expected variation of f_0E with assumed values of α and the observed variation on the eclipse day.

F_1 layer.—It is known that at most places, the F_1 layer is not quite clear during winter months and during times of high solar activity. At high lati-

* A decrease of E_2 layer ionisation during a solar eclipse was more clearly seen during another eclipse observed at Ahmedabad, *viz.*, on 20th June 1955, as shown in Fig. 6. Decreases of E_2 ionisation during solar eclipses have been observed by other workers Schafer and Goodall (1935), Estrabaud (1953), Szedenrei and McElhinny (1956), Bibl and Delobeau (1956).

tudes it is observed only in the summer months in the middle of the day. At Ahmedabad the F_1 layer was most defined during summer and in the period of low sunspot activity. In December 1955, solar activity had increased considerably and the F_1 layer was not very clear. On the control days, the

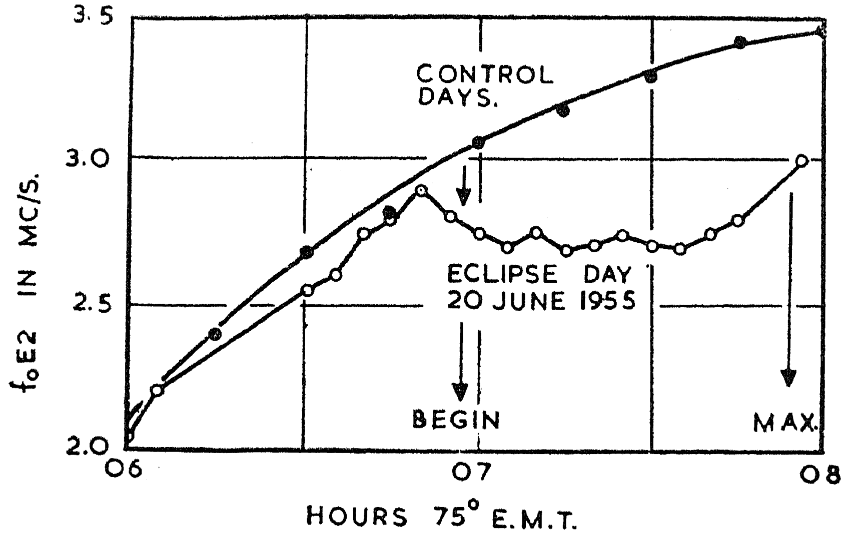

FIG. 6. The variation of f_0E_2 during the eclipse on 20th June 1955 at Ahmedabad.

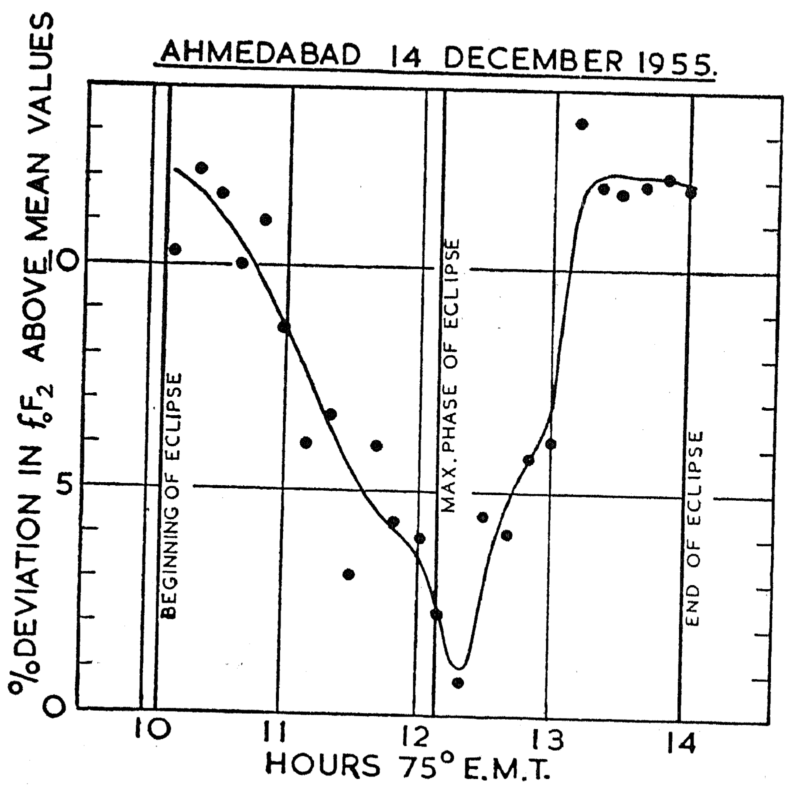

FIG. 7. Percentage deviation of F_2 layer critical frequency on the eclipse day above the control day values.

F_1 layer never gave a sharp cusp on P′-f records and its presence could be detected on the P′-f traces only by a flat cusp. The f_0F_1 values given are the frequencies at the point of inflexion in the P′-f trace and do not represent the maximum electron density in the F_1 layer.

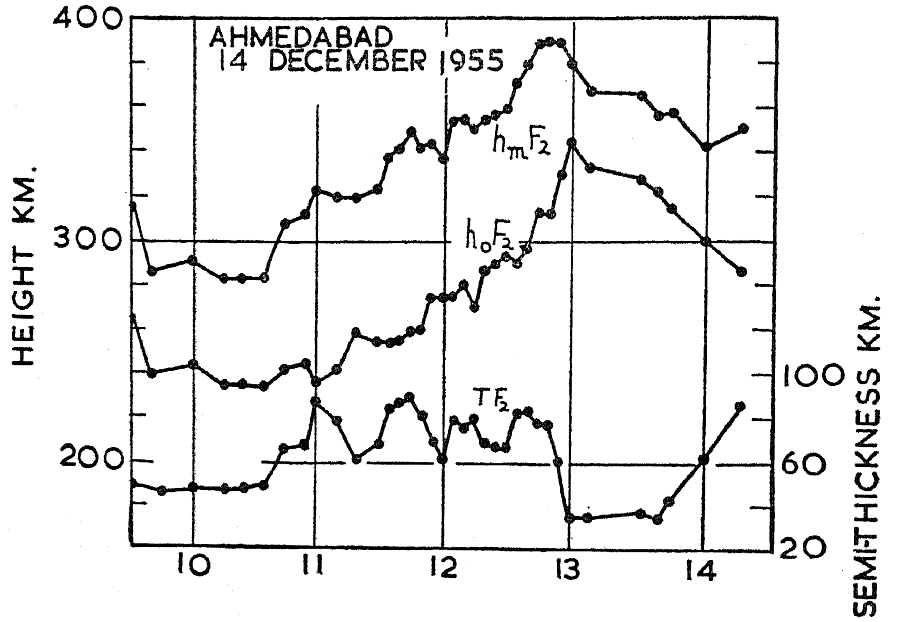

FIG. 8. Variation of the height of the base (h_0F_2) height of maximum ionisation (h_mF_2) and semi-thickness of the F_2 layer during the eclipse.

The f_0F_1 values during the eclipse showed a decrease but the data cannot be considered to be on par with those of the E layer.

F_2 layer.—On the eclipse day, f_0F_2 values were higher than those on the control days, during the entire period of the eclipse. The deviation of f_0F_2 on the eclipse day above the control day values was minimum at the middle of the eclipse as shown in Fig. 7. On control days f_0F_2 increased steadily from 10–14 hours with the same rate. On the eclipse day, the rate of increase of f_0F_2 during the first half of the eclipse was smaller than that on normal days, while after the maximum of the eclipse, f_0F_2 increased more rapidly than on normal days.

The minimum virtual height ($h'F_2$) and the virtual height at $0 \cdot 834 \times f_0F_2$ (h_pF_2) on the eclipse day were not very different from those on control days till about 1130 hours. After 1130 hours both $h'F_2$ and h_pF_2 increased above the control day values and reached the maximum at about 13 hours, after which they returned to normal at about 14 hours. The values of the semi-thickness (TF_2), the height of base (h_0F_2) and the height of maximum electron density h_mF_2 of the F_2 layer were determined by Booker and Seaton's method

(1940). The variations of these quantities during the eclipse period are shown in Fig. 8. The changes in the maximum electron density (N_mF_2) and the total electron content in a unit vertical column upto h_mF_2 ($nF_2 = 2/3\ T\ N_m{}^2$) are shown in Fig. 9. h_mF_2 increased shortly after the beginning of the eclipse,

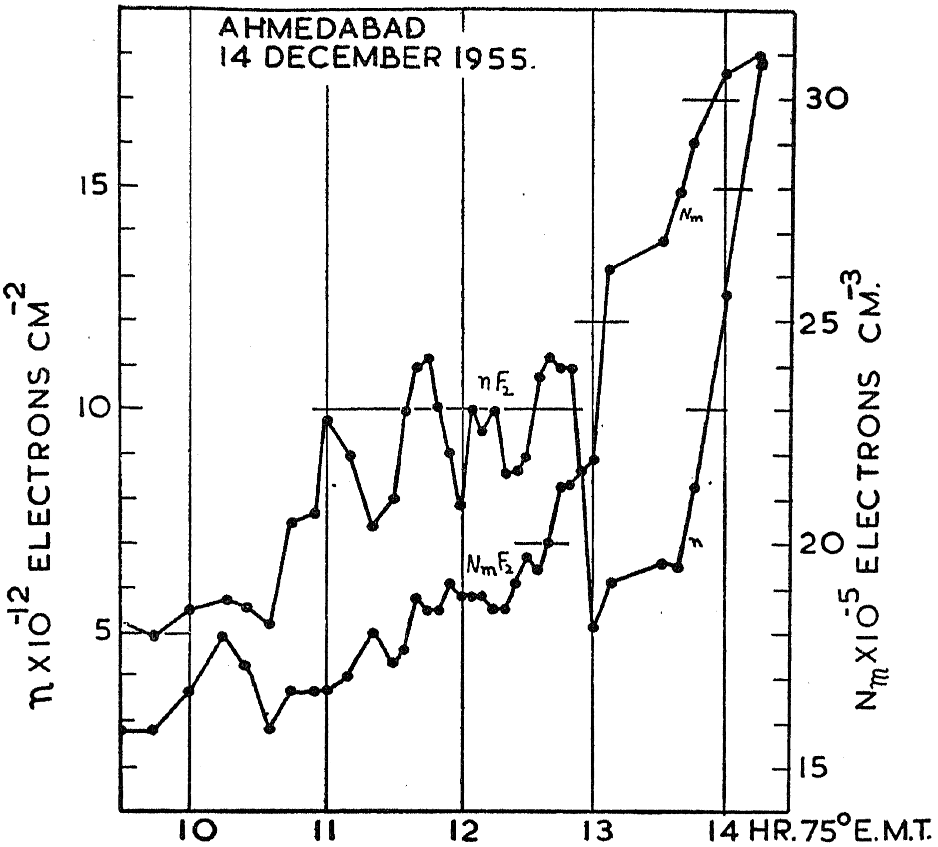

FIG. 9. Variation of the maximum electron density ($N_m F_2$) and total electron content (nF_2) of the F_2 layer during the eclipse.

reached a maximum about an hour after the maximum phase of the eclipse and dropped to its normal value after the end of the eclipse. h_0F_2 also increased similarly and reached a value as high as 340 km. at 13 hours. A few P'-*f* traces during the eclipse are redrawn in Fig. 10. It is easily seen that though the structure of the F_2 layer near the region of maximum electron density did not change much, the P'-*f* traces at the junction of F_1 and F_2 showed remarkable changes during the eclipse. The variation of virtual heights of reflection of a few fixed frequencies are shown in Fig. 11. Virtual heights of reflections of 5 Mc./s. and of 11 Mc./s. waves did not vary much during the eclipse while those of intermediate frequencies showed a maximum at about 13 hours. The height of reflection of the 6 Mc./s. wave showed the

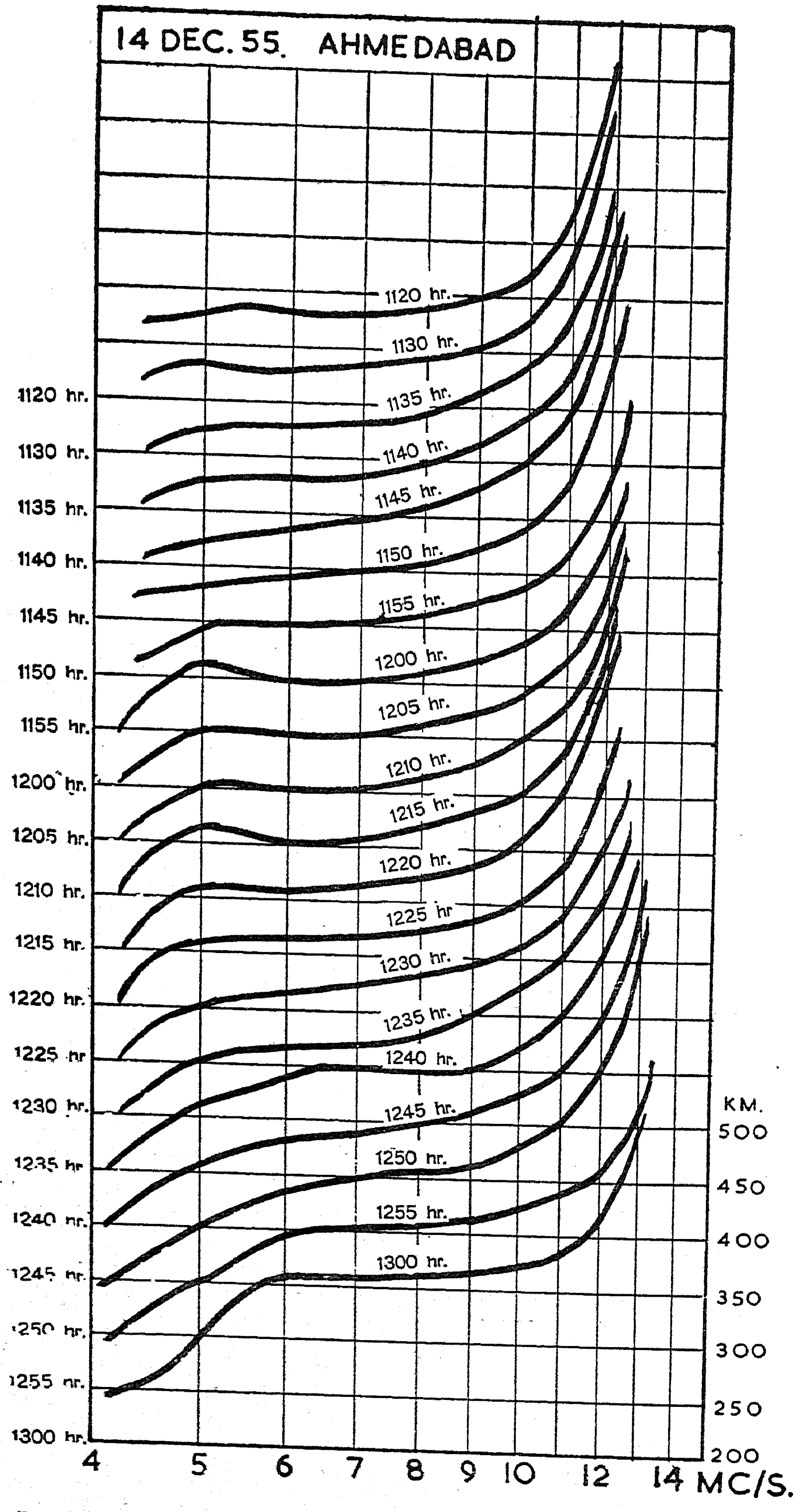

FIG. 10. A few redrawn P′-*f* records obtained on the eclipse day.

maximum change, which was probably at or about the junction of F_1 and F_2 layers.

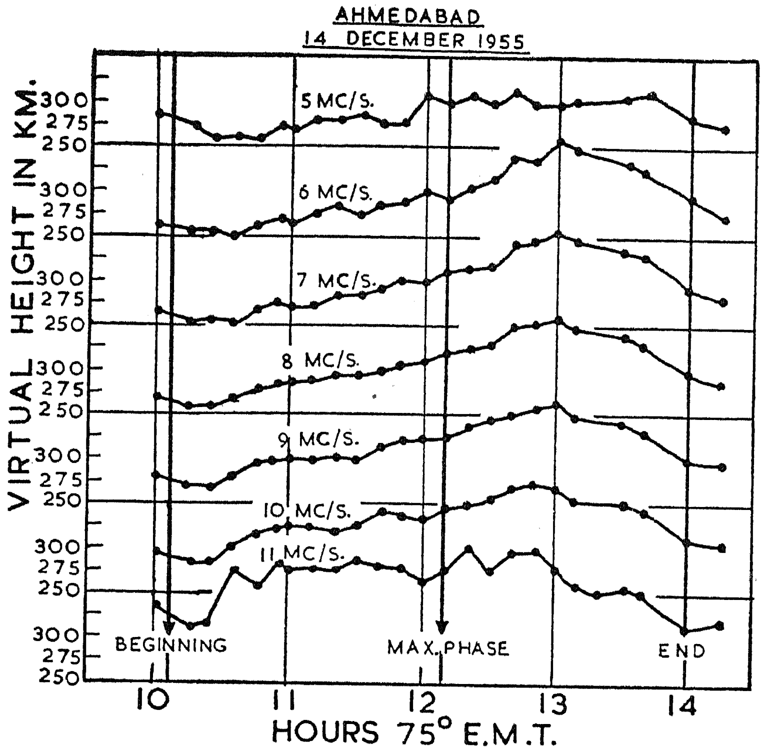

FIG. 11. The variation of the virtual height of reflection for a few fixed frequencies on the eclipse day.

Es layer.—There was no change in the sporadic E layer which could be attributed to the eclipse.

CONCLUSION

The behaviour of E layer during the eclipse was roughly consistent with that of Chapman layer with a recombination coefficient of about $0 \cdot 8 \times 10^{-8}$ cm.^{3}-sec.$^{-1}$

There was no clear effect of the eclipse on the E_1 and E_2 layers; the critical frequencies were lower on the eclipse day.

F_1 layer ionisation decreased during the eclipse but the variation was irregular.

The eclipse caused a fall in the rate of increase of f_0F_2. There was indication of the formation of $F_{1\frac{1}{2}}$ during the later part of the eclipse.

Es was not affected by the eclipse.

ACKNOWLEDGEMENTS

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