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Electric agitations in the atmosphere

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ABSTRACT. Atmospheric electrical agitation has been studied from observations of electrical potential gradient recorded for one year, November 1969 to October 1970 at Roorkee University, Roorkee. The pulse frequency of the agrimeter was 515 per sec., while the maximum frequency of electrical agitation is roughly of the order of ·005 per sec. The observed electric agitations have been explained as arising from climatic and atmospheric electrical variations and the effect of local influences.

1. Introduction

Electrical agitation is defined as the fluctuations in the potential gradient and other electrical elements whose periodicity is of the order of few minutes. Such agitation is caused by convection currents and cells, variations of space charge, the electrode effect, air turbulence and variations of the aerosol content of the atmosphere. Studies of these short-time fluctuations have been made by Israel (1958, 1959), Ogawa (1960), Bent and Hutchinson (1966) and Kamra (1969). The present paper presents the results of a study of electrical agitations in amplitude and frequency made from the observations of variations of potential gradient recorded for one year, November 1969 to October 1970 at Roorkee University, Roorkee. The amplitude of agaitation gives the total range of the fluctuations within one hour and is measured by the difference in the maximum values of potential gradient recorded within that hour. The frequency of agitation is defined by the number of secondary maxima and minima in one hour. They are represented by u_A and u_F respectively.

2. Equipment used

The electrical potential gradient was measured by means of an agrimeter (Kamra and Varshneya 1968), a differential D. C. amplifier and a strip chart pen recorder. Wind speed was recorded with a four cup anemometer and a separate strip chart pen recorder.

2.1. *Agrimeter* — The agrimeter installed at the Roorkee University, Roorkee consists of a horizontal iron shaft 40 cm long and supported by two ball bearings fixed on two very strong pillars on the two sides (Fig. 1). Over this shaft two perspex discs D_1 and D_2 of radius 12 cm and thickness 2 cm have been fixed at a distance 35 cm apart leaving 2.5 cm length of shaft on each side. Three more ebonite discs D_3, D_4 and D_5 of radius 12 cm and thickness 0.7 cm are also fixed on this shaft at equal distances between the perspex discs D_1 and D_2. Eight silvered copper plates T each having a size $35\times6\times0.3$ cm are fixed at equal distances (leaving equal space) on the rims of all the five discs and well clamped. A motor of 0.5 H. P. has been used to rotate the shaft with the help of pulleys and belt arrangement. On the opposite side of the motor and just outside the disc D_2 there is another perspex disc D_6 of radius 6 cm and thickness 2 cm provided with 16 equal copper sectors of breadth 2.1 cm all fixed on its rim. Each sector R is separated from the other sector by a distance of 0.2 cm and is well insulated from the adjacent sector. This arrangement forms the commutator (out of this arrangement of 16 sectors). Moreover each alternate sector is co-axially in line with one of the plates T and is connected with it with copper leads. Two carbon brushes B_1 and B_2 provided with springs always move on this commutator such that B_1 comes in contact with a sector when its corresponding plate is at the top and is horizontally flat, while the brush B_2 touches that very sector when its corresponding plate has moved through 60° with the vertical. The brush B_1 is connected with the earth while the brush B_2 is connected with the measuring instrument. Fig. 2 represents the side view of the agrimeter and commutator C. The output of the agrimeter from the carbon brush B_2 is fed through a co-axial wire to the amplifier.

2.2. *Effect of the agrimeter : Pulse frequency on the agitation frequency* — The value of grid leak

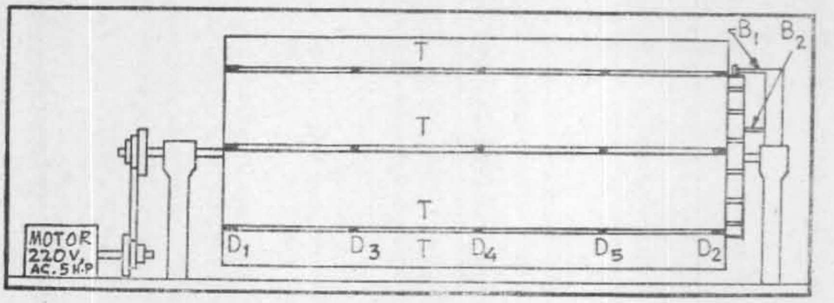

Fig. 1

Line diagram of agrimeter for recording the potential gradient

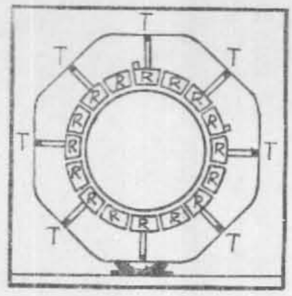

Fig. 2

Side view of agrimeter and commutator

resistance is 3.3×10^8 ohms and the capacity C between the rotating plate and the shielding plate is about 40 picofarad, so that the time constant RC of the arrangement is :

$$RC = 13.2 \text{ m.s.}$$

As there are 8 plates each of width 6 cm and separated by a space of 3.4 cm from one another and the radius of the agrimeter cylinder is 12 cm, the angle subtended by the width of plate at the centre of the cylinder is 28.6° and that subtended by the space of separation is 16.4°.

The cylinder rotates at the speed of 23.5 revolutions per second, its angular velocity

$$\omega = 2^{\pi} \times 23.5$$
$$= 147.8 \text{ rad. sec}^{-1}$$

The time taken by the plate in rotating through an angle of 28.6° = 3.4 m.s. and through 16.4° is 1.94 m.s.

The flow of charge through the plate is given by

$$Q = Q_0 \sin \omega t \qquad (1)$$

and the corresponding current is given by

$$I = \frac{dQ}{dt} = \omega Q_0 \cos \omega t$$

when the agrimeter plate of area 35×6 sq.cm is exposed to a potential gradient E Vm^{-1}, the charge developed on the plate is

$$Q_0 = \epsilon_0 A E = 1.86 \times 10^{-13} E \qquad (3)$$

(ϵ_0 being permittivity of free space=8.854×10^{-12} Farad/m)

Hence the maximum current

$$I_0 = Q_0 \omega = 0.275 \times 10^{-10} E \qquad (4)$$

Fig. 3 represents the rotation of copper plates with the shaft as the axis. To explain the development of the pulse we consider only two plates AB and CD having a space BC between them. At t=0, the first plate A just enters the slit made on the cover of the agrimeter and the charge starts developing (Fig. 3 a) and continues for a time 3.4 m.s. (the time taken by the plate to cross the slit), *i.e.*, till the end B reaches the slit (Fig. 3 b).

As soon as A goes out of the slit, the space reaches under the slit and the development of charge stops for a time, 1.94 m.s. (the time taken by the space to cross the slit). So the charge will start developing again after a time 1.94 m.s. The plate AB when rotated through 60° such as to make contact with the brush B_2 (Fig. 3 c) gives out the pulse and after a gap of 1.94 m.s. the pulse is again given by the next rotating plate. Thus the time interval between every two consecutive pulses is 1.94 m.s. The total charge develops on the plate in half the time it crosses the slit which can be shown by a quadrant of the sine wave OX (Fig. 4). The charge then leaks to the resistance with a time constant RC=13.2 m.s. according to XM (Fig. 4). At the instant when the succeeding plate enters the slit to take its place, it follows the same pattern of development and leaking of charge. But this happens with a time lag of 1.94 m.s. Each successive pulse would have the same time lag and pulses are shown in Fig. 4. The resultant pulse has been shown there by thick line which is more or less a saw-tooth wave. The frequency of the pulse developed on the agrimeter has been solved by Fourier analysis and its value has been found of the order of 515 approximately.

These considerations of the frequency of the output signals are relavant for consideration of the electrical agitation frequency, whose highest value has been found to be roughly 20 per hour or 0.005 per sec.

This is much smaller as compared to the pulse-frequency of the agrimeter. Hence the pulse frequency of the agrimeter is in no way reflected in the agitation frequency which is a genuine atmospheric phenomenon.

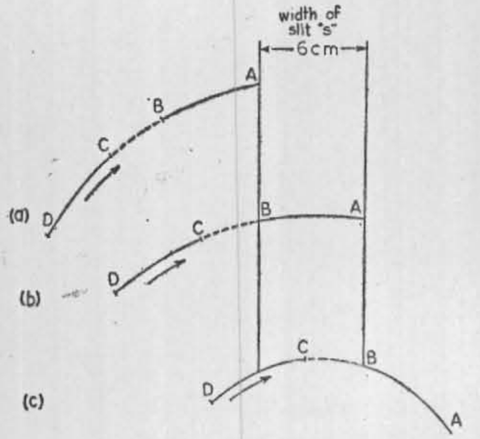

Fig. 3

Rotation of copper plates of the cylinder across the slit made in the cover of the agrimeter

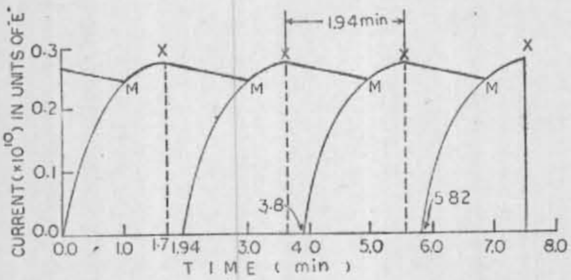

Fig. 4

Graph showing development of pulse with time in agrimeter

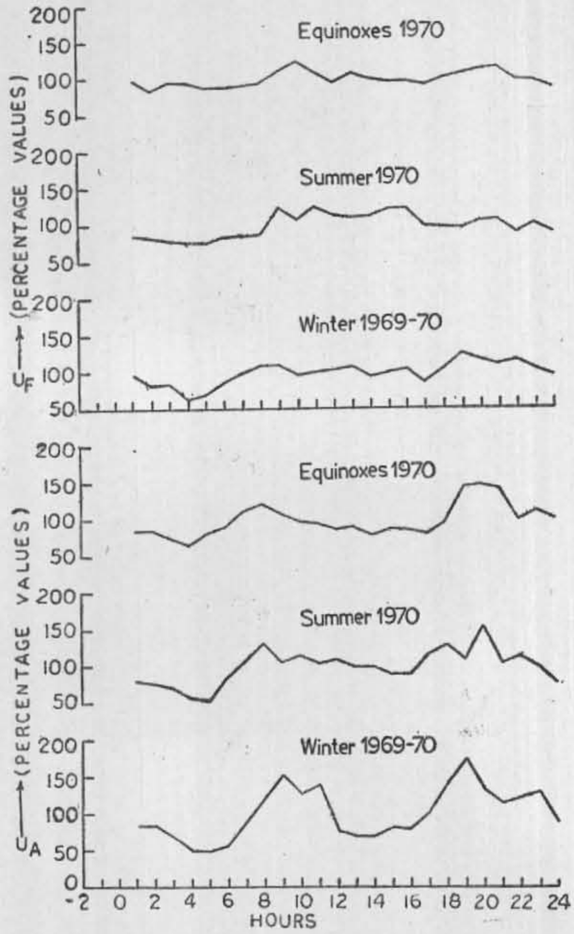

Fig. 5

Seasonal variations of electrical agitations (amplitude and frequency) in potential gradient

3. Diurnal and seasonal variations of electrical agitation

From the recorded values of potential gradient, the hourly values of u_A and u_F for various months were calculated and plotted against time for all the months.

To study the nature of diurnal variation in electrical agitation with season, hourly average values for fair weather days were calculated for winter (November to February), summer (May to August) and the equinoxes (March-April and September-October) separately. Fig. 5 shows the diurnal variation of u_A and u_F respectively for the three seasons of the year. The values are represented as percentages of the respective 24-hr mean values for the corresponding season.

3.1. *Amplitude agitation* — The amplitude agitation u_A shows a double periodic variation in all months and all seasons, the first maximum occurring in the forenoon (8 to 10 hr) and the second maximum in the afternoon (19 to 20 hr).

The variation in u_A from its mean value of the corresponding month (season) is different for different seasons being maximum in winter and minimum in early summer.

3.2. *Frequency agitation* — The frequency agitation u_F shows a double periodic variation from November to March, but later on tends to become single periodic from April to June and becomes double periodic from July to October. During winter and equinoxes with double periodic variation, the two maxima are recorded in the forenoon (8 to 10 hr) and afternoon (19 to 20 hr) respectively, while in summer with single periodic variation the central maximum falls almost at noon.

The variation in u_F from its mean value of the corresponding season is different for different seasons being maximum in winter and minimum in early summer.

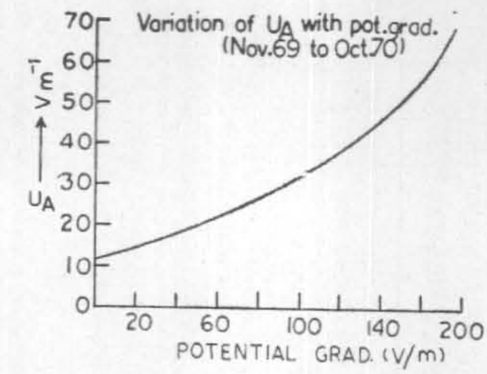

Fig. 6
Variation of electrical agitation (amplitude and frequency) with potential gradient for November 1969 to October 1970

TABLE 1

Factor	1969		1970									
	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct
u_A (Vm^{-1})	36·0	24·0	28·0	31·0	28·0	35·5	26·0	28·0	23·0	22·0	26·4	25·6
u_F (cycle/sec)	8·7	6·5	7·1	6·0	5·8	6·6	6·6	6·3	7·4	7·4	6·6	8·1

3.3. *Monthly and seasonal values of electrical agitation* — The absolute values of u_A and u_F for all months from November 1969 to October 1970 are given in Table 1 and for the three seasons are shown in Table 2. Both u_A and u_F are higher in winter than in summer.

4. Variation of electrical agitation with electrical potential gradient

To explain the variation of electrical agitation with potential gradient, Israel (1959) and Ogawa (1960) had taken the average values of potential gradient and amplitude agitation for some individual fair weather days and prepared diurnal variation curves. In order to obtain a better understanding of the relation of the electrical agitation with the potential gradient we have first calculated the hourly average values of potential gradient, amplitude and frequency agitation for all the months separately and then all possible values of u_A and u_F corresponding to a particular hourly average value of potential gradient (within 5 Vm^{-1}) have been selected and grouped together. The average of all such values has been calculated. The process has been repeated for various values of potential gradient (ranging from 20 to 180 Vm^{-1}). From these different sets we have drawn the variation curves for amplitude agitation and frequency agitation separately. Figs. 6 and 7 represent these variation of u_A and u_F respectively with potential gradient.

TABLE 2

Factor	Seasons		
	Winter	Equinoxes	Summer
u_A (Vm^{-1})	30·0	29·0	25·0
u_F (cycle/sec)	7·1	6·8	6·9

4.1. *Variation of u_A with potential gradient* — It is seen from Fig. 6 that the amplitude agitation u_A increases gradually with the increase of potential gradient upto 50 Vm^{-1} and increases rapidly for higher values of potential gradient. Thus our results are different from the results obtained by Israel (1959) and Ogawa (1960) who had found this variation to be linear. The difference in the nature of variation curve is more predominant for lower values of potential gradient. Secondly, in our curves there is almost no scattering at all as compared to that found in the curves obtained by Ogawa and Israel.

4.2. *Variation of u_F with potential gradient* — Fig. 7 represents the variation of frequency agitation with electric potential gradient. The value of electric frequency agitation fluctuates in an irregular way and does not appear to have any particular relation with potential gradient.

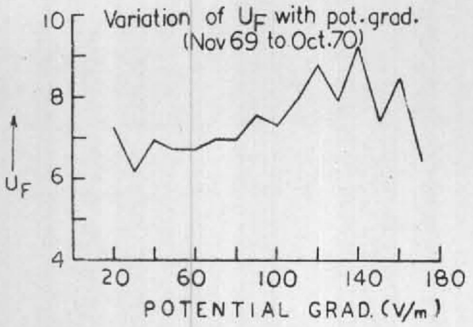

Fig. 7

Variation of electrical agitation (amplitude and frequency) with potential gradient for November 1969 to October 1970

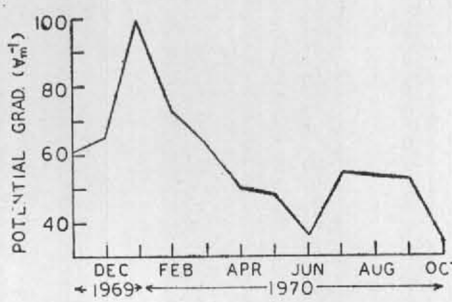

Fig. 8

Monthwise variation of potential gradient for November 1969 to October 1970

4.3. *Monthly variation of potential gradient* — In order to study the relation between the monthly variation in electric potential gradient and in electric agitation (amplitude and frequency) we calculated the average values of potential gradient for each month separately. Finally these average values of potential gradient have been plotted for all months as shown in Fig. 8.

We do not find any particular relation between the variation of electric potential gradient, the variation of amplitude agitation and the variation of frequency agitation. A similar result was also obtained by Ogawa and Israel.

5. Discussion of results and conclusions

Fluctuations in the atmospheric potential gradient usually arise either from (*i*) changes in the potential of the global atmospheric condenser or from (*ii*) changes in the conductivity of the atmosphere at the place of measurement. The short periodicity of electrical agitations indicates that these fluctuations are due to changes in the conductivity of the atmosphere, which are in turn caused either by changes in the space charge distribution or by changes in nuclei content of atmosphere.

Israel (1960) explained the electric agitation on the basis of atmospheric turbulence in which air masses of different origin have different aerosol content and cause changes in the atmospheric conductivity. It can be said that the atmospheric agitation is in general a direct result of the atmospheric exchange processes, which produce turbulence cells. These cells, due to their different aerosol content, have different conductivities and the various space charges thereby produced, give rise to change in the field and current at the station over which they pass.

Israel also found that in fair weather the electrical agitation was minimum at night and increased with time till noon. Contrary to these, our observations give very clearly two maxima in all months, one in the forenoon and another in the afternoon. The existence of two maxima confirms that atmospheric turbulence cannot be alone held responsible for the electric agitation.

Recently, Bent and Hutchinson (1966) have measured the space charge at different altitudes near the earth's surface and found that space charge variations coincided with the variations in wind speed, temperature and humidity. The presence of a few peaks in the space charge records were explained on the basis of turbulence cells rising from the earth's surface and carrying positive charge in them due to the electrode effect. The periodicity of these peaks being of the order of 10 minutes is in perfect agreement with the periodicity of the frequency agitation of potential gradient as mentioned in Table 1.

Following both the above arguments we suggest the following explanation for the production of electrical agitation.

We know that at the time of intense fields due to the electrode effect there is a concentration of positive space charge close to the earth's surface. The convection currents set up in the atmosphere carry this positive space charge columns rising in the atmosphere from the surface of the earth. These convection cells have almost the same frequency as that of the electrical agitation of potential gradient.

Secondly, turbulent winds raise dust particles from the surface of the earth. The aerosols in the atmosphere further increase the electrical agitation. Thus, in short, the main causes of electrical agitations are :

(*i*) Convection currents and turbulence cells

(*ii*) Variation of aerosol content

(*iii*) Variation of space charge.

The latter two factors cause the variation in the conductivity of atmosphere. Various factors become predominant under various conditions to cause electrical agitation in the atmosphere.

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