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The Variation of Atmospheric Electrical Conductivity as the Function of Altitude

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***Abstract:** In the present work we will calculate the electrical conductivity of atmosphere. Generally earth's atmosphere is about 480 km thick but most of it is within about 16 km. At different altitudes the meteorological conditions are different. In this work we will calculate the atmospheric electrical conductivity at different altitude.*

***Keywords:** Altitude, Electrical conductivity, Meteorological conditions.*

I. INTRODUCTION

Deshpande and Kamra [1] reported about aerosol concentrations of 13 to 1000 nm size and some meteorological parameters on the basis of three hourly measurements. AgainDeshpande and Kamra [2] made the surface measurements of atmospheric electrical conductivity during the 10thJanuary 1997 to 24th February 1997.The total conductivity does not show any substantial diurnal variation. At the ground surface the higher growth rate electric field is produced by lower thundercloud, which is responsible for maximum value of ground electric field. Thus the atmospheric electrical conductivity is affected at large extend by lower base thunderclouds.

Covert et. al. [3] suggest a model for construing their mid pacific observations. According to this model under suitable conditions the new particle forms in outflow regions of the frontal or convective clouds in the free troposphere. The condensation and coagulation are the suitable condition forgrowing the newly formed particles. The movement of aerosols from the free troposphere to the marine boundary layer are the cause of convective mixing in vertical and horizontally general circulation. The vapour deposition is the best process for the growing of these particles therefore in the marine boundary layer the growth of these particles is very faster because of the concentration of gases at that region.

In thunderstorm the electrical conductivity produced by the charged cloud and precipitation particles calculated by Kamra [4]. It is found that the conductivity increases with the precipitation intensity, electric field and the electrical charge on the particles and content of liquid water.

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II. THEORETICAL CONCEPT:

Mukku [5] suggested the use of Gerdien`s condenser for the measurement of atmospheric conductivities. This instrument is shown in figure 1.

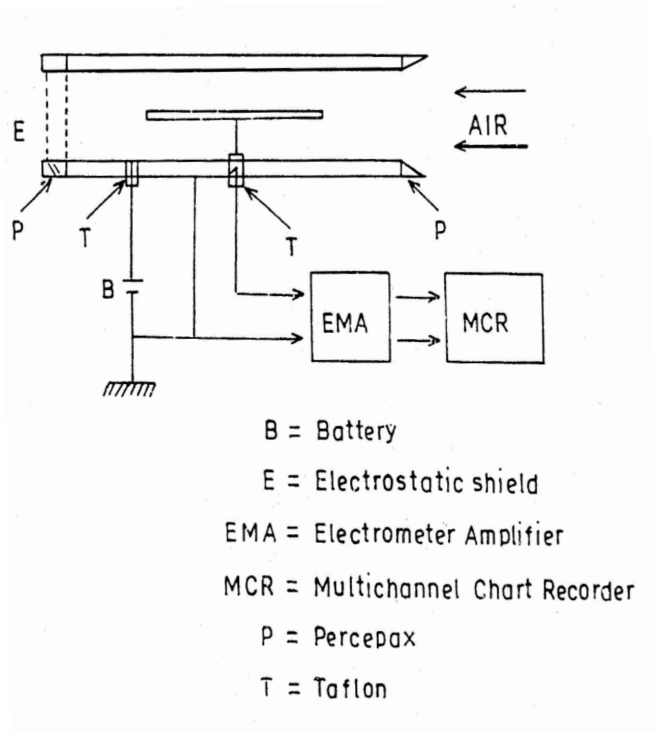

Fig.-1 The Gerdien`s Apparatus

The current voltage characteristics of the condenser are used for determination of conductivity of the air.

The total conductivity σ can be written as

$$\sigma = \sigma_p + \sigma_n \quad (1)$$

Here σ_p is the positive conductivity.

and σ_n is the negative conductivity.

Mukku [5] obtained the positive and negative conductivities from the measurement of output current of EMA (Fig. 1).

The current $i_p$due to positive ions is

$$i_p = Me\, n_p \frac{w_p}{w_e} \qquad (2)$$

Where M is the aspiration rate

e is the electronic charge

n_p is the number of positive ions

w_p is the mobility of positive ions

w_e is the critical mobility of ions.

Similarly the current i_n due to negative ions is

$$i_n = \frac{M\,e(n_n W_n + n_e W_e)}{W_e}$$

$$= \frac{M\sigma_n}{W_e} \quad (3)$$

\Where n_n is the number of negative ions

n_e is the number of electrons

and W_n and W_e are the motilities of negative ions and electrons respectively.

The critical mobility is given by

$$W_e = 2.6624 \text{ x } 10^4 m^2 V^{-1} s^{-1}$$

The atmospheric electrical circuit is explained by the help of a model which comprise the pollution close to the earth's surface due to aerosol particles of anthropogenic and volcanic origins, due to acute electric field below the thunderclouds in the atmospheric layer and due to ionization by the coronal discharges.

With the help of this model the effect of solar activity and stratospheric aerosol particles on the circuit have also been studied.

The variation of atmospheric conductivity at different height have been calculated from the known variation of ionizations.

The small positive and negative ions concentration is

$$n = \frac{2q}{[\beta N_0 + ((\beta N_0)^2 + 4\alpha q)^{0.5}]} \quad (4)$$

Where q is the ionization rate due to cosmic rays and radioactivity, α is the recombination coefficient, N_0 is the concentration of aerosols of all sizes and β is the effective ion attachment coefficient.

Manes [6] assumed the value β is $3 \text{ x } 10^{-12} m^3 s^{-1}$.

The atmospheric electrical conductivity λ is mainly determined by the highly mobile small air ions concentration n through the relation as follows

$\lambda = nek$ (5)

Where n is the concentration of ions

e is the electrical charge of highly mobile small air ions

and k is the mobility.

Basically, λ is related to concentration of air pollutant through demolition processes of small air ions due to recombination or neutralization of small ions with opposite charges and attachment of the small ions to large particles.

Israel[7] described it in the following form –

$\frac{dn}{dt} = q - \propto n^2 - \beta n N$ (6)

Here q is the small ion formation rate by radioactive and cosmic sources,

$\propto$ is the recombination coefficient.

β is the attachment coefficient.

N is the number of large particles.

and t is the time

Tverskoi [8] explained that the ion concentration n is controlled by the ion production process from radioactivity, cosmic rays, UV radiation etc.

and by the ion destruction process from recombination or neutralization and attachment with large molecular and aerosol particles.

Within the thunder cloud the value of conductivity is uncertain.

The ion have extremely low mobility inside the cloud.

III. ELECTRICAL CONDUCTIVITY IN AND ABOVE THE THUNDER CLOUD

Within the thunder cloud the value of conductivity is uncertain. The ion have extremely low mobility inside the cloud. At the cloud boundaries there are the regions of shielding charges are the evidence of low conductivity.Evans [9] and Kamra [10] suggested that the conductivity within the

thundercloud is 10 to 18 times greater than that of clean air conductivity.

The altitude profile of atmospheric conductivity $\lambda_c(Z)$ can be written as

$$\lambda_c(Z) = \lambda_{CN}\, exp\left[-\frac{(Z - Z_G)}{S_c}\right] \quad (7)$$

Where λ_{CN} is the conductivity near the earth`s surface

$(Z\text{-}Z_G)$ is the altitude above the sea level

and $S_c = -Z_n / ln(\lambda_G / \lambda_{CN})$ (8)

Where Z_n is the height of negative charged region of thunderstorm above the groundand λ_G is the ambient conductivity at the altitude Z_n.

From the equation (7) and (8) the calculated values of electrical conductivity $\lambda_c(Z)$ as the function of altitude Z_n are shown in Table-I.

Table-I calculated values of electrical conductivity $\lambda_c(Z)$ as the function of altitude Z_n

Altitude Z_n (x 10^2) m	S_c	Electrical conductivity $\lambda_c(Z)$ (x 10^2) S/m
5	15.787	580
10	32.076	500
15	46.509	450
20	61.531	400
25	76.478	340
30	91.243	300
35	105.984	280
40	116.733	260
45	130.884	260
50	144.764	270
55	158.388	300
60	172.049	370

and the variation of electrical conductivity $\lambda_c(Z)$ with altitude Z_n shown in Figure 2.

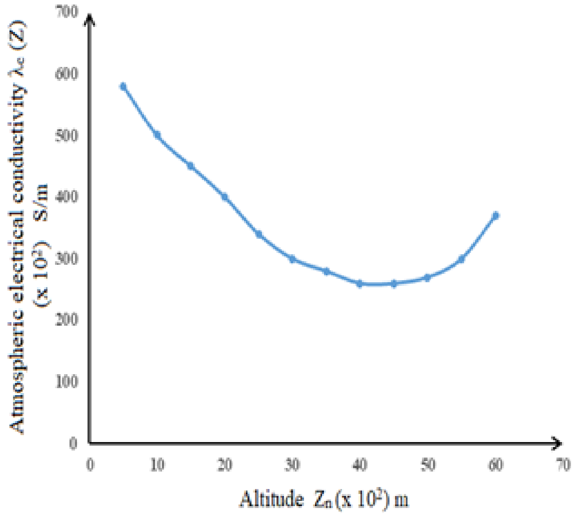

Fig.-2 Variation of electrical conductivity with Altitude

IV. RESULT AND DISCUSSION:

By using equation (7) and (8) the altitude profile of atmospheric electrical conductivity $\lambda_c(Z)$ is calculated at the time when thundercloud is active. The Table I shows these calculations. We have consider the conductivity near earth's surface (λ_{CN}) to be order of magnitude higher than its ambient value as $\lambda_{CN} = 4.4 \text{ x } 10^{-13}\ s/m$. We find that as Z_n is increases the $\lambda_c(Z)$ decreases exponentially. The value of $\lambda_c(Z)$ is minimum at$Z_n = 4500$ m and above the value of $Z_n = 4500$ m the $\lambda_c(Z)$ increases. Thus the value of $\lambda_c(Z)$ depends on the conductivity λ_G and altitude Z_n. Also at altitude 6000 m the λ_G and $\lambda_c(Z)$ both are remain same and at higher altitude both are increase.

V. CONCLUSION:

From the table-I and figure-2 we can conclude that the electrical conductivity decreases with altitude near the ground. As the altitude increases the conductivity decreases and attain a maximum value at the height 4000 m to 4500 m. if altitude further increases it starts again increase in order.The main reason of decrement of electrical conductivity is the decrement of ion concentration, because of ion get attached with aerosol particles or CCN and other particles present in the atmosphere. Due to this reason at higher altitude the conductivity increases because ion concentration also increases at this altitude. The reason of enhancement in concentration of ions is the ionization caused by galactic cosmic rays.

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