ON THE MEASUREMENT OF THE ELECTRICAL POTENTIAL GRADIENT IN THE UPPER AIR OVER POONA BY RADIOSONDES

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1. INTRODUCTION

IT has been considered for some time that measurements of electrical potential gradient may provide an exact method of identification of air masses in the upper air, but it could not be measured so far due to the want of a simple and reliable device for the same. A number of methods are available for the measurement of the electrical potential gradient near the ground, but, in most of them the equipment used is not easily portable and cannot therefore be adapted to measure the distribution of this element in the upper air with the help of balloons. A simple method of using a tetrode valve as an electrometer was devised by R. P. Lejay[1] and used by Idrac[2] for measuring the electrical potential gradient in the atmosphere. This was not found satisfactory as the losses were considerable. In this system the controlling electrode of the valve, namely the grid, was in the electron stream from the filament to the plate and can therefore account for the losses. Recently R. E. Belin[3] has described another system employing discharge points in association with the audio frequency modulated type of radiosonde used in the U.S.A., but objections can be raised on these methods also, as they cannot function satisfactorily when the potential gradient varies suddenly; the temperature of the air will also have an effect on the discharge points.

L. Koenigsfeld and Ph. Piraux[4] have described a simple portable electrometer using the HL 23 valve to measure the atmospheric potential, and have shown how it can be adapted for use with the type of radiosonde employed in Belgium. The transmitter in the radiosonde described in this paper was working on a wave-length of about 10 metres and the frequency of modulation of the carrier wave gave successively the measurements of temperature, pressure and humidity. The frequency modulation due to the changes in the meteorological elements is caused by varying the inductance due to the changes in the air gap. In adapting this instrument to measure the electrical potential gradient in the atmosphere with their valve electrometer, they kept the air gap constant, and the coefficient of self-induction of the iron bobbin was controlled by the current from the valve electrometer. The current from the valve electrometer depended upon the potential gradient.

A radiosonde equipment of the type used by the U.S. Army during World War II was available at the Meteorological Office at Poona. The meteorological elements are measured with this type of instrument from the audio frequency modulation of a carrier wave on about 4 metres (72·2 mcs.). The signal is modulated by varying the resistance in the meteorological control circuit by means of resistors. An attempt was made to see whether this type of radiosonde can be used with the valve electrometer devised by Dr. Koenigsfeld to measure the electrical potential gradient in the atmosphere. The method adopted and the observations made at Poona on a few days are described in this paper.

2. The Valve Electrometer of Dr. Koenigsfeld and Piraux

The electrical potential gradient in the atmosphere can vary near the ground in the clear weather between 10 and 200 volts per metre and the electrometer employed for this purpose should consume only an extremely feeble current. Generally, lead nitrate fuses or radioactive substances like polonium or ionium are used as "collectors" for measuring the electrical potential, and the air-collector resistance is of the order of about 5×10^{10} ohms. Therefore the smallest leakage current in the measuring apparatus would cause voltage changes that would completely falsify the measurements. Koenigsfeld and Piraux have shown a method of measuring these potentials with a Mazda HL 23 valve, by keeping the leakage losses at a minimum value.

Firstly, they removed the base of the valve whose insulation was found to be unsatisfactory.

Secondly, there can be losses due to the grid current in the valve depending on the mode of use. The chief causes when used as Type A amplifier are:

(1) Electronic grid current due to the initial speed of electrons which reach the grid insufficiently polarised.

(2) Ionic grid current due to the attraction of a negative grid on positive ions produced by the collision of electrons emitted by the cathode against the molecules of residual gases.

(3) Electronic grid current.

(4) Photo-electric current generated by external light or by X-rays emitted by the anode at the time of impact of electrons.

It is clear from the above that the valve cannot be expected to function as an electrometer in the normal way. Koenigsfeld and Piraux have modified the use and have employed the plate instead of the grid as the governing electrode of the valve. They have also shown that by this innovation, the leakages referred to above can be reduced to a negligible value. The only extra precautions to be taken in designing the apparatus are in enclosing the valve in a light tight box to reduce photo-electric effects and by employing polysterene wires to obtain suitable insulation. They have also recommended the use of the acorn triode 958 A in which the leakages by insulation defects were less than in the case of HL 23.

3. The Method Adapted for Using the Valve Electrometer with the American Radiosonde to Measure the Electrical Potential Gradient

The American radiosonde consists of two oscillators operating on a frequency of about 1 mc. and 70 mcs. respectively (Fig. 1). The 1 mc.

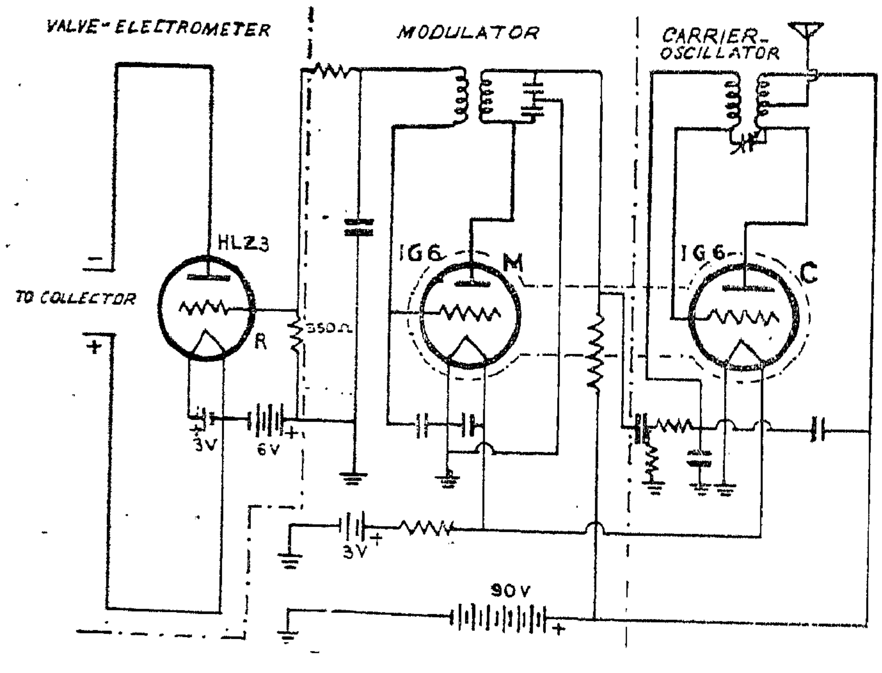

FIG. 1

oscillator is the modulating oscillator (M) and is of the squegging type. The other is the carrier oscillator (C), also of the squegging type and is "on" when M is "off" and *vice versa*, thus in effect producing a frequency modulation of the carrier oscillator. The modulating frequency of the oscillator M is controlled by the RC combination in the grid circuit. Hence by varying the value of the resistance R in the grid circuit, the modulating frequency is altered. In the American radiosonde the signal is modulated by varying the resistance in the meteorological control circuit by means of resistors sensitive to temperature and relative humidity. It also contains a baro-switch with a contacting arm moving on a commutator due to the changing pressures and it indicates the pressure values during the sounding and switches into the control circuit in a definite order, the temperature, humidity and standard reference resistors.

In adapting this radiosonde for use with the valve electrometer, the resistances for measuring the temperature and humidity were removed and in their place a negative bias developed in the valve electrometer circuit was applied in the grid circuit of the modulating oscillator M. The modulating frequency depended on the amount of bias applied.

A positive voltage of the order of 6 volts is applied through a resistance (R) of about 350 ohms in the grid circuit of the HL 23 valve (Fig. 1). The voltage and resistance in the grid circuit being fixed, the current through R will be controlled by the negative potential applied on the traditional plate. If this bias voltage is applied in the grid circuit of the modulating oscillator M of the American radiosonde, the modulating frequency of the carrier oscillator will be a measure of the negative potential on the plate circuit of the HL 23 valve.

To measure the electrical potential gradient in the atmosphere, the two collectors (either lead nitrate fuses or polonium collectors) were fixed on polysterene insulators and hung at a known distance of one or two metres. The lower collector was connected to the plate of the HL 23 valve and the upper collector to the negative side of the filament. As generally in the atmosphere, the electrical potential increases with height, the effective potential on the plate of the HL 23 valve will be negative, and the modulating frequency of the carrier oscillator will be a measure of the potential gradient in the atmosphere.

In an actual sounding, the HL 23 valve and its leads were well insulated with polysterene sheets and alkathene sleevings and placed in a cardboard box with holes at proper places for the leads and fixed inside the American radiosonde in the space for the temperature and humidity elements, and covered with the flaps to reduce external light to a minimum. Before releasing the instrument it was calibrated by applying different known voltages from a H.T. battery to the HL 23 valve at the collector terminals and the audio frequency modulation measured on the radiosonde recorder. A calibration curve is drawn with the data thus obtained. The baro-switch on the radiosonde is also adjusted suitably after reading the atmospheric pressure on the ground.

As the modulated frequency which is a measure of the electrical potential gradient, depends on the voltage developed across the resistance R (350 ohms) in the grid circuit of the HL 23 valve, it is essential to see that the value of this resistance does not change with the large fall in temperature experienced during the ascent. This resistance was therefore specially wound with constantan wire.

It is also necessary that the batteries used in the sounding are of suitable capacity. For this purpose light acid batteries, after charging suitably, were used with the radiosonde transmitter.

Both lead nitrate fuses and polonium were used during the few ascents so far made to measure the potential gradient. Dr. Koenigsfeld was kind enough to spare a few polonium collectors for our use. These collectors were of pure silver plates, about one square centimetre in area and about 1/10 mm. thick, dipped in a solution of Radium D, and the emission from these collectors were estimated to be more than 40,000 α per minute. They were fixed in polysterene sheets and separated by a distance of two metres, one vertically below the other. The leads from these were also covered with alkathene or polysterene sleevings to keep the leakage losses at a negligible value.

When polonium collectors were not available, burning lead nitrate fuses were employed. These fuses were made by dipping narrow strips (about $\frac{1}{4}''$ wide, $\frac{1}{8}''$ thick cardboard pieces, about $2'$ in length) in a solution of 5% lead nitrate and drying them. Two of these strips were tied together from opposite sides of a steel wire, supported on polysterene on a wooden frame. Two such units, at a distance of two metres, formed the collectors. They were ignited just before release, and laboratory trials showed that these fuses could burn for nearly half an hour.

But it may be mentioned in this connection that polonium collectors should be preferred to lead nitrate fuses, as they are more handy and can be expected to function in any weather. Moreover, polonium collectors are more active and will attain the surrounding potential much faster than lead nitrate fuses—2 to 3 seconds as against 8 to 10 seconds. The radiosonde and collectors were suspended from the balloon by a chord of 50 metres with polysterene insulators in the middle in order to isolate the radiosonde from the balloon which can acquire electrical charges by friction in the air.

During the ascent, the baro-switch on the radiosonde keeps the valve electrometer connected to the transmitter except occasionally when the contact arm connected to the aneroid moves to the commutators corresponding to previously calibrated pressure values, when the modulated signal at a fixed frequency of about 180 c/s. is received. Thus a record of the modulated frequency due to electrical potential gradient is obtained almost continuously with occasional breaks of short duration when the pressure signals are obtained. From these one can easily evaluate the variation of potential gradient with height.

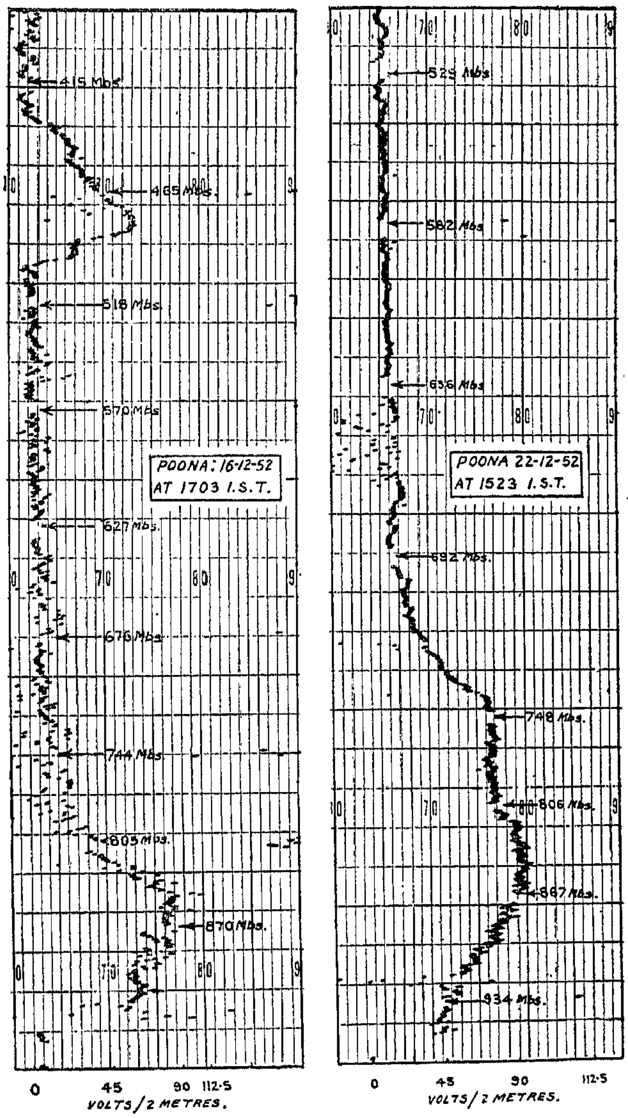

FIG. 2

To record positive potential gradient, the plate of the HL 23 valve is onnected to the lower collector and the filament to the upper. If negative gradients are to be measured, the connections are reversed. But to measure positive and negative potentials during the same sounding, a battery, say of 100 volts, is introduced between the upper collector and the plate of the HL 23 valve (positive of the battery to the collector). In that case the potential difference across the plate and filament of the HL 23 valve will be the difference between the battery potential and the atmospheric potential.

Fig. 2 shows the records obtained at Poona during soundings on the 16th and 22nd December 1952. The ascent on the 16th was with lead nitrate fuses two metres apart. At the time of ascent the sky was covered 4/8 with altostratus and 2/8 with cirrus. On the 22nd December, polonium collectors were used at a distance of two metres and at the time of ascent there was a trace of fair weather cumulus.

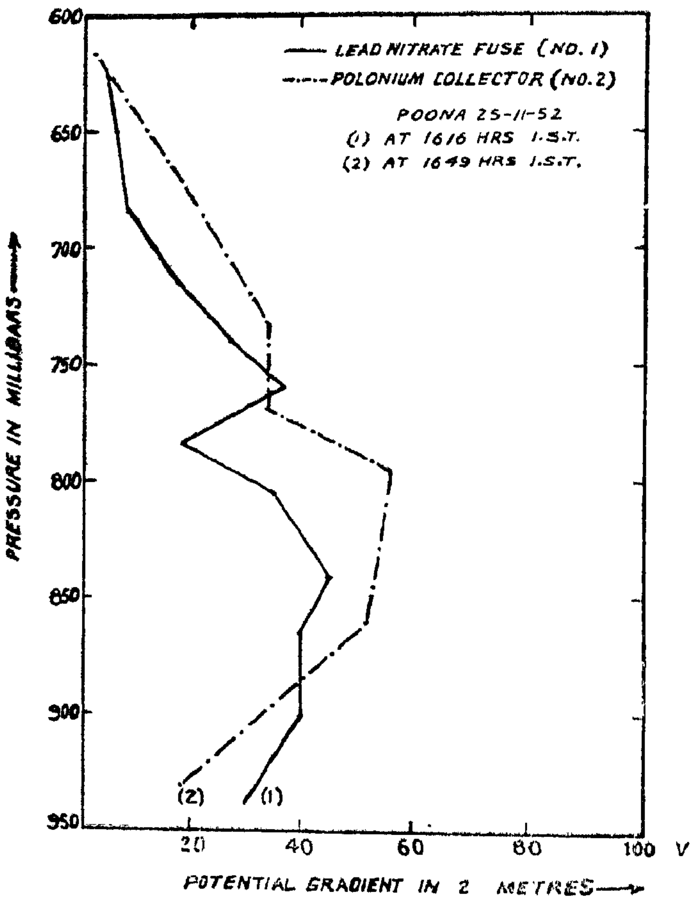

FIG. 3

Fig. 3 shows the distribution of potential gradient obtained from two soundings made consecutively with polonium and lead nitrate fuses on the 25th November 1952, when the skies were clear. The variation in the potential gradients are similar and the differences may be due to rapid fluctuations which occur towards the evening.

The present paper represents the results obtained from preliminary trials and further experiments are in progress to improve the technique and to obtain regular data. The authors are grateful to Dr. L. Koenigsfeld for his kind interest and help in developing the technique.

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