551.594.11 : 551.508.822

Measurement of the electrical potential gradient in the atmosphere by radiosonde

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(*Received 16 March 1953*)

1. In a recent paper Venkiteshwaran, Dhar and Huddar (1953) have described a method to measure the electrical potential gradient in the atmosphere by radiosondes. They have adapted the valve electrometer of Koenigsfeld and Piraux (1951.) with the audio frequency modulated type of radiosonde used in the U.S.A. The HL 23 valve which works as an electrometer is coupled to the modulator circuit of the American radiosonde transmitter by disconnecting its temperature and humidity elements and replacing them with a wire wound resistance of about 350 ohms. This resistance formed the load between the grid and the cathode of the valve electrometer. A small potential of 6 volts is applied between the grid and the cathode of the HL23. The terminals from the collectors at known distances are connected to the plate and the cathode of this valve. The variations in the atmospheric potential gradient cause a corresponding change in the voltage across the load resistance which in turn alters the audio frequency of the modulator circuit of the radiosonde which is recorded on the ground equipment.

2. Though the above technique has been satisfactory and gave reliable data, it was felt that it could be improved and simplified and the attempts in this direction are described below. Some of the difficulties in the present method are the following :

(*a*) No variation of the load resistance, which is also the coupling resistance, should occur due to temperature changes experienced during the sounding, as otherwise, it may be a source of error. The resistance had, therefore, to be specially wound with materials with low temperature coefficient of resistance.

(*b*) For reliable data, it was essential to have a steady potential source of 6 volts between the grid and the cathode of HL23 and any variation in this potential will alter the calibration of the valve as an electrometer.

(*c*) Due to the variations in the characteristics from valve to valve of the same type, the load resistance had to be adjusted to suit the straight portion of the characteristic curve.

(*d*) It was found that the audio frequency range on the radiosonde was restricted. For zero potential difference between the collectors the audio frequency was 100 cycles per second and it was about 170 cycles per second when the potential difference was 200 volts. This meant a total range of only 70 cycles per second for a variation of 200 volts.

3. It was, therefore, examined whether the specially wound load resistance can be dispensed with by utilising the internal resistance of the HL23 valve between the grid and the cathode. For this purpose, the grid of the HL23 valve is connected to the earth of the radiosonde (Fig. 1) and the cathode to the grid of the modulator before the 1000 ohms resistance in the radiosonde. By doing so, both the high and low reference marks are obtained during the pressure contacts of the baro-switch. The HL23 valve remains in conduction due to the bias developed at the grid of the modulator valve of the radiosonde. When the atmospheric potential between the cathode and the plate of the HL23 valve varies, the internal resistance of this valve will also vary and cause a corresponding variation in the audio frequency of the radiosonde.

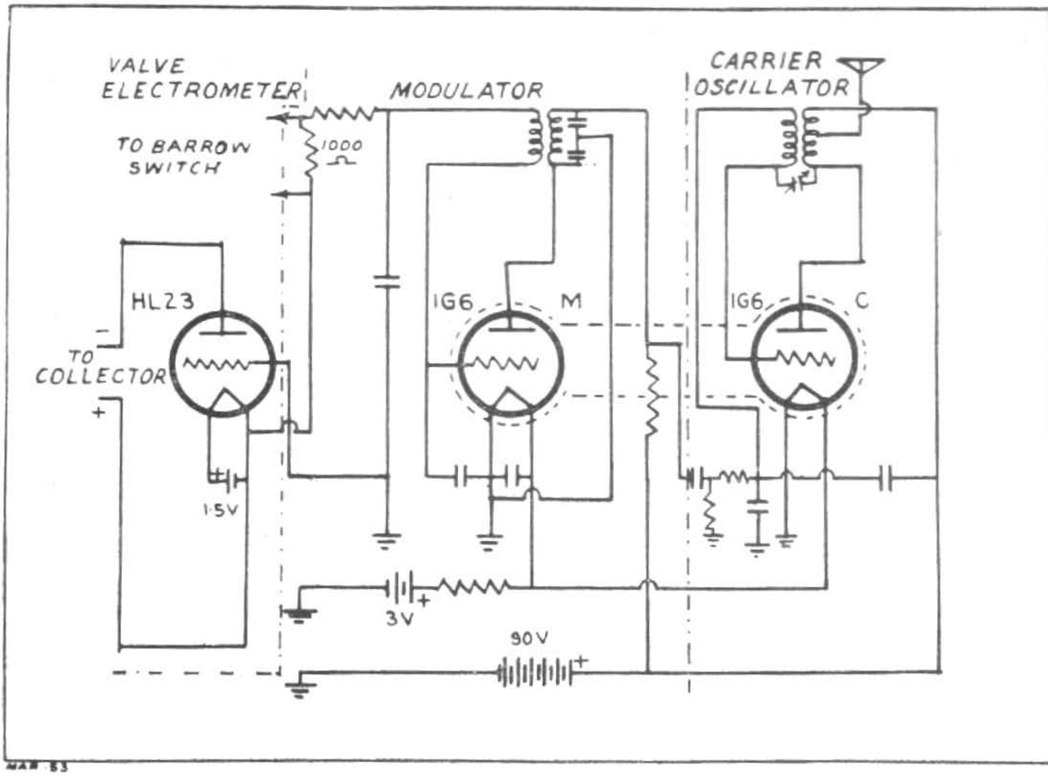

Fig. 1

4. A filament voltage of only 1·5 was used with the HL 23 valve to reduce the photo-electric emission from the electrodes due to the cathode glow.

5. It was observed that by adopting the above changes the audio frequency range available for the measurement of potential gradient was doubled to about 170 cycles per second varying from 10 cycles per second to 180 cycles per second. This improved technique reduced the total weight of the equipment to be carried by the balloon by nearly 200 gm.

6. By this method, it is very simple to rig up the equipment for a sounding of the electrical potential gradient in the atmosphere. The HL23 valve has to be fixed inside the radiosonde box in the place occupied by the temperature and humidity elements, and closed with the flaps to reduce all extraneous light and the polonium (or lead nitrate) collectors hung below the instrument. Fig. 2 shows a record of a flight made on 4 March 1953, with polonium collectors; the sounding reached well into the stratosphere, namely about 22 km above sea level (pressure 31 mb).

7. At the time of release of the balloon at 1718 IST the sky was covered with *Cu* 4/8, *Ac* 3/8, but after 52 minutes the sky was covered with *Cu* 4/8, *Ac* 2/8, *Cb* 1/8 and *Cc* 1/8 and the balloon burst after 72 minutes from the time of release. The *Cb* cloud was not a fully developed one and neither thunder was heard, nor lighting seen at the time of flight or even later in the night. It dissipated also by 1900 IST. It is observed from the record that when the balloon reached a height of about 4·2 km (A-618 mb) the potential gradient sharply fell to about 10 volts/metre. Probably this represents the base of the cumulus clouds. However, the positive potential gradient again rose fairly rapidly reaching a value of about 33 volts/metre in the region of 5·5 km (B-541 mb) and gradually decreased to

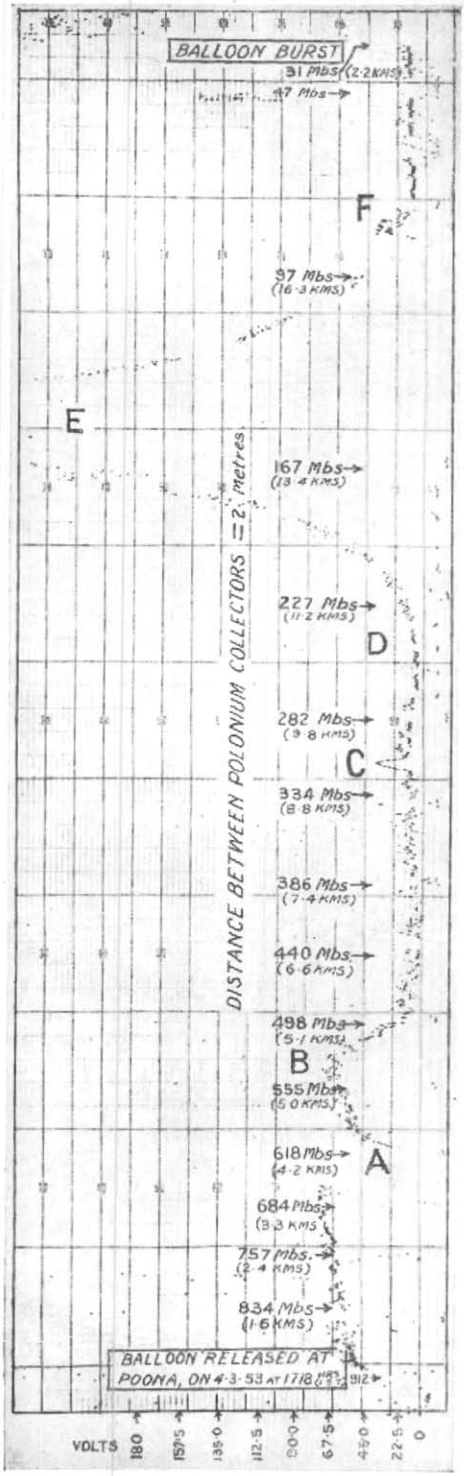

Fig. 2

about 5 volts/metre at 440 mb and remained almost at this value till it reached a level of about 11·2 km (D-227 mb) when the potential gradient began to rise rapidly to above 115 volts/metre (E), decreasing as sharply to 8 volts/metre at 17·5 km (F-78 mb). The maximum value of the potential reached in this region is not known, but it can be said that between the 167-mb and 134-mb levels it was above 150 volts/metre. This maximum value was reached at a height of about 14 km and is definitely above the anvil of the thunderstorm. It is quite possible that this has been caused by the cumulonimbus clouds though it is observed just below the lower transition of the tropopause over Poona. The sharp rise in the positive potential gradient and an almost similar fall are noteworthy. It is also observed that the potential gradient in the stratosphere is about 11 volts/metre, a value usually observed in the lower regions in fine weather. In the region between the 5·6 km (440 mb) and 11 km (225 mb) where the potential gradient was almost constant and equal to about 6 volts/metre, there is a small but sharp rise in the region of 8·5 km (C-312 mb). During the sounding, high altocumulus clouds were being formed from cirrus type of clouds. It is probable that the observed small variation in the potential gradient corresponds to this region. On the whole, it appears from this sounding that the technique is capable of giving new and valuable information regarding the conditions obtaining in the upper air.

8. It may be useful in this connection to describe briefly the methods of making the collectors used with the radiosonde for measuring the potential gradient. One can either use a burning fuse or polonium for this purpose. Polonium collectors are to be preferred as burning fuses will not be satisfactory and are likely to be extinguished in rainy weather. Moreover polonium collectors are more active and attain equalisation of potential in 2 or 3 seconds while lead nitrate fuses may take about 8 to 10 seconds. Also it is more easy to make and handle polonium collectors. The methods for making collectors from lead nitrate fuses and polonium are described below.

9. Lead nitrate fuses are made by dipping narrow strips of cardboard about 1/4″ wide and 1/8″ thick in a 5% solution of lead nitrate and drying them. Two of these strips are tied together from opposite sides of a steel wire supported on polysterene sheets on a wooden frame. Two such units, supported at a known distance of 0·5, 1 or 2 metres, one vertically below the other, will form the collectors. A collector of about 2-ft length can burn for nearly half an hour. The fuse must burn slowly without bursting into flame. If the fuse burns into a flame and too rapidly, it indicates that the solution of lead nitrate is weak while if it is extinguished easily, the solution is very concentrated. The connections from these collectors to the HL 23 valve are made with thin wires through alkathene sleevings.

10. A radio-active isotope of polonium emitting two rays and with a half life of 140 days is obtained from the disintegration of radium and is also known as RaF. When pure silver is dipped in a solution of polonium in nitric acid, polonium is deposited on the silver plate. 1 millicurie of polonium dissolved in about 1 cc of 0·5 n nitric acid was kindly obtained for us by the Tata Institute of Fundamental Research, Bombay, from Radiochemical Centre, Whitelion Road, Amersham, Bucks., England. This was diluted with distilled water to about 15 cc. Pure silver plates, 1 square centimetre in area and about 0·1 mm thick were soldered at one edge to stiff copper wires 18 S. W. G. The silver plates were then dipped in the polonium solution for about 30 minutes taking care to see that the solution is not contaminated with the copper wire or the solder. One millicurie of polonium is sufficient for about 100 collectors. Lest all the polonium should deposit itself on the first few plates of silver dipped in the solution, the 100 silver pieces were immersed in the solution, simultaneously. Later they were washed in water. To obtain a good collector, it should emit more than 40,000 α per minute. This was tested with the ion counter at the National Chemical Laboratory at Poona and the collectors were found to emit betwen 40-80,000 α per minute. As polonium has a half life of only 140 days, these collectors cannot be kept for indefinitely long periods.

11. An alternative method of making polonium collectors is from a solution of Radium D (half life 22 years) which disintegrates to RaE (half life 5 days) and then to RaF, that is, polonium. If the silver plate is dipped in the solution of RaD, polonium which is a derivative of RaD will be deposited on the silver. All the silver plates to be treated should be placed simultaneously in the solution as otherwise almost all of it will be deposited on the first plate. The advantage of using a solution of RaD is that it continuously distintegrates into polonium and it can, therefore, be used again after some months. The silver plates should, however, be washed to see that they retain no RaD.

12. Old radon tubes, no longer of any value in hospitals will contain RaD, RaE and RaF and it may, therefore, be possible to use them for making polonium collectors ; but it will be necessary to treat these tubes suitably to extract the material we need. As the substances in the radon tubes are somewhat dangerous in handling, the extraction should be entrusted to some radiochemists.

13. The authors are thankful to Dr. Koenigsfeld for his interest and help in rigging up this technique.

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