

## An improved radiosonde for the measurement of electric potential gradient in the atmosphere

G. P. SRIVASTAVA, C. R. SREEDHARAN and B. B. HUDDAR

*Meteorological Office, Poona*

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**ABSTRACT** The electrical potential gradient sonde developed by Venkiteshwaran and his co-workers and used during the I.G.Y. for regular soundings at Delhi and Poona though satisfactory for low altitude measurements was not quite suitable for high altitudes where the electric field is normally of the order of a few volt per metre or less. As a result of a series of experiments to improve its performance, the improved sonde now has a much faster response time with a very stable and consistent reference zero. Provision has been made to make the transmitter and the batteries much less temperature dependant throughout the sounding and to monitor the reference zero during the flight. The sonde thus has an accuracy of  $\pm 1$  volt per metre and has been continuously used during the IQSY successfully.

### 1. Introduction

The electrical potential gradient sonde developed by Venkiteshwaran and his co-workers (1953) and used during the IGY and part of the IQSY for regular atmospheric soundings at Poona and Delhi, consisted of the conventional HL23 valve electrometer and audio-modulated 72 mc transmitter, housed in a cardboard box which was later replaced by a styrofoam case. Polonium 210 collectors were used for the two probes. The sonde though satisfactory for low-altitude, high-field measurements was not quite suitable for use at high altitudes where the electric field is normally of the order of a few volts per metre or less. The various laboratory experiments carried out to study and improve its performance, the modifications made and the results of twin soundings are described in the present communication.

### 2. Design considerations

For satisfactory performance, the sonde must in addition to reliability, sensitivity, simplicity of design and convenience of operation, have the following features —

(1) An accuracy of measurement of the order of  $\pm 0.5$  volts/metre, (2) Quick response, with a response time less than 0.3 second, (3) Constancy of calibration, (4) Absence of drift in transmitter frequency, (5) Freedom from fluctuations due to stray R.F. pick up, and (6) Very high leakage resistance of the insulator ( $> 10^{14}$  ohms).

It is also necessary to monitor a reference zero to check the performance of the sonde during flight.

Descriptions of the earlier model are available in published papers (Venkiteshwaran 1958). The electrometer, radio transmitter and batteries were housed in three separate compartments, with the plate electrode of the electrometer connected to the probe through a 'perspex' insulator. The sonde was, however, not quite free from fluctuations in its zero and calibration values.

The main source of trouble was traced to the foam plastic container. While foam plastic is an ideal thermal insulator for radiosondes and is, universally used, it is quite unsuitable for use in atmospheric electricity measurements. Even with very careful and controlled movements in assembling the box and sonde, it picks up static charges at times of great magnitude and retains it for considerable periods of time, vitiating the true values of potential gradient given by the probes. The "thermocole" box in the improved sonde was, therefore, replaced by a plain but strong corrugated paper case.

The second source of trouble was the dependence of the zero on the aerial configuration and the positioning of various elements and their proximity to each other, the zero varying even with the degree of stretching of the aerial. This was caused primarily by R.F. pick up by the electrometer and its leads. The R.F. energy picked up by the probe in the grid circuit and grid-cathode section acting as a detector, supplies variable d.c. voltage depending on the R.F. pick up, which in turn depended on the transmitter and aerial configuration, to the modulator, giving an erratic 'zero' voltage frequency. A 100 pf by-pass capacitor connected between grid and cathode was found to eliminate the trouble completely. The reference 'zero' and calibration values were now very steady. The circuit diagram of the new sonde is given in Fig. 1.

### 3. Laboratory experiments

A series of experiments were carried out to determine the effect of battery voltage drain and of temperature on the electrometer, transmitter and battery.

#### 3.1. Battery voltage

The H. T. power supply to the transmitter is provided by an Eveready type X831 dry battery 112-108 V. 3 Volt L.T. supply is from two Eveready type 950 dry batteries. It had been observed that

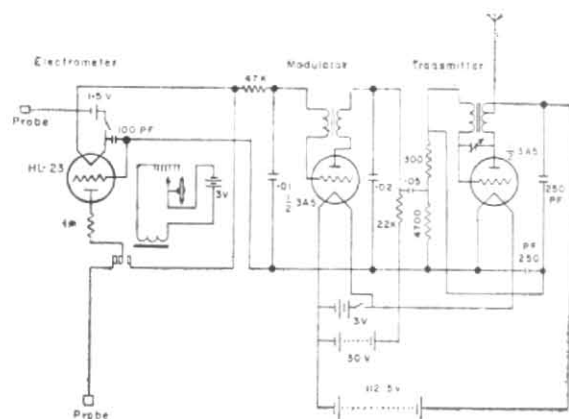


Fig. 1. Circuit diagram of potential gradient sonde

the reference 'zero' frequency gradually shifted with time by about 3–4 cs/hr mainly due to the fall in the H.T. voltage with the time and to a lesser extent to the L.T. voltages. It was also noticed that a common battery supplying H.T. to both the transmitter and the modulator adversely affected the performance of the modulator. So an independent H.T. supply of 30 volts was provided to the modulator. It was also noticed that the fall in H.T. voltage was rapid in the initial stages but the voltage became almost constant after about half an hour of run, when the battery presumably became stabilised. The use of the sonde, after the transmitter had been kept 'on' about half an hour before release, was found to reduce the drift of modulation frequency to negligible values.

Calibration of the sonde is normally carried out by applying known D.C. voltages across the plate and filament of the electrometer valve and noting the audio-frequency values. Fig. 2 gives the calibration curves (frequency in cycles/second against potential difference in volts) at 0, 1 and 3 hours. The difference in frequency and the error arising from drop in battery voltage is now less than 5 per cent after 1 hour of operation.

### 3.2. Temperature effect

To study the effect of low temperature on the electrometer, the transmitter and batteries, the electrometer unit was first placed in a low temperature chamber, the sonde frequencies were measured at various temperatures down to  $-17.0^{\circ}\text{C}$ . The transmitter and batteries were kept outside. The results are shown in Fig. 3.

The experiment was next repeated with the battery at low temperatures and the electrometer at room temperature. The cold chamber available was too small for the complete sonde to be placed in it. The results are shown in Fig. 4. It was noticed that the H.T. voltage fell from 90 volts at room

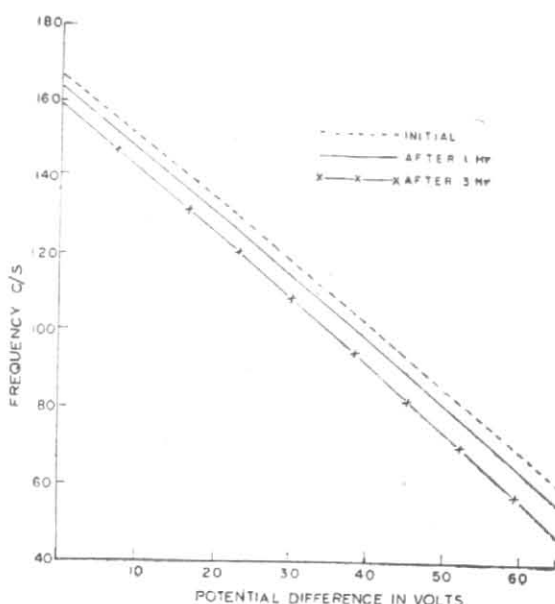


Fig. 2. Potential gradient sonde calibration

temperature to 60 volts at  $-60^{\circ}\text{C}$ . If, however, the battery is drained at about 15 ma as in an actual sounding, the temperature inside the battery housing falls only to  $-8^{\circ}\text{C}$ , even when the outside temperature is maintained at  $-67^{\circ}\text{C}$  for half an hour. The drift in frequency due to temperature is observed to be almost negligible.

The transmitter alone was next tested by keeping it in a polyethene bag filled with ice and salt for some time. The drift was found to be negligible.

Thermal insulation of the transmitter and H.T. and L.T. is all the same desirable and therefore the battery compartment was lined with 13 mm thermocole sheets and then enclosed in a suitably earthed, thin copper case, so that any charges developed on the thermocole insulation would be instantly earthed and the electrometer remain unaffected. The system proved to be successful.

### 3.3. Reference zero

In order to check the performance of the sonde at high altitudes, when the potential gradient is of the order of about 1 volt/m, it is necessary to check the values telemetered by the sonde. Accordingly a baroswitch was incorporated to short-circuit the two probes at predetermined pressure levels to give a 'zero' V/m reference signal. This value is also recorded on the ground before release and any shift in this value gives an indication of the shift in the reference zero which is taken into account while computing the values of potential gradient in the atmosphere. Incorporation of the baroswitch also gives pressure values, eliminating the need of an additional radiosonde.

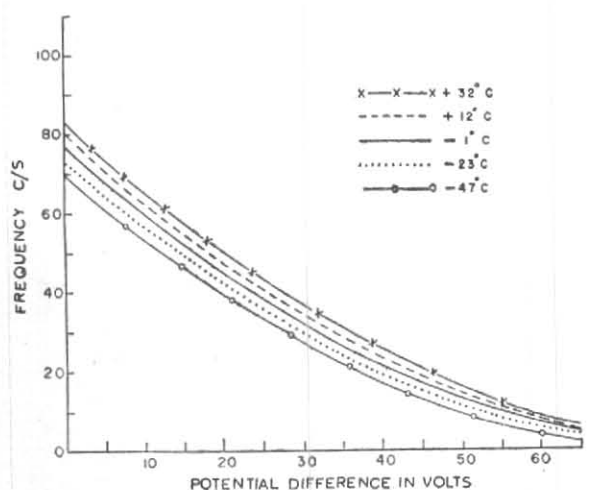


Fig. 3. Potential gradient sonde — Electrometer at different temperatures

### 3.4. Insulation

Experiments were carried out to minimise surface leakage of the charges. The electrometer valve base mounting is removed and the glass surface repeatedly cleaned with alcohol and dried before the electrometer sonde is assembled. The electrometer is enclosed in an air sealed compartment, the inner walls of which are blackened to prevent any photoelectric electron emission. An insulator made of teflon gives a very large surface area to obtain a leakage resistance greater than  $10^{14}$  ohms and connects the active terminal from the sonde to the polonium collector.

### 3.5. Response time

Studies were also carried out to determine the response of the polonium collectors used. The response time of the probes used so far appeared to be rather large, and were of the order of a few seconds; this could cause serious errors with rates of ascent of balloon of about 300 metres/minute. To reduce the response time to 0.3 to 0.5 second, silver foils 1 cm  $\times$  1 cm coated with 4 microcurie of Polonium 210 were found suitable.

## 4. Characteristics of the improved sonde

4.1. The detailed characteristics of the new sonde now are —

- A response time of the collectors of about 0.3 sec
- Transmitter and batteries thermally protected and negligible temperature effects during the sounding
- Elimination of stray static charges built up on the housing or any R.F. pick up by the probes

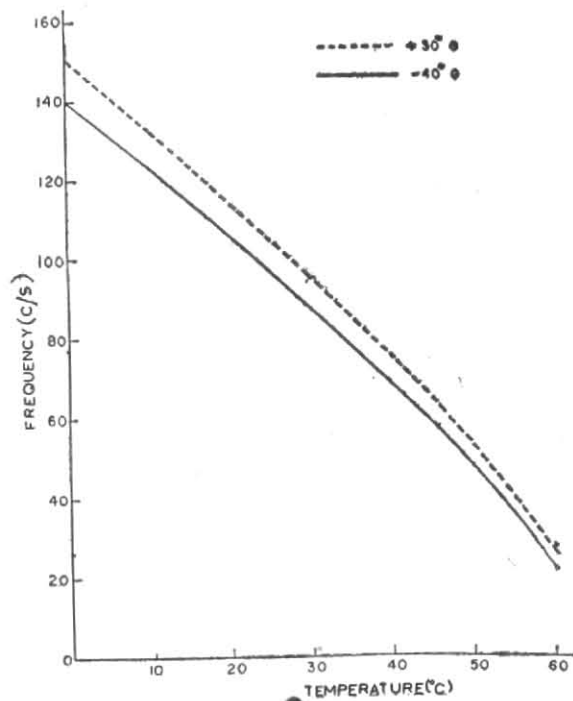


Fig. 4. Potential gradient sonde — Temperature effect on battery

- Leakage resistance greater than  $10^{14}$  ohms
- Reference 'zero' voltage during flight at predetermined pressure levels
- The gradual shift of the reference voltage to low frequency due to drop in H.T. voltage with time is only about 3 cycles/hr and is measured during flight for computation.

4.2. The main features are —

- Range : 0 to +200 volts/metre by using a collector distance of 50 cm. The sensitivity can be increased by increasing the collector distance
- Probes : Two silver plates 1 cm square and 30 SWG coated with polonium Po-210 ( $4 \mu\text{C}$ ), 1,000,000 counts/min
- Accuracy :  $\pm 1$  volt/metre
- Modulation : Frequency modulation, audio-frequency, 0—200 c/s
- Transmitter frequency and power : 72 mc/s 100 mW
- Antenna : End fed  $\lambda/2$  vertical dipole
- Power supply :
  - HT 112.5 volts, 5 blocks of 22.5 V from [type] X831 dry batteries or Type BB 208/AMT acid batteries 3  $\times$  36 volts

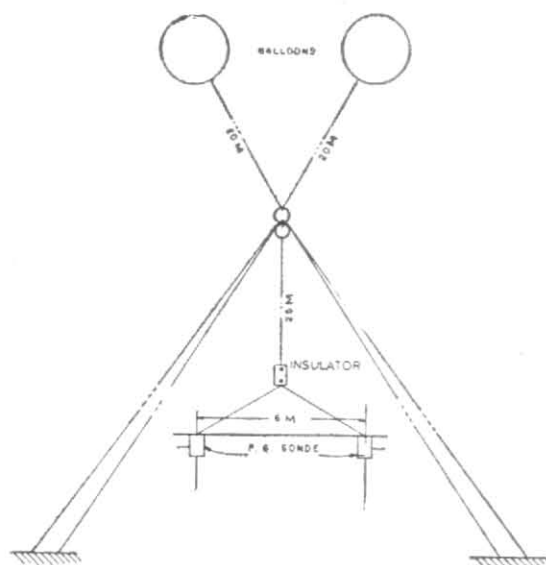


Fig. 5. Tethered balloon

- (2) Modulator H.T. 30 V type 413 battery
- (3) L.T. 3 volts Eveready type 950 dry battery
- (h) Operation time: 3 hours
- (i) Weight: 2000 gm

#### 5. Twin soundings

A series of twin soundings were made with two instruments tied about 6 m apart on a bamboo pole. The instruments were tied to two 2000 gm rubber balloons and 'surface' observations free from ground effects were first made by keeping the balloon sonde system floating, the balloons being held by two threads passing through a metal loop below the balloon (Fig. 5). Observations were made with the sondes 20, 30 and 50 m above ground for about 30–45 minutes. The instruments may be assumed to have acquired the potential of the ambient atmosphere after this time, any extraneous charge acquired by the instruments during preparation or from the balloon having equalised with that of the atmosphere. After the whole system stabilizes and the records show steady values the sondes are released, by releasing the two anchoring threads. Flight records for both the sondes are obtained and values computed. The results of the twin sounding taken on 27 April 1965 are shown in Fig. 6. The difference in the values obtained by the two

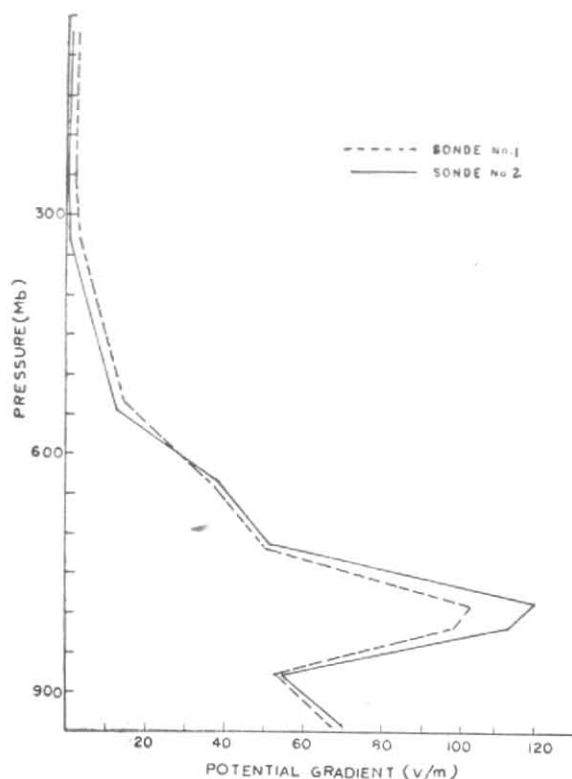


Fig. 6. Potential gradient sonde—Twin sounding Poona—27 April 1965, 0105 IST

sondes in terms of 'deviation'  $D = \frac{|I_1 - I_2|}{(I_1 + I_2)} \times 100$  are within 12 per cent up to 500 mb and within 50 per cent at higher levels where the potential gradient values become comparable to the sonde's sensitivity.

#### 6. Ionospheric potential

The total earth-ionosphere potential was calculated by integrating the potential difference from the surface to the ionosphere (70 km). The values obtained at Poona during April 1965 are as follows: 25 April 1965: 318.2 Kv, 27 April 1965: 390.0 Kv, 29 April 1965: 439.0 Kv.

#### 7. Acknowledgement

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