

## Aircraft measurement of electrical parameters inside monsoon clouds

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**ABSTRACT.** Instruments were fabricated for measurement from aircraft, of (i) vertical component of potential gradient, (ii) cloud droplet charge and (iii) static discharge current. The instruments were flight tested on seven days in maritime and continental clouds during the 1974 summer monsoon. The paper describes the instruments and the preliminary results.

### 1. Introduction

The electrical state of a cloud and its precipitation characteristics are closely associated (Sivaramakrishnan 1960). The behaviour of the atmospheric electrical quantities is governed by the precipitation physical processes (Reiter 1972). The electrical characteristics of a cloud vary vertically and also with the stage of its development (Takahashi 1973). A knowledge of the variation, in all aspects, of the electrical characteristics of monsoon clouds is, therefore, considered to be useful while planning weather modification experiments during the monsoon.

Measurements of potential gradient and conductivity have been reported for the free atmosphere over Poona (Venkiteshwaran and Mani 1962), using radiosonde techniques. For studies of the variation of the electrical state of clouds, the use of aircraft is essential. Aircraft-based measurements have been made in warm clouds in other countries (Gunn 1952, Fitzgerald and Byers 1959, Vonnegut and Moore 1961 a, Imyanitov and Chubarina 1965). Such measurements have not been made in India. A programme of measurement of the electrical state of warm clouds in selected regions has, therefore, been undertaken by the authors. The equipment developed, the methods used for measurement and a summary of the preliminary results obtained in maritime and continental clouds are presented in this paper.

### 2. Equipment and methods

#### (i) Potential gradient

The potential gradient (electric field), in a direction perpendicular to the flight path of the

aircraft, was measured using two radioactive probes. 500 microcurie PO-210 source supplied by M/s Radio Chemicals, U.K. was used as the sensor for each probe. The mounting of the probes (Fig. 1), the electrostatic coupler (Fig. 2) and the electronic circuit (Fig. 3) are similar to those used by Vonnegut *et al.* (1961 b).

*Mounting*—The circular disc type 'auto pilot source' with a wire mesh in front was mounted at the end of a hollow L shaped stainless steel mast 55 cm long and 1.8 cm in diameter using a teflon bushing as shown in Fig. 1. The teflon bushing was shaped such that a continuous water film will not form over it in flight through clouds. Connection to the electrostatic coupler was taken from the rear of the auto pilot source through the centre of the hollow stainless steel mast by means of teflon bushings placed at intervals along its length. The lower end of the mast was fitted to a teflon insulated connector fixed to the body of the aircraft. The stainless steel mast arrangement was fixed through the centre of a tripod stand fitted to the body of the aircraft for additional support. The two masts are fitted symmetrically one above and one below the point of intersection of the wing to wing and nose to tail axes of the aircraft, with the sensors facing the tail of the aircraft. Teflon insulated cables were used for taking the signal from the two probes to the electrostatic coupler.

*Electrostatic coupler*—The rotor is an asymmetrical vane mounted to the shaft of a 1500 rpm synchronous motor. Two insulated aluminium plates are fixed just behind the rotor parallel to it and are connected to one probe each. The distance

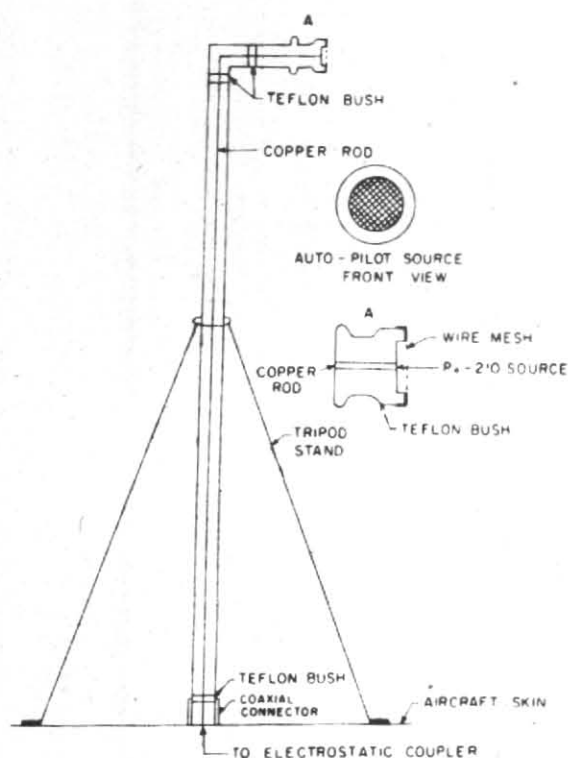


Fig. 1. Probe for mounting radio active sensor.

A: Cu rod with beryllium-copper brush connecting rotor to electrometer.

C: Rotor.

D: Teflon insulated nuts for plates adjustment.

of the plates from the rotating vane can be adjusted by means of the nuts D. As the vane rotates, it makes contact with two beryllium copper brushes, mounted one in front of each fixed plate, by means of a pin P fixed to it. The contact with the brush in front of the fixed plate connected to the lower probe earths the vane while the other brush connects it to the measuring circuit. The asymmetric vane acting as a rotating capacitor transmits, as a current signal, the voltage difference between the two probes.

**Electronic circuit** :—A feed back impedance of 108 ohms, with suitable attenuation ranges at the output, was found suitable for the range of values encountered during the flights. The circuit was battery-operated, while the synchronous motor required an inverter to give 220V, 50 Hz from the aircraft batteries.

#### (ii) Cloud droplet charge

The shielded induction ring technique, described by Latham and Stow (1969), was employed. The apparatus was made of stainless steel and is shown at Fig 4. The two induction rings, each

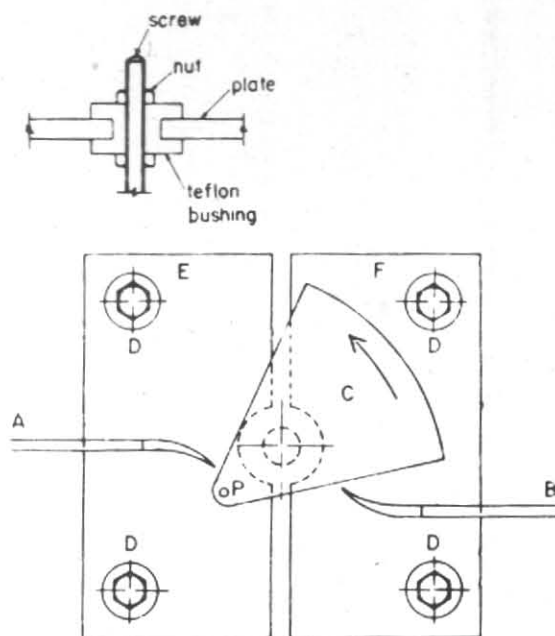
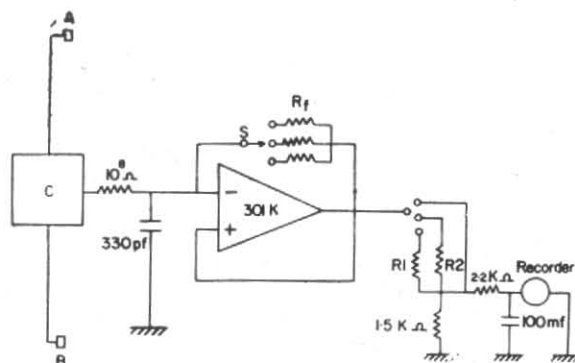


Fig. 2. Electrostatic Coupler

B: Cu rod with beryllium-copper brush connecting rotor to ground.

F: Insulated aluminium plates. Connections from upper and lower probes come to plates E and F respectively. E, P: Contact pin.



A & B: 500 microcuire PO-210 Probes.

C: Electrostatic coupler.

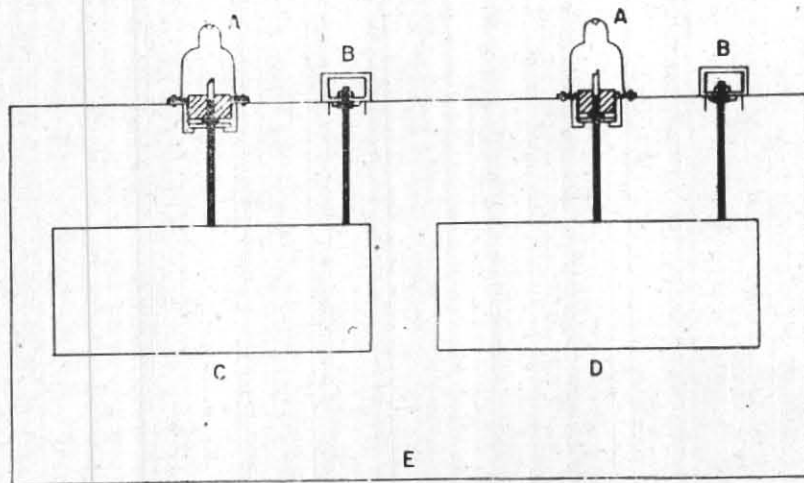
301K: Keithley Mos-FET input electrometer amplifier.

R<sub>f</sub>: Feed back resistance (10<sup>6</sup>, 10<sup>7</sup>, and 10<sup>8</sup>, ohms.)

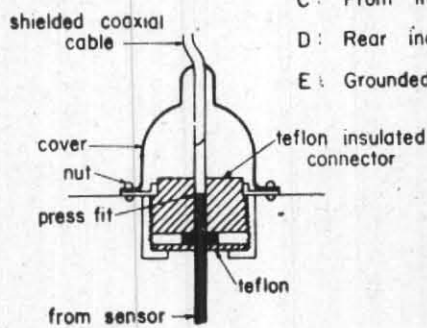
S: Teflon insulated shielded switch.

Fig. 3. Electronic circuit for measurement of potential gradients

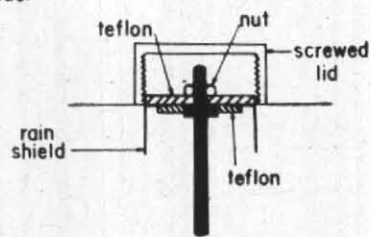
of length 10 cm and 4.5 cm diameter, were mounted symmetrically and co-axially inside the outer earthed cylinder of length of 25 cm and diameter 12 cm. Each induction ring was supported by two



- A: Input to electrometer.
- B: Mechanical support.
- C: Front induction ring.
- D: Rear induction ring
- E: Grounded outer cylinder



Connector A



Connector B

Fig. 4. Apparatus for measurement of cloud droplet charge

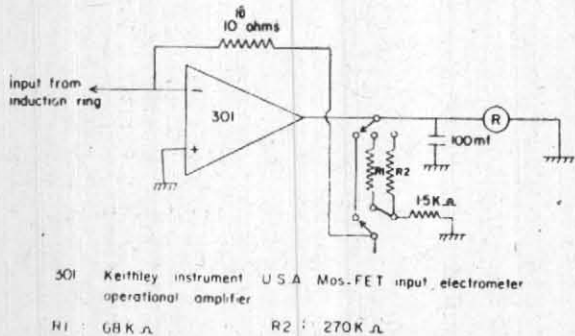


Fig. 5. Electronic circuit for measurement of cloud droplet charge

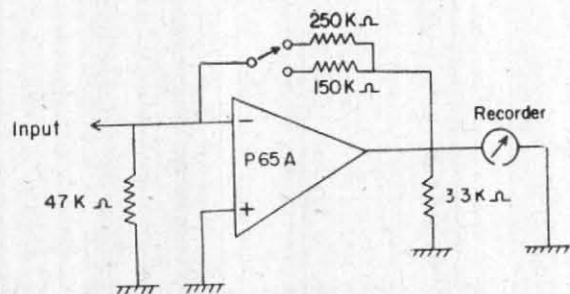


Fig. 6. Electronic circuit for measurement of static discharge current

TABLE 1  
Measurements of electrical and physical parameters during September 1974

Date (Sep 1974)	Altitude range (in 1000ft)	Average potential gradient (V/m)				Average cloud droplet charge ( $10^{-7}$ c.s.u)				Average static discharge current ( $10^{-6}$ amp)			Average temp. °C		Average liquid water content ( $\text{gmm}^{-3}$ )		
		Average		Maximum		Average		Maximum		Average		Maximum	Clear air	In cloud	Average	Maxi- mum	
		+	-	+	-	+	-	+	-	+	+	-					
RIHAND																	
9	1.3	35		43									22.0	21.6			
		(4)		(4)									(2)	(4)			
	3.5	127		141									18.2	18.0			
		(13)		(13)									(43)	(13)			
10	5.7	46	3	93	6	0.6	1.2	1.2	2.1			Not available	18.6	17.0	0.5	1.2	
		(15)	(2)	(15)	(2)	(12)	(15)	(12)	(15)				(52)	(15)	(15)	(15)	
	7.9	157		191		0.6	2.4	1.5	3.0			Not available	13.2	13.0	0.4	0.7	
		(2)		(2)		(2)	(2)	(2)	(2)				(12)	(2)	(2)	(2)	
11	1.3	62		85		2.4	2.7	2.4	3.0	0.3	0.6		20.6	20.8	0.3	0.5	
		(10)		(10)		(9)	(6)	(9)	(6)	(5)	(5)		(16)	(9)	(9)	(9)	
	3.5	130	40	163	40	2.4	1.8	2.7	2.1	0.7	1.3		18.8	17.7	0.3	0.5	
		(11)	(1)	(11)	(1)	(9)	(4)	(9)	(4)	(1)	(1)		(24)	(11)	(11)	(11)	
	5.7	82	34	111	45	1.2	1.8	1.5	2.1	0.1	0.3	0.2	1.7	17.1	16.2	0.4	0.7
		(30)	(2)	(30)	(2)	(26)	(21)	(26)	(21)	(1)	(29)	(1)	(29)	(42)	(32)	(32)	(32)
	7.9	57		102		1.8	1.8	2.4	3.0				14.3	12.8	0.8	1.0	
		(3)		(3)		(3)	(3)	(3)	(3)		(3)	(3)	(5)	(3)	(3)	(3)	
BOMBAY																	
22	3.4	35	106	36	155	3.0	1.5	3.6	2.4			Not available	19.1	18.5	0.5	1.0	
		(4)	(14)	(4)	(14)	(11)	(14)	(11)	(14)				(29)	(14)	(14)	(14)	
24	1.3	15	7	22.5	14							Not available	20.5	20.1	0.4	0.5	
		(24)	(10)	(14)	(10)								(69)	(25)	(23)	(25)	
25	2.3	4	11	7	18							Not available	21.2	21.4	0.3	0.4	
		(14)	(26)	(14)	(25)								(25)	(29)	(29)	(29)	
28	2.3					0.9	0.9	1.2	1.5	0.2	0.5		21.5	21.7	0.3	0.6	
						(29)	(10)	(29)	(10)	(12)	(12)		(21)	(30)	(30)	(30)	

stainless steel rods with teflon insulators. Connection to the electrometer was taken from the rod at the front with a suitable connector. The sensor was attached, with its axis parallel to the flight path, to the belly of the aircraft, with the connectors from the two induction rings taken inside the aircraft.

The electrometer circuit used for the measurement (Fig. 5) has a response time of 10 milli-seconds with a feed back impedance of  $10^{10}$  ohms.

A four pen heated stylus recorder with a response time of 50 milliseconds was used for recording. The potential gradient was recorded on one channel and the cloud droplet charges from the two induction rings were recorded on two adjacent channels.

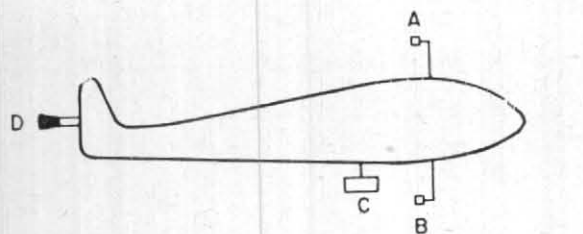
### (iii) Static discharge current

The corona current emitted from the body of the aircraft, while flying through cloud, was measured by means of the electronic circuit shown at Fig. 6. The static discharger employed for this purpose consists of an insulated cotton wick, about 3 cm long and 1 cm in diameter, dipped in a conducting solution and dried. This was mounted at the tail of the aircraft and teflon insulated cable was used for bringing the connection to the measuring circuit which was kept at the nearest accessible location. The static discharge current was measured on a direct writing milliamper strip chart recorder (Esterline-Angus).

### (iv) Liquid water content

The liquid water content of the cloud was meas





- A & B : Po-210, 500 microcurie radio-active probes for measurement of the atmospheric electric field.  
 C : Induction ring for measurement of cloud droplet charges.  
 D : Static discharger for measurement of corona current emitted by the aircraft.

Fig. 7. Locations of various sensors on aircraft

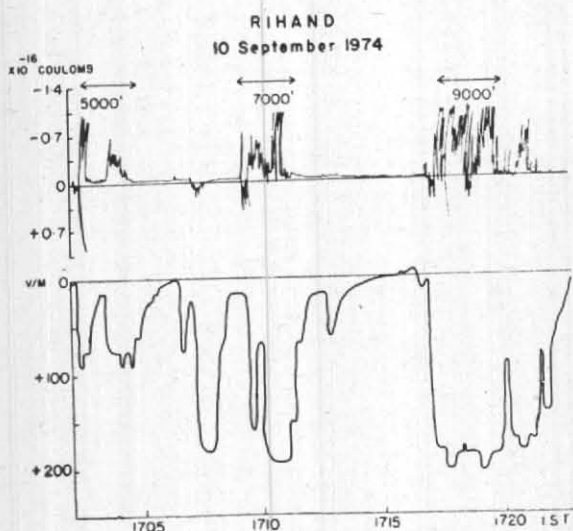


Fig. 9. Vertical variation of potential gradient in one cloud case

ured with the help of a  $0-3 \text{ gm m}^{-3}$  J-W hot-wire model LWC meter supplied by M/s Johnson Williams Inc. USA. Its record was obtained on one of the channels of the four pen stylus recorder referred to above.

#### (v) Temperature

The values of temperature inside and outside cloud were obtained with the help of a Weston-make vortex thermometer mounted on board the aircraft.

Fig. 7 shows the locations of the various sensors on the aircraft.

### 3. Clouds studied

Observations were made in a coastal region (Bombay  $18^\circ 51'N$ ,  $72^\circ 49'E$ , 11 m msl) and also in a region well inland (Rihand  $24^\circ 12'N$ ,

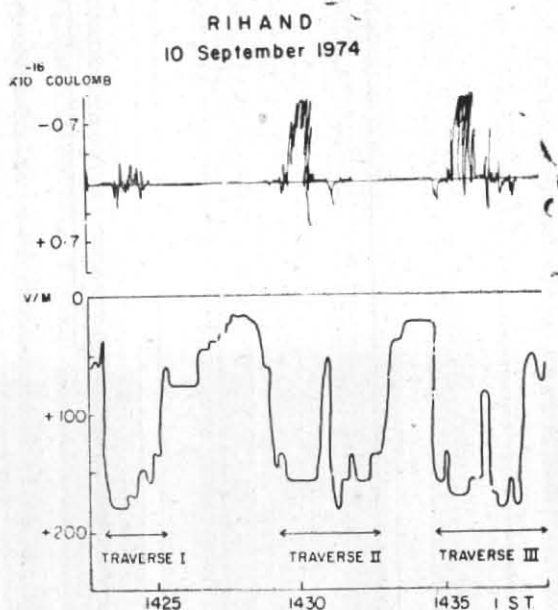


Fig. 8. Lateral variation of potential gradient in one cloud case

$83^\circ 03'E$ , 310.5 m msl). At Bombay, observations were mostly in isolated warm cumuli made over the sea, having bases at 1000-1500 ft and tops at 8000 ft. At Rihand they were made in overcast stratocumuli with bases at 2000 ft and tops at 12000 ft. On one occasion a profile observation of a single cloud was made, at Rihand, up to a height of 10,000 ft.

### 4. Data and analysis

The equipment was flight-tested on three days at Rihand (9-11 September 1974) and four days at Bombay (22, 24, 25 and 28 September 1974). The values of potential gradient, droplet charge and static discharge current recorded during the flights are given in Table 1. Penetrations, in clouds, were made at more than one level at Rihand and at a single level at Bombay. The number of clouds penetrated, of which the given value (of potential gradient, droplet charge and static discharge current) was the mean, was given in brackets. The values of temperature and liquid water content noted on each of these occasions are also given in the table.

*Potential gradient*—At Rihand, where the clouds are more continental, the average maximum potential gradient recorded was 191 V/m. The maximum value recorded in the clouds at Bombay, which are maritime, was less than one-fifth (36 V/m) of this value. The negative sign for the field was noted more frequently in maritime clouds.

Figs. 8 and 9 represent the lateral and vertical variations of potential gradient in two individual

clouds which were in the mature stage of development. Fig. 8 relates to the record obtained in three successive traverses made in the cloud at 5000 ft. Fig. 9 relates to the record obtained in three traverses made in the cloud successively at 5000, 7000 and 9000 ft levels. The potential gradient was positive at all the three levels, the maximum value noted in the traverse increasing with height.

No correction was made for the distortion effect of the aircraft on the potential gradient. The values of potential gradient given are, therefore, underestimates.

*Droplet charge* — There are no marked differences either in the magnitude or in the predominant sign of the droplet charge between the continental and maritime clouds. The maximum values recorded in the continental and maritime clouds are respectively 3.0 and  $3.6 \times 10^{-7}$  e.s.u.

In the successive traverses made at 5000 ft level in a continental cloud (Fig. 8) charges of both signs were noted with positive charge predominating. The maximum value noted for the positive charge in the first traverse increased substantially in the subsequent traverses. Also, in the traverses made at different levels in another cloud (Fig. 9) positive charge was more frequently noted at higher levels.

*Static discharge current* — This is mostly negative in sign, i.e., directed from the body of the aircraft, and is conspicuously high in the continental clouds. Higher values, extending up to  $1.9 \times 10^{-6}$  amperes, were noticed in thicker clouds having

higher liquid water content, *vide* figures in column 13 and 18 against 11 September 1974 for Rihand.

*Temperature* — In the continental clouds, the average in-cloud temperature was lower than the clear air temperature up to 1.6°C. In maritime clouds, the average in-cloud temperature was some times in excess of the clear air temperature by 0.2°C.

*Liquid water content* — The continental and maritime clouds sampled did not exhibit appreciable difference in liquid water content on the occasions of measurement.

## 6. Conclusion

The instruments which were fabricated and installed on board Dakota aircraft for the study of electrical characteristics of clouds were flight tested on six days in warm clouds during the summer monsoon of 1974. The instruments functioned satisfactorily.

Observations, which are preliminary, were made both in continental and maritime regions. All the clouds penetrated in the two regions were electrically charged. The characteristics noted of the potential gradient and droplet charge are consistent with what have been reported in literature for warm clouds (Takahashi 1973 and 1975).

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