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Thunderstorm observations during the I.G.Y. at Poona with local lightning flash counters

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1. Introduction

Instruments which record automatically the number of lightning flashes occurring within a given area round the point of observation are of considerable value to radio and electrical engineers and to meteorologists. Special radio receivers for recording lightning flashes based on their response to the radiation and electrostatic field changes have been designed during the last few years (Gane and Schonland 1948, Pierce 1956, Ito *et al.* 1955, Sullivan and Wells 1957). A lightning flash counter based on the model designed by Sullivan and Wells (1957) and recommended by the International Radio Consultative Committee (CCIR) has been used at Poona to study thunderstorms and the present paper summarises the results of such observations made during the IGY.

2. The Lightning Flash Counter

The field-change E associated with a lightning flash varies with the distance D of the observing station from the discharge and may be expressed with sufficient accuracy as—

$$E = \frac{M}{D^3} + \frac{1}{cD^2} \cdot \frac{dM}{dt} + \frac{1}{c^2D} \cdot \frac{d^2M}{dt^2}$$

where M is the change of electric moment that occurs and c the velocity of light. The three terms in the above equation are often denoted by E_S, E_I and E_R and termed the electrostatic, induction and radiation components respectively. The form of variation of the three terms with distance indicates that near the discharge for $D < 100$ km, the electrostatic field is of the greatest importance, while for very great distances for $D > 500$ km, the radiation field, more familiarly known as "atmospherics" predominates. The CCIR model local lightning flash counter depends for its action on the electrostatic field change; and the choice of the electrostatic and induction components over the radiation component represents in effect a choice of response at very low rather than high frequencies. The counter is designed to have a frequency response from 1 to 20 kc/sec; the lower limit is chosen to include the induction field component and the upper to include the frequency of maximum energy for most strokes. The operation of the counter is limited by its frequency response to ranges less than 100 km and it is so set to record only those atmospherics that exceed a certain amplitude. It is found from practice that a counter set to operate on a 3 volts input, records most flashes within a range of 30 km.

The block diagram of the counter is shown in Fig. 1. A broad band untuned amplifier at very low frequencies is used in order to obtain a reasonable chance of recording both ground and air discharges. The frequency response is obtained by means of a filter circuit. A full-wave rectifier permits operation on atmospherics of either polarity and a hard-valve multivibrator is used as a triggered circuit between the amplifier and the counting circuit. The prime mover of the counting circuit is the relay in the multivibrator circuit, the contacts of which are in the circuit of the register itself. The maximum count rate is six per second and is determined by the time constant of the multivibrator. Calibration is carried out by applying a

Fig. 1

measured step-function voltage from a condenser. Because of the variations in wave forms encountered in thunderstorms, it is difficult to specify a method of calibration which could be related to the actual flash; the arbitrary calibrating method is simple, easily reproduced and requires only a voltmeter for the actual calibration.

The circuit of the counter is shown in Fig. 2. An RC network is used to restrict the frequency response of the counter. Potentiometer R_4 adjusts the input level required to trigger the multivibrator and serves as a "range" control. The first half of the amplifier tube 6SN7 is direct-coupled to a split load phase inverter, and its output fed to the multivibrator input through two 6H6 diodes. Only positive portion of the signal is passed through the diodes so that a positive pulse is obtained regardless of the input polarity. The one-shot multivibrator is of the conventional type and the relay which operates the counter is in the plate circuit of the second half of the 6SN7. The relay used is a Carpenter polarised relay type 5A7 TR and the register an Ametron pulse counter recorder type Sc. I. The magnet coil has a resistance of 60 ohms and requires about 6 ma. to operate. An electric clock with a one-minute contact mechanism triggers the Ametron counter-printer to print the count every minute. A low impedance head-phone is connected to the place of the second half of the 6SN7 amplifier so that the flashes can be heard aurally and the operation of the counter checked. The "calibrate" switch S_2 applies the voltage on the calibrate discharge condenser C_9 to the input of the unit. This voltage is adjusted by the potentiometer R_{18}. Calibration is carried out by applying a step function of 3 volts. The sensitivity control was adjusted by a Beat Frequency Oscillator for the range 2-20 kc/sec and the sensitivity setting adjusted by trial and error during an actual storm. The performance of the counter was also checked with a weather radar.

3. Results

3.1. *Observations of lightning flashes at Poona during 1958*—Thunderstorms occur in Poona during the premonsoon months, April to June and the post-monsoon months, September to October. The local lightning flash counter was operated at Poona from April to October 1958, with the aerial installed on the roof of the meteorological office about 15 metres above ground level. The number of lightning flashes recorded per minute during five thunderstorms in May, June and October are shown in Fig. 3. It will be seen that (*i*) the lightning flashes occur in spells, each spell lasting from about 10 to 30 minutes, and (*ii*) the frequency of lightning flashes per minute is greater during the premonsoon months than in the post-monsoon.

There were two main spells on 26 May 1958 from 1501-1511 and from 1528-1558 IST and on 16 June 1958 from 1828-1850 and 1901-1910 IST. On 4 October 1958 there were three spells ending at about 1730, 1900 and 2200 IST. At about 1700 IST the thundercloud was observed towards north to north-west of Poona, where it appeared almost stationary. While there was no rain at Poona, 7 mm of rain fell at 1830 IST at a distance of 6 km to the north of the observatory, at the College of Military Engineering, Kirkee. A spell of lightning and thunder associated with very heavy rain started at about 2124 IST over the station ending at 2303 IST, 4·7 mm of rain being recorded at Poona during this period and 11·5 mm at Kirkee between 2120 and 2200 IST. On 9 October 1958 also there were three spells from 1657-1725,

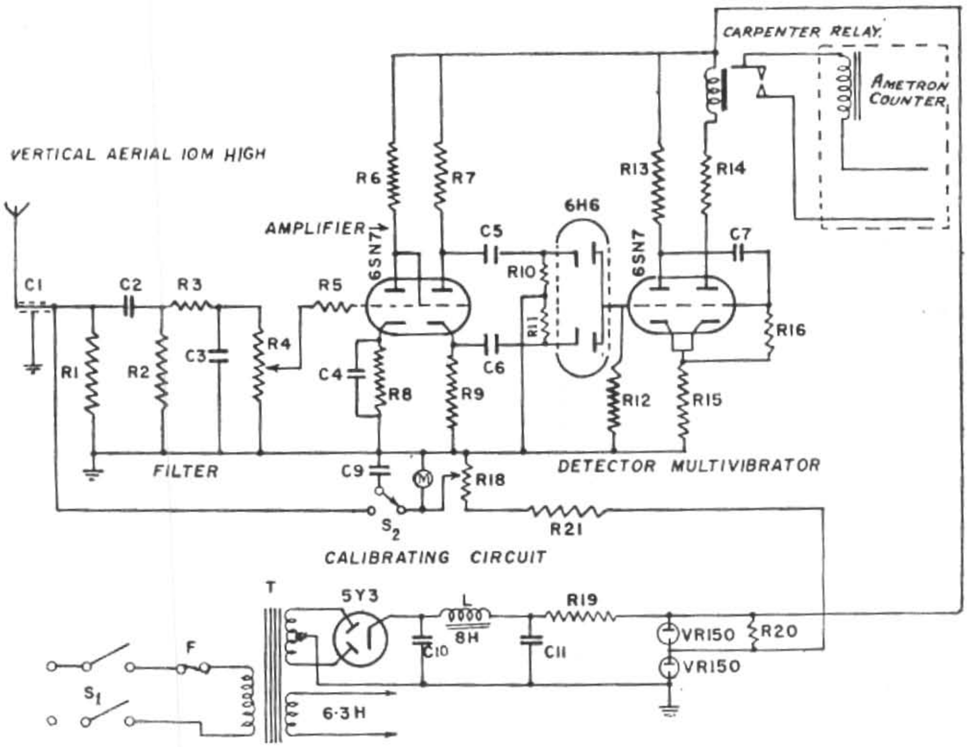

Fig. 2. Circuit diagram of lightning flash counter

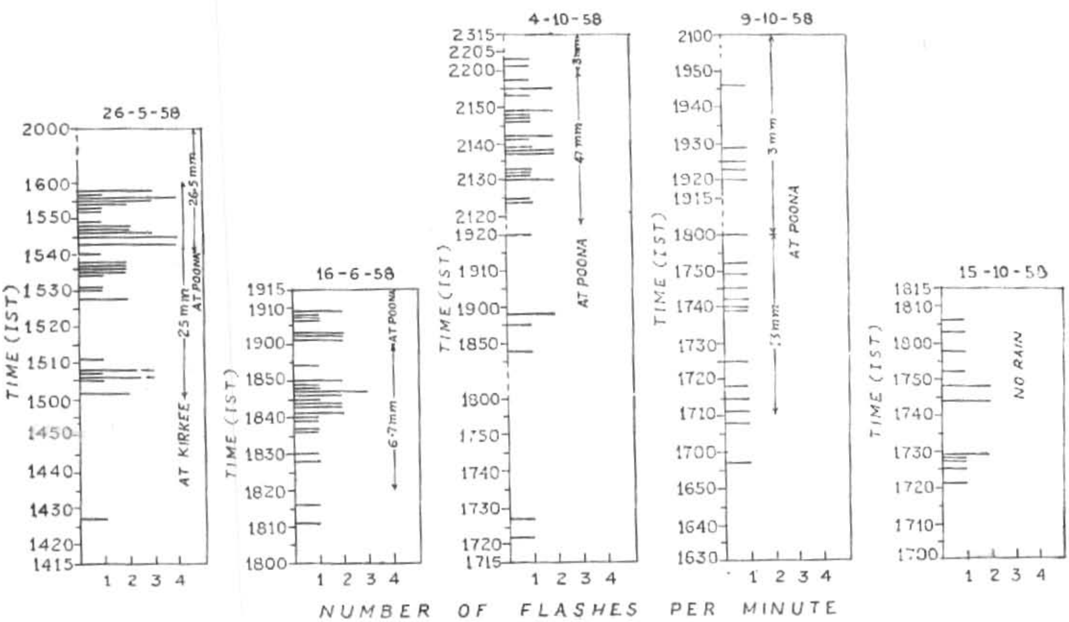

Fig. 3. Number of lightning flashes recorded at Poona during a few thunderstorms in May, June and October 1958

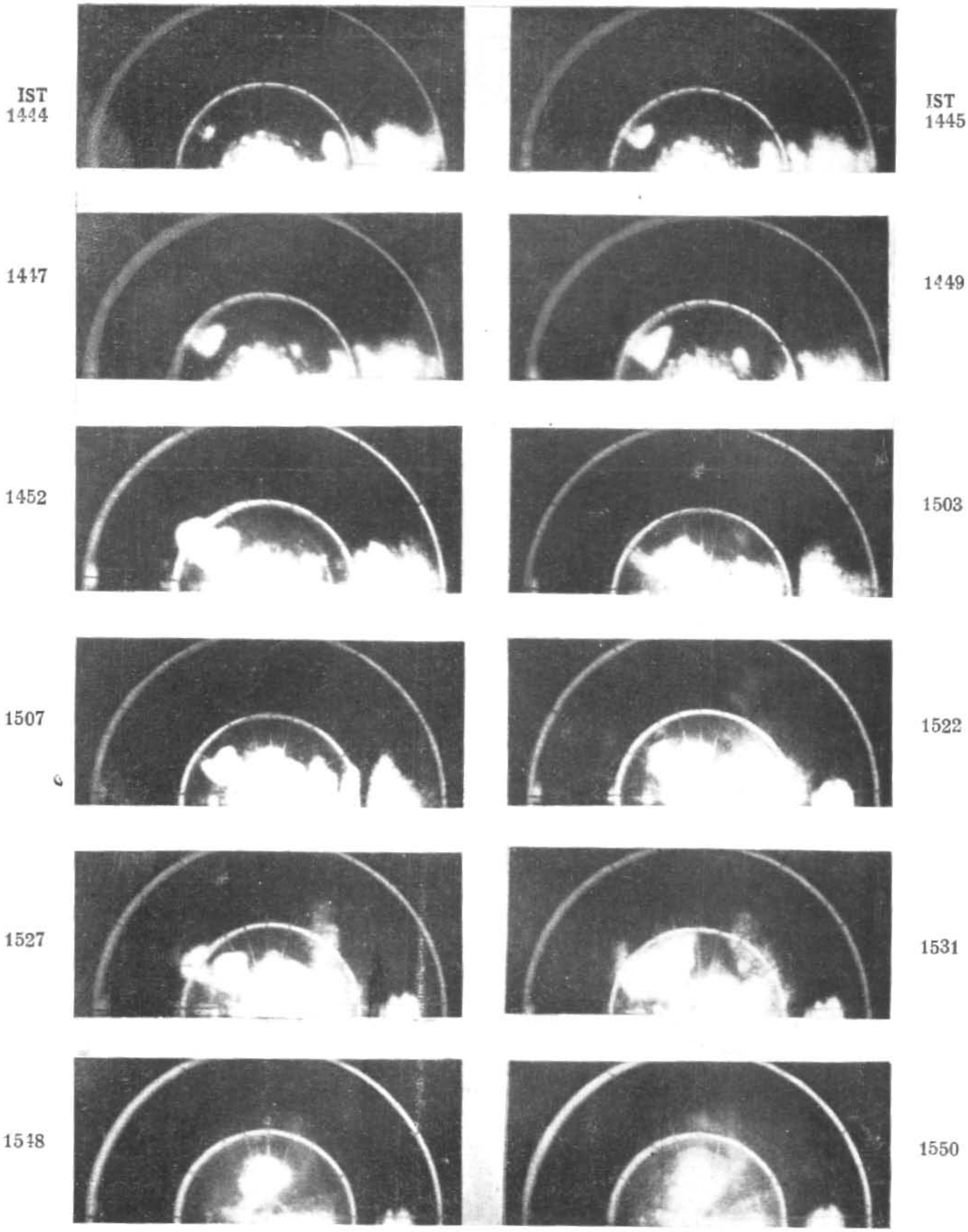

Fig. 4. Radar observations of thunderstorm on 26 May 1958

1739-1800 and 1920-1946 IST, associated with two spells of rain (16 mm at Poona from 1700-2100 IST and 8 mm at Kirkee from 1715-2100 IST). On 15 October 1958 there were two spells from 1720-1730 IST and again from 1745-1805 IST. There was very light rain with thunder during the first spell. The range of the flashes was estimated by timing the periods between the flash counts and arrival of the thunder and was found to be 2-3 miles and sometimes as much as 5-6 miles. Workman and Reynolds (1953) have reported a periodicity of 25-40 minutes in the occurrence of lightning flashes. They observed that starting with a high frequency of strokes, the interval between the strokes becomes greater; the frequency again increases and the cycle is repeated as new cells become effective.

The maximum rate of flashing per minute recorded was four in the premonsoon thunderstorms and only two per minute in the post-monsoon ones. The radar studies of these thunderstorms at Poona have shown that the premonsoon storms are associated with more vigorous convection and the height upto which supercooled water is raised is greater in them than in the post-monsoon thunderstorm (Gupta and Venkiteshwaran 1958).

3·2. *Lightning flash and radar observations of the thunderstorm on 26 May 1958*—The thunderstorm of 26 May 1958 was studied with a search radar type SCR-717C as well, of operating on a wave length of 9·1 cm, with a peak power of 40 KW and a pulse duration of 1·125 μ secs. A series of photographs of the radar echoes from the thunderstorm of 26 May 1958 from 1444-1550 IST is shown in Fig. 4. The main feature of the thunderstorm of this day was that it was local, almost stationary and was associated with the growth and dissipation of a number of cells over almost the same area.

The radar echo associated with the first main spell of rain, lightning and thunder made its appearance on the radar screen at 1444 IST, at a height of about 4 km a.s.l., 7 km to the NNW of the station. This echo rapidly grew in all directions and its top reached a height of about 7 km a.s.l. and its base approached the ground by 1452 IST. No lightning flash nor rain was reported during this period, although a few drops of rain had begun to fall over the station at 1445 and continued intermittently till 1457 IST. The echo top began to descend after 1500 IST; the first lightning flash was recorded at 1501 IST and thunder heard ; 11 flashes of lightning were recorded between 1501-1511 IST and heavy rain recorded from 1500 IST at the College of Military Engineering, Kirkee. The first spell of lightning was presumably associated with the cells to the north of the station which caused rain over Kirkee.

The different cells began to merge with each other by 1514 IST into a large conglomerate mass and develop upwards till by 1525 IST the top of the radar echo had reached about 10-12 km. The cloud top began to descend after 1530 IST; lightning flashes were again recorded from 1528-1538 IST, with thunder and light rain which though again not recorded at the station, was recorded at Kirkee. The flashes started again at a faster rate at 1543 IST, presumably associated with the renewed growth of a cell, which appears as a well-developed echo extending to about 8 km a.s.l. sloping over the station 3 km to the NNE. By 1549 IST, the top of the echo had reached 12 km and the lightning flashes were very frequent, reaching a maximum of 4 per minute. Heavy rain fell over the station at 1555 IST, 25 mm being recorded in 20 minutes. The last flash was recorded at 1558 IST. There were thus three separate cycles of development of radar echoes, each associated with spells of rain, thunder and lightning and each lasting about 10-15 minutes.

It will be seen that the frequency of lightning discharges and intensity of rain are a measure of the height to which the cloud has been lifted. The heavy rain commences only after the updraughts weaken and radar echo starts to descend and the first precipitation and first lightning flash occur together, with the maximum lightning frequency occurring after the radar echo has started to descend. This is supported by the observations of Byers and Braham (1953) who state that the heaviest rain and greatest lightning activity are associated with the downdraughts and Kuettner (1950) who remarks that the electrical activity is always associated with heavy precipitation, the central lightning area being coincident with the area of highest precipitation within the cloud.

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