A new photographic instrument for analyzing lightning flashes.

By

Zyungo YOSIDA and Masando HANAZIMA.

1. Introduction.

The photographic cameras which have hitherto been widely used for the purpose of analyzing lightning flashes are of two types: Boys type[1] and Walter type[2]. Boys camera is used by many observers more frequently than Walter's type, as it is more conveniently handled and has a high resolving power. Some of the photographs taken with the Boys camera are very beautiful and sharply defined as shown in Schonland's paper[3]. But the present authors consider that the relative motion between lens and plate, which is the essential point of the Boys camera, may likely be the cause of slight bluntness of the image if the camera is not exactly constructed. The motion of the vibration of camera may introduce unavoidable fluctuations in the distance between lens and plate and damage the sharpness of the image. Another difficulty is that the image on the plate runs on a circular track when the common moving lens type Boys camera is used. The picture is sometimes of little value, when the images of flashes overlap with each other in the longitudinal direction.

Walter's camera is an ordinary photographic camera revolving about a vertical axis. This camera is free from the defects above mentioned, but the chance of catching the flash is very small, because it faces the lightning only for a short moment during its revolution. The limited lateral length of the plate reduces the resolving power of the camera, as the whole course of the lightning phenomenon must be caught on one plate. This point is a serious defect, because it is impossible to take a photograph of a series of many strokes belong-

1) C. V. Boys: Nature, **122**, 310, (1922).
2) B. Walter: Phys. ZS., **3**, 168, (1902).
3) B. F. J. Schonland: Proc. Roy. Soc., (A); **152**, 595, (1935).

ing to one lightning flash, if the speed of revolution is increased in order to attain a high resolving power. With respect to the chance of catching the flash, Boys camera is also imperfect. The flashes occurring outside its confined visual angle escape the camera, and this chance of securing flashes becomes small especially when the thunderstorm is near.

In consideration of the above stated defects of the camera hithertofore in use, the authors attempted to make an instrument which meets the following requirements:

1. large visual angle.
2. sharpness of image.
3. high resolving power.
4. ability to catch the whole course of lightning phenomenon extending over a considerable period of time.

For requirement 2, i.e. for getting sharp images, the authors adopted Walter's type. Several cameras are used instead of a single one. They are so arranged about a vertical axis of revolution that the whole field is covered by those cameras. In order to mount many cameras on one axis of revolution, a small type camera must be employed. It is well known that the modern high class camera of small type gives by enlargement as good a picture as that of an excellent camera of ordinary size. In the present case ten cameras are used. Revolving the cameras at a speed of 5 rev/sec, the whole width of the picture which is ten times that of each film covers a time interval 0.2 sec, which is in most cases longer than the duration of a series of strokes belonging to one lightning flash. With this speed of revolution the resolving power reached as high as 50 μsec.

2. Description of the instrument.

The small type cameras used for the instrument are Leitz's Leica cameras with Elmar lenses (focal length: 5 cm.)*. As one Leica camera has a visual angle ca. 40°, ten cameras arranged at an angle of 36° with each other cover altogether a visual angle of 360°, i.e. the whole visual angle.

* They were private possessions of the authors' friends kindly lent for the period of the observations.

The appearance of the instrument is shown in Photo. 1, Pl. I. A stout cast iron frame holds through ball bearings a vertical steel rod which is rotated by a motor fixed at the lower part of the frame. Ten cuttings are made along the steel rod, each at an angle of 36° from the next, and the cameras are fastened to the cuttings by means of aluminium holders. The motor is driven by 50-volt batteries. Time marks are printed on two of the rotating cameras at the instant when the lightning flash is caught. As the source of the time mark a capillary neon tube is used, which is flashed intermittently with an induction coil and a tuning fork of frequency 100/sec. The neon tube is put in the focal plane of a projecting lens, and the parallel rays are focused on the film of the rotating cameras which are focused at infinity. The time marks are reproduced in Photo. 3, Pl. II. The distance between the neighbouring two marks corresponds to 0.01 sec.

Although the cameras can be rotated safely at a speed of 10 rev/sec or more, the authors chose 5 rev/sec as a convenient speed. As the focal length of the camera is 5 cm, the translational speed with which the image of the flash runs on the film is 157 cm/sec at its centre. Near the extremities of the film the speed is about 10% larger than this value. As it is easy with a microscope to distinguish on the film two points 0.1 mm or less apart, a time interval of $0.01/157=0.000064$ sec or less can be clearly distinguished; i.e. the resolving power of the rotating camera is about 50 μsec.

Ordinary photographs of the lightning are also taken with fixed Leica cameras. Four cameras are fixed on the side of a wooden framework as shown in Photo. 2, Pl. I. Each of them makes an angle 36° with its neighbours and as a whole they cover a visual angle ca. 150°, which is large enough in most cases.

Except for the time interval of one minute or two, during which the rotating camera is stopped and the next exposure is prepared, no lightning can escape this camera. As a matter of fact, working with this instrument last summer (1941), the authors missed no flash throughout the whole season of observation.

3. Results of observations.

Lightning flashes were observed in the summer of 1941. Unfortunately thounderstorms were not frequent during the summer and the chances for taking photographs of flashes occurred only

twice. Both of them were distant thounderstorms. A few of the results of observations will be described below.

(1) Photos. 4, 5 and 6. Pl. II.

Photo. 4 was taken with the fixed camera and Photos. 5 and 6 were with the rotating camera. This lightning was so distant that no thunder was heard and accordingly the distance of the flash could not be determined. The rotating camera reveals that this flash was composed of two strokes, the one occurring 0.15 sec before the other. The first stroke had many branches but the second none. The leader stroke was observed in the second stroke but in the first one no image of the leader is detected. It is highly probable that the leader of the first stroke was too faint to be photographed, as the thunderstorm was so far away. Although it is impossible to determine the length of the lightning track without knowledge of its distance, it is not a serious error to estimate the length at 1000 meters. By means of this estimated value of the length of the flash the speed of the leader of the second stroke is calculated and the value 4.5×10^7 cm/sec is obtained. This value is much less than that given by Schonland[1] as the usual dart leader, but he notes that, in cases when a stroke occurs at a long time interval after the preceding one, a dart leader

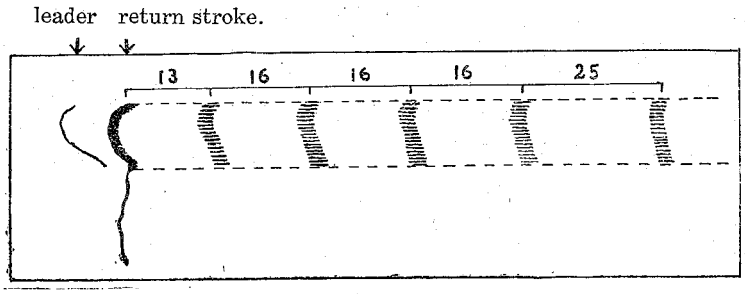


Fig. 1.

with low speed is frequently observed. As is shown clearly in Photos, the strokes had a very long after-glow which ran for 0.014 sec in the first stroke and for 0.027 sec in the second. Careful examination of the after-glow of the second stroke reveals a band structure in it. Fig. 1 shows this structure schematically. The numerical figures in the figure give the time intervals between the bands in 0.0001 sec.

1) l. c.

(2) Photos. 7 and 8. Pl. III.

Photo. 7 was taken with the fixed camera and Photo. 8 with the rotating camera. Three flases occurred almost simultaneously and their distance was determined to be 4.5 kilometres by means of the lightning-thunder interval. Marking the three flashes from the left as A, B and C; A occurred first, followed by C and B, the time interval being 0.0038 sec between A and C and 0.0023 sec between C and B. While both B and C were single strokes, A was composed of two strokes. The interval between the two strokes of A was 0.14 sec, the second stroke of A not being reproduced in Photo. 8.

Flash B had a leader which is faintly observable on reproduced photograph, Photo. 8. The B flash of Photo. 8 is shown schematically in Fig. 2, in which the leader is drawn with broken lines and the

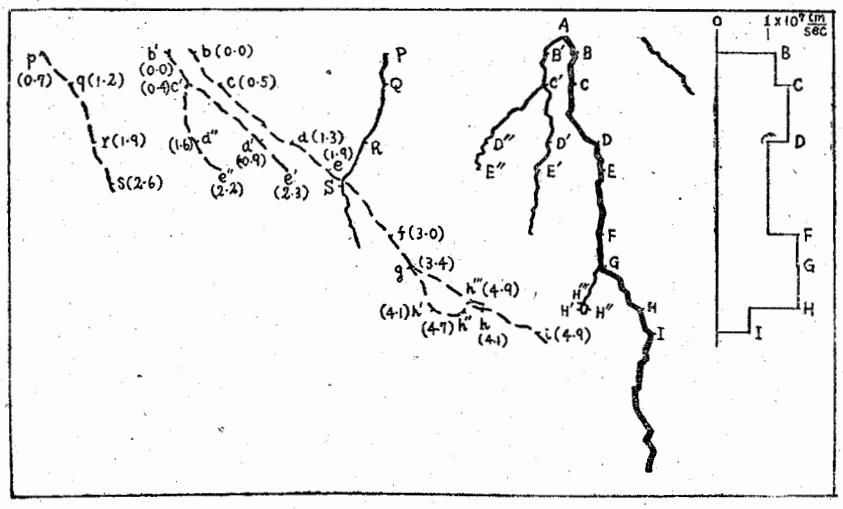


Fig. 2.

return stroke with continuous thick lines. The corresponding capital and small letters along the return stroke and the leader indicate the same points along the lightning path. The numbers in brackets beside the small letters show the time moment at which the leader reached that point. The time is measured in 0.001 sec, taking the points b and b′ as origins. The diagram in the right hand side of Fig. 2 shows the advancing speed of the leader b, c, d, ... i, calculated under the assumption that the lightning occurred in a plane

perpendicular to the visual direction. Although speed varies conspicuously along the lightning path, it does not necessarily follow that the true speed varies in such a manner, because the speed shown in the figure is only the lateral component of the true speed. Its component in the visual direction cannot be determined. At any rate it is reasonable to estimate the advancing speed of the leader at 1×10^7 cm/sec, which coincides with the speed given by Scholand for the leader of the first stroke. Although a very careful examination was made of the photograph of the leader, no stepped structure was detected, in agreement with Scholand's case. At the end of branches c′, d″, e″ and g, h′, h″, h‴ the leader took a form in the photograph to proceed thenceforth horizontally to the right, showing that the speed was much reduced at those points.

The present observations were made as a part of the general work planned for the prevention of thunderstom disasters by the Nippon Gakuzyutu Sinkôkwai. The authors worked under the leadership of Prof. Nakaya and they should like to express here their deep gratitude to him. Thanks are also due to Messrs. Sugaya and Kagami who assisted the authors in the observation and to the friends who kindly lent their cameras to them.

Summary.

A photographic instrument of new design was made for the purpose of analyzing lightning flashes and it was used in the field with good results. The instrument is composed of ten Leica cameras attached along a revolving steel rod. The cameras are so arranged that a lightning flash occurring in any direction is caught by some one of cameras; i.e. the visual angle is 360°. Revolving the cameras at the rate of 5 times per sec the resolving power as high as 50 μsec is obtained, and at the same time the whole series of strokes of a lightning flash can be photographed without overlapping.

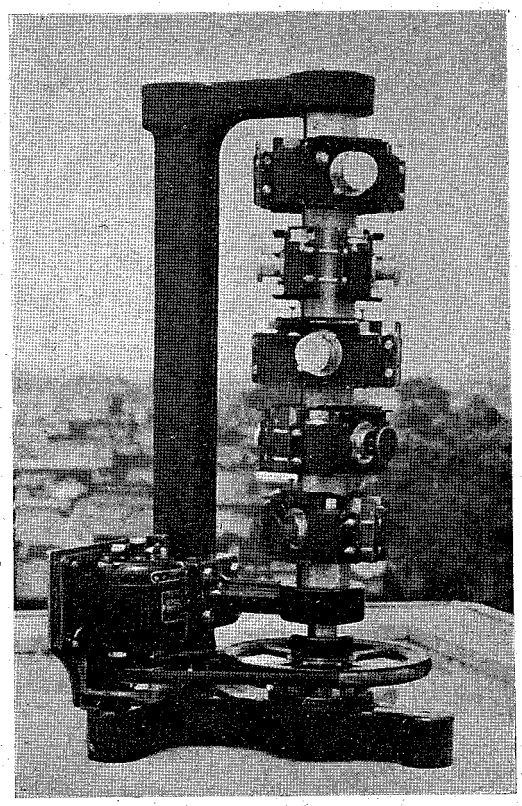


Photo. 1. Rotating Camera.

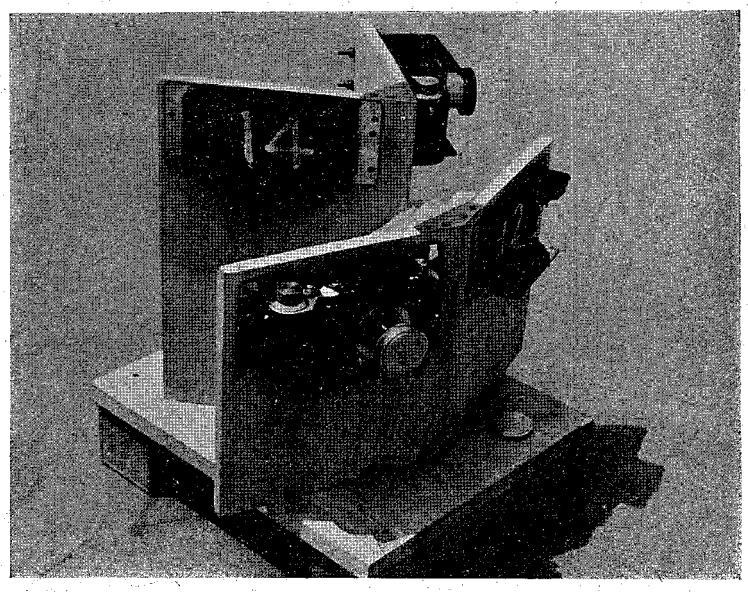


Photo. 2. Fixed Camera.

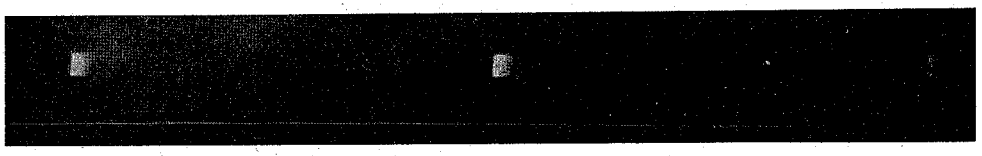


Photo. 3 Time Marks, the Interval 0.01 sec.

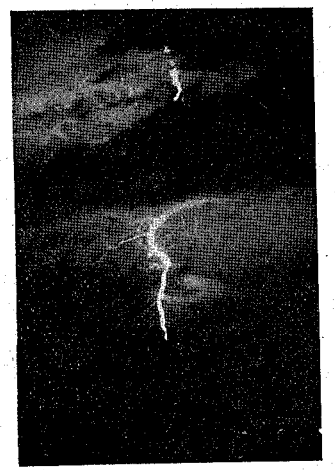


Photo. 4. Fixed Camera.

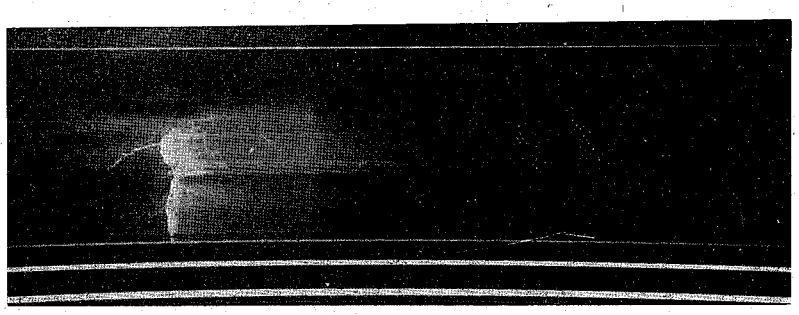


Photo. 5. Rotating Camera, the First Stroke.

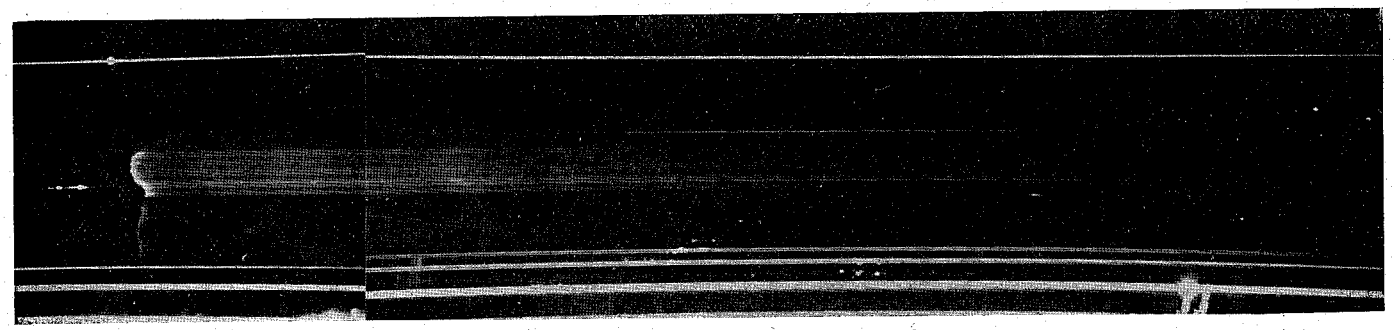
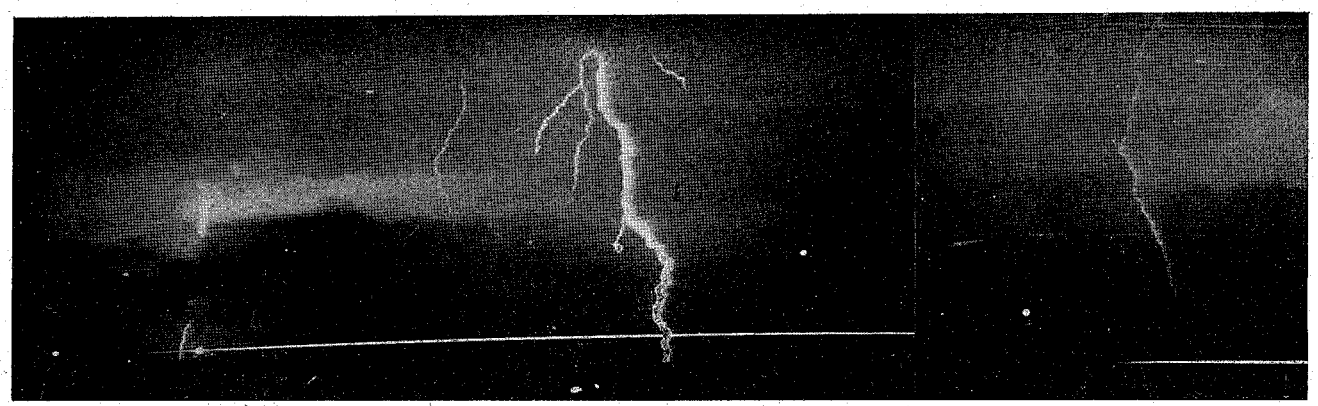


Photo. 6. Rotating Camera, the Second Stroke.

A B C

Photo. 7. Fixed Camera.



A B C

Photo. 8. Rotating Camera.