A Laboratory Study of Spark Discharge Between Conducting Clouds

It is usually assumed that the lightning flash and the laboratory spark are essentially the same phenomenon when account is taken of the greater magnitude of the voltage, current, and path length of the lightning flash. There are, however, important differences since the lightning discharge takes place between two charged clouds, or between a charged cloud and the ground, while the laboratory spark is between metal electrodes. Little is known of the manner in which the initial leader stroke is started from the cloud or what happens in the cloud during the flash.

It seemed to us that an investigation of these obscure points necessitated the production of discharges on a small scale between conducting, charged clouds. The preliminary work reported here does not reproduce lightning cloud conditions exactly but is sufficiently similar to be of interest.

It is well known that steam passing through a properly designed nozzle becomes charged. This is the basis of the generator designed by Armstrong.[1] This generator was copied and attempts made to obtain a discharge between the steam cloud and a grounded metal point electrode. A field at the point sufficient to start an intermittent corona discharge visible in a slightly darkened room was easily obtained. The current to this point, observed by means of an oscillograph, had the usual characteristics of a discharge of this type, starting suddenly and then decreasing comparatively slowly (maximum 10–20 μamp.). This is evidently the type of discharge known popularly as St. Elmo's fire. We were not able to produce a distinct spark by this method. This is probably to be expected, since there is no appreciable ionizing process in the cloud after it leaves the nozzle. As a consequence its conductivity rapidly decreases because of the formation of large ions, so that a long spark discharging a considerable region of the cloud is unlikely to occur.

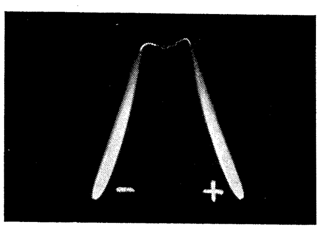

FIG. 1. Snapshot of a spark discharge between the tips of two oxygen gas flames.

A more promising approach to the problem involving the use of long flames at various temperatures arose in a discussion with Dr. F. T. Holmes, of this laboratory. An impulsive voltage (80 kv) was applied between two adjacent oxygen gas flames about 30 cm long. With the flames inclined toward each other so that the tips are about 10 cm apart, sparks will pass from tip to tip. A snapshot of this discharge is shown in Fig. 1. The flames are overexposed but it will be noted that the bright part of the spark channel starts and ends rather abruptly in the highly conducting core of the flame. Consequently this is effectively the same as a discharge between a negative cloud and an adjacent positive cloud. In nearly every picture several short faint channels in addition to the main channel can be seen. Unfortunately they are so faint on the original film that they are lost in the reproduction. Branching of the main channel is also observed. This would indicate that at least over part of the path the initial ionizing process proceeds similarly to that of the lightning flash. We do not as yet know whether or not the leader stroke is "stepped."

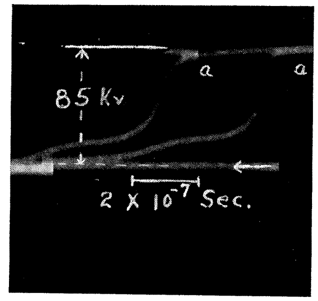

FIG. 2. Two oscillograms of the potential difference between two gas flames during the period of spark formation, the breakdown in each case starting at the point (a).

An oscillogram of the potential difference between two gas flames during the period of spark formation is shown in Fig. 2. The discharge is characterized by a long and erratic time lag and by the slow breakdown taking place in stages as shown. Since the gas flames were relatively cool with low conductivity, compared to the oxygen gas flames, the discharge channel does not end abruptly but extends through the flame to the metal nozzles. Consequently the last part of the oscillogram probably represents the formation of an arc. These results would seem to indicate that a lightning flash should penetrate some distance into a poorly conducting cloud but scarcely at all into a cloud in which the air is highly ionized.

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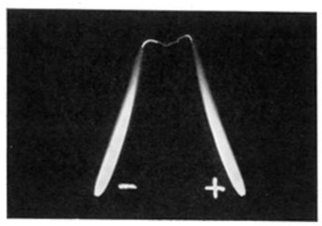
[1] Armstrong, Ann. d. Chim. et Phys. **10**, 105 (1844).



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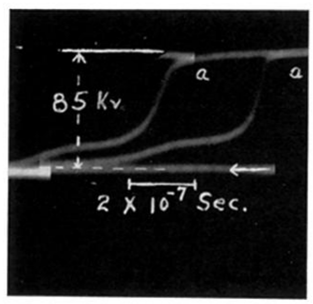

FIG. 2. Two oscillograms of the potential difference between two gas flames during the period of spark formation, the breakdown in each case starting at the point (a).