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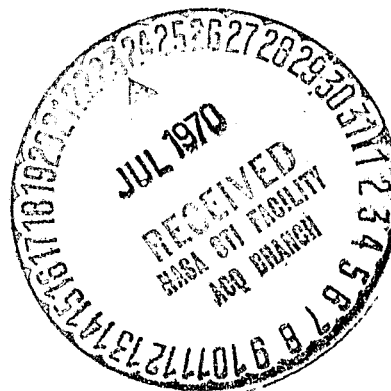


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Lightning Hazard to Rockets During Launch II

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LIGHTNING HAZARD TO ROCKETS DURING LAUNCH II.

Heinz W. Kasemir

1. INTRODUCTION

In designing a lightning warning system for rocket launch areas, one has to take into account that the greatest danger to a rocket is not an accidental strike by natural lightning but the high probability that a rocket will trigger its own lightning discharge, if it enters areas inside a cloud with strong electric fields (Kasemir, 1969). Fields in the order of 20 to 50 kV/m may be enough to produce rocket triggered lightning discharges, and fields of this magnitude can be found in a small cumulonimbus, or rain shower, which does not contain natural lightning discharges. This situation is aggravated by the fact that the electric fields are sustained inside the cloud for some time (one-half hour) after the rain or lightning has stopped. On the other hand, there are precipitating clouds, namely of the nimbostratus type, that do not generate electric fields in excess of a few 100 V/m. It would be perfectly safe to launch a rocket through such a cloud.

The consequence of these facts is that meteorological observation, including radar, is not sufficient for a lightning warning system at rocket launch areas - the key parameter of such a warning system

has to be the electric field inside the cloud. If this has been measured, one has to know in addition the threshold value of the field for the different types of rockets that will cause (a) corona discharge or (b) lightning discharge by rocket penetration.

The field distribution and its time history inside different types of clouds, the corona threshold field, and the lightning threshold field are the three particular research areas that have to be explored before an effective warning system can be designed or even before an investigation of the possibility of discharging the cloud can be successfully carried out.

It is the purpose of this report to discuss a program of investigation of the above mentioned research areas. Section 2 deals with the determination of electric fields inside a cloud and section 3 with artificially triggered lightnings by test rockets.

2. DETERMINATION OF ELECTRIC FIELDS INSIDE THE CLOUD

There are three ways to determine an electric field inside a cloud:

- (a) By direct measurement from an airplane penetrating the cloud (Fitzgerald, 1967; Cobb and Holitza, 1968).
- (b) By analysis of field measurement from an airplane outside the cloud (Kasemir, 1968; Schuman, 1969).

(c) By analysis of field measurement taken at ground level.

The direct measurement of the field inside the cloud from an airplane seems to be the best method; however there are two problems.

First, it is relatively easy to measure the two components of the electric field at right angles to the flight path (i.e., the up-down and the left-right components). It is quite difficult to measure the field component in direction of the flight (i.e., the nose-tail component) during precipitation because precipitation particles impinging on the sensitive segment of the field mill facing into the rain generate a strong electrostatic signal that saturates the nose-tail field component amplifier. It is very important that all three components of the electric field vector be measured with the same accuracy; therefore, one of the first items of a research program would be to improve existing equipment so that all three field components can be recorded, even in precipitation, with equal accuracy.

The second problem is that the maximum fields inside the cloud, which are the main interest, can only be located by a trial and error method. This problem can be solved by a second airplane, which stays outside the cloud and determines from its field measurement the charge distribution and the altitudes of maximum fields inside the cloud. The absolute value of the maximum field cannot be calculated from field measurements outside the cloud because the conductivity

inside the cloud is not known, but the second plane could guide the first plane to the areas of maximum field inside the cloud, and from comparison of the measured and calculated field, the conductivity inside the cloud can be obtained. If from a number of such test flights it follows that the conductivity inside the cloud is fairly constant, or at least has a constant ratio to the conductivity outside the cloud at the same altitude, the field distribution inside the whole cloud can be calculated. The obvious advantage of an analytical calculation is that the complete charge and field distribution inside the cloud can be obtained from one pass outside the cloud, whereas the field measurement of one cloud penetration will give only the field distribution along that one pass. There is no assurance that such a pass would lead through the area of maximum field or that there are not several areas with high fields in the cloud. The detection of these areas with high fields is the main purpose of the investigation.

Theoretically an analysis of the field measurement along the pass inside the cloud should result in a complete charge and field distribution throughout the whole cloud; however this requires that all three field components be measured with the same accuracy also in rain (which with the present state of the art cannot be done) and that the airplane pass the different charge centers in distances of similar magnitude. Otherwise the field of the closest charge center becomes overwhelmingly large and blanks out the field of the other

charge centers. A plane flying outside the cloud at midaltitude can fulfill this condition much easier than a plane penetrating the cloud. My conclusion, based on the discussion above, is that two airplanes are necessary to obtain the complete charge and field distribution in a cloud. The first airplane has to be capable of cloud penetration and should be equipped with instruments for recording the vertical and at least one horizontal component of the electric field. The second airplane remains outside the cloud at about a 20,000 ft. altitude and should be equipped to measure all three components of the electric field with about the same accuracy.

The third method mentioned earlier, field measurements taken at several ground stations at its best has several severe handicaps. The requirement that the stations should be at similar distances from the different charge centers can obviously not be fulfilled for the charges at the top and the base of the cloud. Consequently, a high demand of accuracy and dynamic range is put on ground instrumentation. Furthermore one charge center in the cloud has four parameters: namely, the three coordinates and the charge magnitude. Field measurements at four different ground stations are required to calculate these four parameters. If the cloud contains three charge centers, twelve ground stations would be required, and if two tripolar clouds are located in an area of the ground network, twenty-four stations would be necessary for an analysis. It is assumed that the conductivity in the cloud is known, that local

disturbances like spacecharge pockets from exhaust fumes, from corona discharge of power lines, or a nearby surf are absent and that a sufficiently accurate solution of the twenty-four simultaneous equations is possible. All these assumptions are probably not fulfilled; however, if a flight program is carried out to determine the maximum fields in the different types of clouds, a comparison of the ground and flight results can be used to determine the benefit and the limitations of a ground network.

3. ARTIFICIALLY TRIGGERED LIGHTNINGS BY TEST ROCKETS

The necessary equipment to artificially trigger lightning by test rockets is:

- (a) Two airplanes equipped with field mills to determine the maximum electric fields in the cloud.
- (b) Test rockets equipped with corona discharge point and transmitter to ground.
- (c) Lightning plotting system.

The preliminary tests should be carried out with small rockets driven by compressed air and equipped with parachutes, so that they can be launched from a mobile station and be recovered after descent, if they are not destroyed by the triggered lightning.

A corona discharge point would be mounted on the tip of the rocket and the onset of corona discharge transmitted to the ground station. Using Kasemir's (1969) equation 1, the external field to

produce corona discharge can be calculated. The two airplanes will check the clouds for their maximum fields and if these surpass the corona onset field, the rocket is launched into the cloud. The main purpose of this test is to determine how much the corona breakdown field has to be surpassed in order to turn corona discharge into lightning discharge. Another objective of this task is to determine how long a cloud remains discharged by a triggered lightning.

It is well known that after a lightning discharge the electric field of a thunderstorm at the ground recovers in about 10 sec to its predischARGE value. This fast recovery curve has been - and to some extent still is - a big mystery in the thunderstorm charging mechanism. A medium thunderstorm may produce one lightning discharge every 20 sec, which would indicate that the charging mechanism after a lightning stroke is accelerated to restore the destroyed charge in about 10 sec.

The questions that arise here are: will the charge in the shower cloud also be restored in about 10 sec after an artificially triggered lightning, or what is the recovery time in this case; how long a time interval has to elapse before a second lightning will be triggered by a second test rocket. Such an investigation will be useful in establishing the feasibility of discharging shower clouds by rockets.

Another variation of the test program will be to use test rockets

of different sizes and to equip some of them with trailing wires of different lengths. This will prove the validity of equation 1 of Kasemir (1969). It will also explore the possibility of replacing larger rockets by smaller rockets trailing a wire.

Large rockets with the larger field concentration factor will trigger lightning discharges in much weaker fields than small rockets.

If a cloud has to be tested for a launch of a large rocket the test rocket should be of the same size. If this is economically not feasible, the test rocket may be of smaller size with a trailing wire making up for the length deficiency. It is to be expected that such a test rocket will go into corona discharge at the same field as the large rocket but will need much larger fields to trigger lightning discharges.

To test whether lightning is triggered by the test rocket, a lightning plotting system has to be developed which will consist of three ground stations located at the corners of an equilateral triangle with a side length of about 15 miles. The direction of the lightning stroke will be obtained with crossed loop antenna at each station and the position by triangulation.

The tests to trigger lightning by penetrating rockets have to be carried out during disturbed weather conditions where the presence of other thunderstorms in the test area is quite likely. The lightning plotting system provides the means to differentiate between triggered lightning and that produced by surrounding thunderstorms.

4. REFERENCES

Cobb, W. E., F. J. Holitza. (1968), A note on lightning strikes to aircraft, Monthly Weather Rev. 9, No 11, 807-808.

Fitzgerald, D. R. (1967), Probable aircraft "triggering" of lightning in certain thunderstorms, Monthly Weather Rev. 95, No. 12, 835-842.

Kasemir, H. W. (1968), Charge distribution in the lower part of the thunderstorm, Proc. of Intern. Conf. on Cloud Phys., Toronto, Canada, 668-672.

Kasemir, H. W. (1969), Lightning hazard to rockets during launch I, ESSA Tech. Rept. ERL 143-APCL 11 (U.S. Government Printing Office, Washington, D. C.)

Schuman, E. (1969), The inference of the charge distribution in thunderstorms from airborne measurements of the electric field, J. Appl. Met. 8, No. 5, 820-824.