ARTIFICIAL LIGHTNING

A Summary of a Study of Natural and Artificial Lightning Discharges

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A STUDY of lightning is of scientific importance because there is manifest in the flash the dynamic effect of the electrons and ions, the elemental bricks of which, it is believed, all matter is made; it is of engineering importance because an exact knowledge of the characteristics of lightning will make it possible to protect life, buildings, powder magazines, oil tanks and transmission lines against it. The ideal method of making such a study is by observations of natural lightning in the field and researches with artificial lightning in the laboratory. This lecture is a report on such a combined study.

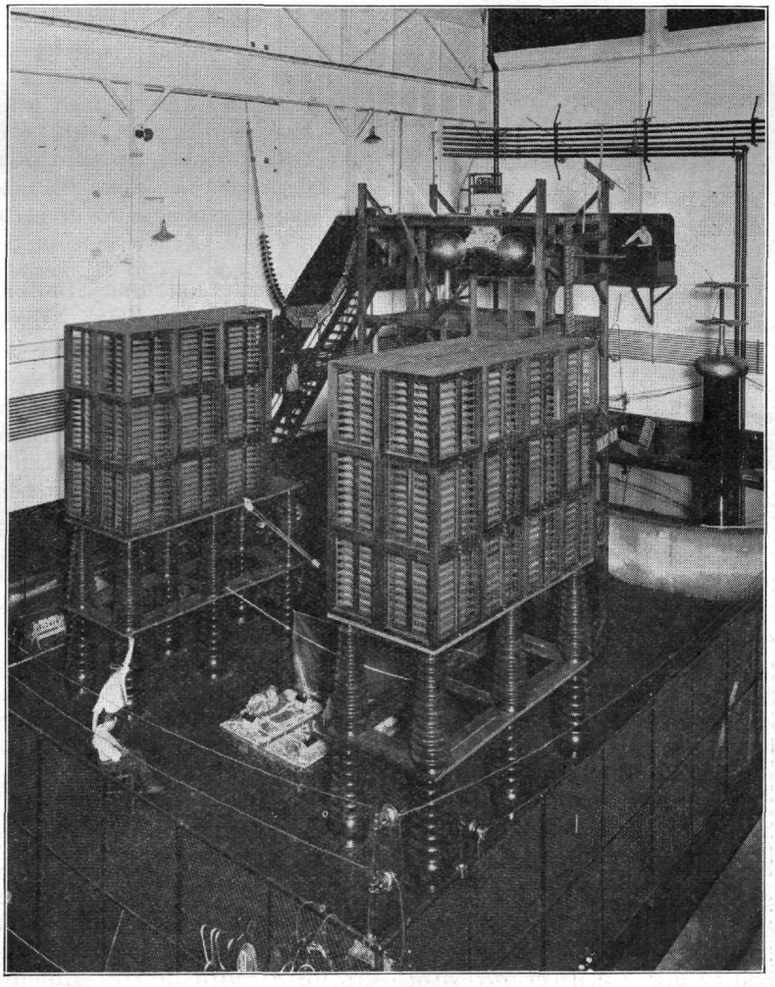
The artificial lightning was obtained by means of the author's lightning generator which supplies 2,000,000 volts at an energy of 2,000 watt seconds. 8he power may be several million kilowatts or horse power. The character of the discharge is similar to that of natural lightning. The destructive effects are also similar; fires may be set, metal conductors disappear, wood may be blown apart, discharges in water or oil produce explosive results, etc.

The experiments with natural lightning were made in the mountains of Colorado and elsewhere. The conclusions from this study are as follows:

The Voltage, Energy and Charatcer of Lightning

A thunder cloud discharges to earth when the voltage along the discharge path is about 100,000 volts per foot. The effect of the thunder cloud is not local, but the atmosphere becomes electrified for a considerable distance. 32,000 volts for each foot above ground may occur at a quarter of a mile from the flash; 12,000 volts at a half mile and 3,000 volts at a mile.

When the flash occurs current flows from the cloud to ground and the potential of the cloud becomes zero in a few micro-seconds.* The cloud may become charged in the opposite direction at a lesser voltage a few micro-seconds later and so on. This is called an ascillatory discharge. Most discharges seem to be non-oscillatory or impulsive. The electrical energy is changed into heat, light, sound and chemical energy. The chemical changes take place in the path of the



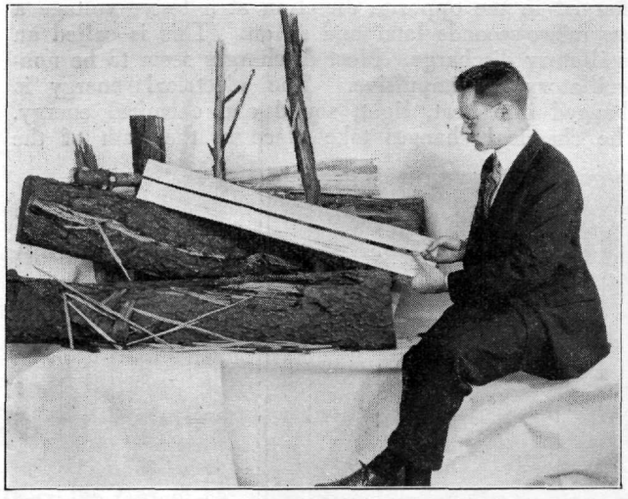
TWO MILLION VOLT LIGHTNING GENERATOR

Power from low voltage lines is stepped up to very high voltages and stored in the artificial clouds or condensers and discharged in a small fraction of a milionth of a second as lightning.

discharge. The oxygen molecude is split up and partly recombines as ozone. Nitrous oxides are also formed as well as nitric acid in the presence of moisture. Along the discharge path are untold numbers of electrons and ions moving at enormous velocities. It is a matter of speculation whether this intensive ionic bombardment of the oxygen and nitrogen atoms transmutes some of them into helium or hydrogen.

The voltage of lightning is of the order of 100,000,000. This is about one million times the voltage of the ordinary lighting circuit or one thousand times the voltage of very high voltage transmission line. The current may be 80,000 amperes and the energy 13,500 Kw-seconds or 3.8 Kw-hours. The energy is sufficient to operate an automobile about five miles or an electric toaster for a day. Since this energy is dissipated in a very short time the power may be several million kilowatts or horse power. The effect is thus explosive and destructive.

The voltage was arrived at by researches with artificial lightning on models of clouds, etc., built to scale. This voltage measurement was described in a lecture before the Institute last year and caused considerable in-



WOOD SPLIT BY ARTIFICIAL LIGHTNING

terest. It has since been further confirmed. It may be of interest to point out that the voltage of the lightning generator is about 2 per cent and the power about 2 hundredths per cent of natural lightning. This practically corresponds to the lightning energy that appears on transmission lines.

Voltage Disturbances on Transmission Lines

A lightning flash in the vicinity of a transmission line may cause dangerous voltage on the line. The line is very seldom directly struck but the effect is generally by induction. The line, as well as the atmosphere around it, becomes electrified b ythe cloud. The charge on the line is released when the cloud discharges to ground. The voltage on the line reaches its maximum at about the time the cloud voltage reaches zero. The line voltage becomes equal to the voltage of the atmosphere above ground at that position in space just previous to the discharge but of opposite sign.

The maximum voltage induced on the line is one or two per cent of the cloud voltage. The energy is of the order of 1350 watt-seconds. The character of the discharge is generally impulsive and reaches its maximum in a few micro-seconds. In fact, it corresponds closely with the discharge from the lightning generator in voltage, energy and duration. The maximum possible voltage on any line can be found by multiplying the height of the line in feet by 100,000. Thus by "wireless" action 1 to 2 per cent of the voltage and 2 hundredths per cent of the energy of a lightning flash can appear on transmission lines several thousand feet from the cloud. These maximum conditions rarely occur on transmission lines.

A lightning disturbance travels over the line at the velocity of light and is dissipated to a considerable extent by losses; it may double in value when it strikes the end of the line where it starts back. If the voltage is high enough it may break down insulators or discharge over an arrester. If no break occurs it is eventually dissipated by losses.

A grounded wire placed near the line conductors reduces lightning voltages on transmission lines to less than half. Several ground wires reduce the lightning voltages still more. The ground wire is also a good protector against direct strokes.

The strength of the insulation of lines operating at various voltages was determined by measurements with artificial lightning. By comparing the insulation strength with the maximum lightning voltage the ability to withstand lightning was determined.

The insulation of transmission lines is increased with the operating voltage. The higher the operating voltage the better able the insulation is to withstand lightning voltage. The exact voltage where danger from lightning disappears varies with conditions but in general there will probably be little trouble on 220 KV lines. Special precautions must be taken, however, to cause the lightning voltages to divide evenly over the apparatus.

Where Lightning Strikes and Chance of Being Struck

Researches in the laboratory show that lightning from a cloud overhead does not always strike the highest object or rod unless the height of that object is over 2.5% of the cloud height. The division of hits is about equal between cloud and ground when the rod is 1.1% of the cloud height. The chance of being hit is less when the cloud is not directly overhead. Lightning either strikes the rod or some distance away. There is a protected area around the rod with a radius equal to four times the height of the rod where no ground hits occur.

These researches show that a man standing directly under the storm center would be hit fifteen times out of a hundred strokes, while a man flat on the ground would be struck about once in one hundred strokes. A 25-foot building would be struck every time. The chance of a thunder cloud of sufficient voltage to cause a discharge being over any particular object is small. The chance of any particular object being struck is thus generally very small indeed.

The lightning rod seems to be of real value for the protection of buildings. Except for buildings in exposed positions or in special cases, as magazines, the cost of a rod, unless it is quite low, is not warranted from the standpoint of the cost of insurance.

Under certain conditions lightning may cause sparks within metal tanks.

* Micro-second equals a millionth of a second.