Has Lightning Any Practical Use?

by Martin A. Uman

ORIGINALLY PUBLISHED IN
ALL ABOUT LIGHTNING
DOVER PUBLICATIONS, NEW YORK, 1986

ORIGINALLY PUBLISHED IN
ALL ABOUT LIGHTNING
DOVER PUBLICATIONS, NEW YORK, 1986

Has Lightning Any Practical Use?

by Martin A. Uman

Energy is neither created nor destroyed. Rather, it is converted from one form to another. For example, in a light bulb the input electrical energy is converted to light and heat. The energy content of the output light and heat equals that of the input electrical energy. No energy is lost. A charged thundercloud contains stored electrical energy derived from the energy of winds and particle motions and from the energy released by condensing water vapor. Some of the stored electrical energy of the cloud is transferred to lightning. We consider now the energy and power available to lightning and the possibility of its controlled use for the benefit of man.

Each cloud-to-ground lightning flash involves tens of coulombs of charge at a voltage of between 100 million and a billion volts. The resultant electrical energy is about 1 to 10 billion watt-seconds per flash. If there are 100 flashes to ground each second over the whole world, a maximum value for the total electrical power input to worldwide cloud-to-ground lightning is 1,000 billion watts. By comparison, the total capacity of all electric power generators in the United States in 1970 was about 500 billion watts. It is evident, therefore, that the power and energy available to lightning is appreciable.

Unfortunately, no efficient method of tapping lightning's power and energy is presently available - for two reasons: (1) It is impractical to intercept (for example, with tall towers) any significant number of the world-wide cloud-to ground flashes. (2) Most of the energy available to the lightning is converted along the lightning channel to thunder, heat, light, and radio waves, leaving only a fraction available at the channel base for immediate use or storage.

The first problem is the more serious. If its total energy were available, a *single* lightning flash would run an ordinary household light bulb for only a few months. It is the high rate of occurrence of world-wide lightning (100 per second) which provides for the high total power and energy levels. A 1,000 ft. tower in a region of moderate thunderstorm activity is struck by lightning about 10 times a year. It would take one hundred thousand such towers, each collecting all the energy from ten strokes per year, to equal the 100 million watts generated by a typical small power station. It is impractical to erect a sufficient number of towers to capture significant quantities of energy from lightning, and no more practical means of intercepting lightning has been proposed.

Ancient man considered lightning the ultimate weapon. Its use and control were generally attributed to the gods. The Norse god Thor hurled lightning from his chariot while riding across the sky. In ancient Greece, Zeus threw the thunderbolts; in Rome, Jupiter. The advent of our modern civilization has not eliminated man's interest in the use of lightning as a weapon. Military research in several countries has recently been concerned with the feasibility of directing lightning and ball lightning at specific targets. While technology is not capable of achieving these goals at present, it would not be surprising if they were attained in the not too distant future. In view of the awesome destructive power of modern weaponry, the military use of lightning or ball lightning would probably be more as a psychological than as a destructive weapon.

Nitrogen comprises about 80% of the atmosphere surrounding the earth, yet it cannot be used directly by the large majority of plants and animals until it is "fixed". "Fixed" nitrogen is nitrogen incorporated in chemical compounds necessary to the chemical processes of life, as opposed to the relatively inert form of nitrogen, the nitrogen molecule, found in the air. Fixing is accomplished by (1) special organisms in the soil and waters, (2) industrial processes, and (3) ionizing atmospheric processes including lightning. Nitrogen which has been fixed in the atmosphere is brought to earth in rain. It has been estimated that of the 100 million tons of nitrogen fixed per year, about 8% is atmospheric, about 30% industrial, and the remainder biological (Ref.17.1). Estimates of this sort are difficult to make and subject to large errors. The role played by lightning in generating fixed nitrogen is frequently accorded prominence in the popular literature. We can, however, show that lightning is not as important in nitrogen fixing as is generally believed.

About 8 million tons of fixed nitrogen are thought to be brought to earth each year in rain. If we assume that (1) there are 500 lightning discharges (cloud-to-ground and intracloud) occurring each second, (2) each lightning channel is 2 in. in diameter and 4 miles long, (3) every nitrogen atom in every channel is "fixed" (a great overestimate), then the total amount of nitrogen fixed by the lightning channels is about 20,000 tons per year. Since 20,000 tons is a very small fraction of 8 million tons, we conclude on theoretical grounds that the lightning channel itself is not an important producer of fixed nitrogen. Experimental evidence to support this conclusion has been given by several investigators (Refs. 17.2 to 17.5) who show that the nitrate and ammonia content in precipitation is not correlated with the amount of lightning activity. In fact, there is roughly the same nitrate and ammonia content in precipitation in winter when there are few thunderstorms as in summer when there are many (Ref. 17.2). What, then, is the source of the atmospheric nitrogen compounds? The answer is not known, but there are two reasonable possibilities: (I) They are generated in the lower regions of the ionosphere (the ionized layer of atmosphere beginning about 40 miles above the earth) and diffuse downward, and/or (2) they are created by corona discharges in all types of precipitating clouds and along the ground under those clouds (Ref. 17.5). If possibility (2) is important, a close relative of lightning has contributed and continues to contribute significantly to the world's fixed nitrogen supply.

The lightning channel generates radio waves (sometimes called atmospherics or sferics) which have been used for practical purposes. Lightning is the strongest terrestrial source of electromagnetic noise in the radio band. The lightning radio noise is strongest near a frequency of 5 kilocycles per second and extends with decreasing intensity up and down the frequency scale as far as has been measured. Everyone is familiar with the lightning static produced on AM radios and the "snow" on TV pictures (particularly on the lower channel numbers) due to lightning radiation. Studies of the lightning electromagnetic noise have led to several practical applications. (1) Measurements made on lightning radio waves can be used to pinpoint the location of the thunderstorm area producing the lightning. Among those who use this information are meteorologists (who study as well as predict the weather) and aircraft pilots. Radiolocation techniques can spot thunderstorms thousands of miles away. (2) Measurements of the properties of lightning radio waves returned from the ionosphere and from ionized layers above the ionosphere have yielded valuable information about the numbers and kinds of charged particles in those regions. (3) Measurements of the properties of lightning radio waves as they propagate along the earth's surface have enabled the electrical resistivity of various portions of the earth to be determined. Similarly, lightning radio waves can be used in some kinds of geophysical prospecting (e.g., in the search for low resistivity ore lying far below the earth's surface).

References

17.1. Delwiche, C. C., The Nitrogen Cycle, Sci. American, 223 (No. 3), 137-146, September 1970.

17.2. Viemeister, P. E., Lightning and the Origin of Nitrates Found in Precipitation, Jour. of Meteorology, 17, 681-683 (1960).

17.3. Wetselaar, R., and J. T. Hutton, The Ionic Composition of Rainwater at Katherine, N. T., and its Part in the Cycling of Plant Nutrients, Australian J. Agr. Res., 14, 319-329 (1963).

17.4. Gambell, A. W., and D. W. Fisher, Occurrence of Sulfate and Nitrate in Rainfall, J. Ceophys. Res., 69, 4203-4210 (1964).

17.5. Reiter, R., On the Causal Relation between Nitrogen-Oxygen Compounds in the Troposphere and Atmospheric Electricity, Tellus, 22, 1-135 (1970).

Additional Reading

Chameides, W. L., D. H. Stedman, R. R. Dickerson, D. W. Rusch, and R. J. Cicerone, NOx Production in Lightning, J. Atmosph. Sci., 34, 143-149 (1977).

Griffing, G. W., Ozone and Oxides of Nitrogen Production during Thunderstorms, J. Geophys. Res., 82, 943-950 (1977).

Hill, R. D., R. G. Rinker, and A. Coucourinos, Nitrous Oxide Production by Lightning, J. Geophys. Res., 89, 1411-1421 (1984).

Levine, J. S., T. R. Augustsson, I. C. Anderson, and J. M. Hoell, Jr., Tropospheric Sources of NOx: Lightning and Biology, Atmospheric Environment, 18, 1797-1804 (1984).

THE EVENT

PETRIFIED LIGHTNING FROM CENTRAL FLORIDA

A PROJECT BY ALLAN MCCOLLUM

CONTEMPORARY ART MUSEUM
UNIVERSITY OF SOUTH FLORIDA

MUSEUM OF SCIENCE AND INDUSTRY
TAMPA, FLORIDA