"HIGH POTENTIAL" AREAS IN NORTH AMERICA.

RONALD L. IVES.

ABSTRACT. North American areas in which an isolated conductor in free air will normally accumulate a heavy static charge are outlined, the causes of this charging are discussed, the rates of charge accumulation, as determined from field tests, are stated, and conditions peculiar to areas of rugged topography are discussed. Possible applications of these data are suggested, and a more rigorous investigation of the subject is recommended.

INTRODUCTION.

IN many parts of the United States, particularly during very dry weather, or in regions chronically arid, wire fences, steel buildings, and other isolated metal bodies in free air, become heavily charged with static electricity, sometimes constituting a hazard to human beings and livestock; often creating a communications nuisance. This state of charge is separate from the heavy charges that may be induced in suitable objects anywhere, as a result of nearby thunderstorm activity.

Field investigations over large parts of the United States, and in smaller adjacent parts of Mexico and Canada, coupled with studies of reports of peculiar static phenomena, indicate that definite areas may be classed as "High Potential," and others as "Low Potential." Extent of these areas is roughly outlined in Fig. 1. It is certain that there are seasonal shiftings of the boundaries here shown, and there are probably long-term variations also, at least in some areas, such as southeastern Colorado and southwestern Kansas (The "Dust Bowl").

SOURCES OF CHARGES.

Studies of the electrical potential gradient of the atmosphere, largely done by the Division of Terrestrial Magnetism, Carnegie Institution of Washington (Bauer and Swann, 1934; Humphreys, 1940), indicate that the atmosphere is normally charged positive with respect to the earth, and that the potential gradient in the lower layers of the atmosphere is about 30 volts per foot.

Combining these data with the known settlement of cold air from above during normal convection, it can be demonstrated that an insulated body near the earth's surface could become highly charged solely as a result of convectional air motion. Quantitative studies, however, indicate that while a small portion of a charge could be supplied by this method, the mechanism is inadequate to account for charge renewal rates.

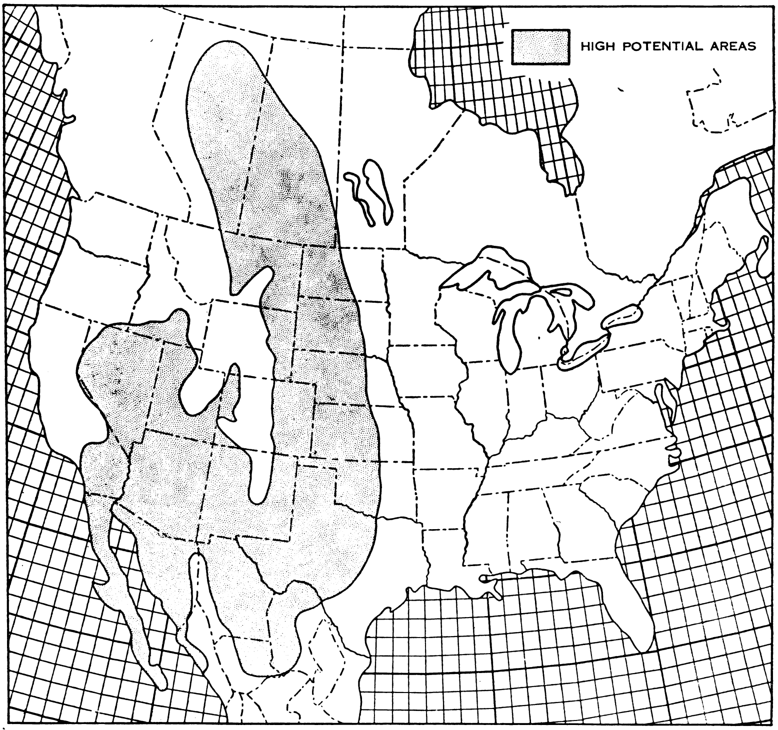

Fig. 1. Approximate boundaries of "High Potential" areas in North America. Sea areas, and areas not shaded are "Low Potential" areas.

A somewhat related mechanism, definitely present, but not fully explained by current theories is the atmospheric charge due to electron radiation by the sun. As propounded in these theories, the earth's atmosphere is a gaseous skin on one of a number of "free grids" (planets) spaced irregularly about a radiator (sun). By correcting this concept for ionization of the atmosphere, more common at high altitudes than low, some electrical phenomena in the atmosphere are explained. Magnitude of this effect, however, is too slight to account for any of the commonly observed surface electrical phenomena.

Field studies on the Colorado Plains, and in the Utah Desert, indicate a definite, although not simple, relationship between wind motion and the rate of renewal of charges on isolated bodies. These studies indicate that wind, wind-carried dust, and wind-carried snow, are the major sources of these charges, and that, for practical purposes, a dust or snow carrying wind can be considered as electrically akin to the belt of a Van de Graaf generator.

RATE OF CHARGE ACCUMULATION.

Very crude measurements of the rate of renewal of the charge on an isolated conductor (wire fence) exposed to dusty winds, made in southeastern Colorado during the "dust bowl" regime,

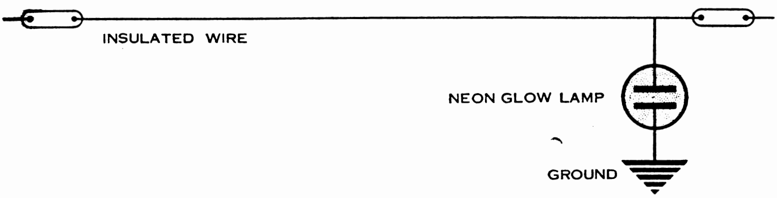

Fig. 2. Arrangement for determining charge renewal rates.

indicated that the renewal rate varied directly as the wind speed in localities that were not themselves a dust source, and directly as the amount of dust carried, when the wind speed was substantially constant. These figures are believed accurate within plus or minus twenty percent, field conditions at the time precluding more accurate observations.

Further observations, made as opportunity permitted in the Salt Lake Desert between 1942 and 1946, supported these general findings, and supplied additional data.

The measuring device, during these tests, was a well-insulated wire (also used as a radio antenna), with a glow lamp shunted from the wire to ground (Fig. 2). In this installation, the glow lamp is dark until the applied voltage reaches a definite high value (the striking voltage—about 85 in this case), then is bright until the applied voltage falls to a definite lower voltage (the extinction voltage—about 60 volts in this case).

Hence, each flash of the glow lamp indicates that the potential difference between the wire and ground has arisen to the striking voltage, and then fallen to the extinction voltage. With the glow lamp used, rate of flashing of the glow lamp then indicates rate of accumulation of definite voltage increments (about 25 in this case) by the wire. This procedure is roughly analogous to the use of a tipping-bucket rain gauge to measure precipitation rates.

From these measurements, the following findings, believed accurate to within plus or minus five percent, were made:

1. When wind speed was constant, charge renewal rate varied directly as the number of dust particles carried.

2. When number of dust particles was constant, charge renewal rate varied directly as the wind speed.

When the wind blew across an adjacent source of dust (sand dune), charge renewal rate varied directly as some power of the wind speed. Various determinations gave values of from 1.1 to 1.4 for this power. Rough computations indicated that at no time was the wind loaded to maximum theoretical capacity. As the transporting power of the wind varies as the square of its speed, it seems probable that the maximum rate of charge renewal, assuming an adequate supply of uniformly-sized dust particles, also varies as the square of the wind speed.

MAXIMUM POTENTIALS.

Simple arithmetic would suggest that the maximum charge attained by an insulated body exposed to free air for a given time should be the sum of the charge increments applied to that body (or an identical one, when increments are measured by draining) during the same time. Thus, if a body received twenty-five volt increments at the rate of five per second for half an hour, its charge at the end of that time should be 225,000 volts, or more than enough to jump a four-inch air gap.

At no time during these tests did the maximum potential, as determined by air-gap tests, approach within 50 percent of the computed maximum value, even when generous corrections were made for leakage due to insulation resistance and atmospheric ionization. Tests indicated, although did not, because of their crudity, prove, that there is a "ceiling" value to the charge attainable by a given insulated body, regardless of the number of charge increments supposedly received by it.

So far as can be determined from these tests, the maximum charge equals the sum of the charge increments minus leakages (within a reasonable margin of error, as these are somewhat difficult to determine under field conditions) up to somewhere between 15,000 and 25,000 volts. Above this value, the maximum voltage attained is always much less than the sum of the increments.

A part of the discrepancy between total voltage attained and theoretical maximum voltage can be attributed to corona loss, although no coronas were seen during tests (The dust storms investigated uually occurred at 1700 on CAVU days). Another explanation, presented with some misgivings, is that, when the receptor attains a certain charge, its field repels some of the charged dust particles despite wind force.

FACTORS CREATING "HIGH POTENTIAL" AREAS.

For an area to be classed as "High Potential," isolated bodies in free air must accumulate charges faster than they lose them. Factors leading to a high charging rate are adequate:

1. dust.
2. wind.

Factors leading to a low leakage rate are relatively low:

1. moisture.
2. conducting films.
3. atmospheric ionization.

Hence, theoretical considerations suggest that high potential areas will be those in which evaporative capacity exceeds rainfall (Hoyt, 1942; Visher, 1945), where the altitude is relatively low (low ionization), and where industrial or volcanic fumes are lacking (low conducting films). It is notable that the "High Potential" areas of North America (Fig. 1) coincide very closely to those fitting the above-stated conditions. Further study, to locate the boundaries more accurately, may well increase the coincidence.

MOUNTAIN STATIC.

Static electrical phenomena in mountain regions have long been the subject of travellers' and mountaineers' tales, and, in general, have been received with slight to great incredulity. A mountain static storm must be seen to be appreciated. Checking of a number of reports of mountain static from

Colorado, (Ives, 1938), coupled with considerable field work in the same area, indicates that the majority of reports are either actual accounts of what occurred, or of the sensations perceived during the occurrence.

Static displays accompanying thunderstorm disturbances in mountain areas are frequently brilliant and violent, and approximate, on a larger scale, the electrical conditions on the tip of a lightning rod just prior to a discharge. When the shortening of the cloud to ground discharge path, as the cloud drifts toward a mountain, is considered, and the slightly increased

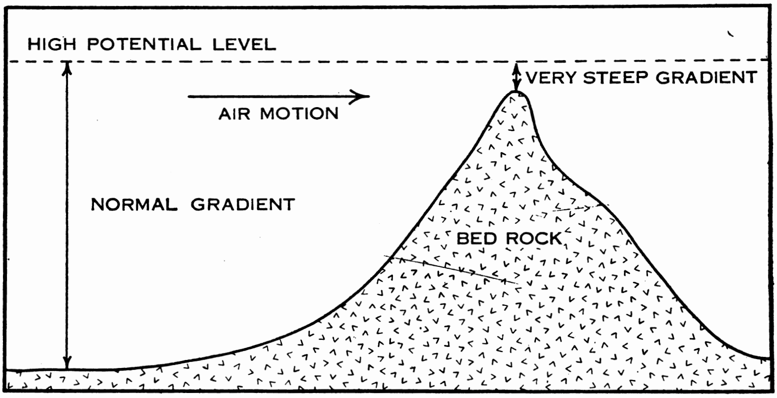

Fig. 3. Suggested mechanics of fair weather mountain static.

conductivity of air at high altitudes, due to ionization, is taken into acccount, the spectacular and violent nature of mountain thunderstorms is no longer "incredible."

Mountain static, however, is not confined to thunderstorm periods, but occurs at all times, with increasing activity in very windy weather. Brush discharges, "fireballs" (probably optical illusions), and brilliant sparks, apparently of great length, may be seen on some high peaks at almost any time.

The suggested mechanics of fair weather mountain static is shown in Fig. 3, and may be explained briefly as follows:

When a quantum of air, having a charge normal to its initial position, moves toward a topographic high, its charge will tend to adjust to that of its new environment. When air motion over a topographic high is relatively slow, the potential gradient, over the topographic high, will be substantially normal. In contrast, when air motion is relatively fast, the charge on the moving air will not have time to adjust, and the potential gradient, over the topographic high, will be steeper than that over the initial position, this gradient being a function, all other factors being the same, of the speed of air motion.

It is notable that mountains, and parts of mountains, having a good electrical ground, are more subject to violent static disturbances than those having a poor ground. For this reason, alpine tundra areas, and the near vicinities of mineral veins (as, for example, the black dike atop Quandry Peak, Mosquito Range, Colorado) are type areas for mountain static displays, while the summits of some other peaks, which are non-mineralized, and usually dry, are *relatively static-free*.[1]

CONCLUSIONS.

The foregoing summaries and reports of field experiments indicate that static electrical conditions are not the same over the whole of the North American continent. Although boundaries and divisions shown in this preliminary report will probably differ greatly from those which will eventually be determined, it appears that the continent can be divided into three main divisions with regard to static electric conditions. These are:

High Potential areas.
Low Potential areas.
Mountain areas.

Very exact determination of the potential boundaries will be quite important to industry, for the protective grounding needed in Hoboken, New Jersey, or Santa Monica, California, for example, will be entirely inadequate at such points as Pioche, Nevada, or even Van Nuys, California. In some instances the transition from low to high potential occurs in a zone many miles in extent; in others, it is sharply defined by the summit of a ridge, or by some other topographic feature. Seasonal and other variations in the zone boundaries likewise need more accurate definition.

Mechanics of charge accumulation likewise need further

[1] The term *dry*, as here used, means that liquid water is absent. In many high mountain areas, the soil contains crystalline ice as a permanent component (Ives, 1941a), yet soil resistance is extremely high.

study. Although the analogy between wind charging and the behavior of a Van de Graaff generator seems correct for low and medium potentials, its applicability to higher potentials is somewhat questionable.

Relationship between atypical potential distribution in the atmosphere and certain physiological conditions, such as "Chinook jitters" (Dexter, 1904; Ives, 1941b) has been repeatedly hinted. As radio equipment, electroscopes, and vacuum-tube voltmeters all indicate such disturbed potential conditions at approximately the same time as the onset of the physiological disturbances, further investigation, to determine the causal relationships, if any, is suggested.

ACKNOWLEDGEMENTS.

The writer is indebted to Dr. O. C. Lester, of the Department of Physics, University of Colorado, for helpful suggestions and a critical reading of this manuscript; to many residents of the Colorado and California mountain regions for field reports and assistance in the field; and to Sgt. Norma L. Lewis, WAC, for stenographic assistance.

REFERENCES.

Bauer, L. A., and Swann, W. F. G.: 1934, *Carnegie Institution of Washington Publication 175*, 3.

Dexter, E. G.: 1904, *Weather Influences*, New York, 79-80, 152-153.

Hoyt, W. G.: 1942, in *Physics of the Earth—IX Hydrology*, New York, 579-591. Complete and pertinent bibliography included.

Humphreys, W. J.: 1940, *Physics of the Air*, New York, 397-400.

Ives, R. L.: 1938, *Weather Phenomena of the Colorado Rockies*, Jour. Franklin Inst. **226**, 742-751.

————: 1941a, *Tundra Ponds*, Jour. Geomorphology, **4**, 286.

————: 1941b, *Colorado Front Range Crest Clouds and Related Phenomena*, Geog. Rev. 31, 34-35:

Visher, S. S.: 1945, *Climatic Maps of Geologic Interest*, Bull. Geol. Soc. Amer. **56**, 723-724.

DUGWAY PROVING GROUND,
TOOELE, UTAH.