Substituting for a and b their numerical values, 0.8 cm. and 0.7325 cm., respectively, it is found that,

$$P=\frac{I^2}{379.1}.$$

If we assume P, the pressure in dynes per square centimeter of the inner surface to be 10^6 or approximately one atmosphere, then $I=19,470$ amperes, approximately.

If the lightning discharge were alternating the current density would be greatest in the outer portions of the conductor, and therefore the total current would have to be still heavier than the above computed value to produce the assumed pressure. However, it seems probable that the discharge is unidirectional and not alternating,[4] and therefore that the computed strength of current, though of minimum value, is substantially correct.

Estimated charge and strength of current.—To determine the amount of electricity involved in a lightning discharge it is necessary to know both its duration and the average strength of current. Both factors and, therefore, the total charge are known to vary greatly, though actual measurements have been comparatively few and even these, as a rule, only crudely approximate.

It has often been stated that the duration of a single discharge, or single component of a multiple discharge, is not more than 1/1,000,000 of a second. Some have computed a duration of roughly 1/100,000 of a second, while others have estimated that it can not be greater than 1/40,000 or, at most, 1/35,000 of a second. Possibly many discharges are as brief as some of these estimates would indicate, but there is ample reason to believe that others are much longer. Thus one occasionally sees a streak of lightning that lasts fully half a second without apparent flicker, while more or less continuous or ribbon discharges are often photographed by moving cameras. But in addition to these evidences we have also a number of time measurements made by Rood[5] with a rotating disk, ranging from less than 1/1,600 second up to 1/20 second, and others, 38 in all, by De Blois[6] with an oscillograph, ranging from 0.0002 second to 0.0016 second. In one case De Blois found the durations of five sequent discharges to be 0.0005, 0.0015, 0.0016, 0.0014, and 0.0012 second, respectively, or 0.0062 second as the summation time of these principal components of the total discharge. Hence it seems probable that the actual time of a complete discharge, that is, the sum of the times of the several components, may occasionally amount to at least 0.01 second.

The second factor, the strength of discharge, is even more difficult to determine, and but few estimates of it have been made. Pockels,[7] adopting the ingenious method of measuring the residual magnetism in basalt near a place struck by lightning and comparing these quantities with those similarly obtained in the laboratory, concluded that the maximum strength of current in such discharges amounted occasionally to at least 10,000 amperes. However, the loss of magnetism before the measurements were made, and other unavoidable sources of error, indicate that the actual current strength was much greater than the estimated value—that the maximum strength of a heavy lightning discharge certainly amounts to many thousands of amperes, occasionally perhaps to even one hundred thousand.

Since the above estimates are very rough it would seem well to check them, even though the check itself be equally crude. Hence it may be worth while further to consider the crushed lightning rod with this particular object in view.

From the dimensions of this rod, outside diameter 1.6 cm., inside diameter 1.465 cm., it follows that its cross-sectional area is about 0.325 sq. cm., and its weight, therefore, approximately 2.9 grams per centimeter. Further, from the fact that the brazed joint was opened and most of the solder removed—apparently volatilized—and the further fact that the condition of the rod itself in several places indicates incipient fusion, it would seem that the final temperature may have been roughly 1,050° C. If so, the rod must have been heated about 1,025° C., since its temperature just before being struck probably was approximately 25°C. But the average specific heat of copper over this temperature range is roughly 0.11, and therefore about 327 calories per centimeter were generated.

Now one ampere against one ohm generates 0.24 calories per second. Hence, since the resistance[8] of the uninjured or check rod is practically that of pure copper, the average resistance of the crushed conductor over the assumed temperature range probably was about 17 microhms per centimeter length,[9] we have the equation,

$$\frac{24}{10^2}I^2\frac{17}{10^6}t=327,$$

in which I is the average strength of current, and t the actual time of discharge. Assuming $t=0.01$ second we get, roughly,

$$I=90,000 \text{ amperes.}$$

A current of this average value would indicate a maximum value of perhaps 100,000 amperes.

It was computed above that a current of 19,470 amperes in the given hollow conductor would produce on it a radial pressure of 10^6 dynes per square centimeter or about one atmosphere. Hence 100,000 amperes would give a pressure of 2638×10^4 dynes per square centimeter, or approximately 400 pounds per square inch; enough, presumably, to produce the crushing that actually occurred.

A current of 90,000 amperes for 0.01 second would mean 900 coulombs, or 27×10^{11} electrostatic units of electricity; certainly an enormous charge in comparison with laboratory quantities, but after all a surprisingly small amount of electricity, since it would electrolyze only 0.084 of a gram of water. It must be clearly kept in mind, however, that these estimates are exceedingly rough and that at most they only tend to confirm certain previous estimates in regard to the lightning discharge, namely, that in some cases the strength of current probably amounts to many thousands of amperes, and that the total duration of the individual or partial discharges may be several thousandths of a second.

[4] *Humphreys*, MONTHLY WEATHER REVIEW, June, 1914, **42**: 377. *Marvin*, idem, August, 1914, p. 499–501.
[5] Amer. jour. sci., 1873, **5**: 163.
[6] Proceedings, Am. inst. elec. eng., 1914, **33**: 568.
[7] Annalen d. Phys., 1897, **63**: 195; 1898, **65**: 458; Met. Ztschr., 1898, **15**: 41; Phys. Ztschr., 1901, **2**: 306.
[8] Measured by the U. S. Bureau of Standards.
[9] *Northrup*, Jour. Franklin inst., 1914, **177**: 15.

A NOTE ON THE RELATION OF CLIMATE TO AGRICULTURE IN CALIFORNIA.

By ANDREW H. PALMER, Observer.

[Dated Weather Bureau, San Francisco, Cal., Aug. 1, 1915.]

It has been remarked that in the climatic conditions affecting agriculture California shows an epitome of the whole United States, with added climatic characters peculiarly her own. Indeed the statement might have been made more inclusive. With the sole exception of those tropical conditions which involve continuous high temperature and excessive humidity, California has samples of the climates of every part of the world which permit successful agriculture. An enumeration of her fruits alone is a catalog of the known fruits of the world, with the exception of those strictly tropical. This is also true of certain individual counties, which in several instances are larger than whole states.

Throughout the greater part of the United States the strictly agricultural pursuits associated with the cultivation of the soil are limited to the summer half-year. In California the period from January 1 to December 31, inclusive, constitutes the agricultural period. It is no exaggeration to say that crops are growing and maturing all the time within the State. Residents of other States sometimes have difficulty in realizing these facts. From the point of view of the consumer they are interested primarily in the harvest period. At the request of Mr. G. H. Willson, Section Director, U. S. Weather Bureau, San Francisco, Cal., Prof. E. J. Wickson, of the Agricultural Experiment Station, College of Agriculture, University of California, and one of the leading authorities on the subject of agriculture in this State, has compiled a summary of the usual time of harvesting the principal crops in California. This compilation, which takes account only of the time of harvesting of the crop directly from the plant or from the open ground in which it grew, is as follows:

Almonds—August and September.
Apples—June to November.
Apricots—May to August.
Artichoke (globe)—October to May, for commercial crop. Continuous, for garden crop.
Artichoke (Jerusalem)—November to March.
Asparagus—January to May.
Barley—May to August.
Beans (dry)—August to November.
Beets—Throughout the year.
Cabbage—Throughout the year. (Chief commercial, Jan. to Apr.).
Cantaloups—May to October.
Carrots—Throughout the year.
Celery—Throughout the year. (Chief commercial, Nov. to Feb.)
Cherries—March to July.
Corn—August to October.
Cotton—June to November.
Cucumbers—May to November.
Figs—June to September.
Grapes—July to December.
Hay (alfalfa)—March to December.
Hay (grain hay)—April to June.
Hops—August to September.
Lemons—Throughout the year. (Chiefly Feb. to Aug.)
Oats—June to September.
Olives—November to January.
Onions (green)—Throughout the year.
Onions (dry)—July to November.
Oranges—Throughout the year. (Chiefly Dec. to Aug.)
Peaches—May to November. (Chiefly Aug. and Sept.)
Peas (green)—Throughout the year.
Peas (field peas)—May to August.
Pears—July to November.
Peppers (green)—Throughout the year.
Peppers (crop for drying)—September and October.
Plums—June to October.
Potatoes—Throughout the year. (Chiefly July to Nov.)
Potatoes (sweet)—August to October.
Prunes—July and August.
Rhubarb—Throughout the year, with summer and winter varieties.
Rice—September to November.
Rye—June to August.
Sorghum (grain varieties)—July to September.
Spinach—Throughout the year.
Squashes and pumpkins—August to November.
Sugar-beets—July to November.
Tomatoes—Throughout the year.
  Table crop—June to November.
  Canning crop—August to October.
Turnips—Throughout the year.
Walnuts—September and October.
Watermelons—June to September.
Wheat—May to August.
Wool—Two clips; March and September.

It is apparent from the above that in California there is a continuous seedtime and harvest for something, and that there is but occasional coincidence with eastern crop periodicity. In his book, "California Fruits," Prof. Wickson has also pointed out why, from an agricultural point of view, there are wider differences within its borders than are found in a long sweep of States from the Gulf of Mexico to Canada. An enumeration of some of the principal facts in the relation of climate to agriculture in California, together with a brief explanation of some of these facts, is given in the following:

In latitude California extends from 33° N. to 42° N., corresponding roughly to that from Charleston, S. C., to Boston, Mass., on the Atlantic side of the continent. Its coast line runs northwest-southeast, not north-south, as many imagine. Owing to the proximity of the Pacific Ocean and the prevailing westerly direction of its winds, the isotherms run north-south, not east-west, as in the interior of the continent. The mean annual temperatures range from 42.1°F. to 76°F., while extremes of −21°F. and 134°F. have been recorded in different parts of the State in the same year. The mean annual precipitation ranges from 2 to 113 inches, with extremes at different stations ranging from no rainfall to 154 inches. Altitude above the sea level rather than latitude controls the temperature, while altitude together with latitude control the precipitation. The southern and lower parts of the State are drier than the northern and higher portions. Summer and winter are terms synonymous with dry and wet periods, respectively, rather than with hot and cold periods. Most of the precipitation is of cyclonic origin, and since cyclones dominate the winter only the agricultural portion of the State receives more than 90 per cent of its rainfall during that season. Generally speaking, topography is of more importance as a control of climate than is latitude.

The agricultural significance of these facts is evident in a great variety of ways. The terms "northern" and "southern" have little climatic, and no agricultural, application in California. Northern fruits reach perfection, under proper conditions, at the south, and vice versa. In the words of Prof. Wickson, "The apple and the orange, fruit kings whose kingdoms lie at opposite borders of the Temperate Zone, so far distant that one may be called semifrigid and the other semitropical, have in California utter disregard for the parallels of latitude, which set metes and bounds upon them in other lands, and flourish side by side, in suitable localities, from San Diego to Shasta." Moreover, some fruits can be successfully grown through a north and south distance of 500 miles, but can not successfully be carried through a few hundred feet of either less or greater elevation. Furthermore, the long growing season results in second and sometimes in third crops of considerable commercial importance, while altitude differences make possible a long period during which fresh fruits and vegetables are procurable. Again, some regions of greatest annual rainfall require the most frequent irrigation—a fact dependent upon the rainfall periodicity, as well as upon the character of the soil and the needs of the plant. Some of the interior regions having the highest temperatures also have the most marked valley frosts. Occasionally snow-clad mountains and groves of delicate orange trees are in close juxtaposition laterally, though at different altitudes above the level of the sea.

From the agricultural point of view the climates of California may be classified as follows: (1) Coast climate, (2) valley climate (including foothill climate), and (3) mountain climate. In brief, the characteristics of the coast climate are equable temperature, increasing as one approaches the south; relatively cool summers and relatively warm winters, compared with the interior; abundant rainfall, increasing as one approaches the north; prevailing west winds; and a humid atmosphere, with frequent fogs and overcast skies. The valley climate is one of higher summer and lower winter temperatures than that of the coast, with little north and south differences; high afternoon temperatures in summer and occasional early morning frosts in winter; abundant rainfall in the north and decreasing rapidly toward the south, necessitating irrigation in the interior valleys of the southern half of the State; dry air; almost constant sunshine, with freedom from fogs and from dew in summer time; and with winds occasionally stormy and cold in winter, and hot and desiccating in summer. The foothills include places up to 2,500 feet in elevation. The foothill climate differs from the valley climate principally in the lower midday temperatures in summer, fewer frosts in winter, and a slightly higher annual rainfall, the same increasing regularly with increase of height above sea level. The valley and foothill regions together form the principal agricultural portions of the State. The mountain climate resembles somewhat that of the Eastern States, and is characterized by moderately warm summers and moderately cold winters, without great temperature ranges, however; abundant precipitation, which increases up to a height of 6,500 feet, and decreases beyond that point; and with much of the winter precipitation in the form of snow, the heaviest known in the United States, and one of the principal resources of the State in that it furnishes, upon melting, most of the water used for irrigation and power purposes.

Of the various agricultural activities in the State horticulture is one of the leading, and its importance is increasing year by year. From the point of view of the horticulturist the chief characteristics of California climate are (1) abundance of sunshine, (2) freedom from extremely low temperatures, and (3) an atmosphere with a low per cent of humidity. Temperature is of prime importance in fruit-growing, since not only must the mean annual temperature be sufficiently high but the mean temperature of the various seasons must also be favorable, and there must be no extremely low temperatures at any time. Sunshine is to be considered, since direct and not diffused sunshine is necessary for fructification. Moreover, a considerable amount is needed for ripening some fruits, and still more is necessary for their curing and preserving. In California the humidity, both absolute and relative, is high in winter and low in summer, just the reverse of that in the East. The dry air of summer not only favors the access of light and heat, but it also permits certain chemical actions necessary for fruit ripening. Moreover, a consideration of some moment is the fact that it prevents certain fungoid diseases. The horticultural year begins with the blossoming of the almond trees in January, an event which marks the advent of spring in California. The period of greatest fruit growth is from June to October. The rest period in trees and vines just following the gathering of the fruit is a dry season climatically, not a cold season as in the East. While strong winds are not of frequent occurrence in the agricultural portions of California, those which do occur come during the season when the trees are bare. Furthermore, the soil moisture has its origin in the winter rains, when the trees and vines are inactive, but gathering strength for the coming season.

Further theoretical considerations are unnecessary. Perhaps the best evidence of the favorable characteristics of California climates is seen in the variety, size, quality, quantity, color, and aroma of its fruit. Again using the exact words of Prof. Wickson, "All things considered, it is doubtful whether any area in the world excels California in possession of natural adaptation to fruit production and preservation."

CLASSIFICATION OF AMERICAN SUMMERS.

By HENRY F. ALCIATORE, Section Director.

[Dated: Local Office, Weather Bureau, Reno, Nev., Aug. 17, 1915.]

Climatologies abound, in which the effects of the weather on growing crops, stock raising, irrigation, etc., are set forth at great length and explained, but where can one find a work that deals exclusively with human aspects of climate, such, for instance, as personal comfort and agreeableness, not to mention exhilarating and debilitating characteristics?[1]

Weather Bureau men are sometimes consulted as to the desirability of this or that climate by people interested in but one phase of the subject, namely, How will the climate affect my physical condition and well being?

Should one desire to compare the climate of one place with that of some other place, how would one go about it? Every climatologist knows that expressions like "Mean annual temperature," "Mean annual humidity," are practically meaningless in comparative climatology. To illustrate: The mean annual temperature of Los Angeles and Little Rock are the same, i. e., 62°F., from which circumstance the reader might infer that, so far as temperature is concerned, the two cities have similar climates. Yet it would be difficult to find two more *dissimilar* climates in the Western Hemisphere. Again, Reno and Des Moines have equal mean annual temperatures, but Reno's summers are considerably cooler and more agreeable than are those of Des Moines, and its winters much milder.

Of course, there is the Angot method of comparing the summers and winters of different places. While it is far more satisfactory than the customary "mean temperature" method, still it falls short of satisfactoriness in that it discusses but one climatic element, namely, the deviation of maximum temperatures above an arbitrarily fixed point (87°F.), and minima below 32°F. Obviously, such a scheme is inadequate to express the contrast between the summer climates of Atlantic City, N. J., and Denver, Colo.; their mean summer temperatures are practically the same, but the first named is one of the dampest spots in the country (in summer) while Denver has a dry summer climate. Nor would the Angot method give good results in the case of Phoenix, Ariz., and Fresno, Cal.; both of these cities are practically in the same class as to excessively high day temperatures, but Fresno's nights are cooler and fairly pleasant. We all know that a summer's day in Washington, D. C., when the thermometer registers 90°F., is quite a

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[1] The following are a few among many works that discuss this subject:
Ward, R. DeC. Climate considered especially in relation to Man. London, 1908.
Bebber, W. J. van. Hygienische Meteorologie. Stuttgart, 1895.
Ratzel. Anthropogeographie. Stuttgart, 1899.
Die Erde und das Leben. Leipzig, etc., 1901. 2 v.
Vincent, J. Nouvelles recherches sur la température climatologique. Annales météorol. de l'Observ. roy. de Belgique. N. S., Ann. météorol. t. **20**, fasc. 1.—C. A. jr.