finer dust cloud, with its accompanying brilliant twilight colors, might well be observed in the clear atmosphere of southern California some days in advance of the denser lower cloud, and, indeed, before the latter had been observed in States farther east.

It also seems fair to assume that this volcanic dust was at least in part the cause of the high haze observed over the South Atlantic States at the end of July; and it may have been a contributing cause of the brilliant twilight colors observed on July 30–31 in the eastern part of the United States.

551.506 : 629.132.1 (969)

FREE-AIR DATA IN THE HAWAIIAN ISLANDS, JULY, 1915.

By Col. Wilmot E. Ellis, Coast Artillery Corps, U. S. Army.

[Dated: Fort Ruger, H. T., Jan. 23. MS. received Feb. 7, 1917.]

The title of this article suggests that the usual paraphernalia of sounding balloons, captive balloons, or standard kites with self-registering instruments were utilized in making our explorations, but such was not the case. Our exploring apparatus consisted of two "home-made" kites and of cast-iron projectiles fired from 12-inch sea-coast mortars. Although our experimental firings were conducted primarily with a view to obtaining ballistical information, we incidentally obtained considerable information of interest to the aerologist. The purpose of this article is to discuss the results obtained with special reference to aerology.

Explorations of the upper air within the Tropics have been very limited in number and in the extent of the territory covered. There has been none whatever in our insular possessions.[1] Systematic exploration work has been carried on at Batavia in the Dutch East Indies. The chief of the U. S. Weather Bureau in a letter to the commanding officer, Fort Ruger, under date of September 10, 1915, states:

> A typical pilot balloon observation made by Mr. Van Bemmelen, in charge of the observatory there [Batavia], shows the trade winds to be about 3 km. deep, with a velocity of 5 m. p. s. The anti-trades extend from 3 to 17 km., their velocity increasing gradually from 5 m. p. s. at 3 km. to 23 m. p. s. at 14 km. The upper trade winds extend from 17 to 18 km., and have low velocities like the surface trades. Between the 18- and 23-km. levels, a high westerly wind, velocity 10 to 15 m. p. s., was found. Above this level, to the highest level explored, easterly winds again prevailed, reaching velocities of 40 m. p. s. in the vicinity of the 30-km. level.

In the Hawaiian Islands, the prevailing winds are the northeast trades and have a temperature of about 70°F. The relative humidity averages 65 per cent. These conditions are greatly modified by mountains and local convection currents. There are two principal ranges on the island of Oahu. The Koolau extends along the northeastern or windward side. The Waianae range is on the southwestern side. Both ranges are covered with dense vegetation. The elevation averages between 2,000 and 3,000 feet, the highest altitude being about 4,000 feet. Between the two ranges is an elevated tableland. The moisture carried by the trades is largely precipitated upon these mountains, but they are not high enough to keep the wind from sweeping over them and through the deep valleys on the leeward side. The trades are at least 4,000 feet deep, and—as will be shown later—our mortar firings indicate that they are about the same depth as the southeast trades at Batavia—approximately 10,000 feet. The trades are generally interrupted by "konas" or southerly gales, from November to the latter part of March. The konas are damp and blustering winds, warmer and more humid than the trades. As might be expected, the winds on the leeward side are—during the prevalence of the trades—more or less capricious. There is considerable diversity in wind directions well above the surface of the earth. True cirrus clouds, whose altitude ranges about 26,000 feet, are not common; but, when observed, they generally indicate a movement with an anti-trade component.

In our system of sea-coast mortar firing, we use a series of imaginary zones described about the mortar battery as a center. These zones are numbered from 1 to 9 outward, zone 1 being nearest the battery. Projectiles of three different weights are used, and the powder charge varies for each zone. The angles of elevation for each zone run from 45° to 65°, the former elevation giving the maximum range and the minimum height of trajectory, and the latter the minimum range and the maximum height of trajectory. Each zone overlaps its neighbor for a distance varying from about 500 yards to about 1,000 yards, so that a change in ammunition can always be smoothly made in firing at a target whose course involves a change in zone. Our plotting board gives us the direction and distance of the target from the battery. Range tables calculated by our ballisticians furnish us with elevations corresponding to ranges, and the drift of the projectile for the various elevations. The drift of the projectile is always to the right, increasing with the elevation. The drift is considerable, and must be allowed for in laying the mortar in direction. For example—the drift at an elevation of 65° in the 9th zone is about 1,450 yards for a time of flight of 75 seconds. In training for direction, the mortar is laid in azimuth, azimuths being reckoned from the south point clockwise through the west point. When a series of shots are fired at a fixed point, using the same elevation, azimuth, and ammunition, it rarely happens that any shot falls within a hundred yards or so of the point, owing principally to variations in the muzzle velocity and the unknown aerological conditions that the projectile encounters in its flight.

Col. Rafferty's experiments, July, 1915, at Oahu.

In February, 1915, Col. W. C. Rafferty, Coast Artillery Corps, commander of the coast defenses of Oahu (located in and near Honolulu) obtained authority from the War Department to fire a series of 74 shots from the 12-inch mortars. The purpose of the firing was:

1. To determine the drift of the 700-pound projectile in the ninth zone, and the 824-pound projectile in the eighth zone;
2. To determine the law which governs the deviation due to wind;
3. To discover any other information relating to mortar firing which may be useful to the service.

The shots were distributed between two batteries, Battery Harlow at Fort Ruger near Diamond Head Crater, and Battery Hasbrouck at Fort Kamehameha adjoining Pearl Harbor. These batteries are about 11 miles apart, the former being about 5½ miles east of Honolulu Harbor, and the latter about the same distance west thereof.

[1] See, however, *O. L. Fassig:* Kite flying in the Tropics. Monthly Weather Review, Dec. 1903, 31:582–587. 5 figs., for an account of upper-air observations by means of kites during the expedition to the Bahamas in 1903, under the auspices of the Geographical Society of Baltimore.—Editor.

The following was the program:

FIRST DAY, JULY 8, 1915.

Fire 12 shots from Battery Harlow.

Shot numbers.	Zone.	Azimuth.	Elevation.
		°	°
1	8	280	55
2	8	100	55
3	8	280	55
4	8	100	55
5	8	280	55
6	8	100	55
7	9	280	55
8	9	100	55
9	9	280	55
10	9	100	55
11	9	280	55
12	9	100	55

SECOND DAY, JULY 9, 1915.

Fire 27 shots from Battery Harlow, and the same number from Battery Hasbrouck in series of nine shots, each series to be in accordance with the following table:

Shot numbers.	Zone.	Azimuth.	Elevation.
		°	°
1, 10, 19	9	315	55
2, 11, 20	8	315	55
3, 12, 21	5	315	55
4, 13, 22	9	45	55
5, 14, 23	8	45	55
6, 15, 24	5	45	55
7, 16, 25	9	0	55
8, 17, 26	8	0	55
9, 18, 27	5	0	55

Shots of the same serial number at each battery were fired as nearly simultaneously as possible.

THIRD DAY, JULY 10, 1915.

Fire 8 shots from Battery Hasbrouck.

Shot numbers.	Zone.	Azimuth.	Elevation.
		°	°
1	8	10	50
2	9	10	50
3	8	10	60
4	9	10	60
5	8	10	50
6	9	10	50
7	8	10	60
8	9	10	60

Col. W. E. Ellis, C. A. C., fort commander at Fort Ruger, was in charge of the firing at Battery Harlow, and Lieut. Col. Frank W. Coe, C. A. C., fort commander at Fort Kamehameha, was in charge of the firing at Battery Hasbrouck.

The target point for each shot was a point on the sea surface at the range-table range corresponding to the elevation, and at the prescribed azimuth. No corrections for height of site were made. Correction for tabular drift was applied to each shot.

The following aerological stations—some temporary, some permanent—were utilized:

No. 1, at Kupikipikio Point.—This Point is about 1½ miles east of Diamond Head Summit. From this station, we noted the direction of the upper wind by kite.

No. 2, at Diamond Head Summit.—At this station, we took the direction of the upper wind by kite, and the velocity of the [lower] wind as indicated by an anemometer located about 40 feet above the ground on a pole.

No. 3, U. S. Army meteorological station at Fort De Russy.—This station is on the beach, 30 feet or so above sealevel and about 2½ miles northwest of Diamond Head Summit. Here we recorded the direction and velocity of the surface wind, the thermometer, and the barometer.

No. 4, the U. S. Weather Bureau Station in Honolulu.—Same data as No. 3.

No. 5, our meteorological station at Fort Kamehameha.—This station is about 30 feet above sealevel. Same data as No. 3.

The kites used were designed by the Coast Defense commander. They were flown to an altitude of about 800 feet above the surface of the earth. The station at Kupikipikio Point is 122 feet above M. L. W., and the one at Diamond Head Summit, 765 feet above M. L. W. The kites, therefore, indicated wind directions about 900 feet and 1,600 feet above sealevel, respectively.

On July 8, the firing began at 6:09 a. m. and ended at 7:55 a. m. The data obtained from the U. S. Weather Bureau station during this period were as follows: Wind E, 4 miles per hour; temperature 74° to 78°F; barometer 30.05 to 30.07 inches.

On July 9, the firing began at 8 a. m. and ended at 1:48 p. m. U. S. Weather Bureau data: From 8 a. m. to 10 a. m., wind S, increasing from 4 to 9 miles per hour; from 10 a. m. to 1:48 p. m., wind E, varying between 9 to 11 miles per hour; temperature 78° rising to 84° ending at 81°; barometer 30.02 to 29.93 inches.

On July 10, the firing began at 8:04 a. m. and ended at 8:39 a. m. U. S. Weather Bureau data: Wind E, 7 miles per hour; temperature 79° to 80°; barometer 29.96 to 29.95 inches.

The essential data for the zones and elevations used are as follows:

Zone.	Zone limits.	Weight of projectile.	Elevation.	Range.	Maximum height of trajectory.
	Yards.	*Pounds.*	°	*Yards.*	*Yards.*
5	4,455-5,976	1,046	55	5,580	2,265
8	8,694-12,150	824	50	11,920	4,251
8	8,694-12,150	824	55	11,255	4,992
8	8,694-12,150	824	60	10,173	5,706
9	10,854-15,291	700	50	15,000	5,047
9	10,854-15,291	700	55	14,115	5,928
9	10,854-15,291	700	60	12,700	6,774

Ballisticians in general, and ours in particular, make the following basic assumptions regarding aerology and wind effects:

(1) Aerological conditions at a given time are regarded as constant over the range and may be obtained from instruments at or near the battery firing.

(2) Irrespective of wind conditions, a definite law connects the fall of temperature and barometer with height above the earth's surface.

(3) A wind—arbitrararily assumed constant over the range—may be divided into two components, one parallel to the line of fire, and the other perpendicular thereto; and each component may be separately considered as regards deviating effects.

Modern researches in aerology have demonstrated the fallacy of the first two assumptions.

To illustrate the third assumption: Suppose a projectile were moving into an oblique head wind of 16 miles per hour, making an angle of 45° with the line of fire. The assumption is made that the retarding effect of the wind is the same as that of a direct head wind of 12 miles; and that the lateral effect is the same as that of a 12-mile wind blowing directly across the range. This assumption, for obvious reasons, has never been tested experimentally, but it carries two fallacies and hence is inherently incorrect. In the first place, the law of the parallelogram of forces assumes the same point of application, which is not the case in the problem we are considering. In the second place, the deviating effect of a 12-mile range wind and that of a 12-mile cross wind are in general different as calculated by ballistical methods, for the formulas used are independent. Yet a little consideration shows that whatever effect the wind may have upon the projectile, *it must move with the wind;* and hence, the deviations longitudinal and lateral—in this case—must be the same. Or otherwise; the longitudinal and lateral deviations must, when compounded, indicate the resultant effect of the wind both as to amount and direction. No wind formulas that have ever come to the writer's notice take this obvious fact into consideration.

It is difficult to explain why these untenable hypotheses have been made by ballisticians, unless it be that their zeal in applying mathematical formulas to a problem that does not admit of an exact mathematical solution has misled them. In any event, one can charge this trio of fallacies with being *one* of the contributing causes to the inaccuracy of coast artillery fire. The other causes, being beyond the scope of aerology, will not be discussed in this paper.

Conclusions.

The present writer collected all available data and made a special study of the Oahu experimental firings. A brief synopsis, in so far as wind phenomena are concerned, follows.

After consideration of the Batavia data, and of the results of the experiments conducted by the U. S. Weather Bureau at Avalon, Cal., the following tentative hypothesis was formulated:

(1) The winds of the trophosphere are arranged in strata. The elements—velocity, direction, and depth—of each stratum are variable, and the elements of any one stratum are not definitely connected by any ascertainable law with the elements of any other stratum.

(2) A variation in the elements of any stratum involves or indicates an undeterminable variation in the other strata.

(3) The wind effect upon a given projectile varies indeterminately with the elevation, because, as the elevation changes, the number of strata traversed, and the time the projectile is subject to the wind effect in any given stratum, vary.

(4) The conception of a "resultant wind," or of a "mean motion of the atmosphere," is inconsistent with the hypothesis of variable wind strata.

(5) The resultant *effect* of the wind—both as to direction and amount—corresponding to a given elevation may be deduced from firing at two or more target points; but the data so obtained are of little or no value for calculating the effect at any other elevation; or, for that matter, at the same elevation, after stratum conditions have materially changed.

Based upon these hypotheses, certain formulas were deduced, which it will not be necessary to elaborate. Briefly, the problem involves four unknown quantities: (1) The variation in range due to causes other than wind; (2) the error or variation in the calculated drift; (3) the maximum resultant effect of the wind strata passed through; and (4) the direction of the resultant effect. Two target points—each giving a plotted range deviation and lateral deviation—afford the data for determining the unknowns, and three target points afford the data for independent checks. Unfortunately, our powder was not uniform and therefore the number of independent checks was quite limited.

Table 1 summarizes the results obtained.

TABLE 1.

Battery.	Zone.	Elevation.	Date.	W.[1]	$Az.W$.[2]	$Az. K.W$.[3]
		°	1915.	*Yards.*	°	°
Harlow	8	55	July 8	124	101	80
Harlow	5	55	July 9	90	94	89
Hasbrouck	5	55	July 9	60	94	89
Harlow	8	55	July 9	146	112	91
Hasbrouck	8	55	July 9	222	106	91
Harlow	9	55	July 9	160	108	94
Hasbrouck	9	55	July 9	131	112	94

[1] W is the resultant effect of the wind in yards.
[2] $Az.W.$, azimuth of same, or azimuth of that line of fire which would give the maximum increase of the range due to wind.
[3] $Az. K.W.$, azimuth *toward* which the free surface wind was blowing, as indicated by the kite flown from the summit of Diamond Head.

Firings in the ninth zone, July 8, did not furnish sufficient data to calculate W and $Az.W$.

Table 1 warrants the following conclusions:

(1) During the firings, the free surface wind was about east.

(2) The resultant effect of the wind corresponded quite closely in direction with the free surface wind, although there are indications that in the upper strata reached by the projectiles, southwesterly winds were encountered. This is shown by an increase of azimuth of W over $K.W.$ and a value of W less in the ninth zone than in the eighth zone.

(3) Free winds along and offshore are quite uniform. The two batteries were, as stated, 11 miles apart; yet the values of $Az.W.$ show a remarkable agreement. The values of W, except for the eighth zone, also agree quite closely.

The following supplementary table shows the results of the third day's firing at Hasbrouck. They were not incorporated in Table 1, because exact data for calculation were insufficient. Hence, the results are only approximate; but they have not been rejected, because they are so anomalous as to merit investigation, even on an approximate basis.

TABLE 2.

Battery.	Zone.	Elevation.	Date.	W.	$Az.W$.	$Az.K.W$.
		°	1915.		°	°
Hasbrouck	8	50	July 10	239	131	93
Do	8	60	...do...	127	105	96
Do	9	50	...do...	399	162	93
Do	9	60	...do...	190	125	96

The indications are that on the morning of July 10, the surface Trades were quite shallow and that, as the projectile ascended, it encountered first southeasterly winds; and then, later, strong northwesterly winds.

Other conclusions—not deducible from the above tables—are:

The winds close to the surface of the earth showed considerable variation at different points along and on shore,

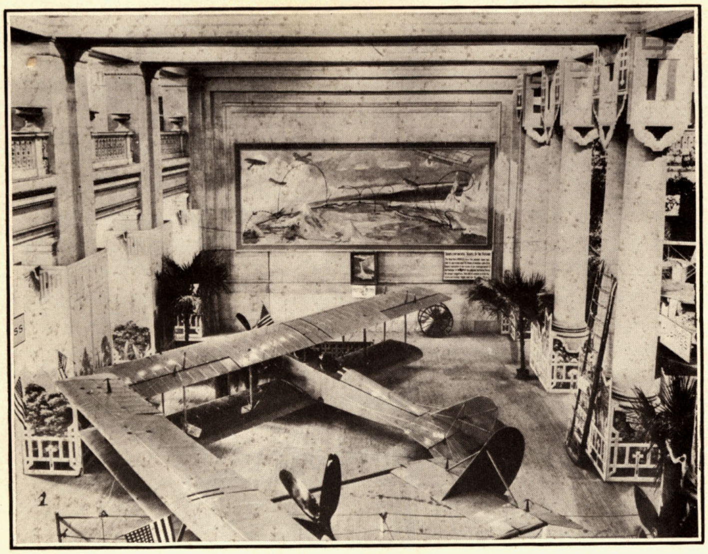

Fig. 1.—View of part of first-floor exhibit. Imaginary wall decoration at back.

Fig. 2.—Corner of Weather Bureau exhibit, showing glass map and the regular station instruments (at left).

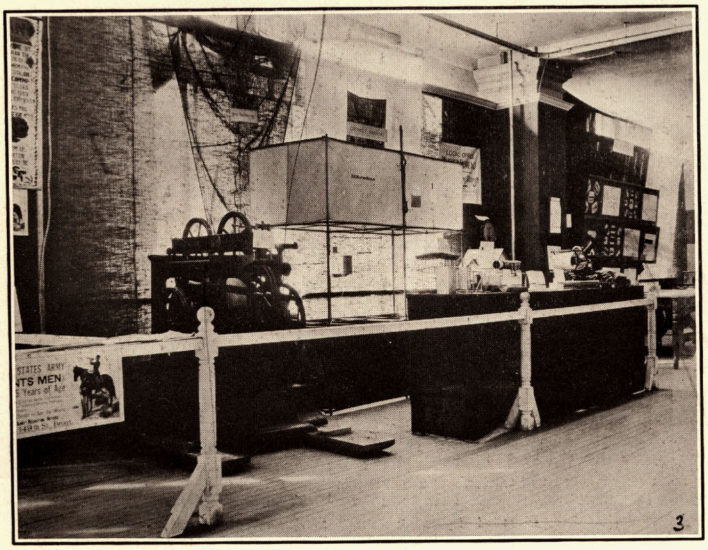

Fig. 3.—General view of Weather Bureau's aerological exhibit.

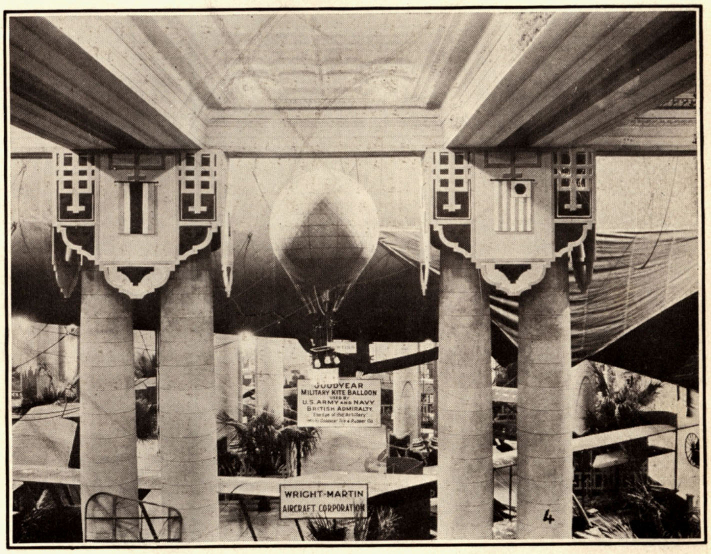

Fig. 4.—View of part of first-floor exhibit.

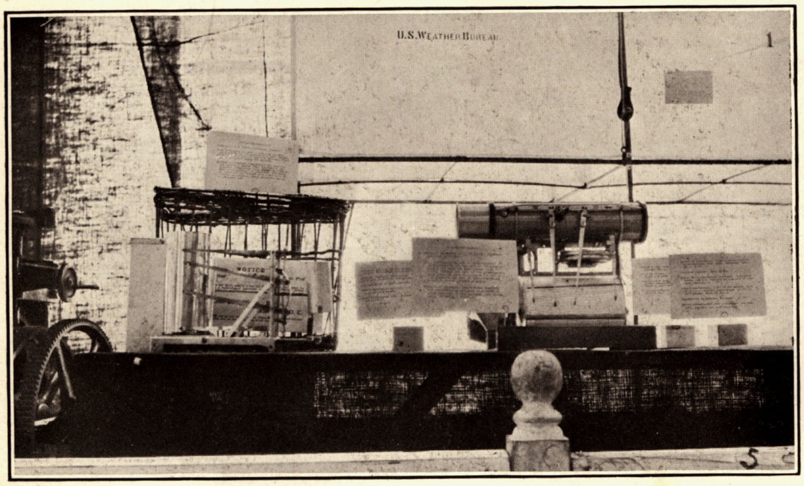

Fig. 5.—Detail views of Bosch balloon meteorograph (left) and modified Marvin kite meteorograph (right), exhibited by the Weather Bureau.

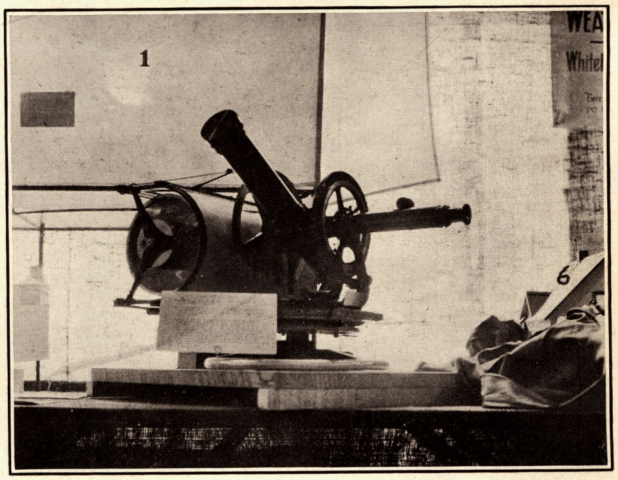

Fig. 6.—Detail view of the Blair recording balloon theodolite, exhibited by the Weather Bureau.

and such winds did not, as a rule, correspond at all with the "kite winds." Wind data taken on shore and near the earth—say within 100 feet or so—are utterly at variance with those obtained in the "free air" above the surface of the sea. Hence, empirical formulas based upon surface data are worthless.

The velocity of the wind as indicated on the summit of Diamond Head was from two to three times as great as that indicated at the United States Weather Bureau station in Honolulu.

Ballisticians have arbitrarily assumed that the drift of the projectile is independent of wind conditions, whereas a little a priori reasoning would have shown the fallacy of this assumption. But, be this as it may, our firings proved conclusively that the drift did vary with changes in wind conditions.

All who have followed this discussion will undoubtedly agree that the coast artilleryman attempting to hit a moving target at sea has a pretty problem to solve, considering that his accuracy of fire depends upon unknown aerological conditions, unknown variations in drift, and unknown changes in the muzzle velocity of the powder employed.

551.5 (73)

WEATHER BUREAU EXHIBIT AT THE FIRST PAN AMERICAN AERONAUTIC EXPOSITION.

By WILLIS RAY GREGG, Meteorologist.

[Aerological Investigations, Weather Bureau, Mar. 14, 1917.]

The First Pan American Aeronautic Exposition was held in the Grand Central Palace, New York City, February 8 to 15, 1917. The purpose of this exposition was to stimulate general interest in aeronautics by means of exhibits and to promote the more rapid advancement of this science by means of addresses and discussions. The latter were given each day in the Convention Hall and were illustrated by lantern slides and motion pictures. Of considerable interest among these was the Weather Bureau's motion-picture illustration of meteorological kite flying at the Drexel Aerological Station.

The exhibits occupied the two lower floors of the palace. Those on the first floor consisted, for the most part, of different types of aeroplanes, an interesting feature being the first motor-driven machine, in which the Wright brothers made a successful flight at Kitty Hawk, N. C., in 1903. In the open court above the first floor were suspended a large military kite balloon and a model of a manned free balloon. These and some other details of the first-floor exhibit are shown in figures 1 and 4.

On the second, or mezzanine, floor were shown models of aeroplanes and dirigibles, various types of motors and some of the later designs of propellers. There were also exhibits, consisting principally of pamphlets for distribution, by the Pan American Union, the National Security League, and the National Advisory Committee for Aeronautics. A part of this floor was devoted to exhibits by some of the Government departments, including the Bureau of Standards, Coast and Geodetic Survey, Army and Navy, Postal Service, and the Weather Bureau.

The Weather Bureau exhibit consisted of most of the instrumental equipment usually shown at expositions and, in addition, some of the instruments, apparatus, etc., used by the Aerological Division. The usual exhibit has already been described in previous numbers of the MONTHLY WEATHER REVIEW. (Vol. **43**, p. 452, and vol. **44**, p. 459.) Besides these instruments there was also shown a Robinson anemometer so modified that electric contact is made for each one-sixtieth of a mile of wind blown, thus enabling the observer to determine the current hourly velocity by merely counting the number of contacts made in one minute (see this REVIEW, **44**:288). An electric fan operated this anemometer; also one connected in the usual way with the triple register. The latter and a barograph and thermograph were kept continuously recording. Much interest was shown in these instruments and in the glass weather map, which showed the weather conditions and the forecast for each day. The general arrangement and appearance of this part of the Weather Bureau exhibit are shown in figure 2. A large number of descriptive pamphlets on "The Weather Bureau" and "Explanation of the Weather Map"; also cards explaining the flags used for warnings were distributed during the exposition.

The aerological exhibit included a kite, kite reel, recording theodolite, 2 kite meteorographs, 1 balloon meteorograph, piece of sounding balloon rubber, a number of free air records obtained by means of kites, captive and sounding balloons, and copies of the Mount Weather Bulletin and Monthly Weather Review containing summaries of free air work. Figure 3 shows the kite, with meteorograph attached, kite reel and some of the instruments; in figures 5 and 6 the instruments can be seen in somewhat greater detail. All of this apparatus has been in regular use by the Weather Bureau, except the recording theodolite which is of recent design and construction. Its use in pilot or sounding balloon work will require but one observer, whereas, with the nonrecording theodolite, it has been necessary to have two observers; one to keep the balloon on the cross hairs, the other to record the angular readings. Much interest was shown in these instruments and in the piece of sounding balloon rubber, it being pointed out that all of our pure rubber balloons have been obtained from Europe and that no satisfactory samples have yet been produced in this country.

Greatest interest was apparent in the meteorograph records, which were briefly described on attached cards, and in the summaries of free-air data. It was evident that comparatively few of those actively engaged in aviation are aware of the existence of tables and charts showing temperature and wind conditions at various levels and under different conditions of pressure distribution at the earth's surface. The direct bearing and value of this work to aviators was emphasized, with the result that there were numerous requests for the summaries already published and for all publications along this line that may be issued in the future.

551.596 (41)

SOUND AREAS OF THE EXPLOSION AT EAST LONDON, JANUARY 19, 1917.[1]

By CHARLES DAVISON.

It is not often that a great explosion occurs near the center of a populous area, and the recent disaster in East London, England, thus offers an opportunity of adding to our knowledge on the transmission of sound waves by the atmosphere. * * * The most remarkable result [of recent investigations in this subject] is the recognition of the fact that there exists sometimes, not always, a zone of silence which separates two detached sound areas. This zone has been traced in 20 recent explosions (excluding that of Friday, January 19), two

[1] *Condensed from* Nature, London, Feb. 1, 1917, 98: 438-439, by W. G. Reed.