"Report on the Atmospheric Electrical Conductivity Tests Conducted in vicinity of Los Alamos, Scientific Laboratories, New Mexico".

by

Mr. Samuel C. Coroniti
Atmospheric Physics Laboratory
Geophysical Research Directorate
Air Force Cambridge Research Laboratories

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General Purpose of the Tests

The objects of the tests were first to track a radioactively gaseous cloud as long as possible, second, to study the rate at which the ionization produced by the radioactive matter decreases and diffuses, and finally, to analyze the "fall out" of radioactive substance from the cloud. The last mentioned objective is in reality the determination of radioactive contours on the surface.

Theory of Measurements

The apparatus used in these experiments is based on an instrument first used by Gerdien.[1] The apparatus consists of two concentric cylinders through which the air stream flows. (figures 1,2,3) A potential difference is applied between cylinders a and b. The charge collected on the central cylinder is measured with a vibrating reed electrometer.[2] A Brown Electronik Recorder is placed in the output of the electrometer so that a continuous record of current variations is obtained. In order to measure conductivity with this instrument, the voltage between the cylinders must be less than the saturation voltage for a given air flow. For potential differences greater than the saturation voltage all ions in a given volume of air are being collected and the instrument measures ion concentrations. The magnitude of the potential difference applied to the cylinders was such as to measure small ion concentrations.

1. Terr May 10, 65-79 1906
2. R.S.I. Vol 18, No. 5 PP-3?8-311..May.1947

Swann[1] has shown that when this apparatus is operated below saturation the current measured by the electrometer is given by, $i = 4\pi C V \lambda$ where C is the capacity of that part of the system exposed to the air flow, V is the potential between the cylinders and λ is the electrical conductivity of the air sample. Rewriting equation I in the form $\lambda = \frac{i}{4\pi C V}$, it is seen that the conductivity is proportional to the electrometer current. Since the conductivity is also defined as $\lambda = nke$ the ion concentration can also be determined from these measurements. In this equation, n is the number of ions per c.c., k the average mobility of the ions and e is the charge per ion.

The two chief sources of ions in the atmosphere are (1) emanation from radioactive matter in the earth and air and (2) from cosmic radiation. It has been found experimentally that ionization due to cosmic rays increases with altitude and is the most important source of ions above 5000 feet. The ion concentration at any given time and place is dependent on local meteorological conditions such as winds, humidity, and temperature. The dependence of ion concentration on vertical drafts of winds is illustrated in figure 4A and 4B. These records were made during a test designed to simulate a radioactive cloud by releasing smoke pots at the base of a canyon, hereafter referred to as "Point Able". After the smoke pots were released the conductivity value over "Able" has increased from 1.98 to 2.58×10^{-4} E.S.U. The increase is due to the fact that upon release of the smoke pots, the vertical movement of the mass of air from the bottom of the canyon, carried with it radioactive matter and charged nuclei, formed around the smoke particles.

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Description of Tests

The electronic equipment used in these tests was mounted in the nose of a B17, Serial No. 42-8635. The theory of operation and the installation will be discussed in detail in a subsequent report.

The tests were divided into three parts, the measurement of background conductivity, the tracking of the radioactive cloud, and, finally, the measurement and the mapping of the radioactive "fall out".

In order to evaluate the effect of the radioactive cloud, it was necessary to study the behavior of the atmospheric electrical conductivity over the entire area over which the cloud might traverse. This data was required one day prior to the actual firing. It was accomplished by flying the B17 along parallel grids running north to south and having a separation of 2 miles. These flights were made at pressure altitudes of 8300 feet, 9000 feet, and 14,000 feet. The actual altitudes above the ground were computed from the navigator's data and by use of the available maps of the area. Flying in a B17 over the canyon regions of Los Alamos, at an average indicated air speed of 180 M.P.H., the navigator found it very difficult to pin point ground positions.

The terrain over which these tests were conducted is characterized by high plateaus cut by deep canyons. The wide fluctuations in conductivity such as valleys and plateaus are directly attributed to the valleys and plateaus of the terrain. It has been observed in these tests and other tests that the value of conductivity increases while flying over valleys and decreases over mountainous regions. This corresponds with the accepted theory.

Figure 5 illustrates the flight path of the B17 in tracking the cloud.

"A" is the cloud directly over "Able"; "B" and "C" are its positions sometime later. The arrow indicates its direction of motion. For positions "A" and "B" it was decided to fly tangent to the outer fringes of the cloud, so that its diameter and its rate of diffusion could be computed. However, the cloud was visible for a short time, 5 to 15 minutes, after its generation. Thereafter it was decided to pilot the aircraft through the center of the cloud as shown in figure 5C. This feat was accomplished with the aid of a conductivity meter on the pilot's instrument panel. The pilot was instructed to strive to get a maximum reading on the meter. In the meantime, this information was relayed to the navigator who recorded the ground positions. From his ground wind data and previous positions of the cloud, he computed future position of it.

The ground contour tests were made one day after the firing. The method used was to measure the electrical conductivity first along the path traversed by the cloud during the previous day; second, to measure conductivity along parallel paths, one, two, and three miles distant on both sides of the main course; and, finally, to measure conductivity along orthogonal paths, spaced at intervals of 2 miles. Unfortunately the complete execution of this plan was not possible because of dust storms.

Discussion of the Graphical Records

The graphs are true reproductions of continuous records obtained on the Brown Recorder. Along the ordinate is plotted the ratio, $R_{(-)}$, of the conductivity of small negative ions at any given instant to the background conductivity. Along the obscissa is plotted the actual local time of the tests. Since the average ground speed of the aircraft was approximately [illegible] M.P.H., one minute is equivalent to [illegible] miles. Included also are the positions on the ground. Wherever possible, the name of the ground position is given; otherwise, its position is designated in terms of longitude and latitudes.

It is intended in this report to include all pertinent reproduction of the records, especially those near the firing point, which is "Able",

Discussion of Background Conductivity

The atmospheric electrical conductivity varies considerably when the measurements are within an altitude of 5000 feet above ground. Atmospheric conditions also affect the value of conductivity. For instance, haze, no matter how thin, generally decreases, sometimes increases the value. Pollution of the air, such as dust, and temperature variation decreases the value. The latter two effects are strikingly noticeable within the Los Alamos area, where the contamination due to radio active sources is more prevalent than in any other area. Analysis of the background test made on 23 March and the background data obtained on 24 March shows clearly this variation in conductivity at an altitude of approximately 1000 feet above ground. In contrast for altitudes of 10,000 feet or greater above ground, the conductivity for a given altitude is relatively constant.

The first background of small negative ion conductivity test was conducted on 23 March between hours 1128 to 1246 at a pressure altitude roughly of 9000 ft. or approximately 1700 feet above ground. The area covered was bounded by 106° 17' W, 36° 00' N to 105° 55' W, 36° 00' N to 105° 55' W, 35° 30' N to 106° 25W 35° 30' N. The average value of conductivity over this area was 1.56 x 10^{-4} E.S.U. with a low value of .86 x 10^{-4} E.S.U. over Algondonis and 1.9 x 10^{-4} E.S.U. over "Able". The conductivity at 9,000 feet in an area around "Able" of radius greater than 0.9 miles has an average value of 1.7 x 10^{-4} E.S.U. but in area less than 0.9 miles radius the value is 1.98 x 10^{-4} E.S.U. This indicates that area immediately around "Able" is contaminated with radioactive substances. In comparison the value around Boston, Mass. area for this same altitude is 0.75 x 10^{-4} E.S.U. and for Tampa, Fla., it is 1 x 10^{-4} E.S.U. These latter figures are average over many readings.

Background conductivity measurements were repeated on 31 March, two days after the second firing. The writer was informed by participants in this test that cloud moved westward from point "Able". No measurements were made within the prohibited area surrounding Los Alamos. The area covered was east of the Rio Grande River, as far east as 105° 15' W longitude and bounded by the latitudes 35° 30' N and 36° 00' N. The aircraft flew north and south along fixed longitudes.

The data is presented in table 1 in which the geographical position is given, the ratio, $R_{(-)}$, the local time, and remarks. There is no desire to review and to discuss the significance of the data. It is only intended to present it and to stress the highlights. The conductivity along the Rio Grande river basin was approximately equal to the background value which is exactly equal to the background value obtained on previous tests and the one obtained on 4 April. However, in the mountainous region east of Santa Fe, the value of $R_{(-)}$ varied from 1.23 to 1.64. The majority of the large values of $R_{(-)}$ were found within the area bound by 105° 50' W, 35° 60' N, 105° 30' W and 35° 30' N. Exploring this area again on 4 April, it was found that the value of $R_{(-)}$ varied from 1.06 to 1.18. A more effective depiction of the variation $R_{(-)}$ in this area is shown in Figures 6, 7 & 8. Since high readings were repeated over this area on different occasions, it seems to indicate the presence of radioactive material above or below the ground.

Returning to Kirtland AFB, it was noticed that the conductivity was unusually high in and around Tijeras, N.M. The mountainous area around Tijeras, Cedar Crest, Sandia Park and South of Tajeras, was investigated. Two high peaks of conductivity, yielding of values of $R_{(-)}$ = 1.24 and 1.38 were observed.

TABLE I

Date 3-31-50

Position	R(-)	Time (local)	Remarks
35° 18' N 106° 28' W	1	1159	
Santa Fe	0.82	1210	
Espanola	1.04	1218	
35° 48' N 106° 07' W	1.04	1225	
3 mi E San I'Defonso	1.14	1237	
Over Black Mesa	1.20-	1244	
35° 36' N 106° 09' W	0.87	1252	
35° 49' N 106° 11' W	1.14	1259	
35° 38' N 106° 01' W	0.84	1311	
Pojoaque	1.09	1317	
Nambe	1.00	1323	
N.E. of Santa Fe	1.02	1330	
2 Mi. N.E. of Nambie	1.1	1335	
35° 58' N 105° 55' W	1.02	1340	
35° 41' N 105° 48' W	1.23	1413	See Fig. 6
35° 34' N 105° 48' W	1.37	1415	" " "
35° 43' N 185° 43' W	1.54	1430	
35° 58' N 105° 37' W	1.54	1443	See Fig. 7
35° 36' N 105° 37' W	1.52	1448	
35° 35' N 105° 37' W	1.43	1449	See Fig. 8
34° 34' N 105° 37' W	1.40	1450	

On 4 April background tests were conducted over the "Able" site. Graph 18 and 19 show the results. The highest conductivity readings were obtained northwest of "Able" and specifically, around the golf course. The values of $R_{(-)}$ respectively were 5.46 and approximately 6.0. It must be stressed that these values are unusually high, indicating a large concentration of small ions.

Tracking the Radioactive Cloud

The first small simulated bomb of radioactive material was exploded at point "Able" on 29 March 1950. The purpose of the test was to track the resulting cloud, to measure the rate of decrease of activity, and to measure its rate of diffusion. The results of this test are listed in Table II which lists the number of passes made near or through the cloud. The value of $R_{(-)}$ elapsed time in minutes after the firing, pressure altitude and position or geographical location at which the pass was made. Prior to the firing, the aircraft was circling 2 miles SE of "sand paper". After the firing, the cloud was followed eastward toward San Ildefonso, Pojoaque Nambie, over the mountain range of Sangre de Cristo, and finally toward Watrous. The total time of tracking was one hour and 34 minutes.

The initial passes were an attempt to skirt the fringes of the cloud. The results are shown in figures 11A and B. Seven minutes after the firing a pass was made over "Able" for the purpose of measuring the radioactive contamination over the area. The conductivity increased by a factor of 0.26 times the normal background. (See Fig. 11C) All the passes made henceforth were through the center of the cloud.

The first indication of the disintegration of the cloud was noticed

18 minutes afterwards, at which time the cloud was 1 mile NW of OTOWI bridge, approximately 5 miles distant from "Able". It possesed three maxima. (See Fig. 12A) The width of the cloud increased from 2.04 to 4.1 miles within a period of 7 minutes. The rate of diffusion is 0.295 miles per min.

No of Passes	R(-)	Elapsed time in Min.	Refer to.	Width of Pass Mi	Pressure Alt.	Position
1	2.25	0.5	Fig 11A	0.9	9000 Ft	½ mi NE of Able
2	2.75	2.0		2.06	9000	35°53'N106° 15'
3	3.75	4.5	Fig 11B	1.6	9000	3/4 mi ENE of Able
4	6.26	7.0	Fig 11C	2.05	9000	Able
5	3.12	11.0	Fig 11D	2.04	9000	2 mi NE of Able
6	2.25	18.0	Fig 12A	4.1	9000	Dbl. hump 1 Mi NW of Otowi Bridge
7	2.1	21.5	Fig 12B	5.8	10,000	35°53'N106°08' W
8	(2.16 (1.54	25.5 26.5	Fig 13A Fig 13A	4.9 2.3	10,500 10,500	1 Mi NE San Ildefonso
9	1.51	31.0	Fig 13B	1.34	11,000	
10	1.80	33.5	Fig 13B	5.30	12,000	35°59'N105° 01' W
11	1.86	39.0	Fig 14A	6.5	12,000	35°55'N 105° 57'W
12	1.84	43.5	Fig 14B	5.5	12,000	35°55'N 105° 58'W
13	1.84	47.0	Fig 14C	5.5	11,500	35°55' N105° 57'W
14	1.83	50.0	Fig 14D	5.5	12,000	35°56'N 105° 53'
15	1.90	54.0		6.0	12,000	35° 56N 105° 53'
16	1.37	62.0	Fig 15A	3.0	13,000	35°47'N 105° 45'W
17	(1.03 (1.03	90.0 94.0	 Fig 15B	3.2 2.0	13,500 13,500	35°49'N 105° 00' 35°49'N 105° 00'

In order to study the vertical variation of conductivity above the cloud, passes were made over it at pressure altitude 9000, 10,000 and 10,500 feet. The results are shown in figures 12A, 12B, 13A and 13B.

Figure 14A to D shows the records made of the cloud at the foot of the Sangre de Christo Mountain range.

Five passes were made during an interval of 23 minutes. The value of $E_{(-)}$ was practically constant at 1.84. The slope of the mountain acted as a barrier to the progress of the cloud. The investigation was continued east of this position by flying at an altitude of 14,000 feet over this range of mountains. Two peaks, one 3.2 and the other 2.02 miles wide, (See Fig. 15B) were definitely detected near Watrous, which was approximately 70 miles distant from "Able."

From this data the rate of decay and the variation of the width of the cloud can be determined by plotting variation of the peak value of conductivity against time. The curves depicting these variations are shown in figures 16 and 17. It is seen that the activity decays exponentially. From figure 17 it is obvious that a rapid increase in diffusion occurs within the first 25 minutes after the firing. After this interval of time, the rate of increase of radius is much slower. It must be remembered that width of the cloud is defined as that part of the cloud through which the plane passed. Therefore, only the average values formany passes have significance.

The third firing occured on 6 April. As soon as the cloud rose above the canyon, it appeared to disperse in all directions. It was visible for only a few minutes. Its immediate disappearance made it impossible to pilot the aircraft along the pattern followed during the first test. The first problem was to find the cloud. Consequently, the area in the immediate vicinity of "Able" was explored. The first pass over "Able" yielded a value of $R_{(-)}$ equals 17.4, which was twice as large as highest value of $R_{(-)}$ obtained during the first test. What significance this fact has in relation to the quantity of radioactive material used in the two tests the author does not know. The measurements seem to indicate that this third test was more intense.

The cloud apparently diffused radially northward from point "Able." Rather than discuss the various patterns of flight, the records will be presented. It is apparent from the records that the cloud did split into two sections; one drifted north and northeast toward Chamita and Alcalde; whereas, the other drifted north, northwest of Los Alamos.

In Fig. 18A, seven and one-half minutes after the shot, a double peak was detected, indicating a breaking up process. The peaks are 1.6 miles apart. Approximately two minutes later the plane flew thru the same cloud again. See Figure 19A. The center of the peaks are the same as the previous one. However, the width of the cloud has increased from 2 to 3 miles. In this latter cloud a small third peak has developed. The trend, therefore, is toward greater dispersion. The degree of disintegration is evident from records shown in Fig. 19B. The conductivity, twenty minutes after the shot, is equal to 5.7. A section of the cloud was detected over Truchas 1 hour after the blast, yielding a maximum value of $R_{(-)}$ equals 1.35. (See Figure 22).

Graph 25 shows the variation of conductivity over "Able" 1 1/2 hrs. after the shot. The rate of decay for this cloud is shown in Figure 24. Comparing the values of $R_{(-)}$ from curve with the one on Figure 16, it is [illegible] this value is approximately 5 times greater for the latter cloud. Approximately two hours after the shot, the cloud was about 10 miles N. northwest of Los Alamos. The average value of $R_{(-)}$ for this area is 1.53. Table III lists some of the peak values.

Table III

Location	Elapsed Time	R(-)	Width of Peaks
4 Mi. N.NW "Able"	1 Hr. 46 Min.	1.9	22 Miles
4 Mi. E of Espanol	1 Hr. 49 Min.	2.06	3.0 Miles
5 Mi. N.NW of Los Alamos	1 Hr. 55 Min.	1.93	2.5 Miles

The cloud could have been tracked for a considerably longer period. The test was terminated because it was deemed unnecessary to continue.

Ground Contours

The discussion of ground conductivity contours resulting from the first test will be presented. During the test of the previous day, 24 March 1950, four geographical positions were chosen as check points. These are 35° 55' 30" N, 105° 57' W which is 3 miles N.E. of Nambie, 35° 54' 30" N, 105° 58' 50" W, which is 1 mile N.E. of Nambie, 35° 54' 25" N, 106° 01' W which is 1 mile north of Pojaque, and 35° 53' 40" N, 106° 08' 20" W. Figure 25 is a record of the conductivity along the path of the cloud and Figures 26, 27 and 28 are the conductivity records along parallel paths 3/4 mile south, 1 mile north, and 1 1/2 miles north distance from the original path. By studying the variation of the value of $R_{(-)}$ listed in Table IV, one can better understand the variation of "fall out." It must be pointed out here that the values of $R_{(-)}$ less than 1 means that the large ion population is greater than that for small ions. Large ions cause a reduction of the average small ion conductivity. The theory and experimental facts will be published in an unclassified report now in preparation. Tabulated also are the respective values of $R_{(-)}$ evaluated on the previous days and resulting from the cloud. To avoid any misinterpretation, it must be stated, since ratios are involved, that actual maximum value of conductivity was greater during the wet run than during the test on the succeeding day. On the other hand, the background conductivity values were also higher. It is difficult to interpret the "fall out" data without making qualifying remarks or assumptions about wind directions, which were unpredictable over the Mesa area. It is not uncommon to experience violent shifts in winds. Considering these facts, deviations in position are to be expected. Over the remaining three check points, the values of $R_{(-)}$ correspond indicating the maximum "fall out" over these points.

In Figure 29 an attempt is made to illustrate the pattern of the "fall out." Line 'ab' is the projection to ground of the cloud path "of ". The dotted line "def" is the path over which the maximum conductivity indication was recorded one day after the firing. Assuming, therefore, that "fall out" occurred along "agb" the wind direction was such so as to transport the ions in the direction shown by the arrows. For the region "ag," the maximum conductivity indication occurred north of the cloud path.

The conductivity was measured around the site of point "able" for both positive and negative ions and also at various altitudes. The readings around this area varied appreciably. This variation is attributed to contamination of the area and to the direction of winds. Three passes were made over the area measuring negative and two passes were made measuring positive conductivities. Figures 30, 31 and 32 show the variation of R +

with time. Relevant geographical locations are marked on the charts. Figures 30, 32 show the variation of R_t at an altitude of 8300 feet and Figure 31 at an altitude of 7900 feet. A sharp maximum is shown over "Able."

Table IV

Value of R

Geophysical Positions	Center	1 Mi N of Center	1½ Mi N of Center	3/4 Mi S of Center	Number of Checkpoint	Mile from "Able"	R Cloud Reading 20 March 50
35° 53' 40" N 106° 08' 20" W	1	1.3	2.0	.4	1	7.5	2.1
35° 54' 25" N 106° 01' W	2.3	2.0	1.8	1.6	2	12.8	1.8
35° 54' 30' N 105° 58' 50" W	1.8	1.5		1.4	3	15.5	1.84
35° 55' 30' N 106° 57' W	1.5		0.3		4	17	1.84

Fall Out Readings on 25 March

Table V

Altitude (feet)	Max. $R_{(-)}$	Max. $R_{(+)}$
7400	---	6.3
7900	5.2	---
8300	3.2	
8300	3.7	
9250		3.5
9310		2.05 (dusty)

The maximum values of $R_{(-)}$ and $R_{(+)}$ are listed in Table V. Figure 33 shows the variation of $R_{(+)}$ with time around area. There is one striking and important difference between the negative, and positive values of R. The average background conductivity of the negative small ion is 0.89 x 10^{-4} sec $^{-1}$, whereas for the positive small ion is 2.1 x 10^{-4} sec $^{-1}$. The ratio $\frac{\lambda_{(+)}}{\lambda_{(-)}}$ (background) = 2.5. At 8300 feet over "Able" this ratio is = 4. In other words the population of small positive ions is greater by a factor 2.5 to 4 over this area. No attempt will be made at this time to present a reason for this difference. At some later time, it is planned to repeat these tests and to investigate experimentally the causes for this difference. Heretofore, the measurements were confined to the measurements of small negative ions because, under fair weather conditions, the values of conductivities obtained for small positive and negative ions

[redacted]

respectively are identical.

The variation of positive conductivity with altitude over "Able" site is shown in Figure 34. Along the ordinate is plotted positive conductivities, Rw and along the abscissa distance from "Able" in miles. It can be seen from these curves that the accuracy of contour mapping can be improved considerably by making the measurements as close to the surface as possible. These curves also depict graphically the variations of small ion density with altitude.

Acknowledgement

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Abstract

The atmospheric conductivity background was determined for area contiguous to Los Alamos, N. M. All unusual values were recorded. The geographical positions are given. No attempt is made to discuss the significance of this data. The first cloud was tracked for 1 hour and 50 minutes, whereas, the second for two hours. The first cloud moved East and the second dispersed toward Northeast and Northwest. The "fall out" resulting from the first cloud was measured.

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