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# San Joaquin Valley fog : attempts at electrical dissipation

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SAN JOAQUIN VALLEY FOG: ATTEMPTS AT ELECTRICAL DISSIPATION

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ABSTRACT

This report summarizes the results of a two night field operation in the San Joaquin Valley of California. The purpose of this operation was to test the feasibility of using a corona discharge mechanism to dissipate warm fog. Heavy fog was encountered on two nights and during both fogs we monitored visibility and droplets size distribution while injecting electrical charge into the atmosphere with a 90kVolt discharge. No effects which could be attributed to modification of the fog by the corona discharge were detected.

## I. INTRODUCTION

On January 22nd and 23rd, 1975, the Naval Weapons Center (NWC) and the Naval Postgraduate School (NPS) conducted a joint field operation in the San Joaquin Valley of California at a weather observation station semi-permanently located at the Visalia Airport by NWC. This location was chosen because of the frequent occurrence of very heavy fog which sometimes lasts for several days, disrupting traffic over a wide area. It is not an infrequent occurrence to have multi-car collisions occurring on route 99, which is immediately adjacent to the Visalia Airport.

NWC has an ongoing program to attempt to dissipate warm fog by means of injection of electrical charge and the purpose of the installation at the airport was to test various schemes for electrical dissipation.

The purpose of NPS participation in this two day field operation was to test a corona discharge mechanism for the injection of electrical charge into the atmosphere. The desire to test this type of apparatus grew out of laboratory experiments[1] which had been performed at the Postgraduate School, which indicated that corona discharge could be a viable means for charge injection to cause fog dissipation. At the conclusion of the successful laboratory experiments it was apparent that it was necessary to go into field to determine if the results obtained could be scaled to real atmospheric conditions.

The results being reported here consist of two parts; (1) microphysics of the fogs which occurred on the nights of January 22nd and January 23rd and, (2) the results of the attempts at electrical dissipation during these two fogs.

## II. EXPERIMENTAL EQUIPMENT

NWC Installation: The weapons center installation consisted of a wide variety of experimental equipment, however, only those portions of the equipment which are pertinent to this report will be indicated in what follows. For a complete description of the installation and for descriptions of the various pieces of apparatus refer to the internal report of the NWC Department of Earth and Planetary Sciences[2]. The pertinent measurements were as follows:

- air temperature at two heights,
- horizontal wind speed and direction at two heights,
- atmospheric aerosol particle size distribution,
- horizontal visibility,
- atmospheric electric field.

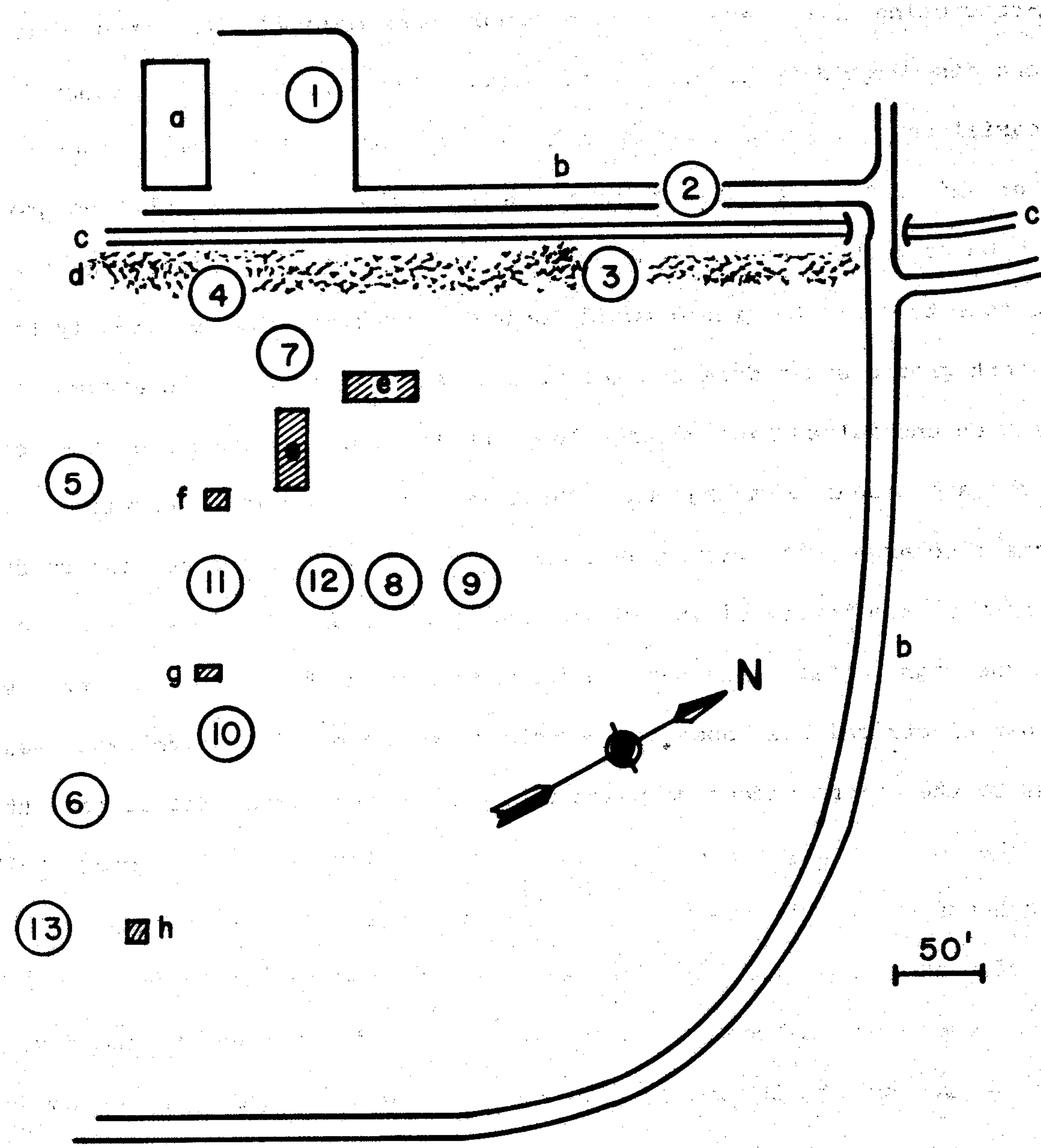
All of these measurements were made at approximately the same location at the field test site (refer to Fig. 1 showing an approximately to scale map of the experimental layout at the Visalia Airport).

NPS Equipment: The power supply for the corona discharge was a hipotronix model 8GP-160, 150 KV, 6ma power supply. In order to perform the fog dissipation experiments it was necessary to have a corona discharge electrode which could be elevated some distance above the ground and would also be portable. For this purpose a forty foot extendable tower made from PVC pipe was constructed and mounted on a trailer. A portable discharge mechanism is needed since it is necessary to locate the corona discharge directly upwind from the experimental test area. Since injected charge attaches to atmospheric aerosols, which drift with the prevailing wind, we expect no charge in the test area unless we have correct "targeting" using the prevailing wind.

The design criteria which dictated the configuration of the 40 foot tower

FIGURE 1

# Visalia Test Site




a. two story airport building

b. paved roads

c. canal

d. dirt access road

e. NWC Vans

f. particle counters and visiometers

g. laser visiometer reflector

h. electrometers

Numbers are positions for ion generation tests and associated discharge equipment were as follows: It was necessary to use a non-conducting tower because of the problems associated with conducting the corona discharge directly to ground rather than through the atmosphere A coaxial cable is used for the high voltage output of the power supply, however the ground of the coax was cut near the base of the tower so that no grounds would be near the corona discharge point. Electric field lines from the corona electrode to a nearby ground would conduct electrical charge directly to the adjacent ground and reduce the amount of charge going into the atmosphere. Having an unshielded high voltage lead running the full length of the tower has the additional advantage that the tower is at the high potential of the corona discharge. The resultant field lines repell the emitted charge from the vicinity of the tower, aiding in dispersing the charge. It was also necessary that the high voltage lead have an insulation with a very high electric strength so that electrical breakdown between the atmosphere and high voltage lead previous to the corona discharge point would not occur. For this reason, the lead from the power supply to the corona discharge point was cable number RG-17A/V which has a breakdown strength in excess of the 100 KV being used.

Of course, one problem which cannot be avoided is the increase in conductivity of the tower when it becomes coated with a film of water due to the fog. This increase in conductivity results in charge being conducted down the tower to ground, decreasing the amount of charge which is injected into the atmosphere. With the experimental configuration employed here it was impossible to determine what fraction of the current supplied by the power supply was actually being injected into the atmosphere, and what fraction was being conducted down the surface of the tower. As we shall see in what follows, there are indications that the increasing conductivity of the tower during the periods of fog occurrence may have been a problem during this experiment.

The discharge electrode was a piece of copper screen 12 inches long by 1 inch wide. Thus, relative to the size of the experimental area, the discharge is from a point source.

## III. EXPERIMENTAL PROCEDURE

Wind, temperature, and visibility were monitored continuously and recorded on strip chart recorders during the full two day period of the tests. The aerosol droplet spectra were recorded only as needed and records are available only for those periods during which fog occurred. The two Keithley electrometers which were used to measure the earth's electric field were in operation continuously, their output being presented on strip chart recorders. During a portion of the experiments, one of the electrometers was wired to measure current; this will be described below.

The purpose of the corona discharge equipment was to attempt to observe modification of the fog by means of injection of electrical charge. If sufficient clearing of the fog were accomplished one would be able to see a change in visibility as monitored by the laser visiometer. If the modification of the fog were too slight to be observed on the visiometer one would hope that it would be possible to detect a change in the fog droplet size spectrum. That is , if the electrical charge is becoming attached to fog droplets this should cause an increased collision colessence[3,4,5], resulting in a shift towards larger sizes.

One problem with the experimental setup used in these tests is that when using a single corona discharge electrode extreme care must be exercised in order to ensure that the charge being injected into the atmosphere arrives at the region of the experimental test area. We know that injected electrical charge attaches to atmospheric aerosol particles[1,6] which drift with the existing winds. Therefore it was necessary to attempt to always have the discharge apparatus immediately upwind of the experimental area. Another problem is the height of the atmospheric charge above the ground. The visiometer and Royco counter were located at a height of approximately 8 ft above the ground. If the existing wind carries the electrical charge and the supposedly affected fog droplets over the test area at too great a height no effect would be observed. Since the corona discharge electrode is at the top of the 40 ft tower this could occur unless the discharge mechanism is a fairly great distance away from the experimental area. On the other hand if the electric field lines from the top of the tower to the ground result in electrical charge being transported fairly directly to ground from the top of the tower one would not have charge transported to the experimental area unless the tower were close to the area. The experiments performed at NPS[1] and other tests[3] have shown that electrical charge can be transported large distances away from a corona discharge electrode. However, those experiments were performed in clear air with a fairly moderate breeze and not in the fog. Therefore, we are not certain as to how the charge will be transported away from the corona discharge electrode for the conditions which prevailed at the Visalia Airport and there is a fair amount of uncertainty when a test is being performed as to whether or not the injected electrical charge is arriving at the experimental area. This necessitated a great deal of moving about of the corona discharge equipment when the experiments were being performed.

## IV. TESTS PERFORMED

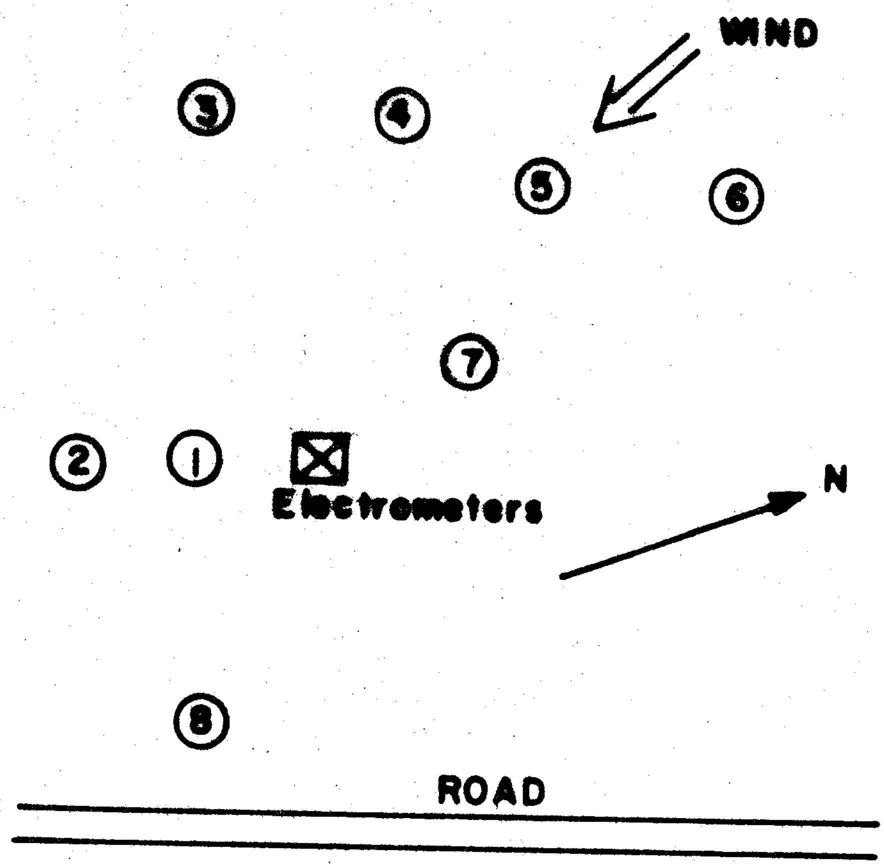
Table 1 shows details of the clearing tests performed on the nights of January 22nd and 23rd. In the table we show the wind direction and speed, average visibility, location of the corona discharge mechanism, distance from the discharge to the Royco counter, and duration of each test. The location of the various positions where discharge was performed are shown in Fig. 1, 90 KV

Table 1. Details of Corona Discharge Tests

| Time | Site | Site Distance (ft) | Site Direction | Wind Direction | Wind Speed (knts) | Average Visibility (ft) | Test Duration (min) |
|---|---|---|---|---|---|---|---|
| 2353 | 1 | 250 | 310 | 315 | 4 | 300 | 8 |
| 0038 | 1 | 250 | 310 | 350 | 3 | 250 | 4 |
| 0050 | 1 | 250 | 310 | 15 | 1-2 | 225 | 12 |
| | 2 | 400 | 0 | 350 | | | |
| 0218 | 4 | 120 | 300 | 345 | 1 | 300 | 16 |
| 0257 | 4 | 120 | 300 | | 1-2 | 250 | 12 |
| 0327 | 4 | 120 | 300 | 300 | 2-3 | 270 | 30 |
| 0445 | 4 | 120 | 300 | 295 | 4 | 310 | 35 |
| | 5 | 80 | 240 | 250 | 0 | | |
| 0539 | 5 | 120 | 240 | 325 | 2 | 300 | 23 |
| | 6 | 220 | 140 | 345 | 3 | | |
| 0632 | 7 | 80 | 325 | 40 | 2 | 270 | 5 |
| 2309 | 13 | 220 | 140 | 110 | 3 | 2000 | 35 |
| | 8 | 100 | 50 | | | 200 | |
| | 9 | 120 | 45 | 80 | | 1700 | |
| 0129 | 10 | 130 | 120 | 80 | 2 | 270 | 19 |
| 0200 | 11 | 30 | 115 | 70-110 | 2 | 190 | 10 |
| 0242 | 12 | 50 | 60 | 90-140 | 3 | 190 | 11 |

FIGURE 2

# POSITIONS FOR ELECTROMETER TESTS




| Position | Distance (ft) |
|---|---|
| 1 | 33 |
| 2 | 63 |
| 3 | 102 |
| 4 | 96 |
| 5 | 90 |
| 6 | 150 |
| 7 | 33 |
| 8 | 66 |

was used for all of the tests. The duration of the tests ranged from 4 min. to as long as 20 min. Twenty different tests were performed at the various locations over the two night period, and in all cases we attempted to have the discharge electrode immediately upwind of or immediately adjacent to the experimental area. This was somewhat difficult since the winds were rather variable in direction, causing a great deal of moving about the test site, however, a number of tests were performed where good targeting was accomplished.

In addition to the discharge tests which were performed in order to accomplish fog modification, a number of tests were performed to see the effect of the discharge on the atmospheric electric field. These tests were performed on the first night of operation and the afternoon of the second day. The tests during the first night were performed in the fog while those on the second afternoon were performed in clear air conditions. A map of that portion of the test site adjacent to the electrometer, showing the positions where the atmospheric electric field tests were performed, is shown in Fig. 2. The distances from the discharge electrode to the electrometer site are also shown on this figure.

## V. FOG CHARACTERISTICS

On both of the evenings during which tests were performed the fog began forming about 11 PM and persisted until 10 or 11 the next morning. The first evening was a classic example of fog formation due to radiative cooling of the ground. The temperature during the day had been fairly warm, after sunset the temperature of the air near the ground dropped to near freezing and fog formed first at ground level and then deepened in the upward direction. The fog formed quite rapidly, the time lapse from the first observation of fog forming at ground level to a decrease of the visibility to 200 ft was only about 20 min. During most of the night this fog never deepened to more than one or two hundred feet and for parts of the evening was as shallow as perhaps 20 to 30 feet. The second nights fog formed first in the upwind direction, then in the test area, giving the impression that the fog was "blowing in". This second fog was much deeper than the first, persisted longer on the next day and had somewhat lower visibility through most of the night.

Figures 3 through 8 show droplet size spectra obtained during the two night tests. The Royco instrument which was used for these measurements operates as follows: There are a total of 15 size ranges: 0.3, 0.4, 0.5, 0.6, 0.8, 1.0, 1.2, 1.5, 2.0, 3.0, 4.0, 5.0, 6.0, 8.0, and 10.0μ. The instrument counts in each range stepping from range to range sequentially, a complete counting cycle taking approximately 5 min. In each size range all particles are counted that have a minimum size specified by the size for that range and a maximum size specified by the next size range, e.g. for the 0.8μ range particles from 0.8 to 1.0μ are counted. The last range counts all particles of size greater than 10.0μ.

Figures 3 through 6 show the number of particles in each size range as a function of time for the first nights fog. The dark bars at the bottom of the graphs show the times during which corona discharge tests were performed. In figures 9 and 10 we show histograms of the fraction of the total number of droplets which occur in a particular size range, plotted on a log scale, vs. the size range.

As can be seen from Figures 3 through 8 the numbers of particles observed in the various size ranges vary greatly as a function of time. Also, there is an indication that an increase in the number of large droplets is accompanied by a decrease in the number of small droplets, and vice-versa. This could be accounted for by evaporation, condensation and coalescence processes. That is, vapor condensation would lead to growth of droplets to larger sizes and an increase in the

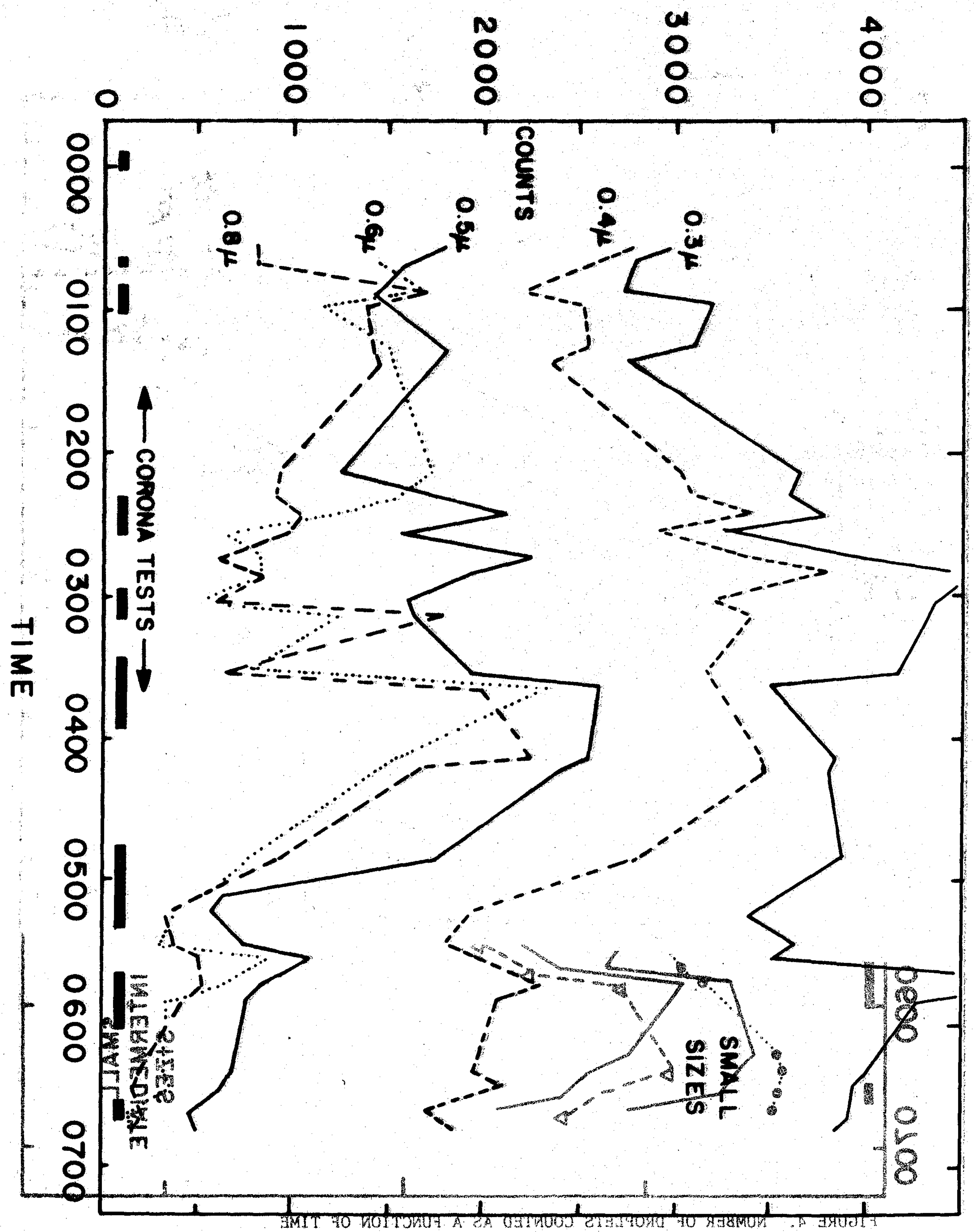



FIGURE 3. NUMBER OF DROPLETS COUNTED AS A FUNCTION OF TIME

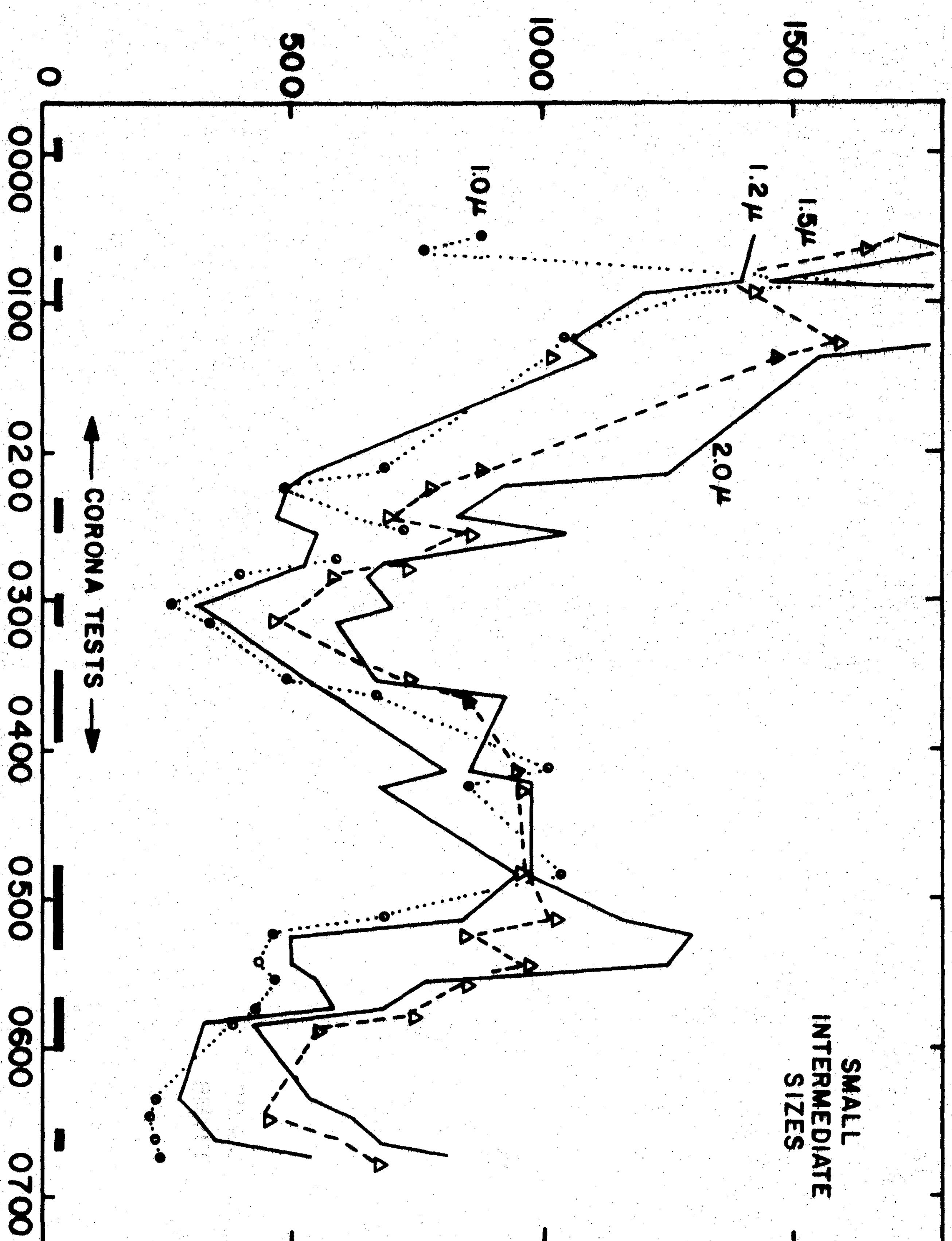



FIGURE 4. NUMBER OF DROPLETS COUNTED AS A FUNCTION OF TIME

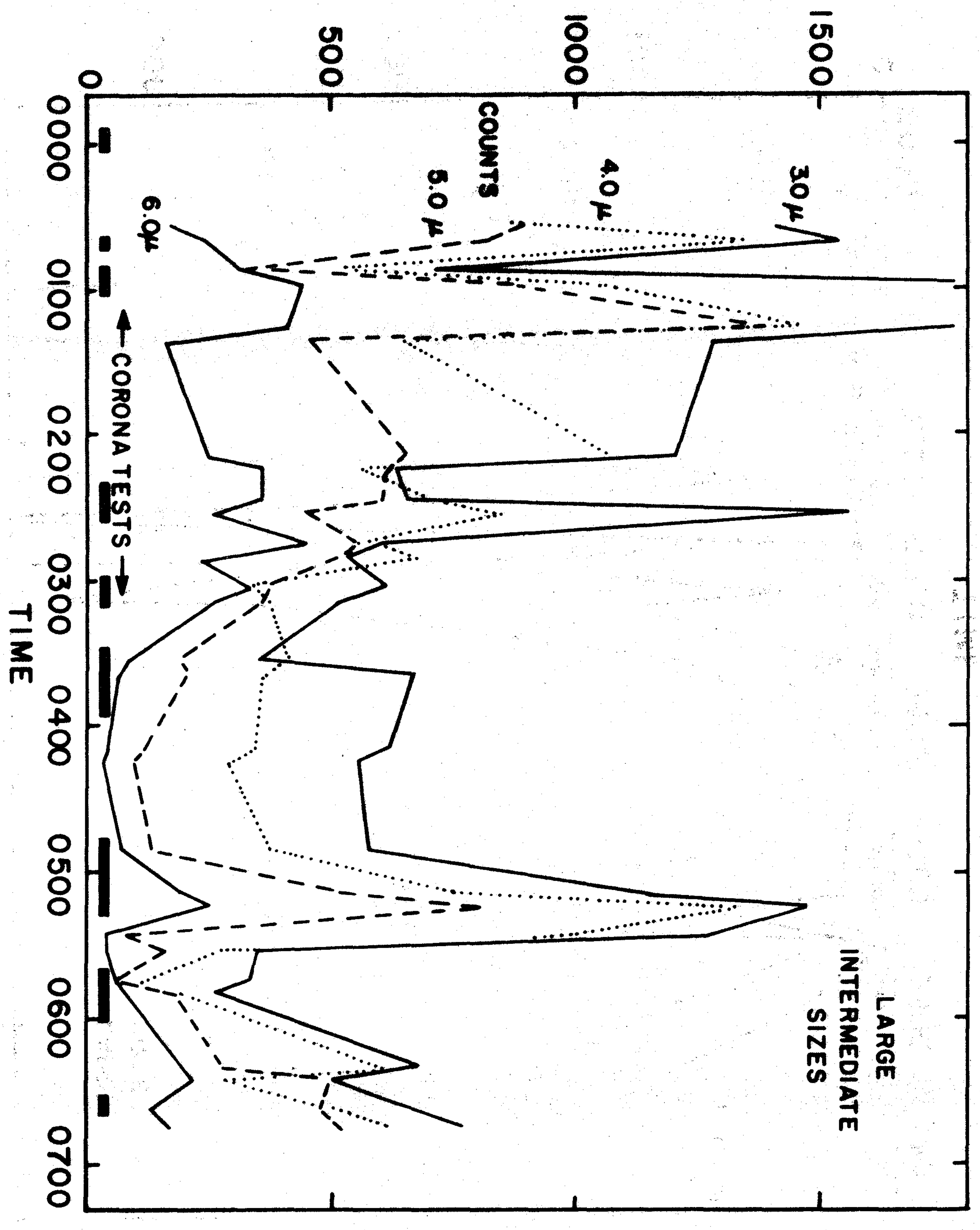



FIGURE 5. NUMBER OF DROPLETS COUNTED AS A FUNCTION OF TIME

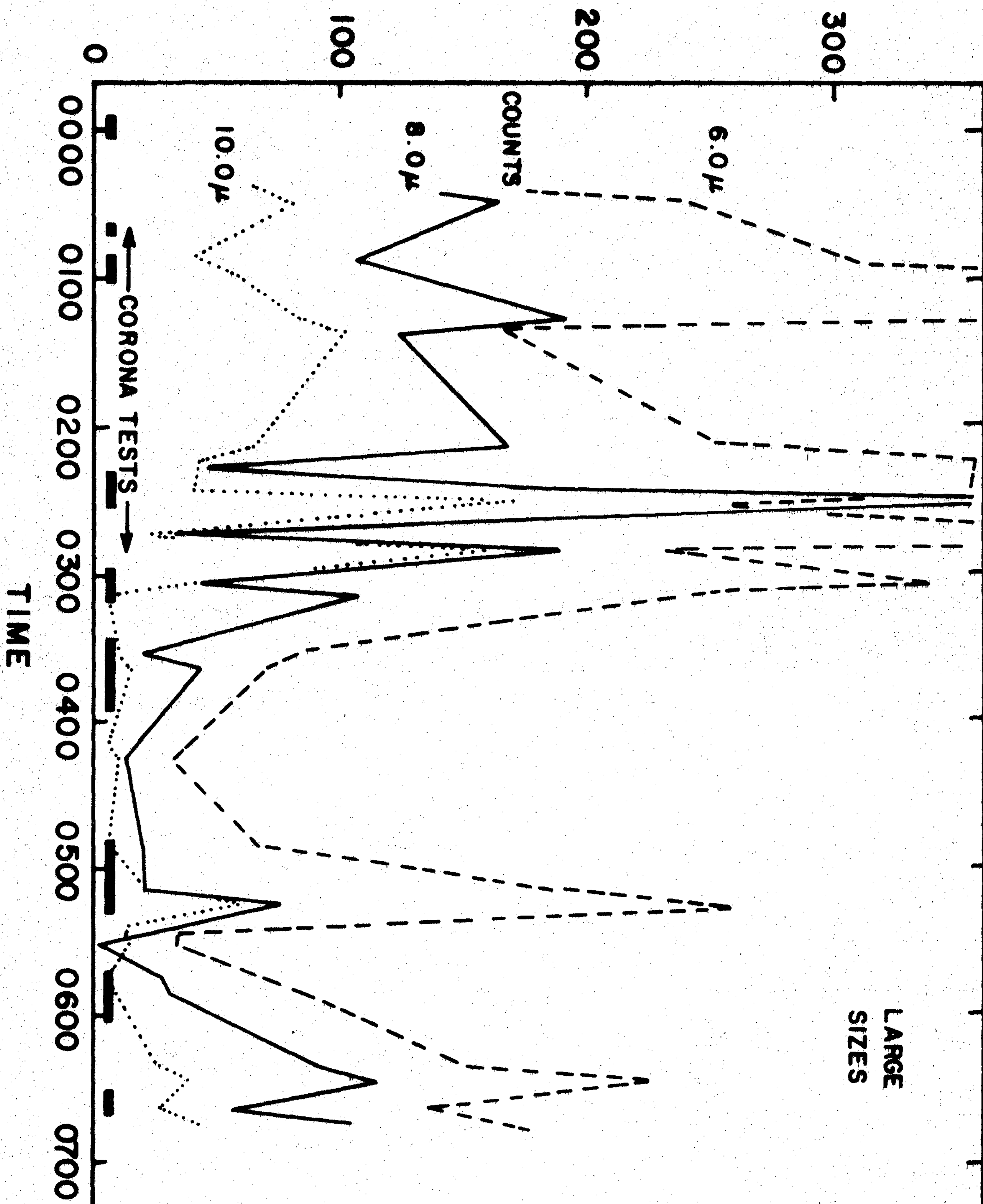



FIGURE 6. NUMBER OF DROPLETS COUNTED AS A FUNCTION OF TIME

number of small droplets and a decrease in the total number of droplets, coalesence would lead to an increase in the number of large droplets with the liquid water content remaining constant.

We have calculated the liquid water content and using this and the total number of droplets observed have attempted to determine which of the processes listed above were occurring. Both of these parameters, and also the visibility, fluctuate with time over a wide range and there are no correlations among the parameters that allows one to identify a particular process as being operative at a given time. Rather, our results are apparently due to spatial inhomogeneities in the fog, so that volumes of air with differing properties flow past the sensors, causing the observed fluctuations. This was particularly true in the shallow fog that occurred during the first night.

The situation was somewhat different on the second night. Again, the experimental variables which are being observed fluctuated over a fairly wide range, however, there were two periods of definite growth of the droplet spectrum from small to large droplets. These results are shown in Figures 7 and 8 which shows the fraction of the total number of droplets occurring in a particular size range, plotted on a log scale, vs. the size range. In both Figures we show four droplet spectra with each succeeding spectrum being at a later time, so that we are able to see the change of the full droplet spectrum with time. In both cases we see that at the beginning of the time period there is a very large fraction of droplets in the small size ranges and a much smaller fraction in the larger size ranges. As time changes the spectrum shifts quite markedly, resulting in the highest percentage of droplets in the intermediate size ranges. Therefore there is definitely a growth process occurring taking particles from the smaller to larger sizes.

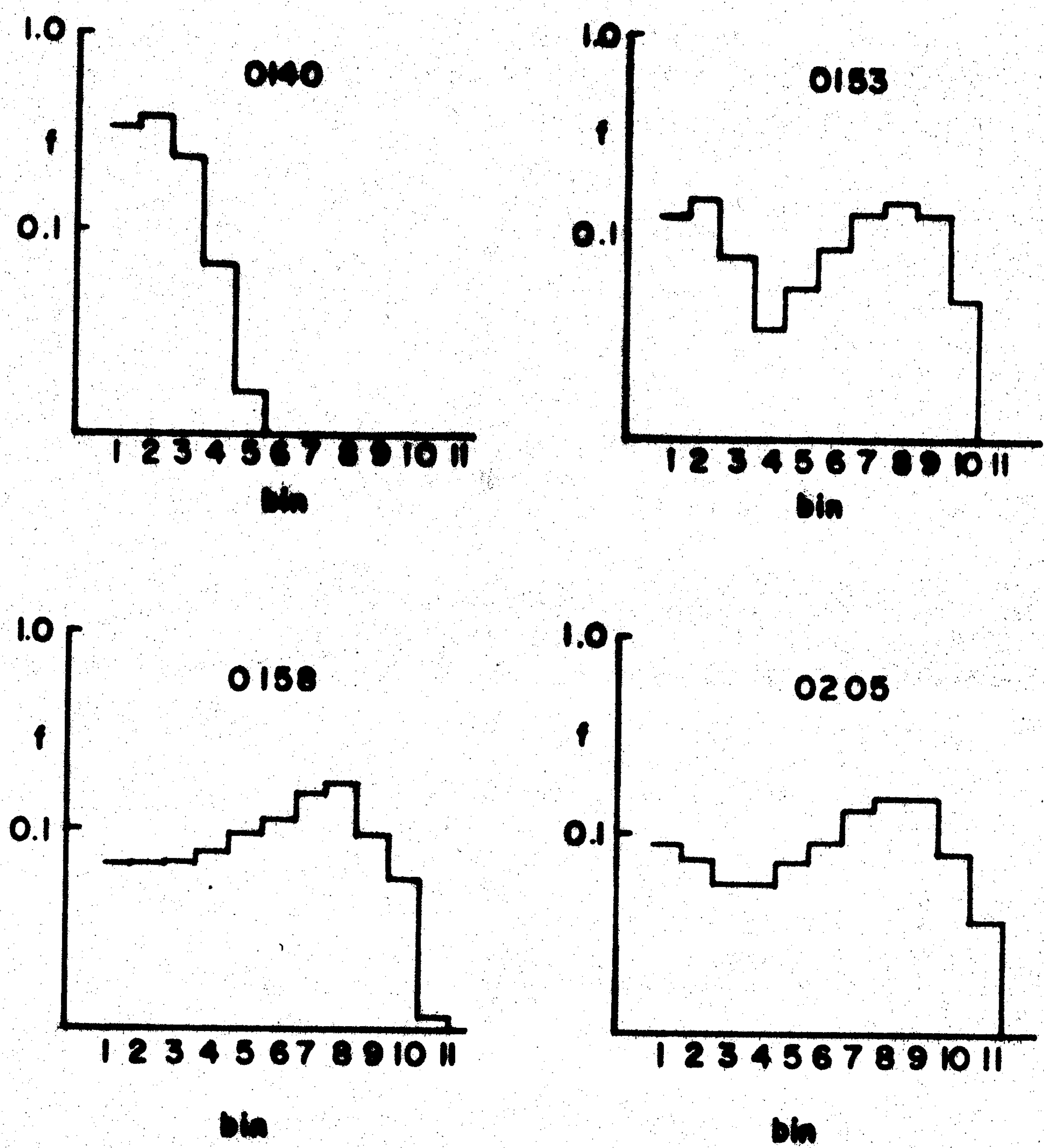



FIGURE 7. FRACTION OF DROPLETS AS A FUNCTION OF SIZE RANGE

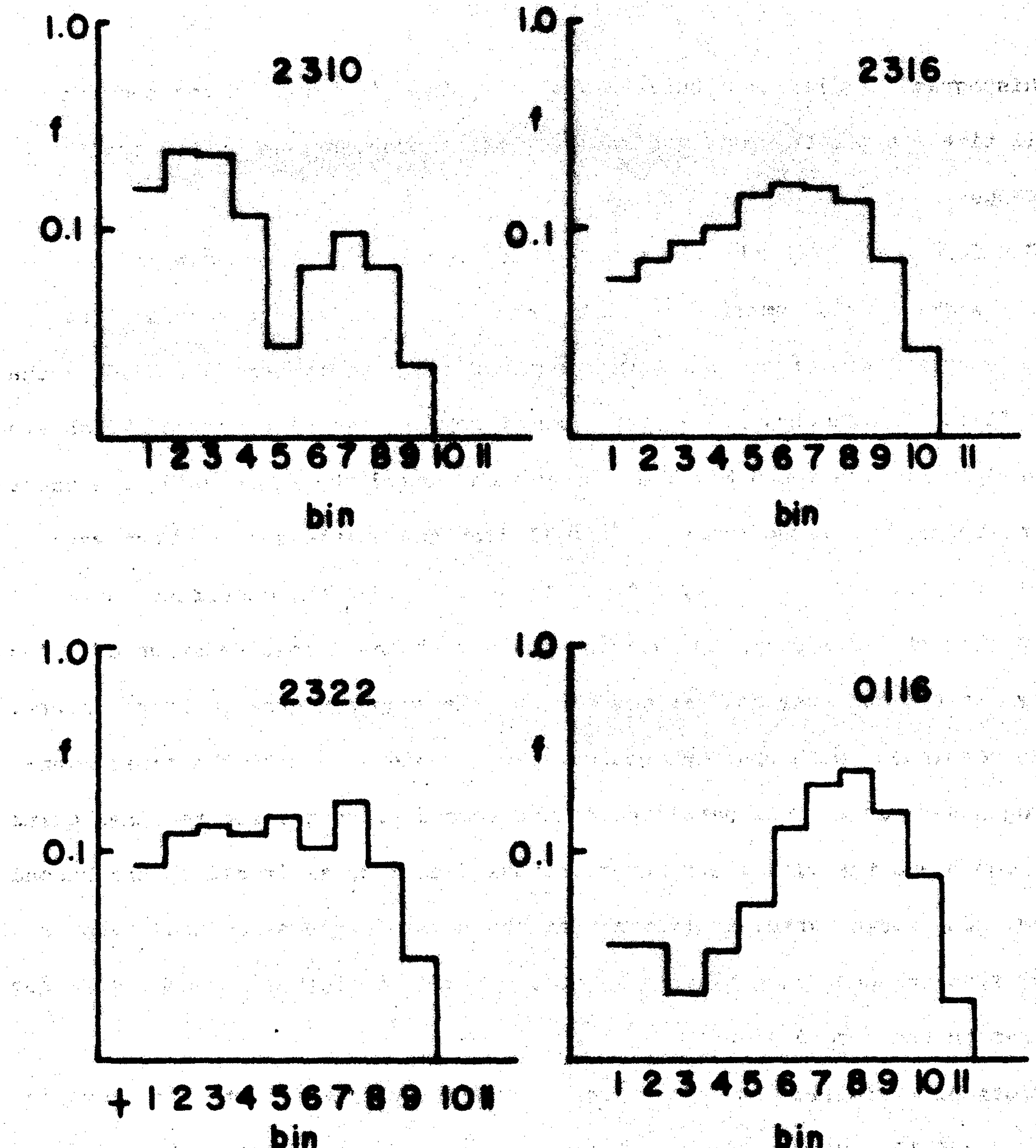



FIGURE 8. FRACTION OF DROPLETS AS A FUNCTION OF SIZE RANGE

Histograms similar to Figures 7 and 8 for the first nights fog show that for all time periods the predominant fraction of droplets was in the small size ranges.

The full history of the first nights fog was one in which most of the droplets were of quite small size, less than 0.5μ. During the second nights fog the converse was true; the largest numbers of droplets were observed in the intermediate size ranges, 1.0 - 2.0μ, except for the two time periods which are indicated in Figures 7 and 8. The time periods immediately preceding the occurrence of relatively large numbers of small droplets on the second night were periods of increased visibility. Thus, it appears that the occurrence of a large number of small droplets was associated with the formative stage of a fog whereas, as the fog ages and becomes denser, the droplets grow to larger sizes. This is consistent with what one would expect. Note also that the first evenings fog never was as well developed as the second since the fog remained quite low in depth and the visibility never decreased as much as it did on the second evening. One would expect therefore that the first evenings fog would show a droplet spectrum much more closely associated with the formative stage of a fog than that on the second evening.

Plots of visibility as a function of time for the two nights are shown in Figures 9 and 10. Figure 11 shows the visibility for the first night and for a short period on the second night when the fog was quite dense. The data is presented in this manner in order to be able to directly compare the average visibility level in the fog of the first night with that of the second night. Figure 12 shows the visibility over the full time period on the second night for which measurements were made. As can be seen the early time period of the second night shows large fluctuations in visibility. Large fluctuations of this type were not observed on the first evening due to the fact that the fog formed in the

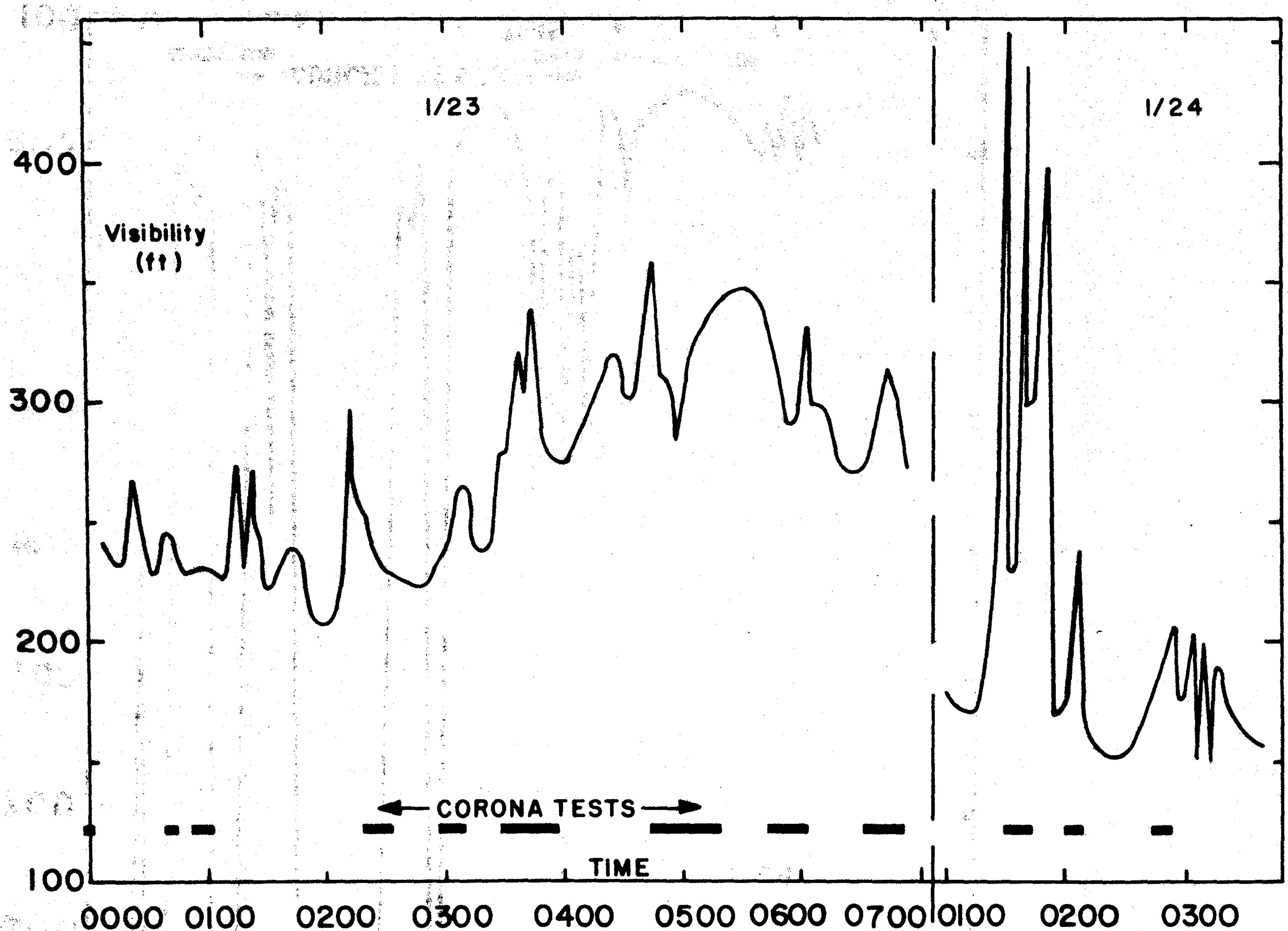



FIGURE 9 VISIBILITY VS TIME

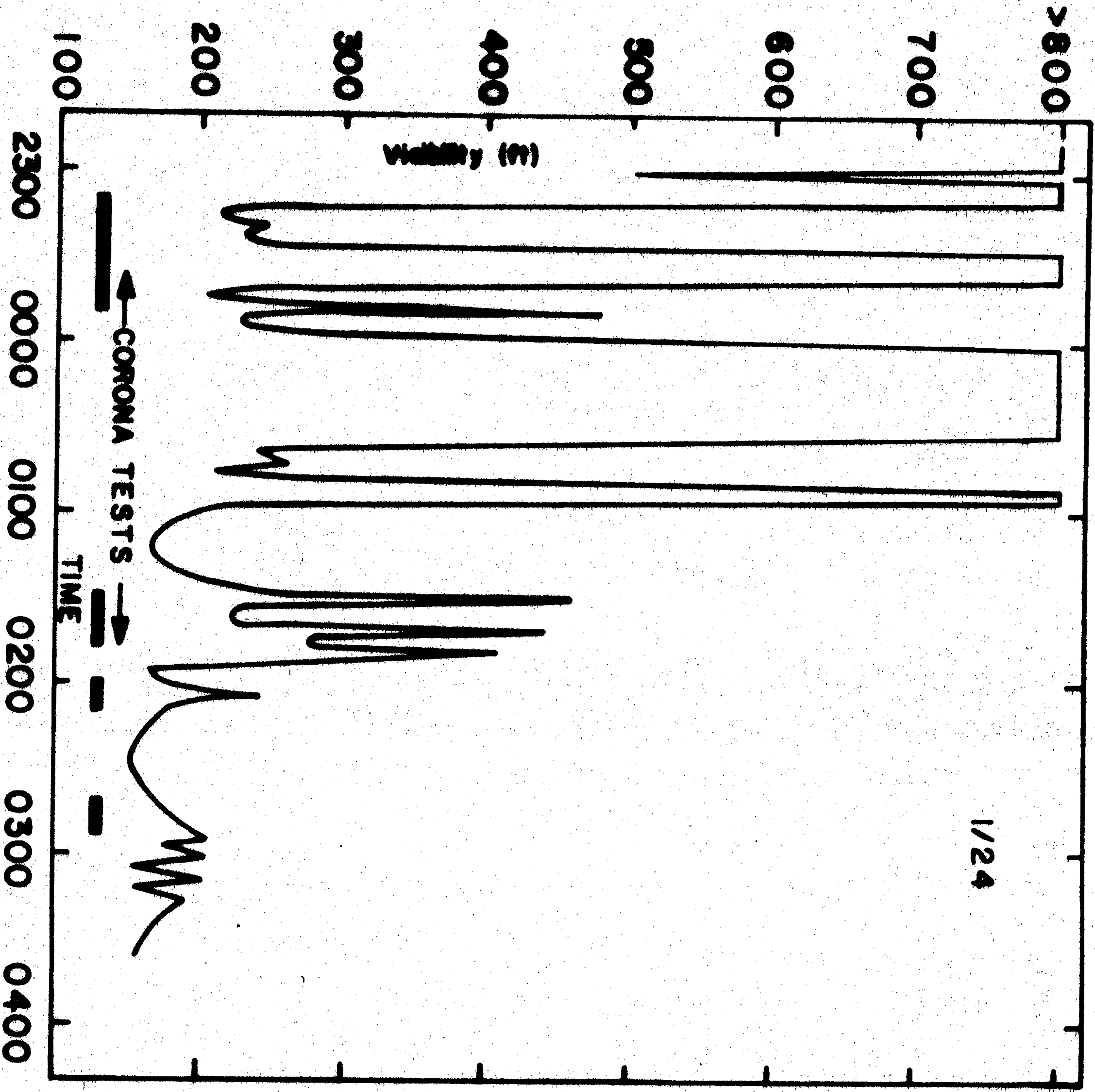



FIGURE 10 VISIBILITY VS TIME

immediate neighborhood of the experimental area as has been previously described.

It is interesting to compare these data for a valley fog with similar data taken in the Chemung River Valley near Elmira, New York.[7] Data were taken for eleven fogs which occurred near sunrise. At that location the visibility would drop to a minimum of 600 ft., a minimum of visibility being accompanied by a droplet distribution with a peak near 8μ. They measured droplet distributions by impacting the droplets on gelatin slides, so that droplets of diameters less than 2μ were not detected. Even though their technique does not detect droplets in the range where we measure a spectral peak the results show the occurrence of the largest number of droplets in the 4-10μ range. The Elmira results demonstrate a real difference in the fog characteristics for the two areas. No such peak occurs for the San Joaquin Valley fogs, they are characterized by a large number (∿200/cc) of very small droplets. This fact is important when one considers attempts at electrical dissipation.

## VI. RESULTS OF CORONA DISCHARGE TESTS

A. Electrometer Tests: As was discussed above, electrometer measurements of the earth's electric field were performed during the fog of the first night and during the afternoon before the second nights fog. On the first night, the first electrometer test was made with the corona discharge equipment at position one, shown in Figure 1. This location is approximately 250 ft from the electrometers. After the corona discharge was turned on the measured electric field slowly varied reaching an equilibrium value after about 3 min. After the voltage was turned off the earth's electric field recovered to the original value in approximately the same time period. The corona discharge mechanism was then moved to position four on Figure 1 which is approximately 125 ft from the electrometers. When the high voltage was turned on there was no response on the electrometers initially, at which time we noted that the wind was not from a favorable direction but in a direction such that the charge would be carried somewhat to the West of the electrometer area. After about 3 min. of operation the wind shifted to a more favorable direction, at which time the electrometer began to indicate a change in the earth's electric field. The magnitude of the change of the field was the same as when the corona discharge mechanism was at position one. Thus, decreasing the distance from the corona discharge to the electrometers by a factor of 2 had no observable effect on the magnitude of the change in the earth's electric field. It was readily apparent from these results that the charge injected into the atmosphere by the corona discharge head was being picked up by wind born particles and carried a considerable distance downwind from the discharge apparatus with little decay in the magnitude of the charge.

For all subsequent electrometer tests performed during the fog of the first night the corona had no observable effect on the earth's electric field. This could be interpreted as poor targeting, however, in many instances it was felt that the electrometer test station was immediately downwind of the corona discharge. A second possibility for the lack of an effect is that the ability of the discharge apparatus to inject charge into the atmosphere was impaired by the fog. Operation in the fog can result in an large increase in the conductivity of the corona discharge tower due to collection of impure fog water. If this were the case it would mean that very little charge was being injected into the atmosphere by the corona discharge mechanism, most of the charge flowing down the tower. (The first two tests were performed very early in the occurrence of the first evenings fog and the tower was fairly dry.)

The next afternoon's electrometer tests, which were performed in the absence of fog, showed favorable results. Fig. 4 shows the locations at which corona discharge tests were performed in the neighborhood of the electric field test area. At each location we observed a change in the electric field, the change being approximately the same as observed on the first two tests of the previous evening. That is, the observed field change was independent of the location of the discharge apparatus. This is difficult to explain since, during these tests, there was a moderate wind (approximately 5 knots) so that not all test locations should have had good targeting of emitted charge over the electrometer area. Based on the previous evenings results one expects a wide variation in the change of the field as a function of corona discharge location. A possible explanation is that the measured field change was due to the field created by the discharge head and not due to injected charge in the measurement area. It appears that the amount of charge we were injecting into the atmospheric is much less than we expected, which would be due to the injected charge remaining in the region of the discharge electrode and hindering further discharge by the resultant screening field.

One further experiment was performed which tends to corroborate that little charge was actually being injected into the atmospheric during the daytime test. One of the two electrometers used in the field measurements was also used to measure atmospheric current. For this purpose we used a large collector electrode that was approximately 3 ft square to pick up any current which would be traveling from the discharge head to the ground in the area of the electrometers. No current was observed for the corona discharge apparatus at any of the locations shown in Fig. 2. When similar tests were performed by NPS on Del Monte Beach near the Postgraduate School, current was easily detected a considerable distance from the discharge head. The main difference in these two experiments was that the one performed at Del Monte Beach was near the ocean, during conditions where there was a fairly strong onshore breeze, which would be expected to carry large number of sea salt spray particles past the corona discharge head. Evidently the strong sea breeze and the large numbers of sea salt particles which were present to carry charge away from the discharge head resulted in enhanced current being emitted into the atmosphere. This was not the case at the Visalia Airport where the wind speeds were quite low and perhaps the aerosol particle count was much smaller, resulting in much less favorable conditions for emission of charge.

B. Chronology of Clearing Tests:

In table 1 we show the times, locations, and other specific information about the corona discharge clearing tests. This brief chronology includes more general information, mainly the purpose for operating at the various times and locations. This gives perspective to the sequence of events in the operation and will have some bearing on the final conclusions.

The tests began shortly before midnight of January 22. At about 2330 fog began to form in the immediate area of the test site and we began the first clearing test at 2353. The corona discharge voltage was 90kV, which was also used for all subsequent tests. During this first test, which lasted for approximately 8 min., the visibility decreased from 1800 ft to 300 ft, and remained at about that value until the tests were concluded on the following morning.

The first test was conducted at approximately 250 ft from the visiometer and Royco counter, and the wind was initially from a favorable direction. The wind began to shift and it was apparent that we would have to move the discharge to obtain favorable targeting. At 0050 on the 23rd we moved along the road next to the irrigation ditch but felt that we were too far from the experimental area when favorable targeting was achieved. We moved to the other side of the ditch, much closer to the experimental area, even though there is no good driving surface in that area. At 0218, 0257, 0327, and 0445 we performed discharge tests approximately 125 ft from the counter and visiometer, with favorable wind targeting.

From approximately 0500 to 0630 we moved the discharge to the vicinity of the electrometers to attempt to see the effect of the discharge on the earths electric field. Several tests were made in that area with no attempt at good targeting.

The clearing tests performed on the second night were made much closer to the visiometer and particle counter than on the previous night. This was due to preliminary evaluation of the first nights results indicating no clearing was accomplished. Fog began to move into our area about 2300, the visibility lowering to 200 ft in 20 min.

The tests were begun at 2309 on the 23rd. The first test was in the vicinity of the electrometers and at 2318 we moved the discharge to a position near the NWC instrument vans. This was done to attempt to see clearing by eye in a large light placed on top of one of the vans. Since we were unable to observe clearing by eye or instruments we felt that the injected charge might be passing too high over the area, and lowered the discharge electrode to a height of 20 ft.

At 2330 the fog cleared for a short period of time due to natural causes and the visibility fluctuated widely until about 0130 on the 24th. At 0129 the corona discharge was turned on for 19 min (the tower still at the reduced height). During this and the subsequent two tests the corona discharge apparatus was moved about in the immediate area of the instruments, and at one time was placed immediately adjacent to the laser visiometer beam to check the possibility that the injected charge was being transported very quickly to ground by the electric field between the discharge electrode and ground.

All tests were concluded at about 0300 on the 24th.

C. Visibility and Droplet Spectra Results: The figures which show the visibility and droplet spectra as functions of time also show the times for which corona discharge tests were made. The corona discharge apparatus was turned on during the time indicated by the black bars at the bottom of the graphs. In Table 1 we show the wind direction and the direction from the discharge electrode to the visibility and droplet spectrum test area. When the wind direction and the direction of the location of the discharge apparatus correspond one has a favorable targeting situation. From the table we see that approximately 50% of the discharge situations resulted in favorable targeting.

As can be seen from the figures, there is no observable correlation between the times during which the discharge mechanism was activated and the changes in the droplet spectrum or visibility. Thus, it was not possible for this experiment to demonstrate modification of in-situ fog by means of corona discharge. This is not necessarily a negative result but the lack of positive results merit some concern since it does indicate that it may not be feasible to clear warm fog by means of corona discharge injection of electrical charge.

Possible reasons for the lack of positive results are as follows:

(1) Insufficient charge injected into the atmosphere,

(2) Improper targeting,

(3) Natural fluctuations of the parameters observed prevented observation of a small amount of clearing accomplished with a single electrode.

(4) There is no effect to be observed.

There are indications that the current being injected into the atmosphere is quite low during fog situations. One indication was discussed above where the observed change in the earth's electric field with corona discharge disappeared after the fog had been present for approximately one hour. Also, the measured high voltage supply current when corona discharge was being used during the fog was approximately 300 microamps while the discharge current was about a factor of 10 lower during the clear air electrometer tests. The large current during the fog indicates that a large amount of charge flows down the wet tower with, perhaps, little current actually being injected into the atmosphere.

Poor targeting would certainly cause a lack of observable effects, however, as indicated above it was felt that the targeting was quite good for a number of the experimental situations. In these experiments good targeting merely refers to the fact that the wind direction is from an appropriate direction so that the test area is immediately downwind from the corona discharge. We do not know that the electric charge being injected into the atmosphere is passing through the experimental area, it could be passing too high, or flowing to ground before reaching the area. In order to improve the targeting we made several corona discharge tests in locations immediately adjacent to the laser visiometer and the Royco particle counter. One of these tests was even made with the discharge tower parked immediately adjacent to the visiometer, again with a lack of positive results.

As can be seen from the figures, the fluctuations in the parameters that we are measuring are quite large. It may well be that the electrical effects we are trying to measure are too small to be seen in the presence of the large natural atmospheric fluctuations. There is nothing that can be done to control this problem when measurements are being made in the field, except to attempt to produce larger effects.

There is the possibility that injection of electrical charge into the atmosphere by a corona discharge apparatus will have no effect. This is unlikely in view of laboratory experiments which have been made at NPS. These experiments showed that corona discharge could be used to dissipate warm fog in both a small laboratory fog chamber and in a room sized environmental chamber which was used to simulate field conditions. Unfortunately, these experiments were not of the type to allow us to determine how to scale the apparatus used in the small experiments to the apparatus needed to effect dissipation in the open atmosphere.

## VII. RECOMMENDATIONS

At this point in the series of experiments we have undertaken it is meaningful to ask whether or not continuing the investigations of dissipation of warm fog by means of electrical charge injection by corona discharge is worthwhile. If one accepts the fact that warm fog can be dissipated by attaching an electrical charge to the fog droplets, then, corona discharge offers some very attractive possibilities. The most obvious is that, when using corona discharge, it is not necessary to inject any other material into the atmosphere other than the electrical charge. This offers a great saving in the material and/or equipment that must be used to accomplish this type of clearing. However, the results of the experiments being reported here indicate that there is a great deal of fairly basic research that needs to be done before discharge can be a viable mechanism.

Extensions of the current research must be planned in order to answer two questions. The first is whether it is possible at all to use corona discharge to dissipate warm fog in the atmosphere (not only in the laboratory). The second question is whether, if fog can be dissipated by this means, is it financially feasible to do so on a large scale? The answers to both of these questions depend on some rather basic parameters describing the behavior of electrical charge in the fog. These parameters are the life time of the electrical charge in the atmosphere, the area over which injected electrical charge spreads, the increased coalescense probability of fog droplets which are electrically charged, and the probability that injected charge will attach itself to water droplets rather than some other atmospheric particle.

In order to obtain this type of data it will not be possible to perform discharge experiments in a small laboratory fog chamber. This is due to the fact that many of the effects which one wishes to measure probably occur over a reasonably long period of time whereas the life time of fog is a small chamber is fairly short. Also, when an electric discharge is present in a small fog chamber droplets which have attached charge are rapidly blown away from the corona discharge electrode by the created electric field. These droplets stream to the walls of the chamber and are lost very quickly. Therefore, if laboratory experiments to gather the needed data are to be performed, a very large fog chamber will be necessary. We feel that carefully controlled experiments in a fog chamber at least 20 ft on a side would be necessary to gather the data. The experiments must be fairly carefully designed so as to separate the various effects that one is attempting to observe. It would certainly be necessary at a minimum to gather data on the droplet size spectrum in the chamber, the electric currents at various positions in the chamber, the lifetime of the injected charge, and visibility at various distance away from the discharge electrode.

Of course, it would be possible to perform another set of field experiments. If one were to do so we believe a rather elaborate array of discharge electrodes would be necessary in order to obtain any meaningful data. That is, one must have a large enough array of discharge electrodes so that targeting can be eliminated as a problem. The use of point discharge electrodes would probably be ill advised, rather one should attempt to use long wires located parallel to the ground. One must also be prepared to make measurements at fairly large distances from the discharge array, especially if the effects to be measured take fairly long periods of time to develop. An installation of this type would be quite costly and also quite expensive to operate. It would be necessary to make measurements over a fairly long period of time in view of the large natural fluctuations of the atmospheric parameters. That is, enough data must be gathered in order to statistically ensure that any observable change in the measured parameters is due to the electrical discharge rather than atmospheric fluctuations.

Our recommendation is that the laboratory experiments is a room size chamber be undertaken before any further corona discharge tests in the field are made. It may well be that data of the type that would be obtained in the laboratory experiment would be useful not only in predicting the performance of a corona discharge mechanism but also in predicting the performance of other schemes which utilize electrical charge to dissipate warm fog.

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