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PROJECT FOG DROPS

INVESTIGATION OF WARM FOG PROPERTIES AND FOG MODIFICATION CONCEPTS

QUARTERLY PROGRESS REPORT

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I. INTRODUCTION

The Office of Aeronautical Research of the National Aeronautics and Space Administration has authorized this Laboratory, under Contract No. NASr-156, to investigate warm fog properties and possible fog modification concepts. The program to date has emphasized analytical and experimental work on:

1. Models of the micro- and macroscopic properties of warm fogs.

2. The characteristics of aerosol droplets and means of favorably altering these properties, such as by enhancing the growth or evaporation rate of otherwise stable aerosol droplets.

3. The design and construction of apparatus for measuring fog characteristics, for simulating certain fog conditions and for measuring cloud and fog nucleus concentrations.

4. Field observations to obtain more information about the properties of natural fog.

5. Formulation and evaluation of fog modification concepts based on the above findings, as well as a review of other possible techniques.

6. Assessment of the supercooled fog problem in the United States and specification of the geographic areas where an operational seeding program might be practical.

This report briefly describes accomplishments of the third quarter of the fourth contract year. Plans for the next quarter are outlined.

II. TECHNICAL DISCUSSION

A. Summary of Visibility Improvements Achieved in Laboratory Fog Seeding Experiments

During the past quarter additional fog seeding experiments were conducted in the 600 m^3 cloud chamber at Ashford, N. Y. The objectives of these experiments were to 1) determined the maximum improvement in visibility that could be achieved by seeding with NaCl nuclei of carefully controlled size and 2) determine the minimum amount of material required to achieve the desired visibility improvement. Results of these experiments have demonstrated that visibility in warm fog in the laboratory can be improved by a factor of at least three and as much as ten by seeding with properly sized salt particles. Significant improvement in visibility was achieved with as little as 1.7 milligram of salt per $meter^3$ of foggy air.

Three types of seeding experiments were conducted:

1. Preseeding the atmosphere with NaCl nuclei to inhibit the formation of dense natural fog,

2. Seeding an atmosphere in which fog had already formed but was dissipating,

3. Seeding an atmosphere in which a persistent fog had formed (i.e. a fog showing no improvement in visibility over approximately a 25 minute period).

The primary goal in each of these experiments was to modify the drop size distribution in such a way as to reduce the Mie scattering coefficient without necessarily altering the liquid water content. The procedure for conducting experiments 1. and 2. were discussed in the last quarterly report-No. RM-1788-P-15. Briefly, fog was formed on natural nuclei existing in the rural atmosphere that was drawn into the chamber after the walls had been thoroughly wet. The chamber was evacuated in a controlled manner after first permitting the internal temperature and humidity to approach equilibrium with the moist walls. The expansional cooling of the moist air produced the fog. Visibility was determined at two heights from measurements made with transmissometers having a 60 ft path length through the fog. Temperature, humidity, Aitken nucleus counts and droplet replicas were made by an observer inside the chamber.

For preseeding experiments seeding was accomplished shortly before expansional cooling of the air, i.e., before the fog formed. By careful control of our venting procedures we were able to approximate the initial stages of fog formation in the cloud chamber. Cooling rates of approximately $4^{\circ}C/hr$ were used throughout these experiments. (Note: this is still quite high since actual temperature changes in natural radiation fog are usually of the order of $0.1^{\circ}C/hr$ after the fog has formed.)

For fog seeding experiments (types 2 and 3) the procedure was to wet the walls then pressurize the chamber and allow conditions to come to equilibrium. After a sufficient period of time (usually $\sim$ 10 minutes) the moist air was vented to the atmosphere at a fairly rapid rate to produce a near adiabatic expansion. Dense fog suitable for seeding could consistently be formed in this manner.

In Table I the visibility improvement for various seeding experiments are summarized. The persistent fog experiment (type 3 in the aforementioned list of experiments) is discussed separately and in somewhat more detail later in this section.

In the preseeding experiments substantial visibility improvement in seeded fogs occurred for several minutes after the start of expansion. These experiments have demonstrated that dense fog can be prevented from forming in the chamber as long as the artificial nuclei remain in the atmosphere, provided of course, that the cooling rates are not unrealistically high. In our cloud chamber most of the hygroscopic nuclei had settled out of the foggy atmosphere after about 15 minutes, as reflected by data in the Table. Note that 16 minutes after the start of expansion only slight improvement was noted in the seeded fogs.

Table I

VISIBILITY IMPROVEMENT FACTOR* FOR TWO TYPES OF SEEDING EXPERIMENTS

PRE-FOG SEEDING				FOG SEEDING			
TIME FROM START OF EXPANSION				TIME FROM START OF SEEDING			
SEEDING MASS IN 600 m^3 VOLUME	+8 MIN	+12 MIN	+16 MIN	SEEDING MASS IN 600 m^3 VOLUME	+4 MIN	+8 MIN	+12 MIN
10 gm NaCl	(5.0) 2.0	(2.1) 2.1	(1.2) 1.4	30 gm NaCl	(1.5) 0	(5.7) 1.6	(3.6) 6.7
5 gm	(3.2) 1.7	(3.3) 1.5	(1.6) 1.7	5 gm	(1.8) 5.1	(5.0) 9.1	(1.1) 2.9
2.5 gm	(3.3) 2.1	(3.3) 2.4	(1.6) 1.4	2.5 gm	(1.4) 2.3	(7.6) 9.4	(1.8) 1.6
VISIBILITY IMPROVEMENT FACTOR AT 15 FT LEVEL ( ) AND IMPROVEMENT FACTOR AT 4 FT LEVEL				1.0 gm	(1.2) 1.2	(1.7) 4.0	(4.5) 6.7
				0.5 gm	(-) 0	(0) -1.1	(0) -1.1
				30 gm NaCl (APRIL 67)	(1.6) 0	(10) 4.9	(2.4) 3.9

*IMPROVEMENT FACTOR IS DEFINED AS THE RATIO OF THE VISIBILITY OF THE CONTROL FOG TO THE VISIBILITY OF THE SEEDED FOG AT THE SAME TIME AFTER INITIATION OF THE EXPANSION

In the fog seeding experiments, substantial improvement in visibility was achieved with as little as 1 gm of properly sized salt nuclei (1.7 milligram of NaCl per meter^3 of air). By contrast 0.5 gm of NaCl in 600 meter^3 of air was found to be insufficient to produce any noticeable visibility improvement. Of relevance here is the fact that a substantial shift in drop size distribution was achieved with only modest seeding payloads. We consider post-fog seeding techniques as the most promising for large scale testing for at least three reasons:

1. Significant increases in visibility can be obtained with relatively small amounts of material.

2. Accurate fog prediction is not a requirement since seeding is done after fog forms.

3. The desired clearing objective can more readily be made to coincide with aircraft landings.

It became apparent to us during the course of our experiments that provisions would have to be made to produce fogs of greater persistence since out type 2 fogs were already dissipating, a characteristic not often found during the lifetime of most natural radiation fogs. Such provisions were made. After the initial expansion in the control fog we allowed the chamber to remain at ambient pressure for sufficient time to accomplish the seeding and then resumed expansion by evacuating the chamber at a rate sufficient to maintain constant low visibility in the control fog. Results are shown in Figure 1. The continuous curves show fog visibility as a function of time in the control fog which (except for actual dispersal of salt between time 8 and 11 minutes) was formed and sampled by procedures as nearly identical as possible to those used in the corresponding seeded fog, for which visibility is shown with dashed lines. The upper solid and dashed curves show visibility at the 15 foot level in the chamber while the lower curves show visibility approximately 4 feet from the chamber floor. Eight milligrams of NaCl per meter^3 were injected into the fog top in this experiment. It is noteworthy that even though the secondary expansion caused additional cooling at a rate of four degrees per hour, visibility was improved

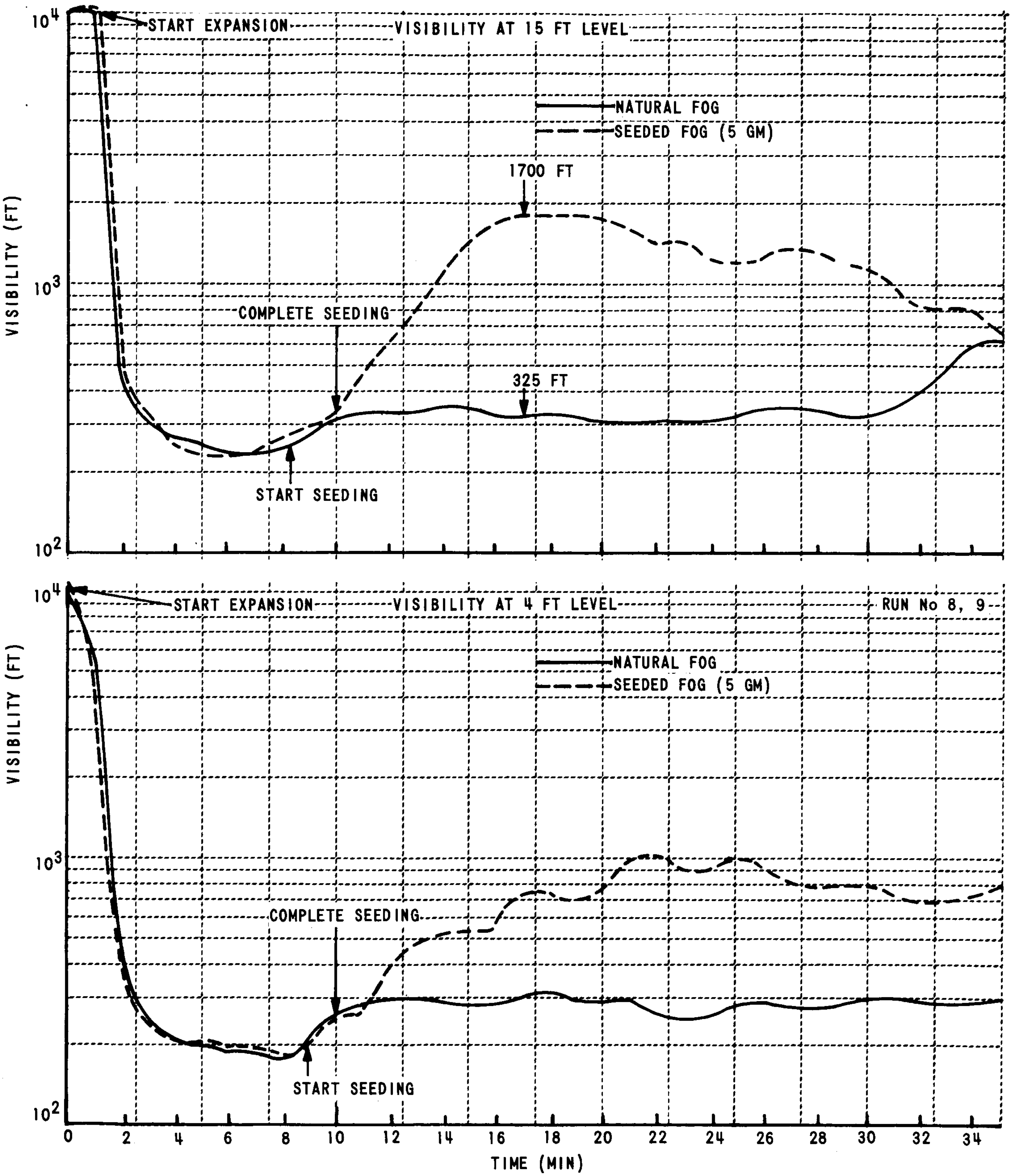


Figure 1 VISIBILITY AS A FUNCTION OF TIME FOR A SEEDED AND UNSEEDED FOG

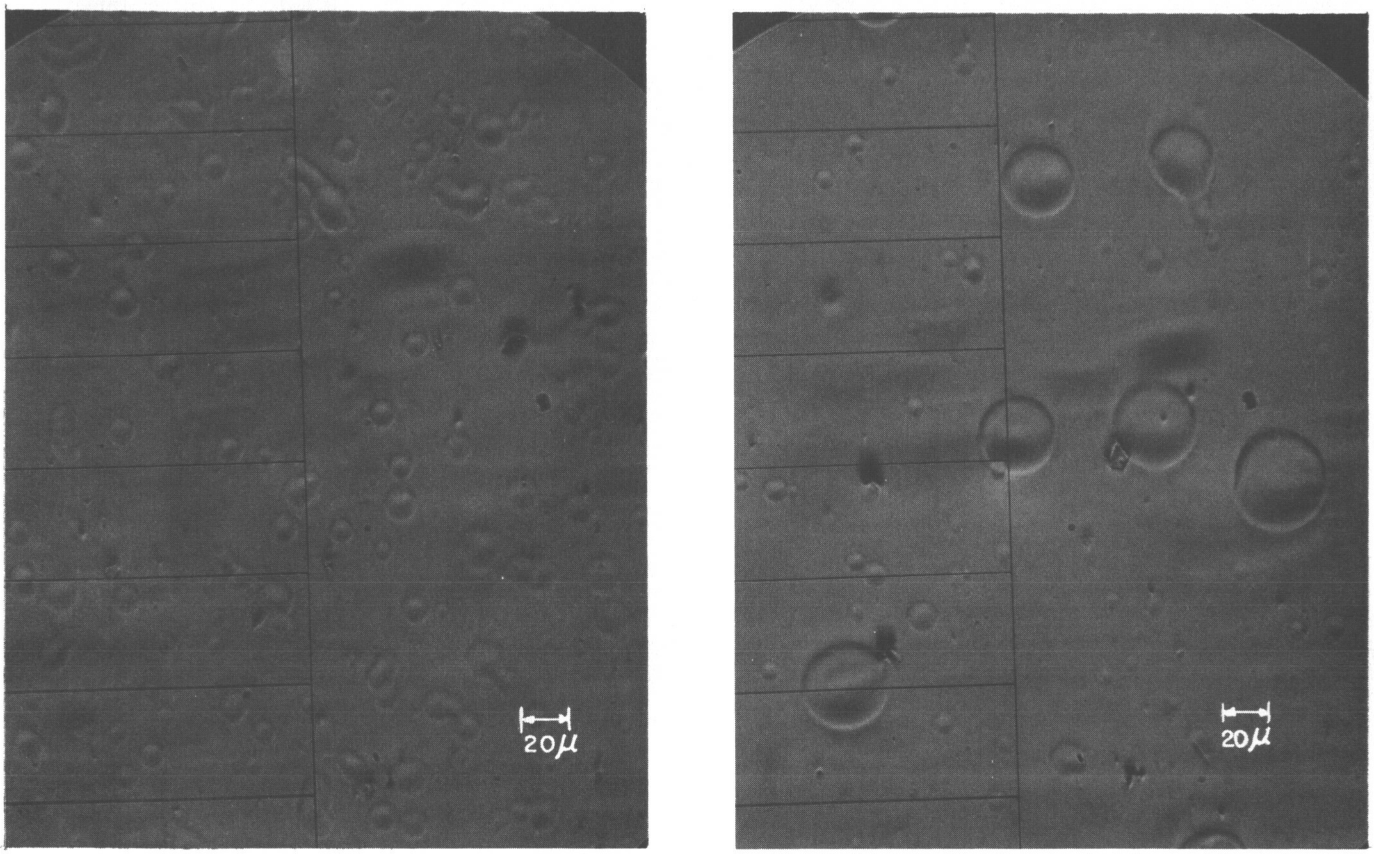
by a factor of more than five at the upper transmissometer level and more than three near the fog base. The marked change in drop size distribution produced by seeding is illustrated by the photomicrographs of droplet replicas in Figure 2 and the drop size data shown in Figure 3. The droplet samples were obtained at time = 20 minutes in both the control fog and the seeded fog.

B. Analysis of the Processes Responsible for Visibility Improvements

The fact that our seeding procedures produced significant improvements in visibility is certain from the transmissometer data. The mechanisms that could have caused that improvement are the change in drop size distribution and the possible decrease in liquid water content caused by precipitation of large drops. This analysis is aimed at determining which of the two mechanisms, of what combination of the two, contributed to the visibility improvement.

The liquid water content could have been altered in our experiments by several mechanisms: In the control experiments some droplets could have fallen to the floor of the chamber and, at least in the post-seeding experiments, some certainty evaporated causing a decrease in LWC. In the seeded experiments water could have condensed on the artificial nuclei faster than natural droplets evaporated to cause an increase in LWC. (This was almost certainly the case in early stages after seeding.) Once the droplets formed and artificial nuclei had grown to very large sizes, significant amounts of water could (and did) fall out of the chamber. Yet at low levels (4 ft), where both the transmissometer and drop size distribution measurements were made, the precipitated water could have been replaced by droplets settling from higher levels to the 4 ft level. This consideration is particularly important when extrapolating our results to the airport situation where a 100 meter depth of fog must be treated.

Measurements of drop size distribution made on droplet samples collected on gelatin coated slides show that we were successful in modifying the drop size distribution of the fog in the desired manner. With the equipment used for droplet collection it was not possible to determine the absolute concentration of droplets, so that only relative or normalized distributions are



(a) (b)

Figure 2 DROPLET IMPRESSIONS TAKEN IN UNSEEDED (a) AND SEEDED (b) FOG 20 MINUTES AFTER THE START IF FOG FORMATION

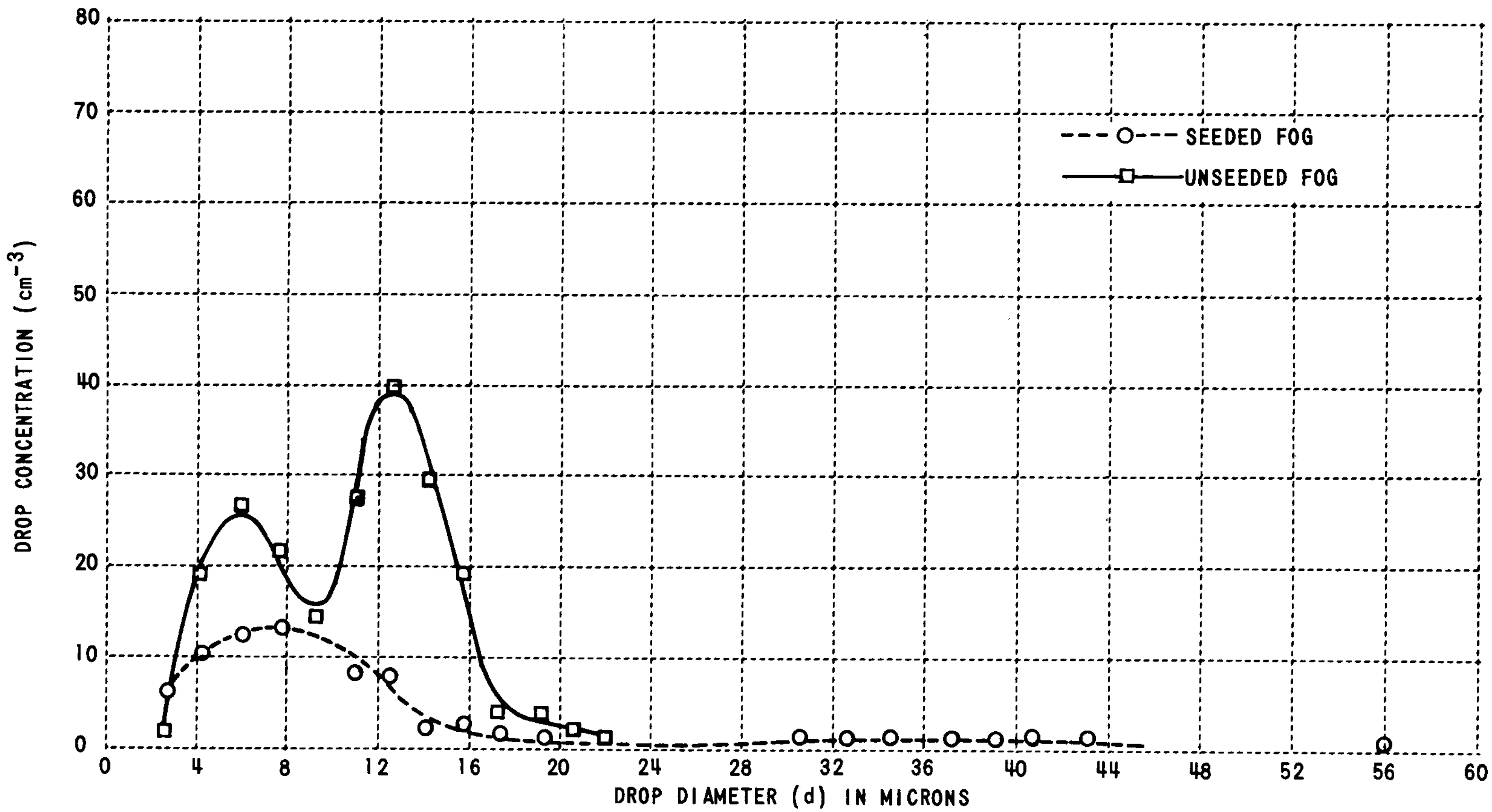


Figure 3 DROP SIZE DISTRIBUTION FOR SEEDED AND UNSEEDED FOG AT +20 MINUTES

known. Liquid water content therefore could not be computed directly from the distributions. By using a combination of transmissometer data and normalized drop size distributions it is possible to determine the relative liquid water content of different fogs. The procedures for performing such an analysis are developed here.

The intensity of light observed with a transmissometer is given by

$$I = I_o \, e^{-\beta x} \tag{1}$$

where I_o is the intensity observed in clear air, β is the extinction coefficient and x is the length of the transmission path in the fog. Visibility is computed from such data according to

$$V = \frac{K}{\beta} \tag{2}$$

where K is a constant

β is related to the drop size distribution, $N(r)$ according to

$$\beta = E \int_0^\infty N i(r) \; r^2 \; dr \tag{3}$$

where the subscript i designates the particular fog being sampled and E is the scattering efficiency factor. E is equal to 2π .

From the drop sample data we are able to compute

$$\frac{\beta_i}{N_i} = \frac{E \int_0^\infty N_i(r) r^2 dr}{\int_0^\infty N_i(r) dr} \tag{4}$$

which is the average scattering cross section (extinction coefficient) per droplet. N_i is the number of droplets per unit volume, which is not yet known. Since β is determined independently from equation (1) using transmissometer data, N_i can be determined:

$$N_i = \beta_{TRANS} \Big/ \left(\frac{\beta_i}{N_i} \right) \tag{5}$$

where the quantity in the denominator is given by equation (4).

The liquid water content of the fog is given by

$$W_i = \frac{4}{3}\pi\rho\int_0^\infty N_i(r)\, r^3 dr \tag{6}$$

where ρ is the density of liquid water. Again, from the drop sample data we can determine only

$$\frac{W_i}{N_i} = \frac{4}{3}\pi\rho\,\frac{\int_0^\infty N_i(r)\, r^3 dr}{\int_0^\infty N_i(r)\, dr} \tag{7}$$

Using the value of N_i determined from equation (5) in equation (7) provides the estimate of liquid water content.

C. Results Obtained From Seeding Existing Fogs*

In Figures 4(a) and 5(a) the observed visibility is shown as a function of time as determined from transmissometer data for representative cases of the post-fog seeding experiments. In the (b) portion of each of these figures we show, in normalized units, how the changes in liquid water content (determined from the above analysis) would have contributed to these variations in visibility if the drop size distribution had not changed. Under these conditions visibility would be inversely proportional to LWC. In the (c) portions of these figures we show, again in normalized units, how changes in drop size distribution would have contributed to visibility variations if liquid water content had been invariant. (The ratio of equation (4) to equation (7) is an estimate of the Mie extinction coefficient per unit volume of water. The quantity plotted is the normalized value of the reciprocal of this ratio.) Since in the actual fog the visibility variations were due to a combination of the two effects shown, the actual variation in visibility is equal to the product of the variations due to liquid water content changes

*Drop size distribution data for preseeding experiments are now being analyzed and results will be included in the next report.

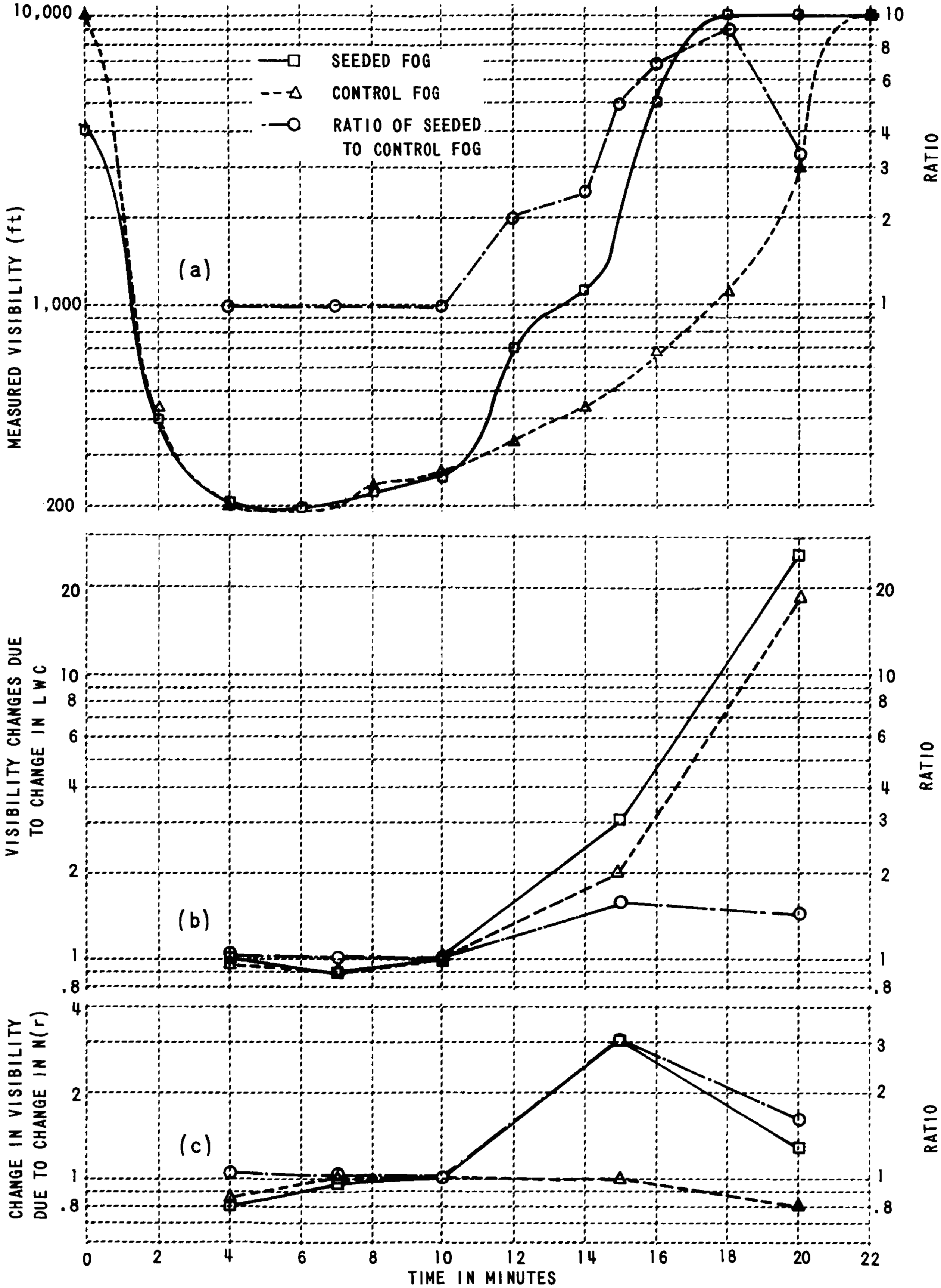


Figure 4 FOG SEEDING RESULTS - DISSIPATING FOG

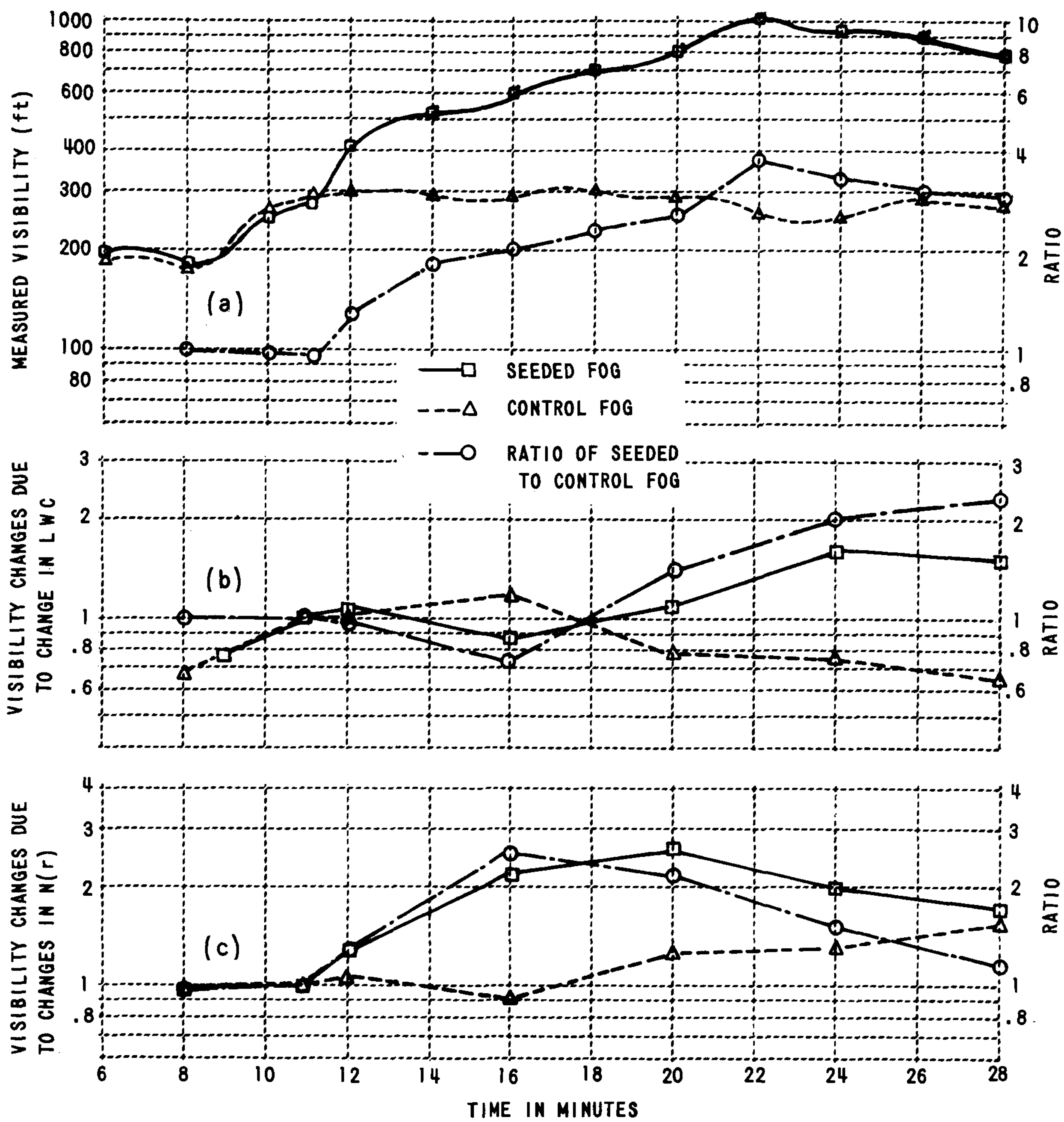


Figure 5 SEEDING RESULTS - PERSISTENT FOG

and drop size distribution changes. For example, in the seeded fog shown in Figure 4 the visibility at t = 10 minutes was 250 feet and at t = 15 minutes was 2500 feet, a factor of ten improvement. From Figure 4b it can be seen that the change in drop size distribution caused an additional improvement by a factor of 3.2. For the control case the entire variation in visibility (a factor of two) over the same interval was due to a decrease in liquid water content. Such an analysis lets us describe the time variations of a given fog.

In order to compare seeded and unseeded fogs it is necessary to consider the ratios of the various quantities in question. These ratios are plotted on the corresponding portions of the two figures. For example the improvement in visibility of the seeded fog over the control fog at t = 15 minutes in Figure 4 is a factor of 5.0. The improvement due to liquid water content differences was a factor of 1.5 and the improvement due to changes in drop size distribution was a factor of 3.3. The data presented therefore are useful for studying variations in individual fogs and for comparing seeded fogs to control fogs.

Before discussing our conclusions relative to the cases studied it is necessary to discuss the accuracy of the measurement and analysis procedures.

The transmissometer itself is accurate to about 1%. When operated with the mirror in the chamber, condensation and splashing of drops falling off of the chamber walls and impacting near the mirror limit overall uncertainty in determination of I and I_o to approximately 10%. This in turn transforms to an uncertainty in β (the scattering coefficient) of approximately 5%. The estimates shown for visibility are therefore considered to be very good.

The accuracy of droplet samples are limited primarily by the relatively small number of droplets counted in the determination of each drop size distribution. Our samples usually consisted of between 200 and 300 droplets. Thus, with many of the drop size distributions in the seeding experiments, only fifteen to thirty of the very large droplets (i.e. larger than found in the corresponding control fog) were counted. A 20 to 25% uncertainty in the concentrations of these large particles can therefore be expected as an average for a large number of experiments. Errors of 50% are not unlikely for individual experiments. Since these particles contribute most, both to the Mie scattering coefficient and liquid water content, our estimates of both of these quantities are expected to contain random errors of at least 25% and probably in some cases as much as 50%. The analyses shown appear to be consistent to this degree but should not be given more precise interpretation.

All data discussed in this section were obtained by methods described in earlier reports and with equipment located within a few inches of the four-foot height in the chamber. Droplet samples were obtained approximately eight feet from the center of the chamber and from the transmissometer beam.

Figure 4 shows the results obtained by seeding a slowly dissipating fog with 4.2 mg of NaCl m^{-3} of air. The expansion was terminated for both the seeded and control fog at $t = 9$ minutes. The slow dissipation of the control fog began almost immediately and accelerated throughout the period analyzed. It is evident from the data shown that this visibility increase was almost entirely due to a decrease in liquid water content, probably caused by evaporation of the droplets as air temperature increased toward that of the chamber walls.

In the seeded fog, the rapid visibility improvement was produced by a combination of liquid water content decreases and drop size distribution changes. Up to $t = 15$ minutes these two factors appear to be of equal importance. By $t = 17$ minutes the visibility had increased to 10^4 feet, the upper limit of sensitivity of the transmissometer. The next drop sample was not obtained for three minutes thereafter. The relative importance of the two processes in the final observable visibility improvement therefore cannot be ascertained. Results of the analysis of the droplet sample obtained at $t = 20$ minutes, assuming 10^4 ft visibility, indicate that the drying effect by far predominated at that time.

The overall effect of seeding, determined by comparing the seeded fog with the control fog, is an improvement by a factor of five in visibility at $t = 15$ minutes, five minutes after the nuclei had been introduced, and an improvement by a factor of ten within seven minutes after completion of seeding. Analysis of the droplet sample obtained at t = 15 minutes indicates that the five fold improvement was due to a factor of 1.6 associated with the LWC decrease and a factor of 3.2 associated with the drop size distribution modification. The relative importance of these two factors during the next two minutes cannot be ascertained because droplet samples were not obtained. Assuming the indicated 10^4 ft visibility for the seeded fog at t = 20 minutes, analysis of the sample obtained at that time indicates that the two factors are approximately of equal importance. Since true visibility was probably greater than 10^4 feet it seems probable that the actual decrease in LWC computed from the drop size distribution was greater than that indicated. Though indicated trends may be significant, the numerical results of the analysis for time after t = 15 minutes should be treated with extreme caution.

The data shown in Figure 5 were obtained in fog produced by an initial expansion from an overpressured chamber into the ambient atmosphere. This initial expansion was terminated at t = 8 minutes. To prevent the natural dissipation that complicates interpretation of the data of Figure 4, a secondary expansion was initiated at t = 11 minutes in order to maintain a constant low visibility in the control fog. The expansion rate necessary to maintain visibility was such as to produce a cooling rate of $4^oC\ hr^{-1}$. This severe cooling rate caused different complications in interpretation of the data that became apparent during analysis of the droplet sample data.

The transmissometer data and the droplet sample data indicate that the seeded and control fogs at the four foot level were essentially identical up to t = 11 minutes. (At the 15 foot level initial effects of the seeding were observed at t = 10 minutes, the time seeding was terminated.) Our analysis indicates that at this time the liquid water content of both fogs was approximately 180 mg m^{-3}. The trend of the data indicate that LWC of the control fog increased from 180 to 280 milligrams $meter^{-3}$ from t = 11 minutes to t = 28 minutes. While this increase is 56% and within the accuracy of the measurements the fact that the trend is rather persistent leads us to believe that it is probably real. It was apparently associated with growth of the droplets in such a way that the visibility degradation by a factor of 0.65 that would be expected from the increased LWC was compensated for by a visibility improvement factor of 1.6 calculated from the observed change in drop size distribution. Visibility throughout this period remained essentially constant at 300 ft.

The fluctuations in our estimate of liquid water content of the seeded fog after $t = 11$ minutes are well within the accuracy of the analysis procedures, so that it cannot be said with certainty that significant changes in LWC did occur. From the trends in the data points obtained it appears that there was initially a slight increase in LWC between $t = 11$ minutes and $t = 16$ minutes, followed by a return to the initial value at $t = 20$ minutes and a continued decrease to about 120 milligrams meter^{-3} at $t = 28$ minutes. This sequence is consistent with our concept of what should be happending, i.e. water should condense rapidly on the salt particles for the first few minutes after they are introduced, thereby increasing LWC; as these particles grow they begin to fall out and remove water from the fog. If these trends are indeed correct the increased precipitation rate due to seeding apparently slightly over-compensated for the liquid water made available by the additional expansion (as indicated in the control fog).

During the period from $t = 11$ to 20 minutes when liquid water content almost certainly did not decrease and may have increased slightly, the visibility of the seeded fog increased by a factor of 2.6, a factor entirely attributable to the change in drop size distribution. Visibility continued to increase until achieving a value of 950 feet, a three-fold increase over the initial value. Of this, an improvement factor of 2 was associated with the drop size distribution change and a factor of 1.6 associated with the indicated decrease in LWC. Visibility then degraded slightly from this maximum value to approximately 800 ft at $t = 28$ minutes and remained in this vicinity until the end of the experiment at $t = 35$ minutes. Analysis of the last droplet sample, which was obtained at $t = 28$ minutes, indicates that the net increase in visibility of the fog at that time, a factor of 2.6 over the initial value, was due to a factor of 1.9 associated with drop size distribution modification and a factor of 1.5 associated with the LWC decrease.

The process attributable to seeding that caused the improvement of visibility of the seeded fog relative to the control fog changed in a consistent manner during the experiment. During the first eight to ten minutes after seeding, the difference in drop size distributions caused virtually the entire visibility improvement. From that time on the difference in liquid water content of the two fogs, due undoubtedly to the precipitation of water condensed on the larger salt nuclei, became increasingly important. By $t = 28$ minutes (18 minutes after seeding was completed) virtually the entire visibility difference between the two fogs was due to the liquid water content difference. This, we believe, continued to be the predominant effect through $t = 35$ minutes when the experiment was terminated, though no droplet samples were acquired during the last seven minutes.

D. Tentative Conclusions

It is noteworthy that the physical characteristics (drop size distribution, liquid water content and visibility) of both the control fogs and the seeded fogs at the time of seeding were characteristic of dense natural radiation fogs. These characteristics changed rapidly, however, even in the control fogs. In one type of experiment rapid natural drying was causing the fog to dissipate; in the other, abnormally high cooling rates, intentionally produced to maintain constant visibility, were causing a rapid increase in liquid water content. We cannot therefore claim simulation of natural fog throughout the experiments. Except for the early stages and the dissipating stages of natural fog, liquid water content changes occur relatively slowly. Because the two conditions produced in the laboratory straddle the desired natural condition some inferences relative to the effects of seeding natural fog may be drawn. In fact since the visibility improvement in the first five minutes due to drop size distribution modification was a factor of 3 for the dissipating fog and 2.6 for the fog of increasing LWC, we believe that the initial rate of visibility improvement to be expected in natural fog is reasonably well tied down to the vicinity of these values.

The visibility improvements observed at later times in our experiment are strongly influenced by the increased precipitation rates. While increased precipitation rates will occur in a natural fog, the precipitation cannot become important as soon after seeding as was observed in the shallow laboratory fogs which were sampled only about ten meters below the fog top. Water that does precipitate out of each ten meter thick layer of a natural fog in the first five minutes will precipitate into the next lower layer of the fog, so that visibility improvements due to increased precipitation rate cannot be expected to occur so rapidly.

We should not expect however that the visibility improvement will be limited to the factor of about three observed in the first five minutes of our experiments. It is obvious from our observed drop size distributions that all natural droplets had not evaporated during that time. In fact, calculations* made from the drop size distribution obtained at $t = 16$ minutes show that about 60% of the extinction coefficient at that time was due to droplets having radii smaller than the largest droplet present at the same time in the control fog.

Five minutes after seeding the equilibrium vapor pressure over solution droplets formed on our salt nuclei is equivalent to approximately 99.3% relative humidity, so that these droplets continue to grow and cause evaporation of natural droplets. If the water of the existing natural droplets is redistributed on the solution droplets, each solution droplet grows in volume by a factor of 1.5 and in radius by a factor of 1.15. Correspondingly the extinction coefficient for these droplets increases by $1.15^2 = 1.3$. Since these larger droplets originally accounted for only 40% of the extinction coefficient, the new value is 52% of the measured extinction coefficient at $t = 16$ minutes.

The maximum improvement in visibility that might be expected solely from the drop size distribution modification in deep fogs appears to be of the order of a factor of five to six. The time required for the solution droplets

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*These calculations have only recently been considered and have not been completed for all data. They will be shown in a later report.

formed on our salt nuclei to increase in volume by a factor of 1.5 over the volume achieved in the first five minutes is approximately five additional minutes. At about that time, i.e. 10 minutes after seeding, droplets formed at the 100 meter level on the largest nuclei should begin reaching the ground. Thus visibility improvement should be continuous.

E. Recommendations for Continued Research

Results of our laboratory experiments indicate that a zone two kilometers long, 500 meters wide and 100 meters high might be opened for landings with 200 to 400 kilograms of NaCl nuclei having the proper size distribution. In view of these results we are recommending that field experiments be conducted to evaluate the proposed seeding concept. We have considered the sizeable task of effectively distributing large quantities of seeding material in the given volume of fog and have made a preliminary design for a seeding unit for large scale experiments. The design includes a Trost T-40 jet mill for particle classification and an aircraft propeller, driven by an auto engine, for particle dispersal to altitudes approaching 100 meters. The jet mill and propeller would be mounted on a flat bed truck to facilitate mobile seeding operations.

We are recommending that the main field site be at the Buffalo Airport which experiences about 23 dense fogs per year. We feel that the proximity of the airport to the Laboratory, U. S. Weather Bureau Station and to FAA-operated airport equipment make this site for field experiments desirable. Formal requests to local ATC and FAA representatives for permission to conduct the experiments have been granted.

It is anticipated that the initial full-scale seeding trials will be conducted (under contract extension) during the late winter and early spring months when fog frequency is greatest in the Buffalo area. If sufficient seeding opportunities are not available by late spring we will move to a secondary experimental site in the valley regions south of Buffalo. We hope to seed five or six fogs during the coming year.

In addition to the experiments outlined above we recommend approximately two weeks of laboratory tests be conducted at the CAL Ordnance Laboratory in Ashford, N. Y. We are planning these experiments primarily for clarifying unresolved questions that will undoubtedly remain after completion of analysis of existing data and for testing new procedures, materials and techniques as the occasion may arise. New concepts can also be tested at this facility if they show sufficient promise.

III. OUTLINE OF FUTURE PLANS

1. Complete data analysis of laboratory fog seeding experiments at Ashford, N. Y.

2. Continue measurements of cloud and fog nuclei and make observations using the recently completed haze chamber.

3. Prepare and submit the final report of this year's warm fog research.