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CONTACT-FREEZING NUCLEATION
MEASURED BY THE DFC INSTRUMENT

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Measurement Concept

The basic concept of the contact-nucleus counting instrument (or drop freezing counter, DFC) is to force aerosol particles into contact with supercooled water drops and to observe the individual freezing events which result. The supercooled drops, which are to serve as detectors, are supported on a cold stage whose temperature is controlled. Aerosol particles are deposited onto the drops by electrostatic precipitation.

With the contact being enforced, rather than depending on diffusion or aerodynamic capture, the sizes of the detector drops are only of indirect consequence, and there is no need to account for the complex processes which normally influence the coagulation of aerosol particles with cloud droplets. Because of the need to detect the freezing of each drop when it occurs, relatively large (about 2 mm diameter) drops are used. High purity water is used to form the drops, since nucleation by particles suspended in the drops should not occur until temperatures much colder than the intended test temperature.

Instrument Design

The design of the instrument is schematically represented in Fig. 1. A cold plate supports the drops and forms the bottom plate of a precipitator chamber. The precipitator is a modified form of a commercial unit (Thermo-Systems, Inc., Model 3100). Aerosols are drawn into the chamber and are given a small charge by diffusive attachment of small positive ions. Subsequently, as the carrier air moves along the chamber (with a velocity of 19 cm sec^{-1})

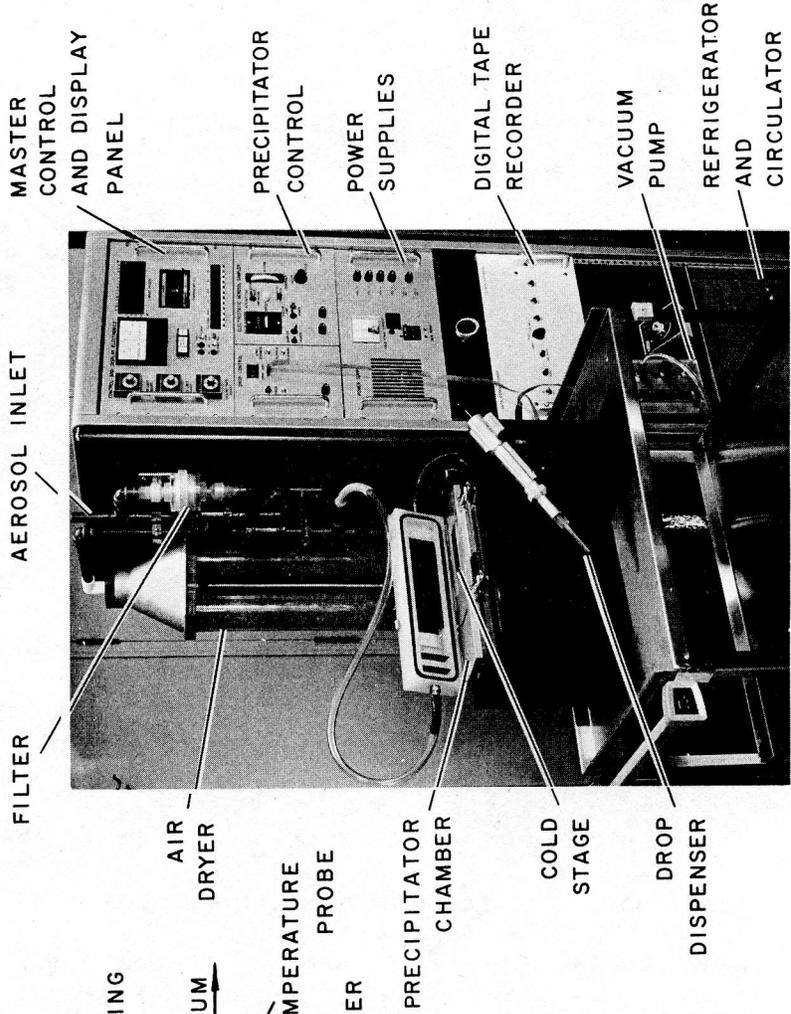
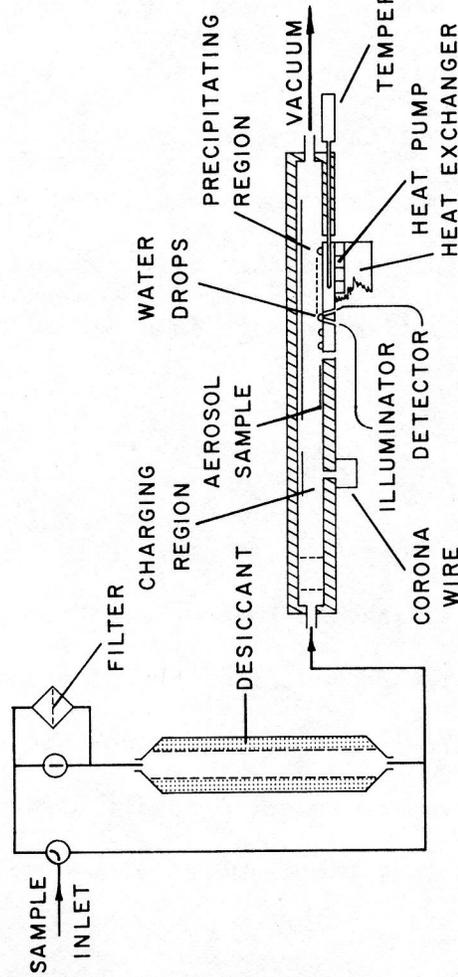


Figure 1. (above) Schematic of DFC components.
 DFC (DEPOSITION/FREEZING /CONTACT)
 ICE NUCLEUS COUNTING SYSTEM

Figure 2. (right) Photograph of DFC instrument.
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aerosol particles are forced into contact with the water drops by pulse-wise application of a positive voltage (4,200 V) to the top electrode plate. The magnitude of the particle charges varies with particle size: the mean charge on 0.1 μm particles is about 8 elementary charges, and on 1 μm particles it is 40 elementary charges. The fraction of particles which get charged decreases with decreasing particle size and becomes quite small below 0.01 μm particle diameter. Consequently, aerosol collection takes place with incomplete efficiency. The collection efficiency has been evaluated empirically, together with other calibration factors, and will be described in a later section. Details of the operation of the charger and precipitator were given by Liu, Whitby and Yu (1967).

The electric field does not in itself cause freezing of the target drops, as is evident from the experiments of Doolittle and Vali (1975). Ions attached to the aerosol particles can, in principle, modify the nucleating abilities of the particles. In view of the smallness of the charges, and the fact that only 0.01% or less of the surface area of the particles is covered by ions, it is not considered likely that nucleating ability is in fact altered. There is no indication in the literature that influences due to charges should be expected under the conditions encountered in the instrument. Gabarashvili and Glikli (1967) reported enhanced nucleation on charged naphthalene and cholesterol particles but they were dealing with $10^6 \mu\text{m}^{-2}$ elementary charges on the particle surfaces whereas the corresponding number in the DFC instrument is about $10^2 \mu\text{m}^{-2}$. It can also be argued that the presence of charges on nuclei within the instrument is not unrealistic, as atmospheric aerosol particles also carry charges, although usually those charges are smaller.

The cold stage holds 75 drops. Illuminator and detector optical fibers are embedded in the stage underneath each of the drops. Illumination is provided for all drops by a single incandescent source. A separate photoresistor is

used as detector for each drop. The fibers are so arranged underneath the drops that, if the drops are properly positioned with respect to the fibers, no light is reflected to the detectors as long as the drops remain liquid. Upon freezing, the opacity of the drops increases and light is reflected to the detectors. This increase in light triggers the counting, display and recording circuits. There is about a 5-20 sec response time (depending on temperature) associated with this technique of detection due to the time it takes for a sufficient amount of ice to freeze in the drops following nucleation.

To prevent the drops from freezing due to nucleation by the supporting surface, the cold stage is covered with a mylar film of 0.01 mm thickness, the film being further coated with a silicone varnish (General Electric DF-88, or equivalent).

The dew point of the sample air must be below the temperature at which the measurements are made to avoid the formation of frost between the drops. A diffusion dryer is used for samples carried in moist air. The dryer is not used for artificial aerosols prepared with dry air, or for natural air samples when the dew point temperature is below the test temperature. With the dryer the dew point is lowered to about -25C. To minimize drop evaporation, the optimum operating condition would be to have the dew point of the carrier air only slightly below the operating temperature, but the humidity control necessary for this has not yet been added to the instrument. A photograph of the complete instrument is shown in Figure 2.

Measurement Routine

The first portion of each measurement is a control run: the target drops are cooled to the desired operating temperature and held at that temperature without the admission of aerosol for 2 to 5 min. The air drawn into the chamber is passed through an absolute filter. A few drops might freeze during this

period in tests carried out at colder operating temperatures (-16 to -20C) but this merely reduces the sample size for the contact measurements and does not cause an error in the results. It has been found that drops which do not freeze during this initial period will remain supercooled with 95% certainty unless nuclei are admitted into the chamber for periods of up to one hour.

The main part of the measurement, following the control period, consists of continuously maintaining the drops at the preselected temperature and admitting the sample air into the chamber. Precipitating pulses are applied at the rate of 15 min^{-1} and the number of drop-freezing events is monitored, together with the number of precipitating pulses that has been applied. The latter number determines the sample volume from which aerosol has been impacted onto the drops, each pulse corresponding to a sampled volume of about 5 cm^3 . Nucleus concentrations are derived as the ratio of the number of drops frozen to the sampled volume. A correction factor is applied to the number of drops frozen to account for the collection of potential nuclei by drops which are already frozen. This correction factor is readily calculated on the basis of Poisson statistics.

The main part of a measurement run is terminated when about 80% of the drops are frozen, or after about 1 hour. The first limit arises from a reduction in effective sampling rate (few unfrozen drops remaining); the second limit is due to drop evaporation becoming appreciable after long periods of time.

In the third part of each experiment, filtered air is admitted to the chamber and the sample drops are melted by warming the cold stage to +10C for about 2 min. Then, the temperature is lowered again to the test temperature for 5 min and the number of drops which refreeze during this period is noted. Actually, not only the total number of drops which freeze is recorded but also a position identifier for each drop. By comparing which drops were frozen in

the second part of the experiment and which ones refreeze in the third cooling cycle, one can establish the fraction of drops which refreeze and also the number of new freezing events, if any, that occur.

Sampling Efficiency

The main determinant of the effective aerosol sampling rate is the rate of collection of aerosol particles by the water drops in the precipitator chamber. Collection efficiency for a flat collecting electrode was determined by Liu, Whitby and Yu (1967) for particles in the size range 0.03 to 3 μm diameter. They found the collection efficiency to be a weak function of particle size, rising from 60% to 80% over the indicated range. This collection efficiency is defined as the ratio of the number of particles collected to the theoretically predicted number, the latter being determined by the product of the number of particles contained in the column of air over the collecting surface between the two electrodes times the number of precipitating pulses applied.

With hemispherical water drops as the collectors, the electric field inside the precipitator chamber is no longer parallel but converges to the collector drops. This can lead to collection efficiencies greater than unity if the above definition is used. Since the water drops occupy only $1/4.8$ of the total area of the collecting plate, the collection efficiency could reach a limiting value of 4.8.

Experimental determinations of the collection efficiencies yielded the results shown in Fig. 3, Curve A. These data were derived from measurements using monodispersed Rhodamine-WT dye particles as test aerosols and by comparing the mass concentration of dye particles entering the chamber with the concentration achieved in the water drops after a known sampling period. The dye concentration entering the chamber was determined by capturing the dye particles

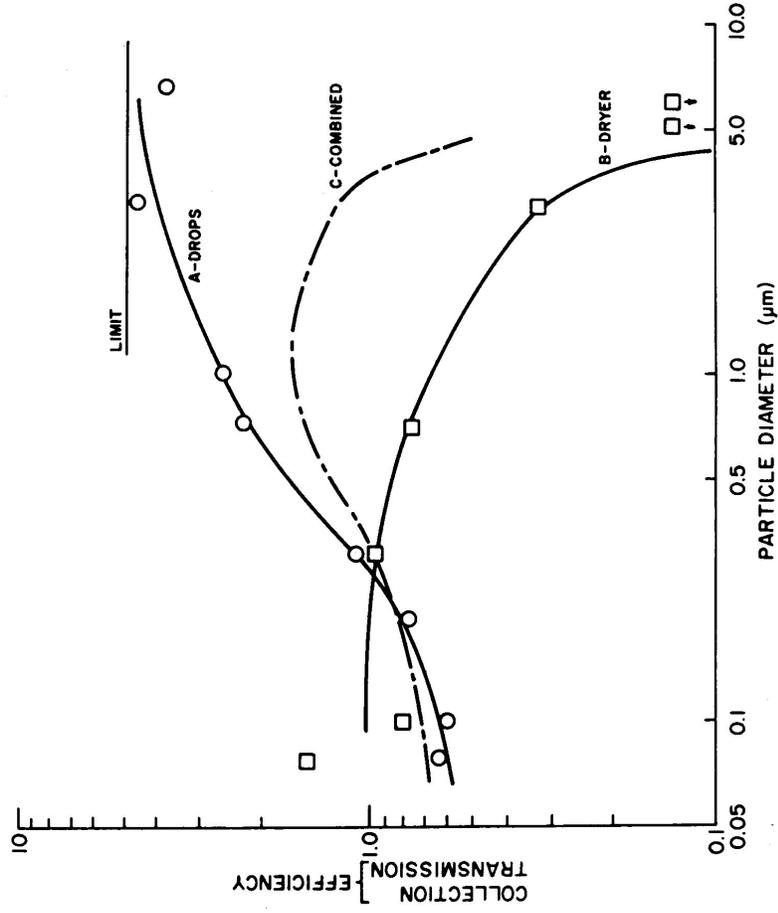


Figure 3. Collection and transmission efficiencies as a function of particle size for the DFC instrument. See text for details.

on filters, dissolving the filters in acetone and making a mass determination by fluorometry. The concentration of dye in the water drops was measured by direct fluorometry on the water drops retrieved from the precipitator chamber. As is indicated by Fig. 3, the collection efficiency approaches the predicted upper limit for large particles and then falls off substantially for particles of $0.1 \mu\text{m}$ diameter. A possible explanation for the more rapid decrease in collection efficiency with decreasing particle size in these measurements than the measurements of Liu, Whitby and Yu, is that the disturbance of the airflow around the water drops influences the collection of small aerosol particles. Another potentially significant area where aerosol losses can occur in the system is the diffusion dryer. The transmission efficiency of the dryer for particles of different sizes was also determined, again using dye aerosols and fluorometry, the resulting data being shown in Fig. 3, Curve B. As could be expected the transmission falls off for particles larger than $1 \mu\text{m}$ and approaches unity for smaller particles. The combined collection efficiency is shown by Curve C in Fig. 3.

The data shown in Fig. 3 suffer from the absence of measurements much below $0.1 \mu\text{m}$. This is due to the difficulties encountered in the generation of dye aerosols below that limit and the loss of sensitivity of the fluorometric technique. A different calibration technique, perhaps involving radioactive aerosols, will be needed to complete the data in that area.

Application of the measured collection efficiencies for correcting the measured concentration of ice nuclei would require that the sizes of the ice nuclei be known. Yet further complications arise with nucleating aerosols consisting of aggregates rather than of single spherical particles. In view of these problems, it seemed best to adopt a collection efficiency of 0.8 for the combination of drier and precipitator chamber and to use this single value for all measurements. This choice is most justified for nuclei smaller than

about 0.2 μm , which is probably the size range of most natural and artificial nuclei. Further work will be required to refine the sampling efficiency for different test aerosols.

Using a sampling efficiency of 0.8 and with 75 collector drops, the sampling rate of the instrument becomes $5.35 \text{ cm}^3 / \text{pulse}$ or $83.5 \text{ cm}^3 \text{ min}^{-1}$. This is the effective sampling rate assumed for all of the results reported here.

Dynamic Range

Fundamentally, the conditions of operation and detection in the DFC instrument have no dependence on temperature, i.e. the measurement of nuclei can be accomplished with nearly equal sensitivity at all temperatures.

One practical limitation arises from the freezing of the target drops due to suspended nuclei; this limits measurements to temperatures warmer than about -22C . Other practical limitations exist with respect to the concentration of nuclei in the carrier gas. Given the sampling rate of $8.35 \times 10^{-2} \text{ L min}^{-1}$ and the maximum experiment duration of 60 min, the minimum detectable concentration of nuclei becomes 0.2 L^{-1} . The upper limit for measurable concentrations is due to detector response times and the flushing times for the connecting tubing and for the chamber. This upper limit is about $3 \times 10^3 \text{ L}^{-1}$, but can be readily extended to about 10 L^{-1} by controlled dilution of the nuclei-bearing gas.

In summary, the temperature range (T) and concentration range (Nc) over which measurements can be carried out with the DFC instrument are:

$$-22\text{C} < T < 0\text{C}$$

$$0.2 \text{ L}^{-1} < N_c < 10^5 \text{ L}^{-1}$$

Additional Considerations

There are a number of other factors which are relevant to the evaluation of what processes of nucleation are detected by the DFC instrument, and which impact on the interpretation of the results in terms of contact-nucleation.

a. Some aerosol particles may impact onto the water drops due to the airflow past the drops. For small particles, and for the flow velocity involved, the collection rate will be small. In any event, as far as the determination of nucleus concentrations is concerned, aerodynamic impaction need not be distinguished from what is produced by the electrostatic precipitation as the effective sampling rate includes both processes.

b. It may be argued that some aerosol particles may nucleate embryonic ice crystals from the water vapor surrounding the drops even before impaction onto the drops. Precise statements concerning this could only be made after a detailed examination of the time-dependent temperature and vapor fields in the chamber to which particles are subjected. Such analyses have not yet been performed. The qualitative aspects of the problems are as follows: the sample air enters the chamber at room temperature and is cooled to some degree by the cold stage and the drops. A shallow layer of air near the cold plate will cool to nearly the plate temperature; combined with the fact that the tops of the target drops are at somewhat warmer temperatures than the plate, it seems possible that some regions of supersaturation may occur. Since the flow of air through the chamber is basically laminar and the temperature gradient stable, such regions of supersaturation are likely to be quite small, but their existence cannot be ruled out. Nuclei may thus become activated in the supersaturated zones and some ice embryos may survive long enough to be impacted onto a target drop. The combined contributions of the processes discussed in paragraphs **a** and **b** was evaluated by operating the instrument in the usual manner but without

the application of precipitating pulses. It was found that the rate of drop freezing under such conditions was on the order of 1% of the rate observed with the precipitating pulses applied.

c. There is yet another source of information concerning the nucleation mechanism involved in the DFC instrument. Special experiments were conducted to determine whether freezing of the drops follows particle deposition instantaneously or with some time lag. In the standard experimental procedure this question cannot be examined because the response time of the optical detectors is comparable to the time interval between pulses. Therefore, for a special series of experiments, single pulses were applied and the freezing of drops was monitored for long periods of time following each pulse. The test aerosol was admitted to the chamber only for a brief period bracketing the application of the pulse, filtered air being used both before and after that. A summary of a series of experiments is shown in Fig. 4. These tests were conducted between -8°C and -10°C using silver iodide aerosols. A high concentration of nuclei is required for these tests so that even a single pulse will result in an adequate number of freezing events. Zero time on the abscissa refers to the instant of application of the precipitating pulse, and the percent of drops frozen is expressed in terms of the number that were frozen 200 sec after the pulse. The vertical column centered at 10 sec represents the range of detector response times; if nucleation of all the drops had taken place at the instant of the pulse, all freezing events would have been recorded within that time range (the width of the column arises from the scatter in response times of the individual detectors). It is seen that no freezing events occurred prior to the precipitating pulse and that freezing of the drops just barely commences after the time required for detector response. Most of the freezing events occur at considerably later times, the approximate time constant for the nucleation events is 70 sec. Aerosol particles which did not make contact with

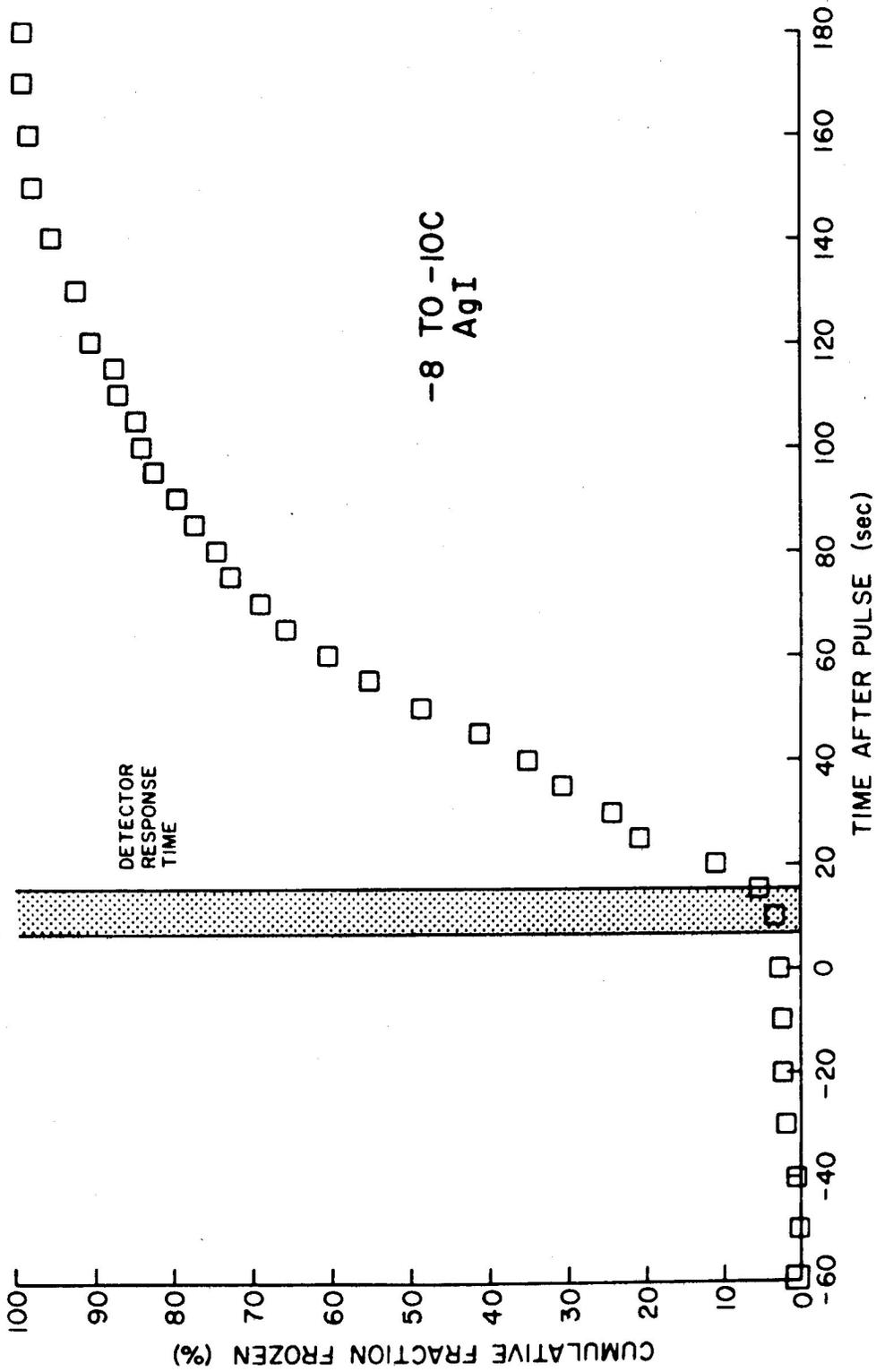


Figure 4. Combined results for a series of experiments with AgI between -8C and -10C demonstrating the lag of time between particle collection (at t = 0) and freezing of the drops.

the water drops were flushed from the chamber within a few seconds of $t = 0$ so that the observed freezing events are positively the results of nucleation by particles which made contact with the drops at $t = 0$. The implication of these results is that nucleation events follow the collection of nuclei by the water drops with a very considerable lag of time. It is likely that the collected aerosol particles remain at the surface of the water drops, and that the particles undergo some gradual change while in contact with water or that nucleation occurs when a particular spot on the particles comes into contact with the water due to the random motion of the particles. The observations certainly deserve further study. Irrespective of the precise explanation for the time lag, one may surmise that similar time lags would occur following the collection of aerosol particles by natural cloud droplets. Although there may be some differences in the details of the events that take place at the interface during and following collection for particles deposited electrostatically and those collected by diffusion or impaction, such differences will be small. Different nucleating materials will also produce, no doubt, different degrees of time lag. The point here is that, at least for AgI, there is evidence that contact between nuclei and water is a necessary precursor for producing freezing events in the DFC instrument.

d. The drop sizes employed in the DFC apparatus are considerably larger than natural cloud droplets and this raises the question of applicability of the measurements to cloud conditions. There is as yet no information on the dependence of contact nucleation efficiency on drop size. The mass ratios of nucleating particles to natural cloud droplets is on the order of 10^{-3} or smaller; it is difficult to envisage processes where it would be of significance that the corresponding ratio is 10^{-9} in the DFC instrument. In other words, cloud droplets as well as the target drops in the DFC can be considered to be "bulk" water as far as the ice nuclei are concerned. However, only with a more

complete understanding of the molecular processes involved in the nucleation events will this question become truly tractable.

Results

A tabulation of all the measurement results obtained during the Workshop is contained in the Appendix to this report. For a description of the nuclei sources, reference should be made to the section of this report (by D. C. Rogers and G. Vali) which deals with aerosol generation and measurements.

Measurements on natural nuclei yielded the following average concentrations.

$$-16C \quad 0.30 \pm 0.21 \text{ L}^{-1}$$

$$-20C \quad 1.47 \pm 0.63 \text{ L}^{-1}$$

where the indicated variability is one standard deviation. There were four tests with detectable concentrations, plus one below the limit of detectability, for -16C and nine tests at -20C. These results are somewhat lower than the average concentrations measured at Laramie over a much longer period of time during 1974-75.

For tests using the thermal AgI nuclei Fig. 5 summarizes the measured concentrations. Measurements were restricted to the temperature range -6 to -12C by the limitations in dynamic range of the instrument, combined with the abrupt drop in activity at temperatures between -8 and -6C for the AgI nuclei. The differences in results among experiments must be ascribed to differences in the test aerosols.

The size distribution of the nuclei was quite similar for Experiment 7, 18 and 22 (the mode of the distribution was 0.1 μm for those experiments) - the observed nuclei spectra are also quite alike. Experiment 7* refers to measurements on the undiluted aerosol, hence the high activity at -8C and -10C; interestingly no measurable activity was evident at -7C, in contrast with

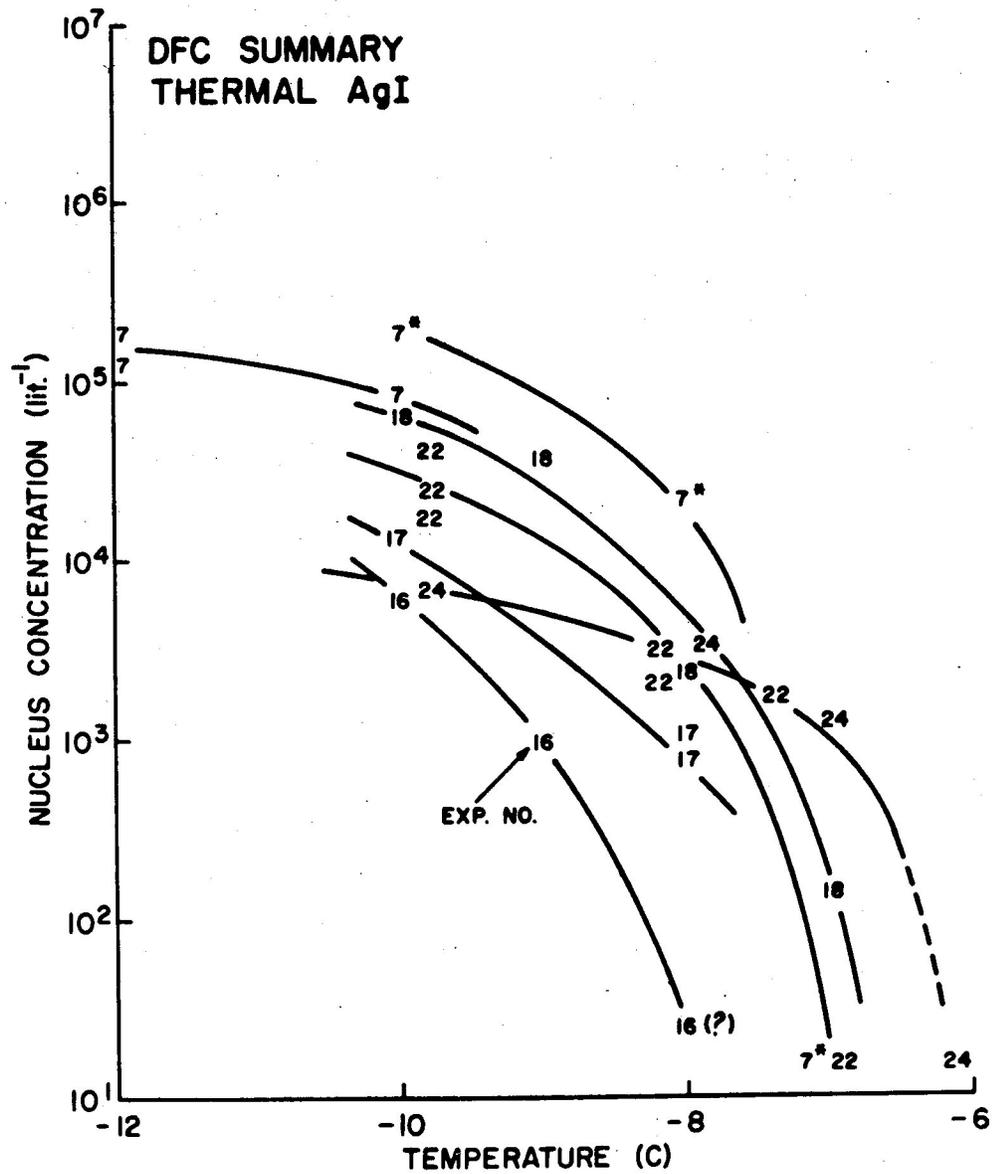


Figure 5. DFC results for experiments with thermal AgI. Numbers defining curves are experiment numbers given in listing of Workshop Experiments.

Experiment 18 and 22, in which the diluted and aged aerosol was used.

Experiment 16 and 17 were with smaller nuclei the peaks of the size distributions were at 0.03 μm . This led to diminished activity at -8 and -9C in Experiment 16, but not in Experiment 17.

The shape of the spectrum for Experiment 24 differs from the other experiments. In this experiment the Agl aerosol was diluted with outside air, whereas in the other experiments dry nitrogen was used. Why the presence of the additional aerosol from the outside air altered the activity of the Agl nuclei is difficult to explain; it seems certain that the Agl nuclei coagulated with the "other" aerosol so that the observations are indicative of what results from having mixed nuclei instead of pure Agl.

The results of the DFC measurements for other artificial nuclei used during the Workshop are depicted in Figure 6 and 7. In Experiment 13 (Fig. 6) a powder dispersion of LDN was used. In comparison with the SCC (settling cloud chamber) and especially the CSU operated Mee-counter, the DFC detected much higher nucleus concentrations. Similarly, in Experiment 23, using small Agl particles generated by a burner, the DFC detected higher nucleus concentrations than either one of the two Mee-counters.

The best agreement between the DFC and another instrument was obtained in Experiment 19, when additional condensation nuclei were used in the SCC to increase the density of the cloud. These results are shown in Figure 8.

Only a few re-freezing experiments were conducted during the Workshop. As the table of results in the Appendix indicates, the fraction of nuclei which remained active following heating to +10C was highly variable for natural as well as for Agl nuclei. Rough average fractions would be 0.5 for natural nuclei and 0.7 for the Agl nuclei. In agreement with previous results, LDN yielded more activity upon refreezing than prior to warming of the drops.

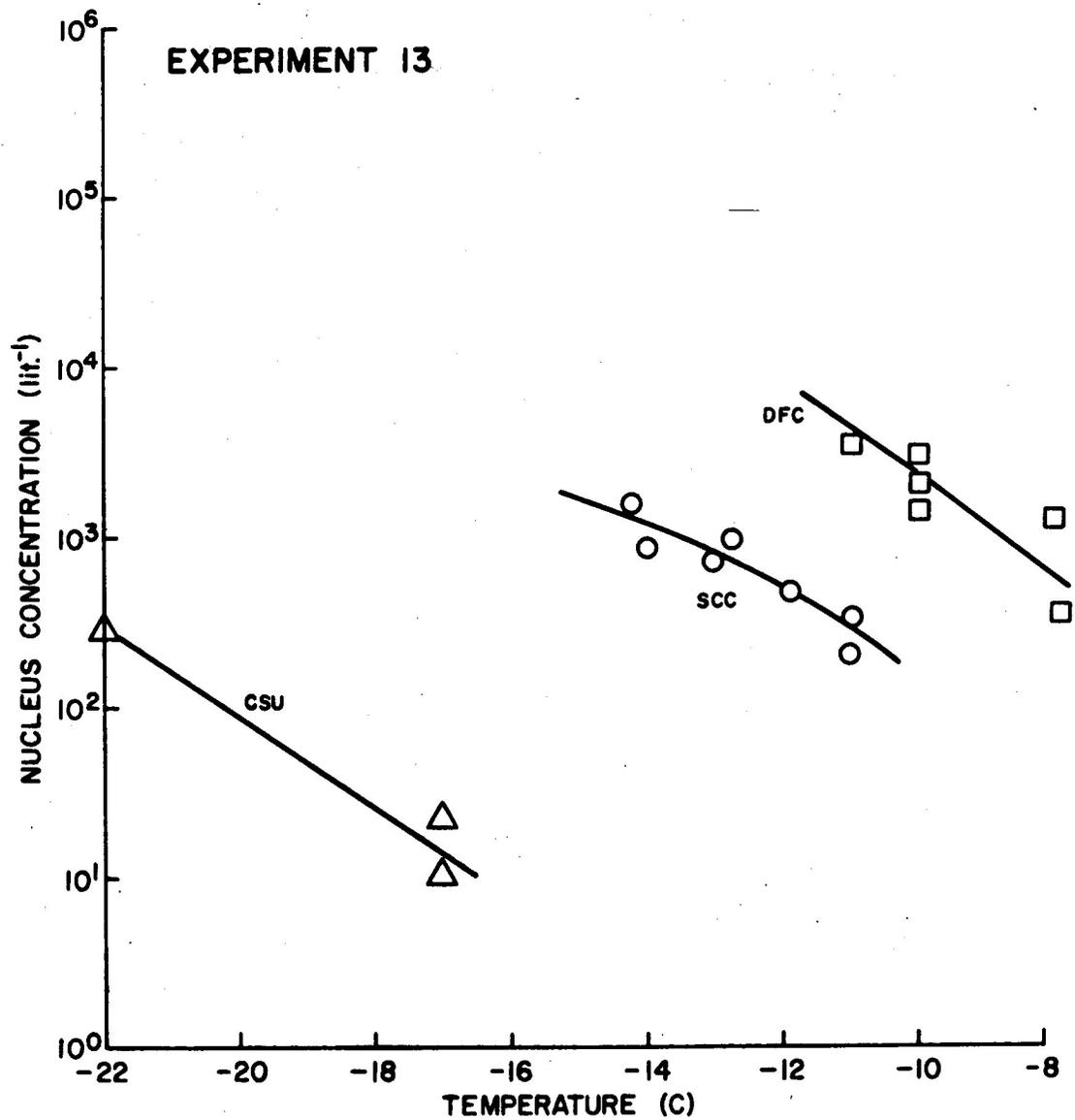


Figure 6. Experimental results for LDN (leaf derived nuclei) for DFC, for SCC (settling cloud chamber) and for CSU (Mee-counter).

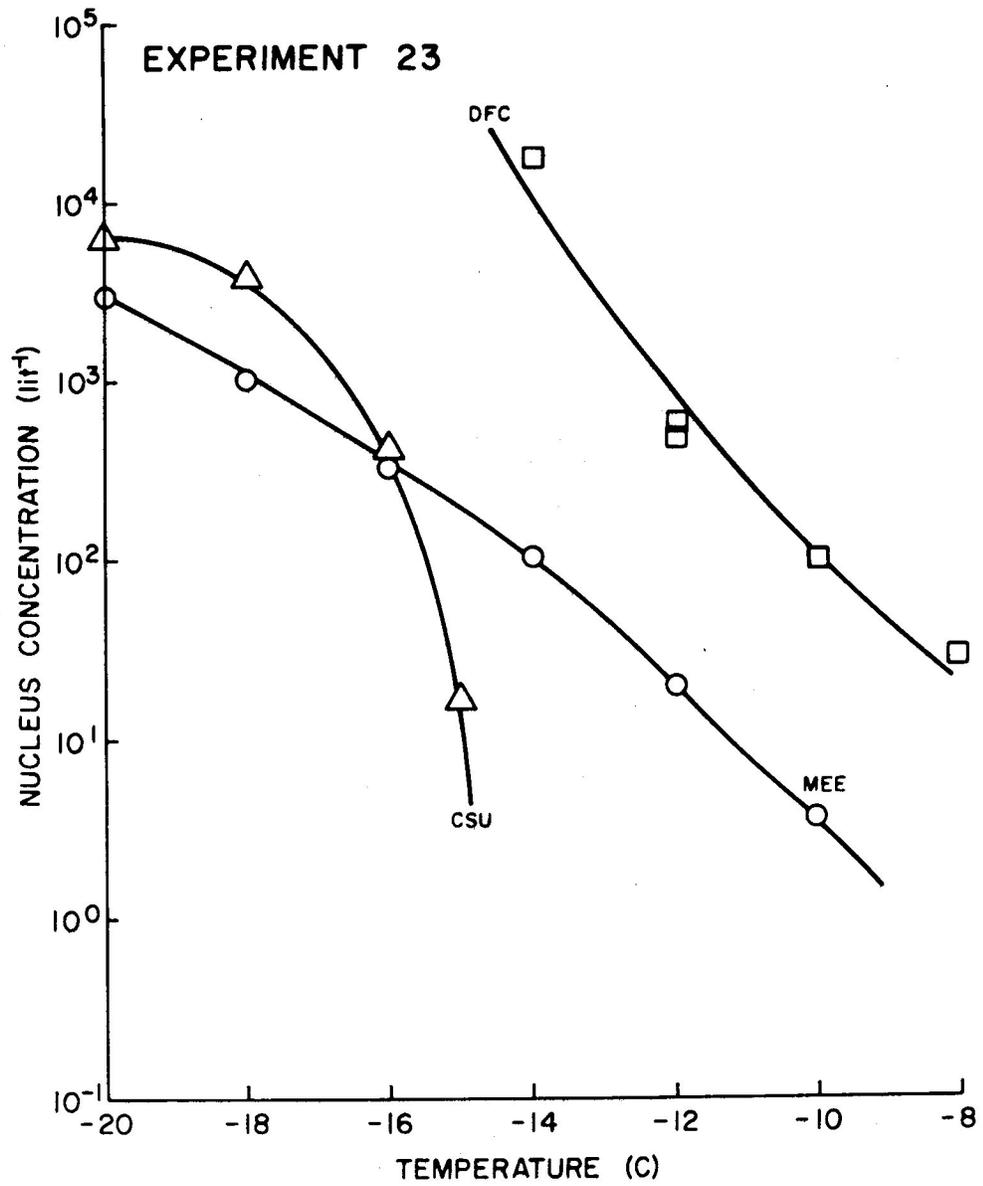


Figure 7. Nucleus concentrations for nuclei from AgI burner as measured by the DFC and the two Mee-counters.

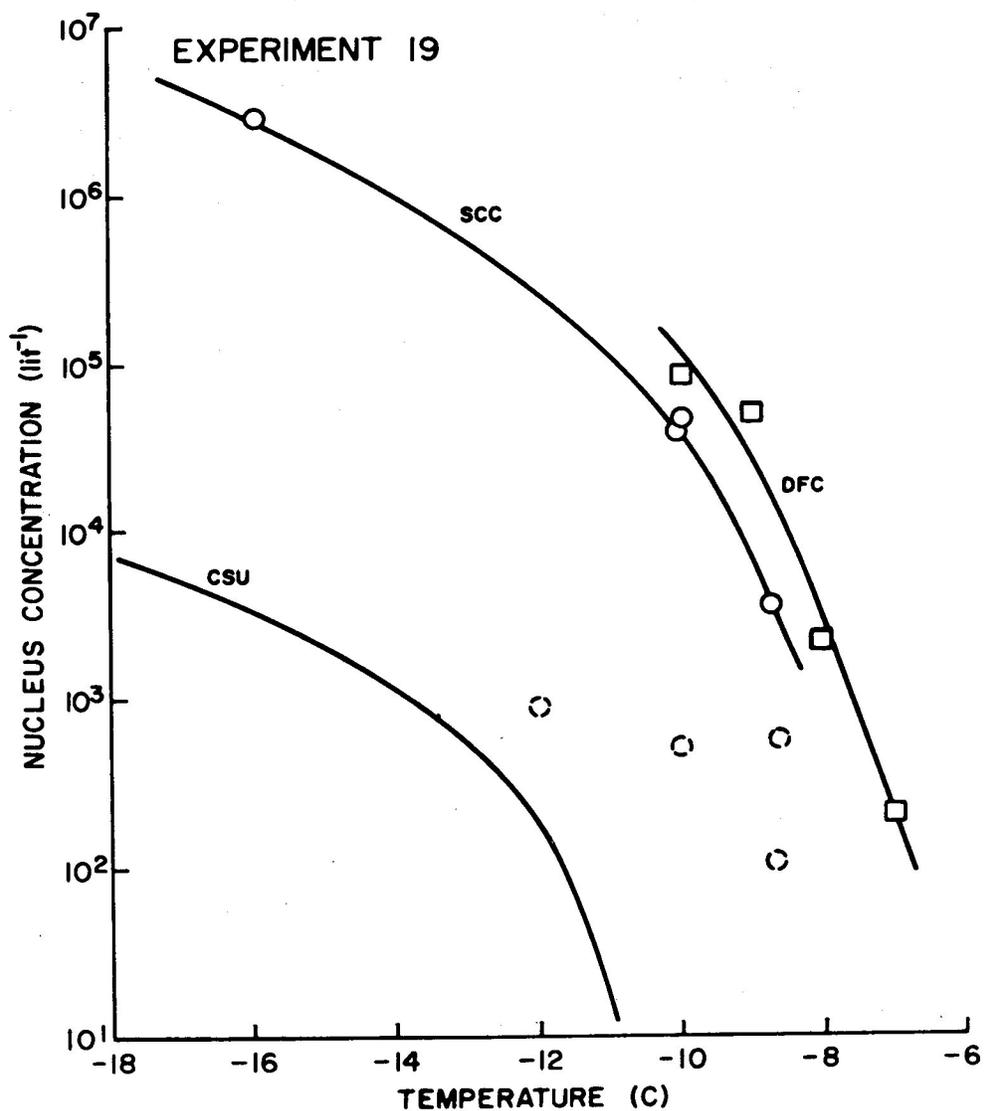


Figure 8. Results for Experiment 19. The two sets of points (broken and full circles) indicate the concentrations measured by the SCC without and with additional condensation nuclei.

Summary

The principle of operation, and evidence bearing on the actual performance of the instrument were presented. Based on what is known about the instrument, it is claimed that the measurements reflect the ability of aerosols to nucleate ice following contact with supercooled water. Thus, the basic mode of nucleation detected by the DFC is freezing; freezing caused by nuclei located at the air-water interface. This mode of nucleation closely resembles what would be expected to result from the collection of nuclei by supercooled droplets or drops in natural clouds.

The concentrations of nuclei measured by the DFC usually exceeded the results obtained by the other instruments or was close to the highest values measured. Good agreement was found between the SCC and DFC for natural aerosols and also for Agl if additional condensation nuclei were provided for the SCC.

In general, the DFC performed reliably and consistently during the Workshop experiments. No shortcomings were discovered except for the inherent limitations imposed by the relatively small sampling rate of the instrument.

References

- Doolittle, J. B. and G. Vali, 1975: Heterogeneous freezing nucleation in electric fields. Jour. Atmos. Sci., 32, 375-379.
- Gabarashvili, T. G. and N. V. Gliko, 1967: Origination of the ice phase in supercooled water under the influence of electrically charged crystals. Izvestiya Acad. Sci: USSR, Atmospheric and Oceanic Physics, 3, 324-327.
- Liu, B.Y. H., K. T. Whitby and H. S. Yu, 1967: Electrostatic aerosol samples for light and electron microscopy. The Rev. of Sci. Instru. 38, 100-102.

LIST OF WORKSHOP EXPERIMENTS

This list was prepared to provide a ready reference to the calendar of Workshop activities. In addition to these experiments, there were a number of non-group experiments conducted by participants.

CODE:

Date following experiment number: date of aerosol generation and sampling; dates of filter processing not necessarily the same

Time following aerosol designation: time of generation or interval of sampling

Th. Agl: Agl aerosol generated with hot-wire technique

CCN: cloud-condensation nuclei measured over indicated time interval
(W) - Wyoming diffusion chamber with camera; (M) - Mee continuous counter

EM: samples collected for electron microscope

FILT WS -: filter sampled on 'octopus'; WS is serial number in parenthesis after FILT; units in which filters were processed

SU: SUNYA static diffusion chamber

WY: Wyoming static diffusion chamber

FR: Frankfurt low-pressure diffusion chamber

AR: Arizona low-pressure diffusion chamber

NC: NCAR - filters taken for subsequent processing

NO: NOAA - filters taken for subsequent processing

CS: CSU - filters taken for subsequent processing

SCC: Settling cloud chamber

DFC: Wyoming drop-freezing by contact

MEE 1: Mee-counter operated by D. Garvey

MEE 2: Mee-counter operated by T. Mee

S-C: Stöber centrifuge

G-C: Götz centrifuge

LIST OF WORKSHOP EXPERIMENTS

EXPERIMENT 1 750519

Objective: Preliminary comparisons of different filter processing instruments

Aerosol: Outside air, 0933-1147
Spectra - 0945, 1150

Measurements: FILT WS 1-12 (FR, SU, WY); DFC

Prelim. Concl.: WY factor 5 higher than SU and FR

EXPERIMENT 2 750521

Objective: Contamination check of filter sampling manifold

Aerosol: Outside air, 1024-1105

CCN - 0930-1045

Measurements: FILT WS 13-20 (FR, WY); DFC

Prelim. Concl.: No evidence of contamination. WY factor 8 higher than FR

EXPERIMENT 3 750521

Objective: Comparison measurement with silver iodide aerosol

Aerosol: Th Agl, 1405

Spectra - 1511, 1530

Measurements; DFC, G-C; S-C; MEE 1

EXPERIMENT 4 750521

Objective: Repeat of Experiment 3

Aerosol: Th Agl, 1611; diluted at 1755

Spectra - 1640, 1734, 1817 EM - 1731-1746

Measurements: FILT WS 29-44 (AR, SU, NR, WY, FR, NO, NC) on
diluted aerosol DFC, MEE 1, S-C, G-C on high concentrated aerosol

Prelim. Concl.: MEE 1 cannot detect nuclei at -10C

EXPERIMENT 5 750522

Objective: Contamination check of filter sampling manifold (octopus)

Aerosol: Room air through absolute filters, 0913-1013

Measurements: FILT WS 45-52 (SU, WY, NO, NC)

Prelim. Concl.: Cleaning process is adequate

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EXPERIMENT 6 750522

Objective: Sample outside air

Aerosol: Outside air

Spectra - 0900, 0920, 0930, 1345, 1530, 1535, 1605, 1700 CCN - 1415-1530

Measurements: DFC, MEE 1

EXPERIMENT 7 750523

Objective: An independent evaluation of the consequences of filter preparation methods from the possible differences in processing chambers was desired. A three-way stratification of filters was set up:

- a) individual treatment followed by individual processing
- b) filters treated by different techniques processed in a common unit (WY), and
- c) filters treated in a common way (SU vaseline saturation) and processed in the individual units.

Aerosol: Th Agl 0905; diluted 1055

Spectra - 0935, 1031, 1115, 1234 CCN - 1155-1230 EM - 1120-1235

Measurements: SCC, DFC, S-C, G-C, MEE 1

FILT WS 55-78 (SU, AR, WY, NR, NC, NO, FR)

Prelim. Concl.: Treatment differences are inconsequential. SU, WY and AR processing results close, FR much higher.

EXPERIMENT 8 750523

Objective: Compare fast and slow humidification rates in FR low-pressure diffusion chamber

Aerosol: Outside air

Spectra - 1420 Measurements: FR

Prelim. Concl.: Slow humidification activates about 1/10 the number with "puff" humidification.

EXPERIMENT 9 750524

Objective: Measure supersaturation spectrum for Agl

Aerosol: Th Agl, 0858; diluted, 1013

Spectra - 0906, 0943, 1018, 1045, 1145

Measurements: SCC, G-C, S-C; FILT WS 79-102 (SU, WY, AR, FR)

Prelim. Concl.: S. is relevant parameter; T, Sw, of only indirect interest. Fair agreement of all filter systems except FR.

EXPERIMENT 10 750526

Objective: Determine the volume-effect for filter measurements at different S.-values

Aerosol: Outside Air

Spectra - 1519, 1600, 1625, 1642, 1705, 1748, 1818 CCN - 1430-1515 (W); 1530-1638 (M) EM - 1432-1715

Measurements: FILT WS 103-126 (WY, SU, FR, NC) Prelim. Concl.: $N \propto V^{-0.8}$

EXPERIMENT 11 750526

Objective: Obtain size distribution for deposition nuclei in natural air.

Aerosol: Outside air

Spectra - 12 times over period of sampling

Measurements: Stober-centrifuge - Wyoming diff. chamber processing
Prelim. Concl.: 80-90% of nuclei at $Si = 20$ are less than $0.5 \mu\text{m}$ in size

EXPERIMENT 12 750527

Objective: Determine temperature and supersaturation spectrum for natural aerosols.

Aerosol: Outside air, 1400-1800

Spectra - 1345, 1525, 1637, 1715, 1815 CCN - 1540-1630 (W & M) EM - 1426-1726

Measurements: FILT WS 127-174 (WY, SU, FR, AR, NC, NO); DFC, SCC, G-C

Prelim. Concl.: Fair agreement of filter data on S. spectrum. DFC, SCC and G-C agree; all somewhat above filters.

EXPERIMENT 13 750528

Objective: Compare DFC with cloud chambers for large particles

Aerosol: LDN (leaf-derived nuclei) gen at 0945,1453

Spectra - 0947, 1110, 1146, 1243, 1458, 1615 EM - 1120-1140

Measurements: DFC, SCC, MEE 1, S-C

Prelim. Concl.: DFC:SCC = $1:10^{-1}$; DFC:MEE 1 > $1:10^{-3}$; as would be anticipated for large aerosols, but other factors might have also been present.

EXPERIMENT 14 750528

Objective: Find the degree of scatter among filters sampled in parallel.

Aerosol: Outside air, 0905-1008

Spectra - 0900 EM - 0714-0918

Measurements: FILT WS 175-198 (SU, WY)

Prelim. Concl.: Standard deviation for SU is 18% on 8 filters; for WY it is 41% on 15 filters.

EXPERIMENT 15 750529

Objective: Evaluate the effect of changing the separation between filters and ice surface in the static diffusion chambers.

Aerosol: Outside air, 1351-1448

CCN - 1315-1420 (M)

Measurements: FILT WS 199-214 (SU, WY)

Prelim. Concl.: Counts increase with decreasing separation; more rapidly in SU chamber than in WY chamber

EXPERIMENT 16 750529

Objective: (i) determine volume effect on filters for Agl
(ii) obtain S.-spectra on filter for Agl
(iii) compare different instruments

Aerosol: Th Agl, 1412; diluted at 1503, 1554; diluted at 1650

Spectra - 1418, 1506, 1604, 1638, 1655, 1830 EM - 1724-1842

Measurements: FILT WS 215-270 (SU, WY, FR, AR, NC, NO, CS) DFC,
SCC, MEE 1, S-C

Prelim. Concl.: (i) volume effect on filter was present but the pattern was somewhat unclear; best estimate $N \ll v^{-3}$ (ii) S^-spectrum as before
(iii) deposition nuclei are much fewer than freezing nuclei

EXPERIMENT 17 750530

Objective: Determine effect of added CCN on filter measurements

Aerosol: Th Agl, 0927; diluted at 1015

Spectra - 0951, 1015, 1045, 1143, 1223, 1505, 1535, 1603

1713 CCN - 1100-1230 (M), 1600-1800 (M), 1900-1930 (M)

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(EXP. 17 continued)

Measurements: FILT WS 271-318 (SU, WY, AR, FR, NC, NO, CS); DFC, SCC,
MEE 1

Prelim. Concl.: Addition of outside air increased numbers of active nuclei
on the filters, except in AR processing.

EXPERIMENT 18 750531

Objective: Check on suggestion that Sartorius filters have smaller
vapor-depleting effect than Millipore filters.

Aerosol: Th Agl, 0936; diluted at 1050

Spectra - 0942, 1024, 1051, 1200 CCN - 1230-1330 (W & M) EM - 1103-1240

Measurements: FILT WS 319-342 (SU, WY, FR)

Prelim. Concl.: Dramatic differences between filter types - hydrophobic
Sartorius filters gave highest counts, regular Sartorius filters
somewhat less and Millipore filters very much less.

EXPERIMENT 19 750531

Objective: Determine effect of CCN concentration on performance of SCC.

Aerosol: as EXP. 18 and EXP. 22

Measurements: SCC

Prelim. Concl.: With copious CCN, count increased by about 102 .

EXPERIMENT 20 750531

Objective: Repeat of EXP. 15

Aerosol: Outside air, 1655-1803 and 2020-2130

Spectra - 1655, 1705, 1755, 2025, 2028, 2120, 2124

CCN - 1745-1815 (W & M)

Measurements: FILT WS 343-390 (SU, WY) Prelim. Concl.: as for
EXP. 15

EXPERIMENT 21 750524, 26, 29, 30, 31

Objective: (i) compare aerosols caught on filters from air sucked
through the filter with aerosol settled onto filters (ii) compare
different surfaces onto which aerosols have been put by settling

Aerosol: Th Agl (750524, 26, 29, 30); outside air (750531)

(EXP. 21 continued)

Measurements: S-C, elstatic precipitation

Prelim. Concl.: (i) filters with either collection technique produce about the same result

(ii) fewer nuclei activated on metal foils; surface preparation causes differences also

EXPERIMENT 22 750602

Objective: Because of the large differences found between the different types of filters (in EXP. 18) the question arose whether the filter material could have an effect on the supersaturation spectrum, thus casting doubt on the results of EXP. 9. Similarly, it might have been suspected that with the different filters the results of EXP. 17 (effect of added CCN) would also be different. The objective of this experiment was therefore to repeat those two experiments using different filter types. At the same time the effect of CCN on the SCC was to be checked by preparing different batches of silver iodide: one with dry nitrogen and one using outside air.

Aerosol: Th Agl (i) 1003 diluted with dry N2 at 1100
 (ii) 1400 with dry N2, undiluted
 (iii) 1520 diluted with outside air at 1616 Spectra -
 1010, 1037, 1105, 1335, 1405, 1425, 1445,

1505, 1523, 1612, 1620, 1726 CCN - 1210-1300 (W & M) ; 1645-1725 (W & M) EM - 1656-1735

Measurements: FILT WS 391-438 (SU, WY, FR, CS, NC, NO); SCC; DFC

Prelim. Concl.: Filter results same as before. CCN have no influences on the DFC results. SCC results unclear.

EXPERIMENT 23 750605

Objective: Tests with smaller Agl particles

Aerosol: Roof-top acetone burner (2.5% NH4I mixture)

Spectra- 1310, 1315, 1325, 1349, 1354, 1359, 1404,

1410, 1417, 1423, 1428, 1437, 1441, 1453,

1458, 1520, 1524 EM - 1240-1536

Measurements: FILT WS 439-462 (SU, WY, FR, CS); DFC, S-C, G-6
 (?) Prelim. Concl.: Qualitatively similar results to Th Agl.

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EXPERIMENT 24 750606

Objective: Observe effect of additional CCN on the Mee-counters

Aerosol: Th Agl, 0940; diluted with outside air 1032

Spectra - 0943, 1025, 1042, 1200

Measurements: MEE 2

Prelim. Concl.: Even though air had natural concentrations of CCN, counts could be increased further 50 to 100-fold by adding CCN (propane flame or heated NaCl)

EXPERIMENT 25 750606

Objective: Check if differences between filter types (EXP. 18) are also present with natural aerosol.

Aerosol: Outside air, (0908-1013)

Spectra - 0850,0950

Measurements: FILT WS 467-470 (WY)

Prelim. Concl.: Same difference present as for Agl, but probably smaller magnitude.