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Brief Abstracts of some Papers on Seeding Agents

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by

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Introduction

During the preparation of a work plan for a study of the atmospheric water resources in Utah, a number of publications were studied which presented information pertaining to agents used to modify weather. These publications have been compiled to eliminate repetition of this laborious task. Brief abstracts of these papers were prepared to help investigators determine whether or not they wish to see the original publications.

Abstracts

1. Aksenov, M. Ia, et al. "Production of ice forming lead iodide aerosol from pyrotechnical compounds." Moscow, Tsentral'naia Aerologicheskaia Observatoriia, Trudy, No. 44(6):3-69, 1962.

   Abstract: Pyrotechnical compounds with lead iodide have been produced and tested for the purpose of obtaining ice forming PbI_2 aerosol. The production of ice forming particles was measured and found to come close to the production of AgI particles from similar compounds.

2. Aksenov, M. Ia, et al. "Investigation of the ice forming activity of silver iodide aerosol generated by burning pyrotechnical compounds. Akademiia Nauk Gruzinskoi SSR Institut Geofiziki, Trudy, 20:197-207, 1962.

Abstract: A laboratory experiment is described, in which the ice-forming capacity of AgI particles produced by burning three different pyrotechnical compounds was investigated. Relative effectiveness of each compound is determined. Data are also presented on the temperature dependence of crystal formation. The upper temperature limit of crystal formation was found to be -5° C. At this temperature the number of crystals formed per gm. of AgI was $5 \times 10^{9} - 1 \times 10^{10}$. At -20° C the number of crystals was 10^{14} per gm. of AgI. The AgI particles were also examined with an electron microscope. (Microphotographs are presented.) The mean radius of the particles was found to be 5×10^{-6} cm.

3. Bakulina, E. V.; Gromova, T. N.; and Krasikov, P. N. "Method for the use of aqueous solutions of lead iodide as agents in supercooled clouds and fog." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 126:10-15, 1962. Russian Summary, p. 10. Transl. into English as U. S. Joint Publication Research Service, JPRS, No. 18, 696. April 15, 1963, p. 11-19.

Abstract: With the aid of laboratory experiments, the authors demonstrate that aqueous solution of lead iodide, PbI_2, can be used to act upon supercooled clouds. A method was established for obtaining solutions of PbI_2 by using solutions of $Pb(NO_3)_2$, and any iodide salt soluble in water, such as ammonium iodide NH_4I or potassium iodide KI or sodium iodide NaI. Mixtures of $Pb(NO)_2$ and NH_4I remain transparent and do not give precipitates in the tank. In vaporizing, the solution does not soil the pipes and burners. The solutions of PbI_2 introduced in supercooled fog at a temperature of -10° C yield up to 10" ice crystals per 1 gm. of substance.

4. Balabanova, V. N. and Zhigalovskaia, T. N. "Crystallization of supercooled water by silver iodide." Akademiia Nauk SSSR, Izvestiia, Sev. Geofiz., No. 10:1453-1455, October 1962. Transl. into English in the corresponding issue of its Bulletin [of the] Academy of Sciences USSR, Geophysics Ser., issued Washington, D. C.

Abstract: The position of nuclei of crystallization within ice crystals was investigated by introducing silver iodide particles into a cloud chamber after filling it with fog droplets. The experimental procedure is described.

The silver iodide particles are situated within ice crystals primarily at the faces and rarely in the center. The number of silver iodide particles participating in crystallization can exceed the number of crystals by as much as 60%. The critical dimensions

of crystallization are established by determining the area S_i, from the equation $S_i/stot = n_1/n^{20}$ where S_i is the area under the curve of distribution of smoke particles according to dimensions, n/is the number of nucleating particles of smoke at a given temperature and n^{20} their number at -20° C. The initial dimensions also can be computed by Thomson's formulas

$$r\,Cr = \frac{2\,T_s\,\sigma_s\,M}{\Delta T Q d} \quad (\Delta T = T_s - T_r)$$

where T_s = temp. of sublimation of ice, T_r = temp. of sublimation or formation of ice crystals of given size, σ_s = surface attraction between liquid and solid phases of water, Q = heat of sublimation of ice, M = molecular weight of water, d = specific weight of ice. The experimental determination of the minimum dimensions of silver iodide particles which can serve as crystallization nuclei of water agree satisfactorily with the dimensions of critical crystallization nuclei arising in the liquid phase as calculated with Thomson's formula. The critical dimensions of foreign crystallization nuclei are close to the dimensions of spontaneously forming crystallization nuclei.

5. Balabanova, V. N. and Viadrov, G. Z. "Methods of introducing reagents into clouds for the purpose of modifying them." Akademiia Nauk SSSR, Izvestiia, Ser. Geofiz, No. 6:951-952, June 1961. Transl. into English in the corresponding number of its Bulletin of the Academy of Sciences, USSR, Geophysics Series.

Abstract: The introduction of silver iodide crystals into clouds either using ascending currents from the ground surface or balloons, and the most suitable ways of obtaining silver iodide crystals such as a powder impregnated with an acetic acid solution of silver iodide, a mixture of crystals of phosphorus and silver iodide, etc., are discussed on the basis of experiments carried out in the Alazani Valley. It was found that smoke boxes containing iodine forming substances are a sufficiently productive and suitable method for generating crystallization nuclei.

6. Balabanova, V. N.; Maleev, M. N.; and Zhigalovskaia, T. N. "The extent of destruction of the silver iodide particles under the thermal methods of dispersion." Akademiia Nauk SSSR, Izvestiia, Ser. Geofiz. No. 9:1413-1416, Sept. 1960. Transl. into English in the corresponding number of its Bulletin of the Academy of Sciences, USSR, Geophysics Series.

Abstract: Thermal dispersion methods are applied for obtaining crystallization nuclei of silver iodide used to bring about phase transitions in supercooled clouds and fogs. The relation of the chemical composition of silver iodide smoke, obtained by the condensation method, to the temperature of the sublimation source was studied. It was found that only 3 to 5 percent of silver iodide decomposes into metallic silver and iodide during the sublimation process. An increase of sublimation temperature does not noticeably affect the decomposition of silver iodide.

7. Balabanova, V. N.; Zhigalovskaia, T. N.; and Maleev, M. N. "Influence of air-temperature on the activity of AgI particles as crystallization nuclei." Akademiia Nauk, SSSR, Izvestiia, Ser. Geofiz. No. 12:1889, 1890, Dec., 1959. Transl. into English in the corresponding number of its Bulletin of the Academy of Sciences, USSR, Geophysics Series.

Abstract: On the basis of experimental data, the author examines the problem of the dependence of the crystallization capacity of AgI particles upon the temperature of the atmosphere. Data are given showing the dependence of the observed number (n) of ice crystals in a cloud chamber upon the time that the smoke is in the chamber at different temperatures, the mean values of the amount of AgI settling (m) on the smoke in the chamber at different temperatures, the mean values of the amount of AgI settling (m) on the entire surface of the vessel during different time intervals, the amount of material remaining in the chamber in suspension for a given time, and the ratio of $n20^{o}/n60^{o}$ and $m20^{o}/m60^{o}$. The basic cause of the decrease in the appearance of ice crystals in a cloud chamber as the temperature at which the smoke is maintained is increased, is the decrease in the concentration of AgI smoke resulting from particles settling upon the surface of the vessel before the release of smoke into the cloud chamber. Hence, the temperature of the environment containing AgI in a cloud vessel does not influence, perceptibly, the crystallization capacity of the particles. It is therefore assumed that under natural conditions atmospheric temperature does not affect the activity of the AgI particles. The inactivation of such particles as crystallization nuclei is, in the atmosphere, a consequence of solar radiation.

8. Bartnicki, L. "Artificial rain." Przeglad Meteorologiczny i Hydrologiczny, Warsaw, 7(3/4):185-187, 1954.

9. Bashkirova, G. M. and Pershina, T. A. "Characteristics of the freezing of drops of aqueous solutions of lead iodide." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 176:35-42, 1965. Russian Summary, p. 35.

Abstract: The experimental procedure for investigating the process of freezing droplets of a saturated PbI_2 solution is described and the results of freezing at temperatures of -9° to -19° C are presented. The results of freezing of drops in unsaturated PbI_2 solution also are presented. The freezing of drops of a saturated PbI_2 begins from within because particles of dissolved substances recrystallize during cooling even with a small amount of supercooling. The freezing of drops of a saturated PbI_2 solution proceeds, usually, without explosion when the drops are blown intensely and for a long time. When the droplets are cooled rapidly they either divide in half or crevices form on their surface. When the drops freeze, PbI_2 particles are extracted from the surface. Particles of PbI_2 can fly out from the drops when they freeze.

10. Bashkirova, G. M. and Krasikov, P. N. "Experiments with certain substances as crystallization agents for supercooled fog." Leningrad. Glavnaia Geofiziches - Kaia Observatoriia, Trudy, 72:118-126, 1957.

Abstract: The methods and results of such experiments carried out in a 250 - liter refrigerating chamber, with the following substances--cadmium oxide, zinc oxide, silver iodide, iron sulfide, fluoroglycine, silver dioxide, gasoline tank deposits, and magnesium oxide--are described and discussed. It is shown that silver iodide is the most effective of all agents tested. Properties of the other agents mentioned are also presented. Photos of ice crystals formed at the introduction of these various agents into fog are included.

11. Beliaev, V. I.; Gairoronskii, I. I.; Kolesnikov, A. G.; et al. "Spreading of crystallization in supercooled clouds seeded with dry ice." Akademiia Nauk SSSR, Izvestiia, Ser. Geofiz., No. 12:1844-1851, Dec. 1961. Russian Summary p. 1844. Transl. into English in the corresponding number of its Bulletin of the Academy of Sciences of the USSR, Geophysics, Ser., issued Washington, D. C.

Abstract: An equation was developed for calculating the rate of cloud dispersal due to seeding with dry ice. The formula is based on calculating the turbulent diffusion of ice nuclei formed by seeding

and the rate of water diffusion from cloud drops onto the ice crystals. Vapor concentration, average droplet size, and droplet concentration have to be known. Using this formula, rates of cloud dispersal were calculated for conditions prevailing in St and Sc clouds seeded from aircraft in autumn and winter 1956 - 1957 at the Central Aerological Observatory, Moscow. Although general agreement existed between calculated rates of dispersal and rates of clearing observed visually, it is believed that the theory could be further improved by refining the computation of the turbulent diffusion coefficient. Both calculations and observations show that the propagation of the front of crystallization is greatest at the beginning of the process and decreases with time. It is more strongly affected by the turbulent diffusion coefficient than by the concentration of ice nuclei.

12. Bidault, G. "Comparative counts of silver iodide ice-producing nuclei generated by various cloud seeding techniques." Puy de Dôme, Observatiore Bulletin, No. 4:169-171, Oct./Dec., 1960.

Abstract: Using a Soulage-Bigg type nuclei counter with a volume of cold chamber limited to 1000 cm^3, the author counted artificial ice nuclei produced by the various techniques employed in hail prevention. The counts permit a quantitative comparison of some silver iodide diffusion techniques. Good results are obtained through dispersing or pulverizing acetone solutions containing 20 percent AgI.

13. Birstein, S. J. "The role of adsorption in heterogeneous nucleation, Pt. 2, The adsorption of water vapor on photolyzed silver iodide." Journal of Meteorology, 13(4):395-398, Aug. 1956.

Abstract: The effectiveness of AgI as a nucleating agent depends on its ability to adsorb and orient water molecules, and is destroyed by photolyzation by UV or sunlight. Adsorption by photolyzed and unphotolyzed AgI and lead iodide was studied at +20 and -20° C. As the AgI surface is reduced, adsorption increases, but the orientation of the water molecules changes in such a way as to inhibit adsorption of ice-oriented layers, so that at -20° C the photolyzed material does not form an ice crystal.

14. Birstein, S. J. and Anderson, C. E. (Air Force Cambridge Research Center). "The mechanism of atmospheric ice formation, I: The chemical composition of nucleating agents." Manuscript rec'd May 10, 1954. Journal of Meteorology, 12(1):68-73. Feb. 1955.

Abstract: A careful study was made of the nucleating ability of various chemicals. The nuclei were prepared in a nitrogen atmosphere, rather than air, to prevent a reaction at the hot filament with atmospheric oxygen. With use of these carefully controlled conditions, numerous materials previously reported as effective were found to be poor nucleating agents. The discrepancies among the various sets of data were found to be due to reactions at the filament of the solid material and oxygen in previous investigations. The results are examined to determine how they support prevailing theories on ice-crystal formation.

References: (1) aufm Kampe, H. J., and H. K. Weickmann, 1951, "The effectiveness of natural and artificial aerosols as freezing nuclei." J. Meteor. 8:283-288.

(2) Bigg, E. K., 1953. "The formation of atmospheric ice crystals by the freezing of droplets." Quart. J. R. Meteor. Soc., 79:510-519.

(3) McDonald, J. E., 1953. "Homogeneous nucleation of supercooled water drops." J. Meteor., 10:416-433.

(4) Weickmann, H. K., 1951. "A theory of the formation of ice crystals." Arch. Meteor., Geophysik Bioklim, A, 4:309-323.

(5) Schaefer, V. J., 1952. "The formation of ice crystals in ordinary and nuclei-free air." Industr. Eng. Chem., 44:1300-1304.

(6) Vonnegut, B., 1947. "The nucleation of ice formation by silver iodide." J. Appl. Phys., 18:593-595.

(7) Birstein, S. J., 1954. "Adsorption studies of heterogeneous phase transitions." Geophys. Res. Paper No. 32, 37 pp.

(8) Hosler, C. L., 1951. "On the crystallization of supercooled clouds." J. Meteor., 8:326-331.

(9) King, H. P., 1937. "Photographic recording of thermal transitions in solids." Northwest Sci., 11:36-40.

(10) Guichard, M., 1907. "Surl'iodine cuivreux, "Bull. Soc. Chem., 4, seriel, 754-762.

(11) Wilkinson, J. A., 1909. "The phosphorescence of some inorganic salts," J. Phys. Chem., 13:691-728.

(12) Nicholson, D. G. and A. R. Matheson, 1940. "Bleaching of lead pigments after darkening by exposure to hydrogen sulfide." Paint, Oil Chem. Rev., 102(18):9-10.

(13) Madelung, E., and R. Funchs, 1921. "Kompressibilitätsmess ungen an festenen Körpern." Ann. Physik, 65:289-309.

(14) Regener, E., 1941. "Versuch über die Kondensation und sublimation des wass erdamptes bei tiefer temperatur." Schrif. Deutsch. Akad. Luftfahrtforschung, No. 37.

(15) Thomas, V. and P. Dupuis, 1906. "Sur quelques reactions du chlore liquide." Comptes Rend., 143:282-298.

(16) Fischer, W., and R. Gewehr, 1939. "Die thermischen Eigenschaffen von Halogenen." Z. Anorg. Allgem. Chem., 242:188-192.

(17) Mason, J. E., 1954. "An X-ray diffraction study of silver iodide aerosols." J. Appl. Phys. (in press).
(18) Schaefer, V. J., 1954. "Silver and lead iodides as ice-crystal nuclei." J. Meteor., 11:417-419.
(19) Facy, L., 1950. "Lex noyaux artificiels de congelation." J. Sci. Metéor., 2:7-18.
(20) Hosler, C. L., 1953. "On the influence of droplet radius and the nature of impurities present upon the freezing of water droplets in clouds." Presented at 120th Natl. Meeting of Amer. Meteor. Soc.
(21) Fournier, D'Albe, E. M., 1949. "Some experiments on the condensation of water vapour of temperatures below 0° C." Quart. J. R. Meteor. Soc., 75:1-14.

15. Birstein, Seymour J. (Air Force Cambridge Research Center). "The role of adsorption in heterogeneous nucleation, I: Adsorption of water vapor on silver iodide and lead iodide." Journal of Meteorology, 12(4):324-331. Aug. 1955. Manuscript rec'd Nov. 1, 1954.

Abstract: The adsorption of water vapor on silver iodide and lead iodide was measured to determine whether a relationship exists between the ability of a particle to take up water vapor on its surface and its nucleating ability. It was found that nucleating ability is closely linked with the capacity of a solid to adsorb water vapor on its surface. From the adsorption isotherms on the silver iodide and lead iodide at -20 C, and supplementary experiments, it was determined that it is not necessary for the nucleating system to go through water saturation before ice-crystal formation can occur.
References: (1) Vonnegut, B., 1947. "The nucleation of ice formation by silver iodide." J. Appl. Phys. 18:593.
(2) D'Albe, F., 1949. "Some experiments on the condensation of water vapor at temperatures below 0 C." Quart. J. R. Meteor. Soc., 75:1-14.
(3) Coulter, L. V., 1952. "A preliminary report on the adsorption of water vapor on silver iodide." Presented at meeting of Bunsen Gesellschaft, Berlin.
(4) Brunauer, S., P. Emmett, and E. Teller, 1938. "Adsorption of gases in multimolecular layers." J. Amer. Chem. Soc., 60:309.

16. Birstein, S. J. (Geophysics Res. Directorate, Air Force Cambridge Research Center, Air Research and Development Command, 230 Albany St., Cambridge, Mass.) "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." (Presented at the 114th Natl. Meeting of the American Meteorological Society, Jan. 1952.) American Meteorological Society Bulletin, 33(10) Dec. 1952.

Abstract: The effect of adsorbed water vapor on the photolysis of silver iodide has been studied. Inn found that when silver iodide nuclei are exposed to ultraviolet light before injection into a cold chamber containing a cloud of supercooled water droplets, no ice formation was observed. Reynolds, Hume, Vonnegut, and Schaefer investigated the effect of bright sunlight on the action of silver iodide as a sublimation nucleus, and found a decrease in the magnitude of nucleating effectiveness which was less than that observed by Inn.

Birstein's studies concerned the effect of relative humidity on the photolysis and subsequent nucleating properties of silver iodide particles. Known amounts of water vapor were introduced into a stream of nitrogen passing over a silver iodide generator. The silver iodide particles, covered with adsorbed water, were collected in a cell and exposed to ultraviolet light of known intensity for varying amounts of time. After irradiation, the silver iodide particles were injected into a cloud of supercooled water droplets and ice formation was observed. The nucleating effectiveness of silver iodide exposed to ultraviolet light was directly dependent on the relative humidity of the gas stream passing over the generator.

References: (1) Mott, N. F., and R. W. Gurney. 1948. "Electronic processes in Ionic Crystals." Sec. ed. Oxford Univ. Press, Chap. 7.

(2) Inn, Edward C. Y. 1951. "Photolytic inactivation of ice-forming silver iodide nuclei." Bulletin of the American Meteorological Society, 32(4), April 1951.

(3) Coulter, Lowell V. 1952. "A preliminary report on the adsorption of water vapor on silver iodide." Presented at a meeting of the Bunsen Gesellschaft, Berlin, Jan. 1952.

(4) Reynolds, S. E., William Hume II, Bernard Vonnegut, and Vincent J. Schaefer. 1951. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." Bulletin of the American Meteorological Society, 32(2), Feb. 1951.

(5) Vonnegut, Bernard, and Raymond Neubauer. 1951. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." Bulletin of the American Meteorological Society, 32(9), Nov. 1951.

(6) Reynolds, S. E., William Hume II, and Max McWhirter. 1952. "Effects of sunlight and ammonia on the action of silver iodide particles as sublimation nuclei." Bulletin of the American Meteorological Society, 33(1), Jan. 1952.

17. Birstein, S. J. (U.S.A.F. Cambridge Research Center, Cambridge, Mass.) "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." American Meteorological Society, Bulletin, 33(10):431-434, Dec. 1952.

Abstract: Laboratory experiments were conducted on the effect of relative humidity or adsorbed water vapor upon the photolysis and nucleating ability of AgI particles. In order to produce various degrees of relative humidity, known amounts of water vapor were introduced into a stream of nitrogen passing over a AgI generator. The particles ranging from 0.004 to 0.4 micron were irradiated by UV for varying times and injected into a cloud of supercooled water droplets. The results of experiments with varying degrees of relative humidity indicated that increasing relative humidity raises the resistance of AgI to destruction by UV light. A possible mechanism for the phenomenon was discussed.

18. Bolton, J. G. (Div. of Radiophysics, Commonwealth Scientific and Industrial Research Organization, Univ. Grounds, Sydney, NSW, Australia) and N. A. Qureshi (Pakistan Meteorological Dept. --at present at the Radiophysics Lab.) "The effects of air temperature and pressure on the decay of silver iodide." American Meteorological Society, Bulletin, 35(9):395-399. Nov. 1954.

Abstract: Experiments on the deterioration of silver iodide freezing nuclei produced with a kerosene burner are described. It is found that the number of particles effective as freezing nuclei decreases with time as does the rate of decay. The decay rate is critically dependent on the ambient air temperature, and to a lesser extent on the air pressure. The results suggest that for artificial rain making, silver iodide smoke released from the ground in warm climates is of little use, but may be very effective when released from high mountains or aircraft. References: Reynolds, S. E., W. Hume, B. Vonnegut, and V. J. Schaefer. 1951. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." Bulletin of the American Meteorological Society, Bulletin, 32(2):47. 1951.

(2) Inn, E. C. Y. "Photolytic inactivation of ice-forming silver iodide nuclei." Bulletin of the American Meteorological Society, 32(4):132. 1951.
(3) Vonnegut, B. and R. Neubauer. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." Bulletin of the American Meteorological Society, 32(9):356. 1951.
(4) Reynolds, S. E., W. Hume, and M. McWhirter. "Effects of sunlight and ammonia on the action of silver iodide smoke particles as sublimation nuclei." Bulletin of the American Meteorological Society, 33(1):26. 1952.
(5) Birstein, S. J. "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." Bulletin of the American Meteorological Society, 33(10):431. 1952.
(6) Smith, E. J. and K. J. Heffernan. "Airborne measurements of the concentration of natural and artificial freezing nuclei." Quart. Journal of the Royal Meteorological Society (at press).

19. Boucher, Roland J. "Operation overseed." (In: U. S. Advisory Committee on Weather Control, Final Report, pub. 1957, 2:127-136.)

Abstract: The purpose of "operation overseed" in the Mount Washington, (New Hampshire) area was to determine the effects produced in atmospheric clouds by AgI generators operated at minimum distances from the target clouds, and to obtain data on the dispersal and concentration in the free air, both clear and cloudy, of AgI released at some distance from the sampling point. The equipment, consisting of 28 AgI generators of the propane-acetone type and a cold box, and the operational technique are described with the aid of photographs and a map showing the experimental area and the location of the generators. The results of the 76 full scale seeding operations carried out between Sept. 16, 1955, and June 15, 1956, were judged according to the following criteria; Nuclei counts were made at Mount Washington Observatory, the cloud liquid water and drop size measurements at Mount Washington Observatory and visual observation made in the valley. The concentration of ice nuclei can be increased significantly at a distance up to 12 miles by AgI generators emitting about 10^{13} particles at -20° C. The nuclei are most effective in producing nucleation of supercooled clouds in the range of -4° C to -15° C. Concentration of artificial nuclei suggest that "overseeding" by "flooding" of supercooled clouds with nuclei is not feasible with generators having an output limited to 10^{13} particles per second at -20° C. Extreme stability of the atmosphere is a strong deterrent to

the vertical transport of artificial nuclei. AgI nuclei produced by the propane-acetone method appear to have a slow rate of decay. A summary of the data, photographs showing examples of glaciation of supercooled clouds, diagrams of nuclei counts, and operation maps are presented.

20. Bowen, E. G. (Division of Radiophysics, C. S. I. R. O., Sydney, Australia) "Induced precipitation (In: White, Gilbert F.,(ed.). "The future of arid lands." Washington, D. C., American Assoc. for the Advancement of Science, 1956, p. 291-299.)

Abstract: Experimental studies were conducted to determine whether AgI remains effective as a freezing nucleus when exposed in the atmosphere and whether it can attain the required height which, in summer, may be between 14,000 and 20,000 feet. The studies of Smith and Heffernan and Bolton and Qureshi indicate AgI released from aircraft operating at moderately high altitudes shows a moderately low decay rate and is already at an effective height, and that ambient temperature is the most important single factor controlling decay rate. A review of studies on the influence of meteoric dust on rainfall is presented.

21. Braham, Roscoe, R., Jr. (Cloud Physics Lab., Univ. of Chicago). "Phloroglucinol seeding of undercooled clouds." Journal of the Atmospheric Sciences, Boston, 20(6):563-568. Nov. 1963. Also issued as: Chicago Univ., Dept. of the Geophysical Sciences, Technical Note, No. 26, April 1963, 36 p.

Abstract: A series of 12 releases of phloroglucinol were made into stratus clouds at temperatures of - 7 C to - 17 C. Showers produced by dry ice seeding were used to identify particular spots in the layer clouds from which the exact locations of the phloroglucinol releases could be obtained by simple navigation. Visual observations of the cloud behavior and for form variation replicas of cloud and precipitation particles provided a means for judging the effects of the phloroglucinol. It was concluded that phloroglucinol induced the formation of ice in undercooled clouds; however, in these experiments it was not nearly as effective as dry ice in causing shower formation.

22. Bryand, G. W. and Mason, B. J. (Imperial College, London). "Photolytic de-activation of silver iodide as an ice-forming nucleus." Quarterly Journal of the Royal Meteorological Society, Ed. J. S. Sawyer, 86(369):354-357. July 1960.

Abstract: The rate at which the ice-nucleating ability of silver iodide decays when irradiated with the equivalent of strong sunlight has been determined by measuring the density of oriented ice crystals appearing on single crystals of silver iodide after various periods of exposure to a mercury arc lamp. Wavelengths greater than 4,400 Å cause very little photolysis and decay of nucleation. The ice crystal density decreases 10 to 20 fold after the silver iodide has been exposed to the equivalent of one hour's strong sunlight. This result is in fair agreement with the findings of the Australian workers where the activity of silver iodide smoke falls by 1 to 2 orders of magnitude after one hour in the atmosphere in sunlight.

23. Burley, G. and Herrin, D. W. (student trainee-summer, 1961) (Natl. Bur. of Standards). "Effect of additives on silver iodide particles exposed to light." Manuscript rec'd 16 Jan. 1962. (This work was supported by the Natl. Sci. Foundation under grant no. G9456.) Journal of Applied Meteorology, 1(3):355-356. Sept. 1962.

Abstract: A number of available compounds were tested for their ability to inhibit the deteriorating effect of light on the ice-nucleating properties of silver iodide. They were evaluated by a comparison of the powder x-ray diffraction diagrams before and after irradiation. A characteristic change of the diffraction profile occurs for silver iodide, which was completely suppressed by a number of additives. A total of 18 compounds were grouped into 3 different ranges of effectiveness.
References: (1) Alexander, P. and D. J. Toms. 1958. "Protection provided by added substances against the direct action of ionizing radiations." Radiation Research 9:509-524.
(2) Birstein, S. J. 1952. "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." Bull. Amer. Meteor. Soc., 33:431-434.
(3) Horwitz, L. and J. S. Friedman. 1955. "Desensitizers and structures of desensitizing agents." Photo. Sci. Tech., 2:68-75.
(4) Inn, E. C. Y. 1951. "Photolytic inactivation of ice forming silver iodide nuclei." Bull. Amer. Meteor. Soc., 32:132-135.

(5) Mees, C. E. K. 1954. "The theory of the photographic process." New York, Macmillan Co., Chap. 11, Sensitizing and desensitizing dyes, 371-429.
(6) Reynolds, S. E., W. Hume, B. Vonnegut, and J. V. Schaefer. 1951. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." Bull. Amer. Meteor. Soc., 32:47.
(7) Reynolds, S. E., W. Hume, and M. McWhirter. 1952. "Effects of sunlight and ammonia on the action of silver iodide particles as sublimation nuclei." Bull. Amer. Meteor. Soc., 33:26-31.
(8) Smith, E. J., H. J. Heffernan, and B. K. Seely. 1955. "The decay of ice-nucleating properties of silver iodide in the atmosphere." J. Meteor., 12:379-385.
(9) Smith, E. J., K. J. Heffernan, and W. J. Thompson. 1958. "The decay of the ice-nucleating properties of silver iodide released from an aircraft." Quart. R. J. Meteor. Soc., 84:162-165.
(10) Vonnegut, B. 1950. "Techniques for generating silver iodide smoke." J. Colloid Sci., 5:37-48.
(11) Vonnegut, B., and R. Neubauer. 1951. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." Bull. Amer. Meteor. Soc., 32:356.

24. Chao, Po-ling (Peking Univ.). "Study of the mechanism of ice particle formation and of the process of evaporation of dry ice in supercooled clouds." Acta Meteorologica Sinica (Chi Hsiang Hsüeh Pao), Peking 34(1):87-93. 1964. In Chinese. Chinese summary, p. 87, Russian summary, p. 93.

Abstract: The mechanism of formation of ice particles during evaporation of dry ice is examined. The results agree with experimental data.

25. Chattopadhyay, N. N. (Jadavpur Univ.). "On the effect of continuous diffusion of salt nuclei into the atmosphere on local rainfall." Indian Journal of Meteorology and Geophysics, Delhi, 15(3):381-392, July 1964.

Abstract: It is generally recognized that the presence of salt nuclei in clouds has a powerful influence on rain formation. This was a study to find out if continuous diffusion of salt nuclei into air from a powerful atomizer, placed at a height of 60 feet above ground, fed by salt solution, and worked by compressed

air at 20 atmospheres, would have any effect on local rainfall. Experiments were undertaken at the Jalarpur University in 1958 and 1959. The atomizer was kept in continuous action throughout the daylight hours April to October 1958, and July to October 1959. During 1958 and 1959, West Bengal had deficient Monsoon rainfall. The departures of rainfall, from the normal in each of the months during the experiments were plotted and the lines of equal departures were drawn. These showed that the curves of least negative departures, and in some cases highest positive departures, were generally oval-shaped extending from north of Calcutta to about 100 miles toward the prevailing wind direction in all months during the experiments. This area came under the influence of the salt nuclei which permeated into the air, and a fair proportion of which reached cloud levels after a travel of a short distance from South Calcutta. This factor may have contributed to the increase in rainfall.

26. Chuvaev, A. P. "Characteristics of the method of influencing convective clouds by dry ice in order to produce precipitation." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, 72:110-117, 1952.

Abstract: Based on an experiment June 1, 1956, in the Kiev Region, the author describes an effective method of seeding small particles of solid CO_2 at the rate of 2.0 - 2.5 kg per Km flight in the crest of convective clouds, and obtaining substantial precipitation even when the lower cloud limit is relatively high (2000 m), the vertical development is not great (2000 m), and the upper cloud limit reaches only the lower boundary of the effective supercooling zone. The paper concludes with the assertion that although cumulus clouds often have no icing in their tops and do not produce natural precipitation, they can be easily triggered by appropriate methods of seeding.

27. Cochet, Robert. "Growth of a charged water droplet in a cloud at temperatures above freezing." Annales de Géophysique, Paris, 8(1):33-54, Jan./March 1952. English Summary, p. 33, Shorter version in: Académie des Sciences, Paris, Comptes Rendus, 233(2):190-192. July 9, 1951.

Abstract: Expressions are derived for the growth of water droplets as a function of their size and electric charge. Results are graphically presented. Small droplets with a high electric charge grow most rapidly within short trajectories. Thus

droplets with a diameter of 30 μ, if sufficiently charged, show the same properties in growth as uncharged droplets of 120 μ diameter. The use of charged droplets for cloud seeding purposes is advantageous because a small amount of the seeding agent is sufficient.

28. Corrin, M. L.; Edwards, Harry W.; and Nelson, John A. (all, Univ. of Ariz., Tucson). "Surface chemistry of condensation nuclei, Pt. 2, the preparation of silver iodide free of hygroscopic impurities and its interaction with water vapor." Journal of the Atmospheric Sciences, Boston, 21(5):565-567, Sept. 1964.

Abstract: AgI was prepared in finely divided form by the reaction in Vacuo between metallic silver and iodine and subsequent treatment with liquid ammonia. The compound thus prepared is considerably more stable toward sunlight than is AgI prepared by precipitation. (The latter form contains a small amount of hygroscopic contaminant.) Adsorption isotherms of water at 30° C have been measured on AgI prepared by direct reaction and on material prepared by precipitation. The isotherm on the latter material is essentially type III. This is characteristic of cooperative adsorption on a hydrophobic surface. The isotherm on the salt prepared by the direct reaction is almost linear and does not fit into the Brunauer classification. The amount of water adsorbed per unit surface area at relative pressures exceeding 0.5 is considerably greater on the contaminated AgI. The results are discussed in terms of the surface properties of pure AgI as they affect the nucleation of ice from supercooled water vapor.

29. Corrin, M. L. and Storm, Nancy S. (both, Dept. of Chem., Univ. of Ariz., Tucson). "Surface chemistry of condensation nuclei, Pt. 1, The sintering of silver iodide." Journal of Physical Chemistry, Easton, Pa., 67(7):1509-1511, July 1963.

Abstract: Several methods for the preparation of finely divided reasonably pure AgI were investigated. The most satisfactory involved the solution of precipitation AgI in liquid NH_3 and the removal of the NH_3 under anhydrous conditions. Specific surface areas on the order of 0.6 m^2/g thus were obtained. The surface area was found to decrease slowly with time at room temperature. The area was reduced by a factor of 30 on gentle grinding. All samples investigated were contaminated

to some extent with NH_4NO_3. The rate of change of surface area with time at 77, 100, and 125° was determined. The rate data could be fitted to a second order rate equation if it were assumed that only 62 percent of the surface was involved in the sintering process. Activation energy for the sintering process was on the order of 16 K cal/mole. The extreme lability of the AgI surface is pointed out.

30. Coulter, Lowell Vernon; Kland-English, Malhilde June; and Zdanuk, Edward. "The role of surface forces in water vapor adsorption on foreign nuclei. The adsorption of water vapor on silver iodide." Boston Univ., Contract AF19(122)-361, Report No. 4, Dec. 3, 1951.

Abstract: The 34° F adsorption isotherm of water on AgI has been completed. The isotherm exhibits a sharp rise in adsorption at $P/P_o \simeq 0.5$ which is tentatively regarded as an indication of the coexistence of two phases in a localized monolayer.

31. Davies, D. A.; Hepburn, D.; and Sansom, H. W. "Report on experiments at Kongwa on artificial control of rainfall, Jan. - April 1952." East Africa High Commission. Meteorological Dept. Memoirs, 2(10):14, 1952.

Abstract: A series of rain-making experiments conducted at Kongwa, Tanganyika, during Jan. through April 1952 are described, and the results are presented in graphic form. Both AgI and hygroscopic particles in water drops consisting of sea salt and calcium chloride were used as seeding agents and their dispersal was effected by means of balloons. The theoretical basis for the use of hygroscopic particles to induce rainfall is discussed, and the method of releasing the seeding agent, the preparation of the balloon charges for the AgI and hygroscopic mixtures, and the general weather conditions during the experiments are described. It was found: 1) "that on days when AgI and hygroscopic particles were released the total rainfall in the area of release, on both sets of days, was substantially less than on days when no experiments were conducted; the number of days in each of the three sets of days being the same; 2) on days when hygroscopic particles were released, the total area in the rainfall 6 - 12 miles downward from the area of release was substantially greater than the total rainfall in the same area on days when no experiments

were conducted; and 3) in some cases the release of hygroscopic particles into small cumulus clouds resulted in their complete dispersal."

32. Davies, D. A. "Artificial stimulation of rain at Kongwa." Nature, London, 167(4250):614-615, April 14, 1951.

Abstract: This report describes two methods used in East Africa to produce particles of AgI, burning charcoal impregnated with acetone solution of AgI, and exploding small charges of impregnated gunpowder. The charges are carried by hydrogen balloons into suitable clouds and released at freezing level by time fuses.

33. Dessens, H. and Soulage, G. "New experiments on precipitation from supercooled clouds, winter 1953/54." Puy de Dôme Observatoire, Bulletin, No. 2:43-52, April/June 1954.

Abstract: During the winter of 1953-1954, when dense and stable stratus clouds were over the Puy de Dôme Observatory, wood charcoal impregnated with silver iodide was burned from 1600 to 2600 hours. Small crystals were precipitated. These crystals were hexagonal plates. Similar results were obtained on other occasions with stratocumulus clouds. Such clear cut results were not obtained with the use of dry-ice. A possible explanation of nucleation with silver iodide and observations on natural precipitations from supercooled stratus are discussed.

34. Downie, Currie S. "Cloud modification with carbon black." Conference on Cumulus Convection. 2nd, Portsmouth, N. H., May 1959, Proceedings, Pub. N. Y., Pergamon Press, 1960, p. 191-209.

Abstract: Experiments by several investigators are described wherein fine particles of carbon black were dispersed in clouds to cause dissipation, and in clear air near the natural condensation level to form clouds. Calculations show that appreciable heating by the absorption of solar radiation can occur, and that the optimum size of the carbon particle is about 0.13 μ diameter. The results so far are inconclusive, but seem to indicate that limited cloud modification is possible. Systematic comprehensive observations of a randomized modification program are recommended, using comparatively

large quantities of carbon black to evaluate the potential of the solar energy conversion techniques for dissipating warm fog and stratus, small or medium cumulus clouds, and for producing cumulus convection during clear days.

35. du Chaxel, Raoul. "First experiments with artificial rainfall in French Equatorial Africa." French Equatorial Africa Service Météorologique, Publication No. 2, July 1955, 67 p.

Abstract: Experiments used a mixture of 90 percent anhydrous NaCl, 10 percent pure $CaCl_2$ and 0.25 percent $MgCl_2$, pulverized and heated with infrared rays, with diameter from 75 to 125 μ and kept for 36 hours at 115° C, then vibrated for 5 hours and reheated for 84 hours to produce crystals of the form of talc, with 1 to 100 μ size and mean size of 5 μ (much smaller than those used at Kongwa and Madagascar). Preparation at the ground and release from an airplane was described. Location of the Basin (Dimonika) and procedures on the systematic tests of May 11, 12, and 14, 1954, inside and outside the Dimonika Basin on May 11 and 13 (14 tests in all) and occasional tests on June 14, 1954, at Brazzaville, Aug. 3, 1954 at Bangui and on October 6, 1954 at Brazzaville were described in detail with synoptic and upper air conditions outlined for each of the 21 tests. Effect of altitude of seeding was also considered in tests No. 18 and 20. Similar treatment is given to the 18 tests made in Oct. - Dec. 1954 at Niari and 4 in Feb. - March, 1955 at Malodo. Methods of analysis, primary or immediate, and secondary effects were analyzed and the results of water seeding tabulated for 14 cases, and for the 29 cases where salt was used; both segregated according to St Cu and Cu clouds. Charts show local results on river basins and diagrams show changes in Cu cloud development with height in relation to adiabatic temperature curve. Seven cases failed to produce visible results owing to reasons given. Of the 21 Cu clouds seeded with salt, 13 produced rain, one virga, six dissipated the cloud, and one produced no reaction, of the four Cu seeded with water, all produced rain, of the St Cu seeded with water, four produced precipitation, one virga, four produced secondary reaction and one partially dissipated. Of the six St Cu seeded with salt, one gave large drops, three produced secondary reactions and two could not be observed. Results were observed in every case within 16 minutes, and often within three minutes. Seeding at 300 m above base of cloud (with salt) is recommended.

36. Eadie, William J.; and Mee, Thomas R. (both, Cornell Aeronautical Lab., Inc. of Cornell Univ.). "Effect of dry-ice pellet velocity on the generation of ice crystals." Journal of Applied Meteorology, Boston, 2(2):260-265, April 1963.

Abstract: The influence of fall velocities of dry-ice pellets on the nucleation of slightly supercooled clouds is discussed and the conditions necessary for the production of ice crystals are examined. A theoretical argument is presented, which suggests that when cloud temperatures are warmer than about - 5 C, the number of ice crystals produced by a pellet of dry ice moving at its terminal velocity decreases rapidly as the temperature approaches 0 C. In contrast to the pellet moving at terminal velocity, it is shown that the ice-crystal productivity of a slow moving pellet remains high up to 0 C. An experimental verification of this predicted dependence upon pellet velocity is described, data are presented, and the implications of these findings for future seeding experiments are discussed.

37. Edwards, G. R.; and Evans, L. F. "Effect of surface charge on ice nucleation by silver iodide." Faraday Society, London, Transactions, 58(8):1649-1655, Aug. 1962.

Abstract: The ability of silver iodide to nucleate ice in supercooled droplets of aqueous solutions has been studied as a function of the concentration of the potential-determining ions, Ag^+ and I^-, in the droplets. In order that the results should not be influenced by variations in equal number of individual silver iodide particles of known size. Nucleation was least efficient when the silver iodide was highly charged. The proposed explanation being that ice, growing on a charged substrate, is ordered by the electric field and therefore is more difficult to nucleate than unordered ice.

38. Edwards, G. R.; Evans, L. F.; and LaMer, V. K. (all, CSIRO, Melbourne, Australia). "Ice nucleation by monodisperse silver iodide particles." Journal of Colloid Science, N. Y., 17(8):749-758, October 1962.

Abstract: By preparing silver iodide particles in a monodisperse form it has been shown that particles of the same size are not equally active as ice nuclei, but behave as if the number of nucleation sites per particle is proportional to the surface area of the particle. This finding has made it possible to calculate

the probability that a particle of given size shall contain at least one nucleation site active at a given temperature.

39. Edwards, G. R.; and Evans, L. F. (CSIRO, Melbourne, Australia). "Ice nucleation by silver iodide: II Collision efficiency in natural clouds." Manuscript rec'd March 23, 1961. Journal of Meteorology, 18(6):760-765. December 1961.

Abstract: An attempt has been made to estimate the contribution of diffusiophoresis to the collision rate between silver iodide nuclei and cloud droplets growing under conditions simulating those in a natural cumulus cloud. Diffusiophoresis is shown to be of no practical importance and consequently certain limitations have been placed on the use of silver iodide as a cloud seeding agent.

References: (1) Derjaguin, B. V. 1956. "Movement of aerosol particles in a diffusion field." Dok A Kad. Nauk SSSR, 106:851-854.
(2) Edwards, G. R. and L. F. Evans. 1960. "Ice nucleation by silver iodide: Part I." J. Meteor. 17:627-634.
(3) Facy, L., 1955. "Kinetic capture of aerosols in the process of condensation." Arch. Meteor. Geophys. Bioklim, A., 8:229-236.
(4) Junge, C. E., 1955. "Remarks about the size distribution of natural aerosols. Artifical stimulation of rain." N. Y., Pergamon Press, p. 3.
(5) Picca, R. 1959. "De-activation of silver iodide ice nuclei." Trav de l' Inst. Sci. Chem. Phys. Sci., 4:1-74.

40. Edwards, G. R. and Evans, C. F. (Commonwealth Scientific and Industrial Research Organization, Melbourne, Australia). "Ice nucleation by silver iodide: I. freezing vs. sublimation." Manuscript rec'd April 1, 1960, Journal of Meteorology, 17(6):627-634. 1960.

Abstract: The ability of silver-iodide particles to act as ice nuclei was studied under controlled conditions of temperature and humidity. Particles up to 100 Å in radius are largely ineffective as ice nuclei unless the relative humidity exceeds 110 percent. Consequently, in natural clouds where the relative humidity rarely exceeds 101 percent, such particles will only be useful if they collide with cloud droplets.

An apparatus was developed which allows the number of ice nuclei in an aerosol to be counted with a probable error of less

than 10 percent. The particular advantage of this apparatus is its continuity of operation, which enables one to count either a rapid succession of aerosol samples or, if the fall-out is prolonged, to follow the variation of fall-out with time.

The delayed appearance of ice crystals in a cold chamber is not due to a time lag in the nucleation process, but to the time required for aerosol particles to collide with cloud droplets or to migrate to more humid regions of the cloud chamber where condensation can take place on each particle.

The activity, as a freezing nucleus, of the silver iodide described herein is much greater than that found by previous authors, particles of radius 75 Å being active at - 8 C.

References: (1) Bigg, E. K., 1956. "Counts of atmospheric freezing nuclei at Carnavon, Western Australia, Jan. 1956." Austral. J. Phys., 9:561-565.

(2) Birstein, S. J. 1955. "The role of adsorption in heterogeneous nucleation." J. Meteor., 12:324-331.

(3) Cwilong, B. M., 1949. "Sublimation in outdoor air and seeded sublimation." Nature, 163:727-728.

(4) Facy, L., 1957. "Displacement of aerosols in a vapour pressure gradient." J. Meteor. Soc., Japan, 75th Anniv. Vol. (Nov.) 15 - 24.

(5) Fletcher, N. H., 1958. "Size effect in heterogeneous nucleation." J. Chem. Phys., 29:572-576.

(6) Fletcher, N. H., 1959. "erratum to Fletcher, (1958)," J. Chem. Phys., 31:1136.

(7) Fletcher, N. H., 1959. "On ice crystal production by aerosol particles." J. Meteor., 16:173-180.

(8) Fournier, D'Albe, F., 1949. "Some experiments on the condensation of water vapour at temperatures below 0^{o} C." Quart. J. R. Meteor. Soc., 75:1-14.

(9) Green, H. L., and W. R. Lane, 1957. "Particulate clouds." London (Spon.) p. 130.

(10) Howell, W. E., 1949. "The growth of cloud droplets in uniformly cooled air." J. Meteor., 6:134-149.

(11) Junge, C. E., 1955. "Remarks about the size distribution of natural aerosols, in artificial stimulation of rain." New York, Pergamon Press, p. 3.

(12) Mason, B. J. 1959. "Recent developments in the physics of rain and rainmaking." Weather, 14:81-97.

(13) Mossop, S. C., 1956. "Sublimation nuclei." Proc. Phys. Soc. - B, 69:161-164.

(14) Reiss, H., 1950. "Time lag in the nucleation of super-cooled clouds by silver iodide smokes." J. Chem. Phys., 18:529-533.

(15) Schaefer, V. J., 1954. "Silver and lead iodides as ice crystal nuclei." J. Meteor., 11:417-419.

(16) Schiff, D. C., H. I Schiff, and P. R. Gendron, 1953. "Use of a diffusion cloud chamber to characterize condensation nuclei." Canadian J. Chem., 31:1108-1117.
(17) Smith, E. J., and K. J. Heffernan, 1954. "Airborne measurements of the concentration of natural and artificial freezing nuclei." Quart. J. R. Meteor. Soc., 80:182-197.
(18) Smith, E. J., K. J. Heffernan, and W. J. Thompson. 1958. "The decay of the ice-nucleating properties of silver iodide released from an aircraft." Quart. J. R. Meteor. Soc., 84:162-165.
(19) Vonnegut, B., 1949. "Nucleation of supercooled water clouds by silver iodide smokes." Chem. Rev., 44:277-289.

41. Ehrenberg, Wolfgang, W. "Contribution to the problem of ice formation in clouds." Archiv für Meteorologie, Geophysik und Bioklimatologie, Ser. A, 5(2):158-165, 1952. German, English, and French Summaries, p. 158.

Abstract: By spraying the glass of a container with paraffin or smearing it with vaseline, distilled water drops could be supercooled to -10^{o} C. A method of finding total surface of fine particles is described. Supercooling at formation of ice nuclei increased with log (total surface) of quartz pampa dust, cellulose, volcanic ash, or charcoal. AgI prepared by various methods gave rather similar results, so that chemical composition is less important than surface area. An effective area is 1/20 cm^2per/cm^3 water. The energy of agitation determines the probability of ice nuclei formation. Theoretical implications are discussed.

42. Facy, L. (Météorologie Nationale, Paris). "Freezing effectiveness of silver iodide nuclei." Geofisica Pura e Applicata, Milan, 40:227-234. 1958. French and English Summaries, p. 227.

Abstract: The author first recalls the ideal physicochemical properties for ice forming nuclei, and with particular reference to silver iodide he observes that, despite its very weak solubility, there is a critical dimension of the nuclei below which they are ineffectual, owing to the fact that they dissolve when introduced into clouds at positive or weakly negative temperatures. As a result, contrary to the techniques used up til now, it is not advisable to try to obtain dispersion with a high output, since the number of nuclei measured in the laboratory or in the cold chamber, does not represent the effectiveness of the nuclei introduced, for instance, from the ground into a cloud of positive temperature.

For seeding techniques, a dimensional optimum should be respected, taking into consideration both solubility and the photochemical or purely chemical de-activation.

43. Falconer, Raymond E. and Vonnegut, Bernard. "Smoke from smelting operations as a possible source of silver iodide nuclei." General Electric Research Laboratory, Occasional Report No. 4, Project Cirrus. Schenectady, July 15, 1948. 4 p.

Abstract: Possibility that silver iodide from smelter stacks might increase rainfall investigation by comparing rainfall data for Utah with data 1896 - 1946 for states west of Rocky Mts. and years with high smelter production with years of low production in regard to anomalies of precipitation. No significant correlation could be found.

44. Fletcher, N. H. (CSIRO Radiophysics Lab, Sydney, Australia). "A descriptive theory of the photodeactivation of silver iodide as an ice crystal nucleus." Original manuscript rec'd Sept. 30, 1958; revised manuscript rec'd Jan. 16, 1959. Journal of Meteorology, 16(3):249-255. June 1959.

Abstract: The photo deactivation of silver iodide as an ice crystal nucleus is ascribed to the production of photolytic silver at trapping centers in the volume and on the surface of the nucleating particle. Silver produced at the surface raises the free energy of the interface between the nucleus and ice and so reduces the activity of the particle. The rate of deactivation is found to depend upon the size of the particle, and thus the size distribution of particles in a smoke has a strong influence upon its decay behavior. Calculations on the basis of this theory explain the wide variations in the decay rate reported in different experiments.
References: (1) Smith, S. J.; Heffernan, K. J.; and Seely, B. K. 1955. "The decay of ice-nucleating properties of silver-iodide in the atmosphere." J. Meteor. 12:374-385.
(2) Smith, E. J. and Heffernan, K. J. 1956. "The decay of the ice nucleating properties of silver iodide released from a mountain top." Quart. J. R. Meteor. Soc., 82:301-309.
(3) Smith, E. J.; Heffernan, K. J.; and Thomson, W. J. 1958. "The decay of the ice nucleating properties of silver iodide released from an aircraft." Quart. J. R. Meteor. Soc., 84:162-165.
(4) Reynolds, S. E.; Hume, W.; Vonnegut, B.; and Schaefer, V. J. 1951. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." Bull. Amer. Meteor. Soc., 32, 47.

(5) Inn, E. C. Y., 1951. "Photolytic inactivation of ice forming silver iodide nuclei." Bull. Amer. Meteor. Soc., 32:132-135.
(6) Vonnegut, B. and R. Neubauer, 1951. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." Bull. Amer. Meteor. Soc., 32:356.
(7) Reynolds, S. E., W. Hume, and M. McWhirter, 1952. "Effects of sunlight and ammonia on the action of silver iodide particles as sublimation nuclei." Bull. Amer. Meteor. Soc., 33:26-31.
(8) Birstein, S. J., 1952. "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." Bull. Amer. Meteor. Soc., 133:431-434.
(9) Fletcher, N. H., 1959. "On ice-crystal production by aerosol particles." J. Meteor., 16:175-182.
(10) Fletcher, N. H., 1958. "Size effect in heterogeneous nucleation." J. Chem. Phys., 29:572-576.
(11) Mitchell, J. W., 1955. "The photographic process, Chemistry of the solid state." ed. by W. E. Garner, London Butterworth's Pub., 311-335.
(12) Van de Hulst, H. C., 1957. "Light scattering by small particles." N. Y., Wiley Publ. Co. 276.
(13) Seitz, F., 1951. "Speculations on the properties of the silver halide crystals." Revs. Mod. Phys., 23:328-352.
(14) Koller, L. R., 1952. "Ultraviolet radiation." N. Y., Wiley Pub. Co., 106-139.
(15) Fletcher, N. H., 1959. "Optimum performance of silver iodide generators." J. Meteor., to be publ., Aug. 1959.
(16) Mason, B. J. and J. Hallett, 1956. "Artificial ice-forming nuclei." Nature, 177:681-683.
(17) Pruppacher, H. R. and R. Sänger, 1955. "Mechanismus der Vereisung Unter Kühlter Wassertropfen durch disperse Keimsubstanzen." Zeitsf ang Math. u. Phys. 6:407-416.
(18) Smith, E. J. and K. J. Heffernan, 1954. "Airborne measurements of the concentration of natural and artificial freezing nuclei." Quart. J. R. Meteor. Soc., 80:182-197.
(19) Sano, I. and N. Fukuta, 1956. "Effects of water vapour, ammonia, and hydrogen sulphide against the decay of silver iodide smoke under irradiation of ultraviolet light." J. Meteor. Soc., Japan, Series II, 34:34-40.

45. Fournier d' Albe, E. M., (Inst. de Ciencias Aplicadas, Univ. Nac'l de Mexico). "Cloud-seeding trials using common salt." (In: Conference on the physics of cloud and precipitation particles, Sept. 1955, Proceedings, Pub. N. Y., Pergamon Press, 1957, p. 207-212.

Abstract: Results of NaCl seeding in 1954 by the Pakistan Meteorological Service are analyzed, discussed, and illustrated. Cloud bases were usually about 20° C, so it was assumed clouds were of the warm type. Seeding from ground generators at Lahore was carried out from July 16 to September 15, 1954, on 39 days out of 61 (some seeding was done at Jauharabad in the Tahl District, 210 km WNW of Lahore). Seeding was attempted only when winds were easterly and low clouds visible from the station. Results of a comparison of seeding areas with control area (upwind) show an increase of precipitation in 1954 compared with control area precipitation for 1901 - 1942. Results and significance thereof are discussed at length.

46. Fukuta, N. (Present affiliation: Met. Res. Inc., Altadena, Calif.), K. J. Heffernan, W. J. Thompson, and C. T. Maher (Radiophysics Lab., CSIRO, Sydney, Australia). "Generation of metaldehyde smoke." (This paper was presented in abridged form at the International Conf. on Cloud Physics, Tokyo and Sapporo, 1965.) Manuscript rec'd Dec. 10, 1965. Journal of Applied Meteorology, 5(3):288-291. June 1966.

Abstract: A technique has been developed for generating fine particles of metaldehyde for possible use in nucleating ice in supercooled clouds. The number of particles effective as ice nuclei is 10^{12} gm^{-1} at -12 C and 6 x 10^{9} gm^{-1} at - 4 C. Attention is drawn to the unusual rapidity with which concentrated metaldehyde smokes coagulate. The evaporation of the particles has also been studied.
References: (1) Fukuta, N., 1963. "Ice nucleation by metaldehyde." Nature, 199:475-476.
(2) Green, H. L. and W. R. Lane, 1957. "Particulate clouds: Dusts, smokes, and mists." London, E. and F. N. Spon Ltd., p. 33.
(3) Pauling, L., and D. C. Carpenter, 1936. "The crystal structure of metaldehyde." J. Amer. Chem. Soc., 58:1274-1278.

47. Fukuta, N. (Radiophysics Lab., CSIRO, Sydney). "Ice nucleation by metaldehyde." Nature, London, 199(4892):475-476, Aug. 3, 1963.

Abstract: Experiments show that metaldehyde (CH_3 CHO_4), a cyclic tetramer of acetaldehyde, can be used as an ice nucleating material. Under suitable conditions ice crystals could be produced at temperatures as high as - 0.4° C. At lower

temperatures the metaldehyde was not quite as efficient as silver iodide smoke. The nucleating properties of the metaldehyde was found to be unaffected by its exposure to sunlight at temperatures below 33° C. At temperatures above 55° C the nucleating property was found to disappear quickly in sunlight. Metaldehyde is therefore considered to be a preferred material for cloud seeding studies. Possible explanations for the observed nucleating ability is sought in terms of the molecular and crystal structure.

48. General Electric Res. Lab., Schenechtady, N. Y. "Project cirrus." Contract DA-36-039-Sc-15345, Second Quarterly Progress Report; Quarterly Progress Report on Project Cirrus, No. 17, Jan. 31, 1952.

Abstract: In this report prepared by V. J. Schaefer, a list of the six active members on the project is presented. Investigation on large scale cyclic periodicities in weather, on ice nuclei, on ice crystals formed by sudden expansion of air and on silver iodide nuclei exposed to ultraviolet radiation is briefly summarized. Instruments used during the period covered by the report include cloud chamber, flame particle detector, flight instruments, and airborne silver iodide generator.

49. Gromova, T. N. and Krasikov, P. N. "Study of ice-forming properties of silver iodide and lead iodide solutions." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 176:25-34, 1965, Russian Summary, p. 25.

Abstract: The results of laboratory experiments on the ice forming properties of water solutions of AgI and PbI_2 when dispersed in supercooled clouds are presented. The experimental apparatus and procedure are described. Water solutions of PbI_2 cause crystallization of supercooled fog at temperature of - 5° C, - 7° C and lower. The number of ice crystals formed depends upon the concentration of the solution. The optimum concentration for modification is 0.06 percent; the formation of ice crystals per 1 gm of PbI_2 occurring at a temperature of - 10° C is 10^{12} and at a temperature of - 15° C it is 10^{13}. Solutions of PbI_2 produce a somewhat smaller number of ice crystals than colloidal solutions of AgI; but because of the delay and prolongation of the ice forming properties of PbI_2 in comparison with those of AgI, the laboratory experiments with solutions of PbI_2 were somewhat low.

50. Gromova, T. N. et al. "Experiments in treating supercooled clouds with aqueous solutions of lead iodide." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 126:16-21, 1962. Russian summary p. 16. Transl. into English as U. S. Joint Publications Research Service, JPRS No. 18,696, April 15, 1963, p. 20-28.

Abstract: The results of experiments on the effect of aqueous solutions of PbI_2 upon a supercooled cloud introduced from an aircraft were examined. The manner in which the PbI_2 was introduced into the clouds is described. When solutions of PbI_2 were introduced into cumulus clouds, with a thickness of 2 km and more at a temperature below 7° C, precipitation was produced in all the trials. By vaporizing solutions of PbI_2 in continuous stratocumulus cloud with a thickness of 200 - 400 m it was possible to dissipate them at a temperature below - 15° C. When the temperature was around - 20° C an effect of cloud dissipation similar to that following the vaporization of PbI_2 was observed with pure water.

51. Halsey, George D., Jr.; Karasz, Frank E.; Piero Hi, Robert A. et al. "The structure of absorbed multilayers." Washington State Univ., Dept. of Chemistry, Contract AF19(604):247, Final Report, 1955. 70 p.

Abstract: This document contains several reports of research conducted at the University of Washington, Seattle, on the following: the adsorption of argon in xenon layers, the solution of argon in layers of krypton, the growth of crystalline layers on foreign surfaces, a new multilayer isotherm with reference to entropy, the interaction of rare gas atoms with surfaces, the interaction of gas molecules with capillary and crystal lattice surfaces, the interaction of pairs of gas atoms with surfaces, heats of adsorption in pre-adsorbed xenon layers, regular solution theory applied to other systems, and the research on the adsorption of pre-adsorbed layers of polar molecules. The last section describes the preliminary results of the method developed to the growth of layers of ice on anatase and silver iodide. The result is that silver iodide appears to be completely incompatible with the ice structure at low temperatures. The meteorological interpretation of this result is not included in this report.

52. Hoffer, Thomas E. and Ogne, Marshall, L. (Both, Lockheed California Co., Burbank). "Difference in the behavior of phloroglucinol and silver iodide nuclei." Journal of Geophysical Research, Washington, D. C., 70(16):3857-3860, Aug. 15, 1965.

Abstract: Large particles of AgI and phloroglucinol ($C_6H_3(OH)_3 \cdot 2H_2O$) agents commonly used in weather modification, were subjected in the laboratory to a modeled condensation process to determine whether their ability to serve as ice-forming nuclei was altered. A difference was observed. After being wetted and redried at temperatures above 0° C, AgI nuclei were observed to be less effective whereas ($C_6H_3(OH)_3 \cdot 2H_2O$) nuclei were more effective. The experimental techniques, equipment, and procedure are described.

53. Howell, Wallace E. "Conceptual models that guide applied cloud seeding." Bulletin of the American Meteorological Society, 47(5):397-400, May 1966. (W. E. Howell Associates, Inc., Lexington, Mass.) Paper presented at the Reno Meeting of the American Meteorological Society, 21 October 1965.

Abstract: Natural precipitation is the consequence of natural cloud seeding. Cloud seeds are particles whose significant property is their ability to acquire water or ice from clouds under certain circumstances and thereby grow large enough to fall. In attempting to extend man's power over nature, he has learned how to produce cloud seeds by several means, among which the following are those that enter into this particular account:

a) Dry ice dropped into supercooled clouds, where the falling fragments leave behind trails of natural ice particles of very small size.

b) Silver iodide particles released from generators, for the most part ground-based, that produce about 10^{12} particles per second active as ice-forming nuclei at - 10 C.

c) Water spray in droplets of about 50 microns diameter, and salt particles that grow by deliquescence to this size after only a short ascent above cloud base.

d) Particles carrying a high electrical charge, which move rapidly in strong electric fields and whose presence in aggregations create such fields.

Particles in the first two categories are assumed to grow by sublimation in the vapor pressure field nourished by supercooled cloud droplets until they become big enough to fall, and that thereafter they may grow also by collision. Particles in the other

two categories are assumed to grow by coalescence consequent to the speed of their motion, relative to the cloud droplets, and that after they have reached a diameter of about 500 microns they may freeze. It is assumed also that in clouds where some ice particles are present and some other conditions not well understood are fulfilled, additional small ice particles are generated in large numbers. These are the items in the arsenal.

54. Iartseva, N. N.; Bromberg, A. V. and Bychkov, N. V. "Indirect method of evaluating the ice forming ability of seeding agents." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 145:30-35, 1963. Russian summary, p. 30.

Abstract: A method of evaluting the ice forming ability of seeding agents is described. The method is based on the interaction between the substance investigated and a super saturated solution of AgI in a mixture of acetone and diglycol.

55. Inn, Edward C. Y. (Air Force Cambridge Research Labs., Cambridge, Mass.). "Photolytic inactivation of ice-forming silver iodide nuclei." Bulletin of the American Meteorological Society, 32(4):132-135, April 1951.

Abstract: Photolytic decomposition of silver iodide crystals has been observed when the crystals were exposed to light of wave lengths less than 4300 Å, as indicated by darkening of the exposed crystals. Qualitative observations indicate exposed silver iodide crystals undergo reversible photolysis, although the exact conditions under which this takes place is not well understood. When silver iodide nuclei were similarly exposed to light, the ability to form ice particles, when injected into a cloud of supercooled water droplets, was found to be essentially destroyed. It is believed that, as a result of photolysis of the exposed silver iodide nuclei, the physico-chemical nature of the surface of the nuclei has been altered to minimize effectively the surface-structure-sensitive process of ice nucleation.
References: (1) Frenkel, J. "Kinetic theory of liquids." Oxford Univ. Press, 1946, Chap. 7.
(2) Pound, G. M. "Kinetics of nucleation in atmospheric phase transitions." July 1, 1950, Report No. 1, Contract No. AF19(122)-185, Carnegie Institute of Tech.
(3) Mott, N. F., and R. W. Gurney. "Electronic processes in ionic crystals." Sec. Ed., Oxford Univ. Press, 1948, Chap. 7.

(4) Vonnegut, B. "Final report, project cirrus." Contract No. W-36-039-Sc-32427, Dec. 31, 1948, G. E. Res. Lab.
(5) Workman, E. J., and S. E. Reynolds. "Outline of thunderstorm research program at New Mexico School of Mines with suggested problems." Paper presented in a conference on thunderstorm electricity, Chicago, April 1950.

56. Inn, Edward C. T. "Photolytic inactivation of ice-forming silver iodide nuclei." American Meteorological Society, Bulletin 32(4):132-136, April 1951.

Abstract: Silver iodide crystals are decomposed photolytically by the action of light having wave lengths below 4300 Å. Photolysis is reversible when crystals are exposed to subdued light. Exposure of AgI nuclei to wave lengths, 4300 Å and less, of a quartz mercury arc light sources for 10 - 20 minutes destroys their capacity to form ice particles when injected into a cloud of supercooled water droplets. Exposure of photolyzed AgI nuclei to subdued light in a darkened room either did not bring about complete recovery from photolysis or had no effect at all. It is suggested that the surface-structure-sensitive process of ice nucleation by AgI is destroyed when the entire surface layer has been decomposed photolytically.

57. Inn, Edward C. T. "Photolytic inactivation of ice forming silver iodide nuclei." American Meteorological Society, Bulletin, 32(4):132-136, April 1951.

Abstract: AgI crystals were decomposed photolytically by the action of light having wave lengths below 4300 Å. Photolysis was reversible when crystals were exposed to subdued light. Exposure of silver iodide nuclei to wave lengths 4300 Å and less, of a quartz mercury arc light source for 10 - 20 min. destroyed their capacity to form ice particles when injected into a cloud of supercooled water droplets. Exposure of photolyzed AgI nuclei to subdued light in a darkened room either did not bring about complete recovery from photolysis or had no effect at all. It is suggested that the surface-structure-sensitive process of ice nucleation by AgI is destroyed when the entire surface layer has been decomposed photolytically.

58. Isono, K.; Fujita, H., and Komabayasi, M. (all Geophysical Inst., Tokyo Univ.). "Change in droplets spectrum and water content

of a cloud induced by salt water seeding." Meteorological Society of Japan, Tokyo, Journal, Ser. 2, 34(4):177-184, August 1956.

Abstract: An experiment on the cloud modification by spraying NaCl saturated solution directly into clouds was conducted. An atomizer was set at the windward slope of a mountain, and droplets of the salt solution were introduced into clouds when the clouds were ascending along the slope and covered the observation points which were located 1800 miles above sea level. Marked changes in size spectrum of cloud elements, and the subsequent rapid decrease in cloud water content caused by onset of precipitation were observed. This result showed that the first stage of precipitation was induced within a few minutes by spraying a relatively small number of NaCl droplets into the cloud which had been colloidally stable.

59. Kamiyama, K. and Moriguchi, M. "Infra-red spectrometry of condensation nuclei." Papers in Meteorology and Geophysics, Tokyo, 3(4):307-312, March 1953.

Abstract: Near infrared rays (1.307 and 1.216 μ) which have no connection with the absorption band of water vapor were applied to fog produced with adiabatic expansion in an expansion chamber. From the ratio of the light transmission of each wave length the sizes of fog particles were estimated. The effect of AgI and NaCl nucleation on light attenuation and the effect of ultraviolet irradiation of AgI and NaCl nucleation are investigated.

60. Katchalsky, E. and Keumann, Hava. "Preparation of colloidal silver-iodide water-suspensions for nucleation of supercooled clouds." Nature, London, 165(4189):244-245, Feb. 11, 1950.

Abstract: The method of preparing colloidal silver iodide water suspension is described. The size of the particles is 0.1 μ in diameter and the particles are of the same order of magnitude as those obtained in the generation of smoke by vaporizing silver iodide. The silver iodide produced clouds in a refrigerator and showed no aging when tested after 14 days.

61. Katz, Ulrich (Univ. of Chicago, Chicago, Ill.). "An improved cloud chamber for the study of artificial ice nucleants." Program of 244th Natl. Meeting of the American Meteorological Society

on Cloud Physics and Severe Local Storms, October 18 - 22, 1965, Reno, Nevada, American Meteorological Society Bulletin, 46(8):495, August 1965.

Abstract: This paper briefly describes a new small cloud chamber for the investigation of the effectiveness of artificial ice nucleants as a function of the temperature. Some of the special features are: quantitative replication of the ice crystals from which the nuclei can be retrieved for further study; quantitative seeding sample on membrane filter; reliability and reproducibility due to automatic control of the whole apparatus. The system is carefully sealed so that no lubricants or other contaminants can affect the nucleant.

62. Katz, Ulrich (Zürich). "Cloud chamber studies of the ice nucleating activity of a few selected substances." Zeitschrift für Angewandte Mathematik und Physik, Basel, 13(4):333-358, 1962. English summary, p. 357-358.

Abstract: The author investigated the problem of whether artificial ice nuclei are formed from vapor molecules which are adsorbed at the surface of a particle or whether they arise during collision of dust particles with water drops when icing begins. The contents of this paper include the following: construction and operation of the cloud chamber and the measurement procedure; the temporal variation of the observed number of ice crystals; collisions of dust particles with fog droplets; ice nuclei formation and surface-ice nuclei density involving a study of Cu_2O and FeS and a porous substance such as silica gel; and the temperature dependence of surface ice nucleation. The cloud chamber studies have demonstrated the following; the inoculation particles collide only to a slight extent with fog particles; the temperal course of the appearance of ice crystals corresponds to theoretical expectation; the activity $q(T)$ enables the calculation of a surface ice nucleus density δ as a function of temperature if $q(T) < 1$; the variation of $q(T)$ or $\delta(T)$ is not a function of the dust particle size distribution but of the "initial temperature distribution" of the ice nucleation loci upon the surface ice of the particles; the surface ice nuclei density has considerable importance in meteorology for in the case of experiments on weather control it allows approximate calculation of the number of ice crystals which can be produced at a particular temperature and humidity by a given amount of dust like inoculation material in case the dust particle diameter is $> 0.5\ \mu$ and the relative humidity is 100 percent.

63. Katz, Ulrich (Lab. of Atmospheric Physics, Swiss Federal Inst. of Tech., Zurich). "On the temperature and humidity dependence of the ice forming activity of silver iodide." Zeitschrif für Angewandte Mathematik und Physik, Basel, 12(1):76-79, 1961. German Summary p. 79.

Abstract: To determine the effectiveness of AgI powder with a given distribution of granulation size, ice nucleus formation was measured in a cloud chamber with special attention to temperature. The results are briefly discussed and compared to experiments and theories of other authors. A guiding test, in which the undercooled mist consisted of droplets of a rock-salt solution, showed the dependence of ice nucleus formation activity on vapor pressure. With vapor pressure greatly reduced it was found that throughout its realm of ice nucleus formation activity AgI acts as a sublimation nucleus.

64. Kissinger, H. E. and Mitchell, E. Z. "Studies on the crystallography of silver iodide nuclei." [Report] to the Advisory Committee on Weather Control, April 1 - June 30, 1957. U. S. National Bureau of Standards, NBS Report 5474, (1957) 6 p. Text is carbon of type script.

Abstract: A review of studies on the crystallography of iodide nuclei. Silver iodide is often used in weather modification experiments. Experiments with supercooled vapor in test chambers have demonstrated a loss of nucleating ability, with aging. Under certain conditions the ice crystals resulting from silver iodide nuclei are prismatic rather than the more common hexagonal shape. This laboratory has begun an intensive study of the crystal structure of nuclei. Electromicrograph and x-ray diffraction photographs are shown.

65. Koenig, C. Randall (Douglas Aircraft Co., Inc., Santa Monica, Calif.). "Some chemical and physical properties of silver-iodide smokes." Manuscript rec'd December 26, 1963. Journal of Applied Meteorology, 3(3):307-310. June 1964.

Abstract: The aerosols, produced by several devices, used to provide silver iodide for cloud-seeding purposes have been studied by micro-chemical techniques which permitted the characterization of individual smoke particles. The water sorptive properties, composition, and chemical uniformity of the particles were sought. Marked differences in the generator outputs were noted.

Some effort has been made to relate the findings of this work to the suitability of the different aerosols to cloud-seeding tasks.
References: (1) Birstein, S. J., 1962. "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." Bulletin of the American Meteor. Soc., 33:431-434.
(2) Edwards, G. R. and C. F. Evans, 1960. "Ice nucleation by silver iodide." I. J. Meteor. 17:627-634.
(3) Hoffer, T. E., 1961. "A lab investigation of droplet freezing." J. Meteor., 18:766-778.
(4) Inn, E. C. Y., 1951. "Photolytic inactivation of ice-forming silver iodide nuclei." Bulletin of the American Meteor. Soc., 32:132-135.
(5) Mason, D. J. and A. P. Van den Heavel, 1959. "The properties and behavior of some artificial ice nuclei." Proc. Phys. Soc., 74:744-755.
(6) Pruppacher, H. R., and M. Neiburger, 1963. "The effect of water soluble substances on the supercooling of water drops." J. Atmos. Sci., 20:376-385.
(7) Smith, E. J., K. J. Heffernan, and B. K. Seely, 1955. "The decay of ice-nucleating properties of silver iodide in the atmosphere." J. Meteor., 12:379-385.
(8) Tomkins, L. M., D. A. Muus, and T. Parson, 1963. "Water absorption in the system AgI - KI - H_2O." J. Geophys. Res., 68:3537-3539.
(9) Vonnegut, B., 1947. "The nucleation of ice formation by silver iodide." J. Appl. Phys., 18:593-595.
(10) Vonnegut, B., and R. Neubauer, 1951. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." Bulletin of the American Meteor. Soc. 32:356.

66. Koenig, L. Randall (Univ. Chicago). "The chemical identification of silver-iodide ice nuclei: A laboratory and preliminary field study." Journal of Meteorology, Boston, 17(4):426-434, August 1960.

Abstract: The technique and results of the application of a chemical test explicitly for silver iodide, sensitive to a mass of 3×10^{-17} gm, to laboratory nucleated ice crystals and atmospheric ice crystals from cloud-seeding experiments in the field are described. In laboratory ice crystals, it was found that the silver iodide nucleus was not always in the apparent "C" axis of the ice crystals. This deviation is discussed. Because of difficulties in the preservation of the ice crystals from the field experimentation, no evidence of the true role of silver iodide in cloud seeding was obtained.

67. Koenig, L. Randall. "The chemical identification of silver iodide ice nuclei." Chicago Univ. Dept. of Meteorology, Cloud Physics Laboratory, Grant NSF-G4644, Technical Note No. 19, June 15, 1959, 39 p.

Abstract: This report describes a method of chemically identifying silver iodide particles within ice crystals and discusses the results of this test on laboratory ice crystals nucleated by means of silver iodide.

68. Koenig, L. Randall (The Univ. of Chicago). "The chemical identification of silver iodide ice nuclei: A laboratory and preliminary field study." (The research reported in this article has been sponsored by the National Science Foundation under grant No. NSF-G4644). Manuscript rec'd Dec. 17, 1959, p. 426-434.

Abstract: The technique and results of the application of a chemical test, explicit for silver iodide, sensitive to a mass of 3×10^{-17} gm, to laboratory-nucleated ice crystals and atmospheric ice crystals from cloud-seeding experiments in the field are described. In laboratory ice crystals, it was found that the silver iodide nucleus was not always in the apparent "C" axis of the ice crystals. This deviation is discussed. Because of difficulties in the preservation of the ice crystals from the field experimentation no evidence of the true role of silver iodide in cloud seeding was obtained.

References: (1) Battan, L. J. and A. R. Kassander, 1958. "Randomized seeding of orographic cumulus, 1957: Part I." Tech. Note No. 12, Cloud Physics Lab., Chicago Dept. Meteor., Univ. Chicago, 17 pp.
(2) Braham, R. R., B. K. Seely, and W. D. Crozier, 1952. "A technique for tagging and tracking air parcels." Trans. Amer. Geophys. Union, 33:825-833.
(3) Carreras-Patxot, R. and R. Sanger, 1958. "A method for studying the diffusion of silver iodide particles in the atmosphere by means of I^{13}!" Z. angew. Math. Phys. 9a:375-380.
(4) Fletcher, N. H., 1959. "On ice-crystal production by aerosol particles." J. Meteor., 16:173-180.
(5) Isono, K., 1953. "An electron-microscope study of ice crystal formation--a preliminary report." J. Meteor. Soc. Japan, 31:318-322.
(6) Isono, K., 1955. "On ice-crystal nuclei and other substances found in snow crystals." J. Meteor., 12:456-462.

(7) Koenig, L. R., 1959. "The chemical identification, of silver iodide ice nuclei." Tech. Note No. 19, Cloud Phys. Lab., Chicago, Dept. Meteor., Univ. Chicago, 39 pp.
(8) Koenig, L. R., 1959. "Submicron determination of silver iodide." Anal. Chem. 31:1732-1735.
(9) Kumai, M., 1957. "Electron-microscope study of snow crystal nuclei II." Geofis. pura e Appl., 36:169-181.
(10) Maruyama, H., 1956. "Electron-microscope study of the ice crystal nucleus." Pap. Meteor. Geophys., 7:251-266.
(11) Nakaya, U. and M. Kumai, 1957. "Electron-microscope study of the center nuclei of snow crystals: III." J. Meteor. Soc. Japan, 75th Anniversary Vol. 49-55.
(12) Smith, E. J. and K. J. Heffernan, 1954. "Airborne measurements of the concentration of natural and artificial freezing nuclei." Quart. J. R. Meteor. Soc., 80:182-197.

69. Kolesnikov, A. G. and Beliaev, V. I. "Methods for calculating the crystallization of supercooled clouds during artificial modification." Mezhduvedomstvennaia Konferentsiia po Voprosam Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestra, 6th; June 15 - 19, 1959, Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestva, Pub. 1961, p. 10-15.

Abstract: The methods of calculating the processes of propagation of crystallization within clouds by seeding with CO_2 or ice forming nuclei are based upon the assumption that the processes are reduced to the diffusion of ice nuclei resulting from the actual seeding and the sublimation of water from drops onto the surfaces of ice crystals. The computations of the propagation of crystallization within a cloud as a result of seeding with CO_2 are presented for a single dimensional problem and for a two-dimensional problem with cylindrical symmetry. The computational equations are developed and an example of the numerical calculation of the course of the concentration of water vapor in a cloud is presented. A generalization of the methods for a cloud which is polydisperse at the initial moment so that it influences the rate of growth of the crystallization nuclei is outlined.

70. Krasikov, P. N. and Mamontov, N. V. "Determination of the size of particles, isomorphous with ice, used in experiments on the phase transition of water." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 67(129):144-153, 1957.

Abstract: In order to obtain AgI and PbI smoke, the reagents were evaporated in a carbon electric arc, or evaporated by means of an electric spiral placed within a large bottle, or birch charcoal containing these substances was burned. The dimensions of the particles were determined by an electron-microscope of the 50 kw magnetic microscope type. The method of preparing the specimens for observation under the microscope, in particular the special plates for holding the specimens, is described. Numerical data are presented on the size, distribution of AgI obtained by the spark of an electric arc by an electric spiral and by the burning of charcoal, and on the size distribution of PbI_2 obtained by burning charcoal and pulverization in a vacuum. It is seen that 80 to 90 percent of the AgI and PbI_2 have dimensions in the range of 1×10^{-6} to 8×10^{-0} cm. No evidence of crystalline shapes was apparent.

71. Krasnovskaia, L. I. "Physical bases of artificial modification of supercooled clouds by means of refrigerants." Moscow Tsentral'naia Aerologicheskaia Observatoriia, Trudy, No. 58, 1964, 76 p.

Abstract: This monograph constitutes a theoretical and experimental investigation of the physical processes that take place when supercooled clouds are seeded with such cold reagents as solid CO_2. The contents of this paper consist of the following, viz: a review of investigations of the modification of supercooled clouds and fogs with freezing reagents, including investigations of the possibility of modification with cold reagents up to and including the work of Langmuir and Schaefer; the value of formation of artificial ice crystals in clouds and natural ice crystals in the atmosphere; investigation of reagents for artificial modification of supercooled clouds; experimental investigation of processes of dispersing supercooled clouds during seeding with solid CO_2 and theoretical methods for investigating the process of dispersion of supercooled clouds with the aid of solid CO_2; formation of the ice nucleus phase during the introduction of solid CO_2, in supercooled clouds including the formation of solid phase at temperatures below -40° C fundamental propositions of the theory of homogeneous condensation in supersaturated vapor; the temperature field of a granule of solid CO_2 during different environmental temperatures and different air velocities; rate of fall of temperature in a temperature field of a granule in different conditions; application of condensation theory to CO_2 the total amount of nuclei of the new phase former per 1 gm of solid

CO_2 under different temperature conditions and analyses of the results of effective CO_2 during different environmental conditions; propagation of ice crystals formed in a cloud layer as a result of modification, including the causes of the propagation of crystals in a cloud; fundamental laws of the theory of turbulent diffusion in the atmosphere; the type of propagation source formed during the introduction of solid CO_2 from an aircraft and laws of variation of the width of a zone of propagation of crystals during different meteorological conditions; and experimental investigations of the process of propagation of crystallization zones in supercooled clouds, including a description of the experimental procedure; experimental errors and experimental results given in graphs and tables.

72. Krasnovskii, G. L. "Construction, use and further improvement of an automatic disperser and granulating device (ADG-1)." Mechduve-domstvennaia Konferentsiia po voprosam Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestva, 6th, June 15-19, 1959, Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestva Pub. 1961, p. 318-321.

Abstract: The ADG-1 (automatic dispersing and granulating device) is designed for dispersing supercooled clouds and fogs by means of CO_2 granules ejected from aircraft. The device transforms granules 1.0 to 0.5 cm^2 in size blocks of CO_2, and CO_2 in the form of "snow" or briquettes obtained from balloons with liquid CO_2. The granules are ejected automatically into the atmosphere at intervals of 2 to 3 seconds in amounts of 100 to 3000 granules/minute. The dispensing and granulating mechanisms comprise a single block so as to eliminate losses and to increase the weight efficiency. The article contains the following information: such technical data as voltage rate of rotation of the cutting blades, weight, etc.; principles of operation; interaction of the mechanism of the installation; designation of the individual units of the device associated with the use of briquettes and liquid CO_2, the system of control; life of the device; and possible ways for its improvement.

73. Krutskaia, L. I. "Methods of calculating the number of ice nuclei forming under the influence of freezing agents." Moscow Tsentral'naia Aerologichokaia Observatoriia, Trudy No. 19:81-100, 1958.

Abstract: The article treats the question of artificial dissipation of fog and the computation of needed quantities of seeding agents.

At the beginning the article mentions that excessive quantities of the agent introduced into clouds may not produce the desired effect and therefore a strict control of the quantity introduced is needed. The method of determining the number of ice crystals that may grow in size is described. The heat field of dry ice particles is investigated. The process of ice nuclei formation and the conditions for their growth are discussed with analytical derivations. An approximate method of calculating the number of ice nuclei forming is described and applications to dry ice as a seeding agent are indicated.

74. Langmuir, Irving. "Cloud seeding by means of dry ice, silver iodide, and sodium chloride." New York Academy of Science, Transactions, Ser. II, 14(1):40-44, November 1951.

Abstract: The theory of precipitation formation and cloud seeding developed during recent years is summarized by the leading research scientist in this field. Effects of various cloud-seeding experiments are discussed with special emphasis on the controversial experiments with silver iodide on October 14, 1948, and July 21, 1949, in New Mexico, and on regular weekly silver iodide seedings in New Mexico started in December 1949, and carried on for several months. The results of these periodic experiments are analyzed in terms of comparative precipitation and upper air temperature data which are found to show a definite periodicity following the rhythm of the experiments.

75. Langer, G.; Rosinski, J.; and Bernsen, S. (all, Armour Res. Foundation, Chicago). "Organic crystals as ice nuclei." Journal of the Atmospheric Sciences, Boston, 20(6):557-562, November 1963.--Also issued with title "Study of organic crystals as icing nuclei." As Armour Research Foundation (Illinois Institute of Tech.), Chicago, Contract AF19(628)-208, Final report, May 1962. 30 p.

Abstract: Laboratory work showed that organic compounds have considerable promise as cloud seeding agents. The following substances gave complete nucleation: phloroglucinol at - 2° C, trichlorobenzene at - 12° C, D(+) - Rafinose at - 14° C, trimesic acid at - 15° C, and melamine at - 15° C. Thirty-two organic compounds were investigated. The tests were conducted in a deep freeze cloud chamber and a Bigg-Warner chamber. Field tests by the University of Chicago (Braham, 1963) confirmed

the activity of phloroglucinol. Theoretical analysis indicates that activity of organic icing nuclei is determined by configuration of electric link-dipole moments in the molecule.

76. Lisgarten, N. D. "An electron diffraction study of ice deposits formed on silver iodide." Philosophical Mag., London, 8 ser., 3(35):1306-1311, November 1958.

Abstract: Oriented deposits of hexagonal ice have been formed by condensing water vapor on the silver iodide substrates at temperatures of about - 100° C and examined by electron diffraction methods. A feature of the diffraction patterns, obtained from the oriented hexagonal ice, is the appearance of strong spots in the "forbidden" hk4 positions. At lower substrate temperatures only unoriented deposits of cubic ice were obtained.

77. List, Roland. "Influence of silver iodide on the atmospheric ice forming process." Zeitschrift für Angewandte Mathematik und Physik, Basel, 12(15):474-476, 1961.

Abstract: This is an account of an experiment carried out in a hail chamber with the purpose to prove the effect of silver iodide on atmospheric ice formation. Two curves are presented showing ice formation with and without the addition of silver iodide. The influence of silver iodide becomes apparent below - 10° C, especially between - 10° C and - 15° C. It was found that the theory of controlling hail by freezing all supercooled cloud particles is basically sound.

78. Ludlam, Frank Henry. "Artificial and natural shower formation." Weather, 7(7):199-204, July 1952.

Abstract: This report sets out physics of growth of cloud particles exceeding critical diameter of .01 in., growth of ice crystals into hailstones and raindrops, and artificial shower stimulation by dry ice or AgI or by spraying large droplets into cloud base.

79. MacCready, Paul B., Jr. (Atmospheric Res. Group, Altadena, California). "Review of small cumulus studies and the modification of hail." Nubila, Verona, Italy, 4(1):20-28, 1961, Italian and English Summaries, p. 20-21.

Abstract: The initiation of precipitation and electrification in small cold summer cumulus clouds at Flagstaff, Arizona, has been studied for several seasons. Measurements on the timing of first radar echoes have agreed rather well with theory, both for natural precipitation and for dry ice seeding. The electrification observed after seeding is consistent with the concept that a strong charging mechanism is related to the growth and fall of ice hydrometeors. The field site and measurement techniques are reviewed. Although the small, predominantly supercooled clouds of the Flagstaff study are not of direct economic concern, they do demonstrate basic factors which may be pertinent to hail considerations. Simple calculations imply that conventional silver iodide seeding may inhibit the development of hail from clouds with such cold bases. Large clouds with warmer bases pose a more severe hail problem, but the direct effects of silver iodide seeding are still in the right direction. Seeding creates secondary effects on cloud dynamics which could be of value at very early stages of the development of hail storm systems.

80. MacCready, P. B., Jr., Smith, T. B.; Todd, C. J.; and Beesmer, K. M. "Nuclei, cumulus, and seedability studies: Project seabreeze, Pasadena Cooperative program of ice nuclei measuring techniques, Mt. Withington Project. Santa Barbara radar evaluation and other studies." (In: U. S. Advisory Committee on Weather Control, Final Report, Pub. 1957, 2:137-200.

Abstract: This is a comprehensive and detailed report on the physical evaluation of the validity of cloud seeding effects in the formation of rain, snow, hail, and lightning in the experiments carried out by Meteorology Research, Inc. under the sponsorship of the Advisory Committee on Weather Control. Part I contains a historical account of the various projects from their beginning in the summer of 1955 to their termination in the summer of 1957. A description of the organization, conduct, and equipment of a typical field experiment is included. With the aid of photographs the authors describe the various types of equipment used, namely: time - lapse cameras; projectors, portable cold box, aircraft, radar, silver iodide generators, ion collector, cloud droplet samples. Part II, cumulus studies, is concerned with the execution and evaluation of the experiments in which clouds were seeded with silver iodide ground generators in order to introduce freezing nuclei into convective clouds and obtain precipitation. Part III, nucleation and natural nuclei

studies, deals with studies on the dimensions, concentration, and distribution of natural freezing nuclei with the aid of the Australian expansion box, the application of laboratory observations on natural nuclei to conditions within clouds, and the reactivation of nuclei and the role of industrial nuclei as freezing nuclei. Part IV, report on the Pasadena Cooperative Program of ice nuclei measuring techniques, deals with freezing nuclei concentration measurements using the Australian expansion box, MRI dual temperature box, Australian Bigg box, Signal Corps box, and deep freeze box. The various types of apparatus are described with the aid of photographs, and the discussion covers the following: the results of comparative measurements of natural nuclei concentrations, effect of moisture on nuclei counts, silver iodide, and dust measurements with these boxes, effect of fragmentation or generation of ice crystals at the interior of walls of the boxes, etc. Part V, silver iodide study, includes studies of plumes from silver iodide ground generators and their tracing and decay, the nature of a plume model, and the use of the portable cold box for simulating temperature and moisture conditions inside a "typical cloud" at the precipitation producing stage. Part VI is concerned with the procedures and results of the Santa Barbara radar evaluation study, the cloud electrification studies at Boca Raton, Missoula (Montana) and the value of electrification as a research tool, the results of traverse seeding with light aircraft at Missoula, and the results of small scale seeding low supercooled stratus with silver iodide and dry ice at Missoula.

81. Malkina, A. D. "Results of investigations on certain physico-chemical properties of iodide smoke." Mezhvedomstvennaia Konferentsiia po voprosam Issledovaniia Oblakov, Osadkov i Grozovogo Elektrichestva, 5th, Leningrad, 1956, Issledovanie Oblakov, Osadkov i Grozovogo Elektrichestva. Pub. 1957, p. 127-128.

Abstract: Properties of particles of silver, lead, and cadmium iodide smoke obtained by sublimation of the corresponding salts at temperatures of 600 - 900° C, were investigated by means of electron-microscopic and microchemical methods. This investigation, and a study of the interaction of these particles with water, show that the chemical structure of a part of aerosol formed in the process of sublimation does not correspond to that of the original iodide. The change of state involves the formation of oxides of metals having no hexagonal

structure. In AgI aerosol formation by the method described, AgI losses on account of oxidation amount to 10 to 15 percent. In aerosol formation by burning coal impregnated with an AgI solution the losses are higher. The experiments have shown that water vapor does not affect the form and size of iodide aerosol particles. Water droplets, while leaving AgI particles unaffected, will dissolve PbI_2 particles considerably.

82. Manson, James E. "X-ray diffraction of silver iodide aerosols." Journal of Applied Physics, N. Y., 26(4):423-425, April 1955.

Abstract: A source of silver iodide aerosols has been studied to determine the effect of the temperature of generation on the crystal structure of the particles in the aerosol output. Sampling was done by use of a novel thermal precipitation which gave samples in the proper form for direct analysis in a Debye-Scherer x-ray diffraction camera. Patterns were obtained indicating the presence of both cubic and hexagonal modifications (zns and zno type). As the source temperature was raised an increase of the proportion of hexagonal particles was observed, 95 percent hexagonal particles resulted when the source was operated at 800° C. An explanation of this behavior is proposed.

83. Mason, B. J. and J. Maybank (Imperial College, London). "Ice-nucleating properties of some natural mineral dusts." Quarterly Journal of the Royal Meteorological Society, 84(361):235-241, July 1958. Manuscript rec'd January 8, 1958; in revised form April 30, 1958.

Abstract: A fairly wide range of 28 naturally-occurring mineral dusts has been tested for ability to act as ice nuclei. Nineteen substances, mainly silicate minerals of the clay and mica groups, are formed to be effective at - 18° C; seven of these are active above - 10° C. The most abundant of these is Kaolinite with a threshold temperature of - 9° C. Ten of the 28 substances, again mainly silicates, are found to become more efficient ice nuclei having once been involved in ice-crystal formation, i. e. they can be preactivated. Thus, ice crystals grown on kaolinite nuclei, which are initially active at - 9° C, when evaporated and warmed to near 0° C in a dry atmosphere, leave behind nuclei which are thereafter effective at - 4° C. Particles of montmorillonite, another important constituent of some clays and initially inactive even at - 25° C, may be preactivated to serve as ice nuclei at temperatures as high as - 10° C. It is

suggested that although such particles can initially form ice crystals only at cirrus levels, when the ice crystals evaporate they may leave behind some 'trained' nuclei which may later seed lower clouds at temperature only a few degrees below 0° C. On this hypothesis, the fact that efficient nuclei are occasionally more abundant at higher levels would not necessarily imply that they originate from outer space; indeed in view of the poor nucleating properties of some meteoritic material that was tested, it appears that atmospheric ice nuclei are predominately of terrestrial origin, with the clay minerals, particularly kaolinite, a major source.

84. Mason, B. J. "Recent research on cloud physics at Imperial College, London." Simposio Internazionale sulla Fisica delle Nubi e Relative Applicazioni all Agricoltura, Asti, Italy, April 1958, AHi, pub. December 1958, p. 64-75. English, French, Italian, and German Summaries, p. 74-75.

Abstract: This report summarizes some recent research at Imperial College, London, on the supercooling and freezing of water, the properties of natural and artificial ice nuclei, and the growth of snow crystals in the laboratory. Heterogeneous nucleation has been found for water droplets containing small foreign nuclei and proportionality could be established between the logarithm of the droplet and its freezing temperature. Spontaneous nucleating, on the other hand, was homogeneous. Empirical relationships between droplet volume and nucleation temperature, for both heterogeneous and homogeneous nucleation have been established for a wide range of droplet sizes. Photos of the bursting of water droplets and of spicules formed during freezing are shown. Tables are presented of substances (mainly silicates and minerials of the clay and mica groups) found to be initially active as ice nuclei at temperatures above - 18° C, and of artificial ice nuclei, with their crystal structure, lattice parameters and threshold temperatures. However, if all traces of silver or free iodide are removed, many of the substances are found to be quite ineffective. The most effective nucleating agents are, like ice, hexagonal crystals in which the lattice spacing differs from that of ice by less than 10 percent and they are almost insoluble in water. Perfect orientation of ice crystals has so far been observed on the basal faces of silver iodide, lead iodide, cadmium iodide, cupric sulphide and freshly-cleared mica, and on the (001) plane of iodide. Finally, the results of experiments are summarized on the artificial growth of snow crystals on a thin fibre, covering

a temperature range of 0° C to - 50° C and supersaturation varying from a few percent to about 300 percent. Radical changes in crystal shape could not be produced by varying the supersaturation at constant temperature but were produced by temperature changes at constant supersaturation.

85. Mason, Basil John, and Hallett, J. "Artificial ice-forming nuclei." Nature, London, 177(4511):681-683, April 14, 1956.

Abstract: Silver iodide is an effective nucleating substance below - 5° C. A number of other pure substances were tested by an experimental procedure which is described, but most failed to produce ice crystals above - 40° C. Lead iodide was effective at - 7° C and mercuric chloride at - 25° C. The techniques used in silver iodide generators may not be the most efficient; AgI particles are reduced at high temperatures and by ultraviolet radiation, and their ice-nucleating properties largely inhibited. Lead iodide is more stable and may be a practical substance.

86. Miura, Akira (Tohoku Univ. Geophysical Inst.). "On the concentration of silver iodide particles in the atmosphere." Tohoku Univ. Science Reports, 5th Ser., Geophysics, 7(2):73-81, November 1955.

Abstract: Using experimental results of the large scale diffusion of smoke particles in the free atmosphere by Braham, Seely, and Crozier, and those of the effectiveness of silver iodide smoke particles as freezing nuclei by Bolton and Qureshi, the author calculated the concentration of silver iodide particles as freezing nuclei for the - 5° C level and the - 20° C level in the atmosphere.

87. Montmory, R. and Jaffray, J. "Ice forming properties of silver iodide." Académie des Sciences, Paris, Comptes Rendus, 246(9):1391-1394, March 3, 1958.

Abstract: Experiments demonstrate that the threshold of ice-forming action varies with the circumstances accompanying the emission of silver iodide particles. This fact seems to prove the interrelations of the surface states. The ice-forming properties of dispersed silver iodide vary depending on whether or not it previously acted as a condensation nuclei. It also varies according to the composition of the atmosphere in which it has been dispersed and where it acts; and according to the temperature and type of generator from which it was dispersed.

88. Montmory, R. (CNRS Thermodynamic Lab. Clermont-Ferrand). "Freezing of supercooled water on a crystaline surface." Puy de Dome. Observatoire, Bulletin, Ser. 2, No. 4:126-147, October/December 1956. French and English Summaries, p. 126.

Abstract: This is a report on elaborate experiments to see what actual processes are involved in freezing of supercooled water on crystals of Mica, PbI_2, AgI and silver. Photomicrographs (100 x enlargement) show orientation of the epitaxy or ice formation in relation to the orientation of the nucleating crystal. It is concluded that the nucleus does not need to resemble an ice crystal in form to be effective (silver worked just as well as AgI), and that two kinds of active nuclei do not interfere with each other. Data are given for each type of nucleating agent and conditions in the experiment, molecular structure, explanation of results, etc., are set forth and illustrated.

89. Montmory, R. "Detection of pseudo-isomorphic particles of ice." Puy-de-Dôme. Observatoire, Bulletin, New Ser., No. 1:9-15, January/March 1955. English Summary, p. 9.

Abstract: The method for preparing a supersaturated solution of AgI in triethéleneglycol is described. Such a solution may be used to detect pseudo-isomorphic ice particles. The process of nucleation by AgI and by other substances such as carbon or dust particles and other objects is discussed, and photographs of AgI acting as centers of nucleation are presented.

90. Mount Washington Observatory, Gorham, New Hampshire. "Operation overseed: final report to the Advisory Committee on Weather Control, December 1955 - June 1956." Issued, Milton, Massachusetts, November 14, 1956, 116 p.

Abstract: An analysis of 61 attempts at seeding clouds in the Mt. Washington area to show the efficacy of AgI in producing ice nuclei downwind was made. From 3 to 28 ground generators were used during 3,000 hours from December 1, 1955, to June 15, 1956. The maximum concentration at 12 mile distance was 10^4 to 10^5 nuclei/m^3 at -20° C. Each seeding attempt is analyzed synoptically (surface and 850 mb synoptic charts) and aerologically (Portland, Maine Sounding), and from the point of view of meteorological cloud physics parameters. Decay occurred at the rate of 2 orders of magnitude in 30 minutes exposure at -15° C when the AgI in acetone and propane method

was used. A definite increase in nuclei was noted in half of the cases. Photos, tables, and graphs are included along with the discussion and synoptic analysis. It was concluded that "over-seeding" supercooled clouds with large numbers of AgI particles was not possible even with 28 generators operating simultaneously. Proper targeting was a most important factor and best results occurred with unstable lapse rates. The 61 attempts were made under carefully chosen conditions with respect to air flow between generators and Mt. Washington Observatory where the nuclei counts were made.

91. Naitô, Hideo, and Sugawara, Ken (Nagoya Univ.). "Determination of chemical composition of silver iodide smoke for rain making." Committee for rain making in Japan, Tokyo, Report of Rain making in Japan, 1:77-81, 1954.

Abstract: The chemical composition of silver iodide smoke emitted by a cloud-seeding generator was tested by two different techniques (Cottrell precipitator and thermal precipitation). Despite the discrepancies between the results obtained by the two methods the author concludes that "more than 1/2 and frequently more than 90% of the silver iodide is emitted into the air without decomposition."

92. Nikandrov, V. Ia. "Use of hygroscopic salts in antihail rockets." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy No. 126:8-9, 1962. Russian Summary, p. 8. Transl. into English as U. S. Joint Publications Research Service, JPRS, No. 18:696, April 15, 1963, p. 8-10.

Abstract: The results of laboratory investigations on hygroscopic salts employed with explosive substances in Italian antihail rockets are presented. These salts are sodium chlorate and potassium chlorate. The salts were vaporized in a chamber with a volume of 1.3 M^3 and the variations in transparency during natural dissipation and during the vaporization of the reagents are presented in a graph. The reagents were found to exert a stabilizing effect. The time of persistence of the fog increased perceptibly with an increase in the amount of the vaporized reagent. This increase is explained by the formation of a large number of drops out of the hygroscopic nuclei as a result of the recondensation of moisture from earlier drops on newly formed ones.

The stabilization of clouds in combating hail and flash floods is discussed.

93. Nikandrov, V. Ia. "Solid fuel torches as a means for introducing crystallization nuclei from the ground into fog." Leningrad. Glavnaia Geofizicheskaia Observatoriia, Trudy, No. 126:22-24, 1962. Russian Summary, p. 22, Transl. into English as U. S. Joint Publications Research Service, JPRS, No. 18:696, April 15, 1963, p. 29-33.

Abstract: The use of torches whose fuel contains admixtures of silver iodide for dissipating fogs is described. The fuel consisted of 36 gms (49.2%) barium nitrate, 49 gms (5.6%) aluminum powder, 9 gms (12.3%) dextrine, 21 gms (28.8%) metallic dust and 3 gms (4.1%) silver iodide. The number of dispersed particles of ice forming substances per unit volume is given by the equation

$$N' = \frac{M}{4Dfmt^2}$$

wherein M = mass of ice forming substance, m = mean mass of the individual silver iodide particles, f = wind speed, t = time of burning of the flare, D = coefficient of turbulent diffusion, and N' = the number of dispersed particles.

94. Nikandrov, V. Ia. (MGO, Leningrad). "The problem of the artificial control of cloud and fog." Transl. of Original Russian (Source not given), from 1957 [?] imprint, 13 p.

Abstract: A summary of laboratory and field experiments in seeding supercooled clouds with dry ice (at the GGO in Leningrad since 1946) and with other substances such as AgI. A table shows the relative success of 60 solid carbon dioxide seeding tests classified into 5° C temperature categories from - 60 to - 20° C, (and - 3° to - 5° C, - 1° to - 2° C and 0° C). Slight precipitation occurred in 43 cases and precipitation reached the ground in 28 cases. Failures were, respectively, 6 and 10, and indefinite, 11 and 22 cases. Greatest percent success was at - 6° to - 10° C. Cloud dissipation (for clouds of < 800 m thickness) was said to be almost always effective at temperature < - 40° C (supercooled). The practical value for aviation is stressed. The addendum gives more information on the physical processes of cloud nucleation and rain formation.

95. North American Weather Consultants. "Facts about increasing precipitation through cloud seeding." Pasadena, January 1951.

Abstract: This brief discussion of the salient points in cloud seeding techniques is written for popular consumption. Paragraphs on cloud physics, dry ice seeding, silver iodide seeding, natural nuclei, effects of over-seeding, moisture robbed from areas down wind, formation of clouds by seeding and difficulty in evaluating results without long and careful statisical checks, are included along with schematic diagrams.

96. Palomares Casado, Manuel. "Production of atmospheric precipitation by coagulation between drops of very different volume." Revista de Geofisica, Madrid, 15(57):35-43, January/March 1956. Spanish and English Summaries, p. 35-36.

Abstract: A theoretical study of precipitation from liquid-water-drop clouds, for the purpose of determining the feasibility of producing artificial rain by introducing drops that exceed a critical size at a time when the small size of drops or lack of turbulence prevents natural precipitation. The ratio between the size of the drops introduced into the cloud and the density distribution in the clouds, the distance the drop must travel to reach a given size, time involved, and amount of rain theoretically evoked, are considered on a mathematical basis but without concrete numerical examples.

97. Papée, Henry M. (Univ. of Ottawa). "Activated salt surfaces in ice nucleation and growth and the formation of droplets." Journal of Meteorology, Boston, 16(2):217-218, April 1959.

Abstract: A review of various studies on nucleating agents and nucleating properties, leads to the conclusion that a nucleating agent should have a somewhat distorted lattice in the immediate vicinity of the surface, a surface which would not sinter too quickly under exposure to water vapor, and perhaps, a surface which might become electrically charged under the influence of conditions available in the atmosphere. Experimental studies show that colored varieties of NaCl (color being the result of lattice defects) exist in nature and such colored NaCl crystals can be obtained from normal NaCl by the action of x-rays, electron beams, electric discharges or by heating NaCl with sodium. Colored NaCl has a low rate of sintering and its water vapor adsorption is accompanied by very large heat evolution. Since NaCl is present in the atmosphere where processes leading to strong radiochemical excitation take place these results seem to be significant. The possibility of electrical gradients across a blue surfaced NaCl particle is considered.

98. Parungo, Farn P. and Lodge, James P., Jr. (National Center for Atmosphere Research, Boulder, Colo.). "Molecular structure and ice nucleation of some organics." Journal of the Atmospheric Sciences, 22(3):309-313, May 1965. Manuscript rec'd June 8, 1964, in revised form March 2, 1965. Operated by Univ. Corp. for Atmospheric Research with sponsorship of the National Science Foundation.

Abstract: The ice nucleating abilities of a series of substituted phenols and benzoic acids were determined. Two different measures of activity were utilized: the onset temperature of freezing, as determined on a cold stage microscope, and the realtive number of ice nuclei formed at a fixed temperature in a cold chamber. Reactivity was generally found to vary with the potential strength of a hydrogen bond between the hydroxyl or carboxyl group and a water molecule. In a given series of compounds (i.e., either the phenols or the benzoic acids), it was found that the onset temperature could be predicted from the sigma value of Hammett for the individual substituent, so long as the substituent was in the meta and para position, and was not more strongly hydrogen bonding than the functional group of the parent compound. This suggests a free-energy relationship between molecular structure and nucleating power. These observations are offered for further discussion; it is clearly premature to offer a detailed mechanism for the effect.
References: (1) Fletcher, N. H., 1960. "Ice crystal nucleations by aerosol particles." Disc. Faraday Soc., 30:39-45.
(2) Fukuta, N., 1963. "Ice nucleation by metal dehyde." Nature, 199:475-476.
(3) Hammett, L. P., 1940. "Physical organic chemistry." N. Y., McGraw Hill, 184-199.
(4) Head, R. B., 1961. "Steroids as ice nucleators." Nature, 191:1058-1059.
(5) Head, R. B., 1962. "Ice nucleation by Jaffé, H. H., 1953: Re-examination of the Hammett equation." Chem. Rev., 53:191-261.
(6) Komabayasi, M. and Y. Ikeve, 1961. "Organic ice nuclei: Ice forming properties of some aromatic compounds." J. Meteor. Soc., Japan, II, 39:82-95.
(7) Langer, G.; J. Rosinski; and S. Bernsen, 1963. "Organic crystals as icing nuclei." J. Atmos. Sci., 20:557-562.
(8) Nikandrov, V. Ya., 1959. "Artificial actions on cloud and fog." Leningrad. Hydrometeorological Publishing House, 190 pp.
(9) Power, R. F., 1962. "Some amino-acids as ice nucleators." Nature, 194:1170-1171.
(10) Zettlemoyer, A. C.; N. Tcheurekdjian; and J. J. Chessick, 1961. "Surface properties of silver iodide." Nature, 192, 653.

99. Pena, Rosa G. de (Consejo Nacional de Investigaciones Cientificas y Techicas de la Republica Argentina) Caimi, Emilio A, and Iribarne, Julio V. (both Inst. de Fisica de la Atmosfera Univ. Nacional de Buenos Aires, Argentina). "Measurement of diffusion of silver iodide ice nuclei." Journal de Recherches Atmosphériques, Clermont - Ferrand, No. 1:19-27, January/ March 1964. French, English, and Spanish Summaries, p. 19-20.

Abstract: Measurements of ice nuclei at different altitudes in the area of Mendoza were made on days on which silver iodide was seeded from the ground and on control days. In every case conditions were vertically unstable with a dry adiabatic lapse rate up to 2 km over the ground. Seeding was performed with about 100 charcoal generators.

100. Picca, R. "De-activation of ice-forming silver iodide nuclei: its importance for the problem of induced precipitation." Rabat, Morocco. Institut Scientifique Chérifien, Travaux; Série Sciences Physiques, No. 4, 1959. 76 p. Transl. into English by E. B. Reece and B. Hobson issued by American Meteorological Society under contract AF19(604)-6113, as its Translation T-F-36, August 1961, 93 p. complete.

Abstract: In this monograph the author reports his laboratory experiments aimed at determining changes in nucleating ability of silver iodide particles and causes of such changes, for example ultraviolet radiation, repeated condensation, etc. Cold chamber experiments included studies of (a) droplet formation on spider webs (with or without AgI nuclei, under ultraviolet irradiation, repeated condensation and evaporation, as a function of time, etc.); (b) effectiveness of AgI smoke; and (c) effectiveness of AgI Deposited on a glass plate. The experimental procedures and methods of analysis are described in detail and illustrated, and results are presented. AgI nuclei were found to be subject to deactivation both as a result of repeated condensation and due to lapse of time. The author explains this deactivation by attachment of impurities to the surface of the nuclei. Solar radiation was also found to have a deactivating effect. Practical implications of these findings for cloud seeding operations are discussed. Previous experiments on AgI deactivation are reviewed extensively.

101. Picca, Robert. "New experiments on the deactivation of silver iodide as an icing agent." Académie des Sciences, Paris Comptes Rendus, 24(4):489-492, January 23, 1956. Also issued as Puy de Dôme. Observatoire Publications, No. 2A, 1956.

Abstract: A cloud-chamber experiment is described in which silver iodide nuclei suspended on spider webs were subjected to various treatments and the effects of these treatments on the icing properties of the nuclei were observed. Condensation followed by evaporation totally deactivated 35 percent of the nuclei, partially deactivated 60 percent while 5 percent remained active. The same figures apply to melting of ice crystals followed by their evaporation. For sublimation the percentages of totally deactivated nuclei are 25 percent, partially 50 percent, active 25 percent. For condensation only, the percentages are total deactivation 15 percent, partial 35 percent, active 50 percent. For melting the percentages are partial deactivation 60 percent, active 40 percent. Placing the deactivated nuclei in a vacuum for one or two hours failed to reactivate them. Under ultraviolet light the active nuclei lost their icing properties after exposure of around 30 minutes. The author further mentions experiments in which the aging of AgI nuclei was investigated and in which there was shown to be 90 percent deactivation after 5 days, 95 percent after 10 days and total deactivation after 10 to 20 days.

102. Pierson, Willard J., Jr. "Large scale control of weather by introduction of sublimation nuclei into the atmosphere." New York Academy of Sciences, Transactions, 2nd Ser., 12(8):268-270, June 1950.

Abstract: A critical discussion is given of several instances in which rainfall was produced presumably by seeding of clouds with AgI. A case was cited (Life, February 20, 1950) in which a cloud 25 miles away from the AgI generator gave rise to a full scale thunderstorm. The surface and vertical wind velocities were such as to have prevented the AgI from reaching atmospheric levels where it could become effective. In the other instance, which involved rain making over New York State (April 25, 26, 1950), the air into which AgI was released was capped by an inversion and the prevailing lapse rates would have prevented the AgI from reaching the freezing level where it becomes effective.

103. Piriz, Nestor A. "Artificial rain in Uruguay." Revista Orientación Meteorológica, Montevideo, No. 7:33-34, June 1954.

Abstract: Rainmaking experiments in Uruguay were conducted with a novel technique described in this article. The technique is based on the fact that if the electron equilibrium in a cloud is disturbed, a sudden growth of the cloud droplets by coalescence may ensue. Since clouds have a negative charge, the introduction of a positive field will lead to the desired effect. This is achieved by means of ionized aluminum powder exploded in the cloud. On April 10, 1954, rain was produced by means of ionized aluminum powder exploded in the cloud. On April 10, 1954 rain was produced from a stratocumulus (showing little promise of rain) over an area several km in diameter. This experiment was carried out before a selected audience comprising public figures and representatives of press and radio.

104. Podzimek, J. (Inst. de Phys. de l'Atmos., Acad. Tchecoslovaque des Sc., Praque). "Influence of the stefan current on the capture of AgI particles upon cloud elements." Journal de Recherches Atmospheriques, Clermont-Ferrand, No. 1:19-26, January/March 1965. French and English Summaries, p. 19-20.

Abstract: The aim of this paper is to explain the binding of aerosol AgI particles in the growing ice crystals and water droplets, when the cloud elements grow in the atmosphere mainly by the condensation of water vapor. The distribution of water vapor around the droplet and main forms of ice crystals were investigated on the basis of the measurement of the electrostatic field in an electrolytical vessel. The number of AgI particles caught on cloud elements in such idealized conditions is relatively small, with the exception of rare cases in mixed clouds. The velocities of the stefan current, dependent on the water vapor gradients, indicate that the efficiency of capture of AgI particles is greater only in the case of small droplets which begin to grow, and it does not last for a long time.

105. Poppoff, I. G., and Sharp, G. W. "Inhibition of freezing nuclei by absorbed contaminants." Journal of Meteorology, Boston, 16(3):288-294, June 1959.

Abstract: An investigation was made of the effect of amines, ammonia, and alcohols on the nucleation of supercooled water droplets by silver iodide crystals. It was found that these compounds inhibit nucleation and that the vapor concentrations required for inhibition increase as droplet temperatures decrease. Further, it was demonstrated that the adsorption of inhibitor on freezing nuclei is readily reversible and is, therefore, probably physical adsorption of the van der Waals type, rather than an irreversible chemisorption producing surface complexes.

106. Pruppacher, Hans Rudolf, and Sänger, Raymond. "Freezing mechanism of supercooled water drops by dispersed nuclei, Pt. I. Experimental investigations on the nucleating ability of substances." Zeitschrift für angewandte Mathematik und Physik, Basel, 6(5):407-416, 1955, English Summary, p. 416.

Abstract: A systematic laboratory investigation of the icing nucleability of 104 substances was made, 43 were active above - 18° C. Temperatures for the formation of first ice crystals and complete icing of a fog were listed. The following substances gave nucleability at - 4° to - 7° C: AgI, Ag_2S, CuI, CuS, CuSe, CdTe, PbI_2, V_2OS, HgTe, Ag_2O, Cu_2O, CdSe and $AgNO_3$. The best of these seems to be CuS with slightly better nucleability than AgI, a material much less expensive and more permanent than the widely used AgI. Experimental procedures are described in detail. No distinguishable crystallographic influence has been found, but the polarization capacity of anions in the given substance seems to be a favorable factor.

107. "Rainmaking with common salt." Current Science, Bangalore, 21(10):295, October 1952.

Abstract: This paper presents a brief account of a report by D. A. Davies of trials in East Africa (Nairobi) by Overseas Food Corp. using a mixture of 90 percent sea salt and 10 percent $CaCl_2$ ground to 0.5 μ particle size. The salt is taken aloft in balloons which burst at the base of Cu clouds (gunpowder with time fuse used for release). AgI is only effective in clouds below freezing. Hygroscopic particles may be effective above freezing, and hence, useful in seeding nonfreezing clouds in the tropics.

108. Reynolds, S. E.; Hume, William, II; and McWhirter, Max (New Mexico Institute of Mining and Technology, Socorro). "Effects of sunlight and ammonia on the action of silver-iodide particles as sublimation nuclei." (This work was supported by the Signal Corps of the U. S. Army. A partial report was given at the Vancouver meeting of the American Physical Society, June 25 - 28, 1951) Bulletin of the American Meteorological Society, 33(1):26-31, January 1952.

Abstract: Tests involving exposure of AgI smoke to bright sunlight show a decrease in concentration of effective nuclei (at - 20° C) of approximately two orders of magnitude per hour. The concentration of effective nuclei is increased greatly (as much as two orders of magnitude) by the addition of a little ammonia vapor to the AgI smoke. Smoke samples which have been deactivated completely by exposure to ultraviolet light can be caused to form large numbers of ice crystals by the addition of ammonia vapor. If ammonia is added before exposure to light, the rate of decay is the same or greater, and the effectiveness cannot be restored by further addition of ammonia. The effect of ammonia is believed to be due to the adsorption of ammonia on the silver iodide surfaces or to the formation of an amine of silver iodide.
References: (1) Workman, E. J., and S. E. Reynolds. "Electrical phenomena occurring during the freezing of dilute aqueous solutions and their possible relationship to thunderstorm electricity." The Physical Review, Vol. 78, No. 3, May 1, 1950.
(2) Schaefer, V. J. "The occurrence of ice crystal nuclei in the free atmosphere." G. E. Lab., Project Cirrus Occasional Report No. 20, January 15, 1950.
(3) Inn, Edward C. Y. "Photolytic inactivation of ice-forming silver iodide nuclei." Bulletin of the American Meteorological Society, Vol. 32, No. 4, April 1951.
(4) Vonnegut, Bernard. "Nucleation of supercooled water clouds by silver iodide smokes." Chemical Reviews, Vol. 44, No. 2, April 1949.

109. Reynolds, S. E.; Hume, William, II; and McWhirter, Max (New Mexico, Inst. of Mining and Technology, Socorro). "Effects of sunlight and ammonia on the action of silver-iodide particles as sublimation nuclei." American Meteorological Society, Bulletin, 33(1):26-31, January 1952.

Abstract: This is a report on the experimental determination of the behavior of silver iodide particles exposed to mineralite ultraviolet radiation and to sunlight, with or without the addition of ammonia. It was found that the concentration of effective nuclei in AgI will noticeably decrease under exposure to sunlight or ultraviolet radiation. By adding ammonia the AgI nuclei become reactivated. Data obtained during the experiments are presented on graphs. It is pointed out that addition of ammonia before exposure to sunlight will decrease rather than increase the number of effective silver iodide nuclei. An explanation of this phenomenon is offered.

110. Reynolds, S. E.; Hume, Wm., Jr.; Vonnegut, Bernard, and Schaefer, Vincent J. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." American Meteorological Society, Bulletin, 32(2):47, February 1951.

Abstract: Photochemical deterioration of AgI nuclei has been studied by the New Mexico School of Mines, in Socorro, N. M. and by the General Electric Research Laboratories in Schenectady, N. Y. Methods and installations are briefly described. At both places it was found that under dark conditions the number of active nuclei decreased about one order of magnitude in 24 hours. Decay rate under conditions of radiation by sunlight showed great variation with very light cloud cover and with the hour of day, but in general the number of effective nuclei decreased about two orders of magnitude per hour. The authors conclude that far greater numbers of AgI particles will be required for seeding operations in bright sunlight than at night.

111. Reynolds, S. E.; Hume, Wm., II; Vonnegut, Bernard; and Schaefer, Vincent J. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." American Meteorological Society, Bulletin, 32(2):47, February 1951.

Abstract: Short wave radiation, such as from sunlight, was found to increase the deterioration of silver iodide particles from that in dark of one order of magnitude in 24 hours, to two orders of magnitude in one hour in the light. These results obtained in open air at Socorro, New Mexico, were duplicated in the laboratory (with use of UV lamp) at Schenectady, N. Y.

112. Robertson, Charles E. "Analytical methods for determining silver iodide smoke characteristics." Program of 244th Nat. Meeting of American Meteorological Society on Cloud Physics and Severe Local Storms, October 18-22, 1965, Reno, Nevada, American Meteorological Society Bulletin 46(8):496, August 1965.

Abstract: Three characteristics of a silver iodide smoke were examined and found to be related to each other in a previously unreported manner. These characteristics are the size distribution of smoke particles, the number of these particles which are effective as ice-forming nuclei at different temperatures, and the effect of particle size in heterogeneous nucleation. Methods are presented which allow the determination of any one of these if the other two are known.

113. Rosinski, J. and Parungo, F. (Nat. Center for Atmospheric Res., Boulder, Colo.) Manuscript rec'd November 1, 1965. "Terpene-iodine compounds as ice nuclei." Journal of Applied Meteorology, American Meteorological Society, 5(1):119-123, Febrary 1966.

Abstract: Silver iodide particles deposited on vegetation may photolyze and combine with natural terpenes from three oils to form compounds which either themselves become aerosols, or become attached to aerosol particles. In either case the new compounds may become active centers acting as freezing nuclei. Silver iodide particles may persist for several months when deposited on coniferous trees, and may release variable doses of such freezing nuclei during that time. Although the concentrations of ice nuclei so produced are probably too small to influence precipitation, they may nevertheless contaminate large areas and thus may be significant for long-range research programs. The study is concerned with measuring natural concentrations of freezing nuclei.
References: (1) Bigg, E. K., S. C. Mossop, R. T Meade, and N. S. C. Thorndike, 1963. "The measurement of ice nucleus concentration by means of millipore filters." J. Appl. Meteor. 2:266-269.
(2) Grant, L. O., 1963. "Indication of residual effects from silver iodide released into the atmosphere." Proc. Western Snow Conf., Colo. State Univ., Ft. Collins, Colo., Atmospheric Science Tech. Paper No. 49:109-115.
(3) Rasmussen, R. A. and F. W. Went, 1965. "Volatile organic material of plant origin in the atmosphere." Proc. Nat. Acad. of Sciences, 53:215-220.

(4) Rosinski, J. and F. Parungo, 1965. "Freezing nuclei from photolytic decomposition of silver iodide." Proc. Intern. Conf. on Cloud Physics, Tokyo, Japan (Met. Soc. of Japan).
(5) Rosiński, J. and C. T. Nagamote, 1965. "Particle deposition on and re entrainment from coniferous trees." Kolloid-Zeitschrift, 204:111.

114. Rowland, S. Clark, et al. (all Univ. of Utah). "Photolytic activation of silver iodide in the nucleation of ices." Journal of the Atmospheric Sciences, Boston, 21(6):698-700, November 1964.

Abstract: Consideration is given the photolytic activation of AgI which originally was observed by Bryant and Mason (1960) and was discovered recently by S. C. Rowland. Information is given on experimental apparatus and the preparation of specimens, experimental results, and the conclusion. It is indicated that AgI prepared by two different methods yields the same results: AgI is not active as an ice growing nucleus until impurities are introduced on the surface. Photolytic decomposition is one way in which these impurities can be introduced with striking results.

115. Saint-Amand, Pierre (Research Department) and Henderson, Graeme W. (Technical Information Department). "Project Cyclops: an experiment in hurricane modification." U. S. Naval Ordnance Test Station, China Lake, Calif., NOTS TP 2751, May 1962, 33 p.

Abstract: In 1961 NOTS scientists and engineers developed a new method of generating silver iodide nuclei and a new means of dissemination. The new device, cyclops, was used for the first time in a seeding operation on Hurricane "Esther" in September 1961. The operation was carried out in cooperation with the Weather Bureau from the U. S. Naval Station, Roosevelt Roads, Puerto Rico. The first day's operation produced a dramatic and radical change in the thermodynamics of the hurricane for about 1 1/2 hours. Had more cyclops units been available to continue the attack, far more conclusive results might have been achieved. It is hoped to continue these experiments during the West Indian hurricane season of 1962 with modified cyclops units.

116. Sänger, Raymund. "Efficiency of ice forming seeding substances as affected by their water solubility." Zeitschrift für angewandte Mathematik und Physik, 7(6):538-540, 1956.

Abstract: Mason and Mellet assumed that the nucleating power of CuS and CrTe samples were due to contamination by AgI. Careful tests did not reveal any contamination. However, Sänger maintains that the different water solubility of the substances can explain the observed discrepancies. It should be important whether the seeding substance is already included in droplets or approaches undercooled droplets from the outside.

117. Sano, I. and Fukuta, N. "Effects of storage temperature, particle size, and air contamination on the ice nucleability of silver iodide smokes." U mi to Sora [sea and sky] Tokyo, 35(4):16-25, 1959.

Abstract: The temperature of the silver iodide smoke has no importance except through the coagulation and sedimentation of particles. Small fragments of greasy contaminants in the air could mix with smoke. Adding vaporized paraffin to the smoke reduces their property for producing ice nuclei.

118. Sano, I.; Fijistani, Y.; and Kawase, K. "An experiment on the supercooling of water-droplets containing foreign solid particles." Meteorological Society of Japan, Tokyo, Journal, 36(3):112-117, June 1958.

Abstract: A number of water droplets, uniform in size at 1.0, 0.6, 0.3, or 0.2 mm diameter, were prepared from water-holding powder suspended as well as water having no addition, by electrical atomization, on a paraffin-covered glass-plate. This glass-plate was placed horizontally in a flat case tightly made of two brass plates with a rubber frame between, and was cooled at various temperatures down to -30° C in a cryostat. Following this, the plate was quickly taken out from the case, and the droplets which had frozen were counted without delay in a low temperature chamber, using a phase contrast microscope and, on occasions, by the naked eye. The powder materials suspended were iodides of silver, mercury, and lead, and further, oxides of copper, cadmium, and zinc. Lead iodide was the most soluble of the materials examined, so that an investigation into the influence of aging of the powder

in suspended state upon the supercooling phenomenon was carried out in the following manner: the suspension of lead iodide was, after its production, allowed to stand in a closed vessel with frequent stirring for the periods of 0, 2, and 8 days at 5° C or thereabouts, and these three samplings dispersed each to droplets by the same method as with the other materials. The results are roughly as follows: 1) The smaller the droplets, the more likely they are to exhibit supercooling, the findings are the same in both the absence and presence of solid particles in water. There appears to be a linear relation between the logarithm of droplet-diameter and the freezing temperature; 2) of the materials tested, silver iodide is most effective in solidifying water under supercooled conditions, and its effectiveness goes up, though slightly, as the amount added to water is increased; lead iodide deteriorates considerably on account of its solubility; 3) the equation $[X/(100 - X)]^2 - K \cdot (\theta \cdot \theta')$ is presented as giving the fraction (X %) of droplets frozen at 10° C supercooling expressed in terms of the lowering from 0° C, K being a constant depending on the conditions of the experiment such as the droplet size, the nature and amount of the powder suspended, etc. and θ' the supercooling at which X = 50.

119. Sano, I.; Fijistani, Y.; Ito, Ki; and Kitani, S. (Chemical Institute Faculty of Science, Nagoya, Univ.). "A field experiment of snow-making by seeding with nickel oxide." Meteorological Society of Japan, Tokyo, Journal, Ser. 2, 34(4):185-189, August 1956.

Abstract: Nickel oxide has, next to silver iodide, an excellent ice-nucleating ability (Nucleation temperature, - 7° C). With the intention of testing its practical applicability to rain-making, a field experiment was performed from January 27 to February 4, 1956 on the outskirts of Takayama City, Gif u Prefecture. Nickel oxide was prepared through thermal decomposition of the carbonate, and the powder obtained was set up, after thorough pulverization, into the sky by a dust ejector. There was success in deriving snow from the atmosphere at temperatures as low as - 12° to - 16° C, but never experienced, as expected, any appreciable snow-fall when the air temperature was higher than - 7° C. In order to find the diffusion of the nickel oxide smoke in the atmosphere, nickel oxide in the air around the seeding station by a dimethyl glyoxime indicator method was tried. The ice crystals, whose formation is considered to be due to the seeding, were fixed to replicas;

they were classified according to their shape to plate-like, columnar, stellar, dendritic and so on; the size of the plate crystals was measured in particular and were found to range from 30 to 210 μ in diameter.

120. Sansom, H. W.; Bargman, D. J.; and England, G. "Report on experiments on artificial stimulation of rainfall at Mityana, Uganda, September - December, 1954." East Africa High Commission Meteorological Department, Memoirs, 3(4), 1955, 6 p.

Abstract: Experiments were conducted by the East African Meteorological Department from September to December 1954 in Uganda by means of salt dispersal (balloon bomb technique). The results are evaluated by comparing rainfall amounts on seeding days (selected randomly) with amounts on control days, the former showing considerably higher amounts. Out of 33 clouds seeded 24 yielded precipitation.

121. Schaefer, Vincent J. (State Univ. of N. Y., Albany) and Fuquay, James J. (Battelle, N. W. Lab., Hanford, Richland, Washington). "Detection of silver iodide in snow by neutron activation analysis." Journal de Recherches Atmosphériques, Clermont-Ferrand, No. 2:49-52, April/June 1965. French and English Summaries, p. 49.

Abstract: Laboratory and field samples of ice crystals grown on submicroscopic AgI aerosol particles have been collected and subjected to neutron activation analysis. The residue was found to contain a concentration of silver more than an order of magnitude greater than samples from an area in the Colorado Rockies where AgI seeding has not occurred. This analysis technique may constitute a new approach to the physical evaluation of cloud seeding effects.

122. Schaefer, Vincent J. (Atmos. Sci. Res. Center, State Univ. of N. Y., Albany). "Adirondack Conference on Silver Iodide Phenomena, November 13 - 16, 1962." American Meteorological Society, Bulletin, 44(7):430-437, July 1963.

Abstract: Information is given on the organizational procedures and summaries of the highlights of the sessions. The first session gave attention to ice nucleation theory and the role of

silver iodide as reported by a Russian investigator. The second session considered some of the theoretical problems related to a proper understanding of the behavior of water on solids at temperatures colder than 0° C. The third session was given to work on monodisperse hydrosols. The fourth session discussed silver iodide and luminescent solids. Other sessions involved discussions related to the practical problems that have developed with the use of silver iodide in field operations.

123. Schaefer, Vincent J. "Formation of ice crystals by sublimation." (Simple experiments in atmospheric physics, Pt. 4). Weatherwise 8(5):118-119, 123, October 1955.

Abstract: Various types of sublimation nuclei on which snow crystals start growing are characterized by their temperature-activity relationship, which is shown graphically for 21 species. Simple methods for determining the effectiveness of dust particles as ice crystal nuclei are described.

124. Schaefer, Vincent J. (Div. of Res., Munitalp Found, Inc.). "Silver iodide as an ice nucleus (simple experiments in atmospheric physics, Pt. 5)." Weatherwise, Boston 8(6):141-143. December 1955.

Abstract: The properties of silver iodide and the behavior of AgI and of Ag and I separately, and the adsorption of iodide vapor on microscopic Ag particles are discussed with respect to the nucleating activity of AgI--up to now the most effective agent for production of ice particles from supercooled clouds of water vapor. A single silver particle can be detected in the air if the methods described are carried out with care. Methods of production of AgI vapor of .01 μ diameter are discussed and compared. 5 gms of AgI powder produce 10^{18} particles if vaporized.

125. Schaefer, Vincent J. (G. E. Lab., Schenectady, N. Y.). "Economic aspects of experimental meteorology." (In: United Nations Scientific Conference on the Conservation and Utilization of Resources, Lake Success, N. Y., 1949). Proceedings, Water Resources, 4:2-27, 1951.

Abstract: This is a carefully prepared report with numerous photographs showing some effects of cloud seeding, mostly

with dry ice. A general review is given about nuclei in the atmosphere, causes of natural precipitation, fundamental experiments in cloud physics and requirements for cloud seeding. A diagram shows the temperature dependence of ice nuclei on different natural substances which may occur as aerosols in the atmosphere. The greatest activity occurs with CO_2 at 0° C or lower, and in lesser degree with AgI, which obtains full activity at -10° C.

126. Schaefer, Vincent J. (G. E. Res. Lab., Schenectady, N. Y.). "Localized efforts induced by seeding supercooled clouds with dry ice and silver iodide." 19th Annual Meeting (Proceedings) Western Snow Conference, Victoria, British Columbia, Dominion of Canada, April 1951, p. I - XI.

Abstract: This paper reports a part of the field studies under Project Cirrus, a joint project of the U. S. Signal Corps, Air Forces, and the Office of Naval Research, concerned with the formation of snow and rain in the atmosphere, many experiments have been conducted by Project Cirrus using aircraft to introduce seeding agents into the atmosphere. The results of some of these experiments have been described previously in brief form (1, 2, 3), but much additional analytical work is required before a complete summary of the flight results is possible.

As planned and carried out, Project Cirrus flight studies were not designed to accumulate statistical data for evaluating the economic aspects of cloud seeding activities. Instead, the attempt was made to carry out experiments in the atmosphere as nearly as possible using the techniques of basic research. Each flight was conducted to explore the feasibility of an idea, the validity of a theory, or the establishment, if possible, in quantitative terms of the physical properties of various features of the atmosphere deemed pertinent to the formation of clouds and precipitation.

Although much new information about the atmosphere has been accumulated in the course of these studies, it would be a mistake to assume that clear-cut answers to all the various problems encountered have been obtained. As invariably happens in such a study, the advances made are offset to a considerable degree by the discovery of new and unexpected problems requiring further investigation.

Despite these limitations, and quite aware that they exist, it is still possible at this time to cite definite advances toward a better understanding of the physical properties of various cloud systems.

To illustrate some of these points, it is necessary for the sake of brevity to mention only what are believed to be the salient points of the experiments. More information will be presented in the form of Project Cirrus occasional reports in 1951.

References: (1) Schaefer, V. J. 1948. "The natural and artificial formation of snow in the atmosphere." Trans. Amer. Geophys. Union, 29:492-498.

(2) Schaefer, V. J. 1949. "The formation of ice crystals in the lab and atmosphere." Chem. Rev., 44:291-320.

(3) Schaefer, V. J. 1950. "Effects produced by seeding supercooled clouds with dry ice and silver iodide." Presented Oxford Symposium, Royal Met. Soc., April. In Press.

(4) Vonnegut, B. 1949. "A continuous recording condensation nuclei meter." Proc. First Nat. Air Pol. Symp., 36-44, Pasadena.

(5) Smith-Johannsen, Robert. 1948. "Some experiments on the freezing of water." Science, 108:652-654.

(6) Schaefer, V. J. "The formation of frazil and ancher ice in cold water." Trans. Amer. Geophys. Union. To be published.

(7) Schaefer, V. J. 1949. "The occurrence of ice-crystal nuclei in the free atmosphere." Proc. First Nat. Air Pol. Symp., 26-35, Pasadena.

(8) Schaefer, V. J. "The possibility of modifying lightning storms in the Northern Rockies." Occasional Report No. 11, Project Cirrus, 12 pages. G. E. Res. Lab. Pub. Schenectady, N. Y.

(9) Schaefer, V. J. 1950. "Experimental meteorology." Jour. Appl. Math. and Phys., 1:153-184; 217-236, Basel, Switzerland.

(10) Schaefer, V. J. 1948. "The production of clouds containing supercooled water droplets or ice crystals under lab conditions." Bull. Amer. Met. Soc., 29:175-182.

(11) Woodman, C. A. and I. Langmuir. "A gamma pattern seeding of stratus clouds, flight 52, and a racetrack pattern seeding of stratus clouds, flight 53." Occasional Report No. 23, Project Cirrus, 27 pages, G. E. Res. Lab. Pub. Schenectady, N. Y.

(12) Langmuir, I. "Studies of the effects produced by dry ice seeding of stratus clouds." Occasional Report No. 10, Project Cirrus, 15 pages. G. E. Res. Lab. Pub. Schenectady, N. Y.

(13) Conover, J. and S. H. Wollaston. 1949. "Cloud systems of a winter cyclone." Blue Hill Observatory Records, Milton, Mass.

(14) Vonnegut, B. 1949. "Nucleation of supercooled water clouds by silver iodide smokes." Chem. Rev., 44:277-289.
(15) Schaefer, V. J. "Report on cloud studies in Puerto Rico." Occasional Report No. 12, Project Cirrus, 16 pages. G. E Res. Lab. Pub. Schenectady, N. Y.
(16) Langmuir, I. 1948. "The production of rain by a chain reaction in cumulus clouds at temperatures above freezing." Jour. Met. 5:175-192.
(17) Vonnegut, B. 1950. "Vortex thermometer for measuring true air temperatures and true air speeds in flight." Rev. Scien. Instru., 21:136-141.
(18) Langmuir, I. 1950. "Control of precipitation from cumulus clouds by various seeding techniques." Science, 112:35-41.
(19) Langmuir, I. 1950. "Widespread modifications of synoptic weather conditions induced by localized silver iodide seeding." Presented before Nat. Academy of Sciences, October 12, Schenectady, N. Y. To be published.
(20) Lewis, W. 1949. "The importance of artificial nucleation for the production of precipitation." Trans. N. Y. Acad. Scien., 12:264-267.

127. Schleusener, Richard A.; Grant, Lewis O.; and Steele, Roger (Colo. State Univ., Ft. Collins, Colo.). "Preliminary tests on a non-combustion type silver iodide generator." Proceedings of the 31st annual meeting of the Western Snow Conference, Yosemite National Park, Calif., April 17-19, 1963, p. 122-131.

Abstract: The preliminary tests conducted to date indicate that the ammonia generator is capable of producing effective ice nuclei. The nuclei have sufficient stability to retain their effectiveness for a period in excess of 6 hours. When retained within a closed chamber, the efficiency (approx. 5×10^{12} nuclei per gram of silver iodide, effective at - 20 C) is not satisfactory for field use, but the other advantages of using this type of nuclei generation is sufficient to warrant further investigation with the objective of improving the efficiency.

Comparison of crystal counts with observed droplet size distributions suggests that more than one ice crystal is being produced from each droplet of ammonia.

Further work on the generator is planned to attempt to develop a generator of acceptable efficiency and satisfactory operating characteristics.

References: (1) Fletcher, N. H. 1959c. "The optimum performances of silver iodide smoke generators. J. Met. 16:385.

(2) Fuguay, D. M. 1960. "Generator technology for cloud seeding." Journal of the Irrigation and Drainage Div., Amer. Soc. of Civil Engineers, I. R., p. 79-91.
(3) Lodge, J. P. 1963. "Personal communications."
(4) MacCready, Paul B. 1962. "The continuous particle sampler at the Puy de Dorme Comparison Conference." Bull de L-Observatorie Du Puy De Dome, 1:19-30.
(5) Schaefer, V. J. 1946. "The production of ice crystals in a cloud of supercooled water droplets." Science, 104:457-459.
(6) Todd, C. J., and Edward Hindman. 1963. Third Annual Yellowstone Field Res. Seminar, Atmospherics Science Res. Center, State Univ. of N. Y.
(7) Tominago and Kinumaki. 1954. "Note on a method of spraying AgI in liquid NH_3 solution for the purpose of artificial seeding." Sci. Rep. Tokyo Univ., Ser. 5, 6, 39.
(8) Vonnegut, B. 1957. "Early work on silver iodide smokes for cloud seeding." Final report, Advisory Committee on Weather Control; U. S. Congress, 2:283-285.
(9) Vonnegut, B. 1947. "The nucleation of ice formation by silver iodide." Jour. of Applied Physics, 18(7):593-595.

128. Smith, E. J. (Radiophysics Div., CSIRO, Sydney). "Diffusion and decay of silver iodide in the atmosphere." [Summary only] In: seminar on rain, Sydney, August 1960 [Papers], vol. 4; issued October 1960. Session 5, Paper 2, 2 p.

Abstract: Silver iodide smoke was released into the air from generators and downwind measurements were made. Smoke released from ground generators rose quite slowly. Only in favorable conditions would smoke released from the ground be expected to reach clouds in a short time. Silver iodide released from an aircraft gives similar results regarding decay. The rate of diffusion depends mainly on atmospheric conditions.

129. Smith, E. J.; Heffernan, K. J.; and Thompson, W. J. (all Div. of Radiophysics, Commonwealth Scientific and Indust. Res. Organiz., Sydney, Australia). "The decay of the ice-nucleating properties of silver iodide released from an aircraft." Royal Met. Soc., Quart. Journal, 84(360):162-165, April 1958.

Abstract: Silver-iodide smoke was released from an aircraft, together with a tracer of zinc sulphide, and both aerosols were detected in another aircraft. About 2×10^{14} freezing nuclei

were emitted per gram of silver iodide burned. The number of effective nuclei decreased on exposure to the air in the daytime by a factor of 1000 in two hours. At night there was no detectable decay.

130. Smith, E. J. and Heffernan, K. J. (Div. of Radiophysics, Commonwealth Scientific and Industrial Res. Org., Sydney, Australia). "The decay of the ice-nucleating properties of silver iodide released from a mountain top." Quarterly Journal of the Royal Meteorological Society, 82(353):301-309, July 1956. (Communicated by E. G. Bowen, Manuscript rec'd February 10, 1956, in revised form April 27, 1956.)

Abstract: Silver-iodide freezing nuclei, together with a tracer of zinc-sulphide particles, were released from a mountain top and detected in an aircraft. The ice-nucleating properties of the silver iodide decayed in the daytime but not at night. The ambient temperature did not appear to affect the daytime rate of decay. The top of the smoke plume rose no higher than in previous experiments when it was released from a flat plain.

131. Smith, E. J.; Heffernan, K. J. (Commonwealth Scientific and Ind. Res. Org., Australia) and Seely, B. K. (New Mexico Institute of Mining and Technology). "The decay of ice-nucleating properties of silver iodide in the atmosphere." Manuscript rec'd October 27, 1954. Journal of Meteorology, 12(4):379-385, August 1955.

Abstract: Finely divided zinc sulfide and freezing nuclei in the form of silver-iodide smoke were released from separate generators at the same time from the same position on the ground. Both were detected simultaneously at distances up to 56 kilometers downwind from the respective generators, by apparatus installed in an aircraft. The comparative concentration was used as a measure of the deterioration in the ice-nucleating properties of the silver iodide. The total number of freezing nuclei, effective at -17 C, in silver-iodide smoke from a hydrogen burner, decreased by a factor of ten, after 8 minutes of exposure in the free atmosphere. The corresponding time with use of a kerosene burner was 50 minutes. The rate of decrease in the number of freezing nuclei was not influenced by the cloud cover.
References: (1) Birstein, S. J. 1952. "The effect of relative humidity on the nucleating properties of photolyzed silver iodide." Bull. Amer. Meteor. Soc., 33:431-434.

(2) Bolton, J. G. and N. A. Qureshi. 1954. "The effects of air temperature and pressure on the decay of silver iodide." Bull. Amer. Meteor. Soc., 35:395-399.
(3) Braham, R. R., B. K. Seely, and W. D. Crozier. 1952. "A technique for tagging and tracing air parcels." Trans. Amer. Geophys. Union, 33:825-833.
(4) Crozier, W. D. and B. K. Seely. 1954. "Concentration distributions in aerosol 'plumes' 3 to 22 miles from a point source." Trans. Amer. Geophys. Union, 36:42-52.
(5) Inn, E. C. Y. 1951. "Photolytic inactivation of ice-forming silver iodide nuclei." Bull. Amer. Meteor. Soc., 32:132-135.
(6) Reynolds, S. E., Wm. Hume, B. Vonnegut, and V. J. Schaefer. 1951. "Effect of sunlight on the action of silver iodide particles as sublimation nuclei." Bull. Amer. Meteor. Soc., 32, 47.
(7) Reynolds, S. E., Wm. Hume, and M. McWhirter. 1952. "Effects of sunlight and ammonia on the action of silver iodide particles as sublimation nuclei." Bull. Amer. Meteor. Soc., 33:26-31.
(8) Smith, E. J. and K. J. Heffernan. 1954. "Airborne measurements of the concentration of natural and artificial freezing nuclei." Quart. J. R. Meteor. Soc., 80:182.
(9) Vonnegut, B. and R. Neubauer. 1951. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." Bull. Amer. Meteor. Soc. 32:356.

132. Solov'ev, A. D. "Methods for the artificial formation of ice particles in supercooled clouds." Moscow Tsentral'raia Aerologicheskaia Observatoriia, Trudy, No. 17:57-70, 1956.

Abstract: This paper makes a review of the non-Russian literature on the formation of ice crystals in clouds by ice seeding and by the use of AgI, on the methods of use of AgI, and on the artificial production of rain.

133. Soulage, G. (Observatoire de Puy de Dôme). "Concerning atmospheric freezing nuclei of meteoric origin." Puy de Dôme, Observatoire, Bulletin, Ser. 2, No. 1:15-17, January/March 1956.

Abstract: Although not rejecting Bowen's hypothesis regarding nucleation by means of meteoric dust, the author cautions against jumping to conclusions merely because of a coincidence between maxima or minima of dust and of rainfall. Meteoric

dust does not appear to be a good nucleating agent, whereas other kinds of dust and pollen, etc., usually present in the air do provide good nucleation under proper conditions.

134. Soulage, Guy. "Cold chamber for the study of ice crystals artificially induced in a supercooled cloud." Puy de Dôme. Observatoire, Bulletin, Ser. 2, No. 4:81-90, October 1953.

Abstract: A cold chamber is described and illustrated in which the cooling power is supplied by a melting eutectic (low melting point) mixture. This technique permits exact temperature control. An experiment is described in detail, involving use of the apparatus for counting ice-forming nuclei produced by an AgI smoke generator.

135. Steele, R. L. "Characteristics of silver iodide ice nuclei originating from anhydrous ammonia-silver iodide complexes." Program of 244th Nat. Meeting of American Meteorological Society on Cloud Physics and Severe Local Storms, October 18-22, 1965, Reno, Nevada, American Meteorological Society Bulletin, 46(8):496, August 1965.

Abstract: This paper reports the nucleating characteristics of silver iodide ice nuclei originating from anhydrous ammonia-silver iodide complexes. Two systems were investigated: (a) an aerosol system in which the silver iodide crystal was produced by evaporation of the ammonia from an aerosol droplet in ambient air; (b) a combustion system in which the ammonia is sprayed into a hydrocarbon flame and the ammonia is violently driven away from the silver iodide and burned. Both systems are simple and reliable, with system (a) better than (b) from an operation's point of view owing to the absence of a combustion process.

The nucleating characteristics are examined by introducing the nuclei into a cloud chamber to evaluate the effects of cloud temperature and density. Effects of silver iodide crystal size on nucleation as a function of temperature along with the effects of ultraviolet radiation are reported. Particle and mass efficiency are evaluated.

The paper concludes with a comparison of the ammonia complex systems with conventional silver iodide generators.

136. Sunlight spoils particles. "Science News Letter." 59(22):341. June 2, 1951.

Abstract: This is a brief report on the findings of Edward C. Y. Inn that sunlight changes the shape of AgI crystals so that they lose their ice forming capacity.

137. Switzerland, Eidg. Kommission zum Studium der Hagelbildung und Hagelabwehr. "Project 3 for hail control in Tessin, 1st year of experimentation." Its Tätigkeitsbericht, No. 10, 1957, 11 p.

Abstract: As in previous years (for reports covering the 1953-1956 seasons, see GJ-338, October 1955; 8:7-24, July 1957; and 9:2-35, February 1958, MAB) hail preventing experiments were continued by means of ground-operated silver iodide generators. The area of coverage was extended to include not only the Magadino Plain as heretofore, but the entire Tessin south of the Bellinzona-Cordada-Gridone line. The number of generators used was increased to 20. Another change was the conducting of operations according to a statistical evaluation scheme developed (and discussed in this report) by P. Schmid. Results of the operations are described and illustrated in the same detailed manner as in previous reports. Due to the paucity of data, no definite conclusions can be drawn either of a positive or negative effect, or of no effect of AgI seeding upon hail formation, but a definite positive correlation appears to exist between AgI seeding and precipitation intensity (the ratio of precipitation amounts per unit time on unseeded and seeded days was 1/2). Thus it can be safely assumed that AgI smoke reaches effective levels under orographic conditions. Experiments are expected to be continued for several years before their final statistical evaluation can be undertaken.

138. Takeda, K. (Kyusku Univ., Fukuoka, Japan). "Evidence of effects of dry-ice seeding on artificial precipitation." Journal of Applied Meteorology, Boston, 3(1):111, February 1964.

Abstract: This paper reports evidence on effects of dry ice seeding of a widespread cloud system from an aircraft. Six experiments were conducted on March 8, 1963 at Hitoyoshi, Kyushu, Japan. The idea was to seed the clouds in a unique pattern and then to look for a corresponding pattern in the

precipitation. In each case a precipitation pattern corresponding to the wind distorted seeding pattern was observed between 20 and 30 minutes later at a position downwind from the area seeded.

139. Todd, Clement J. "Initiation of precipitation by silver iodide seeding." Program of the 151st National Meeting of the American Meteorological Society and Conference on Hydrometeorology, Chicago, Illinois, March 19-21, 1957, American Meteorological Society Bulletin, 38(2):92, February 1957.

Abstract: If precipitation is initiated by condensation-coalescence the time of appearance at the base of a cloud is a function of vertical velocity and moisture content. If precipitation is initiated by sublimation, time of appearance at the base of a cloud is a function of vertical temperature distribution, moisture content, sublimation nuclei concentration and activation temperatures. Based on simplified models, curves are presented comparing theoretical time required for condensation-coalescence and sublimation precipitation to appear at the base of clouds. Data are also presented to compare theoretical with observed time of precipitation for the Presidential Advisory Committee on Weather Control's "Project Scabreeze," Florida, summer 1956. Comment is made about favorable conditions for observation of silver iodide effects.

140. Toye, M. J. (Obs. du Puy de Dôme). "Drying of droplets of a sodium chloride solution." Puy de Dôme. Observatoire, Bulletin, Ser. 2, No. 3:71-77, July/September 1956.

Abstract: The smaller the diameter of a droplet of pure saline solution (NaCl) placed in an atmosphere with decreasing relative humidity, the more difficult becomes the crystallization of the salt in supersaturation. Thus at < 50% relative humidity, the only drops remaining in solution are the very small ones. These were visible with a 40 power microscope but did not appear in the photographic experiments (with lower resolution) since no drop size-relative humidity relationship could be found except in the critical low limits. An introduction of pollution crystals of AgCl tended to cause crystallization by epitaxy at a higher relative humidity. This may explain the quicker crystallization of the larger droplets (which are more likely to be struck by a small polluting crystal than are the small droplets).

141. Turnbull, David, and Vonnegut, Bernard (G. E. Res. Lab. Schenectady). "Nucleation catalysis." Industrial and Engineering Chemistry, 44(6):1292-1298, June 1952.

Abstract: It is known that the structures of crystals and the substances that catalyze their formation closely resemble each other in atomic arrangement and lattice spacing on certain low index planes. A crystallographic theory of crystal nucleation catalysis predicts that the order of catalytic potency should be identical with the order of the reciprocal of the disregistry (1/8) between the catalyst and forming crystal on low index planes of similar atomic arrangement; that for small δ nuclei should form coherently with the catalyst--i.e., with a strain $\epsilon = \delta$; and that for δ very large $\delta >> \epsilon$ and the interface between nucleus and catalyst can be thought of as consisting of regions of good fit separated by a dislocation grid work. The energy of this interface should be proportional to the dislocation density, hence to $\delta - \epsilon$. There is evidence that ice nuclei may form coherently on silver iodide surfaces ($\delta = 0.0145$). Experience indicates that in general nuclei form coherently with catalysts only for $\delta \lesssim 0.005$ to 0.015.

142. Vernidub, I. I., et al. "Ice forming properties of aerosols of lead iodide obtained by oxidation of metal iodide compounds." Akademiia Nauk SSSR, Izvestiia, Ser. Geofiz, No. 8:1278-1284, August 1963. Russian Summary, p. 1278. Transl. into English in the corresponding issue of its Bulletin [of the] Academy of Sciences USSR, Geophysics Ser., Washington, D. C.

Abstract: The results of a preliminary investigation of the crystallizing action of aerosol of lead iodide on supercooled fog are described. The aerosol was formed by burning of metaliodide compounds as a result of a chemical reaction between the highly dispersing lead powder and the various iodine-containing combinations.

143. Vernidub, I. I. et al., "Investigation of ice forming properties of lead iodide." Akademiia Nauk SSSR, Izvestiia, Ser. Geofiz., No. 9:1286-1293, September 1962. Russian Summary, p. 1286. Transl. into English in the corresponding issue of its Bulletin [of the] Academy of Sciences USSR, Geophysics Ser., issued Washington, D. C.

Abstract: The possibility and feasibility of using aerosol of lead iodide in field experiments to artificially modify clouds are examined. The method of obtaining PbI_2 under laboratory conditions, the determination of the ice forming effectiveness of lead iodide and the determination of the disperse composition of the aerosol are described. The results of experiments carried out in the laboratory lead to the following conclusions: the disperse constitution of lead iodide obtained by the method of lead iodide sublimation and concentration of vapor depends upon the method of sublimation. The content of particles up to 0.20 microns varies from 60.8 percent for aerosols obtained by sublimating lead iodide upon an electric heater ($+ \approx 900^{\circ}$ C) to 86.7 percent for aerosol formed during the burning of a pyrotechnical compound with 50 percent lead iodide. The predominant number of particles are 0.05 to 0.15 microns in size. When the temperature of the fog falls, the crystallizing activity of lead iodide rises because of the crystallizing action of small fractions. The ice forming effectiveness of aerosols of lead iodide increases with an increase in the content of small crystallizing fractions within them.

144. Vonnegut, Bernard. "Thin films of supersaturated solutions for detecting, counting, and identifying very small crystalline particles." U. S. Air Force, Cambridge Research Center, Geophysical Research Papers, No. 37: Vol. 1:53-59, July 1955. Also as: G. E. Research Lab., Schenectady, Contract DA-36-039-Sc-15345, Project Cirrus, Occasional Report No. 34, April 15, 1952, 3 p.

Abstract: A simple method for identifying and counting crystalline nuclei is described. Experiments have been made with sodium chloride and silver iodide nuclei. This technique may have general use as a method for investigating homogeneous and heterogeneous nucleation.

145. Vonnegut, Bernard. "Spray-nozzle type silver-iodide smoke generator for airplane use." (Paper presented before meeting of the American Meteorological Society, Minneapolis, Minnesota, October 9 - 11, 1951) (Present address: Arthur D. Little, Inc., Cambridge, Mass.) and Kiah Maynard (G. E. Research Lab. Schenectady, N. Y.) Bulletin of the American Meteorological Society, 33(10):420-428, December 1952.

Abstract: A spray-nozzle type silver iodide smoke generator has been constructed that is suitable for airplane operation. This apparatus has been used successfully to seed cumulus clouds and to produce trails of ice crystals in regions of the atmosphere supersaturated with respect to ice.

146. Vonnegut, Bernard, and Neubauer, Raymond. "Recent experiments on the effect of ultraviolet light on silver iodide nuclei." American Meteorological Society, Bulletin, 32(9):356, November 1951.

Abstract: Experiments have been carried out in which AgI smoke produced by burning AgI impregnated charcoal was placed in a box with ultraviolet light in the center. It was found that during each hour the concentration of active ice forming nuclei in the smoke decreased exponentially. In other experiments the concentration was found to decrease to 30 percent - 50 percent per hour. These results are in marked contrast to the previously published data which indicated 10 percent to 1 percent remaining concentration at the end of 1 hour. It is probable that the effect of sunlight on AgI is greatly influenced by traces of certain impurities either in the atmosphere or in the nuclei.

147. Vonnegut, Bernard. "Experiments with silver iodide smokes in the natural atmosphere." American Meteorological Society, Bulletin 31(5):151-157, May 1950.

Abstract: The author presents a description of seeding experiments carried out from an airplane on December 21, 1948, using silver iodide and dry ice alternately. Photographs of the tops of the stratus deck after seeding showed the results. Preliminary experiments on tracing silver iodide smokes and ground released smokes, and apparatus used in dispensing chemicals for seeding purposes, are also described.

148. Vonnegut, Bernard. "Techniques for generating silver iodide smoke." Journal of Colloid Science, 5(1):37-48, February 1950.

Abstract: Silver iodide smoke for seeding supercooled clouds may be generated either by a charcoal burning device (wherein the charcoal is impregnated with silver iodide) or a spray

nozzle type smoke generator. Charcoal burners for ground or airplane use, and a new turbojet burner for producing large numbers of particles, are described. Methods for preparing solutions of silver iodide, number of nuclei produced per second, etc., are discussed.

149. Vonnegut, Bernard, (G. E. Res. Lab., Schenectady, New York). "Experiments with silver iodide smokes in the natural atmosphere." Bulletin of the American Meteorological Society, 31(5):151-157, May 1950.

Abstract: Preliminary experiments were conducted on seeding natural supercooled clouds with silver iodide smoke. It was believed that in many cases positive effects were observed. In a majority of the experiments it was impossible to prove beyond doubt that the effects were the result of the seeding. However, certain of these experiments demonstrated conclusively that modification of natural clouds with silver iodide smokes could be achieved. Areas of supercooled ground fog several hundred feet in diameter were changed to ice at a temperature of - 5° C by small scale releases of silver iodide smoke from the ground. Similarly, areas up to a mile in diameter were filled with small ice crystals by releasing the smoke at - 20° C when the air was supersaturated with respect to ice.

On December 21, 1948, a supercooled stratus cloud layer approximately 1,000 feet thick at a temperature of - 10° was seeded from an airplane with silver iodide smoke produced by dropping 3 or 4 pounds of burning charcoal which had been impregnated with 1 percent by weight of silver iodide. For purposes of comparison, and in order to definitely establish the position of the seeding, dry ice seedings were made about 3 miles away on either side. The results of the silver iodide seeding were clearly visible in photographs taken from the airplane. About 6 square miles of the supercooled cloud layer were transformed into ice crystals as the result of seeding with somewhat less than 1 ounce of silver iodide.

References: (1) Schaefer, V. J., 1946. "The production of ice crystals in a cloud of supercooled water droplets." Science 104:457-459, November 15.

(2) Schaefer, V. J., 1949. "The formation of ice crystals in the lab and the atmosphere." Chem. Rev. April.

(3) Bergeron, T., 1949. "The problem of artificial control of rainfall on the globe, I. General effects of ice nuclei in clouds." Tellus, I:1-12, February.

(4) Vonnegut, B., 1947. "The nucleation of ice formation by silver iodide." Journal of Applied Physics, 18:593-595, July.
(5) Vonnegut, B. 1949. "The nucleation of supercooled water clouds by silver iodide smokes." Chem. Rev., April.
(6) Vonnegut, B. 1947. "Supplement to first quarterly progress report." Met. Res. G. E. Res. Lab., Contract No. W-36-039-Sc-32427, November.
(7) Vonnegut, B. 1950. "Techniques for generating silver iodide smoke." Journal of Colloid Science, 5(1):37-48, February.
(8) "First Quarterly Progress Report." 1947. Met. Res. G. E. Res. Lab., Contract No. W-36-039-Sc-32427, July.
(9) Langmuir, I. 1949. "Studies of the effects produced by dry ice seeding of stratus clouds." G. E. Res. Lab., Contract No. W-36-039-Sc-32427, February.

150. Vonnegut, Bernard. "Nucleation of supercooled water clouds by silver iodide smokes." Chemical Reviews, 44(2):277-289, April 1949.

Abstract: Measurements carried out in a cold box on the nucleation of ice in supercooled clouds by silver iodide smoke particles showed that ice crystals do not form immediately on these particles. Silver iodide can be regarded as greatly increasing the probability of ice crystal formation. The number of effective ice nuclei which can be produced per gram of silver iodide varies with temperature.

151. Warburton, J. A. and Heffernan, K. J. (Radiophysics Lab., CSIRO, Sydney, Australia). "Time lag in ice crystal nucleation by silver iodide." Manuscript rec'd 17 July 1964. Journal of Applied Meteorology, 3(6):788-791, December 1964.

Abstract: Measurements have been made of the time lag which silver iodide particles exhibit in the nucleation of ice crystals at temperatures between -8 C and -16 C. The time lag is approximately exponential, the decay constants being 3.6 min. and 1.4 min. at -8.5 C and -15.5 C, respectively. The decay constant at -15.5 C is smaller by a factor of 4.5 than that for natural ice nuclei. The observed time lag is in qualitative agreement with Fletcher's theory.
References: (1) Fletcher, N. H., 1958. "Time lag in the ice crystal nucleation in the atmosphere. Pt. 2, theoretical." Bulletin Obs. Puy de Dome, No. 1, 11-18.

(2) Isono, K., M. Komobayasi, A. Ono, and Y. Ikebe, 1960. "Report on cloud seeding experiments in Okutama area." Department of Water Supply and Geophysical Inst., Tokyo Univ., p. 11.
(3) Smith, E. J. and K. J. Heffernan, 1954. "Airborne measurements of the concentration of natural and artificial freezing nuclei." Quart. J. R. Meteor. Soc., 80:182-197.
(4) Smith, E. J., K. J. Heffernan, and W. J. Thompson, 1958. "Decay of the ice-nucleating properties of silver iodide released from an aircraft." Quart. J. R. Meteor. Soc., 84:162-165.
(5) Vonnegut, B., 1949. "Nucleation of supercooled water clouds by silver iodide smokes." Chem. Rev., 44:277-289.
(6) Warner, J., 1957. "An instrument for the measurement of freezing nucleus concentration." Bull. Obs. Puy de Dome, No. 2, 33-46.
(7) Warner, J., and T. D. Newnham, 1958. "Time lag in ice crystal nucleation in the atmosphere, Pt. 1, Experimental." Bull. Obs. Puy de Dome, No. 1, 1-10.

152. Warner, J. and Bigg, E. K., (Division of Radiophysics, CSIRO, Sydney, Australia). "The effects of air temperature and pressure on the decay of silver iodide." American Meteorological Society Bulletin, 37(2):94-95, February 1956.

Abstract: Bolton and Qureshi's lab experiments on the decay of silver iodide smokes were reported and it was shown that for dilute smokes the deterioration was very slight and there was no important temperature effect. It was concluded that the coagulation of concentrated smokes used was responsible for the high rates of decay they observed at warm tem eratures.
References: Bolton, J. G. and N. A. Qureshi, 1954. "The effects of air temperature and pressure on the decay of silver iodide." Bulletin of the American Meteorological Society, 35:395.
(2) Reynolds, S. E., W. Hume, II, and M. McWhirter, 1952. "Effects of sunlight and ammonia on the action of silver iodide particles as sublimation nuclei." Bulletin of the American Meteorological Society, 33:26.
(3) Smith, E. J. and K. J. Heffernan, 1954. "Airborne measurements of the concentration of natural and artificial freezing nuelci." Quart. T. R. Met. Soc. 80:182-197.

153. Warner, J. and Bigg, E. K. (Both Division of Radiophysics, CSIRO, Australia). "Effects of air temperature and pressure on the decay of silver iodide." American Meteorological Society, Bulletin, 37(3):94-95, March 1956.

Abstract: Bolton and Qureshi's laboratory experiments on the decay of silver iodide smokes were repeated and it was shown that for dilute smokes the deterioration was very slight and there was no important temperature effect. It was concluded that the coagulation of concentrated smokes used was responsible for the high rates of decay observed at warm temperatures.

154. Weickmann, H. "Current understanding of the physical processes associated with cloud nucleation." Beiträge zur Physik der Atmosphäre, Frankfurt a.m. 30(1):97-118, 1957. German, French, and English Summaries, p. 97. Special abstract in English, p. 118.

Abstract: Cloud dissipation experiments and AgI seeding to produce rainfall and hail prevention possibilities are discussed and illustrated graphically and quantitatively in the text and tables. The author discovered that 1 gm of dry ice would generate nearly 10^9 ice crystals at -10° C (not 10^{16} as Langmuir claimed for -20° C). A graph shows the number of ice crystals formed by AgI, CdI_2, and CoI_2 at temperatures of 0° C to -20° C and natural nuclei at -10° C to -33° C. Formation of artificial warm front and artificial shower precipitation are also discussed at length. Modest precipitation increases may be attained in warm front clouds by markedly increasing the number of nuclei. This increase tends to increase the showery activity of these clouds. The increase in precipitation is proportional to the natural rate of precipitation. Increase in the number of freezing nuclei in shower clouds, might also increase the number of hail particles and thus the precipitation. It is believed that any attempt at hail prevention by seeding would increase the probability of hail, but more research is needed.

155. Werle, D. K. "The formation of metallic aerosols." Armour Res. Foundation, Chicago, Contract AF19(122)-472, Project C 022, Scientific Report, No. 17, September 23, 1953, 30 p.

Abstract: Metallic aerosols were made by the use of (1) a nichrome resistance furnace (1000° C), (2) a graphite

resistance furnace (2200° C), (3) a tungsten filament (3000° C) and (4) exploding wires (over 5000° C) in a laboratory investigation of metal aerosol formation. Particle sizes were found to be very dependent on the kinds and numbers of nuclei present. Cadmium vapor condenses readily on silver iodide nuclei and resulted in near monodisperse aerosols at high nuclei concentration. At low nuclei concentrations, the aerosol particles were larger and fewer in number. NaCl appears to be comparatively ineffective as a nucleating agent for cadmium. Small amounts of oxygen and water vapor (1 % - 3 %) present during the formation of cadmium and zinc aerosols appear to hinder the growth of large particles, especially in the case of zinc, the greater the tendency to oxidize, the smaller was the resultant particle size. A similar result was observed with metals that tend to react with nitrogen, i.e. magnesium and aluminum. The largest particles resulted when the vapor concentration was highest and consisted of a metal not easily oxidized such as cadmium or copper. Aerosols made by exploding wires electrically resulted in dense, highly agglomerated aerosols. Nichrome, silver, and copper apparently produced the largest particles (in air) of the metals tested. Metals such as tungsten, iron, and aluminum when exploded in air result in a fine, fluffy, agglomerated aerosol.

156. Yamaguchi, Shigeto. "On artificial rain nuclei." Kolloid Zeitschrift, Darmstadt, 144(1/3):154, November/December 1955.

Abstract: Cadmium bromide sublimation at 400° C in the air forms an aerosol and so does cadmium chloride, as shown by electron-microscope photographs. The droplets increase in humid air without hydrolysis. The cadmium halogens, therefore, can act as condensation and freezing nuclei.

157. Zarea, St.; Diaconescu, Ch. I.; and Capuz, C. "Question of cloud and fog seeding in Rumania." Rumania Institutul Meteorologic, Bucharest, Culegere de Lucrări, 1962. Bucharest, 1964, p. 199-208, Rumanian summary, p. 199-200; Russian and English summaries, p. 207-208.

Abstract: The authors present the analysis of 66 experiments on artificial stimulation of precipitation and fog dissipation with AgI carried out in Rumania during 1959 - 1962. The experiments were meant to verify the seeding technique (in view of establishing the minimum and optimum quantities of AgI required for acting

upon clouds and fog from ground and by means of balloons), to set off the favorable atmospheric conditions for the carrying out of these experiments and to ascertain the influence exerted by local factors. Experiments were performed on some isolated cumuliform clouds, on some cloud systems, as well as on fog, both in the plains (at the Băneasa Met. Obs.) and in the mountainous region (the Bucegi Mts.) in different seasons. The seedings were carried out at the ground surface, on mountain peaks (Omu, Postăvarn, and Caraiman), or from meteorological balloons, and consisted of volatilizing AgI by dint of smokeless powder.

The correlation existing between the macrophysical conditions, the cloud type and the seeding results was established. The positive results of the experiment were more obvious and conclusive in the case of isolated cumulonimbus clouds. The most significant experiment took place on August 9, 1961, when it rained nowhere in Rumania except in the experimental area. In cases of nephsystems, positive results were obtained with cold fronts and in the mountainous region, where the orographic element played a certain part. The fog dissipation experiments were carried out during the winter season and resulted in bettering visibility conditions at the Băneasa Airport. The experiments on the stimulation of precipitation and fog dissipation were in the nature of preparatory research for future organized and systematic activity.