YU ISSN 0015-3206
FZKAAA 19 (4) 433 (1987)

CHARACTERISTICS OF THE COLD CHAMBER »VINČA«

MIODRAG A. HUTER and MILISAV M. ĆURIĆ

Laboratory of Solid State Physics and Radiation Chemistry, »Boris Kidrič« Institute of Nuclear Sciences, Vinča, 11001 Belgrade, P. O. Box 522, Yugoslavia

Received 11 September 1987

UDC 541.182.2

Original scientific paper

In the Aerosol Laboratory at the »Boris Kidrič« Institute the cold chamber »Vinča« has been constructed for investigation of artificial ice nuclei used in weather modification. The experiments are performed in a supercold cloud without the surface influence, in conditions very similar to natural. Parameters like temperature and liquid water content can be chosen and maintained for an indefinitely long time, which makes possible a reliable determination of aerosol particles, efficiency and the mechanism by which ice crystals are formed.

1. Introduction

For many years there has been a great interest in the world in getting various kinds of aerosols and in constructing cold chambers for investigation of their properties, for ice particles showed to have a great importance in weather modification. Today, it is mainly the precipitation stimulation and hail suppression. In order to realize this effect as successfully as possible, and to improve it, it is necessary to study, besides the chemical and physical properties, their behaviour in the conditions which exist in the atmospheric cloud environments and to understand the mechanisms by which they make ice crystals in various conditions. Therefore, it is very important to simulate such experimental conditions in which the temperature and liquid water content (LWC) will be controlled as best as possible.

The first attempt to measure the efficiency of an aerosol in the process of ice crystals formation was made forty years ago$^{1,2)}$. For that purpose an ordinary cold box was used in which a supercooled cloud has being formed by injection of humid air. This way of measuring is still in use, but with many improvements; however, the main shortcomings are impossible to eliminate. Short cloud living, uncontrolled supersaturation due to a constant cloud cooling and strong diffusion toward the walls through which it is cooled, make this system very unstable and do not allow a reliable study of these processes.

An improvement of experimental conditions was made by Warner$^{3)}$ when in 1957 he constructed a small (a few liters) expansion cloud chamber. His idea was to achieve cloud formation by a quick expansion and thus to avoid wall effects. Before each experiment, an overpressure was made in the chamber, and then cooling followed as in the previous case. At pressure equalization, the temperature decreased temporarily to the value determined by the overpressure and thus the supercooled cloud was formed. But, this method also had the problem of short-lived cloud, as well as the high, transient supersaturation caused by quick cooling.

A completely new approach to this problem was made by Bigg$^{4)}$ in 1963, which was considerably improved by Stivenson$^{5)}$ in 1968. By this method, the aerosol particles are gathered on the membrane filters, and then examined in a diffusion chambers with the controlled supersaturation conditions. Which degree of saturation is to be achieved depends on the difference between the temperatures which are maintained on the surface with the membrane filter and the surface with ice above the filter. In that way, satisfactory conditions are fulfilled for investigation of the aerosol nucleation abilities, but only from the vapour phase, while the influence of water droplets is here neglected. This method has serious disadvantages concerning the surface influence$^{6)}$.

In order to find out the right procedure for these investigations, a number of similar, very original attempts has been made with very important theoretical explanations$^{7-9)}$; but, none of them, however, maintains to a necessary extent the conditions that exist in the natural cloud. That is why it is now considered that such conditions can only be simulated in the large cloud chambers which allow a reliable control of temperature, supersaturation, size and concentration of water droplets$^{10)}$. At the »Boris Kidrič« Institute a 400 litars cloud chamber has been constructed, which now can function as isothermal; it is also planned to adapt it for operation in dynamic conditions, by which the procedure for the cumulus cloud conditions simulation would be completed. By previously chosen evacuation rate and by injection of a certain number of condensation nuclei, a full control over the formed cloud would be achieved as well as its reproducibility. The rate of the walls cooling would be synchronized with that of the water droplets due to expansion.

2. *Description of the »Vinča« cold chamber*

The chamber consists of two cylindric vessels, of which the outer one, 900 mm in diameter and 1000 mm high, of 6 mm thin steel, contains vacuum (Fig. 1). The inner vessel, 720 mm in diameter and 1012 mm high, is of 1 mm thin copper and is cooled by means of freon. Copper tubing is soldered to its outside wall, as well as two separate heaters whose role is a slowdown of cooling or an abrupt heating. Thermal isolation is of *polyurethane* 80 mm thick, protected by a polyester resin. For the need of opening the chamber and rendering feasible the access to the inside of this vessel, the chamber bottom is cooled by a separate compressor mounted on the lower calotte, with the same cooling principle as in the big vessel. The cooling system is controlled by an electronic thermoregulator, in which a semiconductor diode, placed by the evaporator tubes, is used as sensor. A soon as the given temperature is achieved, there starts the heating with warm freon from the

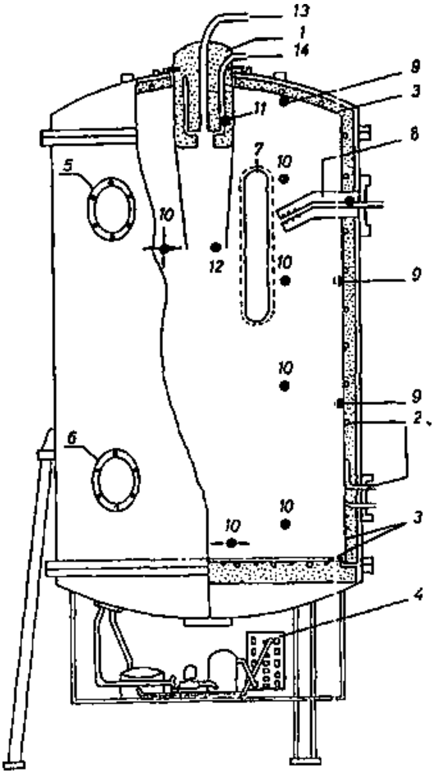

Fig. 1. Schematic of the cold chamber »Vinča«:

1) Mixer
2) Copper tubing of the cooling system
3) Heater
4) Cooling compressor
5) Hole for cloud seeding
6) Hole for taking out microscope slides
7) Window for observation
8) Insulated tube for taking samples for dew point measurement with a heater and a thermocouple
9) Thermocouples for measurement of the wall's temperature
10) Thermocouples for the cloud temperature measurements
11) Thermocouple for the supercooled air temperature measurements
12) Thermocouple for the introduced cloud temperature measurement
13) Inlet of cloud air
14) Inlet of supercooled air

high pressure branch, and its intensity, according to need, can be especially finely regulated. In that way wall's temperature stability does not vary more than ±0.3°C. These temperatures, as all others, are measured by chromel-constant thermocouples 0.1 mm thick, which practically have no inertia, and with the aid of which even the smallest changes can be detected. Registration is done by means of a 16-channel printer MECI, where to the whole measuring interval of 2 mV, i. e. 35°C, corresponds the scale length of 250 mm. Distribution and measuring points of thermocouples are shown by filled circles in Fig. 1.

When the chamber operates at isothermal conditions, cloud mixer, made of polyurethan with a cylindrical silk fabric at the end, is put through the hole in the middle of the upper calotte. Inside the cylinder, the final formation, homogenization and equilibration of the supercooled cloud is done before it is introduced into the chamber. The sample for the cloud liquid water content determination is taken by means of a thermally isolated pipe with the heater at the top, which evaporates the taken sample. Up to 1 litre per minute of the cloud mass is passed through the tube, and the dew point is measured by a Dew Point Hygrometer Model 1211 — General Eastern. The difference between the water vapour quantity corresponding to this dew point and that corresponding to the cloud temperature is taken as the liquid water content of the cloud.

The cloud is generated continuously by atomizing distilled water at room temperature with an ultrasonic humidifier (Hankseraft 5930) which produces droplets with diameters of about 1—10 μm. Most of them are about 3 μm in diameter and such distribution remains in the cold cloud; but it should be noted that at liquid water contents higher than 1.5 and 2.0 g m^{-3} that number is by several per cents smaller in favour of larger droplets. The mean droplet distribution with respect to the liquid water content is represented in Fig. 2.

Introducing of the cloud into the chamber is achieved by means of a controlled air flow through the humidifier, and its cooling is done by mixing with precooled air whose temperature is about —30°C and whose flow is also controlled. By changing the flow rate it is possible to reach the temperatures from 0 to —20°C and liquid water contents from 0 to 3 g m^{-3}. To achieve steady conditions, it takes about

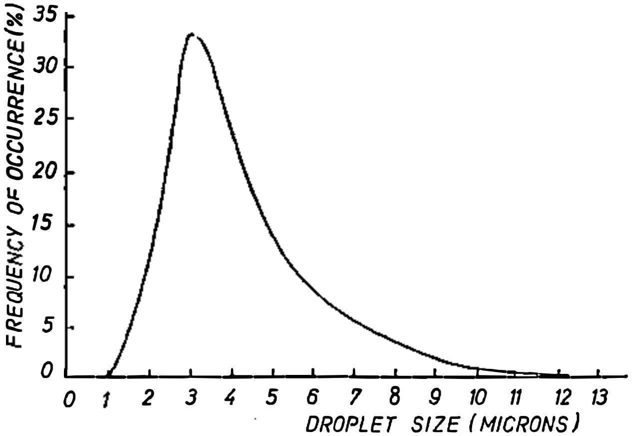

Fig. 2. Cloud droplet size (radius) distribution determined from soot coated slides.

three hours and then the temperature variations of the introduced cloud are considerably below the temperature gradient existing in the whole chamber volume. This gradient is smaller than ±0.5°C, while the homogeneousness of the cloud is in the interval in which the dew point varies within the limits of ±1.5°C. In order to prevent formation of a greater quantity of frost during a longer operation, and a direct contact of the cloud with the metal walls, the bases of the chamber are coated with velvet, while the vertical wall is in a silk fabric fixed only along the upper edge.

For the detection of the formed crystals, microscope slides are used which are settled in the tray at the bottom of the chamber. After the cloud seeding with an aerosol the slides are pulled from the bottom of the chamber in intervals of 1, 3, 6, 10, 15... minutes and collected crystals counted on the microscope in a separate refrigerator. For better statistics, the counting is done at five different places and then the mean value is taken; the slides are pulled out successively until the number of crystals in the microscope view area is less than 1. From this time distribution, as well as from the influence of different liquid water contents and temperature, important data can be obtained about the nucleation mechanisms, while the total number of crystals shows the effectiveness of the tested aerosol. It is calculated through the equation:

$$E = \frac{N \cdot V \cdot S}{m \cdot v \cdot s}$$

where N is the number of crystals, V volume of the bag in which the aerosol is produced, S the chamber cross-sectional area, m the sample mass, v the syringe volume used for seeding and s microscope viewing area.

Since the so far conducted experiments have dealt only with the aerosols obtainable from the burnt pyrotechnics, the system for their generation is adapted to these purposes. It consists of a plastic bag placed such that under a normal pressure it can have the volume of 3.5 m^3, and can be completely evacuated. In this volume, the pyrotechnic sample of approximately 0.5 g is burnt out in the fan directed air stream. Burning is electrical, and the formed aerosol is homogenized by means of another fan. After the sample has been taken, the bag is cleaned

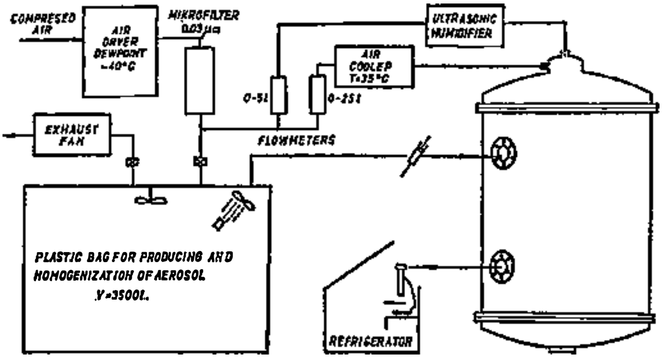

Fig. 3. Schematic of the experiment with the corresponding equipment.

out with a dry air (dew point —40°C), so that the aerosol is always in a dry atmosphere and a transit supersaturation is not possible to occur during the seeding of the supercooled cloud. The samples are taken by means of 0.01 to 1.5 l syringes. The whole experiment and all the mentioned facilities are schematically presented in Fig. 3.

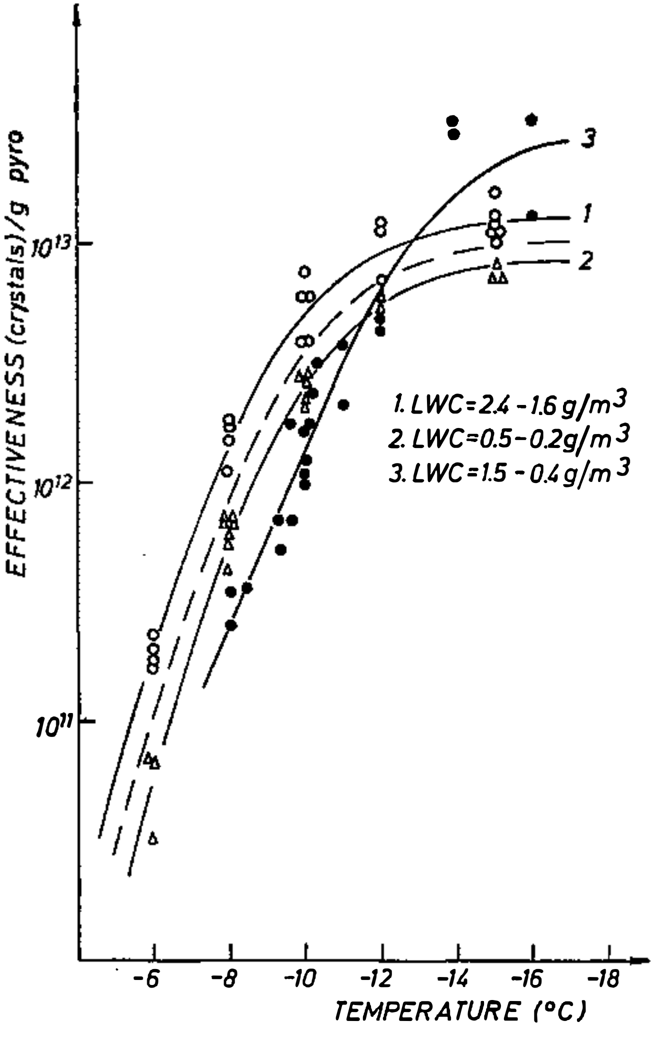

Fig. 4. Efficiency of the VTG-8 reagent, measured in the cold chamber »Vinča« — curves 1 and 2, and in the CSU isothermal cloud chamber — curve 3.

Fig. 4 represents experimental efficiency curves for the reagent VTG-8, which as an active component contains 8% of silver iodide. Curves 1 and 2 show the efficiency, i. e. number of active ice nuclei per gram of the pyrotechnic measured in the cold chamber »Vinča«. Curve 3 presents the same activity measured in the CSU isothermal cloud chamber in Fort Collins, USA, with a liquid water content corresponding to the mean curve in relation to the curves 1 and 2 and with a considerably different way of aerosol formation[10]. In the CSU Laboratory the aerosols are generated by burning the pyrotechnic in the wind tunnel in which a larger number of smaller particles are obtained due to smaller coagulation. The shape of the curve 3 indicates that just this fact is the main cause of the disagreement with our results; for all former works and theories show the larger particles to be more active at higher temperatures. Regardless of this disagreement, for this type of measurement even the disagreement of the results for the factor of two is considered as quite good.

3. *Conclusion*

By designing and constructing this chamber we got an equipment in which it is possible to define and reliably controle various conditions of temperature and liquid water content. Thus, a good simulation of stratus clouds or slowly settling fog without supersaturation with respect to water have been achieved in laboratory conditions. By measuring the nucleation rate in such conditions and in the way presented in this paper, it is possible, by analogy to the chemical kinetics proposed by DeMott[11], to obtain important data on the nucleation mechanisms. These data and the known corresponding experimental conditions give significant parameters for mathematical process modelling. It is also possible, with additional equipping, to make in the chamber the same conditions as in the cumulus clouds, which would make possible the investigation of aerosol particles under the influence of controlled supersaturation, which would considerably improve the method for their characterization. Activity curves in Fig. 4 show the chamber susceptibility to the change of the liquid water content, while the represented system and the measuring method, as well as the shown comparison with the CSU isothermal cloud chamber which is considered as the most reliable in the world, give a standard method for aerosol efficiency determination.

References

1) V. J. Schafer, Science 104 (1946) 457;
2) B. Vonnegut, Chem. Rev. **44** (1949) 277;
3) J. Warner, Bull. L'Obs. Puy de Dome **2** (1957) 33;
4) E. K. Bigg, S. C. Mossop, R. J. Meade and N. C. Thorndike, J. Appl. Meteor. **2** (1963) 266;
5) C. M. Stevenson, Quart. J. Roy. Meteor. Soc. **94** (1968) 35;
6) N. Fukuta, J. Atmos. Sci. **23** (1966) 741;
7) R. C. Schaller and N. Fukuta, J. Atmos. Sci. **36** (1979) 1788;
8) N. R. Gokhale and J. Goold, J. Appl. Met. **7** (1968) 870;
9) G. Vali, Scientific Report **MW-58** (1968) 51;
10) D. M. Garvey, J. Appl. Meteor. **14** (1975) 883;
11) J. P. DeMott, W. G. Finnegan and G. O. Lewis, J. Clim. and Appl. Meteor. **22** (1983) 1190.

KARAKTERISTIKE HLADNE KOMORE »VINČA«

MIODRAG A. HUTER i MILISAV M. ČURIĆ

Laboratorija za fiziku čvrstog stanja i radijacionu hemiju, Institut za nuklearne nauke »Boris Kidrič«, Vinča, 11001 Beograd, p. fah 522

UDK 541.182.2

Originalan naučni rad

U Laboratorji za aerosole Instituta za nuklearne nauke »Boris Kidrič« konstruisana je, izgrađena i testirana hladna komora »Vinča« za ispitivanje veštačkih nukleanata leda, koji se koriste u modifikaciji vremena. Ispitivanje se vrši u prehlađenom oblaku bez uticaja podloge, u uslovima koji su vrlo slični prirodnim. Parametri kao što su temperatura i vodnost oblaka mogu se po želji zadavati i održavati neograničeno dugo, što pored pouzdanog određivanja efikasnosti aerosolnih čestica omogućava i ispitivanje mehanizama po kojima se na njima formiraju ledeni kristali.