AN EXPERIMENTAL DEVICE USED TO MEASURE ICE NUCLEATION PROPERTY OF PYROTECHNICS FORMULA

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Abstract: **Ice rain annually causes huge economic losses, so the research of freezing rain suppression and glaze ice decrease has a huge economic and social significance. We designed an experiment device, which could offer icing rate to characterization ice nucleation property. Experimental device consists of 0.5 m ³ cloud chamber, temperature control system and fog system, etc. The results show that nucleation rate and icing rate have a good consistency in a certain range. Repetitive experimental obtained icing rate data are stability, and test is simple, convenient and feasible.**

1. INTRODUCTION

Ice rain annually causes huge economic losses, so the research of freezing rain suppression and glaze ice decrease have a huge economic and social significance. We designed a kind of experimental device to simulate freezing rain, and explored the experimental methods to reduce the glaze ice. The schematic diagram of experiment device is shown in Figure 1. The experimental principle is to control the quality of supercooled fog which enter into the cloud chamber, and then measure the quality of ice in the chamber, finally calculate icing rate by icy weight increment.

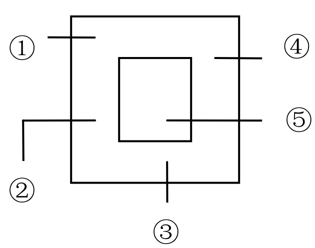

Figure 1: The schematic diagram of experiment device

①Temperature control system; ②Fog system; ③Ignition system; ④thermal insulation layer; ⑤Temperature and humidity monitors, Ignition controller and Fog controller

2. RESULTS AND DISCUSSION

Table 1 shows the icing rate test results. Experiment results show that repetitive experimental obtained icing rate data stability. In a certain range icing rate and nucleation rate have a good consistency.

Table 1: Icing Rate Test by the Same Temperature

sample	AgI content /%	nucleation rate /（ g^{-1}AgI）	Icing rate/(g· g^{-1}AgI)	$N/\overline{N}$
Formula 1	5		2739.8	0.960
Formula 1	5		2793.0	0.979
Formula 1	5	6.98×10^{13}	4176.0	1.463
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Formula 2	5	2.56×10^{13}	1729.0	0.970
Formula 2	5		1835.4	1.030
Formula 3	15	1.33×10^{13}	469.9	0.738
Formula 3	15		274.9	1.262

3. CONCLUSION

(1) Experiments show that the inspection results by using the cloud chamber conducted are reliable and repeatable. the cloud chamber has reasonable structure and stable performance. Its good refrigeration and temperature control performance, provides a useful test tool for simulating freezing rain in the laboratory.

(2) The cloud chamber designed and built for the purpose to laboratory simulation experiments of freezing rain, and also to contribute to select aerosol pyrotechnics formula and study of ice nucleating properties. Icing rate can reflect the ice nucleation property of aerosol pyrotechnics formulas, and it has a good consistency with nucleation rate in a certain range.

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An Experimental Device Used to Measure Ice Nucleation Property of Pyrotechnics Formula

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Abstract

Ice rain annually causes huge economic losses, so the research of freezing rain suppression and glaze ice decrease has a huge economic and social significance. Ice nucleation property determines the property of pyrotechnics formula, usually characterization by nucleation rate. Due to nucleation rate high cost and the operation test cycle is long, thus we designed an experiment device, which could offer icing rate to characterization ice nucleation property. Experimental device consists of 0.5 m ³ cloud chamber, temperature control system and fog system, etc. The experimental principle is to control the quality of supercooled fog which enter into the cloud chamber, measure the quality of ice in the cloud chamber, and then calculate icing rate by icy weight increment, finally get icing rate which is used for characterization ice nucleation property. In the experiment, selected different formulas for ice nucleation property study, obtained the data of icing rate. The results show that nucleation rate and icing rate have a good consistency in a certain range. Repetitive experimental obtained icing rate data are stability, and the test is simple, convenient and feasible.

Through the experiment, it shows that the experimental device has good repeatability, it is convenient and reliable, and icing rate in a certain range can reflect the ice nucleation property of pyrotechnics formula.

Keywords: weather modification; nucleation rate; icing efficiency; device; glaze ice

1. INTRODUCTION

For the past few years, serious persistent freeze disaster occurred frequently in several provinces in southern of China. The main cause was ice accumulation of glaze ice and rime. Glaze ice and rime appeared alternately, ice accumulation was on the surface of the object, particularly on surface of transmission lines and towers, which resulted in serious persistent freeze disaster

There are two main reasons for freezing: One is the temperature of objects near the ground surface is low(generally 0 ~ -10℃); another is low-altitude (3000m or less), where is rich in supercooled water, and gas temperature is mainly in 0 ~ -15℃, as the time there is abundant condensation nuclear and water vapor, but is lack of freezing nucleus. Raindrops temperature is lower 2 ~ 4℃ than environmental temperature when they drop, and they could low to -40℃ still maintain liquid state because of curvature constraints, once they got freezing nucleus, or fallen on the surface which the curvature reduced, they could instantly freeze, thus form to glaze ice and rime. In order to reduce the disaster losses, low the disaster mitigation costs, protect the national grid safety, there is need to study a kind of technology to intervene in the process glaze ice forming manual. However, due to weather modification work is mainly focused on the artificial rainfall and artificial hail suppression, etc. The study on manual intervention glaze ice is less, there is no experiment in this aspect domestically. Internationally, there are some tentative plans to spread ice crystals in supercooled cloud to reduce aircraft icing events or mitigate icy roads and highways problems, but how could reduce the freeze disaster and how to work in this aspect are still lack of basic physical model concepts. For these reasons, the research in the manually intervention glaze ice forming including nucleation mechanism and searching for high efficient pyrotechnics, should be in experimental method, and be tested and discovered in a certain controllable in door conditions.

There are plenty of water vapor and supercooled water when glaze ice occurs in the low-altitude. If it could release countless nanometer or sub-micron solid aerosol particles, to be the freezes nuclear of supercooled water, and start "Bergeron process" artificially, which makes supercooled cloud droplets and raindrops turned to ice, in this way it could destroy the critical link which supercooled water reach to the ground and form glaze ice, would probably only snow (graupel or icy particles) but not freezing rain, so that it could reduce freezing rain intensity significantly, and form an artificial anti-freezing rain reserve in key areas. Therefore, we need to simulation cloud in the cloud chamber for studying glaze ice and selecting the aerosol pyrotechnics formula which could promote the increase of supercooled water droplets to fall. Based on the experimental requirements, we designed a kind of experimental device to simulate freezing rain, and explored the experimental methods to reduce the glaze ice.

2. EXPERIMENT DEVICE

Experiment device consists of cloud chamber, temperature control system, fog systems, aerosol pyrotechnics ignition system and measurement system, etc. The schematic diagram of experiment device is shown in Figure 1.

2.1 Cloud chamber

The cloud chamber interior assumes rectangle, and the volume is 0.5m^3. The wall is made of stainless steel plate, which has thermal insulation layer outside, and there are multiple observational holes for experiment and instrument in front and side of the chamber. In addition, there is an aerosol pyrotechnics ignition system in the clamber.

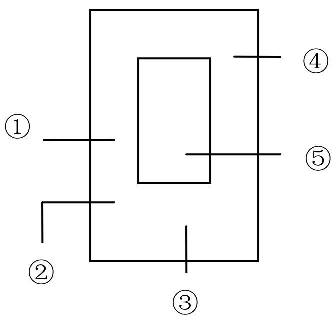

Figure 1 The schematic diagram of experiment device

①Temperature control system; ②Fog system; ③Ignition system; ④thermal insulation layer; ⑤Temperature and humidity monitors, Ignition controller and Fog controller

2.2 Temperature control

Temperature control system controls the temperature of the cloud chamber. Cycle refrigeration is well used to cool the cloud chamber and keep it at the required experimental temperature. Pre-set the experimental temperature in the beginning, and then start the refrigeration plant. When the temperature close to the pre-set temperature, refrigeration plant would stop and maintain at the temperature. If the temperature belows the pre-set temperature, the system automatically starts heating device, which can make sure the temperature maintain at the pre-set temperature.

TABLE 1 Refrigeration Performance Test

No.	T_1/℃	T_2/℃	T_3/℃	T_4/℃	Average cooling rate/(℃·min^{-1})
1	-5.0	9.1	-5.0	-4.6	0.707
2	-10.0	9.1	-10.2	-9.7	0.704
3	-15.0	9.1	-15.2	-15.0	0.710

Table 1 shows the refrigeration performance of the cloud chamber testing. T1、T2、T3 and T4 respectively represent pre-set experimental temperature, ambient temperature, thermal insulation layer temperature and the cloud chamber core temperature (all the temperature are stable). Experiments show that refrigeration plant can reduce the temperature effectively, prophase cooling speed is fast, but the time which the temperature closed to pre-set experiment temperature and keep it stable takes a long time. Cooling rate is concerned with ambient temperature and pre-set experimental temperature. The cloud chamber temperature is controlled by the system automatically. It needn't to be care after pre-set temperature. The system could control the temperature within a certain error range, and keep it constantly for a long time.

2.3 Fog environment

Fog in the cloud chamber is produced by ultrasonic nebulizer, and ultra-pure water atomized provided supercooled fog to cloud chamber for minimizing the disturbance to the temperature of the cloud chamber. Normally the temperature between the fog and the cloud chamber are closer, the thermal disturbance produced by fog is less. However, the temperature of the fog slightly higher than it in the cloud chamber is conducive to fog rise and proliferation rapidly and remain stable. Table 2 shows the changing of temperature by senting fog in 40min continuously. T_1、T_2 represent the thermal insulation layer and the cloud chamber core temperature before sending fog, T3、T4 represent the thermal insulating layer and the cloud chamber core temperature after sending fog. The fog temperature is slightly higher than the cloud chamber temperature in the experiment. Table 2 shows that continue sending fog has limited impact on the temperature of the cloud chamber, and won't cause too much interference to the experiment.

TABLE 1 The Temperature Influence Test

No.	T_1/℃	T_2/℃	T_3/℃	T_4/℃
1	-10.0	-9.7	-10.0	-7.7
2	-10.0	-10.2	-10.0	-8.7
3	-10.0	-10.0	-10.1	-8.5
4	-10.0	-9.5	-10.0	-7.9
5	- 5.0	-4.6	- 5.0	-2.4

2.4 Aerosol pyrotechnics ignition system

There is an aerosols ignition release device in the cloud chamber. Aerosol particles are produced by burning aerosol formula and spread with supercooled fog. Aerosol particles in the cloud chamber are relatively evenly distributed. Experimental results show that there are little differences between two experiment sequences: 1. first release aerosol and then sent the fog, 2. release aerosol after sent fog until saturation.

3. EXPERIMENTAL PROCEDURE

Experimental procedure as follow: (1) experimental preparation phase, clean the cloud chamber, place aerosol formula and two measuring plates which have the same shape and quality in the cloud chamber bottom, set a required temperature and start the refrigeration; (2) experimental stage, when the cloud chamber is cooled to the required temperature and keep 10 min, ignite aerosol formula to release aerosol particles, and wait 1 min in order to fully spread, then send the supercooled fog produced by ultrasonic nebulizer to the cloud chamber, continuous 40 min; (3) end of the experiment, remove the measuring plates weighing and then record the ice quality, finally calculate the icing rate. Monitor cloud chamber temperature during the experiment. Calculate icing rate by icy weight increment, and the icing rate in terms of per gram AgI can be calculated as follows:

$$M = M_2 - M_1 \qquad (1)$$

$$\mathbf{N} = M \times \frac{S_1}{S_2} \times \frac{1}{m} \qquad (2)$$

Where N is the icing rate in terms of per gram AgI, M the icy weight increment, M_2 the icy weight after release aerosol particles, M_1 the icy weight without aerosol particles, S_1 the cross section area of the cloud chamber, S_2 the total area of the measuring plates, m the mass of pyrotechnic column.

4. RESULTS AND DISCUSSION

Testing repeatability is an important indicator to measure the performance of cloud chamber. Select 3 different aerosol formulas to do testing experiments under the same temperature (-10℃) and the same condition (the same burning quality: 0.1g). The 3 formulas test results were shown in Table 3. $\overline{N}$ is the average, $N/\overline{N}$ is used to measure the experimental discrete degree, usually the value is closer to 1, explain experimental discrete degree is lower. The results show that the value in this experiment is between 0.625 and 1.463. It means the experimental discrete degree is low. With the same temperature, and the same experiment method, icing rates of a formula have not much fluctuation. Meanwhile, the cloud chamber has good repeatability.

Table 3 also shows that the formula with higher nucleation rate have a higher icing rate at -10℃, illustrating that in a certain range icing rate and nucleation rate have a good consistency. The reason could be the higher nucleation rate formula combustion release more aerosol particles, provide more freezing nucleus to the environment, increasing the transformation probability which supercooled cloud droplets and raindrops turn to ice, so that icing rate increase.

During the experiments, we found that there is a layer of thin ice on the measuring plate when the experiment without aerosol, but a layer of snow on the measuring plate when the experiment release aerosol, this phenomenon shows that after release aerosol, the transformation which supercooled cloud droplets and raindrops turn to ice is obvious. In future experiments, could consider to observe snowflake size, shape and other characteristics, and to analyze its impact to the ice nucleating properties

TABLE 3 Icing Rate Test by The Same Temperature

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