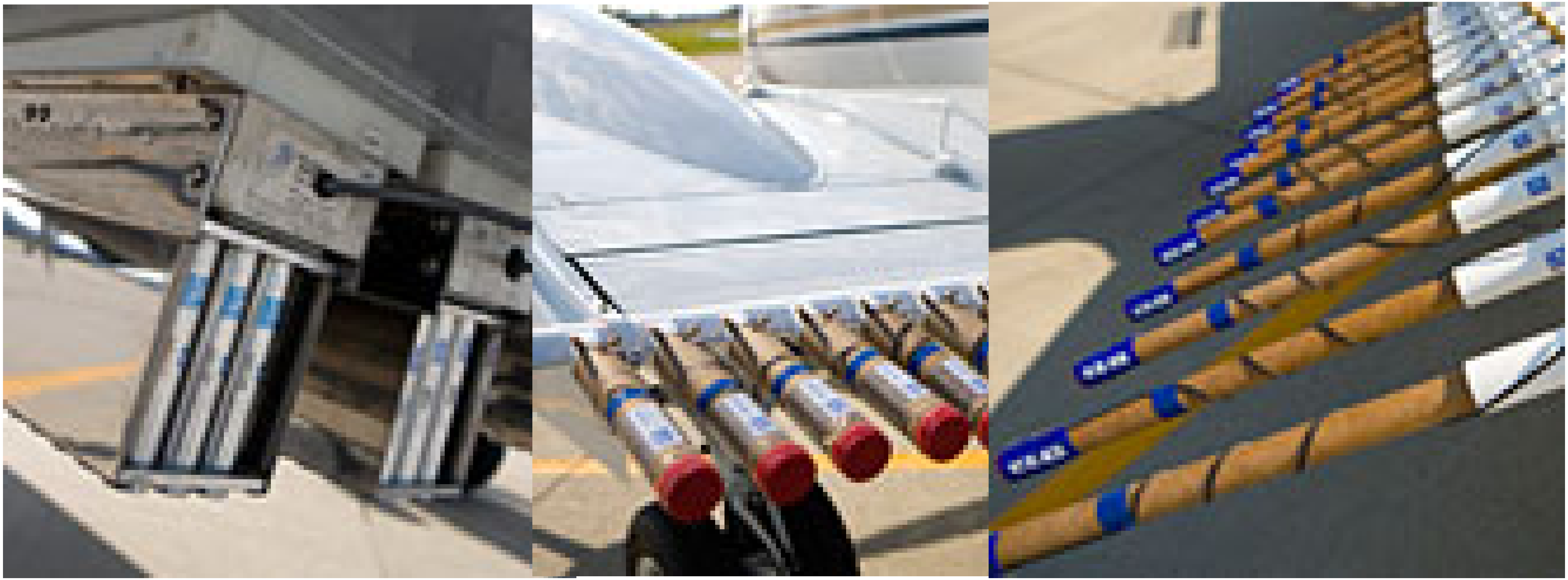
Seeding Materials



Goals

- Produce Large Droplets or Ice Crystals in Cloud
- Need: Proper Material and Equipment

Considerations

- 1. Program Objectives
- 2. Cost ($$)
- 3. Delivery/Production

Hygroscopic Materials

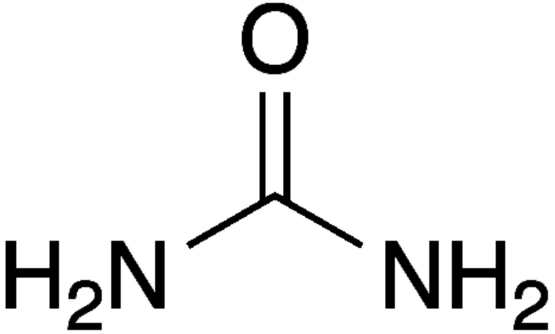
- Hygroscopic

→ Absorbing or Attracting Water Vapor

Hygroscopic Nuclei

- Objective is to broaden the cloud droplet size distribution in order to promote the collision-coalescence mechanism.

- Commonly used materials (various mixtures):
  - NaCl - most common.
  - NH_4OH (Ammonium Hydroxide)
  - Urea (Also Called Carbamide)



Generators

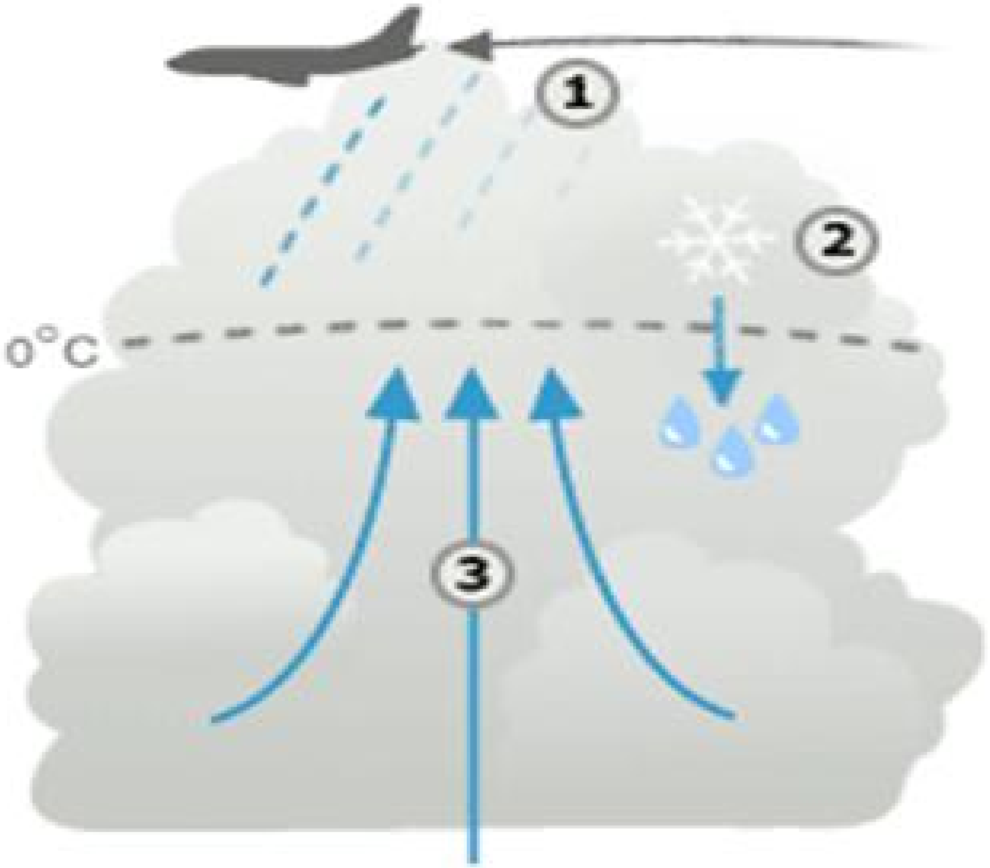
- Device designed to produce seeding particles
- May be either liquid or solid
- Normally used for glaciogenic materials, but also works for certain hygroscopic
- Works by vaporizing the seeding material
- Greater Than 1000 °C

Hygroscopic Seeding Requirements

- Must create many hygroscopic particles.
- Particles must be dispersed through the cloud volume.

Glaciogenic Seeding Requirements

- Must generate AgI particles (small).
- Particles must nucleate ice crystals.
- Material/Crystals must be dispersed through cloud volume.



Generation of Ice Nuclei

- Want to get maximum number of effective IN per mass of AgI for
  - Cost efficiency
  - Operations efficiency (I.e., weight, time of operations, etc.)

Generation of Ice Nuclei

AgI is a Powder

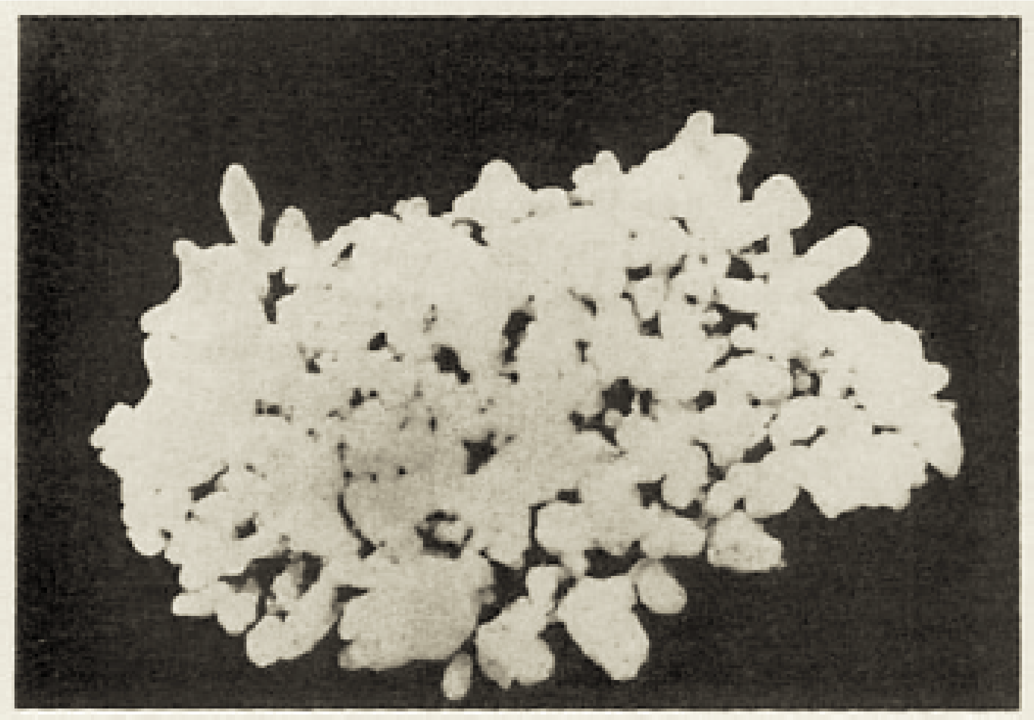
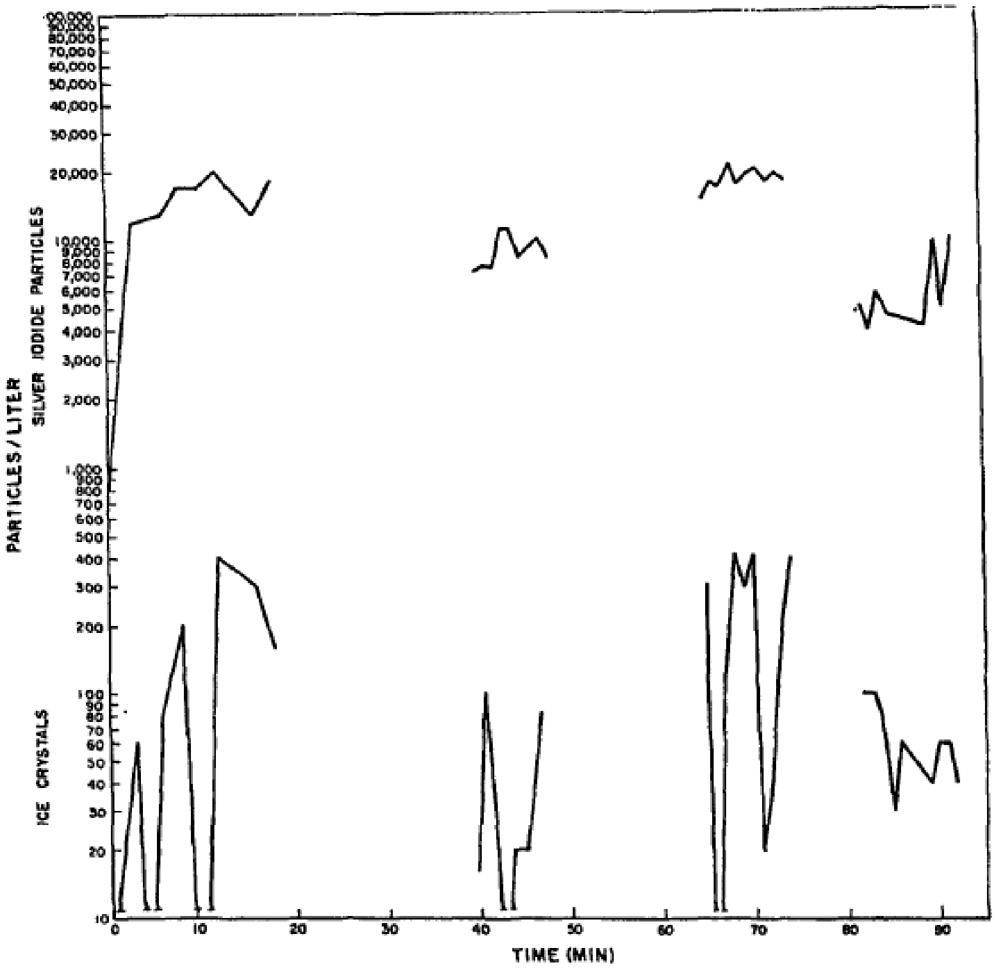


FIG. 3. Electron microscope photograph of typical AgI powder particle. Long dimension approximately 1.45 μ.

Sliver Iodide Activity



Ice Nucleation Efficiency of Silver Iodide at −20C on a Particle Count Basis

Langer, et al., 1967, J. Appl. Meteor., 6, 963-965

Generators

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Generator Types

- Liquid
  - Uses acetone for hot flame
  - Needs a carrier to put AgI into solution
- Pyrotechnic
  - AgIO3, Al, Mg, binder
  - Burn-in-place or ejectable

Hygroscopic Flares

- Flares burn hot (>2000 ºC)
- Solids are vaporized
- Vapors quickly cool and form very small solid compounds in extremely large numbers
- These particles coagulate (stick together) to form larger seeding particles
- CCN concentrations ~20,000 cm^{-3}

Particle Yields

- Particles created by cooling of vapor.
- Need good airflow.
- Particles coagulate.
- Maximum yield about 10^{15} particles per m^3.
- Approximately 10^{14} Ice Nuclei per gram AgI.

Initial Losses of Nuclei

Initial Rate of Decrease Due to Brownian Coagulation in Concentration of a Monodisperse Aerosol as a Function of Particle Diameter d and Concentration N [a]

		N (m^{-3})		
		$10^{13.5}$	10^{14}	$10^{14.5}$
	10	1%	3%	10%
	1.0	1	3	10
d (μm)	0.1	2	7	20
	0.01	3	9	30

[a] Percent decrease per second.

Efficiency

- Definition: Number of particles per gram of AgI producing ice crystals at a given Temperature.
- May vary as a function of Temperature.
- Difficult to test.

Efficiency

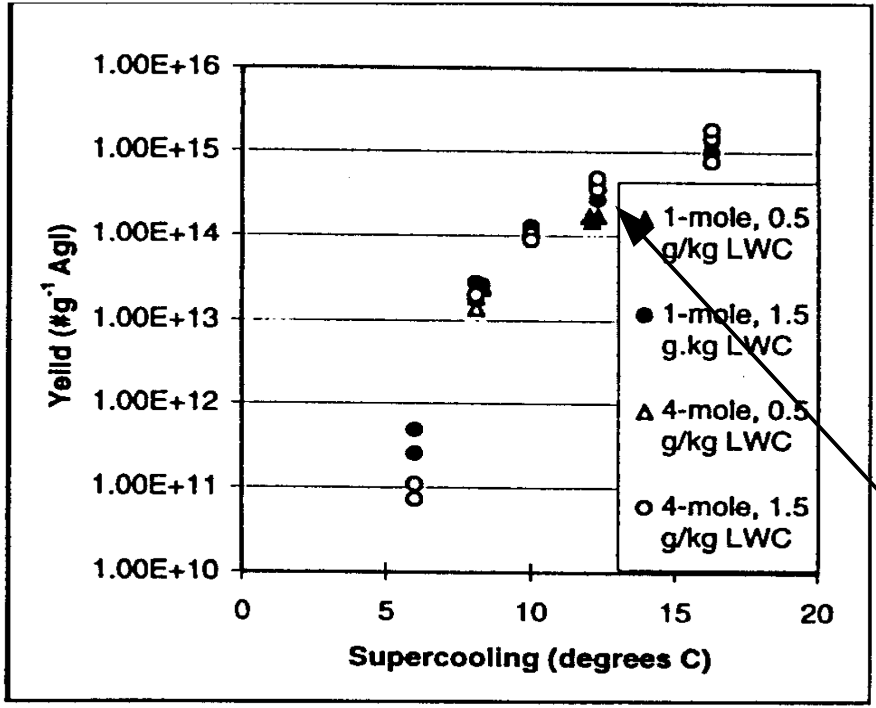


***Figure 32.** Effectiveness for $AgI_{0.8}Cl_{0.2}$-NaCl and $AgI_{0.8}Cl_{0.2}$-4NaCl nuclei (DeMott 1997).*

5.3 ACTIVITY OF SILVER IODIDE PARTICLES 111

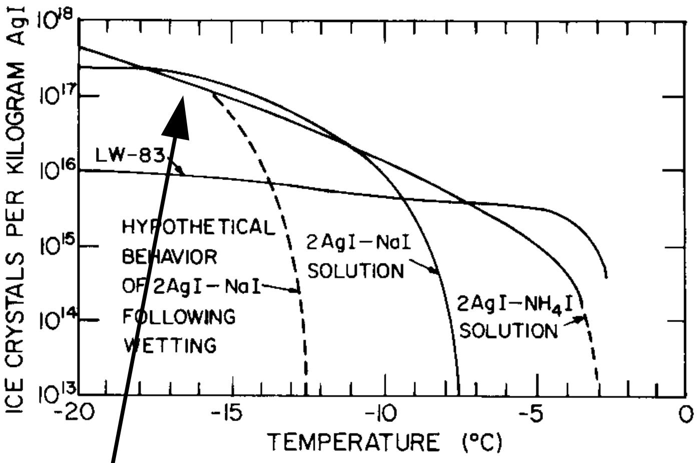


Fig. 5.5. Activity curves for AgI generator products measured in wind tunnel/cloud chamber facility at South Dakota School of Mines and Technology by J. A. Donnan. [After P. St.-Amand *et al.* (1971b). *J. Weather Modification* **3**, 31, by permission of Weather Modification Association and senior author.]

Approximately 10^{14} Ice Nuclei per gram AgI.

Activity

- Ideal: many crystals at warm temps (-5° C), none at cold.
- Activation: formation of an ice crystal on a nucleus
- Modes of activation: deposition, condensation/freezing, contact, bulk freezing

Activiation

- Deposition – requires larger nuclei, effective only at colder temps
- Condensation/freezing – relatively effective
- Contact – requires high concentrations to act very quickly
- Bulk freezing – nucleus may dissolve

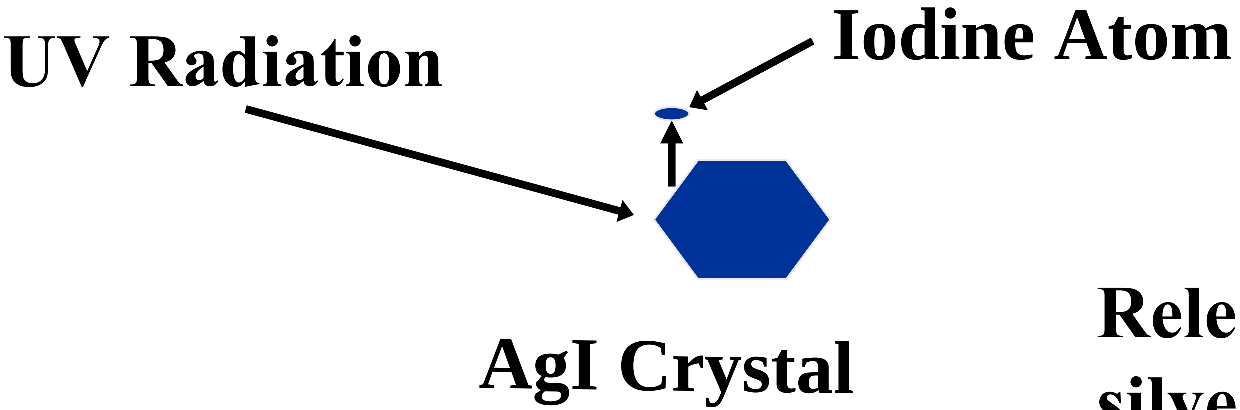
Deactivation

- By UV rays: loss of nucleation ability, up to 90% in one hours
- By solution

Photodeactivation of AgI

- When exposed to UV radiation, the iodine is dissociated from the silver and will go off as a gas.
- The silver remains on the outside of the particle, leaving a coating of silver.
- Pure silver is not an effective IN.

Photodeactivation of AgI



Release of iodine from the silver iodide leaves silver behind as a coating on the AgI crystal

Activation Rate

- Speed of nucleation is critical
- Rate is a function of formulation, temp, liquid water content
- Condensation/freezing is fastest

Activation Rate

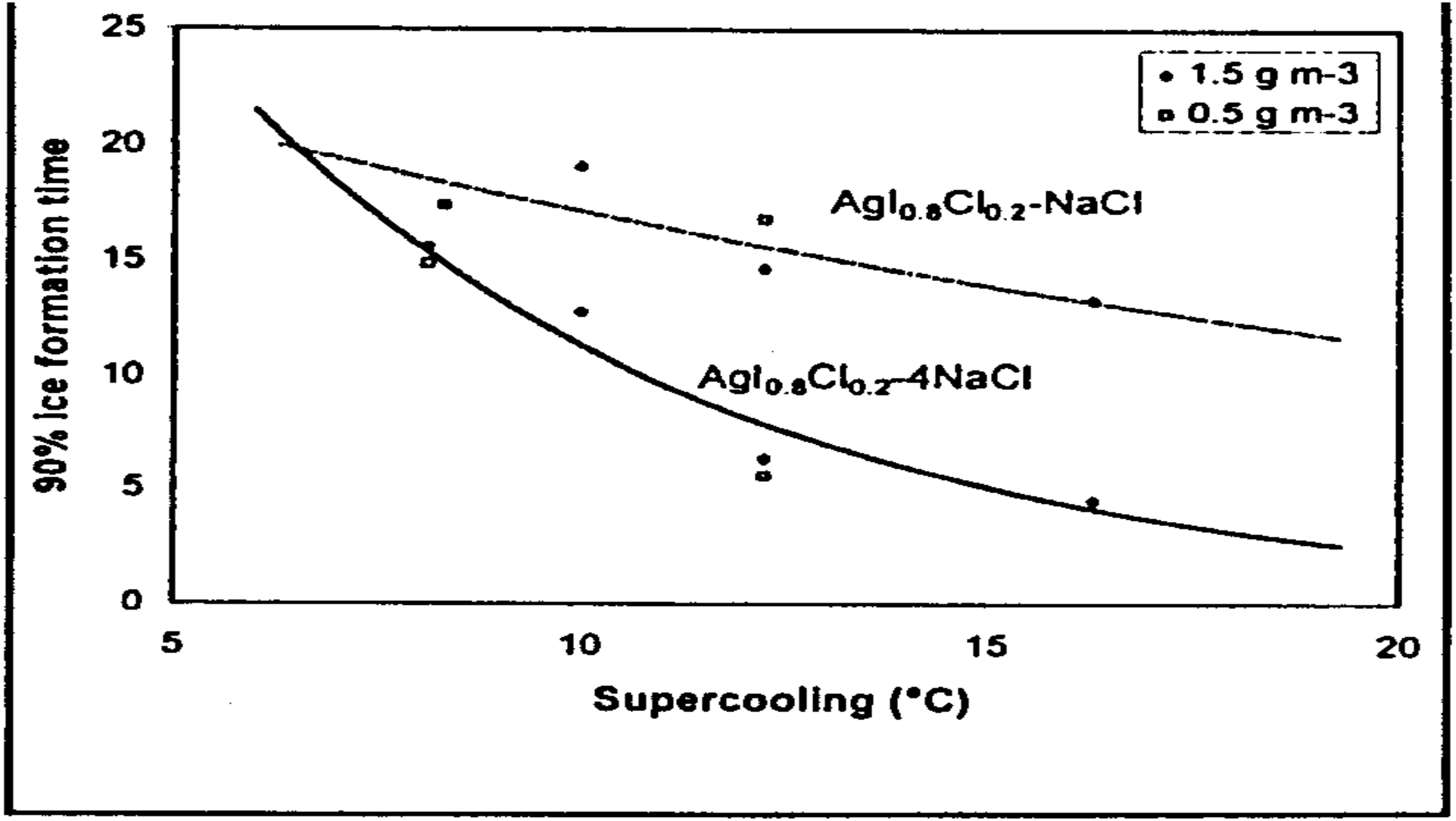


Figure 33. Activation times for $AgI_{0.8}Cl_{0.2}$-4NaCl and $AgI_{0.8}Cl_{0.2}$-NaCl, *the latter being used in the NDCMP (DeMott 1997).*

Summary of Key Attributes

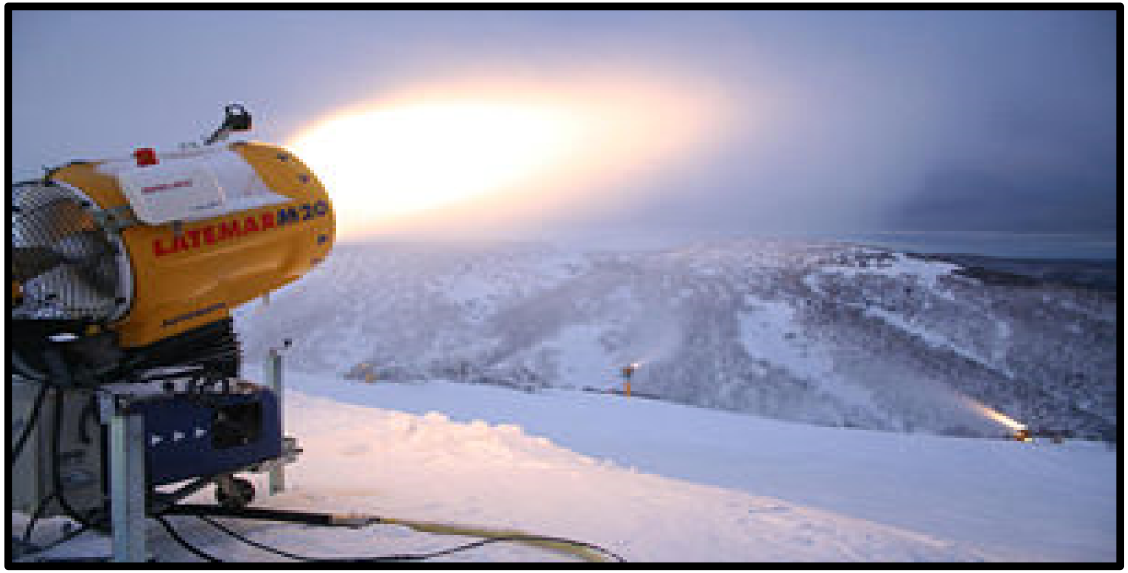
- Efficiency
  - Number of active IN per gram of seeding agent.
- Activity
  - Number of active IN as a function of temperature.
- Activation Rate
  - Speed of activation.

Other Materials

- Pseudomonas syringae is a rod-shaped, Gram-negative bacterium with polar flagella. (Wikipedia, 2015)
- Naturally occurring
- Causes water to freeze on plants

Pseudomonas Syringae

- These proteins serve as effective nuclei to initiate the formation of ice crystals at relatively high temperatures, so that the droplets will turn into ice before falling to the ground.



Liquid Propane

- Release of liquid propane as a gas from a LP dispenser chills the air to as cold as -100°C
- Because of the tremendous local chilling, LP release can generate ice crystals at temperatures as warm as -0.5°C
- Rate ~ 4 oz/min