LABORATORY STUDIES OF COLD FOG DISPERsal BY COMPRESSED AIR

Thomas E. Lukow and James R. Hicks

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PREFACE

This report was prepared by SP Thomas E. Lukow and James R. Hicks, Meteorologist, Physical Sciences Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory. The work was performed under DA Project 1T161102B52A, Mobility and Environmental Research, Task 02, Military Aspects of Cold Regions Research, Work Unit 007, Fog Dispersion, Creation and Interaction of Electromagnetic Radiation with Cold Regions Environment.

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by

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INTRODUCTION

Cold fog is a major weather hazard for most means of transportation, but those most adversely affected are aircraft and automobiles. Airports are frequently closed because fog causes the visibility to fall below the minimum required for safe aircraft operation. Fog-covered highways are especially hazardous to motorists and the danger increases as the number of vehicles on the highways increases. An efficient fog dispersal system is therefore needed to provide safe, reliable and economical air and surface transportation.

In 1948 Bernard Vonnegut first seriously considered the use of compressed air as a nucleating agent for cold fog. Vincent Schaefer (1953), using a systematic laboratory approach, studied this phenomenon extensively. More recent work was done by Clement Todd (1965) who studied the feasibility of using compressed air from aircraft engines as a source of ice crystal production for seeding purposes. From these and many other sources of information, the present research was developed.

This report describes two basic types of laboratory fog dispersal experiments using compressed air. One, the sudden expansion technique, uses a quick burst of expanding air of a given volume followed by a period of time for recharging the system for another burst of compressed air. In the other method a constantly flowing stream of compressed air at a given pressure produces a continuous formation of ice crystals. These two techniques were compared to determine which was more efficient and which would probably be the better system for field study in the future.

THEORY OF FORMATION, GROWTH AND PRECIPITATION OF ICE CRYSTALS

In a supercooled fog (where the temperature of the fog is below 0°C) the water droplets are in the liquid state, an abnormal condition for water at that temperature. If the temperature of some of these water droplets is lowered either naturally or artificially to below the spontaneous freezing temperature, approximately −42°C, the droplets will freeze. Then, due to the difference in vapor pressure between the surfaces of the ice crystals and the surfaces of the water droplets, the ice crystals will grow, the remaining droplets will evaporate, and the crystals will precipitate as light snow, provided enough moisture is available to allow that much crystal growth. By using this, the Bergeron-Findeisen theory, a supercooled fog can be readily dissipated.

Compressed air undergoes intense cooling as it expands through a nozzle. This adiabatic expansion cooling effect for compressed air in relation to temperature drop is shown in Table I. Since a temperature drop of about −42°C is necessary for spontaneous nucleation, the approximate lower limit in pressure would be about 1.85 atmospheres (27 psig). Any pressure equal to or greater than that pressure should and does cause spontaneous ice crystal nucleation in a moist, supercooled environment.
**LABORATORY STUDIES OF COLD FOG DISPERSAL BY COMPRESSED AIR**

Table 1. Computation of temperature change $\Delta T$ (K or °C) from adiabatic expansion.

<table>
<thead>
<tr>
<th>Initial press.</th>
<th>$T_0$ (K or °C)</th>
<th>$\Delta T$ (K or °C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_0$ (Atm abs)</td>
<td>$T_0$</td>
<td>$T$ = $T_0 - \frac{\ln(P)}{0.287}$</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1.1</td>
<td>0.710</td>
<td>0.737</td>
</tr>
<tr>
<td>1.2</td>
<td>13.41</td>
<td>13.92</td>
</tr>
<tr>
<td>1.3</td>
<td>19.08</td>
<td>19.80</td>
</tr>
<tr>
<td>1.4</td>
<td>24.21</td>
<td>25.13</td>
</tr>
<tr>
<td>1.5</td>
<td>28.59</td>
<td>29.99</td>
</tr>
<tr>
<td>1.6</td>
<td>33.19</td>
<td>34.45</td>
</tr>
<tr>
<td>1.7</td>
<td>37.15</td>
<td>38.56</td>
</tr>
<tr>
<td>1.8</td>
<td>40.83</td>
<td>42.38</td>
</tr>
<tr>
<td>1.9</td>
<td>44.25</td>
<td>45.92</td>
</tr>
<tr>
<td>2</td>
<td>47.44</td>
<td>49.25</td>
</tr>
<tr>
<td>2.1</td>
<td>50.44</td>
<td>52.36</td>
</tr>
<tr>
<td>2.2</td>
<td>53.26</td>
<td>55.29</td>
</tr>
<tr>
<td>2.3</td>
<td>55.91</td>
<td>58.05</td>
</tr>
<tr>
<td>2.4</td>
<td>58.43</td>
<td>60.66</td>
</tr>
<tr>
<td>2.5</td>
<td>60.81</td>
<td>63.13</td>
</tr>
<tr>
<td>2.6</td>
<td>63.08</td>
<td>65.48</td>
</tr>
<tr>
<td>2.7</td>
<td>65.23</td>
<td>67.71</td>
</tr>
<tr>
<td>2.8</td>
<td>67.29</td>
<td>69.84</td>
</tr>
<tr>
<td>2.9</td>
<td>69.25</td>
<td>71.88</td>
</tr>
<tr>
<td>3</td>
<td>71.12</td>
<td>73.83</td>
</tr>
<tr>
<td>4</td>
<td>86.33</td>
<td>89.81</td>
</tr>
<tr>
<td>5</td>
<td>97.29</td>
<td>100.99</td>
</tr>
<tr>
<td>6</td>
<td>105.74</td>
<td>109.76</td>
</tr>
<tr>
<td>7</td>
<td>112.54</td>
<td>116.82</td>
</tr>
<tr>
<td>8</td>
<td>118.20</td>
<td>122.69</td>
</tr>
<tr>
<td>9</td>
<td>123.01</td>
<td>127.69</td>
</tr>
<tr>
<td>10</td>
<td>127.18</td>
<td>132.01</td>
</tr>
<tr>
<td>11</td>
<td>130.85</td>
<td>135.82</td>
</tr>
<tr>
<td>12</td>
<td>134.11</td>
<td>139.21</td>
</tr>
<tr>
<td>13</td>
<td>137.03</td>
<td>142.24</td>
</tr>
<tr>
<td>14</td>
<td>139.68</td>
<td>145.00</td>
</tr>
<tr>
<td>15</td>
<td>142.10</td>
<td>147.51</td>
</tr>
</tbody>
</table>

$\Delta T = T - T_0$ where:

- $T$ = Final temp after expansion (K)
- $T_0$ = Initial temp (K)
- $P$ = Final pressure (1 atmosphere absolute)
- $P_0$ = Initial pressure (compressed state - atmosphere absolute)

Related to this spontaneous ice crystal nucleation is the question of where the moisture for the ice nuclei is obtained. There are two theories which have been advanced and supported to answer this question. They are 1) the theory of entrainment of available moisture where the bulk of the ice crystals formed comes from the fog immediately surrounding the plume of the nozzle, and 2) the theory of self-contained moisture where the bulk of the ice crystals formed comes from the moisture contained in the seeding air. For compressed air to be most effective in clearing a cold fog, the air containing the ice crystal nuclei must mix as completely as possible with the fog. This holds true for either of the above stated theories. Any ice nuclei that are formed and fail to enter the moist air are wasted.
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FOG CHARACTERISTICS

Liquid water content (LWC)

The liquid water content is the amount of liquid water contained in a given volume of air. This value varies with the density of the fog but was kept as nearly equal as possible during all the tests in this study. The average liquid water content was determined using a 250-ml flask filled with glass wool connected to a vacuum line. The flow rate was determined by recording the time necessary to evacuate a plastic bag of known volume at a constant partial vacuum. It was then arbitrarily decided that two minutes would be appropriate for each LWC test. The volume of air sampled in two minutes was found to be 0.11 m³. On every test for LWC, frost formed on the surface of the glass wool on the intake end of the flask and no frost was visible on the exhaust end of the flask. From this indication, it was determined that all the liquid water had been removed from the filtered air. The weight of the flask was recorded before and after each test, and thus the weight of liquid water content for the fogs developed in the coldroom tests was calculated to be 1.28 g/m³. Shown below is the formula used to calculate the LWC.

\[ \text{LWC} = \frac{\text{weight of water collected (g)}}{\text{volume of air drawn through filter (m}^3\text{)}} \]

The apparatus used to measure LWC is shown in Figure 1.

![Figure 1. LWC measurement.](image)

Size distribution of liquid water droplets

Although size distribution analysis of the liquid water droplets making up the supercooled fogs was not an essential aspect of the research undertaken, it was felt that a sample should be taken for reference purposes. Two different fogs were sampled. One sample consisted of only one slide and the other consisted of three slides taken at varying time intervals of fog decay. The samples were collected on microscope slides coated with a water-soluble dye, eosin B. The droplet data were obtained in the coldroom at a temperature of -12°C in the center of the room about 1.2 m above the floor. Shown in Table II are the data obtained from the analysis of the fog water droplet samples taken with the average liquid water content of 1.28 g/m³ used in the calculations to determine mean radius. The number of liquid water droplets/cm³ was determined by photographing a selected portion of each slide and then counting the number of replicas seen on the print. The number of water droplets counted was then multiplied by the appropriate factor to get the number of water droplets/cm³ in the air.* The mean radius was calculated using the formula shown below.

\[ r = \sqrt[3]{\frac{\text{LWC}}{4\pi N}} \]

where \( \pi = 3.1416 \)

- \( N = \text{total number of water droplets/cm}^3 \)
- \( r = \text{average droplet radius} \).

* The sampling, photographing and counting of these slides were done by Ulrich Katz (1973).
LABORATORY STUDIES OF COLD FOG DISPERSAL BY COMPRESSED AIR

Table II. Mean radius determination of liquid water.

<table>
<thead>
<tr>
<th>Sample</th>
<th>Slide</th>
<th>Time from formation of fog (min)</th>
<th>Concentration (droplets/cm³)</th>
<th>Mean radius (µ)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>1</td>
<td>23,000</td>
<td>2.36</td>
</tr>
<tr>
<td>2</td>
<td>B</td>
<td>1</td>
<td>22,000</td>
<td>2.40</td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>3</td>
<td>14,000</td>
<td>2.79</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>6</td>
<td>4,000</td>
<td>4.24</td>
</tr>
</tbody>
</table>

RESULTS AND DISCUSSION

Sudden expansion system

The sudden expansion system was designed with a very large exhaust opening to create as little nozzle restriction as possible and to allow almost instantaneous injection of the compressed air into the cold fog. The success of this system gives support to the theory of spontaneous nucleation using self-contained moisture: The air is expelled somewhat as a unit with little mixing with or entrainment of the surrounding moist air; however, no study was made of these phenomena.

Dispensing apparatus. The sudden expansion cold fog dispersal system used in this research is shown in Figure 2.

The source of compressed air for seeding was the laboratory's piped air, controlled in the coldroom by an air pressure regulator. The purpose of the constant humidity tank was to enable the compressed air to become saturated with respect to ice so that all tests would be at the same relative humidity. The sudden expansion chamber was used both as the dispensing apparatus (through the flapper mouth) and as the source of a known volume of air.

Figure 2. Sudden expansion system.

Testing procedure. After the pressure regulator was adjusted to the desired test pressure, the compressed air was allowed to stand in direct contact with the ice in the constant humidity tank for about 30 minutes to make sure the air was completely saturated with respect to the ice. The coldroom was then filled with steam to create a heavy fog (visibility = 5 m). (Tests had previously been conducted to determine how much warming occurred when the steam was introduced into the coldroom. It was found that the initial temperature of the coldroom had to be approximately 2°C cooler than the actual test temperature desired.) The shut-off valve on the sudden-expansion chamber was then closed and the flapper quickly released. The cover was forced open by the pressure of the compressed air. The time needed to completely glaciate the room was recorded and samples of the crystals produced were taken on dry formvar-coated microscope slides.
Laboratory Studies of Cold Fog Dispersal by Compressed Air

Figure 3. Crystal production/cm³ vs absolute pressure.

Table III. Pressure efficiency values (sudden expansion), temperature -4°C.

<table>
<thead>
<tr>
<th>Pressure (psig)</th>
<th>E_Air (10⁵ crystals/cm³)</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>29.7</td>
<td>38.6</td>
<td>63.2</td>
<td>24.9</td>
</tr>
<tr>
<td>27</td>
<td>41.7</td>
<td>58.4</td>
<td>66.5</td>
<td>41.1</td>
</tr>
<tr>
<td>39</td>
<td>55.7</td>
<td>39.7</td>
<td>51.4</td>
<td>27.8</td>
</tr>
<tr>
<td>59</td>
<td>73.7</td>
<td>26.3</td>
<td>32.8</td>
<td>18.9</td>
</tr>
</tbody>
</table>

Table IV. Temperature efficiency data (sudden expansion), pressure 41.7 psig.

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>E_Air (10⁵ crystals/cm³)</th>
<th>Avg</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4</td>
<td>52.4</td>
<td>66.5</td>
<td>41.1</td>
<td></td>
</tr>
<tr>
<td>-8</td>
<td>55.3</td>
<td>90.2</td>
<td>32.0</td>
<td></td>
</tr>
<tr>
<td>-12</td>
<td>55.7</td>
<td>75.6</td>
<td>35.1</td>
<td></td>
</tr>
<tr>
<td>-16</td>
<td>47.5</td>
<td>57.8</td>
<td>29.8</td>
<td></td>
</tr>
<tr>
<td>-20</td>
<td>73.3</td>
<td>85.7</td>
<td>55.5</td>
<td></td>
</tr>
</tbody>
</table>

Chloroform vapor was used to soften the formvar on the microscope slides to allow permanent replicas to be formed by the crystals lying on the slides. The total number of crystals produced and the efficiency of the sudden expansion chamber for each pressure and temperature tested with respect to air were calculated from the slides. Each efficiency (E_Air) shown in Tables III and IV is an average obtained from six individual tests.

The first variable that needed to be determined before any detailed research could be attempted was the pressure at which the efficiency of air was at an optimum. This peak for the sudden expansion chamber was found to be 27 psig (41.7 psig) as shown in Table III. All further tests of the sudden expansion system used this pressure with the changing variable being the temperature of the coldroom. The data shown in Table II are also plotted in Figure 3 to show more clearly the relationship between the efficiency of air and the pressures tested. The next step was to determine
what effect the change in temperature would have on crystal production at 27 psig (41.7 psia). The temperatures used ranged from -4°C (which had already been measured) through -20°C. These data are shown in Table IV.

The efficiency of compressed air was quite consistent over the range of temperature at which testing was done. The seeming discrepancy in crystal production at -16°C where the value drops to $47.5 \times 10^7$ crystals/cm$^3$ instead of rising as the rest of the data are doing is a point of interest. Other investigators, using other techniques for ice crystal production, have observed this phenomenon. Figure 4 shows similar curves for other cold fog dispersal materials (St. Amand 1966).

Discussion. It was found through this experimentation that for the sudden expansion system of laboratory fog dispersal, the most efficient compressed air pressure was 27 psig (41.7 psia). From this it was experimentally found that a change in temperature did not radically affect crystal production efficiency but at about -16°C there was a definite loss of efficiency. By -20°C the values were back up and were even higher than previously recorded data. At the warmest test temperature (~4°C), the crystal production efficiency for air was still very high for fog clearing ($52.4 \times 10^7$ crystals/cm$^3$). From this information it was determined that the sudden expansion system was very effective in dispersing laboratory cold fogs at the temperatures tested and has definite possibilities as an effective atmospheric cold fog dispersal system.

Continuous flow

In the continuous flow technique compressed air was discharged continuously through five different nozzles at various temperatures and pressures with the best nozzle being selected for its crystal production efficiency.

Dispensing apparatus. The continuous flow system (Fig. 5) contained the same basic equipment as the sudden expansion system plus a simple on-off solenoid valve controlled by an electronic phototimer having a minimum timing capacity of 0.1 sec. This valve was attached directly to the constant humidity tank.

Five types of nozzles were tested using the continuous flow system (see Table V). Two of the nozzles tested used a 0.2-sec time interval and three used a 0.1-sec time interval. These time intervals allowed the discharge of approximately the same volume of seeding air for each nozzle; the volume was also approximately the same as was contained in the sudden expansion chamber.

Testing procedure. The testing procedures for the continuous-flow system were the same as for the sudden-expansion system except for the actual injection of the air into the fog. This was accomplished by actuating the solenoid for the proper time interval of the nozzle being used.
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Figure 5. Continuous flow system.

Table V. Nozzle types (continuous flow).

<table>
<thead>
<tr>
<th>Nozzle</th>
<th>Flow time (sec)</th>
<th>Orifice diam (in.)</th>
<th>Manufacturer</th>
<th>Flow pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supersonic</td>
<td>0.1</td>
<td>0.040</td>
<td>CRREL design</td>
<td>Supersonic speed, full cone</td>
</tr>
<tr>
<td>Whirljet 1/8 A 0.5</td>
<td>0.1</td>
<td>0.046</td>
<td>Spraying System Co.</td>
<td>Hollow cone, = 112°, extra wide angle</td>
</tr>
<tr>
<td>Fulljet 3001.4</td>
<td>0.2</td>
<td>0.028</td>
<td>Spraying System Co.</td>
<td>Full cone, = 30°</td>
</tr>
<tr>
<td>Teejet 0001</td>
<td>0.2</td>
<td>0.028</td>
<td>Spraying System Co.</td>
<td>Straight cone, = 0°</td>
</tr>
<tr>
<td>1/4 Ln 10</td>
<td>0.1</td>
<td>0.064</td>
<td>Spraying System Co.</td>
<td>Hollow cone, = 80°, atomizing</td>
</tr>
</tbody>
</table>

All five nozzles were tested at -4°C, -8°C, -12°C and -16°C at 27 psig (41.7 psia), but only two of the five nozzles were tested at pressures of 15, 27, 45 and 60 psig at -4°C. These were the supersonic and Whirljet 1/8 A 0.5 nozzles. These nozzles were selected from the five because they showed the greatest promise as fog dispersal nozzles and the other three were essentially useless for this purpose. The Whirljet 1/8 A 0.5 nozzle was then dropped from further study because its efficiency did not improve with increased pressure and only the supersonic nozzle was tested at 75 and 90 psig at -4°C.

Minus 4°C was chosen as the temperature to be extensively studied because cold fogs are most difficult to dissipate near 0°C and the measured efficiencies of all the nozzles were least at -4°C which was the warmest temperature studied. The maximum efficiency for each nozzle and that which was most efficient overall was determined in this manner.

Data obtained. The average values for the samples taken are shown in Table VI for each nozzle type in order of decreasing efficiency. Each value shown under $E_{air}$ for the supersonic, Whirljet 1/8 A 0.5, and the Teejet 0001 nozzles is an average of six individual tests. The 1/4 Ln 10 and the Fulljet 3001.4 nozzle values are averages obtained from three individual tests each. It was decided that six tests were unnecessary for these nozzles because of poor efficiencies. For each individual test, two microscope slides were taken and the better was counted and used for calculations. Figure 6 shows the efficiency of each nozzle with respect to air (crystals/cm²) at the temperatures tested and its resultant curve.

Discussion. From the samples collected and the calculations made, it was found that a compressed air pressure of =27 psig was great enough to allow adiabatic expansion cooling of approximately 42°C, thus creating temperatures low enough to freeze water droplets in the fog and/or to create ice embryos from the water vapor. Any increase in pressure above 27 psig had no measurable effect on the crystal production efficiency and any larger number of crystals in the fog after
LAboratory Studies of Cold Fog Dispersal by Compressed air.

Table VI. Nozzle efficiency data (continuous flow).

<table>
<thead>
<tr>
<th>Temp (°C)</th>
<th>Pressure (psig)</th>
<th>Pressure (psia)</th>
<th>E_{air}(10^7 \text{ crystals/cm}^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Avg</td>
</tr>
</tbody>
</table>

**Supersonic**
-4 15 29.7 No crystals produced
-4 27 41.7 19.48 22.63 15.89
-4 45 59.7 25.07 40.77 11.03
-4 60 74.7 16.88 22.46 12.66
-4 75 89.7 24.64 31.52 20.96
-4 90 104.7 19.87 25.63 15.90
-8 27 41.7 22.71 31.88 12.13
-12 27 41.7 29.46 46.58 12.90
-16 27 41.7 18.93 22.08 17.24

**Whirljet 1/8 A 0.5**
-4 27 41.7 0.012 * *
-4 45 59.7 3.27 3.53 3.00
-4 60 74.7 0.238 * *
-8 27 41.7 4.50 5.87 3.82
-12 27 41.7 15.98 16.42 15.69
-16 27 41.7 3.83 4.99 2.75

**Teejet 0001**
-4 27 41.7 0.0034 * *
-8 27 41.7 0.036 * *
-12 27 41.7 4.72 9.51 4.03
-16 27 41.7 0.32 0.53 0.149

**1/4 Ln 10**
-4 27 41.7 0.0045 * *
-8 27 41.7 0.036 * *
-12 27 41.7 0.33 * *
-16 27 41.7 0.012 * *

**Fulljet 3001.4**
-4 27 41.7 0.003 * *
-8 27 41.7 0.067 * *
-12 27 41.7 0.168 * *
-16 27 41.7 0.0067 * *

* The efficiency of each nozzle under certain conditions gave such poor results that only visual estimates of the distance between ice crystals could be made in the coldroom for purposes of calculating E_{air}.

The drop in crystal production efficiency between -12°C and -16°C follows the same pattern as that found using the sudden expansion system. Additional support is given to the phenomenon expansion was produced by the larger volume of air being injected into the room rather than being an increase in crystals/cm³ of compressed air.

Figure 6 shows that the supersonic nozzle far surpassed the other four nozzle types in crystal production. The Whirljet 1/8 A 0.5 nozzle seemed to be quite temperature-dependent because its efficiency was very low at the warmer temperatures (-4°C) but rose rapidly as the temperature moved towards -12°C. Even at that the Whirljet 1/8 A 0.5 nozzle never did reach the efficiency of the supersonic nozzle. The other three nozzles had very little fog dissipating capacity and were therefore eliminated early in the experimentation. The supersonic nozzle was the only one that was very effective at the warmer temperature (-4°C) and the others were essentially useless for fog dissipation that close to 0°C.
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Figure 6. Efficiency (air) of nozzles vs temperature (°C).

by Figure 4 (St. Amand 1966) which shows similar curve deviations at the same temperature range for several different types of fog dispersal agents studied.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

These two series of tests, sudden expansion and continuous flow, have shown that releasing compressed air into a laboratory cold fog under the proper conditions will produce significant changes in the fog's structure and subsequently improve visibility. The sudden expansion system has shown itself to be more efficient than any of the continuous flow systems although both the sudden expansion and the supersonic nozzle systems are in the same order of magnitude as far as crystal production is concerned (10^7 crystals/cm^3 of air).

Mechanically, the continuous flow system is much easier to use because of its steady, unchanging characteristics. The sudden expansion system on the other hand requires a significant recharge time between seeding bursts. Furthermore, it is mechanically complicated in that the discharge mechanism must release, close itself, relatch, and after a few seconds recharge time release again. To make an automatic system capable of doing all these steps quickly and economically would necessitate research into the design of this apparatus.

It was also found that pressure was a very important factor in increasing crystal production up to approximately 27 psig but above that pressure no measurable increase in crystal production
was noticed. Twenty-seven psig (41.7 psia) gives an adiabatic temperature drop of about 42°C, to a temperature cold enough to cause ice crystal nucleation in a moist, supercooled fog.

The effect of temperature on crystal production was one of increasing production to approximately -12°C, at which temperature there was a decrease in production to about -16°C. This phenomenon was noted throughout both series of tests and had been previously noticed by St. Armand (1966).

**Recommendations**

Full-scale studies should be made in the field to determine what effect compressed air will have on natural atmospheric supercooled fogs. Major areas that should be studied are:

1. The speed and effectiveness of the compressed air method in clearing a supercooled fog under field conditions.

2. The ease with which each system could be put into operation. This would mean that a prototype of each should be built which could be used to answer the questions brought into focus by 1.

3. Analysis and testing of several different types and sizes (shapes and capacities) of supersonic nozzles.

There are also several areas of research that should be conducted in the laboratory:

1. A comparison of liquid propane and compressed air with respect to cost of set-up and operation, effectiveness in the field, ease of operation and safety.

2. Testing to see how well compressed air works near 0°C and if its crystal production is greater than that of other known supercooled fog dispersal agents at these temperatures.

3. Determination of the extent to which moisture in the compressed air affects crystal production; and inversely, the extent to which entrained moisture affects crystal production.

4. Determination of the role of turbulence or cavitation in the creation of ice embryos.

**LITERATURE CITED**


LABORATORY STUDIES OF COLD FOG DISPERSAL BY COMPRESSED AIR

Two compressed air systems for glaciating supercooled clouds were studied in the laboratory. The first system used the sudden expansion of compressed air and was found to be most efficient at 27 psig producing an average of $5.2 \times 10^9$ ice crystals per cm$^3$ of air. The second system used a continuous flow of air through nozzles of various designs, of which the supersonic nozzle was found to be the most efficient, producing a maximum of $2.5 \times 10^8$ crystals per cm$^3$ of air at 27 psig. The above data were obtained at an ambient temperature of $-4^\circ$C, but data for other temperatures and pressures were obtained and are presented in the text.

14. KEY WORDS

Fog
Fog dispersal
Visibility