
The Success of Super-cooled Fog Seeding for Airline Operations

I. E. SOMMERMEYER

Senior Vice President, Flight Operations

and W. BOYNTON BECKWITH

Manager of Meteorology

United Air Lines, Inc., U.S.A.

SUMMARY

For three winters super-cooled fogs, which close airport operations in the North-Western United States, have been dispersed by seeding with crushed dry ice from light aircraft. The method used is operationally 80% reliable. This technique is economical with cost-benefit ratios averaging about 1 to 5. Improvement approaching 100% reliability may be expected by engineering applications and supplemental ground methods, but the air method of dispensing the seeding agent has distinct advantages in many airport environments. Results obtained from this programme have prompted further development and re-evaluation of warm-fog-dispersal techniques which appear more feasible today when coupled with present-generation, instrument-landing systems, but competitive with those programmed in the next few years.

1. INTRODUCTION

Man's efforts to modify the weather to fit his special needs have been documented through the centuries, beginning as early as a recorded observation attributed to Plutarch⁽¹⁾. Because of the basic potential benefits in alleviating famine, flood, drought and economic disaster, it is natural that most efforts in weather modification, both in ancient and modern times, have been focused towards altering either the amount or form of natural precipitation. That some techniques for dispersing low clouds and fog were to come as by-products of research aimed at other goals was inevitable. Nor was fog

dispersal itself completely forgotten, particularly as aviation grew in acceptance.

I should like to confine my remarks to the dispersal of super-cooled fogs, an activity my organisation first spearheaded in the United States for scheduled air carriers and presently continues as one of several participating airlines.

Veraart of the Netherlands may have produced the first dry-ice dispersal of fog in 1930 (without knowledge of the theory involved). Three years later Tor Bergeron of Sweden published his precipitation theory⁽²⁾ which recognised the growth of ice crystals at the expense of water vapour in certain natural atmospheric conditions. It was the research by Langmuir, Schaefer, and Vonnegut in 1946^(3,4), however, that raised the curtain on modern weather modification, including the chain-reaction technique which has been employed successfully for the past three winters in some 200 individual airport seeding operations in the United States.

Following the extensive field research of the late 1940s, it might have been expected that immediate application of this new knowledge would be made on a large scale in the U.S. in the dispersal of winter cold fogs. Two factors were deterring: pre-occupation with surmounting the total fog problem, and second, the regional or seasonal nature of super-cooled fogs. The operational successes which have been reported since 1959 at Orly Airport in France⁽⁵⁾ and in the Soviet Union⁽⁶⁾ bear witness to the impact of frequency and severity of dense cold fogs on economically strategic airports.

In the Pacific Northwest of the U.S. where super-cooled fog is most prevalent, local aircraft operators at Medford, Oregon, conducted dry-ice seeding drops as early as 1950. Here the motivating factors were the sustained dense winter fogs and the urgency of operating an air ambulance service in a relatively underdeveloped region.

2. CURRENT PROGRAMME

United Air Lines initiated formal arrangements for airport fog dispersal four years ago⁽⁷⁾. The decision to take this step was brought about by: (i) failure to generate government action on a fog-seeding proposal, (ii) recent experience with a fog-generated paralysis of air transportation at an important air terminal, (iii) increasing costs of cancellations and diversions with larger aircraft, and (iv) failure of other industry attempts to eliminate all dense fogs.

Starting with contract seeding operations at two airports, the successes each year have engendered interest by other air carriers and airport managements until the programme was expanded to fifteen airports this last winter (1965–1966). Fig. 1 summarises the operational results of the three winters. Seeding operations were required at only eight of the fifteen airports this

past winter when dense super-cooled fog formed at only half of the seeding sites.

The standard technique used in producing these airport weather modifica-

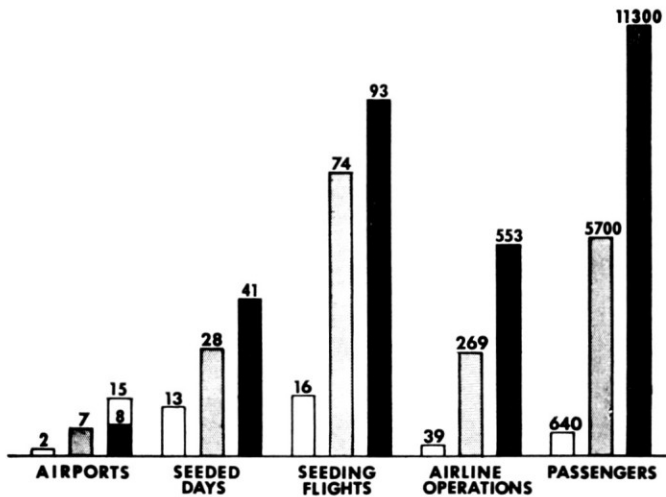


FIG. 1 — 3-year operations summary — all airlines

tions consisted of dispensing crushed dry ice from light aircraft over the ILS runway and approach zones⁽⁸⁾. Fig. 2 is a typical seeding aircraft as employed in this operation. Seeding drops are conducted near the top of the fog layer, allowing the agent to initiate the chain reaction through the full depth of the fog. Fig. 3, taken 30 minutes later, shows a part of the cleared area produced by the weather modification. All operations are conducted under control of local approach and tower facilities, including airport radar guidance where available. Fig. 4 is the transmissometer trace accompanying an average seeding operation, showing length of seeding drop, time to fog break, and typical residual effect interval.

The aircraft seeding techniques have some distinct advantages over ground seeding methods. Flexibility of operations is perhaps the most important, particularly when the seeder must make his runs outside of airport boundaries to counteract a 10- to 12-knot drift of the fog, or when approach zones are in residential areas or over bodies of water. The subtle changes that occur during the conversion of fog from water to ice crystals are detected readily from above and modification of the seeding drops can be made immediately to produce the improvement in the desired air-space.

By a system of alerts and stand-by notices, the seeding operation can be initiated within an hour after the airlines have established a target time for



FIG. 2 — Light aircraft employed in dry-ice seeding of supercooled fog in Salt Lake Valley, Utah. Seeding drop is conducted just above top of fog deck

dissipation of an existing or pending fog situation. Sufficient residual effects normally persist in the cleared zone to permit the seeding aircraft to land, refuel, reload, and resume seeding operations. During one persistent fog regime last winter during Christmas week, seeding aircraft were aloft for 22 hours at one airport and kept this terminal operational for 34 hours.

The capability of dispersing super-cooled fogs with an operational effectiveness approaching 100% is well within reach by supplementing the aircraft



FIG. 3 — Photograph taken 30 min later than in Fig. 2, showing part of cleared area produced by the seeding operations

seeding with low-cost ground techniques. In the few cases where the desired results were not obtained by aircraft, it was determined that the upper layers of the fog deck were well above freezing and therefore not responding to the dry ice. By the simple expedient of dispersing the seeding agent with a surface vehicle, one such condition was effectively changed on a night test from zero visibility to 1600 metres. Several other low-cost methods of surface seeding have been developed by civil and military organisations which make use of tethered, towed, or zero-lift balloons supporting small clusters of dry-ice cakes. Other systems for introducing the seeding agent employ frangible rockets and portable dispensers of low-boiling-point liquids.

Some airports also have the combination of super-cooled-fog frequency and air-traffic level to justify permanent ground installations, such as developed by the French at Orly. However, extensive use of the more sophisticated ground-based systems for the dispersal of cold fogs may be premature in view of promising developments in the elimination of both warm and cold fogs.

In assessing the value of various methods of fog dispersal, it should be emphasised that from an airline-operational standpoint (and from much of general aviation's too), it is not necessary that all fog be removed from the

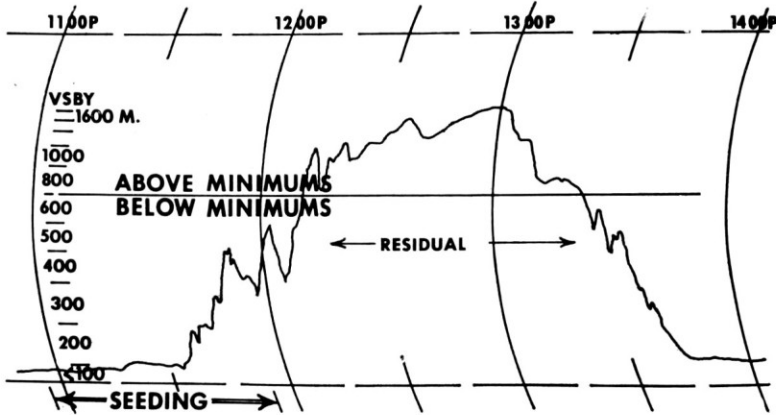


FIG. 4 — Visibility changes responding to seeding operation as shown by transmissometer

approach path and landing area. With present-generation landing aids, such as have been in use since 1962, it is only necessary to improve the meteorological visibility to the threshold of 800 metres or a Runway Visual Range of 730 metres. Conversion of the fog droplets to ice crystals appears to produce the necessary improvement in transmissivity, and the precipitation of fine snow is not always a necessary accompaniment. This simplifies the problem of weather modification by not requiring close control of seeding-agent output. Furthermore, operationally successful results have been produced by this dry-ice method through the full super-cooled range up to and including 0°C.

3. FUTURE PROGRAMMES

The three-year programme conducted by the airlines and airports in the United States is summarised in Fig. 5. As important as these cold-fog-dispersal programmes have been to the flying public and to the airlines, they represent only a small fraction of the potentials to be made by weather modification towards the goal of all-weather flying. Of the twenty most active airports in the United States ranked highest in number of air-carrier operations⁽⁹⁾, only three of them are exposed to super-cooled fog with frequencies great enough to justify organising dispersal operations using present techniques⁽¹⁰⁾. Fig. 6 is a sample of five airports, including small- and large-traffic generators, showing the relationship of cold-fog to warm-fog exposures on a seasonal and annual basis. For comparison, we have added London's annual fog pattern. The first four airports have been organised for

3-YEAR SUMMARY

Seeding Flights ██████████ 183
Airline Movements ██████████ 861
Passengers ██████████ 17635
Seeding Costs ██████████ \$48100.
Direct Benefits ██████████ \$225000.

FIG. 5

cold-fog dispersal for at least one winter; the fifth airport (New York — Kennedy) for its one-hour-per-year incidence has obviously not been so organised. Although Chicago O'Hare airport is exposed to only nine hours of dense super-cooled fog per year, the traffic levels here justify the relatively small expense of organising for seeding operations. O'Hare was one of the fifteen airports prepared this past winter to combat the fog problem at its source.

One need not dwell at length on what happens to air transportation when a major airport is tied up by even a few hours of dense fog. The millions of dollars budgeted annually by industry and government in research, development, hardware and training to overcome the greatest stumbling block to all-

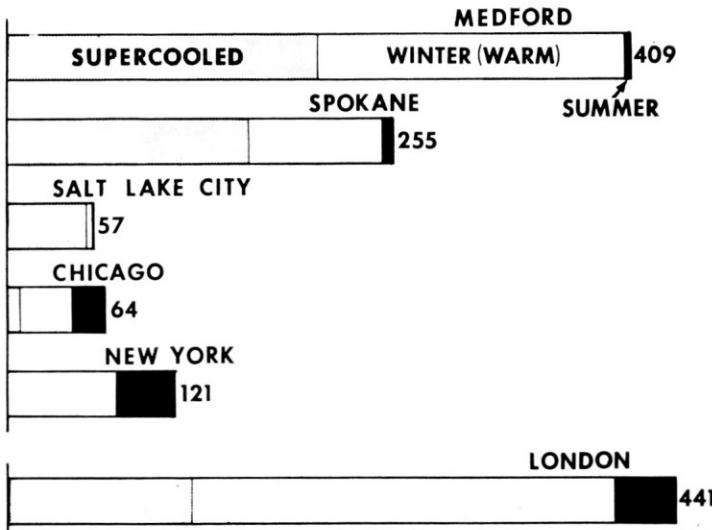


FIG. 6 — Hours of warm and supercooled fog (VSBY < 800 M.)

weather operations is evidence enough of the urgency to overcome this obstacle, not only for present-generation aircraft, but most certainly for those now taking shape in Bristol and Toulouse.

May I suggest, however, that the ultimate solution may not necessarily be by electronics alone, but by getting at the root of the problem through fog dispersal. There has been an accelerated interest and preoccupation with warm-fog-dissipation techniques in the past two years, precipitated to a degree by the successes in cold-fog modification. Some of the development work shows great promise; other systems previously abandoned may now be feasible when coupled with the lower visibility requirements of present-day landing minimums.

Money and manpower diverted to this attack could well provide an economical solution to the problems attending the dense fogs encountered throughout the world, not only for aviation, but for other forms of commercial and human activity⁽¹¹⁾. On a larger scale, the elimination of fog from harbours and canal systems, from highways and railroads and over large metropolitan areas is a necessary complement to the air transport systems of today and those visualised in the near future.

This form of weather modification, while recognised as one of the few in preliminary operational status, is but a small segment of the total potential that can be realised. Through action initiated by the United Nations⁽¹²⁾, which has enlisted the participation of several international scientific societies, we can expect a continuation of an already accelerating programme of research in, and application of, weather control benefiting all mankind in his peaceful pursuits.

REFERENCES

- (1) WARD, R. D., 'Artificial Rain: A Review of the Subject to the Close of 1889,' *American Meteorological Journal*, Vol. VIII, May 1891–April 1892.
- (2) BERGERON, T., 'On the Physics of Cloud and Precipitation,' *Proceedings, I.G.G.U., Fifth General Assembly, Lisbon, 1933*.
- (3) SCHAEFER, V. J., 'The Production of Ice Crystals in a Cloud of Supercooled Water Droplets,' *Science*, 93, 1946.
- (4) VONNEGUT, B., 'The Nucleation of Ice Formation by Silver Iodide,' *Journal of Applied Physics* 18, 1947.
- (5) COT, P. D., 'Dissipation des Brouillards, Negatifs, Compte-rendu des Essais Effectues sur l'Aeroport d'Orly au Cours de l'Hiver 1963–64,' *Aeroport de Paris*, 1964.
- (6) GAIVORONSKII, L. L., 'Investigations Conducted at the Central Aerological Observatory on Artificial Modification of Clouds and Fog,' Moscow, *Central Aerol. Obs. Trudy. No. 26*, 1959.
- (7) BECKWITH, W. B., HARRISON, H. T., 'The History and Status of Artificial Fog Dispersal,' United Air Lines Special Study No. 110, 1964.
- (8) BECKWITH, W. B., 'Supercooled Fog Dispersal for Airport Operations,' *Bulletin American Meteorological Society*, 46, 1965.

- (9) Federal Aviation Agency. 'Table 7 — FAA Operated Airport Traffic Control Towers by Rank Order of Air Carrier Operations, Fiscal Year 1965,' FAA Air Traffic Activity, 1965.
- (10) HARRISON, H. T., 'UAL Exposure to Supercooled Fog,' UAL Meteorology Circular No. 58, 1965.
- (11) SEWELL, W. R. D., 'Human Dimensions of Weather Modification,' University of Chicago, Department of Geography Research Paper No. 105, 1966.
- (12) U.S. Congress, Senate Committee on Commerce. 'Weather Modification and Control.' Report by Library of Congress No. 1139, 1966.

DISCUSSION

Prof. N. Frössling (Chalmers University of Technology, Göteborg, Sweden):
Can you give some typical figures of the dimensions (vertical and horizontal) of the free path through the cloud, achieved by a single flight?

I. E. Sommermeyer and W. Boynton Beckwith: A typical volume of cleared fog resulting from a single seeding flight (series of seeding passes) would be 3000 metres long, by 500 metres wide, by 300 metres deep. All dimensions will vary according to the depth of the improved area and the requirement for working on the up-wind edge and also, according to the depth of the fog.