Technical Report 205

THE OPERATIONAL DISSIPATION OF SUPERCOOLED FOG: PROJECT COLD COWL 1967-1968

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PREFACE

Project Cold Cowl is one of a number of weather modification techniques under test by Air Weather Service (see AWS TR 203). Although further testing is required before the technique can be standardized, it is already being used at Elmendorf AFB to support flight operations. Last winter, the project was credited with enabling 185 take-offs and landings that would otherwise have been diverted or seriously delayed. Analysis of the results has not yet been completed. However, because the technique is applicable to many bases other than Elmendorf, it has been decided to make available to the field the knowledge so far obtained.

In addition to the author, others involved in designing the test procedure included Maj T. Studer, Maj R. Lininger, Capt F. Coons, Lt L. Mendenhall, and Lt L. Vardiman of Headquarters AWS. Lt Mendenhall also served as a technical advisor at Elmendorf AFB. Capt B. Grubbs and Capt R. McCollum, 11 Weather Squadron, served as on-site project directors, and Squadron Leader B. Earle as the AAC liaison officer. Maj Lininger directed the silver iodide tests using flares provided by the Naval Weapons Center. The WC-130 aircraft and crew were furnished by the 54th Weather Reconnaissance Squadron. A backup aircraft and crew were supplied by AAC.

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TABLE OF CONTENTS

ILLUSTRATIONS

I. INTRODUCTION

Elmendorf AFB near Anchorage, Alaska, is a major stop for cargo aircraft operating between the United States and the western Pacific. The most important weather problem affecting aircraft operations at Elmendorf is fog. Fortunately, most of the fog occurs in the supercooled state and thus is amenable to dissipation by seeding techniques. In July 1967, the Alaskan Air Command (AAC) requested that Air Weather Service (AWS) initiate a project to dissipate supercooled fog over Elmendorf AFB. The mission was officially assigned to AWS on 8 August.

AWS cloud physicists reviewed the Elmendorf climatology and talked to Elmendorf meteorologists to determine the nature and extent of the problem. A 10-year period of record showed an average of 67 hours per year of dense (visibility $<1/2$ mile) supercooled fog occurring under "treatable" conditions--temperature between 0 and $-30^{o}C$, winds less than 7 knots, and no precipitation. Unfortunately, the physical location of the base causes certain problems. One of these is the radical change in low-level wind direction that often occurs over short distances, particularly under the weak-gradient conditions frequently existing during wide-spread fog situations. The winds are largely a result of gravity-induced flow between the adjacent mountains and the valley, and may change drastically with both time and distance. Similarly, the nearby open water (Cook Inlet) affects the fog source region and, when combined with the orographic influences and wind fluctuations, results in inhomogeneities in the fog layer.

We next contacted a number of private companies engaged in supercooled fog dissipation over civilian airports to obtain advice on seeding equipment and techniques. All companies proved most cooperative in providing the requested information, but it immediately became clear that there was no generally accepted seeding pattern, rate, altitude, or pellet size. Making use of all available information, we developed our own procedure for use at Elmendorf, and at the same time arranged for a series of supplemental tests of other procedures to be carried out in outlying areas. Project Cold Cowl was officially implemented on 15 November.

II. PROCEDURE

The seeding aircraft was a four-engine AWS WC-130 normally used for hurricane reconnaissance during the warmer seasons. Although larger than required for fog seeding, this aircraft could readily carry the dry ice crusher and several thousand pounds of dry ice. Its great endurance enabled it to remain aloft for many hours, carrying out repeated seedings when required by airport traffic or flying to outlying areas to engage in supplemental testing.

Dry ice was available in Anchorage in 25-pound blocks. A dry ice crusher was obtained that was capable of crushing the blocks at a rate of 75 pounds per minute. The resulting fragments ranged in size from granualar sugar to 3/8-inch diameter. Initially the blocks were crushed on the ground just prior to take-off, but later the crusher was installed in the seeding aircraft. An initial seeding rate of 25 pounds per mile was selected for the Elmendorf test. This quantity has been used with apparent success by several commercial seeders, although rates from a few ounces to over 50 pounds per mile have been tried. Since ice crystal production per gram of dry ice is a function of various parameters, particularly temperature, there is obviously no single correct value. As Project Cold Cowl progressed, operations were carried out at a rate of 12.5 as well as 25 pounds per mile.

We had questioned the commercial seeders regarding dry ice pellet sizes. Most preferred a range of sizes from powder up to 1/4 or 1/2 inch diameter, although some used only powder and others only pellets. The powder must, of course, be disseminated in the fog itself or at least along the top of the fog deck. Air Force flight rules required us to operate above the fog unless it extended at least 500 feet above the ground, in which case our WC-130 could fly through the fog at that altitude. Consequently, we decided to use a spectrum of pellet sizes ranging from powder to 3/8 inch. The varying fall speeds would result in formation of a continuous curtain of dry ice particles in the fog, with the powder more or less floating at the top, the small particles falling slowly through the fog until they evaporate, and the larger pellets falling rapidly in the upper part of the fog, then more slowly as they sublimed, but eventually reaching the ground. It was hoped that this curtain of dry ice particles would result in quicker clearing.

The selected target area was the approach end of the runway, extending from the middle marker to the touchdown point. Although only 1/2 to

3/4 miles visibility is required for most Air Force operations, it was decided to seed a much larger area in order to have a margin for error. (Note: all distances are in nautical miles.) The selected seeding pattern consisted of five parallel lanes, each 2 mi long, and 1/4 mi apart (see Figure 1). Large holes have been cut in stratocumulus decks using much greater lane spacings; however, in view of the lesser mixing rate in fog, it was decided to begin with 1/4 mi intervals. Since past experience indicated that clearing would generally require somewhat over 30 minutes, the seeded area was offset upwind a distance equivalent to 30 minutes plus the time required to fly the seeding pattern--about 15 minutes.

One of the major problems was to determine the correct displacement of the seeding area from the target area. Fog conditions were generally accompanied by very light winds. Even when the official anemometer reads calm, a drift of about 1 or 2 knots usually existed. However, the direction of drift varied from one point to another. Sensitive wind instruments were placed on top the control tower and on a nearby 150-foot hill. In addition, the aircraft took a Doppler wind reading prior to seeding. Unfortunately, the observations frequently differed radically from one another, resulting in a great deal of subjectivity in determining the offset distance. In several cases it was clear that the selected wind was in error, and follow-up seeding patterns had to be determined and flown. Consideration is being given to making chaff drops over the target area in future operations and determining the seeding-level wind by radar.

III. RESULTS

A total of 37 operational-type missions were flown, as well as a number of supplemental (i.e., experimental) flights. A mission was considered operational when it was carried out to support actual take-offs or landings. In each case the standard seeding configuration was used--five parallel lanes, each 2 miles long, and 1/4 mile apart, seeded with 12.5 or 25 pounds of crushed dry ice per mile, and displaced the proper distance upwind from the target area. In a number of cases the WC-130 remained aloft and carried out several such missions before coming in for a landing. Of the 37 operational missions, 25 successfully cleared the target area, nine failed, and the results of three were questionable due to natural variability. AAC credited the successful missions with enabling the take-off or landing of 185 aircraft that would otherwise have been seriously delayed or diverted. Of the nine failures, a hole was successfully cut in three cases but missed the target. The remaining six failures all occurred over a 12-hour period on 8 January and merit further discussion.

An in-and-out fog situation had set in at Elmendorf on 5 January. The first seeding that day was unsuccessful because of misjudged wind drift. However, this failure was followed by eight successful missions during the period 5-7 January, each mission carried out as required to support flight operations. Throughout this period the field was occasionally above minimums due to natural causes, although the situation gradually deteriorated as time went on. The last successful seeding flight was made at 2237-2246L on 7 January; it improved the visibility to 3 miles. The next seeding, 0009-0023 on 8 January, resulted in no change in the visibility. Five additional missions were flown during the next 12 hours, the last at a 50-pound per mile seeding rate and 200-foot lane spacings. All were ineffective. Further seeding was cancelled. The fog situation dissipated naturally the following day.

There is little question now but that the supercooled fog which had been treated so successfully on 5-7 January had become an ice fog prior to the first flight the following morning. (This conclusion is supported by surface observations studied later.) The phase change may have resulted naturally as the fog aged, or have been a cumulative result of the numerous dry ice seedings, or both. The temperature during the 3-day period had gradually fallen from -7 to -12°F at the 500-foot level, which may have made the fog more subject to phase transformation. Clearly, it is essential that a seeding crew consciously observe the visual phenomena associated with the fog in an attempt to determine its phase. An ice fog cannot be improved by dry ice seeding; in fact, additional crystals might form which would worsen the already poor visibility.

The 25 successful missions were flown on a total of nine different days between 11 December and 17 February. Each resulted in visibility increases above operational minimums. In most cases an easily identifiable hole was observed by the seeding aircraft. Several slide series are available of these clearings. However, because of the press of other missions, it was seldom possible for the seeding aircraft to observe the hole throughout its entire lifetime. Also, many missions occurred at night, and in some daylight cases the holes merged with natural clearings. Consequently, information is incomplete regarding maximum hole sizes and duration.

Despite these limitations, many holes were observed for significant periods. Reaction times varied. Normally the aircraft observer was able to detect texture changes along the seeded lane within several minutes after passage of the aircraft. In a typical case a thin area was reported within 20 minutes after completion of the seeding, and sizable breaks a few minutes later. A large hole generally formed 30 to 45 minutes after seeding and remained open for a protracted period. There were many exceptions to this typical pattern, however; some clearings occurred in less than 20 minutes and some holes remained open only a short time.

IV. SUPPLEMENTAL TEST PROGRAM

During times when no requirement existed to clear Elmendorf for operational traffic, the WC-130 was available for supplemental fog-dissipation tests. These flights generally consisted of an L- or box-shaped pattern, each leg being treated differently to determine the relative effectiveness of various techniques. These procedures included several dry ice seeding rates (5, 12 1/2, 25, and 50 pounds/mile), particle sizes (powder, 1/4-inch pellets, mixture), release distances above the fog deck (in the fog, skimming the top, 200 feet above), and materials (dry ice, liquid CO_2 with and without a horn dispenser, and silver iodide pyrotechnic flares). In most cases one leg of the pattern was seeded with crushed dry ice at a rate of 25 pounds per mile to serve as a standard against which the effectiveness of other techniques was compared.

Insufficient data were obtained to permit a complete analysis of the results. However, the following summation may prove of value to other investigators:

Dry ice seeding rate: Numerous successes were achieved with the 12 1/2 and 25 pound per mile rates. There was some indication that the lower rate may have been most successful when carried out within the fog (or skimming the fog top), the fog was less than 500 feet thick, and the temperature was low. About 50 percent of the crushed dry ice is in the form of powder and is lost when seeding is carried out significantly above the fog deck.

Particle sizes: Successful clearing was achieved with dry ice powder, 1/4-inch pellets, or a mixture of sizes.

Silver iodide pyrotechnics: Successful clearing was achieved with silver iodide flares attached to the aircraft, but a somewhat lower temperature appears to be required than with dry ice. The value of this critical temperature is unknown, but is somewhere between -5 and -10°C. The seeding aircraft must fly through the fog for this technique. The possibility of overseeding is very real, but should be controllable.

Liquid CO_2: Successful clearing was achieved when the aircraft flew through the fog and dispensed the CO_2 through a fire-extinguisher-type horn. This procedure produces dry ice snow. The seeding rate used was 40 pounds per mile. Failures resulted when the aircraft skimmed the fog top and dispensed the liquid CO_2 without a horn.

V. CONCLUSIONS

There is no doubt that supercooled fog can be effectively dissipated on an operational basis using crushed dry ice dropped from an aircraft. The

Alaskan Air Command credited Project Cold Cowl with enabling the take-off or landing of 185 aircraft that would otherwise have been diverted or seriously delayed. Continuation of the project has been requested for the future.

Although no optimum or standard procedure can yet be delineated, it is clear that the Project Cold Cowl seeding pattern produced excellent results. Work will continue next winter to optimize lane spacings, seeding rates, etc. In addition, silver iodide flares and liquid CO_2 offer promise of success provided the aircraft can be flown through the fog. Both materials have obvious logistical advantages over dry ice. Tests will continue on both agents next year.

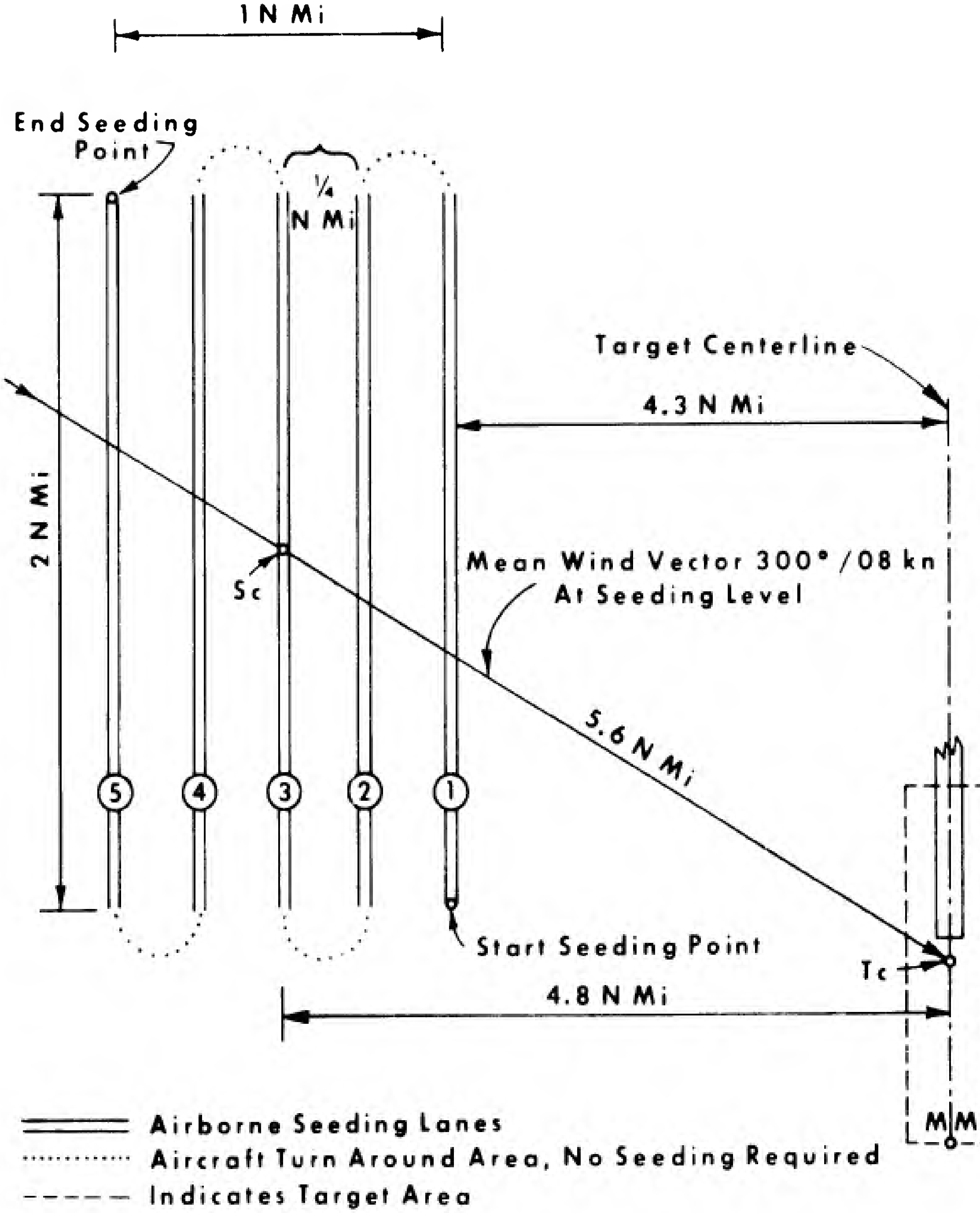

Figure 1. Project Cold Cowl Seeding Pattern

Sc = center of seeding pattern Tc = center of target area MM = middle marker

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13. ABSTRACT

In the winter of 1967-1968, the Air Weather Service (AWS) carried out its first operational weather-modification program at Elmendorf AFB. An AWS weather-reconnaissance aircraft (WC-130E) was used to seed supercooled fog with dry ice. A prescribed flight path was flown a specified distance upwind from the target area, and crushed dry ice disseminated at rates of 12.5 or 25 pounds per mile. It was found that a clearing generally occurred in 30 to 45 minutes. The only real failure occurred in a case that may have been an ice fog; in addition, proper positioning of the hole proved a major problem throughout the program. Despite these difficulties, an estimated 200 successful take-offs and landings were made using the artificially produced clearings. Supplemental tests were carried out using airborne liquid CO_2 dispensers and silver iodide pyrotechnics.

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