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AIR FORCE SURVEYS IN GEOPHYSICS, NO. 176

METEOROLOGY LABORATORY   PROJECT 7605
AIR FORCE CAMBRIDGE RESEARCH LABORATORIES
L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

The Ice Fog Problem at Eielson AFB, Alaska

JOHN H. TAYLOR, LT COL, USAF
JAMES F. CHURCH, MAJOR, USAF

OFFICE OF AEROSPACE RESEARCH
United States Air Force

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Abstract

This report summarizes the findings and conclusions drawn from a survey which was conducted at Alaskan bases. The purpose of the survey was to secure information necessary for making recommendations on the nature and level of effort of research programs which could be directed toward minimizing the disruptive effect of ice fog on air operations at Eielson Air Force Base. The ice fog phenomenon, its principal causes at Eielson, and the nature and extent of its effect on air operations are discussed. An examination is made of engineering approaches to the solution of ice fog problems and their influence on the apparent trend during the past ten years toward a decreasing frequency of occurrence. A recommendation is made for engineering designed to minimize pollutions from what is considered to be the primary source. Finally, there is a discussion of the feasibility of establishing an applied research program designed to provide operationally useful solutions to the ice fog problem.

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The Ice Fog Problem at Eielson AFB, Alaska

1. GENERAL

The Air Force requirement for meteorological research on ice fog was established at least as long ago as 1957. During the intervening years QOR's* have been submitted for techniques to dissipate and suppress ice fog at interior Alaskan air bases, with the stated objective being to improve aircraft operating conditions. Requirements for research and development have changed over the years, as have operating conditions and operational problems. As a result, there now exist a number of conflicting opinions concerning the scope and even the nature of ice fog problems. Since AFCRL is responsible for the research and development in this area and the most recent QOR is still active, it appeared advisable to conduct a survey to determine as well as possible the current nature of the problems and the impact of ice fog occurrence on the Air Force mission. This report outlines the findings of such an on-site survey conducted by AFCRL personnel. The report is intended to serve as a basis for determining what research efforts, if any, can be recommended as a means for increasing the effectiveness of Air Force operations at interior Alaskan air bases, with attention directed primarily to air operations at Eielson AFB.

Those readers interested only in the significant finding of the survey and the recommendations will probably wish to omit the lengthy discussion in Section 3.

(Received for publication 18 February 1966)

* Qualified Operational Requirement

Those who are interested in the ice fog phenomenon, its causes at Eielson AFB, and details of its effect on air operations will find them discussed in Section 3.

2. ITINERARY

Lt Colonel John H. Taylor and Major James F. Church visited Alaskan Air Command Headquarters and 11th Weather Squadron Headquarters on 5 October 1965 and again on 13 October 1965. During the intervening period a survey was conducted, with contacts being made with the several organizations at Eielson most concerned with ice fog problems, and with the 317th Fighter Intercepter Squadron at Elmendorf AFB. In addition, a visit was made on 6 October 1965, to the University of Alaska at Fairbanks, where recent and proposed ice fog research efforts were discussed with the principal investigators.

3. DISCUSSION

3.1 Definition of Ice Fog

Ice fog is defined as a type of fog composed of suspended particles of ice, partly ice crystals 20 to 100 microns in diameter but chiefly, especially when dense, droxtals* 12 to 20 microns in diameter. It occurs at very low temperatures, mainly below -20°F, and usually during clear, calm weather at the higher latitudes. It is usually confined to a shallow, ground-based layer with the sky visible from the ground and the ground visible from above. When the sun is up, dense ice fog may cause a halo phenomenon or if thin, just a scintillating effect.

Ice fog is rare at temperatures warmer than -20°F and increases in frequency and density with decreasing temperatures, until it is nearly always present to some degree at air temperatures of -50°F in the vicinity of water vapor sources. Such sources are the open water areas of fast running streams, herds of animals, but especially the multiple sources associated with urban environments.

An important feature of ice fog is that water vapor acts as a pollutant, even in small amounts which would be considered negligible at higher temperatures. Air at 68°F can retain 255 times more water vapor than air at -145°F (Benson, 1964-1965). Thus, small quantities of water vapor, which are easily accommodated in warm air with no reduction in visibility, are forced to condense and freeze in very cold air. Figure 1, which shows the saturation mixing ratio over

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*A droxtal is a tiny spherical ice particle, about 10 to 20 microns in diameter, formed by the direct freezing of supercooled water droplets at temperatures below -30°C (-22°F).

ice as a function of temperature, dramatically illustrates how little moisture is required for saturation of air at temperatures in the ice fog range.

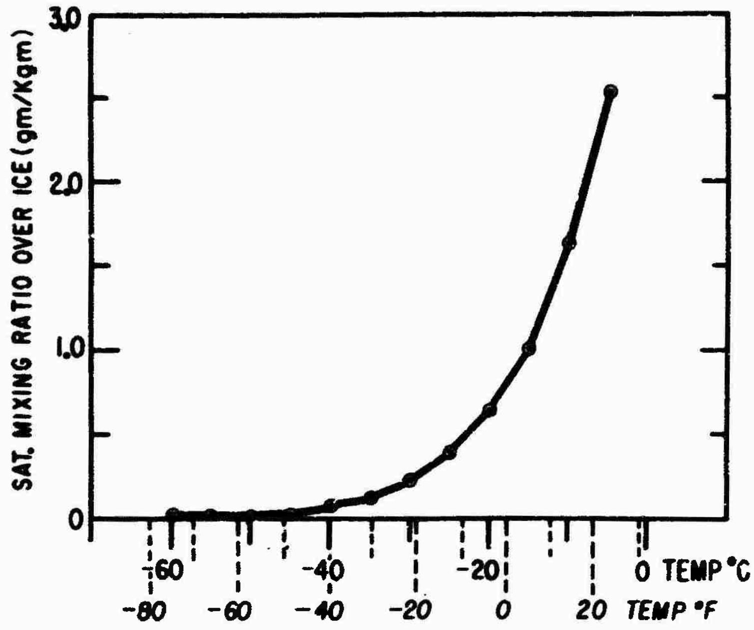

Figure 1. The Saturation Mixing Ratio Over Ice in Gms of Water per Kilogram of Air versus Temperature in both °C and °F

3.2 Description of Eielson Air Force Base

Eielson AFB (64° 41'N, 147° 54'W) is located 23 miles ESE of Fairbanks, Alaska. It is situated on flat terrain on the eastern edge of a broad flat basin drained by the Tanana River, which flows to the north-northwest about three miles west of the base in a series of braided channels. The terrain three miles to the northeast of the base begins to rise gradually into hills which peak at about 2800 feet some 15 miles away. The area surrounding the base is sparsely forested with spruce, willows, and other species common to arctic environments.

The 15,000-foot runway is oriented NNW-SSE, and is parallel to and about 500 feet east of the Richardson Highway. The hangers, the industrial areas, and cantonment areas are located east of the runway (see Figures 2 and 3). The central power plant, which is discussed in detail later in this report, is about 4000 feet to the east of the runway.

The Base Weather Station is located to the south of the hanger area. The representative observation site is located immediately to the west of the runway on the south end. Transmissometers are located at both ends of the runway.

Figure 2. An Aerial View of Eielson AFB Taken During 1965

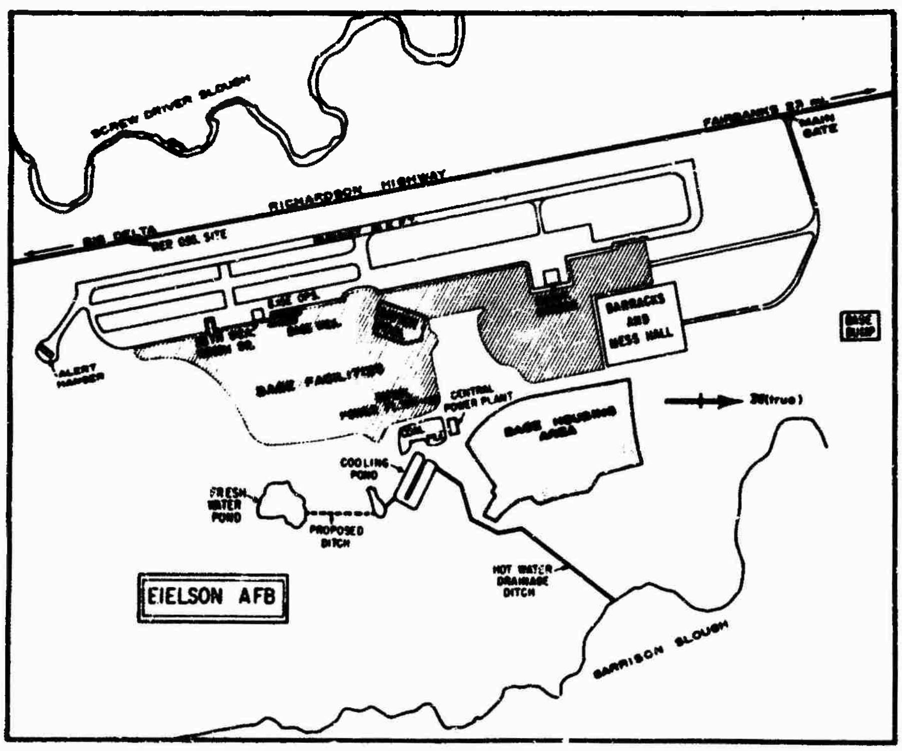

Figure 3. A Schematic Map of Eielson AFB Showing Pertinent Facilities of the Base Seen in Figure 2

3.3 Ice Fog at Eielson Air Force Base

Located at approximately 65°N latitude and situated in the central part of Alaska, Eielson experiences a classical continental arctic climate. During the winter months when the sun never rises far above the horizon, there is but little incoming radiation even during midday hours. When calm, clear conditions prevail, radiational cooling of the layer of air near the surface produces a strong shallow inversion with very low surface temperatures. Figure 4 and Table 1 show that Eielson experiences a high frequency of calms (more than 60 percent of the time during the months of November, December, January, and February), a favorable condition for establishing and maintaining the very low temperature necessary for ice fog occurrence.

While the range of temperature during the winter months is large, the diurnal variation is quite small. This suggests that once the thermal inversion is established, very low temperatures may persist for days. An extreme case was experienced during a two week period in December 1961, when air temperatures never rose above -30°F. Midday temperatures were about the same as those of other hours.

The frequency of ice fog occurrence and the frequency of temperatures in the ice fog range, vary greatly from winter to winter. Figure 5 shows a comparison by winters of the frequency of occurrence of ice fog which reduced visibilities to three miles or less and the frequency of temperature equal to or less than -20°F. These statistics are offered only to illustrate the great annual variability in ice fog occurrence at Eielson AFB. They are <u>not</u> intended as an indication of the difficulty presented by ice fog to aircraft operations. A more meaningful yardstick for that purpose would be the frequency of ice fogs which restrict visibilities to less than one-half mile (AFR 60-16 visibility minimum for Eielson AFB), keeping in mind that ice fog seldom, if ever, obscures vertical visibility.

While these data are not currently available for a direct presentation, a reasonable estimate can be made from special studies prepared by the Eielson Weather Detachment (Johnson, March and April 1965) and from standard weather summaries prepared by the Climatic Center, USAF.

Table 2 shows that visibilities, less than one-half mile in ice fog, occur on the average about four-tenths of one percent of the time in November, three percent in December, two percent in January, and six-tenths of one percent of the time in February. Further, it shows that visibilities of less than one-half mile occur on the average slightly less than one-third as often, as do visibilities of three miles or less. The most significant fact, however, is that visibilities less than one-half mile occur almost exclusively with temperatures of -30°F or below. <u>Ice fogs occurring with temperatures above -30°F rarely reduce visibilities below one-half mile</u>.

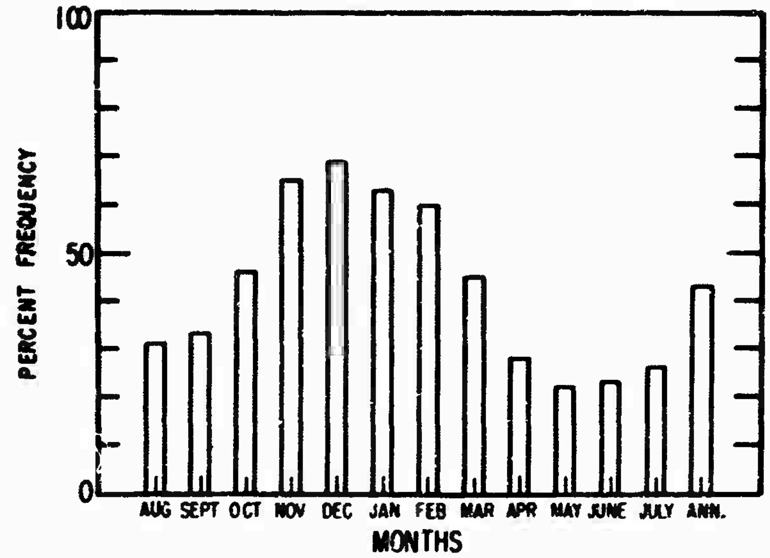

Figure 4. The Percent Frequency of Calm Wind Conditions for All Months of the Year plus the Annual Monthly Average at Eielson AFB, Alaska

Table 1. Abbreviated Climatology for Eielson AFB, Alaska (Period of Record 1947 - 1956)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Absolute Max Temp, deg F	48	49	50	70	93	91	93	85	82	63	49	44	
Mean Daily Max Temp	-1	7	23	39	58	68	70	65	53	33	10	-3	
Mean Daily Min Temp	-18	-15	-6	17	36	47	50	45	34	17	-6	-18	
Absolute Min Temp	-63	-61	-51	-27	-7	30	37	26	12	-21	-44	-61	
Average Precip (Inches)	1.2	.9	.7	.6	.8	1.8	2.6	2.4	1.6	1.0	.6	.9	15.27
Average Snowfall (Inches)	13.1	9.4	7.3	5.6	.4	T	0	T	2.4	9.9	7.7	9.6	67.2
% Calm Winds	63	60	45	28	22	23	26	31	35	46	65	69	43.0
% Less than 4 kts	86	82	61	54	48	51	56	63	66	73	86	89	69.1
% Greater than 10 kts	2	3	3	6	7	7	3	3	4	3	2	2	3.6
Ave # days 0 deg or lower	28	24	25	5	T	0	0	0	0	3	20	28	133
Ave # days -35 deg or lower	7	6	1-1/2	0	0	0	0	0	0	0	1-1/4	6-1/4	22

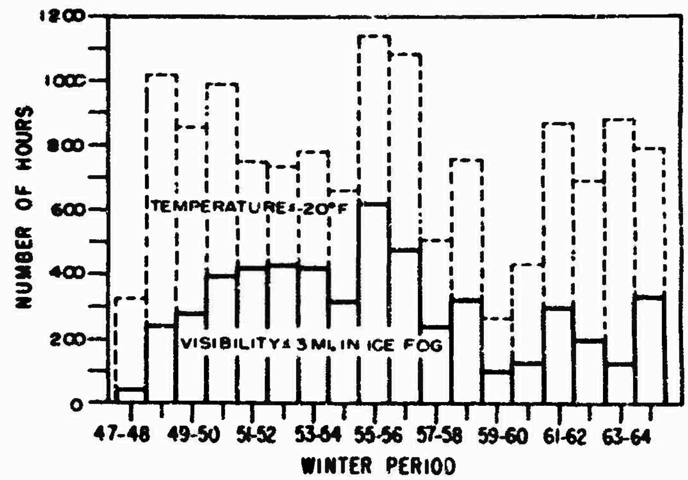

Figure 5. The Frequency of Occurrence in Hours of Temperatures Less Than or Equal to -20°F, and Visibilities Less Than or Equal to Three Miles Due to Ice Fog at Eielson AFB for the Winters from 1947-1948 through 1964-1965

3.4 Moisture Sources

Eielson AFB is a compact industrial and residential community where approximately 5000 people reside and an addition 1500 people work. There are presently 900 family housing units on the base and an additional 200 programmed for construction during the summer of 1966. In addition, there are the normal industrial facilities found on any active Air Force base. The average aircraft operations during the winter months include 800 to 1100 departures and arrivals per month. On an average winter day there are about 3500 moving vehicles in use on the base.

3.4.1 THE CENTRAL POWER PLANT

The one operation which accounts for most of the moisture released into the atmosphere at Eielson is the central power plant located about 4,000 feet east of the runway. The coal-fired steam turbines, capable of generating 15,000 Kw, provide the primary electrical power for the base. The residual steam is used for heating the entire base complex. On a cold (-30°F) day, the plant operation contributes over one million pounds of water vapor to the environment.

About two-thirds of the water vapor is emitted from the exhaust stacks at high temperatures (about 250°F). The resulting cloud generally rises to about 250 feet above the ground before stabilizing well above the surface inversion layer. Personal, undocumented observations suggest that the stack effluents usually, if not always, level off and drift away without merging with the lower ice fog layer. It was observed that the stack exhaust plume occasionally drifted for several miles

Table 2. Probabilities of Ice Fog Occurrences at Eielson AFB

Temperature Range	Probability of Temperature Within Range ***				$P[V \le 3]_T$ *	$P[V < 1/2]_T$ **	Probability of Visibility ≤ 3 miles				Probability of Visibility < 1/2 mile			
	Nov.	Dec.	Jan.	Feb.			Nov.	Dec.	Jan.	Feb.	Nov.	Dec.	Jan.	Feb.
$-20^{\circ}F \ge T > -25^{\circ}F$	.060	.060	.070	.050	.05	≈ .00	.0030	.0030	.0035	.0025	-	-	-	-
$-25^{\circ}F \ge T > -30^{\circ}F$	.060	.060	.050	.050	.10	.01	.0060	.0060	.0050	.0050	.0006	.0006	.0007	.0005
$-30^{\circ}F \ge T > -35^{\circ}F$	.030	.050	.050	.040	.18	.03	.0054	.0090	.0080	.0072	.0009	.0015	.0015	.0012
$-35^{\circ}F \ge T > -40^{\circ}F$	.016	.050	.040	.020	.35	.12	.0056	.0175	.0140	.0070	.0019	.0060	.0048	.0024
$-40^{\circ}F \ge T > -45^{\circ}F$	.004	.050	.030	.010	.71	.24	.0028	.0355	.0213	.0071	.0010	.0120	.0072	.0024
$-45^{\circ}F \ge T > -50^{\circ}F$	-	.032	.027	-	.82	.33	-	.0262	.0221	-	-	.0106	.0089	-
$-50^{\circ}F \ge T$	-	.018	.003	-	.91	.15	-	.0164	.0027	-	-	.0027	.0005	-
Probability Totals	.170	.320	.270	.170			.0028	.1138	.0779	.0297	.0044	.0334	.0236	.0065
Hours							16.4	84.7	58.0	20.0	3.6	24.8	17.6	4.4
							179.1				50.4			

* $P[V \le 3]_T$ is equivalent to: The probability of visibilities equal to or less than 3 miles, given a temperature in the range indicated. This statistic taken from Ref. (Benson, 1964-1965).

** $P[V < 1/2]_T$ is equivalent to: The probability of visibilities less than one-half mile, given a temperature in the range indicated. This statistic taken from Ref. (Johnson, April 1965).

*** Probability of temperatures within indicated range was derived from the Psychrometric Summary, Eielson AFB, compiled by the Climatic Center, USAF.

in a direction opposite to the supposed drift of the ice fog, and remained at its stabilized elevation until it dissipated in an area not covered by the local ice fog. The concensus of opinion of careful observers at Eielson is that the stack effluents do not contribute directly to the severity or duration of the dense ice fog once it is formed. There was speculation, however, that before the steep radiation inversion which caps the ice fog layer is established, the stack effluents might create a condition favorable to the formation of ice fog, thus increasing the frequency of ice fog cases in the higher range of visibilities.

The major pollution source, associated with the power plant operation, is a 13 acre evaporation pond located adjacent to the power plant. The pond is designed to cool the water which has cooled the power-plant steam turbines. During the winter, the temperature of the surface of the pond averages about 45°F. On a day when the surface air temperatures are -30°F, about 375,000 pounds of water are evaporated into the lowest layer of the atmosphere (Richardson, 1964). When the air temperatures are in the upper range for ice fog formation (-20°F to -30°F), the water vapor condenses rapidly as relatively large ice crystals which soon fall out. Thus, ice fog occurring in this temperature range seldom extends more than one-half mile from the pond itself, and has little influence on aircraft operations. When the air temperatures are in the lower ice fog ranges (< -30°F), smaller ice crystals and droxtals are formed which remain suspended for a longer period. This extends the area of dense ice fog over much of the base, often reducing runway visibilities in the process.

As mentioned earlier in this report, the terrain begins to rise gradually about three miles northeast of the base, and crests some 2,800 feet above the Tanana River Basin at a distance of about 15 miles. It has been speculated (Richardson, 1964) that this terrain slope plays some part in the severity of the ice fog conditions at Eielson, since a slight cold wind drainage from the hills toward the river basin would tend to move air from the major base pollution sources towards the runway. The only verification that this is true appears to be personal observations made over one to two winters by interested personnel who are (in the authors' opinion) careful observers. Whether it is true or not, however, may be only academic, since the relocation of the runway relative to the major pollution sources (or vice versa) is not a likely event.

3.4.2 AIRCRAFT OPERATIONS

It is frequently observed that a departing aircraft leaves a trail of dense ice fog which spreads laterally, and temporarily reduces runway visibilities substantially. Contrary to often heard reports that a single departing aircraft will trigger the formation of ice fog and "sock in" the runway for extended periods (ranging from several hours to several days), no shred of evidence was found to support such an occurrence at Eielson. Aircrews and other observers report that during periods of existing ice fog (visibilities 1 to 5 miles) the visibility reduction due to departing aircraft may be drastic, lowering visibilities to near zero; but in 5 to 15 minutes, the visibility is restored to that prevailing prior to the take off. Transmissometer records collected and partially analyzed by the local weather detachment for the winter 1964-1965 support these observations.

3.4.3 MOTOR VEHICLES AND OTHER INTERNAL COMBUSTION SOURCES

There are 3858 private motor vehicles registered on Eielson AFB as of 20 October 1965, and an estimated 600 government vehicles. During heavy cold, the most probable number of moving motor vehicles is estimated to be about 3500. While the estimated amount of moisture introduced into the environment by the combustion products from motor vehicles is only about 15 percent of the amount introduced by the cooling pond, the influence on runway visibilities may be proportionally larger, since many of the vehicles operate much closer to the runway. During very cold weather, dense ice fog is frequently observed along and adjacent to routes of heavy traffic. One of the most heavily traveled routes crosses the approach to Runway 13.

Internal combustion heaters used in aircraft operations contribute a comparatively small amount of moisture to the environment, but their location on the ramp occasionally produces a local, dense ice fog which presents a nuisance and a potential hazard to crews on the flight line. The area of influence of this localized visibility restriction has not been observed to extend to the runway, however. Therefore, the effect on flight operations is not felt to be significant.

3.5 Ice Fog Research

There has been a considerable amount of research done on ice fog over the last 20 years. Most of the experimental work was aimed at characterizing ice fog. Other work includes engineering studies with the ultimate purpose of finding ways to either suppress or disperse ice fog. The research has been conducted mainly at interior Alaskan bases, primarily in the Fairbanks area; in the town of Fairbanks, at Ladd AFB (now Fort Wainwright); and at Eielson AFB. In addition, some research is carried out by the Army in the Big Delta area which is about 60 miles SE of Fairbanks.

Serious research on the Eielson AFB ice fog problem started in 1951. AFCRL in response to the requirements of AAC, sponsored a three year research effort by the Stanford Research Institute (Richardson, 1964) at Eielson AFB. This work included a definitive study of ice fog itself, its probable causes, and recommendations for its suppression and dispersal. Many of the SRI recommendations have since been adopted by the base in an attempt to reduce the incidence of ice fog.

The Eielson Weather Detachment has been conducting an active study program on ice fog. During the past five years, seven special ice fog studies have been completed. Major William R. Johnson, filling the position of Special Research Officer at the detachment, has spent most of his time during the past three years working on ice fog and related problems.

The Geophysical Institute of the University of Alaska has concentrated its experimental work on ice fog crystal studies and on ice fog problems in the metropolitan Fairbanks area, including Fort Wainwright. Dr. Carl S. Benson and Dr. Takeshi Ohtake have been the principal investigators.

The bibliography at the end of this report contains a list of some of the more important papers and recent studies published on ice fog.

There is much still to be learned about ice fog that could be brought to light by research efforts. Acquiring the additional knowledge, however, could well prove to be expensive. In some instances, special meteorological instrumentation would have to be developed to function properly in the extremely cold temperatures encountered. For example, the study of drainage winds, their influence on the radiation inversion, and the advection of moisture across the base poses real instrumentation problems in such an environment. The accurate measurement of dew points at these temperatures is another problem.

It is quite unlikely that further research undertaken at this time would produce results applicable to the operational problems within three to five years. Further, it does not necessarily follow that a solution to the ice fog problem at Eielson AFB would result from such research.

3.6 Aircraft Operations

Most routine flying operations at Eielson AFB are curtailed whenever the temperature drops to -30°F. The reason for this is the human factor of exposure or possible exposure to extreme cold. The flying activities which are stopped at -30°F are: combat readiness training flying, which includes T-33's and C-123's; routine air rescue training flights of H-21's, and the 317th Fighter Intercepter Squadron flights of F-102's. Personnel responsible for flight operations in these units affirm that the elimination of dense ice fog, when temperatures remain below -30°F, would not substantially increase their capabilities in air operations. The only exception is that F-102's would be denied the use of Eielson as an emergency recovery base on those occasions when visibilities are below 1/2 mile.

There are, however, three organizations at Eielson which continue certain scheduled operations regardless of low air temperatures. SAC KC-135's fly six precisely scheduled sorties daily, 365 days a year, and are further unencumbered by AFR 60-16 weather minimums. It was found that during the winter of 1964-1965, low visibilities resulting from ice fog caused five departures to be delayed a maximum of ten minutes and five recoveries to be diverted to Fairbanks International Airport, twenty-five miles away. In order to accomplish this record, some flights were required to operate in sub-marginal weather conditions. The 55th Weather Recon Squadron, operating RB-47's, launch a Ptarmigan flight daily but can tolerate extended delayed departures when required. During the winter of 1964-1965, there were four delayed departures attributable to ice fog and three diverted recoveries. The 58th Weather Recon Squadron operated RB-57's on a schedule which requires that sorties be launched on three consecutive days, once every two weeks. It was found that last winter one sortie was delayed because of the occurrence of ice fog, and two sorties were postponed one day each because of ice fog forecasts for the following day.

3.7 Engineering Approaches

There have been two very costly, but unsuccessful, engineering attempts to eliminate the large amount of moisture from the stack effluents of the central power plant. The first attempt in 1952 involved the installation of a five million dollar heat-exchanger to contain and condense the moisture released by the combustion of coal. During the test runs, water froze in the condensing pipes, plugging the system with ice and finally ruptured the pipes. Since the system could not be made to operate properly, this approach was abandoned. About two years later, a different approach was tried. An ethylene-glycol gas scrubbing system was designed and installed at a cost of three million dollars. On the first day of testing the system, over 6000 gallons of glycol were lost due to evaporation when exposed to the hot stacks gases and through leaks in the system. This approach was quickly abandoned also.

Beginning in about 1953, the Base Civil Engineers initiated a campaign to eliminate as many of the various moisture sources as possible around the base facilities themselves. Changing the method of operation of the base laundry, mess halls, motor pool, etc., suppressed the localized clouds of dense ice fog formed around many of the base facilities. The single most important factor, however, was the installation of a condensate return system for central base heating, thus eliminating the myriad of steam vents throughout the base.

The efforts on the part of the Base Engineers to suppress moisture sources have continued throughout the intervening years. The central power plant, which also supplies steam for central base heating, was moved to its present location in 1960 and the capacity greatly increased. Once it was in operation, three diesel- or oil-fired power sub-stations scattered around the base were shut down. The two oil-fired sub-stations were dismantled, but the diesel sub-station is maintained as a backup for the main plant. Combustion studies resulted in revised operating procedures for the main station, which increased the coal burning efficiency of its boilers and decreased the amount of moisture released by about 10 to 15 percent. The underground steam distribution system has been completely refurnished to eliminate steam leaks and to bring into the system some buildings which had previously been excluded.

This past winter (1964-1965), in an effort to reduce the amount of moisture evaporated from the cooling pond, the Base Engineers made an attempt to allow the surface of the cooling pond to freeze over. To accomplish this, the hot (140°F) water returned from cooling the stream turbines was vented directly into a deep, narrow, drainage ditch instead of being discharged into the cooling pond. The pond water was replenished with a fresh supply from a nearby pit pond. Because of an inadequate supply of replacement water, only about one-half of the pond's surface was frozen. Engineering now planned for the summer of 1966 is expected to allow the entire surface to be frozen during the winter months. The proposed new 14-foot deep ditch (shown in Figure 3) is to be dug from the present cooling pond to a larger fresh water pond about a quarter mile away. The increased supply of cold water should permit the entire surface to be frozen. The plan also calls for the installation of covered conduits for about the first 200 yards of the present drainage ditch into which the hot, discharge water will be dumped. Much of the heat will then be absorbed into the ground and the temperature of the water greatly reduced by the time it is exposed to the atmosphere. Thus, by freezing over the cooling pond and controlling the evaporation of the discharge water, the base's biggest single, low-level source of moisture will virtually be eliminated. The engineers feel that these two ditches can be dug and prepared for about $30,000. In the authors' opinion, this would be by far the cheapest and best investment the Air Force could make in an effort to reduce the frequency and intensity of ice fog at Eielson AFB.

Before the present central power plant was built, there were three smaller power generation plants which were major contributors to the ice fog problem. Prior to building the present central power plant, a comprehensive climatological study was prepared to choose a site which would minimize the effect of the ice fog produced by the new plant. The decision based on this climatological study was to put the new power plant across the Richardson Highway, down-slope and therefore, supposedly, down-wind of the base during ice fog condition. However, overriding engineering considerations dictated the present location for the central power plant. It was much cheaper to install the underground steam heating lines from a centrally located power plant to the base facilities and the planned new base diesel- or oil-fired power sub-stations scattered around the base were shut down. The two oil-fired sub-stations were dismantled, but the diesel sub-station is maintained as a backup for the main plant. Combustion studies resulted in revised operating procedures for the main station, which increased the coal burning efficiency of its boilers and decreased the amount of moisture released by about 10 to 15 percent. The underground steam distribution system has been completely refurnished to eliminate steam leaks and to bring into the system some buildings which had previously been excluded.

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It is quite probable that in spite of the various suppressive and corrective measures devised to alleviate the ice fog problem at Eielson AFB, there will always be some ice fog to hamper base activities. Even if the major moisture sources such as the central heating plant and the cooling pond are eliminated, there still remain the moisture emitted by all motor vehicles on base, the family clothes driers and exhaust fans, and the aircraft activities on base. These will continue to produce local pockets of ice fog around the schools, commissary, base exchange, housing area, and the runway complex during their daily peak activity periods. The people going to work in the morning, going for lunch, and returning home in the evening will continue to cause daily peaks in the density of ice fog along traffic routes. Because the proper conditions (very cold, calm weather) occur during the winter, the normal daily activities of people living at interior Alaskan air bases produce sufficient moisture to produce ice fog under these conditions. It appears that ice fog cannot be eliminated completely, unless the bulk of the people are removed. However, this does not mean that the severity of the ice fog cannot be lessened by proper counter measures.

3.8 Possibilities of Ice Fog Dissipation by Helicopter

One possibility for dissipating ice fog over the runway due to aircraft take-offs is to use a helicopter. Since the ice fog layer is usually less than 100 feet thick, it is possible that a helicopter making slow passes over the runway can mechanically mix enough of the much warmer air from above the ice fog radiation inversion, to locally lower the relative humidity enough to disperse the ice fog over the runway. The Air-Sea Rescue Unit at Eielson has an excellent helicopter for this purpose, the H-21. With its two big rotors, it is capable of producing considerable mixing through a layer of 200 foot thickness under normal conditions. The heat from the helicopter engines would also be available for heating the colder air. Although it is realized that the strong radiation inversion will inhibit mixing, it is felt that adequate mixing can be effected by a helicopter flying just above the ice fog layer. Conversely, the water of combustion produced by the engines would be mixed with the colder air to help maintain its high humidity. There is no certainty that this technique will prove effective, but it is worth attempting.

The possibility of using a helicopter for this purpose was suggested by one of the authors, Major James F. Church, to personnel at both Eielson AFB and

Hq AAC. Both organizations are making arrangements to test the feasibility of this technique this winter at Eielson AFB.

3.9 Ice Fog Trends

The frequency of ice fog from winter to winter at Eielson is influenced by the normal variability of the weather regime between winters. It is of interest to compare the frequency of ice fog occurrences over a period of years without the effect of weather variability. An index designed to minimize the effect of winter temperature variability on ice fog occurrences has been devised by Richardson (1964). To obtain the index, which is also called the "ice fog ratio", the actual number of hours of occurrence during each winter (November to April) of ice fog with visibilities equal to or less than three miles is divided by the number of hours with temperatures equal to or less than -20°F. Hence, an ice fog ratio of 1.0 would mean that ice fog with a visibility of three miles or less occurred every time the temperature was -20°F or lower.

Figure 6 shows a plot of the ice fog ratios calculated for Eielson AFB for the winters of 1947-1948 through 1964-1965. The curve indicates an increasing trend in ice fog ratio in the early years, with a peak during the winters from 1953 to 1954. Then a slow decline follows for the subsequent winters.

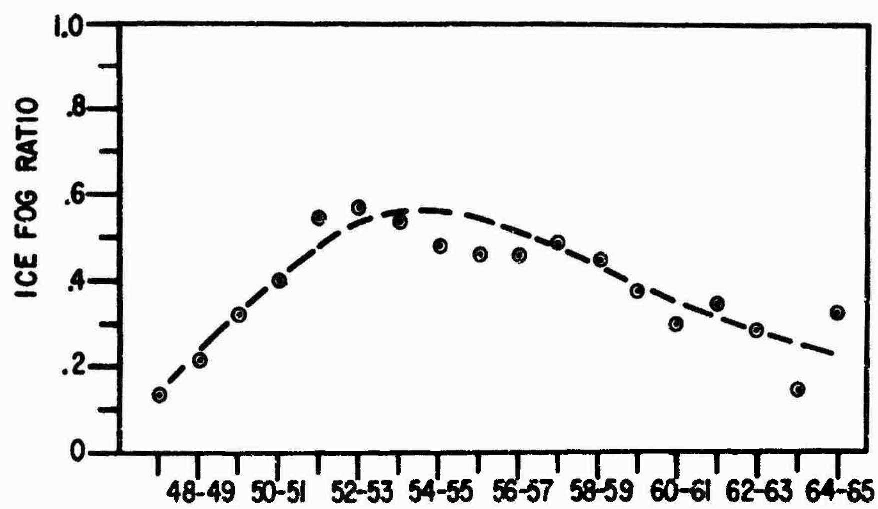

Figure 6. The Eielson AFB Ice Fog Ratios versus Time for the Winters from 1947-1948 through 1964-1965

There are a number of factors which may have influenced the apparent decline in the relative frequency of ice fogs at Eielson in recent years. The ice fog problem was recognized in the late 1940's, and the first comprehensive research program started in 1951. This study was completed in 1954 and the final report published in June 1955. The recommendations, which were made to alleviate the ice fog problem both during the course of the research and in the final report, were accepted and instituted by the base as they became available. This may account, at least partially, for the reversal of the increasing trend and the decline in recent years as more and more of the suggested remedial measures were instituted. The construction of the central power plant was completed in the period of 1953-1954 and, as previously mentioned, helped somewhat in controlling the ice fog pollution around the base. Since 1960, it appears that the ice fog ratio is beginning to level off at about 0.25. It does not seem likely that the ice fog ratio will drop much below 0.25, since most of the known practical and economically feasible corrective actions to suppress ice fog have already been instituted. The last remaining corrective action for the base is to initiate measures for freezing over the cooling pond completely, which could conceivably lower the ratio somewhat but may not do much more than offset an otherwise increasing trend due to an increasing base population.

The change-over from reciprocating engine aircraft to mainly jet aircraft at Eielson AFB in the early 1960's is another factor to consider. There appears to be general agreement among various references that reciprocating engines produce more ice fog than do jets. One reason for this is that reciprocating engines usually require that Nelson heaters be used for about an hour to preheat the engines prior to start. After the engines are started, they are run in idle for about another half hour to warm up completely before a takeoff. All the ground idle plus preheat time produces much ice fog over the ramp and taxiway areas prior to the actual takeoff. In addition, Eielson units have modified their takeoff procedures under ice fog conditions. Normally, the SAC KC-135 tankers start engines one hour prior to takeoff. Under ice fog conditions, procedures have been adopted which shorten the ground idle time, thus minimizing the ice fog over the ramp and runup area prior to takeoff.

Among the different jet aircraft at Eielson, the B-47 is considered to produce the most ice fog. The reason for this is believed to be that the B-47 engines are angled downward, so that the hot exhaust gases melt and evaporate more snow on the ground than do the other jet aircraft. The consensus of observers appears to be that the takeoff plume of ice fog from a B-47 aircraft is denser and more persistent than with other jets.

3.10 Base Plans

During the course of discussions with the various Eielson units, the authors learned of some future base plans which are pertinent to this report.

As mentioned before, 200 additional family units will be built during the summer of 1966. When finished, these units will increase by about 20 percent the moisture contribution by the family units (cars, clothes driers, exhaust fans, etc.). The capacity of the central power plant will be increased by one-third, by the addition of a 5000 KW power generator. The base has also established an emergency electrical power tie-in with Fort Wainwright and the city of Fairbanks power stations. This emergency power network will allow Eielson to continue to service vital base units under any but a massive power failure of the central power plant itself.

There is also the possibility that electrical power from the Rampart Dam will become available in 1975. This is a huge dam on the Yukon River, now in the planning stage, that should have the capacity to supply all of the base power requirements when it is built. However, the Rampart Dam is still under active discussion, and it will be at least ten years before power for the base needs will become available.

4. SIGNIFICANT FINDINGS

This section is devoted to highlighting some of the more significant findings, which bear directly on recommendations found in the following Section 5.

4.1 The Magnitude of the Ice Fog Problems

A wide divergence of opinions exists concerning the magnitude of operational problems resulting from the occurrence of ice fog, and there is very little factual data to support any view taken. Most of the statistics on ice fog interferences with aircraft operations at Eielson were obtained for the winter 1964-1965. While it is recognized that one winter is a poor substitute for a longer period, it does reflect operations under the influence of a "fairly severe ice fog period" and under current operating procedures. One of the most significant procedures relating to the magnitude of the problem is that most aircraft operations are restricted to air temperatures above -30°F. This constraint is imposed by human factors and is completely independent of the visibility restrictions caused by ice fog. When personnel responsible for aircraft operation are asked the question, "would it substantially increase the effectiveness of your mission if it were possible to prevent the occurrence of dense ice fog <u>when air temperatures are below -30°F?</u>", the answer in most instances is an unqualified negative. Since dense ice fog (visibility less than one-half mile) rarely occurs at temperatures above -30°F, its suppression or prevention would not substantially benefit most air operations at Eielson. This is not to say that low visibilities do not occur in cold weather at temperatures greater than $-30^{o}F$, but the visibility restrictions are attributable to phenomena other than ice fog. Nor is it implied that dense ice fog does not hamper air operations at Eielson. It has already been pointed out that ice fog occasionally causes delayed departures or diversions of planned recoveries of SAC KC-135 tankers and weather recon aircraft which are not restricted by low air temperatures. Furthermore, the fact that these units fully accomplish their missions in spite of ice fog does not make acceptable the potential hazards incurred by operating the aircraft in less than desirable conditions. In addition, it has been pointed out that the occurrence of dense ice fog could prevent the use of Eielson as an emergency recovery base for those aircraft which would not ordinarily operate at temperatures below $-30^{o}F$. Nevertheless, it must be recognized that ice fog accounts for less than one-half of the winter visibility restrictions below one-half mile and that most air operations at Eielson otherwise would be restricted by low temperatures at precisely the times when dense ice fog occurs. This recognition immediately prompted the question, "what level of effort would wisely be expended on research directed solely toward developing a means for suppressing or preventing ice fog?" There is of course no absolute, unqualified answer, but two factors must be considered for research accomplished to satisfy an operational requirement. First, the level of effort must be justifiable on the basis of operational need. Second, there must be a reasonable expectancy that the research will produce operationally useful results commensurate with the expenditures incurred. The magnitude of the operational problem then is one of the prime considerations and must be viewed in proper perspective, if a sound decision is to be made on future ice fog research.

4.2 Ice Fog Research

One of the earliest and most comprehensive studies of ice fogs was made by Stanford Research Institute (1955) under contract to AFCRL. The study was completed during 1954 and included three years of field observations at Eielson AFB. It covered both basic ice fog research and considerations of techniques for suppression and prevention of ice fog. The recommendations contained in the report undoubtedly prompted the successful efforts on the part of base engineers to eliminate many unnecessary moisture sources. This in turn resulted in some reduction of ice fog occurrences at Eielson.

Since the completion of the SRI study, several organizations have been active in ice fog research. Among these are the U.S. Army Cold Regions Research and Engineering Laboratories, the University of Alaska, and Detachment 2, 11th Weather Squadron. It is significant that while the excellent studies conducted by these organizations have extended our understanding of the ice fog phenomenon and have aided in identifying its significance to aircraft operations, they have not produced results which can be applied to increase the efficiency of aircraft operations. Nor have the studies opened up any new avenues which hold promise as fruitful approaches to the solution of ice fog problems. There remains much worthwhile basic research to be accomplished on ice fog, but research justifiable at this time on the basis of operational need is at best difficult and will remain so until it can be shown precisely how and to what extent the results of the research will be operationally useful. We have not arrived at that position in the edifice of research where a program can be outlined which has a reasonable probability of being successful in solving Air Force problems associated with ice fog.

4.3 Elimination of Moisture Sources

Since 1955 there has been a trend toward decreasing frequency of occurrence of ice fog relative to the occurrence of temperatures in the ice fog range. This is attributed mainly to the adoption of procedures which have reduced the amount of moisture released into the environment when temperatures are in the ice fog range. It is encouraging to note the many ways that Eielson engineers have eliminated unnecessary moisture sources. However, a substantial number of pollution sources still remain. The worst offender is probably the power plant cooling pond which releases about 375,000 pounds of moisture at near ground level on a cold day. Attempts made by the Base Civil Engineers during the winter of 1964-1965 to freeze the surface of the pond resulted in a freezing over of about one-half of the pond. It is understood that construction, tentatively planned for the summer of 1966, will permit the entire surface to be frozen during those periods when air temperature are low enough for ice fog formation. Even if completely successful in eliminating this source as a factor in ice fog occurrence, there will remain a sufficient number of sources to cause continuing ice fog problems. However, the relative frequency of occurrence and the severity of visibility restrictions should be reduced, providing there is no increase in the amount of pollution from other sources.

An additional source that will be attacked during the winter of 1965-1966 is the sanitary fill burn pit which has recently been identified as a pollution source. Procedures now call for curtailment of burning when air temperature drops below -20°F. This source, as noted before, is especially effective in obscuring the northern approach to the runway.

The suppression of ice fog caused by aircraft takeoffs has in the past received considerable attention. Proposals to adapt a contrail suppression technique have been proposed and have been rejected for the following reasons. First, it is highly doubtful that the technique would be effective since the contrail suppression technique assumes an unsaturated environment which entrains in the jet exhaust, a condition rarely, if ever, met when ice fog from jet exhausts would be experienced. Second, the materials injected into the jet exhaust to accomplish contrail suppression are toxic. On those rare occasions when the technique might prove effective, meteorological conditions are such that the introduction of these materials into the environment in quantities necessary for ice fog suppression would present a definite health hazard to base personnel. Third, even if nontoxic materials could be used and a contrail suppression technique could be made effective for aircraft on the runway, one would have solved only the minutest fraction of the ice fog problem, that of the ephemeral runway visibility reductions immediately following takeoff.

5. RECOMMENDATIONS

5.1 Research

At the present time, the authors do not recommend research directed solely at the solution of operational Air Force problems resulting from the occurrence of ice fog at interior Alaskan bases. Research, already accomplished by contractors to AFCRL, has identified areas where remedial actions designed to reduce the magnitude of the problem have been completed or are in progress. Subsequent basic research has not identified approaches which are considered at this time to be profitable avenues for further research designed to solve operational Air Force problems.

We do recommend that so long as ice fog continues to be an Air Force problem of sufficient magnitude to warrant a QOR, the requirement remains in force. Also, it is recommended that the profitability of undertaking applied research designed to provide operationally useful solutions be continually evaluated by AFCRL, and that the determination of profitability be based on recent developments in the state-of-the-art.

We would encourage the continued effort on the part of the Eielson Weather Detachment to collect and analyze pertinent meteorological information. Of particular value are the analyses of transmissometer records of runway visibilities and the special ice fog climatic summaries. They are valuable not only in monitoring Eielson's ice fog suppression program, currently being administered by Base Engineering, but should prove useful in future re-evaluations of the magnitude of the problem.

5.2 Engineering

The construction tentatively planned for the summer of 1966, which will enable Base Engineers to freeze the surface of the central power plant cooling pond, appears to be by far the most profitable single engineering effort to be accomplished. We strongly recommend that this engineering effort be accomplished, and that procedures be adopted to allow the entire surface to be frozen during the entire ice fog season.

We would urge that the Base Engineer's ice fog suppression program be pursued and that every feasible effort be made to eliminate unnecessary sources of moisture near the surface during periods of extreme cold. It must be recognized that a continuing effort is required in order to prevent the recurrence of offending situations which are currently under control, and to prevent the introduction of new sources.

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Lt Col R. L. McCluney	Dir. of Operations	SAC, 4157th Strat Wg
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13. ABSTRACT

This report summarizes the findings and conclusions drawn from a survey which was conducted at Alaskan bases. The purpose of the survey was to secure information necessary for making recommendations on the nature and level of effort of research programs which could be directed toward minimizing the disruptive effect of ice fog on air operations at Eielson AFB. The ice fog phenomenon, its principal causes at Eielson, and the nature and extent of its effect on air operations are discussed. An examination is made of engineering approaches to the solution of ice fog problems and their influence on the apparent trend during the past ten years toward a decreasing frequency of occurrence. A recommendation is made for engineering designed to minimize pollutions from what is considered to be the primary source. Finally, there is a discussion of the feasibility of establishing an applied research program designed to provide operationally useful solutions to the ice fog problem.

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