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EFFECT OF WEATHER FACTORS ON AIRCRAFT MAINTENANCE CREWS IN ARCTIC AREAS

Colonel A. L. Karstens

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ARCTIC AEROMEDICAL LABORATORY
AEROSPACE MEDICAL DIVISION
AIR FORCE SYSTEMS COMMAND
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PREFACE

This previously unpublished report was written almost ten years ago by Colonel A. I. Karstens, Commander, 6570th Aerospace Medical Research Laboratories, then a Lieutenant Colonel commanding the Arctic Aeromedical Laboratory. The subject of this report is the effectiveness of aircraft maintenance crews in Arctic areas, and the decrements in their performance with low temperatures. Maintenance crews are still faced with the problems of working at low temperatures; the subject of Dr. Karsten's report, therefore, is still pertinent to USAF operational planning for Arctic areas.

ABSTRACT

Under conditions of dry cold with no wind, loss of aircraft maintenance crew effectiveness at temperatures down to 0^{o} F is small; below 0^{o} F, outdoor maintenance performance falls off until it may reach zero for poorly motivated crews at -30^{o} F; better motivated crews will attain some degree of effectiveness at the lowest temperatures encountered without wind. Under conditions of dry cold with wind, outdoor maintenance usually becomes essentially ineffective when the wind chill factor is comparable to or greater than that produced by a 10 mph wind and -15^{o} F temperature, although some crews will perform some maintenance under these conditions. Winds in excess of 30 mph interfere with visibility due to blowing snow. It is concluded that performance could be markedly improved with adequate motivation and experience; that development of adequate face protection and of clothing less pervious to wind is feasible; and that better solutions to the problem of hand protection and dexterity under high wind chill conditions should be sought.

PUBLICATION REVIEW

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Director of Research

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EFFECT OF WEATHER FACTORS ON AIRCRAFT MAINTENANCE CREWS IN ARCTIC AREAS

SECTION 1. INTRODUCTION

This report is a brief summarizing analysis of the manner in which weather factors influence the effectiveness of aircraft maintenance crews in Arctic areas, it emphasizes the important variable factors operating, and presents a simplified picture of a complex situation.

The statements made herein, while drawing freely on experimental background data, are based largely upon personal observation of routine daily human performance in Alaska during the past four years, augmented by observations in such areas as northern Greenland and Fletcher's Ice Island (T-3) during the early period of its occupancy by the USAF. In addition, these statements are made in the light of a considerable amount of personal experience in the most severe outdoor winter environments available in Alaska.

The weather factors of greatest importance to aircraft maintenance crews in the sub-Arctic and Arctic are low temperature, wind chill and wind driven snow. These factors will be discussed under conditions of dry cold without wind and dry cold with wind. This distinction is appropriate since the major Air Force bases in Alaska are located in areas where winter winds are uncommon, almost a rarity.

SECTION 2. DRY COLD -- WITHOUT WIND

General

Under conditions of dry cold with no wind, the effectiveness of aircraft maintenance crews working outdoors is variable, depending on adequacy of supporting facilities, training and motivation, and time tolerance for working in the cold. If the first of these two factors is considered to be operational and administrative, the time tolerance for working in the cold can be analyzed in the following way.

The end point of time tolerance or time duration for performing maintenance in the cold is the point at which the individual can no longer work effectively at the particular job he is required to do, or is in danger of cold injury as a result of cumulative body cooling. Thus, differences in the end point are possible depending on the nature of the work to be performed. Where dexterity is required, effective working time will be shorter and the end point reached sooner than in cases where less dexterity is required.

For any given job, time tolerance or time duration of ability to work varies with the following factors: (1) Environmental temperature (cooling effect of the environment), (2) effectiveness of insulation, and (3) body (muscular) heat production. The interrelationship of these three factors determines the rate at which the body cools and the time required to cool it to the point where the maintenance man can no longer work effectively. The cooling of the body is reflected in low surface temperatures of the body, especially of the extremities, and is associated with a low heat input into the extremities as a result of constriction of the surface and extremity blood vessels. These constrictions of the surface and extremity blood vessels constitute a normal physiological mechanism for conserving heat as the body chills. This cutting off of the circulation to the extremities, resulting in lack of dexterity and inability to work, occurs regardless of the amount of mittens and gloves worn. After normal body heat balance is re-established by rewarming in a building, the maintenance man can return to the outdoor work and repeat the same period of performance.

Normal body heat balance may also be restored by muscular exercise, which is equally as effective as rewarming inside a building, if clothing is adequate. It is possible for maintenance personnel to remain outdoors at any temperature for a full day by using muscular exercise as a means of increasing the rate of heat production to keep the body warm. However, the nature of maintenance work on aircraft is such that body exercise cannot be used to any practical extent, except intermittently, for heat production; warming shelters are more desirable to maintenance crews.

In addition to keeping the body warm by work or exercise, it is also possible to keep the body warm by the use of electrical heating in clothing. If exercise and electrical heating are not feasible, intermittent rewarming indoors is the most practical solution. A report on the use of electrically heated clothing is being prepared by the Arctic Aeromedical Laboratory, data presented indicate that if maintenance personnel are willing to make the effort, electrically heated clothing can be a practical means of markedly improving maintenance performance under very cold outdoor conditions.

It is emphasized that dexterity or the ability to work with the hands is more closely related to body heat balance than it is to actual outdoor temperature. In other words, a man thoroughly chilled at 0° F cannot work nearly

as well with his hands as a comfortably warm individual can at -40° F. If personnel are highly motivated to perform outdoor maintenance, full indoctrination in the simple relationship existing between insulation, environmental temperature, muscular heat production, and time tolerance, as well as the relationship between body heat balance and circulation to the extremities, will result in greatly improved performance.

Yardsticks of Effectiveness

Effectiveness of maintenance crews in the cold is determined not only by the comparative time required to perform a given maintenance task or group of related tasks, but also by whether it has been possible to perform critically important maintenance tasks at all. Time required to perform a maintenance task in the cold is influenced both by the speed with which the work can proceed during actual working time as well as the relationship between length of required rewarming periods and length of working periods. Maintenance crews in temperate climates do not normally remain continuously on the job. Consequently, accomplishment in Arctic cold of a series of units of maintenance jobs, any one of which can be accomplished in 30 to 45 minutes outdoors, may result in an apparent high degree of crew effectiveness by comparison with work in temperate climates. However, in temperate climates crews can more easily increase their output in emergencies and periods of high workload by remaining continuously on the job.

The total time spent at intermittent rewarming as compared to the time spent at working varies, of course, with the factors discussed above. However, if insulative clothing is a constant and muscular exercise is a constant, the amount of time spent at rewarming as related to the time spent at work will vary essentially with the intensity of the cold, with some spread due to individual variation in ability to maintain circulation to the extremities. When the temperature is lower than -15° F, few individuals will maintain heat balance indefinitely during aircraft maintenance activities, even with the best clothing assemblies available, unless supplementary heat is supplied. Under such conditions, the time tolerance is largely a function of the energy output required to do the work. Conversely, at +10° F nearly all individuals are able to work outdoors continuously without difficulty, if wearing the Arctic clothing provided. When a job requires a relatively high muscular work output, heat balance can be maintained at any temperature encountered on the surface of the earth, provided no winds are blowing. Such high levels of heat output are usually not feasible while conducting outdoor aircraft maintenance work. When a rewarming period is required it will usually equal in duration the preceding working period in more severe degrees of cold; wide variation will occur among individuals and groups.

Estimated Decrements on Outdoor Maintenance Effectiveness Due to Cold

Actual decrement of performance as related to temperature in outdoor maintenance of aircraft under conditions of dry cold without wind remains very difficult to assess because of the marked influence of indoctrination, training, and motivation on effectiveness, as well as a number of associated modern factors such as logistic support, supporting facilities, housing, etc. The following generalizations must be made, rather than hard and fast rules, because of the many variables encountered.

1. Decrement of performance at temperatures down to 0^{o} F is small and is associated largely with the nuisance and encumbrance of necessary clothing; i.e., no indoor rewarming periods are actually required but rewarming breaks will be used by nearly all personnel.

2. Below 0^{o} F, outdoor maintenance performance falls off until it may reach zero for poorly motivated crews at -30^{o} F; i.e., the maintenance crew accomplishes almost nothing between rewarming periods and spends most of the time indoors waiting for hangar space. Effective maintenance by such crews is then accomplished only inside a hangar or during periods of relatively warm weather.

3. Better motivated crews will attain some degree of effectiveness at the lowest temperatures encountered without wind. Availability of warm-up shelters and adequate accessory heat in the form of Herman-Nelson heaters, or similar accessory heat, play an important part in this retention of effectiveness. Crews experienced in the use of portable ground heaters utilize them to heat maintenance personnel to some extent as well as to heat the aircraft part on which they are working; thus, they may remain outdoors working full half days during the most bitter cold. The average effectiveness under such conditions, however, is probably not in excess of 50% of that to be expected for average outdoor maintenance in a temperate climate. Further decrements in efficiency are due to associated difficulty with materiel and logistic support.

4. The use of mobile shelters to place over parts of the aircraft on which maintenance crews are working combined with the use of such sources of heat as the Herman-Nelson heater can make it possible for maintenance crews to do all work on aircraft outside of hangars, as far as the effect of cold on the human being is concerned. However, the logistic problems of providing the shelters and the time spent setting them up and arranging for heating cannot be overlooked.

Cold Injury in Maintenance Crews

Crews performing outdoor maintenance under conditions of dry cold without wind seldom incur cold injury. An occasional accidentally frostbitten nose is usually quickly rewarmed and causes no disability whatsoever. Frostbite of the feet is incurred only by the unwary who occasionally remain on the job too long after their body has cooled to the point where intense vasoconstriction has set in and the feet are thoroughly cooled. This almost never occurs in a single half day of exposure because of the insulation and heat capacity of the clothing and footgear worn, as well as the heat capacity of the human body and the protective response of seeking shelter. Organizations new to the Arctic, however, should be wary of this problem and recognize the need for re-establishing the body heat balance at the necessary intervals. The best rule is that when a man's feet are cold, he should take positive action to restore body heat balance and circulation to the feet by exercise or by entering a warm shelter. The ears and forehead, while very susceptible to frostbite, are seldom injured because of the ever-present pile cap worn in the Arctic. Under windless conditions there is some decrement in performance due to interference with vision by the redundant hood of the issue parka. However, this problem is small and the hood can ordinarily readily be pushed back on the head when necessary.

Handgear used is the standard Arctic mitten over an inner assembly composed of a knit woolen glove and a leather glove shell. When the mittens prevent sufficient hand dexterity, they are removed and work is performed with the gloved hand. These gloves provide a reasonable amount of insulation, are impervious to wind, and permit a fair degree of dexterity with tools. When the degree of dexterity is inadequate, the bare hand is used. As the temperatures go lower, the hand problem becomes more and more acute, and it is frequently the difficulty of maintaining circulation to the hands, with failure to retain adequate dexterity, which drives the maintenance man, such as a radio repairman, into the hangar or warm-up shelter for rewarming. Frostbite of the hands, however, is rare. Maintenance crews learn to recognize that when the hands become painfully cold, the only solution is rewarming of the entire body.

Freezing of hands to metal almost never occurs in Alaska. This is probably due to the fact that firm contact of the bare hand with large metal objects of high heat capacity is rarely necessary; small lightweight objects of low heat capacity are readily handled without injury.

Miscellaneous Influences of Cold on Personnel

The "frost-bitten lung" is deemed a nonentity; no cases have been seen in Alaska by Air Force personnel. * Idiosyncrasies such as cold-urticaria are seen but rarely and are usually recognized early.

The writer has seen one case of collapse from overheating as a result of exhausting work at -15° F and 30 mph wind. The individual concerned kept himself fully clothed in full Air Force Arctic maintenance crew clothing, including parka, while handling full fuel barrels in snow; vasomotor collapse with typical fainting occurred when cooling could not proceed at an adequate rate by either convection or evaporation because of the heavy clothing. Such occurrences are rare and are most likely to occur when men at hard physical labor are reluctant to open or remove parkas in high winds with blowing snow.

Under all Arctic cold conditions, insecurity of underfooting is always a problem. Personnel must learn the hazards of slipping, especially on cold metal surfaces. No type of footgear completely solves this problem. However, rubber soled footgear such as that of the standard Air Force mukluk, the standard shoe-pac, or the Korean boot, offers on the average the best friction for secure footing.

When temperatures remain below +20° F, average below 0° F and range as low as -60° F, humidity and moisture in clothing create no special problem of serious degree to maintenance crews. Significant accumulation of moisture in clothing by condensation does not occur, particularly if attention is given to daily drying of any items of clothing in which vapor impermeable layers occur. In the case of the Arctic Air Force assembly, this is only in such items as the shoe-pac, the rubber soled felt boot, and the rubber soled mukluk. The remainder of the clothing assembly readily dries in the low humidity and warm air of the barracks and quarters. The daily accumulation under such conditions is not significant when the clothes are doffed nightly while the men are at rest. Temporary accumulations of moisture on zippers on the parka front and on the ruff of the parka readily thaw and drip from the wool, nylon and fur combinations when hung up temporarily in shelters. Occasional sticking of a zipper from refreezing following partial thawing occurs, but maintenance crews soon learn to cope with the problem without difficulty.

* Since this was written, several cases of respiratory damage have been seen in Antarctic sojourners who were engaged in heavy work at temperatures below -70° F. See Houk, V. N. Transient pulmonary insufficiency caused by cold. U. S. Armed Forces Med. J. 10:1354-7, November 1959.

The foregoing should not be taken to mean that moisture is not an important consideration in clothing in the field or under survival conditions in the cold, including dry cold.

SECTION 3. DRY COLD -- WITH WIND

Outdoor aircraft maintenance other than that associated with simple preflight and postflight activities and refueling is ordinarily not required under windy conditions in Alaska. This is due to the fact that aircraft are nearly all based on major Air Force bases in areas where winter winds are a rarity. The major factors which influence maintenance crews in dry cold with wind are: (1) The increased chilling effect of the moving air on the body as a whole; (2) excessive local chilling of the exposed parts such as the face and hands; and (3) the effect of blowing snow on visibility. Blowing snow infiltration into clothing, while serious under isolated or survival conditions, is not serious where ready retirement to dry warm shelters is possible.

The relationship between environmental temperature, insulation, and heat production in maintaining normal heat balance and good circulation to the extremities applies in principle in the wind just as in dry cold without wind. The increased cooling power of the environment due to wind shortens the time tolerance at a given temperature. When wind chill factor is comparable to or greater than that produced by a 10 mph wind and -15° F temperature, outdoor maintenance usually becomes essentially ineffective, although occasional crews will perform some maintenance under these conditions. Winds in excess of this amount produce a great chilling of the hands of crews attempting to perform work.

Winds in excess of 30 miles per hour interfere with visibility because the crew man is forced to turn away from the wind with his hood over his face, and because blowing snow frequently swirls around inside the ruff of his parka, continuously blowing in the individual's eyes and preventing him from seeing what he is doing. Ground maintenance personnel at Barter Island say that the major factor which prevents them from accomplishing maintenance work of all kinds around Barter Island during high winds is the factor of blowing snow striking their eyes making it impossible for them to see. Personal observation of their activities confirms this. Wearing of goggles to shield the eyes is totally ineffective since they frost up so rapidly as to be useless in a few minutes. Under any temperatures and wind conditions where take-offs and landings are feasible, maintenance crews can usually perform the necessary prewarming and preflighting of aircraft especially if they are well experienced in the best procedures or sequence of procedures to follow.

Consistently, significant maintenance work can be accomplished on days of wind chill more than that produced by a 10 mph wind and -15° F only by using an improvised "nose-hangar" or similar device to shield workers from the wind and blowing snow. Such nose-hangars must be so constructed as to be mobile for proper orientation into the wind and must be capable of being tied down and able to withstand very high winds so that they will not be destroyed, whether in use or not. Such portable nose-hangars have not been used sufficiently in the Alaskan Air Command to present a practical design from an operating viewpoint, since Alaskan Air Command has always had all major airfields in relatively nonwindy areas. A moveable nose-hangar available at Elmendorf AFB for the past year, for C-124 engine maintenance or engine changes, has not been needed to date.

In locating airfields where outdoor maintenance may be required, consideration should be given to the total number of days with wind at low temperatures which occur annually. The assumption is justified that effective outdoor maintenance is not feasible at wind chill factors in excess of that of 10 mph wind at temperatures lower than -15° F, and is not practical at considerably lesser wind chill levels unless protective shelters (i. e. nose-hangars) are developed.

The limitations on maintenance in cold with winds stated above should not be construed as meaning that a capability for performing necessary maintenance under such conditions cannot be developed. Development of adequate face protection and of clothing less pervious to wind is feasible. Better solutions to the problem of hand protection and dexterity should be studied further for high wind chill conditions. With maximum improvement along these lines, the average performance could be markedly raised under high wind chill conditions.

Furthermore, adequate motivation and experience lead to exceptional performance in the cold which is far above the average to be expected. Engine changes on multi-engine aircraft have been made in almost normal time in -50° F weather. Such work is not done in defiance of the laws of thermodynamics or at great personal suffering; it is done through intelligent planning and use of resources by highly motivated personnel. It is the firm opinion of the writer of this report that much more could be done to make such performance, when needed, the rule rather than the exception. It is a fundamental fact that the coldest Arctic environments recorded are within the range to which man may adapt himself by proper use of protective clothing, combined with an adequate but not excessive heat output; this includes the windy environment.

SECTION 4. WET COLD

Slush and mud, when they do occur in the Arctic, are not different in their effect than in temperate climates. These conditions seldom alternate with deep cold. Problems created by such conditions are in areas where airfields are not adequately surfaced, are poorly drained, and where deep mud occurs from use of vehicles on terrain susceptible to rutting. The problems are then concerned with adequacy of footgear and difficulties of ground transportation. This problem does not occur significantly in the Alaskan Air Command. The sealed insulation type boot is the best solution to the footgear problem under such conditions. If these boots are not available, maintenance crews must be provided with adequate changes of footgear in the form of combat boots, shoe-pacs, felt boots and mukluks in accordance with standard clothing allowances for various climatic zones and seasons in order to have a selection of footgear suitable for all conditions. Rain seldom occurs in Arctic Alaska in quantities sufficient to interfere with maintenance crews. No raincoat is provided for maintenance crews in Alaska other than the standard Air Force blue, which is seldom utilized by maintenance crews; cotton field jackets (QM issue) are more commonly used.

SECTION 5. INFLUENCE OF LOGISTIC SUPPORT, HOUSING, ETC.

Factors which may indirectly affect the efficiency of maintenance crews by detracting from their effective working time are: (1) Poor housing, with necessity for increased attention to mere living problems during very cold weather; (2) inadequate transportation, along with difficulty in operation of private and government vehicles due to inadequate warm storage, lack of power for head-bolt heaters, inadequate cab and engine heating on government vehicles; and (3) difficulties with supply and logistic support during very cold weather operations.

SECTION 6. MAINTENANCE OTHER THAN AIRCRAFT

Other maintenance activity which must be accomplished outdoors follows the same principles. Telephone or power linemen, for instance, require rewarming periods; when maintenance is far from shelters, adequately heated vehicles should be provided for rewarming. At such work, intermittent exposure during which jobs are rapidly accomplished is quite practical. Failure to supply adequate space heating in maintenance vehicles markedly reduces crew efficiency.

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