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MAN AND MATERIEL IN THE COLD REGIONS. PART 1.(U)
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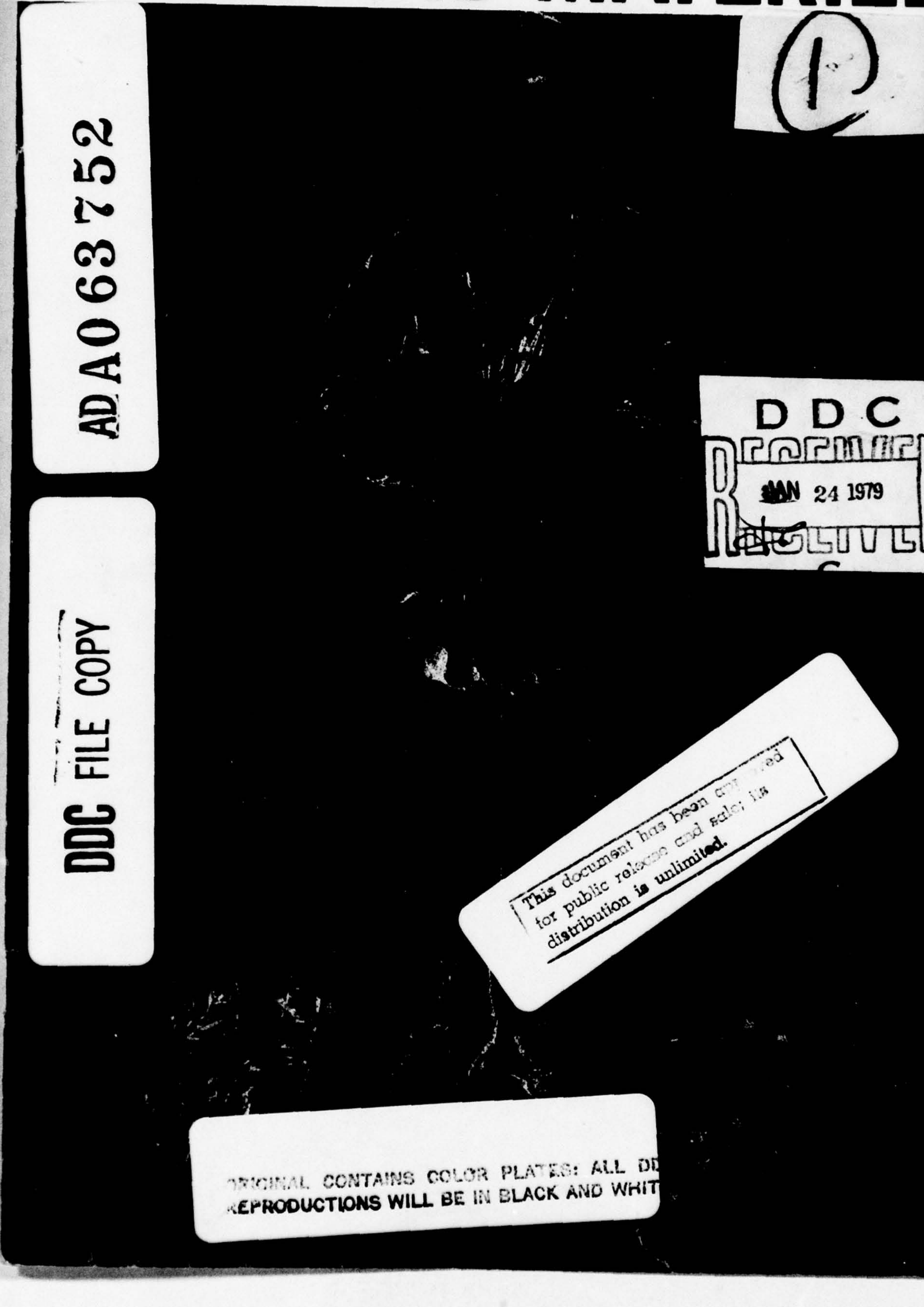
MAN AND MATERIEL in the COLD REGIONS

(Part 1)



U.S. Army Cold Regions Test Center

Fort Greely, Alaska

FOREWARD

The man and materiel in the Cold Regions Book represents a collection of pertinent information pertaining to cold regions. It is primarily oriented toward the soldier, operator, maintainer, tester likely to be assigned to one of the many associated geographical locations. However, much of the discussion can be useful and interesting to any individual who expects to encounter cold weather conditions regardless of location.

Substantial portions of the chapters that follow are written based on experience gained by men and women of the Cold Regions Test Center. The brochure is therefore dedicated to them. It is their hope that Man and Materiel in the Cold Regions will provide a partial answer to Alexander Solzhenitsyn's famous statement:

"How can you expect a man who's warm to understand a man who's cold!"

June 1978

(6) Man and Materiel in the Cold Regions. Part 1.

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CHAPTER 1. - INTRODUCTION

Definition of Cold Regions and Locations

In 25 years of testing all classes of military materiel under the operational conditions of cold regions, the U.S. Army Cold Regions Test Center has amassed a unique store of experience. This brochure has been prepared to summarize portions of this experience, and to present attendant requirements and doctrine needed for successful military operations in cold regions.

Later sections of this text will develop in detail the conditions that are unique to this theater of operation. It is, however, important at the start to define what we mean when we talk of cold regions, i.e., the physical and geographic parameters. An example of a principal physical parameter is, of course, ambient air temperature. The unique manifestations of precipitation, land surface, vegetation, etc., that are also of critical importance are largely derivative from the prevailing temperature.

As a first step in defining the geographical parameters, let us dispose of the word "arctic". It conveys a meaning of the basin of the Arctic Ocean or the area above 66°32' north latitude. Regions in which phenomenon discussed in this brochure drastically effect military operations are far more extensive and of a greater importance than this narrow interpretation allows. These regions will be generally termed cold regions.

Cold regions include both arctic and subarctic and areas immediately south. As part of cold regions, the arctic is best defined as the regions where the mean of the warmest month of the year does not exceed 50°F (10°C) and the subarctic as the region where the mean of the warmest four months of the year does not exceed 50°F (10°C). The 50° isotherm roughly representing the southern boundary of the subarctic, is illustrated in figure 1.1. The shaded region above the isotherm encompasses a number of areas of tremendous military importance and is one in which the factors we will be discussing have had catastrophic effect on major military campaigns.

A similar definition of these areas for use by the materiel developer has been stated by the Army in AR 70-38, Research and Development, Test and Evaluation of Material for Extreme Climatic Conditions. (See also paragraph 4.1.3) The AR establishes eight numbered worldwide climatic categories with quantitative descriptions of key parameters in each. The three categories of interest are shown in table 1.1, and are illustrated in figure 1.2.

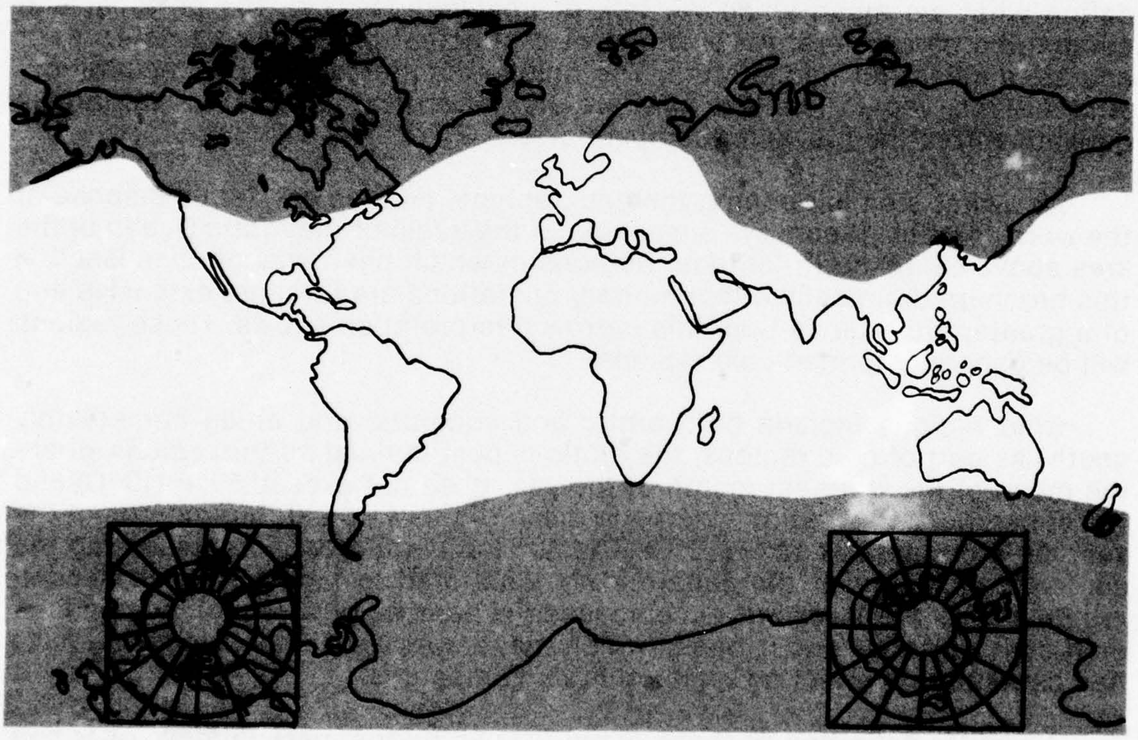


Figure 1.1.-Cold Regions within the 50° Isotherm

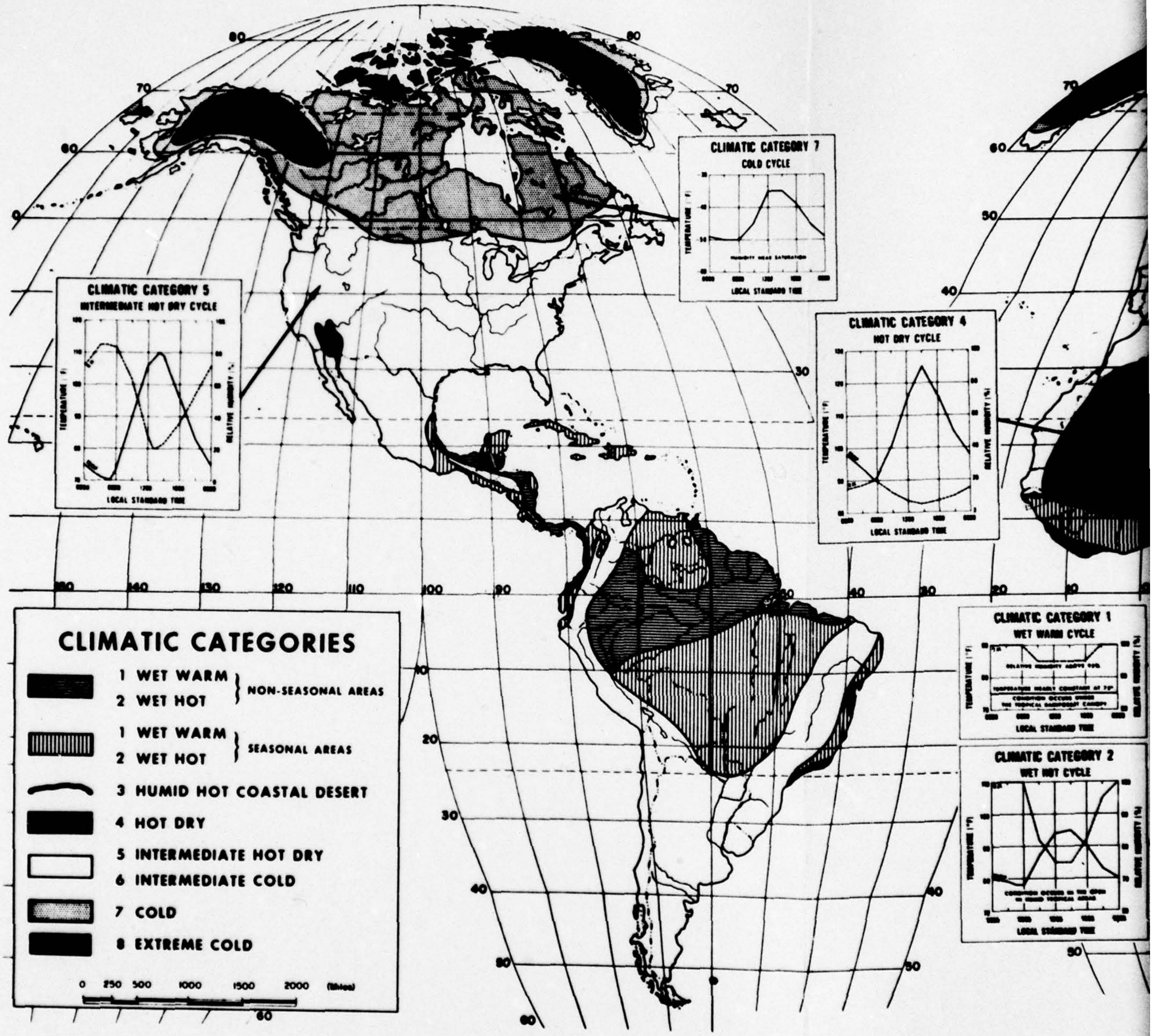
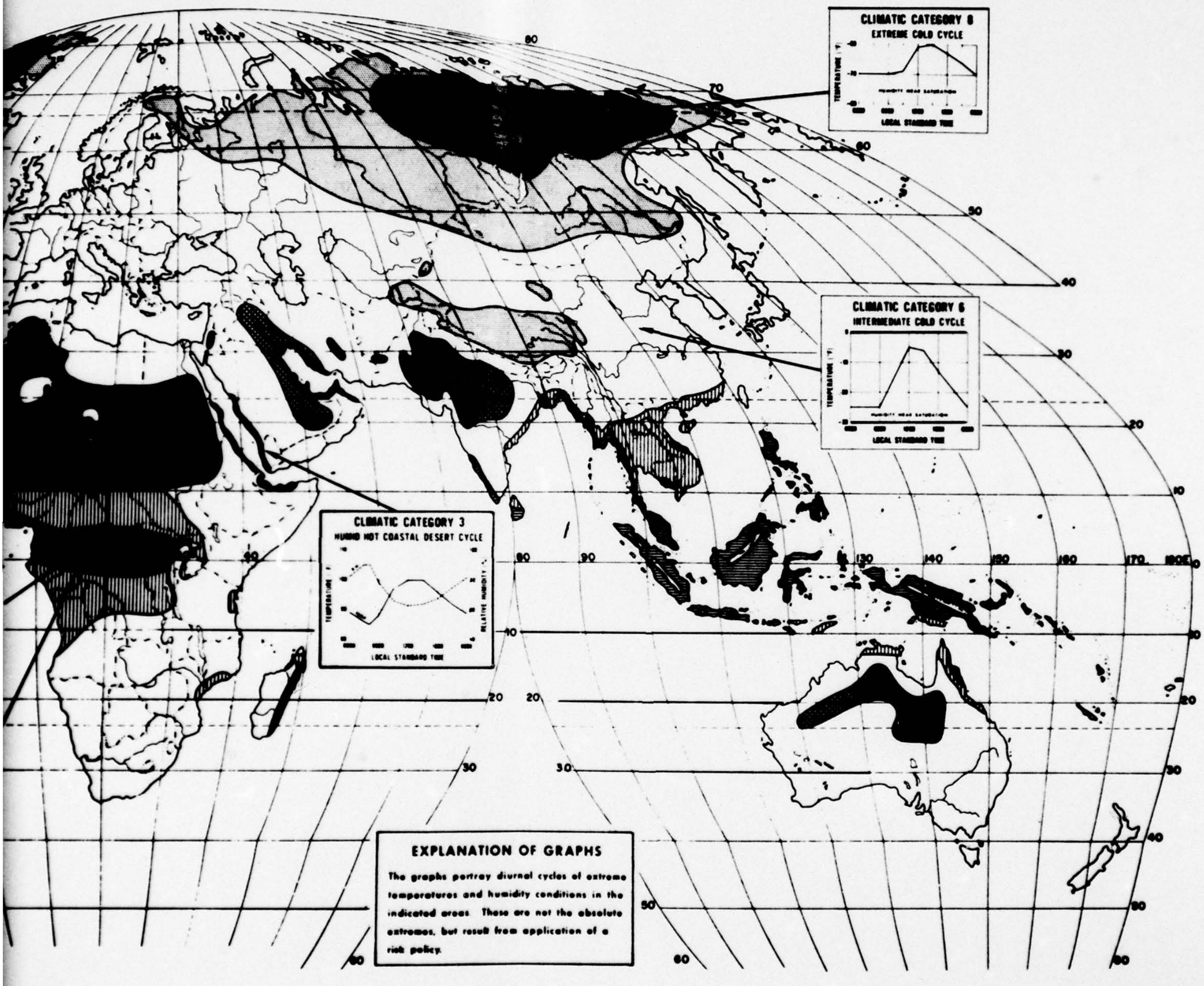


Figure 1.2.-Climati



Categories of the World

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TABLE 1.1.--Temperature Ranges of Cold Climatic Categories, AR 70-38

Category	Operational Range °F(°C)
6 - Intermediate Cold	- 5° to -25° (-21° to -32°)
7 - Cold	-35° to -50° (-37° to -46°)
8 - Extreme Cold	-60° to -70° (-51° to -57°)

The temperature bounds in table 1.1 were determined from records of hourly observations taken over a number of years. In each category, a temperature colder than the upper limit of the band occurred 99 percent of the time. A temperature colder than the cold end of the band occurred 1 percent of the time or less in the most extreme weather month in the most extreme location for the associated climatic category. The regulation also presents the geographical limits of the two most severe categories. Category 6 is contiguous to Category 7, but its southern boundaries are not defined. DARCOM Pamphlet AMCP 706-115, Basic Environmental Factors, indicates that the 40th parallel, with minor exceptions, is the southern limit of the cold regions in the Northern Hemisphere. The 40th parallel therefore may be considered the appropriate southern boundary for category 6 regions. Category 7 and the adjacent category 6 embraces terrain of the greatest importance to this country, and areas (such as the Sino-Soviet border) which continue to see major military activity. The trace of category 8 illustrates the interesting fact that the Northern Hemisphere's coldest regions are not at the North Pole, or even particularly above the Arctic Circle.

Climatic Factors of Importance to Military Operations

While the Cold Regions Test Center is a materiel test agency, it has nevertheless been required to assess the psychological and physiological impacts of the environment its' people must work in, and these will be addressed in succeeding paragraphs and chapters. Comprised largely of professional military men in a position to observe a number of operations in Alaska, considerable thought has been generated by this Center on the tactical, doctrinal, and organizational impacts of the environment. The mission of this Center requires it to be expert in assessing the impact of the environment on **materiel,** and this will therefore be covered in the greatest depth. The reader should keep in mind that the total influenced of this environment is made up of the interacting effects of a large number of factors not the least of which are:

a. Hostile climate.
b. Formidable terrain.
c. Extensive water and ice obstacles.
d. Acute trafficability problems.
e. Massive distances.

f. Poor lines of communication.
g. Low population densities.
h. A lack of shelter and developed resources.

That the total influence of the northern climate on warfare is severe, no one doubts; indeed, there is a tendency to overstate it. "No one can operate in those temperatures" is a statement our personnel often hear. It does no good to point out that we can and do operate effectively; most people remain convinced that, whatever a few "nuts" suffering from frostbite of the brain may be doing, no Army in its right mind would attempt military activites in the cold regions of the world.

Historical Importance of Climate to Military Operations

Despite the difficulties, there are armies that have and that can conduct large scale, sustained operations in cold environments; and there are a few elements of the U.S. Army trained in northern operations. To the troops so trained, cold climate is as valued an ally, as it is a deadly enemy to the uninitiated opponent. Thus it was in 1812, that the Russians, after losing every battle and their capital during the summer, used the winter to harry Napoleon's Army, the finest Europe had ever seen, without fighting a single pitched battle. Finally, after the invading Army was reduced by the cold to a mob of desperate refugees, the Russians administered a coup de grace at the crossing of the River Berezina, and the bones of 600,000 out of 650,000 Frenchmen who comprised that Army remained forever under the winter snow of northern Russian.

In their turn, during the first phase of their war with Finland in November and December of 1939, an overwhelming Russian Army was stopped in its tracks and sustained over 150,000 casualties when confronted by the highly skilled Finish Army, initially numbering only 127,000 men. This was a humiliation no professional Soviet soldier is ever likely to forget. How well they learned their lession was amply demonstrated upon the hapless Germans only a few years later as, returning from the brink of defeat in the summer of 1941, the Russians held the line before Lenningrad and Moscow that winter, turning the German offense south. Then in the final winter of the war, the Russians conducted massive offensive operations across the frozen plains of northeastern Europe.

It is reasonable to suppose that the Russian's present dispute with their Chinese neighbors in the heart of the Asian land mass is giving the current generation of both Armies a good indoctrination in the cold weather operations. There are still a few senior officers and NCOs left in our Army who were present at a demonstration by the last generation of the Chinese Army that they, too, were capable of mounting major offensive operations in the Korean subzero weather. We learned a lot in a hurry on that occasion, but there is room for concern that too little of that learning experience has survived our recent involvement with tropical warfare.

Why, in view of the remoteness and severity of the cold regions, does there appear to have been so much military activity in them? Wars, after all, are fought for reasons of national policy. What is there in cold regions that can be of so much interest to the policy makers?

Historically, the northern warfare operations in Europe were based on defending or attacking the large population centers in the subarctic or near subarctic regions there, such as Moscow, the southcoast of Finland, or Lenningrad. It is worth noticing that we do have NATO commitments to several northern European nations and the remainder, other than the Soviet Union itself, are satellite or hostages to Soviet idealogy. Our last venture in cold weather warfare in northern Korea was brought on by another of these commitments to our allies; a commitment we still honor with troops on the ground.

Other than doctrinaire recital of our alliances and hostilities in far northern theaters and consequent hypothetical requirements for our military presence there, can further reasons be adduced for our military interest? A glance at a map (figure 1.1) shows that appreciable area of some importance on the North American continent lies inside the various cold regions defined. So if our commitments to our allies are not sufficient reason, the defense of our own shores necessarily involves preparation for cold weather warfare.

Present Reasons for Military Interest

Political consideration may appear academic in the absence of any "real" reason for a threat. Evidently, enough agressors have judged sufficient real reasons do exist. The Germans thought preservation of their sources of Scandinanvian iron and manufacturing sufficient for their action in Norway in 1941. The Chinese and Russians consider the ancient border disputes of their Imperial predecessors sufficient reason today. How many border disputes remain unresolved around the northern regions? What resources are in these potentially contested regions? For that matter, what resources lie even in uncontested regions, since, when agression is cheap, and the results worth it, our opponents have never paused over a pretext for the action? Then, too, all of this discussion has been based on causes arising in the northern regions leading to wars there. What of the global conflict? Is Alaskan oil a worthwhile objective in conventional hostilities? The threat of nuclear hostilities justifies our establishment of the DEW lines bases. The presence of these bases across the shortest line of attack for strategic missiles ought to lead to some future thought on what is the shortest distance between major centers for any mode of attack that does not have to treat the arctic as an obstacle. Has strategic airlift reached this level yet? We are too often slaves of the equatorial projections in our school geography books, because man is basically a temperate creature and comfort oriented.

Unique Problems of Northern Warfare

There are, therefor, a variety of good reasons for the U.S. Army to have adequate competence in cold weather warfare. This section and chapter 2 will develop in some detail the direct operational factors of northern warfare that create these unique challenges.

Some significant military factors derive from the generally sparse population in cold regions. Though there are some large population centers, the region as a whole is thinly populated, and wilderness surrounds the population centers. Roads, railroads, airfields, and industrial facilities are few and their control critical to any large scale operations. While a dense population may be an obstacle to warfare, the almost total absence of one can also be a problem, with no source of civilian labor, no houses, hospitals, or communications other than what the Army can bring with it.

The surface and land forms of the northern regions present a number of natural obstacles to mobility, both surface and air, which will be thoroughly discussed. It will be seen that these combine with the vast distances between objectives and the paucity of prepared routes and facilities to create a major problem area.

Added to the difficulties of a unit attempting to overcome the problem of space and time is the extraordinary response of many ordinary items of materiel to this environment. It is of course, this Center's mission to evaluate responses and report the efficiency, or lack of it, of military materiel. It will be seen that in association with unprepared and untrained personnel, the climate may destroy the ability of equipment to operate more surely than any enemy could hope to.

Of particular importance to an Army such as ours, most of whose members are not native to cold regions, and which has most of its training centers well to the south, is the physiological and psychological effect of the cold, wind, darkness, and loneliness of the northern environment. It is these factors, more than any other, that makes this environment the ally of the soldier who knows and understands it and the deadly enemy of the one who does not. It is our hope that the reader, be he in a tactical unit, a planner, a logistician, or a materiel developer, will be interested and challenged by the experiences presented in the following chapters, give thought to how he would cope with them in his field; and, if some day his reflections become other than theoretical, we hope we will have made him a little better prepared.

CHAPTER 2. - DESCRIPTION OF THE COLD REGIONS OF THE NORTHERN HEMISPHERE

Overview of the Cold Regions Environment

It has been computed that 48 percent of the total land mass of the Northern Hemisphere could be classified as a cold region due to the influences and extent of air temperatures, snow cover, ice cover, or permanently frozen ground. Many methods have been used to classify the limits of the "cold regions". Each method used imaginary lines to delineate "cold regions" to support a given climatic or operational requirement. Some of these definitions in common usage (including those mentioned in section 1.1) define "cold regions" by the 32°F (0°C) isotherm of the coldest month, the 40th parallel as the southernmost limit, the 50° isotherm, as well as varying delineations by climatic categories. Additionally, there are almost as many definitions for terms such as polar, arctic, northern latitudes, etc., as there are insitutes of science interested in these environments.

For the purpose of the remainder of this text the 40th parallel will be considered the southern limit of the true cold regions of the Northern Hemisphere. Minor exceptions will be necessary as a result of climatic phenomena and terrain evaluation.

For example, major ocean currents may improve the climate of the adjacent land masses, accounting for the relatively mild climate of southeast Alaska and the northwest coast of Europe as well as the closeby island coutries such as Great Britain. The warm ocean currents can create the opposite effect when the Gulf Stream, for example, is warmer than usual; the low atmospheric pressure associated with the large mass of warm water forces the major storm tracks to the south bringing abnormally cold winters with much snow and ice to otherwise milder temperate areas. Thus large areas, which normally are included in the Temperate Zone may fall within the cold regions during winter periods.

Elevation also has a marked effect on the climate and the defining of the cold regions. Vertical temperature gradients up mountain slopes are much steeper than latitudinal temperature gradients at sea level. The worldwide lapse rate (change of temperature with elevation) varies from 1°C/100 meter for dry air to 0.5°C/100 meter for saturated air. The extension of the cold regions of the Northern Hemisphere south of the 40th parallel in southeast Asia and in the mountainous regions of North and South America is due mainly to the high elevation in these areas.

A high elevation climatic regime in the temperate zone has certain similarities and many anomalies when compared with a high latitude regime. Annual temperature extremes may be similar in both regimes, but the great difference of insolation has a marked influence on the diurnal temperature cycle. Snowfall volume and distribution patterns also are much different at higher elevations.

The degree to which the elements of the environment of the cold regions of the world affect military operations, and the mechanisms by which these effects are realized are discussed in other chapters of this text. The environmental elements which produce these effects on men and materiel, and which are considered the most important in the development and evaluation of military systems include the following:

a. Low air temperatures during the winter months with widely varying fluctuations.

b. Extensive coverage of the land mass with snow and ice.

c. Poor drainage and frequent mountain and coastal fogs during the summer months.

d. The frequency of ice fog around sources of moisture vapor during winter months.

e. Low-angle sun and wide variations, seasonally and dinurally, in the insolation.

f. Frequently severe disturbances in the electromagnetic environment.

g. Large areas and fluctuating depths of permanently frozen ground.

h. Loss of depth perception and the absence of light differences between the horizon and overcast sky (whiteout).

i. Prolonged hours of daylight and darkness.

j. Extensive water and fog obstacles.

Temperature

The basic concept of a cold region requires acceptance of the temperature as the dominant climatological factor. AR 70-38 defines climatic categories of cold by a 1-percent probability of occurrence of 6 continous hours with a maximum ambient temperature (4 to 6 feet above the ground) of -25°F (-32°C), -50°F (-46°C), and -70°F (-57°C) for the cold, intermediate cold, and extreme cold categories, respectively. (See table 1.1 and figure 1.2).

Each of the three temperature categories may be further subdivided into lowlands and highlands, because both latitude and elevation must be taken into consideration when comparing climatic information from one part of the cold region to another. The difference in range of average annual temperature (mean maximum for the highest month minus mean minimum for the lowest month) increases progressively as latitude increases from the intermediate cold zone to the extreme cold zone. Although seasonal temperature is lower at higher elevations than lower elevations within the same latitude, the annual temperature range is little affected by change in elevation. The seasonal change in temperature with latitude is most affected by the seasonal change in length of day and the available amount of solar radiation. At a given latitude, there if little change in these factors with respect to elevation. Climatically, the high mountain or alpine regions of the intermediate cold zone are not analogous to lowland regions of the cold and extreme cold regions. Any assumption that an alpine climate is analogous to an arctic or subarctic climate ignores the difference in stresses created by length of day, diurnal temperature cycles, and diurnal differences in both solar and longwave radiation.

The most distinctive and widely recognized element of the cold regions which is significant for operational purposes is the low air and surface temperatures during the long winters. Temperature is probably the most important weather consideration from an operational standpoint, since most military equipment must be designed to operate at low temperatures, including extremes which have a small probability of occurring more than a few hours in a typical month. In spite of the popular image of extreme cold in the cold regions, air temperature fluctuates widely from location to location and from time to time, both as a result of local atmospheric and terrain influences and as a function of migrating pressure fields and storms. The net radiation loss resulting from short hours or the absence of sunlight during the winter have produced temperatures in the subarctic regions as low as -90°F (-68°C). The high reflectivity of snow and ice surfaces, the drainage of dense cold air into the low levels, and the entrapment of cold air by a semipermanent temperature inversion occasionally combine to produce local concentrations of extreme low air temperatures.

For this reason, the coldest regions are those which can combine the effect of radiation loss at the surface with large masses of high pressure continental air. Such a combination maintains clear skies and intensifies an inversion of the temperature lapse rate at the lower levels of the atmosphere. The arctic inversion results from subsidence of dense stable air combined with radiational cooling from the surface of the ground or snow cover. These conditions prevail more frequently over the interior of the continental masses and the subarctic regions of Siberia, Alaska, and Canada.

Windchill

Windchill adds to operational problems in cold regions. Low air temperature accompanied by wind increases the cooling effect of the atmosphere which increases human discomfort. Siple and Passel developed a windchill formula which has become widely accepted as the most satisfactory measure of potential human discomfort in the cold regions.

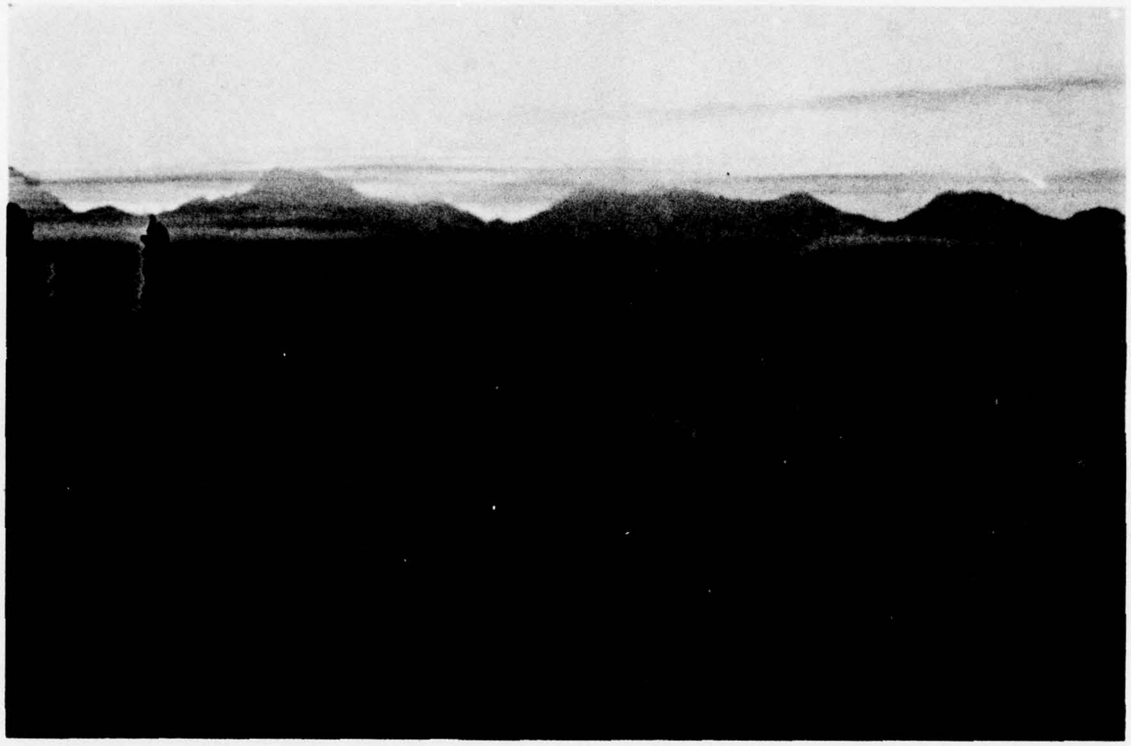
From experiments, it was determined that windchill values could be associated with a subjective sense of cold by the human body, but windchill has no meaning when used to indicate the cooling rate of inanimate objects since it does not include all avenues of heat transfer.

The United States Air Force prepared the windchill chart presented at table 2.1. This chart, in one form or another, is used by the Armed Forces in planning activities in cold regions.

WIND SPEED		COOLING POWER OF WIND EXPRESSED AS "EQUIVALENT CHILL TEMPERATURE"																				
KNOTS	MPH	TEMPERATURE (°F)																				
CALM	CALM	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	10	[illegible]	[illegible]	[illegible]	-10	[illegible]	[illegible]	-25	-30	-35	-40	-45	-50	-55	-60
		EQUIVALENT CHILL TEMPERATURE																				
3 - 6	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	-15	[illegible]	-25	-30	-35	-40	-45	-50	-55	-65	-70
7 - 10	10	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-25	-35	-40	-45	-50	-60	-65	-70	-75	-80	-80	-85
11 - 15	15	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-25	-30	-40	-45	-50	-60	-65	-70	-80	-85	-90	-100	-105	-110
16 - 19	20	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-25	-30	-35	-45	-50	-60	-65	-75	-80	-85	-95	-100	-110	-115	-120
20 - 23	25	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-30	-35	-45	-50	-60	-65	-75	-80	-90	-95	-105	-110	-120	-125	-135
24 - 28	30	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-25	-30	-40	-50	-55	-65	-70	-80	-85	-95	-100	-110	-115	-125	-130	-140
29 - 32	35	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-30	-35	-40	-50	-60	-65	-75	-80	-90	-100	-105	-115	-120	-130	-135	-140
33 - 36	40	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-30	-35	-45	-55	-60	-70	-75	-85	-95	-100	-110	-115	-125	-130	-140	-150
WINDS ABOVE 40 HAVE LITTLE ADDITIONAL EFFECT.		LITTLE DANGER					INCREASING DANGER (Flesh may freeze within 1 min.)						GREAT DANGER (Flesh may freeze within 30 seconds)									
		DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSONS																				

TABLE 2.1 — WINDCHILL INDEX EXPRESSED AS EQUIVALENT CHILL TEMPERATURE

Temperature Inversion



Frequent and persistent temperature inversions are a characteristic of cold regions. Normally, the temperature of the lower level of the atmosphere decreases with height. The lighter warm air near the ground rises through the dense cooler air, setting up convectional processes which induce a thorough mixing of the air. When the ground surface is chilled by radiation heat losses or evaporative cooling, or when there is in flow or intrusion of a low temperature layer of air near the surface, and arctic temperature inversion develops.

The cool air in contact with the ground, being heavier and denser than the warm air above, establishes a stagnant condition which can prevail for days. With radiation or convection warming of the ground surface at a minimum, the air temperature may be lowered to the dewpoint and fog may form. Radiation fogs formed during the onset of cold spells, are generally of short duration because the air soon becomes very dry. These fogs consist of supercooled water droplets until the air temperature goes below the spontaneous freezing point for water droplets (approximately -40°F (-40°C)); the fog then becomes ice crystal fog, or simply "ice fog".

Ice Fog

One of the important phenomena of cold regions which results from low air temperatures, is the occurrence of ice fog in inhabited areas at temperatures of about -30°F (-34°C) and below. Near this temperature, water passes directly from a vapor state to a solid phase and freezes spontaneously on any available airborne nuclei. The absolute moisture content of saturated air at such low temperatures is so low that the introduction of any moisture from humans or machines brings about super-saturation immediately. Vapor from organic activity and from the burning of hydrocarbon fuels provide condensation nuclei for ice fog crystals that vary from 2 microns to 30 microns in diameter according to the temperature at which formed. Ice fog layers extend from the surface up to 900 feet or more above the surface, lowering ground level visibility to almost zero. In densely populated areas, the fog contains contaminants from automobile engines and other sources. This subject is further treated in Section 3.6.

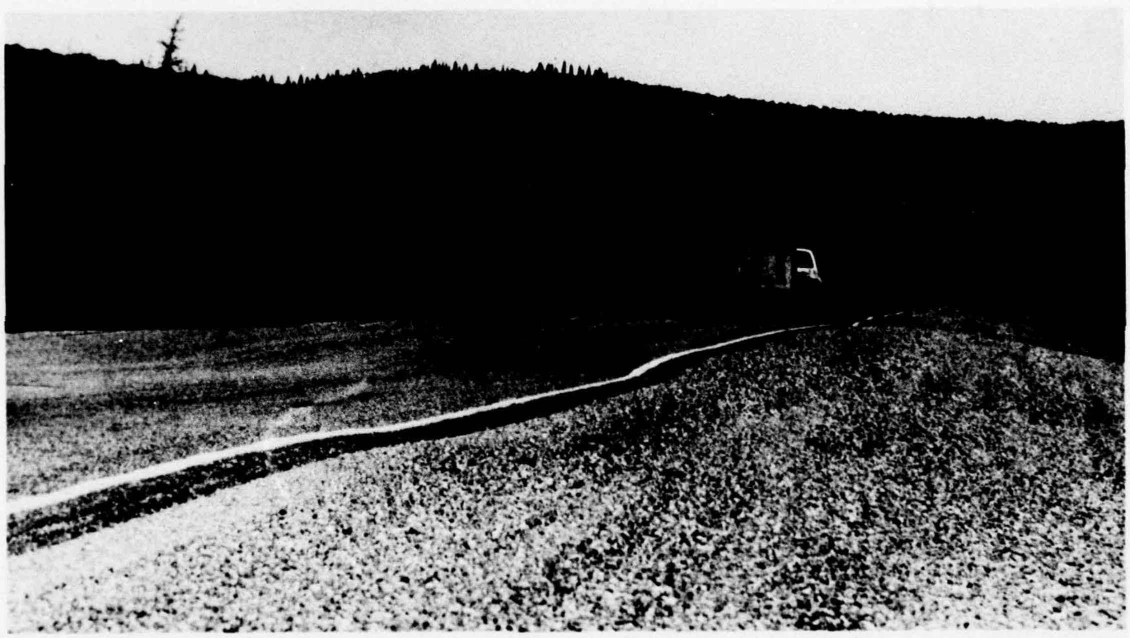
The temperature inversions which occur during cold spells begin at ground level, and among the large built-up areas of the cold regions are among the strongest and most persistent known. The density of ice fog near built-up areas will be three times or more greater than in outlying areas. The inversions which occur during -30°F (-34°C) and lower temperatures in the city of Fairbanks, Alaska, for example, are among the strongest and most persistent on earth; and can be three times stronger than the inversion layer (and resulting pollutants) over Los Angeles.

The threshold temperature of ice fog formation resulting from weapons firing has been measured to be -31°F (-35°C) under calm air conditions.

Whiteout

If the ground is warmed by solar radiation during an inversion without sufficient energy being developed to establish normal convective processes, the inversion may lift a few tens of feet above the ground. If the ground is covered by snow, diffused sunlight penetrating the overcast and reflected between the snow surface and any of the types of fog or cloud base produces the classic whiteout. Under whiteout conditions, perception is lost and navigation becomes extremely difficult. Pilots and vehicle operators report that it causes fatigue and is a serious navigational safety hazard.

Permafrost

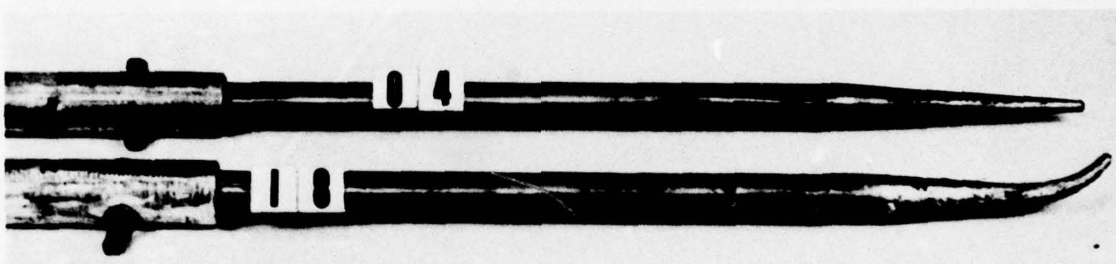


The distribution and depth of permafrost affects the stability of the top level of the ground surface.

Illustration of instability caused by permafrost can be seen in many Alaskan roads.

Another operationally important feature of the cold regions is the existence of permanently frozen ground. As a result of the net annual radiation loss from the ground surface, about one-half of the land area of Alaska, Canada, and the USSR are underlain by permafrost. The distribution of permafrost varies from discontinuous in the southern portions of the cold regions to continuous in the north. In the discontinuous zone, permafrost exists in combination with areas and layers of unfrozen ground. The ground above per-

Poles of the XM133 Hand Emplaced Mine Field Marking System are driven into frozen earth.



Poles of the XM133 Hand Emplaced Mine Field Marking System are photographed after being driven into frozen earth. Illustrating a problem encountered with this item in the cold regions environment.

mafrost which thaws in summer and refreezes in winter varies in thickness from near zero to approximately 10 feet, and the thickness of permafrost varies from a few inches at the southern limit to up to 1,600 feet in central Siberia. The type and texture of the soil, the topographic features of the area, the amounts of precipitation as well as the temperature of the air, affect the distribution and depth of permafrost, which in turn affects many aspects of the drainage, vegetation, and stability of the top level of the ground surface. The quantity of water entrapped in frozen layers is a major influence on the stability of buildings and highways constructed in the cold regions.

Although the affects of the snow and ice cover must be considered, trafficability in cold regions is best in the winter and worst during the remaining three seasons of breakup, summer, and freezeup. Where low temperatures are the nemesis in the winter, the vast expanses of water, poorly drained soils and permafrost combine to make mobility the military's most serious problem on a year-round basis.

Arctic Tundra

December sun at high noon at Fort Greely.

The particular combination of climatic and terrain features found in the cold regions produce a unique grassland biochore formation which is limited to very cold climates having ample available moisture and often saturated soils. The grassy tundra of the arctic regions flourishes under a regime of long summer days during which time the ground ice melts only in a shallow surface layer. The ground beneath (permafrost) remains impermeable and melt water cannot readily escape. Consequently, in summer a marshy condition prevails for at least a short time over wide areas. Humus develops in a well-developed layer.

Plants of the arctic tundra plains are low and mostly herbaceous, although dwarf willow occurs in places. Sedges, grasses, mosses, and lichens dominate the tundra in a low layer. Typical species are ridge sedge, arctic meadow grass, cottongrasses, and snow lichen. There are also many species which flower brightly in summer, most of which are perennials. Considerable variations in composition of the tundra are seen and range from wet to well-drained habitats. One form of tundra consists of sturdy hummocks of plants with low, water-covered ground between (muskeg). In the regions of arctic tundra will also be found areas of arctic scrub vegetation composed of willows and birches. Size of plants is in part limited by the mechanical rupture of roots during freeze and thaw of the surface layer of soil, producing shallow-rooted plants. In winter, drying winds and mechanical abrasion by wind driven snow tend to reduce any portions of a plant that project above the snow.

In all latitudes, where the elevation is sufficiently high, an alpine tundra is developed above the limit of tree growth and below the vegetation free zone of barren rock and perpetual snow. Alpine tundra resembles arctic tundra in many physical respects.

Arctic Fell Field

An arctic equivalent of the dry desert is found in the extremely cold tundra and icecap climates. The arctic fell field consists of rocky ground surfaces, produced by intense frost shattering and having only small patches of fine textured mineral soil. Vegetation is very sparse and consists mostly of lichens, mosses, and a few small shrubs. Arctic fell fields can be found as far north as the extreme limits of land, namely up to 80° N latitude and southward to ice free parts of Antarctica. Soil forming processes consist of little more than rock disintegration by frost action, manifested in the formation of stone polygons in which finer particles are sorted from the coarse into patches.

The Environment of Fort Greely

Fort Greely, Alaska, is approximately 670,000-acre military reservation which houses the U.S. Army Cold Regions Test Center (CRTC), and the U.S. Army Northern Warfare Training Center (NWTC). It is located at latitude 64°00'N and longitude 145°44'W. Maps showing the relative location of Fort Greely and the extent of the military reservation are found at figures 2.1 and 2.2

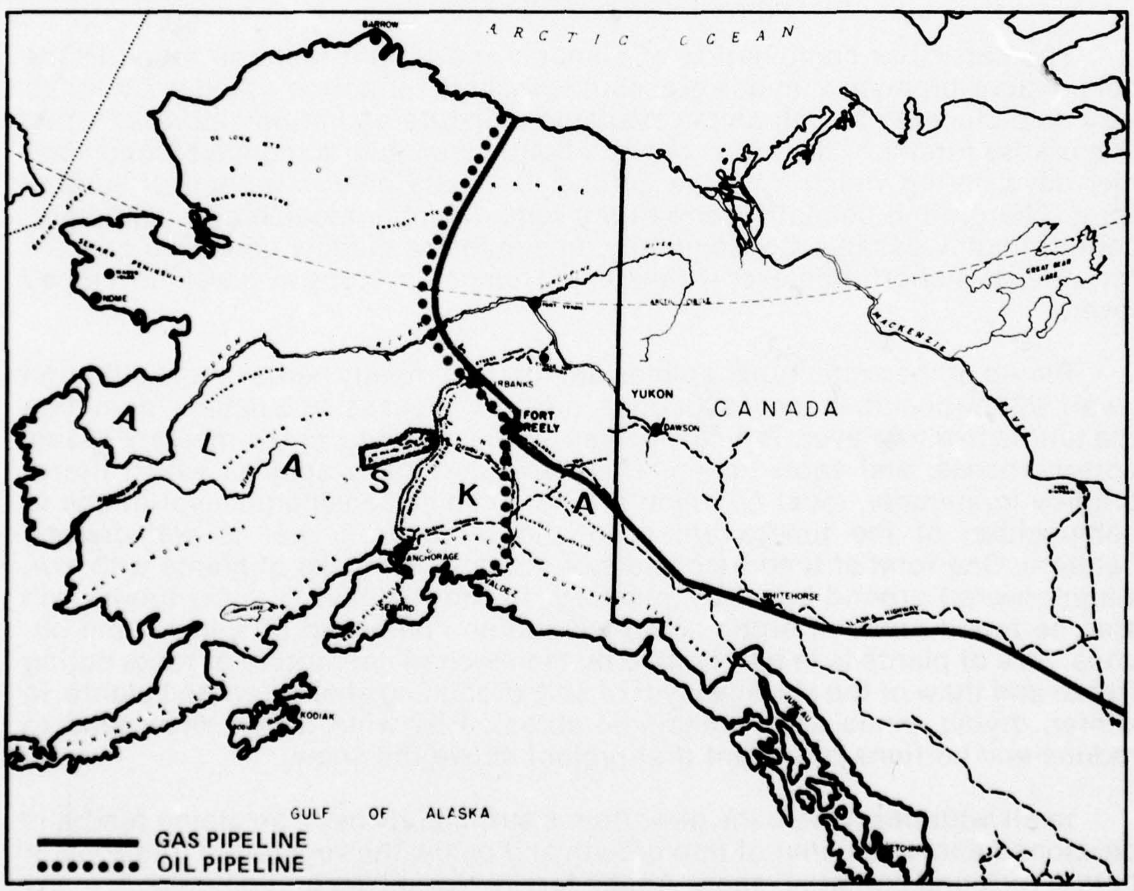
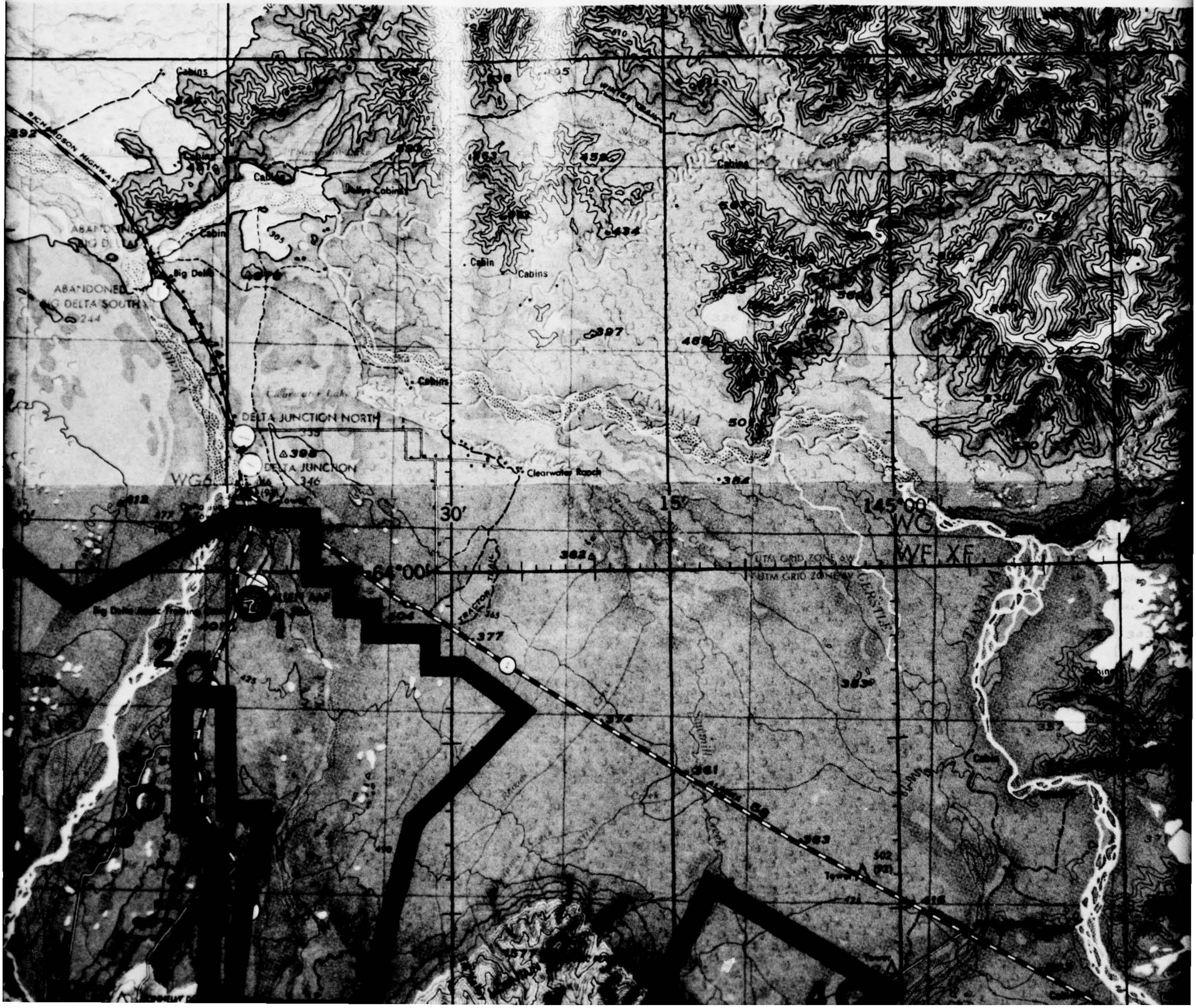


Figure 2.1.–Map of Alaska Showing Location of Fort Greely


Cabins
WINTER TRAIL
WINTER TRAIL
FORT GREELY
CREEK
481
30
15
915
1143

f Fort Greely Reservation



Fort Greely, located near the junction of the Alaskan and Richardson Highways in central Alaska, is about 100 miles southeast of Fairbanks and 340 miles north of Anchorage. The small community of Delta Junction is located 5 miles from the post. It is located on one side of a narrow valley near the junction of two major Alaskan rivers. The Brooks Mountain Range to the north and the Alaskan Range to the south prevent the moderating effect on temperature of the Arctic and Pacific Oceans from playing a major role in the local climate.

Cold weather at Fort Greely, as in most subarctic areas, is a transient phenomenon associated with clear skies and little or no winds. Periods of cold and extreme cold weather lasting from several hours to two weeks are interrupted by the onset of winds and associated warmer weather.

Fort Greely has a dry climate. The average annual precipitation of the main post is only 38.7 inches of snow, less than 2.5 inches of water equivalent, which combined with summer rains, adds up to only 11.6 inches of water in an average year. However, the precipitation rate varies greatly within and in the vicinity of this large reservation. Although the reservation elevation varies from 1,150 to 5,993 feet within a 60-mile radius of main post are elevations ranging from 1,000 to 13,832 feet. Snow cover varies greatly by month, elevation and locality and each sheltered valley can be different. Table 2.2 illustrates this point.

TABLE 2.2–SNOWFALL WITHIN THE TANANA VALLEY

Elevation (ft)	Annual Precipitation (in)	Percent Snowfall
1,000-1,500	10 to 12	25
4,000	40	50
9,000	100	100

Short, cool summers and long, very cold winters identify the climate of Fort Greely as subarctic in type - a type common to much of the high latitude boreal zone of northern North America, northern Eurasia, and other cold regions. Temperature extremes from 92°F (34°C) to -70°F (-57°C) (-75°F (-60°C) unofficially recorded) have been recorded with 85°F (29°C) to -60°F (-51°C) representing a more typical annual temperature spread.

A climatology chart of the official weather station located on the main post of Fort Greely is shown at table 2.3 (see page 24). Because of the temperature inversion wintertime minimum temperatures are strongly dependent on elevation and terrain conditions, as a result, lower temperatures and longer durations of lower temperatures are encountered on the CRTC ranges and outlying test sites than on main post. Although colder areas exist than Fort Greely, no area that is within the United States, accessible, and available to the U.S. Army exists for this purpose. The mean temperature for the main post, Fort Greely's four warmer months is 54°F (12°C) (mean minimums for these same months is 43°F (6°C)), while the mean temperature for the coldest month (January) is -8°F (-22°C).The mean annual temperature for the past 29 years is 26.8°F (-3°C). Depending primarily on the absence of winds which effect main post, temperatures in the outlying test sites can be 10° to 30° colder than the main post. The Bolio Lake Test Site, for example has averaged 32.4 test days (minimum of 6-hour day) below -40°F (-40°C) and an average annual low of -59.2°F (-51°C). Wintertime temperatures are strongly dependent on elevation, terrain conditions and prevailing winds. Lower elevations and enclosed valleys are the coldest areas. Located near 64° North latitude, very little solar radiation is received during much of the winter, and snow cover which normally persists from November through March reflects a large portion of the radiation received. Since there is a net loss of heat from the ground throughout most of the winter, the temperature trend is downward until approximately mid-February. This heat loss and lack of cloud cover in the dry winter air combine to produce temperature inversion conditions during most of the winter. The numerous valleys located south and west of the main post tend to further concentrate this cold air, as it flows downslope and settles at the valley floor. Some of these valleys are closed at both ends and form natural cold basins. Others allow the cold air to drain out and downward into the bed of the Delta River where the CRTC firing ranges are located. As a consequence of the prevailing winds blowing on the Fort Greely main post approximately 50 percent of the days during the winter months, the relatively calm conditions of Fairbanks, Alaska, provides that location with from 25 to 152 percent more test days of -25°F (-32°C) and lower than Fort Greely proper. However, the Bolio Lake Test Site compares favorably with Fairbanks in -25°F (-32°C) temperatures, and experiences approximately 48 percent more days with -50°F (-46°C) and 27 percent more days with -40°F (-40°C) minimums than Fairbanks.

Generalizing, within the Fort Greely reservation, 0°F (-18°C) will be encountered by mid-October, -25°F (-32°C) occurs from 15 November to 15 February and the lows are encountered between 15 December and 15 February. Temperatures as low as -40°F (-40°C) have been experienced from late October to early April, but the effects of increased solar radiation and the longer days seriously limit this possibility. A summary of the average number of useable test days by temperature for the period 1961-74 for three typical test sites is shown in table 2.4

CLIMATOLOGY CHART
Fort Greely, Alaska

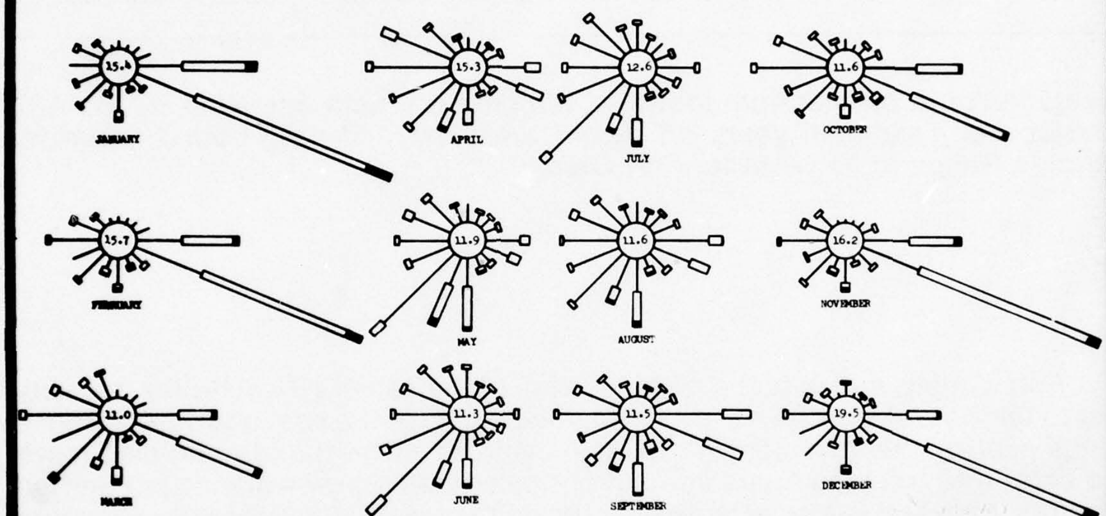
LATITUDE: 64° 00' NORTH

LONGITUDE: 145° 44' WEST

TEMPERATURE 24 Years of Records (Degrees F)						
MONTH	MEAN	MAXIMUM	MINIMUM	HIGHEST	LOWEST	YEARS OF RECORDS
JAN	-3.8	3.7	-11.2	48	-63	24
FEB	8.7	11.7	-6.6	51	-60	24
MAR	10.7	21.4	-2.5	52	-48	24
APR	28.6	38.5	18.4	71	-37	24
MAY	45.3	54.6	36.0	90	-1	25
JUN	56.6	66.3	46.5	88	32	23
JUL	59.5	68.6	50.1	91	35	23
AUG	55.0	64.3	45.6	86	22	24
SEP	44.3	52.5	36.0	77	7	24
OCT	24.9	31.9	17.8	62	-24	23
NOV	5.8	13.3	-1.4	50	-46	23
DEC	-5.3	2.8	-12.5	48	-62	23
ANNUAL	27.0	35.8	18.0	91	-63	24

CEILING — VISIBILITY (Percent of Time)					
MONTH	LESS THAN 500 &/OR 1 MILE	LESS THAN 1000 &/OR 3 MILES	LESS THAN 2000 &/OR 7 MILES	2000 & OVER 7 MILES	YEARS OF RECORDS
JAN	3.8	8.0	12.3	75.7	20
FEB	2.5	6.9	9.6	81.0	20
MAR	1.8	6.1	11.3	80.8	20
APR	0.4	3.4	6.3	89.8	20
MAY	0.3	1.4	4.2	94.0	20
JUN	0.1	0.7	3.6	95.6	20
JUL	0.2	2.1	6.1	91.6	20
AUG	0.6	2.3	6.2	90.9	20
SEP	1.8	6.0	9.9	82.3	20
OCT	4.4	11.4	16.5	67.8	20
NOV	2.4	8.2	13.5	76.0	20
DEC	4.9	8.8	13.8	72.4	20
ANNUAL	1.9	5.4	9.4	83.2	20

SKY CONDITIONS (Percent of time)						
MONTH	CLEAR	SCATTERED	BROKEN	OVERCAST	OBSCURED	YEARS OF RECORDS
JAN	26.0	17.3	17.0	31.6	8.1	20
FEB	25.0	16.7	17.8	32.8	7.6	20
MAR	25.1	18.5	19.5	32.9	4.0	20
APR	17.4	20.7	25.2	34.0	2.7	20
MAY	10.8	21.0	30.8	36.8	0.7	20
JUN	5.7	21.1	35.8	37.4	*	20
JUL	6.6	18.8	31.0	43.0	0.4	20
AUG	7.9	19.0	28.7	43.2	1.1	20
SEP	10.5	15.5	23.0	48.0	2.8	20
OCT	12.7	14.8	17.9	45.9	8.8	21
NOV	22.6	16.6	17.0	35.4	8.4	20
DEC	22.2	17.0	18.1	34.2	8.5	21
ANNUAL	16.0	18.1	23.5	37.9	4.4	20



PRECIPITATION
(Percentage of Occurrence)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
RAIN	*	*	*	0.6	5.0	8.5	10.7	10.8	9.3	0.8	0.1	0.1
RAIN SHOWERS	0	0	0.2	0	1.4	2.4	2.7	1.3	0.3	0	0	0
FREEZING RAIN	0.1	0	0	0	0.1	0	0	*	*	*	*	*
SNOW	17.0	19.0	16.9	10.5	2.3	0.1	0	*	3.9	19.6	20.5	19.3
SNOW SHOWERS	0.1	*	0.1	0.5	0.9	0	0	0	0.1	0.1	0.1	0.1
SNOW PELLETS	0	0	0	0.1	*	0	0	0	*	*	*	0.1
SNOW GRAINS	0.1	0.1	0.1	*	*	0	0	0	0	0.1	0	0.1
DRIZZLE	*	0.1	0.1	*	0.3	0.3	0.6	0.6	1.7	0.3	0	*
FREEZING DRIZZLE	0.1	*	0	*	0	0	0	0	*	0.6	0.3	0.1
ICE CRYSTALS	1.1	0.7	0.2	*	0	0	0	0	0	0.1	0.5	1.5
HAIL	0	0	0	0	*	*	*	*	0	0	0	0
THUNDER	0	0	0	0	*	0.3	0.3	0.1	0	0	0	0
YEARS OF RECORDS	20	20	20	20	20	20	20	20	20	21	20	21

* Less than 0.05 percent

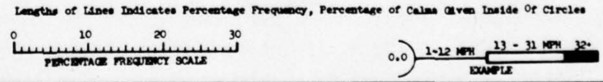
AVERAGE MONTHLY AMOUNT IN INCHES

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SNOWFALL	6.2	1.6	5.5	3.0	0.5	T	0	T	0.9	7.1	6.4	5.9
PRECIPITATION	.37	.50	.37	.31	.90	2.35	2.70	2.00	1.23	.55	.43	.48
YEARS OF RECORDS	24	24	24	24	24	24	24	23	23	23	24	24

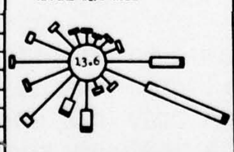
AVERAGE ANNUAL SNOWFALL 37.1 | AVERAGE ANNUAL PRECIPITATION 12.19

WIND ROSE LEGEND

Lengths of Lines Indicates Percentage Frequency, Percentage of Calms Given Inside Of Circles



ANNUAL WIND ROSE



DATA PREPARED BY: U. S. ARMY METEOROLOGICAL TEAM (RDT&E SPT) ALASKA FORT GREELY, ALASKA

CHART PREPARED BY: WEATHER BUREAU OFFICE FORT HUACHUCA, ARIZONA DECEMBER 1968

OBSTRUCTIONS TO VISION

Average monthly percentage of occurrence

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
FOG	3.2	3.6	3.4	2.5	1.3	0.7	1.4	1.5	3.8	7.3	4.9	4.4	3.2
GROUND FOG	0.3	0.2	*	*	*	0.2	0.1	0.1	0.4	0.2	0.2	0.2	0.2
ICE FOG	5.3	3.9	0.3	*	0	0	0	0	0.1	*	1.1	6.0	1.4
BLOWING SNOW	1.2	0.3	0.1	0.1	*	*	0	0	0	0.1	0.5	0.7	0.3
SMOKE	*	0.1	0	0	0	0.6	1.0	0.9	*	*	0.1	0.2	0.2
YEARS OF RECORDS	20	20	20	20	20	20	20	20	20	21	21	20	20

* Less than 0.05 percent

WIND
(21 years of records)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANNUAL
AVERAGE SPEED	12.7	11.6	8.7	8.5	9.0	7.8	7.1	7.8	8.6	9.2	10.5	9.9	9.3
EXTREME SPEED	75	104	96	67	82	63	79	93	75	86	82	98	104
DIRECTION	ESE	S	E	SSW	SSE	SSW	S	S	NE	SE	SE	S	S

TABLE 2.3.--CLIMATOLOGY CHART

TABLE 2.4--TEMPERATURE SUMMARY
Available Test Days per Site*

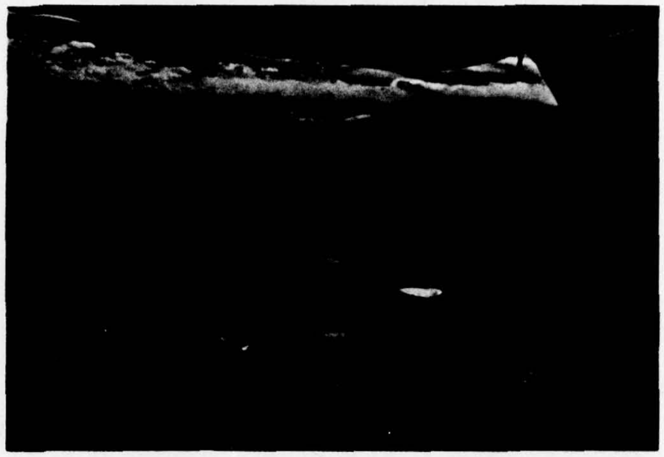
Temperature	Fort Greely Proper	Georgia Range (Delta River)	Bolio Lake
-25°F (-32°C) or below	26.9	37.9	49.1
-40°F (-40°C) or below	7.7	24.7	32.4
Average Annual Low:	-55°F (-46°C)	-61.4°F (-52°C)	-59.2°F (-51°C)

*Includes both official and unofficial temperature data compiled by the ASL Alaska Met Team. All years on record are used and vary from 7 years for Georgia Range to 29 years for Fort Greely.

Fort Greely, and in fact a major portion of the Tanana River Valley, are subject to periodic strong winds from either the south or the east-southeast. These winds destroy the inversion by mixing in warmer air from aloft, and also move the snow into forested areas and out of open areas. Snow which is not shifted about by the wind is also affected, as the wind greatly accelerates evaporation and heat transfer processes which produce a new layer consisting of hard, dense lenses up to several meters in diameter embedded in masses of soft, weak, low-density snow. This condition is typical of arctic snow, and its existence at Fort Greely is quite useful in that it is available for test purposes. The snow found in wooded and other areas sheltered from the wind are typical of the soft dry subarctic snow.

Fort Greely is in a discontinuous permafrost zone, and the permafrost is within 6 to 12 inches of the surface in many areas. The long summer days allow the ground ice (permafrost) to melt only in a shallow surface layer, creating marshy conditions that prevail for a relatively short time over wide areas. During this melting period, the ground beneath the surface remains impermeable and the melt water cannot readily escape. A grassland biochore develops on the saturated soil and its development is limited by the very cold climate. Humus develops in a well developed layer under these conditions. Considerable variations in composition of the tundra are seen and range from wet to well drained habitats. Dense spruce forests (Taiga) cover much of the areas overlying the permafrost.

Four separate periods of glaciation have reduced the area in which Fort Greely is situated into a pitted outwash plain. Literally thousands of kettles (small depressions, most with ponds) are present. These range in size from a few dozen meters to scores of acres. Most of the areas around the kettles are marshy and hinder man/machine mobility. Some of the kettles may be fed by underground springs caused by percolation or melting of the permafrost.



The ground beneath the relatively thin veneer of humus where there is no permafrost consists chiefly of glacial till (unstratified drift). In the summer months this material is readily exposed on man-made clearings and roads. Fine dust and pitting materials are present and often prove detrimental to the longevity of vehicles. In the winter the till freezes into a conglomerate that resists most known mechanical forces.

The climatology and topography of the Fort Greely area have been exhaustively described in several publications (ref 16, 20, 29, 34, 41) and the characteristics and engineering influences of the cold regions environment are covered in detail in the new DARCOM Engineer Design Handbooks, Environmental Series (see section 4.3).

For purposes of evaluating military equipment, most test operations are scheduled for and accomplished in specific temperature, wind, or terrain requirements. The frequency of occurrence of specific air temperature levels below the freezing point at selected CRTC test sites is presented at table 2.5. The frequency of occurrence of wind levels at the same test sites is presented at table 2.6. The light data is at figure 2.1.

TABLE 2.5.–FREQUENCY OF OCCURANCE OF AIR TEMPERATURES

Below 30ºF (-1ºC) at Selected Sites During Cold Weather Test Season

1. Fort Greely - Main Post

Temperature	January (7)*		February (7)		March (7)		November (6)		December (6)	
Range °F (°C)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
30 to 21 (-1 to -6)	1.7	11.1	9.6	5.9	26.3	5.1	5.8	10.6	7.7	12.3
20 to 11 (-7 to -12)	6.3	10.8	15.0	5.7	29.4	4.8	15.3	12.1	11.3	10.6
10 to 1 (-12 to -17)	14.3	8.2	19.6	6.7	28.3	4.3	22.	8.4	15.3	9.2
0 to -9 (18 to -9)	17.7	6.3	21.6	4.9	22.6	3.9	18.7	6.2	18.7	6.9
-10 to -19 (-24 to -28)	17.9	6.7	19.1	4.2	14.9	3.0	12.	4.4	17.2	5.7
-20 to -29 (-29 to -34)	18.1	5.3	13.7	4.4	9.6	2.8	5.5	3.6	10.3	6.6
-30 to -39 (-34 to -39)	16.6	4.6	8.4	4.3	4.4	3.8	2.8	7.6	5.2	4.5
-40 to -49 (-40 to -45)	13.	6.2	4.0	5.2	0.9	5.0	0.2	12.0	2.7	8.4
-50 to -59 (-46 to -51)	4.6	8.3	1.0	3.3					0.5	10.0
-60 to -69 (-51 to -56)			0.1	1.0						
-70 to -79 (-57 to -62)										

*Number of years in record.

TABLE 2.5.– (continued)

2. Bolio Lake Test Site

Temperature	January (14)*		February (14)		March (14)		November (6)		December (6)	
Range °F (°C)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
30 to 21 (-1 to -6)	6.1	6.1	11.4	4.7	14.7	4.5	7.5	5.4	9.6	5.2
20 to 11 (-7 to -12)	7.9	6.7	16.6	5.0	18.1	4.3	13.2	7.2	13.7	6.7
10 to 1 (-12 to -17)	12.1	7.3	21.4	4.9	20.4	3.8	19.3	7.0	16.4	5.6
0 to -9 (18 to -9)	16.5	6.4	22.4	4.8	19.4	3.4	18.9	4.6	17.2	6.8
-10 to -19 (-24 to -28)	17.1	5.7	21.4	4.5	16.4	3.4	13.8	5.2	15.4	6.1
-20 to -29 (-29 to -34)	15.1	5.5	16.4	3.7	12.4	3.2	9.4	5.5	11.0	6.2
-30 to -39 (-34 to -39)	13.4	6.3	10.2	4.1	7.6	3.9	6.1	8.4	7.3	8.4
-40 to -49 (-40 to -45)	10.1	8.0	4.6	6.5	2.8	5.2	2.0	10.1	4.4	10.2
-50 to -59 (-46 to -51)	11.2	9.8	1.0	7.1	0.1	8.5			2.4	15.0
-60 to -69 (-51 to -56)	3.2	10.1							0.5	8.4
-70 to -79 (-57 to -62)										

*Number of years in record.

TABLE 2.5.–(continued)

3. Georgia Indirect Fire Range

Temperature Range °F (°C)	January (6)*		February (6)		March (6)		November (6)		December (6)	
	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
30 to 21 (-1 to -6)	3.8	11.1	11.3	4.8	17.2	5.1	6.7	6.7	6.7	8.3
20 to 11 (-7 to -12)	7.7	7.9	16.5	5.7	17.7	4.3	18.3	9.7	12.0	10.8
10 to 1 (-12 to -17)	13.7	9.8	19.2	4.9	18.0	4.7	24.	7.4	16.0	8.9
0 to -9 (18 to -9)	17.0	6.7	17.5	5.1	20.7	3.6	20.7	4.5	19.5	5.3
-10 to -19 (-24 to -28)	15.0	8.4	1.5	5.3	19.7	3.3	16.5	4.0	20.5	5.4
-20 to -29 (-29 to -34)	13.2	4.0	12.7	3.3	15.8	2.8	12.2	4.3	14.7	3.9
-30 to -39 (-34 to -39)	12.2	4.4	9.5	3.0	9.3	3.2	9.7	4.7	10.3	3.6
-40 to -49 (-40 to -45)	11.3	3.8	4.7	4.7	2.5	3.7	5.3	4.8	7.5	4.1
-50 to -59 (-46 to -51)	7.7	5.7	0.8	4.6	0.3	4.0	1.0	11.2	5.5	5.3
-60 to -69 (-51 to -56)	2.0	8.4					0.2	1.0	2.8	5.9
-70 to -79 (-57 to -62)	0.3	8.5							0.5	11.0

*Number of years in record.

TABLE 2.5.–(continued)

4. Texas Range

Temperature Range °F (°C)	January (8)* Mean No. of Periods	January (8)* Mean Duration (Hrs)	February (7) Mean No. of Periods	February (7) Mean Duration (Hrs)	March (5) Mean No. of Periods	March (5) Mean Duration (Hrs)	November (5) Mean No. of Periods	November (5) Mean Duration (Hrs)	December (4) Mean No. of Periods	December (4) Mean Duration (Hrs)
30 to 21 (-1 to -6)	7.0	5.8	8.9	4.7	20.0	5.1	9.4	4.9	5.5	5.7
20 to 11 (-7 to -12)	9.5	5.0	13.1	4.2	22.0	3.4	21.0	5.0	10.5	8.7
10 to 1 (-12 to -17)	12.8	5.6	20.3	5.3	24.2	4.0	29.4	5.0	12.2	6.7
0 to -9 (18 to -9)	17.0	5.6	26.7	4.9	24.8	3.7	30.0	4.9	15.2	7.9
-10 to -19 (-24 to -28)	16.0	6.9	26.7	4.3	24.2	4.0	20.4	3.8	14.8	5.2
-20 to -29 (-29 to -34)	14.2	5.4	19.6	4.5	18.0	3.4	8.2	4.6	15.5	3.9
-30 to -39 (-34 to -39)	16.4	4.9	9.3	4.4	9.6	4.3	0.8	10.5	15.5	6.6
-40 to -49 (-40 to -45)	11.6	6.4	2.9	5.3	2.2	5.5			7.5	8.0
-50 to -59 (-46 to -51)	2.9	4.6	0.1	2.0					3.2	2.6
-60 to -69 (-51 to -56)									1.5	4.2
-70 to -79 (-57 to -62)										

*Number of years in record.

TABLE 2.6.– FREQUENCY OF OCCURRENCE OF WINDS AT SELECTED SITES DURING COLD TEST SEASON

1. Fort Greely - Main Post

Wind	January (7)*		February (7)		March (7)		November (6)		December (6)	
Speed Kts (m/s)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
Calm	27.3	14.6	29.4	10.4	38.7	6.7	30.8	10.3	28.8	10.9
1 to 5 (0.5 to 2.5)	43.6	3.5	47.4	3.6	65.1	4.0	52.3	3.2	50.7	2.5
6 to 10 (3 to 5)	28.9	3.6	37.7	3.18	40.7	3.0	45.3	3.2	47.8	3.2
11 to 15 (5.5 to 7.5)	13.0	2.4	23.0	2.14	16.7	1.9	29.2	2.1	29.7	2.4
16 to 20 (8 to 10.5)	4.1	1.6	13.4	1.4	5.7	2.1	13.7	1.8	14.2	1.6
21 to 25 (11 to 13)	1.7	1.1	4.7	1.2	2.1	1.6	4.3	1.3	5.8	1.4
26 to 30 (13.5 to 15.5)	0.9	1.2	1.6	1.0	0.7	1.2	2.2	1.3	2.2	1.1
31 to 35 (16 to 18)	0.1	4.0	0.4	1.0	0.4	1.3	0.8	1.0		
36 to 40 (18.5 to 20.5)	0.1	1.0	0.3	2.5			0.3	1.0	0.2	1.0
41 to 45 (21 to 23)			0.1	2.0			0.2	1.0	0.2	2.0
46 to 50 (23.5 to 26)										

*Number of years in record.

TABLE 2.4.– (continued)

5. Black Rapids Training Area

Temperature	January (5)*		February (4)		March (5)		November (3)		December (5)	
Range °F (°C)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
30 to 21 (-1 to -6)	6.8	5.6	23.2	5.6	23.4	6.1	18.3	6.2	22.8	5.5
20 to 11 (-7 to -12)	10.2	4.6	21.0	3.9	19.2	4.4	25.0	5.8	18.2	4.2
10 to 1 (-12 to -17)	17.2	5.5	20.8	4.4	18.8	5.1	21.7	8.0	16.2	6.3
0 to -9 (18 to -9)	21.8	5.1	23.0	4.4	18.4	5.2	12.0	11.0	14.6	6.6
-10 to -19 (-24 to -28)	21.1	5.5	19.8	5.3	11.8	4.9	6.3	10.9	8.6	7.1
-20 to -29 (-29 to -34)	21.0	5.6	9.8	4.6	4.2	5.2	2.3	7.6	3.6	9.5
-30 to -39 (-34 to -39)	13.8	9.6	2.8	5.1					0.8	17.2
-40 to -49 (-40 to -45)	4.6	5.0								
-50 to -59 (-46 to -51)	0.6	1.0								
-60 to -69 (-51 to -56)										
-70 to -79 (-57 to -62)										

*Number of years in record.

TABLE 2.6.– (continued)

2. Bolio Lake Test Site

Wind Speed Kts (m/s)	January (14)* Mean No. of Periods	January (14)* Mean Duration (Hrs)	February (14) Mean No. of Periods	February (14) Mean Duration (Hrs)	March (14) Mean No. of Periods	March (14) Mean Duration (Hrs)	November (14) Mean No. of Periods	November (14) Mean Duration (Hrs)	December (14) Mean No. of Periods	December (14) Mean Duration (Hrs)
Calm	13.8	33.3	13.6	25.5	25.5	17.5	14.0	14.0	19.3	25.1
1 to 5 (0.5 to 2.5)	19.6	3.1	19.6	3.3	32.2	3.4	18.0	3.4	26.5	3.3
6 to 10 (3 to 5)	9.9	2.2	13.9	1.9	24.8	2.3	10.1	2.7	17.1	1.9
11 to 15 (5.5 to 7.5)	6.1	1.6	8.4	1.7	12.7	2.0	5.3	1.7	9.3	1.6
16 to 20 (8 to 10.5)	3.1	2.0	6.8	1.8	9.4	2.4	3.1	2.1	6.0	2.1
21 to 25 (11 to 13)	1.9	1.9	3.9	1.4	4.5	1.8	1.6	1.8	3.3	1.5
26 to 30 (13.5 to 15.5)	1.1	2.0	1.9	1.5	1.1	1.6	0.4	3.0	2.5	1.5
31 to 35 (16 to 18)	0.3	1.5	1.4	1.4	0.1	1.0			0.9	1.6
36 to 40 (18.5 to 20.5)			0.9	1.3					0.3	1.3
41 to 45 (21 to 23)			0.4	1.0					0.1	1.0
46 to 50 (23.5 to 26)	0.1	2.0	0.1	1.0						
51 to 55 (26.5 to 28.5)			0.1	1.0						

*Number of years in record.

TABLE 2.6.–(continued)

3. Georgia Indirect Fire Range

Wind	January (6)*		February (6)		March (6)		November (6)		December (6)	
Speed Kts (m/s)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
Calm	22.7	13.1	15.7	13.5	20.7	12.3	27.8	12.1	27.2	13.8
1 to 5 (0.5 to 2.5)	32.	2.4	27.7	2.1	31.7	3.2	42.8	4.0	49.8	2.7
6 to 10 (3 to 5)	26.7	3.2	27.7	2.5	16.8	3.5	23.8	2.7	32.5	3.8
11 to 15 (5.5 to 7.5)	10.3	2.1	7.7	1.4	2.0	1.3	7.5	1.8	7.3	3.8
16 to 20 (8 to 10.5)	5.0	1.9	4.5	1.2			3.0	1.7	1.5	1.4
21 to 25 (11 to 13)	1.5	1.4	3.2	1.2			1.8	1.9		
26 to 30 (13.5 to 15.5)	0.5	1.0	1.7	1.6			0.5	1.3		
31 to 35 (16 to 18)	0.2	1.0	0.5	1.3			0.2	1.0		
36 to 40 (18.5 to 20.5)			0.2	1.0						
41 to 45 (21 to 23)										
46 to 50 (23.5 to 26)										

*Number of years in record.

TABLE 2.6.–(continued)

4. Texas Range

Wind	January (8)*		February (7)		March (5)		November (5)		December (4)	
Speed Kts (m/s)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
Calm	5.6	17.4	11.1	9.1	6.4	10.6	3.8	35.1	2.8	26.7
1 to 5 (0.5 to 2.5)	5.4	2.0	12.6	3.4	9.6	4.3	3.8	3.1	4.0	4.7
6 to 10 (3 to 5)	0.5	1.0	2.3	2.1	3.6	1.5	1.4	2.7	2.5	1.8
11 to 15 (5.5 to 7.5)	0.1	2.0	1.7	2.1	1.0	4.4	0.6	3.3	1.5	1.0
16 to 20 (8 to 10.5)	1.1	2.8	2.0	2.0	0.8	3.0	0.4	4.5	0.8	1.3
21 to 25 (11 to 13)	1.0	1.1	1.9	1.5	0.2	5.0				
26 to 30 (13.5 to 15.5)	1.0	2.1	0.9	1.8					0.2	5.0
31 to 35 (16 to 18)	1.2	1.7	0.3	1.0					0.5	2.5
36 to 40 (18.5 to 20.5)	0.5	1.7	0.1	1.0						
41 to 45 (21 to 23)										
46 to 50 (23.5 to 26)										

*Number of years in record.

TABLE 2.6.–(continued)

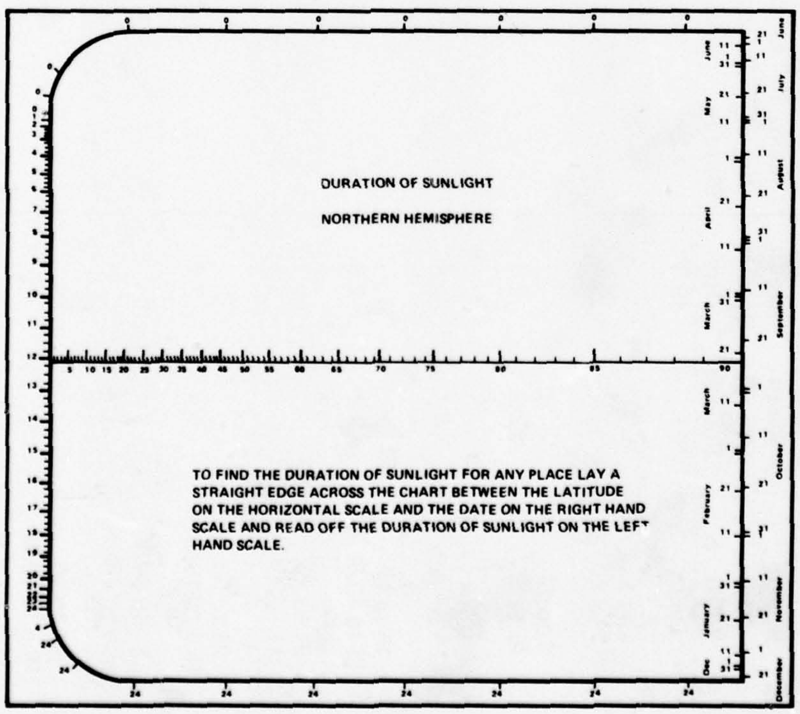
5. Black Rapids Training Area

Wind	January (5)*		February (4)		March (5)		November (3)		December (5)	
Speed Kts (m/s)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)	Mean No. of Periods	Mean Duration (Hrs)
Calm	21.	19.3	24.2	10.2	16.6	8.4	26.3	8.7	17.0	9.7
1 to 5 (0.5 to 2.5)	33.4	3.5	43.8	3.1	36.4	3.9	54.	3.8	40.4	3.9
6 to 10 (3 to 5)	22.6	2.6	53.2	2.7	31.6	3.7	53.	2.8	46.0	2.7
11 to 15 (5.5 to 7.5)	10.6	2.5	37.	2.0	14.2	3.3	29.3	2.2	27.2	2.2
16 to 20 (8 to 10.5)	3.2	2.8	11.2	1.4	7.6	2.3	8.0	2.3	10.4	1.8
21 to 25 (11 to 13)	0.6	1.3	2.0	1.1	2.8	2.8	1.3	2.2	2.6	1.5
26 to 30 (13.5 to 15.5)	0.4	1.5	0.5	1.5	0.8	1.5			1.6	1.8
31 to 35 (16 to 18)									1.4	1.3
36 to 40 (18.5 to 20.5)									0.2	1.0
41 to 45 (21 to 23)							0.3	1.0		
46 to 50 (23.5 to 26)										

*Number of years in record.

Figure 2.1.–Duration of Sunlight Chart

More than any other operational area of the world, combat success in cold regions is highly dependent upon near perfect performance of men and materiel. This factor, combined with the fact that most U.S. Army equipment is designed for optimum performance under Temperate Zone conditions, has required an extensive program of evaluation and field testing of military systems under the cold environmental conditions in which they may be employed. While there is probably no place in the world where all operationally important environmental conditions can be simulated or found to occur, Fort Greely and vicinity has proven to be an efficient and convenient location to obtain the operational environment necessary for a wide variety of test conditions on a year-round basis.



Demographic Characteristics

The area requiring northern techniques as outlined in chapter 1 (fig 1.2) contains land masses that are either all or portions of 12 different countries. The area of northern operations as defined by FM 31-71, Northern Operations is that area in the Northern Hemisphere that requires special techniques and equipment that are not required in a more temperate climate. Table 2.7 lists the countries, in alphabetical order, that have land masses located within this boundary. This table also lists specific statistical data for these countries. The statistical data pertains to the entire country and not just that portion within that area defined as requiring northern operations techniques.

Table 2.8 lists some large cities, the population and latitude, that are located in northern regions. In northern regions the population is primarily concentrated around some natural resources, i.e. rivers, coastal area, mineral deposit, etc. Improved roads and railways become more widely dispersed as the latitude increases. Alaska, as an example, contains 586,400 square miles of land area and is serviced by a 584 mile railroad running from Seward through Anchorage and Fairbanks to Eielson Air Force Base.

Almost the entire road system of Alaska is contained in the southeast quarter of the state. A pipeline service road does extend from Valdez to Prudhoe Bay. This is the only road north of the Yukon River allowing access to Alaska's northern boundary. Air transportation becomes increasingly important in Alaska outside the established road system and many airfields for light aircraft are located throughout the state. Industry located in the northern latitudes is primarily oriented toward the processing of natural resources (fisheries, mining, timber, etc.).

TABLE 2.7.–NORTHERN OPERATIONS COUNTRIES

Country	Area Sq. Mi.	Population Estimated	Form of Government	Capital and Largest City (Unless Same)	Predominent Language
Canada	3,851,801	22,865,000	Monarch	Ottawa, Montreal, Quebec	English
China	3,691,500	838,500,000	People's Republic	Peking Shanghai	Chinese Mongolian
Japan	147,700	89,275,000	Monarchy	Tokyo	Japanese
Finland	119,110	4,700,000	Republic	Helsinki	Finnish Swedish
Greenland	736,520	50,000*	Territory (Denmark)	Godthad	Greenlandic Danish, Eskimo
Iceland	39,800	225,000	Republic	Reykjavik	Icelandic
Korea (North)	46,540	15,915,000	People's Republic	Pyongyang	Korean, Chinese, Japanese
Korea (South)	38,020	34,010,000	Republic	Seoul	Korean
Mongolia	600,000	1,440,000	People's Republic	Ulan Bator	Mongolian Russian

TABLE 2.7 – NORTHERN OPERATIONS COUNTRIES (Continued)

Country	Area Sq.Mi.	Population Estimated	For of Government	Capital and Largest City (Unless Same)	Predominent Language
Norway	125,000	4,020,000	Monarch	Oslo	Norwegian
Soviet Union	8,600,350	254,390,000	Federal So-Viet Republic	Moscow	Russian Ukraninian
Sweden	173,650	8,175,000	Monarch	Stockholm	Swedish
United States	3,679,630	213,500,000	Republic	Washington,DC New York	English

*1972 Estimate

TABLE 2.8.-NORTHERN CITIES

City	Country	Population	Census Year	Latitude
Fairbanks	Alaska (US)	30,000	(Approx)	65°
Godthab	Greenland	6,790	1965	64°30 (approx)
Hammerfest	Norway	5,900	1972E	70°38'
Helsinki	Finland	507,654	1972E	60°10'
Leningrad	USSR	4,133,000	1973E	59°56'
Moscow	USSR	7,410,000	1973E	55°45'
Nome	Alaska (US)	5,749	1970	64°25'
Oslo	Norway	472,609	1973E	59°57'
Reykjavik	Iceland	82,892	1973E	64°4'
Stockholm	Sweden	681,318	1973	59°17'

E = Estimate

*Reference 2

CHAPTER 3. - CHARACTERISTICS OF MILITARY INTEREST

Temperature and Weather

Implicit in the name "cold regions" is the dominance of low temperature as a climatological factor. No environmental factor is more pervasive than temperature. All natural and induced environmental factors are greatly affected by temperature. Anyone who has spent extended periods of time out-of-doors or operated an automobile for any length of time at subzero temperatures has experienced the effects of low temperature on both man and materiel.

Effects of Low Temperatures on Materials (Portions of this section are exerpted from AMCP 706-116; Natural Environmental Factors)

Most engineering materials exposed to low temperatures show a substantial loss of useful structural properties. While wood, ceramics, and glass are virtually unaffected, metals, rubber, and plastics are subject to mechanical failure. Rubber materials usually lose flexibility and become hard and brittle. Many of the newer synthetic elastomers, however, retain flexibility down to extremely low temperatures. Most plastics harden and embrittle, and will fracture on shock loading or impact. Structural metals, particularly the steels, are subject to catastrophic brittle failure.

Metals

The significant effect of cold environments on the mechanical behavior of metals is the tendency to induce brittle failure. With a temperature decrease, metallic materials actually become stronger, as reflected in higher measured yield strengths and ultimate tensile strength. On the other hand, most metals also develop lowered resistance to impact or shock loading and become dangerously brittle. The lack of toughness then becomes an overriding consideration, with an important governing factor being the so-called transition temperature range. This is the temperature below which a material behaves in a brittle manner (the mode of failure being primarily a cleavage mechanism), and above which it behaves in a ductile manner (the mode of failure being predominantly a shear mechanism.).

The transition temperature depends on a variety of metallurgical and mechanical factors. The austenitic stainless steels, aluminum, cooper, nickel, lead, silver, gold, and platinum group do not exhibit brittleness at any temperature (except when a second metallurgical phase is present). Most of the structural steel alloys (columbium, molybenum, tantalum, tungsten, vanadium, and chrominum) display abrupt ductile-to-brittle transitions. Titanium, zirconium, magnesium, beryllium, cobalt, zinc, and cadmium characteristically exhibit low temperature behavior similar to that of the structual steel alloys. An important exception is some high purity titanium alloys that display increased strength at low temperatures, with little sacrifice of ductility.

The fact that the transition temperature of a metal is below the environmental temperature provides no guarantee against brittle failure; the presence of notch-type defects increases the susceptibility of structural parts to low temperature failure. The effects of temperature and notches are additive, since notches can raise the transition temperature and notch-type defects geometry changes can also initiate brittle fractures. Special care should be taken during design to eliminate or reduce notch-type defects such as keyways, holes, sharp fillets, threads, scratches, nicks, machining marks, corrosion pits, inclusions, tiny cracks, and discontinuities in equipment intended for extreme cold weather use, since such defects serve to concentrate stresses.

Nickel is very effective in reducing the transition temperature behavior of low carbon alloy steels. Alloys containing above 8.5 percent nickel are suitable for use at temperatures down to -320°F (-195°C). Titanium alloys also have considerable potential for low temperature applications, particularly an alloy composed of titanium, 5 percent aluminum, and 2 percent tin. With adequate control of impurities, this alloy possesses excellent high strength, accompanied by good toughness and ductility down to cryogenic temperatures.

Nonmetallic Materials

The low temperature behavior of nonmetallic materials is discussed by material categories as follows:

(1) Plastics. The strength of plastics increases as temperature decreases, but the durability of nearly all plastics subject to shock decreases in cold environments. Many classes of plastics can be used successfully at temperatures as low as -40°F (-40°C) provided that they are not subject to shock loading. Polyethylene, a thermoplastic polymer, remains tough at temperatures as low as -100°F (-73°C). Only the fluorocarbon plastics (polytetrafluoroethylene (Teflon) and polychlorotrifluoroethylene) retain useful ductility at extremely low temperature. Engineering data on plastic properties at low temperatures are available.

(2) Rubber. Cold adversely affects the serviceability of such rubber components as tires, inner tubes, cable, hose, bushings, and seals. The cold-temperature effects of greatest concern are changes in flexibility and compression-set characteristics, and the development of brittleness. Low-temperature changes in rubber are classed as visco-elastic effects, crystallization, vitrification, and effects associated with changes in properties of plasticizers.

Simple temperature effects are shown by loss of resilience, increase in stiffness, and increase in hardness. First-order transitions (crystallization) are time dependent and may require periods ranging from hours to months. They are accompanied by changes in hardness, volume, the coefficient of thermal expansion, and an increase in stiffness. Second-order transitions (vitrification) are exhibited by all elastomers and occur quite rapidly within a narrow temperature range. Rubber materials usually become unserviceable due to simple temperature effects well above the second-order transition temperatures. When rubber compositions are highly loaded with certain plasticizers, time effects not necessarily associated with crystallization may be evident. Low-temperature flexibility may be improved by the addition of selected plasticizers but this may be done at the sacrifice of other more desirable properties such as tear and abrasion resistance, and bondability.

Many low temperature rubbers do not possess adequate chemical resistance for use in hoses that convey fuels, hydrocarbon oils, hydraulic fluids, and lubricants. These fluids extract the compounds from the rubber that impart the original low temperature qualities. Table 3.1 shows low temperature characteristics of some elastomers.

(3) Lubricants. Commercially available engine and gear lubricants are useful down to at least -65°F (-54°C) and instrument greases to at least -100°F (-73°C). Solid film lubricants, based on molybdenum sulfide or polytetrafluoroethylene, can provide lubricity down to cryogneic temperatures. The conventional mineral based engine lubricants are not adequate for winter operations. Without exception both single and multi-viscosity products harden and adversely affect engine starting at temperatures below freezing and especially at temperatures below -25°F (-32°C). In addition, the multiviscosity lubricants do not have the anti-wear and oxidation stability characteristics necessary for use in diesel engines. An Army developmental program has perfected and resulted in the availability of a synthetic lubricant formulated from a diester base stock. This lubricant is available under the specification MIL-L-46167 and is referred as OIL ENGINE ARCTIC (OEA). The lubricity and viscosity properties of this lubricant are adequate over a wide temperature range and it does not become volitile at high temperatures as does the mineral bases multi-viscosity products. Published doctrine for equipment maintenance and operation are TM 9-207 (Operation and Maintenance of Ordnance Materiel in Cold Weather (0° to -67°F). This document specifies that the OEA products are to be used in all crank case applications spark ignition and compression ignition during winter conditions and temperatures from +40°F to -65°F (-54°C).

TABLE 3.1.–RELATIVE LOW TEMPERATURE CHARACTERISTICS OF ELASTOMERS

Type	Typical Brittleness Temperature		Temperature Range for Rapid Stiffening	
	°F	(°C)	°F	(°C)
Neoprene	-40	-40	10 to -20	(-12 to -29)
Butyl	-50	-46	0 to -20	(-18 to -29)
Natural Rubber	-65	-54	-20 to -50	(-29 to -46)
Styrene-butadiene	-75	-59	-50 to -60	(-46 to -51)
Polyurethanes	-90 below	-68	-10 to -30	(-23 to -34)
Silicones (general purpose)	-90	-68	-65	(-54)
Fluorosilicones	-90	-68	-75	(-59)
Silicones (extreme low temperature	-150	-101	-105	(-76)

Effects of Low Temperature on Components (Portions of this section are exerpted from AMCP 706-116, Natural Environmental Factors)

The composition of materials used in equipment will largely determine the extent of temperature effects on equipment performance. Generally, failure rates are lower on many kinds of electronic equipment at low temperature than for high temperature, where heat dissipation may be a problem. Some typical low temperature effects on specific components are as follows:

Resistors. Resistors employed in military equipment generally perform satisfactorily at low temperatures, although large resistance variations in high value category 8 (-60°F to -70°F). This is due to expansion and contraction properties which increases or decreases resistance. By contrast the conventional wire wound resistor is stable at all temperature ranges and usually varies less than one percent. Use of dissimilar metals for control spindles and spindle bearings of continuously variable resistors (Potentionmeters and reostats) can result in excessive tightness of looseness of spindles at low temperatures. Excessive binding of variable resistor spindles can also result if temperature sensitive lubricants are used. The effort required to rotate the adjustment spindle of some variable resistors can be substantially greater at the category 8 temperature range than at room temperature. Temporary electrical discontinuity in variable resistors, due to ice formation or hardening of lubricant on the resistor element has been encountered in the colder climatic categories.

Capacitors. Electrolytic capacitors exhibit large reductions in effective capacitance at low temperatures, the extent depending upon the electrolyte, type of foil, voltage rating, and manufacturing technique. The series resistance, and consequently, the impedance of electrolytic units increases greatly at subzero temperatures. Variations in reactance and resistance with temperature become greater at higher frequencies. Low temperatures result in two favorable effects: (1) The dielectric breakdown voltage increases and (2) the DC leakage values show an extreme decrease. Storage of electroytic capacitors at temperatures as low as -67°F (-55°C) results in no permanent harm and may even inhibit deterioration due to aging.

Oil-impregnated paper, air, and mica capacitors function well at cold temperatures, but wax-impregnated capacitors are subject to extensive cracking of the impregnate below -4°F (-20°C), resulting in permanent changes in capacitance, insulation, resistance and AC losses.

Transformers. Transformers operate satisfactorily at temperatures as low as -67°F)-55°C), provided that precautions have been taken in their design to prevent mechanical damage due to thermal contraction. Coil-winding resistance decreases with decreasing temperature. The DC resistance for copper wire at any gage at -67°F (-55°C) is about 70 percent of its value at 77°F (25°C). Cracking of potting compounds and terminal bushings can also occur, especially if the temperature drops rapidly.

Electron Tubes. Low temperatures have few serious effects on tubes. Below 32°F (0°C), tube cathode heating time takes longer. Also, if the condensed-mercury temperature in a mercury-vapor rectifier tube is below the minimum value of the operating range, arc-back can occur, which will damage the tube. Low temperatures can also cause tube basing cement to crack.

Semiconductors. Semiconductor devices with good circuit design give satisfactory performance at low temperatures. Temperature changes can be compensated for.

Relays. Relays perform their intended functions, provided that the mechanical problems encountered at low temperatures are taken into account. The decrease in winding resistance tends to alter relay operating characteristics, particularly if small or critical currants are involved, as in the case with sensitive relays. At low temperatures, operating (closing) margins are impaired. Variations in spring stiffness and magnetic properties can also change these characteristics. Ice formation on operating parts and contacts can cause trouble at low temperatures. In addition, lubricants and dashpot oils tend to congeal.

Magnetic and Thermal Circuit Breakers. Magnetic circuit breakers with silicone oil damping perform well at subzero temperatures. As the temperature drops, the time required for the breaker to trip due to overload or short-circuit conditions increases. Thermal circuit breakers are affected at reduced temperatures by the increased heat transfer away from the bimetallic actuating elements, with a resulting change in operating characteristics. The tripping time at temperatures near -67°F (-55°C) can be about double the time required at 77°F (25°C) for a given overload current.

Switches. Exposure to low temperatures can cause the molded body or plastic wafers of a switch to contract and thus be stressed sufficiently to cause cracking. This is especially true in the proximity of attached metal parts, which may contract more severely or more rapidly than the phemolic, plastic or ceramic body of the switch. A cracked body or wafer may allow entrance of moisture or other foreign matter that can cause a short circuit.

Electrical Indicating Instruments. Most electrical indicating instruments operate satisfactorily at reduced temperatures; changes in incation may be less than 10 percent at -67°F (-55°C). Thermocouple and rectifier type meters normally have the greatest temperature errors. Low temperature can cause meters to read incorrectly by altering the properties of such basic meter movement parts as control springs, magnets, and coils, as well as range and function-changing accessories.

Rotating Devices. Motors and dynamotors will start and operate satisfactorily at temperatures as low as -67°F (-55°C), provided that lubricants specially developed for low temperatures are used. In general, as the temperature is decreased from 77°F to -67°F (25°C to -55°C), the final operating speed is lowered and the input power increases somewhat. Generators become less efficient at low temperatures and have a higher voltage output because of the reduced resistance of the windings. On the other hand, the output voltage may decrease due to increased air-gap spacing as a result of metal shrinkage. Low temperatures change the electrical characteristics of resolvers, synchros, and gyros, with the most important effect being a decrease in accuracy.

Mechanical Components. Mechanical components include such items as pumps, valves, hydraulic and pneumatic actuators, and shock and vibration isolators.

Differential contraction at low temperatures results in binding, fluid leakage, and pumps and actuator difficulties. Entrapped moisture freezes, clogging metering orifices. Stiffening of vibration mounts at cold temperatures increases their natural frequency and thereby reduces isolation from the structure in which they are mounted. The performance of these components in large part depends on the materials used in their construction and the type of lubricants used.

Differential expansion due to temperature gradients causes binding of movable parts, loosening of joints, distortion of assemblies, and rupture of seals. Valves may bind or leak. Fuel leaks are aggravated by the cyclical use of fuels of different aromaticity at high temperatures, and occur in check valves, boost pumps, and selector valves.

Effects of Low Temperature on Systems

Low temperature effects upon entire systems is a complex, and somewhat unpredictable matter. The effectiveness of an entire hardware system is a function of not only the hardware itself, but also the operator and maintainer. Low temperature places stress on the man and the machine, sometimes to the point where proper functioning may be almost impossible to obtain.

Cold Chamber Testing vs. Natural Environment Testing

While materials and components can be adequately evaluated in cold chambers, realistic and accurate evaluation of entire systems in chambers is difficult and risky. Component evaluation often misses the synergistic effects of materiel, climate, and man. For instance, the cold starting characteristics of a tactical vehicle can be evaluated in a test chamber, but such testing does not enter the man into the evaluation. More engines have been ruined by towing to start than by low temperatures.

Human factors are an essential element in the evaluation of complete systems in a cold environment. Often a developer tends to explain away human factors failures by saying that the equipment was not operated in strict accordance with the operator's manual. However, if either the equipment or the operator's literature is such that typical operators have a propensity to commit the same errors, then the design is not adequate. This can only be evaluated by testing the entire system in the natural environment using soldier operator/-maintainer/testers.

Like the chain, a materiel system is no better than its weakest link. The best electrical system is of little use if its cables cannot be used at low temperatures or if a generator cannot be started to provide it with power. This is one of the weaknesses of the Army developmental process. Developers are specialized and tend to develop and test pieces of equipment in isolation. Different developers engineer separate components of a system at different times. For instance the system developer of a shelter system may have another agency develop the heating/air-conditioning equipment, a second agency develop a CBR protection system, and a third agency develop the power generation system. Each engineers his component and tests it as a component. Frequently, incompatibility of the components will only be discovered during testing of the entire system. CRTC has seen numerous examples of systems which were set up in a cold chamber, operated for a specified time, and given a clean bill of health by the developer only to go on to fail in the natural environment. The reasons for failure are obvious. The system was not set up and taken down in the cold environment. Cables which were connected in a chamber before the temperature was lowered did not fail, even though they did stiffen. But flexing those same cables to set up the system in the natural environment produced entirely different and more realistic results. This principle is true for all components of a system, not just for cables.

A tremendous advantage of systems testing in the natural environment over chamber testing is that it is more realistic and thorough. Chambers are expensive to operate and must be scheduled to test many projects, therefore chamber tests tend to be of very limited duration. The environmental tests in military standards are widely used and are of very short duration. For example, the low temperature test in MIL-STD-810, Environmental Test Methods, is strictly short term, specifying only that the item reach temperature stability and be operated for an unspecified duration. Generally, the duration is short, often less than 48 hours. There is no sound data which provides a correlation between the results of chamber testing and actual performance of the equipment in the field. Certainly, longer term tests of entire systems in the natural environment using soldiers as operators and maintainers is more realistic, and should correlate better with actual troop usage. Low temperatures in the natural environment are pervasive; the soldier tester cannot escape the environment and must deal with it realistically.

Human Response to Cold

Psychological Effects

Psychological effects characteristic of cold weather operations may be generally categorized as morale effects, isolation effects, disorientation, and social factors.

Conditions of cold, darkness, and silence common to winter operations in cold geographic areas create problems of psychological adjustment. Tests suggest that personnel exposed to these conditions show general unfavorable dispositional trends, such as, increased depression, dissatisfaction, insomnia, and lack of motivation indicative of non-adjustive behavior. Long periods of darkness as experienced in high latitude regions tend to bring out the less desirable elements of human behavior, such as, conceit, jealousy, suspicion, excitability, and a generally unbalanced disposition.

The mere idea of being isolated can create adverse psychological effects in a person. Immobilization due to extreme cold and reduced trafficability only accentuate the isolation, resulting in feelings of anxiety and potentially a condition referred to as "cabin fever". Northern operations characteristically occur in areas remote from civilization, accentuating other effects of cold climate. Especially among the untrained, there is an irrational fear of the cold climate.

Disorientation is a significant contributing factor to psychological stress in cold climate areas. Dense forests and wilderness offer few landmarks and limit visibility. Barren, monotonous tundra areas north of the tree line are characterized by a lack of landmarks. Photographs and maps of many areas are difficult to read and interpret because of the absence of relief and contrast and absence of man-made objects for use as reference points. Heavy snow may completely obliterate existing trails, tracks, and outlines of small lakes and other landmarks. In winter the short periods of daylight, fog, snowfall, blizzards and drifting snow drastically limit visibility. At times overcast sky and snow-covered terrain combine to form a phenomena known as whiteout which obliterates the horizon and makes recognition of irregularities in terrain extremely difficult. The same factors exist in the heavily forested (taiga) land areas of the subarctic.

Group social factors sharply influence individual motivation and sociability. Several factors are particularly germane to cold climate operations. Understanding of behavioral reactions to be expected under extreme environmental conditions provide insight into sociability problems. Some well supported conclusions are the following:

a. The greater the motivation to achieve a particular goal, the greater the individual's tolerance of frustration and stress in activities leading to that goal.

b. Close-knit, well trained groups contribute to mitigation of stress through the effects of team leadership and team spirit.

c. Other social factors involving intra- and inter-group relations such as the effects of success or failure on communications, content of communications etc. have a significant effect on individual stress tolerance.

Not all individuals will bear up to the cold and hence leaders must know themselves and their followers and react/adjust personnel to task.

In summary, such insight and preplanning in conjunction with strong leadership and training are essential to psychological well being in cold climate areas. Personnel must be "goal oriented" to achieve maximum effect.

Physiological Effects (Portions of this section are exerpted from *"Man in a Cold Environment"*, by A.C. Burton and O.G. Edholm, and from FM 31-70, Basic Cold Weather Manual.)

Physiological effects of the cold are determined by man's ability to control his body temperature and the environmental temperature that he is living and working in. Man is a homeotherm meaning that he tries to keep a constant body temperature despite changes in the environmental temperature. This physical temperature regulation is accomplished by controls of heat production and heat loss.

Man has partially conquered the environment by relying on the supraphysiological factors such as the use of clothing, shelter, and heating of dwellings. Trying to adopt man's physiological mechanisms to the cold has little value compared to his use of engineering knowledge to produce cold weather equipment and heating devices. Still, a general knowledge of physiological temperature regulation, its mechanisms and its limitations, is needed to utilize this equipment to its fullest possibilities. War-time experience has shown that success in living in adverse conditions depended as much upon the knowledge of how to behave and use the protective equipment available, as upon that equipment itself.

For man to maintain his homeothermy he must maintain a heat balance. In other words, a balance must be reached between the heat produced and the heat lost through the body and the clothing being used.

The body has several pathways for the heat to flow through when going from the "core" to the surface. In the equation of the thermal steady state, the insulation of the tissues denotes the overall mean insulation, i.e., the total resistance to the flow of heat from the core to the surface. This overall average is the resultant of the resistances of a number of pathways that are in parallel with each other like heat flow down the separate arms and legs. Each of these pathways will consist of a number of resistances in series, for example, for heat reaching the surface of the hand it must flow down the length of the arm, through the arteries to the distributing subcutaneous vascular bed, and finally out through the skin itself.

The thermal insulation of the skin has been the object of some study. However, most of the research has been done upon dead skin and obviously the blood flow in the skin must play a large part in determining its effective insulation capabilities. The blood flow in the skin shows an enormous physiological variability, at times over a 100-fold increase has been found. This large variability can be expected to cause a similar variability in the thermal insulation of the skin.

Studies completed on the thermal conductivity, the inverse of thermal insulation, of the skin and subcutaneous layers found a mean value for the conductivity of the skin to be 0.65 clo per inch.

The clo unit for thermal insulation is an important unit whenever a study of heat flow through the body or clothing is being done. A brief discussion of what the clo unit is and why it was developed follows.

The clo unit was developed so that nontechnical persons could understand the results of work in the field. This unit can be translated into established systems used by physicists and engineers by merely using the appropriate numberical constant. The magnitude of the clo unit was chosen to approximate that of a familiar garb, the normal indoor clothing worn by sedentary workers in comfortable indoor surroundings, i.e., a business suit and the usual undergarments.

The insulating effects of clothing far outweigh the insulating effects of the body. Thus, this aspect has been studied and developed extensively to achieve the arctic clothing that is in use today.

The main point in designing cold weather clothing is to remember the importance of "dead air" since it provides the best thermal insulation obtainable.

The thermal insulation is directly proportional to the thickness of dead air enclosed. The air entrapped should be immobilized as much as possible by preventing leaks of air which would allow air currents. Also, the maximum thickness of dead air must be maintained under service conditions of compression by external forces and in conditions of moisture. The bulk density of materials used should be low enough so that conduction by the textile itself is negligible.

There are four basic principles for winter use of clothing in order to keep warm:

a. Keep clothing clean.

b. Avoid overheating.

c. Wear clothing loose and in layers.

d. Keep clothing dry.

Despite the thermal adequacy of arctic clothing, the maintenance of temperature in the extremities above critical levels is still a problem. Extremities are particularly susceptible to heat loss and are difficult to insulate without a dramatic increase in bulk and surface area to retain the heat. The extremities are also particularly prone to vasoconstriction, which reduces their circulatory heat input. When the hands are encased in arctic mittens, tasks requiring finger dexterity are impossible to accomplish.

The combined factors of body heat production and the insulation of clothing working together provide the necessary heat balance for survival in a cold climate. The thermal insulation required for comfort depends to a very great extent upon the activity of the man exposed to the environment. A man working at a desk would be comfortable with a clo unit of clothing and a temperature of 70°F (21°C), while that same man with the same clothing working very hard could be warm at temperatures below freezing.

The amount of increase in heat production necessary to maintain a heat balance is directly related to the insulation present. An unclothed man with a total insulation of 1.6 clo will have to double his resting metabolic rate for each 15°F (7°C) drop in temperature. A heavily clad man with a total insulation of 6 clo units would have to double his metabolic rate for each 46°F (23°C) drop in temperature. It is interesting to note that the arctic fox, which does not have to call upon increased heat production until the temperature is below -40°F (-40°C), could maintain a heat balance down to -184°F (-120°C) (theoretically) by doubling its metabolic rate. The fur of an artic fox has an insulation value of approximately 10 clo units.

When heat loss exceeds heat production, the body uses up the heat stored in its tissues causing a drop in body temperature. Excessive heat loss can result in shivering. Shivering uses body energy to produce heat which at least partially offsets the heat loss and slows the rate at which the body temperature will drop. Shivering is an important warning to start action to rewarm, either by adding more clothing, by exercising, or by entering a warm shelter.

Cold acclimatization in man is an important subject when studying cold effects and one that is not completely understood or agreed upon by different researchers.

It has been shown in different experiments that man can develop an increased tolerance to cold over a period of time. This was shown by finding the time required for different subjects to become uncomfortable cold when exposed to a specific cold temperature. As the number of exposure times increased, the length of time a man could remain comfortable at a given temperature increased.

It has been found that an acclimatized man has an altered method of maintaining a heat balance. He will maintain a relatively lower level of metabolism and will make up for less of the heat loss by adjusting his metabolism.

An acclimatized man also maintains a smaller body core, where the temperature is not allowed to drop greatly as compared to the skin temperature. Thus he has a smaller portion of his body to maintain at constant maximum temperature and can, in effect, store up more heat to be used when exposed to the cold. Using this effect of having a thicker shell, he can lose more heat before his metabolism must increase. This reduction in body core has the advantages of:

a. The person can be under conditions of cold stress for longer periods of time.

b. He can drop the total heat load to a lower level before he must rewarm.

c. His level of exercise to keep him from shivering will be lower.

d. He will be able to maintain circulation in the extremities longer with consequent increased exterity and protection against frostbite.

Cold injuries are a common danger in an arctic environment and one that everyone should be aware of so proper precautions can be taken. They can be divided into two main types, whole body cooling, called hypothermia, and local cold injury. Some of the local cold injuries are frostbite, trenchfoot, immersion-foot, and chilblain.

Hypothermia is a term used to describe general lowering of body temperature due to loss of heat at a rate faster than it can be produced. It can occur with or without frostbite depending on the temperature and whether the extremities are receiving adequate circulation and/or insulation. Freezing temperatures are not necessary for hypothermia to occur, especially for the cases of immersion in cold water or from the effects of wind. Physical exhaustion and insufficient food may raise the risk of hypothermia.

The dangers from hypothermia are: retarded circulation of the blood, reduced coordination, impaired judgement, and if the core temperature falls below 85°F (29°C), there is increased risk of disorganized heart action and death. Table 3.2 shows some of the critical core temperature effects induced by low temperatures.

TABLE 3.2.–COLD INDUCED CORE TEMPERATURES

°F	°C	
		[illegible]
[illegible]	[illegible]	
[illegible]	[illegible]	
92	34	Poor temperature regulation by human subjects
90	32	
88	31	
86	30	
84	29	
82	28	
80	27	
78	26	The hardiest subject at Dachau died at this temperature
76	25	Aviators in ice water for 25 minutes reach this temperature.
74	23	Rabbits die at this temperature
72	22	
70	21	
68	20	
		One child survived this temperature
[illegible]	[illegible]	
[illegible]	[illegible]	
[illegible]	[illegible]	

Hypothermia can be treated by rewarming of the body evenly and slowly, too rapid warming can further disorganize body functions. The person can be placed in a sleeping bag or wrapped in dry clothing to aid in the rewarming process. Warm beverages can be given as long as the person is conscious, otherwise strangling may result.

Frostbite is the freezing of some part of the body by exposure to temperatures below freezing. The danger is greatly raised when the wind is strong and/or if the temperature is far below freezing. Usually there is an uncomfortable sensation of coldness followed by numbness. There may be a tingling, stinging, or aching sensation, even a cramping pain. The skin initially turns red, later becoming pale gray or waxy white.

Frostbite can be classified as either superficial or deep. Superficial frostbite is not nearly as dangerous and once the frozen part is thawed, the damage done can be small. However, deep frostbite can be very serious and result in the loss of the frozen extremities even if proper medical attention is received.

Trench-foot and immersion-foot are very similar and no advantage is gained in trying to separate the two. When persons are exposed to wet or damp cold conditions for many hours or days, damage to the extremities, particularly the feet, is likely to occur. Immersion-foot was first described in shipwreck survivors who spent days on rafts with their feet in cold sea water. Soldiers standing or sitting for many hours or days in wet trenches are liable to suffer from trench-foot.

In either case the feet become cold, swollen, and have a waxy appearance. Walking or balancing becomes difficult and the feet feel heavy and numb. The main damage is found in the nerves and muscles, but gangrene can also occur. In extreme cases the flesh dies and amputation of the foot or leg may be necessary.

Chilblain is a milder form of cold injury; it is similar to trench-foot. It is not due to freezing but to prolonged cooling of the part with some body cooling. Chilblains are usually found on fingers and toes and may be observed on ears. The part affected becomes red, swollen, hot, painful, and tender and there is intense itching.

There are a few other miscellaneous cold weather effects, these include: diet requirements, dehydration, cold diuresis, sunburn, and sun blindness.

Man's caloric intake increases in a cold environment. A figure of 20 percent difference in basal metabolism between the tropic and arctic has been suggested. The increase in the cold is not entirely due to increased heat loss from the body, part of it seems to be caused by the hobbling effect of the heavy clothing worn in the cold environment. The appetite increases immediately while the heat production increases more slowly, and a weight gain is usually seen. There are other theories that the correlation between food intake and environmental temperature is due to a stimulating effect of cold on the appetite.

There are many reports on the role of fat in the diet in arctic conditions which indicate that an increased fat content is preferred and that it is not harmful. It has also been shown that a high carbohydrate or high fat diet is significantly more effective than a high protein diet for maintaining a thermal balance. A high fat diet has proved better than a high carbohydrate diet when the meals are given at short intervals, otherwise there is no significant difference.

Dehydration is another problem in the arctic. It is as prevalent in cold regions as it is in hot, dry areas. The difference is that in hot weather the individual is aware of the fact that he is losing liquids and salt because he can see and feel the perspiration on his skin. In cold weather it is extremely difficult for an individual who is bundled up in many layers of clothing to realize this condition exists. The perspiration is rapidly absorbed by the heavy clothing or evaporated by the air and is rarely visible on the skin.

The symptoms of dehydration are the mouth, tongue, and throat becoming parched, general nausea, spells of faintness, and vomiting. A feeling of general tiredness and weakness sets in and muscle cramps may occur, especially in the legs. It becomes difficult to keep the eyes in focus and fainting or "blacking out" may occur.

Dehydration can incapacitate an individual for a period of from a few hours to several days. The person also runs the risk of a secondary and more dangerous effect, that of becoming a cold weather casualty while incapacitated.

Cold diuresis is an increased output of urine on exposure to cold, and it is sometimes assumed that it is due to a decreased water loss from the skin. During exposure to cold there is a gradual fall in plasma volume, and it has been suggested that the diuresis and decreased blood volume are related. Other researchers consider the increased urinary output to be regulated by the posterior pituitary and not due to a change in renal blood flow. It has also been noted that diuresis is affected by posture, increased when lying down and reduced in the upright position.

Two other effects that are not necessarily due to the cold weather but to the secondary effect of the snow that is present so much of the time are sunburn and snow blindness. An individual can still receive a sunburn when the air temperature is below freezing. On snow, ice, and water the sun's rays reflect from all angles, attacking man where the skin is sensitive; around the lips, nostrils, and eyelids. Also, the exposure time which will result in a burn is reduced in the clear air of high altitudes. Sunburn cream and lip salve should be carried and applied to those parts of the face exposed to direct or reflected light. Skin salves/oils are not recommended for use at low temperatures.

Snow blindness occurs when the sun is shining brightly on an expanse of snow and is due to the reflection of ultraviolet rays. In most cases it is due to negligence or failure on the part of the soldier to use his sunglasses. The symptoms are a sensation of grit in the eyes with pain in and over the eyes made worse by eyeball movement, watering, redness, headache, and increased pain on exposure to light. While this condition may heal in a few days, it should be considered as serious and may, if exposure is of a sufficient duration, result in permanent eye damage.

Related and Synergistic Effects

The foregoing sections of this chapter concentrate on low temperatures. There are many other climatic factors related to the low temperatures. For instance, ice fog is a low temperature related phenomena which is of increasing importance as the northern regions become more populated and industrialized.

Ice fog consists of suspended particles of ice, partly ice crystals 20 to 100 microns in diameter but chiefly, tiny ice particles 12 to 20 microns in diameter. The smaller size particles are predominant in dense fog. Ice fog occurs in very low temperatures, generally at temperatures below about -30°F (-34°C), and usually in clear, calm weather. It is usually associated with atmospheric water vapor produced by man-made sources or activities. Ice fog forms most readily when small nuclei are available. Thus, polluted areas such as cities or industrial areas are especially susceptible. Ice fog is a major winter problem in Fairbanks, Alaska, restricting vision at times to a quarter of a mile or less. Ice fog can be of military significance also. At low temperatures any internal combustion engine produces an easily identified visual signature and large vehicles such as tanks produce large quantities of ice fog. Concealment of operating engines is a near impossibility. Another factor of critical importance is the obscuration effect produced by firing a weapon (TOW, DRAGON, recoilless rifle) at low temperatures, producing an instantaneous cloud of ice fog which can "blind" the operator for a considerable period of time. The cloud dispersion rate is a function of windspeed, but the worst ice fog conditions occur during calm, clear periods in which there is rarely any wind at all. This condition increases the importance of having a high first-round hit probability, because it may be some time before a second round can be fired, if at all.

Another synergistic effect of cold climates is what is referred to as "whiteout." Whiteout, sometimes referred to as "milky weather," is pronounced in polar regions in which no object casts a shadow, the horizon becomes indistinguishable, and light colored objects are difficult to see. A whiteout occurs when there is complete snow cover, and the clouds are so thick and uniform that light reflected by the snow is about the same intensity as that from the sky. Whiteout presents serious navigational difficulties, both for land and air travel. The disorientation and inability to perceive surface features can make any movement during such a condition extremely dangerous.

A third effect of the climate is simply blowing snow. In cold-dry climates the snow is very dry and snowflakes are highly crystalline. A wind easily transports the snow along the ground, breaking the crystals into small fragments. The wind-driven snow soon becomes very fine, capable of penetrating the smallest crack or opening. This phenomenon can cause some depositing snow (and moisture) in unwanted places. Blowing snow is the greatest factor limiting visibility at near surface level.

Terrain in Cold Regions

Terrain is the term used to describe physical features of land, including lakes, streams, vegetation, and surface properties. Terrain can include manmade features, but the word, as normally used, refers to natural features of the land. In cold regions it is impossible to describe "typical" terrain because of the great variation that exists. The terrain of the coastal areas along the Arctic Ocean is quite different from the mountainous terrain farther to the south, such as in interior Alaska. Even within a geographic region, there are great variations within a matter of only a few miles. There are, with a few exceptions, some characteristics of the northern regions which are quite prevalent. Some of these are:

a. Many rivers and lakes.

b. Complex and abnormal valley patterns.

c. A complex system of divides.

d. Steep-walled valleys which restrict approaches to streams.

e. Alluvium-filled basins at the mouths of streams.

f. Locally steep slopes.

g. Extensive areas of tundra and taiga.

h. Uniform cover of spruce and birch on the lower slopes, open stands of small spruce on upper slopes and lower summits, and treeless shrub tundra and rock deserts at higher altitudes. Flood plain terrain and filled basins are covered by sedge marsh or shrub-moss bog or black spruce muskeg vegetation. Stands of spruce, balsam poplar, and willow form dense forests along streams.

One of the features of cold regions terrain that stands out from typical temperate terrain is the vast river networks, consisting of swift, silt-laden, and braided rivers that have strong seasonal and daily fluctuations in flow. These rivers can be both aids and impediments to travel. Another outstanding feature is the widely present evidence of glaciation. Many glaciers are present and actively in the process of changing the terrain. Most valleys are deeply incised, flooded by course gravels or glacial tills, and are headed by glaciers. Moraines, both recent and ancient are plentiful. Of course, permafrost, permanently frozen soil, is another unique feature and is especially important in all military construction in the far northern cold regions.

Terrain has a profound effect on all military operations. It dictates fields of fire, routes of approach, visibility, cover, and concealment. It has a overriding effect on ground mobility, for terrain is the factor that permits or restricts vehicle and personnel movement. It also affects aircraft operations, determining landing sites, routes during nap-of-the-earth flying, and, to some extent, weather patterns. To the combat soldier, terrain is especially important, requiring study, knowledge, and understanding in order to take proper advantage of it.

As important as the differences in terrain from region to region are, differences in surface conditions resulting from seasonal changes is of equal importance. Contrary to popular opinion, the most difficult season for overland mobility is not necessarily winter. In temperate zones, mud is the biggest single impediment to surface mobility. The same is true for operations in cold regions. Spring breakup and summer temperatures, combined with permafrost which keep moisture on the surface, create extensive areas of boggy, muddy terrain which is extremely difficult to travel over. In winter, these areas are frozen solid and do not present any great problem to properly designed equipment.

Winter does present unique problems to mobility, however, for special oversnow equipment must be used. This varies from individual equipment such as skis, snowshoes, and crampons to larger mechanical equipment such as trucks and personnel carriers. The present high reliance upon personal equipment and unit load bearing equipment (ahkio) places great demands on the individual soldier. A unit-size oversnow vehicle is needed for effective movement in cold regions. The M116 and M29C (Weasel), both obsolete now, once performed this function. The M113 armored personnel carrier can be employed, but it is too heavy and large to be fully effective as an oversnow vehicle and is not transportable by Army helicopters. Wheeled vehicles are confined to roads during winter in cold regions.

Even equipment designed for oversnow operation must be capable of being started, operated, and maintained under conditions of extreme cold. Historically, problems with cold starting, fuels and lubricants, batteries, seals, and heaters have been prevalent in testing vehicles in cold regions. Most of these problems can be solved, but not without considerable trouble to the operator or maintainer. Most cold adaptation features of vehicles are achieved by use of add-on kits, not by integral design of the vehicle itself. Consequently, these kits tend to be inefficient, cumbersome and generally less-than-satisfactory. Some desirable design features used on older vehicles such as the M29 Weasel have not been carried over to more recent vehicles (e.g., using exhaust gases to heat tunnel containing drive line components). These experiences indicate that the design of equipment for operation in cold regions is a low priority item.

Operations of large units in cold regions terrain are constrained by the same limitations previously discussed. Wheeled vehicles are generally limited to roads and cannot operate successfully in snow deeper than the vehicle ground clearance, with very limited slope capability. Tracked vehicles, to be fully effective, should have low ground pressure. When the terrain is unfrozen, all wheeled and tracked vehicles having found pressures of over 9 pounds/inch^2 are road-bound for all practical purposes. Because of the varied snow conditions encountered it is impractical to state definite rules for oversnow operations. Large scale military operations would require a high reliance on air support and the security of road networks.

Cold regions terrain differs from temperate terrain with regard to target acquisition and concealment. During winter the ever present snow mandates the use of camouflage. Even with proper snow camouflage, extremely low temperatures cause ice fog wherever engines are operated or weapons are fired. Forested areas pose few concealment problems in comparison with open areas. Snow is an abundant camouflage material in open areas and tree branches and foilage as well as snow may be used to good effect. Tents and shelters must be camouflaged, as well as vehicles. Vehicles should be pattern painted to blend in with the landscape. Target acquisition is, to a large degree, dependent upon the camouflage effectiveness of the enemy. Ice fog aids detection, while the enemy's camouflage actions can tend to inhibit detection and acquisition. In summer, concealment and target detection problems are basically the same as in temperature climates unless operations are conducted above the snow line in mountainous terrain.

CHAPTER 4. - REGULATORY GUIDANCE

Regulations and Policies Affecting the Testing of Materiel in Cold Environments

Introduction

Policy, procedures, and responsibilities for the research and development of Army materiel are contained essentially, within the AR 70 series of Army Regulations. Specific guidance pertinant to the testing of materiel in extreme environments such as the cold regions of interior Alaska is, however, limited in content and permissive rather than restrictive in the statement of requirements.

AR 70-10, Test and Evaluation During Development and Acquisition of Materiel

Control of test and evaluation during development and acquisition of materiel is regulated by AR 70-10. This regulation defines and relates categories of tests to program phases within the materiel acquisition process. Responsibilities for testing are also defined, but in very general terms, as are funding responsibilities and test organizations. Although the discussion of responsibilities include those of the Operational Test and Evaluation Agency (OTEA) and of the Materiel Developer, no mention is made of responsibilities of individual program managers, the Army Materiel Systems Analysis Agency (AMSAA) or the *Test and Evaluation Command* (TECOM).

AR 70-10 addresses climatic testing only at the policy level. The regulation states that climatic testing is conducted to satisfy provisions of AR 70-38 (to be discussed below) and other appropriate requirement documents. The regulation further states that "The results of Climatic Center testing under all specified extreme climatic conditions are not required for evaluation prior to a program decision review unless identified in the CTP (coordinated test program) as a critical issue. However, the materiel will be completely tested for those climates associated with priority or high density employment".

The effect of these policy statements is to largely relieve the materiel developer from testing at Climatic Centers. Consider first that AR 70-10 does not state a requirement for Climatic Center testing under normal climatic conditions, nor as will be seen, does AR 70-38. Second, requirements documents such as ROCs, MNs, etc., state climatic conditions under which materiel is expected to operate safely and effectively; but, the time (within the development cycle), manner and location of testing to evaluate materiel climatic capabilities is usually, left to the discretion of the developer. Third, policy dealing with testing under extreme climatic conditions is stated with emphasis on what is **not** required rather than what is required. The result of the approach is that no action is really demanded except when climatic requirements are identified by the CTP as critical, and this usually occurs only when the materiel for test is specifically designated for cold regions use. Extreme climatic testing of other materiel may be postponed by a developer almost indefinitely. In many cases if materiel is tested by a Climatic Center at all, the test occurs too late in the development cycle for the results to stimulate economical materiel revisions. Fourth, the last statement quoted gives impetus to the viewpoint that cold regions testing is only necessary for materiel designed for "priority or high density employment" in cold regions.

AR 70-38, Reasearch and Development, Test and Evaluation of Materiel for Extreme Climatic Condition

AR 70-38 is the only regulation devoted entirely to research and development, and test and evaluation of materiel under the range of natural climatic conditions. As was the case with AR 70-10, AR 70-38 defines responsibilities in a very general manner. In addition, the assignment of responsibilities includes no more than selected DA staff and major commanders.

The regulation defines regions of the world in terms of eight climatic categories. With each category is associated ranges of temperatures and humidities that reflect diurnal extremes (highest and lowest values in a 24-hour cycle Table 4.1)).

TABLE 4.1.–SUMMARY OF TEMPERATURE, SOLAR RADIATION, AND RELATIVE HUMIDITY DIURAL EXTREMES

	Operational Conditions			Storage and Transit Conditions	
Climatic Category	Ambient Air Temperature °F (°C)	Solar Radiation BTU/Ft² /Hr	Ambient Relative Humidity Percent	Induced Air Temperature °F (°C)	Induced Relative Humidity Percent
1 Wet-Warm	Nearly Constant 75 (24)	Negligible	95 to 100	Nearly Constant 80 (27)	95 to 100
2 Wet-Hot	78 to 95 (26 to 35)	0 to 360	74 to 100	90 to 160 (32 to 71)	10 to 85
3 Humid-Hot Costal Desert	85 to 100 (29 to 38)	0 to 360	63 to 90	90 to 160 (32 to 71)	10 to 85
4 Hot-Dry	90 to 125 (32 to 52)	0 to 360	5 to 20	90 to 160 (32 to 71)	2 to 50

Climatic Category	Operational Conditions: Ambient Air Temperature °F (°C)	Solar Radiation BTU/Ft² /Hr	Ambient Relative Humidity Percent	Storage and Transit Conditions: Induced Air Temperature °F (°C)	Induced Relative Humidity Percent
5 Inter-mediate Hot-Dry	70 to 110 (21 to 43)	0 to 360	20 to 85	70 to 145 (21 to 63)	5 to 50
6 Inter-mediate Cold	-5 to -25 (-21 to -32)	Negligible	Tending Toward Saturation	-10 to -30 (-23 to -34)	Tending Toward Saturation
7 Cold	-35 to -50 (-37 to -46)	Negligible	Tending Toward Saturation	-35 to -50 (-37 to -46)	Tending Toward Saturation
8 Extreme Cold	-60 to -70 (-51 to -57)	Negligible	Tending Toward Saturation	-60 to -70 (-51 to -57)	Tending Toward Saturation

The selection of diurnal temperatures is based on what is termed the "One Percent Risk Policy". The intent of the policy is to guard against the excessive costs of, designing, developing, and testing materiel to withstand the most severe extremes that can occur within a region. These most severe extremes are those which have not more than a one percent probability of being exceeded during the worst month at the worst location for the climatic category. For example, in a category 6 region, materiel should be expected to operate at -25°F (-32°C). The Department of Army accepts a "one percent risk" that in a category 6 region temperatures may fall below -25°F (-32°C) and therefore cause equipment failure. In addition to the "Risk Policy", AR 70-38 contains some other policy statements of significance. According to the regulation, climatic requirements for operation, storage, and transit of materiel will be stated in all requirements documents; however, such climatic requirements will not be overly stringent since they can have a substantial impact on acquisition and support costs and configuration. The regulation also states that standard general-purpose materiel will be designed to operate safely and effectively in climatic categories 1, 2, 5, and 6. Materiel for use in other climatic categories will be provided by designing: (a) standard materiel capable of such use; (b) special materiel exclusively for such use; (c) modification kits which adapt standard materiel for other specified climatic categories. Finally the regulation directs the use of test sites which have the extreme climatic conditions specified for the eight climatic categories.

There appears to be no misunderstanding of the requirement for Climatic Center testing with regard to materiel developed specifically for use in extreme cold regions (categories 7 and 8); however standard general purpose equipment is required to operate in category 6 which means, applying the "Risk Policy", that materiel should be tested and operate at temperatures down to -25°F (-32°C); but AR 70-38 does not require Climatic Center testing in category 6. This shortcoming combined with the regulation's prohibition on "overly stringent" climatic criteria in requirements documents allows the conclusion to be reached that alternatives to Climatic Center testing such as similated environment (chamber) tests are all that is really necessary. In fact, the regulation encourages simulated tests, and states that "when climatic conditions during field test are not as extreme as the climatic conditions specified in the relevant climatic categories . . . consideration will be given to test results under-simulated extreme conditions."

The need and location for Climatic Center testing of general purpose materiel in category 6 extremes should be obvious. Figure 1.2, chapter 1, shows the climatic categories superimposed upon a world map. As has been previously noted, category 6 regions may be approximated as areas north of 40th parallel which roughly divide Asia, Europe and the United States. It is particularly important to realize that temperatures freezing and below are common in category 6 highly industrialized and populated areas of Europe, Russia, Red China, and Korea; all locations where the U.S. Army has or could fight. At present the Cold Regions Test Center is the only Army Climatic Center capable of testing a wide variety of materiel in temperatures from 32°F(0°C) to -25°F(32°C) on a sustained basis. While temperatures ranging and holding below 32°F(0°C) are relatively rare in CONUS, temperatures below 32°F(0°C) exist more than 80 percent of the time during the winter months in interior Alaska. The waiting time for proper test conditions is reduced and the equipment is subjected to the full range of synergetic effects of an adverse environment.

It must be pointed out that many of the policy problems discussed may be solved by the revision of AR 70-38 currently in progress. Under the auspices of the U.S. Army Topographic Laboratories the AR is being changed to make it compatible with MIL-STD-210B, dated 15 December 1973.

Published Sources of Doctrine

Field Manuals (FM) and Training Circulars (TC)

The FM's and TC's used by the Army as a whole relate to specific subject areas such as tactics, survival, etc. These manuals have a Temperate Zone base line, but include summaries which relate the subject to climatic and topography differences. For example, FM 21-26 "Map Reading" explains map reading in the total environment to include the tractless arctic and heavily forested taiga. However, the techniques of map reading that require special treatment, e.g. pacing while on skis, are covered in FM's and TC's which are cold regions oriented. The following FM's and TC's fit into this category:

FM 30-70	Basic Cold Weather Manual
FM 31-71	Northern Operations
FM 31-75	Riverine Operations
FM 90-6	Mountain Operations
TC 21-3	Soldiers Handbook for Individual Operations and Survival in Cold Weather Areas
TC 36-72-1	Military Mountaineering.

Logistical Doctrine

For each item of Army equipment a maintenance support package (MSP) is developed and evaluated. In production, these MSP's take many forms and vary from instruction tags or decals on relatively simple items, to a series of technical manuals (TM) on a complex hardware item or system. As appropriate, each MSP includes operator instructions, direct and general support maintenance instructions, maintenance allocation charts, repair parts and basic issue items listings and lubrication orders. These publications give specific DA guidance on the use of a given piece of equipment. In the 10-series TM's which are the operators manuals, guidance is presented on how to operate the item under unusual conditions. Cold is specifically covered. For example, how one cold starts or lubricates a specific vehicle is explained in the 10-series TM's. Additionally, the following publications give specific and general knowledge concerning preparing equipment for, and operation of equipment in cold regions.

SB 9-16	General Supply: Winterization Equipment for Automotive Materiel
SB 11-6	Dry Battery Supply Data
SB 700-20	Army Adopted items of Materiel and List of Reportable Items
DA Pamphlet 385-3	Protective Clothing and Equipment
SNL ORD 7-8-9,G249	Winterization Equipment Series
TM 9-207	Operation and Maintenance of Ordnance Materiel in Cold Weather (0°F to 65°F)
TM 9-1300-203/2	Artillery Ammunition
TM 9-2610-200-20	Care and Maintenance of Pneumatic Tires
TM 9-3305-1	Principles of Artillery: Weapons
TM 9-3305-2	Principles of Fire-Control Materiel
TM 9-6140-200-15	Operations and Organizational Maintenance: Storage Batteries Lead-Acid Type
TM 9-800	Principles of Automotive Engines
TM 9-8638	Organizational Maintenance: Spark plugs used in Ordnance Materiel
TM 9-8662	Fuel-Burning Heaters for Winterization Equipment
TM 743-200-1	Storage and Materiels Handling
TM 750-116	Purging and Charging Fire Control Instruments
TM 750-254	Cooling Systems: Tactical Vehicles
TB Med 81	Cold Injuries

TB Med 269	Carbon Monoxide Poisoning, Etiology, Systems, Treatment and Prevention
TB Ord 537	Procedures for Starting Engines with Slave Cable
TB 750-651	Use of antifreeze Solutions and Cleaning Compounds in Engine Cooling Systems
TB Sig 189	Cold Weather Photography
TB Sig 346	Maintenance of Radiac Equipment
TM 5-330	Planning and Design of Roads, Airbases, and Heliports in the Theater of Operations
TM 5-349 Series	Arctic Construction
TM 9-273	Lubrication of Ordnance Materiel
TM 10-275	Cold Weather Clothing and Sleeping Equipment
TM 10-735	Stove, Yukon, M1950

Engineering Guidance

A series of AMCP's have been published titled "Engineering Design Handbook, Environmental Series". This is a five-part series of which four will be addressed: AMCP 706-115, 706-116, 706-119.

AMCP 706-115 (Part one), Basic Environmental Concepts, is a lead-in to the other volumes and is an introduction to the environment faced by the military. It discusses, in general, the importance of the environmental concepts, testing and simulation, and materiel categorization.

AMCP 706-116 (Part Two), Natural Environmental Factors discusses in detail the terrain, temperature, humidity, pressure, solar radiation, rains, solid percipitation, fog and white-out, wind, salt-salt fog, salt water, ozone, macrobiological organisms, and microbological organisms. This provides the design engineer with a body of practical information that will enable him to design materiels so that its performance during use is not affected seriously by the environment.

AMCP 706-118 (Part Four), Life Cycle Environments, this part is directed at the materiel design engineer to (1) alert him to the multiplicity of environmental effects that affect materiel in a given instance, and (2) provide him with sufficient information to identify the specific environmental effects that requires more intensive analysis. The emphasis is on the totality of the factors characterizing a climate, on the totality of effects experienced by classes of materiel, and on the totality of factor combinations experienced in the life cycle-separated into logistics and operational phases.

AMCP 706-119 (Part Five), Glossary of Environmental Terms is the last in a series on the nature and effects of the environmental phenomena on materiel. The purpose of this handbook is to provide precise definitions of words and terms comprising the other four handbooks in the series. The definitions may differ slightly from those found in other references. The definitions, however convey the exact meaning intended when used in context with the environmental series.

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