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14. ABSTRACT
This is an overview TOP and is organized to provide background information on the cold regions environment. In this Test Operations Procedure (TOP) an over view of the location and characteristics of the cold regions are presented along with the effects of cold weather on human physiology and military materiel. This information should be used in preparing for and understanding the need for testing in a cold environment

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COLD REGIONS ENVIRONMENTAL CONSIDERATIONS

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1. SCOPE.

This is an overview TOP and is organized to provide background information on the cold regions environment and the effect of cold weather on human physiology and military materiel. The common characteristics of a cold region are cold temperatures, strong seasonality with distinct changes in insolation, frozen atmospheric moisture, frozen soil, and freeze/thaw of water. Military systems are tested in the cold natural environment to replicate the exposure the systems will have when used by the Soldier in the field. Therefore, the effects described in this document apply to the tester and the equipment under test and the Soldier who uses the same systems. This information should be used in preparing for and understanding the need for testing in a cold environment.

2. BASIC INFORMATION.

2.1 Where the Cold Regions Are Found.

a. The most distinctive and widely recognized element of the cold regions is low air and surface temperatures during the winter months. In fact, the area has been identified solely with these low temperatures even though the temperature fluctuates widely from location to location and from time to time as a function of local atmospheric and terrain influences, seasons, and large scale meteorological systems. The approach taken here recognizes the cold regions as a more complex environment which has, besides cold winter temperatures, specific terrain, vegetation, and latitude or altitude considerations that also define it. Temperate regions and even dry regions may have climate regimes analogous to the cold regions during winter months or at higher elevations.

b. To describe the global scale of the cold regions, this TOP makes use of an ecoregion classification system developed by R. G. Bailey[1*] and based on the broad climate zones defined by W. Koppen[2] (as modified by Trewartha[3]). Bailey's ecoregions, which he calls Domains, are large, regional-scale ecosystems that exhibit common climatic and physical characteristics. The Military Operating Environments (MOEs) shown in Figure 1 are defined as Bailey's Divisions, which are subdivisions of his Domains. In this document Domains are referred to as World Climatic Regions (WCRs) and Divisions are referred to as MOEs.

c. The MOEs shown in Figure 1 are defined not by the extreme temperatures occurring on the coldest days but by considering mean temperatures in the coldest and warmest month, annual precipitation, moisture budget, and the effect on plant development and soil formation. For example, in the Tundra MOE, part of the Polar WCR, the mean monthly temperature for every month, including the warmest, is below 50° F (10° C). In the Subarctic MOE the mean temperatures of one to three of the warmest months of the year are greater than 50° F (10° C). The summer temperature is important to delineate boundaries between these areas as it results in dissimilar frost action and determines plant development and soil formation.

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[*] Superscript numbers correspond to those in Appendix A, References.

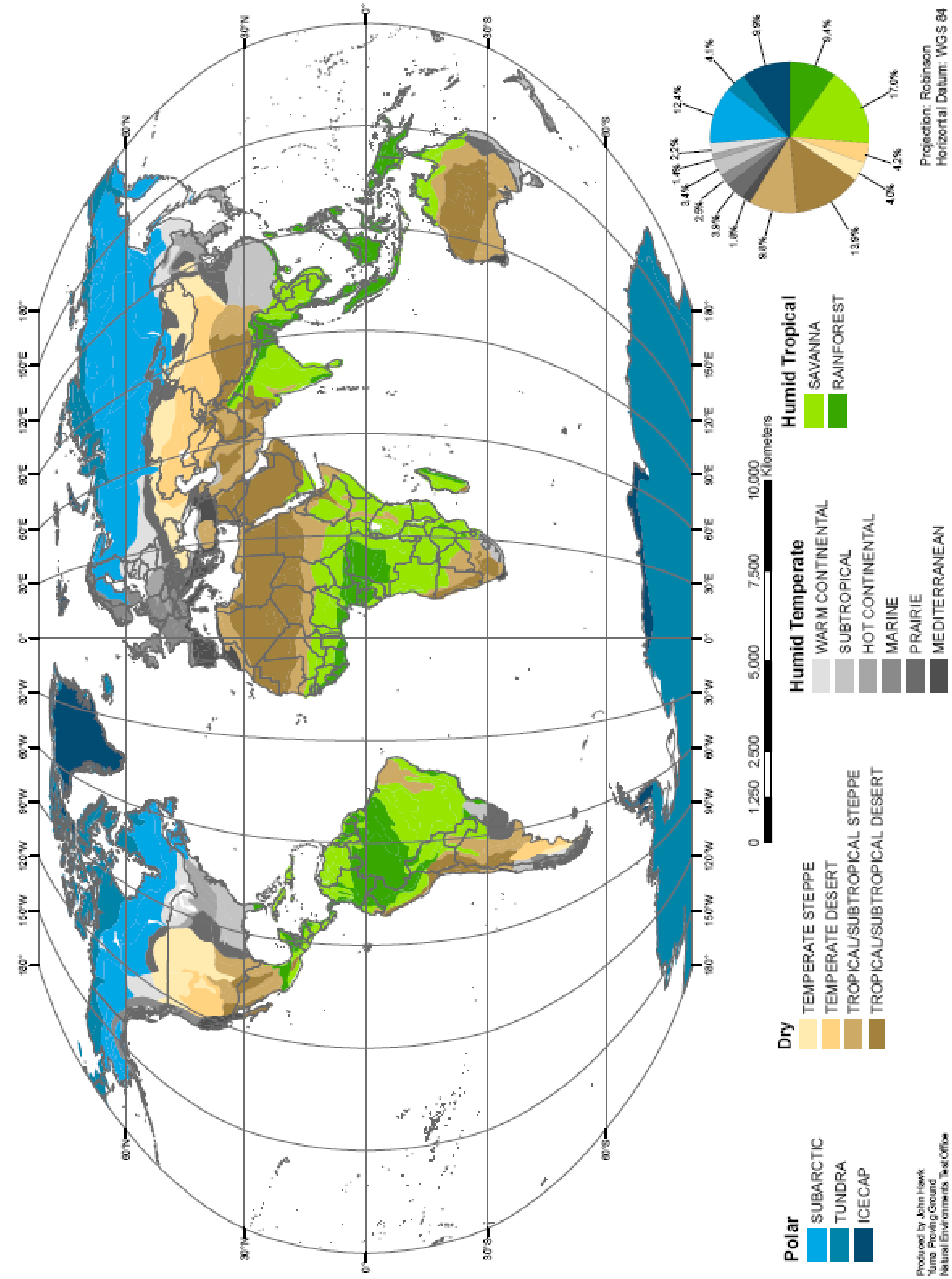

Figure 1. Military Operating Environments (MOE), from Bailey (1998).

d. Clearly the Polar WCR is part of the cold regions. But additional areas within the MOE framework are also cold regions during part of the year. This can be seen by comparing other methods used by the military to describe the cold regions. A description of some of these methodologies follows.

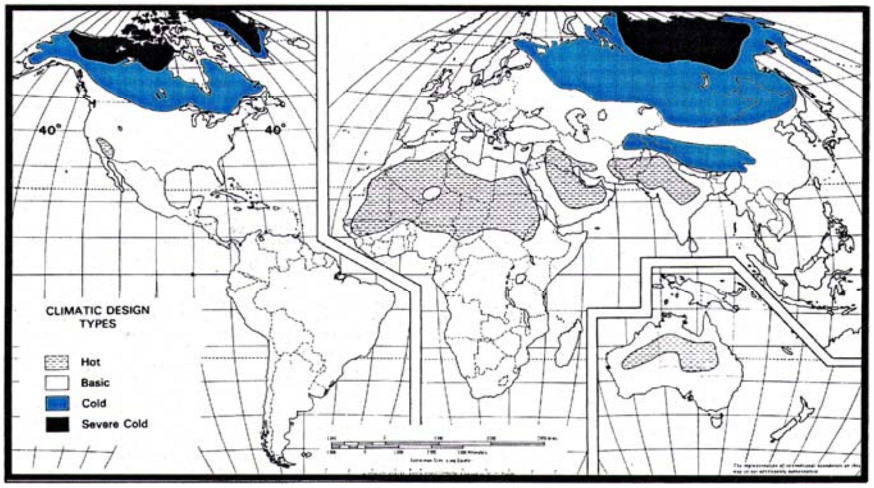

Figure 2 Climate Design Types from Military Handbook 310

e. When considering the area covered by climate design types Cold and Severe Cold, as defined in the Army Regulation (AR) 70-38, dated 1979) and the Military Handbook (MIL-HDBK) 310[4], these areas correspond closely, but not exactly, to the MOEs included in the Polar WCR. A notable difference is the exclusion from the Polar WCR in Figure 1 of the south central region of Asia shown as 'Cold' in Figure 2. This area includes the steppes and desert-steppes of a continental climate and on closer examination, it can be seen that the cold regions of MIL-HDBK 310 also included many mountainous and desert-steppe regions of the northern hemisphere. In the center of the North American continent the line marking the southern edge of the Cold climate design type includes the interior continental region of North America.

f. Other methodologies that have been used to define and describe cold regions have resulted in similar divisions. For example, in 1966, Bates and Billello[5] used a mean annual air temperature below 0° C (32°F), maximum snow depths exceeding 60 cm (24 in), and lakes and rivers ice covered for more than 180 days to define a region that is approximately one-quarter of Earth's land mass (all of Siberia, Greenland, and Antarctica; most of Canada and Alaska; and parts of China and northern Europe). This area corresponds roughly to the Polar WCR. Another one-quarter (including the northern United States and Eurasia) have mean air temperatures during the coldest month below 0° C (32°F). These areas correspond roughly to the warm and hot continental and the temperate steppes and deserts which Bailey likewise defines as having a mean temperature less than 0° C (32°F) during the coldest month. Figure 3 shows the boundary of the area described by Bates and Billelo in relation to the MOE map.

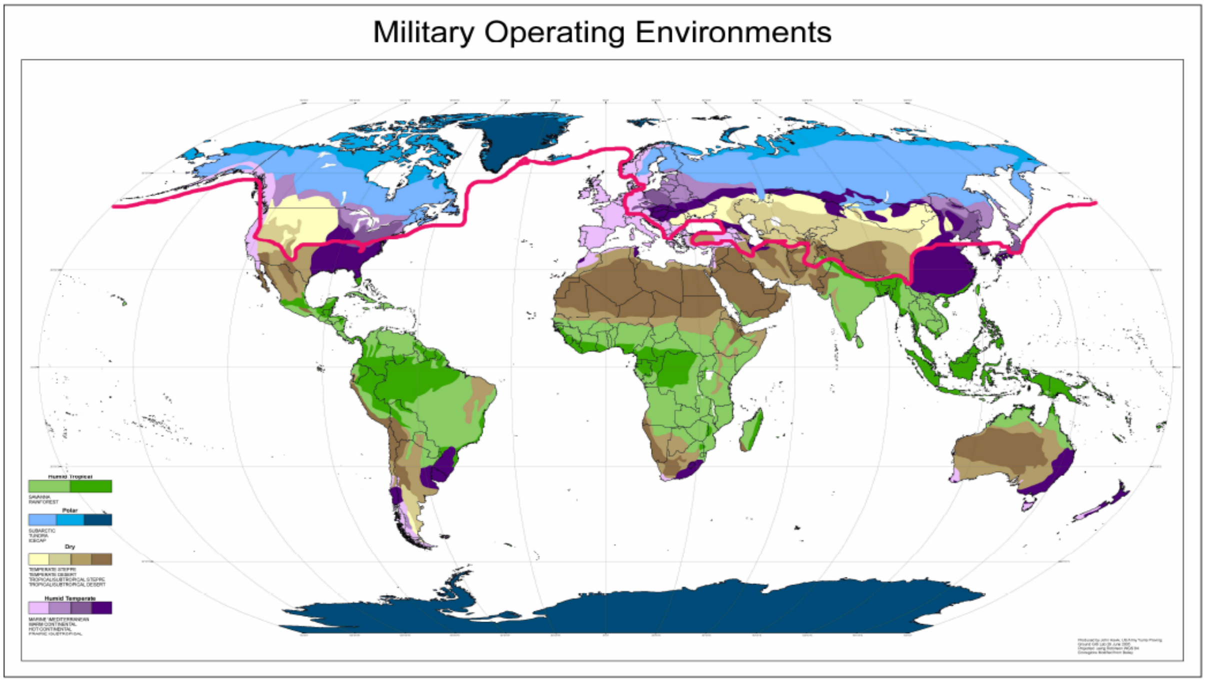

Figure 3. MOEs modified with line depicting mean temperature of coldest month below 0°C (32° F) (adapted from Bates and Billello)

g. Also, the 1975 publication AMCP 706-115, Basic Environmental Concepts[6] indicates that generally the 40th parallel can be considered the southern limit of cold regions in the continents of the Northern Hemisphere. Exceptions are mainly caused by proximity to the ocean and elevation. Major ocean currents may warm the climate of the adjacent land masses, creating a relatively mild Marine division in southeast Alaska and the north-west coast of Europe and Great Britain. 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 America is due mainly to the high elevation in these areas. These are identified as temperate steppe and deserts when using Bailey's classification.

h. Therefore besides the Icecap, Tundra, and Subarctic MOEs, the cold regions are also found seasonally in Warm Continental, Hot Continental, Temperate Steppe, and Temperate Desert MOEs. All these areas are characterized by seasonally cold temperatures, strong seasonality with distinct difference between summer and winter, freeze/ thaw of water occurring on a daily to seasonal time scales, frozen atmospheric moisture (snow, freezing rain), and seasonally frozen soils. These characteristics also result in specific vegetation regimes.

i. The MOE framework provides a useful tool to understand and compare the characteristics of areas worldwide. Areas described by the same MOE, regardless of their location in the world, have similar environmental conditions (Atmospheric/climatic, terrain, and biological/vegetation) and can be directly compared. Therefore, areas available to the U.S. Army for the purpose of testing and/or training are analogous to other areas throughout the world that are described by the same MOE. Materiel RDTE activities can be conducted at accessible analog sites which accurately represent other areas of the world.

2.2 The Environment in the Cold Regions.

a. Temperature: Extremely low temperatures, e.g. sustained temperatures below -40º C (-40º F), can be found during winter months in the Polar region, on the Greenland ice cap, at extremely high elevations, in central Alaska, parts of northern Canada, and Siberia. These winter cold temperatures are encouraged by a combination of low sun angle, short daylight periods, and a highly reflective snow surface creating long, dark winters with bitterly cold temperatures lasting for extended periods. When compared with the Subarctic MOE, the Warm Continental, Temperate Steppe and Temperate Desert MOEs have similarities in temperature, frozen surfaces, and snow cover in the winter and warm temperatures in the summer. But although winter temperature extremes may be similar in both regimes, the Hot and Warm Continental, Temperate Steppes, and Temperate Desert MOEs receive more sunlight in winter and the sun angle is higher. This results in a greater diurnal temperature cycle and shorter and less frequent occurrences of cold temperatures.

b. Moisture: Frozen precipitation is a hallmark of a cold region. In the Polar WCR, moisture tends to be somewhat evenly distributed throughout the year with snow remaining on the ground with little or no melting for 6 or more months. The cold season can be very dry. The amount of precipitation, distribution patterns, and type can be much different at higher elevations and continental MOEs, with a positive moisture balance throughout the year. Temperate steppes and deserts have a positive moisture balance in the winter months only.

c. Vegetation: Vegetation types in the subarctic are primarily forest-tundra, taiga, and open woodlands. The northern edge of the Subarctic MOE (the boundary between the Tundra and Subarctic MOEs) coincides fairly well with the northern limit of tree growth. The southern edge of the Subarctic MOE is marked by the areas dominated by extensive coniferous forests (mainly spruce and pine) mixed occasionally with hardier deciduous species such as birch, aspen, willow, and cottonwood. Most of the trees are relatively small in diameter compared to related species in lower latitudes due to the shorter and cooler growing season in the subarctic division. In the continental MOE, there are mixed deciduous and coniferous forests, or deciduous forests. As indicated above, with a longer, warmer growing season, a positive moisture balance throughout the year, and winter season without long extreme cold, the continental MOE forests are made up of a greater variety of larger trees. The dry conditions encountered during summers in the Temperate Steppes and Temperate Desert MOEs provide only enough moisture for a vegetation regime of short grasses and shrubs or barren areas.

d. Soil conditions: The Subarctic MOE is characterized by discontinuous permafrost in the south, graduating to virtually continuous permafrost in the north. The Tundra MOE is totally underlain by permafrost. Soils can be organic and are usually moist. Soils in the continental MOE can be similar but with the inclusion of subsurface clay soils. Soils are usually moist but may be dry during the warm season. Soils in the Temperate Steppe and Temperate Desert MOEs are often low in organic matter and dry more than 6 months of the year. A key issue in the cold regions is that soils alternate between frozen and thawed states. This is seasonal in the Tundra, and Subarctic MOEs and can occur frequently during the winter season in other MOEs.

e. Table 2.2 shows important environmental factors present in the Polar WCR (adapted from Harmon, et al, 2008[10]). The temporal variability is a fundamental characteristic of cold regions and many of these environmental parameters depend on the freezing and thawing of water. The transition between frozen and thawed states may occur only seasonally as is typical in the Polar WCR or it can occur repeatedly in warm and hot continental MOEs where winter thaws are common. Thirty years of climate data were analyzed to calculate the 5% extreme minimum temperature used in Table 2.2. The 5% extreme was chosen for consistency across all MOEs, including those outside the Polar WCR. The area of the earth considered for analysis and the method of analysis are different than that done for the cold climate category of MIL-HDBK 310 and AR 70-38 (1979). However, the values in table 2.2 are consistent with the low temperatures of the daily cycles used to describe the Cold climate design type.

Table 2.2 Summary of environmental factors commonly found in the Polar World Climate Region

Environmental factors	**Icecap**	**Tundra**	**Subarctic**
5th percentile of extreme minimum temperature	below -50°C	below -50°C	below -50°C
Mean minimum temperature of coldest month	-40°C	-30°C	-25°C
Diurnal temperature range in mid-winter	<5°C	<10°C	<10°C
Mean maximum temperature of warmest month	~0°C	~20°C	~20°C
Diurnal temperature range in warmest month	small	moderate	moderate
Amount of light in coldest month	very limited	very limited	limited
Temporal variation of relative humidity in coldest month	very limited	moderate	moderate
Presence of all phases of H2O, with frequent phase change	present seasonally	present seasonally	present seasonally
Snow and ice (in air and on ground)	present	present seasonally	present seasonally
Snow cover	permanent	persistent	persistent to intermittent
Hydrology (braided streams, variable discharge, seasonal breakup)	limited	seasonally limited	abundant
Hydrology (frozen lakes and bogs)	not present	seasonally abundant	seasonally abundant
Landforms/Physiography - glaciers	abundant	very limited	limited
Landforms/Physiography (ruggedness, exposed bedrock, relief)	very limited	limited	limited to abundant
Soils/Permafrost (wet solid with strong active layer processes)	not present (covered by ice)	continuous	discontinuous
Soils (sediments, loess, dust)	very limited	limited	abundant
Vegetation (boreal forest, taiga)	not present	not present	present
Vegetation (tundra, muskeg)	not present	abundant	limited to alpine areas
Microbiology	very limited	limited	seasonally abundant
Macrobiology (insects, birds, fish, mammals)	limited	abundant seasonally	abundant

2.3 Environmental Factors.

a. As stated above, the most characteristic element of a cold region or other winter environments are the low air temperatures during the winter months. The cold can be intensified by the occurrence of ground based temperature inversions. The white snow covered surface becomes colder than the air mass above it, thus creating a very stable temperature condition with warmer air at higher elevations. The warm air above effectively acts as a lid trapping the colder air below. This situation usually occurs during winter under clear skies with no wind. Another common effect of temperature inversions are optical conditions such as looming (i.e. objects which appear to be much closer and higher than they really are).

b. Windy conditions mix the air thus eliminating temperature inversions but at the same time cause the air to feel colder. This may occur at any temperature but is especially dangerous at colder temperatures. It is important to realize that the air temperature is not actually colder but the wind increases the cooling rate of the ambient temperatures, the difficulty of heating, and the discomfort on humans at those temperatures. The National Weather Service has developed a windchill chart (Figure 4) which provides a comparative guide to the effect of temperatures at various wind speeds. This is a formula based windchill index which takes advantage of science, technology, and computer modeling to provide an accurate and useful method of calculating the effective dangers from winter winds and freezing temperatures.

NWS Windchill Chart

Temperature (°F)

Wind (mph) / Calm	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45
5	36	31	25	19	13	7	1	-5	-11	-16	-22	-28	-34	-40	-46	-52	-57	-63
10	34	27	21	15	9	3	-4	-10	-16	-22	-28	-35	-41	-47	-53	-59	-66	-72
15	32	25	19	13	6	0	-7	-13	-19	-26	-32	-39	-45	-51	-58	-64	-71	-77
20	30	24	17	11	4	-2	-9	-15	-22	-29	-35	-42	-48	-55	-61	-68	-74	-81
25	29	23	16	9	3	-4	-11	-17	-24	-31	-37	-44	-51	-58	-64	-71	-78	-84
30	28	22	15	8	1	-5	-12	-19	-26	-33	-39	-46	-53	-60	-67	-73	-80	-87
35	28	21	14	7	0	-7	-14	-21	-27	-34	-41	-48	-55	-62	-69	-76	-82	-89
40	27	20	13	6	-1	-8	-15	-22	-29	-36	-43	-50	-57	-64	-71	-78	-84	-91
45	26	19	12	5	-2	-9	-16	-23	-30	-37	-44	-51	-58	-65	-72	-79	-86	-93
50	26	19	12	4	-3	-10	-17	-24	-31	-38	-45	-52	-60	-67	-74	-81	-88	-95
55	25	18	11	4	-3	-11	-18	-25	-32	-39	-46	-54	-61	-68	-75	-82	-89	-97
60	25	17	10	3	-4	-11	-19	-26	-33	-40	-48	-55	-62	-69	-76	-84	-91	-98

Frostbite Times: 30 minutes; 10 minutes; 5 minutes

$$\text{Wind Chill (°F)} = 35.74 + 0.6215T - 35.75(V^{0.16}) + 0.4275T(V^{0.16})$$

Where, T= Air Temperature (°F) V= Wind Speed (mph)

Effective 11/01/01

Figure 4 National Weather Service updated chart of the effect of wind on various temperatures (http://www.nws.noaa.gov/om/windchill/index.shtml).

c. Ice fog and blowing snow are serious conditions which occur in the cold regions. Ice fog is a type of fog composed of suspended particles of ice, 20 to 100 microns in diameter. Ice fog occurs naturally at about -40º C (-40º F) but will also occur at higher below-zero temperatures in the presence of sufficient water vapor and airborne particulate matter. Visibility can be dangerously reduced in the worst ice fog occurrences and it may form over areas of human activity, a herd of animals, a convoy of vehicles, and gun positions during firing. Blowing snow is also a serious obstacle to observation and movement.

d. Whiteout is a condition of visibility which exists when an overcast sky prevents shadows, and snow covered terrain reflects light at about the same intensity as the sky causing the horizon to be indistinguishable and the recognition of irregularities in terrain very difficult. Loss of depth perception and the absence of light differences between the horizons, snow covered surface and overcast sky (whiteout) can cause extreme disorientation. Only dark objects can be seen. Fog, ice fog, and blizzard conditions will sometimes create a similar condition.

e. In winter the cold region is extensively covered with snow and ice. Snow depths vary considerably over the region. In the Polar WCR, there are areas with various depths of permanently frozen ground (permafrost) which may have only a very shallow active layer that thaws in the summer. These frozen surfaces are very hard, uneven, and impossible to penetrate during the winter. But, depending on depth of snow and roughness of the surface, they can provide a reasonable surface for cross country mobility when frozen. If these areas are thawed, poor drainage and moist soil conditions create conditions which may quickly become impassible by any vehicle.

f. Low-angle sun and prolonged hours of darkness (during the winter) and daylight (during the summer) are other identifying features of the Polar WCR. The diminished solar radiation in the winter contributes to the cold winters with little variation in daily temperatures. A cold night is not much relieved by sunlight during the day. However, in the summer the long periods of daylight, even though the sun is not directly over head, help sustain warmer summertime temperatures.

g. Moisture is created by a variety of sources, e.g. vehicle exhausts, heating from combustion, human activity, and melting snow. When this moisture comes in contact with cold surfaces it will condense on them. For example, outdoor activity causes moisture from sweat or breathing to accumulate on clothing, eye glasses, and head gear. Equipment that is rapidly brought into a warm area will have moisture accumulate on it.

h. In the high latitudes of the cold regions, there may be severe disturbances in the electromagnetic environment. The northern lights (Aurora Borealis) occur more frequently as one moves north in latitude. They occur over 200 days a year north of 64 degrees latitude whether they are visible or not. The magnetic storms effect magnetic instruments and can both increase and reduce signals in the Radio Frequency band.

3. Military Operational Challenges in the Cold Regions.

3.1 Low Temperatures.

Vehicles begin to experience problems whenever temperatures drop below freezing. Below temperatures of about -20º C (-5º F) problems with lubricants, batteries, and materials can start to be significant. Also, regardless of temperature, the presence of snow cover, ice, frozen or thawing ground, or freezing precipitation frequently creates problems for vehicle travel. It is important to note that daily minimum temperatures can be much lower than monthly means, and snowdrifts can be several times deeper than the average snow cover. The cold region presents particular challenges to a military organization. The winters are very long and mostly dark with bitterly cold temperatures lasting for extended periods. During the middle of winter, the sun is very low in the sky or does not rise at all in the far north. This causes the daily cycle of temperatures to be very narrow. In other words, if it is very cold in the early morning, you cannot count on the sun to warm things up much by afternoon.

3.2 Frozen Soil.

In the winter, solidly frozen permafrost can be traversed by even large, heavy vehicles. The depth of frost creates a very hard surface which when combined with cold temperatures can damage vehicle suspension systems. During the summer, the presence of permafrost can cause mobility problems. The upper layer of soil thaws a few feet down with the underlying permafrost trapping large amounts of water in the thawed layer. Even one or two passes with a vehicle can cause the soil to turn into a slippery mud. The problem is compounded by the fact that the cool temperature of the soil prevents organic matter from decaying, resulting in very poor traction for most wheeled and tracked vehicles.

3.3 Night Operations.

Night operations are the rule in the northern latitude winter not the exception. On clear, cold, windless, moonlit nights, you can hear and see exceptionally well over open snow-covered terrain. However, in a deep snow-covered forest (taiga), it becomes extremely dark. Sunrise, sunset, and the amount of useable light available for operations becomes relative to where you are physically located or going (e.g. in the taiga or in a narrow north-to-south valley, there will be very little useable light for much of the winter season).

3.4 Windchill.

Windchill adds to operational problems by increasing the convective heat transfer rate resulting in difficulty of heating and the discomfort of humans. As noted in paragraph. 2.3. b above, windchill creates an effective temperature much lower than the ambient temperature. It can be extremely dangerous for humans who are exposed to the wind at cold temperatures and it increases the possibility of hypothermia and frostbite.

3.5 Temperature Inversions.

Deep temperature inversions can affect both sound and light transmission and degrade frequency modulated (FM) communications signal strength.

3.6 Ice Fog.

Ice fog greatly limits visibility and can conversely indicate the presence of Soldiers, weapons and vehicles. Ice fog forms when a weapon is fired and in still conditions hangs over a recently fired weapon and follows the path of the projectile. It hinders accurate second round engagement and tracking of the projectile, and serves as a target acquisition aid for enemy gunners.

3.7 Whiteout Conditions.

White out conditions are caused by the absence of light differences between the horizons, snow covered surface, and overcast sky to such an extent that only dark objects can be seen. These conditions lead to loss of depth perception, disorientation, and can create serious safety hazards for vehicle and personnel operations.

3.8 Falling and Surface Snow and Frozen Precipitation.

Frozen precipitation such as snow, sleet, or hail cause a variety of effects on military material are varied, ranging from severe limitation on mobility, decreased visibility, and destruction of communications, to increased stress on personnel and damage to exposed equipment. Vehicle mobility and personnel movement can be impeded by both by falling snow and by the accumulation of snow on the surface. Electromagnetic signal propagation is also affected by falling snow and by snow and ice that accumulates on antennas. Snow loading on buildings or other exposed structures, such as tents, can cause their collapse or failure. Features of the terrain can be obscured by a snow cover affecting cross country navigation and movement.

4. CHALLENGES TO WORKING IN THE ENVIRONMENT.

a. Because a human can only live in a cold environment with appropriate clothing and shelter, much time and energy in cold weather is spent in self-preservation. This recognized fact has implications for testing military equipment in this environment. Test teams must operate test vehicles, conduct firing missions, and perform the tasks necessary to prove the functionality of the system under test. Cold weather directly affects the individual’s performance and makes these tasks more difficult. Under these conditions, the safety of the test personnel has to be the primary concern.

b. All tests in a cold environment require an understanding of the effects of a cold environment on personnel. If personnel become cold during the conduct of a test; they will want to get warm, attention to the test will falter, data collection may suffer, and test procedures may be hastened in order to complete the test and get into a warm shelter. Because of these very natural results, it is important to exercise leadership and pay attention to all personnel conducting tests. Additional information is provided in TOP 1-1-003[7].

4.1 Cold Weather Clothing.

Bulky cold weather clothing restricts movement and dexterity. Cold weather clothing systems are based on insulation, layering and ventilation. Insulation is the primary means to slow heat transfer from the body heat to the cold environment. It is important to keep clothes clean, since when clothing is dirty the material tends to pack down and compromise the insulation. Wearing clothes in multiple layers allows the individual to adjust how much they are wearing to accommodate changes in physical activity or the environment. Clothing must be kept dry so it is important to avoid overheating which increases perspiration and moisture buildup in clothing. Ventilation is therefore critical to allow moisture to evaporate in order to keep clothes dry.

4.2 Cold Weather Injuries

a. The cold weather injuries related to exposure to cold and the resulting loss of body heat include hypothermia, frostbite, frostnip, trench foot, and chilblains.

(1) Hypothermia which is the general lowering of the core body temperature and frostbite which is freezing of tissue beneath the skin are serious cold weather injuries which can be life threatening and are difficult to reverse without immediate medical attention.

(2) Trench foot, a non-freezing injury caused by prolonged exposure of the feet to damp, cold conditions above the freezing point, is also serious and may result in permanent nerve damage and gangrene if left untreated.

(3) Frostnip which is freezing of the skin surface only is painful but often not damaging. However, it must be treated seriously as it may be the first signs of possible frostbite.

(4) Chilblains are ulcers or red, swollen skin on the hands and feet. It can develop quickly on skin exposed to cold/wet conditions but generally causes no permanent damage or health risk.

4.3 Dehydration.

The requirement of the individual who is working in the cold for water is high during cold weather testing. Depending on level of activity, individuals can become dehydrated due to sweating, respiratory losses in dry air, decreased thirst, cold-induced diuresis, and conscious under-drinking.

4.4 Shelter.

A heated shelter should be available for personnel when conducting test operations in the cold. Depending upon work levels and the temperature and wind conditions, it may be necessary to divide tasks into shorter segments to allow for breaks to re-warm in a heated shelter.

4.5 Exhaustion.

Maintaining core body temperature while working in the cold environment can be physically tiring over a period of time. The combination of exhaustion, cold, and dehydration can lead to the more serious consequences of hypothermia and frostbite, not to mention the possibility of incomplete or inaccurate tests, damage to equipment, or other injuries to personnel.

4.6 Leadership.

Good and knowledgeable leadership is critical. Cold weather operations demand a well organized plan so individuals understand the tasks required. It is important to anticipate and understand the effects of working in the cold environment on the equipment and personnel. Early planning builds efficiency into the test conduct, reduces wasted effort, and helps alleviate the difficulties encountered when operating in a cold environment. In all cases using a 'buddy' system to make sure personnel aware of all individuals that are out in the field is also required. All personnel should watch each other closely for signs of hypothermia, frostbite, other cold injuries, dehydration, and exhaustion.

5. MATERIEL EFFECTS.

The cold environment presents a severe challenge to the performance of all military systems, other equipment as well as personnel. Though most often associated with the effects of temperature, the challenge also includes the detrimental effects of snow, ice, and frozen or thawing ground. Equipment malfunctions occur more frequently in cold regions and often for reasons different than those experienced in more temperate environments. Some of the more common problems are listed below. Cold weather adaptation kits, materiel, and procedures for operation in cold weather environments below -31° C (-25° F) are often required. Additional information on the effects of the cold environment on materiel is provided in TOP 1-1-005.

5.1 Effects on Material.

a. Metals become brittle at cold temperatures. Therefore, metal parts cannot withstand the same shock and vibration loads they can sustain at higher temperatures. Different metals expand and contract at different rates for a given change in temperature causing changes in clearance and tolerances, which can effect item operation, bearings, gears, dissimilar metals mechanically fastened together, tolerance between threaded fittings, and adds to the problems of seals leaking, poor fit of rubber covers, and leaks in coolant lines, for example.

b. All chemical reactions slow down as the temperature decreases. This causes, for example, propellant to have a slower burning rate as temperatures decrease. The slowed chemical reactions cause the available energy in a cold-soaked battery to sharply decrease so that the battery may be inadequate to power or start equipment. Cold batteries also have a slower rate of recharging. Discharged batteries are more subject to freezing and if frozen, must be thawed completely before attempting to recharge.

c. Rubber, plastic, and other manmade fabrics and materials become more brittle and less resilient to stresses. Under this condition, fuel hoses may crack increasing the potential for fuel spills. Extreme care must be used when handling cables at cold temperatures, protecting the cable from shock loads and bending which can easily cause breaks in the covering. It can be almost impossible to recoil cables once they are cold soaked without re-warming them.

d. Lubricants, fuels, and hydraulic fluids increase in viscosity as temperatures decrease. Unless properly specified for operations in a cold environment to extreme cold temperatures, they can gel or solidify, damaging or making equipment inoperable. JP-8 for diesel engines will properly atomize for the correct fuel-air mixtures but there may still be a difference in the viscosity of fluids as temperatures get colder even though they have been developed for cold operations.

e. Fabrics, like canvas, can become extremely difficult to fold or smooth out in cold temperatures and in some cases must be warmed first. Plastics become brittle in cold weather and may break as a result of cold and vibration.

f. Snow, ice, and frozen ground dramatically alter the propagation of acoustic and seismic energy and IR / MMW signatures. This greatly reduces the effectiveness of weapon systems and sensors.

g. When any item such as weapons, sighting, and fire control materiel, parts, or assemblies are brought indoors after having been outside at low temperatures, water vapor in the warm air condenses on the cold parts. The condensation causes corrosion if not immediately removed. In some cases, permanent damage may occur.

5.2 Effects on Equipment.

Cold operations will have some adverse effect on all equipment. The properties of the component material and its reaction to cold will determine the combined effect on equipment use and operation. Additional information on the effects of the cold environment on the operation of equipment is provided in TOP 1-1-005, Cold Regions Materiel Effects[8].

a. All subsystems of a vehicle, e.g. engine staring and operation, brake system, suspension, tracks or tires, may be adversely effected by the cold, before, during, and after operations. Common problems include:

(1) Engines: Military equipment must operate without modification to temperatures of -32° C (-25° F) (ref AR 70-38[9]). Below this temperature, modifications, such as an external heat source may be used to warm an engine prior to staring. Diesel engines are particularly

difficult to start in cold weather without preheating the intake air, providing direct combustion chamber heat, or raising the compression ratio.

(2) Moisture released from compressed air may freeze in the tank, lines or valves of the air brake system and prevent proper brake operation. Condensation that accumulates between brake shoes and brake drums while the vehicles is moving may freeze when the vehicle stops, making it impossible for the vehicle to move again. Air valves on the Central Tire Inflation Systems (CTIS) common to many vehicles may freeze and fail to operate properly.

(3) Ice and snow adhere to tracks, hindering operation and reducing traction. Snow and ice can also accumulate under wheel wells and in sufficient quantities to impede turning and maneuver of wheeled vehicles.

(4) Shock absorber may not operated correctly in cold weather because of increased viscosity of the fluid, the seals in the shock absorber leaking, and metal becoming brittle. This results in increased stress on other suspension parts, broken shock absorbers, and contributes to a harsh riding vehicle.

(5) Tires become rigid in the cold, developing flat spots when parked.

(6) Springs become brittle and break easily at low temperatures.

(7) Hydraulic systems may have a slow response because of the increased fluid viscosity. This can affect power steering systems, automatic transmissions, and other hydraulically activated systems.

b. Weapons are also affected by common conditions of the cold regions and the resulting effects on material properties, e.g. increased viscosity of lubricants and hydraulic fluids causing slow response, accumulation of frozen moisture, breakage of cable insulation, and failure of seals. Additional problems include:

(1) Propellants in munitions may have a slower burn rate because of the slowed chemical reactions.

(2) Ice fog resulting from the exhaust from weapons firing reduces visibility in the immediate area and may prevent tracking.

(3) Howitzer spades are difficult if not impossible to emplace in frozen ground. Also frozen ground increases the stress to the weapon during firing. In softer ground, much of the shock of firing is absorbed by the ground and not by the weapon. The opposite happens when the ground is frozen and much of the shock will be absorbed by the weapon resulting in additional movement and possible damage to the weapon.

c. Communication and Information Systems may often require proper heating to above freezing temperatures to operate at all. Most computers and computer displays are not designed to operate at cold temperatures and are generally unavailable for use until warmed. Displays when first turned on are faint and difficult to read. All communication systems may be affected by the difficulty in establishing an adequate ground, static buildup, noise interference, and magnetic storms common in the high latitude environment. Electromagnetic signal propagation is adversely affected by falling snow, snow or ice accumulation on antennas.

d. Small arms, optical systems, and other equipment used, worn, or carried by the Soldier can be adversely effect by the cold environment. Besides the hazards to Soldier health caused by the cold, equipment may be difficult to use because of material changes in the cold. Some examples follow.

(1) Seals on NBC protective masks may harden and fail and moisture from warm breath may freeze on lenses, eye pieces, and optical equipment.

(2) Exposed metal surfaces on small arms require more frequent application of smaller amounts of lubrication to remain functional and condensation forms on weapons when they are taken from the cold environment into a warm shelter. Condensation that is not dried can refreeze when the weapon is taken back into the cold temperatures

6. SUMMARY.

The cold region is a complex environment that has major impacts on personnel and equipment. To mitigate these impacts and to keep personnel and equipment operating safely and effectively, knowledge of the environment is necessary. Additionally, operations require leadership that is well versed in the environment, its risks to personnel and equipment, and the methods to mitigate those risks. An understanding of the environment and its effect on personnel and materiel provides the ability to anticipate and overcome any potentially adverse consequences. This understanding combined with leadership will allow safe testing of military equipment

APPENDIX A. REFERENCES.

1. Bailey, R. G. (1998) Ecoregions: the Ecosystem Geography of the Oceans and Continents. New York: Springer-Verlag.

2. Koppen, W. (1931) Grundriss der klimakunde Berlin: Walter de Gruyter.

3. Trewartha, G. T. (1968) An Introduction to Climate, 4th ed. New York: McGraw-Hill.

4. Mil Handbook 310, Global Climatic Data for Developing Military Products, June 1997.

5. Bates, R. E., and M. A. Billello (1966) Defining the Cold Regions of the Northern Hemisphere U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, New Hampshire, Cold Regions Technical Report 178.

6. AMC Pamphlet, AMCP 706-115, Engineering Design Handbook, Basic Environmental Concepts Part 1, April, 1975, DTIC Accession Number AD0784999.

7. Test Operations Procedure (TOP) 1-1-003, Cold Regions Personnel Effects, 15 September 2008.

8. TOP 1-1-005, Cold Regions Materiel Effects, 22 September 2008.

9. Army Regulation (AR) 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions, 15 September 1979.

10. Harmon, R. S., Palka, E. J., Collins, C, Doe, W., McDonald, E. Redmond, K, Ryerson, C, Shoop, S, Spears, L, Sturm, M, 2008, Scientific Characterization of Cold Regions Environments for Army Testing of Materiel and Systems and a Technical Analysis of Interior Alaska, (to be published September 2008).

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