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14. ABSTRACT
This Test Operations Procedure (TOP) provides background information on testing of military systems for operation in the cold regions. Information is presented on the effects of the cold environment on materiel and Military Systems. Materiel covered includes tank/automotive systems, weapons, soldier systems, support equipment, communications and information systems equipment, and small arms. This is an overview TOP and is organized to provide knowledge on what material effects can be expected in order to safely conduct tests in the cold environment.

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TEST OPERATIONS PROCEDURE

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COLD REGIONS: MATERIEL EFFECTS

*This TOP supersedes TOP 1-1-005, dated 13 October 1984.

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1. SCOPE.

This document provides background information on the test and evaluation of Army materiel in the cold regions and general guidance for operating equipment in these environments. Information is presented to familiarize testers, operators and crews on special procedures and techniques and supplemental devices designed to adapt materiel for operation and use under cold conditions. Materiel covered includes wheeled/tracked and special purpose vehicles, NBC protective equipment, communications and information systems equipment, weapons, munitions, fire control, and soldier equipment. Further guidance can be found in Field Manual (FM) 9-207[1*], Operations and Maintenance of Ordnance Materiel in Cold Weather. This is an overview TOP and is organized to provide needed knowledge on what material effects can be expected in order to safely conduct tests in the cold environment.

2. BASIC INFORMATION.

2.1 Effects on Materiel.

Most military materiel is designed to operate without modification at ambient (i.e. the surrounding air) temperatures down to -32 °C (-25 °F) and with modification to -46° C (-50° F). At these temperatures, it is important to be prepared for changes in materiel. All equipment must be maintained in the best mechanical condition in order to withstand the added difficulties of operating properly during sub-zero operations. Following are a few of the common material effects.

a. Antifreeze, fuels, hydraulic fluids, lubricants. Operating in the cold environment will require increased use of petroleum, oils, lubricants and fuel because of increased idling, increased heating needs, and difficulty in movement resulting in less efficient operation. 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 harden, damaging or making equipment inoperable. According to the FM 9-207, antifreeze, hydraulic fluids, and lubricants must be specified for cold operations at temperatures to -54° C (-65° F). There can still be a difference in the viscosity of fluids as temperatures get colder even though they have been developed for cold operations. For example at these temperatures, JP-8, which is the single fuel used in military diesel engines, should atomize for the correct fuel-air mixtures in these cold conditions but there may still be difficulty with combustion and gelling.

b. Batteries. Because chemical reactions proceed more slowly as the temperature decreases, a cold soaked battery’s available energy sharply decreases and depending on the power draw may be inadequate to power or start equipment. In addition, cold batteries have a slower rate of recharging because of the slowed chemical reactions. Discharged batteries are more subject to damage because of freezing. A frozen battery must be thawed completely before attempting to recharge.

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

c. Metals become brittle at cold temperatures. Therefore, metal parts cannot withstand the same shock loads they can sustain at higher temperatures. Different metals expand and contract at different rates for a given change in temperature. This may lead to a change in clearance and tolerances, which can effect item operation. This may affect bearings, different metals that are mechanically fastened together, gears of different metals, tolerance between threaded fittings which may vibrate and loosen, and adds to the problems of seals leaking, poor fit of rubber covers, and leaks in coolant lines to name a few problems.

d. Rubber and synthetic rubber gradually stiffens as it cools although it may retain most of its elasticity until about -29° C (-20° F). It will continue to remain somewhat flexible until approximately -51° C (-60° F), when it becomes brittle. Also, rubber can become brittle if it remains at -29° C (-20° F) over a long period of time. Under these conditions, care must be used when handling cables and hoses. Hoses may crack increasing the potential for fuel, oil, and other fluid spills and the polymer covering on cables may break from shock loads and bending. It can be almost impossible to recoil cables or rubber hoses once they are cold soaked without re-warming them.

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 and other polymers become brittle in cold weather and may break as a result of cold and vibration.

f. Because chemical reactions slow down as the temperature decreases propellant has a slower burning rate.

2.2 Winterization Equipment.

In cold temperatures, kits may be required to allow operation without degradation in the mission or the materiel. If the material is adversely affected by the cold then these kits must be used to attempt to add heat and/or conserve heat. These kits may accomplish one or more of the following:

a. Provide protection for sensitive components from the cold environment. In the case of electronic equipment, computers, computer displays, etc., the electronic equipment must be allowed to warm from several minutes to several hours. These systems will generally rely on heat provided by the vehicle in which it is installed.

b. Provide capability of prompt and reliable starting and warm-up of equipment.

c. Maintain internal temperature in the equipment high enough for efficient operation and reasonable reliability and durability with minimum increase in maintenance.

d. Provide protection, reasonable comfort, and visibility for the crew.

e. Minimize heat loss from sensitive components such as engines and batteries when not operating.

3. EFFECTS OF THE COLD ENVIRONMENT ON EQUIPMENT.

3.1 General.

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.

3.2 Wheeled, Tracked, and Special Purpose Vehicles.

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. Appropriate attention must be paid to these subsystems.

a. Engines.

Military vehicles are required to start without additional heat source down to -32° C (-25° F). Below this temperature, a heat source to warm the engine may be used. For gasoline engines, a successful start in cold weather requires that the viscosity of the engine lubricating oil permit cranking, and that the battery be fully charged and warm enough to supply adequate cranking current and ignition spark. Diesel engines are particularly difficult to start in cold weather without preheating the intake air or using other means of raising combustion temperature. Since the air is heated by compression, it must attain a temperature hot enough to ignite the injected fuel. This preheating can be accomplished as follows, however in all cases follow the operator's manual for starting and operation in the cold. Ensure all preheating systems, such as glow plugs or fuel fired preheaters, are operating properly prior to use.

(1) Use air manifold heaters when the engine is turned over. Switch off the air manifold heater when the engine starts.

(2) If so equipped, operate the engine coolant fuel-fired preheater for the prescribed amount of time before starting.

(3) Use glow plugs to pre-heat the air in the cylinder prior to starting the engine.

(4) Inject chemicals, such as ether, which more easily ignites at low temperatures...

(5) Raise the compression ratio to increase the charge temperature.

b. Brake Systems.

(1) Hydraulic brakes generally use a brake fluid which is capable of all season use.

(2) Air brakes can be seriously affected by cold temperatures. Moisture released from compressed air may freeze in the tank, lines or valves. This frozen moisture in the brake system may prevent proper brake operation. Brake lines, air brake filters, brake chambers, pushrods, valves, and seals are all subject to more defects and failure in cold. Condensation that accumulates between brake shoes and brake drums while the vehicles is moving may freeze when the vehicle stops, making it difficult for the vehicle to move. Army vehicles, including the Family of Medium Tactical Vehicles (FMTV), Heavy Equipment Transporter (HET), Palletized Load System (PLS), and High Mobility Multi-Purpose Wheeled Vehicle (HMMWV) heavy variant, have Central Tire Inflation Systems (CTIS) that operate off an air compressor. It is not unusual for frozen air valves and air leaks to cause locked brakes or flat tires.

c. Tracks: Ice and snow adhere to tracks, hindering operation and reducing traction. When operating in snow-covered and icy terrain, it may be necessary to remove track pads and/or employ traction aids (such as reversing every third track center guide or using ice cleats). Tension on tracks must be adjusted to accommodate metal contracting in cold temperatures.

d. Shock absorbers may not operate 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 a vehicle which usually has a harsher ride, causes increased stress on other suspension parts, and can brake shock absorbers. To prevent damage to the shock absorber, the operating rod, or the mounting brackets during extreme cold, it may be necessary to operate the vehicle slowly for the first few miles until the oil in the shocks warms.

e. Tires become rigid in the cold, and at temperatures below about -40° C (-40°F) after being parked in one spot, the tires may develop flat spots where the tire is in contact with the ground. The tires will round out when the vehicle moves and the tires warm but this will also cause additional vibration. Extreme cold temperatures can cause sidewalls to become brittle and to crack.

(1) Tires must be inflated to the proper pressure but since tire pressure changes with temperature, a tire inflated to the correct pressure indoors will have lower pressure outdoors at a cold temperature. Generally, tire inflation should be checked in the cold and adjusted appropriately. As stated above, CTIS may fail to operate properly and maintain adequate pressure.

(2) Snow and ice can accumulate under wheel wells and in sufficient quantities to impede turning and maneuverability.

f. Springs become brittle and break easily at low temperatures. Mechanical fasteners, moving parts, and systems subjected to high stresses must be in good condition and correctly and securely mounted.

g. 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.

h. Air filters can become plugged from wind blown or falling snow or from vehicle movement over snow covered roads and trails.

3.3 NBC Protective Equipment.

a. Material used in protective equipment can become brittle, crack, and tear easily in the cold. Because of the changes in material properties, seals may leak. Moisture or frost may accumulate on the mask lens and in valves.

b. Filters on air handling systems can become plugged with snow because of wind blown or falling snow. On NBC vehicles, as noted above, vehicle movement over snow covered roads and trails may result in plugged filters.

3.4 Communications and Information Systems Equipment.

Cold temperatures, dry air, condensation resulting from rapid temperature changes (e.g. moving from outside to indoors), frozen ground, snow, visibility, and electromagnetic conditions can all effect communications, computers and electronic equipment. Electronic systems, including communication and computers, must be capable of operation in temperatures to -32° C (-25° F). Electronics have special challenges with respect to this requirement and may often require proper heating to above freezing temperatures to operate at all.

a. 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. This improves as the display warms due to self heating. Most computers in a cold soaked vehicle will not be available until the air inside the vehicle has warmed. In general, all computer systems will need to be operated in a warmed environment or have individual heaters or devices to pre-heat.

b. Communications equipment, including antennas, can be adversely affected by the following:

(1) Grounding problems. It can be difficult to establish an adequate ground for most electronic equipment. It may be impossible to drive grounding rods into the frozen ground and if emplaced, the frozen earth has low conductivity and therefore does not provide adequate electrical earth ground. In general, it is recommended to install any grounding rods or antennas before the ground freezes or use alternative methods.

(2) Static buildup. The cold dry air and poor ground conductivity increase the likelihood of static buildup on equipment and personnel. It is important to discharge any static buildup prior to touching electronic equipment.

(3) Noise interference. This may result from inadequate ground of other electronic equipment, portable generators, or vehicles.

(4) Snow or ice accumulation on antennas. Snow or ice accumulation on antennas and radar systems attenuates signals and interfere with signal propagation.

(5) Magnetic storms. Magnetic storms occur in the ionosphere and are associated with solar disturbances (aurora borealis). They can cause severe static, fading, and blackout of radio signals. The degree to which these disturbances affect radio signals depends on the frequency used to transmit the signal. Low frequency (100-500 KHz) provides the best medium for long distance, point to point radio communications. Higher frequency systems should make use of multiple frequencies to allow changing to a different frequency in the event of a magnetic storm.

(6) When operating in high latitude cold environments, the accuracy of Global Positioning Systems (GPS) (such as the Precision Lightweight GPS Receiver (PLGR)) can be reduced because there are fewer GPS satellites, and most are positioned low in the horizon.

c. Most communication and information system equipment has lower temperature limits at which it can be operated and stored. To prevent damage to equipment if the equipment is left installed in a cold soaked vehicle (for example), the equipment should be allowed to come up to operating temperature before turning on power to it. It may be advisable under some circumstances, to uninstall equipment from vehicles that are being cold soaked.

3.5 Weapons, Munitions, and Fire Control.

Weapons are affected by common conditions of the cold regions and the resulting effects on material properties, e.g. increased viscosity of lubricants and hydraulic fluids, dissimilar metal expansion/contraction rate, accumulation of frozen moisture, and failure of seals. Propellants in munitions may have a slower burn rate. Ice fog resulting from the exhaust from weapons firing reduces visibility in the immediate area and may prevent tracking. The following may occur in weapons (FM 9-207):

a. The increased viscosity of hydraulic or recoil fluids, caused by lower temperatures, causes greater resistance to motion and sluggish response. This results in stiffness of operation and shortening of the recoil cycle.

b. Over-lubricating in cold weather may cause parts to bind, resulting in misfires. It is important to keep machined surfaces clean and not over-lubricated. The proper lubricant must be used to avoid the lubricant becoming too viscous as the temperature drops.

c. Hand wheels on both elevating and traversing mechanisms require greater effort.

d. Gascheck pads fail to seal perfectly and deteriorate rapidly. Scoring of the gascheck seat is possible.

e. Cable insulation and covering may fail when coiled or straightened. Frozen hand brakes on towed weapons may be difficult to release, and attempts to move weapons without thawing may cause serious damage.

f. Equalizing bars and travel locks of towed weapons must be covered or wrapped before towing over snow-covered terrain. The snow and ice buildup which can occur during movement may interfere with moving parts during firing.

g. In cross-country operations, a prime mover with the same tread/track width as the weapon should be used to ensure tracking.

h. Firing lanyards must be kept dry and covered to prevent freezing and breakage.

i. Howitzer spades are difficult if not impossible to emplace in the frozen ground found in the cold regions. Frozen ground is slippery and extremely hard. The majority of the shock of firing is absorbed by the weapon rather then being transmitted into softer ground. This can result in additional movement and possibly damage to the weapon.

j. 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.

k. Snow, ice, and frozen ground alter the propagation of acoustic and seismic energy and Infrared/Millimeter Wave (IR / MMW) signatures. This greatly reduces the effectiveness of weapon systems and sensors which depend on these signatures for target acquisition.

l. Damage to weapons systems and components can be caused by ice accumulation as well as the de-icing techniques, such as tools or de-icing fluids, used to remove ice. Ice on weapon systems with fly through seals can damage the missile and ice accumulation can significantly increase weight and can keep missile storage and transport containers from being opened.

3.6 Soldier Equipment.

a. Optical instruments may fog when the breath of operators or maintainers comes in contact with the eyepiece. Moisture from the breath may freeze on the cold eyepiece. There is no satisfactory antifog solution known for all situations.

b. Small arms: Cold adversely affects the functioning of small arms.

(1) Lubrication: Exposed metal surfaces require more frequent application of smaller amounts of lubrication to remain functional.

(2) Condensation forms on weapons when they are taken from the cold environment into a warm shelter. This can continue for as long as one hour. This is especially serious when it occurs on internal parts of the weapon. Condensation that is not dried can refreeze when the weapon is taken back into the cold temperatures.

4. SUMMARY.

The cold regions environment can cause damaging effects to military equipment and operations because of the response of material to the winter time extreme cold temperatures, low absolute humidity, frozen ground, snow, ice, and magnetic disturbances common to this environment. An understanding of the environment and its effect on material provides the ability to anticipate and overcome any adverse consequences. This understanding combined with leadership well versed in the cold environment will allow complete and safe testing of military equipment.

APPENDIX A. REFERENCES

1. Field Manual (FM) 9 -207, Operation and Maintenance of Ordnance Materiel in Cold Weather (0° to -65°F), 1998

For information only:

a. AMCP 706-116, Engineering Design Handbook, Environmental Series, Part 2, Natural Environmental Factors, April 1975, DTIC Accession Number ADA012648.

b. AMCP 706-118, Engineering Design Handbook, Environmental Series, Part 4, Life Cycle Environments, April 1975, DTIC Accession Number ADA015179.

c. MIL-STD-1472 F (1), Human Engineering, 5 December 2003.

Recommended changes to this publication should be forwarded to Commander, U.S. Army Developmental Test Command, ATTN: TEDT-TMB, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: U.S. Army Cold Regions Test Center, ATTN: TEDT-YPC-CO, PO Box 665, Delta Junction, AK 99737. Additional copies can be requested through the following website: http://itops.dtc.army.mil/RequestForDocuments.aspx, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.