TM 4-33.31

# Cold Weather Maintenance Operations

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## Headquarters Department of the Army

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Technical Manual
No. 4-33.31

Headquarters
Department of the Army
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# Cold Weather Maintenance Operations

## Contents



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# Preface

TM 4-33.31, *Cold Weather Maintenance Operations*, describes principles for planning, establishing, and executing maintenance operations in protracted cold weather environments. Further, this publication describes principles of cold weather maintenance procedures and precautions for equipment operators and their supervisors.

Commanders, staffs, and subordinates shall ensure that their decisions and actions comply with applicable United States, international, and in some cases host-nation laws and regulations. Commanders at all levels shall ensure that their Soldiers operate in accordance with the law of war and the rules of engagement. (See FM 27-10, *The Law of Land Warfare*.)

TM 4-33.31 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text. There are no terms for which TM 4-33.31 is the proponent publication (the authority).

The primary audience for TM 4-33.31 is operational and tactical unit commanders, maintenance leaders, primary equipment operators and their direct line supervisors. It is intended for trainers and educators throughout the Army to also use this publication as a part of their instruction. TM 4-33.31 applies to the Active Army, Army National Guard/Army National Guard of the United States and United States Army Reserve unless otherwise noted.

The proponent of TM 4-33.31 is the United States Army Ordnance School. The preparing agency is the G-3/5/7 Doctrine Division, United States Army Combined Arms Support Command (USACASCOM), of the Training and Doctrine Command (TRADOC). Send comments and recommendations on a Department of the Army (DA) Form 2028 (Recommended Changes to Publications and Blank Forms) to Commander, United States Army Combined Arms Support Command, ATTN: ATCL-TDID (TM 4-33.31), 2221 Adams Ave, Building 5020, Fort Lee, VA, 23801-1809; or submit an electronic DA Form 2028 by e-mail to: usarmy.lee.tradoc.mbx.leee-cascom-doctrine@mail.mil. In addition to submission of DA Form 2028, provide same comments and recommendations in MilWiki for rapid dissemination to doctrine authors and for universal review at: https://www.milsuite.mil.

# Introduction

It is the Army's fundamental purpose to win wars through land force dominance regardless of location or climate. This technical manual (TM) provides general principles and technical guidance for field maintenance, for the operation and repair of equipment under cold weather conditions from freezing down to temperatures below -65 degrees Fahrenheit (°F) -54 degrees Celsius (°C).

This manual assists unit commanders, supervisors (maintenance officers, motor sergeants, and section leaders), and maintenance personnel in anticipating and planning for the onset of cold weather or an arctic deployment.

Operations in cold environments occurs at the limit of what is safe and what is dangerous. Maintainers and operators should refer to the item specific technical manual (TM) or lubrication order (LO) as the primary source of information and guidance for maintenance procedures. Failure to follow this guidance and item specific TMs can result in injury to personnel and damage to equipment, impairing or preventing mission accomplishment. In a field environment, operators must make every reasonable effort to follow TM procedures.

This manual is intended to familiarize equipment operators and item maintainers with information on the unique difficulties that equipment operators and maintainers can expect to encounter in cold weather operations. It shows ways to adjust maintenance operations in cold weather, and the properties of materials they can expect in below freezing temperatures. It provides a consolidated overview of the special and unique difficulties that equipment operators and maintainers can expect to encounter in cold weather operations. Although much of the information in this TM is available in other doctrinal and technical publications, this TM provides a general summary of cold weather operations that ties together and prioritizes ADRP 4-0, *Sustainment*, ATP 4-33, *Maintenance Operations*, FM 4-30, *Ordnance Operations*, and ATP 3-90.97, *Mountain Warfare and Cold Weather Operations*, along with related technical publications into a broad spectrum of best practices for maintainers and equipment operators.

This TM is focused on a combat environment where Soldiers cannot always count on the resources that sustained them in garrison to always be available. In a crises, Soldiers in combat do field expedient things to survive, even if it means destroying equipment to complete a mission and avoid losing their lives. Though such expedient repairs are temporary in nature until more reliable repairs can be performed. Principles in this manual are based on ATP 4-31, *Recovery and Battle Damage Assessment and Repair (BDAR)*. The intent is to stimulate critical thinking that is unit specific, to support development of mission focused standard operating procedures.

During the first Persian Gulf War (1991), one of the fire direction center (FDC) tracks (M577) in an artillery battalion blew a seal on its transmission and lost all its oil, a day after crossing into Iraq on the march to the Euphrates River. To keep his track going, the vehicle chief duct taped the transmission seals, and filled it with engine oil. When the engine oil wept out, he went through 15 gallons of antifreeze. When that was gone, he ran a gallon of water every hour. - - In spite of the vehicle belching smoke as its speed dropped to below 20 miles per hour, the chief followed the advance of his infantry division on its Hail-Mary pincer move. His FDC with its radio capability became the rolling collection point for a conglomeration of broken vehicles limping along to stay in the fight. For two days and 250 miles the FDC chief nursed that vehicle along, always maintaining communication, ultimately rejoining his battalion to play his part in the final battle. That FDC and its crew never quit. Such acts of tenacity and resourcefulness, along with that of many others, contributed to his battalion being awarded the Valorous Unit Citation.

This manual is for commanders who are preparing their troops for the fight; and for the troops working hard to stay in the fight. If the combat situation forces them to resort to a field expedient solution, this manual is intended to help Soldiers make the right decision with the right information. Commanders and leaders must weigh the information in this manual to determine what is relevant to the mission and situation they are confronting. Dealing with cold is not an issue that can be well defined with black and white limits. For some equipment and products, the adverse effects of cold can occur even at temperatures above the freezing point of water. Although this manual deals with temperatures under 40 °F (4 °C), it is slanted toward the severe cold temperatures at about +19°F (-20°C) to -50°F (-45°C).

TM 4-33.31 is written within a very narrow context. The focus of this TM is planning and execution of maintenance operations in severe cold environments. The tactical combat employment of weapons and equipment is beyond the scope of this publication. Likewise, this manual addresses human factor concerns in a general context, but the primary medical guidance source is the U.S. Army Medical Department Center and School (AMEDDC&S).

This is a general subject TM. For item specific equipment operation and maintenance instructions (TMs conforming to, MIL-STD-40051-1, *Preparation of Digital Technical Information for Interactive Electronic Technical Manuals [IETMs]*, and MIL-STD-40051-2, *Preparation of Digital Technical Information for Page-Based Technical Manuals [TMs]*) operators and maintainers must refer to the appropriate operator TM or higher-level manual. Though little is written here about preventive maintenance checks and services (PMCS) doing that is still a very important practice. To avoid redundancy, the focus here is more on general material characteristics. While this TM is much more detailed than its predecessor, TM 4-33.31 (converted from FM 9-207), it does not replace item specific TMs for equipment operations, servicing, or repair. Considering the broad number of subjects covered here, readers should expect that advances in technology will render some of the specifics found in this TM obsolete in a short time. None the less, the principles that underpin this TM ought to remain valid and relevant.

The major changes to TM 4-33.31 include a complete rewrite on the subject of cold weather maintenance management, related to planning staff, operators and the maintainers. Recent industrial changes in electronic, automotive and chemical technologies during the last generation have seen the advent of new synthetics, alloys and microcircuit based computing that compel a fresh version of this manual. This TM is now brought in line with the temperature categories found in ATP 3-90.97. Further, information on petroleum now reflects the Department of Defense Single Fuel Policy as expressed in AR 70-12, *Fuels and Lubricants Standardization Policy for Equipment Design, Operation, and Logistics Support*; and the Single Common Powertrain Lubricants (SCPL) standard found in MIL-PRF-2104K, *Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service*.

The maintenance process for supporting General Service Administration (GSA) supplies, and commercial off the shelf (COTS) items and their appropriate management in cold is reviewed for maintainers. Information on GSA or COTS items that is presented in this TM is only for technical consideration.

TM 4-33.31 contains eight chapters and six appendices. Each chapter is written as a stand-alone treatment of the chapter subject material. Hence, there is some repetition of information and guidance:

**Chapter 1** - *Cold Weather Considerations:* This chapter is primarily intended to provide commanders and leaders with key tasks and an overview of cold weather ordnance operations. Prior planning, proper training, and proper equipment are the keys to successful cold weather operations, even for an unexpected contingency operation. This chapter looks at the situational characteristics of maintenance operations in the cold. Discussion is focused on maintenance planning with a greater emphasis on risk management, quality and safety. This chapter concludes with information and discussion on the Soldier’s working environment and supporting facilities.

**Chapter 2** - *Equipment Maintenance*: Cold weather can have a profound effect on what are otherwise common materials. This chapter provides general information on the properties and performance of parts and materials. Although the information does not delve into materials at the level of chemical structure, the TM information presents a side by side comparison that is of a technical nature. Whereas, most TMs provide a direct step by step procedure, cold operations will require adjustments in procedures. In extreme situations, Soldiers need to be alert to the vulnerabilities, limits, and safety threats the cold poses to the materials they are using. For new technologies, the SCPL is introduced.

**NOTE:** There are a variety of three or four letter military symbol supply codes, which may or may not also be abbreviations or acronyms. This TM will treat these military symbols as whole words.

**Chapter 3** - *Batteries and Electrical Energy Storage*: In the past 15 years, battery technology has experienced a number of scientific discoveries and technological developments. This TM examines the best practices for each type of battery technology.

**Chapter 4** - *Petroleum, Oils and Lubricants (POL) Management*: When Soldiers receive a POL product, they assume it will function, believing that procurement agents have tested and certified the capability of the product. What they need is direct real world answers about the upper limits, lower limits, and storage parameters of the various POL products, without extraneous data. Special attention has been made to introduce Single Fuel Policy (SFP) and address how it might be managed in a cold environment.

**Chapter 5 –** *Vehicle Operation:* This chapter highlights a variety of issues common to the operation of any vehicle or motor in a cold environment. Much of the discussion is focused on starting an engine without damaging the vehicle. Automotive chemistry is presented with consideration toward combat solutions, should Soldiers be faced with limited supply or repair resources. Soldiers need to be prepared to deal with situations where the ideal upper and low limits of policy are confronted with situational reality.

**Chapter 6** - *Small Arms:* This chapter highlights a variety of issues common to maintaining the functional capability of any small arms in a cold environment. Special advice is presented on handling ammunition in conjunction with its designated weapon.

**Chapter 7** - *Weapons, Munitions, and Fire Control Equipment:* This chapter provides an overview of crew served weapons systems. The focus is on how cold threatens weapons (as different from the combat employment of the weapons). These threats are prioritized and examined separately.

**Chapter 8** - *Electrical and Electronic Devices:* Over the last two decades, electro mechanical engineering has undergone a major evolution. However, this new technology is still laboring to address cold conditions. This chapter looks at ways that Soldiers can act to protect and operate Intelligence, Surveillance, and Reconnaissance Operations equipment, including target acquisition devices in cold. Much of the critical operational character of this equipment is not visible to the operator. Likewise, how the cold acts to impede, degrade or damage the utility of such devices can be very abstract. The susceptibility of computers, radios and generators to cold cannot be overstated. Equipment operators have to be very conscientious of which equipment is hardened for field use, and which is not.

**Appendix A** – *Planning considerations for a Unit Maintenance SOP*: Any unit that is expected to encounter operations in a cold weather environment will need to formulate policies, priorities and procedures that are unique to the unit's mission and situation. The list of considerations reiterates planning recommendations already expressed in the body of this manual, and is not proscriptive.

**Appendix B** - *Weather and Climatic Extremes*: Reference information related to worldwide and regionalized climatic extremes. It is presented to give staff planners a rough idea of the types of conditions that can occur, for which they might have to make plans.

**Appendix C** - *Electrolyte Spills*: This information is provided as a quick reference for any reader who has question about what battery maintenance personnel have to be prepared for in the event of an emergency.

**Appendix D** - *Slaving or Jump Starting*: A brief list of best practices for starting a vehicle engine in cold weather.

**Appendix E** - *Properties of Petroleum, Oils and Lubricants (POL)*: A catalog listing the properties of the common POL products used by U.S. ground forces. This list is intended for planning purposes, and will not be exactly the same as the actual products that become available during the course of an actual deployment.

**Appendix F –** *Environmental Protection Concerns:* A reminder for units to comply with federal, state, local, and host-nation environmental regulations. Conformity to such regulations becomes a part of the commander's risk assessment and response planning.

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# Chapter 1

# Planning for Cold Weather

Cold weather has been identified as an enemy of military forces and equipment since the beginning of recorded history. When employed in a cold region, a force actually faces two enemies—the tactical enemy and the geographic environment that aggressively attacks and destroys equipment and Soldiers. Due to the United States (U.S.) global response imperative, Army forces must prepare to operate in a variety of climates, including cold.

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**NOTE:** Maintainers and operators should refer to the item specific technical manual (TM) or lubrication order (LO) as the primary source for maintenance procedures.

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## SECTION I – THE COLD WEATHER CHALLENGE

1-1. Each venture into the cold will have its own unique challenges. The role of leaders begins with ensuring that weapons, vehicles and any other equipment are fully winterized to accommodate the cold, as prescribed by the item TM. However, the TM solutions are only the beginning of preparations for dealing with the cold. Leaders will have to draw upon their years of experience to find viable creative solutions that will contribute to the resilience of their command and fellow Soldiers.

1-2. Over half of the planet's dry land surface experiences freezing cold for at least a month during the year. However, there is the chance that Army forces may be required to conduct sustained operations in temperatures as low as -65°F (-54°C), or lower. For military purposes, a cold region is defined as any area where snowfall or cold temperatures restrict movement or operations for more than one month of each year. Under such conditions, personnel are subject to decreased efficiency and cold casualties, equipment is prone to breakdowns, supply problems may be increased, and operations are restricted and complicated by the environment.

1-3. In cold operations, maintenance issues have command wide implications. To say that something is cold-soaked means that it poses a risk to Soldiers' welfare or that a risk of material damage occurring during moderate operation. Getting ahead of the cold challenge will require adaptive leadership, and innovative or creative thinking. Collaboration will be needed between the maintenance organization and the unit leadership. For maintainers and operators, the challenge is to harmonize the various properties of the divergent materials used in their equipment.

1-4. Unit leaders are responsible for ensuring that personnel and equipment can withstand the challenges of cold weather (temperatures of about +40°F [3°C] or lower). U.S. Army equipment is among the best in the world for use in cold climates. However, Soldiers and their leaders must understand the effects of cold weather and adapt operations and maintenance to overcome environmental conditions.

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**NOTE:** Army regulation and doctrine standards do not specify a minimum temperature down to which military units must be ready to, and capable of operating.

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## SECTION II – COLD WEATHER PREPARATIONS

1-5. Commanders and leaders should be prepared to accept that as temperatures drop below freezing, the unit's ability to maintain its normal high degree of operational pace will decline. This decline is caused by both human factors and materiel factors. This is manageable and success is achievable with good prior planning and adherence to cold weather best practices.

# COLD EFFECTS ON MISSION FUNCTIONS

1-6. Operating equipment in temperatures above 10°F (-12°C) presents few problems. Conditions are similar to those experienced during winter in the northern part of the continental United States (CONUS).

1-7. The Army groups cold temperatures (ATP 3-90.97) into five categories (figure 1-1) below that of temperate weather. The temperature categories are:

- Temperate weather (a nominal temperature that is above and outside the cold weather categories).
- Wet-cold: +39°F to +20°F (4°C to -6°C).
- Dry-cold: +19°F to -4°F (-7°C to -20°C).
- Intense-cold: -5°F to -25°F (-20°C to -32°C).
- Extreme-cold: -25°F to -40°F (-32°C to -40°C).
- Hazardous-cold: -40°F (-40°C) and below.

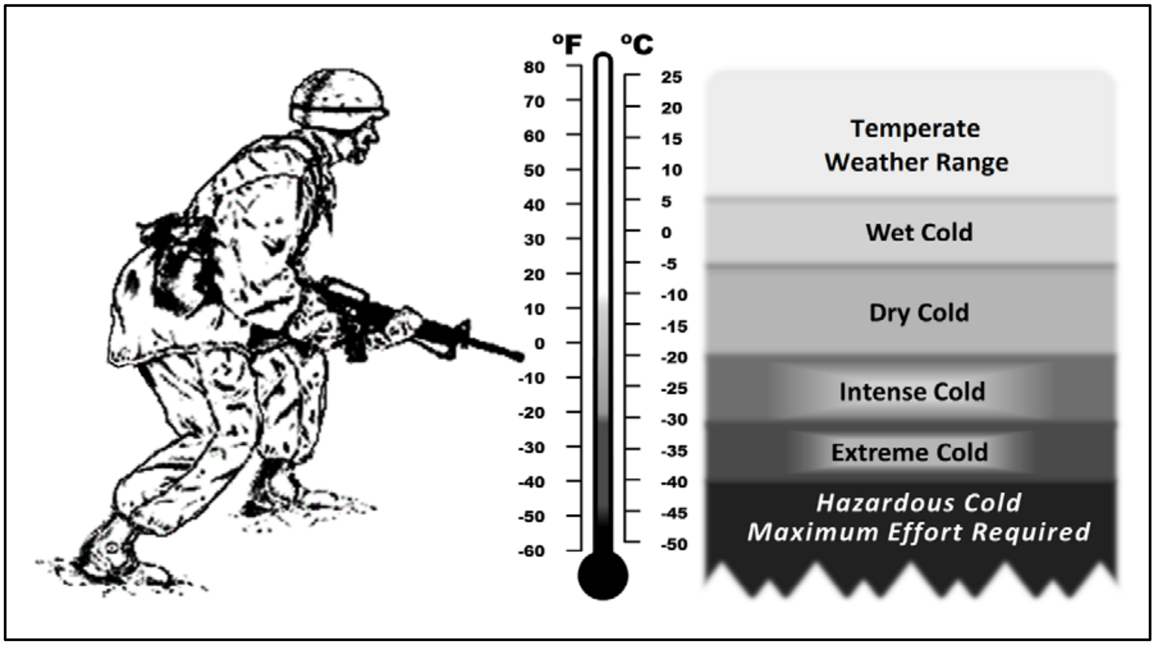


**Figure 1-1. Categories of cold at various temperature ranges**

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**NOTE:** All temperatures and temperature conversions between Fahrenheit and Celsius in this manual are approximate and rounded off to the nearest whole number.

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1-8. Wet-cold conditions occur when wet snow and rain often accompany cold conditions. A wet-cold environment is more dangerous to troops and equipment than a dry-cold environment because the ground becomes slushy and muddy and clothing and equipment becomes perpetually wet and damp. Under wet-cold conditions, the ground alternates between freezing and thawing as the temperatures fluctuate above and below the freezing point. As temperatures warm, heavy equipment can sink into the softening mud; then as temperatures turn colder, the equipment becomes immobilized in frozen ground. This makes planning equipment recovery operations problematic.

1-9. Under dry-cold and intense-cold temperatures, from +19°F (-7°C) to -25°F (-32°C), operations become more difficult (figure 1-1). At the warmer end of this range, lack of winterization results in only a slight loss of operating efficiency. Proper training prevents many failures of materiel and injuries to operators. Nevertheless, non-acclimated troops usually show signs of having difficulty at temperatures above -10°F (-23°C).

1-10. When temperatures drop below -25°F (-32°C), operations become extreme. At temperatures nearing -40°F (-40°C) and lower, operations become hazardous, requiring the maximum efforts of well-trained personnel to perform even the simplest tasks, even with fully winterized materiel.

# PLANNING

1-11. About one quarter of the earth's land mass may be termed severely cold. Another quarter of the earth is termed moderately cold. Areas (including most of North America and Eurasia) where the mean temperatures during the coldest months reach extreme-cold and below, as shown in figure 1-2. Although the following figure does not conform to general military temperature categories, it can help provide planners with historical information on the temperature extremes which have occurred around the world (ATP 3-34.5, *Environmental Considerations*).

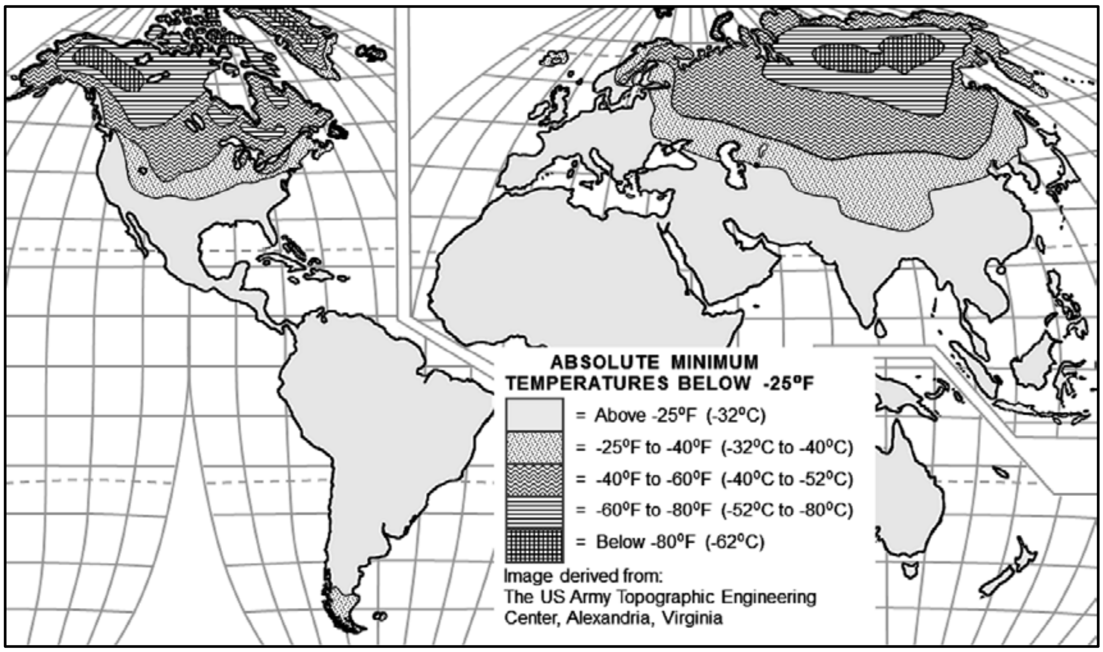


**Figure 1-2. Cold regions of the world**

1-12. Before acquisition, much of the Army's equipment undergoes testing for proper operation at temperatures down to -25°F (-32°C). Soldier welfare considerations usually don't become an issue prompting equipment winterization until temperatures reach -10°F (-23°C). Almost all equipment procured by the Army functions correctly at the -25°F (-32°C) threshold. However, at temperatures below -30°F (-34°C), equipment begins to malfunction. The drop in temperature directly relates to decline in materiel performance.

1-13. Extreme-cold and hazardous-cold adversely affects the capability of a unit to accomplish its mission. Understanding the specific impacts of a cold environment can assist a unit in planning measures to counter these affects. Maintenance leaders need to identify the probable duration and severity of the cold weather, and adjust their plans and policies accordingly. For example, maintenance personnel working with cold-soaked metals and petroleum are at a higher risk for cold injury, creating a greater need for medical attention. Lying on their backs, on frozen ground to get under vehicles can expose mechanics to a hypothermia or pneumonia risk that standing Soldiers would otherwise avoid. Maintainers and operators performing maintenance are subjected to different risks than, for example, Soldiers on foot patrol. It is not to say that one risk is greater than the other; only that they are different.

1-14. Planning for cold weather operations requires the full range of Army planning methodologies as found in ADP 5-0, *The Operations Process,* AR 5-1, *Management of Army Business Operations*. When planning for missions in cold weather, leaders must realistically evaluate the impact that physical factors will have on operations, both tactical and logistical. For example, units are less maneuverable in icy conditions or deep snow. Deep snow reduces vehicles traction on hills and increases the chances of breakdown/damage caused by hidden obstacles. Wheeled vehicle units are restricted almost exclusively to roads. Trailers and towed artillery pieces further reduce mobility. Emplacement of artillery pieces for fire missions is very difficult. Here, operators must be very proficient in basic skills that in more temperate zones they might have taken for granted, such as keeping moving parts free to cycle, equipment recovery, working with tire chains and slave starting. Before this situation, line supervisors will need to identify where specialized cold weather training, or refresher training is necessary. This will be an issue that the commander and senior staff will have to anticipate and resolve.

1-15. Just in case of a "no-notice" deployment into a cold region, leaders should draft contingency plans for their unit. For maintenance, leaders should develop stand-by requests for winterization equipment, or draft procedures for cold weather operation of each weapon, vehicle, power generation system, item of equipment, and shelter. Even if deployment to a cold region is not projected, cold weather operation rehearsals of capabilities (ROC) drills are ideal for developing junior leaders; officers and noncommissioned officers. Operators should train on snow chain battle drills, alternative lubricants, cold starting procedures, and other related cold region supplements to maintenance. Such training helps Soldiers adjust to thinking analytically (outside the box), and provides the unit with a defined and rehearsed contingency plan.

1-16. Commanders should schedule a specific day or trigger event for the unit to convert from normal temperate weather operations to cold weather operations. It is at this point that the rules change for personal care and the care of equipment. Up to that point, the unit has to make a number of preparations in order to be ready for such an operational conversion.

1-17. Planning is critical to the general success and survival of units operating in cold weather. Planning for cold weather operations should begin long before the actual onset of freezing temperatures. It takes sufficient time to inventory and order necessary winterization items. After arrival of winterization items, further time is needed for supervisors to train and license (or certify) their crews in proper cold weather procedures and use of specialized equipment. Planners should consider the following:

- Plans must be both detailed and flexible.
- Unit operating procedures that conform to doctrine (ATP 5-19, *Risk Management*), major command policy, and local command supplements on: Army safety management, and risk management.
- Cold will make mission command more difficult.
- Personnel must be properly trained and prepared.
- Cross training will be needed to maintain operational tempo.
- If deploying to a cold weather region, the S-4 must identify from where the unit will draw the Extended Cold Weather Clothing System (ECWCS: Technical Bulletin, Medical [TB MED] 508, *Prevention and Management of Cold-Weather Injuries*, and TM 10-8415-236-10, *Operator's Manual for Extended Cold Weather Clothing System Generation III [ECWCS GEN III]*) items. It is a collection of cold weather clothing that is mixed and layered to protect the Soldier from the cold, in a range of 40°F (4.4°C) to a frigid -60°F (-51°C). The exact content of issued items and authorized accessories for the ECWCS evolves as newly developed items are brought about by new fabric technology. Logisticians should confirm that such clothing is in stock now, to supply the unit (as well as other competing units that could deplete supplies before the unit has a chance to draw enough ECWCS for itself).
- All units, especially mechanized and armored, will require more time to accomplish tasks; cold will increase fuel consumption and the demand for both wet cell and dry cell batteries.
- Although equipment is designed to function in the cold, it will be less reliable, thereby increasing maintenance time, and supply problems. Maintenance, supply, and engineer units may require an augmentation of additional personnel, or accept a reduction in the achievable workload.
- A potential increase in medical problems (for example: injuries from fatigue, frostbite, hypothermia, pneumonia, dehydration and even heat casualties [FM 90-3, *Desert Operations*, TB MED 505, *Altitude Acclimatization and Illness Management*, TB MED 507, *Heat Stress Control and Heat Casualty Management*, and TB MED 508]) must be anticipated. Parasites and vermin tend to congregate or proliferate in areas kept warm by Soldiers.
- Prolonged exposure to cold and extended hours of darkness will lead to increased psychological stress.

- Due to higher caloric demands by the body in cold weather, the field feeding operations will need to plan on providing a continuous supply of warm supplemental rations to accommodate the increased caloric demands of working in the cold.
- A regimen to more carefully monitor Soldier hygiene must be established by leadership to prevent Soldiers from cutting corners on personal care and hygiene due to fatigue and the discomfort of the cold.
- Policy and procedures to ensure the documentation in a Soldier's medical records of all cold injury medical diagnoses.

1-18. Commanders will need maintainers' expertise of to assess the serviceability of cold weather items (AR 70-38, *Research, Development, Test, and Evaluation of Materiel for Extreme Climatic Conditions,* and ATP 4-33). Commanders will need the expertise of medical personnel to assess the procedures for Soldier care in cold weather. Planning considerations are dependent on the situation and mission objectives. Listed below are potential maintenance related issues in preparation for cold weather operations:

- Heated shelter for equipment maintenance.
- Individual heated storage for the components of end items, basic issue items, additional authorization list items, and radios for each vehicle in the fleet.
- Proper clothing and tools for mechanics.
- Adequate portable heaters.
- Identify equipment susceptible to condensation damage and provide anti-condensation containers.
- Capability to store and issue antifreeze materials, winterized fuels, hydraulic fluids, lubricants, and other fluids.
- Extra lighting, to accommodate limited daylight in northern latitudes.
- Increased velocity or volume to supply repair parts.
- Sufficient equipment for snow and ice removal.
- Direct medical support present in maintenance areas.
- Adequate first aid kits, eye wash stations, and toxic chemical rinse off stations.
- Hazardous Material (HAZMAT): Understand current laws and command policy.
- Survival kits and bags to protect against the cold.

1-19. The upper and lower temperature limits presented for fluids or semi-fluid (such as a grease) materials within Appendix E are intended for planning purposes. Operators of specific items of equipment must refer to the TM or LO regarding the actual hydraulic fluid to be used. If unit operations are conducted where temperatures are outside the useful limits, planning staff should contact the theater's petroleum office for advice on maintaining operational ability. At lower limits, maintenance managers will need to consider substitute fluids or make plans to take remedial action to preserve an item's usefulness.

# TRAINING

1-20. Since most U.S. units are stationed in temperate or tropical climates, Soldiers in general lack adequate training or experience in cold weather operations and maintenance. Soldiers stationed in temperate climates must be prepared by commanders if they are to be expected to move into cold climates and perform their missions (TC 3-34.489, *The Soldier and the Environment*). This preparation entails proper planning, training, and equipping (TC 21-3, *Soldier's Handbook for Individual Operations and Survival in Cold-Weather Areas*, restricted official use, only). Expertise in cold weather operations will grow from experience and cannot be gained solely from reading a manual. To develop successful cold weather field techniques, applicable training and operational experience is necessary.

1-21. In the maintenance arena, training for cold will drive in three directions:

- Soldier health and welfare.
- Changes in physical properties and performance of equipment and materials, caused by the cold.
- Adaptations of processes and procedures to protect successful results from the impact of the cold.

## SOLDIER HEALTH AND WELFARE

1-22. Cold injuries are most likely to occur when an unprepared individual is exposed to winter temperatures. They can even occur with the proper planning and equipment. The extent of cold weather, prior experience or training, and the type of operation in which the individual is involved impacts on whether a Soldier is likely to be injured and to what extent. The Soldier’s clothing, physical condition, and mental makeup are also determining factors. Well-disciplined and well-trained Soldiers can be protected, even in the most adverse conditions.

1-23. Cold weather training begins when all unit elements have reviewed and updated their policies and plans that address cold weather operational standards and injury prevention. Commanders should ensure that a cold weather injury prevention program is established, and that training has been provided to all personnel assigned to the command and subordinate commands. This task is complete when all unit elements have reported their compliance to the command’s safety office.

## RESOURCES

1-24. For maintenance to be effective, operators and maintainers need to be trained in how to anticipate the effects of the cold on their equipment. Severe cold can change the physical properties of metals and fluids. Metals become more brittle as temperatures drop below freezing. Petroleum products which are focused on withstanding high temperatures, break down and cease to function as fuels or lubricants in the cold.

1-25. For processes or procedures, cold has an effect on the resources fed into any task, whether it’s on the materials or the labor. Usually that effect is adverse, where an otherwise adequately resourced task fails to achieve its projected standards. Leaders and supervisors will find that the input resources of every process and procedure will have to be reassessed in the light of the effects caused by the cold. Such changes in procedures will result in Soldiers having to be retrained in even the most basic of tasks. Here, doing things based on common sense, or by a set routine, can be dangerous for Soldiers from temperate weather regions.

1-26. Good training is targeted to the audience relative to the situation and the mission. There is a general level of basic understanding that needs to be conveyed about personal conduct, health and safety, relevant to anyone engaged in cold weather operations. Then all leaders, instructors, cadre, and even selected civilians need to be provided with leader development training for cold weather operations. There is also training that is equipment oriented for operators and handlers on special or unique cold weather procedures pertaining to space heaters and vehicle or generator engine heaters. Most important is the provision of more intensive training that is needed by young first time Soldiers who are at highest risk for suffering a cold injury, or causing equipment damage.

## TEMPO OF MAINTENANCE ACTIVITY

1-27. Cold weather will cause maintenance work to take longer, impeding the mission. Operators and maintenance personnel must be proficient in the use of all winterization and arctic kit items, which include heating devices, and added insulated covers. The PMCS instructions for winterization kits will often come as a new task for operators, requiring at least initial supervision and instruction by experienced and mechanically inclined leaders. Operators are responsible for knowing and understanding the TM's guidance for operating under unusual conditions, as they pertain to their specific pieces of equipment. Complete winterization, diligent maintenance, and well-trained crews are the keys to reducing the adverse effects of cold weather.

1-28. For any given unit of work, more man hours of labor or time are required in cold weather operations. By temperatures below -20°F (-32°C) workflow has seriously slowed down. Mechanics usually must allow equipment to thaw out and warm up before making repairs. This time lag cannot be overemphasized and must be included in all planning. Personnel efficiency also is reduced by the bulky and clumsy clothing worn in severely cold areas. Because it is dangerous to handle cold metal with bare hands, operators/mechanics must wear mittens or gloves at all times. Losing the sense of touch further reduces the Soldier's efficiency. Even the most routine operations, such as handling latches or opening engine compartments, become frustrating and time-consuming when performed with protected hands.

1-29. This may be addressed by finding more personnel to perform the labor or by allocating more time to complete the tasks. Some of this constraint upon productivity can also be offset by providing heated buildings or shelters to increase work efficiency and morale. Here, shelter can mean anything from a building to a vehicle cab, tent or even a windbreak; anything that can be used to effectively mitigate the extremes of the exposed environment. At a minimum, a highly organized, more intensive effort is required of mechanics.

1-30. Commanders may want to try obtaining additional personnel to keep the tempo of maintenance activity from slowing. They can consider a program to provide on the job training for vehicle and equipment operators to perform some maintainer job tasks. Additional duty Soldiers assisting with maintenance; should be formally trained, under a command approved program, by a highly experienced maintainer, and issued a signed document affirming approval from the unit commander. Such a program will need a defined curriculum of training, and defined limits of what maintainer tasks a supporting Soldier can perform. This is not something where anyone at random can assume they know how to do a mechanics job. Maintenance is a risky job for both equipment and personnel, especially in cold weather. Even the simple task of starting an engine is riskier than normal, in the cold.

# RISK MANAGEMENT, QUALITY AND SAFETY

1-31. The commander is responsible for all aspects of health and sanitation within the command. Only the commander can make command decisions concerning the health of the unit in consideration with:

- Mission objectives.
- Situational obstacles.
- Condition of troops.

1-32. With the onset of cold weather and increased mission rigor, the cold environment and the potential for cold weather injuries can hinder a unit's mission accomplishment. Leaders must remain vigilant to this threat (TB MED 508). Effective application and training of cold weather protection measures can minimize the incidence of cold weather injuries throughout the command. Units should prepare for hazards associated with the winter season or cold environments by reviewing and updating policies and plans that address cold weather operational techniques, cold injury prevention, and the preservation of material resources, such as equipment. The development of a cold weather deployment program should be organized as a quality management process.

1-33. Inventories of winterization kits, vehicle supplemental heating systems, space heaters, and the like should be conducted well in advance of cold weather operations. This will afford operators and unit supply staff with sufficient lead time to process requests and receive new parts or end items. Such inventories should check that the items are present, serviceable, and complete.

1-34. Maintenance managers should be ready to train and certify at least 20% of Soldiers within the command in the proper assembly and operation of shelters in conjunction with shelter heaters (this is a TM best practice recommendation and not mandated doctrine or regulation). Special attention should be given to the proper handling of combustible heating fuels, avoiding runaway fires and avoidance of carbon monoxide poisoning. Even in those situations where Soldiers are billeted in heated structures, such training will still be valuable at field training sites.

1-35. For ammunition handlers, arms room personnel, and ammo section transporters specialized training and certifications are available through the internet from the Defense Ammunition Center at McAlester, Oklahoma, and the Munitions History program at Redstone Arsenal in Huntsville, Alabama. Although this training is generic to all weather conditions, the added distractions of cold weather means that heightened awareness and current training proficiency is critical to mission success. It is vital for units to have not only the Soldiers in these positions properly trained and fully certified, but that an extra number of qualified personnel be cross-trained and available to compensate for the reduction in individual performance caused by the cold environment.

1-36. Quality of safety and risk avoidance during cold weather operations have to be uniquely managed. Staying ahead of threats to the quality of work products or Soldier safety is a function of risk management.

1-37. Cold weather is a distraction to operators performing maintenance. To reduce the risk of lax maintenance, supervisors and section leaders of line elements need to work in close coordination. They must ensure that otherwise well trained equipment operators stay focused on performing preventive maintenance and operator maintenance according to TM standards.

1-38. Commanders and maintenance supervisors should consider the support of medical personnel to inspect the human factors of maintenance operations. The results of such inspections should be compiled and reviewed to keep unit operating procedures relevant, and find where special attention or added resources might be necessary. Army quality management (an outgrowth of "Total Quality Management" from the 1970s) is the product of recorded performance, beyond just anecdotal evidence.

# SOLDIER WELFARE

1-39. The commander holds the authority to establish, and the unit's senior medical officer is responsible for implementing and applying, standards for medical personnel and combat lifesaver qualifications. Medical refresher training focused on cold weather casualties and their proper treatment is needed for medical personnel and combat lifesaver certified Soldiers.

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**NOTE:** Only qualified medical personnel have authority to diagnose and treat cold injuries. Medical evasive treatment can only be performed by medical personnel. Only the unit medical officer can verify who is qualified and competent to handle cold injuries.

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1-40. A large part of a Soldier's time and energy in cold weather is spent on self-preservation. This naturally reduces the efficiency of personnel when operating and maintaining materiel. Besides operating equipment, Soldiers must learn to protect themselves against climatic factors by dressing properly, constructing shelters, and improvising further protective measures.

1-41. Assistance from senior medical personnel should be sought for developing Soldier training in cold weather injury prevention and treatment. Such training should also include the proper wear of ECWCS.

1-42. Provisions for Soldier needs in cold weather maintenance operations are much more rigorous than such operations in a temperate environment. A few Soldier welfare factors of cold-weather operations are:

- Shelter from the elements is secondary only to defending against enemy actions.
- Eat and drink more food and water than normal.
- Be prepared for sudden weather changes.
- Avoid cold injuries by using a buddy system and frequent self-checks especially when individuals are not active or their duties require them to remove their gloves.
- Immediately treat persons showing any sign/symptom of cold injury.
- Sick, injured, and wounded individuals are very susceptible to additional cold injuries.
- Each Soldier should be individually prepared to survive if separated from the unit.
  - In wet-cold weather, Soldiers must have immediate access to their wet weather gear.
  - In dry-cold or colder weather, Soldiers must have a survival kit attached to their person.
  - Anytime Soldiers are traveling by vehicle, they need to have their cold weather survival bag with them to include a sleeping bag, water, and extra clothing (at least dry socks, underwear, and the next level of ECWCS) in their vehicle.

## BATTLE BUDDY PROTECTION

1-43. Safety awareness is especially vital during the early part of a cold weather operation, or for newly arrived Soldiers who lack experience with the cold. Leaders should consider instituting a battle buddy program; having Soldiers working in small teams to keep tasks and projects moving in a timely manner. Individual safety, as well as mission accomplishment, has the highest chance of success when Soldiers are assigned battle buddies to watch over each other. This is especially true for Soldiers that are not fully acclimated and still learning how to deal with an unusually cold environment. It is here that the battle buddy's second set of eyes on a problem can save a situation from going dangerously wrong.

## HUMAN FACTORS

1-44. To remain functional, Soldiers must be kept reasonably warm to maintain the body's normal metabolic process. Rest and nourishment are vital. This sub-section is not intended as a full discussion of cold injuries, symptoms and treatment. However, during maintenance operations there are some basics that leaders and planners need to keep in mind.

1-45. The correct approach to cold weather living will go a long way toward keeping Soldiers healthy and seeing them through difficult times. There are five basic rules to remember:

- Know the hazards of exposure to the cold. Soldiers and their leaders must know the importance of personal hygiene, exercise, care of the feet and hands, and the use of ECWCS protective clothing.
- Keep in shape: Cold weather clothing is heavy and an additional burden on top of a Soldier's normal equipment. Along with the difficulty of walking in snow, a Soldier will expend a lot of energy just staying warm. The importance of being in excellent physical condition cannot be over emphasized.
- Drink plenty of water:
  - Because water may be hard to get, a Soldier may drink less than needed.
  - Normally, in cold climates, Soldiers only drink when thirsty, and cold can short-circuit the thirst mechanism. This may not move them to drink the water needed to prevent dehydration.
  - Likewise, Soldiers may be reluctant to drink cold water since it detracts from keeping the core body temperature warm. Still, they need to drink plenty of water to avoid dehydration and the fatigue that will follow.
  - Do not allow Soldiers to eat raw snow as a substitute for water; the moisture content of snow is relatively low and its cold nature will lower the body's core temperature.
- Eat to replenish energy: Regular, satisfying, hot food is essential for top performance. Even if not hungry, Soldiers must eat. If they do not replace lost calories, they will not stay fit very long. (This becomes an added burden on cooking staff, also.)
- Maintain a positive attitude: Soldiers will find themselves confronting many new and challenging problems, but none that a properly trained Soldier cannot overcome. Soldiers' attitudes toward the cold will reflect that of their leader.

1-46. In a cold environment, the greater part of what Soldiers eat and drink goes towards maintaining their body heat, while a much reduced proportion is spent on producing energy for physical work. A larger intake of calories is therefore needed in a cold climate than is needed in temperate areas. A minimum of 4500 calories per day has been found necessary for personnel performing hard work in the cold, and efficiency is likely to fall off rapidly if this level of nutrition is not maintained. Under conditions of severe stress, Soldiers may require as many as 6000 calories per day to maintain health and performance.

1-47. The body loses liquid at an exceptional rate in cold conditions, up to 2 quarts of water per day by respiration alone. No matter how carefully the amount of clothing and ventilation is adjusted, any heavy exertion exacts a toll in sweat and loss of moisture through breathing. These liquids must be regularly replaced, preferably by hot drinks. Drinks that contain sugar have the additional advantage of providing extra calories. The daily requirement will vary from a minimum of 3½ to over 5 quarts of water a day in circumstances involving heavy exertion.

1-48. All too often heat injuries are forgotten in a cold weather or mountain environments, but they are as likely to strike as cold injuries due to the tendency of Soldiers to overdress in the cold. Indeed, heat injuries may be more likely in a cold environment due the difficulties encountered in maintaining proper hydration. Leaders should allow extra time for clothing adjustments (up scaling or down scaling the layers of clothing as the temperature climbs or drops) and provide additional liquids for proper hydration.

1-49. During winter operations in more temperate regions, leaders should be alert to changes in weather and drops in temperatures. This is when cold injuries unexpectedly occur. Such situations need to be anticipated in unit policy, and on-call resources should be positioned pending activation, in advance. During 24 hour operations, such safety risks are likely to materialize at the most inconvenient time, such as from the middle of the night to sunrise, when temperatures dip below freezing.

## COLD INJURIES

> **CAUTION**
>
> Any injury that draws blood, incurs bruising that breaks skin, shows any discoloration, swelling of skin, or has pain that persists for over half an hour is serious!
>
> What is otherwise a minor injury in a temperate environment should be brought to the attention of medical personnel within the hour.
>
> Supervisors, battle buddies or combat life-savers should next regularly monitor such injuries for the rest of the work period.

1-50. Leaders should identify Soldiers who have previous cold weather injuries. Personnel with prior cold weather injuries are more susceptible to additional injury to the affected area/limb. It is suggested that a colored tape marking system be used on outer garments and head gear to alert buddies and responders to earlier cold injuries. Such injuries could hinder the blood system's ability to regulate skin temperature in the affected area. In each instance, medical personnel should be consulted to ascertain the degree of threat the cold poses to the Soldier, and if precautions or limitations in activities are needed.

1-51. An apparently minor injury occurring in cold weather can rapidly escalate into a serious injury, if not proactively addressed. There is no such a thing as a minor injury in a cold environment. Even the mildest of cold injuries can have lifelong residual effects on the Soldier. For a full discussion on cold injuries, leaders should consult with senior medical personnel.

1-52. During maintenance operations in sub-freezing conditions, a military occupational specialty qualified medical Soldier needs to be available to provide direct support within motor pool and maintenance activities, whenever possible. Medical support is done as specified by unit command policy, with the intent of having medical services forward employed to the point of highest risk. Medical support tasks provided to maintenance operations should make available:

- On site diagnosis and medical treatment of injured personnel.
- Referral or evacuation of personnel with serious cold injuries to higher medical services, when warranted by the nature of the injury.
- Make appropriate recommendations to the commander regarding a Soldier's return to duty, with or without profile limitations.
- Spot checks that proper hygiene and injury prevention measures are practiced, as specified by command policy and Army standards. These checks also include unit adherence to proper field sanitation, and the adequacy of sanitation resources (TB MED 577, *Sanitary Control and Surveillance of Field Water Supplies*).
- Weather monitoring as it applies to working conditions.
- Documentation of all injuries treated, and assurance that such documentation is properly filed in the service members medical records. Future commanders or the Veteran's Administration should not have to rely on the Soldier's word alone that they previously sustained a cold injury.
- Follow-up examination at the end of the duty period for Soldiers who incurred an initial injury. In those instances where the injury has gotten worse or exhibits more symptoms, the medic will reassess the correctness of a profile, provide the commander with updated information, and make appropriate annotations to the Soldier's health records.

1-53. Soldiers should be cautioned against warrior-bravado which leads them to discount or conceal a supposedly minor injury. Cold injuries can arise and escalate suddenly, in minutes under certain circumstances.

1-54. Once a cold injury has occurred, the commander and site leaders should immediately reassess all the protective measures that are in place; re-validating operating procedures. The concern of the site leader is not only for the injured Soldier, but also the remainder of the force on duty. Where one injury has occurred, more are capable of following, if the circumstances leading to the first injury are not proactively addressed.

1-55. When a cold injury occurs, medical personnel on site should make inquiries and provide a root-cause analysis for the site leader. This information should be provided to the site leader as promptly as possible. Leaders can then use it to assist in determining what corrective action should be taken to safeguard Soldiers and mission accomplishment on the work site.

1-56. In worsening weather situations, further corrective action and protective measures may be warranted. Site leaders should expect that such events will occur at the most inconvenient times, such as late at night. It is at these times that commanders or site leaders may have to draw additional resources to protect Soldiers on duty from the worsening cold. Where additional resources are not available or inadequate to curtail the threat, it is the commander's prerogative to consider procedural changes or mission adjustments.

## SURVIVAL EQUIPMENT SYSTEM FOR STRANDED SOLDIERS

1-57. During cold weather field operations, soldiers need to have survival gear. Leaders should develop survival kits and bags for Soldiers operating outside a base camp. In a base camp, garrison or installation there is only a limited risk of such dire cold weather emergencies, and in the event of an emergency survival resources are more likely to be available. However, in the field or a combat area, a Soldier can become isolated or separated from the sustainment resources of their unit. Such situations can make survival gear necessary.

1-58. The purpose of a survival gear is to sustain a Soldier in emergencies outside of normal mission operations and normal sustainment activity. Although the Army provides survival kits for aircraft, such kits are intended for generic long duration situations. They are usually too bulky for the urgent short duration needs ground troops. In principle, the function of emergency survival gear is to:

- Sustain a Soldier.
- Protect the Soldier from threats (mostly natural, and the enemy to a lesser extent).
- Signal for help.

1-59. These three functions of survival gear remain the same regardless of whether the Soldier is lost on a mountain, at sea, or in a desert. If the Soldier is sick or injured, it means first aid. If the Soldier is wet, hungry or cold, if means keeping him dry, fed, and warmed. It means providing the Soldier with the means to call for help, as covertly as possible. At the same time, different situations can alter the exact components needed for a survival equipment system. Survival kits and bags need to be as small and as unobtrusive as possible while still maintaining their utility.

**NOTE:** Army regulations do not require, nor does the Army have a defined military standard that proscribes a survival kit equipment list, for ground forces.

1-60. The establishment and implementation of emergency survival equipment and the procedures for its use are the unit commander's option and responsibility. The determination that Soldiers need survival kits, or survival bags, and the contents wherein is based upon the commander's risk assessment, or SWOT (strengths, weaknesses, opportunities, and threats) analysis. Survival kits are carried on the Soldier for sudden emergencies of a short duration; 36 hours or less. Survival bags are carried on a vehicle, for emergencies which may last for a protracted period of time; usually lasting for over 24 hours.

## RAPID TEMPERATURE SHIFTS

1-61. If Soldiers are to be repeatedly moving between the outdoors to work and the indoors for shelter, Soldiers should maintain their acclimation to the cold. Although personnel should go indoors as often as the mission allows, they should avoid rapid or extended warming around heaters. Such over-heating of a Soldier can cause perspiration on the skin and condensation in the clothing. Perspiration will compromise cold weather clothing's ability to retain body heat. Overly heated shelters will cause Soldiers to suffer rapid cool off when it's time to step out of the shelter. Repeated rapid temperature shifts with large variations in temperature can contribute to metabolic fatigue, weakening the immune system; possibly even making

Soldiers sick. The principle is that after removing only the outer layer of their ECWCS, the Soldier does not get so warm as to begin sweating (even slightly). Soldiers should stay cool even while avoiding the strenuous cold.

1-62. Soldiers expecting to return to the cold after a heated shelter break should not spend extended time in the shelter. The purpose of a break shelter is:

- Temperature control: The break shelter should be kept above freezing, but only moderately warm (about 35°F [1.5°C] to 40°F [4.5°C]).
- Ventilate built-up moisture: In here, Soldiers are encouraged to take off the outer ECWCS level VII parka and trousers, and the level VI extreme-cold jacket and trousers. Then they can give the level VI gear a good shake to wick out moisture.
- Air out feet: Soldiers are encouraged to take off socks and boots for a moment to dry off the skin. Further, at least once during a work-cycle lasting over six hours, Soldiers should apply foot powder and fresh socks (as the mission allows).
- Check health: Battle buddies should check their partners for signs of cold injuries. Those Soldiers with previous cold injuries should have the area of injury rechecked. Then, a quick show of face, hands and feet should be sufficient.
- Eat and drink: After the Soldiers have re-dressed, then they can take a moment to rest, eat a light snack and drink a warm liquid.

1-63. Following this process in sub-freezing temperatures helps to keep Soldiers dry and acclimated to the cold. Where a tent or structural shelter is not available, the cab of a vehicle can serve the same purpose. The only requirement is that the cab have sufficient room to perform the above five tasks. Medical personnel should be consulted about further precautions that might be applicable to this process, in consideration with the specifics of the situation.

## FLESH ON COLD METAL

1-64. Personnel should avoid touching or leaning on cold-soaked equipment (equipment that has been standing in below freezing temperatures for an extended period) or kneeling and lying on the ground. Body fluids at the skin surface can directly freeze, and even adhere to frozen metal. Also, rapid body cooling caused by heat transfer to the equipment or ground may result in deep tissue cold injury. There are several basic protections that Soldiers can use to avoid such cold injuries.

### Gloves

**WARNING**

**Handwear may become saturated with fluids when Soldiers perform maintenance on fuel and cooling systems. Saturation reduces the insulating value of the handwear, causing cold injuries. Soldiers should carry extra handwear when performing maintenance under arctic winter conditions.**

1-65. When using tools, calibration equipment, or sighting and fire control materiel at freezing temperatures, operators' hands need protection. Gloves with liners, trigger-finger shells with liners, or arctic mitten sets should be worn. Standard issue light duty leather gloves are appropriate around 35°F (1.6°C) and higher, but the arctic mitten set or the trigger-finger mitten should be worn at colder temperatures. Mechanical motion of most nuts and bolts, knobs, and levers will be less free than at milder temperatures. Making adjustments will at first seem awkward and difficult to operators who are not used to working with gloved hands. Small parts are more readily dropped and lost in the snow. Eventually, awkwardness and difficulties will lessen with practice.

## Anticontact Gloves

1-66. Anticontact gloves should be available and used when touching cold metal equipment. Because many vehicle bodies, tools, knobs and handwheels are difficult to manipulate while wearing arctic mittens, it may be necessary for operators to wear anticontact gloves. These gloves have light material body featuring a deerskin leather reinforcement patch covering front side of fingers, palm and thumb. They provide greater dexterity then regular gloves. In cold weather, anticontact gloves are effective protection for a short time, then hands need to be returned to mittens.

1-67. If anticontact gloves are not available and it is necessary to use bare hands, the discomfort of contact with cold metal can be lessened by wrapping adhesive tape around the tools, knobs or handwheels. Also, common tools, such as the TL-13A lineman's pliers, should have handles wrapped in plastic or electrical tape to provide protection.

**CAUTION**

Anticontact gloves and work gloves are sufficient for insulation against touching dangerously cold metal. However, they are not suitable for protecting hands against protracted cold exposure in same sense as winter gloves, or mittens with inserts.

## Insulating the Body for Work

1-68. In cold, the insulating capabilities of the ECWCS clothing is the principle way for Soldiers to stay warm. Yet, coveralls and other sustainment Military Occupation Specialty specific personal protective equipment (PPE) that fit over a Soldier's uniform in temperate areas will not fit over the higher levels of a bulky ECWCS clothing system. Mechanics and operators performing maintenance, fuel handlers and others handling or storing Petroleum, Oils and Lubricants (POL), cooks and other sustainment workers will find that standard PPE garments mixed with ECWCS are usually not effective in cold. Mixing PPE with ECWCS together becomes constrictive, obstructing the Soldier's movement and reducing the insulating ability of the ECWCS. It is risky for Soldiers to take off items of the ECWCS so that they can to fit into their PPE. Without the ECWCS, Soldiers become vulnerable to the physical and health risks of the cold weather. Likewise, if Soldiers try to work while not dressed in their PPE, they risk ruining the protective qualities of their ECWCS or worse problems. For the same reasons, the use of any type of body armor is prohibited for use "over the top" of Petroleum, Oils and Lubricants (POL) or sustainment Military Occupation Specialty specific PPE that could negate the flame resistance, anti-static, POL chemical resistance, and other properties required by sustainment Soldiers.

1-69. Commanders have to ascertain what is available within the supply system for cold weather PPE. If there is nothing in the supply system, Commanders need to consider local purchase of commercial-off-the-shelf (COTS), or custom made PPE garments. Sustainment Military Occupation Specialty substitute PPE such as fuel handler's gloves, mechanic's coveralls, splash-proof cooking mitten-covers, face shields, or comparable items must be worn over ECWCS garments, and body armor. Substitute PPE must reasonably conform to flame resistant, anti-static, electric non-conductivity, HAZMAT corrosion resistance, or other Soldier protection standards as it relates to the work being done. Ensure that cold weather PPE is sized large enough to fit over all layers of body armor and ECWCS, and will still allow body humidity to evaporate.

1-70. Mechanics should place insulating material; such as fiber packing material, corrugated cardboard, rags, or tarpaulins; between themselves and cold-soaked equipment, or the frozen ground. When performing maintenance under severe winter conditions, a box or pan should be used to hold small parts. A tarpaulin should be placed under each vehicle (figure 1-3, on page 1-14) to catch parts that may be dropped. This prevents the parts from becoming lost in the snow, and further limits rapid body cooling from contact with cold-soaked equipment.

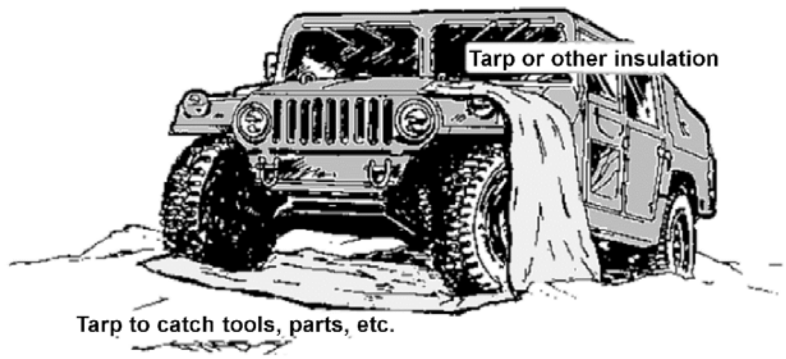


**Figure 1-3. Tarps are used to protect from cold and to catch dropped parts**

**NOTE:** Occupational Safety and Health Agency (better known as, OSHA) holds the employer responsible for the availability of PPE, and how it is used; even if the employee buys it.

### MAINTENANCE SITE SANITATION

1-71. In temperate weather regions, Soldiers in the field tend to relieve themselves indiscriminately, under the assumption that nature will dispose of their waste. However in sub-freezing weather, liquids do not soak into the ground. Such waste will remain suspended in the snow on or above the ground, covered by more snow. As fellow Soldiers walk through the area, they unsuspectingly pick up human waste on their garments and foot gear. This becomes a double threat because Soldiers are already struggling with their metabolism and immune system being challenged by the cold.

1-72. It is important to set up a number of extra field latrines, laid out around the motor pool. Maintenance managers should incorporate field sanitation measures (TB MED 577, and TC 4-02.3, *Field Hygiene and Sanitation*) into their cold weather contingency plans, and secure such equipment as needed for the execution of such plans. A means of warming outdoor toilet seats may be necessary where skin contact is painfully cold. This may also include a means of removing and hanging ECWCS off the ground while a person relieves himself, so that clothing is not soiled by mud or waste.

## FUEL BURNING PERSONNEL HEATERS

1-73. Field tent heaters become a safety risk if TM procedures are not followed in detail. In very cold weather, shelter which protects the Soldier from exposure to the elements becomes an added logistics effort. Fuel burning heaters are used in cold weather to keep Soldiers functioning. Army regulations for tent heaters are stringent, due in large part to deaths and injuries caused by:

- Improperly vented heaters, which expelled their fumes directly into tents, leading to carbon monoxide poisoning.
- Unsafe heaters, which caused fires.
- Ineffective heaters, which due to their poor performance caused Soldiers to perform unsafe acts in order to stay warm.

1-74. Fuel driven heating systems have three input requirements, and four byproducts. The basic inputs are fuel (with a hydrogen component), oxygen (or a solid oxidizer), and an initial heat catalyst. Hydrocarbons (such as liquid fuel or a solid combustible like wood) and an oxidizer (usually fresh air, but possibly a solid) are used because they are stable at normal temperatures, and don't need special handling in the field. The byproducts of fuel driven heating systems are heat energy, water (as moisture), unburned carbon based byproducts, and carbon monoxide. The safety risk is not only in the fire, but just as equally in the other byproducts (including water as moisture) that can damage equipment or jeopardize the health of Soldiers.

1-75. There are four types of heating systems used to keep Soldiers functioning in cold weather:

- Direct heat generation.

- Single stage heat generation.
- Two stage heat generation.
- Three stage heat transfer system.

**NOTE:** The above bullet groupings of heating systems are colloquial descriptions of heating technology, and not defined military terminology.

1-76. The first three heating systems (figure 1-4) are most common to tents and temporary shelters. Each of these heating systems has its own advantages and operational constraints. Maintenance personnel and operators should understand the principles of each heating system, with the intent of achieving the best performance while minimizing safety risks.

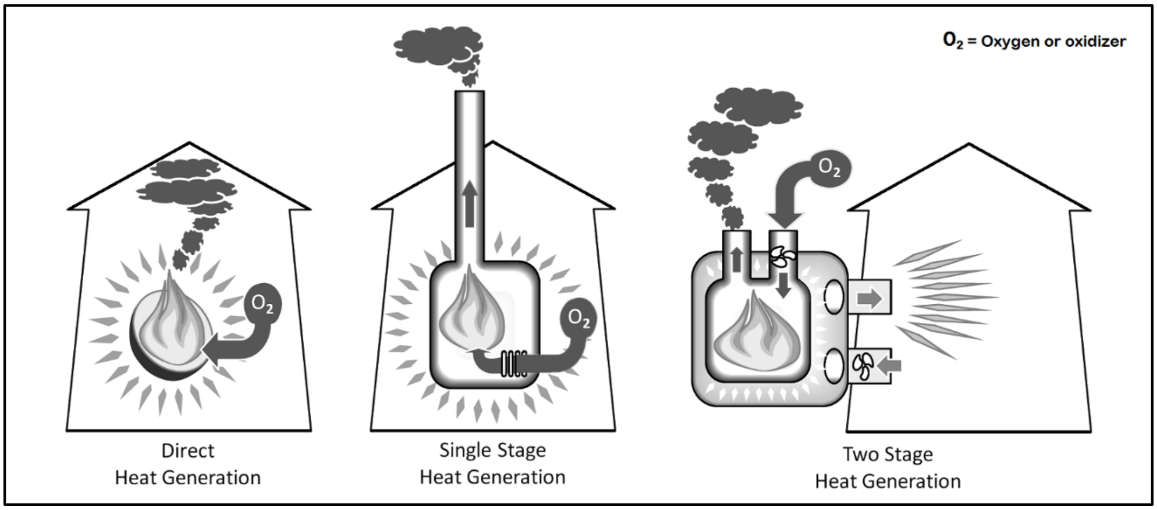


**Figure 1-4. Heat generation systems most commonly used to warm shelters**

## CREOSOTE

> **WARNING**
>
> **When operating a heater in solid fuel mode, a buildup of creosote can cause a fire inside the stack. Such fires can result in severe injury or death.**

1-77. Depending on the type of solid or liquid fuel used, the resulting carbon byproducts can form a creosote buildup. Creosote soot is a flammable and corrosive substance that can build up on the walls of exhaust pipes and chimneys. Smoke is released by the initial fire, or primary combustion. Burning wood or fuel, no matter how it is done, releases pollutants in the form of gases and particulate matter. Creosote is formed when unburned particles, soot and other volatile gases combine as they exit the fire. As smoke cools while exiting the chimney or exhaust pipe, the gases liquefy, combine, and solidify to form creosote.

1-78. If there is too much wood fuel for the available oxygen, wood smolders creating more smoke and carbon monoxide, than heat. Likewise with a poor draft, unburned particles and gases can condense and build up on the walls of the exhaust, in the flue, or on the walls of the shelter. Restricted air supply, unseasoned or rain-soaked wood, and cool surface flue all encourage creosote to build up. Over time, creosote soot buildup can become a danger, resulting in a chimney fire. Creosote buildup is the primary cause or a major contributing factor in over 70% of heating fires.

1-79. The commander and maintenance leaders should treat heaters as they would any vehicle or weapon system, in terms of tracking weekly maintenance in the months leading up to winter weather. This will involve operators performing and reporting weekly PMCS of heating devices. It will involve after operation cleaning and maintenance routines. Heater equipment TMs or manufacturer's manuals must be available to operators for each item.

## DIRECT HEAT

1-80. Direct heat is also referred to as an open flame. This is the oldest and most common way to use a controlled heat source. An open flame is considered direct because the heat source is exposed and not fully contained within an enclosure. Direct heat is used to cook food, warm frozen brakes and other moisture frozen parts, and to comfort Soldiers in a shelter. Examples of direct heat equipment include an open hearth, pit, burner or a gas flow barrel to support the flame; a radiator bowl to direct the heat; and a flue to catch and vent the fire exhaust. Bunsen burners or blow-torches represent mechanically complicated direct heating devices.

1-81. Occasionally, units purchased powerful kerosene-fueled or multi-fueled forced air "jet-heaters" due to the need to keep the large space of tactical operations centers (and other shelters) as warm as possible. While these heaters produce a useful blast of heated air, they are also an unsafe open flame which vents exhaust, carbon monoxide, and moisture into the enclosed area of a tent or shelter. For this reason, it should not be used in troop shelters or enclosed areas. In addition, they often require the electrical power of 120-volt alternating current, which is not always available in field environments.

**WARNING**

**Do not use open flame direct heat, forced air jet heaters or other non-electric direct heat heaters inside a shelter. They release too much moisture, unburned carbon based byproducts, and carbon monoxide for use in the contained area of a tent.**

**Exhaust of hydrocarbon fueled heaters in a contained area must be vented by a smokestack, chimney, or exhaust piping.**

## SINGLE STAGE HEAT GENERATION

1-82. This equipment is noted for keeping the primary heat source fully contained, as in the screened in hearth of a fire place with chimney, Franklin stove or pot-belly stove. The stove containing the flame has a high level of heat conduction without being damaged by the heat. The amount of heat can be regulated by controlling the flow of fuel and oxidizer (air) into the fire. Most significantly, flame byproducts are kept contained and deliberately channeled out of the enclosed area into the open air with this system, usually by the convection of rising heat through a stove pipe or chimney.

## TWO STAGE HEAT GENERATION

1-83. This system, also called a "duct heater," is commonly used to heat large shelters. Shelter or room air is moved through ducting from the shelter to the heat source without directly making contact with the exhaust of the combustion process. The air is heated in a heating chamber segregated from the combustion chamber, and then returned to the shelter or room, referred to as 100% recirculation. For the proper operation of a two stage heating system, the heating chamber must be able to keep the room air completely segregated from the fuel combustion and its affiliated byproducts. They can be complicated, cumbersome, and some military versions need a trailer. The large ones can also take a considerable amount of time to set up and dismantle.

## THREE STAGE HEAT GENERATION

1-84. A three stage heat generation system uses a liquid or fluid medium (figure 1-5) to transfer heat from the point of heat production to the place of heat radiation. This is the engineering principle most commonly used for heating the passenger compartment of vehicles where the engine is the heating source. In cold, this heating method is often used to keep batteries and fluids of a motor warm enough to be restarted after a vehicle has been turned off and cooled. It is also the principle heat transfer method used for nuclear reactor heat exchange.

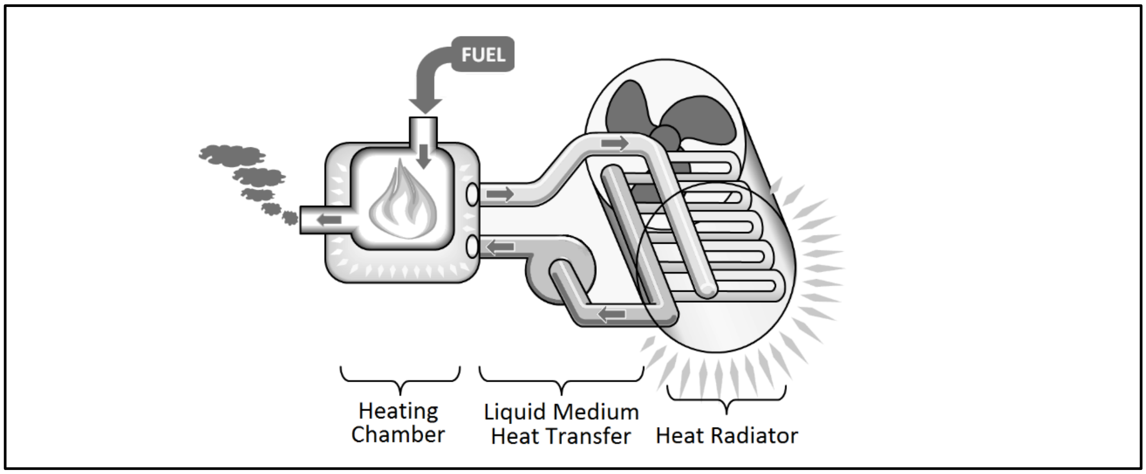


**Figure 1-5. Three stage heat generating system**

## SHELTER AND HEATER SAFETY

**DANGER**

**Exhaust must be vented to the outside of an enclosed area.**

**DANGER**

**Gasoline (MOGAS) should never be used in any heater.**

**DANGER**

**Do not use wood, paper or any solid fuel in heaters or stoves lacking an ember trap screen at the end of the exhaust pipe. Such embers will burn fabric, damaging tents and clothing.**

**DANGER**

**Deadline any military issue shelter heater or stove that is lacking an exhaust pipe capable of venting fumes to the outside of the personnel space.**

**Do not use COTS heaters in a shelter that vents its exhaust fumes into the shelter.**

1-85. Planned provisions for additional heating of billets, shelters and tents are necessary, but come with risk that must be managed. Even for something as common as Soldiers sleeping in tents, every part of the activity has to be reexamined in the context of cold weather challenges. Fire and carbon monoxide from heaters can injure or kill Soldiers. Operate all heaters and stoves in accordance with the applicable TM. Safety equipment such as extinguishers, as well as fireguards must be present. Before the onset of cold weather or entering a severely cold environment, leaders are responsible for cold weather planning, obtaining sufficient heating assets (military or COTS), performing risk assessment on all heater assets, defining operating procedures, and providing Soldier training. Soldiers must be licensed or certified to operate field shelter heaters.

1-86. Carbon monoxide results from the incomplete combustion of carbon based fuels or other organic matter. When the smoke cools, carbon monoxide settles to ground level. As a Soldier inhales, this gas suffocates a person by obstructing the blood’s ability to carry oxygen through the body.

1-87. Personnel shall not be exposed to concentrations of toxic substances in excess of the limits specified in either the Department of Defense (DOD) regulations, Occupational Safety and Health Agency (OSHA) standards or specialized standards applicable to military unique equipment, systems, or operations. From the practical standpoint of controlling health hazards, the critical contaminants are: carbon monoxide, ammonia, nitrogen oxides, sulfur dioxide, and aldehydes (methane). In sufficient concentrations, these substances may incapacitate personnel or substantially reduce their performance through eye irritation, nausea, headache, reduced mental alertness, unconsciousness, and death.

1-88. Exposure to carbon monoxide is more common during the cold months when doors and windows of buildings are closed to preserve heat. Vehicle and motor exhaust in garages and shops are a common source of carbon monoxide exposures. Furnaces and stoves which are improperly fired or are located in poorly ventilated areas present a health hazard. Oxygen starved flames of heating devices produce a greater amount of carbon monoxide than a well ventilated heater. Excessive carbon monoxide buildup can occur in heaters that have chimney soot (creosote) buildup, improper ventilation, or are not fully burning the heating fuel. While working in sheltered maintenance areas, attention should be paid to room ventilation and piping to funnel exhaust out of the working area.

1-89. The type and degree of ventilation control required must be adjusted for the specific operation and location. If only one small engine is operated for a short period of time in a large room, natural ventilation may be adequate to prevent an excessive carbon monoxide concentration. However, if three or four engines are operated in the same room, the amount of carbon monoxide in the atmosphere may rise to a dangerous level. If passive ventilation is not adequate because of the size and number of engines being operated, active mechanical-exhaust ventilation may have to be installed. Flex-hoses or tailpipe extensions are a common control in maintenance shops.

1-90. When motor vehicles move within a building (such as materials handling equipment operating in a warehouse), carbon monoxide concentrations must be kept down. This can be done by either fresh air general dilution ventilation or by limiting the number of vehicles being operated at one time.

1-91. While COTS heaters and stoves may seem to be a good solution for heating problems in the field, Soldiers must be trained on proper operating procedures before using a piece of COTS equipment. Though Army policy doesn’t limit the use of COTS heaters, very few COTS heaters on the market meet the field environment demands that the Army faces. Military shelters and military issued heaters are designed and have been tested to complement each other. Propane COTS heaters, though noted for their low carbon monoxide emissions, still produce a large quantity of water vapor that can contribute to condensation. Further, once used propane replenishment is usually not available for a field mission. Although military heaters are not without risk, they are preferred over COTS heaters. This does not prohibit the use of a COTS heater.

1-92. The following caution warnings apply to using fuel fed (non-electric) space heaters:

- For those shelters (or tents) heated by combustible fuel heaters and stoves, a fully dressed and alert fireguard must be on duty before anyone is allowed to sleep in the shelter.
- Provide proper ventilation in heated shelters to avoid the danger of carbon monoxide poisoning caused by exhaust gases from running engines and contaminated hot air from defective heaters.
- Control loose stove pipe opening flaps to prevent contact with hot stove pipes. This is a leading cause of tent fires.
- Insure all fuel spillage control measures are in place before using a liquid fuel operated heater.
- For safe operation, be sure to allow at least two feet of space between the heater and the shelter wall.
- Do not use any type of accelerant (gas, kerosene, jet fuel or others) to help ignite solid fuel. Explosion or uncontrolled fire may result. Tinder should be used to ignite solid fuel or wood.
- DO NOT USE UNAUTHORIZED FUELS: Use only approved liquid and solid fuels. Using unauthorized fuels in a heater will create a fire danger and potential for explosion.
- Never use open flame direct heat, or forced air heaters inside a shelter or tent. Heater exhaust in a contained area must be vented by a flue, chimney or duct.
- Stoves lacking the convection to draw enough oxygen into the flame cause an incomplete burn of hydrocarbons. This produces heightened levels of carbon monoxide.
- If the fuel flow control valve assembly bracket is bent or improperly positioned, a fuel overflow could occur inside burner assembly and cause a fire or explosion. Deadline the heater and notify field level maintenance.
- The stack assembly (exhaust pipe) should be cleaned daily when operating with solid fuel to prevent creosote buildup (see the subsection on “Creosote” (paragraph 1-76 and 1-77) for more information).
- Heater components may warp from excessive heat caused by an over fueled fire. Wood and coal can burn extremely hot depending on the type and size of fuel used. If coal is being used as a fuel, add only a small amount of coal at a time. Coal is very dense and provides high heat output. Overfilling the heater with coal will cause the heater to run extremely hot and it will be very difficult to control the heater's temperature output.
- Do not over-fuel wood or coal burning fire. Clean ashes frequently. Over fueled or excessive soot buildup in heaters can cause an oxygen starved flame. This will result in a high carbon monoxide release with little heat. Eventually, it will lead to a flame-out and the sudden release of excessive smoke. Operators should plan on shutting down a solid fueled heater once every two to four hours to remove ash.
- Fireguards of tent heaters (direct heat, or single stage stove heaters) should have two heat-protective gloves (of the type used to swap barrels on a machine gun) and a fire extinguisher with the heater. Inventory heaters and order sufficient supplemental items; at least one set for each heater.
- Do not attempt to replenish the fuel supply while operating a heater.
- When lighting or refueling an in-shelter heater, all personnel in the tent must be awake and prepared for emergency exit. A second fireguard must be standing by with a fire extinguisher at the ready.
- Never re-light a heater when it is still hot. Be sure to allow the heater to cool completely before attempting to re-light.
- The use of propane-fueled lanterns during harsh cold weather operations is not recommended. Propane turns to liquid at approximately –40°F (-40°C). It may spray in a liquid state from its container when the valve is opened, creating an extremely hazardous condition.

# MAINTENANCE FACILITIES

1-93. Operational variables and unit resources will always be the driving factor in any planning considerations. Where applicable, prior planning considerations for maintenance facilities should seek to:

- Ensure that tents and supporting frames are complete and in good repair.
- Check that shelter heaters are complete and operational.
- Check that generators are complete and operational.
- Obtain oversized ground covers to keep moisture from rising up within the maintenance shelters.
- Ensure that there are adequate personnel who are licensed to operate and repair heaters, and generators.

**WARNING**

**When vehicles, generators, and POL containers are brought into warm storage from the cold, the fuel tanks/containers should only be filled three quarters full. If this procedure is not followed, the expansion of the cold POL products in the fuel containers could cause spillage and create a serious fire hazard.**

1-94. The availability of maintenance facilities, heated buildings or shelters, can be critical to the maintenance mission. Human engineering standards for facilities, and work spaces for soldiers use is set forth by MIL-STD-1472, *Department of Defense Design Criteria Standard: Human Engineering*. Proper servicing is difficult unless personnel are working in reasonably comfortable temperatures. Maintenance in the field will require gloves that will impede repairs that require careful and precise servicing. Although it's hard to quantifiably forecast, a shortage of heated shelters will cause an increase in maintenance man-hours needed for any particular task. Without some type of permanent or temporary shelter, even routine maintenance in the open can become extremely difficult. Additional personnel or the attachment of additional elements may be needed to accommodate the constraints in workflow or the drag against the maintenance process caused by the cold.

1-95. When buildings are not available, maintenance tents are a temporary solution. If possible, tents should have wood flooring and be heated by portable duct heaters or tent stoves. Tarpaulins or even parachutes may be used to create overhead shelter and windbreaks. A framework of poles erected around a vehicle can support a tarpaulin. A parachute could be deployed over the vehicle, securely staked down at the bottom, and then inflated by the air from a portable duct heater. Extreme care should be taken to avoid the danger of carbon monoxide poisoning from running engines or direct heat devices, by ensuring proper ventilation.

# COTS EQUIPMENT

1-96. In situations where a unit must deploy into an environment for which military issued equipment is insufficient, the commander may feel compelled to spend discretionary funds to procure specialized items.

1-97. If a COTS item is to be considered, a maintenance supervisor and medical person who is familiar with carbon monoxide should asses its proper use, preventive maintenance, and lifecycle upkeep requirements; establishing a COTS-PMCS routine. Planners need to consider the availability of the fuel used to power COTS items in the area where the unit will be deployed and operating. Though such items might be readily maintained in home station garrison, it is important to ascertain that such COTS items can be serviced and will function during deployment.

1-98. Soldiers who are specialized in their jobs usually have a pretty good idea when modified personnel gear or COTS-PPE is needed. Occupational Safety and Health Agency (OSHA) holds the employer responsible for the availability of personal protective equipment, and how it is used; even if the employee buys it. Soldiers should be directed to consult with platoon leaders or the unit's senior sergeant before taking such action on their own initiative. Good ideas that relieve constraints should be openly discussed, while only taking actions which minimizes personal risk and wasted money.

1-99. Avoid buying various items for a specific type function from different manufacturers. Such inconsistent redundancy will cause maintenance and supply lifecycle support problems. It will mean that replacement parts will have to be obtained from different sources, and won't be interchangeable or compatible.

1-100. Daylight will become limited during the winter in northern latitudes. Additional lighting equipment is usually required to furnish adequate illumination for maintenance services. Lights with ample power generation, cable extensions, attachment plugs, connectors, and spare bulbs are essential.

1-101. When equipment such as brake-pads, weapon bolts, or similar moving parts becomes seized up with moisture, extra heaters are needed. For outdoor work, consider using a COTS portable forced air "jet heater."

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## Chapter 2

# Equipment Maintenance

Cold weather can cause problems with equipment not normally encountered during operations in more moderate or temperate weather conditions. This chapter contains specific information about the cold performance of materials and component parts to consider when conducting vehicle and equipment maintenance and operations.

**NOTE:** Maintainers and operators should refer to the item specific TM or LO that are the primary sources for maintenance procedures.

## SECTION I – MAINTENANCE CONSIDERATIONS

2-1. The importance of maintenance, especially the correct performance of PMCS, must be impressed on all Soldiers in cold regions. Operators and maintenance personnel need to not only be proficient in the maintenance procedures of their TMs and LO, but they must further exercise an analytical understanding of characteristics related to the cold environment. Daily maintenance in a cold weather environment cannot be taken for granted and done by routine; fore-thought is required. Ensure that added care is taken during before-operations checks because this is the point where the majority of critical issues can be found and fixed before damage occurs. In cold weather, operators performing PMCS must anticipate that extra time will be needed.

2-2. The TM and LO are the primary sources of reference for maintenance procedures. However, in cold weather circumstances, situations can arise that are not covered in the text of reference documents (ATP 4-31). Commanders need to first establish policy for when and how Soldiers may resort to an alternate-procedure solution. This will require the selection of a maintainer subject matter expert who can assess when a specific situation or event exceeds or is outside of published standard procedures. The use of an alternate-procedure solution must be based on the likelihood of a risk to Soldiers or equipment that is not addressed in TM documents. Never use a non-TM solution just to simplify procedures, or perform makeshift repairs when the requisite resources are available.

**DANGER**

**The safety of life and limb take precedence over TM procedures and doctrine.**

## SECTION II - GENERAL EFFECTS OF COLD ON MATERIEL

2-3. As different pieces of equipment reach freezing temperatures, component materials change their physical properties and functional characteristics. Special care and procedures must be followed to keep equipment and materials functioning properly, affecting all levels from the operator to maintenance facilities. If maintenance Soldiers and equipment operators are to anticipate maintenance demands, they need to have a general idea of what to expect and what remedial efforts or special procedures are needed to keep equipment functioning.

## THE IMPACT OF COLD TEMPERATURES

2-4. Three general categories of issues account for most of the specific maintenance issues that are not otherwise found in temperate zones:

- Cold Altered Material Properties: Operators must be very cautious when using severely cold equipment that has been inactive for a long time. For example, since metals contract at lower temperatures and expand at higher temperatures, improper clearances may result in either binding or excessive looseness. Many items become brittle in the cold, which could break if forced. Severe cold has a different effect on different materials, with which mechanics and operators must be familiar.
- POL Degradation: Under severely cold conditions, the cold acts to degrade (not preserve) petroleum products. If the cold has caused lubricants to congeal in the various mechanical components, then friction will occur and part failure can follow. Chapter 4 covers this subject in more detail.
- Condensation Freezing: This subject is addressed in Section III.

## METALS

2-5. Metals become brittle in cold temperatures; thus, parts cannot withstand the shock loads that they sustain at higher temperatures. For example, at -20°F (-28°C) certain steels can withstand only 50% of the shock load that they can sustain at room temperature. For a given change in temperature, various metals will expand or contract by different amounts. These characteristics especially affect bearings in which the bearings and shaft are of different metals, are of different metals bolted together, or meshing gears are of different metals. In cold weather, special care should be taken in adjusting parts of this type, especially when adjusting bearing clearances.

## RUBBER

2-6. Besides natural rubber, there are hundreds of rubber substitutes. Synthetic rubbers look and usually react the same as natural rubber, although most do not attain a greater flexibility at high temperatures. As it cools, natural rubber gradually stiffens, but retains a large part of its elasticity until reaching temperatures below -20°F (-28°C).

2-7. Below -20°F (-28°C), certain phenomena occur. When cooled gradually but continuously over a short time, rubber remains flexible until it reaches approximately -60°F (-51°C). It then quickly loses its elasticity and becomes brittle. Also, if rubber is consistently kept at the relatively higher temperature of just under -20°F (-28°C) for a long time, an effect similar to crystallization occurs, causing it to become brittle. For example, hoses for fueling may crack, increasing the potential for spills.

## RUBBER-COVERED ELECTRIC CABLES

2-8. Extreme care must be taken in handling electric cables at low temperatures. If the rubber jackets become hard, the cables must be protected from shock loads and bending to prevent short circuits caused by breaks in the covering. If cables are to be bent, they must first be warmed. Neoprene jackets on cables become brittle and break readily at low temperatures.

## PLASTICS

2-9. Plastics expand and contract much more than metal or glass, causing them to be brittle in cold weather. Vehicular canvas covers with plastic windows may break due to a combination of cold and vibration. This has an impact on the reliability of electrical components supported on plastic. In cold, operators should be extra careful not to drop or rough handle equipment with plastic components.

2-10. In dry-cold environments (or colder), operators should be conscious that plastics have the potential to buildup static charges on surfaces due to lower humidity. An increased possibility of static charge can cause potential hazards in explosive gas environments and potential problems with electronics and other electrical equipment. Additionally, static can cause devices such as analog meters with plastic faces to give incorrect or erratic readings and can also affect the operation of sensitive electronic devices.

### GLASS

> **CAUTION**
>
> Splashing warm water on frozen (cold-soaked) glass to clear a frosted windshield can shatter glass. Use warmed air to defrost glass.

2-11. Glass, porcelain, and other ceramics perform normally at low temperatures if handled carefully. However, cracking may result if windshields or other vehicle glass is heated too rapidly.

### FABRICS

2-12. If kept dry, fabrics generally retain their flexibility, even at extremely low temperatures. However tarpaulins may shrink, and wrinkles are extremely difficult to smooth out at below freezing temperatures. Whenever possible, tarpaulins should be unfolded in heated enclosures or kept installed on equipment.

## PREPARING EQUIPMENT

**NOTE:** Before cold weather operation of vehicles, crews shall use the appropriate TM's operator manual and LO for operation, lubrication, PMCS, and maintenance. These manuals usually include a section subtitled, *Operations under Unusual Conditions*. The following information in this subsection is not a substitute for the item or platform TM. This TM provides information that is broad and only general in nature.

2-13. Soldiers must maintain equipment in the best mechanical condition to withstand the added difficulties and prevent failures during below freezing operations. Commanders can place special emphasis on maintenance inspections, and spot inspections of issued equipment pertaining to item operation and safety. This leadership control is especially helpful during the initial period of freezing cold weather operations.

2-14. In this age of expeditionary missions, commanders can never know with certainty whether or not their unit will be deployed to a cold weather region. In the face of resource limitations versus the uncertainty of future mission requirements, the commander will need to define a level of preparedness that suppliers, maintainers, and supervising trainers will need to meet. Placing equipment in proper mechanical condition before the onset of cold weather requires added time for necessary and careful repair and cleaning. Low temperatures should be anticipated far enough in advance to permit time to acquire winterization parts and the complete installation of those parts.

2-15. Proper maintenance is very important under any operating condition. It takes on additional significance in the cold. Taking equipment that is not in top condition out into the field in subzero weather is taking a chance on not getting back with it. Operators are responsible for rigid adherence to maintenance schedules, and procedures set forth in their TMs and LOs. It affects the extent of emergency repairs or adjustments that will have to be made in bitter cold, without shelter or where established repair facilities are very limited.

2-16. Movement in cold weather environments can be one of the most difficult tasks that a unit may encounter. Vehicles are the most preferred method of movement, but, with cold weather comes a higher maintenance requirement and incidence of problems. Some of the most commonly encountered problems are listed in the following subsections, along with some useful problem-solving tips, which may assist in mission accomplishment.

### STANDARD WINTERIZATION

2-17. Winterization is a specific set of modifications listed in the item's TM for preparing the item or vehicle for cold weather operations. The following are typical maintenance actions that accompany winterization:

- Ensure that proper antifreeze/water mixture is utilized. Generally a 60% antifreeze, 40% distilled water mixture offers the best protection against cold temperatures.

- Inspect all belts and hoses for cracks, dry-rot, or breaks, and replace as necessary.
- Install winterfronts or radiator shutters.
- Ensure that the vehicle personnel heater is mounted and operational.
- Ensure that tire chains, engine heaters, ice scrapers, and other equipment required for operation in cold/icy/deep snow conditions are present, and that vehicle crews are thoroughly trained in their use.
- Pre-fit tire chains or track cleats to vehicles ensuring that kits are complete and in good condition. (Their mounting and dismounting should be trained as a crew drill).

## ENGINE BELTS

2-18. Rubber belts lengthen in severe deep cold. Operators must check belt tension by regularly looking for lose belts, or listening for squealing when the engine is running.

## TIRES

2-19. Tires are made of multiple materials which each have their own properties.

- Tires become more rigid and develop flat spots when parked in cold temperatures.
- Inflate tires, in a warm environment such as sheltered parking garage, to 10 pounds per square inch above normal. This allows for air contraction and pressure loss once vehicle is out in the cold.
- Place barrier materials (branches, cardboard, or such similar material) under tires to prevent them from freezing to the ground when parked for long periods of time.
- In harsh cold, rubber expands while metal contracts which threatens to break tire seals. Tires should have a steel wire cord running the edge of the tire, which will contract with the tire rim.

## BATTERIES

2-20. Cold weather can affect batteries adversely.

- Their capacity to provide power is less at low temperatures.
- Cold temperatures increase the vehicle power demands that the battery must satisfy.
- Ensure batteries are fully charged; they can freeze when partially or completely discharged.
- Frozen vehicle batteries can burn or explode if the operator attempts to “jump start” the vehicle.
- A fully charged battery can withstand -70°F (-56°C) to about -77°F (-60°C) without freezing.
- Use float-chargers to ensure that a rechargeable battery maintains an adequate state-of-charge (SOC) for its given application.

**NOTE:** Batteries are covered in greater detail in Chapter 3.

## FUELS

2-21. Most fuels react to cold the same to cold, it’s usually distinguished by the temperatures at which breakdown occurs.

- Jet propulsion fuel, JP-8, under the SFP, is usable down to -53°F (-47°C).
- Motor gasoline is not significantly affected by cold temperatures.
- Clouding, (formation of waxes), occurs in diesel fuel at low temperature.
- Additives can greatly inhibit icing and fuel line freeze-up.
- Fuel dropped through the air also generates static electricity. (Know any static control safety procedures specified in the item TM, or fuel handling procedures, as appropriate.). Reference: ASTM D4865, Standard Guide for Generation and Dissipation of Static Electricity in Petroleum Fuel Systems.

**NOTE:** Fuels are covered in greater detail in Chapter 4, Section II, and Appendix E.

## TRANSMISSIONS/TRANSFER CASES/DIFFERENTIALS/FINAL DRIVES

2-22. All transmissions should be drained, flushed, and completely refilled with lubricant as prescribed in the LO. Before draining the transmission fluid from a transmission, be prepared to capture the drainage for proper recycle or disposal. Transmission fluid is a hazardous waste.

## LUBRICATION

2-23. The best general reference for Army lubricants is POL Products Guide for Ground Vehicle and Equipment Materiel Systems January 2014, from the Tank Automotive Research and Development Engineering Command (TARDEC). The Army qualifies heavy duty (HD) diesel engine oils against the requirements of specification MIL-PRF-2104. The latest version, MIL-PRF-2104K has introduced the Single Common Powertrain Lubricant (SCPL).

- Transmissions are designed (in general) to use lower viscosity oils. Most MIL-PRF-2104 oils (15W-40, 40, 30, 10W and SCPL or OEA-30) can be used at temperatures up to a high of 120°F (49°C).
- Society of Automotive Engineers, SAE 10W oils are typically not recommended for engine applications, but make good transmission fluids.
- Store lubricants in a temperate warm place.
- LAW (supply symbol for, lubricant, arctic weight) is used in low temperature for the lubrication and preservation of small arms and light caliber weapons up to 20mm.

**NOTE:** Lubricants are covered in greater detail in Chapter 4, Sections III & IV, and Appendix E.

## LOW OR NO OIL PRESSURE

2-24. The two most common failures of the engine lubrication system are caused by low or no oil pressure, and the accumulation of sludge in the lubricating oil. Even though the pressure gauge indicates low or no oil pressure, a stick check may indicate the oil is at the correct mark. Here, fuel-diluted oil, hot oil, or low viscosity oil may have caused a low oil pressure reading. No oil pressure may be caused by cold, congealed, high viscosity oil; a clogged strainer; a defective oil pump; the lack of lubricant; or engine component failure (such as an engine bearing). In either case, the problem is serious, but not resolvable by simply adding oil.

**NOTE:** Do not overlook the possibility that the oil pressure gauge may be defective. If the gauge is working correctly, the oil is up to the full mark, and the oil filter element is not clogged, the failure is probably in the pump or line.

## VEHICLE STARTING

2-25. Starting a vehicle and getting it underway in severe cold weather is not the same as temperate weather.

- Always PMCS vehicle using the TM before, during, and after vehicle operation.
- Be ready to draw additional power from a supplemental energy source. (See paragraph 5-5 through 5-8, and Appendix D.)
- Start engine and allow vehicle to idle for approximately 3 minutes before moving.
- Drive slowly at first, allow time for moving parts to reach operating temperatures before increasing engine speed.
- Downgrade all hoist and winch capabilities. Certain metals will lose up to half of their shock load tensile strength at temperatures of –20°F (-29°C) or colder.
- Ensure that the engine idle is set for proper battery recharging. This is usually done by engaging equipment high idle switch. (It usually brings the engine idle up to about 1100-1200 revolutions per minute [rpm]). The idle may have to be increased where posable, for vehicles that operate as a command or communications vehicle. High idling is done to produce enough electric power to run the engine while overcoming the cold induced resistance, and still provide enough surplus power to recharge the electricity the battery spends to start and run the engine.

### Universal and Slip Joints

2-26. Thoroughly lubricate joints with grease, molybdenum disulfide. Remove dirt and ice, and then check for good condition.

## SECTION III - CONDENSATION

2-27. Condensation is the liquidizing of moisture within warm air, when the air contacts a relatively colder item. It is a very common threat to equipment serviceability and even Soldier health in cold environments. Condensation is often called, "sweating" due to its appearance. This condition has an effect on almost every type of material (to include personnel) found in an Army unit. Yet, the debilitating effect on each item of material is varied and unique.

2-28. The most common cause of condensation occurs when a cold-soaked item of equipment is brought into an above freezing environment. Immediately, the moisture in the warm air will settle on the cold equipment in all the hidden places, such as between the gaps of the moving parts. Then when the item is returned to the cold, the water condensation freezes. It results in a large number of problems.

2-29. There are two common ways to avoid the problems of freezing condensation on mechanical items. The simplest is to leave mechanical items (including weapons) out in the freezing cold, and not bring them into a warm shelter. The second solution is to heat the item past being cold-soaked, to a temperature that is equal or warmer than the shelter (such as by using anti-condensation containers, or hot air blowers), and wiping them off before taking it back into the freezing cold. Allowing a metal item to sweat while it warms only invites corrosion, rust or oxidation to occur.

2-30. If a cold-soaked item is operated indoors, the moisture forms an emulsion within the lubricants that degrades the protection. To fix a corrupted lubricant requires removing all the lubricant and performing a detailed cleaning (usually involving degreasing solvent, type two [SD-2]) of the item. Further, if the materiel is taken outside into low temperatures before the condensed moisture is removed or has evaporated, the parts may freeze and become inoperable.

2-31. The most common unrecognized source of high humidity, and consequently of condensation is the byproduct of an open flame. Water is a major byproduct of fire. For its weight, propane and natural gas create and exceptional amount of moisture. In the outdoors, propane thermal heaters and forced air heaters are excellent for loosening frozen brakes, or other mechanical components. However, in a tent or cold-soaked vehicle compartment, such a fire source can create an ice buildup on the walls. Twenty pounds of propane can produce almost three gallons of moisture. Ventilation is important to wick away moisture any time direct heating is done in an enclosed area.

# CONDENSATION THREATS TO AUTOMOTIVE EQUIPMENT

2-32. In freezing cold, moisture condensation turns into ice crystals suspended in the POL or fuel, causing the degradation of the POL or fuel. In the case of oils and lubricants, it can obstruct the free movement of equipment function, and lead to breakage. In the case of fuels, it results in water contamination that causes an engine to stop running. Brush snow or wipe water from the tops of fuel lube containers, spouts, and plugs before using to prevent contamination.

2-33. Air compressors are used in vehicle air-brakes, air-hydraulic brakes, and central tire inflation systems. They are especially prone to internal condensation. In cold, moisture may freeze within the compressor. Follow after-operation maintenance procedures by draining condensation from air compressor tanks. If the bleed valve is frozen, report it immediately to maintenance personnel.

2-34. Frozen moisture in an air brake or pneumatic system seriously affects operation. Brake line, air brake filters, brake chambers, pushrods, valves, and seals are subject to more defects and failure in cold. Condensation between brake shoes and brake drums may freeze, making it impossible for the vehicle to move. When this happens, portable heating equipment is needed to thaw the brake shoes from the drums or warm obstructed air passage.

2-35. Low engine operating temperature results in excessive fuel consumption, dilution of engine oil by unburned fuel, and formation of sludge from condensation of water in cylinders and crankcase. This will degrade the useful life and effectiveness of engine lubricants, requiring more frequent oil changes.

# CONDENSATION ON A PERSONAL WEAPON

2-36. Condensation forms on weapons when they are taken from a cold into a warmer environment. When weapons are taken into heated shelters for cleaning purposes, sweating may continue for as long as an hour. When time permits, wait one hour, remove all condensation, and then clean the weapon. If weapons are taken back into the cold without removing the condensation it can turn to ice, which will result in stoppages.

2-37. Condensation on weapons is a constant threat to weapon function in cold weather. It will cause icing and corrosion of machined surfaces, raw metal surfaces, and especially in the bores of weapons. Such condensation is often referred to as sweating, but this is not moisture coming out of the metal. When 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. Any opening that allows air to enter will easily become a condensation problem area. Such condensation can freeze moving parts when the weapon is returned to the freezing cold. Condensation causes corrosion if not immediately removed.

2-38. Under extremely cold conditions, is especially serious when it occurs in the internal parts of the weapon, causing stoppages and malfunctions. Parts such as recoil and counterrecoil rods and variable recoil cams must be wiped dry and lubricated lightly with LAW every day.

2-39. It is best to leave weapons outside when temperatures are below freezing. When left outside, weapons should be readily accessible, but sheltered, so that ice and snow will not get into the working parts of the weapon (sights, barrel).

# CONDENSATION ON OPTICAL DEVICES

2-40. Humidity and cold air combine to form condensation when temperatures change rapidly. A combination of body warmth and breathing may cloud the optics of sights and fire control mechanisms. For optical equipment, condensation can build up behind the lens, obstructing vision with streaking or by frosting over. Special cleaning procedures reduce problems caused by condensation.

2-41. Maintenance personnel should anticipate the buildup of condensation within optical devices that are not hermetically sealed or leaking humid air. Maintainers will need to perform field maintenance involving opening lens assemblies, cleaning the glass, removing corrosion, and resealing the assembly, free of internal moisture. If this cannot be done, supply personnel will have to arrange for exchange of the item.

2-42. It is best to leave fire control items outdoors, but covered, to protect it from the snow. Snow-tight lockers or sealed containers issued with the materiel maintained at outdoor temperatures are recommended for storing binoculars, telescopes, and other fire control equipment. Leave aiming instruments outside, or use anti-condensation containers to bring them into a heated shelter.

2-43. When in the field, leave winterized cold-soaked weapons and ammunition outdoors and covered from precipitation. (Security is a separate concern.) An alternative method is to place individual weapons between the tent and tent liner. This method allows for rapid access to the weapons, provides security, and still protects the weapon from excessive condensation.

2-44. Avoid the use of plastic sheets or tarps that tend to trap moisture and condensation against the equipment. Here, cloth that breaths is best at covering or wrapping up items.

2-45. If necessary, weapons may be taken inside for cleaning. The condensation will continue for approximately one hour after introduction of the weapon into a warm shelter. Wait until the condensation process has concluded. At that point, Soldiers can begin to thoroughly clean the weapon. If weapons are to be kept in heated shelters, they should be kept near, but not on, the floor to minimize condensation.

# CONDENSATION ON AMMUNITION

2-46. At a firing point, condensation on a round which freezes in the breech may lead to a misfire. At weapon ranges, ammunition should not be brought into warmed rooms for breakdown from packaging and issue, unless they are allowed to warm for long enough to evaporate any condensation. In a rapid ammunition distribution situation, it is better to keep the munitions cold.

2-47. Taping over ends of detonation cord, caps, and the igniter may prevent condensation contamination of an explosive charge's firing system. Otherwise, moisture will travel through the exposed explosive material degrading its performance.

# CONDENSATION ON ELECTRICAL ITEMS

2-48. Condensation damage is the primary threat to electronic equipment that is not sealed, waterproofed, or ruggedized. Condensation on electronic equipment occurs when a cold unit is brought in to a warm area. The cold temperature of the equipment causes warm air moisture to condense on the item and its circuit wiring. When power is applied, short circuiting can happen. Electrical equipment should be warmed to room temperature before being turned on. Even then, the condensation threatens to corrode the fine wires found on circuit boards causing intermittent failures.

**NOTE:** Manufacturers of COTS electronics generally consider condensation damage to be post manufacture damage, and usually will not repair or replace such items under warranty. Soldiers who carry such non-ruggedized personal items (such as cell phones) into cold weather environments are at personal financial risk. Commanders will need to weigh the risk to the unit when taking non-ruggedized COTS electronics into a cold weather environment.

# CONFINED AREA CONDENSATION

**CAUTION**

Most direct heat sources, especially propane and natural gas heaters discharge large quantities of moisture into the air. In cold-soaked vehicle cabs, this can cause sweating on the walls, fogging of windows, and water condensation to form within electrical equipment.

2-49. There is a second serious condensation threat that commonly occurs in vehicles, and likewise in the confines of small tents. Condensation can occur on the walls of uninsulated heated crew compartments. It can come from the moisture of people breathing. For example, frosting from the breath of the operators can render microphones inoperable. When the temperature is 95°F (35°C) at 75% humidity the body's loss of water is 7 milliliters per hour (ml/h). At +14°F (-10°C) and 25% humidity, the lungs give off 20 ml/h. Further, after heavy exertion the body can give off four times as much water than it does at rest. Four Soldiers working or resting in a cab can produce a cup of water condensation during an eight hour shift. If a bottle-tank with 17 pounds of propane is used to provide heat in an enclosed area, it can produce three and a half gallons of water. The rise in humidity, followed by its contact with the walls of a cold-soaked vehicle will cause sweating that will threaten exposed metal, weapons and electrical components.

# CONDENSATION FROM BREATH OR PERSPIRATION

2-50. Condensation and ice from a Soldier breathing tends to form on a weapon during freezing temperatures. A combination of body warmth and breathing may cloud the optics of sights and fire control mechanisms.

2-51. Moisture condensing on the eyepiece can render a fire control system useless. When a gunner initially tries to gain a sight picture, moisture from his breath and his body heat near the lens may cause condensation on the lens.

2-52. Condensation can result from a large number of overheated people placed in a confined area. When enemy contact is imminent, the interior climate of troop compartments of transportation platforms (especially aircraft) should be maintained close to freezing (32°F [0°C]). This prevents overheating of troops dressed in heavy cold region uniforms. It also prevents moisture from condensing and refreezing on weapons as troops disembark into the cold from warm aircraft and vehicles.

2-53. Soldiers and aircraft crews must exercise caution when loading Soldiers after periods of heavy exertion. Sweat buildup and body heat of Soldiers loaded on an aircraft can cause extreme and rapid fogging of the aircrafts windshields, blocking pilot vision. Soldiers preparing for extraction should ventilate their uniforms and remove as much body heat buildup as possible. Doors, windows or hatches should be kept open enough for the crew compartment to ventilate, until Soldiers' body heat has moderated, when possible. Condensation in a crew compartment is a threat to not only the pilot or driver's ability to see, but also a threat to electrical components in the crew cab.

2-54. Despite precautions, weapons parts may still freeze. If they do, slow and careful manual operation may free them and prevent breakage. Remember, plastic and metal become brittle in the freezing cold.

## ANTI-CONDENSATION CONTAINERS

2-55. If it is necessary to bring instruments or other material from low outdoor temperatures into higher room temperatures, use anti-condensation containers to prevent condensation of moisture (known as, sweating) on the metal and glass of weapons and instruments. The containers can be specially made boxes, covered cans, or other fairly airtight containers with heat-conducting walls. Have containers kept outside so that they are at the low outside temperature. Before entering a warmer inside area, put instruments into its anti-condensation container, and close it tightly. Then bring the container indoors and let stand until its inner temperature has had time to equalize with the room's temperature. Being near a stove can hasten a container's warm-up. If the seal on a container is not air tight, it will not function as an anti-condensation container.

2-56. If air in a container is cold and dry, it expands and presses outward when it is warmed. Therefore, no warm, humid air from the room can come in contact with instruments and cause condensation. When the instruments and inner container reach room temperature, the instruments can be removed with no danger of condensation.

2-57. If anti-condensation container for an item is not available, wrap materiel in blankets or similar material before it is brought into a heated enclosure. Air tight self-sealing plastic freezer bags make a good moisture barrier for small items. This will retard or impede the condensation process.

## SECTION IV – VEHICLE WINTERIZATION

2-58. Special winterization equipment is provided to protect both Soldiers and vehicles against cold weather. This equipment is issued as a part of specific kits. For vehicle protection when temperature falls only a few degrees below freezing, ordinary preparations are needed, as specified by the TM. Though any temperature below freezing becomes an issue for vehicle fluids, most vehicles components are fairly resistant to temperatures affects down to about +10°F (-12°C), for a short period of time.

2-59. Human engineering standards for facilities, work spaces and vehicles purchased by the Government for soldiers use is set forth by MIL-STD-1472. The crew compartment shall be provided with a heating system capable of maintaining temperatures above 68°F (20°C) during vehicle occupancy. When arctic clothing is worn, cab heaters shall be capable of maintaining a reference temperature of not less than 41°F (5°C).

2-60. For anticipated freezing temperatures, personnel heater kits and hardtop closures are available for installation. Unit operations will not be attempted without winterization kits on equipment in areas where temperatures from -25°F (-28°C) to -65°F (-59°C) are likely. Since some winterization kits require use at temperatures warmer than -25°F (-28°C), consult the TM for the correct starting and operating procedures.

# VEHICLE CREW HEATERS

2-61. Most wheeled vehicles heat the crew compartment by cycling antifreeze from the engine into the crew compartment heater. This is a three stage heat transfer system. Generally, vehicles heaters provide ample heat until the ambient temperature drops below -25°F (-28°C). At extreme-cold temperatures, the engine will struggle to generate enough heat to stay functional (see the subsection, Engine Temperature Maintenance, of this chapter). Although Arctic Antifreeze Solution can stay liquid down to -90°F (-68°C), it is unlikely that in extreme-cold the crew compartment heater be effective. Below -25°F (-28°C), electric or fuel-burning supplemental heaters (where available as a part of a winterization kit) are needed to provide more heat.

2-62. Tracked vehicles usually produce heat separately from the engine in a blower or turbine type burner module. Because tracked vehicles store more of the ambient cold temperature in their thick walls, these tracked vehicle heaters produce a lot more heat than wheeled vehicle heaters. These heat producing burner modules can be mounted inside or outside the crew compartment. Where the burner is outside the crew compartment, it is a three stage heating system. It that may use either antifreeze or oil to transfer heat from the burner into a crew compartment heat radiator. If the burner is in the crew compartment, is a single stage heater system.

2-63. Tracked vehicle operators have an added burden for operating and maintaining a heater system. Since these heaters have a burner module operators should making sure that soot, sludge or creosote does not build up in the burner unit. (Refer to vehicle specific TM for PMCS and maintenance procedures before attempting to clean.)

2-64. For those vehicles with burner modules mounted in the crew compartment, operators must be watchful that fuel feeds are not leaking.

**DANGER**

**Contact with burner modules can burn a person.**

**WARNING**

**Combustible fuel driven/powered personnel and crew cab heaters should be shut off at least 20 minutes prior to entering any shelter. In the event of faulty heater components, this procedure prevents the fire hazards created from accidental pumping of fuel on building floors, or fuel vapors from hot heater components.**

# PREHEATING BEFORE STARTING

2-65. Getting a cold-soaked engine to start can be very difficult. Then, even if it does start, it could still be damaged in cold situations. At temperatures below -20°F (-29°C), operators may have to start vehicle engines periodically to maintain an acceptable state of readiness. Periodic engine running should not be done if other means are available, such as engine heaters external heat, or indoor parking. A properly winterized engine with some type of preheating will easily keep an engine ready for operation. There are four general strategies for keeping a vehicle engine warm enough for use:

- Periodic or continuous engine running.
- Warm shelter parking.
- Electrical quick heat, heating elements.
- Standby fuel powered heaters.

2-66. The present generation of engine heaters are both electrically powered or fuel powered heating devices. They provide preheating to engines, drivetrain gears, batteries and other components of equipment which have to be warmed before or during the initial startup of equipment. For operators, such heaters can be as simple to operate as an electrical oil-pan, direct contact, heater pad, to the complex (and possibly dangerous) fuel powered heating devices that circulate scolding hot antifreeze through a vehicle while its sitting idle.

2-67. Slave starting or jump starting with another running vehicle (Chapter 3, Starting Procedures) can provide enough power to complete turning over the engine to catch the ignition and start. Make sure the battery electrolyte is not frozen. (Though this is a possible solution to starting, it is not true engine heating prior to starting.) In a motor pool, it is possible to keep one vehicle sheltered, and use it to slave or jump start the other vehicles in the fleet, when needed.

2-68. For maintenance planners, standby heaters are usually not a standard piece of equipment on a vehicle, and have to be ordered as a part of a vehicle winterization kit.

**NOTE:** Not all vehicles have government provided engine heater systems (as discussed below) as a part of a winterization kit. If the government issued options are inadequate, notify the U.S. Army's Tank-Automotive and Armaments Command (TACOM), or the Logistic Support Activity (LOGSA) liaison or representative of the need. Otherwise, the unit commander will have to decide about procuring COTS items.

## ELECTRICAL QUICK HEAT SYSTEMS

2-69. Quick heat is a technique that uses electrical engine block heaters to heat the antifreeze or engine oil (uses external power to generate heat). It allows quick warm-up and reliable starting when the engine block or transmission temperatures have dropped to as low as the cold ambient temperature. At some pre-determined time prior to vehicle operation, electrical heat is applied to the engine, batteries, and components, raising their temperatures enough to ensure starting. For operational planners, electrical quick heaters are dependent upon access to a facility's power sources. Such electrical power would be easy to obtain in garrison, but a challenge to find in a tactical field situation.

2-70. The time from initiating quick heat to achieving reliable starting temperatures can vary from a few minutes to one hour. Such systems use heater elements inserted into the engine block, or heating pads placed against the oil pan and battery to prepare the vehicle for starting. The military objective is to achieve reliable starting within a maximum of one hour regardless of ambient temperature. There are several electro-mechanical devices for keeping a coolant from freezing in a vehicle:

### Heater Harness

**WARNING:**

**Do not operate engine unless the heater harness cord has been disconnected from power source and secured in place. The heater harness power cord must be secured in its retaining clips and routed away from exhaust manifolds and moving parts.**

2-71. Attached to electrical heater systems is a heavy appliance power cord. This cord is usually woven through the engine compartment to a point near the front fender. The heater cord usually ends with a standard three prong male connector, and only occasionally uses a polarized two prong. A protective cap is necessary for keeping the end-plug connectors free of ice fouling or corrosion.

### Battery Blankets or Battery Insulator

2-72. This is anything from an electrical heating pad to a battery case with a self-regulated, thermostat-controlled heating element to keep the battery warm. A battery blanket protects a battery charge from freezing. It is the chemical reactions within a battery that release energy. Those reactions occur best within a warm battery.

### Float-charger

2-73. It maintains a battery's state of charge (SOC) in storage or when installed in an infrequently used vehicle. This type of charger ensures the battery is charged to its rated capacity. In bitter cold, a float-charger can also ensure the battery is capable of starting a vehicle or generator set engine. However, only use float-chargers designed to prevent battery over-charging. These chargers monitor the SOC and adjust the charging current automatically. If the charger detects a problem, it can prevent damage to the battery.

### Engine Block Immersion Heater

2-74. This is an electrical heating element that is mounted directly into the engine block through an engine's core plug. The block mount can be threaded into the engine block or wedged into a core hole by using a compression gasket. There is no pump with this type of heater.

### Inline Coolant Hose Heater

2-75. This is an electrical heating element that is mounted along the hose between the engine and the radiator. Like the block heater, it is electrically powered. A circulating coolant inline heater is a related device. It heats the coolant as well as circulates it through the engine by tapping into the engine water jacket. They use 400 to 1500 Watts to heat antifreeze up to about 135°F (57°C) to 175°F (79.5°C). It is spliced into the coolant hose (usually to the heater core hose returning to the engine), then uses a built-in pump to circulate coolant over its heating element and through the engine block antifreeze system. For vehicles, this means almost immediate crew cab heating.

### Engine Oil Heater

2-76. This is an electrical heating element that is mounted to maintain contact with the engine oil or oil pan. Then at startup the engine oil is less viscous, minimizing fuel and water accumulation in the crankcase.

### Transmission Heaters

2-77. This ensures that the transmission fluid is thin enough (lowered viscosity) to avoid rupturing a seal. Usually it is an electrical heater pad (like that used for oil heating) attached to the side of the transmission cowling which keeps the oil in a transmission warm.

### Heating Pad

2-78. The simplest form of quick heating is provided by an electrical heating pad. These are pressed against the side of an oil pan and/or the side of a battery to keep the item warmed.

## ENGINE STANDBY HEATERS

2-79. Standby heaters are fuel fired coolant heating units that run on the vehicle's own fuel supply (internally powered heat source). They are usually mounted in the engine compartment. They can heat and circulate coolant through the engine, a battery box heat exchanger, and even the crew compartment. After stopping a warm engine, the fuel driven heater is started, and the auxiliary water circulation pump circulates warmed antifreeze through tubing into the engine and through a battery box heat exchanger. A hybrid of this heater system has an option for electrically powered heater coils to conserve on fuel, when electrical power is available.

2-80. The standby heating systems use a small fuel fired boiler and fuel fed engine that pumps antifreeze through the engine, and may also warm the transmission and battery. The device does not allow vehicle components to fall below a certain minimum temperature. For this to happen, the fuel-burning heater is continuously operated during the standby period. Continuous operation maintains engine and battery electrolyte temperatures at levels that provide adequate cranking and battery recharging potential.

2-81. The standby system includes an engine coolant heater, hoses, control valves, fuel pump, battery heat exchanger (commonly known as a battery pad), and miscellaneous hardware. This system is not designed to start a vehicle engine after it has been off and the vehicle becomes cold-soaked for an extended period in extreme below freezing temperatures (-25°F [-32°C] or below). However, in an emergency, the standby system can assist in getting an engine to start if adequate time and auxiliary power are available.

2-82. Tactical vehicles and field equipment with liquid-cooled engines are best winterized with engine heaters. When the engine is not in use, the heater element keeps the antifreeze hot enough to warm the engine. An engine heater warms the coolant by about 35°F (19.5°C) above ambient temperature, which warms the engine block and lubricants. This results in the engine easily starting and reaching peak operating conditions more quickly. It also improves fuel economy by 5% or more since fuel is not being coughed up, unused during the attempts to start. Trying to start a cold-soaked engine also risks damage from forcing cold metal parts that have contracted outside their design tolerances to move against each other.

2-83. An engine heater must be properly maintained year round. Some engine heaters must not be operated when vehicle engine is operating; check the TM before installation and operation. Make sure the end-plug connector is free of corrosion and caked-on mud, before use.

### ENGINE PRE-STARTUP CONSIDERATIONS

2-84. Many winterization kits for starting below -25°F (-32°C) include a fuel-fired engine coolant standby heater. It is very important to understand the operating instructions of fuel-fired engine heaters before use. For example, the failure to turn on or ensure the auxiliary water circulation pump is running will most likely cause coolant hoses to burst.

2-85. Once the engine is operating after starting, observe the temperature gauge to ensure that the temperature rises gradually. A sudden rise in temperature indicates either a frozen radiator, insufficient coolant, or an inoperative thermostat. Stop the engine immediately and determine cause.

2-86. Because they are not used often, problems surrounding these heaters include:

- Low voltage.
- Contaminated fuel.
- Already frozen components.
- Inexperienced or inattentive operators and mechanics.

**NOTE:** Soldiers operating vehicles with fuel feed compartment heaters or engine heaters will need specialized training and should be separately licensed or certified to operate such equipment. Their training should reach further than the simple steps to turn the equipment on and off. They need to be proficient in the underlying principles of the equipment's operation. Mechanically, they need to be able to assemble and disassemble the heater; recognizing when the equipment is fouled and how to clear stoppages; and be able to identify broken or missing parts. The failure of these fuel driven heaters can result in not only runaway fires, but also a vehicles freezing over, and its crew becoming stranded in the cold.

## SECTION V – CHASSIS AND BODY COMPONENTS

2-87. Though any temperature below freezing becomes an issue for vehicle fluids, most vehicles components are fairly resistant to temperatures affects down to about +10°F (-12°C). At about that temperature the tensile strength, brittleness, and thermal contraction of many materials will noticeably change a mechanical item's performance properties.

2-88. Ice, mud, and snow can build up to such an extent on operating vehicles that they overload vehicle components, reduce ground and other clearances, and prevent or interfere with normal operation of moving components. Buildup and freezing of slush and water around the wheels of an operating vehicle can cause a loss of steering ability.

# TIRES

**NOTE:** The objective of this sub-section is to high-light the need for adequate inflation and deflation equipment. It is further intended to point out the complexity of maintaining appropriate tire pressure during cold weather operations, for any specific situation. The actual procedures must be taken from the vehicle TM.

2-89. Tire rubber expands in cold, and contracts in a warm environment; which is the opposite of the metal rims. Tire pressure rises and falls with the temperature. Monitor tire pressure frequently to avoid under inflated tires or over inflation. If radial tires are over-inflated, the center of the tire will bow outward causing the tire edges to lose ground contact. If radial tires are under-inflated, the center of the tire will bow inward causing the tires to run on their edges with lose ground contact in the center. In temperate weather incorrect tire pressure is hard on radial tires causing uneven ware, shortening the tire life. In icy or snow covered roads, this can also lead to a life threatening loss of traction.

2-90. For any fixed volume of air, as temperatures cool the air pressure in a tire will drop. For overnight or extended parking, increase tire pressure about 10 pounds per square inch, as shown in the TM, to compensate for the cold effects on tires. Tires should be deflated to proper pressure before operations.

2-91. Operators and maintainers in cold weather operations need to pay attention to the matchup or dissimilarities between the tires and rims. It is possible at about -13°F (-25°C) for a tire (without a steel wire in the bead) and rim to break its seal. If aluminum is in the mix of components, it contracts more than steel.

2-92. Check valve stems and tighten cores. Replace cores if rubber seals are brittle or show wear. Examine tire casings for cuts, bruises, or breaks. Caps must be installed on all valve stems.

2-93. For tires that have tire tubes lining the tire it is not uncommon in the cold for the tires to loosen and rotate on their rims. If for any reason the tires lose pressure, they may drag the valve stem on tubes through the hole in the rim, breaking the stem.

2-94. At -50°F (-45°C) tires become rigid enough to support a load at 0 pressure without apparent deflation. This is a risk problem because sidewalls become brittle and may crack.

2-95. Aviation tires are usually nitrogen filled. Nitrogen is not as prone to the expansion and contraction of volume caused by change in temperature or altitude, as are those of tires filled with normal air.

## TIRE SELECTION

2-96. Three types of non-directional tires are available for use on standard tactical vehicles. They are the cross-country tire, the mud-&-snow tire, and the radial street tire. It is best not to mix tires on a vehicle. However, if tire stocks are depleted, different types may be used as long as only one type is used on any one axle. Some commercial vehicles in the Army inventory use commercial all-terrain radial tires. These tire/wheel combinations should not be mixed on specific vehicles.

2-97. When driving on mud or snow with mud-&-snow tires, do not use tire chains. These tires will provide sufficient traction to equal the advantages of tire chains. Tire chains suffer the risk of breaking belt cords within street tires (of which the mud-&-snow tire is a specialized type of radial tire). If too many cords are broken in succession, blisters may appear on the tire, a sign which precedes a tire rupture.

## WHEEL BEARINGS

2-98. Usually no change of lubricants is required when wheel bearings are serviced with grease, automotive and artillery (GAA). It has a temperature range from -65°F (-54°C) to +225°F (+107°C) for year-round operations.

## CHAINS

2-99. Although it's a commander's responsibility to conduct a 10% accountability inventories monthly, supervisors and operators have a responsibility for their individual readiness. Supervisors need to have tire chains and snow chain adjuster bungees accounted for prior to cold season to ensure that they are available when needed.

2-100. Chains always go on the drive wheels. For rear wheel drive vehicles, there needs to be at least two chains for the back wheels; likewise the same for front wheel drive vehicles. For all wheel drive vehicles, each wheel needs a snow chain. Supervisors should check vehicle chains during a summer or autumn inventory to ensure that they are serviceable. This allows lead time for replacing worn, unserviceable or missing chains. Inspect that chain connector mechanisms function smoothly, and will latch through the upcoming cold weather season. Replacement inventory ordering should also include obtaining fresh elastic chain adjusters. Have extra work gloves or rubberized gloves available, packed with the chains in a water proof bag. Mounting chains while on the road will soak through a set of leather gloves.

2-101. Each vehicle's TM should instruct Soldiers on specifically how to install and adjust chains and the size required. During cold weather periods, the operator inspection of tire chains should be done as a post operation check, and as a part of a weekly PMCS. Drivers should practice mounting and removing chains. During the installation of chains, drivers should deploy road side safety warning markers. Under normal (wet, snowy, dark) conditions, it can take an hour or more to install chains.

2-102. Tire chains should only be applied hand tight to allow for tire creep, and avoid gouging the tires. To minimize chain flapping when the vehicle is rolling, use chain adjuster bungees or rubber tensioner cords to snug down chains. Remove the chains when not needed; this practice keeps them in good condition, and reduces tire stress.

2-103. Keep vehicle speeds under manufacturer's recommended speed limit; usually 20 to 30 miles per hour (30 to 45 kilometers per hour) while driving with snow chains.

2-104. It is important to have the right size tire chains, since one size doesn't fit all. The wrong size chain can fail to provide traction, and furthermore damage the vehicle tires. Check the additional authorization list to determine the correct tire chains for a vehicle. Chains wear out in approximately 350 miles of asphalt road operation. Also, they can damage vehicle and body suspension components if used when not needed.

# BRAKES

2-105. Do not park with brakes set during freezing weather; they may freeze in this position and not release. Instead, use chock blocks to hold wheels or tracks in place. If brake components do freeze in the set position, use a portable duct heater for thawing to prevent damage to the vehicle powertrain. For the Small Unit Support Vehicle (SUSV) (figure 2-1), parking brakes must be applied when stopped, since this vehicle doesn't have a neutral-park gear.

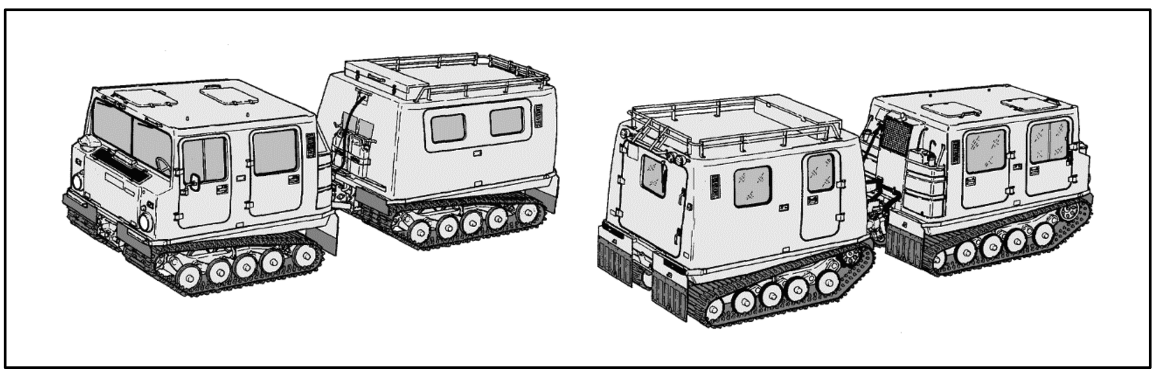

**Figure 2-1. M973, Small Unit Support Vehicle (SUSV), or Hagglunds BV206 Personnel Carrier**

## HYDRAULIC BRAKES

2-106. Check the reservoir of hydraulic brakes for proper fluid level. No seasonal change of fluid for hydraulic brake systems is required. Brake fluid, silicone (BFS), MIL-PRF-46176, *Brake Fluid, Silicone, Automotive, All-Weather, Operational and Preservative*, should be retained in the system for all-season use.

### AIR BRAKES

**CAUTION**

The pneumatic (air pressure based) systems of vehicles re-entering cold weather after being in a warm shelter are prone to condensation freezing. As the vehicle cools, the pneumatic systems should be exercised to flush out moist air.

**CAUTION**

Drain water from brake system air filters and reservoirs after every eight hours of continuous operation.

2-107. Frozen moisture in the air brake system seriously affects operation. Brake line, air brake filters, brake chambers, pushrods, valves, and seals are subject to more defects and failure in cold. Condensation between brake shoes and brake drums may freeze, making it impossible for the vehicle to move. When this happens, use portable heating equipment to thaw the brake shoes from the drums. Ensure the alcohol evaporator kit, if part of the system, is functioning. Check brake lines, brake chambers, relay valves, pushrods, seals, and slack adjusters. Check air compressor, unloader valve, and governor for good condition and satisfactory operation. With the air pressure at the governed maximum and the brakes applied, stop the engine. There should not be a noticeable drop in pressure within one minute. Drain reservoirs immediately after operation, and close drain cocks immediately after draining to prevent freezing in the open position. In the morning, build up pressure before moving the vehicle. Make certain that the alcohol evaporator jar is filled with alcohol or the desiccant cartridge is serviceable. During scheduled service, clean brake pads, remove oil and grease from units to avoid hardening and splitting. This helps to ensure a good air seal under pressure.

2-108. The new fleet of Army vehicles, which include the family of medium tactical vehicles (FMTV), Heavy Equipment Transport System (known as, HET) truck, palletized load system (PLS), and heavy expanded mobile tactical truck (known as, HEMTT) heavy variant, now have central tire inflation systems (called a, CTIS) that operate off an air compressor. It is not unusual for air valves to freeze resulting in locked brakes or flat tires. For vehicles with central tire inflation systems, a few pounds of air should be vented from tires, and then be re-pressurized while in the cold to verify proper function.

## STEERING GEAR

2-109. The use of an improper lubricant will congeal or harden, which will make steering difficult or impossible. Hydraulic power steering reservoirs should be filled with hydraulic fluid, petroleum base (military symbol OHT and North Atlantic Treaty Organization [NATO] symbol C-635), OE/HDO-SCPL (original equipment, heavy-duty oil, single common powertrain lubricant; or simply SCPL), or OEA-30, and not Dexron VI. Examine arms, tie rods, drag links, seals and boots, pitman arm, gear column, and wheel for good condition and secure mounting.

## SPRINGS

2-110. Springs become brittle and break easily at low temperatures. Clips, leaves, U-bolts, hangers, and shackles must be in good condition and be correctly and securely mounted. Spring leaves should not be broken or shifted out of their correct position. Tighten all spring U-bolts, assembly, and mounting bolts securely. When starting out, proceed with caution to allow springs time to attain flexibility. Avoid driving into depressions or over obstacles; this practice may create shocks that could break springs in cold.

## SHOCK ABSORBERS

2-111. Shock absorber fluid congeals in below freezing temperatures, resulting in a hard-riding vehicle or broken shock absorbers. Make certain shock absorber bodies are securely mounted to the frame. Replace shock absorbers if they are leaking or if their action is unsatisfactory. To prevent damage to the shock absorber, the operating rods, or the mounting brackets during cold, operate the vehicle slowly for the first three to five miles. This allows the oil in the shocks to warm up.

## TRACK AND SUSPENSION

2-112. Check oil-lubricated road wheel bearings to ensure that water has not collected during operation. If significant amounts of water have collected, seals may rupture as the water freezes and expands. If possible, avoid quick starts, stops, sharp turns, and side slippage on ice and snow, as they can throw tracks and/or cause loss of control.

2-113. Ice and snow adhere to tracks, hindering operation. Cold contracts metal and makes rubber brittle. When operating in snow-covered and icy terrain, remove track pads as the commander directs, and/or employ traction aids (such as reversing every third track center guide). Remove dirt and ice and inspect for good condition and proper lubrication. Check track adjustment. Do not adjust tracks too tightly in a warm shelter, since they contract and easily break in temperatures of -40°F (-40°C) and below. Adjust track so that the slack is 50% greater than that specified for normal operation in the vehicle TM (figure 2-2). Another method is to allow the vehicle and track to cool to outside temperature before making adjustments.

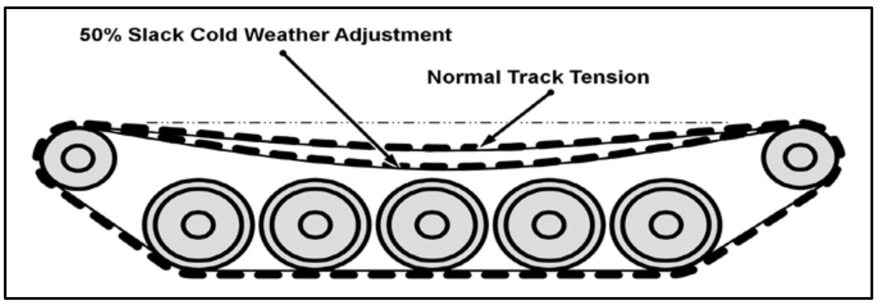


**Figure 2-2. Cold weather adjustment**

2-114. Some tracks use cleats to force traction on icy roads. However, such cleats are very destructive to road surfaces. Their use should be limited to situations where the road surface is not visible, covered by a thick layer of ice and snow.

2-115. For the M-1 series tanks with T158 track, special ice cleats are available. For best performance, every fifth track shoe should receive a set of cleats. A total of 64 cleats per vehicle (32 per side) and 64 new self-locking nuts are needed. These cleats are for the T158 track only; they will not work with the T156 track. Also, cleats are not yet available for the T156 track.

## CAB CLOSURES

2-116. Cab closures protect Soldiers from below freezing temperatures and wind. Ensure cab closure mountings are secure and in good condition. Replace broken windows, and ensure that closures are tight-fitting.

## FIRE EXTINGUISHERS

2-117. Winterize carbon dioxide ($CO_2$) fire extinguishers according to the appropriate fire extinguisher technical bulletin (TB).

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# Chapter 3

# Batteries and Electrical Energy Storage

One of the greatest hindrances to successful military operations in a winter environment is the effect of cold on batteries. While the cold reduces the cranking power of a battery, the cold usually increases the power needed to start an engine or drive a device. Maintenance managers and unit planners should anticipate an increased level of battery usage, failure and parts replacement. Likewise, proprietary COTS devices will have unique battery power requirements that have to be accounted for. Commanders should consider delegating leadership oversight on this issue which reaches across the whole command.

Battery power is as critical to mission capability as petroleum availability. The challenge for maintainers and operators is that all battery types possess different characteristics. Storage batteries are usually identified by the material used for the electrodes (or plates) within each cell. They must be maintained in accordance with the battery's TM or manufacturer's recommendations.

Supervisors of equipment operators will need local unit guidance on policies and procedures with listed references for each battery type in their inventory. Because of the increased workload batteries in the cold impose upon maintainers, supervisors and operators must be ready for greater cooperation and mutual support with their maintainers.

**CAUTION**

Operators are limited to performing PMCS and reporting discrepancies on batteries.

Only qualified maintainers are allowed to perform recovery or maintenance on batteries, in accordance with the item specific TM.

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**NOTE:** Temperature ranges and performance values presented in this chapter on batteries are generalized. Actual battery properties will vary according to the manufacture's design specifications and the specifics of the field situation. For detailed information on a specific battery, operators and maintainers must consult the appropriate item specific TM or military standards performance specification document (manufacturer's or military).

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## SECTION I – MAINTAINING ELECTRICAL POWER STORAGE IN COLD

**DANGER**

**• Never, never, never attempt to charge a frozen battery.**

**• Do not attempt to operate equipment with frozen batteries.**

**• Do not attempt to slave or jump start equipment with a battery that is or has been frozen.**

**Attempting any of these actions may cause the battery to rupture electrolyte acid or even explode. This applies to any type of lead-acid storage battery!**

**DANGER**

**If a lithium battery overheats, hisses or bulges, immediately move the device away from flammable materials and place it on a non-combustible surface. If at all possible, remove the device & battery, and put it outdoors.**

**If flames appear, Do Not handle. Allow ample ventilation while the battery burns itself out.**

**WARNING**

**Assume any C-E battery contains corrosive and/or flammable materials and treat accordingly. In general, any lithium-ion type battery has more stringent handling, storage and disposal requirements compared to more benign chemistries**

**CAUTION**

Baking soda and household ammonia solution are two substances that can neutralize the acid contained in the battery electrolytes. Have this on hand to clean up shop spills. (Not for first aid or medical treatment use.) Mix equal parts of either one with water to create a solution that neutralizes the battery acid.

3-1. In cold situations, a battery's total energy storage capacity is reduced. This not only applies to the energy that can be drawn out of a battery, but for rechargeable batteries it is also applies to the rate at which energy can be absorbed into the battery after its depleted. Low temperatures can increase the time required to charge rechargeable batteries. Cold lead-acid batteries in tactical vehicles can take twice as long to recharge compared to fair weather temperatures.

3-2. To conserve batteries from freeze damage, equipment operators need to be trained in how to avoid those circumstances that might cause batteries to freeze. Even in hazardous-cold situations, an operator who is following the TMs (both the TM for the platform in general, and the TM specifically for the battery) and the unit's supplemental procedures developed by the maintainers can still prevent batteries from freezing.

3-3. Where batteries are used for cold weather operations, there are several questions that maintainers and operators need to ask. The answers to these questions should be found in the unit's supplemental procedures, and presented as a part of the training the unit provides to the Soldier:

- What are the operator's responsibilities? What are the maintainer's responsibilities?
- What maintenance efforts could damage the battery, and how are they avoided?
- How are batteries to be kept operational for the longest period of time, or at the coldest projected temperatures?
- At what temperature will battery power begin to degrade?
- At what temperature will a battery stop functioning?
- If the battery power degrades, how can it be restored to a useful power level; without damaging the battery?
- What hazards do batteries present and how can a Soldier avoid or respond appropriately to them?
- What are the disposal considerations for a battery after use?

# COMMUNICATIONS-ELECTRONICS (C-E) BATTERIES

3-4. The Communications-Electronics (C-E) category represents many battery types used in a vast number of Army and Joint systems. C-E batteries refers to any type of non-rechargeable, rechargeable, dry-cell, and wet-cell batteries. The applications are too numerous to mention here, but they include everything from flashlights to aircraft radios. C-E batteries are comprised of different electro-chemical systems. Consequently, their response to cold varies. Likewise, some battery chemistries are more suitable for cold weather operations, than others. Individual equipment technical manuals usually address climatic limitations in Section IV: "Operation under Unusual Conditions". Most batteries perform to their specifications at a room temperature of 68°F (20°C), or in temperate weather.

3-5. C-E battery performance suffers at low temperatures. Internal resistance increases as temperatures lower; rendering them less able to provide their rated output current. The resistance is the decreasing speed of chemical interactions that acquire or release energy, as the temperature decreases. In addition, cold temperatures reduce the battery's energy storage capacity. The capacity decrease depends on the battery chemistry. For example, a given battery's capacity can drop to about 50% at 0°F (-18°C) compared to warmer ambient temperatures. In other words, if the C-E battery that provides power to a load for 10-hours at 68°F (20°C), it would only power the same load for only 5-hours at 0°F (-18°C). Warming a battery to room temperature will help restore much of the battery's capacity and performance.

3-6. Any battery should be treated with care. Issues include:

- C-E batteries are composed of "dry cells", but they still contain caustic electrolytes (such as potassium or sodium hydroxide). They are corrosive and can cause chemical burns.
- Only use the charger intended for a specific rechargeable battery. Note: some "universal" chargers in the DOD inventory are designed to charge different battery types simultaneously. Follow the charger's technical manual.
- Never attempt to charge a primary battery (non-rechargeable): it can ignite or explode.
- Protect battery terminals from short circuiting on a metal surface or on other batteries (applies to coin cells). If short-circuited, batteries can cause burns, explode or ignite flammable materials.
- Do not attempt to disassemble batteries; the materials inside are corrosive and some are toxic.
- Warning: Do not cut, puncture, open, or otherwise mutilate C-E batteries.
- Warning: Do not subject batteries to fire they can ignite or explode.
- Warning: Do not use $CO_2$ directed into a battery compartment to effect cooling!
- Always follow the warning and caution statements for batteries in the end item's technical manual.

3-7. Batteries are prone to leaking potassium hydroxide or sodium hydroxide, which are used as the electrolyte in various types of batteries. These hydroxide based electrolytes are caustic, highly corrosive agents that can cause respiratory, eye and skin irritation. Assume any C-E battery contains corrosive and/or flammable materials and treat accordingly. If exposure occurs in a cold situation, treat and seek medical attention. To reduce the risk of battery electrolyte leakage, or minimize contamination:

- Store batteries in a dry place.
- Never attempt to recharge a disposable battery.
- Do not mix different battery types in the same device.
- Replace all of the batteries at the same time; as a group for equipment with multiple batteries.
- Remove batteries before storage of devices.
- $CO_2$ is an acceptable fire extinguishing agent for hydroxide based electrolyte.
- If batteries show signs of leaking use rubber gloves, rubber apron and protective goggles. Follow FIRST AID instructions if you believe any caustic has gotten on you.
- In general, any lithium-ion type battery have more stringent handling, storage and disposal requirements compared to the more benign hydroxide chemistries.

3-8. For planning purposes, the following procedures for conserving batteries in cold weather environments applies to both operators, as well as stock control handlers:

- Dry batteries (non-rechargeable types) must be stored at temperatures above 10°F (-12°C) and must be warmed gradually, either with body or vehicle heat, before use.
- In subzero weather (32°F [0°C]), additional battery chargers (especially float-chargers) must be on hand to meet heavy requirements for rechargeable battery maintenance.
- Supply controllers should expect for battery stocks (both non-rechargeable and rechargeable) to need replenishment more often.
- While in storage (on the vehicle, platform, in the equipment, or on the shelf), pay particular attention to the unique proprieties of the specific battery type.
- While in storage or when not in use, automatic float-chargers should be used to keep rechargeable batteries fully charged.

# KEEPING A BATTERY CHARGED

**WARNING**

**When staring and running an engine, disconnect float-chargers, trickle chargers, and related devices; unless item TM says it can remain hooked up.**

3-9. In cold, keeping a battery serviceable involves a different set of priorities from those which occur in temperate weather, even though the rules and procedures are the same. A cold-soaked (not frozen) battery takes longer to recharge since the cold causes greater internal resistance, reducing its ability to accept a charge. This limitation applies to all battery chemistries in common use. The cold temperatures slows the electro-chemical energy conversion process. Though as the process continues, waste heat due to the internal resistance can warm the battery. This effect then improves the charging rate to some extent. The correct charging system's voltage regulator maintains a specific voltage intended for a given battery's structure and chemistry. In the case of tactical vehicles, the voltage regulators are designed to keep the charging system voltage at an optimum setting of temperate weather, and prevent the alternator from overcharging the battery. However, such default settings may not be adequate for overcoming cold induced resistance.

3-10. How well prepared a battery is to deliver electrical energy is expressed as the, SOC, or the depth of discharge. The SOC is expressed as a percentage of the battery's highest energy rating. The counterpart of the SOC is the question of how much energy is not available, known as the depth of discharge, expressed as an ampere-hour or amp-hours delivered (which is not the amount of usable time that a battery has). An amp-hour is the charge transferred by a steady current of one ampere flowing for one hour. The depth of discharge is the complement of SOC: as the one increases, the other decreases.

**NOTE:** The abbreviation, DOD is the common abbreviation used for depth of discharge in civilian literature.

## KEEPING A BATTERY CHARGED WHILE USING IT

3-11. At normal temperatures, it takes an engine alternator approximately 20 to 30 minutes (40 to 50 minutes for Absorbed Glass Mat [AGM] batteries) of engine-run time just to replace the energy that was used to start the engine. If temperature is 32°F (0°C) to 0°F (-18°C), double the run time; if temperature is below 0°F (-18°C), tripling the run time is recommended (possibly as much as four or five times longer) just to recover from having started an engine.

3-12. An alternator is meant to maintain a battery, not fully recharge a depleted battery. While the engine is just idling in temperate weather, the alternator really doesn't begin recharging the gap in battery energy. Thus, if the engine is turned off after a shot trip, the batteries which were not fully recharged during operation, might freeze because of a reduced SOC. Numerous short periods of operation (less than 20 minutes at a time) will eventually discharge the battery, even if the engine is operated at high speed.

3-13. Regardless of the type of battery, all existing tactical vehicle batteries are based on lead-acid chemistry. When a vehicle or equipment will not start at low temperatures, turn-off the starting switch. Check for a frozen battery before attempting to slave start, jump start, or charge it. For the traditional flooded cell batteries, this means removing the filler caps for each cell and check the electrolyte to see if it is frozen. For the new technology lead-acid gel (GEL for gelatin silicate electrolyte) or AGM type batteries, it is important to allow a frozen GEL or AGM battery to warm-up naturally [indoors] as circumstances allow. If the battery case is swollen or cracked, a maintainer must verify if the battery is usable or unusable (frozen).

3-14. Operators must never attempt to thaw and recharge a frozen flooded cell type battery. Just, tag them "frozen" and turn them in for proper disposal. In cold situations, maintainers should be proactive in checking and testing batteries. If a battery is cold-soaked (but, not frozen) during recharging, there will be resistance by the battery to the volume of current. How much resistance there is will increase as the battery gets colder. Any resistance to recharging results in spot heating or over heating within the battery. What this does to the battery will depend upon the type of battery, the materials it's made from, and the method of recharge.

**NOTE:** Unit maintenance trainers should regularly refresh all operators and maintainers who work with automotive batteries on all safety warnings pertaining to automotive batteries. The full list of warnings can be found in TM 9-6140-200-13, *Operator and Field Maintenance for Automotive Lead-Acid Storage Batteries.*

**CAUTION**

DO NOT mutilate, incinerate, or throw away batteries with trash. Batteries are a potentially environmentally hazardous material.

The Defense Property Disposal Service is responsible for disposal of batteries as hazardous items.

**CAUTION**

Field Maintenance: Do not leave recharging batteries unattended if they have been subjected to temperatures below their total discharge freezing point. Check for electrolyte leakage or thermal runaway, as appropriate.

### BATTERY SELF-DISCHARGED

3-15. Even when a battery is not in use, batteries self-discharge. The challenge for the operator or maintainer is to keep the battery charge high enough to keep it from not only freezing, but to also be able to crank over a cold-soaked sluggish engine. This marginal zone between fully charged and the minimum voltage is called the floating voltage.

3-16. Trickle chargers are only good for a spot situation to raise the energy level of a depleted battery, which has not frozen. Trickle chargers are not apt to push too much charge through cold electrolyte that is resisting a recharge. However, an unattended trickle charger could overcharge a battery. They don't have the ability to detect a battery's SOC and regulate the volume and rate of energy flowing into a battery.

3-17. To keep an idle or stored battery at its optimum charge, a float-charger should be used. They have circuitry to prevent a battery from overcharging. It means that they can be hooked up and left unattended, almost indefinitely. Flooded battery fluid levels should be checked regularly against evaporation.

## BATTERY FIRE PREVENTION

3-18. As mentioned above, batteries heat up as they are being charged. Likewise, batteries generate some heat as they discharge. However, if energy is pushed through a battery at a rate that is higher than it can absorb; or the heat builds faster than it can shed to remain cool; the extra heat can burn or ignite the battery's material. This battery overheating is known as thermal runaway. It is a catastrophic event for a rechargeable battery. In a flooded cell battery, the water boils causing a gas emission of hydrogen in large quantities, eventually burning the electrodes that store energy. In sealed batteries, it can rupture the casing spilling the electrolyte. In lithium batteries, it can cause them to erupt on fire. Battery fires can happen under any weather condition, but is most associated with excessive energy being pushed across the available battery plates at a rate which exceeds the battery's ability to dissipate. Referred to as an exothermic reaction, it usually happens in extremely high or very low temperature environments; or if the battery is not properly maintained. It can happen to both automotive and non-automotive batteries. Thermal runaway doesn't happen out of nowhere; there are (aside from lithium batteries) always warning signs. If a depleted battery is cold-soaked, it is important to get the battery warmed back up as soon as circumstances allow to avoid sulfation.

### BATTERY SULFATION

3-19. Sulfation is a major threat to any fluid filled battery (flooded wet cell, or sealed). Sulfation occurs in discharged flooded electrolyte type lead-acid batteries regardless of being in storage or installed in a vehicle. "Sulfation" describes the formation of lead sulfate crystals (PbSO4) on the battery's electrodes (plates) over time. These crystals raise the battery's internal resistance to energy absorption. When a battery has lost its charge in the cold, crystals form on the battery plates acting as a physical barrier to recharge. As a result, longer charging times are required. Once sulfation or crystal growth is severe enough, it can damage the battery permanently. Although lead-acid GEL and AGM type batteries are not as prone to sulfation, based on their physical construction, they are still at risk for sulfation damage and thermal runaway.

**NOTE:** If the operator finds that a battery case is buckled, swollen, or cracked, or if ice or frost can be seen inside any cell, they should notify maintenance that the battery is possibly frozen.

### CAUSES OF THERMAL RUNAWAY

3-20. The initial cause for thermal runaway is different in high heat weather from cold weather. Electrical energy is a product of the chemical interactions between the electrolyte and plates within the battery. However, another byproduct of this chemical interaction is, heat. The process of heat generation and buildup within a battery is called an, exothermic reaction. In temperate weather, a properly filled and charged battery can generate electrical power and dissipate the excess heat of the exothermic reaction through the battery walls as fast as the heat is produced.

3-21. This heat cannot be allowed to get so hot that it burns the electrical plates within the battery. The heat has to be able to dissipate. If the air temperature is too hot, the battery will not be able to shed heat as fast as it is generated, causing heat to pile-up on the plates. As the heat builds, lead and sulfur in the electrolyte separates and crystalizes on the battery plates; sulfation. When the chemical interaction can't dissipate energy as electricity through the battery plates, it bakes the sulfation crystals onto the surface of the plates, blocking the electrical charge from reaching the plates.

3-22. In cold weather, if the electrolyte freezes, it causes the energy of the electro-chemical reaction to build up on localized areas of the plates, which again converts directly into a localized exothermic heat that burns the plates. In an over charging, high heat or frozen situation, the resulting excessive heat generation is followed by thermal runaway. The following acts, in hot, temperate or cold weather, can cause a battery rupture, explosion or even a fire:

- The whole battery is surrounded by too much outside heat, preventing the heat of chemical reaction from dissipating as fast as it is being generated.
- A normal charge being forced through a limited surface area of available negative plates used to perform ion bonding, preventing the heat of chemical reaction from dissipating as fast as it is being generated.
  - Electrolyte is not properly filled, or has leaked out of the battery, limiting the available surface area of the plates.
  - Sulfation, limiting the available surface area of the plates.
  - Frozen electrolyte covering plate surface, limiting the available area of the plates.
- Excessive charge voltage, forcing a high overcharge current into the whole battery.
- Dysfunctional voltage regulator on the charger, vehicle, or equipment, forcing a high overcharge current into the whole battery.

## PROCESS OF THERMAL RUNAWAY

3-23. One of the greatest hazards to battery life in the cold is a "thermal runaway." The thermal runaway in subfreezing temperatures usually occurs in basically the following sequence:

1) If a battery is partially frozen or corroded by sulfation, it will limit the available surface area on the negative plates. This causes the recharging current to not be absorbable evenly throughout the whole of the plates.
2) Next, the current gets redirected through the spots on the available plate areas which have contact with active electrolyte.
3) The recharge current then overloads the limited available plate surfaces with more internal heat than the battery can effectively dissipate.
4) As the excess heat scorches the lead sulfate crystal into the plates and boils off the hydrogen of the electrolyte, expanding the obstructed area of the plates. This reduces the plate area available to support the heat of the recharge current.
5) This forces the available areas of the plates to carry an increasingly greater volume of current and heat. It cooks even more lead sulfate crystals into the plates.
6) As less and less plate surface area is left available to support the charge and dissipate the heat, more heat becomes concentrated on the remaining plate area in a vicious cycle. This becomes a cascading plate failure at an ever increasing temperature, at an ever increasing speed.
7) Within a short period of time this heat will sulfation scorch (lead-sulfur crystal, non-conductive coat) the plate material and accelerate the battery towards end-of-life. It could become so hot, it melts the battery or catches on fire.

**NOTE:** The initial cause (steps 1 & 2) of thermal runaway is theoretically the same, though structurally different between cold weather and hot weather battery damage. However, the latter stages and end results are the same.

### PREVENTION OF THERMAL RUNAWAY

3-24. Operators should not try to force a depleted battery to start an engine. After a third failed attempt to start an engine, operators should get help from a maintainer. As long as the battery can deliver enough energy to turn on the lights (even if only for a moment), the battery might still be recovered and recharged. Otherwise, operators must assume the battery is frozen and treat it as such in accordance with unit policy. By forcing a depleted battery to start an engine, it only zaps out the last measure of energy that is holding the battery back from fully freezing. An operator risks permanently destroying the battery if any more than three attempts are made to start the engine without the assistance of supplemental power.

3-25. Both operators and maintainers each have a role to play in preventing battery thermal runaway. By understanding how thermal runaway occurs in cold weather, it can be prevented in various ways:

- It begins with using the TM to perform regular preventive maintenance.
- Maintain a full charge on the battery.
- Record float voltage, checking for unusual increases over time.
- Check that the battery has not leaked electrolyte or that it's not lacking electrolyte.
- Check that the battery casing is not deformed or cracked.
- Warm a battery to above freezing before attempting to recharge it.
- Use the battery charger that is specified by the TM. These chargers will indicate in the instructions that they are capable (or not) of electronically detecting the start of a thermal runaway condition. Those which can will automatically adjust the power flow, or shut off the charger once the battery is ready.

## VEHICLE BATTERIES

3-26. There are two basic types of lead-acid storage batteries, in four types of construction technologies commonly found in the military:

- Flooded batteries or wet cell, are those where the electrolyte is in a free flowing state:
  - Vented Lead-Acid (VLA) battery (the traditional "flooded" cell car battery).
  - Nickel-Cadmium (NiCd or NiCad) wet-cell battery (not commonly used for ground vehicles).
- Valve-Regulated Lead-Acid (VRLA) battery (more commonly known as a sealed battery) is where the electrolyte is immobilized so it won't spill (Technical Bulletin (TB) 9-6140-252-13, *Recharging Procedures for Automotive Valve Regulated Lead-Acid Batteries*):
  - Gelatin Silicate Electrolyte (GEL) (sulfuric acid suspended in silica) battery.
  - Absorbed Glass Mat (AGM) battery.

3-27. Generally, a charged battery is capable of storage in uncontrolled temperature conditions of -40°F to +100°F (-40°C to +38°C) for at least 18 months without damage. Though a typical AGM battery lasts 12-18 months in storage unattended, some manufacturers can get an AGM battery to last 2 years. Yet, wet cell batteries have high self-discharge rates and die much sooner. The point is battery maintainers will have to research the specifics of battery storage based upon the manufacturer specifications.

3-28. Operators and maintainers working with batteries in cold weather should observe the following guidelines:

- Never charge a frozen battery.
- Inspect a battery using the item specific TM.
- Maintainers should verify that new batteries are fully charged before their initial use.
- Thoroughly clean new battery (tapered terminals and clamp terminals) connections before battery installation.
- Make sure lead acid batteries are fully charged after use to prevent sulfation. Do not leave low charged batteries sitting in a vehicle, or stored with only a low charge.
- Do not allow a lead acid battery to freeze. A discharged battery freezes at higher temperatures compared to a fully charged one.
- Do not charge batteries at temperatures above 120°F (49°C).

- Lead-acid batteries being charged produce highly explosive hydrogen gas during the charging process.
  - Keep sparks, open flames and other ignition sources away from the charging area.
  - Charge in a well-ventilated area.
- Choose the appropriate charging program for flooded, GEL and AGM batteries. Check the TM or manufacturer's specifications on recommended voltage thresholds.

## VENTED LEAD-ACID BATTERIES

**NOTE:** Due to advances in battery technology, the traditional flooded VLA batteries are being replaced and upgraded wherever posable with VRLA (sealed) batteries. Flooded VLA batteries are no longer common in the Army. Much is written here because of how complex they are to service and maintenance.

3-29. The operator has two questions he needs to answer before starting a vehicle or motor:

- Does the battery hold enough power to start the engine?
- Did the battery freeze?
- At what point could the battery freeze?

3-30. There are three ways to test a flooded VLA battery:

- Amperage load test.
- Hydrometer, specific gravity tester.
- Refractometer, specific gravity tester.

3-31. A vehicle's storage battery's available energy decreases sharply when temperatures fall (figure 3-1). At the same time, power requirements for starting an engine increases by about two or three times when the battery is least capable of delivering that power. The delivery of electrical current at +15°F (-9.4°C) is only 50% of that produced at normal temperatures. The amount delivered at -30°F (-34.4°C) is only a little over 10% of that produced at room temperature. At -40°F (-40°C) and below, the available current is about zero, even if the fluid is not frozen.

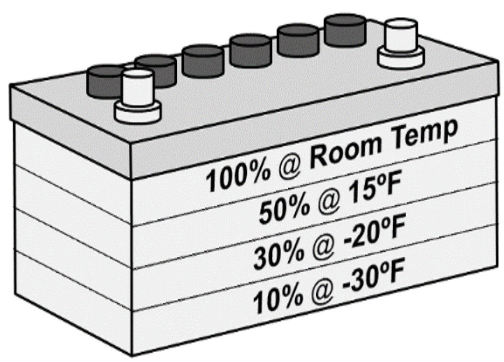


**Figure 3-1. Flooded VLA battery power availability at varying temperatures**

### State of Charge

3-32. The freeze points of a flooded VLA (figure 3-2, on page 3-10) depend on the battery's SOC. The SOC infers, and equates to the battery's remaining energy at any given concentration of sulfuric acid in the electrolyte. The electrolyte begins as a solution of about 30% sulfuric acid and 70% distilled water. The specific gravity of the solution is a measure of the sulfuric acid suspended in the water after discharging or recharging.

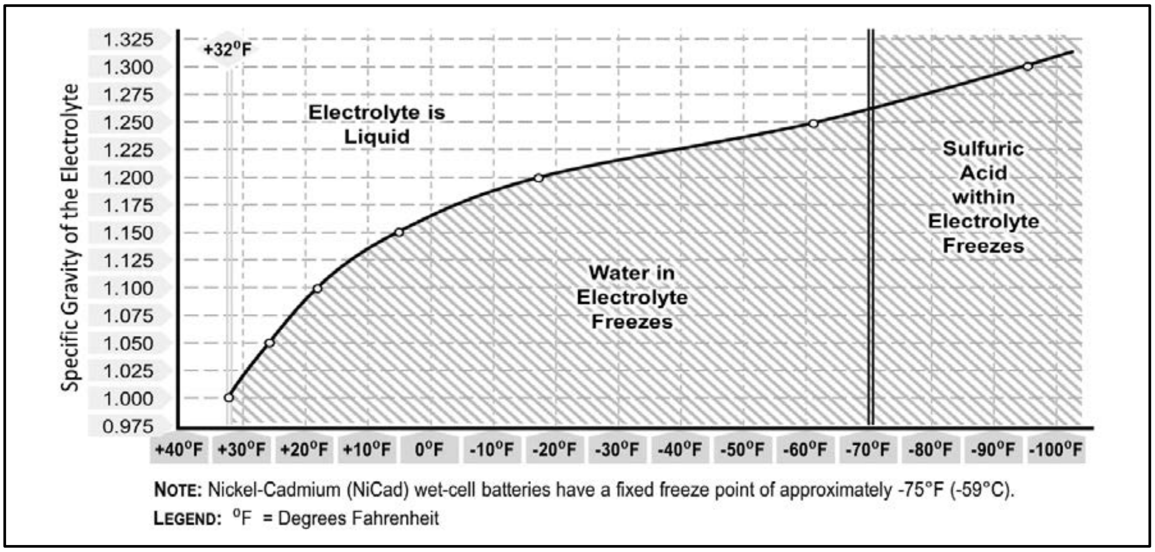


**Figure 3-2. Freezing points of VLA (flooded) battery at various specific gravities**

3-33. As the battery discharges, chemical reactions remove the sulfuric acid gradually from the solution. This process reduces the sulfuric acid concentration, as the water percentage increases. As the electrolyte's water content increases, the specific gravity of the solution approaches that of pure water (1.00). So, the freezing point of the electrolyte depends on the ambient temperature and the water percentage as indicated by the specific gravity. In this way, the specific gravity indicates (indirectly) the available energy or SOC.

3-34. A fully charged battery will not freeze unless the ambient temperature falls below -70°F (-57°C). Thus, it is essential to keep batteries fully charged. Once a battery freezes, it is no longer serviceable. Frozen electrolyte will expand and damage the battery.

**NOTE:** Maintainers must wear the appropriate personal protective equipment (PPE) when handling the sulfuric acid electrolyte and servicing flooded batteries.

## Hydrometer Electrolyte Specific Gravity Test

3-35. The electrolyte's specific gravity is a measure of the battery's SOC. Figure 3-2 shows the relationship between specific gravity and temperature. For example, if the hydrometer reading is "1.150", the water in the electrolyte can freeze at -5°F (-20°C). As the specific gravity drops, the battery's ability to start a vehicle or generator set engine drops too. Additionally, the electrolyte will freeze at higher temperatures. A hydrometer can determine the battery's SOC if one checks each cell. It can spot bad cells too. However, even under favorable temperature conditions the process is lengthy. A hydrometer measures the electrolyte's specific gravity in flooded cell type batteries only.

**NOTE:** One cannot use a hydrometer with the increasingly more prevalent sealed batteries. Determining the SOC of sealed GEL and AGM type batteries requires an electrical analyzer.

## Refractometer, Specific Gravity Test

3-36. For specific gravity testing, the refractometer (figure 3-3) is the preferred testing tool. As with the hydrometer, operators and maintainers can only use the refractometer to measure the electrolyte of flooded batteries. When testing the battery acid:

- Use goggles or face shield to protect eyes.
- Use rubber gloves to protect skin and clothing.

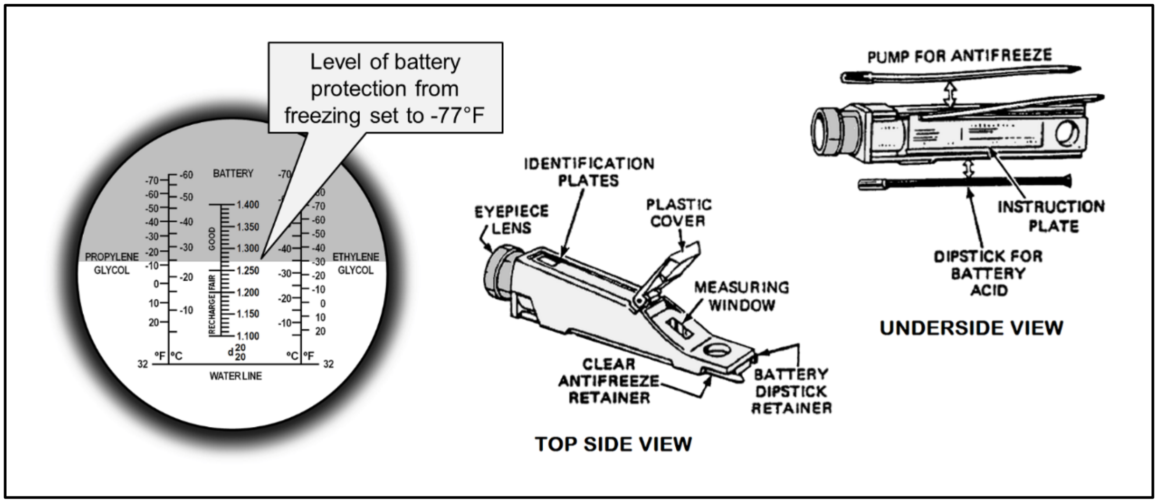


**Figure 3-3. Refractometer for testing electrolyte**

3-37. The refractometers need to be zero adjusted before use. This ensures that neither rough handling nor the ambient temperature shifts have altered the readings from the tool.

- Place one or two drops of distilled water on the prism (not tap water).
- Makes sure that the entire measuring window or prism plate is covered with the liquid; without dry spots or bubbles.
- Close the plastic cover or cover plate; without bubbles.
- Observe the location of the light/dark boundary underneath a light source, verifying that the boundary falls at the waterline. If not, use equipment instructions to locate the adjustment screw.
- Rotate the adjusting screw so that the light/dark boundary lines up with the "waterline," or 1.000 kilograms per liter (kg/L)
- Once the zero adjustment has been completed, clean the prism with soft cloth.

3-38. Add distilled water as needed to properly fill each cell. It is best that a battery is warm before checking battery fluid level. If water is added to a battery that is exposed to freezing temperatures, the layer of new water will usually stay at the top and freeze before it has a chance to mix with the electrolyte. Warming a battery to above 32°F (0°C) will allow water to evenly mix into the electrolyte. If the battery is cold at or below freezing, distilled or raw water will freeze into surface ice on top of the electrolyte or become ice crystals within the electrolyte. Frozen water within a battery will skew and invalidate the specific gravity testing.

**WARNING**

**Never add water to a cold battery (under 32°F [0°C]) since it can separately freeze, before mixing with the electrolyte. Ensure battery is warm before adding water.**

**WARNING**

**Only add distilled water. Impurities of tap water will corrode the lead plates inside the battery.**

3-39. Operators should observe that flooded VLA batteries are filled to the top-off marker with electrolyte, and charged to a 1.280 specific gravity, not the temperate zone 1.250 specific gravity standard. Recharging batteries to meet this standard is a maintainer's job. Unit operating procedures should specify when such changes are to be made, in accordance with item TMs.

## Battery Load Test

3-40. It isn't enough to know if a battery is delivering the 12 volts for which the battery is rated. The next question is whether the battery has the reserve power to overcome the cold engine's resistance to starting.

3-41. Load testing determines if the battery can provide enough current (in amperes) to start an engine. The tester actually simulates an electric starter's current draw and evaluates the battery's ability to crank the engine. The tester draws current from the battery while measuring its voltage. The voltage level of a charged or otherwise good battery will remain relatively steady under load. A defective battery or one with a low SOC will show a rapid voltage drop: 12-volt battery voltage could drop to 10.5-volts or less. A battery's Cold Cranking Ampere (CCA) rating and the ambient temperature will affect the test results. The CCA is the maximum current the battery can provide continuously for 30 seconds at 0°F (-18°C) before its voltage drops too low. The CCA rating is usually printed on the battery's label. Though the load tester might apply a load for 15 seconds. After the test, a good battery will show an open circuit voltage above 10.5-volts. If voltage drops below 10.5-volts, more charging followed by a re-test is required. In addition, the maintainer performing this test must compensate for low temperatures. For example, at 0°F (-18°C), they subtract 300 CCA from the battery's CCA rating. Importantly, follow the load tester's operating instructions very carefully.

3-42. Using a hand held load tester (figure 3-4), maintainers can tell the actual voltage being delivered, and if the available amperage will hold up long enough for the starter motor to turn over the engine without damaging the battery. If the battery needs the amperage boosted, let the maintainers charge the battery or slave start the engine.

**Figure 3-4. Battery load tester, both digital and analog**

## Guidelines for Charging Vented Lead-Acid Batteries

3-43. Unless a storage battery is warmed to above 32°F (0°C), it will resist receiving a full charge from the vehicle's generator. If the vehicle is equipped with a battery preheater, it should be used according to the operator's TM. A battery preheater is a pad, wrap or blanket made of heat resistant synthetic material with wire heating elements running through it, which plugs into an external electrical power source. If the vehicle does not have a preheater, an insulated battery box can help maintain specific gravity at higher levels for longer periods. Again, ensuring the starting batteries remain fully charged is very important.

> **CAUTION**
>
> Check flooded VLA battery vent. Batteries produced hydrogen gas. Hydrogen gas can cause a battery casing to explode due to blockage of the battery vent by ice.

3-44. When it is necessary to recharge a flooded battery at low temperatures (under 32°F [0°C]), reduce the normal charging current to prevent excessive gassing and boiling of the electrolyte. The charging process takes longer at low temperatures due to lower electro-chemical reaction rates. Follow the battery charger's instructions for low temperature operation for all starting batteries; flooded, AGM and GEL types. This makes the permissible charging current much less, increasing the charging time.

---

**NOTE:** If adding water to a battery at temperatures of 32°F (0°C) to approximately 50°F (10°C), do not fill to level indicated on cell cover or vent plug, since the electrolyte will expand as it is heated and the battery will flood. The acid of electrolyte should never be added to a battery once initiated into service. Use only distilled water.

---

- Before charging, check that the plates of flooded batteries are fully submerged in electrolyte.
- Never add the acid to the electrolyte solution. Operators are not authorized to add electrolyte to flooded batteries; only distilled water.
- Do not add water to a battery with an ambient temperature below 32°F (0°F), or cold-soaked.
- Fill battery with distilled or de-ionized water to cover the plates if low. Check with the maintenance supervisor before using tap water, in critical emergencies.
- Formation of gas bubbles in a flooded battery indicates that the battery is reaching full SOC (hydrogen on negative plate and oxygen on positive plate).
- Check again, and fill water level to designated level after charging. Overfilling when the battery is empty can cause acid spillage.

## NICKEL-CADMIUM BATTERIES, WET-CELL

3-45. Nickel-Cadmium (NiCd or NiCad) wet-cell batteries are commonly found in aviation (MIL-PRF-81757, *Batteries and Cells, Storage, Nickel-Cadmium, Aircraft, General Specification for*, and MIL-PRF-8565, *Battery Storage, Aircraft, General Specification for*), maritime, or industrial uninterrupted power supply (known as, UPS) backup systems. They are almost never used in ground vehicles since they cannot be serviced together with lead-acid batteries.

> **CAUTION**
>
> It is extremely dangerous for the batteries, to transport, store or service lead-acid and NiCad (wet or sealed) batteries in the same area. Introduction of acid electrolytes by vapor emissions into alkaline electrolyte corrodes or destroys both lead-acid and NiCad batteries

3-46. The only accurate way to determine the SOC of a NiCad battery is by a measured discharge with a NiCad battery charger. A NiCad battery's SOC does not affect electrolyte specific gravity. Measuring the specific gravity of the potassium hydroxide electrolyte will not reveal anything about its SOC. NiCad battery potassium hydroxide electrolyte is not that susceptible to freeze damage because no appreciable chemical change takes place between the charged and discharged states. However, the electrolyte medium (the water within the solution) itself will still freeze at approximately -75°F (-60°C), and may rupture the battery cell.

## VALVE-REGULATED LEAD-ACID BATTERIES

3-47. In VRLA batteries, the electrolyte is immobilized and prevents any leakage if the case is cracked. There are two types of VRLA batteries: Gelatin Electrolyte (GEL) type batteries; and sealed Absorbed Glass Mat (AGM). Charged VRLA batteries can withstand severe cold without damage. Though they will freeze with a low SOC or when discharged (figure 3-5). Temperatures below -70°F (-57°C) will freeze VRLA batteries regardless of SOC.

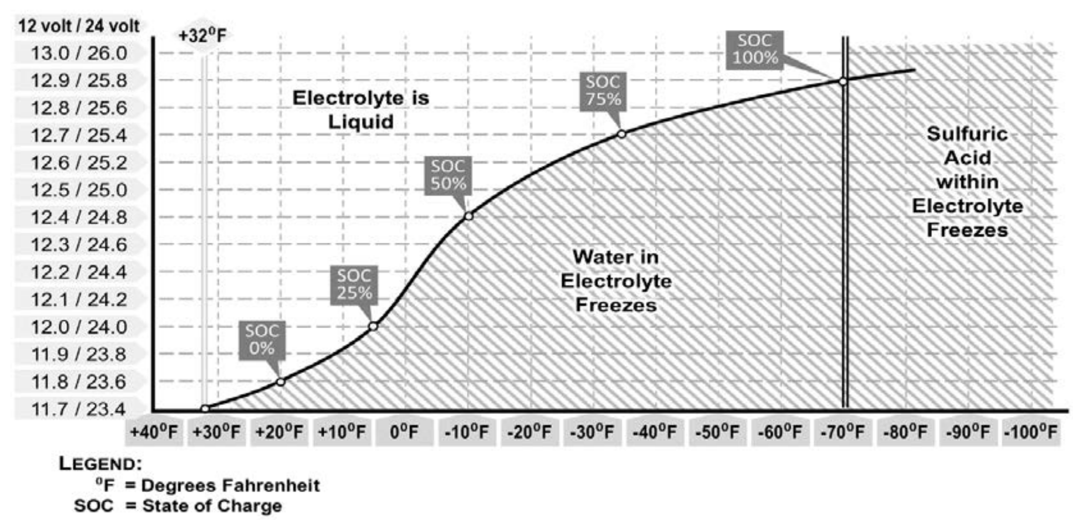


**Figure 3-5. The SOC for sealed VRLA batteries needed to avoid freezing at a given temperature**

3-48. Battery maintenance is much less compared to wet cell types. However, they still have a water based electrolyte, and this is why severe cold can still damage discharged GEL or AGM batteries. Ensuring they are fully charged will prevent them from freezing. Again, monitoring and maintaining these batteries properly is essential in cold environments.

**CAUTION**

Never leave a VRLA battery stored in a discharged state. It will cause battery sulfation; interfering with the battery's ability to be charged, and vulnerable to thermal runaway.

**CAUTION**

VRLA (GEL and AGM) and other sealed batteries are also sensitive to overcharging (as are flooded VLA types). Overcharging can also cause thermal runaway.

## GEL BATTERIES

3-49. Though GEL batteries are not flooded in the traditional sense, these are still lead-acid batteries which have mixed silica or polymer particles as a gelling agent into hydroxide based electrolytes. They may have up to 15% greater energy output compared to flooded VLA batteries of the same size.

3-50. The freeze point for GEL batteries is the same as any VRLA battery using sulfuric acid electrolyte. Therefore, temperatures below -70°F (-57°C) will freeze GEL batteries regardless of SOC. If the operator thinks the battery is frozen, do not attempt to charge it and contact a field maintenance level maintainer. A qualified maintainer can determine if the battery is serviceable.

3-51. By using a silicon dust (silica) to suspend the electrolyte, there is very little water expansion that could rupture a GEL battery. Though not imposable, it is unlikely that the cold will rupture the battery case. Still, it should be checked by an authorized maintainer. Once warmed to normal operating temperatures of about 65°F (18°C) to 70°F (21°C), they can usually be recharged. There are three causes for GEL battery damage:

- Batteries sitting for too long in a frozen and discharged state.
- Charging a battery with partially frozen GEL.
- Overcharging.

**CAUTION**

Only use battery chargers intended for GEL batteries. Follow the charger's operating instructions for GEL cell batteries. Use a constant voltage charger and restrict charging voltage from 13.5 to 14.5-volts (maximum) for 12-volt batteries. When charging two series-connected 12-volt batteries (24-volt system), ensure charging voltage is from 27 to 29-volts. Using the wrong charger will damage the battery and shorten its life.

3-52. A partially frozen GEL will localize the recharging into those plates in the thawed areas of the battery, overheating the active plates. Under these conditions the heat produced inside the battery can lead to thermal runaway due to the increasingly localized electro-chemical reaction within the battery.

3-53. Not all equipment has a charging system to maintain its battery's SOC as vehicles do. For example, a GEL battery in a piece of equipment is subject to self-discharge over time; cooler temperatures slow this process, but it still occurs. In fact, once the GEL battery is discharged, its gelatin electrolyte can freeze too. A frozen battery is useless and there is a strong likelihood it is no longer serviceable. A qualified maintainer can determine if the battery is serviceable.

3-54. If the maintainer suspects it is frozen (or with a freezing external temperature, and discharged), maintainers should in principle do the following:

- Ascertain that the battery is both frozen and discharged.
- Move the battery to an area that has been designated by the maintenance shop for GEL battery warming, to slow the sulfation process. The battery might be recoverable.
- If the frozen battery was part of a set, keep the whole set together.
- Record that the batteries were pulled from service as a set, and which ones were found to have been frozen.
- Let a mechanic who has been trained and possesses the appropriate authority to determine which batteries will be returned to service. Otherwise, the unrepairable batteries are pulled from service and turned in to the unit's supply support activity.

3-55. If while the unit stored the batteries, they became discharged and then froze, and found to be no longer serviceable, dispose according to Army regulations. This is type of loss is avoidable by performing regular PMCS and keeping the batteries properly charged.

## ABSORBED GLASS MAT

3-56. AGM batteries are sealed lead-acid batteries which that have a fiberglass mat sandwiched between the plates. In theory, it is no different from a flooded VLA. However, the fibers that compose the fine glass mat suspends and supports the electrolyte, but does not absorb nor is it affected by the acidic nature of the electrolyte. AGM batteries have much better resistance to vibration and shock due to their construction than most flooded batteries. By the plates being packed together with a glass mat, the mat reduces plate movement and vibration to nearly zero making these batteries very rugged. Since glass mats are not totally saturated, the liquid does not expand to cause plate or case damage.

3-57. AGM batteries are not nearly as susceptible to sulfation compared to their flooded VLA counterparts. As with other types though, AGM batteries can freeze when stored in a discharged state. A fully charged AGM battery can withstand -70°F (-57°C) temperatures. If discharged, the same battery can freeze at 10°F (-12°C). Properly maintained AGM batteries are capable of a cyclical 80% depth-of-discharge without damage. In comparison, automotive flooded VLA batteries can only endure a 20% depth-of-discharge before damage can occur.

3-58. AGM battery features make them a good choice for the applications below:

- Tactical vehicles and generator sets since both experience transportation induced shock and vibration routinely.
- AGM batteries can provide back-up and “silent watch” power since they are designed for deep discharge applications.
- Use AGM batteries for applications where acid electrolyte leakage is not acceptable under any circumstances. AGM batteries will not leak electrolyte even when punctured or cracked. Nor are they classified “hazardous” in contrast to flooded VLA batteries.
- Suitable for cold temperature operations (below 32°F [0°C]) when charged and maintained properly.

# NON-RECHARGEABLE DRY CELL BATTERIES

3-59. Also known as “primary batteries” because they do not draw energy (recharge) from another energy source. Primary batteries are very useful when charging is impractical or impossible, such as in military combat, rescue missions, implanted medical devices, and other austere situations (MIL-PRF-49471, *Batteries, Non-Rechargeable, High Performance*). High specific energy, long storage times and instant readiness give primary batteries a unique advantage over other power sources. They can be carried to remote locations and used instantly, even after long storage.

3-60. Advances in non-rechargeable dry cell battery technology has resulted in dozens of different chemistries for making different types of batteries. In spite of the scientific advances, most are not cost effective for commercial or military use. All batteries used today are simple variations of the early battery, called a voltaic cell. Any primary battery’s performance is negatively affected by excessive heat, excessive cold, high humidity, and high altitude. The only thing that protects a battery’s performance is the construction of the casing surrounding the battery. Still, almost none of the new battery chemistries (especially those that use water in the electrolyte) offer any distinct advantage in resisting the cold induced slowdown of the electro-chemical energy generation process.

3-61. Traditional wisdom says, to keep batteries warm, wear them under your coat or jacket. That might work for flashlight batteries, but most military equipment today uses rather large battery packs that won’t fit under clothing. Consequently, unit maintainers will have to think or plan for ways to keep primary batteries viable for equipment use in a wet or cold field environment.

## LITHIUM BATTERY

3-62. Amongst primary lithium battery types, several different chemical systems are commonly used. In the consumer area, Li/CFX (poly carbon monofluoride) and Li/MnO2 (manganese dioxide) are found in cameras, calculators and watches. In the military community, Li/SO2 (sulfur dioxide) batteries are used in high power radios (MIL-PRF-32271 series, *Batteries, Non-Rechargeable, Lithium General Specification For*). Li/SOCl2 (thionyl chloride) and LiI2 (lithium iodine) are commonly utilized in industrial and medical applications.

3-63. Lithium sulfur dioxide (Li/SO2) is the most common primary battery chemistry used by the military, followed by Lithium-manganese dioxide (Li/MnO2). They have an estimated shelf life of 10-15 years at 68°F (20°C). Lithium batteries can usually provide a somewhat satisfactory power performance with a 40-60% decrease in battery life, down to about -4°F (-20°C). Beneath that, performance greatly diminishes. For planning purposes:

- Li/SO2 batteries have an operating temperature range of -58°F to 140°F (-50°C to 60°C).
- Li/MnO2 is not as cold tolerant with an operating range of -22°F to 140°F (-30°C to 60°C). Below those temperatures, the lithium electrolyte stops functioning. Above that, it burns.

3-64. Lithium batteries begin aging as soon as they are manufactured. Yet, lithium batteries have a low self-discharge rate and long shelf-life, maintaining over 85% of their charge, even after 10-15 years in storage.

### ALKALINE BATTERY, NON- RECHARGEABLE

3-65. Better than almost any other primary battery, alkaline-manganese dioxide (/MnO2) batteries resist degradation of performance in the cold. Their energy output remains fairly constant, and undiminished by the cold, until it freezes. Alkaline batteries freeze somewhere around -4F (-20C). They have an estimated shelf life of 5-7 years, at 68°F (20°C).

3-66. Many localities around the world consider spent alkaline batteries to be hazardous waste, and must be disposed of according to theater or installation policy; which follows host nation, federal, state, and local environmental laws and regulations. Usually, they are to be treated as hazardous waste.

### DISCONTINUED BATTERIES

3-67. Discontinued battery types are only mentioned because they may have to be procured to support COTS devises. Carbon-Zinc Batteries, and Mercury-Oxcide Batteries are non-rechargeable batteries that have been discontinued from inventory, and are treated as hazardous waste.

## RECHARGEABLE DRY CELL BATTERIES

3-68. Rechargeable batteries are divided by Army specifications (MIL-PRF-32383 [series], , *Batteries, Rechargeable, Sealed, General Specification for,*) into the following four category types:

- Type I – Batteries with a nickel cadmium (NiCad) electro-chemical system.
- Type II – Batteries with a nickel metal hydride (NiMH or Ni-MH) electro-chemical system.
- Type III – Batteries with a lithium ion (Li-Ion) electro-chemical system.
- Type IV – Batteries with a lithium polymer (Li-Po) electro-chemical system.

3-69. Army specifications for Type I and II rechargeable device batteries (MIL-PRF-32052 [series], *Battery, Rechargeable, Sealed*) are that they shall be capable of operating over a normal temperature range of -4°F (-20°C) to 122°F (50°C). Type III and IV have broader temperature range specifications of 22°F (-30°C) to 131°F (55°C).

3-70. The technology behind lithium batteries (Type III and IV) is still evolving, which means that the technical specifics in this TM will become dated in five to ten years. Still, in principle the information has value. Li-Ion battery shelf-life is about 60-months, though it is extendable beyond that period. Operators and maintainers should not only rely primarily on the item specific TM, but with lithium batteries, check that the information is current to less than three or four years old.

### RECHARGEABLE BATTERY STORAGE

3-71. Military acquisition standards for rechargeable batteries require storage temperatures that may vary between the limits of -4°F (-20°C) to 122°F (50°C). The recommended storage temperature for most batteries is around 59°F (15°C). While lead acid must always be kept at full charge during storage, nickel and lithium based chemistries should be stored at around a 40% SOC; with extreme allowable partial discharge at somewhere above 35%, to as much as 80% of its total capacity is best, as a rule of thumb. This keeps nickel and lithium based batteries operational while minimizing storage time related capacity loss due to self-discharge. Nickel-based batteries can be stored in a fully discharged state with no apparent side effect. However, priming becomes necessary if the voltage drops below 1volt per cell. Li-Ion batteries cannot dip below 2volts in each cell for any length of time, or they will have to be turned in for disposal.

3-72. For thermal shock (resilience to physical damage at extreme temperatures), batteries shall not bulge, crack, break, leak electrolyte, rupture, burn, or explode as a result of varying rates of thermal expansion or contraction of cell and battery components when subjected to thermal shock temperature cycling in the range of -59°C (-75°F) to 75°C (167°F).

3-73. Different battery chemistries often demand different storage conditions. Rechargeable military batteries are capable of more than 3 years of warehouse storage, without any maintenance during storage. To ascertain how old a battery actually is, the military uses a four-digit number in which the first two digits shall indicate the number of the month and the last two digits shall indicate the year of manufacture. Months earlier than the tenth month have a single digit preceded by "0". A forward slash ("/") separates the first two digits from the last two: 01/13 indicates January 2013. Knowing the age of a battery will give the user some idea of the available remaining battery life, even for a rechargeable.

**CAUTION**

Do not store a fully charged or fully discharged lithium battery, for a variety of technical reasons.

## General Operation of Rechargeable Batteries

3-74. A rechargeable battery's service life is affected by several factors: ambient operating temperatures, physical use/abuse and depth of discharge as a function of the load's duty cycle. In general, rechargeable batteries will experience a longer service life at shallow depths of discharge. In other words, a battery discharged to somewhere within 40% to 50% of its capacity at the time of recharge will last longer compared to one discharged to near zero capacity, each time. However, the depth of discharge depends on the application's (load) duty cycle and if it is practical to recharge the battery well before discharging it completely. Only using a fraction of the battery's capacity before recharging would demand more batteries for a given application. The shallow depth of discharge to recharge strategy is not always operationally practical.

3-75. Though in cold climates, the low ambient temperatures can increase the demand for batteries (see paragraph 3-39). The military performance specification for rechargeable batteries specifies they must withstand at least 224 discharge/charge cycles without significant performance degradation. Here, a "cycle" can be defined as a fully charged battery being drained to almost no charge (without reversing polarity), and then being brought back fully charged again. However, depending on the battery chemistry and the factors noted earlier, rechargeable C-E batteries can often withstand over 500 cycles.

3-76. Though new technology and better chemistries promise broader temperature ranges and longer life expectancies, the above parameters represent the most reliable planning information. If rechargeable batteries are used in cold temperatures, and subjected to daily use, equipment maintainers should expect that most will not last two years. Most equipment designers prefer lithium batteries because of their greater power capacity, but with the shorter life expectancy that begins aging at the time of manufacturer, the Army has stopped sending batteries with replacement items. The part may have sat in a warehouse for years, but the battery should be fresh. It is important that planners expect to order fresh lithium batteries along with the related devices.

3-77. Some rechargeable battery packs have control circuitry inside their cases to control their performance. Most rechargeable battery packs have to be at temperatures above +30°F (-1°C) before the control circuits will allow the recharging process of the individual cells within the case. Some cases have heating pads that engages during a low temperature recharge. The item specific TM will identify temperatures where recharging can occur, and should indicate if the case has a built in heating element. If the battery doesn't have a functioning heating element, temperatures below freezing will obstruct the chemical reaction processes for recharging.

3-78. If during the course of using a rechargeable battery a cell discharges into reverse polarity, the battery can heat up, and may erupt on fire. Normally, the control circuitry will detect unusual heat, and shut down the battery pack before such a situation occurs. Operators can check for localized hot-spots on a discharged battery pack to ascertain if the pack is failing. The material out of which these batteries are made can become combustible, aside from an electrical discharge. If a localized hot-spot is detected during the recharging process, deadline the battery and turn it in for evaluation, servicing or disposal to the unit maintenance activity. This during-operation check is very important to prevent fire damage.

## TYPE I - NICKEL-CADMIUM BATTERIES, RECHARGEABLE

3-79. These batteries are made in a wide range of sizes and capacities, from portable sealed types interchangeable with carbon-zinc dry cells, to large ventilated wet-cells used for standby power and mobility power. NiCad batteries that are used in a variety of Army equipment (such as range finders, some night vision sights, and ground surveillance radars). The NiCad battery is capable of performing to its rated capacity when the ambient temperature of the battery is in the range of approximately 70°F (-56.5°C) to 90° F (32°C). When properly maintained, they are very effective low-temperature power sources (figure 3-6). However, below 40°F these batteries need to be warmed to help keep their current up for meeting an energy demand. At +25°F (-4°C), these batteries lose about 30% of their useful life or service time before needing a recharge.

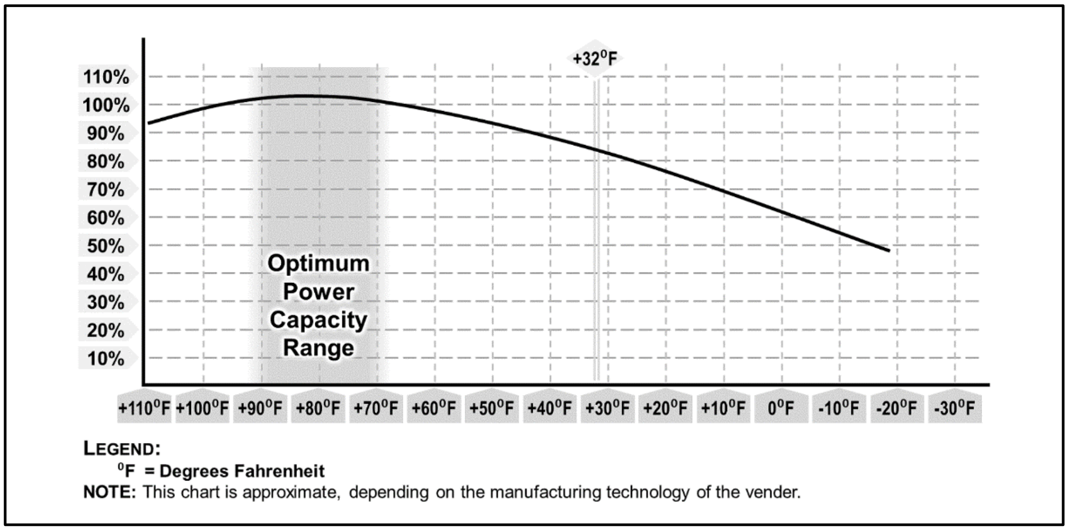


**Figure 3-6. Nickel-cadmium power capacity at various temperatures**

3-80. When first pulled from storage, NiCad batteries need to be primed. This involves hooking up the batteries which will form a habitual relationship, and trickle charge the battery(s) for 16 to 24 hours when new and after a long storage. This allows the cells to adjust to each other and to bring them to an equal charge level. A slow charge also helps to redistribute the electrolyte to eliminate dry spots on the separator that might have developed by gravitation. Follow the item specific TM instructions for this procedure.

3-81. NiCad batteries have what is called, battery memory. To get maximum effectiveness when charging NiCad batteries, one must destroy the charging memory characteristic of the battery. For example, if a NiCad battery is continually called upon to delivery an average of only 25% of its capacity before it is recharged, it will eventually “memorize” this fact and become incapable of supplying the remaining 70% of its capacity. Operators must condition the battery to get past the memory. Conditioning entails discharging NiCad batteries down to their lowest operating levels, then recharge them fully, then discharge them again to their lowest operating levels, then once again recharge them fully to destroy the memory. Follow the item specific TM instructions for this procedure.

## TYPE II - NICKEL–METAL HYDRIDE BATTERY, RECHARGEABLE

**CAUTION**

NiCad chargers overcharge NiMH. (NiMH chargers can charge NiCad, but not the other way).

3-82. A nickel–metal hydride (NiMH or Ni-MH), battery is similar to the NiCad. A NiMH battery can have two to three times the capacity of an equivalent size NiCad. The significant disadvantage of NiMH batteries is the high rate of self-discharge (when in storage or not in use). They have a life expectancy of two to five years. Battery memory might be a problem if the battery has a cadmium electrode, otherwise it is not an issue.

3-83. At low temperatures, the NiMH provides a consistent level of power, all the way through discharge. At freezing, NiNH batteries only provide 80% of the capacity, where at -4°F (-20°C) these batteries only provide 20% of their normal power capacity or service time before needing a recharge (figure 3-7).

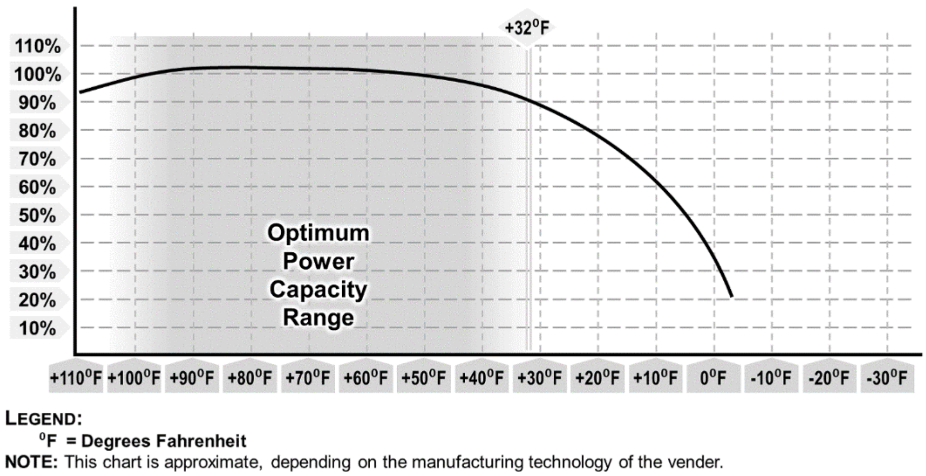


**Figure 3-7. Nickel–metal hydride power capacity at various temperatures**

## LITHIUM BATTERIES, RECHARGEABLE, IN GENERAL

**WARNING**

**Lithium-ion batteries can rupture, ignite, or explode when exposed to high temperatures.**

**They should not be stored in a vehicle during hot weather.**

**Short-circuiting a Li-Ion battery can cause it to ignite or explode.**

**Never open a Li-Ion battery's casing. Li-Ion batteries contain safety devices that protect the cells inside from abuse. If damaged, these dysfunctional safety devices may allow the battery to ignite or explode.**

3-84. The lithium rechargeable batteries are the most common type of rechargeable battery found in small electrical devices. Army specifications are, MIL-PRF-32383:

- Discharges energy over a temperature range: -22°F (-30°C) to 131°F (55°C).
- Thermal shock resistance (the ability to avoid temperature caused physical damage) range: -75°F (-59°C) to 167°F (75°C).
- Rechargeable range limits, between: 40°F (4.5°C) to 110°F (43°C).
- Don't ever try to charge Lithium batteries below 41°F (5C). Doing that causes plating to form on the anode, and a permanent loss of capacity.

3-85. Most lithium battery electrolytes actually freeze at approximately -40°F (-40°C). Freezing can damage a cell by causing dendrites (crystallization) in the electrolyte components which can pierce a separator element or damaging material bonds. Though new technology and better chemistries promise broader temperature ranges, the above parameters represent the most reliable planning figures.

3-86. Modern lithium batteries do not contain solid lithium metal; instead, they use lithium ions, suspended in a polymer-and-electrolyte GEL. Old-style batteries made with solid lithium metal were subject to "thermal runaway" after repeated discharges. Today's lithium-ion batteries can have a variety of positive and negative electrode materials, resulting in an energy density and voltage that vary, accordingly. Still, for its size, it holds five to five and a half times the energy of an old style lead-acid battery, for the same weight.

3-87. Since Type IV lithium batteries use a polymer, not water, as an electrolyte medium, their behavior is not related to water's freezing temperature. They incur a drop in performance beginning at about +30°F (-1°C), which becomes more pronounced at -5°F (-20.5°C) or lower. Cell capacity is also reduced during these lower temperatures. If these cells are used or stored at -55°F (-48°C), irreparable damage may occur under certain conditions to internal separators within the cells, making the cells a safety hazard. These batteries have insignificant memory effect that limits the duration of charge, and usually requires no battery conditioning during recharge. The ideal storage temperature for lithium batteries is at a cool or moderate room temperature above water freezing temperatures (32°F [0°C]), and not in the freezer.

3-88. Drawbacks to these batteries are:

- Limited Battery Life: They begin degrading as soon as they are manufactured, regardless of whether they are sitting in storage or being used. The rate of capacity degradation for a maintained battery (having been properly charged) is less than 5% per year. If stored without charge, they can be dead in a year. Their effective lifespan is about two or five years. (Technology to counter this problem is under development, but not yet available.)
- Computer Chip Monitor: A battery pack needs a small computer (microchip) to manage the battery's energy charge and temperature. Some are built into the battery pack; some are regulated by circuitry in the device.
- Sensitive to High Temperatures: High temperatures increase the rate of battery life degradation. Lithium batteries should be kept cool. Aging will take its toll much faster at higher temperatures.
- The high temperatures found in vehicles may cause lithium batteries to degrade rapidly.
- Requires a Constant Positive Charge: Lithium batteries need to maintain a positive charge. If cell voltage drops too low the battery can become ruined. Then a subsequent charging may result in thermal runaway.
- Flammable: If the battery overheats, it can burst into flames. Although this is uncommon, it does happen.

## TYPE III - LITHIUM-ION BATTERIES, RECHARGEABLE

3-89. The type III, lithium-ion (Li-Ion) batteries are distinguishable by their hard case enclosures (typical of any liquid filled battery). These batteries are filled with an electrolyte gelatin, or a porous separator, which is soaked with electrolyte.

## TYPE IV – LITHIUM POLYMER BATTERIES, RECHARGEABLE

3-90. Lithium polymer (Li-Po) batteries operate on the same electrochemistry as the Li-Ion battery. It's distinguished by using a dry-electrolyte separator material that is only a millimeter thick. It allows the ions to pass through, but keeps the cathode and anode plates separated. Because the dry-electrolyte medium resists leakage, these batteries can be packaged in soft and light weight polymer pouches. This type of packaging results in a battery that is 20% lighter than the equivalent Type III Li-Ion battery. Its drawback is the dry-electrolyte separator's lower conductivity due to the electrolyte's molecular stability which impedes the movement (compared to the gelatin of a type III) of chemical interactions that release energy.

3-91. Because of the soft packaging, the rigid structures of integrated safety devices (such as a current interrupting device or a positive temperature coefficient material that is able to protect against an over-current or an over-temperature) are not built into lithium polymer (Li-Po) pouches. Such safety devices must be built into the item of equipment as battery management circuitry.

## SECTION II – ELECTRICAL AND IGNITION SYSTEMS

3-92. In general, electrical and ignition systems perform satisfactorily down to about -30°F (-34°C). Below this temperature, cracking of the insulation on ignition wires, failure of condensers, and the fouling of glow plugs or spark plugs can occur, causing maintenance problems. Check, clean, and tighten all wiring connections, especially check battery and starter terminals. Check for breaks and shorts in high-tension ignition wiring. Clean and replace glow plugs or spark plugs, making sure that the porcelain is not chipped or cracked. Operator attention in keeping battery cables clean and tight is necessary for dependable winter starting. Improvements in battery materials and connectors have decreased the problems related to poor battery connections, but a high percentage of vehicles that have slow cranking engines are caused by corroded connections.

3-93. Before attempting to start an engine in cold weather, operators are responsible for visually inspecting installed batteries for cleanliness and obvious damage (case, filler caps, battery cables, terminal posts, rust, corrosion, and the rest of the battery) using the applicable TM. Operators or crew will report observed faults to maintenance. If the battery fails to start the engine after a third attempt, report it to the maintainers.

# Chapter 4

# Petroleum, Oils and Lubricants Management

This chapter is focused on the properties of petroleum based fuel oils, lubricants, greases products, and solvents. These four products are available as crude oil based products, synthetic oil derivative products, and bio-synthetic oils and lubricants. Crude oil based petroleum products are economical and easy to procure. Synthetic oil derivative products are more resilient over a broader temperature range, though more expensive. Bio-synthetic lubricants are synthesized from organic matter, and are either easier to make, cheaper to make, or eco-friendly. For units operating in cold or cold environments, maintainers and operators need to be knowledgeable about the limitations of POL products. They must especially know where the point of non-functionality will occur and how to minimize adverse effects.

**NOTE:** Performance characteristics of the POL products presented in this manual are general in nature, for planning purposes or general education on the subject. The true POL product performance is subject to evolving technologies. A product's manufacturer will have to be contacted for the actual low temperature threshold performance characteristics if it cannot be found in manufacture's safety data sheets documents.

**NOTE:** Maintainers and operators should refer to the item specific TM or LO which are the primary sources for maintenance procedures.

## SECTION I – MAINTENANCE CONSIDERATIONS

4-1. Commanders and maintenance leaders should establish a trigger event or turnover point when the fuels, antifreezes, and POLs will be converted to cold weather operations before deployment into cold regions. Setting a trigger event even applies to units which are otherwise not originally programed for a cold region deployment. They would benefit from having contingency plans and policies. It is prudent for a unit to identify what resources would be needed and where they can be rapidly procured. Once the turnover point is established, maintenance leaders should develop a transition program for the unit's equipment and vehicle fleet. Then once deployed, units operating in a cold environment can expect a dramatic increase in POL and fuel requirements due to POL property changes, movement difficulty, extended idling, and heating requirements. Prior planning is critical to mission success.

4-2. Maintenance Soldiers and equipment operators need to understand how POL products change their physical and performance properties as their temperatures become increasingly colder. Always consult the appropriate TM or LO for any piece of equipment. Identify any special fuel and lubricants that must be used to prevent freezing or congealing. Different grades of antifreezes and hydraulic fluids are usually necessary for cold equipment operation.

4-3. Synthetic oils and lubricants are preferable in cold situations. They are made from pure component chemicals, free of the impurities or molecular inconsistencies found in crude oil. The highs and lows of the gap between flash points and pour points (to be discussed in Appendix E) is broader for synthetics than conventional oil products. The added resiliency at high temperatures results in synthetics having two to three time's greater mileage or a longer lubrication life. A 0W-30 qualified to MIL-PRF-46167, *Lubricating Oil, Internal Combustion Engine, Arctic,* standards is capable of pumping through a crankcase at -67°F (-55°C) and may still flow at even lower temperatures. Conventional oils usually freeze into a gelatinous solid at those temperatures. Synthetic oils can be mixed with conventional oils, but then the gap between the upper and lower lubricating limitations becomes governed by the lower capabilities of the two products. When mixed, synthetic oils versus crude oils, the crude oil properties dominate.

4-4. For POL products, the DOD only tests down to -65°F (-54°C). However, unit commanders, operators, and maintainers may need to know: how safe is it to use (most of which can NOT be found on data sheets)? How cold can it get, and still work normally (information which only the manufactures or qualifying DOD activities have)? What procedures and precautions are needed to keep a POL product working in cold environments? To answer these questions, the results of four tests are usually considered:

- The “flash/fire point” is a commercial or manufacturer’s test to determine the lowest temperature above which the application of a flame will cause fuel or lubricant vapors to ignite (flash point) and sustain burning for five seconds (fire point). POL products with higher flash and fire points exhibit more stable volatility characteristics and are safer to use and transport.
- The “pour point” test determines the lowest temperature at which it still flows (before crystallization [freezing]). The lower a lubricant or diesel fuels’ pour point, the better functional performance it provides in low-temperature service.
- The “freeze point” test for fuels is the lowest temperature at which fuel remains free of solid hydrocarbon crystals. At which it first begins to turn into a waxy slush (which is well before the whole substance hardens). At this temperature, fuel flow disruptions could be expected to occur with equipment.
- The “viscosity” test determines the fluidity at various temperatures where oil flows and properly lubricates in a system. As temperatures drop to their lower limits, the oil’s stiffness interferes with lubrication or hydraulic functions in a machine or gear box. This test is also applied to fuels.

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**NOTE:** For viscosity, the specific test result is not as important to the operator as is the availability through supply of a more fluid low-viscosity POL products. Operators are to use the TMs to direct the conversion to substitute lubricants for lower temperatures.

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## SECTION II – PETROLEUM AND ENGINE FUEL PLANNING

4-5. The DOD has adopted a Single Fuel Policy (SFP), under Army in AR 70-12. This policy has the goal of focusing on a single kerosene based fuel (SKBF) for use in all equipment. This is considerably easier to manage than multiple fuels, allowing the functions of fuel storage, transportation, and distribution to be tailored for maximum efficiency. In coordination with the respective service policy guidance, the theater Joint Petroleum Office, sets policy for any deviation from the SFP. In expeditionary situations commanders and their logistics staff may have to deviate from JP-8, and rely upon secondary fuels or commercial sources with multiple petroleum products whose performance can be seriously affected by the cold. When authorized to deviate from the SFP, the order of preference is:

- JP-8 outside the continental United States (OCONUS), or F-24 within CONUS (the standard, and not a deviation).
- JP5.
- Commercial Jet fuels with additives:
  - Fuel System Icing Inhibitor (FSII).
  - Static Dissipater Additive (SDA).
  - Corrosion Inhibitor/Lubricity Improver (CI/LI).
- Commercial Jet fuels without additives.
- Commercial Diesel (limited to one tank, ground use only).

4-6. Command planning staff and maintainers can be familiarized with what to expect from the assortment of military standard and commercial fuels they may encounter. The information in this manual on petroleum and fuels is intended to be limited in scope to cold environments. Further fuel planning considerations can be found in Appendix E, under the listed fuel type.

4-7. Safety is a principal concern. Petroleum products are hazardous due to their toxicity, explosiveness, flammability, and potential to create environmental damage. Prescribed safety precautions found in equipment specific TMs, facility, military or governmental regulations, are followed for the protection of personnel, equipment, and the environment. For safety reasons, fuel handlers and equipment operators need to be familiar with fuel characteristics.

4-8. In cold, the freezing point of fuel is the temperature were the fuel first begins to turn into a waxy slush. In petroleum fuel, the crystallization process does not solidify the fluid all at once at a set temperature, the way water does. Operators focus on the fuel's freeze point temperature (as different from the point of solidification) because it is the point were problems getting the fuel to flow through the fuel system begin to occur.

**NOTE:** It is important for the Commander and purchasing agents of COTS to consider the type of fuel needed to operate a COTS item. It is best for COTS to function on SFP fuels common to the unit's TO&E fleet. This will make it easier to obtain fuel for the COTS and avoid causing supply to carry a larger list of fuels.

# FUEL STORAGE

**WARNING**

**Fuel flowing over a surface generates static, which can cause a spark unless means are provided to ground the electricity. A metallic contact between the dispensing tank and the container being filled must be provided to ensure an effective bond. This hazard is particularly increased in cold, dry air.**

**WARNING**

**Fuel handlers must be extra careful to avoid getting fuel on exposed skin. Spilled fuel has a super cooling effect upon the skin and may cause rapid frostbite.**

4-9. Successful operation of vehicles at low temperatures depends greatly on the condition of the fuels used. Water in fuel can cause serious difficulties so it is important to remove water accumulation as soon as possible. Daily inspections of water content in vehicle water filter separators and draining will go a long way to prevent problems. Trouble occurs in some engines even at temperatures above the freezing point of water if other than JP-8 fuel is used. Diesel fuel, for example, is a seasonal fuel that gelatinizes if used in the wrong season as the cloud point (where waxy material starts forming) of the fuel varies across season.

4-10. Moisture and condensation caused contamination of fuels is the source of many difficulties. Moisture can be the result of snow getting into the fuel, condensation due to breathing of a partially filled container when taken outdoors from a warmer temperature, or from fuel consumption during normal operation. To prevent contamination, the following precautions must be observed:

4-11. Store barrels with outlet end slightly higher than the other end to allow sediment and water to settle out (figure 4-1, on page 4-4). Upright storage of barrels should be avoided to keep water and snow from accumulating around fill cap. The last few gallons that remain in the barrel should be dumped into collecting barrels where foreign accumulation can settle and the usable fuel can be salvaged. Make sure all containers are thoroughly dry, clean and rust-free before storing fuel in them. When barrels are stored, they need to have a secondary containment to catch and collect any spills to prevent soil contamination.

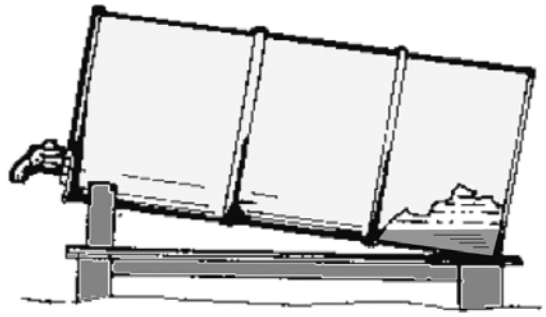


**Figure 4-1. POL barrel storage**

4-12. Wipe all snow or ice from dispensing equipment and around fill cap of fuel tank before removing cap. After filling tank, replace cap securely.

4-13. Keep the fuel tank filled to proper markings at all times. Refuel only to the expansion marking immediately after halting to reduce condensation in the fuel tank. The more fuel there is in the tank, the smaller the volume of air from which moisture can be condensed.

**NOTE:** Secondary containment must be used under barrels to collect any spillage and to prevent contamination of the soil.

4-14. Arctic fuels for gasoline or diesel engines are developed and selected to obtain the proper atomization necessary for a combustible fuel-air mixture. It is essential that pump units tankers be provided with JP-8 or appropriate cold-weather-grade fuel if other that JP-8 use has been approved. Standard JP-8 fuel has a minimum specification requirement of -52°F (-47°C), which ensures gelling will usually not occur at extreme-cold or even hazardous-cold temperatures.

4-15. Where commercial fuels have to be used, cold weather calls for the use of a special grade of diesel fuel (signified as, DF when referring to a specific grade) called, DF-1. (For example - Diesel fuel gets thicker and cloudier at lower temperatures. Under extreme conditions, it can gelatinize and refuse to flow at all.) Diesel Fuel grade 1-D should be used in applications where abnormally low operating temperatures are encountered.

# FUEL SYSTEMS

4-16. For a satisfactory start, engine fuel must produce a combustible mixture with air. Atomization, which increases the rate of vaporization of the fuel to produce combustible mixtures, is adversely affected by low temperatures. Engines using commercial diesel fuels are particularly difficult to start in cold weather. Many fuels, such as DF-2, contain waxes that congeal at temperatures below 0°F (-18°C). If this occurs, the filter will clog and the fuel will not flow. Diesel fuel grade 1-D is designed for use in cold regions. Military specified JP-8 is the preferred fuel for all systems.

**NOTE:** Using additive in greater proportions than two pints of additive to 40 gallons of fuel results in poor engine performance and possible engine damage.

4-17. Water accumulates in tanks, drums, containers, and fuel pumps because water from the air condenses. At low temperatures, this water forms ice crystals that clog fuel lines, fuel filters, fuel pumps, injector nozzles, and carburetor jets.

4-18. Fuel filters should be cleaned or changed at frequent intervals. Conditions may require daily cleaning under field use. Take special care to ensure 5-gallon fuel cans used in refueling are clean and serviceable.

Fuel nozzles may contain screens to catch solid contaminates. Clean nozzle screens daily. Nozzles used to refuel aircraft are required to have #100 mesh screens.

4-19. Remove and service all engine and air compressor air cleaner elements. Dry-type air cleaners, both felt and paper, should be cleaned with either low pressure air, or replaced.

4-20. Check for any indication of fuel leaks. Trace all leaks to their source and correct or replace parts. Follow equipment/vehicle TMs for proper maintenance and operation in cold weather.

# FUEL SYSTEM MAINTENANCE

4-21. Use the following instructions to prepare fuel systems for operation in cold weather:

- If necessary due to water ingestion in fuel system and when using diesel fuels as approved, add FSII (Diethylene Glycol Monomethyl Ether [DIEGME]) to diesel fuels to prevent water from freezing. However, DIEGME will not convert the fuel to an arctic or low temperature fuel.
- The appropriate grade of fuel for low temperature or geographical location operation must be ordered. Mix additive with the diesel fuel, normally at a ratio of one pint of additive to 40 gallons of fuel, prior to refueling.

4-22. Satisfactory cold weather performance of fuel-related systems depends on careful servicing. Proper maintenance by unit mechanics precludes many malfunctions and failures that would otherwise occur in below freezing temperatures. Maintenance checks should include the following during cold weather:

- The throttle controls may operate with difficulty at low temperatures. If the engine does not respond properly to operation of controls, check for loose or broken controls, and for loose or broken control linkage or cable. Adjust linkage or replace defective parts as required according to applicable TM. Clean wires with environmentally safe cleaning solvents and thoroughly dry them. Newer fuel injected systems are computer-controlled electronically, with no mechanical links to control throttle speed. These new systems are found on the palletized load system, FMTV, and the new heavy equipment tractors (Heavy Equipment Transport System), and other tactical and combat vehicles. Operators must become thoroughly familiar with cold weather starting procedures for these vehicles. For example, when starting and operating these vehicles, there is little or no throttle response until the engine temperature sensors send information to the computer that the engine is warm enough to operate. Other steps are also required, such as the use of an exhaust restrictor for the FMTV when starting in cold.
- Inspect fuel filters for good condition and replace contaminated elements. Dispose of unserviceable fuel filters in an environmentally safe manner as outlined in the unit operating procedures. Clean the metal disc type filters with dry-cleaning solvent, dry, and install. Make sure there are no leaks.
- Drain fuel filters at the end of each day of operation. Do not assume that filters are dry if nothing flows from the drain cock. If water is present, it could have frozen solid overnight. Drain filters into an approved and appropriately marked and labeled container and turn in according to unit operating procedures for disposal.
- Check the diesel-fuel injection pump, including transfer pump, to ensure that it is in good condition, correctly assembled, and securely mounted, and that connections are not leaking.
- Check diesel-fuel nozzles and lines to ensure good condition.
- Check whether the fuel gauge is operating and registering amount of fuel in the tank.
- Identify any special host nation disposal requirements in advance.

## SECTION III – LUBRICATION OIL

**NOTE:** The Army only qualifies 15W-40, 40, and SCPL for use in diesel engines. SCPL is replacing OEA/OEA-30. The grades 5W-20, 10W-30, and 10W-40 are for gasoline engine grades and are not for use in military equipment with diesel engines. If for any reason (emergency) an engine oil intended for gasoline engines is used in a diesel engine, cut drain interval by half since gasoline engine-block oils cannot hold much soot.

**WARNING**

**If the lubricant (oil or grease) in a vehicle or weapon system has frozen or solidified; the lubricant has to be brought to a temperature high enough to flow; or be dissolved, removed, and replaced by a lubricant with better low temperature properties.**

4-23. Oils (non-fuel type) and lubricants are intended to reduce the wear of parts moving against each other and reduce or negate the heat generated by the friction from that movement. In normal conditions, the viscosity of lubricants creates a protective layer between the moving parts of an engine or weapon. The principal difficulty is in providing lubricants that are viscous enough to protect working parts, yet fluid enough to afford reasonable ease in weapon system operation, starting of cold engines, shifting gears in transmissions, and/or operating clutches.

4-24. From an engine lubrication perspective, severe driving cycles encompass frequent short trips, particularly during cold weather, stop-and-go driving, cold-start and high speed-high load driving. Each of these driving cycles impacts the different types of lubrication mechanisms, ultimately promoting oil degradation.

4-25. The mechanical efficiency of an engine or weapon depends on the proper functioning of the lubrication system. Careful attention to PMCS by the operator and unit mechanic is required to keep a vehicle or weapon system in the best working condition.

4-26. Commanders and maintenance mangers need to establish and communicate to operators the procedures which account for the effects of cold on their equipment. For example, the incomplete combustion of fuels in a cold engine, and the piston rings not sealing tightly until the engine reaches operating temperatures, causes rapid fuel dilution of the oil.

4-27. Lubrication required for any specific piece of Army equipment is specified in the LO or TM. The provisions of Army LOs are mandatory and shall be adhered to at all times, unless the Department of Army authorizes a deviation. LOs usually prescribe lubricants based on three anticipated temperature ranges:

- +15°F (-9°C) and above.
- 40°F (4°C) to -15°F (-26°C).
- 40°F (4°C) to -65°F (-54°C).

4-28. If vehicles move into a cold weather area with temperate grade automatic transmission fluids and becomes cold-soaked (when a vehicle's hardware temperatures drops to being as low as the existing freezing ambient temperatures), shifting gears may occur very slowly or not at all. In addition, seals may leak temporarily until the transmission has reached operating temperature. Trying to operate the vehicle at temperatures below the pour point of the transmission fluid may result in severe damage to the transmission.

4-29. Cold weather promotes water and fuel accumulation in the crankcase because the engine operating temperature is not achieved quickly or not maintained at a high level long enough to induce evaporation. These contaminants, if excessive in amount, will affect the lubrication boundary between moving parts. In addition, accumulated water accelerates the oxidation of the base oil, quickening a reduction in the additive content. Water will also extract acids and additives out of the oil, trapping then into the formation of emulsions. Emulsions restrict oil flow by blocking passages in the oil gallery, leading to premature wear on engine parts due to insufficient amounts of oil reaching these components. By products from oxidation will eventually lead to depletion of the additive package. In the end, this leads to corrosion on engine part surfaces.

4-30. When oil contamination by fuel occurs, the oil film thickness is reduced, resulting in cylinder, ring, and piston wear. Then compounds generated due to oil oxidation may deposit on the piston rings and grooves, causing ring-sticking and promoting blow-by. Excessive blow-by will in turn decrease the engine power and increase fuel consumption.

# VISCOSITY

4-31. For lubricants (oil or grease), cold weather tends to increase its fluid viscosity (make it thicker). The runnier the fluid is, the lower the viscosity. The thicker the fluid, the higher the viscosity. Equipment operators should understand that in extreme environments, oils and greases can both thin out or thicken due to age and contamination, as well as due to cold or hot weather.

4-32. Cold temperatures can put a lubricant's viscosity outside of an equipment's acceptable operating tolerance as it thickens. Maintainers will need to check the TM of a specific item of equipment to identify its viscosity requirements and limitations for proper operation. Then for environments where lubricants are operating at the margin of its limits, they will need to consider a method of identifying the threat of lubricant failure or expect an increase in broken parts.

4-33. A significant reduction in viscosity (thinning of the lubricant) can result in:

- Loss of oil film between moving parts causing excessive wear.
- Increased mechanical friction causing excessive energy consumption.
- Heat generation due to mechanical friction.
- Internal or external leakage.
- Increased sensitivity to particle contamination due to reduced oil film.
- Oil film failure at high temperatures allowing parts to rub directly against each other.
- High stress loads or during start-ups or coast-downs.

4-34. Likewise, too high a viscosity (thickening of the lubricant) can cause:

- Excessive heat generation resulting in oil oxidation, sludge and varnish build-up.
- Gaseous cavitation (air pockets) due to inadequate oil flow to pumps and bearings.
- Lubrication starvation due to inadequate oil flow.
- Oil whip in journal bearings.
- Excess energy consumption to overcome thickened fluid resistance.
- Poor air detrainment (regulation of air flow) or poor demulsibility (separation of water from oil).
- Poor cold-start pumpability.

# ACCUMULATION OF SLUDGE IN LUBRICATING OIL

4-35. Cold weather tends to prevent engines from reaching normal operating temperatures, increases the development of carbon in the engine, and increases oil dilution and condensation. These factors combine to create engine sludge (figure 4-2, on page 4-8). The Army Oil Analysis Program (AOAP) is the activity primarily responsible for identifying contaminated or degraded oil needing to be changed. To correct a sludge condition, drain oil while engine is warm (not hot or cold-soaked) enough for oil to flow and refill with the appropriate lubricating product.

4-36. After operation, inspect the oil pan, valve cover, timing gear cover and gaskets, and external oil lines for oil leaks; correct as necessary. To protect the environment, drip pans must be placed under vehicles. Turn in all used oil according to host nation, federal, state, and local environmental laws and regulations and unit operating procedures.

4-37. The best way to prevent sludge buildup within a vehicle fleet is for the maintenance manager to ensure oil and filter changes occur according to the schedule provided in the TM or LO. Proactive participation in the Army Oil Analysis Program can also help to identify the propensity of an oil to produce sludge.

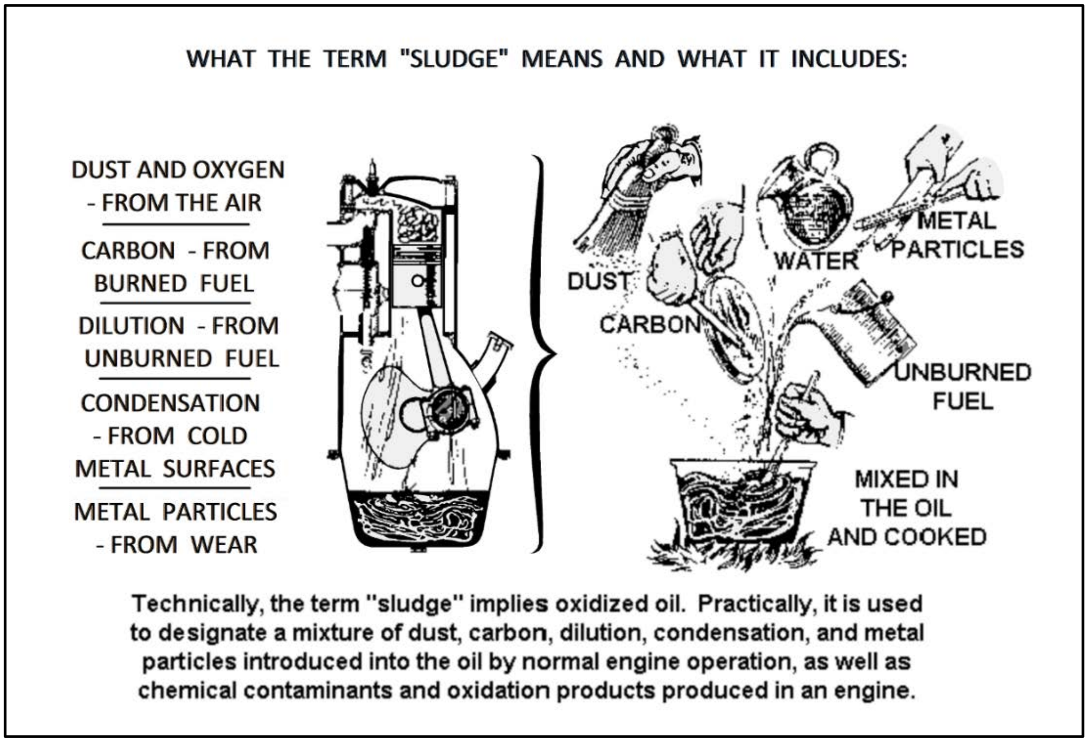


**Figure 4-2. Engine sludge**

# AUTOMOTIVE LUBRICANTS

4-38. In cold, using ordinary oil thickens, increasing the fluid friction on cylinder walls, in bearings, or within weapons to the extent that it may not be possible to crank an engine or fire a weapon. Using an oil appropriate for cold weather operation such as OEA-30 (engine oil, arctic) or OE/HDO-SCPL, as prescribed by the LO, will prevent this condition during cold starts. OEA-30 and SCPL are synthetic lubricants designed for cold environments.

4-39. The Army established SCPL as of 15 January 2016, which is now expressed under; MIL-PRF-2104K qualification standards. SCPL is a multi-purpose, all-season (0W-20), full synthetic heavy-duty powertrain lubricant that reduces fuel consumption, increases oil life, and reduces logistical burden. The previous MIL-PRF-2104 revisions had 4 grades: 15W-40, SAE-40, SAE-30, and 10W. With the introduction of SCPL in version “K,” the 10W and SAE-30 grades became redundant and were removed. MIL-PRF-2104K now qualifies 15W-40, SAE-40, and SCPL. SCPL, and may be used as a drop-in replacement for equipment already using the older MIL-PRF-2104 standard military oil. Just drain the old oil, and fill with SCPL.

- Check applicable TM for recommended lubricants.
- SCPL is generally best for cold weather operations, and can be used in both the engine and transmission for both arctic and temperate conditions. This allows vehicles to be winterized prior to deploying from a temperate to a cold region.
- Use of SCPL in high output 2-cycle diesel engines is not recommended when the ambient temperature exceeds 90°F (32°C); use 15W-40 or SAE-40 grade oil under those conditions.
- SCPL is not a replacement for Dexron VI in the transmissions of Caterpillar "CAT" or high mobility multi-purpose wheeled vehicle (HMMWV), nor a replacement for the 10W in the transmission of the Hercules recovery vehicle (M88A and M88A2); except in arctic conditions.
- SCPL is not recommended for use in the transmission of the Abrams main battle tank; except in arctic conditions.

**NOTE:** OEA engine oil is listed as EOS (meaning, engine oil supplement) in some older LOs. Here, the supplement being referred to is the synthetic component of the oil. Equipment being prepared for future cold weather operation must use arctic-type lubricants, even if considerable operation in warmer climates is involved prior to cold weather operation. This gets ahead of equipment components being disabled because of lubrication failure when low temperatures are encountered.

**NOTE:** In 2006, the name of the Society of Automotive Engineers has changed to SAE International. However, SAE followed by numbers and letters refers to specific POL standards.

**NOTE:** When engine oil (SAE 10 or OE/HDO-10) is prescribed for gear cases, drain and fill with OEA-30 or OE/HDO-SCPL lubricating oil or GO-75 gear oil as prescribed by LO. (SAE [Society of Automotive Engineers]. OE/HDO [original equipment, heavy duty oil]).

4-40. General procedures for preparing the lubrication system for cold weather are as follows:

- If possible, store lubricating oils and grease in a warm place. Lubricants are much easier to pour or apply if they are warm.
- Prevent snow or moisture from entering the crankcase when lubricants are added. Use only newly opened cans of oil to eliminate the possibility of using contaminated oil.
- Keep lubricating equipment free of moisture, snow, ice, or dirt to avoid contamination.
- Inspect the engine oil pan and gasket for leaks.
- Drain the engine lubrication system when the weather is warm (temperate weather). Replace the oil filter element. When the system is clean, fill with OEA-30 or OE/HDO-SCPL lubrication oil in the amount specified in the operator TM or LO. Run the engine for 10 minutes and check for oil leaks. Stop the engine and wait 1 to 5 minutes before checking the oil level. This reading will be approximate only and should be between the ADD and FULL marks. This is due to the many oil passages of the engine.

4-41. When a temporary rise in temperature occurs, drivers should not change or vary their maintenance operation of the vehicle. Lubricant levels and points, however, should be closely observed, and proper steps taken to replenish lubricants. Instructions in LOs apply when a definite change to higher environmental temperatures is expected, such as a change of seasons.

## SECTION IV – GREASE LUBRICATION

**CAUTION**

Different types of greases should not be mixed together.

4-42. Grease is distinguished by its being a gelatinous lubricant (a, "gel") that cleaves to the surface of the item or inhabiting a cavity without draining out; as different from a fluid oil. In principle, grease is like a sponge saturated with oil. As the stresses of heavy loads or high temperatures is applied to the grease, the thickener (sponge) releases the oil to lubricate the mechanical parts; when the stress is removed the thickener re-absorbs a portion of the released oil for later use. Greases are applied to mechanisms in which a lubricant cannot stay in position, or re-lubrication is infrequent, difficult, or just not efficient. It has to remain in contact with moving surfaces, providing lubrication without leaking out under the force of gravity, centrifugal action or being squeezed out under pressure. It should retain its basic properties under shear forces at all temperatures it experiences during use.

4-43. Due to the increasing presence of COTS equipment in military inventory, a wide variety of new lubricating greases are being encountered that are needed to maintain such equipment. Statistics show that nearly 50% of all bearing damage can be attributed to incorrect lubrication. In cold environments, it is critical for unit planners and maintenance managers to know the required greases for all pieces of equipment within the unit's inventory. GAA is no longer the dominant solution to Army grease applications. Operators and maintainers need a deep well-rounded understanding of the technical attributes and application principles of the different greases which they can expect to encounter. Maintainers will need to know the pour point of the base oils within the greases being used to avoid cold stiffening of these greases. They will need to know the next in line alternative grease, and how to transition from one grease to the next. Being armed with such understanding will help Soldiers preserve their equipment in cold environments.

4-44. Greases are typically formulated with three components: base oil, thickener, and additives. Since the base oil can account for more than 90% of the total product, it's important to understand how well each of the most common base oils can withstand extreme temperature environments. What makes a grease effective in cold is its ability to maintain viscosity and flow as temperatures drop. As they get cold, all greases will naturally stiffen and harden to some degree. As a result, the cold reduces and eventually prevents a grease from protecting equipment. Most base oils and grease are able to withstand moderate temperature dips to 32°F (0°C), and many to +15°F (-10°C) without too much of a decrease in performance. At -5°F (-20°C) and below, some lubricants become fully non-functional. There are three temperature characteristics related to grease of which maintainers should be familiar: dropping point, oxidation, and stiffening at low temperatures.

# DROPPING POINT

4-45. Grease dropping point is the upper temperature at which the grease will fail to be of any further use as a lubricant. This is when the gel structure breaks down, and the grease becomes semi-liquid. Once this happens, even after the grease is allowed to cool, it will never fully recover its gel character and its performance will no longer provided the needed lubrication for the equipment. If the grease is made from multiple products (such as both distilled oil and synthetic oil), and the dropping point temperature of just one of the components is reached, the whole grease is likewise ruined.

# OXIDATION

4-46. Normally, with correct application, grease oxidation is a slow ongoing process in grease that shouldn't diminish its usefulness in less than a year. When the grease oxidizes, it usually darkens as acidic oxidation products build-up. These products can have a damaging effect on the grease, causing it to soften, allowing oils to weep or even bleed out of the grease. Once grease has oxidized, it has to be cleaned out and replaced. Grease does not conduct heat easily. Serious oxidation can begin at a hot point and spread slowly through the grease. A heavily oxidized grease usually has a distinct black color and burned odor. This produces carbonization that gets stiffer in composition and leaves a crusty surface formation.

# STIFFENING

4-47. This is the lower temperature where the grease becomes too hard for the bearing, or other greased component, to be of practical use. Stiffened grease can become so viscous that it could be classified as a hard grease, but is no longer useful for its intended use. As a general principle, the base oil's pour point is considered the low-temperature limit of a grease. The base oil of the grease for low-temperature service must be made from oils that can maintaining a low viscosity at the lower temperatures.

# SOLID-FILM LUBRICANTS

4-48. A variety of solid materials with inherent lubricating capability are available for use in solid-film lubricants. The most commonly used are molybdenum disulfide, graphite and polytetrafluoroethylene. Solid lubricants are used primarily as extreme pressure or anti-wear type additives and are applied in one of three ways. The first and most popular application for solid lubricants, particularly molybdenum disulfide and graphite, is as an extreme pressure additive in grease formulations. The plate-like molecular structure of these solid lubricant particles reduces friction by allowing the surfaces in motion to easily slide over each other.

4-49. Molybdenum disulfide generally has the highest load-carrying capability with a corresponding low coefficient of friction. However, in an oxidative atmosphere (air with oxygen) in excess of 750°F (400°C), it begins to decompose.

4-50. Graphite is particularly beneficial where moisture is present. In fact, the presence of moisture is necessary to ensure graphite's full benefit as a friction reducer.

## SECTION V – HYDRAULIC FLUIDS

4-51. There are several hydraulic fluids which a maintenance organization must accommodate to keep their unit's vehicle fleet and weapon systems operational. The Army's pursuit of hydraulic fluids reflects an effort to minimize flammability and corrosiveness. Hydraulic fluids are expressed as three letter symbols used to represent OHT, FRH (fire resistant hydraulic), and OHA hydraulic fluids, which are supply codes that may or may not be acronyms.

**NOTE:** OHT and FRH should not be used in aviation assets.

## SECTION VI – COOLING SYSTEMS AND ANTIFREEZE

4-52. Engines are cooled in two ways: liquid cooled, and air cooled. The objective of a cooling system is to regulate the heat generated within the engine's combustion cylinders. For vehicles, generators and other motor driven equipment going into cold environments, operators and maintenance personnel must take precautions to keep liquid cooling systems from freezing when the engine is not running. In cold conditions liquids and automotive materials can behave and interact in ways which operators and maintainers of limited experience might not expect. If the liquid coolant becomes frozen in the radiator, the engine block, or the hoses conducting the coolant flow, the system might rupture.

4-53. Operators must be vigilant, and check the applicable TM. Once a discrepancy or defect is discovered maintaining a cooling system usually turns to the maintainers. Managing the proper balance between water and antifreeze is important to engine care, regardless of the weather's temperature.

# ANTIFREEZE COOLING SYSTEMS

**NOTE:** The Army is shifting away from Soldier mixed antifreeze, to pre-mixed antifreeze. Always refer to the item specific TM or LO for servicing an item of equipment with antifreeze. The depth of background information presented here is only to help leaders understand underlying principles of antifreeze properties, for decision making in emergency situations.

4-54. Antifreeze is typically added to distilled water in the cooling system of internal-combustion engines so that they can be used below the freezing point of pure distilled water (32°F [0°C]) without freezing. Ethylene glycol is the most widely used automotive cooling-system antifreeze. In automotive windshield-washer fluids, an alcohol (commonly methanol) is usually added to keep the mixture from freezing; it also acts as a solvent to help clean the glass. The brine used in some commercial refrigeration systems is an antifreeze mixture; it is typically a distilled water solution of calcium chloride or propylene glycol.

4-55. The proper antifreeze materials as specified in TB 750-651, *Use of Antifreeze Multi-Engine Type Cleaning Compounds and Test Kit in Engine Cooling Systems,* is critical for cold operations. Engine cooling systems usually use distilled water circulating around the combustion cylinder heads to absorb and carry away heat. Antifreeze serves as a corrosion inhibiter to prevent the distilled water from rusting the engine. In freezing temperatures, it reduces the freeze point of distilled water.

4-56. The over use of ethylene-glycol antifreeze (above 68% of the cooling system's total capacity) reduces the cooling system's effectiveness at removing piston heat from the engine. It is the distilled water in the system that is the foremost means of keeping an engine from overheating while running. Though antifreeze does wick some heat from the engine, it is not as effective as distilled water. On the other hand, antifreeze is instrumental in deterring the corrosive effects of distilled water on metal, as well as keeping distilled water from freezing when the engine is not running.

# ANTIFREEZE COOLANTS

**DANGER**

**Do not drink ethylene glycol based antifreeze.**

**HARMFUL OR FATAL IF SWALLOWED.**

**If swallowed, induce vomiting immediately. Call a physician.**

**Do not store in open or unlabeled containers.**

**CAUTION**

It is essential that antifreeze compounds be kept clean. Use only containers and distilled water that are free from dirt, rust, and oil

**CAUTION**

Antifreeze is a hazardous waste.

4-57. There are three major types of antifreeze that the General Services Administration (GSA) has authorized, and is commonly used by the military. They are specified by A-A-52624, *Commercial Item Description*, *Antifreeze, Multi Engine Type,* and TB 750-651:

- Ethylene-glycol, for mixing with distilled water to make an antifreeze solution.
- Arctic antifreeze solution, premixed with 60% ethylene-glycol.
- Propylene-glycol, for mixing with distilled water to make an antifreeze solution.

4-58. Ethylene-Glycol-Distilled water Mixed Solution is the most common antifreeze agent used for both military and commercial engines. It is used for temperatures of 32°F (0°C) down to -50°F (-45.5°C). To use, mix with distilled water (table 4-1, on page 4-14). Verify antifreeze capability to -50°F (-45.5°C) with a refractometer.

4-59. Arctic Antifreeze Solution is an ethylene-glycol based antifreeze with several additives that are mostly used by the military. It is used for temperatures of -40°F (-40°C) down to -90°F (-68°C). To use, do not dilute; use full strength as packaged. Do not add an antifreeze extender additive with arctic antifreeze.

4-60. Propylene-Glycol-Distilled water Mixed Solution is only used by the military in commercial products under warranty, as prescribed by manufactures instructions. It is used for temperatures of 32°F (0°C) down to -76°F (-60°C). Commercial items that are under warranty are to follow the manufacturer’s recommendations until the warranty has expired. Do not use it in Army vehicles past the warranty period. When switching over to military standard automotive antifreeze, flush the cooling system to remove all of the commercial antifreeze.

4-61. Propylene-Glycol is of a different composition from ethylene-glycol. It is non-toxic. Commercially available propylene glycol-based antifreezes should never be mixed with ethylene glycol-based antifreeze.

4-62. Waste antifreeze contains heavy metals such as lead, cadmium, and chromium in high enough levels to usually make it a regulated hazardous waste. Most states strictly regulate antifreeze disposal. Spent antifreeze should not be dumped on land or discharge it into a sanitary sewer, storm drain, ditch, dry well, or septic system. It can cause serious distilled water quality problems and might harm people, pets, or wildlife. Any type of antifreeze is considered hazardous and should be reused, recycled, or disposed of properly.

4-63. Cooling systems containing deteriorated antifreeze or lacking solution should be drained and flushed, before the onset of freezing temperatures. Soldiers should then add the correct antifreeze solution.

4-64. If premixed antifreeze is not available, use table 4-1 as a guide for mixing concentrated antifreeze. The antifreeze should then be tested with an antifreeze refractometer (figure 4-3). (The actual sight radical's appearance may vary in different refractometers.)

- A 68 percent antifreeze to distilled water ratio provides maximum low temperature protection.
- Use at least 25 percent antifreeze to distilled water ratio to provide protection against rust and corrosion. Army doctrine requires 50 percent antifreeze unless in arctic conditions, where its 60 percent.

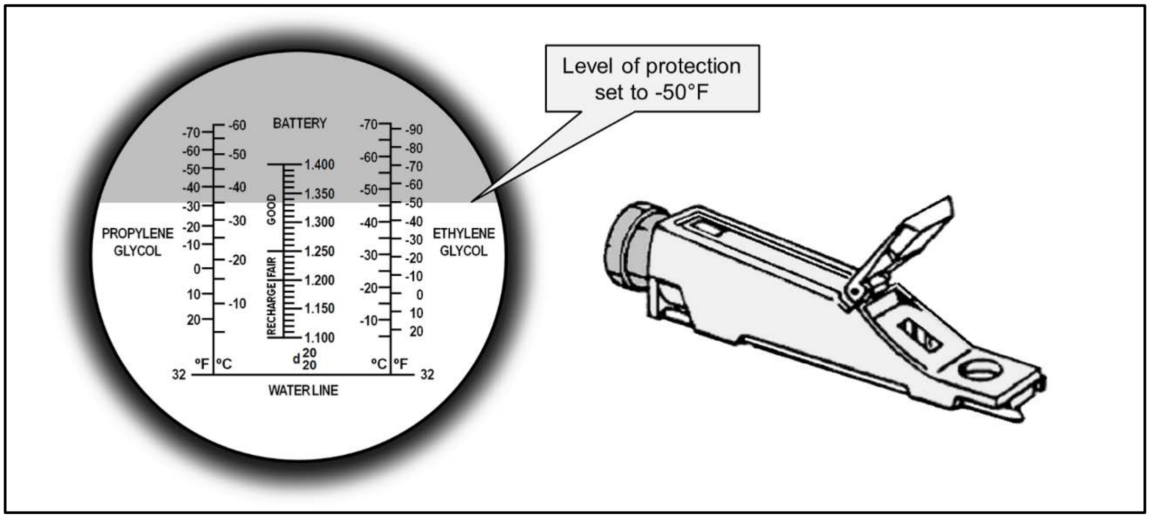


**Figure 4-3. Antifreeze and battery refractometer sight picture and testing device**

4-65. Add the appropriate antifreeze. If filling with Arctic Type Antifreeze, add it as it is without mixing. If using concentrated ethylene-glycol based antifreeze, it must be mixed with distilled water.

- First, identify the total cooling system capacity in quarts from off the vehicle or item of equipment.
- Then go down the left column of the table to locate the number that equates to the vehicle or item's cooling system's total capacity in quarts.
- Scan to the right on the row until reaching the level of how cold the protection must reach.

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**NOTE:** In temperate weather regions, antifreeze protection is primarily needed to protect the engine's metal from rust and corrosion. Distilled water is more efficient at absorbing heat and regulating the cooling of an engine.

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- Look up that column to find the number of quarts of antifreeze will be needed for mixing with the distilled water.

4-66. To fill the engine, first pour in the antifreeze according to the proscribed number of quarts indicated by table 4-1 on page 4-14. The antifreeze should equal 50% to 60% of the cooling system's total capacity. Next add distilled water to fill the remainder of the system.

4-67. When preparing concentrated ethylene-glycol antifreeze for use:

- Do not use without some distilled water.
- Use the refractometer to verify the new level of protection from cold weather.

4-68. All engines with antifreeze must be labeled with a heat resistant sticker or string tag indicating the type of antifreeze, and its level of cold protection. An antifreeze tag should read:

- THE COOLING SYSTEM IS FILLED WITH ETHYLENE-GLYCOL ANTIFREEZE SOLUTION. PROTECTED TO -62°F (-52°C) (or whatever the corrected protection temperature should be); or,
- THIS COOLING SYSTEM IS FILLED WITH ARCTIC-TYPE ANTIFREEZE. PROTECTED TO -90°F (-68°C). CAUTION: DO NOT ADD DISTILLED WATER OR ANY OTHER TYPE OF ANTIFREEZE.

4-69. The equipment's maintenance records should then be annotated with the date that work was completed, the condition of the cooling system and the degree of freeze protection.

**Table 4-1. Concentrated antifreeze protection table mixing guide**

| *Cooling System Capacity in Quarts* | *CONCENTRATED ANTIFREEZE COOLANT REQUIRED IN QUARTS For Protection to Temperature Points (in °F) Shown Below* | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 5 | *-12°F* | *-62°F* | | | | | | | | | | |
| 6 | *0°F* | *-34°F* | | | | | | | | | | |
| 7 | *6°F* | *-17°F* | *-54°F* | | | | | | | | | |
| 8 | *10°F* | *-7°F* | *-34°F* | *-69°F* | | | | | | | | |
| 9 | | *0°F* | *-21°F* | *-50°F* | | | | | | | | |
| 10 | | *4°F* | *-12°F* | *-32°F* | *-62°F* | | | | | | | |
| 11 | | *8°F* | *-6°F* | *-23°F* | *-47°F* | | | | | | | |
| 12 | | *10°F* | *0°F* | *-15°F* | *-34°F* | *-57°F* | | | | | | |
| 13 | | | *3°F* | *-9°F* | *-25°F* | *-45°F* | *-66°F* | | | | | |
| 14 | | | *6°F* | *-5°F* | *-17°F* | *-34°F* | *-54°F* | | | | | |
| 15 | | | *8°F* | *0°F* | *-12°F* | *-26°F* | *-43°F* | *-62°F* | | | | |
| 16 | | | *10°F* | *2°F* | *-7°F* | *-19°F* | *-34°F* | *-54°F* | | | | |
| 17 | | | | *5°F* | *-4°F* | *-14°F* | *-27°F* | *-42°F* | *-58°F* | | | |
| 18 | | | | *7°F* | *0°F* | *-10°F* | *-21°F* | *-34°F* | *-50°F* | *-65°F* | | |
| 19 | | | | *9°F* | *2°F* | *-7°F* | *-16°F* | *-28°F* | *-42°F* | *-56°F* | | |
| 20 | | | | *10°F* | *4°F* | *-3°F* | *-12°F* | *-22°F* | *-34°F* | *-48°F* | *-62°F* | |
| 21 | | | | | *6°F* | *0°F* | *-9°F* | *-17°F* | *-28°F* | *-41°F* | *-54°F* | *-68°F* |
| 22 | | | | | *8°F* | *2°F* | *-6°F* | *-14°F* | *-23°F* | *-34°F* | *-47°F* | *-59°F* |
| 23 | | | | | *9°F* | *4°F* | *-3°F* | *-10°F* | *-19°F* | *-29°F* | *-40°F* | *-52°F* |
| 24 | | | | | *10°F* | *5°F* | *0°F* | *-7°F* | *-15°F* | *-24°F* | *-34°F* | *-46°F* |

# AIR-COOLED ENGINE SYSTEMS

4-70. Since an air cooled system does not use an antifreeze liquid coolant, it is often assumed that air alone acts as the cooling medium. This is not true. The lubrication system also helps in cooling the engine and transmission; it prevents heat buildup from part's movement friction. The cooling process often includes oil pumps that circulate the oil between the engine and the coolers and between the transmission and the cooler, removing heat from the engine and transmission. Some engine cooling also results from the fuel contacting metal parts prior to combustion. The effects of cold on an air-cooled system are basically the same as the effects on the engine with an antifreeze cooled system.

## Chapter 5

# Vehicle Operation

This chapter provides automotive focused considerations for dealing with vehicles or engine driven equipment - before, during, and after - operations PMCS. The primary challenge with vehicles is getting them started. Often, TMs express procedures without explaining the situational considerations or underlying mechanical principles. This manual is intended to supplement the operators' and maintainers' TM for any vehicle or motor driven piece of equipment operating in cold weather.

In cold weather, operators must think beyond a repetition of procedures to have a real understanding of how the cold will affect their vehicles. Operators and maintainers must be able to balance the volume of actual variables affecting equipment and vehicle mechanics. Operators consult their equipment's manuals for operator maintenance, and monitor standards of equipment performance. They report to maintenance personnel if equipment performance cannot be maintained. Where needed, maintainers provide support (field or sustainment maintenance) as specified in the TM and unit policy and operating procedures. Operators and maintainers must work together as a team to keep their vehicles mission ready in the face of threats from cold weather.

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**NOTE:** Maintainers and operators should refer to the item specific TM or LO that are the primary sources for maintenance procedures.

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## SECTION I – VEHICLE STARTING

5-1. Starting a vehicle in cold can present a number of challenges. Unlike temperate weather, drivers must give engines and transmissions ample time to warm up in stages before engaging in normal driving. Ensure proper procedures are followed to safeguard personnel and equipment.

## DIESEL ENGINES

5-2. Diesel engines are particularly difficult to start in cold weather without preheating the intake air. 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:

- Use air manifold heaters when the ambient temperature drops below 32°F (0°C). Employ this device only when the engine is turned over. Switch off the air manifold heater when the engine starts.
- Warm the engine with external heat to preheat the engine.
- If so equipped, operate the engine coolant fuel-fired preheater for the prescribed amount of time before starting.
- Ether cold starts (for temperatures below 32°F [0°C]) is done ONLY while cranking the engine. (Use sparingly since excessive ether can cause piston and ring damage.) Ether is used as an emergency starting aid only if auxiliary power and/or portable heater are unavailable for preheating. Exercise extreme caution and use ether only as a last resort to prevent mission failure. Consult appropriate operator's manual when using emergency starting aids. (Drivers should have prior training in this procedure by a maintenance supervisor before attempting.)

> **CAUTION**
>
> Ether should be injected into engine air intake system only while the engine is being turned over. Otherwise, flashback may occur.

## GASOLINE ENGINES

5-3. For the most part, the Army has discontinued gasoline powered equipment. Still there are some local commands that have acquired gasoline powered COTS equipment (rental vehicles, for example). To successfully start gasoline powered engines in cold weather, ensure the following conditions exist:

- The viscosity of the engine lubricating oil permits cranking without overtaxing the capacity of the starting system. The engine oil must splash and be distributed easily by the oil pump to the various parts and bearings.
- The battery is fully charged and warm enough to supply current to crank the engine and the spark needed for ignition. In cold weather, storage batteries become less efficient and provide much less output. A cold battery alone can become over taxed by trying to energize the starter to turn over the engine at the required cranking speed and also supply the current needed to ignite the spark plugs.
- In cold, fuel is often not volatile enough to supply proper fuel-air mixture to the combustion chamber. It might be necessary to have supplemental battery power.
- The ignition primary and secondary circuits are clean and free of cracks, frost, and moisture to prevent shorts or current leaks.

## ICE CLOGGED AIR FILTERS

5-4. Dust, sand and dirt are commonly the major cause of a clogged filter. In cold weather, water by rain or snow can become another solid particle which obstructs air flow through a filter. Operators must be vigilant if it’s rained or snowed recently while the engine was running followed by freezing weather. In such situations, filters then need to be checked to verify that ice is not imbedded into the fiber of the filter restricting air flow. Likewise, when the engine is at rest, operators may need a tarp to ensure that rain mist or snowflakes have not drifted into filter intakes.

## STARTING PROCEDURES

5-5. Maintenance leaders should plan on a systematic way to start the unit's vehicle fleet in a cold environment. Severe cold weather can leach battery power making supplemental power necessary to start vehicles. Such a system may involve having a warm vehicle on stand-by to slave start other vehicles. It may involve having extra battery jump starters. Added supplies of battery chargers are often necessary to meet the heavy requirements for battery maintenance in below freezing temperatures. If the situation permits, motor pool electrical sockets ought to be used to power preheaters or trickle chargers. In one fashion or another, it is safest and more expeditious to have a startup plan at the unit maintenance level, to support operators during vehicle startup at any time, day or night.

5-6. The storage battery functions are the heart of the electrical system, especially during the starting phase. Pay particular attention to the battery terminals and clamps during cold weather. A loose connection or a small amount of corrosion will add enough resistance to obstruct vehicle starting and reduce performance.

5-7. In extreme-cold (-25°F to -40°F [-32°C to -40°C]) or hazardous-cold (below -40°F [-40°C]), a storage battery that otherwise has viable liquid electrolyte might be too cold to produce enough electrical current to turn over the engine’s starter motor. A current drop that would be modest in warm weather can keep the starter from turning over a cold-soaked engine. Just the battery’s effort to push power into the starter motor could cause the electrolyte to lose specific gravity and freeze. All current vehicle batteries (except lithium batteries) use lead/acid chemical reaction. For operators, when equipment with conventional wet batteries will not start at low temperatures, turn off all starting switches and check for a frozen battery before attempting to slave start or boost charge. Take off all filler caps and visually examine the electrolyte. For GEL (gelatin silicate electrolyte) batteries or AGM (absorbent glass mat) batteries, a battery load tester is needed because their filler caps are not removable.

5-8. If the vehicle's battery is too weak to start the engine, or not able to get the starter motor to engage, auxiliary power will be needed to slave or jump start the vehicle. If the battery cannot engage the starter motor or the electrolyte appears frozen, mark the battery and notify the unit's maintenance section. A qualified battery mechanic must make the determination if the battery is usable.

### WARMUP OF TRANSMISSIONS

5-9. Due to this diversity in way that transmissions are brought up to operational temperature, it is important that operators be very familiar with transmission warmup procedures. In garrison, electric preheaters might be available, but that isn't the case in the field. Operators need to train on the specifics of starting the transmissions even as they need to understand warming and starting their engines and batteries.

5-10. Automatic transmissions warm up differently, depending on the type. Some warm up in park, while others only warm up if the selector lever is in the neutral position; still others must be placed in gear during warm-up. In cold (-25°F [-32°C] and below), many transmissions will not warm up unless placed in gear, allowing the torque converter to pump and preheat the transmission fluid. Forced movement of the vehicle prior to warm-up can cause transmission failure. Always consult the TM for proper transmission warm-up procedures.

**NOTE:** If vehicle is equipped with a transfer having a selector lever, transfer lubricant may be heated the same way by placing selector level in neutral and transmission in low.

5-11. Standard transmissions have been mostly removed from military inventory, but may be occur with COTS equipment. To start a standard transmission, depress the clutch pedal while starting engine with gear shift in neutral. Once the engine is running smoothly, release the clutch cautiously; maintain the engine at idle for two minutes or longer to warm lubricant in the transmission.

## SECTION II – OPERATING VEHICLE ENGINES IN COLD WEATHER

5-12. Vehicles need unique preparation for the harsh conditions and cold weather. Operators must remain vigilant of the special problems cold weather can cause as they begin the operation of the vehicle or equipment. Then at the conclusion of vehicle or equipment use, the process for concluding operations are made longer by the added storage precautions that must be taken to protect the equipment and its readiness from the cold.

**NOTE:** Normalizing an engine is a state of vehicle operation where, in an engineering context, all the component engine features which contribute to its proper function are performing according to their intended design parameters. This means for example, that the water coolant and antifreeze is keeping the engine at the right temperature. It would mean that the battery is ready to power the starter motor and glow-plugs. It means that the lubricants are preventing friction damage. As engines transition through various states (off, start, idling, moving, stopping), electro-mechanical controls act to normalize an engine for optimal performance. This normalizing function is performed by the vehicle, and monitored by the operator. In cold, normalizing takes longer and may require patience until complete before the operator goes to the next event.

5-13. Maintaining vehicle and equipment readiness extends to fully stimulating the movement of all hydraulic fluids, antifreezes, oils or lubricants. In cold weather, power production and full system stimulation have to be incorporated into a unit's regular PMCS maintenance policies. This may involve having vehicles driven for half an hour on a circuit around the instillation or camp. It may involve having engineering equipment engage in an Earth moving exercises. Cranes, wenches, and turrets may have to be system stimulated by two or three repetitions of moving heavy weighted items. A generator or power production equipment can be load tested for thirty minutes to verify its true readiness, while keeping fluids functional.

Different types of equipment will need different plans to keep them mission ready in cold weather situations. It is not enough to turn on an engine and let it idle.

# IDLING

5-14. Engine idling creates a double jeopardy situation. It is done to warm and circulate lubricating oil. Otherwise, if the oil gets too cold it can thicken to the point where it obstructs movement, preventing an engine from starting. However, this is not an efficient way to maintain vehicle readiness. Trying to start a cold-soaked engine risks damage from forcing cold metal parts, which have already contracted to being outside their design tolerances, to move against each other.

5-15. Efficient vehicle maintenance, float-chargers, and winterization kits with engine heaters can help reduce starting problems. Otherwise, vehicles lacking engine heaters with diesel engines may have to be idled to eliminate starting difficulties. At temperatures below -20°F (-29°C), operators may have to start vehicle engines every 2 ½ hours for a minimum of 20 minutes to maintain an acceptable state of readiness. Intervals between engine operations depend upon wind speed and temperature. At temperatures below -25°F (-32°C), it may be necessary to continuously idle engines; especially heavy equipment, tracked vehicles, and heavy trucks.

5-16. Yet at these cold temperatures, a normal idle speed may not produce sufficient generator power for the batteries to overcome the cold resulting in a net battery discharge. To warm engine fluids and recover the battery charge, engines usually need to operate at higher than normal revolutions.

## ENGINE IDLING POLICIES

5-17. The commander and maintenance leaders determine starting and shutdown intervals. Depending on the situation, concealment and noise discipline may have to be sacrificed to maintain readiness of the vehicles. Commanders must consider fuel supplies when considering the authorization of periodic starting of engines. Factors such as ambient or expected temperatures, vehicle condition, and readiness conditions influence scheduling. Also, they must establish starting and shutdown schedules to ensure engines do not run continuously (unless continuous running is what they intend to have happen).

**NOTE:** Vehicle engines might be idled to keep lubricants and antifreeze from freezing, but should not be idled just to operate personnel heaters.

## OPERATOR TASKS

5-18. Battery electrolyte fill levels of a flooded VLA battery, engine oil and coolant levels must be checked daily prior to initial starting of a vehicle or any other engine. To high idle the vehicle, adjust the hand throttle to the engine speed specified in the operator TM until the engine is running smoothly. When engine operation is required for battery recharging or engine warm-up, a high engine idle speed as prescribed in the vehicle TM, must be maintained. Occasional variance of speed for short periods is allowed. Cold batteries (that are not frozen) can take over 20 minutes of engine idling before the alternator can recover energy that the battery lost in trying to start the engine.

5-19. Operators must also consider the following, and coordinate with supervisors on any deviations from unit policy and item specific TM defied procedures:

- Vehicles should only be cold-started using the procedures outlined in the TM. This is particularly important for operating the engine starter and induction manifold (when present). Most equipment publications contain cautions relative to the time of engine starter engagement. However, it is sometimes necessary to exceed the recommended starter time. This is due to the cold-starting characteristics of most internal combustion engines. If a starter time limit is 30 seconds, and engine firing is intermittent during cranking, it may be necessary to briefly extend the starter engagement time; but with caution (consult with supervisors, first).
- Vehicles (especially the engine) should not be allowed to become cold-soaked.
- Engines should be warmed by engine heaters, or be started periodically to keep lubricants warm.
- Batteries must be kept warm and fully charged.

### IDLING LIMITATIONS

5-20. Vehicle engine idling is wasteful and may be hazardous. For drivers, more than any other operator activity, starting and idling require an understanding of cold weather engine operational principles. Idling an engine has detrimental effects on fuel supply, tactical missions, and safety for the following reasons:

- Increases fuel consumption.
- Discharges batteries, when the generator or alternator fails to produce enough surplus energy to run the engine, and to further maintain or restore battery power.
- Causes engine wear and reduces time between engine overhaul periods.
- Causes glow plug or spark plug fouling especially in two stroke cycle engines such as all-terrain vehicles, snowmobiles, outboard motors, and others.
- Causes possible carbon monoxide hazards.
- Endangers concealment and camouflage.
- Potentially causes engine overheating.
- Potentially causes slobber of diesel engines, which is unburned diesel fuel and exhaust that builds up around the exhaust pipe in cold weather during idling. To reduce slobber of diesel engines, increase the idle speed. Otherwise, this condition should clear up after a short period of normal operation at normal operating temperatures.

## OPERATION

**WARNING**

**Operation of the main engine or auxiliary generator engine when a vehicle is stationary exposes the crew to possible carbon monoxide gas poisoning. The possibility is greatly increased when hatch doors are closed. To minimize this hazard, position vehicle wherever possible so that wind will carry fumes away from crew compartment; then turn on turret ventilation blower. Be sure engine compartment bulkhead doors are secured before operating engines. When there is not outside air movement, personnel must dismount for at least 10 minutes each hour (tactical situation permitting).**

5-21. Operators should avoid short trips. Each time a vehicle is started, energy is used out of the battery. This is called a deficit charge where power is drained from the battery faster than the alternator can recharge the battery. At normal temperatures this energy is quickly replaced as the battery is recharged by the vehicle's alternator. However, cold batteries don't charge well. Cold-soaked batteries needs about thirty minutes of driving before the batteries even gets warm enough to fully accept a fresh recharge from the alternator (20 minutes for wet cell, and longer for the other types). While the engine is idling, avoid turning on lights and accessories before the batteries are warmed up. Most vehicles' generators cannot run all the vehicle's lights, radios, heaters, and other accessories while the vehicle is idling without drawing power from the batteries.

5-22. During vehicle operation, adhere to the following guidelines:

- Allow the engine to warm up to the recommend temperature for below freezing operation (thermostats usually open at 165°F [74°C] or 180°F [82°C]).
- Check operation of instruments during warmup, especially the oil pressure gauges and warning lights.
- Take advantage of all methods available to keep the battery at recommended temperature. If the battery is warm enough to accept a charge (above 35°F [1.6°C]), the battery generator indicator should read in the high green immediately after starting.

- Check any unusual noise from the alternator. Fan belts break at a high rate below -50°F. Inspect belts for cracks prior to cold weather operation; replace cracked belts. Adjustable length belts are available for emergency roadside repair for "V" belts. They come in ⅜-, ½-, and ¾-inch widths and require a connector tool to fit to size. Vehicles such as the HMMWV are equipped with serpentine belts, and only another serpentine belt can be used.
- Checking engine oil prior to starting and fill to prescribed level. As soon as the engine starts, check the reading on the oil pressure gauge. Within 30 seconds after starting the engine oil pressure should register on the oil pressure gauge. On vehicles or equipment outfitted with warning lights, wait 30 seconds for the oil light to go off. If after 30 seconds the oil pressure gauge does not register the pressure or the oil warning light stays lit, stop the engine and investigate the engine and determine the cause.
- Engine temperatures usually ranging from 160°F (71°C) to 180°F (82°C) must be maintained for normal operation (figure 5-1). This temperature can be attained by adjusting the air inlet shutters or covers and by having a serviceable thermostat.
- The oil pressure gauge and/or warning light must be observed frequently during operation because of increased equipment failures in cold. Low oil pressure warning lights may blink on and off at 500 rpm to 650 rpm when using OEA-30 or OE/HDO-SCPL lubricant at idle, but they should not stay on at higher rpms.

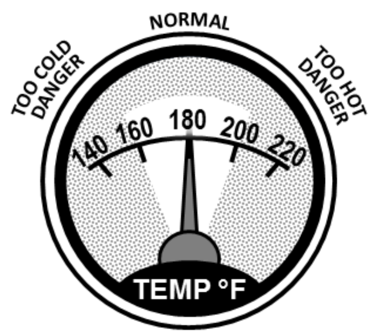


**Figure 5-1. Normal operating temperature**

## ENGINE TEMPERATURE MAINTENANCE

**CAUTION**

An engine that fails to reach normal operating temperature or overheats must be reported to maintenance personnel for correction. Failure to do so may result in serious damage to the engine.

5-23. Cooling systems must be carefully maintained to ensure normal operating temperatures. Temperatures must be monitored throughout vehicle or engine operations. Operate vehicles at normal engine temperatures as indicated in operator's TM. Efforts to regulate engine temperatures can involve both chemical and mechanical solutions:

- Antifreeze.
- Lubrication.
- Heaters.
- Winterfronts or radiator shutters.

5-24. By using engine compartment air inlet shutters or radiator covers to limit the cold from reaching the engine, temperatures can be maintained. To minimize cold weather effects on engine oil performance, operators should avoid operating vehicles until the engine has reached normal operating temperatures. It might be helpful to cover radiators that keep an engine cool. For tractors and generators with exposed engine blocks, shielding can be installed to keep engine heat contained in a compartment.

5-25. Low engine operating temperature results in excessive fuel consumption, dilution of engine oil by unburned fuel, and formation of sludge from condensation of water in cylinders and crankcase. Operators need to constantly check the engine's operating temperature. A cooling system with an appropriate mix of antifreeze should allow the engine to reach 160°F (71°C) to 180°F (82°C) no matter how cold it is outside.

### VEHICLES EQUIPPED WITH RADIOS

5-26. When radios in radio-equipped vehicles are in use, keep the engine operating at approximately 1,200rpm. This helps maintain a satisfactory battery charge. If this procedure is not followed, batteries will fail rapidly.

5-27. When starting radio-equipped vehicles, operators must protect the radios. Ensure that the power amplifier switch is in the OFF position, or that the radio function switch is in the OFF or STANDBY position when starting (figure 5-2).

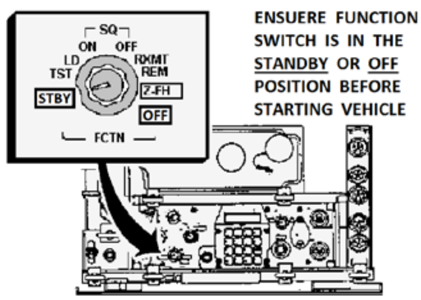


**Figure 5-2. Protect radios when starting vehicles**

## VEHICLE DRIVING SAFETY

5-28. A licensed operator must be present in the driver's compartment whenever the main and/or auxiliary engine is being operated. However being licensed is only the beginning. Verification of vehicle operators' competency to handle driving in the cold environment is important (TC 21-305-20, *Manual for the Wheeled Vehicle Driver*), and may require additional training. Novice drivers need to understand that extreme-cold reduces traction. Even on dry surfaces, cold alters the performance of tire and tread rubber, as well as the hydraulics of suspension systems. Drivers should not take the driving feel of their vehicle for granted since the cold usually degrades the responsiveness of the steering and breaking controls against driving surfaces.

5-29. Driving on snow, ice, slush or frozen mud is very different than driving in rain or loose mud. Many novice drivers have little idea how differently a large vehicle handles from their personal vehicle, given the same cold weather driving conditions. Drivers should be taught by road practice to:

- Clear condensation from brake lines and know how to test to ensure break function before operation. This procedure may require the use of electric or forced-air heaters.
- Recognize the different braking systems and driving characteristics for: direct cable, power assist, positive pressure pneumatic, negative pressure, and engine compression breaking.
- Never mix positive pressure or negative pressure towing vehicles to trailers with the opposite type braking system.
- Use of alcohol based windshield deicer on side mirrors.
- Install tire-chains in slushy road conditions.
- Manage tire pressure when driving on snow. (It is not effective to reduce tire pressure with radial tires.)
- Use the engine brake (found on some large trucks) to decelerate on ice or black-ice. (Wheel brakes are prone to locking-up, resulting in an out of control skid.)

- Reduce speed well before corners, and take cornering very slowly.
- Brake well in advance of the desired stop point, and creep up to the actual stop point.
- Use low gear or first gear to accelerate uphill from being stopped on an inclined road or slope.
- Down-shift into low gear whenever driving up hill or downhill.
- When towing, trailers and weapon systems, to compensate for wide swings during turns and winding roads.
- Recognize vehicle deficiencies that might expose personnel to carbon monoxide poisoning.

## CONVOY OPERATIONS

**DANGER**

**Drivers: never sleep in a vehicle with the engine running.**

**AR 385-10, para 11-4, k, (3) prohibits sleeping in a parked vehicle with the engine or heater running.**

**DANGER**

**Do not open-burn combustible fuel, propane, paper, or wood in an enclosed cab to stay warm.**

**WARNING**

**Personnel must be constantly on the alert to detect vehicle deficiencies that expose personnel to carbon monoxide poisoning. Passenger and crew compartments of wheeled and tracked carriers must be inspected and tested at regular intervals.**

**AR 385-10, para 11-4, k, (4) requires an annual carbon monoxide test for all vehicles that have engine access panels separating the engine compartment from the crew area.**

**WARNING**

**Do not run the engine of a stationary vehicle when snow pileup prevents open ventilation of the exhaust system. There is the danger of carbon monoxide backing up into the crew compartment.**

5-30. Convoy leaders have to accept that convoys take longer to line-up, and convoy speeds need to be 30% to 40% slower than the normal speeds they might travel at in more temperate weather conditions. It is common for ice to form at the bottom of dips in the road or on bridges. Areas subjected to shading from tree cover or hidden by terrain from the sun will ground freeze, concealing road ice, while the rest of the road might have normal traction. This means that as vehicles transit a road in cold weather, they will encounter intermittent black ice patches. At otherwise normal high speeds the drivers will find vehicle handling to be very inconsistent and very hard to control. For those vehicles dragging trailers, the sudden loss of traction can escalate into a jackknife before the driver can recognize what is happening.

5-31. In the event that a vehicle becomes immobilized, Soldiers need to be ready to remain with the vehicle for an extended period. Move survival gear into the crew compartment; at once. Vehicles should always have a complete issue of component end items, basic issue items, and additional authorization list items. Furthermore, vehicles should have an emergency stranded-kit. There should be at least a gallon (or four liters) of water per person. In regions prone to blizzards where a vehicle might become covered with snow, having a ten to fifteen foot pole with a blinking light or strobe can help search and recovery teams to find stranded snow-covered vehicle crews.

### FROZEN WATER CROSSING HAZARDS

5-32. When crossing frozen streams or other bodies of water, open cab doors to permit quick escape of personnel in case vehicle should break through the ice.

**NOTE:** Do not cross deep water obstacles covered with ice without checking with supporting engineer units for safe crossing ice thickness.

## AFTER OPERATION

5-33. Shutting down a vehicle in cold can have unexpected results. In principle, when preparing a vehicle for shutdown, place transmission and transfer shift levers in the neutral (not the park) position. This prepares the vehicle for the next start by preventing the gears from freezing in an engaged position. Wheel or tread chalks should always be used when parking a vehicle set in neutral gear. Maintenance leaders should alert operators and their supervisors when to initiate or cease cold weather parking precautions.

5-34. During each after operation PMCS in cold weather, special attention to inspecting and servicing the system as follows:

- Inspect oil pan, valve covers, gaskets, and any external units of the lubrication system for leaks; correct deficiencies or report them to maintenance mechanics. During periods of cold, it is not uncommon to observe leaks from various seals on hydraulic systems and oil filled components upon start-up. After the component reaches normal operating temperature and the seal becomes soft and flexible, these leaks should stop. Reporting leaking components before allowing sufficient time for the seal to warm up causes an undue burden on the maintenance system and unnecessary seal replacement.
- Check engine oil and fill to prescribed level. Oil consumption may be higher when using OEA-30 or OE/HDO-SCPL. Engines may run out of oil before the next maintenance check. Check frequently.
- Check the radiator after shutdown to determine coolant level. If the coolant level is low, add antifreeze to return radiator to full level.
- At the end of each operating period, for about five minutes prior to shutdown, normalize the vehicle engine to allow a coating of cooled oil to be retained on the cylinder walls and pistons. This prevents damage at the time of restarting. It can be accomplished by lowering the engine revolution to the prescribed high idling speed (see item TM) and by maintaining it for about five minutes. This procedure is extremely important to preventing engine damage and is called for in many TMs.
- Servicing the fuel tank at the end of the day’s activities will also help keep water out of the fuel, as filling the tank drives out any moisture-laden air. Avoid having a partially filled tank stand overnight or during a long halt.

## SECTION III – COMPONENT AND AUXILIARY EQUIPMENT

5-35. Auxiliary equipment cannot be overlooked in preparing for cold weather operations. Failure of these items can also lead to mission failure. In preparation for cold weather, the TM care of auxiliary equipment should be performed by operators under the oversight of maintenance managers using a transition plan.

5-36. In temperate weather environments, it is not uncommon for operators to let worn out or decomposed grease and lubricants accumulate on the working parts of auxiliary equipment. Where possible before going into the cold, auxiliary equipment should be detached from the vehicle, wiped-off, dried-out, and cleaned of old, contaminated, or oxidized lubricants. While decupled, the item should be inspected by maintenance personnel. Three critical concerns of inspection are: seals, hydraulic lines, and wire cables.

# POWERTRAIN

5-37. In severe conditions, specific procedures must be followed to safeguard a vehicle's powertrain; as different from the engine. Following these procedures will ensure smooth operations.

5-38. The driver must be extremely careful when placing the vehicle in motion when gear case lubricants or wheel bearing greases are congealed and tires are frozen to the ground. Trying to operate under these conditions damages powertrain components, such as clutch facings, universal joints, or gear teeth. When placing the vehicle in motion, put transmission in low gear and transfer unit in low range. Drive the vehicle about 100 meters, being careful not to stall the engine, then upshift. Continue slowly in the higher gears until the vehicle moves freely and the tire thumping ceases.

5-39. For convoy operations, this means that drivers should try to exercise their vehicles during the half hour before convoy serials begin their line-up. Maintenance leaders should try to establish a short vehicle exercise track or route just outside the motor pool or around the base perimeter. At the completion of the 150 to 200 meter vehicle exercise track, operators under supervision should perform a during operation check before exiting the area. As needed, a forced air jet heater should be on stand-by to heat frozen brakes or pneumatic lines. Special attention based on cold weather effects should be payed to:

- Engine temperature.
- Transmission shifting.
- Braking systems.
- Pneumatic lines, and air compressor systems.
- Fluid levels.
- Heating equipment.
- Tire pressure and tire chains.
- Lights and safety equipment.
- Trailer connections, electrical, and braking.
- Electronics and communications systems.

# PERSONNEL HEATERS

**CAUTION**

Petroleum fed heaters can reach temperatures of 300°F (149°C).

5-40. As cold weather approaches, operators should take measures to prepare their vehicles heaters for the cold. The primary threat to a heaters operation is a dust buildup. Maintenance personnel should instruct operators in how to remove heater ducts to access the heater fan. Once exposed, operators can clean the inside of the heater, heater fan, heating radiators, and heating ducts.

5-41. Three stage heaters (standard in light vehicles) which use antifreeze to pass heat through heating radiators will lose their capacity to provide enough heat to warm crews as the temperatures drop below -40°F (-40°C).

5-42. Most severe cold petroleum fed heaters (common to armored vehicles, or which may be a part of the winterization kit) use two stage heater systems. To avoid carbon buildup or heater flooding, allow heaters to purge during shut down for at least five minutes before turning off the master switch (see the TM for details). This usually involves three steps: turn off the heater switch, wait until the unit working light goes out, then turn off the battery switch.

5-43. Before the onset of cold weather, petroleum fed heaters should be removed from the vehicles and have their fuel burning cylinders cleaned. If the cylinder is not cleaned, the creosote buildup will harden, interfere with heat radiation, and could erupt into a runaway fire that might destroy the heater unit.

# AUXILIARY ENGINES AND GENERATORS

5-44. The auxiliary engine and generator are operated when:

- Supporting communications and electronics equipment.
- Other types of auxiliary equipment is being used.
- The main engine is not running.
- Batteries are being charged.
- The current furnished by the main engine is inadequate for the imposed load.

5-45. The auxiliary engine, generator, spark plugs, and magneto should be prepared in a manner similar to the main engine and components. Carefully warm the engine block with the duct from a portable heater, to assist in starting. Many small engines have a summer/winter air intake diverter which allows warm air to be pulled over the exhaust in winter and directly from the outside in summer. If the engine is so equipped, ensure the diverter is set for winter operation.

**NOTE:** Some small engines have a low oil pressure shutoff switch to stop the engine in case of low oil pressure. The oil in the engine block must be warmed sufficiently so the cranking rpm can build up enough oil pressure to close the switch so the engine will start.

# AIR COMPRESSORS

5-46. An air compressor is an engine-driven device used to compress air to predetermined and controlled pressures. It is used in vehicle air-brake, air-hydraulic brake, and central tire inflation systems. Condensed moisture may freeze within the compressor.

5-47. Follow after-operation maintenance procedures by draining condensation from air compressor tanks. If the bleed valve is frozen, report it immediately to maintenance personnel. Some 900 series vehicles (M911/977), the new FMTV (2½-ton and 5-ton trucks), Palletized Load System vehicle and the Heavy Equipment Transport System trucks use air driers in the air brake system. The system must be checked for frozen vapors in the drip tube.

5-48. Alcohol evaporators, usually found near the air compressors of cargo trucks and semitrailers, should be filled with alcohol during operations in temperatures of -20°F (-29°C) and below. These evaporators are usually plastic bottles of alcohol included in winterization kits. They are designed to draw water out of the air going into the compressor to prevent freezing. Check the container as a part of the before, during, and after operations.

5-49. Air Compressors either have their own lubricating system (self-lubricated) or are lubricated from the engine lubrication system. No further preparation is necessary for the engine-lubricated, air-cooled compressor, provided the engine crankcase has been filled with lubrication oil (OE/HDO-SCPL or OEA-30).

**NOTE:** If an oil-bath-type air cleaner is used on a compressor, drain the oil, clean, and fill to proper level with a winter grade oil.

5-50. The cooling system of liquid-cooled air compressors is connected to the cooling system of the vehicle engine. Drain, flush, and clean the compressor cooling system and inspect for leaks. Ensure all connections are in good condition. Tighten cylinder head bolts to correct torque tightness specified in the vehicle TM. The engine coolant system must be adequately protected with antifreeze compound. Inspect the compress for leaks.

5-51. To ensure air compressors function properly, operators must:

- Check to see if the compressor is maintaining required pressure.

- Examine that there are no coolant or oil leaks.
- Listen for excessive noise.
- Examine air compressor to ensure that it is in good condition, properly aligned with drive pulleys, and securely mounted.
- Equipment using air dryers must also be checked for frozen vapors in the drip tube.
- Ensure that all water, oil, and air lines in the engine compartment are in good condition and securely fastened, and that there are no leaks.
- Check oil in self-lubricated air compressors to determine proper condition and level.
- Check alcohol evaporators.

# POWER TAKEOFF ASSEMBLIES

5-52. A power takeoff (PTO) uses hydraulic lines or a drive shaft to power auxiliary equipment affixed to a vehicle. The PTO and control linkage should be checked to ensure they are in good condition, securely mounted, and that seals are not leaking. PTO connection assemblies are usually visible on the side of the transmission with a hydraulic pump mounted inside the transmission. Sometimes, they are mounted on the side of a transfer case. They provide a means for taking power from the engine to drive accessories or auxiliary equipment that may be attached to a vehicle. PTO driven auxiliary equipment includes: wenches, cranes, air compressors, hydraulic pumps, trench diggers, earth boring machines. When not attached to a device, PTOs usually have a protective cover or cap.

5-53. In freezing temperatures, ensure that the PTO uses the proper lubricant, keeping it filled to the proper level. Since the PTO is operated from the transmission or transfer case, the lubricant should be that specified for cold temperatures. Drain the gear cases while the weather is still warm and fill with prescribed grade of cold weather gear lubricant. In cold weather, improper lubricants will solidify, making operation of the power takeoff difficult or impossible.

5-54. Use the TM to inventory all component parts. See that the transmission and/or breather and ventilation openings and lines are clear. Tighten all mounting bolts, power takeoff assembly screws, and bolts to the torque tightness specified in the TM.

## SECTION IV – RECOVERY EQUIPMENT

5-55. Vehicle recovery in cold, snowy conditions can be extremely dangerous. Every precaution must be taken to maintain Soldier safety and ensure equipment is functioning properly. Exercise care when towing cold-soaked vehicles. Drive trains may have to be disconnected to prevent further damage.

5-56. For any cold weather recovery operation where a recovery vehicle has to use more than half (50%) of its rated capability or capacity, a second recovery vehicle should be sent to reinforce the operation. Cold temperatures reduce the tensile strength of cables. It also thickens the hydraulic fluid’s viscosity in recovery cranes offering greater resistance to motion. Recovery in mountainous, snowy or icy terrain may not allow a single recovery vehicle to achieve good leverage. Vehicle recovery is often extremely difficult due to reduced mechanical capacity, ice, snow, and limited approach routes. The hardest recoveries will occur in wet-cold situations where vehicles have sunk into softening mud, and the recovery vehicle has to cross treacherous soft mud to reach the immobilized vehicle.

# WINCH OPERATION

**CAUTION:**

When using the winch, operate the vehicle engine at a reasonable speed as specified in the operator’s manual. High engine speeds risk damaging the winch mechanism.

5-57. Read all caution plates and estimate a 25% reduction in capacity when determining load. EXAMPLE: If capacity of the winch is specified as 5,000 pounds on "Winch Caution Plate," lower the rated capacity for cold weather operations to 3,750 pounds. This safety factor is essential to prevent damage to the winch.

5-58. Use a snatch block or pulley whenever possible to reduce the load on the winch.

5-59. In preparing a winch for operation, the following steps should be taken:

- Remove mud, dirt, and rust from exterior of winch.
- Inspect cable for rust and apply lubricating oil, general purpose, preservative (military symbol, PL-S).
- Flush and clean gear housing, and fill to level with recommended seasonal gear oil (military symbol, GO-75).
- Inspect safety brake for satisfactory operation.
- Check drum brake and adjust if necessary.
- Check for iced bleeder and selector valves, controls and linkage, and winch cable sheaves.

## OUTRIGGER STABILITY

5-60. Many vehicles with cranes have outriggers to provide added stability. However, on an iced over surface, wheels and outriggers might not be sufficient to keep a vehicle from side-slipping as the crane lifts and rotates while moving heavy items.

5-61. Before the onset of freezing cold, vehicle supervisors and maintenance managers should inspect that each vehicle has a planned minimum number of tire chains (with elastic or rubber chain tighteners) and outrigger traction pads (local unit fabricated) with cleating for hard ice operations. This should be supported by line supervisors who provide battle-drill training of crews on how to dawn vehicle chains and traction devises rapidly and safely under field conditions. In wet-cold weather, recovery vehicles with outriggers will need to carry reinforced pallets (local unit fabricated) that can disburse vehicle weight and prevent outrigger shoes from drilling into the mud.

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# Chapter 6

# Small Arms

Caring for small arms in the cold is different than normal care in temperate weather. From the maintenance perspective, the effects of cold on weapons are similar to vehicles, but not the same. Vehicles produce a consistent and steady stress on the system, once started. On the other hand, weapons produce a very intense intermittent stress on the equipment at the time of discharge, with sudden heating and shock force, followed by a cool off.

**NOTE:** The procedures in this section are general for small arms, and not specific to any particular weapon. Maintainers and operators should refer to the item specific TM that is the primary source for maintenance procedures.

## SECTION I –COLD WEATHER CARE AND MAINTENANCE

6-1. Cold weather situations will force operators of small arms to adjust the way they employ their weapons. It will have a carry-over effect on the Soldier's tactics. For example, combat operations on frozen tundra will have very different tactical considerations from mountain warfare. For the maintenance mission, these challenges are related to the:

- Susceptibility to cold of the materials which the weapons are made.
- The different type terrain upon which the weapon is operating.
- Physical fitness of the Soldiers encountering the cold.
- Interference in weapon use caused by other adaptations (such as winter clothing [ergonomics]).
- Limitations due to reduced mobility.

6-2. The greatest risk to a weapon is that of the cold effects on the metal itself. Rifle barrels are tempered to increase strength and resist warping under high heat and pressures. However, when tempered metal is exposed to freezing temperatures it can become brittle. The sudden increases in heat and pressure during discharge can stress the metal and create abnormally fast wear, or even small stress fractures. This is especially true of weapons fired in full automatic mode. The use of weapon lubricants follows approximately the same principles as vehicle lubricants. At about +5°F (-15°C), operators and maintainers should transition to cold lubricants. Unit armorers should carry plenty of spare parts, especially those most prone to failure (firing pins, extractors, feed pawls, and so forth), and need to have a constant supply of server cold lubricants.

**NOTE:** Re-zero weapons when deploying from a temperate to a cold environment. Cold temperatures may cause a decrease in the burning rate of propellants, which can significantly change projectile trajectories. Re-zero with cold ammunition. Decreased burn rates will invalidate the previous zero of the weapon.

## SECTION II –LUBRICATION IN COLD WEATHER

6-3. DOD small arms multipurpose lubricant specifications require products to have cleaning, lubrication, and preservation properties. (DOD tests lubricants from a minimum flash point of 150°F [65.5°C], to a maximum pour point of -75°F [-59.5°C].) The lubrication challenge for cold runs in two directions that almost contradict each other. Lubricants are helpful in mitigating the seizure of moving parts, until they get so cold that the lubricant itself binds the weapon. Lubricants are designed to endure extreme heat, resisting break down during the fast and repetitive cycling of automatic firearms. Yet few are capable of retaining their viscosity when exposed to below freezing temperatures. In freezing weather, lubricants becoming gummy, and begin to harden. As temperatures fall, some lubricants can even begin to freeze, rendering them almost as hard as epoxy. It is the responsibility of weapon operators to know at what temperature their lubricants will fail, ceasing to function; and what are the alternatives.

# COLD WEATHER APPLICATION

**CAUTION**

Do not use graphite on weapons. It accelerates galvanic corrosion on alloys, and aluminum to steel (or iron) parts as they move against each other.

**CAUTION**

Under cold conditions [less than -10°F (-23°C)], a small amount of CLP or LSA remaining on moving parts can prevent weapon from firing. Ensure that all CLP or LSA is thoroughly removed from weapon, and apply LAW prior to cold operations.

6-4. Units should plan on converting from Cleaner Lubricant Preservative (CLP) or Lubricant, Small Arms (LSA) to Lubricant Arctic Weight (LAW) once temperatures routinely falls below +5°F (-15°C) (figure 6-1 6-2 and 6-3). CLP is fluid to -65°F (-54°C), however at -10°F (-23°C) it thickens enough to affect a weapon's automatic cycling. Under cold conditions, even a small amount of CLP or LSA on moving parts can prevent some weapons from firing. Planning for the transition of lubricants for cold weather operations should be communicated throughout the unit. Yet, operators must be mindful that various weapons will have different lubrication requirements as temperatures drop. The exact temperature for any specific weapon's transition to cold weather lubricants will differ (figures 6-2 and 6-3).

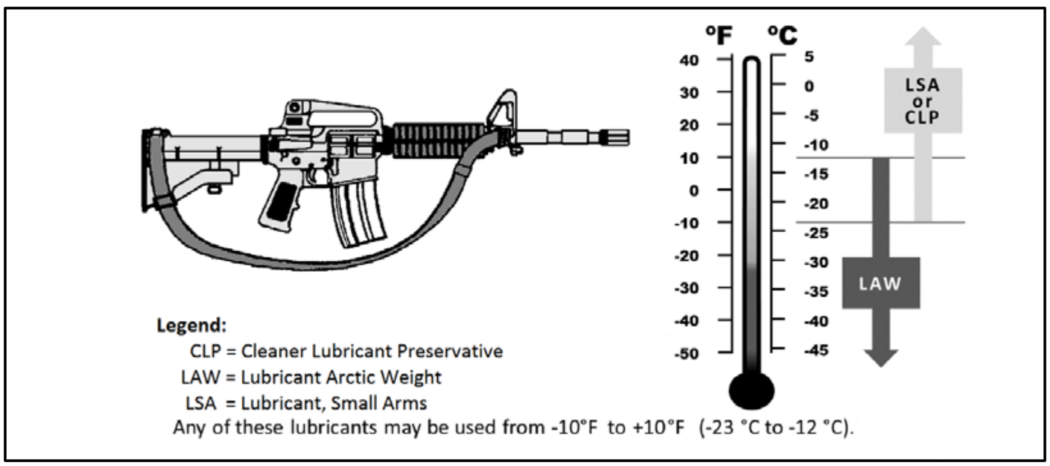


**Figure 6-1. Common weapon lubrication use in cold**

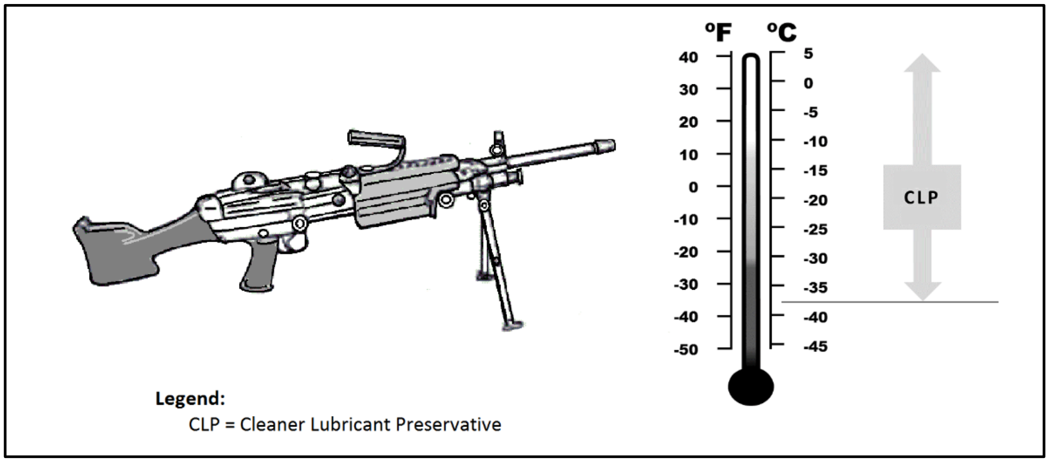


**Figure 6-2. Alternative lubrication plan for weapon use in cold**

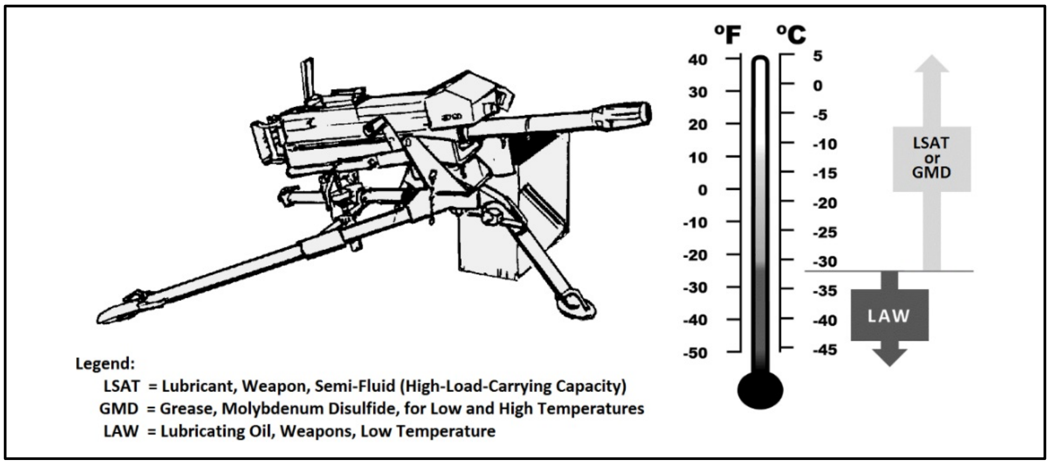


**Figure 6-3. Alternative lubrication plans for various weapons**

6-5. Exposed metal surfaces require more frequent applications of smaller amounts of lubrication in order to remain fully functional in dry-cold air. Whatever is used to lubricate a weapon in cold weather situations, it should be used sparingly.

**NOTE:** LSA and Rifle Bore Cleaner (RBC) are intended for use, together. Never use RBC alone; it's a cleaner (not a lubricant or solvent) whose residue provides no lubricating affect. RBC is designed to remove carbon buildup without stripping away the soaked-in oil, in the way that SD-2 does. However, RBC decomposes CLP and LAW, and they do not work together.

6-6. Before applying LAW, ensure all CLP or LSA is thoroughly removed from a weapon, preferably by using an SD-2 solvent. LAW has Teflon and synthetic additives that can be negatively affected by mixing them with other lubricants.

6-7. Apply a light coat of LAW to all functional parts. Soldiers should not use CLP, LSA, preservative lubricants, special lubricating oils, automotive oils, grease (distilled petroleum or synthetic based), or RBC (unless specified by the TM) in difficult operational cold situations.

6-8. When the weapon is brought inside a warm place, keeping the weapon dry is the first priority. It should be disassembled and wiped dry several times as it warms to room temperature. The alternative is to secure the weapon in an air tight anti-condensation container while it warms up.

6-9. Cleaning and lubrication should be accomplished inside a warm room and the weapon should be at room temperature, if possible. Weapons under storage should be cleaned and lubricated at least once every 90 days.

- Apply a light coat of LAW to all functional parts.
- Always work to keep a weapon dry. When moving a cold weapon into a warm place, condensation (moisture) will form in and on your weapon. If possible, leave your weapon in a protected but cold area outside.
- To minimize the condensation of moisture and freezing, keep the weapon covered when moving from a warm to a cold area to allow gradual cooling. Use fabric not plastic covers.
- Outside, unload and hand function the weapon every 30 minutes to help prevent freezing of functional parts.
- Do not lay a warm weapon directly in snow or ice.
- Keep the insides of magazines and your ammo wiped dry. Moisture will freeze and cause malfunctions.
- Do not lubricate ammunition.
- The use of the muzzle cap, protective magazine bag, and an overall weapon cover to help protect a weapon. Use them whenever the tactical situation permits.

# SNOW AND ICE

6-10. Snow and ice on ammunition can obstruct cyclic action of automatic weapons increasing the chances of a misfire. Ice in a weapon can foul a weapon just as surely as a heavy carbon buildup. Worse, the snow or ice on ammunition can obstruct a bolt from seating, resulting in a backfire. Regularly check magazines and ammo-belts that they are free of introducing snow and ice into a weapon. Keep muzzles covered, ejector ports closed, and do not lay weapons down on the ground.

6-11. Do not lay a warm weapon directly in snow or ice. Automatic weapons with gas pistons must keep their cylinder vents or gas regulators clear of moisture or water that could freeze and stall the cyclic action.

6-12. Blowing snow tends to get into working parts, sights, barrels, magazines, and ammunition, especially when moving in deep snow under combat conditions. The use of the muzzle cap, protective magazine bag, and an overall weapon cover will help protect your weapon. Use them whenever the tactical situation permits, but remove them prior to firing.

6-13. Unload and hand function the weapon every 30 minutes, or so, to help prevent freezing of functional parts. (Be careful to not drop ammunition rounds into the snow.)

# FUNCTIONING DIFFICULTIES

6-14. Cold adversely affects the functioning of small arms. Care must be taken to correctly identify the problem and apply an appropriate corrective action.

## SLUGGISHNESS

6-15. A common weapons problem in cold weather is sluggish operation. Normal lubricants thicken at low temperatures, causing stopped or sluggish action of firearms. During the winter weapons must be stripped completely and cleaned with an SD-2 to remove all lubricants and rust prevention compounds. Below +10°F (-12°C), LAW helps moving parts to slide better than CLP or LSA. LAW provides proper lubrication during the winter and help minimize freezing of snow and ice on the weapons. Be sure and select the correct lubricant and to clean off all regular gun oils before applying the stipulated cold weather lubricant. Avoid allowing different lubricants to become mixed on the surface of a weapon

## METAL BREAKAGES AND MALFUNCTIONS

6-16. Another problem that Soldiers face in cold is a higher rate of breakage and malfunctions. This can be attributed primarily to the cold, although snow in weapons can also cause stoppages and malfunctions. The hardened metal parts of automatic weapons are more brittle than soft metal in cold temperatures. When the weapon is fired at below freezing temperatures, parts will at first micro-fracture and then suddenly break within the initial burst of fire. When posable, weapons should first be fired at a slow rate (short bursts) of fire to provide gradual warming of the weapon. Short bursts provide a less stressful uniform expansion of the weapon's metals. Once the parts have warmed up, the rate of fire may be increased to a normal cyclic rate.

### PLASTICS AND RESIN

6-17. Sudden changes in temperature can cause plastic parts to crack. Wrapping the weapon in a blanket or poncho before bringing it from a cold to a warm area helps warm it gradually.

## SECTION III – OPERATOR USE OF SMALL ARMS

6-18. In the field, weapons operators will find that the precautions used in temperate climates to keep weapons functioning are different than those of cold weather actions. Metals and plastics become brittle and more easily break. Ice from breathing on the weapon can seize bolt movement. Cold ammunition seems to have lost its reach.

## ARMORER PREPARATIONS

6-19. Maintainers and operators can expect that in cold, parts subjected to high stress from rapid variations in temperature, and shock will break or become unserviceable more rapidly. It will be important to identify weapon parts that in one form or another are vulnerable to cold and have extra parts in reserve.

## ADAPTATION TO THE COLD

6-20. Weapon stabilization on snow or ice covered ground is a challenge for crew served weapons. Maintenance managers and weapon systems experts need to plan field expedient methods to keep weapons stable and employable. Where possible good ideas should be tested under live fire field conditions to validate the solution. The desired solution should try to:

- Stay away from altering how the weapon engages the enemy.
- Keep weight to a minimum.
- Avoid additional fuel or heating cost.
- Protect moving components and very hot parts of the weapon from snow and ice.
- Seek command approval for deviations from procedures in doctrine or TMs.
- Be an asset to the safety of Soldiers and protection of materials.
- Be producible with tools from within the unit.

## AMMUNITION

6-21. Cold weather does affect the performance of small arms ammunition, artillery rounds, and rockets. The general considerations are:

- Cold air is denser than temperate weather air. This creates greater drag, reducing range.
- Severe cold slows down chemical reaction processes, reducing the propulsion energy of a round exiting a tube, or the pressure of flame exiting a nozzle.
- Unpacked munitions moving from cold to warm areas are subject to the same condensation threat as weapons. Munitions usually cannot be lubricated to protect them from moisture corrosion.

6-22. Resupply in cold climates is also difficult, especially the resupply of heavy, bulky ammunition. All Soldiers must practice ammunition economy and fire discipline to reduce resupply requirements. Ammunition should be kept at the same temperature as the weapon and should be carried in bandoleers. Loaded clips, magazines, or single rounds dropped into the snow are often lost. Careful handling of ammunition is essential. Additional ammunition should be protected in the pockets of the parka or rucksack.

6-23. For as long as possible, store ammunition in original containers. Try to keep storage containers raised off the ground and covered with tarpaulins, ponchos, salvage tents, or any other material that affords protection from the snow. Storage location of ammunition on the ground should be marked with poles to assist with relocating it if the storage containers become snow-covered.

6-24. Ammunition, clips, and magazines must be cleaned of all oil and preservative and must be frequently checked. Remove all snow, ice and condensation. The most common cause for malfunction and weapon stoppage is ice and snow on the ammunition. Ammunition is prone to dragging snow and ice into a weapon. Once it is removed from its packaging, it should be regularly checked to ensure it is free of ice and snow. Keep cartridge containers, magazines, and ammunition drums closed to prevent the formation of rust or ice.

# PISTOLS

6-25. Cold weather can make a pistol's metal brittle, creating difficulties that arise to include damage to moving parts. Malfunctions can be caused by snow or ice-plugged magazines.

6-26. Firing a pistol while wearing arctic mittens increases the likelihood of the weapon being dropped. The shock of the weapon hitting the ground is more likely to result in damage because of the metal's weakened state. Also, having a weapon fall into snow or mud can introduce a large quantity of ice or snow to the pistols inner workings.

# RIFLES

6-27. Malfunctions and breakages of rifles may be caused by snow or ice-plugged magazines. Apply LAW to prevent bipods, movable sights and other working components to keep them from freezing in position.

# MACHINE GUNS

6-28. Machine gunners should strive to be very selective and accurate in target engagement. There are two reasons. A sudden long hard burst of fire from a cold weapon will cause rapid uneven metal expansion in the weapon. Such expansion will stress fracture it, crack it, and may cause the casehardened metals to break. Likewise in calm winds, the propellant will generate moisture amongst the smoke that will freeze into suspended ice crystals, betraying their position. Furthermore, considering the complexities of resupply in cold environments, gunners need to be very conservative about ammunition consumption during engagements.

6-29. One common malfunction that occurs early in firing is short recoil (bolt does not recoil fully to the rear). The prescribed immediate action for the particular weapon should be applied. As the metal warms, the problem will diminish.

6-30. A second type of malfunction is caused by the freezing and hardening of buffers. This in turn causes great shock and rapid recoil, thereby increasing the cyclic rate. When this happens, parts usually break.

6-31. All internal parts and friction surfaces of machine guns should be coated with LAW, when not prohibited by the TM. If lubricants for below freezing temperatures are not available then the next best option is to fire the weapon cold and dry. The use of temperate weather lubricants runs the risk of it gumming up or freezing hard. A dry weapon has fewer misfires and malfunctions than a weapon with the wrong lubricant. Firing should consist of short, two or three-round bursts fired at close intervals.

6-32. After changing barrels, if the hot barrel is laid directly on snow or ice, it may warp or disappear in deep snow. Gunners or their assistant should carry a piece of wood with side ridges (to prevent the barrel from rolling out) to keep a hot or spare barrel off the snow. This helps keep barrels from warping or becoming lost in the snow.

# FROZEN FOG

6-33. Blowing snow and ice fog inhibit Soldiers' abilities to acquire and engage targets with small arms. Also, weapons fire creates a shroud of ice fog that can hang over the weapon position, not only blocking the gunner's vision, but revealing the position to enemy gunners.

6-34. In cold, all weapons create a frozen fog, ice crystals that become suspended in the air just in front of the weapon. Water is the byproduct of spent propellant. If the wind is moving, this will have little effect on the shooter’s ability to engage targets. However if the wind is calm, it will hover in the air obstructing the shooter’s visibility. Worse yet, the puffs of floating ice crystals betray the shooter’s location. Where a rifle will create a puff of frozen fog, a machine gun will create a very annoying cloud. Since ice fog greatly impairs the gunner’s vision along his line of sight, crews must prepared to change the firing positions during combat engagements. Crews should prepare at least two firing positions covering the same sector, and be proficient at displacing to maintain concealment.

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# Chapter 7

# Weapons, Munitions, and Fire Control Equipment

Large crew served weapons system experience a variety of maintenance problems in the cold that reflect a mixture of being like small arms mixed with characteristics of vehicles. Large weapon system can be uniquely challenging to keep mission ready.

**NOTE:** Maintainers and operators should refer to the item specific TM that is the primary source for maintenance procedures.

## SECTION I –EFFECTS OF COLD WEATHER

7-1. All large weapons systems have both unique system vulnerabilities and common concerns in the cold. This section provides a general overview of the issues that most commonly affect all large weapon systems.

## WEAPONS FUNCTIONING

7-2. Just as with small arms, cold can adversely affect the more robust crew served fire support weapons. Special care and procedures must be followed to keep them functioning properly, affecting all levels from the operator to maintenance facilities. The following problems or conditions affect the operation of direct fire and fire support weapons:

- The increased viscosity of hydraulic or recoil fluids, caused by lower temperatures, offers greater resistance to motion. This results in stiffness of operation and shortening of the recoil cycle.
- Over-lubricating in cold weather may cause parts to bind, resulting in misfires.
- Handwheels on both elevating and traversing mechanisms require greater effort.
- Gascheck pads in the breach of a weapon fail to seal perfectly and deteriorate rapidly. Scoring of the gascheck seat is possible.
- Cable insulation, if not arctic type, may fail when doubled or straightened.
- Frozen hand brakes on towed weapons may be difficult to release, and attempts to move weapons without thawing may cause serious damage.
- Equalizing bars and travel locks of towed weapons must be covered or wrapped before towing over snow-covered terrain. The wrapping should be replaced, if wet, to prevent freezing of both the wrapper and the protected mechanism.
- In cross-country operations, a prime mover with the same tread/track width as the weapon should be used to ensure tracking. (Towed weapons not tracking in the wheel furrows of the tractor vehicle will jump from side to side, making it hard to control driving.)
- Firing lanyards must be kept dry and covered to prevent freezing and breakage.
- Cold air is denser than warm air, creating more resistance to a projectile passing through it, and more force pushing the projectile off course in a crosswind.
- Ice fog forms when the weapon is fired.

## CLIMATIC CONDITIONS

7-3. Severe conditions can interfere with the proper functioning of weapons, ammunition, and fire control equipment. Knowledge of these effects can minimize their impact on mission accomplishment.

7-4. Depending on the type of ammunition, there may be an increased need for ammunition in cold weather. This is because cold temperatures adversely affect firing, responsive, effectiveness, and accuracy. Also, it is often necessary to fire several light-to medium-zone rounds prior to maximum propellant charges to avoid stressing the hydraulic recoil mechanisms of mortars, cannons, or howitzers. Support units must be prepared to handle and transport the added volume of ammunition. Severe cold conditions also make it more difficult to prepare ammunition storage areas.

## OPERATIONAL CONSIDERATIONS

7-5. In cold environments, Soldiers will not be able to freely carry cold-soaked weapons and optics in and out of heated buildings and shelters. Doing such will cause a condensation buildup, followed by water freezing that can lock down the weapon's action, or blind the optics with ice crystals.

7-6. Leadership will need a plan to manage weapon serviceability as Soldiers move between the cold and heated environments. If it is determined that weapons are to be kept outside in the cold, Soldiers will need weapon security policies and procedures.

## COLD-DRY CONDITIONS

7-7. Cold-dry weather causes sluggish motion and increased stress on moving parts lubricated by products manufactured for temperate climates. Rubberized parts and surfaces, as well as painted surfaces, are more likely to crack and break.

## TRANSPORTING

7-8. Vehicle operators must exercise extra care in covering weapon systems and ammunition before movement. Wind pressure of a moving vehicle will force water into the smallest spaces and crevices of cargo. Truck-beds need to have a complete set of suspension hoops and tarps. Towed weapons should be covered by fitted tarps and coverings which protect gears, springs, recoil slides, and any moving components from rain and snow.

7-9. Where weapons are to be mounted on open turrets, fitted covers can help to keep the weapons from becoming clogged with ice. The advantage of a fitted cover has to be its ability to be quickly removed for immediate action against threats.

## FROZEN SURFACES

7-10. Frozen ground alters the relationship between any weapon system and its ground placement. Firing of flat trajectory weapons, such as tank guns, may cause the vehicle chassis to move away from the direction of fire on frozen surfaces (back sliding). Emplacement of stabilizing ground cleats for crew served weapons, such as mortar baseplates and howitzer spades becomes increasingly difficult and time-consuming. The inability of frozen ground to absorb the shock of weapons firing from frozen surfaces can damage the systems themselves and degrade accuracy.

7-11. Most crew-served combat weapons need a natural base or gun platform to fire accurately. In warm weather, the ground provides a solid base and yet has enough resiliency to act as a shock absorber. If the weapon is emplaced on solid, frozen ground, there is no "give" that cushions the recoil or holds the weapon in place. Ether, all the shock of firing ends up being absorbed by the weapon itself, resulting in damage. Or, the hard slippery surface of the frozen ground allows the weapon to slide out of registration from its aiming points.

7-12. Maintenance personnel will need to be prepared for operators to call on them to fabricate a means for stabilizing weapons systems. These ad hoc devices will have to be safe for the user, and mitigate the effects that cold will have upon weapon performance.

7-13. Weapons mounted on vehicle platforms are ideal candidates for supplemental heating systems. In particular, electrical engine oil or battery heating pads can be used to keep the oil in recoil mechanisms fluid.

### SNOW AND ICE

7-14. Exposed gears and racks (that is, elevating arc, traversing rack, and pinions) can collect snow and ice in sufficient amounts to impede movement. Snow and ice can also contaminate lubricants and ammunition creating a gunky paste that obstructs the movement of gears or moving parts.

7-15. Operators need to be prepared for such challenges by keeping their weapons covered. The barrels of weapons should have covers. Tarps are ideal for weapons and other equipment that are susceptible to corrosion or fluid contamination.

### MAGNETIC CONDITIONS

7-16. The farther north one travels, the more care one must take with magnetic instruments. These instruments are affected by increasing declination changes and by Aurora Borealis. Maintainers should be conscious that some equipment misbehavior for magnetically sensitive items is not due to breakage, but the proximity to the magnetic poles.

## FREEING A SEAZED WEAPON

7-17. There are three major methods for freeing weapons and their firing platforms: non-toxic antifreeze spray, direct heat, and SD-2. First, always determine if the weapon is loaded, and if so take appropriate precautions. It is important for the maintainer to next identify whether the mechanism is jammed due to part failure, ice obstruction, or solidified lubricant. Never force a jammed mechanism to move.

### DE-ICING WITH PROPYLENE-GLYCOL

7-18. For the de-icing of helicopters and aircraft, a non-toxic propylene-glycol water mixed solution is used. The military also uses this chemical as an antifreeze in commercial products under warranty, as prescribed by manufactures instructions. Undiluted, it is used for temperatures of 370°F (188°C) down to -60°F (-51°C). Though non-toxic, it still must be used with a containment system to capture the used liquid, so that it cannot seep into the ground and water table. Propylene-glycol based antifreezes shall not be mixed with ethylene-glycol based antifreeze, or any other lubricant. Propylene-glycol based antifreezes are very seldom used in Army ground vehicles.

### DE-ICING WITH HEAT

7-19. For ice obstructed gear mechanisms, direct heat is used to free frozen brake pads and clear moving parts. Heaters that are used to defrost immobilized gears and parts includes: space heaters, forced air heaters, propane heaters, and ducted air heaters (two stage heating). Care must be exercised to not fast heat or spot heat parts to temperatures above 90°F (32°C) because this may burn plastics, scorch parts or carbonize lubricants. As a field expedient solution, a tarp can be draped over a weapon system, and the hot exhaust from a large vehicle can be funneled under the tarp to warm the equipment. An exhaust pipe flexible hose extension will need to be obtained in advance.

### SOLIDIFIED LUBRICANT REMOVAL

7-20. If the lubricant (oil or grease) in a weapon system has frozen or solidified, the lubricant has to be dissolved, removed, and replaced. The weapon will need to be warmed to above freezing, and a penetrating oil will have to be applied to loosen the hardened lubricant. This will take some time for the penetrating oil to take effect. Once a hardened lubricant is loose, it is corrupted and has to be removed. Removal of hardened lubricants requires the use of SD-2, followed by replacement of the correct cold weather lubricant in very moderate amounts. Although this procedure is most common to large weapon systems, it also applies to vehicles and small arms.

## PROCEDURES FOR LUBRICATING WEAPONS

> **CAUTION**
>
> Extreme care must be taken to ensure that moisture, snow, ice, and dirt are not introduced into weapon system mechanisms during the changeover process.

7-21. It is imperative to keep machined surfaces clean and not over-lubricated. Lack of lubrication may cause rust to form on uncoated surfaces and create friction between rubbing surfaces. These conditions impede the functioning of the weapon. On the other hand, use of too much lubricant may impede the motion of the components or result in a buildup of gummy oil or solidified grease.

7-22. The proper type and grade of lubricant must be used. Certain lubricants are selected for different temperature ranges because the physical properties of oils and greases vary with changing temperatures, usually becoming thick and viscous as the temperature drops. Thus, a lubricant designed for use at room temperature may become thick and unsatisfactory at below freezing temperatures, or may become too thin to lubricate metal surfaces at high temperatures. Lubricants can also be selected because they are environmentally preferable.

7-23. Field maintenance facilities winterize artillery weapons. Prior to issue, recoil mechanisms must be modified to ensure satisfactory operations to -65°F (-54°C). Often, preparation of artillery requires special winterization of component parts. Follow instructions in LOs and TMs with the following changes in emphasis. Usually, such preparations can consist of the following:

- Lubricants must be applied in smaller quantities more frequently. For example, a biweekly interval may need to be changed to a weekly reapplication.
- Wide temperature range (WTR) grease is recommended for use on artillery at all temperature ranges. Use WTR whenever special lubricating grease is specified. It displays superior lubricating qualities at extremely low temperatures.
- Petroleum-based hydraulic fluid, (OHT) or “fire resistant, rust inhibited, hydraulic fluid” (FRH), as specified, should be used in hydraulic gears as well as in hydro-spring and hydro-pneumatic recoil mechanisms. These products replace special-recoil and light-recoil oil for low-temperature operation. The changeover to petroleum-based hydraulic oil in recoil mechanisms is accomplished as follows.
  - Drain existing recoil oil. Raise, lower, and rotate the mechanism to aid in removing the original oil.
  - Fill recoil mechanism with OHT or FRH as specified. Establish oil reserve and install mechanisms on carriage or mount.

7-24. Replace preservative lubricating oil, bore cleaner, or normal lubricating oil with CLP in cold temperatures. The exception is in the bores of mortars where copper remover and LAW may be used. To put a temporary finish on corroded exterior metal surfaces, use solid film lubricant, except on moving parts and stocks. Always refer to the specific equipment TM for lubricants and cleaners that are for use in the bore of any weapon.

7-25. Follow all federal, state, and local laws and regulations and unit operating procedures regarding the storage, transportation, and final disposition of all greases, oils, and solvents. Spills of such materials must be promptly cleaned up and reported via the chain of command according to the unit’s spill-plan.

# SECTION II –HOWITZER, MORTAR, AND DIRECT FIRE WEAPONS

7-26. Large bore weapons are characterized by their need to be ground stabilized, and recoil recovery mechanisms the keep them aimed at targets which the operators can’t see. From the operator perspective, tanks and self-propelled artillery cannon are fairly well protected from the cold, aside from condensation related issues. It is towed mortar and cannon, or open vehicle mounted gun systems that require added vigilance to remain operational. From the maintainer's position, these are all very complex machines with a large number of vulnerabilities to the cold.

# COMMON CONCERNS

> **CAUTION**
>
> Under cold conditions [less than -10°F (-23°C)], a small amount of CLP or LSA remaining on moving parts can prevent weapon from firing. Ensure that all CLP or LSA is thoroughly removed from weapon, and apply LAW prior to cold operations.

7-27. Most of the problems and precautions involving operations and maintenance of artillery pieces are the same as for weapons in general. However, consider the following aspects of artillery operations in cold regions:

- Recoil oil indicators may show low readings when pieces are cold. Firing a few rounds warms the oil and raises the indicator level.
- Artillery tube bores require more frequent cleaning at low temperatures as a result of the greater residue left behind from the diminished burning of propellant charges. However, bore cleaner can freeze in the chamber and prevent loading a round. CLP is an authorized alternative to bore cleaner, and is effective down to -10°F (-23°C). Below that temperature, LAW is preferred.
- Special care is required for gascheck pads. A dry cloth is enough to clean the gascheck pad and electrical ring mechanism.
- Adjustable recoil respirators should be left open as far as possible before firing the first round in cold weather. Respirators should be kept clear of ice and snow.
- Congealed lubricants and grit hinder movement of elevation and traversing handwheels.
- Some towed weapons, use year-round lubricants, even in cold weather.
- Only the ammunition required immediately should be prepared for firing to prevent snow and ice from contributing to set propellants.
- On frozen surfaces, stability and accuracy diminish at lower firing elevations.
- The choices for firing surfaces should be shallow muskeg (or bog), gravel, and frozen ground, and ice, in that order. Even with cushioning, firing from ice is one of the greatest causes of damage to artillery pieces in cold regions. Waste lubricants on trails and spades in snow and ice can prevent freezing to the ground. So can laying tree boughs or straw under trails and spades. Such cushions can also be placed under firing jacks and firing platforms.
- Crews wearing the bulky cold region uniform, especially handwear, must practice drills and maintenance to gain proficiency in cold weather cannoneering.

7-28. Cold weather not only affects personnel and equipment but ammunition as well. Failure to understand the possible problems and how to prevent them can make a unit combat-ineffective. The burning rates of various types of propellant charges are reduced by the cold. When cold-soaked ammunition is fired from a weapon that was zeroed under temperate conditions, the zero or targeting registration will change. Weapons that will be used in cold temperatures should be zeroed or registered in similar conditions.

7-29. Cold weather can materially affect the accuracy of weapons and the performance of ammunition. Weapons that are fired from warmed turrets should be loaded with similarly warmed ammunition. Weapons that are fired from the cold of ambient temperatures should be loaded with ammunition that is likewise cold. The ammunition should be kept as the same temperature as the weapon. Additional ammunition stored in its shipping containers, covered and stored off the ground. Otherwise, as much as possible, ammunition should remain in its protective containers, boxes, or cans.

7-30. While cold, dry conditions do not drastically alter the terminal effects of direct fire weapons, deep snow-covered surfaces tend to diminish the blast effects of artillery and mortar rounds with point detonating fuses. The total effect is that range and burst effects drop off dramatically, necessitating added tactical training in adjusting fire, and operational planning for crews of indirect systems.

7-31. At the firing point, condensation on a round which freezes in the breech may lead to a misfire. Icing can cause misfires, damage to the pieces, and injuries to crewmembers. Misfire procedures employed in temperature climates for a round stuck in a howitzer must be modified in cold regions. Pouring a solution high in antifreeze down the tube may be effective in forcing out a stuck round. Another technique involves the use of hydraulic fluid, which does not freeze during the process and acts like a penetrating oil to dislodge the stuck round.

**NOTE:** The use of antifreeze or hydraulic fluid to unstick a live round obstruction must be supported by command policy or have the commander's approval.

## Breech and Firing Mechanisms

7-32. A frozen breechblock (figure 7-1) usually cannot be forced to move. If ice prevents opening or closing the breech, use a portable heater for thawing. Remove the breechblock and dry it thoroughly. Otherwise, keep the breech mechanism tightly covered.

**CAUTION**

Do not use dry-cleaning solvent, mineral spirits paint thinner, or rifle-bore cleaner on gascheck pad. Simply wipe it clean and permit it to dry; do not lubricate.

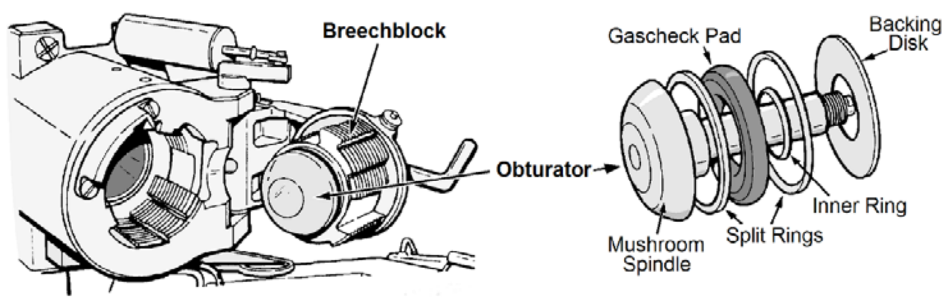


**Figure 7-1. Cannon breechblock and obturator mechanism**

7-33. Clean all parts daily, except gascheck pads, with dry-cleaning solvent or mineral spirits (MIL-PRF-680, *Degreasing Solvent*) or lubricate as prescribed in the TM.

7-34. Frozen manual and electric firing linkages render a weapon useless. Frozen solenoids do not close contacts for electric firing.

7-35. After firing, the breech and firing mechanisms of weapons using fixed and semifixed ammunition should be disassembled, cleaned with dry-cleaning solvent or mineral spirits, dried and oiled sparingly. Mechanisms on weapons using separate loading ammunition should be disassembled. All parts (except gascheck pad and electrical ring mechanisms) should be cleaned with RBC, dried, and oiled sparingly.

7-36. The asbestos covering of Gerdom-type gascheck pads becomes very brittle in cold. If the asbestos has cracked and the wire mesh is exposed, it causes the gascheck seat to become scored and impossible to repair. A new pad is required if wire is exposed.

7-37. The breech and firing mechanisms must be completely disassembled for cleaning and lubrication. Clean all parts, and apply a light film of LAW, by wiping the surfaces with a clean cloth that has been wet with oil and thoroughly wrung out. Excessive lubrication of the firing mechanism can cause misfires.

## RECOIL MECHANISMS

**WARNING**

**The possibility of injury to personnel or damage to materiel is present when adjusting gas pressure in the recuperator. Therefore, adjusting the gas pressure in the recuperator is a function of Field Maintenance and Sustainment Maintenance support. The person in charge of the unit is responsible for having the gas pressure in the recuperator adjusted to correspond with the existing temperature conditions.**

**CAUTION**

Extreme caution must be exercised to keep the parts of a respirator free of snow and ice.

7-38. All hydro-pneumatic and hydro-spring recoil mechanisms should be filled with hydraulic fluid, OHT or FRH as specified. Keep close check on length of recoil during cold weather firing. Take precautions to prevent snow, water, or dirt from entering the reservoir. Hydro-pneumatic mechanisms are affected by reduction of gas pressure at low temperatures, as well as thickening of recoil oil.

7-39. Care of recoil mechanisms is nearly the same during cold weather as it is under normal conditions. Using units must maintain a careful check on recoil mechanisms. On self-propelled guns, the recoil fluid surrounds the gun tube and is subject to a larger range of temperature changes and subsequent pressure variations. These pressure changes must be watched and adjustments made to keep within the required pressure range.

7-40. While the oil is cold, the cycle of recoil may take longer than usual. As further firing is conducted, the action gradually warms the recoil oil and thins it so that normal cycle time is obtained. A sticking recoil mechanism may result in severe damage to the weapon when it is fired; therefore:

- Exercise the recoil mechanism frequently. Intervals of exercise depend on the existing temperature, becoming more frequent as the temperature decreases.
- To ensure that recoil parts are free from frost binding, exercise the recoil mechanism prior to firing whenever the weapon is subjected to freezing rain, windblown snow and ice, or fluctuating temperatures.
- Refer to pertinent weapon TMs for methods of exercising the recoil mechanism.

7-41. If the recoil mechanism is equipped with an adjustable respirator, it should be opened as far as possible when commencing fire in low temperature.

7-42. Check the oil level of the recoil mechanism at the intervals prescribed in the applicable TM and whenever there is a marked change in temperature. Inspect all partially filled hydraulic fluid containers to avoid the possibility of using contaminated fluid. Discard all contaminated fluid.

## RECOIL SLIDES

7-43. Friction between recoil slides and guides absorbs an appreciable amount of recoil energy. Thickened or congealed lubricants increase friction, shorten recoil, and retard counterrecoil. Snow and condensation on the slides contaminate the lubricant and destroy its lubricating properties. To ensure proper recoil and counterrecoil action, remove the old lubricant from the slides every day by using SD-2 (or as a last resort, mineral spirits paint thinner). Smooth all surfaces and lubricate lightly.

7-44. When exposed to windblown snow and ice, dry operation of the recoil slides and other exposed metal working surfaces may be necessary. Lubrication, however, should be applied during standby periods. Guns treated with dry lubricants need only be kept clean and free of ice and snow.

## EQUILIBRATORS

7-45. Equilibrators (figure 7-2) can be found on machine guns and cannons when the majority of weight is forward of the elevation pivot point. Equilibrators can be made of pull-springs, push-pistons, or wound-springs used to act as a counter balance mechanism.

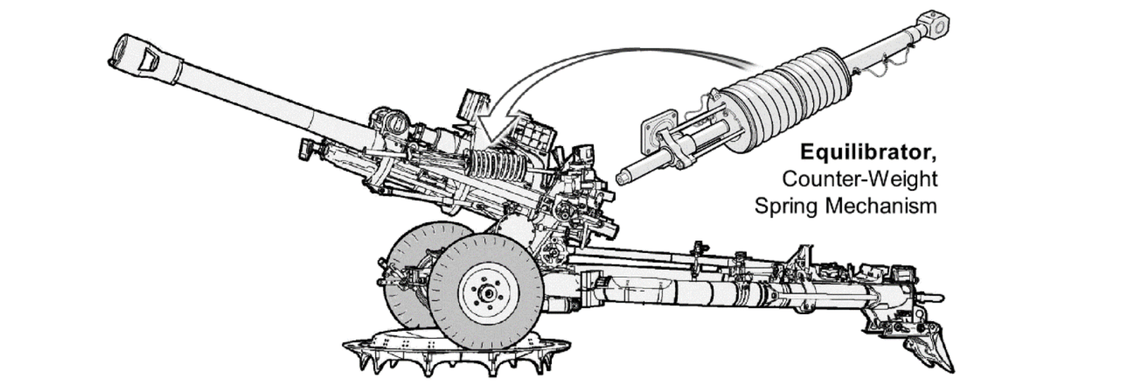


**Figure 7-2. Equilibrator**

7-46. Clean, dry, and lightly lubricate the piston rods or tubes of equilibrators every day during cold weather operations to prevent icing. Carefully examine and remove any corrosion or marring of the smooth, unpainted surfaces with crocus cloth.

**CAUTION**

The some howitzers use nitrogen to pressurize the equilibrators. Since temperatures fluctuate, equilibrator pressures require frequent checks (see operator's TM). If a cold howitzer is brought into a warm shelter, pressures will increase dramatically, and if the elevation handwheel is then released, the howitzer will elevate rapidly, possibly causing injury to the user and damage to the equipment or the building.

7-47. Lubricate the designated equilibrator parts with Winter Temperature Range (WTR) lubricant at the intervals prescribed in the LOs and the TMs. Too much lubricant at cold temperatures may cause the gun to stay out of battery after firing. This is compounded if the pressure in the equilibrators has not been adjusted for cold temperatures. Wash the bearing thoroughly with dry-cleaning solvent or mineral spirits paint thinner, dry thoroughly, and lubricate. It is necessary to remove the equilibrator in order to wash bearings properly.

7-48. After the daily cleaning and drying of the equilibrator piston rod or tube, protect the smooth unpainted surfaces against corrosion by applying a very light film of LAW. Wipe the metal surfaces with a clean cloth that has been wet with oil and thoroughly wrung out.

7-49. Adjust the nitrogen pressure of pneumatic-type equilibrators to provide proper equalizing action. If the equilibrator is equipped with a low-temperature control, make the adjustment according to the temperature scale provided.

## DAILY CARE

7-50. Inspect a weapon system, daily. Whenever possible, use gun covers and shelters for protection. The following points are important in providing maximum protection for weapons.

- Keep all parts thoroughly clean.
- Clean and oil the breech mechanism daily.
- Lubricate sparingly.
- Do not let snow and ice collect on moving parts.

**CAUTION**

Never use graphite on an aluminum-receiver weapon. The graphite reacts chemically with aluminum and will ruin the weapon.

## WEAPON BORES

7-51. In severely cold weather, bores are susceptible to increased impact loads and may crack due to metal brittleness. Constant inspection and care is required to prevent failure. Never take it for granted that the weapon is rugged and mechanically sound. Micro-fractures are an ever-present concern of all tank, mortar, and artillery crews. Mortars and cannons incur micro-fractures every time the tube is fired. It is when those micro-fractures merge into visible fractures that the tube becomes a threat to the crew. It is the job of the ordnance weapons inspectors to determine if a mortar or cannon has reached the end of its useful service life, and must be retired.

### Daily Care

7-52. In below-freezing temperatures, wipe the bore dry every day and apply a light film of LAW. Exposed metal surfaces require more frequent applications of smaller amounts of lubrication in order to remain fully functional in the cold-dry air. Whatever is used to lubricate a weapon in cold weather situations, it should be used sparingly. LSA and RBC are intended for use, together. Never use RBC alone; its residue has no lubricating or anticorrosive affect. The advantage of RBC is that it is mild enough that it doesn't extract the oil that has socked into the micro-fractures the way SD-2 would, which affords some protection from rusting caused by humidity.

7-53. Before applying LAW, ensure all CLP or LSA is thoroughly removed from a weapon. LAW has Teflon and synthetic additives that are degraded when mixed other lubricants. Clean weapons with SD-2 during the change over from one lubricant to another. Do not use SD-2 on rubber, plastic, or sealed buffers. Apply a light coat of LAW to all functional parts. Soldiers should not use CLP, LSA, preservative lubricants, special lubricating oils, automotive oils, grease (petroleum or synthetic based), or RBC (unless specified by the TM) in difficult operational cold situations. Do not use SD-2, and then leave a weapon to sit without some fresh lubrication.

### Before Firing

7-54. Before firing, wipe the bore and chamber dry. Clean and coat bore evacuator, muzzle brake, blast deflector, and counterweight as prescribed in the TM.

### During Firing

7-55. At every opportunity during firing, inspect the muzzle end of the tube, bore evacuator, muzzle brake, blast deflector, counterweight (as applicable), and the breech ring. Examine for the development of cracks.

7-56. In cold, metal becomes brittle and more susceptible to failure under impact loads that a weapon receives when fired. Cracks generally indicate materiel deficiencies or metal fatigue. However, tool marks may be mistaken for cracks, and some cracks are not always visible. Cease firing when cracks develop; notify Field Maintenance or Sustainment Maintenance support.

## After Firing

7-57. Due to the colder temperatures burnt artillery and mortar propellants are apt to cool and collate more rapidly into carbon or creosote buildup. Be sure to wipe dry and lubricate with TM approved lubricant after each cleaning. When RBC is to be used, ensure it is used to thoroughly clean the cannon bore after firing and for two consecutive days thereafter.

7-58. CLP can be used as a cold weather bore cleaner and preservative down to -10°F (-23°C). Below that temperature, LAW is preferred. If it is not available, clean the bore evacuator, muzzle brake, bore, and chamber with rifle-bore cleaner while the weapon is still warm, but not too hot to be touched with bare hands. For temperatures below -20°F (-29°C), warm the solvent cleaning compound before using so that it is thin enough to use effectively. All cleaner residue must be wiped off. Any residue remaining in the tube will freeze and make firing dangerous. Complete the second and third cleaning of the bore and chamber after firing, as prescribed for mild and moderate conditions in the pertinent LOs and TMs.

## CRADLE, SLEIGH, CARRIAGE, AND MOUNT

7-59. Disassemble the mechanism as required by unit policy to obtain access to all parts. Thoroughly clean all parts, ensuring that all rust, dirt, and old lubricant are removed before applying prescribed lubricant. Lubricate sparingly as prescribed in LOs and TMs.

## EXERCISING WEAPONS

7-60. Weapons should be elevated and traversed at regular intervals that ensure operation when the weapon is needed. The rammer should be cycled several times before ramming rounds and at intervals to ensure proper operation. Although recoil mechanisms can be moved only a short distance under below freezing temperatures, always exercise the recoil mechanism before firing to make sure recoil parts are not iced up.

7-61. Snow and ice particles frequently collect on the arcs and pinions and cake under pressure of the gears. Since this interferes with elevating and traversing, remove the snow by brushing vigorously with a stiff bristle or wire brush. After snow is removed, the parts should be left dry for firing or swabbed with a light application of LAW to permit smooth and easy operation and prevent rusting.

## USE OF COVERS

7-62. Whenever materiel is to remain idle for a time, it should be covered for protection. Wind will drive snow under the covers unless snugly and securely fastened.

7-63. Prevent tents, tarps, or other types of fabric materiel from freezing to the ground. Make a footing of planks, brush, or matting. Straw or hay may also be used for this purpose. Pedestals, rails, outriggers, skids, generating units, and points of tripods that go into the ground can be covered with grease to prevent them from freezing to the ground. Seal exposed openings to ensure that parts are free of ice or snow. Keep the ends of canvas tarpaulins off the ground to prevent them from freezing to the ground.

## TRAVEL

7-64. Before starting a road march, make a thorough inspection and provide as much protection as possible for all parts, as follows:

- Ensure all covers are properly installed and securely lashed. If covers are inadequate, improvise by using canvas, burlap, or any other suitable or available material.
- Perform all preventive maintenance operations and precautions prescribed in manuals pertinent to the materiel.
- During travel, take more than usual driving care because suspension assemblies become stiff in cold weather and break easily.
- Wheeled vehicles and trailer systems must have chains available.

### EMPLACEMENT

7-65. The selection and preparation of weapon sites in ice and snow requires more consideration than when a weapon is to be emplaced on bare, level ground. If ice and snow are melting, select a site that will not become mired or flooded.

7-66. Prepare a platform of pierced steel planking (materiel used for improvised airstrips), boards, brush, and matting at the spot chosen for the emplacement. Push or tow the weapon onto the platform so that the platform is beneath the wheels and firing jack float (or auxiliary firing jack platform). Prepare recoil pits and spade positions. When an artillery piece is to be fired from a soft, spongy, surface, a deeper recoil pit must be dug to prepare for the sinking of the weapon during firing.

7-67. Coat all metal parts of the trails and spades coming in contact with snow or frozen ground with waste lubricant. This prevents freezing in place and facilitates subsequent shifting of the trails or baseplates. Waste lubricants may be used on any parts, except rubber, that touch the ground.

7-68. Special, large frost-spades or spade attachments may be improvised to suit local conditions. In hard, frozen ground, protect trails against the tendency to buckle and break by placing logs between the spades and ground. This provides added resilience.

7-69. The firing jack and its locking lug may become covered with ice and frozen mud in transit. Ice and mud must be entirely removed before the jack can be completely lowered and locked in firing position. Swab the exterior of the jack with grease, molybdenum disulfide (GMD) and see that all seals are tight and serviceable.

**CAUTION**

Do not pack grease in the jack housing.

7-70. Aiming posts should not be driven into frozen ground. A hole should first be made with a pick or crowbar. A 1½ inch screw-auger bit mounted to a two or three foot metal bar, topped with a T-bar, can be used to drill a nine to twelve inch whole for planting aiming posts into frozen ground. Ground supports such as a tripod or flag stand can be made that rests on top of frozen ground or ice can be used to support an aiming post. An aiming post is self-supporting in about 26 inches of packed snow. Use of the aiming light, equipped with dry-cell batteries, is possible only for short periods. Batteries are kept warm and serviceable by carrying them or the light next to the body.

## MORTARS

**WARNING**

**Condensation and rain can make the disassembly of large mortar cannons dangerously slippery. Before the tube is removal from the base plate trunnion socket, wrap a rope or strap around the breach cap neck above the pinion ball. This rope or strap provides a reliable handhold. It is critical during hang-fire procedures to hold the strap by fingers, and not wrap it around the wrist.**

7-71. Apart from of the specifics of any model of mortar, all infantry mortars have certain characteristics in cold weather operation that are common to most systems (figure 7-3, on page 7-12). The following technical procedures have operator maintenance principles that overlap with crew tactical procedures. Otherwise, consult with the individual item TM.

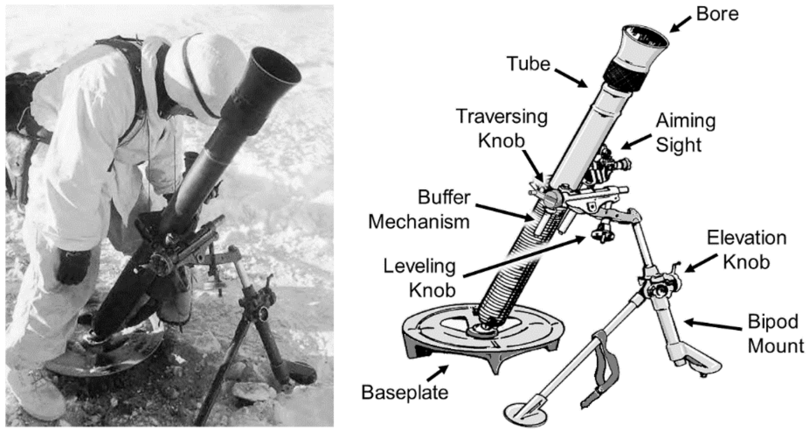


**Figure 7-3. Mortar components needing protection from cold and ice clogging**

> **CAUTION**
>
> Anticontact gloves (secured by a wrist strap) should be used to muzzle load mortar shells. The wearing of bulky or loose fitting gloves may cause the glove to become pinched between the round and the bore of the mortar tube as the assistant gunner follows through in dropping the round, damaging equipment, and causing injury or death.

## OPERATOR ISSUES

7-72. Mortars are predominantly comprised of bare metal. They cannot be handled without contacting the metal, unlike other infantry weapons with wooden or plastic handles and stocks. Hand protection must always be worn (contact gloves). The crew must keep their gloves or mittens on and avoid touching the metal surface with bare flesh.

7-73. The gloves must not be loose, because when the ammo is being dropped into the tube, a vacuum occurs which can suck the glove into the tube creating a hazardous situation. Ensure mortar crewmen use and do not remove anticontact gloves when temperatures fall below +20°F (-7°C). These gloves help prevent cold burns while still providing enough dexterity.

7-74. Breathing on sites, or on the mortar’s ballistic computer will cause fogging and freezing of equipment. Gunners should train to operate the mortar without breathing on the optics. Optical instrument should be kept sheltered but unheated when not in use, preferably in their cases. Doing this protects them against cold, condensation, and shock.

7-75. Muzzle and sight covers should be used when not firing the weapon to prevent snow and ice from entering the tube. A mortar’s ballistic computer is programmed to accept temperatures down to -50°F (-45°C). This automatically compensates for cold-induced slow burning of charges when computing firing data. A mortar’s ballistic computer is not programmed for temperature inputs colder than -50°F (-45°C).

7-76. Practice using compensated sight picture (the rule rather than the exception), when firing from frozen surfaces. Aiming stakes will become loose when placed in snow. Use sandbags or an anchoring device to keep them in place once set.

7-77. Baseplates become brittle when exposed to the severe cold; this, coupled with the tremendous shock that the baseplate receives when a round is fired, and the decreased ability of frozen ground to absorb shock; results in baseplates being more prone to breakage than normal. Frozen ground has limited resiliency to cushion the full shock of firing, putting greater stress upon the baseplate and other bracing parts of the weapon to absorb.

7-78. When emplacing a mortar, select a position with vegetation on the ground surface whenever possible. If a mortar must be emplaced on frozen ground:

- The mortar's baseplate must be solidly positioned to prevent sliding. It may be necessary to dig into the ground to accomplish this.
- Coat the bottom with waste oil to prevent freezing to ground surfaces.
- Use two men on the bipod when seating on ice or at high elevation (1,300 mils or higher).

7-79. One field expedient solution that reduces the possibility of a cracked baseplate is to place a brush matting or any organic material under the baseplate. The matting should be thick enough to act as a shock absorber, but not so thick or to an extent which will prompt the baseplate to bounce out of its position.

7-80. Another method of positioning is to place bags of dry sand or snow beneath the baseplate. The sandbags provide the weapon with a solid, yet resilient, shock-absorbing base. The baseplate is best seated by firing at a quadrant elevation of 1,200 mils and a middle charge. If the baseplate must be seated in snow, the bottom should be coated with waste lubricant.

7-81. Avoid using maximum or near maximum charges if the mortar baseplates is seated on a frozen surfaces. Even when the baseplate appears to be properly seated when firing at elevations below 900 mils, the crew can expect the mortar to shift to the rear, and even collapse.

7-82. Cold affects mortar ammunition the same way as other types of ammunition. Firing tables may be used provided the proper range corrections, based on cold weather conditions, are established through experience. Consult the applicable ammunition data sheets and applicable firing tables for charge restrictions at low temperatures. The following guidelines usually apply to ammunition in a winter warfare environment:

- For best results, ammunition and mortars tubes should be about the same temperature.
- Due to incomplete burning of propellants, expect a decrease in achieved range versus the plotted range. This decrease may be as much as 10% at -10°F (-23°C) and 20% at -40°F (-40°C).
- Keep ammunition and tube dry. Only open as many rounds as required for the current fire mission and then afterword use the tube cover provided.
- Due to incomplete burning of propellants, dry swab the tube after every tenth round or after every fire-for-effect. Swab bores thoroughly after each mission to remove any excess propellants or condensation.
- Boresight frequently.

**WARNING**

**When firing at low temperatures, double misfire wait times due to the possibility of delayed ignition. The new 60 mm and 81 mm mortars employ a trigger mechanism that allows the firing pin to be recocked and fired. With these mortars, misfire times do not have to be increased.**

## TUBE FRACTURING

7-83. In cold, the metal for mortar tubes becomes increasingly brittle. This brittle condition increases the rate of micro-fracturing as the tube is fired. Mortar units should have their tubes inspected prior to cold weather live fire operations to affirm that the tubes will remain safe during the duration of the operation. Tell the weapons inspectors that the weapon will be working in severe cold.

7-84. At the conclusion of cold operations, mortar tubes should be taken back to the weapons inspector to verify that the cold has not caused serious accelerated degradation. Tell the weapons inspectors that the weapon had been subjected to live fire in severe cold.

7-85. Due to the tremendous shock and off center weight of the sight, sight-mounts are prone to breaking if the baseplate is not solidly positioned. Remove the sight each time before firing until the baseplate is settled.

7-86. Mortars present practically no lubrication or ice fog problems, but are very susceptible to outer surface condensation. At least a half-hour should be allowed before cleaning after the mortar is moved from a cold to a warm location. This helps avoid condensation from mixing with cleaning solutions and lubricants.

7-87. Lubricate mortars sparingly and do not use PL (SP) below 0°F (-18°C). Use LAW instead of General Purpose Lubricant (GPL) below +10°F (-12°C) as a lubricant and bore cleaner on the newer 60 mm, 81 mm, and 120 mm mortars. The bore should be kept dry, and lubricant kept away from the firing pin. All moving parts and the bore should be checked for snow and ice before firing. Otherwise, use a heavy cloth muzzle bag to keep snow out of the bore. Never lubricate mortar shock absorbers.

**NOTE:** CLP is not to be used in the bore of a mortar.

7-88. Mortar gunners and assistant gunners normally use the standing position to avoid cold ground. In this position, they must properly execute round-firing and be conscious of added noise problems inherent with firing the mortar in the cold, dry air. Ear protection is a must.

7-89. Operator attention to detail sits at the center of keeping a weapon system ready for action. In the cold, operators cannot afford to cut corners or be lax in protecting their systems from the elements.

## TURRET STORED AMMUNITION

7-90. Temperature changes can have major effects on the ammunition for tanks and artillery. Lubrication and breakage problems are not as frequent as those for towed artillery pieces because most of the weapon's working parts are enclosed in a warm turret. Towed artillery ammunition is also affected (perhaps more so since that ammunition tends to be more exposed) to weather. That's why artillery crews always need to regularly check the powder temperature and keeping the rain, snow, and direct sun off ammunition stacked at the gun positions.

7-91. Ammunition stored inside the turret will be warm and have the same general ballistic characteristics as ammunition fired in temperate climates. Propellants tend to burn slower in the cold, reducing the velocity of projectiles. This effects cannon accuracy when gunners switch ammunition between that stored in a warm turret verses rounds stored outside in very cold weather. The weapon of an enclosed turret is usually zeroed with warmed ammunition. However, as a tank or armored artillery moves on to its next event, picking up fresh rounds can cause inconsistent trajectory performance. When cold ammunition is fired, the powder burns slowly causing completely different ballistic characteristics, rendering the initial zero useless.

7-92. If possible, the ammunition brought in from the outside should be allowed to warm in the turret before firing. In a combat situation, this may not be practical when the ammunition has to be used immediately. Temperature limitations are not stamped on all individual items of ammunition. However, temperature limitations are contained in the ammunition data sheets. The gunner must have his own data for cold ammunition or be ready to hastily re-zero the weapon. Either way, he will have to make a sight adjustment, or the weapon must be zeroed for the temperature in which it is being fired.

# SECTION III – MISSILES AND ROCKETS

7-93. From the viewpoint of Soldier operators, rockets and missiles differ from each other by their targeting systems. Rockets are dependent on the launcher's targeting systems to function. Then once fired, rockets usually just follow a ballistic trajectory. Missiles usually have internal guidance systems that allow them to alter or adjust their flight path in route to their target. Both weapon types are very susceptible to ice and condensation in their optics, electronics, and lubricants. In all other regards, rocket and missile systems are similar to any other type of artillery system when it comes to cold weather maintenance. Consult the TMs applicable to a particular rocket or missile to determine exact firing limits.

## ROCKETS

7-94. A rocket is a self-propelled, un-guided projectile. Rockets generally operate satisfactorily in cold weather (freezing cold, down to -40°F [-40°C]). Still, particular attention must be taken by handlers, transporters, and operators to keep connectors, rockets and rocket pods dry. Once water works its way into the crevices of componentry, and freezes, ice expansion can work lose sensitive circuitry.

# MISSILES

7-95. A missile is a self-propelled projectile with a guidance system capable of altering direction of flight from a ballistic path. Consult the specific TM for cold weather storage, transporting, and operation.

**WARNING**

**Double the back-blast area of all missile systems in cold weather.**

## LIGHT MISSILES

**CAUTION**

Electrically powered tracking and guidance systems encounter difficulties in obtaining an effective electrical ground when firing from frozen surfaces. This may be overcome through training or use of expedient grounding techniques.

7-96. Light missiles are those missiles which can be carried or loaded by an individual Soldier. Commonly, those missiles that are guided by optical equipment which is susceptible to condensation build-up on the lenses. It hampers line of sight missile target acquisition and tracking. This is not a significant issue for radar guided missiles.

7-97. If a missile round is delivered in a sealed container, do not open the seals of a cold-soaked missile in a warm shelter. The higher humidity could condense on or within the optics of the guidance system, making the missile unserviceable.

7-98. Likewise, fire control optics on a launcher must also be protected from condensation. Moisture condensing on the eyepiece can literally blind the fire control system. When a gunner initially tries to gain a sight picture, moisture from his breath and his body heat near the lens may cause condensation on the lens. To offset this phenomenon, use the protective mask with the winterization kit installed. An anti-condensation container must be used if the sights are to be brought into a warm shelter or building.

7-99. In the field, cold causes distortion for the cooled thermal imaging night sights when cold hits the heat rising from the vehicle engine to which the sight is mounted. Missile system operators should position the vehicle so the missile is aiming away from the engine, or position the engine downwind from the optical sights.

7-100. Depending on the direction of the wind, activation of the launch drive motors after initial firing creates some ice fog at -30°F (-34.5°C) and colder. This hinders the gunners' ability to track targets after firing, attempt second-round engagements, or acquire new targets.

7-101. Wing nuts on the battery of the missile guidance set freeze in place and then pop off when the battery is loaded. Prevent seized nuts by twisting each one before loading the battery.

7-102. Rubber eye shields on optical and night sights freeze, collect ice, and crack, thereby leaving optics vulnerable to ice and snow. Snow and ice can also cause poor electrical connections on clamping surfaces on the traversing unit, sights, and missiles.

### ARTILLERY MISSILES

7-103. Artillery missiles (field [surface-to-surface] or air defense [surface-to-air]) are usually stored or transported in containers or sealed pods (figure 7-4, on page 7-16). The most significant cold complication is related to ice covering the electrical connecters and sockets, or container pressure vents. Storage facilities have to avoid placing containers and pods on the ground where water can accumulate and freeze around low mounted connectors, sockets, or pressure vents. Likewise, if the connectors, sockets, or pressure vents are top mounted precautions are needed to cover them. Ammunition storage sites need to rely on the specific TM guidance for each missile type, and avoid applying a generic policy to all missile handling.

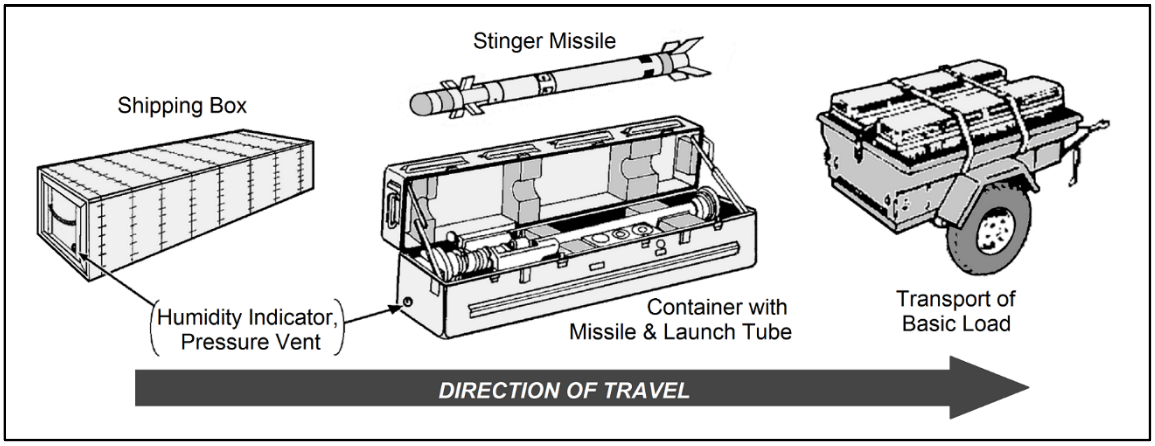


**Figure 7-4. Protect shipping vents and connectors from over pressure and moisture freeze**

7-104. When transporting artillery missiles in containers or sealed pods the warhead's direction of travel is not as important as the location of exposed connectors, sockets, and pressure vents. If a pre-launch or detonation were to occur, it would most likely be the result of a kicked-up rock strike to the exposed electrical connectors or launch squib (and not necessarily the warhead). During cold wet or snowy weather transporting, the pressure build-up facing the direction of travel will force water and moisture into the sockets and vents of exposed, and even capped componentry.

7-105. Transporting a full load of artillery missiles creates a higher center of gravity for trucks. A risk assessment has to be considered for truck movement on ice and snow covered roads. Commanders might lower the risk of accidents by reducing the load height and center of gravity.

7-106. Soldiers performing PMCS or moving heavy artillery missiles while dressed in bulky ECWCS clothing must be cautious. Gloves are necessary for such operations. Yet, bulky clothing obstructs finger sensitivity and manipulation while trying to set tie-downs, or connect electronic cables. Likewise, the bulky clothing can interfere with the clarity of hand and arm signals. All of this will contribute to a slow-down in operations and fatiguing Soldiers. Safety of the Soldiers and safeguarding the missile munitions is a priority.

## SECTION IV – FIRE CONTROL EQUIPMENT

7-107. Sighting and fire control materiel operate satisfactorily at below freezing temperatures if properly winterized and if certain adjustments are made. Maintenance of fire control equipment in cold weather is difficult, especially where repair shop facilities are scarce.

## PRECAUTIONS

7-108. Whether it is planned to service a piece of equipment in a shelter or in a heated trailer, prepare the materiel to operate at the lowest expected temperatures. Thoroughly inspect and winterize all materiel before the onset of cold weather.

7-109. When the LO for fire control materiel specifies oil, lubricate sparingly with instrument lubricating oil (OAI). In cold weather operations, a thin film of oil is more effective for lubricating fire control mechanisms than a heavy application. It also affords adequate corrosion protection. When the LO for fire control materiel specifies grease, lubricate sparingly with grease, instrument and aircraft (GIA) MIL-PRF-23827, *Grease, Aircraft and Instrument, Gear and Actuator Screw* (NATO, G-354).

7-110. Do not suddenly transfer sighting and fire control materiel from cold to warm or warm to cold temperatures. Condensation induced by this action may cause clouding of optics and rusting of internal parts. Use anti-condensation containers as prescribed in Chapter I, Section II.

7-111. Do not put severe bends in interconnecting cables. All electrical cables should be removed periodically from under accumulated snow. This eliminates locating and digging out cables when preparing to shift the emplacement. Use a cable reel to take up cable when shifting positions, and take care not to allow kinks to form. To prevent heavy equipment from running over interconnecting cables, use stake markers to define the cable paths. Markers also facilitate locating cables for repairs.

## FOGGING OF EYEPIECES

**CAUTION**

Never pour alcohol directly on the lens surfaces, as excess alcohol will damage the lens sealing compound. Do not use ethyl alcohol near an open flame or excessive heat source.

7-112. When using optical instruments in cold weather, do not breathe on the eyepieces. When warm breath comes in contact with the eyepieces, the moisture in the breath condenses on the lenses and turns to frost. The frost fogs the eyepieces, making observation impossible.

7-113. There is no satisfactory antifogging solution for use on eyepieces of optical instruments at low temperatures. Some solutions prevent fogging, but they streak the lens, making observation difficult or impossible.

7-114. The cold weather mask is the preferred method of keeping breath away from eyepieces. However, a face mask of any type is useful only as long as it directs the breath away from the lens or absorbs the moisture from the breath.

7-115. A serviceable face mask can be made from any piece of cloth, woolen scarf, or piece of gauze tied across the face just below the eyes. A mask made from any of these materials not only protects the operator's face from the wind but also deflects the breath from the lens. Change the mask periodically to avoid freezing the face.

7-116. When using a range finder, a blanket thrown over the operator and part of the tube increases the time of observation from 2 to 3 minutes to about 20 minutes before the eyepiece fogs. Clean optical surfaces by using tissue lens paper moistened with a few drops of optical lens liquid cleaning compound.

**NOTE:** Ethyl alcohol can substitute for cleaning compound. If neither lens cleaning compound nor alcohol is available, use dry lens paper. Wrap lens paper around the end of a sliver of wood to make swab. Dip the swab in optical lens liquid cleaning compound, shake off the excess, and clean lens. Wipe away any compound with lens paper, rubbing from the center outward in a spiral pattern.

## PURGING

7-117. Most sighting and fire control instruments are filled with dry nitrogen to prevent accumulation of moisture inside the instruments. Mechanics purge and charge sighting and fire control materiel according to applicable TMs or when condensation is evident in the instrument.

7-118. The gunner's primary sight on the M1 series tank has a defroster which does not automatically shut off after clearing the sight's day window. Excessive heat so generated can crack the window.

## POWERED SYSTEMS

7-119. While some fire control systems use unpowered devices, most of the new systems require a power source, either from batteries or external sources. As temperatures drop, the prescribed batteries begin to lose their effectiveness. At lower temperatures, operators may be required to discontinue battery operation and connect the power cable and adapter to a vehicle auxiliary power (slave) receptacle.

7-120. Expect temperate zone dry batteries to lose considerable electrical capacity because of decreased chemical activity. These batteries may be used to operate equipment at low temperatures if the internal temperature of every battery is kept high enough to permit normal chemical activity. Dry batteries warmed to approximately 70°F (21°C) retain sufficient heat for an appreciable period before replacement is necessary. The period of use depends on the rate that heat is conducted away from the battery. Battery life can be extended if it is insulated from cold-conducting surfaces by means of nonconductive materials.

7-121. When Soldiers must carry replacement batteries, they can use the following means to retard heat loss. After warming, place the batteries in bags lined with kapok or spun-glass fiber materials, wrap in woolen clothing, or carry them close to the body. Under certain conditions, it is advantageous to carry the batteries separate from the equipment by using a connecting cord and plug. This arrangement may require certain modifications to the using equipment to permit installation of the connecting cord and plug. Usually, the modifications are minor and readily accomplished by the using unit.

7-122. If replacement batteries can be carried in a vehicle, a well-insulated box that has small heater elements powered from the vehicle battery will ensure maximum usable life of the batteries without heat loss.

## PROTECTION OF TUBE EXTENSIONS AND EYEPIECES

7-123. Snow can collect in uncovered eyepieces and tube sunshades or extensions, rendering instruments useless until the snow is removed. Use a small, stiff brush or small, rubber bulb with nozzle to remove the snow. Do not try to blow the snow out of these parts or wipe it out with gloves or bare hands. Some of the particles of snow will melt and freeze on the lenses, causing further difficulty.

7-124. A temporary method of keeping snow out of eyepieces and tube extensions is to put loose wads of tissue lens paper in them when the instrument is not in use. These wads can be removed easily. Care should be taken to prevent the tissues from becoming wet and freezing the tube.

## LEVEL VIALS

7-125. When cold-soaked at temperatures below approximately -40°F (-40°C), the level vials on sighting and fire control items encounter sluggish movement, elongation of the bubbles, and at times, bubble separation. Sluggish bubble movement and elongated bubbles do not affect the precision of the piece. However, bubble separation does affect accuracy. When bubble separation occurs, briskly rub the top surface of the level vial, and the bubbles will join to become a single bubble.

## COMPASSES, BINOCULARS, AND OTHER OPTICAL INSTRUMENTS

7-126. The liquid in the lensatic compass thickens in cold. The heavy liquid slows the action of the compass and may make it inaccurate. Carry this type of compass near the body in the inner clothing to keep the liquid warm and thin. The dry-type compasses are not affected by cold weather.

7-127. Cold weather does not affect binoculars and other liquid free optical instruments. However, condensation does form when instruments are taken from cold air into warm air. Leave instruments outside or use anti-condensation containers.

7-128. Cover equipment such as telescopes while not in use. If a cover cannot be made to include the whole instrument, make bag-type cloth covers to go over the eyepieces and tube extensions. Cloth covers are better than airtight covers, such as the leather covers provided for some instruments. The cloth covers allows air circulation in contact with the lens. This prevents condensation when the instrument encounters lower temperatures. Cloth bag covers can be made with a spring, elastic, or drawstring at the mouth so they can be held in place and easily/quickly removed.

7-129. When temperatures drop, the pressure on the hydraulic accumulator of the independent thermal viewer must be lowered, or its pump will work too hard and wear out quickly. The image transfer assembly also needs attention when the seasons change to preclude excessive purging and desiccant changes.

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# Chapter 8

# Electronic Devices

The cold weather presents a unit and its leaders with challenges that are unique to each situation. As the severity of the cold and the duration of the cold increase, the impact of the cold upon the unit and its mission performance will increase. Often, there is no single solution. Leaders have to anticipate problems to avoid unfavorable surprises, and use critical thinking skills to mitigate such problems, in advance of and during a deployment into a cold region.

The revolution in computers has had a profound effect on the Army down to the individual Soldier. Electronic devices such as radios and computers are very susceptible to cold temperatures. In every sense cold has a severe impact on the military's tactical mission to move, shoot and communicate. This chapter raises a host of issues related to communications, computer, power generation and electronic devices.

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**NOTE:** Maintainers and operators should refer to the item specific TM that is the primary source for maintenance procedures.

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## SECTION I – COLD WEATHER THREATS TO EQUIPMENT OPERATION

8-1. The issue of equipment functional capability in cold weather environments is not solely affected by just the temperature. Certain climatic conditions affect communications and electronic (CE) equipment in cold regions. Beyond the steps found in the TM, the equipment operator needs to recognize each of these affects in order to understand how to get the best performance form the equipment and how to report function problems.

## IMPACT OF VARIOUS COLD RELATED FACTORS ON CE DEVICES

8-2. Cold weather regions have other weather characteristics from mild or temperate weather, beyond it being colder. The cold can alter the performance characteristics of electro-magnetic energy. Communications equipment, including antennas, can be adversely affected by any of the following:

- Rapid temperature changes.
- Obstructed visibility.
- Stabilizing or securing equipment to the ground to erect systems or masts.
- Electrical current grounding problems.
- Static (excess energy ionization) buildup.
- Radio Noise (radio frequency static emissions) interference.
- Snow or ice (weight) accumulation on antennas and wires.
- Magnetic storms (frequency blackouts).
- Accuracy reduction of Global Positioning System (GPS).
- Lower temperature limits of materials.

## COLD-DRY AIR

8-3. In cold-dry air, cold-soaked equipment is especially difficult to assemble. Assembly of equipment is also complicated by the bulky gloves or mittens worn by operators and maintainers. Increased attention to detail, patience, and special preparation to prevent damage is required. This includes working with tight connections, electrical contacts, inflexible cables, power cords, grounding, control knobs, rubber covers, binding posts, and other moving parts. (Also see, chapter 1, subsections titled Productivity, and Flesh on Cold Metal for further reading.)

8-4. As mentioned in chapter 2, cold shortens the operational life of batteries. At -40°F (-40°C) the storage battery for secure radio sets cease to operate, resulting in lost codes, and requiring reloading after warming.

8-5. The dry air, coupled with the wind and cold, can cause considerable buildup of static electricity on non-conducting surfaces. This buildup can be a hazard to operators and technicians, as well as to equipment.

8-6. Temperature inversions that occur on the coldest days in cold regions degrade frequency modulation communications signal strength drastically. A temperature inversion happens when; as one goes up in altitude, and the temperature drops; there is a zone where the temperature levels or even reverses, before returning to decreasing. These anomalous temperature zones can obstruct, scatter, or reflect radio transmission. This must be considered when planning troop dispositions and locations of mission command centers.

## FROZEN SURFACES

8-7. Frozen surfaces present two unique challenges; the ground is hard to work with, and are by their nature heat sinks that can rapidly cool equipment. A good rule is to keep all communications equipment off the ground. Whereas, adequate grounding is important on many pieces of communications equipment, yet is very difficult to achieve on frozen surfaces.

**NOTE:** Standard grounding systems will require considerable effort to construct, and in some cases prove to be impossible. Shaped charges, coupled with water-saturated salt/soil backfill poured over the grounding device, provide one of the best means for penetrating frozen earth.

8-8. In severe cold, ropes can freeze to the ground and to guys tied to these anchor ropes. This is a problem if the antenna system should fall over. In a severe cold situation, mountain pitons are very good alternative anchors for guy ropes. As weather warms and the ground softens these alternative anchors need to be monitored, and at the soonest moment have standard stakes to replace the alternative.

8-9. Extraction of grounding devices is more than likely possible only after seasonal thawing. Use of existing grounds (pipes, established grounds, and buried steel) is desirable. Ensure existing grounds are not conduits for gas or flammable liquids before use.

## SNOW AND ICE

8-10. Snow and ice can get into any unprotected openings in equipment. Use the equipment covers provided for most communications equipment.

8-11. As snow and ice accumulate on wires, and then thaw; that water will run down the wire and then work its way into splices or connections. To prevent electrical shorting caused by dripping water, install drip loops (figure 8-1). A drip loop is nothing more than the decent and rise in a wire causing water to puddle up and drip before the water can reach the connection. A drip loop provides the added advantage of providing slack in the line to accommodate wire shrinkage as the wire cools. Overhead connections, especially power connections, are required to accommodate cold contraction of wires.

8-12. Signal attenuation (absorption of energy reducing signal strength) due to ice on antennas is common in cold regions.

8-13. Since small items dropped in the snow are easily lost, more frequent inventory of radio sets and antenna kits is advised.

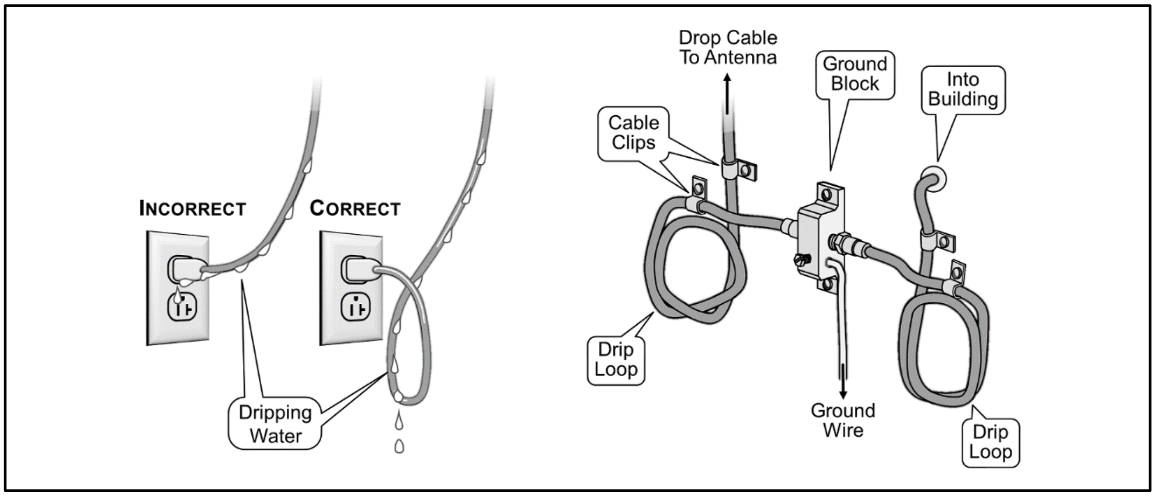


**Figure 8-1. Drip loop**

### OTHER FACTORS

8-14. Temperature alone is not the only factor affecting electronic and electric equipment, or the formation of frost and condensation. Altitude and humidity play an important role in the safe and successful operation of such items. Operators and maintenance technicians must consult the TM for the specific piece of equipment and, be knowledgeable about industry best practices as professionals.

## EFFECTS OF COLD ON ELECTRICAL AND ELECTRONIC DEVICES

8-15. Severe cold has certain effects on materials out of which most communications and information systems equipment is manufactured. Most electrical and electronic equipment is resistant to the effects of cold temperatures (down to about -4°F [-20°C]), provided it stays dry. However, there are regions of the world where temperatures can reach -58°F (-50°C) for days on a stretch, or fluctuate by 35°F (20°C) on a single day. Low temperatures can make such items unsafe or unsuitable for use by changing the properties of the materials used in the construction of electrical equipment. While this TM primarily discusses only the effects of low temperatures on equipment, there are other conditions in cold weather regions such as low humidity, wind, and snow and ice formation that can also have an effect on electrical equipment. It is important to follow equipment TM or manufacturers' instructions.

### BATTERY FAILURE

8-16. This is a reoccurring issue for electrical and electronic items operating in cold. (Refer to chapter 3, section III.) For rechargeable batteries, NiCad and lithium computer batteries do not last as long in below +32°F (0°C) weather. Change rate for cold-soaked batteries is also slower. For planning purposes, military non-rechargeable batteries (usually lithium type) are developed to operate in temperatures of -22°F (-30°C) to +131°F (+55°C); with a storage temperature range of -40°F (-40°C) to +158°F (+70°C). This is dictated by the chemistry used. Be careful that lithium batteries do not become fully depleted, continuing on into a negative charge and thermal runaway.

### OFFICE COMPUTERS

8-17. Most computers are not designed to operate at extremely low temperatures and may become unreliable or unavailable for use (0°F [-18°C] for larger work stations, -30°F [-34°C] for small handheld devices). Liquid crystal displays (LCD), especially, may be affected by cold. Frozen knobs, dials, and switches should not be forced. Electronic computer equipment used in a field environment such as computers, printers, peripheral devices and radios, which have blower vents or exposed circuit boards, are in jeopardy of condensation and freezing on both the circuit boards and within the accumulated dust.

## INTERNAL CIRCUITS

8-18. As temperatures decrease, changes can occur in the resistance and capacitance resulting in timing changes on integrated circuits, waveform changes, and other electrical properties of electrical and electronic components. If not taken into account, this can have an effect on the behavior of sensitive electronic equipment.

8-19. There are precautions that can be taken to mitigate condensation damage to electronic equipment. Cold-soaked electronic equipment that is not ruggedized or sealed should be heated or blown out with hot air. This assures the evaporation of internal condensation and moisture before power is applied.

## DUST

8-20. If the item is dust laden, the dust can retain condensation crystals even after the item is warmed. To mitigate dust, an information technology specialist should go around regularly (such as bi-monthly) and blow out the dust. A towel with a light mist of lubricating oil could be placed over the cooling intake vents to help to reduce dust from being sucked into electronic equipment. This is particularly true of COTS computing equipment.

## POWER-UP FRACTURING

8-21. Most electronic equipment produces its own heat with temperatures of about 70°F (21°C) to 80°F (27°C). Be mindful of cold-soaked equipment that has been powered off and cooled to sub-freezing temperatures. If not preheated, the sudden change in temperature at power-up risks cracking internal components. This is a more serious risk for COTS equipment, where ambient temperature should be above freezing. During such power-up heat surges, electrical crystals, diodes and LEDs have been known to pop and shatter. Maintainers and suppliers need to be ready for the increased workload due to power-up heat-shock.

## CONTRACTION AND WARPING

8-22. Severe cold temperatures cause many parts of electronic equipment to contract; on the same principle that warm temperatures cause things to expand. Contraction can cause the keys on the keyboard to warp and a touch pad to fail. This is a major cause of equipment failure for devices using liquid crystal technology.

## TRANSFORMERS

8-23. If frost builds up on non-ruggedized electrical equipment, circuit boards, or electronic computing equipment, it has to be removed before being connected to power (even if it’s not turned on). When plugged in, they go to immediate stand-by for full power-up. Operators should treat power supply transformers as being, always on.

## GROUNDING

8-24. The ability to ground generators and communications equipment is an important task. This task is complicated by frozen ground. Cold substantially increases soil resistance and also, earth grounding impedance. Hence, it is important to drive ground rods or install ground plates below the area's frost line, if possible. Try to ground to an extension of a buried metal object such as an underground pipe or a building frame. If no buried object is available, drive in several ground rods as deeply as possible. The most effective tactical ground system for use in frozen ground is the, “surface wire ground system.” This system consists of pins connected together with cable to form a grounding grid. Space them at least two rod lengths from each other. Alternatively, a trench can be dug to insert a horizontal rod or conductor. The trench should be filled with salt water which will improve conductivity when frozen. Typically, the best grounding that can be obtained with either a six-foot grounding rod or the surface wire ground system is about 3,000 ohms of resistance. For guidance, refer to Communications-Electronics Command (CECOM) Technical Report 98-6, *Earth Grounding and Bonding Pamphlet, A Guide to Proper Earth Grounding and Bonding Methods for Use with Tactical Systems*.

## SPECIALLY DESIGNED FIELD EQUIPMENT

8-25. Sealed, waterproofed, or ruggedized electronic modules are usually not susceptible to the same general freezing condensation problems of exposed components. Likewise, electronic equipment which is kept and used in a heated shelters usually does not need special precautions. See the item specific TM for exceptions.

## INFORMATION TO DECISION DISPLAY EQUIPMENT

> **CAUTION**
>
> When a monitor/display/TV is removed from cold storage do NOT plug it in immediately. Let it acclimate to the ambient temperature of the room for 20-45 minutes, at bear minimum. Keep the item secured in an anti-condensation container while the item stabilizes to room temperature.

8-26. For planning, the command's maintainers and operational staff need to be conscious of plasma display panels (PDP) screens, LCD, light-emitting diode (LED) displays, and projectors used throughout the command. Cold plays upon the lower margins of the operating capabilities for these types of equipment. Usually (although, not all), ruggedized military versions of display or projection equipment can handle temperatures down to -4°F (-20°C) without being augmented with built in heating. However, most COTS displays and projectors are not rated for use below 32°F (0°C).

8-27. The primary cold weather vulnerability of displays and projectors is the very strict design tolerances of screen construction and the reaction of supporting materials in the display screen or electrical circuitry. Cold causes the expansion and contraction of screen and chassis construction materials, supporting the liquid crystal or plasma of these systems, to expand and contract to being outside of design parameters. As with any other electronic device, humidity and condensation is a prominent threat to projectors and displays. All of these equipment items need to have a storage case that is air tight to prevent condensation buildup. Maintenance supervisors should establish defined policy in Standard Operating Procedures (SOPs) for the proper operation or storage of display and projector devices.

8-28. When preparing to use any PDP, LCD, or LED that was stored at less than 40°F (4°C), it should not be rapidly reheated. Avoid power-up electrical heat surges by pre-warming the item. Wrapping the item in a clingy air-tight cellophane can serve as an anti-condensation container, until the item reaches the warmer ambient temperature. These procedures will help preserves the crystalline character of the display, and also help to mitigate condensation on electronics, and avoid water streaking on the inner side of the screen.

### Plasma Display Pannels and Screens

8-29. PDP are essentially a matrix of very small fluorescent tubes with red, green, and blue phosphors. The active gas in a plasma screen is xenon or neon gas. These gases won't freeze in the coldest of weather. Cold weather freeze damage is more related to the quality of the electronics manufacturing, or condensation on the component materials. Unless manufacturer's instructions or the TM says otherwise:

- PDP operating temperature range: … 50°F (10°C) to 104°F (40°C).
- PDP storage temperature range: …... -4°F (-20°C) to 113°F (45°C).
- COTS PDPs are sensitive to altitudes above 9,000 feet (3000 meters).

### Liquid Crystal Based Technology

> **CAUTION**
>
> Never touch or apply pressure to a cold LCD screen.

8-30. LCD flat screen technology dates back to the 1960s. It evolved significantly over the first fifty years. Today, these liquid crystal items are known by various names: the original LCD made with silicon or germanium, LCD back lit with LED (called an, LED screen), LCD with thin film transistor backing (better known as a, LCD-TFT), organic chemistry based LED (known as an, OLED), digital light processing (better known as a, DLP) for projectors, and a few other names. From the standpoint of this TM, the distinctions are not significant. The actual liquid crystal material is midway between solid and fluid, whose properties should not be equated to water.

8-31. To keep reserves of liquid crystal based equipment available, supply activity personnel need to plan on and store this within the lowest common temperature range: Likewise, operators should dismount and store displays and monitors within the unit policy approved temperature range. Unless manufacturer's instructions or the TM says otherwise, the safest temperatures for LEDs is generally in the range of:

- Ruggedized LCD operating and storage temperatures: -4°F (-20°C) to 140°F (60°C).
- Non-ruggedized LCD operating temperatures: 40°F (4°C) to 90°F (38°C).
- Non-ruggedized LCD storage temperature: 40°F (4°C) to 100°F (45°C).

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**NOTE:** The temperatures above, for LEDs presented are only intended for planning purposes. Otherwise, the actual performance characteristics of a specific item will vary greatly.

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8-32. Manufacturer limitations on cold storage of large screen LCD monitors (television sized) varies greatly. Some are rated to handle storage temperatures of -15°F (-26°C) to -20°F (-28°C), while others are hardly able to be stored at 40°F (4°C).

8-33. As liquid crystal cools (below 50°F [10°C]), its image refresh rate becomes sluggish to the point where its display quality is active but blurred. Image blurring occurs for all LCDs at around -4°F (-20°C) to -40°F (-40°C), depending on the exact chemical composition of the liquid crystal. Low temp effects are usually reversible, as long as the crystal doesn't actually freeze solid. Still, at around -67°F (-55°C), the crystal material can freeze solid breaking the crystalline substructure (the exact temperature failure point will depend upon chemical composition). Once frozen for a few days, damage becomes irreversible. (Don't confuse LCD freezing with water freezing.)

8-34. LCD screens are backlit by either a florescent tube (old tech) or an LED. When initially turned on, an LCD screen in cold weather (below 50°F [10°C]), at first it will be faint and hard to read. Also, a cold LCD's refresh rate for motion pictures will be sluggish and images might appear broken up. If it is left on, it should improve in a short time due to self-warming. If the broken image or sluggish performance persists after the screen has reached about 32°F (0°C) to 50°F (10°C), then the item needs to be turned in per unit policy.

8-35. Operators must use anti-condensation containers to store and transfer an LCD item from a cold vehicle into a heated shelter. For COTS items, wrap displays in a towel, felt, or flees blanket to protect screens from scratching when not in use. Store any LCD item in an air-tight anti-condensation container, cellophane wrap, or a self-sealing plastic bag.

8-36. When operators return an LCD monitor to a cold environment vehicle or platform after off-duty storage, it should be removed from the container, connected and powered up as soon as possible to avoid the effects of low temperature. Make sure the vehicle's motor is running before connecting an LCD item to a vehicle.

## Light-Emitting Diode

8-37. LCD-LED screens use liquid crystals with an LED transistor material that glows for screen backlighting. The light emitting diode itself, won't freeze since it's already solid. The threat occurs when power is applied to a diode. The sudden rapid heat expansion can fracture (pop) a diode. When possible, pre-warm electronics before turning it on. The key issue is the durability of every component that makes up the LED. Otherwise, the care of LED display items is the same as any item made with liquid crystal technology.

### Digital Light Processing Projectors

8-38. Digital light processing based projectors consist of six major components including a light source, optics, color filters, a digital micro-mirror device (known as a, DMD), electronics and a projection lens, These projectors function at temperatures from a low of -40°F (-40°C), to a high of +158°F (+70°C).

## VISIBILITY AND ELECTROMAGNETIC CONDITIONS

8-39. Polar Regions of the earth where cold usually occurs is prone to two problems that effect electronic equipment: reduced hours of visibility, and electromagnetic disturbances. Prolonged hours of darkness affect communications equipment operation and maintenance in several ways:

- Inventory, assembly, and disassembly in the dark are difficult and time-consuming, especially when wearing required gloves or mittens.
- High frequency wave propagation which markedly deteriorates as darkness approaches due to changes occurring in the ionosphere.
- Good high frequency communications between stations 100 kilometers or more apart might be limited to only six hours.
- Lower frequency assignments that need longer antennas are also required.

8-40. The Aurora Borealis activity can cause static noise, suppress signals, and cause unusual wave propagation in radio communications. While electromagnetic interference does not damage equipment, planners must anticipate this degradation in choosing unit locations. Fading and severe static can cause speech secure devices to lose signal, requiring numerous retransmissions of long messages.

8-41. Units reportedly use Aurora activity to gain greater range for high frequency radio by reflecting directional signals off the light fields. However, this innovative use of conditions is the exception. The greater magnetic declination angles encountered as one moves farther north also greatly affect radio communications positioning and orientation of directional antennas. These problems increase the need for strict supervision.

## SECTION II – OPERATION AND MAINTENANCE OF COMMUNICATIONS AND ELECTRONIC SYSTEMS

8-42. Cold weather operations have always been concerned about communications and power generation. Now, with advent of microcircuits, operators have to be concerned about low power components within these high power systems. A few quick points:

- Carry small batteries inside your clothes to keep them warm. Reactivate cold-soaked batteries by warming them under your clothes.
- If a radio set must be set up outside, put it in a sheltered place. A wind block, like a lean-to, helps keep sets away from direct exposure to cold air.
- Raise cables above the ground to keep them from freezing to the ground. Use poles or tree limbs to raise the cables. If you can't get cables off the ground, keep them out from under the snow. Pull them free after every snowfall. A cable hidden under snow is hard to find except when it's pulled loose by a big foot or run over by a track.
- Check antenna systems often and remove snow, ice or slush that might diminish your signal or create a "failing ice" hazard.
- Put frost shields over microphones. If you don't have a shield, or your handset doesn't have a place to fit one, a piece of plastic--like a battery bag--will do the job.
- Remove all snow, ice, water and dirt from cable connections before connecting them. You'll get a poor connection or broken connectors, if you don't.
- Rubber and rubber compounds become stiff and brittle as temperatures plunge. In cold weather, cables and wire should be flexed slowly and carefully to keep them from cracking and breaking.
- Lube, but don't over-lube. Lubricants can get stiff in cold weather and fail to do their job. One key to lubing in the cold is frequent checks to make sure lube hasn't gotten stiff. Another key is frequently applying lube. Use lighter lubes, too!

- Plugs, jacks, keys, shafts, bearings, dials, and switches can malfunction due to contraction of metal parts in severe cold. Check them often and keep them warm and clean.
- Make sure all motors and fans run freely. Snow and ice build-up can shut down a critical fan and kill a much-needed motor.
- Make sure all knobs and controls move easily. Stiff controls might indicate a frozen moisture problem.
- Any equipment that generates heat during operation will "breathe" or draw in cold air as the equipment cools. If heated equipment is brought into contact with extremely cold air, the glass, plastic and ceramic parts may break. So give hot equipment time to cool down before taking it out of a shelter into the cold.

# RADIO SYSTEMS

**CAUTION**

To prevent damage to equipment left installed in a cold-soaked vehicle, allow the equipment to come up to operating temperature before turning on the power.

8-43. Several considerations for radio equipment were addressed in the previous section. A good rule to follow and enforce is to handle all communications/electronic equipment very carefully when cold. A radio dropped on cold ground or thrown into the back of a vehicle is easily damaged. Control knobs may be sluggish or even frozen and require careful handling; they can't be forced.

8-44. Even well-maintained equipment requires considerable warm-up time. For example, 15 to 20 minutes warm-up before voice transmission may be required. Keeping equipment as warm as possible can be achieved with careful planning and innovation. Use chemical heat pads and Styrofoam to keep equipment, especially speech secure devices, operational. Placement of radios and switchboards off the ground and away from exterior tent or shelter walls is advisable.

8-45. Another hazard is, ironically, too much heat. Needless damage to equipment is often incurred by improperly placing the equipment too near shelter heat sources, such as a stove or heater. Electronic components and insulators can easily melt or burn, and some batteries explode when placed too close to a heat source.

8-46. Lithium batteries, are especially effective in cold weather and do not need warming at temperatures above -20°F (-29°C). Dry cells should be kept warm until needed. Extra batteries can replace cold batteries in use; after warming, they can be used again. Batteries should not be installed in cold-soaked equipment. Plastic pins on battery connections get brittle in the cold; install them carefully.

8-47. Each user of a portable man-packed radio should carry the handset inside at least one layer of clothing to prevent the push-to-talk button from freezing. This requirement, combined with the operator wearing a parka hood, severely hampers the ability to hear incoming transmissions. This may be overcome by using external speakers. Use plastic coverings, such as battery packaging, to cover the mouthpieces of handsets. These should be used even with the presence of moisture shields to keep moisture from the operator's breath from freezing the handset. Placing an unthawed handset directly against lips or ears can cause physical injury.

8-48. Spare connectors, cables handsets, and antennas should be readily available for replacement when failures happen. Metals and plastic become remarkably brittle and crack and break easily in the cold. Friction tape is advised rather than plastic tape, which loses its adhesiveness in the cold.

8-49. Vehicular radios also require careful attention. Small physical shocks can cause whip antenna damage when in the upright position. Radios should be given time to warm even after being turned on. This involves three to four minutes on low power before transmitting or changing to high power settings. The vehicle for the particular radio being used should be cycled periodically according to its item specific TM when temperatures dip below -30°F (-34.5°C). The vehicle, when cycled, should be high idled at approximately

1,200rpm (or as prescribed by the vehicle TM. Otherwise, the high cold weather discharge rate necessary to operate the vehicle, radio, and the heater soon wears out vehicle batteries.

# ANTENNA SYSTEMS

8-50. Attention to proper assembly of antennas is a commonly overlooked requirement in the cold and dark. Shortcuts and failure to follow prescribed instructions often result in interruption or degradation of communications and damage to equipment. Antenna masts must be erected with enough mast sections to ensure necessary height.

8-51. Standard stakes are often useless in frozen ground. Cold-weather stakes can be ordered for antenna masts. However, since they are slimmer than standard stakes, they do not hold as well when the ground thaws. Heavy 12-inch steel tent pins, and short segments of rebar (reinforcing steel rods) have been used successfully. Tree and rock tie-offs are also acceptable. Another method for erecting a frequency modulation antenna is to guide the mast carefully alongside a tree and secure it to the trunk using one of the attached guy lines. Exercise care not to damage any of the elements, cable, or mast sections, upon erecting.

8-52. Proper inventory of unused hardware is essential since parts are easily lost in snow and darkness. Care must also be taken not to let moisture accumulate due to condensation or precipitation and ground out the antenna.

**NOTE:** Prior to assembly, expose antenna components to the cold, and then inspect those components for ice or ice crystal buildup from sweating and freezing. This prevents problems later with disassembly.

8-53. Keep the mast sections clean and free of foreign matter. Lubricate the male and female ends of each mast section only with silicone lubricant. After applying the silicone and joining the sections, back off the joints by approximately one turn as a precaution against sticking.

8-54. The RG213 coaxial cable (rated to work at +167°F to -40°F [+75°C to -40°C] is recommended over RG-8 cable; the latter becomes brittle and cracks at temperatures below -20°F (-29°C). Operators should have spare cable connectors and adaptors on hand, since damage and loss are common. Loop and tape coaxial antenna cable near the top of the mast to ease pressure on the connector. Tape the cable at intervals along the mast to prevent the whipping action of the wind from causing damage to the antenna. Tap the mast periodically to shake free snow and frost accumulation, which can degrade transmission signal strength. Make guy lines in a manner to prevent tripping on the antenna guys and disabling the antenna. Normal tape loses some of its staying power in sub-freezing temperatures, so use cold-weather tape.

8-55. Keep ceramic bowls dry because water collects in them during warm weather. When temperatures drop, they freeze, causing the more brittle glass to crack. Applying silicone where the two bowl halves join assists in sealing against further cold damage.

8-56. High frequency and long wire antennas can approach 75 meters in length, depending on the frequencies used. Attention to measurement is critical. The same applies to frequency modulation antennas.

8-57. Orienting an azimuth is important and often difficult because of the requirement to compute large declination angles in northern latitudes. Directional antennas are often required to compensate for other conditions causing range degradation.

# WIRE AND CABLE SYSTEMS

8-58. Laying wire over long distances in deep snow is greatly facilitated by the use of over-snow vehicles. These vehicles can also be the worst enemy of wire systems. Their skis and tracks damage surface-laid wire and cable that they pass over, dragging away large sections and cutting critical circuits. Standard wire-laying techniques, ties, and tagging apply in cold regions as well as in temperate zones. Aerial laying is advised when tactically feasible. Burial is desirable, but often difficult or impossible. Retrieving wire in cold regions is tedious and usually results in excessive salvage work due to ice and traffic damage. Stringing wire overhead is preferred because the wire will not freeze to the ground.

8-59. Wire insulation is often brittle, and impedance is increased in snow or damp conditions. Splices performed in the cold are often done improperly, and fewer can be allowed for continued use of serviced wire. A slack factor of 30% is recommended for wire-laying teams over the 20% called for in the TM. This allows for cold weather shrinkage (unless the wire is already cold-soaked).

8-60. Reeling wire and cable should be done carefully; reeled wire freezes into a coiled shape and should be warmed up before unreeling. The use of bigger coils also reduces the chances of pinches or breaks.

# GENERATOR POWER SOURCES

8-61. Units must inspect their mobile electric power (MEP) generator sets thoroughly and prepare them for cold weather operations according to the technical manuals and local procedures. Follow generator set LO; they specify the correct lubricants to use in cold weather. There are several DOD standard families of MEPs and their power distribution equipment used by the Army:

- MTG: Military Tactical Generator (only one model).
- TQG: Tactical Quiet Generators.
- AMMPS: Advanced Medium Mobile Power Sources.
- PU/PP: Power Units/Engines (a combination of a trailer with either a TQG or AMMPS).
- DPGDS: Deployable Power Generation & Distribution equipment.
- PDISE: Power Distribution Illumination System, Electrical (supporting components).

## POWER GENERATION OPERATIONS

8-62. The DOD standard family of MEP generator sets operates in ambient temperatures as low as -25°F (-31°C) without special winterization equipment. Winterization kits for the 5kW to 60kW TQG are available for temperatures of -25°F (-31°C), down to -50°F (-45°C). They can be requisitioned as individual kits by national stock number (better known as, NSN) and kilowatt size. Read the generator set's TM section on cold weather procedures, "Operation under Unusual Conditions." To ensure satisfactory operation during cold weather, perform the tasks below for best results:

- Generator sets can be stored at temperatures down to -60°F (-51°C).
- Winterize the generator set by using the correct cold weather lubricants. Read the generator set's LO. Temperate weather lubricants are the prominent cause for cold weather generator failure
- An optional winterization kit is available for installation in cold weather climates. Field level maintainers (military occupational specialty 91D, Power Generation Equipment Repairer) are authorized to install the kits.
- Keep engine starting batteries free from corrosion and fully charged to prevent them from freezing. If practical, store batteries in a warmer location; install them when the unit needs to use the set.
- Use the correct fuel for the anticipated temperature range. Ensure the fuel is clean and free of water contamination.
- Keep the generator set and surrounding area as free of ice and snow as practical.
- Soldiers should allow generator sets to reach their normal operating temperature before applying a full load to reduce the possibility of engine damage.
- Follow the correct shut-down procedures detailed in the generator set's technical manual.
- Ensure Soldiers do not leave fuel containers open (caps off) to prevent snow and moisture intrusion. Water in the fuel can cause freezing of fuel lines. These military generator sets have fuel filter/water separators. The separator element removes impurities and water from the fuel. Though too much water can negate the separator's effectiveness.
- Keep the fuel tank full to protect against moisture intrusion, its condensation and water accumulation.
- Check, drain and clean fuel filter/water separators daily and at shut-down to prevent icing. Follow the maintenance allocation chart in the generator set's technical manual.
- Grounding generators sets properly is an important safety precaution regardless of the ambient temperature. When the ground is frozen and the standard ground rod assembly (see Basic Issue

Items in technical manual) cannot penetrate, Soldiers can use the Surface Wire Grounding Kit (also called, SWGK); national stock number (NSN) 5820-01-263-1760.

- This surface wire grounding kit contains a sledge hammer, two 10-foot steel connector cables with 75 ampere connecting clips; 15 each 10" steel grounding pegs and 75-feet of steel grounding cable. Follow the kit's instructions and refer to CECOM TR-98-6. Alternatively, the unit can bury a ground plate in warmer weather, connect a ground wire to it and mark its location for later use. Use a plate at least 2-feet square of 1/4" steel or 1/16" thick non-ferrous metal (not aluminum). Bury the plate deep enough to contact moist soil. When needed, connect the plate to the generator set's ground terminal lug with #6 AWG wire. Moreover, it is important to remember, any ground electrode (rod, peg or plate) should penetrate deep enough to contact moist soil below the frost line. See paragraph 10.6 in CECOM TR-98-6 for grounding procedures for Arctic areas. Units can also use an existing underground metal pipe for a satisfactory earth ground. Though it must reach below the frost line.

## TACTICAL ELECTRICAL PRODUCTION AND DISTRIBUTION

8-63. Low temperatures can affect the materials used in electrical equipment. Generator sets can be started, and will operate at temperatures down to -25°F (-32°C) without a winterization kit. Cold weather can affect these items adversely by degrading their performance or causing malfunctions. At temperatures below -25°F (-32°C), starting diesel engines is difficult. In general:

- Severe cold weather can impair the function of circuit breakers in electrical equipment.
- Metals and plastics can lose ductility and become brittle to varying degrees in very low temperatures.
- These effects can compromise their ability to withstand transportation shock or rough handling. Elastomer (rubber or flexible plastic) components such as cabling and seals becomes much less flexible and brittle at low temperatures.
- Loss of flexibility in cold can lead to inadequate sealing of electrical enclosures.
- Wire and power cable insulation can become brittle as temperatures decrease. Cable damage can then occur when installing them at low temperatures. If practical, store cables at 50°F or above for 1-day before installing them in cold weather.

8-64. Other conditions often prevalent during cold weather operations can affect equipment, such as low humidity, wind, snow and ice formation. The MEPs generator sets will operate at elevations up to 4000-feet above sea level without special adjustment or reduction in capacity. At elevations above 4000-feet, the kilowatt rating drops by 3.5% for each additional 1000-foot increment. Information about operating a generator set equipment at higher altitudes is printed on its data plate. Refer to the technical manual for information on a given generator set model.

8-65. Operators and Maintainers must perform cold weather maintenance on all electrical systems. Remember, a generator set's technical manual covers cold weather operating procedures.

- Install winterization kits before deployment to cold climate areas.
- The majority of DOD standard generator sets use liquid-cooled diesel engines. Operators must use an antifreeze solution to protect a generator set at the lowest temperature expected.
- Ensure the engine's starting batteries are fully charged to prevent freezing.
- In some cases, ice fog caused by engine exhaust at -25°F (-32°C) and below can occur. To eliminate or reduce ice fog, the operator can attach an extension tube to the generator set's exhaust pipe to direct the exhaust into the snow.
- For safety, Soldiers must not touch the cold metal parts and enclosures with bare hands to prevent a cold injury.

## GENERATOR SPECIFIC CHARACTERISTICS

8-66. Each family of generators has unique characteristics that operators should know, and maintainers should be familiar.

## Military Tactical Generator

8-67. The 2kW MTG has a built-in cold weather starting system for temperatures at +23°F (-5°C) down to -50°F (-45°C). The 2kW MTG set and 3kW TQG set are the only air-cooled sets.

## Tactical Quiet Generators

8-68. The TQG sets have three starting aids:

- Integral air intake heaters mounted in the intake manifold. The air intake heaters warm the air in the combustion chamber to assist with ignition when the air temperature is below +21°F (-6°C) to -25°F (-32°C).
- Optional winterization kit. The winterization kit warms the coolant and the engine block when temperatures range from -25°F (-32°C) to -50°F (-46°C).
- Ether is used to help start the engine because of its low 320 °F (160 °C) auto ignition temperature.

8-69. The 3kW TQG is designed to operate from -25°F (-32°C) to 120°F (49°C).

## Advanced Medium Mobile Power Sources

8-70. AMMPS have a fuel-fired standby heater, which warms the coolant when temperatures range from -25°F (-32°C) to -50°F (-46°C). This winterization kit starts automatically, depending on the temperature and it regulates the heat automatically. Its digital control system turns-on the "ready to crank" indicator when the heater has completed its cycle.

## Power Distribution and Illumination System, Electrical

8-71. Along with the generators, the Army provides a power distribution illumination system, electrical. This equipment is designed to operate down to -25°F (-32°C). Ensure the electrical feeder system and distribution center enclosure lids are closed and latched to prevent moisture intrusion. When coiling load cables or making connections to the electrical loads, form large loops since the power cables are more difficult to bend in below freezing temperatures.

# Appendix A
# Cold Weather Policy Considerations

The following is a list of planning and policy considerations that commanders and unit leaders may want to utilize in developing unit policy documents. This appendix should be modified to supplement the unit's unique mission, equipment, and local policies. As appropriate, some of the points can be incorporated into a unit's SOP. Some of the preparation functions mentioned below will require months of lead time to properly execute, though here that is not specifically detailed. This appendix is developed with the expectation that the commander will delegate the staff to perform planning and express actions in a plan or SOP.

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**NOTE:** Although this TM is not focused on hot weather and desert operations, some of the consideration points for severe cold have parallel points in common with, and can be applied to high temperature operations.

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## SECTION I – STAFF RESPONSIBILITIES

A-1. The Commander and staff will need to produce a staff analysis and unit policies in advance of a unit mission involving cold weather environments.

- Develop risk analysis and threat management policy upon notification of a unit move into a severe weather environment. All DOD units use the DD Form 2977, Deliberate Risk Assessment Worksheet. This risk assessment policy, and supporting worksheets should at least cover:
    - Medical operations.
    - Maintenance operations.
    - Velocity of supplies, and support constraints.
    - Changes in safety policy and procedures.
    - Security procedures.
    - Limitations to operational and training activities, which is categorized according to the severity of the weather.
- Identify gaps between table of organization and equipment (TO&E) authorized for temperate environments, and supplemental material requirements for each of the severe weather categories:
    - Arid high temperature, desert: 90°F (32°C) or greater during the summer days; with some below freezing winter nights; and day-to-night fluctuations of 20°F (11°C) to over 60°F (33°C).
    - Wet-cold: +39°F to +20°F (4°C to -6°C).
    - Dry-cold: +19°F to -4°F (-7°C to -20°C).
    - Intense-cold: -5°F to -25°F (-20°C to -32°C).
    - Extreme-cold: -25°F to -40°F (-32°C to -40°C).
    - Hazardous-cold: -40°F (-40°C) and below.
- Establishes a date or situation (trigger event) when the unit converts to cold weather operations. This plan should specify a limited time to complete conversion once the process begins.
- Develop and establish the unit's severe weather maintenance policy. Focus on additional duty staffing and severe weather tasks, adjusted for each weather category.
- Establish command policy for the field use of COTS. One should assume that commercial infrastructure will not be available; and that COTS will have to be transported and powered by the available battalion or company resources.
- Set unit severe weather PPE policy, adjusted for each weather category.

- Draft a survival kit, and survival bag list for each severe weather category, anticipated to be encountered.
- Establish command policy on the use of survival gear.
- Establish policy for the site supervisor to communicate once every four hours with the motor pool duty medic, duty roster combat life saver in the motor pool, or the senior medically trained Soldier supporting post security guard.
- Inquire after each Soldier with prior cold injuries, and then about any new injuries (preferably delegated to the medical NCOIC, or the senior medical NCO, if available).
- Establish planned quality controls and inspections of the commander's unit severe weather policies.
- Conduct AARs of severe weather preparations and training events. Use feedback to make adjustments in advance of deployment on a mission.

**NOTES:** Don't wait for the conclusion of a mission to conduct an AAR. The conclusion of scheduled preparations is also an ideal time for an AAR.

## SECTION II – TRAINING

A-2. Unit leadership is responsible for training Soldiers to individually and collectively perform their duties in cold weather conditions.

- Identify the mission focused tactical training priorities.
- Identify the mission focused maintenance training priorities.
- Identify the mission focused medical training priorities.
- Identify the mission focused vehicle movement training priorities.
- Draft training curriculum to cross-train and command-certify a few soldiers (junior enlisted) from each platoon to support unit maintenance. This training should focus on severe weather conditions by having candidates train while waring heavy gloves with glove liners:
    - Battery technology and maintenance.
    - Generator operation and repair.
    - Powertrain disassembly, repair and rebuild.
    - Vehicle fleet safe engine starting, auxiliary power supply procedures.
    - Vehicle heater operation, maintenance, and inventory administration.
    - Shelter heater operation, maintenance, and inventory administration.
    - Base camp or cantonment area sanitation.

**NOTE:** It is probably not reasonable to expect that any one Soldier-operator can be expected to get certified on all, or even most, of the above additional duties. Such a heavy duty load would interfere with their regulator operator line duties.

- Conduct a bi-annual re-certification of all previously qualified (E-1 through E-6) combat lifesavers; emphasizing severe weather conditions.
- Ensure that Soldiers receive proper training in environmental awareness, and comply with HAZMAT regulations. Soldiers must be able to recognize all hazardous materials with which they routinely handle, its proper disposal. More importantly, they must know how to contain and mitigate emergency situations (HAZMAT spills), in severe weather conditions.
- Train operators on adherence to procedures publicized in the TMs and LOs for equipment in their element.
- Administer and oversee the licensing of Soldiers to operate field heater equipment.
- Administer and oversee driver's refresher training in ice and snow driving.
- Insure that within the element, all operators and a backup Soldier of each piece of equipment are licensed or certified where required.

## SECTION III – LOGISTIC PREPERATION FOR SEVERE WEATHER

A-3. The senior staff logistics leaders need to establish and implement the Commander's policies and leadership procedures which enable the unit to function in cold weather.

- Establish a default cold weather standard, with the unit prepared to function in wet and dry-cold conditions at temperatures down to -5°F (-15°C), on order.
- Establish a date or trigger event when the unit converts to cold weather capability; or upon orders to conduct a cold weather operation.
- Develop a contingency plan for logistic activities within the unit to, on order, convert the unit to being operational in dry-cold, intense-cold, and extreme-cold; that is beyond the default weather standard.
- Identify the sourcing where the unit can draw Extended Cold Weather Clothing System (ECWCS) items.
- Inspect 100% of the ECWCS levels 1 through 5 and wet weather gear of all Soldiers in the fall. Shortages should be reported and resolved within a month.
- Perform 100% inventory of all tents, and tent heater systems (especially, component parts); well in advance of the winter.
- Identify kitchen PPE not suitable for severe weather conditions, and recommend alternatives to the commander.
- Identify POL PPE not suitable for severe weather conditions, and recommend alternatives to the commander.
- Procure COTS PPE as directed by the commander, before a severe weather mission.
- Inventory all COTS equipment; in advance of winter.
- Draft maintenance procedures and lifecycle parts list for all unit COTS items that might be used in a field situation. Account for additional logistic demand to support the use of COTS in the field. Identify and account for all unit COTS that uses or is powered by:
    - Petroleum (gas, liquid, or solid).
    - Commercial electrical power.
    - Battery electrical power.
    - Lubricants.
- Notify senior medical NCO of scheduled activities which will probably occur under severe weather conditions.
- Coordinate with food services for supplemental hot/cold beverages, snacks, and hot food, to occur on a regular bases at work sites and training sites. The supplemental rations plan works best when broken up into different groupings (a matrix) for each of the weather categories.
- Encourage Soldiers to notify their NCO leader of missing and unserviceable initial issue items, and TA-50.
- Arrange for comprehensive sanitation facilities.
- Organize heated overnight storage for electronics (radios, computers, and monitors) of parked vehicles.
- Provide electrical power connections to keep engines and batteries of parked vehicles warmed. This pertains to vehicles with winterization kits that accommodates external electrical power.

## SECTION IV – MEDICAL ACTIVITIES

**CAUTION**

In the cold, no injury is a minor injury. Documentation is valuable to a soldier's future wellbeing.

A-4. Cold weather conditions place additional work load on medical Soldiers.

- Establish and administer quality control policy and procedures for the presence and proper resourcing of medical support.

- Establish battle buddy system to monitor health and welfare practices, during severe weather conditions (temperatures below 35°F (2°C)).
- Have medical support immediately available where there is significant risk to Soldiers.
- Maintain current and detailed documentation in Soldier's records of severe weather, cold injuries. During a duty period with cold weather, all Soldiers who have sustained an injury should be ordered to report to a special "post duty sick call" before being released for the day, or from an outside duty roster event.
  - Delegate a medical NCO to make inquiries and write a root cause report on any serious cold weather injuries. Give findings of this report to the unit medical officer (Chief of Staff or Executive Officer) for consideration, when making recommendations to the commander. Such reports might warrant making changes to the unit cold weather policy. Perform reports in accordance with AR 385-10, *The Army Safety Program*, DA Pam 385-40, *Army Accident Investigations and Reporting*, and local command police.
- Establish policy and procedures which coordinates for medical coverage to be routinely available for:
  - Sick-call clinic.
  - Training sites.
  - Maintenance areas, and wash racks.
  - Rest areas and base camps.
  - Convoy and movement activities.
  - POL distribution activities.
  - Munition distribution activities.
  - Guard post, or related long-lasting outside duties.
- Establish and conduct a duty roster of NCO combat lifesavers with special training and brigade surgeon certification to recognize and treat cold weather injuries.
- Actively identify and proactively monitor specific Soldiers who are new to the cold or have experienced prior cold injuries.
- Establish directions and policy for senior NCOs to check Soldiers for proper articles of ECWCS, rain gear, survival or first aid gear, correct gloves, and foot gear appropriate for the cold or wet. (Leaders should check leaders to assure that no one is cutting corners.)
- Maintain proficiency of combat lifesavers, certifying skill in severe weather related first aid and rehydration. Ensures that combat lifesavers are proficient in mitigating and stabilizing cold injuries.
- Verify that medical staff is documenting all cold injuries, and inserting the information into the Soldier's records.
- Conduct AARs of severe weather preparations and training for medical events. Use feedback to make adjustments in advance of deployment on a mission.

## SECTION V – MAINTENANCE ACTIVITIES

**NOTE:** In garrison, Soldiers tend to think of maintenance activities as being just a "once a week motor stables." However, when out on a mission, they need to be reminded that maintenance is continuous and that they need to take the initiative for their own well-being and personal security.

A-5. Cold weather conditions place additional work load on maintenance Soldiers.

- Establish unit specific procedures for the operation and maintenance of unit equipment in severe weather conditions. (See, Section VI, on page A-5.)
- Verify that supervisors (both maintainers and functional line) have both leadership and technical skills to oversee the proper performance of cold weather maintenance and services.
- Maintain a current list of winterization kits and POL products needed for transitioning the unit to cold weather operations.
- Perform a serviceability inspection of all vehicle heaters; well in advance of the winter.
- Perform an inventory of all vehicle winterization kits and tire chains (including rubber bungy-tighteners); well in advance of the winter.

- Line officers and noncommissioned officers will acquire winterization kits, shelters and heaters as they become available through supply channels. They should insure that the kits are correctly installed, and that operators understand the proper use and maintenance of these items.
- Perform cold weather maintenance and troubleshooting according to appropriate TMs, LOs, and SOPs.
- Operate vehicles and equipment according to the cold weather sections of appropriate TMs and special instructions given by maintenance personnel.
- Assist operators with vehicle starting using maintenance power resources to actively augmented starting procedures for the unit's vehicle fleet.

## SECTION VI – VEHICLE OPERATOR RESPONSIBILITIES

A-6. All unit vehicle operators and maintenance personnel must comply with operational checks outlined in vehicle TMs, and include the following procedures:

## BEFORE OPERATIONS

A-7. Operators need to anticipate an increase in lead-time need to ready vehicles and equipment for use.

- Check to ensure that brakes are not frozen and can be released. The use of portable heating equipment may be required.
- Check springs for cracking due to metal brittleness.
- Ensure tracks/wheels do not freeze to the ground by placing matting under the tires.
- Remove built-up dirt and ice from the suspension system.
- Ensure track tension has been adjusted for cold operations by increasing the amount of slack.
- Check vehicle operator manual for inflation pressure. Ensure tires are inflated properly for operation. Deflate tires to normal pressure if pressure was increased to compensate for extended parking. Do not over-inflate tires.
- Ensure all $CO_2$ fire extinguishers have been winterized according to appropriate fire extinguisher TB.
- When adding lubricants to an engine, prevent snow or ice from entering crankcase.
- Ensure cooling systems are protected with the correct antifreeze compound.
- Ensure vehicle is fueled with the proper grade arctic fuel or with JP-8, as specified by the TM or appropriate TB.
- If engine is difficult to start, check spark plugs for ice coating due to condensation. For diesel engines check battery for proper charge to insure glow plug operation.
- Check batteries to ensure that they are fully charged by measuring the specific gravity of the electrolyte, or by performing a conductance test.
- Roll and store tarps for ease of employment later, for after operations.

## DURING OPERATIONS

A-8. Operators should make a pocket list of checks that they review at regular intervals during the operation of a vehicle or equipment. Along with TM checks, the operator should consider additional points that are weather related, requiring close observation.

- Do not tow-start vehicles.
- Avoid powering up radios, LCD, or LED electrical equipment until it is first preheated (warmed up) to an above freezing temperature. (Once powered up or turned on, such electronics may be allowed to cool.)
- Drive vehicles around the 150 meter warm-up course at under 15 miles per hour (25 kilometers per hour), and then do a During Operation Check before leaving the unit area.
- At temperatures of -20°F (-29°C) to -60°F (-51°C), start vehicles periodically to maintain readiness. (This practice can be avoided if any other means of keeping engines operable, such as engine heaters or external heaters, are available.)

- Avoid idling engines if at all possible. This practice tends to waste fuel and adds to engine maintenance cost.
- Ensure engine heaters are used properly and maintained according to the appropriate TM.
- Operate vehicles not equipped with engine or battery heaters at prescribed intervals. Also ensure that portable duct-type heaters are available for engine compartment preheating.
- Check chassis and body components for ice, mud, and snow buildup. Remove buildup at every opportunity to ensure proper ground clearance and to prevent interference with moving components.
- Check vehicle chains to ensure they are serviceable and properly fit the tires. As chains become loose, retighten them to prevent damaged vehicle parts.
- Ensure engine oil pressure is maintained for safe engine operation.
- Maintain normal engine operating temperature through the adjustment of engine compartment inlet shutters or radiator covers.
- Run the engine at a high enough rpm, for long enough to recharge batteries and recover lost energy from the initial starting.

# AFTER OPERATIONS

A-9. Operators must not only follow the after operations PMCS procedures, but they must pay attention to how they park, keep electrical devices protected from freezing, and prevent snow and condensation from freezing onto the equipment.

- At the end of each operating period, and for five minutes prior to shutdown, run the vehicle engine to normalize its mechanical working and retain oil on cylinder walls.
- Do not park vehicles with the brakes set since they may freeze and not release. Use chock blocks to hold vehicles in place.
- Never park overnight where snow has melted that day; tracks and wheels will freeze to the ground.
- Park with tracks and wheels on brush, cardboard, or any similar material to prevent direct contact with the ground.
- Protect radiators from wind, snow, and ice buildup.
- Ensure the fuel tank is topped-off to prevent condensation buildup.
- Drain air tanks.
- Electronics equipment with LCDs and sensitive components should be taken from vehicles and stored in a heated CONEX, warm tent, or a warm vehicle. Be careful to avoid condensation buildup.

# Appendix B
# Electrolyte Spills

Electrolyte spills are serious events. Proper accident management is a critical skill for anyone handling batteries.

## FIRST AID INSTRUCTIONS

B-1. For Contact with electrolyte; liquid, GEL or powder.

- Before battery maintenance operations, personnel should identify and write down the electrolyte being handled for emergency reference.
- Remove to fresh air and provide cardiopulmonary resuscitation (also called, CPR) if needed. Obtain medical attention.
- Eye Contact: Immediately flush eyes with water and continue to flush for 15 minutes. Hold eyes open. The first few seconds after contact are critical and immediate flushing of the eyes may prevent damage. An eyewash fountain is preferred, however, an eyewash hose or any other source of clean water should be used in an emergency.
- Skin Contact: Begin flushing the area with large quantities of clean water immediately.
- Contaminated Clothing: Remove and discard any article of clothing that has made contact with electrolyte. Don’t depend upon spilled chemicals to evaporate from your clothes. Re-use of contaminated clothing can re-expose skin to chemical burning. (Exposure through the skin can kill.)
- Ingestion: Do not induce vomiting. Dilute by giving water. If available give 2 to 4 cups of milk. Do not give anything by mouth to an unconscious person.
- After flushing, seek immediate medical attention without delay. Inform medical personnel that you have been contaminated with:
  - Sulfuric acid, or sulfuric hydroxide.
  - Potassium hydroxide.
- The precautionary warnings on the product label should be consulted for full first-aid information. Provide the label information to the attending physician.
- Neutralizers and solvents (baking soda, household ammonia solutions, alcohol, amongst others.) should not be used by the first aid responders.

## SPILL OR LEAK PROCEDURES

B-2. Electrolyte is a hazardous material. Consult with the HAZMAT agency of the local instillation for policies regarding the establishment of battery or electrolyte storage and handling areas.

- Storage and handling areas should be equipped with proper containment to capture and neutralize spills. In addition, these areas should be equipped with eyewash stations and safety showers.
- Wear acid-resistant clothing, boots, gloves, and face shield when working with batteries and electrolyte.
- Stop flow of material, contain/absorb small spills with dry sand, earth, vermiculite. Do not use combustible materials.
- If possible, carefully absorb and neutralize the spill with soda ash, sodium bicarbonate, lime, sand or earth.
- Baking soda and household ammonia solution are two substances that can neutralize the acid contained in the battery electrolytes. Have this on hand to clean up shop spills. (Not for first aid use.) Mix equal parts of either one with water to create a solution that neutralizes the battery acid.
- If water alone is used, cautiously dilute with water.

- Do not allow discharge of un-neutralized acid into waterways, sewers, basements or confined areas.
- Place neutralized slurry in sealed containers and dispose of as hazardous waste, as applicable.

B-3. Large water-diluted spills, after neutralization and testing, should be managed in accordance with local, state and federal requirements. Consult state environmental agency and/or federal Environmental Protection Agency.

## Appendix C

# Weather and Climatic Extremes

This appendix provides some reference information related to worldwide and regionalized climatic extremes.

## REGIONS OF COLD TEMPERATURE TABULAR DATA

C-1. There are three basic sources for this information: AR 70–38, "Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions;" MIL-STD-810, "Environmental Engineering Considerations and Laboratory Tests;" and MIL-HDBK-310, "Global Climatic Data for Developing Military Products," includes extensive information regarding extreme natural environments. Consult MIL-HDBK-310 directly for more specific details.

C-2. The following data table (table C-1) was extracted from a publication by Dr. Paul Krause and Ms. Kathleen Flood of the Army Topographic Engineering Center, in 1997. Weather and Climate Extremes (Technical Report TEC-0099), U.S. Army Topographic Engineering Center, Alexandria, VA.

**Table C-1. Weather and climatic extremes – brief summary**

| ***Lowest*** | ***°C (°F)*** | ***Location*** | ***Date*** |
|---|---|---|---|
| *North America (excluding Greenland)* | *-63 (-81.4)* | *Snag, Yukon Territory* | *3 February 1947* |
| *U.S. Coolest Summer Average* | *2.2 (36)* | *Barrow, AK* | *1941-1970* |
| *U.S. Lowest Annual Mean* | *-12.8 (9)* | *Barrow, AK* | *1941-1970* |
| *U.S.* | *-62.1 (-79.8)* | *Prospect Creek, AK* | *23 January 1971* |
| *U.S. (excluding Alaska)* | *-56.5 (-69.7)* | *Rogers Pass, MT* | *20 January 1954* |
| *U.S. Coldest Winter Average-* | *26.7 (-16)* | *Barter Island, AK* | *1941-1970* |
| *CA Lowest Annual Mean* | *-19.4 (-3)* | *Eureka, NW Territories* | *1947-1980* |
| *North America - Mean (Month) (excluding Greenland)* | *-47.8 (-54)* | *Eureka, NW Territories* | *February 1979* |
| *Greenland* | *-66.1 (-87)* | *Northice* | *9 January 1954* |
| *Europe* | *-55 (-67)* | *Ust'Shchugor, Russia* | *15 Year Period* |
| *Northern Hemisphere* | *-67.8 (-90)* | *Verkhoyansk & Oimekon, Russia* | *5 & 7 Feb 1892, and 6 Feb 1933* |
| *Africa* | *-23.9 (-11)* | *Ifrane, Morocco* | *11 February 1935* |
| *South America* | *32.8 (-27)* | *Sarmiento, Argentina* | *1 June 1907* |
| *Australia* | *-23 (-9.4)* | *Charlotte Pass, New South Wales* | *29 June 1994* |
| *Antarctica Mean Monthly* | *-73.2 (-99.8)* | *Plateau Station* | *July 1968* |

**Table C-1. Weather and climatic extremes – brief summary (continued)**

| *Lowest* | *°C (°F)* | *Location* | *Date* |
|---|---|---|---|
| *Antarctica Annual Mean* | *-57.2 (-71)* | *Sovietskaya* | *1957 & 1958* |
| *World* | *-88.9 (-128)* | *Vostok, Antarctica* | *21 July 1983* |
| *U.S. Winter Average* | *22.8 (73)* | *Honolulu, HI* | *1941 to 1970* |
| *Western Hemisphere* | *56.7 (134)* | *Greenland Ranch, CA* | *10 July 1913* |
| *Western Hemisphere Summer Average* | *37 (98)* | *Death Valley, CA* | *1941-1970* |
| *CA* | *45 (113)* | *Midale & Yellow Grass, Saskatchewan* | *5 July 1937* |
| *Europe* | *50 (122)* | *Seville, Spain* | *4 August 1881* |
| *World* | *56.7 (134)* | *Greenland Ranch, CA* | *10 July 1913* |
| *Asia* | *53.9 (129)* | *Tirat Tsvi, Israel* | *21 June 1942* |
| *World Annual Mean* | *34.4 (94)* | *Dallol, Ethiopia* | *Oct 1960 to Nov 1966* |
| *Australia* | *50.7 (123.3).* | *Oodnadatta, South Australia* | *2 Jan 1960* |
| *South America* | *48.9 (120)* | *Rivadavia, Argentina* | *11 December 1905* |
| *South Pole* | *-13.6 (7.5)* | *South Pole* | *27 December 1978* |
| *Antarctica* | *15 (59)* | *Vanda Station* | *5 January 1974* |

# Appendix D
# Slaving or Jump Starting

It is common in cold situations for a vehicle to need its battery power augmented during initial startup. Such procedures are risky for cold-soaked batteries, even if they are not frozen. Because of the risk, slaving or jump starting a vehicle is usually limited to maintainers. The commander should state in the unit SOP under what circumstances an operator can slave or jump start a vehicle. Otherwise, maintainers can expect that in cold, most cold-soaked vehicles will require assistance with starting.

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**NOTE:** Maintainers and operators should refer to the item specific TM that is the primary source for maintenance procedures.

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## COMMAND POLICY

D-1. When the cold begins to slow the workflow, and maintainers need additional duty Soldiers to keep the mission on schedule. This section in this appendix presents selected techniques for power augmented startup. Commanders should consider establishing startup procedures that protect equipment. It should include defined trigger events, where maintainers using maintenance resources become actively involved in augmented starting procedures for the unit's vehicle fleet.

## INITIAL STARTING EFFORT

D-2. Supervisors of operators must know that operators comprehend and are using maintainer approved procedures for starting a cold engine. Cold starting may not (or may) be the same as starting in temperate weather conditions. Each vehicle or power plant has to be treated as unique in the cold.

- Operators should have performed preventive maintenance as proscribed by the specific item TM, and the unit's operating policies.
- Disconnect any external or supplemental power sources, unless otherwise specified by the specific item TM.
- Turn off or disconnect any equipment pulling power from the batteries, aside from the engine.
- Once all TM procedures and unit policies are met, the operator may attempt to start the engine.

D-3. If after the third attempt to start an engine it does not start and idle unassisted, the operator or supervisor must contact a maintainer for assistance.

## PRIOR TO POWER AUGMENTED STARTUP

D-4. In a cold weather situation, vehicles or batteries need preparation before attempting power augmented startup. Along with the stating procedures specified in the item TM, maintainers should pay very close attention to the following cold weather starting considerations:

- Before starting work, soldiers must take safety precautions:
  - Ware gloves that protect from electrolyte contact and electrical shock.
  - Ware eye protection.
- Check that batteries fluids are not frozen. (If ice is found in a battery cell or suspected, STOP!)
- Check that at least minimal current is present (see if lights go on, for example).
- Check that batteries are of the same voltage.
- Check that both negative posts are grounded.
- Check battery posts, ensuring that they are free of deposit buildup and have solid connection.
- Make sure that vehicles are not touching.

- Make sure that master switches are off, ignition off, accessories off, communications equipment off; for both vehicles.
- Both vehicles are to have gears in "Park" or "Neutral," with brakes on. (This brake setting only applies during starting. (Otherwise, in cold, do not apply parking breaks to just park a vehicle.)
- Attach terminals, first to dead vehicle followed by vehicle with power.
- Start the engine of the vehicle supplying the auxiliary power.
- Adjust the engine idling speed of the powered vehicle to higher than normal.
- Wait 15 minutes for the battery(s) to charge before trying to start, if possible.

# USING AUXILIARY POWER RECEPTACLE

D-5. The auxiliary power (slave) receptacle is used to start a vehicle when otherwise good batteries are unable to supply enough starting current. The auxiliary power (slave) receptacle (figure D-1) is an electrical outlet located at a readily accessible place on the vehicle. It receives current from other tracked or wheeled vehicles. This provides direct boosting of the cold vehicle current when starting an engine in cold weather. The military is completing the transition from the U.S. slave cable connector system to the NATO connectors.

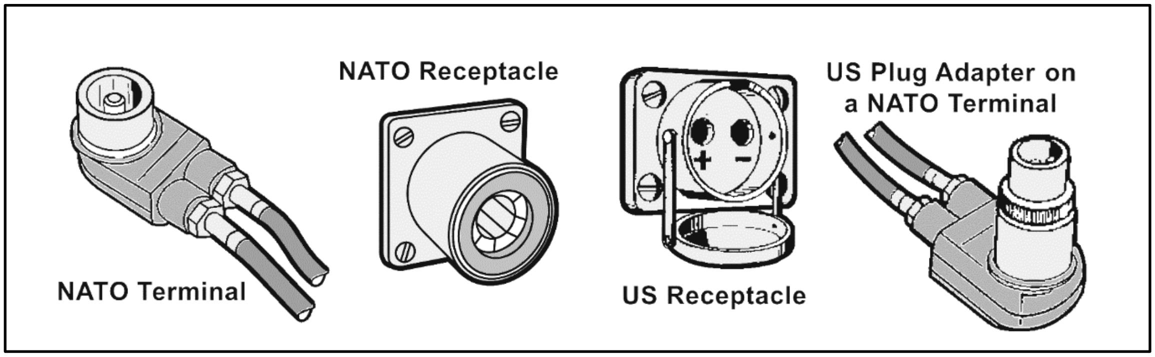


**Figure D-1. Auxiliary power receptacles and terminals**

## Appendix E

# Properties of Petroleum, Oils and Lubricants

This appendix provides planning information for commanders and staff pending their arrival in theater. The information herein represents what Soldiers and the unit must be prepared to deal with; not what they will actually encounter all of these products. The properties of POL products in this appendix are derived from military performance specifications which represent minimal capabilities, and not the full capabilities of any specific product. Units can consult with the theater Joint Petroleum Office, in coordination with the Army Petroleum Center for specific information on a POL product made available in theater.

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**NOTE:** Maintainers and operators should refer to the item specific TM or LO that is the primary information source for maintenance procedures.

**LEGEND NOTES:**

n/a = Information is "not available."

Flash point = The temperature at which the vapors of the liquid will ignite when there is a source of ignition.

Pour point = The lowest temperature at which a fuel or mixed fluid can remain totally liquid, below which the first components of the fluid freeze, or crystalize into a slush.

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## PETROLEUMS

E-1. The Army has adopted a single fuel policy (SFP), which is found in AR 70-12. This is focused on a single kerosene based fuel (SKBF) for use in all equipment. As maintainers and operators approach temperatures below -35°F (-37°C), they should be familiarized with alternative fuels for their equipment.

## JP-8

E-2. It is a kerosene based aviation fuel, blended with three additives. Under AR 70-12, it is the primary fuel for land-based air and ground forces in all theaters of operation outside the continental United States. For cold temperature environments, use it in accordance with MIL-DTL-83133 since A-A-52557A (28 June 2010) replaced the obsolete VV-F-800 specification that had included Diesel Fuel Arctic (DF-A). In CONUS F-24 is the primary fuel except when a fuel with a freeze point below -40°F (-40°C) (see F-24 section below) is required, then JP-8 shall be used.

- Definitive Standard: MIL-DTL-83133.
- NATO Code Number F-34.
- Special Characteristics: There are three additives for JP-8:
  - Fuel System Icing Inhibitor (FSII); MIL-DTL-85470; NATO#, S 1745.
  - Corrosion Inhibitor/Lubricity Improver (CI/LI); MIL-PRF-25017; S-1747.
  - Static Dissipater Additive (SDA).
- Flash point: 100°F (38°C), minimum.
- Freezing point: -53°F (-47°C), maximum.

**NOTE:** If JP-8 is not available outside the continental United States, the policy from the theater Joint Petroleum Office, in coordination with the Army Petroleum Center shall be sought for guidance on the use of the secondary fuels or any deviation from the SFP.

# F-24

E-3. In CONUS, F-24 is the primary fuel for air and land based forces. The exception is when a fuel with a freeze point below -40°F (-40°C) is required, then JP-8 is used. Having a NATO designation of F-24, it is defined in STANAG 3747/AFLP 3747 as meeting all performance requirements of ASTM International D1655 grade Jet A and must contain the three military additives: FSII, CI/LI, and SDA.

**NOTE:** ASTM used to stand for American Society for Testing and Materials. Today it is a part of the proper name for an international company. It is also used as a part of the short title to documents developed by this company.

E-4. The F-24 conversion in CONUS was a supply chain initiative to increase fuel sources available, increase operational flexibility, and increase procurement competition to reduce costs. The key difference between JP-8 and F-24 is freeze point. Otherwise, JP-8 and F-24 are completely compatible fuels for all CONUS operations. The Army Petroleum Center will monitor all product testing and stock rotation requirements. However, field testing requirements are as directed in the appropriate TM:

- Definitive Standard: NATO Standard, STANAG 3747/AFLP 3747.
- NATO Code Number F-24.
- Special Characteristics: There are three mandatory additives for F-24:
  - Fuel System Icing Inhibitor (FSII).
  - Corrosion Inhibitor/Lubricity Improver (CI/LI).
  - Static Dissipater Additive (SDA).
- Flash Point: 100°F (38°C), minimum.
- Freeze Point: -40°F (-40°C), maximum.

# COMMERCIAL JET FUEL

E-5. ASTM D1655 is the formulating specifications for purchases of “A” series aviation turbine fuel under contract. These specifications are international standards developed by ASTM International. The “A” series fuels are essentially identical to F-24 and JP-8 except that they do not necessarily contain the three military required additives found in F-24 or JP-8.

## JET A

E-6. This grade of fuel is only available within the U.S. where temperatures are expected to be relatively temperate. Commercial airlines have used this fuel for other than domestic flights when considering its freeze point and adjustment to flight pattern:

- Definitive Standards: ASTM D1655.
- Flash Point: 100°F (38°C), minimum.
- Freeze Point: -40°F (-40°C), maximum.

## JET A-1

E-7. This is the grade of commercial aviation turbine fuel available worldwide. This fuel can serve as an alternative to diesel fuel. Not recommended for use in ground equipment for more than one tankful without the addition of CI/LI:

- Definitive Standards: ASTM D1655.
- Flash Point: 100°F (38°C), minimum.
- Freeze Point: -52.6°F (-47°C), maximum.

### JET B

E-8. Jet B is a 70% naphtha- 30% kerosene based fuel used for its enhanced cold-weather performance:

- Definitive Standards: ASTM D6615.
- Flash Point: Due to the volatility of the fuel, Flash Point is not tested. Jet B will flash at extremely low temperatures.
- Freeze Point: −58°F (−50°C), maximum.

### JP-5

E-9. JP-5 is a unique military aviation fuel for use on Navy ships. Due to the Navy's shipboard safety requirements, it is required to have a substantially higher flash point than commercial aviation turbine fuels:

- Definitive Standard: MIL-DTL-5624.
- NATO Code: F-44.
- Flash Point: min. 140°F (60°C), minimum.
- Freeze Point: -51°F (-46°C), maximum.

### JP-4

E-10. JP-4 is a naphtha based fuel. This fuel is not considered to be an acceptable fuel in ground vehicles. The chief difference between JP-4 and Jet B is that JP-4 contains the three mandatory additives while Jet B does not unless requested during procurement. Where prevailing low temperatures warrant a fuel with very low temperature operability, the use of JP-4 is recommended by the U.S. Army Research and Development Engineering Command (RDECOM). Otherwise, JP-4 is classified as inactive:

- Definitive Standard: MIL-DTL-5624.
- NATO Code: F-40.
- Flash Point: Due to the volatility of the fuel, Flash Point is not tested. JP-4 will flash at extremely low temperatures.
- Freeze Point: −74°F (−58°C), maximum.

### NATO FUEL

E-11. Alternate and emergency ground fuels available with NATO are listed in the STANAG 1135.

### COMMERCIAL DIESEL

E-12. Commercially available fuel oil, diesel will be used as the primary fuel for all mobile and stationary compression ignition and turbine engine powered ground materiel in theaters of operation where the SFP cannot be or has not yet been implemented.

- Definitive Standard: ASTM D975.
- Flash Point: Number 1-D= 100°F (38°C) / Number 2-D= 126°F (52°C) minimum.
- Special Characteristics: The performance characteristics of diesel fuels vary greatly, due to the broad variety of regional standards and seasonal blends.

## OILS AND LUBRICANTS

E-13. Due to the tempo of modern warfare, and the scarcity of resources on a severe cold battlefield, operators need to be acutely aware of their options for keeping their equipment functioning.

## AUTOMOTIVE LUBRICANT PROPERTIES

E-14. Various Lubricating Oil, Internal Combustion Engine, Combat/Tactical Service, of various grades have been historically used in engine crank cases by the military. This is changing with the introduction of an original equipment / heavy duty oil (OE/HDO), termed the Single Common Powertrain Lubricant (SCPL).

The old oils were identified by the SAE classification for crude oil based lubricants. The crude oil products are characterized by a limited temperature range relative to synthetic oils.

## ENGINE OILS

E-15. OE/HDO-SCPL: It is recommended for extreme-cold conditions to help deliver quick starts and fast lubrication. Usually (based on item specific TM), this lubricant is approved for use in engines, power steering systems, and both automatic and standard transmissions. SCPL is intended to be a direct replacement for previous applications requiring a SAE 10W or the arctic engine oil. It is necessary to consult the LO prior to use. It is not recommended for 2-Cycle or aviation engines, unless specifically approved by the TM.

E-16. Operators must be careful, because the use of OEA or OE/HDO-SCPL may void the warranty in some transmission applications. As a general recommendation, when switching from OE/HDO-15/40, OE/HDO-40, OE/HDO-30, or OE/HDO-10 to SCPL, the oil drain interval may be doubled. For example, if you have a fleet of HMMWVs currently using OE/HDO-15/40 in the engine with a recommended oil drain interval of 6000 miles or 1-year and you change the oil to SCPL, your new oil drain interval would be 12000 miles or 2-years:

- Definitive Standard: MIL-PRF-2104.
- Military symbol: OE/HDO-SCPL
- NATO Code: n/a.
- Upper limitation: 120°F (49°C).
- Lower limitation: -58°F (-50°C).
- Flash Point: 410°F (210°C), minimum.
- Pour Point: -67°F (-55°C), maximum.

E-17. Oil, Engine, Arctic, OEA 0W-30: This oil is being phased out in favor of SCPL:

- Definitive Standard: MIL-PRF-46167.
- Military symbol: OEA-30.
- NATO Code: O-183.
- Upper limitation: 40°F (4°C).
- Lower limitation: -58°F (-50°C).
- Flash Point: 428°F (220°C), minimum.
- Pour Point: -67°F (-55°C), maximum.

E-18. Monograde lubricating oil, SAE 40:

- Military symbol: OE/HDO 40.
- NATO Code: n/a.
- Upper limitation: 120°F (49°C).
- Lower limitation: +20°F (-7°C).
- Flash Point: 437°F (225°C), minimum.
- Pour Point: +5°F (-15°C), maximum.

E-19. Multigrade lubricating oil, only rated for gasoline engines 10W-30:

- Military symbol: OE/HDO-10/30.
- NATO Code: n/a.
- Upper limitation: 120°F (49°C).
- Lower limitation: -15°F (-26°C).
- Flash Point: 401°F (205°C), minimum.
- Pour Point: -40°F (-40°C), maximum.

E-20. Multigrade lubricating oil, only rated for gasoline engines 5W-40 :

- Military symbol: OE/HDO-5/40.
- NATO Code: n/a.

- Upper limitation: 120°F (49°C).
- Lower limitation: -30°F (-34°C).
- Flash Point: 401°F (205°C), minimum.
- Pour Point: -40°F (-40°C), maximum.

E-21. Multigrade lubricating oil, 15W-40:

- Military symbol: OE/HDO-15/40.
- NATO Code: O-1236.
- Upper limitation: 120°F (49°C).
- Lower limitation: 0°F (-18°C).
- Flash Point: 419°F (215°C), minimum.
- Pour Point: --13°F (-25°C), maximum.

## TRANSMISSION OILS

E-22. The same difficulties which affect engine oils at low temperatures apply to transmission oils and greases used in other parts of military equipment. For automatic transmissions and hydraulic and power steering systems, OE/HDO-SCPL or OEA-30 can be used. OE/HDO-SCPL or OEA-30 is compatible with all types of automatic transmission fluids (including Dexron III). OE/HDO-SCPL or OEA-30 can be mixed with other transmission fluids or other transmission fluids can be added to it but degradation of the low temperature properties or other performance limits of the fluid may occur.

E-23. Some manufacturers for manual transmissions, transfers, differentials, and final drives may require different lubricants in specific applications.

E-24. For semiautomatic transmissions 15W-40 is the preferred oil (including in all Caterpillar series transmissions, and for 4500SP Allison transmissions for M1074 and M1075 model trucks), when temperatures permit:

- NATO Code: O-1236.
- Upper limitation: 212°F (100°C).
- (Transition point is at about, 0°F [-18°C]).
- Lower limitation: -10°F (-23°C).

## GEAR LUBRICATING OILS

E-25. The gear lubricating oils (military symbol, GO) are available in the following grades:

E-26. SAE Grade 75W-90:

- Definitive Standard: SAE J2360 (supersedes, MIL-PRF-2105 as of August 2008).
- Military symbol: GO-75.
- NATO Code: O-186.
- Upper limitation: 120°F (49°C).
- Lower limitation: -50°F (-45°C).
- Flash point: 302°F (150°C), minimum.

E-27. SAE Grade 80W-90:

- Definitive Standard: SAE J2360.
- Military symbol: GO-80/90.
- NATO Code: O-226.
- Upper limitation: 120°F (49°C).
- Lower limitation: -18°F (-27°C).
- Flash point: (165°C), minimum.

E-28. SAE Grade 85W-140:

- Definitive Standard: SAE J2360.

- Military symbol: GO-85/140.
- NATO Code: O-228.
- Upper limitation: 120°F (49°C).
- Lower limitation: +4°F (-15°C).
- Flash point: (180°C), minimum.

E-29. SAE 75W-90 synthetic oil is the alternative for manual transmissions, transfers, differentials, and final drives that normally use crude oil based GO85/140:

- Military symbol: GO-75.
- NATO Code: O-186.
- Upper limitation: 120°F (49°C).
- Lower limitation: -50°F (-45°C).
- Flash point: 302°F (150°C), minimum.

# WEAPON LUBRICANTS

E-30. Unless otherwise specified by MIL-PRF, the chemical formula of the oil is the prerogative of the contractor. All articles submitted to the Government must fully meet the operating, interface, support and ownership, and environmental standards that are specified in the MIL-PRF or procurement requirements. For example, some COTS synthetic oil versions of GPL/PL-S have an operating range of over +500ºF (+260°C), down to below -65ºF (-54°C). Deployment planners can only rely upon published generic information. However, maintenance leaders have the option to rely on product capability from data sheets for the products as they become available.

E-31. Lubricating Oil, General Purpose, Preservative (Water-Displacing, Low Temperature), is a crude oil based weapon systems lubricant for low temperatures. It is intended for lubrication and protecting against corrosion of certain small arms and automatic weapons and whenever a general purpose, water-displacing, low-temperature lubricating oil is required for other items besides weapons. This preservative oil should not be used to protect the fuel system or combustion chamber of engines.

- Standard: MIL-PRF-32033.
- Military symbol: PL-S (current), or GPL (the obsolete reference).
- NATO Code: O-190.
- Storage temperatures: 120°F (49°C) maximum.
- Upper limitation: 212°F (100°C).
- Lower limitation: -49°F (-45°C).
- Flash Point: 395°F (135°C), minimum.
- Pour Point: -60°F (-57°C), maximum.

E-32. Lubricant, Cleaner and Preservative for Weapons and Weapons Systems, is the primary lubricant for use in small arms weapons. It is a multi-purpose product that performs three functions of braking up carbon residue, lubricating metals as a penetrating oil, and repressing corrosion.

- Standard: MIL-PRF-63460.
- Military symbol: CLP.
- NATO Code: S-758.
- Storage temperatures: n/a.
- Upper useful limit: 160°F (71°C).
- Lower useful limit: -60°F (-51°C).
- Flash point: 149°F (65°C), minimum.
- Pour point: -74°F (-59°C), maximum.

E-33. Lubricant, Small Arms, Semi-Fluid, Automatic Weapons, is strictly a lubricant. It was deactivated in 1987, and then reactivated in September 2011. It is a petroleum-based (non-synthetic) lubricant mixed with a combination detergent, oxidation inhibitor, and corrosion inhibitors. It provides oxidation and corrosion resistance as well as rust protection and anti-wear properties.

**NOTE:** The M16 family of weapons was originally designed to be cleaned with RBC and lubricated with LSA. Before using them, Soldiers first have to use a dry cleaning solvent (SD-2) to remove any traces of CLP or any other lubricant.

- Standard: MIL-L-46000.
- Military symbol: LSA.
- NATO Code: O-158.
- Storage temperatures: n/a.
- Upper useful limit: 260°F (127°C).
- Lower useful limit: -65°F (-54°C).
- Flash point: n/a.
- Pour point: n/a.

**WARNING**

**CLP must NOT be mixed with any other lubricant, or it will gum up. It is design is to be the only thing used on a working weapon, when used.**

E-34. Lubricant, Weapons, Semi-Fluid (High Load-Carrying Capacity), is a lubricant that consists of LSA lubricant with polytetrafluoroethylene (PTFE, better known by the trade name Teflon®) molding powder added for improved lubrication. It is used on several large-caliber weapons systems, various aircraft, naval ships, and grenade launchers. It’s still authorized for use on rifles, pistols, and as a cleaning and sharpening oil for bayonets. Because the Teflon® is suspended in the petroleum, shake it well, before use.

- Standard: MIL-L-46150.
- Military symbol: LSAT.
- NATO Code: none.
- Storage temperatures: n/a.
- Upper useful limit: 250°F (121°C).
- Lower useful limit: -30°F (-34°C).
- Flash point: n/a.
- Pour point: n/a.

E-35. Lubricating Oil, Weapons, Low Temperature, is used for the lubrication and preservation of small arms and light caliber weapons up to 20mm. It is based on synthetic hydrocarbon oil with hydrolysis, corrosion and oxidation inhibitors.

- Standard: MIL-PRF-14107.
- Military symbol: LAW.
- NATO Code: O-157.
- Storage temperatures: Keep below 122°F (50°C), and out of direct sunlight.
- Upper useful limit: 0°F (-17.8°C).
- Lower useful limit: -70°F (-56.6°C).
- Flash point: 305°F (162.7°C), minimum.
- Pour point: -75°F (-59.4°C), maximum.

# GREASE LUBRICANTS

E-36. The function of a grease is to adhere to an item and provide lubrication, regardless of position or open exposure. The upper and lower limits are general functional temperature regions that most equipment is engineered to accept. Beyond those temperatures the properties of the grease changes. It becomes too thick or thin to maintain its optimum protection. At the dropping point or freeze point, the grease ceases to be functional. The dropping point represents when a grease becomes so hot that it could fall free of the item it supposed to be protecting; the petroleum component runs like water, and the thickener burns such that it can no longer gel with the lubricant oils. At the freeze point, the lubricants begin to crystalize into a solid, leaving the thickener to be damaged by the friction.

E-37. Grease, Automotive and Artillery.

- Standard: MIL-PRF-10924.
- Military symbol: GAA.
- NATO Code: G-403.
- Upper Limit: 356ºF (180°C).
- Lower Limit: -65ºF (-54°C).
- Dropping point: 428°F (220°C), minimum.
- Freeze Point: n/a.

E-38. Grease, Aircraft, General Purpose, Wide Temperature Range (Grease).

- Standard: MIL-PRF-81322.
- Military symbol: WTR.
- NATO Code: G-395.
- Upper Limit: 350°F (177°C).
- Lower Limit: -65°F (-54°C).
- Dropping point: 450°F (232°C), minimum.
- Freeze Point: -80°F (-62°C), maximum.

E-39. Grease, Aircraft and Instrument, Gear and Actuator Screw

- Standard: MIL-PRF-23827.
- Military symbol: GIA.
- NATO Code (for Type-I): G-354.
- Upper Limit: 250°F (121°C).
- Lower Limit: -99°F (-73°C).
- Dropping point: 165°F (165°C), minimum.
- Freeze Point: n/a.

E-40. Grease, Molybdenum Disulfide, For Low and High Temperatures

- Standard: MIL-G-21164.
- Military symbol: GMD.
- NATO Code: G-353.
- Upper Limit: 250°F (121°C).
- Lower Limit: -100°F (-73°C).
- Dropping point: 329°F (165°C), minimum.
- Freeze Point: n/a.

E-41. Grease, Graphite.

- Standard: VV-G-671G.
- Military symbol: n/a.
- NATO Code: G-412.
- Upper Limit: 140°F (60°C).
- Lower Limit: -9°F (-23°C).
- Dropping point: 185°F (85°C), minimum.
- Freeze Point: n/a.

# HYDRAULIC FLUIDS

E-42. Hydraulic Fluid, Petroleum Base, For Preservation and Operation, is the oldest of the Army's hydraulic fluids. Its utility was called into question when the Middle East conflicts in 1973 initially revealed that the hydraulic fluids were contributing to fires in armored vehicles.

- Standard: MIL-PRF-6083.
- NATO Code: C-635.
- Military symbol: OHT.
- Storage temperatures: -70°F (-57°C) to 120°F (49°C).
- Upper useful limit: 275F (135°C)
- Lower useful limit: -65°F (-54°C).
- Flash point: 180°F (82°C).
- Pour point: -76°F (-59°C).

E-43. Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base, is a corrosion inhibited, synthetic-based hydraulic using polymer, alpha-olefins (PAO) that are up to 70% more fire resistant than OHT. It is intended for use in recoil mechanisms and hydraulic systems of military ground vehicles and equipment. However, not all vehicles and equipment have been revised to accommodate FRH, in part because FRH does not perform well at low temperatures.

- Standard: MIL-PRF-46170.
- Military symbol: FRH.
- NATO Code: H-544.
- Storage temperatures: -71°F (-57°C) to 160°F (71°C).
- Upper useful limit: 392°F (200°C).
- Lower useful limit: -40°F (-40°C).
- Auto-ignition temperature: 649°F (343°C), minimum.
- Fire point: 475ºF (246°C), minimum.
- Flash point: 424°F (218°C), minimum.
- Pour point: -65°F (-54°C), maximum.

E-44. Hydraulic Fluid, Petroleum Base; Aircraft, Missile, And Ordnance, is intended for aircraft, it can occasionally be found in ground equipment, such as generators and tracked personnel carriers. However, TARDEC recommends OHT or FRH because OHA does not contain corrosion inhibitors.

- Standard: MIL-PRF-5606 (superseded by MIL-PRF-87257 and/or MIL-PRF-83282).
- Military symbol: OHA.
- NATO Code: H-515.
- Storage temperatures: -71°F (-57°C) to 120°F (49°C).
- Upper useful limit: 275°F (135°C).
- Lower useful limit: -65°F (-54°C).
- Flash point: 180°F (82°C), minimum.
- Pour point: -76°F (-60°C), maximum.

E-45. Bio: This is a family of biobased hydraulic fluid (BHF) made with renewable resources for use in environmentally sensitive areas. It was developed to cover hydraulic fluid requirements for military construction equipment, bridging, tactical vehicles, shipboard hydraulic systems, and metal tool hydraulic systems. Since these fluids are compatible with existing petroleum-based fluids, changing to biobased fluids does not require a major hydraulic system cleaning. Within this performance specification, biobased hydraulic fluids are divided into five grades (table E-1), whose key temperature properties are presented below.

- Standard: MIL-PRF-32073.
- Military symbol: BHF.
- NATO Code: n/a.

**Table E-1. Biobased hydraulic fluid key temperature properties**

| *Property* | *Military Grade* | | | | |
|---|---|---|---|---|---|
| | ***1*** | ***2*** | ***3*** | ***4*** | ***5*** |
| ***Flash point, minimum*** | 320°F (160°C) | 320°F (160°C) | 464°F (240°C) | 482°F (250°C) | 509°F (265°C) |
| ***Pour point, maximum*** | -65°F (-54°C) | -44°F (-42°C) | -22°F (-30°C) | -13°F (-25°C) | -9°F (-23°C) |
| ***Low temperature storage*** | -65°F (–54°C) | –40°F (–40°C) | -13°F (–25°C) | +5°F (–15°C) | +5°F (–15°C) |

E-46. Hydraulic Fluid, Fire Resistant, Synthetic Hydrocarbon-Base, Metric, is intended for aviation use in automatic pilots, shock absorbers, air compressor gear boxes, brakes, flap-control mechanisms, missile hydraulic servo-controlled systems and other hydraulic systems using synthetic sealing material.

- Standard: MIL-PRF-83282.
- Military symbol: n/a.
- NATO Code: H-537.
- Storage temperatures: -40°F (-40°C) to 122°F (50°C).
- Upper useful limit: 401°F (205°C).
- Lower useful limit: -40°F (-40°C).
- Flash point: 401°F (205°C), minimum.
- Pour point: -67°F (-55°C), maximum.

E-47. Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile, is a synthetic hydrocarbon base hydraulic fluid for use in in aircraft and missile hydraulic systems.

- Standard: MIL-PRF-87257.
- NATO Code No. H-538.
- Upper useful limit: 392°F (200°C).
- Lower useful limit: -65°F (-54°C).
- Flash point: 320°F (160°C), minimum.
- Pour Point: -76°F (-60°C), maximum.

E-48. Brake Fluid, Silicone, Automotive, All-Weather, Operational and Preservative.

- Standard: MIL-PRF-46176.
- Military symbol: BFS
- NATO Code No. H-547.
- Upper useful limit: 131°F (55°C).
- Lower useful limit: -67°F (-55°C).
- Flash point: 401°F (205°C), minimum.
- Pour Point: -67°F (-55°C), maximum.

# SOLVENTS AND CLEANERS

E-49. Cleaning Compound, Solvent (for the bore of weapons), is designed specifically for cleaning out carbon and powder from the chamber and bore of a weapon; it is *NOT* a lubricant or a degreaser. It works best for really tough cleaning after heavy shooting. After using RBC (meaning, rifle bore cleaner), weapons must be re-lubricated.

- Standard: MIL-PRF-372.
- Military symbol: RBC.
- NATO Code: none.

- Storage temperatures: -65°F (-54°C) to 77°F (25°C).
- Upper useful limit: 110°F (43°C).
- Lower useful limit: 32°F (0°C).
- Flash point: 110°F (43°C), minimum.
- Pour point: 32°F (0°C).
- Freeze point: -65°F (-54°C), maximum.

E-50. The solvents under MIL-PRF-680 are petroleum distillate degreasing solvents used for degreasing of machine parts in equipment maintenance. They is also known as "mineral spirits" or as "petroleum spirits." Degreasing Solvent, Type II, High Flash Point, is used for weapons or lubricated parts cleaning during the change over from one lubricant to another. As a dry cleaning solvent, it will remove all petroleum and synthetic lubricants, including penetrating oils which have soaked into the micro-fractures of the metal, leaving a totally dry weapon or part. SD-2 does not remove rust and oxidation. Do not use SD-2 on rubber, plastic, or sealed buffers. Always degrease thoroughly when changing lubes.

- Standard: MIL-PRF-680.
- Military symbol: SD-2.
- NATO Code: S-753.
- Storage temperatures: n/a.
- Flash point (range): 140°F-198°F (61°C –92°C).
- Upper useful limit: n/a.
- Lower useful limit: n/a.
- Freeze point: n/a.

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## Appendix F

# Environmental Protection Concerns

F-1. In spite of the difficulties cold weather may present to unit operations and maintenance, leaders must remember that units are still required to comply with federal, state, local, and host-nation environmental regulations. The accumulated waste fluid should be disposed of through a waste oil recovery program unless prohibited by local law. The reference for federal regulations are promulgated by the U.S. Environmental Protection Agency under Public Law 94-580, the Resource Conservation and Recovery Act of 1976.

F-2. Many cold weather areas contain fragile environmental ecosystems that could be damaged significantly by spills or improper hazardous waste and materials disposal. Increased fuel consumption coupled with the use of special oils, lubricants, batteries, and the failure of equipment from low temperatures increases the possibility of environmental damage.

F-3. In light of the increased risk, it is important that leaders conduct unit environmental self-assessments prior to deploying to a cold weather area. They must ensure that the resulting risks are made part of the unit environmental awareness training program.

F-4. Guidance for Risk Management/Operational Risk Management (RM/ORM) process is contained in appendix C, ATP 3-34.5. JP 3-0, *Doctrine for Joint Operations,* outlines the RM/ORM process and provides the framework for integrated RM/ORM as a routine part of planning, preparing, and executing operational missions and everyday tasks. Probability and severity are estimates requiring individual judgment and a working knowledge of the RM/ORM process and its terminology. (See ATP 5-19 and GTA 05-08-002, *Environmental-Related Risk Assessment*, for the five degrees of probability for a hazard, the four degrees of severity for a hazard, and how to determine the risk category.) The self-assessment looks at the following: management, waste-oil storage, hazardous material/ hazardous wastes, solid-waste management, spill prevention, recycle program, wash-racks, and land management. RM/ORM is the primary tool for conducting a unit environmental assessment and should be supplemented by local regulations.

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# Glossary

## SECTION I – ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| **ADP** | Army doctrine publication |
| **ADRP** | Army doctrine reference publication |
| **AFLP** | Air Force lead program |
| **AGM** | absorbent glass mat |
| **AMEDDC&S** | Army Medical Department Center and School |
| **AMMPS** | Advanced Medium Mobile Power Sources |
| **AOAP** | Army oil analysis program |
| **AR** | Army regulation |
| **ASTM** | American Society for Testing Materials, International |
| **ATP** | Army techniques publication |
| **BFS** | brake fluid, silicon |
| **BHF** | biobased hydraulic fluid |
| **CASCOM** | Combat Arms Support Command |
| **C-E** | communications electronics |
| **CI/LI** | corrosion inhibitor/lubricity improver |
| **CLP** | cleaner lubricant preservative |
| **CONUS** | continental United States |
| **COTS** | commercial off the shelf |
| **DF** | diesel fuel |
| **DF-A** | diesel fuel, arctic |
| **DIEGME** | diethylene glycol monomethyl ether |
| **DLA** | Defence Logistics Agency |
| **DLP** | digital light processing |
| **DOD** | Department of Defence |
| **DMD** | digital micro mirror device |
| **ECWCS** | extended cold weather clothing system |
| **FM** | field manual |
| **FMTV** | family of medium tactical vehicles |
| **FRH** | fire resistant hydraulic |
| **FSII** | fuel system icing inhibitor |
| **GAA** | grease automotive and artillery |
| **GSA** | General Services Adminitration |
| **GEL** | gelatin silicate electrolyte |
| **GIA** | grease, instrument and aircraft |
| **GMD** | grease, molybdenum disulfide |
| **GO** | gear oil |
| **GPL** | general purpose lubricant |
| **HMMWV** | high mobility multi-purpose wheeled vehicle |

| | |
|---|---|
| **JP** | jet propulsion fuel |
| **SKBF** | kerosene based fuel |
| **LAW** | lubricant arctic weight |
| **LCD** | liquid crystal display |
| **LCD-TFT** | liquid crystal display, thin film transistor |
| **LED** | light emitting diode |
| **Li-Ion** | lithium-ion (rechargeable battery) |
| **Li-Po** | lithium polymer |
| **LO** | lubrication order |
| **LSA** | lubricant, small arms |
| **LSAT** | lubricant, small arms, teflon® |
| **MED** | medical |
| **MEP** | mobile electric power |
| **MIL-PRF** | military performance (standards) |
| **m/s** | military supply symbol |
| **MTG** | military tactical generator |
| **NATO** | North Atlantic Treaty Organization |
| **NiCd** | nickel cadmium |
| **NiMH** | nickel metal hydrayte |
| **NSN** | national stock number |
| **n/a** | not available |
| **OCONUS** | outside the continental United States |
| **OEA** | oil, engine, arctic |
| **OE/HDO** | original equipment / heavy duty oil |
| **OHA** | supply code for MIL-H-5606, hydraulic fluid |
| **OHT** | supply code for MIL-PRF-6083, hydraulic fluid |
| **OLED** | organic light emiting diode |
| **OSHA** | Occupational Safety and Health Agency |
| **PDISE** | power distribution illumination system, electrical |
| **PDP** | plasma display panel |
| **PLS** | palletized load system |
| **PL-S** | preservative lubricant, |
| **PMCS** | preventive maintenance, checks and services |
| **POL** | petroleum, oils, and lubricants |
| **PPE** | personal protective equipment |
| **PTO** | power takeoff |
| **PU/PP** | Power Units/Power Plants |
| **RBC** | rifle bore cleaner |
| **RM/ORM** | risk management/operational risk management |
| **RG** | radio guide |
| **ROC** | rehearsal of capabilities |

| | |
|---|---|
| **SAE** | Society of Automotive Engineers |
| **SCPL** | single common powertrain lubricant |
| **SD** | solvant, degreasing |
| **SDA** | static dissipater additive |
| **SFP** | single fuel policy |
| **SHF** | single hydraulic fluid |
| **SKBF** | single kerosene based fuel |
| **SOC** | state-of-charge, battery |
| **STANAG** | standard aggrement, NATO |
| **SWGK** | surface wire grounding kit |
| **SWOT** | strengths, weaknesses, opportunities, and threats |
| **TARDEC** | Tank Automotive Research, Development and Enginering Center |
| **TB** | technical bulletin |
| **TFT** | thin film transistor |
| **TR** | Training and Doctrine Command regulation |
| **TRADOC** | Training and Doctrine Command |
| **TM** | technical manual |
| **TO&E** | table of organization and equipment |
| **TQG** | tactical quiet generators |
| **UPS** | uninterrupted power supply |
| **U.S.** | United States |
| **USACASCOM** | United States Army Combined Arms Support Command |
| **WTR** | wide temperature range |

## SECTION II – TERMS

**acclimatization**

The natural process of a person or organism's adjusting to changes in the environmental situation over time.

**cold-soaked**

An item or material has cooled to an ambient air temperature that impedes it proper functioning. Material that is so cold it poses a risk to Soldiers' welfare or a risk of material damage occurring during routine use.

**engine heater**

An electrical or mechanical heating device used to preheat engine fluids (antifreeze or lubricants), to ease engine starting.

**equalizing bars**

A part within some equilibrator mechanisms used to hold counter-balance springs for cannons in position.

**equilibrator**

A spring or hydraulic mechanism used to counter balance the weight of a cannon's overhanging barrel.

**freezing point (fuel)**

The temperature were the fuel first begins to turn into a waxy slush.

**gas-check pad**

A gasket at the rear of a cannon (a part of the breach mechanism) which under the pressure of exploding gasses, seals the gasses from venting out the back of the cannon barrel.

**personal protective equipment**

Any clothing, accessories, equipment, or substance which protects personnel from suffering job related injuries, or damage to personal clothing and equipment during mishaps.

**pour point (lubricants)**

The temperature were the lubricant become so thick or stiff that it fails a pour test.

**space heater**

A portable heating device intended for use in a shelter or temporary structure.

**severe cold**

Situations in general of about +19°F (-7°C), or colder. Cold weather conditions of around-the-clock freezing temperatures.

**SWOT analysis**

A comprehensive strategic analysis and structured planning method for identifying and evaluating strengths, weaknesses, opportunities, and threats involved in a venture.

**travel lock**

A bracket with a cradle or pinion for securing a cannon or weapon barrel from swinging about while traveling.

**trigger event**

A predefined event that when it occurs, causes something else to happen.

**turnover point**

A place or time during the progression of an operation where a prominent factor or resource is changed.

**winterization**

Modifications listed in the item's TM made to vehicles, weapons, equipment, machines, or related apparatus that restores or extends its serviceability for cold weather operations.

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