
**ARCTIC AND COLD WEATHER MAINTENANCE
OPERATIONS**

DECEMBER 2025

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ARCTIC AND COLD WEATHER MAINTENANCE OPERATIONS

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Preface

TM 4-33.31 describes principles for planning, establishing, and executing maintenance operations in protracted extreme cold weather environments. Furthermore, this publication describes principles of maintenance operations and precautions for equipment operators and their supervisors.

The principal audience for this TM is all members of the profession of arms. Commanders and staffs of Army headquarters serving as joint task force or multinational headquarters should also refer to applicable joint or multinational doctrine concerning the range of military operations and joint or multinational forces. Trainers and educators throughout the Army will also use this publication.

Commanders, staffs, and subordinates need to ensure their decisions and actions comply with applicable United States, international, and, in some cases, host-nation laws and regulations. Commanders at all levels will ensure that their Service members operate in accordance with the law of armed conflict and the rules of engagement (see FM 6-27 for legal compliance).

TM 4-33.31 uses joint terms where applicable. Selected joint and Army terms and definitions appear in both the glossary and the text. TM 4-33.31 is not the proponent publication for any terms or definitions. For other definitions shown in the text, the term is italicized, and the number of the proponent publication follows the definition.

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 stated.

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. Send comments and recommendations on a 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.list.cascom-g3-5-7-tdid-doc@army.mil.

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Introduction

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

Leaders must be familiar with ATP 3-90.96—the Army's manual for cold weather operations. It provides the doctrinal foundation to understand the Arctic region's operational environment and how to conduct military operations in it. The fundamentals of the manual are applicable to all cold weather environments.

Military operations in extreme cold conditions occur at the limit of what is safe and what is dangerous. TM 4-33.31 is focused on a combat environment where Soldiers cannot always count on the availability of resources that sustain them in garrison. This manual assist unit commanders, supervisors (maintenance officers, maintenance technicians, motor sergeants, and section leaders), and maintenance personnel in anticipating and planning for the onset of extreme cold weather or an arctic deployment. Further, it is the intent of this manual to stimulate creativity and forward thinking and support the development of mission-focused standard operating procedures.

TM 4-33.31 is intended to familiarize equipment operators and maintainers on the unique difficulties of maintenance in extreme cold weather. This TM shows ways to adjust maintenance operations in arctic and extreme cold weather, and the expected performance of materials below freezing temperatures. It provides a consolidated overview of the special and unique difficulties that Soldiers can expect to encounter while performing field maintenance in extreme cold weather environments.

Maintainers and operators should refer to the equipment or weapon system specific TM or lubrication order (LO) as the primary source of information and guidance for equipment maintenance and operation. Failure to follow this guidance and the instructions provided in the item-specific TM can result in injury to personnel and damage to equipment.

This TM provides general information on ground equipment maintenance in cold weather environments and compliments ADP 4-0, FM 4-0, ATP 4-33, ATP 3-90.96, and other related technical publications.

TM 4-33.31 is written within a very narrow context. The focus of this TM is planning and execution of maintenance operations in arctic and extreme cold environments. The tactical combat employment of weapons and equipment is beyond the scope of this publication. Likewise, these 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.

Although little is written here about preventive maintenance checks and services, conducting them at the required interval remains a critical task. To avoid redundancy, the focus of this publication is more on general material characteristics; it does not replace equipment 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. Nonetheless, the principles that underpin this TM should remain valid and relevant.

TM 4-33.31 contains eight chapters and five appendices. Each chapter is written as a stand-alone treatment of the chapter subject material. There may be some repetition of information and guidance:

Chapter 1 provides commanders and leaders with key tasks and an overview of maintenance operations in extreme cold conditions. This chapter discusses maintenance planning with a greater emphasis on risk management, quality and safety.

Chapter 2 provides general information on the properties and performance of parts and materials in cold environments.

Chapter 3 examines the best practices for each type of automotive battery technology as applicable to the Army.

Chapter 4 discusses petroleum, oils and lubricant products and the Army's single fuel policy.

Chapter 5 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.

Chapter 6 highlights a variety of issues common to maintaining the functional capability of any small arms in a cold environment.

Chapter 7 provides an overview of crew-served weapons systems.

Chapter 8 looks at ways that Soldiers can act to protect and operate electrical and electronic devices and equipment in cold.

Appendix A provides considerations for unit maintenance standard operating procedures, policies, priorities and procedures.

Appendix B provides a quick reference for battery maintenance personnel in the event of an emergency.

Appendix C discusses best practices for starting a vehicle engine in cold weather.

Appendix D provides information on the properties of common petroleum, oils and lubricant products used by U.S. ground forces.

Appendix E serves as a reminder for units to comply with federal, state, local, and host-nation environmental regulations. Conformity to such regulations becomes a part of the command risk assessment and response planning.

Chapter 1

Cold and Arctic Weather Maintenance

This chapter provides an overview of arctic and cold weather maintenance and identifies maintenance challenges relating to cold weather operations. It provides guidance on risk management, quality, safety, and soldier welfare. The chapter also discusses fuel-burning personnel heaters, maintenance facilities, and commercial off-the-shelf equipment considerations.

THE COLD WEATHER CHALLENGE

1-1. Operating in the cold has its own unique challenges. Leaders must ensure that weapons, vehicles, and any other equipment are fully winterized to withstand the cold as outlined in their respective technical manuals (TMs). Leaders will also have to draw upon experience and find viable and creative solutions to overcome maintenance challenges in the cold and successfully conduct operations.

Note. Leaders must be familiar with ATP 3-90.96, the Army's manual for cold weather operations.

Maintainers and operators should refer to equipment TMs and lubrication orders (LOs) as the primary sources of information for equipment operations, component or system theories of operations, characteristics, limitations, and maintenance procedures.

1-2. More than half of the earth's dry land surface encounters freezing temperatures for at least one month every year. In some cases, military forces may need to carry out sustained operations in temperatures as low as -65 Fahrenheit (°F) (-54 Celsius [°C]) or lower. For military purposes, a cold region is an area where snow or cold temperatures hinder movement or operations for more than one month per year. In such challenging conditions, personnel may suffer from decreased efficiency and are at risk of cold-related injuries. Additionally, vehicles, equipment, and devices are susceptible to frequent breakdowns, supply issues may become more prominent, and operations may be significantly constrained and complicated in extreme cold weather environments.

1-3. Operations in extreme cold weather conditions have command-wide implications for equipment readiness. To say that something is cold-soaked means that it poses a risk to Soldier welfare or a risk of equipment damage occurring during moderate operation. Getting ahead of the cold challenge will require adaptive leadership and innovative or creative thinking. Collaboration will be required between the maintenance team and the unit leadership.

1-4. Unit leaders are responsible for ensuring that personnel and equipment can withstand the challenges of extreme cold weather. Army equipment and devices are exceptional in performing in extreme cold climates. However, it is crucial for Soldiers and their leaders to understand the effects of extreme cold weather on equipment. Leaders must plan, train, and practice unit operations in harsh weather conditions.

Note. Army regulations and doctrine standards do not specify a minimum temperature down to which military units must be capable of operating.

1-5. 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 are shown in Figure 1-1 on page 2. Although the following figure does not conform to general military temperature categories, it can help provide planners with historical weather data.

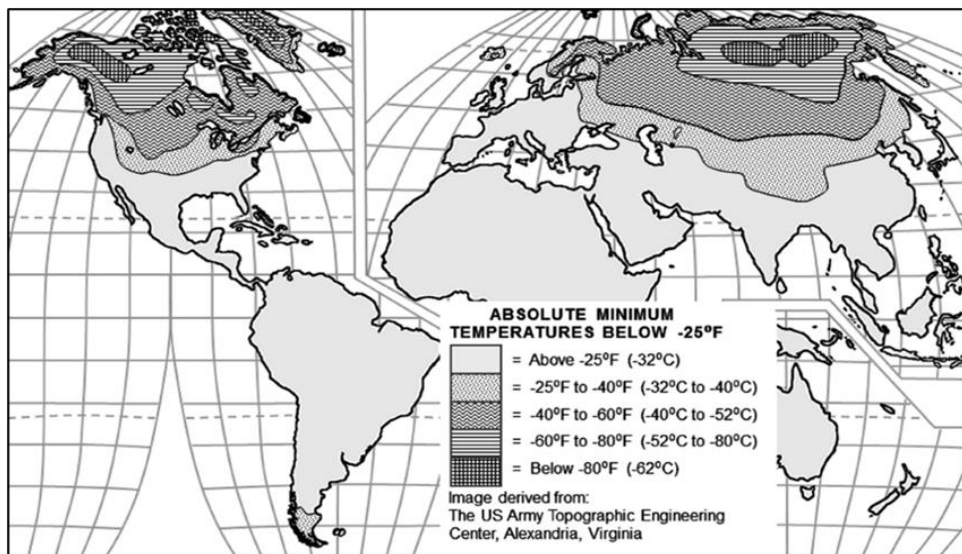


Figure 1-1. Cold regions of the world

COLD WEATHER OPERATIONS

1-6. Commanders and leaders understand that as temperatures drop below freezing, the unit's ability to maintain its normal high degree of operational pace will decline due to both human factors and materiel factors. However, this decline can be managed, and units can still achieve mission success through deliberate planning, intentional realistic training, and effective leadership.

1-7. Operating equipment in temperatures above 10°F (-12°C) presents few problems. Conditions are like those experienced during winter in the northern part of the continental United States (CONUS).

1-8. ATP 3-90.96 classifies cold temperatures below the temperate weather range into five categories as depicted in Figure 1-2. The temperature categories are as follows:

- Wet cold is between 39°F and 20°F, (4°C to -6°C).
- Dry cold is between 19°F and -4°F, (-7°C to -20°C).
- Intense cold is between -5°F and -25°F, (-21°C to -32°C).
- Extreme cold is between -25°F and -40°F, (-32°C to -40°C).
- Hazardous cold is -40°F (-40°C) and below.

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

1-9. Wet-cold conditions occur when wet snow and rain often accompany cold conditions. A wet-cold environment poses a greater threat to troops and equipment than a dry and cold environment due to the ground becoming slushy and muddy and clothing and equipment becoming 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. The freezing point is the temperature at which a liquid or liquid-like substance or material changes its state to solid. As temperatures warm, heavy equipment can sink into softening ground or mud and become immobilized. Should the temperatures turn back to freezing, the immobilized vehicle can freeze in place as the ground hardens. This makes planning equipment recovery operations problematic.

1-10. Operations become more difficult under dry cold and intense cold temperatures (from 19°F [-7°C] to -25°F [-32°C]). At the warmer end of this range, lack of winterization results in only a slight loss of operating efficiency. Winterization is a modification listed in the equipment TM that is made to vehicles, weapons, equipment, machines, or related apparatus to adapt to the environmental conditions and restore or extend serviceability.

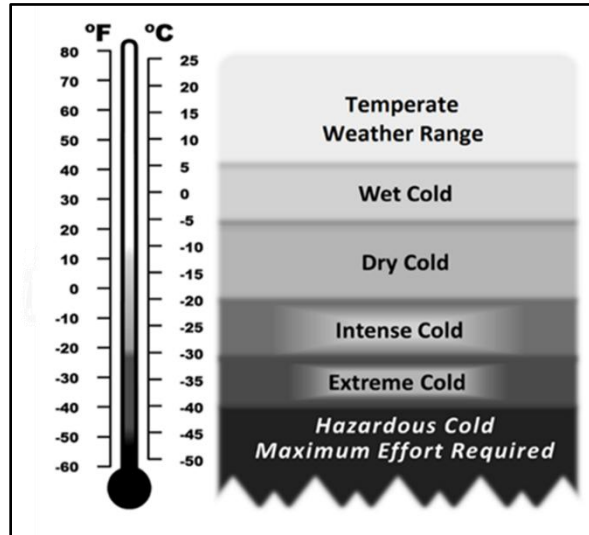


Figure 1-2. Categories of cold at various temperature ranges

1-11. Non-acclimated troops usually show signs of having difficulty at cold temperatures above -10°F (-23°C). Operations become extreme when temperatures drop below -25°F (-32°C). Operations become hazardous at near -40°F (-40°C), and temperatures lower than that require maximum efforts of well-trained personnel to perform the simplest tasks. These difficulties occur even with fully winterized uniforms and equipment.

1-12. The wind chill effect makes the atmospheric temperature feel colder than the actual air temperature. It is a concept that relates to the rate of heat loss from personnel under windy conditions. Wind chill removes heat from the body faster, driving down skin temperature and, eventually, internal body temperature. Commanders and staffs need to factor in the wind chill index during planning, and leaders must constantly evaluate weather conditions as operations are underway.

PLANNING

1-13. Extreme-cold and hazardous-cold adversely affect the ability of a unit to accomplish its mission. Understanding the specific impacts of a cold environment on materiel and personnel performance can help units in planning measures to counter these effects. Maintenance leaders need to identify the probable duration and severity of the cold weather and adjust their plans and policies accordingly. Maintainers and operators performing maintenance are subjected to different risks than Soldiers on foot patrol. For example, bulky clothing is easily caught on jagged edges, moving parts, or in tight spaces, which can cause personal injury. Also, mechanics laying on their backs on frozen ground to get under vehicles can expose them to hypothermia or pneumonia risk that standing Soldiers would otherwise avoid.

1-14. Planning for cold weather operations requires the full range of Army planning methodologies found in ADP 5-0 and ADP 4-0. When planning for missions in cold weather, leaders must realistically evaluate the impact that physical factors will have on both tactical and sustainment operations. For example, units are less maneuverable in icy conditions or deep snow. Deep snow reduces vehicle 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 have reduced mobility. Emplacement of artillery pieces for fire missions is very difficult. Operators must be very proficient in basic skills that in more temperate zones they might have taken for granted, including keeping moving parts free to cycle, equipment recovery, working with tire chains, and slave starting.

1-15. Cold weather environments hinder mobility and restrict supply lines. Maintenance planners must account for potential delays in the resupply of repair parts and may consider advanced manufacturing solutions (where practical) to overcome supply shortfalls. See ATP 4-31 for more information on advanced manufacturing.

1-16. Leaders should draft contingency plans for their units in case of a “no-notice” deployment into a cold region. For maintenance, leaders should develop standby requests for winterization equipment and 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 anticipated, conducting cold weather operations rehearsal of capabilities (called ROC) drills is beneficial for developing unit leaders. Operators should train on using snow chains, 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.

1-17. Planning is critical to the success and survival of units operating in cold weather. Planning for cold weather operations should begin long before the actual onset of freezing temperatures. Sufficient time must be allotted to inventory and order necessary winterization items. After the arrival of winterization items, additional time is needed for leaders to train and license (or certify) Soldiers in proper cold weather procedures and the use of specialized equipment. Planners should consider the following:

- Plans must be both detailed and flexible.
- Unit operating procedures must conform to command policy and local command supplements on Army safety management and risk management.
- The cold will make mission command more difficult.
- Personnel must be properly trained and prepared.
- Cross training will be needed to maintain operating tempo.
- All units, especially mechanized and armored, will require more time to accomplish tasks; the 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.
- Anticipate a potential increase in medical problems (for example, injuries from fatigue, frostbite, hypothermia, pneumonia, dehydration, and even heat casualties). 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.
- Field feeding operations will need to include providing a continuous supply of warm supplemental rations to accommodate the increased caloric demands of working in the cold.
- Leadership must establish a regimen to more carefully monitor Soldier hygiene to prevent Soldiers from cutting corners on personal care and hygiene due to fatigue and the discomfort of the cold.
- Establish policy and procedures to ensure that documentation in Soldier medical records identifies all cold injury medical diagnoses.

1-18. Commanders will need their maintainers’ expertise to assess the serviceability of cold weather protection equipment and devices. Commanders will also need the expertise of medical personnel to assess the procedures for Soldier care in cold weather. Considerations may include—

- 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.
- Identifying equipment susceptible to condensation damage and providing 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 presence in maintenance areas.

- Adequate first aid kits, eye wash stations, and toxic chemical rinse-off stations.
- Hazardous materials (HAZMAT) storage. Understand current laws and command policy.
- Survival kits and bags to protect against the cold.

TRAINING

1-19. Since most U.S. units are stationed in temperate or tropical climates, Soldiers generally lack adequate training or experience in cold weather operations and maintenance. Commanders must ensure that Soldiers stationed in temperate climates are prepared to deploy to cold climates and conduct operations effectively. This preparation entails proper planning, training, and equipping. Expertise in cold weather operations will grow from experience and cannot be gained solely from reading a manual. Applicable training and operational experience are necessary to develop successful cold weather field techniques. Refer to ATP 3-90.96 and TC 21-3.

1-20. First-line supervisors will need to assess their personnel to determine what types of specialized cold weather training or refresher training may be necessary. Maintenance training for cold weather environments should focus on—

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

1-21. Commanders should schedule a specific day or trigger event for the unit to convert from normal temperate weather operations to cold weather operations. A trigger event is a predetermined or predefined event that causes a change or something to happen. It is at this point that the rules change for personal care and the care of equipment. The unit must prepare for such an operational conversion prior to the trigger event.

Soldier Health and Welfare

1-22. Cold injuries are most likely to occur when unprepared personnel are exposed to cold temperatures, even with the proper planning and equipment. The category of cold weather, experience and training of personnel, and the type of operation will help planners anticipate the severity of injuries that personnel may experience. The Soldier's clothing, physical condition, and mental makeup are also determining factors. A well-disciplined and well-trained Soldier can be protected in even 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 is 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 safety office.

Resources

1-24. For maintenance to be effective, operators and maintainers need to be trained in anticipating 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 that are focused on withstanding high temperatures can break down and fail in the cold.

MAINTENANCE TEMPO

1-25. Cold weather will cause maintenance work to take longer. Operators and maintenance personnel must be proficient in the use of all winterization and arctic kit items including heating devices and added insulated covers. The preventive maintenance checks and services (PMCS) instructions for winterization kits may be unfamiliar tasks for operators and require at least initial supervision and instruction by experienced and mechanically inclined leaders. Operators are responsible for knowing and understanding the procedures outlined in equipment TMs for operation under unusual conditions.

1-26. Workflow seriously slows down in temperatures below -20°F (-29°C). Maintainers must allow equipment to thaw and warm up before making repairs. This time lag seriously impacts workflow and must be considered in all planning.

1-27. Personnel efficiency is also reduced by the bulky and clumsy clothing worn in severely cold areas. It is dangerous to handle cold metal with bare hands; operators/mechanics must always wear mittens or gloves. Losing the sense of touch further reduces the Soldier's efficiency. Even most routine operations, including handling latches or opening engine compartments, can become time-consuming and frustrating when performed with protected hands. This can be offset by providing heated buildings or shelters to increase work efficiency and morale. Shelter can refer to anything from a building to a vehicle cab, tent, windbreak, or anything that can effectively mitigate the extremes of the exposed environment. At the very least, a more organized and intensive effort is required from maintainers to maintain workflow in the extreme cold.

1-28. Commanders may want to try to obtain additional personnel to maintain maintenance tempo. They may consider providing on-the-job training for vehicle and equipment operators to perform some maintainer tasks. This training should be provided by a highly experienced maintainer and, upon completion, the personnel trained should receive a signed document affirming approval from the unit commander. Such a program requires a defined training curriculum and defined limits of what maintainer tasks supporting Soldiers can perform.

RISK MANAGEMENT AND SAFETY

1-29. 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 equipment. Units should develop a cold weather deployment program as a quality management process.

1-30. Units should conduct inventories of winterization kits, vehicle supplemental heating systems, space heaters, and other cold weather equipment well in advance of cold weather operations. This ensures operators and unit supply staff have sufficient lead time to process requests and receive maintenance supplies, tools, devices, and equipment. During these inventories, check that on-hand items are present, serviceable, and complete.

1-31. 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. The training should give special attention to the proper handling of combustible heating fuels, avoiding runaway fires, and preventing carbon monoxide poisoning.

1-32. Cold weather is a distraction for operators performing maintenance. Supervisors and section leaders of line elements should work in close coordination to prevent lax maintenance. They must ensure that otherwise well-trained equipment operators stay focused on performing preventive maintenance and operator maintenance according to TM standards.

SOLDIER WELFARE

1-33. The commander establishes standards for medical personnel and combat lifesaver qualifications. The unit's senior medical officer is responsible for implementing and applying these standards. Medical personnel and combat lifesaver certified Soldiers should receive medical refresher training focused on cold weather casualties and their proper treatment.

Note. Only qualified medical personnel have authority to diagnose and treat cold injuries. Only the unit medical officer can verify who is qualified and competent to handle cold injuries.

1-34. Cold weather training should include the proper wear of Army-issued cold weather protection clothing such as the extended cold weather clothing system (ECWCS). This system can be worn in any combination of layers depending on the mission requirements and the needs of the individual Soldier. However, first-line leaders must monitor each Soldier for overheating and excessive sweating. Sweating and moisture on clothing in cold weather can cause injuries to personnel.

1-35. Cold weather operations require more rigorous preparation than those in temperate environments. The following is a list of a few factors that affect personnel performance.

- Adequate heated shelter. Shelter from the elements is secondary only to defending against enemy actions.

- Proper nutrition. Soldiers need to eat more food and drink more water than normal.
- Preparedness for sudden weather changes. Weather change can alter behaviors, mood, and morale of individual Soldiers and the unit overall.
- Training. Avoid cold injuries by using a buddy system and conduct frequent self-checks, especially when individuals are not active or their duties require them to remove their gloves.
- Robust medical support. Immediately treat personnel showing any sign/symptom of cold injury. Sick, injured, and wounded individuals are susceptible to additional cold injuries.
- Adequate planning and preparation. 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 must 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 the vehicle.

Battle Buddy Protection

1-36. 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 paired in battle buddy teams to watch over each other. This is especially true for Soldiers that are not fully acclimated and are still learning how to deal with an unusually cold environment. Both Soldiers may identify dangers and save a situation from going dangerously wrong.

Human Factors

1-37. Soldiers must be kept reasonably warm to maintain normal metabolic processes. Rest and nourishment are also vital. This section highlights some key considerations that leaders and planners should bear in mind during maintenance operations.

1-38. The correct approach to operating in cold weather will go a long way toward keeping Soldiers healthy and seeing them through difficult times. There are five basic principles 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 weight to carry. Along with the difficulty of walking in snow, Soldiers 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. In the cold, Soldiers may only drink when thirsty. However, the cold can short circuit the thirst mechanism, so Soldiers drink less water than they need to prevent dehydration. Soldiers may also be reluctant to drink cold water because 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 it will lower the body's core temperature.
- Eat to replenish energy. Ensuring adequate nutrition is crucial for maintaining high performance. It is important for Soldiers to consume regular, satisfying, and hot meals to replenish their energy. Even when they are not feeling hungry, it is essential for them to eat to replace lost calories and to sustain their fitness levels. It is also worth noting that this places an additional burden on the cooking staff.
- 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.

1-39. Soldiers must consume more calories per day in cold climates than in temperate areas. Most of the food Soldiers eat and drink in cold weather goes towards maintaining their body heat. A smaller proportion is spent on producing energy for physical work. A minimum of 4,500 calories per day is necessary for personnel

performing hard work in the cold. Under conditions of severe stress, Soldiers may require as many as 6,000 calories per day to maintain health and performance.

1-40. 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.

1-41. Heat injuries are also a hazard in cold environments. Soldiers tend to overdress and not hydrate enough in the cold, increasing the likelihood of heat-related issues during periods of exertion. 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.

1-42. Leaders should be alert to changes in weather and drops in temperatures. This is when cold injuries unexpectedly occur. Such situations must be anticipated in unit policy, and on-call resources should be positioned for immediate activation. In a 24-hour operational setting, safety hazards are more likely to occur during the most inopportune times, particularly from the late hours of the night to daybreak when temperatures plummet to freezing temperatures.

Cold Injuries

1-43. Personnel with prior cold weather injuries are more susceptible to additional injury to the affected area or limb. Cold injuries hinder blood circulation that regulates skin temperature in the affected area. Leaders should identify Soldiers who have previous cold weather injuries. A colored tape marking system can be used on outer garments and head gear to help other Soldiers and medical personnel identify individuals with prior cold injuries. Consult medical personnel to determine the degree of threat of cold weather, required precautions, and limitations in activities.

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.

1-44. An injury that seems minor in cold weather can rapidly turn serious issue if not promptly addressed. In cold environments, even seemingly mild injuries can have lasting effects on the Soldier. It is important to be proactive in treating cold injuries to prevent long-term consequences. Leaders should consult senior medical personnel for a full discussion on cold injuries.

1-45. Whenever possible, medics should provide direct support within motor pools and maintenance activities during maintenance operations in sub-freezing conditions. Medical support is provided as specified by unit command policy and should be located at the point of highest risk. Medical support for maintenance operations should provide—

- 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.
- Appropriate recommendations to the commander regarding an injured Soldier returning to duty (with or without profile limitations).
- Spot checks that Soldiers are practicing proper hygiene and injury prevention measures as specified by command policy and Army standards. These checks also include unit adherence to proper field sanitation and the adequacy of sanitation resources.
- Weather monitoring as it applies to working conditions.
- Documentation of all injuries treated, and filing of that documentation in the Soldier's medical records.

- 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 on the medical records.

1-46. Once a cold injury has occurred, the commander and site leaders should immediately reassess all the protective measures that are in place and validate operating procedures. The site leader's concern is not only for the injured Soldier, but also for the rest of the force on duty. Where one injury has occurred, more can follow if the circumstances leading to the first injury are not addressed.

1-47. 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 soon as possible. Leaders can then use it to help determine what corrective action should be taken to safeguard Soldiers and mission accomplishment on the work site.

1-48. 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, like 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 mitigate the threat, the commander may consider procedural changes or mission adjustments.

Survival Equipment System for Stranded Soldiers

1-49. Soldiers need to have survival gear during cold weather field operations. Leaders should develop survival kits and bags for Soldiers operating outside of base camps. In a base camp, garrison, or installation, there is only a limited risk of dire cold weather emergencies, and survival resources are more likely to be available in the event one occurs. However, in the field or a combat area, Soldiers can become isolated or separated from the sustainment resources of their unit, making survival gear necessary.

1-50. The commander conducts a risk assessment to determine if survival kits or bags are required and their contents. 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 longer than 24 hours.

Note. Army regulations do not require, nor does the Army have a defined military standard that prescribes a survival kit equipment list for ground forces.

1-51. There are three functions of survival gear that remain the same regardless of geographical location and climate:

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

1-52. Different situations can alter the exact components needed for a survival equipment system, but it should include first aid materials and means to keep the Soldier dry, fed, and warmed. It should also provide the Soldier with a way to call or signal for help as covertly as possible. Survival kits and bags need to be as small and as unobtrusive as possible while still maintaining their utility.

Rapid Temperature Shifts

1-53. Personnel should go indoors as often as the mission allows, but they should avoid rapid or extended warming around heaters; this can cause perspiration on the skin and condensation in the clothing. Perspiration will compromise the ability of cold weather clothing to retain body heat. Overly heated shelters will cause Soldiers to suffer rapid cool-off when it is time to step out of the shelter. Repeated rapid shifts in temperature with large variations can contribute to metabolic fatigue, weakening the immune system and possibly 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.

1-54. 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 at about 35°F (2°C) to 40°F (4°C).
- Ventilate built up moisture. Soldiers are encouraged to take off the outer layer of the cold weather system parka and trousers and the extreme cold jacket and trousers. Shake the garments to remove 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 changed into clean and dry clothing, then they can take a moment to rest, eat a light snack, and drink a warm liquid.

1-55. 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 must have sufficient room to perform the above five tasks. Medical personnel should be consulted about further precautions that might be included in this process.

Flesh on Cold Metal

1-56. 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 these injuries.

Gloves

1-57. Soldiers must protect their hands and fingers when using with tools, calibration equipment, or sighting and fire control devices in freezing temperatures. Consider wearing gloves with liners, trigger finger shells with liners, or arctic mitten sets to keep hands warm. Standard issue light-duty leather gloves are appropriate around 35°F (2°C) and higher, but the arctic mitten set or trigger finger mittens should be worn at colder temperatures. The movement of nuts, bolts, knobs, and levers will be less smooth at colder temperatures and small parts are more likely to be dropped and lost in the snow. Operators who are not used to working with gloved hands will require time to adjust.

WARNING

**Handwear may become wet and cause injuries to personnel.
Carry extra handwear when performing maintenance under arctic conditions.**

Anticontact Gloves

1-58. Anticontact gloves should be worn when touching cold metal equipment. Many vehicle bodies, tools, knobs, and handwheels are difficult to manipulate while wearing arctic mittens, so it may be necessary for operators to wear anticontact gloves. These gloves are constructed with a lightweight material body and a durable deerskin leather reinforcement patch that covers the front side of the fingers, palm, and thumb. They are designed to provide enhanced dexterity compared to regular gloves. These gloves offer effective protection for a limited time, after which it is recommended to switch to mittens.

1-59. 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 like pliers should have handles wrapped in plastic or electrical tape to provide protection.

CAUTION

Anticontact gloves and work gloves are sufficient insulation against touching dangerously cold metal. However, they are not suitable for protecting hands against protracted cold exposure.

Insulating the Body for Work

1-60. ECWCS clothing is the principal way for Soldiers to stay warm in extreme cold conditions. However, coveralls and other sustainment military occupational specialty (MOS)-specific personal protective equipment (PPE) that fit over a Soldier's uniform in temperate areas may not fit over the higher levels of a bulky ECWCS clothing system. Soldiers often 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 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 injury or ruining the protective qualities of their ECWCS. Do not use any garments over MOS-specific PPE that negates its flame resistance; anti-static; petroleum, oils, and lubricants (POL) chemical resistance; and other protective properties.

1-61. PPE is any clothing, accessories, equipment, devices, or substance that protects personnel from exposure to hazards that cause serious workplace injuries, illnesses, or damage to personal clothing and equipment. When the normal supply chain cannot provide approved PPE on time, the commander may need to consider procuring commercial off-the-shelf (COTS) or custom-made PPE items. 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 the cold weather clothing system that allow body humidity to air evaporate.

1-62. Mechanics should place insulating material such as fiber packing material, corrugated cardboard, rags, or tarpaulins between themselves and cold-soaked equipment or frozen ground. Use a box or pan to hold small parts when performing maintenance under severe winter conditions. A tarpaulin should be placed under each vehicle 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 the ground.

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

FUEL BURNING PERSONNEL HEATERS

1-63. Field tent heaters become a safety risk if TM procedures are not followed in detail. Improperly set up or operated tent heaters can cause death or injury:

- Improperly vented heaters that expel their fumes directly into tents may lead to carbon monoxide poisoning.
- Unsafe heaters can cause fires.

1-64. Fuel-burning 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 (like 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 do not need special handling in the field. The byproducts of fuel-burning 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 also in the other byproducts (including water as moisture) that can damage equipment or jeopardize the health of Soldiers.

1-65. There are four types of common heating systems:

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

1-66. The heating systems illustrated in Figure 1-3 are most common for Army 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 to achieve the best performance while minimizing safety risks.

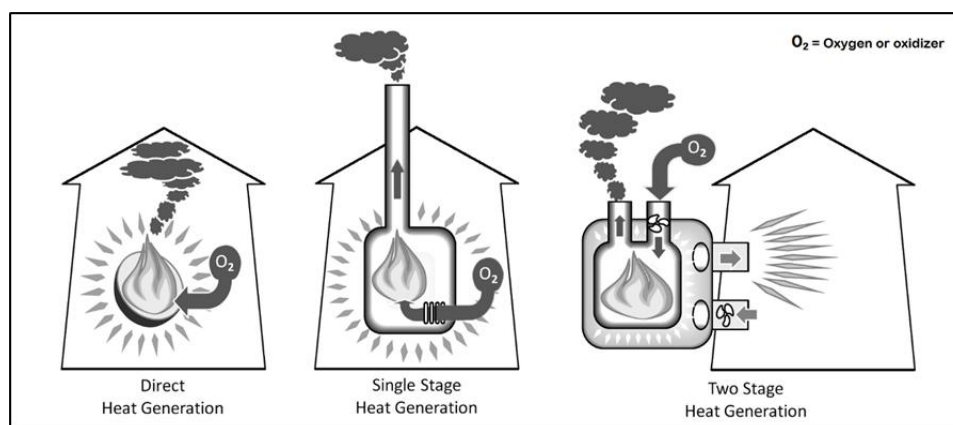


Figure 1-3. Heat generation systems most used in warm shelters

Direct Heat

1-67. 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 frozen parts, and to warm Soldiers in a shelter. Examples of direct heat equipment include an open hearth, pit, burner, or 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 blowtorches represent mechanically complicated direct heating devices.

1-68. Occasionally, units purchase powerful kerosene or multi-fueled forced air “jet heaters” to keep the large spaces of tactical operations centers (and other shelters) as warm as possible. These heaters produce a strong blast of heated air, but they also pose a safety risk due to the release of exhaust, carbon monoxide, and moisture into the enclosed area of a tent or shelter.

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.

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

Single-Stage Heat Generation

1-69. This equipment is designed to fully contain the primary heat source, like a fireplace with a chimney, a Franklin stove, or a potbelly stove. The stove can withstand high levels of heat without being damaged, and the heat output can be controlled by regulating the flow of fuel and air into the fire. 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

1-70. This system, also called a “duct heater,” is commonly used to heat large shelters. Shelter or room air is moved through the air ducts from the shelter to the heat source without directly contacting 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 two-stage heating systems, the heating chamber must be able to keep the room air completely segregated from the fuel combustion and its byproducts. They can be complicated, cumbersome, and some military versions require a trailer. The large ones can also take a considerable amount of time to set up and dismantle.

Three-Stage Heat Generation

1-71. A three-stage heat generation system (Figure 1-4) uses a liquid or fluid medium 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 the cold, this heating method is often used to keep batteries and fluids of a motor warm enough to restart after a vehicle has been turned off and cooled.

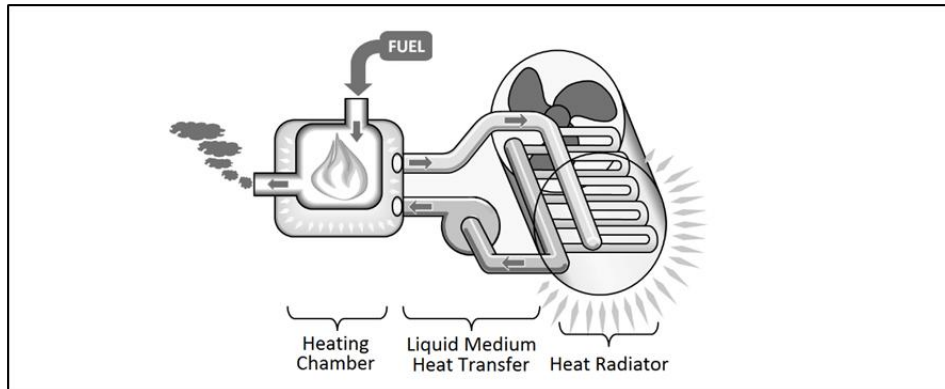


Figure 1-4. Three stage heat generating system

Creosote

1-72. Depending on the type of solid or liquid fuel used, 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.

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.

1-73. If there is too much wood fuel for the available oxygen, the wood will smolder and create 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 and possibly result in a chimney fire. Creosote buildup is the primary cause or a major contributing factor in over 70% of heating fires.

1-74. Units should treat heaters like 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 and conducting after-operation cleaning and maintenance. Heater equipment TMs or manufacturer's manuals must be available to operators for each item.

Shelter and Heater Safety

1-75. Operate all heaters and stoves in accordance with the applicable TM or owner's manual. Ensure fire extinguishers are present and fireguards are posted. Before the onset of cold weather or entering a severely cold environment, leaders are responsible for cold weather planning, obtaining COTS fuel-burning personnel heating systems, performing risk assessments on all heater assets, defining operating procedures, and providing Soldier training. Soldiers must be licensed or certified to operate field shelter heaters.

1-76. Follow the guidance of Department of Defense (DOD) regulations and Occupational Safety and Health Agency on limitations of personnel exposure to hazardous substances. 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.

DANGER

Heaters pose a risk of fire and carbon monoxide poisoning that can cause injury and death.

1-77. 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 exposure. Furnaces and stoves that are improperly fired or are 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, pay attention to room ventilation and the piping used to funnel exhaust out of the working area.

1-78. 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. Active mechanical exhaust ventilation may have to be installed if passive ventilation is not adequate due to the size of the area or the number of engines being operated. Flex hoses or tailpipe extensions are a common control in maintenance shops.

1-79. 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. Always read and follow the TM and follow these safety tips when using fuel-burning heaters and stoves:

- Exhaust must be vented to the outside of an enclosed area.
- Gasoline should never be used in any heater.
- Do not use wood, paper or any solid fuel in heaters or stoves not equipped with an ember trap screen at the end of the exhaust pipe. Such embers will burn fabric, damaging tents and clothing.

- Render unusable 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 any type of fuel-burning heater in a shelter that vents its exhaust fumes into the shelter.
- 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.
- Ensure all fuel spillage control measures are in place before using a liquid fuel-burning 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 hazard and the potential for an 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 through a flue, chimney, or duct.
- Stoves lacking the convection to draw enough oxygen into the flame cause an incomplete burn of hydrocarbons. These byproducts increase the 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.
- 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 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 fires. Clean ashes and creosote 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 -44°F (-42°C). It may spray in a liquid state from its container when the valve is opened and create an extremely hazardous condition.

MAINTENANCE FACILITIES

1-80. 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.
- Ensure that shelter heaters are complete and operational.
- Ensure that generators are complete and operational.

- Obtain oversized ground covers to keep moisture from rising within the maintenance shelters.
- Ensure that there are adequate personnel who are licensed to operate and repair heaters and generators.

1-81. The availability of maintenance facilities, heated buildings, or shelters can be critical to the maintenance mission. Human engineering standards for facilities, and workspaces for Soldier use are set by MIL-STD-1472. 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. A shortage of heated shelters will cause an increase in maintenance man-hours needed for any task. Without some type of permanent or temporary shelter, even routine maintenance in the open can become extremely difficult.

1-82. Maintenance tents are a good temporary solution when buildings are not available. If possible, tents should have wood flooring and be heated by portable duct heaters or tent stoves. Tarpaulins or 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. Ensure proper ventilation and take extreme care to avoid the danger of carbon monoxide poisoning from running engines or direct heat devices. Do not overheat the shelter as the frozen ground will thaw and may cause equipment to shift unexpectedly or get stuck in the mud and then freeze again, making it difficult to move equipment on its own power.

COMMERCIAL OFF-THE-SHELF EQUIPMENT

1-83. 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. Non-military equipment that is purchased locally is commonly known as COTS equipment. 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 them. Although Army policy does not limit the use of COTS heaters, few COTS heaters on the market meet the Army's demands for field environments.

1-84. 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. Furthermore, propane gas may not be readily available in the area of operations.

1-85. If COTS items are authorized to supplement Army equipment, a maintenance supervisor and medical person who is familiar with carbon monoxide should assess their proper use, preventive maintenance, and lifecycle upkeep. COTS items must also be included in the unit PMCS schedule. Planners must consider the availability of the fuel used to power COTS items in the area where the unit will be deployed and operating. Though COTS items might be readily maintained in home station garrison, it is important to ascertain that they can be serviced and will function during deployment.

1-86. Soldiers who are specialized in their jobs usually have a pretty good idea when modified personnel gear or COTS PPE items are needed. Occupational Safety and Health Agency places the responsibility on employers to ensure that PPE is available and used correctly, even if it is purchased by the employee. Soldiers are advised to seek guidance from their leaders before buying their own PPE.

1-87. Avoid buying various items for a specific type of function from different manufacturers. This will cause maintenance and supply lifecycle support problems. It will mean that replacement parts will have to be obtained from different sources and will not be interchangeable or compatible.

1-88. Daylight will become limited during the winter in northern latitudes. Additional lighting equipment is usually required for maintenance services. Lights with ample power generation, cable extensions, attachment plugs, connectors, and spare bulbs are essential.

1-89. Extra heaters may be needed when equipment including brake pads, weapon bolts, or similar moving parts becomes seized up with moisture. For outdoor work, consider using a COTS portable forced air heater.

Chapter 2

Equipment Maintenance

This chapter contains specific information about the performance of materials and component parts during equipment operation and maintenance in cold environments.

MAINTENANCE CONSIDERATIONS

2-1. Cold weather will demand more from equipment and maintainers. Routine maintenance may be extremely difficult or in some situations impossible. The cold can cause problems with equipment not normally encountered during operations in more moderate or temperate weather conditions. The importance of maintenance, especially the correct performance of PMCS, must be emphasized for all Soldiers in cold regions. Daily maintenance in a cold weather environment requires forethought; it should not be taken for granted and done by routine. Take extra care during before-operations checks; this is the critical point for identifying and fixing potential issues before any damage occurs. Operators must anticipate that additional time will be required when performing PMCS in cold weather.

2-2. TMs and LOs are the primary sources of reference for maintenance procedures. However, in cold weather environments, unique maintenance requirements can arise that are not covered in these manuals. Commanders need to first establish policy for when and how Soldiers may resort to an alternate procedure or solution. This will require selecting a maintainer subject matter expert who can assess when a specific and unique situation or event exceeds or is outside of published standard procedures. The use of an alternative procedure or solution must be based on the likelihood of a risk to Soldiers or equipment that is not addressed in TMs and other publications. Never use a non-TM solution just to simplify procedures or perform makeshift repairs when the requisite resources are available.

GENERAL EFFECTS OF COLD ON ITEM COMPOSITION

2-3. The physical properties and functional characteristics of materials can change as they reach freezing temperatures. Maintainers and operators must anticipate the effects of cold on equipment and its components, as well as the resulting increase in manhours and maintenance challenges.

2-4. Three general categories of issues specific to cold weather account for most maintenance issues:

- Cold alters material properties. Operators must be very cautious when using severely cold equipment that has been inactive for a long time. For example, the contraction of metals at lower temperatures and expansion at higher temperatures may result in improper clearances between components and cause binding or excessive looseness. Many items become brittle in the cold and could break if forced.
- Petroleum, oils, and lubricants can degrade under extremely cold conditions. If the cold leads to the congealing of lubricants in mechanical components, it can result in friction and eventual failure.
- Condensation freezing. This subject is addressed later in the chapter.

Metals

2-5. Metals become brittle in cold temperatures and cannot withstand the shock loads that they sustain at higher temperatures. For example, at -20°F (-29°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 specially affect bearings in which the bearings and shaft are of different metals bolted together, or the 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.

Welding

2-6. Welding and metalworking are very technical processes and much more complicated when performed in adverse weather conditions like freezing to subzero temperatures. In these environments, welding requires

additional equipment, protection, and high levels of experience. Welders must consider several factors before, during, and after a welding task, including—

- Metal thickness.
- Welding machine capabilities and limitations.
- Moisture in metals and welding materials.
- Welding method.
- Preheating techniques.
- Proper cooling techniques.

2-7. Welding and metalworking are essential for regular equipment maintenance and are fundamental to battle damage assessment and repair (refer to ATP 4-31 for more information). Welders and machinists must consistently practice various welding methods, techniques, and processes in controlled or ideal environments to improve and maintain a high level of proficiency.

2-8. Water in all forms (liquid, condensation, moisture) poses a significant risk to the electronic components of welding machines and many metalworking devices. High-quality equipment and devices are more resistant to weather conditions and do not require cumbersome protection. Pay special attention to protecting welding equipment; parts may not be readily available.

Compressed Gas (Cylinders)

2-9. The Army uses compressed gas for maintenance activities, medical requirements, and various applications in different fields. Cold weather can have a significant effect on the metal cylinders, regulators, hoses, and auxiliary instruments associated with the use of gas cylinders.

Oxygen

2-10. Liquid oxygen is a transparent liquid. Oxygen can be made into a liquid through pressurization, which involves lowering the temperature below -297°F (-183°C) where the molecules slow down and condense into a liquid state. This process is also known as liquefaction. The extreme temperatures in the Arctic region do not affect the quality of the oxygen; however, they do affect the condition of the container and metering devices. For general and industrial use, liquid oxygen is stored in a green cylinder bottle. When the pressure inside oxygen cylinders drops to 50 pounds per square inch (psi) or below, consider them empty. This prevents air with water vapor from entering the cylinder, which could cause corrosion and potentially lead to ice formation in the metering devices. Store oxygen bottles in a protected storage and according to local and federal rules.

Nitrogen

2-11. Nitrogen is used in many applications within the Army maintenance operations. Nitrogen gas is used in metal shops for various cutting or welding processes. It is also used to charge heavy equipment suspension systems, for purging the gas of optic devices and equipment, and for maintaining environmental control units. However, when handling nitrogen in cold environments, it is important to take certain precautions to ensure safety and prevent accidents. Here are some tips for nitrogen safe handling in cold environments:

- Always wear appropriate PPE, including insulated gloves, face shields, and safety goggles.
- Ensure proper ventilation in the work area where nitrogen is being used. Nitrogen can displace oxygen and lead to a lack of oxygen in the air, which can be dangerous to personnel.
- Be aware of the potential for cold burns when handling nitrogen in cold environments. Prolonged exposure to extremely cold temperatures can cause frostbite or other injuries.
- Never allow liquid nitrogen to touch the skin, eyes, or clothing. Nitrogen can cause severe burns and other injuries upon contact.
- Train all personnel who handle nitrogen in cold environments on proper safety procedures and protocols. Regular training and refresher courses can help ensure that everyone is aware of the risks and knows how to handle nitrogen safely.

Acetylene

2-12. Acetylene is a highly flammable gas that is commonly used in welding and cutting applications. When using acetylene in cold weather, it is important to take certain precautions to ensure safety and prevent accidents. Here are some tips for using and caring for acetylene in cold weather:

- Always store acetylene cylinders in a well-ventilated area away from open flames, sparks, and other sources of ignition. In cold weather, ensure that the cylinders are not exposed to freezing temperatures; this can cause the cylinder's pressure to drop and make it difficult to use.
- Before using acetylene in cold weather, ensure that the cylinder and regulator are free of ice and snow. Ice and snow can interfere with the cylinder's pressure and cause leaks or other hazards.
- Use a hose that is designed for cold weather use. Cold weather hoses are typically made of materials that are less likely to become stiff or brittle in low temperatures.
- When using acetylene in cold weather, be aware of the potential for condensation to form inside the hose. Condensation can mix with the acetylene gas and create a flammable mixture that can ignite or explode. To prevent condensation from forming, use a hose with a water trap or a check valve.
- When transporting acetylene cylinders in cold weather, ensure that they are properly secured and protected from freezing temperatures. This can help prevent damage to the cylinder and ensure that it is safe to use.
- Always follow proper safety procedures when using acetylene, including wearing appropriate PPE and ensuring proper ventilation. In cold weather, it may be necessary to use additional heating equipment to maintain a safe working environment.

Rubber

2-13. Besides natural rubber, there are hundreds of rubber substitutes. Synthetic rubbers look and usually react the same as natural rubber, although most do not become more flexible at high temperatures. Natural rubber gradually stiffens as it cools, but retains a large part of its elasticity until reaching temperatures below -20°F (-29°C).

2-14. When rubber cools, it remains flexible until it reaches approximately -60°F (-51°C). At this point, it quickly loses its elasticity and becomes brittle. Additionally, if rubber consistently stays at a temperature just under -20°F (-29°C) for an extended period, it undergoes a crystallization effect causing it to become brittle. For example, fuel hoses may crack, increasing the potential for spills.

Rubber-Covered Electric Cables

2-15. Take extreme care 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 easily at low temperatures.

Plastics

2-16. 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.

2-17. In dry cold environments (or colder), operators should be conscious that plastics have the potential to build up 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 including analog meters with plastic faces to give incorrect or erratic readings and can also affect the operation of sensitive electronic devices.

Glass

2-18. 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.

CAUTION

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

Fabrics

2-19. If kept dry, fabrics generally retain their flexibility, even at extremely low temperatures. However, tarpaulins may shrink, and wrinkles and are extremely difficult to smooth out at below freezing temperatures. Whenever possible, tarpaulins should be unfolded in heated enclosures or kept installed on equipment.

EQUIPMENT WINTERIZATION

2-20. Almost all equipment procured by the Army functions correctly at the -25°F (-32°C) threshold, but it usually begins to malfunction at temperatures below -30°F (-34°C). The drop in temperature directly relates to a decline in materiel performance. Proper equipment winterization can mitigate some of these issues and help ensure proper operation in cold weather. Low temperatures should be anticipated far enough in advance to permit time to acquire and install winterization parts.

2-21. Winterization is a specific set of tasks listed in the equipment TM that prepare equipment for cold weather operations. There are other winterization techniques in different areas of this publication, but the following are some typical winterization techniques and tasks:

- Ensure that the equipment has a proper antifreeze/water mixture. Generally, a mix of 60% antifreeze and 40% distilled water provides the best protection against cold temperatures.
- Inspect all belts and hoses for cracks, dry rot, or breaks and replace as necessary.
- Install winterfronts, grille covers, or radiator shutters. These devices are installed on the equipment grille at the front of the radiator to help the engine retain heat at the optimum operating temperature.
- 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.
- Install auxiliary engine block heaters.
- Install solar battery chargers to maintain battery charge and prevent premature unserviceability.

Note: Before cold weather operation of vehicles, crews should use the appropriate equipment TM and LO for operation, lubrication, PMCS, and maintenance. These manuals usually include a section titled Operations under Unusual Conditions. The following information in this subsection is not a substitute for the equipment TM.

ENGINE BELTS

2-22. Rubber belts lengthen in severe deep cold. Operators must check belt tension by regularly looking for loose belts or listening for squealing when the engine is running.

TIRES

2-23. Tires are made of multiple materials that each have their own properties. Tires may develop flat spots and become more rigid when parked in cold temperatures. These cold flats typically diminish as tires warm up with use. Adjust tire pressure as needed. Inflate tires to 10 psi above normal pressure in a warm environment such as a sheltered parking garage or shop. This allows for air contraction and pressure loss once the vehicle is out in the cold.

2-24. In extreme cold, rubber expands while metal contracts; this could break tire seals. Tread rubber, especially on non-winter-rated tires, can lose grip and become stiff on winter surfaces at colder temperatures.

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.

BATTERIES

2-25. Cold weather can adversely affect batteries:

- Battery power capacity is decreased at low temperatures.
- Cold temperatures increase the vehicle power demands that the battery must provide.
- Frozen vehicle batteries can burn or explode if the operator attempts to slave start or charge the vehicle.

2-26. Ensure batteries are fully charged; they can freeze when partially or completely discharged. A fully charged battery can withstand -70°F (-57°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

2-27. Most fuels react the same to the cold and are usually distinguished by the temperatures at which breakdown occurs. The following are some known facts about the effects of cold on fuel:

- Jet propellant (JP), JP-8, under the single fuel policy (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 freezing.
- The pumping, filtering, and tank filling of petroleum products, particularly refined distillates, can cause the generation and accumulation of electrostatic charges. Be familiar with static control safety procedures specified in the item TM or fuel handling procedures as appropriate.

Note. Fuels are covered in greater detail in Chapter 4 and Appendix D.

LUBRICANTS

2-28. The POL Products Guide for Ground Vehicle and Equipment Materiel Systems contains information on Army lubricants and serves as a quick reference for military personnel to correctly use petroleum and related products in the supply system. This guidance covers essential fuels, fuel additives, lubricants, and associated products that are required and used in DOD ground vehicles, equipment, and materiel. The Army qualifies heavy duty diesel engine oils against the requirements of specification MIL-PRF-32626.

2-29. Transmissions are designed (in general) to use lower viscosity oils. The Society of Automotive Engineers (SAE) -10W oils are typically not recommended for engine applications but make good transmission fluids. Most MIL-PRF-32626 oils can be used at temperatures up to a high of 120°F (49°C). Use lubricant, arctic weight (LAW) in low temperatures for the lubrication and preservation of small arms and light caliber weapons up to 20mm. Lubricants should be stored in a warm place.

Note. Lubricants are covered in greater detail in Chapter 4.

LOW OR NO OIL PRESSURE

2-30. 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 (like an engine bearing). In either case, the problem is serious and 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

2-31. Starting a vehicle in cold weather is not the same as in a temperate weather. The following tips will help ensure personnel safety and optimum equipment performance:

- Always PMCS vehicles using the TM before, during, and after vehicle operation. It is critical that operators must follow PMCS procedures and steps. Starting the engine is not the first step in PMCS.
- Be ready to draw additional power from a supplemental energy source.
- Start engine and allow vehicle to idle for approximately 20 to 30 minutes before moving.
- Depress brake pedal and slowly cycle through transmission and transfer gears before moving the vehicle.
- Drive slowly at first, allowing 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 the equipment high idle switch. This usually brings the engine idle up to about 1100 to 1200 revolutions per minute (RPM).
- The idle RPM may need to be increased on certain vehicles like the command or communications vehicle. High idling is done to produce enough electric power to run the engine while overcoming cold-induced resistance and still providing enough surplus power to recharge the electricity the battery spends to start and run the engine.

CAUTION

DO NOT engage high idle or excessively increase engine RPM before engine is warm. Damage to engine or transmission may occur.

MOISTURE AND CONDENSATION

2-32. Condensation is the process of moisture liquidizing 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 affects almost every type of material, but the effect on each item of material is varied and unique.

CAUSES AND SOURCES OF CONDENSATION

2-33. The most common cause of condensation occurs when a cold-soaked item of equipment is brought into an above-freezing environment. When warm, humid air contacts cold equipment, the moisture in the air will condense on the surfaces, especially in hidden areas and between moving parts. When the equipment is returned to a cold environment, the condensed water freezes, leading to multiple issues and potential damage.

2-34. There are two common ways to avoid the problems of freezing condensation on mechanical items:

- The easiest method is to keep mechanical items (including weapons) outside in the freezing cold and avoid bringing them into a warm shelter.
- The second solution is to warm the item to a temperature that is equal to or warmer than the shelter (for example, by using anti-condensation containers or hot air blowers), and then wiping them off before taking them back into the freezing cold. Allowing a metal item to sweat while it warms only encourages corrosion, rust, or oxidation to occur.

2-35. When a cold-soaked item is used indoors, the moisture combines with the lubricants to form an emulsion. The emulsion then weakens the protective properties of the item. To address corrupted lubricant,

it is necessary to completely remove all the contaminated lubricant and then perform a detailed cleaning process that often entails using a degreasing solvent, like type two [SD-2]. If the item is taken outside into low temperatures before the condensed moisture is removed or has evaporated, the parts may freeze and become inoperable.

Propane-Burning Heaters

2-36. One of the most frequently overlooked causes of high humidity and condensation is open flame. When a fire burns, it produces a significant amount of water as a byproduct, contributing to increased humidity levels in the surrounding environment. Propane and natural gas produce a significant amount of moisture for their weight due to their molecular composition.

2-37. 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, these fire sources 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.

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.

Breath or Perspiration

2-38. Condensation can result from overheated people placed in a confined area. When enemy contact is imminent, the interior temperature of transportation platform troop compartments (especially aircraft) should be maintained close to freezing (32°F) [0°C]. This prevents troops dressed in heavy cold region uniforms from overheating. It also prevents moisture from condensing and refreezing on weapons as troops disembark into the cold from warm aircraft or vehicles.

2-39. 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 aircraft's windshields, blocking pilot vision. Soldiers should focus on ventilating their uniforms and minimize body heat buildup. They can achieve this by loosening clothing and ensuring proper airflow.

2-40. There is a significant risk of condensation that commonly occurs in vehicles and small tents. The walls of uninsulated heated crew compartments can become coated with condensation that is caused by the moisture from people breathing. Frosting from the breath of the operators can render microphones inoperable.

2-41. It is important to keep doors, windows, or hatches open to allow for effective ventilation in the crew compartment and help moderate Soldiers' body heat. 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.

2-42. 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. 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. 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.

EFFECTS OF MOISTURE AND CONDENSATION

2-43. Moisture and condensation may lead to malfunctions, corrosion, and decreased capability of equipment and weapon systems and affect munition efficiency. Combating moisture sources is paramount to preventing condensation.

Automotive Equipment

2-44. In extremely cold conditions, the moisture in the air condenses and freezes into ice crystals that become suspended in fuel or POL products and degrade them. In the case of oils and lubricants, it can obstruct the free movement of equipment and lead to breakage. In the case of fuels, it can result in water contamination that causes an engine to stop running. Brush snow or wipe water from the tops of fuel and lubricant containers, spouts, and plugs before use to prevent contamination.

2-45. Air compressors used in vehicle air brakes, air hydraulic brakes, and a central tire inflation system (CTIS) are especially prone to internal condensation. In the cold, moisture may freeze inside the compressor. Follow after-operations maintenance procedures by draining condensation from air compressor tanks. If the bleed valve is frozen, attempt to unfreeze it or report it immediately to maintenance personnel.

2-46. Frozen moisture in an air brake or pneumatic system can significantly impact operation. Brake line, air brake filters, brake chambers, pushrods, valves, and seals are more susceptible to defects and failure in cold conditions. 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 passages.

2-47. 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 crankcases. This will degrade the useful life and effectiveness of engine lubricants and require more frequent oil changes.

Weapons

2-48. When weapons are transferred from a cold environment to a warmer one, condensation forms on their surfaces due to the change in temperature. This occurs because the warmer air can hold more moisture, causing the moisture in the air to condense on the cooler surfaces of the weapons. Additionally, when these weapons are brought into heated shelters for cleaning purposes, the difference in temperature may cause the weapons to sweat (continue to produce condensation) 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 and result in stoppages.

2-49. Condensation on weapons poses a constant threat to their function in cold weather. It can lead to icing and corrosion on machined surfaces, raw metal surfaces, and especially in the bores of weapons. This type of condensation is often referred to as sweating, but it 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.

2-50. In extremely cold conditions, condensation can cause problems inside the weapon and lead to 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.

2-51. 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).

Optical Devices

2-52. 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 and obstruct vision by streaking or frosting over. Special cleaning procedures reduce problems caused by condensation.

2-53. Maintenance personnel should anticipate the buildup of condensation within optical devices that are not hermetically sealed or are leaking humid air. As part of field maintenance, personnel will be required to open lens assemblies, meticulously clean the glass, remove any corrosion, and reseal the assembly to ensure it remains free of internal moisture. If this cannot be done, supply personnel will have to arrange for exchange of the item.

2-54. When storing fire control items, it is recommended to keep them outdoors in covered areas to shield them from snow. Store binoculars, telescopes, and other fire control equipment in snow-tight lockers or sealed containers issued with the materiel at outdoor temperatures. Leave aiming instruments outside or use anti-condensation containers to bring them into a heated shelter.

2-55. 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.

2-56. When storing equipment, it is important to avoid using plastic sheets or tarps as they tend to trap moisture and condensation against the equipment. Instead, use breathable cloth to cover or wrap up items as this will allow for better air circulation and prevent potential damage.

Munitions

2-57. When preparing to fire a weapon, it is important to be aware that if there is condensation on a round that freezes in the breech, it could result in a misfire. At weapon ranges, do not bring ammunition into heated rooms for unpacking and distribution unless it has been given sufficient time to warm up and allow any condensation to evaporate. In a rapid ammunition distribution situation, it is better to keep the munitions cold or stored in dry cold storage.

2-58. Taping over ends of detonation cord, caps, and igniters may prevent condensation contamination of an explosive charge's firing system. Otherwise, moisture will travel through the exposed explosive materiel and degrade its performance.

Electronics

2-59. 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 into a warm area. The cold temperature of the equipment causes warm air moisture to condense on the item and its circuit wiring. Short circuiting may then happen when power is applied. Electrical equipment should be warmed to room temperature before being turned on. Even then, condensation may 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 items under warranty. Soldiers who carry non-ruggedized personal items (like 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.

ANTI-CONDENSATION CONTAINERS

2-60. If it is necessary to bring weapons or other items from low outdoor temperatures into higher room temperatures, use anti-condensation containers to prevent condensation of moisture on metal and glass. These containers can be specially made boxes, covered cans, or other airtight containers with heat-conducting walls. Keep containers outside so that they are at the low outside temperature. When transitioning from a colder outdoor environment to a warmer indoor space, place items into the anti-condensation container and secure tightly. Once indoors, allow the container to reach the same temperature and 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 airtight, it will not function as an anti-condensation container.

2-61. Cold, dry air expands and presses outward when it is warmed. Therefore, no warm, humid air from the room can come in contact with items inside the container and cause condensation. When the items reach room temperature, they can be removed with no danger of condensation.

2-62. If an anti-condensation container for an item is not available, wrap the item in blankets or similar materiel before it is brought into a heated enclosure. Airtight self-sealing plastic freezer bags make a good moisture barrier for small items. This will retard or impede the condensation process.

VEHICLE WINTERIZATION

2-63. Special winterization equipment (provided as a part of specific kits) can protect both Soldiers and vehicles against cold weather. For vehicle protection when the temperature falls only a few degrees below freezing, only ordinary preparations are needed as specified by the TM. Though any temperature below freezing becomes an issue for vehicle fluids, most vehicle components are resistant to temperatures effects down to about 10°F (-12°C) for short periods of time.

2-64. Human engineering standards for facilities, workspaces, and vehicles purchased by the Government for Soldier use are set forth by MIL-STD-1472. Vehicle crew compartments should have an adequate heating system that can maintain temperatures above 68°F (20°C) during vehicle occupancy. When arctic clothing is worn, cab heaters are expected to maintain temperature of not less than 41°F (5°C).

2-65. Personnel heater kits and hardtop closures may be installed in anticipation of freezing temperatures. Do not attempt to conduct operations in areas where temperatures from -25°F (-32°C) to -65°F (-54°C) are likely without installing equipment winterization kits. Consult the appropriate TM for installing and using winterization kits.

VEHICLE CREW HEATERS

2-66. In most wheeled vehicles, the crew compartment is heated by circulating antifreeze from the engine into the crew compartment heater in a three-stage heat transfer system. Generally, these vehicles heaters can effectively provide adequate heat until the ambient temperature drops below -25°F (-32°C). At extreme cold temperatures, the engine will struggle to generate enough heat to stay functional. Although arctic antifreeze solution remains liquid down to -90°F (-68°C), the crew compartment heater may not be effective in extreme cold. Electric or fuel-burning supplemental heaters (where available as a part of a winterization kit) are needed to provide more heat below -25°F (-32°C).

2-67. Heavy equipment like tanks usually produce heat separately from the engine in a blower or turbine type burner module. These vehicles store more ambient cold temperature in their thick walls, so their heaters produce more heat than those of wheeled vehicles. The heat-producing burner modules can be mounted inside or outside of the crew compartment. If the burner is outside the crew compartment, it is a three-stage heating system. It 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 it is a single stage heater system.

2-68. Tracked vehicle operators operate and maintain the personnel heater system. Operators must ensure that soot, sludge, or creosote does not build up in the burner unit. Refer to the vehicle TM for PMCS and maintenance procedures before attempting to clean. For those vehicles with burner modules mounted in the crew compartment, operators must watch for leaking fuel feeds.

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 before bringing the vehicle into a 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.

ENGINE PREHEAT

2-69. Starting a cold-soaked engine can be very difficult and may lead to damage. In temperatures below -20°F (-29°C), operators may need to start vehicle engines periodically to maintain an acceptable state of readiness. Periodic engine running should not be done if other preheating means are available, including engine heaters, external heat, or indoor parking. A properly winterized engine with some type of preheating component or device will stay 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 systems.
- Standby fuel-powered heaters.

2-70. There are two major types of engine heaters: electrical and fuel-burning. These heaters are designed to warm up engines, drivetrain gears, batteries, and other essential components before or during the initial startup of equipment. These heaters can be as simple to operate as electrical oil-pan, heating pads, and as complex (and possibly dangerous) as fuel-powered heating devices. These devices circulate scolding hot antifreeze through a vehicle while it idles.

2-71. Standby heaters are usually not a standard piece of equipment on a vehicle and are ordered as a part of a vehicle winterization kit.

Note. Not all vehicles have military-designed engine heater systems as a part of a winterization kit. If the government-issued options are inadequate, notify the U.S. Army Tank Automotive and Armaments Command logistics assistance representative. Otherwise, the unit commander will have to decide about procuring COTS items.

Electrical Quick-Heat Systems

2-72. Quick heat is a technique that uses electrical engine block heaters to heat the antifreeze or engine oil using external power. 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. Prior to vehicle operation, electrical heat is applied to the engine, batteries, and components, raising their temperatures enough to ensure starting. Electrical quick heaters are dependent upon access to a facility's power sources. Such electrical power sources would be easy to obtain in garrison but may be challenging to find in tactical situations.

2-73. The time from initiating quick heat to achieving reliable starting temperatures can vary from a few minutes to one hour. These 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 goal is to achieve reliable starting within a maximum of one hour regardless of ambient temperature. There are several electromechanical devices for keeping a coolant from freezing in a vehicle.

Heater Harness

2-74. A heater harness is a heavy appliance power cord attached to electrical heater systems. This cord is usually woven through the engine compartment to a point near the front fender. The heater cord typically 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.

WARNING:

Do not operate the engine unless the heater harness cord has been disconnected from the 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.

Battery Blankets or Battery Insulator

2-75. These can range from an electric heating pad to a battery case equipped with a self-regulated, thermostat-controlled heating element designed to keep batteries warm. Chemical reactions within a battery release energy, and these reactions occur best within a warm battery. A battery blanket protects battery fluid from freezing.

Float charger

2-76. This type of charger maintains a battery's SOC in storage or when installed in an infrequently used vehicle and ensures the battery is charged to its rated capacity. Float chargers are critical in the bitter cold, ensuring that the vehicle or generator set engine will start. 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

2-77. 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

2-78. The inline coolant hose heater consists of an electrical heating element installed along the hose connecting the engine and the radiator. Like the block heater, it is electrically powered. The circulating coolant inline heater heats coolant and circulates it through the engine by tapping the engine water jacket. It uses 400 to 1500 watts to heat antifreeze up to 135°F (57°C) to 175°F (80°C). The heater is spliced into the coolant hose (usually to the heater core hose returning to the engine) and uses a built-in pump to circulate coolant over the heating element and through the engine block antifreeze system. For vehicles, this means almost immediate crew cab heating.

Engine Oil Heater

2-79. This electrical heating element is mounted to maintain contact with the engine oil or oil pan. This ensures that the engine oil is less viscous at startup, minimizing fuel and water accumulation in the crankcase.

Transmission Heaters

2-80. These heaters keep transmission fluid thin enough (lowered viscosity) to avoid rupturing seals. They are usually electrical heater pads (like those used for oil heating) attached to the side of the transmission cowl that keep the transmission oil warm.

Heating Pad

2-81. The simplest form of quick heating is provided by an electrical heating pad. These are pressed against the side of an oil pan or the side of a battery to keep them warmed.

Engine Standby Heaters

2-82. Standby heaters are fuel-fired coolant heating units that run on the vehicle's own fuel supply (internally powered heat source). This type of quick-heat system heater is becoming rare in newer military equipment. They are typically installed in the engine compartment and 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.

2-83. Standby heating systems are designed to ensure that vehicle components do not fall below a certain minimum temperature. These systems use a small fuel-fired boiler and fuel-fed engine to pump antifreeze through the engine and also warm the transmission and battery. To ensure proper operation, 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.

2-84. 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, the standby system can help start an engine in an emergency if there is enough time and auxiliary power available.

Engine Pre-Startup Considerations

2-85. 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.

2-86. Once the engine is operating after starting, watch 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. If this occurs, stop the engine immediately and determine the cause.

2-87. Technical problems with these heaters include—

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

CHASSIS AND BODY COMPONENTS

2-88. Though any temperature below freezing becomes an issue for vehicle fluids, most vehicles components are resistant to temperatures down to about 10°F (-12°C). Near that temperature, the tensile strength, brittleness, and thermal contraction of many materials will noticeably change a mechanical item's performance properties.

2-89. Ice, mud, and snow can build up to such an extent on vehicles that they overload vehicle components, reduce ground and other clearances, and prevent or interfere with the 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

2-90. The expansion and contraction of tire rubber in response to temperature changes is important to note, as it is opposite to the behavior of metal rims. Tire rubber expands when exposed to cold temperatures, but it contracts in warmer environments. These temperature fluctuations directly impact tire pressure. Frequently monitor tire pressure to prevent issues like underinflation or overinflation; these directly affect vehicle handling and fuel efficiency. If radial tires are overinflated, the center of the tire will bow outward causing the tire edges to lose ground contact. If radial tires are underinflated, the center of the tire will bow inward causing the tires to run on their edges and lose ground contact in the center. In temperate weather, incorrect tire pressure causes uneven wear and shortens tire life; in icy or snow-covered roads, it can also lead to a life-threatening loss of traction.

2-91. The air pressure in a tire will drop as temperatures cool. Increase tire pressure about 10 psi for overnight or extended parking to compensate for the cold effects on tires. Tires should be deflated to proper pressure before operations.

2-92. Operators and maintainers need to pay attention to the matchup or dissimilarities between the tires and rims. It is possible for a tire (without a steel wire in the bead) and rim to break its seal at about -13°F (-25°C). If aluminum is in the mix of components, it contracts more than steel.

2-93. 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. At -50°F (-46°C), tires

become rigid enough to support a load at 0 pressure without apparent deflation. This is a problem because sidewalls become brittle and may crack.

2-94. Using nitrogen gas to inflate tire is a good practice. Tires filled with nitrogen are not as prone to expansion and contraction as those filled with regular air.

2-95. Winter-rated all-season tires are available on some tactical vehicles and should be used where appropriate. In some less severe conditions, the use of winter-rated tires may replace the need to install tire chains. Do not mix winter-rated all-season tires fitment with other non-winter rated tires. For applications where winter rated all season tires are not available, standard all season tires may be mixed if approved for mixed fitment under the same national stock number.

WHEEL BEARINGS

2-96. Usually, no change of lubricants is required when wheel bearings are serviced with grease, automotive and artillery (known as GAA). It has a temperature range from -65°F (-54°C) to 225°F (107°C) for year-round operations.

SNOW CHAINS

2-97. Supervisors should conduct a thorough inspection of vehicle chains prior to cold weather to ensure that they are serviceable. This inspection should include checking for signs of wear and tear like rust and weak links that may lead to chains becoming unserviceable. Inspect chain connector mechanisms to ensure that they function smoothly and will latch. Include fresh elastic chain adjusters when ordering replacement inventory. Have extra work gloves or rubberized gloves available, packed with the chains in a waterproof bag. Mounting chains while on the road will soak through a set of leather gloves.

2-98. Chains always go on the drive wheels. Rear-wheel and front-wheel drive vehicles require two chains, one for each drive wheel. For all-wheel drive vehicles, each wheel needs a snow chain.

2-99. Each vehicle's TM should identify the size snow chains required and instruct Soldiers on how to install and adjust them. 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; they can take an hour or more to install under normal (wet, snowy, dark) conditions. Drivers should deploy roadside safety warning markers during chain installation.

Note. Always follows the equipment operator's TM on tire chain installation procedures. Improper installation may damage the CTIS, brake lines, and other final drive components.

2-100. 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 in use. This simple practice helps keep them in good condition and reduces tire stress.

2-101. When equipped with chains, keep vehicle speeds according to the operator TM. The speed is usually 10 to 30 miles per hour or 15 miles per hour on average (16 to 45 kilometers per hour) while driving with snow chains.

2-102. It is important to have the right size tire chains as one size does not fit all vehicles. Using the wrong size chain can lead to a lack of traction on slippery roads. Additionally, incorrect tire chains can damage the vehicle's tires or even the body of the vehicle. Check the additional authorization list to determine the correct tire chains for a vehicle. Chains wear out after approximately 350 miles of asphalt road operation.

2-103. Unless otherwise directed, do not run tire chains on bare clear pavement. The vehicle TM will specify chain type/size, allowed speed, and axle line installation positions. When using chains, maintain correct installation tension and avoid harsh acceleration/braking resulting in wheel spin or lockup whenever possible.

2-104. Use the correct pressure setting and transfer case range for the usage conditions. If chains should fail, repair them immediately; broken chains could result in vehicle damage. When using tire chains on public roads, ensure it is legal and in-season. Install chains in safe, level areas free of traffic hazards. Some chains are heavy and require a two-man lift for installation.

2-105. The use of tire chains on fuel tankers is authorized. When used, they must be used on all four rear tanker trailer tires. Do not use tire chains for fuel tankers on dry clear pavement or during conditions that could create excessive sparks.

BRAKES

2-106. When parking in freezing weather, avoid setting the brakes as they may freeze and become stuck. Instead, use chock blocks to secure the wheels or tracks in place. If brake components do freeze in the set position, use a portable heater for thawing to prevent damage to the vehicle powertrain.

Hydraulic Brakes

2-107. Check the reservoir of hydraulic brakes for proper fluid level. No seasonal change of fluid for hydraulic brake systems is required. Use brake fluid, silicone, MIL-PRF-3270, Brake Fluid, Polyglycol, Automotive, All-Weather, Operational and Preservative.

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.

2-108. Frozen moisture in the air brake system seriously affects operation. Brake lines, air brake filters, brake chambers, pushrods, valves, and seals are subject to more defects and failure in the 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. Monitor the pressure closely for one minute to ensure that there is no noticeable drop in air pressure.

2-109. The air dryer is equipped with a heating element and a desiccant cartridge designed to remove moisture from air before it enters the primary and secondary air tanks. If the air dryer is unable to eliminate all excess moisture, it is automatically released when the air system reaches 120 psi. Drain reservoirs immediately after operation, and close drain valves immediately after draining to prevent freezing in the open position. In the morning, build up pressure before moving the vehicle. Follow -10 TM PMCS procedures on air dryer proper operation and maintenance.

2-110. Several tactical vehicles types are equipped with a CTIS. It is not unusual for air valves to freeze resulting in locked brakes or flat tires. For vehicles with CTIS, 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

2-111. Improper lubricants will congeal or harden and make steering difficult or impossible. Fill hydraulic power steering reservoirs with hydraulic fluid, petroleum base (military symbol supply code (OHT) [MIL-PRF-6083] and North Atlantic Treaty Organization [NATO] symbol C-635); original equipment/heavy duty oil (OE/HDO) synthetic multipurpose lubricant (SMPL); or oil, engine, arctic (OEA)-30 (do not use DEXRON VI). Examine arms, tie rods, drag links, seals and boots, pitman arm, gear column, and wheel for good condition and secure mounting.

SPRINGS

2-112. Springs can become brittle and prone to breaking at low temperatures. Clips, leaves, U-bolts, hangers, and shackles must be in good condition and correctly and securely mounted. Spring leaves should not be

broken or shifted from their correct position. Ensure that all suspension spring retainers, assemblies, and mounting bolts are securely tightened. When starting out, proceed with caution to allow the springs enough time to attain flexibility and adjust to the load they are supporting. This will allow for smoother and safer operation of the equipment. Avoid driving into depressions or over obstacles; this practice may create shocks that could break springs in the cold.

SHOCK ABSORBERS

2-113. When the temperature drops below freezing, the fluid in shock absorbers can thicken and cause the vehicle to ride hard or break the shock absorbers. Ensure that the shock absorber bodies are securely mounted to the frame. Replace shock absorbers that are leaking or not working properly. Operating the vehicle slowly for the first three to five miles allows the oil in the shocks to warm up and helps prevent damage to the shock absorber, the operating rods, and the mounting brackets.

TRACK AND SUSPENSION

2-114. Check oil-lubricated roadwheel 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 or cause loss of control.

2-115. 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 employ traction aids (such as ice cleats or 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 because they contract and can 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 2-1). Another method is to allow the vehicle and track to cool to outside temperature before adjusting.

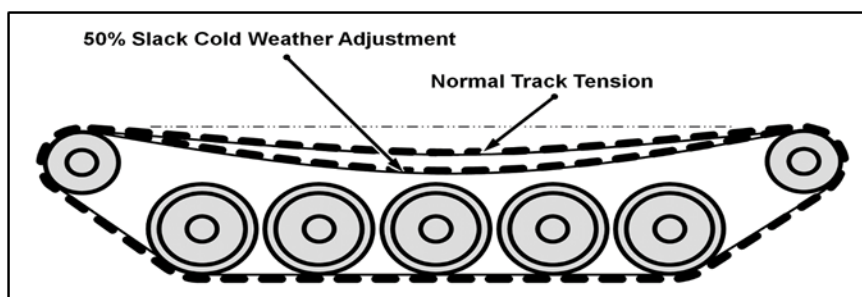


Figure 2-1. Cold weather adjustment

2-116. Ice cleats improve traction on icy roads. However, these cleats are destructive to road surfaces. Limit their use to situations where the road surface is covered by a thick layer of ice and snow and not visible. Ice cleats designed for the T158 track of the M1 series tank are available to enhance performance on icy terrain. Install a set of cleats on every fifth track shoe for best performance. A total of 64 cleats and 64 new self-locking nuts are required per vehicle (32 per side). These cleats are for the T158 track only; they will not work with the T156 track (cleats are not yet available for the T156 track).

CAB CLOSURES

2-117. 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 fit tightly.

FIRE EXTINGUISHERS

2-118. Fire protection is essential for the survivability of equipment and personnel. Most up-armored vehicles are equipped with an automatic fire suppression system that protects the crew inside the vehicle and the powertrain. Perform PMCS of the equipment fire suppression system. Ensure nozzles are free of clogged ice or debris and that photo sensors are not covered, obstructed, or damaged. Winterize carbon dioxide (CO_2) fire extinguishers according to the appropriate fire extinguisher technical bulletin (TB).

Chapter 3

Batteries and Electrical Energy Storage

This chapter provides general information on types of batteries and considerations for their storage, care, and use in a cold or arctic environment.

POWER STORAGE BATTERY MAINTENANCE

3-1. One of the greatest hindrances to successful operations in cold or arctic environments is the effect of the cold on power storage or batteries. Battery power is as critical to mission capability as petroleum. Maintainers and operators face the challenges of dealing with different battery types that have distinct characteristics. Power storage or batteries are typically characterized by the materiel used for the electrodes (or plates) within each cell. They must be maintained in accordance with the TM or manufacturer's recommendations.

3-2. The cold usually increases the amount of power required to start an engine or power a device and reduces the cranking power of batteries. Maintenance managers and unit planners should anticipate an increased level of battery use, failure, and parts replacement. Proprietary COTS devices will have unique battery power requirements that must also be accounted for. For more information on Army power storage, visit <https://battery.army.mil/>.

BATTERY MAINTENANCE AND MANAGEMENT PROGRAM

3-3. The Battery Maintenance and Management Program provides guidance and sets procedures for the use and maintenance of military or commercial standard non-rechargeable, rechargeable, and reusable batteries. It establishes actions of the operators, supervisors, and maintainers to optimize battery life in accordance with AR 750-1 and DA Pam 750-1. Supervisors of equipment operators will need local unit guidance on policies and procedures with listed references for each battery type in the inventory.

3-4. Maintenance personnel will order and use valve-regulated lead-acid (VRLA) batteries as replacements for flooded wet-cell batteries. As an exception, flooded wet-cell batteries may only be used when VRLA batteries are not available or not yet approved for use by the TM. Do not mix flooded wet-cell and sealed batteries.

CAUTION

Only trained personnel are authorized to perform maintenance on batteries in accordance with the equipment TM.

3-5. Temperature ranges and battery performance values presented in this chapter are generalized. Actual battery properties will vary according to manufacturer design specifications and the specifics of the field situation. For detailed information on a specific battery, consult the appropriate item-specific TM or military standards performance specification document (manufacturer or military).

3-6. Assume any communications-electronics batteries contain corrosive and/or flammable material and treat accordingly. In general, any lithium-ion type battery has more stringent handling, storage, and disposal requirements than that of batteries with more benign chemistries.

WARNING

- **Never attempt to charge a frozen battery.**
- **Do not attempt to operate equipment with frozen batteries.**
- **Do not attempt to slave equipment with a battery that is or has been frozen.**

Attempting any of these actions may cause the batteries to explode and may cause injuries to personnel.

3-7. If a lithium battery overheats, hisses, or bulges, immediately move the device away from flammable materials and place it on a noncombustible surface. Move the device and battery outdoors if possible, but do not handle it if flames appear. Allow ample ventilation while the battery burns itself out.

Note. Baking soda and household ammonia solution are two substances that can neutralize the acid contained in battery electrolytes. Always have baking soda available 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.

3-8. A battery's total energy storage capacity is reduced in cold environments. This not only applies to the energy that can be drawn out of a battery, but it also applies to the rate at which energy can be absorbed into the battery after it is depleted. Low temperatures can impact the charging time of rechargeable batteries. Specifically, cold lead-acid batteries in tactical vehicles can take up to twice as long to recharge compared to when operating in fair weather temperatures.

3-9. The SOC of a battery indicates how well it is prepared to deliver electrical energy and is expressed as a percentage of the battery's highest energy rating. Understanding the SOC is important for optimizing battery usage and ensuring efficient energy management. The SOC shows how much energy a battery has remaining (full charge = 100% SOC, middle charge = 50% SOC, or fully discharged = 0% SOC). Conversely, the depth of discharge (DOD) is a measure of how deeply discharged a battery is (fully charged = 0% DOD, middle = 50% DOD or fully discharged = 100% DOD). The DOD is the opposite of SOC, so as one increases, the other decreases.

3-10. It is important for equipment operators to receive training on how to prevent situations that may lead to battery freezing. Even in hazardous cold situations, operators can still prevent batteries from freezing by following the TM (both the TM for the platform in general, and the TM specifically for the battery) and unit supplemental procedures developed by the maintainers.

3-11. Maintainers and operators need to ask several questions when using batteries in cold weather operations. The answers to these questions should be found in unit supplemental procedures and presented as a part of Soldier training:

- 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 should batteries be maintained for optimal performance and longevity, especially in extremely cold weather?
- 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 Soldiers avoid or respond appropriately to them?
- What are the disposal considerations for a battery after use?

CAUTION

When starting and running an engine, disconnect float chargers, trickle chargers, and related devices unless the TM says it can remain hooked up. Failure to do so may cause damage to equipment.

3-12. In cold, keeping a battery serviceable involves a different set of priorities from those that occur in temperate weather, even though the rules and procedures are the same. A cold-soaked (not frozen) battery takes longer to recharge because the cold will increase internal resistance, reducing its ability to accept a charge. This limitation applies to all battery chemistries in common use. The cold temperatures slow the electrochemical energy conversion process. However, as the process continues, waste heat caused by internal resistance during charging can warm the battery. This effect then improves the charging rate to some extent. The voltage regulator in the charging system plays a crucial role in maintaining a specific voltage intended for a given battery's structure and chemistry. In the case of tactical vehicles, voltage regulators are designed to keep the charging system voltage at an optimum setting for temperate weather and prevent the alternator or a charger from overcharging the battery. However, such default settings may not be adequate for overcoming cold-induced resistance.

KEEPING A BATTERY CHARGED WHILE USING IT

3-13. At normal temperatures, it takes an engine alternator approximately 20 to 30 minutes (40 to 50 minutes for absorbed glass mat batteries) of engine run time at normal idle to replace the energy that was used to start the engine. If the temperature is between 32°F (0°C) and 0°F (-18°C), double the run time; if the temperature is below 0°F (-18°C), it is recommended to triple the run time, possibly even four or five times longer, just to recover from starting an engine.

3-14. An alternator is meant to maintain the optimum SOC of a battery, not to fully recharge a depleted battery. When the engine is idling, the alternator does not start recharge the battery. Thus, if the engine is turned off after a short trip, the partially recharged batteries might freeze due to 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.

3-15. 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 or charge it. For traditional flooded cell batteries, remove the filler caps for each cell and check if the electrolyte is frozen. For the newer lead-acid gels to include gelatin silicate electrolyte (GEL) or AGM batteries, it is important to allow frozen batteries 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).

3-16. Operators must never attempt to thaw and recharge frozen flooded cell type batteries. Instead, tag them as "frozen" and turn them in for proper disposal. Maintainers should be proactive in checking and testing batteries in cold environments. When recharging a battery that has been cold soaked (but not frozen), the battery will resist the flow of current. The amount of resistance to recharging will cause localized heating or overheating within the battery.

Note. Unit maintenance trainers should regularly refresh all operators and maintainers who work with automotive batteries on all safety warnings pertaining to them. The full list of warnings can be found in TM 9-6140-200-13.

CAUTION

DO NOT mutilate, incinerate, or throw away batteries with trash. Batteries are a potentially environmentally HAZMAT. The Defense Property Disposal Service is responsible for disposal of batteries as hazardous items.

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-Discharge

3-17. Even if a battery is not in use, it is self-discharging. The challenge for the operator or maintainer is to keep the battery charge high enough to keep it from freezing and able to crank over a cold-soaked sluggish engine. This marginal zone between fully charged and the minimum voltage is called the floating voltage.

3-18. Trickle chargers are only good for a spot situation to raise the energy level of a depleted battery that 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 do not have the ability to detect a battery's SOC and regulate the volume and rate of energy flowing into a battery.

3-19. A float charger should be used to keep an idle or stored battery at its optimum charge. These types of chargers have circuitry to prevent batteries from overcharging. It means that they can be hooked up and left unattended almost indefinitely. Flooded battery fluid levels should be checked regularly for evaporation.

State of Charge

3-20. The freezing point of a lead-acid battery (Figure 3-1) depends on its SOC. The SOC 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.

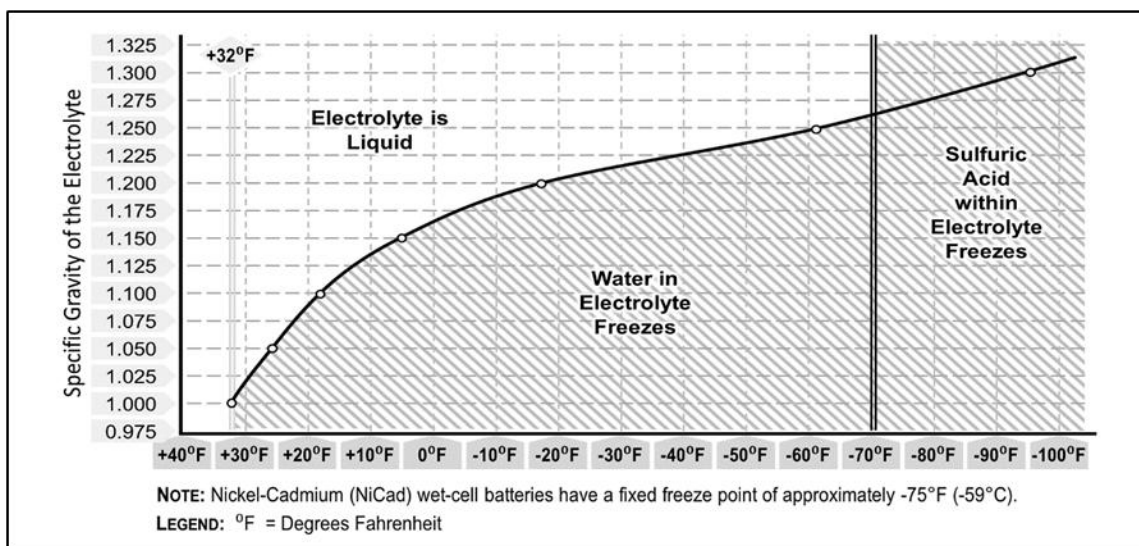


Figure 3-1. Freezing points of lead-acid battery at various specific gravities

3-21. As a battery discharges, chemical reactions gradually remove the sulfuric acid from the electrolyte solution. This process reduces the concentration of sulfuric acid as the percentage of water increases. As the water content of electrolyte increases, the specific gravity of the solution approaches that of pure water (1.00).

Therefore, 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.

Hydrometer Electrolyte Specific Gravity Test

3-22. The battery's SOC is indicated by the specific gravity of the electrolyte. For instance, if the hydrometer reading is "1.150", the water in the electrolyte can freeze at -5°F (-21°C). As the specific gravity decreases, the battery's ability to start a vehicle or generator set engine also decreases. 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

3-23. The refractometer (Figure 3-2) is the preferred testing tool for conducting specific gravity testing. Like the hydrometer, the refractometer is specifically designed 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.

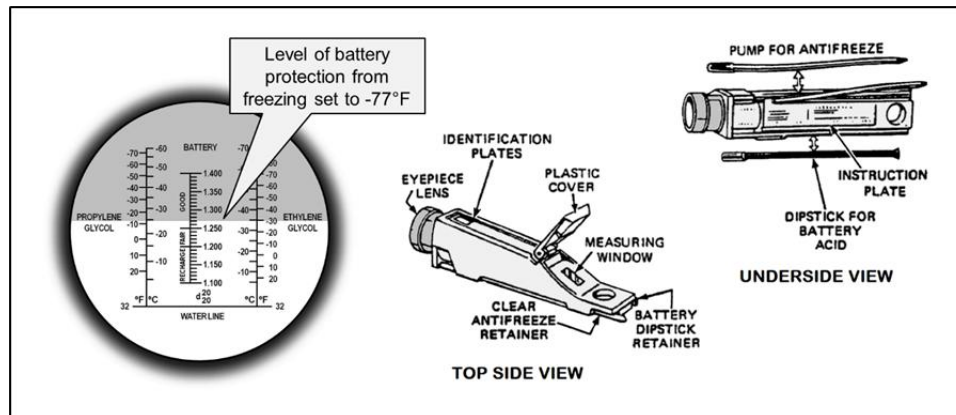


Figure 3-2. Refractometer for testing electrolyte

3-24. 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).
- Make 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.
- Once the zero adjustment is complete, clean the prism with a soft cloth.

3-25. Add distilled water as needed to properly fill each cell. The battery should be warm before checking the 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.

3-26. 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 PPE when handling sulfuric acid electrolyte and servicing flooded batteries.

Frozen Batteries

3-27. Wet cell batteries may freeze if they are not fully charged, as the electrolyte fluid in a battery contains water and sulfuric acid, both of which can freeze. When a battery is not fully charged, the sulfuric acid and distilled water are not mixed properly; this could cause the distilled water to freeze. For example, the electrolyte of a lead-acid battery can freeze at approximately -16°F (-27°C) when the battery is only 40% charged, but at around -92°F (-69°C) when it is fully charged.

3-28. If a flooded battery freezes, it can expand, break the plates, and crack the case. A frozen battery may need to be replaced and should not be slave-started or charged. If one of the following is present, refer to the equipment's TM for removal and follow-on tasks. Notify the maintenance personnel if these conditions are present—

- Bulging sides.
- Cracks.
- No liquid sound when moving battery.

3-29. Other signs that the batteries are having cold weather issues include—

- Electronic device errors in functions.
- Warning lights. The charging system warning light or battery indicator light may be illuminated.
- Engine starting difficulties. The engine may crank slowly or sluggishly when starting the vehicle.
- Dim headlights. The headlights may dim when the vehicle is idling but brighten back up after the engine is revved.
- Strange smell. A noticeable strange smell inside the vehicle that could smell like rotten eggs. This can happen when the battery's internal mechanism shorts out due to freezing or overheating.

3-30. 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.

WARNING

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

3-31. Operators should observe that flooded vented lead-acid (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.

3-32. Only add distilled water into the batteries. The impurities of tap water will corrode the lead plates inside the battery and prevent the battery from charging to full capacity.

Battery Load Test

3-33. It is not sufficient to only know if a battery is delivering the 12 volts for which it is rated. The question is whether the battery has the reserve power to overcome the cold engine's resistance to starting.

3-34. Load testing determines if the battery can supply enough current (in amperes) to start an engine. The tester 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. For example, a 12-volt battery voltage could drop to 10.5 volts or less.

3-35. A battery's cold cranking amps (CCA) rating and the ambient temperature can affect the test results. CCA refers to the maximum current the battery can continuously provide 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. After the test, a good battery will show an open circuit voltage above 10.5 volts. If the voltage drops below 10.5 volts, add more charge, then retest the battery. In addition, the maintainer performing this test must compensate for low temperatures. For instance, at 0°F (-18°C) subtract 300 CCA from the battery's CCA rating. It is crucial to carefully follow the load tester's operating instructions.

3-36. Using a handheld load tester (Figure 3-3), 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 3-3. Battery load testers (digital and analog)

BATTERY FIRE PREVENTION

3-37. Batteries generate heat due to chemical reactions during charging and discharging. 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 that can result in a rapid increase in temperature and potential fire or explosion. 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 they are most associated with excessive energy being pushed across the available battery plates at a rate that exceeds the battery's ability to dissipate. This is commonly referred to as an exothermic reaction; it typically happens in extremely high or low temperature environments or when the battery is not maintained properly. These reactions can happen to both automotive and non-automotive batteries. Thermal runaway does not occur abruptly; it is typically preceded by warning signs (except for lithium batteries). When a depleted battery is cold soaked, it is important to warm the battery back up as soon as circumstances allow to avoid sulfation.

BATTERY SULFATION

3-38. 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 whether they are in storage or installed in a vehicle. "Sulfation" describes the formation of lead sulfate crystals (PbSO_4) 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 becomes severe, it can damage the battery permanently. Lead-acid GEL and AGM type batteries are not as prone to sulfation based on their physical construction; however, 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

3-39. Thermal runaway refers to a dangerous, self-sustaining chain reaction where a battery rapidly heats up due to internal chemical reactions, causing a significant increase in temperature and pressure and potentially leading to fire or explosion if not contained. It occurs when the heat generated within the battery exceeds its ability to dissipate heat, creating a positive feedback loop where rising temperature further increases the reaction rate and causes even more heat generation.

3-40. In theory, the initial cause for a thermal runaway differs between high heat and 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 accumulation within a battery is referred to as 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.

3-41. This heat cannot be allowed to get so hot that it burns the electrical plates within the battery. The heat must 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 build up on the plates. As the heat builds, lead and sulfur in the electrolyte separates and crystallizes on the battery plates, causing sulfation. When the chemical interaction cannot dissipate energy as electricity through the battery plates, it bakes the sulfation crystals onto the surface of the plates and blocks the electrical charge from reaching the plates.

3-42. If the electrolyte freezes, it causes the energy of the electro-chemical reaction to build up on localized areas of the plates, that again converts directly into a localized exothermic heat that damages the plates. In situations of overcharging, high heat, or freezing, the resulting excessive heat generation is followed by thermal runaway. The following situations, whether in hot, temperate, or cold weather, can cause the battery to rupture, explode, or catch on fire:

- When 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.

- When a normal charge is 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:
 - If electrolyte is not properly filled or has leaked out of the battery, limiting the available surface area of the plates.
 - When sulfation occurs, limiting the available surface area of the plates.
 - When frozen electrolyte covers plate surfaces, limiting the available area of the plates.
- If excessive charge voltage forces a high overcharge current into the whole battery.
- If there is a dysfunctional voltage regulator on the charger, vehicle, or equipment, forcing a high overcharge current into the whole battery.

PROCESS OF THERMAL RUNAWAY

3-43. One of the primary risks to battery life in the cold temperatures is the occurrence of “thermal runaway.” Thermal runaway commonly occurs in the following sequence in subfreezing temperatures:

- 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 that 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) 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 remains available to support the charge and dissipate the heat, more heat becomes concentrated on the remaining plate area and 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 cause sulfation, leading to the formation of non-conductive lead sulfur crystals on the battery plates. This will cause an increase in battery deterioration, potentially causing it to overheat, melt, or catch on fire.

Note. The initial cause (steps 1 and 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

3-44. Operators should not attempt to start an engine with a depleted battery. After three failed attempts to start an engine, operators should find help from a maintainer. If 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. Forcing a depleted battery to start an engine uses 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.

3-45. Both operators and maintainers can help prevent battery thermal runaway in cold weather:

- Use 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 is 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 chargers that can will automatically adjust the power flow or shut off the charger once the battery is ready.

VEHICLE BATTERIES

3-46. There are two basic types of lead-acid storage batteries in four types of construction technologies commonly found in Army automotive equipment:

- Flooded batteries (also known as wet-cell batteries) contain free-flowing electrolyte fluid:
 - VLA batteries (the traditional “flooded” cell car battery).
 - Nickel Cadmium wet-cell batteries (not commonly used for ground vehicles).
- VRLA batteries, commonly known as sealed batteries or maintenance-free batteries, are designed with immobilized electrolytes to prevent spills:
 - Gel batteries.
 - AGM batteries.
 - Deep-cycle lead-acid batteries are specifically designed for deep cycling applications. These batteries are typically discharged to 50% of their capacity and recharged again. This type of battery is generally used in applications where constant power is required for long periods of time like in the case of most heavy construction equipment.

3-47. Generally, a well charged battery can be stored in uncontrolled temperature conditions of -40°F to 100°F (-40°C to 38°C) for at least 18 months without damage. On the other hand, wet-cell batteries have high self-discharge rates and tend to die much sooner. Therefore, it is important for battery maintainers to know the specific storage requirements based on the manufacturer’s specifications.

FLOODED BATTERIES

3-48. Flooded batteries require routine maintenance. Flooded batteries use lead plates, a sulfuric acid as electrolyte, and plate separators. Most flooded batteries are not sealed and do not recombine the gases to liquids internally. Instead, these gases are vented out to the atmosphere. Acid, steam, and condensation can flow through these same vents causing possible maintenance issues.

3-49. The normal flooded batteries require extra care and regular maintenance in the form of watering, equalizing charges, and keeping the terminals clean. Flooded cell batteries must be mounted the right way up and can be susceptible to spillage.

Vented Lead-Acid Batteries

3-50. Known properly as a VLA battery, a wet-cell battery is equipped with vents to allow gas to escape to the atmosphere. VLA batteries have a longer lifespan and require more maintenance over the life of the battery. These batteries vent electrolyte to the atmosphere; it is essential to monitor electrolytic fluid on a continual basis. Add distilled water periodically to properly maintain fluid levels.

3-51. VLA battery installations are physically larger than most other battery solutions and require a spill containment system or a floor coating to manage the liquid electrolyte as this liquid is corrosive and environmentally hazardous.

Note. Due to advances in battery technology, the traditional flooded VLA batteries are being replaced and upgraded with VRLA (sealed) batteries. Flooded VLA batteries are no longer common in the Army. They are noted here due to the complexity of their service and maintenance.

3-52. Unless a storage battery is warmed above 32°F (0°C), it will resist receiving a full charge from the vehicle’s generator. If the vehicle has a battery preheater, use it as described in the operator’s TM. A battery preheater is a pad, wrap or blanket made of heat-resistant synthetic material with wire heating elements that 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. It is important to ensure that the starting batteries remain fully charged.

CAUTION

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

3-53. 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 electrochemical reaction rates. Follow the instructions of the battery charger for low-temperature operation of all types of starting batteries, including flooded, AGM, and GEL. This will reduce the permissible charging current, thereby increasing the charging time.

Note. If adding distilled 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. 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.

3-54. Consider these tips when working with flooded batteries include to avoid premature unserviceability, and accidents.

- 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).
- Fill battery with distilled or deionized water to cover the plates if low. In emergencies, check with the maintenance supervisor before using tap water.
- 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.

3-55. The available energy in vehicle batteries decreases sharply when temperatures fall (See Figure 3-4). At the same time, the power requirements for starting an engine increase by about two or three times when the battery is least capable of delivering that power.

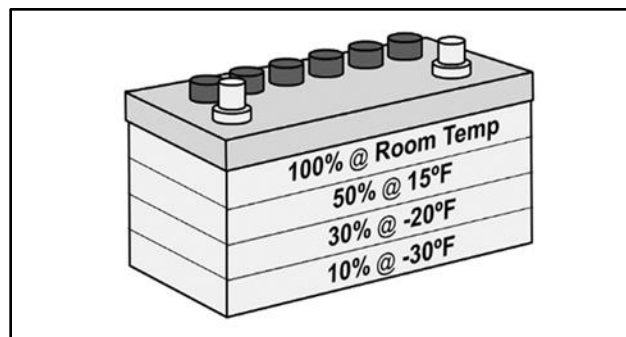


Figure 3-4. Flooded battery power availability at varying temperatures

Nickel-Cadmium Batteries, Wet-Cell

3-56. Nickel-cadmium wet-cell batteries are commonly found in aviation (MIL-PRF-81757 and MIL-PRF-8565), maritime, or industrial uninterrupted power supply (commonly known as UPS) backup systems. They are almost never used in ground vehicles because they cannot be serviced together with lead-acid batteries.

CAUTION

Do not transport, store, or service lead-acid and nickel-cadmium (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 nickel-cadmium batteries

3-57. The only accurate way to determine the SOC of a nickel-cadmium battery is by a measured discharge with a nickel-cadmium battery charger. A nickel-cadmium 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. The potassium hydroxide in the battery is not prone to freeze damage due to limited chemical change between charged and discharged states. However, the water within the electrolyte solution can freeze at approximately -75°F (-59°C), potentially rupturing the battery cell.

SEALED BATTERIES

3-58. These batteries are known properly as VRLA batteries (also known as maintenance-free batteries). They feature immobilized electrolytes that prevent leakage in the event of a cracked case. When fully charged, VRLA batteries can withstand severe cold conditions without sustaining damage. However, under low SOC or when discharged, these batteries may freeze (as shown in Figure 3-5). Temperatures below -70°F (-57°C) will freeze VRLA batteries regardless of SOC.

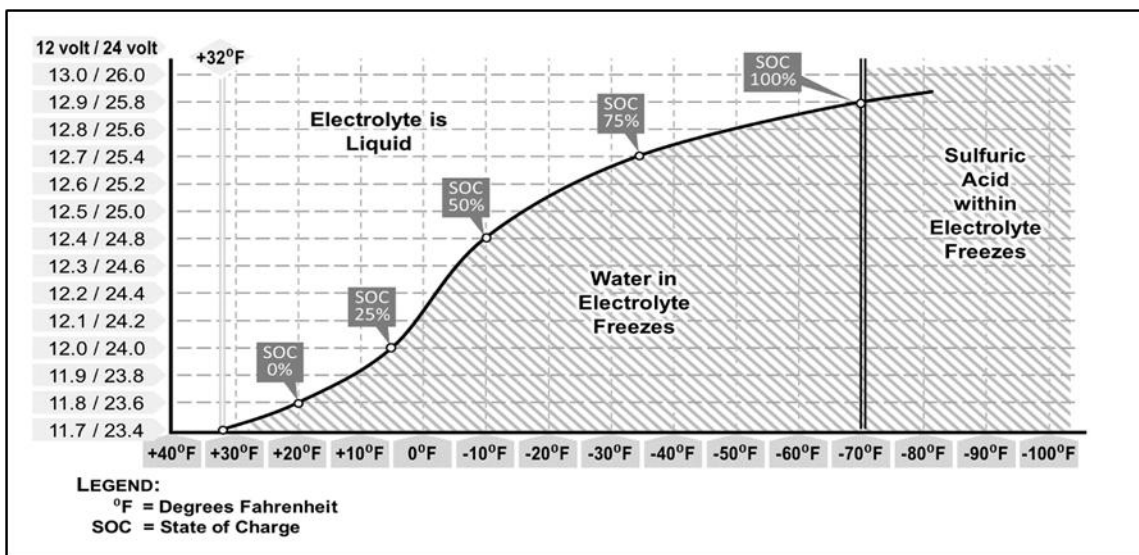


Figure 3-5. SOC required for VRLA batteries to prevent freezing at a given temperature

3-59. Maintenance requirements for VRLA batteries are lighter compared to wet-cell types. However, they still have a water-based electrolyte; 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 making it vulnerable to thermal runaway.

Gel Batteries

3-60. Gel batteries contain a gel-like electrolyte that is mixture of sulfuric acid and silica fume. These batteries are completely maintenance-free and non-spilling. These batteries do not need to be kept or installed upright and do not require special handling when shipping. They are resistant to electrolyte evaporation, spillage and corrosion. They are resistant to extreme temperatures, shock, and vibration. They are capable of withstanding over-discharging.

3-61. Even though GEL batteries are not flooded in the traditional sense, they are still lead-acid batteries that incorporate silica or polymer particles to create a gel-like agent into hydroxide-based electrolytes. They may have up to 15% greater energy output compared to flooded VLA batteries of the same size.

3-62. 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 suspects the battery is frozen, do not try to charge it and contact a field maintenance level maintainer. A qualified maintainer can determine if the battery is serviceable.

3-63. By using a silicon dust (silica) to suspend the electrolyte, there is very little water expansion that could rupture a GEL battery. Though not impossible, 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.

3-64. 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 electrochemical reaction within the battery.

3-65. 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. Once the GEL battery is discharged, its gelatin electrolyte can freeze. 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.

3-66. If the maintainer suspects a battery is frozen (or with a freezing external temperature and discharged), maintainers should do the following:

- Ascertain that the battery is both frozen and discharged.

- Move the battery to an area 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 qualified mechanic identify which batteries to return to service. Unrepairable batteries should be removed from service and sent to the supply support activity.

3-67. Dispose of unserviceable batteries according to Army regulations. This type of loss is avoidable by performing regular PMCS and keeping the batteries properly charged.

Absorbed Glass Mat

3-68. AGM batteries are a type of sealed lead-acid battery featuring a fiberglass mat situated between the plates. The fibers that compose the fine glass mat suspend and support the electrolyte but do not absorb, nor are affected by the acidic nature of the electrolyte. AGM batteries are characterized by a superior resistance to vibration and shock due to their construction. Packing the plates together with a glass 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.

3-69. AGM lead-acid batteries offer the best price point in the VRLA variety. These batteries provide much larger capacity in a smaller size and can be mounted on their side and shipped using standard shipping processes. A typical AGM battery can last 12 to 18 months in storage without being attended to, but some manufacturers claim that an AGM battery can last up to two years.

3-70. AGM batteries are not nearly as susceptible to sulfation compared to their flooded VLA counterparts. AGM batteries can freeze when stored in a discharged state, but a fully charged one can withstand temperatures as low as -70°F (-57°C). 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.

3-71. AGM battery features make them a good choice for the applications below:

- Tactical vehicles and generator sets are prone to experience shock and vibration routinely during transport operations.
- These batteries are designed for deep discharge applications and can provide back up and “silent watch” power.
- Use AGM batteries for applications where acid electrolyte leakage is not acceptable under any circumstances. These batteries will not leak electrolyte even when punctured or cracked. They are also not classified as “hazardous” in contrast to flooded VLA batteries.
- Suitable for cold temperature operations (below 32°F [0°C]) when charged and maintained properly.

COMMUNICATIONS ELECTRONIC BATTERIES

3-72. The communications electronics category represents many battery types used in a vast number of Army and joint systems. Communications electronics batteries refer 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. Communications electronics batteries consist of various electrochemical systems, each with its own unique response to cold temperatures. Some battery chemistries are better suited for cold weather operations than others. Typically, cold weather climatic limitations are addressed in individual equipment TMs. Most batteries perform to their specifications at a room temperature of 68°F (20°C), or in temperate weather.

3-73. Like other type of batteries, communications electronics battery performance also degrades 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. For example, if the communications electronics battery 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. Any battery should be treated with care. Issues include the following:

- Communications electronics 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. Universal chargers in the DOD inventory are designed to charge different battery types simultaneously. Follow the charger's TM.
- Never attempt to charge a non-rechargeable battery; 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.
- Always follow the warning and caution statements for batteries in the end item's TM.

WARNING

Do not cut, puncture, open, or otherwise mutilate communications electronics batteries.

Do not subject batteries to fire; they can ignite or explode.

Do not use CO₂ directed into a battery compartment to effect cooling.

3-74. 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 communications electronics 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 the batteries at the same time as a group for equipment with multiple batteries.
- Remove batteries before storage of devices.
- Use a CO₂ agent fire extinguisher in case of fire. CO₂ is an acceptable fire extinguishing agent for hydroxide-based electrolyte.
- Follow first aid instructions when any caustic substance has spilled on personnel. If batteries show signs of leaking, use rubber gloves, rubber apron and protective goggles.
- Provide careful handling of any lithium-ion type battery.

3-75. For planning purposes, the following procedures for conserving batteries in cold weather environments apply to operators, maintainers, and 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 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 properties 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.

NON-RECHARGEABLE DRY CELL BATTERIES

3-76. Also known as “primary batteries,” these batteries do not draw energy (recharge) from another energy source. They are very useful in situations where recharging is impractical or impossible, including combat, rescue missions, implanted medical devices, and other austere situations (MIL-PRF-49471). 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 immediately, even after extended storage.

3-77. Advances in non-rechargeable dry cell battery technology has resulted in dozens of different chemistries for making different types of batteries. Despite scientific advances, most are not cost effective for commercial or military use. Batteries today are patterned on legacy technology called a voltaic cell. Any primary battery’s performance can be affected by excessive heat, cold, high humidity, and high altitude. The battery casing is crucial for protecting its performance. It helps shield the battery from these environmental factors. 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 electrochemical energy generation process.

3-78. Traditional wisdom suggests keeping batteries warm by putting them under a coat or jacket. While this may work for flashlight batteries, most military equipment today uses rather large battery packs that do not 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

3-79. There are several different types of primary lithium batteries that are commonly used. In the consumer market, Li/CFX (poly carbon monofluoride) and Li/MnO₂ (manganese dioxide) batteries 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]). Li/SOCl₂ (thionyl chloride) and LiI₂ (lithium iodine) are commonly utilized in industrial and medical applications.

3-80. 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 to 15 years at 68°F (20°C). Lithium batteries can usually provide a somewhat satisfactory power performance down to about -4°F (-20°C) with a 40-60% decrease in battery life. Performance is greatly reduced at temperatures below that. 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 that range, the lithium electrolyte stops functioning. Above that, it will catch on fire.

3-81. 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 to 15 years in storage.

ALKALINE BATTERY, NON-RECHARGEABLE

3-82. Better than almost any other primary battery, alkaline manganese dioxide (/MnO₂) batteries resist degradation of performance in the cold. Their energy output remains constant and undiminished by the cold until they freeze. Alkaline batteries freeze somewhere around -4°F (-20°C). They have an estimated shelf life of 5-7 years at 68°F (20°C).

3-83. Many localities around the world consider spent alkaline batteries to be hazardous waste. They must be disposed of according to theater or installation policy, which follows host-nation, federal, state, and local environmental laws and regulations.

DISCONTINUED BATTERIES

3-84. Discontinued battery types may be required to support COTS devices. Carbon Zinc batteries and Mercury Oxide batteries (both non-rechargeable) have been discontinued from inventory and are classified as hazardous waste.

RECHARGEABLE DRY CELL BATTERIES

3-85. The technology behind power storage and dry cell batteries is constantly evolving, and the technical specifics in this TM will become obsolete as battery technology improves. Operators and maintainers should rely primarily on the item-specific TM and check current battery technology, trends, and applications.

3-86. 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). Lead-acid batteries require maintenance. They should always be kept at full charge when in storage. On the other hand, nickel and lithium-based batteries should be stored at around a 40% SOC. Partial discharge of these batteries (ranging from above 35%, to as much as 80% of their total capacity) is acceptable. Following these guidelines will keep nickel and lithium-based batteries operational while minimizing capacity loss due to self-discharge during storage. 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 1 volt per cell. Lithium-ion batteries cannot dip below 2 volts in each cell for any length of time, or they will need to be disposed of properly.

3-87. For thermal shock (resilience to physical damage at extreme temperatures) in the range of -75°F (-59°C) to 167°F (75°C), batteries are not expected to bulge, crack, break, leak electrolyte, rupture, burn, or explode due to varying rates of thermal expansion or contraction of cell and battery components when subjected to thermal shock temperature cycling.

3-88. 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 determine the age of a battery, the military uses a four-digit number to represent the month/year of manufacture (for example, 01/25 indicates January 2025). Knowing the age of a battery helps estimate the remaining battery life, even for a rechargeable.

CAUTION

Do not store a fully charged or fully discharged lithium battery.

GENERAL OPERATION OF RECHARGEABLE BATTERIES

3-89. The service life of rechargeable batteries is affected by several factors: ambient operating temperatures, physical use and abuse, and depth of discharge. In general, rechargeable batteries will experience a longer service life at shallow depths of discharge. In other words, a battery that is discharged to around 40% to 50% of its capacity before recharging will last longer compared to one that is consistently discharged to near zero capacity. However, the depth of discharge depends on the application's (load) duty cycle and whether it is practical to recharge the battery well before discharging it completely. Using only a small fraction of the battery's capacity before recharging would require more batteries for a given application. The strategy of recharging after a shallow depth of discharge is not always practical.

3-90. In cold climates, low ambient temperatures can increase the demand for batteries. The military performance specification for rechargeable batteries specifies they must withstand no less than 224 discharge/charge cycles without significant performance degradation. A "cycle" refers to a fully charged battery being drained to almost no charge (without reversing polarity) and then being brought back to full charge. The number of cycles a rechargeable battery can withstand depends on various factors including battery chemistry and usage conditions. For example, rechargeable communications electronics batteries can often withstand over 500 cycles.

3-91. Though new technology and better chemistries promise broader temperature ranges and longer life expectancies, the above parameters represent the most reliable planning information. When using rechargeable batteries daily in cold temperatures, equipment maintainers should expect a lifespan of less than two years for most batteries. Most equipment designers prefer lithium batteries due to their higher power capacity. However, these batteries have a shorter life expectancy that starts declining from the time of manufacture. As a result, the Army has discontinued including batteries with replacement items. Even if the

equipment sat in a warehouse for years, it is important to ensure the battery is fresh. Planners should expect to order fresh lithium batteries along with the related devices.

3-92. Some rechargeable battery packs have control circuitry inside their cases to control their performance. Most rechargeable battery packs must 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 engage during a low-temperature recharge. The item-specific TM will identify temperature ranges for recharging 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.

3-93. If a rechargeable battery discharges into reverse polarity, it can heat up and may even catch fire. Normally, the control circuitry will detect unusual heat and shut down the battery pack before this occurs. Operators can check for localized hot spots on a discharged battery pack to ascertain if the pack is failing. If a localized hot-spot is detected during the recharging process, deadline the battery and turn it in to the unit maintenance activity for evaluation, servicing, or disposal. This during-operations check is very important to prevent fire damage.

3-94. Rechargeable batteries are divided by Army specifications (MIL-PRF-32383A) into the following four categories:

- Type I – Batteries with a nickel-cadmium electrochemical system. Nickel-cadmium is now the older technology and are cheap because they suffer “memory” problems. The golden rule with nickel-cadmium batteries is to completely discharge them every time before charging them again, that way they will always be at their best performance. nickel-cadmium batteries can be cycled around 1000 times or charged once a day for around 3 years before they become unserviceable.
- Type II – Batteries with a nickel-metal hydride (NiMH or Ni-MH) electrochemical system. These can be partially discharged and charged as many as 1000 cycles and provide full capacity. They have much larger capacity than nickel-cadmium batteries.
- Type III – Batteries with a lithium-ion electrochemical system. These batteries solve both the problems associated with the other two types of batteries (full voltage and no memory problems).
- Type IV – Batteries with a lithium-polymer (LiPo) electrochemical system.

3-95. Army specifications for Type I and II rechargeable device batteries (MIL-PRF-32052) can operate above normal temperature range of -4°F (-20°C) to 122°F (50°C). Type III has broader temperature range specifications of -22°F (-30°C) to 131°F (55°C).

TYPE I NICKEL-CADMIUM BATTERIES, RECHARGEABLE

3-96. 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. Nickel-cadmium batteries are used in a variety of Army equipment including range finders, night vision sights, and ground surveillance radars. These batteries can perform at their rated capacity when the ambient temperature of the battery is in the range of approximately -70°F (-57°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 maintain their current for meeting energy demands. At 25°F (-4°C), these batteries lose about 30% of their useful life or service time before needing a recharge.

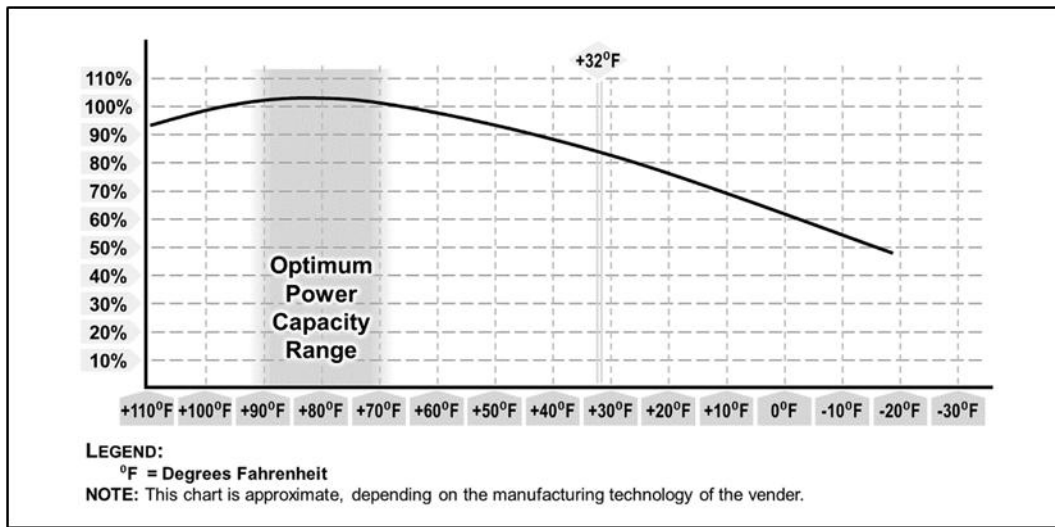


Figure 3-6. Nickel-cadmium power capacity at various temperatures

3-97. When nickel-cadmium batteries are first pulled from storage, it is important to prime them. This process involves connecting the batteries to establish a habitual relationship and trickle charging them for 16 to 24 hours when they are new or after a long period of 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.

3-98. Nickel-cadmium batteries have what is called, battery memory. To get maximum effectiveness when charging nickel-cadmium batteries, one must destroy the charging memory characteristic of the battery. For example, if a nickel-cadmium battery is continually called upon to deliver 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 nickel-cadmium 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 BATTERIES, RECHARGEABLE

CAUTION

Nickel-cadmium chargers will overcharge NiMH. (NiMH chargers can charge nickel-cadmium, but not the other way).

3-99. The NiMH or Ni-MH battery is similar to the nickel-cadmium. A NiMH battery can have two to three times the capacity of an equivalent size nickel-cadmium battery. 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.

3-100. At low temperatures, the NiMH provides a consistent level of power, all the way through discharge. At freezing, NiMH 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 on page 52).

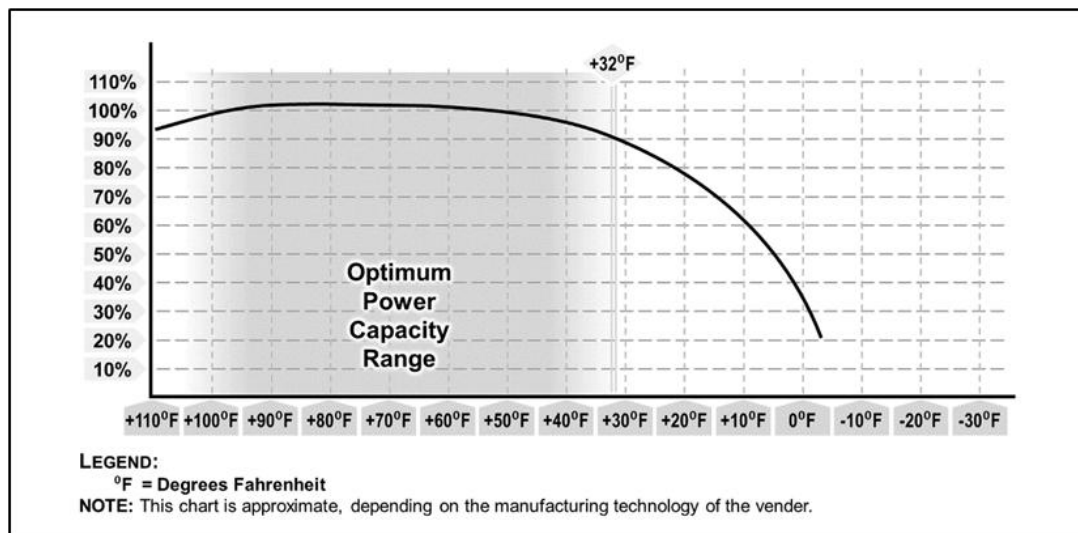


Figure 3-7. Nickel-metal hydride power capacity at various temperatures

RECHARGEABLE LITHIUM BATTERIES (GENERAL)

3-101. Lithium rechargeable batteries are the most common type of rechargeable batteries found in small electrical devices. Army specifications (MIL-PRF-32383) include the following:

- Discharges energy over a temperature range of -22°F (-30°C) to 131°F (55°C).
- Thermal shock resistance (the ability to avoid temperature caused physical damage) ranges from -75°F (-59°C) to 167°F (75°C).
- Rechargeable range limits are between 40°F (4°C) to 110°F (43°C).

Note. Never attempt to charge lithium batteries below 41°F (5°C). Doing so can cause plating to form on the anode and lead to a permanent loss of capacity.

3-102. Most lithium battery electrolytes freeze at approximately -40°F (-40°C). Freezing can damage a cell by damaging material bonds or causing dendrites (crystallization) in the electrolyte components that can pierce a separator element. Though new technology and better chemistries promise broader temperature ranges, the above parameters represent the most reliable planning figures.

3-103. Modern lithium batteries do not contain solid lithium metal. Instead, they use lithium ions suspended in a polymer and electrolyte gel. Older batteries with solid lithium metal could overheat after being used repeatedly. Today's lithium-ion batteries can have a variety of materials for their positive and negative electrodes and have varying energy density and voltage.

3-104. These batteries have the following drawbacks:

- 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.
- 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. The battery can become ruined if cell voltage drops too low. 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

3-105. Type III lithium-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 that is soaked with electrolyte. Never open a lithium-ion battery's casing. These batteries contain safety devices that protect the cells inside from abuse. If damaged, these safety devices may allow the battery to ignite or explode.

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 lithium-ion battery can cause it to ignite or explode.

TYPE IV LITHIUM POLYMER BATTERIES, RECHARGEABLE

3-106. Lithium polymer batteries operate on the same electrochemistry as the lithium-ion battery. It is 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. The dry electrolyte medium resists leakage and 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 lithium-ion battery. The drawback is the dry electrolyte separator's lower conductivity due to the electrolyte's molecular stability that impedes the movement (compared to the gelatin of a type III) of chemical interactions that release energy.

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Chapter 4

Petroleum, Oils, and Lubricants Management

This chapter is focused on the properties of petroleum-based fuel oils, lubricants, grease products, and solvents. These four products are available as crude oil-based products, synthetic oil-derivative products, and bio-synthetic oils and lubricants. This chapter discussed each of the four products.

MAINTENANCE CONSIDERATIONS

4-1. Both maintainers and operators must understand the limitations of petroleum, oils, and lubricant products in cold or frigid environments. They must 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.

4-2. Commanders and maintenance leaders should establish a trigger event or turnover point when POL products will be transitioned to support operations in cold weather. Units which are otherwise not originally programed for a cold region deployment should set a trigger event as part of cold weather contingency plans and policies. Units should identify what resources would be needed for cold weather deployment and where they can be rapidly procured. Once the trigger event or 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 changes in POL properties, movement difficulty, extended idling, and heating requirements. Prior planning is critical to mission success.

4-3. Maintenance Soldiers and equipment operators need to understand how the physical and performance properties of POL products change 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. Although crude oil-based petroleum products are economical and easy to procure, synthetic oil-derivative products are more resilient over a broader temperature range.

4-4. Synthetic oils and lubricants are the preferred choice in cold situations. They are made from pure component chemicals that are free of the impurities or molecular inconsistencies found in crude oil. The range between flash points and pour points (discussed in Appendix D) is broader for synthetics compared to conventional oil. The added resilience to high temperatures results in synthetics having two to three times greater mileage or extended lubrication life. 0W/20 oil qualified to MIL-PRF-32626 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 synthetic oils are mixed with crude oils, the crude oil properties dominate.

4-5. The DOD tests POL products for extreme temperatures down to -65°F (-54°C). However, personnel using these products 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 manufacturers or qualifying DOD activities have)?
- What procedures and precautions are needed to keep a POL product working in cold environments?

4-6. These questions are usually answered by the results of four tests:

- 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 fuel's 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. Below this temperature, the fuel 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 cloud point is the temperature at which paraffinic wax crystals start to appear. It is the lower operating limit for diesel fuel. The cloud point of diesel fuel varies with location and season. The cloud point of the fuel should be below the expected lowest ambient temperature. Diesel fuels with too high a cloud point may be blended with similar or kerosene fuels (1-K kerosene, JP-5, JP-8) with lower cloud points to obtain a usable product. Blending for cloud point also takes into consideration the locality sulfur requirements as EPA-mandated sulfur maximums cannot be exceeded.
- 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.

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 must use the TMs to direct the conversion to substitute lubricants for lower temperatures.

PETROLEUM AND ENGINE FUEL PLANNING

4-7. The DOD has adopted the SFP as outlined in AR 70-12. This policy has the goal of focusing on a single kerosene-based fuel 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.

4-8. In coordination with the respective Service policy guidance, the theater Joint Petroleum Office sets policy for any deviation from the SFP. In expeditionary situations units 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 as follows:

- JP-8 (military detail specification [MIL-DTL] -83133 Turbine Fuel, Aviation, Kerosene Type, JP-8 [NATO F-34 and F-35]) outside CONUS, or F-24 within CONUS (the standard, not a deviation).
 - F-24 (STANAG 3747, Guide Specifications [Minimum Quality Standards]).
 - F-24, F-27, F-34, F-37, F-40 and F-44 (AFLP 3747) for Aviation Turbine Fuel.
- JP-5 (MIL- DTL-5624 Turbine Fuel, Aviation, Grades JP-5 [NATO F-44]).
- Commercial jet fuels with additives:
 - Fuel System Icing Inhibitor, (MIL-DTL-85470 Inhibitor Icing, Fuel System, High Flash NATO Code Number S-1745).
 - Static Dissipater Additive (MIL-DTL-83133).
 - Corrosion Inhibitor/Lubricity Improver (MIL-PRF-25017 Inhibitor, Corrosion Lubricity Improver, Fuel Soluble [NATO S-1747]).
- Commercial jet fuels without additives (limited to one tank of fuel without additives, ground use only).
- Commercial Diesel (recommended to consume diesel fuel within 6 months).

4-9. Command planning staff and maintainers should familiarize 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 D, under the listed fuel type.

4-10. Safety is of utmost importance when dealing with petroleum products, given their toxicity, explosiveness, flammability, and potential environmental impact. Fuel handlers and equipment operators need to be familiar with fuel characteristics and follow prescribed safety precautions found in equipment-specific TMs and facility, military, or governmental regulations to protect personnel, equipment, and the environment.

4-11. The freezing point of fuel is the temperature where 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 in the way that water does. Operators focus on the fuel's freeze point temperature (as different from the point of solidification), because it is the point where 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 equipment to consider the type of fuel needed to operate it. It is best for COTS to function on SFP fuels common to the unit's fleet. This will make it easier to obtain fuel for COTS equipment and avoid causing supply to carry a larger list of fuels.

FUEL STORAGE

4-12. Water in fuel can cause serious problems 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. Engines may experience operational issues even when operating at temperatures above the freezing point if fuel other than JP-8 fuel is used. For example, diesel fuel is a seasonal fuel that can gelatinize if used in the wrong season, as the cloud point of fuel varies across seasons.

WARNING

Fuel flowing over a surface generates static that 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.

4-13. Moisture and condensation can contaminate fuel and cause many issues. Moisture may come from snow entering the fuel, condensation from a partially filled container being taken outside from a warmer environment, or from fuel consumption during regular operation. Follow these precautions to help prevent fuel contamination:

- Store barrels with outlet end slightly higher than the other end to allow sediment and water to settle out (Figure 4-1 on page 58). Avoid upright storage of barrels to keep water and snow from accumulating around the 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.
- Wipe all snow or ice from dispensing equipment and around the fill cap of fuel tanks before removing the cap. After filling the tank, replace the cap securely.
- Always keep the fuel tank filled to the proper markings. 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.

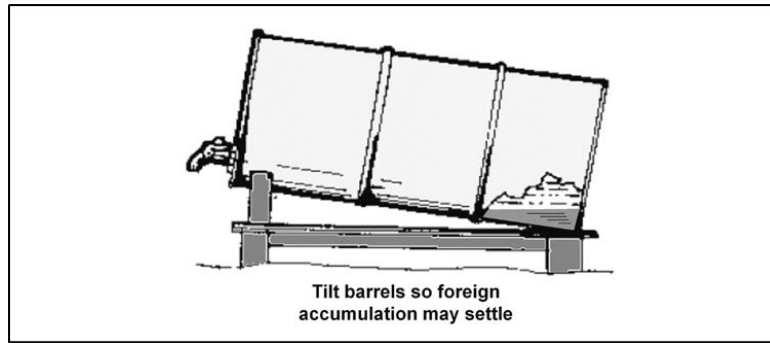


Figure 4-1. POL barrel storage

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 units be provided with JP-8 or appropriate cold-weather-grade fuel if other than 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 must be used, cold weather calls for the use of a special grade of diesel fuel called DF-1. 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 abnormally low operating temperatures.

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 can accumulate in tanks, drums, containers, and fuel pumps due to the condensation of water vapor from the air. 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 designed to catch solid contaminants; clean them daily. Nozzles used to refuel aircrafts 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 either be cleaned with 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 the TMs for proper maintenance and operation in cold weather.

FUEL SYSTEM MAINTENANCE

4-21. Add Fuel System Icing Inhibitor (Diethylene-Glycol Monomethyl Ether) to diesel fuels if necessary due to water in fuel systems and when using diesel fuels as approved. It will prevent water from freezing, but it will not convert the fuel to an arctic or low temperature fuel.

4-22. Order the appropriate grade of fuel for low temperatures. Mix additive with the diesel fuel prior to refueling, normally at a ratio of one pint of additive to 40 gallons of fuel.

WARNING

Fuel handlers and maintainers 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.

4-23. Satisfactory cold weather performance of fuel-related systems depends on careful servicing. Proper maintenance by unit mechanics prevents many malfunctions and failures that would otherwise occur in sub-freezing temperatures. Conduct the following maintenance checks during cold weather:

- The throttle controls may operate with difficulty at low temperatures. If the engine does not respond properly to the operation of controls, check for loose or broken controls and for loose or broken control linkages or cables. Adjust linkages or replace defective parts as required according to the 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 systems can be found on the palletized load system, family of medium tactical vehicles (FMTV), heavy equipment tractors (Heavy Equipment Transport Systems), 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 the 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 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 the amount of fuel in the tank.
- Identify any special host-nation disposal requirements in advance.

LUBRICATION OIL

4-24. Non-fuel oils and lubricants are intended to reduce the wear and heat resulting in friction between moving parts. In normal conditions, the viscosity of lubricants creates a protective layer between the moving parts of an engine or weapon. The primary challenge is determining the proper lubricants that possess enough viscosity to protect working parts while remaining sufficiently fluid to allow the smooth operation of weapon systems, cold engine startups, gear shifts in transmissions, and clutch engagements.

Note. The Army only qualifies SMPL for use in many diesel-powered vehicles and equipment. SMPL is a direct replacement for the former Single Common Powertrain Lubricant. 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. In the event of an emergency where an engine oil intended for gasoline engines is used in a diesel engine, it is important to reduce drain interval by half. This is necessary as oils designed for gasoline engine blocks are incapable of retaining soot.

WARNING

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

4-25. Severe driving cycles encompass a range of conditions including 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 and ultimately promotes oil degradation.

4-26. The lubrication required for any specific piece of Army equipment is specified in the LO or TM. The provisions of Army LOs are mandatory and followed unless the Department of the 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).

4-27. If a vehicle with temperate grade automatic transmission fluids moves into a cold weather area and becomes cold-soaked (when a vehicle's hardware temperature drops as low as the existing freezing ambient temperature), shifting gears may occur very slowly or not at all. Additionally, 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.

4-28. In cold weather, water and fuel can accumulate in the crankcase because the engine does not reach operating temperature quickly enough or maintain it at a high level long enough to cause evaporation. These contaminants can degrade the lubrication between moving parts. Additionally, accumulated water accelerates the oxidation of the base oil and quickly reduces the additive content. Water will also extract acids and additives out of the oil, trapping them and forming emulsions. Emulsions restrict oil flow by blocking passages in the oil gallery, which leads to premature wear on engine parts due to insufficient amounts of oil. By-products from oxidation will eventually lead to depletion of additives and cause corrosion on engine part surfaces.

4-29. When fuel contaminates oil, it reduces the oil film thickness and leads to cylinder, ring, and piston wear. Then, compounds generated by 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

4-30. Viscosity refers to the thickness of a lubricant. Fluids with low viscosity are thinner and flow more easily. High viscosity fluids are thicker and have a greater resistance to flow. The thicker the fluid, the higher the viscosity. Cold weather increases the fluid viscosity of lubricants. Equipment operators should understand that in extreme environments, oils and greases can either thin out or thicken due to age, contamination, and temperature.

4-31. Cold temperatures can increase a lubricant's viscosity and push it outside of equipment acceptable operating tolerances. Maintainers will need to check the appropriate TM to identify equipment viscosity requirements and limitations for proper operation. Then, for environments where lubricants are operating at the margin of their limits, they will need to determine a method of identifying the threat of lubricant failure or expect an increase in broken parts.

4-32. 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.
 - Damage under loads, during startups, or coast downs.
- 4-33. 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

4-34. 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). The Army Oil Analysis Program is the activity primarily responsible for identifying contaminated or degraded oil needing to be changed. To correct a sludge condition, drain oil while the engine is warm (not hot or cold-soaked) enough for oil to flow and refill with the appropriate lubricant.

4-35. After operation, inspect the oil pan, valve cover, timing gear cover and gaskets, and external oil lines for oil leaks and 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.

4-36. 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.

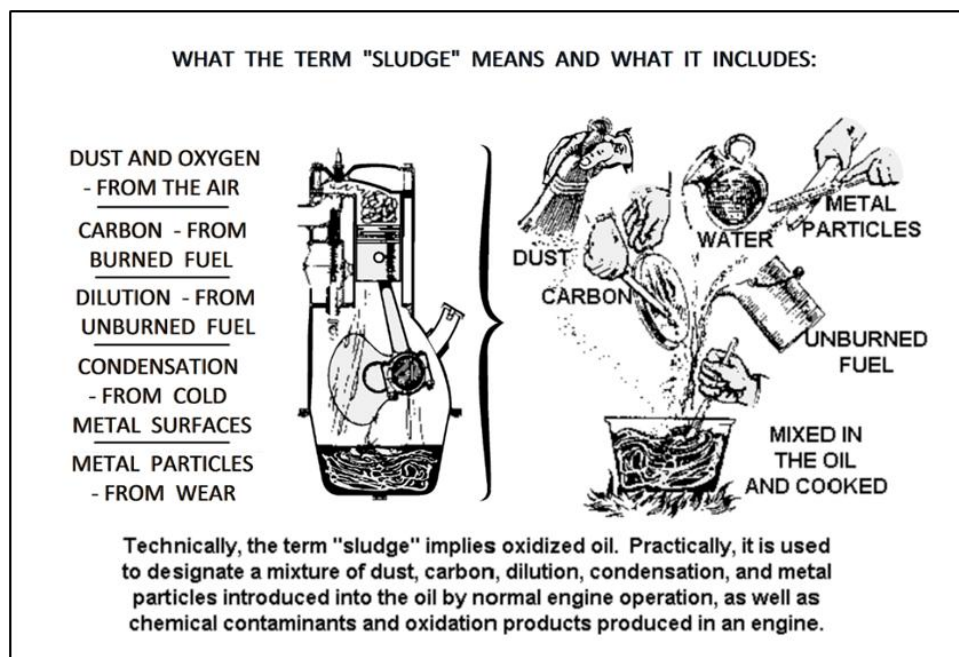


Figure 4-2. Engine sludge

AUTOMOTIVE LUBRICANTS

4-37. In low temperatures, conventional oil thickens and increases the fluid friction within an engine's cylinders and bearings to the extent that it will not run. Using an appropriate oil in cold weather as prescribed by the LO (like OEA-30 or OE/HDO-SMPL) will help prevent issues during cold starts. OEA-30 and SMPL are synthetic lubricants specifically made for cold environments.

4-38. The Army established SMPL as of 15 January 2016. It is now expressed under MIL-PRF-32626 qualification standards. SMPL is a multipurpose, all season (0W-20), full-synthetic, heavy-duty powertrain lubricant that reduces fuel consumption and increases oil life. The MIL-PRF-32626 revisions have four grades:

- OE/HDO-15/40.
- OE/HDO-40.
- OE/HDO-30.
- OE/HDO-10.

4-39. SMPL serves as a suitable replacement for equipment designed for the older MIL-PRF-32626 standard military oil. SMPL 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. Always refer to the equipment TM and LO for recommended lubricants. The following considerations apply when using SMPL oils:

- Use of SMPL 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.
- SMPL is not a replacement for DEXRON VI in the transmissions of any tactical vehicles except in arctic conditions.
- SMPL is not recommended for use in the transmission of the M1 Abrams main battle tank except in arctic conditions.

Note. OEA engine oil is listed as EOS (meaning, engine oil supplement) in some older LOs. The supplement being referred to is the synthetic component of the oil. Equipment being prepared for future cold weather operations 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. When engine oil (SAE-10 or OE/HDO-10) is prescribed for gear cases, drain and fill with OEA-30 or OE/HDO-SMPL lubricating oil or GO-75/90 gear oil as prescribed by LO.

4-40. Follow these general procedures for preparing the lubrication system for cold weather:

- 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 SMPL 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 1-5 minutes before checking the oil level. This reading will be approximate only and should be between the ADD and FULL marks.

4-41. When a temporary rise in temperature occurs, drivers should not change or vary the maintenance of their vehicles. However, they should closely monitor lubricant levels and lube points and replenish lubricants as necessary. Instructions in LOs apply when a definite change to higher environmental temperatures is expected, including the change of seasons.

GREASE LUBRICATION

4-42. Grease is a gelatinous lubricant (gel) that clings to the surface of an item or inhabits a cavity without draining out, unlike fluid oils. Greases are applied to mechanisms in which a lubricant cannot stay in position or for which re-lubrication is infrequent, difficult, or inefficient. Grease must remain in contact with moving surfaces and lubricate without leaking out under the force of gravity, centrifugal action, or by being squeezed out under pressure. It should retain its basic properties under shear forces at all temperatures it experiences during use.

CAUTION

Do not mix different types of grease. Incompatibility of greases may cause premature wear of equipment components.

4-43. The increasing presence of COTS equipment in military inventory requires a wide variety of new lubricating greases to maintain it. In cold environments, it is critical for unit planners and maintenance managers to know the required greases for each equipment type within the unit inventory. Grease, automotive and artillery 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 that 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 also need to know the next alternative grease in line and how to transition from one grease to the next.

4-44. Greases are typically formulated with three components: base oil, thickener, and additives. It is important to understand how well each of the most common base oils can withstand extreme temperature environments as they account for more than 90% of the total product. What makes 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 grease from protecting equipment. Most base oils and grease can withstand moderate temperature dips to 32°F (0°C), and many to 15°F (-9°C), without too much of a decrease in performance. At -5°F (-21°C) and below, some lubricants become fully nonfunctional. There are three temperature characteristics related to grease that maintainers should be familiar with: dropping point, oxidation, and stiffening.

DROPPING POINT

4-45. Grease dropping point is the upper temperature that the grease will fail to be of any further use as a lubricant. This is the point 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 form and will no longer provide the lubrication required 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 that shouldn't reduce effectiveness 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 and cause it to soften, allowing oils to weep or even bleed out of the grease. Once grease has oxidized, it must 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 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 maintain a low viscosity at the lower temperatures.

SOLID FILM LUBRICANTS

4-48. A variety of solid materials with inherent lubricating properties 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.

4-49. 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.

4-50. Molybdenum disulfide generally has the highest load-carrying capability with a corresponding low coefficient of friction. However, in an oxidative atmosphere (air with oxygen) more than 750°F (399°C), it begins to decompose.

4-51. 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.

HYDRAULIC FLUIDS

4-52. There are several hydraulic fluids that maintenance organizations use to maintain their vehicle fleets and weapon systems. 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, fire resistant hydraulic (FRH), and OHA hydraulic fluids, which are supply codes that may or may not be acronyms. OHA is the supply code for MIL-H-5606, hydraulic oil.

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

COOLING SYSTEM

4-53. 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 that 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.

4-54. 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 COOLANTS

4-55. 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.

4-56. The antifreeze materials specified in TB 750-651 are 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 inhibitor to prevent the distilled water from rusting the engine. In freezing temperatures, it reduces the freeze point of distilled water.

4-57. The overuse 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. 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.

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.

4-58. There are three major types of antifreeze that the General Services Administration has authorized and are commonly used by the military. They are specified by A-A-53624, Antifreeze, Multi Engine Type, and TB 750-651:

- Ethylene glycol, for mixing with distilled water to make an antifreeze solution. 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 (-46°C). To use, mix with distilled water. Verify antifreeze capability to -50°F (-46°C) with a refractometer.
- Arctic antifreeze solution, premixed with 60% ethylene glycol. Arctic antifreeze solution is an ethylene glycol-based antifreeze with several additives used mostly 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.
- Propylene glycol, for mixing with distilled water to make an antifreeze solution. This solution is only used by the military in commercial products under warranty, as prescribed by manufacturer's instructions. It is used for temperatures of 32°F (0°C) down to -76°F (-60°C). 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. 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 the commercial antifreeze.

DANGER

Do not drink ethylene glycol-based antifreeze. It is harmful or fatal if swallowed. If swallowed, induce vomiting immediately and call a physician. Do not store in open or unlabeled containers.

4-59. Waste antifreeze contains heavy metals including lead, cadmium, and chromium in high enough levels to make it a regulated hazardous waste. Most states strictly regulate antifreeze disposal. Never dump spent antifreeze on the ground or discharge it into municipal sewers, storm drains, ditched, dry wells, or septic systems. It can cause serious 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.

4-60. 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. If premixed antifreeze is not available, use Table 4-1 on page 64 as a guide for mixing concentrated antifreeze. The antifreeze should then be tested with an antifreeze refractometer. The actual sight appearance may vary in different refractometers. Consider the following ratio when mixing antifreeze with distilled water:

- A 68/32 ratio provides maximum low temperature protection.
- A 25/75 ratio provides protection against rust and corrosion.
- A 50/50 ratio in normal weather conditions.
- A 60/40 ratio provides protection in arctic conditions.

4-61. To fill the engine, first pour in the antifreeze according to the prescribed number of quarts indicated by table 4-1. 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. The guide to the table is below:

- First, identify the total cooling system capacity in quarts for 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.
- Look up that column to find the number of quarts of antifreeze will be needed for mixing with the distilled water.

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	-53°F
24					10°F	5°F	0°F	-7°F	-15°F	-24°F	-34°F	-46°F

4-62. A refractometer (Figure 4-3) is a device that measures the efficacy of antifreeze solution by determining its ability to regulate temperature or the set level of protection. It is also used to measure battery acid (sulfuric acid) capacity to hold charge.

4-63. When adding (topping off) coolant level with arctic antifreeze, add coolant as it is without mixing with water, directly into the reservoir or radiator. If using concentrated ethylene glycol-based antifreeze, it must be mixed with distilled water.

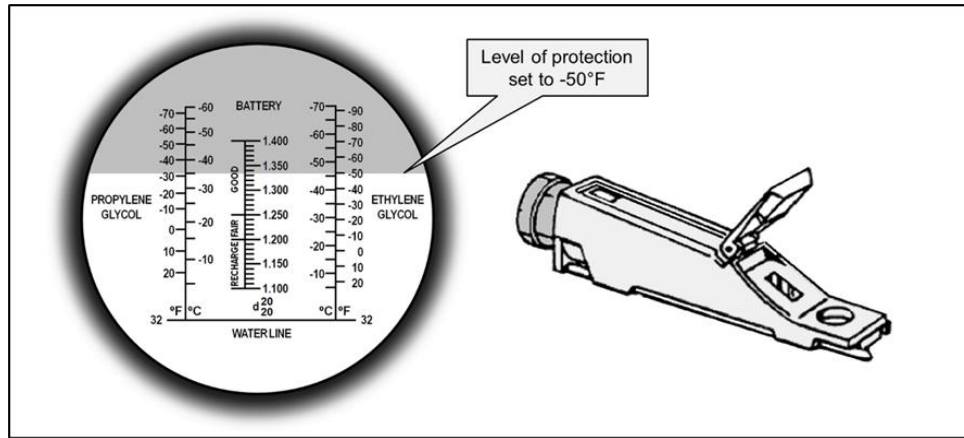


Figure 4-3. Antifreeze and battery refractometer sight picture and testing device

4-64. 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 correct protection temperature should be) or,
- **This cooling system is filled with arctic-type antifreeze. Protected to -90°F (-68°C)** (or whatever the correct protection temperature should be). **Caution: do not add distilled water or any other type of antifreeze.**

4-65. 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.

AIR-COOLED ENGINE SYSTEMS

4-66. 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 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.

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Chapter 5

Vehicle Operation

This chapter provides automotive-focused considerations for dealing with vehicles or engine-driven equipment before, during, and after operations. The primary challenge with vehicles in cold environments is getting them started. This chapter is intended to supplement operator and maintainer TMs.

OPERATING VEHICLE ENGINES IN COLD WEATHER

5-1. Vehicles need unique preparation for the harsh conditions of cold weather. Operators must be aware of the special problems cold weather can cause with starting and operating the vehicle or equipment. Completing operations takes longer due to additional storage precautions needed to protect the equipment and maintain its readiness in cold conditions.

5-2. Normalizing an engine is a state of vehicle operation where, in an engineering context, all the component engine features that contribute to its proper function are performing according to their intended design parameters. For instance, the coolant and antifreeze must effectively regulate the engine's temperature, while the battery must be fully prepared to power the starter motor and glow plugs. It means that the lubricants are effectively preventing friction damage. As an engine transitions through various states of operation (off, start, idling, moving, stopping), electro-mechanical controls act to normalize the 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.

5-3. Maintaining vehicle and equipment readiness extends to fully stimulating the movement of all hydraulic fluids, antifreeze, oils, or lubricants. In cold weather, power production and full system stimulation must be incorporated into unit regular PMCS maintenance policies. This may involve having vehicles driven for half an hour on a circuit around the installation or camp. It may involve having engineering equipment engage in earth moving exercises. Cranes, winches, and turrets may have to be system stimulated by two or three repetitions of moving heavy items. Generators or power production equipment can be load tested for thirty minutes to verify 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.

5-4. Dust, sand, and dirt are commonly the major causes of clogged air filters. However, in cold weather conditions, moisture resulting from rain or snow can also introduce solid particles that restrict the airflow through a filter. Operators must exercise caution following instances of rain or snowfall while the engine is in operation, particularly when accompanied by freezing temperatures. In these situations, it's important to check the filters often to ensure that ice has not become embedded into the filter fibers. Additionally, when the engine is at rest, operators should use a tarp to protect the filter from both rain and snow that could drift into the filter intake.

STARTING PROCEDURES

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

5-6. Maintenance leaders should plan on a systematic way to start the unit's vehicle fleet in a cold environment. Severe cold weather can leech battery power, making supplemental power necessary to start vehicles. Such a system may involve having a warm vehicle on standby 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 should be used to power preheaters or trickle chargers.

5-7. 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.

5-8. 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 drop in current 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. 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 or AGM batteries, a battery load tester is needed because their filler caps are not removable.

5-9. If the battery cannot engage the starter motor or the electrolyte appears frozen, mark the battery and notify the unit is maintenance section. A qualified battery mechanic must make the determination if the battery is usable.

OPERATOR TASKS

5-10. Check battery electrolyte, engine oil, and coolant levels 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, maintain a high engine idle speed as prescribed in the vehicle TM (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.

5-11. Operators must coordinate with supervisors on any deviations from unit policy and TM-defined procedures, and must also consider the following:

- 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 related to the time of engine starter engagement. However, it is sometimes necessary to exceed the recommended starter time due to the cold-starting characteristics of most internal combustion engines. For example, 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 (consult with supervisors first and use caution when attempting).
- 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.

MAJOR COMPONENT WARM-UP

5-12. There are various methods operators can use to safely bring vehicles up to operating temperature in cold weather environments. Operators should know the warm-up procedures for the vehicle's major components and understand that effectively warming one component does not mean the vehicle is safe to operate. For example, immediately operating a cold vehicle after the engine has warmed up may damage the cold transmission if it has not also been properly warmed.

Transmissions

5-13. Automatic transmissions warm up differently depending on the type. Some warm up in park, others only warm up if the selector lever is placed in neutral, and 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 to allow the torque converter to circulate 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 a vehicle is equipped with a transfer or torque converter having a selector lever, the component's lubricant may be heated the same way by placing selector level in neutral and transmission in low.

5-14. Standard transmissions have been mostly removed from military inventory but may occur with COTS equipment. To start a standard transmission, depress the clutch pedal while starting the engine with the gear shift in neutral. Once the engine is running smoothly, release the clutch cautiously and maintain the engine at idle for two minutes or longer to warm lubricant in the transmission.

5-15. 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 may damage powertrain components such as clutch facings, universal joints, or gear teeth. When placing the vehicle in motion, put the 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.

Diesel Engines

5-16. Diesel engines are particularly difficult to start in cold weather without preheating the intake air. Because the air is heated by compression, it must get 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). Use this device only when turning the engine over. Switch off the air manifold heater when the engine starts.
- Warm the engine with external heat (like electric heater pads) 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, excessive ether can cause piston and ring damage.) Ether is used as an emergency starting aid only if auxiliary power and/or portable heaters are unavailable for preheating. Exercise extreme caution and use ether only as a last resort to prevent mission failure. Always refer to the appropriate operator's manual when utilizing emergency starting aids.
- In dire circumstances, the use of direct fire or any heat-producing sources may be used. Employ good judgement, risk assessment, and viable safety techniques.

CAUTION

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

Gasoline Engines

5-17. The Army has largely phased out gasoline-powered equipment. However, some local commands still use gasoline-powered COTS equipment (for example, rental vehicles). To successfully start gasoline engines in cold weather, make sure the following conditions exist:

- 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 provide the spark needed for ignition.
- Supplemental battery power is available.
- The ignition primary and secondary circuits are clean and free of cracks, frost, and moisture to prevent shorts or current leaks.

Auxiliary Engines and Generators

5-18. The auxiliary engine and generator are operated when—

- Supporting communications and electronics equipment.
- Other types of auxiliary equipment are 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.

5-19. 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 that allows air to be pulled over the exhaust and warmed 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.

DURING OPERATION

5-20. Operators should minimize short trips due to the impact on battery performance. Each time a vehicle is started, energy is extracted from the battery, leading to a deficit charge. A deficit charge is a condition where the battery drains at a faster rate than the alternator can replenish it. 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 need about thirty minutes of driving before the batteries get warm enough to fully accept a fresh recharge from the alternator (20 minutes for wet cell, and longer for the other types).

WARNING

Operation of the main engine or auxiliary generator engine when a vehicle is stationary exposes the crew to possible carbon monoxide gas poisoning.

5-21. During vehicle operation, adhere to the following guidelines:

- Allow the engine to warm up to the recommended temperature for below-freezing operation according to the TM. The engine thermostat usually opens at 165°F (74°C) or 180°F (82°C).
- Check the operation of instruments during warmup, especially the oil pressure gauges and warning lights.
- Take advantage of all methods available to keep the battery at the recommended temperature. If the battery is warm enough to accept a charge (above 35°F [2°C]), the battery generator indicator should read in the high green immediately after starting.
- Check and listen for 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.
- Before starting the engine, check the oil and fill it to the prescribed level. Once the engine starts, check the reading on the oil pressure gauge. Within 30 seconds after starting the engine, the oil pressure should register on the oil pressure gauge. For vehicles or equipment equipped with warning lights, wait 30 seconds for the oil light to turn 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 to determine the cause.

- Frequently monitor the oil pressure gauge and warning light during operation in cold conditions. When using OEA 30 or OE/HDO SMPL lubricant, the low oil pressure warning lights may blink on and off between 500 RPM to 650 RPM when idling. They should not stay on at higher RPMs.

5-22. Monitor engine temperature throughout operations. Operate vehicles at normal engine temperatures as indicated in the operator's TM. Efforts to regulate engine temperatures can involve both chemical and mechanical solutions like—

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

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. Maintain engine temperatures by using engine compartment air inlet shutters or radiator covers to limit the cold from reaching the engine. 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. Shielding can be installed on tractors and generators with exposed engine blocks to keep engine heat contained in a compartment.

5-24. Operating an engine at low temperatures can lead to several issues, including increased fuel consumption, dilution of engine oil by unburned fuel, and the buildup of sludge from water in the cylinders and crankcase. 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 150-200 meter vehicle exercise track, operators should perform a during operations check under supervision before exiting the area. As needed, a forced air jet heater should be on standby to heat frozen brakes or pneumatic lines. Give extra attention 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.

IDLING

5-25. Engine idling is done to warm and circulate lubricating oil. If the oil gets too cold, it can thicken to the point where it obstructs movement, preventing an engine from starting. However, 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 RPMs.

5-26. Proper vehicle maintenance, float chargers, and winterization kits with engine heaters can help reduce starting problems. An engine heater is an electrical or mechanical heating device used to preheat engine fluids (antifreeze or lubricants) to ease engine starting. Diesel engines without heaters may need to be started and idled intermittently or continuously (depending on the ambient temperature) to maintain an acceptable state of readiness. See the appropriate vehicle TM for guidance.

5-27. The commander and maintenance leaders determine starting and shutdown intervals to ensure engines do not run continuously (unless continuous running is the intent). Depending on the situation, concealment and noise discipline may have to be sacrificed to maintain readiness of the vehicles. Commanders must carefully consider fuel supplies when authorizing periodic engine starts. Factors including ambient or expected temperatures, vehicle condition, and readiness conditions influence scheduling.

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

5-28. Vehicle engine idling is wasteful and may be hazardous. 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 maintain or restore battery power.
- Causes engine wear and reduces the time between engine overhaul periods.
- Causes glow plug or spark plug fouling, especially in two-stroke cycle engines like all-terrain vehicles, snowmobiles, and outboard motors.
- Creates a carbon monoxide (CO) hazard.
- Endangers concealment and camouflage.
- Potentially causes engine overheating.
- Potentially causes diesel “slobber” or “wet stack”. These terms refer to the unburned diesel fuel and exhaust that build up around exhaust pipes in cold weather during idling.

AUXILIARY ELECTRONIC EQUIPMENT

5-29. Vehicles with command-and-control devices like radio, computer devices, mine-defeating attachments, motorized ring mounts, and other electrical devices require the engine to operate at approximately 1,200 RPM to maintain a satisfactory battery charge. A battery with low charge is at risk for failure and freeze. To avoid malfunctions of auxiliary devices, ensure each device switch is on the OFF or standby position before starting the vehicle.

VEHICLE OPERATION SAFETY

5-30. 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 not the only requirement. Units must verify the vehicle operator’s competency to drive in a cold environment (TC 21-305-20) and identify and provide any additional training required.

5-31. Novice drivers must 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 understand that the cold usually degrades the responsiveness of the steering and braking controls against driving surfaces.

5-32. 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 in cold weather driving conditions. It’s important for drivers to receive practical road training to learn to—

- Clear condensation from brake lines and test the brakes to ensure they function properly before operation. This procedure may require the use of electric or forced-air heaters.
- Recognize the different braking systems along with their respective driving characteristics. This includes direct cable, power assist, positive pressure pneumatic, negative pressure, and engine compression braking.
- Never mix positive pressure or negative pressure towing vehicles to trailers with the opposite type braking system.
- Use 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 uphill or downhill.
- Compensate for wide swings during turns and winding roads when towing trailers and weapon systems.
- Recognize vehicle deficiencies that might expose personnel to carbon monoxide poisoning.

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 chocks should always be used when parking a vehicle set in neutral gear. Maintenance leaders should tell operators and their supervisors when to initiate or cease cold weather parking precautions.

5-34. During each after operations PMCS in cold weather, pay 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. During periods of cold, it is not uncommon to observe leaks from various seals on hydraulic systems and oil-filled components upon start up. These leaks should stop after the component reaches normal operating temperature and the seal becomes soft and flexible. 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 the prescribed level. Oil consumption may be higher when using OEA-30 or OE/HDO-SMPL. Engines may run out of oil before the next maintenance check. Check frequently.
- Check the radiator after shutdown to determine the coolant level. If the coolant level is low, add antifreeze to return the radiator to full level.
- At the end of each operating period, for about five minutes prior to shut down, normalize the vehicle engine to allow the cylinder walls and pistons to retain a coating of cooled oil. This prevents damage at the time of restarting. It is done 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 prevent engine damage and is called for in many TMs.
- Service the fuel tank at the end of the day's activities to 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.

OPERATING VEHICLE SUB-COMPONENTS

5-35. Sub-components cannot be overlooked in preparing for cold weather operations. Failure of these items can also lead to mission failure. Prepare for cold weather by referencing the TM for PMCS and operations instructions for operators, maintainers, and managers.

PERSONNEL HEATERS

5-36. Operators should take measures to prepare their vehicle heaters as cold weather approaches. The primary threat to heater operation is dust buildup. Maintenance personnel should provide operators with instructions on the proper procedures for removing heater ducts to access the heater fan. Maintenance personnel should instruct operators on 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.

CAUTION

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

5-37. Three-stage heaters, standard in light vehicles, use antifreeze to transfer heat through heating radiators. However, they lose their ability to adequately warm crews when temperatures drop below -40°F (-40°C).

5-38. Most severe cold petroleum-fed heaters (common to armored vehicles or 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.

5-39. Before the onset of cold weather, petroleum-burning heaters should be removed from vehicles and have their 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.

AIR COMPRESSORS

5-40. An air compressor is a device powered by an engine that compresses air to predetermined and controlled pressures. It is used in vehicle air brake, air-hydraulic brake, and CTIS. Condensed moisture can freeze within the compressor.

5-41. Follow after-operations 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 FMTV (2½ ton and 5-ton trucks), palletized load system vehicles, and heavy equipment transport trucks use air driers in the air brake system. The system must be checked for frozen vapors in the drip tube.

5-42. 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 typically consist of plastic bottles of alcohol that are 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 before, during, and after operations PMCS.

5-43. Air compressors can either have their own self-lubricating system or rely on the engine's lubrication system. No further preparation is necessary for engine-lubricated, air-cooled compressors, provided the engine crankcase has been filled with lubrication oil (OE/HDO-SCPL or OEA-30).

5-44. 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 compressor for leaks.

5-45. 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 the compressor to ensure that it is in good condition, properly aligned with drive pulleys, and securely mounted.
- Check for frozen vapors in the drip tube on equipment using air driers.
- Ensure that all water, oil, and air lines in the engine compartment are in good condition, securely fastened, and have no leaks.
- Check oil in self-lubricated air compressors to determine proper condition and level.
- Check alcohol evaporators, if equipped.

POWER TAKE-OFF ASSEMBLIES

5-46. A power takeoff uses hydraulic lines or a drive shaft to power auxiliary equipment affixed to a vehicle. The power takeoff and control linkage should be checked to ensure they are in good condition, securely mounted, and that seals are not leaking. The system's connection assemblies are usually visible on the side of the transmission with a hydraulic pump mounted inside the transmission. They are sometimes 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. Power takeoff-driven auxiliary equipment includes winches, cranes, air compressors, hydraulic pumps, trench diggers, and earth boring machines.

5-47. In freezing temperatures, ensure that the power takeoff is filled to the appropriate level with the correct lubricant. Because the power takeoff 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 even impossible.

5-48. Use the TM to inventory all component parts. Ensure 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.

RECOVERY EQUIPMENT

5-49. Recovering damaged or disabled vehicles in cold and snowy conditions can be extremely dangerous. Take every precaution to maintain Soldier safety and ensure that equipment is functioning properly. Exercise care when towing cold-soaked vehicles. Drive trains may have to be disconnected to prevent further damage.

5-50. For any cold weather recovery operation where a recovery vehicle must use more than half 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 viscosity of hydraulic fluid in recovery cranes, which creates 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 that the recovery vehicle must cross to reach the immobilized vehicle.

5-51. 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 recovery equipment. Before going into the cold, equipment should be wiped off, dried out, and cleaned of old, contaminated, or oxidized lubricants. While decoupled, the item should be inspected by maintenance personnel. Three critical concerns of inspection are seals, hydraulic lines, and wire cables.

WINCH ASSEMBLY

5-52. Read all caution plates and estimate a 25% reduction in winch capacity when determining load. For example, if the capacity of the winch is specified as 5,000 pounds on the 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. Use a snatch block or pulley whenever possible to reduce the load on the winch.

5-53. Take the following steps when preparing a winch for operation:

- Remove mud, dirt, and rust from the exterior of the 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.
- Inspect safety brake for satisfactory operation.
- Check drum brake and adjust if necessary.
- Check for frozen bleeder and selector valves, controls and linkage, and winch cable sheaves.

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.

OUTRIGGER STABILITY

5-54. Many vehicles equipped with cranes have outriggers to provide added stability. However, when operating on icy surfaces, the wheels and outriggers might not be sufficient to keep a vehicle from slipping sideways as the crane lifts and rotates while handling heavy items.

5-55. 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. Line supervisors should train crews to install vehicle chains and traction devices 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.

Chapter 6

Small Arms Preventive Maintenance

This chapter provides general information and recommendations on small arms preventive maintenance in a cold or arctic environment.

GENERAL EFFECTS OF COLD

6-1. Operating and maintaining weapons in cold climates is much more of a challenge than in temperate environments. In the cold, metals and plastics become brittle and break more easily. Ice formed from breathing on the weapon can seize bolt movement, and cold ammunition is less effective when fired. Weapon parts are subject to high stress from rapid variations in temperature, and the shock of firing can break weapon components or render weapons unserviceable more rapidly. Identify weapon parts that are vulnerable to cold and more prone to breakage and have extra parts on hand before conducting operations.

6-2. Firing a pistol while wearing arctic mittens increases the likelihood of dropping the weapon. The shock of the weapon hitting the ground is more likely to result in damage due to the metal's weakened state, and falling into snow or mud can introduce a large quantity of ice or snow to the pistol's inner workings.

6-3. Machine gunners should strive to be selective and accurate in target engagement for multiple reasons. A sudden long burst of fire from a cold weapon will cause rapid uneven metal expansion. Such expansion can cause stress fractures, cracking, and may cause casehardened metals to break. Selective and accurate target engagement will also conserve more ammunition and help reduce the need for resupply, which is more complex in cold environments.

6-4. Snow or ice plugged magazines can cause rifle malfunctions and breakage. Apply LAW to prevent bipods, movable sights, and other working components from freezing in position. Empty casings may cause weapon jams early in firing due to short recoil (bolt does not recoil fully to the rear), requiring immediate action as prescribed by the TM. This problem should stop as the metal warms. Buffers may also harden and freeze, which increases shock and causes rapid recoil (this increases the cyclic rate of fire and usually breaks parts).

6-5. 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. Temperate weather lubricants used in extreme cold environment can gum up or freeze hard. A dry weapon has fewer misfires and malfunctions than a weapon with the wrong lubricant.

6-6. Machine gun firing should consist of short, two or three round bursts fired at close intervals. After changing barrels, a hot barrel laid directly on snow or ice may warp or disappear in deep snow. Gunners or their assistants should carry a piece of wood with side ridges (to prevent the barrel from rolling out) for keeping hot or spare barrels off the snow.

6-7. 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. Consider the following when determining solutions:

- Avoid altering how the weapon engages the enemy.
- Keep weight to a minimum.
- Avoid additional fuel or heating requirements.
- 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.

6-8. The greatest risk to a weapon is 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 fully automatic mode. The use of weapon lubricants follows some of 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 cold weather 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 weapons.

6-9. When a weapon is brought inside a warm place, keeping it dry is the 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 airtight anti-condensation container while it warms up.

6-10. Cleaning and lubrication should be conducted 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. Consider the following best practices to ensure weapons are always ready for use:

- 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 it. If possible, leave the weapons in a protected but cold area outside.
- To minimize the condensation of moisture and freezing, keep the weapon covered when moving from warm to cold areas 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 inside of magazines and ammunition dry. Moisture will freeze and cause malfunctions.
- Do not lubricate ammunition.
- Use muzzle cap, protective magazine bag, and an overall weapon cover to help protect the weapons. Use them whenever the tactical situation permits.

LUBRICANT APPLICATION

6-11. DOD small arms multipurpose lubricant specifications require products to have cleaning, lubrication, and preservation properties. The DOD tests lubricants from a minimum flash point of 150°F (66°C), to a maximum pour point of -75°F (-59°C).

6-12. Lubricants are designed to endure extreme heat and resist breakdown during the fast and repetitive cycling of automatic firearms, yet few can retain their viscosity when exposed to below freezing temperatures. In freezing weather, lubricants become 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 individual Soldiers, maintainers, and master gunners to know at what temperature their lubricants will fail and what the alternatives are.

6-13. The solvent CLP is in fluid form down to -65°F (-54°C) and above, however at -10°F (-23°C) it begins to thicken enough to affect a weapon's automatic cycling. Under cold conditions, even a small amount of CLP or lubricant, small arms (LSA) on moving parts can prevent some weapons from firing.

6-14. Small arms repairer, armorers, and 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. Planning for the transition of lubricants for cold weather operations should be communicated throughout the unit.

6-15. Units should plan on converting from CLP or LSA to LAW once temperatures routinely fall below 5°F (-15°C) (Figure 6-1 and 6-2).

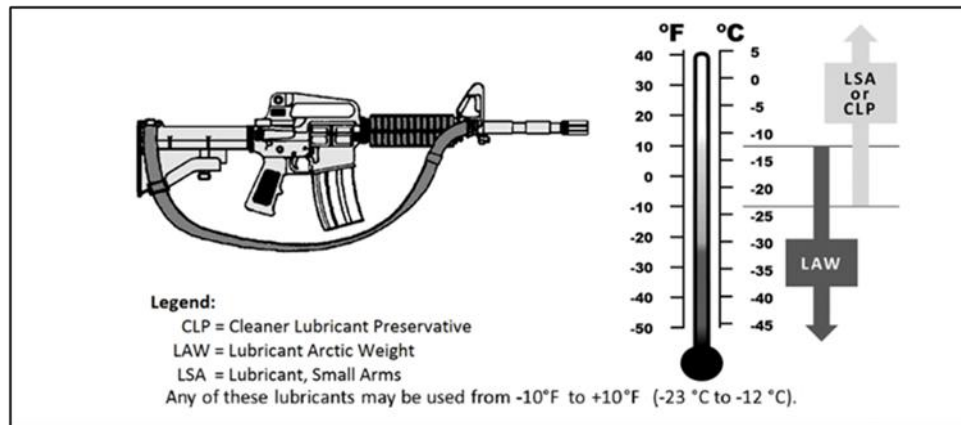


Figure 6-1. Cold weather weapon lubrication plan

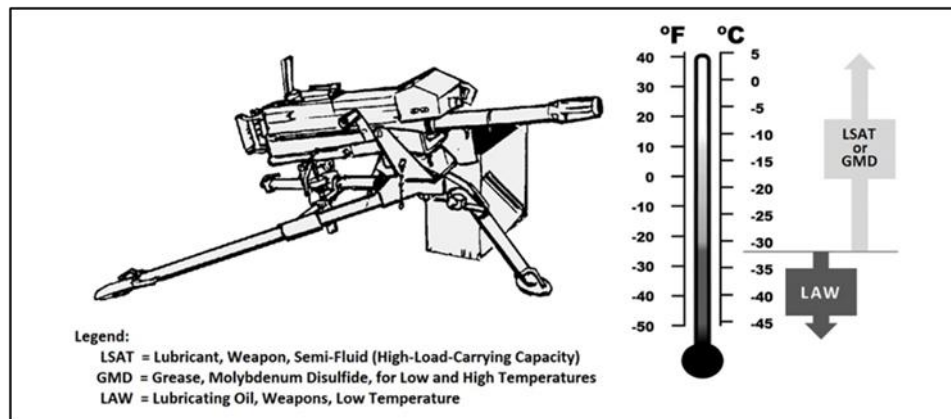


Figure 6-2. Alternative lubrication plans for various weapons

6-16. Under cold conditions less than -10°F (-23°C), a small amount of CLP or LSA remaining on moving parts can prevent weapons from firing. Ensure that all CLP or LSA is thoroughly removed from weapons (preferably by using an SD-2 solvent) and apply LAW (MIL-PRF-14107D) prior to cold operations. LAW has Teflon and synthetic additives that can be negatively affected by mixing them with other lubricants.

6-17. 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 rifle bore cleaner (RBC) (unless specified by the TM) in difficult operational cold situations.

Note. LSA and RBC are intended for use together. Never use RBC alone. It is a cleaner (not a lubricant or solvent) and does not have a lubricating property. 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 are not compatible together in any application.

6-18. Exposed metal surfaces require more frequent applications of smaller amounts of lubrication to remain fully functional in dry cold air. Whatever is used to lubricate a weapon in cold weather situations, it should be used sparingly.

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.

WEAPON MALFUNCTIONS

6-19. Cold adversely affects the functioning of small arms. Take care to correctly identify the problem and apply an appropriate corrective action.

SLUGGISHNESS

6-20. A common weapons problem in cold weather is sluggish operation. Normal (not engineered for cold) lubricants thicken at low temperatures, causing stoppage 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 helps minimize the freezing of snow and ice on weapons. Select the correct lubricant and clean off all regular gun oils before applying the appropriate cold weather lubricant. Avoid allowing different lubricants to become mixed on the surface of a weapon.

METAL BREAKAGE

6-21. 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. If possible, 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.

PLASTIC AND RESIN BREAKAGE

6-22. 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.

JAMMING AND MISFIRE

6-23. Snow and ice on ammunition can obstruct cyclic action of automatic weapons and increase the chances of a misfire. Ice build-up inside a weapon can foul its operation just as surely as a heavy carbon buildup. Worse, the snow or ice on ammunition can prevent a bolt from seating and result in a backfire. Regularly check magazines and ammunition belts to ensure that they are free of snow and ice. Keep muzzles covered, ejector ports closed, and do not lay weapons down on the ground.

6-24. 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.

6-25. 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 weapons. Use them whenever the tactical situation permits but remove them prior to firing.

6-26. Unload and conduct weapon function check every 30 minutes to help prevent freezing of functional parts. Be careful not to drop ammunition rounds into the snow.

AMMUNITION MALFUNCTION

6-27. Cold weather affects 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 and reduces range.

- Severe cold slows 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.

6-28. Resupply in cold climates is also difficult, especially the resupply of heavy, bulky ammunition. 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.

6-29. Store ammunition in original containers for as long as possible. 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.

6-30. Ammunition, clips, and magazines must be cleaned of all oil and preservative and must be checked frequently. Remove all snow, ice and condensation. The most common cause of malfunctions 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.

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Chapter 7

Large Crew-Served Weapon Systems, Munitions, and Fire Control Equipment

Large weapon systems have unique vulnerabilities to cold. These weapons often face a range of maintenance issues when exposed to cold or arctic conditions. This chapter provides general considerations and recommendations to maintain these weapon systems operational in cold or arctic environment.

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.

WEAPON FUNCTION

7-2. Like small arms, cold weather conditions can adversely affect the proper functioning and operation of weapons, ammunition, and fire-control equipment. 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 weapons, ammunition, and fire-control weapon systems:

- 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.
- Gas-check pads in the breach of a weapon fail to seal perfectly and tend to deteriorate rapidly. Scoring of the gas-check seat is possible.
- Cable insulation that is not designed for arctic conditions may fail when doubled or straightened.
- Frozen handbrakes on towed weapons may be difficult to release; attempting to move the 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. If the wrapping becomes wet, replace immediately to prevent freezing of both the wrapper and the protected mechanism.
- In cross-country operations, use a prime mover with the same tread or track width as the towed weapon to ensure proper tracking. Towed weapons not tracking in the wheel furrows of the tractor vehicle will jump from side to side and make 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.

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. There may be an increased need for ammunition in cold weather depending on the type; cold temperatures adversely affect firing, 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 and deal with increased difficulty in preparing ammunition storage areas in extreme cold climates.

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 so 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 take extra precautions to cover weapon systems and ammunition before movement. The wind pressure created by a moving vehicle can force water into even the smallest spaces and crevices in cargo. Truck beds need to be equipped with a complete set of suspension hoops and tarps. Towed weapons should be covered with fitted tarps and coverings to 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 them from becoming clogged with ice. The advantage of a fitted cover is its ability to be quickly removed, allowing for rapid response to threats.

Frozen Surfaces

7-10. Frozen ground alters the relationship between any weapon system and its ground placement. Firing of flat trajectory weapons, like tank guns, may cause the vehicle chassis to move away or slide backward from the direction of fire on frozen surfaces. Emplacing ground cleats for crew-served weapons (such as mortar baseplates and howitzer spades) becomes increasingly difficult and time consuming in frozen ground. The inability of frozen ground to effectively absorb the shock of weapons firing can lead to damage to 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. Either 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 need to anticipate support requirements to fabricate means to stabilize weapon systems. These ad hoc devices will have to be safe for the user and mitigate the effects that cold will have on weapon performance.

7-13. Weapons mounted on vehicle platforms are well-suited for supplemental heating systems. Electrical engine oil or battery heating pads can be utilized to keep the oil in recoil mechanisms fluid.

Snow and Ice

7-14. Exposed gears and racks, including the elevating arc, traversing rack, and pinions, can accumulate enough snow and ice to impede movement. Additionally, snow and ice can 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 protecting weapons and other equipment susceptible to corrosion or fluid contamination.

Magnetic Conditions

7-16. When traveling north, it is crucial to be careful with magnetic instruments. These instruments can be affected by changes in declination and by the Aurora Borealis. Maintainers should understand that some issues with the equipment may not be due to damage, but rather because of its proximity to the magnetic poles.

FREEING A SEIZED WEAPON

7-17. Before handling any weapon, always perform a thorough inspection to ensure whether it is loaded. If the weapon is found to be loaded, take appropriate precautions. Subsequently, the maintainer must ascertain whether the mechanism is jammed due to component failure, ice obstruction, or solidified lubricant. Avoid forcing a jammed mechanism to move. There are three primary methods for freeing weapons and their firing platforms, that are the application of:

- Nontoxic antifreeze spray.
- Direct heat.
- SD-2 cleaner.

Deicing with Propylene Alcohol

7-18. For de-icing helicopters and aircraft, use a non-toxic propylene-glycol water mixed solution. The military also uses this chemical as an antifreeze in commercial products under warranty as prescribed by the manufacturer's 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.

Deicing with Heat

7-19. For ice-obstructed gear mechanisms, use direct heat to free frozen brake pads and clear moving parts. Space heaters, forced air heaters, propane heaters, and ducted air heaters (two stage heating) can be used to defrost immobilized gears and parts. Be careful not to 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 to funnel hot vehicle exhaust and 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, it must be dissolved, removed, and replaced. Warm the weapon to above freezing first, then apply a penetrating oil to loosen the hardened lubricant, allowing some time for the oil to take effect. Once a hardened lubricant is loose, it is corrupted and must 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. This process is mainly for large weapon systems but also applies to vehicles and small arms.

CAUTION

Take extreme care to ensure that moisture, snow, ice, and dirt are not introduced into weapon system's mechanisms during the changeover process.

PROCEDURES FOR LUBRICATING WEAPONS

7-21. It is important to keep machined surfaces clean and lubricated (but not over lubricated). Insufficient lubrication may cause rust to form on uncoated surfaces, increasing friction between rubbing surfaces and

impairing the functioning of the weapon. Excessive lubrication can impede the motion of the components or result in a buildup of gummy oil or solidified grease.

7-22. Always use the appropriate type and grade of lubricant. The physical properties of oils and greases vary with changing temperatures. A lubricant designed for use at room temperature may become thick and unsatisfactory at below freezing temperatures or 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 at temperatures down to -65°F (-54°C). Typically, preparation of artillery requires special winterization of component parts. Follow instructions in LOs and TMs and consider these general guidelines:

- 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 grease is recommended for use on artillery at all temperature ranges. Use wide temperature range when special lubricating grease is specified. It retains superior lubricating qualities at extremely low temperatures.
- Petroleum based hydraulic fluid, identified as OHT or FRH, are recommended for use in hydraulic gears as well as in hydro-spring and hydro-pneumatic recoil mechanisms. These products effectively serve as the replacements for specialized recoil and light recoil oils used in low temperature operations. The transition to petroleum based hydraulic oil in recoil mechanisms is conducted according to the following procedures:
 - Drain the existing recoil oil. Raise, lower, and rotate the mechanism to help remove the original oil.
 - Fill recoil mechanism with OHT or FRH as specified. Establish an 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, except 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 these materials must be promptly cleaned up and reported via the chain of command according to the unit's spill-plan.

HOWITZER, MORTAR, AND DIRECT FIRE WEAPONS

7-26. Large-bore weapons require ground stabilization and recoil recovery mechanisms that keep them aimed at targets which the operators can't see. From the operator perspective, tanks and self-propelled artillery cannon are well protected from the cold, although they may face issues related to condensation. Towed mortars and cannons and open vehicle mounted gun systems require additional attention to ensure they remain operational.

COMMON CONCERNS

CAUTION

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

7-27. Most of the problems and precautions involving operations and maintenance of artillery pieces in the cold 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 cold. Firing a few rounds warms the oil, elevating the indicator level.
- Artillery tube bores require more frequent cleaning at low temperatures due to the increased residue left from the reduced combustion 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 remains effective down to -10°F (-23°C). LAW is preferred below that temperature.
- 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 needed for immediate use should be prepared for firing to prevent snow and ice from affecting the propellants.
- On frozen surfaces, both stability and accuracy diminish at lower firing elevations.
- The recommended choices for firing surfaces should be shallow muskeg (or bog), gravel, frozen ground, and ice, in that order. Waste lubricants can be applied to trails and spades that are used in snow and ice to prevent them from freezing to the ground. Laying tree boughs or straw under trails and spades can also help. These cushioning materials can be placed under firing jacks and firing platforms. Even with cushioning, firing from ice is one of the greatest causes of damage to artillery pieces in cold regions.
- Crews wearing the bulky cold region uniform, particularly handwear, must practice drills and maintenance to gain proficiency in cold weather operations.

7-28. Cold weather significantly impacts not only personnel and equipment, but also ammunition. 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 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 cold ambient temperatures should be loaded with ammunition that is also cold. The ammunition should be kept at the same temperature as the weapon. Additional ammunition should be stored in its shipping containers, covered, and stored off the ground and remain in its protective containers, boxes, or cans as much as possible.

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, requiring added tactical training in adjusting fire and operational planning for crews of indirect fire systems.

7-31. At the firing point, condensation on a round that freezes in the breech can lead to a misfire. Icing can cause misfires, damage to the equipment, and injuries to crew members. The misfire procedures used in temperate climates for a round stuck in a howitzer must be modified for cold regions. Pouring a solution high in antifreeze down the tube can be effective in dislodging a stuck round. Another technique involves the use of hydraulic fluid, which does not freeze and acts like penetrating oil to help dislodge the stuck round.

Note. The use of antifreeze or hydraulic fluid to free 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 on page 90) 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 RBC on gascheck pad. Simply wipe it clean and permit it to dry; do not lubricate.

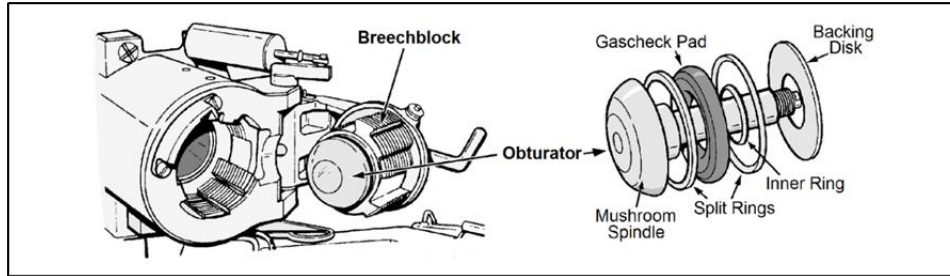


Figure 7-1. Cannon breechblock and obturator mechanism

7-33. Clean all parts daily, except for gascheck pads, using 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 pads and electrical ring mechanisms) should be cleaned with RBC, dried, and oiled sparingly.

7-36. The asbestos covering of Gerdome-type gas check pads becomes very brittle in cold temperatures. If the asbestos cracks and exposes the wire mesh, it can score the gascheck seat, making it 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 thoroughly, then 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 lead to misfires.

RECOIL MECHANISMS

7-38. All hydro-pneumatic and hydro-spring recoil mechanisms should be filled with hydraulic fluid (either OHT or FRH) as specified. Monitor the 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 a reduction in gas pressure at low temperatures, as well as by the thickening of recoil oil.

WARNING

The possibility of injury to personnel or damage to equipment 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.

7-39. Care of recoil mechanisms is nearly the same during cold weather as it is under normal conditions. Operators must closely monitor the recoil mechanisms. In self-propelled guns, the recoil fluid surrounds the gun tube and is subject to a large range of temperature changes and subsequent pressure variations. It is important to monitor these pressure changes and adjust as necessary to maintain the required pressure range.

7-40. The recoil cycle may take longer than usual while the oil is cold. As additional rounds are fired, the action gradually heats the recoil oil and thins it, restoring the cycle time to normal. A sticking recoil mechanism may result in severe damage to the weapon when it is fired; therefore—

- Exercise the recoil mechanism frequently. The frequency of exercise depends on the existing temperature and becomes more frequent as the temperature decreases.
- To prevent recoil parts from frost binding, exercise the recoil mechanism before firing whenever the weapon is exposed to freezing rain, windblown snow and ice, or changing 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 fully opened when firing in low temperatures.

7-42. Check the oil level of the recoil mechanism at the intervals prescribed in the applicable TM and whenever there is significant change in temperature. Inspect all partially filled hydraulic fluid containers to avoid the possibility of using contaminated fluid. Properly discard any 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 counter-recoil. Snow and condensation on the slides contaminate the lubricant and destroy its lubricating properties. To ensure proper recoil and counter-recoil 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 where most 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 counterbalance mechanism.

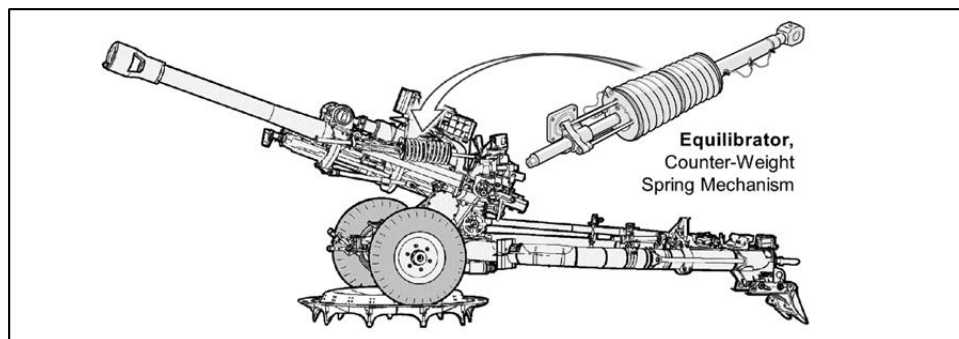


Figure 7-2. Equilibrator

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

Some howitzers use nitrogen to pressurize the equilibrators. Evaluator pressures require frequent checks due to temperature fluctuations (see operator's TM). If a cold howitzer is brought into a warm shelter, pressures will increase dramatically. 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. Use wide temperature change lubricant (MIL-PRF-81322) to lubricate the designated parts of the evaluator 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 evaluators 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 evaluator to wash the bearings properly.

7-48. After daily cleaning and drying of the evaluator piston rod or tube, protect the smooth, unpainted surfaces against corrosion by applying a 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 evaluators to provide proper equalizing action. If the evaluator is equipped with a low-temperature control, make the adjustment according to the temperature scale provided.

DAILY CARE

7-50. Inspect weapon systems 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 damage the weapon.

WEAPON BORES

7-51. In extremely cold weather, weapon bores are more susceptible to increased impact loads and may crack due to metal brittleness. Constant inspection and care are required to prevent failure. Do not assume that a weapon is rugged and mechanically sound. Microfractures pose an ongoing concern for tank, mortar, and artillery crews. Mortars and cannons incur microfractures every time the tube is fired. When those microfractures merge into visible fractures, the tube becomes a threat to the crew. Ordnance weapons inspectors must 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 daily and apply a light film of LAW. Exposed metal surfaces require more frequent applications of smaller amounts of lubrication to remain fully functional in the cold-dry air. Any lubricant used for weapons in cold weather situations should be applied sparingly. LSA and RBC are designed to be used 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. Ensure all CLP or LSA is thoroughly removed from a weapon before applying LAW. LAW has Teflon and synthetic additives that are degraded when mixed with 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 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. Check for the development of cracks.

7-56. In cold temperatures, metal can become brittle and more susceptible to failure when subjected to the impact loads experienced during weapon firing. The presence of cracks generally indicates materiel deficiencies or metal fatigue. However, it is important to note that tool marks can be mistaken for cracks, and some cracks may not be easily visible. If cracks are detected, stop firing immediately, and notify immediate supervisor and maintenance support.

After Firing

7-57. Due to the colder temperatures, burnt artillery and mortar propellants are more likely to cool and accumulate rapidly, leading to the buildup of carbon or creosote. After each cleaning, ensure to wipe dry and apply a TM-approved lubricant. When using RBC, make sure 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). LAW is preferred below that temperature. If LAW is not available, clean the bore evacuator, muzzle brake, bore, and chamber with RBC 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 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 according to unit policy to access all components. Thoroughly clean all parts, ensuring that all rust, dirt, and old lubricant are removed. After cleaning, apply the prescribed lubricant sparingly as prescribed in the LOs and TMs.

EXERCISING WEAPONS

7-60. Weapons should be elevated and traversed at regular intervals to ensure they are operational when needed. The rammer should be cycled several times before loading rounds and at regular intervals to guarantee proper operation. Although recoil mechanisms can only move short distance in below freezing temperatures, always exercise the recoil mechanism before firing to ensure that no parts are frozen or iced up.

7-61. Snow and ice particles frequently collect on the arcs and pinions and cake under pressure of the gears, which can interfere 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. When materiel is idle for a period of time, it should be securely covered for protection. Wind will drive snow under the covers unless they are 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 can also be used). 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, exercise extra caution when driving, as suspension assemblies become stiff in the cold and prone to breaking.
- Wheeled vehicles and trailer systems must have chains available.

EMPLACEMENT

7-65. Selecting and preparing weapon sites in ice and snow requires more consideration than when 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 utilizing pierced steel planking (materiel often used for the improvised airstrips), boards, brush, and matting at the designated spot. Maneuver the weapon onto the platform so it adequately supports both 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 that are in contact with snow or frozen ground with waste lubricant. This prevents freezing and facilitates the subsequent shifting of the trails or baseplates. Waste lubricants may be used on any parts (except rubber) that contact 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 buckling and breakage 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 (known as 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. Make a hole with a pick or crowbar first. A 1½ inch screw-auger bit mounted to a 2-3 foot metal bar topped with a T-bar can be constructed for use as a drill. Create a 9-12 inch hole for planting aiming posts into frozen ground. Ground supports such as tripods or flag stands can be used on top of frozen ground or ice to support aiming posts. Use of the aiming light, equipped with dry-cell batteries, is possible only for short periods. Batteries can be kept warm and serviceable by carrying them or the light next to the body.

MORTARS

WARNING

Condensation and moisture can make the disassembly of large mortars dangerously slippery. Wrap a rope or strap around the breach cap neck above the pinion ball before removing the tube from the base plate trunnion socket. This rope or strap provides a reliable handhold. It is critical during hang-fire procedures to hold the strap and not wrap it around the wrist.

7-71. All infantry mortars have certain characteristics in cold weather operation that are common to most systems (Figure 7-3). The following technical procedures have operator maintenance principles that overlap with crew tactical procedures. Otherwise, consult with the individual item TM.

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. It is essential that mortar crewmen use anti-contact gloves when temperatures fall below 20°F (-7°C). These gloves help prevent cold burns while still providing enough dexterity. Gloves must fit tightly; when ammunition is dropped into the tube, it creates a vacuum that could suck a glove in and create a hazard.

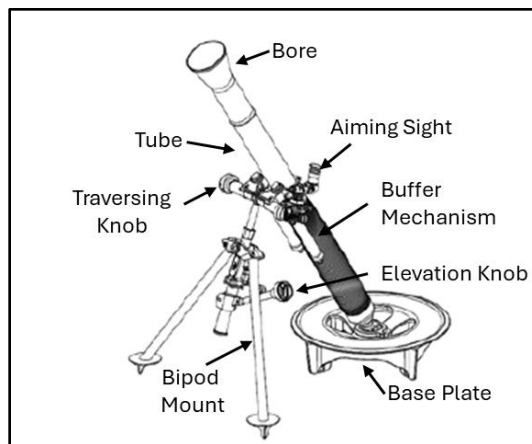


Figure 7-3. M25A1 components needing protection from cold and ice clogging

7-74. Breathing onto equipment like sights or on the mortar's ballistic computer will cause fogging and freezing. Gunners should practice operating the mortar without breathing on the optics. When not in use, optical instruments should be stored in a sheltered location that is unheated, preferably in their cases. This protects them against cold, condensation, and shock.

7-75. Use muzzle and sight covers when not firing the weapon to prevent snow and ice from entering the tube. The mortar's ballistic computer is programmed to accept temperatures down to -50°F (-46°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 (-46°C).

CAUTION

Anticontact gloves, secured by a wrist strap, should be used when handling muzzle-loaded mortar shells. Avoid wearing bulky or loose-fitting gloves, as they may get pinched between the round and the bore of the mortar tube. This can occur when the assistant gunner follows through on dropping the round, damaging equipment and resulting in injury or death.

7-76. Practice employing a compensated sight picture as the standard method when firing from frozen surfaces. Aiming stakes placed in snow will inevitably become loose. Use sandbags or an anchoring device to secure them firmly in place once set.

7-77. Baseplates become brittle when exposed to 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.

7-78. When emplacing a mortar, select a position with vegetation on the ground surface whenever possible. Follow these techniques to place mortar on frozen ground:

- The mortar's baseplate must be solidly positioned to prevent sliding. It may be necessary to dig into the ground.
- Coat the bottom with waste oil to prevent freezing to ground surfaces.
- Use two personnel on the bipod when seating on ice or at high elevation (1,300 mils or higher).

7-79. Placing brush matting or any organic material under the baseplate is one field expedient method to prevent the baseplate from cracking. The matting should be thick enough to serve as a shock absorber, but not so thick that it causes the baseplate to bounce out of 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 using a middle charge. If the baseplate must be seated in snow, coat the bottom with waste lubricant to prevent freezing to the ground.

7-81. Avoid using maximum or near-maximum charges if the mortar baseplates are seated on a frozen surface. 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 in 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 mortar 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 the ammunition and tube dry. Only open as many rounds as required for the current fire mission and use the provided tube cover afterward.
- 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 60mm and 81mm mortars employ a trigger mechanism that allows the firing pin to be re-cocked and fired. With these mortars, misfire times do not have to be increased.

7-83. The metal used for mortar tubes becomes increasingly brittle in cold conditions. This increased brittleness leads to higher rates of microfracturing when the tube is fired. Mortar units should have their tubes inspected before conducting cold weather live fire operations to ensure the tubes will remain safe throughout the operation. It is important to inform the weapons inspectors that the weapon will be used in severe cold conditions.

7-84. At the end of cold operations, mortar tubes should be returned to the weapons inspector to verify that the cold conditions have not caused significant accelerated degradation. Inform the weapons inspectors that the weapon has been subjected to live fire in severe cold conditions.

7-85. 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. Allow at least 30 minutes 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. Use LAW instead of general-purpose lubricant (also known as GPL) for lubricant and bore cleaning of the newer 60mm, 81mm, and 120mm mortars when the temperatures fall below 10°F (-12°C). 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. Do not use CLP in the bore of a mortar tube. CLP may congeal and cause the tube to crack.

7-88. Mortar gunners and assistant gunners typically adopt a standing position to avoid contact with the 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 essential.

TURRET STORED MUNITIONS

7-89. Temperature changes can have major effects on tank and artillery ammunition. 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.

7-90. 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.

7-91. If possible, ammunition brought in from outside should be allowed to warm in the turret before firing. In a combat situation this may not be practical if ammunition needs to be used immediately. Temperature limitations are not stamped on all individual items of ammunition, but they can be found in the ammunition data sheets. Gunner must have their own data for cold ammunition or be prepared to quickly re-zero the weapon. In either case, make a sight adjustment or ensure the weapon is zeroed for the temperature in that it is being fired.

MISSILES AND ROCKETS

7-92. 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 en route to the 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 like 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

7-93. A rocket is a self-propelled, unguided 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. If gets into the crevices of components, it can freeze and result in ice expansion that can damage sensitive circuitry.

MISSILES

7-94. 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, transport, 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 the use of expedient grounding techniques.

7-95. Light missiles are designed to be carried or loaded by an individual Soldier. These missiles are often guided by optical equipment that is susceptible to condensation build up on the lenses. This buildup can hamper line of sight missile target acquisition and tracking. However, this issue is not significant for radar guided missiles.

7-96. 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 can condense on or inside the optics of the guidance system, making the missile unserviceable.

7-97. Fire control optics on a launcher need protection against condensation. Moisture that collects on the eyepiece can impair the effectiveness of the fire control system. When a gunner initially tries to gain a sight picture, moisture from breath and body heat can cause condensation on the lens. To prevent this issue, use a protective mask with the winterization kit installed. An anti-condensation container must be used if the sights are taken into a warm shelter or building.

7-98. The rising heat of the engine may distort the view through cooled thermal imaging night sights mounted on vehicles. 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.

7-99. Turning on the launch drive motors after firing the weapon in temperatures at 30°F (-1°C) or lower will cause ice fog. Depending on the direction of the wind, the ice fog may hinder the gunners' ability to track targets after firing, attempt second-round engagements, or acquire new targets.

7-100. Wing nuts on the battery of the missile guidance set can freeze in place and then pop off when the battery is loaded. Prevent seized nuts by twisting each one before loading the battery.

7-101. Rubber eye shields on optical and night sights freeze, collect ice, and crack, 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

7-102. Artillery missiles, including field (surface-to-surface) and air defense (surface-to-air) types, are usually stored or transported in containers or sealed pods (Figure 7-4). The most significant cold complication is related to ice covering the electrical connectors, sockets, or container pressure vents. Storage facilities must avoid placing containers and pods on the ground where water can accumulate and freeze around low-mounted connectors, sockets, or pressure vents. Precautions are also needed to cover the connectors, sockets, or pressure vents if they are top mounted. 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.

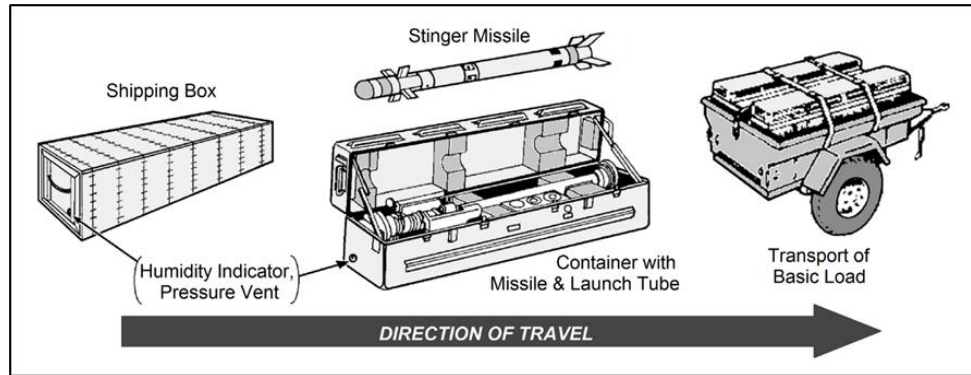


Figure 7-4. Protect shipping vents and connectors from over pressure and moisture freeze

7-103. When transporting artillery missiles contained within sealed pods or containers, the orientation of the warhead during transit is less critical than the positioning of exposed connectors, sockets, and pressure vents. A pre-launch or detonation would more likely be attributed to impacts from displaced rocks striking the exposed electrical connectors or the launch squib, rather than directly involving the warhead itself. During transport in cold wet or snowy weather, the pressure build-up facing the direction of travel can force water and moisture into the sockets and vents of exposed (and even capped) components.

7-104. Transporting a full load of artillery missiles creates a higher center of gravity for trucks. A risk assessment must be conducted 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.

7-105. Soldiers must exercise caution when performing PMCS or moving heavy artillery missiles while wearing bulky ECWCS. Gloves are necessary for such operations but can significantly impair finger sensitivity and manipulation, complicating tasks like trying to set tie-downs or connecting electronic cables. Bulky clothing can also interfere with the clarity of hand and arm signals.

FIRE CONTROL EQUIPMENT

7-106. Sighting and fire control equipment operate effectively at below freezing temperatures if they are properly winterized and certain adjustments are made. Maintaining fire control equipment in cold weather can pose challenges, particularly when repair shop facilities are scarce.

PRECAUTIONS

7-107. Prepare equipment to operate at the lowest temperatures expected. Thoroughly inspect and winterize all equipment before the onset of cold weather.

7-108. Lubricate fire control materiel sparingly as directed by the LO. In cold weather, a thin film of oil is more effective for lubricating fire control mechanisms than a heavy application. It also provides 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]).

7-109. Do not suddenly transfer sighting and fire control materiel between cold and warm temperatures. This can cause condensation that can cloud optics and rust internal parts. Use anti-condensation containers as prescribed in Chapter 2.

7-110. Avoid creating 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. Use stake markers to define the cable paths; this helps locate interconnecting cables for repairs and prevents heavy equipment from running over them.

FOGGING OF EYEPieces

CAUTION

Never pour alcohol directly on the lens surfaces, as excess alcohol will damage the lens sealing compound.

7-111. Avoid breathing on the eyepieces when using optical instruments in cold weather. The moisture in warm breath condenses on the lenses and turns to frost. This frost will fog the eyepieces and make it impossible to see through them.

7-112. There is no effective antifogging solution available for eyepieces of optical instruments in low temperatures. Some solutions can prevent fogging, but they often leave streaks on the lens and make observation difficult.

7-113. The cold weather mask is the preferred method of keeping breath away from eyepieces. However, any type of face mask is useful if it directs the breath away from lenses or absorbs moisture from the breath.

7-114. A serviceable face mask can be constructed from various materials, including cloth, a woolen scarf, or 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 prevent the face from freezing.

7-115. When using a range finder, draping a blanket over the operator and part of the tube effectively increases the observation time from 2-3 minutes to around 20 minutes before the eyepiece fogs up. Clean optical surfaces with tissue lens paper moistened with a few drops of optical lens liquid cleaning compound.

Note. Ethyl alcohol can be used as a substitute for lens cleaning compound. If neither lens cleaning compound nor alcohol is available, use dry lens paper. To create a swab, wrap lens paper around the end of a small stick or sliver of wood. Dip the swab in optical lens liquid cleaning compound, shake off the excess, and clean lens. Wipe away any excess compound with lens paper, rubbing from the center outward in a spiral pattern.

PURGING

7-116. 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 equipment according to the applicable TMs or when condensation is evident in the instrument.

7-117. The gunner's primary sight on the M1 series tank features a defroster that does not automatically shut off after clearing the sight's day window. Excessive heat generated can crack the window.

POWERED SYSTEMS

7-118. While some fire control systems use unpowered devices, most newer systems require a power source, either from batteries or external sources. Batteries begin to lose their effectiveness as temperatures drop. At lower temperatures, operators may be required to discontinue battery operation and connect the power cable and adapter to a vehicle auxiliary power receptacle.

7-119. Dry batteries designed for use in temperate zones are likely to lose considerable electrical capacity due to decreased chemical activity at lower temperatures. These batteries are capable of operating equipment effectively at low temperatures if their internal temperature is kept high enough to permit normal chemical activity. When armed warmed to approximately 70°F (21°C), these batteries can retain sufficient heat for a considerable duration before replacement is necessary. The period of use depends on the rate that heat is dissipated from the battery. Battery life can be extended by insulating them from cold conducting surfaces with nonconductive materials.

7-120. There are several methods Soldiers can use to reduce heat loss when carrying replacement batteries. After warming, place the batteries in bags lined with kapok or spun-glass fiber materials, wrap them in woolen clothing, or carry them close to the body. Under certain conditions, it can help to carry the batteries separately from the equipment by using a connecting cord and plug. This arrangement may require certain modifications to the equipment to allow for the installation of the connecting cord and plug. Usually, these modifications are minor and readily accomplished by the unit.

7-121. 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

7-122. Snow can collect in uncovered eyepieces and tube sunshades or extensions, rendering instruments inoperable until the snow is removed. To effectively clear the snow, use a small, stiff brush or small rubber bulb equipped with a nozzle. Do not try to blow the snow out of these parts or wipe it out with gloves or bare hands, as some snow particles may melt and freeze on the lenses, resulting in further complications. 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. Take care to prevent the tissues from becoming wet and freezing the tube.

LEVEL VIALS

7-123. In temperatures below -40°F (-40°C), the level vials on sighting and fire control equipment can experience sluggish movement, elongated bubbles, and bubble separation. Sluggish bubble movement and elongated bubbles do not affect the precision of the device; however, bubble separation does affect accuracy. When bubble separation occurs, briskly rub the top surface of the level vial and the bubbles will merge into a single bubble.

COMPASSES, BINOCULARS, AND OTHER OPTICAL DEVICES

7-124. The liquid in the lensatic compass thickens in the cold. The heavier 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.

7-125. Cold weather does not affect binoculars and other liquid-free optical instruments. However, condensation does form when these instruments are taken from cold air into warm air. To prevent this issue, leave instruments outside or use anti-condensation containers.

7-126. Cover equipment like telescopes when they are not in use. If a cover cannot be made to fit the whole instrument, use bag-type cloth covers to go over the eyepieces and tube extensions. Cloth covers are preferable to airtight covers (such as the leather covers provided for some instruments). Cloth covers allow air circulation in contact with the lens, preventing condensation when the instrument is exposed to lower temperatures. Cloth bag covers can be made with a spring, elastic, or drawstring at the opening to hold them in place and allow for quick and easy removal.

7-127. 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.

Chapter 8

Electrical Equipment and Electronic Devices

Electronic devices such as communications equipment, computing devices, optics, and robotics are highly susceptible to cold temperatures. This chapter discusses cold-induced issues related to communications equipment, computers, power generation, and electronic devices and mitigation techniques to prevent equipment damage and ensure proper operation.

COLD WEATHER THREATS

8-1. The functionality of electronics in cold weather environments is influenced by more than just temperature; certain climatic conditions can affect this equipment as well. In addition to the steps provided in the TM, equipment operators must be able to recognize each of these effects to maximize equipment performance and accurately report functional problems. Maintainers and operators should refer to the item-specific TM that is the primary source for maintenance procedures.

8-2. Cold weather regions exhibit different weather characteristics compared to mild or temperate weather regions. Cold can alter the performance of electromagnetic energy and battery power consumption. 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 devices.
- Lower temperature limits of materials.

COLD-DRY AIR

8-3. Cold-soaked equipment is especially difficult to assemble in cold-dry air. The use of bulky gloves or mittens by operators and maintenance personnel further complicates the process. Heightened attention to detail, patience, and special preparation to prevent damage is imperative. This includes working with tight connections, electrical contacts, inflexible cables, power cords, grounding, control knobs, rubber covers, binding posts, and various other moving parts. When temperatures reach -40°F (-40°C), the storage battery used in radio sets becomes inoperative, leading to the loss of codes and requires reloading after warming.

8-4. The combination of dry air, 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.

8-5. Temperature inversions that occur on the coldest days in cold regions significantly degrade the strength of frequency modulation communications signals. A temperature inversion occurs when, as altitude increases, the temperature drops to a certain point, where it levels off or even reverses before resuming its downward trend. These abnormal temperature zones can obstruct, scatter, or reflect radio transmissions. This must be considered when planning troop placements and determining the locations of mission command centers.

FROZEN SURFACES

8-6. Frozen surfaces act as heat sinks that can rapidly cool equipment. Communications equipment should be kept off the ground and frozen surfaces. Adequate grounding is important for many pieces of communications equipment but can be very difficult to achieve on frozen surfaces.

Note. Standard grounding systems will require considerable effort to construct, and in some cases, it can be impossible. One of the most effective methods for penetrating frozen ground is to use shaped charges in combination with water saturated salt or soil backfill poured over the grounding device.

8-7. Antenna systems may be difficult to anchor in frozen ground, and ropes can freeze in cold environments. Mountain pitons are good alternative anchors for guy ropes in severe cold. As weather warms and the ground softens these alternative anchors need to be monitored and replaced with standard stakes.

8-8. The extraction of grounding devices is likely possible only following seasonal thawing. Use existing grounding options like pipes, established grounds, and buried steel if possible. Ensure existing grounds are not conduits for gas or flammable liquids before use.

SNOW AND ICE

8-9. Snow and ice can get into any unprotected openings in electronic equipment; use any equipment covers provided.

8-10. As snow and ice accumulated on wires begins to thaw, the water will run down and work its way into splices or connections. Install drip loops as pictured in Figure 8-1 to prevent the risk of electrical shorts caused by dripping water. A drip loop consists of a downward curve in the wire followed by an upward curve, which allows water to collect and drip before it reaches the connections. 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.

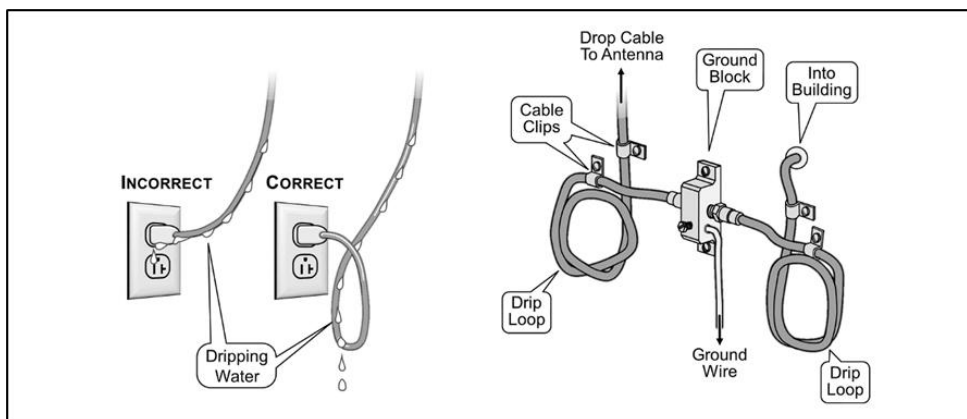


Figure 8-1. Drip loop

8-11. Other common issues regarding snow and ice include—

- Signal attenuation (absorption of energy reducing signal strength) due to ice on antennas.
- The loss of small items dropped in the snow. Units should conduct more frequent inventories of radio sets and antenna kits.

EFFECTS OF COLD ON ELECTRICAL AND ELECTRONIC DEVICES

8-12. Severe cold can affect the materials used to manufacture most communications and information systems equipment and make it unsafe or unsuitable for use. 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 at a time or fluctuate by 35°F (20°C) on a single day. While this TM primarily discusses only the effects of low temperatures on equipment, other cold weather conditions like low humidity, wind, and snow and ice formation that can impact electrical equipment. It is important to follow the equipment TM or manufacturers' instructions.

BATTERY FAILURE

8-13. Battery failure is a reoccurring issue for electrical and electronic items operated in the cold. Rechargeable batteries, specifically nickel-cadmium and lithium batteries, do not last as long in temperatures below 32°F (0°C). The charge rate for cold-soaked batteries is also slower. 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). It is important to prevent lithium batteries from becoming fully depleted, which could lead to a negative charge and thermal runaway.

INTERNAL CIRCUITS

8-14. As temperatures decrease, changes can occur in the resistance and capacitance of electrical and electronic components resulting in timing changes on integrated circuits, waveform changes, and changes to other electrical properties. This can affect the behavior of sensitive electronic equipment.

8-15. 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

8-16. If an item is covered in dust, the dust can retain condensation crystals even after the item is warmed. To mitigate dust, an information technology specialist should conduct regular cleaning (such as bi-monthly) by blowing out the dust. Placing a towel lightly misted with lubricating oil over the cooling intake vents can help to reduce dust from being sucked into electronic equipment (especially COTS computing equipment).

POWER-UP FRACTURING

8-17. Most electronic equipment produces its own heat, typically reaching temperatures between 70°F (21°C) and 80°F (27°C). Be mindful of cold-soaked equipment that has been powered off and cooled to sub-freezing temperatures. If this equipment is not preheated, the sudden temperature change during power-up can lead to cracks in internal components or pop and shatter crystals, diodes, and light emitting diodes. This is a more serious risk for COTS equipment, where ambient temperature should be above freezing. Maintainers and suppliers should be ready for the increased workload due to power-up heat shock.

CONTRACTING AND WARPING

8-18. Severe cold temperatures can cause various components of electronic equipment to contract, just as warm temperatures cause expansion. This contraction can lead to issues including warping of keyboard keys and failure of touch pads. Contraction is a major cause of equipment failure for devices using liquid crystal technology.

TRANSFORMERS

8-19. Frost accumulated on non-ruggedized electrical equipment, circuit boards, or electronic computing equipment must be removed before connecting the equipment to power, even if the device is turned off. When plugged in, these devices will immediately enter standby mode in preparation for full power up. Operators should always assume that power supply transformers are on.

GROUNDING

8-20. Properly grounding generators and communications equipment is a critical task that becomes more difficult in frozen ground conditions. Cold substantially increases soil resistance and impedes earth grounding. It is essential to drive ground rods or install ground plates below the frost line whenever possible to ensure effective grounding. In situations where there are no accessible buried objects for grounding, like underground pipes or building frameworks, drive multiple ground rods as deeply as possible. The most effective tactical grounding system for use in frozen ground is the surface wire ground. This system consists of pins connected with cable to form a grounding grid. Ensure that the pins are spaced at least two rod lengths apart. 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 maximum grounding resistance

that can be achieved with a six-foot grounding rod or the surface wire ground system is about 3,000 ohms. For guidance, refer to Communications-Electronics Command (CECOM) Technical Report 98-6.

SPECIALLY DESIGNED GROUNDING EQUIPMENT

8-21. Sealed, waterproof, or ruggedized electronic modules are usually not susceptible to the same general freezing condensation problems of exposed components. Likewise, electronic equipment that is kept and used in heated shelters typically does not require special precautions. Refer to the item-specific TM for exceptions.

OFFICE COMPUTERS

8-22. 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 workstations, -30°F [-34°C] for small handheld devices). Liquid crystal displays (LCDs) are particularly susceptible to cold weather. Do not force frozen knobs, dials, or switches. Electronic computer equipment used in a field environment such as computers, printers, peripheral devices, and radios that have blower vents or exposed circuit boards are at risk of condensation and freezing on both the circuit boards and within the accumulated dust.

INFORMATION TO DECISION DISPLAY EQUIPMENT

CAUTION

When removing a monitor, display, or TV from cold storage, do NOT plug it in immediately. Allow the device to acclimate to the ambient temperature of the room for 20-45 minutes. Keep the item secured in an anti-condensation container while the item stabilizes to room temperature.

8-23. Maintainers and operational staff must be aware of the various display technologies used throughout command, including plasma display panels (PDP), LCD screens, light emitting diode (LED) displays, and projectors. Cold temperatures can significantly impact the operating capabilities for these types of equipment. Generally, ruggedized military versions of display or projection equipment can handle temperatures down to -4°F (-20°C) without requiring built-in heating mechanisms. However, most COTS displays and projectors are not rated for use below 32°F (0°C).

8-24. The main vulnerability of displays and projectors in cold weather is due to the strict design tolerances of their construction and the reaction of supporting materials in the display screen or electrical circuitry. Cold temperatures can cause the expansion and contraction of the materials used in the screen and chassis, potentially pushing them outside of their designed limits. Additionally, humidity and condensation pose significant threats to both projectors and displays. Store the equipment in airtight cases to mitigate the risk of condensation buildup. Maintenance supervisors should establish defined policies within the standard operating procedure (SOP) for the proper operation and storage of display and projector devices.

8-25. When preparing to utilize any PDP, LCD, or LED display that was stored at temperatures below 40°F (4°C), it is essential to avoid rapid reheating. Avoid power-up electrical heat surges by gradually pre-warming the item. Wrapping the item in a clingy, airtight cellophane can serve as an anti-condensation container until the device adjusts to the warmer ambient temperature. These procedures will help preserve the crystalline character of the display, mitigate condensation on electronic components, and prevent water streaks from forming on the interior surface of the screen.

PLASMA DISPLAY PANELS AND SCREENS

8-26. The PDP consists of a matrix made up of very small fluorescent tubes that contain red, green, and blue phosphors. The active gases used in plasma screens are xenon and neon, both of which exhibit resistance to freezing in extremely low temperatures. Cold weather freeze damage is usually related more to the quality of the electronics manufacturing or condensation on the component materials. Unless specifically stated otherwise in the manufacturer's instructions or the TM—

- PDP operating temperature range is between 50°F (10°C) to 104°F (40°C).
- PDP storage temperature range is between -4°F (-20°C) to 113°F (45°C).
- COTS PDPs are sensitive to altitudes above 9,000 feet (3,000 meters).

Liquid Crystal Based Technology

CAUTION

Never touch or apply pressure to a cold LCD screen.

8-27. Supply personnel must plan to store liquid crystal-based equipment within the lowest common temperature range. Additionally, operators should dismount and store displays and monitors within the temperature range approved by unit policy. Unless specified otherwise by the manufacturer's instructions or the TM, the safest temperatures for LCD devices generally fall within the following ranges:

- Ruggedized LCD operating and storage temperatures at -4°F (-20°C) to 140°F (60°C).
- Non-ruggedized LCD operating temperatures at 40°F (4°C) to 90°F (32°C).
- Non-ruggedized LCD storage temperature at 40°F (4°C) to 100°F (38°C).

Note. The temperatures listed above for LCDs are only intended for planning purposes. Actual performance characteristics of a specific item will vary significantly.

8-28. Manufacturer limitations on cold storage of large screen LCD monitors (television sized) varies greatly. Some are rated to handle storage temperatures as low as -15°F (-26°C) to -20°F (-28°C), while others can hardly be stored at temperatures below 40°F (4°C).

8-29. As the liquid crystal cools to temperatures below 50°F (10°C), the image refresh rate becomes sluggish to the point where its display quality is active but blurred. Image blurring occurs for all LCDs around 40°F (4°C) and below depending on the exact chemical composition of the liquid crystal. The effects of low temperatures are usually reversible if the crystal does not freeze solid. However, at temperatures around -67°F (-55°C), the liquid crystal can freeze solid, breaking the crystalline substructure. Once frozen for a few days, damage becomes irreversible. (Do not confuse LCD freezing with water freezing.)

8-30. LCD screens are backlit by either a florescent tube (old technology) or an LED. When powered on in cold weather conditions (below 50°F [10°C]), an LCD screen may initially be faint and hard to read. Additionally, the refresh rate for motion pictures may be reduced and result in fragmented images. However, if the screen remains powered on, the display 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.

8-31. Operators must use anti-condensation containers to store and transfer LCD items from a cold vehicle into a heated shelter. For COTS items, wrap displays in a towel, felt, or fleece blanket to protect screens from scratching when not in use. Store any LCD item in an airtight anti-condensation container, cellophane wrap, or a self-sealing plastic bag.

8-32. 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

8-33. LCD-LED screens use liquid crystals with an LED transistor material that glows for screen backlighting. The light emitting diode itself will not freeze since it is already solid. The threat occurs when power is applied to the diode. The sudden rapid heat expansion can fracture (pop) a diode. When possible, pre-warm electronics before turning them 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

8-34. Digital light processing projectors consist of six major components, including a light source, optics, color filters, a digital micromirror device, electronics, and a projection lens. These projectors function at temperatures from -40°F (-40°C) to 158°F (70°C).

VISIBILITY AND ELECTROMAGNETIC CONDITIONS

8-35. Polar regions of the Earth where cold weather occurs are prone to two issues that affect electronic equipment: reduced 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 challenging and time consuming, especially when wearing required gloves or mittens.
- High-frequency wave propagation deteriorates significantly as darkness falls due to changes occurring in the ionosphere.
- Effective high frequency communications between stations that are 100 kilometers or more apart may be limited to six hours.
- Lower frequency assignments (that need longer antennas) are also required.

8-36. The Aurora Borealis 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.

8-37. Units reportedly use Aurora activity to enhance the range of high-frequency radio communications by reflecting directional signals off the light fields. However, this innovative use of conditions is the exception. The greater magnetic declination angles encountered when moving further north considerably affect radio communications positioning and orientation of directional antennas. These problems increase the need for strict supervision.

COMMUNICATIONS AND ELECTRONIC SYSTEMS

8-38. Cold weather operations have always been concerned about communications and power generation. Now, with the advent of microcircuits, operators must 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 (for example a lean-to) helps protect the equipment from direct exposure to cold air.
- Use poles or tree limbs to raise cables above the ground to keep them from freezing to the ground. If you can't get cables off the ground, keep them out from under the snow. Pull them free after every snowfall.
- Check antenna systems often and remove snow, ice, or slush that might diminish your signal or create a falling 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 work.
- Remove all snow, ice, water, and dirt from cable connectors before connecting to prevent breaking them or having a poor connection.
- Rubber and rubber compounds become stiff and brittle as temperatures drop. In cold weather, cables and wire should be flexed slowly and carefully to keep them from cracking and breaking.
- When applying lubricant, make sure not to over-lubricate. Lubricants can become stiff in cold weather, hindering their effectiveness. When using lubricant in the cold, check to ensure it hasn't gotten stiff and apply frequently. Use lighter lubricants if available.
- 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 operate freely. Snow and ice buildup can shut down critical fans and potentially damage motors.

- Make sure all knobs and controls move easily. Stiff controls might indicate a frozen moisture problem.
- Any equipment that generates heat during operation will draw in cold air as the equipment cools. When heated equipment contacts extremely cold air, there is a risk that glass, plastic, and ceramic parts may break. Allow hot equipment adequate time to cool down before taking it out of shelter into the cold.

RADIO SYSTEMS

8-39. Handle all communications/electronic equipment carefully when cold. A radio dropped on cold ground or thrown into the back of a vehicle can be damaged easily. Control knobs that may be sluggish or even frozen require careful handling; do not attempt to force them.

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.

8-40. Even well-maintained equipment requires considerable warm-up time. For example, 15 to 20 minutes warm-up may be required before voice transmission is possible. Plan to use innovative solutions such as chemical heat pads and Styrofoam to keep equipment (especially speech secure devices) as warm as possible and operational. Try to keep radios and switchboards off the ground and away from exterior tent or shelter walls.

8-41. Equipment can suffer damage if it is improperly positioned too close to heat sources like stoves or heaters. Electronic components and insulators are at risk of melting or burning, and some batteries can even explode if placed too near a heat source.

8-42. Lithium batteries perform particularly well in cold weather and do not require warming at temperatures above -20°F (-29°C). Dry cell batteries 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.

8-43. 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, can severely impair the ability to hear incoming transmissions. This may be overcome by using external speakers. Use plastic coverings (such as battery packaging) and moisture shields to cover the mouthpieces of handsets and keep moisture from the operator's breath from freezing them. Placing a frozen handset directly against lips or ears can cause physical injury.

8-44. Spare connectors, cables, handsets, and antennas should be readily available for replacement when failures occur. Metals and plastic become remarkably brittle and may crack and break easily in the cold. When using tape on components, use friction tape rather than plastic tape, which loses its adhesiveness in the cold.

8-45. Vehicular radios require careful attention. Small physical shocks can damage whip antennas when they are in the upright position. Allow radios to warm up for about three to four minutes on low power before transmitting or switching to high power settings. The vehicle for the radio being used should be cycled periodically according to its TM when temperatures dip below -30°F (-34°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 will quickly wear out the vehicle batteries.

ANTENNA SYSTEMS

8-46. Proper assembly of antennas is often overlooked, especially in cold and dark conditions. Shortcuts and failure to follow prescribed instructions often result in interrupted or degraded communications and damage to equipment. Antenna masts must be erected with enough mast sections to ensure necessary height.

8-47. Standard stakes are often ineffective in frozen ground. Cold-weather stakes can be ordered for antenna masts, but they do not hold as well when the ground thaws since they are slimmer than standard stakes. Heavy 12-inch steel tent pins, short segments of rebar (reinforcing steel rods), and tree and rock tie offs are also acceptable options for anchoring antennas. Another method for erecting a radio antenna is to carefully guide the mast alongside a tree and secure it to the trunk using one of the attached guy lines. Be careful not to damage any of the elements, cables, or mast sections while erecting the antenna.

8-48. Proper inventory of unused hardware is essential since parts are easily lost in snow and darkness. Be careful not to let moisture accumulate due to condensation or precipitation and ground out the antenna.

Note. Prior to assembly, expose the antenna components to the cold and inspect them for ice or ice crystal buildup due to condensation and freezing. This prevents problems later with disassembly.

8-49. 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.

8-50. 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. 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. Use cold-weather tape when assembling the antenna; normal tape becomes less adhesive in sub-freezing temperatures.

8-51. Keep ceramic bowls dry, as water may collect in them during warm weather. When temperatures drop, the accumulated water can freeze, causing the more brittle glass to crack. Applying silicone where the two bowl halves join helps in sealing against further cold damage.

8-52. 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.

8-53. 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 CABLING SYSTEMS

8-54. It is significantly easier to lay wire over long distances in deep snow with over-snow vehicles. However, these vehicles can also pose a serious threat to the wire systems. Their skis and tracks can damage surface-laid wire and cable, often 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 recommended when tactically feasible. Burying wires is desirable, but it is often difficult or impossible in frozen ground and snow. 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.

8-55. Wire insulation is often brittle, and impedance increases 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% specified in the TM. This allows for cold weather shrinkage (unless the wire is already cold-soaked).

8-56. 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.

POWER GENERATION OPERATIONS

8-57. Units must inspect their mobile electric power (MEP) generator sets thoroughly and prepare them for cold weather operations according to the TMs and local procedures. Follow generator set lubricating orders that specify the appropriate lubricants to use in cold weather. Winterization kits for the 5-kilowatt to 60-kilowatt tactical quiet generators (TQG) are available for temperatures of -25°F (-32°C) down to -50°F (-46°C). They can be requisitioned as individual kits by national stock number and kilowatt size. Read the generator set's TM section on cold weather procedures outlined in "Operation under Unusual Conditions." Perform the tasks below to ensure satisfactory operation during cold weather:

- 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 with MOS 91D (Power Generation Equipment Repairer) are authorized to install the kits.
- Keep the batteries clean, fully charged, and protected from freezing. If possible, store the batteries in a warmer environment and install them only when the equipment is ready for use.
- 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 free of ice and snow.
- 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 TM.
- Keep fuel containers closed to prevent snow and moisture from entering. Water in the fuel can freeze the fuel lines. Military generator sets have filters that remove impurities and some water, but too much water decreases their effectiveness.
- Keep the fuel tank full to prevent moisture intrusion, condensation, and water accumulation.
- Inspect, drain, and clean fuel filter and water separators daily and at shutdown to prevent icing.
- 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 the TM) cannot penetrate, Soldiers can use the surface wire grounding kit; national stock number 5820-01-263-1760.
- The surface wire grounding kit contains a sledgehammer, two 10-foot steel connector cables with 75 ampere connecting clips, 15 10" steel grounding pegs, and 75-feet of steel grounding cable. Follow the kit's instructions and refer to CECOM TR 98-6.
- Units can bury a ground plate in warmer weather and mark its location for future use. Use a plate at least 2 feet square of 1/4-inch steel or 1/16" thick nonferrous metal (except aluminum), buried deep enough to reach moist soil. When needed, connect the plate to the generator set's ground terminal lug with #6 AWG wire.

Note: Remember, any ground electrode (rod, peg or plate) should penetrate deep enough to contact moist soil below the frost line. See CECOM TR 98-6 for grounding procedures in Arctic areas. Units can also use an existing underground metal pipe for a satisfactory earth ground. Though it too must reach below the frost line.

TACTICAL ELECTRICAL PRODUCTION AND DISTRIBUTION

8-58. 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 requiring a winterization kit. However, starting diesel engines becomes challenging at these temperatures. 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 become 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.

8-59. Other conditions often prevalent during cold weather operations can affect equipment, such as low humidity, wind, and snow and ice formation. 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 generator sets at higher altitudes is printed on the data plate. Refer to the TM for information on a given generator set model.

8-60. Operators and maintainers must perform cold weather maintenance on all MEP generators and power distribution illumination system electrical (PDISE) equipment. Refer to the generator set TM for specific procedures for cold weather operation and follow these general guidelines:

- 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 generator sets at the lowest temperature expected.
- Ensure the engine's starting batteries are fully charged to prevent freezing.
- In certain conditions, ice fog can form due to engine exhaust when temperature is at or below -25°F (-32°C). 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.

MOBILE ELECTRIC POWER SYSTEMS

8-61. Each family of generators has distinct characteristics and features that operators and maintainers need to understand to operate, troubleshoot, and maintain them effectively. MEP generators are the DOD standard family of power generator sets. They are designed to operate in ambient temperatures as low as -25°F (-32°C) without requiring specialized winterization equipment. The Army uses several DOD standard families of MEP generators along with their associated power distribution equipment:

- Military tactical generator (MTG).
- TQG.
- advanced medium mobile power sources (AMMPS).
- power unit/power plant is a combination of a trailer-mounted TQG or AMMPS.
- Deployable Power Generation and Distribution equipment.
- PDISE.

Military Tactical Generator

8-62. The 2-kilowatt MTG sets (models MEP-501A and MEP-531A) are self-contained, skid mounted, portable units. They are equipped with the controls, instruments, and accessories necessary for operation as single units. The generator set consists of a diesel engine, direct-drive alternating current (AC) alternator, speed governing system, fuel system, 24V direct current auxiliary cold weather starting system, and generator control system. The generator sets are portable and require a four-person lift. They can be stacked three high while in storage.

8-63. The 2-kilowatt MTG has a built-in cold weather starting system for temperatures at 23°F (-5°C) down to -50°F (-45°C). These generators do not have protective enclosures for main components.

8-64. MTGs provide electric power to—

- Modern burner unit of the mobile kitchen trailer.
- RQ-7A tactical unmanned aerial vehicle.

- Enhanced position location reporting system.
- Assault hose system.
- Woodworking set.
- High mobility artillery rocket system.
- Prophet signal intelligence system.
- Tactical messaging system.
- Maintenance tent lights and battery charging system.
- Lights, laptops, and miscellaneous support equipment.

Tactical Quiet Generators

8-65. The 3-kilowatt TQG sets (models MEP-831A and MEP-832A) are self-contained, skid mounted, portable units. They are equipped with controls, instruments, and accessories necessary for operation. The generator sets consist of a diesel engine, permanent magnet AC generator, control box assembly, output/load panel, primary and auxiliary fuel systems, enclosure cooling and ventilation system, engine exhaust assembly, and a 24V direct current battery. The generator sets are designed to be used with any equipment requiring a small source of AC power and operate in a “Hot and Basic” climatic condition range of -25°F (-32°C) to 120°F (49°C). The generator sets are portable and require a six-person lift.

8-66. These are two configurations of the 3-kilowatt TQG:

- 120V and 120V/240V AC 60 hertz.
- 120V and 120V/240V AC 400 hertz.

8-67. The 3-kilowatt TQG is equipped with cold weather engine starting aids:

- Integral air intake heaters are mounted in the intake manifold. These heaters raise the air temperature in the combustion chamber to assist with ignition when the air temperature drops below 21°F (-6°C) to -25°F (-32°C).
- An optional winterization kit is available and designed to heat the coolant and engine block when temperatures range between -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.

Advanced Medium Mobile Power Sources

8-68. AMMPS are a standard family of reliable, efficient, light weight, electronically controlled, diesel-fueled power systems to support tactical units in the battlefield. They will eventually replace all comparably sized TQGs. AMMPS features include the following:

- Available in 5-kilowatt, 10-kilowatt, 15-kilowatt, 30-kilowatt, and 60-kilowatt.
- Skid and trailer mounted.
- Consume less fuel, require fewer maintenance hours, have significantly better failure rates, and allow for multiple sets paralleling while providing high quality power in extreme operational and environmental conditions.
- Electronically controlled with digital Soldier interfaces.
- Environmental Protection Agency compliant engines to reduce harmful emissions.
- Use diesel fuel, DF-2D, DF-1D, jet fuel JP-5, and JP-8.
- Operate in temperatures ranging from -25°F to 125°F and can withstand humidity, sand, dust, and rain.
- AMMPS generators can be paralleled to increase power output or connected to create a microgrid without the need for external control devices.
- AMMPS is equipped with fuel-fired standby heater that warms the coolant when temperatures range from -25°F (-32°C) to -50°F (-46°C). This winterization kit starts automatically based on the temperature and regulates the heat automatically. Its digital control system activates the “ready to crank” indicator when the heater has completed its cycle.

POWER DISTRIBUTION AND ILLUMINATION SYSTEMS, ELECTRICAL

8-69. The principal power distribution system for the Army is called the PDISE. PDISE is basically a more rugged version of home distribution boxes/panels (with various size circuits and circuit overload protection), plus the connecting cables and a utility subsystem.

8-70. This equipment is designed to operate at temperatures as low as -25°F (-32°C). To prevent moisture intrusion, ensure the electrical feeder system and distribution center enclosure lids are closed and latched. When coiling load cables or making connections to electrical loads, form large loops since the power cables are more difficult to bend in below freezing temperatures.

8-71. PDISE characteristics:

- Man-portable electrical distribution system for safe, all-weather electrical power distribution from generator sets to multiple users (like vehicles, shelters, field unit complexes, and tents).
- Comes in four sizes of distribution boxes (40, 60, 100, and 200 Amps), connecting cables, and assemblage of utility extension cords, branch circuits, and lighting equipment.
- Supports mobility by enabling quick assemble/dissemble.
- Various sizes allow selection to match generator sets from 5-kilowatt to 100-kilowatt.

Appendix A

Cold Weather Policy Considerations

This appendix provides planning and policy considerations that commanders and unit leaders may want to use 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 SOP. Some of the preparation functions mentioned below will require months of lead time to properly execute.

STAFF RESPONSIBILITIES

A-1. The staff will need to conduct analysis to produce 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 units use 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, categorized according to the severity of the weather.
- Identify gaps between authorized organizational equipment and supplemental materiel requirements for each of the following cold weather categories:
 - Arid high temperature, desert can be around 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 (16°C).
 - Wet cold is about 39°F to 20°F (4°C to -6°C).
 - Dry cold is about 19°F to -4°F (-7°C to -20°C).
 - Intense cold is about -5°F to -24°F (-21°C to -31°C).
 - Extreme cold is about -25°F to -40°F (-32°C to -40°C).
 - Hazardous cold is about -40°F (-40°C) and below.
- Establish a date or situation (trigger event) when the unit converts to cold weather operations. This plan should specify a limited time to complete the 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 cold weather protection equipment, clothing, and devices. Consider added space, transportation, maintenance, and fuel requirements for the additional non-standard equipment.
- Set unit severe weather PPE policy, adjusted for each weather category. Anticipate requirements in each severe weather category and develop a survival kit and survival bag list for each one.
- 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 lifesaver 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 noncommissioned officer (NCO) in charge [known as NCOIC], or the senior medical NCO, if available).
- Establish planned quality controls and inspections of the commander's unit severe weather policies.
- Conduct after action review of severe weather preparations and training events. Use feedback to adjust in planning and policies ahead of deployment or mission.

TRAINING

A-2. Unit leadership is responsible for training Soldiers on individual and collective tasks in cold weather conditions:

- Identify the mission focused—
 - Tactical training priorities.
 - Maintenance training priorities.
 - Medical training priorities.
 - Movement training priorities.
- Draft training curriculum to cross-train and certify select Soldiers (junior enlisted) from each platoon to support unit maintenance. The training should focus on cold weather conditions that require Soldiers to be in PPE. The following are several areas to train on:
 - Battery technology and maintenance.
 - Power generator operation and repair.
 - Powertrain disassembly, repair, and rebuild.
 - Vehicle fleet safe engine starting and auxiliary power supply procedures.
 - Vehicle heater operation, maintenance, and inventory administration.
 - Shelter heater operation, maintenance, and inventory administration.
 - Base camp or cantonment area sanitation.
- Conduct a recertification of all previously qualified combat lifesavers with the emphasis on cold weather conditions.
- Ensure that Soldiers receive proper training in environmental awareness and comply with HAZMAT regulations. Soldiers must be able to recognize all HAZMAT that they routinely handle and their proper disposal. More importantly, they must know how to contain and mitigate emergency situations (like HAZMAT spills) in severe weather conditions.
- Train operators on adherence to procedures outlined in the TMs and LOs for their equipment.
- Administer and oversee the licensing of Soldiers to operate field heater equipment.
- Administer and oversee driver's refresher training in ice and snow driving.
- Ensure operators are trained and licensed on assigned equipment, weapon, or vehicles.

LOGISTICS PREPARATION FOR SEVERE WEATHER

A-3. Senior staff logistics leaders need to help establish and implement the commander's policies and leadership procedures that 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).
- Establish a date or trigger event when the unit converts to cold weather operations.
- Develop a contingency plan for logistics activities within the unit to convert the unit to being operational in all levels of cold weather extremes on order.
- Identify where the unit can draw 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 before conducting training or missions in cold weather.
- Perform 100% inventory of all tents and tent heater systems (especially component parts) well in advance of the winter to replenish shortages.
- Identify PPE not suitable for severe weather conditions and recommend alternatives to the commander.
- Procure COTS PPE before severe weather missions as directed by the commander.
- Inventory all COTS equipment before winter. Draft maintenance procedures and lifecycle parts lists for all unit COTS items that might be used in the field. Account for additional demands to support the use of COTS items. Identify and account for all unit COTS that use or are powered by—
 - Petroleum.
 - Commercial electrical power.
 - Batteries.
 - Lubricants.

- Notify the senior medical NCO of scheduled activities that will probably occur under severe weather conditions.
- Coordinate with food services to provide supplemental hot/cold beverages, snacks, and hot food regularly at work 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 leaders of missing and unserviceable initial issue items and individual equipment.
- Arrange for comprehensive sanitation facilities.
- Organize heated overnight storage for electronics (radios, computers, and monitors) of parked vehicles.
- Provide electrical power connections to winterization kits that keep engines and batteries of parked vehicles warmed.

MEDICAL ACTIVITIES

A-4. Cold weather conditions place an additional workload on medical Soldiers. Consider the following for the prevention and treatment of cold weather injuries:

- Establish and administer quality control policy and procedures for the presence and proper resourcing of medical support.
- Establish a 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 of cold weather injuries in Soldier records. During duty periods with cold weather, all Soldiers who have sustained an injury should report to a special “post duty sick call” before being released for the day or from an outside duty event.
- Delegate a medical NCO to make inquiries and write a root cause report on any serious cold weather injuries. Give the report to the unit medical officer for consideration when making recommendations to the commander. The findings might warrant making changes to the unit cold weather policy. Perform reports in accordance with AR 385-10, DA Pam 385-40, and local command policy.
- Coordinate 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.
 - Munitions distribution activities.
 - Guard posts or other long-lasting outside duties.
- Establish a duty roster of NCO combat lifesavers who have received special training and are certified by the brigade surgeon 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 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.
- Ensure that combat lifesavers are certified in severe-weather-related first aid and rehydration and maintain proficiency in mitigating and stabilizing cold injuries.
- Verify that medical staff is documenting all cold injuries and inserting the information into Soldier records.
- Conduct after action reviews of severe weather preparations and training for medical events; use the feedback to adjust preparations for deployment.

MAINTENANCE ACTIVITIES

A-5. Cold weather conditions place an additional workload on maintenance Soldiers. The following policies may help mitigate the impact of the cold on maintenance operations:

- Establish procedures for the operation and maintenance of unit equipment in severe weather conditions.
- Verify that supervisors have both the leadership and technical skills to oversee the proper performance of cold weather unplanned maintenance and planned 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 tighteners) well in advance of the winter.
- Manage winterization kits, shelters, and heaters as they become available through supply channels. Ensure the kits are correctly installed and that operators understand their proper use and maintenance.
- 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 and equipment starting using maintenance auxiliary power resources.

VEHICLE OPERATOR RESPONSIBILITIES

A-6. Equipment operators and maintenance personnel must comply with the operational checks outlined in vehicle TMs and include the procedures listed below.

BEFORE OPERATIONS

- A-7. Operators should anticipate an increase in the time required 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 the 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 CO₂ fire extinguishers have been winterized according to the appropriate fire extinguisher TB.
 - Prevent snow or ice from entering crankcase when adding lubricants to an engine.
 - Ensure cooling systems are protected with the correct antifreeze compound.
 - Ensure vehicle is fueled with the proper grade arctic fuel or 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 ensure glow plug operation.
 - Check batteries to ensure that they are fully charged by measuring the specific gravity of the electrolyte or performing a conductance test.
 - Roll and store tarps for ease of employment after operations.

DURING OPERATIONS

A-8. Operators should review the quick-lookup list of checks at regular intervals during the operation of vehicles and equipment. Along with TM checks, the operator should consider additional points that require close observation during cold weather operations:

- Do not tow-start vehicles.
- Avoid powering up radios, LCD, or LED electrical equipment until it is first 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 operations check before leaving the unit area.
- Start vehicles periodically to maintain readiness at temperatures of -20°F (-29°C) to -60°F (-51°C). (This practice can be avoided if any other means of keeping engines operable, like engine heaters or external heaters, are available.)
- Avoid idling engines if 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 after operations PMCS procedures but also give attention to how they park the equipment, 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 shut down, run the vehicle engine to normalize its mechanical working and retain oil on cylinder walls.
- Do not park vehicles with the brakes set because they may freeze and not release. Use chock blocks to hold vehicles in place.
- Never park vehicles overnight where snow has melted that day; tracks and wheels could 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 removed from vehicles and stored in a heated room, warm tent, or a warm vehicle. Be careful to avoid condensation buildup.

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Appendix B

Electrolyte Spills

Electrolyte spills are serious events. Proper accident management is a critical skill for anyone handling batteries. This appendix covers basic electrolyte spill procedures and first aid instructions.

FIRST AID INSTRUCTIONS

B-1. Before battery maintenance operations, personnel should identify and write down the electrolyte being handled for emergency reference. In an event that personnel are exposed unprotected to electrolyte (battery acid), whether liquid, GEL, or powder, follow these instructions immediately:

- Move unresponsive personnel to fresh air and provide cardiopulmonary resuscitation (known as 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 is contaminated with electrolyte. Do not assume spilled chemicals on clothing are not harmful. The contaminated clothing can expose skin to chemical burning. Exposure of contaminant through the skin may cause severe pain, damage to organs, and could result in death.
- 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. Provide medical personnel with the name of the type of contaminant or chemical.

Note. Consult the precautionary warnings on the product label for full first aid information. Provide the label information to the attending physician.

SPILL OR LEAK PROCEDURES

B-2. Electrolytes are HAZMAT. Consult with the local installation HAZMAT agency for policies on establishing 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 a face shield when working with batteries and electrolyte.
- Stop the flow of material and contain/absorb small spills with dry sand, earth, or 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 battery electrolytes. Have these 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. After neutralization and testing, large water-diluted spills should be managed in accordance with local, state, and federal requirements. Consult the state environmental agency and/or the federal Environmental Protection Agency.

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Appendix C

Jump Starting

It is common in cold situations for a vehicle to need its battery power augmented during initial startup. This appendix provides limited and general information on equipment start assistance through the jump start method.

COMMAND POLICY

C-1. Maintainers can expect that most cold-soaked vehicles will require assistance with starting. The commander should state in the unit maintenance and tactical SOP under what circumstances an operator can slave start a vehicle. Commanders should consider establishing startup procedures that protect equipment. The SOP should also include defined trigger events where maintainers may receive additional manpower to perform maintenance, and equipment operators will start all vehicles, equipment, and devices to prevent cold-soak status.

INITIAL STARTING EFFORT

C-2. Supervisors of operators must know that operators understand and use maintainer-approved procedures for starting cold engines. Cold starting may or may not be the same as starting in temperate weather conditions. Each vehicle or power plant must be treated as unique in the cold:

- Performed preventive maintenance as prescribed by the specific item TM and the unit SOP.
- 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.

C-3. After the third unsuccessful attempt to start a vehicle using its own battery power, contact the maintenance team for assistance.

PRIOR TO AUXILIARY POWER ASSIST STARTUP

C-4. Vehicles or batteries require preparation before attempting an auxiliary power assist startup in cold weather conditions. Along with the procedures specified in the applicable TM, maintainers should pay very close attention to the following cold weather starting considerations:

- Wear gloves that protect from electrolyte contact and electrical shock.
- Wear eye protection.
- Check that batteries fluids are not frozen. If ice is found or suspected in a battery cell, stop the process. Remove and replace frozen batteries.
- Check to see if a minimal current is present. A good indicator is if the lights turn on or the horn works.
- Confirm that batteries are of the same voltage.
- Check negative posts to ensure they are properly grounded.
- Check all battery posts and ensure they are free of corrosion buildup. Ensure cables are secured snugly.
- Make sure that vehicles are not touching.
- Make sure that all master switches, ignition switches, accessories, and communications equipment are off for both vehicles.
- Put both vehicles in either park or neutral with brakes on. The brake setting only applies during starting (otherwise, in cold, do not apply parking brakes to just park a vehicle).
- Attach cables to terminals, first to the dead vehicle followed by the vehicle with power.
- Start the engine of the vehicle supplying the auxiliary power.
- Increase the engine idling speed of the powered vehicle to higher than normal.
- Wait 15 minutes for the battery to charge before trying to start, if possible.

AUXILIARY POWER RECEPTACLE

C-5. The auxiliary power receptacle is used to start a vehicle when otherwise good batteries are unable to supply enough starting current. The auxiliary power receptacle (Figure C-1) is an electrical outlet located at a readily accessible place on the vehicle. It receives current from other vehicles. This provides direct boosting of the cold vehicle current when starting an engine in cold weather.

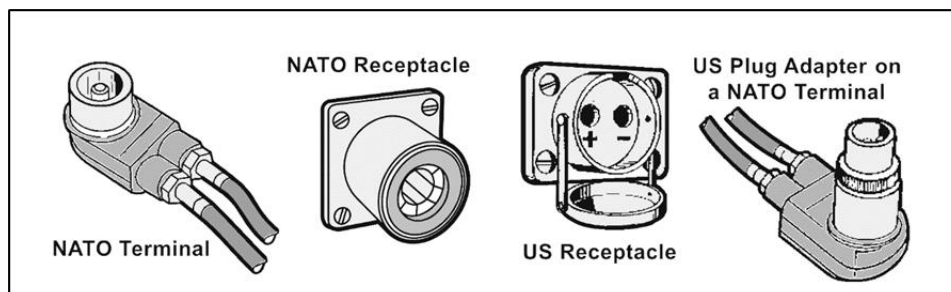


Figure C-1. Auxiliary power receptacles and terminals

Appendix D

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. It is unlikely that Soldiers will encounter all these products.

PETROLEUM

D-1. The Army adopted the SFP, which can be found in AR 70-12. This is focused on a single kerosene-based fuel for use in all equipment. Soldiers should be familiar with alternative fuels for their equipment when operating in temperatures below -35°F (-37°C).

Note. The properties of POL products in this appendix are derived from military performance specifications that represent minimal capabilities, and not the full capabilities of any specific product. Units should 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.

Within this appendix, flash point refers to the temperature at which the vapors of the liquid will ignite when there is a source of ignition. Pour point refers to 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.

JET PROPELLANT 8 (JP-8)

D-2. This fuel type is a kerosene-based aviation fuel blended with three additives. Under AR 70-12, JP-8 is the primary fuel for land-based air and ground forces in all theaters of operation outside the CONUS. For cold temperature environments, use it in accordance with MIL-DTL-83133. JP-8 is also used in CONUS when a fuel with a freeze point below -40°F (-40°C) is required (otherwise F-24 is the primary fuel used).

D-3. JP-8 technical data:

- Definitive Standard: MIL-DTL-83133.
- NATO Code Number F-34.
- Special Characteristics. There are three additives for JP-8:
 - Fuel System Icing Inhibitor; MIL-DTL-85470; NATO# S-1745.
 - Corrosion Inhibitor/Lubricity Improver (CI/LI); MIL-PRF-25017; S-1747.
 - Static dissipater additive.
- Flash point: 100°F (38°C), minimum.
- Freezing point: -53°F (-47°C), maximum.

Note. If JP-8 is not available outside the CONUS, the policy from the theater Joint Petroleum Office, in coordination with the Army Petroleum Center, provides guidance on the use of the secondary fuels or any deviation from the SFP.

FUEL 24 (F-24)

D-4. F-24 is the primary fuel used for air and land-based forces in CONUS (except when a fuel with a freeze point below -40°F [-40°C] is required, then JP-8 is used). This fuel has a NATO designation of F-24 and is defined in STANAG 3747/AFLP-3747 as meeting all performance requirements of the American Society for Testing and Materials (ASTM), International D1655 grade Jet A. It must contain the three military additives Fuel System Icing Inhibitor, CI/LI, and static dissipater additive.

D-5. The F-24 conversion in CONUS is 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.

D-6. F-24 technical data:

- 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.
 - CI/LI.
 - Static dissipater additive.
- Flash Point: 100°F (38°C), minimum.
- Freeze Point: -40°F (-40°C) maximum.

COMMERCIAL JET FUEL

D-7. 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

D-8. 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.

D-9. Jet A technical data:

- Definitive Standard: ASTM-D1655.
- Flash Point: 100°F (38°C), minimum.
- Freeze Point: -40°F (-40°C), maximum.

Jet A-1

D-10. 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.

D-11. Jet A-1 technical data:

- Definitive Standard: ASTM-D1655.
- Flash Point: 100°F (38°C), minimum.
- Freeze Point: -52.6°F (-47°C), maximum.

Jet B

D-12. Jet B is a 70% naphtha–30% kerosene-based fuel used for its enhanced cold-weather performance.

D-13. Jet B technical data:

- Definitive Standard: 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.

Jet Propellant 5 (JP-5)

D-14. JP-5 is a unique military aviation fuel for use on Navy ships. Due to Navy shipboard safety requirements, it is required to have a substantially higher flash point than commercial aviation turbine fuels.

D-15. JP-5 technical data:

- Definitive Standard: MIL-DTL-5624.
- NATO Code: F-44.
- Flash Point: 140°F (60°C), minimum.
- Freeze Point: -51°F (-46°C), maximum.

Jet Propellant 4 (JP-4)

D-16. JP-4 is a naphtha-based fuel. JP-4 is classified as inactive. 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, United States Army Combat Capabilities Development Command recommends using JP-4.

D-17. JP-4 technical data:

- 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

D-18. Alternate and emergency ground fuels available with NATO are listed in STANAG 1135.

Commercial Diesel

D-19. Commercially available diesel fuel 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.

D-20. Diesel fuel technical data:

- 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

D-21. Different lubricating oils of various grades have been historically used in engine crank cases by the military. This is changing with the introduction of an OE/HDO, termed the SMPL. The old oils were identified by the SOE international classification for crude oil-based lubricants. Crude oil products are characterized by a limited temperature range relative to synthetic oils.

ENGINE OILS

D-22. OE/HDO-SMPL is recommended for extreme cold conditions to help deliver quick starts and fast lubrication. This lubricant is usually approved for use in engines, power steering systems, and automatic/powershift transmissions (based on the item-specific TM). SMPL is intended to be a direct replacement for previous applications requiring SAE 10W or arctic engine oil. It is necessary to consult the LO prior to use. It is not recommended for two-cycle or aviation engines unless specifically approved by the TM. The use of OEA or OE/HDO-SMPL 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 SMPL, the oil drain interval may be doubled.

D-23. SMPL:

- Definitive Standard: MIL-PRF-32626.
- Military symbol: OE/HDO-SMPL.
- 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.
- 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.
- Multigrade lubricating oil, 10W-30 (only rated for gasoline engines):
 - Military symbol: OE/HDO-10/30.
 - NATO Code: n/a.
 - Upper limitation: 120°F (49°C).
 - Lower limitation: 15°F (-9°C).
 - Flash Point: 401°F (205°C), minimum.
 - Pour Point: -40°F (-40°C), maximum.
- Multigrade lubricating oil, 5W-40 (only rated for gasoline engines):
 - 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.
- 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

D-24. Low temperatures can adversely impact the performance of transmission oils and greases used in parts of military equipment other than the engine. OE/HDO-SMPL or OEA 30 can be used for automatic transmissions and hydraulic and power steering systems. Both are compatible with most types of automatic transmission fluids (including DEXRON III). OE/HDO-SMPL and OEA-30 can be mixed with other transmission fluids, but that may degrade the low temperature properties or other performance limits of the fluid.

D-25. Some manufacturers for manual transmissions, transfers, differentials, and final drives may require different lubricants in specific applications.

D-26. 15W/40 is the preferred oil for semiautomatic transmissions (including in all Caterpillar manufactured transmissions, and for 4500SP Allison transmissions for M1074 and M1075 model trucks) when temperatures permit.

D-27. 15W/40 technical data:

- 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

D-28. Gear lubricating oils (military symbol, GO) are available in the following grades:

- SAE Grade 75W/90:
 - Definitive Standard: SAE J2360
 - Military symbol: GO-75/90.
 - NATO Code: O-186.
 - Upper limitation: 120°F (49°C).
 - Lower limitation: -50°F (-46°C).
 - Flash point: 302°F (150°C), minimum.
- 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 (-28°C).
 - Flash point: (165°C), minimum.
- 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 (-16°C).
 - Flash point: (180°C), minimum.
- SAE 75W-90:
 - Military symbol: GO-75.
 - NATO Code: O-186.
 - Upper limitation: 120°F (49°C).
 - Lower limitation: -50°F (-46°C).
 - Flash point: 302°F (150°C), minimum.

D-29. Synthetic oil is the alternative for manual transmissions, transfers, differentials, and final drives that normally use crude oil-based GO 85/140.

WEAPON LUBRICANTS

D-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 general-purpose lubricants have an operating range of over 500°F (260°C) down to below -65°F (-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.

D-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 protection against corrosion of certain small arms and automatic weapons. It may also be used 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. Technical data is as follows:

- Standard: MIL-PRF-32033.
- Military symbol: PL-S
- 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 (-51°C), maximum.

D-32. Cleaner, lubricant, and preservative (CLP) is the primary lubricant for small arms, crew-served, and artillery weapon systems. It is a multipurpose product that performs three functions of breaking up carbon residue, lubricating metals as a penetrating oil, and repressing corrosion. Technical data is as follows:

- 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.

WARNING

DO NOT use CLP with any other lubricant. CLP when mixed with other lubricants may break down into gum and cause weapon malfunction or damage the weapon.

D-33. Lubricant, Small Arms, Semi Fluid, Automatic Weapons is strictly a lubricant. It is a petroleum-based (non-synthetic) lubricant mixed with a combination of detergent, oxidation inhibitor, and corrosion inhibitors. It provides oxidation and corrosion resistance as well as rust protection and anti-wear properties. Technical data is as follows:

- 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.

D-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 is authorized for use on rifles, pistols, and as a cleaning and sharpening oil for bayonets. The lubricant must be shaken well before use as the Teflon® is suspended in the petroleum. Technical data is as follows:

- 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.

D-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. Technical data is as follows:

- 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 (-18°C).
- Lower useful limit: -70°F (-57°C).
- Flash point: 305°F (152°C), minimum.
- Pour point: -75°F (-59°C), maximum.

GREASE LUBRICANTS

D-36. The function of 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. The properties of the grease changes beyond those temperatures and may become 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 is 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.

D-37. The technical data for some different grease lubricants is listed below:

- Grease, Automotive and Artillery:
 - Standard: MIL-PRF-10924.
 - Military symbol: GAA.
 - NATO Code: G-403.
 - Upper Limit: 356°F (180°C).
 - Lower Limit: -65°F (-54°C).
 - Dropping point: 428°F (220°C), minimum.
 - Freeze Point: n/a.
- Grease, Aircraft, General Purpose, Wide Temperature Range (Grease):
 - Standard: MIL-PRF-81322.
 - Military symbol: WTR [wide temperature range].
 - 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.
- 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 (74°C), minimum.
 - Freeze Point: n/a.
- 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.
- 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

D-38. Different hydraulic fluids and their corresponding technical data are discussed below.

D-39. Hydraulic Fluid, Petroleum Base, for Preservation and Operation is the oldest of the Army's hydraulic fluids:

- 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: 275°F (135°C)
- Lower useful limit: -65°F (-54°C).
- Flash point: 180°F (82°C).
- Pour point: -76°F (-60°C).

D-40. Hydraulic Fluid, Rust Inhibited, Fire Resistant, Synthetic Hydrocarbon Base is a corrosion inhibited, synthetic based hydraulic using polymer, alpha-olefins 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: 475 °F (246°C), minimum.
- Flash point: 424°F (218°C), minimum.
- Pour point: -65°F (-54°C), maximum.

D-41. Hydraulic Fluid, Petroleum Base; Aircraft, Missile, and Ordnance is intended for aircraft. It can occasionally be found in ground equipment like generators and tracked personnel carriers. However, the Army's Ground Vehicle Systems Center recommends OHT or FRH because OHA does not contain corrosion inhibitors:

- Standard: MIL-PRF-5606.
- 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.

D-42. Biobased hydraulic fluid is made with renewable resources for use in environmentally sensitive areas. It was developed to cover hydraulic fluid requirements for military construction and bridging equipment, tactical vehicles, shipboard hydraulic systems, and metal tool hydraulic systems. These fluids are compatible with existing petroleum-based fluids, so changing to biobased fluids does not require a major hydraulic system cleaning. Technical data is as follows:

- Standard: MIL-PRF-32073.
- Military symbol: BHF.
- NATO Code: n/a.

D-43. Biobased hydraulic fluids are divided into five grades, whose key temperature properties are presented below in table E-1.

Table D-1. Biobased hydraulic fluid 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)
C Celsius F Fahrenheit					

D-44. 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.

D-45. Hydraulic Fluid, Fire Resistant; Low Temperature, Synthetic Hydrocarbon Base, Aircraft and Missile is a synthetic hydrocarbon base hydraulic fluid for use in aircraft and missile hydraulic systems:

- Standard: MIL-PRF-87257.
- NATO Code: 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.

D-46. Brake Fluid, Silicone, Automotive, All-Weather, Operational and Preservative:

- Standard: MIL-PRF-46176.
- Military symbol: BFS.
- NATO Code: 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.

D-47. Brake Fluid, Polyglycol Automotive, All-Weather, Operational and Preservative:

- Standard: MIL-PRF-32701.
- Military symbol: PBF.
- NATO Code: None.
- Upper useful limit: 131°F (55°C).
- Lower useful limit: -40°F (-40°C).
- Flash point: 302°F (150°C), minimum.
- Pour Point: -40°F (-40°C), maximum.

SOLVENT AND CLEANERS

D-48. Cleaning Compound, Solvent (for the bore of weapons) or RBC, 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 tough cleaning after heavy shooting (weapons must be lubricated after using RBC):

- 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.

D-49. The solvents under MIL-PRF-680 are petroleum distillate degreasing solvents used for degreasing machine parts in equipment maintenance. They are also known as “mineral spirits” or “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 that 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:

- Standard: MIL-PRF-680.
- Military symbol: SD-2.
- NATO Code: S-753.
- Storage temperatures: n/a.
- Flash point (range): 140°F to 198°F (60°C to 92°C).
- Upper useful limit: n/a.
- Lower useful limit: n/a.
- Freeze point: n/a.

Appendix E

Environmental Protection Concerns

E-1. Despite the difficulties cold weather may present to unit operations and maintenance, leaders must remember that units are required to comply with federal, state, local, and host-nation environmental regulations. Accumulated waste fluid should be disposed of through a waste oil recovery program unless prohibited by local law. The references 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.

E-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.

E-3. Considering the increased risk, it is important that leaders conduct unit environmental self-assessments prior to deploying to a cold weather area. The self-assessment looks at the following: management, waste oil storage, HAZMAT/hazardous wastes, solid waste management, spill prevention, recycle program, wash racks, and land management. They must ensure that the resulting risks are made part of the unit environmental awareness training program.

E-4. GTA 05-08-002 provides information on the environmental risk management process, including the steps of the process, hazard probability, hazard severity, and how to determine the risk category.

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Glossary

AC	alternating current
ADP	Army doctrine publication
AMMPS	advanced medium mobile power source
AR	Army regulation
ASTM	American Society for Testing and Materials
ATP	Army techniques publication
°C	Celsius
CCA	cold cranking amps
CECOM	Communications-Electronics Command
CI/LI	corrosion inhibitor/lubricity improver
CLP	cleaner, lubricant, and preservative
CO₂	carbon dioxide
CONUS	continental United States
COTS	commercial off-the-shelf
CTIS	central tire inflation system
DA	Department of the Army
DA Pam	Department of the Army pamphlet
DD	Department of Defense form
DOD	Department of Defense
ECWCS	extended cold weather clothing system
°F	Fahrenheit
FM	field manual
FMTV	family of medium tactical vehicles
FRH	fire resistant hydraulic
GEL	gelatin silicate electrolyte
GTA	graphic training aid
HAZMAT	hazardous materials
JP	jet propellant (fuel)
LAW	lubricant, arctic weight
LCD	liquid crystal display
LED	light emitting diode
LO	lubrication order
LSA	lubricant, small arms
MEP	mobile electric power
MIL-DTL	military detail specification (standards)
MIL-PRF	military performance (standards)
MIL-STD	military standard

MOS	military occupational specialty
MTG	military tactical generator
NATO	North Atlantic Treaty Organization
NCO	noncommissioned officer
NiMH	nickel-metal hydride
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
PDISE	power distribution illumination system, electrical
PDP	plasma display panel
PMCS	preventive maintenance checks and services
POL	petroleum, oils, and lubricants
PPE	personal protective equipment
psi	pounds per square inch
RBC	rifle bore cleaner
RPM	revolutions per minute
SAE	Society of Automotive Engineers
SFP	single fuel policy
SMPL	synthetic multipurpose lubricant
SOC	state-of-charge
SOP	standard operating procedure
STANAG	standardization agreement (NATO)
TB	technical bulletin
TC	training circular
TM	technical manual
TQG	tactical quiet generator
U.S.	United States
VLA	vented lead-acid
VRLA	valve-regulated lead-acid

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12 December 2025

By Order of the Secretary of the Army:

RANDY A. GEORGE

*General, United States Army
Chief of Staff*

Official:

A handwritten signature in black ink, appearing to read 'M. Sannito', with a horizontal line extending from the end of the signature.

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