Arctic Munitions Operations

Munitions Safety and Suitability for Service

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The winter was our disaster. We became the victims of Russia's climate.

—Napoleon Bonaparte

The 2022 Russian invasion of Ukraine escalated the region to an all-out conflict, one like Europe had not seen since 1945. The war has proven disastrous for the Russian military, just as Napoleon and his Grand Army experienced when it occupied Moscow in 1812. The onset of winter and its cold weather, lack of supplies, and other factors forced the French to retreat from Moscow, leading to its ultimate defeat in the campaign—a bitter loss to what has been known as "General Winter."[1] Winter is an enemy that Ukraine and Russia have had to endure throughout the conflict. "Battles take place day and night, regardless of the weather," said Ukrainian lawmaker and soldier Yegor Firsov from the front lines of the Russian-Ukrainian War.[2] Protracted military operations in arctic cold weather require endurance in unfavorable conditions that most Americans are unfamiliar with. Sustainment, including munitions supply, provides the logistical means to apply lethal effects in arctic conditions.

Arctic Competition

The Arctic Circle is a shared region with overlapping claims by various nations. Russia and China want to expand their influence and capabilities in the Arctic. While Russia continues its invasion of Ukraine, it still maintains large-scale arctic military capabilities (see figure 1). As a pacing threat, China's growing economic, scientific, and military activities increase to influence the Arctic region. China has gone so far as to declare itself a "near-Arctic state," created to gain a more significant role in regional Arctic relations.[3]

The Arctic is immense, with segments in three geographic combatant command areas of responsibilities: United States Northern Command, United States European Command, and United States Indo-Pacific Command (see figure 2). These different commands require extensive coordination as they create a framework to guide their approaches to address emerging challenges and take advantage of opportunities in the Arctic in support of the *Department of Defense Arctic Strategy* and the *National Strategy for the Arctic Region*.[4] Enhancing capabilities and increasing capacity for arctic operations is the principal way and initiative the U.S. Army can build upon to create Arctic dominance in the region. However, extreme temperatures, variable periods of daylight, mountain ranges, and glacier changes are arguably the greatest hindrance to creating military capabilities and increasing capacity during arctic operations.

Arctic Capability

The central hub of the U.S. Arctic presence is Alaska. The U.S. Army has had an almost continuous presence in the state since the territory was purchased from Russia in 1867.[5] Army forces in Alaska reside on three major installations: Fort Wainwright, Fort

The U.S. Army Cold Regions Test Center tests the Army's Next Generation Squad Weapon at Fort Greely, Alaska, 23 January 2024. The XM7 and XM250 are successors to the M4 rifle and M249 light machine gun that U.S. forces have used for decades. The new weapons boast improved accuracy and range, weigh less, and fire with less recoil even though the 6.8 mm round is larger than the two legacy weapons' 5.56 mm cartridge. (Photo by Sebastian Saarloos, U.S. Army)

NOTE: AFB = Air Force base. AS = air station. JBER = Joint Base Elmendorf–Richardson. NATO = North Atlantic Treaty Organization. SFS = Space Force station. Finland joined NATO in 2023, and Sweden had submitted its NATO letter of application as of 2022.

(Figure from *Report on the Arctic Capabilities of the U.S. Armed Forces*)

Figure 1. Russia's and the North Atlantic Treaty Organization's Postures in the Arctic

Greely, and Joint Base Elmendorf-Richardson. Other government and military facilities include Joint Rescue Coordination Center Juneau, Coast Guard Air Station Kodiak, Eareckson Air Station, Eielson Air Force Base, Pituffik Space Base (formerly Thule Air Base), and Clear Space Force Station.

The Army provides land-component forces to the joint force that complement the capabilities of the other services and governmental departments. The capabilities are needed in the Arctic region to ensure that the United States has an overwhelming advantage in strategic competition between nations. The installations, ports, and facilities provide an anchorage point for military forces in the region to defend national interests. Nothing exemplifies commitment to the Arctic region more than the activation of the U.S. Army's 11th Airborne Division, the "Arctic Angels," to conduct multidomain operations in the Arctic.

Arctic Division

A former World War II-era unit, the 11th Airborne Division, was reorganized from Alaskan-based brigade elements to focus operations on the Arctic region. The 1st Stryker Brigade Combat Team and the 4th Infantry Brigade Combat Team (Airborne) of the 25th Infantry Division were reflagged to the 1st and 2nd Brigades of the 11th Airborne Division to focus on Arctic and cold-weather combat operations.[6] Creating a division from Alaskan-based organizations provides the ability to maintain institutional knowledge and have a cohesive identity.

Cold Region Sustainment

Equipment and sustainment infrastructure are vital in sustaining the Arctic Division in its specialized environment. The sustainment function provides maneuver forces support and services to ensure freedom of action, extend operational reach, and prolong endurance. The elements of logistics include maintenance, transportation, supply, field services, distribution, operational contract support, and general engineering.[7] In the Arctic, ground mobility is most favorable during the winter months, while in the spring, ground movement becomes impossible across large parts of Arctic territory.[8] Thawing permafrost affects infrastructure, and the warming of the Arctic has led to longer windows and reduced ice conditions that can open new waterways and increase transit through the region.[9]

(Figure from *Regaining Arctic Strategy*)

Figure 2. Geographic Combatant Command Areas of Responsibility in the Arctic

Distribution of munitions material into the Arctic region is critical for support of maneuver units and their ability to apply lethal effects. The physical infrastructure for munitions storage, such as ammunition bunkers and igloos, is essential to ensure the reliability of munitions. Ammunition magazine temperature control is essential for storing munitions that are adversely affected and susceptible to temperature extremes.[10] Soldiers should not exceed military published temperature limitations under prevailing climate conditions in the region conducting Army operations (see, for example, table 1).

Army Publications

The Army Ammunition Data Sheets are reference handbooks published to aid in planning, training, familiarization, and identification of military munitions; for each item, there are illustrations with characteristics and related data such as weights, dimensions, performance data, shipping and storage data, type classification, and logistics control codes.[11] The Army Ammunition Data Sheets fall into different categories and federal supply classes (FSC), which include small caliber ammunition (FSC 1305); artillery ammunition for guns, howitzers, mortars, recoilless rifles, and 40 mm grenade launchers (FSC 1310, 1315, 1320, 1390); grenades; rockets systems and rocket fuses (FSC 1340); land mines (FSC 1345); military pyrotechnics; demolitions material; cartridges, cartridge actuated devices, and propellant actuated devices (FSC 1377); armor tiles; and remote munitions (FSC 1346). The technical publications provide performance data of munitions to ensure safe operations.

The performance data for munitions are not haphazardly applied. The data points are created from a systematic approach that allows commanders to trust in the reliability of their weapons systems and the munitions employed regardless of the environment. The Joint Ordnance Test Procedure (JOTP) and Allied Services Safety and Suitability (S3) publications provide the planning and implementation of S3 assessment testing covering the entire life cycle of munitions material (see figure 3).

Testing covers the material life cycle from shipping and transportation from the manufacturer to storage and logistics-supply-using units. The environmental tests performed under JOTP and Allied S3 publications are the most relevant to munitions endurance in arctic environments; they provide any temperature limitations or restrictions in expected environmental conditions.

Joint and Allied Testing Publications

JOTP and Allied S3 publications apply to various ammunition categories, and specific publications cover S3 assessment testing of all munitions for government production and procurement. For example, JOTP-022, *Safety and Suitability for Service Assessment Testing for Small Caliber Ammunition Less Than 20mm*, provides the U.S. joint services S3 test procedures until the Allied Ammunition Safety and Suitability for Service Assessment Test Procedure (AAS3P)-22 is approved by NATO Allied Committee 326.[12] Currently, AAS3P-22 Edition A, version 1, is effective and is quite similar to JOTP-022 because joint ordnance test procedures tend to be the basis for the allied services safety and suitability publications. JOTP-020 covers large caliber ammunition greater than 40 mm; and JOTP-011, *Safety and Suitability for Service Assessment Testing for Surface and Underwater Launched Munitions*, covers surface and underwater launched munitions; each has a corresponding allied S3 publication. The United States has in the past developed its own JOTP and then submitted it to NATO as the basis for the associated AAS3P since the NATO process for ratification of standards can take several years.[13] This technique ensures the most rigorous testing and validation of munitions for both U.S. and NATO operations.

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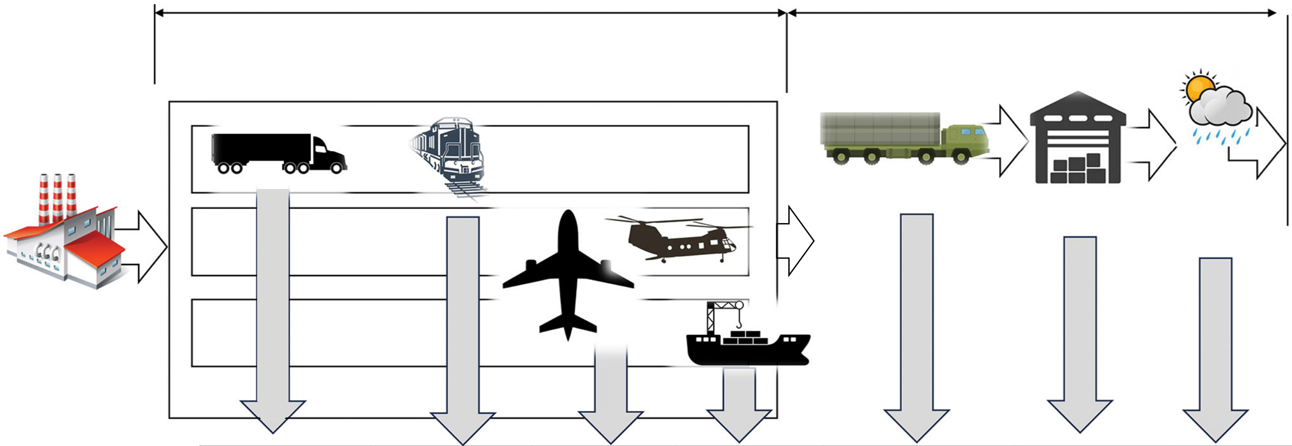
Generally, a representative life-cycle environmental profile is based upon the applicable environmental factors for storage, transportation, and deployment and is used in part to create the S3 test program.[14] For example, S3 assessment testing of small-caliber ammunition requires a series of functional/firing tests, life-cycle environmental profile tests, and standalone (nonsequential) tests.[15] Ammunition is transported from the munitions industrial base to a joint security area and then on to a tactical area, where it is put into storage. Munitions can receive exposure to arctic conditions through many phases of multimodal operations, and ammunition is required to remain safe and suitable for service at extreme temperatures for military operations within NATO climate category C2.[16] Additionally, ammunition is expected to remain safe and suitable for service following storage at extreme cold conditions (C3 climate category) but would not necessarily be expected to move during the coldest period within this climate zone due to difficulties with vehicles and the temperatures outside the human comfort zone.[17] The Arctic region varies regarding cold temperatures, and the term "arctic" is often used synonymously as an adjective for cold weather. However, that is not the case in testing; cold categories have specific meanings.

Standardization Agreement (STANAG)-4370, *Environmental Testing*, is a NATO standardization document specifying member countries' agreement to Allied Environmental Conditions, and Test Publication (AECTP)-230, *Climatic Conditions*, and contains the standard climate conditions.[18] A subset of the agreement is Leaflet 2311/1, which contains climatic categories and their geographical locations, including the categories Mild Cold C0, Intermediate (Basic) Cold C1, Cold C2, Severe Cold C3, and Extreme Cold C4;



	Handling & Road Transportation	Handling & Rail Transportation	Handling & Air Transportation	Handling & Ship Transportation	Handling & Logistics Transport (Worst Route)	Storage, Sheltered (tent, Shed, Igloo)	Storage, Open
Environmental Stress Generation Mechanisms (Induced)	Road Shock (large Bumps/Potholes) Road Vibration (Random) Handling Shock (Dropping/overturning)	Rail Shock (Humping) Rail Vibration Handling Shock (Dropping/Overturning)	In-Flight Vibration (engine/Turbine induced) Landing Shock Handling Shock (Dropping/Overturning)	Wave-Induced Vibration (Sinusoidal) Wave Sine Shock Mine/Blast Shock Handling Shock (Dropping/Overturning)	Road Shock (Large Bumps/Potholes) Road Vibration (Random) Handling Shock (Dropping/overturning) Thermal Shock, (Air Drop)	None	None
Environmental Stress Generation Mechanisms (Natural)	High Temperature (Dry/Humid) Low Temperature Rain/Hail Sand/Dust	High Temperature (Dry/Humid) Low Temperature Rain/Hail Sand/Dust	Reduced Pressure Thermal Shock (Air Drop Only) Rapid Decompression	High Temperature (Humid) Low Temperature Rain Temporary Immersion Salt Fog	High Temperature (Dry/Humid) Low Temperature/ Freezing, Rain/Hail Sand/Dust, Salt Fog, Solar Radiation, Reduced Pressure	High Temperature (Dry/Humid) Low Temperature/ Freezing Salt Fog Fungus Growth Chemical Attack	High Temperature (Dry/Humid) Low Temperature/Freezing Rain/Hail Sand/Dust Salt Fog Solar Radiation Fungus Growth Chemical Attack

(Figure partially from Military Standard 810H, *Environmental Engineering Considerations and Laboratory Tests*)

Figure 3. Generalized Life Cycle Histories for Military Hardware (Partial)

the last three categories apply to the operational environment of the Arctic (see figure 4).[19]

The U.S. Army in Alaska operates from Intermediate Cold C1 to Severe Cold C3 (see table 2). Meanwhile, Category C4 applies to the coldest areas of Greenland and Siberia.[20] Climate categories are an important factor when considering operational usage of munitions in an arctic environment, along with the possible limitations or restrictions placed on munitions in specific operational environments that fall outside normal environmental conditions.

Sequential environmental tests are for normal usage in typical environmental conditions. Cold logistic storage testing consists of low-temperature and thermal shock testing for extreme expected environmental conditions. Military Standard (MIL-STD)-810H, Method 502.7, "Low Temperature," directs testers to "use low temperature tests to obtain data to help evaluate effects of low-temperature conditions on material safety, integrity, and performance during storage, operation, and manipulation."[21] MIL-STD-810H also states the purpose of Method 503.7, "Temperature Shock":

> Use the temperature shock test to determine if materiel can withstand sudden changes in the temperature of the surrounding atmosphere without experiencing physical damage or deterioration in performance. For the purpose of this document, "sudden changes" is defined as "an air temperature change greater than 10°C (18°F) within one minute."[22]

It is essential to ensure adequate testing of munitions in environmental conditions. Climate Category C3 conditions for small arms ammunition are expected during storage but unlikely during transportation and deployment. In Climate Category C3, a constant low temperature of -51°C is likely to predominate significantly due to a lack of sunlight and solar radiation during the coldest period of the year.[23] For low-temperature testing, a minimum of seventy-two hours is sufficient to stabilize the ammunition thermally and has proven sufficient to demonstrate short-term safety in cold climates.[24] And for thermal shock testing, small-caliber ammunition is exposed to a low temperature of -51°C and sequentially exposed to a high

Table 1. Ammunition Temperature Limits for the M3 Multi-Role, Anti-Armor Anti-Personnel Weapon System

Weapon	Model	Type	DODIC	Operating		Storage	
M3 MAAWS	HE 441D RS, 84-MM cartridge	High explosive	CA27	-40ºF (40ºC)	+140ºF (+60ºC)	-60ºF (-51ºC)	+160ºF (+71ºC)
	HEDP 502 RS, 84-MM cartridge	High explosive dual purpose	CA21	-40ºF (40ºC)	+140ºF (+60ºC)	-60ºF (-51ºC)	+160ºF (+71ºC)
	TPT 141, 84-MM cartridge	Target practice with tracer	CA10	-40ºF (40ºC)	+140ºF (+60ºC)	-60ºF (-51ºC)	+160ºF (+71ºC)
	ADM 401/B, 84-MM cartridge	Area defense munition	CA23	-4ºF (20ºC)	+140ºF (+60ºC)	-60ºF (-51ºC)	+160ºF (+71ºC)
	ASM 509, 84-MM cartridge	Antistructure munition	CA41	-40ºF (40ºC)	+140ºF (+60ºC)		
	HEAT 551, 84-MM cartridge	High explosive anti-tank	CA383	-40ºF (40ºC)	+140ºF (+60ºC)		
	Illuminator 545C, 84-MM cartridge	Illumination	CA36	-40ºF (40ºC)	+140ºF (+60ºC)		
	MT 756, 84-MM cartridge	Multi-target	CA51	-40ºF (40ºC)	+140ºF (+60ºC)		
Notes							
TC 3-22.84							
DISTRIBUTION: Approved for public release; distribution is limited							

(Table by author; data from Training Circular 3-22.84, *M3 Multi-Role, Anti-Armor, Anti-Personnel Weapon System*)

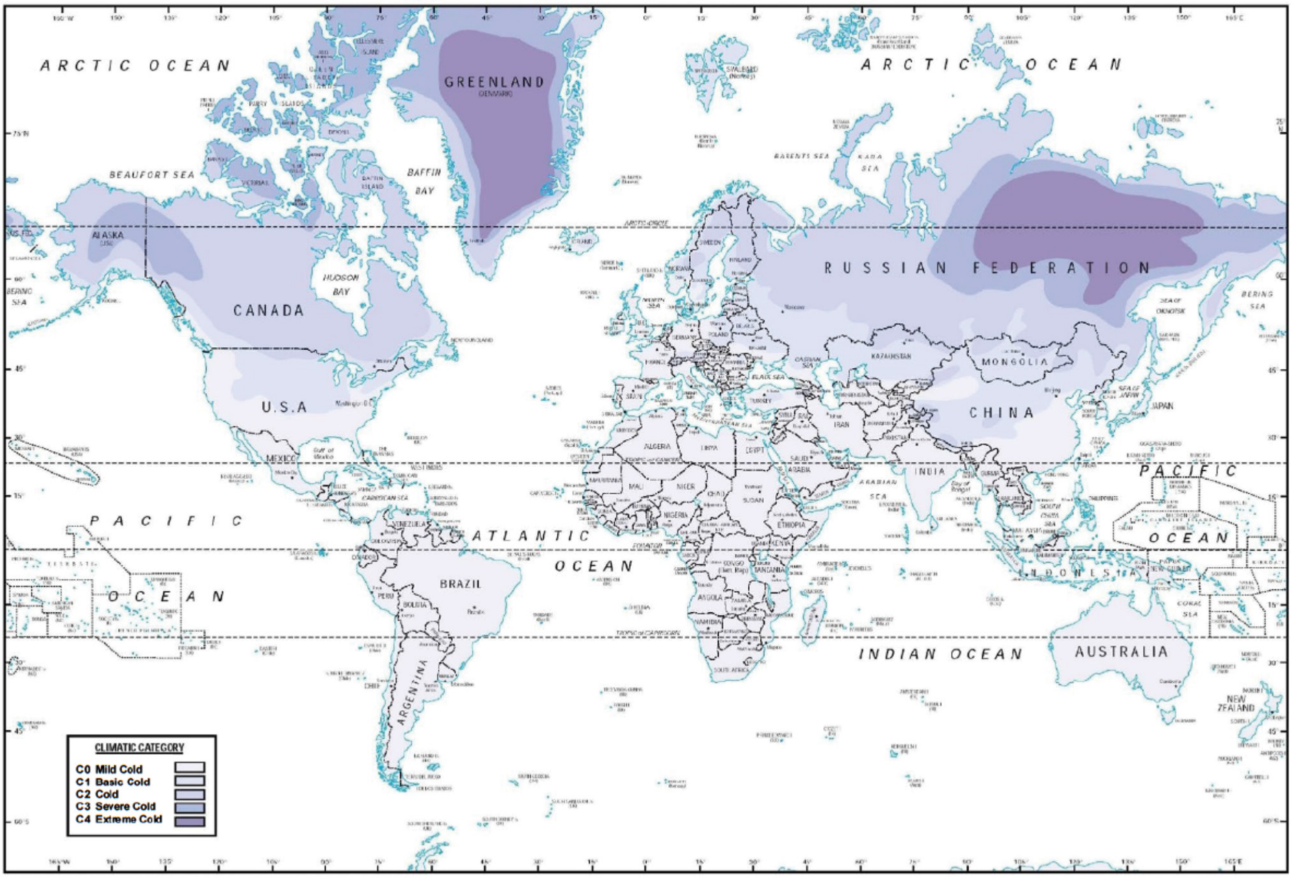
temperature of +71°C.[25] Vigorous testing is required to ensure that the effects of low-temperature environments do not affect ammunition safety and suitability for service. For instance, Allied Ordnance Publication (AOP)-4172, *Technical Performance Specification Providing for the Interchangeability of 5.56mm x 45 Ammunition*, only has environmental requirements down to -54°C, just a few degrees outside the Climate Category C3 range.[26] Low temperatures have adverse effects on material and can affect combat operations. Consideration must be applied when exposed to temperatures outside of limitations, and adverse effects include the possibility of

- hardening and embrittlement of materials;
- changes in electronic components;
- changes in performance of transformers and electromechanical components;
- cracking of explosive solid pellets or grains, such as ammonium nitrate;
- cracking and crazing, change in impact strength, and reduced strength;
- effects due to condensation and freezing of water in or on the equipment; and
- change of burning rates.[27]

Commanders must be familiar with Army ammunition data sheets and associated technical manuals for their munitions, and they must ensure all operating and storage limitations are followed, even more so when environmental conditions are colder than usual for a given period. Precautions should also be taken for proper care and maintenance during cold weather operations.

Cold Weather Care and Maintenance

Ammunition (Class V) planners expect increased use of indirect fire ammunition because of dead space, deep snow, and other effects of mountainous terrain, and the preparation of ammunition supply points is more difficult due to freezing and mud, making resupply in cold climates difficult for large munitions over land.[28] As discussed, cold weather and low temperatures adversely affect the performance of munitions. General considerations include the following:



(Figure from Military Standard 810H, *Environmental Engineering Considerations and Laboratory Tests*)

Figure 4. Area of Occurrence of Climate Categories C1, C2, and C3

- Cold air is denser than temperate weather air, which creates greater drag, reducing range;
- Severe cold slows down chemical reaction processes, reducing the propulsion energy of a round exiting a tube or the pressure of flame exiting a nozzle;
- Unpacked munitions moving from cold to warm areas are subject to the same condensation threat as weapons; and
- Munitions usually cannot be lubricated to protect them from moisture corrosion.[29]

Ammunition should be kept at the same temperature as the weapons, and storage containers should be raised off the ground and covered with tarps or salvage tents.[30] Open munitions storage should be marked with poles to assist with relocating if snow covered.[31] The Army has not collectively conducted munitions operations in an arctic environment, so they require a greater degree of planning and an understanding of the operational environment.

Recommendations

The contested Arctic region has created a new environment for strategic competition. While Russia has formable capabilities in the Arctic, the United States has closed extensive military installations such as Camp Century, an Arctic U.S. military scientific research base that was first constructed in 1959 with covered trenches linking laboratories, storage, quarters, kitchen, post exchange, and library; it also included a PM-2A portable nuclear reactor to supply power.[32] Arguably, Camp Century was the height of U.S. Arctic operations outside of Alaska. Now, the Department of Defense's (DOD) northernmost installation, Pituffik Space Base, provides missile warning, defense, and space surveillance missions.[33]

While the DOD is increasing the U.S. presence in the Arctic region, there are three arctic-specific munitions recommendations to ensure an increased capacity of lethal effects in Climate Category C1 through C3 of the Arctic and sub-Arctic regions:

Table 2. Low Temperature Cycle Ranges

DESIGN TYPE	LOCATION	TEMPERATURE[1]	
		AMBIENT AIR °C (°F)	INDUCED ENVIRONMENT (STORAGE AND TRANSIT) °C (°F)
Basic Cold (C1)	Most of Europe; Northern contiguous U.S.; Coastal Canada; High-latitude coasts (e.g., southern coast of Alaska); High elevations in lower latitudes	-21 to -32 (-5 to -25)	-25 to -33 (-13 to -28)
Cold (C2)	Canada, Alaska (excluding the interior); Greenland (excluding the "cold pole"); Northern Scandinavia; Northern Asia (some areas), High Elevations (Northern and Southern Hemispheres); Alps; Himalayas; Andes	-37 to -46 (-35 to -50)	-37 to -46 (-35 to -50)
Severe Cold (C3)	Interior of Alaska; Yukon (Canada); Interior of Northern Canadian Islands; Greenland ice cap; Northern Asia	-51 (-60)	-51 (-60)

[1]These cycles were derived from AR 70-38, 1 August 1979, and essentially conform to those in MIL-HDBK-310 and NATO STANAG 4370, AECTP 230 (except for category C0). These values represent typical conditions. Induced conditions are extreme levels to which materiel may be exposed during storage or transit situations. Do not use these levels carte blanche, but tailor them to the anticipated storage or transit situation.

(Table from Military Standard 810H, *Environmental Engineering Considerations and Laboratory Tests*)

An ice core drill rig is operated inside a covered snow trench at Camp Century, northwestern Greenland, in 1964. Adopting previous techniques for fashioning such structures could prove effective for current arctic sustainment operations. (Photo by Langway, U.S. Army Corps of Engineers/Cold Regions Research and Engineering Laboratory)

Construction of expeditionary munitions storage in arctic environments. Experience in Iraq and Afghanistan provided invaluable tactics, techniques, and procedures for the construction of expedient protective structures. Civil engineers can quickly create infrastructure to support military operations and missions using earth-filled protective barriers. Underground storage facilities may consist of excavated or natural geological cavities, but current DOD regulations do not cover Arctic regions. Munitions storage in snow tunnels (cut-and-cover type), open trenches covered with timber trusses, and undercut trenches with and without metal arch forms are possibilities for storage validated at Camp Century, but they now require more research and development.

Field expedient munitions operations in arctic environments. Establishing munition holding areas requires interim storage periods before constructing permanent and semipermanent facilities. No doctrine exists regarding the use of military shelter systems and military base camps for munitions operations in arctic environments. Munitions surveillance and

Soldiers of the 70th Brigade Engineer Battalion build a snow berm 18 April 2024 in the Yukon Training Area, Alaska, to test the use of snow for constructing hasty fighting positions on the battlefield. The series of experiments demonstrated that properly compacted snow shaped into berms can provide significant protection against small and medium arms rounds at similar levels to those of earthen works. (Photo by Chief Warrant Officer 2 Jomar R. Perez, 70th Brigade Engineers)

maintenance can be supported using medium shelters and small shelters, but specified systems are not centered on the safety of explosives in arctic conditions.

Modernized arctic support vehicles and engineer equipment. The newest U.S. Army Cold Weather All-Terrain Vehicle provides greater flexibility in operations and replaces its aging Small Unit Support Vehicles. However, more investment is required to complement robust cross-country tactical mobility vehicles to support the delivery of munitions in the Arctic. For example, engineering equipment to support snow berming, which effectively stops small arms during cold to extremely cold weather operations in the Arctic region, will be invaluable.

Conclusion

While the Russian invasion of Ukraine has become catastrophic for the Russian military, the Arctic is still an area where the Russian military maintains dominance. Cold weather operations in Climate Category C1 through C4 of the Arctic require a different approach and skill set for sustainment to provide freedom of action, extended operational reach, and prolonged endurance. Munition sustainment, the logistical element that provides a means to apply lethal effects, needs access to new expeditionary construction plans for munitions arctic storage and doctrine that provides for field expedient munitions storage in the case of escalation of conflict in the Arctic region. Having the capacity to store munitions is critical to winning in a conflict. At the same time, munitions safety and suitability for service assures commanders that they can apply overwhelming combat power in the Arctic area of operations against an enemy more versed in the operational environment. ■

Notes

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