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This TOP provides background information on the problems and adaptations associated with instrumentation, photographic and video equipment required for conducting tests in cold regions. Basic information and procedures are presented as general guidelines to planning and using instrumentation systems for cold environments.

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U.S. ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

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COLD REGIONS INSTRUMENTATION CONSIDERATIONS

1. SCOPE. This document provides background information on the problems and adaptations associated with instrumentation, photographic and video equipment required for conducting tests in cold regions. Basic information and procedures are presented as general guidelines to planning and using instrumentation systems for cold environments.

2. BASIC INFORMATION. The basic mission of the US Army Cold Regions Test Center (CRTC) is to provide an unbiased evaluation of Army materiel to perform in cold regions environmental conditions. Instrumentation systems are generally required to define test conditions and to determine performance levels achieved in developmental equipment. Since most instrumentation is not designed to function at extreme low temperatures, special consideration is required for instrumentation to operate in cold regions environments.

3. GENERAL ENVIRONMENTAL EFFECTS.

3.1 Most materials are affected by low temperatures. Most materials become more brittle at low temperatures, thereby reducing their resistance to shock loading. Also, the differences in the coefficients of expansion affects all fits between dissimilar materials. Some bearing clearances must be adjusted for the temperatures at which they will operate. The electrical resistance of metals is also temperature dependent. Most rubbers, natural and synthetic, lose their flexible characteristic as do most plastics at temperatures below -29°C. Insulation and vibration absorbers easily fail if not made to withstand cold temperatures. Glass and most materials which conduct heat poorly are extremely sensitive to thermal shocks. Precautions should be taken to avoid rapid increases or decreases in temperature. Lubricants and fluids are adversely affected by cold temperatures, by increased viscosity or solidification if not developed primarily for cold environments. Chemical

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reactions may be significantly slowed as temperatures photographic processes and chemical analysis measurements. Further information on cold temperature effects on materials is contained in AMCP 706-116[a**], AMCP 706-118[b], and CRTC Materiel in the Cold Regions (Part I)[c].

3.2 Consideration must be given to other effects of a cold environment. Snow accumulations on the ground cause special problems. A warm object placed in snow may cause melting and refreezing resulting in adherence of ice to the surface of the object. Winds, which may reach in excess of 74 km/hr (40 knots), can carry large amounts of snow in fine particles; care in storage and placement of instruments may be required to minimize drift formation and damage due to snow intrusion.

3.3 A third consideration involves the transfer of instruments from the cold-dry environment into warm, sheltered areas. Condensation on these instruments may cause corrosion and short circuits. Furthermore, if the equipment is not properly cleaned and dried afterwards, returning it to the cold environment may cause freeze-up of mechanical parts. If instruments must be brought indoors, an anticondensation container (such as a plastic bag) may be used to prevent damage, by placing them inside the container before they are brought indoors. Once the instrument has reached, room temperature, it can be removed from the container without damage.

4. EQUIPMENT SAFEGUARDS.

4.1 General.

a. Since few manufacturers have developed equipment capable of functioning at -54°C, steps must be taken to ensure that instruments are operated in environments in which they are designed to function. This can be accomplished by building heated structures at stationary sites to house the equipment and operators. Heated vans can be modified to contain most of the test equipment and can be driven to test sites as required. Electrically powered enclosures can also be used to protect instrumentation. Also, modifications to the equipment allowing it to function in the cold environment may be possible. Development of solutions to test requirements necessitates a thorough knowledge of the instruments and equipment used and a thorough understanding of the effects of cold on the components. Operators of instrumentation in cold regions should recognize the general hazards to be encountered and the precautions which must be taken to prevent damage to the equipment.

b. A large number of items which comprise the instrumentation package are affected by the cold and a few of the problems and precautions have been addressed below. Cables and connectors, though properly selected and of materials suitable for cold regions conditions, are more susceptible to damage

**Superscript letters correspond to those in Appendix A, References.

if overly flexed or strained, and radios or microwave telemetry systems might be considered as replacements in appropriate situations. Cold-soaked cables which are rolled should be straightened only after being sufficiently warmed. Soldered connections are extremely weak and connectors must be chosen which transmit tensile load away from the soldered joint. Since most parts are more brittle at cold temperatures, generous safety factors must be used in designing for strength, especially when impact loads are to be expected. Due to the high susceptibility to damage of cables, connectors, and miscellaneous supports, spare items must be maintained at the test site. Design of the system must allow for rapid disassembly and assembly of these items under cold regions conditions to enable quick replacement if a failure occurs.

4.2 Batteries.

a. Wet cell batteries are extremely sensitive to cold and precautions must be taken to ensure adequate power for operating instruments. Wet cell output voltage and available energy are reduced at low operating temperatures and freeze-up can occur at low states of charge. Smaller batteries can be carried close to the body inside clothing utilizing body heat to maintain a functional temperature. Special battery vests or belts are also available. Adaptation of the instrument for external power connections may be required. Special batteries, such as Nicad or lithium batteries designed for use in cold should be considered, if available. The following are general guidelines for maintaining lead acid batteries in cold weather. (More information is found in TM 9-6140-200-14[d] and FM 9-207[e].)

(1) Keep batteries fully charged. (Minimum of 1.250 specific gravity at 75% charge for lead acid storage batteries.)

(2) Keep electrical connections tight, clean and free of moisture or corrosion.

(3) Check water level often and add only when battery electrolyte temperature is above freezing. If water is added to a battery whose temperature is below freezing, it will not mix properly with the acid and may freeze.

(4) Never add acid to a battery electrolyte. It may explode or splatter acid and cause injury.

(5) Never attempt to charge a battery when the electrolyte temperature is less than 2°C. At lower temperatures it will not accept a full charge and may freeze.

(6) To obtain full power, warm up a cold-soaked battery at room temperature before charging or use. A frozen battery should be thawed at room temperature prior to charging.

b. Some types of the newer core-wrapped, sealed, lead acid batteries will eliminate many of the problems associated with use of automotive lead acid batteries. These batteries are highly portable, extremely cold tolerant, can be quickly recharged (even at low temperatures) and will operate nearer rated capacity at -46°C than any other commercial battery.

4.3 Photographic Equipment.

a. Most methods of achieving consistent reliable photographic coverage in the cold is based on common sense by protecting the equipment from the cold.

b. Newer or well maintained older film cameras, lubricated with clean silicone or molybdenum lubricants, can be expected to operate reliably to temperatures as low as the -29°C range. Temporary expedients (i.e. placing cameras under the operator's cold weather clothing) are an effective protection for film and camera equipment.

c. The simpler the camera equipment, the more reliable operation can be expected.

d. If camera power is provided by external batteries, try to keep the batteries warm and do not expose them to low temperatures. If provisions can be made for a remote battery pack, keep it in a warm place.

e. Lenses or other auxiliary equipment should be treated in the same manner as cameras.

f. For operation below -34°C, heated environmental enclosures will be required for reliable operation. Insulated containers similar to those used to keep 5- gallon water cans from freezing can also be used in all but the most severe cold. If power is not available, hand warmers, heat packs (water activated types are available through medical channels) are effective for short term protection (1/2 to 1 hour).

g. Cracking and failure of plastic covered remote, release, or electrical cables can be expected at -34°C or below.

h. Below -29°C, film starts to stiffen and, unless handled delicately, will crack. If not kept sufficiently warm, sprocket holes will tear out during operation, and the pieces could damage or scratch the remainder of the film as it passes by.

i. Static electricity can build up in the film and cause streaks as discharges take place. To combat this, use films with backings that help dissipate static electricity buildup.

j. Film tends to lose speed, (i.e., sensitivity to light will drop) as it gets cold. Color films may also exhibit a color shift as one emulsion layer slows more than another.

k. Bright sun and glare from snow increases inaccurate light meter readings. Therefore, use reflected light meters to take a reading of a gray card or similar target. Incident light meters are better because they measure the light at the scene and are not affected by reflections.

l. Snow also affects picture quality of films (and video cameras) by increasing the amount of ultraviolet light impinging on the camera lens. Color correction filters or their equivalent must be used to achieve normal color balance. Polarizer filters are also very effective in providing contrast in snow-covered terrain or haze.

m. Condensation leading to freeze-up is a problem at cold temperatures, and causes most damage, but is simple to prevent. Equipment brought indoors from cold temperatures, if no preventive action is taken, will be subjected to condensation in/on the camera. The condensed water may also freeze if not allowed to dry out prior to being taken out-of-doors. To prevent this, leave equipment in moderate cold (-4°C to -1°C) areas. If possible, prior to re-entering a building, place the equipment in an airtight desiccated case. Do not remove it until it reaches the indoor temperature or if it is moved out-of-doors again.

n. For additional special techniques, equipment and systems information see TM 11-401-1[f].

4.4 Video Equipment. Video cameras and recorders are susceptible to many of the same problems for still and motion picture cameras. Some of these problems are not as easy to correct. Operation of video tape recorders should not be attempted in the cold without heated environmental enclosures or shelters, not so much due to equipment problems, but due to the lower operating temperature limits of the video tape itself. Most tapes stiffen and will not track properly at tape temperatures below 4°C. (See TM 11-401-1)

5. ACCURACY OF DATA.

5.1 Instrument accuracy will be degraded in the cold. Instrumentation equipment may not only be damaged or rendered inoperable due to the effects of the cold environment, but a seemingly functional system might be so affected by cold as to produce data outputs which are inaccurate and useless. Consideration must be given to temperature effects in relation to accuracy requirements of the data. Consideration must be given to special calibration for expected temperatures. Knowledge of the parameters to be measured during test is essential and recognition of and allowance for reduced accuracies should be made. Whenever possible, provision should be made for test equipment to be operated in normal temperature ranges.

5.2 Batteries used for constant input voltage may have reduced voltage at low temperature. Provisions should be made for periodic voltage checks. Changes in resistance, capacitance, or inductance of components can cause significant errors at low temperatures. Transistor circuits are extremely intolerant to low temperatures and must be kept heated for consistent output accuracy. Allowance should be made for adequate warm-up of heated equipment. Specific solutions are not given here since this TOP is only intended to provide a basic knowledge of the hazard.

5.3 Mechanical linkage and fits can become stiff causing errors or long response time. Spring-type scales may be affected due to coefficient of expansion and other physical changes in the material. Gauge response times and values of readings may be affected due to the changes of viscosity, differences in the coefficient of expansion, and increased brittleness and stiffness.

5.4 Since all instrumentation may yield unreliable data when operated in a cold climatic environment, an instrument should be operated or checked out in the worst condition in which it must operate. If possible, instrumentation should be operated in a cold chamber prior to use in the field. These checks will show the temperature dependence and reliability of the data obtained and ensure proper functioning of the system at expected operating temperatures.

6. HUMAN FACTORS CONSIDERATIONS.

6.1 Another consideration in instrumenting for cold regions' testing is compatibility of the system with operators. All manipulations are complicated by the cold environment. For man to survive at temperatures of -45°C, suitable cold weather clothing complete with arctic mittens is required. All movement is restricted and dexterity of the hands is reduced. Most knobs, switches, and levers are too delicate to be operated while wearing arctic mittens. Operators must wear contact gloves for fine adjustments while taking care to expose hands for the minimum necessary time to prevent frostbite. If possible, modifications of controls could make them operable with arctic mittens. Manual collection of data is difficult. Notes written while wearing arctic mittens are often illegible and probability of frostbite exists if the volume and time required is too great for wearing more flexible gloves with less insulation. To minimize the quantity of data which must be read in the field, preprinted collection forms may be developed to reduce the job to a fill-in-the-blanks operation. It is highly desirable to use automatic-mechanical recorders, or digital systems to further reduce the complexity of operations that must be performed by the individual in the cold.

6.2 A second human factor consideration is the effect of extreme cold on attitude and morale of the individual working in the environment. This adverse effect must be considered when developing the instrumentation system and choosing the personnel to perform the test and collect the data. As the duration and complexity of the operations performed in the cold increases, there is a marked decrease in attitude and morale. This is evidenced by the operator attempting to shorten procedures, and general disregard for the equipment or the quality of data he or she is gathering. While this situation can be reduced by choosing competent individuals who are properly motivated, even the best individuals may be affected when they get cold. The test director should closely supervise the test and be constantly aware of this problem.

Preprinted data collection forms are helpful because they force the collection of all data, and increase planning, thereby reducing last minute changes or omissions, and give a good indication of test progress. Only properly motivated test personnel can reduce abuse of test equipment and guarantee accurate test data. Additional guidance is provided by Military Standard 1472(A)[8].

7. SUMMARY.

In general, almost any piece of equipment can be made to work in the cold by individuals who are familiar with cold regions' conditions although procedures may differ from those used in warmer climates. Conversely, any piece of equipment may malfunction in the cold if special precautions are not taken. Virtually all instrumentation equipment is not designed for use at extreme cold temperatures and will require experienced personnel to operate the equipment.

APPENDIX A. REFERENCES

a. AMCP 706-116, Natural Environmental Factors.

b. AMCP 706-118, Life Cycle Environments.

c. CRTC, Man and Materiel in the Cold Regions (Part 1).

d. TM 9-6140-200-14, Storage Batteries, Lead-Acid Type.

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

f. TM 11-401-1, Army Pictorial Techniques, Equipment and Systems.

g. MIL-STD-1472, Human Engineering Design Criteria for Military Systems, Equipment and Facilities.

Recommended changes to this publication should be forwarded to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-CT-T, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: U.S. Army Cold Regions Test Center, ATTN: STECR-ID Unit 45818, APO AP 96508-7850. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22304-6145. This document is identified by the accession number (AD No.) printed on the first page.