METHOD 502.5

LOW TEMPERATURE

NOTE: Tailoring is essential. Select methods, procedures, and parameter levels based on the tailoring process described in Part One, paragraph 4.2.2, and Annex C. Apply the general guidelines for laboratory test methods described in Part One, paragraph 5 of this standard.

1. SCOPE.

1.1 Purpose.

Use low temperature tests to obtain data to help evaluate effects of low temperature conditions on materiel safety, integrity, and performance during storage, operation, and manipulation.

1.2 Application.

Use this method to evaluate materiel likely to be deployed in a low temperature environment during its life cycle and the effects of low temperature have not been assessed during other tests (e.g., a temperature-altitude test).

1.3 Limitations.

a. This method is not intended for testing materiel to be installed in and operated in unpressurized aircraft, since such materiel would usually be tested according to Method 520.3.

b. Although low temperature testing may be considered for safety or hazard assessment of munitions, accomplish such testing in accordance with MIL-STD-2105C (reference 6.1d).

2. TAILORING GUIDANCE.

2.1 Selecting the Low Temperature Method.

After examining requirements documents and applying the tailoring process in Part One of this standard to determine where low temperatures are foreseen in the life cycle of the materiel, use the following to confirm the need for this method and to place it in sequence with other methods.

2.1.1 Effects of low temperature environments.

Low temperatures have adverse effects on almost all basic material. As a result, exposure of materiel to low temperatures may either temporarily or permanently impair the operation of the materiel by changing the physical properties of the material(s) of which it is composed. Consider low temperature tests whenever the materiel will be exposed to temperatures below standard ambient, and consider the following typical problems to help determine if this method is appropriate for the materiel being tested. This list is not intended to be all-inclusive.

a. Hardening and embrittlement of materials.

b. Binding of parts from differential contraction of dissimilar materials and the different rates of expansion of different parts in response to temperature transients.

c. Loss of lubrication and lubricant flow due to increased viscosity.

d. Changes in electronic components (resistors, capacitors, etc.).

e. Changes in performance of transformers and electromechanical components.

f. Stiffening of shock mounts.

g. Cracking of explosive solid pellets or grains, such as ammonium nitrate.

h. Cracking and crazing, embrittlement, change in impact strength, and reduced strength.

i. Static fatigue of restrained glass.

j. Effects due to condensation and freezing of water in or on the materiel.

k. Decrease in dexterity, hearing, and vision of personnel wearing protective clothing.

l. Change of burning rates.

2.1.2 Sequence among other methods.

a. General. See Part One, paragraph 5.5.

b. Unique to this method. There are at least two philosophies related to test sequence. One approach is to conserve test item life by applying what are perceived to be the least damaging environments first. For this approach, generally apply the low temperature test early in the test sequence. Another approach is to apply environments to maximize the likelihood of disclosing synergetic effects. For this approach, consider low temperature testing following dynamic tests, such as vibration and shock. Although not written for such, this test may be used in conjunction with shock and vibration tests to evaluate the effect of dynamic events (i.e., shipping, handling, and shock) on cold materials. Also, this test may significantly alter the performance of seals during the low pressure testing of Method 500.5.

2.2 Selecting Procedures.

This method includes three test procedures, Procedure I (Storage), Procedure II (Operation), and Procedure III (Manipulation). Based on the test data requirements, determine which test procedure, combination, or sequence of procedures is applicable. In most cases, all three procedures will apply.

NOTE: The materiel's anticipated Life Cycle Environmental Profile (LCEP) may reveal other low temperature scenarios that are not specifically addressed in the procedures. Tailor the procedures as necessary to capture the LCEP variations, but do not reduce the basic test requirements reflected in the below procedures. (See paragraph 2.3 below.) **Consider the potential synergistic effects of temperature and altitude (and possibly humidity), and the use of method 520.3 in addition to this method.**

2.2.1 Procedure selection considerations.

When selecting procedures, consider:

a. The operational purpose of the materiel. From the requirements documents, determine the functions to be performed by the materiel in a low temperature environment and any limiting conditions, such as storage.

b. The natural exposure circumstances.

c. The test data required to determine whether the operational purpose of the materiel has been met.

(1) The expected temperature at the deployment location.

(2) The expected duration at the deployment location.

(3) The test item configuration.

d. Procedure sequence.

(1) Procedure II can be preceded by Procedure I, Procedure III, or both. If the materiel is to be stored at low temperatures before use, Procedure I is conducted before Procedure II. If a manipulation test is required, Procedure III can precede the operational test. If the materiel is not intended to be stored at low temperature or manipulated before use, Procedure II is conducted directly.

(2) Storage testing, operational testing, or both can precede the manipulation test if required.

2.2.2 Difference among procedures.

While all procedures involve low temperatures, they differ on the basis of the timing and nature of performance tests.

a. Procedure I - Storage. Use Procedure I to investigate how low temperatures during storage affect materiel safety during and after storage, and performance after storage.

b. Procedure II - Operation. Use Procedure II to investigate how well the materiel operates in low temperature environments. For the purpose of this document, operation is defined as excitation of the materiel with a minimum of contact by personnel. It does not exclude handling (manipulation).

c. Procedure III - Manipulation. Use Procedure III to investigate the ease with which the materiel can be set up and disassembled by personnel wearing heavy, cold-weather clothing.

2.3 Determine Test Levels and Conditions.

Having selected this method and relevant procedures (based on the test item's requirements documents and the tailoring process), complete the tailoring process by identifying appropriate parameter levels and applicable test conditions and techniques for these procedures. Base these selections on the requirements documents, the Life Cycle Environmental Profile (LCEP), and information provided with this procedure. Consider the following when selecting test levels.

2.3.1 Climatic conditions.

Select the specific test temperatures, preferably from the requirements documents. If this information is not available, determine the test temperature(s) based on the world areas in which the materiel will be used, plus any additional considerations. Although the natural low temperature environment is normally cyclic, the effect of solar loading is minimal, if not absent, so in most instances it is acceptable to use a constant low temperature test. Only in those instances where design assessment suggests that exposure to varying low temperatures may be important are the appropriate cold cycles from MIL-HDBK-310, AR 70-38, or STANAG 4370, AECTP 200 (paragraph 6.1, references a, b, and c) recommended. The information below provides guidance for choosing the test temperatures for selected regions (climatic categories), for worldwide use without extended storage (two years or longer), and for worldwide use with extended storage periods.

a. Selected regions. Table 502.5-I in this method, and Figure C-3 and Table C-I in Part One, Annex C, Part One of this standard can be used to determine the test temperature when the test item is to be used within specific regions only. Air temperature extremes shown in Table 502.5-I are based on a one percent frequency of occurrence of the hours during the most severe month at the most severe location within the geographical area encompassed by the climatic region, except for severe cold, that is based on a 20 percent frequency of occurrence. The values shown in Table 502.5-I represent the range of the diurnal cycles. The diurnal cycles can be found in Part Three, Tables 9 and 11. For this method, the lowest value in each range is usually considered.

b. Worldwide use. When the materiel is to be stored or operated worldwide, temperature selection must not only include consideration of the absolute cold, but also of the frequency of a given cold condition. Unless frequency is considered, it is possible to create an overtest condition. In terms of frequency, the frequency-of-occurrence values shown in Table 502.5.I refer to the percent of total hours, in the most extreme month and area in the world, during which the given temperature is equaled or exceeded. For example, the 20 percent frequency of occurrence of a temperature of -51°C (-60°F) means that -51°C (-60°F) or lower temperatures during an average year may be expected to occur 20 percent of the hours during the most extreme month in the cold area of the world. A 20 percent probability of occurrence is used for most applications with normal development cost considerations. However, to satisfy specific applications or test requirements, other more extreme values may be appropriate if justified. (See Table 502.5-II.)

NOTE: Antarctica is excluded from consideration by international treaty restrictions.

Table 502.5-I. Summary of low temperature cycle ranges.[1/]

DESIGN TYPE	LOCATION	TEMPERATURE	
		Ambient Air °C (°F)	Induced Environment (Storage & Transit) °C (°F)
Basic Cold (C1)	Most of Europe; Northern contiguous US; Coastal Canada; High-latitude coasts (e.g., southern coast of Alaska); High elevations in lower latitudes	-21 to -31 (-6 to -24)	-25 to -33 (-13 to -27)
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 -51)	-37 to -46 (-35 to -51)
Severe Cold (C3)	Interior of Alaska; Yukon (Canada); Interior of Northern Islands; Greenland ice cap; Northern Asia	-51 (-60)	-51 (-60)

NOTE: See Part Three Tables IX and XI for low-temperature diurnal temperatures.

Table 502.5-II. Frequencies of occurrence of extreme low temperatures.

Low Temperature	Frequency of Occurrence
-51°C[1] (-60°F)	20 percent
-54°C (-65°F)	10 percent
-57°C (-71°F)	5 percent
-61°C (-78°F)	1 percent

[1]Corresponds to the "Severe Cold" condition.

c. Worldwide use with extended storage periods. If materiel is to be stored for extended periods (years) without shelter or protection in areas that experience extreme low temperatures such as the "cold pole" of northeast Siberia or central Greenland, there is an increased chance that the materiel may experience much lower temperatures (approaching -65°C (-85°F)). Such prolonged exposure to extreme low temperatures can affect the safety of items such as munitions, life support equipment, etc.

2.3.2 Exposure Duration.

The duration of exposure to low temperature may be a factor in materiel safety, integrity and performance.

a. Nonhazardous or non-safety-related (non-life-support type) materiel. Most materiel in this category (in a non-operating mode), with the possible exception of organic plastics, will not experience deterioration following temperature stabilization of the materiel at low temperatures. Following temperature stabilization of the test item, use a storage period of four hours for this materiel if no other value is available.

[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 200, Category 230 (except for 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.

b. Explosives, munitions, organic plastics, etc. These items may continue to deteriorate following temperature stabilization; consequently, it is necessary to test them at low temperatures for long periods of time. Use a minimum storage period of 72 hours following temperature stabilization of the test item, since durations of exposure of this period of time are typical for these types of items.

c. Restrained glass. Glass, ceramics, and glass-type products (such as those used in optical systems, laser systems, and electronic systems) that require mounting or restraining in specific positions may experience static fatigue. A more extended period of low temperature may be required to induce this phenomenon. Although we do not have a specific reference, it has been reported that a 24-hour exposure usually gives an 87 percent probability of uncovering this type of design defect.

2.3.3 Test item configuration.

The configuration of the materiel is an important factor in how it may be affected by temperature. Therefore, use the anticipated configuration of the materiel during storage or use during the test. As a minimum, consider the following configurations:

a. In a shipping/storage container or transit case.

b. Protected or unprotected.

c. Deployed (realistically or with restraints, such as with openings that are normally covered).

d. Modified with kits for special applications.

2.3.4 Additional guidelines.

Review the materiel specifications and requirements documents. Apply any additional guidelines necessary. Part Three of this document includes further information on the low temperature environment (e.g., paragraphs 2.2, 2.3, 4.2.6, and 4.3).

3. INFORMATION REQUIRED.

3.1 Pretest.

The following information is required to conduct low temperature tests adequately.

a. General. Information listed in Part One, paragraphs 5.7 and 5.9, and Part One, Annex A, Task 405 of this standard.

b. Specific to this method.

(1) Test temperatures, type of protective clothing required, and any additional guidelines.

(2) Temperature sensor locations. The component/assembly/structure to be used for thermal response and temperature stabilization purposes. (See Part One, paragraph 5.4.)

c. Tailoring. Necessary variations in the basic test procedures to accommodate LCEP requirements and/or facility limitations.

3.2 During Test.

Collect the following information during conduct of the test:

a. General. Information listed in Part One, paragraph 5.10, and in Annex A, Tasks 405 and 406 of this standard.

b. Specific to this method.

(1) Record of chamber temperature versus time conditions.

(2) Test item temperatures (measurement locations).

(3) Protective clothing used during manipulation tests.

3.3 Post Test.

The following post test data shall be included in the test report.

a. General. Information listed in Part One, paragraph 5.13, and in Annex A, Task 406 of this standard.

b. Specific to this method.

(1) Length of time required for each performance check.

(2) Temperature-time versus data (test item and chamber).

(3) Clothing and special equipment used to set up or disassemble the test item.

(4) Appropriate anthropometric measurements of personnel performing manipulation tests.

(5) Any deviations from the original test plan.

4. TEST PROCESS.

4.1 Test Facility.

a. The required apparatus consists of a chamber or cabinet and auxiliary instrumentation capable of maintaining and monitoring (see Part One, paragraph 5.18) the required conditions of low temperature throughout an envelope of air surrounding the test item.

b. Unless otherwise justified by the materiel platform environment and to prevent unrealistic heat transfer in the materiel, maintain the air velocity in the vicinity of the test item so as to not exceed 1.7 m/s (335 ft/min).

4.2 Controls.

a. Temperature. Unless otherwise specified in the test plan, if any action other than test item operation (such as opening the chamber door) results in a significant change of the test item temperature (more than 2°C (3.6°F)), restabilize the test item at the required temperature before continuing. If the operational check is not completed within 15 minutes, reestablish the test item temperature conditions before continuing.

b. Rate of temperature change. Unless otherwise specified, control the rate of temperature change to not exceed 3°C (5°F) per minute to prevent thermal shock.

c. Temperature measurement. Install temperature sensor instrumentation on or in the test item to measure temperature stabilization data (see Part One, paragraph 5.4).

d. Temperature recording. Record chamber temperature at a sufficient rate to capture data necessary for post-test analysis (see Part One, paragraph 5.18).

4.3 Test Interruption.

Test interruptions can result from two or more situations, one being from failure or malfunction of test chambers or associated test laboratory equipment. The second type of test interruption results from failure or malfunction of the test item itself during operational checks.

4.3.1 Interruption due to chamber malfunction.

a. General. See Part One, paragraph 5.11 of this standard.

b. Specific to this method.

(1) Undertest interruption. Follow an interruption that allows test temperatures to fluctuate outside allowable tolerances toward ambient conditions by a complete physical inspection and operational check (where possible). If no problems are encountered, restabilize the test item at the test temperature and continue from the point of the interruption. Since no extreme conditions were encountered, consider any problems as a test item failure.

(2) Overtest interruption. Follow any interruption (loss of chamber control) that results in more extreme exposure of the test item than required by the materiel specification by a complete physical examination and operational check (where possible) before any continuation of testing. This is especially true where a safety problem could exist, such as with munitions. If a problem is discovered, the preferable course of action is to terminate the test and reinitiate testing with a new test item. If this is not done and test item failure occurs during the remainder of the test, the test results could be considered invalid because of the overtest condition. If no problem has been encountered, reestablish pre-interruption conditions and continue from the point where the test tolerances were exceeded. See paragraph 4.3.2 for test item operational failure guidance.

4.3.2 Interruption due to test item operation failure.

Failure of the test item(s) to function as required during operational checks presents a situation with several possible options.

a. The preferable option is to replace the test item with a "new" one and restart from Step 1 of the pretest requirements.

b. A second option is to replace / repair the failed or non-functioning component or assembly within the test item with one that functions as intended, and restart the entire test from Step 1 of the pretest requirements.

> **NOTE**: When evaluating failure interruptions, consider prior testing on the same test item, and consequences of such.

4.4 Test Setup.

a. See Part One, paragraph 5.8.
b. Unique to this method. There is no guidance unique to this method.

4.5 Test Execution.

The following steps, alone or in combination, provide the basis for collecting necessary information concerning the test item in a low temperature environment. Conduct pretest and post test operational checkouts after storage and after manipulation to verify successful completion of both procedures.

4.5.1 Preparation for test.

4.5.1.1 Preliminary steps.

Before starting the test, review pretest information in the test plan to determine test details (e.g., procedures, test item configuration, cycles, durations, parameter levels for storage/operation, etc.).

4.5.1.2 Pretest standard ambient checkout.

All test items require a pretest standard checkout at standard ambient conditions to provide baseline data. Conduct the checkout as follows (change of step sequence may be required for large test items):

Step 1. Conduct a complete visual examination of the test item, with special attention to stress areas such as corners of molded cases, and document the results.

Step 2. Install temperature sensors in or on the test item as required to determine the test item temperature(s). If not possible to instrument internal components, base any additional soak time on thermal analysis to ensure temperature stabilization throughout the test item.

Step 3. Conduct an operational checkout at standard ambient conditions (See Part One, paragraph 5.1), and in accordance with the approved test plan and record the results.

Step 4. If the test item operates satisfactorily, proceed to the first test procedure as determined from the test plan. If not, resolve the problems and repeat Step 3 above.

4.5.2 Procedure I - Storage.

Step 1. Place the test item in its storage configuration and install it in the test chamber.

Step 2. Adjust the chamber air temperature to that specified in the test plan for storage at a rate not to exceed 3°C/min (5°F/min).

Step 3. Following temperature stabilization of the test item (Part One, paragraph 5.4), maintain the storage temperature for a period as specified in the test plan. If not possible to instrument internal components, base any additional soak time on thermal analysis to ensure temperature stabilization throughout the test item.

Step 4. Conduct a visual examination of the test item and compare the results with the pretest data. Record any pertinent physical changes or the fact that there were no obvious changes.

Step 5. Adjust the chamber air temperature to standard ambient conditions (at a rate not to exceed 3°C/min (5°F/min)), and maintain it until the test item has achieved temperature stabilization.

Step 6. Conduct a complete visual examination of the test item and document the results.

Step 7. If appropriate, conduct an operational checkout of the test item and document the results. See paragraph 5 for analysis of results.

Step 8. Compare these data with the pretest data.

4.5.3 Procedure II - Operation.

Step 1. With the test item in its operational configuration and installed in the test chamber, adjust the chamber air temperature to the low operating temperature of the test item as specified in the test plan at a rate not to exceed 3°C/min (5°F/min). Maintain this for at least two hours following temperature stabilization of the test item. If not possible to instrument internal components, base any additional soak time on thermal analysis to ensure temperature stabilization throughout the test item.

Step 2. Conduct as complete a visual examination of the test item as chamber access limitations will allow, and document the results.

Step 3. Conduct an operational checkout of the test item as in paragraph 4.5.1.2, Step 6, and document the results. If the test item fails to operate as intended, see paragraph 5 for analysis of results, and follow the guidance in paragraph 4.3.2 for test item failure.

Step 4. If manipulation of the test item is required at low temperature, proceed to Step 4 of paragraph 4.5.4. If not, proceed to Step 7 of this procedure.

Step 5. Adjust the chamber air temperature to standard ambient conditions at a rate not to exceed 3°C/min (5°F/min), and maintain it until temperature stabilization of the test item has been achieved.

Step 6. Conduct a complete visual examination of the test item, and document the results.

Step 7. If appropriate, conduct an operational checkout and record results for comparison with data obtained in paragraph 4.5.1.2, Step 6. If the test item fails to operate as intended, see paragraph 5 for analysis of results.

4.5.4 Procedure III - Manipulation.

Step 1. With the test item in the test chamber and in its storage configuration, adjust the chamber air temperature to the low operating temperature of the test item as determined from the test plan at a rate not to exceed 3°C/min (5°F/min). Maintain it for two hours following temperature stabilization of the test item.

Step 2. While maintaining the low operating temperature, place the test item in its normal operating configuration by using the options of Step 3.

Step 3. Based on the type of test chamber available, select one of the two following options:

<u>Option 1</u> - To be used when a "walk-in" type chamber is available: With personnel clothed and equipped as they would be in a low temperature tactical situation, disassemble the test item as would be done in the field, and repack it in its normal shipping/storage container(s), transit case, or other mode and configuration.

<u>Option 2</u> - To be used when small chambers (non-walk-in) are used: Perform the option 1 procedure, except the disassembly and packing will be performed by personnel reaching through chamber access holes or the open door while they are wearing heavy gloves such as would be required in the natural environment.

> **NOTE** - Opening of the chamber door may cause frost to form on the test item in addition to a gradual warming of the test item. Limit manipulation necessary to perform the required setup or teardown to 15-minute intervals, between which reestablish the temperature of Step 1 above.

Step 4. Reestablish the temperature to that used in Step 1, above and maintain it for two hours following temperature stabilization of the test item

Step 5. If operation of the test item is required at low temperatures, proceed to Step 1 of paragraph 4.5.3. If not, proceed to Step 6 of this procedure.

Step 6. Conduct a complete visual examination of the test item, and document the results for comparison with the pretest data.

Step 7. Adjust the chamber air temperature to standard ambient conditions (at a rate not to exceed 3°C/min (5°F/min)), and maintain it until the test item has reached temperature stabilization.

Step 8. Conduct a complete visual examination of the test item, and document the results.

Step 9. If appropriate, conduct an operational checkout of the test item and record results for comparison with data obtained in paragraph 4.5.1.2, Step 6. If the test item fails to operate as intended, see paragraph 5 for analysis of results.

5. ANALYSIS OF RESULTS.

In addition to the guidance provided in Part One, paragraph 5.14, the following information is provided to assist in the evaluation of the test results. Apply any data relative to failure of a test item to meet the requirements of the materiel specifications to the test analysis, and consider related information such as:

a. Nondestructive test/examination following exposure to low temperature may be conducted at the low test temperature.

b. Degradation allowed in operating characteristics when at low temperatures.

c. Necessity for special kits or special cold weather procedures.

d. Evidence of improper lubrication and assurance that lubricants specified for the environmental condition were used.

e. For starting failure on internal combustion engines, assurance of the presence of proper fuels and deicers, if appropriate.

f. Condition and adequacy of the power source.

6. REFERENCE/RELATED DOCUMENTS.

6.1 Referenced Documents.

a. MIL-HDBK-310, Global Climatic Data for Developing Military Products.

b. AR 70-38, Research, Development, Test and Evaluation of Materiel for Extreme Climatic Conditions.

c. NATO STANAG 4370, AECTP 200, Category 230, Section 2311.

d. MIL-STD-2105C, Test Method Standard – Hazard Assessment Tests for Non-Nuclear Munitions.

6.2 Related Documents.

a. Synopsis of Background Material for MIL-STD-210B, Climatic Extreme for Military Equipment. Bedford, MA: Air Force Cambridge Research Laboratories, January 1974. DTIC number AD-780-508.

b. STANAG 4370, Environmental Testing.

c. Allied Environmental Conditions and Test Publication (AECTP) 300, Climatic Environmental Tests (under STANAG 4370), Method 303.

d. Egbert, Herbert W. "The History and Rationale of MIL-STD-810," February 2005; Institute of Environmental Sciences and Technology, Arlington Place One, 2340 S. Arlington Heights Road, Suite 100, Arlington Heights, IL 60005-4516.

(Copies of Department of Defense Specifications, Standards, and Handbooks, and International Standardization Agreements are available online at http://assist.daps.dla.mil/quicksearch/ or from the Standardization Document Order Desk, 700 Robbins Avenue, Building 4D, Philadelphia, PA 19111-5094.)

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