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14. ABSTRACT
The procedures in this Test Operations Procedure (TOP) describe Snow Testing performed in Environmental Chambers. The primary focus is the application of snow for the purposes of snow load structural testing and for assessing snow removal procedures.

15. SUBJECT TERMS
snow, arctic environment, low temperature, snow removal

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

*Test Operations Procedure 01-2-631 9 July 2020
DTIC AD No.

ENVIRONMENTAL CHAMBER SNOW TEST

* Approved for public release; distribution unlimited.

1. SCOPE.

a. The procedures in this Test Operations Procedure (TOP) describe snow testing performed in environmental chambers. The primary focus is the application of snow for the purposes of snow load structural testing and assessing snow removal procedures. This procedure includes information that is applicable to the blowing snow environment, but is not intended for the application of this environment. Outdoor snow testing is addressed by TOP 01-2-630[1**].

b. Effects of the environment.

(1) Structural Loading. Test items, especially those with a large horizontal area, will experience structural loading that may cause unacceptable deflections and damage.

(2) Clogging. More applicable to blowing snow, but pertinent to this test, is the clogging of areas with snow. Examples include blocking openings, ingestion of snow into fan assemblies, and obstruction of filters.

(3) Binding of Mechanisms. This can occur from snow intrusion and through melted snow refreezing as ice. Snow buildup may block the motion required for a mechanism to operate as in vehicle brakes.

(4) Snow Removal Damage. While not directly associated with the environment, for many systems the snow must be cleared to allow for operations. The following damage can occur:

(a) Scratching of surfaces. Snow removal is typically carried out with a brush and scraper, which can result in scratches to surfaces.

(b) Denting of surfaces. Snow can melt and refreeze, causing ice formation. Removal of the ice can be performed in ways that cause dents and other damage to the test items.

(c) Contamination by Fluids. The de-icing fluid used to aid in the removal of snow and ice may damage the test items. The de-icing fluid may have been previously addressed in the Contamination by Fluids Test, Method 504, Military Standard (MIL-STD)-810H[2].

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

a. Chamber. A chamber is required to provide the low temperature environment for generating snow. The chamber should be large enough to allow for snow generation equipment and the test item. It should also include a means to maintain low temperature while allowing for defrost of the refrigeration coils.

** Superscript numbers correspond to Appendix B, References.

b. Snow Generation Equipment. This equipment may be either custom or commercially available. It typically consists of an array of water spray nozzles. Distribution of the snow particles may be performed by the nozzle pressure or a combination of nozzle pressure and fan speed/location.

c. Water Supply. The water supply should be relatively clean of particulates and impurities. Particulates in the water can clog nozzles on the snow generation equipment. The ability to pre-cool the water and control water temperature can be advantageous for achieving specific snow densities. This also reduces the thermal load on the chamber.

2.2 Instrumentation.

Devices for Measuring	Permissible Measurement Uncertainty/Control Tolerance
Temperature	Accuracy to within ± 1 °Celsius (°C) (1.8 °Fahrenheit (°F). Control tolerance to within ± 3 °C (5.4 °F).
Snow Density	As required. If required, this should be defined in the test plan.
Snow Depth	Precision to within ± 6.5 percent. Control tolerance to within ± 10 percent.
Water Pressure	As required. This is driven by the snow density requirement and other control parameters.
Air Pressure	As required. This is driven by the snow density requirement and other control parameters.

3. REQUIRED TEST CONDITIONS.

3.1 Temperature(s).

Test temperature(s) that may be used to produce the required environmental conditions are recommended in this test procedure. The recommended temperatures for the chamber air temperature may have to be adjusted based on the snow generation equipment used and the snow density required. Lowering the water temperature will reduce the thermal load on the chamber. Controlling the water temperature will provide more repeatable results.

3.2 Snow Load.

The following guidelines are provided in MIL-STD-810H and are routinely applied as test requirements.

a. Portable materiel usually involves small items, such as tentage, that may be moved daily. This materiel will generally shed snow, but in instances where it does not, distortion will be noticeable and daily cleaning mandatory. The design criterion for this materiel is based on 24-hour snowfalls. The snow load value is 48.9 kilogram per square meter (kg/m^2) (10 pounds per square foot (lbs/ft^2)), which is equivalent to a depth of 508 millimeters (mm) (20 inches) of snow with a specific gravity of 0.1.

b. Temporary materiel usually involves large items on which snow can collect (rigid shelters, portable hangars, etc.) and be cleared between storms. This materiel will not sag much due to the snow loading, but may collapse when its limits are exceeded. The design criterion for this materiel is based on snowfalls associated with storms lasting longer than 1 day. The snow load value is 97.7 kg/m^2 (20 lbs/ft^2), which is equivalent to a snow depth of 1016 mm (40 inches) with a specific gravity of 0.1.

c. Semi-permanently installed materiel is usually demountable and not very mobile. Snow is not removed between snowfalls. The design criterion for this materiel is based on seasonal accumulation of snow. The snow load value is 235 kg/m^2 (48 lbs/ft^2), which is equivalent to a snow depth of 2438 mm (96 inches) with a specific gravity of 0.1.

3.3 Dwell Time.

After the snow is applied, it should remain in place for a minimum dwell period of 4 hours. This can be extended, typically overnight, to allow for personnel schedules. The snow laden dwell period is to allow the snow to settle/pack and harden. The dwell period will have a greater effect when wet snow is applied as this increases the difficulty in removing the snow. The longer the dwell period, the more moisture that will be removed by the refrigeration system from the chamber.

3.4 Snow Density.

The specific gravity of 0.1 used in the paragraphs above is a design criterion per MIL-STD-810H. In practice, this low of a specific gravity (density) is not readily achievable in the chamber test. Typical snow densities range from 0.3 to 0.6 gram cubic meter (g/m^3). The density can provide an indication of wetness of the snow, with wetter snow being denser. The wetness of the snow also typically correlates with more difficult snow removal.

3.5 Operation.

a. This procedure assumes that the system is: (1) emplaced and non-operational, (2) snow is encountered, (3) and then the system is brought to an operational state. For systems that

will be deployed and operational for extended periods of time, it may be appropriate to tailor these procedures so that the system is operational during the application of snow.

b. Assess any operational impacts caused by snow. Examples include deploying masts and tower systems, actuating mechanical devices such as turrets and gimbals, opening and accessing critical areas of the system, and analyzing the capability if anti-icing heaters to preclude the buildup of snow.

4. TEST PROCEDURES.

If military personnel are required for testing, determine if Military Occupational Specialty (MOS) qualified Soldier-Operator/-Maintainer Test and Evaluation (SOMTE) personnel assigned to the U.S. Army Test and Evaluation Command (ATEC) are available to support the testing. If SOMTE are not available, ensure a Test Schedule and Review Committee (TSARC) request is submitted one year prior to the start of testing, or as early as possible. A Safety Release (SR) and Human Research Protection Plan (HRPP) must be obtained from ATEC prior to using military personnel as test participants.

4.1 Snow Calibration.

a. The snow load value is calculated from the snow density and depth measurements that are taken during the application of snow. These measurements are taken periodically throughout the application of snow at multiple points. The snow accumulation on a surface is sampled using a snow sampling tool or collection devices with a known volume. This sample is weighed and the snow density is calculated by dividing the weight by the volume. See Section 6 for examples. This value combined with observed measurements on the depth gauges placed on the test item(s) ensure that the required snow load is applied across the horizontal surfaces of the test item(s).

b. Prior to performing the test, checkout procedures should be performed to ensure that the snow generation equipment and environmental chamber can produce the required snow accumulation. Parameters such as water pressure, number of nozzles, chamber air temperature, and refrigeration defrost cycle may be adjusted to provide acceptable snow generation.

c. Depending on the objectives of the specific test, the density or wetness of the snow may be specified. In this case, perform a calibration test prior to applying snow on the test item.

4.2 Safety.

a. Use caution when climbing on, or working around, equipment in snow-laden conditions. Equipment and vicinity will be slick, resulting in the potential for falling, and possibly cause death or serious injury.

b. Equipment surfaces can become extremely cold and increase the chance of frostbite, or damage to exposed skin surfaces in contact with cold equipment. Exposure to low temperature can result in death or serious injury through hypothermia, frostbite, or other cold related injury. Personnel should wear the appropriate cold weather gear.

c. The following Personal Protective Equipment (PPE) should be considered in addition to cold weather gear:

(1) Goggles. To provide eye protection from snow and provide warmth.

(2) Traction cleats. To reduce slip hazards on the snow. Recommend using over the shoe type cleats to allow for easy removal prior to encountering areas with no snow.

4.3 Snow Removal Procedures.

The snow removal procedures should be provided by the Product Developer prior to the start of testing. As noted in Section 1, damage to the test items can occur during snow removal. These procedures should include warnings and cautions about sensitive areas of the test item. Snow removal may include the use of brushes, brooms, scrapers, and de-icing fluid. If appropriate, heat sources may be utilized. The tools specified in the snow removal procedures should be consistent with those that will be available with the fielded system. The number of personnel required for snow removal operations should be defined. Due to safety issues identified in paragraph 4.2, a minimum of two personnel should be involved in the operation.

4.4 Test Procedure.

4.4.1 Preparation for Test.

a. Install temperature sensors on test item(s) as described in the test plan.

b. Install the test item(s) in the chamber in the required orientation and configuration.

c. If not previously accomplished, ramp the chamber to standard ambient conditions of +25 °C ± 10 °C (+77 °F ± 18 °F), 20 percent to 80 percent Relative Humidity (RH), and site pressure in accordance with MIL-STD-810H.

d. Perform a visual inspection of the test item(s) with special attention to stress areas. Document the results.

e. Conduct an operational checkout of the test item(s).

f. Install depth gauges in critical areas and over the surface of the test item(s) to ensure uniform coverage.

NOTE: These procedures can be performed in the most logical and expedient order.

4.4.2 Procedure - Snow Load.

a. With the test item(s) powered down and installed in the chamber, ramp the chamber temperature from standard ambient conditions to the temperature specified by the facility. This value is typically between -9 °C (15 °F) to -6 °C (22 °F).

NOTE: The facility must have the flexibility to adjust the chamber air temperature as needed to ensure the proper quality of snow.

b. Allow the test item(s) to reach temperature stabilization. Temperature stabilization is defined by Section 5.4, Part One of MIL-STD-810H.

c. Apply snow to the test item(s) until the snow load reaches the required level (see paragraph 3.2). The snow load is determined by measuring the density of the snow and calculating the required depth. The depth of the snow is measured by the depth gauges placed on the test items. See paragraph 4.1 on techniques for measuring snow density.

NOTE: The application of snow can be interrupted as needed to allow the chamber to maintain acceptable conditions for the snow generation. The refrigeration coils may require defrost. During defrost the conditions in the chamber must remain below freezing.

NOTE: In order to ensure a uniform application of snow depth, the snow generation equipment position may need to be adjusted throughout the period of snow application.

d. After the required snow load has been applied, stop the snow generation equipment and maintain the chamber air temperature. Ensure uniform coverage of snow across the test item. Unless otherwise specified, a uniformity tolerance of ± 20 percent of the depth is acceptable.

NOTE: For test items with small horizontal dimensions, the depth of snow buildup will be limited. This is consistent with what the test items will see in the natural environment. In these cases, apply snow until the height of the snow no longer increases. Document the snow depth achieved.

e. Examine the chamber, snow generation equipment, and test items to identify safety hazards before proceeding.

f. Document the snow results, providing photography of test item(s) and the witness depth gauges. Calculate the snow load applied and ensure that it is within ± 10 percent of the specified load.

g. Following the snow load application, allow 4 hours for the snow to harden.

h. Remove the minimum amount of snow accumulation required for safe operation for personnel and equipment using current snow removal procedures supplied by the test item(s)

developer. Annotate the start and stop times of snow removal. Document the effectiveness of the snow removal methods. It is recommended that the snow removal be recorded on video.

i. Operate the test item. Document the results and any degradation to performance. See paragraph 3.5 for operational considerations.

j. If required, perform removal of the remaining snow using current snow removal procedures supplied by the test item(s) developer. This is typically required when the fielded product will require periodic snow removal from horizontal surfaces to preclude overloading the structure.

5. DATA REQUIRED.

The following data are required:

a. A complete list of all test chamber, test equipment, and accessories used for this test, including (as applicable) the manufacturer name, nomenclature, Part Number (P/N), Serial Number (S/N), calibration date, and calibration due date.

b. Provide photographic documentation of the locations of the witness depth gauges.

c. Snow delivery periods and conditions.

d. Provide photographic documentation of the snow accumulation on the test items and the witness depth gauges.

e. Report the start and stop times of snow removal operations.

f. Complete record of chamber temperature versus time, and RH versus time.

g. Complete record of test item(s) temperature versus time.

h. Record of snow generation equipment settings.

i. Snow Density

6. PRESENTATION OF DATA.

a. Examples of photographic presentations are provided in Figures 1 through 5.

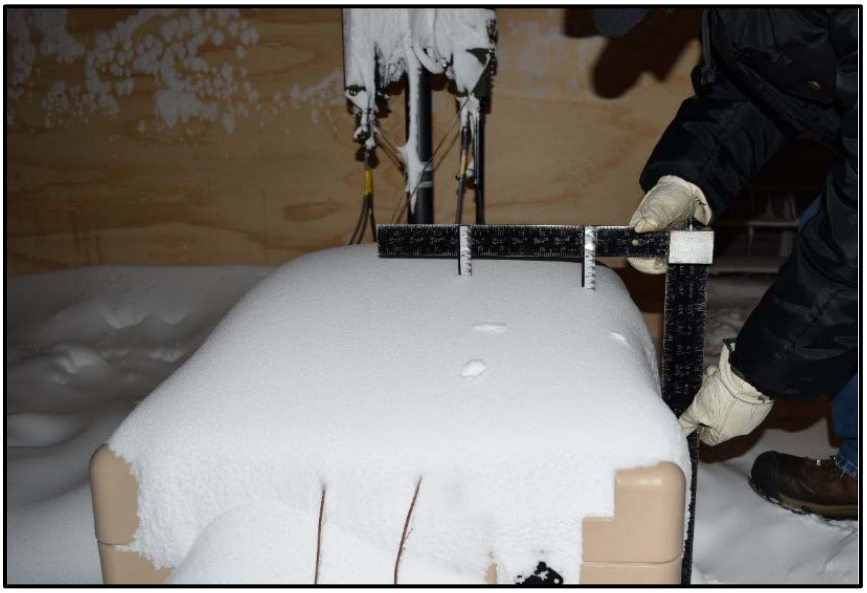

Figure 1. Depth measurement example.

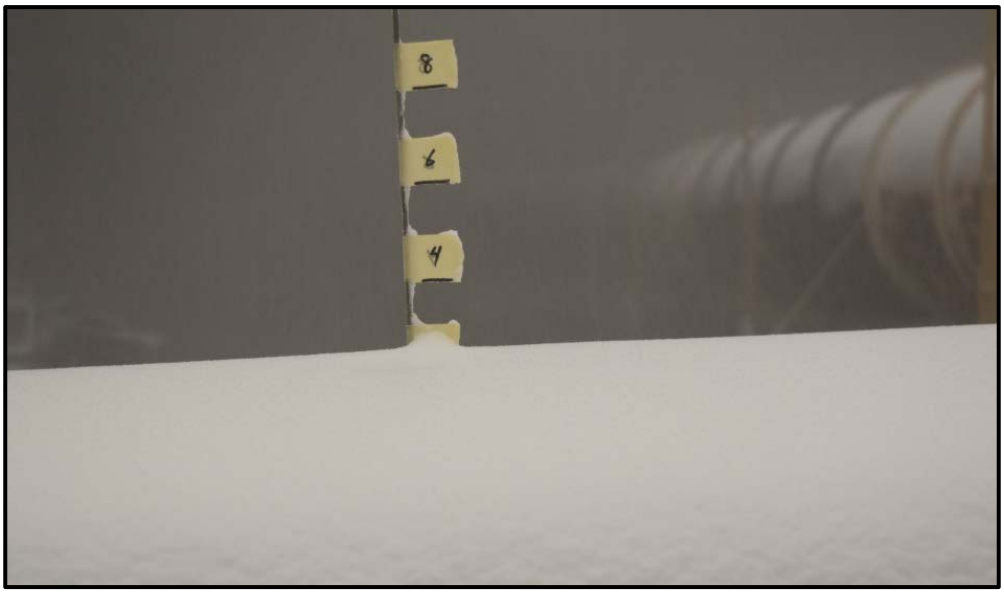

Figure 2. Depth gauge example.

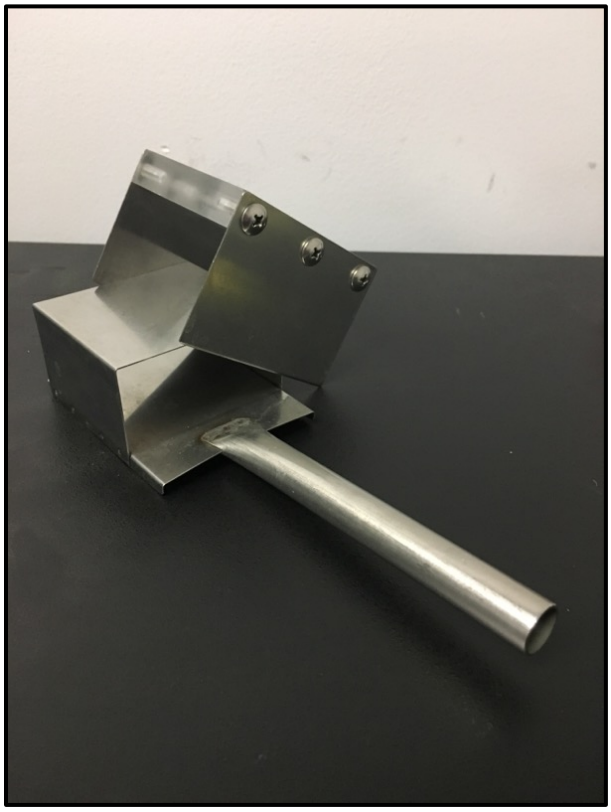

Figure 3. Snow density measurement sampling tool.

Figure 4. Snow density measurement sample. Sampling tool of known volume and weight.

Figure 5. Snow density sampling technique, dish of known volume and weight.

b. An example data table is shown in Table 1.

TABLE 1. EXAMPLE TABLE OF RESULTS FOR SNOW LOAD APPLIED TO THE TEST ITEM

DATA	LOCATION 1	LOCATION 2	LOCATION 3	LOCATION 4	AVERAGE
Measured depth (inches)	4.7	4.5	4.3	4.6	4.53
Measured density[a] (lb/ft^3)	26.2	26.2	26.2	26.2	
Calculated snow load (lb/ft^2)	10.26	9.83	9.39	10.04	9.88
Percent from target of 10 lb/ft^3	2.6%	-1.8%	-6.1%	0.4%	-1.2%

[a] Average of 9 density measurements taken from three locations at three times near the beginning, middle and end of the application of the snow. This assumes a relatively small test item. For a large test item or multiple test items, a density measurement for the area of prime interest should be applied as the density may vary across the test item(s).

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APPENDIX A. ABBREVIATIONS AND ACRONYMS.

ATEC	U.S. Army Test and Evaluation Command
°C	degrees Celsius
DTIC	Defense Technical Information Center
°F	degrees Fahrenheit
g/m^3	gram cubic meter
HRPP	Human Research Protection Plan
kg/m^2	kilogram per square meter
lbs/ft^2	pound per square foot
MIL-STD	Military Standard
mm	millimeter
MOS	Military Occupational Specialty
P/N	Part Number
PPE	Personal Protective Equipment
RH	Relative Humidity
RTC	U.S. Army Redstone Test Center
S/N	Serial Number
SOMTE	Soldier-Operator/-Maintainer Test and Evaluation
SR	Safety Release
TOP	Test Operations Procedure
TSARC	Test Schedule and Review Committee

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APPENDIX B. REFERENCES.

1. TOP 01-2-630, Outdoor Artificial Snow Rate Testing, 9 July 2020.

2. MIL-STD-810H, Department of Defense Test Method Standard for Environmental Engineering Considerations and Laboratory Tests, 31 January 2019.

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APPENDIX C. APPROVAL AUTHORITY.

CSTE-CI 9 July 2020

MEMORANDUM FOR

Commander, U.S. Army Operational Test Command
Director, U.S. Army Evaluation Center
Commanders, ATEC Test Centers
Technical Directors, ATEC Test Centers

SUBJECT: Test Operations Procedure 01-2-631, Environmental Chamber Snow Test, Approved for Publication

1. Test Operations Procedure (TOP) 01-2-631, Environmental Chamber Snow Test, has been reviewed by the U.S. Army Test and Evaluation Command (ATEC) Test Centers, the U.S. Army Operational Test Command, and the U.S. Army Evaluation Center. All comments received during the formal coordination period have been adjudicated by the preparing agency.

2. Scope of the document. This TOP describe snow testing performed in environmental chambers. The primary focus is the application of snow for the purposes of snow load structural testing and for assessing snow removal procedures.

3. This document is approved for publication and has been posted to the Reference Library of the ATEC Vision Digital Library System (VDLS). The VDLS website can be accessed at https://vdls.atc.army.mil/.

4. Comments, suggestions, or questions on this document should be addressed to U.S. Army Test and Evaluation Command (CSTE-CI), 6617 Aberdeen Boulevard-Third Floor, Aberdeen Proving Ground, MD 21005-5001; or e-mailed to usarmy.apg.atec.mbx.atec-standards@mail.mil.

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Director, Directorate for Capabilities Integration (DCI)

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Policy and Standardization Division (CSTE-CI-P), U.S. Army Test and Evaluation Command, 6617 Aberdeen Boulevard, Aberdeen Proving Ground, Maryland 21005-5001. Technical information may be obtained from the preparing activity: U.S. Army Redstone Test Center (RTC), Climatic Test Division (TERT-ECC), 7250 Briar Road, Redstone Arsenal, AL 35898. Additional copies can be requested through the following website: https://www.atec.army.mil/publications/documents.html, or through the Defense Technical Information Center, 8725 John J. Kingman Rd., STE 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.