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14. ABSTRACT

This Test Operations Procedure (TOP) provides guidance for outdoor artificial snow rate testing when long term artificial snowfall cannot be generated within a climatic chamber, or the test item requires an outdoor environment to fully evaluate its operational capability during snowfall. Documented in this TOP are the recommended equipment, required test conditions, setup and procedures, and discussion of the possible difficulties and limitations that can be anticipated.

15. SUBJECT TERMS

Snow Snow Making Machine Snowfall Rate

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 01-2-630 9 July 2020
DTIC AD No.

OUTDOOR ARTIFICIAL SNOW RATE TESTING

1. SCOPE.

1.1 General

a. This Test Operations Procedure (TOP) provides guidance for outdoor artificial snow rate testing when long term artificial snowfall cannot be generated within a climatic chamber, or the test item requires an outdoor environment to fully evaluate its operational capability during snowfall.

b. This test is for verification of the test item, and shall include:

(1) Operation at a specific snow rate (inches per hour).

(2) Structural integrity under snow load (pounds per square foot).

(3) Snow mitigation/manipulation procedures during or after exposure to snow.

c. Documented in this TOP are the recommended equipment, required test conditions, setup and procedures, and discussion of the possible difficulties and limitations that can be anticipated.

1.2 Limitations

This TOP relies on the environmental conditions of the test site and testing is only feasible in winter conditions.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Outdoor test area	The outdoor test area selected should have ample space for both the test item, in its operational configuration, and the snow making equipment. Cold weather ambient conditions must be factored in when selecting the test area. Temperatures must be below freezing during test.
Water Source	Identify a water source capable of sustaining the estimated quantity for the duration of test. See paragraph 3.2 for more detail.
Power Source	Facility or generator power should be deemed capable of meeting the power demands of both the test item and the required test equipment.

	Wet conditions will be present during testing and a certified electrician should be consulted for proper wiring.
Snow Making Machine	The snow making machine should be characterized prior to testing and shall be capable of meeting the snowfall rate requirement.
Water Pressure Booster Pump	The water pressure booster pump should be capable of providing the water pressure required to operate the snow making machine.

2.2 Instrumentation.

Data Element	Devices	Tolerance
Temperature Data Acquisition System	Computer, data logger, and signal conditioning unit.	± 2.0 °Celsius (°C) (± 3.6 °Fahrenheit (°F))
Temperature	Type-T thermocouple for moderate temperature measurement of the test conditions and points of interest on the test item.	Accuracy within ± 1 °C (± 1.8 °F)
Humidity (optional)	Relative humidity sensor	Accuracy within ± 3 percent (local meteorology data may be used)
Snow Depth Gauges	Meter stick, measuring tape, or depth gauges are all appropriate forms of measuring the accumulated snow.	± 10 percent of the specified value.

3. REQUIRED TEST CONDITIONS.

3.1 Environmental Test Conditions.

a. Testing should be performed at outdoor ambient conditions of -5 °C (23 °F) or colder. Slightly warmer temperatures will likely produce an unwanted ice/freezing rain mixture.

b. Local weather forecasts should be monitored and consideration of the deleterious effects of the expected weather should be made before testing. Adverse conditions such as wind, rain, ice, or any other phenomena could impact test safety, procedures, or results.

c. Wind and wind direction will factor into the ability to successfully complete testing. Wind speeds under 19.3 kilometers per hour (kph) (12 miles per hour (mph)) is considered ideal. Adjust the trajectory and position of the snow machine as needed to account for directional winds.

d. Natural snowfall may or may not be desired during testing. Plans to halt or proceed with testing in the event of natural snow/ice precipitation should be agreed upon prior to testing. Safety hazards, including commuting to and from the test site, should be taken into consideration.

e. Test items should be acclimated to the low temperature test conditions in accordance with the approved test plan.

f. Personal Protective Equipment (PPE) such as gloves, boots, mask, jacket, and trousers are required when working in cold weather conditions. See Appendix B, Figure B-14 for an example.

3.2 Water Source.

a. An adequate water source should be identified for testing. Estimation of the total amount of water required is derived from the booster pump flow rate and overall test duration as shown in Equation 1.

$$\text{Total amount of Water}_{(\text{gallons})} = \text{Booster Pump Flow Rate}_{(\text{gpm})} * \text{Test Duration}_{(\text{minutes})} \qquad \textit{(Equation 1)}$$

b. Reliable sources, such as a fire hydrant or a facility high flow water tap, should first be considered.

c. If such sources are not available, a standing water pool or tank may be used with a primary sump pump in place to move the standing water from the reservoir to the secondary booster pump as shown in Figures 1 and 2.

Figure 1. Truck delivering water to a reservoir tank for test.

Figure 2. Water reservoir tank and trailer mounted booster pumps. Snow making machines operating in the background.

3.3 Snow Making Machine.

a. Characterize the performance of the snow making machine, without test item present, prior to the test. Adjust water spray trajectory of the snow machine, booster pump flow rate, and snow machine operating pressure to achieve the desired snowfall rate in inches per hour.

b. Integrating mobility into the snow making equipment test setup, as shown in Figures 3 and 4, will allow the test operators to reposition snow producing equipment during test in the event of a change in weather conditions.

Figure 3. Example of integrating mobility to the snow machine for easy movement.

Figure 4. Example of integrating mobility into the snow machine for easy movement.

c. Adjust the aforementioned, as needed, as testing progresses.

4. TEST PROCEDURES.

4.1 Preliminary Steps.

4.1.1 Test Plan.

The test plan shall include test item configuration, orientations, instrumentation requirements, procedures, snowfall rate and snow depth. Test item performance criteria will also be specified in the approved test plan.

4.1.2 Test Setup.

A typical outdoor snow testing setup is shown in Figures 5 and 6. When identifying test location; it is desirable to choose a site with ample amounts of space to allow for easy positioning of the various equipment.

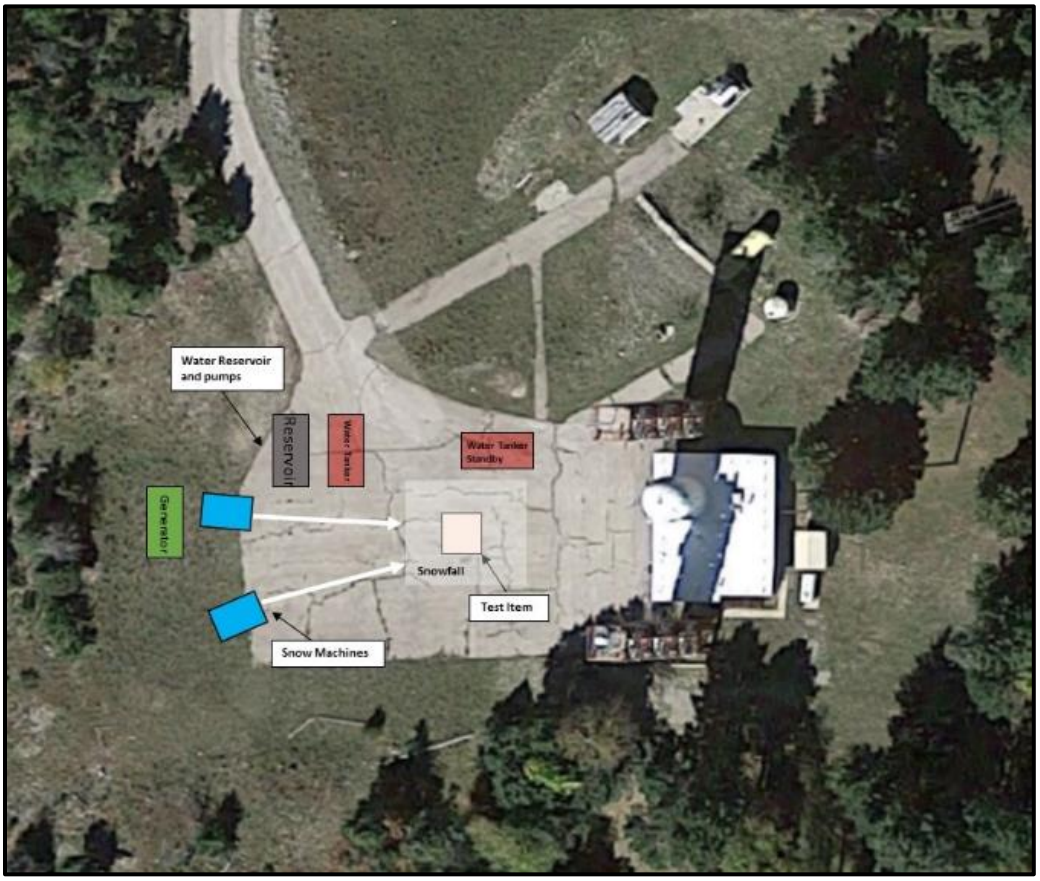

Figure 5. Example snow test site layout.

Figure 6. Snow test setup showing two snow making machines, generator, and trailer with water reservoir tank with mounted booster pumps.

4.1.3 Test Item Positioning.

The test item should be positioned at a predetermined distance from the snow making machine to produce the desired snowfall rate. Water pressure, spray trajectory, and wind conditions are factors that may increase or decrease the distance. Start with a separation distance of 61 meters (200 feet) and a water pressure of 200 pounds per square inch (psi). Adjust values as required to achieve the desired results.

4.1.4 Pre-test at Ambient Checkout.

The test item shall be deemed ready after performing nominally at local ambient conditions. Visual inspection of the test item shall be completed with any concerns being documented. Testing may commence upon satisfactorily completing the checkout.

4.1.5 Instrumentation.

Instrumentation required by the test plan should be installed and a verification of the data collection system shall be completed prior to test.

4.1.5.1 Temperature Data Acquisition System.

The data acquisition system, at a minimum, will include the following.

a. Computer and/or hard drive for data storage.

b. Data Acquisition (DAQ) system. The DAQ system should be capable of recording at 1 to 10 samples per minute.

c. Signal conditioning. Signal conditioning is recommended when measurements are collected in an uncontrolled environment (i.e., non-laboratory environments). The uncontrolled environment can produce unwanted interference (noise) with the measurement.

d. Transducer. Type-T thermocouples are recommended for moderate temperature measurement of the ambient environment and any locations of interest on or around the test item.

4.1.5.2 Snow Depth Gauges.

a. Meter stick, measuring tape, or depth gauges are all appropriate forms of measuring the accumulated snow on selected points of the test item.

b. Snow depth gauges within the test area should conform to National Weather Service practices and shall be constructed of a 406 x 406 millimeter (mm) (16 x 16 inch) wood base, painted white. Attachment of a ruler or yard/meter stick permanently to the base is recommended.

For further guidance on snowfall measurement see https://www.weather.gov/jkl/snow_measurement[1**]. Figures 7 and 8 show some examples snow depth gauges.

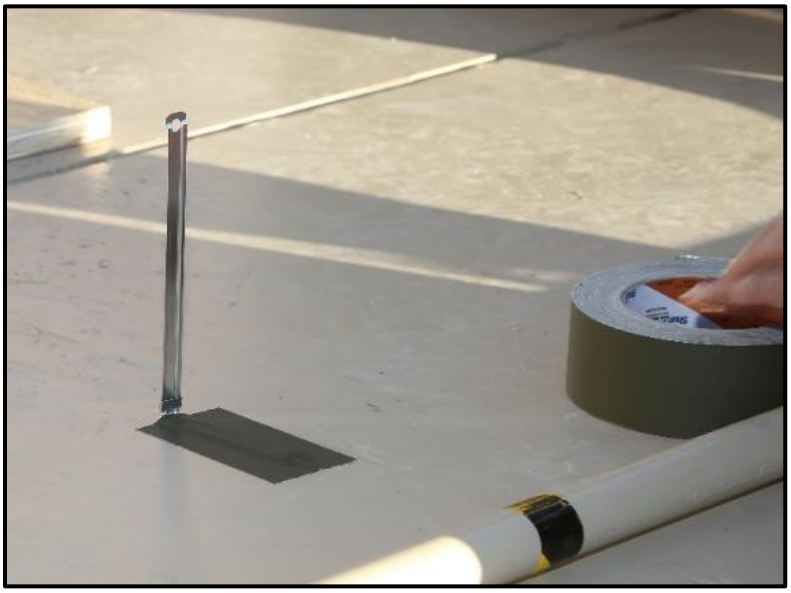

Figure 7. Snow depth gauge mounted on test item surface.

Figure 8. 16 x 16 inch wood base with yard stick mounted for snow measurement.

** Superscript numbers correspond to those in Appendix C, References.

c. The depth gauges are to be placed on and around the test item in accordance with the test plan. The structure of the test item itself may influence the snowfall reading; impeding or augmenting the measurement. Gauges should be placed in multiple locations to provide an average of the overall depth and reveal the uniformity of the snowfall in the area as testing progresses.

4.2 Test Execution.

The outdoor artificial snowfall rate test is performed as follows:

Step 1. Perform characterization of the snow making machine setup to determine distance, trajectory, and water pressure needed to obtain the desired snowfall rate (mm/inches per hour).

Step 2. Conduct a complete pre-test inspection and operation of the test item(s) in the required test configuration to establish baseline data.

Step 3. If the test item performs adequately proceed to Step 4, if not, resolve any issues found and repeat Step 2.

Step 4 Monitor and record the local ambient temperature. If local ambient temperature is greater than -5 °C (23 °F), postpone test until the desire temperature of -5 °C (23 °F), or lower, is achieved.

Step 5. Install the test item(s) in the configuration defined in the test plan and position them at the predetermined distance established in Step 1.

Step 6. Initiate snow making machine and water circulation pumps. The snow machine pump(s) and operating pressure should be set to the levels identified during system characterization. Adjust as needed.

Step 7. Adjust snow making machine position, distance and/or trajectory, to achieve snow accumulation in the targeted area.

Step 8. Continue snowfall for the duration specified in the test plan. Snowfall measurements from the snow depth gauges should be recorded once per hour. Use video or photographic recordings to document the results.

Step 9. If required, operate the test item to validate performance in accordance with the test plan. Operation may be started any time before or during test.

Step 10. Perform pre-approved snow mitigation procedures to improve test item performance, if needed.

Step 11. At the conclusion of the exposure time, terminate snowfall.

Step 12. Perform post-test functional checks and inspections.

5. DATA REQUIRED.

The following data are typically required:

a. Plots of the complete record of snowfall depth measurements, temperature, and humidity over the time period of exposure.

b. Calibration information for the instrumentation.

c. Video and photographic documentation of the pre-test inspections, site setup, test execution, post-test inspections, and any other informative data.

6. PRESENTATION OF DATA.

6.1 Temperature Data.

Plots of temperature versus time data shall be included in the final report. An example is shown in Figure 9.

6.2 Snow Depth Data.

Snow depth measurement data shall be reported in tabular format. Table 1 shows typical snow depth data captured during outdoor artificial snow rate testing.

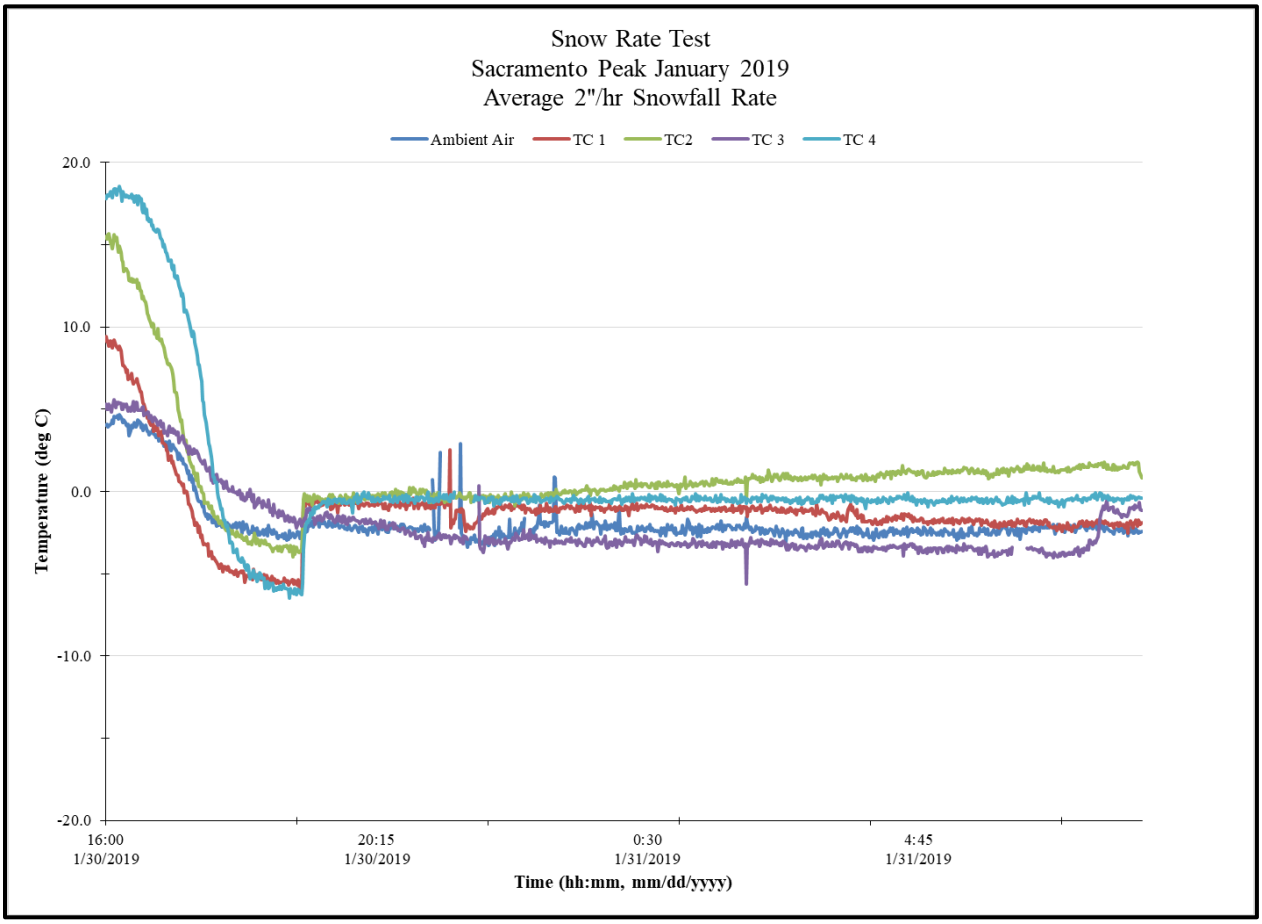

Figure 9. Example temperature data plot.

TABLE 1. EXAMPLE OF TABULATED SNOW DEPTH MEASUREMENTS AND NOTES

Date	Time	Temp (°C)	Accumulation Roadside (RS) (inch)	Accumulation Curbside (CS) (inch)	Average (RS & CS) (inch)	Average hourly fallout (RS &CS) (inch)	Notes
1/30/2019	19:08	-2.5					Start of Test
1/30/2019	20:00	-2.3	0.5	0.5	0.5		
1/30/2019	21:00	-2.0	2.5	2.5	2.5	2.0	Mitigated (wiped off) after measurement
1/30/2019	22:00	-3.3	1.8	1.8	1.8	1.8	Mitigated (wiped off) after measurement
1/30/2019	23:00	-1.9	2.3	2.3	2.3	2.0	
1/31/2019	0:00	-2.4	2.5	3	2.8	1.5	
1/31/2019	1:00	-2.5	3.5	5	4.3	1.5	
1/31/2019	2:00	-2.3	4.5	7.5	6.0	1.8	
1/31/2019	3:00	-2.9	6.0	10	8.0	2.0	
1/31/2019	4:00	-2.7	8.0	12	10.0	2.0	
1/31/2019	5:00	-2.5	10.0	14	12.0	2.0	
1/31/2019	6:00	-2.2	12.0	16	14.0	2.0	
1/31/2019	7:00	-2.4	14.5	18.5	16.5	2.5	
1/31/2019	8:00	-2.2	17.5	19.5	18.5	2.0	Center of trailer accumulated 22" of snow.
1/31/2019	8:08	-2.6					End of Test
						2	**Average hourly snowfall rate (inches)**

APPENDIX A. ABBREVIATIONS.

°C	degrees Celsius
°F	degrees Fahrenheit
CS	curbside
DAQ	Data Acquisition
gpm	gallons per minute
hr	hour
kph	kilometers per hour
MIL-STD	Military Standard
mm	millimeter
mph	miles per hour
PPE	Personal Protective Equipment
psi	pounds per square inch
RS	roadside
TOP	Test Operations Procedure
U.S.	United States

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APPENDIX B. EQUIPMENT.

Figure B-1. Snow Machine SMI Standard PoleCat***, 18 nozzles and 15 horsepower fan.

Figure B-2. 1500 gallon water reservoir.

*** The use of brand names does not constitute endorsement by the Army or any other agency of the Federal Government, nor does it imply that it is best suited for its intended application.

APPENDIX B. EQUIPMENT.

Figure B-3. Sump pump - Ebara Model 50DWXU61.54. Sump pumps feed standing reservoir water to booster pumps. One pump per booster pump.

Figure B-4. Booster pump (53 gallons per minute, operational) - Goulds Model 10SV19GK4C60. One pump per snow machine.

APPENDIX B. EQUIPMENT.

Figure B-5. Generator (350 kilowatt). Displaying fuel tank, generator, and electrical panel.

Figure B-6. Snow machine electrical panel connections (fuses, wiring, 480 and 208 Volt, 100 and 60 amp fuses).

APPENDIX B. EQUIPMENT.

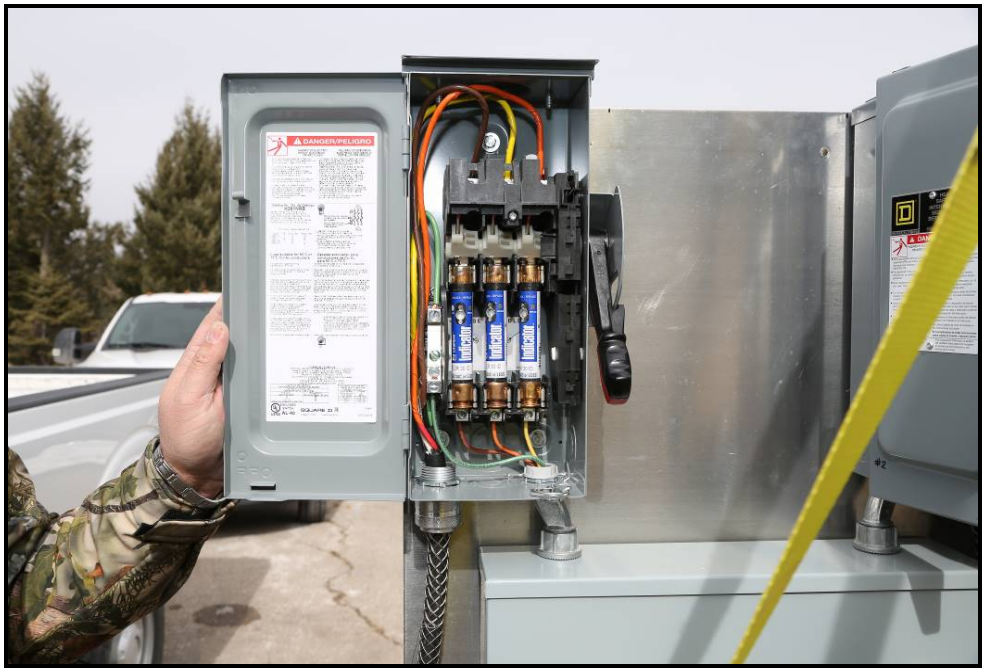

Figure B-7. Water pumps electrical panel connections (fuses, wiring, 208 Volt, 60 amp fuses).

Figure B-8. Water hose connections from booster pump to manifold with emergency return to reservoir tank.

APPENDIX B. EQUIPMENT.

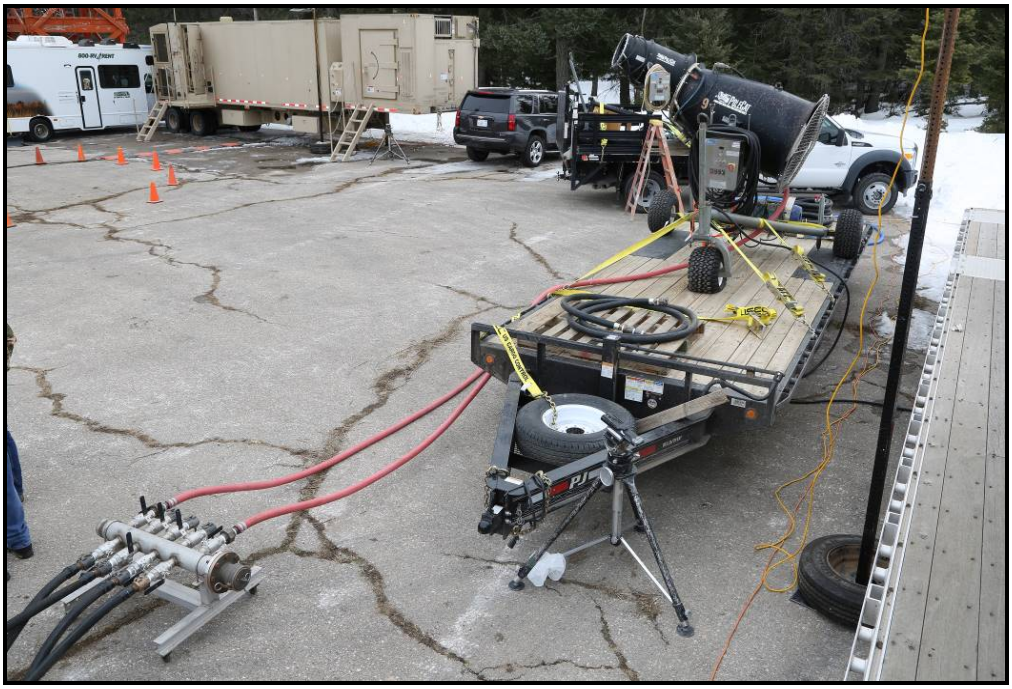

Figure B-9. Water hose connections from manifold to snow machines.

Figure B-10. Water hose connections from manifold to snow machine.

APPENDIX B. EQUIPMENT.

Figure B-11. Water tankers.

Figure B-12. Snow depth gauge (large), 16 x16 inch wood base with yard stick mounted for snow measurement.

APPENDIX B. EQUIPMENT.

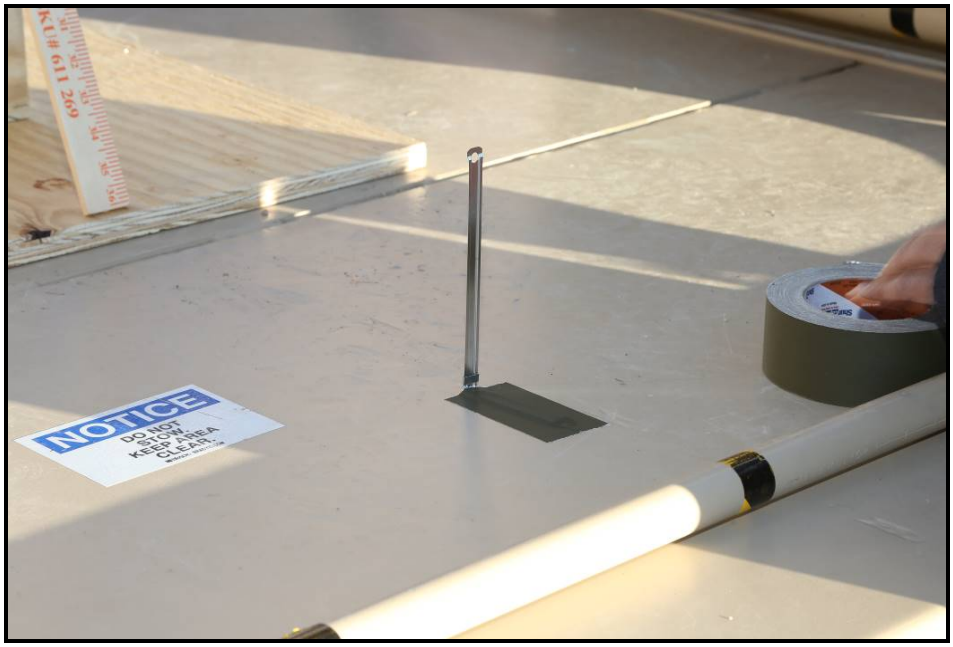

Figure B-13. Snow depth gauge (small) mounted on test item surface.

Figure B-14. Standard Personal Protective Equipment for low temperature testing.

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APPENDIX C. REFERENCES.

1. National Weather Service, National Oceanic and Atmospheric Administration, https://www.weather.gov/jkl/snow_measurement.

For information only (related publications).

a. Military Standard (MIL-STD)-810H, Department of Defense Test Method Standard, Environmental Engineering Considerations and Laboratory Tests, 31 January 2019.

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APPENDIX D. 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 01-2-630, Outdoor Artificial Snow Rate Testing, Approved for Publication

1. Test Operations Procedure (TOP) 01-2-630, Outdoor Artificial Snow Rate Testing, 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 provides guidance for outdoor artificial snow rate testing when long-term artificial snowfall cannot be generated within a climatic chamber, or the test item requires an outdoor environment to fully evaluate its operational capability during snowfall. Documented in this TOP are the recommended equipment, required test conditions, setup and procedures, and discussion of the possible difficulties and limitations that can be anticipated.

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 White Sands Missile Range, Applied Environmental Effects Division (TEWS-SV-A), White Sands Missile Range, New Mexico, 88002-5178. 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.