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Provides a method of evaluating the effects of rain, hail, splash, and freezing rain on Army equipment. Includes simulated free-falling and blowing rain and high-velocity impacts with raindrops. Describes test facilities. Applies to vehicles, equipment, ammunition, small arms, and clothing. Not applicable to large missiles and rockets; to snow, sleet, high humidity, mud, submerging, and swimming; or to slippage of tires on wet roads.

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U. S. ARMY TEST AND EVALUATION COMMAND
DEVELOPMENT TEST II - COMMON TEST OPERATIONS PROCEDURES

AMSTE-RP-702-101
*Test Operations Procedure 2-2-815 19 June 1975

RAIN AND FREEZING RAIN

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SECTION I
GENERAL

1. Purpose and Scope. This TOP describes the procedures for evaluating the effects of rain, hail, splash, and freezing rain on Army equipment. Included are techniques for evaluating the effect of high-velocity impacts with raindrops and the effect of rain on clothing under simulated field conditions. The environments of snow, sleet, high humidity, mud, submerging and swimming are not covered. Rain tests of large missiles and rockets are covered in TOP/MTP 5-2-591.

*This TOP supersedes MTP 2-2-815, 8 Dec 1970.

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2. Background. According to MIL-STD-210B, ground equipment is expected to operate in steady-state rainfalls equivalent to 1.89 inches (48.0 millimeters) per hour. This represents a 0.5-percent risk that a heavier rainfall will be encountered in regions where heavy rainfalls occur. Raindrop sizes will range between 0.5 and 6.4 millimeters with a heavy concentration in the smaller sizes and less than two drops per cubic meter in sizes of 4.5 millimeters or above. MIL-STD-210B also stipulates the maximum rainfalls that items should be able to withstand (being operable immediately afterward but not during the heavy rainfall rate) for periods of 1, 12, and 24 hours. Most significant is the requirement that if the equipment has an expected duration of exposure (EDE) in the field of at least 5 years, the item should be able to withstand an average rainfall of 4.7 inches (119.4 millimeters) per hour for 1 hour with a wind of 110 fps (33 m/s) at 10 feet (3.0 meters) above the ground. This represents a 10-percent risk that a heavier rainfall will occur sometime during the 5-year period. For testing purposes, MIL-STD-810C stipulates raindrops between 0.5 and 4.5 millimeters, a water temperature between 52° and 95° F (11° and 35° C), and a wind of 40 mph (17.9 m/s) that will cause raindrops to impact at angles of up to 45° from the horizontal. The test of MIL-STD-810C, which stipulates rainfall rates up to 5 inches (127.0 millimeters) per hour is in conformance with the rate given for a 5-year EDE in MIL-STD-210B.

The terminal velocity of medium-sized raindrops is about 25 fps (7.6 m/s) while that of very large drops is about 30 fps (9.1 m/s). Terminal velocities can be attained by a free fall of about 32 feet (9.8 meters); 90 percent of terminal velocity can be attained in a 20-foot (6.1-meter) fall (ref. 6, appendix). Medium-sized drops blown by a 35-knot wind may travel up to about 65 fps (19.8 m/s). Direction of fall may range up to about 65° from the vertical, but testing specifications (e.g., MIL-STD-810B) generally state 45°.

Hail is composed of pellets of ice that, under special conditions, fall at the beginning of thunderstorms in hot weather. Their usual shape is somewhat oblately spheroidal and the usual size about 1/4 to 3/4 inch (6 to 19 millimeters) in diameter; occasionally they will reach 2 to 3 inches (51 to 76 millimeters) in diameter.

Freezing rain usually occurs in nature when supercooled (i.e., below 32° F/0° C) droplets freeze upon impingement on a surface. Freezing rain may also occur with droplets slightly above freezing, provided that the rainfall is light and the surface is below freezing. The latter condition is used to simulate freezing rain. AR 70-38 stipulates that rime (granular ice) and glaze (clear ice coating) from freezing rain may be several inches in thickness. Glaze may have a specific gravity as high as 0.85. AR 70-38 also mentions hoarfrost, which is a frozen water condensate such as found on windshields.

3. Equipment and Facilities. Equipment and facilities are covered in the applicable paragraphs of section II.

SECTION II
TEST PROCEDURES

4. Preliminary Activities. Before exposure to the conditions below, the test item is examined to ascertain pretest condition. In the case of equipment, it must be operated to assure satisfactory performance; in the case of ammunition, identical items from the same lot must demonstrate satisfactory functioning.

5. Rain and Blowing Rain. The effects of falling rain generally increase in severity with increase in rate of fall, wind velocity, temperature, and total fall. The significance of raindrop size, once it is above the mist stage, is not firmly established except for fuze sensitivity tests. Some possible effects from free-falling and windblown rain are:

a. Washing away of lubricants, causing disruption motion (e.g., in machine guns).

b. Corrosion.

c. Short circuits or current leakage in electronic and electrical components.

d. Wet explosives and propellants.

e. Crew discomfort from leakage into vehicles and shelters.

f. Contaminated fuels and lubricants.

g. Water in ports or breathers made for passage of air or gases in weapons.

h. Water in recesses, containers, and weapon barrels.

i. Interference with moving parts.

j. Obscured visibility through glass and lenses.

k. Rot, decay, and fungus growth.

l. Added weight.

m. Penetration of engine air intakes.

n. Slippery, hazardous surfaces.

5.1 Rain Test Conditions. For most items of equipment the rain test will follow as closely as facilities permit the rain test of MIL-STD-810C, Method 506.1, Procedure I or Procedure II. Procedure I is a cycling test involving

wind-driven rain and rates of rainfall of 2 ± 0.5 inches (50.8 ± 12.7 millimeters) per hour and 5 ± 1 inch (127.0 ± 25.4 millimeters) per hour. Procedure II, which is a less desirable test used only because of facility limitations, employs a steady-state vertical rainfall of 2 ± 0.5 inches (50.8 ± 12.7 millimeters) per hour. The test item is tilted 45° in various directions to develop the same effect as wind. Both procedures call for 2-hour exposures, with raindrops between 0.5 and 4.5 millimeters and a water temperature between 52° and 95° F (11° and 35° C). With Procedure II however, no wind at all is provided (paras 5.3 and 5.4) in contrast to the cycling of the wind in Procedure I.

Some test items may await the completion of the exposure period before being operated. Most equipment, however, should be operated in the rain, several times if necessary. Vehicle tests include an evaluation of the effectiveness of windshield wipers. In addition, an attempt should be made to estimate the volume of water (milliliters and liters) that enters the vehicle at various points.

When lubricant washaway is a factor, it may be appropriate to test under several conditions of lubrication; e.g., over-lubricated, under-lubricated, and properly lubricated.

For equipment with components that must be watertight, fluorescein dye tracer should be added to the water in the ratio of 50 grams of dye per 250 gallons of water. Visual inspection after exposure is conducted with the ultraviolet light.

Rain test data must contain all details on the rain, including air temperature, water temperature, rates of flow, total volume, droplet size distribution (when practicable), and wind velocities, as well as all of the effects on the test item.

5.2 Rain Test of Vehicles, Equipment, Containers, and Ammunition. The test item is placed in a rain facility in its normal operating position and exposed to rainfall simulating the specified rain environment (5.1 above) as closely as facility limitations permit. For items that cannot be adequately tested with free-falling rain, wind-blowing devices are used to create blowing rain.

5.2.1 Free-Falling Rain Facility. A large, indoor rain facility at Aberdeen Proving Ground is used to provide a free-falling rain environment for both large and small items of equipment. Varied amounts of rainfall up to 24 inches (609.6 millimeters) per hour in an area approximately 300 square feet (27.9 square meters) are obtainable. Droplet size and distribution are regulated by the size of the nozzle used.

Seldom is a rainfall test without wind satisfactory, since rain penetration is influenced by windspeed. Thus, the facility of 5.2.2 below is almost always preferred. For very large items, however, improvised wind, using fans of propellers, can be employed in the free-falling rain facility.

5.2.2 Wind-Driven Rain Facility. Blowing rain can be simulated using a mobile wind-driven rain facility (fig.1). One such facility is located at Aberdeen Proving Ground. This facility is a modified commercial tree sprayer which has been equipped with capillary tubes instead of nozzles for injecting drops of water into the airstream. Droplet size can be regulated from 1 to 4 millimeters. (Reference para 5.1) Rainfall rates from 1 to 25 inches (25.4 to 635 millimeters) per hour can be achieved with wind velocities of 20 to 60 mph (8.9 to 26.8 m/s). An area 6 feet (1.8 meters) in diameter can be covered at a distance of 35 feet (10.7 meters), but the normal distance is 10 to 30 feet (3 to 9 meters) where the coverage is about 4-1/2 to 5-2/3 feet (13.7 to 17 meters) in diameter, respectively.

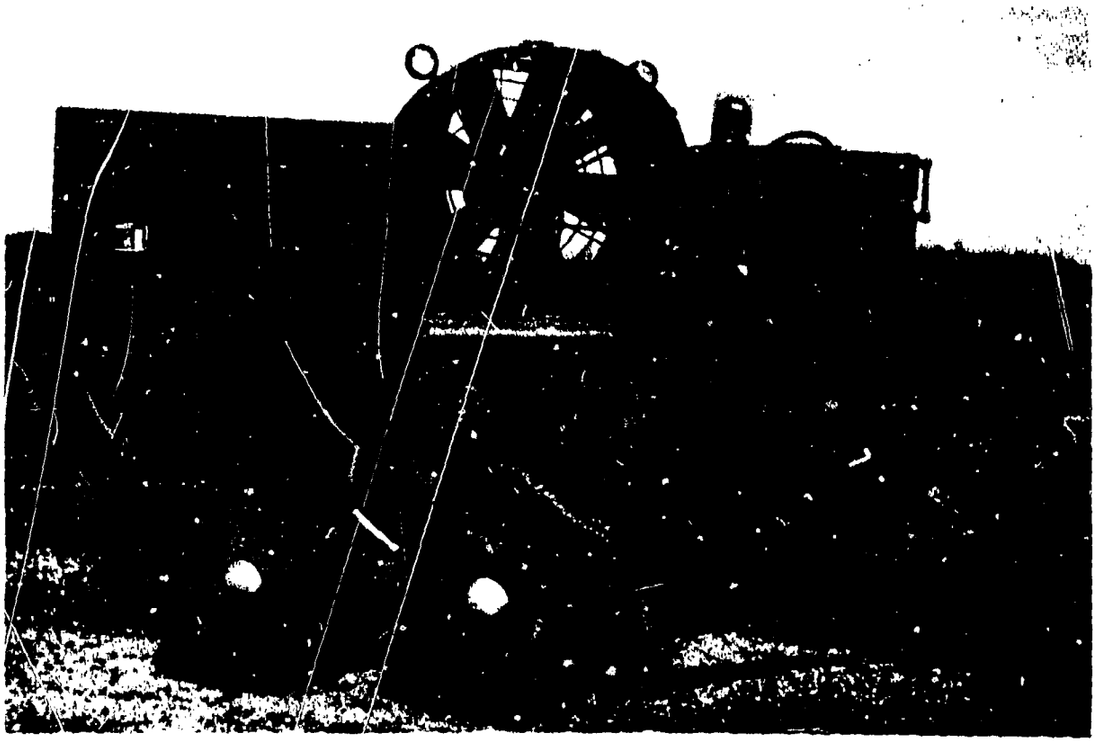


Figure 1. Wind-Driven Rain Facility.

The blower assembly can be pivoted both vertically and horizontally to obtain the desired test position. When using the facility to test large items of equipment, the blown rain is usually directed at areas suspected as being critical. Complete exposure can be achieved by repositioning the facility and repeating the test procedure.

The standard test is a 2-hour test that follows MIL-STD-810C, Method 506.1, Procedure I, except that the wind is blowing for the entire 2 hours.

5.3 Rain Test of Small Arms. The effects of heavy rainfall on small arms can be evaluated in a free-falling rain facility without wind if the expedients of increasing the volume of rain and changing the orientation of the weapon are used to compensate for lack of wind. This method of testing small arms is described in TOP/MTP 3-2-045 and 3-2-059.

Weapons that must be fired either during or after exposure to rain are fired remotely (e.g., lanyard, solenoid, etc.) with personnel adequately protected. When weapon damage occurs during such tests, it is usually desirable to develop in subsequent tests a field expedient procedure that will permit the weapon to be safely fired during rain (e.g., depressing the muzzle and retracting the bolt of a rifle before attempting to fire).

5.4 Rain Test of Clothing. Garments are tested against the effects of wet weather using the outdoor rain course described in TOP 10-2-021. Simulated rainfall of varying intensities from 0.1 to 4.0 inches (2.5 to 101.6 millimeters) per hour can be produced over the course. There is no provision for wind other than that occurring naturally.

6. High-Velocity Impacts with Raindrops. In addition to the effects of rain described in 5 above, the rapid movement of an item through rain may cause the following effects:

a. Erosion (e.g., on very soft-nosed projectiles).

b. Fuze functioning (highly sensitive impact fuzes only).

c. Aggravated washing away of lubricant (e.g., from machine guns on moving helicopters).

6.1 Erosion Tests. Rain erosion tests of projectiles, fuzes, and rockets are conducted on a rocket sled at Holloman Air Force Base, New Mexico. Rainfalls of 2 to 8 inches (50.8 to 203.2 millimeters) per hour over a track length of 6000 feet (1828.8 meters) are readily attainable. The rocket sled can provide velocity profiles that follow the velocity-versus-range curves of the projectile under consideration. Insofar as projectiles are concerned, only high velocity projectiles with soft noses or windshields are considered for erosion tests. Inert projectiles are mounted horizontally side by side, nose forward, to a stand which is attached to the rocket sled in accordance with Holloman's procedures. The array of projectiles will not exceed the width at which uniform rain is obtained. Several runs, with new projectiles each time, are made at velocities to simulate various portions of the trajectory and at several rainfall rates. Following each run, the nose, windshield, and fuze are examined for damage and the implications of the damage assessed.

6.2 Fuze Sensitivity Tests. The sensitivity of fuzes, using plywood and aluminum to simulate raindrops, is covered in TOP/MTP 4-2-806. Fuze sensitivity may also be evaluated in an elongated rain facility. The average number of raindrops that a fuze 1/2 inch (12.7 millimeters) in diameter will strike when passing 100 feet (30.5 meters) through a 4-inch (101.6-millimeter) -per-hour rainfall of 2.8-millimeter-diameter drops is 1.46.

The probability of striking at least one drop is 0.997 when four projectiles are fired under these conditions (ref. 4, appendix). In addition to the track facility mentioned above, Holloman AFB has a firing range, over a portion of which artificial rain with 2.5- and 4.0-millimeter raindrop sizes is provided. This range is used for evaluating the sensitivity of fuzes and can accommodate gun firing of any caliber.

6.3 Airborne Equipment Tests. The impact of rain on equipment mounted to Army aircraft in flight is difficult to simulate realistically because of the high-velocity raindrops that would be required and the washing and suction conditions that exist. Although the forward motion of the aircraft multiplies the effective amount of water per hour that strikes it from the front, this is in part balanced by the likelihood that the aircraft will not fly in a rainstorm for very long. A suitable test is as follows: Blowing rain is aimed at the direct front of the equipment at a minimum of 35 knots (18 m/s) for the entire duration of the rain test. The rates are high - i.e., 8 inches (203 millimeters) or more per hour (measured in a vertical rather than a horizontal plane) - and the test is continued until the equivalent of 40 inches (1016 millimeters) of rainfall is obtained. This would be equivalent to 1 hour traveling at 170 mph (273.5 km/hr) in 4-inch (101.6-millimeter) -per-hour rain measured in the horizontal plane.

7. Hail. Hail may cause many of the effects described in 5 above, and it may also aggravate the erosion and fuze functioning problems mentioned in 6 above. In addition, large hailstones may damage relatively fragile items through shock impact.

Hail will rarely be mentioned in ROC's/DP's. If an item is required to resist the impact of hail, however, a test may be conducted by dropping ice cubes 3/4 to 1 inch (19 to 25.4 millimeters) in size on the test item from 40 feet (12.2 meters). If an impact fuze is required not to function on being hit by hail of a certain size, the hail may be simulated by the technique shown in TOP/MTP 4-2-806.

8. Splash. Vehicles, trailers, and their mounted equipment incur more damage from splash from passing through puddles than from the rain that created the puddles. In particular, splash may wash away lubricants from the underside of the vehicle; enter brake seals, causing brake slippage or seizure; penetrate the interior of the vehicle; affect operation of ignition and other electrical systems; and cause other problems as noted in 5 above. The effects of splash may be complicated by deposits on the ground that contaminate the water; for example, road grime can make windshield wiping ineffective, and salts on the roadway will result in corrosive deposits on the underside of the vehicle. Low-slung equipment or stationary materiel may be mud-splattered by passing vehicles or even raindrops.

Rather than use a splash test, per se, most vehicle tests to determine the effect of water on running gear components are conducted in a fording basin and on a mud course. Effectiveness of windshield wipers and washers can also be evaluated on muddy courses provided that lead vehicles are used to splash the windshield.

Wheeled vehicles may also be tested for effects of splash by repeated passes through water approximately 1/2 inch (12.7 millimeters) deep at speeds up to that which safety permits. The vehicle is frequently braked to determine the effects on the brakes. At the conclusion of the splashing, the vehicle is inspected for leakage and all electrical accessories are tested for operation.

To test tracked vehicles for effects of splash, the water must be deep enough to cover the tracks to permit splashing by both roadwheels and tracks.

To determine the effects of splashing mud, trucks may be used to splash the mud on materiel resting nearby. Occasionally, it may be desirable to place infantry equipment on soft ground in the rain chamber and have the rain splash mud.

9. Freezing Rain. A layer of ice from freezing rain (or from frozen water condensate) deposited on equipment is of concern primarily because of the following potential problems: prevents moving parts, such as a windshield wiper, from functioning; adds weight, causing failure or, as with a radar antenna, bending; reduces clearances, causing effects such as projectile failure to chamber; and produces a safety hazard, as when ice is on a platform.

Freezing rain is produced in a cold chamber into which the icing facility of figure 2 has been placed. The test item is positioned in the icing facility and soaked to 0° F (-17.8° C) until temperature equilibrium is established (about 24 hours for large items). The chamber temperature is then increased to 20° F (-6.7° C) and the icing facility operated to produce a uniform spray of precooled water (35° F/ 1.7° C) at a rate of 1 inch (25.4 millimeters) per hour to cover the top and sides of the test item. When approximately 1/4 inch (6.3 millimeters) of glaze is accumulated, an attempt is made at 20° F (-6.7° C) to operate the test item including all of its accessories. If difficulties are encountered, ice should be broken away or melted with expedients normally available to men in the field. For nonoperating equipment the effect, if any, of the weight of the glaze is appraised.

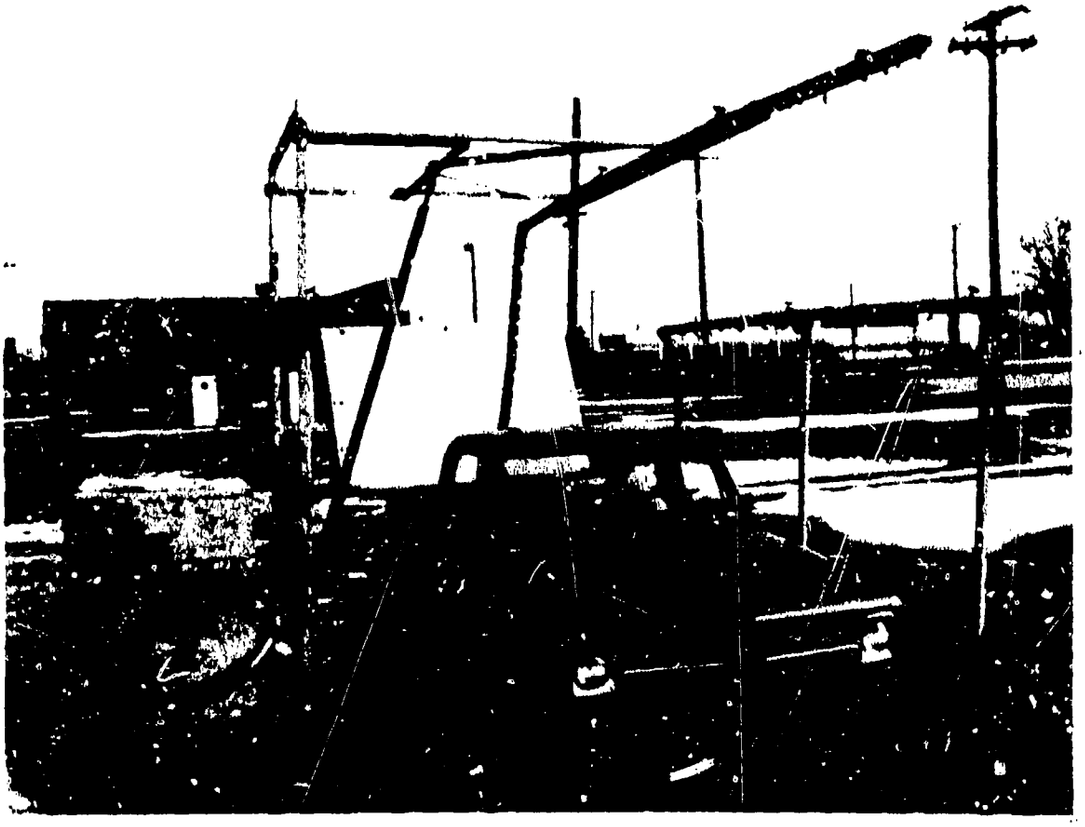


Figure 2. Icing Facility Removed from Cold Chamber.

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APPENDIX
REFERENCES

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