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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Provides a method of evaluating the performance of disintegrating projectiles used for troop practice firings and air defense test firings. Includes safety of handling, storing, firing, and transporting. Describes procedures for calculating probabilities of number and location of projectile pieces that fall.

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US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-103 27 August 1980
Test Operations Procedure 4-2-017
AD No. A088611

DISINTEGRATING PROJECTILES

1. SCOPE. This TOP describes procedures for evaluating the performance of disintegrating (breakup) projectiles which are used for troop practice firings and air defense test firings. These projectiles provide shock, vibration, noise, and smoke of conventional rounds, but do not endanger pilots or aircraft.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENTS
Test site	Area that provides for personnel safety with regard to shelters and minimum distances down range and behind weapon.
Temperature chambers	To condition ammunition to within ±1°C of the extreme temperatures specified.

ITEM (CONT'D)	REQUIREMENTS (CONT'D)
Witness screen	Cloth screen 9 x 30 meters to capture or detect projectile debris traveling beyond demarcation limits.
Drop test facility	As described in TOP/MTP 4-2-601.
Package tester	As described in Appendix D, TOP 4-2-602.
High-speed cameras	16-mm framing camera and 35-mm smear camera for recording tests.

2.2 Instrumentation.

ITEM	MAXIMUM ERROR OF MEASUREMENT*
Weapon pressure-sensing equipment (TOP 3-2-810) or strain gage patches and magnetic tape recorder	Chamber pressure to 100,000 psi (690,000 kPa) ±2%.
Gunner's quadrant M1A1	Weapon tube elevation ±0.4 mil.
Temperature-measuring devices (e.g., thermocouples and recorder)	Weapon tube temperature ±1°C.
Meteorological equipment to measure wind speed and direction, ambient temperature, and relative humidity	0 to 44.7 m/s (±0.8 m/s); ±3°; -35° to +50°C (±0.2°C); and 5% to 100% RH (±1%), respectively.

3. PREPARATIONS FOR TEST.

3.1 Test Site.

a. Defoliate and grade the test site as required to insure fragment recovery. The cleared area should extend at least twice the distance of the expected fragment fallout.

b. Mark off demarcation lines at 100 and 150 meters down range or at other ranges as appropriate for the projectile being tested.

c. Place a witness screen 5 meters beyond the most distant demarcation line.

*Values may be assumed to represent ±2 standard deviations; thus, the stated tolerances should not be exceeded in more than 1 measurement of 20.

3.2 Weapon.

a. Borescope all weapon tubes furnished for the test, in accordance with TOP 3-2-803, and record the condition of the rifling.

b. Gage and record the diameters of the lands and grooves at predetermined distances from the breech face, in accordance with TOP 3-2-802. Measure and record chamber dimensions.

c. Inspect critical weapon components such as breechblock assemblies, feed pieces and feed-piece levers, pistons and carrier blocks, trigger blocks, and barrel assemblies for cracks and peening. The various nondestructive methods of inspection used for determining the presence and extent of defects are described in TOP 3-2-807. The most commonly used is the magnetic particle inspection.

3.3 Ammunition.

a. Inspect each test item for damage and defective or missing parts.

b. Check and compare model and lot numbers with the infomation on the ammunition data card.

c. Place internal pressure gages (TOP 3-2-810) in all rounds to be used for chamber pressure measurement before loading.

3.4 Instrumentation.

a. Instrument the weapon to measure chamber pressure versus time, in accordance with TOP 3-2-810. If this instrumentation cannot be used, mount strain gage patches over the chamber portion of the weapon tube and electrically connect them to a magnetic tape recorder.

b. Attach thermocouples to the outside surface of the weapon tube to measure the thermal response of the tube to firing.

c. Position a smear camera to record projectile debris at a point 6 meters from the muzzle.

d. Position high-speed framing cameras to record flash and smoke at the muzzle and projectile debris at the downrange witness screen.

e. Mount a gunner's quadrant on the weapon to measure the tube elevation.

3.5 Data Required. Record the following:

a. Weapon tube identification number.

b. Cartridge lot number

c. Bore inspection data

d. Date of test

e. Ambient air temperature

4. TEST CONTROLS.

a. Review all instructional material (including system support packages) issued with the test item, and review reports of previous tests on similar items.

b. Review the safety statement provided by the developer to determine whether any hazards have been identified. If hazards do exist, write the test plan to include subtests suitable for evaluating them.

c. Make sure applicable Standing Operating Procedures (SOPs) are available at the test site. Observe SOPs during testing.

d. Make sure all personnel involved in testing are thoroughly familiar with provisions of pertinent SOPs and are fully capable of implementing them before any testing is begun.

e. Record both surface and aloft meteorological data (TOP/MTP 3-1-003) immediately before firing, and at least every hour while firing is in progress. When the maximum ordinate is below 300 meters, record surface meteorological data for each round fired.

f. Restrict firings to times when winds are below 5 m/s.

5. PERFORMANCE TESTS. In the past, disintegrating projectiles have consisted mostly of iron or tungsten particles/granules encased in a plastic body. When the projectile is fired, centrifugal force causes the granules to break out of the plastic body and fall to the ground within a short distance (about 90 meters). Disintegrating projectiles break up of their own accord without the use of an explosive charge; they are of various sizes, two of which are the 20 mm and the 57 mm. The 20-mm projectile resembles a peeled banana after firing, while the more brittle 57-mm projectile entirely disintegrates when fired.

Disintegrating projectiles were developed for testing weapons (e.g., air defense) and for training troops when the down-range safety area is very short or the target must not be hit (such as aircraft).

5.1 Method. The test is mainly a safety evaluation in accordance with TOP 4-2-504, modified to add rounds to evaluate down-range safety. This test provides the testing activity with sufficient information to recommend that a safety release be issued by TECOM.[1/] Unless otherwise specified, temperature extremes of -33°C and +63°C (basic cold and hot-dry climates of AR 70-38) are adequate in consideration of the possible limited environmental exposure of the cartridges from the time of manufacture to the time of expenditure.

Since the projectile design produces metal particle fallout, gunners and other personnel near the weapon during firing are required to wear ear protectors and goggles. The weapon must be inspected frequently during testing for indications of excessive wear or damage to weapon mechanisms due to metal granule fallout.

If a nonfired round remains in the chamber when firing ceases, care must be taken when extracting the round to ensure that the projectile has not remained in the bore. If the projectile has ruptured, examine the weapon to ensure that none of the metal particles is embedded in the mechanism. Firing should not be attempted when metal particles are in the weapon mechanism.

Place the witness screen at a fixed distance from the muzzle, based on requirements documents (for 20 mm and 57 mm, usually 100 meters). Any fragment discovered at or beyond the witness screen should be measured and recovered.

5.1.1 Propellant Compatibility and Checkout. Test the propelling charge and projectile combination for compatibility with the pressure limits of the weapon as follows:

a. Fire 10 rounds loaded to the assessed propelling charge, and conditioned to 63°C. The average pressure must be below the weapon design pressure by three standard deviations. If the assessed charge fails to meet this restriction, assess new charges until an acceptable one is found.

b. Fire 10 rounds loaded to the final assessed charge, and conditioned to -33°C. Use these rounds as a baseline for the remainder of the safety tests.

5.1.2 Systems Compatibility. Test the ammunition to ensure that it is compatible with the weapons system. Fire 10 rounds at 21°C, measuring recoil pressures and cycle times to determine that they are within limits. Examine the weapon for unusual wear or damage, e.g., damage to a muzzle brake.

If the system is an automatic weapon, the rounds should be fired at the maximum cycle rate to ensure that they will cycle the weapon and withstand the forces associated with automatic feed.

[1/] DARCOM-R 385-12 with TECOM Suppl 1, Life Cycle Verification of Materiel Safety.

5.1.3 Safety During Handling, Storage, Transport, and Firing. Conduct a safety test in accordance with the basic guidelines of TOP 4-2-504 (Table B-III, Nonexplosive Projectile Category) and as described in the subtests below to provide a reasonable assurance that the test items can be handled, stored, transported, and fired with minimal risk to personnel. It is assumed that the basic cold and hot-dry conditions of AR 70-38 are specified.

To conserve ammunition, conduct the firing phase of each subtest in accordance with the firing conditions of the down-range safety test (see 5.1.5 below), and use the resulting data for both the safety subtests and the down-range safety test.

a. Secured Cargo Vibration. Subject a portion of the rounds to be fired in a safety test phase to a laboratory vibration test simulating the mode of transportation that the test item will probably encounter in use. Condition 20 test rounds to 63°C and 10 test rounds to -33°C. Securely fasten the test rounds in their shipping configuration to the vibrator, and vibrate them in the transverse and longitudinal planes. (Schedules of vibration rates and durations are contained in TOP 1-2-601, and an explanation of laboratory vibration techniques is contained in TOP 1-1-050.) Following vibration, inspect the rounds (X-ray as appropriate); then fire them at the conditioned temperatures as described in Paragraph 5.1.5.

b. Storage. Store the test rounds in both the packaged and loose configurations at each extreme temperature; then fire them to evaluate the effects of storage on round functioning. For cold temperature storage, soak 10 packaged rounds for 3 days at -33°C. For high temperature storage, store 10 packaged rounds in accordance with the high-temperature high-humidity schedule in TOP 4-2-820.

c. Rough Handling. Subject the test rounds to the 2-meter (7-foot) packaged drop, the loose cargo test, and the 1.5-meter (5-foot) unpackaged drop, as described in TOP 4-2-602. Nominal sample sizes are 40 at -33°C and 40 at 63°C. Sample sizes may vary, depending on packaging configuration. Firing of rounds will be according to Paragraph 5.1.5.

d. Worn Tube. For this subtest, the normal requirements of TOP 4-2-504 are expanded. Fire 40 rounds conditioned to 63°C through each of two worn tubes having different wear characteristics: one tube worn extensively in the chamber area (characteristic of tubes worn through firing high-explosive ammunition) and one tube worn extensively down bore (characteristic of tubes worn through firing breakup ammunition). Fire according to Paragraph 5.1.5.

5.1.4 Noise. Record sound pressure levels during representative firing operations in accordance with TOP 1-2-608 and MIL-STD-1474A, Noise Limits for Army Materiel.

5.1.5 Down-range Safety. Test the rounds for proper disintegration of the projectile when fired as follows:

a. Prepare the test site, weapon, and instrumentation as required in Paragraph 3.

b. Fire the test round in the automatic mode in bursts of 3 to 6 rounds, using Table 1.

c. For 0° elevation firings, aim the weapon at the center of the 9- by 30-meter screen. For firings at 30° and 40° quadrant elevations, aim the weapon over the center of the screen.

d. After firing each group of rounds, physically search the area between 100 and 300 meters down range, and record the nature and location of any debris found, removing the debris before each subsequent firing.

e. Inspect (TOP 3-2-803) and measure (TOP 3-2-802) the weapon bore after every 100 rounds of firing.

Table 1. Typical Firing Schedule

Group	No. of Rounds	Firing Temperature		Weapon Elevation	Phase
		°F	°C		
1	As applicable	70	21.1	0°	Acceptance test [a/]
2	70	-50	-33	0°	Safety tests (para 5.1.1)
3	160	145	62.8	0°	Safety tests (para 5.1.1)
4	25 [b/]	0	-17.8	30°	Breakup performance
5	25 [b/]	0	-17.8	40°	
6	55 [b/]	0	-17.8	0°	
7	25 [b/]	145	63	30°	
8	25 [b/]	145	63	40°	
9	55 [b/]	145	63	0°	

a/ If a requirement exists for conducting acceptance tests and firing conditions permit, use the firing data from these tests to provide increased confidence.

b/ Sample size used for each test phase and condition is based on expected variations between specimens, availability of the test item, and confidence level desired in test results (TOP/MTP 3-1-002).

5.2 <u>Data Required</u>. Record the following:

a. Test phase and time of firing.

b. Test round numbers.

c. Ammunition temperature.

d. Chamber pressure.

e. Length of recoil.

f. Location and nature of each piece of projectile debris recovered on ground.

g. Location and size of holes in the witness screen.

h. Measurement data in accordance with TOPs 3-2-802 and 3-2-803.

i. Sound pressure level data in accordance with TOP 1-2-608 and MIL-STD-1474A.

j. Meteorological data.

k. Cyclic rate.

6. DATA REDUCTION AND PRESENTATION.

a. Tabulate all data.

b. Compare chamber pressure data with that of the conventional round. Pressure should match conventional round pressure.

c. Compute average pressure and standard deviation for each test temperature to determine temperature effect (if any) on propellant performance.

d. Plot tube wear as a function of location within the bore and rounds fired, and determine the down-bore wear rate of each 100 rounds.

e. From the measured distances of pieces recovered beyond to 100-meter distance, derive estimates on a per-round basis of the probability that no piece will fall beyond a specified distance. It can be assumed that the number of pieces at points exceeding a specified distance is a Poisson random variable. The parameter would be the average number of pieces per round. Since more than one distance (between 100 and 150 meters) is being considered, it is necessary to form an empirical cumulative distribution and calculate the average number of pieces per round exceeding specified distances. From these limits, calculate lower 99% confidence limits for the probability that no piece exceeds a specified distance.

Since breakup characteristics of each design cartridge will probably differ, the analysis will be a function of the characteristics for that specific design and caliber.

A more detailed discussion of the calculation procedure is given in Appendix A. The selection of the distances is somewhat arbitrary, and the limits are empirical; i.e., based on the number of data points falling beyond these distances. The table provides data for the attached graph.

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APPENDIX
USE OF POISSON DISTRIBUTION

The probability density function for the Poisson random variable x is given as

$$e^{-\lambda} \lambda^{x}/x! \qquad x = 0, 1, \ldots.$$

The cumulative distribution function is given as

$$P(\underline{\overline{X}} \leq k) = \sum_{j=0}^{k} e^{-\lambda} \lambda^{j}/j!$$

Applying this distribution to the projectile recovery problem:

Suppose we observe k pieces beyond some distance d after firing n rounds. The point estimate of the Poisson parameter λ is

$$\hat{\lambda} = k \quad \text{pieces per n rounds} \tag{1}$$

The upper 100 γ% confidence limit on λ is obtained from

$$\sum_{j=0}^{k} e^{-\lambda_u} \lambda_u^{j}/j! = 1 - \gamma \tag{2}$$

by reference to standard cumulative Poisson tables.

The Poisson parameter may be scaled and the distribution is still Poisson. This enables us to scale the estimates to a per-round basis; i.e.,

$$\hat{\lambda}/n = \text{point estimate, pieces per round} \tag{3}$$

$$\lambda_u/n = \text{upper limit, pieces per round.} \tag{4}$$

The probability that m or fewer pieces per round exceed distance d is given by

$$\hat{P}(\underline{\overline{X}} \leq m) = \sum_{j=0}^{m} e^{-\hat{\lambda}/n} \left(\frac{\hat{\lambda}}{n}\right)^{j}/j! \tag{5}$$

$$P_1(\underline{\overline{X}} \leq m) = \sum_{j=0}^{m} e^{-\lambda_u/n} \left(\frac{\lambda_u}{n}\right)^{j}/j! \quad \text{(lower confidence limit)} \tag{6}$$

If $m = 0$, $\hat{p} = e^{-\hat{\lambda}/n}$ and $P_1 = e^{-\lambda_u/n}$.

Example:

Suppose 11 pieces of debris were found to exceed 120 meters during the firing of 510 cartridges. The point estimate and the upper 99% confidence limit on the number of pieces per round and the lower 99% confidence limit on the probability that no pieces exceed 120 meters are to be calculated.

$$\hat{\lambda} = k = 11 \text{ pieces per 510 rounds}$$

$$\sum_{j=0}^{11} e^{-\lambda u} \lambda u^j/j! = 1 - \gamma = 0.01.$$

Reference to the cumulative Poisson tables with the number of occurrences equal to k + 1 = 12 and cumulative probability equal to 0.01 gives

$$\lambda u = 21.490 \text{ pieces per 510 rounds.}$$

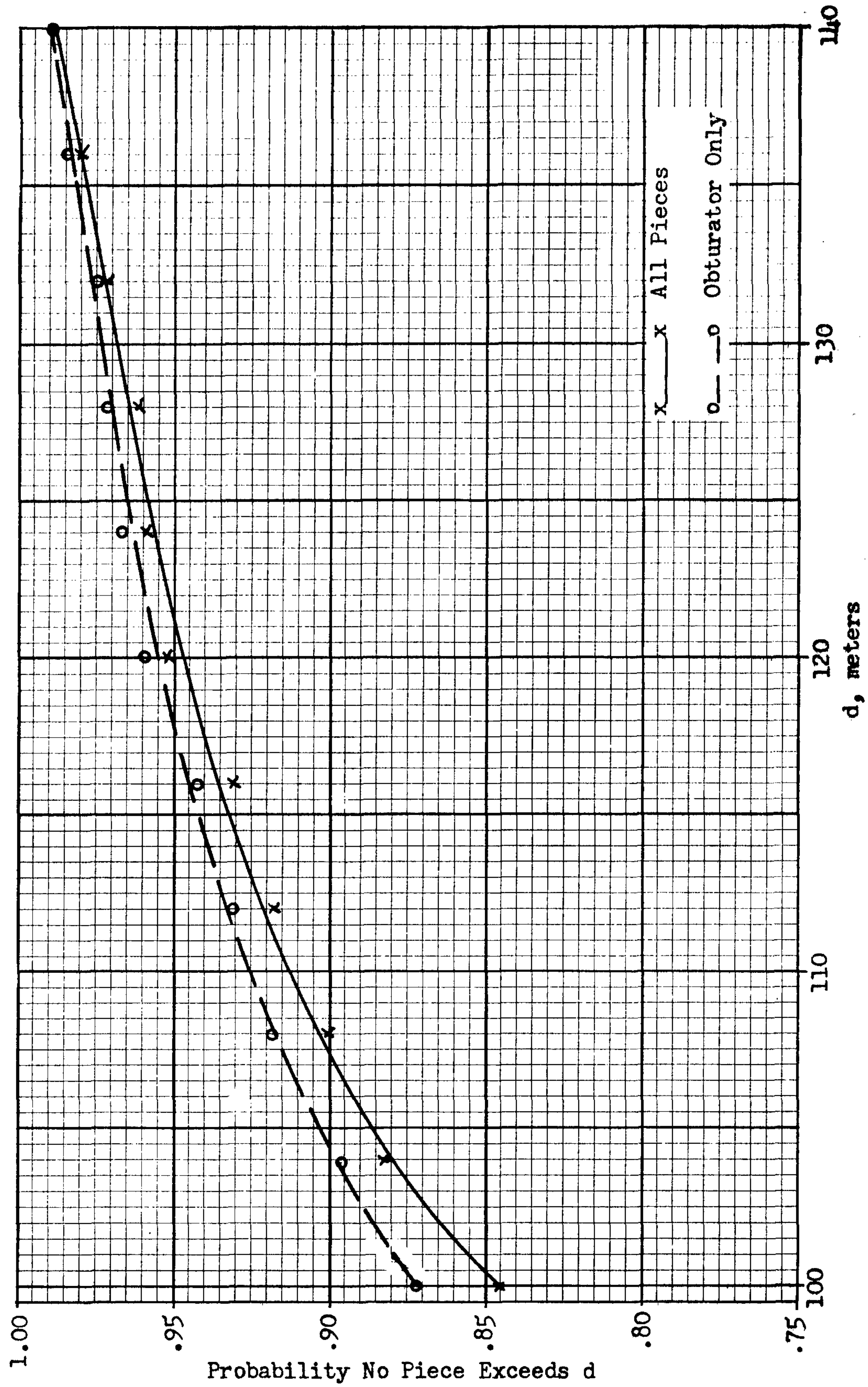
$$\frac{\hat{\lambda}}{n} = \frac{11}{510} = \underline{0.0216} \text{ pieces per round}$$

$$\frac{\lambda u}{n} = \frac{21.490}{510} = \underline{0.0421} \text{ pieces per round}$$

$$P(\overline{X} \leq m) = \sum_{j=0}^{m} e^{-\lambda/n} (\lambda/n)^j/j! = e^{-\lambda/n}, \text{ for } m = 0$$

$$\hat{P} = e^{-\hat{\lambda}/n} = e^{-0.0216} = \underline{0.9787}$$

$$P_1 = e^{-\lambda u/n} = e^{-0.0421} = \underline{0.9588}$$



Empirical 99% Confidence Limit (Lower) on Probability (No Piece Exceeds Distance d).