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

Test Operations Procedure (TOP) 3-2-051 31 March 1994
AD No.

AUTOMATIC LOADERS FOR TANK SYSTEMS

1. SCOPE. This TOP provides procedures for safety testing and evaluation of developmental and production autoloaders for tank systems. The purpose of this TOP is to provide uniform guidance for evaluating the safety and performance of an autoloader and the effect the autoloader has on the integrity of the handled ammunition. A complete evaluation is based on physical test, safety analysis and evaluation of potential hazards, and observation of performance. Procedures include baseline shock and vibration, subsystem shock and vibration, subsystem ammunition handling shock and vibration, system safety evaluation, steady-state noise, system ammunition handling, and performance of handled ammunition.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Automotive Test Courses	As described in TOP 1-1-011[a*] or to suit test requirements.
Laboratory Vibration Exciter	As described in ITOP 1-1-050[1].

*Superscript letters/numbers correspond to those in Appendix A, References.

Item	Requirement
Industrial X-ray Facility	To perform radiographic inspection to applicable specifications for material tested.
Firing Range	Selected to suit test requirements and to provide adequate protection for personnel and equipment.
Temperature Chambers	To condition ammunition to the appropriate conditions for firing.

2.2 Instrumentation.

Devices for Measuring	Measurement Accuracy
Meteorological Conditions	As required
Shock and Vibration (guidance in ITOP 1-1-050)	As required
Projectile Velocity (guidance in ITOP 4-2-805[2])	±0.15% of reading
Impact Coordinates	±0.50 projectile diameter; typically ±25 mm
Weapon Elevation	±0.05 mil in accuracy; ±0.02 mil in repeatability
Muzzle Movements	±0.1 mil
Steady-State Noise	±2 dB from 25 Hz to 10 kHz
Time	±1 sec

3. REQUIRED TEST CONDITIONS.

3.1 Test Planning.

The following subtests outlined in paragraph 4 provide technical and user testing for an autoloader in a tank system. The subtests are segregated into two categories: those subtests to be conducted with the autoloading system separate from the vehicle, and those subtests conducted with the autoloading system integrated with the vehicle.

3.1.1 Initial Inspection.

a. Inspect vehicle in accordance with technical manuals and perform all Preventative Maintenance Checks & Services (PMCS) as required.

b Inspect autoloader in accordance with technical manuals and perform PMCS.

c. Inspect ammunition lot both visually and radiographically and reject items that fail applicable ammunition serviceability criteria (guidance per TOP 9-2-305[3]).

3.2 Vibration Schedules.

The vibration schedules are developed to replicate realistic scenarios that will affect the system. The vibration environment is segregated into two categories: vibration encountered by material during logistic transportation and shipment as cargo, and vibration encountered by material during tactical operation. ITOPs 1-2-601[4] and 1-1-050 contain the guidelines for developing the proper scenarios.

3.3 Firing Preparations.

Preparations for determining the performance of the handled ammunition follow guidelines established in ITOPs 3-2-605[b] and 4-2-829[c].

4. TEST PROCEDURES.

The following are subtests which are recommended guidance for technical and user testing for a generic autoloading system. The subtests are divided into two categories as applicable; those subtests to be conducted with the cell/magazine separate from the vehicle and the subtests to be conducted with the autoloading system installed in the vehicle.

4.1 Initial Vibration/Shock Determination.

The objective of this test is to obtain data required to develop realistic vibration/shock schedules. These data are to be collected on an early or prototype vehicle using accelerometers mounted in the cell and magazine. "Completely inert" ammunition is to be used in the magazine.

4.1.1 Method.

a. Attach triaxial accelerometers to the ammunition and structural members of the magazine and the cell. The vibration and shock will be measured along the vertical, transverse, and longitudinal axes (guidance per ITOP 1-1-050).

b. Use minimum hazard ammunition. Ammunition is to be representative in weight and center of gravity of actual combat load.

c. Operate the vehicle over various types of terrain which include bump, serpentine, and gravel at speeds of 5 km/hr to maximum safe speeds in 5 km/hr increments. Guidelines are provided in TOPs 2-2-808[5] and 1-1-011.

Recommended Test Courses

Paved road
Gravel road
Cross-country
6-inch washboard

Safe speeds are determined by vehicle operational guidelines, test course operational guidelines, and guidelines stated in TOP 2-2-808.

4.1.2 Data Required.

a. Course type.

b. Course conditions.

c. Speed, km/hr.

d. Test duration.

e. Triaxial accelerations over time.

f. Visual and nondestructive inspections.

g. Vehicle operational checks.

h. Potential safety hazards.

4.2 Cell Vibration/Shock Test.

The objectives of this test are: to establish the resonant natural frequencies of the ammunition being vibrated in its normal state in the cell; to determine whether the ammunition is sufficiently supported to prevent degradation during simulated vehicle operation; and to verify individual cell structure design strength.

4.2.1 Method.

a. A vibration fixture shall be designed by utilizing the actual cell, panels, and platform structures of the vehicle to minimize introduction of nonrepresentative responses to the sample (guidance per ITOP 1-2-601). Inspect the cell visually and perform other nondestructive tests as required.

The vibration fixture is then mounted appropriately to the vibration table.

b. Inspect the ammunition sample visually and radiographically, and perform other nondestructive examinations as required (guidance per TOP 9-2-305).

c. Attach accelerometers and strain gages to the selected ammunition sample. Place the instrumented ammunition samples into the vibration fixture and simulate the proper configuration, attitude, and restraint of the ammunition cell. Attach accelerometers and strain gages to the cell in the vibration fixture.

d. Select the schedule for vibration excitation through the vertical, transverse, and longitudinal axes based on results obtained from paragraph 4.1. ITOP 1-2-601, Appendix C contains vibration schedules. Duration should reflect actual mission scenario. Perform shock and vibration testing based on guidance provided in ITOP 1-1-050, Appendix C, Uniformity of Laboratory Vibration Testing.

e. Completion of the vibration testing will be followed by re-examination of the ammunition. Inspect the ammunition sample visually and radiographically, and perform other nondestructive examinations as required.

f. The cell structure and ammunition lock and support points are to be verified for strength of design. Inspect the cell visually and perform other nondestructive tests as required (guidance per TOP 9-2-305).

A determination must be made whether the autoloader environment is more or less severe for the various types of ammunition than previous environments under which the ammunition has already been tested for other systems. The means by which the cartridge is supported and handled as well as the amplitude and frequency of the shock and vibration are to be considered. If the environment is more severe, then it is necessary to test all ammunition types which are to be fielded with the system.

4.2.2 Data Required.

a. Inspection results before and after vibration tests.

b. Vibration schedules selected.

c. Scenario developed for determining schedules and durations.

d. Orientation of test item during vibration.

e. Test duration.

f. Potential safety hazards.

g. Acceleration and strain measurements.

h. Results of nondestructive tests.

4.3 Magazine and Ammunition Handling System Vibration/Shock Test.

The configuration to be vibrated depends on the capability to remove system components and operate them independent of the vehicle. The objectives of this test are to:

a. Verify that the magazine and all components will withstand a predetermined amount of simulated vehicle operation.

b. Determine that the autoloader can function properly while being vibrated.

c. Determine the subsequent performance of all types of ammunition after being subjected to a vibration/shock environment while in an autoloader.

4.3.1 Method.

a. A vibration fixture shall be designed by utilizing the actual magazine and ammunition handling system, panels, and platform structures of the vehicle to minimize introduction of nonrepresentative responses to the sample (guidance per ITOP 1-2-601). Inspect the magazine and ammunition handling system visually and perform other nondestructive tests as required. The vibration fixture is then mounted appropriately to the vibration table.

b. Inspect the ammunition sample visually and radiographically, and perform other nondestructive examinations as required (guidance per TOP 9-2-305). Inert or minimum hazard ammunition should be used initially.

c. If applicable, place the magazine and ammunition handling system onto the vibration fixture simulating the proper configuration, attitude, and restraint of the system. Upload the magazine with the ammunition sample. Attach accelerometers and strain gages to the magazine and ammunition handling system.

d. Select the schedule for vibration excitation through the vertical, transverse, and longitudinal axes based on results obtained from paragraph 4.1. ITOP 1-2-601, Appendix C contains vibration schedules. Duration should reflect actual mission scenario. Perform shock and vibration testing.

e. Operate magazine and ammunition handling system during vibration schedules. Operation time of the magazine and ammunition handling system should reflect actual mission scenario. Observe magazine and ammunition handling system in operation and note any misalignment or malfunction during the loading sequence.

f. Completion of the vibration testing will be followed by re-examination of the ammunition. Inspect the ammunition sample visually and radiographically, and perform other nondestructive examinations as required. Verify that ammunition is serviceable.

g. The magazine and ammunition handling system, lock and support points are to be verified for strength of design. Inspect the magazine and ammunition handling system visually and perform other nondestructive tests as required.

h. Determine performance characteristics (velocity profile, jump, and dispersion) of all test ammunition handled by the autoloader. Fire all affected test ammunition using procedures as described in ITOPs 3-2-605 and 4-2-829. Compare performance data of handled test ammunition with control ammunition lot. Refer to ITOP 4-2-602[6] for additional guidance.

All ammunition types which are to be fielded with the system must be exposed to the vibration/shock environment (as determined above) and have performance verified.

4.3.2 Data Required.

a. Inspection results before and after vibration tests.

b. Vibration schedules selected.

c. Scenario developed for determining schedules and durations.

d. Orientation of test item during vibration.

e. Test duration.

f. Potential safety hazards.

g. Performance characteristics of handled test ammunition.

4.4 System Safety Evaluation.

The purpose of this test is to perform a mechanical, electrical, and chemical safety inspection with the autoloader integrated in the vehicle. The system safety study is to include an evaluation which will verify that proper interlocks are incorporated to prevent personnel injury or system damage in the event of a system failure during ammunition handling. Any discrepancy which does not comply with standard safety practices is to be recorded.

4.4.1 Method.

a. Perform an initial evaluation of potential hazards, examinations, and limited tests to certify the system is safe for testing in the vehicle

(TOP 3-2-503[7]). Review developer's safety assessment report (SAR) prior to initiation of test operations. The SAR is used as preliminary reference in the hazard evaluation.

(1) Evaluate safety interlocks.

(2) Evaluate manual overrides.

(3) Develop misfire procedures.

b. Evaluate the following hazards based on the checklists in TOP 1-1-060[8], Appendix A.

(1) Mechanical.

(2) Electrical.

(3) Chemical.

(4) Health.

(5) Fire.

(6) Explosive.

(7) Procedural.

(8) Software.

c. Observe the system throughout all phases of testing and identify and investigate any actual or potential hazards to personnel and equipment.

d. Investigate the safety of the system through "fault insertion". Predetermined faults are to be introduced into the system's operation in an effort to evaluate the ability of the system to maintain safe operation. The faults may be inserted by disconnecting status switches or by inserting faults in the software. The fault selection should be based on the logic flow diagram of the software/hardware interlocks.

4.4.2 Data Required.

a. Potential or actual hazards.

b. Classify all hazards in accordance with AR 385-16[9] and MIL-STD-882B[10].

c. Include data from measured conditions.

d. Include photographs or video to clarify hazards.

4.5 Steady-State Noise.

The objective is to determine the steady-state noise levels of the autoloader system when operating. The decibel levels recorded are to be compared with those in MIL-STD-1474[11] to determine the level of hearing protection required for safe operation.

4.5.1 Method.

a. Place microphones at all crew positions at the center of the probable head position (guidance per TOP 1-2-608[12]).

b. Operate autoloader with inert rounds while vehicle is stationary without operation of engine or any other auxiliary equipment that is unnecessary.

c. Operate the vehicle over paved test course in 10 km/hr increments to maximum safe speed. Operate autoloader and any auxiliary equipment during these test runs.

4.5.2 Data Required.

a. Meteorological data.

b. Test site conditions.

c. Test item condition.

d. Microphone locations.

e. Sound levels in dB(A), dB(C), and in each octave band with center frequency of 63 to 8000 Hz.

4.6 Loading Cycle and Ammunition Handling Test. The objectives of this test are to:

a. Verify the integration of the autoloader in the vehicle.

b. Determine if there is any instability or alignment problems during the load/unload cycle of the autoloader while the vehicle is moving.

c. Verify the ammunition storage and retrieval systems' abilities to maintain a record of round type and location.

d. Determine that the autoloader will load/unload/transfer ammunition without degrading the integrity of the round.

The vehicle will perform these tests at different hull attitudes.

4.6.1 Method.

a. Inspect the ammunition sample visually and radiographically, and perform other nondestructive examinations as required.

b. Attach triaxial accelerometers to the structural members of the magazine and the cell. The vibration and shock will be measured along the vertical, transverse, and longitudinal axes (guidance per ITOP 1-1-050).

c. Install video cameras to record operation of the autoloader.

d. The system is to load and unload ammunition with the vehicle stationary at various pitch angles (maximum $\pm 30°$) and cant angles (maximum $\pm 20°$). The subtest is to be repeated five times at 5° increments with all ammunition types utilizing both a full and partial complement of ammunition.

e. The system is to load and unload ammunition with the vehicle moving over bump, gravel and serpentine courses in 5 km/hr increments to maximum safe speed. The subtest is to be repeated five times for both a full and at 1/2 and 1/4 complement of ammunition and at each speed increment.

f. Inspect the ammunition sample visually and radiographically, and perform other nondestructive examinations as required. Verify that ammunition is serviceable (i.e., no damaged or loose sabots, crimp not loose, projectile still tight, primer not loose, etc.).

g. Verify that the ammunition storage and retrieval systems have the ability to transfer various round types and maintain a record of each round type and its location.

h. Determine performance characteristics (velocity profile, jump, and dispersion) of all test ammunition handled by the autoloader. Fire all affected test ammunition using procedures as described in ITOPs 3-2-605 and 4-2-829. Compare performance data of handled test ammunition with control ammunition reference lot.

All ammunition types to be fielded with the system are to be considered. Inert ammunition is to be used initially followed by service ammunition.

4.6.2 Data Required.

a. Course Type.

b. Course Conditions.

c. Speed, km/hr.

d. Test duration.

e. Triaxial accelerations.

f. Inspection results before and after test.

g. If applicable, the accuracy with which the gun returns to the load position will be measured using a gunner's quadrant (±0.05 mil) or other means. The gun lock will be verified that it is properly aligned and engaged.

h. The time duration of the individual steps of the loading and unloading sequences. This can include:

(1) The time required for the gun to move from maximum and typical gun elevations to the load position and return.

(2) The time required for the ammunition cell to cycle and the round to be loaded.

(3) The time required for the loading and unloading of the gun by the rammer mechanism.

i. Observed system misalignment, failures, round type designation, and potential failures.

j. Potential hazards.

k. Performance characteristics of handled ammunition.

5. PRESENTATION OF DATA.

Summarize data obtained during testing using narration, tables, photographs, video, charts, and graphs as appropriate. Respective TOPs referenced in the Test Procedure will also describe and explain proper presentation of data. Evaluate compiled data on the basis of system safety hazard analysis. Review cause and effect relationships of failures and other test incidents (TOP 1-1-012[13]). Explain system interfaces and associated safety implications.

APPENDIX A REFERENCES

1. FR/GE/UK/US ITOP 1-1-050, Development Of Laboratory Vibration Test Schedules, 14 May 1993.

2. FR/GE/UK/US ITOP 4-2-805, Projectile Velocity and Time of Flight Measurements, 29 November 1991.

3. US TOP 9-2-305, Radiographic Equipment Set, 26 January 1973.

4. FR/GE/UK/US ITOP 1-2-601, Laboratory Vibration Schedules, 19 October 1992.

5. US TOP 2-2-808, Field Shock and Vibration Tests of Vehicles, 1 October 1981.

6. FR/GE/UK/US ITOP 4-2-602, Rough Handling Tests, 19 October 1993.

7. US TOP 3-2-503, Safety Evaluation of Fire Control Systems - Electrical and Electronic Equipment, 14 September 1982.

8. US TOP 1-1-060, Systems Safety Engineering, 7 April 1986.

9. AR 385-16, System Safety Engineering and Management, 3 September 1985; DARCOM Supplement 1, 22 January 1982; TECOM Supplement 1, 11 June 1982; APG Supplement 1, 5 January 1983.

10. MIL-STD-882B, System Safety Program Requirements, 30 March 1984.

11. MIL-STD-1474, Noise Limits for Military Materiel, 8 March 1991.

12. US TOP 1-2-608, Sound Level Measurements, 17 July 1981.

13. US TOP 1-1-012, Classification of Deficiencies and Shortcomings, 3 December 1985.

REFERENCES FOR INFORMATION ONLY

a. US TOP 1-1-011, Vehicle Test Facilities at APG, 6 July 1981.

b. FR/GE/UK/US TOP 3-2-605, Accuracy Firing of Tank Weapons, 23 October 1992.

c. FR/GE/UK/US ITOP 4-2-829, Vertical Target Accuracy and Dispersion, 23 October 1992.

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Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to Commander, U.S. Army Test and Evaluation Command, ATTN: AMSTE-CT-T, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: Commander, U.S. Army Combat Systems Test Activity, ATTN: STECS-PO-I, Aberdeen Proving Ground, MD 21005-5059. Additional copies are available from the Defense Technical Information Center, Cameron Station, Alexandria, VA 22314-6145. This document is identified by the accession number (AD No.), printed on the first page.