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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER TOP 4-2-012	2. GOVT ACCESSION NO. AD-A126789	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) US ARMY TEST AND EVALUATION COMMAND TEST OPERATIONS PROCEDURE "MORTAR AMMUNITION"		5. TYPE OF REPORT & PERIOD COVERED Final 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US ARMY ABERDEEN PROVING GROUND (STEAP-MT-M) ABERDEEN PROVING GROUND, MARYLAND 21005		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DARCOM-R 310-6
11. CONTROLLING OFFICE NAME AND ADDRESS US ARMY TEST AND EVALUATION COMMAND (DRSTE-AD-M) ABERDEEN PROVING GROUND, MARYLAND 21005		12. REPORT DATE 7 April 1983 13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ammunition
Mortars
Mortar Systems

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

Describes procedures for testing and evaluating mortar ammunition to ensure compliance with requirements documents. Includes accuracy and dispersion, fuze sensitivity, safety testing, reliability, human factors, logistic supportability, and fragmentation.

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Enclosure 1

US ARMY TEST AND EVALUATION COMMAND
TEST OPERATIONS PROCEDURE

DRSTE-RP-702-103
*Test Operations Procedure 4-2-012 7 April 1983
AD No.

MORTAR AMMUNITION

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Appendix A. REFERENCES A-1

1. SCOPE. This TOP describes procedures for testing and evaluating mortar ammunition to ensure compliance with requirements documents. These procedures can be used as a basis for writing a test plan for DT II or other type of test. The test director selects those applicable to the particular test requirements. Requirements documents may not be specific regarding certain important features such as lethality, blast overpressure, and temperature at cookoff, but the test plan must provide some basis for evaluating the test item with respect to these features. The usual method is to use the ammunition item to be replaced as a control.

Examples of mortar systems for which this ammunition is required are: light (60-mm M-224 [drop- and trigger-fired]; medium (81-mm M29A1 [drop-fired]); and heavy (4.2-inch M30 [drop-fired]) categories of weapons. The 60-mm and 81-mm mortars have smooth bores, and the 4.2-inch mortar is rifled. Procedures for testing mortars are described in TOP/MTP 3-2-050.[1]** The ammunition types used with each are shown in Table I; the HE type is illustrated in Figures 1-2.

*This TOP supersedes TOP/MTP 4-2-012 dated 2 August 1971.

**Footnote numbers correspond to reference numbers in Appendix A.

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Figure 1. 60-mm HE mortar.

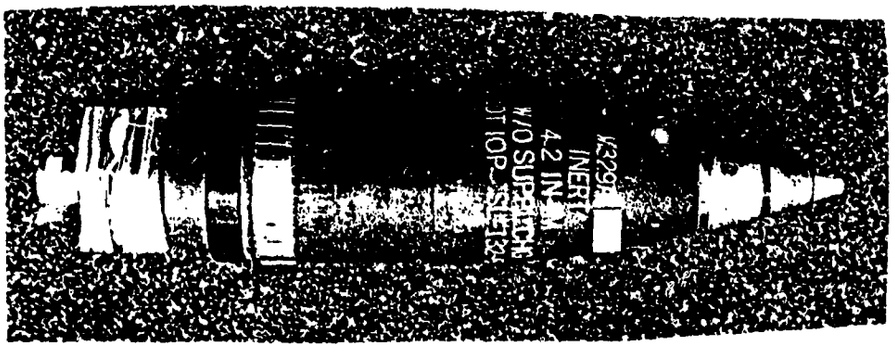


Figure 2. 4.2-in HE mortar.


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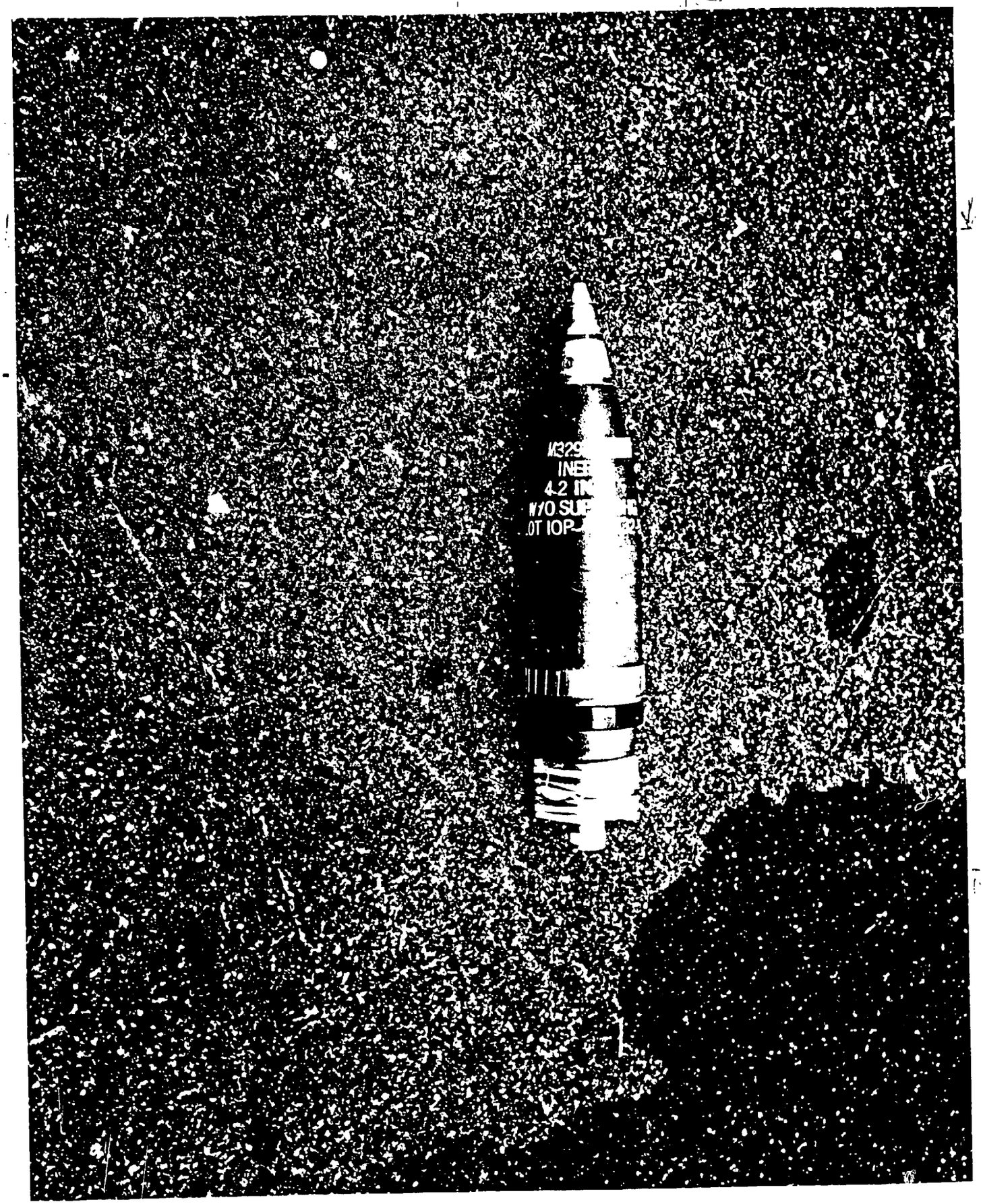


TABLE I
Current Mortar Cartridges

Type	60-mm	81-mm	4.2-inch
HE	M720	M374A3	M329A2
WP	M302A1	M375A2	M328A1
Illum	M83A3	M. J1A3	M335A2

Mortar ammunition is designed to be used by the infantry against personnel and targets of light structure. While accuracy is important, it must be coupled with the ability to deliver a high volume of fire against the target. With the increased use of carriers as firing platforms, stability of the weapon has been greatly improved. The ability to maintain a good rate of fire depends on the ammunition as well as the weapon (e.g., "cool burning" propellant would permit more rounds to be fired than usual before the weapon reaches its maximum operating temperature).

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

ITEM	REQUIREMENT
Camera/TV	
Vertical plywood target	
"Trombone" loader	
Sandbags	
Silver solder/ceramic spray	
Arctic mittens	

2.2 Instrumentation.

ITEM	MAXIMUM PERMISSIBLE ERROR OF MEASUREMENT*
Transits	
Gunner's quadrant	±0.4 mil
Digital theodolite	±1 meter (3 SD)
Stargage and borescope	±0.025 mm
Thermocouples and recorder	±1° C
Velocity coils and counter	±0.1%
Muzzle velocity radar	±0.1%
External pressure gages	

3. REQUIRED TEST CONDITIONS.

3.1 Safe Operations During Testing. All hazardous test operations must be covered by a local standing operating procedure (SOP) that provides compulsory

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

safety measures. Some typical operations classified as potentially hazardous are: misfire removal, rapid fire tests, and tests requiring defined blast danger areas.

Safety measures for routine operations are prescribed in the DARCOM safety manual.[2] Review the safety assessment report furnished by the developer for any unusual requirements. Make sure the test plan specifies any special precautions and provides guidance for writing an SOP to safely conduct the test.

3.2 Testing Sequence. Arrange the order in which subtests are conducted so that high-risk, short-duration tests are first, and low-risk, long-duration tests are last. The safety test takes precedence, with subtests covering this requirement being conducted before any others. After this requirement is met, all other subtests should be performed in a risk-oriented sequence as stated above. When possible, two or more subtests should be conducted concurrently for economic purposes and to meet deadlines. The test program may also require alteration of the sequence in consideration of facility availability.

3.3 Sample Size. Establishing adequate sample sizes is one of the most difficult problems in testing ammunition - particularly since most of the tests are destructive, and the test items are from limited development samples. Use statistical techniques to the maximum to ensure that sample sizes will be adequate to support conclusions. When requirements cite reliability criteria and confidence levels, compute sample sizes to ensure that such levels are met. If the number of samples available is not sufficient to meet the stated requirements, the test plan will indicate the confidence level attainable with the samples available. Also include a statement to show the number that would be required to fully meet the stated requirements. Guidance in selecting sample sizes for desired confidence levels is contained in TOP/MTP 3-1-002.[3]

4. TEST PROCEDURES. Throughout testing, maximum use of inert-loaded projectiles and fuzes will be made, unless live rounds and fuzes are specifically required such as during safety testing.

4.1 Initial Inspection and Measurements Phase. An initial inspection is conducted to ensure that the ammunition is not damaged. The ammunition components are identified by comparison with the producer's data card. If the samples have not been numbered, sample numbers are assigned to them before testing. Characteristics data (TOP 4-2-500[4]) of the ammunition and its components are collected at the same time to ensure that the materiel complies with military specifications. A characteristics data sheet consisting of a photograph of the test item and a tabulation of important features is assembled (see Figure 3).

4.2 Safety Testing.

4.2.1 12-meter Drop Test. Conduct this test in accordance with TOP 4-2-504.[5]

4.2.2 Verification of Propelling Charge. Conduct this test in accordance with TOP 4-2-504.

4.2.3 Determination of Peak Testing Pressures. Conduct this test in accordance with TOP 4-2-504.

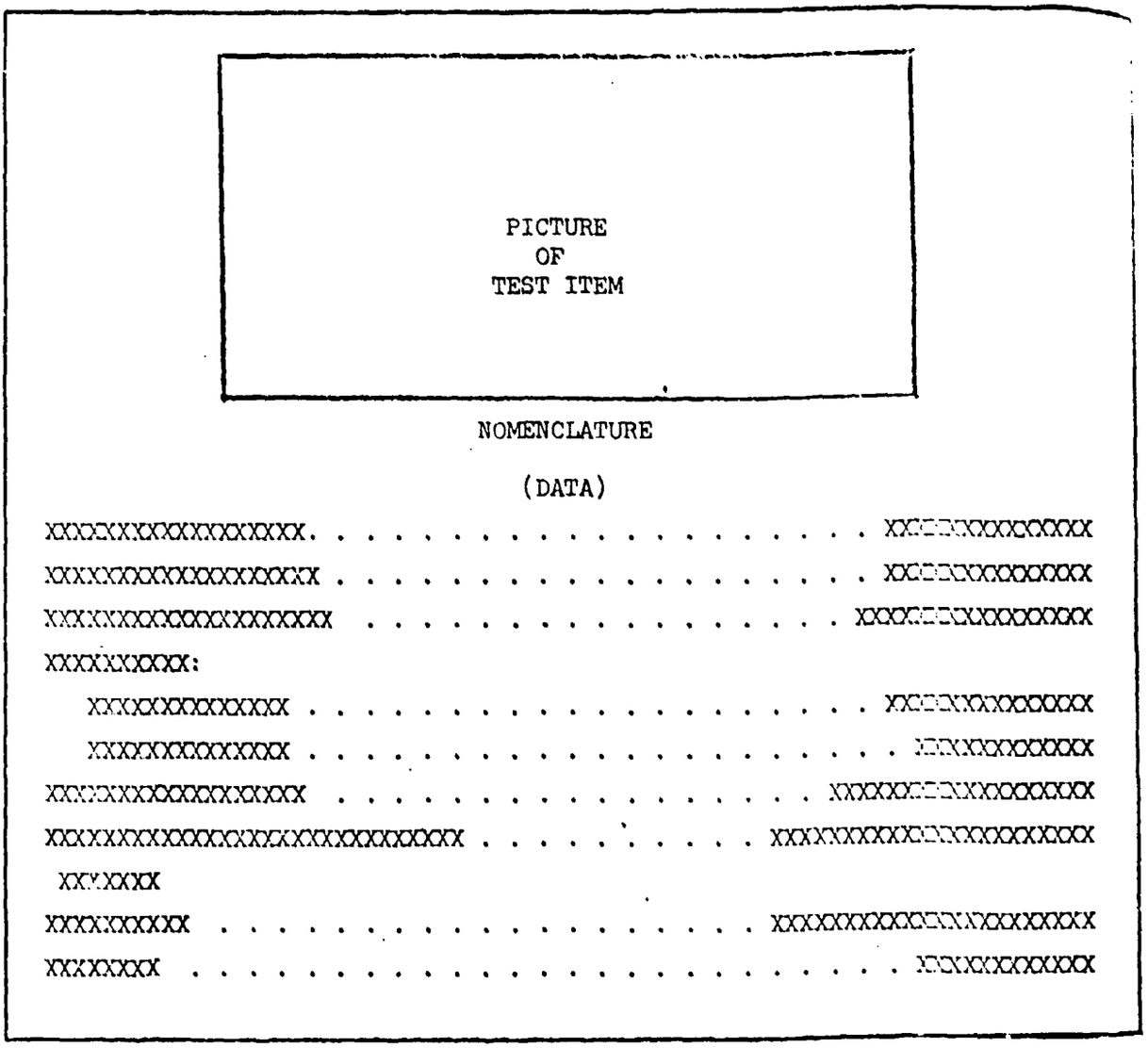


Figure 3. Characteristics data sheet.

4.2.4 Establishing Propellant Weights for Safety Tests. Conduct this test in accordance with TOP 4-2-504.

4.2.5 Strength-of-Design Test. Conduct this test in accordance with TOP 4-2-501.[6]

4.2.6 Sequential Rough Handling Test. Conduct this test in accordance with TOP 4-2-504.

4.2.7 Sequential Transportation Test. Conduct this test in accordance with TOP 4-2-504.

4.2.8 Cookoff. Conduct this test in accordance with TOP 4-2-504. NOTE: This test may be performed as part of the rate-of-fire test described in 4.2.14.

4.2.9 Blast Overpressure. For each change of propellant, conduct this test in accordance with TOP 4-2-822.[7]

4.2.10 Rain. Conduct this test in accordance with MIL-STD-810C[8], Method 506.1.

4.2.11 High Humidity. Conduct this test in accordance with TOP 4-2-820.[9]

4.2.12 Immersion.

4.2.12.1 Method. When there is a requirement for water resistance, subject 20 inert test rounds, with live fuzes, to the leakage test outlined in Procedure I, Test 512.1, of MIL-STD-810C. Exposure time will be limited to 30 minutes. After removal, inspect the rounds and inner walls of the containers for evidence of water entry. By hand, shake the water off 10 of the 20 rounds. NOTE: Each round should be shaken individually on an as-fired basis. With the fuzes set "PD", fire the rounds as soon after inspection as possible. It is advisable to use videotape coverage of the weapon during firing, particularly if abnormal operation of the ignition/propellant system is expected.

4.2.12.2 Data Required. Record muzzle velocity and chamber pressure.

4.2.13 Misfire Removal.

4.2.13.1 Method. Review the instructions concerning misfires and their removal (the field manual is the best reference for this) to determine whether modifications are needed to cover the peculiarities of the test item. Follow the misfire removal procedure using an inert simulated misfire round. The cookoff data concerning the ammunition must be known to complete this evaluation, as the required waiting time before attempting misfire removal must be sufficient to give the ammunition the opportunity to cook off. Proposed changes or warnings should be included in the safety release statement.

4.2.13.2 Data Required. Record procedure followed, ease of removal, safety, recommended waiting time, and whether any deviation from standard procedure is necessary.

4.2.14 Rate of Fire.

4.2.14.1 Method. Conduct these tests with a well-emplaced mortar. Use sandbags on the bipod legs to improve stability. NOTE: Make sure sandbags do not touch the tube. Use convenient elevations to establish the maximum physical rate of fire and the maximum sustained rate of fire.

For all rate-of-fire tests, instrument the mortar tube, and monitor for temperature to ensure that the limiting tube design temperature is not exceeded. Determine the "hot spot" on the tube by using previous test results and/or customer-provided data, and place thermocouples at this point, in the immediate vicinity, and other points of interest such as the carrying handle (if the weapon has one). Figures 4-6 show temperature data for maximum and sustained rates of fire for representative mortar rounds. Techniques used to measure tube temperatures include attaching thermocouples with silver solder or ceramic spray. NOTE: Ceramic spray is preferred because silver solder often causes the metallurgical characteristics of the tube to change due to the temperature used to melt and attach the silver solder to the tube. This can result in the tube cracking or developing a perforation after repeated firings. Secure the thermocoupled mortar in a baseplate that has been firmly seated and located within a 3-sided shield to serve as personnel protection and a wind barrier.

To determine maximum rate of fire, fire cartridges as quickly as possible for the required duration (usually 1 or 2 minutes) at the maximum physical capability of the mortar crew. To determine sustained rate of fire, fire cartridges at a prescribed rate until limiting tube temperature or tube temperature equilibrium is reached. Fire all rounds at maximum service charge. NOTE: The rate-of-fire test is an appropriate time to measure muzzle flash and provide cookoff data.

4.2.14.2 Data Required. Record the following for both maximum and sustained rates of fire:

a. Rate of fire; number of rounds fired; and time required to fire rounds
b. Elevations at which rounds were fired
c. Tube temperatures at various locations, including the hot spot
d. Method used to measure temperature
e. Any unusual occurrences such as burning residue

4.2.15 Residue Evaluation.

To measure residue accumulation, conduct firing at a charge that has historically resulted in the most residue (usually a low charge). If such a charge is not known, fire all charges a sufficient number of times to determine which charge causes maximum residue accumulation. Use a clean tube for each phase.

Stargage the tube, and take borescope photographs of residue accumulations after each customer-requested group is fired. If the number of rounds is not specified, periodic cleaning can indicate how many rounds it takes to accumulate residue. Any unusual occurrences such as misfires, hangfires, or slow descent of the round should be noted for subsequent investigation and analysis. Ease of cleaning should be noted as supplemental information.

4.2.16 Fuze Arming Distance. The delayed arming of mortar fuzes is especially important since mortar crews are often unprotected from premature functioning.

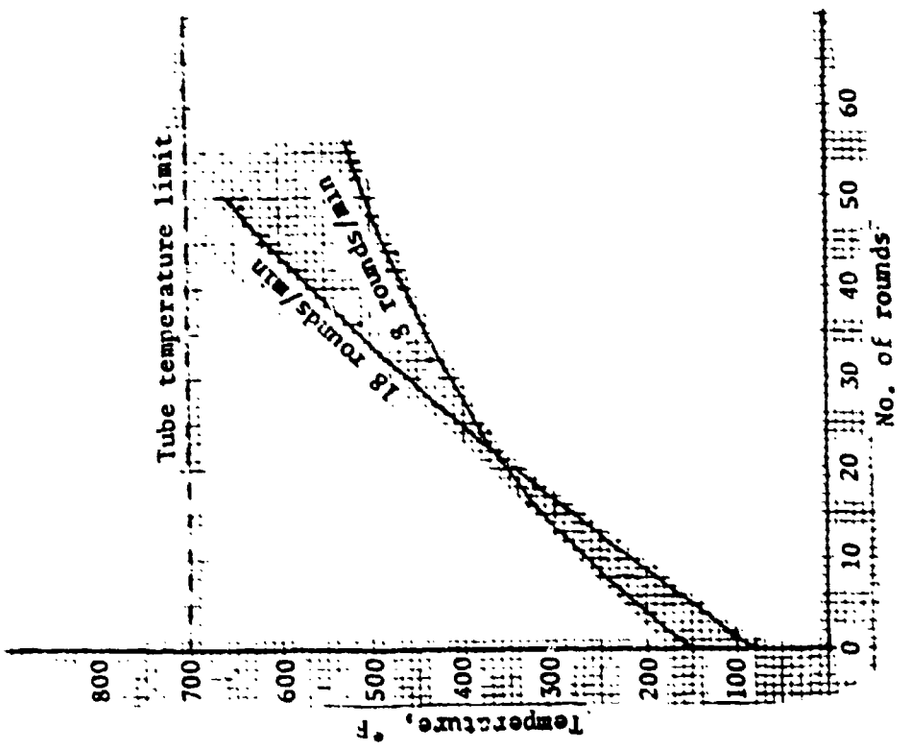


Figure 4. Effects of rates of fire on tube temperature: 60-mm mortar tube M19. (Temperature taken on tube 43 cm from muzzle; type round: M49A4.)

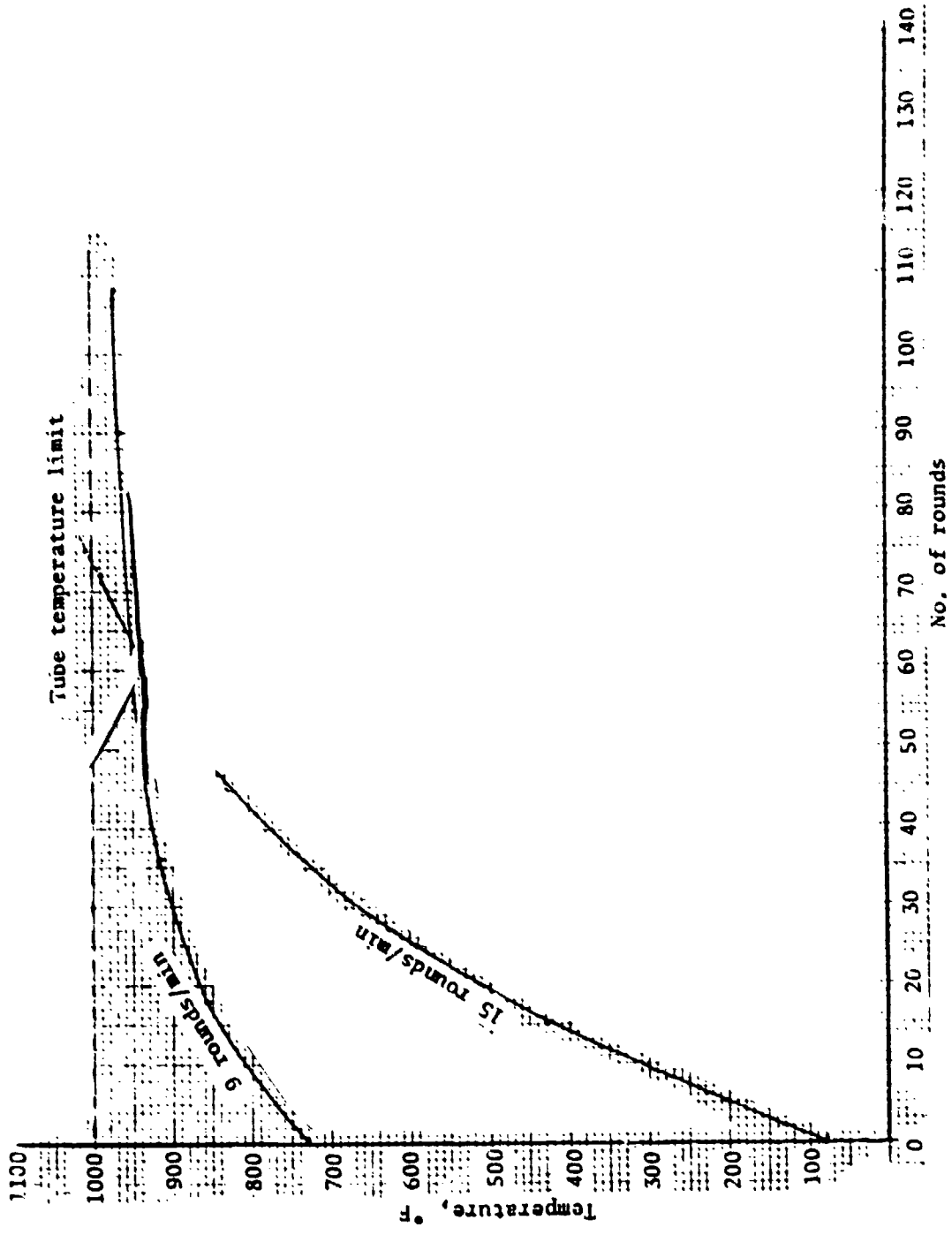


Figure 5. Effects of rates of fire on tube temperature: 81-mm mortar tube M29E1. (Temperature taken on tube at 91 cm from muzzle; type round: M374.)

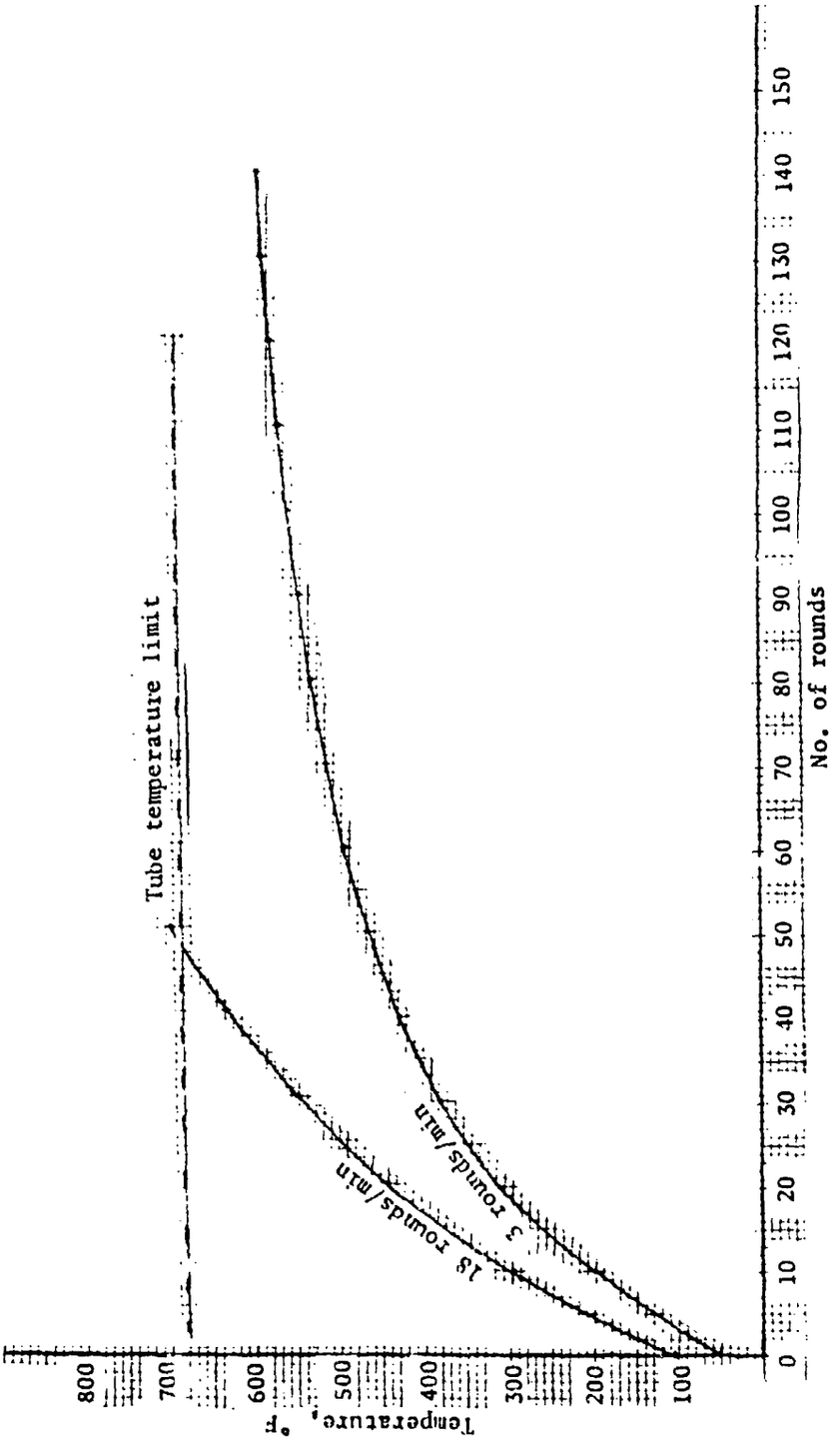


Figure 11. Effects of rates of fire on tube temperature: 4.2-in mortar tube M30. (Temperature taken on tube at 132 cm from muzzle; type round: M329A1.)

In most cases, the lowest charge is used to establish nonarming at a specific distance, although it is also necessary to verify arming at higher charges.

4.2.16.1 Method. Have a statistician select the sampling method (sensitivity testing strategy) to be used: the Probit Method (MIL-STD-331A[10], Test 208.1), the Up-and-Down Method (TOP 4-2-806[11]), the Langlie Method (MIL-STD-331A and TOP 4-2-806), or the One-Shot Transformed Response (OSTR) Method (MIL-STD-331A). Install a vertical plywood target thick enough to cause the fuze to function but not thick enough to cause deflagration of the filler charge in the projectile at the down-range distance specified by the sampling technique. Use inert filler if possible; this will ensure that functioning was caused by the fuze, and will be in keeping with the policy of using minimum hazard ammunition. Change down-range distances to the target in accordance with the sampling technique. Conduct the test at ambient temperature using live fuzes. A spotting charge may be used if required. The required number of rounds depends on the strategy used and on the time and cost constraints. This will be determined jointly by the test director and the statistician.

For this firing, a trigger-firing mechanism is used, and the mortar is fired at or near horizontal elevation, using a lanyard. A muzzle boresight and/or mortar sight unit is used for aiming. Loading of the round into the mortar is accomplished by use of a "trombone" type loader that does not require the crew to be in front of the weapon at any time during the loading operation. This loader must be designed so that no force is applied directly on the fuze striker.

4.2.16.2 Data Required. Record target material and thickness, muzzle velocity, distance to each target, firing elevation, whether the fuze functioned, propellant charge used, temperature, and other observations.

4.2.16.3 Presentation of Data. Functioning results and distances from the muzzle to the target will be summarized and used to estimate the mean arming distance, and if a zone of mixed results occurs, to determine the standard deviation of arming distance. It is assumed that probability of arming versus distance from the muzzle is described by a cumulative normal distribution. It is further assumed that if a fuze functions, it was armed. Regardless of the strategy employed, the method of maximum likelihood is used to obtain the estimate of the distance at which 50% of the fuzes are armed and the standard deviation whenever a zone of mixed results occurs. Otherwise, only the mean arming distance is estimated by averaging the farthest distance at which non-arming occurred and the shortest distance at which arming occurred. If a zone of mixed results occurs, an approximate upper confidence limit on functioning probability can be calculated for critical distance from the muzzle (consult statistician).

4.2.17 Fuze Safety at Muzzle. This test is used as a supplementary one to ensure that the safety devices in the fuzed ammunition provide bore safety as well as prevent detonation at close impact to the muzzle. The test is based on MIL-STD-331A, Test No. 208.1.

4.2.17.1 Method. Fire the test at ambient temperature using a live fuze and inert projectile or spotter charge if required against the target specified in paragraph 4.2.16. Fire at least 150 rounds at maximum charge, firing the weapon horizontally as in paragraph 4.2.16. Position the target at the specified distance for assessment of objective and criteria.

4.2.17.2 Data Required. Record target type, thickness, and location; ammunition temperature, propellant charge; and number of rounds fired and number of rounds that functioned.

4.2.17.3 Presentation of Data. The point estimate and lower 95% confidence limit on the nonfunction rate will be calculated. The functioning of any fuze is unacceptable.

4.2.18 Double Loading. A test to determine whether accidental double loading will cause an unsafe condition is currently being studied, but is not ready at the date of printing.

4.2.19 Obturation Test. This test is conducted only with mortar ammunition, and only if there is some question about whether a short round will result if a mortar round does not have an obturator. (Often, sufficient data are available from firings of previous models to make this test necessary.) This test consists of firing, at ambient temperature, 10 rounds at maximum charge, 10 rounds at an intermediate charge, and 10 rounds at minimum charge.

4.2.20 Range Danger Areas. The acquisition and reporting of range danger data for use in training and combat is described in AR 385-63.[12]

4.3 Fuze Functioning Time. When required, test impact fuzes in accordance with TOP 4-2-807.[13] For airburst fuzes, conduct time-to-burst and height-of-burst tests in accordance with TOP 4-2-808.[14] Conduct tests at -46° C, 21° C, and 63° C.

4.4 Accuracy and Dispersion. The ammunition is fired for accuracy and dispersion from the appropriate weapon in a manner that will minimize errors other than those attributable to the ammunition. Since firing from various ground conditions may affect the evaluation of the ammunition quality, control rounds are included in the test plan. These control rounds must be of known quality and all from the same lot. The accuracy and dispersion test is part of the firing table test. In addition to firings from the baseplate positioned on ground, firings will be conducted from the armor plate fixture. This will eliminate the variable ground mounting effect and provide data equivalent to vehicle mounting. Sufficient charge increments should be fired to establish the ground mount versus armor plate for various velocity levels.

4.4.1 Method. Conduct accuracy and dispersion tests and the firing table test in accordance with TOP 3-1-004.[15]

4.5 Reliability. Tests must be designed so that the functioning reliability of the major components (e.g., the fuze) can be determined. This information may be required not only during the safety evaluation (4.2 above) but also after the ammunition has been exposed to the various environments outlined in 4.6 below. Seldom, however, is the test item subjected to all the environmental conditions in a single test program. As stated in paragraph 3.3, the sample size must be consistent with the reliability criteria. The functioning results from all the subtests are usually combined to determine the overall reliability of the test item. Most of the functioning reliability is determined from the test in paragraph 4.4. Care must be taken to exclude fuze functioning data for rounds that

were "overstressed" such as some safety tests, if the data are not representative of "normal" conditions.

4.6 Environmental Tests. Most environmental tests are covered under safety testing. Other environmental tests to consider are:

Fungus - follow MIL-STD-810C
Salt Fog - follow MIL-STD-810C
Dust - follow MIL-STD-810C, Method 510.1
Solar radiation - follow MIL-STD-810C or TOP 4-2-826[16]
Humidity - follow TOP 4-2-820

4.6.1 Method. Following each of the above exposures, inspect to determine effects on operability; fire the ammunition at a representative range, and measure chamber pressure, muzzle velocity, and range.

4.6.2 Data Required. Record the following:

a. Environmental tests conducted
b. Range, chamber pressure, and muzzle velocity
c. Wind velocity and direction

4.7 Human Factors Engineering. Human factors involved in the use of mortar ammunition are evaluated through time-task checklist observations (TOP 1-2-610[17]), questionnaires (TECOM PAM 602-1[18]), and relevant physical measurements, e.g., light, workspace force/torque (TOP 1-2-610).

4.7.1 Method.

a. Obtain physical characteristics of the weapon and ammunition as they affect operation.

b. Determine ease/difficulty in opening ammunition containers and obtain times to accomplish preparation of ammunition with various hand gear (e.g., hot, cold, etc.) when adjusting charges, setting or changing fuzes through time-task checklist analysis.

c. Measure blast overpressure (TOP 1-2-608[19] and TOP 4-2-822) noise, flash, or smoke resulting from firing the rounds.

d. Determine ease/difficulty in handling or loading the round through time-task checklist analysis.

e. Determine ease/difficulty in removing charges and confirming the number of charges during darkness through time-task checklist analysis.

f. Issue questionnaires to ammo users during testing to determine good features and any areas of required improvement, e.g., fin design for ease of loading.

g. Measure the light and any work space restrictions at the location where tasks take space. Measure the force/torque of any operations judged to require either too much or too little force.

h. Obtain anthropometric and demographic data of participants in the task analyses and questionnaires.

4.7.2 Data Required. Record the following:

a. Data obtained from 4.7.1.

b. Any features of the mortar ammunition not compatible with skills/aptitudes of the mortar crew.

4.8 Logistic Supportability. Test and analysis of logistic supportability are required for all advanced development verification test - Government (ADVT-G), prototype qualification test - Government (PQT-G), production verification test - Government (PVT-G), first article-initial production test (FA-IPT), and product improvement TECOM Supplement 1 to DARCOM R 700-15.[20] Maintenance problems are reported by EPR in accordance with DARCOM Reg 70-13[21] and included in the test report. Testing and reporting requirements are specified in TECOM Suppl 1 to DARCOM R 700-15.

4.9 Fragmentation. Conduct fragmentation test in accordance with TOP 4-2-813.[22]

4.10 Fuze Sensitivity. Conduct test in accordance with TOP 4-2-806.

4.11 Electronic Countermeasures. No test procedures currently exist for this.

Recommended changes of this publication should be forwarded to Commander, US Army Test and Evaluation Command, ATTN: DRSTE-AD-M, Aberdeen Proving Ground, Md. 21005. Technical information may be obtained from the preparing activity: Commander, US Army Aberdeen Proving Ground, ATTN: STEAP-MT-M, Aberdeen Proving Ground, Md 21005. Additional copies are available from the Defense Technical Information Center Cameron Station, Alexandria, Va. 22314. This document is identified by the accession number (AD No.), printed on the first page.

APPENDIX A
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