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FINAL REPORT  
TECHNICAL FEASIBILITY TEST  
OF  
M16A1E1 RIFLE

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SUBJECT: Final Report for Technical Feasibility Test for M16A1E1 Rifle, TECOM  
Project No. 2-WE-600-016-026

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FOR THE COMMANDER:

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as

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<p>20. inspections, parts interchange, endurance, high and low temperature, sand and dust, mud, unlubricated, accuracy/dispersion, cookoff, rough handling, position disclosure, and sustained fire subtests. The test cartridges were subjected to salt fog, high and low temperature, mud, and cookoff during the rifle tests. Safety, human factors, logistic supportability, and reliability evaluations were performed on the data.</p>	
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## SUMMARY

Ten samples of both the standard M16A1 rifle and the improved version, M16A1E1, were subjected to tests or evaluations during the technical feasibility test (TFT). These weapons were tested side by side for comparison purposes to determine if the changes in configuration from the standard rifle affected performance.

The initial test performed was a series of inspections to ascertain the baseline structural integrity and performance and compliance of various parameters (headspace, trigger pull, etc.) with the military specification. Four of the M16A1 rifles failed to meet the accuracy and dispersion requirements. Two of the improved rifles did not meet the same requirement while others failed the requirements for trigger pull and firing pin indent.

During the endurance test the improved barrel of the M16A1E1 failed to meet the barrel life (6000 rd) criterion when used in conjunction with the XM855E1(FN) cartridge. By direction of TECOM, the test was repeated with new barrels of the same type and the Belgian (Fabrique Nationale) SS109 cartridge was substituted. Under those conditions, the barrel criterion was met.

Cookoff testing (para 2.5) showed that the M16A1E1 could fire 170 rounds of SS109 ammunition without a cookoff. This exceeds the results of the M16A1 control rifles using M193 ball ammunition which could safely fire 150 rounds. These cookoff data were generated using an 85-shot per minute (spm) firing schedule; different schedules produce different cookoff levels.

In the course of environmental testing (para 2.4), the M16A1E1 with XM855E1(FN) ammunition was satisfactory in the high temperature +68° C (155° F). However, in the low temperature -46° C (-50° F) and the salt water immersion, the M16A1E1 with XM855E1(FN) exhibited a higher amount of misfires than did the control M16A1s with M193 ball. The low temperature test was redone substituting SS109 ball ammunition for XM855E1. This combination gave satisfactory results; however, it should be noted that there may be an interface problem between rifle and ammunition (para 2.4.5.2). In the mud test and the sand and dust tests, the M16A1E1 was equal to the M16A1 control rifles.

The damage assessment after the sequential rough handling and 1.5-meter drop test (para 2.4.4.1, 2.4.4.2, and 2.7.4) disclosed that the minimal damage sustained by the product improved plastic parts would not affect operational use. The product improved handguards were superior to the standard handguards.

There was one potential safety problem (para 2.14) in relation to the spent case ejection pattern of the M16A1 and M16A1E1 designs.

Noise level tests were conducted with the levels indicating a noise level range requiring hearing protection, either plugs or muffs, during training.

The M16A1E1 was considered to have met most of the human factors requirements; however, minor human engineering changes could be incorporated to refine the system (para 2.12).

There were no significant maintenance problems with the M16A1E1. It is notable that cleaner, lubricant, preservative (CLP) reduces performance of the

system in low temperatures. The use of lubricant arctic weapons (LAW) is required for proper operation. The CLP thickened in the cold causing energy loss between the closely fitted surfaces of the receivers on both model rifles and is not compatible with the system in extreme cold. Time constraints did not permit a determination as to exactly what temperatures would be compatible.

There were two significant maintenance problems in relation to the rear sight of the M16A1E1 rifle. Parts of the sight, i.e., detent balls and springs are quite small and easily lost. Disassembly of the rear sight should not be attempted below the direct support level.

The second problem is that the elevation dial cover and elevation base are not interchangeable with others due to tolerance mismatch. These two parts require selective assembly procedures.

During the testing, the M16A1E1 model exhibited fewer stoppages/malfunctions over the range of testing as indicated in the various subtests. This may be attributable to projectile shape, feed ramp dimensions, or action spring constant.

FOREWORD

XXXXXXXXXX

The Materiel Testing Directorate (MTD), US Army Aberdeen Proving Ground (APG), was responsible for the test planning, execution, and reporting. Mark Humphreville was the responsible field test director under direction of John Scheuren. Due to the complexity of this test, George B. Niewenhous coauthored (as senior test director) a major portion of the report with Mark Humphreville.

## CONCLUSION

Twenty-eight criteria were identified for evaluation. Of these, one was deleted by TECOM direction prior to testing. The M16A1E1 rifle met 19 of the remaining 27, partially met five, and failed to meet three.

RECOMMENDATIONS

None.

## SECTION 1. INTRODUCTION

### 1.1 BACKGROUND

The M16A1 rifle evolved from the independently developed AR 15 rifle designed in the late 1950s. Following testing and modification, it was type classified in February 1967 as the rifle, M16A1, 5.56-mm. Since that time, several minor problem areas have arisen that, when considered independently in time, could not be solved in a cost effective manner. In 1980 the NATO community approved a heavy ball 5.56-mm cartridge (Belgian SS109) as a second small arms cartridge.

With the expected US approval of STANAG 4172, a strong consideration was given to changing the barrel twist on the M16A1 to a 1 in 7 configuration to accommodate the heavier SS109 type round. In the process of producing a barrel with different rifling, the opportunity to strengthen this new barrel to correct a bending problem was also implemented. These two improvements, plus improved plastic handguards and buttstock, constitute the primary emphasis of this modification. The US Marine Corps fully supported the use of the heavy bullet. Accordingly, the Joint Services Small Arms Program (JSSAP) office at ARRADCOM procured modified M16A1 rifles (designated M16A1E1) that incorporated those potential improvements for evaluation.

Prior to the start of testing three other components were added. These included a muzzle brake compensator (MBC), a burst control device (BCD) that limits automatic fire to 3-round bursts, and an adjustable rear sight (ARS) that allows adjustment out to 800 meters.

These modified rifles (M16A1E1) and the standard rifle (M16A1) were tested at APG, MD starting in December 1981. Testing was completed in November 1982.

A test execution directive for the TFT of M16A1E1 rifle was issued by TECOM Headquarters in December 1981 (ref 1).

### 1.2 DESCRIPTION OF MATERIEL

The M16A1 rifle is a lightweight, air-cooled, direct gas-operated, 5.56-by 45-mm rifle which is fed from a 20- or 30-round detachable magazine. It may be fired from the shoulder or hip, either semiautomatic or full automatic at a cyclic rate of 700 to 940 rounds a minute.

The weapon is powered by propellant gas pressure acting directly against the bolt carrier group. The gas is transferred from a porthole, midway along the barrel, through a stainless steel gas tube to the mating key of the bolt carrier. During firing, the carrier is impulsed rearward by the gas, and in turn unlocks the multilug bolt by forcing the bolt cam pin through the cam path cut in the carrier.

The weapon fires from the closed bolt position. When firing in the full automatic mode, the forward movement of the bolt carrier trips the automatic sear mechanism which releases the hammer. The hammer pivots forward under spring tension and impacts the firing pin. The rotational lock-up of the bolt in the barrel extension is accomplished just prior to the hammer impacting on

## 1.2 (Cont'd)

the firing pin. When firing semiautomatic and on the first round of an automatic burst, the hammer is released from the primary sear by trigger actuation.

The improved barrel is similar to the standard barrel with the exception of a slightly larger diameter from 2.5 cm behind the front sight base out to the muzzle. It is proposed that by increasing the diameter in this area, incidents of barrel bending under field conditions will be significantly reduced.

The barrel is provided with a flash suppressor which also serves as a front support for the bayonet and other accessories. The MBC is of similar size and is required to perform the same functions as the suppressor. In addition, its function is intended to improve accuracy and dispersion by providing resistance to muzzle climb during automatic fire. This is accomplished by directing a portion of the existing propellant gases in a direction to oppose muzzle climb. While the suppressor has six longitudinal slots spaced evenly around its circumference, the MBC has five which are evenly positioned in the top half of the circumference.

The barrel is surrounded by a heat-resistant fiberglass material which serves as a handguard and forearm. A metallic, heat-reflecting, inner shield is designed to keep the handguard cool. The improved handguard is proposed to increase part durability by changing the material to supertough nylon. The standard handguard tapers lengthwise while remaining triangular in cross section, with a smooth surface finish. The new handguard has no taper and is basically round in cross section. The outer surface is rough as an aid in gripping. To alleviate problems of logistic supportability, the two halves of the new handguard are separated on a horizontal plane and are identical in shape and size while the standard item separates on a vertical plane and requires two distinct halves, a left and a right.

The standard buttstock is a foam filled, fiberglass shell with a butt cavity for in-weapon stowage of cleaning items. It is very susceptible to damage due to the low impact resistance of the shell material and the low resistance of the shell design to compressive forces. The improved buttstock is similar to the standard in fit, finish, size, and function. It uses an improved material for the shell and the shell resistance to compressive force is aided by a full length, horizontal support.

The BCD replaces the standard fire control selection of safe, semiautomatic and full automatic with safe, semiautomatic and 3-round burst. The users requirement for this device relates more to ammunition conservation than hit probability.

The standard rear sight, adjustable for windage only, is replaced on the improved rifles with a sight capable of windage and range adjustments, out to 800 meters. The windage is adjusted by a finger manipulatable knob as opposed to the detent locked, adjustable disk of the standard rifle that required a tool for detent release. With the short range requirements of the standard rifle, this arrangement was rugged and dependable but the proposed longer range requirement of the improved rifle calls for a faster sight adjustment.

The front sight of the standard and improved rifles are similar in function but the improved post is square in cross section as opposed to round for the standard. It is proposed that this will give better post edge definition to the shooter's eye under a variety of lighting conditions.

The rifle normally accommodates the standard US 5.56- by 45-mm ball cartridge (M193), which has a 3.64-g bullet propelled at a muzzle velocity of approximately 990 m/s with a muzzle energy of approximately 179.4 kgm. The test ammunition included (1) heavy ball cartridges made up of SS109 projectiles (made by Fabrique Nationale, Herstal, Belgium) loaded in US cartridge cases with US propellant and primers by Lake City Ammunition Plant (XM855E1) and (2) heavy ball cartridges (Belgian SS109).

The M16A1E1 model also incorporates a spent case deflector to deflect hot cases away from the firer. In production, the spent case deflector will be milled from the forging as a permanent projection of the upper receiver group. Due to cost considerations, these deflectors were temporarily glued in place and were not to be considered as the final production product.

### 1.3 TEST OBJECTIVES

- a. To evaluate the physical and technical characteristics of the weapon system using the SS109 type round.
- b. To compare the strengths of the new handguards and buttstock to the old ones.
- c. To evaluate the function and reliability of the ARS and the BCD.
- d. To evaluate the effects of the MBC on control and accuracy.
- e. To evaluate the new heavy barrel's resistance to bending.
- f. To obtain data for production of a new bore erosion gage.

### 1.4 SCOPE

The TFT was conducted at APG on the product improved M16A1 rifle components during the December 1981 through November 1982 time frame. The test was assigned to APG by TECOM by letter (ref 1).

Testing consisted of inspections, endurance/accuracy, high and low temperatures, cookoff, sustained fire, rough handling, strength of materials, and accessory functioning. Evaluations included human factors, reliability, and safety/health. Hit probability tests were conducted by the ARRADCOM Test Site, Fort Dix, NJ, and the results reported by APG.

1.4 (Cont'd)

The number of rounds and weapons scheduled to be fired were considered adequate to estimate and to compare performance parameters and to address the criteria. The test scope was expanded to include limited investigative firings and to repeat some tests originally conducted with the XM855E1 cartridge by substituting the Belgian SS109 cartridge.

The environmental impacts of this program were assessed; no significant consequences were identified. No safety and health hazards were identified other than those normally associated with the firing of small caliber weapons.

1.5 TEST OBJECTIVES

- a. To evaluate the physical and technical characteristics of the weapon system using the SS109 type round.
- b. To compare the strengths of the new handguards and buttstock to the old ones.
- c. To evaluate the function and reliability of the ARS and the BGD.
- d. To evaluate the effects of the MBG on control and accuracy.
- e. To evaluate the new heavy barrel's resistance to bending.
- f. To obtain data for production of a new bore erosion gauge.

1.4 TESTS

The TTT was conducted at APG on the product improved M16A1 rifle components during the December 1981 through November 1982 time frame. The test was assigned to APG by TECOM by letter (ref.).

Testing consisted of inspections, endurance/accuracy, high and low temperatures, cockoff, sustained fire, rough handling, strength of materials, and accessory functioning. Evaluations included human factors, reliability, and safety/health. Hit probability tests were conducted by the ARADCOM Test Site, Fort Dix, NJ, and the results reported by APG.

SECTION 2. DETAILS OF TEST

2.1 INTRODUCTION

The standard and product improved M16A1 rifles were subjected to the tests and evaluations as shown in table 2.1-1. During the extensive endurance and accuracy subtest, the weapons were cleaned, inspected, and lubricated (CIL) after each 1200 rounds of firing. In other subtests, the weapons were CIL before and after the subtest or as specified in the pertinent data acquisition procedure. Cleaner, lubricant, preservative (CLP) conforming to MIL-L-63460A (ref 2) was the lubricant used throughout the test. Lubricant LAW (MIL-L-14107C, ref 4) was substituted at low temperature (-46° C) when stoppages attributed to the CLP were noted.

Unless otherwise stated in the data acquisition procedure for the various subtests, all firing throughout the test was done with the rifle fired from the shoulder using 30-round capacity magazines.

Rifles of each type were numbered by APG 1 through 10 following the same sequence as the manufacturer's serial numbers. The subscript A will be assigned to the standard rifles and B to the modified. Magazines will be assigned to each rifle and numbered accordingly.

TABLE 2.1-1. PLANNED WEAPON USAGE

Subtest	Weapon No.									
	1	2	3	4	5	6	7	8	9	10
Inspections	X	X	X	X	X	X	X	X	X	X
Endurance/Accuracy	X	X	X	X	X					
High Temperature						X	X	X	X	X
Low Temperature						X	X	X	X	X
Salt Water Immersion							X	X		
Cookoff <sup>a</sup>									X	
Sustained Fire										X
Rough Handling						X	X	X		
Sand and Dust									X	X
Mud									X	X
Unlubricated										X
Position Disclosure	X									
Hit Probability <sup>a</sup>										

<sup>a</sup>Denotes tests that require weapons with modified barrel in lieu of or in addition to the limited number of modified weapons.

## 2.2 INITIAL INSPECTION

### 2.2.1 Objectives

- a. To determine that the test items and support material were complete and had been received in proper condition for test.
- b. To inspect and record certain physical characteristics and to test-fire each rifle.

### 2.2.2 Criteria

- a. The test items shall be adequately and clearly marked and undamaged (devised by test agency, TECOM approved).
- b. The trigger pull shall be free of creep and shall be within the range of 5.5 and 8.5 pounds. Creep shall be interpreted to mean any perceptible rough movement between the time the trigger slack is taken up and the hammer is released. After partial or completed trigger pull, the trigger shall return to its normal forward position (cocked and uncocked) under spring action (MIL-R-45587A, para 3.4.3, ref 7).
- c. The headspace shall not be less than 1.4646 inches nor more than 1.4706 inches when measured to the 0.330 inch datum diameter on the first shoulder of the chamber (MIL-R-45587A, para 3.4.1).
- d. Firing-pin protrusion shall be 0.028 to 0.036 inch (MIL-R-45587A, para 3.3.4.2).
- e. When the bolt is closed and firing mechanism is released, the firing pin indent shall be not less than 0.020 inch. The firing pin indent shall not be off-center more than one-half the maximum diameter of the indent. When in a vertical, muzzle down position, the bolt carrier assembly is released from the full recoil position and the firing mechanism is not actuated, the firing pin indent shall not be more than 0.008 inch (MIL-R-45587A, para 3.4.2).
- f. The cyclic rate of fire for a 30-round continuous burst using a 30-round magazine shall be within 700 to 900 rounds per minute. Standard weapon (M16A1) and ammunition (M193 ball) only (MIL-R-45587A, para 3.4.5).
- g. The before-test condition of the product improved plastic components must be free from defects or deviations from normal production that would adversely influence test results (devised by test agency, TECOM approved).
- h. Targeting and accuracy. A series of 10 rounds fired from each rifle at a range of 91.4 meters shall be within the rectangular outline (17.6 by 11.6 in.) of the targeting and accuracy diagram when front and rear sights are set up as follows: the normal rear sight peep (sight rotated fully rearward) shall be used with rear sight set centrally in the slot for windage within plus or minus two clicks; the top edge of the front sight post flange shall be set flush to 0.030 inch below the bottom surface of the front sight slot; ammunition shall be Government standard M193, 5.56-mm ball cartridges and shall be certified by the Government to be of quality that will group within a mean radius of 1.2 to 1.4 inches at 200 yards (MIL-R-45587A, para 3.4.6).

### 2.2.3 Data Acquisition Procedure

- a. The testing was conducted in accordance with procedure described in TECOM TOP/MTP 3-2-059 (ref 12).
- b. All test items were examined for completeness and any damage incurred during shipment. Identifying APG numbers were assigned to each weapon and test item and recorded along with the original serial numbers.
- c. The weapons were disassembled and all major components visually examined for conformance with specifications for mechanical integrity. A magnetic particle inspection (MPI) of components subjected to high stress during weapon functioning was conducted as per TECOM TOP/MTP 3-2-307 (ref 15). The free length of the recoil springs were measured. The extractor spring, as required, was not removed from the extractor at any time except for replacement.
- d. A photographic record of the weapon was made, comparing the standard and product improved test items. A radiographic record of each standard and product improved plastic component was made.
- e. The weight of the M16A1 rifle with the standard and product improved components and basic accessories was determined.
- f. The barrel chamber and bore were measured and inspected using standard test methods. In addition, baseline measurements were made using the bore erosion and barrel straightness gages. Baseline measurements of gas tube back pressure were also measured. Firing pin indent, firing pin protrusion, and headspace were measured before and after parts interchange.
- g. The standard parts interchange test for the M16A1 rifle (para 4.7.7, ref 7) was performed, amended as needed by the extra parts in the M16A1E1 rifle. Prior to interchange, 120 functioning rounds were fired according to the schedule in table 2.3-1. Cyclic rate of fire was recorded on the last 30 rounds. After interchange, the functioning test was repeated for comparison purposes with the addition of velocity measurement on the last 30 rounds. Instrumental measurement distance was 15 meters.
- h. Following interchange, baseline accuracy-dispersion was determined as per paragraph 2.2.2h.
- i. The five weapons of each type selected for the endurance/accuracy testing were used to compare cartridge compatibility. Three 10-round groups of each cartridge were fired semiautomatically from each weapon. Targets at ranges of 300 and 600 m were used to record yaw and dispersion. Weapons were mounted in an APG test stand. The endurance weapons were then sighted in with their appropriate cartridges.
- j. Most of the data measurements listed above were repeated at intervals as specified in the applicable subtests.
- k. All safety features and problems, human factors concerns, and maintenance problems encountered with the inspection of weapons and components were observed and noted throughout all subtests.

## 2.2.4 Results

a. All test items were received complete, clearly marked, and in undamaged condition.

b. All rifles were submitted to initial inspection and parts interchange tests for the M16A1 rifle per paragraph 4.7.7 of MIL-R-45587A, the military specification for the M16A1 rifle. An MPI of components receiving high stress loads during operation revealed acceptable parts integrity. Additionally, a radiographic record of each standard and product improved plastic component was made. No discrepancies indicative of structural failure were found.

c. A photographic record of each rifle type was made and is presented in appendix B. The weight of the M16A1 rifle, less sling and magazine, was 2.88 kg (6.35 lb). The weight of the M16A1E1, less sling and magazine was 3.52 kg (7.75 lb). Other characteristic measurements are the same for both weapon models.

d. The barrel chambers and bores were measured and inspected using standard test methods. No anomalies relative to nonconformance with the specification or indicative of poor barrel performance were noted. However, it was discovered that in 6 rifles, the gas port hole had been drilled into the opposite side of the bore. While this probably would not affect accuracy, these rifles were, nonetheless, not used in the accuracy and endurance tests.

e. Firing pin indent, firing pin protrusion, headspace, trigger pulls and cyclic rates were measured before and after parts interchange. Inspection summaries for each rifle are presented in tables 2.2-1 and 2.2-2 for the M16A1. Tables 2.2-3 and 2.2-4 present data for the M16A1E1 model.

TABLE 2.2-1. INITIAL INSPECTION DATA, M16A1 STANDARD RIFLE BEFORE PARTS INTERCHANGE

APG Rifle No.	Rifle SN	Head-space (in.)	Firing Pin Protrusion (in.)	Firing Pin Indent (in.)			Trigger Pull (lb)			Cyclic Rate (spm)
1A	5372628	1.4656	0.033	0.023	0.023	0.023	8.1	8.0	8.2	812
2A	5377711	1.4666	.034	.023	.022	.023	7.4	7.7	7.4	863
3A	5377813	1.4656	.032	.020	.021	.021	7.7	7.5	7.8	812
4A	5377832	1.4656	.033	.023	.022	.023	8.2	7.7	8.1	788
5A	5378164	1.4656	.032	.023	.023	.023	8.2	7.8	8.1	843
6A	5378234	1.4656	.034	.021	.021	.021	7.7	7.7	7.8	865
7A	5378296	1.4656	.033	.023	.020	.022	8.1	8.3	8.2	832
8A	5378552	1.4656	.032	.024	.023	.023	7.6	7.7	7.5	851
9A	5378567	1.4656	.033	.024	.023	.024	7.6	7.4	7.6	813
10A	5378578	1.4646	.032	.022	.022	.022	7.3	7.3	7.3	837
Requirement per MIL-R-45587A:		<sup>a</sup> 1.4646 <sup>b</sup> 1.4706	<sup>a</sup> 0.028 <sup>b</sup> 0.036	<sup>c</sup> 0.020			<sup>a</sup> 5.5 <sup>b</sup> 8.5			<sup>a</sup> 700 <sup>b</sup> 940

<sup>a</sup>Minimum.

<sup>b</sup>Maximum.

<sup>c</sup>Not less than.

TABLE 2.2-2. INITIAL INSPECTION DATA, M16A1 STANDARD RIFLE AFTER PARTS INTERCHANGE

AFG Rifle No.	Rifle SN	Air Flow Back Press. (psi)	Head-Space (in.)	Spring Buffer Length (in.)	Firing Pin Protrusion (in.)	Firing Pin Indent (in.)	Inertia Firing Pin Indent (in.)	Trigger Pull, Single Shot (lb)	Trigger Pull, Automatic (lb)	Avg Cyclic Rate (spm)	Erosion Gage Depth (mm)	Accuracy Dispersion Met						
1A	5372628	1.75	1.4646	12.1	0.032	0.023	0.007	0.003	0.007	6.4	6.3	6.7	8.4	8.7	8.9	818	6.5	No
2A	5377711	1.87	1.4666	11.9	.032	.022	.006	.006	.006	7.6	7.7	7.5	9.6	9.5	9.9	798	6.5	No
3A	5377813	1.87	1.4666	12.1	.034	.022	.006	.007	.006	6.8	7.3	7.0	9.4	9.6	9.7	826	6.5	Yes
4A	5377832	1.81	1.4646	12.3	.030	.023	.007	.007	.007	7.3	7.5	7.5	10.0	10.0	9.7	822	6.3	Yes
5A	5378164	1.81	1.4656	12.2	.033	.024	.007	.007	.007	7.2	7.3	7.3	10.2	10.3	9.9	812	6.5	Yes
6A	5378234	1.75	1.4646	12.2	.031	.023	.006	.007	.007	8.0	8.1	8.0	10.0	9.9	10.1	879	6.4	Yes
7A	5378296	1.81	1.4656	12.2	.033	.022	.005	.006	.005	7.6	7.7	7.4	8.5	8.4	8.5	807	6.5	Yes
8A	5378552	1.81	1.4656	12.3	.031	.024	.008	.008	.007	7.5	7.3	7.6	10.0	9.9	9.9	868	6.5	No
9A	5378567	1.87	1.4646	12.3	.031	.023	.006	.007	.007	6.5	6.6	6.5	9.5	9.8	9.6	839	6.4	Yes
10A	5378578	1.81	1.4656	12.3	.031	.023	.007	.007	.007	6.8	7.0	6.9	8.3	8.5	8.3	853	6.5	No

Requirement per MIL-R 45587A:

- a. Minimum.
- b. Maximum.
- c. Not less than.

c. 0.020

b. 0.008

a. 5.5  
b. 8.5

NA

a. 700  
b. 940

TABLE 2.2-3. M16A1E1 INITIAL INSPECTION DATA BEFORE INTERCHANGE<sup>a</sup>

APG Wpn No.	Wpn SN	Head-Space (in.)	Firing Pin Protrusion (in.)	Firing Pin Indent (in.)	Trigger Pull (lb)	Trigger Pull Burst Mode (lb)	Avg Cyclic Rate (spm)						
1D	9566628	1.4676	0.033	0.021	0.022	0.021	8.2	8.2	8.9	10.5	9.1	9.4	717
2D	9566652	1.4676	.032	.020	.020	.019	9.0	9.2	8.9	10.4	10.4	10.3	743
3D	9566657	1.4686	.034	.020	.021	.020	8.8	8.7	9.3	10.4	10.6	10.7	780
4D	9566658	1.4666	.032	.020	.020	.021	8.3	8.5	8.4	10.5	10.0	10.7	721
5D	9566704	1.4666	.032	.019	.018	.018	10.5	10.4	10.9	10.3	10.4	10.6	786
6D	9566721	1.4676	.033	.021	.021	.021	9.5	8.9	9.3	11.0	10.9	10.5	753
7D	9566735	1.4646	.034	.021	.021	.021	7.8	7.7	7.9	10.5	9.3	9.6	757
8D	9566761	1.4656	.032	.020	.021	.020	8.0	8.9	8.7	8.9	9.5	9.3	807
9D	9566767	1.4676	.033	.020	.020	.021	9.0	8.6	8.8	10.8	10.5	11.1	768
10D	9566770	1.4666	.034	.019	.020	.020	8.7	9.0	8.8	10.0	10.4	10.2	823
Requirement per MIL-R-45587A:		b 1.4646 c 1.4706	b 0.028 c 0.036	d 0.020			b 5.5 c 8.5					NA	

<sup>a</sup>All weapons were subjected to parts interchangeability test.  
<sup>b</sup>Minimum.  
<sup>c</sup>Maximum.  
<sup>d</sup>Not less than.

TABLE 2.2-4. INITIAL INSPECTION DATA, M16A1E1 MODIFIED, AFTER INTERCHANGE

APG Wpn No.	Wpn SN	Air Flow Back Press. (psi)	Firing Pin Protrusion (in.)	Head-Space (in.)	Spring, Buffer Erosion (mm)	Firing Pin Indent (in.)	Firing Pin Indent (in.)	Inertia Firing Pin Indent (in.)	Trigger Pull (lb)	Trigger Pull Burst Mode (lb)	Avg Cyclic Rate (spm)	Accuracy Dispersion Met								
1D	9566628	1.87	0.032	1.4666	13.2	6.0	0.019	0.019	0.019	0.006	0.005	0.005	8.5	8.1	8.3	10.0	9.9	10.2	709	Yes
2D	9566652	1.81	.034	1.4646	13.1	6.0	.022	.022	.021	.008	.007	.007	9.8	9.6	9.7	11.4	11.5	11.1	764	No
3D	9566657	1.87	.031	1.4646	13.0	6.0	.022	.021	.022	.006	.007	.007	9.3	9.2	8.8	10.5	10.4	10.3	799	Yes
4D	9566658	1.81	.033	1.4646	13.1	6.4	.020	.020	.021	.006	.006	.006	8.9	8.0	8.5	11.0	11.0	11.1	684	Yes
5D	95666704	1.81	.032	1.4646	13.1	6.2	.023	.024	.023	.006	.006	.007	8.2	8.5	8.5	9.9	9.5	9.8	752	Yes
6D	9566721	1.81	.033	1.4646	13.1	6.0	.021	.020	.020	.006	.008	.007	9.3	9.2	9.2	10.2	10.5	11.0	830	Yes
7D	9566735	1.87	.034	1.4646	13.1	6.5	.019	.020	.020	.007	.007	.007	8.7	8.7	8.9	9.6	9.9	9.3	685	Yes
8D	9566761	1.87	.034	1.4646	13.0	6.2	.021	.021	.022	.008	.008	.009	7.9	8.3	8.4	10.1	10.9	10.5	739	No
9D	9566767	1.75	.032	1.4647	13.0	6.0	.021	.021	.021	.007	.007	.007	9.6	9.9	9.8	11.5	11.0	11.3	711	Yes
10D	9566770	1.75	.033	1.4646	13.1	6.3	.017	.019	.018	.007	.007	.007	9.3	9.5	9.1	12.4	12.5	12.7	704	Yes

Requirement per MIL-R-45587A:

NA a0.036 b0.028

NA a1.4706 b1.4646

NA a0.008 b8.5 c5.5

NA a0.020 b0.028

NA a8.5 b5.5

NA

NA

NA

NA

NA

NA

NA

NA

NA

NA

NA

NA

NA

NA

Note: During the interchange phase, it was found that the rear sight parts had tolerance mismatch and would not interchange. These parts were not interchanged and remained in "as issued" condition.

#### 2.2.4 (Cont'd)

f. Trigger pulls were examined for creep and weight per MIL-R-45587A, paragraph 3.4.3 (ref 7). The acceptable range was to be between 2.5 and 3.9 kg (5.5 and 8.5 lb). The M16A1E1 models were above the maximum on eight of the ten rifles received. After parts interchange, six of the ten rifles were above the acceptable limit.

g. The headspace dimensions to be between 3.72 and 3.73 cm (1.46 and 1.47 in.) when measured to the 0.84 cm (0.33 in.) datum diameter on the first shoulder of the chamber (MIL-R-45587A, para 3.4.1). All rifles of each type were acceptable.

h. Firing pin protrusion was to be between 0.071 and 0.091 cm (0.028 and 0.036 in.) (MIL-R-45587A, para 3.3.4.2). All rifles of each type were acceptable.

i. Firing pin indent (i.e., firing pin energy) was to be not less than 0.05 cm (0.02 in.) when the firing mechanism was released. One rifle of the ten M16A1E1 models was below this requirement prior to interchange. After parts interchange, two of the ten rifles were below the 0.05 cm indent requirement. All M16A1 models met the minimum indent requirement prior to and after parts interchange.

j. The standard parts interchange test for the M16A1 rifle (MIL-R-45587A) was performed. The breakdown of nonmating part groups is shown in table B-1. The additional parts of the burst control device and adjustable rear sight assemblies of the M16A1E1 were randomly distributed throughout the ten groups of nonmating parts.

k. With one exception, the M16A1E1 was totally interchangeable. The elevation dial cover consists of two parts, i.e., cover and base. There was a tolerance mismatch and these two pieces were treated as one in the interchange scheme. The exploded drawing in figure 19 of appendix B shows details of these parts.

l. All M16A1 control rifles were interchangeable without any difficulties being experienced.

m. The before test condition of the product improved plastic components were inspected for defects or deviations from normal production that would adversely influence test results. Minor porosity and shrinkage features were noted but components were considered structurally sound.

n. Targeting and accuracy targets were fired from each rifle at a range of 91.4 m with 10-round group series being used to record results. Four of the ten M16A1 rifles failed to print all shots within the required acceptance target. Two of the M16A1E1 models failed to print all shots within the limits.

o. The five rifles of each type selected for endurance and accuracy testing were used to compare cartridge compatibility. Both M193 and XM855E1(FN) cartridges were fired in each sample rifle. Three 10-round groups, with each round type, were fired on each of two ranges, 300 and 600 meters. The resultant data are summarized and analyzed in tables 2.2-5 through 2.2-10.

p. The only safety problem noted during the initial inspection period is the spent case ejection pattern which is addressed fully in paragraph 2.14.

q. Upon opening the original cartons of XM855E1(FN), it became evident that ammunition had been damaged in manufacture. A sample of damaged cartridges is shown in figure 37 of appendix B. The condition of the ammunition was such that gun crew personnel had to visually inspect each round of XM855E1(FN) ammunition prior to loading.

### 2.2.5 Analysis

a. The M16A1 models met all acceptance tests of MIL-R-45587A except accuracy and dispersion at 91.4 meters. Four of the ten rifles did not meet this requirement.

b. The M16A1E1 models did not meet MIL-R-45587A in three different areas:

(1) Two of the ten rifles did not meet the accuracy and dispersion requirements.

(2) Excessive trigger pull weights were experienced on eight of the rifles as received. Six of the ten exceeded the limits after parts interchange.

(3) Firing pin indents (i.e., firing pin energy) were below acceptance requirements on one of the ten rifles prior to interchange. Two of the ten rifles were below acceptance requirements after interchange.

c. Means and standard deviations for each group of rounds in the cartridge compatibility test were obtained for the horizontal and vertical components of impact. These data were analyzed using a three-way nested analysis of variance model. The main effects were ammunition (2 levels - M193 and XM855E1 cartridges), systems (2 levels - M16A1 and M16A1E1), and weapon within system (5 levels - those rifles selected for the endurance and accuracy test). This was a mixed effects model where ammunition and system were considered fixed and weapon within system random. There were three replications per cell. It is assumed that the horizontal and vertical components of impact are independent, normally distributed random variables. In addition, for the analysis of variance, it is assumed that the dispersion estimates are normally distributed. All significance tests are at the 5% level; these tests are called one tail tests.

d. Since the area of interest in this test was the compatibility of the ammunition with the system, the important variable in the analysis of variance test is the interaction effect of the cartridge type and system.

e. Regardless of the type of cartridge, each system performed uniformly at each range, with respect to the mean horizontal CIs, i.e., cartridge-system interaction not significant. Table 2.2-5 presents these dispersion results.

2.2.5 (Cont'd)

TABLE 2.2-5. MEAN HORIZONTAL CI FOR EACH AMMUNITION-SYSTEM COMBINATION

Range (m)	Ammunition	M16A1 Rifle (cm)	M16A1E1 Rifle (cm)
300	M193	58.4	149.7
	XM855E1	52.0	125.0
600	M193	3.3	17.6
	XM855E1	-29.9	1.2

f. With respect to the mean vertical CIs, the performance of the systems at 600 m range was affected by the type of cartridge. However, when one looks at just the magnitude of the mean vertical CIs, system performance would be the same no matter what cartridge type was used. No significant difference between system performance at the 300 m range was detected due to the type of ammunition, with respect to the mean vertical CIs. See table 2.2-6.

TABLE 2.2-6. MEAN VERTICAL CI FOR EACH AMMUNITION-SYSTEM COMBINATION

Range (m)	Ammunition	M16A1 Rifle (cm)	M16A1E1 Rifle (cm)
300	M193	14.2	150.9
	XM855E1	-27.6	112.9
600	M193	84.6	-82.4
	XM855E1	-26.8	27.9

g. The mean vertical and horizontal standard deviations for each system were affected by the type of cartridge used at each range. In fact, in all cases the mean standard deviations increased for the M16A1 rifle and decreased for the M16A1E1 rifle as ammunition was changed from the M193 cartridge to the XM855E1 cartridge. See table 2.2-7.

TABLE 2.2-7. MEAN HORIZONTAL AND VERTICAL STANDARD DEVIATIONS FOR EACH CARTRIDGE-SYSTEM COMBINATION, CM

Range (m)	Ammunition	Horizontal Std Dev (cm)		Vertical Std Dev (cm)	
		M16A1 Rifle	M16A1E1 Rifle	M16A1 Rifle	M16A1E1 Rifle
300	M193	10.8	98.5	8.2	97.1
	XM855E1	30.9	78.9	30.2	76.1
600	M193	16.0	23.9	41.9	28.2
	XM855E1	79.3	17.4	98.5	22.2

2.2.5 (Cont'd)

h. The following discussion is presented to address any significant differences with respect to the main effects (ammunition, system, and weapon within system) and is presented for information only. A significant difference was detected between cartridge types with respect to the mean vertical CIs at the 300 m range and with respect to the mean horizontal CIs and mean horizontal and vertical standard deviations at the 600 m range. See table 2.2-8.

TABLE 2.2-8. MEAN HORIZONTAL AND VERTICAL CIs AND STANDARD DEVIATION BY AMMUNITION TYPE

Range (m)	Horizontal CI (cm)		Vertical CI (cm)		Horizontal Std Dev (cm)		Vertical Std Dev (cm)	
	M193	XM855E1	M193	XM855E1	M193	XM855E1	M193	XM855E1
	Ctg	Ctg	Ctg	Ctg	Ctg	Ctg	Ctg	Ctg
300	104.0	38.5	32.6	42.7	54.7	54.9	52.6	53.1
600	10.4	- 14.4	1.1	0.6	19.9	48.4	35.1	60.3

i. A significant difference was also detected between systems regardless of range, with respect to all CIs and standard deviation, except the horizontal CI at the 600 m range. See table 2.2-9.

TABLE 2.2-9. MEAN HORIZONTAL AND VERTICAL CIs AND STANDARD DEVIATION BY SYSTEM

Range (m)	Horizontal CI (cm)		Vertical CI (cm)		Horizontal Std Dev (cm)		Vertical Std Dev (cm)	
	M193	XM855E1	M193	XM855E1	M193	XM855E1	M193	XM855E1
	Ctg	Ctg	Ctg	Ctg	Ctg	Ctg	Ctg	Ctg
300	55.2	137.4	- 6.7	131.9	20.9	88.7	19.2	86.6
600	- 13.3	9.4	28.9	- 27.3	47.6	20.6	70.2	25.2

j. Likewise, a significant difference was detected among weapon within system, regardless of range, with respect to all CIs and standard deviations, except the vertical standard deviation at the 300 m range. See table 2.2-10.

k. In summation it may be stated that the M193 cartridge is compatible with both rifles with respect to accuracy, though not equally, and the XM855E1 cartridge is compatible with the M16A1E1 rifle only.

TABLE 2.2-10. MEAN HORIZONTAL AND VERTICAL CIs AND STANDARD DEVIATION BY WEAPONS WITHIN SYSTEM

Characteristics	Range (m)	M16A1 Rifle (cm)					M16A1E1 Rifle (cm)				
		1	2	3	4	5	1	2	3	4	5
Horiz CI	300	37.3	100.8	0.9	62.2	76.6	136.7	114.9	116.7	194.4	124.1
Vert CI		-55.1	-52.9	-85.2	80.0	79.8	156.9	165.4	105.6	151.3	120.2
Horiz Std Dev		14.8	28.2	16.2	16.0	29.2	85.6	80.3	79.3	115.0	83.3
Vert Std Dev		14.7	24.5	21.2	13.3	22.2	93.9	87.6	71.4	86.8	93.3
Horiz CI	600	-14.6	-14.7	-52.7	-4.4	19.7	66.8	7.9	1.6	-12.5	-16.7
Vert CI		83.0	24.7	13.8	20.7	2.2	-36.5	-40.5	-73.4	-2.3	16.4
Horiz Std Dev		49.2	59.8	47.6	19.4	62.2	25.2	27.4	16.8	21.9	20.5
Vert Std Dev		52.6	58.9	9.7	110.1	71.8	27.4	29.7	22.3	24.8	21.9



## 2.3 ENDURANCE AND ACCURACY

### 2.3.1 Objectives

- a. To determine the durability and reliability of the test barrels.
- b. To determine the accuracy and dispersion characteristics of the test rifles in comparison with the standard rifles.
- c. To determine if weapon function and performance are comparable between test ammunition and standard ammunition.

### 2.3.2 Criteria

a. The accuracy of the product improved rifles will be equal to or better than the standard rifles at ambient temperatures (devised by Test Agency, TECOM approved).

b. The life of the product improved barrel is required to be 12,000 rounds with serviceability being determined by the following:

(1) At no time shall 20% or more of the rounds in a group exhibit a yaw of 15 degrees or more.

(2) The velocity loss during the firing of a hot barrel shall not be more than 200 fps or more than 6% of that initially recorded during inspection (devised by Test Agency).

(3) Extreme spread shall not exceed 17.8 cm at 91.4 meters.

c. The reliability and durability of the test weapons during the first 6000 rounds of a firing shall not exceed the malfunctions and unserviceable parts cited in table I of MIL-R-45587A (MIL-R-45587A, ref 7).

d. Function and performance of the test weapons must not be affected by the product improved plastic components (devised by Test Agency, TECOM approval).

### 2.3.3 Data Acquisition Procedure

a. Testing was in general accordance with the procedures of TECOM TOP/MTP 3-2-059 (ref 12).

b. Five test (M16A1E1) utilizing XM855E1(FN) ammunition and five control (M16A1) rifles utilizing M193 ball ammunition were each fired for a minimum of 6000 rounds. Firing was conducted in a series of 120-round cycles with a cooling period after each cycle. Forced air was utilized to cool the barrels. The firing procedure for all normal cycles was as shown in table 2.3-1. Forty new 30-round magazines were numbered consecutively and used with each rifle.

2.3.3 (Cont'd)

TABLE 2.3-1. FIRING SCHEDULE

<u>No. of Rd</u>	<u>Procedure</u>
60	Automatic - 3-round bursts
30	Semiautomatic - 60 to 90 spm
30	Semiautomatic - 10 to 30 spm
Total 120	

c. Accuracy targets were fired with all five rifle samples, of each type, at the start of the test. After the initial firings, only those rifles with the maximum, minimum, and median (or closest to it) extreme spread were fired for accuracy. Initially, the M16A1 rifles were fired at ranges of 200, 300, 500, 600, and 800 m while the M16A1E1 rifles were fired at 200 through 800 m at each 100-m increment. After 3600 rounds, both, types were fired at 200, 300, and 500 m. At the 6000-round increment, the M16A1 rifles were fired at ranges of 200, 300 and 500 m, while the M16A1E1 rifles were fired at 200, 300, 500, 600, and 800 m.

d. After the accumulation of 6000 rounds, it was noted that the dispersion had deteriorated on the M16A1E1 rifles and the barrels were considered to have reached the end of their accurate life. At that point an effort was made to determine if the barrels were shot out or fouled. A 100 yard (indoor) dispersion test was conducted using the XM855E1 and SS109 cartridges to determine the effects of various barrel conditions, as follows:

- (1) Cold and fouled barrel.
- (2) Cold and clean barrel.
- (3) Warm and fouled barrel.

Two barrels were used with each type of cartridge and three 10-round groups were fired on each barrel under each condition.

e. Following the barrel condition effects test, another test was performed to determine the effect caused by combinations of cartridge type and rifling twist rate. The combinations tested were as follows:

- (1) XM855E1 in 1 turn in 7 in. (1:7) barrel.
- (2) M193 in 1:7 barrel.
- (3) XM855E1 in 1:12 barrel.
- (4) SS109 in 1:7 barrel.

Three barrels were used with each rifling twist/cartridge type combination and a total of 6000 rounds was fired on each barrel. Dispersion was checked after each 1200 round interval. Per the direction of TECOM no malfunction data was required.

f. Following these supplementary tests, the original endurance test was continued in a slightly altered form. Because of time constraints, the sample size of each rifle type was reduced to three. On the M16A1 rifles testing was continued with the samples with the maximum, minimum, and closest to median dispersion as measured after 3600 rounds. As the original barrels of the M16A1E1 rifles were no longer in acceptable condition, they were replaced with the three barrels from the previous test that fired the SS109 cartridge. Testing was continued with those six samples (three M16A1 rifles utilizing M193 ball ammunition and three M16A1E1 rifles utilizing SS109 ball ammunition) for another 6000 rounds each. Dispersion was checked at a range of 91 m (100 yd) (indoors) at every 1200 round interval. All malfunction data were recorded. All of the forgoing changes from the original test plan were requested by the development proponents and approved by TECOM.

g. All accuracy-dispersion firing was in the semiautomatic mode. Three 10-round groups were fired, from each weapon, at each range, by each of two shooters, from a benchrest. At least one shooter was always a current qualified NRA Master Class Shooter. All outdoor firings were done with a transverse wind of 16 km/hr (10 mph) or less and varied by not more than 9 km/hr (5 mph).

h. The rifles were cleaned, inspected, and lubricated (CIL) after each ten cycles. On the last 30 rounds of each tenth cycle in succession, hot-barrel velocities (15 m) and yaw (25 m) were recorded. After cleaning at 3600, 6000, 7200, 8400, 9600, 10,800, and 12,000 rounds the barrels were inspected to include borescoping, bore measurements, and bore straightness/erosion gage measurements. Headspace, firing-pin protrusion and gas-flow back-pressure measurements were taken at the same intervals (prior to accuracy firings).

i. For round-count purposes, the velocity and accuracy firings are included in the test totals as endurance rounds. The first 120 round cycle after the accuracy firings was reduced to maintain 120-round increments on the rifles.

#### 2.3.4 Results

a. Upon completion of the first 6000 rounds on the five M16A1 rifles, there was a total of 82 stoppages, equating to a mean round between stoppages (MRBS) of 371. At the completion of all test firing there were 162 stoppages equating to 358 MRBS. The stoppage data are presented in more detail in table 2.3-2. Dispersion stayed within acceptable limits throughout the test.

2.3.4 (Cont'd)

TABLE 2.3-2. SUMMARY OF STOPPAGES, ENDURANCE TEST, M16A1 RIFLE

Rifle No. (APG)	Total Rd Fired	Ctg Type	Cumulative Number of Stoppages					Total	MRBS
			FF1	FFD	FBC	FFR	FEJ		
1A	6,080	M193	4					4	1,520
	12,066		4	12		1		17	710
2A	6,080	M193	9	1	2			12	506
	<sup>a</sup> 10,920		19	1	5			25	437
3A	6,080	M193	36	8				44	138
	12,080		65	14				79	153
4A	6,080	M193	1					1	6,080
	12,066		1	12		2	2	17	710
5A	6,080	M193	17	2	1	1		21	290
	<sup>a</sup> 10,920		20	2	1	1		24	455
Cum total	30,400	M193	67	10	2			82	371
	58,052		110	41	6	3	2	162	358

<sup>a</sup>Rounds accumulated prior to change of test plan.

- FF1 = Failure to feed first round in magazine.
- FFD = Failure to feed.
- FBC = Failure of bolt to close.
- FFR = Failure to fire.
- FEJ = Failure to eject.
- MRBS = Mean rounds between stoppages.

b. At the conclusion of the first 6000 rounds fired on the M16A1E1 rifles there was a total of 23 stoppages for an MRBS of 1322. No stoppage data were recorded on the second 6000 round group. The last 6000 round group had 14 stoppages for an MRBS of 1290. The stoppage data are summarized in table 2.3-3. The first and last 6000 round groups were not summarized together due to the change in cartridge type used in each group.

2.3.4 (Cont'd)

TABLE 2.3-3. SUMMARY OF STOPPAGES<sup>a</sup>, ENDURANCE TEST, M16A1E1 RIFLE

Rifle No. (APG)	Total Rd Fired <sup>a</sup>	Ctg Type	Number of Stoppages							Total	MRBS
			FF1	FFD	FBC	FFR	FXT	FEJ	FBR		
1D	6,080	XM855E1	1				3			4	1,520
	<sup>b</sup> 6,080	SS109								-	NA
	6,022	SS109	1		2		1		1	5	1,204
2D	<sup>c</sup> 6,080	XM855E1		2				1		3	2,027
3D	6,080	XM855E1		2						2	3,040
	<sup>b</sup> 6,080	SS109								-	NA
	6,022	SS109	1	1				4	1	7	860
4D	<sup>c</sup> 6,080	XM855E1	4	1			3			8	760
5D	6,080	XM855E1	1				4	1		6	1,013
	<sup>b</sup> 6,080	SS109								-	NA
	6,022	SS109	1						1	2	3,011
Total	30,400	XM855E1	10	1			10	1	1	23	1,322
	<sup>b</sup> 18,240	SS109								-	NA
	18,066	SS109	3	1	2		1	4	1	14	1,290

<sup>a</sup>Per cartridge type and test interval.

<sup>b</sup>Original barrel was unacceptable after initial 6080 rounds. Barrel was replaced. Stoppages were not recorded on initial 6080 rounds of new barrel per TECOM direction.

<sup>c</sup>Original barrel was unacceptable after initial 6080 rounds.

FF1 = Failure to feed first round.

FFD = Failure to feed.

FBC = Failure of bolt to close.

FFR = Failure to fire.

FXT = Failure to extract.

FEJ = Failure to eject.

FBR = Failure of bolt to remain to rear after last round in magazine.

MRBS = Mean rounds between stoppages.

c. The dispersion results of the first 6000 round interval are summarized in table 2.3-4. More detailed results are presented in table 2 of appendix B.

## 2.3.4 (Cont'd)

TABLE 2.3-4. SUMMARY OF DISPERSION DATA, FIRST 6000 ROUNDS, ENDURANCE TEST

Range (m)	Rifle Type	Extreme Spread (cm)		
		Avg	High	Low
Initial Accuracy Firing <sup>a</sup>				
200	M16A1	19.6	29.7	9.9
	M16A1E1	27.1	39.4	17.8
300	M16A1	33.9	50.6	23.1
	M16A1E1	43.1	59.6	22.4
400	M16A1	b -	b -	b -
	M16A1E1	56.6	95.0	35.9
500	M16A1	64.2	112.6	47.4
	M16A1E1	70.6	129.8	49.6
600	M16A1	78.5	148.7	50.9
	M16A1E1	97.9	188.7	55.1
700	M16A1	b -	b -	b -
	M16A1E1	106.7	182.8	58.9
800	M16A1	152.4	210.2	93.3
	M16A1E1	132.3	175.9	89.0
After 3600 Rounds <sup>c</sup>				
200	M16A1	18.7	25.5	13.0
	M16A1E1	31.2	65.6	16.5
300	M16A1	27.2	38.3	17.7
	M16A1E1	49.8	86.7	27.8
500	M16A1	51.5	123.2	34.5
	M16A1E1	88.6	218.6	40.6
After 6000 Rounds <sup>c</sup>				
200	M16A1	17.7	33.3	11.9
	M16A1E1	62.2	93.8	33.6
300	M16A1	29.4	70.0	19.3
	M16A1E1	85.3	110.1	34.6
500	M16A1	117.2	142.3	35.0
	M16A1E1	171.7	251.8	116.3
600	M16A1	b -	b -	b -
	M16A1E1	177.2	230.8	130.2
800	M16A1	b -	b -	b -
	M16A1E1	219.2	283.4	144.1

<sup>a</sup>Results of 5 rifle samples per type.

<sup>b</sup>M16A1 rifles were not fired at this range.

<sup>c</sup>Results of 3 rifle samples per type.

d. In the course of firing the first 6000-rounds on the M16A1E1 rifles, the dispersion deteriorated at an accelerated rate. At the end of the first 6000-round group the barrels were considered to have reached the end of their accurate life, using the XM855E1(FN) cartridge. A barrel condition effects test was performed with the dispersion results as shown in table 2.3-5.

## 2.3.4 (Cont'd)

TABLE 2.3-5. SUMMARY OF DISPERSION DATA<sup>a</sup>, BARREL CONDITION EFFECTS TEST, M16A1E1 RIFLE

M16A1E1 Rifle No. (APG)	Ctg Type	Extreme Spread (cm)			
		Target No.			Avg
		1	2	3	

Data from previous 6000 round endurance/dispersion test.

B1	XM855E1 (FN)				16.8
B2	XM855E1 (FN)				25.6
C5	SS109				7.7
C7	SS109				11.1

Condition 1: Fired from a cold and dirty barrel.

B1	SS109	9.1	9.2	9.7	9.33
B2	SS109	7.9	8.3	11.4	9.2
C5	XM855E1 (FN)	9.4	11.8	9.9	10.36
C7	XM855E1 (FN)	15.7	13.8	12.5	14.0

Condition 2: Fired from a cold and clean barrel.

B1	SS109	10.4	8.0	8.6	9.0
B2	SS109	11.5	8.7	6.7	8.96
C5	XM855E1 (FN)	9.0	5.2	6.7	6.96
C7	XM855E1 (FN)	9.8	12.2	12.8	11.6

Condition 3: Same as condition 2 except that ammunition was of type used during 6000-round endurance.

B1	XM855E1 (FN)	12.5	5.3	16.0	11.26
B2	XM855E1 (FN)	13.4	16.4	16.1	15.3
C5	SS109	10.0	7.8	12.4	10.06
C7	SS109	11.0	9.8	13.8	11.53

Condition 4: Fired from warm and dirty barrel.

B1	XM855E1 (FN)	9.0	10.3	16.9	12.06
B2	XM855E1 (FN)	33.3	19.0	21.7	24.66
C5	SS109	11.0	9.0	8.8	9.6
C7	SS109	11.0	10.8	12.5	11.43

<sup>a</sup>Range = 91.4 m (100 yd).

e. In a further effort to isolate the root cause of the dispersion degradation problem, another test was run to show the effect of combinations of cartridge type and rifling twist rates. The resultant average instrumental velocity, bore erosion gage, and average extreme spread measurements are summarized in table 2.3-6.

## 2.3.4 (Cont'd)

TABLE 2.3-6. SUMMARY OF AFFECTS, RIFLING TWIST RATE/CARTRIDGE TYPE, M16A1E1 RIFLE

Rifle No. (APG)	Rifling Twist Rate	Ctg Type	Total Rd Fired	Avg IV <sup>a</sup> (mps)	Bore Erosion Gage Insert Depth (mm)	Avg ES <sup>b</sup> (cm)
B1	1:7	XM855E1 (FN)	0	934	6.5	11.2
			1200	933	6.0	9.3
			2400	930	5.5	10.7
			3600	927	5.0	10.5
			4200	931	4.0	11.0
			4800	934	3.5	10.4
B2	1:7	XM855E1 (FN)	0	924	6.5	11.0
			1200	929	6.0	10.7
			2400	921	5.0	11.8
			3600	925	4.5	15.3
			4200	931	4.0	15.8
			4800	927	3.5	13.7
B3	1:7	XM855E1	0	926	6.5	10.7
			1200	931	6.0	10.5
			2400	933	5.0	7.9
			3600	924	4.5	8.6
			4200	929	4.5	10.3
			4800	928	3.5	9.9
C8	1:7	M193	0	954	6.0	8.9
			1200	962	6.5	10.8
			2400	963	6.5	11.5
			3600	973	6.0	11.8
			4200	964	5.0	12.2
			4800	957	5.2	11.4
C9	1:7	M193	0	959	6.5	10.3
			1200	964	6.0	11.1
			2400	968	6.0	10.6
			3600	973	6.0	10.5
			4200	970	5.0	11.4
			4800	962	4.8	8.7
C10	1:7	M193	0	956	6.0	10.5
			1200	962	6.5	11.4
			2400	964	6.5	13.3
			3600	970	6.0	12.2
			4200	967	5.0	9.7
			4800	960	4.0	13.4
			6000	958	3.5	10.8

<sup>a</sup>Instrumental velocity point at 4.57 m from muzzle.

<sup>b</sup>Average of three 10-shot groups for each of two shooters, range 91.4 m (100 yd).

## 2.3.4 (Cont'd)

TABLE 2.3-6 (CONT'D)

Rifle No. (APG)	Rifling Twist Rate	Ctg Type	Total Rd Fired	Avg IV <sup>a</sup> (mps)	Bore Erosion Gage Insert Depth (mm)	Avg ES <sup>b</sup> (cm)
C4	1:7	SS109	0	918	6.0	8.6
			1200	919	6.0	10.0
			2400	920	6.5	8.8
			3600	924	5.0	8.6
			4200	924	5.0	9.4
			4800	921	4.0	9.9
			6000	921	3.0	8.2
C5	1:7	SS109	0	920	6.0	10.0
			1200	925	6.0	8.5
			2400	934	6.5	9.0
			3600	932	5.0	9.5
			4200	931	5.0	9.8
			4800	928	4.0	8.6
			6000	928	2.5	7.7
C7	1:7	SS109	0	921	6.5	7.2
			1200	921	6.5	7.9
			2400	928	6.0	7.6
			3600	924	5.0	9.6
			4200	930	5.0	10.7
			4800	926	4.0	11.5
			6000	927	2.0	11.1
B8	1:12	XM855E1 (FN)	0	898	6.5	30.3
			1200	905	6.5	36.4
			2400	908	6.0	25.9
			3600	908	4.0	37.8
			4200	899	3.7	42.5
			4800	910	1.5	39.9
			6000	890	-0.5	34.9
B9	1:12	XM855E1 (FN)	0	896	6.5	28.8
			1200	904	6.5	30.1
			2400	905	6.0	24.4
			3600	901	4.0	31.7
			4200	901	3.5	35.8
			4800	909	3.3	38.7
			6000	893	0.5	25.3
B10	1:12	XM855E1 (FN)	0	904	6.2	35.1
			1200	910	6.2	41.4
			2400	918	6.0	34.3
			3600	901	3.5	37.7
			4200	903	2.7	41.5
			4800	905	1.3	37.0
			6000	892	-4.0	34.5

<sup>a</sup>Instrumental velocity point at 4.57 m from muzzle.

<sup>b</sup>Average of three 10-shot groups for each of two shooters, range 91.4 m (100 yd).

ES = Extreme spread.

IV = Instrumental velocity.

2.3.4 (Cont'd)

Only in the 1:12/XM855E1(FN) combinations was any excessive yaw noted and then only after 2400 rounds.

f. Endurance testing was continued on the M16A1E1 rifles with the SS109 cartridge, rather than the XM855E1(FN) rounds. As the original barrels were no longer useable, the barrel/upper receiver assemblies from rifles C4, C7, and C5 were assembled to rifles 1D, 3D, and 5D, respectively. Testing was also continued on the M16A1 rifles, but only three of the original five. The chosen three were the samples with the largest, smallest, and closest to average extreme spread; as derived from the first 6000 round test. Dispersion and instrumental velocity data are summarized in table 2.3-7.

TABLE 2.3-7. SUMMARY OF DISPERSION AND INSTRUMENTAL VELOCITY DATA, ENDURANCE TEST, M16A1 AND M16A1E1 RIFLES

	Rifle No. (APG)	Total Rounds Fired				
		7,200	8,400	9,600	10,800	12,000
M16A1						
Avg ES <sup>a</sup> , cm	1A	9.9	10.6	8.2	9.5	10.0
	3A	9.3	10.6	9.6	9.6	9.2
	4A	9.2	9.1	10.4	10.0	10.6
	Avg	9.5	10.1	9.4	9.7	9.9
	Avg IV <sup>b</sup> , mps	1A	<sup>c</sup> -	3164	3161	3157
	3A	<sup>c</sup> -	3160	3169	3161	3149
	4A	<sup>c</sup> -	3195	3190	3184	3190
M16A1E1						
Avg ES <sup>a</sup> , cm	1D	9.8	9.1	12.1	11.8	13.1
	3D	8.9	7.8	8.8	12.5	12.2
	5D	14.2	12.6	13.7	15.4	14.6
	Avg	10.9	9.8	11.5	13.2	13.3
	Avg IV <sup>b</sup> , mps	1D	3081	3062	3053	3066
	3D	3076	3083	3070	3084	3044
	5D	3077	3068	3066	3076	3035

<sup>a</sup>Average of three 10-shot groups for each of two shooters, range 91.4 m (100 yd).

<sup>b</sup>Instrumentation point = 4.57 m from muzzle.

<sup>c</sup>Instrumentation down.

ES = Extreme spread.  
IV = Instrumental velocity.

g. Initially, the XM855E1(FN) ammunition as loaded by Lake City Army Ammunition Plant showed poor quality (see initial inspection). Not only was outward appearance of the ammunition poor but performance was poor. On several occasions the ammunition exhibited short rounds failing to reach the target and indicating hits short of the target. This was ammunition that had been 100% visually inspected for defects prior to release for use. All cartridges of this type had to be visually inspected again at APG to preclude use of damaged cartridges in tests, especially those where weapon functioning was of principle interest.

### 2.3.5 Analysis

a. During the first 6000-round interval, the M16A1 rifle group had a total of 82 stoppages for an MRBS of 371. With respect to the lower 90% confidence limit the MRBS was 320. The M16A1E1 rifle group during the same interval, had a total of 23 stoppages for an MRBS of 1322. With respect to the lower 90% confidence limit the MRBS was 998.

b. The predominant functional failure mode (table 2.3-2 and 2.3-3) was failure to feed, especially the first round in a magazine. The majority of these failures occurred on the standard system, that is the M16A1 rifle using the M193 ball cartridge. In the cases of failure to feed the first round, the point at which the bolt stopped (stoppage) varied from the time it struck the base of the cartridge and moved it slightly forward to just short of bolt closure and lock. In most cases the use of the bolt forward assist mechanism cleared or would have cleared the stoppage. The failures to feed on other than the first round were usually related to stubbing of the projectile nose on the rear face of the barrel.

c. Within the confines of the cyclic path of the bolt mechanism and the feeding mechanism both types of rifles are identical by design. Both rifles were manufactured by the same factory (Colt Industries) except at different times. The M16A1 rifles were provided from depot storage. The magazines were randomly assigned to each weapon from the same batch received for the test, all were from the same manufacturer (Adventure Line, Inc.). All magazines were loaded on the same APG magazine loading fixture utilizing, in both cases, carton-packed cartridges. The rifles were tested side by side by the same gun crews. The projectile weights and shapes (fig. 36, app B) are slightly different but not so much as to affect feeding by themselves. At this point, there is no apparent reason for the disparity in the number of feeding stoppages between the two rifle types. The number of feeding stoppages for the M16A1 far exceeds the limits imposed by MIL-R-45587A (ref 7) and the results of the most recent production comparison test performed by APG (ref 30). Areas for further investigation might include the force of the action springs and dimensional differences in the barrel extensions.

d. Because of the changes in data required and acquisition methods used throughout the three basic intervals of the test, only the first 6000-round interval was used to address the accuracy criterion. Means and standard deviations for each group of rounds were obtained for the horizontal and vertical components of impact. These estimates were used to address the criterion which states the accuracy of the product improved rifles will be equal to or better than the standard rifles at ambient temperature. Firings at 200-, 300-, and 500-m ranges were analyzed using a four-way nested

2.3.5 (Cont'd)

analysis of variance model. The main effects were time (3 levels-zero rounds, after 3600 and 6000 rounds), shooter (2 levels), system (2 levels-M16A1 and M16A1E1), and weapon within system (3 levels-those rifles with maximum, minimum, and median ES during initial firings). This was a mixed effects model where time and system were considered fixed and shooter and weapon within system were considered random. There were 3 replications per cell.

e. Throughout the following discussion, statements of statistical significance are made. It should be emphasized that statistically significant differences may or may not be differences of practical concern. The units of measurement, in this case centimeters, must be considered. It is assumed that the horizontal and vertical components of impact are independent, normally distributed random variables. In addition, for the analyses of variance it is assumed that the dispersion estimates are normally distributed. All significance tests are at the 5% level; these are called one tail tests.

f. Before discussing any results and analysis, it is first necessary to note that there will be no mention of shooter effect in this report. Though it was stated that there were two levels of shooters, when in fact, as many as 5 or 6 shooters, were used for this test. No one shooter completed the full test firing schedule. Since all shooters were qualified master shooters, it was assumed that, for analytical purposes, shooter 1 and shooter 2 were actually two individuals, when there may have been more than one individual assigned as shooter 1 and/or 2. For a particular firing exercise, no one individual would have been assigned both No. 1 and No. 2 shooter.

g. No significant difference was detected among systems with respect to the mean horizontal CI for all three ranges, as shown in table 2.3-8.

TABLE 2.3-8. MEAN HORIZONTAL CI, SYSTEM, CM

Range (m)	M16A1 Rifle	M16A1E1 Rifle
200	3.9	0.4
300	-0.9	- 1.8
500	2.1	12.7

A significant difference was detected among weapons within system effects with respect to the horizontal CI for all ranges. Table 2.3-9 presents those results.

TABLE 2.3-9. MEAN HORIZONTAL CI, WEAPON WITHIN SYSTEM, CM

Range (m)	M16A1 Rifle			M16A1E1 Rifle		
	1	2	3	1	2	3
200	-2.1	14.9	- 1.2	5.1	-0.5	- 3.3
300	-6.5	14.8	-11.0	9.8	-5.1	-10.1
500	-5.4	33.7	-21.8	28.7	6.4	3.1

2.3.5 (Cont'd)

Since a difference existed among weapons within system, caution should be taken when interpreting any significance statement regarding the system, as this difference in weapon within system might overshadow any conclusion about systems. Table 2.3-10 presents the mean horizontal CI for number of rounds fired in weapon. For all ranges there was no significant difference in mean horizontal CI, regardless of system, due to the number of rounds that have been fired in the weapon.

TABLE 2.3-10. MEAN HORIZONTAL CI, ROUND LIFE, CM

Round Life	200 Meters		300 Meters		500 Meters	
	M16A1	M16A1E1	M16A1	M16A1E1	M16A1	M16A1E1
Initial	1.8	2.8	-10.0	-7.6	-22.1	17.6
3600	8.8	-1.4	8.0	5.2	8.2	6.3
6000	1.0	0.0	-0.8	-3.0	20.3	14.2

h. In comparing the mean horizontal standard deviations, a significant difference was detected between systems at the 200- and 300-m ranges. See table 2.3-11.

TABLE 2.3-11. MEAN HORIZONTAL STANDARD DEVIATION, SYSTEM, CM

Range (m)	M16A1 Rifle	M16A1E1 Rifle
200	4.2	9.9
300	6.8	15.1
500	13.7	28.6

Likewise a significant difference also existed for weapon within system effect at the 200-m range. Those results are presented in table 2.3-12.

TABLE 2.3-12. MEAN HORIZONTAL STANDARD DEVIATION, WEAPON WITHIN SYSTEM, CM

Range (m)	M16A1 Rifle			M16A1E1 Rifle		
	1	2	3	1	2	3
200	4.4	4.1	4.1	8.0	9.3	12.5
300	6.8	6.8	6.9	13.6	15.1	16.4
500	14.2	15.6	11.3	26.6	24.7	34.4

It should also be noted that the mean horizontal standard deviation for the M16A1 rifle was lower than that of the M16A1E1 rifle over all ranges. Table 2.3-13 presents the mean horizontal standard deviation for number of rounds fired in the weapon.

2.3.5 (Cont'd)

TABLE 2.3-13. MEAN HORIZONTAL STANDARD DEVIATION, ROUND LIFE, CM

Round Life	200 Meters		300 Meters		500 Meters	
	M16A1	M16A1E1	M16A1	M16A1E1	M16A1	M16A1E1
Initial	4.4	6.7	7.0	10.4	14.6	17.2
3600	4.3	7.0	6.6	11.4	11.8	22.0
6000	4.0	15.8	6.8	23.4	14.8	46.4

For all ranges there was no significant difference in horizontal standard deviation due to number of rounds fired for the M16A1 rifle and the same holds true for the M16A1E1 rifle for initial and over 3600 rounds. However, a significant increase in horizontal standard deviation is detected after 6000 rounds for the M16A1E1.

i. Table 2.3-14 presents the mean vertical CIs for system at the various ranges.

TABLE 2.3-14. MEAN VERTICAL CI, SYSTEM, CM

Range (m)	M16A1 Rifle	M16A1E1 Rifle
200	- 5.7	7.3
300	- 16.8	18.4
500	-143.1	61.4

A significant difference was detected between systems with respect to the mean vertical CIs at the 300- and 500-meter ranges. Again a significant difference was also detected among the weapons within system for all ranges. See table 2.3-15.

TABLE 2.3-15. MEAN VERTICAL CI, WEAPON WITHIN SYSTEM, CM

Range (m)	M16A1 Rifle			M16A1E1 Rifle		
	1	2	3	1	2	3
200	- 6.0	- 12.2	1.2	- 4.7	13.6	12.6
300	- 21.8	- 27.0	- 1.6	6.0	22.3	26.8
500	-136.8	-171.4	-121.2	47.5	68.5	68.3

Table 2.3-16 presents the mean vertical CIs for number of rounds fired in the weapon.

TABLE 2.3-16. MEAN VERTICAL CI, ROUND LIFE

Round Life	200 Meters		300 Meters		500 Meters	
	M16A1	M16A1E1	M16A1	M16A1E1	M16A1	M16A1E1
Initial	12.0	13.2	13.0	23.7	46.0	48.0
3600	5.4	- 3.2	-15.0	1.8	-130.0	45.4
6000	-31.6	11.6	-48.4	29.7	-345.4	90.8

### 2.3.5 (Cont'd)

For all ranges, a significant drop in the mean vertical CI was detected as the number of rounds fired increased on the M16A1 rifle, but no significant difference was detected among the mean vertical CIs for the M16A1E1 rifle.

j. In comparing the mean vertical standard deviation, a significant difference was detected between systems at the 200- and 300-meter ranges as shown in table 2.3-17.

TABLE 2.3-17. MEAN VERTICAL STANDARD DEVIATION, SYSTEM, CM

<u>Range (m)</u>	<u>M16A1 Rifle</u>	<u>M16A1E1 Rifle</u>
200	5.3	11.1
300	5.8	15.7
500	17.5	29.0

Again a significant difference existed among weapons within system effects for all ranges as shown in table 2.3-18.

TABLE 2.3-18. MEAN VERTICAL STANDARD DEVIATION, WEAPON WITHIN SYSTEM, CM

<u>Range (m)</u>	<u>M16A1 Rifle</u>			<u>M16A1E1 Rifle</u>		
	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>2</u>	<u>3</u>
200	5.3	5.1	5.4	8.3	11.5	13.6
300	7.7	7.5	8.8	11.3	16.2	19.7
500	13.7	12.4	26.3	24.0	28.3	34.6

As in the horizontal standard deviation results, the mean vertical standard deviation for the M16A1 rifle was also lower than that of the M16A1E1 rifle for all ranges. Table 2.3-19 presents the mean vertical standard deviation for number of rounds fired in the weapon.

TABLE 2.3-19. MEAN VERTICAL STANDARD DEVIATION, ROUND LIFE

<u>Round Life</u>	<u>200 Meters</u>		<u>300 Meters</u>		<u>500 Meters</u>	
	<u>M16A1</u>	<u>M16A1E1</u>	<u>M16A1</u>	<u>M16A1E1</u>	<u>M16A1</u>	<u>M16A1E1</u>
Initial	5.5	6.9	9.0	10.2	15.3	17.2
3600	5.2	7.8	7.6	11.6	13.3	21.6
6000	5.0	18.6	7.4	25.3	23.8	48.2

For all ranges, there was no significant difference in mean vertical standard deviation due to the number of rounds fired for the M16A1 rifle, although at the 500-m range, after 6000 rounds, there was a substantial increase in the mean standard deviation. Likewise with the M16A1E1 rifle, no significant differences exist for the initial and after 3600 rounds, however, a significant increase is detected after 6000 rounds.

k. For those firings at 600- and 800-m ranges where only the initial firing was done for both rifle types, a three-way nested analysis of variance was used to analyze the results. The main effects were shooter (2 levels),

### 2.3.5 (Cont'd)

system (2 levels - M16A1 and M16A1E1) and weapon within system (3 levels - those rifles with maximum, minimum, and median ES during initial firings). One significant difference was detected among systems with respect to the horizontal CI at the 800-m range and one significant difference between systems with respect to vertical standard deviation for the 800-m range. No significant difference was detected among weapon within system. Tables 2.3-20 and 2.3-21 present the mean horizontal and vertical CIs and standard deviation for systems and weapons within system, respectively.

TABLE 2.3-20. MEAN VERTICAL AND HORIZONTAL CIs AND STANDARD DEVIATION FOR SYSTEM, CM

	Range (m)	M16A1 Rifle	M16A1E1 Rifle
Horiz CI	600	-16.3	- 3.4
	800	85.3	-11.3
Horiz std dev	600	18.6	21.8
	800	25.0	31.4
Vert CI	600	40.0	57.5
	800	31.0	40.2
Vert std dev	600	20.5	24.2
	800	42.2	33.4

TABLE 2.3-21. MEAN VERTICAL AND HORIZONTAL CI AND STANDARD DEVIATION, WEAPON WITHIN SYSTEM, CM

Range (m)	M16A1 Rifle			M16A1E1 Rifle			
	1	2	3	1	2	3	
Horiz CI	600	- 23.7	- 2.9	-22.2	0.1	-15.6	5.3
	800	103.6	68.0	84.3	1.9	-23.8	-11.9
Horiz std dev	600	19.9	17.0	18.8	20.3	21.3	23.8
	800	25.6	19.8	29.7	30.0	32.5	31.7
Vert CI	600	46.9	28.5	44.7	52.7	79.0	40.7
	800	90.0	25.9	-23.0	66.7	26.6	27.1
Vert std dev	600	19.0	18.4	24.2	27.9	22.8	21.8
	800	40.6	39.0	46.9	32.6	35.2	32.5

1. To summarize the analysis of the initial accuracy tests, first there seems to be no difference in mean horizontal CIs between the systems. With respect to the vertical CIs, a significant difference did exist between the systems. The magnitude of the vertical CIs increased as range increased for the M16A1 rifle, where no effect was apparent for the M16A1E1 rifle. Likewise, with the mean horizontal and vertical standard deviations, there existed a significant difference between systems. But in this case the dispersion for the M16A1 rifle was always smaller than that of the M16A1E1 rifle. It should also be remembered that these results are based largely on firings at 200-, 300-, and 500-m ranges, due to the lack of firings at the 600-, and 800-m ranges.

### 2.3.5 (Cont'd)

m. With respect to the dispersion tests made during the last 6000-round interval (table 2.3-7) ES (maximum distance between all possible pairs of impacts) was recorded for each group of rounds. These data were analyzed using a four-way nested analysis of variance model. The main effects were time (5 levels - after 7200, 8400, 9600, 10800, and 12000 rounds), shooter (2 levels), system (2 levels - M16A1 and M16A1E1) and weapon within system (3 levels - those rifles with maximum, minimum, and median ES during initial firings). This was a mixed effect model where time and systems were considered fixed and shooter and weapon within system were considered random. There were three replications per cell. It is assumed that ES is a normally distributed random variable. All significance tests are at the 5% level; these tests are one tailed tests.

No significant difference was detected among systems with respect to the mean ES. See table 2.3-22 below.

TABLE 2.3-22. MEAN EXTREME SPREAD, SYSTEM, CM

Range (yd)	M16A1 Rifle	M16A1E1 Rifle
	w/M193 Ball Ammo	w/SS109 Ball Ammo
100	9.7	11.8

A significant difference was detected among weapons within system effects with respect to the mean ES. As can be seen from table 2.3-23, the mean ES among the weapons within system for the M16A1 rifle was lower and more consistent than that of the M16A1E1 rifle.

TABLE 2.3-23. MEAN EXTREME SPREAD, WEAPON WITHIN SYSTEM, CM

Range (yd)	M16A1 Rifle			M16A1E1		
	W/M193 Ball Ammo			w/SS109 Ball Ammo		
	1	2	3	1	2	3
100	9.6	9.2	9.9	11.2	10.1	14.4

Table 2.3-24 below presents the mean ES for number of rounds fired in the weapon (time). No significant difference in mean ES was detected due to the number of rounds that have been fired in the weapon.

TABLE 2.3-24. MEAN EXTREME SPREAD, TIME, CM

Time	M16A1 Rifle	M16A1E1 Rifle
	w/M193 Ball Ammo	w/SS109 Ball Ammo
7,200	9.5	11.0
8,400	10.1	9.9
9,600	9.4	11.6
10,800	9.7	13.2
12,000	10.0	13.3

A significant difference was detected between shooters with respect to the mean ES (shooter 1-9.4 cm and shooter 2-12.1 cm).

n. The criteria for ES states that the ES shall not exceed 17.8 cm at 91.4 m (100 yd). There were 108 individual targets fired with the M16A1E1 rifle of which 8 targets had an ES which exceeded 17.8 cm. It should be noted that these 8 targets were dispersed over the rounds fired such that two were after 6000 rounds, one after 7200 rounds, one after 8400 rounds, two after 9600 rounds, one after 10800 rounds, and one after 12000 rounds. There were 90 individual targets fired with the M16A1 rifle of which none of the targets had an ES which exceeded 17.8 cm. The overall mean ES for the M16A1 rifle (9.7 cm) and the M16A1E1 rifle (11.8 cm) did not exceed the criteria of 17.8 cm.

o. Reliability is addressed in paragraph 2.13.

2.3.6 Conclusions

Criteria 2.3.2a and d were considered met.

Criteria 2.3.2b was not met when the XM855E1(FN) cartridges were used but was met when the SS109 cartridge was used.

Criteria 2.3.2c was not met (see para 2.13.5).

TABLE 2.3-23. MEAN EXTREME SPREAD, WEAPON WITHIN SYSTEM, CM

Range (yd)	M16A1 Rifle		M16A1E1 Rifle	
	1	2	1	2
100	9.6	9.2	9.9	11.2
				10.4
				14.4

Table 2.3-24 below presents the mean ES for number of rounds fired in the weapon (time). No significant difference in mean ES was detected due to the number of rounds that have been fired in the weapon.

TABLE 2.3-24. MEAN EXTREME SPREAD, TIME, CM

Time	M16A1 Rifle	M16A1E1 Rifle
7,200	9.2	11.0
8,400	10.1	9.9
9,600	9.4	11.6
10,800	9.7	13.2
12,000	10.0	13.3

## 2.4 EXTREME TEMPERATURE AND SALT-WATER IMMERSION

### 2.4.1 Objective

The objective was to evaluate the performance of the test rifles in comparison with that of control rifles under low- and high-temperature conditions.

### 2.4.2 Criteria

a. The product improved barrel will accommodate the mounting of all accessories or munitions presently mounted on or fired from the standard barrel to include the following (devised by Test Agency, TECOM approved).

- (1) M203, 40-mm grenade launcher.
- (2) M7, bayonet.
- (3) MILES.
- (4) M234, RAG launcher (for information only).
- (5) M261, conversion kit.
- (6) M29 rifle grenade.
- (7) M15A2, blank firing attachment.

b. The performance and durability of the product improved weapon shall not be adversely affected by the extreme temperature ( $-46^{\circ}$  and  $+68^{\circ}$  C) conditions (devised by Test Agency, TECOM approved).

c. The durability of the product improved plastic components must equal or surpass that of the control components at ambient temperatures of AR 70-38 (categories A1 and C2;  $-46^{\circ}$ ,  $+21^{\circ}$ ,  $+68^{\circ}$  C) and in adverse conditions) devised by Test Agency, TECOM approved)

d. The performance and durability of the product improved weapon shall be equal to or better than that of the standard weapon after salt water and high-temperature humidity conditioning (devised by Test Agency, TECOM approved).

### 2.4.3 Data Acquisition Procedure

Testing was in general conformance with TECOM TOP 4-2-602 (ref 17) and TOP/MTP 3-2-059 (ref 12). All weapons were CIL with CLP prior to temperature conditioning. Inspections included MPI and zygo which were repeated after each phase. Plastic component damage was visually noted; therefore, no X-rays were required.

2.4.3.1 High-temperature phase. High-temperature testing was in accordance with paragraph 6.2.6.3 of TECOM TOP 3-2-059.

### 2.4.3.1 (Cont'd)

Five weapons of each type, 12,000 rounds of ball ammunition, and the required accessory ammunition were placed in the climatic chamber facility and conditioned at +68° C (+155° F) for a minimum of 8 hours. One weapon of each type had an M203 grenade launcher attached. Testing was broken down into four subphases, the test and standard components were inspected for damage.

a. Phase 1, rifle firing. All five rifles of each type were fired from a benchrest in 120-round cycles, as per table 2.3-1. A 2-hour reconditioning period was allowed between cycles. At the beginning of each cycle, attempts were made to flip and adjust the rear sights.

b. Phase 2, M203 grenade launcher firing. One weapon of each type, as per table 2.4-1 was used to fire 25 rounds of 40-mm, M407A1 ammunition, from the shoulder, at each of two elevations (+6 and +45°).

TABLE 2.4-1. EXTREME TEMPERATURE SCHEDULE OF WEAPONS USAGE

Phase	Sub-phase	Weapons No. (APG)
High temperature +68°C	1	6, 7, 8, 9, 10
	2	6
Low temperature -46°C	3	7, 8
	4	6, 9, 10

c. Phase 3, rifle grenade firing. Two weapons of each type, as per table 2.4-1, were used to fire 25 M29 inert loaded rifle grenades from the test stand at an elevation of +45° under two conditions:

(1) With butt of stock completely supported with a sandbag.

(2) With only the toe of the stock resting flat, on a reinforced 3/8-inch sheet of plywood (firing platform).

d. Phase 4, 1.5 m drop. Three weapons of each type, as per table 2.4-1, were dropped from a height of 1.5 m (5 ft) above a flat concrete floor. Each weapon was dropped in the following attitudes:

(1) Butt plate impacting flat on the floor.

(2) Toe of butt plate impacting on floor, rifle at 45° angle.

(3) Heel of butt plate impacting on floor, rifle at 45° angle.

(4) Left-hand edge of butt plate impacting on floor, rifle at 45° angle.

(5) Right-hand edge of butt plate impacting on floor, rifle at 45° angle.

(6) Top of handguard impacting on edge of a section of timber (pine), 30.4 by 30.4 cm (12 by 12 in.), at a 90° angle.

(7) Bottom of handguard impacting on edge of a section of timber, 30.4 by 30.4 cm, at a 90° angle.

(8) Side of handguard impacting on edge of a section of timber, 30.4 by 30.4 cm, at a 90° angle.

(9) Rear sight impacting on floor, rifle at 0° angle (200-m setting on M16A1E1).

2.4.3.2 Low-temperature tests. Low-temperature testing was in accordance with paragraph 6.2.6.2 of TECOM TOP/MTP 3-2-059.

a. Five weapons of each type (and 1200 rounds of ammunition for each weapon) were placed in the climatic chamber facility and conditioned at -46° C (-50° F) for a minimum of 8 hours. M407A1 and M29 grenades were included, as in the high temperature test.

b. The same series of drop tests performed at high temperatures, were repeated, with new plastic test components assembled to each weapon. Before the test, barrel straightness was checked with the appropriate gage.

c. Due to the abnormally high malfunction/stoppage incidence during low-temperature testing, a retest was conducted substituting SS109 ammunition for XM855E1(FN) in the M16A1E1 rifles.

2.4.3.3 Salt-water immersion. This test was conducted in accordance with the general guidelines of TOP/MTP 3-2-059, paragraph 6.2.6.10, 1 September 1971.

a. A salt-water solution of 20% salt (sodium chloride (NaCl)) to 80% distilled water by weight was prepared. The salt did not contain more than 0.1% sodium iodide or more than 0.2% impurities. The temperature of the solution was  $32.0 \pm 2.8^{\circ} \text{C}$  ( $95 \pm 5^{\circ} \text{F}$ ). The pH and specific gravity of the salt solution was 7.1 and 1.142, respectively.

b. Ten weapons (two of each type) were subjected to this test. Prior to test, the weapons were disassembled, cleaned, oiled with CLP for firing, and reassembled with the safety applied. The fully-loaded weapons and one additional loaded magazine for each weapon were submerged in the NaCl solution for 60 seconds. When the weapons were removed from the solution, the muzzle of each weapon was depressed and the bolt slightly retracted to allow the salt water to drain from the bore. Each weapon and the ammunition in the attached and separate magazines exposed to the NaCl solution were then fired. After the firing was completed, the weapons and empty magazines were placed in the temperature-humidity cabinet on stainless steel, wire mesh racks and subjected for 10 days to the schedule described below. On the third, fifth, eighth, and tenth days of the diurnal cycle described in table 2.4-2, a full complement of ammunition from each of the two magazines provided for each weapon was fired. This ammunition was not exposed to salt water immersion or temperature-humidity, but was fired from magazines exposed to these two environments. The weapons were also visually inspected for any evidence of deterioration or corrosion when they were removed from the temperature-humidity chamber for firing. The points in time the weapons were removed from the diurnal cycle were as follows.

- (1) Third day between the 74- and 76-hour points.
- (2) Fifth day between the 122- and 124-hour points.
- (3) Eighth day between the 194- and 196-hour points.
- (4) Tenth day at the completion of 240 hours.

c. Following firing, the weapons were returned to the chamber and the total time the weapons were in a temperature-humidity environment outside the  $\pm 1.7^\circ \text{C}$  and  $\pm 5\%$  limitations, respectively, was regained in conditioning prior to completion of the diurnal cycle.

TABLE 2.4-2. STORAGE SCHEDULE FOR 24-HOUR HUMIDITY TEST CYCLE

Phase	Temperature ( $^\circ\text{C}$ )	Rel Hum (%)	Duration (hr)
1	Gradually increase to $40.6 \pm 1.7$ and ...	$90 \pm 5$	2
2	Maintain at $40.6 \pm 1.7$ and ...	$90 \pm 5$	16
3	Gradually decrease from $40.6$ to $21.2 \pm 1.7$ and increase to ...	$95 \pm 5$	2
4	Maintain at $21.2 \pm 1.7$ and repeat	$95 \pm 5$	4

#### 2.4.4 Results

##### 2.4.4.1 High temperature test

a. There was a total of 19 stoppages with the M16A1 rifles as opposed to nine stoppages with the product improved models. The numbers and types of stoppages are summarized in table 2.4-3. The average cyclic rates of fire are given in table 2.4-4.

2.4.4.1 (Cont'd)

TABLE 2.4-3. SUMMARY OF STOPPAGES, HIGH TEMPERATURE TEST

Rifle No. (APG)	Total Rd Fired	Cartridge Type	Number of Stoppages				Total	MRBS
			FFD	DFD	FTL	FFR		
M16A1 Rifle								
6A	1200	M193		1		a <sub>1</sub>	2	600
7A	1200	M193	2		1	a <sub>1</sub>	4	300
8A	1200	M193	2			a <sub>1</sub>	3	400
9A	1200	M193	8				8	150
10A	1200	M193		2			2	600
Total	6000		12	3	1	3	19	316
M16A1E1 Rifle								
6D	1200	XM855E1				b <sub>3</sub>	3	400
7D	1200	XM855E1	3				3	400
8D	1200	XM855E1			1		1	1200
9D	1200	XM855E1						
10D	1200	XM855E1		1		1	2	600
Total	6000		3	1	1	4	9	667

<sup>a</sup>Did not fire after second attempt, satisfactory primer indent.

<sup>b</sup>Fired on second attempt.

FFD = Failure to feed.

DFD = Double feed.

FTL = Failure to lock.

FFR = Failure to fire.

## 2.4.4.1 (Cont'd)

TABLE 2.4-4. AVERAGE CYCLIC RATE OF FIRE, HIGH TEMPERATURE TEST

Cycle No.	Avg Cyclic Rate of Fire (spm)				
	M16A1 Rifle No. (APG)				
	6A	7A	8A	9A	10A
1	842	846	904	869	867
2	846	839	884	864	866
3	848	822	909	870	890
4	848	851	887	905	848
5	820	848	896	892	850
6	856	850	896	872	856
7	848	831	883	843	870
8	850	856	892	868	865
9	861	876	893	841	866
10	845	851	881	857	871

Cycle No.	M16A1E1 Rifle No. (APG)				
	6D	7D	8D	9D	10D
1	921	811	879	820	862
2	918	832	882	818	875
3	871	784	861	808	791
4	889	834	806	775	836
5	906	836	876	810	845
6	909	839	846	809	841
7	896	787	857	819	838
8	916	819	874	800	847
9	898	782	853	768	866
10	894	792	845	732	837

b. All the grenade firing, either the muzzle type or those fired in conjunction with the M203 launcher, was satisfactory with no resultant damage to weapon components of either type.

c. The various accessories and munitions listed in 2.4.2a were found to be compatible/interchangeable with the M16A1E1 rifles with the exception of the M234 RAG launcher. The M234 was not compatible with the improved barrel configuration. The MILES device was not available for testing.

d. Damage common to both weapon types consisted of bent or dented front and rear sight protective ears and broken buttplates. On the M16A1 rifles, the buttstock either split along the comb of the stock or a large piece broke away at the heel. The handguards usually had severe cracks and fell off the rifle. On the M16A1E1 rifles, the butt stocks had no apparent damage. The handguards sustained minor cracks and remained on the rifles. Photographs of typical damage sustained are presented in appendix B.

e. The three-round burst device, adjustable rear sight, and cartridge case deflector of the M16A1E1 rifles performed satisfactorily during the firing phase of the test.

f. The only parts broken as a result (apparently) of the function test were the bolt carrier key screws (FSN 1005-992-7284) on rifle No. 8A (M16A1).

g. The XM855E1(FN) cartridges initially conditioned with the rifles, were found to be coated with glue when the packaging was opened. Apparently the carton sealing glue was applied in excessive quantities and after hours of conditioning, melted down over the individual cartridges. Fresh cartridges were unpacked outside the chamber and brought in to be conditioned in bulk form without packaging. A photograph of the glue-bound cartridges is presented in figure 38 of appendix B.

#### 2.4.4.2 Low temperature test.

a. It was found immediately upon firing commencement at -46° C, that the weapons would not function when lubricated with CLP. TECOM was notified and a directive was received to clean the weapons and relubricate with LAW. Firing was resumed.

b. There was a total of 40 stoppages with the M16A1 rifles, during the initial test, as opposed to 181 with the M16A1E1 rifles. A summary of the stoppages is presented in table 2.4-5. For the retest, the SS109 cartridge was substituted for the XM855E1(FN) and three rifles of each type were retested. In this case, the M16A1 rifles had a total of 16 stoppages, while the M16A1E1 rifles had five stoppages. Details of the stoppages during retesting are summarized in table 2.4-6. In addition to the stoppages, there were several instances, M16A1 (3) and M16A1E1 (2), where the bolt was difficult to open at the start of a cycle. The charging handle was struck with the heel of the hand to free the bolt.

TABLE 2.4-5. SUMMARY OF STOPPAGES, LOW TEMPERATURE TEST, INITIAL TEST

Rifle No. (APG)	Total Rd Fired	Cartridge Type	Number of Stoppages					Total	MRBS
			FFD	DFD	FTL	FFR			
M16A1 Rifle									
6A	1200	M193			14	a	1	15	80
7A	1200	M193	2		7	a	1	10	120
8A	1200	M193			1	a, b <sub>2</sub>		3	400
9A	1200	M193	3	1	4			8	150
10A	1200	M193			4			4	300
Total	6000		5	1	30		4	40	150

<sup>a</sup>Did not fire after second attempt, satisfactory primer indent.

<sup>b</sup>Fired on second attempt.

2.4.4.2 (Cont'd)

TABLE 2.4-5 (CONT'D)

Rifle No. (APG)	Total Rd Fired	Cartridge Type	Number of Stoppages				Total	MRBS
			FFD	DFD	FTL	FFR		
M16A1E1 Rifle								
6D	1200	XM855E1			3	a	34	32
7D	1200	XM855E1	1		4	b	52	21
8D	1200	XM855E1			1	a,b	2	400
9D	1200	XM855E1	1		2	b	65	18
10D	1200	XM855E1			10	b	6	75
Total	6000		2		20	b	159	33

<sup>a</sup>Did not fire after second attempt, satisfactory primer indent.

<sup>b</sup>Fired on second attempt.

FFD = Failure to feed.

DFD = Double feed.

FTL = Failure to lock.

FFR = Failure to fire.

TABLE 2.4-6. SUMMARY OF STOPPAGES, LOW TEMPERATURE TEST, RETEST

Rifle No. (APG)	Total Rd Fired	Ctg Type	Number of Stoppages					Total	MRBS
			FFD	FTL	FFR	F2R	FEJ		
M16A1 Rifle									
6A	1200	M193		3	a	1		4	300
9A	1200	M193			b	3	5	8	150
10A	1200	M193			b	3		3	400
Total	3600			3		7	5	15	240

<sup>a</sup>Did not fire after second attempt.

<sup>b</sup>Fired on second attempt.

2.4.4.2 (Cont'd)

TABLE 2.4-6 (CONT'D)

Rifle No. (APG)	Total Rd Fired	Ctg Type	Number of Stoppages					Total	MRBS
			FFD	FTL	FFR	F2R	FEJ		
M16A1E1 Rifle									
6D	1200	SS109	1	-	b <sub>1</sub>	-	-	2	600
9D	1200	SS109	1	-	-	-	-	1	1200
10D	1200	SS109	-	-	-	-	1	1	1200
Total	3600		2		1		1	4	900

<sup>a</sup>Did not fire after second attempt.

<sup>b</sup>Fired on second attempt.

FFD = Failure to feed.

FTL = Failure to lock.

FFR = Failure to fire.

F2R = Fired two rounds on one trigger pull.

FEJ = Failure to eject.

c. Cyclic rates of fire for each test are presented in tables 2.4-7 and 2.4-8.

TABLE 2.4-7. AVERAGE CYCLIC RATE OF FIRE, LOW TEMPERATURE TEST, INITIAL TEST

Cycle No.	Avg Cyclic Rate of Fire <sup>a</sup> (spm)				
	M16A1 Rifle No. (APG)				
	6A	7A	8A	9A	10A
1	-	-	-	-	-
2	-	-	-	-	-
3	-	-	-	-	-
4	720	-	685	-	-
5	-	-	-	-	-
6	691	720	701	766	750
7	695	681	647	755	743
8	-	-	-	-	-
9	585	618	605	647	727
10	669	660	674	715	707

<sup>a</sup>Average cyclic rates taken on three-round bursts.

TABLE 2.4-7 (CONT'D)

Cycle No.	Avg Cyclic Rate of Fire <sup>a</sup> (spm)					Total Fired	Rifle No. (APG)
	M16A1E1 Rifle No. (APG)						
	6D	7D	8D	9D	10D		
1	-	-	-	-	-	1200	6D
2	-	-	-	-	-	1200	9D
3	-	715	-	-	-	1200	10D
4	-	-	-	-	-	-	-
5	820	686	720	-	-	3600	Total
6	842	672	687	675	-	708	-
7	718	661	675	650	-	677	-
8	789	-	-	762	-	-	-
9	731	659	688	719	-	708	-
10	750	670	650	678	-	715	-

<sup>a</sup>Average cyclic rates taken on three-round bursts.

Note: Some cyclic rates were not obtainable due to instrumentation difficulties.

TABLE 2.4-8. AVERAGE CYCLIC RATE OF FIRE, LOW TEMPERATURE TEST, RETEST

Cycle No.	Avg Cyclic Rate of Fire (spm)		
	M16A1 Rifle No. (APG)		
	6A	9A	10A
1	688	718	666
2	633	694	645
3	-	-	-
4	-	-	-
5	623	662	677
6	-	-	-
7	610	657	676
8	610	652	682
9	620	636	688
10	-	638	693

2.4.4.2 (Cont'd)

TABLE 2.4-8 (CONT'D)

Cycle No.	Avg Cyclic Rate of Fire (spm)		
	M16A1E1 Rifle No.		
	6D	9D	10D
1	739	699	685
2	728	669	645
3	687	667	644
4	-	-	-
5	698	651	651
6	-	-	-
7	642	651	634
8	634	640	630
9	683	674	632
10	648	-	-

Note: Some cyclic rates were not obtainable due to instrumentation difficulties.

d. In an effort to determine the cause for the failures to fire during the initial test, the firing pin indent was measured before and after the retest. Measurement data are summarized in table 2.4-9.

TABLE 2.4-9. FIRING PIN INDENT<sup>a</sup>

Rifle No. (APG)	Pretest			Post-Test				
	Measurements (in.)	Avg	Measurements (in.)	Avg				
M16A1 Rifles								
6A	0.024	0.024	0.023	0.024	0.022	0.024	0.021	0.022
9A	.023	.023	.023	.023	.022	.021	.022	.022
10/11A	.023	.022	.021	.022	.021	.021	.020	.021
M16A1E1 Rifles								
6D	0.020	0.018	0.019	0.019	0.016	0.016	0.017	0.016
9D	.020	.019	.020	.020	.017	.016	.016	.016
10D	.020	.018	.019	.019	.019	.019	.019	.019

<sup>a</sup>Not to be less than 0.020 inch per MIL-R-45587A.

e. All the grenade firing from the M203 was satisfactory. The muzzle-launched grenades fired satisfactorily except for three incidents of failure to fire with the blank cartridges (M195) in rifle (APG) 7D (M16A1E1). In each case, the cartridge fired on the second attempt. Neither weapon type was damaged as a result of grenade firing.

f. The various accessories listed in 2.4.2a were found to be compatible/interchangeable on the M16A1E1 rifles with the same exception as noted in the high temperature test.

g. The drop test was performed with results generally similar to the high temperature test. The major difference was with M16A1 rifle 10A (with M203). After the drop in the last position, it was found that the lower receiver had broken through the threaded ring that accepts the lower receiver extension (buffer tube). On M16A1E1 rifle 10D (with M203), the rear sight windage adjustment drum or knob was broken off. Photographs of typical damage sustained are presented in appendix B.

h. A total of four buffer assemblies failed in the low temperature environment. The same buffer is common to both models and all had identical failure modes. Three failures were on the M16A1E1 and one on the M16A1 model.

i. The cam clutch spring of one M16A1E1 rifle failed. ARRADCOM advised that examination of the part revealed that the spring had been improperly formed, creating an overstressed area. This is considered to be an isolated failure.

j. The M16A1E1 product improved rear sight was fully operational in the low temperature environment. The windage knob on one rifle failed in one drop test. Other than cosmetic damage, no other problems were encountered.

2.4.4.3 Salt-water immersion.

a. Light to heavy corrosion was found on various ferrous components of each weapon. The corrosion was observed on those components that the preservative oil came off as a result of the salt-water immersion, handling and firing. A photograph of typical corrosion observed on each type of weapon at the completion of testing is contained in appendix B. Light corrosion was also observed on ferrous components of the rifle magazines.

b. There was a total of 51 stoppages recorded on the M16A1 rifles as opposed to 58 stoppages for the M16A1E1 rifles. The stoppage data is summarized in table 2.4-10. In addition to the functional stoppages, each individual weapon experienced two incidents where the bolt was stuck and the charging handle had to be hammered to open the mechanism.

TABLE 2.4-10. SUMMARY OF STOPPAGES,  
SALT-WATER IMMERSION TEST

Rifle No. (APG)	Total Rd Fired	Ctg Type	No. of Stoppages				MRBS
			FFD	FTL	FFR	Total	
M16A1							
7A	300	M193	3	11		14	21
8A	300	M193	31	5	1	37	8
Total	600	M193	34	16	1	51	12

TABLE 2.4-10 (CONT'D)

Rifle No. (APG)	Total Rd Fired	Ctg Type	No. of Stoppages				MRBS
			FFD	F <sup>T</sup> L	FFR	Total	
M16A1E1							
7D	300	XM855E1	1	15	15	31	10
8D	300	XM855E1	11	14	2	27	11
Total	600	XM855E1	12	29	17	58	10

FFD = Failure to feed.

F<sup>T</sup>L = Failure to lock.

FFR = Failure to fire.

c. All of the failures to fire, except one on rifle 7D, went off on the second attempt.

#### 2.4.5 Analysis

##### 2.4.5.1 High temperature test.

a. Comparisons between the test and standard rifles indicate the M16A1E1 was not adversely affected by the high temperature. In fact, it had a much higher MRBS (667 rd) than that of the standard rifle (316 rd).

b. The durability of the product improved plastic parts was superior to the standard parts.

c. The CLP lubricant appears to be a satisfactory lubricant in the high temperature environment with both the test (M16A1E1) and standard (M16A1) rifles.

##### 2.4.5.2 Low temperature test.

a. The initial test of both rifle types at low temperatures gave the opposite indication of reliability from the high temperature test. The MRBS for the standard M16A1 was 150 rounds, while that for the M16A1E1 was significantly lower at 33 rounds. The stoppage rate of the M16A1 was not satisfactory in comparison to the performance of the same rifles at normal and high temperature.

b. The results of the retest, in general, indicate that the problem lies in the interaction of the M16A1E1 test rifles and the XM855E1 cartridges. The MRBS for the test rifles firing SS109 cartridges increased to 900 rounds versus 240 rounds for the M16A1 rifles. However, this test was performed with three samples of each rifle type as opposed to five in the initial test. A clear view of the performance changes is shown in table 2.4-11, where only the results of rifles used in both tests are shown.

2.4.5.2 (Cont'd)

TABLE 2.4-11. STOPPAGE COMPARISON OF THE SAME RIFLES  
IN BOTH LOW TEMPERATURE TESTS

<u>Test</u>	<u>Rifle Type</u>	<u>No. of Rifles</u>	<u>Total Rd</u>	<u>Ctg Type</u>	<u>Total Stoppages</u>	<u>MRBS</u>
Initial	M16A1	3	3600	M193	27	133
	M16A1E1	3	3600	XM855E1	121	20
Retest	M16A1	3	3600	M193	16	240
	M16A1E1	3	3600	SS109	5	900

c. The M16A1E1 sustained 159 initial failures to fire with two total failures to fire on the second attempt (see table 2.4-5). In each case, the rounds were examined prior to the attempted refire. The primer indents were considered light to marginal. This is attributable to the change in ammunition used in testing the M16A1E1 model. The SS109 round as produced by Fabrique Nationale has a Berdan type primer construction which is common to cartridges produced in Europe, to both NATO and non-NATO specifications. The 5.56-mm series of cartridges produced to US specification are constructed with standard boxer primers.

d. As indicated in the initial inspection procedure, the firing pin indent had marginal to unacceptable levels per MIL-P-45587A, paragraph 3.4.2, on the M16A1E1 models. The firing pin indent on the M16A1E1 models was taken prior to and after the second low temperature test. It is noted (table 2.4-9) that the firing pin indent was lower after the test and below the specified level. It should be noted that the hammer spring had been redesigned to accommodate the three shot burst control device. This may relate to the light primer indent.

e. The M16A1E1 may not reliably give sufficient firing pin energy under all conditions with ammunition manufactured to US specification. Additionally, there exists the possibility that SS109 may exhibit lighter primer sensitivity, possibly producing accidental discharge caused by firing pin inertia energy. This can occur as the bolt comes into battery on a loaded round.

f. The CLP appears to be an unsatisfactory lubricant in the low temperature (-46° C) environment with both the test (M16A1E1) and standard (M16A1) rifles; whereas, LAW performed satisfactorily.

### 2.4.5.3 Salt-water immersion test.

a. The predominant stoppage types (table 2.4-10) may be summarized as those relating to movement of the bolt assembly. The restriction of bolt movement was caused by oxidation, carbon buildup, and salt crust aggravated by the high temperature and humidity. The longer the weapons were conditioned, without cleaning, the greater the number of stoppages. Therefore, a rearrangement of the number of stoppages by the day fired, table 2.4-12, as opposed to types encountered gives a clearer picture of performance.

TABLE 2.4-12. STOPPAGE COMPARISON BY DAY FIRED,  
SALT-WATER IMMERSION TEST

Rifle No. (APG)	Total Rd Fired	Ctg Type	No. of Stoppages					Total
			Day 1	Day 3	Day 5	Day 8	Day 10	
M16A1								
7A	300	M193				3	a, b <sub>11</sub>	14
8A	300	M193		1	2	a 6	a, b <sub>28</sub>	37
Total	600	M193		1	2	9	39	51
M16A1E1								
7D	300	XM855E1			1	a <sub>10</sub>	a, b <sub>20</sub>	31
8D	300	XM855E1			2	a <sub>16</sub>	a, b <sub>9</sub>	27
Total	600	XM855E1			3	26	29	58

<sup>a</sup>The bolt was initially opened by hammering the charging handle.

<sup>b</sup>The bolt assembly required repetitive hand cycling to work freely.

b. The excessive number of failures to fire with the M16A1E1/XM855E1 rifle/cartridge combination are thought to be weapon caused, weak hammer spring. The primers used in both cartridges (M193 and XM855E1) are of the same design and made to the same specification, although manufactured at different facilities.

c. The new plastic components and rear sight assembly performed satisfactorily during the salt-water immersion test.

### 2.4.6 Conclusions

2.4.6.1 High temperature test. Criteria 2.4.2a, b, c, and d were considered met. However, neither combination tested performed at the level demonstrated at ambient temperature.

2.4.6.2 Low temperature test.

a. Criteria 2.4.2a and c were considered met. Criteria 2.4.2b was considered met when the SS109 cartridge was used but was not met with the XM855E1(FN) cartridge in conjunction with the M16A1E1 rifle. However, as might be expected none of the combinations tested performed at the level demonstrated at ambient temperature.

b. The primer sensitivity of the SS109 ammunition should be examined for conformance to US specification if a decision should be made by the user to use SS109 ammunition.

c. The M16A1E1 hammer spring does not deliver sufficient energy to the firing pin during low temperature firing. This condition is most notable when US specification ammunition is used.

2.4.6.3 Salt-water immersion test. Criteria 2.4.2c was considered met; 2.4.2d was not met.

Cartridge	Condition	Number of Rounds	Number of Hits	Number of Misses	Number of Failures
M193	300	7A	1	0	0
M193	300	8A	1	0	0
M193	600	Total	2	0	0
XM855E1	300	7D	1	0	0
XM855E1	300	8D	2	0	0
XM855E1	600	Total	3	0	0

The bolt was initially opened by hammering the charging handle.  
The bolt assembly required repetitive hand cycling to work freely.

b. The excessive number of failures to fire with the XM855E1 rifle/cartridge combination are thought to be weapon caused, weak hammer spring. The primers used in both cartridges (M193 and XM855E1) are of the same design and made to the same specification, although manufactured at different facilities.

c. The new plastic components and rear sight assembly performed satisfactorily during the salt-water immersion test.

2.4.6 Conclusions

2.4.6.1 High temperature test. Criteria 2.4.2a, b, c, and d were considered met. However, neither combination tested performed at the level demonstrated at ambient temperature.

2.5 COOKOFF

2.5.1 Objective

The objective was to compare the cookoff levels of the modified barrels with those of the standard barrel.

2.5.2 Criterion

The cookoff level obtained with the modified barrel should be equal to or higher than that of the standard barrel, under similar conditions (devised by Test Agency, TECOM approved).

2.5.3 Data Acquisition Procedure

a. The cookoff test was done in accordance with procedures in paragraph 5.2.1 of TECOM TOP 3-2-504, Safety Evaluation of Hand and Shoulder Weapons (ref 12).

b. The test weapons (one weapon of each type) were instrumented for recording temperature data. Six iron/constantan (type J) thermocouples were prepared and attached to each barrel using a capacitance discharge welder. The thermocouples were further secured by metal clips which held the wire snug against the barrel. One thermocouple was attached to each handguard. Attachments were made on the handguard by slightly roughing the surface for good adhesion and applying an epoxy cement over the thermocouples. Thermocouple positions and applicable data acquisition system channel numbers were as shown in table 2.5-1.

TABLE 2.5-1. THERMOCOUPLE LOCATIONS AND CHANNELS, COOKOFF TEST

Ch No.	Thermocouple Locations, Barrel	
	Distance <sup>a</sup>	9 O'Clock 3 O'Clock
	Barrel Location	
	47.5 cm	Ch 1 Ch 2
	M16A1-32.7 cm	Ch 3 Ch 4
	M16A1E1-32.4 cm	
	2.9 cm	Ch 5 Ch 6
	Handguard Location	
7	Base of thumb positions on handguard at a 7 o'clock position from rear face of barrel, 27.0 cm (M16A1) and 26.7 cm (M16A1E1) from outer edge of sight bracket.	

<sup>a</sup>Measured from muzzle end of barrel.

TABLE 2.5-1 (CONT'D)

Ch No.	Thermocouple Locations, Barrel		
	Distance <sup>a</sup>	9 O'Clock	3 O'Clock
8	Finger positions on handguard at a 2 o'clock position from rear face of barrel, with the same distances as Ch 7.		
9	Ambient measurements near weapon system, shielded from solar radiation.		

<sup>a</sup>Measured from muzzle end of barrel.

c. The data acquisition system consisted of a data logger with an integral discharge printer interfaced to a digital magnetic tape drive. The rate of data collection was approximately 15 channels per second. The integral discharge printer was set for a sampling rate of every 30 seconds and was used as a back up source for data as well as immediate data evaluation at the time of testing. Data collection began shortly before firing, continuing throughout the firing sequence and cool down period of the barrel.

d. A remote firing exercise was performed on each instrumented weapon, firing was done in three-shot bursts at a sustained firing rate of 85 spm until the predetermined number of rounds estimated to be the cookoff point (150 rd) was reached. At that time another fully loaded magazine was inserted, the cookoff round chambered and the bolt closed. Should the cartridge not cookoff, the number of cartridges to be fired was increased in 10-round increments and the test repeated.

e. At the end of a firing sequence, the gun barrel was allowed to cool down naturally until the hottest portion of the gun barrel reached 150° C. Further cooling was by forcing compressed air through the gun barrel.

f. The intention was to ascertain (within 10 to 20 rounds) the maximum number of rounds that could be fired from each weapon type without cookoff for a given rate of fire. Once this was achieved, four confirming trials were required.

g. The total number of rounds fired for all barrels prior to this test was approximately 7000 rounds. Any damages to the weapon were noted and repaired as necessary before continuing the test. Special attention was paid to the breech-locking components of the weapons; therefore, these and other highly stressed parts were subjected to an MPI before and following the cookoff tests (as well as during, if considered necessary).

#### 2.5.4 Results

Detailed cookoff results are summarized in table 2.5-2. Sample time versus temperature plots are in appendix B, figures 52 and 53. A summary of maximum temperature measured per channel per trial is presented in table 2.5-3.

## 2.5.4 (Cont'd)

TABLE 2.5-2. SUMMARY OF RESULTS, COOKOFF TEST

Trial No.	Rifle Type <sup>a</sup>	Rd Fired	Firing Rate in Rd per Min	Max Temp, in °C and Location (Ch No.)		Chamber Temp °C at Cookoff Ch 1 and Ch 2	Cookoff Time in Sec
				For Test	Cookoff		
1	M16A1E1	150	85	457-8	-	-	-
2	M16A1E1	180	85	499-4	453-4	172,170	87
3	M16A1E1	170	85	481-4	-	-	-
4	M16A1E1	170	85	480-4	-	-	-
5	M16A1E1	170	85	484-4	-	-	-
6	M16A1E1	170	85	480-4	-	-	-
7	M16A1E1	170	85	482-4	-	-	-
8	M16A1	150	85	471-3,4	-	-	-
9	M16A1	180	85	518-3	497-3	181,179	39
10	M16A1	170	85	496-3,4	468-3,4	176,174	58
11	M16A1	160	85	479-3	454-3	175,173	49
12	M16A1	150	85	449-3	-	-	-
13	M16A1	150	85	454-3	-	-	-
14	M16A1	150	85	452-3	-	-	-
15	M16A1	150	85	454-3	-	-	-

<sup>a</sup>M16A1 - APG No. 9A.  
M16A1E1 - APG No. 9D.

TABLE 2.5-3. SUMMARY OF MAXIMUM TEMPERATURES MEASURED PER CHANNEL PER TRIAL - COOKOFF TEST

Trial No.	Rifle Type	Maximum Temperature (°C) Per Channel								
		1	2	3	4	5	6	7	8	9
1	M16A1E1	163	161	456	457	264	293	64	79	29
2	M16A1E1	176	173	497	499	314	314	69	86	30
3	M16A1E1	171	169	480	481	299	299	72	86	29
4	M16A1E1	159	157	478	480	301	300	52	68	18
5	M16A1E1	165	162	481	484	304	304	58	74	19
6	M16A1E1	164	162	478	480	297	294	57	76	20
7	M16A1E1	163	161	480	482	298	297	54	74	19
8	M16A1	166	163	471	471	366	361	54	72	24
9	M16A1	182	179	518	517	386	387	58	80	24
10	M16A1	177	175	496	496	377	378	54	82	25
11	M16A1	176	173	479	478	371	369	54	84	26
12	M16A1	160	157	449	448	358	356	40	54	18
13	M16A1	165	162	454	453	360	357	42	56	18
14	M16A1	162	159	452	450	362	360	39	55	18
15	M16A1	162	159	454	451	362	360	39	56	18

2.5.5 Analysis

a. The cookoff level established (a safety limit where a cookoff does not occur) for the M16A1 rifle was 150 rounds. The highest temperature reached after firing 150 rounds of M193 ammunition was 454° C and was located 32.7 cm from the muzzle end of the barrel.

b. The cookoff level established for the M16A1E1 rifle was 170 rounds. The highest temperature reached after firing 170 rounds of SS109 ammunition was 484° C and was located 32.4 cm from the muzzle end of the barrel.

2.5.6 Conclusion

The cookoff level of the M16A1E1 rifle in conjunction with the SS109 cartridge, is higher than that for the standard M16A1 rifle with M193 cartridges. The criterion was considered met.

TABLE 2.5-7. SUMMARY OF MAXIMUM TEMPERATURES MEASURED PER CHANNEL PER TRIAL - COOKOFF TEST

Trial No.	Rifle Type	Maximum Temperature (°C) Per Channel							
		1	2	3	4	5	6	7	8
1	M16A1E1	167	161	486	457	364	297	64	79
2	M16A1E1	176	175	497	499	314	314	69	86
3	M16A1E1	171	169	480	481	299	299	73	86
4	M16A1E1	159	157	478	480	301	300	52	68
5	M16A1E1	165	162	481	484	304	304	58	74
6	M16A1E1	164	162	478	480	297	294	57	76
7	M16A1E1	167	161	480	482	298	297	54	74
8	M16A1	166	169	471	471	366	361	54	75
9	M16A1	185	179	518	517	366	387	58	80
10	M16A1	177	178	496	496	377	378	54	82
11	M16A1	176	173	479	478	371	369	54	84
12	M16A1	160	157	449	448	358	356	40	54
13	M16A1	165	162	454	457	360	357	42	56
14	M16A1	162	159	452	450	362	360	39	55
15	M16A1	162	159	454	451	362	360	39	56

## 2.6 SUSTAINED FIRE

### 2.6.1 Objective

The objective was to determine the ability of the test and standard barrels and plastic components to withstand sustained fire without damage, to not degrade velocity, and to not adversely affect the functional performance of the M16A1E1 rifle.

### 2.6.2 Criteria

a. The M16A1E1 rifle should permit a sustained rate of fire in the semiautomatic mode, without system damage or cookoff, equal to or greater than the standard rate possible with the M16A1.

b. Function and performance of the test weapons must not be affected by the product improved plastic components (devised by Test Agency, TECOM approved).

### 2.6.3 Data Acquisition Procedure

a. The sustained fire tests were in general accordance with TECOM TOP/MTP 3-2-509, Hand and Shoulder Weapons (ref 12), but details were arranged so as to evaluate sustained fire effects as opposed to requirements.

b. One rifle of each type was shoulder fired from a benchrest and three 10-round dispersion groups were fired semiautomatically at a range of 91.4 m (100 yd).

c. Each rifle in turn was mounted in a test stand and fired semiautomatically using the following sequence of cycles:

- (1) Fifteen spm for 30 min (450 rd).
- (2) Twenty spm for 22 min, 30 sec (450 rd).
- (3) Thirty spm for 15 min (450 rd).
- (4) Forty spm for 11 min, 15 sec (450 rd).
- (5) Sixty spm for 7 min, 30 sec (450 rd).

d. The test weapons (one weapon of each type) were instrumented for temperature data by installing thermocouples at the barrel muzzle behind the muzzle device, on the exterior of the barrel immediately over the chamber mouth, on the exterior of the barrel proper at the point of the smallest outside diameter or at the midpoint and at a point 21.6 cm forward of the bolt face. Thermocouples were also secured to the finger positions on both sides of handguards. The thermocouples were located on the weapon as noted in table 2.6-1. Velocity was measured on the first and last 20 rounds in each cycle. The weapons were cooled to ambient temperature between cycles and cleaned or lubricated as necessary. A continuously moving target, at 25 m, was used to monitor projectile yaw or breakup. Magazines, 20- or 30-round, were preloaded in a manner best suited to the performance of each cycle. After the sustained

fire sequence was fired, three 10-round groups were fired, as at the beginning of the test, and dispersions compared. An MPI was performed post-test.

TABLE 2.6-1. THERMOCOUPLE LOCATIONS AND CHANNELS, SUSTAINED FIRE TEST

Ch No.	Thermocouple Locations		
	Distance <sup>a</sup>	9 O'Clock	3 O'Clock
Barrel Location			
	47.5 cm	Ch 1	Ch 2
	M16A1-32.7 cm	Ch 3	Ch 4
	M16A1E1-32.4 cm		
	2.9 cm	Ch 5	Ch 6
Handguard Location			
7	Base of thumb positions on handguard at a 7 o'clock position from rear face of barrel, 27.0 cm (M16A1) and 26.7 cm (M16A1E1) from outer edge of sight bracket.		
8	Finger positions on handguard at a 2 o'clock position from rear face of barrel, with the same distances as Ch 7.		
9	Ambient measurements near weapon system, shielded from solar radiation.		

<sup>a</sup>Measured from muzzle end of barrel.

#### 2.6.4 Results

a. The M16A1E1 using SS109 ammunition had higher cookoff levels than did the M16A1 control rifles using M193 ball ammunition. Resultant test data is summarized in table 2.6-2.

b. The test weapons (one weapon of each type) were instrumented for temperature data by installing thermocouples at the barrel muzzle behind the muzzle device, on the exterior of the barrel immediately over the chamber mouth, on the exterior of the barrel proper at the point of the smallest outside diameter or at the midpoint and at a point 21.6 cm forward of the bolt face. Thermocouples were also secured to the finger positions on both sides of handguards. The thermocouples were located on the weapon as noted in table 2.6-1. Velocity was measured on the first and last 20 rounds in each cycle. The weapons were cooled to ambient temperature between cycles and cleaned or lubricated as necessary. A continuously moving target, at 25 m, was used to monitor projectile yaw or breakup. Handguns, 20- or 30-round, were preloaded in a manner best suited to the performance of each cycle. After the sustained

TABLE 2.6-2. SUMMARY OF RESULTS,  
SUSTAINED FIRE TEST

Rifle Type	Rd per Min	Total Time		Instrumental Velocity (mps)		Cookoff <sup>a</sup>	
		Min	Sec	Pretest	Post-Test	Yes/No	Time, seconds to Cookoff
M16A1	15	30	00	965	982	No	
M16A1E1	15	30	00	923	936	No	
M16A1	20	22	30	971	984	No	
M16A1E1	20	22	30	927	934	No	
M16A1	30	15	00	972	975	Yes	104
M16A1E1	30	15	00	927	932	No	
M16A1	40	11	15	973	968	Yes	69
M16A1E1	40	11	15	931	933	Yes	47
M16A1	60	7	30	976	967	Yes	12
M16A1E1	60	7	30	929	920	Yes	14

<sup>a</sup>Cookoff times are measured from the conclusion of firing.

b. The maximum temperatures recorded at each thermocouple position in relation to the rate of fire are presented in table 2.6-3.

TABLE 2.6-3. SUMMARY OF MAXIMUM TEMPERATURES  
DURING SUSTAINED FIRE TEST

Trial No.	Rifle Type	Rate of Fire (spm)	Maximum Temperature (°C) per Channel								
			1	2	3	4	5	6	7	8	9
1	M16A1	15	122	124	408	409	188	188	51	62	22
2	M16A1E1	15	119	118	395	395	187	187	55	77	17
3	M16A1	20	144	146	467	468	247	247	70	90	21
4	M16A1E1	20	135	133	456	456	219	220	65	87	17
5	M16A1	30	167	169	548	549	296	297	84	107	23
6	M16A1E1	30	166	165	542	542	282	282	94	127	19
7	M16A1	40	173	176	566	568	316	316	85	116	20
8	M16A1E1	40	187	185	585	585	311	312	104	151	23
9	M16A1	60	216	220	657	658	395	395	104	146	26
10	M16A1E1	60	225	223	682	681	380	378	126	181	26

### 2.6.5 Analysis

a. The sustained rate of fire is defined as "the actual rate of fire that a weapon can continue to deliver for an indefinite length of time without seriously overheating" (ref 6). Based on the results presented in table 2.6-2, the upper limit firing rate for the M16A1E1, that did not cause overheating (cookoff), was 30 spm as compared to 20 spm for the M16A1. However, the generally accepted upper surface temperature limit that the unprotected human hand can indefinitely maintain contact with is 49° C (120° F) (ref 32).

Considering the temperatures generated by barrel heat transferred through the handguards, as presented in table 2.6-3 (channels 7 and 8), the usable sustained firing rate is more likely 15 spm. The published (ref 6) sustained rate of fire for the M16A1 rifle is 12 to 15 shots per minute; therefore, the M16A1E1 rifle sustained rate is at least equal to that of the M16A1.

b. Function and performance of the M16A1E1 rifle was not degraded by the product improved plastic components.

2.6.6 Conclusion

The criteria of paragraphs 2.6.2a and 2.6.2b were met.

Rate of Fire (spm)	Rifle Type	Max Temp (°C)	Min Temp (°C)	Test No
15	M16A1	188	151	985
15	M16A1E1	187	152	986
20	M16A1	247	171	987
20	M16A1E1	247	170	988
30	M16A1	395	207	989
30	M16A1E1	395	206	990
40	M16A1	408	216	991
40	M16A1E1	408	215	992
40	M16A1	468	247	993
40	M16A1E1	467	246	994
60	M16A1	549	307	995
60	M16A1E1	548	306	996
60	M16A1	568	316	997
60	M16A1E1	567	315	998
7	M16A1	381	181	999
7	M16A1E1	380	180	1000

Cookoff times are measured from the conclusion of firing.

d. The maximum temperatures recorded at each thermocouple position in relation to the rate of fire are presented in table 2.6-3.

TABLE 2.6-3. SUMMARY OF MAXIMUM TEMPERATURES DURING SUSTAINED FIRE TEST

Trial No.	Rifle Type	Rate of Fire (spm)	Maximum Temperature (°C) per Channel							
			1	2	3	4	5	6	7	8
1	M16A1	15	123	124	408	409	188	188	188	188
2	M16A1E1	15	119	118	395	395	187	187	187	187
3	M16A1	20	144	146	467	468	247	247	247	247
4	M16A1E1	20	132	133	456	456	219	219	219	219
5	M16A1	30	167	169	548	549	297	297	297	297
6	M16A1E1	30	166	165	542	543	285	285	285	285
7	M16A1	40	173	176	568	568	316	316	316	316
8	M16A1E1	40	187	185	565	565	311	311	311	311
9	M16A1	60	216	220	657	658	395	395	395	395
10	M16A1E1	60	222	222	681	681	380	380	380	380

2.6.5 Analysis

a. The sustained rate of fire is defined as "the actual rate of fire that a weapon can continue to deliver for an indefinite length of time without seriously overheating" (ref 6). Based on the results presented in table 2.6-2, the upper limit firing rate for the M16A1E1, that did not cause overheating (cookoff), was 30 spm as compared to 20 spm for the M16A1. However, the generally accepted upper surface temperature limit that the unproctored human hand can indefinitely maintain contact with is 49° C (120° F) (ref 2).

## 2.7 ROUGH HANDLING

### 2.7.1 Objective

The objective was to evaluate the standard and product-improved plastic components during simulated rough handling conditions.

### 2.7.2 Criterion

The durability of the product-improved plastic components must equal or surpass that of the control components at ambient and extreme temperatures of AR 70-38 (categories A1 and C2;  $-46^{\circ}$  and  $+68^{\circ}$  C), and under adverse conditions (devised by Test Agency, TECOM approved).

### 2.7.3 Data Acquisition Procedure

a. The rough handling was conducted in accordance with appendix C and D of TOP 4-2-602, Rough Handling Tests, 1 April 1979.

b. Three standard rifles (APG No. A6, A7, and A8) and three rifles with product-improved components (APG No. D6, D7, and D8) were subjected to a loose cargo test at the prevailing ambient temperature.

c. The rifles were tested in two loads in each orientation. For testing in the horizontal orientation, the rifles were placed with their longitudinal axis parallel to the transverse axis of the table. For testing in the other horizontal orientation, the rifles were rotated  $90^{\circ}$  so the longitudinal axis of the rifle was parallel to the longitudinal axis of the table.

d. A wooden retaining fence was placed around the rifles to prevent them from falling off the table (fig. 29 in app B). The fence sections did not secure the rifles to the table and were positioned so a space of approximately 25 mm (1 in.) existed on all sides of each rifle. Testing was accomplished on the steel-covered bed of the "LAB-8000" package tester with the temperature enclosure in position. The temperature within the enclosure was  $21^{\circ}$  C ( $70^{\circ}$  F).

e. The laboratory test represented 240 km (150 mi) of loose cargo transport over the Belgian block road course. The table was operated, shafts in phase, in a circular motion with a constant displacement of 25.4 mm (1.0 in.), DA, at a speed of 300 rpm thus producing a table acceleration of 1.3 g.

f. The rifles were tested for 15 minutes in each orientation for a total of 30 minutes.

g. The rifles were visually inspected for damage following the loosely-stowed cargo test.

### 2.7.4 Results

a. No damage or irregularities were reported as a result of the pretest inspection.

b. All of the rifles sustained minor damage as a result of the loosely-stowed cargo test. The general results of the post-test visual

inspection were (1) damage to the rifles which consisted of minor abrasions and scratches and (2) the rear sight setting changed position on rifle No. D7.

#### 2.7.5 Analysis

The durability of the product-improved plastic components is at least equal to that of the control items when subjected to rough handling at 21° C.

#### 2.7.6 Conclusion

The criterion for the durability of the product-improved plastic components was considered met.

## 2.8 STRENGTH OF MATERIALS

### 2.8.1 Objective

The objective was to evaluate the product improved components with regard to the effects of applied force and chemical attack.

### 2.8.2 Criteria

a. The durability of the product improved components must equal or surpass that of control components at ambient and extreme temperature ( $-46^{\circ}$ ,  $+21^{\circ}$ , and  $+68^{\circ}$  C) and under adverse conditions (devised by Test Agency, TECOM approved).

b. The material of the product improved plastic components must not be degraded by chemical reaction to various fuel and lubricant compounds (devised by Test Agency, TECOM approved).

### 2.8.3 Data Acquisition Procedure

#### 2.8.3.1 Barrel bending test.

a. Structure testing was, in general, based on TECOM TOP/MTP 3-2-059, Hand and Shoulder Weapons, 1 September 1971 (ref 12).

b. To demonstrate, for comparison purposes, the force required to attain the elastic-plastic deformation point of barrels, a force was applied to the muzzle with the fulcrum point located at the bayonet stud. A fixture was fabricated to hold the weapon in a plane perpendicular to the loading direction. The load was applied by a 26,689 N (6000 lb) Universal Tester. The three exterior load points were 4.13, 7.30, and 9.21 cm (1.625, 2.875, and 3.625 in.) from the muzzle end of the flash suppressor (fig. 2.8-1).

c. The muzzle deflection was measured with a vernier height gage in the strained and unstrained (set) mode of testing. Additionally, a strain gage was installed as a backup in the vertical (axial) direction 15.3 cm (6 in.) from the muzzle end of the flash suppressor. Micro-measurements were taken throughout each phase of testing.

d. A barrel straightness gage was inserted in the bore after each strain-unstrain cycle to determine a go - no go condition.

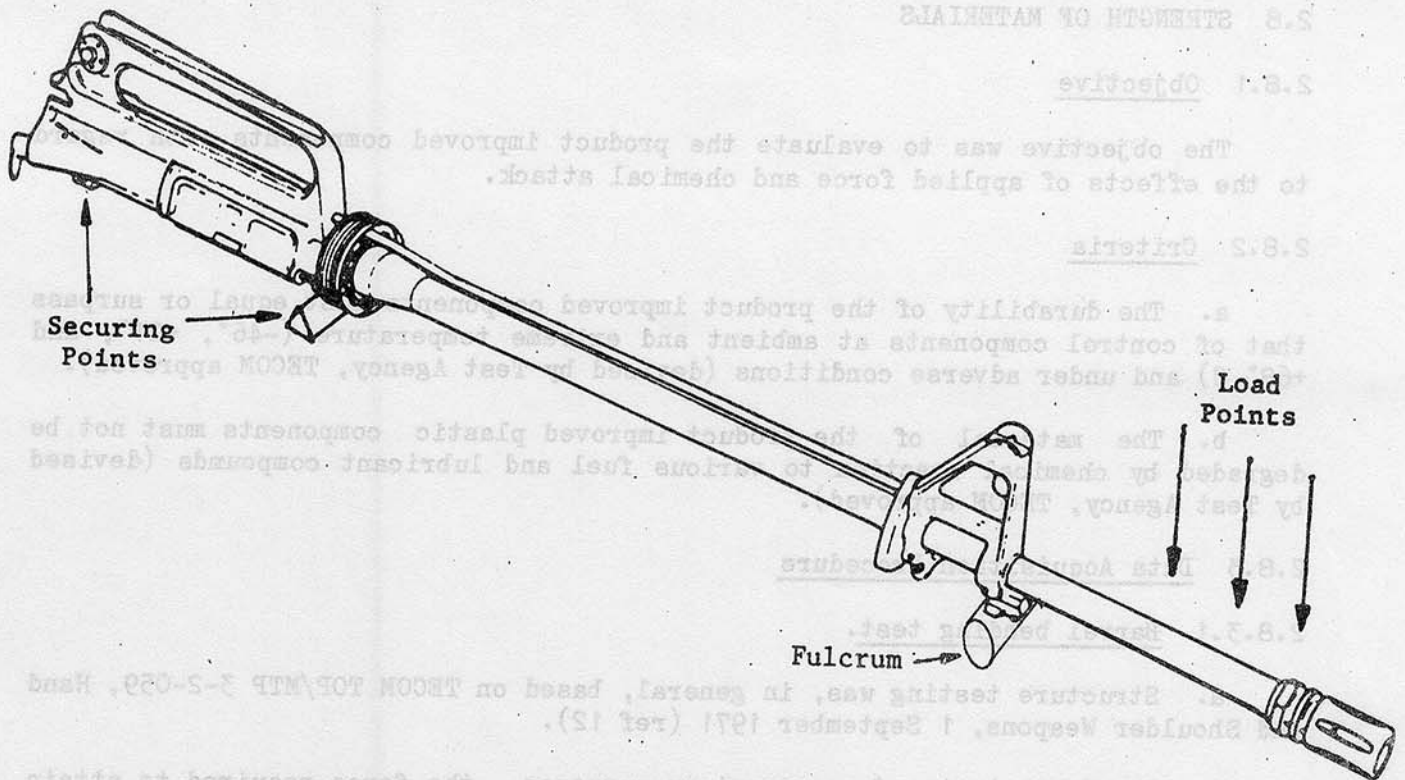


Figure 2.8-1. Structures test points of contact.

2.8.3.2 Chemical compatibility test.

- a. Testing was based on ASTM Procedures D543 and D2240 (ref 29 and 30).
- b. A sample of the standard stock (sample A) and handguards (sample B) were submitted for comparison testing with the proposed stock (sample C) and handguards (sample D). The four sample types which were submitted were tested for compatibility with 19 different chemicals. The effect of these chemicals on the plastic components was determined.
- c. Samples were cut into approximately 2.5 cm (1 in.) pieces and ragged edges were smoothed by sanding or filing. Nineteen pieces of each sample type were tested for hardness by a Shore Durometer, Type 'A-2', and weighed. One piece of each sample was immersed in one of each of the 19 solvents (table 2.8-1) for 7 days at room temperature. At the end of 1 week the samples were removed from the test chemical, quickly rinsed with an appropriate volatile solvent, dried, weighed and tested for hardness. Differences in hardness and weight were calculated.

TABLE 2.8-1. CHEMICALS UTILIZED IN CHEMICAL COMPATIBILITY TEST

- a. Bore cleaner, MIL-C-372B (RBC) (ref 3).
- b. Dry-cleaning solvent, P-D-680, type 1 (SD-1).
- c. Trichlorethane solvent.
- d. Lubricating oil, MIL-L-46000B (LSA) (ref 5).
- e. Lubricating oil, MIL-L-14107 (LAW) (ref 4).
- f. Lubricating oil, VV-L-800 (PL-S).
- g. Cleaner, lubricant, preservative, MIL-L-63460A (CLP) (ref 2).
- h. Gasoline, VV-G-1690.
- i. Kerosene.
- j. Diesel fuel, VV-F-800, DF2.
- k. Jet fuel, JP-4.
- l. Insect repellent (NSN 6840-00-558-0918).
- m. Hydraulic fluid, MIL-H-6083.
- n. Antifreeze (ethylene glycol), MIL-A-46153.
- o. Carbon-removing compound, P-C-111B, type 2.
- p. Water.
- q. Salt-water (20% sodium chloride).
- r. Chemical agent decontaminates, STB, MIL-D-50030(MU) (ref 20).
- s. Chemical agent decontaminates, DS2, MIL-D-12468B (ref 21).

2.8.4 Results

2.8.4.1 Barrel bending test.

a. The elastic-plastic deformation load points (referred to as "yield points") and the corresponding deflections of the two barrel models for each of the three loading positions is contained in table 2.8-2. The tabulated results were read from graphical representations of the load affects, contained in appendix B, figures 40 through 51.

TABLE 2.8-2. LOAD AND DEFLECTION YIELD POINTS, BARREL BENDING TEST

Parameters	Load Application Points (inches from muzzle)								
	1.625		2.875		3.625				
	M16A1	M16A1E1 Ratio <sup>a</sup>	M16A1	M16A1E1 Ratio <sup>a</sup>	M16A1	M16A1E1 Ratio <sup>a</sup>			
Load-deflection									
Load, lb	700	980	1.40	924	1428	1.55	1175	1990	1.69
Deflection, in.	0.686	0.603	-	0.590	0.582	-	0.592	0.630	-
Load-deflection set <sup>d</sup>									
Load, lb	483	759	1.59	755	914	1.18	1021	1559	1.53
Deflection set, in. <sup>d</sup>	0.018	0.020	-	0.025	0.008	-	0.020	0.021	-
Deflection total, in.	0.448	0.456	-	0.462	0.363	-	0.500	0.474	-
Load-strain									
Load, lb	732	c	-	c	c	-	1188	c	-
Load-strain set <sup>d</sup>	830	1140	1.37	b	b	-	1012	c	-

<sup>a</sup>Ratio is M16A1E1/M16A1.

<sup>b</sup>Faulty strain gage.

<sup>c</sup>Data show only a straight load line in the observed range.

<sup>d</sup>Permanent (set) deformation after a strain-unstrain cycle.

b. The bore straightness gage was used to measure a go - no go barrel deformation condition after each load was applied. As loads increased the barrels retained a measurable set. The bore straightness gage would not pass (free) through the bore of each model when the retained set reached approximately 0.46 mm (0.018 in.). Comparing the muzzle deflection versus "yield point" (graphs, app B) the maximum muzzle deflection each model can withstand is about 11.4 mm (0.45 in.) when enough set is developed to prevent the straightness gage from passing through the bore.

#### 2.8.4.2 Chemical compatibility test.

a. Detailed weight change results from the chemical compatibility test are given in table 2.8-3. It is not known to what degree physical changes are acceptable.

TABLE 2.8-3. WEIGHT CHANGE

Immersion Chemical	% Weight Change (g)			
	Sample Code			
	A	B	C	D
Bore cleaner	-0.05	1.27	0.08	-0.0
Dry cleaning solvent	0.24	1.72	0.06	0.6
Trichloroethane solvent	0.20	0.89	1.48	1.35
Oil, LSA	-0.05	1.96	0.02	0.37
Oil, LAW	0	1.33	-0.15	2.69
Oil, PL-S	0.17	2.68	0.04	1.60
CLP	0.19	1.19	0.15	0.69
Gasoline	-0.11	2.92	-0.01	2.47
Kerosene	-0.14	3.32	0.09	1.41
Diesel fuel	0.02	2.51	0.06	2.28
Jet fuel	-0.10	0.82	0.26	1.17
Insect repellent	0.07	2.28	0.46	0.98
Hydraulic fluid	-0.02	1.75	-0.12	0.82
Antifreeze	0.29	3.02	1.04	1.41
Carbon-removing compound	1.99	4.10	2.11	3.24
Water	3.19	4.66	4.71	4.46
Salt water (20%)	0.98	2.89	1.64	4.49
STB, MIL-D-12468B	2.23	2.70	2.88	5.85
DS2, MIL-D-50030	-0.27	2.40	0.40	0.65

- A = M16A1 stock.
- B = M16A1 handguard.
- C = M16A1E1 stock.
- D = M16A1E1 handguard.

b. The butt stock samples A and C both had slightly significant weight gain in carbon-removing compound, water, and STB. In addition sample C also had slightly significant weight gain in trichloroethane, antifreeze, and salt water.

c. The handguard sample B was slightly affected by all tested chemicals except trichloroethane and jet fuel. Sample D was slightly affected by all tested chemicals except bore cleaner, dry cleaning solvent, LSA and CLP oil, insect repellent, hydraulic fluid, and DS2.

d. No significant changes in hardness of samples A and B were found.

e. Sample C showed a small loss of hardness after exposure to trichloroethane and gasoline. Sample D showed a small loss of hardness only after exposure to dry-cleaning solvent.

## 2.8.5 Analysis

### 2.8.5.1 Barrel bending test.

a. The deflection measurements made at the muzzle provided the most complete set of results. The most sensitive in this category is the load-deflection set or permanent deformation results. The measurements show that a load of 2148 N (483 lb) will cause a permanent deformation (set) in the M16A1 barrel when the load is applied at the distance of 4.13 cm (1.625 in.) from the muzzle, which is the point of highest leverage in the test. A load of 3376 N (759 lb) is required to cause permanent deformation under similar conditions in the M16A1E1 barrel. When a load is applied at the point of least leverage, 9.21 cm (3.625 in.) from the muzzle, the corresponding loads are 4541 N (1021 lb) for the M16A1 and 6934 N (1559 lb) for the M16A1E1. Ratioing the loads at each distance, discloses the M16A1E1 barrel is 1.59X and 1.53X more resistant to permanent deformation than the M16A1 barrel.

b. The strain gage results did not give a "yield point" indication in every case. This may in part be due to the placement of the strain gage, at a site, away from the point of maximum strain/stress. This was unavoidable because the front sight bracket location is over the fulcrum point. In the two instances where "yield points" were obtainable, the strain results compare favorably with those given by the load-deflection results (table 2.8-2).

c. The plastic set, as determined by the muzzle deflection measurements, begins to occur at extremely low loads. The results reflect what is happening near or in front of the fulcrum point. A stress condition of some type puts the cantilevered barrel into immediate yielding. The origin of this stress could be a residual stress or a stress riser condition existing at the pinned sight bracket above the fulcrum.

### 2.8.5.2 Chemical compatibility test.

a. None of the four samples showed any signs of disintegration by the test chemicals. Although stock samples A and C showed some absorption, it was very small. Stock sample C showed a slightly lower tolerance to three chemicals (evidenced by weight change) than stock sample A. Sample C showed a slight loss of hardness in two chemicals where sample A demonstrated no significant loss of hardness. Handguard samples B and D showed a small but significant absorption of the majority of the chemicals tested. Handguard sample D demonstrated a lower weight change in five of the chemicals than sample B. Sample D showed a loss of hardness in one chemical where sample B demonstrated no significant loss of hardness.

b. Even though both the standard and proposed stocks and handguards showed some reaction to some of the test chemicals, the test chemicals, all four samples would be satisfactory choices.

c. Overall, stock sample A performed better than stock sample C but only to a small degree, and handguard sample D performed better than handguard B but only to a small degree.

#### 2.8.6 Conclusion

The criteria, with respect to the tests performed in paragraph 2.8, were considered met.

## 2.9 ADVERSE CONDITIONS

### 2.9.1 Objective

The objective was to evaluate the performance of the weapons and ammunition under various required adverse conditions.

### 2.9.2. Criterion

The function and reliability of the modified rifle under adverse conditions shall be at least equal to that of the standard rifle under equal conditions (devised by test agency, TECOM approved).

### 2.9.3 Data Acquisition Procedure

#### 2.9.3.1 Sand and dust tests.

a. Testing was performed in general accordance with paragraph 6.2.6.6 of TECOM TOP/MTP 3-2-059 (ref 12). This test determined the effect of firing the weapons while simultaneously exposing them to blowing sand and dust.

b. Two rifles of each type were cleaned and lubricated. Four magazines were loaded for each rifle. The test was conducted with each rifle exposed to the dynamic dust environment during firing. The sand and dust feeder of the test facility was calibrated to dispense the mixture at a rate of  $100 \pm 25$  g/min/m<sup>2</sup> over the area where the rifle was positioned.

c. The first magazine was fired with the rifle outside the chamber to insure weapon functioning. The second magazine was then installed, a round loaded into the chamber, and the dust cover closed. The operator entered the chamber and placed the remaining two magazines in an exposed position near the weapon.

d. While the dust was being dispensed through the pour hole at the above rate, a blower was turned at a speed of 60 rpm. Attempts were made to fire 90 rounds (3 magazines) in bursts of three to five rounds. A chronological record of total test time, time to first stoppage, time to clear, etc., as well as cyclic rates were obtained. The total time that the bolt remained open (to clear stoppages, to change magazines, etc.) was a critical measurement in this test.

#### 2.9.3.2 Mud tests.

a. Testing was done in accordance with paragraph 6.2.6.8 of TOP/MTP 3-2-059 (ref 12) and paragraphs 6.2.15 and 6.2.16 of TECOM TOP/MTP 3-2-045 (ref 23).

b. Test weapons were cleaned and lubricated. Three magazines were loaded for each rifle with the first magazine being fired prior to conditioning, to insure weapon function.

c. A mud-bath mixture as described in paragraph 6.2.15 of TECOM TOP/MTP 3-2-045 was prepared. The two mud tests, as described in paragraphs 6.2.15 and 6.2.16 of TECOM TOP/MTP 3-2-045, were performed. The weapons were exposed with

loaded magazines and the weapons were fired after each mud test. The immersion time was 60 seconds. Prior to immersion, the muzzle was taped closed, the second magazine was then installed, first round chambered, selector lever positioned on safe, and dust cover closed.

d. After immersion, each weapon was wiped with the hands to remove excess mud. After removing the tape, the two magazines were fired in three-round bursts.

### 2.9.3.3 Unlubricated test.

a. The unlubricated test was performed in accordance with paragraph 6.2.7 of TECOM TOP/MTP 3-2-059 (ref 12).

b. One rifle of each type was prepared by disassembling, cleaning, and inspecting; MPI was performed on key components. The rifles were reassembled without the application of lubricants. A total of 600 rounds were fired from each test rifle per the schedule in table 2.3-1, with cooling periods at 120-round intervals. Should the rifle fail to operate or become inoperable during the test, small quantities of lubricant would be applied to suspected problem areas, such as bolt, sear mechanisms, etc. The rifle would be refired, noting the effect of each such action.

### 2.9.4 Results

2.9.4.1 Sand and dust tests. The number of rounds fired, types of stoppages encountered, and time delays are listed by rifle number in table 2.9-1. The majority of stoppages were cleared through the use of the bolt forward assist feature, common to both rifle types. The bolt remained open during magazine changes.

TABLE 2.9-1. SUMMARY OF RESULTS, SAND AND DUST TEST

Rifle No. (APG)	Avg Cyclic Rate (spm)	Mag No.	No. of Stoppages FBC	Mag Change Time (sec)	Total Time (sec)	Total Rd Fired
-----------------	-----------------------	---------	----------------------	-----------------------	------------------	----------------

#### M16A1 Rifle

9A	756	a <sub>1</sub>	-			
		2	-			
		3	-	7		
		4	1	48		90

(First round of last magazine jammed - stoppage cleared and cartridge reinserted in magazine.)

<sup>a</sup>Magazine No. 1 was fired with rifle outside conditioning chamber to check functioning and is not included in the total time.

<sup>b</sup>Stoppage cleared by manipulation of bolt forward assist, average time seconds.

TABLE 2.9-1 (CONT'D)

Rifle No. (APG)	Avg Cyclic Rate (spm)	Mag No.	No. of Stoppages FBC	Mag Change Time (sec)	Total Time (sec)	Total Rd Fired
	741				205	120
10A	675	a <sub>1</sub>	-			
		2	b <sub>1</sub>			
		3	b <sub>1</sub>	8		
	704	4	-	8	123	120
M16A1E1 Rifle						
9D	764	a <sub>1</sub>	-			
		2	-			
		3	b <sub>2</sub>	15		
	679	4	b <sub>1</sub>	10	160	120
10D	729	a <sub>1</sub>	-			
		2	-			
		3	b <sub>1</sub>	21		
	659	4	-	7	147	120

<sup>a</sup>Magazine No. 1 was fired with rifle outside conditioning chamber to check functioning and is not included in the total time.

<sup>b</sup>Stoppage cleared by manipulation of bolt forward assist, average time seconds.

FBC = Failure of bolt to close.

2.9.4.2 Mud test. There were no stoppages experienced with either type rifle or ammunition. The sights were checked and found to remain operable. Notable during this test was that these rifles (which were treated with CLP) seemed to immediately reject the clinging effects of the mud (from lubricated metallic surfaces) as they were removed from the mud bath. Summary performance data is presented in table 2.9-2.

TABLE 2.9-2. SUMMARY OF RESULTS, MUD TESTS

Rifle No. (APG)	Avg Cyclic Rate (spm)	Total Rd Fired	Mud Test No. <sup>a</sup>
M16A1 Rifle/M193 Cartridge			
9A	743	90	1
	719	90	2
10A	688	90	1
	657	90	2
M16A1E1 Rifle/SS109 Cartridge			
9D	732	90	1
	721	90	2
10D	741	90	1
	746	90	2

<sup>a</sup>Test No. 1 fired after wiping off of excess mud. Test No. 2 fired after 4-hour drying period that followed the wiping off of excess mud.

2.9.4.3 Unlubricated test. The unlubricated test was performed without the application of lubricants to either model rifle. A total of 20 stoppages were recorded for the M16A1 control rifle using M193 ball ammunition. No stoppages were recorded for the M16A1E1 rifle using SS109 ball ammunition. Stoppage summaries are presented in table 2.9-3.

TABLE 2.9-3. SUMMARY OF RESULTS, UNLUBRICATED TEST

Rifle No. (APG)	Total Rd Fired	Stoppages per Type		
		FFD	FBC <sup>a</sup>	BOB
10A (M16A1)	600	8	5	7
10D (M16A1E1)	600	0	0	0

<sup>a</sup>Bolt forward assist required to clear stoppages.

FFD = Failure to feed.

FBC = Failure of bolt to close.

BOB = Bolt over base of cartridge.

## 2.9.5 Analysis

2.9.5.1 Sand and dust test. Stoppage rates encountered indicated equal performance between rifle types.

2.9.5.2 Mud test. No stoppages or failures encountered, indicating equal performance between rifle types.

2.9.5.3 Unlubricated test. The M16A1E1 performed without any stoppages or failures being encountered. The M16A1 control rifles sustained 20 stoppages.

#### 2.9.6 Conclusions

2.9.6.1 Sand and dust test. Function and reliability were considered equal. Criterion was considered met.

2.9.6.2 Mud test. Function and reliability were considered equal. Criterion was considered met.

2.9.6.3 Unlubricated. The M16A1E1 using SS109 ball ammunition was considered superior to the M16A1/M193 ball combination. Criterion was considered met.

## 2.10 POSITION DISCLOSURE

### 2.10.1 Objective

The objective was to determine if the sound and flash signature produced by the test weapon/ammunition combination was comparable with the signature results of the standard weapon/ammunition.

### 2.10.2 Criteria

The aural and visual signature produced when firing the improved weapon and ammunition shall not be greater than the signatures that exist when firing the standard weapon and ammunition (devised by Test Agency, TECOM approved).

### 2.10.3 Data Acquisition Procedure

#### 2.10.3.1 Noise-level tests.

a. The method was from TECOM TOP 1-2-608, Sound Level Measurements (ref 24), paragraphs 6.2.2, 6.2.2.1a(1), and paragraph 6.2.2.1g as modified by MIL-STD-1474B(MI) (ref 25).

b. Transient-noise-level characteristics were determined during the firing of the test and control weapons. One weapon of each type was setup in the bipod-supported position, in an open area, with no reflecting structures within 15 m. Instrumentation microphones were placed in positions simulating the following ear positions: shooter, person standing 5 m to the side, person standing 5 m to the rear, and persons standing 50 and 100 m to the front.

c. Five single shots were fired from each weapon type with their respective cartridge types. Simultaneous records of SPL versus time were made at each of the aforementioned locations, with suitable recording instrumentation.

#### 2.10.3.2 Flash tests.

a. The flash test was done in accordance with paragraph 6.2.10 of TECOM TOP/MTP 3-2-059, Hand and Shoulder Weapons (ref 12).

b. Two weapons of each type were disassembled, cleaned, lubricated, and reassembled. One weapon was in new condition and the other was in used condition, the latter being a weapon and barrel previously fired to approximately its service life. (Weapons are identified in para 2.1.)

c. A reference flash scale was fabricated as illustrated in TECOM TOP/MTP 3-2-059. A scale was mounted parallel with the barrel at the muzzle of the weapon under test.

d. A 4- by 5-in. camera, with a lens opening of 3.5 and using Polaroid 3000 film, was positioned perpendicular to the muzzle of the test weapon at a distance of 1 m. Another camera was mounted 50 m in front of the muzzle and out of the line of fire.

e. A photograph was made to establish the scale for subsequent photographic records of flash. Thirty rounds of ammunition were fired in 3-shot bursts to accumulate the flash of an entire 30-round magazine. This procedure was followed for each weapon with its respective ammunition with notation made of any visually observed variations of flash during the firings.

#### 2.10.4 Results

2.10.4.1 Noise level tests. The results of the peak sound pressure level measurements and pulse durations are summarized in table 2.10-1. Atmospheric conditions at the test site were: temperature 23° C, relative humidity 38%, pressure 1017.9 mbars, and windspeed 3.2 km/hr. The M193 cartridges were from lot TW-2-606 and the SS109 cartridges from lot 01-FNB-81.

2.10.4.1 (Cont'd)

TABLE 2.10-1. PEAK SOUND PRESSURE LEVELS AND PULSE DURATIONS<sup>a</sup>

Rifle Type	Cartridge Type	Position 1		Position 2		Position 3		Position 4 Peak (dB)	Position 5 Peak (dB)
		Peak (dB)	Duration (msec)	Peak (dB)	Duration (msec)	Duration (msec)			
						A	B		
M16A1	M193	157	0.25	142	0.27	155	0.38	155	149
		158	.25	142	.35	155	0.40	155	149
		157	.29	143	.35	155	0.39	155	149
		158	.23	143	.32	155	0.43	155	149
		158	.29	142	.36	b -	b -	155	149
	Avg	158	.26	142	.33	155	0.40	155	149
M16A1E1	SS109	155	0.32	141	0.27	b -	b -	155	149
		155	.30	140	.35	b -	b -	155	149
		155	.26	141	.32	b -	b -	155	149
		155	.26	140	.30	b -	b -	155	149
		155	.29	141	.25	b -	b -	155	149
	Avg	155	.29	140	.30	155	b -	155	149

<sup>a</sup>Microphone position 1 was at the shooter's left ear position.

Microphone position 2 was 5 meters to the rear of the muzzle.

Microphone position 3 was 5 meters perpendicular to the muzzle.

Microphone position 4 was 50 meters in front of the muzzle.

Microphone position 5 was 100 meters in front of the muzzle.

<sup>b</sup>A and B time durations were not measured due to cable malfunction.

<sup>c</sup>Cumulative peak measured on auxiliary equipment.

2.10.4.2 Flash tests. The photographic results from the flash test (perpendicular to muzzle) are presented in figure 2.10-1 on the following page. Results from the camera positioned downrange showed no significant difference between test rifles or cartridges.

2.10.5 Analysis

2.10.5.1 Noise-level tests.

a. When compared to table 5 and figure 5 of MIL-STD-1474B(MI), the peak impulse noise levels at all microphone positions for both the M193 ball and the Belgian SS109 ball require hearing protection, either plugs or muffs.

b. The peak dB readings at all positions and the A and B durations of positions 1 and 2 are in close agreement. Therefore, the absence of a measured pulse duration at position 3, for the test lot, is not deemed as critical. The A and B durations of position 3, for the test lot, would correspond closely to that measured for the standard lot. Further, according to figure 5 of MIL-STD-1474B(MI), the B duration is only a critical factor in peak impulse measurements greater than 160 dB.

2.10.5.2 Flash tests. When compared, the photographs show that the M16A1E1 using SS109 ball ammunition produced slightly less flash than the control M16A1 rifles using M193 ball ammunition. Both ammunition types produced a dull orange flash.

2.10.6 Conclusion

2.10.6.1 Noise-level tests. The test lot of Belgian SS109 ball ammunition, when fired from the M16A1E1 rifle, meets the criteria of paragraph 2.10.2. In addition, it is mandatory to wear either ear plugs or muff-type hearing protection when firing either the M16A1 or M16A1E1 rifle with their respective ammunition.

2.10.6.2 Flash tests. The Belgian SS109 ball ammunition, when fired from the M16A1E1 rifle meets the criteria of paragraph 2.10.2.

2.10.6.2 (Cont'd)

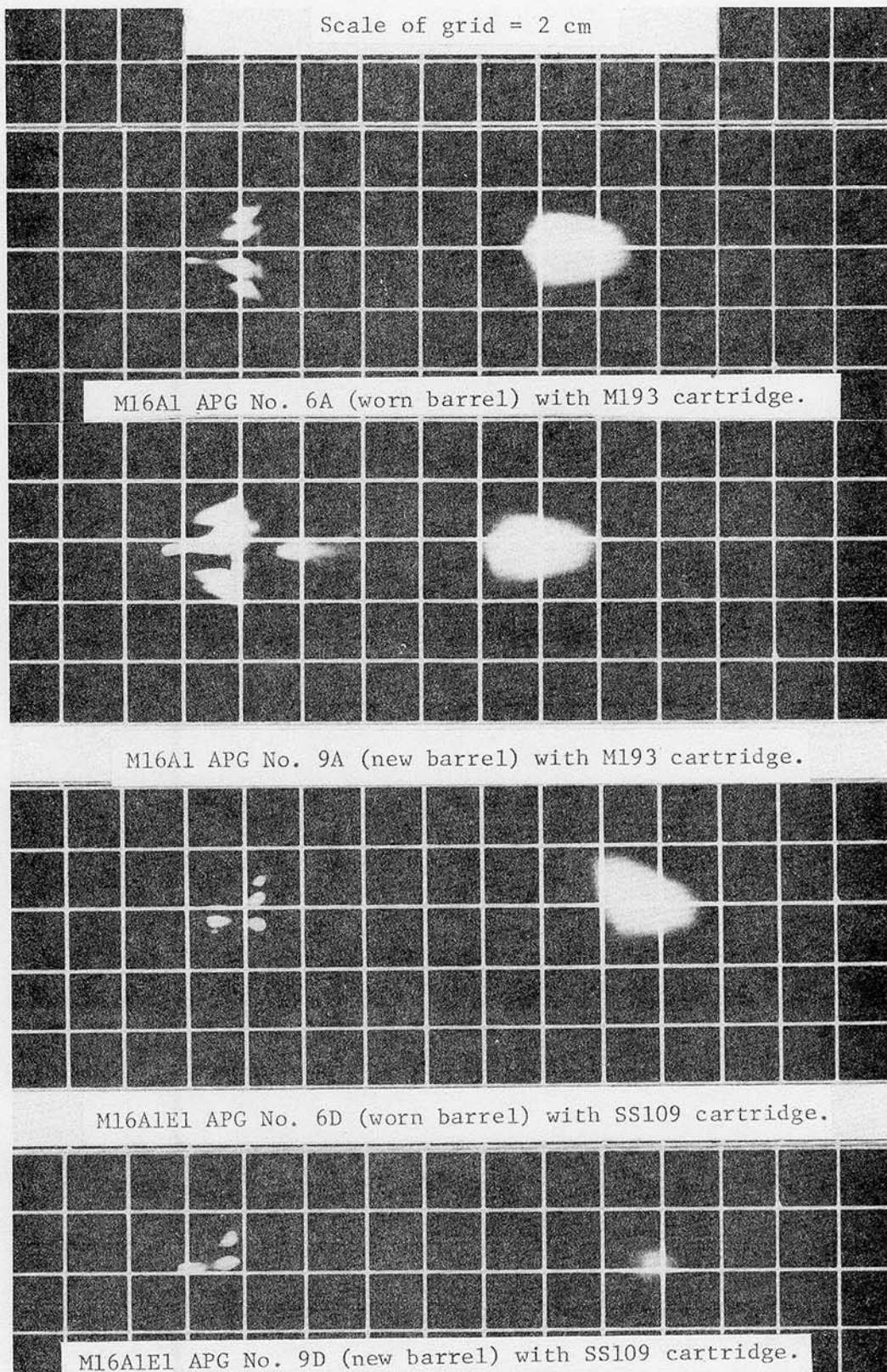


Figure 2.10-1. Comparative muzzle flash test results.

2.11 HIT PROBABILITY

2.11.1 Objective

The objective was to determine the effects of the burst control device, muzzle brake compensator, and the heavy barrel on burst accuracy.

2.11.2 Criteria

a. The hit probability of the rifles equipped with the BCD should be equal to or better than those using the automatic sear (devised by Test Agency, TECOM approved).

b. The hit probability of the rifles equipped with the MBC should be equal to or better than those using the standard flash suppressor (devised by Test Agency, TECOM approved.)

2.11.3 Data Acquisition Procedure

a. Guidance for this procedure was drawn from TECOM TOP/MTP 3-2-059 (ref 12). Testing was conducted by ARRADCOM Test Site, Fort Dix, NJ.

b. Two rifles of each type were used. Each rifle was fired twice by each of two gunners at each of the three ranges (25, 50 and 100 m). At each range, firing was from the standing, prone supported (bipod), and prone unsupported positions. The rifle sling was not utilized for support purposes.

c. All firing was in 3-round bursts or automatic fire. Automatic fire was to consist of 30-round groups with every six rounds color coded to examine the gunners ability to return the rifle to the target after its initial rise. A sample test matrix is shown in table 2.11-1. Sandbags were utilized for weapon support.

Note: The numbers in parentheses are rounds required if, after the initial ten 30 round bursts, it is determined that the gunners cannot bring the rifle back on target and all rounds after the first five should be considered misses.

4. The standard E-type silhouette target was utilized, superimposed on a large background target in order to determine the location of misses. Point of aim was on the target center mid-distance between shoulder and bottom. All target coordinates were measured from that point.

2.11.3 (Cont'd)

TABLE 2.11-1. HIT PROBABILITY TEST MATRIX

Mode of Fire	Position	Rifle No.	Total Rd	Range (m)
3RB	Standing	1	60	25
		2	60	
FA	Standing	1	600 (100)	25
		2	600 (100)	
3RB	Standing	1	60	50
		2	60	
FA	Standing	1	600 (100)	50
		2	600 (100)	
3RB	Standing	1	60	100
		2	60	
FA	Standing	1	600 (100)	100
		2	600 (100)	
3RB	Prone supported	1	60	25
		2	60	
FA	Prone supported	1	600 (100)	25
		2	600 (100)	
3RB	Prone supported	1	60	50
		2	60	
FA	Prone supported	1	600 (100)	50
		2	600 (100)	
3RB	Prone supported	1	60	100
		2	60	
FA	Prone supported	1	600 (100)	100
		2	600 (100)	
3RB	Prone unsupported	1	60	25
		2	60	
FA	Prone unsupported	1	600 (100)	25
		2	600 (100)	
3RB	Prone unsupported	1	60	50
		2	60	
FA	Prone unsupported	1	600 (100)	50
		2	600 (100)	
3RB	Prone unsupported	1	60	100
		2	60	
FA	Prone unsupported	1	600 (100)	100
		2	600 (100)	

Note: The numbers in parenthesis are rounds required if, after the initial ten 30 round bursts, it is determined that the gunners cannot bring the rifle back on target and all rounds after the first five should be considered misses.

d. The standard E-type silhouette target was utilized, superimposed on a large background target in order to determine the location of misses. Point of aim was on the target center mid-distance between shoulder and bottom. All target coordinates were measured from that point.

e. All firings were done with a traverse wind of 16 km/hr or less and varying by not more than 8 km/hr. The weapons were checked for battle sight zero as per FM 23-9 (ref 6).

f. ARRADCOM Test Site, Fort Dix conducted the hit probability segment of the TFT. The test was not completed. TECOM directed that testing be terminated when the original endurance testing at APG was cancelled because of the 1:7 inch twist/XM855E1(FN) rifle/ammunition compatibility problem (ref para 2.3).

#### 2.11.4 Results

a. The data was sent to APG to be analyzed. The data was not in raw form but was summarized in two sets (hits per rifle, hits per right and left handed shooter). Both of these sets had the data combined as follows: The 3-round burst data showed average center of impact (CI) which was the average of the individual 3-round burst CIs over the ten targets. Along with the CI data were the number of shots fired, number and percent of hits on the E-silhouette target, and number and percent of hits on the 2 by 2 m (6 by 6 ft) background target.

b. The 30-round burst data were broken down and summarized as follows: Each 30-round burst contained 6 each of 4 color-coded rounds (red, blue, yellow, and black) and 6 uncolored rounds. The CIs of each individual color-coded group and the uncolored group were computed for each burst, then the average CI (within color coding) was calculated for the 10 targets shot (60 rounds). These average (color coded) CIs were then averaged for an overall 300 round average CI. The hit probability data were the same as the 3-round burst data, except that they too were listed by color coded groups. It should be noted that in cases where not all rounds of a burst hit the 6 by 6 ft target, all those rounds which missed were assumed to have hit the target at a point using the procedure outlined in the obsolete Ordnance Proof Manual; volume 3: Test Methods for Small Arms Ammunition, TECP 700-700. Use of this method to fill in coordinates for misses, however, can lead to severe biases in the CI data. Since all CI data received by MTD were already summarized using these guidelines, they are assumed to be biased and therefore, were not used in any analysis of the two systems' performances. The CI data, however, are in the summary tables for information purposes, but only those CI data with a 100% hit rate on the 6 by 6 ft target were considered unbiased.

c. Table 2.11-2 shows the hit rate data against the E-silhouette target which could be used to address the criteria of the test.

TABLE 2.11.2. SUMMARY OF HIT RATE DATA (M16A1E1 VERSUS M16A1) AGAINST E-SILHOUETTE TARGET

Firing Position	Range (m)	Burst Size	Total Rd Fired	M16A1		M16A1E1	
				No. Hits	% Hits	No. Hits	% Hits
Prone supported	25	3	120	117	98	117	98
Prone unsupported	25	3	120	96	80	102	85
Standing	50	30	1200	284	24	210	18
Prone supported	50	30	1200	793	66	883	74
Prone unsupported	25	30	1200	1013	84	1074	90
Unsupported	50	30	1200	797	66	699	58

d. From this table, the 3-round burst data were used to address the first criteria, the 30-round burst firings were used to address the second criteria, with the M16A1E1 being equipped with the Burst Control Device (BCD) and Muzzle Brake Compensator (MBC) in each respective case. The analytical procedure stated that analysis of variance techniques at the 0.05 significance level were to be used to address the criteria; however, in 4 of the 6 cases shown in table 2.11.2, the M16A1E1 performed as well as, or better than, the M16A1 with respect to hit rates, therefore, analysis of variance was not required. In 2 of the cases, 3-round bursts-standing at 50 m and 30-round bursts-prone unsupported at 50 m, the hit rates of the M16A1E1 were less than the hit rates of the M16A1 by 6% and 8%, respectively. In these two instances, nested two-way analysis of variance techniques, using arc sine transformations on hit rates, were considered. However, the number of degrees of freedom associated with this particular design were quite small (1 in 2). As such, only extremely large differences in hit rates would be detected as being significant, therefore, chi-square contingency tests were employed. No significant differences were detected between the two systems, with respect to hit rates, at the 0.05 significance level.

e. Analysis of hit rates for 30-round burst firings versus hit rates for 3-round burst firings, within weapon system was also performed. For the M16A1E1, in both cases where comparisons of hit rates were possible, the 3-round bursts and the 30-round bursts were not found to be significantly different with respect to hit rates (ref table 2.11.2). Comparison of 30-round burst hit rates versus 3-round burst hit rates for the M16A1 also showed the same results as the M16A1E1.

#### 2.11.5 Analysis

Based upon the limited data available, the M16A1E1 rifle seems to have performed at least as well as the M16A1 control rifle, with respect to hit probability.

#### 2.11.6 Conclusion

The criteria were considered met.