DTIC FILE COPY

Research Report 1400

AD-A180 438

Training Program Development for the M249 Bipod-Mounted Squad Automatic Weapon (SAW)

James E. Fusha
Mellonics Systems Development Division
Litton Systems, Inc.

Thomas J. Thompson
Army Research Institute

ARI Field Unit at Fort Benning, Georgia
Training Research Laboratory

U. S. Army

Research Institute for the Behavioral and Social Sciences

February 1985

Approved for public release; distribution unlimited.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER
ARI Research Report 1400

2. GOVT ACCESSION NO.
AD-A180438

3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle)
TRAINING PROGRAM DEVELOPMENT FOR THE M249 BIPOD MOUNTED SQUAD AUTOMATIC WEAPON (SAW)

5. TYPE OF REPORT & PERIOD COVERED
Final Report
June 1983 - June 1984

6. PERFORMING ORG. REPORT NUMBER
--

7. AUTHOR(s)
James E. Fusha (Litton) and
Thomas J. Thompson (ARI)

8. CONTRACT OR GRANT NUMBER(s)
MDA 903-80-C-0545

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Litton Mellonics
P.O. Box 2498
Fort Benning, GA 31905

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
2Q263743A794
3231 102
5710

11. CONTROLLING OFFICE NAME AND ADDRESS
U.S. Army Research Institute for the Behavioral and Social Sciences
5001 Eisenhower Avenue, Alexandria, VA 22333-5600

12. REPORT DATE
February 1985

13. NUMBER OF PAGES
98

14. MONITORING AGENCY NAME & ADDRESS (If different from Controlling Office)
ARI Field Unit
P.O. Box 2086
Fort Benning, GA 31905

15. SECURITY CLASS. (of this report)
Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
--

16. DISTRIBUTION STATEMENT (of this Report)
Approved for public release; distribution unlimited

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

18. SUPPLEMENTARY NOTES
Seward Smith, Contracting Officer's Representative

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

Familiarization firing	Zeroing procedures	Shot group dispersion
Squad automatic weapon	Target engagement	High/low gas setting
Test firing	Range configurations	Trajectory
Qualification standards	Burst fire	Qualification firing

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

Research was conducted to develop a program of instruction (POI) that includes both familiarization and qualification courses of fire for the squad automatic weapon (SAW). An extensive analysis of test fire data, firing techniques and procedures, weapon characteristics and training requirements was performed. Major findings were: (1) successful engagement of targets at ranges greater than 400 meters is limited by system design deficiencies, (2) the most effective beaten zone is created by firing rapid two to three round bursts with short intervals between bursts for reacquiring (Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

UNCLASSIFIED

 SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

ARI Research Report 1400

19. (Continued)

Ammunition
Ballistics
Training development (interim)
FC 23-10

20. (Continued)

and relaying on the target, (3) the M856 tracer round is impossible to observe from behind the sights, (4) the most effective position for firing the SAW is the M60 position published in FM 23-67 (1964), (5) the SAW should be zeroed using single shot fire at a range of 10 meters with a 500 meter range setting on the sight, (6) SAW transition firing can be conducted on a record fire range (TRAINFIRE Qualification), a rifle field fire range, or a machinegun transition range, (7) both M855 and M193 ammunition are suitable for SAW training; however, ballistic variances preclude mixing of training ammunition and limit use of M193 ammunition to ranges of 300 meters and less.

Research Report 1400

Training Program Development for the M249 Bipod-Mounted Squad Automatic Weapon (SAW)

James E. Fusha
Mellonics Systems Development Division
Litton Systems, Inc.

Thomas J. Thompson
Army Research Institute

Submitted by
Seward Smith, Chief
ARI Field Unit at Fort Benning, Georgia

Approved as technically adequate
and submitted for publication by
Donald F. Haggard, Acting Director
Training Research Laboratory

U.S. ARMY RESEARCH INSTITUTE FOR THE BEHAVIORAL AND SOCIAL SCIENCES
5001 Eisenhower Avenue, Alexandria, Virginia 22333

Office, Deputy Chief of Staff for Personnel
Department of the Army

February 1985

Army Project Number
2Q263743A794

Education and Training

ARI Research Reports and Technical Reports are intended for sponsors of R&D tasks and for other research and military agencies. Any findings ready for implementation at the time of publication are presented in the last part of the Brief. Upon completion of a major phase of the task, formal recommendations for official action normally are conveyed to appropriate military agencies by briefing or Disposition Form.

FOREWORD

The Squad Automatic Weapon (SAW) is a new lightweight, one-man portable automatic weapon that is capable of delivering a large volume of sustained, and lethal fire on a target. It provides the infantry squad with improved suppressive fire and a high volume of close and continuous assault fire necessary to better accomplish its mission. Beginning in 1984, the SAW is being fielded to replace the M16A1 rifles carried by the two members of the infantry squad who are designated as automatic riflemen. In support of the USAIS, the U.S. Army Research Institute has initiated training development research for the SAW weapon system. One of the purposes of the ARI research is to develop a Program of Instruction (POI) that includes courses of fire for both familiarization and qualification.

Edgar M Johnson

EDGAR M. JOHNSON
Technical Director

TRAINING PROGRAM DEVELOPMENT FOR THE M249
BIPOD MOUNTED SQUAD AUTOMATIC WEAPON (SAW)

EXECUTIVE SUMMARY

Requirement:

Beginning in 1984, the SAW is being fielded to replace the M16A1 rifles carried by the two members of the infantry rifle squad who are designated as automatic riflemen. Accordingly, the US Army Infantry School (USAIS) has initiated research to develop training materials and programs of instruction (POI) to accompany the fielding of the SAW. In support of the USAIS, the US Army Research Institute (ARI) has conducted research to determine firing characteristics and weapon system performance as part of the interim training program development. The primary purpose of the ARI research to date has been to identify effective training procedures to meet the Army requirements and SAW capabilities in order to field a program compatible with training facilities and the capabilities of the SAW.

Procedure:

A series of test firings by skilled marksmen was conducted to determine weapon characteristics, fire dispersion patterns, ammunition performance differences, and overall system performances. The tests were conducted from a rigid bench rest mount at ranges out to 300 meters, at the 10-meter zeroing range, and from the bipod mount at anticipated operational ranges out to 900 meters. Experiments were conducted to determine proper holding techniques, optimum burst size, bullet trajectory, variances between ammunition types, automatic fire beaten zone capabilities, and probability of target hit under typical user conditions. Finally, an evaluation of SAW performance capabilities was undertaken to prepare trainers for its introduction and to determine whether the weapon could meet the standards set for it based on developmental testing criteria. Major objectives were to:

- o Develop a Program of Instruction
- o Develop Familiarization Course of Fire
- o Develop Qualification Course of Fire

Findings:

Familiarization and qualification marksmanship instructional programs were developed. As part of the program implementation process, a variety of range configurations, targets, and training materials were evaluated. Procedures and materials in the area of instruction and performance criteria were developed. Further, constraints that hinder performance and the implementation process were identified, together with areas of future research having the potential to partially overcome the effects of these constraints.

Utilization of Findings:

The interim programs for basic marksmanship training with the bipod mounted squad automatic weapon reported herein have been approved for adoption Army-wide by the U.S. Army Infantry School (as proponent). Refinements to the weapon system and process of implementation/evaluation are currently being addressed.

TRAINING PROGRAM DEVELOPMENT FOR THE M249
BIPOD MOUNTED SQUAD AUTOMATIC WEAPON (SAW)

CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Background

Development of the Squad Automatic Weapon (SAW) began in 1971 with a materiel need document which was subsequently accepted by the Department of the Army in 1973 (Niewenhous, 1982). Developmental testing of candidate weapons began in 1974 at the US Army Aberdeen Proving Ground and continued through the 1970s. In May of 1980, the XM249, in 5.56mm caliber was selected as the US Army's SAW. At the same time, the Belgian SS109 ball and L110 tracer cartridges, which were later designated XM855/XM856 respectively, were selected for use in the weapon instead of the standard M193/M196 ball and tracer combination available in the inventory. The newer ammunition was designed to be compatible with the 1 in 7 inch twist barrel of the SAW and the M16A2 rifle as well, which is to be fielded as a replacement for the current standard M16A1. The ammunition and barrel combination was designed to provide a greater effective range for these weapons.

Purpose

Beginning in 1984, the SAW is being fielded to replace the M16A1 rifles carried by the two members of the infantry rifle squad who are designated as automatic riflemen. Accordingly, the US Army Infantry School (USAIS) has initiated research to develop training materials and programs of instruction (POI) to accompany the fielding of the SAW. In support of the USAIS, the US Army Research Institute (ARI) has conducted research to determine firing characteristics and weapon system performance as part of the interim training program development. The primary purpose of the ARI research to date has been to identify effective training procedures to meet the Army requirements and SAW capabilities in order to field a program compatible with training facilities and the capabilities of the SAW.

The Mellonics Systems Development Division of Litton Systems, Inc., under contract to ARI, has been conducting research supported by USAIS through the Fort Benning ARI Field Unit. This research has involved test firing, data collection, and the determination of optimum firing techniques and procedures, as well as identification of SAW peculiar characteristics and training requirements. This report presents research findings which resulted from field experimentation and discusses their implications for time and cost effective marksmanship training with the SAW. The product of this research is FC 23-10, Basic Marksmanship Training Bipod Mounted Squad Automatic Weapon (SAW), dated March 1984.

The process of developing the SAW marksmanship training programs involved much more than simply test firing the M249 SAW to determine weapon capabilities in order to provide new programs of instruction for training personnel. Results of research include outlined efforts that supported the development/implementation process. For clarity of presentation, these interrelated efforts are detailed within the areas of equipment, ammunition, and range configuration.

Objectives

Specific objectives of this research include:

- Development of a Program of Instruction (POI) for the Squad Automatic Weapon.

- Development of a course of fire for familiarization for the Squad Automatic Weapon.

- Development of a course of fire for qualification for the Squad Automatic Weapon.

In order to pursue these objectives, engineering and service tests of the SAW were reviewed to better understand its characteristics, capabilities, and expected performance. In addition, liaison with the Fire Control and Small Caliber Weapon Systems Laboratory, U.S. Army Research and Development Command produced on-site visits and working conferences with engineers and personnel responsible for SAW system quality control and acceptance.

METHODS

A series of test firings by skilled marksmen was conducted to determine weapon characteristics, fire dispersion patterns, ammunition performance differences, and overall system performances. The tests were conducted from a rigid bench rest mount at ranges out to 300 meters, at the 10-meter zeroing range, and from the ipod mount at anticipated operational ranges out to 900 meters. Experiments were conducted to determine proper holding techniques, optimum burst size, bullet trajectory, variances between ammunition types, automatic fire beaten zone capabilities, and probability of target hit under typical user conditions. Finally, an evaluation of SAW performance capabilities was undertaken to prepare trainers for its introduction and to determine whether the weapon could meet the standards set for it based on developmental testing criteria.

Six experienced shooters, both military and civilian, participated in each phase of test firing. These personnel were joined later by two expert marksmen from the U.S. Army Marksmanship Unit (USAMU). The test firing schedule sequence followed a test firing plan developed specifically for testing and evaluating the SAW (see Appendix A, SAW Test Fire Plan). The test firing consisted of 10 subtests. Each subtest was independent in both purpose and data collection; however, results from each subtest were used to make necessary determinations before progressing to subsequent testing. Testing was initiated with bench rest firing for weapon accuracy checks at 10, 100, and 300 meter ranges. This was followed by test personnel firing the bipod mounted SAW on the 10-meter range. Next, the firers using the bipod mounted SAW fired at ranges beginning at 100 meters out to 900 meters with range increases made in 100-meter increments. Test firings were then conducted on existing M-60 machinegun and M-16 qualification ranges to determine performance limitations under typical range conditions. After receipt of a second SAW, testing involved repeating the bipod mounted firing protocols for a comparison between new and old weapon performance at ranges out to 600 meters. The detailed objectives of the complete test firing plan were to determine the following:

- Proper holding techniques and firing positions
- Zeroing procedures
- Techniques of observation and adjustment of fire at battlefield ranges by the gunner
- Alternate sighting/observation techniques
- Assault fire techniques
- Techniques for moving target engagement
- Night fire techniques with and without night observation devices
- Range configurations for training and qualification firing
- Qualification and familiarization standards

Results

The SAW test firing that took place at targets at ranges of 10 meters and 100 meters from a stabilized bench rest (rigid mount) was conducted to determine SAW performance under conditions that would allow near optimum holding and stability. This firing condition has typically shown the maximum capabilities of the weapon without the firer's intervention. Test firing included single shot group development and burst fire at 10, 100, and 300-meter ranges. The tests were conducted to determine firing characteristics, differences in single shot firing versus burst fire techniques, ammunition characteristics (SS109, L110, M193, and M196), and weapon performance at high and low gas settings.

Initial firing began with single shot, five round groups from a bench rest mount at a known distance range of 300 meters. The purpose of this firing was to establish a field zero for the squad automatic weapon. The sighting system is designed to allow range increases in one hundred meter increments between 300 and 1000 meters. The minimum range setting available was selected. It was also the maximum distance available on the firing range being used. Performances achieved during early group firing are recorded in tables in Appendix B. The first bench rest firing was conducted to determine field zero sight settings, shot group sizes, and by-round group dispersion (Table B-1). Field zero firing at 300 meters was followed by 5 round burst firing from the bench rest at the same range (Table B-2). The extreme spreads for the burst fire groups were larger than those obtained under single shot grouping conditions, and the mean extreme horizontal dispersion for the burst fire groups was almost double the mean of the single shot groups (Table 1).

Table 1

SAW 300 Meter Bench Rest Firing
for Field Zero (SS109 Ammunition)

Number of Groups		Mean Extreme (cm) Horizontal	Vertical	Spread	Firing Condition
15	$\bar{X}$ =	15.3" (38.86)	19.87" (50.47)	23.53" (59.77)	5 Rd Single Shot
4	$\bar{X}$ =	28.75" (73.03)	15.0" (38.10)	31.0" (78.74)	5 Rd Burst

The SAW was then fired using the bench rest established 300 meter zero to determine appropriate sight settings for point-of-aim/point-of-impact performance on the 10 meter firing line. This again was bench rest firing to insure a stable and accurate firing platform. Range settings between 300 meters and 1000 meters were tested to determine the appropriate one (Table B-3). Both single shot and burst fire five-round groups at this range produced a demonstrated 600 meter sight setting for coincidental point-of-aim/point-of-impact for all ammunition types tested. It must be noted that ballistic performances for the different ammunition types are known to differ at the actual operating ranges for the SAW (Niewenhous, 1982). The groups fired at the point-of-aim/impact sight setting of 600 meters were comparable (Table 2). Also, while the L110 tracer produced relatively the same center of group impact, the mean dispersion of all groups fired during this test was a bit larger than that of the two ball ammunition types (Table 3).

Table 2

SAW 10 Meter Bench Rest Firing
for Point-of-Aim/Point-of-Impact
Determination (600 Meter Sight Setting)

Number of Groups	Mean Extreme (cm) Horizontal	Vertical	Spread	Firing Condition	Ammunition
2	.645" (1.64)	.495" (1.26)	1.10" (2.79)	5 Rd Single Shot	SS109
4	.84" (2.13)	.69" (1.75)	1.27" (3.23)	5 Rd Burst	SS109
2	.38" (.97)	1.2" (3.05)	1.71" (4.33)	5 Rd Single Shot	L110
4	.49" (1.25)	.54" (1.37)	.998" (2.53)	5 Rd Burst	L110
6	.47" (1.19)	.46" (1.17)	1.14" (2.88)	5 Rd Single Shot	M193
5	.48" (1.23)	.38" (.96)	1.13" (2.86)	5 Rd Burst	M193

Table 3

SAW 10 Meter Bench Rest Firing for
Point-of-Aim/Point-of-Impact Determination of Ammunition Differences

Number of Groups	Mean Extreme Spread (cm)	Ammunition
23	1.19" (3.02)	SS109
12	1.47" (3.74)	L110
12	1.15 (2.93)	M193

The next test condition included firing at a range of 100 meters from the bench rest to determine close operational range shot group dispersion. It was noted during this firing phase that shot group centers were migrating around the point-of-aim (Figure 1). The procedure during this phase of testing had been to re-aim and re-lay the bench rest after each shot group; however, it was determined that uncontrolled movement in the rear sight aperture and feed tray cover was altering the sight picture and subsequently indicating an unnecessary shift in the lay of the weapon. Early 300 meter field zero firing (Table B-1) best illustrates this migration (Figure 1).

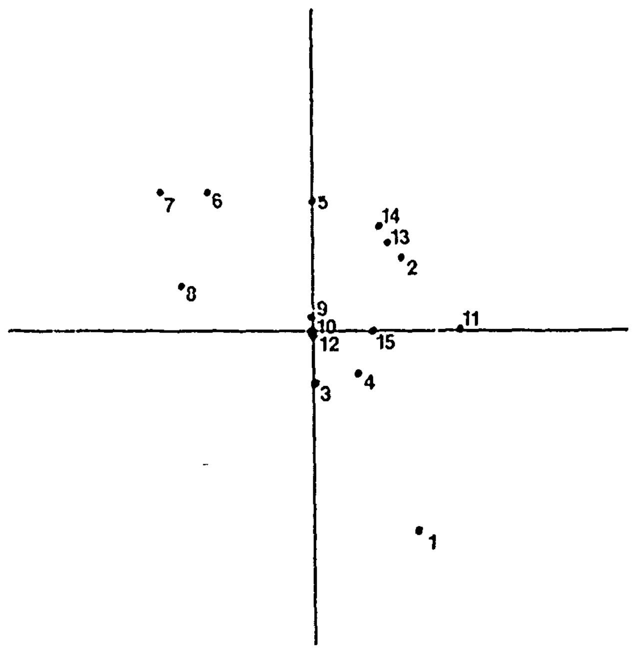


Figure 1. 15 Shot group centers at 300 meters

The shot group sizes, based on a limited number of groups fired, indicated that M193 ammunition might serve as a reasonable substitute for SS109 ammunition at closer training ranges (Table 4). It must be assumed as well that the production M855 ammunition planned for use in the SAW will provide comparable performance to the SS109.

Table 4

100 Meter Bench Rest
Group Dispersion SS109 & M193*

Number of Groups	Mean Extreme (cm) Horizontal	Vertical	Spread	Group Type	Ammunition
6	3.08" (7.83)	4.21" (10.69)	8.58" (21.80)	5 Rd Single Shot	M193
3	5.33" (13.55)	3.75" (9.53)	10.17" (25.82)	5 Rd Burst	M193
3	3.83" (9.74)	2.82" (7.15)	7.83" (19.90)	5 Rd Single Shot	SS109

*Fired prior to noting aiming point migration.

The performance of SS109 ammunition, fired from the bench rest at a range of 100 meters, was measured by additional firing without re-laying the bench rest. Consistency in shot group placement was increased and a better indication of shot group dispersion was obtained (Table 5 and Table B-5).

Table 5

100 Meter Bench Rest
Mean Group Dispersion SS109 Ammunition

Number of Groups	Mean Extreme (cm) Horizontal	Vertical	Spread	Group Type
4	3.38" (8.57)	5.44" (13.81)	10.38" (26.35)	5 Rd Single Shot
4	5.13" (13.02)	5.38" (13.65)	10.38" (26.35)	5 Rd Burst

Firing continued at a range of 300 meters from the bench rest. A total of 16 shot groups were fired including single shot fire and ten round bursts (Table B-6). This sequence of shot groups permitted the first direct comparison of the production SAW performance with earlier reported materiel test performances (Niewenhous, 1982). While the bench rest firing position provided the best possible performance opportunity for the weapon in its production configuration, the previous materiel tests produced optimum performances for the ammunition fired from a rigid mount test barrel. Table 6 presents a comparison of these data summaries for single shot groups fired at 300 meters.

Table 6

300 Meter Single Shot Groups
SAW vs. Mann Barrel
(SS109 Ammunition)

Number of Groups	Mean Extreme Spread (cm)		Weapon
5 - 5 Rd	43.01"	(109.25)	Production SAW
	25.02"	(63.55)	
	25.5"	(64.77)	
	13.98"	(35.50)	
	20.0"	(50.80)	
	All = 25.46"	(64.77)	
3 - 10 Rd	8.67"	(22.01)	Test Barrel/ Ammunition
	7.37"	(18.71)	
	7.26"	(18.45)	
	All = 7.76"	(19.72)	

Operating gas pressure in the SAW is controlled by a two position regulator. One position is used for normal operating conditions and the other for delivering additional gas power to overcome sluggish operation. The SAW is designed to fire at a cyclic rate of 725 rounds per minute (normal setting, TM 9-1005-201-10), although it has been factory set to an 800 plus rate (Trifiletti, 1983), and approximately 1000 rounds per minute (high gas setting, TM 9-1005-201-10), with the latter being employed only when the weapon will not function properly (cycle) in the normal gas setting position. This would commonly occur under extremely cold conditions. Rounds fired from a bench rest with a maximum gas setting on an otherwise properly functioning weapon tended to impact with wider dispersion and in more erratic patterns at the 100 meter range (Table 7). Similar differences were not noted at 10 meters.

Table 7

SAW Bench Rest Firing SS109 Ammunition
Normal vs. High Gas Setting
(850/900 vs. 1100 Shots Per Minute)

Number of Groups	Mean Extreme (cm) Horizontal	Vertical	Spread	Range	Type Fire
4	.84" (2.13)	.69" (1.75)	1.27" (3.23)	10 meters	5 Rd Burst/ Normal
4	.53" (1.35)	.53" (1.33)	1.15" (2.92)	10 meters	5 Rd Burst/ High
4	5.13" (13.02)	5.38" (13.65)	10.38" (26.37)	100 meters	5 Rd Burst/ Normal
4	8.0" (20.32)	4.63" (11.75)	14.94" (37.94)	100 meters	5 Rd Burst/ High

Test firing was conducted with experienced automatic weapons firers at the 10 meter range to determine optimum individual holding techniques and to confirm the 600 meter sight setting zero for this range. The emphasis on performance at 10 meters is based on the extensive use of this range for current machinegun (M60, 7.62mm) training. It has been assumed that SAW training will be conducted on available rifle and machinegun ranges where feasible. Single shot and burst firing results which were obtained at 10 meters using an M60 machinegun bipod firing position indicated that a 500 meter sight setting produced a more consistent coincidental point-of-aim/impact than did the 600 meter sight setting which previously had been determined best on the bench rest mount (Table 8).

Burst fire at the 10 meter range produced shot groups which were consistently centered left and often high of the point-of-aim (Table 8). Tables B-8 and B-9 present the individual group measurements.

Table 8

SAW 10 Meter Zeroing Performance
5 Shot Groups

Sight Setting	Number of Groups	Mean Distance of Group Center from Point-of-Aim (cm) Windage	Elevation	Firing Condition	Ammunition
500 m	8	R .05" (0.14)	- .05" (0.12)	Bipod Mt. Single Shot	SS109
500 m	5	0 (0)	+ .03" (0.08)	Bipod Mt. Single Shot	M193
600 m	2	L .11" (0.28)	+ .63" (1.60)	Bipod Mt. Single Shot	M193
500 m	22	L .48" (1.21)	- .40" (1.01)	Bipod Mt. Burst	SS109
500 m	22	L .59" (1.50)	- .37" (0.94)	Bipod Mt. Burst	M193
600 m	22	L .57" (1.44)	- .97" (2.46)	Bipod Mt. Burst	M193

The firers experimented with several different bipod firing positions but did not produce significantly different results which would indicate a clearly superior technique. Among the test firers, the standard M60 machinegun bipod position was preferred. This position required the firer to exert pressures to pull the weapon to the rear and down into the holding shoulder. Preference for this position was probably due to prior machinegun training and familiarity with the position. Results of a test condition comparing the M60 machinegun position and a position requiring a two-hand hold on the pistol grip (Table 9) indicate a slight decrease in the firer's ability to hit point-of-aim and to control dispersion with the latter position. Ammunition differences may have contributed to performance differences; however, other direct ammunition matches did not show significant differences at the 10 meter firing range (Tables 2 and 8).

Table 9

SAW 10 Meter Bipod Holding Techniques
M60 and Two-Hand Hold on Grip

Position	Number of Groups	Mean Spreads (cm) Horizontal	Vertical	Group Center Mean Distance from Point-of-Aim (cm) Windage	Elevation	Ammunition
M60 Hold	12	1.29" (3.28)	1.31" (3.32)	R 0.91" (2.32)	- 0.2" (0.51)	SS109
Two Hand Grip	8	1.64" (4.15)	2.29" (5.81)	L 1.45 (3.67)	+ 0.86 (2.19)	M193

In all positions, the horizontal direction of pressure (front or back) placed on the bipod support directly affected point-of-aim/point-of-impact. Options available to the firer were either forward (pushing) pressure or rearward (pulling) pressure. One direction did not prove significantly better than the other; however, in relation to point-of-aim, rearward pressure consistently produced shot groups that were located higher than with forward pressure (Table 10).

The bipod mounted SAW was fired at known distance ranges beginning at 100 meters and subsequently increased at 100 meter increments for each iteration to a distance of 900 meters. Test firing did not take place at the 1,000 meter range (maximum sight setting) primarily because of the unavailability of an acceptable range with a measured 1,000 meter distance and target capability. Firing data was collected in an attempt to measure the most effective burst size, confirm projectile trajectory, beaten zone development, dispersion of hits, hit probability, and ammunition variances for each firing distance. The initial target used to capture hits was a 6 foot by 6 foot (1.8 m x 1.8 m) witness panel with a prone "D" silhouette (approximately 24" x 19") superimposed (Figure 2). The established point-of-aim used by all firers was the center base of the prone "D" silhouette. Later testing was conducted using the same dimension witness panel with an "E" silhouette (19" x 39") superimposed (Figure 3). A change was made to use the "E" silhouette since it was more representative of the targets used in most existing rifle marksmanship training programs. Again, the point-of-aim used by firers was the center base of the silhouette. Data for each firer was recorded by range and firing scenario on a duplicate scaled target (Figure 4) and is presented in Appendix B. Specific data recorded included the number of hits recorded on the panel, actual target hits and, shot group size and location of shot group center when possible.[1] In many instances, the shot group size exceeded the dimensions of the witness panel making accurate and consistent measurements impossible.

---

[1] Not included as a part of this report. Raw data is available from Dr. T. J. Thompson, ARI Field Unit, Fort Benning, Georgia.

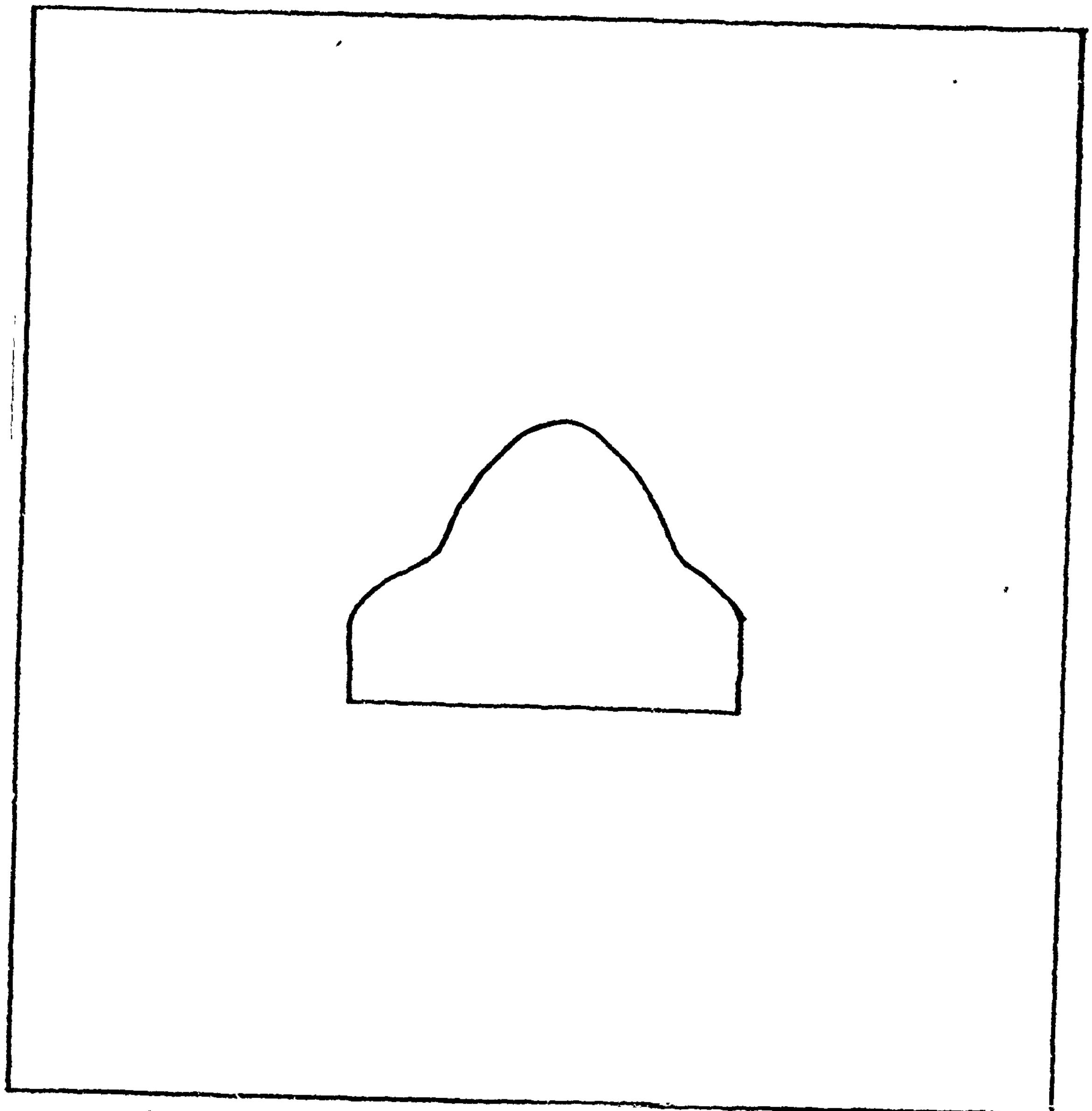
Table 10

SAW 10 Meter - Bipod Pressure
Single Shot, Five Shot Group (SS109)

Sight Range Setting = 500 m

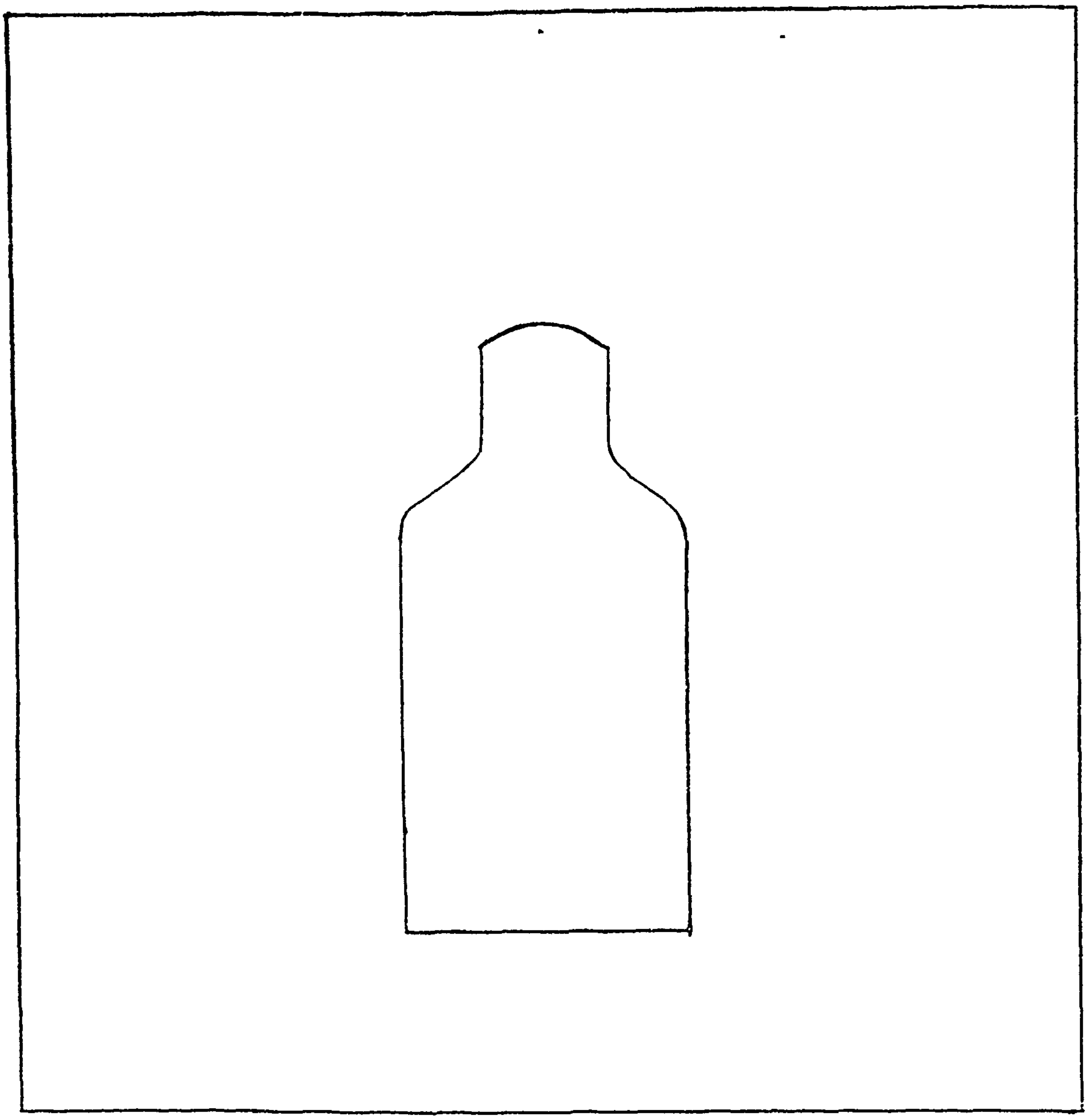
Firer	Pressure on Bipod	Horizontal ES	Vertical ES	Location of Group Center from Point of Aim: Wind	ELE
1	Forward	2.4	.77	0	-1.0
	Rearward	1.26	1.12	0	+ .95
2	Forward	.53	1.0	R .75	- .90
	Rearward	.71	.58	R .70	0
3	Forward	.57	.58	R .20	- .27
	Rearward	.98	.75	R .50	+ .35
4	Forward	1.0	.26	R .40	-2.10
	Rearward	.50	.99	R .35	- .50
5	Forward	1.0	1.58	R .50	- .95
	Rearward	.25	.60	R .15	0
6	Forward	.72	.84	R .98	- .46
	Rearward	.48	.70	R .30	+ .48
7	Forward	.58	1.0	R .98	+1.0
	Rearward	.50	1.0	R .98	0
8	Forward	.10	.98	R1.48	- .38
	Rearward	.29	.48	R .75	+ .42
$\overline{X}$	Forward	0.86" (2.19)	0.88" (2.23)	0.66" (1.68)	-0.63" (1.61)
$\overline{X}$	Rearward	0.62" (1.58)	0.78" (1.98)	0.47" (1.18)	0.21 (0.54)

( ) cm



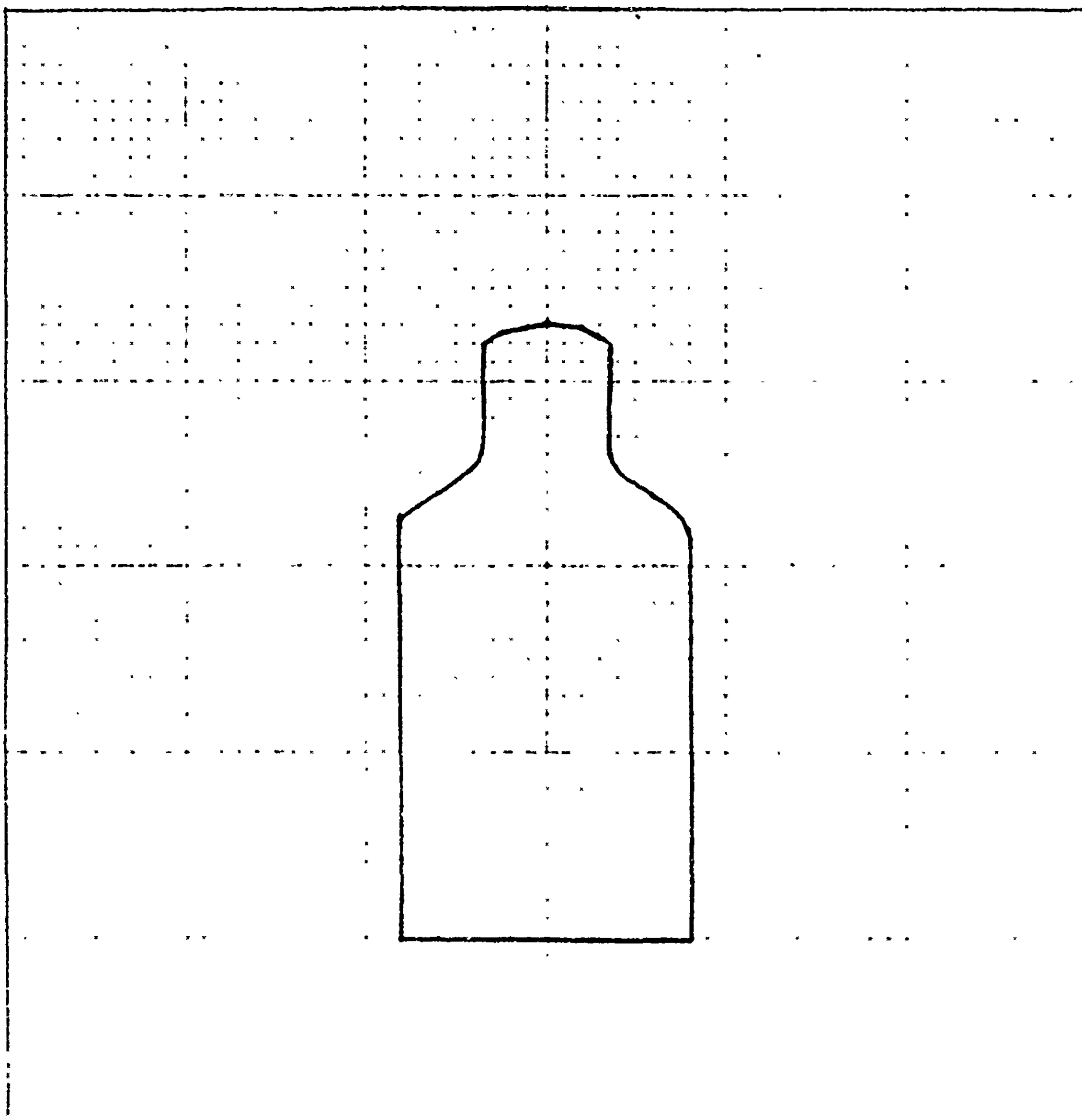
(Actual Size - Panel 6′ x 6′ - Silhouette 24" x 19")

Figure 2. Test Fire Target - Ranges 100 - 900 Meters.



(Actual Size - Panel 6′ x 6′ - Silhouette 20" x 40")

Figure 3. Test Fire Target - Ranges 100 - 900 Meters.



(Actual Size)

Figure 4. Scaled Test Fire Target - (Scale = 1 cm square = 1.2")

Initial test firing was conducted at ranges from 100 meters through 600 meters. Firing scenarios included five round bursts and ten round bursts using both SS109 and M193 ammunition for comparison. The number of rounds on witness paper and target hit performance of the SS109 ammunition was marginally better than the M193 ammunition (Table 11 and Figures 5 and 6) at all ranges in this limited test. As firing distances increased, shot group sizes and dispersion rapidly enlarged to a point where many rounds in the burst from 5 to 10 had a negative effect in relation to number of hits captured by the panels as well as target silhouettes actually hit (Tables 11 and 12).

Table 11

M193 Ammunition
5 rd Burst

Range/Rounds	Shot Groups/Captured	(6´ x 6´) Hits Recorded	Silhouette Hits
100 m/20 rds	4/4	20 (100%)	14 (70.0%)
200 m/40 rds	8/8	40 (100%)	7 (17.5%)
300 m/40 rds	8/3	28 (70.0%)	2 (5.0%)
400 m/60 rds	12/2	23 (38.3%)	3 (5.0%)
500 m/40 rds	8/2	12 (30.0%)	2 (5.0%)
600 m/40 rds	8/0	3 (7.5%)	0 (0%)

SS109 Ammunition
5 rd Burst

Range/Rounds	Shot Groups/Captured	(6´ x 6´) Hits Recorded	Silhouette Hits
100 m/60 rds	12/12	60 (100%)	38 (63.3%)
200 m/80 rds	16/13	60 (80.0%)	30 (37.5%)
300 m/100 rds	20/13	61 (61.0%)	18 (18.0%)
400 m/120 rds	24/12	62 (51.6%)	13 (10.8%)
500 m/40 rds	8/2	16 (40.0%)	2 (5.0%)
600 m/40 rds	8/0	7 (17.5%)	2 (5.0%)

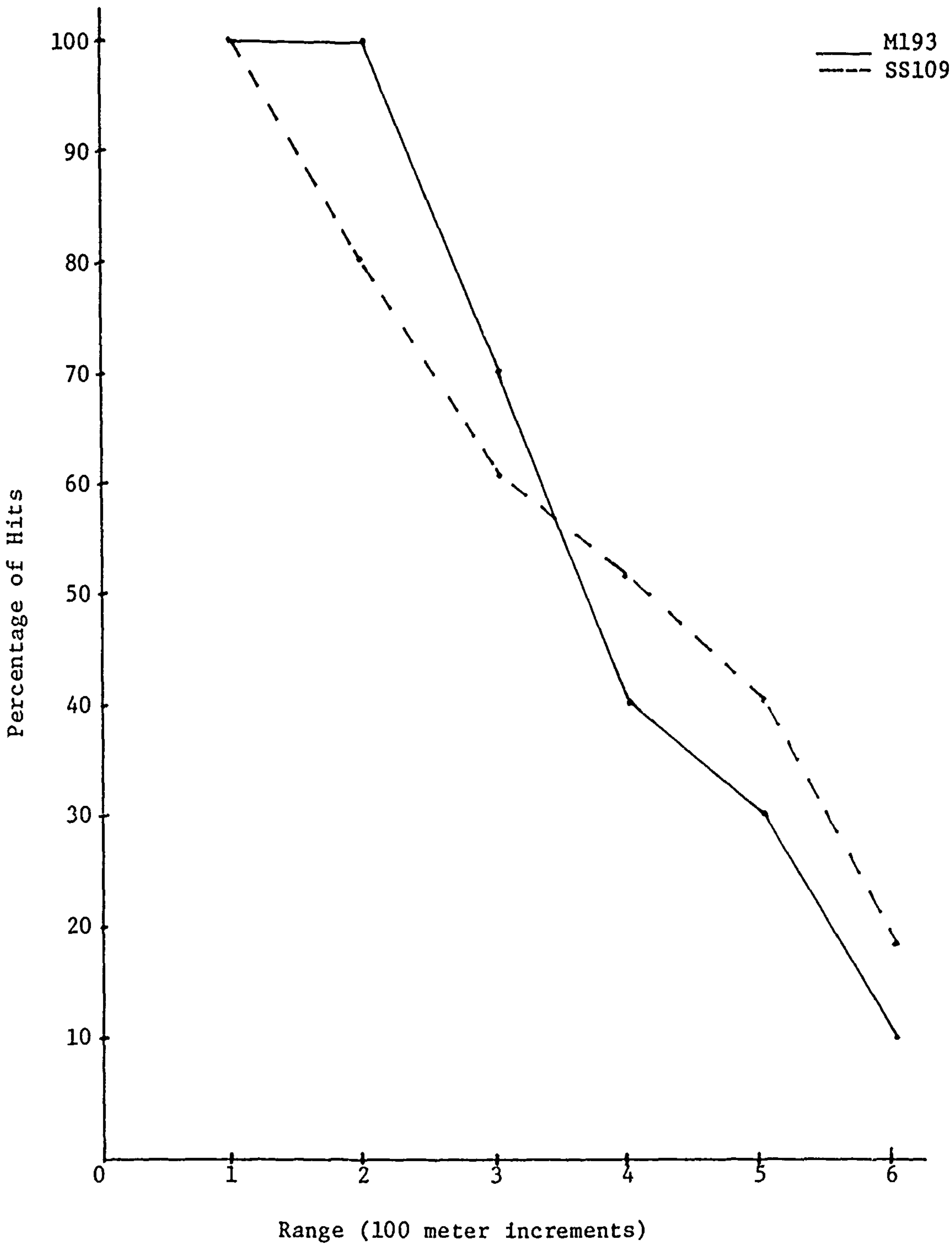


Figure 5. Rounds Captured - 6′ x 6′ Target

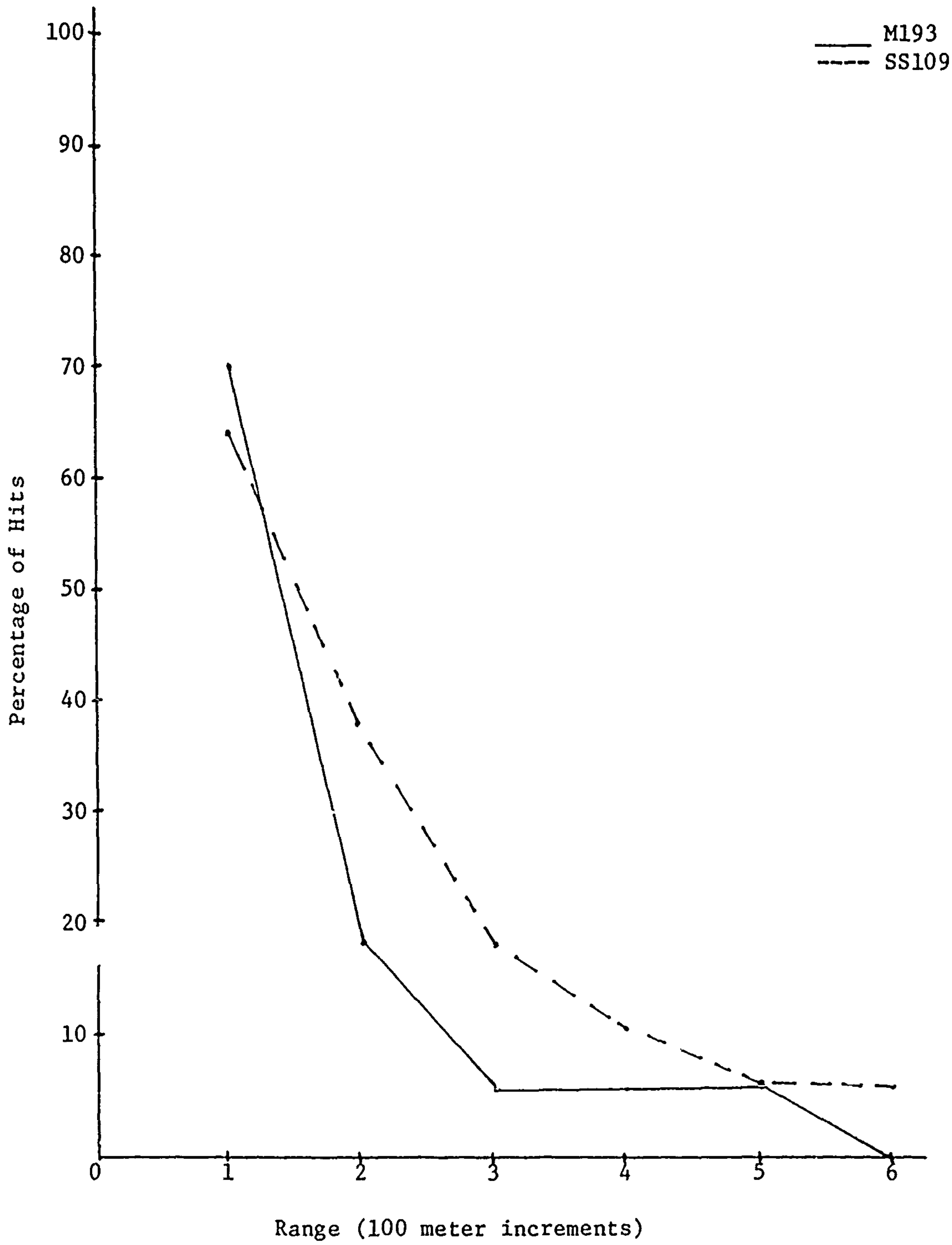


Figure 6 Silhouette Target Hits

Table 12

SS109 Ammunition
10 rd Burst

Range/Rounds	(6´ x 6´) Rounds Captured	Silhouette Hits
200 m/30 rds	24 (80.0%)	4 (13.2%)
300 m/30 rds	10 (33.3%)	3 (10.0%)
400 m/30 rds	5 (16.6%)	0 (0%)
500 m/20 rds	3 (15.0%)	0 (0%)
600 m/80 rds	19 (23.75%)	3 (3.75%)

Note: M193 ammunition was too scarce to replicate the 10 rd burst firing, given the poor results obtained with the SS109.

The next phase of testing involved firing at 700, 800, and 900 meter ranges; however, due to the limited availability of M193 ammunition as well as its lack of stability at these greater ranges (Niewenhous, 1982), only SS109 was fired. In an effort to better control the action of the weapon and the resulting dispersion of rounds caused by the high cyclic rate of operation, burst size for this phase was reduced from 5 round bursts to 2-3 round bursts. The test scenario required each of five firers to fire 30 rounds at a target (6´ x 6´ panel) at each range using a 2-3 round burst. After each burst, the firer had to quickly re-lay on target, re-acquire his sight picture, and fire another 2-3 round burst as he would have when providing suppressive fire. This process was repeated until all 30 rounds were expended. All five test firers reported experiencing extreme difficulty in maintaining a target sight picture during the firing sequence. Firers also reported that observation of tracers and/or impacting rounds in the target area was not possible. At these ranges, hits captured on witness paper and target hits could be best described as random rather than as recognizable groups (Table 13).

Table 13

SAW 700, 800, 900 Meter Firing
2 to 3 rd Bursts of SS109 in 30 Round Groups

Range/Rounds	Rounds Captured	Silhouette Hits
900 m/180 rds	16 (8.8%)	3 (1.6%)
800 m/150 rds	50 (33.3%)	9 (6.0%)
700 m/150 rds	40 (26.6%)	6 (4.0%)

Note: Five skilled automatic weapon marksmen were used in this test series. One firer shot an additional 30 rounds at 900 meters to demonstrate the task differently for a group of observers.

At this point in the SAW test firing schedule, a second SAW was received at the USAIS during a visit by materiel and engineering specialists from the Armament Division of the U.S. Army Research and Development Command. The reported advantage of this weapon was that it was newer and that its cyclic rate of fire was closer to specifications than the single weapon used for testing until this time. It therefore should have been easier to control and it should also have been more accurate. Comparison firing of the two weapons was conducted at ranges of 200 meters through 600 meters to determine the accuracy of these assumptions. Test firers during this additional exercise included two world class service riflemen, with machinegun experience, from the Army Marksmanship Unit. A third firer in this testing segment was a researcher who had been a SAW test participant and a trained machinegunner. The firing scenario required test firers to fire 30 rounds from each of the two weapons at each range using the 2-3 round burst method for optimum accuracy. After each burst, the firers would re-lay on target, re-acquire their sight pictures, and fire another 2-3 round burst. This process was repeated until all 30 rounds were expended each time. Next, the size of the burst was increased to 5 rounds and each firer again fired 10 rounds at each range (2 bursts). Finally, in the third iteration of the test burst fire was increased to 10 rounds and each firer fired one 10 round burst. All firers reported that the lower firing rate of the new weapon allowed better control of the burst length during 2-3 round bursts; however, the accuracy of the new SAW when firing a 2-3 round burst did not appear to be significantly better than the old, comparatively loose and more extensively fired SAW (Table 14). Accuracy of the newer SAW appeared to be marginally better, however, when burst sizes were increased to 5 and then to 10 rounds (Table 14).

Table 14

Summary of SAW Burst Fire

Table of Fire For Each SAW	New SAW (001030)		Old SAW (001011)		Mean Performance	
	Rounds Captured(%)	Silhouette Hits(%)	Rounds Captured(%)	Silhouette Hits(%)	Rounds Captured(%)	Silhouette Hits(%)
200 Meters						
90 rds/2-3 rd burst	90 (100)	26 (28.88)	79 (87.78)	48 (53.33)	84.5 (93.89)	37.0 (41.11)
30 rds/5 rd burst	26 (86.67)	6 (20.0)	21 (70.0)	5 (16.67)	23.5 (78.33)	5.5 (18.33)
30 rds/10 rd burst	28 (93.33)	16 (53.33)	24 (80.0)	4 (13.33)	26.0 (86.67)	10.0 (33.33)
300 Meters						
90 rds/2-3 rd burst	75 (83.33)	7 (7.78)	70 (77.78)	20 (22.22)	72.5 (80.56)	13.5 (15.0)
30 rds/5 rd burst	27 (90.0)	11 (36.67)	12 (40.0)	3 (10.0)	19.5 (65.0)	7.0 (23.33)
30 rds/10 rd burst	27 (90.0)	9 (30.0)	10 (33.3)	3 (10.0)	18.5 (61.67)	6.0 (20.0)
400 Meters						
90 rds/2-3 rd burst	55 (61.11)	5 (5.56)	59 (65.56)	13 (14.44)	57.0 (63.33)	9.0 (10.0)
30 rds/5 rd burst	19 (63.33)	9 (30.0)	11 (36.67)	3 (10.0)	15.0 (50.0)	6.0 (20.0)
30 rds/10 rd burst	18 (60.0)	2 (6.67)	5 (16.67)	0	11.5 (38.33)	1.0 (3.33)
500 Meters						
90 rds/2-3 rd burst	53 (58.89)	15 (16.67)	29 (32.22)	7 (7.78)	41.0 (45.56)	11.0 (12.22)
30 rds/5 rd burst	19 (63.33)	4 (13.33)	13 (43.33)	2 (6.67)	16.0 (53.33)	3.0 (10.0)
30 rds/10 rd burst	12 (40.0)	4 (13.33)	5 (16.67)	0	8.5 (28.33)	2.0 (6.67)
600 Meters						
90 rds/2-3 rd burst	30 (33.33)	2 (2.22)	23 (25.56)	3 (3.33)	26.5 (29.44)	2.5 (2.78)
30 rds/5 rd burst	10 (33.33)	2 (6.67)	9 (30.0)	0	9.5 (31.57)	1.0 (3.33)
30 rds/10 rd burst	10 (33.33)	3 (10.0)	6 (20.0)	0	8.0 (26.67)	1.5 (5.0)

Information from the Armament Division of the Army Research and Development Command indicates that the rate of fire of SAWs currently being produced will increase with prolonged firing. This is due primarily to a defect in the design of the present buffer mechanism which causes it to weaken and thereby permit (after approximately 4000 rounds) a gradual increase in the rate of fire from approximately 800 rounds per minute, established during production, to a point in excess of 1,100 rounds per minute (Trifiletti, 1983). The impact of this condition is that the production model SAWs soon to be issued to units can be expected, within a short period, to perform similarly to the extensively fired weapon used during this training development. Consequently, the accuracy, rate of fire, controllability, and dispersion/beaten zone patterns attained with the primary test weapon are probably indicative of population weapon performance and therefore better define the upper limits of the standards soldiers should be expected to achieve until weapon modifications can be shown to contribute to better performance. It must be noted that the new weapon, as designed, could be tuned to a rate of fire of 700 rounds per minute but is not. This lower initial rate would not change the increasing rate phenomenon which occurs with moderately worn M249s.

Test firing to evaluate the appropriateness of the M16 rifle record fire range first required that test firers zero and fire the M16A1 rifle using established firing tables and conditions for qualification (Figure 7). This was done to establish a proficiency base against which SAW firing performance would be compared. Next, using a 2-3 round burst, test personnel fired the SAW using the same firing tables and conditions; however, ammunition for SAW firing was increased from 40 rounds for 40 target exposures to 120 rounds for 40 target exposures to permit a 3 round burst for each engagement.

Target data (number of hits in each target) for each firer was collected as each of the two firing scenarios were completed. When considering target kills, test personnel fired almost equally well with each weapon. However, rounds fired versus target hits indicate that the SAW achieved slightly less than 50 percent (48.0%) of rounds on target with decreasing numbers of hits occurring at ranges beyond 200 meters (Table 15). All three firers were disciplined enough to maintain burst sizes at 2-3 rounds, average, to engage all targets in the tables. It must be noted that this, as well as the majority of the test results, reflect a minimum expenditure of resources to obtain initial SAW performance data.

Firing performance was obviously a critical test issue in developing a training program for the U.S. Army's new SAW. Other issues were raised during the firing protocol by the fact that firers interacted with a new weapon and commented on its feel and capabilities. The one weapon available entered the testing phase to serve as the focus for the training program development and it was quickly made evident that the M249 did not match the expectations established for it by reports from the combat developers. If there had been reason to suspect that performance and human factors issues were still unresolved, and if additional advanced time were available, a different and more inclusive research program would have been initiated. The one SAW arrived at Fort Benning just in time to begin testing. Material and design shortcomings became evident during the series of tests. These issues and shortcomings will be incorporated in the Discussion section. The disparity

RECORD FIRE SCORECARD

NAME	SSAN	UNIT	DATE	RANGE	LANE

TABLE 1. FOXHOLE POSITION

RD	RANGE (M)	TIME (SEC)	HIT	MISS	NO FIRE
1	50	3			
2	200	6			
3	100	4			
4	150	5			
5	300	8			
6	250	7			
7	50	3			
8	200	6			
9	150	5			
10	250	7			
TOTAL					

TABLE 2. FOXHOLE POSITION

RD	RANGE (M)	TIME (SEC)	HIT	MISS	NO FIRE
1	100	8			
2	200				
3	150	10			
4	300				
5	100	9			
6	250				
7	200	6			
8	150	5			
9	50	6			
10	100				
TOTAL					

TABLE 3. PRONE POSITION

RD	RANGE (M)	TIME (SEC)	HIT	MISS	NO FIRE
1	100	5			
2	250	8			
3	150	6			
4	50	8			
5	200				
6	150	12			
7	200				
8	50	8			
9	150				
10	100	5			
TOTAL					

TABLE 4. PRONE POSITION

RD	RANGE (M)	TIME (SEC)	HIT	MISS	NO FIRE
1	150	6			
2	300	9			
3	100	10			
4	200				
5	150	12			
6	250				
7	100	8			
8	150				
9	200	9			
10	100				
TOTAL					

TABLE	HIT	MISS
1		
2		
3		
4		
TOTAL		

SCORER'S SIGNATURE

QUALIFICATION SCORES AND RATING:

POSSIBLE	40
EXPERT	36-40
SHARPSHOOTER	30-35
MARKSMAN	23-29
UNQUALIFIED	22-BELOW

FIRER'S QUALIFICATION SCORE________

OFFICER'S SIGNATURE

Figure 7. M16A1 Rifle Record Fire Range Firing Tables

between the anticipated and the actual capabilities of the SAW caused a more intensive inquiry into past developmental test results. The findings from these inquiries open the report Discussion section.

Table 15

M16A1 Rifle Record Fire Range

M16A1 Rifle Hits at Range

Firer	Target Range/Exposures 50/5	100/9	150/10	200/8	250/5	300/3	Total/40
1	5	8	10	3	1	0	27
2	5	9	10	6	5	1	36
3	5	8	7	8	4	0	32
Hits Exposures	15/15	25/27	27/30	17/24	10/15	1/9	

M249 SAW Hits at Range

Firer	Target Range/Exposures (Hits) 50/5	100/9	150/10	200/8	250/5	300/3	Total Rds Fired	Total Target Kill	Total Target Hit
1	5(10)	7(15)	4(9)	6(6)	3(6)	1(1)	120	26	(47)
2	5(10)	8(17)	9(22)	7(8)	4(5)	2(2)	120	35	(64)
3	5(10)	9(15)	9(18)	7(10)	4(8)	1(1)	120	35	(62)
Targets Hit (Total hits in target)	15(30)	24(47)	22(49)	20(24)	12(19)	4(4)	360		(173)

DISCUSSION

Historical

An examination of historical test data which addressed development, comparative evaluations of the candidate weapons, and eventual acceptance of the M249 had been made earlier. Access to the results of the Operational Test (OT-1A, 1979) which had been conducted by the U.S. Army Infantry Board, at Fort Benning, Georgia, December 1979, had been difficult to obtain. In contrast, developmental test data had been readily available (Niewenhous, 1982). The OT1A (1979) used test soldiers selected from a tenant unit as being representative of typical users. The test soldiers fired scenarios which matched four candidate SAWs with the M16A1 rifle (automatic mode), used to provide comparative baseline performance for the OT1A. Criteria for OT1A came from a draft version of the Joint Services Operational Requirement (JSOR) which initiated the SAW development and acquisition process. Unclassified versions of a test criteria for individual live fire exercises required the successful SAW candidate to:

(1) Provide a 30 percent probability of hitting a standing man-sized target (identified as a point target) at least once at ranges up to 600 meters within 4 seconds from the prone, bipod supported firing position.

(2) Engage four standing man-sized targets (area target) appearing simultaneously (spaced 10 meters apart to either flank of the base target), at ranges up to 600 meters within 22 seconds with a 30 percent probability of at least one hit in each of the four targets from the prone, bipod supported firing position.

(3) Provide a 30 percent probability of hitting each of three targets appearing simultaneously, at least once, (consisting of E type targets spaced 20 meters apart) at ranges up to 100 meters within 9 seconds from the standing, shoulder supported firing position.

In addition, all candidate systems were to be test fired at the following range bands:

(1) 0 - 150 meters
(2) 150 - 300 meters
(3) 300 - 450 meters
(4) 450 - 600 meters
(5) 600 - 800 meters
(6) 800 - 1000 meters

In an independent evaluation of Operational Test 1A (March 1980), the U.S. Army Operational Test and Evaluation Agency (OTEA) determined that none of the three performance criteria were met by any of the candidate systems or by the baseline M16. However, performance data did reveal that the M16 (AR) performed significantly better in all test categories than any of the other systems. A breakdown of performance data by range band clearly indicated that the probability of hit was high (45% to 65%) only at the lowest range band 0 -

150 meters. Beyond that point, hit probability quickly dropped to 20 percent and below. Test firing from the present research effort supports this finding (Table 14).

OTEA also conducted analyses which considered data from various target ranges, the firing positions used, and the types of targets engaged (point stationary, point moving, etc.). The scenario included three firing positions (prone, standing, and foxhole), point stationary and point moving targets, the three range bands from 0 to 450 meters, with the baseline M16A1 and all four competing weapons. Significant variable interactions were found to include: position with target, position with range, and target with range. Results indicated significant differences among weapons, ranges, and firing positions. Under this scenario the M16A1 (AR) was the most effective weapon, prone firing was shown to be the most effective firing position (while standing was clearly the worst), and it was much easier to fire at targets located between 0 and 150 meters than beyond that range. A longer range scenario with targets between 800 and 1000 meters resulted in hit performance that was essentially random, and that no variable--weapon, position, range, or target--proved to have significant influence on the final results. A direct comparison of competing weapons to one another, according to OTEA, revealed that when overall relative performance was considered, the baseline M16 (AR) was clearly the dominate weapon.

Test personnel were trained/directed to fire in bursts of 5 to 6 rounds each. However, the burst size used was typically half the desired 6 rounds across all weapons as was found to be beneficial with the present testing as well. Examination of hit probability as a function of burst size indicated relatively little fluctuation. Hit probability of all rounds of a burst as a function of burst size was not reported by OTEA. The highest hit probability achieved was with the M16A1 (AR), with a burst size of 2 (38.8%). Across all weapons, hit probabilities averaged 28.1 percent with a burst of 2 rounds and 24.3 percent with a burst of 3 rounds. For larger burst sizes, hit probabilities were reported as being lower. These performance findings have been supported by the present research effort (Table 14).

The exact test results remain classified, however, a final conclusion of OTEA's independent report suggested that no candidate system appeared to offer a significant operational advantage over the baseline M16A1 (AR). OTEA suggested that the established target hit performance criteria may have been too ambitious, and that the criteria should have been reviewed for possible change.

In January 1982, a Department of the Army approved JSOR was published. The performance criteria in this document differed from those in the draft JSOR. Exact criteria are classified, however, in general they were less demanding than those used for OT1A. One unclassified requirement was that the SAW should perform better than the M16A1 (AR) at 600 meters. It should be noted that this range has been clearly considered beyond the capability of the M16A1. Another requirement involved hit probability related to of an area target at 600 meters, and the last, hit probability for targets at 100 meters. Evaluation of the new criteria involved test personnel from the U.S. Marine Corps and was reported in Addendum 1 to the Final Report of Developmental Test

II (DT-II) of the XM249E1 Squad Automatic Weapon, conducted by TECOM (Niewenhous, 1982). In this report, approved JSOR criteria were claimed to have been met and that the SAW performed better than the M16A1 (AR). However, when the data were examined in terms of the draft JSOR criteria applied in OT1A and the less demanding criteria of DT-II, demonstrated weapon performances were not found to be significantly different.

The test report data summarized above were not readily available to ARI researchers until much of the experimentation and test firing of the research protocol had been completed. Interestingly, however, is the similarity of results and the fact that conclusions reached during the present testing for training program development tended to parallel those of both the original operational test results as well as those of the independent evaluation of that test by OTEA. In addition, conclusions reached by the Army Marksmanship Unit during its evaluation of SAW weapon physical characteristics and marksmanship capabilities provided further support for some of the previous findings (see Appendix C).

In designing an automatic rifle marksmanship training program for the SAW, an understanding of both the positive and negative operational characteristics of the SAW system was essential. The most systematic and comprehensive equipment research effort conducted to date focused on SAW developmental aspects (Niewenhous, 1982). In addition, less formal equipment analyses have been conducted during the present test firing program in three specific qualities to determine appropriate expectations for the SAW when placed in a troop unit for typical training and employment. These qualities are: reliability, accuracy, and design characteristics. These elements are critical to program development in that trainers must be made aware of the performance characteristics of the weapon they are training.

Weapon Considerations

Reliability

During all phases of test firing and training development, observations of weapon breakage and/or malfunctions were recorded. With the exception of two weapon failures relatively earlier in the test program, the SAW's firing reliability while using belted ammunition was extremely good. Several malfunctions occurred while firing ammunition from standard M16 magazines; however, these were determined to be magazine-related problems rather than weapon problems. Similar problems have been recorded as part of ARI-Benning research with the M16 rifle (Evans & Osborne, 1983).

After approximately 600 rounds had been fired through the weapon, the ejection port dust cover separated from the weapon, allowing the spring and retaining bar to drop into the receiver, causing the weapon to fail. After a few minutes to discover the source of the problem and to subsequently remove the loose parts from the weapon, the weapon again functioned with no apparent loss in efficiency.

After firing approximately 1,300 rounds in the test program, the cocking handle exited the forward opening of the slide track on the right side of the receiver and separated from the weapon. The retaining pin at the forward end of the cocking handle slide track had sheared at a point of 1/3 of its length, allowing the cocking handle to separate. The handle and the remaining portion of the pin were reassembled and firing continued, but after approximately 50 additional rounds the cocking handle began to bind in the slide track and severe friction was encountered at the forward position. Firing was discontinued and inspections revealed that the retaining pin dislodged during firing and a metal burr had been forged on the cocking handle by uneven pressure distribution from impact against the damaged pin. Proper repair was accomplished locally.

With the exception of the two minor weapon parts failures and the malfunctions while using magazines, approximately 7,000 rounds of belt-fed ammunition were fired under normal range conditions without a single jam or malfunction.

Accuracy Variables

Quick change barrel. The SAW is equipped with a quick change barrel. When locked into position, a small amount of movement around the rotational axis was found. When the SAW is held in a steady position, this barrel movement has the potential of moving the strike of a round as much as 1/2 to 3/4 inches when firing at a 10-meter target. Changing barrels indicated that the looseness on this weapon is in the chamber recepticle of the receiver and not in the barrel. It is not clear whether the test SAWs available are typical and were manufactured with faulty chambers, or that the looseness found is a result of fair wear and tear on the alloy receiver. Only one weapon was available for the majority of testing. A second weapon examined did not exhibit as much looseness. Some barrel/receiver movement, controlled by the direction of pressure on the bipod legs (pull rearward/push forward), contributed to the vertical displacement of shot groups during testing.

Rear sight on cover. The rear sight is mounted on the feed tray cover which has some noticeable horizontal and vertical play caused by its use of spring tension to retain it in place. Each time the rear cover is closed, the rear sights may be in a different position, causing significant horizontal and vertical changes in the placement of bullets.

Rear sight windage adjustment. The rear sight has about 4 1/2 clicks of uncontrolled movement which is equivalent to a 4-1/2 mil angle. It can be pushed to the left or right or it may move easily to either left or right during firing as a result of the action of the weapon. When normal windage adjustments were made from either the extreme right or left, the sight typically did not move any noticeable amount for the first two clicks, it moved a small amount on the third click, and made a complete move only on the fourth and subsequent clicks. This detracts considerably from the accuracy of the zeroing process and the subsequent consistent placement of bullets. Replacement of the windage adjustment screw with one milled by U.S. Army Marksmanship Unit gunsmiths was successful in substantially reducing the excess lateral movement of the sight.

Rear sight (peep) aperture. Doctrine calls for the SAW to be employed as a one-man automatic rifle, so the gunner must be able to observe and subsequently adjust his own fire. However, the very small peep aperture on the SAW (2mm) provides a very limited field of view. During the firing sequence of the SAW, gun vibration and flash from the muzzle completely obscured the gunners' view of the target and their opportunity for the observation of impacting rounds was minimal. A larger aperture would allow better viewing of the target area, and more importantly, better observation of impacting rounds. In the opinion of the test firers, the trade-off of observation versus sight alignment precision favors a large rear peep sight on an automatic weapon such as the SAW. Earlier comparison firings between the lightweight M60 machinegun and the standard M60, conducted by two experienced shooters who were SAW firers in the present test, indicated that the larger peep sight on the lightweight M60 was more usable in terms of target viewing and observation of impacting rounds. Initial indications are that a larger aperture on the SAW would enhance both training and combat effectiveness.

Design Characteristics

Bipod. The bipod has been designed to help prevent horizontal movement; however, because the flat spade of the feet are on the sides as opposed to front or rear, the SAW freely moves on a line with the target when supported by firm or frozen ground. In addition, extending the bipods to raise the front of the weapon appeared to contribute to degradation in firing accuracy during some tests. Stability of the firing platform appears to be reduced.

Butt stock and folding shoulder rest. The butt stock and folding shoulder rest are slick surfaced and very difficult for the firer to hold securely into the shoulder. The addition of a rough material on the surface of the butt stock appeared to improve firing performance according to firers. The folding shoulder rest on the SAW is a heavy wire spring device which easily moved past its upper limit when relatively moderate downward pressure was applied. This caused the weapon to slip from the firer's shoulder and while firing, go out of control placing the burst fired well over the top of the target. During test firing, this problem was overcome by the construction of a 1/4" soft metal band (by USAMU) which when positioned on the shoulder rest near its mounting point prevented the wire spring from spreading and moving beyond its upper limit.

The design of the weapon does not permit the firer to establish a good stockweld and comfortable holding position. The stock appears generally to be too short for adequate holding. The addition of a pad to the butt plate improved the firer's ability to hold the weapon. Finally, the short distance from the comb of the stock to the rear sight aperture makes it impossible to see through the sights at all the lower range settings while wearing the M17 protective mask.

Cyclic rate of fire. The SAW is designed to fire at a cyclic rate of 725 rounds per minute (normal setting) and 1,000 rounds per minute (maximum setting) with the latter being employed only when the weapon will not function properly in the normal position. It must be noted that the weapons are being tuned to fire at a rate of 800 rounds per minute or more at the normal gas setting. Rounds fired at the maximum setting on an otherwise properly functioning weapon tend to impact with wider dispersion and in more erratic patterns. Information from the Research and Development Command indicates that continued firing of the SAW in the normal mode (approximately 4,000 rounds) will result in the gradual increase of the cyclic rate to a point in excess of 1,100 rounds/minute. This is apparently due to a weakening of the buffer mechanism. A buffer block or new assembly that will maintain the normal low cyclic rate of fire appears critical to achieving the most controlled, and therefore effective, SAW performance for employment.

Ammunition. The SAW gunner should be able to depend on tracer observation to adjust much of his fire. However, the M856 tracer round, as it presently exists, ignites much later (140m) and burns with less brilliance than does the M196 round. The M856 tracer is particularly difficult to see at assault ranges (out to 150m), making the tracer almost useless at close range. From the gunner's position behind this gun, it has been reported that it is also extremely difficult to observe tracers at any range. The trajectory and muzzle flash of the weapon, coupled with the weak illumination of the trace, make the tracer an ineffective round. A more brilliant trace will not overcome the total scope of the problem for long-range target engagement; however, a trace which is bright and begins burning early would contribute to the gunner's ability to observe and adjust fire on close targets as well as enhance the assault fire capabilities of the weapon.

Range Considerations

Another major consideration during SAW testing and training development was training range needs. It was critical, where possible, to take advantage of range facilities currently available at the various US Army installations that could support SAW training with few modifications. The final phase of the SAW Test fire plan was directed specifically at evaluating this aspect of the SAW training resource requirements and the relevant impact on program development and implementation along with SAW fielding. The SAW, like other individual weapons, can be trained initially at short distance firing ranges (10 meter, 25 meter, etc.) in order to provide closely controlled immediate shot grouping and zeroing feedback to the firer. Since the SAW's point of aim and point of impact match ballistically at 10 meters when a 500 meter sight setting is used, and since this range configuration is frequently found on Army installations, a need does not exist to develop a new short distance range. However, the SAW in the role of an automatic rifle could benefit from a specific target configuration to support its unique role in the squad. Training at this range on a SAW specific target could better prepare the gunner to engage point and area targets as well as teach distribution of suppressive fire. Until the SAW 10 meter targets can be developed and published, the standard M60 machinegun 10-meter target is certainly suitable for all interim 10-meter training.

Transition range firing includes a series of live fire exercises which requires the gunner to apply all the fundamentals of marksmanship learned in preparatory marksmanship training and 10-meter range firing. It is on the transition range that the SAW gunner demonstrates his proficiency in automatic weapon marksmanship by engaging the types of targets he would be expected to engage in combat. Evaluation of several possible SAW transition ranges revealed that given ranges with appropriate limits and safety fans, most rifle and automatic weapon ranges currently available could be used or modified for use by the SAW.

The M16 Rifle Record Fire Qualification range appears to be appropriate for interim adaptation to SAW use. Test firers were able to exercise sufficient burst control to distribute the 120 rounds available during engagements to all 40 targets in the rifle qualification coure (see Table 15). Hit performances from these expert shooters were comparable to those obtained using the standard M16A1 rifle. It should be noted that all three firers had become quite familiar with the SAW by this point in the testing and may have performed better than the typical user. The M16A1 used was only zeroed and fired for qualification by each, not fired enough to provide peak performance though each was an expert shot. Given these caveats, and the limited number of firers available in the test, these performances may represent better than average firing when compared to typical users.

Test firing on the M60 machinegun transition range required test firers to engage targets (single "E" silhouette) at ranges from 400 meters to 800 meters. Test personnel fired approximately 600 rounds while varying the burst size from 2-3 rounds to 20 rounds. Targets were killable single "E" silhouettes remotely controlled from the firing line. Target hits were achieved only at the 400 meter and 500 meter ranges. Safety regulations prevented the collection of actual hit/miss data typically accomplished by counting hits in the target area. Test personnel reported they could not observe their rounds at the greater ranges and, consequently, were unable to adjust their fire. An attempt to adjust rounds on target by an observer using binoculars was not sufficient to overcome the low brilliance and wide dispersion patterns of tracer rounds. In general, test personnel felt that this range demonstrated potential for SAW training using its closer range targets; however, targets at closer ranges (100, 200, and 300 meters) would be required to enhance suitability. The performance data obtained during this subtest, however, was insufficient to develop positive recommendations.

Current Interim Training Development

Implementation

The SAW individual and collective training plan currently approved by the SAW proponent, the USAIS, proposes institutional familiarization training for infantrymen with qualification training and record fire being conducted in the unit (United States Army Infantry School, 1983). Other personnel are expected to receive only familiarization training in order to have the ability to place the SAW into operation and then to apply basic marksmanship skills with very little practice. An approved USAIS SAW training task list is presented in Table 16.

Table 16

SAW Training Tasks

Training task	Status of standards and conditions	Training environment
Perform operator maintenance on SAW and ammunition	Established and use will validate	Institution/unit
Load, reduce stoppage, and clear SAW	Established and use will validate	Institution/unit
Prepare a range card*	Identical to M60 machinegun	Unit, if at all appropriate
Zero the SAW at 10 meters	To be established	Institution/unit
Qualify with the SAW	To be established	Unit
Field zero the SAW	Research will validate proposed standards	Institution/unit
Zero the AN/PVS-4 to the SAW at 25 meters	To be established	Unit
Place into operation the AN/PVS-4 and SAW	To be established	Institution/unit
Mount/dismount an AN/PVS-4 to the SAW	Established, but included in other tasks	Institution/unit
Lay the SAW using field expedients	Established and complete	Institution/unit
Fire the SAW for familiarization	Established and use will validate	Institution/unit
Perform assault fire techniques	To be established	Institution/unit
Fire the SAW while wearing protective gear	To be established	Unit

*Since the SAW is not expected to be employed in the tripod mode, preparation of a sector sketch should be taught in lieu of preparation of a range card.

Training Issues

Many of the tasks in Table 16 require extensive firing tests to establish and validate appropriate training conditions and performance standards for the initial entry soldier. Delays in the receipt of production weapons prevented this phase of training development to begin until the 1st Quarter FY84 (November, 1983). In addition, only limited quantities of ammunition (SS109/L110 not production M855/M856) were available at the same time. Finally, acceleration of the development effort to provide training materials that would accommodate 3rd Quarter FY84 fielding of the SAW required the development of a program of instruction for immediate implementation using minimum resources and existing ranges.

Zeroing

Past research has shown that the development of an appropriate zeroing procedure for the SAW would be a primary topic of the present research (Smith, Thompson, Evans, Osborne, Maxey, & Morey, 1980). Based upon trajectory data, a battlesight zero distance is established which maximizes hit probability for high priority targets throughout the expected range of employment. In order to maximize hit probability, the zero trajectory closely follows the weapon's line of sight for the greatest possible distance. This is critical in establishing a range limit for grazing fire with machineguns as well. Once a battlesight zero distance and its associated trajectory curve have been selected, a procedure is developed to obtain an approximate zero at a reduced range to save training range time and enhance immediate feedback (e.g., 10 or 25 meters).

In the case of the SAW, however, the problem with and objective of, establishing a weapon zero was somewhat different. Because the sighting system is incremented for range, the need to establish a "battlesight zero" is subordinate to zeroing the weapon for point of aim/point of impact. Once the firer is assured that rounds will impact on point of aim, theoretically, the weapon is zeroed for any range increment on the sight. Test firing from a rigid bench rest at a 10 meter target indicated that rounds would impact at the point of aim with a 600 meter sight setting on the weapon. This, however, did not hold true during firing by personnel at the same 10 meter range. It was determined that a 500 meter sight setting provided a more accurate point of aim/point of impact for zeroing.

After determining the proper range setting for 10 meter zeroing, the next question concerned procedure. The SAW is to be employed using burst fire, however, attempts made to zero the SAW with various burst sizes produced groups that were too large and erratically dispersed to determine appropriate centers and to make subsequent corrections.

The chief problems encountered were determining the sequence of impacting rounds and maintaining a tight shot group to measure. Single shot fire at this range, therefore, proved to be a more effective zeroing method. Once the weapon had been properly zeroed using single shot fire, creating a beaten zone on and around the point of aim was then more easily achieved. Single shot fire also permitted development of measurably tight groups which eased the zeroing process as well.

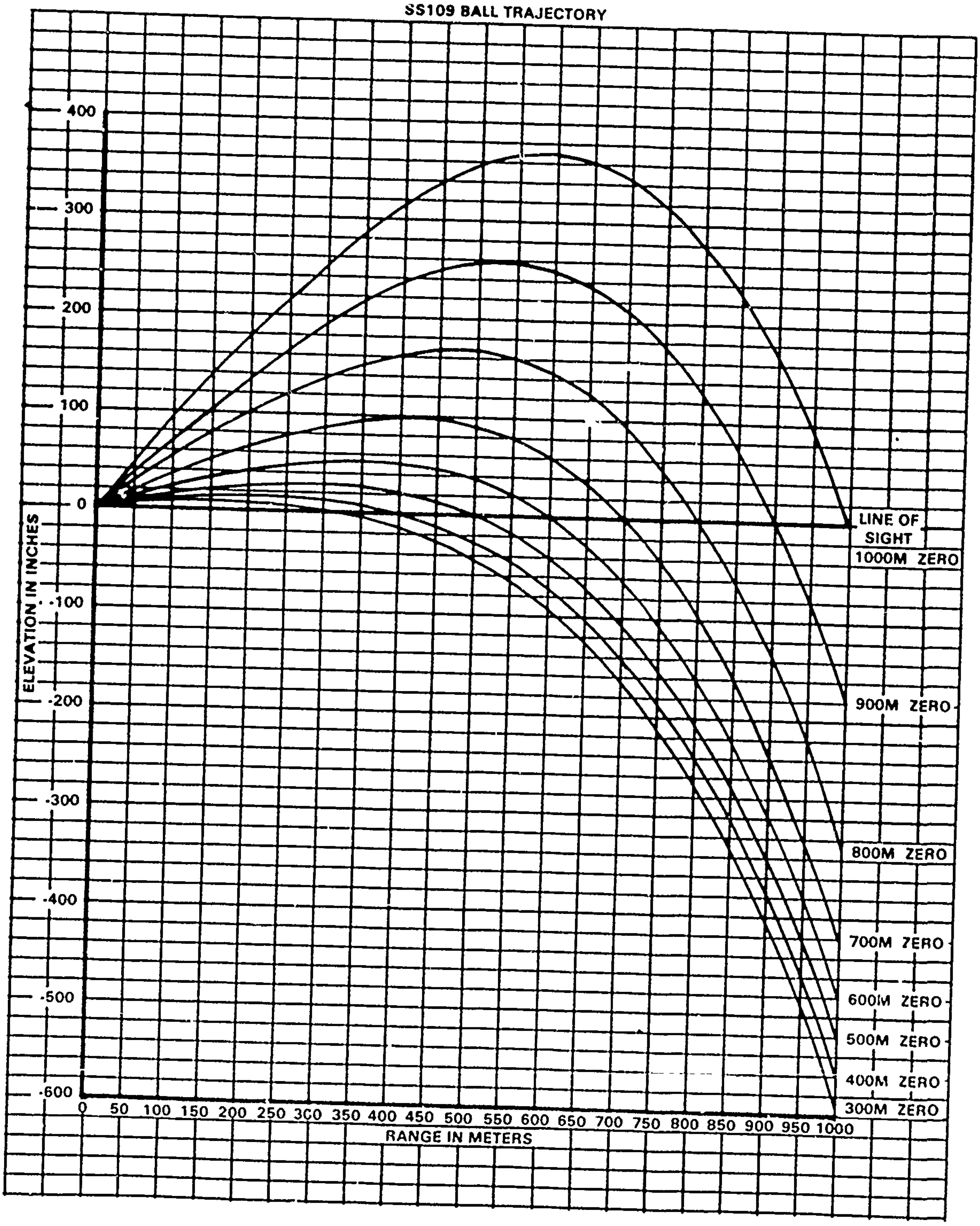
Determination of a "battlesight zero" or, more accurately, a range setting that would maximize hit probability throughout the expected range of employment required analysis of trajectory and maximum ordinate data. Since trajectory information for all ranges and ammunition has not been completed by the appropriate ballistics laboratory, the most accurate data available is that which is depicted in Figures 8 and 9. Infantry doctrine states that an effective battlesight setting for automatic fire is one that will provide fire that is approximately parallel to the ground so that the maximum ordinate does not exceed one meter of elevation above the ground anywhere along the trajectory flight path (FM 101-5-1, p. 1-56). This is grazing fire and an examination of Figure 8 reveals that a 500 meter sight setting is the maximum range that satisfies this criteria.

Accuracy

Ammunition

To date, M16A1 rifle marksmanship training has focused on engaging targets at 300 meters and less. One purpose in acquiring the SAW was to extend both the range and volume of accurate fire that can be delivered by squads in combat. However, the ammunition to be used in the SAW (M855/M856) may not be available in useful quantities in the near term. Ballistic data have indicated that the use of M193 ball ammunition will not substantially alter SAW firing performance out to ranges of 600 meters (Niewenhous, 1982). Figure 10 illustrates that the theoretical ballistic difference between M193 and SS109/L110 ammunition (which should meet production M855/M856 standards) does not exceed one milliradian of elevation difference until rounds reach 600 meters, and if the maximum practical range for the squad automatic weapon and targets is extended, this comparability of ammunition has been expected to permit consistent training procedures to 600 meters.

The current test firing of limited quantities of M193 ammunition produced comparable performance to SS109 ammunition only out to the 300 meter range. Beyond 300 meters, M193 round performance became so erratic and widely dispersed in burst fire that it was impossible to capture all the groups on a 6′ x 6′ target panel. Subsequent discussions with Ammunition Branch, U.S. Army Research and Development Command (Trifiletti, 1983) indicated that performance tests have shown that variances in ballistics and projectile stability have caused the M193 round to begin "floating" after 200 meters of flight. This "floating" action alters the trajectory of the round in such a manner that the accuracy of fire beyond 200 meters is unpredictable and extremely difficult to achieve. Also noted during M193/SS109 test firing is the different zero required for each of the two rounds. The initial variances noticed during 10 meter firing was thought to be caused by shooter instability, however, longer range firing using the same zero for each round produced otherwise unexplained divergence between shot group locations. Field zeroing at range (100 - 300 meters) and refiring at 10 meters confirmed that the M193 ammunition consistently required a sight setting difference of one and one-half milliradians of right lateral (windage) adjustment when compared with SS109/M855 ammunition.



SAW ASSUMPTIONS: Muzzle Velocity 3036 fps
Bore to Front Sight 2.0 inches
Bullet Weight 62.0 grains
Standard Metro.

Figure 8. SS109 Ball Trajectory

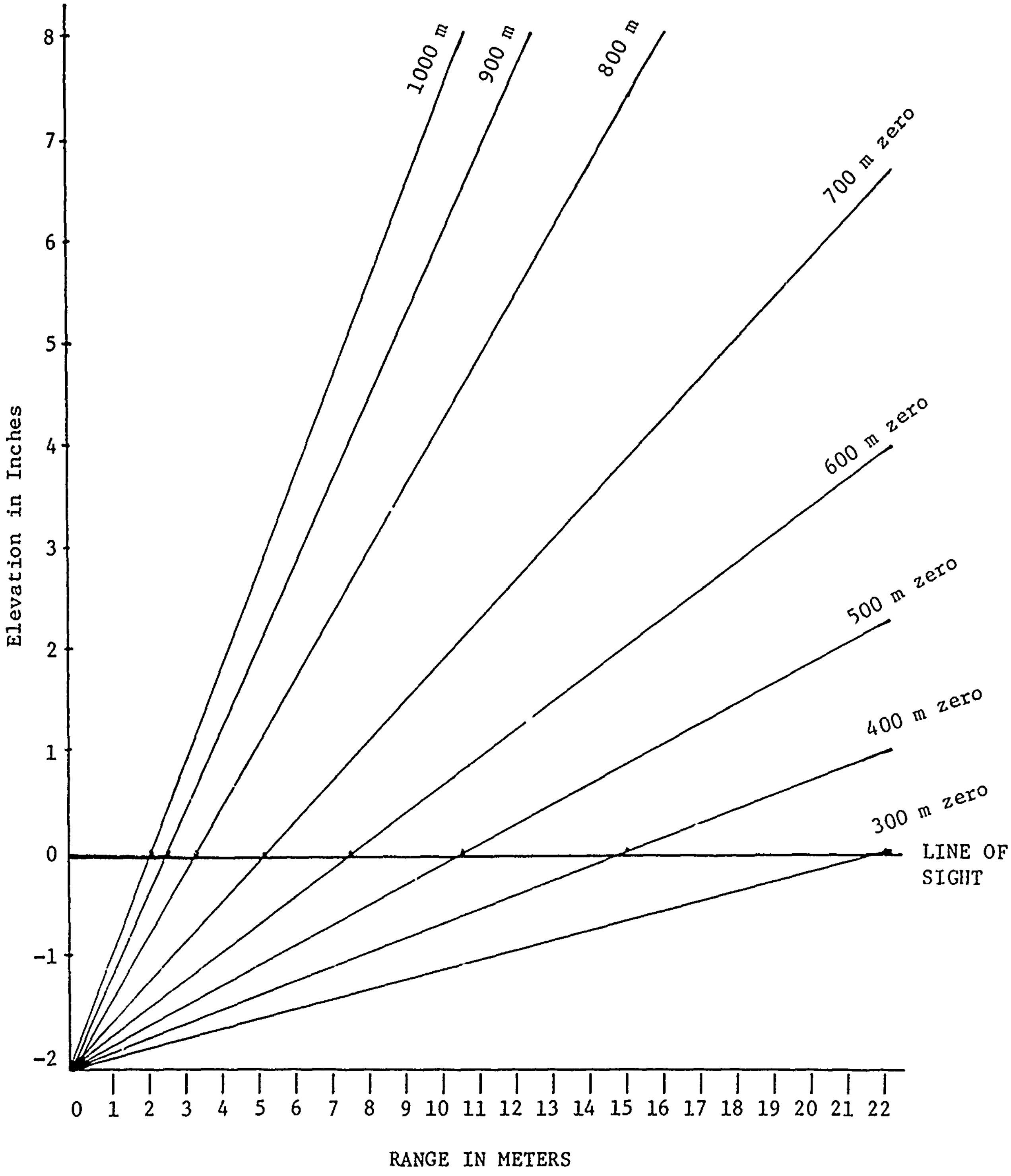


Figure 9. SAW Trajectory: SS109 Ball

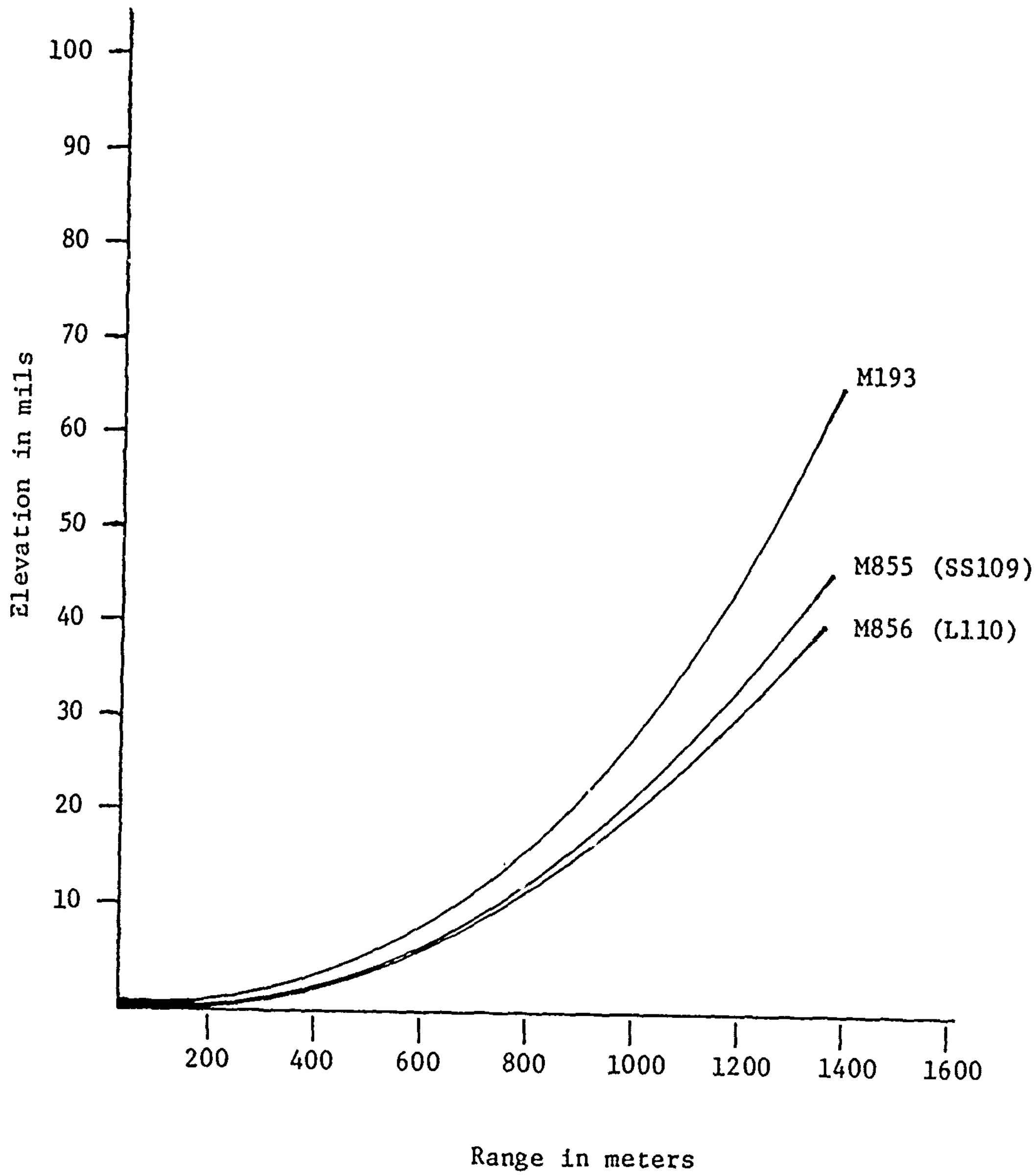


Figure 10. A ballistic comparison of M193 and XM855/XM856 (SS109/L110) ammunition.

Burst Size

One critical factor which affects SAW employment and was measured in an extensive small arms suppression study was burst size (Combat Developments Experimentation Command, 1976). It was found that the actual burst size had little effect on suppression, but along with proximity to the target intervals between bursts did. Other studies and tests have been conducted to determine the optimum burst size of both automatic rifles and general purpose machineguns. In a service test conducted by the U.S. Army Infantry Board, optimum burst sizes differed somewhat between machinegun and automatic rifles (Roberts et al., 1965). Burst sizes in excess of three rounds were relatively ineffective, even with bipod mounts, using automatic rifles (5.56mm to 7.62mm) and carbines. Further, it was found that the M60 machinegun bursts of six rounds provided optimum effectiveness. Although there was not a reported significant difference in hit capability between machinegun bursts of three and six rounds, the highest combination of hit capability, hit probability, and percentage of actual hits was obtained with six-round machinegun bursts (Roberts et al., 1965). Larger bursts, 10 or 15 rounds, did not provide corresponding increases in target coverage.

Current testing to determine the optimum burst size for SAW employment involved experimentation with 2 to 3, 5, and 10 round bursts. Figures 11 and 12 illustrate percentages of hits achieved for each range when engaging an "E" silhouette on a 6′ x 6′ witness target frame. Clearly, the 2 to 3 round burst was the most effective in terms of accuracy (rounds captured/silhouette hits) and hit probability at range. The proximity of the burst to the target equates to effective suppression as well. The primary problem encountered during SAW burst fire testing was that the shooter lost control very early in the burst (could not hold the weapon on target), perhaps after two or three rounds which does not provide adequate target coverage. For any given firing scenario, the SAW′s high cyclic rate of operation (700 (800)-1100 rds per minute), vibration, and muzzle blast all contribute to target obscuration or they at least hinder target observation. Consequently, close targets (out to ranges of 300 or 400 meters) can be hit by engaging as one would with a rifle, but the SAW′s erratic, widely dispersed fire cannot be controlled for the extended burst to develop the beaten zone necessary to hit distant targets. After extended practice and familiarity with the SAW, a gunner is more likely to increase his skill at engaging greater range targets with possibly larger size bursts. However, for the novice firer the most effective weapon familiarization and/or qualification will be achieved using the more observable, more easily controlled 2 to 3 round burst.

Range Firing

The SAW was developed for the primary purpose of replacing the two M16A1s carried by the automatic riflemen in the rifle squad. Part of the rationale in support of the SAW was that threat squads carried a light machinegun which was effective to ranges of 800 meters. The requirements document stated that the SAW was to be effective against point and area targets at 600 meter ranges and area targets at the 800 meter range by achieving a 30 percent probability of hit on each target. As reported by antecedent test reports (OT1A 1979, Independent Evaluation, OTEA 1980, and DT-II, 1982) neither the SAW nor any other candidate weapon met the established test criteria. The highest probability of hit (45%) achieved by all weapon systems was at ranges of 150 meters or less.

Based on the results of previous tests, concern arose regarding the actual maximum effective range of the SAW when employed as an individual weapon. To address this issue, the SAW was test fired using ordinary bipod support at ranges from 100 to 900 meters. The results illustrated in Figures 11 and 12 reveal that probability of hit was less than 50 percent (41.11%) at 200 meters and decreased rather quickly to less than 30 percent at 300 meters. These measures were obtained using two to three round bursts fired by three expert marksman while performing side-by-side gun comparisons.

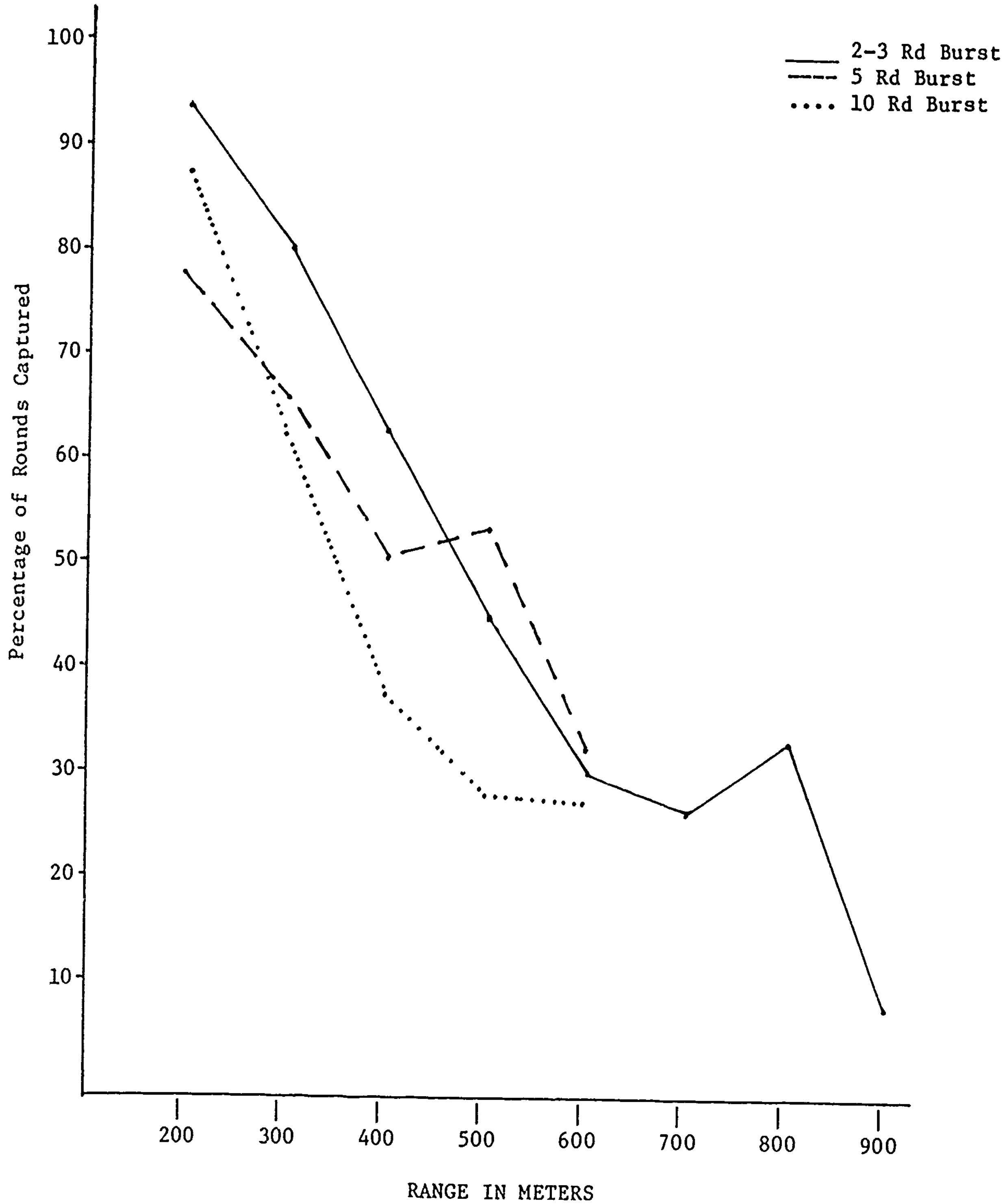
Training Program Development

Based on previous test data, the emerging results of current testing, and the anticipated further development of ammunition and weapon modifications, the SAW proponent (USAIS, Fort Benning) decided that interim training programs for familiarization and qualification of Squad Automatic Weapon gunners would be most appropriate to accompany the SAW to the field. This interim guidance was to take the form of a Field Circular (FC 23-10, March 1984) which would assist commanders and their staffs in developing immediately useful unit training programs. It was anticipated that as modifications and improvements could be incorporated into the ammunition and weapons, revisions to the training programs would be made.

With this guidance, ARI/Litton Mellonics test and research personnel developed the field circular 23-10, Basic Marksmanship Training - Bipod-Mounted Squad Automatic Weapon (March, 1984). Major concepts and considerations incorporated into the field circular are outlined below:

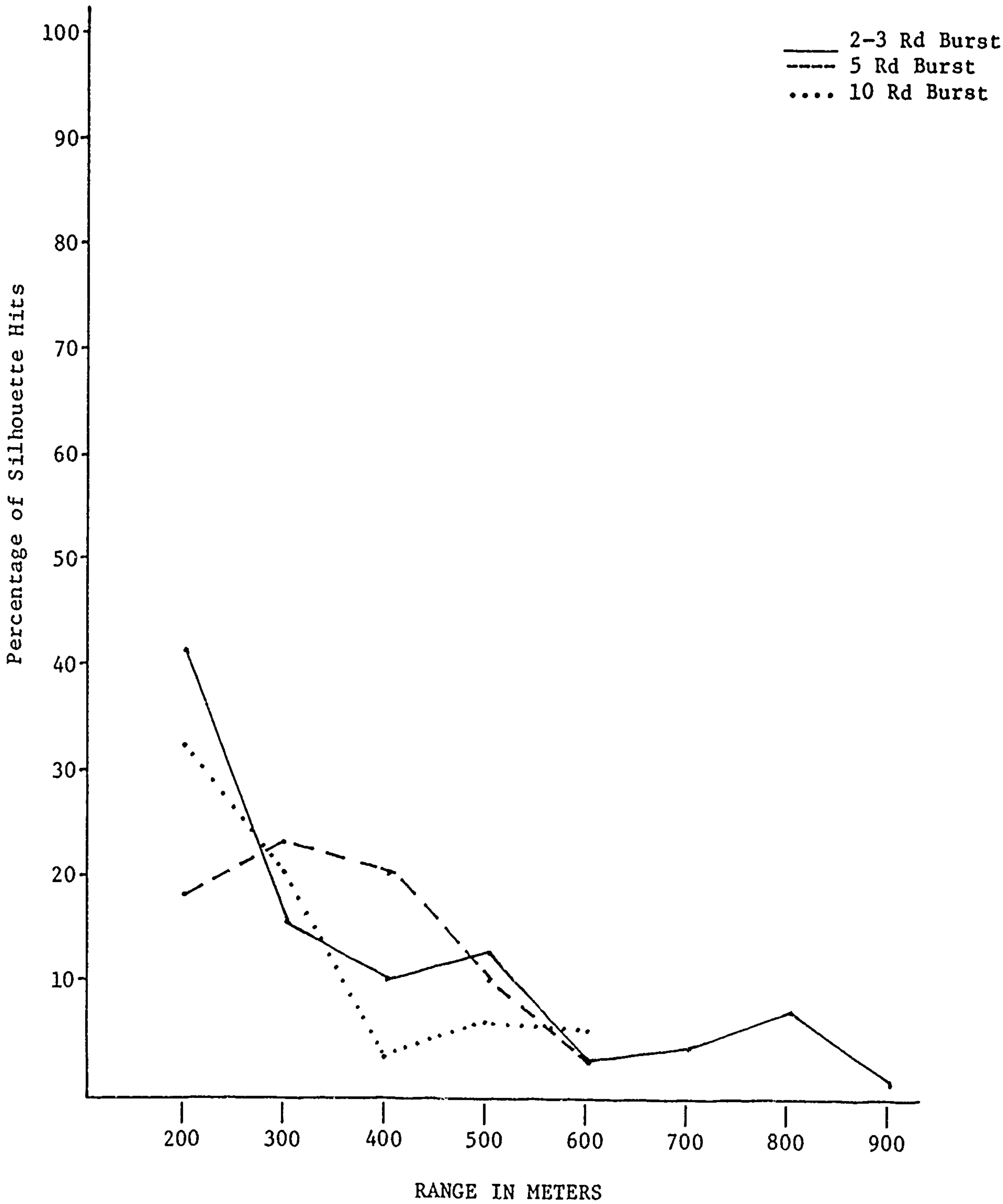
- The maximum range for SAW familiarization and qualification firing does not exceed 400 meters.
- All training is to be accomplished using existing equipment, targets, and range facilities.
- Ammunition allocations are limited to essential amounts and include use of either SS109, or M193 if the new ammunition is not available.
- The prescribed burst size is a 2-3 round burst.
- Initial zeroing is accomplished using single shot fire to develop groups.
- Assault fire and night fire techniques will be developed and published as improved tracer ammunition becomes available.

As published, Field Circular 23-10 introduces the scope, purpose and objectives of SAW training. This is followed by a discussion of the weapon's characteristics to include weapon functioning and ammunition performance.



Note: Data presented from Tables 13 and 14.

Figure 11. Burst Fire Performance Rounds Captured on 6′ X 6′ Panel.



Note: Data presented from Tables 13 and 14.

Figure 12. Burst Fire Performance Silhouette Hits

Next, the SAW's characteristics of fire and preparatory marksmanship training are presented. The final section is devoted to detailed explanations of range firing to include qualification and familiarization firing. The appendices of the circular contain the detailed training programs for both qualification and familiarization as guidance to using units. In addition, a dry fire performance examination is provided along with proposed ammunition allocations and interim firing tables. The final appendix item is a composite record score card depicting firing subtables, target scenarios, and time requirements. Table 17 presents the table of contents of the field circular while Figure 13 presents an overview of the interim training programs.

The circular was delivered to the proponent for the addition of graphics, formatting, and formal staffing in February and March 1984. In April 1984 it was approved for publication and is currently being reproduced and distributed to units as they receive production weapons.

Constraints in Program Development

The development and implementation efforts described in this report have been largely pursued with consideration for the limited existing training resources in the overall education system of the US Army. In a training environment with unlimited resources, it is expected that SAW marksmanship instruction could be greatly improved. During the process of developing SAW marksmanship training programs the results of a system wide evaluation of training constraints suggest that the potential effectiveness of these programs is limited. In particular, it is believed that the following factors have or will limit the potential effectiveness of SAW marksmanship training:

1. The SAW was scheduled for fielding in early 1984. Due in part to the non-availability of test weapons and ammunition, the training materials which must precede or at least accompany the fielding of a new weapon system had not been developed. The training package (interim) development required the accelerated testing effort and delivery of training programs to be accomplished in a four (4) month period. This period began with the first actual observation, by training program researchers and developers of the SAW.

2. The performance results obtained during the majority of this training development were based on the availability of only one M-249 SAW (Number 001011). A second weapon (Number 001030), received late in the research effort, was immediately integrated into the remaining test firing scenarios; however, this small representation of the potential weapon population can only detract from the potential validity of the test findings.

3. Efforts to meet early expectations for the weapon and to establish realistic and obtainable standards at the maximum allowable engagement range were prevented by weapon system design deficiencies as well as by poor ammunition (tracer) performance. Considerable effort was expended in the attempts to document and overcome the discrepancies between expected and achieved performance which ultimately resulted in training criteria that are significantly less than the weapon's earlier reported capabilities.

Table 17

Table of Contents of the

BASIC MARKSMANSHIP TRAINING BIPOD-MOUNTED SQUAD AUTOMATIC WEAPON

Field Circular 23-10, March 1984

Table 17 Continued

- Dry Fire Exercises
  - Firing Sequence
  - Sight Setting and Sight Changes
- Dry Fire Proficiency Exam
- Remedial Training

SECTION V - RANGE FIRING

- General
- 10 Meter Firing
  - Grouping and Zeroing
  - Point Targets
  - Area Targets
- Transition Range
  - M-16 Rifle Record Fire Range
  - M-60 Machinegun Transition Range
  - Rifle Field Fire Range
- Range Configurations

SECTION VI - QUALIFICATION FIRING

- 10 Meter Practice Firing
- 10 Meter Qualification Firing
- Remedial Training
- Transition Range Practice Firing
- Transition Range Qualification Firing
- Target Scoring

SECTION VII - FAMILIARIZATION TRAINING

- Concept
- 10 Meter Firing
- Transition Firing

SECTION VIII - NIGHT FIRE TECHNIQUES (TBP)

SECTION IX - ASSAULT FIRE TECHNIQUES (TBP)

APPENDIX A QUALIFICATION TRAINING PROGRAM
B FAMILIARIZATION TRAINING PROGRAM
C PROFICIENCY (PERFORMANCE) EXAMINATION
D INTERIM FIRING TABLES
E SCORECARD
F AIMING PADDLE

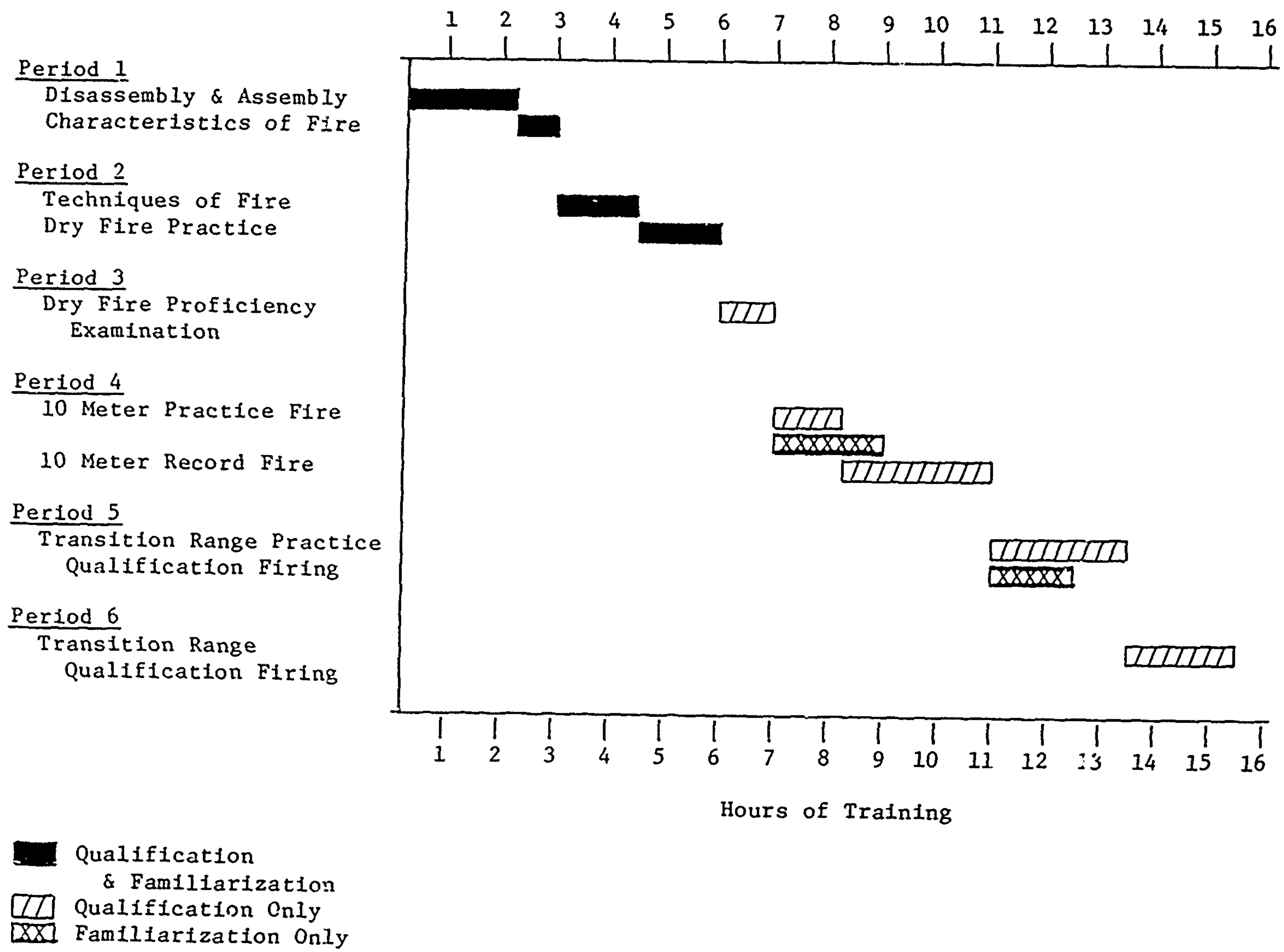


Figure 13. SAW Qualification & Familiarization Training Programs Overview

4. Available resources for training development were limited. While a total of approximately 7,000 rounds of ammunition were expended for training development purposes, limited availability of SS109/L110 ammunition prevented further testing and evaluation. The ammunition available may not match later production M855/M856 ammunition either. In addition, while it is believed that the proposed ammunition allocation levels are adequate for initial SAW training purposes, they are considered the minimum essential and reductions beyond these levels are likely to decrease substantially the effectiveness of SAW marksmanship programs. Nevertheless, the interim training procedures developed for the SAW do maximize the learning opportunities obtainabl through the systematic use of each round.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The first and most telling general conclusion of this testing and training development program is that the squad automatic weapon, in its present configuration, does not perform to its expected capability and, therefore, the average gunner will not be capable of placing accurate volumes of fire on targets at extended ranges.

The SAW has several design deficiencies which make distant targets (greater than 400 meters) difficult to successfully engage. The SAW is difficult to control for the extended bursts of fire which are necessary to hit more distant targets. This tends to suggest that the SAW cannot be employed efficiently and effectively at greater ranges. In fact, however, the SAW can engage targets at greater range, but test firing has shown that the skill to successfully hit targets at long range (500 - 800 meters) with accurate short bursts or to hit targets at 300 - 400 meters with longer bursts would take considerable practice to develop.

Automatic fire is employed in bursts so as to develop a beaten zone with an adequate number of rounds to provide target area coverage. The size of the burst should logically depend on the nature of the target. However, test firing of the SAW indicates that burst sizes in excess of three rounds (5 and 10 round bursts) were relatively ineffective and did not provide corresponding increases in target coverage. With the SAW the most effective beaten zone is created by firing rapid two to three round bursts with short intervals between bursts for reacquiring and relaying on the target. Theoretically, this will provide the most effective form of suppressive fire as well.

The XM856 tracer round in flight and the strike of all the 5.56mm projectiles tested are difficult to sense and almost impossible to observe from behind the sights. Gunners will have difficulty observing and making subsequent adjustments of fire and will therefore need some assistance when field zeroing to determine adjusted points of aim. Since the SAW is not a crew-served weapon, this will require support from a team leader or fellow rifleman during zeroing.

The most consistently effective position for firing the bipod-mounted SAW is the M6C machinegun position published in FM 23-67 (1964). In terms of stability and the gunner's ability to control the action (movement) of the weapon, the M60 position provides the best body alignment, a steadier grip, and the least dispersion of rounds in a group.

The SAW should be zeroed at a range of 10 meters with a 500 meter range setting on the sight. During the conduct of zeroing procedures, the use of single shot fire to develop groups provides the most useful diagnostic feedback to the new gunner as well as the most accurate and reliable weapon zero.

SAW transition training can be conducted on a rifle record fire range (TRAINFIRE Qualification), a rifle field fire range, or a machinegun transition range. On all ranges, close to moderate distance targets (100 - 400 meters) should be used. Targets at ranges greater than 300 meters should be "double E" silhouette or larger.

Both the M855 and M193 ammunition may be used while conducting training with the SAW. An important consideration, however, is not to mix different types of ammunition during live-fire exercises. Variances in ballistics and projectile stability result in differences in zeroing adjustments and down range dispersion patterns. In addition, these differences limit the training use of M193 ammunition to ranges of 300 meters and less.

Recommendations

In an attempt to overcome training development problems and employment constraints described earlier, research in the following four areas is appropriate: training program validation (both familiarization and qualification), assault fire techniques, night fire, and testing of anticipated product improvements.

Training Program Validation

The majority of test firing during this training development effort was conducted by expert military and civilian automatic weapon marksmen and for some (few) exercises, novice shooters were used briefly. Unfortunately, this cross section of shooting experience was limited in its ability to evaluate training developments by the fact that only one SAW was available for test firing. In addition, extensive evaluation of the recommended training programs with initial entry soldiers prior to fielding of the weapon was prevented by time and resource constraints. As a consequence, the tasks to be trained, instructional procedures used, and training program recommendations require further evaluation and validation to determine optimum effectiveness for combat performance.

Assault Fire Techniques

Assault fire is that fire delivered by maneuvering forces as they traverse the last 100 - 150 meters to reach the objective area. It is normally delivered while walking rapidly and firing from the underarm or hip positions. To engage targets effectively using assault fire techniques, the gunner relies primarily on tracer rounds and, to a lesser extent, impacting rounds when observing and adjusting his fire. The SS109 tracer round, which was available during testing, ignites at a range of 140 meters or greater and burns with less brilliance than the other 5.56mm tracer round (M196). The SS109 tracer is extremely difficult to see at assault ranges, making the tracer useless at close range (less than 100 m). New tracer ammunition (M856) for the SAW which is supposed to ignite approximately 20 meters from the weapon and burn with increased brilliance has been developed and is in production. After the anticipated date of receipt (1st quarter FY85), evaluation is necessary to determine the ability of the new tracer to overcome problems encountered by the individual gunner when observing and adjusting fire and to then determine optimum assault fire techniques.

Night Firing

The night vision sight mount for the SAW is still in the engineering phase of development. Consequently, night firing techniques have not been completely developed. It is anticipated that the SAW will initially employ the AN/PVS-4 night firing sight having the M60 machinegun sight reticle, and that zeroing and firing techniques for both guns will be similar. Although this similarity is expected to facilitate learning transfer and ease the training burden, night firing techniques and procedures for the SAW require more comprehensive evaluation.

Test Product Improvements

Discussions and working conferences with representatives of the research and development command (ARADCOM) have resulted in the identification of several areas where product improvement are appropriate. Depending on final evaluation, many of these recommended improvements will be incorporated into later production weapons. As improved weapons are fielded, testing and evaluation of improved systems will be required to determine their effects as they relate to weapon capabilities and performance as well as possible revisions t o current training programs. These will include:

- Sight modifications to improve tolerances,
- Improved buffer assembly to control cyclic rate of fire,
- Modifications to the bipod feet to improve stability, and
- Modifications to the shoulder-rest assembly.

Potential Areas for Further Study

Location of Miss and Hit Equipment (LOMAH)

Only a small portion of the current testing used LOMAH equipment which is designed to provide precise location information regarding bullets either hitting or missing a target as well as a replay of the sequence of each bullet in a burst. Further development of this type of equipment will make it feasible to initiate systematic research on weapons training that has previously been difficult, impractical, or impossible to conduct. Examples include research in the areas of rifle marksmanship, automatic fire, night fire, firing with the protective mask, and moving target engagement. In addition, the improved performance feedback that could be provided to soldiers via LOMAH equipment has the potential to significantly increase the effectiveness of current SAW marksmanship training programs.

Low-Cost Simulation

Given the constraints of limited time, ammunition, instructors and facilities in current marksmanship programs, the low-cost simulation of SAW marksmanship tasks may have the potential to be used as an effective adjunct to existing training. The Multi-purpose Arcade Combat Simulator (MACS) is a relatively inexpensive training/simulation system being developed at the Fort Benning Field Unit of the U.S. Army Research Institute (Schroeder, 1982). Its lower cost in relation to other weapon simulators rests with its incorporation of less expensive technology. In the current prototype configuration of MACS, hardware features include a microcomputer, two disk drives, a video monitor, and a light pen modified with corrective lenses and attached to a dummy M16A1 rifle with an electronic trigger switch. Software has been developed for both the M16A1 rifle and M72 LAW weapon systems. Major design features of current MACS software include automatic zeroing, realistic targets and backgrounds, an exercise incorporating the effects of wind and gravity in firing at stationary targets, auditory and visual feedback related to the location of hits and misses, moving target exercises, and programs to diagnose errors in marksmanship fundamentals. Future MACS development efforts will include the establishment of a recommended hardware configuration, the improvement and extension of existing software, an analysis of the applicability of the MACS concept to other weapon systems, and an evaluation of the effectiveness of MACS in rifle marksmanship training. The potential of MACS to provide voluntary opportunities for practicing marksmanship skills in an entertaining and compelling manner will also be explored.

Videotaped Instructor Training

Videotape instruction for SAW marksmanship doctrine, unit training, qualification standards, and operator tasks to include preventive maintenance is currently under development at the United States Army Infantry School (USAIS). A logical extension of this teaching medium would be the development of videotapes for SAW mark... nship instructor training. These videotapes would focus on the demonstration of coaching techniques for instructing soldiers in the fundamentals of SAW marksmanship. Together with the field circular (FC 23-10, 1984), these videotapes could be used as an exportable training package for marksmanship instructors at Army Training Centers and in Army units.

Performance Sustainment Research

Research is needed in the area of SAW marksmanship performance sustainment, particularly since the quantity and types of training necessary for the development and long-term retention of marksmanship skills remain unknown. Despite the inherent difficulties associated with conducting retention research of this type (Thompson, Morey, Smith, & Osborne, 1981), the information it could provide might enable better decisions to be made regarding such matters as the establishment of appropriate performance standards and the optimal scheduling of SAW marksmanship training activities.

REFERENCES

Combat Developments Experimentation Command. (1976), August). Small arms suppression evaluation, Vol. 1, final report (USACDEC Experiment FC 029E). Fort Ord, CA: U.S. Army Combat Developments Experimentation Command. (DTIS No. ADB 013210).

Evans, K. L., & Osborne, A. D. (1983). The Development and Implementation of Basic, Advanced, and Unit M16A1 Rifle Marksmanship Training Programs. ARI Research Product in preparation.

Evans, K. L., & Schendel, J. D. (1984). Development of an advanced rifle marksmanship program of instruction. ARI Research Product 84-16.

Field Manual 23-8. (1974, April). M14 and M14A1 Rifles and Rifle Marksmanship, Washington, DC: HQ, Department of the Army.

Field Manual 23-12. (1967, October). Technique of Fire of the Rifle Squad and Tactical Application. Washington, DC: HQ, Department of the Army.

Field Manual 23-15. (1961, May). Browning Automatic Rifle Cal. .30 M1918A2. Washington, DC: HQ, Department of the Army.

Field Manual 23-16. (1965, June). Automatic Rifle Marksmanship. Washington, DC: HQ, Department of the Army.

Field Manual 23-67. (1964, October). Machinegun 7.62mm, M60. Washington, DC: HQ, Department of the Army.

Lucker, H. A. (1982, May 14). SAW test firing. Unpublished raw data (available from Thompson, T. J., ARI Fort Benning Field Unit, U.S. Army Research Institute for the Behavioral and Social Sciences).

Niewenhous, G. B. (1982, August). Final report development test II (POT-G) of XM249E1 squad automatic weapon (SAW). (Report No. APG-MT-5693). Aberdeen Proving Ground, MD: Materiel Testing Directorate.

Roberts, E. D., Ball, R. E., Dishman, B. E., Duryea, L. C., Jr., Knauer, W. M., & LeBada, B. G. (1965, December). Small arms weapons systems (SAWS) (USAIB Project No. 3110). Fort Benning, GA: U.S. Army Infantry Board.

Schroeder, J. E. (1984). A Multipurpose Arcade Combat Simulator (MACS). U.S. Army Research Institute, Technical Report 629.

Smith, S., Thompson, T. J., Evans, K. L., Osborne, A. D., Maxey, J. L., & Morey, J. C. (1980, June). Effects of down range feedback and the ARI zeroing target in rifle marksmanship training (Research Report 1251). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Technical Manual 9-1005-201-10. (1983, September). Operator's Manual, Machinegun, 5.56mm, M249. Washington, DC: HQ Department of the Army.

Thompson, T. J., Evans, K. L., & Lucker, H. A. (1983). Training Effectiveness Analysis: M60 Machinegun and Squad Automatic Weapon. ARI Research Product in preparation.

Thompson, T. J., Morey, J. C., Smith, S. & Osborne, A. D. (1981). Basic Rifle Marksmanship Skill Retention: Implications for Retention Research (Research Report 1326). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences.

Trifiletti, R. A. (1983, December). On-site visit to Fort Benning, GA, Fire Control and Small Caliber Weapon Systems Laboratory (representative of the U.S. Army Armament Research and Development Command, Dover, NJ).

United States Army Infantry Board. (1979, December). Operational Test IA of XM249E1 Squad Automatic Weapon (SAW). Fort Benning, GA.

U.S. Army Operational Test and Evaluation Agency. (1980, March). Independent Evaluations of the XM249E1 Squad Automatic Weapon (SAW) Operational Test IA. Falls Church, VA.

APPENDIX A

SAW TEST FIRE PLAN

SUBTEST 1 - Preliminary Familiarization and Preparatory Marksmanship Training

Time/Location: 2 days - Bldg 75

Purpose: To train/familiarize test firers with the overall test program and the mechanical characteristics of the SAW to include its operations and functioning. Instructions will be provided on the proper sight picture and steady holding through burst fire. Firing positions will be analyzed in a dry-fire mode to determine compatibility with different size soldiers. Firing positions will also be analyzed for stability in holding, suitability for prolonged firing, simplicity, and compatibility with standard sights and the AN/PVS-4 night sight. Analyze the sling carry position and its impact on assault fire. Testing and analysis will be conducted with combat equipment to include SAW ammunition pouches, MOPP, and cold weather gear.

Data Collection: Physical characteristics of each test firer. Test firer in each position and his ability to obtain a sight picture, stabilize the weapon, maintain the positino and ease of operating the weapon.

SUBTEST 2 - Holding Techniques - 10-Meter Firing

Time/Location: 2 days - Farnsworth Range

Purpose: Validation of potential firing positions and holding techniques identified in Subtest 1. Identify shot group and beaten zone sizes obtainable by typical firers. Further refine targets for instructional firing. Conduct firing on test landscape target.

Data Collection: Collect all targets. Measure and analyze shot groups and beaten zone for size, consistency in size and location.

SUBTEST 3 - Beaten Zone and Zeroing - 10-Meter Firing

Time/Location: 2 days - Farnsworth Range

Purpose: To determine best method of zeroing the SAW using either single shot fire or burst fire method. Additional subtest during this firing is to determine if mean point of impact is the same for single shot and burst fire. Determine criteria for effective zero. Further refine instructional target for zeroing purposes. Determine number of rounds required for zeroing. Determine amount movement in strike of a round on a 10-meter target with a one click change in either windage or elevation.

SUBTEST 3 - Continued

Data Collection: Collect all targets. Measure and analyze shots, shot groups, and beaten zones for size, consistency in size and location.

SUBTEST 4 - Beaten Zone and Trajectory

Time/Location: 2 days - Farnsworth Range

Purpose: To determine compatibility between 10-meter zero and long range targets. To determine beaten zone sizes and hit capability of typical test firers. Determine optimum battlesight zero.

Data Collection: Firing conducted on Prone "D" silhouette target (6′x6′) on known distance (KD) range. Location of target hit data will be reordered on a scaled plot sheet for measurement and analysis.

SUBTEST 5 - M16 Record Fire Range

Time/Location: 2 days - Simpson Range

Purpose: To determine firer′s ability to observe his own fire. Determine hit capability of targets at 50 to 300 meters by typical firers. Determine suitability of a standard rifle record fire range to be used for SAW qualification. If suitable, establish qualification standards. Determine suitability of minimum range setting (300 meters) for targets at ranges less than 300 meters.

Data Collection: All targets will have witness paper attached. Targets will be scored from firing line as hit or miss. The number of hits will be recorded from witness paper. This procedure will be followed for targets in prone position and 20 targets in foxhole position.

SUBTEST 7 - Assault Fire

Time/Location: 1 day - Simpson Range

Purpose: Evaluate three positions (shoulder, underarm, and hip) for assault fire using two techniques (burst and cyclic) of fire. Based on time to first hit and number of hits determine the best position(s) and technique(s) of fire for targets at 50 to 100 meters.

Data Collection: Fire on Double "E" targets at 50 and 100 meters. Targets will have witness paper for recording number of hits. Times will be recorded manually.

SUBTEST 8 - Moving Targets

Time/Location: 2 days - Malone 18

Purpose: Evaluate two techniques (conventional lead with burst fire and ambush technique with long burst) of engaging moving targets. Determine most successful technique.

Data Collection: Fire on killable moving IRETS targets at ranges of 75 and 185 meters. Record hit/miss data and scorers observations of size and location of beaten zone.

SUBTEST 9 - Night Fire Without Scope

Time/Location: 1 day - Malone 4

Purpose: To determine firing technique for engaging targets at night with standard sights. Determine firer's ability to observe his own fire. Determine suitability of 5-round burst for night fire.

Data Collection: Fire on Malone 4 with moonglow targets. Record hit/miss data. Record scorers and firers observations as to suitability of using conventional rifle method with the SAW engaging targets at night. Determine suitability of altnernate techniques.

SUBTEST 10 - Night Fire With AN/PVS-4 Scope

Time/Location: 2 days - Malone 14 and Maertens Range

Purpose: Determine zeroing procedures. Determine hit capability at night. Determine techniques for observation and adjustment of fire for both close and long range when using AN/PVS-4. Identify characteristics peculiar to the SAW when firing using AN/PVS-4.

Data Collection: Fire zeroing procedure on standard 25-meter zero-in target. Fire to determine if 25-meter zero is valid at full range capability of scope. Record hit or miss data by range.

NOTE: During all firing subtests observations of weapon breakage and/or malfunction will be recorded.

SAW TEST FIRE PLAN AMMUNITION REQUIREMENTS

SUBTEST	DESCRIPTION	ROUNDS PER FIRER	TOTAL ROUNDS REQUIRED
1	Preliminary Familiarization and Preparatory Marksmanship Training	0	0
2	Holding Techniques (10 meters)		
	M60 position	30	180
	Russian position	30	180
	Alternate as may be required	30	180
3	Beaten Zone and Zeroing (10 meters)		
	Zeroing procedures	50	300
	Landscape target	100	600
4	Beaten Zone and Trajectory		
	100 meters	25	150
	200 meters	25	150
	300 meters	25	150
	400 meters	25	150
	500 meters	25	150
5	Record Fire (M16 Range)		
	1 burst of 5 rounds per exposure (40 exposures) [foxhole (100 rounds); prone (100 rounds)]	200	1,200
	Alternate sighting/observation techniques	200	1,200
6	Transition Range		
	8 targets (2 burst of 5 rounds) [per target (fire twice)]	160	960
	Alternate sighting/observation	160	960
7	Assault Fire [2 targets (50m and 100m)]		
	Positions: Shoulders, Underarm, Hip		
	Burst technique: 3 bursts of 10 rounds each per target	180	1,080
	Cyclic technique: 30-round burst per target	180	1,080

SAW TEST FIRE PLAN (Continued)

SUBTEST	DESCRIPTION	ROUNDS PER FIRER	TOTAL ROUNDS REQUIRED
8	Moving Targets [Foxhole position (2 targets)]		
	Lead technique		
	10 (5-round bursts per target)	100	600
	Ambush technique		
	10 (15-round bursts per target)	150	900
9	Night Fire Without Scope	100	600
10	Night Fire With Scope		
	Zeroing procedures	30	300
	Target engagement (2 targets)	50	300
	Night Fire (Long Range)		
	Hit capability		
	Observation and adjustment of fire techniques		
	100 meters	50	300
	200 meters	50	300
	300 meters	50	300
	400 meters	50	300
	500 meters	50	300
	TOTAL	2,125	12,750

APPENDIX B
Table B-1

Bench Rest
300 Meter Field Zero - 5 Shot Groups (Fired Single Shot)
SS109 Ammunition

Group	EH	EV	ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE	
1	9	17	18	R14	-26	(correction 6 up - 3 left)
2	10	20	20	R12	+ 9	(correction 2 down - 2 left)
3	19	16	24	0	- 7	
4	17	15	17.5	R 6	- 6	
5	10	31	32	0	+16	
6	16	20	21	L14	+17	
7	7	16	17	L20	+17	
8	24	20	31	L17	+ 5	
9	13	41	41	0	+ 1	
10	18	23	25.5	0	0	
11	25	14	28	R19	0	
12	13	11	16	0	0	
13	18	18	21.5	R10	+11	
14	24	22	25.5	R 9	+13	(correction 1 down)
15	6.5	14	15	R 8	0	
MEAN =	15.3	19.87	23.53			
(cm)	(38.86)	(50.47)	(59.77)			

NOTE: 1. All measurements in inches
2. EH = Extreme horizontal
3. EV = Extreme vertical
4. ES = Extreme spread

Table B-2
Bench Rest
300 Meter Field Zero - 5 Shot Burst Fire
SS109 Ammunition

Group	EH	EV	ES	Location of Group [illegible] from Point of Aim: Wind	Location of Group [illegible] from Point of Aim: ELE
1	38	15	39	0	+22
2	37	20	42	0	+23
3	23	15	23	L18	+19
4	17	10	20	R 6	+14
MEAN =	28.75	15.0	31		
(cm)	(73.03)	(38.1)	(78.74)		

NOTE: 1. All measurements in inches
2. EH = Extreme horizontal
3. EV = Extreme vertical
4. ES = Extreme spread

Table B-3

10 Meter Bench Rest - Single Shot and Burst Fire
SS109, L110, M193 Ammunition

Group	Range Setting	EH	EV	ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE	Type Fire	Ammunition
1	300	.72	.50	1.1	L .25	-1	5 rd single shot	SS109
2	300	1.0	.73	1.2	R .50	- .75	5 rd single shot	SS109
3	300	.25	.54	.98	0	-1.5	5 rd single shot	SS109
4	400	.50	.23	.99	R .25	- .50	5 rd single shot	SS109
5	400	.76	.25	1.23	0	- .75	5 rd single shot	SS109
6	500	.75	.28	1.48	0	- .50	5 rd single shot	SS109
7	500	.52	.48	.77	L .25	- .50	5 rd single shot	SS109
8	600	.51	.49	1.0	0	0	5 rd single shot	SS109
9	600	.78	.50	1.20	R .50	0	5 rd single shot	SS109
10	700	1.18	.74	1.25	R .25	+ .75	5 rd single shot	SS109
11	700	.73	.25	.98	L .25	+ .75	5 rd single shot	SS109
12	800	.50	.50	1.5	0	+1.5	5 rd single shot	SS109
13	800	.75	.24	1.0	0	+1.5	5 rd single shot	SS109
14	900	.50	.50	1.47	0	+3.5	5 rd single shot	SS109
15	900	.26	.75	.71	0	+2.75	5 rd single shot	SS109
16	1000	.70	.50	1.30	0	+5.0	5 rd single shot	SS109
17	1000	1.47	.77	1.58	L .50	+4.75	5 rd single shot	SS109
18	600	1.0	.75	1.23	L .50	+ .50	5 rd burst	SS109
19	600	.85	.50	1.22	R .25	0	5 rd burst	SS109
20	600	.76	1.0	2.1	L .50	+ .25	5 rd burst	SS109
21	600	.75	.50	.53	L .50	+ .25	5 rd burst	SS109
22	600	.75	.51	1.25	R .50	+ .50	10 rd burst	SS109
23	600	1.0	.75	1.25	L .50	+ .50	20 rd burst	SS109
24	300	.58	.60	1.25	0	-1.75	5 rd single shot	L110

Table B-3 (Continued)

10 Meter Bench Rest - Single Shot and Burst Fire
SS109, L110, M193 Ammunition

Group	Range Setting	EH	EV	ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE	Type Fire	Ammunition
25	300	.50	1.20	2.50	0	-1.75	5 rd single shot	L110
26	400	.51	1.23	1.75	0	- .75	5 rd single shot	L110
27	400	.50	.26	1.5	R .25	-1.0	5 rd single shot	L110
28	500	.97	1.0	1.76	L .25	- .75	5 rd single shot	L110
29	500	.53	.75	1.52	R .25	-1.0	5 rd single shot	L110
30	600	.26	1.25	1.76	0	+ .50	5 rd single shot	L110
31	600	.50	1.15	1.65	0	- .25	5 rd single shot	L110
32	600	.60	.50	1.24	L .50	+ .50	5 rd burst	L110
33	600	.35	.60	.75	L .25	+ .50	5 rd burst	L110
34	600	.50	.55	1.25	L .25	0	5 rd burst	L110
35	600	.52	.50	.75	L .25	+ .25	5 rd burst	L110
36	600	.60	.50	1.26	L .75	+ .50	5 rd single shot	M193
37	600	.50	.25	1.25	L .50	- .25	5 rd single shot	M193
38	600	.25	.25	.85	L .50	- .25	5 rd single shot	M193
39	600	.60	.50	1.35	L .25	- .55	5 rd single shot	M193
40	600	.52	.51	1.0	0	- .50	5 rd single shot	M193
41	600	.35	.76	1.1	L .50	0	5 rd single shot	M193
42	600	.52	.50	1.35	L .50	0	5 rd burst	M193
43	600	.25	.60	1.0	L .50	+ .50	5 rd burst	M193
44	600	.50	.25	1.1	L .50	+ .25	5 rd burst	M193
45	600	.85	.25	.98	L .50	+ .25	5 rd burst	M193
46	600	.30	.28	1.2	L .50	0	5 rd burst	M193
47	600	.53	.71	1.4	L1.0	+ .50	10 rd burst	M193

Table B-4

100 Meter Bench Rest - Single Shot and Burst Fire
SS109 and M193 Ammunition

Group	Range Setting	EH	EV	ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE	Type Fire	Ammunition
1	300	2.5	5.0	8.[illegible]	L7.0	-1.5	5 rd single shot	M193
2	300	3.0	4.5	11.0	L4.0	-1.0	5 rd single shot	M193
3	300	2.5	4.0	8.0	L3.0	-3.0	5 rd single shot	M193
4	300	2.75	1.75	4.75	L3.75	-2.5	5 rd single shot	M193
5	300	3.75	4.5	9.0	R4.25	-1.5	5 rd single shot	M193
6	300	4.0	5.5	10.75	R5.75	+1.0	5 rd single shot	M193
7	300	5.75	4.0	11.25	R1.0	+5.0	5 rd burst	M193
8	300	5.5	4.25	11.0	L1.0	+5.75	5 rd burst	M193
9	300	4.75	3.0	8.25	R1.25	+5.25	5 rd burst	M193
10	300	3.0	3.50	7.75	R2.0	+3.75	10 rd burst	M193
11	300	5.25	3.75	11.75	0	+3.75	10 rd burst	M193
12	300	3.75	2.25	7.75	R4.25	-2.75	5 rd single shot	SS109
13	300	3.25	3.0	8.0	R6.0	-1.75	5 rd single shot	SS109
14	300	4.50	3.2	7.75	L2.5	-3.75	5 rd single shot	SS109

Table B-5

100 Meter Bench Rest - Single Shot and Burst Fire
SS109 Ammunition

Group	Range Setting	EH	EV	ES	Location of Group Center from Point of Aim: Wind	ELE	Type Fire	Ammunition
1	300	3.75	4.0	7.0	L2.0	-1.5	5 rd single shot	SS109
2	300	3.75	4.75	8.75	L2.25	+4.5	5 rd single shot	SS109
3	300	2.75	6.75	14.25	L2.25	+2.75	5 rd single shot	SS109
4	300	3.25	6.25	11.50	L1.0	+3.5	5 rd single shot	SS109
5	300	6.0	7.75	14.25	R .50	+6.75	5 rd burst	SS109
6	300	5.0	6.0	10.75	L4.25	+8.75	5 rd burst	SS109
7	300	6.75	3.75	8.75	L3.0	+9.50	5 rd burst	SS109
8	300	2.75	4.0	7.75	R5.25	+11.0	5 rd burst	SS109
9	300	6.0	5.25	12.75	L3.25	+9.25	10 rd burst	SS109
10	300	4.5	6.0	10.75	0	+3.0	20 rd burst	SS109
11	300	6.75	7.75	17.25	L5.75	+6.75	20 rd burst	SS109
12	300	7.25	5.25	13.5	L2.75	+12.25	20 rd burst	SS109

Table B-6

300 Meter Bench Rest - No Re-lay on Point-of-Aim
SS109 Ammunition

Group	EH	EV	ES	Location of Group Center from Point of Aim: Wind	ELE	Type Fire
1	28	36	43	0	0	5 rd single shot
2	24	19.5	25	L17	-12	5 rd single shot
3	11	25	25.5	L 8	-16	5 rd single shot
4	11	12	14	L12	-10	5 rd single shot
5	17	17	20	L 9	-15	5 rd single shot
6	21.5	12	21.5	L 5	+ 7	5 rd burst
7	11	23	23	L 4	+ 7	5 rd burst
8	19	26	30	L23	+15	5 rd burst
9	21	20	26	L16	+12	5 rd burst
10	23	43	43	0	0	5 rd burst
11	36	20	36	L14	-10	5 rd burst
12	23	34	34	L 5	- 5	5 rd burst
13	26	12	26	L11	- 6	5 rd burst
14	38	38	38	L11	+14	10 rd burst
15	31	24	31	L13	+ 8	10 rd burst
16	32	17	32	L 6	- 6	10 rd burst

Table B-7

10 and 100 Meter Bench Rest Burst Fire
(High Gas Setting)
SS109 Ammunition

10 Meters

Group	Range Setting	EH	EV	ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE	Type Fire	Ammunition
1	600	.52	.75	1.26	L .75	− .50	5 rd burst	SS109
2	600	.75	.60	1.24	L .25	− .50	5 rd burst	SS109
3	600	.60	.50	1.1	L1.0	+ .50	5 rd burst	SS109
4	600	.25	.25	1.0	L .50	+ .50	5 rd burst	SS109
5	600	.53	.50	1.4	L .50	+ .50	10 rd burst	SS109
6	600	1.25	1.20	2.4	L .75	+ .75	10 rd burst	SS109
7	600	1.1	.98	2.3	L .25	+ .50	20 rd burst	SS109

100 Meters

Group	Range Setting	EH	EV	ES	Wind	ELE	Type Fire	Ammunition
8	300	5.0	6.75	13.25	L3.0	0	5 rd burst	SS109
9	300	8.5	7.5	15.25	L2.5	-2.75	5 rd burst	SS109
10	300	8.75	2.5	15.50	L1.75	+9.0	5 rd burst	SS109
11	300	9.75	1.75	15.75	L4.0	+8.25	5 rd burst	SS109

Table B-8

10 Meter M60 Firing Position
SS109 Ammunition

Range Setting = 500 Meters

Single Shot (5 rds)

Group	Horizontal ES	Vertical ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE
1	.52	1.27	0	- .30
2	.60	1.72	R.48	+1.0
3	.80	1.40	R.25	- .40
4	.62	1.0	L.30	+ .45
5	.76	.80	0	- .10
6	.79	1.25	0	0
7	.98	.85	0	- .50
8	1.0	.87	0	+ .48
Burst Fire (5 rds)				
9	2.1	.51	L.77	0
10	.62	1.86	L.50	0
11	1.23	1.70	0	- .20
12	1.75	1.80	L.25	0
13	.90	1.0	0	- .35
14	1.50	1.35	0	- .49
15	1.0	.50	0	+ .50
16	2.30	1.22	L.50	+ .80
17	1.90	1.15	L.30	+1.0
18	1.70	1.98	L.65	0
19	2.62	1.12	L.80	+.65
20	2.57	1.98	L1.54	+.73
21	2.98	1.37	L1.62	+.62

Table B-8 (Continued)

10 Meter M60 Firing Position
SS109 Ammunition

Range Setting = 500 Meters

Burst Fire (5 rds)

Group	Horizontal ES	Vertical ES	Location of Group Center from Point of Aim: Wind	ELE
22	1.85	.62	L1.10	+1.20
23	1.40	1.75	L1.10	+1.10
24	2.12	1.23	R .10	0
25	1.52	2.06	0	+ .68
26	1.95	1.50	R .25	- .30
27	1.75	.63	L .30	+ .72
28	1.80	.62	L .90	+ .61
29	1.25	1.21	L .60	+ .23
30	1.08	1.95	0	+1.21

Table B-9

10 Meter M60 Firing Position
M193 Ammunition

Group	Range Setting	Horizontal ES	Vertical ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE
Single Shot					
1	600	1.2	.25	0	+ .75
2	600	.75	.73	L .22	+ .51
3	500	.60	.52	0	+ .25
4	500	.77	.75	0	+ .25
5	500	.73	.28	0	0
6	500	1.1	.85	0	- .35
7	500	.75	1.0	0	0
Burst Fire					
8	600	2.1	.75	0	+ .51
9	600	.75	1.4	L .72	+ .25
10	600	.60	.75	L1.0	+1.24
11	600	1.50	.71	L1.35	+1.25
12	600	1.52	.75	0	+1.2
13	600	1.25	.73	L .47	+1.25
14	600	1.23	.50	L .50	+1.78
15	600	.85	1.22	L .51	+1.0
16	600	1.75	.75	L .25	+ .98
17	600	1.35	.98	R .23	+1.0
18	600	2.0	1.5	L1.0	+1.46
19	600	1.2	.85	L .76	+ .75
20	600	.75	1.75	0	+ .57
21	600	1.20	2.4	R1.1	- .25
22	600	1.0	1.0	0	+1.16

Table B-9 (Continued)

10 Meter M60 Firing Position
M193 Ammunition

Burst Fire Group	Range Setting	Horizontal ES	Vertical ES	Location of Group Center from Point of Aim: Wind	ELE
23	600	1.22	1.47	0	+1.0
24	600	.75	.50	L1.25	+1.1
25	600	1.5	2.13	L1.43	+1.25
26	600	2.1	1.75	L1.25	+ .97
27	600	1.0	.96	L1.22	+ .75
28	600	1.23	1.0	L .75	+1.1
29	600	1.25	1.1	L1.30	+1.0
30	500	1.25	1.24	0	+1.2
31	500	1.1	3.25	L1.35	+2.0
32	500	1.25	.54	0	- .85
33	500	2.2	.75	0	0
34	500	1.75	.71	R .25	0
35	500	3.65	1.75	L .60	- .25
36	500	2.75	.97	L1.5	0
37	500	.98	.75	L1.45	+ .35
38	500	.99	.98	L1.0	+ .50
39	500	1.15	1.75	L .85	-.45
40	500	1.35	.65	L1.0	+ .25
41	500	.50	.50	R .35	+ .26
42	500	1.43	.78	L .50	+ .25
43	500	.75	.50	L .26	+ .35
44	500	.72	1.15	L .25	+ .50
45	500	1.25	.75	L .45	+ .52

Table B-9 (Continued)

10 Meter M60 Firing Position
M193 Ammunition

Burst Fire				Location of Group Center from Point of Aim	
Group	Range Setting	Horizontal ES	Vertical ES	Wind	ELE
46	500	1.6	.45	L .25	+ .75
47	500	1.55	1.25	L .52	+ .98
48	500	1.25	.35	L1.75	+1.0
49	500	2.15	1.75	L .72	+ .50
50	500	.75	.47	0	0
51	500	1.35	.75	L1.1	+ .28

Table B-10

10 Meter Bipod Holding Techniques

Range Setting = 500 m

Group	Horizontal ES	Vertical ES	Location of Group Center from Point of Aim: Wind	ELE	Condition
1	1.4	.50	R1.15	- .75	M60 Hold SS109
2	1.75	.78	R .75	- .55	
3	.60	.50	R1.1	-1.1	
4	1.75	1.30	R1.0	0	
5	1.20	2.0	R1.35	0	
6	1.25	1.40	R1.25	- .25	
7	1.40	1.50	R1.20	0	
8	2.25	1.26	R .50	0	
9	1.60	1.25	R1.40	0	
10	1.0	1.1	R .51	0	
11	.52	1.75	R .74	- .25	
12	.75	1.85	0	+ .50	
	$\overline{X}$ = 1.289" (3.275)	1.306" (3.321)	R .913" (2.317)	-0.2 (0.508)	
1	3.65	2.25	L2.15	+1.5	Two Hands on Grip M193
2	.75	2.15	L1.0	+ .53	
3	1.47	2.0	L1.85	+ .25	
4	1.5	2.40	L1.75	+ .60	
5	2.1	2.75	L .71	+1.0	
6	1.25	2.1	L1.50	+ .57	
7	1.35	2.0	L1.1	+1.25	
8	1.0	2.65	L1.5	+1.2	
	$\overline{X}$ = 1.634" (4.150)	2.288" (5.810)	L1.445" (3.670)	+0.863" (2.191)	

Table B-11

SAW TEST FIRE
SS109 and M193 Ammunition
100 - 600 Meter 5 Round Burst Fire

Group	Range	EH	EV	ES	Location of Group Center from Point of Aim	
			M193		Wind	ELE
1	100	18	20	25	L12	+17
2	100	9	7	11	0	+11
3	100	7	7	8.5	0	+10
4	100	17	14	21	L10	+18
		(100 m Groups = 4 Attempted - 4 Captured)				
5	200	41	15	41.5	0	-14
6	200	34	6	34	R11	+ 6
7	200	5	21	21	R17	0
8	200	22	23	30	R21	0
9	200	23	19	23.5	L26	+21
10	200	4	17.5	17.5	R10.5	+ 4
11	200	27	26	36	R 7	0
12	200	27	15	27	L15	+16
		(200 m Groups = 8 Attempted - 8 Captured)				
13	300	44	26	44	0	+23
14	300	31	36	36	L 7	+11
15	300	28	43	36	L18	+24
		(300 m Groups = 8 Attempted - 3 Captured)				
16	400	25	2	31	R28	- 7
17	400	31	26	37	R26	+ 6
		(400 m Groups = 12 Attempted - 2 Captured)				
18	500	30	35	38	R10	+15
19	500	28	29	37	R13	+14
		(500 m Groups = 8 Attempted - 2 Captured)				
		(600 m Groups = 8 Attempted - 0 Captured)				

Table B-11 (Continued)

SAW TEST FIRE
SS109 and M193 Ammunition
100 - 600 Meter 5 Round Burst Fire

Group	Range	EH	EV	ES	Location of Group Center from Point of Aim: Wind	Location of Group Center from Point of Aim: ELE
			SS109			
1	100	12.5	5.5	13.5	R 4	+ 9
2	100	16	13	16	R 6	+ 7
3	100	15	6.5	15.5	R 7	+ 7
4	100	5	9	10	L 2	+10
5	100	12	30	31	R10	+19
6	100	28	12	29.5	L20	+16
7	100	17	22	24	L12	+ 9
8	100	25	22	25	L15	+13
9	100	9	8	14	R 4	+ 5
10	100	13	21	25	L 9	+14
11	100	17	7	21	R13	+ 4
12	100	5	0	12	0	- 2
		(100 m Groups = 12 Attempted - 12 Captured)				
17	200	24	14.5	27	L 2	+16
18	200	35	10	35.5	0	+ 8
19	200	23	13	23	L 6	+ 5
20	200	44	30	55	L22	+21
21	200	18	8	19	R14	+11
22	200	25	16	29	R13	+11
23	200	12	4	22	R 8	- 3
24	200	14	16	20	R12	+ 9
25	200	31	25	51	R 7	+23

Table B-11 (Continued)

SAW TEST FIRE
SS109 and M193 Ammunition
100 - 600 Meter 5 Round Burst Fire

Group	Range	EH	EV	ES	Location of Group Center from Point of Aim	
			SS109		Wind	ELE
26	200	10	16	23	0	+ 9
27	200	32	33	55	0	+23
28	200	9	16	29	R 5	+ 6
29	200	29	28	41	L10	+17
		(200 m Groups = 16 Attempted - 13 Captured)				
30	300	23	10	30	L 8	+ 2
31	300	10	18	32	0	+16
32	300	20	22	24	L 5	+ 9
33	300	31	37	38	L22	+27
34	300	9	9.5	12	R21	+ 6
35	300	2	22	22	R23	+ 9
36	300	24	35	42	R15	-13
37	300	25	26	32	R15	+12
38	300	27	9	25	R17	0
39	300	22	26	42	0	+10
40	300	14	33	42	L 7	+15
41	300	10	34	21	0	+24
42	300	36	32	48	R 7	0
		(300 m Groups = 20 Attempted - 13 Captured)				
43	400	17	28	44	R15	+ 9
44	400	34	14.5	51	L 9	+ 4
45	400	20	36	40	L 9	+12
46	400	18	13	19	L 9	+ 6

Table B-11 (Continued)

SAW TEST FIRE
SS109 and M193 Ammunition
100 - 600 Meter 5 Round Burst Fire

Group	Range	EH	EV	ES	Location of Group Center from Point of Aim: Wind	ELE
		SS109				
47	400	27	7	45	L12	+ 4
48	400	26	43	51	L 2	+19
49	400	28	28	41	L19	+16
50	400	20	19	23	R11	+10
51	400	21	4	33	R 6	0
52	400	55	17	56	L13	+17
53	400	35	38	47	0	+26
54	400	20	29	43	0	+23
		(400 m Groups = 24 Attempted - 12 Captured)				
55	500	31	21	24	L25	+ 7
56	500	26	40	43	L10	+21
		(500 m Groups = 8 Attempted - 2 Captured)				
		(600 m Groups = 8 Attempted - 0 Captured)				

Appendix C

ARMY MARKSMANSHIP UNIT

SAW FIRING TEST--COMMENTS

1. In order to obtain best results, the weapon must be precisely zeroed by each firer. It is also recommended that zeroes be obtained at a range of 300 meters. Zeroing to point-of-aim at 10 meters with sights at 500 meters resulted in a great variation in point of impact at actual ranges. Accuracy of a new M249 SAW does not appear to be any better than an old, extensively used SAW. The only difference is that the rate of fire of the new weapon is slower and allows the firer to control the length of burst better. This allows the firer to conserve ammunition by firing 2 to 3 rounds burst and, therefore, fire more 2 to 3 round bursts and obtain more hits. The rate of fire is too fast, even on new guns and the weapon is too light to be controlled well while firing.

2. The length of burst required to hit an "E" type silhouette at ranges of 300 meters or less should not exceed 2 to 3 rounds. Firing longer bursts wastes ammunition and does not increase hit probability. At 400 meters, the same firing techniques should be used but may require multiple bursts to obtain a hit on the silhouette. At ranges exceeding 400 meters, obtaining a hit on an "E" type silhouette is largely a matter of luck and engaging targets at these ranges is not recommended.

3. The bipod seems to be too flexible and causes difficulty in obtaining and maintaining a good firing position. Firing from a tripod does not seem

to have a significant effect in improving accuracy over the bipod firing method.

4. The tracer and ball amunition are not ballistically matched. The tracer impacts approximately 2 to 3 feet higher than ball at 550 meters when fired from a machine rest. The same appear to be true when fired from a bipod or tripod. The tracer is not visible to the firer at ranges shorter than 500 to 600 meters during daylight hours and is seldom visible to an observer at less than 400 meters.

5. The front sight base is easily loosened and was loose on one of the weapons fired. The hood surrrounding the front sight requires the firer to force his head to the rear in order to prevent the hood from obscuring the rear sight aperture and causing sight alignment problems. The hood also greatly reduces the firer's ability to observe tracers bullet impacts, or the immediate area around the target. It is recommended that hoods be removed and sight guards be installed or, if this is not possible, the stock be lengthened to reduce the possibility of sight alignment error.

6. The rear sight aperture has approximately 1 to 4 mils sideplay. This looseness should be removed as it causes great difficulty in zeroing or obtaining consistent, first burst hits on target. The rear sight has a loose aperture and is constructed of thin, flimsy sheet metal. Because of the looseness, construction, and the relatively exposed way in which

it is mounted, the rear sight is susceptible to being easily damaged.

7. The aluminum receiver is more susceptible to wear than a receiver made of steel. This is especially true in the receiver ring area where the barrel connects to the receiver. As barrels are changed or removed for cleaning, this area may wear more rapidly than steel and cause looseness between the barrel and receiver. This will further degrade accuracy and in extreme cases may cause function problems.

8. The barrel is not constructed for long life, especially when one considers the rate of fire. The chamber and throat areas are not stellite lined to prevent erosion. Since double base spherical (ball) powder is used in the cartridge, the muzzle end of the barrel will heat up first and may wear as fast or faster than the throat area. The muzzle end of the barrel, however, is much smaller than the chamber area and does not dissipate heat as well. This may cause excessive wear/erosion at the muzzle area which is the area most critical to accuracy.

9. The two-speed rate of fire is unnecessary as the rate of fire is already too high on slow rate. If the high rate position is there to allow functioning in cold weather or when heavily fouled, then the action may be underpowered and/or may suffer from some other fundamental defect. In any case, the rate of fire selector and target engagement techniques, as concerns marksmanship, only serves to increase the cost of manufacture.

10. The weapon is constructed so it may be rapidly disassembled for cleaning or repair, except in the case of the firing pin which is one of the most critical parts of any weapon. The firing pin, if broken, cannot be changed by the operator as it is held in place by a roll pin. Removal of the roll pin requires a hammer and the appropriate sized drift pin plus a replacement roll pin if the first pin is deformed during removal. It is recommended that a solid steel, captive pin, like the pin which secures the bolt carrier to the operating rod, replace roll pin, which secures the firing pin. It is also recommended that the firing pin be modified to a double ended (reversible) configuration as used in the Mendeze RM-2 light machinegun. This would facilitate rapid replacement by the operator and eliminate the necessity to carry spare firing pins.

11. The weapon is basically well designed, except in the case of final production engineering. In its current configuration, it is suitable as a replacement for the bipod fired M16A1 squad automatic weapon, when used at ranges not exceeding 400 meters. It is NOT, however, equal or superior to the M60 general purpose machinegun in terms of effective range or accuracy and probably not equal as to durability or sustained fire capability.

SFC RECHTENWALD

USAMU, Fort Benning