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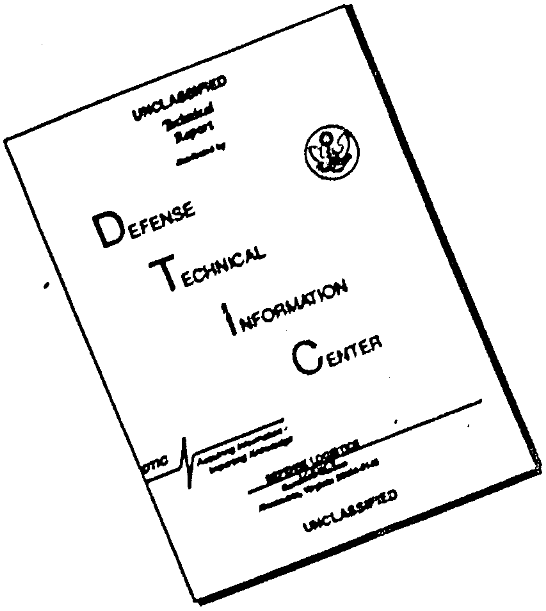

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The Johns Hopkins University

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TECHNICAL MEMORANDUM
ORO-T-397

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SALVO II
Rifle Field Experiment (U)

by

Leon Feldman
Duncan Love
William Pettijohn
J. David Reed
Richard E. Tiller
Kenneth L. Yudowitch
Paul [illegible]
William [illegible]

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William Pettijohn
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Kenneth L. Yudowitch
Paul Michelsen
William W. Walton

OPERATIONS RESEARCH OFFICE
The Johns Hopkins University
Bethesda, Maryland

[redacted]

[redacted]

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CONTENTS

PROBLEM

To measure the relative hit probabilities of several multiple- and single-bullet rifle ammunitions in combat-simulated aimed rifle fire, to use them to compare ammunition effectiveness, and to examine the effects of various parameters, such as range, target-exposure time, TRAINFIRE qualification scores, etc., on the accuracy of aimed rifle fire.

FACTS

The SALVO II field experiment was conducted by ORO at the request of the SALVO Steering Committee of which representatives of the Office of the Chief of Ordnance (OCO), Office of the Chief of Research and Development (OCRD), and US Continental Army Command (USCONARC) are members.

DISCUSSION

SALVO II is a further examination of ammunition types previously investigated in the SALVO I experiment reported on in ORO-T-378.[1] The SALVO II experiment, like SALVO I, examines the ammunitions in a combat-simulated environment when fired by experimental subjects having various degrees of rifle proficiency. The results of the controlled experiment were analyzed to indicate differences in ammunition effectiveness and also to determine the effects of target-system and other environmental characteristics on the accuracy of rifle fire. The following ammunitions were examined in SALVO II:

(a) Test ammunition: .30-cal duplex in standard .30-cal cartridge; .30-cal triplex in standard .30-cal cartridge; .22-cal duplex in necked-down .30-cal cartridge; and 12-gage-shotgun 32 flechettes fired from Remington autoloading shotgun (Model 11-48A).

(b) Control ammunition: .30-cal [M2 ball and armor-piercing (AP)] and .22-cal (high-velocity) simplex ammunition. *

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* The control ammunition is designated throughout as .30- and .22-cal simplex ammunition.

SUMMARY

CONCLUSIONS

General

1. SALVO II confirmed in detail the predictions of the salvo theory. It also firmly supports the major conclusions and recommendations of the SALVO I experiment.

2. Average aiming error for the SALVO II system is 3.1 mils. If ricochet hits are included it is equivalent to 2.8 mils.

3. Ricochet characteristics of the various ammunitions were widely different and account for deviations from expected ammunition performance. Better ricochet characteristics account for the 10 percent higher number of recorded hits achieved with .22-cal duplex ammunition compared with those with .30-cal duplex ammunition.

4. No significant difference can be observed between the precision of the first rounds of the .30-cal duplex ammunition and that of .30-cal simplex ammunition. The effect of drop and improper hold-off of the former, compared with the latter can be observed at ranges greater than 250 yd when the ammunitions are zeroed at 165 yd.

5. Multiple correlation results indicate that target-exposure time and presented area (angular target size) are the major factors determining hit probability in the SALVO II experiment. Other factors influencing hit probability, but to a very much smaller degree, are target activities such as movement and simulated firing.

6. No accuracy differences ascribable to caliber (i.e., .22 cal vs .30 cal) were observed.

.30- and .22-cal Duplex Ammunition

7. In the SALVO II experiment .30-cal duplex ammunition achieved over-all casualty gains, relative to .30-cal simplex (M2 ball) ammunition, of 49 percent. For moving targets its gain was ~~approximately~~ 60 percent, and for firers having the largest aiming errors (averaging 5 mils) the duplex ammunition achieved an average of twice as many casualties as simplex ammunition.

8. .22-cal duplex ammunition achieved an over-all casualty gain, relative to .30-cal simplex ammunition, of 44 percent. For moving targets and for firers having average aiming errors of 5 mils it achieved an average of twice as many casualties as simplex.

9. Both the .30- and .22-cal duplex ammunition fired from a modified M1 rifle functioned satisfactorily through the experiment.

.30-cal Triplex Ammunition

10. .30-cal triplex ammunition achieved an over-all casualty gain, relative to .30-cal simplex ammunition, of 32 percent. On the moving targets its gain was 75 percent, and for firers whose aiming error averages 5 mils it achieved an average of twice the number of casualties as simplex.

.22-cal Simplex Ammunition and 12-Gage-Shotgun Flechettes

11. .22-cal simplex and the 12-gage-shotgun flechette ammunition-weapon combinations were of such poor technical quality that no useful data concerning their combat potential were collected.

RECOMMENDATIONS

1. .30-cal and/or 7.62-mm NATO duplex ammunition should be adopted as standard for combat use.
2. The value and feasibility of improving the ricochet characteristics of .30-cal duplex ammunition should be investigated.
3. Current flechette development programs should emphasize the achievement of satisfactory salvo patterns. In this respect research and development (R&D) of multiple-launched flechettes should be emphasized.
4. Accuracy requirements for new shoulder-fired weapons to be used in aimed fire should be based on an aiming error of no less than 3 mils.

SALVO II
RIFLE FIELD EXPERIMENT

INTRODUCTION

In this study the problem was to measure the relative hit probabilities of various ammunitions in combat-simulated aimed rifle fire, and to use these hit probabilities to compare ammunition effectiveness. An additional problem was to examine the effects of various parameters, such as range, target-exposure time, TRAINFIRE qualification scores, etc., on the accuracy of aimed rifle fire.

BACKGROUND

The SALVO II field experiment is part of the salvo program initiated by ORO in 1951. In 1954 a SALVO Steering Committee was set up under the leadership of the Chief of Ordnance. Work in the program has included several studies by ORO[1–10] and the development of prototype salvo ammunitions by OCO. The potential gain in combat effectiveness of these ammunitions was examined in a field experiment (SALVO I) conducted at Ft Benning, Ga., in June and July 1956. SALVO I results are reported in ORO-T-378.[1] The field experiment (SALVO II) reported in this memorandum is a continuation of the salvo program. It was conducted during December 1957 at Ft Benning by ORO under the auspices of the SALVO Steering Committee. Troops and facilities for the experiment were furnished through USCONARC by the Infantry Center.

Previous ORO publications[1–10] describe in detail the objectives of the salvo program. In brief they are to increase the firing effectiveness of infantrymen by increasing hit probabilities while maintaining sufficient lethality of individual projectiles. The method by which the salvo program has achieved this increase is through the design and development of weapons and ammunitions that more efficiently distribute energy expended in rifle fire and that compensate for the inherent human error in small-arms fire. The ammunition and weapons developed so far fire more than one projectile per aiming effort (trigger pull) and in the SALVO I experiment proved to offer significant advances in effectiveness in aimed rifle fire under simulated combat conditions.

SALVO I examined the effectiveness of .30-cal duplex or tandem-round ammunition and automatic fire as an approximation of the salvo principle and furnished limited information on .30-cal triplex and 12-gage-shotgun 32-flechette ammunition. In SALVO I, firing was conducted under conditions of limited visibility as well as in daylight, and from two firing positions, standing and sitting.

Since the SALVO II experiment was an extension of SALVO I requested by the SALVO Steering Committee, its main purposes were to furnish a final check on duplex ammunition prior to its submission for user tests and possible adoption, to collect more data on triplex and flechette ammunition effectiveness, and to examine .22-cal duplex ammunition. These objectives are detailed below.

(a) The evaluation of .30-cal duplex ammunition in standard cartridge cases. The SALVO I duplex ammunition utilized a long-necked cartridge case that required an elongation of the standard rif. chamber. The second bullet in the SALVO II ammunition rests in the powder charge.

(b) The evaluation of .30-cal triplex ammunition in the standard cartridge case. The SALVO I triplex ammunition, in addition to being in an elongated case, blew up on one occasion and the experimentation was stopped at that point.[1]

(c) The evaluation of .22-cal duplex ammunition in a necked-down standard case. In the .22-cal duplex it was hoped to combine advantages of a smaller caliber with those of a duplex round.

(d) The evaluation of 12-gage-shotgun 32-flechette ammunition, which in SALVO I was limited to 700 rounds. The results of SALVO I indicated a full-scale examination would be justified, and 3000 rounds were procured for SALVO II.

(e) More detailed measurement of weapons effects and their relation to man and target-system variables was desired than was achieved in the SALVO I experiment.

WEAPONS AND AMMUNITION

Weapons and ammunitions for the SALVO II experiment were furnished by OCO. The weapons were fabricated by Springfield Armory and the ammunitions (see Fig. 1) were fabricated by the Olin Mathieson Chemical Corp., Frankford Arsenal, and Aircraft Armaments Inc. The weapon-ammunition combinations included:

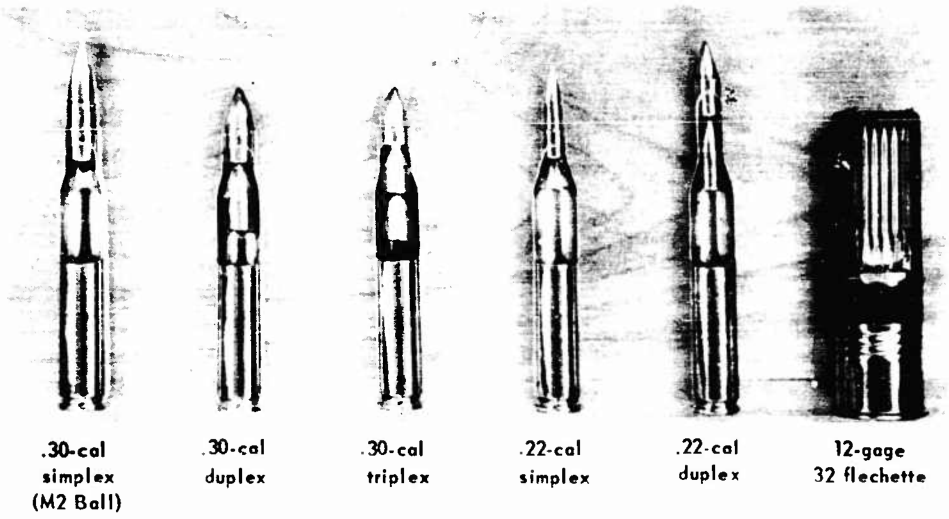

Fig. 1—SALVO II Test Ammunition

(a) Standard M1 rifle firing .30-cal simplex ammunition (standard issue) and .30-cal duplex ammunition (controlled dispersion*) made by Olin Mathieson.

(b) Standard M1 rifle with modified rifling firing .30-cal triplex ammunition (random dispersion†) made by Olin Mathieson.

(c) M1 rifle modified with .22-cal bore firing .22-cal simplex ammunition made by Frankford Arsenal.

(d) M1 rifle modified with .22-cal long-chamber barrel firing .22-cal duplex ammunition made by Olin Mathieson.

(e) 12-gage autoloading shotgun, Remington Model 11-48A, firing a 32-flechette load made by Aircraft Armaments Inc.

EXPERIMENTAL CONTEXT

The derivation of the target system used for evaluating the salvo concept in the SALVO I and II experiments is described in detail in App D of ORO-T-378.[1] This system consists of 22 E and F silhouette pop-up targets at ranges of from 70 to 340 yd. This layout is shown in Figs. 2 and 3. Also shown in Fig. 2 are the distributions of disclosing fire, target concealment, and target movement. Another feature is the simulation of combat stress through the use of electronic shocking devices attached to the firers. Although the simulation of stress, range to the targets, and general layout of the target system remains the same from SALVO I to SALVO II, there are certain differences between the two target systems:

(a) Light. All firing during SALVO II was conducted in daylight, using only the daylight target positions of SALVO I. The system in SALVO II is generally oriented toward the north, as opposed to a general orientation toward the south in SALVO I. The effect of this change was more uniform visibility conditions from run to run than those obtained in SALVO I.

(b) Exposure times. Exposure times for the pop-up targets were reduced by roughly one-third from SALVO I. This reduction was not uniform, and the specific amounts are shown by target in Table 1.

The exposure times were shortened at the suggestion of OCO and OCRD. It was felt that the target-exposure times collected in interviews, which formed the basis of the SALVO I system, were overestimated by the interviewees. Since a good common-sense argument can be made for this point of view and since a quick trial of time estimates revealed such overestimation, ORO concurred in the suggestion to shorten the exposure times by about one-third.

(c) Fatigue of firers. The firers were double-timed for 5 min before each run. This was an attempt to introduce fatigue, and its subjective effect is discussed in App A.

(d) Weather conditions. In contrast to SALVO I, which was conducted at Ft Benning in June and July, SALVO II was conducted on the same post during December. The weather conditions during the experiment exhibit considerable variation. This variation is shown in Table 2.

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*For controlled-dispersion duplex ammunition used in SALVO II the second bullet deviates at about 2½ mils from the path of the first.

†For the random-dispersion triplex ammunition the paths of the second and third bullets are, within certain limits, random with respect to the lead bullets. A complete description of random and controlled dispersion is given in App B of ORO-T-378.[1]

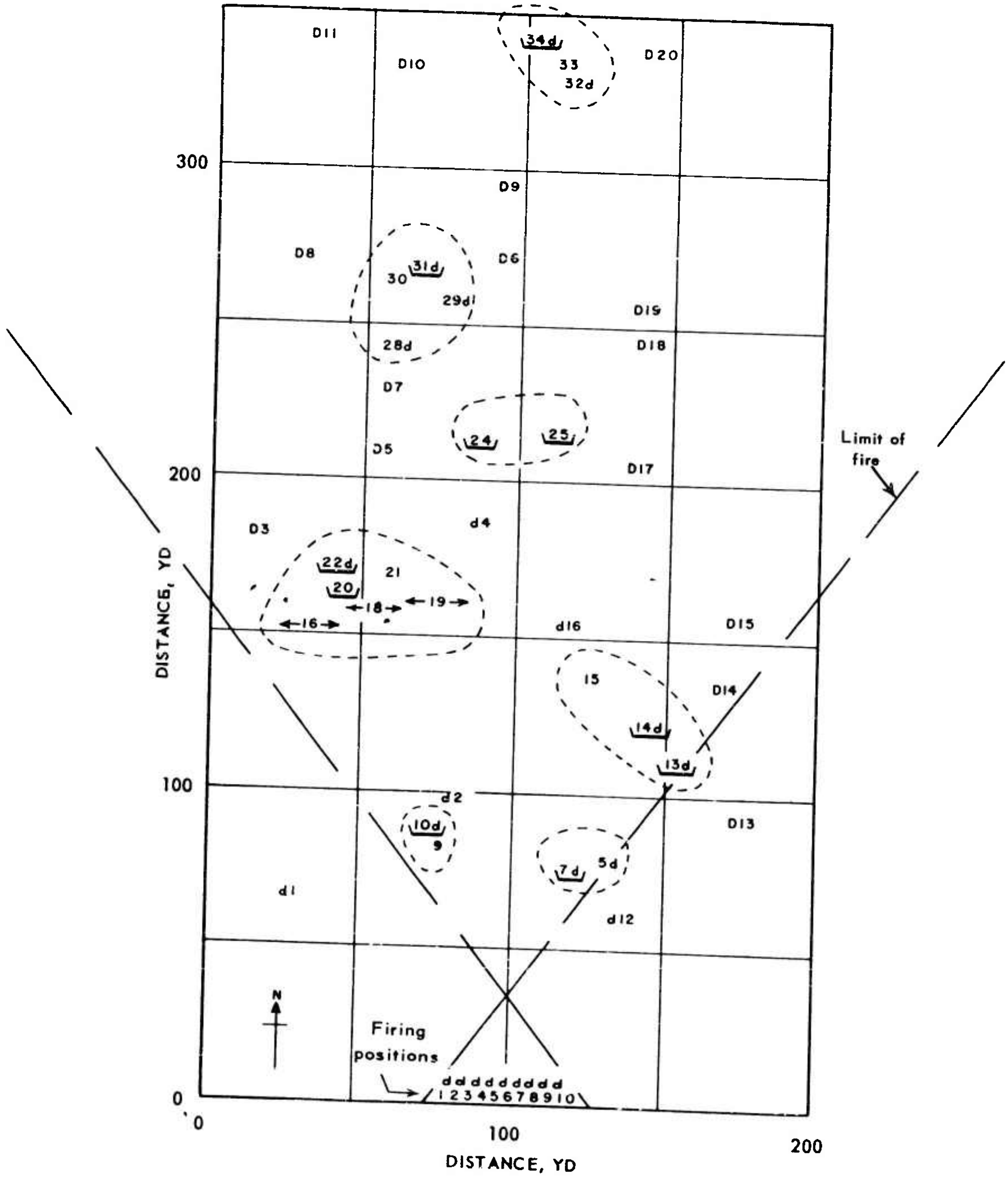

Fig. 2—Salvo II Target System

d Small demolition

D Large demolition

← → Moving target

◌ Target group (consecutive)

___/ Partial concealment

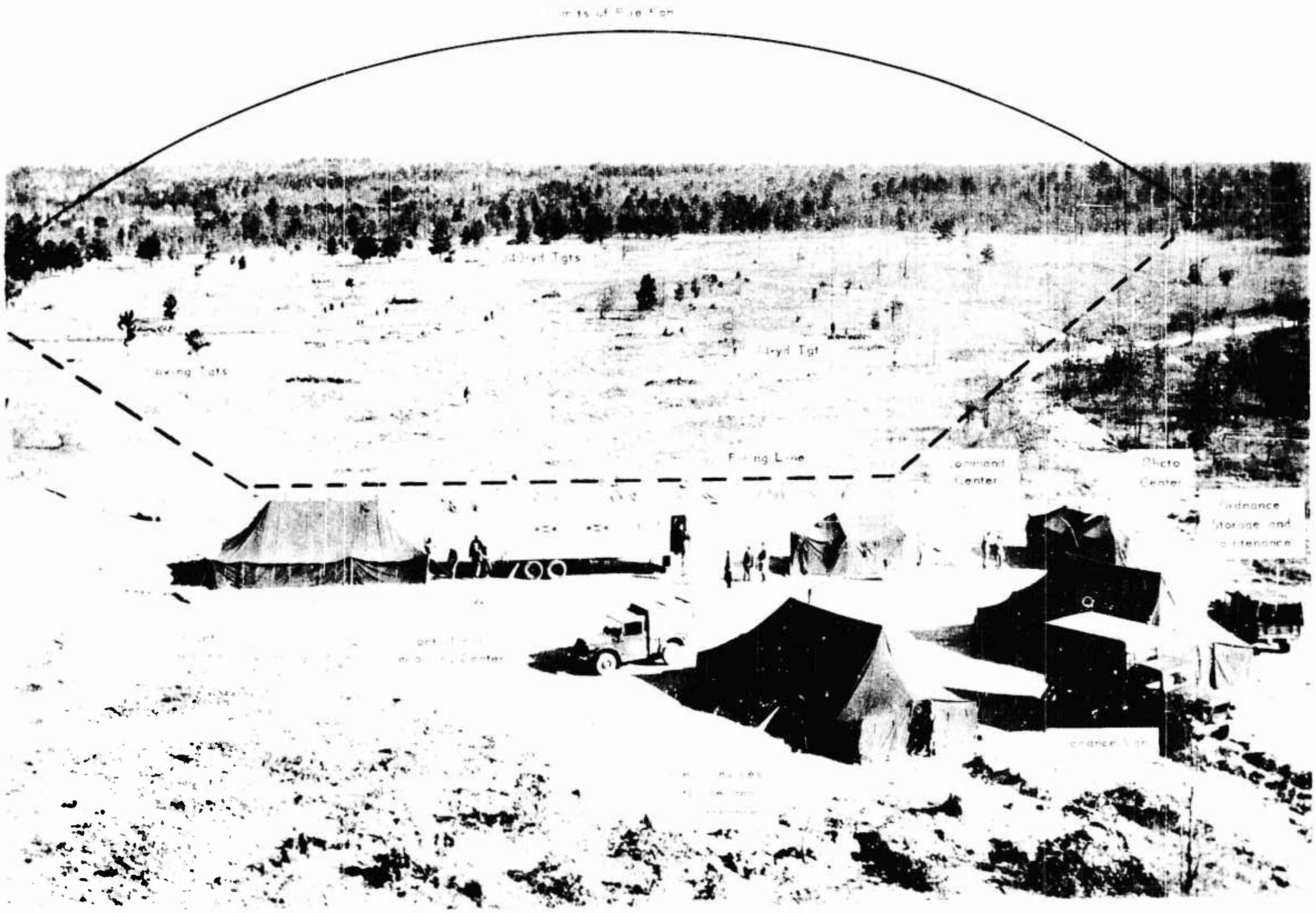

Fig. 3—Location of Equipment and Representative Target Positions in SALVO II during Servicing of Target System

TABLE 1

TARGET-EXPOSURE TIMES: SALVO I VS SALVO II

Range, yd	Target type	Exposure time, sec	
		SALVO I	SALVO II
74	F	4.5	3.0
77	F	15.0	10.0
86	E	4.5	3.0
89	F	15.0	10.0
111	F	19.5	13.0
127	F	9.0	6.0
139	F	4.5	3.0
152	E (moving tgt)	9.0	8.0
162	E (moving tgt)	6.0	6.0
164	E (moving tgt)	15.0	11.0
165	E	31.5	18.0
169	E	3.0	2.0
176	E	4.5	3.0
216	F	4.5	4.0
218	F	9.0	6.0
245	E	6.0	4.0
259	E	10.5	7.0
267	E	3.0	3.0
269	F	25.5	16.0
334	F	7.5	5.0
336	F	7.5	4.0
339	F	21.0	12.0
Total		235.5	157.0

TABLE 2

WEATHER CONDITIONS DURING SALVO II

Day	Runs conducted	Mean temperature, °F	Mean wind velocity, mi/hr	Direction	Weather condition
1	8	50	7	Cross range	Clear
2	6	32	15.5	Cross range	Intermittent light snow
3	11	35	3	Cross range	Clear

The most extreme weather conditions were experienced on the second day. The wind and snow plus the freezing temperature made firing conditions very unpleasant. The number of firers who wore gloves while firing was much higher than on the first and third days (see App A). The .22-cal simplex and duplex runs (two each) and two shotgun runs were fired on the third day, and the weather conditions may account for the slightly lower rate of fire on these runs compared with the rest of the experiment (see subsection on learning).

(e) Firing line and firing position. Whereas SALVO I firing was conducted from sitting and standing positions, the SALVO II firing line was constructed so that firing was done from a modified prone position (see Fig. 4). An earthen breastwork was constructed, and firing was conducted from this parapet. This change was made as the result of suggestions by the Army. Its effect was to provide a very much more stable firing position than those used during SALVO I and hence reduced aiming error.

Fig. 4—SALVO II Firing Line Showing Modified Prone Position

In addition the firing line for SALVO II was equipped with devices that detonated electric blasting caps among the firers. The devices protected the firers from the blast but were designed to add noise and confusion to the firing line. The firers, however, were seldom aware of their detonation (see App A).

(f) Weapon zeroing. Each rifle was zeroed by the man firing it. (SALVO I rifles were zeroed by experts.) The sights were then adjusted to a battle setting that yielded the least-miss distance for the total range complex of the target system. This process is described in App B. The shotguns were prezeroed at the Development and Proof Services (D&PS), Aberdeen Proving Ground (APG), and were not changed during the experiment.

EXPERIMENT SUBJECTS

The SALVO II experiment utilized 20 subjects selected from the trainees assigned to the Human Research Unit of the Human Resources Research Office at Ft Benning. They had just completed basic training and their rifle marksmanship qualifications on the TRAINFIRE range totaled 3 experts, 7 sharpshooters, and 10 marksmen. They were organized into two balanced 10-man firing orders. (A detailed description of the firers is found in App A.)

These firers differed in the following respects from those in the SALVO I experiment:

(a) They had received TRAINFIRE rifle-marksmanship training.

(b) Ninety percent of the subjects were enlisted reservists whereas 75 percent of the SALVO I subjects were Regular Army.

(c) They were from a special test unit and had participated in other experiments of various kinds.

From the point of view of realism, there were both advantages and disadvantages in using the TRAINFIRE troops. In that the rifle training they received is being implemented in the Zone of Interior (ZI) by USCONARC, it adds to the realism of the experiment. The fact that they were drawn from a special test unit, however, detracts from realism. The SALVO I troops were more typical of the over-all Army population in motivation and experience.

EXPERIMENTAL DESIGN

The simplification of SALVO II, as compared with SALVO I, consists of the use of only one position for firing and the exclusion of night firing. This permitted a shorter experiment—24 runs in SALVO II vs 68 runs in SALVO I. The troop qualifications and test-material specifications involved in the experiment are shown in Tables 3 and 4.

A total of 24 runs were fired as specified in Table 5, each weapon-ammunition-squad combination being fired twice on the target system (2 × 6 × 2).

TYPICAL RUN OR FIRING SEQUENCE

A typical run or firing sequence followed a set pattern. Appropriate rifles and ammunition were placed at the firing positions (1 to 10 on Fig. 2). The firers then took their places at their assigned firing positions. After the stress simulators (electric shockers) had been placed on each firer's leg the firers took up a comfortable position on the earth parapet on the firing line (see Fig. 4). As soon as the firing line was ready, the programed target-system sequence was initiated in the control and recording center. At that point the target-system events began, i.e., target appearances, demolitions, electric shock for the firers, etc., as described in the programs in App C. The targets appeared sequentially, all men firing at every target seen. The electronic chronological recording system made possible the identification of shots fired and hits by each individual. The program ran for 300 sec.

TABLE 3

TROOP QUALIFICATIONS AND DIVISION

Squud	Experts	Sharpshooters	Marksmen
A	1	4	5
B	2	3	5

TABLE 4

WEAPON-AMMUNITION COMBINATIONS

Ammunition	Weapon
.30-cal simplex (M2 ball)	Fired from stundard M1 rifle
.30-cal duplex	Fired from standard M1 rifle
.30-cal triplex	Fired from modified M1 rifle
.22-cal simplex	Fired from modified M1 rifle
.22-cal duplex	Fired from modified M1 rifle
12-gage flechette	Fired from Model 11-48A Remington autoload shotgun

TABLE 5

SALVO II FIRING SCHEDULE

Date	Weapon-ammunition combination	Squad	Program[a]
10 December	.30-cal triplex (M1)	A	3
	.30-cal triplex (M1)	B	3
	.30-cal triplex (M1)	B	4
	.30-cal triplex (M1)	A	4
	.30-cal duplex (M1)	B	5
	.30-cal duplex (M1)	A	5
	.30-cal simplex (M2) AP[b]	B	6
	.30-cal simplex (M2) AP	A	6
11 December	.22-cal simplex (.22-cal M1)	A	1
	.22-cal simplex (.22-cal M1)	B	1
	.22-cal duplex (.22-cal-long-chamber M1)	A	2
	.22-cal duplex (.22-cal-long-chamber M1)	B	2
	12-gage flechette (shotgun)	A	3
	12-gage flechette (shotgun)	B	3
12 December	.22-cal duplex (.22-cal-long-chamber M1)	B	4
	.22-cal duplex (.22-cal-long-chamber M1)	A	4
	.22-cal simplex (.22-cal M1)	B	5
	.22-cal simplex (.22-cal M1)	A	5
	12-gage flechette (shotgun)	B	1
	12-gage flechette (shotgun)	A	1
	.30-cal simplex (M2 ball) (M1)	A	3
	.30-cal simplex (M2 ball) (M1)	B	3
	.30-cal duplex (M1)	A	2
	.30-cal duplex (M1)	B	2

---

[a] The programs [i.e., the sequence in which groups of targets appeared (see Fig 2), demolitions were detonated, and electronic shock was administered] were prepared by randomizing the sequence of their occurrence to prevent learning. As is noted in Table 1 six different programs were used. These programs appear in App C.

[b] AP ammunition was brought to the field by mistake. Rather than miss a day's firing it was used. Its characteristics differ slightly from M2 ball ammunition.

DATA COLLECTION

The following types of data were collected in the experiment:

(a) Hits on targets recorded on paper-target faces.

(b) Hits on targets recorded electronically in time.

(c) Trigger pulls recorded electronically in time.

(d) Target movement and up times recorded by an elapsed-time camera (also electronically recorded).

(e) Weapon malfunctions and the time during which the weapon was out of action recorded electronically by an observer.

(f) Hits on targets by flechettes recorded by AN-N/6 gun cameras at the targets.

(g) Ammunition expended recorded by ammunition count before and after each run.

(h) Meteorological data (previously described).

(i) Subjective information concerning the firers collected in debriefing interviews after each run.

INSTRUMENTATION

The objectives of the instrumentation of the SALVO II experiment were twofold: First to ensure reproducibility from run sequence to run sequence, and second to collect the data mentioned in items b to f above. The central aspect of the reproducibility function of the instrumentation is the sequence controller or programer, which is described and illustrated in App E. This unit, by means of a paper punch tape, permitted the precise reproducibility in time of all scheduled events on the target system.

The main problem in the data-recording functions of the instrumentation was to record target hits and trigger pulls with a resolution time of 50 msec. Resolution time of this magnitude permitted the identification of first-, second-, and third-bullet hits and single, double, and triple hits. It also made possible relating trigger pulls to hits on the target, thus permitting the analysis of the data by man, although all men were able to fire at each target when it appeared.

The only serious problem encountered in reducing the data was the result of varying ammunition velocities. Although the average time of flight from each firing position to each target was known accurately, the identification of hits from the second and third projectiles from a single trigger pull depended on the fact that these projectiles traveled more slowly than the first projectile. Hence they could be identified by the amount of time it took them to reach the target. In actual practice it was found that bullet velocities varied from round to round and the time of flight of a second bullet from one duplex round might be shorter than the time of flight of a first bullet from another duplex round. The problem was even more severe in triplex ammunition and is illustrated in Tables C30 and C31 in App C. This was not a problem that the ORO instrumentation could solve, but it did not affect the identification of double hits from a single trigger pull. These could be determined by the characteristic time separation between bullet strikes. It did affect the accuracy, however, of the identification of first- vs second- vs third-bullet hits.

The complete description of the salvo programing and data-recording system is found in Apps D and E of ORO-T-378[1] and App E of this paper. Taken together these appendixes furnish sufficient information for the reproduction of the system. The SALVO II system performed its functions of control and data collection with almost perfect reliability.

From the point of view of comprehensiveness, SALVO II accurately measured two factors that could only be estimated in SALVO I: (a) the number and duration of weapon malfunctions, and (b) the effect of malfunctioning targets. In SALVO I one of the major difficulties in the analysis was the fact that it could only be roughly estimated how long a weapon malfunction kept a given weapon out of action. To remedy this situation in SALVO II a monitor system was instituted. It consisted of observers at each firing position who could signal the duration of weapon malfunctions. The system is described in App E and the monitors are shown in Fig. 4.

An allied problem concerned the malfunctions of targets. Occasionally, a target did not appear, did not stay up for the entire duration of its programed appearance, or stayed up too long. This type of malfunction occurred more frequently in SALVO I, but only observational records were taken. Two methods were used in SALVO II to measure the actual duration of target exposure: (a) an electronic record was kept of the up and down times for the targets, and (b) the lapsed-time cameras (one frame per second) synchronized with the system program afforded a visual indication of target exposure. This was used as a detailed check on all aspects of the operation of the field layout of the target system.

The photographic hit recording of the flechette runs did not prove very successful because identification of flechette hits from the film data was in most cases impossible and camera film speeds could not be adequately controlled. This type of recording was required because of the lack of time separation of flechettes from one trigger pull and the tendency of the flechettes to short-circuit the aluminum sandwich targets. Both faulty data recording and poor ammunition performance render the flechette results almost unusable. The results that are available are included in Table 5 and are detailed in App B.

Data Reduction

The principal problems of data reduction concern the relating of hits on targets to individual trigger pulls and, in the case of multiple-bullet ammunition, the identification of each hit as a first-, second- (in the case of duplex and triplex), or third- (in the case of triplex) bullet hit. The hit-trigger-pull relation and the identifications depend on accurate knowledge of the time of each bullet strike on the target, the time of the trigger pull, and the time of flight from the firing line for each type of projectile. The first two pieces of data were measured as described previously and times of flight were determined by examining a large number of individual hits with simplex ammunition, double hits with duplex ammunition, and triple hits with triplex ammunition fired from each firing position. Time data were recorded on Esterline-Angus tapes in the field and later transferred to International Business Machines (IBM) cards through the use of a Telereader analog-to-digital computer. This information was then printed out, and the numerical time relations were individually examined.

In relating hits to trigger pulls, the accuracy with which the data were collected permitted the almost complete allocation of hits. Only 1 percent of the hits could not be ascribed with certainty to a given trigger pull. In the case of the identification of first-, second-, and third-bullet hits, however, less accuracy was achieved. This is due not so much to the recording as to the variation in time of flight or bullet velocity from round to round. This is illustrated in Fig. C1, where it can be seen that triplex first- and second-bullet times of flight overlap, i.e., in some cases a lead triplex bullet's velocity was such that its time of flight to the target was the same or slower than the second bullet of another round. Thus there are cases where it is impossible to determine for a given single bullet strike whether it was a first or second bullet. The same is true to a lesser extent for the duplex ammunition. The magnitude of the error for the four analyzed ammunitions is shown in Table C31.

In actual practice in the data reduction every effort was made to identify bullet hits from the logical context as well as by using time-of-flight data. Cutoff points were used at the points where time-of-flight distributions intersect. Since the overlapping times of flight presumably occurred randomly and affected a very small percentage of the data, they can be assumed to have little effect on the analysis described below.

DATA ANALYSIS

The first problem in the analysis of the data after they were reduced was dealing with cases where data were missing. In SALVO I there was a considerable amount of missing data, and compensating for it was one of the most difficult problems in the analysis. In SALVO II, however, owing to the improved and more comprehensive instrumentation and to better weapon and target performances, it was not a serious problem.

Missing data in the SALVO experiments occurred for one of three reasons. First a target failed to appear, second a weapon malfunctioned and the firer did not fire his usual number of shots, or third the target appeared but the electronic recording did not function properly.

There was only one target that did not appear in the course of the 16 runs that were used in the major comparisons (.22-cal simplex and flechette runs excluded), and for it an average value determined on the basis of the other runs was filled in. The second case, that of weapon malfunction, was extremely important in the SALVO I analysis. In SALVO II, however, only 20 minor weapon malfunctions occurred during the 16 runs. These malfunctions were of such short duration (they are shown in detail in Table B7) that they are ignored in the SALVO II analysis. In the third case, where the data were not recorded electrically because of a target shorting out or a ricochet failing to register properly, alternative data from the paper target faces were used.* Serious malfunctions of this type occurred 16 times during these 16 runs (or 352 target appearances) and affected 329 out of the 4252 hits (see Table C22). These 8 percent of the hits

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*Ricochets always perforated the targets but occasionally, because of their broad aspect of presentation to the target, would not properly broach the insulating rubber layer in time to record (see App E).

on the paper target faces were prorated as to first-, second-, and third-bullet hits on the basis of average values of other runs and as to the firers on the basis of the individual firer's aiming error determined in the other runs. This process is described in detail in App C.

The only other discrepancy between electronic-record and target-face count encountered in the data analysis was the result of a target failing to drop because of mechanical failure. Because the electronic recording ceased at the programed drop time, it was accepted as correct and the target-face count was ignored. However, because of this malfunction the following target that appeared did not receive as many hits as it normally would have, and again average numbers were used in adjusting its hits.

In summary it may be said that adjustments to actual hits on the targets, i.e., holes in the paper faces, were made for less than 1 percent of the total hits. Adjustments to the electronically recorded data to bring them into line with the holes in the paper faces were made for 6 percent of the total hits and always on the basis of average values determined on other runs or on aiming errors computed for the man and ammunition involved.

RESULTS

This section considers two types of experiment results: (a) those pertaining to ammunition differences and (b) those pertaining to the general nature of rifle fire on the salvo target system.

Ammunition Differences

The effectiveness criterion used in this analysis is casualty gain per trigger pull, i.e., test-ammunition score minus control-ammunition score, divided by control-ammunition score. Ammunition and weapon weights for those ammunitions on which usable data were obtained were essentially the same. In addition production costs of the ammunitions are comparable. Hence comparisons by weight and cost are not of primary pertinence. Another criterion, gain in number of targets hit per trigger pull, is included in the major tables.

The effects of overkills for double and triple hits from one trigger pull are computed in App O of ORO-T-378,[1] and this same method is used here. The specific casualty probability used for single hits is .7; for double hits, .91, i.e., $.7 + [0.7\,(1 - 0.7)]$; and for triple hits, .97 (similarly deduced). The detailed analysis of overkills is presented by man, by target, and by run in Tables C1 to C16. The casualty probability for triplex hits is degraded by a factor of 18 percent at ranges of 200 yd and beyond. This is based on the fact that at those ranges the triplex ammunition used will not penetrate helmets, and the equivalent approximation of the decrease in lethality based on App B of ORO-T-378[1] is 18 percent. In contrast to SALVO I ammunitions, the .30- and .22-cal duplex ammunitions penetrate helmets at a 400-yd range (see App B).

Major ammunition differences are shown in Tables 6 to 8. The .22-cal simplex ammunition-weapon combination was of such low technical quality that comparisons are of extremely limited value and results are included only in Table 6. Its failure is described in App B. A combination of poor ammunition functioning and data-recording failure also make the flechette results of little value. Partial results are included in Table 6 and a detailed discussion is presented in App B. As a result the major comparisons are between .30-cal simplex, .22-cal and .30-cal duplex, and .30-cal triplex ammunition. Table 6 shows total shots, hits, casualties, and hits and casualties per shot for these ammunitions.

TABLE 6

TOTAL SHOTS, HITS, CASUALTIES, AND HIT AND CASUALTY PROBABILITIES PER TRIGGER PULL WITH SALVO II AMMUNITION

Ammunition	Shots	Hits	Casualties	Probabilities	
				Hit	Casualty
		Excluding Ricochets			
.30-cal simplex	2636	612	428	.232	.162
.30-cal duplex	2659	1054	643	.396	.242
.30-cal triplex	2739	1133	586	.414	.214
.22-cal duplex	2539	1005	593	.396	.234
.22-cal simplex	2438	346	242	.142	.0993
		Including Ricochets			
.30-cal simplex	2636	733	513	.278	.195
.30-cal duplex	2659	1118	686	.420	.258
.30-cal triplex	2739	1214	643	.443	.234
.22-cal duplex	2539	1187	718	.467	.283
.22-cal simplex[a]	2438	434	304	.178	.125
12-gage flechettes	—	—	—	(.34)[b]	(.11)[b]

[a] Owing to its poor showing, which was later demonstrated to be due to large ballistic error, .22-cal simplex ammunition is not used as a control ammunition.

[b] These are partial results based on all flechette data that could be evaluated for the effects of multiple hits and hence are not comparable with the other ammunition results. Comparable .30-cal simplex ammunition results are 0.43 hits/round and 0.31 casualties/round. In addition the individual flechette casualty criterion used was 0.35. Further Ballistic Research Laboratories (BRL) study indicates that these flechette lethalities may be lower than this, further depressing the flechette results.

It is noted that major test results are given both with ricochets counted as ordinary hits and with ricochets excluded. Since little is known concerning the lethality of ricochets or their occurrence in conditions other than those of this particular experiment, emphasis is placed on results that do not include ricochet hits. This does not imply that the study team believes ricochet hits are not effective but only that information concerning them is lacking.

TABLE 7

PERCENTAGE OF CASUALTY AND HIT GAINS[a] WITH .30-CAL DUPLEX AND TRIPLEX AND .22-CAL DUPLEX AMMUNITION OVER .30-CAL SIMPLEX AMMUNITION

(95% confidence limits included)

Ammunition	Gain, %	
	Hits	Casualties
	Excluding Ricochets	
.30-cal duplex	71 ± 10	49 ± 11
.30-cal triplex	78 ± 8	32 ± 6
.22-cal duplex	71 + 9	44 + 10
	Including Ricochets	
.30-cal duplex	51 ± 8	32 ± 9
.30-cal triplex	59 ± 6	20 ± 5
.22-cal duplex	68 + 8	45 + 7

[a] [(Duplex or triplex ammunition) – simplex ammunition]/simplex ammunition.

TABLE 8

TARGETS HIT PER TRIGGER PULL FOR SALVO II AMMUNITION

Ammunition	Shots	Targets hit	Target hit/shot	Gain, %[a]
		Excluding Ricochets		
.30-cal simplex	2636	612	0.232	—
.30-cal duplex	2659	866	0.326	41
.30-cal triplex	2739	772	0.282	22
.22-cal duplex	2539	813	0.320	38
		Including Ricochets		
.30-cal simplex	2636	733	0.278	—
.30-cal duplex	2659	921	0.346	24
.30-cal triplex	2739	830	0.303	9
.22-cal duplex	2539	956	0.376	35

[a] [(Duplex or triplex ammunition) – simplex ammunition]/simplex ammunition.

Aiming Error

The total rifle firing error includes ballistic dispersion, wind-correction error, drop-correction error, etc., as well as the human error in pointing the rifle at the target. In normal circumstances, however, this human aiming error is much larger than any or all the other errors. As is shown in App D, these other errors comprise such a small percentage of the total error that their contribution is negligible. Hence, for simplicity, the term aiming error is used in this report synonomously with total error. Since hits and shots by each man could be differentiated, errors for .30-cal simplex ammunition were computed by man for the target system and are included in Table D1. Average total error for the 20 firers in SALVO II is 2.8 mils if ricochet hits are scored and 3.1 mils excluding ricochet hits. The 20 individual firer errors for .30-cal simplex ammunition range from 2 to 3.7 mils.*

The major assumptions used in computing these errors were that (a) an F target is adequately represented by an equivalent-area circle 20 in. in diameter and an E target by a 28-in. circle, (b) the center of aim is the center of the target, and (c) projectiles are normally distributed around the center of aim.

The over-all average figures above are simple averages, i.e., aiming errors on 10 target groupings (the targets within each group having roughly the same presented area, see Table D7) are summed and the linear mean computed. The individual errors for the 20 firers are also simple averages on these same 10 target groupings. Errors on the individual 22 targets are also computed and presented in App D along with a discussion of the aiming-error computations.

Examination of Major Ammunition Differences

The main problem in the initial examination of SALVO II results was explaining why two ammunitions, i.e., .30- and .22-cal duplex, having almost identical ballistic and other fundamental characteristics achieved differing hit-probability gains as compared with the control ammunition (.30- and .22-cal simplex). The difference of a 51 percent gain for the .30-cal duplex ammunition as compared with a 68 percent gain for the .22-cal duplex, including ricochet hits, as illustrated in Table 6, is not only surprising but requires an explanation. In this regard the experimental conditions were examined carefully both during and subsequent to the experiment. The only data that appear to apply to the problem are the relative number of ricochet hits by the various ammunitions. These data are obtained from the paper target faces, and are recognizable as hits that went through the targets sidewise or nearly sidewise. The percentage of ricochets for each ammunition is shown in Table 9. In Tables 6 and 7 the ricochets that occurred on each target face are subtracted from the hits on that target. It was assumed that first and second bullets were equally as likely to ricochet. As is shown in these tables, subtracting ricochets in this manner affords surprisingly close agreement between .30- and .22-cal duplex results.

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*These figures include ricochet hits since it was not possible to subtract these hits by individual men. They therefore underestimate the true aiming error.

Salvo theory, as developed in several ORO studies,[1,6–8,10] predicts the increase in direct hits for duplex salvo ammunition under various conditions. It also predicts the kind of hits that will occur, i.e., the percentages of first-bullet hits, hits from duplex pairs, and second-bullet hits. What it does not do, however, is predict the number of ricochets. Thus one method of checking the veracity of the experimental results is to subtract the ricochets made by each ammunition and compare the resultant experimental results with theoretical predictions.

TABLE 9

PERCENTAGE OF RICOCHET HITS FOR SALVO II AMMUNITION

Ammunition	Ricochets, %
.30-cal simplex	16
.30-cal duplex	6
.30-cal triplex	7
.22-cal duplex	15
.22-cal simplex	20

TABLE 10

EXPERIMENTAL AND PREDICTED HIT PROBABILITIES FOR DUPLEX AMMUNITION

(95% confidence limits included; Ref 11, p 698)

Ammunition	Experimental hit probabilities		Predicted[a] hit probability
	Including ricochets	Excluding ricochets	
.30-cal duplex	.420 ± .024	.396 ± .023	.416
.22-cal duplex	.467 ± .024	.396 ± .023	.416

[a] The predicted over-all hit probability is based on the experimental number of shots fired at each target grouping.

The predictions are made by computing the .30-cal simplex aiming error minus ricochets and on this basis computing expected duplex hit probabilities for the 10 target groupings having approximately the same angular size. These hit probabilities are then compared with duplex experimental hit probabilities minus ricochets. The comparisons by target grouping are shown in Table D6. The experimental hit probabilities are derived from Table C17 and the master data tables. Table 10 summarizes the results of this analysis for .30-cal and .22-cal duplex ammunition.

In Table 10 it is seen that if ricochets are excluded the theoretical values fall within the 95 percent confidence limits of the experimental values. More important, however, is the fact that the predicted values also fall within the 95 percent confidence limits of the .30-cal duplex score, ricochets included, but fall outside this limit for .22-cal duplex ammunition, which would be expected. There are many more extra or ricochet hits in the .22-cal duplex data than in the .30-cal duplex data, i.e., 6 vs 15 percent.

Firer Accuracy and Gain from Salvo Ammunitions

There is still another method of checking the agreement of SALVO II experimental results with salvo theory, which states that duplex and triplex ammunitions tend to compensate for the firer's inaccuracy and that the greater this inaccuracy, the greater the gain from the use of salvo ammunition. There were wide differences in firing accuracy among the firers in the SALVO II experiment. These differences are best expressed as a standard deviation in mils or, roughly speaking, the aiming error. Firer errors for various ammunitions ranged from 2 to over 5 mils. One would expect that there would be a strong relation between the size of the aiming error and the casualty gain from the use of duplex or triplex ammunitions; this is confirmed by the experimental results.

The results can be examined in two ways. First, aiming errors can be computed for each man on the .30-cal simplex ammunition. These errors can then be correlated with the casualty gain achieved by each man when firing duplex and triplex ammunitions. When this is done a strong positive correlation is found between the size of error and amount of casualty gain. The correlation coefficients are 0.747 for .30-cal duplex ammunition, 0.628 for .22-cal duplex ammunition, and 0.549 for .30-cal triplex ammunition.

These results, however, are partly obscured by the fact that the ammunitions have different ricochet factors. A more precise method of looking at casualty gain as a function of aiming error is to compute the aiming error from the lead projectiles of the salvo ammunitions. Then casualties can be assessed for the lead rounds, the casualty gain that accrues from the following rounds can be computed, and this gain can be correlated with lead-round aiming error. In this way the effects of differing ricochet factors are excluded. Table 11 summarizes the results of this analysis.

There is a very strong relation between the casualty gain and the aiming error in all three cases. The lowest correlation of the three occurs with .22-cal duplex ammunition—the ammunition having the highest percentage of ricochets. The theoretical relation between the aiming error in mils and the percentage gain in casualties appears as an increasing curve; a "logistic curve" (see App D) was fitted to the experimental results. These are shown in Figs. 5 to 7. To further illustrate the agreement between salvo theory and the experimental results, Figs. 5 and 6 also show the predicted casualty gain as a function of aiming error. The fact that the predicted values fall below the average experimental values presumably is due to the extra ricochet hits included in the experimental data. The 95 percent confidence limits are computed as explained in App D, the section "Experimental Curve and Confidence Bounds."

Another graphic illustration of salvo theory in action appears in the moving-target results. Here, owing to lateral movement, hit probability was decreased from an average of .28 to .21 for simplex ammunition, for example, and large gains would be expected from the use of salvo ammunitions. Table 12 shows these gains.

TABLE 11

CORRELATION BETWEEN AIMING ERROR AND CASUALTY GAIN FROM SALVO AMMUNITIONS

Ammunition	Range of aiming errors, mils	Range of gain from salvo ammunitions, %	Correlation coefficients[a]	Residual variation, % of original variation[b]
.30-cal duplex	2.18–4.88	29–207	0.866	25
.30-cal triplex	2.34–6.76	51–282	0.915	16
.22-cal duplex	2.16–4.44	28–115	0.640	59

[a] The correlation coefficient is a measure of the relation between the aiming errors of the firers and the gain from using salvo ammunition.

[b] The residual variation is the standard deviation of the test results after aiming error is taken into account. In this table the residual variation is shown as a percentage of the original variation.

TABLE 12

CASUALTY GAIN ON MOVING TARGETS VS ALL TARGETS FOR .30- AND .22-CAL DUPLEX AND .30-CAL TRIPLEX AMMUNITION OVER .30-CAL SIMPLEX AMMUNITION

Ammunition	Casualty gain, %	
	Moving targets	All targets
.30-cal duplex	77 ± 37[a]	49 ± 11[a]
.30-cal triplex	76 ± 43	32 ± 6
.22-cal duplex	127 ± 56	44 ± 10

[a] Ninety-five percent confidence limits.

Ammunition Precision

As illustrated in Table 13, the first bullets of salvo ammunition have comparable ballistic precision with the .30-cal simplex ammunition. Error for triplex first bullets is slightly larger than for the other ammunitions but not so much larger that a discernible difference on the target system would be expected given an aiming error of about 3 mils. When the raw data are examined, however, a large difference is found in simplex vs first-round .30-cal duplex and triplex hit probabilities, as is also shown in Table 13. This effect was also observed in tests of duplex ammunition at the Infantry Board.[12,13]

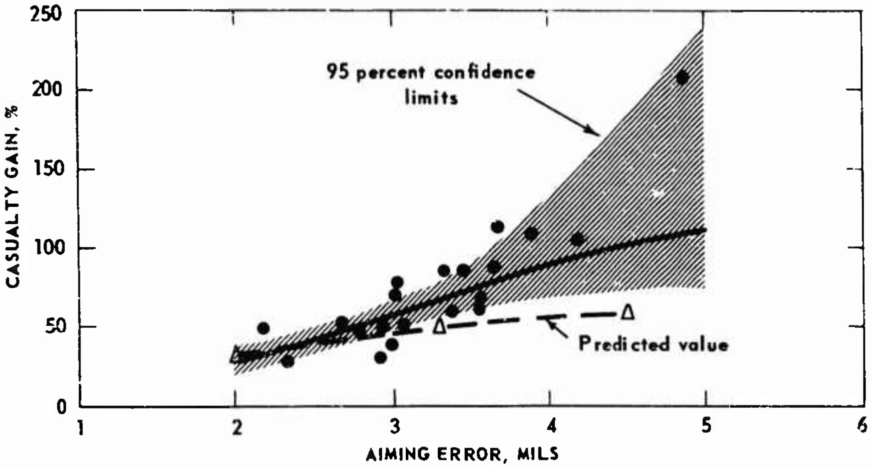

Fig. 5—Casualty Gain as a Function of Individual Aiming Error for .30-cal Duplex Ammunition

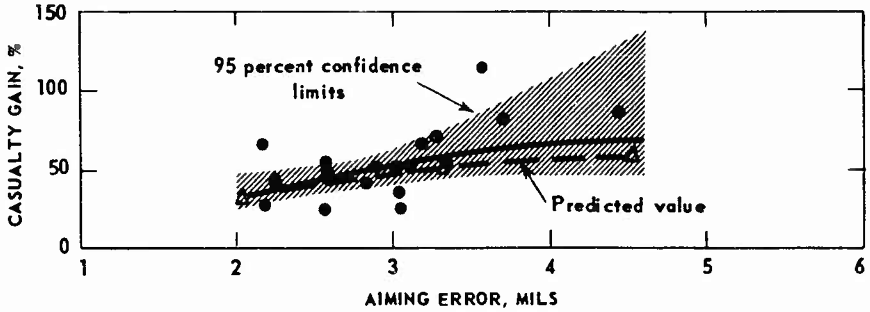

Fig. 6—Casualty Gain as a Function of Individual Aiming Error for .22-cal Duplex Ammunition

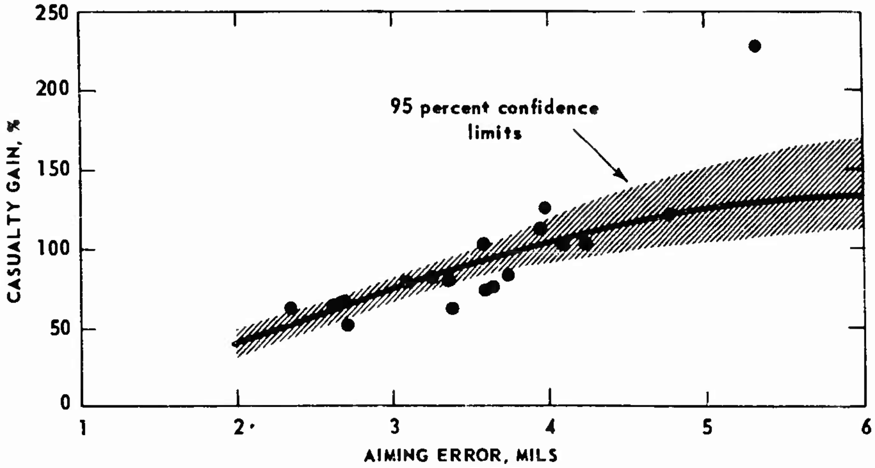

Fig. 7—Casualty Gain as a Function of Individual Aiming Error for .30-cal Triplex Ammunition

In that case differences in the relative hit probabilities between simplex ammunition and the first bullet of the duplex ammunition were attributed to lack of precision on the part of the latter. It was noted in the Board tests that at the range at which the rifles were zeroed (300 yd) and where one would expect hits to be equal the simplex ammunition got about 20 percent more hits than did duplex first bullets.*

TABLE 13

PRECISION CHARACTERISTICS OF SALVO II AMMUNITIONS

Ammunition	Mean radius of first-bullet ballistic error at 100 yd, in.	First-bullet hit probability[a]
.30-cal simplex (M2 ball)	1.5	.278
.30-cal duplex	1.6	.226
.30-cal triplex	2.2	.182
.22-cal duplex	1.8	.277

[a] The accuracy of these hit probabilities is subject to the previously mentioned problem of identifying first and second bullets but is considered to be a very good estimate. They also include ricochets.

When the SALVO II data were examined in detail it was found that at the zeroing range the same effect as that found in the Infantry Board test appeared. Duplex first-bullet hits at the zeroing range (165 yd) were about 20 percent less than simplex hits. In fact they were generally lower at all ranges. The ballistic data obtained by D&PS, APG were carefully examined.[14] In addition extensive ballistic tests under as close to SALVO II conditions as possible were conducted by Springfield Armory. Neither of these tests found large operational differences in ballistic precision among .30- or .22-cal duplex ammunition and .30-cal simplex (M2 ball) ammunition. The same slightly larger ballistic error for .30-cal triplex ammunition was observed in these tests.

As a result of these tests the SALVO II data were examined more closely. Again the problem of ricochets was encountered, and it was hypothesized that they explained the difference in hits at the zeroing range, i.e., 165 yd. Table 14 and Fig. 8 show the result of this analysis. Here it is evident that with ricochets removed, first-bullet hits for duplex and simplex ammunition are roughly comparable on the over-all target system. The .30-cal triplex hits are somewhat lower. Figure 8 is a more detailed examination, where the ratio of first-bullet hits with the salvo ammunitions, as compared with .30-cal simplex ammunition, is plotted as a function of range. Also shown are the 95 percent confidence limits of the .30-cal simplex data.

Two effects appear in Fig. 8. First it is evident that once ricochets are removed, .30-cal duplex first-bullet hit probabilities are closely comparable out to about 250 yd. The .22-cal duplex and .30-cal triplex ammunitions do not

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*This detailed result did not appear in the Infantry Board report and was obtained informally from the Board.

TABLE 14

RICOCHET HITS AND FIRST-BULLET HIT PROBABILITY

Ammunition	Ricochets, %	First-bullet hit probability (excl ricochets)
.30-cal simplex	16	.232
.30-cal duplex	6	.212
.30-cal triplex	7	.168
.22-cal duplex	15	.224

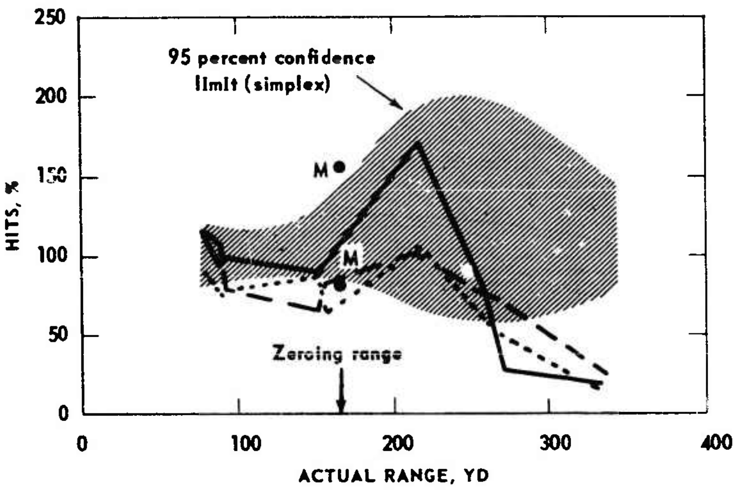

Fig. 8—Duplex and Triplex First-Bullet Hits, Excluding Ricochets, Relative to .30-cal Simplex Ammunition
——.30-cal duplex; — —.22-cal duplex; -----.30-cal triplex.

look so good. Between a range of approximately 100 and 160 yd the number of .22-cal duplex and .30-cal triplex first-bullet hits are low, and in this range they do not fall within the 95 percent confidence limits of .30-cal simplex (M2 ball) ammunition. Second the first-bullet hit probabilities of all the salvo ammunitions are significantly different from .30-cal simplex ammunition at the extreme range of the target system. Here the greater drop of the lighter and slower salvo bullets plus the limited instruction on hold-off given the firers becomes apparent. With respect to this effect, however, it must be remembered that hits at this range constitute a very small percentage of the total and that this percentage is compensated for by the second bullet. These data also indicate that what the Infantry Board observed at the range at which the rifles using .30-cal duplex ammunition were zeroed in their test was not primarily a difference in ballistic precision but a difference in ricochet characteristics. Hence the Board's recommendation that more work be done on "the combat accuracy" of the salvo ammunition is inappropriate if taken to mean improvement in ballistic precision.

Rate of Fire

The over-all rates of fire in SALVO II were about one-third greater than those in SALVO I. Although target-exposure times were reduced by one-third in SALVO II, about the same number of rounds (620 in SALVO I vs 660 in SALVO II) were fired per run. In SALVO II the median time to fire the first shot for all firers using all ammunition (excluding .22-cal simplex and flechette) was 2.8 sec; the median rather than the average is used since it avoids the extreme durations represented by clip-loading time, which cannot be distinguished from aiming and firing time. The median gives a good estimate of the time actually required to reaim and fire. A more detailed look at the time between shots showed that firers tend to fire more quickly at targets having a larger presented area (see Fig. C2). The median time between shots for targets 31 to 34, i.e., those having the smallest presented area, was 1.8 sec. For targets 5 and 7, those having the largest presented area, it was 1.2 sec. There was no observable effect of this type from the time of target appearance until the first shot was fired.

In the case of average time until the first shot was fired, SALVO II times were about one-half those computed for SALVO I—2.8 vs 5.3 sec. To compare time between shots in SALVO I and II averages were computed, and, as expected, SALVO II times were more than one-third lower than SALVO I, averaging about 1.9 instead of 3.5 sec. In addition late fire, i.e., fire that occurs after the target has gone down and has no chance of hitting, was less in SALVO II, constituting about 4 percent of the total fire vs 12 percent in SALVO I.

The reasons for these differences in rate of fire cannot be precisely defined, but several factors appear to contribute—two primary causes especially. First was the different background and training of the experimental troops. In addition to being test wise, as is mentioned in App A, their TRAINFIRE training was nearly ideal for the salvo target system. In TRAINFIRE emphasis is placed on identifying targets very similar to salvo targets, and, in addition, a certain amount of time pressure is placed on the firer. Hence a higher rate of fire would be expected than that for SALVO I firers who were trained on known-distance and transition ranges. The second major factor affecting the rate of fire was the number of weapon malfunctions. These are to some extent eliminated in the average figures for SALVO I given above, but they were so prevalent that it was impossible to eliminate them altogether. In SALVO II, on the other hand, there were essentially no malfunctions. Another minor contributing factor was the increased tempo of the target system on SALVO II. Since there was a larger number of 2-, 3-, and 4-sec targets, time pressure was more severe than in SALVO I.

The decrease in late fire can for the most part be attributed to an improved method for isolating this fire used in SALVO II. In SALVO I all fire that occurred after the target accepted a down signal was considered late fire. Using this same criterion 12.5 percent of the fire in SALVO II was late fire. Through an examination of the hit recording in SALVO II it was determined that the assumption that a target could no longer be hit at the moment it accepted a down signal was incorrect. Hits could actually be achieved and electronically recorded up to 0.4 sec after the down pulse was accepted by the target. Hence late fire in SALVO II was computed from the time the target accepted the down pulse plus 0.4 sec. On this basis it was found that late fire then accounted for about 3.5 percent of total shots fired and took place during a 0.6-sec interval. This latter period is less than half that reported in SALVO I, where late fire occurred, on the average, 1.27 sec after the target was supposed to have gone down.

There was visual indication that late fire may have been a somewhat greater factor in SALVO I than in SALVO II. There was very much less dust on the target system in SALVO II, and consequently it was easier to tell when a target had gone down. It must be concluded, however, that truly late fire in SALVO I was less than the 12.5 percent reported.

In addition to differing rates of fire as a function of target size, it was also observed that the rates of fire (both time to fire first shot and time between subsequent shots) of individual firers varied considerably. Both of these were compared with the computed aiming errors for each man. There was a very low correlation, a fact that indicates that for a given rate of fire no prediction as to accuracy can be made, i.e., because an individual fires rapidly it does not necessarily mean that he will get more or less hits per shot. The implication is that individuals tend to achieve some sort of natural rate of fire. Whether this is the best that an individual can do was not determined in this experiment.

TRAINFIRE, Army General Classification Test (AGCT) Scores, and Accuracy on Salvo Target System

The aiming error for each man was computed for the .30-cal simplex runs. These necessarily include ricochets. The aiming errors were then compared with the firers' TRAINFIRE scores. A relatively high correlation results, indicating that in general those firers who did well on TRAINFIRE also did well on the salvo system, (i.e., the higher their TRAINFIRE score the lower their aiming error). Results are shown in Table 15. Average values were experts, 2.5 mils; sharpshooters, 2.7 mils; and marksmen, 3.1 mils. (The over-all average noted earlier was 2.8 mils.) Since these values of aiming error are based on all hits including ricochets, the true absolute values are higher. If no significant bias exists among qualifications these values should be corrected by the over-all ratio 3.1 to 2.8.

The process above was also done for AGCT scores, and a lower but still significant correlation was observed. This indicates that intelligence as measured by the Army AGCT tests is also a factor in the individual's ability to do well on the salvo target system (the higher the AGCT score the lower the aiming error). These results are also shown in Table 15. Average values in the range of scores were from 117 to 131, 2.7 mils; 97 to 116, 3.0 mils; and 76 to 96, 3.0 mils.

TABLE 15

CORRELATION OF TRAINFIRE VS AGCT AIMING ERROR

Exercise	Aiming-error range, mils	Range of scores	Correlation coefficient	Residual variation, % of original variation
TRAINFIRE	1.97–3.70	41–83	−0.408	83
AGCT	1.97–3.70	76–131	−0.347	88

Learning

In SALVO I there was no discernible learning if hit probabilities alone were examined. When rates of fire and total hits were considered, however, it became obvious that learning, in the form of getting more fire on the target system, had occurred. The SALVO II experiment is extremely difficult to analyze from the point of view of learning. Where in SALVO I there were 3 weeks of firing under relatively stable weather conditions, in SALVO II there were 3 days of firing under widely differing weather conditions. As noted in Table 2, the weather on the second day of the experiment was very cold, and hence instead of the rate of fire increasing as the experiment continued, it actually decreased.

There is a negative correlation between run sequence and rate of fire and a positive correlation between temperature and rate of fire. The correlation coefficient between temperature and run sequence appears to be an entirely chance occurrence. Since weather was a chance occurrence, and yet has the highest value of any in the correlation, it obscures any learning that might have occurred. Learning is also obscured by other factors in the SALVO II experiment. As was mentioned before, the experimental subjects were used to this type of testing and were quick to exploit factors that might improve their score. There was a competition between the two squads for prizes distributed at the end of the experiment, and the squad scores, i.e., total shots, total hits, and hit percentages, were posted at the end of each day. The basis on which these prizes were to be awarded was kept secret from the experimental subjects, mainly because the experimenters could not decide whether total hits or hit probability was the better criterion. The troops, however, assumed, and assumed correctly, that hit probability would be the ultimate measure. Thus the emphasis, particularly on the last day of the experiment, was on making every shot count—another factor possibly tending to decrease the rate of fire.

The next alternative is to examine hit probabilities for effects of learning. This analysis is based on a sample of ten runs* spaced fairly evenly over the 3 days of firing. In two of the runs .30-cal simplex ammunition was used; in four .30-cal duplex ammunition was used; in two .22-cal duplex ammunition was used; and in two .30-cal triplex ammunition was used. In order to place all these runs on a common basis, only the hit probabilities of the first bullets from the salvo ammunitions were considered. Ricochets were removed from the analysis, as was done previously, in an additional attempt to make the runs more comparable. Using these data the hit probability was correlated with run sequence, shots, hits, and temperature. Only the run sequence and the number of shots fired had a significant correlation with the hit probability (see App D). The results of this multiple correlation indicate that hit probabilities do increase at the rate of about 0.3 percent per run. In addition it was found that the hit probability is negatively correlated with rate of fire. Hence learning in SALVO II, obscured to a very great extent by weather effects, takes the form of a decreasing rate of fire with an attendant increase in hit probability. This is opposed to SALVO I where learning took the form of an increasing rate of fire and a stable hit probability.

Target-System Effects

One important aspect of an experiment is how completely the variability in the results can be accounted for by the identifiable variables. The SALVO II targets were characterized by five variables: (a) exposure time, (b) angular or presented area, i.e., target radius divided by target range, (c) movement i.e., stationary or moving, (d) target size, i.e., E or F targets, and (e) target concealment or percentage of target visible. Targets firing back were so confused with the other five variables that they were not considered. The method used to measure the relative contribution of each variable was a multiple correlation analysis conducted on the ORO high-speed-computer facilities.

In Table 16 partial and multiple correlation coefficients show the sources of the observed variation for shots fired and simplex and first-bullet salvo hits for 16 analyzed runs. Table 16 shows the strong effect, as would be expected, of exposure time on shots fired. The second part of Table 16 shows that the five variables account for 76 percent of the variation observed in shots fired and that target-exposure time and angular or presented area both exerted a strong influence on hits. Here, as would be expected, the residual or experimental error is larger, the five variables accounting for 55 percent of the observed variation.

The analysis showed consistently that the most important variables in predicting shots fired were the target-exposure time and the presented angular area of the target. Moving targets attracted significantly more shots than did the stationary targets. In terms of either hits or casualties, the most important variables were shots fired at the target and the presented angular area of the targets (see Tables D14 and D15). Moving targets significantly decreased the number of hits or casualties obtained with simplex ammunition or with the first bullet of duplex or triplex ammunition (see App D). The latter tend to compensate for the effect of movement as is illustrated in Table 12.

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*Ten runs were selected since all the runs were not usable in this analysis, i.e., flechette and .22-cal simplex. Four runs were selected on the first day, two on the second, and four on the third.

TABLE 16

SOURCES OF VARIATION IN SHOTS FIRED AND IN SIMPLEX AND FIRST-BULLET HIT PROBABILITIES PER TARGET

Observed independent variable	Variance σ^2	Partial correlation coefficients	Percentage of variance remaining
	Shots Fired		
None	415.38	None	100.0
Exposure time Angular area Movement Target size Percentage of target visible	102.89	0.871	24.2
Angular area	369.16	0.334	88.9
Exposure time	140.72	0.813	33.9
Movement	381.79	0.284	91.9
Target size (E or F)	399.05	−0.198	96.1
Percentage of visibility	415.31	−0.013	100.0
	Simplex and First-Bullet Hit Probabilities		
None	73.30	None	100.0
Exposure time Angular area Movement Target size Percentage of target visible	33.84	0.741	45.1
Angular area	46.62	0.604	63.6
Exposure time	44.71	0.625	61.0
Movement	73.30	0.017	100.0
Target size (E or F)	71.24	−0.169	97.2
Percentage of visibility	70.95	0.180	96.8

The regression coefficients, which appear in the prediction equations, estimate the effect of a particular variable without any correction for the effects of the other variables. The use of three variables (target movement, target-exposure time, and the presented angular area of the target) to a very major extent predicts the number of shots that will be fired on any target appearance. If two additional variables—target size and degree of concealment—are added, the accuracy of the predicted value increases and the effects of the original three variables become more clear. With the use of five variables, the equation predicting the number of shots fired at a target appearance becomes

$$Y = 0.25 + 0.24X_1 + 3.16X_2 + 10.32X_3 - 4.52X_4 - 0.01X_5{}^* \qquad (1)$$

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*Not statistically significant at 95 percent confidence level (see Table D15).

where Y is the predicted number of shots for 10 men

X_1 is the presented angle of the target, in mils

X_2 is the target-exposure time, in seconds

X_3 is movement, 0 indicating a stationary target and 1 indicating a moving target

X_4 is a target size, 0 indicating an F-type target and 1 indicating an E-type target

X_5 is the percentage of the target face that is visible

The prediction equation for simplex and first-bullet hits is

$$X = -8.94 + 0.30X_1 + 1.19X_2 + 0.33X_3^* - 2.19X_4 + 0.06X_5 \qquad (2)$$

A practical application of Eqs. 1 and 2 for .30-cal simplex ammunition is as follows:

Assume that a 2-mil, 6-sec, stationary E-type target (at about a 200-yd range) is 100 percent visible. From Eq. 1, the expected number of shots by 10 men at this target is 14.17. From Eq. 2 the expected number of hits is 2.16, a hit probability of about 18 percent. Now make some arbitrary changes in the target. If the target size is increased to 4 mils, keeping all its other characteristics constant, the expected number of shots goes to 8.33 and expected hits to 0.83, or a hit probability of 10 percent. If the original target is used with an 8-sec exposure time and all other factors remain as stated, expected shots go to 20.49 and hits to 4.99, or a hit probability of 24 percent. On the other hand if the same target is moving, expected shots are 24.49, hits are 2.94. Thus hit probability for the stationary target is about 18 percent and for the moving target about 12 percent.

These illustrations of the use of the prediction equations indicate the applicability of SALVO II data to other possible target systems. The main restrictions on their use is that they tend to break down at, and will not extend beyond, the extreme conditions examined in the SALVO II experiment. It is noted that in the case of targets having very short exposure times and very small mil sizes a negative number of hits is predicted. This illogical result is simply the effect of simulating the distribution with a straight line.

DISCUSSION OF RESULTS

The major contributions of the SALVO II experiment are (a) to further confirm the predicted utility of duplex ammunition in combat rifle fire; (b) to indicate that duplex ammunition is ready for user test and adoption; and (c) to further validate the general salvo theory for duplex, triplex, and multiple flechette ammunition. It is interesting to examine the spectrum of results that were obtained in the ORO SALVO I and II experiments and the Infantry Board test of NATO duplex ammunition. Table 17 shows these results.

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*Not statistically significant at 95 percent confidence level (see Table D15).

Table 17 illustrates the relation between hit probability or accuracy and gain through the use of duplex ammunition. The lower the accuracy the greater the gain. The major question concerns the nature of combat rifle fire, i.e., its accuracy or hit probability. The SALVO I report[1] attempted to relate effectiveness gain measured under experimental conditions to combat fire. Its conclusion was that a conservative estimate of over-all gain from the use of duplex ammunition in combat would be 60 percent. A further ORO study[15] indicates that combat accuracies approximate those observed in SALVO I night firing, i.e., hit probabilities of about 5 percent. Hence a 60 percent gain is indeed a conservative estimate. The SALVO II experiment furnishes further basic and confirmatory data on which the SALVO I reasoning rests.

TABLE 17

SUMMARY OF DUPLEX AMMUNITION RESULTS: SALVO I AND II AND INFANTRY BOARD EXPERIMENTS

Experiment and firing condition	Accuracy (simplex hit probability), %	Relative duplex ammunition casualty gain (duplex-simplex/simplex), %
Infantry Board		
Transition semiautomatic	64	9[a]
TRAINFIRE	54	10[a]
SALVO I		
Day sitting	19	48
Day standing	15	49
Night sitting	6	69
SALVO II, day prone	28	32

[a] In Refs 12 and 13 target hits only are reported. However, the Infantry Board kindly furnished detailed data from which casualty gain was computed.

One factor not recognized in SALVO I and not previously recognized as being significant in combat rifle effectiveness was isolated in the SALVO II experiment—the importance of the ricochet characteristics of ammunitions. The best example of this is the difference in hits of .22-cal duplex ammunition compared with .30-cal duplex ammunition. Here a difference in total hits recorded of almost 10 percent is due directly to the superior ricochet characteristics of .22-cal duplex ammunition. This particular effect is worthy of further study. SALVO II ricochet data are limited in their application since they were derived from the soil conditions of Ft Benning and do not include lethality considerations. If it is found to be an effect that occurs under most conditions of combat rifle fire, it may be well worth while modifying .30-cal duplex or 7.62-mm NATO duplex ammunition for improved ricochet characteristics.

With respect to ricochets, a question was answered concerning the precision of the salvo ammunitions. The smaller number of first-bullet hits, as compared with simplex hits, noted both in the SALVO II raw data and in

Infantry Board tests had led to the tentative conclusion that somehow the salvo ammunitions were to a major extent ballistically less precise. This conclusion was shown to be false, and what actually was observed was a smaller number of ricochet hits on the part of the .30-cal duplex ammunition. For triplex ammunition this effect was also found. Although a statistical difference cannot be substantiated, .30-cal triplex first bullets do appear to reflect less ballistic precision.

In respect to the suitability of duplex ammunition the Infantry Board tests[11,12] indicate that there is little difference between .30-cal duplex and 7.62-mm NATO duplex ammunition. On the basis of the SALVO II experiment and these tests it is concluded that either ammunition is suitable for adoption for combat use.

In relation to the confirmation of the salvo theory, the triplex results and moving-target data are of great importance. In the case of moving targets, where aiming error is greater, the gains from the salvo ammunitions are correspondingly larger. This is also very well demonstrated in the multiple-correlation analysis. The over-all predicted gain of triplex ammunition in SALVO II is less than that for duplex ammunition. However, in situations where the aiming error is larger than that in SALVO II, and these situations constitute the very large majority of combat situations, predicted triplex ammunition casualty gain would be much higher than that using duplex ammunition. The SALVO II experiment confirms both these predictions. Triplex ammunition actually did achieve a lower over-all casualty gain. However, for the SALVO II firers having poorer accuracy, it was found that gain from triplex ammunition was on the average higher than that for duplex ammunition. This finding has implications for the future ammunition-development program. The triplex ammunition used in the experiment has inherent disadvantages. The major one is that in a conventional design the triplex bullet becomes too small and has too low a velocity—hence its failure to penetrate helmets beyond 200 yd. If there were no further competetive alternatives, further development of triplex ammunition would be justified. However, there are new developments that promise the same type of increase in effectiveness but with few of the inherent disadvantages. These are the various flechette configurations.

The implication of the triplex results for current flechette developments is that to achieve any real increase in effectiviness in the fire fight, i.e., in the period of intense fire with many targets, flechettes must be fired in a salvo pattern. The development of flechettes for small arms, which are fired singly (not in bursts) in the same way that .30-cal simplex ammunition is now fired, will achieve a substantial saving in weight. Radical increases in hit probability are not, however, to be expected from single flechettes. It is obvious that if a real increase in effectiveness is to be achieved development of flechettes must have as its primary goal the achievement of a salvo pattern either by an effective controlled burst or by simultaneous discharge of a bundle of flechettes.

The disappointing aspects of the SALVO II experiments were the failure of .22-cal simplex and the shotgun flechette ammunitions. The former was of minor importance but did represent a supplementary control on the experiment results. The flechette failure, however, has assumed the proportions of a minor tragedy. Considering the problems of design in an ammunition of this type and the development funds that had been allotted to the fabrication of this ammunition, a failure of the type encountered in SALVO II is not surprising. The ostensible risk involved in including the ammunition in the SALVO II experiment was merely that of the cost of procurement—a relatively small sum. The actual risk, as it turned out, was deemphasis of the development of multiple-launched flechettes. This was considered to be an unwarranted and unwise decision, particularly in the light of the triplex results above, since multiple launch was one of the most promising methods of achieving a flechette salvo pattern.

The differences in rate of fire in SALVO II vs SALVO I indicate that TRAINFIRE training apparently increased the rate of fire without decreasing firer accuracy. The SALVO II firers fired about one-third faster and got one-third more total hits. The increase came both from faster target identification and from less time taken to reaim and refire.

The over-all aiming error on SALVO II for .30-cal simplex ammunition was 2.8 mils, rising to 3.3 mils when ricochet hits were excluded. This was considered to be an upper bound on accuracy in combat rifle fire. It differs markedly with the accuracy that is standard on both the known-distance and TRAINFIRE courses (1 to 2 mils). The indication here is that although these courses may be excellent training devices the accuracies achieved on them are not appropriate for use as parameters in weapon design.

As for the target system and learning effects, certain differences between SALVO I and SALVO II were observed and other areas of uncertainty clarified. Learning in SALVO II, as far as it was observable, took the form of a decrease in rate of fire and an increase in hit probability. Multiple correlation also shows the overwhelming effect of angular target size, exposure time, and to a lesser extent movement.

Appendix A

PERSONNEL

DISCUSSION

The test subjects on the SALVO II experiment were all recent graduates of basic training. They arrived at Ft Benning, Ga., on 13 Sep 57 after less than a week in the Army and were assigned to Human Research Unit 3 of the Human Resources Research Office (HumRRO) for their basic training. In the course of this training they were given the standard TRAINFIRE I exercise, and in addition most of them were given experimental training called Patrol II and Moonlight XII. These experimental training procedures were designed to give the soldier squad training and also experience in seeing targets and rapidly taking them under fire. The troops had fired over 750 rounds apiece with the M1 rifle—536 rounds in TRAINFIRE I, approximately 200 rounds in Patrol II, depending on rapidity of fire, and 24 rounds in Moonlight XII. A summary of their training and marksmanship and Army General Classification Test (AGCT) scores is given in Table A1. In addition this table shows the previous experience of the men in target shooting or hunting as determined from interviews.

The men were apparently well motivated; they were used to being subjects in experiments and were very cooperative. They had been test troops and consequently were presumably somewhat better motivated and more familiar with experiments than their degree of training and marksmanship qualifications alone would imply. There was no evidence throughout the experiment, either as shown on the firing line or in the debriefings that were given after each run, that any were not trying or were uncooperative. All the men were in excellent physical condition.

Two 10-man squads were picked to be as comparable as possible: squad A consisted of 1 expert rifleman, 4 sharpshooters, and 5 marksmen; squad B consisted of 2 experts, 3 sharpshooters, and 5 marksmen. This distribution approximated that found in the basic training unit. As a precaution four other men were kept as reserves; however, it was not necessary to use any of them. On the TRAINFIRE I record firing, the median score for squad A was 55 and for squad B, 53; the median AGCT scores were 100 and 99.5, respectively.

Based on more than 800 TRAINFIRE cases the percentage of men in each marksmanship category was unqualified, 0.5; marksman, 21.0; sharpshooter, 51.0; and expert, 27.5. For 20 men this resulted in percentages of 0, 4, 10, and 6 respectively. The troops used in the SALVO II test were not as good in their TRAINFIRE I record firing (0, 10, 7 and 5 percent) as the troops previously assigned to the Human Research Unit on which these percentages were based.

After the first run each man was interviewed individually; subsequently the men were interviewed together in their squad. They were asked specific questions and also invited to make any comments on any features that seemed relevant to the experiment. As the men became used to the experiment, their subjective reactions altered and consequently the initial report may be misleading. For example, the men were required to run for 5 min preceding the firing and they tended to be puffing and blowing; their first report stressed the undesirability of this stage for careful firing, but subsequently, as they fired in colder weather, they felt that the running warmed them and, if anything, improved their performance.

TABLE A1

TRAINING AND EXPERIENCE FOR SALVO II TEST SUBJECTS

Firer	TRAINFIRE I qualification score[a]	AGCT score	Patrol II training[b]	Moonlight XII training[c]	Previous shooting experience[d]
Squad A[e]					
1	83	97	C	DOD	H
2	67	96	E	DOA	H
3	61	124	C	DOD	None
4	62	96	E	DOA	H
5	57	120	E	DOA	None
6	53	131	C	DOA	s
7	53	97	E	DOD	None
8	51	110	None	DOA	s
9	51	103	None	None	H
10	41	93	None	DOA	L
Squad B[e]					
1	79	87	C	DOD	S
2	72	81	C	DOD	H
3	60	101	None	None	H,S
4	61	76	C	DOD	L
5	54	117	C	DOA	H
6	52	110	E	DOD	None
7	51	95	C	DOD	None
8	51	117	E	DOD	None
9	46	98	None	DOD	L
10	41	117	C	DOD	s

[a] Unqualified, 35 and below; marksman, 36 to 53; sharpshooter, 54 to 57; expert, 58 or more.

[b] C, standard training; E, experimental training.

[c] DOD, double orientation on defense; DOA, double orientation on assault.

[d] H, much hunting prior to service; L, some hunting prior to service; S, much target shooting prior to service; s, some target shooting prior to service.

[e] Firers A3, B6, B8, B9, and B10 wore glasses. The others had normal uncorrected vision.

The most important conclusion that can be drawn from the report of the men is how little they felt their accuracy was affected by the experimental stresses. Questions on fatigue, effect of electric shock, battle noise, and explosions in the area all tended to elicit the same reaction: the men were not even aware of these stresses most of the time. The low temperature, snow, and rain did, in their opinion, adversely affect their scores, and they also complained about the heavy recoil of the shotgun. As the experiment went on, the weight of the weapons was a source of comment.

The following are the reported reactions:

(a) Did the running affect your performance?

Initial reaction (temperature and wind less cooling than later): tired—no effect, 25 percent; not tired, 50 percent; tired—some effect, 25 percent.

Subsequent reactions were almost 100 percent in favor of running to keep warm.

(b) Did the shock on the leg or fear of it affect your performance?

Initial reaction: shock affected performance, 5 percent; fear of shock affected performance, 5 percent; no effect from shock or anticipation, 90 percent.

Subsequent reactions even further degraded the effect of shock on the leg. An initial problem of shock from the triggers of three rifles had no effect.

(c) Did the battle noise or demolitions in the field affect your performance?

Initial reaction: some small distraction, 50 percent; no effect, 50 percent.

Subsequent reactions did not report degradation.

(d) Did the small explosions right next to the firing line have any effect?

Initial and subsequent reactions: not aware of them, 100 percent.

(e) Did the recoil have any effect?

Initial reaction to the different rifles and ammunition: no different than what used to, 90 percent; duplex and triplex ammunition slowed rate of aimed fire, 10 percent.

Subsequent reactions indicated that the men felt that all the rifles had approximately the same degree of recoil, although the shotgun was very different from the rifles and, as mentioned, all complained about the heavy recoil. One man stated that he flinched. All had somewhat sore shoulders from the shotgun. It is of interest to note that the feeling that the salvo rounds slowed the rate of fire is not borne out by the actual results.

(f) Did the cold have any effect on your performance?

Initial reaction: no effect, 10 percent; effect on loading only, 60 percent; effect on loading and squeezing, 5 percent; uncertain or didn't think of it, 25 percent.

Subsequent reactions depended very much on the state of the weather. In general loading was affected, but squeezing was affected only when the men were shivering. Most of the men wore gloves on the hand that supports the rifle but not on the loading hand. Questions were asked concerning the target system in order to determine whether the men were seeing all the targets from their positions, the effects of camouflage, and whether they reacted fast enough to fire at those targets that were up for only a short time. In general they could see all targets and reacted to them. Since an objective record of their trigger pulls is available, no summary of their subjective impressions is given. An attempt was made to get their reaction to the target system; the most common report was that they couldn't tell whether they were hitting the targets because they stayed up and also because the dust from other firers' bullets made their own point of impact difficult to discern. This reaction apparently persisted. Another recurring source of complaint dealt with the bank from which they fired; all the men at least once complained of tiredness in the arm that held the rifle. They felt that firing from a foxhole would have permitted them to get a better score.

The subjective reaction of the firers to the weapons and ammunition was explored with mixed results. Before the experiment was about halfway through they preferred the .22-cal duplex ammunition to the other rounds; later they stated that they preferred .30-cal to .22-cal ammunition and simplex to duplex ammunition. Probably the scores of the different weapon-ammunition combinations that were posted on the trailer influenced their reactions, and the relief of firing the rifle after the shotgun also influenced them. Some of their stated reasons, e.g., that the .22-cal duplex seems "to leave the weapon smoother than the .22-cal simplex," are difficult to understand. The major conclusion is that there is almost no difference in the rifles with respect to the individual's feeling but that the reported differences are the product of extraneous factors. One possible cogent point was made comparing duplex with simplex loads: it is easier to tell where one's bullets are going with the simplex than it is with the duplex.

All the men were dissatisfied with the shotgun. Fourteen had fired shotguns before.

During the test it became clear that the .22-cal duplex ammunition was recording higher scores than any other weapon-ammunition combination, and an attempt was made to determine whether there were any subjective reasons for this. Only 10 percent of the firers reported any difference in recoil, and this was felt to be minor. The men were unable to give any reason for the better performance of the .22-cal duplex ammunition. The effects of the factors in Table A1 are discussed in the main body of this memorandum.

Appendix B

WEAPONS AND AMMUNITION

FIGURES

TABLES

WEAPONS

The weapons used in the SALVO II test were:

(a) Standard M1 rifle firing .30-cal simplex [M2 ball and armor-piercing (AP)] and duplex ammunition.

(b) M1 rifle with specially rifled barrel for firing .30-cal triplex ammunition.

(c) M1 rifle with .22-cal barrel.

(d) M1 rifle with .22-cal barrel modified to accept .22-cal longneck duplex cartridges.

(e) Remington Model 11-48A shotgun with four stiffening ribs on the barrel and an aperture sight.

Table B1[16,17] lists the characteristics of the various versions of the M1 and the shotgun used in SALVO II. All weapons were supplied by Springfield Armory.

TABLE B1

CHARACTERISTICS OF SALVO II TEST WEAPONS[16,17]

Characteristic	Weapon				
	M1	M1 (triplex)	M1 (.22-cal simplex)	M1 (.22-cal duplex)	Shotgun
Grooves	4	4	4	5	Smooth
Rifling twist	1/10	1/20	1/9.68	1/14	None
Weight, lb	9.6	9.6	9.6	9.6	9
Clip or magazine capacity	8 rds	8 rds	8 rds	8 rds	4 rds in magazine; 1 rd in chamber

The standard and modified M1's were tested for dispersion at D&PS, APG, and all proved to be comparable to standard-issue M1 rifles under test conditions (bench rest at an average rate of 2 rounds/5 min). Owing to unexpected results in the experiment, the weapons were retested by D&PS under rapid-fire conditions (bench rest at 10 rounds/min), and the .22-cal simplex rifle-ammunition combination proved to have radically higher dispersion than any of the other rifle-ammunition combinations.

No particular differences were observed in the operation of any of the versions of the M1. In contrast to SALVO I, malfunctions were not a serious problem; there were only 20 minor rifle malfunctions during the experiment in which about 13,000 rounds were fired. Some small differences were observed in the recoil of the weapons, but this is more properly a function of

TABLE B2

BALLISTIC DATA FOR SALVO II AMMUNITIONS[16,18]

Characteristic	.30-cal simplex		.30-cal duplex	.30-cal triplex	.22-cal simplex	.22-cal duplex	12-gage 32 flechette
	M2 ball	M2 AP					
Bullet wt, grains	152	163	96	61	63	50	13
Propellant wt, grains	50	53	53.5 (no separation charge)	53 (1.5 grains between first and second bullet)	54.4	53 (1.0 grains between first end second bullet)	30
Case wt with primer, grains	190	190	190	190	207	196	169
Total cartridge wt, grains	390	414	435	427	322	352	738
Muzzle velocity, ft/sec							
First bullet	2750	2760	2591	2820	3540	2926	1423
Second bullet	--	—	2448	2664	—	2849	—
Third bullet	—	—	—	2170	—	—	—
Recoil energy, ft/lb	9.5	10.9	12.1	11.6	4.09	5.7	15.4

TABLE B3

AVERAGE ACCURACIES[a] FOR WEAPON SYSTEMS FIRED FROM A MACHINE REST[14,17]

Ammunition[b]	Single bullet		First bullet		Second bullet		Second and third bullets	
	Mean radius, in.	Extreme spread, in.	Mean radius, in.	Extreme spread, in.	CEP,[c] in.	Extreme spread, in.	CEP,[c] in.	Extreme spread, in.
.30-cal simplex[d] (M2 ball and AP)	1.5 (approx)	—	na[e]	na	na	na	na	na
.30-cal duplex	na	na	1.6	5.5	11.2	19.0	na	na
.30-cal triplex	na	na	2.2	7.2	na	na	9.5	24.4
.22-cal simplex[f]								
Mann barrel	0.3	2.2	na	na	na	na	na	na
Rapid-fire .22-cal M1	7.0	26.4	na	na	na	na	na	na
.22-cal duplex	na	na	1.8	6.0	9.6	20.1	na	na

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[a] Measured in inches at 100 yd by Frankford Arsenal except for the simplex ammunition, which had met the standard Army acceptance test.

[b] These measures not applicable for the 12-gage-shotgun 32-flechette ammunition. Accompanying text presents data for the 10- and 30-yd test firing.

[c] Circular probable error.

[d] This ammunition met the standard requirement—average mean radius of shots from accuracy barrel not greater than 6.5 in. at 500 yd.

[e] Not applicable.

[f] Results of special text conducted by D&PS, APG.[14]

the ammunition and is discussed in that section. All weapon-ammunition combinations except the shotgun were zeroed individually, and each firer used the same set of weapons throughout the test.

In contrast to M1 operation, malfunctions were numerous in the shotguns. Most were feed or ejection failures, which may have been due to modification of either the barrel (stiffening ribs were added, which increased the weight to be moved rearward by the recoil-operated action) or the chamber (a straight shoulder at the forward end replaced the usual tapered forcing cone). The frequency of malfunctions precluded the use of the shotgun magazine, a problem further compounded by the 25 to 30° F temperature that made single loading very difficult. It was also apparent that the "pointing" type of stock of the shotgun made it more difficult to fire from the modified prone position than the M1.

AMMUNITION

The special ammunitions developed for the test were:

(a) .30-cal duplex (controlled-dispersion type), which differed from that used in SALVO I in that it used a case of standard dimensions that fit the standard M1 chamber.

(b) .30-cal triplex (random-dispersion type), which also used a case of standard dimensions.

(c) .22-cal simplex.

(d) .22-cal duplex (controlled-dispersion type) in necked-down .30-cal cartridge.

(e) 12-gage-flechette shotgun ammunition containing 32 fin-stabilized steel darts 1.25 in. long.

(f) .30-cal simplex (M2 ball and AP) ammunition was used for purposes of comparison with the above ammunitions.

The ammunitions are shown in Fig. 1, and Table B2[16,18] lists ballistics data. Table B3 gives average weapon-system accuracies, and helmet-penetration data are given in Table B4.

TABLE B4

HELMET PENETRATION[14]

Ammunition	Marginal-penetration range, yd
.30-cal simplex (M2 ball)	500
.30-cal duplex	400
.30-cal triplex	200
.22-cal duplex	400
.22-cal simplex	900
12-gage 32 flechette	200

Following is a discussion of the observations of ammunition behavior during the experiment.

.30-cal Simplex (M2 Ball). This ammunition functioned satisfactorily throughout the experiment.

.30-cal Simplex (M2 AP). This ammunition was erroneously delivered to the experiment site and was used to avoid a delay in the test program. It was used on runs 11 and 12 and functioned satisfactorily, although it caused more electronic target malfunctions owing to breakup of the jacket on impact.

.30-cal Duplex (Controlled Dispersion). The major way in which this ammunition differed from that used in SALVO I was that it was contained in a standard .30-cal M2 cartridge case. Figure 1 in the main body shows that the second bullet is seated in the powder and that no modifications of the rifle chamber are necessary. This ammunition functioned satisfactorily throughout the experiment.

When it was determined that the first bullet of the duplex ammunition achieved significantly fewer hits at the zeroing range than the simplex ammunition, the whole problem of ballistic accuracy was reexamined. Postulating that perhaps some effect similar to that caused by barrel heat in the .22-cal simplex was to blame, Springfield Armory retested the duplex ammunition. It was shot by expert firers using the SALVO II rifles at the same rate of fire that occurred in the SALVO II experiment. The results of this test were negative in that they showed: (a) although dispersions became slightly larger for the first bullet of the duplex ammunition when the weapon was heated, it was not a large enough increase to explain the lower number of hits achieved, and (b) although the center of impact for duplex ammunition shifted down in a hot weapon, an effect of the same magnitude was observed in simplex firing. These results were obtained informally from the Springfield Armory.

.30-cal Triplex (Random Dispersion). This ammunition is much like that fired in SALVO I (which is described in detail in ORO-T-378[1]) but lacks the long-necked case. It functioned satisfactorily throughout the experiment.

.22-cal Simplex. Because of the higher velocity, flatter trajectory, and lower recoil for this ammunition, it was expected to record more target hits than .30-cal simplex (M2 ball). In addition Mann-barrel and limited weapon firings indicated a relatively high ballistic accuracy for the ammunition-weapon system. As a result there was considerable consternation and surprise when it was observed that the .22-cal ball ammunition achieved scores much lower than .30-cal ball ammunition. During the experiment the conditions under which this ammunition was fired were carefully examined and ascertained to be very similar to the conditions under which the other ammunitions were fired. There seemed to be no reason attributable to the experiment itself that would explain the relatively poor showing of the .22-cal simplex round. Consequently after completion of the SALVO field test ORO requested that this ammunition be rechecked by D&PS, APG for ballistic accuracy at a rate of fire comparable to that of the SALVO II experiment.

Although only one of the test weapons was subjected to a rate of fire approaching that of the field experiment, the results of these tests offer the likely explanation for the anomalous experimental data. Dispersion appeared to increase as the temperature of the barrel increased. The single weapon subjected to a satisfactory rechecking produced a 100-yd 10-round group having a mean radius of 1.5 in., which represents a σ of 0.3 mil (about average for new .30-cal M1 rifles) when fired at a rate of 1 round/2 min. When the firing rate was increased to 10 rounds/10 min, the mean radius increased to 8.7 in., a σ of 1.9 mil. An increase to 10 rounds/5 min resulted in one round missing the 8- by 8-ft target, and a further increase to 50 rounds/7 min resulted in 2 rounds missing the target. Two of the remaining rifles, which were not rechecked as intensely, failed in two instances each to keep all rounds on the target when fired at a rate of 10-rounds/10 min. A considerable variation among weapons was observed under similar rates of fire, possibly caused by a change in condition of the bore. It was observed that the chromium plating had separated from the bore at several points on these rifles, and, although the affected areas were small, this appeared to be sufficient to affect dispersion. The ammunition performed well in Mann-barrel firings, yielding an average mean radius of 0.5 in. and an average extreme spread of 1.5 in. The bullet jackets were quite fragile and may have tended to break up in flight when fired at high velocities from rough bores that were not uniform in diameter.

The ballistic errors observed in the .22-cal weapon-ammunition combination, when compared with those of the other weapon-ammunition accuracies, appear definitely large enough to explain its poor showing.

This ammunition also had seven failures to extract because of sheared cartridge rims.

.22-cal Duplex. In construction and muzzle velocity this ammunition is very similar to the .30-cal duplex ammunition used in SALVO I. Both employ the long-necked cartridge and a special long chamber. The main difference in the SALVO I and II .30-cal duplex ammunition and the SALVO II .22-cal duplex is in the weight and velocity of the bullets. This ammunition functioned satisfactorily throughout the test.

12-gage 32-Flechette Cartridge. This ammunition was essentially the same as the flechettes fired in SALVO I. The minor changes were: (a) the 1.25-in. flechettes were given a bronze coating; (b) they were observed to be very slightly longer (approximately 0.02 in.) than those used in the SALVO I round; (c) the front closure was made of a light and very frangible material in contrast to the rather tough plastic closure used in the SALVO I round; and (d) the four sabots holding the flechettes in a uniform pattern were made of molded plastic rather than a milled fiber material. The following observations concerning the ammunition were made in the field:

(a) The frangible closure disc was broken on many of the rounds of ammunition, presumably from rough handling during shipping. To eliminate possible erratic behavior from this source, ammunition was sorted and only unbroken rounds were fired. It was probable, however, that considerable breakage of closure discs occurred in the weapon as the shells were seated in the chamber by the recoil-operated action of the shotgun. This has since been confirmed by tests at D&PS. When this occurs, the 16 center flechettes slide forward out of the shells as much as ⅛ in.

(b) The 4 plastic sabots tended to hold the outer 16 flechettes in the sabots themselves in 4 groups of 4 flechettes each. This effect may have been accentuated by the low temperatures and thermal contractions occurring during the SALVO II tests. Some shells were disassembled, and it was observed that a violent movement was required to dislodge the four flechettes from each sabot.

The rechecking of SALVO II test materiel by D&PS included investigation of both these effects. Data obtained from 5 rounds carefully loaded into the chamber to avoid displacement of the flechettes demonstrated no appreciable effect on dispersion. Ten rounds in which the 16 center flechettes were colored for identification in the target pattern failed to show any effect from the possible failure of the outer flechettes to detach from the sabot.

The rounds and the weapons were crude prototypes, and their combined performance was too erratic to derive firm conclusions regarding potential effectiveness. Dispersion was poorly controlled, and because of recording difficulties the determination of total error was not possible from the experimental results. Extensive check firing was conducted by D&PS following the test in an attempt to obtain dispersion data to a range of 400 yd, but satisfactorily complete patterns were obtainable only at 10 and 30 yd. The mean radial dispersion in mils for 105 rounds fired at 30 yd was calculated to be 17.1 mils; for 10 rounds fired at 10 yd it was 15.3 mils. Erratic stabilization delays make the dispersion a function of range for a considerable distance from the muzzle.

In three of the four flechette runs positive identification of flechette multiple hits in SALVO II was possible on only three targets. Electronic-recording and target-face counts were supplemented by motion-picture records taken during firing on the three targets. Single and multiple hits were resolved by association of time-of-flight data with electronic records from trigger switches.

Table B5

SALVO II Hit and Casualty Data[a] for 12-gage 32-Flechette and .30-cal Simplex Ammunition

Run	Target	Rounds fired	Hits	Hits per round	Hits per pound of ammo	Casualties per round	Casualties per pound of ammo
			12-gage 32-Flechette Ammunition				
17	10	30	13	0.43	4.11	0.15	1.40
	14	16	5	0.31	2.97	0.10	0.96
18	7	14	8	0.57	5.40	0.17	1.56
	10	30	18	0.60	5.69	0.20	1.92
	14	11	1	0.09	0.86	0.03	0.30
23	7	23	8	0.34	3.30	0.12	1.16
	10	20	7	0.35	3.31	0.12	1.10
	14	18	2	0.11	1.05	0.04	0.37
Avg		20	7.8	0.35	3.34	0.12	1.10
			.30-cal Simplex				
1a	10	60	39	0.65	11.50	0.42	7.43
	14	24	8	0.33	5.92	0.23	4.15
2a	7	47	26	0.55	9.81	0.39	6.87
	10	56	31	0.55	9.81	0.39	6.87
	14	20	11	0.55	9.73	0.38	6.81
11	7	54	21	0.38	6.88	0.27	4.82
	10	65	22	0.33	5.99	0.24	4.20
	14	33	7	0.21	3.76	0.15	2.63
Avg		49	20.6	0.42	7.90	0.31	5.47

[a] Derived from cameras and target-face counts.

Using these limited data, casualties per round and per pound of ammunition were calculated for these three targets and compared with similar data for the .30-cal simplex (M2 ball) ammunition that served as the experimental control. These data are presented in Table B5.

Although the dispersion of the SALVO I flechette ammunition is not precisely known, it was estimated at about 9 mils, or the same as that used by Sterne[2] in his original firings. The cause of this 80 percent (9- to 16-mil) increase in dispersion of the SALVO II ammunition has not been determined. However, it is obvious that flechette ammunition, if dispersion can be controlled, did not receive a conclusive examination in either SALVO I (limited ammunition) or SALVO II (excessive dispersion). Hence, predictions concerning the increased effectiveness of this type of ammunition must remain largely theoretical.

LETHALITY

A complete discussion of the lethality criteria used in evaluation of the SALVO I results are found in App B of ORO-T-378.[1] The same criteria were used in SALVO II. The lethality values, as determined by Edgewood Arsenal and the Ballistics Research Laboratory (BRL), APG, are the same for .30-cal simplex (M2 ball), .30-cal duplex, .30-cal triplex, and flechette ammunition as those used in SALVO I. It was also determined by Edgewood Arsenal that .22-cal simplex and .22-cal duplex ammunition do not differ materially from those of the other ball ammunitions used in the experiment. In view of this, a composite lethality figure of 0.70 is used for ball projectiles and 0.35 for flechettes.*

SIGHT SETTING

As in SALVO I, the sight setting for SALVO II was selected to maximize the number of hits on the target system. This setting was obtained by computing total miss distances for the expected number of projectiles fired on the target system as a function of various sight settings. The sight setting that minimized this total miss distance was selected as that to be used for the various weapons. The process is described in detail in App M of ORO-T-378,[1] but two minor changes were made in the SALVO II application: (a) instead of predicted values for number of shots fired at each range, actual values obtained in the SALVO I experiment were used, and (b) a correction was made in the calculations to account for the vertical separation of the sights and the barrel. The basis for this correction is outlined in the following three equations and is seen graphically in Fig. B1.

$$(l - h - H) = \tfrac{1}{2} g \, (r / V)^2 \qquad \text{(B1)}$$

$$(l - h = \tfrac{1}{2} g \, (R / V)^2 \qquad \text{(B2)}$$

$$l / r = L / R \qquad \text{(B3)}$$

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*Triplex ammunition is reduced to 0.70 (1–0.18) to account for helmet-penetration failure beyond 200 yd (see App B of ORO-T-378[1]).

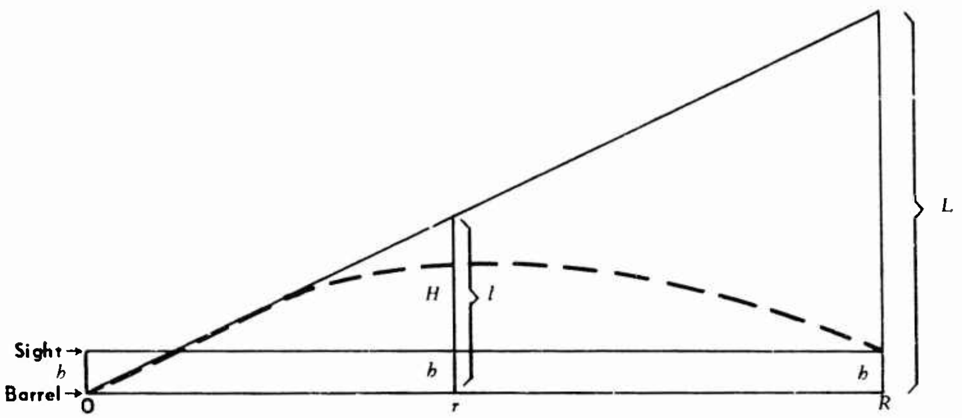

Fig. B1—Diagram of Method Used to Correct for Effect of Separation of Barrel and Sights on Zeroing Precision

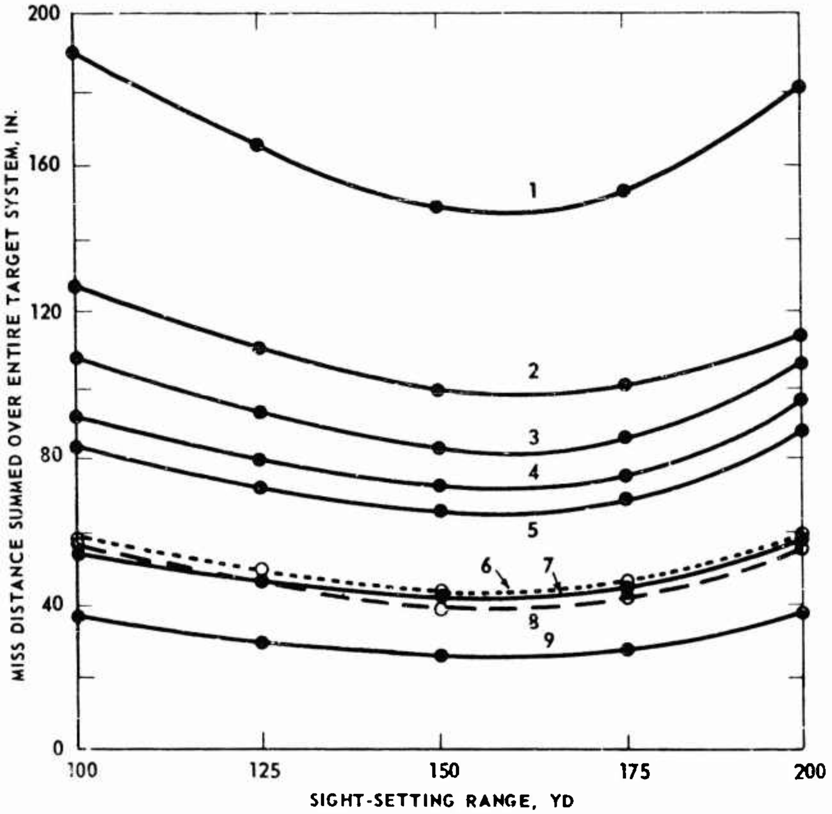

Fig. B2—Miss Distance as Function of Sight Setting on SALVO II Target System

(1) .30-cal triplex (third bullet)
(2) .30-cal triplex (second bullet)
(3) .30-cal triplex (first bullet)
(4) .30-cal duplex (second bullet)
(5) .30-cal duplex (first bullet)
(6) .22-cal duplex (second bullet)
(7) .30-cal simplex (M2 ball)
(8) .22-cal duplex (first bullet)
(9) .22-cal simplex

where l = distance from line of flight without gravitational drop at N
h = vertical separation of barrel and sights
H = miss distance from point of aim at r
L = distance from line of sight without gravitational drop at R
r = 75 yd—actual range at which weapons were zeroed
R = 160 yd—range for which weapons were zeroed
g = gravitational acceleration
V = muzzle velocity of projectile

This method made it possible to determine accurately the center of impact for the test ammunitions, considering only the first projectile in the duplex and triplex rounds. Required distance of the impact point above the aiming point at the 75-yd actual zeroing range and the required "hold-off" for 300 yd were calculated. The firers were instructed prior to each run to use the appropriate hold-off for distant targets. These are presented in Table B6.

TABLE B6

DIFFERENCE BETWEEN AIMING POINT AND CENTER OF IMPACT FOR SALVO II TEST AMMUNITIONS

Ammunition	Center of impact above aiming point at 75 yd, in.	Center of impact below aiming point at 300 yd, in.
.30-cal simplex (M2 ball)	1.7	14.4
.30-cal duplex[a]	2.1	24.2
.30-cal triplex[a]	2.1	36.1
.22-cal simplex	1.0	8.6
.22-cal duplex[a]	1.5	15.8

[a] First bullet.

In Fig. B2 total miss distance on the target system is computed as a function of various sight settings. It can be seen that miss distances were minimized for all projectiles at just less than 160 yd (SALVO I sight setting was 165 yd), and also that between 100 and 200 yd miss distances were not sharply sensitive to sight settings. A more recent study[19] is based on maximizing the net offset hit probability. That criterion is in general agreement with the method described above but tends to yield slightly lower optimum zero range. It is interesting to find that effects that have often been considered to be major differences contribute such a small amount to operational inaccuracy.

WEAPON MALFUNCTION

These data were collected with the assistance of Thomas Cairns and Robert Hoar of the Springfield Arsenal, who assumed full responsibility for sight adjustment, issue and receipt of weapons, emergency service on the firing line, and regular servicing and maintenance of the weapons during the entire test. Considerable difficulty was initially encountered from the recording switches mounted in the trigger assembly of the test weapons. The faulty switches produced an unsatisfactory signal, making resolution and identification of individual shots impossible. Inspection of the switches revealed that the metal in the switch spring was of such poor quality that after a few shots it failed to return the mechanism to the original position. New springs were fabricated at the test site, and virtually no further trouble was encountered from this source.

Weapon malfunctions by run, weapon number, ammunition, and nature of the failure are listed in Table B7.

TABLE B7

WEAPON MALFUNCTIONS IN SALVO II[a]

Run	Weapon no.	Ammunition	Malfunction		Remarks
			Type	No.	
1	6097318	.30-cal simplex (M2 ball)	POR	1	—
8	6097298	.30-cal triplex	POR	2	—
5a	6097298	.30-cal triplex	POR	2	—
14	6094878	.22-cal simplex	BFH	1	—
14	6094548	.22-cal simplex	FX	1	Rim sheared
15	6097984	.22-cal duplex	BFH	2	—
16	6099100	.22-cal duplex	BFH	3	—
19	6099085	.22-cal duplex	FJ[b]	1	Clip failed to eject
21	6097189	.22-cal simplex	FX	1	Rim sheared
21	6094548	.22-cal simplex	FX	1	Rim sheared
21	6095916	.22-cal simplex	FF	1	—
21	6095916	.22-cal simplex	FJ[b]	1	Clip failed to eject
21	6096102	.22-cal simplex	BFH	1	—
22	6094489	.22-cal simplex	FX	3	Rim sheared
22	6097189	.22-cal simplex	FX	2	Rim sheared
22	6096096	.22-cal simplex	FF	1	—
22	6097254	.22-cal simplex	FF	1	—
4a	6099379	.30-cal duplex	FF	1	—
2a	6090333	.30-cal simplex (M2 ball)	BFH	1	—
1a	6096125	.30-cal simplex (M2 ball)	POR	1	—

[a] Excluding flechette weapons.

[b] Failure to eject.

Malfunctions are classified in the accepted categories established by Ordnance specialists. These are:

(a) POR, partial override; bolt slips over the rounds to be chambered and jams.

(b) BFH, bolt not fully home and fails to complete forward movement. This type of failure is nearly always cleared immediately by the firer hitting the bolt handle lightly with the heel of his hand.

(c) FX, failure to extract. In this experiment there were several instances when the .22-cal simplex ammunition caused extraction difficulty due to the cartridge rim shearing from the case.

(d) FF, failure to feed. This type of malfunction was most prevalent in the flechette weapons. A possible explanation was the damping effect on the normal recoil action of the four stiffening ribs welded to the barrel. The additional weight may have reduced the recoil effect sufficiently to cause the numerous incomplete ejections and associated feed failures.

Table B7 includes no data for the flechette weapons. Feed and ejection failures were so numerous that no accurate count could be made. It was observed that many of the firers became so accustomed to ejection failures that had to be manually cleared that they checked the guns after each shot. The end result was that they did not bother to fill expended magazines, preferring to load singly since the action is designed to remain open when the magazine is empty.

Mr. Cairns and Mr. Hoar, the Ordnance specialists stated that in most instances weapon malfunctions other than those resulting from sheared cartridge rims resulted in the loss of only one shot. They also reported that their observations, plus inquiries directed to the malfunction-signal-switch operators, indicated that no shots were fired while the malfunction signal was being transmitted.

Appendix C
DATA REDUCTION

FIGURES

TABLES

SUMMARY

Seven kinds of data were recorded in the SALVO II experiment: (a) bullet holes in the paper target faces, (b) ammunition expended per man per run, (c) continuous recording of rounds fired at each position, (d) continuous recording of bullet hits on each target, (e) malfunctions occurring in the target system, (f) weapon malfunctions, and (g) conditions of weather and light.

In addition a close-up 16-mm photographic (gun camera) record was made of the targets during the time they were under fire on the flechette runs, and an automatically controlled lapsed-time camera photographed the entire firing fan during each run. Subjective information concerning firers was collected in postrun interviews.

Bullet Holes Counted

At the beginning of each run the targets were covered with paper faces, each of which was clearly identified by run and target number. The faces were removed at the conclusion of each run, and the holes were counted and identified as internal or edge holes, since holes at the edges might have failed to be counted by the electronic instrumentation. Ricochets, identified by their characteristically elongated holes, were also included in the totals. Hits, shots, casualties, and multiple hits per run are listed in Tables C1 to C16 by firer and target. Ricochets and total hits are listed by ammunition in Table C17.

Ammunition Expenditure

The second kind of data was taken by simply counting the issued ammunition at each firing position at the start of each run and subsequently counting the unexpended ammunition at each position immediately following the run.

Shots Recorded

The continuous recording from the Esterline-Angus recorder provided a permanent record of trigger action at each firing position. This includes late shots and shots between target appearances.

Hits Recorded

By means of the Esterline-Angus record it was possible to resolve multiple-bullet hits from duplex and triplex rounds and thus to distinguish among single and multiple hits per trigger pull (potential overkills), as well as tallying the total number of hits. However, some ricochets failed to record, and many of the flechette salvos saturated and shorted the recording mechanism. A listing of hits, shots, casualties, hit probabilities P_H, and casualty probabilities P_C per firer (except for .22-cal simplex and flechette ammunition) appears in Tables C18 to C21.

TABLE C1

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 1A BY SQUAD A USING .30-CAL SIMPLEX (M2 BALL) AMMUNITION

Tgt	6	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total
Man																							
1	1 [illegible] -	2 0.94 0.66	2 1 0.70	6 5 3.50	6 4.72 [illegible]	2 0 -	1 0 -	3 1 0.70	5 1 0.70	6 3 2.10	8 6 4.20	1 0 -	1 1 0.70	2 1 0.70	2 0 -	1 1 0.70	3 2 1.40	1 1 0.70	7 0 -	1 0 -	1 0 -	3 0 0	65 28.66 20.06
2	1 0 -	[illegible] 0.42 0.29	1 0 -	6 1 0.70	6 1.12 0.78	3 1 0.70	1 0 -	3 0 -	4 1 0.70	5 0 -	8 3 2.10	1 0 -	0 0 -	2 1 0.70	3 0 -	1 1 0.70	2 0 -	1 0 -	6 1 0.70	1 0 -	1 0 -	6 1 0.70	65 11.54 9.07
3	1 0 -	2 1.87 [illegible]	1 1 0.70	6 5 3.50	3 1.59 1.11	3 3 2.10	1 0 -	2 0 -	2 0 -	7 3 2.10	8 2 1.40	0 0 -	1 0 -	1 0 -	2 1 0.70	1 1 0.70	3 2 1.40	1 0 -	4 0 -	1 0 -	1 0 -	4 1 0.70	55 22.46 15.72
4	[illegible] [illegible] [illegible]	4 [illegible] [illegible]	1 1 0.70	6 5 3.50	8 3.33 2.33	1 0 -	1 0 -	5 2 1.40	4 1 [illegible]	5 3 2.10	10 3 2.10	0 0 -	0 0 -	2 0 -	3 0 -	7 0 -	4 2 1.40	1 0 -	6 0 -	2 0 -	2 0 -	5 0 -	75 24.62 17.25
5	1 0 -	3 1.69 1.18	2 2 1.40	5 4 2.80	5 [illegible] [illegible]	3 1 0.70	0 0 -	3 0 -	4 2 1.40	8 4 2.80	7 3 2.10	1 0 -	0 0 -	1 0 -	1 0 -	1 0 -	3 0 -	0 0 -	3 0 -	1 0 -	1 0 -	4 0 -	57 19.91 13.93
6	[illegible] 1 [illegible]	6 [illegible] [illegible]	[illegible] 1 [illegible]	[illegible] 4 [illegible]	5 [illegible] [illegible]	3 1 0.70	0 0 -	2 0 -	4 1 0.70	[illegible] 4 2.80	8 3 2.10	1 0 -	0 0 -	1 0 -	3 0 -	1 1 0.70	3 0 -	0 0 -	4 0 -	2 0 -	1 [illegible] -	3 [illegible] [illegible]	64 [illegible] [illegible]
7	[illegible] [illegible] -	5 [illegible] [illegible]	[illegible] 0 -	[illegible] [illegible] [illegible]	4 [illegible] [illegible]	4 1 0.70	1 0 -	6 0 -	5 0 -	4 1 0.70	9 1 0.70	0 0 -	1 0 0	1 0 -	3 0 -	2 0 -	4 0 -	1 0 -	5 0 -	0 0 -	1 0 -	7 0 -	72 [illegible] [illegible]
8	[illegible] 1 [illegible]	4 [illegible] [illegible]	[illegible] [illegible] [illegible]	6 [illegible] [illegible]	[illegible] [illegible] [illegible]	[illegible] 0 -	0 [illegible] -	[illegible] [illegible] [illegible]	5 3 2.10	6 2 1.40	4 2 1.40	1 0 -	0 0 -	1 0 -	2 0 -	1 [illegible] 0.70	3 2 1.40	0 0 -	3 0 -	1 [illegible] -	[illegible] [illegible] -	[illegible] [illegible] 0.70	[illegible] [illegible] 13.77
9	[illegible] [illegible] [illegible]	4 [illegible] [illegible]	[illegible] [illegible] -	5 4 [illegible]	[illegible] [illegible] [illegible]	1 0 -	0 0 -	[illegible] [illegible] -	4 1 0.70	5 0 -	9 4 2.80	0 0 -	0 0 -	2 0 -	2 0 -	1 0 -	3 0 -	1 0 -	6 1 0.70	2 0 -	1 0 -	5 0 -	65 [illegible] [illegible]
10	2 [illegible] -	3 [illegible] [illegible]	1 [illegible] [illegible]	[illegible] [illegible] [illegible]	6 3.35 [illegible]	3 1 [illegible]	0 0 -	2 0 -	4 0 -	6 2 1.40	5 [illegible] -	0 0 -	0 0 -	1 0 -	1 0 -	1 0 -	3 0 -	1 0 -	5 0 -	0 0 -	1 0 -	4 1 0.70	57 12.09 [illegible]
Total	14 4 [illegible]	47 22 [illegible]	16 8 [illegible]	[illegible] [illegible] [illegible]	[illegible] [illegible] 15.40	24 8 [illegible]	5 0 -	[illegible] [illegible] 2.80	42 [illegible] [illegible]	59 [illegible] 15.40	75 27 18.90	5 0 -	3 1 0.70	14 2 1.40	22 1 0.70	22 5 3.50	31 8 5.60	7 1 0.70	49 2 1.40	11 0 -	[illegible] 0 -	45 6 4.20	[illegible] 187 [illegible]

TABLE C2

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 2A BY SQUAD B USING .30-CAL SIMPLEX (M2 BALL) AMMUNITION

Tgt Man	5	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total
1	2 1 0.70	5 2 1.40	2 2 1.40	6 6 4.20	7 3 2.10	1 1 0.70	0 0 -	5 0 -	4 0 -	4 2 1.40	8 4 2.80	1 1 0.70	1 0 -	2 0 -	2 0 -	1 0 -	1 0 -	1 0 -	6 0 -	2 0 -	2 0 -	4 0 -	65 22 15.40
2	2 1 0.70	5 3 2.10	2 2 1.40	6 5 3.50	6 1 0.70	4 0 -	1 0 -	4 1 0.70	4 0 -	5 4 2.80	9 5 3.50	1 1 0.70	1 0 -	1 0 -	2 0 -	2 1 0.70	3 0 -	1 1 0.70	5 2 1.40	1 0 -	2 0 -	5 0 -	72 27 18.90
3	2 1 0.70	3 3 2.10	2 2 1.40	5 3 2.10	5 4 2.80	2 2 1.40	0 0 -	2 0 -	3 2 1.40	4 3 2.10	5 1 0.70	0 0 -	0 0 -	1 0 -	1 0 -	2 1 0.70	3 2 1.40	0 0 -	3 0 -	1 0 -	1 0 -	3 2 1.40	48 26 18.20
4	1 1 0.70	7 5 3.50	1 1 0.70	6 1 0.70	6 3 2.10	2 1 0.70	0 0 -	3 0 -	2 0 -	7 3 2.10	8 3 2.10	0 0 -	0 0 -	1 0 -	2 0 -	2 0 -	3 0 -	1 0 -	5 2 1.40	1 0 -	1 0 -	4 0 -	63 20 14.00
5	1 0 -	5 0 -	2 1 0.70	6 4 2.80	0 0 -	0 0 -	1 0 -	1 0 -	0 0 -	4 2 1.40	3 3 2.10	1 0 -	1 0 -	0 0 -	0 0 -	1 0 -	0 0 -	1 1 0.70	6 0 -	1 0 -	1 0 -	5 0 -	40 11 7.70
6	1 1 0.70	3 3 2.10	1 1 0.70	4 2 1.40	4 3 2.10	2 2 1.40	1 0 -	4 0 -	3 0 -	5 0 -	6 1 0.70	1 0 -	0 0 -	1 0 -	1 0 -	1 0 -	2 0 -	1 0 -	4 0 -	1 0 -	1 0 -	3 0 -	48 13 9.10
7	1 0 -	3 1 0.70	1 0 -	7 0 -	6 1 0.70	0 0 -	0 0 -	2 0 -	4 0 -	4 2 1.40	8 4 2.80	0 0 -	0 0 -	1 0 -	3 0 -	2 0 -	3 0 -	0 0 -	5 0 -	1 0 -	1 0 -	4 0 -	56 8 5.60
8	1 0 -	5 3 2.10	0 0 -	6 4 2.80	4 2 1.40	3 2 1.40	0 0 -	4 2 1.40	4 0 -	6 3 2.10	4 0 -	1 0 -	0 0 -	1 0 -	2 0 -	1 0 -	2 0 -	1 0 -	5 0 -	1 0 -	1 0 -	4 0 -	54 6 4.20
9	1 0 -	6 2 1.40	2 0 -	4 2 1.40	4 2 1.40	3 2 1.40	1 0 -	4 0 -	3 0 -	5 2 1.40	6 2 1.40	0 0 -	0 0 -	1 0 -	3 2 1.40	1 0 -	2 1 0.70	1 0 -	5 0 -	1 0 -	0 0 -	2 1 0.70	55 16 11.20
10	2 0 -	7 4 2.80	1 0 -	6 4 2.80	7 3 2.10	3 1 0.70	1 0 -	3 0 -	2 0 -	5 2 1.40	6 3 2.10	1 1 0.70	0 0 -	1 0 -	2 0 -	1 1 0.70	2 0 -	1 0 -	6 0 -	1 1 0.70	1 0 -	4 0 -	63 20 14.00
TOTAL	14 5 3.50	47 26 18.2	14 9 6.30	56 31 21.70	49 22 15.40	20 11 7.70	5 0 -	32 3 2.10	29 2 1.40	47 23 16.10	63 26 18.20	6 3 2.10	3 0 -	10 0 -	18 2 1.40	14 3 2.10	21 3 2.10	8 2 1.40	48 4 2.80	11 1 0.70	11 0 -	38 3 2.10	564 179 125.30

TABLE C3

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 11 BY SQUAD B USING .30-CAL SIMPLEX (M2 AP) AMMUNITION

Tgt Run	3	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total
1	2 1 0.70	6 4.51 3.16	2 0.36 0.39	8 2 1.40	7 1.87 1.31	4 0 -	1 0 -	3 0 -	5 2 1.40	5 1 0.70	9 2 1.40	1 0 -	1 0 -	1 0 -	3 0 -	2 0 -	1 0 -	1 0 -	8 0 -	3 0 -	1 0 -	5 0 -	79 14.94 10.46
2	2 0 -	6 3.54 2.48	2 0.58 0.41	6 1 0.70	8 4.48 3.14	4 2 1.40	1 0 -	3 0 -	5 1 0.70	8 0 -	10 3 2.10	1 0 -	1 0 -	2 1 0.70	2 0 -	2 1 0.70	2 0 -	1 0 -	7 0 -	2 0 -	1 0 -	5 0 -	81 17.60 12.33
3	1 1 0.70	5 0 -	2 1.25 0.87	8 0 -	6 1.71 1.20	4 1 0.70	1 0 -	3 0 -	6 4 2.80	7 3 2.10	9 2 1.40	1 0 -	0 0 -	2 0 -	4 0 -	1 0 -	3 1 0.70	1 0 -	7 0 -	2 0 -	2 0 -	5 0 -	80 14.96 10.47
4	1 0 -	4 1 0.70	1 0.50 0.35	7 2 1.40	8 3.35 2.35	3 1 0.70	1 1 0.70	4 0 -	4 0 -	7 0 -	8 2 1.40	1 0 -	1 0 -	2 0 -	3 0 -	2 0 -	5 0 -	1 0 -	6 0 -	2 0 -	2 1 0.70	3 0 -	76 11.85 8.30
5	2 2 1.40	6 4.84 3.39	1 1 0.70	7 5 3.30	8 4.96 3.47	4 0 -	2 0 -	4 0 -	4 0 -	5 1 0.70	11 9 6.30	1 0 -	1 0 -	2 0 -	3 0 -	2 1 0.70	2 0 -	0 0 -	7 1 0.70	1 0 -	3 0 -	7 0 -	83 29.80 20.86
6	1 1 0.70	4 2.24 1.57	1 0.64 0.45	5 5 3.50	7 4.02 2.81	3 1 0.70	1 1 0.70	3 0 -	3 0 -	6 3 2.10	5 3 2.10	1 0 -	1 0 -	0 0 -	3 0 -	2 1 0.70	2 1 0.70	1 0 -	6 1 0.70	1 1 0.70	2 0 -	3 0 -	61 24.90 17.43
7	1 0 -	7 2.35 1.64	1 0.41 0.29	5 3 2.10	2 0 -	3 1 0.70	0 0 -	5 0 -	3 0 -	6 1 0.70	5 3 2.10	0 0 -	0 0 -	1 0 -	2 0 -	2 0 -	3 1 0.70	0 0 -	8 0 -	1 0 -	2 0 -	2 0 -	59 11.76 8.23
8	1 0 -	3 1.52 1.06	1 0.57 0.40	6 2 1.40	6 2.92 2.04	1 1 0.70	1 0 -	3 0 -	5 1 0.70	4 2 1.40	7 1 0.70	1 0 -	1 0 -	1 0 -	2 1 0.70	1 0 -	3 0 -	1 0 -	5 0 -	2 0 -	1 0 -	3 1 0.70	59 14.01 9.80
9	1 1 0.70	[illegible] 0 -	1 0.49 0.34	6 0 -	5 1.44 1.01	3 0 -	1 0 -	4 0 -	5 0 -	4 0 -	7 4 2.80	1 0 -	1 0 -	1 0 -	2 0 -	2 0 -	3 0 -	0 0 -	8 1 0.70	2 0 -	2 0 -	4 0 -	70 7.93 5.55
10	2 0 -	6 1 0.70	1 0 -	7 1 0.70	8 1.25 0.87	4 0 -	2 0 -	2 0 -	4 1 0.70	7 1 0.70	8 1 0.70	1 0 -	1 0 -	1 0 -	3 0 -	2 0 -	1 0 -	1 0 -	8 0 -	2 0 -	1 0 -	3 0 -	75 6.25 4.37
Total	14 6 4.20	54 21 14.70	13 6 4.20	65 21 14.70	65 26 18.20	[illegible] 7 4.90	11 2 1.40	34 0 -	44 9 5.30	59 12 8.40	79 30 21.00	9 0 -	8 0 -	13 1 0.70	27 1 0.70	18 3 2.10	25 3 2.10	7 0 -	70 3 2.10	18 1 0.70	17 1 0.70	40 1 0.70	723 154 107.80

TABLE C4

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 12 BY SQUAD A USING .30-CAL SIMPLEX (M2 AP) AMMUNITION

Man \ Tgt	5	7	9	10	13	14	15	16	18	19	20	21	22	24	26	26	20	30	31	32	33	34	Total
1	1 1 0.70	4 2 1.40	2 2.00 1.40	8 8 5.60	8 3.12 2.18	3 2 1.40	1 0 -	4 2 1.40	6 1 0.70	7 0.12 0.08	8 5.60 4.08	1 0 -	1 0 -	1 1 0.70	2 1 0.70	2 0 -	2 1 0.70	1 0 -	3 0 -	2 2 1.40	2 0 -	2 1 0.70	89 33.04 23.12
2	1 0 -	6 1 0.70	1 0.81 0.43	5 2 1.40	7 1.20 0.84	3 0 -	1 1 0.70	6 0 -	1 0 -	7 2.04 1.43	8 1.30 0.91	0 0 -	0 0 -	2 0 -	3 0 -	2 0 -	3 0 -	1 0 -	3 0 -	3 0 -	1 0 -	4 1 0.70	66 10.16 7.11
3	0 0 -	5 4 2.80	1 1.00 0.70	7 6 4.20	6 2.70 1.89	1 0 -	1 0 -	6 2 1.40	4 0 -	4 1.10 0.77	7 4.03 3.45	1 0 -	1 0 -	1 0 -	3 1 0.70	2 1 0.70	1 0 -	1 0 -	2 1 0.70	1 0 -	1 0 -	2 0 -	67 24.73 17.31
4	1 1 0.70	6 7 4.90	1 0.92 0.64	7 5 3.50	7 2.55 1.78	5 3 2.10	1 1 0.70	4 1 0.70	6 0 -	8 1.09 0.76	0 3.06 2.77	1 0 -	1 0 -	2 0 -	4 1 0.70	1 0 -	4 0 -	1 0 -	3 1 0.70	3 0 -	2 1 0.70	8 0 -	86 20.52 20.66
5	1 1 0.70	4 1 0.70	1 0.85 0.60	7 4 2.80	7 2.18 1.53	6 2 1.40	1 0 -	3 0 -	2 1 0.70	6 0.16 0.11	10 2.67 1.87	0 0 -	0 0 -	1 0 -	3 1 0.70	2 1 0.70	2 1 0.70	0 0 -	3 0 -	2 0 -	3 0 -	4 0 -	69 17.86 12.51
6	1 1 0.70	7 4 2.80	2 1.93 1.35	8 6 4.20	6 2.43 1.70	4 1 0.70	0 0 -	4 0 -	5 1 0.70	7 2.19 1.53	0 6.31 4.42	1 0 -	2 0 -	3 0 -	4 2 1.40	3 1 0.70	4 2 1.40	1 1 0.70	1 0 -	2 1 0.70	1 0 -	5 0 -	80 32.86 23.00
7	2 1 0.70	8 3 2.10	2 .23 0.66	5 3 2.10	1 0.18 0.13	3 0 -	1 0 -	4 1 0.70	5 1 0.70	7 0.09 0.06	7 3.58 2.51	1 0 -	1 0 -	2 1 0.70	3 0 -	2 0 -	4 2 1.40	1 0 -	4 0 -	2 0 -	3 0 -	3 0 -	69 17.08 11.06
8	2 0 -	8 3 2.10	1 0.82 0.57	8 3 2.10	6 1.71 1.10	3 1 0.70	1 0 -	5 2 1.40	5 0 -	7 3.07 2.15	7 0.91 0.64	1 0 -	1 0 -	2 0 -	4 1 0.70	1 0 -	5 0 -	1 0 -	3 0 -	2 0 -	2 0 -	3 0 -	78 16.51 11.55
9	2 1 0.70	6 3 2.10	3 1.90 1.33	5 5 3.50	5 0.95 0.67	5 0 -	2 0 -	4 0 -	3 0 -	8 1.09 0.76	9 1.23 0.86	1 0 -	1 0 -	2 0 -	4 0 -	1 0 -	6 0 -	1 0 -	2 0 -	3 0 -	4 0 -	7 0 -	87 14.17 9.92
10	1 0 -	4 3 2.10	1 0.74 0.52	7 6 4.20	4 0.85 0.60	3 0 -	1 0 -	4 0 -	6 0 -	4 0.06 0.04	8 4.31 3.02	1 0 -	1 0 -	1 0 -	3 0 -	2 1 0.70	2 0 -	0 0 -	3 0 -	2 0 -	1 0 -	5 1 0.70	64 17.09 11.97
Total	12 6 4.20	55 31 21.70	15 12 8.40	70 48 33.60	55 18 12.60	35 9 6.30	10 2 1.40	42 8 5.60	43 4 2.80	65 11.00 7.60	82 35 24.51	6 0 -	9 0 -	17 2 1.40	33 7 4.90	18 4 2.80	33 6 4.20	8 1 0.70	27 2 1.40	22 3 2.10	20 1 0.70	43 3 2.10	722 213 149.10

TABLE C5

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 3A BY SQUAD A USING .30-CAL DUPLEX AMMUNITION

Tgt Man	5	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
1	1 1 1 1 0.91	5 2 6 2 4.62	[illegible] 1 [illegible] 1 0.91	[illegible] 2 5 4 [illegible]	6 5 5 [illegible]	2 2 2 2 1.82	1 0 0 -	3 1 0 0.70	4 0 0 -	3 0 1 0.70	5 1 4 1 3.01	1 0 0 -	1 0 0 -	2 0 0 -	2 0 1 0.70	1 0 0 -	3 1 1 1.40	1 0 0 -	3 0 0 -	1 0 1 0.70	1 0 1 0.70	1 0 0 -	56 24 9 25.69	9
2	[illegible] 0 [illegible] [illegible]	5 1 2 2 [illegible]	2 0 0 -	7 2 2 2.80	6 1 1 1 0.91	2 0 2 1.40	1 0 0 -	4 1 1 2 1.61	4 1 1 2 1.61	7 2 0 1.40	6 0 3 2.10	0 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	1 0 1 0.70	1 0 0 -	0 0 0 -	7 0 1 0.70	2 0 1 0.70	2 0 0 -	4 0 1 0.70	67 9 19 17.64	4
3	[illegible] 0 0 -	6 2 2 4 [illegible]	[illegible] 1 [illegible] [illegible] 0.91	6 4 [illegible] [illegible]	[illegible] 1 2 [illegible]	2 1 1 1.40	[illegible] 1 0 0.70	5 1 1 2 1.61	2 0 1 0.70	5 1 2 2.10	6 2 0 1.40	0 0 0 -	1 0 0 -	1 0 0 -	2 1 0 0.70	1 0 0 -	2 0 1 0.70	1 0 0 -	5 0 1 0.70	2 0 0 -	1 0 0 -	3 0 1 0.70	57 15 16 19.74	4
4	1 1 [illegible] [illegible] 0.91	7 [illegible] 4 5 [illegible]	2 2 2 2 1.82	5 3 [illegible] 4 [illegible]	6 1 [illegible] 1 [illegible]	3 0 2 [illegible]	1 1 0 0.70	5 0 3 2.10	5 0 0 -	4 0 2 [illegible]	8 0 3 2.10	1 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	1 0 0 -	4 0 1 0.70	1 0 0 -	7 0 1 0.70	1 0 0 -	2 0 0 -	4 0 0 -	74 12 25 21.00	10
5	[illegible]	[illegible]	[illegible]	[illegible] 6 4 [illegible]	6 0 4 [illegible]	[illegible] [illegible] 0 0.70	0 0 0 -	4 0 0 -	4 0 1 0.70	5 1 0 0.70	7 1 6 2 [illegible]	0 0 0 -	1 0 0 -	1 0 0 -	1 0 0 -	1 0 0 -	3 1 0 0.70	0 0 0 -	6 0 1 0.70	1 0 0 -	1 0 0 -	[illegible] 0 1 0.70	57 17 16 20.16	7
6	[illegible]	[illegible]	[illegible]	2 2 [illegible] 2 1.92	6 4 [illegible] [illegible]	[illegible] [illegible] [illegible] -	1 0 0 -	3 1 1 2 1.61	5 0 1 0.70	7 2 3 [illegible] [illegible]	5 - [illegible] [illegible]	0 0 0 -	1 1 0 0.70	2 1 0 0.70	[illegible] 0 0 -	1 0 0 -	3 0 0 -	1 0 0 -	5 0 0 -	1 0 0 -	1 0 0 -	5 0 0 -	65 24 12 21.26	7
7	[illegible]	[illegible]	[illegible]	6 [illegible] [illegible] [illegible]	5 [illegible] [illegible] [illegible]	[illegible]	1 0 0 -	3 0 0 -	5 [illegible] 0 0.70	6 1 2 2 [illegible]	[illegible] 6 0 [illegible]	1 0 0 -	0 0 0 -	2 0 0 -	1 0 0 -	2 0 [illegible] [illegible]	3 0 0 -	1 0 0 -	5 0 0 -	1 0 0 -	[illegible] 0 0 -	2 0 0 -	64 17 15 19.46	6
8	[illegible]	[illegible]	[illegible]	2 0 [illegible] [illegible]	6 [illegible] [illegible] [illegible]	2 2 0 [illegible]	1 0 0 -	3 1 [illegible] [illegible] 0.91	3 0 1 0.70	5 2 0 1.40	3 [illegible] 0 0.70	0 0 0 -	1 0 0 -	1 0 0 -	[illegible] [illegible] 0 0.70	1 0 0 -	2 0 0 -	1 0 0 -	[illegible] 0 0 -	1 0 0 -	2 0 0 -	[illegible] 0 0 -	50 14 10 15.33	3
9	[illegible]	[illegible]	[illegible]	6 [illegible] [illegible] [illegible]	5 [illegible] [illegible] [illegible]	3 0 2 -	1 1 [illegible] 0.70	4 0 2 1.40	6 0 0 -	5 1 2 1 1.61	5 [illegible] 0 0.70	[illegible] 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	1 0 0 -	1 1 0 0.70	1 0 0 -	6 [illegible] [illegible] -	2 0 [illegible] -	2 0 0 -	4 1 0 0.70	64 13 12 15.54	4
10	1 [illegible] [illegible] [illegible]	5 1 [illegible] [illegible] [illegible]	[illegible]	6 1 4 [illegible] [illegible]	6 [illegible] [illegible] [illegible]	[illegible] [illegible] 0 0.70	[illegible] 0 0 -	3 1 [illegible] [illegible]	4 [illegible] [illegible] 2.10	5 [illegible] [illegible] [illegible]	6 1 [illegible] [illegible] 0.91	[illegible] 0 0 -	1 0 0 -	0 0 0 -	1 0 0 -	0 0 0 -	2 0 0 -	1 0 0 -	- [illegible] 1 0.70	2 0 0 -	[illegible] 0 0 -	4 0 1 0.70	56 15 [illegible] 16.17	7
Total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible] 2 [illegible] 8 [illegible]	9 [illegible] 0 [illegible]	39 6 12 [illegible]	41 1 [illegible] 9 [illegible]	[illegible] 4 [illegible] [illegible] [illegible]	58 3 15 11 [illegible]	5 0 0 -	9 [illegible] 0 0.70	15 1 0 0.70	[illegible] 2 1 2.10	10 0 2 1.40	24 [illegible] [illegible] [illegible]	8 0 0 -	[illegible]	14 [illegible] 2 [illegible]	15 [illegible] [illegible] 0.70	[illegible] 1 4 3.50	610 160 157 192.01	61

TABLE C6

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 4A BY SQUAD B USING .30-CAL DUPLEX AMMUNITION

Man / Tgt	5		7		9		10		13		14		15	16	18	19		20		21	22	24	25	28	29	30	31	32	. 33	34	Total	Multiple Hits
1	2 0 0 -		4 3 2 2.52	2	2 1.00 1.00 0.91	1.0	4 3 3 3.22	2	5 1 4 3.50		3 0.69 0.69 0.97		1 0 0 -	3 0 1 0.70	4 0 0 -	4 0 0 -		7 6 1 4.90		1 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	2 0 1 0.70	3 2 1 2.10	1 0 0 -	5 0 1 0.70	2 0 0 -	2 0 0 -	5 0 0 -	67 16.69 15.69 20.22	5.0
2	1 0 0 -		3 2 5 2.52	2	3 1.55 1.55 1.45	1.5	3 1 1 1.40		3 0 2 1.40		3 0.74 0.74 1.04		1 0 0 -	7 0 0 -	4 1 0 0.70	3 1 0 0.70		5 2 0 1.40		0 0 0 -	1 0 0 -	2 0 0 -	3 0 0 -	2 1 0 0.70	3 0 0 -	1 0 0 -	5 0 1 0.70	2 0 0 -	1 0 0 -	6 0 0 -	68 10.29 9.29 11.99	3.5
3	1 0 1 0.70		8 3 3 3.71	1	1 0.56 0.56 0.54	0.5	7 2 2 2.31	1	5 1 2 1.61	1	3 0.85 0.85 0.94	0.5	0 0 0 -	6 0 3 2.10	3 0 1 0.70	6 3 3 3.71	1	5 0 2 1.40		1 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	0 0 0 -	2 0 0 -	1 0 0 -	6 0 1 0.70	1 0 0 -	1 0 0 -	2 0 0 -	62 10.41 19.41 18.42	5.0
4	1 1 0 0.70		6 2 1 2.10		2 0.90 0.90 1.01	0.5	5 2 2 2.31	1	5 0 1 0.70		3 0.58 0.58 0.82		0 0 0 -	5 4 1 3.50	5 0 0 -	6 0 0 -		6 4 1 3.01	1	1 0 0 -	0 0 0 -	1 0 0 -	2 1 0 0.70	2 0 0 -	3 0 0 -	1 0 0 -	4 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	62 15.48 7.48 14.83	2.5
5	2 0 2 1.40		5 1 2 1.61	1	2 1.14 1.14 1.11	1.0	4 1 1 1.40		5 0 1 0.70		3 0.89 0.89 1.00	0.3	1 0 0 -	5 3 0 2.10	4 0 0 -	4 0 0 -		6 2 1 2.10		0 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	1 0 0 -	3 0 0 -	1 0 0 -	3 0 0 -	2 0 0 -	1 0 0 -	5 0 0 -	64 9.03 9.03 11.42	2.5
6	1 1 0 0.70		3 2 2 2.80		2 1.14 1.14 1.10	1.0	2 2 0 1.40		3 2 1 1.61	1	2 0.62 0.62 0.87		0 0 0 -	2 0 2 1.40	2 0 0 -	4 1 2 1.61	1	6 2 0 1.40		0 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	1 1 0 0.70	2 0 0 -	1 0 1 0.70	3 0 1 0.70	1 0 0 -	1 0 0 -	[illegible] 0 0 -	48 12.76 10.76 14.99	3.0
7	1 0 0 -		6 4 2 3.71	1	1 0.37 0.37 0.52		3 1 1 1.40		6 3 1 2.80		1 0.14 0.14 0.19		0 0 0 -	3 1 0 0.70	1 0 0 -	8 3 3 3.22	2	8 3 3 4.20		0 0 0 -	0 0 0 -	1 0 0 -	1 0 0 -	0 0 0 -	3 0 0 -	0 0 0 -	5 0 0 -	1 0 0 -	1 0 0 -	5 0 0 -	53 15.51 10.51 16.74	3.0
8	1 1 1 0.91	1	2 1 1 0.91	1	1 0.31 0.31 0.47	0.5	5 3 2 3.01	1	6 4 0 2.80		2 0.48 0.48 0.67		1 0 0 -	4 0 1 0.70	4 0 0 -	6 1 1 1.40		3 0 2 1.40		0 0 0 -	0 0 0 -	1 0 0 -	5 2 0 1.40	1 0 0 -	2 1 0 0.70	0 0 0 -	5 0 0 -	1 0 0 -	1 0 1 0.70	1 0 0 -	52 13.99 9.99 15.07	3.5
9	1 1 0 0.70		3 4 3 3.92	2	1 0.44 0.44 0.62		4 1 1 0.91	1	3 3 2 3.50		3 0.53 0.53 0.77		1 0 0 -	6 0 1 0.70	3 0 1 0.70	3 0 0 -		3 1 0 0.70		1 0 0 -	1 0 0 -	2 0 0 -	2 1 0 0.70	1 1 0 0.70	5 2 0 1.40	1 0 0 -	4 0 0 -	1 0 0 -	2 0 0 -	4 0 1 0.70	57 14.99 9.99 16.02	5.0
10	2 1 0 0.70		2 1 2 1.61	1	1 0.39 0.39 0.35		6 3 3 3.71	1	5 2 1 1.61	1	5 0.46 0.46 0.64		1 0 0 -	6 0 2 1.40	4 0 0 -	5 1 1 1.40		4 2 2 2.80		0 0 0 -	1 0 0 -	1 1 0 0.70	2 0 0 -	1 0 0 -	2 0 1 0.70	1 0 0 -	5 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	56 11.85 12.85 15.82	3.0
TOTAL	13 5 4 5.81	1	48 23 21 25.41	11	16 8 8 8.26	6.0	43 19 16 21.37	7	52 16 15 20.23	3	26 6 6 7.91	1	6 0 0 -	49 9 11 13.30	34 1 2 2.10	31 10 10 12.04	4	55 22 12 23.31	1	4 0 0 -	5 0 0 -	14 1 0 0.70	21 4 0 2.80	11 3 1 2.80	26 5 2 4.90	8 0 1 0.70	49 0 4 2.80	13 0 0 -	12 0 1 0.70	33 0 1 0.70	389 131 115 135.54	34

TABLE C7

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 9 BY SQUAD B USING .30-CAL DUPLEX AMMUNITION

Man \ Tgt	5	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
1	1 0 0 -	7 1 2 3 3.01	2 1 1 2 1.61	5 1 1 2 1.61	8 1 2 3 3.01	3 0 2 1.40	1 0 0 -	5 0 1 0.70	6 0 0 -	6 1 2 1 1.61	7 2 0 1.40	1 0 0 -	1 0 0 -	2 0 0 -	4 0 0 -	2 0 0 -	4 1 0 0.70	1 0 0 -	7 0 0 -	2 0 0 -	1 0 1 0.70	5 0 0 -	81 11 15 15.75	5
2	1 0 1 0.70	6 0 2 1.40	1 0 0 -	6 2 0 1.40	8 2 2 3 2.52	3 0 1 0.70	2 0 0 -	7 0 0 -	5 0 0 -	9 0 0 -	8 1 0 0.70	1 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	2 0 0 -	4 0 0 -	1 0 0 -	7 0 0 -	3 0 0 -	2 0 0 -	3 0 0 -	82 5 7 7.42	2
3	1 0 1 0.70	7 2 3 3 3.22	2 1 2 1 1.61	8 1 4 3 4.41	5 1 2 2.10	3 1 1 1.40	1 0 0 -	6 0 3 2.10	5 2 0 1.40	8 2 2 3 2.52	6 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	1 1 0 0.70	2 0 0 -	4 0 0 -	0 0 0 -	7 0 1 0.70	2 0 0 -	3 0 0 -	5 0 0 -	82 16 18 20.86	6
4	1 0 0 -	6 2 2 3 2.52	1 0 0 -	7 3 5 4 4.83	5 3 0 2.10	3 0 0 -	1 1 0 0.70	5 4 1 3.50	2 0 0 -	4 1 0 0.70	6 0 0 -	0 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	3 1 0 0.70	0 0 0 -	8 0 0 -	1 1 0 0.70	2 0 0 -	5 0 0 -	65 18 8 15.75	5
5	1 0 0 -	6 2 3 3.50	2 1 1 1 0.91	8 1 2 3 3.01	7 2 2 2.80	2 0 2 1.40	2 0 0 -	3 3 0 2.10	2 0 0 -	7 1 1 2 1.61	9 1 3 2 3.01	1 1 0 0.70	1 0 0 -	2 0 0 -	2 0 0 -	2 0 0 -	4 1 1 1.40	1 0 0 -	6 0 0 -	1 0 0 -	1 0 0 -	5 0 1 0.70	77 16 17 21.14	4
6	1 1 1 1 0.91	6 1 1 3 2.31	2 1 1 1 0.91	4 1 2 3 3.01	4 2 3 2 2.52	2 1 1 1.40	1 0 0 -	2 0 2 1.40	4 0 0 -	4 2 2 2.60	7 1 0 0.70	1 0 0 -	0 0 0 -	1 0 0 -	3 0 0 -	1 1 0 0.70	1 0 0 -	1 0 0 -	6 0 1 0.70	2 0 0 -	1 0 0 -	3 0 0 -	57 13 16 17.36	6
7	1 0 1 0.70	7 3 4 3 3.43	0 0 0 -	4 1 1 1 0.91	5 2 1 2.10	3 1 0 0.70	1 0 0 -	3 1 0 0.70	4 0 1 0.70	4 0 1 0.70	7 2 0 1.40	0 0 0 -	1 0 0 -	1 1 0 0.70	2 1 0 0.70	1 0 0 -	2 0 0 -	0 0 0 -	6 0 1 0.70	0 0 0 -	1 0 0 -	3 0 0 -	56 13 9 13.44	4
8	1 0 1 0.70	7 1 2 1 1.61	2 1 0 0.70	6 1 1 1.40	4 0 0 -	3 0 0 -	1 0 0 -	4 0 1 0.70	2 0 0 -	4 0 2 1.40	7 2 1 2.10	1 0 0 -	1 0 0 -	2 0 0 -	3 1 0 0.70	1 0 0 -	1 0 0 -	1 0 0 -	7 0 0 -	2 0 0 -	2 0 0 -	6 0 0 -	66 7 7 9.31	1
9	2 1 0 0.70	6 5 5 5 4.55	1 0 0 -	4 2 3 2 2.52	6 1 2 1 1.61	4 1 3 1 2.31	1 0 0 -	4 0 1 0.70	5 1 1 1.40	8 0 2 1.40	8 0 1 0.70	1 0 0 -	1 0 0 -	1 1 0 0.70	2 0 0 -	2 0 0 -	4 0 0 -	1 0 0 -	6 0 0 -	1 0 0 -	2 0 0 -	5 0 0 -	77 16 14 16.59	9
10	2 0 0 -	7 1 3 3 3.71	2 0 1 0.70	4 2 0 1.40	7 1 0 0.70	3 0 0 -	1 0 0	6 0 2 1.40	6 0 1 0.70	6 0 1 0.70	4 0 0 -	0 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	4 0 0 -	1 0 0 -	6 0 0 -	1 0 1 0.70	2 0 0 -	4 0 0 -	71 6 9 10.01	1
TOTAL	12 1 2 5 4.41	65 16 24 29 29.26	15 4 6 6 6.44	54 10 23 19 24.50	59 6 18 14 19.46	29 1 6 8 9.31	12 1 0 0.70	44 8 12 13.30	41 3 3 4.20	59 4 8 14 13.44	71 1 11 4 10.01	7 1 0 0.70	8 0 0 -	15 2 0 1.40	22 3 0 2.10	16 1 0 0.70	31 3 1 2.80	7 0 0 -	66 0 3 2.10	15 1 1 1.40	17 0 1 0.70	44 0 1 0.70	714 121 120 147.63	43

TABLE C8

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 10 BY SQUAD A USING .30-CAL DUPLEX AMMUNITION

Tgt	3	7		9		10		13		14		15		16		18	19		20		21		22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
Man																																		
1	0 0 0 -	7 3 6 3.74	4	2 2 1 1.61	1	7 3 4 3.32	2	3 0 2 1.40		3 0 3 2.10		1 0 0 -		1 1 0 0.70		3 3 0 2.10	7 3 1 3.71	1	6 3 1 2.80		1 1 1 0.91	1	1 0 0 -	2 0 0 -	2 0 0 -	2 1 0 0.70	4 1 0 0.70	1 0 0 -	6 1 0 0.70	2 0 0 -	1 0 0 -	2 0 0 -	68 28 19 28.49	9
2	1 0 0 -	6 2 3 3.01	1	2 1 1 0.91	1	7 2 2 2.80		6 1.38 1.22 1.82		3 0 0 -		1 0 0 -		3 2 1 2.10		3 1 0 0.70	8 1 2 2.10		10 2 1 1.61	1	0 0 0 -		1 0 0 -	2 0 0 -	3 0 0 -	1 0 0 -	3 2 0 1.40	0 0 0 -	7 0 0 -	3 0 0 -	2 0 0 -	4 0 0 -	80 14.38 11.22 16.45	3
3	1 0 0 -	5 3 3 2.73	3	2 2 2 1.82	2	6 4 0 2.80		4 1.62 0.54 1.31		3 0 0 -		1 0 0 -		3 0 0 -		3 1 0 0.70	6 1 1 1.40		8 3 0 2.10		1 0 0 -		2 0 0 -	1 1 0 0.70	1 0 0 -	1 1 0 0.70	2 1 0 0.70	1 0 0 -	6 1 1 1.40	2 0 0 -	2 0 0 -	4 1 0 0.70	69 20.62 7.54 17.26	5
4	1 0 0 -	7 3 3 4.62	2	2 1 0 0.70		5 5 4 3.43	3	6 3.26 3.00 3.99	1	4 1 0 0.70		1 0 0 -		3 1 3 2.80		6 0 0 -	6 2 1 1.61	1	9 3 1 2.31	1	1 0 0 -		1 0 0 -	2 0 0 -	4 0 0 -	2 0 0 -	4 1 0 0.70	0 0 0 -	8 0 0 -	2 0 0 -	3 0 0 -	8 0 0 -	87 20.26 15.00 20.76	8
5	1 0 1 0.70	7 3 0 2.10		2 2 2 1.82	2	7 6 4 3.04	4	8 3.67 3.48 4.31	1	1 0 0 -		1 0 0 -		4 0 1 0.70		4 1 0 0.70	8 2 2 2.31	1	9 4 2 3.71	1	0 0 0 -		0 0 0 -	2 0 0 -	3 0 0 -	1 0 0 -	3 0 0 -	0 0 0 -	7 1 0 0.70	2 0 0 -	1 0 0 -	5 0 0 -	76 22.67 13.48 22.29	9
6	2 1 0 0.70	6 2 4 3.71	1	3 1 2 1.61	1	2 2 2 1.82	2	7 4.76 2.44 4.33	1	4 1 0 0.70		2 0 0 -		3 4 3 3.92	2	3 1 0 0.70	5 2 0 1.40		9 7 0 4.90		0 0 0 -		1 0 0 -	2 0 0 -	4 0 0 -	2 0 0 -	4 1 0 0.70	0 0 0 -	8 0 0 -	3 0 0 -	2 0 0 -	3 0 0 -	79 26.76 13.44 24.71	7
7	1 0 1 0.70	5 4 3 3.43	3	3 2 2 1.82	2	6 1 3 2.31	1	2 0 1 0.70		4 2 1 1.61	1	2 0 1 0.70		6 0 3 2.10		6 1 1 1.40	4 2 2 2.31	1	8 3 1 2.80		1 0 0 -		1 0 0 -	0 0 0 -	4 0 0 -	1 1 0 0.70	4 1 0 0.70	1 0 0 -	4 0 0 -	2 0 0 -	2 0 0 -	2 0 0 -	69 17 19 21.28	8
8	2 1 0 0.70	6 4 2 3.71	1	2 0 1 0.70		2 0 1 0.70		7 1.92 1.69 2.04	1	4 2 0 1.40		1 1 0 0.70		6 0 1 0.70		6 0 0 -	8 0 2 1.40		8 1 0 0.70		1 0 0 -		1 0 0 -	3 0 0 -	1 0 0 -	2 1 0 0.70	4 0 0 -	1 0 0 -	5 0 0 -	3 0 0 -	2 0 0 -	2 0 0 -	77 11.92 8.69 13.43	2
9	2 0 0 -	6 3 1 3.71	1	2 1 0 0.70		6 0 3 2.10		7 2.28 1.13 2.59		4 2 1 2.10		1 1 1 0.91	1	3 0 0 -		5 0 1 0.70	6 0 0 -		9 1 0 0.70		1 0 0 -		2 0 0 -	2 1 0 0.70	4 0 0 -	2 0 0 -	2 0 0 -	2 0 0 -	10 0 0 -	3 0 0 -	2 0 0 -	0 0 0 -	81 13.28 8.13 14.01	2
10	1 0 0 -	5 4 2 3.22	2	1 0 0 -		6 4 3 3.43	3	2 0.32 0.29 0.43		2 2 0 1.40		1 0 0 -		4 0 0 -		3 1 0 0.70	4 1 1 1.40		8 1 1 0.91	1	0 0 0 -		1 0 0 -	1 0 0 -	3 0 0 -	1 1 0 0.70	2 0 0 -	1 0 0 -	6 0 0 -	2 0 0 -	1 0 0 -	5 0 0 -	60 14.32 7.29 12.19	6
TOTAL	12 2 2 2.80	60 37 27 33.98	18	21 12 11 11.69	9	54 27 26 29.73	15	32 19.21 16.79 23.24	4	32 10 5 10.01	1	12 2 2 2.31	1	44 8 12 13.02	2	50 9 2 7.70	62 16 12 17.64	4	86 28 7 22.54	4	6 1 1 0.91	1	11 0 0 -	17 2 0 1.40	29 0 0 -	15 5 0 3.50	32 7 0 4.90	7 0 0 -	67 3 1 2.80	24 0 0 -	18 0 0 -	35 1 0 0.70	746 109.21 124.79 190.89	59

TABLE C9

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 5A BY SQUAD A USING .30-CAL TRIPLEX AMMUNITION

Tgt	5	7	9	10	13	14	15	16	18	19	20	21	2[illegible]	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
Man																								
1	1 0 0 0 -	2 0 2 2 2 1.82	2 1 1 1 0 0.91	6 3 6 2 5 3 4.43	4 4 1 1 2 3 4.23	3 0 2 1 1 1.61	1 1 0 0 -	5 0 1 0 0.70	4 1 1 1 1 0.97	4 1 3 2 2 3 3.49	7 2 2 0 2.80	1 0 0 0 -	1 0 0 0 -	2 1 0 0 0.57	1 1 0 0 0.57	2 1 0 1 1 0.75	2 1 2 1 1 1.37	1 0 0 0 -	7 1 2 0 1.72	2 0 0 0 -	1 0 0 0 -	5 0 0 0 -	65 23 20 15 [illegible]	6 4 5 3
2	1 0 0 0 -	3 0 0 1 0.70	1 1 1 1 1 0.97	[illegible] 1 3 1 2 2 [illegible]	4 0 1 1 1.40	2 0 1 0 0.70	1 0 0 0 -	5 1 1 1 1 0.97	3 0 1 1 0.70	5 1 0 0 0.70	10 1 1 0 1.40	0 0 0 0 -	1 0 0 0 -	2 1 0 1 1 0.75	2 0 0 0 -	1 0 0 0 -	4 1 1 1 0 0.75	1 0 0 0 -	5 0 1 0 0.57	3 0 0 0 -	2 0 0 0 -	3 0 0 0 -	66 9 10 7 12.89	3 2 1 -
3	1 0 0 0 -	6 2 5 2 4 1 3 4.67	1 1 0 0 0.70	6 1 5 1 3 1 2 4.89	5 0 0 0 -	3 1 0 0 0.70	1 0 0 0 -	5 2 0 1 1 1.61	4 2 0 1 1 1.61	6 5 1 1 1 1 3.92	7 2 1 1 0 1.61	1 0 0 0 -	1 0 0 0 -	1 0 0 0 -	1 0 0 0 -	2 0 0 0 -	3 0 0 0 -	1 0 0 0 -	2 0 0 0 -	1 0 0 0 -	1 0 0 0 -	4 0 0 0 -	61 23 9 8 19.71	3 5 5 -
4	1 0 0 0 -	7 1 5 4 6 1 5.31	2 1 1 1 1 0.97	6 0 1 1 1 0.91	5 1 1 3 4 1 3.98	3 0 0 0 -	0 0 0 0 -	5 3 2 4 0 3.92	2 0 0 0 -	5 2 1 1 0 1.61	9 3 1 1 2 2 2.75	1 0 0 0 -	1 0 0 0 -	1 0 0 0 -	3 1 0 0 0.57	2 0 0 0 -	3 0 0 0 -	1 0 0 0 -	5 0 0 0 -	2 0 0 0 -	2 0 0 0 -	5 0 0 0 -	71 16 17 9 20.00	3 8 2 2
5	1 0 0 0 -	4 1 0 1 1.40	1 0 1 0 0.70	7 3 2 3 1 2 1 3.64	5 1 1 1 2 2.31	0 0 0 0 -	1 0 0 1 0.70	3 0 1 0 0.70	4 0 0 0 -	6 0 0 0 -	5 2 0 0 1.40	1 0 0 0 -	0 0 0 0 -	1 0 0 0 -	3 0 0 0 -	1 0 0 0 -	3 1 0 0 0.57	1 0 0 0 -	5 0 0 0 -	1 0 0 0 -	1 0 0 0 -	3 0 0 0 -	57 6 6 6 11.42	- 2 2 1
6	1 1 0 0 0.70	[illegible] 2 4 2 2 3.54	2 1 1 1 1 0.97	6 1 5 1 2 1 3 4.89	7 5 1 1 1 1 3.92	4 1 0 1 1 0.91	1 0 0 1 0.70	4 1 0 1 1 2.51	5 1 1 0 1.40	4 3 2 3 1 1 3.43	8 [illegible] 2 2 0 2.52	1 0 0 0 -	0 0 0 0 -	1 0 0 0 -	3 0 0 0 -	1 0 0 0 -	2 1 0 0 0.57	1 0 0 0 -	6 1 0 0 0.57	2 0 0 0 -	2 0 0 0 -	4 0 0 0 -	72 27 12 13 26.23	4 6 5 -
7	1 0 1 0 0.70	5 2 4 2 5 2 4.46	2 0 1 0 0.70	5 1 1 3 2 1 2.58	5 0 1 1 1.40	2 1 1 2 1 1.67	1 0 0 0 -	2 1 2 1 1 1.67	4 0 0 0 -	6 3 0 1 1 2.51	8 3 1 2 1 1 3.22	1 0 0 0 -	1 0 0 0 -	1 0 0 0 -	1 0 0 0 -	2 0 0 0 -	3 1 0 1 1 0.75	1 0 0 0 -	5 0 0 0 -	1 0 0 0 -	1 0 0 0 -	5 0 0 0 -	63 15 16 10 19.46	5 3 2 2
8	2 0 1 0 0.70	3 1 0 1 1.40	1 1 1 1 0 0.91	6 1 0 0 0.70	8 0 0 0 -	1 0 0 1 0.70	1 1 0 0 0.70	5 0 1 1 1.40	4 0 0 0 -	3 0 0 1 0.70	7 2 1 1 1 2.31	0 0 0 0 -	1 0 0 0 -	1 0 0 0 -	3 1 0 0 0.57	2 1 1 1 0 0.75	3 0 0 0 -	1 0 0 0 -	5 1 0 0 0.57	1 0 1 0 0.57	2 0 0 0 -	5 0 0 0 -	65 9 6 5 11.98	- 2 1 -
9	3 1 1 1 0 0.91	5 1 2 0 2.10	2 1 1 1 1 0.97	6 0 3 1 1 2.31	8 0 0 0 -	3 0 0 0 -	1 0 0 0 -	5 0 0 1 0.70	2 1 0 0 0.70	8 0 0 0 -	12 0 0 0 -	1 0 0 0 -	1 0 0 0 -	1 0 0 0 -	4 0 0 0 -	3 0 0 0 -	5 0 0 0 -	1 0 0 0 -	6 0 0 0 -	4 0 0 0 -	3 0 0 0 -	6 0 0 0 -	88 4 7 3 7.69	1 1 - 1
10	1 1 0 0 0.70	5 2 3 2 1 3 2.95	1 0 1 1 1 0.91	6 0 1 1 1.40	4 0 0 1 0.70	1 0 0 0 -	1 0 0 1 0.70	2 0 0 0 -	5 0 0 0 -	8 1 1 1 2 2.31	7 0 0 1 0.70	1 0 0 0 -	0 0 0 0 -	0 0 0 0 -	3 0 0 0 -	2 0 1 1 1 0.75	2 1 0 0 0.57	1 0 0 0 -	8 1 0 1 1 0.75	1 0 0 0 -	0 0 0 0 -	5 0 0 0 -	67 7 6 12 12.34	2 - 3 2
Total	14 [illegible] 1 [illegible] 0 3.71	47 9 24 8 23 2 16 2 28.05	15 4 7 9 5 8.71	61 7 24 23 5 17 4 30.03	54 1 31 2 8 4 13 1 17.84	24 3 5 4 1 6.29	9 1 0 3 2.80	[illegible] 2 9 2 9 2 8 13.98	[illegible] 1 5 3 1 2 5.38	55 1 18 4 8 6 9 18.47	80 18 5 10 3 5 1 18.69	8 0 0 0 -	7 0 0 0 -	11 2 0 1 1 1.32	26 3 0 0 1.71	18 2 1 2 1 2 1 2.25	30 1 7 1 2 1 2 4.58	10 0 0 0 -	54 4 3 1 1 4.18	18 0 1 0 0.57	15 0 0 0 -	45 0 0 0 -	675 141 109 88 168.56	27 33 26 11

TABLE C10

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 6A BY SQUAD B USING .30-CAL TRIPLEX AMMUNITION

TGT Man	3	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
1	2	5	1 1	7	6 1	4	1	5	3	7 1	8	1	0	2	1	1	4	1	7	2	2	4	74	3.0
	0	2.00 2	1	6 5	5 2	0.96 .6	1	2	0	2	3	0	0	0	0	0	1	0	0	0	0	0	23.96	9.6
	0	2.97	1	5	3 1	0.62 .3	0	1	1	2	0	0	0	1	0	0	1	0	0	0	0	0	18.59	1.3
	1	2.67 1	1	0	2	0.55	0	1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	10.22	1.0
	0.70	3.88	0.97	5.25	4.40	1.05	0.70	2.80	0.70	2.37	2.80	-	-	0.57	-	-	1.14	-	-	-	-	-	27.33	
2	2	3 1	1	7	6	3	1	5	2	6	9	1	1	3	2	2	3	1	6	2	2	4	74	1.0
	0	3.05 2	0	1	0	0.77 .5	0	0	0	2	0	0	0	0	0	0	1 1	0	0	0	0	0	7.82	3.5
	0	4.02	0	3	2	0.50	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	10.52	-
	0	1.71	0	3 2	2	0.44	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	1	10.15	2.0
	-	4.04	-	3.92	2.80	0.93	-	0.70	-	1.40	-	-	-	-	-	-	1.33	-	-	-	-	0.57	15.71	
3	0	6 1	2 1	6	6	3	1	5	5	4	8	1	0	2	3	2	1	1	8	2	1	5	72	2.0
	0	2.91	1	3 1	1	0.88 .5	0	1	2	1	3 1	0	0	0	0	0	0	0	0	0	0	0	17.79	2.5
	0	1.85	1	2 1	2	0.57	0	0	0	1	2	0	0	0	0	1	0	0	0	0	0	0	11.42	1.0
	0	1.29	1	1	0	0.50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3.79	-
	-	3.10	0.97	4.62	2.10	1.12	-	0.70	1.40	1.40	3.01	-	-	-	-	0.57	-	-	-	-	-	-	18.99	
4	0	6	2	6	5	3	1	3	4	7 1	8	0	0	1	2	2	4	0	7	2	2	4	71	1.0
	0	2.74 1	0	1 1	0	0.60 .3	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5.34	2.3
	0	1.69 1	1	3	0	0.59 .2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	8.08	1.2
	0	1.18	0	0	0	0.34	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	4.52	-
	-	2.95	0.70	2.51	-	0.69	-	0.70	-	0.97	0.70	-	-	-	-	-	0.57	-	-	-	-	-	9.59	
5	2	6 1	1 1	7	8 1	4	1	3	3	6	8	1	1	0	4	2	4	1	8	1	1	6	80	3.0
	0	2.37 1	1	3 2	1	1.24 .7	1	0	0	2 1	1 1	0	0	0	0	0	2 1	0	0	0	0	0	14.61	6.7
	0	2.31	1	3	2	0.79 .3	0	1	0	1 1	2	0	0	0	0	0	1	0	1	0	0	1	16.10	1.3
	0	1.60	1	2 1	1	0.71	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	7.31	1.0
	-	2.77	0.97	4.15	1.67	1.43	0.70	0.70	-	1.82	1.61	-	-	-	-	-	1.33	-	0.57	-	-	0.57	18.27	
6	1	3	1	5 1	6	2	1	3	4	6	6	0	0	1	2	1	3	0	5	2	1	4	57	1.0
	0	0.60	0	4 1	3 1	0.63 .4	1	1	0	4	2 1	0	0	0	0	1	0	0	0	0	0	0	19.23	3.4
	0	1.39	1	3 1	1	0.40 .1	0	0	0	0 1	1	0	0	0	0	0	1	0	1	0	0	0	9.99	2.1
	1	0.41	1 1	2	0	0.36	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	1	7.77	1.0
	0.70	1.82	0.91	4.19	3.71	0.73	0.70	1.40	-	3.01	1.61	-	-	-	-	0.57	0.57	-	0.57	-	-	0.57	21.06	
7	1	5	1	7 1	5 1	1	1	3	1	5	7	0	0	0	1	2	3	0	5	2	1	5	56	2.0
	0	1.36 1	1	1	4 2	0.15	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	9.51	3.0
	0	2.32	0 1	1	3	0.09	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8.41	1.0
	0	1.93	1	2	1	0.09	0	1 1	0	1 1	0	0	0	0	0	0	0	0	0	0	0	0	8.02	2.0
	-	2.95 1	0.91	1.67	3.49	0.23	-	1.61	-	0.91	-	-	-	-	-	-	0.57	-	-	-	-	-	12.34	
8	1	6 2	1	4	5	3	1	4	5	4	7	1	0	1	3	1	2	1	3	1	1	1	56	2.0
	0	3.03	1 1	2	2	0.74 .4	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	10.77	1.4
	0	2.97 1	1	1 1	1	0.48	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	8.45	2.0
	1	3.57	0	1	0	0.42	0	0	0	1 1	0	0	0	0	0	0	0	0	0	0	0	0	6.79	1.0
	0.70	3.81	0.91	2.31	2.10	0.95	-	-	-	1.61	0.70	-	-	-	0.57	-	-	-	-	-	-	-	13.66	
9	2	4	1 1	7	5	4	2	5	6	5	6	1	1	2	1	2	3	2	5	2	2	4	72	1.0
	0	0.83	1	0	2	0.77 .4	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	6.60	0.4
	0	0.81	1	0	0	0.49	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	5.50	-
	0	0.56	1	0	0	0.44	0	1 1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	4.00	1.0
	-	1.54	0.97	-	1.40	0.99	0.70	0.91	-	1.40	0.70	-	-	-	-	-	-	-	-	-	-	0.57	9.18	
10	1	7	2	6 1	6	3	1	7	4	5	7 1	1	1	1	3	1	3	1	5	2	2	4	73	2.0
	1	3.08 3	0	2 1	1	0.48 .3	1	0	0	1	3	0	0	0	0	1	0	0	0	0	0	0	13.56	4.3
	0 1	5.05	1	3	0	0.32	0	2	0	0 1	2 1	0	0	0	0	0	0	0	0	0	0	0	13.57	3.0
	1	1.73 1	1 1	3 1	0	0.28	0	0	0	1	2	0	0	0	0	0	0	0	0	0	0	0	10.01	4.0
	0.91	4.94	0.91	3.49	0.70	0.61	0.70	1.40	-	0.91	3.28	-	-	-	-	0.57	-	-	-	-	-	-	18.42	
TOTAL	12	55 5	13 4	62 5	58 [illegible]	30	11	47	37	55 2	74 1	7	4	13	22	16	30	8	59	18	15	41	685	18.0
	1	21.97 10	6 1	25 11	21 5	7.22 4.1	4	5	2	15 1	12 3	0	0	0	1	2	5 2	0	0	0	0	1	129.19	37.1
	0 1	25.58 2	8 1	24 3	14 1	4.65 0.9	1	6	1	8 3	9 1	0	0	1	0	1	4	0	2	0	0	1	110.23	12.9
	4	16.45 3	7 2	14 4	6	4.13	0	6 2	0	7 2	4	0	0	0	0	0	2	0	0	0	0	2	72.58	13.0
	3.01	31.80	8.22	31.89	22.37	8.75	3.50	10.92	2.10	15.80	14.41	-	-	0.57	0.57	1.71	5.51	-	1.14	-	-	2.28	164.55	

TABLE C11

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 7 BY SQUAD B USING .30-CAL TRIPLEX AMMUNITION

Man \ Tgt	5	7	9	12	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
1	[illegible]	6	3	8	8	5	2	7	7	7	13	1	0	3	3	3	3	1	10	2	1	7	102	2
	[illegible]	[illegible]	1	0	1	0	[illegible]	[illegible]	1	0	0.71	0	[illegible]	0	1	0	0	0	0	0	0	1	6.71	-
	[illegible]	[illegible]	[illegible]	0	1	[illegible]	[illegible]	1	0	1	[illegible].43	0	[illegible]	[illegible]	0	0	0	0	0	0	0	0	[illegible].43	-
	[illegible]	2	[illegible]	1	0	0	0	0	0	0	0.27	0	[illegible]	0	0	0	0	0	0	0	0	0	5.27	-
	[illegible]	1.67	0.[illegible]	[illegible].70	1.40	-	-	[illegible].70	0.70	0.70	0.99	-	-	-	0.57	-	-	-	-	-	-	0.57	[illegible].67	
2	2	6	2	8	2	4	0	8	6	0	13	1	[illegible]	2	3	2	2	1	8	3	1	6	81	-
	0	1 1	0	1	0	0	0	0	1	0	1.90	1	0	0	0	0	0	0	0	0	0	0	5.90	1
	0	3	0	2 1	1	0	0	1	0	0	2.54 1	0	0	0	0	1	0	0	0	0	0	0	10.54	2
	0	2 1	2	3 1	0	0	0	0	0	0	1.34	0	0	0	1	0	0	0	0	0	0	0	9.[illegible]4	2
	-	[illegible].22	1.40	3.22	0.70	-	-	0.70	0.70	-	3.56	0.70	-	-	0.57	0.57	-	-	-	-	-	-	15.34	
3	0	4	2	5	3	3	2	4	4	7	9	0	0	2	3	2	4	1	8	2	1	7	73	-
	0	1 1	[illegible]	4 3	0	0	0	0	0	2	1.35 1	0	0	0	0	0	0	0	0	0	0	0	9.35	5
	0	1	0	3 1	0	0	0	1	0	2	1.21	0	0	0	0	0	0	0	0	0	0	0	8.21	1
	0	0	0	1	0	[illegible]	0	2	0	2 2	0.13	0	0	0	0	0	0	0	0	0	0	0	5.1[illegible]	2
	-	0.91	0.7[illegible]	3.64	-	-	-	2.10	-	3.22	1.[illegible]9	-	-	-	-	-	-	-	-	-	-	-	11.96	
4	[illegible]	[illegible] 1	2 1	7	3	3	0	5	4	8 1	8	1	0	2	3	1	4	1	8	3	1	7	79	3
	0	[illegible] 1	1	4 2	1	1	0	1	0	5 1	0.24	0	0	0	1	0	0	0	0	0	0	1	17.[illegible]	4
	1	3	2	2	2 1	0	0	2	0	2	0.14	0	0	0	0 1	0	0	0	1	0	0	0	15.14	2
	1 1	2	1	0	1	0	0	1	0	2	2.09	0	0	0	2	0	0	0	0	0	0	0	12.09	1
	0.91	3.28	1.67	3.22	2.3[illegible]	0.70	-	2.80	-	4.68	1.73	-	-	-	1.32	-	-	-	0.57	-	-	0.57	23.[illegible]6	
5	[illegible]	[illegible]	1	7 2	8	0	[illegible]	5	4	7	[illegible]	1	0	2	3	1	5	1	6	3	1	7	80	2
	[illegible]	0	[illegible]	3	[illegible]	0	[illegible]	0	0	2	2.18	1	0	0	[illegible]	0	0	0	0	0	0	0	11.18	-
	[illegible]	1	0 1	2	2	0	0	1	[illegible]	[illegible] 2	0.11 2	0	0	0	1	[illegible]	0	0	0	0	0	0	8.1[illegible]	5
	0	0	1	2	1 1	0	[illegible]	0	0	2	2.07	0	0	0	1 1	0	1	0	0	0	0	0	10.07	2
	-	0.7[illegible]	0.91	2.64	2.[illegible]	-	[illegible].7[illegible]	0.70	-	1.82	2.07	0.70	-	-	0.75	0.57	0.57	-	-	-	-	-	14.44	
6	1	4	1	5 1	4	1	[illegible]	4	4	3	6	1	0	2	2	2	1	0	5	1	[illegible]	5	55	1
	[illegible]	[illegible]	1 1	2	1	1	[illegible]	0	0	2 1	1.55	0	0	0	0	0	0	0	[illegible]	0	[illegible]	0	12.55	2
	[illegible]	1	1	1	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible].55	0	0	0	0	0	0	[illegible]	0	[illegible]	0	0	6.[illegible]	1
	[illegible]	[illegible]	0	2	0	0	[illegible]	1	1	0	0.2[illegible]	0	0	0	0	0	0	0	[illegible]	0	0	0	[illegible].2[illegible]	-
	[illegible]	[illegible]	0.[illegible]	2.[illegible]	0.70	[illegible]	[illegible].70	2.10	0.70	1.6[illegible]	1.46	-	-	-	-	-	-	-	0.57	-	-	-	[illegible].5[illegible]	
7	[illegible]	4	0	7	7	1	0	4	4	4	3	1	1	1	2	1	2	0	5	1	[illegible]	4	56	-
	[illegible]	2 2	0	4 1	2 1	[illegible] 1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	[illegible].00	5
	[illegible]	[illegible]	0	[illegible] 1	2	[illegible]	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	[illegible].00	1
	[illegible]	[illegible]	0	[illegible]	1 1	[illegible]	0	[illegible]	0	0	1	0	0	0	0	0	0	0	0	0	0	0	3.00	1
	[illegible]	1.8[illegible]	-	3.22	2.5[illegible]	[illegible].9[illegible]	-	1.4[illegible]	-	0.70	0.70	-	-	-	-	-	-	-	-	-	-	-	1.[illegible]	
8	[illegible]	4	1	5	5	1	1	5	4	2	0	1	0	2	2	1	3	1	0	1	1	6	47	-
	[illegible]	[illegible]	[illegible]	1	0	0	0	[illegible]	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1.00	-
	[illegible]	[illegible]	0	1	1	0	0	[illegible]	0	0	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	1.0[illegible]	-
	[illegible]	[illegible]	0	0	1	0	0	0	0	0	0	0	0	0	[illegible]	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible].0	-
	[illegible]	[illegible].70	-	1.40	1.40	-	-	0.70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	[illegible].2[illegible]	
9	[illegible]	4	[illegible]	[illegible]	5	3	1	5	3	4	8	0	0	2	1	2	3	1	2	2	1	4	64	-
	[illegible]	0	[illegible]	0	[illegible]	[illegible]	[illegible]	0	0	[illegible]	1.22	0	0	0	0	0	0	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.[illegible]2	-
	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0	0	1	0	0	0.14 1	0	0	0	0	0	0	0	0	0	[illegible]	[illegible]	5.1[illegible]	[illegible]
	[illegible]	4 1	0	2	0	0	0	0	0	2	3.09	0	0	0	0	0	0	0	0			[illegible]	[illegible].09	1
	[illegible]	[illegible]	[illegible].70	2.[illegible]	-	-	-	[illegible].7[illegible]	-	1.40	2.63	-	-	-	-	-	-	-	-	-	-	-	11.[illegible]	
10	[illegible]	8 1	[illegible]	6	4	[illegible]	0	2	[illegible]	6	7	1	0	2	[illegible]	1	3	1	6	2	1	[illegible]	71	1
	0	4 3	0	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	[illegible]	1.38 1	0	0	0	0	0	1	0	0	[illegible]	[illegible]	[illegible]	6.[illegible]	3
	0	3	1	[illegible]	0	2	[illegible]	0	[illegible]	0	1.23	0	0	0	0	0	0	[illegible]	0	0	[illegible]	0	6.2[illegible]	1
	[illegible]	2	0	2	[illegible]	[illegible]	[illegible]	0	0	1	1.14	0	0	0	0	0	0	0	0	0	0	0	6.[illegible]	1
	[illegible]	[illegible].70	[illegible].7[illegible]	[illegible].61	-	-	-	-	-	[illegible].70	2.[illegible]	-	-	-	-	-	0.57	-	-	-	-	-	9.[illegible]	
Total	[illegible]	[illegible]	[illegible] 2	6[illegible] 3	49	24	8	49	45	5[illegible] 1	74	8	[illegible]	20	25	16	30	8	60	20	[illegible]1	63	[illegible]	9
	[illegible]	[illegible]	[illegible]	[illegible]9	[illegible]	5 1	2	[illegible]	2	12 2	10.[illegible]3 2	2	0	0	2	0	1	0	0	0	0	2	81.[illegible]	2[illegible]
	[illegible]	[illegible] 2	[illegible] 1	[illegible]	9 1	1	[illegible]	12	0	[illegible] 2	[illegible].13	0	0	0	1 1	2	0	0	1	0	0	0	76.13	14
	[illegible]	[illegible] 2	[illegible]	[illegible] 2	4 2	0	0	4	1	9 2	11.[illegible]	0	0	0	4 1	0	1	0	1	0	0	0	7[illegible].34	10
	[illegible]	[illegible].[illegible]2	[illegible].98	2[illegible].[illegible]2	11.[illegible]	2.31	[illegible]	11.90	2.10	[illegible].63	16.66	1.40	-	-	3.21	1.14	1.14	-	1.14	-	-	1.14	126.82	

TABLE [illegible]

[illegible] AND CASUALTIES [illegible]

USING .30-CAL TRIPLEX AMMUNITION

TABLE C12

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 8 BY SQUAD A USING .30-CAL TRIPLEX AMMUNITION

Tgt	3	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
Man																								
	1	3 1	1 1	7	6	3	1	4	6	1	8 1	1	1	2	2	1	2	0	5	1	2	3	63	3
	0	3	1	3 1	2	2 1	1	1	0	1	3 1	1 1	0	1	1 1	1	0	0	0	0	0	0	21	5
1	0	1	1	3	1	1 1	0	1	0	0	2	1	0	0	1	0	0	0	1	0	0	0	13	1
	1	1	1	1	4	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	9	-
	0.70	2.37	0.97	4.41	3.30	1.82	0.70	1.40	-	0.70	2.58	0.91	-	0.57	0.75	0.57	0.57	-	0.37	-	-	-	23.09	
	1	3 1	2	6 2	6 1	2	1	5	2	7	8	0	1	1	3	2	4	0	6	2	1	5	68	3
	0	2	1	6	2	1	0	2	0	2	0	0	0	0	0	1	0	0	0	0	0	0	17	-
2	0	0	0	2	2	0	0	0	0	1 1	2	0	0	0	0	0	0	0	0	0	0	0	7	1
	0	0	0	2	3 1	0	0	1	1	1	1	0	0	0	0	0	0	0	1	0	0	0	10	1
	-	1.40	0.70	4.74	3.28	0.70	-	2.10	0.70	2.31	2.10	-	-	-	-	0.57	-	-	0.57	-	-	-	19.17	
	1	6	2	6	7	1	1	3	4	7	7	1	1	1	1	2	3	1	4	2	1	4	66	-
	0	4 1	0	4 2	2	1	0	0	0	1	4 2	0	0	0	0	0	0	0	0	0	0	0	16	3
3	0	3 1	1	2 1	3 1	0 1	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0	0	14	4
	0	2 1	1 1	2	3 1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3
	-	4.83	0.91	4.13	4.62	0.91	-	-	-	2.80	3.22	-	-	-	-	-	-	-	-	-	-	-	21.42	
	1	5	2	7	7	3	1	5	7	3	10 1	1	1	2	3	1	5	1	6	1	1	6	79	1
	0	1 1	0	3 2	1	1	0	1	3	2 2	4 2	0	0	0	0	0	0	0	0	0	0	0	16	7
4	0	1	0	3 1	1 1	0	0	0 1	0	3	3	0	0	0	0	0	0	0	0	0	0	1	12	3
	0	0	0	2 1	4 1	0	0	3	0	1	1	0	0	0	0	0	0	0	0	0	0	0	11	2
	-	0.91	-	3 64	3.22	0.70	-	2.31	2.10	3.22	3.49	-	-	-	-	-	-	-	-	-	-	0.37	20.16	
	1	5 1	1	6 1	6 2	1	0	4	2	4	7	1	0	2	1	2	3	1	4	1	2	4	58	4
	1	2	1	5 1	6 1	0	0	0	1	1	1	0	0	0	0	1 1	0	0	0	0	0	0	19	3
5	0 1	3	0 1	2 2	4 2	0	0	2	0	1	0	0	0	0	0	1	0	0	0	0	0	0	13	6
	1	1	1	3	4	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	12	-
	0.91	3.07	0.91	4.40	6.07	-	-	1.40	0.70	2.10	1.40	-	-	-	-	0.75	-	-	-	-	-	-	21.71	
	1	8	2 2	4	8	2	2	1	4	6	8	1	1	2	3	2	2	0	5	2	2	6	72	2
	0	4 2	2	2 1	2 2	1	1	0	1 1	1	0	0	1	0	0	1	0	0	1	0	0	0	17	6
6	1	5 1	2	1	4	0	0	1	1	1	1	0	0	0	0	0	1	0	0	0	0	0	18	1
	1 1	3 2	2	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9	3
	0.91	5.95	1.94	2.31	3.92	0.70	0.70	0.70	0.91	2.10	0.70	-	0.70	-	-	0.57	0.57	-	0.57	-	-	-	23.25	
	0	5	2	5	6	1	1	4	4	3	3	1	1	1	2	2	4	1	2	2	1	5	56	-
	0	4 1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	7	1
7	0	1 1	0	2	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0	0	6	1
	0	1	0	1	1	0	0	1	0	2 2	0	0	0	0	0	0	0	0	0	0	0	0	6	2
	-	3.22	-	2.80	0.70	-	-	0.70	-	1.82	1.40	-	-	-	-	-	0.57	-	-	-	-	-	11.21	
	2	4	2	8	3	4	1	4	2	3	7	1	1	2	3	2	5	1	4	3	2	8	74	-
	0	3	1	2	1 1	1	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	10	1
8	0	1 1	1 1	0 1	1	1	0	1	0	0	1	0	0	0	0	1	0	0	0	0	0	2	9	3
	0	1	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	5	-
	-	3.01	1.61	2.31	0.91	1.40	-	0.70	-	-	1.40	-	-	-	-	0.57	0.57	-	-	0.57	-	1.15	14.20	
	2	6	1	8	7	3	2	5	2	3 1	8	1	1	2	3	2	4	0	8	3	2	6	79	1
	1	3 1	1 1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	7	2
9	0	2	1	1	1	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	9	-
	0	0	0	2 1	1	1	0	1 1	0	1	1	0	0	0	0	0	0	0	0	0	0	0	7	2
	0.70	3.01	0.91	1.61	1.40	0.70	-	1.61	-	1.67	1.40	-	-	-	-	-	-	-	-	-	-	-	13.01	
	0	3	1	4	7	1 1	1	3	5	5	7	1	1	1	1	2	2	0	6	1	0	4	56	1
	0	0	1 1	0	3	1	0	0	0	3 1	3 1	0	0	0	0	0	0	0	0	0	0	0	11	3
10	0	0	1	0	0	1	0	1	1	2	1	0	0	0	0	0	1	0	0	0	0	0	8	-
	0	1	0	1	1	1	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	7	-
	-	0.70	0.91	0.70	2.80	0.97	-	1.40	0.70	3.71	2.31	-	-	-	-	-	1.15	-	-	-	-	-	13.35	
T	10	46 2	16 3	61 3	65 3	21 1	11	38	38	44 1	73 2	9	9	16	22	18	34	5	50	18	14	53	671	15
O	2	26 6	8 2	26 7	19 4	8 1	2	4	5 1	12 3	18 6	1 1	1	1	1 1	4 1	2	0	1	0	0	0	141	33
T	1 1	17 4	7 2	16 5	17 4	3 2	0	8 1	2	13 1	13	1	0	0	1	2	2	0	1	0	0	3	109	20
A	3 1	10 3	6 1	17 2	20 3	4	0	7 1	1	8 2	5	0	0	0	0	0	2	0	1	1	0	0	85	13
L	3.22	28.47	8.66	31.03	30.42	7.90	1.40	12.32	5.11	20.43	20.00	0.91	0.70	0.57	0.75	3.03	3.43	-	1.71	0.57	-	1.72	182.37	

TABLE C13

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 15 BY SQUAD A USING .22-CAL DUPLEX AMMUNITION

Tgt / Man	4	7	9	11	13	14	15	16	18	19	20
[illegible]	[illegible]	[illegible]	[illegible]	8 2 5 4 [illegible]	5 [illegible] [illegible] [illegible]	3 2 1 1.61	1 0 0 -	2 2 2 1.40	4 0 1 0.70	7 2 4 3 [illegible]	9 1 3 4 4.41
[illegible]	[illegible]	[illegible]	[illegible]	6 1 1 1.40	[illegible] 0 0 -	3 0 [illegible] -	1 0 0 -	3 0 1 0.70	4 0 0 -	8 2 3 4 3.92	8 1 4 1 3.01
[illegible]	[illegible]	[illegible]	[illegible]	- 1 [illegible] 2 [illegible]	5 2 [illegible] 2 [illegible]	3 2 0 1.40	1 1 1 1 0.91	2 0 0 -	4 1 1 1 0.91	8 3 7 3 [illegible]	8 2 0 1.40
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] [illegible] 3 [illegible]	[illegible] 1 1 1.40	[illegible] 2 0 1.40	1 0 1 0.70	[illegible] 0 0 -	4 0 0 -	6 1 3 2 3.01	9 3 4 3 3.43
[illegible]	[illegible]	[illegible]	[illegible]	5 1 2 [illegible] [illegible]	4 1 [illegible] 2 [illegible]	3 2 [illegible] 2 2.52	1 0 0 -	[illegible] 1 1 1.40	2 0 1 0.70	4 2 2 2 1.62	- 2 5 2 3.92
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] [illegible] 2 [illegible]	[illegible] 1 [illegible] 2 [illegible]	3 0 0 -	1 0 0 -	[illegible] 2 1 2.10	3 0 1 0.70	4 3 1 2.80	5 1 0 0.70
[illegible]	[illegible]	[illegible]	[illegible]	- [illegible] [illegible] 4.20	5 1 [illegible] 1.40	3 [illegible] 0 -	1 0 0 -	[illegible] [illegible] 0 0.70	4 0 0 -	7 1 3 3 3.71	6 1 1 1.40
[illegible]	[illegible]	[illegible]	[illegible]	7 2 [illegible] 3 [illegible]	6 0 0 -	2 0 0 -	1 0 0 -	4 1 1 1.40	3 0 0 -	8 5 0 3.50	8 1 3 2.80
[illegible]	[illegible]	[illegible]	[illegible]	5 [illegible] [illegible] [illegible]	[illegible] [illegible] 0 -	3 1 1 1 0.91	1 0 0 -	- [illegible] 1 0.70	4 1 1 1.40	4 0 0 -	10 1 1 2 1.61
[illegible]	[illegible]	[illegible]	[illegible]	[illegible] [illegible] 1 [illegible]	[illegible] 0 [illegible] -	[illegible] [illegible] [illegible] [illegible]	1 0 0 -	5 0 2 [illegible]	2 0 0 -	4 1 2 2.10	[illegible] 2 1 2.10
[illegible]	[illegible]	[illegible]	[illegible]	62 9 - 22 [illegible]	48 4 [illegible] 4 [illegible]	29 4 [illegible] 4 [illegible]	10 1 [illegible] 2 1.61	58 - - 9.80	34 1 2 5 4.41	60 11 31 20 30.31	75 8 24 17 24.78

Tgt / Man	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
[illegible]	1 0 1 0.70	1 0 0 -	1 0 1 0.70	2 0 0 -	2 0 1 0.70	4 1 1 1.40	1 0 0 -	4 1 0 0.70	1 0 0 -	2 0 0 -	2 0 0 -	67 26 23 23.89	9
[illegible]	0 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	3 1 0 0.70	1 0 0 -	6 0 1 0.70	2 0 0 -	1 0 0 -	4 0 0 -	45 10 8 11.15	3
[illegible]	1 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	3 0 0 -	1 0 0 -	5 0 0 -	2 0 0 -	2 0 0 -	3 0 0 -	67 23 12 19.60	10
[illegible]	1 0 0 -	0 0 0 -	2 0 0 -	2 0 0 -	1 1 1 1 0.91	4 0 0 -	1 0 0 -	6 0 0 -	1 0 0 -	2 0 0 -	3 0 0 -	67 17 13 16.59	9
[illegible]	0 0 0 -	0 0 0 -	1 1 0 0.70	3 0 0 -	0 0 0 -	2 2 0 1.40	0 0 0 -	6 [illegible] 0 0.70	0 0 0 -	0 0 0 -	1 0 0 -	48 13 16 22.40	10
[illegible]	1 1 0 0.70	1 0 0 -	1 0 0 -	3 0 1 0.70	1 0 0 -	3 0 1 0.70	1 0 0 -	5 [illegible] 0 0.70	2 0 0 -	1 0 0 -	4 0 1 0.70	58 18 13 19.74	4
[illegible]	[illegible] 0 0 -	1 0 0 -	1 0 0 -	1 0 0 -	1 0 0 -	4 0 0 -	1 0 0 -	4 0 0 -	2 0 0 -	2 0 0 -	4 0 [illegible] -	65 13 10 14.65	5
[illegible]	0 0 0 -	0 0 0 -	1 0 0 -	2 1 1 1.40	2 0 0 -	3 0 1 0.70	1 0 0 -	4 0 0 -	2 [illegible] [illegible] -	2 [illegible] 0 -	2 [illegible] 0 -	65 15 10 16.05	5
[illegible]	0 0 0 -	1 0 0 -	2 0 0 -	3 0 0 -	3 0 0 -	3 0 0 -	1 0 [illegible] -	8 [illegible] [illegible] -	3 0 0 -	2 0 [illegible] -	4 0 0 -	81 9 13 10.56	6
[illegible]	1 0 0 -	1 0 0 -	0 0 0 -	4 0 0 -	2 0 2 1.40	4 0 1 0.70	1 0 0 -	[illegible] [illegible] 0 0.70	2 0 [illegible] -	2 [illegible] [illegible] -	[illegible] [illegible] [illegible] [illegible]	62 9 [illegible] 11.61	1
[illegible]	6 1 1 1.40	6 0 0 -	11 1 1 1.40	24 1 2 2.10	15 1 1 4 3.01	33 4 4 5.60	9 0 0 -	55 4 1 3.50	17 0 [illegible] -	16 [illegible] 0 -	[illegible] 1 [illegible] 1.40	646 163 125 173.18	58

TABLE C14

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 16 BY SQUAD B USING .22-CAL DUPLEX AMMUNITION

Tgt Man	5	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
1	1 0 0 -	5 3 4 3 3.43	2 0 1 0.70	6 3 4 4 4.13	6 3 4 4 4.13	4 1 1 1 0.91	2 1 1 1 0.91	5 0 0 -	4 1 1 1.40	8 3 6 4 5.53	9 2 6 5 5.32	1 1 0 0.70	2 0 1 0.70	1 0 0 -	5 1 1 1.40	1 0 0 -	4 1 0 0.70	1 1 0 0.70	7 0 1 0.70	3 0 1 0.70	2 0 1 0.70	5 0 0 -	82 31 27 52.76	16
2	2 0 0 -	4 0 3 2.10	2 1 1 1.40	2 2 2 2 1.82	6 2 3 3.50	4 1 0 0.70	1 0 0 -	5 2 0 1.40	5 1 1 1 0.91	4 0 1 0.70	8 2 0 1.40	1 0 0 -	1 0 0 -	1 0 0 -	3 1 0 0.70	1 0 0 -	4 0 1 0.70	1 0 0 -	6 0 0 -	1 1 0 0.70	2 0 0 -	5 0 1 0.70	67 13 13 16.73	3
3	1 0 1 0.70	7 3 2 3.50	2 1 0 0.70	6 2 3 5 3.22	5 0 0 -	2 2 1 2.10	1 0 0 -	3 0 0 -	4 0 0 -	5 1 2 1 1.61	6 0 0 -	1 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	3 0 0 -	1 0 0 -	7 0 0 -	2 0 0 -	2 0 0 -	3 0 0 -	65 11 8 11.83	3
4	1 0 0 -	7 2 3 2 2.52	1 1 1 1 0.91	7 1 2 2 2.31	3 2 2 2.80	5 0 0 -	1 0 0 -	3 0 0 -	4 0 0 -	8 1 4 3 4.41	8 2 1 2.10	0 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	4 0 0 -	0 0 0 -	4 0 0 -	1 0 0 -	1 0 1 0.70	3 0 0 -	63 14 12 15.75	5
5	2 0 1 0.70	6 2 4 2 3.22	1 0 1 0.70	7 1 2 3 3.01	6 0 0 -	4 0 1 0.70	1 0 0 -	3 0 0 -	4 1 0 0.70	6 1 2 2 2.51	9 2 0 1.40	1 0 0 -	1 0 0 -	2 0 0 -	4 0 0 -	2 0 0 -	4 1 0 0.70	1 0 0 -	8 0 0 -	2 0 0 -	1 0 0 -	3 0 0 -	80 12 10 13.44	4
6	1 1 1 1 0.91	6 3 4 3 5.43	1 0 1 0.70	6 1 3 3 3.71	3 1 1 1.40	3 2 0 1.40	1 0 0 -	3 1 0 0.70	4 1 0 0.70	1 1 0 0.70	6 2 0 1.40	0 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	5 0 0 -	1 0 0 -	4 0 0 -	2 0 0 -	1 0 0 -	2 0 0 -	55 16 9 15.05	5
7	0 0 0 -	7 3 6 3 4.83	1 1 1 1 0.91	6 2 3 4 3.92	6 3 1 2.80	2 0 0 -	2 0 0 -	3 0 0 -	3 1 1 1 0.91	4 1 2 3 3.01	6 3 2 3.50	0 0 0 -	0 0 0 -	1 0 0 -	3 0 0 -	1 0 0 -	3 0 0 -	0 0 0 -	3 0 0 -	1 0 0 -	1 0 0 -	3 0 0 -	56 19 13 19.88	8
8	1 1 0 0.70	6 3 4 4 4.13	1 1 1 1 0.91	6 1 0 0.70	3 0 0 -	3 0 1 0.70	1 0 0 -	2 1 0 0.70	1 0 0 -	6 1 3 1 2.31	8 1 3 1 2.31	0 0 0 -	0 0 0 -	1 0 0 -	2 1 0 0.70	1 1 0 0.70	3 0 0 -	0 0 0 -	5 0 0 -	1 0 0 -	1 0 0 -	3 0 0 -	55 16 8 13.86	6
9	2 0 0 -	4 0 1 0.70	1 1 1 1 0.91	7 0 1 0.70	5 0 0 -	4 0 1 0.70	0 0 0 -	2 0 0 -	4 0 0 -	7 1 3 2 3.01	8 1 2 4 3.71	1 0 0 -	1 0 0 -	3 0 0 -	5 0 0 -	2 0 0 -	4 0 1 0.70	1 0 0 -	5 0 0 -	1 0 0 -	2 0 0 -	5 0 0 -	72 6 11 10.43	3
10	2 1 1 2 1.61	4 1 2 2 2.31	2 0 1 0.70	3 0 2 1.40	6 1 0 0.70	4 1 1 1.40	1 1 0 0.70	4 1 1 1.40	4 1 1 2 1.61	4 1 1 1.40	8 0 2 1.40	1 0 0 -	2 0 0 -	2 0 0 -	4 0 0 -	1 0 0 -	4 1 1 1.40	0 0 0 -	4 0 0 -	1 0 0 -	1 0 0 -	5 0 0 -	67 10 15 15.03	3
TOTAL	13 2 3 3 4.62	56 17 30 25 30.17	14 4 6 9 8.54	56 12 20 24 24.92	55 5 13 11 15.33	35 1 7 6 8.61	11 1 2 1 1.61	31 5 1 4.20	37 3 6 5 6.23	53 9 24 18 24.99	76 4 22 13 22.54	6 1 0 0.70	8 0 1 0.70	14 0 0 -	28 3 1 2.80	12 1 0 0.70	36 3 3 4.20	6 1 0 0.70	53 0 1 0.70	15 1 1 1.40	14 0 2 1.40	39 0 1 0.70	664 148 128 165.76	56

TABLE C15

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 19 BY SQUAD B USING .22-CAL DUPLEX AMMUNITION

Tgt	5	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	Multiple Hits
Man																								
1	1	4 1	1 1	6 2	6 1	2	2	5 1	2	6	7	1	1	2	2	2	3	1	2	1	2	5	64	6
	0	4	1	4	3	1	1	3	0	1	3	1	1	0	0	0	1	0	0	0	0	0	24	
	1	1	1	3	3	0	0	1	0	1	0	0	0	0	0	0	1	0	0	0	0	0	12	
	0.70	3.01	0.91	3.92	3.71	0.70	0.70	2.31	-	1.40	2.10	0.70	0.70	-	-	-	1.40	-	-	-	-	-	22.26	
2	1	4	2 1	8 1	4	3	1	5 2	3 1	6	8	0	1	1 1	2	1	3	1	2	2	2	4	64	6
	0	2	2	5	0	0	0	3	1	1	4	0	0	1	0	1	1	0	0	0	0	0	21	
	0	1	1	4	0	0	0	2	1	1	0	0	0	1	0	0	0	0	0	0	0	0	11	
	-	2.10	1.61	5.81	-	-	-	2.52	0.91	1.40	2.80	-	-	0.91	-	0.70	0.70	-	-	-	-	-	19.46	
3	0	5 1	2 1	3	4 1	2	0	2	3 1	6 1	5	0	0	1	2	1	2	1	4	0	1	4	48	5
	0	3	1	2	3	1	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	14	
	0	3	1	1	2	0	0	0	1	3	1	0	0	0	1	1	1	0	0	0	0	0	15	
	-	3.71	0.91	2.10	3.01	0.70	-	-	0.91	3.71	0.70	-	-	-	0.70	0.70	0.70	-	-	-	-	-	17.85	
4	0	5 1	2 1	4	3 1	3	1	5 1	2 1	5 1	7	1	1	1	1	2	3	1	2	2	1	4	56	9
	0	2	1	1	1	0	1	1	1	2	5	0	0	1	0	1	0	0	0	0	0	0	17	
	0	3	1	1	1	0	0	2	1	2	3	0	0	0	0	0	0	0	0	0	0	0	14	
	-	3.01	0.91	1.40	0.91	-	0.70	1.61	0.91	2.31	4.13	-	-	0.70	-	0.70	-	-	-	-	-	-	17.29	
5	1	5 2	2 1	5 3	5 1	4 1	2	4	5 1	6	10 1	1	1	2	3	2	3	1	4	1	1	6	74	10
	0	4	1	3	2	2	0	1	1	2	6	0	0	0	0	0	1	0	1	0	0	0	24	
	0	2	2	3	1	1	0	0	2	0	1	0	0	1	0	0	0	0	0	0	0	0	13	
	-	3.22	1.61	2.73	1.61	1.61	-	0.70	1.61	1.40	4.41	-	-	0.70	-	-	0.70	-	0.70	-	-	-	21.00	
6	0	6 1	2 1	3	3	3	0	5	2	7 3	6	1	1	1	2	1	1	1	6	1	0	4	56	5
	0	5	1	2	1	1	0	3	0	4	2	0	0	0	0	0	1	0	0	0	0	0	20	
	0	1	1	1	0	0	0	0	0	4	0	0	0	0	0	0	0	0	0	0	0	0	7	
	-	3.71	0.91	2.10	0.70	0.70	-	2.10	-	4.13	1.40	-	-	-	-	-	0.70	-	-	-	-	-	16.45	
7	0	2 1	1	4 3	1	2	0	3 1	3	4	5 1	0	0	0	2	1	2	0	4	0	0	3	37	6
	0	1	1	3	0	0	0	1	0	2	1	0	0	0	1	0	1	0	0	0	0	0	11	
	0	2	0	4	0	1	0	1	2	0	1	0	0	0	0	0	0	0	0	0	0	0	11	
	-	1.61	0.70	3.43	-	0.70	-	0.91	1.40	1.40	0.91	-	-	-	0.70	-	0.70	-	-	-	-	-	12.46	
8	1	6 3	1	5 1	3	2	1	4	3	5	9	0	1	1	1	2	1	1	2	2	1	4	56	4
	0	5	1	1	0	1	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	12	
	0	4	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	6	
	-	4.85	0.70	0.91	-	0.70	-	-	-	2.10	1.40	-	-	-	-	-	-	-	-	-	-	-	10.64	
9	1	3 1	2 2	6	4	3	2	5	2	5	7	1	1	1	4	2	3	1	0	2	2	4	61	3
	0	2	2	1	0	0	0	1	0	2	2	0	0	0	0	0	0	0	0	0	0	0	10	
	0	1	2	0	0	1	0	1	0	1	0	0	0	0	1	0	0	0	0	0	0	0	7	
	-	1.61	1.82	0.70	-	0.70	-	1.40	-	2.10	1.40	-	-	-	0.70	-	-	-	-	-	-	-	10.43	
10	2 1	4 2	2	7	5	3	1	5	1	5	7 1	1	1	0	3	2	3 1	1	3	1	0	7	64	5
	1	3	1	0	1	1	0	0	1	1	3	0	0	0	1	0	1	0	0	0	0	0	14	
	1	2	1	2	1	1	0	2	0	3	1	0	0	0	1	1	1	0	1	0	0	0	18	
	0.91	2.52	1.40	1.40	1.40	1.40	-	1.40	0.70	2.80	2.31	-	-	-	1.40	0.70	0.91	-	0.70	-	-	-	19.95	
TOTAL	7 1	44 13	17 9	51 10	38 4	27 1	10	43 5	26 4	55 5	71 6	6	8	10 1	22	16	24 1	9	29	12	10	45	590	59
	1	31	12	22	11	7	2	13	5	20	28	1	1	2	2	2	6	0	1	0	0	0	167	
	2	20	10	20	8	4	0	9	7	16	7	0	0	2	3	2	3	0	1	0	0	0	114	
	1.61	29.35	11.48	24.50	11.34	7.21	1.40	12.95	6.44	22.75	21.56	0.70	0.70	2.31	3.50	2.80	5.81	-	1.40	-	-	-	167.79	

TABLE C16

SHOTS, HITS, AND CASUALTIES RECORDED DURING RUN 20 BY SQUAD A USING .22-CAL DUPLEX AMMUNITION

Tgt Man	5	7	9	10	13	14	15	16	18	19	20	21	22	24	25	28	29	30	31	32	33	34	Total	[illegible]
1	1 0 0 -	4 5 4 5 3.45	1 1 1 1 0.91	7 2.0 5.45 5.27 6.52	5 2 3 3 3.22	3 0 1 0.70	1 1 1 1 0.91	2 1 0 0.70	6 0 2 1.40	6 5 4 5 4.85	9 1 4 4 5.11	1 0 1 0.70	1 0 0 -	1 0 1 0.70	2 0 1 0.70	2 2 0 1.40	3 0 1 0.70	1 1 0 0.70	5 2 0 1.40	2 0 0 -	1 0 0 -	5 1 0 0.70	69 29.45 29.27 34.73	13.[illegible]
2	1 0 1 0.70	6 2 4 5 3.92	1 1 1 1 0.91	6 0.5 2.48 2.42 3.19	2 0 0 -	1 1 0 0.70	1 0 0 -	4 0 1 0.70	4 1 0 0.70	5 0 1 0.70	8 2 4 4.20	1 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	2 0 1 0.70	3 0 0 -	0 0 0 -	5 0 0 -	1 0 0 -	1 0 -	4 0 0 -	59 11.48 14.42 16.42	5.5
3	0 0 0 -	4 1 3 2 3.01	1 1 0 0.70	7 1.5 4.99 4.82 6.13	5 1 3 3 3.71	3 0 0 -	1 1 1 1 0.91	5 1 0 0.70	3 0 1 0.70	7 5 0 3.50	6 3 0 2.10	1 0 0 -	1 0 1 0.70	1 0 0 -	2 1 0 0.70	2 1 0 0.70	4 1 3 1 2.31	1 0 0 -	4 1 0 0.70	1 0 0 -	1 0 0 -	7 2 0 1.40	67 29.99 13.82 27.97	5.5
4	1 0 0 -	8 1 4 3 4.41	1 0 1 0.70	7 1.5 3.39 3.25 3.91	5 1 0 0.70	1 0 0 -	1 0 0 -	3 3 0 2.10	3 0 0 -	6 1 4 1 3.01	9 1 3 1 3.71	1 1 0 0.70	1 0 1 0.70	2 0 0 -	2 0 0 -	2 0 1 0.70	3 0 0 -	1 0 0 -	5 0 0 -	2 0 0 -	1 0 0 -	8 0 1 0.70	76 21.39 12.25 21.34	4.5
5	1 0 1 0.70	6 3 6 3 4.85	1 1 1 1 0.91	6 1.0 3.47 3.37 4.30	5 2 0 1.40	1 1 0 0.70	1 0 0 -	4 1 1 2 1.61	1 0 0 -	4 1 2 1 1.61	7 1 2 2.10	1 0 0 -	1 0 0 -	1 1 0 0.70	1 0 0 -	1 0 0 -	2 0 0 -	1 0 0 -	4 0 0 -	2 0 0 -	1 0 0 -	4 0 0 -	56 18.47 13.57 19.86	7.0
6	1 1 1 1 0.91	5 1 2 1 1.61	2 2 2 2 1.82	6 1.0 3.06 2.94 3.71	4 1 0 0.70	4 0 1 0.70	2 0 0 -	4 1 3 2 3.01	2 1 1 1 0.91	5 3 0 2.10	9 1 5 2 4.41	0 0 0 -	1 0 0 -	1 0 0 -	2 0 0 -	2 0 0 -	3 0 1 0.70	1 0 0 -	4 0 0 -	1 0 0 -	2 0 -	5 0 0 -	66 21.06 13.94 20.58	8.0
7	1 0 0 -	3 2 2 3 [illegible]	1 1 0 0.70	6 0.5 2.54 2.48 3.27	3 1 2 1 1.61	1 0 0 -	1 0 0 -	4 1 1 1.40	3 1 1 1 0.91	4 2 1 2.10	7 2 1 2.10	0 0 0 -	1 0 0 -	1 0 0 -	3 0 0 -	2 0 1 0.70	4 0 1 0.70	1 0 0 -	4 0 0 -	[illegible] 0 0 -	1 0 0 -	[illegible] [illegible] 0 -	58 [illegible] 12.48 [illegible]	4.5
8	2 1 0 0.70	2 2 0 1.40	1 1 0 0.70	5 0.5 1.84 1.77 2.28	3 0 0 -	2 0 1 0.70	2 0 0 -	4 2 0 1.40	2 1 0 0.70	4 1 1 1.4	7 1 1 1.40	1 0 0 -	1 1 0 0.70	1 0 0 -	3 0 1 0.70	1 0 0 -	4 1 1 1.40	1 0 0 -	3 0 0 -	1 0 0 -	1 0 0 -	6 0 0 -	54 12.84 6.77 13.46	[illegible]
9	1 1 0 0.70	8 1 4 4 5.11	1 1 1 1 0.91	7 0.5 1.93 1.85 2.40	6 1 2 2 2.31	3 1 1 3 2.31	2 0 0 -	6 1 2 1 1.61	2 1 0 0.70	5 1 1 1.40	9 2 0 1.40	1 0 0 -	1 0 0 -	2 0 0 -	3 1 0 0.70	2 0 0 -	4 1 2 1 1.61	1 0 0 -	4 0 0 -	2 1 0 0.70	1 0 0 -	[illegible] 0 0 -	78 [illegible] 14.85 21.66	6.5
10	2 0 0 -	6 1 3 1 2.31	2 1 [illegible] 1 1.61	6 1.0 2.39 2.29 2.79	7 0 3 2.10	0 0 0 -	1 0 0 -	4 1 1 3 2.31	3 0 0 -	8 1 3 3 3.71	8 4 2 4.20	0 0 0 -	1 0 0 -	0 0 0 -	1 0 0 -	2 0 0 -	4 1 0 0.70	1 0 0 -	3 0 0 -	2 0 0 -	0 1 0 -	5 0 0 -	66 16.39 15.29 19.74	[illegible]
TOTAL	11 1 3 3 3.71	52 15 34 23 32.55	12 7 11 8 9.87	63 31.54 30.46 34.50	45 5 14 12 15.75	19 1 3 6 5.81	13 2 2 2 1.82	40 4 15 10 15.54	32 2 5 5 6.02	54 6 25 14 24.36	79 5 29 17 30.73	7 1 1 1.40	9 1 2 2.10	11 1 1 1.40	21 2 2 2.80	18 3 3 4.20	34 2 7 6 8.12	9 1 0 0.70	18 3 0 2.10	15 1 0 0.70	10 0 0 -	57 [illegible] 1 2.80	649 195.54 146.46 215.98	58.

Target-System Malfunctions

A log was kept of all malfunctions that occurred in the target-operating mechanisms, shockers, and similar programed devices. These malfunctions are listed in Table C22.

Weapon Malfunctions

An observer stationed behind each firer actuated a switch that recorded the duration and identified the position of each weapon malfunction. The nature of the malfunction was then manually recorded. A list of weapon malfunctions appears in Table B7.

TABLE C17

TOTAL HITS AND RICOCHETS FOR SALVO II AMMUNITION

Target	Ammunition									
	.30-cal simplex		.30-cal duplex		.30-cal triplex		.22-cal duplex		.22-cal simplex	
	Target hits	Round	Target hits	Round	Target hits	Round	Target hits	Round	Target hits	Round
5	20	4	31	4	21	0	26	3	9	0
7	99	18	22	12	225	16	204	37	112	36
9	35	3	74	4	79	4	66	5	19	4
10	136	21	183	5	233	13	197	36	32	3
13	88	24	134	17	148	22	90	30	26	8
14	35	4	56	1	47	4	48	17	11	2
15	4	1	8	0	13	0	12	3	1	0
16	15	1	76	1	79	2	67	2	19	2
18	25	1	31	0	24	1	40	0	28	3
19	68	1	96	0	127	3	168	0	65	0
20	118	27	120	18	122	13	157	36	60	21
21	3	1	3	0	4	1	6	0	1	0
22	1	0	1	1	1	0	5	0	1	0
24	5	2	6	0	5	0	8	2	2	0
25	11	5	10	0	13	1	16	5	8	4
28	15	0	12	1	17	0	16	1	7	0
29	20	1	24	0	30	0	36	0	14	2
30	4	3	1	0	0	0	2	0	0	0
31	11	2	16	0	15	0	11	3	18	0
32	5	0	4	0	2	0	3	1	0	0
33	2	0	3	0	0	0	2	0	0	0
34	13	2	8	0	9	1	7	1	1	1
Total	733	121	1118	64	1214	81	1187	182	434	88

Conditions of Weather and Light

Conspicuous weather, wind, and visibility changes were also logged and are noted in Table 2.

Gun-Camera Record

A 16-mm gun camera emplaced in front of each target recorded flechette hits.

Target-System Programs

The six SALVO II target-system programs are listed in Tables C23 to C28.

TABLE C18

TOTAL SHOTS, CASUALTIES, HITS, AND HIT AND CASUALTY PROBABILITIES ON TARGET SYSTEM USING .30-CAL SIMPLEX (M2 BALL) AMMUNITION, BY FIRER

Firer	Shots	Hits	Casualties	P_H	P_C
Squad A					
1	134	61.70	43.18	.460	.322
2	131	21.69	15.18	.165	.116
3	112	47.19	33.03	.421	.295
4	160	54.14	37.88	.338	.237
5	126	37.76	26.44	.300	.210
6	144	56.27	39.39	.391	.273
7	141	26.01	18.22	.184	.129
8	128	36.18	25.32	.283	.198
9	152	29.88	20.92	.196	.138
10	121	29.18	20.44	.241	.169
Squad B					
1	144	36.94	25.86	.256	.179
2	153	44.60	31.23	.291	.204
3	128	40.96	28.67	.320	.224
4	139	31.85	22.30	.229	.160
5	123	40.80	28.56	.332	.232
6	109	37.90	26.53	.348	.243
7	115	19.76	13.83	.172	.120
8	113	30.01	21.00	.265	.186
9	125	23.93	16.75	.191	.134
10	138	26.25	18.37	.190	.133
Total	2636	733.00	513.10	.278	.195

TABLE C19

TOTAL SHOTS, CASUALTIES, HITS, AND HIT AND CASUALTY PROBABILITIES ON TARGET SYSTEM USING .30-CAL DUPLEX AMMUNITION, BY FIRER

Firer	Shots	Hits	Casualties	P_H	P_C
Squad A					
1	124	90.00	54.18	.726	.437
2	147	53.60	34.09	.365	.232
3	126	59.16	37.00	.469	.294
4	161	72.26	41.76	.449	.259
5	133	71.15	42.45	.535	.319
6	144	76.20	45.99	.529	.319
7	133	68.00	40.74	.511	.306
8	127	44.61	28.78	.351	.227
9	145	46.41	29.55	.320	.204
10	116	49.61	28.36	.428	.244
Squad B					
1	148	58.38	35.97	.394	.243
2	150	31.58	19.41	.210	.129
3	144	63.82	39.28	.443	.273
4	127	48.96	30.60	.385	.241
5	141	51.06	32.56	.362	.231
6	105	52.52	32.35	.500	.308
7	109	48.02	30.18	.440	.277
8	118	37.98	24.38	.322	.207
9	134	54.98	32.61	.410	.243
10	127	39.70	25.83	.312	.203
Total	2659	1118.00	686.07	.420	.258

TABLE C20

TOTAL SHOTS, CASUALTIES, HITS, AND HIT AND CASUALTY PROBABILITIES ON TARGET SYSTEM USING .22-CAL DUPLEX AMMUNITION, BY FIRER

Firer	Shots	Hits	Casualties	P_H	P_C
Squad A					
1	136	107.72	64.62	.792	.475
2	125	43.90	27.55	.351	.220
3	134	78.81	47.57	.588	.355
4	143	63.64	37.93	.445	.265
5	104	70.84	41.26	.681	.397
6	124	66.00	40.32	.532	.325
7	123	49.02	30.64	.398	.249
8	119	44.61	29.51	.375	.248
9	159	54.78	32.22	.344	.203
10	128	50.68	32.54	.396	.254
Squad B					
1	146	94.00	55.02	.644	.377
2	131	58.00	36.19	.443	.276
3	113	48.00	29.68	.425	.263
4	121	57.00	33.04	.471	.273
5	154	59.00	34.44	.383	.224
6	111	52.00	31.50	.468	.284
7	93	56.00	32.34	.602	.348
8	111	42.00	24.50	.378	.221
9	133	34.00	20.86	.256	.157
10	131	57.00	35.98	.435	.275
Total	2539	1187.00	717.71	.467	.283

TABLE C21

TOTAL SHOTS, CASUALTIES, HITS, AND HIT AND CASUALTY PROBABILITIES ON TARGET SYSTEM USING .30-CAL TRIPLEX AMMUNITION, BY FIRER

Firer	Shots	Hits	Casualties	P_H	P_C
Squad A					
1	128	101.00	49.93	.789	.390
2	134	60.00	32.06	.448	.239
3	127	79.00	41.13	.622	.324
4	150	81.00	40.16	.540	.268
5	115	64.00	33.13	.556	.288
6	144	96.00	49.48	.667	.344
7	119	60.00	30.67	.504	.258
8	139	44.00	26.18	.316	.188
9	167	37.00	20.70	.221	.124
10	123	51.00	27.69	.415	.225
Squad B					
1	176	70.18	37.00	.399	.210
2	155	54.27	31.05	.350	.200
3	145	55.69	30.95	.384	.213
4	150	62.41	33.35	.416	.222
5	160	67.38	32.71	.421	.204
6	112	63.08	36.59	.563	.327
7	112	46.94	23.61	.419	.211
8	103	32.01	17.86	.311	.173
9	136	33.35	20.42	.245	.150
10	144	55.69	27.83	.387	.193
Total	2739	1214.00	642.50	.443	.234

Table C22

Summary of Target Malfunctions and Adjusted Hits

Ammunition and run	Target	Electronically recorded hits	Adjusted hits	Difference, adjusted – recorded hits	Malfunction
.30-cal simplex					
1a	7	11	21	10	Short
1a	13	8	22	14	Short
11	7	16	21	5	Short
	9	1	6	5	Short
	13	7	26	19	Short
12	9	0	12	12	Short
	13	0	18	18	Short
	19	10	11	1	Short
	20	20	35	15	Short
.22-cal duplex					
15	24	0	2	2	Target failed to appear; adjusted with run 20
20	10	10	62	52	Short
16	16	5	6	1	Part of face missing
.30-cal duplex					
4a	9	0	16	16	Short
	14	0	12	12	Short
	16	6	19	13	Men still firing at target 20; adjusted with data from run 9
	20				Did not drop; 34 hits, target face showed 60
10	10	1	53	52	Target shot off stake; adjusted with data from run 3. Shots also adjusted 37 to 54
.30-cal triplex					
8	13	13	36	23	Short
	7	51	53	2	Saturation
	10	57	59	2	Saturation
	13	55	56	1	Saturation
	20	33	36	3	Saturation
6a	7	27	64	37	Short
	9	20	21	1	Saturation
	14	0	16	16	Short
7	20	21	28	7	Short
5	9	19	21	2	Saturation
	16	26	27	1	Saturation
Total		417	759	342	8 percent of all hits

TABLE C23

SALVO II TARGET-SYSTEM PROGRAM 1

Time, cum sec	Action[a]	Time, cum sec	Action[a]	Time, cum sec	Action[a]
3	d4	97	10b↑	197	14b↑
7	22b↑	107	10↓	203	14↓
10	22↓	112	S3	204	D13
13	d1	114	9↑	210	28b↑
18	19↑	117	9↓	214	28↓
29	19↓	122	24↑	221	31b↑
30	S7	126	24↓	237	31↓
32	D11	127	d16	212	D19
35	16↑	133	25↑	245	29b↑
43	16↓	139	25↓	252	29↓
44	D9	142	D8	256	D20
46	S6	145	7b↑	258	30↑
48	20↑	155	7↓	261	30↓
66	20↓	157	D5	264	D14
70	d12	158	S1	266	D15
71	S2	160	5b↑	267	34b↑
72	D10	163	5↓	279	34↓
75	21↑	168	D18	284	33↑
77	21↓	171	13b↑	288	33↓
82	D6	184	13↓	289	d2
84	D17	187	D7	291	D3
85	18↑	190	15↑	295	32b↑
91	18↓	193	15↓	300	32↓

[a] D, ¼-lb nitrostarch demolition; d, blasting cap; b, blank firing rifle with the indicated target; ↑ target erected; ↓ target dropped; S, electric shock with the indicated firer. Numbers designate the target, demolition, or position on line, as appropriate.

TABLE C24

SALVO II TARGET-SYSTEM PROGRAM 2

Time, cum sec	Action[a]	Time, cum sec	Action[a]	Time, cum sec	Action[a]
4	14b↑	131	21↓	219	S8
10	14↓	132	D15	220	25↑
18	13b↑	134	D11	226	25↓
31	13↓	137	30↑	231	24↑
34	D19	140	30↓	235	24↓
37	15↑	141	D18	238	D13
40	15↓	145	S10	241	S2
42	D14	147	D20	242	32b
48	18↑	148	29^{b}↑	247	32↓
54	18↓	155	29↓	249	d12
58	D7	162	31b↑	250	D5
61	22b↑	178	31↓	251	d1
64	22↓	179	S4	252	33↑
68	D17	183	D9	256	33↓
69	20↑	184	d16	258	D8
87	20↓	185	28b↑	261	D3
88	D10	189	28↓	262	34b↑
93	16↑	191	d2	274	34↓
101	16↓	192	d4	280	10b↑
107	D6	195	7b↑	290	10↓
109	19↑	205	7↓	296	S5
120	19↓	210	5↑	297	19↑
129	21↑	213	5↓	300	19↓

[a] D, ¼-lb nitrostarch demolition; d, blasting cap; b, blank-firing rifle with the indicated target; ↑ target erected; ↓ target dropped; S, electric shock with the indicated firer. Numbers designate the target, demolition, or position on line, as appropriate.

TABLE C25

SALVO II TARGET-SYSTEM PROGRAM 3

Time, cum sec	Action[a]	Time, cum sec	Action[a]	Time, cum sec	Action[a]
2	D15	87	19↑	198	S2
3	d12	98	19↓	199	D18
6	d16	105	22b↑	200	30↑
7	9↑	108	22↓	203	30↓
10	9↓	116	D14	210	28b↑
12	D7	117	21↑	214	28↓
13	S5	119	21↓	220	15↑
14	d2	123	D13	223	15↓
16	10b↑	124	20↑	228	D5
26	10↓	142	20↓	231	13b↑
33	32b↑	144	S7	244	13↓
38	32↓	147	d1	248	14b↑
43	33↑	150	18↑	254	14↓
47	33↓	156	18↓	261	25↑
52	D8	162	D10	267	25↓
53	34b↑	163	D9	272	24↑
65	34↓	164	29b↑	276	24↓
66	S6	171	29↓	278	d4
67	D17	177	D3	281	5b↑
70	D20	178	31b↑	284	5↓
71	16↑	194	31↓	288	D19
79	16↓	195	D11	290	7b↑
86	D6	196	S1	300	7↓

[a] D, ¼-lb nitrostarch demolition; d, blasting cap; b, blank-firing rifle with the indicated target; ↑ target erected; ↓ target dropped; S, electric shock, with the indicated firer. Numbers designate the target, demolition, or position on line, as appropriate.

TABLE C26

SALVO II TARGET-SYSTEM PROGRAM 4

Time, cum sec	Action[a]	Time, cum sec	Action[a]	Time, cum sec	Action[a]
6	34b↑	90	D5	191	22b↑
18	34↓	91	10b↑	194	22↓
23	33↑	101	10↓	196	d12
27	33↓	102	D17	202	18↑
29	D3	103	d2	208	18↓
30	d1	104	D8	211	D6
31	S9	105	d4	217	21↑
32	D11	107	S3	219	21↓
34	32↑	108	9↑	221	D15
39	32↓	111	9↓	223	D19
45	D9	113	D18	224	20↑
46	25↑	115	14b↑	242	20↓
52	25↓	121	14↓	247	D14
55	S2	129	13b↑	250	29b↑
57	24↑	142	13↓	257	29↓
61	24↓	148	15↑	263	30↑
63	d16	151	15↓	266	30↓
66	5b↑	156	D13	273	28b↑
69	5↓	159	19↑	277	28↓
70	D10	170	19↓	280	D20
71	S1	174	D7	283	S4
75	7b↑	176	16↑	284	31b↑
85	7↓	184	16↓	300	31↓

[a] D, ¼-lb nitrostarch demolotion; d, blasting cap; b, blank-firing rifle with the indicated target; ↑ target erected; ↓ target dropped; S, electric shock with the indicated firer. Numbers designate the target, demolition, or position on line, as appropriate.

TABLE C27

SALVO II TARGET-SYSTEM PROGRAM 5

Time, cum sec	Action[a]	Time, cum sec	Action[a]	Time, cum sec	Action[a]
2	D15	82	29↓	195	18↓
4	D8	85	D18	199	D11
5	5↑	87	24↑	201	34b↑
8	5↓	91	24↓	213	34↓
14	7b↑	98	25↑	218	33↑
24	7↓	104	25↓	222	33↓
25	D20	107	D7	226	D3
26	S3	110	D9	227	d1
28	D17	112	19↑	229	32b↑
29	D10	123	19↓	234	32↓
30	30↑	128	20↑	236	d12
33	30↓	146	20↓	240	10b↑
37	S8	149	S6	250	10↓
39	D6	152	16↑	254	d4
40	28b↑	160	16↓	255	d2
44	28↓	165	D5	257	9↑
45	D13	166	D14	260	9↓
46	D19	168	d16	264	14b↑
47	S4	169	21↑	270	14↓
51	31b↑	171	21↓	278	13b↑
67	31↓	178	22b↑	291	13↓
72	S9	181	22↓	297	15↑
75	29b↑	139	18↑	300	15↓

[a] D, ¼-lb nitrostarch demolition; d, blasting cap; b, blank-firing rifle with the indicated target; ↑ target erected; ↓ target dropped; S, electric shock with the indicated firer. Numbers designate the target, demolition, or position on line, as appropriate.

TABLE C28

SALVO II TARGET-SYSTEM PROGRAM 6

Time, cum sec	Action[a]	Time, cum sec	Action[a]	Time, cum sec	Action[a]
5	24↑	104	7↓	203	19↑
9	24↓	105	S1	214	19↓
14	D6	107	D9	215	D7
16	25↑	110	10b↑	216	D17
22	25↓	120	10↓	217	D19
28	30↑	122	D14	221	22b↑
31	30↓	127	9↑	224	22↓
34	d2	130	9↓	225	D10
38	28b↑	138	13b↑	226	S2
42	28↓	151	13↓	229	20↑
45	d4	152	d16	247	20↓
47	d12	157	15↑	249	S7
50	29b↑	160	15↓	253	D11
57	29↓	164	14b↑	255	18↑
59	S6	170	14↓	261	18↓
61	D13	172	D8	264	d1
64	31b↑	176	16↑	267	34b↑
80	31↓	184	16↓	279	34↓
83	D5	186	D18	281	D15
84	D20	193	21↑	286	32b↑
85	5b↑	195	21↓	291	32↓
88	5↓	200	D3	296	33↑
94	7b↑	201	S8	300	33↓

[a] D, ¼-lb nitrostarch demolition; d, blasting cap; b, blank-firing rifle with the indicated target; ↑ target erected; ↓ target dropped; S, electric shock with the indicated firer. Numbers designate the target, demolition, or position on line, as appropriate.

ELECTRONIC DATA REDUCTION

SALVO II firing data were electronically recorded on a 20-channel Esterline-Angus tape by means of the instrumentation described in App E. Allocation of the channels to different events was as follows:

(a) Channel 1, target activation pulses
(b) Channel 2, 1- and ½-sec time pulses
(c) Channel 3, target response signals
(d) Channels 4–8, hits
(e) Channels 9–18, shots
(f) Channels 19–20, spares

Tape velocity was modified to 3 in./sec, fast enough to aid resolution of multiple hits. Basic data reduction was accomplished on the Naval Ordnance Laboratory model 29 Telereader. The projected tape image was magnified 2 times so that 6 in. (or 1 sec of tape record) measured approximately 2540 Telereader units. Measurements were made of pen alignment (zeroing on the number 2, or timing-channel, pen) and of the distance between second pulses so that adjustments could be made for any variations in tape speed. The Telereader was checked for drift each time the tape was advanced. It was determined that each operator could reproduce his measurements within one or two units. Reading procedures were set up that obviated excess cross-hair manipulation and ensured measuring all pen tracings. Finally both a punched card and a typed record of each measurement were produced simultaneously.

The second stage of the data processing consisted of reading the cards into the 1103A computer, adjusting each event for pen alignment, converting the Telereader measurements to real time, and storing the measurements on magnetic tape for rapid access.

Sorting of all data was accomplished in the computer, using punched cards. Some of the distributions obtained were those of lag time, time between hits, time between shots, etc.

ASSIGNMENT OF HITS

As mentioned, Tables C1 to C16 list hits, shots, and casualties by firer, target, and run. For the salvo ammunitions there are two columns for each target heading. The first column lists (top to bottom) shots, first-bullet hits, second-bullet hits, third-bullet hits (in the case of triplex ammunition), and casualties. The second column lists multiple (double) hits for duplex ammunition and (top to bottom) double hits by first and second bullets, second and third bullets, and first and third bullet hits for triplex ammunition. This is illustrated in the unnumbered table on the following page.

Fractional numbers in the hit and overkill columns occurred when unallocated hits were adjusted by firer.

Two problems emerged in the assignment of hits on target—first, assignment of hits to a man, and the second the resolution between first, second, or third bullets in a tandem round. With respect to the problem of assignment of hits to a man, there is very little error involved. The method used was to measure the elapsed time of flight between the trigger-pull record and the time the target was hit and to assign the hit in terms of the expected times of flight. For example, if the time of flight averaged 0.1 sec to a target, it was possible to determine the firer by examining the trigger switch record for 0.1 sec beforehand. Obviously the error associated with this analysis is a function of the variability in the measured time of flight to the particular target on the one hand and the time between shots taken by the firers on the other. An examination of the variability of the time of flight for the .30-cal simplex ammunition shows that it had a standard deviation of approximately 4 msec at targets 7, 9, and 10 and about 5 msec at target 20. (Targets 7, 9, and 10 were grouped because they were approximately the same distance from the firing line. The different distances of these targets from the different positions on the firing line were taken out in this computation.)

HIT RECORD FOR FIRER

Run 5a (triplex), target 10		Run 9 (duplex), target 13	
Shots	Multiple hits	Shots	Multiple hits
6 (shots)	1 (triple hit)	4 (shots)	2 (double hits)
5 (bullet 1)	1 (double, bullets 1 and 2)	3 (bullet 1)	
2 (bullet 2)	1 (double, bullets 2 and 3)	2 (bullet 2)	
3 (bullet 3)	0 (double, bullets 1 and 3)	2.52 (casualties)	
4.89 (casualties)			

The distribution of shots in time was a function of the target location. In general when a near target went up, the men would see the target simultaneously and fire nearly simultaneously. As time went on the density of fire decreased. Accordingly the greatest strain on allocation of hits occurred for the first shot fired particularly at near targets. An analysis was made of the time between the first shot for each firer at targets 7, 9, and 10, and the number of shots that were taken with less than 4 msec between was approximately 3 percent of all the shots fired (see Table C29). Under these adverse conditions, the ability to allocate the hit to a firer embodies approximately a 3 percent error. On target 20 the men did not fire as uniformly, and the time between shots from one firer to another tended to be greater. Approximately 1 percent of the first rounds fired at target 20 occurred within less than 5 msec.

As opposed to the relatively accurate allocation of hits to firers, the identification of first-, second-, and third-bullet hits is less precise. The method for determining the variability in time of flight for first, second, and third bullets for the triplex ammunition and first and second bullets for the duplex ammunition consisted of identifying what are called "sure duplex" or "sure triplex" hits. A sure multiple hit was recorded when the target received several hits in appropriate time sequence that could have been fired only by a particular firer. Under these conditions, it was certain that the first bullet arriving was a front bullet and its time of flight was measured precisely, the second bullet arriving was the second or third bullet, as the case may be, etc. From the times of flight of the first, second, and third bullets under these conditions of certainty, the variability in the times of flight of the individual

TABLE C29

TIME BETWEEN FIRST SHOTS FIRED

(Lag time in seconds)

Shot	Target																							
	7	9	10	7	9	10	7	9	10	7	9	10	7	9	10	7	9	10	7	9	10	7	9	10
	Squad, run																							
	A, 1a			A, 12			B, 2a			B, 11			A, 15			A, 20			B, 16			B, 19		
	.30-cal simplex (M2 ball) ammunition												.22-cal duplex ammunition											
1	2.391	0.0683	0.166	0.245	0.0263	0.276	0.544	—	0.231	0.420	0.138	1.759	0.0103	—	1.081	0.0448	0.144	0.524	0.0339	0.135	0.476	0.383	0.689	1.104
2	0.224	0.653	0.0577	0.0695	0.0503	0.204	2.35	0.0739	0.0440	0.0517	0.244	0.0146	0.307	0.435	1.290	0.0927	0.257	0.0366	0.389	0.0055	0.0758	0.170	0.0895	0.0523
3	0.0463	0.0637	0.136	0.0109	0.346	0.388	0.0477	0.188	0.124	0.0973	0.255	0.0586	0.0531	0.151	0.613	0.0145	0.0454	0.179	0.125	0.0107	0.131	0.0915	0.0118	0.0454
4	0.166	0.306	0.0326	0.0500	0.0189	0.0027	0.0849	0.0671	0.0550	0.0083	0.100	0.162	0.409	0.0301	0.225	0.151	0.311	0.0917	0.317	0.0622	0.306	0.0047	0.0780	0.0459
5	0.321	0.0686	0.0972	0.0515	0.0435	0.106	0.0552	0.0492	0.0851	0.137	0.0453	0.0906	0.0986	0.200	0.106	0.0328	0.0304	0.312	0.0209	0.124	0.0379	0.0207	0.113	0.0733
6	0.0290	0.153	0.0836	0.0986	0.0064	0.136	0.0681	0.197	0.0380	0.148	0.0458	0.0646	0.182	0.159	0.0795	0.0575	0.131	0.0545	0.147	0.242	0.0894	0.0840	0.0055	0.0606
7	0.0012	0.0220	0.0016	0.0156	0.270	0.0068	0.0847	0.247	0.0232	0.0048	0.110	0.128	0.0244	0.0249	0.110	0.0515	0.0384	0.255	0.0351	0.0733	0.105	0.0426	0.151	0.0956
8	0.0275	0.0129	0.0389	0.196	0.0122	0.100	0.209	0.134	0.0574	0.0043	0.120	0.366	0.0016	0.0830	0.344	0.165	0.0426	0.0721	0.133	0.432	0.339	0.120	0.0598	0.197
9	0.122	0.0852	0.0122	0.396	0.204	0.145	0.0304	0.0224	0.0043	0.0314	0.128	0.114	0.0871	0.135	0.496	0.0079	0.157	0.0424	0.333	0.114	0.0593	0.0372	0.287	0.0356
< 4 msecs	1		1										1											
	A, 3a			A, 10			B, 4a			B, 9			A, 5a			A, 8			B, 6a			B, 7		
	.30-cal duplex ammunition												.30-cal triplex ammunition											
1	0.537	0.266	0.0621	0.0432	0.775	0.300	0.171	0.221	0.535	0.151	—	0.144	0.544	0.172	0.0115	0.101	0.104	3.427	0.974	0.164	0.176	0.0114	—	0.103
2	0.0728	0.0887	0.0267	0.160	0.234	0.886	0.0117	0.0516	0.226	0.0299	0.0808	0.0377	0.0662	0.209	0.222	0.0911	0.0146	0.536	0.146	0.0007	0.270	0.238	0.205	0.309
3	0.0133	0.0662	0.129	0.0972	0.0929	0.409	0.246	0.0951	0.0542	0.0164	0.0954	0.133	0.0090	0.166	0.0165	0.220	0.323	0.128	0.0330	0.171	0.0209	0.0392	0.376	0.0733
4	0.0281	0.0141	0.234	0.0693	0.0086	0.0978	0.0882	0.280	0.0680	0.0488	0.0200	0.0620	0.0247	0.0847	0.0423	0.0295	0.0294	0.263	0.167	0.115	0.0204	0.153	0.285	0.0320
5	0.400	0.0051	0.0310	0.0142	0.0472	0.0214	0.0425	0.0011	0.121	0.0915	0.0188	0.263	0.171	0.111	0.114	0.0031	0.0569	0.0317	0.0017	0.156	0.0595	0.140	0.0535	0.0005
6	0.117	0.0468	0.0172	0.0944	0.0113	0.215	0.0090	0.0932	0.254	0.0734	0.0031	0.0754	0.000	0.143	0.0757	0.144	0.148	0.130	0.0685	0.145	0.0197	0.0888	0.157	0.138
7	0.0254	0.0057	0.0123	0.266	0.125	0.273	0.0219	0.110	0.206	0.139	0.202	0.138	0.0093	0.0482	0.108	0.125	0.0195	0.190	0.0499	0.0554	0.134	0.0042	0.0805	0.553
8	0.216	0.0429	0.110	0.0402	0.0137	0.0396	0.165	0.0431	0.0659	0.0428	0.152	0.133	0.0843	0.132	0.0313	0.183	0.196	0.0373	0.215	0.0888	0.311	0.0687	0.238	0.172
9	0.265	0.0233	0.0412	0.0256	0.134	0.0879	0.125	0.111	0.0637	0.312	0.0587	0.0115	0.170	0.223	0.0627	0.0796	0.290	0.0113	0.0255	0.202	0.0473	0.112	0.112	0.0163
< 4 msecs							1	1			1		1			1			1	1		1	1	1

TABLE C30

VARIATION IN VELOCITIES OF .30-CAL TRIPLEX BULLETS

(Based on sure triple hits on target 7)

Position	Velocity, ft/sec		
	First bullet	Second bullet	Third bullet
1	2535	2374	1832
2	2397	2222	1878
	2520	2435	1901
	2497	2184	2046
3	—	—	—
4	2336	2176	1909
5	2527	2351	2084
	2435	2290	1893
6	2603	2542	2489
	2435	2329	1954
7	2535	2283	2046
	2504	2336	1863
8	2397	2329	1771
9	—	—	—
10	2382	2329	1932
	2512	2390	2069
	2443	2298	1893

TABLE C31

MEAN VELOCITIES AND STANDARD DEVIATIONS OF EACH AMMUNITION

Ammunition	Bullet	Targets 7, 9, 10		Target 20	
		Mean velocity, ft/sec	σ, ft/sec	Mean velocity, ft/sec	σ,[a] ft/sec
.30-cal simplex	First	2542	108.23	2355	63.16
.30-cal duplex	First	2361	88.26	2187	51.5
	Second	2251	91.70	2085	53.5
.22-cal duplex	First	2671	103.32	2475	60.3
	Second	2545	101.41	2358	59.2
.30-cal triplex	First	2426	87.95	2248	57.16
	Second	2258	109.64	2092	63.98
	Third	1921	139.19	1780	81.23

[a] Computed values based on .30-cal simplex ratios for all ammunitions but .30-cal simplex.

bullets can be measured and an estimate of the accuracy of allocation of individual hits to the appropriate position in the round can be gained.

Since it was not possible to find sure multiple hits on distant targets, the determination of the variability in time of flight for the bullets had to be extrapolated from the closer targets. The time of flight for .30-cal triplex bullets fired at target 7 is listed in Table C30 and is illustrated in Fig. C1. Note the overlap between the first, second, and third bullets. It is obvious that if a hit were isolated it would not be readily assignable to the first, second, or third bullet without some degree of error. This figure is an example of the errors involved. The errors associated with the other rounds and at different ranges are given in Table C31.

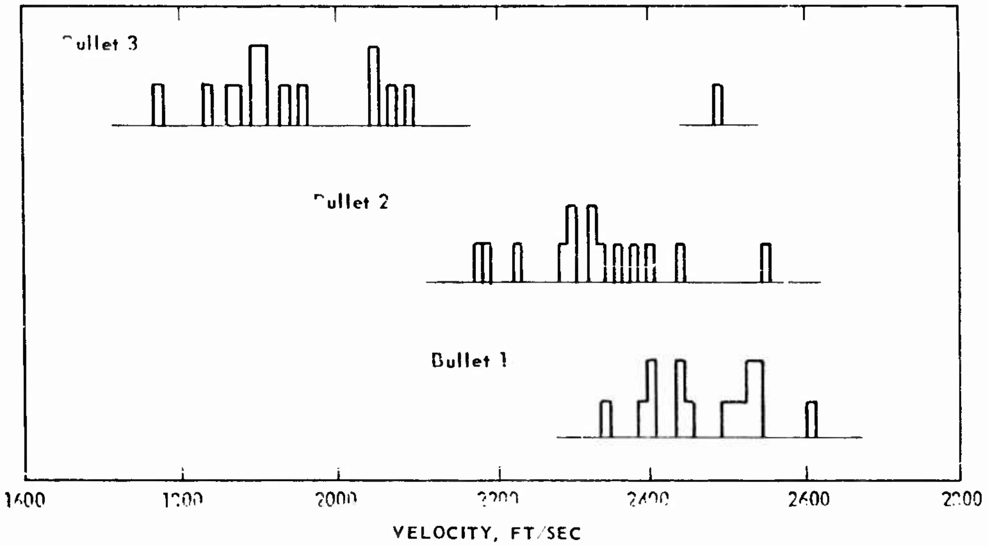

Fig. C1—Variation in Velocities of .30-cal Triplex Bullets
Based on sure triplex hits on target 7.

In extrapolating mean velocities and standard deviations for the salvo ammunitions for target 20, it is assumed that the velocities remain proportional within this range. The accuracy of assignment of hits to the appropriate bullet can be determined with this table.

DATA ADJUSTMENT BY TARGET

The data presented in this memorandum are derived from two sources—the electronic record and the target-hole count. The electronic record agrees in general with the target-hole count, but in several instances the target "shorted out" and the only record is the number of shots taken by each man and the number of holes in the target face. In cases where the electronic record of the number of hits on targets did not agree with the count of the actual number of holes, efforts were made to reconcile this difference. Table C22 lists the causes and number of unresolved hits.

Most of the ricochets were electronically recorded, but apparently some struck the target without making simultaneous electrical contact with the front and back faces as explained in App E and illustrated in Fig. E3. The torn-target-face category accounts for the fact that the crews assigned to put up and take down the target faces tore the paper and lost a section of the target. The remaining category—saturation—occurred on triplex runs; if two firers fired within 12 msec of each other and both of the triplex rounds hit the target, the recording apparatus would be saturated because it could only record five hits in the space of 12 msec. This occurred only on near targets.

The nonrecording of hits was less likely to occur than the spurious recording of nonhits. These cases of "noise" almost always occurred as an indication of more than one multiple hit occurring at the same time, and unless two shots had occurred nearly simultaneously the extra indication would be rejected. The possibility of acceptance of such noise as a hit was slight, as is shown in the following section. The record obtained from the target face count also served as an additional check.

METHOD OF ADJUSTMENT BY FIRER

Since on some of the targets it was not possible to allocate hits accurately to each firer, it was necessary to assign hits. The criteria used for assignment were first the aiming error associated with each firer and second the total number of hits received by the target from all the firers as determined by the target-face count. Knowing the error for a firer, it was possible to predict his expected number of hits based on the number of shots he fired at the target. When all the expected hits for all firers were computed, the sum naturally differed slightly from the target-face count, and accordingly each number of expected hits was multiplied by the appropriate ratio so that the sum of the assigned hits equaled the target-face count.

In actual practice the above method was used without elaboration with respect to the .30-cal simplex rounds. It was necessary to assign not only the first-bullet hit but also subsequent bullet hits for the duplex and triplex rounds. To do this required the additional knowledge of the relative first-, second-, and third-bullet hits on each target. Accordingly all the sure, assigned hits received by the particular target were examined and the relative proportion of the first, second, and third bullets was determined for each kind of ammunition. The final number of assigned first-, second-, and third-bullet hits for each firer always had the same ratio as determined by the total hits of first, second, and third bullets.

One additional problem of adjustment remained—that of determining overkills. The method used was similar in principle to that of determining first-, second-, and third-bullet hits. The total number of overkilling hits expected on the basis of the multiple hits on the other runs was averaged for this run, and these overkills were assigned to firers in terms of their hit expectancies. For example, on run 10 target 10 shorted out. The total number of .30-cal duplex rounds fired by and the aiming error associated with each firer were known. The total number of hits on the target, determined from the target-face count, was 16, whereas the sum of the expected hits, determined by combining aiming error for each man, was 14. Accordingly all the hits computed needed to be multiplied by 16/14. In addition, in an examination of the other three runs, target 10 proved to have received exactly as many first- as second-bullet hits, and accordingly the total number of first-bullet hits assigned had to equal that of the second-bullet hits assigned. In addition the average number of overkills per run was found to be four, as shown by the other three runs with this same ammunition. Accordingly four overkills were apportioned equally among the firers, being certain that no firer received overkills if he had not received enough primary hits to have warranted an overkill.

TABLE C32

LATE FIRE FOR .30-CAL. SIMPLEX AMMUNITION

Run	Late-fire time, sec[a]								
	Target recording				Total	Target not recording			Total
	0 – 0.1	0.1 – 0.2	0.2 – 0.3	0.3 – 0.4		0.4 – 0.5	0.5 – 0.8	0.8 +	
	Rounds								
1	11	4	6	9	30	16	8	0	24
2	10	8	4	4	26	7	13	1	21
11	9	9	13	5	36	10	13	1	24
12	10	11	12	14	47	9	12	4	25
Total	40	32	35	32	139[b]	42	46	6	94[c]

[a] Target 45+ deg erect and can record in this period.

[b] 5.32 percent of all shots.

[c] 3.56 percent of all shots.

The foregoing description of the method of adjustment applies even when a target shorted out in the middle of its exposure time. In such a case the time when it shorted was determined, the total record of hits and shots up to that time was retained, and adjustments were made only on subsequent rounds. As a matter of fact, this kind of adjustment occurred more frequently than the adjustment where all, rather than a portion of, the hits needed to be adjusted. This method of adjustment has the advantage of being consistent with the remainder of the analysis. It does not contribute to the variance, but it does reduce the degrees of freedom. Inasmuch as the relative number of targets requiring adjustment was small and the total number of degrees of freedom was large, it appears that little or no bias was introduced by this method of adjustment.

RATE-OF-FIRE DATA

Target-up and -down signals recorded on the Esterline-Angus tapes enabled time to first shot and shots fired after target down signal was given (late fire) to be measured with an accuracy of 0.1 sec. A table of late fire based on the simplex runs is shown in Table C32, and Fig. C2 illustrates the cumulative

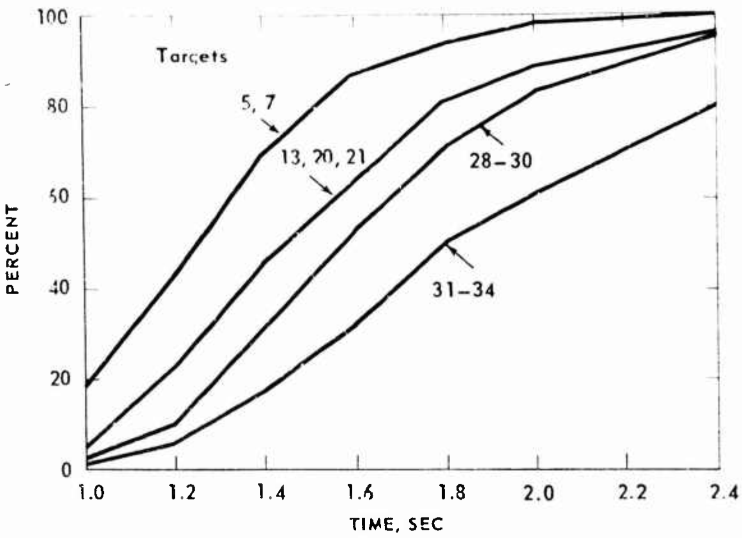

Fig. C2—Cumulative Percentage of Time between Shots for All Firers and All Runs

Target size: targets 5 and 7, 3.7 mils; 13,20, and 21, 2.4 mils; 28 to 30, 1.5 mils; and 31 to 34, 0.9 mils.

percentage of time between shots for all firers on all runs. Each curve represents one of four main presented-area-target groupings. The targets not shown in the figure fell between these curves according to their presented areas. A discussion of average time to first shot appears in the main body of this memorandum.

Appendix D

DATA ANALYSIS

FIGURE

TABLES

AIMING ERROR

The over-all error associated with the firing of the rifles is referred to in this memorandum as aiming error, since all other weapon and environmental sources of inaccuracy are trivial in comparison. For the reasons given in the subsection "Ammunition Differences" in the body of this memorandum the .22-cal simplex and flechette ammunitions are omitted from the analysis given in this appendix.

The method used in determining the over-all aiming error for the firers in the SALVO II experiment is an extension of that used in the SALVO I report.[1] It is assumed that (a) the targets are circles with the same equivalent areas as the E or F targets,* (b) the firers aim at the center of each target, and (c) the errors have a circular normal probability distribution. Error was computed using the following equation:

$$\sigma = \sqrt{-T^2/(2\ln)(1-P)} \tag{D1}$$

where T = angular target size and P = hit probability.

In computing errors for individual firers in SALVO II, targets were grouped in angular size ranges, and hit probabilities were examined for each target group (instead of using an average target size and the over-all hit probability for the entire system).

The aiming errors for multiple-bullet ammunitions can be computed similarly by use of hits obtained from the first bullets. Table D1 shows the aiming errors associated with the different firers and ammunitions. The aiming errors for the .30-cal simplex ammunition are used to represent the firers in the discussions throughout the report with the exceptions of Figs. 5 to 7. It was not possible to subtract ricochets from the hits obtained by individual firers, and as a result the estimates of the true aiming errors are low.

Salvo theory implies that the gain to be derived from the use of multiple-bullet ammunitions becomes greater as the aiming error increases (see the subsection "Firer Accuracy and Gain from Salvo Ammunitions" and Figs. 5 to 7). Table D2 compares the gain in casualties with each firer's individual aiming error (as measured by .30-cal simplex ammunition). The correlation r between aiming error and salvo-ammunition casualty gains was computed for the various ammunitions and is also shown in Table D2. As expected the coefficient of correlation r is quite large and indicates a significant relation between these two variables. (Salvo gain relative to first-bullet hits is presented in Figs. 5 to 7.)

*In the aiming-error computations target size is expressed as angular target radius in mils.

TABLE D1

AIMING ERROR FOR INDIVIDUAL FIRERS

(Ricochets included)

Firer		Ammunition			
		.30-cal simplex (M2 ball)	.30-cal duplex	.30-cal triplex	.22-cal duplex
		Aiming error, mils			
Squad A[a]					
E	1	1.97	2.18	2.34	2.16
S	2	3.67	3.89	3.35	3.70
	3	2.12	2.79	2.70	2.17
	4	2.40	3.33	3.25	2.82
	5	2.68	2.68	3.10	2.24
M	6	2.30	2.35	2.64	2.57
	7	3.59	3.01	3.57	3.18
	8	2.81	3.37	4.06	3.10
	9	3.41	3.56	6.04	3.44
	10	3.06	2.99	3.98	3.39
Squad B[a]					
E	11	2.93	3.46	3.64	2.23
	12	2.73	4.88	5.32	2.90
S	13	2.54	3.69	3.38	3.27
	14	3.12	2.93	3.94	3.02
	15	2.46	3.66	3.75	3.03
M	16	2.37	3.04	2.67	2.56
	17	3.70	2.95	3.60	2.57
	18	2.86	3.56	4.76	3.05
	19	3.52	3.07	6.74	4.44
	20	3.55	4.20	4.25	3.57

[a] E, expert; S, sharpshooter; M, marksman.

Table D2

Correlation between Aiming Error[a] and Salvo-Ammunition Casualty Gains

Firer	Aiming error, (mils)	Casualty gains, %		
		.30-cal duplex ammo	.30-cal triplex ammo	.22-cal duplex ammo
1	1.97	36	21	47
3	2.12	0	10	20
6	2.30	17	26	19
16	2.37	27	35	17
4	2.40	9	13	12
15	2.46	0	−12	−4
13	2.54	22	−5	17
5	2.68	52	37	89
12	2.73	−37	−2	35
8	2.81	15	−5	25
18	2.86	11	−7	19
11	2.93	36	17	111
10	3.06	44	33	50
14	3.12	51	39	71
9	3.41	48	−10	47
19	3.52	81	12	17
20	3.55	53	45	107
7	3.59	137	100	93
2	3.67	100	106	90
17	3.70	131	76	190
$r =$		0.747	0.549	0.628

---

[a] Based on simplex hit probability, ricochets included.

It is not possible to give individual estimates by firer of the aiming error on particular targets because of the relatively small number of shots taken by a single firer at a single target. It is possible, however, to estimate the average aiming error for 20 firers on each target; this error is given by target for .30-cal simplex ammunition in Table D3. These targets were grouped to include one to three targets of approximately equal angular size. In this case it was possible to exclude ricochets since they could be identified on individual targets and then subtracted from total hits.

TABLE D3

AIMING ERROR FOR INDIVIDUAL TARGETS USING .30-CAL SIMPLEX AMMUNITION

Target	Aiming error, mils	
	Including ricochets	Excluding ricochets
5	3.71	4.23
7	2.98	3.43
9	3.33	3.58
10	2.45	2.77
13	2.31	2.80
14	2.42	2.58
15	3.93	4.60
16[a]	4.97	5.18
18[a]	4.07	4.17
19[a]	2.88	2.90
20	2.32	2.72
21	4.78	5.90
22	6.95	6.95
24	2.88	3.76
25	2.63	3.62
28	2.07	2.07
29	2.41	2.47
30	2.84	5.94
31	3.00	3.34
32	2.02	2.02
33	3.20	3.20
34	2.05	2.25
Mean, mils 2.04[b]	3.19	3.66

[a] Moving targets.

[b] Mean target size.

AIMING ERROR COMPARED WITH OTHER MEASURES OF PERFORMANCE

The SALVO II target system was designed to simulate combat in several ways, e.g., the firers did not know how long the targets would be up. They were instructed to get as many hits on each target as possible, and accordingly the men paced themselves, some firing more rapidly than others, some hastening off their first shots at each target, and some trying to fire as quickly as possible. This feature of the SALVO II target system is in contrast to the

TRAINFIRE target system or most other types of target shooting where the firers not only know how long the target will be up but also are to fire a fixed number of rounds at each target, usually 1 round.

The aiming error associated with each firer is compared with measures of the speed of firing in Tables D4 and D5. Table D4 compares the aiming error associated with the first shot taken at each target with the average time required to get off that first shot, and Table D5 compares the firer's over-all aiming error with rate of fire as measured by the median time between shots.

TABLE D4

CORRELATION BETWEEN AIMING ERROR FOR .30-CAL SIMPLEX (M2 BALL) AMMUNITION AND TIME TO FIRE FIRST SHOT

Firer	First shot aiming error, mils	Avg time to first shot, sec
1	1.86	2.60
6	2.30	2.40
3	2.42	2.05
12	2.49	2.31
16	2.49	2.93
4	2.64	2.52
13	2.84	2.81
14	2.90	2.78
15	3.24	2.00
5	3.24	2.72
11	3.42	2.18
18	3.48	3.17
10	3.56	3.04
8	3.60	3.02
17	3.67	3.49
20	3.71	2.73
7	4.04	2.82
19	4.28	2.84
2	4.94	2.76
9	7.98	2.40

r = 0.037

Note that the time between shots does not include the time required to get off the first round. The median is used in Table D5 as opposed to the arithmetic mean used in Table D4. Because the time between shots occasionally involved clip loading as well as firing time, the use of the median avoids the extreme durations represented by clip loading time. It is not necessary to use a median in the time to fire the first shot at a target because if a firer had used up all the ammunition on the previous target, he would have had time before the appearance of the next target to have put in a fresh clip. Aiming error for these two tables is based on .30-cal simplex ammunition only. Note in these tables that the relation between speed of firing and accuracy is not very high, as indicated by the small coefficient of correlation r.

TABLE D5

CORRELATION BETWEEN AIMING ERROR AND MEDIAN TIME BETWEEN SHOTS FOR .30-CAL SIMPLEX (M2 BALL) AMMUNITION

Firer	Aiming error for all shots, mils	Median time between shots, sec
1	1.97	1.64
3	2.12	1.60
6	2.30	1.35
16	2.37	1.98
4	2.40	1.51
15	2.46	1.32
13	2.54	1.32
5	2.68	1.40
12	2.73	1.36
8	2.81	1.38
18	2.86	1.74
11	2.93	1.39
10	3.06	1.50
14	3.12	1.37
9	3.41	1.27
19	3.52	1.60
20	3.55	1.50
7	3.59	1.36
2	3.67	1.63
17	3.70	1.52
$r = 0.143$		

TABLE D6

CORRELATION BETWEEN EXPERIMENTAL AND PREDICTED DUPLEX HIT PROBABILITIES BASED ON .30-CAL SIMPLEX AIMING ERRORS PER TARGET GROUP[a]

Target group	Hit probability		
	Theoretical	Experimental	
		.22-cal duplex	.30-cal duplex
5, 7	.725	.805	.868
9	1.024	1.109	1.029
10	.812	.698	.860
13, 20, 21	.516	.367	.434
14, 15, 22	.374	.246	.348
16, 18, 19	.364	.543	.356
24, 25	.106	.121	.107
28, 29, 30	.287	.240	.185
31	.0843	.0457	.0684
32, 33, 34	.122	.0353	.0549
$r =$		.955	.958

[a] Ricochet hits excluded.

PREDICTIONS

Duplex casualties were predicted using an extension of the method outlined in ORO-T-378 (Ref 1, p 322). Aiming errors per target group, ricochets excluded, were used in computing predicted duplex hits and casualties. Predictions were made for first- and second-bullet hits and double hits. Casualties were computed as described in the body of this memorandum (see the subsection "Ammunition Differences"). Predicted duplex casualties were plotted against over-all aiming errors for the 20 firers. These predictions are displayed in Figs. 5 and 6.

Table D8 presents duplex hit-probability predictions for each of the 10 target groupings and a comparison of these predictions with the actual .30- and .22-cal duplex results. Because the analysis here was by target rather than by firer, it was possible to extract ricochets. The high correlation between the predicted and experimental hit probabilities illustrates the accuracy of the prediction techniques. Theoretical hit probabilities were based on target size and aiming errors by target groups as given in Table D7 (excluding ricochets). The predicted and experimental hit probabilities shown in Table 9 are based on total hits and shots for each duplex ammunition.

TABLE D7

.30-CAL SIMPLEX AIMING ERROR BY TARGET GROUP

Target group	Target-group size, mils	Aiming error, mils	
		Including ricochets	Excluding ricochets
9	4.406	3.33	3.58
5, 7	3.489	3.13	3.57
10	2.982	2.43	2.77
16, 18, 19	2.353	3.52	3.58
13, 20, 21	2.260	2.37	2.82
14, 15, 22	2.043	2.82	3.03
28, 29, 30	1.516	2.33	2.47
24, 25	1.278	2.71	3.65
31	1.023	3.00	3.35
32, 33, 34	0.824	2.20	2.32
Mean	2.22	2.78	3.11

EXPERIMENTAL CURVE AND CONFIDENCE BOUNDS

Confidence Bounds for Salvo Gains

For each of the ammunitions in SALVO II an average number of hits per shot was computed and the gain of multiple-ball over single-ball ammunition was determined (see Table 6). This increased-effectiveness figure depended on the ratio of 2 percentages, both of which were obtained in the experiment and were subject to sampling error. As a result the confidence limits on the gain of salvo ammunitions were obtained through the use of the variance ratio,[20] a statistical technique derived for this purpose. The variance ratio is defined as follows:

$$\sigma_R^2 = R^2\,[(V_x^2/n) + (V_y^2/m) - 2\,(\rho\, V_x V_y/\sqrt{n}\,\sqrt{m})] \qquad \text{(D2)}$$

where $R = P_x/P_y$

P_x = number of hits/number of shots, for x variable

$$V_x^2 = \sigma_x^2/P_x^2 = [P_x\,(1 - P_x)]/P_x^2 = (1 - P_x)/P_x$$ [23]

n = sample size of x variable

m = sample size of y variable

and*

$$\rho = \sum_{i=1}^{K} [(x_i - \bar{x})\,(y_i - \bar{y})]/[(K - 1)\,\sigma_x\,\sigma_y]$$

where K = number of men firing

x_i = number of hits by the ith firer of the x type of ammunition

y_i = number of hits by the ith firer of the y type of ammunition

$\bar{x}$ = average number of hits for the group of firers of the x type of ammunition

$\bar{y}$ = average number of hits for the group of firers of the y type of ammunition

σ_x = standard deviation of x hits

σ_y = standard deviation of y hits.

The 95 percent confidence limits on the gain in hit probability (P_x/P_y) are now expressed as:

$$P_x/P_y + 1.96\,\sigma_R$$

Confidence Bounds for Experimental Hit Probability

The 95 percent confidence bounds for experimental values (.396) of Table 9 are extrapolated from Table XI of Ref 11 (two-sided 95 percent confidence limits for the binomial distribution).

Curve-Fit Technique for Percentage Gain vs Aiming Error

Theoretically the plot of relative percentage gain $[(P_x - P_y)/P_y]$ aiming error should begin at zero and increase, as the error increases without bound, in the shape of an exponential curve becoming asymptotic to a maximum value A $(A > 0)$ (see Fig. D1).

Empirical Curve

The first problem was to select an analytically describable curve that has most of the properties of the theoretical curve and that would also yield a satisfactory solution. The "logistic curve"[11] satisfies the properties with the

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*ρ is a dimensionless correlation of hits by a particular firer of two types of ammunition.

exception of a nonzero value at the origin. Since the data begin at an error of 2 mils and are not extrapolated, this difficulty at the margin is of little consequence.

$$P = 1/(a_0 + a_1 e^{-E})$$

where P = percentage gain
E = aiming error in mils
$1/a_0$ = unknown upper asymptote
$\log_e (a_1/a_0)$ locates the abscissa of the point of inflection

An elementary transformation is

$y \equiv 1/P$
$x \equiv e^{-E}$

Equation D3 then reduces to

$$a_0 + a_1 x = y \qquad \text{(D4)}$$

This is the equation of a straight line and yields a solution by regression analysis. This is accomplished by the simultaneous solution of the two normal equations

$$n a_0 + \sum_{i=1}^{n} x_i \, a_1 = \sum_{i=1}^{n} y_i \qquad \text{(D5)}$$

$$\sum_{i=1}^{n} x_i \, a_0 + \sum_{i=1}^{n} x_i^2 \, a_1 = \sum_{i=1}^{n} x_i \, y_i \qquad \text{(D6)}$$

The x_i and y_i values represent the transformed coordinates of the original data set of observations. Such a solution is very desirable because points in the upper portion of the original plane tended to vary greatly and were weighted very lightly in the transform plane. These curves of average gain are shown in Figs. 5 to 7.

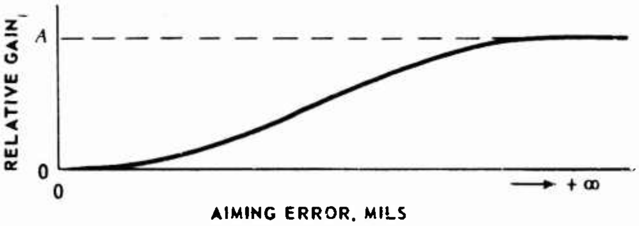

Fig. D1—Plot of Relative Percentage Gains vs Aiming Error

Variance about the Curve for Relative Gain vs Aiming Error

Confidence bounds that would satisfy requirements apparent in the data, such as the relation of scatter to the magnitude of the observed value, were needed about this curve. The bounds also had to reflect a divergence as the x coordinate moved from the average aiming error. The above requirements were satisfied in the technique for confidence bounds using the t distribution.[11]

The equations are as follows:

$$\text{upper bound} = Y_j - t_{.975} S \sqrt{1/n + [(x_j - \bar{x})^2 / \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

$$\text{lower bound} = Y_j - t_{.025} S \sqrt{1/n + [(x_j - \bar{x})^2 / \sum_{i=1}^{n} (x_i - \bar{x})^2}$$

where t = 95 percent confidence value in the above equations

$S = \sqrt{\sum_{i=1}^{n} (y_i - Y_i)^2 / (n-2)}$

Y_j = jth general value on the fitted straight line in the transform plane

Y_i = i th value on the fitted straight line in the transform plane that coincides with some observed y-coordinate value

y_i = transformed ordinate value of an observation

x_i = transformed abscissa value of an observation

$\bar{x}$ = average transformed abscissa value

x_j = associated abscissa value to some general Y_j that can assume any value within the range of definition

The reversal of sign on the bounds is caused by reversing the curve during the transformation into the original plane.

CORRELATION ANALYSIS

The design of SALVO II was based on the experimental design used in the earlier (SALVO I) experiment. In the development of this second experiment, changes were made to facilitate both data recording and weapons testing. The most important of these changes occurred in the average target-exposure time. In SALVO II the average target-exposure time was two-thirds that in SALVO I. In the experimental design the basic ammunition variables had an orthogonal balance, and the total variation was to be separated into the various components to measure the ammunition comparisons. Some of the minor variables were not orthogonally balanced in the experimental design, and it was planned to use a simple correlation analysis for their separation and measurement.

Unfortunately the inaccuracy of the .22-cal simplex ammunition eliminated one of the control ammunitions and forced the experiment into a nonorthogonal design that could not be investigated with the use of the standard techniques of analysis of variance. In the experiment as it was run, there was no possibility of obtaining interactions between the variables. Since the analysis of a nonorthogonal experiment is very similar to correlation analysis and since a multiple-correlation-analysis routine became available for the high-speed computing facilities at ORO, this statistical technique was used for the entire analysis.

The techniques of correlation analysis and analysis of variance are closely related; by successive elimination of variables it is possible to step from correlation analysis to analysis of variance. The latter results are equivalent to those from correlation analysis, and illustrations of the technique are shown in Tables D8 and D9. The square of the multiple correlation coefficient is called the "coefficient of multiple determination" and gives the proportion of the total variation that can be accounted for by the variations in the independent variables. As the variables are eliminated, the amount of variation that can be attributed to each is reflected in changes in this coefficient of multiple determination. This process is followed in both tables. The variance is the error term divided by the degrees of freedom, and the F ratio is computed with the unexplained variance in the denominator; there is no advantage in combining the estimated variances of insignificant factors.

TABLE D8

CORRELATION ANALYSIS AND ANALYSIS OF VARIANCE OF SHOTS FIRED AT TARGET APPEARANCES

Source of variation	Amount of variation	Degree of freedom	Variance	F ratio
Exposure time	76,548	1	76,548	743.47[a]
Angular target size	3,787	1	3,787	36.80[a]
Target movement	1,647	1	1,647	16.01[a]
Target type	1,129	1	1,129	10.98[a]
Target visibility	4	1	4	0.04
Unexplained variation	26,546	258	103	
Total variation	109,661	263	417	

[a] Significant at the 0.1 percent level.

TABLE D9

CORRELATION ANALYSIS AND ANALYSIS OF VARIANCE OF FIRST-BULLET HITS ON TARGET FACES

Source of variation	Amount of variation	Degree of freedom	Variance	F ratio
Shots fired	10,627	1	10,627	494.7[a]
Angular target size	2,698	1	2,698	125.6[a]
Target visibility	163	1	163	7.6[b]
Target movement	309	1	309	14.4[a]
Unexplained variation	5,553	259	21	
Total variation	19,350	263	73	

[a] Significant at the 0.1 percent level.
[b] Significant at the 1 percent level.

Tables D8 and D9 show the division of the total variance into the assigned causes. Table D8 presents the results of the analysis of shots fired at each target appearance. The exposure time in seconds and the angular presented area in mils are the two most significant variables out of the five used in the prediction equations. Target movement and target type are both highly significant variables; target visibility, in terms of the percentage that is not concealed, is not an important variable for the prediction of shots fired. Target movement and target type are both treated as discrete variables; the target either moves or it is stationary. The target is either an E- or an F-type target. Table D9 shows the results of the same sort of analysis of the hits obtained from the first bullets of the salvo ammunitions. The data for this table are obtained from the hits of all .30-cal simplex ammunitions and those from the first bullets of all .22- and .30-cal duplex firings. In this instance target-exposure time and target type are not of importance in the prediction of hits obtained on a target. These two variables are closely enough associated with the number of shots fired that they could be eliminated from the prediction equations. Additional corrections have to be made for the angular presented area of the target and for both target visibility and target movement.

The five basic independent variables—exposure time, target type, target movement, visibility, and presented angular area of the target—are all important variables in the prediction of either shots fired or hits obtained. In the prediction of hits obtained, the use of shots fired as a variable adequately combines exposure time and target type, but not target movement, visibility, or presented angular area. These last three variables affect the accuracy of firing but not the volume.

Computer Program

The initial computations in the correlation-analysis program determine the averages and standard deviations for each of the variables and the corrected sum for each pair of variables. This corrected sum is occasionally referred to as a large covariance; it is the sample size times the covariance. The simple correlation coefficients are then obtained from these corrected sums of pairs and the standard deviations of the variables. The resulting matrix of correlation coefficients is inverted in order to obtain the multiple correlation coefficient, its square, and the standard error of estimate. The standardized regression coefficients appear as ratios of elements of the inverse matrix, and the regular regression coefficients are determined from the standardized coefficients. The constant of the regression equation is obtained through a back solution utilizing the averages of each variable and the regression coefficients of these variables. In the final computation the partial correlation coefficients appear as ratios of elements in the inverse matrix, and a t test is determined on the significance of the regression coefficients. The simple-correlation coefficient measures this same relation, but takes into account any interactions with other variables. The multiple correlation coefficient is a measure of the total relation between the dependent variable and all the independent variables.[21]

Table D10 gives the standard deviations of the dependent variables for three test ammunitions and .30-cal simplex ammunition. The standard deviation is also shown for the grouped data from first bullets. These standard deviations are computed on the basis of n degrees of freedom; the total variance in Tables D8 and D9 is computed on the basis of $n-1$ degrees of freedom. The standard error of estimate for each of the dependent variables is also shown in Table D10. This standard error is the square root of the remaining variance that cannot be explained through the actions of the independent variables. This remaining variance is computed on a basis of $n-k$ degrees of freedom in Tables D8 to D10, k being the number of variables in the correlation analysis and the number of constants in the regression equation.

The averages and standard deviation of the independent variables are constant throughout the experiment; they are given in Table D11. The target subtense is the radius of a circle equivalent in area to the target, divided by the range of the target. For such small angles as these, the tangent of the angle is equal to the radian measure of the angle itself. This target subtense can also be considered as the presented angular area of the target. The target movement is a discrete variable; in the analysis 0 indicated a stationary target and 1 indicated a moving target. The target size is also a discrete variable with 1 indicating an E-type target and 2 indicating an F-type target.

TABLE D10

STANDARD DEVIATIONS AND STANDARD ERRORS OF ESTIMATE FOR SHOTS, HITS, AND CASUALTIES

(Obtained on individual target appearances)

Ammunition	Shots		Hits		Casualties	
	Standard deviation	Standard error of estimate	Standard deviation	Standard error of estimate	Standard deviation	Standard error of estimate
First bullet	20.38	10.14	8.56	5.82	—	—
.30-cal simplex	20.98	10.78	8.75	4.41	6.12	3.08
.30-cal duplex	20.23	6.54	16.63	10.58	8.69	4.57
.22-cal duplex	19.91	12.33	14.91	8.11	10.35	6.51
.30-cal triplex	20.90	9.77	16.84	9.45	8.35	4.56

TABLE D11

AVERAGES AND STANDARD DEVIATIONS OF INDEPENDENT VARIABLES

Variable	Deviation	
	Average	Standard
Angular target size, mils	2.04	0.92
Exposure time, sec	7.534	4.629
Target type, E or F	1.477	0.499
Target visibility, %	82.102	20.598
Target movement, 0 or 1	0.136	0.343

Correlation Coefficients

The multiple correlation coefficient that was obtained in each of the correlation analyses is shown in Table D12. This correlation coefficient was adjusted for both the sample size and the number of constants in the regression equation. A standard F test of the form

$$F = R^2(n-k)/(1-R^2)(k-1)$$

where R is the multiple correlation coefficient, n is the sample size, and k is the number of variables in the correlation, was used to test the significance of the correlation. All the resulting F test values are significant at the 0.1

percent level, and the use of the regression equation is a very real advantage in reducing the unexplained variation.

The proportion of variance remaining is shown in Table D13. This is sometimes called the coefficient of nondetermination because it measures the variation that is not explained by the independent variables. Again adjustments were made for both sample size and the number of constants in the regression equations. The uncorrected coefficient can be obtained as the square of the ratio between the standard error of estimate and the standard deviation given in Table D10.

TABLE D12

ADJUSTED MULTIPLE CORRELATION COEFFICIENT[a]

Ammunition	Predicted variable		
	Shots	Hits	Casualties
First bullets	0.867	0.737	—
.30-cal simplex	0.860	0.866	0.866
.30-cal duplex	0.947	0.774	0.852
.22-cal duplex	0.788	0.841	0.780
.30-cal triplex	0.886	0.830	0.838

[a] All figures are significant at the 0.1 percent level.

TABLE D13

ADJUSTED COEFFICIENT OF NONDETERMINATION

Ammunition	Predicted variable		
	Shots	Hits	Casualties
First bullets	0.248	0.457	—
.30-cal simplex	0.261	0.251	0.249
.30-cal duplex	0.103	0.400	0.273
.22-cal duplex	0.379	0.293	0.391
.30-cal triplex	0.216	0.311	0.298

No single measure of the importance of the relation between an independent variable and the dependent variable exists. The partial correlation coefficient is a measure of the estimated change of the dependent variable for a unit change in the independent variable when both variables are adjusted for possible interactions of other variables. The square of the partial correlation coefficient is a measure of the relative importance of each variable on the actions of the dependent variable. Unfortunately the total of the squares of the partials is not equal to the square of the multiple correlation coefficient, and the individual predicting the variables either overexplains or does not fully explain the total relation. The total of the coefficients of separate determination, sometimes called the "r betas," does equal the square of the multiple correlation coefficient, but some of the individual terms are often negative. The elimination of variables from the analysis is one of the most satisfactory methods of determining the separate effect of a particular variable, but the magnitude of the effect depends to a considerable extent on the order in which variables are eliminated. The partial correlation coefficient is probably the best measure of relations between individual variables; there is no good measure of any relation between the dependent variable and combinations of independent variables.

Tables D14 and D15 give the complete matrix of partial correlation coefficients and regression equations for the analysis of first-bullet data and shots fired at the target. The matrix of partial correlation coefficients for shots fired is fairly stable for all ammunitions; there is no significant difference between ammunitions for them. The partials from the analysis of first-bullet hits are similar only to those from the analysis of simplex ammunition.

TABLE D14

PARTIAL CORRELATION COEFFICIENTS FOR SHOTS FIRED

Variable	Shots (x_1)	Size (x_2)	Exposure time (x_3)	Target type (x_4)	Target concealment (x_5)	Target movement (x_6)
	Partial correlation coefficient					
Shots	1.000	0.334	0.813	−0.198	−0.013	0.284
Size		1.000	−0.346	0.135	−0.086	−0.039
Exposure time			1.000	0.194	−0.293	−0.051
Type				1.000	0.137	0.369
Concealment					1.000	0.334
Movement						1.000

Variable	Regression equation
Shots	$5.044 + 0.244^{a}x_2 + 3.614^{a}x_3 - 4.522^{b}x_4 - 0.008x_5 + 10.318^{a}x_6$

[a] Significant at the 0.1 percent level.
[b] Significant at the 1 percent level.

This full display of the matrix of partials is shown as an illustration of the confusing effects of the nonorthogonality that resulted from the loss of the control ammunition. No partials should have existed between independent variables, only between the dependent and the independent variables. In the regression equation for hits, x_1 is the number of shots fired. The remaining variables in the regression equations are:

(a) x_2, angular area of the target, in mils
(b) x_3, exposure time, in seconds
(c) x_4, size of target—1 indicating an F-type target and 2 indicating an E-type target
(d) x_5, percentage of the target that is not covered by camouflage
(e) x_6, indication of the target movement—0 indicating a stationary target and 1 indicating a moving target

These same subscripts are used in all the regression equations that follow.

Table D16 shows the correlation analysis for the shots fired; Table D17 shows the correlation analysis for hits obtained; and Table D18 shows the correlation analysis of casualties obtained. In each table the simple correlation coefficients, partial correlation coefficients, and regression equations are shown for each ammunition.

TABLE D15

PARTIAL CORRELATION COEFFICIENTS FOR FIRST-BULLET HITS

Variable	Face count	Size (x_2)	Exposure time (x_3)	Target type (x_4)	Target concealment (x_5)	Target movement (x_6)
	Partial correlation coefficient					
Face count	1.000	0.604	0.626	−0.169	0.180	0.017
Size		1.000	−0.461	0.160	−0.183	0.039
Exposure time			1.000	0.149	−0.513	0.242
Type				1.000	0.168	0.331
Concealment					1.000	0.335
Movement						1.000

Variable	Regression equation
Hits	$-8.88 + 0.299^{a}x_2 + 1.187^{a}x_3 - 2.192^{b}x_4 + 0.063^{b}x_5 + 0.332^{b}x_6$

[a] Significant at the 0.1 percent level.
[b] Significant at the 1 percent level.

TABLE D16

CORRELATION ANALYSIS OF SHOTS FIRED AT TARGET APPEARANCES BY TYPE OF AMMUNITION

Ammunition	Angular size (x_2)	Exposure time (x_3)	Target type (x_4)	Target concealment (x_5)	Target movement (x_6)
		Simple Correlation Coefficients			
.30-cal simplex	0.086	0.835	−0.020	−0.362	0.264
.30-cal duplex	0.101	0.920	0.031	−0.371	0.336
.22-cal duplex	0.113	0.764	0.035	−0.291	0.248
.30-cal triplex	0.044	0.873	0.007	−0.371	0.253
		Partial Correlation Coefficients			
.30-cal simplex	0.311	0.808	−0.264	−0.059	0.286
.30-cal duplex	0.508	0.921	−0.206	0.083	0.370
.22-cal duplex	0.288	0.738	−0.147	0.000	0.239
.30-cal triplex	0.259	0.847	−0.210	−0.103	0.267

Ammunition	Regression equations (prediction equations for number of shots fired)
.30-cal simplex	$9.312 + 0.234^{a}x_2 + 3.678^{a}x_3 - 6.345^{b}x_4 + 0.037x_5 + 10.770^{a}x_6$
.30-cal duplex	$-3.871 + 0.256^{a}x_2 + 4.140^{a}x_3 - 2.962x_4 + 0.033x_5 + 8.965^{a}x_6$
.22-cal duplex	$6.696 + 0.246^{a}x_2 + 3.161^{a}x_3 - 3.959x_4 + 0.000x_5 + 9.959^{b}x_6$
.30-cal triplex	$9.772 + 0.174^{b}x_2 + 3.796^{a}x_3 - 4.496x_4 - 0.057x_5 + 9.007^{b}x_6$

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

TABLE D17

CORRELATION ANALYSIS OF HITS OBTAINED ON TARGET FACES BY TYPE OF AMMUNITION

(Ricochets excluded)

Ammunition	Shots fired (x_1)	Target size (x_2)	Exposure time (x_3)	Target type (x_4)	Target concealment (x_5)	Target movement (x_6)
Simple Correlation Coefficients						
.30-cal simplex	0.766	0.418	0.522	−0.054	−0.182	0.077
.30-cal duplex	0.633	0.500	0.459	−0.064	−0.137	0.223
.22-cal duplex	0.731	0.492	0.480	0.063	−0.086	0.292
.30-cal triplex	0.660	0.516	0.452	−0.095	−0.180	0.145
Partial Correlation Coefficients						
.30-cal simplex	0.716	0.537	−0.169	0.005	0.283	−0.346
.30-cal duplex	0.399	0.490	−0.118	−0.197	0.136	0.005
.22-cal duplex	0.597	0.611	0.069	−0.107	0.186	0.150
.30-cal triplex	0.583	0.642	−0.164	−0.215	0.153	−0.041

Ammunition	Regression equations
.30-cal simplex	$- 11.680 + 0.417^{a}x_1 + 0.195^{a}x_2 - 0.317x_3 + 0.045x_4 + 0.075^{b}x_5 - 5.642^{b}x_6$
.30-cal duplex	$- 9.842 + 0.700^{a}x_1 + 0.456^{a}x_2 - 0.858x_3 - 4.645x_4 + 0.087x_5 - 0.206x_6$
.22-cal duplex	$- 15.677 + 0.486^{a}x_1 + 0.431^{a}x_2 + 0.192x_3 - 1.897x_4 + 0.087x_5 + 4.144x_6$
.30-cal triplex	$- 11.804 + 0.690^{a}x_1 + 0.540^{a}x_2 - 0.718x_3 - 4.538x_4 + 0.082x_5 - 1.324x_6$

[a] Significant at the 1 percent level.
[b] Significant at the 5 percent level.

TABLE D18

CORRELATION ANALYSIS OF CASUALTIES OBTAINED ON TARGET FACES BY TYPE OF AMMUNITION

(Ricochets excluded)

Ammunition	Shots fired (x_1)	Target size (x_2)	Exposure time (x_3)	Target type (x_4)	Target concealment (x_5)	Target movement (x_6)
			Simple Correlation Coefficients			
.30-cal simplex	0.766	0.420	0.520	−0.056	−0.181	0.077
.30-cal duplex	0.714	0.497	0.535	−0.107	−0.189	0.164
.22-cal duplex	0.716	0.357	0.494	0.133	−0.006	0.255
.30-cal triplex	0.690	0.487	0.487	−0.078	−0.160	0.197
			Partial Correlation Coefficients			
.30-cal simplex	0.717	0.541	−0.169	0.001	0.286	−0.347
.30-cal duplex	0.544	0.539	−0.186	−0.242	0.193	−0.174
.22-cal duplex	0.560	0.412	0.092	0.051	0.304	−0.030
.30-cal triplex	0.593	0.628	−0.143	−0.228	0.188	0.026

Ammunition	Regression equations
.30-cal simplex	$- 8.178 + 0.292^{a}x_1 + 0.137^{a}x_2 - 0.221x_3 + 0.006x_4 + 0.053^{a}x_5 - 3.947^{a}x_6$
.30-cal duplex	$- 6.030 + 0.460^{a}x_1 + 0.224^{a}x_2 - 0.590x_3 - 2.485^{b}x_4 + 0.054x_5 - 2.973x_6$
.22-cal duplex	$- 18.650 + 0.354^{a}x_1 + 0.203^{a}x_2 + 0.209x_3 + 0.725x_4 + 0.117^{a}x_5 - 0.662x_6$
.30-cal triplex	$- 6.530 + 0.343^{a}x_1 + 0.252^{a}x_2 - 0.302x_3 - 2.337x_4 + 0.049x_5 + 0.410x_6$

[a] Significant at the 1 percent level.

[b] Significant at the 5 percent level.

Appendix E

SALVO II INSTRUMENTATION

FIGURES

INTRODUCTION

Instrumentation requirements for SALVO II were almost identical with those of its predecessor, SALVO I. However, some modifications were made that resulted in improvement in reliability of data obtained. Detailed descriptions of the design and function of all SALVO I instrumentation are presented in App D of ORO-T-378.[1] This appendix deals with the modifications introduced for SALVO II.

In addition to refinements in electronic instrumentation, several additions greatly enhanced the efficiency of field operation. One of these was a modified 30-ft commercial transport trailer that furnished centralized housing for all control and recording equipment (see Figs. 3 and E1). In addition it provided electrical and mechanical maintenance areas and served as a cargo carrier for all field devices. Use of this vehicle made it possible to fabricate, install, and test all the control and recording equipment before leaving the ORO Electronics Laboratory, thus minimizing assembly and test time during field installation. Experience gained on SALVO I indicated the desirability of obtaining wherever possible similar data from alternative sources to minimize the possibility of losing information from failure of some part of the instrumentation complex. A lapsed-time camera, operating on the same time base as the target system and receiving its operating pulse from the sequence controller, was mounted behind the firing line and took one picture per second of all action during each run. This provided an empirical check on weapon malfunction and the appearance and duration of exposure of all targets. In anticipation of the electronic recording difficulties resulting from partial target penetration by the 32-flechette ammunition, 16-mm motion-picture cameras were installed at each target position to photograph the target during its exposure to fire.

SYSTEM BLOCK DIAGRAM

A functional block diagram of the control and data-recording system of SALVO II is shown in Fig. E2. The diagram shows the system separated into three areas: control center, firing line, and field area. The control functions were performed by the timer, the sequence controller, and its associated slave relays. The field and firing-line instrumentation consisted of target devices, demolitions, and shocking devices. The electronic recording system consisted of the recording targets, rifle switches, and Esterline-Angus event recorder. A supplemental record of all events was obtained from the lapsed-time camera already described.

The alternating-current source for the system, not shown on the block diagram, was obtained from two separate 5-kw generators that supplied power

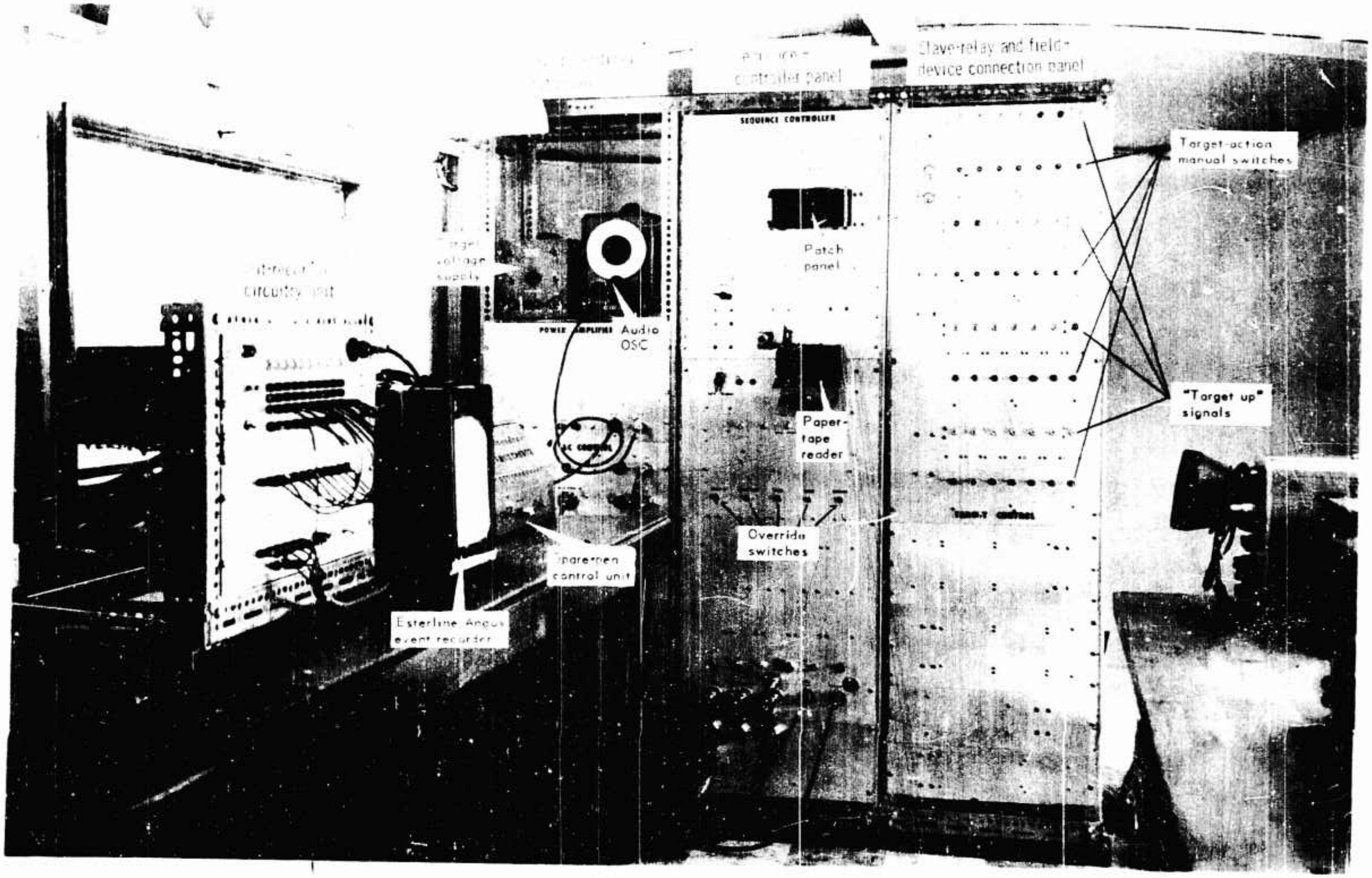

Fig. E1—Control and Recording Equipment in Forward End of Instrumentation Van

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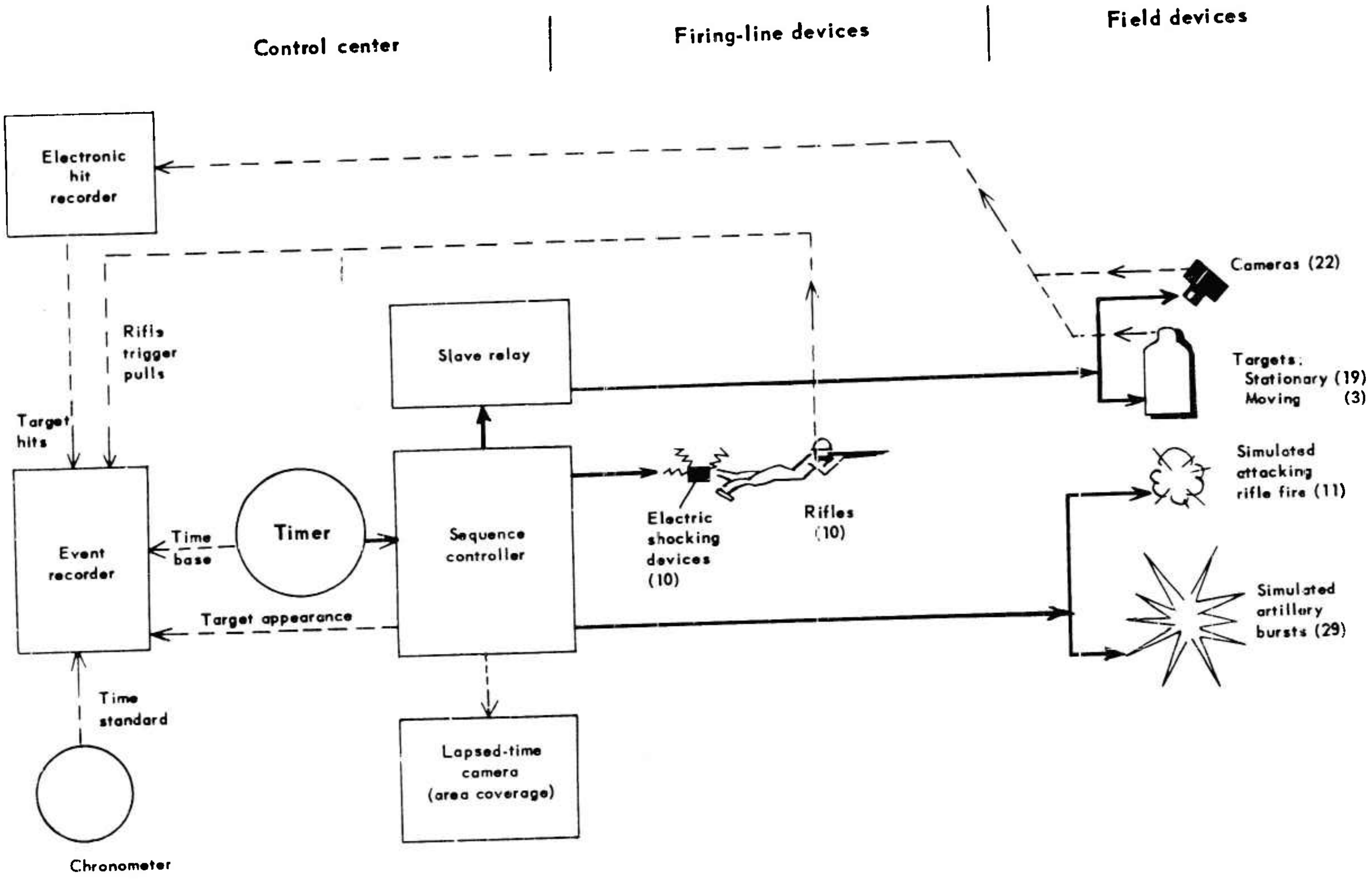

Fig. E2—SALVO II Functional Diagram of Control and Data-Recording System

— — → recording; ——→ control.

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to the recording instrumentation and control elements. These were furnished by the Army.

TIMER

Basically the SALVO II timer was similar to the unit used in SALVO I. As in SALVO I four basic timing pulses were required; however, the pulse rate was changed from one pulse per 1.5 sec to one pulse per second. Action for each run was divided into 300 1-sec intervals, each event taking place at a programed time. An innovation in the SALVO II test was the use of program-sequence punched paper tapes, eliminating the task of manually replugging individual events on the board.

SEQUENCE CONTROLLER

A considerable improvement in ease of program operation and maintenance was achieved by the substitution of a sequence controller for the programer used in SALVO I. The function of the new unit was identical to that of the programer; it provided reproducible control of the events occurring in the target complex, including target appearance, simulated artillery or rifle fire, and simulated "hits" on firing personnel. Operation of the sequence controller can best be described by separating it into four essential blocks: (a) tape transmitter, (b) stepping switches, (c) patch board, and (d) slave relays.

Tape Transmitter. Each of the five types of events in the program was represented on a single channel of a five-channel paper tape. The sequence and duration of the events were determined by the location of holes in the tape. The tape transmitter (Western Electric Model 1A) received one T-1 pulse per second from the timer, advancing the tape one position per pulse. If a hole was sensed in one or more channels of the tape, contacts were closed and the corresponding stepping switches were activated. Spacing of holes in the tape determined the time between events. The rate of the T-1 pulses determined the shortest interval (1 sec); the maximum interval was essentially unlimited.

Stepping Switches. Each type of event was represented by one of five stepping switches. Each stepping switch had 25 positions, limiting the number of actions per event to a maximum of 25. The action of a stepping switch was as follows. For each hole in the paper tape, the stepping switch advanced one position. For example, stepping switch 1, which represented "target appearances," had position 1 for target appearance 1, position 2 for target appearance 2, etc. The sequence of events would always be 1, 2, 3, etc., unless a change in programing was performed. This was accomplished in the patchboard system discussed below.

An automatic homing circuit was incorporated into the stepping-switch circuit so that the switches could be returned to a home or starting position. Increased reliability was obtained by installing a special interrupter-spring circuit in the stepping switch. This special circuit ensured that the switch would advance before advancing power was removed. All stepping switches would be operated manually in case of failure. Indicator lamps provided the operator with a visual check on the operation of the whole system.

Patch Board. As indicated above, the order of events was fixed by the stepping switches. The fixed stepping-switch sequence was fed to a patchboard system that provided a means for programing the switch sequence to include the desired order of events. By use of the patch board, output position 1 of stepping switch 1 could be jumped to activate any target position from 1 to 25. The second and succeeding target appearances could similarly be any desired target of the entire system. Although the patch board is described in terms of a "target-appearance" event, identical flexibility of action could take place for any of the five types of actions in the field installation.

Slave Relays. For most events activating power could be controlled directly through the stepping-switch contacts. However, for the target-appearance events it was necessary to use slave relays with higher power-handling capability. In these cases the stepping switch energized the slave relays, which in turn controlled the direct power to the target devices. Manual relay-operated switches were provided for testing purposes or in the event of failure in the stepping switch or patch board.

The sequence controller proved to be very reliable and relatively easy to maintain. Program tapes and patch boards were punched and wired prior to the test. A program change required only seconds and was accomplished by inserting a new tape and a new patch board.

HIT RECORDING

Although the SALVO II requirements for recording hits were identical, the experience in SALVO I indicated that improved reliability would be desirable.

The basic scheme for developing the hit-recording pulse was unchanged; a switch action was produced by the bullet shorting across two layers of conductive material. However, to achieve increased reliability and target life a different target construction was used. The new target, manufactured by the Reflectone Corp., consisted of two thin sheets of aluminum separated by a layer of insulating plastic and could function satisfactorily after receiving more than 800 hits.

A ricochet broaching the target in a broadside manner would generally lose contact with the first aluminum sheet before piercing the rubber insulating layer and the second aluminum sheet. Thus no short would result and the hit would not be electrically recorded. (See Fig. E3.)

Hits on the targets, trigger pulls of the test weapons, and the 1-sec time base established by a marine chronometer and indicated by the timer were registered on a 20-pen Esterline-Angus event recorder. The problem of identifying individual hits from 10 weapons firing multiple-projectile ammunition had proved difficult in SALVO I. One of the greatest problems was the presence in the system of electronic "noise," indicated by spurious signals on the recording tape that tended to mask the registration of hits. Intensive effort by the ORO Electronics Laboratory was directed toward this problem, and an improved system, capable of resolving hits at intervals of 50 msec was developed. A complete discussion of the improved ORO hit-recording system and a reliability test conducted at the Olin-Mathieson Co., is presented in ORO-SP-62.[9] As stated in the body of this memorandum, preliminary examination of the test data indicates that the reliability of hit recording was very high.

MOVING TARGETS

Basically the moving-target carriage employed in SALVO II was identical to the one used in SALVO I, but several modifications were required to (a) improve reliability, (b) obtain more constant speed, (c) make the target-appearance time independent of target speed, and (d) provide easier access to parts and thereby reduce maintenance time.

Improved reliability was accomplished by using higher-quality components and by redesigning the control circuitry and the construction to facilitate the replacement of parts and subunits.

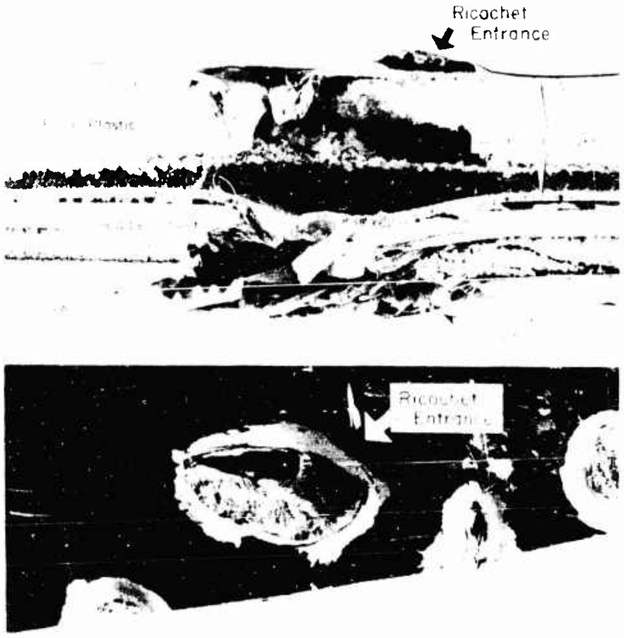

Fig. E3—Plan and Side View of Ricochet Hit

Two major modifications were made in the moving carriage. First the governor action was changed so that it actually detected the speed of the carriage rather than the speed of the drive motor. This change resulted in a more constant and uniform target speed. The second modification was in control circuitry, eliminating the dependency of target-exposure time on speed of the target carriage. In the SALVO I test the target was stopped by a trip switch located near the end of the track; in the redesigned unit used in SALVO II it was stopped by a pulse from the programer. The trip switch was replaced with an added relay and a reverse microswitch. The driving motor was first thrown into reverse by energizing this added relay. Reversal of the driving motor then operated the reverse microswitch, disconnecting the driving power from the carriage. This change made it possible to stop the target after a fixed period of exposure.

TARGET-POSITION CAMERAS

A 16-mm aircraft gun camera (Model AN-N6) was mounted close to the ground on a 2- by 4-in. stake 15 ft in front of each stationary target position. Modified automobile trailer couplings attached to the stakes provided sturdy mounts for the cameras, which were protected from ricochets by steel cases and hinged to allow easy access for loading or adjustment. Cameras for the moving targets were mounted on 6-ft booms attached to the target carriages.

The standard 35-mm-focal-length lenses supplied with the cameras were used to photograph the stationary targets. Cameras for the moving targets were equipped with 17-mm-focal-length lenses to reduce the length of camera boom required.

Self-contained electric motors, powered by dry-battery packs at each position, drove the cameras. Control for each unit was accomplished by a relay activated by the power pulses transmitted to raise the associated target. These "target-up" pulses continued for the duration of target exposure, and the camera relay, repeatedly activated, maintained camera power. When the pulses were discontinued, the cameras, which had an overrun circuit, continued to run at normal speed for a short period of time, identifying each frame of the overrun section of film by a small mark in one corner. Power pulses were delivered in groups of three at evenly spaced intervals, making it possible to determine accurately the time of each frame of film.

The low temperatures prevalent during the experiment prevented wholly satisfactory performance of these cameras. Much power was lost in the dry-battery packs even though fresh batteries were substituted in many of the runs. In some instances the target was not filmed being erected or dropping, and those time references were lost. Other malfunctions resulted in underexposure or in only part of the target faces being photographed.

SIMULATED RIFLE AND ARTILLERY FIRE

Blasting caps, electrically detonated by pulses from the sequence controller, simulated disclosing fire from 11 of the 22 targets. Additional enemy rifle fire and artillery bursts were simulated by the programed firing of 5 or more caps and 15 ¼-lb blocks of TNT in shallow pits throughout the target area. Close bursts of enemy fire were represented by caps exploded in nine 18-in. lengths of 2-in. steel pipe imbedded on the forward side of the firing-line parapet between the gunners' positions.

SIMULATED HITS ON TEST PERSONNEL

As in SALVO I, 5 of the 10 firing troops in each run received a "wound" represented by a programed electric shock delivered through an electrode attached to the calf of one leg. The shocking devices were essentially similar to those used in SALVO I, modified for increased safety to use smaller battery units and equipped with resistors of higher ohmic value.

TARGET ACTIVATION

Target-up and target-down pulses were initiated on signal from the sequence controller. When the target was about 50 percent erect a microswitch was closed, thus completing the hit-recording circuit. Similarly, when the target had traveled about 45 deg of an arc while dropping, the hit-recording circuit was cut off. Each cycle, raising and dropping, required about 0.5 to 0.7 sec after acceptance of the signal. An examination of the data tapes showed that hits were recorded up to 0.5 sec after activation by the down pulse.

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