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SALVO I Rifle Field Experiment (U)

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WORKING PAPER

This is a working paper of members of the technical staff of the Tactics Division concerned with ORO Study 11.3.

The objective of the study is to develop and exploit criteria for improving the infantry weapons system in a manner consistent with trends in infantry weapons development, organization, tactics, and doctrine. This paper, ORO-T-378, deals with one aspect of the study. The findings and analysis of this paper are subject to revision as may be required by new facts or by modification of basic assumptions. Comments and criticism of the contents are invited. Remarks should be addressed to:

The Director
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Published June 1959

SALVO I Rifle Field Experiment (U)

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FOREWORD

The members of the field team that conducted the experiment, including authors, were George Blakemore, Ralph Disney, Carl Hensley, Duncan Love, Paul Michelsen, William Pettijohn, Robert Redick, Kenneth Simpson, William Walton, John Young, and Kenneth Yudowitch, ORO, Thomas Cairns, Lloyd Corbett, Paul Scholtz, and John Stimson, Springfield Armory; Arthur Burns, Olin Mathieson Chemical Corporation; Capt W. C. Sclanick, 1st Lts James Cook and Lindy Dowtin, 2d Lt Oliver Hedges, 3d Div, US Army; David Perrin, Aberdeen Proving Ground, and Charles Dickey, Frankford Arsenal.

The data reduction from target faces and electrical recorder tapes were made by ORO research aides Sheldon Che[illegible], Betty Foster, Carl Hensley, and Kenneth Simpson.

Mrs. Foster in particular devoted much time to painstaking data examination and computations.

In addition to these participants the authors are indebted to numerous others within and without ORO for aid of diverse sorts.

CONTENTS

APPENDIXES

FIGURES

TABLES

PROBLEM

To determine the relative effectiveness of multiple-bullet and single-bullet rifle ammunitions.

FACTS

Earlier ORO study indicated that combat rifle fire would be more effective if hits were increased by causing each trigger pull to fire several bullets (salvo principle). Ammunition designed to fire in this fashion had been fabricated.

DISCUSSION

An experiment designed to compare the salvo cartridges with conventional ammunition in combat-simulating aimed rifle fire, was conducted by ORO in June and July 1956 at Fort Benning, Ga., under the auspices of the SALVO Steering Committee set up by the Chief of Ordnance.

The ammunitions tested include .30-cal duplex and triplex rounds (two and three tandem bullets), compared in hits scored against standard single-bullet AP M2 ammunition. Two "minimum-climb" fully automatic .22-cal (single-bullet) types of fire were also tested: the Gustafson carbine and a modified T48 rifle. Automatic burst fire from these weapons was compared with semiautomatic fire from the same weapons. A 32-flechette load was also fired from a 12-gage semiautomatic shotgun.

These eight types of fire were tested on a combat-simulating range of 22 pop-up (Cocky Ken) targets. Several 10-man groups of firers were used in sitting and standing position, in day and night fire. The experimental data include the number of rounds fired by each man and the number of hits scored on each target. In addition, electrical recording provided chronological firing and hit records by man and target, identifying multiple hits from the salvo ammunitions. The data were subjected to statistical analysis to determine average values of hit probabilities and statistical reliabilities. The analysis, incorporating factors of lethality and weight, leads to conclusions expressed in casualties per salvo, per time unit, and per weight unit for both aimed and unaimed rifle fire. The hit measures were converted to casualty measures, including account of penetration failure and multiple-hit overkilling. Differences are noted in both hits and rate of fire as functions of other experimental variables: firing position, illumination, marksmanship qualification, learning, and target characteristics (size, range, concealment, exposure time, firing activity, and movement).

SUMMARY

Findings

The major findings are summarized in Table 1, which shows the percentages of gain or loss in casualties per salvo (per trigger pull), casualties per time unit, and casualties per weight unit. The six major ammunition comparisons are summarized in this table. The first three lines compare true salvos with single bullets, the fourth line compares automatic bursts with semiautomatic bursts, and the last two lines compare test weapons. "Single" refers to regular M1 fire. The comparison of automatic and semiautomatic fire combines both carbine and T48 results, since they are nearly identical. The carbine and T48 are compared with the M1 in semiautomatic fire only. The "Casualties/time unit" incorporate experimental data on rate of fire. The "Casualties/weight unit" are based on the weight of the weapon plus normal ammunition load (224 rounds).

TABLE 1

OVER-ALL PERCENTAGE CASUALTY GAINS[a]

Ammunition or firing compared	Casualties/salvo	Casualties/time unit	Casualties/weight unit	"Average" gain	2σ
Duplex to single	+ 60	+ 60	+ 60	+ 60	± 7
Triplex to single[b]	+110	+ 70	+110	+100	±11
Flechettes to single[b]	+290	+100	+200	+200	±25
Automatic to semiautomatic[c]	+ 60	+ 10	− 30	+ 10	± 5
.22-cal carbine to .30-cal M1	+ 10	+ 30	+120	+ 50	± 8
.22-cal T48 to .30-cal M1	+ 10	+ 20	+ 30	+ 20	± 6

[a]Over those from .30-cal single bullets or semiautomatic fire.
[b]Based on limited data.
[c]Includes both Gustafson carbine and modified T48 rifle.

Table 1 is deduced by weighting the three firing conditions in the approximate ratio of the amount of experimental firing—2 (day sitting): 1 (day standing): 1 (night sitting). This ratio is extremely conservative in heavily weighting the most accurate firing condition. Secondly, values are derived for unaimed-fire casualties. It is noted that the experiment measured only aimed fire. However, the arbitrary over-all estimate shown is thought to be the better general effectiveness measure. The unaimed "Casualties/salvo" is simply the product of the number of bullets per salvo and the lethality per bullet, adjusted for penetration failure and multiple-hit overkill. The table combines the averages for aimed and unaimed fire on a fifty-fifty basis. The value of this unaimed fire in its neutralizing or harassing effect is assumed to be measured by its casualty-producing potential.

The fifth column, "Average gain," is a crude method of deducing a rough single effectiveness ratio. It is simply an average of the three criteria of the other columns.

Figure 1 shows the average values, together with the 95 percent confidence bands.

The confidence limits (2 σ) estimate (with a 95 percent certainty) the range within which the true gain lies. For example, with a 95 percent certainty it is known that the average duplex over single-bullet effectiveness gain (as defined) is between 53 percent and 67 percent. These limits are deduced from sampling errors only. Systematic errors are found to be up to two to three times larger.

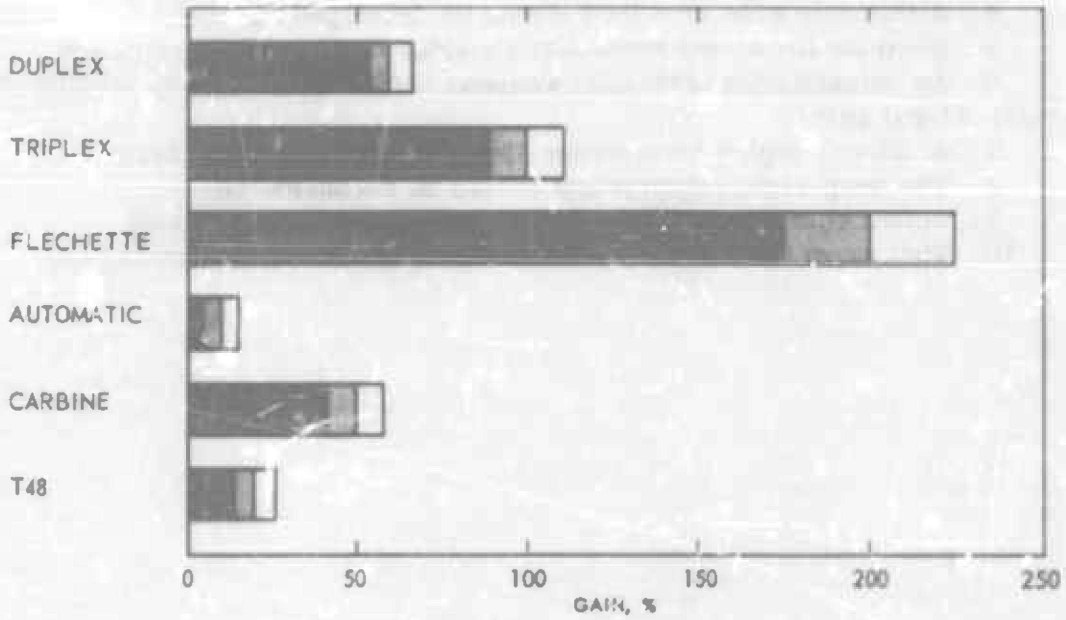
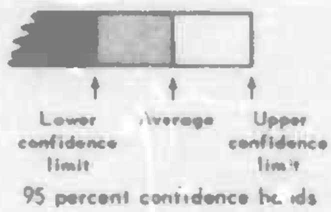


Fig. 1—Average Salvo Gains



MAJOR CONCLUSIONS

1. All salvo ammunitions examined show effectiveness increases. The 60 percent duplex gain is unequivocal; the automatic fire gain is smaller, depending on the criterion selected; and the triplex and flechette gains of 100 and 200 percent require further verification.

2. The smaller weapons examined show effectiveness increases of 20 to 50 percent over the M1 in conventional semiautomatic fire.

3. Typical fire is at a rate of 16 rounds/min after $1^3/_4$ sec to acquire at target. Average test accuracy is 14 percent hit probability, or an error (linear standard deviation) of 3.8 mils.

RECOMMENDATIONS

From these conclusions and the discussion accompanying the 22 conclusions in the body of this memorandum, the following recommendations are deduced:

1. The duplex and triplex ammunitions should be considered for adoption.
2. Additional tests of triplex and flechette ammunitions should be conducted.
3. Flechette development should be accelerated.
4. A flechette side-arm load should be developed for test.
5. Doctrine for aimed automatic shoulder fire should be reviewed.
6. An investigation of smaller weapons should be initiated to identify observed .22-cal gains.
7. A .22-cal duplex ammunition should be fabricated and tested.
8. The peep-sight requirement should be reconsidered.
9. Actual combat accuracy of rifle fire should be determined.
10. This experimental context should be considered for training use.

SALVO I RIFLE FIELD EXPERIMENT

PURPOSE

To determine the relative effectiveness of multiple-bullet and single-bullet rifle ammunitions.

An experiment was performed to determine hit probabilities with salvo ammunitions in combat-simulating aimed rifle fire. The analysis, incorporating factors of lethality and weight, leads to conclusions expressed in casualties per salvo, per time unit, and per weight unit for aimed and unaimed rifle fire.

HISTORY

The salvo concept is by no means new. Probably some clever caveman put several stones in his sling at one time. Stories exist describing the practice of some tribes in early modern warfare who used knives to split their lead bullets. The shotgun is an example of extreme salvo, where lethality and range capabilities have been compromised for the hit increase in the projection of multiple pellets. The massing of artillery fire is a further example of salvo, using separated launchers. The machine gun and the automatic rifle approximate the fundamental characteristic of salvo, which is the projection of more than 1 round with a single aiming and firing effort.

The type of salvo development with which this paper is concerned appears in the 1856 US Army Ordnance Report.[1] This report describes fire of two and three round balls at one time from a "rifle musket." An 1862 US Patent[2] describes "Improvement in Compound Bullets for Small-Arms" (Fig. 2). Official concern appears in the 1879 Ordnance Report to the Secretary of War.[3] That report includes the disclosure and subsequent correspondence of Captain of Ordnance E. M. Wright, who proposed the use of a tandem salvo round—three bullets nose-to-tail in a single cartridge (Fig. 3). Captain Wright's efforts were defeated by Captain of Ordnance J. E. Greer, whose negative report was indorsed by the Chief of Ordnance. An overshadowing development, the introduction of the magazine rifle, squelched further efforts at that time.

In early 1945 the Nazis reported on "Die Infanterie Doppelgeschosz."[4] Their report describes in detail the development and testing of a tandem duplex rifle round and several modifications (Fig. 4). The German reports indicate considerable success (Fig. 5) and plans for special issue in 1945 as is indicated by the following:

PROGRESS REPORT NO. 64 17 March 1945

On the Presentation of the D-Ammunition and Discussion at Friedenthal on 17 March 1945

Subject: Use of D-Ammunition for Special Issue

(SS-Assault groups)

The purpose of the presentation in Finow was to issue the D-Ammunition to the battle front. SS Standartenführer Dr. Heess proposed that this new type of Infantry ammunition be first issued to the Paratroop assault groups because it is possible to obtain an early tactical result [illegible] will be kept 100% secret. SS [illegible] Dr. [illegible]ardt suggested that SS-Ustuf. Schurmann take part in the tests at Finow.

The development of D-Ammunition for the Pistol 08 and the infantry Sturm rifle is also as urgent as for this caliber.

ORO analysts, examining the operational concept of small-arms aimed fire, recommended in 1952[5] the development of a weapon designed to fire simultaneously up to five projectiles:

1. It is recommended that the Ordnance Corps proceed to determine the design or technological feasibility of developing a hand weapon which has the characteristics cited in this analysis, namely:

a. Maximum hit effectiveness against man targets within 300-yd range [Fig. 6]. (This does not mean that the weapon will be ineffective beyond this range.)

b. Small caliber (less than .30).

c. Wounding capability up to 300 yd at least equivalent to the present rifle.

d. Dispersion of rounds from salvos or bursts controlled so as to form a pattern such that aiming errors up to 300 yd will be partly compensated, and hit effectiveness thereby increased for these ranges.

2. As one possible alternative to the current volume of fire (fully automatic) approach to the problem of increasing the effective firepower of infantry riflemen, it is recommended—subject to tentative confirmation of design feasibility—that a rifle incorporating at least in principle the military characteristics here proposed be manufactured for further and conclusive test.

This concept was presented by ORO to the US Army Chief of Staff, Gen Lawton A. Collins, who directed Ordnance to develop materiel to evaluate the proposed concept. In response to this order, the SALVO Steering Committee was formed. In 1953, ORO published a memorandum[6] describing the theoretical performance of duplex and triplex tandem rounds (Fig. 7). Subsequent industrial development and testing of these tandem rounds proceeded under the direction of the SALVO Steering Committee.

In 1954, ORO, in response to a request from the SALVO Steering Committee, designed a field experiment to determine the hit probability of the tandem salvo round in aimed combat rifle fire. By 1956, coordination efforts with Ballistic Research Laboratories (BRL) (see App L) and other interested agencies permitted acceptance of the ORO test plan and assignment of facilities at Fort Benning.[7] In June 1956 the experiment was conducted by ORO.

The recommendations of this memorandum are essentially the same as the preliminary recommendations presented in an earlier report.[8] These conclusions and recommendations have already been disseminated, and in some part carried out. At this writing, duplex ammunition is being procured for official user test with both M1 and T14 rifles. A program is under way (with apparently inadequate priority, however) to examine the shotgun flechette improvement with reduced dispersion. A recommended development of a flechette side-arm or pistol load is currently in the doldrums, but several agencies are interested in supporting the development.

UNITED STATES PATENT OFFICE.

[illegible] SHALER, OF MADISON, [illegible], AND [illegible] W. SHALER, OF BROOKLYN, NEW YORK, [illegible] TO [illegible] W. SHALER.

IMPROVEMENT IN COMPOUND BULLETS FOR SMALL-ARMS.

Specification forming part of Letters Patent No. [illegible], dated August [illegible], [illegible].

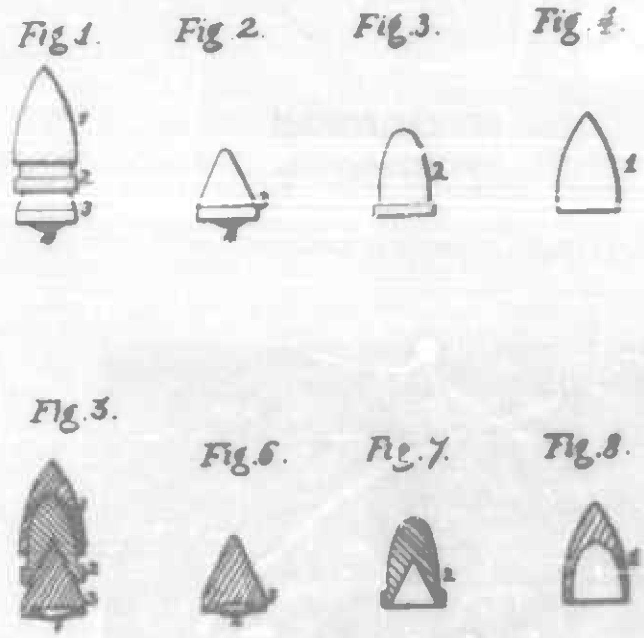


Fig. 2—1862 Salvo Patent

DESCRIPTION OF BUCKSHOT CARTRIDGE, FOR PRESENT SERVICE ARMS AND ALTERED REVOLVERS.—CAL. .45 BUCKSHOT.

Case, present rifle case, uniformly tapered; charge, 40 or 45 grains service powder; 3 round bullets, pure lead; diameter, ".458; lubricant, bullets dipped in Japan wax, bullets pushed in far enough to afford a good crimp on last one.

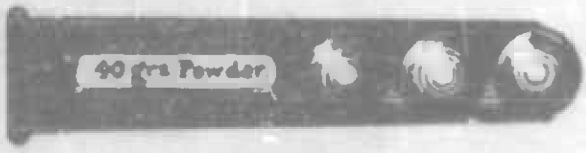


Fig. 3—1879 Ordnance Corps Salvo

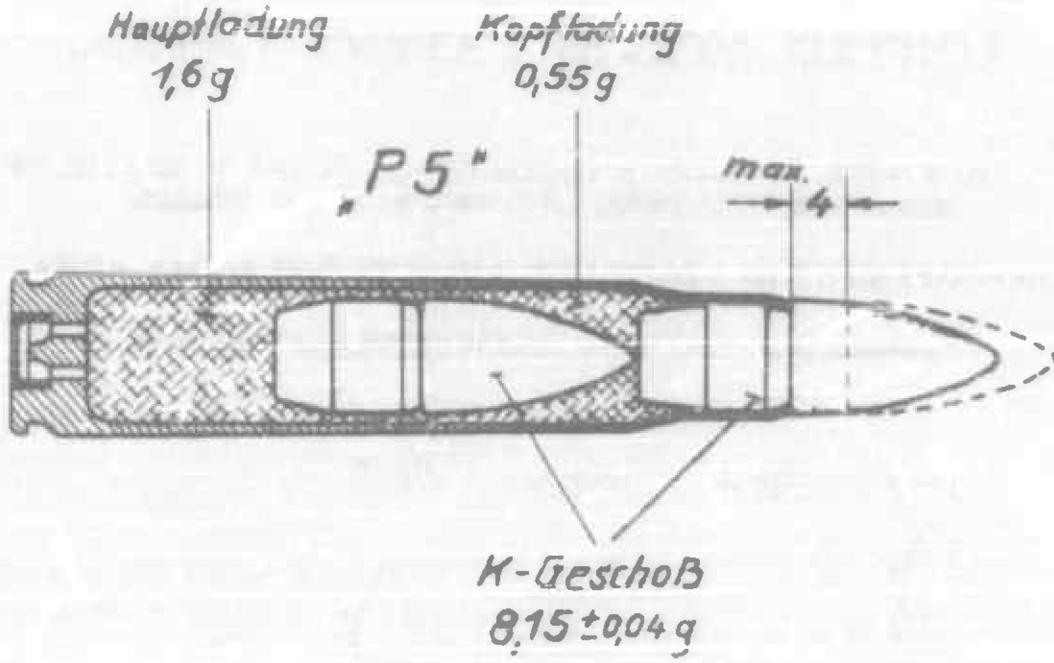


Fig. 4—1945 Nazi Salvo

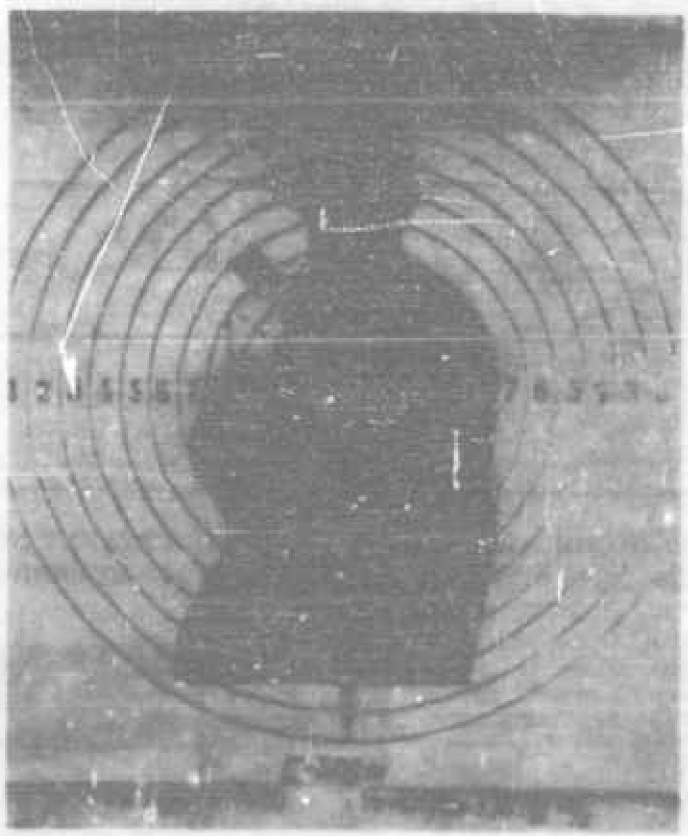


Fig. 5—Nazi Salvo Test Target

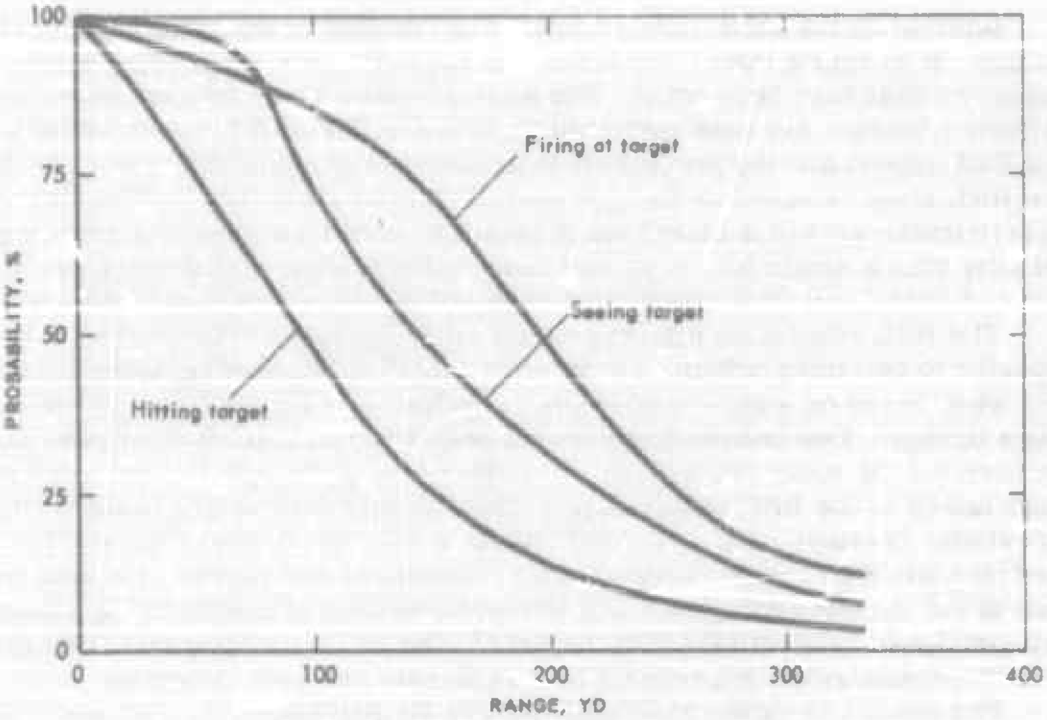


Fig. 6—Probability of Firing at, Seeing, or Hitting Target at Range *R* or Greater

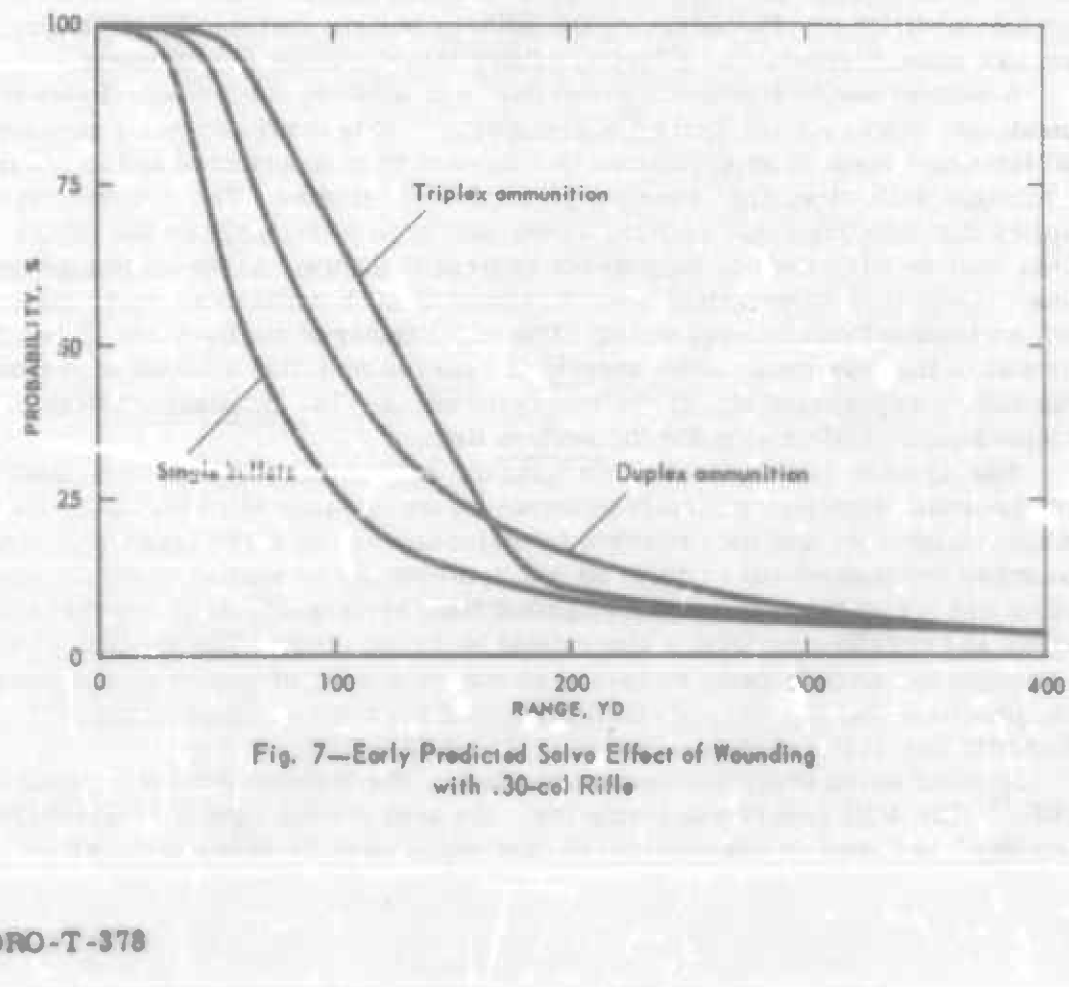


Fig. 7—Early Predicted Salvo Effect of Wounding with .30-cal Rifle

Interest in the salvo rifle program has resulted in the publication of other studies. It is appropriate here to discuss the interpretation of apparent inconsistencies that have been noted. The most pertinent study that has come to the writers' attention has been published by BRL.[9] A major difference between this BRL report and the present study arises from the effectiveness criterion. The BRL study is based on the criterion of "one or more hits." This criterion discriminates against a salvo load in failing to credit multiple hits with more lethality than a single hit. A second assumption is an unrealistically low aiming error of only 1 mil (this experiment showed 3.3 mils average daylight error).

The BRL conclusion that " under no consideration is the duplex bullet superior to two independently aimed projectiles" is misleading, since it is true only when based on a quite inequitable criterion: one duplex firing vs two single-bullet firings. Two independently aimed projectiles require two weapons and two men for the same opportunity, or a repetition of the opportunity. The summary tables in the BRL report suggest that the calculations are based on the unrealistic assumption of no holdoff (elevation) for gravitational drop. The need that the BRL report recognizes for theoretical estimates of the effectiveness of the controlled duplex round was recognized, and a publication was under way simultaneously with the BRL report.[10] The BRL criticism that ORO-SP-2[8] fails to emphasize the superiority of the .22-cal carbine is accepted.

The totality of these criticisms negates the primary BRL conclusion that "the advantages of the duplex round SALVO rifle are marginal." The authors of this memorandum are in agreement with the final statement of the BRL report: "Any promising small arms should be finally evaluated on their mass effectiveness against anticipated number of men in likely patterns, i.e., under service conditions." Furthermore the authors believe that this (ORO) memorandum has made a substantial effort to satisfy this condition of evaluation.

A second study of direct concern has been made by the Armour Research Foundation (ARF) for the Springfield Armory.[11] This study correctly concludes that the exact form of an optimum salvo has not been determined and is not determinable without an ambitious program of basic studies. The Armour report implies that experimental materiel development on items such as the duplex might best be curtailed, as they do not represent theoretical optimum ammunitions. In the light of practical considerations of such matters as lead time, such an implication is unwarranted. The practitioner of military art is generally aware that the materiel he accepts in order to maintain a status of preparedness rarely represents the theoretical optimum, and the satisfactory item is accepted instead of waiting for the perfect item.

The Armour conclusion that an optimum salvo number exists is in itself very tenuous. Clearly, radically different forms of salvo will yield different optimum numbers, and the criterion for selection among these types will surely transcend the theoretical criteria on which the proposed studies would be based. Dollar and logistical cost and development time are significant items that must modify any conclusions from a theoretical technical study. The specific proposal of Armour for an automatic weapon is of course worthy of separate consideration, provided that the weapon could overcome the obvious disadvantages of automatic fire that are demonstrated in this (ORO) study.

Another salvo study has been conducted by the Midwest Research Institute (MRI).[12] The MRI report conclusion that "the best system uses a 64 Flechette cartridge" is based on examination of cartridgee of 64 or less flechettes. It appears that the criterion on which this conclusion is based would yield the more general conclusion that the best number of salvo projectiles is the maximum number possible. The determination of an optimum number requires the application of additional constraints. MRI's conclusion[13] concerning the desirable dispersion of flechettes is in reasonable agreement with a recent study conducted by ORO.[13]

SALVO EFFECTIVENESS

The objective of military fire is either to neutralize or to inflict casualties on an enemy. Casualty infliction in turn may be separated by target characteristics into categories designated as aimed fire and unaimed fire. The application of the salvo principle to unaimed area fire is so elementary as not to require specific field tests at this time. Because area fire targets are characterized by a dispersion in considerable excess of the dispersion of any reasonable salvo, it is clear that the hits are merely proportional to the number of bullets per salvo, ignoring variations in hit probability or lethality with variations in range or other characteristics of the targets. In the case of automatic fire, the definition of a salvo and the deterioration of aim with succeeding rounds are subjects of separate consideration. The experiment made no attempt to include area fire.

The concept of measurable effectiveness of aimed fire has three parts. The stated objective of aimed fire, "infliction of casualties on targets," provides identification of the three essential and commensurate elements. To "inflict," the target must be hit with the bullets, implying a measure of hit probability. "Casualties" implies a measure of the casualty-producing effect or lethality of the bullets. Thirdly, "targets" implies that both of the above measures must be applied to the enemy target system that is anticipated. The first two parts of the concept are well recognized. In general, however, earlier efforts at relative evaluation of firepower have failed to provide an integrated measure reflecting the anticipated target system. As an operational analysis it would appear to be an incomplete study that provides only a table of potential effectiveness against a list of target types. The authors have attempted herein to make a realistic integration of anticipated target types in order to derive a simply expressed measure of relative effectiveness. Withall, the design retains the capability of correction of these measures with modification of our model of the target system.

The potential hit increase of salvo rifle fire depends on the existence of a fairly large error in combat rifle capability. "Combat expenditure of small arms ammunition per hit is prodigious—some 8000 to 12,000 rounds."[14] Measures of rifle aiming error indicate that under target-range conditions, riflemen achieve errors of less than 1 mil. It is evident, however, that typical combat error is larger. From a preliminary experiment,[10] it was estimated that typical combat rifle fire occurs with an error of 3 to 4 mils. This figure is the linear standard deviation (σ) of a radially normal distribution, and may be interpreted as an average value. Examination of weapons used in this test indicates the typical dispersion inherent in the weapon—a few tenths of a mil (App B). Exterior ballistic errors for most combat ranges (< 300 yd) are likewise generally

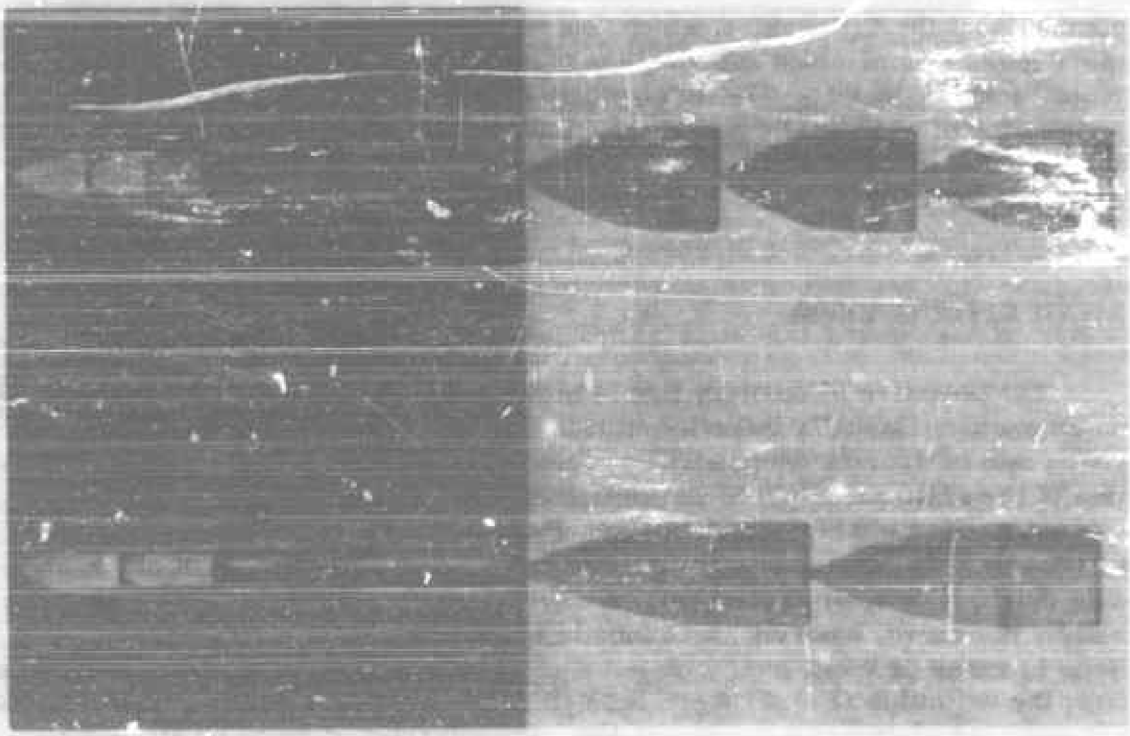


Fig. 8—Duplex and Triplex Cartridges

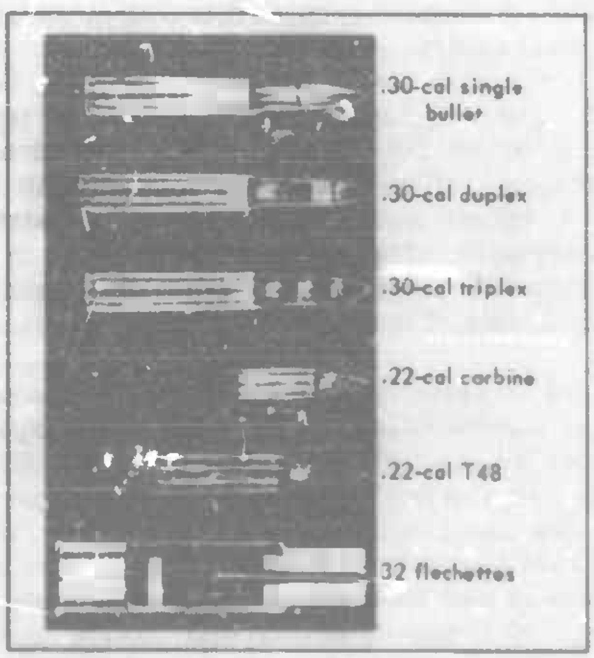


Fig. 9—Test Ammunitions

much less than 3 or 4 mils. It is apparent that the human aiming error represents the preponderant influence among these independent error sources, despite contention to the contrary.[16] The increase of hit probability then becomes a problem of overcoming the predominant human aiming error. This may be accomplished either by reduction of error, or design of a mode of fire compatible with such an error. No recommendations are made here regarding continuation of efforts to reduce the aiming error by training or by any other method. The approach of this study is restricted to the evaluation of materiel designed to increase the hit capability of present riflemen.

AMMUNITIONS TESTED

The salvo system deemed operational at the time of investigation was the tandem round; which is actually not a salvo weapon, but a salvo ammunition for incorporation in conventional small arms. The primary test item is the duplex, second the triplex (Fig. 8) with single-bullet ammunition for comparison. The front duplex bullet maintains dispersion comparable with an ordinary single bullet; the rear bullet of a pair falls in a narrow ring concentric about

TABLE 2

WEAPONS AND AMMUNITIONS TESTED IN THE SALVO I EXPERIMENT

Weapon	Ammunition or firing	Muzzle velocity, ft/sec	Round weight, grains	Bullet weight, grains
M1 rifle (reamed chamber)	.30-cal single-bullet M2	2760	414	163
	.30-cal duplex	2630	449	96
	.30-cal triplex	2630	439	61
Gustafson carbine (M2)	.22-cal semiautomatic	3125	135	41
	.22-cal burst fire	3125	135	41
T48 rifle	.22-cal semiautomatic	3400	280	68
	.22-cal burst fire	3400	280	68
12-gage autoloading shotgun	32 flechettes	1400	720	13

the front bullet. The angular spread between the two bullets is the radius of the ring, approximately 3 mils, which is about optimum, being the width of a man-target at combat range.[16] The .22-cal carbine and the T48 afford two examples of burst (automatic) fire—with semiautomatic fire for comparative controls. These .22-cal weapons were selected as those available offering the least climb—the best hold on target for a salvo burst.

The 32-flechette load was tested as the most promising of several flechette developments.[18] Figure 9 shows the test ammunitions and nominal characteristics. The measured characteristics are given in Table B3, App B.

Four types of weapon were used, and a total of eight different combinations of weapon and ammunition or types of fire were tested. These eight combinations are shown in Table 2.

TABLE 3

TARGET CHARACTERISTICS

Characteristic	Amount or type
Size	E (kneeling) and F (prone)
Range	50–350 yd
Exposure time	3 to 34½ sec
Visibility	Day, night, day-hidden
Movement	3 of 22 targets
Activity	Blanks being fired at 11 of 22 targets
Confusion	20 demolition positions plus a phonograph

TABLE 4

SALVO I TARGET SYSTEM LAYOUT

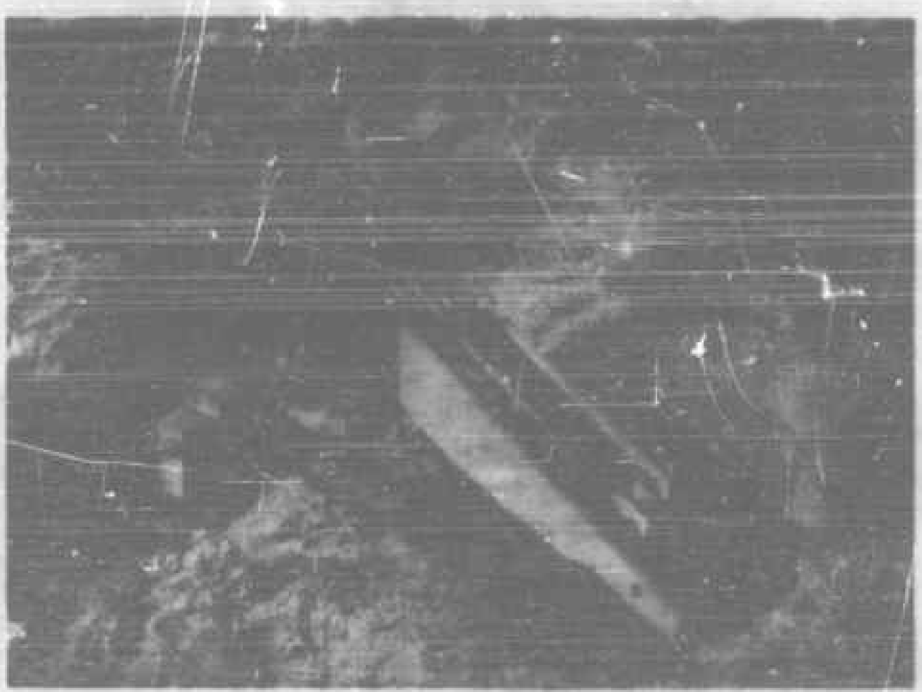
Target number	Range, yd	Target size[a]	Con-cealment	Move-ment	Blank firing	Illumi-nation	Exposure time, sec
1	52	F	C		F	N	28.5
2	63	E	—		—	N	3.0
3	65	E	—		—	N	7.5
4	67	F	C		F	N	12.0
5	74	F	—		F	D	4.5
6	76	E	—		F	N	4.5
7	77	F	C		F	D	15.0
8	78	F	C		F	N	19.5
9	86	E	—		—	D	4.5
10	89	F	C		F	D	15.0
11	90	F	C		F	N	4.5
12	91	F	—		—	N	9.0
13	111	F	C		F	D-N	19.5
14	127	F	C		F	D-N	9.0
15	139	F	—		—	D-N	4.5
16	159	E	—	M	—	D-N	10.5
17	161	E	—		F	N	3.0
18	162	E	—	M	—	D-N	6.0
19	164	E	—	M	—	D-N	18.0
20	165	E	C		—	D-N	34.5
21	169	E	—		—	D-N	4.5
22	176	E	C		F	D-N	9.0
23	209	F	—		—	N	3.0
24	216	F	C		—	D	4.5
25	218	F	C		—	D-N	15.0
26	221	F	—		F	N	7.5
27	223	F	C		F	N	21.0
28	245	E	—		F	D	6.0
29	259	E	—		F	D	10.5
30	267	E	—		—	D	3.0
31	269	F	C		F	D	25.5
32	334	F	—		F	D	7.5
33	336	F	—		—	D	3.0
34	339	F	C		F	D	21.0
Total		14E 20F	15C	3M	19F	10D-N 12D 12N	231.0D 253.5N

[a]E (kneeling) and F (prone) silhouettes.

TEST SYSTEM

To describe combat targets in terms of seven characteristics that critically affect aiming error as shown in Table 3, a questionnaire-interview was administered to veteran riflemen (App C).

A study of the information obtained led to the adoption of two target systems—one for daytime fire and one for nighttime fire. Each of these systems was composed of 22 pop-up (Cocky Ken)[15] targets, 10 of which were common to both systems, making a total of 34. The targets were exposed by spring-loaded mechanisms for time durations of 3 to 34½ sec. None of the targets was



Courtesy of Olin Mathieson Chemical Corp.

Fig. 10—Blank-Fire Rifle and Target

scheduled for exposure simultaneously with another, and the intervals between successive target exposures were varied. The sum of the scheduled exposure times for the 22 targets during a day run was 220 sec, and the total time for the run was 7½ min. This means that during a run some target was scheduled for exposure during about half the total time for the run. Three of the targets moved laterally during exposure. Target activity was indicated by blank fire at half the target positions (Fig. 10).

The 10 firing positions were on a 50-yd firing line. The ranges from the firing line to each of the 34 target positions and other characteristics of these targets are shown in Table 4. Target sizes were limited to two: E (kneeling) and F (prone) silhouettes (F shown in Fig. 11). The minimum target range was limited for safety to 50 yd. The maximum range of 350 yd reflects the occurrence of 95 percent of combat targets within that range (App C). Variations in visibility were limited to three: day, exposed; day, partly concealed; and night, exposed.

Courtesy of Olin Mathieson Chemical Corp.

Fig. 11—F (Prone) Target in Up Position

Courtesy of Olin Mathieson Chemical Corp.

Fig. 12—Firing Line Showing Sitting Position with Elbow Rest

The aiming error also depends on the rifleman (Table 5). To make the experiment applicable to typical US riflemen, four average 10-man squads were constituted of riflemen of qualifications in the same proportion that occurred in the 3d Div: one expert, four sharpshooters, four marksmen, and one unqualified. In addition, one better and one worse squad were tested. The firing positions were limited to two: a stable aiming position, raised enough for all men to see all targets, sitting with elbow rest (Fig. 12); and a poor aiming position, standing. Detonation charges in the target area and recorded battle noises added confusion for the riflemen. In addition, the riflemen were subjected to electrical shocks at irregular intervals during the runs by means of wires attached inside the boot.

TABLE 5

TROOP CHARACTERISTICS

Qualification	Better, average, worse
Position	Sitting, standing
Stress	Shock and noise

To recapitulate, each target system was then composed of 22 Cocky Ken targets, 3 of which were capable of lateral movement, and 11 of which returned blank fire (Figs. 13 and 14). There were 20 demolition positions, including nitrostarch charges to simulate artillery, and blasting caps, readily confused with rifle fire. Squads were deployed on a 50-yd line. For uniform visibility, night firings were conducted with limited floodlighting.

The entire program of target appearances, target movements, demolitions, blank firings, and stress shocks had to be precisely reproducible for a controlled experiment. To accomplish this, electrical controls were plugged into a specially built programmer before each run. To start a run, it was necessary only to push the starting button; operation was then automatic for 7½ min.

The entire schedule was composed of 68 runs. Only two runs were allotted to the flechette test, owing to limitation on available ammunition. Each of the other types of fire was scheduled to fire from the sitting position both day and night, and from the standing position in the day (Table 6).

Deletion of most of the planned triplex runs was necessitated by a malfunction.

The Cocky Ken targets drop on schedule, not when hit. There were no simultaneous target appearances, and the order of target appearances was varied between runs. Ammunition expenditure was unlimited.

Physical details of the test system may be seen from motion pictures taken during the experiment. ORO has prepared a 6-min film showing the installation and operation of the test system. Included are pictures of installation of the electrically operated targets, installation of track for the moving targets, zeroing and familiarization fire of the test weapons, and a view of the several special devices (stress shockers, shot recorders, and target hit recorders). The films also show fire on targets during runs, revealing the general patterns of fire, and giving a clear picture of the environment of the test.

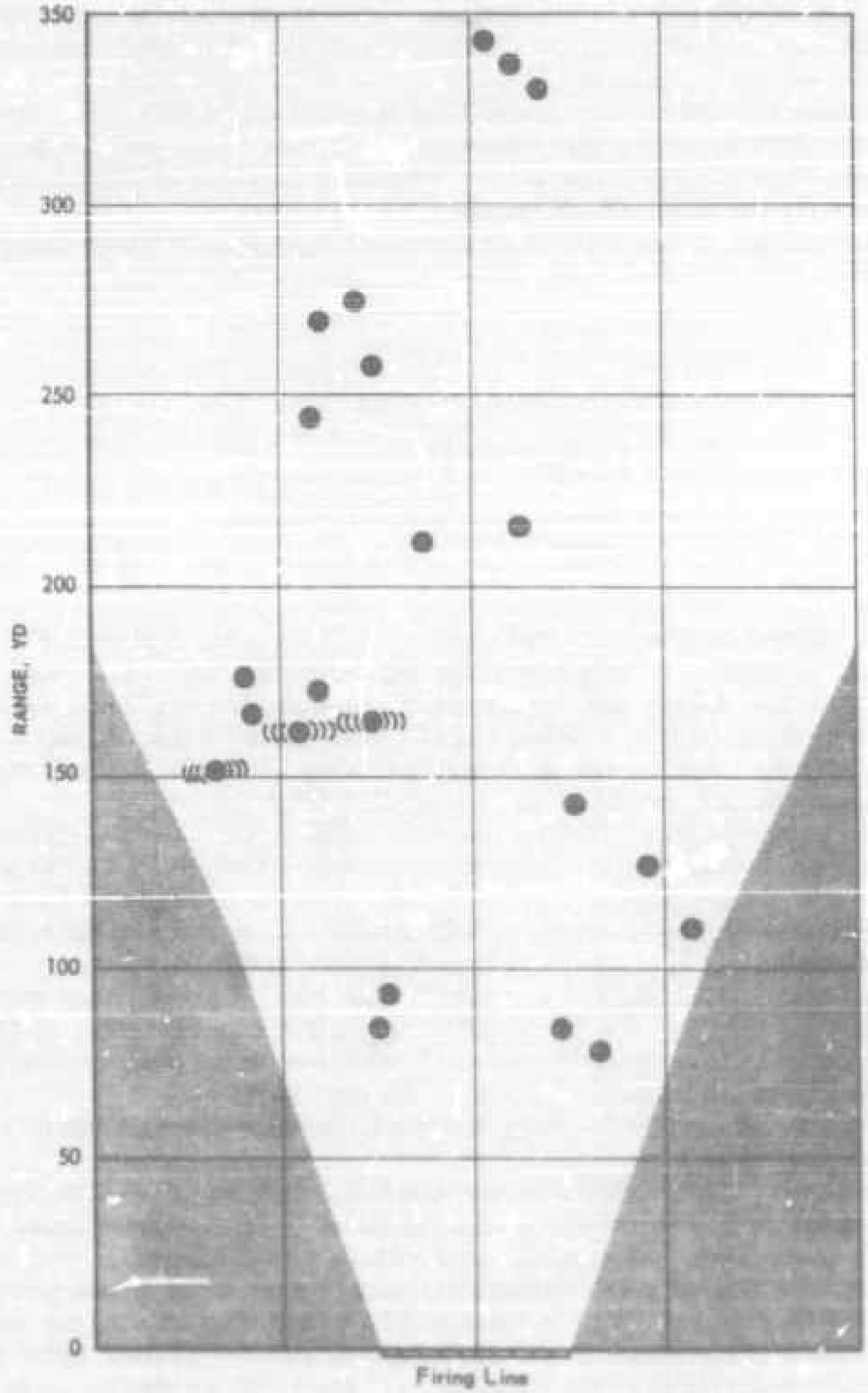


Fig. 13—Day Target Layout

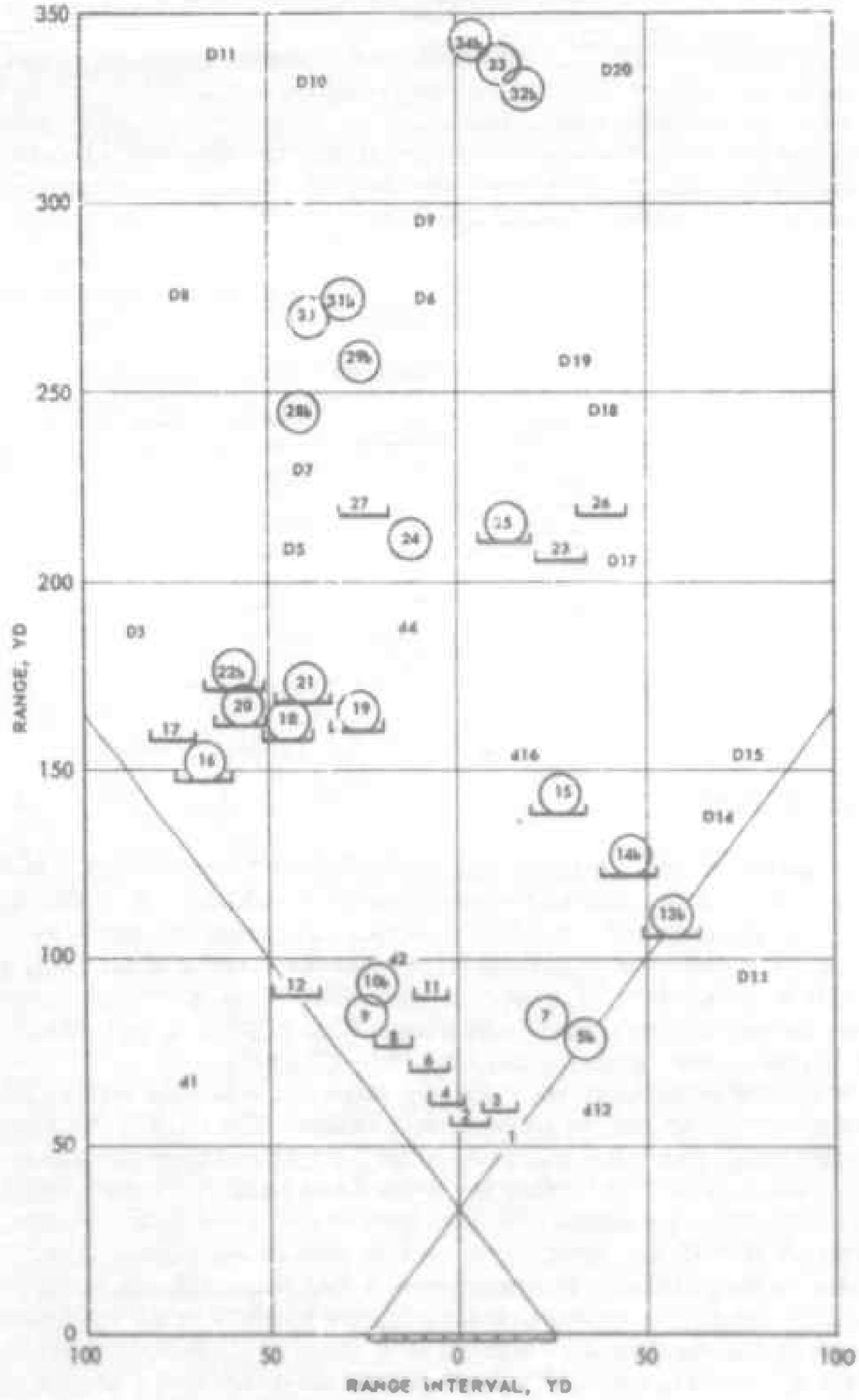


Fig. 14—Complete Field Layout

b, blank fire; d, blasting cap; D, nitrostarch

◯ day target; ⊔ night target.

The test plan, including a summary of requirements drawn up in December 1955, appears as Annex L1 to App L. This annex describes the elements behind the questionnaire of App C for determination of the target system, and outlines that system. It also outlines a schedule of firings and a list of the various requirements. In addition, App L discusses the adequacy of this test plan, and points up the considerations favoring it over others. Considerably more detail on the statistical validity of the test plan is given in App M. A master schedule of the actual experimental runs is given in Table L2.

TABLE 6

ONE DAY'S RUNS

Run no.	Ammunition	Visibility	Position	Squad
1	Control	Day	Sitting	A
2	Test	Day	Sitting	A
3	Control	Day	Sitting	B
4	Test	Day	Sitting	B
5	Control	Day	Standing	A
6	Test	Day	Standing	A
7	Control	Night	Sitting	B
8	Test	Night	Sitting	B

INSTRUMENTATION

The operation of all targets was controlled by a programmer, which was set before each run by means of a patch board of 300 sockets. Eight different programs for daytime runs and four different programs for nighttime runs were used. The different programs presented the targets in different sequences, but the times of exposure, and the intervals prior to target exposure after the preceding target dropped, were held constant for a given target. The intervals between target appearances varied from 6 to $13\frac{1}{2}$ sec.

For recording shots fired, each test rifle was equipped with a specially constructed switch within the trigger mechanism. The switch was closed with each trigger pull, which fed impulses to an Esterline-Angus recorder. Separate channels were used for recording the shots from each of the 10 firing positions.

For recording the number of hits, each target silhouette was covered with two sheets of electrically conductive rubber with an insulating rubber sheet sandwiched between them. The passage of a bullet through the sandwich caused a momentary electrical connection between the conductive rubber sheets. The completion of the electrical circuit between the two conducting sheets activated a mechanical counter, and also recorded on a continuously advancing roll of paper. The circuitry permitted the separation of hit impulses to about 1 msec, which permitted recognition of multiple hits. It was also possible to identify shots fired with hits scored.

The demolition charges in the target area, and the blank-firing rifles were controlled by the programmer to permit precise prescheduling.

At each firing position, a battery and high-voltage coil were connected to electrodes that could be slipped into the rifleman's boot. Under control of the programmer, shocks were delivered to the rifleman to simulate battle stress. The shocks could not exceed 10½ ma in current, but produced jolts of up to 5300 volts.

In view of the complexity of the instrumentation for the SALVO I experiment, it is not surprising that many malfunctions occurred. It seems clear that the electrical data should be appropriately adjusted to eliminate the effect of malfunctions as far as possible.

Fortunately, many questions of interest can be studied and conclusions reached on the basis of manual counts of ammunition used and holes in target faces. The major portion of the analysis in this paper is on this basis. Investigation of hits by individual riflemen on individual targets requires the use of the electrical data, since no manual count of this kind is available; likewise identification of multiple salvo hits requires the electrically recorded chronological hit record.

PREDICTIONS

Before it is determined that there is some reason for conducting an experiment, there is generally some knowledge on which imperfect predictions of the experimental results can be made. The reason for conducting the experiment is to verify the uncertain assumptions on which such predictions may be based, and to demonstrate with greater accuracy and greater reliability the differences being discussed. In the instance of the salvo assumptions tested in this experiment, a good deal of specific detailed information was available. The theory of the controlled duplex pattern was already understood.[10] The patterns of both the random triplex and the flechette loads were also reasonably well predicted.[13] In addition, basic information on rifle aiming errors was also on hand.[15] These earlier examinations of the salvo patterns were readily applied to the salvo target system to yield quantitative predictions on the number of rounds to be fired and the number of hits of each kind expected.

Appendix M discusses these predictions in detail. Table M3 presents the predicted hits and rounds fired for day and night runs, and compares the predictions with the experimental results, showing reasonable agreement. The duplex hit prediction in App M is devoted to a generalized theoretical prediction for controlled duplex hits. The triplex and flechette hit predictions are also presented in App M. Finally Tables M12 and M13 compare in summary form the prediction and experimentally achieved data. The agreement is such as to justify the experiment—i.e., it is close enough to demonstrate that the order of magnitude of differences was anticipated, and it is poor enough to warrant the experiment rather than rely on the theoretical predictions alone.

Finally the experimental design itself is roughly justified by the predicted deviations shown in Table M14. This table compares the predicted hit probabilities of duplex, triplex, and flechette ammunition with the single-bullet control. Approximate standard deviations are then deduced. The significant conclusion is that each predicted salvo value differs from the single-bullet value by at least three predicted standard deviations. This may be interpreted as a prediction that the experimental design is adequate to determine these desired ratios with acceptable reliability.

A companion theoretical consideration made in conjunction with these predictions is the determination of the rifle zero setting for the experiment. This is discussed in App M under the section "Combat Zero." The desired zero setting for the test weapons is defined as that setting which results in the minimum value of total miss distance for all target hits due to gravitational drop. An interesting result of the computations is that this zero setting is insensitive to variations among the test ammunitions. The result is apparently characteristic of the target system. The daytime target system yields an optimum zero setting of 165 yd. All test weapons were accordingly zeroed at 165 yd for both day and night firings.

DATA

The basic data are the manual count of rounds of ammunition expended and the manual count of target holes for each run. In addition, electrical recordings were made of shots fired by each rifleman during the time each target was exposed, and of hits made on that particular target. Malfunctions were experienced in the instrumentation, so that serious disagreement exists between the manual count of rounds and holes and the electrical recordings for corresponding shots and hits. A method for adjusting these electrical data has been developed to minimize the effect of malfunctions. The adjusted data tables support the conclusions reached with the unadjusted or raw data tables.

Preliminary reports have been prepared by ORO on the SALVO I experiment.[17,13] The Systems Analysis Corporation undertook statistical analysis of the SALVO I data under subcontract to ORO.[18]

In analysis of the data, variance-analysis techniques and selected statistical-significance tests have been used in weighing the possible effects of the heavy random error that was evident in some of the preliminary analyses. The analysis scheme generally has been based on the assumption that the SALVO I data are samples from parent populations whose parameters have been estimated. The significance levels of differences that may represent real effects of known changes in controlled variables have been calculated. In this way the possibility that these differences may in fact stem from random error (or sampling variations) has been considered.

The totals of rounds fired and hits scored for each of the 68 runs were tabulated as the basis for analysis. The largest categories of differences are (a) differences among the several types of test ammunition; (b) differences among the three conditions of firing (day sitting, day standing, and night sitting); and (c) differences among the six squads.

Table 7 is a summary of the comparisons that can be made from the results of the SALVO I experiment. It is seen that standard single-bullet ammunition was used on a total of 18 runs; 10 day sitting, 4 day standing, and 4 night sitting. Duplex ammunition was used on a total of 14 runs; 8 day sitting, 3 day standing, and 3 night sitting. The results of each of these 14 duplex runs can be compared with the results of a corresponding single-bullet run

Table 7 shows that only two runs using triplex ammunition were completed. Additional triplex ammunition runs were originally scheduled, but were canceled and largely replaced by duplex runs.

The last four lines of runs tabulated in Table 7 show that balanced comparisons can be made among the following four types of rifle fire: carbine automatic, carbine semiautomatic, T48 automatic and T48 semiautomatic. The results of one run for each of the four average squads (A, B, C, and D) are available for comparisons of these types of fire for the day-sitting firing condition. Squads B and D made each of these four types of run for day standing, and Squads A and C made similar runs for night sitting. The balance, with respect to squad and illumination-position condition, among the 32 runs discussed in this paragraph (and listed on last four lines of the table), enables one to use standard variance-analysis techniques to weigh the possibilities of chance accounting for the observed differences in results.

TABLE 7

TABULATION OF RUNS (1–68) WITH SQUADS (A–F) AND CONDITIONS SHOWN

Ammunition or firing	Day sitting										Day standing				Night sitting			
Single	A1	A25	B3	B27	C34	C56	D36	D60	E65	F67	A5	A29	C38	C62	B7	B31	D40	D64
Duplex	A2		B4		C33	C57	D35	D59	E66	F68	A6		C37	C61	B8		D39	D63
Triplex		A26		B28														
Carbine, automatic	A20		B18		C43		D41				B22			D45	A24		C47	
Carbine, semiautomatic	A19		B17		C44		D42				B21			D46	A23		C48	
T48, automatic	A12		B10		C51		D49				B14			D53	A16		C55	
T48, semiautomatic	A11		B9		C52		D50				B13			D54	A15		C56	

It is seen that 12 pairs of runs using single-bullet and duplex ammunition are available from which possible learning by the squads during the experiment can be assessed. This balance in experience gained between pairs of runs by the same squad enables the authors to evaluate the learning effect with greater confidence than would be possible in a less systematic arrangement of runs.

The last four runs (65–68) were made by the expert (E) and unqualified "bolo" (F) squads.

All the data described above are recorded in App E. The detailed information on rounds fired and hits scored is listed in Table E4. Most of the significant conclusions are drawn from the totals by run, which are summarized in Table E6. In addition a detailed list of weapon malfunctions is included in the 19 parts of Table E5. Deductions of multiple hits from the chronological records are presented in App O. Target-system malfunctions and observed conditions of weather and lighting are included in Table E4.

The adjustment of data to correct for malfunctions and other observed variations are described in detail in App F. Tables F1 to F19 show the adjustments made on hit records, target by target, and run by run. Tables F20 to F38 show the same information for rounds fired. The method of discarding incomplete portions of data is not used in this analysis. The reason for rejecting this technique becomes quite evident when it is attempted—the categories amenable to comparison depend in such complex fashion on the individual pieces of data that discarding even a small percentage of the total data results ultimately in discarding far too great a proportion of the summary data to yield useful results. For example, if targets with only one malfunction in all the 68 runs are discarded from all of the runs, few if any of the targets yield total figures. However, where an obvious malfunction has affected a piece of data, the erroneous data have been eliminated, and replaced with a prorated value. For example, if in Run 4 target 10 was known to remain erected beyond its proper exposure time, the recording of too large a number of rounds fired is anticipated. It would be a statistical luxury that could not be afforded to discard all the other 50 daytime values for target 10 because of this single recognized error. Instead, the excessive value is replaced by a predicted value that is an average for that target and that type of run. It turns out that 13 percent of the hit and round data is adjusted in this fashion. Many of the later analyses illustrate that the adjustment does not significantly affect major conclusions. That is, dual analyses with both raw and adjusted data yield similar results.

The adjusted hit and rounds-fired data are summarized by run in Table F41 (corresponding to the raw-data Table E6). The flechette results, being quite incomplete are handled differently. Instead of adjusting these grossly incomplete flechette results to perfect runs, the comparable single-bullet data are adjusted to match the incomplete flechette data. This adjustment is explained in detail in App F.

Appendix N summarizes both the weapon and target system malfunctions. Table N2 shows four categories of weapon malfunction for each of nine types of fire, with a grand total of two malfunctions per 100 rounds fired. Table N3 shows a trivial 0.1 percent trigger-switch failure in recording rounds fired, and a very substantial 21 percent error in hit recording; i.e., one of the five categories of electrical-hit-recording failure occurred 21 times for each 100 hits. Corresponding target-operation malfunction is noted in Table N5 to be 11 percent.

STATISTICAL ANALYSIS

The experimental data were subjected to detailed statistical analysis with the assistance of the Systems Analysis Corporation.[18] These discussions are presented primarily in App J. In App J the basic data examined are the number of hits per run and number of hits divided by the number of rounds fired per run. The experiment provides eight types of ammunition and three conditions of fire, with three omissions. These 21 ammunition-illumination-position combinations (AIP combinations) then provide four data each: hits and hit probabilities, both raw and adjusted. These 84 numbers as presented in Table J2 form the basis for comparisons.

Appendix J is then devoted to deduction of differences and ratios among the various ammunitions and conditions, and the establishment by analysis of variance, by test, and by deduction of standard deviations of the reliabilities or significance of these differences and ratios. The major differences are summarized as ratios of hits and hit probabilities in Table J1. Figures J2 and J3 are striking graphical presentations of the consistent differences among the major test items--single-bullet, duplex, and triplex ammunitions. Although it is difficult to make a simple summary of the many detailed reliability or significance tests in App J, it is generally clear that the major differences for run totals as listed in Table J1 are quite real.

SEPARATION OF EFFECTS

Appendix K presents the major results of the experiment. In this analysis the number of hits and the number of rounds fired per run are selected as the basic data for analysis. Hits per round or hit probabilities are discussed only after these basic data are appropriately reduced. Appendix K is further arbitrarily based exclusively on the adjusted data of App F rather than on the raw data of App E.

The method of isolating effects of ammunitions and other effective parameters is to sequentially reduce the data by eliminating mean differences. Thus the entire experimental data are used in examining for each effect. For example, if the difference between duplex and single bullets is eliminated, then all sitting runs with both ammunitions may be compared against all standing runs with both ammunitions. It is quite clear that such comparisons ignore interrelations among these effects. Nonetheless rough measures of the separated gross effects are desired. This sequential reduction procedure is made necessary owing to the imbalance of the experimental data. The reductions are made in two stages. The first stage yields results for each ammunition under each condition of illumination and firing position. The second stage further combines still grosser means, so that ammunitions may be compared without reference to illumination and position, and also provides a measure of the effects of illumination and position themselves.

Borrowing from the tables of App K, the following tables (8 to 12) compare the results in two measures: hits H and hit probabilities or hits per round fired P_H. All the data following may be deduced directly from Table K5 and Table K15.

The learning effect is quite evident in terms of absolute hits H. For each successive run by any squad, the number of hits increased by about 2.0 percent per run. As the regular squads fired as many as 18 runs each, this resulted in a total increase of about 40 percent more hits on the last run than on the first run fired by the same squad. From Table K5 it is clear also that the number of rounds fired increases at almost precisely the same ratio; hence the hit probability is practically constant. The computed average shows a total reduction of 2 percent in hit probability over the 18 runs, or an average relative decrease of only 0.1 percent per run—a quite insignificant change.

The squad differences are also deducible from Table K5. If we set the average of the so-called "regular" squads (A, B, C, and D) at 1.00, the relative hits and hit probabilities by squad are as shown in Table 8.

The effectiveness of salvo ammunitions is compared to single-bullet ammunition for each of the illumination-position conditions in Table 9.

Table 10 compares automatic to semiautomatic fire, combining the two comparable weapons (carbine and T48).

TABLE 8

RATIOS OF INDIVIDUAL SQUADS TO ABCD AVERAGE

Squad	H	P_H
A	1.08	0.94
B	1.08	1.15
C	0.95	0.99
D	0.88	0.93
E[a]	1.89	1.14
F[b]	1.01	0.80

[a]Expert squad.

[b]Bolo squad.

TABLE 9

RATIOS OF EFFECTIVENESS OF DUPLEX, TRIPLEX, AND FLECHETTE AMMUNITIONS TO SINGLE-BULLET AMMUNITION

Ammunition compared	IP[a]	H	P_H
Duplex to single	Day sitting	1.59	1.64
	Day standing	1.86	1.64
	Night sitting	1.67	1.86
Triplex to single	Day sitting	1.77	2.25
Flechette to single	Day standing	1.84	3.20
	Night standing	3.43	7.70

[a]Illumination and position firing condition.

TABLE 10

RATIOS OF EFFECTIVENESS OF AUTOMATIC TO SEMIAUTOMATIC FIRE

IP	H	P_H
Day sitting	0.66	0.44
Day standing	0.62	0.42
Night sitting	0.87	0.58

TABLE 11

RATIOS OF EFFECTIVENESS OF T48 AND CARBINE TO M1

Weapons compared	IP	H	P_H
T48 to M1	Day sitting	1.19	1.17
	Day standing	1.23	0.89
	Night sitting	1.93	2.10
Carbine to M1	Day sitting	1.48	1.30
	Day standing	1.59	1.12
	Night sitting	0.62	0.64

TABLE 12

ROUGH GROUPED RATIOS

Item or condition compared	H	P_H
Standing to sitting (day)	0.89	0.79
Night to day (sitting)	0.38	0.32
Automatic to semiautomatic fire	0.71	0.47
Carbine to M1	1.30	1.11
T48 to M1	1.39	1.31
Duplex to Single	1.67	1.70

Table 11 compares the T48 and the carbine to the M1.

Following a more complete separation of effects as presented in Table K15 (App K), it is possible to combine some of the separate conditions of Tables 8 to 11 in Table 12.

MISCELLANEOUS EFFECTS

In addition to the reduction and isolation of differences in Apps J and K, separate analyses were made of several effects. Appendix G examines squad and qualification differences; App H examines learning; App I examines the rate of fire; and App P isolates effects of target characteristics.

The squad analysis of App G agrees quite well with App K. Tables G6 and G12 show good agreement with Table 8 (from App K). More interesting is the deduction of the relative ratings of the several qualifications from the squad ratings and the known squad compositions, which is stated in App G. From App G, for expert rated at 100 in hit probability, sharpshooter scores 88, marksman scores 75, and unqualified scores 43.

The separated learning effect from App K was already shown to be 2 percent increase per run for both hits and rounds fired. The corresponding analysis of App H yields about a 2 percent increase for rounds fired and a 3 percent increase for hits. It is concluded that the 2 percent per run increase in the rate of fire is real, and that the additional indicated 1 percent increase in hits is questionable.

Appendix I examines the chronological firing record. First the steady rate of fire is computed. A figure of 17 rounds/min is deduced for single-bullet day-sitting fire, 15 rounds/min for all M1 rifle runs, including day standing, and night sitting as well as day sitting. A rough average is 16 rounds/min.

The computed average lag time to achievement of this steady rate is 1.77 sec. This is the extra time to acquire and swing onto a new target. Average time from target appearance to first round is 1.77 sec plus something less than the steady rate interval of 3.56 sec, or 5.4 sec. This observed practice is consistent with the recommended optimum of 3.5 sec $(1.8 < 3.5 < 5.4)$.[18]

The record also provided evidence of fire continuing after target disappearance. About 12 percent of all fire comprised this late fire, which continued for an average of $1\frac{1}{4}$ sec after each target dropped. It is thought that typical values might be smaller, because the dusty condition of the experiment occasionally obscured target disappearance, and hence encouraged late fire.

The effects of individual target characteristics on hits and rounds are examined in App P. The major effects on rounds fired are quite naturally found to be exposure time and concealment. The number of rounds fired is proportional to target exposure time (less 1.77 sec lag time), and is about 25 percent less for concealed targets. The smaller targets receive about 10 percent less fire than the larger targets. Target size, movement, and blank fire have small effect on rounds fired.

Hits are also proportional to exposure time (minus 1.77 sec). Hits also decrease with range ($\propto 1/R^2$). Also, for targets of approximately half size, hits drop to about 30 percent, or 64 percent of the hits per target area. In addition the targets exposed shortest (3 and $4\frac{1}{2}$ sec) are hit some 50 percent less than expected from the above general proportionality with time. Finally blank rifle at target positions increases hits some 50 percent. Target movement reduces hits about 10 percent. The light concealment has little observed effect on hits in this experiment.

These effects, beyond their inherent interest, are of potential value for extending the experimental results to target systems composed differently than the ones used. It is possible with these factors to adjust the balance of target characteristics in any suitable fashion, and recompute the integrated experimental results.

INTERPRETATION

The major effects for interpretation are isolated in App K. Table K5 is first modified by the lethality considerations of App O. If the trivial penetration differences arising from the different day and night target-range distributions are ignored, the net lethality figures for each test ammunition listed in Table 13 are obtained. These figures are based on lethalities of 70 percent

TABLE 13

CASUALTIES BY AMMUNITION AND CONDITION

Ammunition or firing	Lethality, %	Condition					
		Day sitting		Day standing		Night sitting	
		C/t	C/R	C/t	C/R	C/t	C/R
Single	70	83	13.4	69	11.3	29	3.5
Duplex	63	118	19.8	116	16.8	44	5.9
Triplex	57	119	24.5	(106)[a]	(19.4)[a]	(45)[a]	(7.8)[a]
Carbine, semiautomatic	70	123	17.4	117	12.7	18	2.2
Carbine, automatic	68	75	7.1	69	5.0	19	1.6
T48, semiautomatic	70	99	15.7	85	10.2	57	7.4
T48, automatic	68	68	7.1	52	4.4	44	3.8
Flechettes	28	(57)[a]	(18.4)[a]	51	14.5	40[b]	10.8[b]

[a]These experimentally missing data are artificially developed from the real data for these ammunitions by using the pertinent ratios from Table 12: Standing to Sitting C/t = 0.89; Standing to Sitting, C/R = 0.79; Night to Day, C/t = 0.38; Night to Day, C/R = 0.32.

[b]Night Standing.

for all conventional bullets and 35 percent for single flechettes (App B). Consideration of salvo overkilling and penetration failure modifies these two values to yield the lethality figures of Table 13. Appendix O describes the detailed considerations. Applying these lethalities to the data of Table K5, the casualties per run (C/t) and casualties per 100 rounds fired (C/R) of Table 13 are deduced. C/t is really a measure of casualties per time unit, as runs were fixed in time (except that day and night times differed). C/R is sometimes referred to as "percentage casualties."

Proper operational salvo consideration for automatic fire requires casualties per trigger pull or per salvo (C/S), rather than casualties per 100 rounds

(C/R). Later tables will use C/S, which is identical with casualties per single round for all other fire. The average number of rounds per trigger pull is deduced in App E. The values from Table E7 are 2.07 rounds/salvo for the T48, and 2.63 rounds/salvo for the carbine (2.33 rounds/salvo over-all). Illumination-position differences are not significant. The automatic-fire total rounds per run was carefully measured, and proved to be 1.50 times the semiautomatic rounds per run.

These two figures then provide the rate of fire in trigger pulls per run (automatic to semiautomatic): 1.50 to 2.33 = 0.64. This one-third reduction in automatic compared with semiautomatic rate of trigger pull also agrees with the observed estimate.

TABLE 14

AMMUNITION, SYSTEM, COMBAT LOAD, AND MAN-AND-LOAD WEIGHTS
(In pounds)

Ammunition	Round	Weapon system	Combat load	Man and load
Single	.0591	26.4	40.8	195
Duplex	.0635	27.4	41.8	196
Triplex	.0620	27.1	41.5	196
Carbine	.0186	13.1	27.5	182
T48	.0410	22.6	37.0	192
Flechette	.1024	34.6	49.0	204

Having translated hits to casualties, further refinement of effectiveness measure becomes difficult. For example, how many casualties per dollar, per pound, per minute, or per trigger squeeze? If dollars, spent for what, if pounds, of what? The answers are not clear; one can only look at several of the seemingly most reasonable criteria.

Costs are not simply accounted for. The prototype flechettes were extremely expensive, and no good estimate is on hand for production cost. The duplex and triplex ammunitions are more in line with conventional single-bullet production cost. The duplex ammunition particularly is loaded in a single-machine operation, and production cost is roughly estimated at about 15 percent over single-bullet cost. Casualties per dollar cost of ammunition is not computed, as it is thought to be a poor criterion. If any effectiveness-cost ratio is sought, better cost data are first required. Secondly, the system must be defined: the pertinent cost is almost certainly not for ammunition alone, but includes weapon and other costs.

Logistical costs are similarly difficult to take into account. Here, however, adequate measures are available. The pertinent weights are listed in Table 14. All weights are given in pounds. The round weight is taken from Table B3. The weapon system includes a Korean average of 224 rounds, the packaging (1 belt, 1.6 lb; 3 bandoleers, 0.4 lb; and 28 clips, 1.7 lb) and the weapon. Weapon weights are taken from Table B2.

The 3.7-lb ammunition packaging is taken as constant for all the test ammunition. The average total issue in Korean use (clothing and equipment) was 40.8 lb. Subtracting the weapon-system weight leaves 14.4 lb. This 14.4

lb is taken as constant for all test-weapon systems and added to produce the "Combat load" column. Finally, the average 154.5-lb man weight is added for the last column.

For normalization to time of firing, it is noted that "up" target time was 231 sec for day runs, 253⅓ sec for night runs. From these quantities it is possible to compute casualties per minute from casualties per run. Dividing by 10 yields average casualty production rate per man. At this time a list of casualties per unit firing time and casualties per unit weight for any of the four categories of weight of Table 14 can be made. As it would be tiresome to inspect a needlessly complex table using all these weights, Table 15 is computed for only the weapon-system weight (rifle plus 224 rounds plus packaging).

TABLE 15

CASUALTIES PER SALVO, PER MINUTE, AND PER POUND

Ammunition or firing	Day sitting			Day standing			Night sitting			"Average"		
	C/S	C/T	C/W	C/S	C/T	C/W	C/S	C/T	C/W	C/S	C/T	C/W
Single	13.4	2.16	1.14	11.3	1.79	0.96	3.5	0.69	0.30	10.4	1.70	0.89
Duplex	19.8	3.06	1.62	16.8	3.01	1.37	5.9	1.04	0.48	15.6	2.54	1.27
Triplex	24.5	3.09	2.02	(19.4)	(2.75)	(1.60)	(7.8)	(1.07)	(0.64)	19.1	2.50	1.57
Carbine, semiautomatic	17.4	3.19	2.98	12.7	3.04	2.17	2.2	0.43	0.38	12.4	2.46	2.13
Carbine, automatic	18.7	1.95	1.21	13.2	1.79	2.17	4.2	0.45	0.27	13.7	1.54	0.89
T48, semiautomatic	15.7	2.57	1.56	10.1	2.21	1.01	7.4	1.35	0.73	12.3	2.18	1.22
T48, automatic	14.7	1.77	0.70	9.1	1.35	0.44	7.9	1.04	0.38	11.6	1.48	0.56
Flechette	(18.4)	(1.48)	(1.19)	14.5	1.32	0.94	10.8	0.95	0.70	15.5	1.31	1.01

C/S columns are taken directly from Table 13 (times 2.63 and 2.07 rounds per salvo for carbine and T48 bursts, respectively). C/T columns list casualties per minute per man, using C/t data from Table 13. C/W columns list casualties per pound of weapon system, using C/R data from Table 13 and weights from Table 14. "Average" casualty values are deduced by arbitrarily lumping the three separate conditions of firing in the approximate ratio of the experiment: 2 (day sitting): 1 (day standing): 1 (night sitting). This ratio is conservative in heavily weighting the most accurate fire.

It is now appropriate to compare salvo with the single-bullet ammunitions: duplex to single bullet, triplex to single bullet, flechette to single bullet; and also carbine automatic to carbine semiautomatic, and T48 automatic to semiautomatic. Because these last two ratios are consistently approximately equal, they are combined in Table 16. It is also of interest to note weapon comparisons: carbine semiautomatic to M1, T48 semiautomatic to M1.

To further generalize the effectiveness measure beyond aimed-fire casualty production, unaimed or area rifle fire must be considered. This unaimed fire is generally directed at specific suspected target areas, and has the primary effect of neutralizing or harassing enemy troops, and hence protecting and encouraging friendly troops.

Neutralization effectiveness has been alternatively measured by (1) number of bangs, (2) number of bullets, (3) number of hits, and (4) number of casualties. Criterion 1 offers no discrimination among the test ammunitions unless perhaps loudness of bang is included. Criterion 2 equates single bullets, scores duplex double, triplex triple, and flechettes × 32. Automatic bursts (from the Table K15 rate of fire) score 50 percent over single bullets on a per time basis. The slower shotgun rate (about half) and ineffective tumbling fraction of flechettes reduce the flechette factor to about 10 times single bullets on a per time basis.

Brief reflection indicates that so long as the target area is larger than the greatest dispersion (a reasonable assumption), the number of hits (criterion 3)

TABLE 16

AIMED-FIRE CASUALTY RATIOS

Ammunition or firing compared	Condition											
	Day sitting			Day standing			Night sitting			Average		
	C/S	C/T	C/W	C/S	C/T	C/W	C/S	C/T	C/W	C/S	C/T	C/W
Duplex to single	1.48	1.42	1.41	1.49	1.68	1.43	1.69	1.51	1.57	1.48	1.50	1.43
Triplex to single	1.83	1.43	1.77	1.72	1.54	1.67	2.23	1.54	2.13	1.81	1.47	1.76
Flechette to single	1.37	0.69	1.04	1.28	0.74	0.98	3.09	1.38	2.30	1.48	0.77	1.12
Automatic to semiautomatic	1.01	0.65	0.42	0.97	0.60	0.41	1.26	0.84	0.59	1.02	0.65	0.43
Carbine to M1	1.30	1.48	2.61	1.12	1.70	2.26	0.63	0.62	1.23	1.19	1.45	2.39
T48 to M1	1.17	1.19	1.37	0.90	1.23	1.05	2.11	1.96	2.43	1.16	1.28	1.36

TABLE 17

UNAIMED-FIRE CASUALTY RATIOS

Ammunition or firing compared	Number of bullets	Relative lethality	Rate of fire	C/S	C/T	C/W
Duplex to single	2	0.90	0.98	1.80	1.76	1.73
Triplex to single	3	0.81	0.78	2.43	1.90	2.36
Flechette to single	16	0.40	0.49	6.40	3.14	4.89
Automatic to semiautomatic	(2.33)	0.97	(0.64)	2.26	1.45	0.97
Carbine to M1	1	1	1.17	1.00	1.17	2.00
T48 to M1	1	1	1.06	1.00	1.06	1.16

is just proportional to the number of bullets (criterion 2). The relative number of casualties (criterion 4) is then deduced from the number of bullets and the bullet lethality, degraded for penetration failure and overkill. The corrected lethality figures from Table 13, together with the numbers of bullets per salvo, yield the relative values of C/S of Table 17. The average value for rounds per burst (both weapons) is taken from Table E7 as 2.33. The average rate-of-fire values for computing C/T are taken from Table K15 for single-bullet, duplex, carbine, and T48 ammunition. The missing triplex and flechette rates of fire are deduced from the incomplete data of Table K5 using the method stated in footnote of Table 13 (corrected for increased night "up" time). These then are averaged in the weighted ratio: 2 (day sitting): 1 (day standing): 1 (night sitting). The C/W values use Table 14 system weights as before.

The number of flechettes in Table 17 is halved to account for the observed effect with the prototype loads tested: many of the flechettes fail to fly properly. These erratic flechettes presumably fail to reach the target area, or at least fail to reach it in an effective orientation. A most conservative estimate is that at least half of the 32 do fly properly. It should be noted that success in correcting this erratic flight will double the flechette effectiveness of Table 17.

Note that only the relative numbers of unaimed-fire casualties have been deduced. If actual casualties were available, experience indicates that the figures might be so much smaller than aimed-fire casualties as to be insignificant. Yet the neutralizing effect of potentially casualty-producing rifle fire is not insignificant. Clearly then, the absolute casualty values are not needed, and the relative values of Table 17 are still valid as measures of potential casualties (casualties suffered by the enemy if he should fail to seek cover and be neutralized).

TABLE 18

OVER-ALL CASUALTY RATIOS

Ammunition or firing compared	C/S	C/T	C/W	σ[a]
Duplex to single	1.64	1.63	1.58	0.03–0.11
Triplex to single	2.12	1.69	2.06	0.06–0.14
Flechette to single	3.94	2.96	3.01	0.16– —
Automatic to semiautomatic	1.64	1.05	0.70	0.04–0.23
Carbine to M1	1.10	1.31	2.20	0.03–0.12
T48 to M1	1.08	1.17	1.2[illegible]	0.03–0.11

[a]Standard deviation of C/S column only.

It is desirable now to deduce over-all ammunition comparisons for all rifle fire. The question is: What relative value to allot to aimed fire (Table 16) and to unaimed fire (Table 17)? Appendix C shows that unaimed fire constitutes 89 percent of all rifle fire. This agrees with informal accepted military opinion that two-thirds to three-fourths of rifle fire is not aimed. Presumably the conditions of battle are such that aimed rifle fire at visible individual targets is generally more critical, and hence an appropriate average weights unaimed fire at something less than 89 percent. For lack of a better basis for value judgment, the ratios of Tables 16 and 17 are weighted equally in deducing the over-all casualty ratios of Table 18. It must be borne in mind that Table 18, although our best over-all effectiveness estimate, involves a crude lumping of aimed and unaimed fire. The firmer experimental results appear in Table 16.

The range of standard deviations is from the minimum purely random or sampling errors, taken from Table J35 and the maximum gross experimental aggregate value from Table J33. The percentage figures from these two tables (divided by $\sqrt{2}$) are applied to the C/S column to yield the absolute values listed. The standard deviations for aimed fire (Table 16) are larger by an average of $\sqrt{2}$. Individual aimed-fire standard deviations may be computed from Tables J33 and J35.

CONCLUSIONS

Major Conclusions*

The major conclusions of this paper may be drawn from Tables 16, 17, and 18. Since the casualty ratios of Table 18 are often not too different for the various criteria (C/S, C/T, C/W), it is sensible in these cases to express average effectiveness ratios. Table 19 shows these averaged-criterion casualty ratios.

1. Duplex ammunition achieves 60 percent more casualties than single bullets over-all. This gain increases with decreasing accuracy (40 percent sitting, 50 percent standing, 60 percent night, and 80 percent unaimed; also 57 percent expert squad, 64 percent average squad, 72 percent unqualified squad). System weight and rate of fire do not differ significantly from those for single bullets.

TABLE 19

MEAN CRITERION CASUALTY RATIOS

Ammunition or firing compared	Day sitting	Day sitting	Night sitting	Unaimed	Over-all
Duplex to single	1.44	1.53	1.59	1.76	1.62
triplex to single	1.68	1.64	1.97	2.23	1.96
Flechette to single	1.03	1.00	2.26	4.81	3.30
Automatic to semi-automatic	0.69	0.66	0.90	1.56	1.13
Carbine to M1	1.80	1.69	0.83	1.39	1.54
T48 to M1	1.24	1.06	2.17	1.07	1.17

2. Triplex ammunition appears to achieve double the casualties of single bullets over-all. This gain increases with decreasing accuracy (70 percent day, 120 percent unaimed). System weight does not differ significantly from that for single bullets. Rate of fire appears to be decreased about 20 percent.

3. Flechettes appear to achieve two to four times the casualties of single bullets over-all (100 to 290 percent gain). This gain increases radically with decreasing accuracy (0 percent day, 130 percent night, and 380 percent unaimed). System weight is about 30 percent more than that of the M1. Rate of fire appears to be decreased about 50 percent.

4. Automatic fire without bipod is compared with semiautomatic fire. Its casualty score varies from a loss to a gain as accuracy decreases (-30 percent day, -10 percent night, +60 percent unaimed). Rate of fire in rounds per minute for short bursts is 50 percent greater than that for semiautomatic fire.

5. The .22-cal carbine achieves 50 percent more casualties than the M1 over-all. This gain decreases with decreasing accuracy (80 percent sitting, 70 percent standing, and 40 percent unaimed). Night fire shows a 20 percent loss, system weight is 50 percent less than the M1, and the rate of fire is increased 20 percent.

6. The .22-cal T48 achieves 20 percent more casualties than the M1 over-all. This gain does not vary appreciably with decreasing accuracy (20 percent

*Conclusions 2 and 3 are based on limited data.

sitting, 10 percent standing, and 10 percent unaimed). Night fire shows a 120 percent gain, system weight is 10 percent less than the M1, and the rate of fire is increased 10 percent.

Discussion of Major Conclusions

It is concluded that duplex ammunition offers an unambiguous gain of 60 percent effectiveness over single-bullet fire. This figure is statistically sound, and holds roughly for considerable modification in the arbitrary weighting of different types of fire.

The average gain of 100 percent effectiveness for triplex ammunition is based on meager aimed-fire data (two runs) but seems quite reasonable. This value, however, fluctuates with the criterion used, particularly to give a lower value (70 percent) on a per time basis because of the observed and unexplained reduction in rate of fire. It is suspected that this observed rate effect is not generally real, as no satisfactory systematic explanation has occurred. Additional testing is required to verify the 100 percent over-all figure.

The flechette gain depends markedly on the criterion selected. Table 18 shows roughly that casualties per minute double, casualties per pound triple, and casualties per salvo quadruple the single-bullet score. Further the gain depends markedly on the type of fire. Aimed fire shows an average gain of 10 percent, unaimed fire a gain of 380 percent. Further the gain varies considerably with accuracy condition in aimed fire: no gain in day fire, 130 percent gain at night. This suggests that the flechette type of highly multiple salvo is particularly valuable in poor accuracy conditions. Very probably the limitations on combat simulation in the experiment produce greater accuracy than true combat, making this study's results conservative. The realization that pistol aiming error is generally about five times rifle error[16] strongly suggests the application of a flechette-type load to a side arm. Furthermore, the 50 percent rate-of-fire decrease and 30 percent weapon-system-weight increase together with estimated 50 percent erratic-flight observation combine to indicate that the considerable additional gains may be achieved with successful further development.

The automatic fire results show 60 percent increased effectiveness compared with semiautomatic fire on a salvo or trigger-pull basis, 30 percent decreased effectiveness on a weight basis, no appreciable difference on a time basis. Further the average loss is 30 percent in aimed fire. The only conditions appreciably favoring automatic fire are night aimed fire on a per salvo basis (+30 percent), unaimed fire on a per salvo basis (+130 percent), and unaimed fire on a per time basis (+50 percent). Other conditions and criteria favor semiautomatic fire. These automatic fire gains are based on the assumption that automatic unaimed fire is confined to the target area. This assumption warrants critical scrutiny. It is noted, however, that the aimed-fire data are restricted to firing without bipod (from the shoulder). On the other hand, all automatic-fire comparisons were made with light .22-cal weapons, which probably hold on target better than heavier weapons such as the BAR and M15.

The .22-cal carbine and T48 both achieve about 20 percent more casualties per round in aimed semiautomatic fire than the M1 with single-bullet ammunition. This accuracy gain may be attributed to the smaller caliber, the light weapon weight, or the reduced recoil effect. A further gain is noted in the increased rate of fire (about 10 percent), resulting in a 20 to 30 percent over-all gain for these weapons on a casualty-per-minute basis. An experiment to identify the source of this accuracy and rate-of-fire gain is indicated. The lighter system weights make the advantage of these weapons still more pronounced on a casualty-per-pound basis (30 percent for the T48, 120 percent for the carbine). Here it becomes essential to select the criterion that will be used to evaluate ultimate effectiveness. Casualties per pound favor the small-carbine single-bullet over .30-cal duplex ammunition; casualties per round or per minute favor duplex. In all cases (except carbine night fire), the .22-cal weapons tested are superior to the .30-cal M1. This result naturally suggests that .22-cal duplex and triplex ammunition be examined to achieve both gains. (Triplex ammunition may not be practicable in .22 cal, considering available muzzle energy and velocity losses).

Of special note are the night aimed-fire comparisons with the three weapons listed in Table 16. Without considering weight differences, it is seen that the carbine drops from a 40 percent average day gain over M1 to a 40 percent night loss. The T48 increases from a 10 percent average day gain over M1 to a 100 percent night gain. To get a better notion of this night effect, the day results for the three weapons (C/R and C/T) are normalized and compared with the resultant night values. This yields a relative carbine night degradation of 60 percent and a relative T48 improvement of 80 percent. These large differences were apparent during conduct of the experiment.

The T48 superiority is attributable to the size and position of the rear peep sight. The T48 was noted in the field to have a sight picture about three times the linear dimension afforded by the M1. This is borne out by the sight dimensions. The angle defined by a pupillary diameter of ¼ in. (night) and the aperture diameters and distances (from Table B2) are: M1, 6 mils; T48, 14 mils; and carbine, 7 mils. The poor carbine night performance is apparently not due to sight dimensions. Possibly aperture reflectivity, depth, and taper are involved. Debriefing revealed that troops generally used the T48 sight in night firing but completely avoided use of the M1 and carbine sights at night.

It should be noted that these experimental firings were all with augmented bright moonlight. Variations in illumination might lead to different results. The lack of explanation for the carbine night degradation and the possible uncertainty in the explanation of the T48 night improvement suggest further field tests on peep sights under conditions of limited illumination.

It is instructive to examine the salvo to single-bullet ratio in casualties per salvo as a function of accuracy. In unaimed fire the accuracy is such that the basic single-bullet hit probability is negligible. The associated casualty ratios are given in Tables 16 and 17.

Furthermore it is possible to deduce the casualty production for each ammunition under the condition of perfect accuracy, or 100 percent hit probability. For this computation only one hit per salvo is first assumed. From App O the penetration degradations are none for single-bullet ammunition and automatic fire, 0.2 percent for duplex, 7.1 percent for triplex, and 7.2 percent for flechette ammunition. Applying these degradations to the App B basic bullet lethalities (35 percent for flechettes, 70 percent for all bullets), the C/S for the one-hit case are deduced.

TABLE 20

PERFECT-ACCURACY CASUALTY RATIOS

Ammunition or firing compared	Number of bullets	C/S		C/T		C/W	
		One hit	All hits	One hit	All hits	One hit	All hits
Duplex to single	2	1.00	1.30	0.98	1.27	0.96	1.25
Triplex to single	3	0.93	1.37	0.73	1.07	0.90	1.33
Flechettes to single	16*	0.46	1.43	0.23	0.70	0.35	1.09
Automatic to semiautomatic	2.5	1.00	1.33	0.60	0.80	0.40	0.53

*Effective number for prototype.

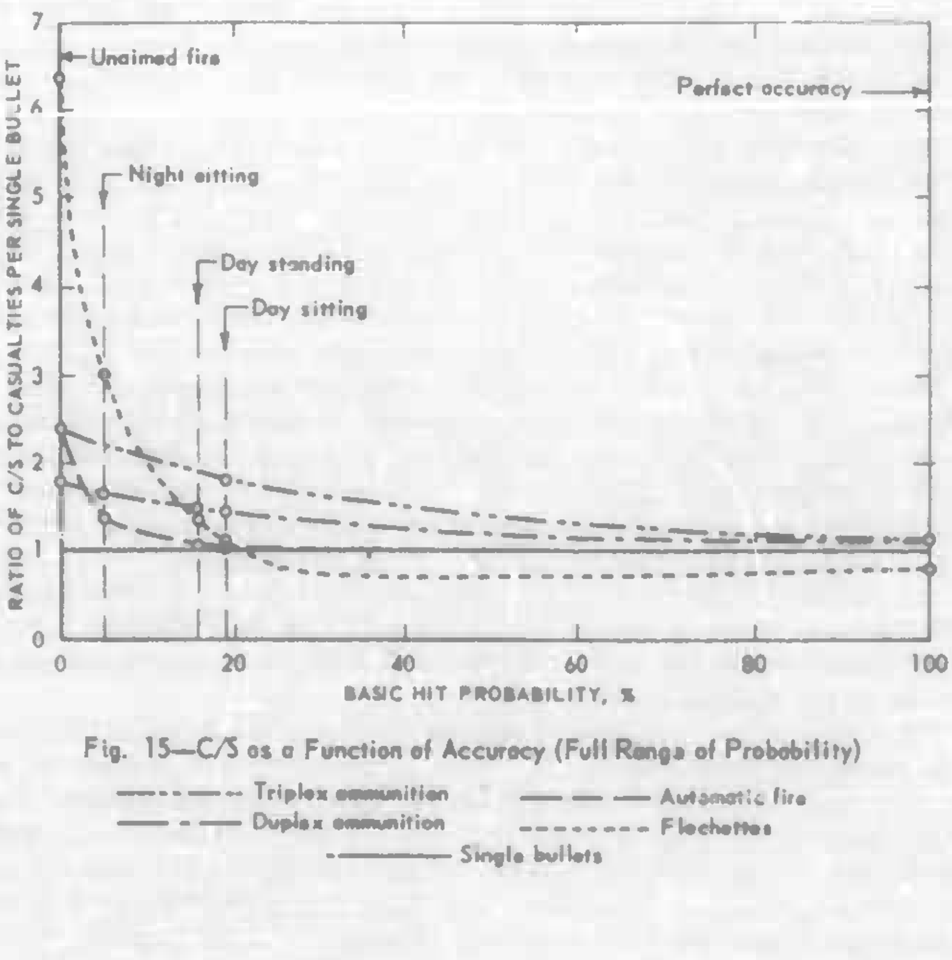


Fig. 15—C/S as a Function of Accuracy (Full Range of Probability)

The C/S for the assumption of all bullets hitting are computed by the usual overkill calculation. For example, duplex ammunition scores 0.7 casualties with the first hit, plus 0.7 × (1−0.7) with the second hit. The total (0.91) is greater than the single bullet (0.7) in the ratio 1.30, shown in Table 20. The C/T and C/W columns are computed from the C/S column as in the earlier tables.

The one-hit values of Table 20 apply to very distant targets, and the all-hits values apply to very close targets. The integrated average for the target system lies between, but would be most tedious to compute. Omitting the artificially generated triplex and flechette data, the C/S are shown in Fig. 15 as a function of accuracy. Intermediate values from Table 20 are used for the perfect-accuracy points. The figure shows clearly the trend of decreasing salvo gain with increasing accuracy. Furthermore the curves demonstrate that this effect is most pronounced for the largest salvos (flechette slope > triplex slope > duplex slope).

As accuracy characterized by hit probabilities of over 20 percent is of little practical military significance, the same data are plotted in Fig. 16 on a larger scale. This is clearly the accuracy range of interest. Similar plots are shown in Figs. 17 and 18 of C/T and C/W. From all three figures, it is clear that in unaimed or very inaccurate fire the effectiveness order is (1) flechettes, (2) triplex ammunition, (3) duplex ammunition, (4) automatic fire, and (5) single bullets. The most accurate fire shows generally (1) triplex ammunition, (2) duplex ammunition, (3) single bullets, (4) flechettes, and (5) automatic fire. Duplex and triplex ammunitions are never shown to be inferior to single bullets.

From the crossover points on these figures it is evident that further data are needed on actual combat rifle accuracy or hit probabilities. Firm decisions on relative combat effectiveness require knowledge of where to make valid comparisons along the abscissa of Figs. 16 to 18. Combat experience must be canvassed to provide an estimate of rifle accuracy in actual combat.

Additional Conclusions

In addition to the six major conclusions on ammunition and weapons differences from Tables 16 to 19, there are 16 other conclusions from the experiment.

7. Most day targets range from 75 to 350 yd; night targets from 50 to 225 yd.

8. Mean ranges of firing are 177 yd for day targets and 121 yd for night targets.

The target system, based on the questionnaire of App C, gives day targets with ranges of 75 to 340 yd with a mean range of 190 yd. Table P1 of App P gives the hits by target and permits the calculation of a mean range of hits. This value is 133 yd. Appendix F gives single-bullet rounds fired by target, and permits calculation of a mean range by rounds fired. This weighted mean range is 177 yd. The mean day-target exposure time is 10½ sec.

Similarly the night targets range from 50 to 225 yd, with a mean range of 135 yd. The computed mean hit range (from Table P2) is 85 yd. The mean range by rounds fired (Table F40) is 121 yd. The mean night exposure time is 11½ sec.

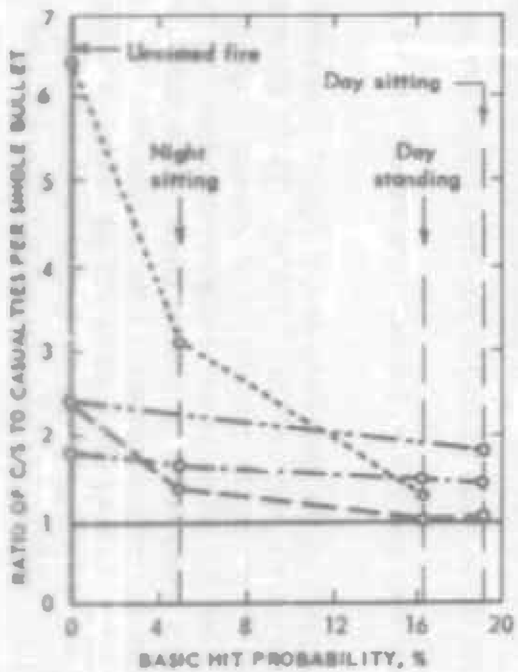


Fig. 16—C/S as a Function of Accuracy

- single bullets
- automatic fire
- duplex ammunition
- triplex ammunition
- flechettes

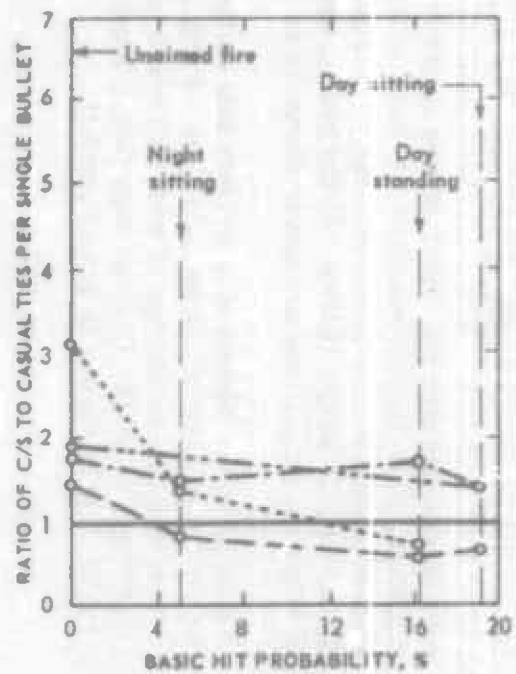


Fig. 17—C/T as a Function of Accuracy

- single bullets
- automatic fire
- duplex ammunition
- triplex ammunition
- flechettes

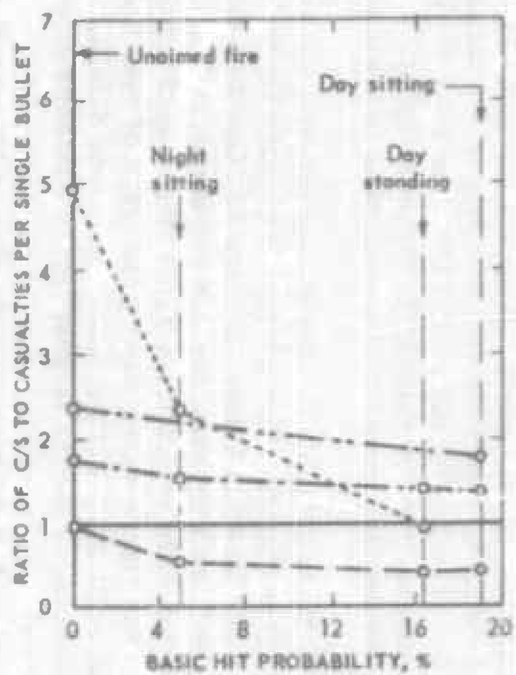


Fig. 18—C/W as a Function of Accuracy

- single bullets
- automatic fire
- duplex ammunition
- triplex ammunition
- flechettes

9. Mean single-bullet hit probabilities are 19 percent for day sitting, 15 percent for day standing, and 6 percent for night sitting; 14 percent average.

10. Mean aiming errors (linear standard deviations) are 3.0 mils for day sitting; 3.4 mils for day standing; and 7.8 mils for night sitting; 3.8 mils average.

The equivalent target sizes (F and E) are circles of radii 9.9 in. and 14.0 in. (shown in App M). As the questionnaire leads to 12 F and 10 E targets for both day and night, the weighted average target radius is 11.8 in. Thus it is concluded that typical rifle targets are representable by a 1-ft-radius circle at about 170 yd for day or 120 yd for night.

It is possible to use these typical targets together with the hit probabilities from Table K15 (19, 15, and 6 percent) to compute representative aiming errors.

From expression M3 of App M the aiming error as a linear standard deviation σ is a function of target size Γ, range R, and hit probability P_{H}.

$$\sigma = \Gamma/R \sqrt{-2 \ln (1 - P_{H})}$$

Using the mean ranges (by rounds fired) 170 and 120 yd yields errors of 3.0 mils for day sitting, 3.4 mils for day standing, and 7.8 mils for night sitting. In graphic terms the circle diameters that include half the rounds fired (2 × CEP) at 100 yd are about 25 in. for day sitting, 29 in. for day standing, and 66 in. or $5^1/_2$ ft for night sitting.

The average hit probability for all test conditions from Table K15 is 14 percent. This corresponds to an average aiming error of 3.8 mils (based on a mean target range of 160 yd). If it is desired to deduce accuracy values for all fire including unaimed, the 14 percent hit probability is reduced to about 4.4 percent by considering that the 69 percent unaimed fire (App C) score negligible hits. This 4.4 percent hit probability corresponds to a 7.0-mil aiming error.

11. Average rate of rifle fire is 3 sec/round.
12. Average time to acquire a target is $1^3/_4$ sec.
13. Average extent of late fire (after target disappearance) is $1^1/_4$ sec.

The time pattern of fire is deduced in App I. These averages hold for this experiment. This late fire constitutes about 12 percent of all fire.

14. Average rate of fire drops to 3.2 sec/round for sitting and increases to 2.8 sec/round for standing or night.

Rates of fire can also be compared for the several firing conditions. The average numbers of rounds fired per run from Table K14, divided by the target up times (231, $253^1/_2$ sec) yield average firing times of 3.2 sec for day sitting; 2.7 sec for day standing; and 2.8 sec for night sitting. This agrees with the App I over-all average of 3 sec/round but shows a slight increase in time for careful aiming and a slight decrease for less careful aiming.

15. The relative hit probabilities by qualification are 100 for expert, 88 for sharpshooter, 75 for marksman, and 43 for unqualified.

Appendix G compares squad performance against squad composition by Army marksmanship qualification, and deduces relative scores by qualification.

16. During the experiment, the hits per round was constant, the hits per unit time increased about 2 percent per run (rate of fire increased about 2 percent per run).

The trends of score with experience in the test firing is examined in App H and App K. This shows a 19 to 29 percent increase in rounds fired, and a negligible increase in hit probability over the learning span. This increase in hits per unit time is large enough to warrant examination of its implications for training.

17. Hits follow inverse-square law with range.

18. Hits and amount of fire are proportional to target appearance time (less $1^3/_4$ sec initial lag) for targets exposed 6 sec or longer.

19. The smaller (F) targets received 10 percent less fire than the large (E) targets, and only about two-thirds as many hits per area.

20. Target movement reduced fire and hits by about 10 percent.

21. Concealment reduced the amount of fire by about 30 percent, the hits by about 10 percent.

22. Blank fire at targets increased hits about 50 percent.

Appendix P on target characteristics leads to conclusions 17 to 22 (from Table P8).

RECOMMENDATIONS

1. The duplex and triplex ammunitions should be considered for adoption.

The increased casualty production of both duplex and triplex ammunitions is considered well enough demonstrated to warrant their official consideration by Department of the Army and CONARC for adoption. This consideration should presumably be based on independent Army tests and appropriate economic and standardization aspects not evaluated in this study. The demonstrated gains warrant more effort on duplex and triplex ammunitions than on conventional single-bullet ammunitions and weapons.

2. Additional tests of triplex and flechette ammunitions should be conducted.

Further tests are needed of the casualty-production capability of triplex and flechette ammunitions. The principles are now clearly shown; these tests should be performed by CONARC or Ordnance Corps.

3. Flechette development should be accelerated.

The flechette potential is so high as to warrant development of a much superior prototype. Fabrication of a system of tighter dispersion and more convenient physical characteristics is an Ordnance Corps responsibility.

4. A flechette side-arm load should be developed for test.

The clear by-product recommendation of this study requires initiation of a project by Ordnance Corps to produce a suitable side-arm flechette load for testing.

5. Doctrine for aimed automatic shoulder fire should be reviewed.

Since automatic fire from the shoulder scored poorly in the SALVO I experiment, the training for such fire should be reviewed (perhaps by HumRRO), and modified if necessary.

6. An investigation of smaller weapons should be initiated to identify observed .22-cal gains.

The improved performance of the two smaller caliber weapons may be due to weight, recoil, or caliber difference. An experimental investigation by CONARC or Ordnance Corps is needed to identify the specific cause.

7. A .22-cal duplex ammunition should be fabricated and tested.

A .22-cal duplex ammunition appears to afford dual advantages of duplex hit increase, and .22-cal, improved operational accuracy. This might well offer the best bet for interim adoption.

8. The peep-sight requirement should be reconsidered.

The night differences observed suggest that the present peep sight is too restrictive, and that a large peep or an open sight is superior. This could be demonstrated by experiment, perhaps by HumRRO.

9. Actual combat accuracy of rifle fire should be determined.

The lack of knowledge of how to extend the results of this study to real combat emphaszies the need for data on combat rifle accuracy. ORO is attempting to extract data from experience; other efforts are needed.

10. This experimental context should be considered for training use.

The learning observed and demonstrated in this experiment suggests the utility of the same sort of context for use in training. HumRRO might examine ORO's test system for useful training features.

Appendix A

PERSONNEL

SUMMARY

Test-subject selection was based on the marksmanship scores found in the eight battalions of the 3d Inf Div in May 1956. In accordance with these scores ORO requested four "average" 10-man squads, each composed of 1 expert, 4 sharpshooters, 4 marksmen, and 1 unqualified firer. Two additional squads were requested—one of 10 experts and one of 10 unqualified firers. The 3d Div furnished 3 experts, 24 sharpshooters, 13 marksmen, and no unqualified firers, unevenly distributed among the four average 10-man squads; 8 experts and 2 sharpshooters for the expert squad; and 2 experts, 2 sharpshooters, 2 marksmen, and 4 unqualified firers for the unqualified squad.

The test subjects were asked a series of questions after each pair of runs, and another after the completion of each week of firing. They reported an overwhelming preference for the T48 with semiautomatic- and automatic-fire option. The reason most commonly given for this preference was the "added firepower" that the automatic fire provided. The test subjects also expressed a dislike for the carbine, which had the same automatic- and semiautomatic-fire option. The reason here was lack of "killing power." Answers to other questions are presented in the section "Debriefing."

TEST SUBJECTS

The major criterion used in the selection of the test subjects was their rifle marksmanship qualifications. In addition each subject was given a complete physical examination, and his medical records were checked to ensure that he had no record of heart disease or epilepsy. This precaution was taken because of the use of electric shock during the test.

The results of a survey[10] of the rifle marksmanship of eight battalions of the 3d Div are shown in Table A1.

To the nearest 10 percent this distribution may be approximated by 10 percent experts, 40 percent sharpshooters, 50 percent marksmen, and no unqualified. It was judged, however, that at least a few of the minimum-score marksmen were "pencil-qualified." Hence it was decided that the test subjects should include 10 percent experts, 40 percent sharpshooters, 40 percent marksmen, and 10 percent unqualified. The 40 test subjects requested from the 3d Div were to be 10-man groups or squads, each group including 1 expert, 4 sharpshooters, 4 marksmen, and 1 unqualified rifleman.

The 2d Bn of the 3d Div sent four 10-man lots to the test site ostensibly having the given qualifications. During the conduct of the experiment, particularly as a result of the debriefing interviews, suspicion arose concerning the marksmanship qualifications of the test subjects. Since it was then too late to change test subjects the test continued with the troops furnished. A subsequent check of the service records[20] of the test subjects indicated deviation from the original criterion as shown in Table A2. Imbalance occurred both in totals and in each 10-man squad. For example, squads E and F were supposed to be composed exclusively of experts and unqualifieds, respectively. Although this was

TABLE A1

3D DIV MARKSMANSHIP QUALIFICATIONS

Inf bn	Expert	Sharpshooter	Marksman	Unqualified	Total
1st	15	95	147	0	257
2d	28	167	150	13	358
3d	20	99	209	5	333
4th	29	113	94	6	242
5th	29	123	164	14	330
6th	46	127	99	4	276
7th	39	111	107	0	257
8th	41	116	100	8	265
Total	247	951	1070	50	2318
Percent of total	11	41	46	2	100

TABLE A2

QUALIFICATIONS FURNISHED AND REQUESTED[a]

Squad	Expert	Sharpshooter	Marksman	Unqualified
A	1(1)	3(4)	6(4)	0(1)
B	1(1)	7(4)	2(4)	0(1)
C	0(1)	6(4)	4(4)	0(1)
D	1(1)	8(4)	1(4)	0(1)
E	8(10)	2(0)	0(0)	0(0)
F	2(0)	2(0)	2(0)	4(10)
Total	13(14)	28(16)	15(16)	4(14)

[a]Parenthetical entries are the requested numbers; the numbers preceding indicate the numbers furnished.

not the case it can be seen that there was in fact a large difference between the qualifications of the two lots, and hence the experimental objective of measuring qualification effects on salvo gain was largely fulfilled.

Table A3 shows the results of the postexperiment study of personnel records of personnel tested in the SALVO I experiment. The subject's weapon qualification listed in the table is the one that had the latest date on his records. Some of the records were not available because of discharges or transfers, and these instances are noted.

Seventy-five percent of these test subjects were enlistees, and 75 percent had over 2 years of service. They had completed an average of $9^{1}/_{2}$ years of schooling, the range being from the third grade to the third year of college.

TABLE A3

INDIVIDUAL QUALIFICATIONS

Squad and test subject	Qualifications from personnel records	3d Div designation	Squad and test subject	Qualifications from personnel records	3d Div designation
Squad A			Squad D		
Sgt Bosarge	a	E	Pfc Hall	E	E
Sgt Lopez	SS	SS	Sfc Melton	SS	SS
Pvt Perez	SS	SS	Sp 3 Swafford	SS	SS
Pfc Dungee	SS	SS	Sp 3 Chapman	SS	SS
Pvt Ladson	MM	SS	Sp 3 Branson	SS	SS
Sgt Barry	MM	MM	Sfc Pina	SS	MM
Sgt Bennett	b	MM	Sp 3 Nuffer	SS	MM
Sp 3 Chitwood	MM	MM	Pvt Perry	SS	MM
Sp 3 Drake	MM	MM	Pfc Brown	MM	MM
Pvt Whelchel	MM	UNQ	Pvt Boaldin	SS	UNQ
Squad B			Expert squad		
Sfc Kunkle	E	E	Pfc Oliver	E	E
Sgt Frawley	c	SS	Sgt Wilson	SS	E
Sp 3 Harris	c	SS	Pfc Hugh	E	c
Pvt Adams	b	SS	Pvt Holder	b	E
Pvt Knowles	SS	SS	Pfc Diaz	SS	E
Sp 3 Lampee	SS	MM	Pfc Kennedy	E	E
Pvt Menzie	SS	MM	Pvt Fowler	E	E
Sfc Perry	MM	MM	Pvt Baiza	E	E
Pvt Roon	MM	MM	Sp 3 Sanchez	E	E
Pvt Zerbe	SS	UNQ	Sfc Pointer	E	E
Squad C			Unqualified squad		
Sfc Zdina	SS	E	Sfc Dahl	SS	UNQ
Sp 3 Mork	SS	SS	Pfc Casper	d	UNQ
Sp 3 Freeman	SS	SS	Sp 3 Edwards	E	UNQ
Sgt O'Reilly	SS	SS	Sp 3 Mifler	E	UNQ
Sp 3 Chambliss	SS	SS	Sp 3 Kennaly	SS	UNQ
Pvt Miller	MM	MM	Sp 3 Sean	MM	UNQ
Sp 3 Wright	MM	MM	Pfc McNabb	UNQ	UNQ
Pvt Ross	MM	MM	Pfc Little	UNQ	UNQ
Pfc Ortiz	MM	MM	Pvt Coame	UNQ	UNQ
Pvt Bonner	SS	UNQ	Pvt Colon	MM	UNQ

[a]Discharged. [b]Transferred. [c]No qualification record. [d]Record missing.

DEBRIEFING

After each set of two runs and at the end of each week of firing the test subjects were asked two series of questions about the experiment itself and about the test and control items. The object of these questions was to obtain subjective information concerning the effect of the experiment on the test subjects, and also to uncover any factors affecting the experiment that were not obvious on the firing line. These questions were asked in individual interviews. Some difficulty was experienced in questioning the Puerto Rican soldiers owing to their imperfect understanding of English. The questions, a numerical tabulation of the answers, and an interpretation of these answers follows.

Questions Asked after Each Set of Two Runs

1. "Did your weapon malfunction? Which run and how many times?"

The answers to these questions were so vague and inaccurate that asking them was discontinued. This information was instead collected on the firing line by the Ordnance representatives and is reported in App N.

2. "Do you feel that the targets, that is, the way they appeared, the time they were up, and the distances at which they appeared, were like what you would expect combat to be like?"

Answer	Response, %
Just like combat	18
Very much like combat	21
Something like combat	57
Not much like combat	3
Not at all like combat	1

3. "Did the wires attached to your rifle interfere with your getting hits?"

Answer	Response, %
Did not interfere	100

4. "How much was your firing affected by concern over getting an electric shock on your leg?"

Answer	Response,%
A lot	0
Some	2
Very little	5
Not at all	93

5. "How much was firing affected by the wires attached to your leg?"

Answer	Response,%
A lot	0
Some	0
Very little	2
Not at all	98

6. "On this run did dust on the target system interfere with your getting hits?"

Answer	Response, % of runs
Dust did not interfere	19
Dust did interfere	61[a]

[a]One or more men reported interference.

On the 81 percent of the runs on which there was some report of dust interference an average of 56 percent of the firers reported this interference. This dust was from low rounds and demolitions in the target system.

7. "What effect did heat have on your getting hits?"

Heat was not reported as affecting hits.

8. "Was there anything else that affected your getting hits? If so, what?"

This was a catch-all question, which sometimes turned up interesting results. One man reported that he had received five inoculations in the upper part of his right arm before coming to the field for the day's firing. By the end of the day the man reported a very painful shoulder. ORO requested that the test subjects be given no more inoculations during the balance of the test.

During one run five men reported receiving light shocks from the trigger housings of their rifles. This situation was investigated and corrected

9. "Were you able to get a sight picture?" (This question was asked after the night runs.)

Weapon used	Yes, %	No, %
M1	0	100
T48	62	38
Carbine	0	100

10. "Have you fired the regular carbine in automatic fire? If so, do you think that the recoil compensator on the carbine caused it to jump less than an ordinary carbine?" (Asked only after the carbine runs.)

Answer	Yes, %	No, %
Have fired carbine in automatic fire	35	65

Of those who had fired the carbine in automatic fire, all thought the modified carbine used in the test jumped less.

<u>Questions Asked at the End of Each Week of Firing</u>

1. "If you had your choice, which of the weapon-ammunition combinations you have fired in the test would you prefer to have in combat?"

Answer	Response, %
T48 automatic and semiautomatic	72
M1 with duplex ammunition	12
No opinion	8
T48 semiautomatic	5
T48 automatic	3

More than 90 percent of those who preferred the T48 with automatic and semiautomatic option gave as the most important reason the automatic-fire capability. Even though the test subjects knew that the 10-man groups as a whole were getting fewer hits with automatic fire the belief persisted in many individuals that they personally were getting more hits. Other factors that contributed to the popularity of the T48 were the larger aperture peepsight and the belief that the T48 was lighter.

2. "Which weapon and ammunition would you least like to have in combat?"

Answer	Response, %
Carbine	62
No opinion	27
M1 with AP	5
M1 with duplex or triplex	3
T48 automatic and semiautomatic	3

In listing their reasons for their dislike of the carbine, 90 percent mentioned a lack of "killing power." The second most common complaint was its high rate of malfunction. Those who disliked the M1 complained about its weight.

3. "How much experience have you had in firing the BAR?"

Answer	Response, %
None	23
Some (a few rounds in basic training)	32
A lot (qualified)	45

4. "How much experience have you had in automatic carbine firing?"

Answer	Response, %
Never fired	35
Some (a few rounds in basic training)	18
A lot (qualified)	47

5. "Do you feel that your concern over getting shocked would be like your concern over getting wounded in combat?"

Answer	Response, %
Very much the same	10
Somewhat the same	43
Not at all the same	47

6. "Have you fired on a range similar to this one before?"

Answer	Response, %
Yes	48
No	52

Of those who said they had fired on a range similar to the test range before, all but two said that they were referring to the Army transition range. Two of the test subjects had fired the HumRRO TRAINFIRE I range[21] and thought this and the test range quite similar.

Appendix B

WEAPONS AND AMMUNITION

SUMMARY

The weapons used in the SALVO I test were four kinds of rifles and one shotgun. The rifles were (a) the standard Army .30-cal M1 rifle, (b) a modified .30-cal M1 rifle with a reamed chamber to accept long-necked duplex and triplex cartridges, (c) a .22-cal (Gustafson) carbine developed at Aberdeen Proving Ground from the standard Army .30-cal M2 carbine, and (d) a .22-cal T48 rifle modified at Springfield Armory from a .30-cal T48 (Fabrique Nationale d'Armes de Guerre). The shotgun was a Remington model 11-48A 12-gage autoloading shotgun with four stiffening ribs welded on the barrel.

TABLE B1

TEST WEAPON-AMMUNITION COMBINATIONS

Weapon	Ammunition	Runs
.30-cal M1[a]	.30-cal M2 AP	8
.30-cal M1	.30-cal M2 AP	10
.30-cal M1[a]	.30-cal duplex	14
.30-cal M1[a]	.30-cal triplex	2
.22-cal T48[a]	.22-cal Sierra	16
.22-cal M2 carbine[a]	.22-cal carbine	16
12-gage shotgun[a]	32-flechette load	2
Total		68

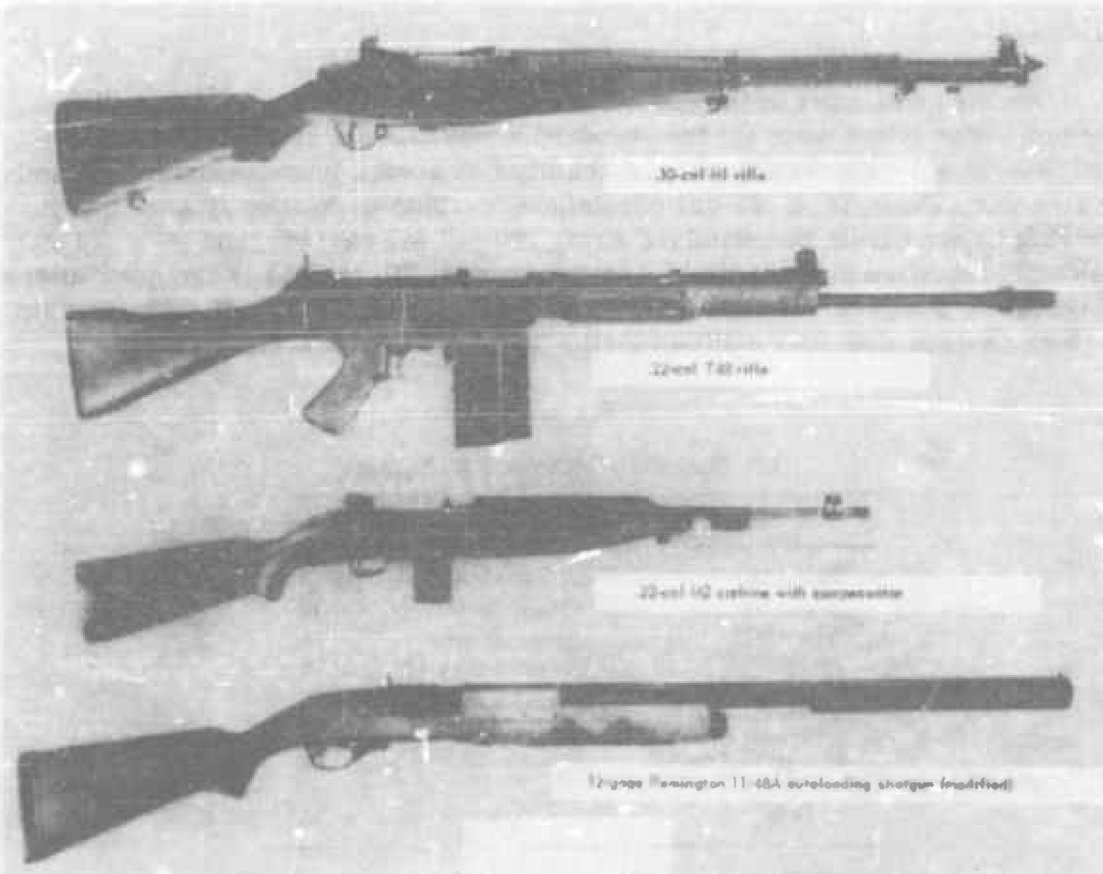
[a]Modified.

Special ammunitions were developed for this test and compared with standard Army-issue .30-cal M2 single-bullet ammunition. The experimental rifle ammunitions were (a) .30-cal duplex (controlled-dispersion type), (b) .30-cal triplex (random-dispersion type), (c) .22-cal Sierra ammunition, all produced by Olin Mathieson Chemical Corp., and (d) .22-cal carbine ammunition developed at Aberdeen Proving Ground. The 12-gage shotgun shell contained 32 flechettes that were 1.25 in. long, developed and produced by Aircraft Armaments Corp.

The experimental single-bullet rifles and ammunition were checked for dispersion, and all proved generally comparable to the standard M1 rifle with single-bullet ammunition. Velocity and lethality were also compared, and showed that the experimental rifle loads were as effective as the standard ammunition against personnel targets out to 350 yd. The weapon-ammunition combinations used in the test are listed in Table B1.

WEAPONS

Figure B1 shows the test weapons, and Table B2 compares the rifles and shotgun with respect to some of their differences in specifications. A comparison of the accuracy of these weapons using the test ammunition is given in the next section in Table B4.



Courtesy of Frankford Arsenal

Fig. B1—Test Weapons

.30-Cal M1 Rifle

The original plan of the experiment was to use modified M1 rifles to fire not only the duplex and triplex rounds but also the single-bullet rounds. The suggestion was made during the experiment that single-bullet performance might be thought to be degraded with the modified M1 rifles. Accordingly Board 3 of The Infantry Center supplied 12 unmodified M1 rifles for half the single-bullet runs. These rifles proved no more accurate or immune from malfunctions than the modified M1's they supplanted. Ten-shot groups were taken after the experiment, using an expert firer from a bench rest.[22] Ten of these unmodified M1's had a linear standard deviation of less than 0.4 mil, but two were quite inaccurate: 1.1 and 1.7 mils. However, even these large errors are generally smaller than the experimental aiming errors and do not therefore notably affect the experimental results.

TABLE B2

CHARACTERISTICS OF TEST WEAPONS

Characteristic	.30-cal M1	.22-cal T48	.22-cal carbine	12-gage shotgun
Weight (empty magazine, no sling), lb	9.5	9.7	5.2	8
Weight (full magazine, with sling), lb	10.0	10.7	6.3	8.5
Rifle length, in.	43.6	43.0	35.6	48.5
Barrel length, in.	24	21	18	26
Barrel rifling (right-hand twist), in.	10	9.7	16	None
Number of grooves	2 or 4	6	6	0
Sight radius, in.	28	22	22	—
Sight-aperture diameter, in.	0.069	0.099	0.079	—
Average eye-to-aperture distance, in.	5	2.5	4.5	—
Trigger pull, lb	6–7	6–7	5–7	—
Capacity, rounds	8	20[a]	15	5[b]
Rate of fire, automatic, rounds/min	None	700	750	None

[a]In practice the 20th round in the T48 magazine (designed for .30 cal) caused the weapon to jam. Hence only 19 rounds were loaded in the T48 magazine.

[b]Four in magazine plus one in chamber.

.30-Cal M1 Rifle (Modified)

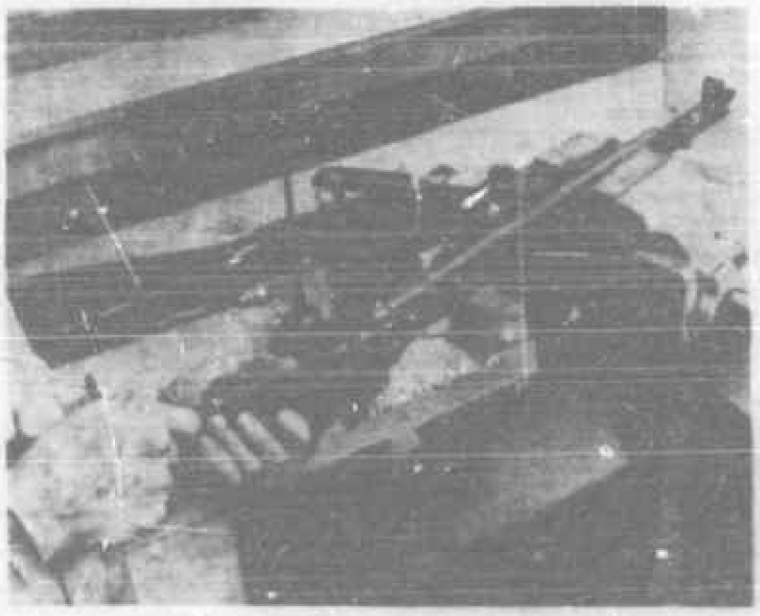
The standard Army rifle was modified by Springfield Armory by elongating the chamber to accept the long-necked experimental rounds. The chamber was lengthened 0.46 in., using reamers supplied by Olin Mathieson Chemical Corp.[23] These reamers are easy to use, even by relatively inexpert technicians. An illustration of this operation is given in Fig. B2.

The rifles were fired from a cradle to check their accuracy before and after chamber elongation. The linear standard deviation (using M2 ball ammunition) before rechambering was 0.31 mil, and after rechambering 0.38 mil.[24] After the test 11 modified rifles were sent to Development and Proof Services, Aberdeen Proving Ground, where their ballistic dispersion was again measured in bench-rest firings at 0.33 to 0.44 mil.[25] This accuracy is just about the same as the 0.38 mil established mean accuracy of standard M1 rifles tested with the same lot of ammunition. The ammunition used was .30-cal M2 single-bullet the range was 100 yd, and the firings were bench rest by two outstanding experts.

.22-Cal T48 Rifle

Twelve .30-cal T48 rifles were modified by Springfield Armory[24] to fire the .22-cal Sierra cartridge. These rifles were first manufactured by Fabrique Nationale d'Armes de Guerre, Liège, Belgium. General characteristics are given in Table B2. The T48 is a light-weight, air-cooled, gas-operated, magazine-fed shoulder weapon designed to deliver selectively either semi-automatic or automatic fire.

The 12 rifles were tested at Springfield Armory before the experiment for function and accuracy. The average linear standard deviation when fired from a bench rest was 0.35 mil.[24]



Courtesy of Aberdeen Proving Ground

Fig. B2—M1 Chamber Reaming

.22-Cal Carbine (Modified .30-Cal M2 Carbine)

The standard Army .30-cal M2 carbine was modified at Aberdeen Proving Ground.[26] A commercial .22-cal barrel blank was machined so that its outside contour was the same as that of a standard .30-cal carbine barrel. Internal modifications were required to accommodate the different cartridge. The muzzle was threaded to accept a compensator designed to minimize vertical and horizontal muzzle movement, and to function as a "muzzle brake," reducing recoil by changing the direction of the expanding powder gases. The average linear standard deviation was about 0.13 mil.

12-Gage Autoloading Shotgun

The shotgun used in SALVO I was a modified version of the Remington model 11-48A sporting arm, utilizing the recoiling-barrel principle to achieve its autoloading action. The tapered shoulder at the forward edge of the chamber was reamed square to accommodate the special flechette ammunition. Four longitudinal ribs were welded to the barrel to minimize whip. These added approximately 1 lb to the weight of the weapon and shifted the balance point 1.75 in. toward the muzzle. The barrel bore is a simple unmodified cylinder. The aim is accomplished with a bead front sight and an open rear sight.

AMMUNITION

Five different kinds of rifle ammunition were fired; three were .30 cal and two were .22 cal. One type of shotgun load was also fired. The ammunitions are compared for selected characteristics in Table B3 and pictured in Fig. B3. Comparisons of the rifle ammunitions with respect to precision are given in Table B4. These dispersion values were obtained from several sources. The ranges indicate variations in these reported values. Some of the larger deviations arise from differences in measurement technique.

TABLE B3

CHARACTERISTICS OF TEST AMMUNITIONS

Characteristic	.30-cal M2 AP	.30-cal duplex	.30-cal triplex	.22-cal Sierra	.22-cal carbine	32-flechette 12-gage shotgun
Total round weight, grains	414	445	434	287	132	717
Case length, in.	2.49	2.94	2.94	2.04	1.30	—
Projectile weight, grains	163	96 × 2	60 × 3	68	41	12 × 32
Propellant weight, grains						
Main charge	53	49	50	44	16	30
Between bullets	—	2	1	—	—	—
Case volume, cu in.	0.23	0.23	0.24	0.19	0.08	—
Charge-to-mass ratio	0.33	0.27	0.28	0.65	0.40	—
Total length, in.	3.34	3.34	3.34	2.62	1.68	2.66
Chamber pressure, psi	50,000	52,000	55,000	54,000	37,000	—
Velocity, ft/sec[a]	2760	2510, 2350	2680, 2560, 2500	3300	2980	1260

[a]Duplex and triplex values for first, second, and third bullets, respectively.

TABLE B4

FRONT-BULLET PRECISION

Cartridge	Linear standard deviation, mils
.30-cal M2 AP	0.33–0.44
.30-cal duplex	0.19–0.42
.30-cal triplex	0.37–3.60
.22-cal carbine	0.12–0.14
.22-cal Sierra	0.16–0.44

Most of the precision data on SALVO ammunitions was supplied as mean radius and extreme radius. It is assumed that the patterns are Gaussian and radially symmetrical, permitting computation of the corresponding linear standard deviations σ from mean radius $\bar{r}$. The transformation is made as follows from the definition of the distribution:

$$dP = (r/\sigma^2)\exp(-r^2/2\sigma^2)\,dr, \qquad \text{(B1)}$$

where dP is the probability of a hit at distance r from the center of the pattern. The mean radius $\bar{r}$ is defined as:

$$\bar{r} = \int_0^1 r \, dP \qquad \text{(B2)}$$

With appropriate substitution this yields the useful conversion factor

$$\sigma = \sqrt{2/\pi}\ \bar{r} = 0.80\ \bar{r} \qquad \text{(B3)}$$

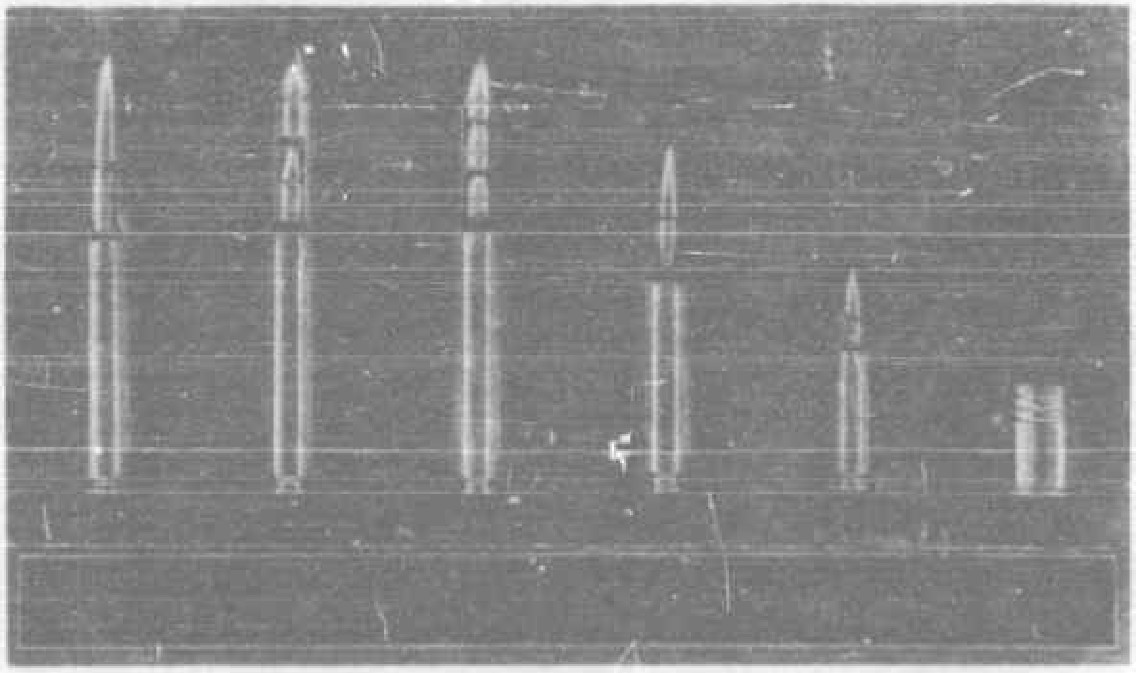


Fig. B3—Test Ammunitions

.30-Cal M2 Single-Bullet Cartridge

The experimental control ammunition used in the test was .30-cal single bullet. This was selected in preference to ball ammunition because the elongation of the M1 rifle chamber was expected to produce a slight decrease in ballistic accuracy of ball ammunition, which it did, from 0.31 mil before reaming to 0.38 mil after. Not so great an effect was expected on the accuracy of single-bullet ammunition. As it turned out the modified M1 rifles were used after the first week of the test only for long-necked duplex and triplex cartridges. Ball ammunition is usually slightly more precise than single-bullet, but proved to be the same in the modified M1; the average linear standard deviation of both was 0.38 mil.[26]

.30-Cal Duplex Cartridge

The duplex round was developed and produced by Olin Mathieson Chemical Corp. and was of the "controlled-dispersion" type.[33] This nomenclature is contrasted with "random dispersion." The second or rear bullet of the controlled dispersion deviates from the path of the first bullet by approximately a 2.4-mil

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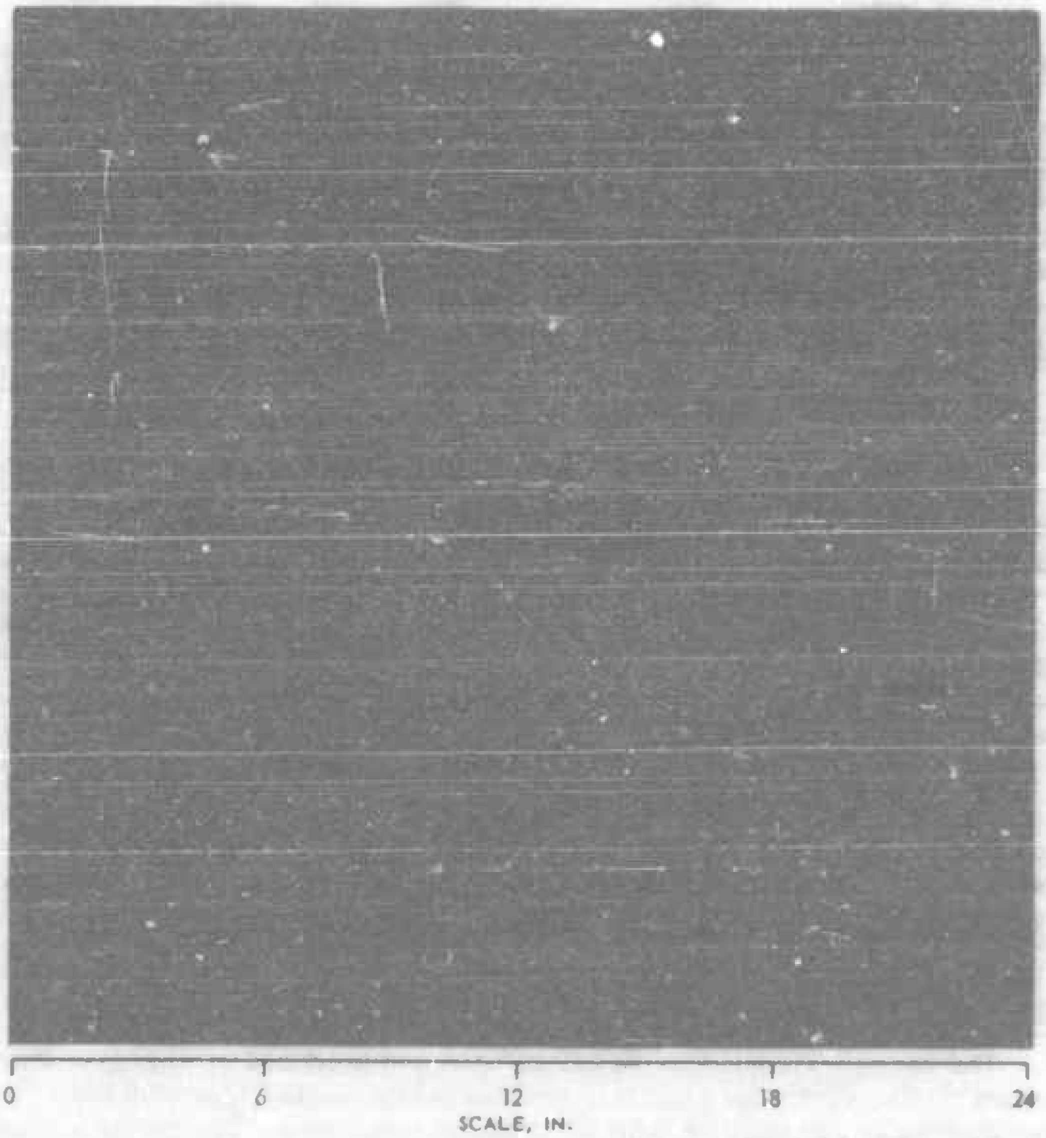


Courtesy of Olin Mathieson Chemical Corp.

Fig. B4—Pattern of .30-Cal Duplex Controlled Dispersion
F, front bullet; R, rear bullet; range, 100 yd; position, machine rest.

average.[27] Tilting the heel of the rear bullet causes that bullet to deviate from the aiming point. The direction of the deviation depends on the original orientation of the bullet in the chamber and, since this orientation was random, the points of impact of the second bullets were randomly oriented around the aiming point. The pattern is described further in App M, indicating an optimum bullet separation (for 70 percent lethality) of 2.8 mils. For practical purposes, Fig. M8 shows that the achieved separation of 2.4 mils is adequate.

The description of the behavior of the duplex ammunition just given is somewhat idealized. An example of this pattern resulting from the duplex ammunition used on the SALVO I test is given in Fig. B4. There is a central group of holes made by the front bullet, and dispersed around this group are the second or rear bullet holes.

Since duplex ammunition is being considered as a substitute for the single bullet a comparison of the relative precision of the two ammunitions becomes of interest. Table B4 gives the front-bullet dispersions for standard and experimental ammunitions. These linear standard deviations were obtained from both bench-rest and Mann barrel machine-rest firings at 100 yd. It is clear from these firings that duplex front-bullet and single-bullet precisions are essentially the same.[27,28] Hence the duplex rear bullet may be regarded as a bonus or gratuitous increase in hit probability.

.30-Cal Triplex Cartridge

The triplex ammunition was manufactured by Olin Mathieson Chemical Corp. using the same long-necked case as the duplex ammunition.[22]

The markedly high error for triplex ammunition in Table B4 is not surprising.[27,28] The higher value comes from bench-rest rather than machine-rest firings.[28] The pattern from the test ammunition is of the so-called "random" type; i.e., all three bullets fit roughly a symmetrical Gaussian pattern about the center, and the front bullet is not notably more accurate than the trailing bullets. Unlike the "controlled" duplex pattern all three bullets had the possibility of central hits. Test firings[27] report that two-thirds of all bullets fired fall within a circle of 11.3-in. average radius at 100 yd. From the Gaussian distribution the hit probability is given by

$$P_H = 1 - e^{-R^2/2\sigma^2} \tag{B4}$$

For $P_H = 0.67$ and $R = 11.3/3.6$ mils, $\sigma = 2.14$ mils. Thus the standard deviation σ of the experimental triplex ammunition is 2.1 mils. Figure M16 in App M shows an optimum triplex σ of 1.7 mils. From that figure the achieved σ of 2.1 mils is quite adequate.

.22-Cal Carbine Cartridge

The carbine ammunition was developed and produced at Aberdeen Proving Ground.[26] The cartridge case is a rimless bottle-necked type with the same head dimensions as the commercial .222-cal Remington. The bullet is a new design not previously tested, a full-jacketed lead-core ball approximately 0.57 in. long. This ammunition showed the least dispersion of all the types tested.[27,28]

.22-Cal Sierra Cartridge

The .22-cal Sierra round was produced as a high-velocity round by the Western Division of Olin Mathieson Chemical Corp.[21] It was made from standard components to fit the modified T48 rifle. Its performance was examined with the other ammunitions.[27,28]

12-Gage 32-Flechette Shell

This round was developed by Aircraft Armaments, Inc., Cockeysville, Md.[29] At the time of its use in the SALVO I experiment it was in early prototype form, and limited data on its performance are available.

The standard high-velocity paper shotgun shell manufactured by Remington Arms Co. was used. Thirty-two fin-stabilized 1¼-in. steel darts replaced the usual shot load. These were seated on a 40-grain aluminum-base plug 0.156 in. thick to develop desired pressure and to prevent tumbling of the flechettes from the passage of propellant powder gases between them. Two paper-base wads separated the flechettes and base plug from the propellant charge of smokeless shotgun powder. The flechettes were nested in a cruciform pattern within four fiber sabots of about 14 grains each. Limited dispersion tests indicated that 52 percent of the projectiles hit within a 30-in. circle at 40 yd. An average linear standard deviation has been given as 9.4 mils.[30]

BULLET LETHALITY

Analysis of SALVO I test ammunitions at Edgewood Arsenal[31] gives the probabilities of incapacitation shown in Table B5.

TABLE B5

BULLET LETHALITY PROBABILITIES

Bullet	Assault, %	Defense, %	Average, %
.30-cal single	44	43	44
.30-cal duplex	44	43	44
.30-cal triplex	44	43	44
.22-cal Sierra	45	41	43
.22-cal carbine	42	41	42
.087-cal flechette	17	18	18

All data in this table are expressed in percentages of incapacitations for hits at 140-yd real range. The average range of hitting for the SALVO I target system is shown in App P to be 133 yd for day fire and 85 yd for night fire. Data for 500-yd range show a lethality drop of less than 7 percent average. These lethality figures are based on hits on the so-called "100 percent vulnerable body area" (vital organs) and neglect hits on nonvital areas, which have vulnerability of less than 100 percent. It seems reasonable to require that small-arms hits incapacitate attacking troops in ½ min and defending troops in 10 or 15 min. Hence the figures in the "Assault" column are the percentages of incapacitations within ½ min. The "Defense" column is composed of simple means between the computed values for 5- and 30-min incapacitation probabilities.[31] The figures of Table B5 reflect the fact that the assaulting man can sustain less damage than the defending man before becoming ineffective in his mission. The .30-cal single-bullet data were actually obtained with the NATO round but are assumed to be applicable for the .30-cal ball or single-bullet round without change. It is quite clear from Table B5 that one may use an average incapacitation figure of 43 percent for all conventional bullets and 18 percent for the individual flechettes. Further, the difference between the assault and defense figures is so trivial that a simple average is easily justifiable for general use. It can also be concluded that the trivial differences among the conventional ammunitions may be neglected.

A refinement of the use of these total incapacitation figures is the extrapolation to over-all operational incapacitation. This is best explained as follows. The total figures of Table B5 for 43 percent probability of total incapacitation represent the actual physical incapacitation or physical impossibility for the victim to perform in combat. Actually it is expected that most victims under typical combat circumstances would fail to function with a level of wounding short of total physical incapacitation. Even allowing for high motivation and lack of secondary or psychological effect it is clear that the combat function of most victims would be at least reduced in effectiveness. In other words it seems reasonable to assume that the values of Table B5 represent minimum operational lethality, which is sure to be grossly exceeded in practice. For example, the Edgewood figures (43 percent) completely ignore a wound such as one causing loss of fine muscular coordination in the leg. Such a wound obviously affects a soldier's performance and might reduce his effectiveness in assault by 50 percent or so. BRL personnel have included such "partial" incapacitations to estimate the operational incapacitation expected from a .30-cal single bullet. They deduce 71 percent or 1.65 times the 43 percent for the absolute incapacitation.

TABLE B6

HELMET PENETRATION RESULTS

Cartridge	Range, yd	Penetration
.30-cal M2 AP	500	Yes
.30-cal duplex	400,	Some
	300	Some
.30-cal triplex	200,	No
	100	Yes
.22-cal carbine	400,	No
	300	Yes
.22-cal Sierre	500	Yes
.087-cal flechette	500	Some (at low obliqnity only)

Use of this same 1.65 ratio for the flechettes results in an extrapolated estimate of 30 percent operational incapacitation for that projectile. Examination of the effects of the flechettes, however, reveals that a larger proportion of their total effect accrues in the non-total vulnerable area. This means that the proper correction from absolute to operational incapacitation for the flechettes is somewhat larger than the bullet factor of 1.65. It is difficult with presently available lethality data to deduce an accurate operational lethality figure for the flechette. A reasonable estimate is a ratio of 1.95, or a flechette operational lethality of 35 percent. Hence it is concluded for purposes of calculation in the other sections of this memorandum that all the conventional bullets have an operational lethality of 70 percent, and the individual flechettes an operational lethality of 35 percent. For special use in an extremely desperate and brief combat situation it may be desirable to use corresponding absolute-incapacitation figures of 43 and 18 percent.

HELMET PENETRATION

Helmet penetration tests of SALVO I ammunitions have also been reported.[34] The results are summarized in Table B6. From these results it is concluded that the helmet protects the head (effectively 18 percent of operationally vulnerable target area[32]) for triplex, duplex, and the carbine beyond ranges of 150, 300, and 350 yd, respectively. Because of its ease of deflection and consequent failure to penetrate at high obliquity the flechettes are somewhat degraded by helmets at all ranges. Roughly some two-thirds of the flechettes can be expected to penetrate at 100 yd, reducing to one-third at 400 yd.

Edgewood Arsenal personnel have reported that all the SALVO I test ammunitions penetrate the standard US body armor beyond the maximum experimental range (350 yd). Although there is some evidence of reduced lethality for rounds that have penetrated helmets, this lethality loss is ignored. Certainly no gross differences exist in lethality losses by the test ammunitions. Further reduced by the 18 percent effectively vulnerable area such differences must indeed be negligible. This 18 percent figure is deduced from the product of two reported data:[32] 29 percent of wounds received are head wounds, 62 percent of the head is covered by the US helmet.

Appendix C

TARGET SYSTEM

TABLES

SUMMARY

The target characteristics that critically affect the aiming error are size, range, exposure time, visibility, movement, disclosing activity, and confusing context. To determine the values of these factors in a model target system, a questionnaire-interview was conducted with 26 company-grade officer recipients of the Combat Infantryman Badge.

On the basis of responses, two target systems were developed, one for day firing and one for night firing. These simulated, as closely as feasible, elements of both offensive and defensive combat situations. The questionnaire revealed that under conditions of good visibility 96 percent of the aimed fire was delivered at less than 400 yd. Under bad visibility all aimed fire was included in this range. It also indicated that aimed fire accounts for about one-third of all combat rifle fire.

Battlefield formations of enemy assaulting and defending forces were developed from sketches prepared by the questionnaire subjects. The centers of the formations were located, and the depths and widths calculated from data on the sketches. Durations of target exposure and directions of movement were likewise developed from questionnaire responses and were computed separately for all targets in each formation.

Thirty-four positions, some partly concealed, were prepared for the 31 stationary Cocky Ken targets and 3 moving targets. Seven stationary and the three moving targets were common to both day and night systems (i.e., 22 targets in each system). Twelve programs were devised, which incorporated random order of appearance for the target groups and for individual targets within each group. The programs allowed target appearances from 3 to 34½ sec. There were no simultaneous exposures, and each appearance was preceded by an interval ranging from 6 to 13½ sec.

All events in these programs—target appearances, simulated artillery, disclosing fire, and "wounding" by electric shock—were programed through the electronic control system described in App D.

RATIONALE

It is apparent that the test depends critically on the model of target system that is selected. The seven primary target characteristics that critically affect the aiming errors are size, range, exposure time, visibility, movement, disclosing activity, and confusing context.

A good model should include a number of targets that are characterized by appropriate distributions in each of these seven characteristics. Whatever interdependencies exist among these characteristics should also be reproduced in the targets of the model.

In order to describe the anticipated target systems in terms of the given characteristics a questionnaire-interview was used. The assumption was made that the anticipated target system would not differ significantly from the target systems experienced by US riflemen in Korea and WWII. The questionnaire-interview was an effort then to describe the targets at which riflemen had actually aimed and fired.

Twenty-six officers provided by The Infantry School filled out the questionnaire at Fort Benning, Ga., on 5 April 1956. All these officers were qualified to wear the Combat Infantryman Badge and had served in combat with an infantry battalion or lower-echelon rifle unit in Europe (5), the Pacific (3), Korea (11), Korea and Europe (5), and Korea and the Pacific (2). Their combat experience ranged from 3 to 32 months with a median of 8 months and a mean of 11 months. Prior to these interviews a preliminary questioning of several dozen experienced officers was conducted at Fort McNair and Fort Myer. From this questioning it was determined that best results could be obtained from intensive interviews with a small number of carefully selected subjects.

The questionnaire was designed to provide the frequency distributions necessary to guide the establishment of a target complex with consideration of the following factors and their interrelations:

(a) Visibility (good or bad)

(b) Enemy attitude (offense or defense)

(c) Mean distance of formation from friendly forces (nearest 100 yd)

(d) Side-to-side intervals between positions within a formation (nearest yard)

(e) Front-to-rear intervals between positions within a formation (nearest yard)

(f) Number of targets in a position

(g) Side-to-side intervals between targets in a position (nearest yard)

(h) Front-to-rear intervals between targets in a position (nearest yard)

(i) Exposure out of cover (none, head only, head and shoulders, full body, full body kneeling, or full body upright)

(j) Movement (still or running)

(k) Direction of movement (eight directions)

(l) Concealment (none, half-hidden, or entirely hidden)

(m) Firing (not firing or firing hand or shoulder weapon)

(n) Duration in this particular attitude (seconds)

Many of these factors were subdivided to account for the effects of other factors in the list. For example, duration was handled separately for offensive and defensive targets. The responses were reduced to yield distributions of each of the seven target characteristics, including relations among dependent characteristics. The distributions were then used to define the characteristics of an integral number of targets for the experiment.

Two target systems were required for the experiment—one for day firing and one for night firing. Each of the two systems was to represent as closely as possible the more common combat rifle targets. In short the problem was to construct target systems to give the closest approximation to those found typically in combat in both defensive and offensive situations.

QUESTIONNAIRE

Following is a copy of the questionnaire. The percentages given illustrate answers for which there was maximum agreement among the respondents. The numbers in parentheses are approximate ranges indicating accuracy of estimate (see Part I of the questionnaire, "Percentage Estimates"). The sketches of the defensive and offensive formations are actual examples received.

AIMED RIFLE FIRE QUESTIONNAIRE

Part I—Percentage Estimates

Make the best estimate you can of the percentages requested in the following questions. Be guided by your knowledge and combat experience, but estimate for the over-all conditions of modern warfare, not for any particular type of terrain or situation.

Do not record your name, but do put in the upper right corner of this sheet the number of months of combat experience you have had with rifle units of battalion size or smaller.

For each percentage that you estimate, put beside it in parentheses the lowest and highest percentage that would be just as acceptable to you. This gives an indication of how approximate you believe your actual estimate to be. For example, if you estimate 20 percent, write 20 (5–35) or 20 (15–40). Your estimate may or may not be halfway between the ends of the range in the parentheses. The parenthetical numbers do not have to add up to 100 percent but your basic estimates do.

Questions 2–4 all refer only to the aimed fire mentioned in question 1a. This includes not only fire at visible targets but fire aimed at a particular point of a hidden area because it is thought more likely to conceal an enemy than other nearby points.

Visibility is good if there is either daylight or very bright flares. Visibility is bad if there is darkness, moonlight, or dim flares.

1. For rifle fire in combat, what percentage of all ammunition is expended in each of these three categories:

Category	Ammunition expended, %
a. Aimed fire at visible or suspected targets	31 (15–40)
b. Neutralizing and harassing area fire	53 (40–60)
c. Panic fire	16 (5–30)
Total	100

2. Substantially all combat actions involving aimed rifle fire at visible or suspected targets (1a above) are fought under conditions of good or bad visibility with enemy forces on the offensive or defensive. Estimate the percentage of all friendly aimed combat rifle fire (other than neutralizing, harassing, and panic fire) in each of the categories below. For example, if 100 million rounds of rifle ammunition represented total ammunition expenditure in aimed fire for a war, what percentage is expended in each of the four categories below. Total of the four percentages should equal 100 percent.

Enemy attitude	a. Good visibility, %	b. Bad visibility, %
(1) Defensive	22 (15–30)	11 (5–25)
(2) Offensive	45 (35–50)	22 (10–35)
Total	67	33

3. Averaging all situations when the enemy is on the defensive [your answers to 2(2) above], what percentage of rifle ammunition (for aimed fire at visible or suspected targets) is directed at targets whose distance from friendly troops is:

Distance, yd	a. Good visibility, %	b. Bad visibility, %
(1) 0-50	12 (5-25)	35 (10-70)
(2) 50-100	17 (10-35)	24 (10-55)
(3) 100-200	35 (10-50)	29 (20-40)
(4) 200-300	17 (5-30)	12 (5-20)
(5) 300-400	12 (3-20)	0 (0-10)
(6) 400-500	6 (0-15)	0 (0-5)
(7) 500+	1 (0-5)	0 (0-1)
Total	100	100

4. Averaging all situations when the enemy force is on the offensive [your answers 2(2) above], what percentage of rifle ammunition (for aimed fire at visible or suspected targets) is directed at targets whose distance from friendly troops is:

Distance, yd	a. Good visibility, %	b. Bad visibility, %
(1) 0-50	6 (5-15)	30 (15-40)
(2) 50-100	13 (5-25)	25 (15-30)
(3) 100-200	37 (20-50)	30 (20-50)
(4) 200-300	25 (20-30)	10 (5-20)
(5) 300-400	13 (5-20)	5 (0-10)
(6) 400-500	6 (0-15)	0 (0-5)
(7) 500+	0 (0-5)	0 (0-2)
Total	100	100

Part II—Battlefield Formations

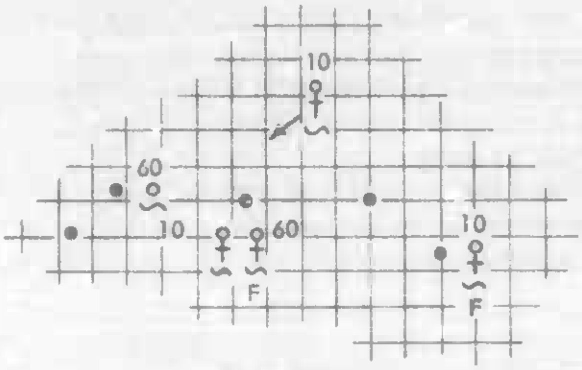
Draw two sketches, one on each of the two graph sheets attached. One will be "Enemy Defending" and the other "Enemy Assaulting."

Each sketch is to be an abstract representation of 10 enemy infantry troops (a "squad") engaged in a fire fight with friendly forces at some distance between 100 and 300 yd. Each picture is to represent a typical moment in a typical engagement with average terrain and visibility. Friendly troops are in the direction of the bottom of the sheet.

The small squares on the graph sheets are 5 by 5 yd. The 10 enemy troops are to be drawn in probable locations with the symbols shown on the accompanying key. The different symbols on this sheet are grouped into five sets. Do one set at a time in order. (1) First locate the 10 men by drawing the symbol for how each man is out of cover (merely put a dot if no part of him is out of cover). (2) Beside any man who is running (not walking, crawling, or still) put an arrow showing his direction of movement. (3) Indicate how much concealment (if any) is in front of each man. (4) Put an F beside those likely to be firing their weapons at this typical moment. (5) Beside each man put the number of seconds he is likely to remain in the position in which you have drawn him. For example, for a running man this would be the number of seconds he will run before stopping to take cover or fire his weapon; for a man whose head is out of cover, it would be the number of seconds that he exposes just this much of himself. Do not omit any of the key symbols if they are applicable.

In drawing these two pictures consider yourself to be an enemy commander and place your 10 men as you think they would probably be located. Then consider yourself to be a friendly rifleman looking out across the battlefield and modify your picture if necessary to achieve maximum realism with regard to concealment, proportion of the 10 enemy troops visible, etc.

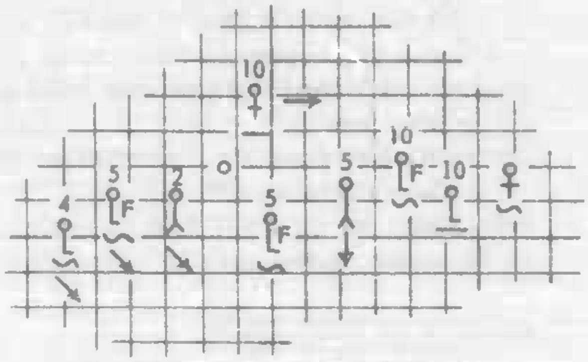
Erase and redraw each picture until you are satisfied that it is your best estimate of the typical situation [Figs. C1 and C2].



_______ Enemy troops _______
front line

_______ Friendly troops _______
front line

Fig. C1—Typical Grouping of Enemy Defending in Actual Combat
5- by 5-yd squares.



_______ Enemy troops _______
front line

_______ Friendly troops _______
front line

Fig. C2—Typical Grouping of Enemy Assaulting in Actual Combat
5- by 5-yd squares.

Key for Figs. C1 and C2

1. Cover (amount exposed; protects against fire as well as observation)

● none

O head

head and shoulders

full body, crouching or kneeling

full body, upright

full body, prone or crawling

2. Running

running in direction shown

3. Concealment (protects against observation only)

— entirely hidden

half hidden

4. Firing

F firing hand or shoulder weapon

5. Duration

Write number of seconds each man is in situation shown

Examples

4 F One man, full body upright out of cover, running in direction of arrow, not hidden, firing, for 4 sec

60 60 Two men, head and shoulders out of cover, not running, entirely hidden, not firing, for 1 min

CHARACTERISTICS OF COMBAT TARGETS
FROM QUESTIONNAIRE

This section utilizes the data from the questionnaire to provide a method for establishing a target complex. The data refer only to aimed rifle fire at visible or suspected targets, which, according to the respondents, accounts for about a third of all combat rifle fire.

Except for Tables C1 and C2, which are based on Part 1 of the questionnaire, the data were all taken from the sketches and reduced in the following manner: A smooth curve was hand drawn through a plot of the raw data. This curve was then normalized by multiplying its plotted values by an appropriate factor so that the sum of the ordinates would be unity.

The curves shown in Figs. C7 to C14 are these smoothed and normalized plots, with the original data points superimposed after having been multiplied by the same factor used to normalize the smoothed curves.

Location of Formations

Table C1 shows the percentages of ammunition expended in categories representing combinations of visibility, enemy attitude, and distance. The breakdown of the first 100-yd interval was obtained on the questionnaire because safety factors prevented use of targets closer than 50 yd in the SALVO I experiment.

The percentages shown are based on the estimates showing greatest agreement on the questionnaire after multiplying by appropriate factors to correct for rounding errors and to bring the sums back to 100 percent. This estimate is somewhat like the mode in that it was agreed to by more respondents than was any other estimate; i.e., it fell within more of the parenthetical ranges indicated on the questionnaires. Each percentage shown was agreed to by about three-quarters of the respondents.

Table C2 contains the same information as Table C1, rearranged under major categories of visibility rather than enemy attitude for later use to form separate target complexes for good and bad visibility. It is assumed that the percentage of targets taken under fire is proportional to the amount of ammunition expended at various ranges. The data for each visibility condition are brought up to 100 percent. Note that the range interval of 0–50 yd is omitted in Table C2 since it could not be used in the experiment for safety reasons. Table C2 is thus computed directly from the data listed in Table C1.

Figures C3 and C4 present graphically the information in Tables C1 and C2 except that the percentages for enemy defending and enemy assaulting are each adjusted to total 100 percent.

The number of targets in each visibility complex at each range interval is selected to be proportional to the percentages in Table C2. An arbitrary total of 22 targets was used for each complex. This small number of targets permitted so few to appear for any range category of Table C2 that each category comprised a single formation. For a large number of targets it might be desirable to have several formations for some categories, but present data provide no guide to the appropriate size for formations. The center of each formation is located at random in the proper range interval, which is considered to be 200 yd wide.

A previous study[33] also supports the conclusion that by far the greater part of all semiautomatic rifle fire in combat occurs in firing on targets at ranges of 300 yd or less. Of 600 men questioned in this study about the use of the M1 rifle in Korea, 85 percent said that all their firing was done at targets within a 300-yd range (daytime offensive fighting). For daytime defensive fighting, 80 percent of the men said that rifles were used at 300 yd or less.[33]

TABLE C1

AMMUNITION EXPENDED IN AIMED RIFLE FIRE AT VARIOUS RANGES IN COMBAT

Distance from friendly forces, yd	Enemy defending		Enemy assaulting	
	Good visibility	Bad visibility	Good visibility	Bad visibility
	Ammunition expended, %			
0–50	3	4	3	7
50–100	4	3	6	5
100–200	8	3	17	7
200–300	4	1	11	2
300–400	2	0	6	1
400–500	1	0	2	0
500+	0	0	0	0
Total	22	11	45	22

TABLE C2

TARGETS AT VARIOUS RANGES IN COMBAT

Distance from friendly forces, yd	Good visibility		Bad visibility	
	Enemy defending	Enemy assaulting	Enemy defending	Enemy assaulting
	Targets, %			
50–100	7	10	13	23
100–200	13	28	13	32
200–300	7	17	5	9
300–400	3	10	0	5
400–500	2	3	0	0
500+	0	0	0	0
Total	32	68	31	69

Figure C5 shows (a) the data for daytime offensive and defensive rifle employment taken from Fig. 1 of ORO-T-18(FEC),[33] and (b) the total fire from Table C1.

For the purposes of the SALVO I experiment, 400 yd is used as the range within which all aimed-rifle-fire targets in combat are to be found.

From the Korean data,[33] it was found that 93 percent of all daytime rifle fire in combat is directed at targets 400 yd or less from the firer. It must be

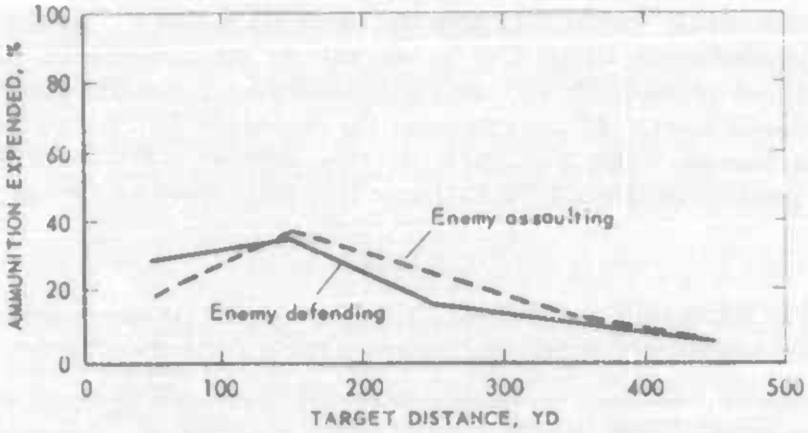


Fig. C3—Rifle Ammunition Expended at Various Ranges in Good Visibility in Combat

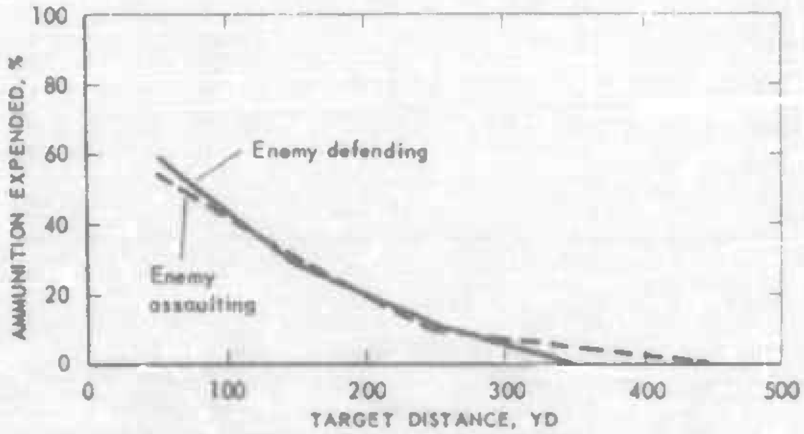


Fig. C4—Rifle Ammunition Expended at Various Ranges in Bad Visibility in Combat

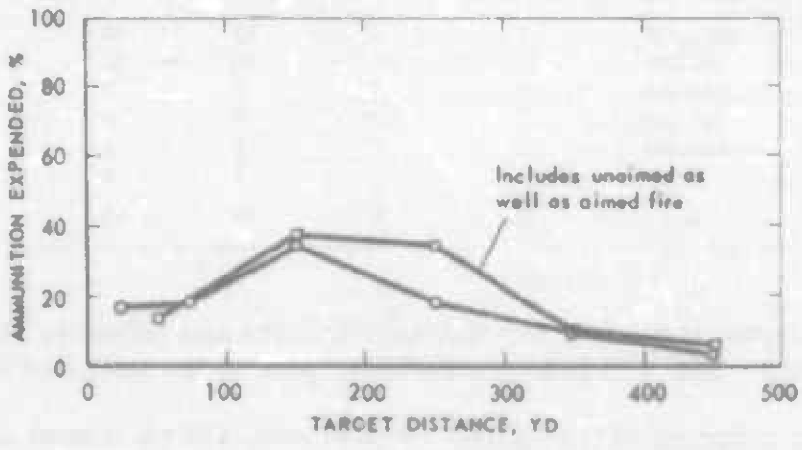


Fig. C5—Ammunition Expended for All M1 Rifle Fire at Various Ranges for Both Offensive and Defensive Fire in Combat

□, data from questionnaire on Korean experience in ORO-T-18(FEC)[38]; ○, data from Table C1.

noted here, however, that the conclusions shown in Fig. C5 represent rifle fire (aimed and unaimed) under conditions of good visibility only.

The responses to the SALVO I questionnaires indicated that 96 percent of aimed fire under conditions of good visibility occurs on targets 400 yd or less from the firer, and the corresponding figure for bad visibility is 100 percent. Of all aimed fire, 97 percent is delivered at targets at ranges of 400 yd or less. The conclusions regarding the range distribution of targets under aimed rifle fire are then substantially in agreement.

The data of Table C1 were combined for all four conditions. The resulting frequency distribution is shown in the block diagram of Fig. C6a. At the suggestion of Dr. J. Bruner of ORO the curve for the expression

$$f(R) = (4R/\bar{R}^2)\, e^{-2R/\bar{R}} \qquad \text{(C1)}$$

was adjusted to the mean range $\bar{R}$ of 170 yd computed from Table C1. This analytical expression[34] for the frequency distribution of range R had been found to fit data on ranges of fire received by US tanks (with a different mean range of course). Figure C6b presents the cumulative frequency and shows the phenomenal agreement of the data of Table C1 with this analytically expressed distribution. It should be remarked that this comparison was made and agreement noted only many months after the data of Table C1 were gathered.

Location of Positions

A formation contains several positions (e.g., foxholes), and each position may contain one or several targets. Positions (containing one or several targets) are located with respect to the previously found center of each formation. Tables C3 and C4 show the distribution of positions in a defense formation, and Figs. C7 and C8 are plots of these data. The intervals are taken from scale sketches as shown in Figs. C1 and C2.

Location of Targets

Table C5 is used to provide the number of targets to fill each position. The data for this table are derived from the sketches on the questionnaire using the assumption that men drawn within 5 yd of each other were by definition in the same position.

For enemy defending, targets are located within a position in the same manner as positions were located within a formation. Tables C6 and C7 (illustrated by Figs. C9 and C10) are used for this purpose.

For enemy assaulting, each position was assumed to contain only one target. Tables C8 and C9 (illustrated by Figs. C11 and C12) are used to locate these targets.

Direction of Movement and Duration of Target Exposure

Table C10 shows the frequency distribution of target type. Omitted combinations of symbols represent types that did not appear at all in the sample, and hence are assumed to occur with a negligibly small frequency for purposes of this study.

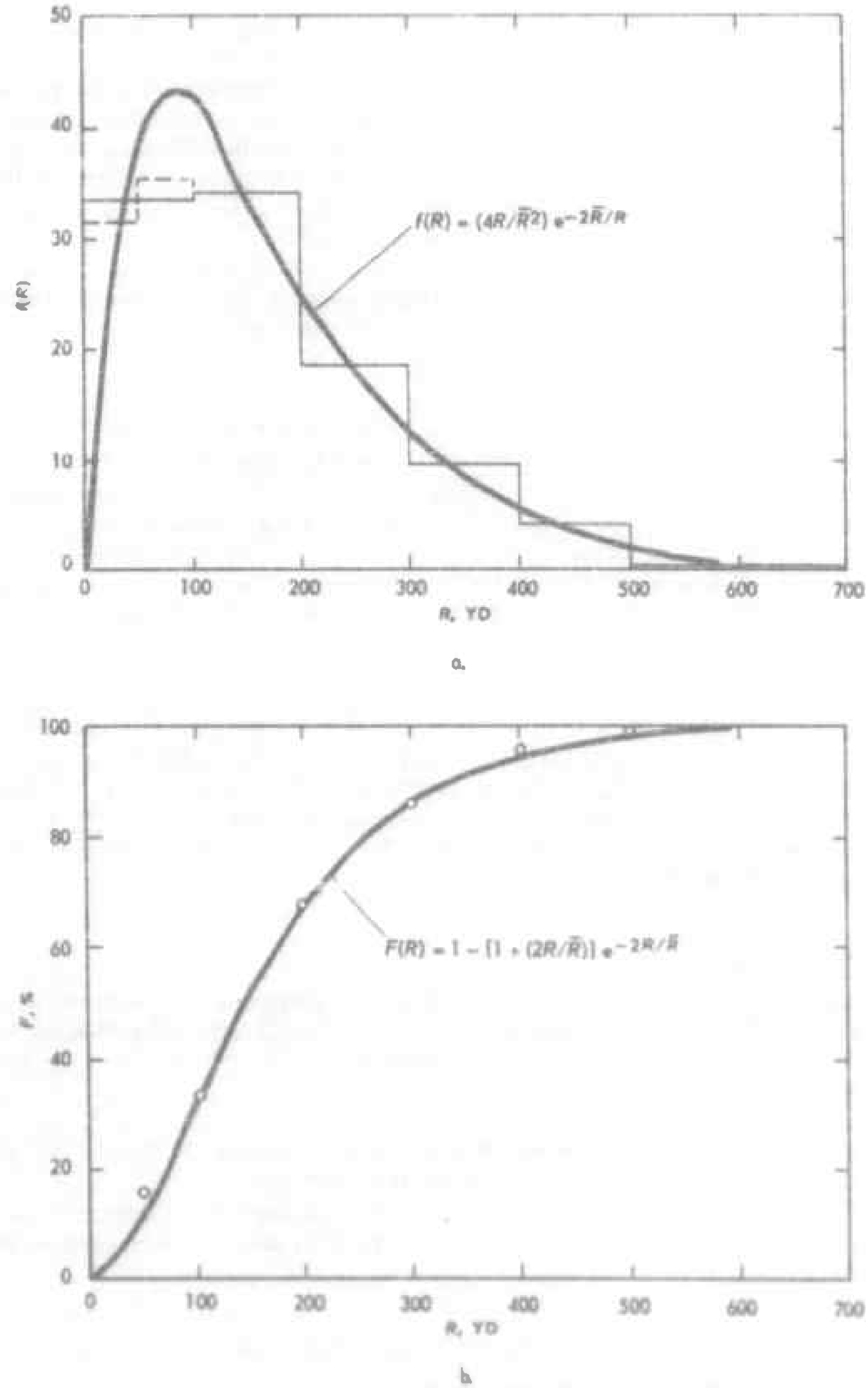


Fig. C6—Frequency Distributions of Range of Aimed Fire in Combat

$\bar{R}$ = 170 yd; o, data from Table C1.

TABLE C3

SIDE-TO-SIDE POSITION INTERVALS IN COMBAT FOR ENEMY DEFENDING

Interval, yd	Occurrences, %	Interval, yd	Occurrences, %
0	1.1	17	2.4
1	1.4	18	2.1
2	2.0	19	1.8
3	2.7	20	1.5
4	3.5	21	1.3
5	4.4	22	1.1
6	5.6	23	1.0
7	7.0	24	0.9
8	8.2	25	0.8
9	8.7	26	0.7
10	8.8	27	0.6
11	8.4	28	0.5
12	7.0	29	0.4
13	5.1	30	0.3
14	4.1	31	0.2
15	3.4	22	0.1
16	2.3	35	0.1

TABLE C4

FRONT-TO-REAR POSITION INTERVALS IN COMBAT FOR ENEMY DEFENDING

Interval, yd	Occurrences, %	Interval, yd	Occurrences, %
+30	0.1	-1	8.6
29	0.1	2	8.4
28	0.1	3	8.0
27	0.1	4	6.5
26	0.1	5	4.6
25	0.1	6	2.8
24	0.1	7	2.0
23	0.2	8	1.7
22	0.2	9	1.4
21	0.2	10	1.1
20	0.2	11	0.9
19	0.5	12	0.7
18	0.3	12	0.6
17	0.3	14	0.5
16	0.4	15	0.4
15	0.4	16	0.4
14	0.3	17	0.3
13	0.6	18	0.3
12	0.7	19	0.3
11	0.6	20	0.2
10	1.0	21	0.2
9	1.2	22	0.2
8	1.4	23	0.2
7	1.6	24	0.1
6	1.9	25	0.1
5	2.4	26	0.1
4	3.3	27	0.1
3	5.2	28	0.1
2	8.0	29	0.1
+1	8.5	-30	0.1
0	8.6		

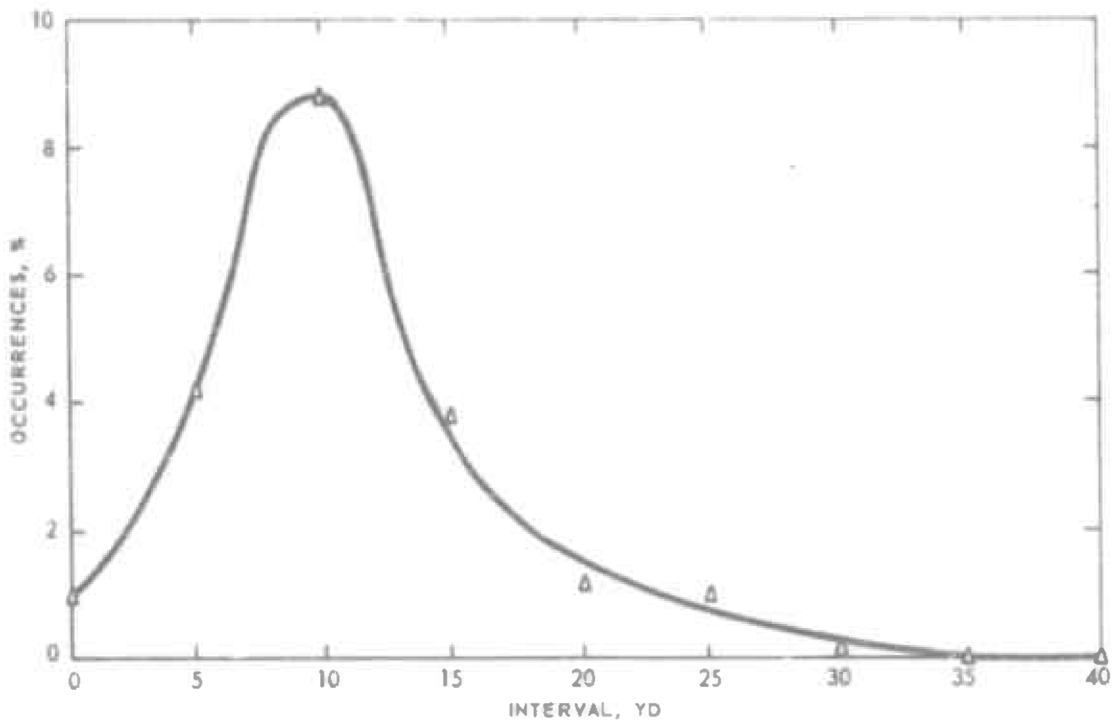


Fig. C7—Side-to-Side Position Intervals in Combat for Enemy Defending

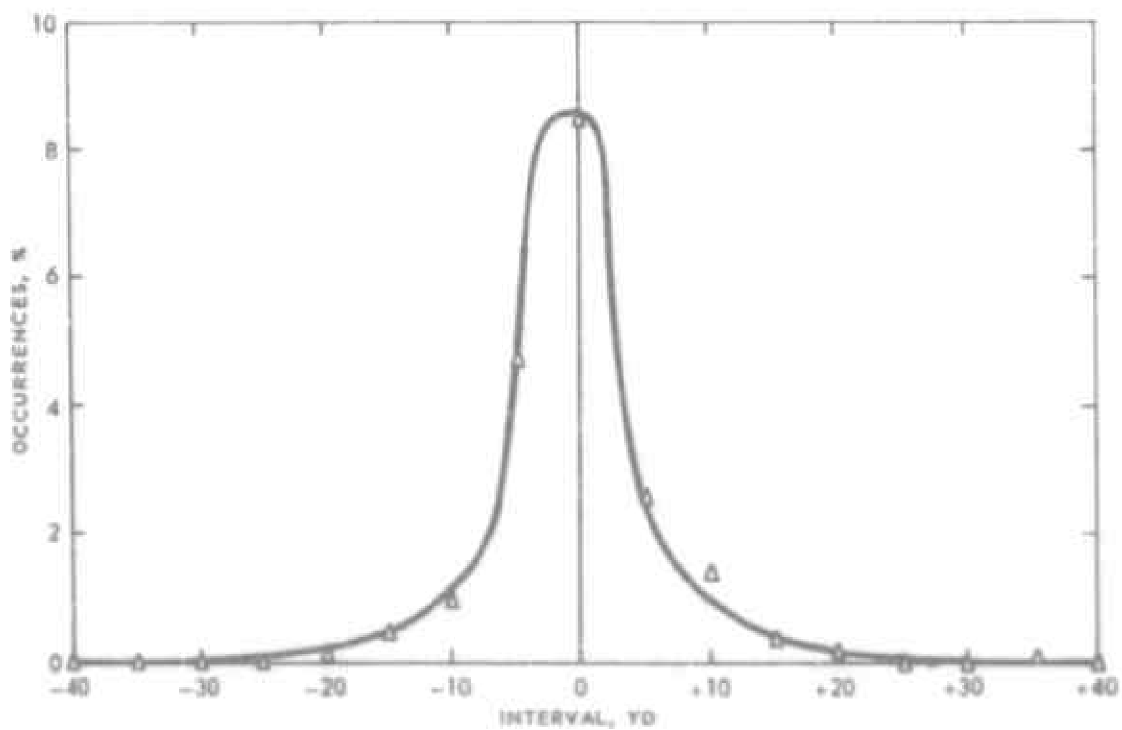


Fig. C8—Front-to-Rear Position Intervals in Combat for Enemy Defending
Positive intervals increase the distance from friendly forces.

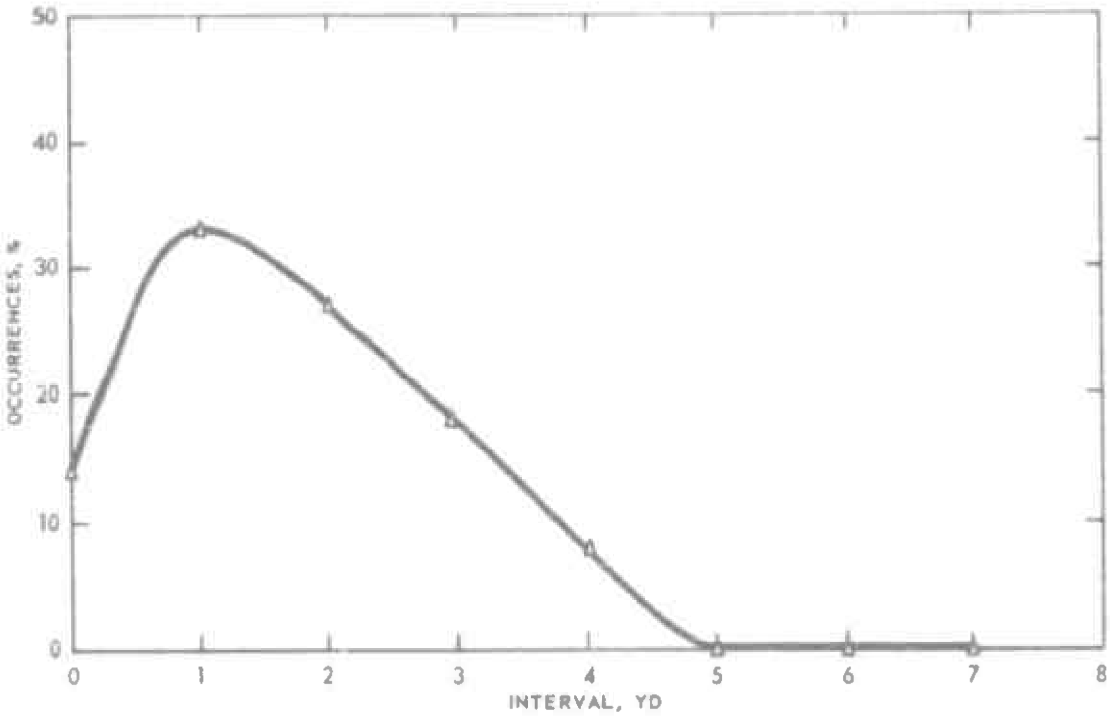


Fig. C9—Side-to-Side Target Intervals within a Position in Combat for Enemy Defending

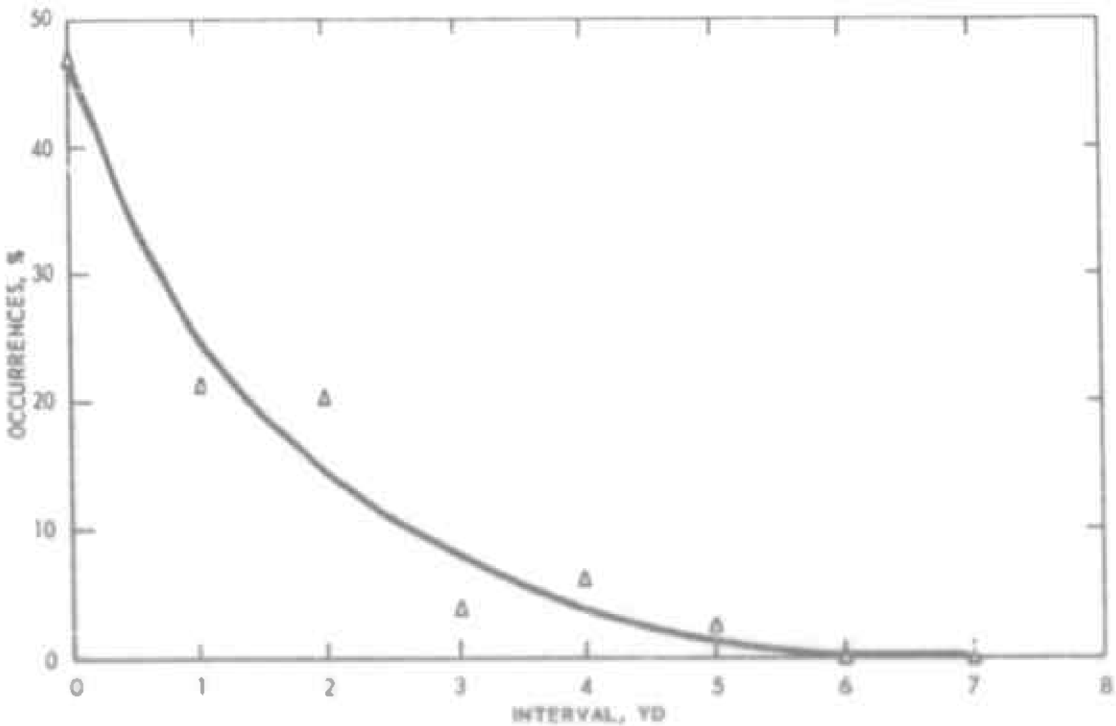


Fig. C10—Front-to-Rear Target Intervals within a Position in Combat for Enemy Defending

TABLE C5

NUMBER OF TARGETS WITHIN A POSITION IN COMBAT FOR ENEMY DEFENDING

Targets in position	Occurrences, %
1	83.5
2	11.8
3	3.7
4	0.5
5	0.5

TABLE C6

SIDE-TO-SIDE TARGET INTERVALS WITHIN A POSITION IN COMBAT FOR ENEMY DEFENDING

Interval, yd	Occurrences, %
0	14
1	33
2	27
3	18
4	8

TABLE C7

FRONT-TO-REAR TARGET INTERVALS WITHIN A POSITION IN COMBAT FOR ENEMY DEFENDING

Interval, yd	Occurrences, %
0	47
1	25
2	15
3	8
4	4
5	1

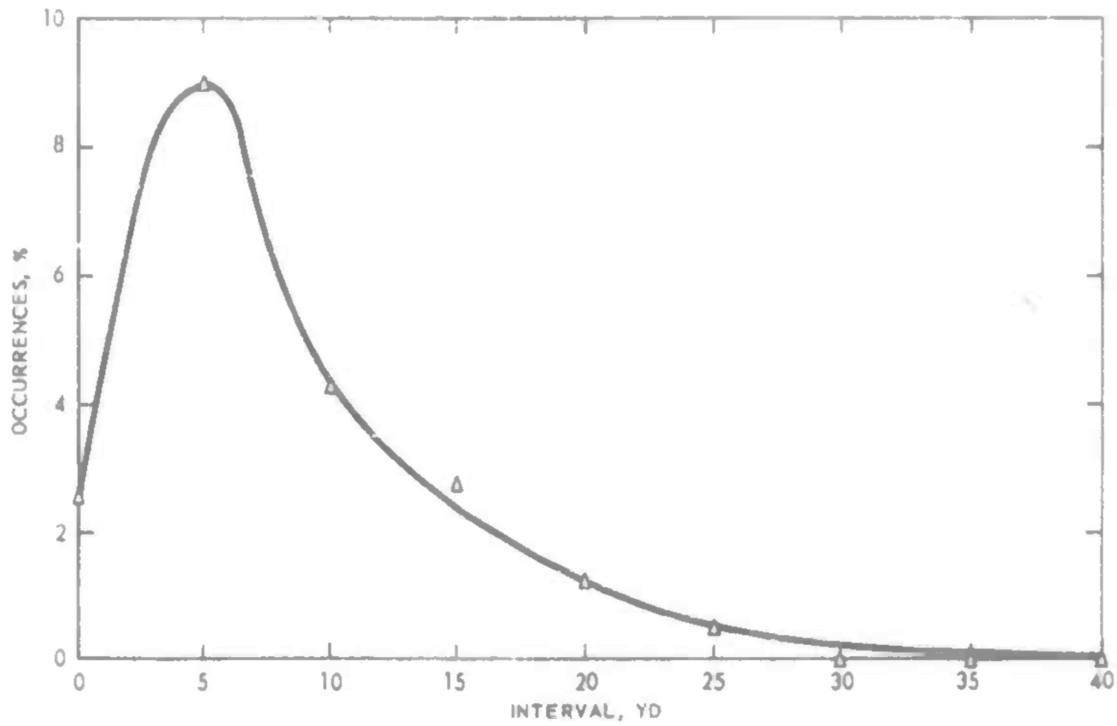


Fig. C11—Side-to-Side Target Intervals in Combat for Enemy Assaulting

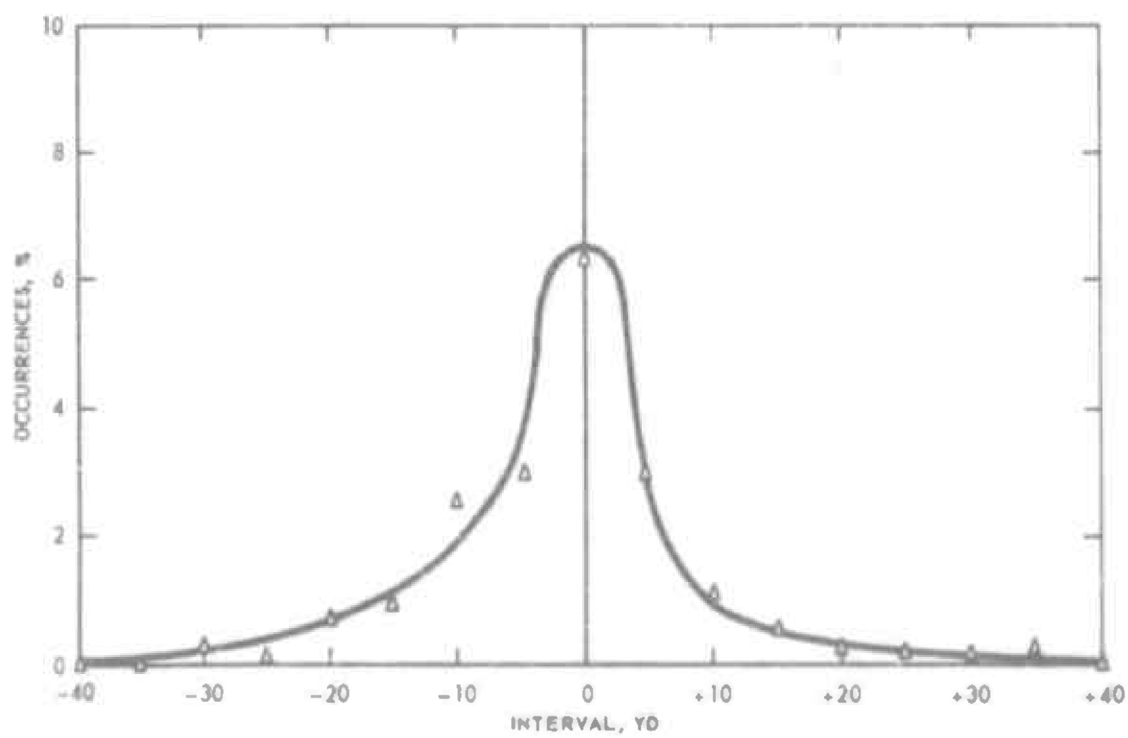


Fig. C12—Front-to-Rear Target Intervals in Combat for Enemy Assaulting

TABLE C8

SIDE-TO-SIDE TARGET INTERVALS IN COMBAT FOR ENEMY ASSAULTING

Interval, yd	Occurrences, %	Interval, yd	Occurrences, %
0	2.7	20	1.3
1	4.3	21	1.0
2	6.3	22	0.0
2	7.9	23	0.7
4	8.8	24	0.0
3	9.0	25	0.2
0	0.0	26	0.4
7	7.4	27	0.4
0	3.9	28	0.3
9	3.0	29	0.2
10	4.3	30	0.3
11	3.0	31	0.3
12	3.4	32	0.3
13	3.0	35	0.2
14	2.7	34	0.2
12	3.4	35	0.1
16	2.1	36	0.1
17	1.8	27	0.1
18	1.6	38	0.1
19	1.4	39	0.1

TABLE C9

FRONT-TO-REAR TARGET INTERVALS IN COMBAT FOR ENEMY ASSAULTING

Interval, yd	Occurrences, %	Interval, yd	Occurrences, %
+39	0.1	0	6.3
38	0.1	−1	6.2
37	0.1	2	0.0
36	0.1	3	0.0
35	0.1	4	2.0
34	0.1	5	3.0
33	0.1	4	2.1
33	0.1	7	2.0
31	0.1	8	3.3
30	0.1	9	3.3
29	0.2	10	1.9
28	0.3	11	1.7
27	0.2	12	1.0
26	0.2	18	1.4
25	0.2	14	1.3
34	0.2	13	1.1
23	0.2	16	1.0
33	0.3	17	0.9
31	0.2	18	0.8
20	0.3	19	0.7
19	0.3	20	0.6
10	0.2	31	0.2
17	0.3	22	0.4
16	0.6	23	0.3
13	0.4	24	0.2
14	0.3	25	0.2
13	0.6	26	0.2
13	0.7	27	0.2
11	0.8	28	0.3
10	0.9	29	0.3
9	1.1	30	0.3
8	1.3	31	0.1
7	1.6	32	0.1
6	3.0	33	0.1
3	2.8	34	0.1
4	4.0	−35	0.1
3	5.2		
3	6.3		
+1	6.3		

TABLE C10

FREQUENCY OF TARGET TYPES IN COMBAT

Target[a]	Enemy defending	Enemy assaulting	Target[a]	Enemy defending	Enemy assaulting
	Occurrence, %			Occurrence, %	
■	44.3	12.8	F	0.8	4.3
○	3.5	1.2	F	0.0	3.5
	5.4	0.8		0.8	3.5
	3.8	0.4		0.4	0.8
F •	2.7	0.4		0.4	0.0
F	6.1	2.0	R	0.8	0.4
F	4.2	2.0	F H	0.0	3.5
	9.4	2.3	F R	0.0	1.2
	3.1	0.8	F	0.4	2.0
	1.2	0.0	F	1.2	3.8
R	1.5	0.0	F	0.0	0.4
F R	0.0	0.8		0.0	3.8
F	4.6	3.1		0.0	2.0
F	8.1	2.3	H	0.8	17.7
F	3.1	0.8	H	0.0	5.0
	0.0	0.8	F H	0.0	6.9
	0.8	2.0	F R	0.0	0.8
	0.8	1.2	F	0.0	4.7
F	0.8	2.0			

[a]Key for Tables C10, C16, and C19

1. Cover (amount exposed)
   - ■ none
   - • head
   - head and shoulders
   - full body, prone or crawling
   - full body, crouching or kneeling
   - full body, upright
2. Running
   - R running in any direction
3. Concealment (protects against observation only)
   - — entirely hidden
   - ~ half hidden
4. Firing
   - F firing hand or shoulder weapon
5. Duration
   - Number of seconds each man is in situation shown

TABLE C11

DIRECTION OF MOVEMENT[a] OF RUNNING TARGETS IN COMBAT

Direction, deg	Enemy defending	Enemy assaulting
	Occurrence, %	
0	15	1
45	5	0
90	4	0
135	5	0
180	15	1
225	20	15
270	16	68
315	20	15

[a]Direction of movement

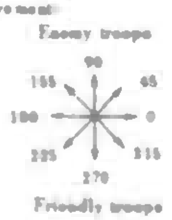


TABLE C12

TARGET DURATION IN COMBAT FOR ENEMY DEFENDING

Duration, sec	Occurrences, %	Duration, sec	Occurrences, %
1	0.3	31	0.4
2	2.6	32	0.4
3	5.7	33	0.4
4	6.9	34	0.4
5	7.1	35	0.4
6	6.9	36	0.3
7	6.4	37	0.3
8	5.8	38	0.3
9	5.0	39	0.3
10	4.4	40	0.3
11	3.9	41	0.3
12	3.5	42	0.3
13	3.1	43	0.3
14	2.7	44	0.2
15	2.4	45	0.2
16	2.1	46	0.2
17	1.8	47	0.2
18	1.6	48	0.2
19	1.4	49	0.2
20	1.3	50	0.2
21	1.2	51	0.2
22	1.1	52	0.2
23	1.0	53	0.2
24	0.9	54	0.2
25	0.8	55	0.2
26	0.7	56	0.1
27	0.6	57	0.1
28	0.5	58	0.1
29	0.5	59	0.1
30	0.5	60	0.1
		60–120	10.0

TABLE C13

TARGET DURATION IN COMBAT FOR ENEMY ASSAULTING

Duration, sec	Occurrences, %	Duration, sec	Occurrences, %
1	0.6	31	0.5
2	5.9	32	0.5
3	8.8	33	0.4
4	9.1	34	0.4
5	9.1	35	0.4
6	9.0	36	0.3
7	6.9	37	0.3
8	5.1	38	0.3
9	4.2	39	0.3
10	3.6	40	0.2
11	3.1	41	0.2
12	2.8	42	0.2
13	2.5	43	0.2
14	2.2	44	0.2
15	2.0	45	0.2
16	1.8	46	0.2
17	1.6	47	0.2
18	1.5	48	0.2
19	1.4	49	0.2
20	1.3	50	0.1
21	1.2	51	0.1
22	1.1	52	0.1
23	1.0	53	0.1
24	0.9	54	0.1
25	0.8	55	0.1
26	0.8	56	0.1
27	0.7	57	0.1
28	0.7	58	0.1
29	0.6	59	0.1
30	0.6	60	0.1
		60–120	2.6

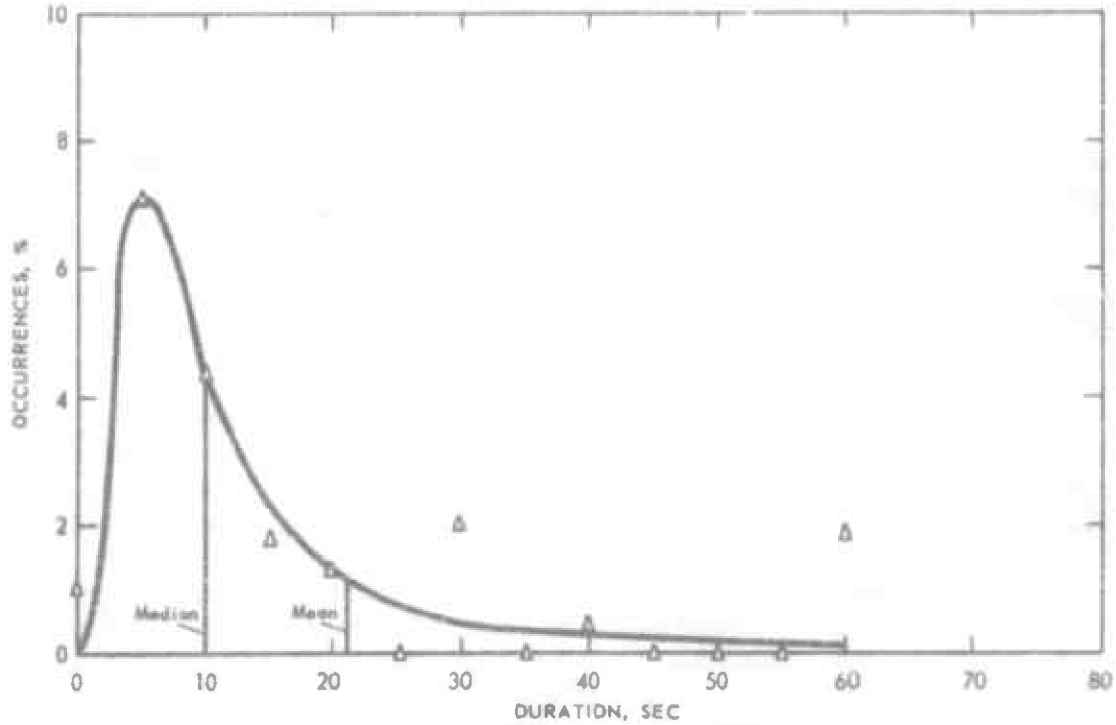


Fig. C13—Target Duration in Combat for Enemy Defending

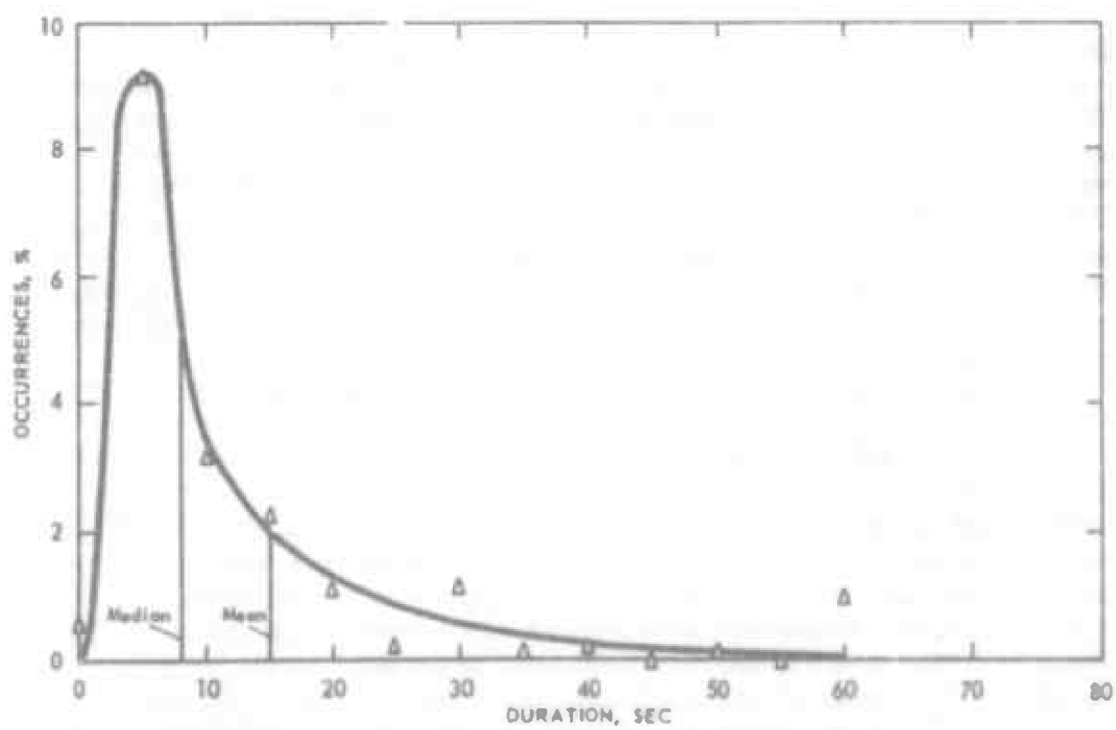


Fig. C14—Target Duration in Combat for Enemy Assaulting

The directions of movement of running targets are given in Table C11. The length of time a target is visible is given in Tables C12 and C13 and plotted in Figs. C13 and C14.

These characteristics are assigned to specific targets in the target systems on an equal-probability basis. The time durations are computed separately for all the targets in each formation.

COMPOSITION OF TWO TARGET SYSTEMS SIMULATING COMBAT CONDITIONS

The results of applying the methods described in the preceding section are summarized here. Table C14 shows the number of targets in each range category as based on the percentages in Table C2. In three instances where a single target would have represented a formation it was combined arbitrarily with another formation so that every formation would have from two to seven targets.

Table C15 gives the location of the center of each formation, and Fig. C15 is a scale plot of this information. The centers for the good-visibility complex were selected first. Those for the bad-visibility complex were placed in the same locations for the convenience of using many of the same targets for both complexes. The one exception to using the same locations was in the close-in zone of 50–100 yd where the first formation to be chosen (formation C) for the bad-visibility complex was selected at random from the two already selected for the good-visibility complex, and the other (formation A) was picked at a new location.

Table C16 shows the kind and number of targets selected as based on the percentages of Table C10. Targets completely concealed and not firing were omitted since they would be unknown to the firing troops. Running targets were limited by availability of equipment to three, and these were chosen only from among those moving in directions other than directly forward or rearward. It was supposed that a target moving in either of these two directions for a short time would not show the firing troops more than a slight difference in appearance from a target that remained stationary. The three moving targets do not fire as they run, the movement itself being sufficient to attract attention. They are located (as are seven other targets) in the same position for both the good-visibility and the bad-visibility complexes.

Table C17 shows target durations selected from Tables C12 and C13. Increments of $1\frac{1}{2}$ sec were used to accommodate the programmer.

The time intervals between (or preceding) targets are listed in Table C18. Only one target was permitted to be up at any given time, thus assuring that each target would not compete for receiving fire. Intervals of 6 to $13\frac{1}{2}$ sec between targets were used. The lower limit of 6 sec was made this large to reduce carryover effects between targets appearing in sequence. The upper limit of $13\frac{1}{2}$ sec reasonably sets a range of intervals such that, when 22 of them were drawn at random, the total time of these intervals plus the target duration times would fit the maximum time capacity of the programmer.

Table C19 is a summary of all the information concerning the target system compiled up to this point. The tabulation includes completely concealed

TABLE C14

DISTRIBUTION OF TARGETS FOR TWO TARGET COMPLEXES[a] SIMULATING COMBAT CONDITIONS

Distance from friendly forces, yd	Target complexes			
	Good visibility		Bad visibility	
	Enemy defending	Enemy assaulting	Enemy defending	Enemy assaulting
	Targets			
50–100	2	2	3	5
100–200	3	6	3	7
200–300	2	4	1	2
300–400	0	2	0	1
400–500	0	1	0	0
Total	7 +	15 = 22	7 +	15 = 22

[a]Targets in single formations are connected by underlining. Figures are based on Table C2.

TABLE C15

LOCATION OF CENTERS OF FORMATIONS FOR TWO TARGET COMPLEXES SIMULATING COMBAT CONDITIONS

Approximate distance from firing line, yd	Target complexes		Distance, yd from		Formation
	Enemy defending	Enemy assaulting	Firing line	Left edge of range[a]	
	Targets				
	Good-Visibility Target System				
50–100	2		77	118	B
		2	86	77	C
100–200	3		127	146	D
		6	162	55	E
200–300	2		219	102	F
		4	267	61	G
300–400		3	336	104	H
	Bad-Visibility Target System				
50–100	3		86	77	C
		5	63	103	A
100–200	3		127	146	D
		7	162	55	E
200–300	1	3	219	102	F

[a]Range interval is 200 yd wide.

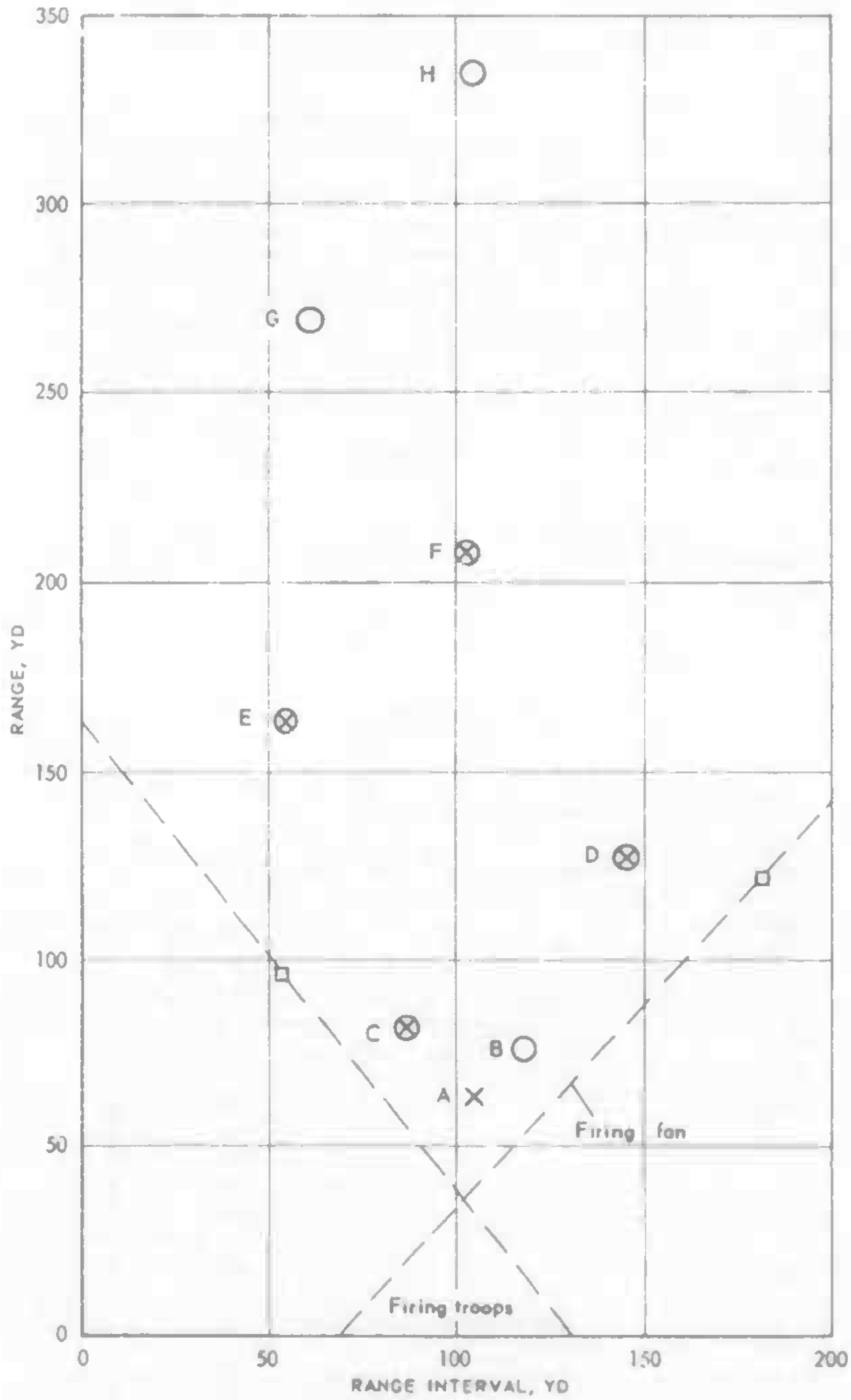


Fig. C15—Centers of Target Formations Simulating Combat Conditions

○, good visibility, ×, bad visibility, and □, location of targets determining extreme angles of fire.

TABLE C16

TARGETS SELECTED TO SIMULATE COMBAT CONDITIONS, BY SIZE

Targets[a]	Enemy defending			Enemy assaulting		
	Occurrences, %	No. used	Type used[a]	Occurrences, %	No. used	Type used[a]
•	44.3	0	•	12.8	0	•
Subtotal		6			2	
o	25.7	4	F [illegible] [illegible] F [illegible] o	6.8	1	F [illegible]
[illegible]	22.0	3	F [illegible] [illegible] F [illegible]	10.1	2	F [illegible] [illegible]
[illegible]	3.2	0		13.8	2	F [illegible] [illegible]
[illegible]	4.0	0		15.6	3	F [illegible] [illegible] R [illegible]
[illegible]	0.8	0		40.9	7	[illegible] R [illegible] R [illegible] [illegible] [illegible] F [illegible] F [illegible]
Total	55.7	7		87.2	15	

[a]See footnote a, Table C10.

TABLE C17

TARGET DURATIONS FOR SIMULATING COMBAT CONDITIONS, BY VISIBILITY AND ENEMY ATTITUDE

Good visibility		Bad visibility	
Enemy defending (7 targets), sec	Enemy assaulting (7 targets), sec	Enemy defending (7 targets), sec	Enemy assaulting (15 targets), sec
4½	3	4½	3
4½	3	4½	3
4½	3	9	3
9	4½	9	4½
9	4½	15	4½
15	6	19½	6
19½	6	19½	7½
	9		7½
	7½		9
	10½		10½
	15		12
	15		18
	21		21
	25½		28½
	31½		34½
Total			
66	165	81	172½
231		253½	

TABLE C18

INTERVALS PRECEDING TARGET APPEARANCES FOR SIMULATING COMBAT CONDITIONS

Good visibility		Bad visibility	
Position and target no.[a]	Interval, sec	Position and target no.[a]	Interval, sec
B7	9	A2	9
B5	7½	A4	7½
C9	10½	A3	6
C10	9	A6	10½
D14	6	A1	7½
D13	12	C8	9
D15	9	C11	12
E18	13½	C12	10½
E20	7½	D14	7½
E21	13½	D13	6
E22	10½	D15	9
E16	9	E18	10½
E19	12	E20	7½
F24	7½	E21	9
F25	10½	E22	13½
G30	9	E16	7½
G28	13½	E19	10½
G31	10½	E17	9
G29	12	F25	12
H33	7½	F23	6
H34	9	F27	9
H32	10½	F26	7½
Total	219		196½

[a]Letters indicate target formation; numbers identify individual targets.

•			6	R 11		•		•						
E16	152	32	10	L 23		[illegible] R		[illegible] R	9	10½	9	7½	270	E
E19	164	72	2	R 17		[illegible] R		[illegible] R	15	18	12	10½	215	E
E17	161	27	1	L 28				[illegible]		3		9		E
•			0	0	•			•						
F24	216	86	2	L 16	[illegible]		•		4½		7½			F
F25	218	113	1	R 11	[illegible]		[illegible]		9	15	10½	12		F
•			5	L 24			•							
F28	209	127	10	R 25				[illegible]		3		6		F
F27	223	72	4	L 30				F [illegible]		21		9		F
F26	221	138	2	R 36				F [illegible]		7½		7½		F
G30	267	61	0	0		[illegible]			2		9			E
G28	245	57	22	L 4		F [illegible]			6		13½			E
G31	260	66	2	R 5		F [illegible]			25½		10½			F
•			7	L 7		•								
G29	259	74	8	R 13		F [illegible]			10½		12			E
H33	336	104	0	0		[illegible]			3		7½			F
H34	339	101	3	L 3		F [illegible]			21		9			F
H32	334	110	2	R 6		F [illegible]			7½		10½			F

[a]A total of 34 different targets is used, 10 of which are in both visibility complexes.
[b]Positive intervals increase the distance from friendly forces; negative intervals decrease the distance.
[c]L, left of center; R, right of center.
[d]See footnote e, Table C10.
[e]Seven targets.
[f]Fifteen targets.
[g]Zero degrees to right (see footnote e, Table C11).
[h]Targets in same position, e. g., foxhole.

targets, but the experimental system omits them, as indicated by the identification numbers in Table C19.

Table C20 gives random sequences of target appearances for each complex such that all targets in a given formation will be used before any targets in another formation appear. The times are in $1\frac{1}{2}$-sec rather than 1-sec units for the programmer, which operated in $1\frac{1}{2}$-sec steps.

TABLE C20

TARGET APPEARANCE PROGRAMS FOR SIMULATING COMBAT CONDITIONS

Programs for good-visibility sequences (day)								Programs for bad-visibility sequences (night)			
1	2	3	4	5	6	7	8	9	10	11	12
Starting point[a] formation, and target											
A-G30	A-F24	A-E22	A-D14	A-C9	A-B5	A-H34	A-F24	A-D14	A-D15	A-A1	A-A2
G28	F25	E19	D13	C10	B7	H33	F25	D13	D13	A4	A4
G31	G28	E16	D15	H32	G30	H32	G30	D15	D14	A6	A3
G29	G31	E20	E18	H33	G28	F25	G28	C8	E22	A2	A1
D14	G29	E21	E22	H34	G31	F24	G29	C11	E19	A3	A6
D13	G30	E18	E20	E16	G29	B5	G31	C12	E20	D13	D15
D15	D15	C10	E16	E19	F24	B7	B5	E18	E18	D15	D13
F24	D13	C9	E19	E22	F25	C10	B7	E20	E21	D14	D14
F25	D14	B-F24	E21	E21	B-E19	C9	C10	E21	E16	B-E16	E18
B-C9	B-E16	F25	B-G30	E20	E20	D14	C9	E22	E17	F22	E22
C10	E19	B7	G29	E18	E16	D13	B-D13	E26	B-A3	E20	E16
E18	E21	B5	G31	B-G29	E21	D15	D15	E19	A6	E19	E21
E20	E20	D13	G28	G31	E22	B-E19	D14	E17	A4	E18	E17
E21	E22	D15	B7	G30	E18	E16	E16	B-A2	A2	E21	E19
E22	E18	D14	B5	G28	H34	E22	E21	A4	A1	E17	E20
E16	B5	G28	F25	D15	H33	E18	E19	A3	C12	F27	B-C11
E19	B7	G31	F24	D13	H32	F21	E22	A6	C8	F26	C12
B7	H34	G29	B32	D14	C10	E20	E20	A1	C11	F25	C8
B5	H33	G30	H33	F25	C9	G29	E18	F25	F25	F23	F23
H33	H32	H34	H34	F24	D14	G30	H34	F23	F27	C11	F27
H34	C10	H33	C10	B5	D13	G28	H32	F27	F26	C12	F26
H32	C9	H32	C9	B7	D15	G31	H33	F26	F23	C8	F25

[a]The letter A or B to the left of the hyphen is the starting point. Each sequence was started at either A or B, e.g., program 2A started with target F24 and ended with C9, whereas program 2B started with target E16 and ended with target D14. The letter A to G to the right of the hyphen or closed up with the target number is the formation.

DETAILS OF TARGET SYSTEMS SIMULATING COMBAT CONDITIONS

Each target system was composed of 22 Cocky Ken targets, 3 of which were capable of lateral movement. The daytime and nighttime range distributions were significantly different, requiring the preparation of additional target positions. As 10 of the positions were common to day and night target systems, it was necessary to prepare a total of only 34 positions to complete two systems of 22 targets each. These positions are indicated schematically in Fig. C16. Table C21 describes several characteristics of the targets.

TABLE C21

LAYOUT OF TARGET SYSTEMS SIMULATING COMBAT CONDITIONS

Target no.	Range, yd	Target size[a]	Concealment[b]	Movement[c]	Blank firing[d]	Illumination[e]
1	52	F	C		F	N
2	63	E				N
3	65	E				N
4	67	F	C		F	N
5	74	F			F	D
6	76	E			F	N
7	77	F	C		F	D
8	78	F	C		F	N
9	86	E				D
10	89	F	C		F	D
11	90	F	C		F	N
12	91	F				N
13	111	F	C		F	D-N
14	127	F	C		F	D-N
15	139	F				D-N
16	152	E		M		D-N
17	161	E			F	N
18	162	E		M		D-N
19	164	E		M		D-N
20	165	E	C			D-N
21	169	E				D-N
22	176	E	C		F	D-N
23	209	F				N
24	216	F	C			D
25	218	F	C			D-N
26	221	F			F	N
27	223	F	C		F	N
28	245	E			F	D
29	259	E			F	D
30	267	E				D
31	269	F	C		F	D
32	334	F			F	D
33	336	F				D
34	339	F	C		F	D
Total		14E, 20F	15C	3M	19F	10 D-N, 12D, 12N

[a]E, kneeling (large) target; F, prone (small) target.
[b]C, camouflage; blank, no concealment.
[c]Three targets moved laterally.
[d]F, blank cartridges fired as target appeared.
[e]D, daytime target; N, nighttime target; and D-N, common to both systems.

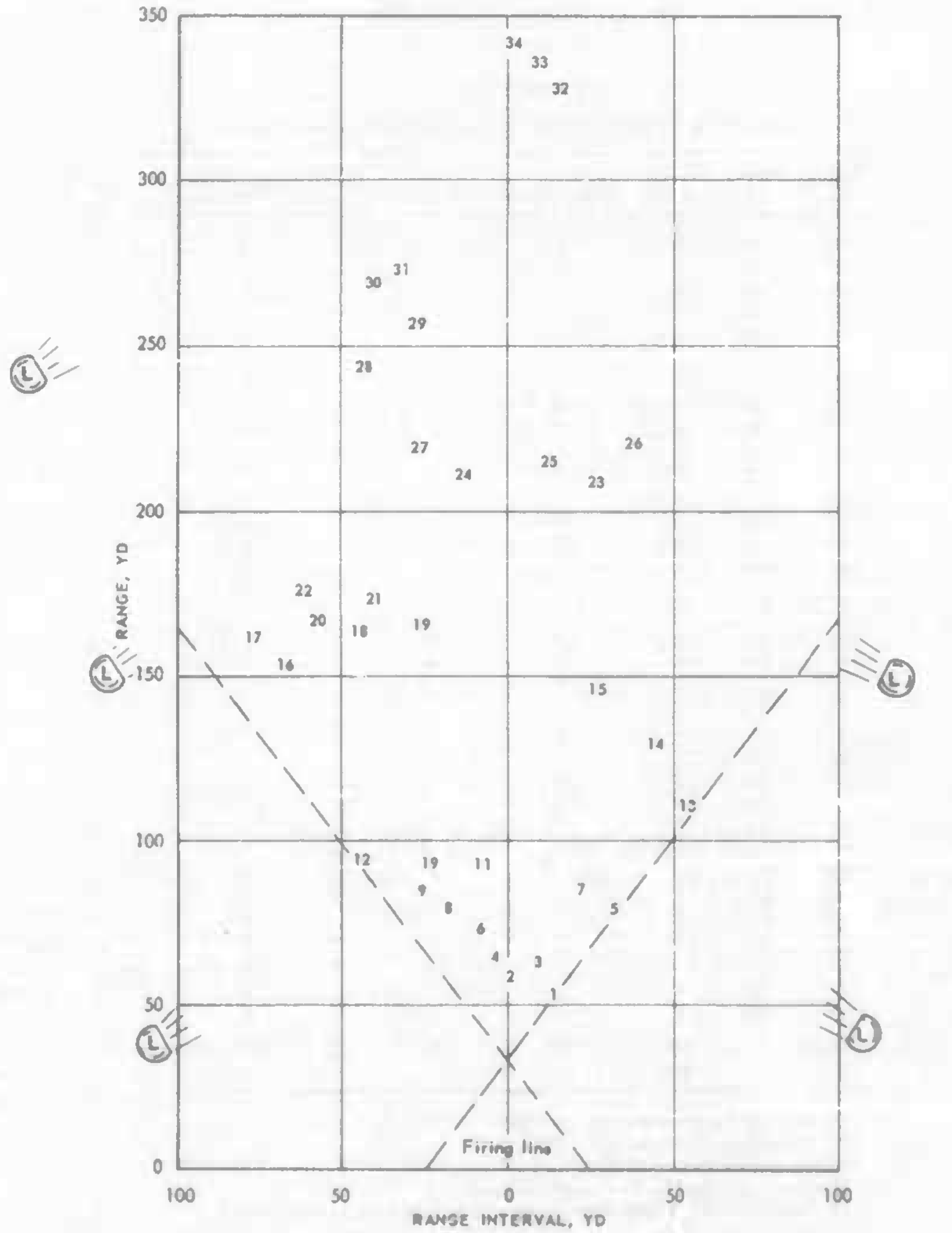


Fig. C16—Layout of Target Systems Simulating Combat Conditions
L indicates position of lights for night firing.

The actual programs allowed target appearance from 3 to $34\frac{1}{2}$ sec. There were no simultaneous target appearances, and each target appearance was preceded by an interval of from 6 to $13\frac{1}{2}$ sec (Table C22). The order in which the targets appeared was also varied to prevent learning bias. The targets were grouped in eight natural operational groupings designated A to H. The several targets comprising any group always appeared successively in random order.

TABLE C22

TIME INTERVALS PRECEDING AND DURING APPEARANCES OF TARGETS SIMULATING COMBAT CONDITIONS

Good visibility			Bad visibility		
Target	Interval preceding, sec	Duration, sec	Target	Interval preceding, sec	Duration, sec
5	7.5	4.5	1	7.5	28.5
7	9.0	15.0	2	9.0	3.0
9	10.5	4.5	3	6.0	7.5
10	9.0	15.0	4	7.5	12.0
13	12.0	19.5	6	10.5	4.5
14	6.0	9.0	8	9.0	19.5
15	9.0	4.5	11	12.0	4.5
16	9.0	9.0	12	10.5	9.0
18	13.5	6.0	13	6.0	19.5
19	12.0	15.0	14	7.5	9.0
20	7.5	31.5	15	9.0	4.5
21	13.5	3.0	16	7.5	10.5
22	10.5	4.5	17	9.0	3.0
24	7.5	4.5	18	10.5	6.0
25	10.5	9.0	19	10.5	18.0
28	13.5	6.0	20	7.5	34.5
29	12.0	10.5	21	9.0	4.5
30	9.0	3.0	22	13.5	9.0
31	10.5	25.5	23	6.0	3.0
32	10.5	7.5	25	12.0	15.0
33	7.5	3.0	26	7.5	7.5
34	9.0	21.0	27	9.0	21.0

Twelve programs were devised that incorporated both random order of the groups and random order of individual targets within each group. Table C20 lists these 12 programs of target appearances. The 20 demolitions were likewise independently randomly programed as shown in Table C23. The figures indicate the demolition time in $1\frac{1}{2}$-sec time increments from the start of the program. Care was taken to avoid any transient obscuration of targets by demolitions by careful coordination of time and position of demolitions relative to target appearances.

The schedule for the stressing shocks is given in Table C24. In this case 16 schedules were used. During each run, 5 of the 10 men on the line received one shock. In each case the entire schedule selected from Tables C23 and C24 was incorporated into a master program. Finally a last variation was introduced in that each of the 12 programs could be started at either of two points as shown in Table C20.

Programs 1 to 12 are presented in Table C25. This master schedule is presented in geometric form identical with the programmer patchboard

TABLE C23

DEMOLITION PROGRAMS FOR TARGET SYSTEMS SIMULATING COMBAT CONDITIONS

Demolition	Program 1	2	3	4	5	6	7	8	9	10	11	12
	Time increments, 1½-sec units											
1[a]	148	36	13	251	147	227	30	264	2	236	26	141
2[a]	75	275	289	192	14	255	102	32	226	159	237	104
3	23	4	291	259	176	226	29	199	292	9	115	253
4[a]	92	221	3	193	278	254	104	45	135	74	181	255
5	255	240	155	250	229	162	89	84	218	285	199	150
6	198	3	83	103	80	40	204	13	61	111	177	120
7	290	158	185	55	12	108	172	213	161	175	40	59
8	112	10	140	256	50	4	103	173	133	73	65	178
9	102	134	41	183	162	111	45	108	130	250	131	55
10	134	63	71	90	161	29	69	223	193	53	188	157
11	262	112	32	133	195	199	32	255	216	288	264	276
12[a]	103	201	70	249	3	236	192	48	60	40	179	219
13	272	126	202	238	120	46	155	61	224	242	198	177
14	125	239	264	42	113	163	245	123	225	149	204	204
15	4	97	266	131	2	2	216	283	122	207	2	256
16[a]	113	202	125	184	6	169	62	153	183	121	105	106
17	51	62	85	67	67	28	101	214	234	75	104	117
18	24	152	166	139	199	87	112	186	92	55	82	32
19	151	192	243	34	288	47	218	215	217	39	197	74
20	269	74	257	145	70	25	280	85	134	11	42	176

[a] Blasting caps used, not nitrostarch.

TABLE C24

SHOCK PROGRAMS FOR TARGET SYSTEMS SIMULATING COMBAT CONDITIONS

Position	Program															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	Time increments, 1½-sec units															
1			148		196		69	102	295		123	96		295		224
2		73	70	243	188		55	223		102			52	184		44
3	178		99			25	107			103	251		105	124	291	
4				178		47	284			260	24	13		6	200	9
5	176			298	13				93		292	22	168		272	
6		228	46		61	120		62					175			
7	219	187	25		130			247	247	96				208	291	121
8		229		221		40		200	186		90	175			60	
9	218	117				74	31		74	140		219				177
10	106			142									23			

TABLE C25[a]

MASTER SCHEDULE FOR TARGET SYSTEMS SIMULATING COMBAT CONDITIONS

Stepping-switch level	Stepping-switch position 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Program 1																								
1	StA →			D15		↑ T30		T30 ↓									↑ T28 b				T28 ↓		D3	D18	
2			↑ T31 b																	T31 ↓					
3	D17		↑ T29 b							T29 ↓				↑ T14 b						T14 ↓					d2
4			↑ T13 b													T13 ↓	d4					↑ T15			T15 ↓
5		D9	d12		↑ T24			T24 ↓				D8	d16		↑ T25						T25 ↓	StB			D14
6			↑ T9			T9 ↓			D10			↑ T10 b										T10 ↓	d1		
7	D19					↑ T18		T18 ↓							↑ T20										
8											T20 ↓									↑ T21		T21	D6		
9				↑ T22 b			T22 ↓						↑ T16		T16 ↓										
10		↑ T19		T19 ↓														↑ T7 b							
11			T7 ↓		D5			↑ T5			T5 ↓	D11				↑ T33		T33 ↓	D20			D13		↑ T34 b	
12													T34 ↓		D7					↑ T32 b					T32 ↓

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Program 2

1	StA →		D6	D3	T24 ↑			T24 ↓		D8					T25 ↑						T25 ↓				
2					↑ T28 b				T28 ↓		d1					↑ T31 b									
3								T31				D17	D10			T29 b							T29	D20	
4				T30 ↑		T30 ↓						T15 ↑			T15 ↓							D15	↑ T13 b		
5											T13 ↓	D11			↑ T14 b						T14 ↓				
6	D13	T16		T16					D9							T19 ↑		T19 ↓							
7		D18						D7		T21 ↑		T21 ↓				T20 ↑									
8													T20 ↓				D19			↑ T22 b			T22 ↓		
9	d12	d16					T18 ↑		T18 ↓							T5 ↑			T5 ↓		d4				T76 ↑
10										T7 ↓				D14	D5	↑ T34 b									
11					T34 ↓					T33 ↑		T33 ↓							↑ T32 b					T32 ↓	d2
12					↑ T10 b										T10 ↓							T9 ↑			T9 ↓

*D, 1/4-lb nitrostarch demolition; T ↑, target erected; T ↓, target dropped; d, blasting cap; b, blank-firing rifle with the indicated target; and StA and StB, two alternative starting instants. Numbers designate the target, the demolition, or the position on line, as appropriate.

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TABLE C25[a] (continued)

Stepping-switch level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Program 3																								
1	StA →		d4				↑ T22 b			T22 ↓			d1					↑ T19		T19 ↓					
2							D11		↑ T16		T16 ↓					D9				T20 ↑					
3																T20 ↓				d12	D10				↑ T21
4		T21 ↓						D6		D17	↑ T18		T18 ↓								↑ T10 b				
5						T10 ↓							↑ T9			T9 ↓				↑ T24				T24 ↓	d16
6						T25 ↓						T25 ↓			D8			T7b ↑							
7			T7 ↓		D5		T5 ↑				T5 ↓					D18			↑ T13 b						
8							T13 ↓			D7			T15 ↑			T15 ↓				↑ T14 b					
9	T14 ↓	D13								↑ T28 b				T28 ↓							↑ T31 b				
10													T31 ↓					D19			↑ T29 b				
11			T29 ↓				D20		T30 ↑		T30 ↓			D14		D15	↑ T34 b								
12						T34 ↓					↑ T33		T33 ↓	d2		D3					↑ T32 b				T32 ↓

Program 4

1	StA →			T14 ↑ b						T14 ↓								T13 ↑ b							
2						T13 ↓			D19			T15 ↑			T15 ↓		D14							T18 ↑	
3	T18 ↓				D7					T22 ↑ b		T22 ↓					D17	T20 ↑							
4														T20 ↓	D10					T16 ↑		T16 ↓			
5			D6						T19 ↑		T19 ↓														
6			T21		T21 ↓	D15		D11			T30 ↑		T30 ↓	D18						D20	T29 ↑ b				
7			T29 ↓							T31 ↑ b															
8		T31 ↓						D9	d16		T28 ↑ b				T28 ↓		d2	d4			T7b ↑				
9						T7 ↓					T5 ↑			T5 ↓							T25 ↑				
10		T25 ↓					T24 ↑			T24 ↓			D13				T32 ↑ b					T32 ↓		d12	D5
11	d1	T33 ↑		T33 ↓		D8			D3	T34 ↑ b														T34 ↓	
12					T10 ↑ b										T10 ↓							T9 ↑			T9 ↓

[a]D, 1/4-lb nitrostarch demolition; T↑, target erected; T↓, target dropped; d, blasting cap; b, blank-firing rifle with the indicated target; and StA and StB, two alternative starting instants. Numbers designate the target, the demolition, or the position on line, as appropriate.

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TABLE C25[a] (continued)

Stepping-switch level	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Program 5																									
1	StA →	D15	d12			d16	↑ T9			T9 ↓		D7		d2		↑ T10 b									
2	T10							↑ T32 b					T32 ↓					↑ T33		T33 ↓					D8
3	T34 ↓ b														T34 ↓		D17			D20	↑ T16		T16 ↓		
4					D6					↑ T19		T19 ↓													
5		↑ T22 b			T22 ↓								D14	↑ T21		T21 ↓				D13	↑ T20				
6																	T20 ↓					d1			
7	↑ T18		T18 ↓								D10	D9	↑ T29 b							T29 ↓					
8	D3	↑ T31 b																	T31 ↓	D11				D18	↑ T30
9		T30 ↓									↑ T28 b				T28 ↓						↑ T15			T15 ↓	
10				D5			↑ T13 b													T13 ↓				↑ T14 b	
11					T14 ↓							↑ T25						T25 ↓					↑ T24		
12	T24 ↓		d4			↑ T5			T5 ↓				D19		↑ T7b										T7 ↓

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Program 6

1	StA →	D15		D8	↑ T5			T5 ↓						↑ T7b										T7 ↓	D20
2			D17	D10	↑ T30		T30 ↓								D6	↑ T28 b				T28 ↓	D13	D19			
3		↑ T31 b																	T31 ↓						
4		↑ T29 b							T29 ↓			D18		↑ T24			T24 ↓							↑ T25	
5					T25 ↓			D7			D9		↑ T19		T19 ↓										
6			↑ T20																					T20 ↓	
7					↑ T16		T16 ↓					D5	D14						d16	↑ T21		T21 ↓			
8				↑ T22 b			T22 ↓									↑ T18		T18 ↓						D11	
9	↑ T34 b														T34 ↓					↑ T33		T33 ↓			
10	D3	d1		↑ T32 b					T32 ↓		d12				↑ T10 b										T10 ↓
11				d4	d2		↑ T9			T9 ↓			↑ T14 b							T14 ↓					
12			↑ T13 b													T13 ↓						↑ T15			T15 ↓

[a]D, ¼-lb nitrostarch demolition; T ↑, target erected; T ↓, target dropped; d, blasting cap; b, blank-firing rifle with the indicated target; and StA and StB, two alternative starting instants. Numbers designate the target, the demolition, or the position on line, as appropriate.

TABLE C25[a] (continued)

Stepping-switch level	Stepping-switch position																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Program 7																								
1	StA →					↑ T34 b														T34 ↓					↑ T33
2		T33 ↓		D3	d1		D11		↑ T32 b					T32 ↓						D9	↑ T25				
3		T25 ↓					T24 ↓			T24 ↓		d16			↑ T5			T5 ↓	D10					↑ T7b	
4									T7 ↓					D5	↑ T10 b										T10 ↓
5	D17	d2	D8	J4			↑ T9			T9 ↓		D18		↑ T14 b						T14 ↓					
6			↑ T13 b													T13 ↓						↑ T15			T15 ↓
7					D13			↑ T19		T19 ↓												D7		↑ T16	
8	T16 ↓											↑ T22 b			T22 ↓		d12							T18	
9	T18 ↓		D6									↑ T21		T21 ↓		D15		D19	↑ T20						
10															T20 ↓					D14			↑ T29 b		
11					T29 ↓						↑ T30		T30 ↓									↑ T28 b			
12	T28 v			D20				↑ T31 b																	T31 ↓

Program 8

1	StA →				T24↑			T24↓					D6		T25↑						T25↓				
2		T30↑		T30↓			d2						T28↑ b				T28↓			d4			d12		T29↑ b
3							T29↓				D13			T31↑ b											
4						T31↓			D5	D20	T5			T5↑						T7b↑					
5					T7↓			D9			T10↑ b										T10↓		D14		
6			T9↑			T9↓								T13↑ b											
7		T13↓	d16					T15↑			T15↓				T14↑ b						T14↓		D8		
8		T16↑		T16↓							D18						T21↑		T21↓					D3	
9		T19↑		T19↓									D7	D17	D19				T22↑ b			T22↓	D10		
10		T20↑																					T20↓		
11					D11		T18↑		T18↓						d1		T34↑ b								
12						T34↓		D15					T32↑ b					T32↓					T33↑		T33↓

*D, 1/4-lb nitrostarch demolition; T↑, target erected; T↓, target dropped; d, blasting cap; b, blank-firing rifle with the indicated target; and StA and StB, two alternative starting instants. Numbers designate the target, the demolition, or the position on line, as appropriate.

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TABLE C25[a] (continued)

Stepping-switch level	Stepping-switch position																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Program 9																								
1	StA →	d1			↑T14 b						T14↓				↑T13 b										
2			T13↓						↑T15			T15↓						↑T8b							
3						T8↓				d12	D6			↑T11 b			T11↓							T12	
4					T12↓							↑T18		T18↓			D18				↑T20				
5																			T20↓			D15			↑T21
6			T21↓		D9			D8	D20	d4		↑T22 b						T22↓					↑T16		T16↓
7											D7	↑T19		T19↓											
8					↑T17 b		T17↓	d16					↑T2		T2↓			D10		↑T4b					
9			T4↓			↑T3						T3↓				D11	D19	D5	↑T6			T6↓		D13	D14
10	d2	↑T1b																			T1↓		D17		
11				↑T25										T25↓				↑T23		T23↓					
12	↑T27 b														T27↓		D3			T26 ↓b					T26↓

Program 10

1	StA →					↑ T15		T15 ↓	D3		D20		↑ T13 b												
2	T13 ↓					↑ T14 b						T14 ↓		D19	d12						↑ T22 b				
3		T22 ↓	D10		D18				↑ T19		T19 ↓												D8	d4	D17
4	↑ T20																							T20 ↓	
5						↑ T18		T18 ↓			D6					↑ T21			T21 ↓		d16			↑ T16	
6	T16 ↓											↑ T17 b		T17 ↓				↑ T3					T3 ↓	D14	
7					↑ T6			T6 ↓	d2				↑ T4b								T4 ↓				D7
8		↑ T2		T2 ↓					↑ T1b																
9			T1 ↓				D15			↑ T12						T12 ↓						↑ T8b			
10										T8 ↓	d1						D13	↑ T11 b			T11 ↓				D9
11				↑ T25										T25 ↓						↑ T27 b					
12										T27 ↓	D5		D11	↑ T26 b					T26				↑ T23		T23

*D, 1/4-lb nitrostarch demolition; T↑, target erected; T↓, target dropped; d, blasting cap; b, blank-firing rifle with the indicated target; and StA and StB, two alternative starting instants. Numbers designate the target, the demolition, or the position on line, as appropriate.

TABLE C25[a] (continued)

Stepping-switch level	Stepping-switch position																								
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
	Program 11																								
1	StA →	D15			↑ T1b																			T1	
2	d1			↑ T4b								T4 ↓			D7		D20		↑ T6			T6 ↓			
3			↑ T2		T2 ↓				↑ T3					T3 ↓	D8			↑ T13 b							
4						T13 ↓	D18					↑ T15			T15 ↓					↑ T14 b					
5	T14 ↓			D17	d1b	↑ T16		T16 ↓							D3							↑ T22 b			
6			T22 ↓			D9		↑ T20																	
7						T20 ↓							↑ T19		T19 ↓										
8		D6		d12		d4	↑ T18		T18 ↓			D19	D10				↑ T21			T21 ↓			D13	D5	
9	↑ T17 b		T17 ↓	D14					↑ T27 b														T27 ↓		
10			↑ T26 b					T26 ↓				d2				↑ T25									
11	T25 ↓				↑ T23		T23 ↓							D11	↑ T11 b		T11 ↓								↑ T12
12						T12 ↓						↑ T8b													T8 ↓

Program 12

1	StA →					T2 ↑		T2 ↓					T4b ↑								T4 ↓				T3 ↑
2					T3 ↓		D18			T1b ↑															
3				T1 ↓	D9				D7		T6 ↑			T6 ↓						T15 ↑			T15 ↓	D19	
4		T13 ↑ b													T13 ↓					T14 ↑ b					
5	T1 ↓			d2		d16		T18 ↑		T18 ↓							D17			D6	T22 ↑ b				
6		T22 ↓					T16 ↑		T16 ↓							d1				T21 ↑			T21 ↓		D5
7				S17 ↑ b		T17 ↓	D10						T19 ↑		T19 ↓										
8	D20	D13	D8		T20 ↑																				
9			T20 ↓	D14							T11 ↑ b		T11 ↓						d12		T12 ↑				
10		T12 ↓						T8b ↑													T8 ↓				T23
11		T23 ↓	D3		d4	D15		T27 ↑ b														T27 ↓			
12	D11	T26 ↑ b				T26 ↓									T25 ↑										T25

[a]D, 1/4-lb nitrostarch demolition; T↑, target erected; T↓, target dropped; d, blasting cap; b, blank-firing rifle with the indicated target; and StA and StB, two alternative starting instants. Numbers designate the target, the demolition, or the position on line, as appropriate.

Appendix D

INSTRUMENTATION

SUMMARY

The instrumentation employed to obtain the realism, control, reproducibility, and accurate recording of data required for the SALVO I experiment is described in this appendix. The design is based on general considerations of hit recording discussed elsewhere.[26]

A sequentially programed $7\frac{1}{2}$-min firing experiment utilized 19 stationary E (kneeling) and F (prone) silhouette targets, and 3 moving E silhouettes, which were exposed at preselected times for periods ranging from 3 to $34\frac{1}{2}$ sec. Additional realism was achieved by including in the electronically sequenced program disclosing fire from emplaced blank-loaded rifles, simulated artillery bursts, simulated wounding of test troops by electric shock delivered to the lower leg, and recorded battle noise played through a public address system.

Switches attached to the trigger mechanisms indicated the time of firing, and hits on targets were recorded electrically when projectiles perforated the two conducting surfaces of specially constructed targets.

The synchronized hit-recording and trigger-switch instrumentation was sufficiently sensitive to identify hits with the weapon from which they were fired, and to determine the instances in which multiple hits resulted from a single round for the salvo ammunitions. Electrical recording was complemented by manual counts of hits on the removable paper target faces.

Night firing utilized the same instrumentation but necessitated the installation of tower-mounted floodlights to provide a constant level of illumination that approximated bright moonlight.

INTRODUCTION

Instrumentation for the SALVO I experiment was designed to provide (a) realism, (b) control, (c) capability for recording, and (d) reproducibility.

The realism of the experiment is reflected in the instrumentation by (a) the activation of the target system, (b) the simulated artillery bursts and simulated disclosing fire, and (c) the simulated hits on the firing personnel.

The control function refers to the sequential appearance and disappearance of the targets, firing of the simulated artillery, and delivery of the simulated wounds on the firing personnel.

The data to be recorded are the times of the hits on targets, the times of target appearances and durations of exposure, and the times of rifle trigger pulls. A common time base was used for all recorded data.

Reproducible action of all these events was controlled by circuitry behind the firing line that permitted changing the sequence of events to minimize the effects of possible learning by the test troops.

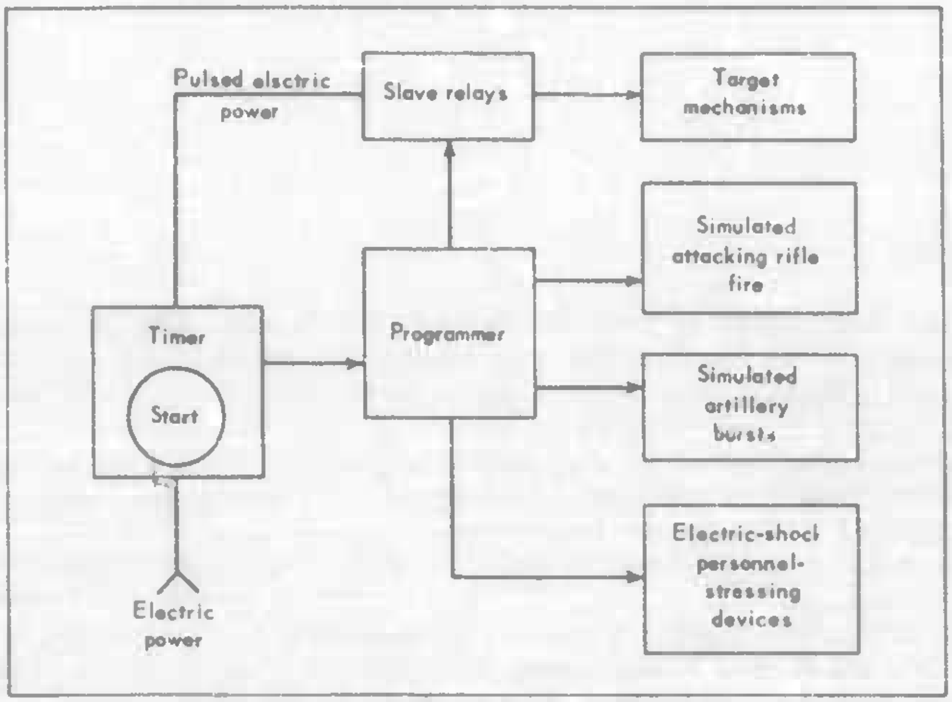

Fig. D1—Functional Diagram of the Control System

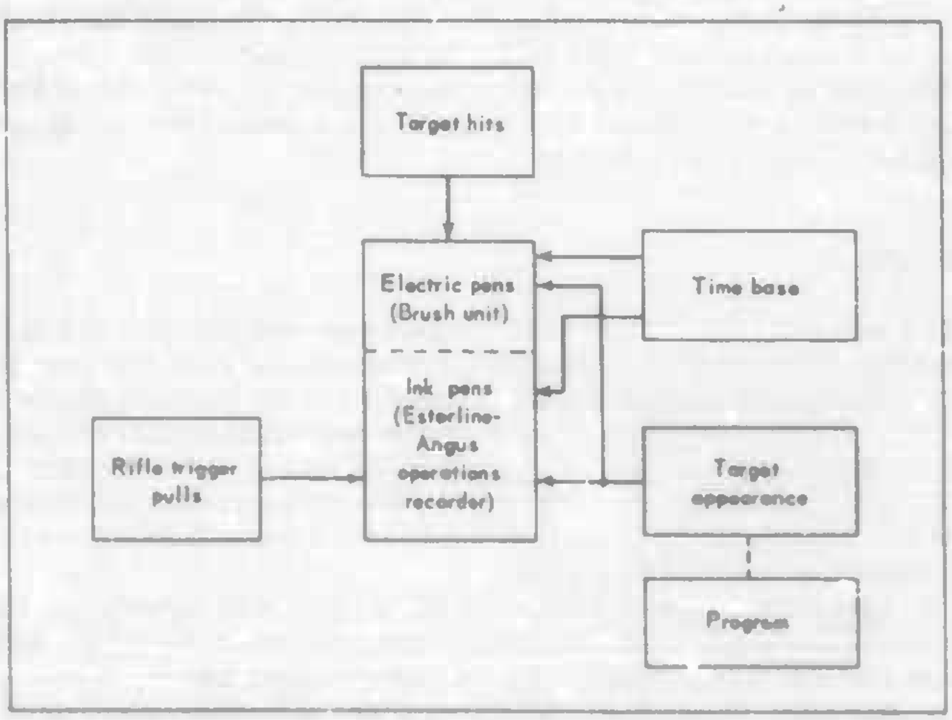

Fig. D2—Functional Diagram of the Data-Recording System

The functional diagram presented in Fig. D1 indicates the importance of two essential components of the control system—the timer, which provides a time base for all events, and the programmer, which determines the sequence of those events.

The target mechanism, known as the Cocky Ken (pop-up target) or ORO-JHU Target Device Type 2, was developed for the SALVO I experiment by the ORO Electronics Laboratory. An electrical signal activates the mechanism that elevates the target by rotating it from a prone position to a vertical position in less than ½ sec. A second electrical signal initiates the action that further rotates the target to a supine position. The mechanism is mounted on a 2- by 4-in. wooden stake, and positioned in a shallow depression that conceals the unerected target and mechanism from the firing line.

Electrically detonated ¼-lb blocks of nitrostarch simulated artillery bursts. Disclosing fire was simulated by electrically fired blank-loaded rifles emplaced near 10 of the stationary target positions. Electric-shock devices, used to simulate hits on test personnel, applied a safe level of voltage to the firer's leg by means of suitable electrodes.

Figure D2 is a functional diagram of the recording system. Two recorders were used—an electric-spark 4-pen Brush unit and a 20-pen Esterline-Angus recorder. The standard timing-pulse and the target-appearance times were recorded on both instruments simultaneously, thereby permitting correlation between the two records.

The very small separation in time between hits with salvo ammunition required instrumentation capable of resolving hits separated in time by as little as 0.5 msec. Hit recording was accomplished by electrically sensing the passage of the bullet through a special target sandwich consisting of two sheets of conductive rubber separated by a sheet of nonconductive rubber. An outer layer of heavy cardboard was added to minimize penetration by ricochet fragments. This target was based on a design developed by the Army Participation Group of the Navy Special Devices Center at Port Washington, N. Y.

The connections between the target sandwich and the recording circuitry utilized small-diameter coaxial leads. These were laid in a trench 1 ft deep and covered with soil, to protect them from damage during firing.

The individual target-hit sensing circuit was not energized until the target's appearance had been called for. This technique eliminated the possibility of interference by other targets and their lines.

Trigger pulls of the test weapons, except for the flechette units, were recorded on separate channels of a 20-pen Esterline-Angus recorder. Switches were designed by ORO's electronics group and installed in the M1 rifles, M2 carbines, and T48 rifles. Switch action resulted from the hammer movement in these weapons. A 15-ft light flexible cable carried the signal to an interconnection block adjacent to the firing position.

SYSTEM BLOCK DIAGRAM

The salvo target system is shown in block form in Fig. D3. This diagram shows all interconnections between the major parts of the system and the flow of power and control signals. The system can be divided into two sections:

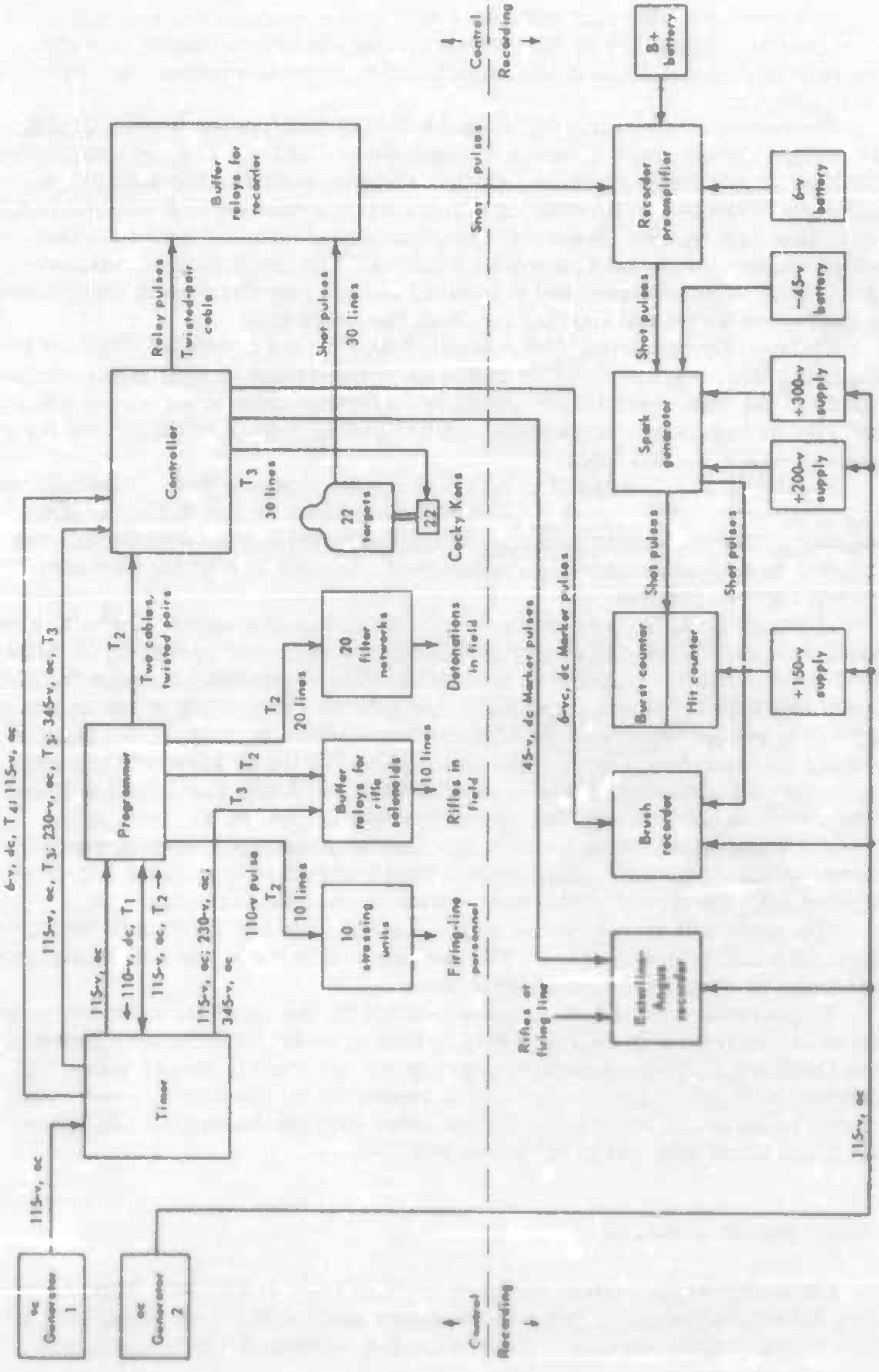

Fig. D3—Instrumentation of the SALVO I Target System one contains the control instrumentation necessary for running the experiment (the timer, programmer, control relays, and field devices); the other comprises the data-recording instrumentation. This involves recording hits scored on the targets, trigger pulls of each rifle, and the recording of the time base and target exposures. The arrows indicate the direction of flow of control, which in general is from left to right on the diagram. Two separate 115-volt 5 kw generators were used to supply the necessary ac power. Generator 1 supplied power for all the control circuits, targets, demolitions, etc. Generator 2 supplied ac power only to the hit recorder. Any heavy power surges of the control

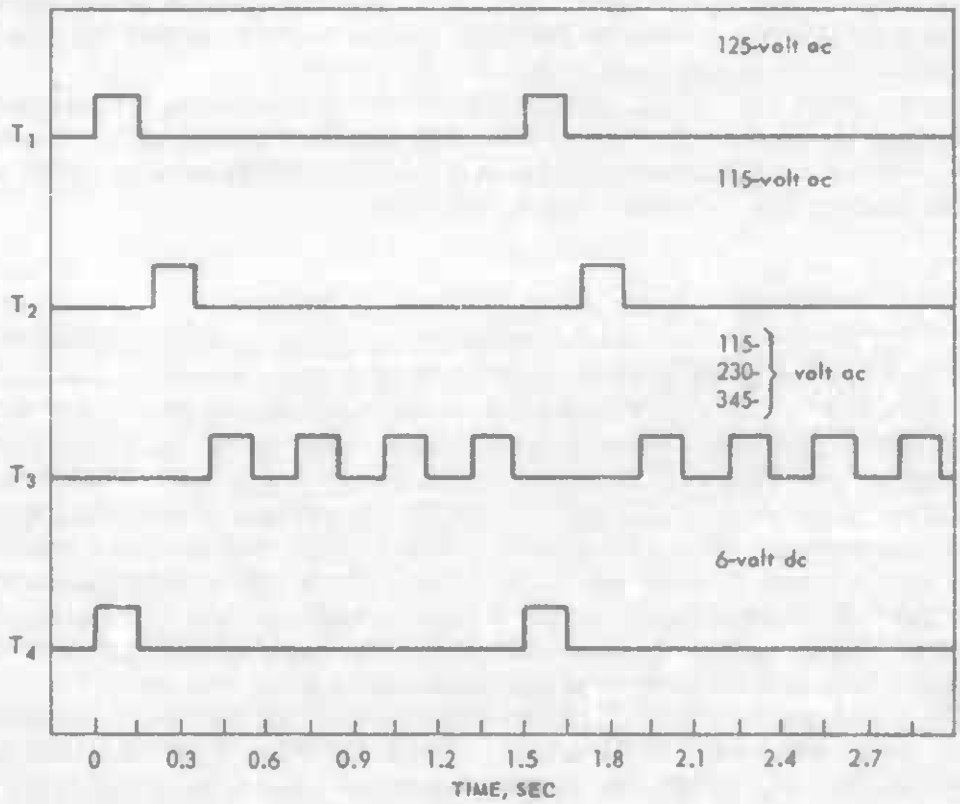

Fig. D4—Pulses from Timer

circuits were thereby isolated from the relatively sensitive hit-recording circuit. The control power was polarized and a common ground used throughout. Power was distributed to the individual control instruments via the timer unit. The recording-instrument power was also polarized; it was, however, individually distributed to each instrument.

The timer, described in detail in a later section, provided all the necessary timing and operating pulses to initiate events in the associated control instruments.

The heart of the control system is the 300-position stepping-switch programmer that determines the sequence of events (duration of target exposure time and the time between target appearances). At this point events followed several paths. The controller, buffer relays, demolition networks, and shock units were plugged into the programmer patchboard to operate in the desired sequence and at the desired time.

The large power and voltage for operating the blank-firing rifle solenoids and the Cocky Ken targets required the use of intermediate buffer relays. T_2 pulses energized the appropriate relay and the relay contacts, and applied 115-, 230-, and 345-volt ac to the blank-firing rifle solenoids. Essentially the buffer relays within the controller performed an identical function for the target devices.

Other contacts on the controller relays controlled marker pulses to the Esterline-Angus recorder and the Brush recorder that were produced at $1\frac{1}{2}$-sec intervals via the T_4 pulses, and indicated the exact time at which the relays were called to activate the targets (Fig. D4). A third function of the controller relays was to select a second buffer relay that in turn connected the hit-recorder preamplifier to the signal lines of the selected target.

Pulses produced by hits on the targets were electronically conveyed through the preamplifier to the spark generator, and then to the pens of the Brush recorder. Pulses received from the trigger-switch mechanisms in the weapons activated pens of the Esterline-Angus recorder.

TIMER

The timer provided all the necessary timing and operating pulses to the control and recording equipment. Figure D5 is a schematic diagram of the timer. Four cams attached to the shaft of the synchronous motor operated microswitches to produce the necessary timing and control operating pulses. The motor output shaft rotated at one revolution every $\frac{1}{2}$ sec. Push-button switches were paralleled with each of the microswitches to provide a manual method of producing each of the pulses. This feature was used extensively in routine maintenance and testing of equipment. Neon lights were placed across each of the microswitches to provide a visual check on each pulse circuit. Resistance-capacitance arc-suppression circuits were installed across all operating contacts to reduce damaging inductive voltage surges.

The T_1 pulses were developed by microswitch MS_1 and were produced once for every revolution of the motor. The pulse was 0.1 sec long and applied 125-volt dc to the programmer sequencing relay. The sequencing relay in turn advanced the stepping switch in the programmer one position. The T_2 pulses (110-volt ac) were then fed through the stepping-switch contacts to operate control equipment. T_2 pulses were delayed a short period of time behind the T_1 pulses to allow the stepping-switch contacts sufficient time to close before a voltage was applied to them. Microswitch MS_3 operated relay A, which in turn produced the three sets of T_3 pulses. A 2-to-1 step-up transformer connected as a booster transformer cascaded with the 115-volt ac line to provide the 230- and 345-volt power. Relay contacts A_1, A_2, and A_3 in the transformer secondary provided the actual T_3 power pulses. The T_3 pulses were delayed in time after T_2 pulses to allow sufficient time for the control relays to operate. This ensured that the control relays merely carried the heavy target power pulses, rather than making or breaking their pulses. T_4 pulses were 6-volt dc, and were developed by microswitch MS_4. These pulses were used as timing pulses for the Brush recorder and the Esterline-Angus recorder.

The timer panel also served as the ac power-distribution panel for the other control equipment. This permitted central control of all equipment power.

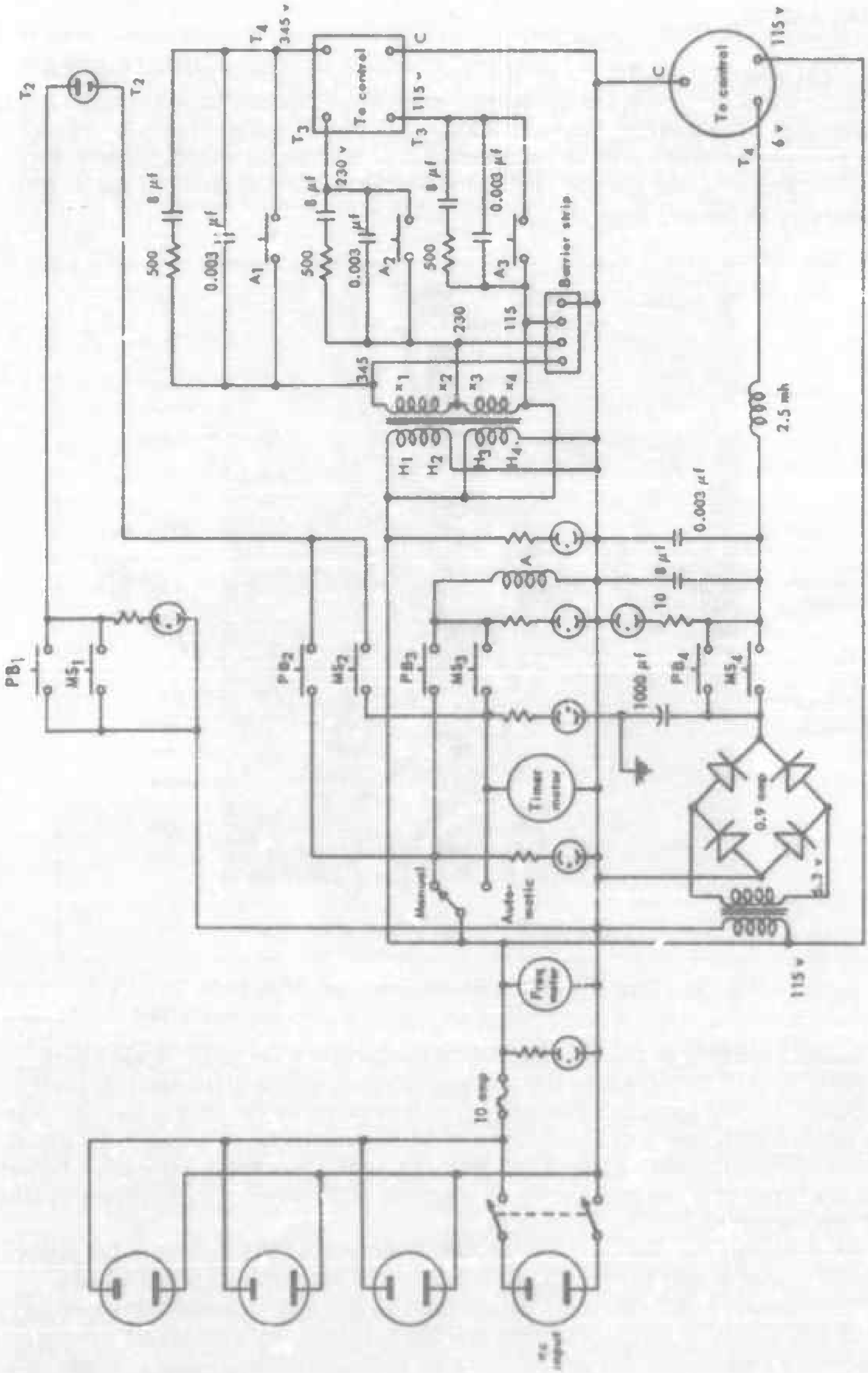

Fig. D5—Schematic Diagram of Timer

TARGET DEVICE

A drawing of the ORO Cocky Ken target device is presented in Fig. D6. The basic parts of the device are the housing, drive spring, target-stake socket, and solenoid. The housing, support clamp, and target socket are aluminum castings, heat-treated prior to machining. The housing is approximately 4 by 4 by 3 in., and contains the electrical and most mechanical parts of the device. An earlier version has been briefly described.[16]

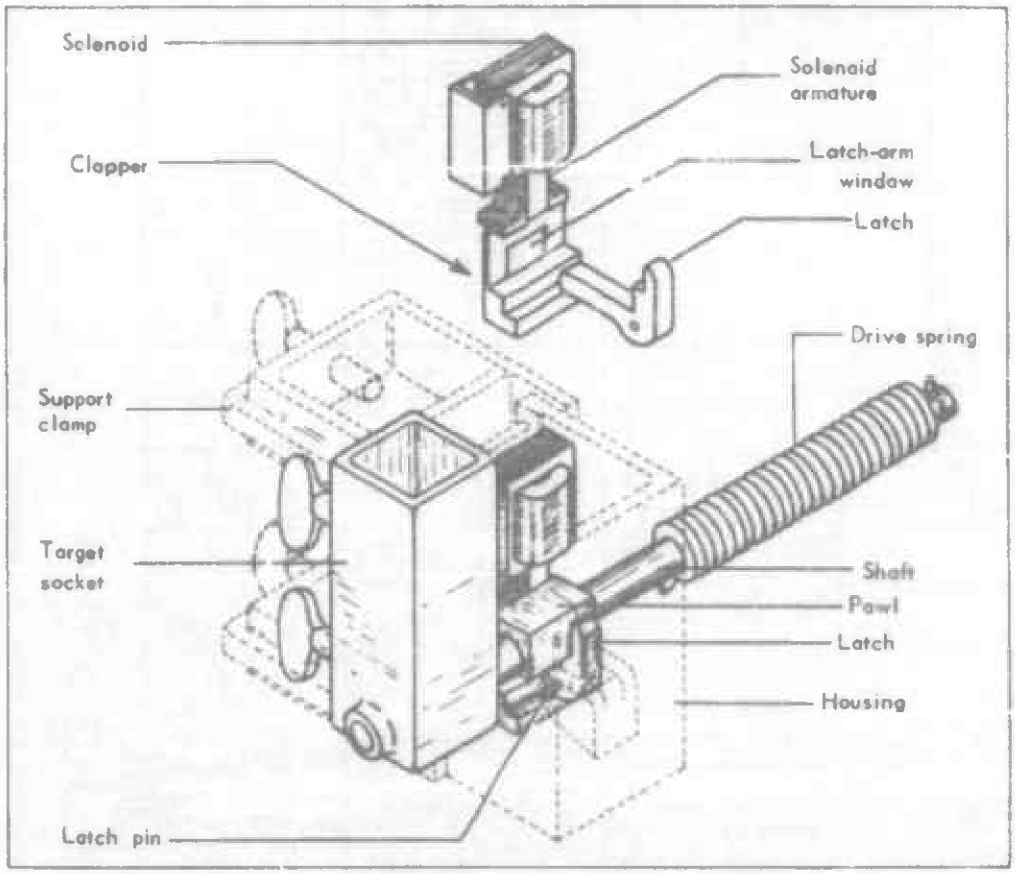

Fig. D6—Cocky Ken Target Device, ORO Type TD-2, Model 2

Manual cocking to the prone position compresses the drive spring that, on signal, rotates the target to the upright and then supine attitudes. Several variations of drive springs were employed depending on the target weight. For the E silhouette target a cocking force of 45 lb (consisting of a heavy spring of 20 turns of $^5/_{16}$-in. steel spring wire) was required. For the F silhouette target a cocking force of 35 lb (consisting of a spring of 20 turns of $^1/_4$-in. steel spring wire) was required.

As shown in Fig. D6 the housing end of the spring is parallel to the drive shaft and projects into the housing through one of four holes spaced 90 deg apart around the $^7/_8$-in.-diameter drive-shaft hole. This feature allows adjustment of the spring tension. Reduced tension results in slower target response, but increases the life of the device. The outside end of the spring fits into one of several holes in a collar that fits into a slot in the end of the drive shaft, allowing further adjustment of spring tension.

The drive shaft passes through the housing and projects on the other side for the target socket. Both shaft holes of the housing are bossed, or thickened, to minimize distortion from latching impact. Lateral movement of the shaft is restricted by collars on either side of the housing. The target socket is pinned to the shaft to facilitate ready replacement of damaged units.

Fig. D7—Target Device with E Silhouette Target

The latch and pawl system encounters heavy shocks when the target is operated, and these parts are therefore prehardened. The latch and pawl system is very sensitive to relative positioning; however, because of the sturdiness required of the latch support, adjustability could not readily be incorporated in the design. Accurate positioning is attained by drilling the drive shaft for the pawl fastening pins after the target socket is joined to the drive shaft and the shaft inserted into the housing. The flats of the pawl are thus aligned with the proper position of the target socket.

A 115-volt Bendix solenoid trips the latch that releases the drive spring, thereby erecting the target. The clapper, made of sheet metal with a latch-arm window in its center position and a weight on its lower end, is loosely pinned to the armature in the solenoid. The adjustment of the solenoid position is determined by the latch and the window engagement when the solenoid is energized, such that the tripped latch will prevent the armature from seating by approximately $\frac{1}{16}$ in.

A microswitch and its operating cam are located in the housing. The function of the microswitch is to disconnect the solenoid from the "up" line, from which it receives pulses, and connect it to the "down" line. This prevents the solenoid from accepting further "up" pulses. The target will thus remain in an erect position until pulses are applied via the "down" line.

The target installation was a quick and simple operation. A 2- by 4-in. stake was driven in the ground and the target mechanism was clamped to the stake. Wires from the control position terminated in a three-pin twist-lock plug, which was inserted into a receptacle on the device. To minimize possible damage to the mechanism, sandbags (up to approximately 9 in. high) were placed between the device and the firing line. An alternative method of installation was to scoop a shallow hole in the ground, so that the mechanism was half below the surface, with the removed soil placed in front of the device. A device with an E target is shown in Fig. D7.

PROGRAMMER

The ORO-developed programmer proved to be a reliable means of obtaining automatic presentation of targets on a reproducible schedule of events controlled by a preselected program of electric pulses. A total of 300 equal time increments was provided such that, beginning with the start-button contact at time zero, event-creating pulses could be obtained from the appropriate terminals on a patch panel in any number up to 300. For this experiment the basic time increment generated by the timer was 1½ sec, permitting a program of 450 sec, or 7½ min.

The basic component of the programmer was a 12-level 25-position rotary stepping switch, which advanced one position for each activation of its motor magnets. A second, smaller synchronized-action stepping switch selected each of the 12 levels of the larger switch in sequence. The top horizontal row of 25 terminals corresponded to the 25 positions of the first level of the main stepping switches; the next row to the next level of the main stepping switches; etc. When the stepping switch had reached the end of the bottom row, other internal circuitry returned the switches to a "homed" position. Pushing the start button set the programmer into its automatic sequencing.

The programmer had two main sections: (a) The control for sequencing the switches (T_1 pulse programing), and (b) the selection of circuits by the contacts of the stepping switch (T_2 pulse programing). From Fig. D8, it can be seen that the small stepping switch selected the contact level of the large stepping switch. To reduce the required number of level selection contacts, two adjacent levels of the large stepping switches were connected to a single contact of the level selector switch. This was possible since the contacts of the large stepping arc were distributed on an arc of only 180 deg, and adjacent levels were not simultaneously engaged. The individual contacts of the large stepping switch were connected to the 300 correspondingly located terminals on the patch panel (Fig. D9). These terminals presented the output of the programmer, demolitions, blank-firing rifle relays, shockers, etc. T_1 pulses were fed through the level selector-switch contacts and then to the large stepping-switch contacts, and from these to the output patchboard terminals. The contacts of the stepping switches did not actually make or break the power to the

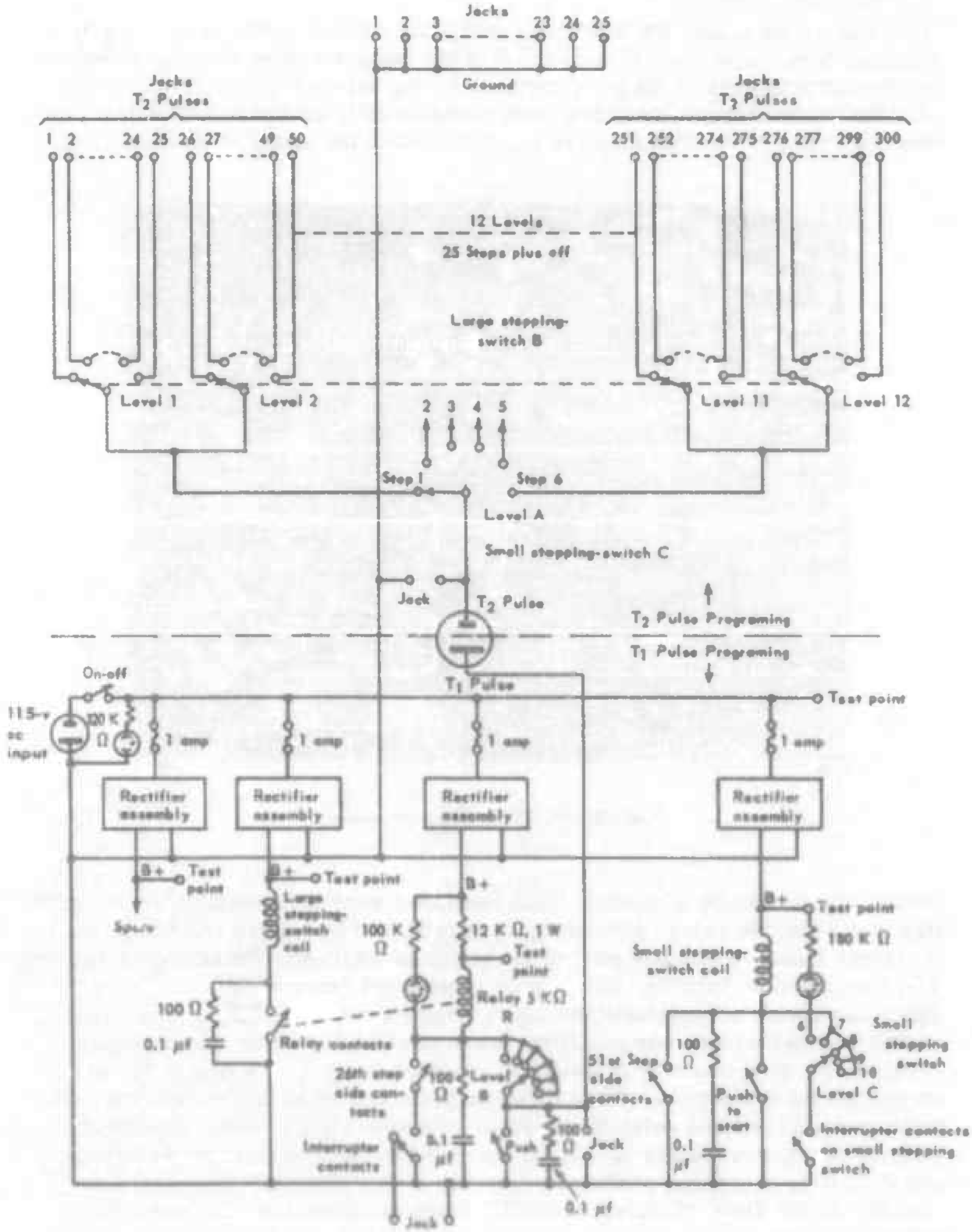

Fig. D8—Schematic Diagram of SALVO I Programmer loads. T_2 pulses, as explained earlier, were applied only after the stepping switches had advanced.

Figure D8 shows the manner in which the control of the programmer was accomplished. Since the 26th position of the large stepping switch was not useful for the progress of the programmer, it was necessary that at every 26th step the large stepping switches were automatically advanced to the next position; on every other 26th step (or every 52d step) the small level-selector

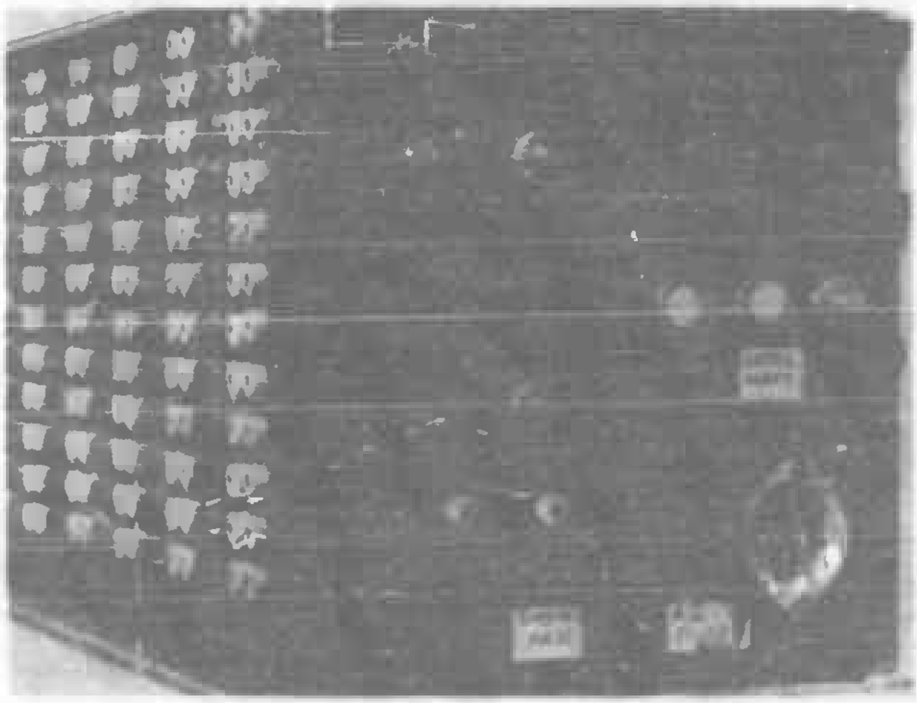

Fig. D9—Patch Panel for Programmer

switch also had to be advanced. Both functions were accomplished by the addition of a separate relay operated by T_1 pulses, and by the separate side and interrupter contacts that are part of the stepping switches. Referring to Fig. D8, this functioned as follows: the T_1 pulses operated relay R each time they closed. The relay contacts controlled the large stepping-switch magnets, causing the switch to index around one position. When the 26th, or blank, position was reached, the side contacts of switch A operated relay R, and hence the large stepping-switch magnets. When these magnets operated, the interrupter contacts were opened and relay R opened the magnet circuit. Since the switch stepped in approximately $^1/_{60}$ sec, it advanced to the next position before the associated T_2 pulse was produced. The 52d step of the switches closed the side contacts of the large stepping switch B, which controlled the indexing level-selector switch C.

To accomplish the automatic resetting of the programmer to its ready or "home" position, two extra levels for the level-selector switch C were used. The second level controlled the operation of relay R by the timing contacts, and by its action ensured that the large stepping switches were stopped in the right position for the next start. The third level and the interrupter springs of level-selector switch C returned switch C to its start.

Two push-button switches located on the control panel provided for manual single-step operation. One, the start switch, also functioned as a manual level-indexing switch. The other switch operated relay R in a manner similar to the timer contacts. Two neon lights on the control panel showed (a) the timer contacts closing, and (b) when the lowest level had been reached by the sequencing stepping switches.

Although the programmer was generally operated from 115-volt ac lines, 115-volt dc lines would have served. For field use where 115 volts is not available, a simple modification could readily be performed to permit operation from 28 volts supplied by storage batteries.

To reduce the sparking of the control circuitry contacts, spark-suppression resistor-capaciter networks were connected as shown in Fig. D8. For other uses of the programmer, interruptor-switch connections were brought out to panel terminals to permit synchronized control of other appropriate exterior circuitry.

BUFFER RELAY PANELS

This panel served as a buffer unit between the programmer and the target mechanisms (Fig. D10). The programmer stepping-switch contacts were too small to carry the 5-amp current surges drawn by the target-device activating solenoid. The control relays were operated by the programmer, and their contacts in turn switched the target power. The relay employed was a two-position latching relay with four double-throw contacts. One such relay was used for each target device. A target was called up by activating the set coil of the relay by means of T_2 pulses via the programmer. T_3 pulses then passed through the up contacts to the target device. The target could be triggered down by activating the reset coil so that T_3 pulses were applied to the down line. Individual switches on each relay provided manual operation of each relay for testing purposes.

The second set of control-line contacts on these relays operated the hit-recorder-circuitry buffer relays. These relays selected the correct target signal lines and were physically separated from the control relays in order to eliminate possible spurious signals being induced on the input of the hit recorder. Neon lights on the third set of contacts gave a visual indication of the state. The fourth set of contacts operated pens on the recorder for the desired duration of target appearance.

MOVING TARGETS

The moving-target carriage was developed by ORO's Electronics Laboratory. Three moving targets were included in the target complex. Each unit moved approximately 60 ft while exposed, and the rates of movement were different for all three.

A trench 3 ft wide and 60 ft long was required to protect the moving carriage and its guiding and supporting track. The excavated material was placed to the front of the unit to permit a reduction of the required trench depth.

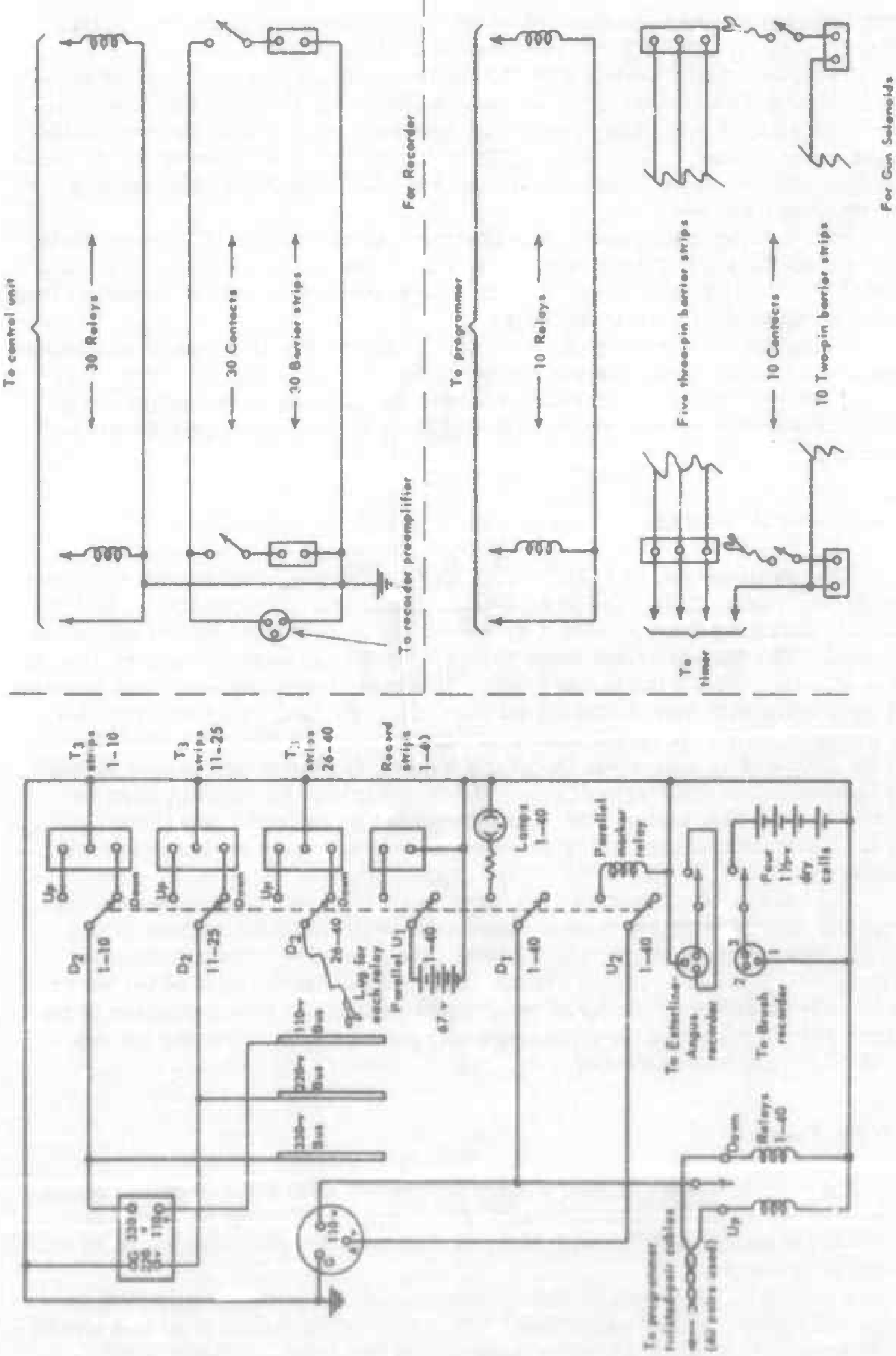

Fig. D10—Buffer Relays

All three moving targets utilized the E silhouette; the target mechanisms were the Cocky Ken units previously described. On command the target was elevated. As the target neared its fully upright position, the carriage started accelerating until the preset top speed was reached. The internal speed-governing circuit then functioned to permit the carriage to coast until its speed decreased approximately 10 percent, at which point the power was again applied to accelerate the carriage to the top speed limit. The effect produced simulated a running man.

Near the end of the desired length of travel, a carriage-mounted trip switch was triggered by a pawl on the track. The switch caused the drive motor to reverse its direction thereby slowing, halting, and finally reversing the direction of the carriage travel. As the carriage reversed its direction, the trip switch was again actuated, the motor power was removed, and the target device actuated to drop the target.

Between runs the carriage was returned manually to its starting position, and the target device was again cocked. The unit was then ready for the next run.

Two light control lines of combat wire and the coaxial lead carrying the hit-recording signal were connected between the carriage and the control point behind the firing lines.

A 6-volt storage battery was mounted on the carriage to provide a power source for the driving motor. For the 60-ft runs, a single charge of the storage battery was sufficient for 2 days of operation (approximately 20 to 30 runs including testing).

Figure D11 shows the general construction of the moving target, and Fig. D12 shows a schematic drawing of the control circuitry. Figure D11 shows the basic parts of the carriage and the way in which it is mounted on the tracks, but does not show the details of the double-flanged wheels that support the carriage from the lower track. The wheels are loosely fitted to their axles and are centered by helical springs from both sides to the channel-shaped iron frame, thus allowing the carriage to follow the horizontal changes of the guiding track without binding. The tracks are two hot-rolled flat-bar iron rails, ¼ by 2 in., spaced vertically about 12 in., and supported by a series of metal posts at approximately 3-ft intervals. The bottom rail supports the carriage. The top rail maintains the unit in a vertical position, and its flat side provides a surface against which the propulsion wheel reacts. This track design provided the flexibility needed to adjust to minor terrain variations.

The supporting structure of the track system is made of "Dexion," perforated light steel and aluminum angle. The vertical stake used for spacing the tracks and supporting the upper one is bolted to a crosspiece that serves to provide the support for the lower track. To achieve rigidity, a third member is attached between the crosspiece and the vertical member on the opposite side from the tracks. Longitudinal Dexion members serve to tie these basic sections together.

The motor used is a Ford starter unit equipped with an extra set of field windings to provide reversibility. A centrifugal-switch speed governor is attached to the shaft of the motor, and allows easy adjustment of the top velocity of the mechanism within a range from 5 ft/sec to 30 ft/sec. Total weight of the target carriage is 65 lb. The unit can accelerate to a velocity of 20 ft/sec in the first 15 ft of track.

Olin Mathieson Chemical Corp

Fig. D11—The Moving Target, Carriage, and Track System

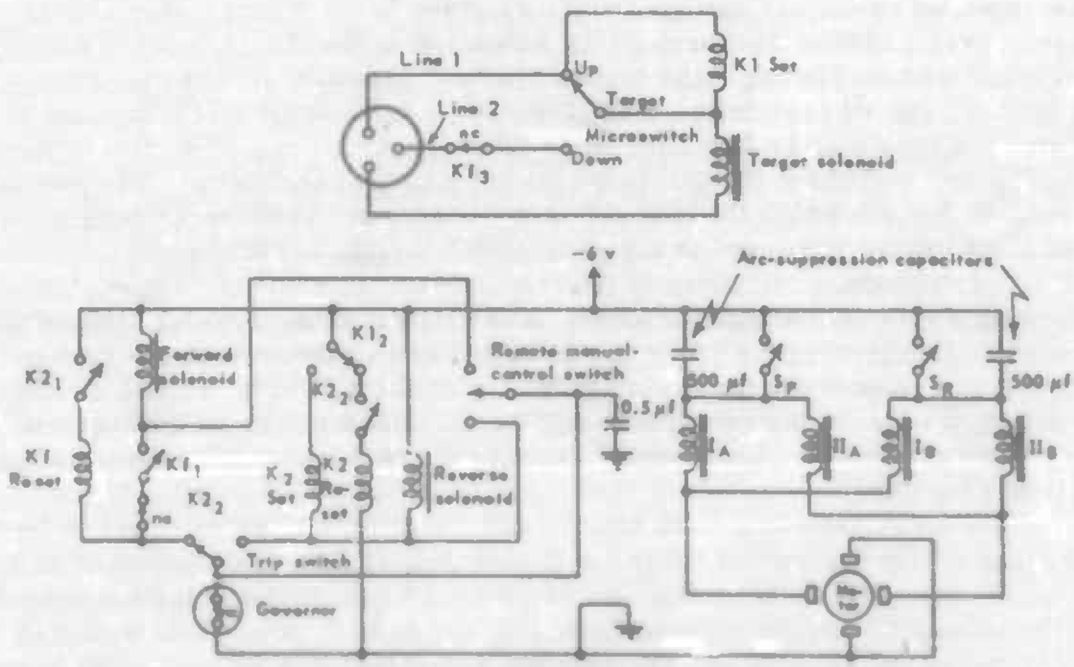

Fig. D12—SALVO I Moving-Target Control Circuitry

The electronic control sequence of the moving carriage is as follows:

(a) Pulses from an external timer are first applied to line 1. The target solenoid is energized; the target is raised.

(b) The cam-operated microswitch, located within the target mechanism, switches from line 1 to line 2.

(c) Latching relay K1 is energized by the up pulses on line 1. Contacts $K1_1$, $K1_2$, and $K1_3$ close.

(d) The $K1_3$ closing of contact $K1_1$ energizes the forward solenoid, which in turn energizes the driving motor.

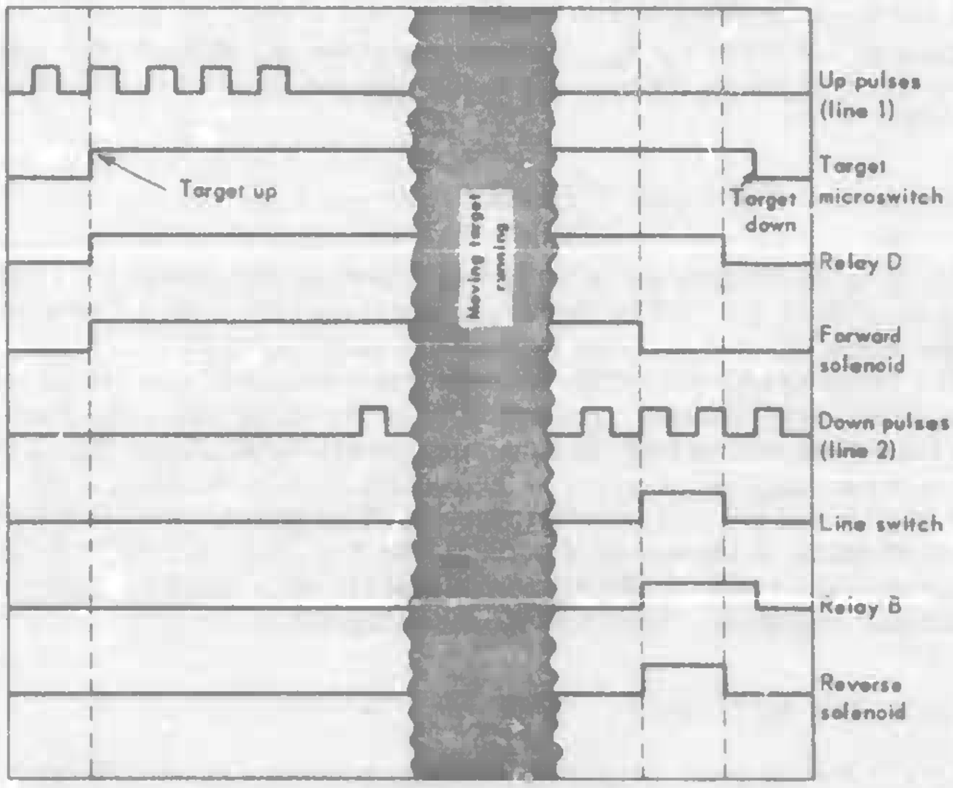

Fig. D13—Wave Forms for Moving Target

(e) The target is now moving along the track, within fractions of a second after the first up pulse.

(f) Up pulses are removed and down pulses are applied to line 2. (Note: K1 is still set; therefore contact $K1_2$ is open, keeping the down pulses off the target solenoid.) Relative wave forms for the operating sequence of the moving targets are shown in Fig. D13.

(g) The target moves along the track under control of its governor. When the target nears the end of the track the trip switch is thrown via a mechanical stop.

(h) The trip switch deenergizes the forward solenoid and thus the forward winding of the driving motor. The trip switch in its new position energizes the reverse solenoid and thus the "reverse direction travel" windings of the motor.

(i) Latching relay K2 is also set through the trip switch, operating contacts $K2_1$, $K2_2$, and $K2_3$.

(j) The target reverses its direction and, in coming back past the limit switch, sets it to its original position. This deenergizes the reverse solenoid.

(k) Relay K1 resets through contact $K2_1$, and the forward solenoid remains deenergized owing to contact $K2_2$ being open.

(l) This has occurred before the target has had time to pick up speed; therefore it coasts to a halt in a very short distance (1 to 2 ft).

(m) Contact $K1_3$ applies the down pulses to the target solenoid and the target pops down. Relay B is reset through contacts $K1_3$ and $K2_3$.

(n) All switches and relays have been reset to their original condition, so that it is only necessary to push the target back to the other end of the track, cock it, and the target is ready to run again.

Loss of control of the unit, particularly at the end of its travel, was experienced and is primarily ascribed to the type and quality of the latching relays used.

DISCLOSING FIRE FROM THE TARGETS

To disclose the position of targets that were partly concealed, a blank round was fired at the time of the target appearance from M1 rifles aimed toward the firing line and mounted in specially constructed boxes.

The rifles were electrically operated and controlled from behind the firing line by the programmer. The operation of the rifles was as follows: T_2 pulses from the programmer operated the correct buffer relay. The relay contacts in turn applied ac power to the control lines of the blank-firing rifle for the duration of the relay contact closure. This power operated a Bendix solenoid identical to the one used in the Cocky Ken target device. The solenoid was mechanically linked to the trigger so that the rifle would fire when the solenoid was energized. Figure D14 is a photograph of the unit.

ARTILLERY AND RIFLE FIRE

To achieve realism, 10 artillery bursts, simulated by exploding $\frac{1}{4}$-lb blocks of nitrostarch, and 11 rifle shots, simulated by No. 6 electric detonating caps, were detonated in the target area.

Combat wire carried the required currents from the control point to the field locations. A connection block terminated the wire in the field, and functioned as a quick connection for the wires from the detonating caps, and as a mount for an arc-suppression resistor-capacitor network.

The panel used to terminate the lines from the field at the control point incorporated a quick-disconnect plug for the leads from the programmer. To provide maximum safety this connector was replaceable with a plug that shorted all leads from the field together and to ground.

ELECTRIC SHOCK UNITS

For additional realism, ORO's Electronics Lab developed a special shocking device that would simulate wounding the subject troops during the experimental firing (Fig. D15).

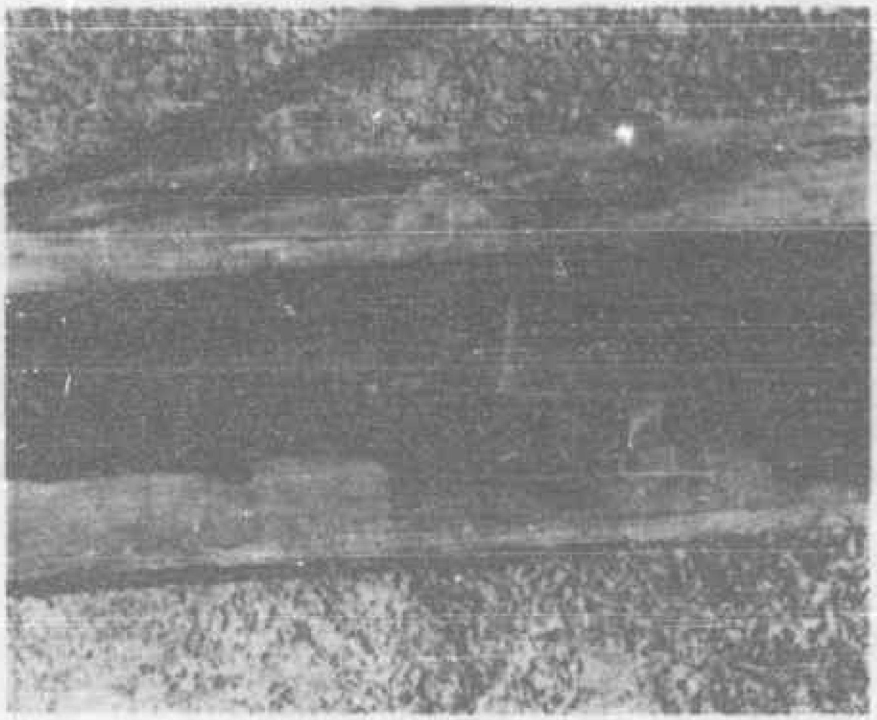

Fig. D14—Blank-Firing Rifle Unit

Fig. D15—Electric Shock Unit (Shown with Three Flashlight Batteries Instead of the Six Penlite Batteries)

Examination of the literature[38] indicated that safe electrical currents through the human body should not exceed 12 ma. Current in excess of 12 ma is dangerous if it exceeds about 8 msec. These limitations are applicable to full-body shock on normal adults. Shock that does not traverse the heart region can safely be considerably higher (with the proviso that no accidental connection across the heart region is possible). On the other hand, the safe conditions for normal adults are not adequate in the event that the subject is prone to heart disease or epilepsy. It was also noted that the maximum safe current is very close to the minimum effective current.

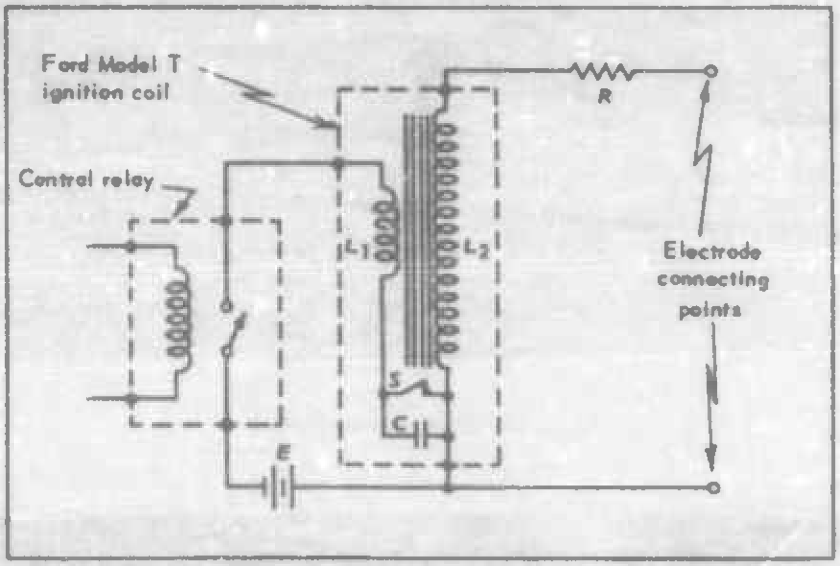

Fig. D16—Schematic Diagram of Electric Shock Unit

For use in the SALVO I experiment it was first thought that violent muscular or psychological reaction to the electric shock might incur secondary danger, since the subjects were handling loaded weapons in close proximity to one another. It was decided therefore to keep the shock off the upper portions of the body entirely. It was felt that application of the shock on the leg would be quite safe in this regard. Use of carefully constructed electrodes on the lower leg or ankle precluded any possibility that the high voltage could be applied to the upper torso. Accordingly aluminum-plate electrodes were designed to slip into the subject's boots. The subjects were screened for heart disease and epilepsy before acceptance. To avoid even a remote possibility of catastrophe, the circuit was designed to limit the current to the indicated 12 ma.

The device used was a Ford Model T ignition coil, which operated with its own interrupter. (Figure D16 shows the circuit used.) The relay shown operated on T_2 pulses from the programmer to close the primary circuit. The identical equipment is supplied by a novelty company under the trade name "Auto-Shocko." To ensure safety the unit was isolated from the ground in a plastic housing, thus eliminating the possibility of the shock passing through any part of the body but the leg to which the electrodes were attached. The resistance R was added to the item as supplied by the manufacturer. Measurements of a dismantled item indicate the following characteristics:

(a) The capacitance C is 0.1 μf.
(b) The transformer turns ratio was measured at 1 to 75.
(c) The transformer secondary inductance L_2 was measured at $17\frac{1}{2}$ henries.
(d) The resistance R that was added is 0.5 megohms.

From these values it is possible to compute the maximum current deliverable from the output terminals on the right side of the figure. Using the two penlite batteries, the primary current with the interrupter S closed was measured at 0.4 amp (I_2).

The maximum delivered current I_2 is then given from Ohm's law by

$$I_2 = (E_2/R) \tag{D1}$$

where E_2 is the peak voltage included on the secondary.

$$E_2 = M(dI_1/dt) = MI_1/\tau \tag{D2}$$

where τ is the decay time, and M is the mutual inductance.

$$\begin{cases} \tau = \sqrt{L_1 C} & \text{(D3)} \\ M = K\sqrt{L_1 L_2} \simeq \sqrt{L_1 L_2} & \text{(D4)} \end{cases}$$

for coefficient of coupling K approaching unity. Combining:

$$I_2 = (I_1/R)\sqrt{L_2/C} \tag{D5}$$

$$I_2 = 10\tfrac{1}{2} \text{ ma}$$

The corresponding maximum voltage E_2 is 5300 volts.

It is thus seen that the delivered current is limited to less than 12 ma. The maximum current actually achieved was probably considerably lower, owing to a variety of factors that increased the decay time, reduced the primary current, decreased the coupling, increased the load resistance, etc.

HIT RECORDING

Figure D17 shows construction details of the hit-recording target. Essentially the target consisted of a front and rear layer of conductive rubber separated by an insulating layer of rubber. The conductive rubber was United States Rubber Company type M8737, and the insulating rubber was type M8671. The conductive layers had copper-screen electrodes stapled to their edges as shown in Fig. D17. This configuration was used so that the distance from a hit to both electrodes and hence the pulse attenuation would be approximately the same regardless of the location of the hit on the target. Several leads were attached to each electrode to ensure having connections even after one or two had been shot away.

The layers of the sandwich were glued together with B. F. Goodrich Co. Vulcalox rubber cement. The sandwich was then attached to a standard Army pasteboard silhouette target previously mounted to an aluminum-channel supporting stake. An additional pasteboard target was glued to the front of the sandwich to prevent some of the ricochet fragments from penetrating it and causing a permanent short.

A previous test showed that the usual wood supporting stake could not withstand the heavy fire to be expected in the SALVO I experiment. Aluminum channel was substituted, and functioned satisfactorily even after sustaining 50 to 75 penetrations.

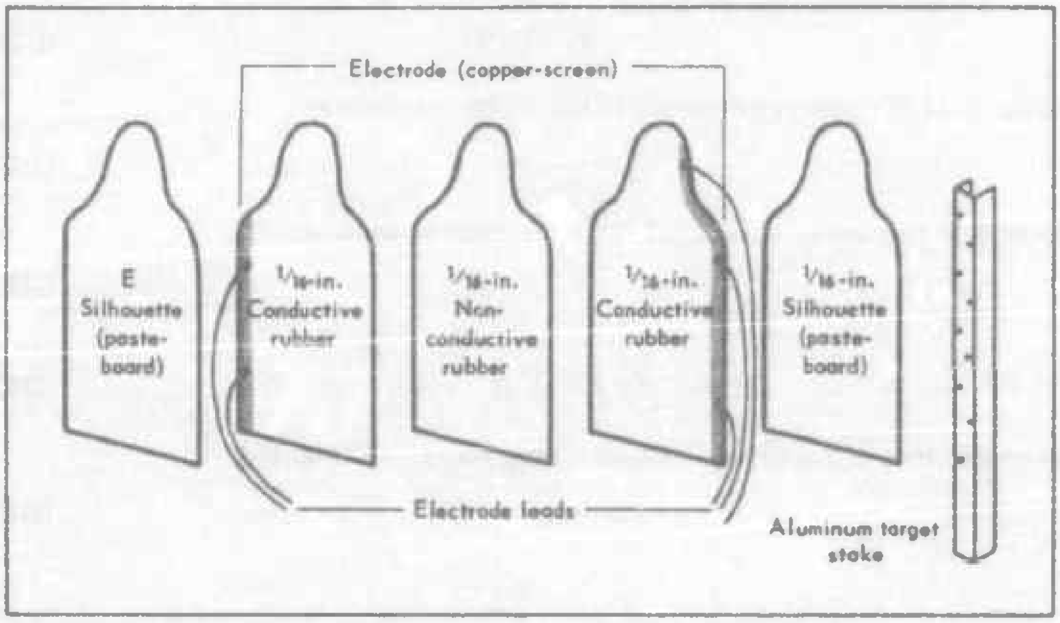

Fig. D17—Hit-Recording Target
Exploded diagram.

The hit indication was obtained when a bullet penetrated the target and produced a transient short between the two layers of conductive rubber. Voltage applied between the two layers produced a pulse by the shorting action. This pulse produced by the target was of very low amplitude, and shielded cable was required between the target and the recording circuitry to reduce undesired pickup and consequent spurious indications. The low-amplitude pulses resulted from the [illegible] resistance of the conductive rubber. Attempts to amplify the pulse by increasing the applied voltage above 200 volts were unsuccessful. Increased voltage produced multiple pulses from a single hit. These multiple pulses were probably caused by arcing across small fragments of conducting rubber torn loose by a bullet.

Figure D18 is a schematic diagram of the target input circuit, preamplifier, and spark generator. The input circuit of the preamplifier consisted of a UTC LS-12X input transformer with a step-up ratio of 10 to 1. A low-pass resistor-capacitor filter was used on the input of the preamplifier to eliminate high-frequency noise that might be recognized as a hit. Three 67-volt batteries

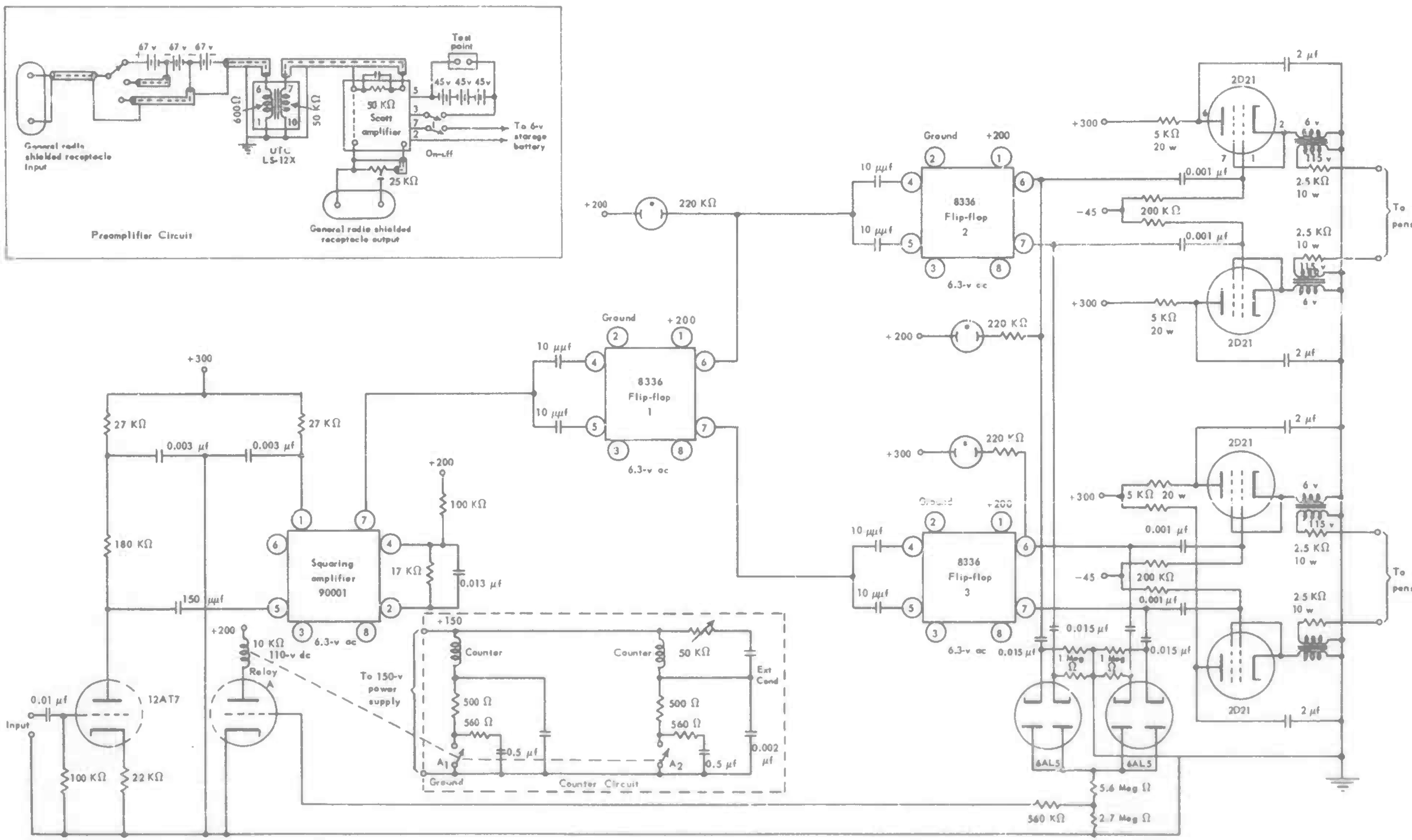

Fig. D18—Hit-Recording Circuitry

were used to develop the target pulse with a resulting signal level at the amplifier input of approximately 10 to 20 mv. The amplifier utilized was a modified commercially available Scott decade amplifier. To eliminate the possibility of noise or interference from the 60-cycle power supply, the preamplifier was modified to be completely battery operated. Specifications on the amplifier are as follows:

Gain—40 db

Equivalent input noise—10 μv for a bandwidth of 500 kc

Output voltage—40 volts

Frequency response—0.2 db from 10 cps to 500 kc

Input impedance—1 megohm

The input of the amplifier was made adjustable by means of a 25,000-ohm potentiometer. This output was then fed into a second unmodified Scott decade amplifier set to a gain of 20 db. The signal thus available at the input to the spark generator was a pulse of approximately 10-volt amplitude. Its width was approximately 50 μsec.

The first stage of the spark generator served as an inverter and amplifier. It was a standard audioamplifier, and a gain of 20 db was obtained from one half of a 12AT7. The pulse available at the output of this stage had sufficient magnitude to drive the succeeding flip-flop stages; however, its leading edge was not sharp enough to trigger the flip-flop. A squaring amplifier followed the first stage and shaped the pulse into an acceptable form by converting the slow rising pulse into a square wave of a standard amplitude and of suitable rise and decay times. The squaring amplifier was a self-contained plug-in unit that operated on a minimum input signal of 30 volts and accepted frequencies between 0 and 100 kc. The magnitude of its output signal was 100 volts. One-μsec rise time and a 3-μsec decay time were required.

As mentioned earlier, hits could occur as close together as 0.5 msec; however, the electric-pen writing circuits were unable to recover in this short time. To allow sufficient time for these circuits to recover, the hit pulses were sequenced to four pens. Each pen was thereby used once for every four hits scored. The desired separation was accomplished through frequency-dividing flip-flop circuitry. Three plug-in interconnected flip-flops (Fig. D18) were used to obtain the desired frequency division of four to one. The wave forms (Fig. D19) show how the division was accomplished and indicate typical response from six randomly spaced hits.

It is easily seen from these wave forms that any one output of flip-flop 2 or 3 went in a positive direction only once for every four hit pulses at the input of flip-flop 1. It was this positive pulse that activated the thyratron pen-writing circuits.

The thyratron (type 2D21) pen-writing circuits were biased with minus 45 volts so that they were normally cut off. The thyratrons were self-extinguishing through the action of the 2-μf condenser on the plates. A positive pulse on the control grid fired the thyratron, and it extinguished itself and remained cut off until the next positive pulse from the flip-flop output. The previously mentioned long recovery time of the thyratrons was the time required for the 2-μf condenser to charge through the 5000-ohm plate load (10 msec). If five hits occurred within this 10-msec period, the thyratron being pulsed to record the fifth hit would not have had time to recover. The probability of getting over four hits within this period of time was small enough to be acceptable.

The discharge of the condenser through the thyratron developed a pulse across the 6-volt winding of an ordinary filament transformer. This pulse was transformed up by a factor of approximately 1 to 20. A pulse of over 500 volts peak was obtained from the secondary of the transformer and applied to the pens of the recorder.

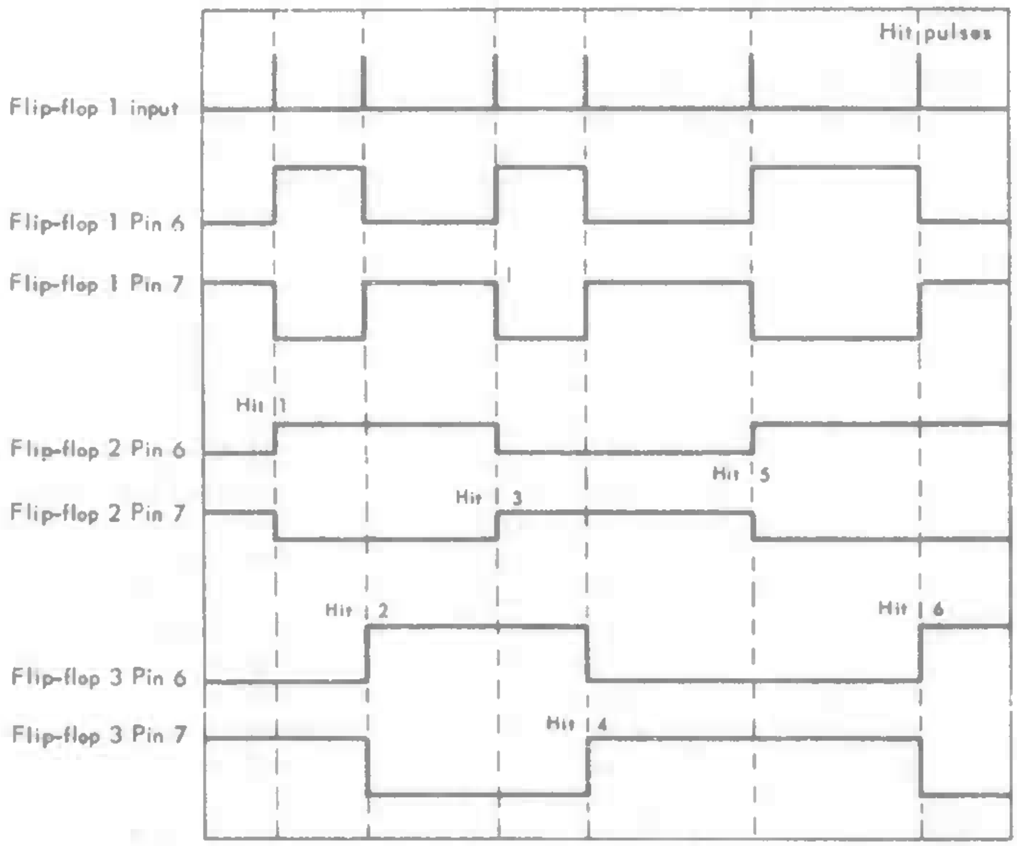

Fig. D19—Wave Forms for Flip-Flop Switch Responses to Six Randomly Spaced Hits

The recorder was a standard Brush Electronics Oscillograph model BL-202 that had been modified by replacing the standard ink-writing pens with four special electric-writing pens. The chart paper had its reverse side coated with a conductive graphite compound. The electric spark developed between the pen and the paper burned a small spot on the paper to provide a permanent record of the time of each hit. A separate inking-type pen applied timing-marker pulses every $1\frac{1}{2}$ sec by responding to T_4 pulses. The recorder-paper transport speed was set to 50 mm/sec.

Electromechanical counters were incorporated as auxiliary hit indicators. The counters were actuated by a relay that in turn was driven by one triode of a type-12AT7 dual triode. The hit pulses were coupled into the grid of the relay driver through an and/or gate of the flip-flop outputs. One of the counters

Fig. D20—M1 Rifle Switch for Recording Trigger Pulls
Old version at bottom, modified version at top.

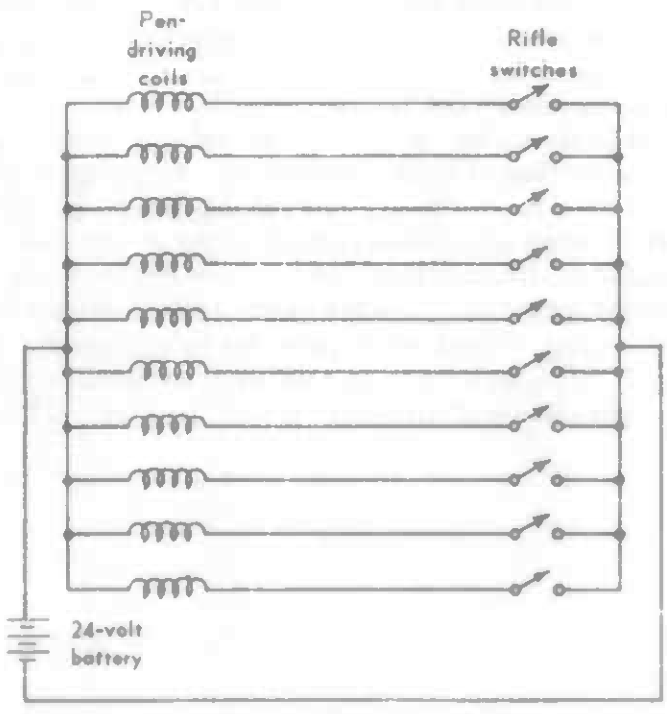

Fig. D21—Trigger-Pull-Recording Circuit

was allowed to operate as fast as it could, to indicate all possible hits. The second counter's action was slowed down by means of a network so that it would only count bursts of fire rather than individual hits. Thus if four hits were scored from one automatic burst, counter 1 would indicate four, whereas counter 2 would indicate only one. Multiplex hits were not resolved by either counter.

TRIGGER-PULL RECORDING

The internally mounted trigger switches used to indicate time of firing utilized the weapon's hammer movement to provide switching action. Figure D20 is a photograph of the M1 rifle switch showing both old and modified versions.

A light 15-ft three-wire cable carried the signal from the weapon to a terminal block at the firing line. Two wires of the cable functioned as electrical leads, and the third served as a mechanical strain-absorbing device. Combat wire carried the signal from the block to the recorder. Figure D21 shows the recording circuit used.

POWER CONSIDERATIONS AND ILLUMINATION

Two 115-volt 60-cycle 5-kw gasoline-driven generators supplied all the power used by the target and recording systems. Although generators of lesser capacity (down to $1\frac{1}{2}$ kw) would have been sufficient, more reliable operation was assured by the larger units. One generator supplied power for the control devices. The second generator supplied power for the recording system only. Separate generators were used to prevent the heavy power surges drawn by the control equipment from affecting the ac supply to the recording instruments, and providing spurious pulses that might record as hits.

The night firings took place under a constant low level of artificial illumination approximating that of bright moonlight. Floodlights were mounted on six 20-ft towers constructed on the site, using Dexion perforated-steel angle. Three towers were spaced along both edges of the firing fan to obtain the required evenness of illumination. In the four fixtures nearer the firing point, 500-watt incandescent lamps were used; 1000-watt units were used in the more distant fixtures. These were powered by a separate generator of 5-kw capacity. The reflectors were pointed slightly upward and away from the firing line, so that illumination on the target area was fairly even.

Appendix E

DATA RECORDED

SUMMARY

Seven kinds of data were recorded in the SALVO I experiment: (1) bullet holes in the paper target faces, (2) count of ammunition expended per run, (3) continuous recording of rounds fired at each position, (4) continuous recording of bullet hits on each target, (5) malfunctions occurring in the target system, (6) weapon malfunctions, and (7) conditions of weather and light.

HOLES COUNTED

At the beginning of each run the targets were covered with paper faces, each of which was clearly identified by run number and target number. The faces were collected 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 noted but omitted from the holes-counted totals. Table E1 illustrates this type of record, and a later table summarizes these data for runs and targets.

ROUNDS COUNTED

The second kind of data were 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 (see Table E2). A summary for runs and men firing appears in a later table.

For flechette runs an observer actually counted the shots fired at each target. (Ammunition was issued in 8-round clips for the M1, in 19-round magazines for the T48, and in 15-round magazines for the carbine.)

SHOTS RECORDED

The continuous recording from the Esterline-Angus recorder provides a permanent record of trigger actions at each firing position. Figure E1 shows an example of trigger-action records. Unfortunately, malfunctions in the trigger-switch mechanisms gave rise to quite frequent failure to record rounds fired, so that this continuous record quite often yielded a lower total than the ammunition count. However the record did permit ascribing all those rounds recorded to individual targets of the system. See App F for adjustment of data (Tables F20 to F36).

TABLE E1

SAMPLE FORM FOR COUNTING TARGET-FACE HOLES

RUN 26	Program 7B-14	M1 (Triplex)	Day (1305)
June 23, 1956	Squad A	Sitting	

Target no.	Complete holes	Edge holes	Total holes	Ricochets
5	6	0	6	0
7	47	4	51	2
9	24	1	25	1
10	46	1	47	0
13	25	0	25	2
14	7	0	7	1
15	0	0	0	0
16	1	0	1	0
18	8	0	8	0
19	17	0	17	1
20	64	3	67	1
21	4	0	4	1
22	1	1	2	1
24	1	0	1	0
25	3	0	3	0
28	8	0	8	0
29	8	0	8	0
30	0	0	0	0
31	12	0	12	0
32	1	0	1	0
33	0	0	0	0
34	7	1	8	1
Totals	290	11	301	11

TABLE E2

SAMPLE FORM FOR COUNTING ROUNDS

AMMUNITION AND WEAPON ISSUE

Date: June 23		Weapon type: M1
Time: 1:15 PM	Firing run: 26	Ammo type: Triplex

Position	Man	Weapon serial no.	Ammunition		
			Issued	Returned	Expended
1	Sgt Bosange	0542	160	77	83
2	Sgt Lopez	7047	160	97	63
3	Pvt Pinez	9081	160	82	78
4	Pfc Dungee	6973	160	92	68
5	Pvt Ladson	7559	160	86	74
6	Sgt Bonny	3453	160	84	76
7	Sgt Bennett	8663	160	95	65
8	Sp3 Chitwood	7349	160	109	51
9	Sp3 Drake	3971	160	82	78
10	Pvt Cobalchal	8016	160	90	70
20 Clips (8)			1600	894	706

D. Love, Data recorder

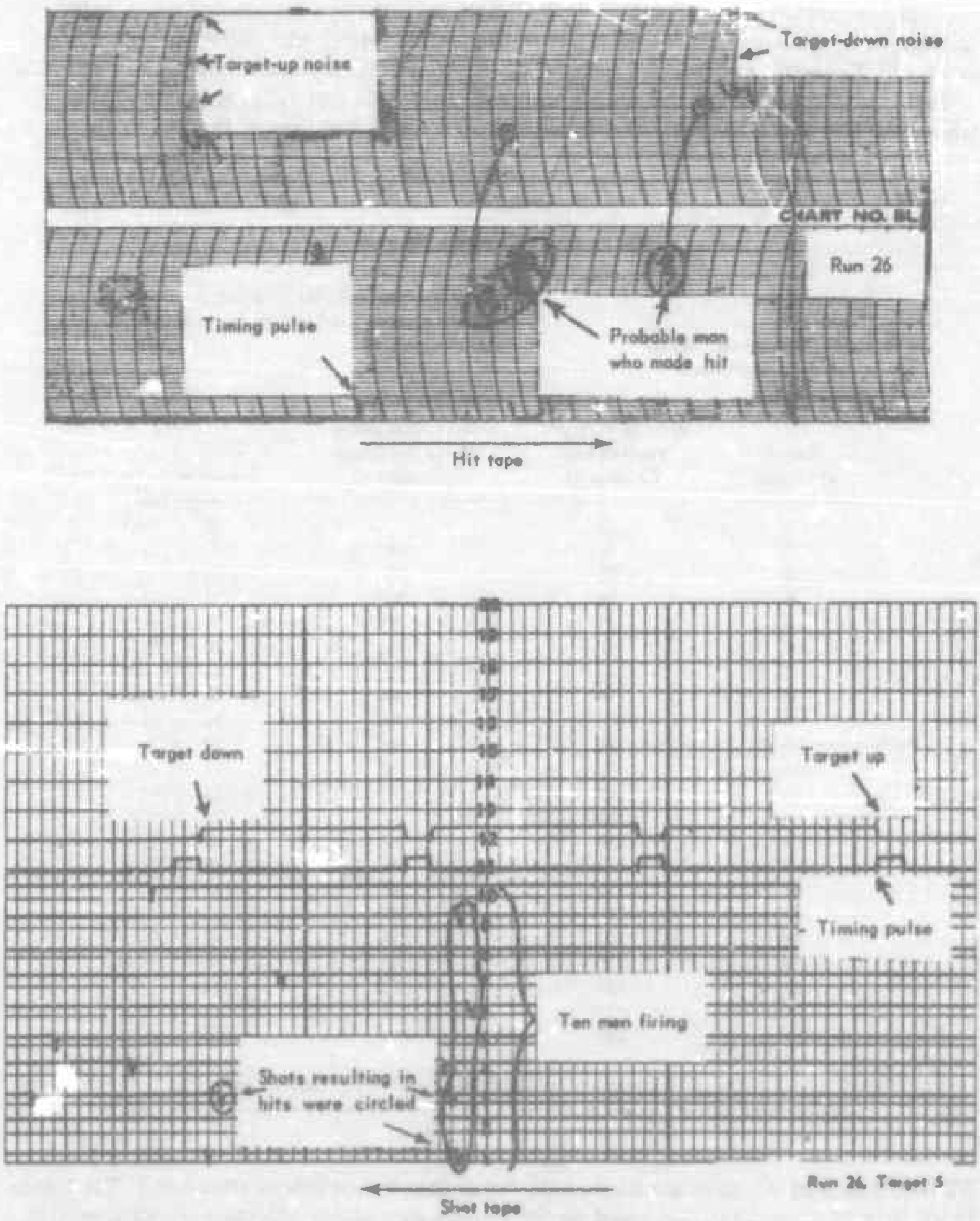

Fig. E1—Hit and Shot Tapes

HITS RECORDED

Brush Recorder. The continuous Brush recorder hit record is capable of resolving multiple bullet hits (from duplex, triplex, and automatic ammunitions). Thus the permanent record of the electrically recorded hits is capable of distinguishing among the single and multiple hits per trigger pull, which comprise the total number of hits as counted from the target faces. (Tables

TABLE E3

MECHANICAL COUNTER RECORD

Date: 3 July	Cumulative resolved hits (Counter 1) 145
Time: 1425	Cumulative unresolved hits (Counter 2) 126
Run: 43 .22-cal Carbine Automatic	Manual-count hits 101

Target sequence	Individual target resolved hits (Counter 1)	Individual target unresolved hits (Counter 2)	Target no.
1	7	5	5
2	18	16	7
3	23	18	30
4	25	20	28
5	39	34	31
6	41	36	29
7	45	40	24
8	48	43	25
9	51	46	19
10	71	66	20
11	77	72	16
12	82	76	21
13	104	88	22
14	110	94	18
15	112	96	34
16	113	97	33
17	114	98	32
18	122	106	10
19	126	110	9
20	134	116	14
21	143	124	13
22	145	126	15

Sgt Robt. H. Casteel, Data recorder

O1 to O4 in App O give multiple hits from these electrical records.) Hit totals from this source were not used as they were seriously affected by malfunctions of the mechanism. The proportions of multiple hits from single trigger pulls are reported in App O.

Veeder-Root Counter. Two Veeder-Root electromechanical counters were incorporated into the hit-recording circuitry. Counter 1 had a resolution time of 100 msec, too slow to distinguish between multiple hits from one round. The resolution time of Counter 2, retarded by condensers to count only once for each 3- or 4-shot burst from the automatic weapons, was about 600 msec. The differences are illustrated in Table E3, which is the record of a .22-cal carbine automatic run. Clearly the counter records include spurious counts, as the run total is 44 hits in excess of the more reliable manual count. If reliable, the counter record implies that 15 percent [(145 - 126)/126] of all hits were multiple hits. Unfortunately this figure is probably biased, with a too-large fraction of spurious multiple hits.

Noise present in the hit-recording system affected the counters also. Furthermore the difficulties present in manually recording the output of the two counters during the course of a run increased the number of inaccuracies. For these reasons these data were not used in adjusting the hit totals.

MALFUNCTIONS

A log was kept of all malfunctions that occurred in the target-operating mechanisms, shockers, and similar programed devices. These malfunctions are included in Table E4.

Malfunctions of the individual weapons occurred with considerable frequency. Unfortunately the recording system included no chronologically quantitative record of these malfunctions. Hence it was not possible to make accurate corrections to compensate for nonfunctioning weapons. However, the test log revealed when weapon malfunctions occurred, and rough adjustment could be made for recognized failure of a weapon to function during specific target appearances.

The tabular qualitative record of weapons malfunctions appears in Table E5.

CONDITIONS OF WEATHER AND LIGHT

Accidental and deliberate changes in concealment, differences of target color (some faces were darker than others), and conspicuous weather changes were also logged and are noted in Table E4. These, plus the weapons and target-complex malfunctions, were used as a guide in adjusting the data (see App F).

The run totals of rounds fired and hits from Table E4 are summarized in Table E6.

ROUNDS PER AUTOMATIC BURST

In order to properly consider the approximate effect achieved with automatic fire, it is necessary to determine the number of rounds fired per burst, or per trigger pull. The instructions given to the test troops were to attempt to fire an average of two or three rounds per burst. Observation during the conduct of the experiment indicated that the discipline in response to this instruction was quite good. The manually recorded data record only the total numbers of rounds expended per run. In order to determine the number of rounds per burst, it is necessary to examine the record of trigger-switch impulses. As the switches were activated by the rifle-bolt action rather than the trigger action itself, these records include a count of the actual number of rounds fired on each trigger pull. Owing to the considerable malfunctioning of these trigger switches, the record is not complete. However, inasmuch as this study is concerned only with the average ratio of rounds per trigger pull, the incomplete record is quite satisfactory. It is reasonably assumed that the recorded data are an unbiased sample, which will give a good estimate of this ratio.

An analysis was therefore made of the unambiguously reported firing impulses from the 16 runs of automatic fire. The total numbers of bursts and corresponding rounds are shown in Table E7. The rounds per burst from the totals for each of the six types of fire are listed in the right-hand column. It is evident that the results indeed do vary between the limits of 2 and 3 rounds per burst. For some purposes, it is adequate to use an average number of rounds per burst for all the automatic fire. Table E7 shows the grand average to be 2.33 rounds per burst. It is observed that the carbine bursts appear to be consistently slightly longer than the T48 bursts. It is instructive therefore to indicate separate averages for the two weapons. These are 2.07 rounds per burst for the T48, and 2.63 rounds per burst for the carbine.

TABLE E4

HOLES COUNTED, ROUNDS COUNTED, TARGET MALFUNCTIONS, DESIGN CHANGES, AND WEATHER VARIATIONS

Target characteristics*								
Range, yd	Movement	Concealment	Type	Time, sec, preceding exposure		Exposure time, sec		Target no.
				Day	Night	Day	Night	
52		X	F	—	7.5	—	28.5	1
63			E		9.0	—	3.0	2
65			E	—	6.0	—	7.5	3
67		X	F	—	7.5	—	12.0	4
74			F	7.5	—	4.5	—	5
76			E	—	10.5	—	4.5	6
77		X	F	9.0	—	15.0	—	7
78			F	—	9.0	—	19.5	8
86			E	10.5	—	4.5	—	9
89		X	F	9.0	—	15.0	—	10
90		X	F	—	12.0	—	4.5	11
91			F	—	10.5	—	9.0	12
111		X	F	12.0	6.0	19.5	19.5	13
127		X	F	6.0	7.5	9.0	9.0	14
139			F	9.0	9.0	4.5	4.5	15
152	X		E	9.0	7.5	9.0	10.5	16
161			E	—	9.0	—	3.0	17
162	X		E	13.5	10.5	6.0	6.0	18
164	X		E	12.0	10.5	15.0	18.0	19
165		X	E	7.5	7.5	31.5	34.5	20
169			E	13.5	9.0	3.0	4.5	21
176		X	E	10.5	13.5	4.5	9.0	22
209			F	—	6.0	—	3.0	23
216		X	F	7.5	—	4.5	—	24
218		X	F	10.5	12.0	9.0	15.0	25
221			F	—	7.5	—	7.5	26
223		X	F	—	9.0	—	21.0	27
245			E	13.5		6.0		28
259			E	12.0		10.5		29
267			E	9.0		3.0		30
269			F	10.5		25.5		31
334			F	10.5		7.5		32
336			F	7.5		3.0		33
339		X	F	9.0		21.0		34

*Malfunction, design, and weather code (a code letter in parentheses indicates questionable data).

Mechanical malfunctions:
- a Target failed to rise.
- b Target failed to move.
- c Target up at wrong time.
- d Another target up simultaneously.
- e Blank failed to fire.
- f Concealment heavy.
- g Concealment light.
- h Firing shocked by rifle.
- i Target face came off.
- j Target down early (number of seconds).
- k Target down late (number of seconds).

Design changes:
- m Postrun observation showed concealment to be too light; concealment increased before subsequent runs.
- n Postrun observation showed concealment to be too heavy; concealment decreased before subsequent runs.
- p Original OD target color changed to white after observation showed OD targets too difficult to acquire.
- q Target deliberately made to come down early for flechette runs because of limited supply of ammunition.

Weather variations:
- r Rain.
- s Light glow.
- t Overly bright moonlight.

TABLE E4 (continued)

Target or man no.	Run								
	1	2	3	4	5	6	7	8	9
	Weapon, ammo, and/or firing								
	Single bullet	Duplex	Single bullet	Duplex	Single bullet	Duplex	Single bullet	Duplex	T48 semi
	Visibility								
	Day	Day	Day	Day	Day	Day	Night	Night	Day
	Position								
	Sitting	Sitting	Sitting	Sitting	Standing	Standing	Sitting	Sitting	Sitting
	Squad								
	A	A	B	B	A	A	B	B	B
	Program								
	1A-1	1B-2	1A-1	1B-2	2A-2	2B-2	9A-1	9B-2	2A-5
Holes Counted by Target and Related Conditions*									
1	—	—	—	—	—	—	24 (t)	9	—
2	—	—	—	—	—	—	0 (t)	2	—
3	—	—	—	—	—	—	11 (t)	14	—
4	—	—	—	—	—	—	0 (t)	0	—
5	4 a	5 pa	2 pa	6 pa	2 pa	9 pa	—	—	4 pa
6	—	—	—	—	—	—	2 (t)	6	—
7	14 h	30 pa	21 pa	27 pa	15 pa	50 pa	—	—	20 pa
8	—	—	—	—	—	—	11 (t)	6	—
9	8	17	3	15	0 a	9	—	—	9
10	10	22 p	15 p	41 p	19 p	25 p	—	—	17 p
11	—	—	—	—	—	—	0 (t)	0	—
12	—	—	—	—	—	—	0 (t)	1	—
13	0	1 p	3 p	0 fp	3 p	0 p	1 (t)	4	9 p
14	2	6 p	1 p	2 p	5 p	10 p	2 (t)	1	1 p
15	0	0 p	0 p	0 p	1 p	0 dp	1 (t)	0	0 (la)p
16	7	8	5	8	3	3	0 (t)	0	6
17	—	—	—	—	—	—	0 (t)	0	—
18	2	5	4	7	2	2 c	0 (t)	0	4
19	7	14	12	9	10	13	0 (t)	1	11
20	23 a	34 a	24 m	40	13	35	1 (t)	0	3 f
21	2	4	0	7	1	1	0 (t)	0	1
22	1	2 a	0 fm	0	0	0	0 (t)	0	0 f
23	—	—	—	—	—	—	0 (t)	0	—
24	0	0 p	0 p	0 p	0 p	0 p	—	—	0 (la)p
25	1	0 p	0 p	0 p	1 p	0 p	0 (t)	0 (g)	0 (la)p
26	—	—	—	—	—	—	0 (t)	0 (g)	—
27	—	—	—	—	—	—	0 (t)	0 (g)	—
28	0 d	2	1	0	1	1	—	—	1
29	4	12	3	5	3	29 k	—	—	6
30	0 d	0	0	0	0	0 a	—	—	0
31	2	0 p	0 p	0 lp	2 p	2 p	—	—	2
32	1	2	0	0	0	0	—	—	0
33	1 c	0	0	0	0	0	—	—	0
34	0	2	5	3	0	1	—	—	0
Total	90	166	105	170	81	199	53	64	97
Rounds Counted by Man Number									
1	41	[illegible]	50	64	56	56	60	56	[illegible]
2	[illegible]	72	63	41	[illegible]	[illegible]	57	67	[illegible]
3	[illegible]	[illegible]	[illegible]	[illegible]	74	[illegible]	57	64	[illegible]
4	64	61	[illegible]	58	[illegible]	[illegible]	62	[illegible]	[illegible]
5	60	[illegible]	57	57	56	61	[illegible]	[illegible]	[illegible]
6	[illegible]	[illegible]	47	[illegible]	56	[illegible]	62	73	47
7	67	[illegible]	51	[illegible]	[illegible]	[illegible]	[illegible]	70	[illegible]
8	[illegible]	[illegible]	[illegible]	[illegible]	62	[illegible]	[illegible]	[illegible]	[illegible]
9	[illegible]	[illegible]	33	[illegible]	47	[illegible]	42	[illegible]	33
10	56	[illegible]	[illegible]	[illegible]	62	[illegible]	[illegible]	[illegible]	[illegible]
Total	[illegible]	[illegible]	671	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

TABLE E4 (continued)

Man									
10	11	12	13	14	15	16	17	18	19
Weapon, ammo, and/or firing									
T48 auto	T48 semi	T48 auto	T48 semi	T48 auto	T48 semi	T48 auto	Cbn semi	Cbn auto	Cbn semi
Visibility									
Day	Day	Day	Day	Day	Night	Night	Day	Day	Day
Position									
Sitting	Sitting	Sitting	Standing	Standing	Sitting	Sitting	Sitting	Sitting	Sitting
Squad									
B	A	A	B	B	A	A	B	B	A
Program									
3B-6	3A-5	3B-6	4A-5	4A-6	10A-7	10B-8	4C-9	4D-10	5A-11
Holes Counted by Target and Related Conditions*									
—	—	—	—	—	0	17	—	—	—
—	—	—	—	—	5	4	—	—	—
—	—	—	—	—	14	5	—	—	—
—	—	—	—	—	5	16	—	—	—
9 pa	8 pa	3 pa	2 pa	3 pa	—	—	3 pa	5 pa	4 pa
—	—	—	—	—	4	5	—	—	—
22 pa	15 pa	20 pa	24 pa	17 pa	—	—	30 pa	12 pa	18 pa
—	—	—	—	—	12	13	—	—	—
4	15	7	10	4	—	—	14	7	9
18 pk 1½	16 p	8 p	15 p	16 p	—	—	16 p	17 p	16 p
—	—	—	—	—	0	0	—	—	—
—	—	—	—	—	4	3	—	—	—
7 p	12 p	12 p	14 p(a)	13 p	8 ;3	4	14 p	13 p	3 p
0 p	8 p	6 p	1 p	3 p	3	3	0 p	11 p	3 p
0 p(f)	0 fa(p)	0 fa(p)	0 p	0	0	0	0 p	0 p	0 p
3	10	5	2	2	0	2	8	5	7 (d)
—	—	—	—	—	0	0	—	—	—
7 i	11	9	5	20 k	0	1	3 (i)	0 (a)	3
6	17	11	13	5	1	0	21 (i)	9	4
0 f0.3	21	13 0.3	19	0	26	2	45	23	37
2	4	0	2	0	1	0	0	4	2
0 f	1	0	0	0 d	1	0	0	0	1 0.4½
—	—	—	—	—	0	0	—	—	—
0 p((a)	0 (fa)p	0 (fa)p	0 p(fa)	0 (fa)p	—	—	0 k 1½	2 k 1½	1
0 p((a)	0 (fa)p	0 (fa)p	0 p(fa)	0 (fa)p	0	0	1	0	4
—	—	—	—	—	1	0	—	—	—
—	—	—	—	—	0	0	—	—	—
0	2	0	1	2 (a)	—	—	7	1	7
2	2	4	7	2	—	—	11	3	10
0	0	0	0	0	—	—	0	0	1
6	0	2	8	3	—	—	1	1	3
0	0	0	2	0	—	—	2	0	1
0 0.3	0 0.1½	0 08	0	0	—	—	0	0	0
0	1	2	2	1	—	—	2	1	1 k
86	143	102	127	91	86	75	178	114	135
Rounds Counted by Man Number									
113	70	106	98	111	38	145	75	82	77
61	65	112	56	74	76	233	73	113	42
64	36	98	63	94	75	114	72	116	90
104	73	98	72	127	76	131	67	113	31
75	47	109	54	88	41	129	57	105	76
77	62	99	107	132	105	59	75	149	101
79	23	95	57	89	76	149	37	111	62
54	75	89	67	76	102	122	36	42	96
76	66	105	64	69	82	192	55	45	92
101	72	150	98	43	105	170	95	140	91
824	588	1056	736	923	782	1444	640	1016	758

TABLE F4 (continued)

Target or man no.	Run 20	Run 21	Run 22	Run 23	Run 24	Run 25	Run 26	Run 27	Run 28
Weapon, ammo, and/or firing	Cbn auto	Cbn semi	Cbn auto	Cbn semi	Cbn auto	Single bullet	Triplex	Single bullet	Triplex
Visibility	Day	Day	Day	Night	Night	Day	Day	Day	Day
Position	Sitting	Standing	Standing	Sitting	Sitting	Sitting	Sitting	Sitting	Sitting
Squad	A	B	B	A	A	A	A	B	B
Program	5B-9	6A-11	6B-12	12A-15	12A-16	7A-13	7B-14	7A-13	7B-14
Holes Counted by Target and Related Conditions*									
1	—	—	—	18	4	—	—	—	—
2	—	—	—	2	6	—	—	—	—
3	—	—	—	6	5	—	—	—	—
4	—	—	—	0	3	—	—	—	—
5	11 par	4 pn	11 pn	—	—	9 pn(e)	6 pn	3 pn	10 pn
6	—	—	—	6	0	—	—	—	—
7	21 par	31 pn	32 pn	—	—	28 pn(e)	51 pn	34 pn	39 pn
8	—	—	—	1	0	—	—	—	—
9	16 r	15	7	—	—	14	25	6	13
10	15 pr	20 p	9 pe	—	—	18 p(e)	47 p	14 p	24 p
11	—	—	—	1	4	—	—	—	—
12	—	—	—	0	0	—	—	—	—
13	12 pr	26 p	14 p	1 03	0 03	13 p	25 p	12 p	0 p
14	5 pr	8 p	3 pe	1	0	1 p(e)	7 p	3 p	5 p
15	0 [illegible]	[illegible]	0 p	1	0	0 p	0 p	0 p	0 p
16	8 (d)r	4	7	1	0	8	1	4	19 k
17	—	—	—	0	0	—	—	—	—
18	11 r	9	8	0	0	4	8	1	12
19	28 dr	15	5	1	0	8	17	14	18
20	1 r	42	22	3	4	32 g	67	36	55 (d)
21	0 r	0	2	0	0	2	4	1	0
22	19 dr	0	1	0	0 j3	4	2	0	0
23	—	—	—	0	0	—	—	—	—
24	1 r	3	1	—	—	0	1	0	0
25	6 r	4	4	0	0	2	3	0	0
26	—	—	—	0	0	—	—	—	—
27	—	—	—	0	0	—	—	—	—
28	5 r	3	5	—	—	2	8	4	2
29	8 r	9 03	3 03	—	—	5	8	3 i	1
30	0 r	1	0	—	—	0	0	0	0
31	9 r	5	4	—	—	3 (e)	12	6	3
32	3 r	0	0	—	—	0 a	1 [illegible]	1	0
33	0 r	0	0	—	—	0	0 a	0	0
34	0 kr	1	4	—	—	4	8	2	0
Total	179	202	142	42	36	157	301	144	201
Rounds Counted by Man Number									
1	197	108	210	86	118	70	83	80	79
2	221	143	159	118	248	100	63	57	8
3	153	90	111	144	166	73	78	65	64
4	121	80	165	91	138	58	68	53	30
5	150	71	181	88	153	63	74	62	45
6	186	108	194	98	83	48	76	73	48
7	148	93	222	130	171	54	65	49	47
8	191	84	90	123	105	74	51	48	19
9	160	68	130	103	194	89	78	48	60
10	161	140	185	45	87	73	70	72	71
Total	1686	985	1656	1034	1463	742	706	590	651

TABLE E4 (continued)

Run									
29	30	31	33	33	34	35	36	37	38
Weapon, ammo, and/or firing									
Single bullet	Triplex	Single bullet	Triplex	Duplex	Single bullet	Duplex	Single bullet	Duplex	Single bullet
Visibility									
Day	Day	Night	Night	Day	Day	Day	Day	Day	Day
Position									
Standing	Standing	Sitting	Sitting	Sitting	Sitting	Sitting	Sitting	Standing	Standing
Squad									
A	A	B	B	C	C	D	D	C	C
Program									
8A-15	12A-15	12A-16	12A-15	8A-1	8B-2	8A-1	8B-2	5B-8	5A-7
Holes Counted by Target and Related Conditions*									
—	Run cancelled	11	Run cancelled	—	—	—	—	—	—
—		3		—	—	—	—	—	—
—		9		—	—	—	—	—	—
—		3		—	—	—	—	—	—
pa		—		5	4	2	2	5	6
		3		—	—	—	—	—	—
15 pa		—		19 i	15	19	5	37	15
—		4		—	—	—	—	—	—
8		—		11	11	10	4	8	6
14 p		—		11	19	13	9	15 j3	19 (e)
		1		—	—	—	—	—	—
—		0		—	—	—	—	—	—
13 p		0 e		18 f	18	13 (e)	0 e	16	8
6 p		1		8	6	8	3	6	9
1 p		0		0	0	1	1	1	1
4		0		10	3	5	1 k	5	3
—		0		—	—	—	—	—	—
4		0		6	5 c	14 k	13 kb	6	2
11		3		15	2	3	7	8	6
31		4		36	13	28	25	57	20
1		0		0	0	0	0	0	1
0		0 j3		1 f	1	0	0 f	5	1
—		0		—	—	—	—	—	—
0		—		0	0	0	1	0	0
4		0		2	0	2	3	0	1
—		0		—	—	—	—	—	—
—		0		—	—	—	—	—	—
4		—		6 e	2 e	3	3	2	3
0		—		6 e	5	7	3	7	5
0 08		—		2 k3	1 k4½	3 k	0 08	0	0
0		—		2 e	3	3	0	9	2
0		—		0	2	0	1	0	0
0		—		0	0	0	0	0	0
0		—		1	3	0 (e)	1	0	2
108		41		159	111	132	81	107	110
Rounds Counted by Man Number									
78		104		43	63	45	50	56	83
74		82		39	67	40	38	55	71
98		104		70	88	41	47	69	82
48		70		43	32	40	65	59	73
83		101		37	33	34	51	56	64
88		112		60	78	53	49	77	78
54		104		59	31	64	48	64	72
79		81		50	39	43	44	63	49
82		56		39	74	53	54	87	59
73		136		37	41	63	36	69	50
767		950		505	546	476	483	686	679

TABLE E4 (continued)

Target or man no.	Run								
	39	40	41	42	43	44	45	46	47
	Weapon, ammo, and/or firing								
	Duplex	Single bullet	Cbn auto	Cbn semi	Cbn auto	Cbn semi	Cbn auto	Cbn semi	Cbn auto
	Visibility								
	Night	Night	Day	Day	Day	Day	Day	Day	Night
	Position								
	Sitting	Sitting	Sitting	Sitting	Sitting	Sitting	Standing	Standing	Sitting
	Squad								
	D	D	D	D	C	C	D	D	C
	Program								
	11A-3	11B-4	6A-5	6B-6	6A-5	6B-6	5A-7	5B-8	12A-7
	Holes Counted by Target and Related Conditions*								
1	17 h	15 (h)	—	—	—	—	—	—	4
2	0 h	2 (h)	—	—	—	—	—	—	1
3	9 h	4 (h)	—	—	—	—	—	—	11
4	6 h	1 (h)	—	—	—	—	—	—	2
5	—	—	3 a(h)	2 h	10	6	2	8	—
6	3 h	2 (h)	—	—	—	—	—	—	0 (j)
7	—	—	21 a(h)	30 h	10	30	12	26	—
8	0 h	0 (h)	—	—	—	—	—	—	0 (j)
9	—	—	5 a(h)	16 h	8	0 j	[illegible]	[illegible]	—
10	—	—	11 a(h)	28 h	10	30	5	25 j3	—
11	1 h	0 (h)	—	—	—	—	—	—	1
12	0 h	0 (h)	—	—	—	—	—	—	0
13	2 h	1 (h)	7 a(h)	0 ha	7	12	0	16	1
14	2 h	0 (h)	1 a(h)	7 h	5	1	4	7	0
15	0 h	0 (h)	0 a(h)	0 h	0	1	0	0	0
16	0 h	0 (h)	2 a(h)k	8 hk	9 k	26 h	3	6	0 (d)
17	0 h	0 (h)	—	—	—	—	—	—	0
18	0 hk	1 (h)	24 a(h)kb	9 h	4	6	3 k	0 a	1 h
19	0 h	0 (h)	3 a(h)	12 h	2	11	7	9	0
20	2 h	1 (h)	6 a(h)f	25 h	20	46	7	17	2
21	0 h	0 (h)	0 a(h)	2 h	1	0	0	0	0
22	0 h	0 (h)	0 a(h)(a)	2 h	5	5	2 h4½	9 c	0 d
23	0 h	0 (h)	—	—	—	—	—	—	0
24	—	—	0 a(h)a	1 h	1	0	0	0	—
25	1 h	0 (h)	0 a(h)	8 h	2	0	1	4	0
26	0 h	0 (h)	—	—	—	—	—	—	0
27	0 h	0 (h)	—	—	—	—	—	—	0
28	—	—	0 a(h)	3 h	2	0	0	5	—
29	—	—	3 a(h)	5 h	5	8	1	0	—
30	—	—	0 a(h)	0 h	0	1	0	0	—
31	—	—	0 a(h)(a)	12 h	7	2	4	3 d	—
32	—	—	0 a(h)	1 h	0	0	0	0	—
33	—	—	0 a(h)	0 h	0	0	0	[illegible]	—
34	—	—	0 a(h)	0 h	0	1	2	[illegible]	—
Total	43	27	86	171	106	184	66	145	28
	Rounds Counted by Man Number								
1	64	80	68	74	149	59	174	113	63
2	58	70	34	84	102	66	108	94	110
3	81	70	55	33	181	143	121	106	96
4	0	144	47	72	[illegible]	71	148	112	98
5	0	88	54	64	31	50	77	63	86
6	22	76	73	66	127	91	108	59	123
7	67	129	60	66	80	80	98	78	60
8	88	87	86	60	99	80	128	73	130
9	83	95	68	59	73	76	70	56	96
10	75	38	90	66	97	62	77	54	35
Total	538	901	680	644	1111	767	1098	808	894

TABLE E4 (continued)

Run									
48	40	50	31	52	33	54	55	56	37
Weapon, ammo, and/or firing									
Cbn semi	T48 auto	T48 semi	T48 auto	T48 semi	T48 auto	T48 semi	T48 auto	T48 semi	Duplex
Visibility									
Night	Day	Day	Day	Day	Day	Day	Night	Night	Day
Position									
Sitting	Sitting	Sitting	Sitting	Sitting	Standing	Standing	Sitting	Sitting	Sitting
Squad									
C	D	D	C	C	D	D	C	C	C
Program									
12B-8	4A-9	4B-10	4A-0	4B-10	3A-11	3B-12	9A-11	9B-12	2A-13
Holes Counted by Target and Related Conditions*									
5	—	—	—	—	—	—	20	13	—
0 (r)	—	—	—	—	—	—	0	0	—
1	—	—	—	—	—	—	8	10	—
3	—	—	—	—	—	—	3	2 a	—
—	1	4	1	0	3	5	—	—	7
0	—	—	—	—	—	—	1	3	—
—	6 (e)	28	21	27	11	21	—	—	36
2 r	—	—	—	—	—	—	6	0	—
—	8	10	8	11	3	4	—	—	13
—	10 (e)	21	11 en	32 en	6 en	13 en	—	—	30 e
1 r	—	—	—	—	—	—	0	29	—
0 r	—	—	—	—	—	—	1	1	—
0 03	50	0 e	9 m	17 m	8 m	20 m	4	5	16 m
1	1	4	4	8	4	0 (a)	2 j4½	1	12
0	1	1	0	0	0	0 (a)	0	1	2
1	8 k	0 e	4	0 e	9	13 k	3	2	10
0	—	—	—	—	—	—	0	0	—
0	5 jb	5	7	8	4	8	1	1	5 b
0	7 (b)	2 b	0 1	6	0 b	2 b	4	2	9
3	11	31	23 e	10 e	15 e	18 e	6	10 k	53 e
0	2	0	2	1	0	1	0	1	4
0	0	2	1 m	0 jm	0 m	0 m	0 j3	1 j3e	2 m
0 r	0	—	—	—	—	—	0	0	—
—	0	1	0	0	0	0	—	—	0
0 (r)	0	0	3	0	0	2	0	0	0
0 (r)	—	—	—	—	—	—	0	0	—
0 (r)	—	—	—	—	—	—	0 k1½	0 k1½	—
—	1	2	0	0	1	2	—	—	6
—	5	9	5	4	2	2	—	—	4 j1½
—	0	0 e	0	0 (e)	0	0 (a)	—	—	0
—	0	5	3	6	2	4	—	—	0 j1½
—	0	0	0	0	0	0	—	—	0
—	0	0	0	0	0	0	—	—	8
—	0	2	1 m	1 m	0 m	2	—	—	8 m
17	86	127	108	140	68	118	59	82	209
Rounds Counted by Man Number									
120	66	59	94	63	[illegible]	97	101	110	50
90	79	90	98	84	114	75	115	59	58
90	93	82	150	82	158	108	98	106	44
67	98	79	112	99	122	91	132	77	51
87	76	61	91	80	129	76	95	22	42
88	76	90	127	82	116	74	73	84	67
88	101	79	96	58	160	88	125	84	54
92	40	90	81	64	104	71	88	111	46
88	78	60	119	72	152	88	112	78	52
58	61	50	136	63	108	94	164	95	71
814	768	616	1112	705	1288	840	1082	864	534

TABLE E4 (continued)

Target or man no.	Run 58	Run 59	Run 60	Run 61	Run 62	Run 63
Weapon, ammo, and/or firing	Single bullet	Duplex	Single bullet	Duplex	Single bullet	Duplex
Visibility	Day	Day	Day	Day	Day	Night
Position	Sitting	Sitting	Sitting	Standing	Standing	Sitting
Squad	C	D	D	C	C	D
Program	2B-14	2A-13	2B-14	1A-15	1B-16	10A-15
Holes Counted by Target and Related Conditions*						
1	—	—	—	—	—	45 e
2	—	—	—	—	—	4
3	—	—	—	—	—	5
4	—	—	—	—	.	10 e
5	3	5	5	3	2	—
6	—	—	—	—	—	7
7	9	30	19	26	18	—
8	—	—	—	—	—	17
9	8	18	9	22 k 1%	12 k 1%	—
10	21 n	26 n	24 n	21 ne	12 n	—
11	—	—	—	—	—	0
12	—	—	—	—	—	1 j1%
13	16 m	0 mj	15 m	17 m	17 m	4 j3
14	3	15	7	7	3	3
15	0	0	4	0	0	C
16	9	2	4 k	2	6	8 (k)
17	—	—	—	—	—	0
18	3	13	0 b	14	1 bj	3 cbk
19	3	12	5	5	6 bk	1
20	18 n	41 n	19 n	26 n	17 n	0 n
21	0	0	1	0	0	0 d
22	0 m(n)	8 (n)m	0 m	0 m	2 m	0 n
23	—	—	—	—	—	0
24	0	0	0	0	0	—
25	0	0	2	0	0	1
26	—	—	—	—	—	0
27	—	—	—	—	—	0 e
28	4 (n)j1%	5	3	6	2 (d)	—
29	1 i	6 (n)	1 j1%	3	2	—
30	0	0	0	0 (m)	0 (d)	—
31	1 j1%	7	0 j1%	6	2 (d)	—
32	0	1	0	0	0	—
33	0	2	0	0	0	—
34	1 m	4 m	2 m	0 m	0 m	—
Total	100	196	120	150	108	109
Rounds Counted by Man Number						
1	56	75	72	56	80	88
2	32	59	64	68	58	78
3	63	70	88	61	92	92
4	60	79	64	60	66	118
5	47	72	72	63	84	102
6	56	78	80	85	96	72
7	50	118	88	60	60	129
8	86	63	80	68	80	102
9	63	64	57	50	64	[illegible]
10	82	73	58	78	[illegible]	68
Total	504	768	663	646	730	918

TABLE E4 (continued)

Run						
64	65	66	67	68	69	70
Weapon, ammo, and/or firing						
Single bullet	Single bullet	Duplex	Single bullet	Duplex	Flechette	Flechette
Visibility						
Night	Day	Day	Day	Day	Day	Night
Position						
Sitting	Sitting	Sitting	Sitting	Sitting	Standing	Standing
Squad						
D	E	E	F	F	C	C
Program						
10B-16	1A-1	1B-2	1A-1	1B-2	1A-1	9A-1
Holes Counted by Target and Related Conditions*						
15 e	—	—	—	—	—	9 eq28%
2	—	—	—	—	—	10
4	—	—	—	—	—	13
2 e	—	—	—	—	—	12
—	7 k	7	1 r	1	12	—
2	—	—	—	—	—	8
—	25 k	51	18 re(c)	22 c	19 eq7%	—
6	—	—	—	—	—	13 eq9%
—	12	19	4 r	8	16	—
—	14 en	23 en	11 ren	27 en	7 eeq7%	—
1	—	—	—	—	—	0 e
0 j1%	—	—	—	—	—	3
2 j3	29 m	43 m	6 rm	15 em	0 jm	3 eq9%
1	4	9	5 r	6	2 e	5
1	3	0	0 r	0	5	[illegible]
3 k	8 k	25 k	10 r	10	8	3
0	—	—	—	—	—	5
1 cbk	9 k	11	7 r	[illegible]	8	1
2	11 kb	12	3 r	13	7	1
0 e	47 ag	49 a	28 ra	34 e	6 aq15%	9 jq17%
0 d	3	0	0 r	0	3	1
2 e	5 meg	3 em	1 rme	3 em	5 m	1
0	—	—	—	—	—	0 q3
—	1	1	0 r	1	1	—
1	2	2	2 r	1	1	0 aq15
0	—	—	—	—	—	0 q7%
0 e	—	—	—	—	—	0 q21
—	3	3 e	2 r	2 e	2 e	—
—	7	11	1 r	3	4	—
—	0	0	0 r	0	0	—
—	7	7	5 re	7 e	3 jq12%	—
—	0	4	0 r	0	0 eq7%	—
—	0	0	0 r	0	0 q3	—
—	5 m	2 m	1 rm	0 m	0 amq21	—
65	202	292	106	160	109	90
Rounds Counted by Man Number						
[illegible]	69	76	75	61	24	32
47	30	56	74	54	24	60
111	71	60	80	71	60	60
78	85	72	73	66	36	31
112	78	72	88	105	30	[illegible]
66	64	90	87	65	[illegible]	28
116	115	99	68	[illegible]	25	22
104	105	90	55	[illegible]	35	30
89	86	107	57	53	25	[illegible]
70	131	88	30	50	25	18
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	264	[illegible]

Table E5

Weapon Malfunctions

A. Modified .30-Cal M1 Rifles for both Single-Bullet and Duplex Ammunitions

Run	Ammunition	Firing condition	Post position 1	2	3	4	5	6	7	8	9	10
			Weapon number									
			5970542	5977047	5979031	5976973	5973453	5978746	5978663	5977349	5973971	5978016
1	Single bullet		1 failed to extract	OK	OK	OK	OK	3 failed to feed, 1 failed to eject clip	OK	OK	OK	OK
2	Duplex		2 failed to feed	OK	Insulator forced hammer-spring plunger out of position causing jam	OK	OK	7 failed to feed, 2 failed to extract; 2 failed to eject clip	1 failed to extract	OK	OK	OK
3	Single bullet		OK	OK	OK	OK	OK[a]	OK	OK	OK	OK	OK
4	Duplex		OK	OK	1 failed to extract	OK	OK[b]	1 failed to extract; 1 failed to eject clip	OK	OK	OK	OK
5	Single bullet		OK	OK	OK	1 failed to extract	OK[b]	OK	OK	OK	OK	OK
6	Duplex		5 failed to extract	OK	1 failed to extract	9 failed to extract	OK[b]	OK	OK	OK	OK	1 failed to extract
7	Single bullet		1 failed to extract stripped case	OK	OK	OK	OK[b]	OK	OK	1 failed to eject clip	OK	OK
8	Duplex		7 failed to extract	1 light strike	OK	3 failed to extract	OK[b]	OK	OK	OK	OK	1 light strike
Run	Ammunition	Firing condition	Weapon number									
			5978746	5976973	5977453	5973971	5977559	5978016	5978663	5970542	5973453	5979031
65	Single bullet		OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
66	Duplex		2 failed to extract	OK	2 failed to extract; 2 failed to feed	OK	OK	2 failed to extract	1 failed to extract; 2 failed to feed	1 failed to extract	OK	OK
67[c]	Single bullet		OK	OK	3 failed to feed	OK	OK	OK	OK	OK	OK	10 failed to feed
68[c]	Duplex		5 failed to extract	1 failed to feed	OK	OK	3 failed to extract	2 failed to feed	OK	OK	OK	2 failed to extract

B. Modified .30-Cal M1 Rifle for Duplex and Standard .30-Cal M1 Rifle for Single-Bullet Ammunition

Run	Ammunition	Firing condition	Weapon number[d]									
			5979031 4440195	5973453 4440144	5970542 4440011	5978663 4402985	5978016 4351224	5977559 4440106	5973971 4440059	5977453 4440465	5976973 5948439	5978746 4440006
33	Duplex	Day sitting	OK	OK	3 failed to extract	1 failed to extract	OK	1 failed to feed	OK	1 failed to feed	OK	1 failed to extract
34	Single bullet	Day sitting	4 failed to feed; 1 incomplete strip	1 failed to eject clip	7 failed to feed	1 failed to feed; 1 failed to eject clip	8 failed to feed	1 failed to feed	6 failed to feed (short recoil)	Short recoil, approx 50% of rounds	1 failed to feed	Short recoil, approx 50% of rounds

51	Duplex	Day sitting	1 failed to extract	OK	OK	2 failed to extract (pulled rim)	OK	OK	OK	—	—	1 failed to feed
52	Single bullet	Day sitting	OK	OK	OK	OK	OK	OK	6 failed to feed (2d round)	4 failed to feed	—	Bolt failed to close
53	Duplex	Day sitting	OK	OK	OK	OK	OK	Switch OK after insulation was fixed	2 failed to extract	OK	OK	OK
54	Single bullet	Night sitting	OK	OK	OK	OK	OK	OK	OK	OK	OK	Failed to lock bolt owing to power lack, owing to insulator
55	Duplex	Night standing	OK	1 failed to eject clip	2 failed to extract	OK	OK	OK	OK	2 failed to extract	OK	OK
56	Single bullet	Night standing	OK[e]	2 failed to eject clip	OK[f] (rounds not to rear in clip)	1 failed to feed	1 failed to feed	6 failed to feed, 1 failed to fire	5 failed to feed, 1 failed to eject clip	OK	3 failed to extract	Approx 50% failed to feed
57	Duplex	Day sitting	1 failed to extract	1 failed to extract	6 failed to extract	3 failed to extract	5 failed to extract	OK	1 failed to eject clip; 1 failed to extract	3 failed to extract	2 failed to extract	OK
58	Single bullet	Day sitting	OK	Trigger-wire trouble, sear not releasing hammer	2 failed to feed	2 failed to feed, 1 incompleted strip	2 failed to feed	2 failed to feed	5 failed to feed; 1 stub round	—	—	—
59	Duplex	Day sitting	OK	OK	4 failed to extract	2 failed to extract	1 failed to fire; 1 failed to extract	OK (slight shock)	OK	2 failed to extract	1 failed to extract	OK
60	Single bullet	Day sitting	OK	OK	OK	OK	OK	2 failed to feed	2 failed to feed	2 failed to feed	2 failed to extract	1 failed to feed
61	Duplex	Day standing	OK	1 stub round	6 failed to extract; 1 short recoil	2 failed to extract	OK	OK	1 stub round	1 failed to extract	OK	OK
62	Single bullet	Day standing	—	—	—	1 failed to extract	OK	1 failed to eject clip, 3 failed to feed	8 failed to feed, 2 failed to eject cartridge; 1 short recoil	6 failed to feed	5 failed to extract	1 failed to feed
63	Duplex	Night sitting	OK	1 stub round	1 short recoil; 8 failed to extract	OK	1 failed to extract[g]	OK	OK[h]	1 failed to extract	OK	OK
64	Single bullet	Night sitting	OK	OK	1 short recoil	1 failed to feed (heavy trigger pull)	OK	1 light firing-pin strike; 2 failed to feed	OK	2 failed to feed	1 failed to feed	OK

C. Modified .30-Cal M1 Rifles for both Single-Bullet and Triplex Ammunition

Run	Ammunition	Firing condition	Weapon number									
			5970842[b]	5977047	5979031	5976?73[b]	5977559	5973453	5978663	5977349	5973971	5978016
26	Single bullet		OK	OK	OK	OK	OK	Failed to eject clip	OK	1 failed to feed	OK	OK
27	Triplex		OK	3 failed to extract	Insulator jammed in trigger-housing	OK	OK	1 failed to feed; 1 failed to extract	OK	Insulator jammed in trigger-housing	OK	1 failed to extract
28	Single bullet		OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
29	Triplex		OK	Rifle exploded (replaced with 5977453)	OK	2 failed to feed; 2 failed to extract	2 failed to extract	1 failed to extract, 1 failed to feed	OK	1 failed to extract	OK	3 failed to extract
30	Single bullet		OK	OK[i]	OK	10 failed to extract (bad cam in op rod corrected before next firing)	OK	OK	OK	OK	OK	OK
31	Single bullet		OK	OK[i]	OK	OK	OK	OK	OK	OK	OK	2 failed to extract

TABLE E5 (continued)

D. Carbine .22-Cal Ammunition for both Automatic and Semiautomatic Fire

Run	Ammunition	Firing condition	Post position 1	2	3	4	5	6	7	8	9	10
			Weapon number									
			7434228	7446327	7437445	7195781	7148450	6626072	7149237	7032745	7003668	7003668
17	Semi-automatic		1 failed to feed	1 failed to extract	2 failed to feed, 1 failed to extract	2 failed to extract	2 failed to feed, 3 failed to extract	1 failed to feed	8 failed to extract	2 failed to extract	2 failed to extract	OK
18	Automatic		1 failed to extract	1 failed to extract	OK	1 failed to extract	1 failed to extract	1 bolt failed to close	1 bolt failed to close	4 failed to feed	9 failed to extract (fired only a few rounds)	4 failed to extract
19	Semi-automatic		1 broken extractor	1 broken extractor	1 failed to feed, 1 failed to extract	1 broken extractor	4 failed to extract	2 bolts failed to close	1 bolt failed to close	4 failed to extract	4 failed to feed	OK
20	Automatic		1 failed to feed; 1 failed to extract, 1 broken operating slide	OK	1 doubled feed	[illegible]	Broken extractor	OK	OK	OK	OK	OK
21	Semi-automatic		1 failed to feed	OK	OK	OK	10 failed to extract, 2 failed to fire	1 stub round	1 failed to extract; 1 doubled feed	1 failed to feed	1 failed to extract	OK
22	Automatic		2 misfires, 1 failed to extract; 1 bolt failed to close	1 failed to feed; 1 bad magazine	2 failed to feed	OK	8 failed to extract	2 failed to feed; 1 misfired	4 failed to extract; 3 failed to feed	1 failed to extract, 6 failed to fire	1 failed to extract	5 failed to extract
23	Semi-automatic		1 broken extractor	OK	1 failed to extract	[illegible]	OK	4 failed to feed	2 failed to extract, 1 bad magazine	8 failed to extract	10 failed to feed	1 stub round
24	Automatic		1 broken extractor	OK	7 failed to extract	8 failed to feed	1 failed to extract, 4 failed to feed	2 magazines failed to lock	2 failed to extract	1 broken extractor	OK	3 failed to extract

Run	Ammunition	Firing condition	Weapon number 7434228	7548327	7437445	7195081	7148450	6626072	7149237	7032745	7125359	7176452
61	Automatic		OK	Magazine failed to lock	5 failed to feed	OK	10 failed to feed	1 failed to feed	7 failed to feed; 1 failed to extract, 1 stub round	1 stub round; 2 failed to extract	2 had bolt trouble	OK
62	Semi-automatic		OK	OK	1 broken extractor	1 stub round	OK	OK	2 failed to feed, 1 failed to extract	1 failed to extract; 1 failed to feed, 1 magazine not seated	OK	OK
63	Automatic		1 failed to latch magazine; 1 bolt failed to close	1 broken extractor	8 failed to feed; 3 doubled feed, 3 failed to extract	3 failed to extract, 4 failed to feed	3 failed to extract; 4 failed to eject clip, 8 failed to feed	1 failed to feed; 1 stub round; 1 bolt failed to close	4 failed to eject clip; 7 failed to feed; 1 failed to extract	14 failed to feed, 1 failed to extract, 1 failed to eject clip	4 bolts failed to close, 4 failed to feed	4 bolts failed to close; 4 failed to feed
64	Semi-automatic		1 failed to seat magazine	OK	10 failed to extract	1 failed to feed	2 failed to extract	OK	OK	2 magazines not seated; 1 failed to eject clip	1 failed to feed, 1 failed to extract	2 bolts failed to close
65	Automatic		2 failed to eject clip	4 failed to extract	4 failed to extract	4 failed to extract, 1 broken extractor	1 failed to feed, 1 failed to extract	2 failed to extract (broken extractor)	4 failed to extract; 18 failed to feed; 1 failed to eject clip	8 failed to feed; 1 failed to extract, 2 failed to eject clip	7 failed to feed	14 failed to feed, 2 failed to extract

46	Semi-automatic		OK	4 failed to eject clip	6 failed to extract	OK	1 broken extractor, 6 failed to extract; 2 doubled feed	3 failed to extract	5 failed to extract; 3 failed to eject clip	3 failed to extract	2 failed to feed, 2 failed to extract, 1 bolt failed to close; 1 broken extractor	3 failed to feed, 1 failed to extract
47	Automatic		5 bolts failed to close, 4 doubled feed	4 doubled feed	6 bolts failed to close, 4 failed to extract	3 failed to extract	15 failed to feed; 7 failed to extract	4 failed to eject clip; 3 failed to extract	4 failed to extract; 3 failed to eject clip, 3 failed to feed	5 failed to extract; 3 failed to feed (broken extractor)	1 failed to extract	1 failed to feed
48	Semi-automatic		OK	5 failed to extract; 1 bolt failed to close; 1 broken extractor	1 hand guard loose, 8 failed to feed	5 failed to feed	4 failed to eject clip, 4 failed to extract, 1 light strike	1 failed to eject clip	2 failed to extract	5 failed to extract; 2 failed to feed	OK	OK

E. T48 with .22-Cal Ammunition for both Automatic and Semiautomatic Fire

Run	Ammunition	Firing condition	Weapon number									
			1587	1804	1750	1708	1675	1816	2103	1813	1616	2068
9	Semi-automatic		1 stub round	2 trapped cases	OK	OK	OK	OK	OK	OK	OK	OK
10	Automatic		3 failed to feed	OK	4 failed to extract; closed four clicks for more power	OK	OK	OK	OK	1 failed to extract; 1 incomplete strip	OK	OK
11	Semi-automatic		OK	OK	OK	OK	OK	OK	1 failed to feed	3 failed to feed	1 failed to feed	2 failed to feed
12	Automatic		OK	2 failed to feed	OK	OK	OK	Trapped case	Trapped case	2 failed to extract; closed four clicks	OK	OK
13	Semi-automatic		4 failed to feed	Projectile lodged in barrel	1 failed to feed	1 trapped case	1 failed to feed, closed two clicks	OK	OK	1 failed to feed	OK	OK
14	Automatic		1 failed to fire (broken firing pin)	1 failed to fire (broken firing pin)	1 failed to feed (magazine not loaded correctly)	1 failed to feed (magazine not loaded correctly)	OK	1 trapped case	OK	1 failed to extract	OK	OK
15	Semi-automatic		OK	OK	OK	1 stub round	1 stub round; 3 failed to extract (Note: put in new extractor spring)	OK	OK	1 failed to extract (Note: put in new extractor spring)	3 failed to feed	OK
16	Automatic		1 failed to feed	OK	OK	OK	OK	1 failed to extract	OK	2 failed to extract	OK	OK
49	Automatic	Dry setting	1 short recoil; 1 magazine follower caught over bolt stop	OK	OK	1 short recoil	OK	1 short recoil; 1 failed to feed	OK	2 failed to extract	1 failed to eject clip; 1 bolt failed to close[h]	1 bolt failed to close
50	Semi-automatic	Dry setting	1 magazine follower caught over bolt stop; 1 failed to eject clip	OK	OK	OK	OK	OK	1 short recoil	2 short recoils; 1 failed to extract	OK[h]	OK
51	Automatic	Dry setting	2 bolts failed to close	1 partial strip	OK	1 stub round	2 magazine followers caught over bolt stop; 1 failed to extract	1 failed to eject clip	3 short recoils	9 failed to extract	OK[h]	OK
52	Semi-automatic	Dry setting	1 stub round; 1 bolt failed to close	OK	2 short recoils	2 short recoils	OK	OK	2 stub rounds	2 failed to extract	OK[h]	OK

TABLE E5 (continued)

E. T48 with .22-Cal Ammunition for both Automatic and Semiautomatic Fire

Run	Ammunition	Firing condition	Post position 1	2	3	4	5	6	7	8	9	10
			Weapon number									
			1587	1804	1759	1703	1675	1816	2103	1813	1616	2068
53	Automatic	Day standing	1 failed to latch magazine properly	OK	1 boss not fully home	1 stub round	3 failed to feed, 1 failed to extract; 1 bolt failed to close; 1 stub round	1 stub round	3 stub rounds, 2 failed to feed	2 failed to feed	OK	OK
54	Semi-automatic	Day standing	OK	OK	OK	OK	OK	OK	2 stub rounds	2 failed to extract, 1 magazine follower caught over bolt stop	2 failed to extract[l]	1 bolt failed to close
55	Automatic	Night sitting	OK	1 stub round	5 bolts failed to remain open	OK	1 failed to extract, 6 failed to eject clip	1 failed to feed	OK	2 failed to extract	OK[l]	1 failed to extract
56	Semi-automatic	Night sitting	1 stub round	OK[m]	2 stub rounds	OK	4 failed to extract	OK	OK	1 failed to extract	OK[l]	OK

F. Shotguns with Flechette Ammunition

Run	Ammunition	Firing condition	Post position 1	2	3	4	5	6	7	8	9	10
69[n]	Flechette		OK	OK	1 malfunction	OK	OK	OK	OK	2 malfunctions	OK	OK
70[n]	Flechette		OK	OK	OK	OK	OK	OK	OK	6 malfunctions	OK	OK

[a] Rifle serial number from ammunition and weapon issue forms.
[b] Rifle 5977550 substituted.
[c] Rifles and post positions revised. Rifle 5979081 to position 1, 5973453 to 2, etc.
[d] Upper weapon number is modified; lower weapon number is standard.
[e] Rifle 4440811 substituted.
[f] Rifle 4440195 substituted.
[g] Rifle 5978036 substituted.
[h] The extractor and extractor springs were changed in the M1's before this firing.
[i] Rifle 5977453 substituted.
[j] Rifle 7125359 substituted.
[k] Rifle 1784 substituted.
[l] Rifle 1789 substituted.
[m] Rifle 1616 substituted.
[n] A different malfunction recording system was used for this run. There were no ordnance experts to report malfunctions. Of the 10 observers (one behind each firer) only two reported malfunctions. There are no logged malfunctions.

TABLE E6

SUMMARY RESULTS BY RUN (RAW DATA)

Ammunition or firing	Firing position	Squad A Run	A Hits	A Rounds fired	B Run	B Hits	B Rounds fired	C Run	C Hits	C Rounds fired	D Run	D Hits	D Rounds fired	E Run	E Hits	E Rounds fired	F Run	F Hits	F Rounds fired
Single bullet	Day sitting	1	90	607	3	105	471	34	111	545	36	81	482	65	202	865	67	105	688
		25	157	742	27	144	598	58	100	504	60	120	663	—	—	—	—	—	—
	Day standing	5	81	579	—	—	—	38	110	679	—	—	—	—	—	—	—	—	—
		29	108	747	—	—	—	62	103	720	—	—	—	—	—	—	—	—	—
	Night sitting	—	—	—	7	53	616	—	—	—	40	27	901	—	—	—	—	—	—
		—	—	—	31	41	950	—	—	—	64	45	849	—	—	—	—	—	—
Duplex	Day sitting	2	166	492	4	179	469	33	159	505	35	132	476	66	292	779	68	160	623
		—	—	—	—	—	—	57	209	534	59	195	748						
	Day standing	6	190	667	—	—	—	37	187	635	—	—	—						
		—	—	—	—	—	—	61	158	645	—	—	—						
	Night sitting	—	—	—	8	44	678	—	—	—	39	43	55[illegible]						
		—	—	—	—	—	—	—	—	—	63	109	918						
Triplex	Day sitting	26	301	706	28	201	451	—	—	—	—	—	—						
Carbine																			
Semiautomatic	Day sitting	19	135	758	17	178	640	44	184	767	42	171	644						
	Day standing	—	—	—	21	20[illegible]	985	—	—	—	46	145	808						
	Night sitting	23	42	1034	—	—	—	48	17	814	—	—	—						
Automatic	Day sitting	20	179	1656	18	114	1016	43	106	1111	41	86	630						
	Day standing	—	—	—	22	142	1655	—	—	—	45	66	1093						
	Night sitting	24	26	1463	—	—	—	47	23	886	—	—	—						
T48																			
Semiautomatic	Day sitting	11	143	588	9	97	422	52	140	705	50	127	616						
	Day standing	—	—	—	13	127	736	—	—	—	54	118	849						
	Night sitting	15	85	782	—	—	—	56	82	856	—	—	—						
Automatic	Day sitting	12	102	1056	10	86	824	51	103	1112	49	86	763						
	Day standing	—	—	—	14	91	923	—	—	—	53	68	1385						
	Night sitting	16	75	1444				55	59	1082									
Flechette	Day standing							69	109	264									
	Night standing							70	99	289									

TABLE E7

ROUNDS PER BURST OF AUTOMATIC FIRE

Weapon	Position-illumination combination	Bursts	Rounds	No. of rounds per burst
T48	Day sitting	254	512	
		405	801	
		321	618	
		452	946	
Total		1432	2,877	2.01
T48	Day standing	383	808	
		455	986	
Total		838	1,794	2.14
T48	Night sitting	392	817	
		313	676	
Total		705	1,493	2.12
Carbine	Day sitting	249	641	
		283	868	
		219	462	
		269	698	
Total		1020	2,669	2.62
Carbine	Day standing	550	1,365	
		310	743	
Total		860	2,108	2.35
Carbine	Night sitting	391	1,197	
		253	666	
Total		644	1,863	2.89
Grand total		5499	12,804	2.33

Appendix F

DATA ADJUSTMENT

SUMMARY

In this appendix the term "holes counted" refers to the raw data of holes counted in the target faces, and the term "hits recorded" refers to the raw data of hits electrically recorded on targets. The category "hits adjusted" is used for the adjusted data after compensation for malfunctions, etc. Similarly the category "rounds counted" refers to the raw data of rounds counted for each run, and the category "shots recorded" refers to the electrically recorded numbers of trigger pulls. The category "shots adjusted" is used for the adjusted data after compensation for malfunctions, etc.

The holes counted are taken from Table E4. From run and target totals, corresponding predicted values are computed. The raw value is replaced by the predicted value if (a) the two differ by one standard deviation, and an appropriate malfunction was recorded, or (b) the two differ by three standard deviations.

The shots recorded are proportionally adjusted to agree with the rounds counted for run totals. Then, only for those cases where hit adjustment was made, corresponding shot adjustments were proportionally made. Finally, predicted shot values are computed, and replace recorded values where differing by three standard deviations.

ADJUSTMENT OF HOLES COUNTED, EXCEPT FOR FLECHETTES

It is desirable to adjust the data to compensate for known and suspected malfunctions of weapons, targets, etc., for drastic changes in weather, and for deliberate alterations in target characteristics such as reduction of the amount of concealment.

After the target column in Tables F1 to F19 is the raw holes-counted column. The next column shows a predicted value for each datum based on the line and column totals of the whole table for holes counted for all runs of the same type of fire. This is computed as follows: The sum of the holes counted for all targets in a given run is multiplied by the sum of the holes counted for all runs of the same type for a given target. The product is divided by the total number of holes counted for the entire table (all targets and all runs of that type), to yield the holes predicted for that target and run. The standard deviation σ is computed for each line of holes counted (for each target).

The raw hole count for a target is rejected for either of the following reasons: (a) there is a known malfunction, weather change, or deliberate design change, and the holes-counted value is different from the holes-predicted value by more than one standard deviation; or (b) the holes-counted value is different from the holes-predicted value by more than three standard deviations. (This is intended to eliminate data affected by malfunctions of which no record was made.)

The final column of hits adjusted for each run is composed of the same values as the original raw holes counted except where rejections occurred for the given reasons. Whenever the raw value was rejected the predicted value is substituted in forming the hits-adjusted column. Such changes were made 185 out of a possible 1452 times; i.e., 13 percent of the hit data was adjusted.

ADJUSTMENT OF SHOTS RECORDED, EXCEPT FOR FLECHETTES

The electrically recorded shot record (trigger pulls) provides the only data showing the apportionment of shots to each target. However, the total shots recorded were often different from the total rounds counted for each run because of recording malfunctions.

It is desirable to adjust the totals of the shots-recorded values for the different targets of a single run to equal the appropriate rounds-counted totals, retaining their relative values or ratios for each target. Moreover, it is desirable to correct for the same malfunctions and weather and design changes that were used to adjust the holes counted. (Correction for particular malfunctions of the shot-recording equipment cannot be done because there was no reliable means of identifying such malfunctions.) This is accomplished in Tables F20 to F38, where the raw shots recorded are shown after each target number.

The first operation performed is the change of each shots-recorded value proportionally to bring the total to equal (within rounding errors) the actual rounds counted.

The next column shows the change of each item proportional to the change made from holes counted to hits adjusted for the corresponding target and run of Tables F1 to F19. This takes into account the adjustments made for malfunctions and weather and design changes. Such changes were made in 155 of 1452 possible cases; i.e., for 11 percent of the data. This value is lower than that for hits adjusted because 30 of the shots-recorded items that would normally have been changed were zero, and therefore did not change.

Next a predicted value is computed using the line and column totals for the whole table of the data as adjusted so far (all targets and all runs of the same type of fire). As before, the predicted value is computed by multiplying the sum of the adjusted-to-total-rounds-counted values in a given column by the sum of those for a given line (target) and dividing by the total for the whole table. This yields the shots-predicted value for the given line and column (target and run). The standard deviation σ is computed for each row of adjusted-to-total-rounds-counted data (for each target).

To eliminate unrecorded malfunction effects, all items are rejected where there is a difference between the adjusted values and the predicted values of greater than three standard deviations. There were 36 such changes, none of which coincided with the 155 changes corresponding to hit adjustments. Thus 191 changes out of a possible 1452 were made, or 13 percent of the shot data was adjusted. By coincidence this is the same as the percentage of hit data adjusted.

The final column of shots adjusted for each run is composed of the adjusted-to-total-rounds-counted values except where rejections occurred. Wherever the adjusted value was rejected the predicted value was substituted in forming the shots-adjusted column.

No special treatment was given to zero values for raw shots recorded. Proportional adjustments, of course, left them still zero. As with other numbers, the zero was used in the final shots-adjusted column unless it differed by more than three standard deviations from the predicted value, in which case the predicted value was substituted.

In Tables F1 to F38 are all the raw and the adjusted data (except for flechettes) broken down by weapon, visibility, firing position, and target.

ADJUSTMENT FOR FLECHETTES

In comparing the two flechette runs (one day-standing run and one night-standing run) with corresponding single-bullet runs, the single-bullet information must be balanced with that of the flechette. The single-bullet runs used 22 targets with a standard program. Run 69, the flechette day-standing run, used only 19 targets, and 4 of those appeared for only half the normal program time.

Table F39 shows the shots-fired information equated to the total adjusted ammunition count of 2824. The second column shows the total shots fired per target for the four single-bullet day-standing runs. The fourth column shows the second-column information adjusted to balance with run 69, the one flechette day-standing run. Targets 7, 10, 20, and 31, which were up only half the normal time, actually had approximately half the number of shots fired at them in that time. Similarly, the last column shows the balanced target-holes information.

Table F40 follows a similar pattern in balancing the four single-bullet night-sitting runs against run 70, the one flechette night-standing run.

Table F41 summarizes the adjusted hits and rounds fired by run.

Table F1

ADJUSTMENT OF HOLES COUNTED, SINGLE BULLETS, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 1			Run 3			Run 34			Run 36				
5	4	3.0		3	3.5		4	3.7		2	2.7		2.3	6.8
7	14	13.9		21	16.2		18	17.2		5	12.5		8.3	24.8
0	8	6.2		8	7.3		11	7.7		4	5.6		3.1	9.3
10	10	11.0		15	13.4		10	14.2		0	10.3		4.7	14.0
13	0	8.3		3	9.7		18	10.2		0	7.5		0.7	26.0
14	2	2.8		1	3.0	3.0	6	3.2		3	2.3		1.0	5.7
15	0	0.6		0	0.7		0	0.7		1	0.5		1.4	4.2
16	7	4.4		5	5.1		3	5.4		1	3.0		2.8	8.3
18	2	3.6		4	4.1		5	4.4		13	2.2	2.2	3.7	11.2
19	7	5.3		12	6.2		2	6.6		7	4.6		3.0	11.7
20	23	10.8		24	22.8		12	24.1		25	17.6		0.5	28.5
21	3	0.7		0	0.0		0	0.0		0	0.7		1.1	3.8
22	1	0.9		0	1.0		1	1.1		0	0.8		1.7	5.2
24	0	0.1		0	0.2		0	0.2		1	0.1		0.6	1.9
25	1	0.8		0	1.0	1.0	0	1.0		2	0.7		0.9	2.6
28	0	1.8	1.8	1	2.1		2	2.2		3	1.6		1.2	3.8
29	4	2.4		3	0.3		5	3.0		3	2.2		1.9	5.7
30	0	0.1		0	0.1		1	0.1	0.1	0	0.1		0.3	0.0
31	2	1.9		0	2.2		2	2.4		0	1.7		2.5	7.4
32	1	0.4		0	0.4		2	0.5		1	0.3		0.7	2.0
33	1	0.1	0.1	0	0.1		0	0.1		0	0.1		0.3	0.0
34	0	1.8		8	2.1		3	2.2		1	1.6		1.7	5.1
Total	90		90.0	105		108	111		110.1	81		71.2		
	Run 25			Run 27			Run 58			Run 60				
8	8	5.3	5.3	3	4.0		3	3.4		6	4.0		2.3	6.8
7	28	24.3		34	22.3	22.2	0	15.9		10	18.6		8.3	24.8
0	14	10.9		6	10.0		6	8.9		0	8.3		3.1	0.3
10	16	20.0		14	18.4		21	12.0	12.0	24	10.3	15.3	4.7	14.0
13	13	14.5		12	13.3		10	0.2		18	11.1		6.7	26.0
14	1	4.5	4.5	2	4.1		3	2.0		7	3.5		1.0	5.7
15	0	1.0		0	0.0		0	0.7		4	0.8		1.4	4.2
16	8	7.6		4	7.0		9	4.9		4	5.8		2.6	8.3
10	4	8.2		1	0.7		3	4.0		0	4.7	4.7	3.7	11.2
19	8	9.2		14	8.5		3	5.0		5	7.1		3.9	11.7
20	32	34.1		36	31.3		16	21.7		10	26.1		9.5	26.5
21	2	1.3		1	1.2		0	0.0		1	1.0		1.2	3.5
72	4	1.6		0	1.4		0	1.0		0	1.2		1.7	8.2
24	0	0.2		0	0.2		0	0.2		0	0.2		0.6	1.0
25	2	1.4		0	1.3		0	0.9		2	1.1		0.9	2.8
28	2	3.1		4	2.8		4	2.0	2.0	3	2.4		1.2	2.8
29	5	4.2		3	3.0		1	2.7		1	3.2	3.3	1.6	8.7
30	0	0.1		0	0.1		9	0.1		0	0.1		0.3	0.9
31	7	3.4		6	3.1		1	2.1		0	2.6	2.6	2.8	7.4
32	0	0.6		1	0.6		0	0.4		0	0.5		0.7	2.0
33	8	0.1		9	0.1		0	0.1		0	6.1		0.3	0.9
34	4	3.1		2	2.[illegible]		1	2.0		2	2.4		1.7	5.1
Total	157		156.8	144		132.2	100		89.6	120		120.9		

Table F1 (continued)

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 65			Run 67			Run			Run				
5	7	6.8		1	3.5	3.3							2.3	0.8
7	25	31.3		18	10.2								8.3	34.8
9	12	14.0		4	7.3	7.3							3.1	0.3
10	14	25.8	25.8	11	13.4								4.7	14.0
13	20	13.6	18.0	6	0.7								0.7	26.0
14	4	5.8		5	3.0	3.0							1.9	5.7
15	3	1.3		0	0.7								1.4	4.2
16	8	9.0		10	5.1	5.1							2.8	0.3
18	9	8.0		7	4.1								3.7	11.2
19	11	12.0		3	6.2								3.0	11.7
20	47	43.9		28	22.8								9.5	28.5
21	3	1.7		0	0.9								1.1	3.5
22	5	2.0	2.0	1	1.0								1.7	5.2
24	1	0.3		0	0.2								0.0	1.0
25	2	1.8		2	1.0	1.0							0.0	3.8
20	3	4.0		2	2.1								1.2	3.6
20	7	5.5		1	2.0								1.9	5.7
30	0	0.2		0	0.1								0.3	0.0
31	7	4.3		5	2.2								2.[illegible]	7.4
32	0	0.8		0	0.4								0.7	2.0
33	0	0.2		0	0.1								0.3	0.0
34	5	4.0		1	2.1								1.7	5.1
Total	202		200.4	105		100.1								

Table F2

ADJUSTMENT OF HOLES COUNTED, SINGLE BULLETS, DAY STANDING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 5			Run 29			Run 38			Run 03				
5	2	2.4		2	3.2		0	3.[illegible]		2	3.1		1.7	5.2
7	15	12.7	12.7	15	10.0	10.9	15	1[illegible].2		18	16.1		1.3	3.9
9	0	5.2	5.2	0	7.0		0	7.1		13	0.7	0.7	4.3	13.0
10	19	12.0	12.9	14	17.2	17.2	10	17.5		12	16.4	10.4	3.1	0.2
13	3	8.3		13	11.0		8	11.3		17	10.5	10.5	5.3	15.6
14	5	4.0		6	6.2		9	6.3		3	5.9		2.2	0.5
15	1	0.6		1	0.0		1	0.8		0	0.8		0.4	1.3
16	3	3.2		4	4.3		3	4.4		0	4.1		1.3	3.7
10	2	1.8		4	2.4		2	2.5		1	2.3		1.1	3.3
10	10	0.0		11	0.9		0	0.0		6	8.5		3.3	6.8
20	13	14.3		21	19.1		20	19.4		17	10.2		3.1	0.3
21	1	0.6		1	0.0		1	6.8		0	0.8		0.4	1.3
22	0	0.6		0	0.8		1	0.6		2	0.8	0.6	0.6	2.5
24	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
25	1	1.2		4	1.6		1	1.0		0	1.5		1.5	4.5
20	1	2.0		4	2.7		3	2.7		2	3.6		1.1	3.4
20	3	2.2		0	3.0	3.0	5	3.0		3	2.8		0.8	2.5
30	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
31	2	1.3		0	1.0		3	1.0		2	1.5		0.0	2.6
32	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.6
33	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
34	0	0.4		0	0.5	0.5	3	0.5	6.5	0	0.5	0.5	0.15	0.45
Total	81		77.8	108		116.6	110		108.3	102		98.7		

Table F3

ADJUSTMENT OF HOLES COUNTED, SINGLE BULLETS, NIGHT SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 7			Run 3[illegible]			Run 40			Run 64				
1	24	20.8		11	16.1		15	10.6		15	17.6		4.8	14.3
2	0	2.2		3	1.7		2	1.1		2	1.9		1.1	3.3
3	11	8.9		9	6.9		4	4.6		4	7.6		3.1	9.2
4	0	1.9	1.9	3	1.5		1	1.0		2	1.6		1.1	3.4
6	2	2.9	2.9	3	2.2		2	1.5	1.5	2	2.4		0.4	1.3
8	11	6.7	6.7	4	5.2		0	3.4		6	5.7		4.0	11.9
11	0	0.6	0.6	1	0.5		0	0.3		1	0.5		0.5	1.5
12	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
13	1	1.3		0	1.0	1.0	1	0.7		2	1.1	1.1	0.7	2.1
14	2	1.3		1	1.0		0	0.7		1	1.1		0.7	2.1
15	1	0.8		0	0.5		0	0.3		1	0.5		0.5	1.5
16	0	1.0		0	0.7		0	0.5		3	0.8	0.8	1.3	3.9
17	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
18	0	0.6	0.6	0	0.5		1	0.3	0.3	1	0.5		0.5	1.5
19	0	1.3	1.3	2	1.0		0	0.7		2	1.1		1.0	3.0
20	1	1.[illegible]		4	1.5		1	1.0		0	1.6	1.6	1.5	4.5
21	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
22	0	0.8		0	0.5		0	0.3		2	0.5	0.5	0.9	2.6
23	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
25	0	0.3		0	0.2		0	0.2		1	0.3		0.4	1.3
26	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
27	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
Total	53		56.2	41		42.0	27		25.8	45		42.0		

Table F4
ADJUSTMENT OF HOLES COUNTED, DUPLEX, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 2			Run 4			Run 57			Run 59				
5	5	4.3		6	1.4		7	5.4		5	5.0		2.0	6.1
7	30	26.2		27	26.8		30	33.0		30	30.0		9.9	29.8
0	17	12.4		15	12.7		13	15.6		18	14.6		3.8	11.3
10	22	22.7		41	23.3	23.3	30	28.6		26	26.7		9.3	26.0
13	1	11.9		0	12.2		16	14.9		0	13.0	13.9	13.3	40.0
14	6	7.4		2	7.6	7.8	12	9.3		15	8.7		3.7	11.1
15	0	0.3		0	0.3		2	0.4		0	0.4		0.7	2.1
16	8	8.7		8	8.9		10	11.0		2	10.3		0.3	19.0
16	5	7.6		7	7.8		5	9.6	9.0	13	8.9		3.4	10.2
19	14	9.7		9	10.0		9	12.3		12	11.4		3.6	10.8
20	34	35.3		40	36.1		53	44.4	44.4	41	41.4		7.7	23.2
21	4	1.7		7	1.7		4	2.1		0	2.0		2.6	7.7
22	2	2.1		0	2.2		2	2.7		8	2.5	2.5	2.4	7.2
24	0	0.2		0	0.2		0	0.3		0	0.3		0.4	1.3
25	0	0.8		0	0.8		0	1.0		0	0.9		0.9	2.6
28	2	3.6		0	3.1		6	3.8		5	3.6		2.0	6.0
29	12	6.0		5	6.2		4	7.6	7.8	8	7.1		3.0	9.0
30	0	0.4		0	0.5		0	0.6		0	0.5		0.9	2.0
31	0	2.8		0	2.9		0	3.5		7	3.3		3.1	9.4
32	2	0.8		0	0.8		0	1.0		1	0.9		1.4	4.1
33	0	0.2		0	0.2		0	0.3		2	0.3		0.7	2.0
34	2	1.3		3	1.4		0	1.7	1.7	4	1.6	1.8	1.4	4.2
Total	166		166	170		157.9	209		213.8	195		201.0		
	Run 33			Run 35			Run 00			Run 68				
5	5	4.1		2	3.4		7	7.5		1	4.1		2.0	0.1
7	19	25.1		19	20.8		51	46.1		22	25.2		9.9	29.0
0	11	11.9		10	9.9		19	21.9		8	12.0		3.8	11.3
10	11	21.8		13	18.1		33	40.0		27	21.9		9.3	28.0
13	18	11.4		13	9.4		43	20.9	20.9	15	11.4		13.3	40.0
14	8	7.1		8	5.9		9	13.0		6	7.1		3.7	11.1
10	0	0.3		1	0.3		0	0.0		0	0.3		0.7	2.1
16	10	8.4		5	8.9		25	15.4	15.4	10	8.4		6.3	19.0
18	6	7.3		14	6.1	6.1	11	13.4		7	7.3		3.4	10.2
19	15	9.3		3	7.7		12	17.1		13	9.4		3.0	10.0
20	36	33.9		28	28.0		49	62.0	62.0	34	40.0		7.7	23.2
21	0	1.8		0	1.3		0	3.0		0	1.6		2.6	7.7
22	1	2.0		0	1.7		3	3.7		3	2.0		2.4	7.2
24	0	0.2		0	0.2		1	0.4		1	0.2		0.4	1.3
25	2	0.8		2	0.0		2	1.4		1	0.0		0.9	2.8
20	6	2.9	2.9	3	2.4		3	5.3	5.3	2	2.9		2.0	6.0
29	6	5.8		7	4.8		11	10.6		3	5.6		3.0	9.0
30	2	0.4	0.4	2	0.4	0.4	0	0.8		0	0.4		0.9	2.6
31	2	2.7		2	2.2		7	4.9		7	2.7	2.7	3.1	9.4
32	0	0.8		0	0.8		4	1.4		0	0.8		1.4	4.1
33	0	0.2		0	0.2		0	0.4		0	0.2		0.7	2.0
34	1	1.3		0	1.1		2	2.4		0	1.3		1.4	4.2
Total	159		154.3	132		122.0	292		275.6	100		150.7		

Table F5

ADJUSTMENT OF HOLES COUNTED, DUPLEX, DAY STANDING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 6			Run 37			Run 61			Run				
5	9	6.0		5	5.9		3	5.0					2.5	7.5
7	40	10.1		37	39.5		26	33.4					9.8	29.4
9	9	13.9		8	13.6		22	11.5	11.5				6.4	19.1
10	25	21.7		15	21.3	21.3	21	18.0					4.1	12.3
13	0	11.7	11.7	16	11.5		17	9.7					7.8	23.4
14	10	8.2	8.2	6	8.0		7	6.8					1.7	5.1
15	0	0.4		1	0.3		0	0.3					0.5	14.1
16	3	3.6		5	3.5		2	3.0					1.2	3.7
18	2	7.8	7.8	6	7.7		14	6.5					5.0	15.0
19	13	9.2		8	9.1		5	7.7					3.3	9.9
20	35	41.9		37	41.2		26	34.8					13.0	39.1
21	1	0.4		0	0.3		0	0.3					0.5	14.1
22	0	1.8		5	1.7		0	1.5					2.4	7.1
24	0	0.0		0	0.0		0	0.0					0.0	0.0
25	0	0.0		0	0.0		0	0.0					0.0	0.0
28	1	3.2		2	3.1		6	2.7					2.2	6.5
29	29	13.9	13.9	7	13.6		3	11.5					11.4	34.3
30	0	0.0		0	0.0		0	0.0					0.0	0.0
31	2	6.0	6.0	9	5.9		6	5.0					2.9	8.6
32	0	0.0		0	0.0		0	0.0					0.0	0.0
33	0	0.0		0	0.0		0	0.0					0.0	0.0
34	1	0.1		0	0.3		0	0.3					0.5	14.1
Total	190		181.7	187		193.3	158		147.5					

Table F6

ADJUSTMENT OF HOLES COUNTED, DUPLEX, NIGHT SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 8			Run 39			Run 63			Run				
1	9	15.9		17	15.6		45	39.5					15.4	46.3
2	2	1.3		0	1.3		4	3.3					1.6	4.9
3	14	6.3		9	6.1		5	15.6					3.7	11.0
4	0	3.6		6	3.5		10	8.9					4.1	12.3
6	6	3.6		3	3.5		7	8.9					1.7	5.1
8	6	5.2		0	5.0		17	12.8					7.0	21.1
11	0	0.2		1	0.2		0	0.6					0.5	14.1
12	1	0.4		0	0.4		1	1.1					0.7	2.2
13	4	2.2		2	2.2		4	5.6	5.6				0.9	2.8
14	1	1.3		2	1.3		3	3.3					0.8	2.4
15	0	0.0		0	0.0		0	0.0					0.0	0.0
16	0	1.8		0	1.8		8	4.4					3.8	8.3
17	0	0.0		0	0.0		0	0.0					0.0	0.0
18	0	0.7		0	0.7		3	1.7					1.4	4.2
19	1	0.4		0	0.4		1	1.1					0.5	14.1
20	0	0.4		2	0.4	0.4	0	1.1	1.1				0.9	2.8
21	0	0.0		0	0.0		0	0.0					0.0	0.0
22	0	0.0		0	0.0		0	0.0					0.0	0.0
23	0	0.0		0	0.0		0	0.0					0.0	0.0
25	0	0.4		1	0.4	0.4	1	1.1					0.5	14.1
26	0	0.0		0	0.0		0	0.0					0.0	0.0
27	0	0.0		0	0.0		0	0.0					0.0	0.0
Total	44		44	43		40.8	109		111.7					

Table F7

ADJUSTMENT OF HOLES COUNTED, TRIPLEX, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 26			Run 28			Run			Run				
5	6	9.6	9.8	10	6.4	6.4							2.0	6.0
7	51	54.0		30	36.0								6.0	18.0
8	25	22.8		13	15.2								6.0	18.0
10	47	42.6		14	28.4								11.5	34.5
13	25	15.0		0	10.0								12.5	37.5
14	7	7.2		5	4.8								1.0	3.0
15	0	0.0		0	0.0								0.0	0.0
16	1	12.0		19	0.0								0.2	27.0
16	8	12.0		12	8.0								2.0	6.0
10	17	21.0	21.0	18	14.0	14.0							0.5	1.5
20	87	73.2		55	48.8	48.8							6.0	18.0
21	4	2.4		0	1.6								2.0	6.0
22	2	1.2		0	0.8								1.0	3.0
24	1	0.6		0	0.4								0.5	1.5
25	3	1.8		0	1.2								1.5	4.5
26	8	6.0		2	4.0								3.0	9.0
29	8	5.4		1	3.6								3.5	10.5
30	0	0.0		0	0.0								0.0	0.0
31	12	9.0		3	6.0								4.5	13.5
32	1	0.6		0	0.4								0.5	1.5
33	0	0.0		0	0.0								0.0	0.0
34	8	4.8		0	3.2								4.0	12.0
Total	301		309.6	201		176.2								

Table F8

ADJUSTMENT OF HOLES COUNTED, CARBINE AUTOMATIC, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 18			Run 20			Run 41			Run 43				
5	5	8.8		11	10.7		3	5.1		10	0.3		3.3	10.0
7	12	15.0		21	23.6		21	11.3	11.3	10	14.0		5.0	15.1
0	7	8.5		16	13.3		5	6.4		8	7.0		4.2	12.5
10	17	12.5	12.5	15	10.6	10.6	11	9.4		10	11.6		2.0	8.6
13	13	9.2	9.2	12	14.4		7	6.0		7	8.5		2.8	8.3
14	11	5.2	5.2	5	8.1		1	3.9		5	4.8		3.6	10.7
15	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
15	5	5.6		6	8.0		2	4.3		9	5.2	5.2	2.7	8.2
16	0	0.2	9.2	11	14.4		24	6.9	6.9	4	8.5		9.1	27.4
10	9	9.9		28	15.5	15.5	3	7.4		2	0.2		10.5	31.4
20	23	11.8		1	18.5	18.5	0	8.9		20	10.9		9.2	27.7
21	4	1.2		0	1.8	1.8	0	0.0		1	1.1		1.6	4.9
22	0	5.2		19	8.1	8.1	0	3.9		3	4.8		7.9	23.7
24	2	0.9	0.0	1	1.5		0	0.7		1	0.9		0.7	21.2
25	0	1.9		6	3.0	3.0	0	1.4		2	1.7		2.4	7.3
26	1	1.9		5	3.0	3.0	0	1.4		2	1.7		1.0	5.6
20	3	4.5		8	7.0		3	3.4		5	4.2		2.0	6.1
30	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
31	1	4.0		9	6.3		0	3.0		7	3.7		3.8	11.5
32	0	0.7		3	1.1	1.1	0	0.5		0	0.7		1.3	3.9
33	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
34	1	0.2		0	0.4		0	0.2		0	0.2		0.4	1.3
Total	114		108.0	179		172.6	86		59.2	104		102.2		

Table F9

ADJUSTMENT OF HOLES COUNTED, CARBINE AUTOMATIC, DAY STANDING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
		Run 22			Run 45			Run			Run			
5	11	8.9		2	4.1								4.5	13.5
7	32	30.0		12	14.0								10.0	30.0
9	7	8.2		5	3.8								1.0	3.0
10	9	9.6		5	4.4								2.0	6.0
13	14	15.0		5	7.0								8.3	25.0
14	3	4.8	4.8	4	2.2	2.2							0.5	1.5
15	0	0.0		0	0.0								0.0	0.0
10	7	6.8		3	3.2								2.0	6.0
18	8	7.5		3	3.5								2.5	7.4
19	5	8.2	8.2	7	3.8	3.8							1.0	3.0
20	22	19.8		7	9.2								7.5	22.5
21	2	1.4		0	0.6								1.0	3.0
22	1	2.0		2	1.0	1.0							0.5	1.5
24	1	0.7		0	0.3								0.5	1.5
25	4	3.4		1	1.6								1.5	4.5
28	5	3.4		0	1.6								2.5	7.5
29	3	2.7		1	1.3								1.0	3.0
30	0	0.0		0	0.0								0.0	0.0
31	4	5.5	5.5	4	2.5	2.5							0.0	0.0
32	0	0.0		0	0.0								0.0	0.0
33	0	0.0		0	0.0								0.0	0.0
34	4	4.1		2	1.9								1.0	3.0
Total	142		159.[illegible]	66		58.5								

Table F10

ADJUSTMENT OF HOLES COUNTED, CARBINE AUTOMATIC, NIGHT SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
		Run 24			Run 47			Run			Run			
1	4	4.2	4.2	4	7.1	7.1							0.0	0.0
2	8	3.7		[illegible]	6.2								2.5	7.5
3	5	8.5		11	14.2								3.0	9.0
4	3	2.7		2	4.4	4.4							0.5	1.5
6	0	0.0		0	0.0								0.0	0.0
8	0	0.0		0	0.0								0.0	0.0
11	4	2.7		1	4.4								1.5	4.5
12	0	0.0		0	0.0								0.0	0.0
13	0	0.5		1	0.9								0.5	1.5
14	0	0.0		0	0.0								0.0	0.0
15	0	0.0		0	0.0								0.0	0.0
16	0	0.0		0	0.0								0.0	0.0
17	0	0.0		0	0.0								0.0	0.0
18	0	0.5		1	0.9								0.5	1.5
19	0	0.0		0	0.0								0.0	0.0
20	4	3.2		2	5.3	5.3							1.0	3.0
21	0	0.0		0	0.0								0.0	0.0
22	0	0.0		0	0.0								0.0	0.0
23	0	0.0		0	0.0								0.0	0.0
25	0	0.0		0	0.0								0.0	0.0
26	0	0.0		0	0.0								0.0	0.0
27	0	0.0		0	0.0								0.0	0.0
Total	26		26.2	23		31.8								

Table F11

ADJUSTMENT OF HOLES COUNTED, CARBINE SEMIAUTOMATIC, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 17			Run 19			Run 42			Run 44				
5	3	4.0		4	3.0		2	3.8	3.8	6	4.1		1.5	4.4
7	30	28.8		18	21.8		30	27.6		30	29.7		5.2	15.0
9	14	10.4		9	7.9		16	10.0		0	10.7	10.7	6.2	18.5
10	16	24.0	24.0	16	18.2		28	23.0		30	24.8		6.5	19.6
13	14	7.7		3	5.9		0	7.4	7.4	12	8.0		5.9	17.7
14	0	2.9		3	2.2		7	2.8	2.8	1	3.0		2.7	8.0
15	0	0.3		0	0.2		0	0.3		1	0.3		0.4	1.3
16	8	13.1		7	9.9		8	12.5		26	13.5	13.5	7.9	23.8
18	3	5.6	5.6	3	4.2		9	5.4	5.4	6	5.8		2.5	7.5
19	21	12.8	12.8	4	9.7		12	12.3		11	13.2		0.0	18.1
20	45	40.8	45.0	37	30.9		25	39.2	33.2	46	42.1		8.4	25.2
21	0	1.1		2	0.8		2	1.0		0	1.1		1.0	3.0
22	0	1.6		1	1.2		2	1.5		3	1.7		1.1	3.4
24	0	0.5		1	0.4		1	0.5		0	0.6		0.5	1.5
25	1	3.5		4	2.6		8	3.3	3.3	0	3.6		3.1	9.3
28	7	4.5		7	3.4		3	4.4		0	4.7		2.9	8.8
29	11	5.1		10	6.9		5	8.7	8.7	8	9.4		2.3	6.9
30	0	0.5		1	0.4		0	0.5		1	0.6		0.5	1.5
31	1	4.8		3	3.6		12	4.6	4.0	2	5.0		4.4	13.2
32	2	1.1		1	0.8		1	1.0		0	1.1		0.7	2.1
33	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
34	2	1.1		1	0.8		0	1.0	0.7	1	1.1		0.7	2.1
Total	178		177.0	135		135	171		178.9	184		182.2		

Table F12

ADJUSTMENT OF HOLES COUNTED, CARBINE SEMIAUTOMATIC, DAY STANDING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 21			Run 46			Run			Run				
5	4	7.0	7.0	8	5.0								2.0	6.0
7	31	33.2		26	23.8								2.5	7.5
9	15	14.0		9	10.0								3.0	9.0
10	20	26.2	26.2	25	18.8								2.5	7.5
13	26	24.4		16	17.0								5.0	15.0
14	8	8.7	8.7	7	6.3								0.5	1.5
15	2	1.2		0	0.8								1.0	3.0
16	4	5.8		6	4.2								1.0	3.0
18	9	5.2		0	3.8								4.5	13.5
19	15	14.0		9	10.0								3.0	9.0
20	42	34.3		17	24.7								12.5	37.5
21	0	0.0		0	0.0	0.0							0.0	0.0
22	0	5.2		9	3.8	3.8							4.5	13.5
24	3	1.7		0	1.3								1.5	4.5
25	4	4.7	4.7	4	3.3	3.3							0.0	0.0
28	3	4.7		5	3.3								1.0	3.0
29	9	5.2		0	3.8								4.5	13.5
30	1	0.6		0	0.4								0.5	1.5
31	5	4.7		3	3.3								1.0	3.0
32	0	0.0		0	0.0								0.0	0.0
33	0	0.0		0	0.0								0.0	0.0
34	1	1.2	1.2	1	0.8								0.0	0.9
Total	202		212.8	145		138.8								

Table F13

ADJUSTMENT OF HOLES COUNTED, CARBINE SEMIAUTOMATIC, NIGHT SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 23			Run 48			Run			Run				
1	18	16.4		5	6.6								6.5	19.5
2	2	1.4		0	0.6								1.0	3.0
3	6	5.0		1	2.0								2.5	7.5
4	0	2.1		3	0.9								1.5	4.5
6	6	4.3		0	1.7								3.0	9.0
8	1	2.1		2	0.9	0.9							0.5	1.5
11	1	1.4	1.4	1	0.6	0.6							0.0	0.0
12	0	0.0		0	0.0								0.0	0.0
13	1	0.7		0	0.3								0.5	1.5
14	1	1.4	1.4	1	0.6	0.6							0.0	0.0
15	1	0.7		0	0.3								0.5	1.5
16	1	1.4	1.4	1	0.6	0.6							0.0	0.0
17	0	0.0		0	0.0								0.0	0.0
18	0	0.0		0	0.0								0.0	0.0
19	1	0.7		0	0.3								0.5	1.5
20	3	4.3	4.3	3	1.7	1.7							0.0	0.0
21	0	0.0		0	0.0								0.0	0.0
22	0	0.0		0	0.0								0.0	0.0
23	0	0.0		0	0.0								0.0	0.0
25	0	0.0		0	0.0								0.0	0.0
26	0	0.0		0	0.0								0.0	0.0
27	0	0.0		0	0.0								0.0	0.0
Total	42		44.5	17		13.4								

Table F14

ADJUSTMENT OF HOLES COUNTED, T48 AUTOMATIC, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 10			Run 12			Run 49			Run 51				
5	9	3.2	3.2	3	3.8		1	3.2		1	3.8		3.3	9.8
7	22	15.7		20	18.7		6	15.7	15.7	21	18.9		6.5	19.6
9	4	6.2		7	7.3		8	6.2		8	7.4		1.6	4.9
10	18	10.7	10.7	8	12.7	12.7	10	10.7		11	12.8		3.8	11.3
13	7	10.9		12	13.0		20	10.9		9	13.1		4.9	14.8
14	0	2.5	2.5	6	3.0	3.0	1	2.5		4	3.0		2.4	7.2
15	0	0.2		0	0.3		1	0.2		0	0.3		0.4	1.3
16	3	4.6		5	5.4		8	4.6	4.6	4	5.5		1.9	5.6
18	7	6.4		9	7.6		5	6.4		7	7.6		1.4	4.2
19	6	5.5		11	6.5		7	5.5		0	6.6	6.6	3.9	11.8
20	0	10.7	10.7	13	12.7		11	10.7		23	12.8	12.3	8.2	24.5
21	2	1.4		0	1.6		2	1.4		2	1.6		1.1	3.4
22	0	0.2		0	0.3		0	0.2		1	0.3	0.3	0.4	1.2
24	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
25	0	0.7		0	0.8		0	0.7		3	0.8		1.3	3.9
28	0	0.2		0	0.3		1	0.2		0	0.3		0.4	1.3
29	2	3.6		1	4.3		5	3.6		5	4.4		1.2	3.7
30	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
31	6	2.5		2	3.0		0	2.5		3	3.0		2.2	6.5
32	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
33	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
34	0	0.7		2	0.8		0	0.7		1	0.8		0.8	2.5
Total	88		86.1	102		103.7	86		92.3	103		98.7		

Table F15

ADJUSTMENT OF HOLES COUNTED, T48 AUTOMATIC, DAY STANDING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 14			Run 53			Run			Run				
5	3	1.4	3.4	3	2.6	2.6							0.0	0.0
7	17	16.0		11	12.0								3.0	9.0
9	4	4.0		3	3.0								0.5	1.5
10	16	12.6		6	9.4								5.0	15.0
13	13	12.0		8	9.0								2.5	7.5
14	3	4.0	4.0	4	3.0								0.5	1.5
15	0	0.0		0	0.0								0.0	0.0
16	2	6.3		9	4.7								3.5	10.5
18	20	13.7		4	10.3								8.0	24.0
19	5	2.9		0	2.1								2.5	7.5
20	0	8.6		15	6.4	6.4							7.5	22.5
21	0	0.0		0	0.0								0.0	0.0
22	0	0.0		0	0.0								0.0	0.0
24	0	0.0		0	0.0								0.0	0.0
25	0	0.0		0	0.0								0.0	0.0
28	2	1.7		1	1.3								0.5	1.5
29	2	2.3		2	1.7	1.7							0.0	0.0
30	0	0.0		0	0.0								0.0	0.0
31	3	2.9		2	2.1								0.5	1.5
32	0	0.0		0	0.0								0.0	0.0
33	0	0.0		0	0.0								0.0	0.0
34	1	0.6		0	0.4								0.5	1.5
Total	91		91.4	68		58.7								

Table F16

ADJUSTMENT OF HOLES COUNTED, T48 AUTOMATIC, NIGHT SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 16			Run 55			Run			Run				
1	17	20.7		20	16.3								1.5	4.5
2	4	2.2		0	1.8								2.0	6.0
3	5	7.3		8	5.7								1.5	4.5
4	16	10.6		3	8.4								6.5	19.5
6	5	3.4		1	2.6								2.0	6.0
8	13	10.6		6	8.4								3.5	10.5
11	0	0.0		0	0.0								0.0	0.0
12	3	2.2		1	1.8								1.0	3.0
13	4	4.5	4.5	4	3.5	3.5							0.0	0.0
14	3	2.8		2	2.2								0.5	1.5
15	0	0.0		0	0.0								0.0	0.0
16	2	2.8		3	2.2								0.5	1.5
17	0	0.0		0	0.0								0.0	0.0
18	1	1.1	1.1	1	0.9	0.9							0.0	0.0
19	0	2.2		4	1.8								2.0	6.0
20	2	4.5		6	3.5								2.0	6.0
21	0	0.0		0	0.0								0.0	0.0
22	0	0.0		0	0.0								0.0	0.0
23	0	0.0		0	0.0								0.0	0.0
25	0	0.0		0	0.0								0.0	0.0
26	0	0.0		0	0.0								0.0	0.0
27	0	0.0		0	0.0								0.0	0.0
Total	75		75.6	59		58.4								

Table F17

ADJUSTMENT OF HOLES COUNTED, T48 SEMIAUTOMATIC, DAY SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 9			Run 11			Run 50			Run 52				
5	4	3.1		8	4.5	4.5	4	4.0		0	4.4		2.8	8.5
7	20	17.2		15	25.4	25.4	28	22.5		27	24.9		5.3	15.9
9	9	8.6		15	12.7		10	11.3		11	12.4		2.3	6.8
10	17	16.5		16	24.3	24.3	21	21.5		32	23.7	23.77	6.3	18.7
13	9	7.3		12	10.7		0	9.5	9.5	17	10.5	10.5	6.2	18.6
14	1	4.0		8	5.9		4	5.3		8	5.8		2.9	8.8
15	0	0.2		0	0.3		1	0.3		0	0.3		0.4	1.3
16	6	3.1		10	4.5		0	4.0		0	4.4	4.4	4.2	12.7
18	6	5.7		11	8.5		5	7.5		8	8.3		2.3	6.9
19	11	6.9		17	10.2		2	9.0	9.0	6	9.9		5.6	16.8
20	3	14.2	14.2	21	20.9		31	18.6		19	20.4		10.0	30.1
21	1	1.1		4	1.7		0	1.5		1	1.7		3.0	9.0
22	0	0.6		1	0.8		2	0.8		0	0.8		0.8	2.5
24	0	0.2		0	0.3		1	0.3		0	0.3		0.4	1.3
25	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
28	1	1.0		2	1.4		2	1.3		0	1.4		0.8	2.5
29	6	4.0		2	5.9		9	5.3		4	5.8		2.6	7.8
30	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
31	3	2.7		0	3.9		5	3.5		6	3.9		2.3	6.9
32	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
33	0	0.0		0	0.0		0	0.0		0	0.0		0.0	0.0
34	0	0.6		1	1.1		2	1.0		1	1.1		1.0	3.0
Total	97		111.2	113		157.2	127		143.5	140		129.6		

Table F18

ADJUSTMENT OF HOLES COUNTED, T48 SEMIAUTOMATIC, DAY STANDING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 13			Run 54			Run			Run				
5	2	3.6	3.6	5	3.4								1.5	4.5
7	24	23.3		21	21.7								1.5	4.5
9	10	7.3		4	6.7								3.0	9.0
10	15	14.5		13	13.6								1.0	3.0
13	14	17.6	17.6	20	16.4	15.4							3.0	9.0
14	1	0.5		0	0.5								0.5	1.5
15	0	0.0		0	0.0								0.0	0.0
16	2	7.8		13	7.2	7.2							5.5	16.5
18	5	6.7		8	6.3								1.5	4.5
19	13	7.8		2	7.2								5.5	16.5
20	19	19.2		18	17.8								1.5	4.5
21	2	1.6		1	[illegible]								1.5	4.5
22	0	0.0		0	0.0								0.0	0.0
24	0	0.0		0	0.0								0.0	0.0
25	0	1.0		2	1.0								1.0	3.0
28	1	1.6		2	1.4								1.5	4.5
29	7	5.2		3	4.8								2.0	6.0
30	0	0.0		0	0.0								0.0	0.0
31	8	6.2		4	5.8								2.0	6.0
32	2	1.0		0	1.0								1.0	3.0
33	0	0.0		0	0.0								0.0	0.0
34	2	2.1		2	1.9	1.9							0.0	0.0
Total	127		131.2	118		108.5								

Table F19

ADJUSTMENT OF HOLES COUNTED, T48 SEMIAUTOMATIC, NIGHT SITTING

Target	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	Holes counted	Holes predicted	Hits adjusted	σ	3σ
	Run 15			Run 56			Run			Run				
1	0	6.6		13	6.4	13							6.5	19.5
2	5	2.5		0	2.5	0							2.5	7.5
3	14	12.2		10	11.8	10							2.0	6.0
4	5	3.6		2	3.4	2							1.5	4.5
6	4	3.6		3	3.4	3							0.5	1.5
8	12	6.1		0	5.9	0							6.0	18.0
11	0	14.8		29	14.2	29							14.5	43.5
12	4	2.5		1	2.5	1							1.5	4.5
13	8	6.6		5	6.4	5							1.5	4.5
14	3	2.0		1	2.0	1							1.0	3.0
15	0	0.5		1	0.5	1							0.5	1.5
16	0	1.0		2	1.0	2							1.0	3.0
17	0	0.0		0	0.0	0							0.0	0.0
18	0	0.5		1	0.5	1							0.5	1.5
19	1	1.5		2	1.5	2							0.5	1.5
20	26	18.3		10	17.7	10							8.0	24.0
21	1	1.0		1	1.0	1							0.0	0.0
22	1	1.0		1	1.0	1							0.0	0.0
23	0	0.0		0	0.0	0							0.0	0.0
25	0	0.0		0	0.0	0							0.0	0.0
26	1	0.5		0	0.5	0							0.5	1.5
27	0	0.0		0	0.0	0							0.0	0.0
Total	85		85	82		82								

Table F20

ADJUSTMENT OF SHOTS RECORDED, SINGLE BULLETS, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	3σ
	Run 1					Run 3					
5	11	12.8		13.3		6	7.2		11.8		36.3
7	51	50.3		45.8		46	55.4		41.0		26.9
9	13	15.1		18.6		14	16.9		16.6		16.5
10	43	50.0		45.6		39	47.0		40.7		61.6
13	3	3.5		30.1		18	21.7		36.0		74.9
14	20	23.3		29.9		5	6.0	18.0	26.7		84.2
15	9	10.5		6.1		4	4.8		7.2		21.1
16	37	43.0		31.1		31	37.3		27.8		24.6
18	21	24.4		23.1		10	22.0		20.6		23.9
19	40	46.5		34.2		27	32.5		30.8		20.5
20	83	96.5		84.7		73	87.9		75.7		55.9
21	9	10.5		8.0		8	9.6		7.1		11.0
22	6	7.0		6.5		7	8.4		7.6		18.8
24	3	3.5		4.5		0	0.0		4.1		12.2
25	11	12.8		11.8		0	0.0		10.6		35.1
28	0	0.0		16.4		14	16.9		14.6		24.3
29	21	24.4		34.9		29	34.9		31.2		60.3
30	0	0.0		5.1		1	1.2		4.5		15.7
31	29	23.3		33.1		0	0.0		29.5		60.0
32	9	10.5		9.1		8	9.6		8.1		28.1
33	64	74.4	7.4	3.7		0	0.0		[illegible]		10.8
34	48	55.8		31.6		42	[illegible]		[illegible]		30.9
Total	522	607.1	540.1		640.1	391	470.8	[illegible]		[illegible]	
Rounds counted	607					471					

Table F20 (continued)

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 25					Run 27			
5	18	20.1	11.8	20.3		7	7.2		14.1		36.3
7	55	61.4		70.2		63	65.2	42.8	48.8		26.9
9	22	24.5		28.5		16	16.6		19.8		16.5
10	59	65.8		69.8		42	43.5		48.6		61.6
13	52	58.0		60.0		66	68.3		41.7		74.9
14	24	26.8	120.6	45.8		23	23.8		31.9		88.2
15	8	8.9		12.4		8	8.3		8.6		21.1
16	41	45.7		47.7		35	36.2		33.2		24.6
16	27	30.1		35.4		27	27.9		24.6		23.9
19	42	46.9		52.4		45	46.6		36.4		20.5
20	113	126.1		129.7		96	99.3		90.3		55.9
21	13	14.5		12.2		12	12.4		8.5		11.0
22	20	22.3		13.1		10	10.3		9.1		18.8
24	10	11.2		7.0		4	4.1		4.8		12.2
25	8	8.9		18.1		0	0.0		12.6		35.1
26	21	23.4		25.1		19	19.7		17.4		29.3
29	33	36.8		53.5		21	21.7		37.2		60.3
30	5	5.6		7.7		3	3.1		5.4		15.7
31	33	36.8		59.6		54	55.9		35.2		60.0
32	0	0.0		13.9		1	1.0		9.7		23.1
33	0	0.0		5.7		2	2.1		4.0		10.8
34	61	68.1		48.5		24	24.8		33.7		50.9
Total	665	741.9	827.1		827.4	578	598.0	575.6		575.6	
Rounds counted	742					598					
			Run 34					Run 36			
5	15	14.6		13.2		9	9.9		11.0		36.3
7	46	44.6		45.6		32	35.3		46.1		26.9
9	18	17.5		18.5		18	19.9		18.7		16.5
10	42	40.7		45.4		39	[illegible]		45.9		61.6
13	57	55.3		38.9		[illegible]	[illegible]		39.4		74.9
14	26	25.2		29.7		23	25.4		30.1		88.2
15	5	4.9		8.1		2	2.2		8.1		21.1
16	23	22.3		30.9		30	33.1		31.4		24.6
16	37	35.9		23.0		45	49.6	12.2	23.2		23.9
19	29	28.1		34.0		31	34.2		34.4		20.5
20	60	58.2		84.4		80	88.2		85.3		55.9
21	4	3.9		8.0		3	3.3		8.0		11.0
22	13	12.6		8.5		2	2.2		8.6		18.8
24	11	10.7		4.8		4	4.4		4.5		12.2
25	18	17.5		11.7		10	11.0		11.9		35.1
29	14	13.6		16.3		[illegible]	13.4		18.4		29.3
29	36	34.9		34.7		[illegible]	[illegible]		35.2		60.3
30	9	8.7	0.9	5.1		10	11.0		5.1		15.7
31	49	47.5		32.9		31	34.2		33.3		60.0
32	10	9.7		9.1		7	7.7		9.2		23.1
33	2	1.9		3.7		0	0.0		3.8		10.8
34	38	36.9		31.4		19	21.0		31.8		56.9
Total	562	545.2	537.4		537.2	437	481.9	444.5		444.5	
Rounds counted	545					482					

Table F 20 (continued)

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 58					Run 60			
6	5	5.1		11.6		15	16.7		17.4		36.3
7	46	46.1		40.0		56	62.2		60.1		26.9
9	17	17.4		16.2		19	21.1		24.4		16.5
10	53	54.3	33.1	39.7		52	57.7	36.8	59.8		61.6
13	59	60.4		34.1		66	73.3		51.4		74.9
14	15	15.4		26.1		30	33.3		39.2		88.2
15	5	5.1		7.0		22	24.4		10.6		21.1
16	34	34.8		27.1		36	40.0		40.8		24.6
16	23	23.6		20.1		13	14.4		30.3		23.9
19	33	33.8		29.8		38	42.2		44.8		20.5
20	77	78.9		73.8		97	107.7		111.1		55.9
21	6	6.1		6.9		6	6.7		10.4		11.0
22	4	4.1		7.4		3	3.3		11.2		18.8
24	1	1.0		4.0		4	4.4		6.0		12.2
25	2	2.0		10.3		19	21.1		15.5		35.1
28	23	23.6	11.8	14.3		18	20.0		21.5		29.3
29	28	28.7		30.4		26	28.9	55.4	45.8		60.3
30	4	4.1		4.1		7	7.8		6.6		15.7
31	26	26.6		28.8		27	30.0		43.4		60.0
32	2	2.0		7.9		18	20.0		11.9		23.1
33	6	6.1		3.3		7	7.8		4.9		10.8
34	24	24.6		27.6		18	20.0		41.6		50.9
Total	492	503.8	470.8		470.8	597	663.0	708.6		708.6	
Rounds counted	504					663					
			Run 65					Run 67			
5	15	14.9		21.4		12	14.2	49.7	15.9		36.3
7	62	61.4		74.0		42	49.7		54.9		26.9
9	29	28.7		30.0		15	17.8	32.5	22.3		16.5
10	59	58.5	107.8	73.6		40	47.4		54.6		61.6
13	66	65.2	54.6	63.2		40	47.4		46.9		74.9
14	32	31.7		48.3		30	35.5	21.3	35.8		88.2
15	20	19.8		13.0		2	2.4		9.7		21.1
16	41	40.6		50.2		31	36.7	18.7	37.2		24.6
16	32	31.7		37.3		32	37.9		27.4		23.9
19	44	43.6		55.2		27	32.0		40.9		20.5
20	121	119.9		136.8		80	94.7		101.4		55.9
21	10	9.9		12.8		11	13.0		9.5		11.0
22	19	18.8	7.5	18.8		16	18.9		10.2		18.8
24	11	10.9		7.3		1	1.2		5.4		12.2
25	41	40.6		19.1		33	39.1	19.6	14.1		35.1
26	24	23.8		26.4		34	40.3		19.6		29.3
29	51	50.6		56.4		31	36.7		41.8		60.3
30	14	13.9		8.2		3	9.5		6.0		15.7
31	89	66.2		53.4		60	71.0	31.2	39.6		60.0
32	21	20.8		14.7		18	21.3		10.9		23.1
33	10	9.9		6.0		6	7.1		4.5		10.8
34	42	41.6		51.1		12	14.2		37.9		50.9
Total	873	864.9	872.1		872.3	581	688.0	646.7		646.7	
Rounds counted	865					688					

Table F21

ADJUSTMENT OF SHOTS RECORDED, SINGLE BULLETS, DAY STANDING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 5					Run 29			
5	20	24.2		13.1		13	13.2		18.3		14.5
7	47	56.8	48.1	44.3		55	55.9	63.0	61.6		30.2
9	0	0.0		12.5		25	25.4		17.3		27.9
10	56	67.7	46.0	48.8		55	55.9	68.7	87.9		27.9
13	33	39.9		45.6		77	78.3		63.5		43.1
14	28	33.8		30.7		43	43.7		42.7		12.0
15	17	20.5		8.8		7	7.1		11.9		21.4
18	23	27.8		24.4		32	32.5		34.0		19.6
18	22	26.6		24.2		28	28.5		33.7		7.1
19	47	56.8		40.2		55	55.9		58.0		25.8
20	67	81.0		61.8		107	108.7		113.8		31.6
21	16	19.3		10.1		12	12.2		14.1		13.4
22	0	0.0		6.9		3	3.0		9.8		24.8
24	0	0.0		7.1		20	20.3		9.9		23.4
25	5	6.0		14.5		28	28.5		20.1		24.3
28	19	23.0		17.7		21	21.3		24.8		6.8
29	27	32.6		29.2		35	35.6		40.7		8.8
30	7	8.5		4.8		2	2.0		6.7		7.3
31	22	26.6		42.2		52	52.8		58.8		45.8
32	0	0.0		12.4		17	17.3		17.2		27.1
33	10	12.1		6.5		6	6.1		9.1		15.9
34	15	18.1		25.3		42	42.7		35.2		37.3
Total	479	581.3	550.9		550.9	735	746.9	766.8		766.8	
Rounds counted	579					747					
			Run 36					Run 62			
5	7	12.8		14.9		12	13.3		17.0		14.5
7	22	39.5		50.3		57	63.0		57.4		30.2
9	10	18.0		14.1		27	29.9	16.7	16.1		27.9
19	30	53.9		55.4		44	48.7	66.6	63.2		27.9
13	30	53.9		51.6		70	77.4	47.8	89.1		43.1
14	19	34.1		34.9		33	36.5		38.8		12.0
15	7	12.6		9.7		1	1.1		11.1		21.4
16	11	19.8		27.7		34	37.6		31.6		19.8
16	16	28.7		27.8		13	14.4	33.1	31.4		7.1
19	20	35.9		45.7		29	32.1	45.5	52.2		28.8
20	58	100.6		92.8		94	104.0		106.9		31.6
21	4	7.2		11.5		9	10.0		13.1		13.4
22	12	21.6		7.9		20	22.1	8.8	9.9		24.8
24	6	10.6		8.1		3	3.3		9.2		23.4
25	11	19.8		16.4		14	15.5		18.8		24.3
28	13	23.4		20.1		18	17.7		42.9		[illegible]
29	19	34.1		33.3		35	38.7		37.9		8.8
30	4	7.2		5.5		8	8.5		8.2		7.3
31	31	58.7		47.9		62	88.8		54.7		45.8
32	10	18.0		14.9		22	24.3		18.0		27.1
32	0	0.0		7.4		12	13.3		8.5		15.9
34	40	71.9	18.9	28.7		39	43.1		32.8		37.3
Total	378	979.3	625.4		625.4	651	720.1	714.0		714.0	
Rounds counted	[illegible]					728					

Table F22

ADJUSTMENT OF SHOTS RECORDED, SINGLE BULLETS, NIGHT SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 7					Run 31					
1	92	107.7		86.4		142	140.7		136.0		44.7
2	12	14.1		12.0		23	22.8		19.0		12.1
3	39	45.7		30.0		61	60.4		47.5		42.5
4	0	0.0		26.8		53	52.5		42.5		68.5
6	20	23.4	33.9	19.9		38	37.6		31.5		28.7
8	59	69.1	42.1	61.3		108	107.0		97.1		72.0
11	14	16.4		20.4		32	31.7		32.3		19.0
12	9	10.5		15.5		20	10.8		24.6		24.9
13	49	57.4		28.9		0	0.0		45.7		68.3
14	29	34.0		34.6		46	45.6		54.8		33.3
15	10	11.7		14.2		25	24.8		22.5		14.6
16	17	19.9		28.4		50	49.5		45.0		71.4
17	0	0.0		7.9		9	8.0		12.5		22.2
18	28	32.8		32.4		47	46.6		51.3		80.4
10	41	48.0		40.0		58	57.5		63.4		16.3
20	76	89.0		62.7		140	138.7		99.4		154.2
21	11	12.9		10.4		27	26.7		16.5		26.5
22	20	23.4		17.0		23	22.8		26.4		26.9
23	0	0.0		0.0		0	0.0		0.0		0.0
25	0	0.0		18.4		29	28.7		29.2		43.1
26	6	0.0		6.7		2	2.0		10.7		24.6
27	0	0.0		24.8		26	25.8		39.3		68.6
Total	526	616.0	599.5		599.5	950	950.1	950.1		950.1	
Rounds counted	616					950					
	Run 46					Run 64					
1	59	104.4		125.9		104	107.2		110.7		44.7
2	7	12.4		17.4		14	14.4		15.3		12.1
3	15	26.6		43.7		26	26.8		38.4		42.3
4	22	38.4		39.1		31	32.0		34.4		68.5
6	11	19.5	14.6	28.9		19	19.6		25.4		26.7
8	56	88.5		99.3		86	88.7		78.5		72.6
11	16	28.3		29.7		31	32.6		26.1		19.6
12	19	33.6		22.6		18	18.6		19.9		24.9
13	30	53.1		42.1		76	78.3	43.1	37.0		68.3
14	23	46.7		50.4		62	63.9		44.3		33.3
15	11	19.5		20.7		19	19.6		18.2		14.6
16	40	76.8		41.4		40	41.2	11.6	38.4		71.4
17	7	12.4		11.5		20	20.6		10.1		22.2
18	18	21.9	9.6	47.2		81	83.5		13.9		80.4
19	27	47.8		58.2		58	59.8		51.3		16.2
20	60	106.2		91.4		6	0.0		80.4		154.2
21	9	15.9		15.2		6	0.6		13.4		28.5
22	21	27.2		26.1		46	47.4	11.9	22.9		26.9
23	0	0.9		0.6		6	0.6		0.0		0.0
25	20	35.4		26.9		33	34.6		23.9		42.1
26	8	14.2		9.8		19	19.6		8.6		24.6
27	25	44.3		34.1		60	91.9		31.8		68.6
Total	500	901.1	873.9		873.9	943	868.1	768.2		768.2	
Rounds counted	901					669					

Table F23

ADJUSTMENT OF SHOTS RECORDED, DUPLEX, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	3σ
	Run 2					Run 4					
5	13	14.7		10.5		—[a]	0.0		10.0		21.7
7	34	38.4		36.0		—[a]	0.0		34.2		50.9
9	27	30.5		20.9		17	28.9		19.8		11.3
10	40	45.1		38.5		48	81.6	46.4	36.6		28.5
13	1	1.1		29.0		4	6.8		27.6		60.0
14	12	13.5		26.5		7	11.9	45.2	25.2		33.3
15	3	3.4		4.4		0	0.0		4.1		17.0
16	25	28.2		29.6		33	58.1		28.1		31.7
18	20	22.6		27.6		18	27.2		28.2		32.9
19	34	38.4		34.3		24	40.8		32.5		18.4
20	103	116.2		96.1		88	149.5		91.3		88.0
21	12	13.5		10.0		12	20.4		9.5		14.5
22	5	5.6		8.2		3	5.1		7.8		15.4
24	0	0.0		3.5		0	0.0		3.3		38.4
25	0	0.0		14.3		0	0.0		13.8		43.5
28	13	14.7		15.1		—[a]	0.0		14.3		24.0
29	25	28.2		33.7		24	40.8		32.0		33.3
30	5	5.6		2.5		—[a]	0.0		2.4		8.1
31	0	0.0		21.9		—[a]	0.0		20.0		56.7
32	8	9.0		8.4		—[a]	0.0		8.0		22.3
33	9	10.2		4.7		—[a]	0.0		4.5		11.4
34	47	53.0		16.1		—[a]	0.0		15.3		55.3
Total	430	491.9	491.9	491.8	491.9	278	469.1	467.2	467.1	467.2	
Rounds counted	492					469					
	Run 33					Run 35					
5	11	12.0		10.4		0	8.4		9.4		21.7
7	27	29.0		35.5		40	42.2		32.1		56.9
9	20	21.9		20.0		18	19.0		18.0		11.3
10	20	30.7		38.0		34	35.9		34.3		26.5
13	49	53.7		28.6		39	41.2		25.0		00.0
14	21	23.0		26.2		31	32.7		25.6		33.3
15	0	0.0		4.3		1	1.1		3.9		17.8
19	32	3.1		29.2		23	24.3		20.4		31.7
10	10	17.5		27.2		45	47.5	20.7	24.0		32.9
19	39	42.7		33.8		24	25.3		30.5		16.4
20	77	64.3		94.7		65	00.0		85.6		00.0
21	15	18.4		9.9		0	0.3		0.9		14.5
22	3	3.3		8.1		14	14.8		7.3		15.4
24	0	0.0		3.5		2	2.1		3.1		28.4
25	17	18.9		14.1		15	15.8		12.7		43.5
20	22	24.1	11.6	14.9		20	21.1		13.4		24.0
29	32	35.1		33.2		21	22.2		30.0		33.3
20	9	9.9	2.0	2.5		13	13.7	2.7	2.3		6.1
31	24	26.2		21.5		20	21.1		19.5		58.7
32	0	0.0		8.3		5	5.3		7.5		22.3
33	0	0.0		4.9		4	4.2		4.2		11.4
24	19	20.6		15.9		3	2.2		14.3		50.3
Total	461	505.0	484.6	485.0	484.6	451	476.0	438.2	438.0	438.2	
Rounds counted	505					476					

[a]Paper jammed on Esterline-Angus recorder; no data on targets 5, 7, 28, 30, 31, 32, 33, and 34 for run 4.

Table F23 (continued)

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 57					Run 59			
5	8	8.8		12.2		17	20.7		15.0		21.7
7	42	45.3		41.9		47	57.3		51.4		56.0
0	21	22.7		24.3		17	20.7		20.8		11.3
10	44	47.5		44.8		28	34.1		54.0		28.8
13	51	55.0		33.7		16	19.8		41.4		80.8
14	20	21.6		30.0		40	48.7		37.8		33.3
16	6	6.5		5.1		15	18.3		6.2		17.8
16	20	21.6		34.4		30	36.5		42.2		31.7
18	25	27.0	51.8	32.1		32	39.0		39.4		32.9
19	36	38.8		39.8		37	45.1		48.8		18.4
20	93	100.3	84.0	111.7		93	113.3		137.0		88.0
21	10	10.8		11.6		4	4.0		14.3		14.5
22	0	9.7		0.5		15	16.3	8.7	11.7		15.4
24	5	5.4		4.1		0	11.0		5.0		38.4
25	2	2.2		16.6		36	43.0		20.4		43.5
28	10	20.8		17.8		21	28.6		21.5		24.0
29	30	32.4	61.6	30.1		31	37.8		48.0		33.3
30	3	3.2		3.0		0	0.0		3.0		6.1
31	23	24.6		25.4		53	64.8		31.2		58.7
32	13	14.0		9.8		19	23.1		12.0		22.3
33	8	8.8		8.5		7	8.5		6.7		11.4
34	7	7.6		18.7		47	57.3	22.9	22.9		85.3
Total	495	534.1	571.8	571.7	571.8	814	748.2	701.2	701.2	701.2	
Rounds counted	834					746					
			Run 66					Run 68			
8	23	24.2		16.4		7	7.8		12.5		21.7
7	64	67.4		56.3		45	50.1		42.9		56.9
0	21	22.1		32.6		25	26.6		24.0		11.3
10	58	81.1		60.2		47	82.3		45.8		28.5
13	60	72.8	36.3	45.4		48	53.4		34.5		60.8
14	26	27.4		41.8		28	31.2		31.8		32.3
15	0	0.5		6.8		1	1.1		8.2		17.8
16	42	44.2	27.2	46.3		38	42.3		35.2		31.7
18	38	40.0		43.2		31	34.0		32.6		32.0
16	44	46.3		53.8		33	36.7		40.8		18.4
20	118	124.2	157.2	150.2		97	107.6		114.4		88.0
21	10	10.5		15.8		6	6.6		11.6		14.5
22	18	18.6		12.8		11	12.2		6.8		15.4
24	11	11.6		5.8		2	2.2		4.2		38.4
25	27	28.4		22.4		20	22.3		17.0		43.6
28	14	14.7	26.0	23.6		17	18.9		16.0		24.0
26	44	46.3		82.6		33	36.7		40.1		32.3
30	5	5.3		4.0		4	4.8		3.0		8.1
31	38	40.0		34.2		55	61.2	23.6	26.0		58.7
32	15	15.8		13.2		9	16.0		10.0		22.2
33	8	8.4		7.4		2	2.3		8.6		11.4
54	38	40.0		26.2		0	0.0		10.2		56.2
Total	740	778.6	788.6	786.0	788.6	660	622.1	586.5	585.5	585.5	
Rounds counted	779					623					

Table F24

ADJUSTMENT OF SHOTS RECORDED, DUPLEX, DAY STANDING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 6					Run 37					
6	21	21.8	14.5	18.8		12	22.2		15.3		14.9
7	74	76.8	61.8	64.3		30	55.5		58.5		9.1
9	22	22.8		18.4		7	13.0		16.7		14.5
10	70	72.8		66.4		23	42.6	60.5	80.4		25.4
13	0	0.0	0.0	47.5		33	61.1		43.2		94.3
14	35	36.3	29.8	30.7		18	33.3		27.8		13.8
15	115	119.3		47.3		4	7.4		43.0		166.6
16	20	20.7		28.3		10	18.5		25.7		28.6
18	8	8.2	24.2	33.5		17	31.5		30.5		18.8
19	43	44.8		42.5		14	25.9		36.6		29.1
20	63	96.5		106.9		57	105.5		97.1		13.3
21	10	10.4		10.4		5	9.3		9.4		1.8
22	0	0.0		8.4		11	20.4		7.7		28.9
24	0	0.0		4.7		6	11.1		4.3		14.5
25	6	0.0		8.8		13	24.1		7.9		34.1
26	21	21.6		28.4		15	27.8		25.8		8.3
29	30	31.1	14.6	36.0		23	42.8		32.7		39.3
30	0	0.0		1.3		2	3.7		1.2		6.1
31	38	39.4	118.2	88.1		30	55.5		78.2		82.2
32	11	11.4		15.9		10	18.5		14.4		8.7
33	4	4.1		2.9		0	0.0		2.7		5.8
34	30	31.1		13.2		3	6.6		12.0		40.6
Total	643	668.6	718.5	718.5	718.5	343	635.1	853.0	853.2	853.0	
Rounds counted	667					635					
	Run 61					Run					
6	10	10.9		14.9							14.9
7	81	82.2		56.6							9.1
9	26	29.5	18.4	16.1							14.8
10	61	52.6		58.3							26.4
13	70	71.3		41.7							94.8
14	22	22.4		28.9							13.8
15	5	5.1		41.5							159.9
16	39	39.7		24.9							28.9
18	37	37.7		29.4							18.9
19	47	47.9		37.3							29.1
20	94	95.8		93.8							13.3
21	9	9.2		9.1							1.9
22	3	3.1		7.4							26.9
24	2	2.0		4.1							14.5
25	0	0.0		7.8							24.1
26	29	29.6		24.9							8.3
29	42	42.8		31.6							39.3
30	0	0.0		1.2							9.1
31	65	66.2		78.6							82.2
32	14	14.3		13.9							8.7
33	4	4.1		2.8							8.9
34	0	0.0		11.8							40.6
Total	633	646.0	630.9	630.8	630.9						
Rounds counted	645										

Table F25

ADJUSTMENT OF SHOTS RECORDED, DUPLEX, NIGHT SITTING

Target	Shots recorded	Adjusted to total rounds countr	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 8					Run 39			
1	90	107.6		105.1		72	72.7		76.1		92.5
2	7	8.4		11.1		9	9.1		6.1		12.1
3	47	56.2		40.7		26	26.2		29.5		37.1
4	0	0.0		30.8		31	31.3		22.3		79.6
8	23	27.5		24.7		15	13.1		17.9		24.1
8	57	68.2		72.1		43	45.4		52.2		62.5
11	15	17.9		20.6		19	19.2		14.2		12.6
12	14	16.7		21.6		16	16.2		15.6		21.4
13	63	75.3		74.7		47	47.4		54.1		78.0
14	39	46.6		39.3		26	29.2		28.6		32.2
15	12	14.3		20.1		19	19.2		14.6		16.9
16	19	22.7		34.5		28	26.3		25.0		44.9
17	7	8.4		6.2		10	10.1		4.5		11.9
18	22	26.3		45.4		29	29.3		32.9		62.6
19	54	64.6		46.5		29	29.3		33.5		43.6
20	69	82.5		30.4		62	82.6	12.5	22.0		106.4
21	9	10.8		4.7		4	4.0		3.4		13.4
22	20	23.9		18.4		27	27.2		11.6		36.4
23	0	0.0		0.3		0	0.0		0.2		1.4
25	0	0.0		14.3		20	20.2	8.1	10.4		47.1
28	0	0.0		5.6		12	12.1		4.2		14.8
27	0	0.0		12.4		0	0.0		8.9		54.9
Total	567	677.9	677.9	677.7	677.9	548	553.1	490.9	490.7	490.9	
Rounds counted	678					553					
			Run 63					Run			
1	146	148.3		147.3							92.6
2	17	17.5		15.6							12.1
3	44	44.7		57.0							37.1
4	64	65.0		43.2							79.8
6	34	34.3		34.6							24.1
8	110	111.7		101.0							82.5
11	27	27.4		28.9							12.6
12	32	32.5		30.2							21.4
13	78	79.2	110.7	104.7							78.0
14	50	50.8		55.4							32.2
15	29	29.4		28.2							18.9
19	56	56.9		46.4							44.9
17	1	1.0		8.7							11.9
16	85	86.3		63.6							62.6
19	50	50.8		64.9							43.6
20	0	0.0		42.6							106.4
21	0	0.0		9.9							13.4
22	0	0.0		22.9							39.4
23	1	1.0		0.4							1.4
25	36	36.6		20.0							47.1
26	9	6.1		8.2							14.6
27	36	36.6		17.3							54.6
Total	904	916.1	949.6	949.7	949.6						
Rounds counted	918										

Table F26

ADJUSTMENT OF SHOTS RECORDED, TRIPLEX, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 20					Run 28					
5	12	12.1	21.0	10.2		11	11.1	7.0	9.8		21.0
7	56	58.3		07.4		45	45.4		30.3		19.2
9	21	21.1		20.1	28.1	22	22.2		15.2	15.2	1.7
10	50	38.3		06.7		45	40.4		37.0		19.2
12	37	37.2		24.2		0	0.0		12.0		56.5
14	10	10.1		33.4		32	22.2		10.0		10.0
15	0	0.0		5.2		8	5.1		2.5		12.2
10	25	25.1		33.1	33.1	01	01.0	20.0	17.9	17.0	1.0
15	28	20.2		32.1		21	21.2		17.3		10.5
10	55	55.2	68.2	50.0		40	48.4	27.0	27.1		40.0
20	115	115.7		115.2		74	74.7	66.3	63.0		74.1
21	12	12.1		11.0		5	6.1		2.4		2.0
22	21	21.1		13.7		0	0.0		7.4		31.7
24	1	1.0		1.2	1.2	1	1.0		0.7	0.7	0.0
25	17	17.1		11.1		0	0.0		5.0		25.7
20	15	15.1		26.2	20.2	22	22.2		14.1	14.1	5.2
20	40	40.2		30.0		21	21.2		21.5		25.5
20	2	2.0		0.2		2	2.0		2.0		0.0
21	70	72.0		52.5		12	12.1		32.1		101.1
22	10	10.1		7.0		2	2.0		4.2		12.2
23	0	0.0		5.3		5	2.1		2.0		12.2
24	68	68.4		47.7		5	5.0		25.7		95.1
Total	702	706.0	726.0	727.1	750.2	447	401.0	292.1	201.2	368.7	
Rounds counted	706					401					

Table F27

ADJUSTMENT OF SHOTS RECORDED, CARBINE AUTOMATIC, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 15					Run 20					
2	24	25.1		27.4		48	52.0		53.2		40.2
7	87	21.1		72.5		112	123.0		142.5		74.2
2	24	25.6		21.2		50	54.2		01.1		33.2
10	121	122.7	93.2	66.4		66	72.2	94.7	122.0		54.2
12	112	112.4	03.2	27.2		32	60.1		131.2	121.0	30.0
14	82	84.0	20.7	23.7		56	60.4		66.0		53.2
12	0	0.0		4.2		12	12.2		2.0		17.7
10	22	86.9		54.2		67	72.0		106.3		50.7
18	0	0.6		24.2		51	56.0		47.2		58.2
12	70	82.7		00.4		153	168.1	93.1	112.2		66.2
20	174	188.3		211.3		287	315.2	283.2	412.2		000.1
21	27	28.2		16.2		8	0.0		20.1		34.0
22	1	1.0		16.0		41	45.0	10.2	22.2		41.2
24	24	25.1	11.2	14.3		24	26.4		27.0		24.5
22	0	2.0		20.7		107	117.2	08.0	40.5		75.2
22	40	21.2		26.0		47	21.0	31.0	21.0		66.4
20	24	25.0		53.3		86	94.2		104.2		83.2
20	2	2.1		2.7		6	2.2		0.2		7.2
21	2	2.1		00.0		100	170.0		111.2		212.0
22	1	1.6		14.0		67	72.0	27.2	27.2		40.2
22	4	4.2		12.3		22	24.2		23.0		37.2
24	40	20.3		22.2		2	0.0		42.0		70.1
Total	970	1012.7	090.0	090.7	090.0	1544	1096.1	1720.0	1720.2	1901.1	
Rounds counted	1010					1696					

Table F27 (continued)

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 41					Run 43					
5	16	17.2		15.6		33	32.9		32.3		40.9
7	96	103.4	35.6	41.6		74	73.8		86.8		74.5
9	24	25.8		17.8		31	30.9		37.1		33.0
10	70	73.4		37.9		50	49.9		79.0		54.2
13	56	62.5		38.4		81	80.8		80.5		30.8
14	14	15.1		19.3		33	52.9		40.1		53.9
15	0	0.0		2.8		10	10.0		5.8		17.7
16	39	42.0		31.0		95	94.7	34.7	64.8		30.7
18	90	96.9	27.5	13.8		30	30.0		28.7		33.5
19	43	46.3		32.2		44	43.9		67.1		65.2
20	52	56.0		120.5		175	174.5		251.1		598.1
21	2	2.2		5.9		18	18.0		12.2		34.9
22	17	16.3		9.3		40	39.9		19.8		41.3
24	6	6.5		8.1		23	23.0		16.9		24.5
25	0	0.0		11.6		39	38.9		24.8		76.3
28	0	0.0		15.2		43	42.9		31.6		38.4
29	54	58.2		30.4		63	62.8		63.3		53.0
30	0	0.0		1.5		3	3.0		3.2		7.0
31	4	4.3		32.4		83	84.8		87.5		213.0
32	0	0.0		8.0		38	37.9		16.6		49.3
33	0	0.0		9.9		29	38.9		14.4		37.3
34	0	0.0		12.7		53	54.9		26.5		79.1
Total	385	630.1	513.3	513.3	313.3	1114	1109.3	1069.3	1069.2	1069.3	
Rounds counted	630					1111					

Table F28

ADJUSTMENT OF SHOTS RECORDED, CARBINE AUTOMATIC, DAY STANDING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 32					Run 45					
5	51	32.0		53.5		35	35.9		25.1		32.1
7	112	114.3		128.8		60	81.6		69.1		49.1
9	50	51.5		83.4	65.4	46	60.0		35.8	35.8	1.5
10	72	73.5		93.1	93.1	69	70.4		50.6	55.8	4.8
12	132	134.7		142.2		94	95.6		81.3		58.4
14	49	30.0	80.5	72.7		77	75.5	43.3	43.3		56.2
15	58	59.2		41.6		5	8.1		22.7		81.2
16	87	88.2		80.6		35	[illegible]		43.9		78.7
18	82	83.7		83.3		44	44.9		45.4		64.8
19	89	90.8	146.9	114.6		51	53.0	28.2	63.5		151.6
20	205	209.3		313.9		115	131.3		119.9		131.9
21	21	21.4		25.5		17	17.3		13.7		8.3
22	26	26.5		24.5		23	23.5	11.6	13.5		22.1
24	43	43.2		41.0		19	19.4		22.3		36.8
25	61	62.3		55.2	35.5	60	61.3		43.5	43.5	1.5
28	67	68.4		72.2		33	23.5		32.4		67.4
29	98	96.9		100.3		67	58.1		54.7		58.2
30	15	15.3		17.1		11	11.2		9.4		6.3
31	141	143.9	197.9	173.9		111	113.3	79.9	94.9		190.7
32	57	58.2		54.2		25	26.2		32.5		49.1
33	11	11.2		21.1		31	21.4		11.2		15.3
34	98	100.0		99.0		22	53.6		24.9		70.5
Total	1622	1855.1	1797.2	1797.4	1828.3	1072	1083.2	980.6	979.6	928.3	
Rounds counted	1625					1083					

Table F29

ADJUSTMENT OF SHOTS RECORDED, CARBINE AUTOMATIC, NIGHT SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	3σ
	Run 24					Run 47					
1	170	177.5	186.4	170.4		65	72.3	128.3	144.3		87.2
2	47	49.1		37.4		18	20.0		21.7		43.7
3	102	106.5		102.9		75	83.5		87.1		34.5
4	97	101.3		96.0		31	34.5	75.9	61.2		38.1
6	60	62.7		34.0		0	0.0		28.7		94.1
8	89	92.9		57.8		12	13.4		48.7		119.3
11	24	25.1		32.9		32	35.6		27.8		15.8
12	27	28.2		23.7		14	15.6		20.1		18.8
13	80	83.5		74.7		[illegible]	[illegible]		62.3		43.5
14	93	97.1		68.9		27	30.1		58.3		100.5
15	36	37.6		39.0		31	34.5		33.1		4.7
16	49	51.2		56.8		48	53.4		48.0	48.0	3.3
17	13	13.6		14.6	14.6	12	13.4		12.4	12.4	0.3
18	53	55.3		62.5		54	60.1		52.9		7.2
19	49	51.2		45.8		30	33.4		38.6		26.7
20	168	175.4		323.5		143	159.2	421.9	273.8		369.8
21	71	74.1		63.6		39	43.4		53.9		46.1
22	29	30.3		41.7		42	46.7		35.3		24.6
23	0	0.0		0.0		0	0.0		0.0		0.0
25	64	66.6		82.1		43	47.9		52.6		28.4
26	21	21.9		11.9		0	0.0		10.0		32.9
27	59	61.6		52.0		31	34.5		44.1		40.7
Total	1401	1462.9	1471.8	1471.8	1472.6	796	866.0	1246.1	1246.1	1239.7	
Rounds counted	1483					965					

Table F30

ADJUSTMENT OF SHOTS RECORDED, CARBINE SEMIAUTOMATIC, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots predicted	Shots adjusted	3σ
	Run 17					Run 19					
5	8	8.1		9.6		5	5.7		11.5		11.7
7	66	66.7		82.3		41	47.1		74.5		39.8
9	19	19.2		16.0		18	20.7		19.2		31.9
10	41	41.5	62.3	53.7		43	49.4		64.2		30.7
13	67	67.7	37.2	40.2		38	43.6		46.2		98.6
14	0	0.0		6.5		18	20.7		10.1		23.1
15	0	0.0		3.0		0	0.0		3.6		15.2
19	37	37.4		36.5		26	29.9		42.5		17.9
18	28	28.3	52.8	35.7		35	40.2		42.7		30.2
19	54	54.9	33.3	48.1		52	69.7		57.6		32.9
20	109	110.2		119.8		112	128.6		143.1		36.4
21	13	13.1		7.4		11	12.6		8.8		14.9
22	2	2.0		11.3		11	12.6		13.5		23.7
24	25	25.3		13.1		14	16.1		15.7		22.7
25	22	22.2		15.3		22	25.3		18.3		26.8
28	21	21.2		20.6		28	22.2		24.6		19.5
29	37	37.4		49.3		50	57.4		59.0		40.9
30	1	1.0		2.0		4	4.9		2.4		4.4
31	14	14.2		13.5		65	74.7		40.1		72.5
32	26	26.3		14.1		17	19.5		18.9		24.4
23	6	6.1		4.4		7	8.0		5.3		8.9
34	37	37.4		30.2		43	49.4		36.1		44.1
Total	633	639.9	633.4	633.4	633.4	66[illegible]	758.0	758.0	757.9	758.0	
Rounds counted	640					75[illegible]					

Table F30 (continued)

Target	Run 42: Shots recorded	Run 42: Adjusted to total rounds counted	Run 42: Adjusted for hits adjusted	Run 42: Shots predicted	Run 42: Shots adjusted	Run 44: Shots recorded	Run 44: Adjusted to total rounds counted	Run 44: Adjusted for hits adjusted	Run 44: Shots predicted	Run 44: Shots adjusted	3σ
5	6	6	11.4	9.3		16	16.1		11.0		11.7
7	70	70		60.1		84	84.3		71.2		39.8
8	29	29		15.4		0	0.0		[illegible]		31.9
10	47	47		51.8		72	72.3		61.3		39.7
13	0	0		38.8		92	92.4		46.0		98.6
14	27	27	10.8	8.3		5	5.0		9.7		23.1
15	12	12		2.9		1	1.9		3.5		15.2
16	39	39		34.2		89	89.3	46.4	40.5		17.6
16	41	[illegible]	24.6	34.4		36	36.1		40.8		30.2
18	54	54		48.4		60	60.2		55.0		32.8
20	85	85	123.3	115.3		142	142.6		138.7		35.4
21	2	2		7.1		4	4.9		8.4		14.9
22	10	10		19.9		24	24.1		12.9		33.7
24	10	10		12.6		5	5.9		15.0		22.7
25	40	40	16.5	14.8		2	2.0		17.5		26.8
28	14	14		19.8		21	21.1		23.5		19.5
29	42	42	73.1	47.5		44	44.2		56.3		40.9
30	1	1		1.9		2	2.9		2.3		4.4
31	100	100	38.3	32.3		17	17.1		38.3		72.5
33	6	6		13.9		9	9.0		16.1		24.4
33	0	0		4.3		5	5.9		5.1		8.9
34	9	9		29.1		34	34.1		34.5		44.1
Total	644	644	611.9	610.7	611.9	764	766.9	724.0	723.9	724.0	
Rounds counted	644					767					

Table F31

ADJUSTMENT OF SHOTS RECORDED, CARBINE SEMIAUTOMATIC, DAY STANDING

Target	Run 21: Shots recorded	Run 21: Adjusted to total rounds counted	Run 21: Adjusted for hits adjusted	Run 21: Shots predicted	Run 21: Shots adjusted	Run 46: Shots recorded	Run 46: Adjusted to total rounds counted	Run 46: Adjusted for hits adjusted	Run 46: Shots predicted	Run 46: Shots adjusted	3σ
5	15	17.9	29.6	34.5		13	13.3		16.5		34.9
7	88	93.6		96.9		74	75.1		73.7		27.8
8	29	39.5		39.2		22	32.3		32.9		13.6
10	69	63.5	53.8	90.9		[illegible]	76.1		68.8		11.3
13	62	87.2		81.2		73	73.1		69.1		21.3
14	26	27.7	39.1	49.4		56	56.6		37.5		49.1
15	26	21.3		18.1		0	9.0		9.3		33.0
16	42	44.7		47.4		38	38.9		35.9		9.2
16	41	43.6		44.4		30	39.5		31.9		19.7
18	56	59.6		89.1	89.1	91	91.9		83.4	53.4	3.9
20	136	138.3		133.4		95	96.4		100.3		59.7
21	6	8.4		9.5		5	5.1		5.0		2.9
28	18	19.1		19.9		0	9.0		9.3		49.5
24	16	19.1		21.3	21.3	16	18.3		19.1	19.1	9.4
25	34	38.3	43.5	44.7		43	43.9	36.9	33.5		9.8
28	23	24.5		39.7		29	89.4		23.2		7.4
29	63	67.0		36.1		0	0.9		29.9		100.5
30	7	7.4		9.5		4	4.1		8.0		5.6
31	67	71.3		30.3		86	87.3		86.4		24.0
33	34	26.5		23.2		15	15.2		17.9		15.5
33	6	9.4		9.9		4	4.1		4.5		3.5
34	73	78.6	81.9	79.1		86	86.6	49.4	59.3		69.[illegible]
Total	926	985.0	1041.6	1041.9	1063.3	796	807.9	788.9	798.9	777.2	
Rounds counted	969					[illegible]					

Table F22

ADJUSTMENT OF SHOTS RECORDED, CARBINE SEMIAUTOMATIC, NIGHT SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 23					Run 48					
1	153	155.3		151.4		75	89.9		98.8		98.1
2	30	30.4		21.0		3	3.6		13.0		40.2
3	55	55.8		48.3		16	19.2		28.7		54.9
4	67	68.0		71.6		40	48.0		44.4		30.0
6	25	25.4		23.8		11	13.2		14.8		18.2
8	59	59.9		48.7		35	42.0		30.1		61.5
11	27	27.4	36.4	32.6		20	24.0	18.9	20.2		38.0
12	22	22.3		41.2		37	44.4	14.4	25.5		33.2
13	86	87.3		99.1		61	73.1		81.2		21.2
14	17	47.7	66.8	58.6		39	46.8	28.1	36.3		52.1
15	28	28.4		30.9		18	21.9		19.1		10.2
16	45	45.7	64.0	55.1		35	42.0	25.2	24.1		58.2
17	5	5.1		6.1	6.1	4	4.8		2.8	3.8	0.5
18	35	35.5		57.4		48	57.6		25.6		23.0
19	58	58.9		60.1		32	38.4		37.2		30.8
20	111	112.6	181.4	136.6		88	106.5	59.8	84.6		152.4
21	24	24.4		23.2		11	13.2		14.4		18.8
22	41	41.6		49.4	49.4	32	38.4		30.6	20.6	4.8
23	0	0.0		0.0		0	0.0		0.0		0.0
25	40	40.8		64.3		53	63.5		39.8		34.4
26	8	8.1		5.7		1	1.2		3.6		10.4
27	52	53.8		48.1		20	24.0		29.7		44.7
Total	1019	1034.2	1131.4	1131.2	1140.2	679	814.3	700.4	700.6	891.6	
Rounds counted	1034					814					

Table F53

ADJUSTMENT OF SHOTS RECORDED, T46 AUTOMATIC, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 10					Run 12					
5	40	50.0	17.8	18.6		27	33.2		28.0		19.8
7	95	118.6		119.2		128	158.1		166.4		104.2
9	23	28.8		19.3		18	22.2		29.9		12.2
10	67	83.8	19.8	61.0		50	81.9	98.1	88.1		55.7
12	53	66.2		80.6		90	111.2		112.4		97.9
14	2	2.5		19.7		54	99.2	94.9	27.4		34.1
15	14	17.5		6.2		1	1.2		11.3		17.7
16	43	53.8		41.2		55	67.9		57.4		36.5
18	55	68.8		45.5		59	72.9		63.5		46.9
19	57	71.2		55.6		100	123.5		77.5		106.9
20	35	42.8		87.2		119	147.0		121.8		124.9
21	11	13.8		11.1		8	9.9		15.5		6.9
22	0	0.0		3.4		9	11.1		4.7		13.7
24	2	2.8		9.1		0	0.0		8.9		27.2
25	0	0.0		7.2		9	0.9		10.2		46.1
26	19	18.8		10.4		29	35.9		42.5		99.9
29	41	51.2		41.1		22	27.2		87.2		41.2
30	8	10.0		5.0		4	4.9		7.9		6.9
31	41	51.2		41.1		39	48.2		57.3		76.0
32	1	1.3		8.7		0	0.0		12.2		53.0
33	26	22.5		17.4		23	96.4		24.2		28.4
34	30	37.5		29.9		18	22.2		41.8		94.8
Total	659	824.4	758.2	708.4	758.2	856	1056.0	1067.7	1067.9	1067.7	
Rounds counted	824					1056					

Table F33 (continued)

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 49					Run 51			
5	15	16.5		20.9		20	22.9		25.0		19.8
7	68	74.8	196.7	134.1		94	107.6		160.5		104.2
2	16	17.6		21.7		22	25.2		25.9		13.3
10	77	64.7		68.6		56	64.1		82.1		55.7
13	90	98.9		00.6		101	115.6		108.4		57.9
14	24	36.4		22.1		28	32.1		26.4		36.1
15	11	12.1		9.2		8	9.2		11.1		17.7
19	68	74.6	43.0	46.3		31	35.5		55.4		36.6
16	34	37.4		61.2		37	42.4		61.3		46.9
12	26	30.6		62.5		39	44.7		74.8		106.2
20	138	140.7		93.1		146	167.2	93.1	117.4		134.6
21	14	15.4		12.5		13	14.9		14.9		6.5
23	0	0.0		3.6		15	17.2	5.2	4.5		13.7
24	4	4.4		8.9		20	23.9		8.3		27.2
29	0	0.0		8.2		31	35.5		9.8		46.1
28	34	37.4		34.2		49	56.1		41.0		39.6
29	53	58.3		46.2		55	63.0		55.3		41.3
30	7	7.7		6.3		4	4.6		7.5		6.6
31	13	14.3		46.1		75	85.9		55.2		76.0
33	0	0.0		9.8		36	41.2		11.8		53.0
33	10	11.0		19.5		11	12.6		23.4		26.4
34	0	0.0		33.6		75	85.9		40.3		94.6
Total	594	723.3	652.3	652.4	652.3	966	1106.3	1020.2	1020.2	1020.2	
Rounds counted	763					1106					

Table F34

ADJUSTMENT OF SHOTS RECORDED, T46 AUTOMATIC, DAY STANDING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 14					Run 53			
5	10	10.2	11.2	28.4		52	63.7	55.2	36.4		65.4
7	98	99.7		86.6	66.6	85	104.2		117.3	117.3	5.6
9	25	35.4		32.7		42	51.5		44.2		39.2
20	107	108.0		76.5		63	79.0		106.4		42.4
15	71	73.3		78.6		93	112.6		106.5		90.6
24	21	21.4	26.8	50.1		73	89.5		67.3		91.5
25	10	10.2		4.8		1	1.3		6.9		13.6
19	57	58.0		56.5		65	79.7		79.2		33.9
22	133	135.3		99.6		81	99.3		135.0		54.0
19	61	63.1		40.4		27	33.1		54.2		43.5
20	58	56.0		54.9		140	171.9	73.2	74.3		25.8
22	4	4.1		12.7		31	25.7		17.1		32.4
22	0	0.0		17.2		33	40.4		23.2		60.2
24	0	0.0		16.9		32	39.2		22.2		58.9
26	0	0.0		21.4		41	50.3		26.2		75.5
28	17	17.3		26.1		39	44.1		25.3		49.9
29	39	39.6		54.5		88	107.9	31.7	73.3		83.7
20	8	8.1		3.4		0	0.0		4.7		12.2
32	93	94.6		101.1		117	143.4		139.3		73.3
32	48	48.8		26.5		11	13.5		35.6		63.0
33	0	0.0		14.6		36	34.3		19.7		81.5
34	63	63.2		24.8		3	3.7		33.1		75.3
Total	907	322.2	931.4	931.7	218.3	1130	1392.1	1262.0	1261.7	1275.1	
Rounds counted	323					1389					

Table F35

ADJUSTMENT OF SHOTS RECORDED, T48 AUTOMATIC, NIGHT SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 16					Run 55					
1	154	200.9		205.3		134	154.6		150.2		69.5
2	24	31.3		34.1		24	27.7		24.9		5.4
3	34	44.4		57.0		47	54.2		41.8		14.7
4	83	108.3		98.5		54	62.3		72.1		69.0
8	60	76.3		69.2		36	41.5		50.8		05.2
8	118	153.9		144.2		83	95.7		105.4		87.3
11	38	49.6		37.9		14	18.1		27.8		50.3
12	49	63.9		47.6		16	18.5		34.8		65.1
13	81	79.6	89.6	91.4		88	78.4	68.6	66.8		31.5
14	51	66.5		58.4		30	34.8		42.7		47.9
15	32	41.7		34.8		18	16.5		25.4		34.6
18	49	63.9		66.3		44	50.8		48.4		19.7
17	5	8.5		15.1		17	19.8		11.0		19.7
16	41	53.5	56.9	59.2		42	48.4	43.6	43.3		23.0
19	00	104.4		101.8		62	71.5		74.3		49.4
20	108	140.9		170.7	170.7	134	154.8		124.8		29.6
21	25	32.6		33.5		22	25.4		24.5		10.8
22	38	49.6		53.9		38	43.8		39.5		0.7
23	0	9.9		0.0		0	0.0		0.0		9.0
25	8	7.8		4.5		0	9.0		3.3		11.7
29	8	7.8		17.2		19	21.9		12.5		21.2
27	48	58.7		59.2		38	43.8		43.3		22.4
Total	1107	1444.1	1459.0	1459.8	1489.3	938	1061.9	1087.3	1087.2	1037.5	
Rounds counted	1444					1082					

Table F36

ADJUSTMENT OF SHOTS RECORDED, T46 SEMIAUTOMATIC, DAY SITTING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
	Run 9					Run 11					
5	18	19.0		10.8		21	22.9	12.9	14.5		16.9
7	43	01.9		56.7		54	06.8	99.6	79.1		62.9
9	12	14.2		17.2		19	29.7		23.1		16.2
10	41	48.0		54.6		48	52.3	79.4	73.8		39.9
13	32	37.9		20.7		36	39.2		34.9		58.9
14	9	9.9		19.4		29	31.8		24.7		43.6
16	2	2.4		2.4		0	0.0		3.2		11.7
19	29	29.6		13.0		35	38.1		18.4		02.3
18	29	34.4		32.3		34	37.9		43.8		16.7
19	44	52.2		42.8		64	59.7		87.9		29.3
20	13	15.4	72.9	76.7		79	76.2		106.9		76.7
21	5	5.9		9.9		6	8.7		9.3		12.9
22	1	1.2		7.9		18	19.0		10.9		28.1
24	1	1.2		4.9		0	9.9		9.4		16.9
29	9	9.9		0.9		9	9.0		9.0		0.9
29	7	9.3		9.1		14	10.2		12.2		6.3
29	24	28.4		21.9		33	25.9		42.9		20.1
30	2	2.4		1.4		1	1.1		1.9		4.1
31	16	17.0		34.2		8	8.4		49.1		96.1
32	0	9.9		9.2		1	1.1		9.2		1.4
33	19	19.9		19.9		19	20.7		12.4		22.2
34	27	32.9		19.3		31	33.9		29.9		20.2
Total	[illegible]	422.1	479.9	479.8	479.6	949	588.9	940.9	646.1	945.9	
Rounds counted	422					688					

Table F28 (continued)

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	2σ
			Run 50					Run 52			
5	15	17.8		14.6		4	4.7		14.6		16.9
7	66	78.5		79.5		56	67.8		79.5		52.9
9	20	23.6		23.2		24	26.1		22.2		15.2
10	69	82.1		73.9		76	88.9	65.9	73.9		29.6
12	0	0.0		34.8		73	86.2	52.7	34.6		56.8
14	19	22.6		24.9		32	28.6		24.9		43.6
15	8	9.5		3.2		0	0.0		2.2		11.7
16	0	0.0		16.5		0	0.0		16.6		62.3
16	34	40.4		43.7		44	51.4		43.7		19.7
19	6	9.5	42.6	57.9		44	51.4		57.9		29.2
20	109	129.6		106.8		102	119.2		106.6		75.7
21	12	15.5		9.3		4	4.7		9.2		12.6
22	16	19.0		10.7		0	0.0		10.7		26.1
24	12	14.3		5.4		4	4.7		5.4		16.6
25	0	0.0		6.0		0	6.0		0.0		0.0
28	11	13.1		12.3		8	9.4		12.3		6.2
29	42	49.9		42.8		29	45.6		42.6		25.1
30	2	3.6		1.9		0	0.0		1.9		4.1
21	60	71.4		46.2		67	76.3		46.3		96.1
22	0	0.0		0.2		0	0.0		0.2		1.4
23	6	7.1		13.5		2	3.5		12.5		22.2
24	7	6.2		26.1		20	23.4		26.1		30.2
Total	516	616.0	649.3	649.4	649.3	603	706.1	649.4	649.5	649.4	
Rounds counted	616					706					

Table F37

ADJUSTMENT OF SHOTS RECORDED, T48 SEMIAUTOMATIC, DAY STANDING

Target	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	Shots recorded	Adjusted to total rounds counted	Adjusted for hits adjusted	Shots pre-dicted	Shots adjusted	3σ
			Run 13					Run 64			
5	10	11.7	21.1	16.1		15	16.0		19.0		7.7
7	56	65.4		67.1		106	113.2		61.8		71.9
9	19	22.2		21.2		25	21.4		22.3		1.2
10	54	62.1		56.2		47	50.2		65.1		16.2
12	62	72.4	91.0	76.6		76	81.3	66.7	80.6		36.5
14	17	16.9		9.7		5	0.5		10.2		26.6
15	2	2.2		1.1		5	5.5		1.2		2.5
16	26	32.7		22.2		60	64.2	35.6	25.0		4.4
16	22	37.4		28.6		29	41.7		40.5		6.5
19	49	67.2		36.8		17	16.2		28.6		58.5
20	83	97.0		94.7	94.7	91	97.2		99.6	99.6	0.5
21	8	9.3		6.2		7	7.5		6.6		2.7
22	6	6.2		6.2		7	7.5		5.6		2.7
24	1	1.2		19.4		38	38.5		20.2		58.0
25	1	1.2		18.3		34	26.4		19.2		52.8
28	17	19.6		18.6		17	16.2		19.6		2.6
29	29	32.6		30.1		29	27.6		21.6		9.2
20	7	6.2		6.1		4	4.2		9.4		5.6
31	68	76.4		66.6		90	96.2		60.0		26.2
32	17	19.6		22.8		27	26.9		26.5		13.6
22	6	5.6		11.2		16	17.1		11.7		17.0
24	57	66.6		61.7		66	63.1	56.6	64.8		10.1
Total	620	736.5	764.0	764.1	761.7	794	648.2	602.8	602.7	606.1	
Rounds counted	736					646					

Table F38

ADJUSTMENT OF SHOTS RECORDED, T48 SEMIAUTOMATIC, NIGHT SITTING

Target	Run 15: Shots recorded	Run 15: Adjusted to total rounds counted	Run 15: Adjusted for hits adjusted	Run 15: Shots predicted	Run 15: Shots adjusted	Run 56: Shots recorded	Run 56: Adjusted to total rounds counted	Run 56: Adjusted for hits adjusted	Run 56: Shots predicted	Run 56: Shots adjusted	3σ
1	0	0.0		47.8		97	100.2		52.4		150.3
2	21	23.8		17.3		12	12.4		18.9		17.1
3	47	53.3		43.7		37	38.2		47.8		22.7
4	31	35.1		46.8		61	63.0		51.3		41.9
6	24	27.2		19.2		14	14.5		21.8		19.1
8	67	75.9		46.0		101	104.3		94.2		42.6
11	12	13.6		14.9		17	17.6		16.3		6.0
12	35	39.7		26.8		20	20.7		31.6		28.5
13	82	92.9		74.4		61	63.0		81.5		44.9
14	42	47.6		42.9		41	42.3		47.0		8.0
15	10	11.3		12.3		14	14.5		13.5		4.8
16	30	34.0		35.9		40	41.3		39.4		11.0
17	9	10.2		9.8	9.8	10	10.3		10.7	10.7	0.1
18	14	15.9		22.4		30	31.0		24.5		22.7
19	42	47.6		44.9	44.9	45	46.5		49.2	49.2	1.7
20	128	145.1		126.4		116	119.8		138.5		38.0
21	16	16.1		17.5		16	18.8		19.2		0.8
22	36	40.8		31.3		24	24.8		34.3		24.0
23	0	0.0		0.0		0	0.0		0.0		0.0
25	17	19.3		17.1		16	16.5		18.7		4.2
26	8	9.1		11.3		14	14.5		12.3		8.1
27	19	21.5		30.5		41	42.3		33.3		31.2
Total	690	782.0	782.0	781.9	778.9	829	856.3	856.3	856.4	859.4	
Rounds counted	782					856					

Table F39

REDUCTION OF SINGLE-BULLET RESULTS FOR COMPARISON WITH FLECHETTE RESULTS, DAY STANDING

Targets	Adjusted shots fired (single bullet)[a]	Correction factor for reduction in exposure time[b] for flechette targets	Shots fired (single bullet)	Adjusted target hits[c]	Reduced target hits
5	15	1	15	3	3
7	51	0.444	23	16	7
9	26	1	26	8	8
10	47	0.444	21	16	7
13	71	0	0	11	0
14	34	1	34	6	6
15	11	1	11	1	1
16	23	1	23	4	4
18	27	1	27	3	3
19	56	1	56	8	8
20	132	0.475	63	18	9
21	13	1	13	1	1
22	5	1	5	1	1
24	4	1	4	0	0
25	21	1	21	1	1
28	22	1	22	3	3
29	26	1	26	3	3
30	6	1	6	0	0
31	50	0.469	23	1	0
32	16	0	0	0	0
33	9	0	0	0	0
34	41	0	0	1	0
Total	705		418	105	65

[a] Best estimate of shots fired per target per run for regular target exposure time.

[b] For the single flechette day standing run 69, targets 32, 33, and 34 were not used. Targets 7, 10, 20, and 31 were up only half normal time, and target 13 flipped over and was not fired on. Assuming a 1½-sec time lag, the adjustment for ½ exposure time is $(t-3)/(2t-3)$.

[c] The average of the adjusted values for the single-bullet day standing runs.

Table F40

REDUCTION OF SINGLE-BULLET RESULTS FOR COMPARISON WITH FLECHETTE RESULTS, NIGHT RUNS

Targets	Adjusted shots fired (single bullet)[a]	Correction factor for reduction in exposure time[b] for flechette targets	Shots fired (single bullet)	Adjusted target hits[c]	Reduced target hits
1	123	0.472	58	16	8
2	16	1	16	2	2
3	41	1	41	7	7
4	45	1	45	1	1
6	25	1	25	2	2
8	84	0.458	38	5	2
11	23	1	23	1	1
12	16	1	16	0	0
13	67	0.458	31	1	0
14	45	1	45	1	1
15	16	1	16	1	1
16	36	1	36	1	1
17	9	1	9	0	0
18	36	1	36	0	0
19	52	1	52	1	1
20	76	0.477	37	2	1
21	14	1	14	0	0
22	36	1	36	0	0
23	0	0	0	0	0
25	33	0	0	0	0
26	7	0	0	0	0
27	53	0	0	0	0
Total	855		574	41	28

[a]Best estimate of shots fired per target per run for regular target exposure time.

[b]For the single flechette night-standing run 70, targets 23, 25, 26, and 27 were not used. Targets 1, 8, 13, and 20 were up only half normal time. Assuming a $1\frac{1}{2}$-sec time lag, the adjustment for $\frac{1}{2}$ exposure time is $(t-3)/(2t-3)$.

[c]The average of the adjusted values for the single-bullet night-sitting runs (there were no night-standing single-bullet runs).

Table F41

SUMMARY RESULTS BY RUN (ADJUSTED DATA)

Ammunition or firing	Firing position	Squad A Run	A Hits	A Rounds fired	Squad B Run	B Hits	B Rounds fired	Squad C Run	C Hits	C Rounds fired	Squad D Run	D Hits	D Rounds fired	Squad E Run	E Hits	E Rounds fired	Squad F Run	F Hits	F Rounds fired
Single bullet	Day	1	91	540	3	106	483	34	110	537	36	71	445	65	200	872	67	100	647
	sitting	25	157	827	27	132	576	58	90	471	60	121	709	—	—	—	—	—	—
	Day	5	78	551	—	—	—	38	109	825	—	—	—	—	—	—	—	—	—
	standing	19	117	767	—	—	—	62	99	714	—	—	—	—	—	—	—	—	—
	Night	—	—	—	7	58	800	—	—	—	40	28	874	—	—	—	—	—	—
	sitting	—	—	—	31	42	950	—	—	—	64	42	788	—	—	—	—	—	—
Duplex	Day	2	186	492	4	158	467	33	154	465	35	123	438	66	278	789	68	158	586
	sitting	—	—	—	—	—	—	57	214	572	59	201	701	—	—	—	—	—	—
	Day	8	182	719	—	—	—	27	193	653	—	—	—						
	standing	—	—	—	—	—	—	61	146	631	—	—	—						
	Night	—	—	—	6	44	676	—	—	—	39	41	491						
	sitting	—	—	—		—	—	—	—	—	63	112	950						
Triplex	Day sitting	26	309	750	28	176	389	—	—	—	—	—	—						
Carbine semiautomatic	Day sitting	19	135	758	17	177	633	44	182	724	42	179	611						
	Day standing	—	—	—	21	213	1053	—	—	—	48	139	777						
	Night sitting	23	45	1140	—	—	—	48	13	892	—	—	—						
Carbine automatic	Day sitting	20	106	1801	18	173	900	43	102	1069	41	59	813						
	Day standing	—	—	—	22	180	1829	—	—	—	45	89	928						
	Night sitting	24	26	1473	—	—	—	47	32	1249	—	—	—						
T48 semiautomatic	Day sitting	11	[illegible]	848	9	111	480	52	130	649	50	144	649						
	Day standing	—	—	—	13	131	782	—	—	—	54	109	806						
	Night sitting	18	85	779	—	—	—	56	62	859	—	—	—						
T48 automatic	Day sitting	22	104	1058	10	88	758	51	99	1020	49	92	652						
	Day standing	—	—	—	14	91	918	—	—	—	53	59	1275						
	Night sitting	16	78	1489	—	—	—	55	58	1038	—	—	—						

Appendix G

SQUAD AND QUALIFICATION EFFECTS

SUMMARY

The hit probabilities for all six squads [including the so-called expert (E) and unqualified (F) squads] were compared. As expected, Squad E is superior to all others and Squad F is inferior. Analysis of the four "average" squads shows Squad B superior in hit probability and Squads A, C, and D similar to each other.

Similar comparisons for total hits instead of for hit probabilities show Squad E superior; Squads A, B, C, and F similar; and Squad D inferior.

The over-all conclusions about the squads are that Squad E fired more rapidly and more accurately than the others; that Squad F fired more rapidly but less accurately than the others; that Squad B fired less rapidly but more accurately, and Squad D fired as accurately but slower than the other average squads.

The average hit probabilities for the various squads and the known composition of the squads in terms of number of experts, sharpshooters, marksmen, and unqualifieds were used to determine relative ratings for each of these marksmanship categories. The technique used was a least-squares best solution of six simultaneous equations. It was found that, for hit probabilities, if the expert rifleman is rated at 100, a sharpshooter is 88, a marksman 75, and unqualified 43.

HIT PROBABILITY BY SQUAD

Table G1 shows the hit probabilities for the seven sets of runs, which are of the same type for the four average squads. These hit probabilities are the ratios of hits to rounds fired taken directly from Tables E6 and F41. The prime entries are adjusted data (from Table F41); the parenthetical entries are raw data (from Table E6). All entries are from the day-sitting firing condition. The mean hit probabilities of Squads A, C, and D are all the same, 19 percent. Squad B is superior with a hit probability of 22 percent. The technique of analysis of variance reveals a statistic F value of 2.2 (adjusted data) or 2.3 (raw data). These values from appropriate statistical tables yield a significance level of about 14 percent. This means that the differences among the mean hit probabilities of Table G1 could occur by chance about 14 percent of the time. It might roughly be said that to an 86 percent confidence level Squad B is really better than Squads A, C, and D. In any case, relative hit probabilities of .219/.191 = 1.15 is the best estimate for Squad B.

Table G2 shows hit probabilities for all 14 sets of runs which are comparable (balanced) for Squads A and C. The difference between Squads A and

TABLE G1

AVERAGE SQUAD HIT PROBABILITIES (DAY SITTING)

Ammunition or firing	Squad[a]			
	A	B	C	D
Single bullet	.169(.148)	.224(.223)	.205(.204)	.160(.168)
	.190(.212)	.229(.241)	.191(.198)	.171(.181)
Duplex	.337(.337)	.338(.362)	.318(.315)	.281(.277)
Carbine				
Automatic	.096(.106)	.120(.112)	.095(.095)	.115(.136)
Semiautomatic	.178(.178)	.280(.278)	.251(.240)	.293(.266)
T48				
Automatic	.098(.097)	.113(.104)	.097(.093)	.108(.112)
Semiautomatic	.243(.243)	.231(.230)	.200(.199)	.222(.206)
Mean	.187(.189)	.219(.221)	.194(.192)	.193(.192)

[a]Values in parentheses are from raw data.

TABLE G2

COMPARISON OF SQUAD A AND SQUAD C HIT PROBABILITIES

Ammunition or firing	Firing condition	Squad[a]		
		A	C	C – A
Single bullet	Day sitting	.169(.148)	.205(.204)	.036(.056)
	Day sitting	.190(.212)	.191(.198)	.001(–.014)
Duplex	Day sitting	.337(.337)	.318(.315)	–.019(–.022)
Carbine				
Automatic	Day sitting	.096(.106)	.095(.095)	–.001(–.011)
Semiautomatic	Day sitting	.178(.178)	.251(.240)	.073(.062)
T48				
Automatic	Day sitting	.098(.097)	.097(.093)	–.001(–.004)
Semiautomatic	Day sitting	.243(.243)	.200(.199)	–.043(–.044)
Single bullet	Day standing	.142(.140)	.174(.162)	.032(.022)
	Day standing	.153(.145)	.139(.143)	–.014(–.002)
Duplex	Day standing	.253(.285)	.296(.295)	.043(.010)
Carbine				
Automatic	Night sitting	.018(.018)	.026(.026)	.008(.008)
Semiautomatic	Night sitting	.039(.041)	.019(.021)	–.020(–.020)
T48				
Automatic	Night sitting	.051(.052)	.056(.054)	.005(.002)
Semiautomatic	Night sitting	.109(.109)	.095(.096)	–.014(–.013)
Mean		.148(.151)	.154(.154)	

[a]Values in parentheses are from raw data.

C is clearly trivial. However, it is instructive to apply the t test to the null hypothesis (that they are not different). This requires computation of the standard deviation:

$$\sigma^2_{\overline{C-A}} = 1/n(n-1)\,[\Sigma(C-A)^2 - [\Sigma(C-A)]^2/n] \qquad \text{(G1)}$$

From Table G2, n is 14, and $\sigma_{\overline{C-A}}$ = 0.00814 (0.00773).

The statistic t is given by

$$t = \overline{C-A}/\sigma_{\overline{C-A}} \qquad \text{(G2)}$$

whence t = 0.75 (0.28). As in the tables, the parenthetical value is from raw data.

TABLE G3

COMPARISON OF SQUAD B AND SQUAD D HIT PROBABILITIES

Ammunition or firing	Firing condition	Squad[a]		
		B	D	B – D
Single bullet	Day sitting	.224(.223)	.160(.168)	.064(.055)
	Day sitting	.229(.241)	.171(.181)	.058(.060)
Duplex	Day sitting	.338(.362)	.281(.277)	.057(.085)
Carbine				
Automatic	Day sitting	.120(.112)	.115(.136)	.005(–.024)
Semiautomatic	Day sitting	.280(.278)	.293(.266)	–.013(.012)
T48				
Automatic	Day sitting	.113(.104)	.108(.112)	.005(–.008)
Semiautomatic	Day sitting	.231(.230)	.222(.206)	.009(.024)
Single bullet	Night sitting	.093(.086)	.030(.030)	.063(.056)
	Night sitting	.044(.043)	.055(.052)	–.011(–.009)
Duplex	Night sitting	.065(.065)	.084(.078)	–.019(–.013)
Carbine				
Automatic	Day standing	.087(.086)	.064(.060)	.023(.026)
Semiautomatic	Day standing	.204(.205)	.179(.179)	.025(.026)
T48				
Automatic	Day standing	.099(.099)	.046(.049)	.053(.050)
Semiautomatic	Day standing	.172(.173)	.135(.139)	.037(.034)
Mean		.164(.165)	.139(.138)	

[a]Values in parentheses are from raw data.

From tables of t for 13 degrees of freedom, the significance level of the difference between Squads C and A is 47 percent (adjusted) or 71 percent (raw). This means that the small differences between the mean hit probabilities of these two squads could occur by chance about half the time or more. It is concluded that the null hypothesis is neither proved nor disproved, and Squads A and C are as likely to be the same as not. In any case, the 4 percent relative difference in mean hit probabilities is trivial for practical purposes. This study concludes that the mean values are valid to two significant figures, and both squads score 15 percent mean hit probability for these comparative runs.

Table G3 shows hit probabilities for the 14 sets of runs that are comparable for Squads B and D. The difference in mean hit probabilities is 16.4 percent as compared with 13.9 percent, which seems considerable. Using Eqs.

G1 and G2 again for Squads B and D, the standard deviation is computed: $\sigma_{\overline{B-D}}$ = 0.0080 (0.0086), and t = 3.2 (3.1). This large value of t would satisfy the null hypothesis (no difference between Squads B and D) less than 1 percent of the time by chance. This study concludes that Squad B is superior to Squad D in hit probability with better than 99 percent confidence. The best estimate is further that the hit probability of Squad B is 1.18 times the hit probability of Squad D.

TABLE G4

HIT PROBABILITY OF ALL SIX SQUADS (DAY SITTING)

Ammunition	Squad[a]					
	A	B	C	D	E	F
Single bullet	.169(.148)	.244(.223)	.205(.204)	.160(.168)	.229(.233)	.155(.153)
Duplex	.337(.337)	.338(.362)	.318(.315)	.281(.277)	.359(.375)	.266(.257)
Mean	.253(.242)	.281(.292)	.262(.259)	.221(.222)	.294(.304)	.211(.205)

[a]Values in parentheses are from raw data.

TABLE G5

COMPARISON OF SQUADS E AND F AND $\overline{ACD}$ HIT PROBABILITIES (DAY SITTING)

Ammunition	Squad[a]				
	$\overline{ACD}$	E	F	E – $\overline{ACD}$	$\overline{ACD}$ – F
Single bullet	.178(.173)	.229(.233)	.155(.153)	.051(.060)	.023(.020)
Duplex	.312(.310)	.359(.375)	.266(.257)	.047(.065)	.046(.053)
Mean	.245(.242)	.294(.304)	.211(.205)	.049(.063)	.035(.037)

[a]Values in parentheses are from raw data.

Table G4 shows hit probabilities for the only two sets of runs that are comparable for all six squads. These are the hit probabilities for the first single-bullet (AP) day-sitting run by each squad. Squads A, B, C, and D made a second run of this type, but Squads E and F made only one single-bullet run each. Hence Table G4 shows all the balanced comparisons that can be made involving all six squads. Based on so few data, the smaller differences in mean hit probabilities are not significant. Squad E, composed largely of expert riflemen, is superior, and Squad F, composed largely of unqualified or low qualified riflemen, is inferior. The data on Squads A, B, C, and D, that appear in Table G4 are included in Tables G1, G2, and G3; therefore the more reliable conclusions already reached about those squads are not altered.

Since Squads A, C, and D were found to be essentially the same in hit probability, they constitute a reasonable basis of comparison for Squads E and F. These comparisons are made in Table G5, using the mean of Squads A, C, and D, designated $\overline{ACD}$. The standard deviations are first computed: $\sigma_{\overline{E-ACD}}$ = 0.0020 (0.0025), $\sigma_{\overline{ACD-F}}$ = 0.0115 (0.0165). The corresponding t values are: $t_{\overline{E-ACD}}$ = 24.5 (25.2), $t_{\overline{ACD-F}}$ = 3.00 (2.24). The t tables for a single degree of freedom yield significance levels, respectively, 0.03 (0.03) and 0.20 (0.26). This means that to a 97 percent confidence level Squad E is really superior to ACD in hit probability, but only about 80 percent confident that Squad F is really inferior to $\overline{ACD}$. The best relative estimates are still given by the mean values of Table G5: $E/\overline{ACD}$ = 1.20 (1.26), and $F/\overline{ACD}$ = 0.86 (0.85).

Finally, from all the comparisons, the relative hit probabilities (shown in Table G6) among all six squads are deduced ($\overline{ACD}$ taken as unity). Adjusted rather than raw values are used in this table, but clearly the effect of adjustment is minor. The superiority of Squad E over Squad B is apparently trivial and not statistically significant.

TABLE G6

RELATIVE HIT PROBABILITIES OF SQUADS

Squad	Probability	Squad	Probability
A	1.00	D	1.00
B	1.18	E	1.20
C	1.00	F	0.86

TOTAL HITS BY SQUAD

Total hits per run are considered in just the same manner as hit probabilities. The same runs already compared in Tables G1 to G6 are now examined for total hits per run in Tables G7 to G12.

Table G7 shows Squad A superior (140 hits) and Squad D inferior (113 hits) to Squads B and C, which are about the same (125 hits). These differences are tested by computing the statistic F for the array. Computation yields an F value of 1.34, which implies a significance level of about 36 percent. This means that the observed differences among the mean hits by squads could occur by chance about 36 percent of the time. This means that the differences so far shown (Table G7) are only slightly more likely to be real than random.

Squads with more comparable data are now compared. Squads A and C are compared in Table G8. This table shows Squad A to be superior in hits in the ratio 1.10 (1.07). The standard deviation of the mean difference $\sigma_{\overline{A-C}}$ = 8.90 (8.32). This yields a statistic t = 1.12 (0.84). This corresponds to a significance level of about 0.47 (0.56). In other words there is about a 50–50 chance that Squads A and C are really different in hits per run.

Table G9 shows a larger difference between Squads B and D, a ratio of 1.29 (1.21). The standard deviation of this difference $\sigma_{\overline{B-D}}$ = 9.22 (7.07). The statistic t = 2.73 (2.81). The corresponding significance level is 0.22 (0.22) or to a 78 percent confidence level this difference is real.

Table G10 compares all six squads. Among the four average squads, it shows A, B, and C about the same, and D inferior. Squad F appears also quite similar to A, B, and C, but E seems definitely superior to all others. Considering all the comparisons of Tables G7 to G10, it is concluded that Squads A, B, and C score the same number of hits per run, and that Squad D is inferior. It is further obvious that Squad F (128 hits) is not significantly different from the average $\overline{ABC}$ (131 hits).

TABLE G7

AVERAGE SQUAD TOTAL HITS (DAY SITTING)

Ammunition or firing	Squad[a]			
	A	B	C	D
Single bullet	91(90)	108(105)	110(111)	71(81)
	157(157)	132(144)	90(100)	121(120)
Duplex	166(166)	158(170)	154(159)	123(132)
Carbine				
Automatic	173(179)	108(114)	102(106)	59(86)
Semiautomatic	135(135)	177(178)	182(184)	179(171)
T48				
Automatic	104(102)	86(86)	99(103)	92(86)
Semiautomatic	157(145)	111(97)	130(140)	144(127)
Mean	140(139)	126(128)	124(129)	113(115)

[a]Values in parentheses are from raw data.

TABLE G8

COMPARISON OF TOTAL HITS OF SQUAD A AND SQUAD C

Ammunition or firing	Firing condition	Squad[a]		
		A	C	A − C
Single bullet	Day sitting	91(90)	110(111)	−19(−21)
	Day sitting	157(157)	90(100)	67(57)
Duplex	Day sitting	166(166)	154(159)	12(7)
Carbine				
Automatic	Day sitting	173(179)	102(106)	71(73)
Semiautomatic	Day sitting	135(135)	182(184)	47(49)
T48				
Automatic	Day sitting	104(102)	99(103)	5(− 1)
Semiautomatic	Day sitting	157(148)	130(140)	27(8)
Single Bullet	Day standing	78(81)	109(110)	−31(−29)
	Day standing	117(108)	99(103)	18(5)
Duplex	Day standing	182(190)	193(187)	−11(3)
Carbine				
Automatic	Night sitting	26(26)	32(23)	− 6(3)
Semiautomatic	Night sitting	45(42)	13(17)	32(25)
T48				
Automatic	Night sitting	76(75)	58(59)	18(16)
Semiautomatic	Night sitting	85(85)	82(82)	3(3)
Mean		114(113)	104(106)	

[a]Values in parentheses are from raw data.

TABLE G9

COMPARISON OF TOTAL HITS OF SQUAD B AND SQUAD D

Ammunition or firing	Firing condition	Squad[a]		
		B	D	B – D
Single bullet	Day sitting	108(105)	71(81)	37(24)
	Day sitting	132(144)	121(120)	11(24)
Duplex	Day sitting	158(170)	123(132)	35(38)
Carbine				
Automatic	Day sitting	108(114)	59(86)	49(28)
Semiautomatic	Day sitting	177(178)	179(171)	– 2(7)
T48				
Automatic	Day sitting	86(86)	92(86)	– 6(0)
Semiautomatic	Day sitting	111(97)	144(127)	–33(–30)
Single bullet	Night sitting	56(53)	26(27)	30(26)
	Night sitting	42(41)	42(45)	0(– 4)
Duplex	Night sitting	44(44)	41(43)	3(1)
Carbine				
Automatic	Day standing	160(142)	59(66)	101(76)
Semiautomatic	Day standing	213(202)	139(145)	74(57)
T48				
Automatic	Day standing	91(91)	59(68)	32(23)
Semiautomatic	Day standing	131(127)	109(118)	22(9)
Mean		116(114)	90(94)	

[a]Values in parentheses are from raw data.

TABLE G10

TOTAL HITS OF ALL SIX SQUADS (DAY SITTING)

Ammunition or firing	Squad[a]					
	A	B	C	D	E	F
Single bullet	91(90)	108(105)	110(111)	71(81)	200(202)	100(105)
Duplex	166([illegible])	158(170)	154(159)	123(132)	276(292)	156(160)
Mean	129(128)	133(138)	132(135)	97(107)	238(246)	128(133)

[a]Values in parentheses are from raw data.

TABLE G11

COMPARISON OF TOTAL HITS OF SQUADS E AND F AND $\overline{ABC}$ (DAY SITTING)

Ammunition or firing	Squad[a]				
	$\overline{ABC}$	E	F	E - $\overline{ABC}$	$\overline{ABC}$ - F
Single bullet	108(102)	200(202)	100(105)	97(100)	3(–3)
Duplex	159(165)	276(292)	156(160)	117(127)	3(5)
Mean	131(134)	238(246)	128(133)		

[a]Values in parentheses are from raw data.

Table G11 compares Squads E and F with the average ABC. Squad E is clearly superior to $\overline{ABC}$ in the ratio 1.82 (1.84); F is essentially the same (ratio 0.98). The standard deviation $\sigma_{\overline{E-ABC}}$ = 12.2 (13.5). The corresponding t = 7.95 (8.67). For a single degree of freedom the corresponding significance level is 0.08; or 92 percent confidence that Squad E is superior to $\overline{ABC}$.

The comparison of Squad F with $\overline{ABC}$ yields $\sigma_{\overline{ABC-F}} = 0$ (4), $t = \infty$ (0.25). The corresponding significance level is 0 (0.84). The adjusted data for the two comparisons agree perfectly; hence the test concludes that the small measured difference is absolutely real. The raw-data test, however, reveals that the difference observed could occur by chance 75 percent of the time. Clearly this

TABLE G12

RELATIVE TOTAL HITS OF SQUADS

Squad	Hits	Squad	Hits
A	1.00	D	0.78
B	1.00	E	1.82
C	1.00	F	1.00

test is meaningless in the adjusted data case (two measures), where the two differences happen to just agree. The raw-data test, however, is acceptable, showing that it is more likely than not that there is no difference between Squad F and $\overline{ABC}$.

Finally, from all the comparisons of total hits per run, the relative hits per run shown in Table G12 for all six squads are deduced ($\overline{ABC}$ taken as unity). Adjusted values are used in Table G12, but again the raw-data values are not significantly different.

HIT PROBABILITY BY QUALIFICATION

Table G13 shows the compositions of the 10-man squads in terms of the riflemen qualification (from App A).

The squad compositions and the average hit probabilities achieved by the different squads can be used to form a set of equations from which an estimate of the effectiveness of the different qualifications can be obtained. The relative hit probabilities of Table G6 are used to form Eqs. G3:

$$\left.\begin{array}{l} E + 3S + 6M = 100 \\ E + 7S + 2M = 118 \\ 6S + 4M = 100 \\ E + 8S + M = 100 \\ 4E + S = 60 \\ E + S + M + 2U = 43 \end{array}\right\} \qquad \text{(G3)}$$

This is a set of six equations in four variables, for which no exact solution is expected. The best solution (in the sense of a solution with minimum variance) is obtained by applying a least-squares method.

The sum of squares of deviations (measured normal to the regression plane) is given by the function:

$$(E + 3S + 6M - 100)^2/46 + (E + 7S + 2M - 118)^2/54 + (6S + 4M - 100)^2/52 + (E + 8S + M - 100)^2/66 +$$

$$+ (4E + S - 60)^2/17 + (E + S + M + 2U - 43)^2/7$$

A necessary condition for this function to be a minimum is that its first partial derivatives be zero. Taking the partial derivatives of this function with respect to E, S, M and U, and setting them equal to zero, a set of four equations is obtained, with solution:

$$\left.\begin{matrix} E = 12.3 \\ S = 10.9 \\ M = 9.3 \\ U = 5.3 \end{matrix}\right\} \text{ or relative to } E = 100\% \quad \left\{\begin{matrix} E = 100 \\ S = 88 \\ M = 75 \\ U = 43 \end{matrix}\right.$$

These relative ratings relate the standard qualification ratings according to experimental hit probabilities.

TABLE G13

SQUAD QUALIFICATIONS

Squad	Expert (E)	Sharpshooter (S)	Marksman (M)	Unqualified (U)
A	1	3	6	0
B	1	7	2	0
C	0	6	4	0
D	1	8	1	0
E	8	2	0	0
F	2	2	2	4

SQUAD-AMMUNITION EFFECTS

To examine the interrelation of any two of the five factors (ammunition, illumination, position, squad, and order), Table F41 is reduced for effects of the other three. Squad-ammunition effects are of interest. The entries in Table F41 are divided by the appropriate order reduction factors from Table K5 and illumination-position reduction factors from Table K15. This elimination of the other three effects yields Table G14.

The bottom row lists the ratios of duplex to single-bullet hit probabilities for each squad. The grand average for the four regular squads ($\overline{ABCD}$) is 1.64. From this it might be concluded that the average gain of 64 percent is increased to 72 percent for the poorest squad (Squad F), and decreased to 57 percent for the best squad (Squad E). These gains are clearly seen in Table G15 where the first line of the single-bullet hit probabilities gives a measure of the basic performance or rating of the squads.

Actually the variations among the four regular squads are so large (25 percent to 111 percent gain) that confidence in the results in Table G15 is low. However, the direction and general nagnitude of the squad qualification effect on salvo gain is consistent and reasonable. As extreme Squads E and F did not fire the other salvo ammunitions, no examination is attempted of the qualification effects on those scores.

TABLE G14

HIT PROBABILITIES BY SQUAD

Ammunition	Squad											
	A		B		C		D		E		F	
	Hits	Rounds	Hits	Rounds	Hits	Rounds	Hits	Rounds	Hits	Rounds	Hits	Rounds
Single bullet	81	637	91	570	96	621	62	515	—	—	—	—
	109	674	91	523	61	420	82	632	178	1030	89	764
	74	525	126	537	102	585	57	766	—	—	—	—
	88	568	[illegible]	671	73	521	73	526	—	—	—	—
Duplex	—	—	—	—	137	572	109	517	—	—	—	—
	145	[illegible]	138	540	148	519	140	636	241	[illegible]	136	677
	—	—	—	—	184	621	92	450	—	—	—	—
	170	672	97	596	111	468	199	661	—	—	—	—
Ratio	[illegible]		1.25		1.72		2.11		1.57		1.72	

TABLE G15

HIT PROBABILITY GAINS

Ammunition	Squad		
	F(poorest)	ABCD (average)	E (best)
Single bullet	11.7	14.5	17.3
Duplex	20.1	23.7	27.1
Percentage of gain	72	64	57

Appendix H

LEARNING EFFECT

SUMMARY

In 12 pairs of runs the same squad fired each run of a pair under substantially the same conditions but at different times. This offered a good opportunity to isolate a learning effect if one was present.

In this experiment there are two ways in which learning might affect results: first, the accuracy of fire might change as the experiment progresses, or, second, the rate of fire might change. An examination of the data over a span of 12 runs shows that accuracy did appear to increase some 1 to 11 percent, at least for the day-sitting runs, and that the rate of fire increased some 25 percent. It is concluded that learning occurred in the experiment, reflected strongly in the number of rounds fired and less strongly in accuracy (hit probability).

LEARNING

Effect on Hit Probabilities

Table H1 lists the 12 paired runs in which each squad used the same ammunition and firing position. All other controllable conditions were the same, and the first run of each pair was separated from the second by 11 intervening runs by the same squad. The raw hit probabilities in Table H1 are simply the ratios of holes counted to rounds counted, taken directly from Table E4. The adjusted hit probabilities are ratios of adjusted hits from Tables F1 to F19 to adjusted shots from Tables F20 to F38.

Table H1 shows the hit probabilities (p_x for the first; p_y for the second run) for each of these 12 pairs of runs, and the differential hit probabilities: $\Delta p = p_y - p_x$. If there was consistent learning, so that the squads did better on the second run of the pair than on the first, the Δp's, except for random error, would all be positive. It is observed that the computed learning effect (Δp) is negative on 5 of the 12 pairs of runs from the raw data, and on 4 of the pairs from adjusted data. On the other pairs of runs the learning effect was positive; and Table H1 shows a net positive learning effect: increase of from 17.7 to 18.6 percent hit probability from raw data, from 18.1 to 18.2 percent from adjusted data. This is a 1 to 5 percent relative improvement.

The expected value of the average Δp, under the null hypothesis (no learning) used in making the test, is zero. The t values are calculated in order to estimate the probability that the average $\overline{\Delta p}$ of +.009 or +.0008, would occur as

TABLE H1

EFFECT OF LEARNING ON HIT PROBABILITIES

Squad	Run x	Run y	Ammunition	Firing condition	Raw data p_x	Raw data p_y	Raw data Δp	Adjusted data p_x	Adjusted data p_y	Adjusted data Δp
A	1	25	Single bullet	Day Sitting	.148	.212	+.064	.169	.190	+.021
	5	29	Single bullet	Day standing	.140	.145	+.005	.142	.153	+.011
B	3	27	Single bullet	Day sitting	.223	.241	+.018	.224	.229	+.005
	7	31	Single bullet	Night sitting	.086	.043	−.043	.093	.044	−.049
C	33	57	Duplex	Day sitting	.315	.392	+.077	.318	.374	+.056
	37	61	Duplex	Day standing	.295	.245	−.050	.296	.235	−.061
	34	58	Single bullet	Day sitting	.204	.198	−.006	.205	.191	−.014
	38	62	Single bullet	Day standing	.162	.143	−.019	.174	.139	−.035
D	35	59	Duplex	Day sitting	.277	.261	−.016	.281	.281	+.006
	36	60	Single bullet	Day sitting	.168	.181	+.013	.160	.171	+.011
	39	63	Duplex	Night sitting	.078	.119	+.041	.084	.118	+.034
	40	64	Single bullet	Night sitting	.030	.052	+.022	.030	.055	+.025
Total					2.126	2.232	+.106	2.176	2.186	+.010
Mean					.177	.186	+.009	.181	.182	+.0008
$\sigma_{\overline{\Delta p}}$							.0118			.0104
t							.765			.077

TABLE H2

EFFECT OF LEARNING ON HIT PROBABILITIES (DAY SITTING ONLY)

Squad	Ammunition	Raw data p_x	Raw data p_y	Raw data Δp	Adjusted data p_x	Adjusted data p_y	Adjusted data Δp
A	Single bullet	.148	.212	+.064	.169	.190	+.021
B	Single bullet	.223	.241	+.018	.224	.229	+.005
C	Duplex	.315	.392	+.077	.318	.374	+.056
	Single bullet	.204	.198	−.006	.205	.191	−.014
D	Duplex	.277	.261	−.016	.281	.287	+.006
	Single bullet	.168	.181	+.013	.160	.171	+.011
Total		1.335	1.485	+.150	1.357	1.442	+.085
Mean		.223	.248	+.025	.226	.240	+.014
$\sigma_{\overline{\Delta p}}$				.0153			.00986
t				1.63			1.42

the result of only random variation in the Δp's. To calculate t, simply take the ratio of the average value $\overline{\Delta p}$ to its estimated standard error:

$$t = \overline{\Delta p}/\sigma_{\overline{\Delta p}} \tag{H1}$$

the standard error of Δp, is given by

$$\sigma_{\overline{\Delta p}}{}^2 = \Sigma_n(\Delta p_n - \overline{\Delta p})^2/n(n-1) \tag{H2}$$

where n is the number of Δp's.

From standard t tables, the probabilities that average hit probability increases as large as the computed Δp's could occur by chance, if there were no real learning effect, are deduced. The raw data t for 11 degrees of freedom could occur by chance 13 percent of the time; the adjusted data t could occur by chance about 90 percent of the time. It is concluded that this analysis reveals no significant learning effect as reflected in hit probabilities of these 12 pairs.

If only the day-sitting data are considered (the standing and night runs being deemed too irregular), the apparent consistency of learning improves (see Table H2).

The higher t values correspond to lower probabilities that the average hit probability increase occurs by chance. The raw data t for 5 degrees of freedom could occur by chance about 9 percent of the time; the adjusted data t could occur by chance about 11 percent of the time.

Examination of the day-sitting hit probabilities reveals a 6 to 11 percent relative increase, which is real to about a 90 percent confidence level. It is concluded that a 12-run initial experience will increase day-sitting accuracy about 10 percent. Standing and night accuracy are not measured reliably enough in the experiment to establish whether they incur real learning.

Effect on Rounds Fired

Table H3 repeats the arrangement of Table H1 for rounds fired instead of hit probabilities. It is noted that the computed learning effect (ΔR) is negative for 2 of the 12 pairs of runs from raw data, and 3 of the 12 pairs from adjusted data. On the majority of runs, however, the learning effect was positive; Table H3 shows a net positive learning effect: increase of from 587 to 720 rounds from raw data, from 560 to 720 rounds from adjusted data. This is a 22 to 29 percent relative increase.

The t values are calculated again to estimate the probability that these net increases would occur as the result of only random variations in the ΔR's. Both raw and adjusted data t values for 11 degrees of freedom could occur by chance less than $\frac{1}{2}$ percent of the time, or less than once out of 200 times. It is concluded that this analysis demonstrates a real learning effect, reflected in some 25 percent increase in number of rounds fired in a run.

The Table H4 increases in rounds fired for day-sitting runs are a relative 23 percent from raw data or 32 percent from adjusted data. These increases are quite real as is indicated by the substantial t values computed. Both raw and adjusted data t values for 5 degrees of freedom could occur by chance less than $2\frac{1}{2}$ percent of the time. It is concluded that, for either day-sitting runs alone or all 12 pairs of runs, a 12-run initial experience increases the rate of fire about 25 percent.

TABLE H3

EFFECT OF LEARNING ON ROUNDS FIRED

Squad	Run x	Run y	Ammunition	Firing condition	Raw data R_x	Raw data R_y	Raw data ΔR	Adjusted data R_x	Adjusted data R_y	Adjusted data ΔR
A	1	25	Single bullet	Day sitting	607	742	+ 135	540	827	+ 287
	5	29	Single bullet	Day standing	579	747	+ 168	551	767	+ 216
B	3	27	Single bullet	Day sitting	471	598	+ 127	483	576	+ 93
	7	31	Single bullet	Night sitting	616	950	+ 334	600	950	+ 350
C	33	57	Duplex	Day sitting	505	534	+ 29	485	572	+ 87
	37	61	Duplex	Day standing	635	645	+ 10	653	631	− 22
	34	58	Single bullet	Day sitting	545	504	− 41	537	471	− 66
	38	62	Single bullet	Day standing	679	720	+ 41	625	714	+ 89
D	35	59	Duplex	Day sitting	476	748	+ 272	438	701	+ 263
	36	60	Single bullet	Day sitting	482	663	+ 181	445	709	+ 264
	39	63	Duplex	Night sitting	553	918	+ 365	491	950	+ 459
	40	64	Single bullet	Night sitting	901	869	− 32	874	768	− 106
Total					7049	8638	+1589	6722	8636	+1914
Mean					587	720	+ 132	560	720	+ 160
$\sigma_{\overline{\Delta R}}$							39.8			50.4
t							3.32			3.18

TABLE H4

EFFECT OF LEARNING ON ROUNDS FIRED (DAY SITTING ONLY)

Squad	Ammunition	Raw data R_x	Raw data R_y	Raw data ΔR	Adjusted Data R_x	Adjusted Data R_y	Adjusted Data ΔR
A	Single bullet	607	742	+135	540	827	+287
B	Single bullet	471	598	+127	483	576	+ 93
C	Duplex	505	534	+ 29	485	572	+ 87
	Single bullet	545	504	− 41	537	472	− 66
D	Single bullet	476	748	+272	438	701	+263
	Duplex	482	663	+181	445	709	+264
Total		3086	3789	+703	2928	3856	+928
Mean		514	631	+117	488	643	+155
$\sigma_{\overline{\Delta R}}$				45.5			57.2
t				2.57			2.71

Appendix I

LAG TIME TO FIRST SHOT, LATE FIRE, AND RATE OF FIRE

SUMMARY

The .30 single-bullet day-sitting runs are examined in detail to determine the lag time from the signal for the target to pop up until achievement of a steady rate of fire. The sum of the squares of the errors between calculated and observed exposure times is written as a function of the lag time and the rate of fire. The values that best fit this function are found to be a lag time of 1.75 sec and a rate of fire is 3.75 shots/sec for 10 men firing.

The electrical record of shots recorded provided a count showing that about 12 percent of shots were fired during an average 1.27-sec period after targets had gone down.

The rate of fire of 2.57 shots/sec for 10 men firing is computed for single-bullet, duplex, and triplex runs. This is lower than the rate for single-bullet day-sitting runs used to develop the estimate of lag time.

LAG TIME AND RATE OF FIRE FOR SINGLE-BULLET DAY-SITTING RUNS

It is evident that some time was required after the target appeared for the riflemen to spot the target and direct fire toward it. The average lag time had been visually estimated as about 3 sec. This section develops a method for estimating the average lag time from appearance of the target to beginning fire at this target and the average rate of fire. Such averages are meaningful, though it is recognized that there may be considerable variation from target to target. The data from which these averages were computed were obtained from the electrical records of shots fired (Table 11). The way in which these data were obtained is described in detail in App D. The computations are based on the shots data (N_i) from Table F20. The adjusted shot values are used. The corresponding values of exposure time (t_i) are noted from Table C22. It is believed that the assumptions made in the least squares method outlined in the paragraphs following are realistic if calculations are confined to a given type ammunition, visibility, and firing position. The method is essentially that of fitting a straight line to observed data.

For a given type run, it is assumed:

t_i is the scheduled exposure time for target i.
α sec is the lag time for beginning fire at each target.
N_i is the number of shots fired at target i.
K is the time in seconds for each shot. This assumes the average rate of fire is constant and $1/K$ is the average rate of fire.

From these four assumptions, it is clear that:

$t_i - \alpha$ = effective exposure time for target i. This may be thought of as the calculated exposure time.

0.88 KN_i = effective exposure time for target i. This is the observed exposure time, since Table 12 shows that 12 percent of the fire is delivered after exposure.

TABLE 11

DAY-SITTING SINGLE-BULLET RATE-OF-FIRE DATA, BY TARGET

t	N	N^2	Nt
4.5	15	225	68
15	52	2,704	780
4.5	21	441	95
15	52	2,704	780
19.5	44	1,936	858
9	34	1,156	306
4.5	9	81	41
9	35	1,225	315
6	26	676	156
15	39	1,521	585
31.5	96	9,216	3024
3	9	81	27
4.5	10	100	45
4.5	5	25	23
9	14	196	126
6	19	361	114
10.5	40	1,600	420
3	6	36	18
25.5	37	1,369	944
7.5	10	100	75
3	4	16	12
21	36	1,296	756
Σ231	613	27,065	9568

The error between the calculated exposure time and the observed exposure time for target i is a function of α and K, and may be written

$$f(\alpha, K) = t_i - \alpha - 0.88\,KN_i \qquad \text{(11)}$$

To determine α and K, the necessary condition is for the sum of squares of these errors for all targets to be a minimum. That is, the expression is written for the sum of the squares of the errors for all M targets (where M is the number of targets), which is:

$$F(\alpha, K) = \sum_{i=1}^{M} (t_i - \alpha - 0.88\,KN_i)^2$$

and set the first partial derivatives with respect to α and K equal to zero. This leads to the following pair of linear equations for determining α and K:

$$\begin{aligned} \alpha M + 0.88\,K\,N_i &= \Sigma t_i \\ 0.88\,\alpha\,\Sigma N_i + 0.77\,K\,N_i^2 &= 0.88\,\Sigma N_i t_i \end{aligned} \qquad (12)$$

General average values for single-bullet day-sitting runs can be obtained by considering all 10 single-bullet day-sitting runs from Table F20.

Table I1 lists the average adjusted rounds fired at each single-bullet day-sitting target N. Also listed are target exposure times t. The quantities N^2 and Nt are computed, and all columns totaled. These sums are substituted into Eqs. I2, which become:

$$\begin{aligned} 22\,\alpha + 539\,K &= 231 \\ 539\,\alpha + 20959\,K &= 8420 \end{aligned}$$

These equations yield:

$$\begin{aligned} \alpha &= 1.77 \text{ sec} \\ K &= 0.356 \text{ sec} \end{aligned}$$

The average time between rounds after initial lag for 10 men firing is K. The average interval for one man is just 10 K, or 3.56 sec, or 17 rounds/min. Of course this interval includes clip change and malfunctions, where they occurred.

The 1.77-sec initial lag reflects the delay in acquiring a new target. It must be appreciated that this delay as deduced here represents the time to achievement of the steady rate of fire, not time until the first round is fired. The average time until the first round is fired by a single man is in fact 1.77 plus 3.56, or 5.33 sec. It is noted that this average value of 5.3 sec to first round is somewhat larger than the theoretical optimum time of 3.5 sec.[13] It should be noted however that the increment before the first round is generally less than the average increment, as the rifle will always be loaded.

RATE OF FIRE FOR SINGLE-BULLET, DUPLEX, AND TRIPLEX RUNS

In the single-bullet, duplex, and triplex runs there was a total of 8011.5 sec of target-up time. (In Table I2 runs 7, 8, 31, 39, 40, 63, and 64 were night runs with target-up times of 253.5 sec/run. All other runs were day runs with target-up times of 231 sec/run. All runs used 22 targets.) Deducting 1.77 sec lag time from each of the 748 targets in all 34 runs, leaves a total of 17,171 shots fired in 6688 sec. Thus 2.57 shots/sec was the average rate of fire for 10 men, 0.257 shots/sec (15 rounds/min) for one man for single-bullet, duplex, and triplex ammunition.

TABLE 12

LATE SHOTS FOR SINGLE-BULLET, DUPLEX, AND TRIPLEX RUNS (RAW DATA)

Run	Shots recorded			Percentage of shots recorded	
	Target up	Target down	Total	Target up	Target down
1	465	57	522	89.1	10.9
2	378	58	436	86.7	13.3
3	356	35	391	91.0	9.0
4	265	11	276	96.0	4.0[a]
5	412	69	481	85.7	14.3
6	472	171	643	73.4	26.6
7	462	64	526	87.8	12.2
8	508	59	567	89.6	10.4
25	582	83	665	87.5	12.5
26	626	76	702	89.2	10.8
27	522	56	578	90.3	9.7
28	405	42	447	90.6	9.4
29	636	99	735	86.5	13.5
31	860	99	959	89.7	10.3
33	403	59	462	87.2	12.8
34	492	70	562	87.5	12.5
35	390	61	451	86.5	13.5
36	351	86	437	80.3	19.7
37	286	57	343	83.4	16.6
38	340	40	380	89.5	10.5
39	498	50	548	90.0	9.1
40	467	42	509	91.7	8.3
57	435	60	495	87.9	12.1
58	433	59	492	88.0	12.0
59	533	81	614	86.8	13.2
60	493	104	597	82.6	17.4
61	569	64	633	89.9	10.1
62	570	81	651	87.6	12.4
63	800	104	904	88.5	11.5
64	755	88	843	89.6	10.4
65	737	136	873	84.4	15.6
66	653	87	740	88.2	11.8
67	517	64	581	89.0	11.0
68	500	60	560	89.3	10.7
Total or Mean	17,171	2432	19,603	87.6	12.4

[a]Data incomplete.

AMOUNT OF LATE FIRE

Table 12 presents shots-recorded data derived from all the .30-cal single-bullet, duplex, and triplex runs (34 of the 68 runs). It includes total numbers and percentages of shots fired while targets were exposed, and after they had dropped. It is seen that 12.4 percent of the shots were fired after the targets were down. This figure may, however, be somewhat higher than might be expected under less dusty firing conditions. The test troops complained on numerous occasions that the targets were partly or completely obscured by dust produced from hits in the target area.

DURATION OF LATE FIRE

A total of 2432 shots (Table 12) was fired after target went down. At the rate of 2.57 shots/sec this took 950 sec. Divided by the 748 targets in all 34 runs, this yields an average of 1.27 sec of late fire per target.

Appendix J

STATISTICAL ANALYSIS OF DATA

SUMMARY

This appendix examines variations in both hits per run and hits per round fired for the 21 ammunition-illumination-position (AIP) conditions. Table J1 in the next section summarizes the basis for all comparisons. The three sections following that one extend the interpretation and justify the inferences on differences that may be attributed to the 21 conditions.

Some of the most outstanding differences in hits and hit probabilities may be shown by listing approximate ratios. Table J2 lists such ratios (all ammunition comparisons except the last as noted are for sitting and standing combined day averages).

HITS AND HIT PROBABILITIES BY AMMUNITION-ILLUMINATION-POSITION CONDITION

The data on hits are drawn entirely from Tables E6 and F33 and presented in a summarized form in Table J1. These tables ignore learning and squad differences by lumping together all runs for a given ammunition-illumination-position (AIP) condition.

The standard deviations in Table J1 are computed from run totals, using the usual expression for variance $\sigma^2_{\bar{x}}$ of the mean of n items (n - 1 degrees of freedom):

$$\sigma^2_{\bar{x}} = [n\,\Sigma(x^2) - (\Sigma x)^2]/[n^2(n-1)] \qquad \text{(J1)}$$

The table entries of error are standard deviations of means and define the 68 percent confidence limits; i.e., if the experiment is repeated many times two-thirds of the time the result will be between $\bar{x} - \sigma_{\bar{x}}$ and $\bar{x} + \sigma_{\bar{x}}$.

Having listed in Table J1 the mean hits and hit probabilities (raw and adjusted) for all 21 AIP conditions, it is instructive to examine pertinent ratios. Also the listing of standard deviations $\sigma_{\bar{H}}$ and $\sigma_{\bar{P}}$ makes convenient the determination of the confidence that each of these ratios is really different from unity. Table J3 lists each of the seven other types of fire relative to single-bullet ammunition for appropriate illumination-position (IP) conditions. The t statistic for the difference between the means of any quantities x and y is given by

$$t = (\bar{x} - \bar{y})/\sqrt{(\sigma_x^2/n_x) + (\sigma_y^2/n_y)} \qquad \text{(J2)}$$

This expression approximates Eq. J4 for large samples. The computed values of t are then sought in statistical tables for (n_x + n_y - 2) degrees of freedom.

Table J1

HITS AND HIT PROBABILITIES BY AIP CONDITION

Ammunition or firing	Day sitting								Day standing								Night sitting							
	$\bar{h}$		$\sigma_{\bar{h}}$		$\bar{p}$(%)		$\sigma_{\bar{p}}$		$\bar{h}$		$\sigma_{\bar{h}}$		$\bar{p}$(%)		$\sigma_{\bar{p}}$		$\bar{h}$		$\sigma_{\bar{h}}$		$\bar{p}$(%)		$\sigma_{\bar{p}}$	
	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data
Single bullet	118	123	12	12	18.3	18.8	0.9	1.0	101	101	8	7	15.3	14.8	0.8	0.6	43	42	6	3	3.2	3.0	1.4	1.2
Duplex	181	185	17	17	32.1	32.1	1.4	1.9	174	176	14	10	28.1	27.3	1.8	1.3	66	63	23	22	9.3	9.1	1.6	1.6
Triplex	243	231	64	50	43.3	43.4	3.3	1.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbine automatic	111	121	24	20	10.3	10.8	2.8	2.2	110	104	50	38	7.9	7.6	1.1	1.3	29	33	3	2	2.1	2.1	1.0	1.0
Carbine semiautomatic	166	187	11	11	24.7	25.5	2.8	0.9	176	174	27	39	18.4	19.4	1.1	1.2	29	30	16	13	3.2	2.3	0.4	0.4
T48 automatic	93	94	4	5	10.3	10.0	0.9	1.0	75	80	16	12	8.8	8.9	1.6	1.7	67	67	9	8	3.3	3.3	0.7	0.7
T48 semi-automatic	136	127	10	11	23.4	21.8	0.4	0.4	120	123	11	5	15.3	15.5	2.6	3.6	84	84	1	2	10.2	10.2	0.3	0.3
Flechette[a]	—	—	—	—	—	—	—	—	205	109	—	—	41.3	50.9	—	—	188[b]	99	—	—	34.3	38.2	—	—

[a] Flechette runs are not directly comparable since target exposures were irregularly reduced. Hence there is gross variation between adjusted and raw values.
[b] Flechette night run was fired standing.

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The C columns in Table J3 give the confidence that the ratio is really different from unity.

Of more interest probably than this difference confidence is some measure of the confidence limits about each mean ratio $\bar{x}/\bar{y}$. Customarily the handling of errors in manipulating laboratory data is done by two rules: (a) for addition or subtraction, add the absolute errors; and (b) for multiplication or division, add the percentage errors. Since independent random errors are being used, addition implies the second power sum of the percentage errors. For the ratio of $\bar{x}$ to $\bar{y}$, the standard deviation is

$$\sigma_{\bar{x}/\bar{y}} = (\bar{x}/\bar{y}) \sqrt{(\sigma_x/x)^2 + (\sigma_y/y)^2} \qquad \text{(J3)}$$

Table J2

SUMMARY OF RATIOS OF MAJOR DIFFERENCES

Conditions compared	Hits	Hit probability
Standing to sitting	0.9	0.8
Night to day	0.4	0.2
Automatic to semiautomatic	0.7	0.5
Duplex to single bullet	1.6	1.7
Triplex to single bullet	2.1	2.2
Carbine/AP	1.5	1.3
T48/AP	1.2	1.1
T48/AP (night)	2.0	2.0

Table J3 lists the computed percentage errors of the ratios $(\sigma_{\bar{x}/\bar{y}})/(\bar{x}/\bar{y})$. The columns headed H are really ratios $(\bar{H}_x/\bar{H}_{AP})$. The columns headed C_H are the t test confidences that the differences $|H_x - H_{AP}|$ are real. The columns headed $\sigma_{\bar{H}}$ are really $\sigma_{H_x/H_{AP}}$. The hit probability columns are similarly defined. Similarly, in following tables, H and P are often used as abbreviations for ratios $\bar{H}_1/\bar{H}_2$ and $\bar{P}_1/\bar{P}_2$.

Table J4 compares sitting to standing and night to day hits and hit probabilities for each of the ammunitions. The means for all ammunitions reveal that standing hit probability was about three-fourths that of sitting, and that night hit probability was one-fourth that of day. As absolute hits per run dropped off less, it is clear that the firing rate increases. From the mean values of Table J4 the firing rate decreases 22 percent for sitting over that for standing and 78 percent for day over that for night.

The comparison of automatic to semiautomatic fire is best made from the balanced data on the two automatic weapons alone. These comparisons are made in Table J5. It appears that for day fire the automatic weapon scores only two-thirds the hits per run scored by the semiautomatic weapon. The hit probability drops even more, showing an increase of 53 percent in the rate of fire. The nighttime degradation is smaller.

Table J3

HITS AND HIT PROBABILITIES OF SALVO AMMUNITION OR FIRING COMPARED TO SINGLE-BULLET AP AMMUNITION[a]

Ammunition or firing	H		C_H		$\sigma_{\bar{H}}$		P		C_P		$\sigma_{\bar{P}}$	
	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data
Day sitting												
Duplex	1.53	1.52	—	99	0.21	0.20	1.66	1.62	—	100	0.11	0.13
Triplex	2.06	2.06	—	99	0.23	0.22	2.24	2.19	—	100	0.19	0.12
Carbine automatic	0.94	0.99	—	3	0.22	0.19	0.53	0.55	—	100	0.14	0.11
Carbine semi-automatic	1.42	1.37	—	95	0.17	0.16	1.28	1.20	—	100	0.16	0.08
T48 automatic	0.81	0.77	—	82	0.09	0.09	0.53	0.50	—	100	0.05	0.06
T48 semiautomatic	1.15	1.04	—	19	0.14	0.14	1.21	1.10	—	93	0.06	0.06
Day standing												
Duplex	1.72	1.76	—	100	0.19	0.16	1.72	1.86	—	100	0.15	0.12
Carbine automatic	1.09	1.03	—	7	0.50	0.38	0.52	0.51	—	100	0.08	0.09
Carbine semi-automatic	1.74	1.72	—	95	0.39	0.31	1.28	1.31	—	98	0.10	0.10
T48 automatic	0.74	0.79	—	76	0.17	0.13	0.45	0.47	—	100	0.12	0.12
T48 semiautomatic	1.19	1.22	—	85	0.14	0.10	1.01	1.05	—	42	0.18	0.17
Flechette[b]	1.73	0.89	—	—	—	—	2.72	3.44	—	—	—	—
Night sitting												
Duplex	1.57	1.55	—	63	0.59	0.56	1.79	1.82	—	100	0.57	0.54
Carbine automatic	0.69	0.60	—	39	0.12	0.09	0.46	0.42	—	100	0.22	0.22
Carbine semi-automatic	1.00	0.71	—	55	0.57	0.32	0.62	0.64	—	92	0.18	0.17
T48 automatic	1.60	1.60	—	90	0.31	0.27	1.02	1.06	—	37	0.30	0.29
T48 semiautomatic	2.00	2.00	—	—	0.37	0.53	1.96	2.04	—	100	0.53	0.49
Flechette[b]	4.12[c]	2.36	—	—	—	—	6.60	7.65	—	—	—	—

[a]Single bullet taken to be 1.00.

[b]Flechette runs are not directly comparable since target exposures were irregularly reduced. Hence there is gross variation between adjusted and raw values.

[c]Flechette night run was fired standing.

Table J4

HITS AND HIT PROBABILITIES OF STANDING COMPARED TO SITTING AND NIGHT COMPARED TO DAY

Ammunition or firing	Standing to sitting, %				Night to day, %			
	H		P		H		P	
	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data
Single bullet	86	83	79	75	38	34	27	25
Duplex	96	96	81	86	26	35	29	28
Carbine automatic	99	88	77	70	26	21	20	19
Carbine semi-automatic	104	105	79	82	17	18	13	13
T48 automatic	79	85	68	69	71	71	5	5
T48 semiautomatic	88	97	65	71	82	66	44	47
Flechette	—	—	—	—	81	91	83	75
Mean[a]	92	92	75	76	41	41	23	23

[a]Except for flechettes.

COMPARISON OF SINGLE-BULLET, DUPLEX, AND TRIPLEX AMMUNITIONS

Table J6 is a tabulation of the raw (i.e., manual count of rounds of ammunition used and count of holes in targets for each run) data for each of the 18 runs in which single-bullet ammunition was used, plus additional calculations to be explained later. Table J7 tabulates the corresponding adjusted data. Tables J8 and J9 are similar tabulations for the 14 duplex runs, and Tables J10 and J11 show the results for the two triplex runs. For each of these runs the probability of hits p has been calculated from the relation

$$p = \frac{\text{number of holes counted (for all 22 targets)}}{\text{rounds of ammunition counted}}$$

The probability q of missing the target is $q = 1 - p$

From elementary statistical theory the standard deviation σ of the quantity p in the binomial distribution $(p + q)^n$ is given by

$$\sigma^2 = pq/n$$

Also the binomial can be shown to tend to normality as n increases. For $n = 100$ the normal approximation for the binomial is sufficiently good for most practical applications; for $n > 400$, a condition satisfied by all runs of this experiment, the normal curve approximation for the binomial will be excellent.

If the eight duplex runs in Table J8 for the day-sitting firing condition are compared with the corresponding eight single-bullet runs in Table J6, the hit probabilities for the duplex runs are from about 50 percent to more than 100 percent greater than those for the single-bullet runs. This appears to remove

Table J5

HITS AND HIT PROBABILITIES OF AUTOMATIC COMPARED TO SEMIAUTOMATIC[a] FIRE

Ammunition	Day-sitting condition, %				Day-standing condition, %				Night-sitting condition, %			
	H		*P*		*H*		*P*		*H*		*P*	
	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data	Adjusted data	Raw data
Carbine	66	73	42	46	63	60	41	39	100	83	66	66
T48	70	74	44	46	62	65	44	45	80	80	52	52
Mean	68	74	43	46	63	63	43	42	90	82	59	59

[a]The semiautomatic is 100.

any doubt as to real effects shown by these data. However, this can be vigorously established in any one of several ways. The t test could be applied to the pairs of corresponding runs. Perhaps the simplest way to examine these hit probabilities statistically is to follow the method of control charts frequently used in quality-control work. If control limits of $p \pm 2\sigma$ are calculated, the probability that another estimate of the same p will fall outside the $\pm 2\sigma$ limits is about 4 percent. These limits were computed; graphs of the results are shown in Figs. J1 and J2. The fact that the hit probabilities for the duplex runs (except for night sitting, Run 8, for which there is no definite explanation) far exceed the upper 2σ limit for the hit probabilities of the corresponding single-bullet runs is very strong evidence that the duplex hit-probability improvements are real under all test conditions of this experiment. There is also strong evidence in Figs. J1 and J2 that some extraordinary condition was experienced in Runs 7 or 8. Possibly an erroneous ammunition count or target hole count was made in Run 7. Another possible explanation of the unexpected results in comparing Runs 7 and 8 is found in a note of an observer written at the time Run 7 was made. This note states that the targets on Run 7 were seen with an excessive glare in the moonlight. Aside from these two comparisons, each of the duplex runs compared to the corresponding single-bullet run gives hit probabilities that are significantly better at least at the 0.1 percent level. This means that under the assumption that there is no real difference in duplex and single-bullet hit probabilities the results of any pair of these comparisons would have less than 1 chance in 1000 of occurring from random or sampling variation.

Figures J1 and J2 also show the results of the only two triplex runs completed. Both Runs 26 and 28 have hit probabilities far beyond the 3σ control limits for Runs 25 and 27, which are the corresponding single-bullet runs. The triplex runs are not directly comparable to duplex runs, but the fact that the hit probabilities for both these runs are above the 2σ control limits for any duplex run is substantial evidence that the triplex ammunition gives a real increase over duplex ammunition in hit probabilities.

Tables J20 to J33 are tabulations for holes counted (total hits) with additional calculations similar to those in Tables J6 to J19.

Tables J34 to J39 contain calculations that compare mean values rather than individual pairs of values.

Table J34 shows a tabulation and the mean value for all day-sitting runs for the single-bullet and duplex ammunition. Two types of t test for significance of differences are calculated in this table. The significance of the difference in the two mean values (121.5 for the single-bullet ammunition and 185.4 for the duplex ammunition) is tested by the calculation

$$t = \frac{[mn/(m+n)]^{1/2}(\bar{x}_2 - \bar{x}_1)}{\{[\sum_i (x_{1i} - \bar{x}_1)^2 + \sum_i (x_{2i} - \bar{x}_2)^2]/(m+n-2)\}^{1/2}} \qquad \text{(J4)}$$

In this expression, m is the size of the first sample with mean $\bar{x}_1$, and n is the size of the second sample with mean $\bar{x}_2$. The value of t calculated in this way from the data in Table J20 is $t = 3.18$. This value of t for 16 degrees of freedom is significant at beyond the 1 percent level.

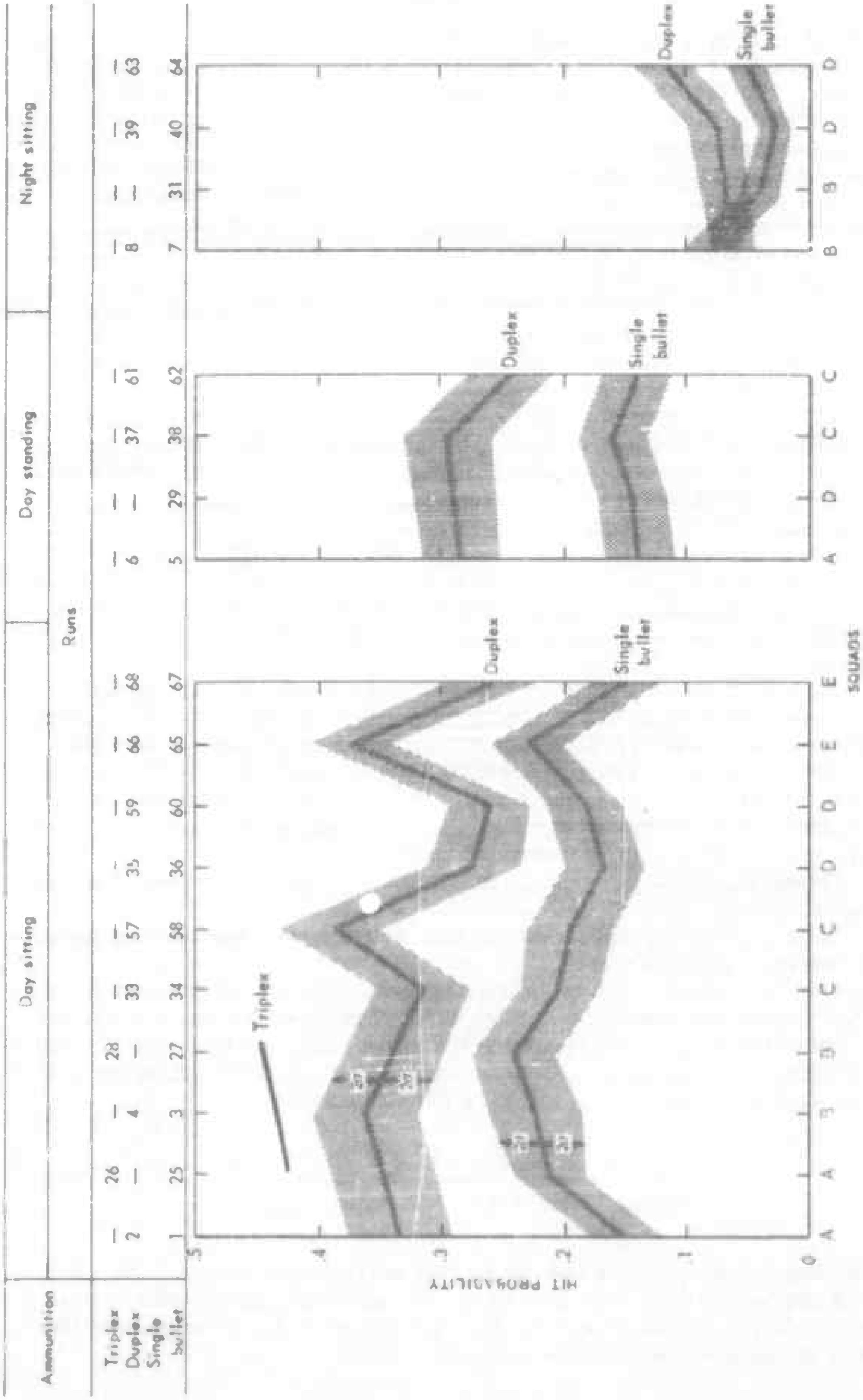

Fig. J1—Single-Bullet, Duplex, and Triplex Hit Probabilities, Raw Data

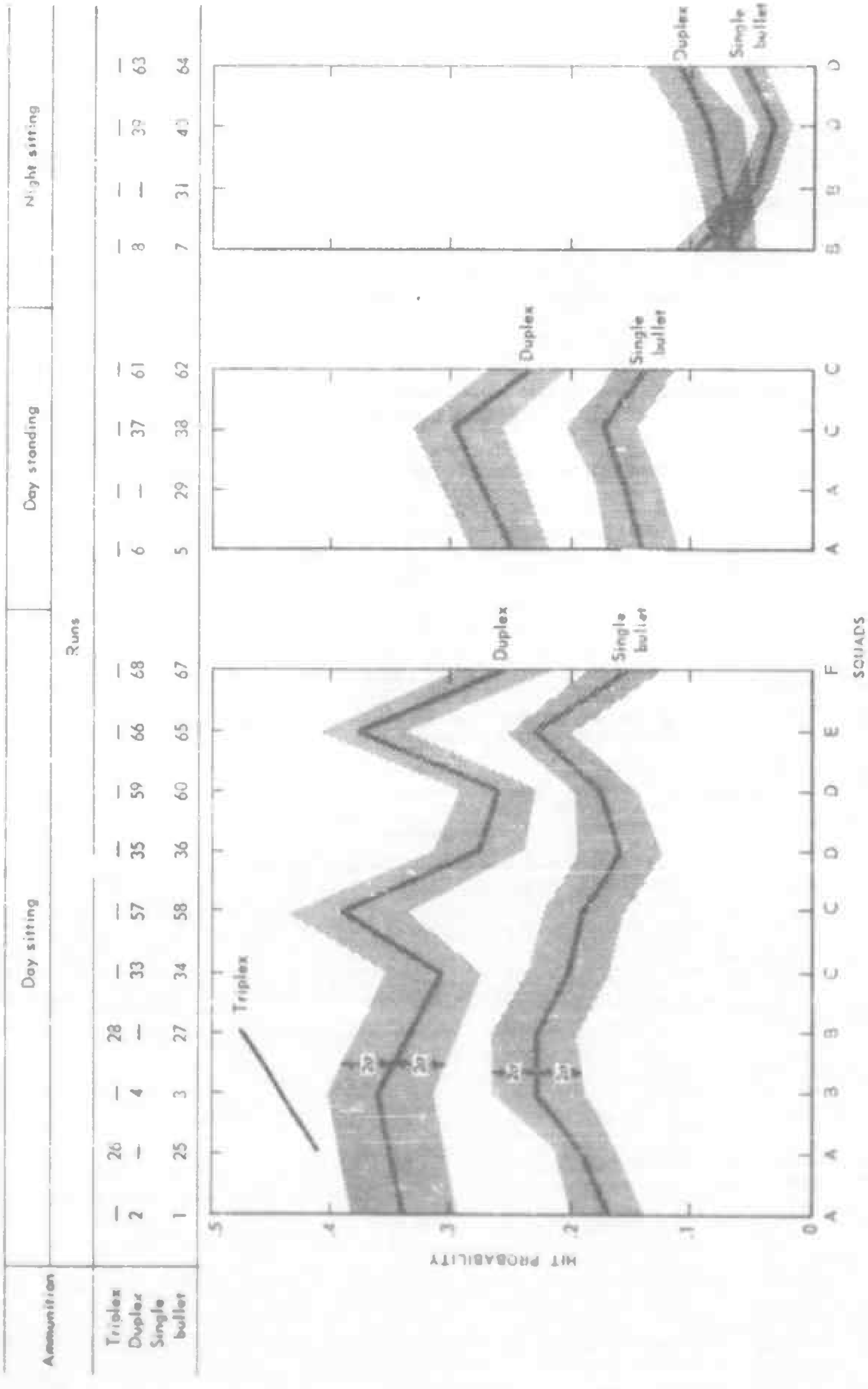

Fig. J2—Single-Bullet, Duplex, and Triplex Hit Probabilities, Adjusted Data

Table J6

SINGLE-BULLET HIT PROBABILITIES AND STANDARD ERRORS, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
1	A	607	90	.146	.014
3	B	471	105	.223	.019
25	A	742	157	.212	.015
27	B	598	144	.241	.016
34	C	545	111	.204	.017
36	D	462	61	.166	.017
[illegible]	C	504	100	.198	.018
60	D	663	120	.161	.015
65	E	865	202	.233	.014
67	F	688	105	.153	.014
Subtotal		8,165	1215	.197	
		Day-Standing Condition			
5	A	579	61	.140	.014
29	A	747	103	.145	.013
38	C	679	110	.162	.014
62	C	720	103	.143	.013
Subtotal		2,725	402	.148	
		Night-Sitting Condition			
7	B	616	53	.086	.011
31	B	950	41	.043	.007
40	D	901	27	.030	.006
64	D	669	45	.052	.008
Subtotal		3,336	166	.050	
Total		12,228	1763	.146	

Table J7

SINGLE-BULLET HIT PROBABILITIES AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
1	A	540	91	.169	.016
3	B	483	108	.224	.019
25	A	827	157	.190	.014
27	B	576	132	.229	.018
34	C	537	110	.205	.017
36	D	445	71	.160	.017
58	C	471	90	.191	.016
60	D	709	121	.171	.014
65	E	872	200	.229	.014
67	F	647	100	.155	.014
Subtotal		6,119	1160	.193	
		Day-Standing Condition			
5	A	551	78	.142	.015
29	A	767	117	.153	.013
38	C	625	109	.174	.015
62	C	714	99	.139	.013
Subtotal		2,657	403	.152	
		Night-Sitting Condition			
7	B	600	56	.093	.012
31	B	950	42	.044	.007
40	D	874	26	.030	.006
64	D	768	42	.055	.008
Subtotal		3,192	166	.052	
Total		11,968	1749	.148	

Table J6

DUPLEX HIT PROBABILITIES AND STANDARD ERRORS, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
2	A	492	166	.337	.021
4	B	469	170	.362	.022
33	C	505	159	.315	.021
35	D	476	132	.277	.020
57	C	534	209	.392	.021
59	D	748	195	.261	.016
66	E	779	292	.375	.017
68	F	623	160	.257	.016
Subtotal		4626	1483	.321	
		Day-Standing Condition			
6	A	667	190	.285	.017
37	C	635	167	.295	.016
61	C	645	156	.245	.017
Subtotal		1947	535	.275	
		Night-Sitting Condition			
8	B	678	44	.065	.009
39	D	553	43	.076	.011
63	D	918	109	.119	.001
Subtotal		2149	196	.091	
Total		6722	2214	.254	

Table J9

DUPLEX HIT PROBABILITIES AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
2	A	492	166	.337	.021
4	B	487	158	.338	.022
33	C	485	154	.318	.021
35	D	438	123	.281	.021
57	C	572	214	.374	.020
59	D	701	201	.287	.017
66	E	769	278	.359	.017
88	F	586	158	.266	.018
Subtotal		4510	1448	.321	
		Day-Standing Condition			
6	A	719	182	.253	.018
37	C	653	193	.296	.018
61	C	631	148	.235	.017
Subtotal		2003	523	.261	
		Night-sitting Condition			
8	B	678	44	.065	.009
39	D	491	41	.084	.013
83	D	950	112	.118	.010
Subtotal		2119	197	.093	
Total		8832	2188	.251	

Table J10

TRIPLEX HIT PROBABILITIES AND STANDARD ERRORS, DAY-SITTING CONDITION, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
26	A	706	301	.426	.018
28	B	451	201	.445	.023
Total		1157	502	.434	

Table J11

TRIPLEX HIT PROBABILITIES AND STANDARD ERRORS, DAY-SITTING CONDITION, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
26	A	750	309	.412	.018
28	B	369	176	.477	.026
Total		1119	485	.433	

Table J12

CARBINE AUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
20	A	1696	179	.106	.00748
18	B	1016	114	.112	.010
41	D	630	86	.136	.014
43	C	1111	106	.095	.009
Subtotal		4453	485	.109	
		Day-Standing Condition			
45	O	1093	66	.060	.007
22	B	1655	142	.086	.0069
Subtotal		2748	208	.076	
		Night-Sitting Condition			
24	A	1463	26	.018	.003
47	C	886	23	.026	.005
Subtotal		2349	49	.021	
Total		9550	742	.078	

Table J13

CARBINE AUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
20	A	1801	173	.096	.007
18	B	900	108	.120	.011
41	D	513	59	.115	.014
43	C	1069	102	.095	.009
Subtotal		4283	442	.103	
		Day-Standing Condition			
45	D	928	59	.064	.008
22	B	1829	160	.087	.007
Subtotal		2757	219	.079	
		Night-Sitting Condition			
24	A	1472	26	.018	.003
47	C	1240	32	.026	.004
Subtotal		2712	58	.021	
Total		9752	719	.074	

Table J14

CARBINE SEMIAUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
		Day-sitting Condition			
17	B	640	178	.278	.018
19	A	758	135	.178	.014
42	D	644	171	.268	.017
44	C	767	184	.240	.015
Subtotal		2809	668	.238	
		Day-Standing Condition			
21	B	985	202	.205	.013
46	D	808	145	.179	.0135
Subtotal		1793	347	.194	
		Night-Sitting Condition			
23	A	1034	42	.041	.006
48	C	814	17	.021	.008
Subtotal		1848	59	.032	
Total		6450	1074	.167	

Table J15

CARBINE SEMIAUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
17	B	633	177	.280	.018
19	A	758	135	.178	.014
42	D	611	179	.293	.018
44	C	724	182	.251	.016
Subtotal		2726	673	.247	
		Day-Standing Condition			
21	B	1042	213	.204	.012
46	D	777	139	.179	.014
Subtotal		1819	352	.194	
		Night-Sitting Condition			
23	A	1140	45	.039	.006
48	C	692	13	.019	.005
Subtotal		1832	58	.032	
Total		5800	944	.169	

Table J16

T48 AUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
10	B	824	86	.104	.001
12	A	1056	102	.097	.009
49	D	763	86	.112	.011
51	C	1112	103	.093	.009
Subtotal		3755	377	.100	
		Day-Standing Condition			
14	B	923	91	.099	.010
53	D	1385	68	.049	.006
Subtotal		2308	159	.069	
		Night-Sitting Condition			
16	A	1444	75	.052	.006
55	C	1082	59	.05[illegible]	.007
Subtotal		2526	134	.05[illegible]	
Total		8589	670	.078	

Table J17

T45 AUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
10	B	758	65	.113	.011
12	A	1053	104	.098	.009
49	D	852	92	.108	.011
51	C	1020	99	.097	.009
Subtotal		3685	361	.103	
		Day-Standing Condition			
14	B	916	91	.099	.010
53	D	1275	59	.046	.006
Subtotal		2193	150	.068	
		Night-Sitting Condition			
16	A	1489	76	.051	.005
55	C	1038	58	.058	.007
Subtotal		2527	134	.053	
Total		8408	865	.079	

Table J18

T48 SEMIAUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, RAW DATA

Run	Squad	Rounds counted, n	Holes counted	p = holes/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
9	B	422	97	.230	.021
11	A	588	143	.243	.018
50	D	816	127	.208	.016
52	C	705	140	.199	.015
Subtotal		2331	507	.218	
		Day-Standing Condition			
13	B	736	127	.173	.014
54	D	849	118	.139	.012
Subtotal		1585	245	.155	
		Night-Sitting Condition			
15	A	782	85	.109	.011
56	C	856	82	.096	.010
Subtotal		1638	167	.102	
Total		5554	919	.166	

Table J19

T46 SEMIAUTOMATIC HIT PROBABILITIES AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Shots adjusted, n	Hits adjusted	p = hits/n	$\sigma = \sqrt{pq/n}$
		Day-Sitting Condition			
9	B	480	111	.231	.019
11	A	646	157	.243	.017
50	D	649	144	.222	.016
52	C	649	130	.200	.018
Subtotal		2424	542	.224	
		Day-Standing Condition			
13	B	762	131	.172	.014
54	D	805	109	.135	.012
Subtotal		1567	240	.153	
		Night-Sitting Condition			
15	A	779	85	.109	.011
56	C	859	82	.095	.010
Subtotal		1638	167	.102	
Total		5629	949	.169	

Table J20

SINGLE-BULLET HITS AND STANDARD ERRORS, RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	s[a]	$h + 2s$	$h - 2s$
			Day-Sitting Condition			
1	A	90			186.8	−6.6
3	B	105			201.8	8.2
25	A	157			253.6	60.2
27	B	144			240.6	47.2
34	C	111			207.6	14.2
36	D	81			177.6	−15.8
58	C	100			196.8	3.2
60	D	120			216.6	23.2
65	E	202			298.8	105.2
67	F	105			201.8	8.2
Subtotal		1215	159,621	48.4	2183.0	247.0
			Day-Standing Condition			
5	A	81			107.6	54.4
29	A	108			134.6	81.4
38	C	110			136.6	83.4
62	C	103			129.6	76.4
Subtotal		402	40,934	13.3	508.4	295.6
			Night-Sitting Condition			
7	B	53			74.8	31.2
31	B	41			62.6	19.2
40	D	27			48.6	5.2
64	D	45			66.6	23.2
Subtotal		166	7,244	10.9	263.2	78.6
Total		1783	217,249	46.9		

[a] $s^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J21

SINGLE-BULLET HITS AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
Day-Sitting Condition						
1	A	91			166.0	16.0
3	B	108			183.0	33.0
25	A	157			232.0	82.0
27	B	132			207.0	57.0
34	C	110			185.0	35.0
36	D	71			146.0	−4.0
58	C	90			165.0	15.0
60	D	121			196.0	46.0
65	E	200			275.0	125.0
67	F	100			175.0	25.0
Subtotal		1180	151,900	37.5	1930.0	430.0
Day-Standing Condition						
5	A	78			111.8	44.2
29	A	117			150.8	83.2
38	C	109			142.8	75.2
62	C	99			132.8	65.2
Subtotal		403	41,455	16.9	538.2	267.8
Night-Sitting Condition						
7	B	56			80.6	31.4
31	B	42			66.6	17.4
40	D	26			50.6	1.4
64	D	42			66.6	17.4
Subtotal		166	7,340	12.3	264.4	67.6
Total		1749	200,695	42.5		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J22

DUPLEX HITS AND STANDARD ERRORS, RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
2	A	166			264.0	68.0
4	B	170			268.0	72.0
33	C	159			257.0	61.0
35	D	132			230.0	34.0
57	C	209			307.0	111.0
59	D	195			293.0	97.0
66	E	292			390.0	194.0
68	F	160			258.0	62.0
Subtotal		1483	291,731	49.0	2267.0	699.0
			Day-Standing Condition			
6	A	190			225.4	154.6
37	C	187			222.4	151.6
61	C	158			193.4	122.6
Subtotal		535	96,033	17.7	641.2	428.8
			Night-Sitting Condition			
9	B	44			119.6	−31.6
39	D	43			118.6	−32.6
63	D	109			184.6	33.4
Subtotal		196	15,886	37.8	422.6	−30.8
Total		2214	403,430	64.0		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J23

DUPLEX HITS AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
2	A	166			261.6	70.4
4	B	166			253.6	62.4
33	C	154			249.6	[illegible]
36	D	123			216.6	27.4
67	C	214			309.6	118.4
69	D	201			296.6	106.4
66	E	276			371.6	160.4
68	F	156			261.6	60.4
Subtotal		1448	273,074	47.8	2212.6	663.2
			Day-Standing Condition			
6	A	182			229.0	136.0
37	C	193			240.0	146.0
61	C	146			196.0	101.0
Subtotal		523	92,277	23.5	664.0	362.0
			Night-Sitting Condition			
8	B	44			124.4	−36.4
39	D	41			121.4	−39.4
63	D	112			192.4	31.6
Subtotal		197	16,161	40.2	438.2	−44.2
Total		2168	386,512	62.5		

[a] $s^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J24

TRIPLEX HITS AND STANDARD ERRORS, DAY-SITTING CONDITION, RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
26	A	301			442.4	159.6
28	B	201			342.4	59.6
Total		502	131,002	70.7	784.6	219.2

[a] $s^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J25

TRIPLEX HITS AND STANDARD ERRORS, DAY-SITTING CONDITION, ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
26	A	309			497	121
28	B	176			364	−12
Total		485	126,457	94.0	661	109

[a] $s^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J26

CARBINE AUTOMATIC HITS AND STANDARD ERRORS, RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
20	A	179			259.8	98.4
18	B	114			194.6	33.4
41	D	86			166.6	5.4
43	C	106			166.6	25.4
Subtotal		485	64,889	40.3	807.4	162.6
			Day-Standing Condition			
45	D	66			173.4	−41.4
22	B	142			249.4	34.6
Subtotal		208	24,520	53.7	422.6	−6.8
			Night-Sitting Condition			
24	A	26			30.24	21.76
47	C	23			27.24	18.76
Subtotal		49	1,205	2.12	57.48	40.52
Total		742		54.2		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J27

CARBINE AUTOMATIC HITS AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
20	A	173			267.0	79.0
16	B	108			202.0	14.0
41	D	59			153.0	−35.0
43	C	102			196.0	6.0
Subtotal		442	56,476	47.0	816.0	66.0
			Day-Standing Condition			
46	D	56			201.6	−83.8
22	B	160			302.6	17.2
Subtotal		216	29,661	71.4	504.8	−66.6
			Night-Sitting Condition			
24	A	26			34.4	17.6
47	C	32			40.4	23.6
Subtotal		58	1,700	4.2	74.8	41.2
Total		716	86,269	55.6		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$.

Table J28

CARBINE SEMIAUTOMATIC HITS AND STANDARD ERRORS, RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
17	B	178			222	134
19	A	135			179	91
42	D	171			215	127
44	C	184			228	140
Subtotal		668	113,006	22.0	644	492
			Day-Standing Condition			
21	B	202			282.6	121.4
46	D	145			225.6	64.4
Subtotal		347	61,829	40.3	508.2	186.6
			Night-Sitting Condition			
23	A	42			77.4	8.8
48	C	17			52.4	-16.4
Subtotal		59	2,053	17.7	129.8	-11.6
Total		1074	176,888	88.4		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$

Table J29

CARBINE SEMIAUTOMATIC HITS AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	S[a]	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
17	B	177			221.6	132.4
19	A	135			179.8	90.4
42	D	179			223.6	134.4
44	C	162			226.6	137.4
Subtotal		673	114,719	22.3	851.4	494.6
			Day-Standing Condition			
21	B	213			317.6	108.4
46	D	139			243.6	34.4
Subtotal		352	64,690	52.3	561.2	142.6
			Night-Sitting Condition			
23	A	45			90.2	-0.2
46	C	13			58.2	[illegible]
Subtotal		56	2,194	22.6	148.4	-32.4
Total		1063	181,603	70.7		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$

Table J30

T48 AUTOMATIC HITS AND STANDARD ERRORS
RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	s[a]	$h + 2s$	$h - 2s$
			Day-Sitting Condition			
10	B	88			105.08	68.92
12	A	102			121.08	82.92
49	D	86			105.08	68.92
51	C	103			122.08	83.92
Subtotal		377	35,805	9.54	453.32	300.68
			Day-Standing Condition			
14	B	91			123.6	58.4
53	D	68			100.6	35.4
Subtotal		159	12,905	16.3	224.2	93.8
			Night-Sitting Condition			
18	A	75			97.6	52.4
55	C	59			81.6	36.4
Subtotal		134	9,108	11.3	179.2	88.8
Total		670	57,818	15.6		

[a] $s^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$

Table J31

T48 AUTOMATIC HITS AND STANDARD ERRORS,
ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	s[a]	$h + 2s$	$h - 2s$
			Day-Sitting Condition			
10	B	86			101.8	70.2
12	A	104			119.8	88.2
49	D	92			107.8	76.2
51	C	99			114.8	83.2
Subtotal		381	36,477	7.9	444.2	317.8
			Day-Standing Condition			
14	B	91			136.2	45.8
53	D	59			104.2	13.8
Subtotal		150	11,762	22.6	240.4	59.6
			Night-Standing Condition			
16	A	76			101.4	50.6
55	C	58			83.4	32.6
Subtotal		134	9,140	12.7	184.9	83.2
Total		665	57,379	17.3		

[a] $s^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$

Table J32

T48 SEMIAUTOMATIC HITS AND STANDARD ERRORS, RAW DATA

Run	Squad	Holes counted, h	Sum of squares Σh^2	S^a	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
9	B	97			139	55
11	A	143			185	101
50	D	127			169	85
52	C	140			162	98
Subtotal		507	65,587	31.0	675	339
			Day-Standing Condition			
13	B	137			139.72	114.38
54	D	118			130.72	105.28
Subtotal		245	30,0[illegible]3	[illegible].36	270.44	319.56
			Night-Sitting Condition			
15	A	85			89.34	80.76
56	C	82			[illegible].24	77.76
Subtotal		167	13,949	2.12	175.48	158.52
Total		919	109,569	24.0		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$

Table J33

T48 SEMIAUTOMATIC HITS AND STANDARD ERRORS, ADJUSTED DATA

Run	Squad	Hits adjusted, h	Sum of squares Σh^2	S^a	$h + 2S$	$h - 2S$
			Day-Sitting Condition			
9	B	111			150.4	71.6
11	A	157			196.4	117.6
50	D	144			183.4	104.6
52	C	130			169.4	90.6
Subtotal		543	74,606	19.7	692.6	384.4
			Day-Standing Condition			
13	B	13[illegible]			163.2	89.6
54	D	109			140.2	77.6
Subtotal		340	29,042	15.6	302.4	177.6
			Night-Sitting Condition			
15	A	85			89.3	80.8
56	C	82			86.3	77.8
Subtotal		167	13,949	2.1	175.4	158.6
Total		949	11[illegible]	[illegible]		

[a] $S^2 = [1/(n-1)]\{\Sigma h^2 - [(\Sigma h)^2/n]\}$

The other value of $t = 9.56$ shown in Table J34 is the test for mean differences of pairs of correlated data, and is calculated as the ratio of the mean difference to the estimated standard error of this mean difference. The value of $t = 9.56$ for the 7 degrees of freedom available is significant at about the 0.1 percent level. Both these tests constitute strong evidence that the increase of duplex over single-bullet ammunition in total hits for day-sitting runs is a real effect. It will be observed that the increase of total hits in this sample is over 50 percent.

In Table J36 the total hits for all the duplex and single-bullet runs are compared, and the same type t tests calculated as explained previously for Table J34.

Table J34

SINGLE-BULLET AND DUPLEX HITS, DAY SITTING, RAW DATA

Squad	Single bullet		Duplex		Duplex minus single bullet
	Run	Holes counted	Run	Holes counted	
A	1	90	2	166	76
B	3	105	4	170	65
A	25	157	—	—	—
B	27	144	—	—	—
C	34	111	33	159	48
D	36	81	35	132	51
C	58	100	57	209	109
D	60	120	59	195	75
E	65	202	66	292	90
F	67	105	68	160	55
No. of runs		10		8	8
Sum (holes counted)		1,215		1,483	569
Mean		121.5		185.4	71.1
Sum of squares		159,621		291,731	43,537

Item	Difference of means	Mean difference
t	3.18	9.56
Degrees of freedom	16	7
Approximate significance level, %	1	0.1

Even with the reversal for one pair of runs for night-sitting condition, where more hits were scored with the single-bullet than with duplex ammunition (shown in Table J36), the two values for t of 3.12 (30 degrees of freedom) and 7.33 (13 degrees of freedom) give strong evidence that the average increase (over 50 percent) for total hits in all duplex runs over all single-bullet runs is a real effect.

Table J38 shows the results of significance tests in comparing triplex with duplex and single-bullet ammunitions in total hits. There are only two triplex runs, which, of course, is a very small sample. When compared with the two corresponding single-bullet runs, even though there is an average increase of nearly 70 percent in total hits for triplex, the difference is significant at only about the 20 percent level. When the average of the 2 triplex runs is compared with the average of the 10 single-bullet day-sitting runs and 8 duplex day-sitting runs, it is found that the corresponding t values are significant at about the 0.2 percent level and the 15 percent level. This is strong evidence that triplex ammunition is superior to the single-bullet ammunition, but not very strong evidence that triplex ammunition is really superior to duplex ammunition in total hits. The relative increase of triplex over duplex ammunitions total hits is over 30 percent, and if this held for a few more triplex runs the significance of the difference would increase rapidly.

Table J35

SINGLE-BULLET AND DUPLEX HITS, DAY SITTING, ADJUSTED DATA[a]

Squad	Single bullet		Duplex		Duplex minus single bullet
	Run	Hits adjusted	Run	Hits adjusted	
A	1	91	2	166	75
B	3	108	4	158	50
A	25	157	—	—	—
B	27	132	—	—	—
C	34	110	33	154	44
D	36	71	35	123	52
C	58	90	57	214	124
D	60	121	59	201	80
E	65	200	66	276	76
F	67	100	68	156	56
No. of runs		10		8	8
Sum (hits adjusted)		1,180		1,448	557
Mean		118		181	69.6
Sum of squares		151,900		278,074	—

[a] t (difference of two means assuming equal variance) 3.14
Degrees of freedom 16
Approximate significance level 1%

COMPARISON OF AUTOMATIC AND SEMIAUTOMATIC CARBINE AND T48 FIRING

Table J40 is a summary of the analysis of the hit probabilities from the 16 day-sitting runs, which are balanced with respect to the four average squads and the four types of fire: carbine automatic, carbine semiautomatic, T48 automatic, and T48 semiautomatic. Table J40 shows that the semiautomatic fire for both the carbine and the T48 is consistently better than the automatic fire. The hit probabilities for the two types of semiautomatic fire are not very different, but on the average they are more than twice the corresponding value for the automatic fire. It might be concluded without further analysis that automatic fire is inferior to semiautomatic fire as far as hit probabilities are concerned.

Table J36

SINGLE-BULLET AND DUPLEX HITS, ALL RUNS, RAW DATA

Squad	Single bullet		Duplex		Duplex minus single bullet
	Run	Holes counted	Run	Holes counted	
Day Sitting					
A	1	90	2	166	76
B	3	105	4	170	65
A	25	157	—	—	—
B	27	144	—	—	—
C	34	111	33	159	48
D	36	81	35	132	51
C	58	100	57	209	109
D	60	120	59	195	75
E	65	202	66	292	90
F	67	105	68	160	55
Day Standing					
A	5	81	6	190	109
A	29	108	—	—	—
C	36	110	37	187	77
C	62	103	61	158	55
Night Sitting					
B	7	53	8	44	–9
B	31	41	—	—	—
D	40	27	39	43	16
D	64	45	63	109	64
No. of runs		18		14	14
Sum (holes counted)		1,783		2,214	881
Mean		99.06		158.14	62.9
Sum of squares		207,799		403,430	68,805

Item	Difference of means	Mean difference
t	3.12	7.33
Degrees of freedom	30	13
Approximate significance level, %	1	0.1

Table J37

SINGLE-BULLET AND DUPLEX HITS, ALL RUNS, ADJUSTED DATA[a]

Squad	Single bullet		Duplex		Duplex minus single bullet
	Run	Hits adjusted	Run	Hits adjusted	
		Day Sitting			
A	1	91	2	166	75
B	3	108	4	158	50
A	25	157	—	—	—
B	27	132	—	—	—
C	34	110	33	154	44
D	36	71	35	123	52
C	58	90	57	214	124
D	60	121	59	201	80
E	65	200	66	276	76
F	67	100	68	156	56
		Day Standing			
A	5	78	6	182	104
A	29	117	—	—	—
C	36	109	37	193	84
C	62	99	61	148	49
		Night Sitting			
B	7	56	8	44	12
B	31	42	—	—	—
D	40	26	39	41	15
D	64	42	63	112	70
No. of runs		18		14	14
Sum (hits adjusted)		1,749		2,168	891
Mean		97.17		154.86	63.64
Sum of squares		200,695		386,512	—

[a] t (difference of means) 3.11
Degrees of freedom 30
Approximate significance level 1%

Table J38

TRIPLEX, SINGLE-BULLET, AND DUPLEX HITS, DAY SITTING, RAW DATA[a]

A Triplex with Corresponding Single-Bullet Hits

Squad	Single bullet		Triplex		Triplex minus single bullet
	Run	Holes counted	Run	Holes counted	
A	25	157	26	301	144
B	27	144	28	201	57
No. of runs		2		2	2
Sum (holes counted)		301		502	201
Mean		150.5		251	100.5
Sum of squares		45,385		131,002	23,985

[a] t (difference of means) 2.31
Degrees of freedom 1
Approximate significance level 20%

B. Triplex with Averages of Duplex and Single-Bullet Hits

Item	Duplex		Triplex		Single bullet	
	Runs	Holes counted	Runs	Holes counted	Runs	Holes counted
Total	8	1,483	2	502	10	1,215
Mean		185.4		251		121.5
Sum of squares		291,731		131,002		159,621

Item	Triplex compared to duplex means	Triplex compared to single-bullet means
	1.59	4.05
Degrees of freedom	8	10
Approximate significance level, %	15	0.2

Table J39

TRIPLEX, SINGLE-BULLET, AND DUPLEX HITS,
DAY SITTING, ADJUSTED DATA[a]

A. Triplex with Corresponding Single-Bullet Hits

Squad	Single bullet		Triplex		Triplex minus single bullet
	Run	Hits adjusted	Run	Hits adjusted	
A	25	157	26	309	152
B	27	132	28	176	44
No. of runs		2		2	2
Sum (hits adjusted)		289		485	196
Mean		144.5		242.5	98
Sum of squares		42,073		126,457	25,040

[a] t (difference of means) 1.77
Degrees of freedom 1
Approximate significance level 33%

B. Triplex with Averages of Duplex and Single-Bullet Hits

Item	Duplex		Triplex		Single bullet	
	Runs	Hits adjusted	Runs	Hits adjusted	Runs	Hits adjusted
Total	8	1,448	2	485	10	1,180
Mean		181		242.5		118
Sum of squares		278,074		126,457		151,900

Item	Triplex compared to duplex means	Triplex compared to single-bullet means
t	1.40	3.47
Degrees of freedom	8	10
Approximate significance level, %	20	0.8

Comparison of the four squads shows that the mean hit probabilities are practically the same for Squads A and C and also for Squads B and D. It is questionable whether Squads A and C are really inferior to Squads B and D. Analysis-of-variance calculations may shed light on this question.

The assumptions made in applying analysis of variance to any rectangular array (which covers the tables of this section) are briefly as follows:

$$x_{ij} = C + \alpha_i + \beta_j + e_{ij} \tag{J5}$$

where x_{ij} = the entry for the ith row and jth column
C = a constant
α_i = the effect of the ith row
β_j = the effect of the jth column
e_{ij} = a normally distributed random error

Expressed in words, this assumption is simply that the entries in the rectangular array are, except for random error, additive functions of the variables represented by the rows and columns. Any departure from additivity of the effects inflates the error and decreases the precision of the tests. The assumption that e_{ij}, the random error, is normally distributed is necessary in order to apply the F test and establish a significance level for rejecting an hypothesis.

The next assumption is that the row and column effects, α_i and β_j are zero. This is the null hypothesis—or the straw-man technique. If this hypothesis can be disproved, there is evidence that the rows, or columns, do have a real effect.

For an n row, m column rectangular array the total variance is subdivided according to the following identity:

$$\sum_{ij} (x_{ij} - \bar{x})^2 = m \sum_i (\bar{x}_i - \bar{x})^2 + n \sum_j (\bar{x}_j - \bar{x})^2 + \sum_{ij} (x_{ij} - \bar{x}_i - \bar{x}_j + \bar{x})^2 \tag{J6}$$

where x_{ij} = the entry for the ith row and jth column
$\bar{x}_i$ = the mean of the ith row
$\bar{x}_j$ = the mean of the jth column
$\bar{x}$ = the general mean

The quantity on the left in Eq. J6 is the total sum of squares of deviations from the general mean, which is subdivided into sums of squares attributable to rows, columns, and error. The degrees of freedom are $mn - 1$, $m - 1$, $n - 1$, and $(n - 1)(m - 1)$, respectively, for the total, row, column, and error sum of squares. The total sum of squares can be shown to be equivalent to

$$\sum_{ij} (x_{ij})^2 - (\sum_{ij} x_{ij})^2 / nm \tag{J7}$$

which is more convenient for numerical calculation. The row and column sum of squares can also be calculated more conveniently from the similar equivalent expressions. The error sum of squares can be calculated directly from the expression shown in Eq. J6, or it can be obtained by subtracting the sum of the row and column sum of squares from the total sum of squares.

The numerical entries in the analysis-of-variance tables in this section were calculated as explained previously. The F values are the ratios of row (or column) mean square to the error mean square. Under the null hypothesis each of the three mean square values shown in any one of these tables is an unbiased estimate of the variance in the array from which it was calculated. The F function is the ratio of two unbiased estimates of the variance of a normal distribution. Its mathematical form is known, and its values for various probability levels have been tabulated.

In the analysis of variance (Table J40), the F value of 30.7 is well beyond the 0.5 percent probability level value of 8.7 found in an F table for 3 degrees of freedom. It is estimated that the 30.7 is at about the 0.1 percent level. This means that under the assumptions used, which except for the null hypothesis are believed to be reasonable for Table J40, the probability of obtaining differences as large as was found for type of fire from chance variation alone in an experiment of this size is no more than 1 in 1000. This is strong evidence that the differences in hit probabilities for types of fire shown in Table J40 represent real differences, and this confirms a previous tentative conclusion that semiautomatic fire was superior to automatic fire in these runs. In contrast, the F value of 1.1 found for squad differences is well within reasonable sampling variation. Hence, there is no substantial evidence from the runs in Table J40 that Squads B and D are really superior to Squads A and C. It should be noted that these calculations do not prove there are no differences in the squads.

In Table J42 a similar analysis is seen for hit probabilities from the eight day-standing runs by Squads B and D. Again there is strong evidence from the results of these runs that the average hit probabilities from the semiautomatic fire, which are more than twice corresponding values for automatic fire, represent real improvements. The F value of 112 for type of fire is at approximately the 0.2 percent significance level, and is strong evidence for rejecting the null hypothesis. The F value of 36.1 for squad differences gives substantial evidence that Squad B is superior to Squad D in these day-standing runs.

Table J44 shows the hit probabilities and analysis for the eight night-sitting runs by Squads A and C. Again there is evidence here that the semiautomatic fire is superior to the automatic fire. This is consistent for the three illumination-position (IP) conditions. A more pronounced effect seen in Table J44 is the superiority of the T48 over the carbine firings. This is a reversal from the results of the daytime firings, where the carbine is slightly better than the T48. There is no substantial evidence in Table J44 of real squad differences. In fact the variance estimated from squad differences is less than the variance estimated from the error.

The total number of holes counted in the same 16 runs that were examined for hit probabilities is shown in Tables J40 to J45.

Table J46 shows that in the 16 day-sitting runs for both the carbine and the T48 rifle, the semiautomatic fire achieved about 30 percent more total hits than the corresponding automatic fire. Also there is evidence here that the carbine achieves more total hits than the T48 for both automatic and semiautomatic fire. The evidence is not very strong that any of the values in Table J46 represent real effects. The type-of-fire differences show significance at only about the 3 percent level.

The means for squads in Tables J40 and J41 and J46 and J47 are of interest even though the differences are not statistically significant in these tables. Squads A and C apparently achieved an increase in total hits compared to Squads B and D at the expense of less accurate fire. This appears to be a reasonable conjecture, but it cannot be given as a substantially supported conclusion.

Table J48 shows the total hit results for the eight day-standing runs by Squads B and D. Here again there is evidence in the row means that semiautomatic fire achieves more hits than automatic fire and that the carbine achieves more hits than the T48. The row means are significantly different at only about the 8 percent level, which is not considered strong statistical evidence that the differences are real. However, the relative consistency in the row means in Tables J48 to J51 gives much stronger evidence, when considered together, that these differences represent real effects than is available from one table alone. It is clear that the consistency in the tables strengthens the evidence that the effects indicated by the row means are real. Methods are available for comparing individual pairs of means or each mean with the general mean.

Tables J48 and J48 also show that in total hits Squad B was superior to Squad D in almost the same ratio as shown for the hit probabilities in Tables J42 and J43. This difference in total hits for the two squads is significant at approximately the 8 percent level. Tables J48 and J49 show that the superior hit probabilities of Squad B on these four pairs of runs (shown in Tables J42 and J43) were not achieved as the result of a slower firing rate. This strengthens the evidence in Tables J42 and J43 that Squad B was superior to Squad D on these runs. However, the fact that there is essentially no difference in the performance of squads B and D on the day-sitting runs (shown in Tables J40, J41, J46, and J47) does not permit any general conclusion concerning these two squads.

Tables J50 and J51 show the total hits for Squads A and C in the four pairs of night-sitting runs. Again the semiautomatic fire for both rifles is superior to the corresponding automatic fire. The superiority of the T48 over the carbine is more pronounced for night firings. This same superiority of the T48 over the carbine in hit probabilities was seen for these runs in Tables J44 and J45. The explanation for this is apparently in the type of sights for the two rifles. For night firings the targets cannot be seen as well through the carbine as through the T48 sight.

Squad A achieved about 25 percent more hits than Squad C on these four pairs of night runs. Significance at approximately the 12 percent level is evidence, but not very strong evidence, that Squad A is really superior to Squad C in these runs. In Tables J44 and J45 Squad B is seen to score an average hit probability of .055, which is about 12 percent better than the .049 scored by Squad D on these runs. This difference is not statistically significant even at the 50 percent level.

From the foregoing analysis of the 32 runs made using the carbine or T48 rifle, the following conclusions are drawn:

1. The semiautomatic fire for both the carbine and T48 rifle is clearly superior to the corresponding automatic fire in both total hits and hit probabilities.

2. In general the carbine scores slightly better for daytime runs than the T48 in both total hits and hit probabilities. The evidence is not strong that the

Table J40

CARBINE AND T48 HIT PROBABILITIES, DAY-SITTING CONDITION, RAW DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	p	Run	p	Run	p	Run	p		
A	20	.106	19	.178	12	.097	11	.243	.624	.156
B	18	.112	17	.278	10	.104	9	.230	.724	.181
C	43	.095	44	.240	51	.093	52	.199	.627	.157
D	41	.136	42	.266	49	.112	50	.206	.720	.180
Total		.449		.962		.406		.878	2.695	
Mean		.11225		.2405		.1015		.2195		.1684

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	.061752	3	.020584	30.7	<0.1
Squads	.002308	3	.000769	1.1	45[a]

[a]No substantial evidence of a real effect.

Table J41

CARBINE AND T48 HIT PROBABILITIES, DAY-SITTING CONDITION, ADJUSTED DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	p	Run	p	Run	p	Run	p		
A	20	.096	19	.178	12	.098	11	.243	.615	.154
B	18	.120	17	.280	10	.113	9	.231	.744	.186
C	43	.095	44	.251	51	.097	52	.200	.643	.161
D	41	.115	42	.293	49	.106	50	.222	.738	.185
Total		.426		1.002		.416		.696	2.740	
Mean		.1065		.2[illegible]05		.1040		.2240		.1[illegible]

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	.071113	3	.023704	33.5	<0.1
Squads	.003237	3	.001079	1.5	37[a]

[a]No substantial evidence of a real effect.

Table J42

CARBINE AND T48 HIT PROBABILITIES, DAY-STANDING CONDITION, RAW DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	p	Run	p	Run	p	Run	p		
B	22	.086	21	.205	14	.099	13	.173	.563	.141
D	45	.060	46	.179	53	.049	54	.138	.427	.107
Total		.146		.384		.148		.312	.990	
Mean		.073		.182		.074		.156		.124

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	.021498	3	.007166	112	0.2
Squads	.002312	1	.002312	36.1	1

Table J43

CARBINE AND T48 HIT PROBABILITIES, DAY-STANDING CONDITION, ADJUSTED DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	p	Run	p	Run	p	Run	p		
B	22	.067	21	.204	14	.089	13	.172	.562	.1405
D	45	.064	46	.179	53	.046	54	.135	.424	.106
Total		.151		.383		.145		.307	.986	
Mean		.0755		.1915		.0725		.1535		.123

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	.020858	3	.006953	73.2	0.4
Squads	.002381	1	.002381	25.1	1.5

Table J44

CARBINE AND T48 HIT PROBABILITIES, NIGHT-SITTING CONDITION, RAW DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	p	Run	p	Run	p	Run	p		
A	24	.016	23	.041	16	.052	15	.109	.220	.055
C	47	.028	48	.021	55	.054	56	.096	.197	.049
Total		.044		.082		.106		.205	.417	
Mean		.022		.031		.053		.1025		.052

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	.007785	3	.002595	31.646	1
Squads	.000072	1	.000072	.878	48[a]

[a]No substantial evidence of a real effect.

Table J45

CARBINE AND T48 HIT PROBABILITIES, NIGHT-SITTING CONDITION, ADJUSTED DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	p	Run	p	Run	p	Run	p		
A	24	.018	23	.039	16	.051	16	.109	.217	.05425
C	47	.026	48	.019	[illegible]	.056	56	.095	.196	.049
Total		.044		.058		.107		.204	.413	
Mean		.022		.029		.0535		.102		.051625

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	.007861	3	.002620	27.292	1.3
Squads	.000055	1	.000055	9.573	—[a]

[a]No evidence of a real effect.

Table J46

CARBINE AND T48 TOTAL HITS, DAY-SITTING CONDITION, RAW DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	Hits	Run	Hits	Run	Hits	Run	Hits		
A	20	179	19	135	12	102	11	143	559	139.75
B	18	114	17	178	10	86	9	97	475	118,75
C	43	106	44	184	51	103	52	140	533	133.25
D	41	88	42	171	49	86	50	127	470	117.5
Total		485		668		377		507	2037	
Mean		121.25		167		94.25		126,75		127.3125

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	10,821	3	3807	5.03	3
Squads	1,438	3	479	0.67	—[a]

[a]No evidence of a real effect.

Table J47

CARBINE AND T48 TOTAL HITS, DAY-SITTING CONDITION, ADJUSTED DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	Hits	Run	Hits	Run	Hits	Run	Hits		
A	20	173	19	136	12	104	11	157	569	142.25
B	18	106	17	177	10	86	9	111	482	120.50
C	43	102	44	182	51	99	52	130	513	128.25
D	41	59	42	179	49	92	50	144	474	118.50
Total		442		673		381		542	2038	
Mean		110.50		188,25		95.25		135,50		127.375

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	12,214	3	4071	4.53	4
Squads	1,392	3	464	0.52	—[a]

[a]No evidence of a real effect.

Table J48

CARBINE AND T48 TOTAL HITS, DAY-STANDING CONDITION, RAW DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	Hits	Run	Hits	Run	Hits	Run	Hits		
B	22	142	21	202	14	91	13	127	562	140.5
D	45	66	46	145	53	68	54	118	397	99.25
Total		208		347		159		245	959	
Mean		104		173.5		79.5		122.5		119.875

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	9,529	3	3176	6.72	8
Squads	3,403	1	3403	7.23	8

Table J49

CARBINE AND T48 TOTAL HITS, DAY-STANDING CONDITION, ADJUSTED DATA

Squads	Type of fire								Total	Mean
	Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic			
	Run	Hits	Run	Hits	Run	Hits	Run	Hits		
B	22	160	21	213	14	91	13	131	595	148.75
D	45	59	46	139	53	59	54	109	366	91.50
Total		219		352		150		240	961	
Mean		109.5		176		75		120		120.125

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	10,542	3	3514	5.18	11.9
Squads	6,555	1	6555	9.65	5.5

Table J50

CARBINE AND T48 TOTAL HITS, NIGHT-SITTING CONDITION, RAW DATA

Squads	Type of fire: Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic		Total	Mean
	Run	Hits	Run	Hits	Run	Hits	Run	Hits		
A	24	26	23	42	16	75	15	85	228	57
C	47	23	48	17	55	59	56	82	181	45
Total		49		59		134		187	409	
Mean		24.5		29.5		67		83.5		51

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	4954	3	1651	30.6	1
Squads	288	1	288	5.33	12

Table J51

CARBINE AND T48 TOTAL HITS, NIGHT-SITTING CONDITION, ADJUSTED DATA

Squads	Type of fire: Carbine automatic		Carbine semi-automatic		T48 automatic		T48 semi-automatic		Total	Mean
	Run	Hits	Run	Hits	Run	Hits	Run	Hits		
A	24	26	23	45	16	76	15	65	232	56
C	47	32	48	13	55	56	56	62	185	46.25
Total		58		58		134		167	417	
Mean		29		29		67		83.5		52.125

Analysis of Variance

Source of variation	Sum of squares	Degrees of freedom	Mean square	F value	Approximate significance level, %
Type of fire	4550	3	1517	10.8	4
Squads	276	1	276	1.97	39[a]

[a]No substantial evidence of a real effect.

results represent a real difference in the two rifles—particularly with respect to the hit probabilities.

3. The T48 is superior to the carbine for night firings. This superiority, at least for the target system used in this test, can probably be attributed to the difference in sights on the carbine and T48.

4. The evidence on the relative skill of the four squads (A, B, C, and D) is not conclusive. On the day-standing runs, Squad B's average hit probability of .141 is significantly better at the 1 percent level than Squad D's average of .107. However, on the day-sitting runs Squads B and D had almost the same average hit probabilities, and both Squads B and D appeared slightly better than Squads A and C, but none of these squad differences on the day-sitting runs were statistically significant even at the 25 percent level. Neither was the difference in hit probability for Squads A and C on the night-sitting runs statistically significant. Thus there appears to be no certain basis from the results of these 32 runs for a difference in rating of the four squads participating.

COMPARISON OF SINGLE BULLETS AND FLECHETTES

In comparing the two flechette runs (one day standing and one night standing) with corresponding single-bullet AP runs, it is necessary to balance the single-bullet information with that of the flechette. The single-bullet runs used 22 targets with a standard program. Run 69, the flechette day-standing run, used only 19 targets, and 4 of these appeared for only half the normal program time. Table F39 shows the shots-fired information equated to the total adjusted ammunition count of 2824. Table F40 follows a similar pattern in balancing the four single-bullet night-sitting runs against Run 70, the one flechette night-standing run.

Table J52

HIT PROBABILITIES AND STANDARD ERRORS OF FLECHETTES COMPARED TO SINGLE BULLETS

Ammunition	Illumination	Firing position	Ammunition count, n	Target holes	p = holes/n	$\sigma = \sqrt{pq/n}$
Single bullet	Day	Standing	418	65	.156	.0177
Flechette	Day	Standing	264	109	.413	.0303
Single bullet	Night	Sitting	574	28	.049	.0090
Flechette	Night	Standing	289	99	.343	.0279

Table J52 shows the relative hit probabilities and standard errors of single-bullets and flechettes, with day and night comparisons. The flechette hit probability is about three times that of the single bullet for day comparison and about seven times that of the single bullet for the night comparison. This table brings out the effectiveness of the flechette ammunition despite the fact that only two such runs were carried out.

Table J53 shows the calculation of the t test as a method of comparing the single-bullet and flechette runs. It is seen that this value of t (t = 14.9) for 1 degree of freedom is significant at approximately the 4 percent level. This is substantial evidence even from this small sample that the flechette ammunition gives hit probabilities that are superior to those obtained with the single-bullet ammunition.

Table J53

HIT PROBABILITIES OF FLECHETTES COMPARED TO SINGLE BULLETS

Item	Hit probabilities		Difference
	Flechette	Single bullet	
Day runs	.413	.156	.257
Night runs	.343	.049	.294
Total			.551
Mean			.275
Sum of squares			.152485
Variance $[(\Sigma x^2 - (\Sigma x)^2/n)/(n-1)]$			.000685
Variance (of mean)			.000342
σ mean			.0185

t = .275/.0185 = 14.9. This value of t for 1 deg of freedom is significant at approximately the 4 percent level.

FIRING POSITION AND ILLUMINATION

The three combinations of firing position and illumination in the SALVO I experiment were day sitting, day standing, and night sitting. Tables J54 and J55 show a summary of the results of 34 day-sitting runs, 15 day-standing runs, and 15 night-sitting runs, with each of these sets of runs further subdivided according to six types of fire. The 64 r ns in Tables J54 and J55 are all the SALVO I experiment runs except for the two triplex and the two flechette runs.

It can be seen from Tables J54 and J55 that the number of runs for each type of fire is the same for day-standing and night-sitting firing conditions. Except for two additional day-sitting runs for both the single-bullet and duplex ammunitions, the number of day-sitting runs for each type of fire is twice the number of corresponding runs for day standing or night sitting, which means nearly balanced comparisons with respect to the different types fire among the day-sitting, day-standing, and night-sitting runs, even though the mean values for the day-sitting runs are from samples about twice the size of the corresponding samples of day-standing and night-sitting runs. It is true that the effects of different squads are not completely balanced out in Tables J54 and J55, and this fact should be kept in mind in drawing conclusions from the computations shown in these tables and in Tables J56 and J57. It was shown earlier that the only substantial evidence of squad differences supported the conclusion of the superiority of Squad B over the other three average squads. This superiority of Squad B is entangled to a limited extent in the effects indicated in Tables J54 and J55. In any case the squad effect is small, and it is believed that squad differences cannot possibly account for the major differences shown in Tables J54 to J57 for the three combinations of firing positions and illumination.

Tables J54 and J55 show that the average rounds of ammunition counted per run increase from day-sitting to day-standing to night-sitting positions. There is only one exception to this increased rate of fire: the carbine automatic firing rate is less for night sitting than for day standing. The fact that the t test for differences in rounds of ammunition counted for day sitting and day standing is significant at approximately the 1 percent level is strong evidence that the indicated increase in rate of fire is real. The increase in rate of fire when comparing the day-standing to night-sitting firings is, on the average, much smaller. This comparison includes the reversal for automatic fire with the carbine mentioned earlier. No statistical test has been applied to the indicated increase in the rate of fire for the night-sitting over the day-standing position. Table J54 shows that the average rounds counted per run for day-standing fire is 924 and for night-sitting fire is 955. It is evident that the increase in rate of fire for night-sitting over day-standing fire is small, and the evidence that this is a real effect is not strong.

The average number of target holes per run decreases progressively from day-sitting to day-standing to night-sitting positions except for one comparison. The average number of target holes for carbine semiautomatic fire is 6.5 holes greater for day standing than for day sitting. In Table J56 the t test shows that the average increase of 9.3 target holes for the day-sitting over the day-standing position is statistically significant at about the 7 percent level. The increases in hits for day sitting were achieved along with a 15 to 20 percent reduction in average ammunition expenditures.

The hit probabilities, of course, show a more pronounced progressive average reduction than the target holes with the change in firing-position–illumination condition. This relation is expected since the rate of fire is progressively increasing. It is seen from Table J56 that the average hit probabilities for all six types of fire show an increase for day-sitting over day-standing positions, and the t test shows that the average increase of about $4\frac{1}{2}$ percent (which is a relative increase of more than 25 percent) in hit probabilities is significant at approximately the 0.1 percent level. This is strong evidence of a real increase in hit probabilities when changing from the day-standing to the day-sitting position. The decrease in hit probabilities, and also the average number of hits, associated with the night firings is so marked that no statistical test appears needed to establish the night effect as real.

In summary, it can be concluded from Tables J54, J55, J56, and J57 that in comparing the day-sitting with day-standing with night-sitting firing positions there is a progressive increase in rate of fire and a progressive decrease in both average number of hits and hit probabilities. There is evidence that the IP effects are real.

The evidence of a real effect is strong in all comparisons except for the following two: The decrease in average number of hits for the day-standing as compared to the day-sitting conditions is less than 10 percent, and the increase in firing rate for the night-sitting over the day-standing conditions is less than 5 percent. The statistical evidence that these indicated effects are real is not strong. The adjusted data are correspondingly examined in Table J57.

Table J54

POSITION AND ILLUMINATION HIT PROBABILITIES AND TOTAL HITS, RAW DATA

Ammunition or firing	No. of runs	Total rounds counted	Total holes counted	Hit probabilities	Average rounds counted per run	Average holes counted per run
Day-Sitting Condition						
Single bullet	10	6165	1215	.198	616	121.5
Duplex	8	4626	1483	.321	578	185.4
Carbine automatic	4	4453	485	.109	1113	121.2
Carbine semiautomatic	4	2809	668	.238	702	167.0
T48 automatic	4	3755	377	.100	939	94.2
T48 semiautomatic	4	2331	507	.218	583	126.7
Total	34			1.183	4531	818.0
Mean				.197	755	136.0
Day-Standing Condition						
Single bullet	4	2725	402	.148	681	100.5
Duplex	3	1947	535	.275	649	178.3
Carbine automatic	2	2748	208	.076	1374	104.0
Carbine semiautomatic	2	1793	347	.193	896	173.5
T48 automatic	2	2308	159	.089	1154	79.5
T48 semiautomatic	2	1585	245	.155	792	122.5
Total	15			.916	5546	758.3
Mean				.153	924	126.4
Night-Sitting Condition						
Single bullet	4	3336	168	.050	834	41.5
Duplex	3	2149	196	.091	718	65.3
Carbine automatic	2	2349	49	.021	1174	24.5
Carbine semiautomatic	2	1848	59	.032	924	29.5
T48 automatic	2	2526	134	.053	1263	67.0
T48 semiautomatic	2	1638	167	.102	819	83.5
Total	15			.349	5730	311.3
Mean				.058	955	51.9

Table J55

POSITION AND ILLUMINATION HIT PROBABILITIES AND TOTAL HITS, ADJUSTED DATA

Ammunition or firing	No. of runs	Total shots adjusted	Total hits adjusted	Hit prob- abilities	Average shots adjusted per run	Average hits adjusted per run
Day-Sitting Condition						
Single bullet	10	6,119	1180	.193	611.9	118.0
Duplex	8	4,510	1448	.321	563.8	181.0
Carbine automatic	4	4,283	442	.103	1070.8	110.5
Carbine semiautomatic	4	2,726	673	.247	681.5	168.3
T48 automatic	4	3,688	381	.103	922.0	95.3
T48 semiautomatic	4	2,424	542	.224	606.0	135.5
Total	34	23,750	4666	1.191	4456.0	808.6
Mean				.199	742.7	134.8
Day-Standing Condition						
Single bullet	4	2,657	403	.152	844.3	100.8
Duplex	3	2,003	523	.261	667.7	174.3
Carbine automatic	2	2,757	219	.079	1378.5	109.5
Carbine semiautomatic	2	1,819	352	.194	909.5	176.0
T48 automatic	2	2,193	150	.068	1096.5	75.0
T48 semiautomatic	2	1,567	240	.153	783.5	120.0
Total	15	12,998	1887	.907	5500.0	755.6
Mean				.151	916.7	125.9
Night-Sitting Condition						
Single bullet	4	3,192	166	.052	798.0	41.5
Duplex	3	2,119	197	.093	706.3	65.7
Carbine automatic	2	2,712	58	.021	1356.0	29.0
Carbine semiautomatic	2	1,832	58	.032	916.0	29.0
T48 automatic	2	2,527	134	.053	1283.5	87.0
T48 semiautomatic	2	1,638	187	.102	819.0	83.5
Total	15	14,020	780	.353	5858.8	315.7
Mean				.059	976.5	52.6

Table J56

TEST FOR DIFFERENCES IN SITTING AND STANDING POSITIONS, RAW DATA

Ammunition or firing	Average rounds counted per run			Average target holes counted			Average bit probabilities		
	Day-sitting condition	Day-standing condition	Difference	Day-sitting condition	Day-standing condition	Difference	Day-sitting condition	Day-standing condition	Difference
Single bullet	616	681	− 65	122	101	21	.198	.148	.050
Duplex	578	649	− 71	185	178	7	.320	.274	.046
Carbine automatic	1113	1374	− 261	121	104	17	.109	.076	.033
Carbine semiautomatic	702	896	− 194	167	174	− 7	.238	.194	.044
T48 automatic	929	1154	− 215	94	80	14	.100	.069	.031
T48 semiautomatic	583	792	− 209	127	123	4	.218	.155	.063
Total			− 1,015			+ 56			.267
Mean difference			− 169			+ 9.3			.0445
Sum of squares			204,929			1040			.012571
Variance (differences)			6,645			103.47			.0001379
Variance (mean difference)			1,107			17.25			.0000229b
Standard deviation (mean difference)			33.3			4.15			.0048
t = mean difference/standard deviation (mean difference)			5.07[a]			2.24[b]			9.27[c]

[a]Significant at approximately 1 percent level.
[b]Significant at approximately 7 percent level.
[c]Significant at approximately 0.1 percent level.

Table J57

TEST FOR DIFFERENCES IN SITTING AND STANDING POSITIONS, ADJUSTED DATA

Ammunition or firing	Average shots adjusted per run			Average hits adjusted			Average bit probabilities		
	Day-sitting condition	Day-standing condition	Difference	Day-sitting condition	Day-standing condition	Difference	Day-sitting condition	Day-standing condition	Difference
Single bullet	612	664	− 52	118	101	17	.193	.152	.041
Duplex	564	668	− 104	181	174	7	.321	.261	.060
Carbine automatic	1071	1379	− 308	111	110	1	.103	.079	.024
Carbine semiautomatic	682	910	− 228	168	176	− 8	.247	.194	.053
T48 automatic	922	1097	− 175	95	75	20	.103	.068	.035
T48 semiautomatic	606	784	− 178	136	120	16	.224	.153	.071
Total			− 1,045			+ 53			.284
Mean difference			− 174			+ 8.8			.0473
Sum of squares			222,677			1059			.014932
Variance (differences)			8,135			116.2			.0002978
Variance (mean difference)			1,356			19.7			.00004963
Standard deviation (mean difference)			36.8			4.36			.00704
t = mean difference/standard deviation (mean differences)			4.73[a]			2.02[b]			6.72[c]

[a] Significant at approximately 1 percent level.
[b] Significant at approximately 10 percent level.
[c] Significant at approximately 0.1 percent level.

CONFIDENCE LIMITS

Table J1 includes directly computed standard deviations of the measured hits and hit probabilities for 19 of the 21 AIP combinations. Table J3 includes standard deviations of 16 ratios of hits and hit probabilities. These standard deviations are confidence measures, defining the 68 percent confidence limits about the mean. Elsewhere in this appendix two standard deviation increments are used to define 95 percent confidence limits. These measures are useful only on the assumption of homogeneous populations. Actually the computed values are grossly swollen by inclusion of known systematically differing segments of the populations. Squad and learning differences, for example, are ignored in Tables J1 and J3.

Of more interest are the further combined values for comparison of ammunitions without separation by IP condition. The problem posed then is the determination of the standard deviation of an inhomogeneous population. The same consideration holds true for the observed effect of learning (demonstrated in App H). A suggested method for determining over-all standard deviation is based on the reduction of each of the subpopulations to a uniform condition before computing individual deviations. The method of reduction of population to achieve the desired homogeneity is demonstrated in App K. The method is most useful for computation of average effects of each difference on the entire population. However, if the reduced data (for a homogeneous population) were used in determining individual deviations, the resultant standard deviation would be too small. This is true because the reduction factors themselves are deduced from data that include the very random deviations that are being searched for. Hence the use of the reduction factors deduced from these data leads to an unrealistically homogeneous population.

It is concluded that the best measure of standard deviation for the combined conditions that are of interest lies somewhere between values of the type listed in Tables J1 and J3 and the lower values that would obtain from the method just outlined. It is possible, however, to make a very crude estimate of maximum standard deviations, based on the uncombined values of Table J1. Since learning and squad differences are already ignored, results are still of a grossly maximum nature. The most interesting figures of the computed standard deviations are given in the last column of Table J3. If, for example, it is desirable to combine the three figures relating duplex to single bullet, an average may be deduced in the following fashion.

The average hit probability is computed (weighting day sitting twice as much as each of the other two conditions) yielding an average duplex-to-single-bullet hit-probability ratio of 1.71. A crude scheme for deducing corresponding average standard deviation has been tried. In general, however, population combination at this level affords only a minor reduction in the computed standard deviations. It is perhaps adequate and certainly simpler to examine the general magnitude of the individual deviations as listed in Table J3 and to regard them as representative of maximum values.

The application of this method to the hit ratios of Table J3 gives standard deviations for the pertinent ratios shown in Table J58 (expressed as percentages of the hit probability).

The average range of these hit probability ratio standard deviations is 9 to 20 percent of the ratio. In considering the method by which these hit probabilities are transferred to the casualty probabilities discussed in the major report interpretation, it is apparent that the relative deviations are not grossly altered. Thus it is concluded that the casualty ratio standard deviations for aimed fire are somewhat less than 9 to 20 percent of the ratios.

For the final comparisons the unaimed fire results are also utilized. These results are based on theoretical considerations and do not include any experimental data to contribute deviations. Since the over-all average values are weighted equally of aimed and unaimed fire, it is concluded that the maximum

Table J58

PERCENTAGE STANDARD DEVIATIONS FOR HITS PER ROUND FOR VARIOUS IP CONDITIONS

Ammunition or firing compared	Day-sitting condition	Day-standing condition	Night-sitting condition	Average σ
Duplex to single bullet	6.6	8.7	31.9	13
Triplex to single bullet	8.5	—	—	(9)
Automatic to semiautomatic	17.7	22.4	23.5	20
Carbine to M1	12.5	7.8	29.0	15
T48 to M1	5.0	17.8	27.1	14

estimate of standard deviations for these final results is reduced by a factor of $\sqrt{2}$. This finally yields maximum standard deviations on the over-all ammunition ratios in the range of 6 to 14 percent, or about 10 percent. Further instructive observations on the statistical validity of the differences are noted in Figs. J1 and J2. In these figures the individually paired runs are examined by squad. It is clear that, with a single exception, the duplex and single-bullet values are separated by more than two standard deviations of each. This means that the possibility of any pair not being different is less than $.05^2$, or that the confidence in the difference is greater than 99¾ percent for every one of the individual pairs of runs (with the single exception noted).

In order to determine the confidence limits of aggregated subpopulations with more precision than can be inferred from the grossly maximum values given, it is possible to deduce the theoretically purely random error associated with the measurements. The results of such a computation will give a minimum value since it does not include any systematic errors whatsoever. It should be recognized that, in general, experimental standard deviations do include at least those systematic errors that have not been causally identified. The method is based on the simple theoretical notion from the binomial distribution that the standard deviation is given by the quantity $\sqrt{pq/n}$.

This simple computation has been made, based entirely on the data presented in Tables F41 and F43. As the aggregates of interest are concerned with differences among the eight types of fire, the data from the 68 runs are reduced by simple addition of appropriate values of hits and rounds fired. Since the quantity of interest is the salvo rather than the individual round fired, the conversion is made for the two classes of automatic fire by dividing the number of rounds fired by 2.33, the average number of rounds per automatic burst. The resulting ratios of hits per salvo are shown in the second column of Table J59.

These hit probability values should not be seriously compared since they are deduced from unbalanced conditions. They are computed here solely for the purpose of arriving at the standard deviations. The third column lists the standard deviations computed by the expression above. In the fourth column the standard deviations are expressed as percentages of the hit probabilities. In the last two rows of the table the carbine and T48 values are combined for semiautomatic and automatic fire.

From the values shown in Table J59 it is now possible to deduce the standard deviations associated with the ratios of hit probabilities. The second column of Table J60 lists the six ratios of primary interest. The standard deviations of these ratios are then computed from Eq. J3.

Table J59

HIT PROBABILITY PER SALVO

Ammunition or firing	Hit probability	Standard deviation, %	Relative standard deviation, %
Single bullet	14.6	0.32	2.2
Duplex	25.1	0.47	1.9
Triplex	43.3	1.48	3.4
Flechettes	37.6	2.06	5.5
Carbine semiautomatic	17.0	0.47	2.8
Carbine automatic	17.2	0.58	3.4
T48 semiautomatic	16.9	0.50	3.0
T48 automatic	18.4	0.64	3.5
Semiautomatic	16.9	0.34	2.0
Automatic	17.8	0.43	2.4

Table J60

RATIO OF HIT PROBABILITIES PER SALVO

Ammunition or firing compared	Hit-probability ratio	Standard deviation, %	Relative standard deviation, %
Duplex to single bullet	1.72	0.05	2.9
Triplex to single bullet	2.97	0.12	4.0
Flechette to single bullet	2.58	0.15	5.9
Carbine to M1	1.16	0.04	3.6
T48 to M1	1.16	0.04	3.7
Automatic to semiautomatic	1.09	0.06	3.1

The last column lists these standard deviations as percentages of the ratios. These relative standard deviations are seen to be in the range of 3 to 6 percent, corresponding to the earlier maximum estimates of 9 to 20 percent for aimed fire. The difference is attributable to recognized plus unrecognized systematic errors and appears to be a quite reasonable difference. Since the range is not very great it is useful to identify an average value, which is 3.9 percent. In considering the over-all results, including unaimed as well as aimed fire, this figure is again reduced by a factor of $\sqrt{2}$. Thus the random standard deviation on the over-all ammunition ratios averages 2.7 percent, compared with the maximum value deduced earlier of about 10 percent.

Appendix K

SEPARATION OF EFFECTS

SUMMARY

This appendix is based exclusively on the adjusted data of Table F41. The analysis begins by recognition of three classes of systematic differences: (a) the 21 ammunition-illumination–firing position (AIP) conditions, (b) the six squads, and (c) the sequence or order of run for each squad. The data considered are (a) hits per run and (b) rounds fired per run.

The method is to reduce the data sequentially by eliminating mean differences among the data for each of the three classes. The process is started with the largest differences (AIP combinations). When the data have been rendered homogeneous relative to AIP combinations, they are reduced for squad differences. Finally, the data are reduced for order differences. These completely reduced data then reflect only random or unrecognized systematic differences.

These reduced data then are made to yield separately the three classes of differences. Each is computed from data that are thus balanced with respect to the other two classes. It is recognized that interrelations among the classes make this procedure imperfect. The isolated effects of the several parameters are then separately listed in a single table.

The process of sequential reduction of the data is then continued to effect separation of the six ammunition conditions from the three illumination-position (IP) conditions (excluding unbalanced triplex and flechette data). The resultant isolated effects are again separately tabulated.

AMMUNITION-ILLUMINATION-POSITION, SQUAD, AND ORDER REDUCTION

The data of Table F41 are first reduced by averaging for each of the 21 AIP conditions. The resultant mean hits per run and rounds fired per run are given in Table K1.

Having determined these means, the next step is to reduce the data individually for each run by dividing by the corresponding AIP class mean (and multiplying by 100 to avoid decimals). This reduction of Table F41 data yields Table K2. In Table K2 advantage is taken of the reduction to array the reduced data according to order as well as squad. An example clarifies the process: Consider the hits per run for the first Squad D single-bullet day-sitting run. From Table F41 this is 71 hits for Run 36. As the mean hits per run for the single-bullet day-sitting runs are 118, the reduced datum is 71/118 × 100, or 60. A glance down the column of Table F41 reveals that Run 36 was the second run for Squad D. Hence in Table K2, 60 is entered in the Squad D column and order row 2. Appendix L in the discussion of Table L2 reveals a few deviations in numbered sequence for the actual run order. These deviations are included in the preparation of Table K2.

Table K2 yields the means for each of the squads. Reduction for squad differences is again accomplished by dividing each datum by its squad mean. For example, the 60 hits for the second run of Squad D is divided by the Squad D mean of 88 (and multiplied by 100) to yield a squad reduced value of 68. Table K3 tabulates these squad reduced values.

TABLE K1

MEAN HITS PER RUN AND ROUNDS FIRED PER RUN BY AIP COMBINATIONS

Ammunition or firing[a]	I[b]	P[c]	Hits	Rounds
SB	D	S	118	611
SB	D	St	101	664
SB	N	S	42	798
D	D	S	181	564
D	D	St	174	668
D	N	S	66	706
T	D	S	243	560
CS	D	S	168	682
CS	D	St	176	915
CS	N	S	29	916
CA	D	S	111	1071
CA	D	St	110	1379
CA	N	S	29	1357
T48, S	D	S	136	606
T48, S	D	St	120	784
T48, S	N	S	84	819
T48, A	D	S	95	922
T48, A	D	St	75	1097
T48, A	N	S	67	1264
Fl	D	St	205	403
Fl	N	St	166	435

[a]SB is single bullet; D is duplex; T is triplex; CS is carbine semiautomatic; CA is carbine automatic; T48, S, is T48 semiautomatic; T48, A, is T48 automatic; Fl is flechette.

[b]D is day, N is night.

[c]S is sitting, St is standing.

The mean values (combining squads) for each order are listed in Table K3. These mean values can now be compared with order number to yield information on the effect of order (learning), independent of squad and AIP differences. Because of the adequacy of data in the 4 × 15 block of data in Table K3 (for the first 15 runs of the four average squads), the unbalanced data for the other 8 runs are ignored in obtaining the means. These mean data are plotted in Figs. K1 and K2. In addition the regression lines are computed and drawn on these figures. These are ordinary linear regression lines (least-square deviation of y on x). The slopes are measures of the learning rate.

The final reduction for order is accomplished by taking reduction factors from these regression lines for each order. These reduction factors are listed on the right side of Table K3. The reduction is again done by dividing each datum by its order reduction factor (× 100). The resultant completely reduced data (for AIP conditions, squad, and order) are reproduced in Table K4. Here

TABLE K2

AIP REDUCED DATA, HITS PER RUN AND ROUNDS FIRED PER RUN

Order	Squad A Hits	Squad A Rounds	Squad B Hits	Squad B Rounds	Squad C Hits	Squad C Rounds	Squad D Hits	Squad D Rounds	Squad E Hits	Squad E Rounds	Squad F Hits	Squad F Rounds
1	77	88	92	79	85	86	68	78	169	143	85	106
2	92	87	87	83	93	88	60	73	152	136	86	104
3	77	83	135	75	111	98	62	70	—	—	—	—
4	105	108	67	96	108	94	62	109	—	—	—	—
5	115	107	82	79	92	100	53	48	—	—	—	—
6	110	115	91	82	107	106	107	90	—	—	—	—
7	101	95	109	97	110	91	97	93	—	—	—	—
8	113	118	121	84	45	76	106	107	—	—	—	—
9	80	111	105	93	104	111	79	116	—	—	—	—
10	97	168	156	84	96	107	91	103	—	—	—	—
11	133	135	121	115	87	82	54	67	—	—	—	—
12	127	134	145	133	98	105	79	85	—	—	—	—
13	116	116	112	94	118	101	111	124	—	—	—	—
14	155	125	72	66	76	77	103	116	—	—	—	—
15	90	109	100	119	85	95	170	134	—	—	—	—
16	—	—	—	—	98	108	100	96	—	—	—	—
17	—	—	—	—	100	100	—	—	—	—	—	—
18	—	—	—	—	100	100	—	—	—	—	—	—
Mean	106	113	106	92	95	96	88	94	161	140	86	105

TABLE K3

AIP AND SQUAD REDUCED DATA, HITS PER RUN AND ROUNDS FIRED PER RUN

Order	Squad A Hits	Squad A Rds	Squad B Hits	Squad B Rds	Squad C Hits	Squad C Rds	Squad D Hits	Squad D Rds	Squad E Hits	Squad E Rds	Squad F Hits	Squad F Rds	Mean Hits	Mean Rds	Reduction factor Hits	Reduction factor Rds
1	73	78	87	86	90	90	77	83	105	102	99	101	82	84[a]	86	85
2	87	77	82	90	98	92	68	78	94	97	100	99	84	84[a]	88	87
3	73	73	125	82	117	102	71	75					97	83	90	89
4	99	96	63	104	114	98	71	116					87	104	92	91
5	108	95	77	86	97	104	60	51					86	84	94	93
6	104	102	86	89	113	111	122	96					106	100	96	95
7	95	84	103	105	116	95	110	99					106	96	98	98
8	107	104	114	91	47	79	121	114					97	97	100	100
9	75	98	99	101	110	116	90	124					94	110	102	102
10	91	149	147	91	101	112	103	110					111	116	104	104
11	125	120	114	125	92	85	61	71					98	100	106	106
12	120	119	137	145	103	109	90	90					113	116	108	108
13	109	103	106	102	124	105	126	132					116	111	110	111
14	146	111	68	72	80	80	117	124					103	97	112	113
15	85	97	94	130	90	99	193	143					114	117	114	115
16					103	113	114	102							116	117
17					105	104									118	119
18					105	104									120	121

[a]Mean of Squads A, B, C, and D only.

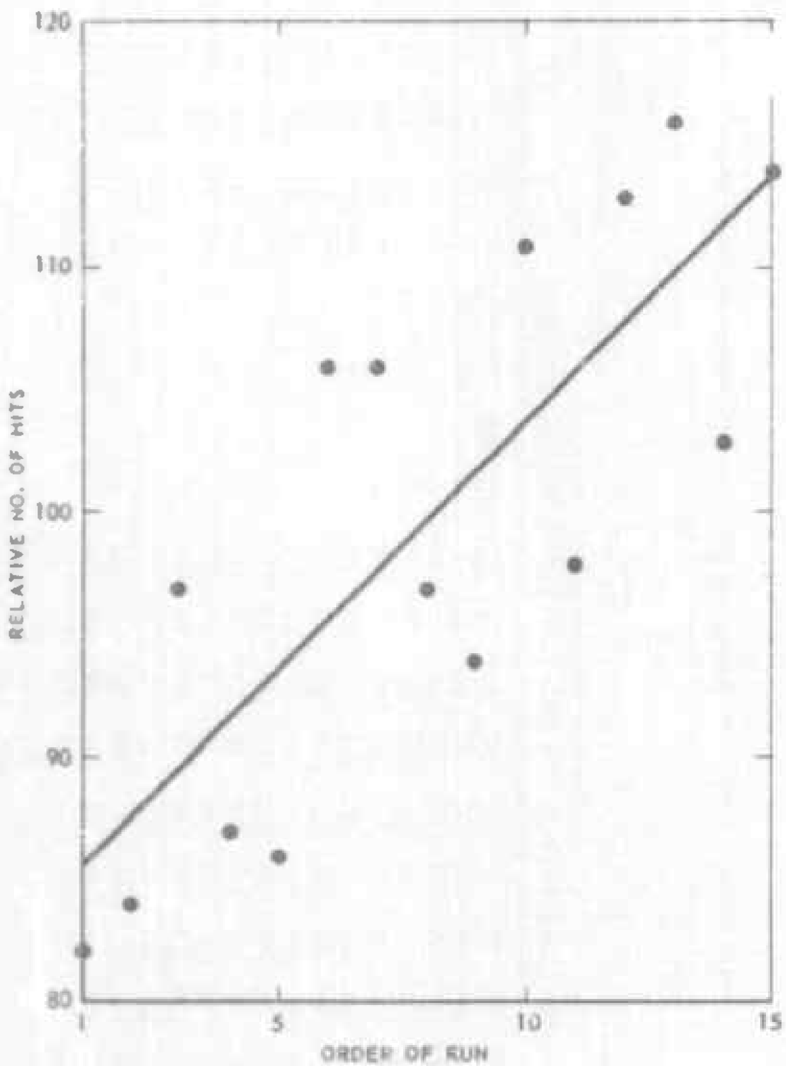

Fig. K1—Order Regression Line for Hits per Run
Intercept = 85.5; slope = 2.03.

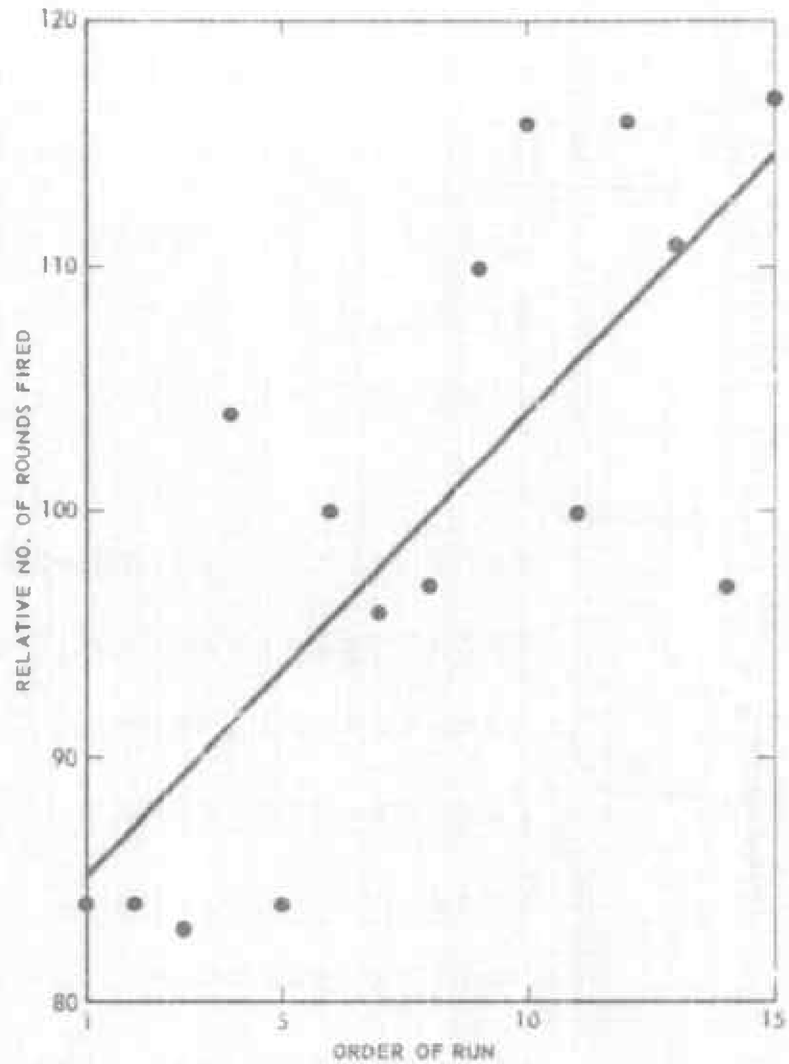

Fig. K2—Order Regression Line for Rounds Fired
Intercept = 85.1; slope = 2.11.

Table K4

AIP, Squad, and Order Reduced Data, Hits per Run and Rounds Fired per Run*

Ammunition or firing	I	P	Squad A Hits	A Rounds	B Hits	B Rounds	C Hits	C Rounds	D Hits	D Rounds	E Hits	E Rounds	F Hits	F Rounds	Mean Hits	Mean Rounds
SB	D	S	118	113	96	92	71	71	104	110	—	—	—	—	—	—
			85	92	101	101	111	106	77	90	122	120	115	119	100	101
SB	D	St	99	93	—	—	89	97	—	—	—	—	—	—	—	—
			81	82	—	—	124	108	—	—	—	—	—	—	98	95
SB	N	S	—	—	82	113	—	—	98	87	—	—	—	—	—	—
			—	—	139	92	—	—	77	128	—	—	—	—	99	105
D	D	S	—	—	—	—	113	95	114	119	—	—	—	—	—	—
			99	89	93	103	105	106	90	98	107	111	114	114	104	106
D	D	St	—	—	—	—	79	86	—	—	—	—	—	—	—	—
			108	105	—	—	130	115	—	—	—	—	—	—	106	102
D	N	S	—	—	—	—	—	—	169	124	—	—	—	—	—	—
			—	—	69	114	—	—	79	84	—	—	—	—	106	107
T	D	S	111	110	61	64	—	—	—	—	—	—	—	—	86	87
CS	D	S	73	96	97	99	118	117	127	101	—	—	—	—	104	103
CS	D	St	—	—	107	118	—	—	83	83	—	—	—	—	95	101
CS	N	S	130	98	—	—	47	79	—	—	—	—	—	—	89	89
CA	D	S	87	143	141	87	103	112	64	55	—	—	—	—	99	99
CA	D	St	—	—	127	134	—	—	58	67	—	—	—	—	93	101
CA	N	S	75	84	—	—	118	97	—	—	—	—	—	—	97	91
T48, S	D	S	115	102	82	92	97	108	121	114	—	—	—	—	104	104
T48, S	D	St	—	—	105	107	—	—	99	106	—	—	—	—	102	107
T48, S	N	S	97	86	—	—	95	101	—	—	—	—	—	—	96	94
T48, A	D	S	108	107	90	94	108	114	112	101	—	—	—	—	105	104
T48, A	D	St	—	—	114	91	—	—	88	122	—	—	—	—	101	107
T48, A	N	S	107	104	—	—	87	80	—	—	—	—	—	—	97	92
Fl	D	St	—	—	—	—	89	87	—	—	—	—	—	—	89	87
Fl	N	St	—	—	—	—	87	86	—	—	—	—	—	—	87	86
Mean			100	100	100	100	98	98	98	99	115	116	115	117		

*See footnotes to Table K1 for abbreviations.

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it is convenient to revert to the original array (by squad as a function of AIP conditions).

Table K4 contains the data for each of the 68 runs sequentially reduced for AIP condition, squad, and order. The order reduction factors in Table K3 are now an adequate measure of learning, as they were deduced from data from which AIP and squad differences were already removed. The AIP and squad (row and column) means are listed in Table K4.

AMMUNITION-ILLUMINATION-POSITION, SQUAD, AND ORDER EFFECTS

The final reduction factors are then computed from the products of these means with the corresponding means from Tables K1 and K2 (÷100). Table K5 lists all these factors for hits per run H and for rounds fired R. These factors themselves are measures of the relative numbers of hits and rounds fired, as independently affected by order, squad, and AIP conditions. For convenience the relative hit probabilities P_H are also listed.

TABLE K5

RELATIVE DATA BY AIP CONDITION, SQUAD, AND ORDER[a]

Ammunition or firing	I	P	H	R	P_H	Squad	H	R	P_H	Order	H	R	P_H
SB	D	S	118	617	191	A	106	113	94	1	86	85	101
SB	D	St	99	611	162	B	106	92	115	2	88	87	101
SB	N	S	42	838	50	C	93	94	99	3	90	89	101
D	D	S	188	598	314	D	86	93	93	4	92	91	101
D	D	St	184	692	266	E	185	162	114	5	94	93	101
D	N	S	70	756	93	F	99	123	80	6	96	95	101
T	D	S	209	487	429					7	98	98	100
CS	D	S	175	702	249					8	100	100	100
CS	D	St	167	924	181					9	102	102	100
CS	N	S	26	815	32					10	104	104	100
CA	D	S	110	1060	104					11	106	106	100
CA	D	St	102	1392	73					12	103	108	100
CA	N	S	28	1233	23					13	110	111	99
T48, S	D	S	141	630	224					14	112	113	99
T48, S	D	St	122	839	145					15	114	115	99
T48, S	N	S	81	770	105					16	116	117	99
T48, A	D	S	100	959	104					17	118	119	99
T48, A	D	St	76	1184	64					18	120	121	99
T48, A	N	S	65	1163	56								
FI	D	St	182	351	519								
FI	N	St	144	374	385								

[a] H is hits, R is rounds, P_H is hit probabilities. See footnotes to Table K1 for other abbreviations.

From the data of Table K5, a number of comparisons are readily made. These comparisons are self-explanatory in Tables K6 to K8. Table K9 is computed by simply adding together the appropriate carbine and T48 data. This is justified as the separate ratios are nearly identical. Tables K10 and K11 compare the indicated weapons in semiautomatic fire only.

Table K6

Comparison of Duplex with Single-Bullet Ammunition[a]

I	P	H	R	P_H
D	S	1.59	0.97	1.64
D	St	1.86	1.13	1.64
N	S	1.67	0.90	1.86

[a]See footnote to Table K5.

Table K7

Comparison of Triplex with Single-Bullet Ammunition[a]

I	P	H	R	P_H
D	S	1.77	0.79	2.25

[a]See footnote to Table K5.

Table K8

Comparison of Flechettes with Single-Bullet Ammunition[a]

I	P	H	R	P_H
D	St	1.84	0.58	3.20
N	—[a]	3.43	0.45	7.70

[a]SB sitting, flechettes standing. Also see footnote to Table K5.

Table K9

Comparison of Automatic with Semiautomatic Fire[a]

I	P	H	R	P_H
D	S	0.66	1.51	0.44
D	St	0.62	1.46	0.42
N	S	0.87	1.51	0.58

[a]See footnote to Table K5.

Table K10

Comparison of T48 with M1 Rifle[a]

I	P	H	R	P_H
D	S	1.19	1.02	1.17
D	St	1.23	1.37	0.89
N	S	1.93	0.92	2.10

[a]See footnote to Table K5.

Table K11

Comparison of Carbine with M1 Rifle[a]

I	P	H	R	P_H
D	S	1.48	1.14	1.30
D	St	1.69	1.51	1.12
N	S	0.62	0.97	0.64

[a]See footnote to Table K5.

TABLE K12

SQUAD AND ORDER REDUCED DATA, HITS PER RUN AND ROUNDS FIRED PER RUN

Ammunition or firing[a]	Day sitting			Day standing			Night sitting		
	Runs	Hits	Rounds	Runs	Hits	Rounds	Runs	Hits	Rounds
SB	10	118	617	4	99	611	4	42	838
D	8	188	598	3	184	692	3	70	756
CS	4	175	702	2	167	924	2	26	815
CA	4	110	1060	2	102	1392	2	28	1233
T48, S	4	141	630	2	122	839	2	81	770
T48, A	4	100	959	2	76	1184	2	65	1163
Mean		140	716		125	880		52	905

[a]See footnote a to Table K1 for abbreviations.

TABLE K13

IP REDUCED DATA, HITS PER RUN AND ROUNDS FIRED PER RUN

Ammunition or firing[a]	Day sitting		Day standing		Night sitting		Mean	
	Hits	Rounds	Hits	Rounds	Hits	Rounds	Hits	Rounds
SB	84	86	79	69	81	93	82	84
D	134	83	147	79	134	83	137	82
CS	125	98	134	105	50	90	107	98
CA	79	148	82	158	54	136	74	148
T48, S	101	88	98	95	156	85	114	89
T48, A	71	134	61	135	125	128	82	133

[a]See footnote a to Table K1 for abbreviations.

TABLE K14

COMPLETELY REDUCED DATA, HITS PER RUN AND ROUNDS FIRED PER RUN

Ammunition or firing[a]	Day sitting		Day standing		Night sitting	
	Hits	Rounds	Hits	Rounds	Hits	Rounds
SB	102	102	96	82	99	111
D	98	101	107	96	98	101
CS	115	100	123	107	46	92
CA	107	100	111	107	73	92
T48, S	89	99	86	107	137	96
T48, A	87	101	74	101	153	96
Mean	100	101	100	97	101	100

[a]See footnote a to Table K1 for abbreviations.

AMMUNITION-ILLUMINATION-POSITION REDUCTION

It is persistently requested that over-all rough comparisons be deduced from unbalanced data such as these salvo data. Therefore, though it is recognized that such comparisons lump unlike figures, an attempt is made to deduce from Table K5 the separate effects of ammunition and the IP combination. The procedure is parallel to the reduction procedure already used in this appendix. However, the computation is complicated by the weighting of each datum from Table K5 by the number of runs on which it is based. Table K12 shows the data and the weighted means by IP combination. The numbers of runs of each type are used as weighting factors to compute the mean values. Unbalanced triplex and flechette runs are omitted in this reduction.

The reduction by the IP combination is done as before, by dividing data of each column by the mean. This process yields Table K13.

The weighted means for each ammunition are computed and listed. These are then the ammunition reduction factors. Division of each row of Table K13 data by these factors yields the completely reduced data of Table K14.

AMMUNITION-ILLUMINATION-POSITION EFFECTS

The means for each IP combination are computed in Table K14, which, together with the means of Table K12, form the ammunition reduction factors. These final reduction factors are listed in Table K15.

TABLE K15

RELATIVE DATA BY AMMUNITION AND IP COMBINATION[a]

Ammunition or firing	H	R	P_H	I	P	H	R	P_H
SB	95	671	14.2	D	S	140	723	19
D	159	655	24.3	D	St	125	854	15
CS	124	783	15.8	N	S	53	905	6
CA	86	1183	7.3					
T48, S	132	711	18.6					
T48, A	95	1063	8.9					

[a]See footnotes to Tables K1 and X5 for abbreviations.

Tables K16 to K19 list the significant comparisons from Table K15.

The weapons comparison of Table K18 for the indiscriminate total data (all three IP conditions) is incomplete. More proper comparisons are made in Tables K10 and K11, where the three IP conditions are separated. The over-all superiority of the T48 is seen to stem from its superiority in night fire; the day results show the carbine to be clearly superior. This night superiority is directly attributed to the larger peepsight, which (as noted in App A) permitted proper use of the sights with the T48, in contrast with the rough "pointing" to which the troops resorted with the M1 and carbine. This effect was noted in ORO-SP-2,[8] and a recommendation was made for more complete testing of this observed effect.

TABLE K16

COMPARISON OF STANDING WITH SITTING AND NIGHT WITH DAY CONDITIONS[a]

Conditions compared	H	R	P_H
St/S (D)	0.89	1.18	0.79
N/D (S)	0.38	1.25	0.32

[a]See footnotes to Tables K1 and K5 for abbreviations.

TABLE K17

COMPARISON OF AUTOMATIC WITH SEMIAUTOMATIC FIRE[a]

Firing compared	H	R	P_H
CA/CS	0.69	1.51	0.46
T48, S/ T48, A	0.72	1.49	0.48
Mean	0.71	1.50	0.47

[a]See footnotes to Tables K1 and K5 for abbreviations.

TABLE K18

COMPARISON OF CARBINE AND T48 WITH M1 RIFLE[a]

Weapons compared	H	R	P_H
C/M1	1.30	1.17	1.11
T48/M1	1.39	1.06	1.31

[a]See footnotes to Tables K1 and K5 for abbreviations.

TABLE K19

COMPARISON OF DUPLEX WITH SINGLE-BULLET AMMUNITION[a]

Ammunition compared	H	R	P_H
D/SB	1.67	0.98	1.70

[a]See footnotes to Tables K1 and K5 for abbreviations.

Appendix L

EXPERIMENTAL DESIGN

SUMMARY

This appendix outlines the authority and coordination of the experiment design. The schedule that was settled on is described in detail; it is also compared with proposed alternative designs. The detailed test plan (Dec 1955 version) is appended in Annex L1. It includes background, test materiel, conditions, structure, and a list of requirements for the experiment.

CHRONOLOGY OF ACTIONS

On 12 October 1954 ORO received a request from the SALVO Steering Committee to "prepare a draft plan of test to affirm or deny the usefulness of the SALVO principle and the utility of the development equipment." An outline was submitted to the committee on 10 December and was discussed at the committee meeting of 25 January 1955. The committee approved the general outline of the test and advised which weapons might best be included in the experiment. ORO agreed to incorporate into the plan of experiment certain suggestions from the meeting, and to collaborate with the Ballistic Research Laboratories (BRL) in making further detailed revisions before submitting the plan to the Continental Army Command (CONARC) for their approval.

A first revised plan was submitted to the Committee Chairman and to BRL on 25 March. A second revision to accommodate BRL comments was submitted on 30 June. A third revision to accommodate further BRL comments was completed in August. On 8 August BRL submitted a disapproving criticism of the ORO plan, offering two alternative plans. On instructions from the Committee Chairman the ORO plan was submitted to CONARC for approval on 16 August. On 22 September ORO responded in disapproval of BRL plans:

> The BRL plans are statistically more elegant in potentially reducing the ease of analysis and the actual variance in some of the results. The departure from symmetry in the ORO schedule is occasioned by recognition of differences in value of the several items of data, in particular, the primary value assigned by our test objective to the multiplex firings.

On 7 October The Infantry School responded: "It is felt that such a test as proposed in ORO Salvo Hit Probability Experiment is somewhat premature."

On 21 November BRL resubmitted their formal criticism of the ORO test plan with the following recommendation:

> It is very strongly recommended that the following statements be given careful consideration:
>
> (1) The BRL plan B be the plan used during the conduct of Project Salvo.
>
> (2) The ORO plan be eliminated as a possible plan for conducting the test because the weekly firing schedule, as designed, is statistically weak.

On 4 January 1956 the SALVO Steering Committee approved ORO's fourth revised plan of December 1955 (reproduced as Annex L1) and requested approval of the Chief of R&D. On 30 January the Chief of R&D requested CONARC to support the ORO test. On 3 April CONARC advised ORO:

> Third Army has selected the Third Division, Fort Benning, Georgia, as the unit to conduct the SALVO Hit Probability Experiment. The Third Division has recommended that the test start 18 June 1956, and will make available personnel and equipment as specified in Inclosure 1.

TEST SCHEDULE

Table L1 compares the requirements of the ORO schedule, first as planned and second as run, and the BRL alternative schedules A and B.

It is clear from examination of Table L1 that the recommended Plan B (and probably the compromise Plan A as well) of BRL would have been impossible to execute. The number of runs is more than six times those accomplished in the 2-week experiment as run. The 8-run/day schedule took about 12 hr; the 28-run/day schedule would presumably require 42 hr/day. In addition, five times during each day reissue of weapons would have been required. The number of test weapons required would have been double, the total ammunition expended would have been almost eight times greater, and the number of test troops required would have been almost four times greater. The daily firing requirement on each man would have been five times greater and probably beyond reasonable endurance.

TABLE L1

SCHEDULE REQUIREMENTS

Parameter	ORO plan	ORO run	BRL A	BRL B
Total runs	120	68	356	424
Runs/day	8	8	18	28
Weapon type/day	1	1	4	5
Weapons/day	9	10	36	45
Total weapons	36	30	48	60
Men	135	60	177	222
Days	15	9	19	15
Man days	675	540	1,554	1,860
Multiplex ammunition	22,000	12,000	46,000	74,000
Single ammunition	51,000	29,000	164,000	244,000
Total ammunition	73,000	41,000	210,000	318,000
Round/man/day	400	400	1,000	2,000

The statistical significance of the differences found justifies the amount of repetition required in the ORO plan, which was ultimately adopted. The differences among the chief salvo ammunitions have been determined with statistical significance that is adequate for practical purposes. Secondary differences have been estimated with sufficient reliability so that those differences which are of practical consequences have been reliably determined. The lack of reliability on triplex and flechette results reflects the emergency failure to achieve more than two incomplete runs with each of these ammunitions.

When the experiment was finally conducted 6 months after the last formally prepared experimental design, further changes were made. The execution of the experiment differed from this design chiefly in two respects: (a) higher-priority activities denied us the terrain for 1 week, reducing the 96 scheduled regular runs to 64; (b) the accident with one run of triplex ammunition caused

TABLE L2

MASTER SCHEDULE

I[a]	P[b]	Run	Squad	Ammunition or firing[c]	Program	Run	Squad	Ammunition or firing[c]	Program	Run	Squad	Ammunition or firing[c]	Program
		Day 1, M1				Day 2, T48				Day 3, Carbine			
D	S	1	A	S	1A	9	B	SA	3A	17	B	SA	4C
D	S	2	A	D	1B	10	B	A	3B	18	B	A	4D
D	S	3	B	S	1A	11	A	SA	3A	19	A	SA	5A
D	S	4	B	D	1B	12	A	A	3B	20	A	A	5B
D	St	5	A	S	2A	13	B	SA	4A	21	B	SA	6A
D	St	6	A	D	2B	14	B	A	4B	22	B	A	6B
N	S	7	B	S	9A	15	A	SA	10A	23	A	SA	12A
N	S	8	B	D	9B	16	A	A	10B	24	A	A	12B
		Day 4, M1				Day 5, M1				Day 6, Carbine			
D	S	25	A	S	7A	33	C	D	8A	41	D	A	6A
D	S	26	A	T	7B	34	C	S	8B	42	D	SA	6B
D	S	27	B	S	7A	35	D	D	8A	43	C	A	6A
D	S	28	B	T	7B	36	D	S	8B	44	C	SA	6B
D	St	29	A	S	8A	37	C	D	5B	43	D	A	5A
D	St	—	—	—	—	38	C	S	5A	46	D	SA	5B
N	S	31	B	S	12A	39	D	D	11A	47	C	A	12A
N	S	—	—	—	—	40	D	S	11B	48	C	SA	12B
		Day 7, T48				Day 8, M1				Day 9, Flechette and M1			
D	S	49	D	A	4A	57	C	D	2A	65	E	S	1A
D	S	50	D	SA	4B	58	C	S	2B	66	E	D	1B
D	S	51	C	A	4A	59	D	D	2A	67	F	S	1A
D	S	52	C	SA	4B	60	D	S	2B	68	F	D	1B
D	St	53	D	A	3A	61	C	D	1A	69	C	Fl	1A
D	St	54	D	SA	3B	62	C	S	1B	—	—	—	—
N	S	55	C	A	9A	63	D	D	10A	—	—	—	—
N	S	56	C	SA	9B	64	D	S	10B	—	—	—	—
N	St									70	C	Fl	9A

[a] I is illumination, D is day, and N is night.
[b] P is firing position, S is sitting, and St is standing.
[c] S is single bullets, D is duplex ammunition, T is triplex ammunition, Fl is flechettes, SA is semiautomatic fire, and A is automatic fire.

deletion of a scheduled six runs of triplex, and replacement of four of these runs with extra duplex runs. Also the limitation on available flechette loads permitted only two incomplete runs with this appended ammunition.

The schedule for the 68 runs accomplished is shown in Table L2. The major change from the originally planned schedule of 96 runs is the deletion of the last 4 days. The other changes include deletion of triplex Runs 30 and 32, and substitution of duplex for triplex in Runs 33, 35, 37, and 39. In addition (not shown in Table L2), emergency shifts caused Runs 21 and 22 to be run at the beginning of Day 4, Runs 23 and 24 to be run at the end of Day 4, and Runs 45 and 46 to be run on Day 7, between Runs 54 and 55. Of the 96 originally scheduled regular runs, 62 were accomplished. In addition two partial runs were appended with flechette ammunition, and two additional runs each were added with Squads E and F, firing single-bullet and duplex ammunition, making a total of 68 runs accomplished.

Annex L1

ORO's FOURTH REVISED PLAN FOR THE SALVO I HIT PROBABILITY EXPERIMENT, DECEMBER 1955

PURPOSE

To measure the combat hit probability obtained with currently available salvo rifle ammunition as compared with single-bullet rifle ammunition.

AUTHORITY

Minutes of the SALVO Steering Committee Meetings of 28 Sep 54, 25 Jan 55, and 6 Dec 55.[37]

BACKGROUND

The proposal was made in ORO-T-160[5] that the large errors typical of combat rifle fire might be partly compensated for by a weapon firing several bullets simultaneously or nearly so. ORO-T-245[6] suggested a ready means of achieving one variety of such salvo fire with two or three tandem bullets fired with a single propellant. Further reports by Olin Mathieson Chemical Corp.[23] describe the development of salvo ammunition. The German report "Die Infanterie Doppelgeschosz," December 1944,[4] describes a similar two-bullet tandem round. Approximation to salvo fire is also regularly accomplished by burst fire with automatic weapons.

MATERIEL

Three types of rifle fire are planned for this experiment:

(1) Control (single bullet)
(2) Duplex (two tandem bullets)
(3) Burst (automatic bursts of 2 or 3 rounds)

Two weapons have been selected for this test:*

(1) M1 rifle (firing single-bullet and duplex rounds) and
(2) The Gustafson .22-cal carbine (firing single rounds and automatic bursts).

CONDITIONS

The human aiming error is a function primarily of eight target and troop conditions:

(1) Target size
(2) Target range
(3) Target visibility
(4) Target exposure time
(5) Target movement
(6) Troop qualification
(7) Troop firing position
(8) Troop stress

Only one of the eight, target range, is associated with inherent weapon error; the other factors are exclusively related to the human error. For comprehensiveness it is necessary to specify for the experiment several conditions for each of the parameters. The values for target size, range, visibility, exposure time, and movement are determined by the design of the target system; troop qualification and firing position are determined by troop selection and test instructions. Stress on the troops will be made as

*The necessity for a second burst-fire weapon had been questioned, and was deleted in this version, though the .22-cal T48 had earlier been suggested, and was actually used.

uniform as possible. Combat-simulating features will be determined with the advice of CONARC, by interrogations of combat experienced personnel, and review of pertinent literature.

Target Size and Shape

Approximate measurements reveal that a prone target is about 20 by 20 in., a kneeling target about 20 by 45 in., and a standing target about 20 by 64 in. It has been estimated that US troops fire approximately 30 percent prone, 30 percent kneeling, and 40 percent standing. These dimensions and proportions will be ascertained by further research. Further account for cover leads to a modified distribution of exposed target area—perhaps 60 percent prone, 20 percent kneeling, 20 percent standing. If it is assumed that the enemy man-targets are presented in the same proportions, the test would accordingly use 12 20- by 20-in., 4 20- by 45-in., and 4 20- by 54 in. targets, rectangular or oval, with the bottom edge about at ground level. Actual dimensions remain to be plotted.

Target Range

The targets will be distributed over the entire effective combat range for rifles. The boundaries for the area for the target range will be determined by a consensus of combat experience. The distribution of targets within this area will likewise be determined from combat experience. The frequency distribution for range may approximate the form shown in Fig. L1.

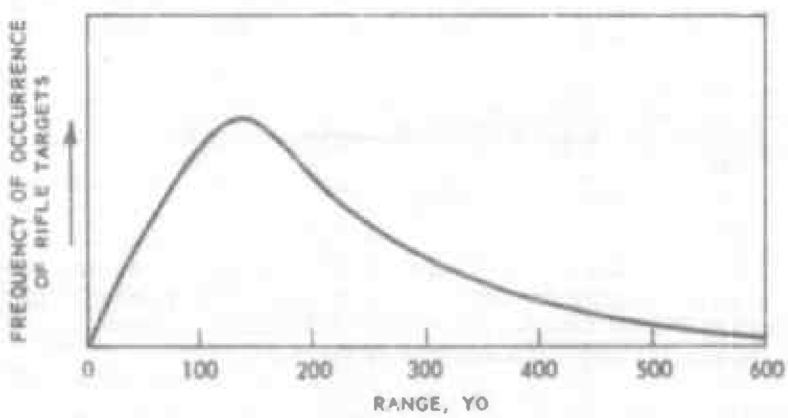

Fig. L1—Target Range Distribution

The actual placement of the targets that must be concealed depends on the existence of suitable cover or suitable locations for construction of appropriate cover. The visible targets may be distributed to approximate the combat range frequency without this restriction. In no case will the actual placement be at obvious ranges (such as even hundred of yards).

Target Visibility

In addition to the inherent visibility differences between the two types of targets (concealed and visible) it will be desirable to have some of the targets partly obscured by camouflage or terrain. Again combat experience will be used to determine the occurence of such visibility obscurations. Experiments will be run both in clear daylight and at night, the latter with controlled illumination equivalent to moderately bright moonlight. HumRRO will be consulted for further advice on night fighting and illumination. Some targets will be indicated by rifle fire from the target.

Target Exposure Time

The exposure times for the visible targets will be deduced from combat experience in a form as shown in Fig. L2.

The concealed targets are also to remain erect for a finite period, such as 15 sec. All targets are capable of appearance or disappearance within $\frac{1}{2}$ sec, and can be made to remain exposed for any number of seconds desired. Both concealed and unconcealed targets can be automatically programed for exact reproducibility of target appearance or indication. The entire program for appearance of all targets will be fixed in advance of the field runs, and the system activated by a single electrical switch. Times of visible target appearances and disappearances and concealed-target rifle fire indications are all recorded automatically on a moving tape. So far as possible, target size and range will be made to correspond with exposure time according to combat experience.

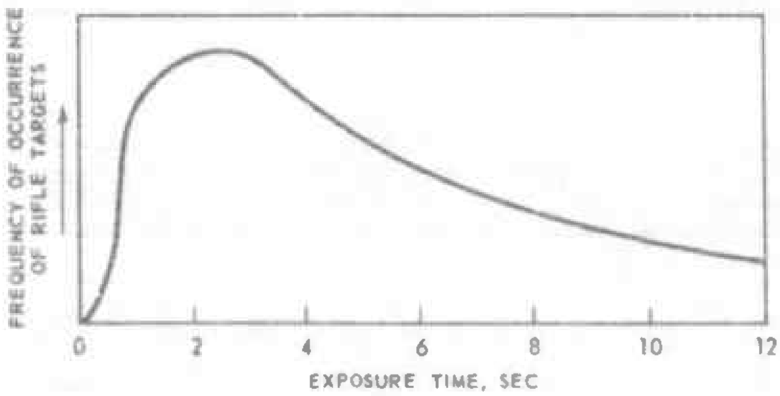

Fig. L2—Target Exposure Distribution

Target Movement

An attempt will be made to include at least one laterally moving target in the target system. The speed of movement, range, size, and exposure time will be determined in consultation with CONARC experts. Technical difficulties (concealment of tracks, expense, etc.) prohibit the employment of many moving targets.

Troop Qualification

Troop qualification will be determined in actual proportions of combat riflemen in each of the categories: expert, sharpshooter, marksman, and nonqualified. The proportions for the "typical" squads of 10 men might be: 1 expert, 3 sharpshooters, 5 marksmen, 1 bolo. Preliminary special qualification firings may be used to confirm paper qualifications. To determine analytically the salvo hit probability difference as a function of troop qualification, runs will also be made with two special squads (experts and bolos).

Firing Position

A preliminary consideration suggests that accuracy extremes in firing may be approximated by two positions: prone with rifle support and standing without rifle support. Results from other firing positions may be estimated by interpolation between these extremes. Typical squads will fire from both positions. All firing will be from the shoulder (no hip firing).

Stress on Troops

Various combat simulations will be used, such as recorded battle noise and such smoke and explosions as will not directly affect physical conditions for target identification. Efforts will be made to assure that environmental conditions throughout the experiment are equivalent. Extremes of rain, for example, will be avoided.

STRUCTURE

Machine-Rest Firings

Fundamental information on the accuracy and dispersion of the weapons independent of aiming error has already been gathered. Further information as needed may be obtained from machine-rest firings. For this purpose it is desirable to vary only the range; firings may be conducted under conditions of negligible wind against fixed targets at known ranges, capable of recording all shots. For each of the weapons and ammunition loads this experiment should record a distribution of errors about the center of impact that is inherent in the weapon and ammunition exclusive of the human aiming error. The detailed design and conduct of these machine-rest firings are to be supervised by Ballistic Research Laboratories.

Incidental to this test, calibration of the target-hit-time apparatus has been accomplished. For analysis of the experimental data it is necessary to make accurate measurement of the time between bullet strikes from duplex rounds as well as automatic fire on targets at several ranges. Time-interval-vs-range curves will be deduced for the multiplex loads. This measurement will be accomplished by attaching a sensing device to each target. When the target is struck by a bullet, the sensing device sends an electrical pulse to the recorder. The pulse is manifested as a spark hole in a moving tape. The combined resolution of the sensing device and recorder is better than 1 msec.

Zeroing and Familiarization

All rifles will be combat zeroed at a predetermined range (such as 200 yd) every firing session (half-day sessions). Each man will zero his own weapon firing about ten times, and have his hits identified progressively. Each man will be issued his weapons and ammunition some time before the experiment to assure his complete familiarization with the functioning of those weapons and the ammunition. Familiarization will include observation of the bullet drop vs range characteristics of each weapon-ammunition combination; it will also then include instruction and practice in allowing for such a drop by a "Kentucky windage" procedure.

Target System

The system will consist of about 20 targets: probably 10 visible and 10 concealed, with 1 moving. All the targets are electrically controlled, spring powered, automatic appearing-disappearing. The concealed targets are indicated by electrically controlled rifle fire.

The visible targets can be placed anywhere on a typical range, requiring a minimum of concealment preparation. The concealed targets require placement behind natural or other cover. The target appearance and disappearance is accomplished by electrical control from behind the firing line. The targets operate by electrically controlled spring releases, such devices being readily installed with a minimum of field preparation, requiring no pits to protect operators or to hide the target mechanisms. They can easily be placed on the field at new positions each day to prevent disclosing the positions to the riflemen.

All targets lie supine on the ground and out of sight until activated, at which time they pop up to a vertical position. The spring mechanism is adequately powerful to complete movement of the target in about ¼ sec even in a strong wind. A second electrical signal releases the spring again to continue the target motion to a prone position, again out of sight.

Electrically fired M1 rifles are placed directly in front of each concealed target to simulate enemy rifle fire. The rifle is fired by an electric solenoid attached to the trigger. It is firmly supported on the terrain, and fires blanks or live rounds into pits some 20 yd ahead. If live the fire is directed 30 deg or so from the end of the firing line. The rifle is sandbagged, with only the tip of the muzzle showing. Probably one laterally moving target will be incorporated in the experiment. ORO has a moving-target prototype that will be modified to a suitable form. This target is electrically driven and can be controlled from the automatic programmer.

Control wires for all 20 targets lead to the control station just behind the firing line. The vulnerable lengths (within 20 yd of a target) are buried; the remaining lengths are laid on the open ground. The control station includes a programing board for individually controlling each of the 20 targets. The circuits are arranged so that any number of seconds may be tapped off the programing board by plugging in appropriate jacks. It is possible to cause any one of the targets to remain erect for any number of seconds and to cause the next target to appear any number of seconds later.

Thus the entire operation is automatic. It is necessary only to preselect the durations of visible appearance, the intervals between target appearances, and the target-appearance order. One run takes 5 min, utilizing the full range of the 300-position programmer with 1-sec intervals.

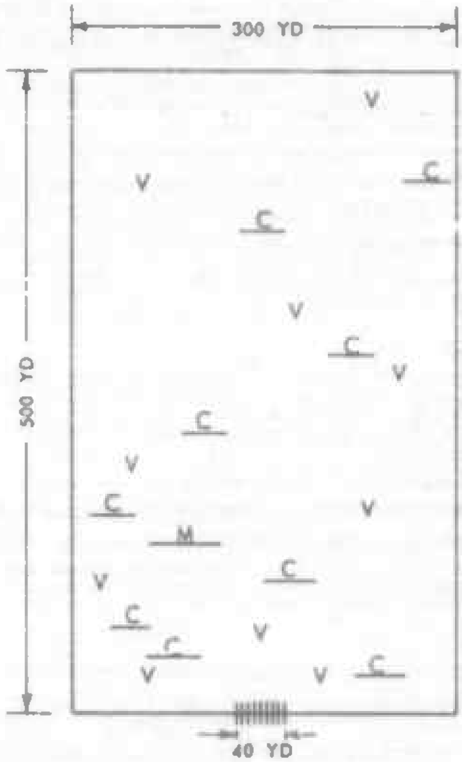

Fig. L3—Representative Target Range

V, visible; C, concealed; M, moving.

A group of 10 riflemen is spaced with 5 yd between men on a firing line, covering a front of 300 yd (see Fig. L3). Since this complete system has not yet been field-tested it is necessary to schedule a preliminary range test. When the complete system is ready, it will be necessary to provide a suitable firing range and a few troops with rifles for a preliminary test.

Range Firings

The variations in the four firing conditions already discussed are:

(a) Squads (3):
1. Typical mixed
2. Experts
3. Bolos

(b) Weapons (4):
1. M1 single bullet
2. M1 duplex
3. .22 Carbine - single round
4. .22 Carbine - automatic

(c) Position (2): 1. Prone
2. Standing

(d) Illumination (2): 1. Day
2. Night

A four-dimensional array would yield $3 \times 4 \times 2 \times 2 = 48$ combined conditions. An unsophisticated experimental design to test each of these conditions would either be impractically lengthy or yield only a single measurement for each condition. To obtain the measures required for statistical reliability it is necessary either to increase the total schedule (by an estimated minimum factor of 3) or to eliminate certain conditions in order to duplicate others of more basic significance. For practical reasons the second alternative is chosen. A systematic design permits approximation of the missing measures by analytical means, at the same time assuring reliable measurement of salvo hit capabilities in the most basic conditions in a reasonable schedule.

Tables L3 and L4 show the schedule.

TABLE L3

DAILY SCHEDULE OF FIRING BY SQUADS[a]

Day		Night	
Prone	Standing	Prone	Standing
A, B, C, D, E	A	B	C

[a]Qualification: A, typical 1; B, typical 2; C, typical 3; D, bolo; and E, expert.

TABLE L4

SCHEDULE OF FIRING BY WEAPONS[a]

Day	Week 1	Week 2	Week 3
Mon	1	3	2
Tues	2	4	1
Wed	3	1	4
Thurs	4	2	3
Fri	Bad-weather allowance		

[a]Weapon: 1, M1 single bullet; 2, M1 duplex; 3, .22 carbine single round; and 4, .22 carbine automatic.

The schedule calls for 32 runs per week—24 day and 8 night runs. In the 3 weeks it is seen that nine measures will obtain for each prone-typical-squad day firing. Three measures will obtain for each of the following: prone-typical-squad night firing, standing-typical-squad day firing, standing-typical-squad night firing, prone-expert-squad day firing, prone-bolo-squad day firing.

The total is 96 measures from 96 runs—48 single-bullet, 24 duplex, and 24 burst measures. The arrangement of the schedule is such as to correct for the effects of extraneous parameters such as weather, learning, fatigue, etc. Several "equivalent" but nonidentical programs of target appearance will be employed (both order and exposure times varied) to minimize target-learning effects.

If each man gets off an average of 2 trigger pulls per target with an average of 2 bullets per trigger pull, then for 10 men firing at 20 targets, there should be $(2 \times 2 \times 20 \times 10)$

about 800 bullets fired for each run. If the hit ratio is only 1 per 8 bullets fired, a total of about (800/8) 100 hits can be expected, or 5 hits per target average, or 15 hits per target with 3 repetitions. Such numbers of hits are adequate for discriminating between scores made in the different types of fire.

Ammunition issue for each run will be unlimited. The useful ammunition expenditure will be limited only by the exposure time and visibility of the targets. The number of rounds fired by each man will be recorded for each run.

Malfunctions of any weapons will be recorded immediately without interrupting the test. The nature of the malfunction will be recorded, together with the number of rounds fired before stoppage and the qualification and position of the firer.

Ammunition Loads

Ammunition loads will be 8-round clips for the M1. For direct comparability, it is essential that the single-bullet and the duplex caliber .30-06 ammunition be packaged in nearly identical 8-round clips.

The Gustafson carbine will load from its 15-round magazine. For control purposes it will not employ its bipod, and will be modified to fire semiautomatically only for the single-round control runs.

Data Recording

Data will be recorded from several sources. The program of target appearances for each run will be recorded beforehand. Each target face will be identified, and the paper target faces recovered after each run for subsequent analysis of hits. In addition each target is equipped with an electrical sensing device, which sends a pulse to an automatic continuous recorder when the target is struck by a bullet. The sensing device and recorder are capable of resolving approximately 1 kc—or separately recording hits as close as 1 msec.

The automatic fire hits will be discernible by the cyclic rate (approximately 100 msec). Duplex hits will be discernible by pulses separated by the exact time determined by the target distance and muzzle-velocity difference between bullets from the same round. The time between bullet strikes for duplex bullets is first determined as a function of range, as described previously. It is thus possible to recognize multiple hits from a single trigger pull. With a muzzle-velocity difference of 250 ft/sec the time between duplex strikes on the nearest likely target at 100 ft is about 3 msec. At 500 yd this time interval is about 50 msec.

REQUIREMENTS

Weapons

10 M1 caliber .30 rifles (modified to accept single-bullet and duplex rounds from 8-round clips).

10 Gustafson caliber .22 carbines (modified to fire semiautomatic as well as automatic).

For avoidance of delay in the event of serious malfunction, it is desirable that the supply of test weapons be 12 of each type (two spares for each), a total of 24 weapons. All weapons should be of equivalent newness. In addition, some 10 or 15 unmodified M1 rifles will be required as part of the target system.

Ammunition

The zero firings previously described are called for each of the 24 half-day sessions. Using the specified weapons, for 10 trigger pulls per zeroing, the requirements (assuming an average of $2\frac{1}{2}$ rounds per automatic burst) are as shown in Table L5.

Ammunition expenditure for the range firings may be deduced by estimating 2 trigger pulls per man per target. For 96 runs with 20 targets and 10 men, this is $2 \times 96 \times$

20 × 10 = 38,400 trigger pulls, or some 80,000 rounds. The requirements are listed in Table L6. The concealed target indicators will fire another 10 × 96 = 960, or about 1000 rounds of .30-06 single bullets, not included in the test or zero firing.

Combining the loads from Tables L5 and L6 gives a grand total of estimated ammunition requirement of roughly 70,000 rounds, including about 12,000 rounds of duplex (see Table L7).

TABLE L5

ZERO-FIRING AMMUNITION REQUIREMENTS

Weapon	Ammunition or firing	Rounds	Loads
.30-06 M1	Single bullet	10 × 240 = 2,400	300 8-round clips
	Duplex	10 × 240 = 2,400	300 8-round clips
.22 Gustafson	Semiautomatic	10 × 240 = 2,400	560 15-round magazines
	Automatic	10 × 600 = 6,000	
Total		13,200	

TABLE L6

TEST-FIRING AMMUNITION REQUIREMENTS

Weapon	Ammunition or firing	Runs	Rounds (100 trigger pulls per run)	Loads
.30-06 M1	Single bullet	24	9,600	1200 8-round clips
	Duplex	24	9,600	1200 8-round clips
.22 Gustafson	Semiautomatic	24	9,600	2240 15-round magazines
	Automatic	24	24,000	
Total		96	52,800	

TABLE L7

TOTAL AMMUNITION REQUIREMENTS

Ammunition	Rounds	Loads
.30-06	13,000	1625 8-round clips
.22 Gustafson	42,000	2800 15-round magazines
.30-06 Duplex	12,000	1500 8-round clips
Total	66,000	

Target Range

The target range needed for this test is sketched in Fig. L4; it is a range area of about 300 by 500 yd, with safety provisions for a wide angle of fire. It is desirable to permit firing at targets as close as about 30 yd, with a lateral displacement of the firers by as much as 60 yd. The ground should be typical battleground—more than enough vegetation to conceal targets so that just any bush does not become too likely a target location. The safety zone is deduced by limiting the area for target positions to beyond the line TT'T in Fig. L4. The firers are restricted to within the segment SS. The minimum angle of fire from the firing line is just arctangent 100/200 = 27 deg.

These dimensions are suggested as a likely compromise between research needs and safety requirements. The over-all dimensions in particular are approximate rather than stringent.

The power requirement for the target system is modest: 115 volts AC, drawing less than 1 kw maximum. The power requirements for the artificial lights and tape players for battle noise are also modest: 115 volts AC, drawing probably less than 5 kw steady. Illumination-measuring equipment as well as the lights themselves will be required for the night tests.

Although ORO will supply the target mechanisms, about 2000 pasteboard targets (96 × 20 = 1920) will be required, mounted on suitable stakes.

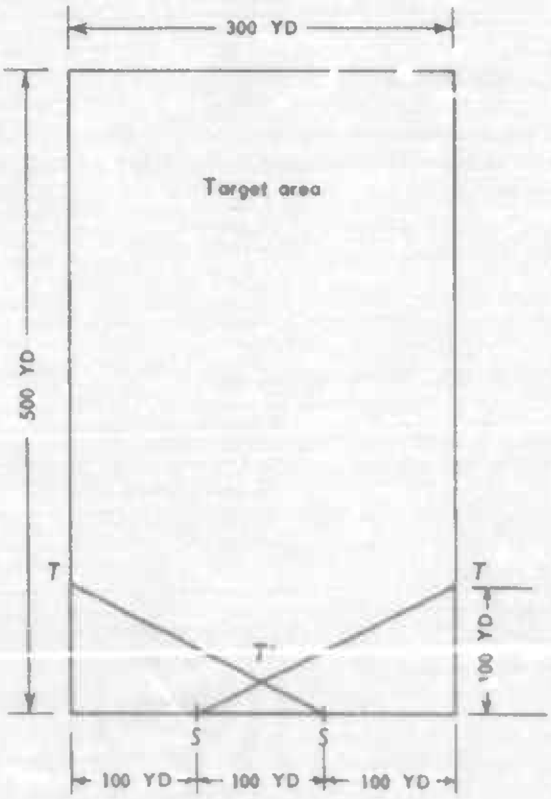

Fig. L4—Range Dimensions

Time

There will be 72 day runs and 24 night runs. The actual runs will take about 5 min each. The preparation between runs (ammunition issue, zeroing, target preparation, programing, illumination) will doubtless take much longer. If an average of 25 min preparation per run and 1 hr preparation per session is estimated, about 48 hr will be spent on 12 day sessions, and 24 hr on 12 night sessions. It should then be possible, with proper preliminary preparation, to perform the entire test in 3 weeks.

Personnel

In Table L2 it is seen that the firings may be reasonably accomplished with the use of 15 selected squads, 5 each week.

The typical mixed squads will be composed of predetermined qualifiers, such as one expert, five sharpshooters, three marksmen, and one nonqualified. These squads will be relieved of other duties for their respective weeks and will be available full time for this experiment, including nights. The expert and bolo squads will be composed of qualified experts and unqualified shooters respectively. These squads will be relieved of most other duties for their respective weeks and will be available part time for this experiment.

Summary of Requirements

Weapons:

12 M1 rifles (chambers reamed to accept duplex rounds)
12 M1 rifles (unmodified)
12 Gustafson caliber .22 carbines

Ammunition (50 percent overallowance):

20,000 rounds caliber .30-06 in 8-round clips
63,000 rounds caliber .22 Gustafson in 15-round magazines
18,000 rounds caliber .30-06 duplex in 8-round clips

Range:

About 300 by 500 yd with provision for wide angle of fire; terrain with small rises and adequate vegetation to provide some potential individual concealment.

Personnel:

600 man-days: 3 sets of 50 men for 4 days each. These men must be preselected with regard to markmanship qualifications. It is anticipated that satisfactory sets of 50 can be selected from random groups of 60 or 70, including standby replacements (almost 48). The men must be free for night firing, as well as day. Project officers will of course also be required.

Time:

12 days and 12 nights—barring extraordinary weather, it will take 3 weeks.

Target system:

About 20 hit-recording pop-up targets and automatic programmer and hit recorder (all designed and probably supplied by ORO); a 115-volt AC 5-kw power line on the range; illumination equipment (to be determined with CONARC and HumRRO); about 2000 pasteboard targets (to be specified).

Appendix M

HIT PREDICTIONS

TABLES

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SUMMARY

In order to determine sensibly the requirements for an experimental design it is necessary to predict the results of the experiment. Without some foreknowledge of the magnitude of differences to be expected, it is not possible to specify some minimum number of measurements required to achieve acceptable reliability. Clearly only rough estimates are possible, or else the experiment itself is quite unnecessary.

In this appendix single-bullet predictions are made for rounds fired and hits scored on both day and night target systems. These values compare reasonably well with experimental results.

An optimum zero setting is deduced, which minimizes total bullet drop for all targets of the day system. The setting is a 165-yd zero for all ammunitions.

The controlled duplex pattern is analyzed theoretically to yield hit predictions as a function of both aiming error and target size. These general results are applied to the experimental target system.

The random-dispersion triplex and flechette loads are also examined theoretically to yield casualties as a function of dispersion. These results are extrapolated to hits for the given ammunition dispersions.

The resultant predictions of hits and rounds fired for all test ammunitions are tabularly compared with the experimental results. Finally the predicted standard deviations are computed to justify the statistical reliability of the experimental design.

SINGLE-BULLET HIT PREDICTION

In order to predict the outcome of the experiment the results of an earlier accuracy experiment were applied to the detailed experimental target system plan for the SALVO I experiment.[16]

In this experiment aiming error was determined for rifles under test conditions for varying times of target exposure. The average errors varied from 3 mils with 8 sec to aim to 20 mils with only 1-sec aiming time. These are radial errors expressed in angular measure. The averages used are the root-mean-square values. This root-mean-square radial error is identical with the radial standard deviation. It is larger by a factor of $\sqrt{2}$ than the commonly used linear standard deviation; it is slightly larger (by 13 percent) than the mean radius.

This accuracy experiment revealed that the shortest time in which an average man can get a sight picture is about 2 sec. The test further revealed that

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for the initial round at a newly sighted target, $3\frac{1}{2}$ sec is optimum (more rapid fire reduces accuracy, and slower fire reduces rate, so that the hits per unit time are decreased). Therefore the basic rate of fire was taken to be about 3 rounds per 10 sec, and the corresponding aiming error was taken to be 4 mils. Actually the preliminary experiment predicted 5 mils with standing fire for this exposure time, but it was felt that the sitting position of the SALVO I experiment would enhance accuracy.

The rate of fire and measure of aiming error next had to be refined for critical target characteristics. This was done by simple judgment according to the following rationale: the number of rounds fired at a target during the day was thought to be reduced by about 2 rounds for lightly camouflaged targets and 5 rounds for heavily camouflaged targets, as compared with unconcealed targets. This leads to the following expression for the number of rounds fired at a given day target:

$$N = (10/3)(t - 1) - 2(LC) - 5(HC) \qquad \text{(M1)}$$

where t = the number of seconds of target exposure
 -1 = the initial firing delay, in seconds
 (LC) = light concealment
 (HC) = heavy concealment

If the target is in (LC) or (HC) classification, that term in Eq. M1 becomes unity; otherwise the term is zero. The aiming error must also be modified to account for concealment and movement (M). The expression used for the radial standard deviation α is

$$\alpha = 4.0 + (T/2)(LC) + 2T(HC) + 2T(M) \qquad \text{(M2)}$$

where T = target radius, in mils.

The rationale here is that a lightly concealed target is likely to be missed by an additional quarter target width, and a heavily concealed target by a full target width. Similarly a laterally moving target M is likely to incur an additional error of a full target width. Using these two equations it became possible to predict the number of rounds fired N and number of hits scored H on the 22 targets of the day target system. The results of these calculations are presented in Table M1. The hit probability is simply computed from the expression:

$$p = 1 - \exp[-(T/\alpha)^2] \qquad \text{(M3)}$$

The target size T was deduced from the known size of the E or F silhouette target and the range. The F target has an area of 328 sq in., or an equivalent-circle radius of 10.2 in. The E target has an area of 653 sq in., or an equivalent-circle radius of 14.5 in. The hit probability on elements of area on the extreme corners of these irregular targets is somewhat less than would be the case for a circular target. By actual measurement on the silhouette targets, for an assumed average error of 5.4 mils, the equivalent circular targets were found to have radii of 9.9 and 14.0 in. These were the values used as radii of circular targets equivalent to the silhouettes in computing T.

The predictions for the night target system were made in a similar fashion. In this case the initial firing delay was increased by an additional 20/3 sec to account for increased difficulty in acquiring the target. On the other hand, this 20/3-sec increase was erased with those targets indicated by blank rifle fire. It is judged that the flash would approximately compensate for the darkness.

Certainly the basic aiming error at night is larger than the day value of 4 mils; an arbitrary judgment provided an estimate of a 5-mil basic error. It was assumed that the additional error incurred by light concealment was a half target width rather than the quarter target width assumed for the day system. It was further assumed that the existence of blank rifle fire at a target reduces the aiming error by a quarter target width. Finally, it was assumed that under

TABLE M1

PREDICTED DAY TARGET HITS

Target no.	Range, yd	Target characteristics	Target silhouette	Target size, mils	Exposure time, sec	Rounds fired	Radial error, mils	Hits	Hit probability, %
5	74	f[a]	F[b]	3.3	4.5	12	4.0	5.9	49.3
7	77	f, HC[c]	F	3.2	15	42	11.3	3.2	7.7
9	86	—	F[d]	3.9	4.5	12	4.0	7.4	61.3
10	89	f, HC	F	2.7	15	42	9.4	3.3	7.9
13	111	f, LC[e]	F	2.2	19.5	60	8.4	4.0	6.6
14	127	f, LC	F	1.9	9	25	5.0	3.4	13.5
15	139	—	F	1.7	4.5	12	4.0	2.0	16.6
16	152	M[f]	E	2.2	9	27	8.4	1.8	6.5
18	162	M	E	2.1	6	17	8.1	1.0	6.1
19	164	M	F	2.0	15	47	8.1	2.8	5.9
20	165	LC	E	2.0	31.5	100	5.0	14.8	14.8
21	169	—	E	2.0	3	7	4.0	1.5	22.1
22	176	f, LC	E	1.9	4.5	10	5.0	1.4	14.5
24	216	LC	F	1.1	4.5	10	4.6	0.6	5.6
25	218	LC	F	1.1	9	25	4.6	1.4	5.6
28	245	f	E	1.4	6	17	4.0	2.0	11.5
29	259	f	E	1.3	10.5	32	4.0	3.2	10.0
30	267	—	E	1.3	3	7	4.0	0.7	10.0
31	269	f, HC	F	0.9	25.5	77	5.8	1.8	2.4
32	334	f	F	0.7	7.5	22	4.0	0.7	3.1
33	336	—	F	0.7	3	7	4.0	0.2	3.1
34	339	f, LC	F	0.7	21	65	4.4	1.6	2.5
Total	4174	11f 7LC 3HC 3M	12F 10E		231	675		64.7	
Mean	190			1.8	10.5	31	5.6	2.9	

[a]Blank fire
[b]Small
[c]Heavy concealment
[d]Large
[e]Light concealment
[f]Movement

conditions of low illumination the outline is vague, even when located, to the extent of an additional half target width. These considerations lead to modified expressions for the number of rounds fired and the aiming error, as indicated in Eqs. M4 and M5.

$$N = (10/3)[t - 3 + 2(f)] - 2(LC) - 5(HC) \tag{M4}$$

$$\sigma = 5.0 + T + T(LC) + 2T(HC) + 2T(M) - (T/2)(f) \tag{M5}$$

The parenthetical designations are defined in the footnotes to Table M1.

Application of these expressions to the information on the 22 targets of the night system yielded the rounds fired and hits scored at night, which are presented in Table M2.

It is of interest to note from the totals of Tables M1 and M2 what some of the average values are. The most meaningful measure of hit probability is probably the integrated value, taken from the total numbers of hits and rounds fired. These numbers yield a predicted hit probability of 9.6 percent during

TABLE M2

PREDICTED NIGHT TARGET HITS

Target no.	Range, yd	Target characteristics	Target silhouette	Target size, mils	Exposure time, sec	Rounds fired	Radial error, mils	Hits	Hit probability, %
1	52	f, HC	F	4.7	28.5	87	16.7	6.6	7.6
2	63		E	5.3	3	0	10.3	0.0	23.3
3	65		E	5.1	7.5	15	10.1	3.4	22.5
4	67	f, HC	F	3.6	12	32	14.0	2.0	6.4
6	76	f, HC	E	4.4	4.5	12	7.2	3.7	31.2
8	78	f, HC	F	3.1	19.5	55	12.7	3.2	5.8
11	90	f	F	2.7	4.5	12	16.3	0.3	2.7
12	91		F	2.7	9	18	10.4	1.2	6.5
13	111	f, HC	F	2.2	19.5	60	8.3	4.1	6.8
14	127	f	F	1.9	9	25	7.9	1.4	5.6
15	139		F	1.7	4.5	5	6.7	0.3	6.2
16	152	M	E	2.2	10.5	25	11.6	0.9	3.5
17	161	f	E	2.1	3	7	6.0	0.8	11.5
18	162	M	F	2.1	6	10	11.3	0.3	3.4
19	164	M	E	2.0	18	50	11.0	1.7	3.3
20	165	LC	E	2.0	34.5	103	9.0	4.9	4.8
21	169		E	2.0	4.5	5	7.0	0.4	7.9
22	176	f, LC	F	1.9	9	25	7.9	1.4	5.6
23	209		F	1.2	3	0	6.2	0.0	3.6
26	221	f	F	1.1	7.5	22	5.5	0.9	3.9
27	223	f, LC	F	1.1	21	65	6.6	1.8	2.8
25	218	LC	F	1.1	15	38	7.2	0.9	2.3
Total	2979	11f 4LC 5HC 3M	12F 10E		253.5	671		40.2	
Mean	135			2.6	11.5	31	9.5	1.8	

the day and 6.0 percent at night. It is also interesting to note that the prediction of total rounds fired is essentially the same day and night (675 and 671). The prediction was 65 hits out of 675 rounds fired in day-sitting control (single-bullet) fire. It was gratifying, and quite surprising, when the first preliminary single-bullet run resulted in 74 hits out of 669 rounds fired. The later test data proved a somewhat higher hit probability, averaged from the 8 regular single-bullet day-sitting runs. The night prediction from Table M2 was 40 hits out of 671 rounds fired. The average result from 4 test runs turned out to be 42 hits out of 834 rounds fired. These comparisons are listed in Table M3.

It should be noted that the night target system is generally composed of longer-appearing and closer targets than the day system, in accord with normal combat practice. A linear mean target distance of 190 yd is reduced to 135 yd at night. It is of further interest to note what the predicted effective range might be. An effective range may be defined by describing the following calculation: the figures in the "Range" and "Rounds Fired" columns of Tables M1 and M2 are multiplied together for each of the targets. The products are totaled, and this total is divided by the total number of "Rounds Fired" alone. The resulting figures represent average ranges, which were weighted by predicted fire. This can then be interpreted as the average hitting range. This calculation was performed, and yielded 191 yd for the day system and 135 yd for the night system.

TABLE M3

COMPARISON OF PREDICTIONS WITH RESULTS FOR SITTING SINGLE-BULLET RUNS

Run	Prediction		Result	
	Hits	Rounds	Hits	Rounds
Day	65	675	114	577
Night	40	671	42	834

TABLE M4

PREDICTED AVERAGE FIRING CONDITIONS

Run	Range, yd	Exposure, sec	Rounds fired	Hits	Hit probability, %	σ, error, mils
Day	191	10.5	3.1	0.29	9.6	4.0
Night	135	11.5	3.1	0.18	6.0	7.4

The average error is also of interest. Simple linear means of the radial errors are shown at the bottom of Tables M1 and M2. The values are 5.6 mils for the day and 9.5 mils for night systems. This linear mean is a rather unsophisticated way of averaging the error; a possibly better method would be based on the integrated hit probability. This calls for the use of some sort of average target size. The linear mean target sizes from Tables M1 and M2 were used. These values are 1.8 mils for the day system and 2.6 mils for the night system. The simple relation for a symmetrically normal error on a circular target is described by Eq. M6:

$$\alpha = T/\sqrt{-\ln(1-P)} \qquad \text{(M6)}$$

where P is hit probability. Equation M6 yields radial standard deviations α of 5.7 mils for the day system and 10.4 mils for the night system. It is noted that these two values are in reasonable agreement with the linear means.

The errors in Table M4 were converted from radial to linear standard deviations, simply by dividing by $\sqrt{2}$. The errors are presented this way for convenience, since the linear standard deviation σ is in more common usage.

COMBAT ZERO

Having predicted hits on the target system, it becomes possible to compute a zero setting for test weapons that will produce a high net hit probability. Of the several possible schemes for defining and computing the combat zero, the following procedure was adopted: First, the ballistic path of all test ammunitions was determined (with the exception of the flechette ammunition). The

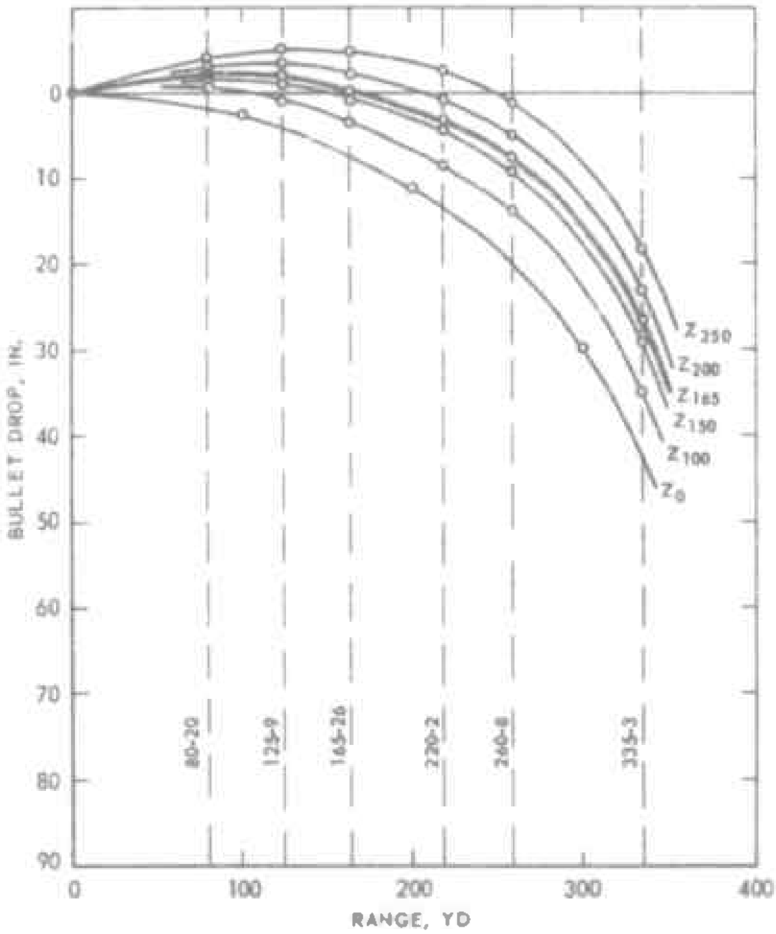

Fig. M1—Bullet Drop as a Function of Range for the .30-cal Single-Bullet M2 Ammunition

The number to the left of the hyphen on the vertical lines indicates range; the number to the right indicates hits (see Table M5).

arsenals and manufacturers were kind enough to provide information on the bullet drop as a function of range for the five rifle ammunitions, which is plotted in Figs. M1 to M5. The lowest curve on each of these figures shows the exaggerated path of the test ammunitions fired horizontally (e.g., zeroed at zero range). In addition the paths were computed and plotted for each ammunition zeroed at 100, 150, 165, 200, and 250 yd. These curves cross the horizontal axis at those ranges respectively.

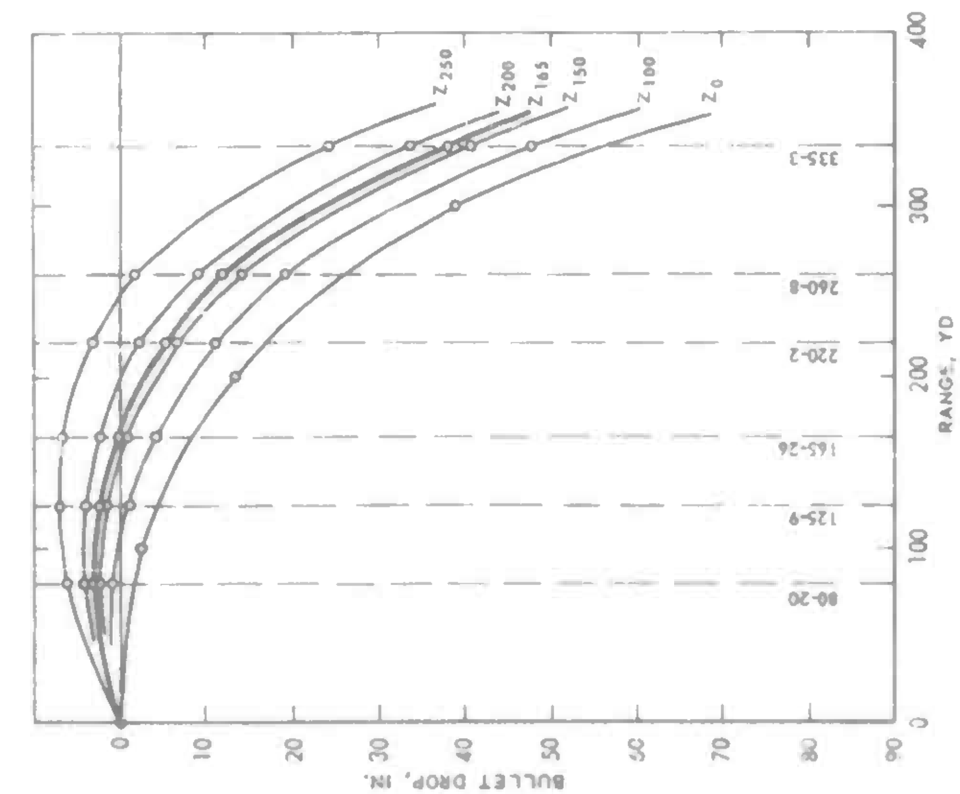

Fig. M2—Bullet Drop as a Function of Range for the .30-cal Duplex Ammunition

The number to the left of the hyphen on the vertical lines indicates range; the number to the right indicates hits (see Table M5).

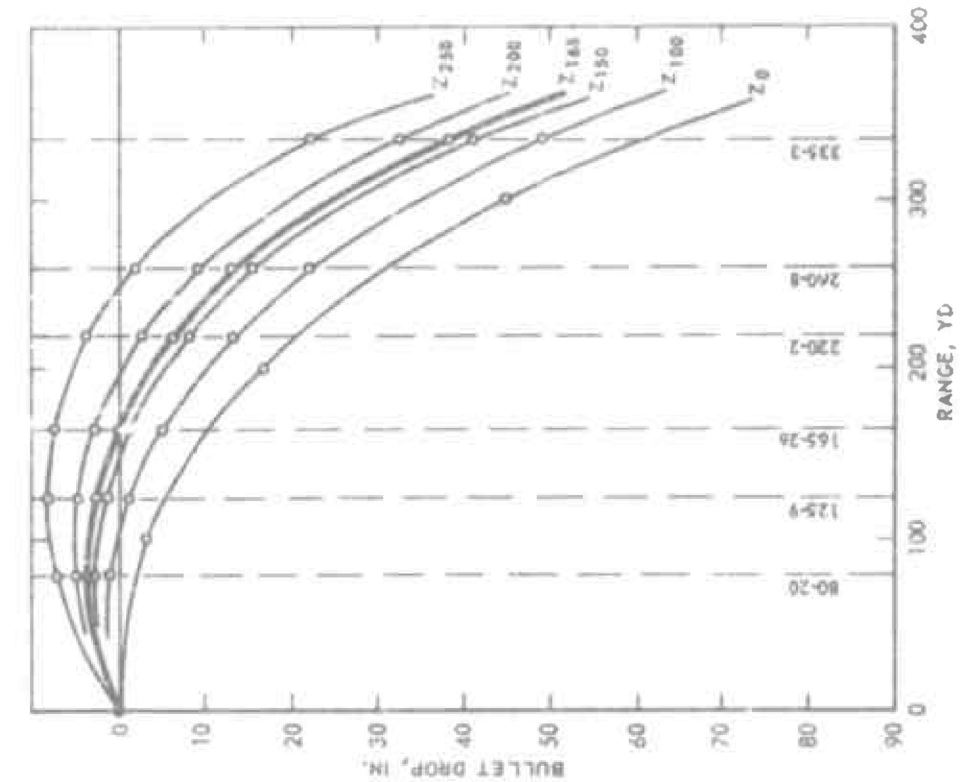

Fig. M3—Bullet Drop as a Function of Range for the .30-cal Triplex Ammunition

The number to the left of the hyphen on the vertical lines indicates range; the number to the right indicates hits (see Table M5).

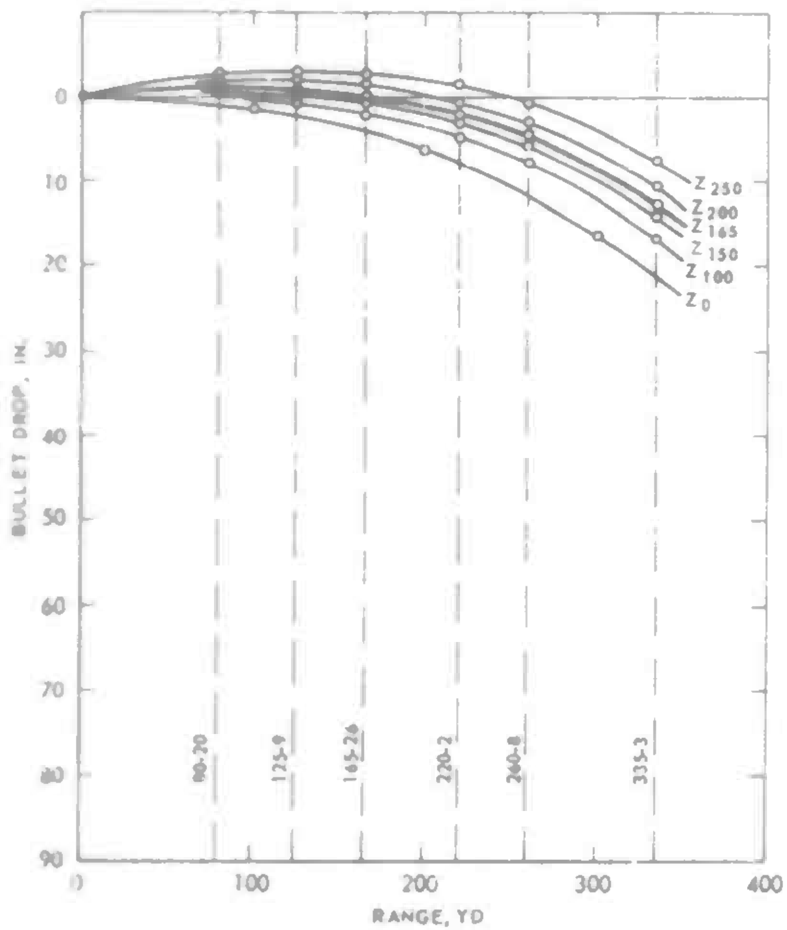

Fig. M4—Bullet Drop as a Function of Range for the .22-cal T48 Ammunition

The number to the left of the hyphen on the vertical lines indicates range; the number to the right indicates hits (see Table M5).

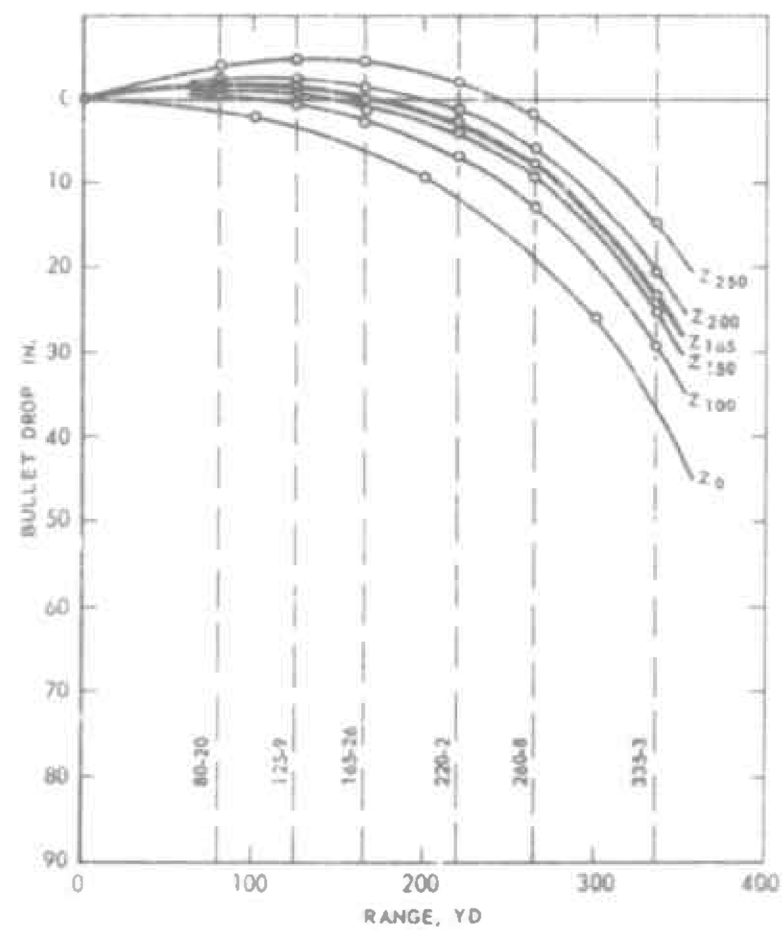

Fig. M5—Bullet Drop as a Function of Range for the .22-cal Carbine Ammunition

The number to the left of the hyphen on the vertical lines indicates range; the number to the right indicates hits (see Table M5).

Next, to reduce the complexity of calculation, the target hits shown in Tables M1 and M2 were aggregated, which was arbitrarily accomplished by lumping three or four targets that occur at nearly the same range and merely attributing the total number of hits on those targets to a representative target at an average of the several ranges. The results of this aggregation yield the simple target system shown in Table M5.

The information on the simplified target system is indicated in Figs. M1 to M5 by the vertical lines drawn at each of the six ranges. Using this hit information as a weighting factor, it becomes possible to compute the total inches

TABLE M5

SIMPLIFIED DAY TARGET SYSTEM

Range, yd	Hits
80	20
125	9
165	26
220	2
260	8
335	3

TABLE M6

TOTAL DROP MISS DISTANCE FOR VARIOUS ZERO RANGES FOR FIVE AMMUNITIONS

Ammunition	Zero range, yd				
	100	150	165	200	250
	Bullet drop, in.				
Single bullet	349	246	218	258	322
Duplex	457	331	305	353	453
Triplex	516	367	331	395	512
Carbine	290	212	193	224	292
T48	186	131	115	139	174

of bullet drop for the entire target system for each value of zero. Consider, as an example, the .30-cal single-bullet ammunition shown in Fig. M1. Look first only at the curve for the 100-yd zero. The first composite target occurs at 80 yd, where the curve shows an error of 0.7 in. Since 20 rounds are expected to hit this composite target, a total error of 20 × 0.7 or 14 in. is indicated. Similarly, the next target at 125 yd experiences a drop of 1.1 in. for 9 anticipated hits, making a total drop of 9.9 in. The same procedure is followed for the other four composite target ranges. Finally, the six drop totals are added to yield a grand total of, in this case, 349 in.

Only this gross total is retained. The same procedure is followed for the 150-yd zero range. In this case the grand total comes to 246 in. This procedure is then followed for each of the other three zero ranges to yield finally five grand totals, corresponding to the five arbitrarily selected zero ranges. This same pattern is then followed for each of the other ammunitions presented in Figs. M2 to M5. The resultant total drop distances are listed in Table M6.

It is clear from this table that a minimum drop value exists for each of the ammunitions. These total bullet-drop values are plotted in Fig. M6. It is observed that the slowest ammunitions and those having the worst ballistic coefficient have the highest values of total drop. More striking is the result that

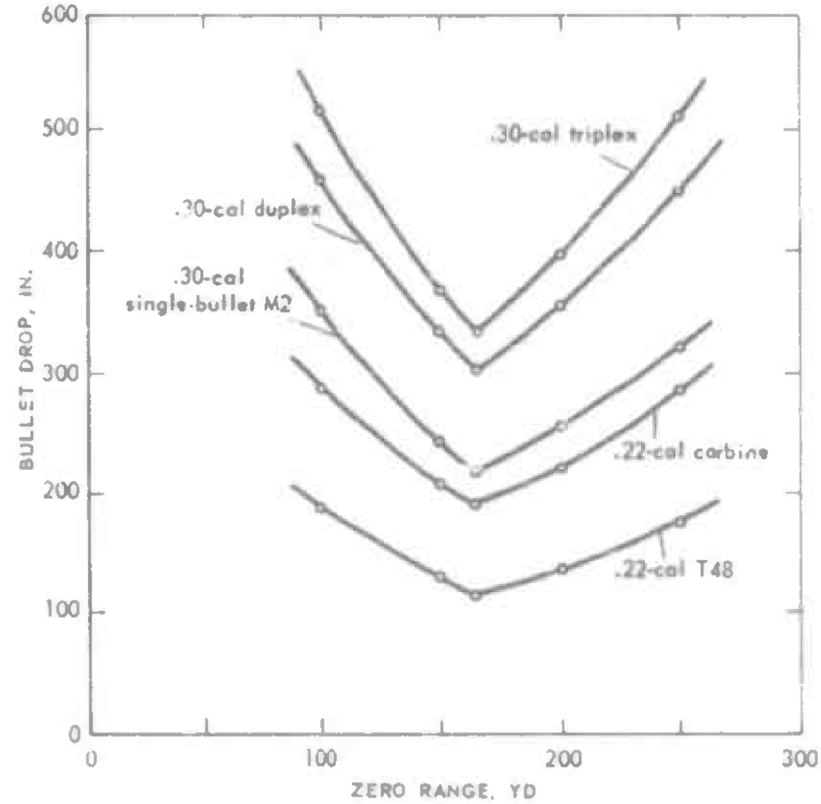

Fig. M6—Total Drop Miss Distance for Various Zero Ranges for Five Ammunitions

the minimum bullet-drop zero range for all five ammunitions is apparently the same—165 yd—which indicates that this zero range is quite sensitive to the target system but insensitive to variations in ammunition. Thus it was decided that all rifles for this test would be set for a combat zero of 165 yd. The computations were not carried through for the night target system; it was assumed that the small difference that such computations might recommend would be insignificant in view of the very large aiming errors in night firing.

DUPLEX AMMUNITION HIT PREDICTIONS

This discussion is summarized from ORO-SP-4.[10] To deal analytically with the controlled-dispersion duplex ammunition tested, a simplified model of the dispersion pattern was assumed. The simplifications basic to the model were (a) the dispersion of front bullets was normal and symmetrical about the line of fire; (b) the ring of second-bullet impacts was narrowed to a circle of negligible width and a 3-mil radius; (c) the circle of second-bullet impact was concentric about the corresponding front-bullet impact; (d) the angular location of second-bullet impacts on the circle was random; and (e) the target was circular.

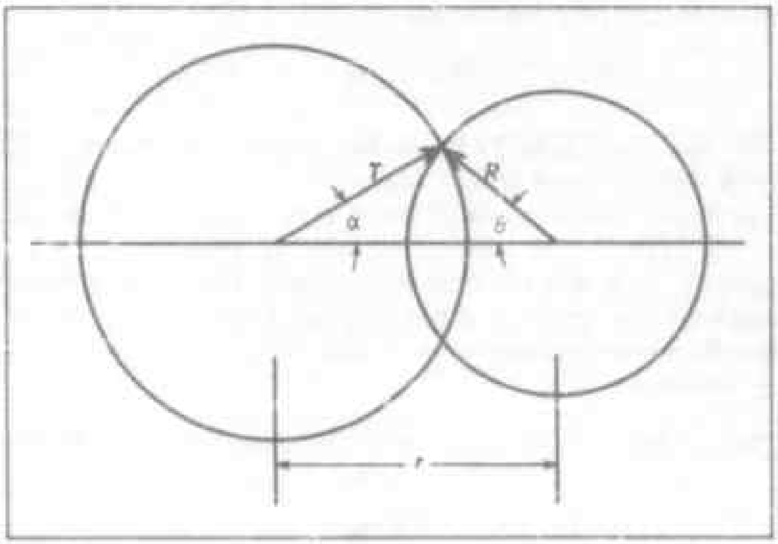

Fig. M7—Geometry of Duplex Hits

T indicates target radius;
R indicates rear-bullet circle radius;
r indicates radius vector from target center to front-bullet impact.

From the geometry of Fig. M7 the fraction of the rear-bullet circle that lies on the target is given by

$$F = (1/180) \arccos \left[(R^2 - T^2 + r^2)/2Rr \right] \qquad \text{(M7)}$$

for the angle in degrees.

For a radially normal distribution of front-bullet impacts, the probability of a front-bullet impact at a distance r to $r + dr$ from the target center is given by

$$dG = (r\, dr/\alpha^2) \exp(-r^2/\alpha^2) \qquad \text{(M8)}$$

where α is the radial standard deviation of aiming error.

Using the fraction F and the probability element dG with the geometry of Fig. M7, duplex hit probabilities are readily deduced.

The single-ball hit probability is

$$N_1 = \int_{r=0}^{T} dG = 1 - \exp(-T^2/\alpha^2) \qquad \text{(M9)}$$

The primary duplex hit probabilities of interest are

$$P_s = N_1 - N_2 + \int_T^{T+R} - \int_{|T-R|}^{T} \qquad \text{(M10)}$$

$$P_d = N_2 + \int_{|T-R|}^{T} \qquad \text{(M11)}$$

where $\int = \int F dG$
P_s = probability of a single hit
P_d = probability of a double hit

$$N_2 = \int_{r=0}^{T-R} dG = 1 - \exp\left[-(T-R)^2/\alpha^2\right] \qquad \text{(M12)}$$

and the proviso that for $T < R$, N_2 vanishes, and for $T < R/2$, $\int_{|T-R|}^{T}$ reverses sign in Eq. M10 and vanishes in Eq. M11.

The hit probabilities are functions of three variables: the duplex spread R, angular target size T, and the angular aiming error α. It is quite possible then to compute the hits of each type that may be expected with a duplex round of known spread on a target of a given angular size under conditions of known aiming error. Numerical integration is substituted for expressions not amenable to integration:

$$\int F dG \to \Sigma F \delta G = (\delta r/90\,\alpha^2) \sum_r r \exp\left(r^2/\bar{\alpha}^2\right) \arccos\left[(R^2 - T^2 + r^2)/2Rr\right] \qquad \text{(M13)}$$

$$= C \Sigma\, r e_\alpha\, \theta \qquad \text{(M14)}$$

The test ammunition has a dispersion characterized by R = 3 mils; hence

$$\int = C(\alpha) \sum_r r\, e(\alpha)\, \theta(T) \qquad \text{(M15)}$$

To evaluate this integral (sum) it is necessary only to substitute values for aiming error α and angular target size T. This was done for a series of values: T = $\frac{1}{3}$, 1, 2, 4, and 8 mils; and α = 1, 2, 4, 8, 16, and 32 mils. Hit probabilities were computed for the 30 pairs of these values and are tabulated in Tables M7 to M11. The products $r e_\alpha \theta$ are indicated as π_α.

In addition to the single (P_s) and double (P_d) hit probabilities, several derived quantities are of interest:

(a) Probability of one or more hits: $P = P_s + P_d$
(b) Total hit probability: $P_t = P_s + 2P_d$
(c) Relative duplex gain in total hits: $I_H = (P_t - N_1)/N_1$
(d) Relative duplex gain in casualties: $I_C = (I_H - LP_d)/N_1$

where L is the individual duplex bullet lethality (0.70). These probabilities are plotted on Figs. 8 to 11. Figures M8 and M9 show the single (N_1) and duplex total (P_t) hit probabilities. Figures M10 and M11 show the relative casualty gain (I_C) of duplex vs single-bullet ammunition.

Using the day target system and predicted single-bullet hit probabilities of Table M1, the casualty increases can be read from Figs. M10 and M11 for a spread R = 3 mils and a lethality L = 0.70. Casualty-gain values can similarly be computed for other values of duplex spread R and bullet lethality L, permitting preparation of the curves of Fig. M12 (for the set of salvo targets of 0.8- to 4.6-mil radius).

TABLE M7

THEORETICAL DUPLEX AMMUNITION HIT PROBABILITY: $T = \frac{1}{2}$ MIL

r	θ	$e_1 (\times 10^5)$	e_2	e_4	e_8	e_{16}	e_{32}	$\pi_1 (\times 10^4)$	π_2	π_4	π_8	π_{16}	π_{32}
Computations for Selected Values of a and T													
2.55	4.5	169	0.222	0.752	1.02	1.10	1.12	194	2.55	8.7	11.7	12.7	12.9
2.65	7.3	101	0.195	0.728	1.01	1.10	1.12	195	3.76	14.0	19.5	21.2	21.7
2.[illegible]	8.9	59	0.170	0.703	1.00	1.10	1.12	145	4.20	17.4	24.8	27.1	27.7
2[illegible]	9.3	34	0.148	0.679	0.99	1.09	1.12	89	3.92	18.0	26.3	29.0	29.6
2.95	9.6	19	0.128	0.655	0.99	1.09	1.12	53	3.62	18.5	27.9	30.9	31.7
$\Sigma_{\|T-R\|}^{T}$								676	18.1	76.6	110	121	124
3.05	9.6	10.3	0.110	0.631	0.976	1.09	1.12	30.2	3.21	18.4	28.5	31.7	32.6
3.15	8.9	5.5	0.094	0.607	0.966	1.09	1.12	15.4	2.64	17.0	27.0	30.4	31.3
3.25	7.7	2.9	0.081	0.588	0.957	1.08	1.12	7.3	2.01	14.6	23.9	27.1	27.9
3.35	6.3	1.5	0.068	0.560	0.947	1.08	1.12	3.2	1.44	11.8	20.0	22.8	23.5
3.45	3.6	0.8	0.058	0.536	0.937	1.08	1.12	1.0	0.71	6.6	11.6	13.3	13.8
Σ_{T}^{T+R}								57.1	10.0	68.4	111.0	125.3	129.1
Computed Values of Probability and Gain													
							$C (\times 10^6)$	984	246	61.5	15.4	3.84	0.960
							N_1 %	22.1	6.06	1.55	0.390	0.097	0.024
							N_2 %	0	0	0	0	0	0
							P_s %	22.2	6.75	2.44	0.730	0.192	0.048
							P_d %	0	0	0	0	0	0
							P %	22.2	6.75	2.44	0.730	0.192	0.048
							P_t %	22.2	6.75	2.44	0.730	0.192	0.048
							I_H %	0.3	11.4	57.4	87.2	97.9	100
							I_C %	0.3	11.4	57.4	87.2	97.9	100

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TABLE M8

THEORETICAL DUPLEX AMMUNITION HIT PROBABILITY: $T = 1$ MIL

r	a	e_1 ($\times 10^4$)	e_2	e_4	e_8	e_{16}	e_{32}	π_1	π_2	π_4	π_8	π_{16}	π_{32}
						Computations for Selected Values of a and T							
2.1	9.9	137	0.375	0.857	1.05	1.11	1.24	0.285	7.8	17.8	21.9	23.1	23.4
2.3	15.6	57	0.301	0.811	1.04	1.11	1.12	0.204	10.8	29.1	38.3	40.8	41.5
2.5	18.2	22	0.237	0.763	1.02	1.10	1.12	0.099	10.8	34.7	46.5	50.1	51.1
2.7	19.3	8	0.182	0.715	1.01	1.10	1.12	0.040	9.5	37.2	52.4	57.1	58.3
2.9	19.4	3	0.138	0.667	0.99	1.09	1.12	0.014	7.8	37.5	5[illegible].5	61.4	62.8
$\Sigma_{1\,T-R\,1}^{T}$								0.642	46.7	156	215	233	237
3.1	18.7	257×10^{-3}	0.162	0.619	0.971	1.09	1.12	0.004	5.92	35.9	56.3	63.0	64.8
3.3	17.4	210×10^{-3}	0.074	0.571	0.952	1.06	1.12	0.001	4.25	32.8	54.6	62.1	64.0
3.5	15.4	54×10^{-3}	0.053	0.525	0.932	1.08	1.12	0	2.85	28.3	50.2	57.9	60.1
3.7	12.0	13×10^{-3}	0.037	0.480	0.911	1.07	1.11	0	1.63	21.3	40.4	47.5	49.4
3.9	7.3	3×10^{-3}	0.025	0.436	0.890	1.06	1.11	0	0.72	12.4	25.3	30.3	31.7
Σ_{T}^{T+R}								0.005	15.4	131	227	261	270
										Computed Values of Probability and Gain			
							C ($\times 10^5$)	197	49.2	12.3	3.08	0.768	0.192
							N_1 %	63.2	22.1	6.06	1.55	0.390	0.097
							N_2 %	0	0	0	0	0	0
							P_s %	63.3	25.2	9.59	2.91	0.769	0.194
							P_d %	0	0	0	0	0	0
							P %	63.3	25.2	9.59	2.91	0.769	0.194
							P_t %	63.3	25.2	9.59	2.91	0.769	0.194
							I_H %	0.2	14.0	58.3	92.9	97.2	100
							I_C %	0.2	14.0	58.3	92.9	97.2	100

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TABLE M9

THEORETICAL DUPLEX AMMUNITION HIT PROBABILITY: $T = 2$ MIL

r	θ	e_s ($\times 10^{-3}$)	e_2	e_4	e_8	e_{16}	e_{32}	π_1	π_2	π_4	π_8	π_{16}	π_{32}
Computations for Selected Values of r and T													
1.2	26.5	267	0.787	1.03	1.10	1.12	1.13	8.49	25.0	32.8	35	36	36
1.6	38.0	87	0.595	0.96	1.08	1.12	1.13	5.38	36.7	59.4	67	69	70
2.0	41.4	21	0.415	0.88	1.06	1.11	1.12	1.71	34.3	72.7	88	92	93
2.4	41.7	4	0.267	0.79	1.03	1.10	1.12	0.36	26.7	78.7	103	110	112
2.8	40.1	0	0.159	0.69	1.00	1.09	1.12	0.05	17.9	77.6	112	123	126
$\Sigma_{1/T-R1}^{T}$								16.0	141	321	405	430	437
3.2	17.4	408 × 10^{-4}	0.087	0.595	0.962	1.08	1.12	0.005	10.4	71.1	115	130	134
3.6	33.8	27 × 10^{-4}	0.044	0.502	0.922	1.07	1.11	0	5.4	61.9	112	131	136
4.0	29.9	1 × 10^{-4}	0.021	0.415	0.879	1.06	1.11	0	2.4	48.1	102	127	129
4.4	22.8	0	0.009	0.336	0.834	1.05	1.11	0	0.9	33.7	84	105	111
4.8	13.1	0	0.004	0.267	0.787	1.03	1.10	0	0.2	16.8	50	65	70
Σ_{T}^{T+R}								0.005	19.3	231	463	558	580
Computed Values of Probability and Gain													
							C ($\times 10^{-5}$)	394	98.4	24.6	6.15	1.54	0.384
							N_1 %	98.2	63.2	22.1	6.06	1.55	0.390
							N_2 %	0	0	0	0	0	0
							P_s %	92.9	63.5	29.4	9.59	2.61	0.663
							P_d %	5.79	7.76	3.17	0.897	0.232	0.058
							P %	98.7	71.3	32.6	10.5	2.84	0.722
							P_t %	105	79.0	35.7	11.4	3.07	0.780
							I_H %	6.41	24.9	61.5	88.0	98.1	100.0
							I_C %	2.28	16.3	51.5	77.6	87.6	89.6

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TABLE K10

THEORETICAL DUPLEX AMMUNITION HIT PROBABILITY: $T = 4$ MIL

r	θ	e_1 ($\times 10^5$)	e_2	e_4	e_8	e_{16}	e_{32}	n_1	n_2	n_4	n_8	n_{16}	n_{32}
Computations for Selected Values of a and T													
1.3	133	208	0.740	1.02	1.10	1.12	1.13	36.0	128	175	199	194	195
1.9	107	31	0.458	0.90	1.07	1.11	1.12	6.2	94	184	213	228	230
2.5	98	2	0.237	0.76	1.02	1.10	1.12	0.5	55	177	233	256	261
3.1	82	0	0.102	0.62	0.97	1.09	1.12	0	26	157	247	276	284
3.7	72	0	0.087	0.48	0.91	1.07	1.11	0	10	129	244	287	299
Σ_{1T-R1}^{T}								42.7	313	822	1137	1241	1269
4.3	63.6	105×10^{-7}	111×10^{-4}	0.355	0.845	1.05	1.11	0	3.04	97.2	237	288	308
4.9	53.3	0	28×10^{-4}	0.252	0.775	1.03	1.10	0	0.73	65.7	207	268	288
5.5	45.3	0	6×10^{-4}	0.170	0.703	1.00	1.10	0	0.15	42.3	175	250	271
6.1	34.3	0	1×10^{-4}	0.110	0.631	0.98	1.09	0	0.02	23.0	132	204	227
6.7	19.4	0	0	0.068	0.560	0.95	1.08	0	0	8.9	73	123	140
Σ_{T}^{T+R}								0	3.94	237	813	1133	1229
Computed Values of Probability and Gain													
							C ($\times 10^5$)	590	148	36.9	9.22	2.30	0.576
							N_1 %	100	98.2	63.2	22.1	6.06	1.55
							N_2 %	63.2	22.1	6.06	1.55	0.390	0.098
							P_s %	12.2	17.5	35.6	17.5	5.41	1.51
							P_d %	87.8	81.3	36.4	12.1	3.25	0.830
							P %	100	98.8	72.0	29.6	8.66	2.33
							P_t %	188	180	108	41.7	12.0	3.16
							I_H %	87.8	88.0	71.5	88.6	96.5	99.4
							I_C %	26.3	25.0	31.2	50.3	59.0	61.9

TABLE M11

THEORETICAL DUPLEX AMMUNITION HIT PROBABILITY: $T = 8$ MIL

r	θ	e_1 (× 10^{15})	e_2 (× 10^5)	e_4	e_8	e_{16}	e_{32}	π_1 (× 10^{12})	π_2 (× 10^8)	π_4	π_8	π_{16}	π_{32}
						Computations for Selected Values of α and T							
5.3	147.9	713	101	0.195	0.728	1.01	1.10	558	788	153	570	792	860
5.9	124.7	1	19	0.128	0.655	0.99	1.09	1	138	94	482	725	803
6.5	109.1	0	3	0.081	0.583	0.96	1.08	0	21	57	414	679	769
7.1	96.1	0	0	0.048	0.513	0.93	1.07	0	3	33	350	632	733
7.7	84.7	0	0	0.028	0.447	0.90	1.06	0	0	18	291	584	694
$\sum_{1T-R1}^{T}$								559	950	355	2107	3410	3860
8.3	73.7	136 × 10^{-17}	374 × 10^{-8}	0.015	0.384	0.862	1.06	0	0.023	9.30	235	528	646
8.9	63.1	0	28 × 10^{-5}	0.008	0.336	0.828	1.04	0	0.001	4.49	189	465	587
9.5	51.8	0	2 × 10^{-5}	0.004	0.275	0.793	1.03	0	0	1.97	135	390	508
10.1	39.1	0	0	0.002	0.229	0.758	1.02	0	0	0.76	91	301	405
10.7	22.0	0	0	0.001	0.189	0.721	1.01	0	0	0.21	44	169	237
$\sum_{T}^{T+R}$								0	0.0246	16.7	694	1853	2383
									Computed Values of Probability and Gain				
							C (× 10^5)	590	148	36.9	9.22	2.30	0.576
							N_1 %	100	100	98.2	63.2	22.1	6.06
							N_2 %	100	99.8	79.0	33.2	9.30	2.41
							P_s %	0	0.05	6.69	17.0	9.24	2.80
							P'_d %	100	100	92.3	52.6	17.1	4.63
							P' %	100	100	98.8	69.6	26.3	7.44
							P_t %	200	200	191	122	43.5	12.1
							I_H %	100	100	94.4	93.3	96.8	99.0
							I_C %	30.0	30.0	28.8	35.1	42.6	45.5

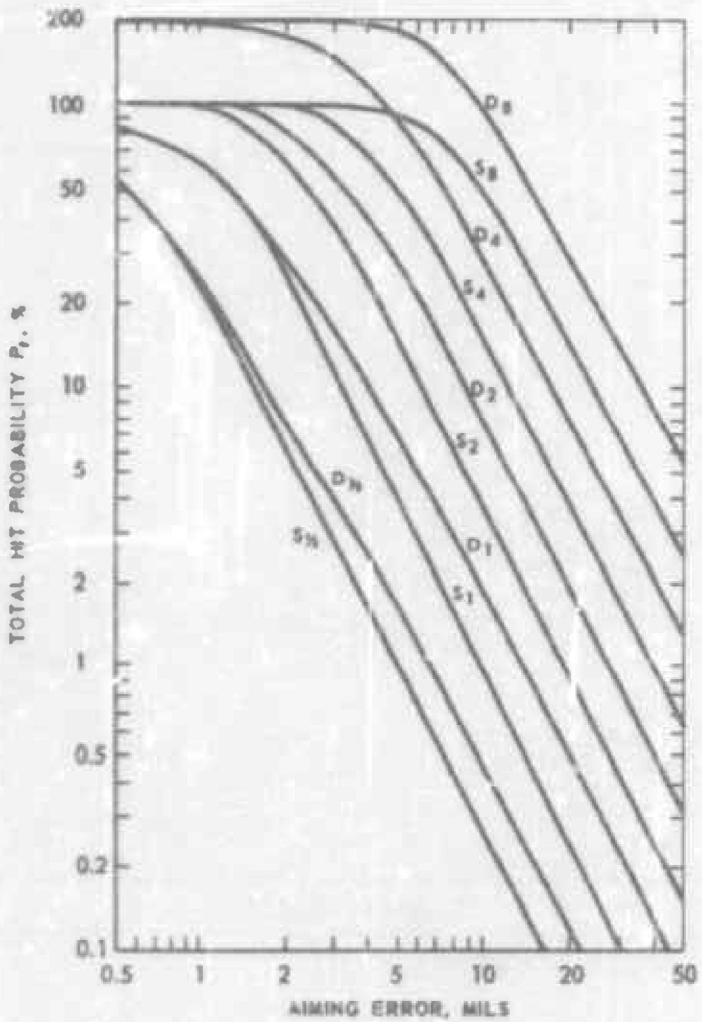


Fig. M8—Total Duplex Ammunition Hit Probability as a Function of Aiming Error for Several Target Sizes
S indicates single-bullet ammunition;
D indicates duplex ammunition.

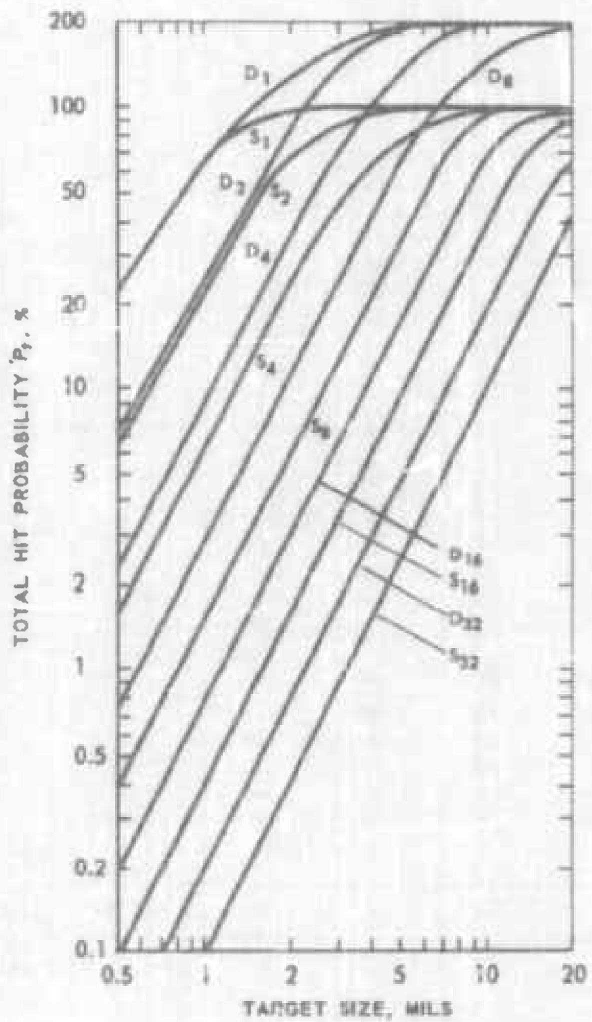


Fig. M9—Total Duplex Ammunition Hit Probability as a F· ction of Target Size for Several Aiming Errors
S indicates single-bullet ammunition;
D indicates duplex ammunition.

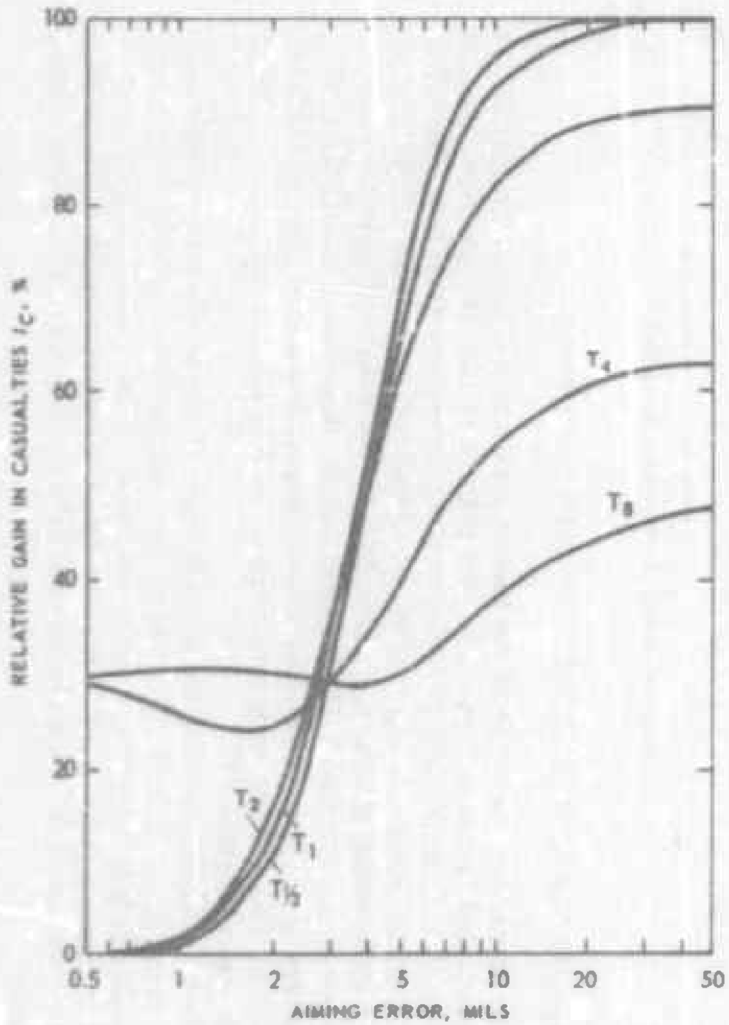


Fig. M10—Duplex Ammunition Gain in Casualties as a Function of Aiming Error for Several Target Sizes

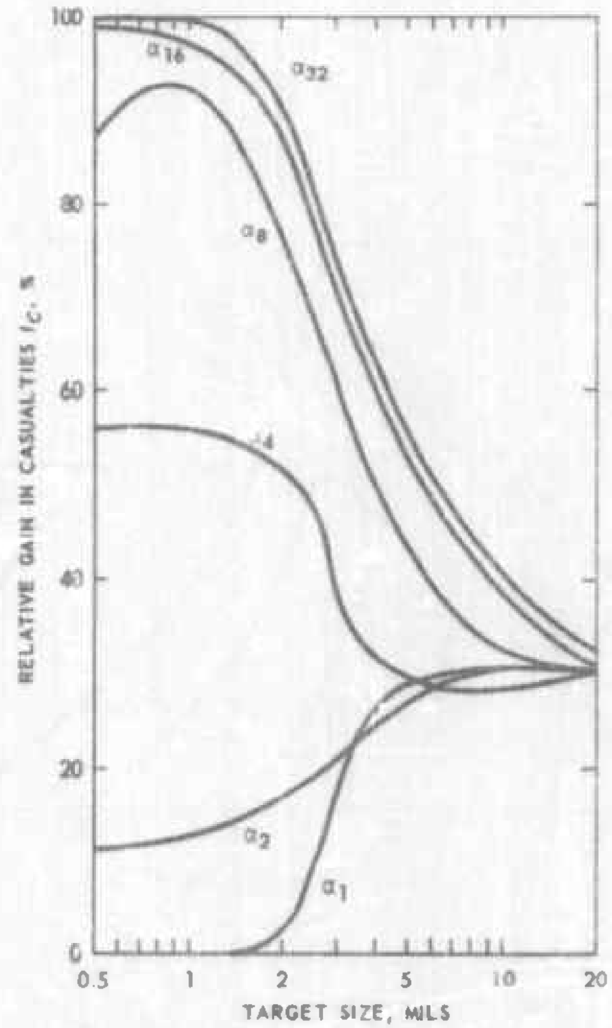


Fig. M11—Duplex Ammunition Gain in Casualties as a Function of Target Size for Several Aiming Errors

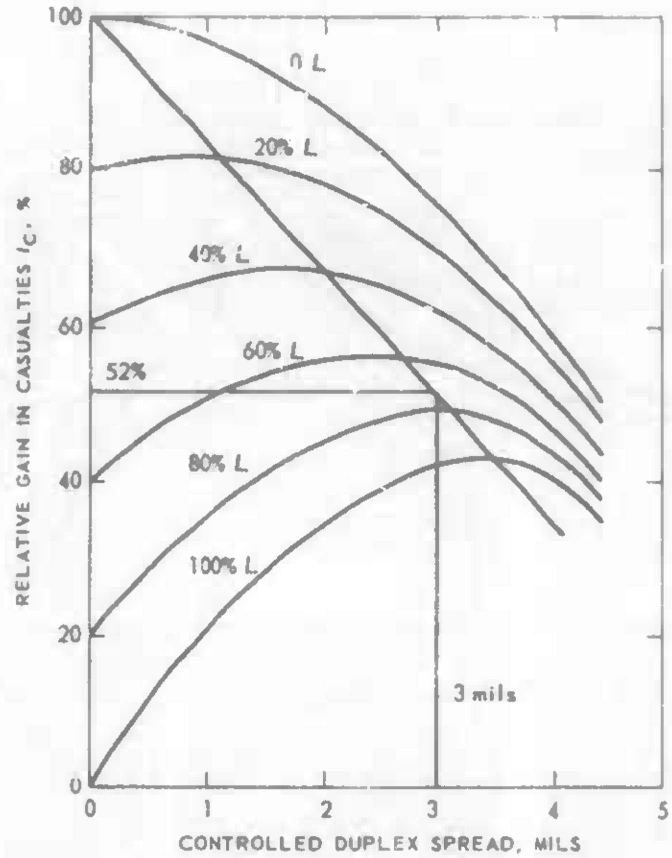


Fig. M12—Duplex Ammunition Gain in Casualties as a Function of Spread for Various Lethalities

TRIPLEX AND FLECHETTE AMMUNITION HIT PREDICTIONS

The dispersion patterns of the test triplex and flechette ammunition are of the so-called "random" type, i.e., the pattern of hits can be approximately described by a symmetrical two-dimensional normal or Gaussian distribution. Each projectile independently follows an initial path, which deviates from the barrel axis by some amount for which this two-dimensional normal curve is the frequency distribution. The tightness of the dispersion is characterized by the shape of this normal curve, usually expressed as the linear standard deviation σ. For the flechette ammunition used in the experiment, a value of 9.4 mils was given for σ.[30]

The triplex ammunition used in the experiment performed in somewhat erratic fashion, but it was indicated by the manufacturer to be at least roughly approximated by considering each of the three bullets to fit into this random normal frequency pattern. The manufacturer also indicated that except for occasional wild rounds the mean spread between any pair of the three bullets was 3 mils.

It is desirable first to convert the 3-mil average separation $\overline{\delta_T}$ of triplex rounds to a deviation σ, which is more commonly used to characterize the dispersion. This conversion is readily made when it is realized that the mean difference between two samples from a two-dimensional normal distribution is identical with the mean radius of a single sample drawn from a distribution having a deviation larger by a factor of $\sqrt{2}$. Recalling further that the mean radius of a two-dimensional normal distribution is larger than the linear standard deviation by a factor of $\sqrt{\pi/2}$, the mean spread can be related to the original dispersion σ by

$$\sigma = 1/\sqrt{\pi}\ (\overline{\delta r}) = 0.565\ (\overline{\delta r}) \tag{M16}$$

For the rough value of mean spread $\overline{\delta r} = 3$ mils, the deviation is 1.7 mils.

The following discussion outlines the considerations leading to the solution of the problem of kill probability with a normal aiming error imposed on a normal dispersion. This solution is taken from ORO-SP-24.[13]

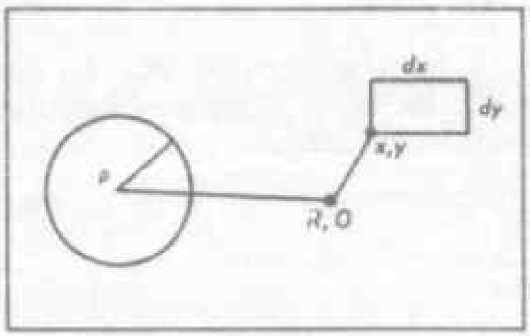


Fig. M13—Geometry of Random-Dispersion Hits

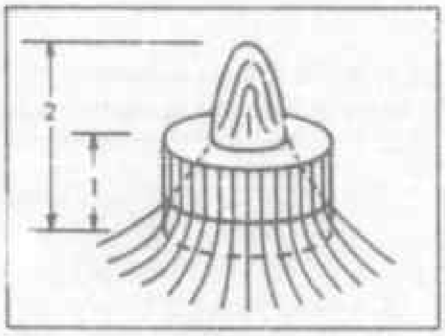


Fig. M14—Diffuse Gaussian Target

Considered first is the probability that a projectile aimed at a distance R from the center of a circle with radius ρ will hit the circle. The actual impact point is assumed to follow a Gaussian distribution with linear standard deviation σ about the aiming point. Let the aiming point be at R,0; then the probability that the fragment impacts within a rectangle of dimensions dx by dy, lying at x, y (see Fig. M13) is

$$P = 1/(2\pi\sigma^2)\exp[-[(X-R)^2 + y^2]/2\sigma^2]\,dxdy \tag{M17}$$

and the probability P that it strikes the circle is the integral of this over the circle:

$$P = \iint_{x^2+y^2 \le \rho^2} P \tag{M18}$$

This is sometimes called the "offset-circle" probability. An approximation is to replace the sharp regular target by a diffuse Gaussian target (see Fig. M14) by fitting by moments. Thus, for the sharp target, any fragment falling within the circle scores 1; a fragment falling outside scores 0. This may be represented by a right cylinder of radius ρ and height 1, centered at the origin. The diffuse target with the same zero—and second-order radial moments—has height 2 and linear standard deviations $\rho/2$. It gives a score of

$$2\exp[-D^2/\rho^2] \tag{M19}$$

to a fragment impacting at distance D from the center. With this approximation in Eq. M18, integrating over the entire x, y plane, this is evaluated to be

$$P = [\rho^2 / 2(\sigma^2 + \rho^2/4)] \exp\{-R^2/[2(\sigma^2 + \rho^2/4)]\} \quad \text{(M20)}$$

Let L be the conditional probability that a hit will be a casualty. Then the probability that the target becomes a casualty K if there are N projectiles is

$$K = 1 - (1 - LP)^N = 1 - e^{-NLP} \quad \text{(M21)}$$

In Eq. M20 P is shown to be a function of the radial distance R of the aiming point from the center of the circle. But the aiming point is itself a random variable, and the probability that the radial distance is between R and $R + dR$ is given by

$$(1/\tau^2) \exp(-R^2/2\tau^2) R\,dR \quad \text{(M22)}$$

where τ is the linear standard deviation at the aiming error. The final complete answer for the casualty probability is therefore obtained by substituting Eq. M20 into Eq. M21 and integrating against Eq. M22:

$$K = 1 - (y/Z)(2y)^{y/Z} \int_0^{1/2y} \eta^{(y/Z)-1} \exp(-\eta)\,d\eta \quad \text{(M23)}$$

where $y \equiv (1/NL)(\sigma^2/\rho^2 + 1/4)$
$Z \equiv (1/NL)(\tau^2/\rho^2)$
$\eta \equiv (1/2y) \exp[1 - ZR^2/2\tau^2 y]$

The last integral is readily recognized as the incomplete gamma function; hence K is expressed in terms of tabulated functions. A relief map showing level lines of K against $\log Z$ and $\log y$ is given in Fig. M15.

In order to perform computations on any random, normally dispersed salvo ammunition, it is necessary to know the number of projectiles N, the lethality per projectile L, and the standard deviation of the dispersion. With the ammunition thus characterized, it is further necessary only to characterize the target or target system sufficiently so that one knows the aiming error and the target size for each element of the target system. From this aiming error and target size, together with the product NL, the value Z is computed; y is likewise deduced from a knowledge of dispersion, target size, and NL. Clearly from Fig. M15 casualty probability may readily be determined by interpolation. This procedure was actually followed in detail for each of the salvo experiment targets for a number of ammunitions.[13] In that case the computations were performed using actual aiming errors deduced from the results of the SALVO 1 experiment. It is felt that the results of these computations would not be grossly altered if they were done with the predicted errors of Tables M1 and M2, or even the simplified predicted values of Table M5. However, the comparative calculations were not performed.

The calculations that were performed are graphically reproduced in Figs. M16 to M19. It is noted that this entire treatment of the random dispersion is based on the number of casualties produced rather than the number of hits. The casualty measure of course takes account of the lethality of each projectile and the attendant overkill. For a first comparsion between the prediction and test results, it is perhaps desirable to present the predictions in terms of the data that are the primary measure—mainly total hits rather than casualties. It is further noted that the results presented in Figs. M16 to M19 are based on salvo hits per single-bullet hit. This method of presentation is convenient and is herein retained.

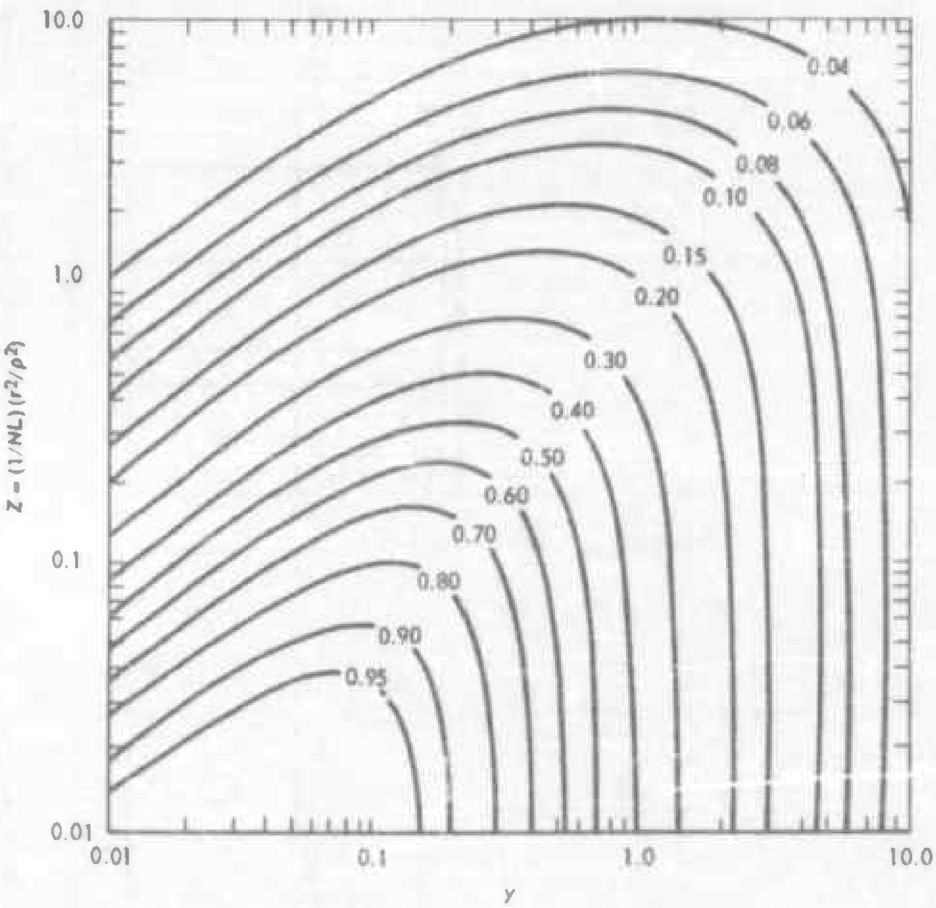


Fig. M15—Relief Map of Salvo Casualty Probabilities
$y = (1/NL)(\sigma^2/\rho^2 + \frac{1}{4})$

Examination of Fig. M16 shows that the 1.7-mil dispersion, which was already identified as characterizing the experimental triplex ammunition, results in a casualty increase of 66 percent over the single-bullet ammunition. As the rate of fire and the lethality per bullet are, for practical purposes, identical for triplex and single-bullet ammunition, this figure must be corrected only for possible overkill by multiple-bullet hits. The theory reveals the extent of overkill as a function of salvo dispersion, aiming error, and target size. However, it is not deemed worth while to perform this tedious computation for the present purpose; instead the available experimental results are used.

It is shown in App O that the proportions of single, double, and triple hits that were so identified are 82, 15, and 4, respectively. These figures correspond to a total of 124 hits [82 + (2 × 15) + (3 × 4)]. Using the same 70 percent

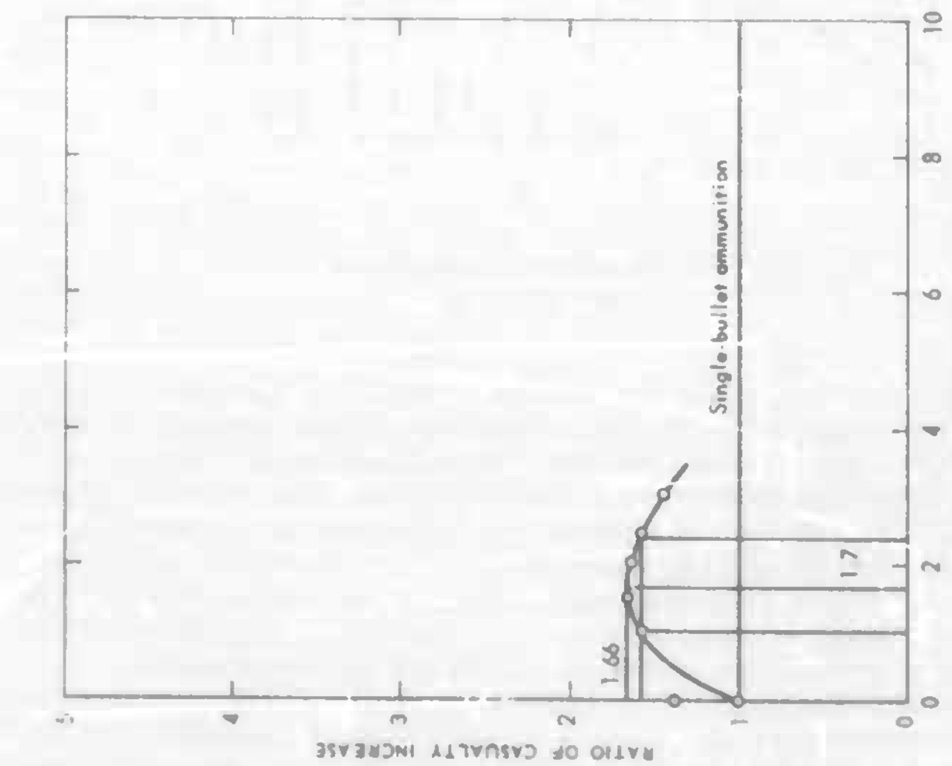


Fig. M16—Random Triplex Ammunition Casualty Increase as a Function of Dispersion for Day

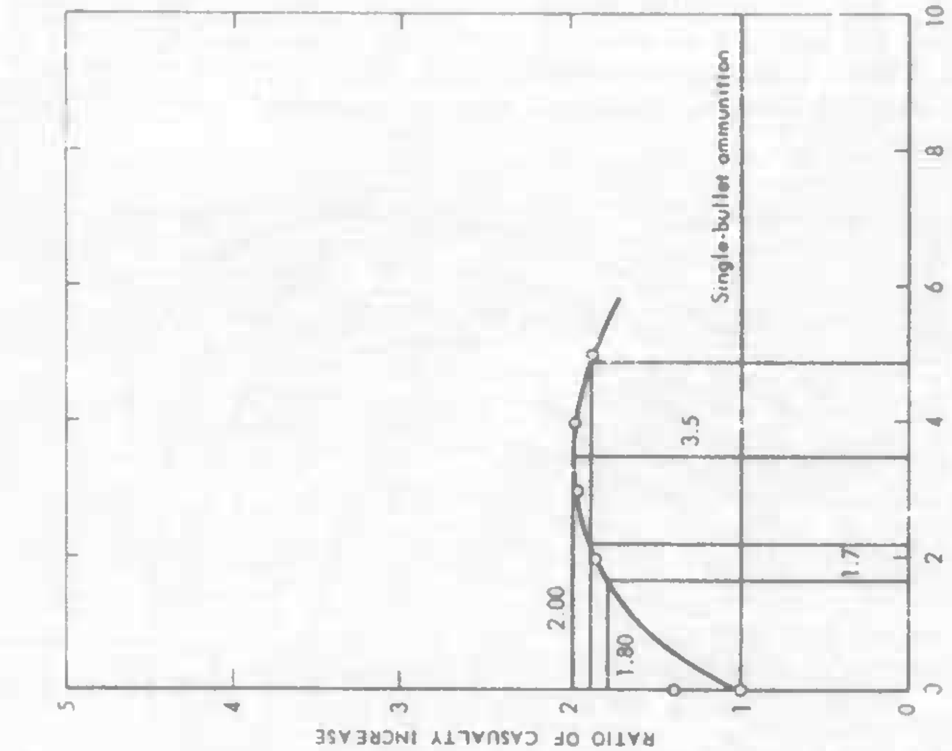


Fig. M17—Random Triplex Ammunition Casualty Increase as a Function of Dispersion for Night

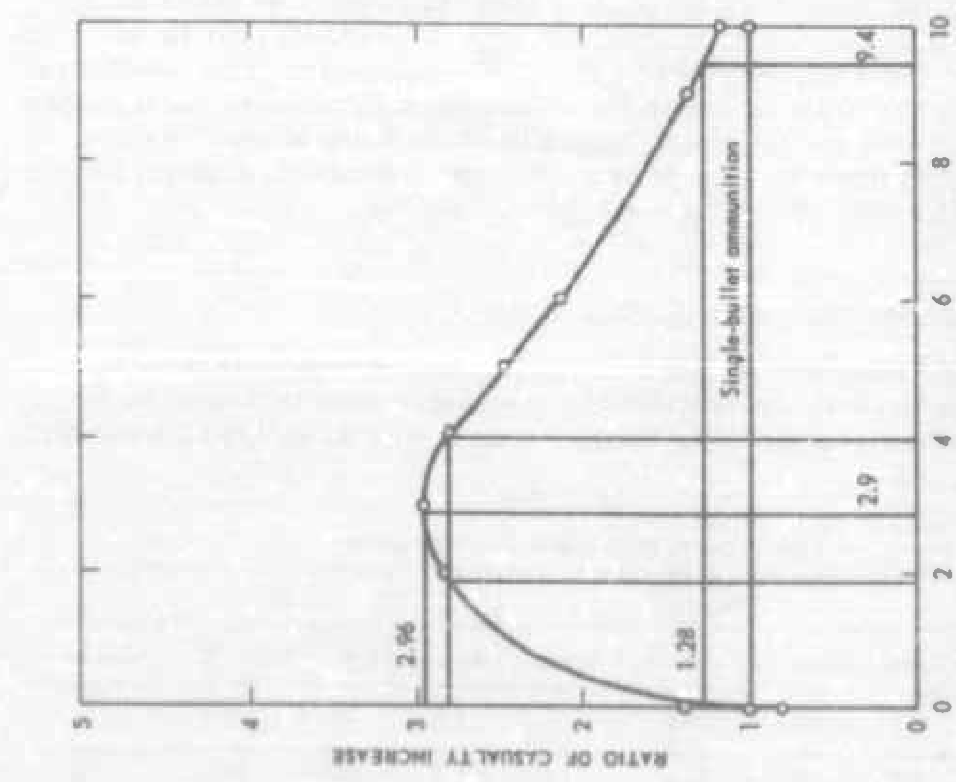


Fig. M18—Random Flechette Casualty Increase as a Function of Dispersion for Day

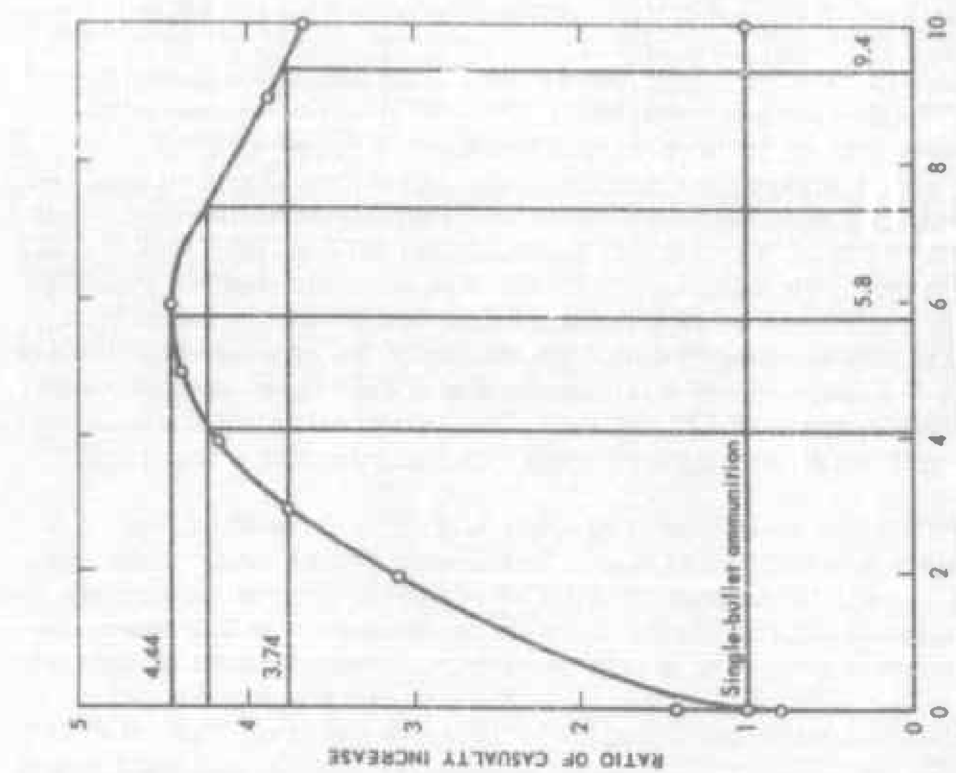


Fig. M19—Random Flechette Casualty Increase as a Function of Disp[illegible]ion for Night lethality value used in ORO-SP-24,[13] overkills can be accounted for in the following manner: Of the 124 hits, 101 are fully credited. The next 19 are second bullets on a target that is only 30 percent vulnerable; hence these hits are credited as 5.7 effective hits. The last 4 hits are third hits on a target that is now only about 9 percent vulnerable, and hence are credited with 0.36 effective hits. Thus the total number of effective or equivalent casualty-producing hits is 107, as compared with 124 actual bullet hits with triplex ammunition. This ratio of 124 to 107 is used to convert the casualties of Fig. M16 to total hits. When this is applied, the 1.66 becomes 1.92. The predicted number of triplex hits is then characterized as 92 percent greater than the single-bullet hits. This prediction may be compared with the results of the experiment, which are an average of 114 single-bullet hits compared with 251 triplex hits per run, or an experimental increase of 120 percent. This agreement is not too bad, considering the very rough assumptions made with regard to the actual triplex pattern.

The night triplex prediction is based on Fig. M17, from which the 1.7-mil dispersion yields a casualty increase of 80 percent over the single-bullet ammunition. If the same 1.16 ratio as for day fire is used to account for overkill, the predicted number of triplex hits for the night target system is 2.09 times the predicted number of single-bullet hits. However, no experimental comparison is available, since night triplex runs were deleted from the experiment.

The flechette predictions are made in the same way from Figs. M18 and M19. It is anticipated that the flechette casualties for the day and night target systems are 1.28 and 3.74 times those for single-bullet ammunition, respectively. In this case the lethality per projectile used in the computations leading to these curves is just half the single-bullet value. Converting from casualties to total hits requires that these factors then be doubled (2.56 and 7.48 times single-bullet casualties). It is further noted that Figs. M18 and M19 are based on an assumption that the flechette rate of fire is 80 percent of the single-bullet rate of fire, which was made as a coarse guess based on the relative cumbersomeness of the shotgun and the troops' unfamiliarity with the weapon. Results of the experiment proved the actual degradation to be somewhat greater, resulting in a rate of fire only 55 to 60 percent that of rifle fire.

PREDICTIONS COMPARED WITH ACTUAL RESULTS

It is instructive now to gather the predictions on rounds fired and hits scored for the several ammunitions and to compare them in tabular form with the corresponding experimental results. This is done in Tables M12 and M13.

TABLE M12

PREDICTED ROUNDS FIRED AND HITS SCORED

Ammunition	Day				Night			
	Rounds	Hits	Percent hits	Increase	Rounds	Hits	Percent hits	Increase
Single bullet	675	65	9.6	—	671	40	5.9	—
Duplex	675	115	17.0	1.77	671	—	—	—
Triplex	675	125	18.5	1.93	671	84	12.5	2.02
Flechettes	540	> 166	> 30.7	> 3.20	538	>299	> 55.6	> 9.42

The experimental flechette data in Table M13 is taken from the incomplete runs and proportionally converted to equivalent complete runs for direct comparison with the other ammunitions. It should further be noted that the values inserted in Table M13 for flechette hits are based only on the predicted flechette casualties. The conversion to total hits regardless of overkill was not made.

TABLE M13

EXPERIMENTAL ROUNDS FIRED AND HITS SCORED

Ammunition	Day				Night			
	Rounds	Hits	Percent hits	Increase	Rounds	Hits	Percent hits	Increase
Single bullet	577	114	19.8	—	834	42	5.0	—
Duplex	505	164	32.5	1.64	716	65	9.1	1.82
Triplex	579	251	43.4	2.19	—	—	—	—
Flechettes	364	151	41.5	2.10	420	144	34.3	6.87

TABLE M14

PREDICTED HIT PROBABILITIES AND THEIR STANDARD DEVIATIONS

Ammunition	Day				Night			
	P, %	σ_P	R	σ_R	P, %	σ_P	R	σ_R
Single bullet	9.6	1.1	—	—	5.9	0.9	—	—
Duplex	17.0	1.4	1.77	0.25	—	—	—	—
Triplex	18.5	1.5	1.93	0.27	12.5	1.2	2.12	0.32
Flechettes	>30.7	1.8	3.20	0.41	>55.6	2.1	9.42	1.50

STATISTICAL RELIABILITY

It is of interest to use these predicted results to estimate the reliability with which conclusions may be drawn from the experiment. Such estimation is a key feature in experimental design, since the predicted reliabilities of computed differences and ratios establish criteria for deciding on the number of repetitions. The predictions of Table M12 are examined to determine the confidence anticipated for the ratios of hit probabilities among the several ammunitions. The procedure starts with the predicted hit probabilities, which are repeated as percentages in Table M14. The standard deviations of each of these percentages are then computed from a knowledge of the percentage of hits P and total rounds fired per run N:

$$\sigma_P = \sqrt{P(1-P)/N} \qquad \text{(M24)}$$

The computed standard deviations σ_P are also listed in Table M14. It is noted that these deviations are much smaller than the differences among the probabilities. The next column (R) of Table M14 lists the most important quantities sought in the experiment, namely, the ratios of each of the three types of salvo hit probability to the control or single-bullet hit probability. Finally the measure of reliability of this ratio is arrived at by using Eq. J3 of App J.

These values are finally listed in Table M14. It is clear from the table that each of the important ratios differs from unity by more than three standard deviations, which means, from the data supplied by a single run, that the expected ratios are more than 99.7 percent certain of being truly greater than unity. The least certainly determined ratio is the ratio of duplex to single-bullet hit probabilities in day firing (1.77). From a single pair of runs it is determined that the probable error of this ratio is 0.17; or, in simplest terms, that there is a 50–50 chance that the actual ratio will be determined to be between 1.60 and 1.94. Six runs (as scheduled for duplex) of each type determine the 50 percent confidence limits on this ratio from 1.70 to 1.84. Clearly this sort of reliability in the significant computed parameters is adequate for interpretation. If it can be concluded that duplex ammunition will score from 70 to 84 percent more hits than single bullets, there is little practical use in refining this advantage any further. There are additional correlations from other firings of the same ammunitions under somewhat different conditions. Although not amenable to simple statistical reliability measures, they afford additional evidence of reliability from observation of consistency.

Appendix N

MALFUNCTIONS

SUMMARY

The SALVO I experiment not only involved many new experimental conditions but also employed measuring and control equipment that had not been completely tested in the field. It is not surprising that a large number of malfunctions of all kinds occurred. These ranged from trivial difficulties such as the misplacement of camouflage to the actual blowing-up of a weapon—the latter is perhaps less a malfunction than a catastrophe. The malfunction data are listed fully in Tables E4 and E5 of this memorandum.

The occurrence of malfunctions necessitated changes in the conduct of the test and in the analysis of the results. Other sections of this memorandum deal with these matters; this appendix merely describes the malfunctions that occurred. They can be grouped into three different classes: (a) weapon malfunctions (2 percent), e.g., failure to feed; (b) malfunctions in data collection (21 percent), e.g., no electronic indication of a hit on a target; and (c) unplanned irregularities in functioning of the target system (11 percent), e.g., a target not appearing at the right time.

WEAPON MALFUNCTIONS

The weapon-ammunition malfunction was particularly serious in that, if the incidence of malfunction was not fairly uniform for all weapons and ammunitions, the effect of malfunction could possibly obscure differences in scores among the various weapon-ammunition combinations. As a result of this possibility, every effort was made during the runs to correct each malfunction quickly, and a record was kept of each malfunction and its type. However, since the malfunctions were not recorded automatically, and since the information concerning the malfunctions was recorded after the run was completed, the record is not highly accurate. There also is no record of how long each test subject was unable to fire because of malfunctions. Weapon malfunctions are detailed in Table E5 of this memorandum.

Fortunately the incidence of malfunction turned out to be fairly uniform for all runs with the exception of the Gustafson carbine in automatic fire. Each weapon had a characteristic major source or sources of malfunction, and some ammunitions tended to malfunction in characteristic ways.

One change in the original test design can be attributed in part to the attempt to minimize malfunctions. Originally it was planned to fire the .30-cal

Table N1

TOTAL WEAPON MALFUNCTIONS

Weapon and ammunition or firing	Failure to			Miscellaneous	Total	Rounds expended
	Feed	Extract	Eject			
M1, unmodified						
.30-cal single bullet	95	11	8	10	124	5,363
M1, modified						
.30-cal single bullet	19	15	3	0	37	6,863
.30-cal duplex	19	114	5	9	147	8,722
.30-cal triplex	4	14	0	3	21	1,157
Carbine						
.22-cal automatic	184	115	17	44	360	9,550
.22-cal semiautomatic	56	113	13	17	199	6,450
T48						
.22-cal automatic	17	29	8	35	89	8,589
.22-cal semiautomatic	17	16	1	26	60	5,554
Shotgun						
32-flechette load	—	—	—	9	9	553
Total	411	427	55	153	1046	52,237

Table N2

WEAPON MALFUNCTIONS PER 100 ROUNDS

Weapon and ammunition or firing	Failure to			Miscellaneous	Total
	Feed	Extract	Eject		
M1, unmodified					
.30-cal single bullet	1.7	0.2	0.2	0.2	2.3
M1, modified					
.30-cal single bullet	0.3	0.2	0.0	0.0	0.5
.30-cal duplex	0.2	1.3	0.1	0.1	1.7
.30-cal triplex	0.3	1.2	0.0	0.3	1.8
Carbine					
.22-cal automatic	1.9	1.2	0.2	0.5	3.8
.22-cal semiautomatic	0.9	1.8	0.2	0.3	3.1
T48					
.22-cal automatic	0.2	0.3	0.1	0.4	1.0
.22-cal semiautomatic	0.3	0.3	0.0	0.5	1.1
Shotgun					
32-flechette load	—	—	—	1.6	1.6
Total	0.8	0.8	0.1	0.3	2.0

single-bullet (AP), duplex, and triplex ammunitions from the same weapon. During the first week of firing, however, it appeared that there was a high rate of malfunction both on the single-bullet and duplex runs (the triplex runs being discontinued because of an accident that will be described later). It was conjectured at the time that these malfunctions (mainly failures to extract) might be due to fouling of the chamber, which resulted from firing single-bullet ammunition in the specially chambered M1 rifles. It was also conjectured that the paint on the nose of ammunition (used to identify hits from the leading bullet for the first two duplex runs) might also be a factor. On the advice of the Ordnance Corps representatives present, it was decided to discontinue coloring the noses of duplex ammunition and also to fire single-bullet ammunition from unmodified M1 rifles, during the second week. Accordingly, Board III at Fort Benning was requested to furnish 12 usable unmodified M1 rifles for the second week of firing.

The substitution of the unmodified M1 rifles provided by Board III did not have the effect of reducing the over-all malfunction rate. In fact, during the second week of firing there was a greater number of weapon-ammunition malfunctions during the single-bullet runs with the unmodified rifles than during the duplex runs. The Ordnance experts at the test felt that the Board III rifles were to some extent mechanically substandard.

A summary of the total weapon malfunctions experienced during the test is given in Table N1, and the number of malfunctions per 100 rounds fired is given in Table N2.

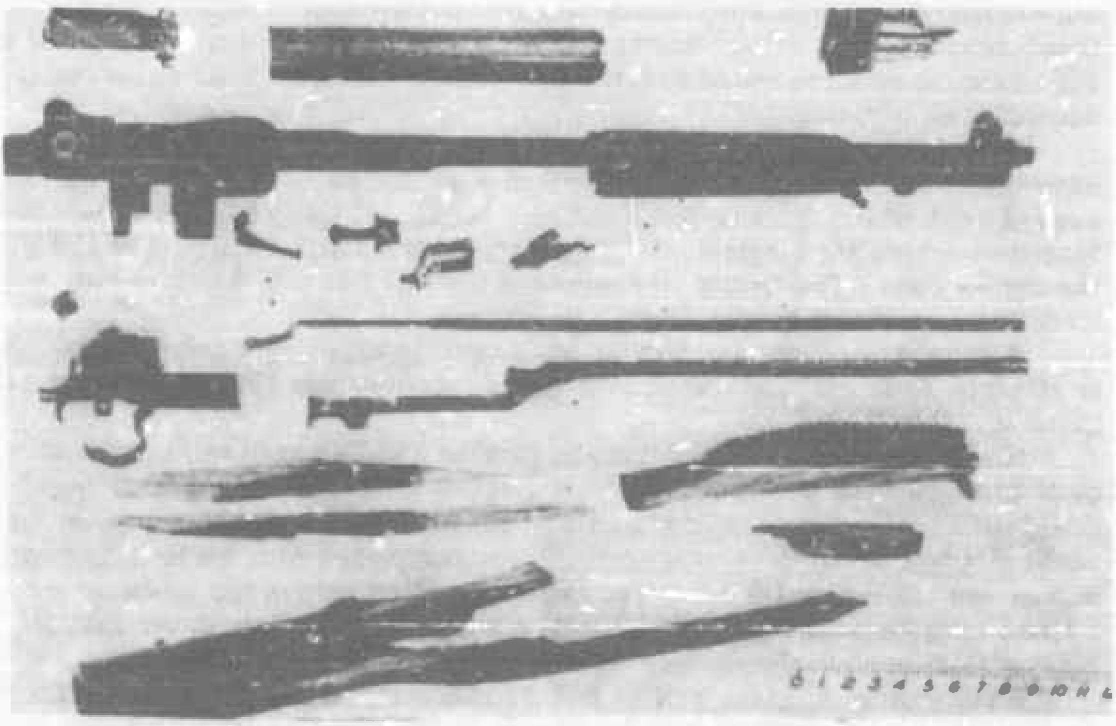
It should be remembered that the carbine and T48 used were weapons quite changed in development from the original weapons, and that the "bugs" could therefore not be expected to have been eliminated. Similar statements could be made about the extraction problem associated with the long-necked duplex and triplex cartridges. The low malfunction rate of the modified M1 rifles firing the single-bullet ammunition points up the much higher rate of malfunction found in the unmodified rifles obtained from Board III.

Each weapon and ammunition had its characteristic malfunctions. Those associated with the long-necked cartridges in the modified M1 rifles were primarily failures to extract; often the rim would be stripped from the cartridge and the firer would require help in clearing his weapon. It was not determined whether a faulty cartridge or fouling of the chamber caused the failure to extract. The carbine's characteristic malfunction was associated with the magazine. In spite of the precautions taken to keep the magazines from being bent or getting dirt in them, failures to feed because of bent or dirty magazines were common. The T48 magazine, which nominally held 20 rounds, would only feed if loaded with 19 rounds or less. Many malfunctions also occurred because of broken extractors, which usually resulted in the loss of several targets for the firers.

A serious complication arose when a modified M1 rifle blew up during the second triplex run, causing the abandonment of further triplex testing. Figure N1 shows the weapon and indicates that the firer's escape from injury was remarkable. A description and possible explanation of this malfunction based on a Springfield Armory observer's reconstruction of events is quoted from a letter of 29 Jun 56 from Springfield Armory to Ordnance Weapons Command:

a. The seventh round of the previous clip appeared to be fired satisfactorily.

b. The eight round was chambered, whether with or without hand assistance was not known. The trigger was squeezed but the round did not fire. (Springfield Armory observer indicated that possibly the mechanism in the trigger grip to record shots fired moved the hammer-spring plunger out of position resulting in the hammer not falling. This had previously occurred in the tests). The eighth round was then manually extracted and the clip ejected. Upon examination of the eighth round by the Springfield Armory observer it was noted that the projectiles were set back into the cartridge case. The case was cut open and the rearmost projectile was in a position where it may or may not have been just held in alignment by the cartridge case.



Springfield Armory, US Army Ordnance Corps

Fig. N1—Rifle Damaged by Triplex Round

c. A new clip was inserted in the rifle and the first round chambered (whether assisted home is not known). The trigger was squeezed and the weapon fired and the aforementioned damage occurred. The bolt was still in the locked position possibly slightly rotated.

A discussion was held with the Springfield Armory observer and other Armory personnel including metallurgists and design engineers, and the following possible causes of the accident were offered:

a. The seventh round of the previous clip fired but the rearmost projectile (having become loose and moved rearward into the powder charge) remained in the barrel bullet seat. The eighth round was chambered forcing its projectile rearward. The first round of the new clip was fired with a projectile already in the bore.

b. The blown-up round could have contained four projectiles instead of three, causing considerable pressure build-up and the resulting damage.

c. The damage may have resulted from a stubbing of the final round, pushing the rearmost projectile back into the cartridge case. Upon firing, if the rear projectile were delayed in the neck of the case, the pressure could possibly be built up sufficiently to cause the case to be blown out to the rear. Examination of the blown case indicates that pressures were in the vicinity of 90,000 to 100,000 psi.

d. The seventh round of the previous clip could have had a reduced powder charge, which upon firing might have left the three projectiles in the bore. Therefore, upon firing the first round of the next clip six projectiles would be in the bore, causing increased chamber pressure.

DATA-COLLECTION MALFUNCTIONS

The original plan had been to collate each firer's trigger pulls with hits on the targets by measuring the time interval. Unfortunately the target and the trigger-pull recording system were very sensitive to line surges, vibration, weather factors, and other conditions. As a result, the records are full

Table N3

DATA-COLLECTION MALFUNCTIONS

Type of malfunction	Week 1	Week 2	Total	Percent of total events or uses
	No. of malfunctions			
Trigger-switch failure	12	30	42	0.1
Hit-recording failures				
Target completely shorted (dampness)	54	151	205	7.8
				5.9
Target intermittently shorted (noise)	44	33	77	5.1
Target with open circuit	5	0	5	0.3
Target faces came off to some degree	4	3	7	0.5
Failure of recording apparatus	22 tgt	2 tgt	24 tgt	1.6
Total	129	189	318	21.3

of "noise," making the distinction of correct from spurious indications most difficult. Firm data were obtained from ammunition counts of rounds fired and holes in target faces. Occasionally, pebbles thrown up by ricochets would make holes, or an edge hit might not show on the target face.

A log was kept of malfunctions on each run; a summary of the data-collection malfunctions is given in Table N3. It is not clear from the record how much overlap exists between some of these malfunctions; e.g. a target might have been recorded as intermittently shorted when it was also noted as completely shorted during the run. The malfunctions increased during the second week as the equipment was more used; this was especially true of the target system, which accumulated dirt in the relays.

TARGET-SYSTEM MALFUNCTIONS

As some of the components were used, they tended to fatigue or function less well. Table N4 shows the malfunctions experienced by week, taken from Table E4 of this memorandum.

Table N4

TARGET-SYSTEM MALFUNCTIONS

Type of malfunction	Week 1	Week 2	Total	Percent of total events or uses
	No. of malfunctions			
Difficulties associated with target functioning				
Failure to rise	21	21	42	2.8
Failure to move, moving targets only	0	13	13	0.9
Up at the wrong time	2	5	7	0.5
Down too soon	3	40	43	2.9
Down too late	8	36	44	2.9
Two targets up simultaneously	9	8	17	1.1
Total	43	123	166	11.1
Difficulties associated with seeing targets				
Target face came off to some degree	4	3	7	0.5
Target face too dark	157	0	157	10.5
Camouflage too heavy	71	34	105	7.0
Camouflage too light	6	47	53	3.5
Total	238	84	322	21.5
Difficulties associated with combat simulation				
Demolitions failed to fire	8	10	18	2.4
Blanks failed to fire	10	45	55	7.4
Total	18	55	73	9.8

Table N5

SUMMARY OF MALFUNCTIONS

Major categories	Malfunctions, %
Weapon firing	2.0[a]
Target operation	11.1[b]
Hit recording	21.3[c]

[a] Of total firings.
[b] Of total operations.
[c] Of total hits.

Some of the malfunctions listed in Table N4 are clearly not malfunctions in equipment but rather incidents that represent changes in the experimental design. For example, the target faces used in the first runs often blended so well into the background that the target was not even shot at, and accordingly the faces were lightened. Another feature about the data in Table N4 is the overlap between some of the items; e.g., if a dark and camouflaged target was scheduled to appear but was not seen by the experimenter who kept the log, the target might be listed as possibly not appearing and as possibly being overly camouflaged. No attempt is made in this table to resolve such overlap.

The major categories of malfunction are summarized by percentage in Table N5.

Appendix O

OVERKILL AND PENETRATION

SUMMARY

The electrically recorded hit data, though incomplete, yield proportions of single, double, and triple hits per trigger pull for duplex and triplex ammunition and carbine and T48 automatic fire. From these proportions, for given bullet lethalities, net lethalities are computed, discounting overkill. Penetration-failure degradations are also computed for duplex, triplex, and flechette ammunitions. Table O6 summarizes the results.

PERCENTAGE OF MULTIPLE HITS

Tables O1 to O4 show the breakdown of the multiple and total salvo hits. These data are obtained exclusively from the electrical hit record. It is noted that the total hits electrically recorded for each run do not agree with the target-hole counts of Table E6 of this memorandum. This is due to imperfect operation of the electric hit-recording system. If it is assumed that the malfunction of the electrical recording system were not itself biased with respect to multiple hits, then the proportions of multiple hits are valid. These proportions may then be used with the more accurate total hit counts from the target faces.

The multiple-hit data plus the bullet lethalities of App B supply the requisite data for discounting overkills by salvo ammunition. Hits and hit probabilities are thus reduced to casualties and casualty probabilities, a superior criterion for comparative effectiveness.

The small sample size makes the illumination-position (IP) differences for each ammunition unreliable. Further considerations will utilize only the total percentages for each ammunition. It is quite possible to compare the percentage of duplex second-bullet hits with theory from ORO-SP-4;[10] the percentage of triplex second- and third-bullet hits can also be compared with theory from ORO-SP-24.[13] These comparisons are laborious and have not been made. However, casual examinations reveal agreement of data and theory in general magnitude.

The excess of carbine over T48 multiple hits is thought to be real and is explained by the deliberately built-in jump compensation on the carbine. The stock shape, muzzle brake, balance, and recoil control were designed to minimize jump in automatic fire. The difference of 3 percent second-bullet hits is rather trivial, however, especially considering that the 3 percent is degraded by a factor $1 - L$, where L is the chance that the first hit incapacitated the target. For $L = 0.7$, the net effectiveness increase due to jump compensation of the carbine over the T48 in automatic fire is just 1 percent.

Table O1

PERCENTAGE OF DUPLEX DOUBLE HITS

Run	I[a]	P[b]	Double hits	Total hits	Double hits, %
2	D	S	14	118	11.9
4	D	S	nd	nd	nd
33	D	S	11	109	10.1
35	D	S	10	76	13.2
57	D	S	13	77	16.9
59	D	S	9	81	11.1
66	D	S	16	100	16.0
68	D	S	10	70	14.3
Subtotal	D	S	83	631	13.1
6	D	St	21	159	13.2
37	D	St	22	187	11.8
61	D	St	23	122	18.8
Subtotal	D	St	66	468	14.1
8	N	S	3	18	16.7
39	N	S	3	17	17.6
63	N	S	8	45	17.8
Subtotal	N	S	14	80	17.5
Total			163	1179	13.8

[a] I is illumination, D is day, N is night.
[b] P is firing position, S is sitting, St is standing.

Table O2

PERCENTAGE OF TRIPLEX DOUBLE AND TRIPLE HITS

Run	Double hits	Triple hits	Total hits	Double hits, %	Triple hits, %
16	21	5	171	15.2	2.9
28	9	3	87	13.8	3.4
Total	30	8	258	14.7	3.1

Table O3

PERCENTAGE OF CARBINE AUTOMATIC DOUBLE HITS

Run	I[a]	P[a]	Double hits	Total hits	Double hits, %
18	D	S	7	97	7.2
20	D	S	nd	nd	nd
41	D	S	1	28	3.6
43	D	S	1	60	1.7
Subtotal	D	S	9	185	4.9
22	D	S	nd	nd	nd
45	D	St	1	41	2.4
24	N	S	2	17	11.8
47	N	S	1	9	11.1
Subtotal	N	S	3	26	11.5
Total			13	252	5.2

[a]For abbreviations see footnotes to Table O1.

Table O4

PERCENTAGE OF T48 AUTOMATIC DOUBLE HITS

Run	I[a]	P[a]	Double hits	Total hits	Double hits, %
10	D	S	2	52	3.8
12	D	S	3	66	4.5
49	D	S	0	31	0.0
51	D	S	1	69	1.5
Subtotal	D	S	6	218	2.8
14	D	St	0	22	0.0
53	D	St	0	32	0.0
Subtotal	D	St	0	54	0.0
18	N	S	1	16	6.3
55	N	S	0	33	0.0
Subtotal	N	S	1	49	2.0
Total			7	321	2.2

[a]For abbreviations see footnotes to Table O1.

OVERKILL CORRECTION

The lethal proportion of total hits for salvos up to three is given by

$$P_L = \Sigma_n (1 - L)^{n-1} L P_n \quad \text{(O1)}$$

where P_L is the lethal proportion of all hits, L is the single projectile lethality, and P_n is the proportion of hits by n projectiles from the same trigger pull.

Table O5 summarizes the net lethalities P_L of the several salvo ammunitions, discounting overkill. All single-bullet lethalities L are taken as 70 percent.

No effort was made to employ electrical recording of flechette hits; hence there are no data on flechette multiple hitting.

Table O5

NET LETHALITIES OF SALVO AMMUNITIONS

Ammunition or firing	Double hits, %	Triple hits, %	P_L, %
Duplex	14	0	63.1
Triplex	15	3	60.7
Carbine automatic	5	0	67.6
T48 automatic	2	0	68.6
All single hits	0	0	70.0

PENETRATION FAILURE

The net effectiveness comparisons require measures of hits, rounds fired, bullet lethalities, multiple hits, and penetrations. Appendixes J and K of this memorandum give the basic data on hits and rounds fired. This appendix gives data on multiple hits (overkills). Appendix B gives data on bullet lethalities. From Apps B and P, penetration indexes are deduced.

Appendix B indicates that the duplex ammunition begins to fail to penetrate helmets at 300 yd. Tables P1 and P2 of this memorandum reveal that for day and night target systems the proportions of hits beyond 300 yd are 1.4 and 0 percent, respectively. As App B indicates that the helmet affords 18 percent effective coverage, this corresponds to a 0.3 percent net day degration for duplex, 0.2 percent average, weighting day three times night.

The triplex fails to penetrate at 150 yd. Tables P1 and P2 of this memorandum give 47.6 percent and 15.2 percent hits beyond 150 yd for day and night, respectively. This corresponds to 8.6 percent day and 2.7 percent night net degradation for triplex, 7.1 percent average, weighting day three times night.

From App B of this memorandum it is estimated that two-thirds of the flechettes penetrate helmets from 0 to 150 yd, and that half of the flechettes penetrate from 150 to 350 yd. Using the percentages above for hits within and beyond 150 yd, it is deduced that there will be 6 percent degradation for the hits to 150 yd, 9 percent degradation beyond 150 yd. The resultant net degradations for flechettes are summed for the two proportions of targets. The net day degradation is 9% × 47.6% plus 6% × 52.4%, or 7.4 percent. The night degradation is 9% × 15.2% plus 6% × 84.8%, or 6.5 percent, 7.2 percent average, weighting day three times night.

If these penetration degradations are now combined with the net lethalities of Table O5, indexes may be deduced that can be used to degrade hits for bullet lethality, salvo overkill, and penetration failure. These indexes are presented in Table O6. When multiplied by hits, they yield casualties.

It is perhaps instructive to estimate what overkill degradation factor seems reasonable for flechettes. The next most multiple salvo, triplex, has

Table O6

OVERKILL AND PENETRATION INDEXES

Ammunition or firing	Day	Night
Single-bullet	0.700	0.700
Duplex	0.629	0.631
Triplex	0.556	0.591
Flechette[a]	0.324 X	0.327 X
Carbine		
Semiautomatic	0.700	0.700
Automatic	0.676	0.676
T48		
Semiautomatic	0.700	0.700
Automatic	0.686	0.686

[a]The flechette overkill degradation X is unmeasured.

a ratio of 82:15:3 for first to second to third bullets. Probably flechettes get no worse multiplicity of hits than a ratio of 64:30:6, double the triplex multiple hits. This ratio for $P_1 : P_2 : P_3$, together with a lethality L of 0.35, yields a net lethality P_L of 30.9 from Eq. O1. This corresponds to a degradation factor X of 0.86 (309/350). For lack of better information, this estimated X in Table O6 yields flechette indexes of 0.279 day and 0.281 night. The lower basic lethality L clearly moderates the overkill degradation.

Appendix P

TARGET-CHARACTERISTIC EFFECTS

SUMMARY

The essential identified target characteristics are range, exposure time, size, movement, concealment, and blank fire. Range is assumed to affect hits as the inverse square; exposure time in direct proportion (less initial lag allowance).

With these two assumptions, the hit data are reduced to eliminate range and time differences and are examined for effects of the other characteristics. Concealment and movement are found to have little effect on the number of hits; small vs large size reduces hits some 70 percent; blank fire increases hits some 50 to 100 percent. Concealment decreases rounds fired by 25 or 30 percent.

These correction factors are applied to standard targets to predict the number of hits on each of the targets of the experiment. The predictions are in reasonable agreement with actual scores.

RANGE AND TIME REDUCTION

The target characteristics considered are those that may substantially affect the number of hits and rounds fired. These include:

a. Range
   52–339 yd

b. Exposure time of target
   3.0–34.5 sec

c. Area of target
   E target (4.59 sq ft)
   F target (2.38 sq ft)

d. Lateral movement of target
   Stationary
   Approximately 4.2 mph

e. Concealment of target
   None
   Partial

f. Blank fire at target

The day and night targets are listed separately in Tables P1 and P2 with their characteristics, and the data from Tables F1 to F19 on hits for all runs with all weapons except the flechette. These include 51 day runs and 15 night runs. Characteristics such as representation of defense vs assault and time and space relations to other targets are omitted, as they are not expected to measurably affect the number of hits achieved.

Tables P1 and P2 show simple linear mean target ranges of 190 yd for day and 135 yd for night. The average ranges of hitting are deduced by weighting each range by the hits scored at that range. This procedure yields average ranges of hitting of 133 yd for day and 85 yd for night.

The change in number of hits with changes in range is first assumed to be inversely proportional to the square of the range. This assumption is justified for hit probabilities of 20 percent or less. The expansion of the exponential expression for hit probability gives a $1/R^2$ term followed by terms

Table P1

DAY-TARGET CHARACTERISTICS AND HITS

Target no.	Range, yd	Moving (~4.2 mph)	Partly concealed	Small size	Not firing blanks	Exposure time, sec	Total hits
5	74	—	—	X	—	4.5	229
7	77	—	X	X	—	15.0	1181
9	86	—	—	—	X	4.5	505
10	89	—	X	X	—	15.0	936
13	111	—	X	X	—	19.5	577
14	127	—	X	X	—	9.0	258
15	139	—	—	X	X	4.5	20
16	152	X	—	—	X	9.0	291
18	162	X	—	—	X	6.0	332
19	164	X	—	—	X	15.0	454
20	165	—	X	—	X	31.5	1387
21	169	—	—	—	X	3.0	61
22	176	—	X	—	—	4.5	58
24	216	—	X	X	X	4.5	15
25	218	—	X	X	X	9.0	58
28	245	—	—	—	—	6.0	127
29	259	—	—	—	—	10.5	258
30	267	—	—	—	X	3.0	4
31	269	—	X	X	—	25.5	178
32	334	—	—	X	—	7.5	20
33	336	—	—	X	X	3.0	2
34	339	—	X	X	—	21.0	70
Total	4174	3	10	12	11	231.0	7133
Mean	190					10.5	

successively smaller by factors of at least 2 times probability squared. For $P = 20$ percent, the second term is only 10 percent. The error in using only the first term of this alternating-sign series is then less than 10 percent. The change in hits with changes in exposure time is assumed to be proportional to the ratio of the time, each less 1.75 sec. This 1.75 sec is deduced in App 1 as the mean lag time from target erection to steady hit rate. For example, to derive reduced hits from actual (or unreduced) hits h_1 from a target of given range R_1 and duration t_1 (in seconds) to an expected hits h_2 for a new target of range R_2 and duration t_2 the procedure is

$$h_2 = h_1 (R_1/R_2)^2 [(t_2 - 1.75)/(t_1 - 1.75)] \qquad \text{(P1)}$$

Tables P3 and P4 show the targets organized into groups (A, B, etc.) having like characteristics. The total hits from all 66 runs on Tables F1 to F19 are adjusted, using Eq. P1, to what would be expected at each target if it were located at the mean range (190 yd) and exposure time (10.5 sec) for all day targets. The night targets are adjusted to the same range and exposure time for direct comparison with day targets.

Table P2

NIGHT-TARGET CHARACTERISTICS AND HITS

Target no.	Range, yd	Moving (~4.2 mph)	Partly concealed	Small size	Not firing blanks	Exposure time, sec	Total hits
1	52	—	X	X	X	28.5	220
2	63	—	—	—	X	3.0	33
3	65	—	—	—	X	7.5	116
4	67	—	X	X	X	12.0	60
6	76	—	—	—	X	4.5	44
8	78	—	—	X	—	19.5	73
11	90	—	X	X	—	4.5	40
12	91	—	—	X	X	9.0	11
13	111	—	X	X	—	19.5	39
14	127	—	X	X	—	9.0	21
15	139	—	—	X	X	4.5	4
16	152	X	—	—	X	10.5	18
17	161	—	—	—	X	3.0	0
18	162	X	—	—	X	6.0	9
19	164	X	—	—	X	18.0	15
20	165	—	X	—	X	34.5	68
21	169	—	—	—	X	4.5	2
22	176	—	X	—	—	9.0	3
23	209	—	—	X	X	3.0	0
25	218	—	X	X	X	15.0	2
26	221	—	—	X	—	7.5	1
27	223	—	X	X	—	21.0	0
Total	2979	3	9	12	15	253.5	771
Mean	135					11.5	

SIZE, MOVEMENT, CONCEALMENT, AND BLANK-FIRING EFFECTS

The targets in any one group in Tables P3 and P4 are assumed now to be alike in important respects. The hits data are combined within each group so the groups may be compared. The run and target product is the total number of items of data on which values are based. The mean number of hits per run is listed for each target group.

The relative variance in hits is $(\sigma_{\bar{h}}/\bar{h})^2$ from the binominal distribution with standard deviation $(\sqrt{Npq})$. For h actual hits, $\sigma = \sqrt{hq}$. For relatively low hit probability, q may be approximated by unity. Hence $\sigma^2 \approx h$. For mean hits h/N, the variance is h/N^2. The relative variance of the mean is by definition

Table P3

DAY-TARGET GROUPS
(Adjusted to 190 yd and 10.5 sec)

Target group	Target no	Moving (~4.2 mph)	Partly concealed	Small size	Not firing blanks	Run and target product N	Total hits h	Mean hits $\bar{h}$	Relative variance $(\sigma_{\bar{h}}/\bar{h})^2$
A	28	—	—	—	—	—	434	—	—
	29	—	—	—	—	—	479	—	—
Group values		—	—	—	—	102	913	8.94	0.00110
B	5	—	—	X	—	—	110	—	—
	32	—	—	X	—	—	94	—	—
Group values		—	—	X	—	102	204	2.00	0.00490
C	9	—	—	—	X	—	329	—	—
	21	—	—	—	X	—	336	—	—
	30	—	—	—	X	—	54	—	—
Group values		—	—	—	X	153	719	4.70	0.00139
D	15	—	—	X	X	—	34	—	—
	33	—	—	X	X	—	46	—	—
Group values		—	—	X	X	102	80	0.78	0.0125
E	7	—	X	X	—	—	128	—	—
	10	—	X	X	—	—	136	—	—
	13	—	X	X	—	—	97	—	—
	14	—	X	X	—	—	139	—	—
	31	—	X	X	—	—	131	—	—
	34	—	X	X	—	—	102	—	—
Group values		—	X	X	—	306	733	2.40	0.00136
F	20	—	X	—	X	—	307	—	—
	22	—	X	—	X	—	157	—	—
Group values		—	X	—	X	102	464	4.55	0.00216
G	16	X	—	—	X	—	225	—	—
	18	X	—	—	X	—	496	—	—
	19	X	—	—	X	—	223	—	—
Group values		X	—	—	X	153	944	6.17	0.00106
H	24	—	X	X	X	—	46	—	—
	25	—	X	X	X	—	92	—	—
Group values		—	X	X	X	102	138	1.35	0.00725

Table P4

NIGHT-TARGET GROUPS
(Adjusted to 190 yd and 10.5 sec)

Target group	Target no.	Moving (~4.2 mph)	Partly concealed	Small size	Not firing blanks	Run and target product N	Total hits h	Mean hits $\bar{h}$	Relative variance $(\sigma_{\bar{h}}/\bar{h})^2$
I	22	—	X	—	—	15	3	0.20	0.333
J	8	—	—	X	—	—	6	—	—
	26	—	—	X	—	—	2	—	—
Group values		—	—	X	—	30	8	0.27	0.125
K	2	—	—	—	X	—	25	—	—
	3	—	—	—	X	—	21	—	—
	6	—	—	—	X	—	23	—	—
	17	—	—	—	X	—	0	—	—
	21	—	—	—	X	—	5	—	—
Group values		—	—	—	X	75	74	0.99	0.014
L	12	—	—	X	X	—	3	—	—
	15	—	—	X	X	—	7	—	—
	23	—	—	X	X	—	0	—	—
Group values		—	—	X	X	45	10	0.22	0.100
M	11	—	X	X	—	—	28	—	—
	13	—	X	X	—	—	7	—	—
	14	—	X	X	—	—	11	—	—
	27	—	X	X	—	—	0	—	—
Group values		—	X	X	—	60	46	0.77	0.022
N	20	—	X	—	X	15	14	0.93	0.071
O	16	X	—	—	X	—	11	—	—
	18	X	—	—	X	—	13	—	—
	19	X	—	—	X	—	6	—	—
Group values		X	—	—	X	45	30	0.67	0.033
P	1	—	X	X	X	—	5	—	—
	4	—	X	X	X	—	6	—	—
	25	—	X	X	X	—	2	—	—
Group values		—	X	X	X	45	13	0.29	0.077

just $(h/N^2)/(h/N)^2$, or $1/h$. This is the relative variance $(\sigma_{\bar{h}}/\bar{h})^2$, shown in Tables P3 and P4 for each group. The hit values are simply the actual hits (h) from Tables P1 and P2, added together for the appropriate groups.

Table P5 compares appropriate groups of targets by the ratios of their adjusted mean hits $(\bar{h}_2/\bar{h}_1)$ to provide an estimate of the effect of each target characteristic on the number of holes counted.

Table P5

EFFECTS OF TARGET CHARACTERISTICS ON HITS

Target characteristic	Target groups compared	Ratio of mean hits per run	Weight $1/\sigma^2$	Weighted ratio
Small target size	B:A	0.224	3310	742
	D:C	0.166	2610	433
	H:F	0.297	1200	357
	L:K	0.222	178	40
	M:I	0.395	18	7
	P:N	0.312	69	22
Total	—	—	7385	1601
Weighted mean ratio	—	—	—	0.22
Movement	G:C	1.313	236	310
	O:K	0.677	46	31
Total	—	—	282	341
Weighted mean ratio	—	—	—	1.21
Concealment	E:B	1.200	111	133
	F:C	0.968	301	291
	H:D	1.731	17	29
	M:J	2.851	1	2
	N:K	0.940	13	12
	P:L	1.318	3	4
Total	—	—	446	471
Weighted mean ratio	—	—	—	1.06
No blank fire	C:A	0.526	1445	760
	D:B	0.390	376	147
	H:E	0.563	365	116
	L:J	0.815	7	5
	N:I	4.650	0	1
	P:M	0.377	71	27
Total	—	—	2263	1056
Weighted mean ratio	—	—	—	0.47

The relative variance of a ratio is approximated by sum of the relative variances of the two numbers of the ratio. This relative variance may then be converted to the ordinary absolute variance, simply by multiplying by the ratio itself. The reciprocal of the variance of the ratio is a good measure of the reliability of that ratio.

$$1/\sigma^2_{\bar{h}_2/\bar{h}_1} = \frac{(\bar{h}_1/\bar{h}_2)^2}{(\sigma_{\bar{h}_1}/\bar{h}_1)^2 + (\sigma_{\bar{h}_2}/\bar{h}_2)^2} \qquad \text{(P2)}$$

For example, the first ratio of Table P5 is 0.224 for B:A. The absolute ratio variance is just this value squared, times the sum of the A and B relative variances from Table P3, which are 0.00110 and 0.00490. The reciprocal of this quantity ($1/\sigma^2$) is the weighting factor 3310, listed in Table P5.

It is concluded that where size is reduced by 48 percent from the E target (4.59 sq ft) to the F target (2.38 sq ft), the number of hits will reduce by 77 percent.

When a target moves (at about 4.2 mph laterally) instead of remaining still, the hits will increase by 15 percent.

When a target is partly concealed instead of being wholly visible, the hits will increase 5 percent.

When there is no blank fire from the target at the time it appears, the hits will decrease by 52 percent.

The data, after account is taken of these four effects, show no further dependence on range or exposure time.

TARGET-CHARACTERISTIC PREDICTIONS

Having determined the effects of each of six apparent target characteristics on hits, it is now possible to extrapolate from the experimental data to hypothetical targets having any combination of values of these characteristics. The purpose of such extrapolation is to permit the critical reader to recompute the experimental results on the basis of alternative target systems, should the selected target systems prove to be incorrect or unacceptable. For example, subsequent analysis may reveal that true combat has a higher percentage of targets at a longer range, but shorter exposure times, or more lateral movement than the proportions used in the experimental target systems. This discussion outlines how the separated effects of these characteristics may be used to modify the results in order to produce an estimate of the results of any modified system of targets.

The effects of range and time have been straightforwardly deduced from simple theory; the effects of target size, movement, concealment, and blank fire have been deduced in the preceding section. To perform illustrative calculation, it is desirable to begin with a standard set of target characteristics. Arbitrarily select the mean range and exposure time that were selected earlier in preparation of Tables P3 and P4 (190-yd range, 10.5-sec exposure time). In addition arbitrarily select for the standard target a large silhouette (E) that is not concealed and not moving.

In order to perform the requisite calculations, a basic starting point is required—i.e., the number of hits scored on a standard target with the above characteristics must be known. In order to arrive at the best figure, all the data are utilized as listed in Tables P3 and P4. Because of the gross difference between the number of hits scored in day and night firing, these two conditions are computed separately. To compute the average number of hits on a standard day target, the number of hits on each of the target groups of Table P3 are taken, and corrected for reduced target size, movement, concealment, or no blank fire as appropriate. This calculation is performed by appropriately dividing the number of target hits by 0.23, 1.15, 1.05, or 0.48, respectively.

The sum is then divided by the total number of targets fired on for the entire experiment, to yield the desired mean number of hits on the standard day target. This mean is 9.68 hits. A similar calculation with the data in Table P4 yields a night standard target mean of 1.81 hits.

It is instructive now to use these mean standard target hit values together with the derived correction factors for the six significant target characteristics to predict the number of hits on all the targets as described in Tables P1 and P2. This has been done, and the results are listed in Table P6. The "Predicted" columns list the computed number of hits based on these deduced factors. The "Counted" columns list the actual number of hits scored on each target. The agreement is reasonably satisfactory. Of course the method of deriving the factors necessarily leads to predictions as good as these.

Table P6

PREDICTED TARGET HITS

Day hits (9.68)			Night hits (1.81)		
Target no.	Predicted	Counted	Target no.	Predicted	Counted
5	5	5	1	9	14
7	22	23	2	1	2
9	7	10	3	5	8
10	16	18	4	2	4
13	14	12	6	2	3
14	4	5	8	5	5
15	1	0	11	1	3
16	7	7	12	1	1
18	4	7	13	1	2
19	11	9	14	1	1
20	22	27	15	0	0
21	1	1	16	2	1
22	4	2	17	0	0
24	0	0	18	1	1
25	1	1	19	2	1
28	3	3	20	5	4
29	5	5	21	0	0
30	0	0	22	2	0
31	3	4	23	0	0
32	0	0	25	0	0
33	0	0	26	0	0
34	2	1	27	1	0
Total	132	140	Total	41	50

It should be quite clear now that one can start with either the day or night standard target, and convert to reasonable values of any of the six critical characteristics and predict the number of hits. This capability, together with the squad differences discussed in Apps G and K, permits fairly flexible extrapolation beyond the limited conditions of the SALVO I experiment.

TARGET-CHARACTERISTIC REDUCTION

Rather than use the conservative method discussed in the section "Size, Movement, Concealment, and Blank-Firing Effects," where the hit data are grouped, it is possible to use all the data as in App K. The interrelated effects of the six target characteristics are deduced from all data. To do this analysis, as in App K, reduction is first accomplished for the major effects. The range and time reductions are made first identically as in the section "Range and Time Reductions." Then a target area reduction is made by multiplying F target hits by the known target area ratio (1.92). The list of hits is now ready for successive reduction for blank fire, concealment, movement, additional-exposure-time effect, and additional-target-size effect.

Similarly, for the data on rounds fired, the exposure-time reduction is identical; no range or target-size reductions are made. The rounds data are also then ready for reduction for the same four effects in the same succession.

These sequential reductions have been performed with day data. Table P7 lists the original hit (h) and rounds (r) data, taken from Tables F1 to F38. The next columns are reduced according to these relations:

$$H = h(R_1/190)^2\,[(t_2 - 1.75)/8.75]\,(4.59/2.38) \qquad \text{(P3)}$$

$$R = r[(t_2 - 1.75)/8.75) \qquad \text{(P4)}$$

The factors for the sequential reduction for the other effects are:

$$H' = H\,(0.831)_B\,(1.291)_C\,(0.732)_M\,(1.606)_{t<6}(1.574)_F \qquad \text{(P5)}$$

$$R' = R\,(1.320)_B\,(1.455)_C\,(1.048)_M\,(0.92\text{[illegible]})_{t<6}(1.107)_F \qquad \text{(P6)}$$

Expressions P5 and P6 indicate the factors required to successively equate means for B, blank fire vs no blank fire; C, concealment vs no concealment; M, movement vs no movement; $t < 6$, exposure less than 6 sec vs exposure of 6 sec or more; F, smaller vs larger target silhouette. Successive application of these factors reduces H and R to the values listed in the columns headed H' and R' in Table P7. As in App K, the reduction factors are isolated.

The completely reduced data H' and R' are now examined for remaining differences of mean for all but the last effect examined (F vs E target size). This examination reveals the following remaining factors:

$$H' - (0.801)_B\,(0.829)_C\,(1.525)_M\,(1.260)_{t<6} \qquad \text{(P7)}$$

$$R' - (0.808)_B\,(0.938)_C\,(1.031)_M\,(1.015)_{t<6} \qquad \text{(P8)}$$

These factors must be multiplied by the factors of Expressions P5 and P6 to yield total corrections for each effect. The reciprocals of these products are then indicative of the effects of the six characteristics involved.

The net size effect also includes the area factor in Eq. P3. The range and time effects of Eqs. P3 and P4 should also be noted. The net effects are

Table P7

DAY-TARGET-CHARACTERISTIC REDUCTION

Target no.	Unreduced		Time, range, size reduced		Completely reduced	
	h	r	H	R	H'	R'
5	229	929	212	2957	445	4005
7	1181	3581	246	2363	414	5024
9	505	1228	329	3906	528	3621
10	936	3113	262	2055	442	4369
13	577	2884	187	1422	315	3023
14	258	1598	267	1929	452	4100
15	20	500	65	1590	164	1632
16	291	1962	225	2369	165	2483
18	332	1943	496	4000	363	4192
19	454	2548	223	1681	163	1762
20	1387	5933	307	1744	396	2538
21	61	543	336	3802	540	3524
22	58	548	157	1743	270	3104
24	15	486	88	1548	288	2311
25	58	844	177	1019	360	1642
28	127	1181	434	2432	361	3210
29	258	2241	479	2241	398	2958
30	4	230	54	1607	87	1490
31	178	2735	252	1007	425	2141
32	20	702	181	1068	236	1561
33	2	445	88	3114	222	3196
34	70	1690	196	769	331	1635

Table P8

DAY-TARGET EFFECTS

Effect	Hit change, %	Round change, %
Blank fire	+50	−6
Concealment	−7	−27
Movement	−10	−7
Smaller size	−67	−10
6-sec exposure	−51	+6
Range R	$\propto 1/R^2$	—
Exposure t	$\propto (t^{-1.75})$	$\propto (t^{-1.75})$

listed in Table P8. The additional-target-size effect reduces the F target hits to 33 percent of E target hits, rounds fired is reduced to 90 percent. The targets that were exposed for only 3 or $4\frac{1}{2}$ sec got 49 percent of the hits received by targets exposed longer, even after reduction by Eq. P1, and rounds fired increased by 6 percent. This suggests the inapplicability of the rate-of-fire concept for such a short exposure. Movement reduces target hits to 90 percent of stationary target hits and reduces rounds fired to 93 percent. Concealment reduces hits to 93 percent of unconcealed target hits, and reduces rounds fired to 73 percent. Blank fire at a target increases hits to 50 percent but reduces rounds fired to 94 percent.

Similar calculations are possible for the night target system. It satisfies the present purpose to demonstrate the method of analysis, and deduce a few major effects.

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