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MEMORANDUM REPORT NO. 1139

APRIL 1958

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A COMPARISON OF PROPOSED SMALL ARMS WEAPON SYSTEMS (U)

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BALLISTIC RESEARCH LABORATORIES



ABERDEEN PROVING GROUND, MARYLAND

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1139

APRIL 1958

A COMPARISON OF PROPOSED SMALL ARMS WEAPON SYSTEMS (U)

W. C. Benjamin, Jr.

R. L. Simmons

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1139

WBenjamin, Jr./RISimmons/is
Aberdeen Proving Ground, Md.
April 1958

A COMPARISON OF PROPOSED SMALL ARMS WEAPON SYSTEMS (U)

ABSTRACT

A comparison of proposed caliber .22, single ball, the proposed caliber .30 duplex and the caliber .30, AP rifle-ammunition combinations has been made in an attempt to determine significant differences between weapon systems. The comparison is based on the expected number of targets killed for ranges out to 400 yards for a fixed weight for rifle and ammunition. Data obtained from the Salvo I experiment and tentative wound ballistic data have been combined with results of earlier Ballistic Research Laboratories studies of small arms effectiveness in order to make the comparison.

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INTRODUCTION

Much information has been generated in an attempt to determine the characteristics of an improved small-arms weapon system which would be sufficiently accurate, lightweight, economical and reliable to produce a significant improvement in kill probability over the standard rifle. Of primary importance in this investigation was the determination of wound ballistic data for various projectile-types under consideration, for this has permitted projectile performance to be isolated from the performance of the weapon itself insofar as the production of casualties is concerned.

The Salvo I Rifle Experiment was designed to determine the hit performance of several weapon-ammunition combinations. This experiment yielded valuable basic data concerning weapon accuracy, rate of fire, hit probability, etc. under simulated tactical conditions.

The data obtained from Salvo I and the wound ballistic data have been combined with results of earlier BRL studies of small-arms effectiveness in order to compare the following weapon systems:

- Cal..30, M1 rifle firing AP ammunition
- Cal..30, M1 rifle firing duplex ammunition
- Cal..22 lightweight rifle firing a 50-grain lead core projectile

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THE SALVO I EXPERIMENT

The Salvo I experiment consisted basically of controlled tests of rifle-ammunition combinations against a programmed sequence of targets where the targets appeared for only small intervals of time. Factors which were included in the test set-up which do not lend themselves readily to quantitative analysis included visibility, movement and confusing context of the target and simulated battle conditions which included detonation of explosive charges, blank fire from some of the target positions, noise emanating from a PA system, etc.

The operation of the target system was controlled automatically by a programmer which insured that each weapon would be tested under the same conditions. Targets consisted of 22 "E" and "F" silhouette-type targets at ranges up to 350 yards. Target exposure times varied from 3 to 35 seconds.

The weapon-ammunition combinations which were tested included the M1 rifle which fired caliber .30, AP, duplex and triplex ammunition; a modified carbine which fired caliber .22 carbine ammunition either automatically or semi-automatically; a modified T48 rifle firing the caliber .22 Sierra ammunition either automatically or semi-automatically; and the 12-gauge shot gun with the 32-flechette round of ammunition.

The data collected from the test consisted of a count of the total number of holes in the target faces and the total number of rounds expended per run. There was also a continuous recording of rounds fired from each firing position and a continuous recording of hits on each target. However, the recorder systems used for such continuous recording, were subjected to an excessive number of malfunctions, which therefore makes questionable the use of data so obtained. The Salvo data which have been used in this analysis are simply the number of hits made and the number of rounds fired. These values were obtained either from the raw data published

search Office * and/or directly from GPO personnel.
 that these data do not give the number of hits
 for the multiplex ammunition.

the relative advantage of the multiplex
 rounds, the relative number of hits (with
 ammunition computed for each weapon-ammunition combi-
 respect to Cal. .30, shown in the histogram of Fig. 1.
 nation tested. This is interesting to note that the caliber .22
 from these values it is seen that the relative number of hits as
 results in approximately the same factors appear to cause this
 obtained for the duplex ammunition
 anomaly.

fire of each of the weapons
 the relat. against the complete target
 First, by determining the relat. against the complete target
 (i.e., the number of rounds fired by each caliber .22 carbine is
 complex) it is seen that the rate of fire of the multiplex
 approximately 125% of that of the caliber .30, AP.
 ammunition gives a rate of fire slightly higher than shown as
 The relative rates of fire of the weapons tested
 a function of muzzle momentum in Fig. 2.

Secondly, by determining the value of dispersion which
 the hit probabilities as measured in Salvo I, where $p_h = \frac{\text{number of hits}}{\text{number of rounds}}$

it is evident that the aiming error for the carbine is somewhat less than
 the aiming error for the heavier weapons. The fact that lightweight
 weapons result in smaller aiming errors was also demonstrated in a series
 of tests of rifles, carbines and pistols where aiming errors for each
 weapon were measured as a function of target exposure time. ** The percentage
 of hits for different target exposure times are shown in Fig. 3 for the

* "Preliminary Report On Salvo", 25 October 1956, Staff Paper by
 Sr. K. L. Yudowitch, Operations Research Office.

** BRL Report No. 969 - "Rifle, Carbine and Pistol Aiming Errors (U)"
 by K. L. Yudowitch and T. E. Sterne.

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caliber .22 carbine and the caliber .30, AP only since the data do not yield such values for the multiplex ammunition. It is felt that the increased rate of fire and the decreased aiming errors which appear to be a function of the weight of the weapon resulted in the higher percentage of hits for the caliber .22 carbine. The relative percentages of hits is plotted in Fig. 4 as a function of range. Combining these data with the relative rate of fire yields the relative number of hits which is plotted as a function of range in Fig. 5. Included is an estimated value for the caliber .22, 50-grain round, assuming the probability of hitting is equal to that for the caliber .22 carbine and the relative rate of fire is a function of the muzzle momentum.

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THE WOUND BALLISTIC DATA

Firings of single projectiles against goats were conducted in order to establish the probability that a hit results in a kill. Tentative data, for 100% "Sure" kills only, have been obtained for the ammunition types which were used in Salvo I. These data, plotted as a function of mass x velocity ^{3/2} are given in Fig. 6. Very stable projectiles such as the caliber .30, AP and the caliber .22, Sierra are seen to be relatively poorer in ability to produce kills than the caliber .30 duplex which, in turn, is inferior to the caliber .30 triplex. However, differences between the curves are not large for most velocities considered.

THE PROPOSED MULTIPLEX AMMUNITION

A modification of the present caliber .30 projectile to replace the single projectile with either 2 or 3 shorter projectiles of the same diameter has resulted in the development of the duplex and triplex rounds. Since the tests of Salvo I, the multiplex principle has been extended to rounds of smaller calibers.

The caliber .30 duplex round contains two 96-grain projectiles packed in tandem in the cartridge case. To accommodate the two projectiles the neck of the cartridge case was extended, resulting in a slight modification of the weapon itself. The triplex round contains three 61-grain projectiles. Since the total weight of projectiles is approximately the same for both the duplex and triplex rounds their muzzle velocity is the same -- about 2600 fps. This is a reduction of about 200 fps. below the velocity of the standard caliber .30 rounds.

The increase in single shot hit probability which results from the multiplex rounds is brought about by the dispersion between the leading projectile and the other projectiles which have canted bases to induce dispersion. The leading projectile is about as accurate as the standard single ball round.

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THE PROPOSED CAL. .22 WEAPON

An earlier BRL study * indicated that a projectile which tended to tumble soon after target impact also tended to result in greater kill probabilities. As a conclusion to this study, it was shown that a caliber .22 projectile weighing 50-grains could be made to result in good wound ballistic performance if the transverse moment of inertia were sufficiently low to encourage tumbling immediately after impact. This resulted in the recommendation of a caliber .22, 50-grain lead core projectile.

The initial velocity required for the proposed projectile has been assumed to be that which satisfies the CONARC requirement for a helmet penetration at 500 yards. For the 50-grain caliber .22 projectile this velocity is approximately 3500 fps.

In order to establish the wounding power of this projectile in the absence of actual wound ballistic data for the specific design and velocities, it has been assumed that the 50-grain projectile which tumbles soon after impact will follow the same $MV^{3/2} - P_{HK}$ laws as those observed with the caliber .22 carbine and the triplex ammunition.

Caliber .22 weapons tested in Salvo I included a modified carbine and a modified T48. Both of these weapons were originally designed as caliber .30 weapons and are, therefore, of greater weight than required for caliber .22 use. Discussions with Springfield Armory personnel have indicated that a more realistic value of weight for a caliber .22 rifle would be approximately 6.5 lbs. This value has been used in this study. However, recent information received has indicated that a caliber .22 rifle which fires a 53-grain projectile at about 3500 fps. has been successfully demonstrated to CONARC personnel. This weapon weighed only 5 lbs. It appears, therefore, that the weight of 6.5 lbs. is probably a conservative estimate.

* "Upon Selecting an Optimum Rifle Round (U)" by Donald L. Hall and Billy S. Campbell - BRL Memo 1055.

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WEAPON ACCURACY

The effectiveness of a small-arms weapon is greatly influenced by the accuracy with which it can be aimed. The tests of Salvo I indicated that the aiming accuracy varies with the weapon. A meaningful comparison of weapons must, then, be based on accurate estimates of aiming accuracy for each rifle.

Using the Salvo I data as fully as possible, the standard deviation of aim error for the caliber .30 weapon was obtained as follows:

The probability of a hit was defined to be the ratio of the number hits per target to the number of rounds expended per target. Assuming that the targets were circular, the standard deviation (σ) for each target at each range was computed by

$$P_H = 1 - e^{-\frac{R^2}{2\sigma^2}}$$

where R is the target radius.

Since some of the targets had many more rounds expended on them than others, because of the varying target exposure times, the individual values of σ were weighted by the corresponding number of rounds expended per target. These values were summed over the complete target system and divided by the total number of rounds expended. The average value of σ thus obtained for the caliber .30 weapon is 3.8 mils.

The accuracy of the caliber .22 carbine, based on the same method of computation is approximately 3 mils. This value has been used to estimate the accuracy of the caliber .22 light-weight rifle. Although test data are not available to support this value it is felt that sufficient data are available to indicate significant differences in aiming errors between weapons. A 3-mil standard deviation can then be used as a rough indication of the gain in effectiveness which can be achieved by a reduction of aiming errors.

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COMBINED RESULTS

A comparison of the proposed caliber .22 projectile, the proposed caliber .30 duplex ammunition, and the caliber .30, AP has been made in an attempt to determine significant differences between weapons.

Interpolating in the graph of Fig. 2 to the muzzle momentum of the caliber .22 50-grain projectile at a velocity of 3500 fps. indicates an expected rate of fire equal to 120% of that measured for the caliber .30 weapons. The expected relative number of hits was then computed and entered in the graph of Fig. 5.

Computation of the wound ballistic data for the three weapons considered, results in the graph of Fig. 7. Limiting ranges for helmet penetrations have been included for comparative purposes.

In order to determine expected hit performance of the duplex ammunition, the standard deviation of miss distance was computed for the caliber .30, AP. Using this value and a fixed angular dispersion of 2.5 mils between the front and the second bullet, probabilities of hit were computed using the method of BRIM 1030.* Probabilities of hitting are plotted in Fig. 8.

The probability of killing for single projectile ammunition is obtained simply by multiplying the probability of hitting by the probability that a hit is a kill. For duplex ammunition, the probability of a kill is given by

$$P_K = P_{h_1} P_{hK_1} + (P_{h_2} P_{hK_2})(1 - P_{h_1} P_{hK_1})$$

where P_{h_1} = the probability of a hit with the first bullet,

P_{hK_1} = the probability that a hit by the first bullet results in a kill,

P_{h_2} = the probability of a hit with the second bullet

P_{hK_2} = the probability that a hit by the second bullet results in a kill.

The probability of killing is given as a function of range in Fig. 9.

* BRIM 1030 - "Evaluation of a Salvo Rifle (U)" by Donald L. Hall and Ed S. Smith

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The relative effectiveness of the rifles compared is defined as the ratio of the products of the kill probability times the relative rate of fire, i.e.,

$$\text{Relative Effectiveness} = \frac{P_{h_1} P_{hK_1} \times (\text{Relative Rate of Fire})_1}{P_{h_2} P_{hK_2} \times (\text{Relative Rate of Fire})_2}$$

where the subscripts denote a specific weapon. For these calculations the reference has been chosen as the caliber .30, AP round fired from the standard M1 rifle. Relative effectiveness over the range of targets in the Salvo I test is given in Fig. 10.

For a fixed weight of rifle plus ammunition the relative expected number of targets killed has been determined. These values are based on the following weights of weapon and ammunition:

<u>Weapon</u>	<u>Weapon WT.</u>	<u>Ammo.</u>	<u>Ammo. WT.</u>
Cal. .30, M1	9.5 lbs.	AP	414 grains
Cal. .30, M1	9.5 lbs.	Duplex	449 grains
Cal. .22	6.5 lbs.	50 grain	170 grains

The relative expected number of targets killed is plotted in Fig. 11 for a rifle plus total ammunition weight of 15 lbs.

CONCLUSIONS

Differences between ammunition-types insofar as wounding power is concerned, are rather small. Because of this small difference it appears that if the military requirement for helmet penetration at 500 yards is met, the choice of one weapon system over another will be based on other characteristics.

Insofar as single shot effectiveness is concerned, a superiority for the duplex ammunition is indicated provided the weight is not a factor to be considered. For sustained fire, the higher rate of fire for the lighter weapons tends to reduce the overall differences so that the differences between the relative effectiveness of the caliber .22 single ball and the caliber .30 duplex are not significant.

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Significant differences between weapons have been obtained when the weight of the weapon is considered or when a difference in aiming errors is assumed. With respect to this conclusion it must be reiterated that aiming errors for lighter weapons are apparently less than for heavier weapons -- a factor which should be investigated more fully by tests.

If the weight of rifle plus ammunition is of great importance the conclusion of this study becomes quite obvious. A light-weight caliber .22 rifle with the 50-grain projectile will result in a considerably greater effectiveness than the other weapon systems compared.

RECOMMENDATION

Since the proposed light-weight caliber .22 weapon system appears to offer considerable promise, particularly in so far as single-shot hit probability and overall weight are concerned, it is recommended that a program be initiated to determine the required data to evaluate more fully the proposal to use a lighter weapon. This program would require some development of a rifle and corresponding ammunition and also include sufficient testing to provide data for comparison with competitive weapons.

W. C. Benjamin, Jr.

W. C. BENJAMIN, JR.

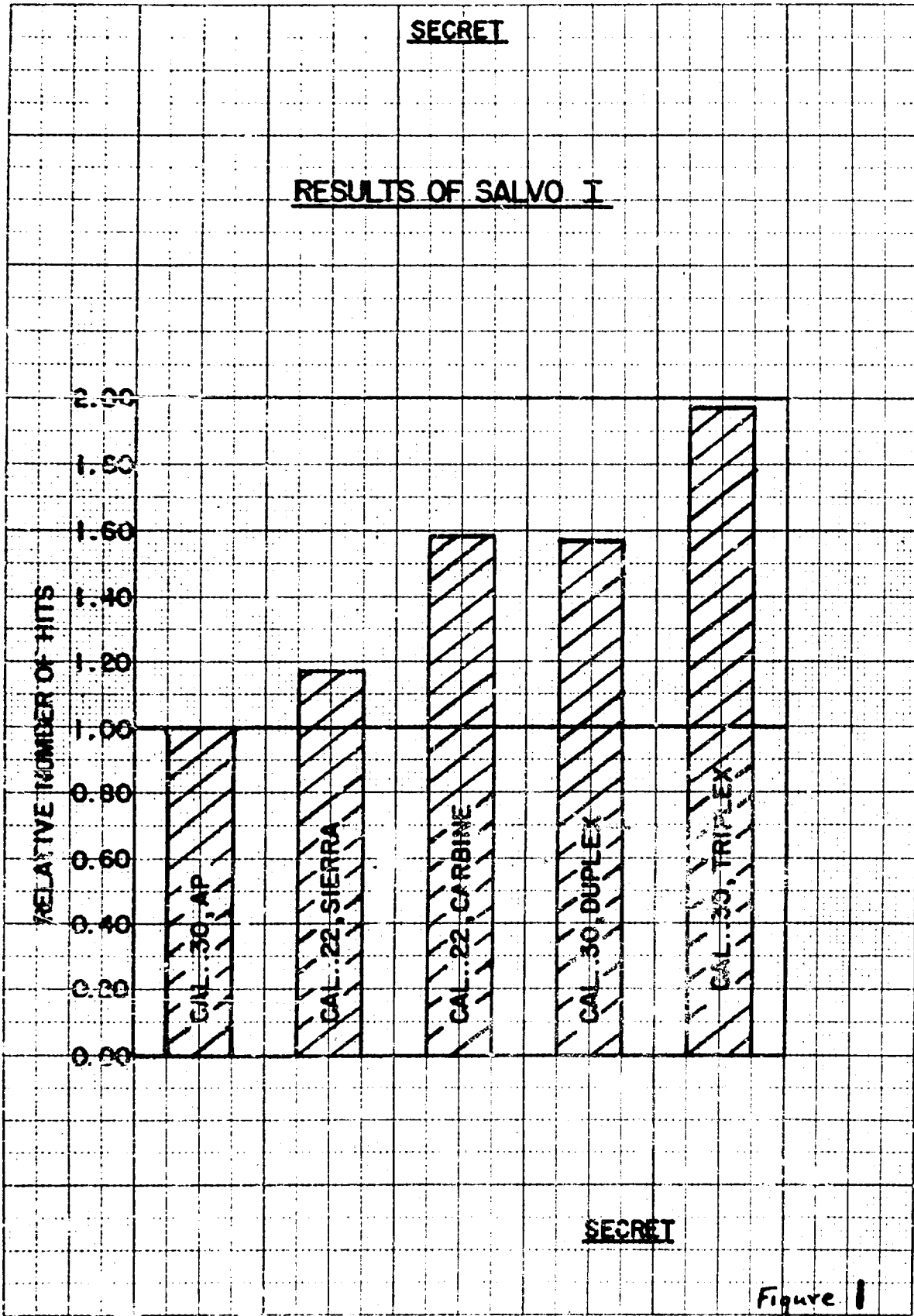
R. L. Simmons

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RESULTS OF SALVO I



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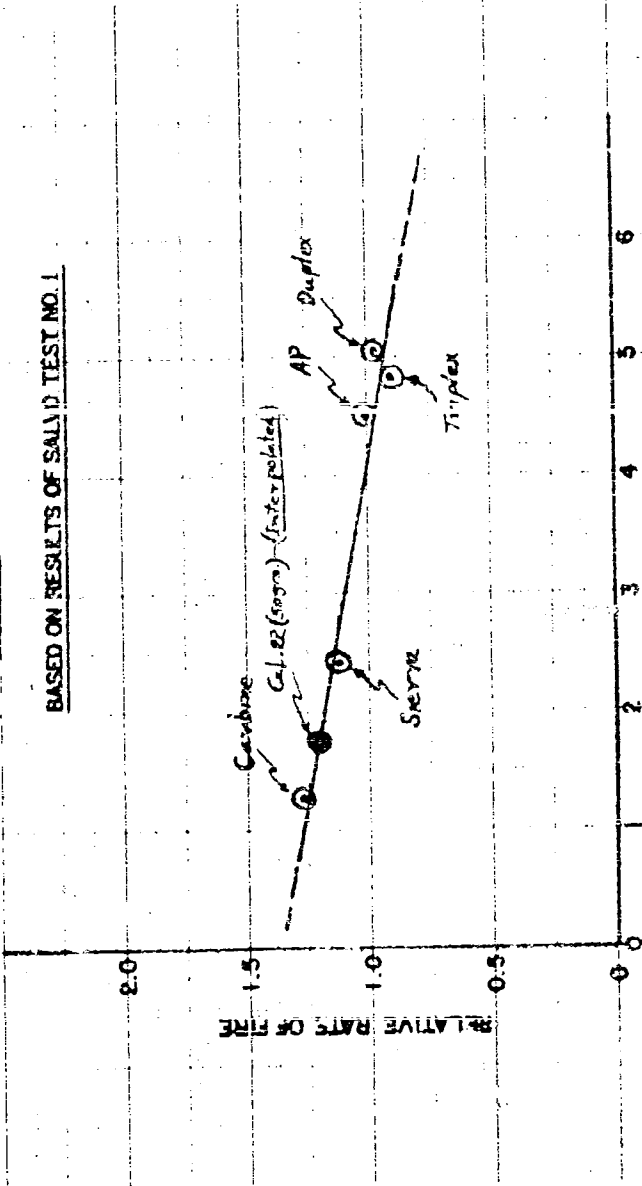
Figure 1

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RELATIVE RATE OF FIRE
VS
MUZZLE MOMENTUM

BASED ON RESULTS OF SALVO TEST NO. 1



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MUZZLE MOMENTUM
(GRS.-FT./SEC.) X 10⁵

Figure 2

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PERCENTAGE OF HITS VS RANGE

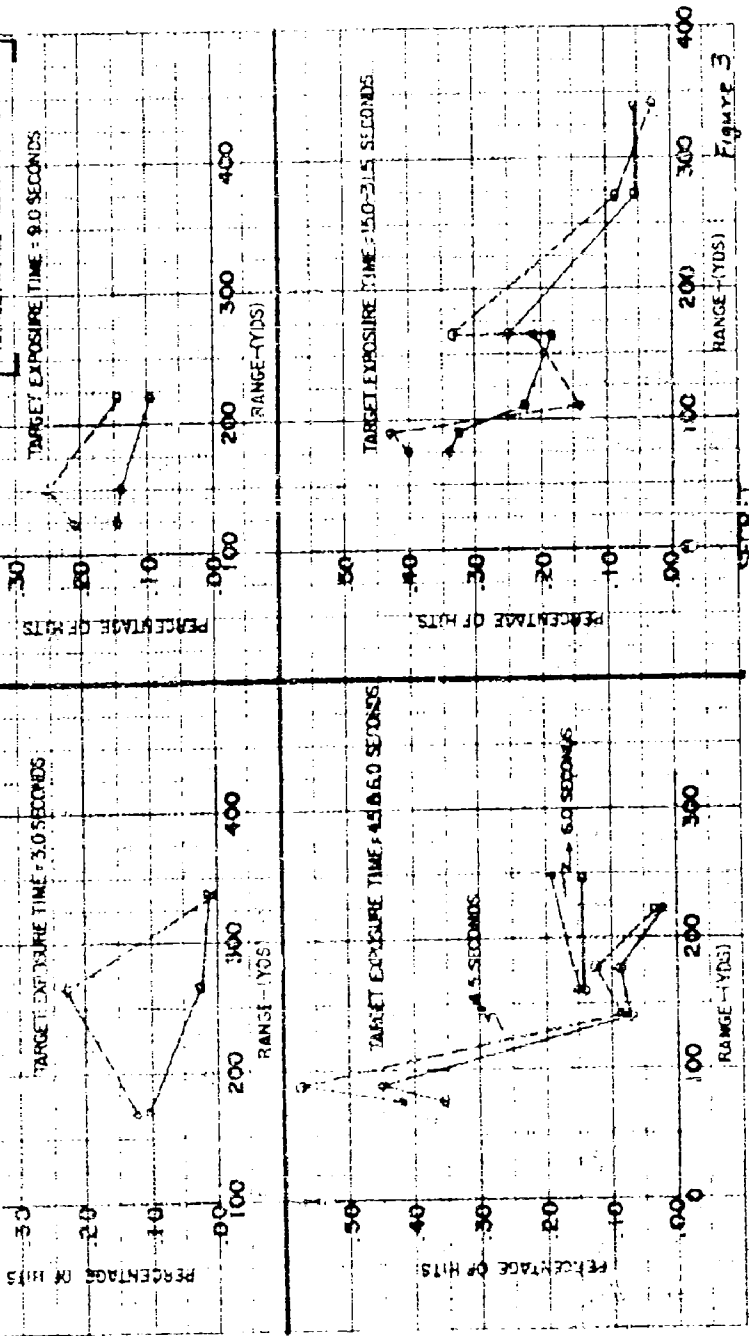
BASED ON RESULTS OF SALVO TEST NO. 1

LEGEND:

○ CAL. 30 AP

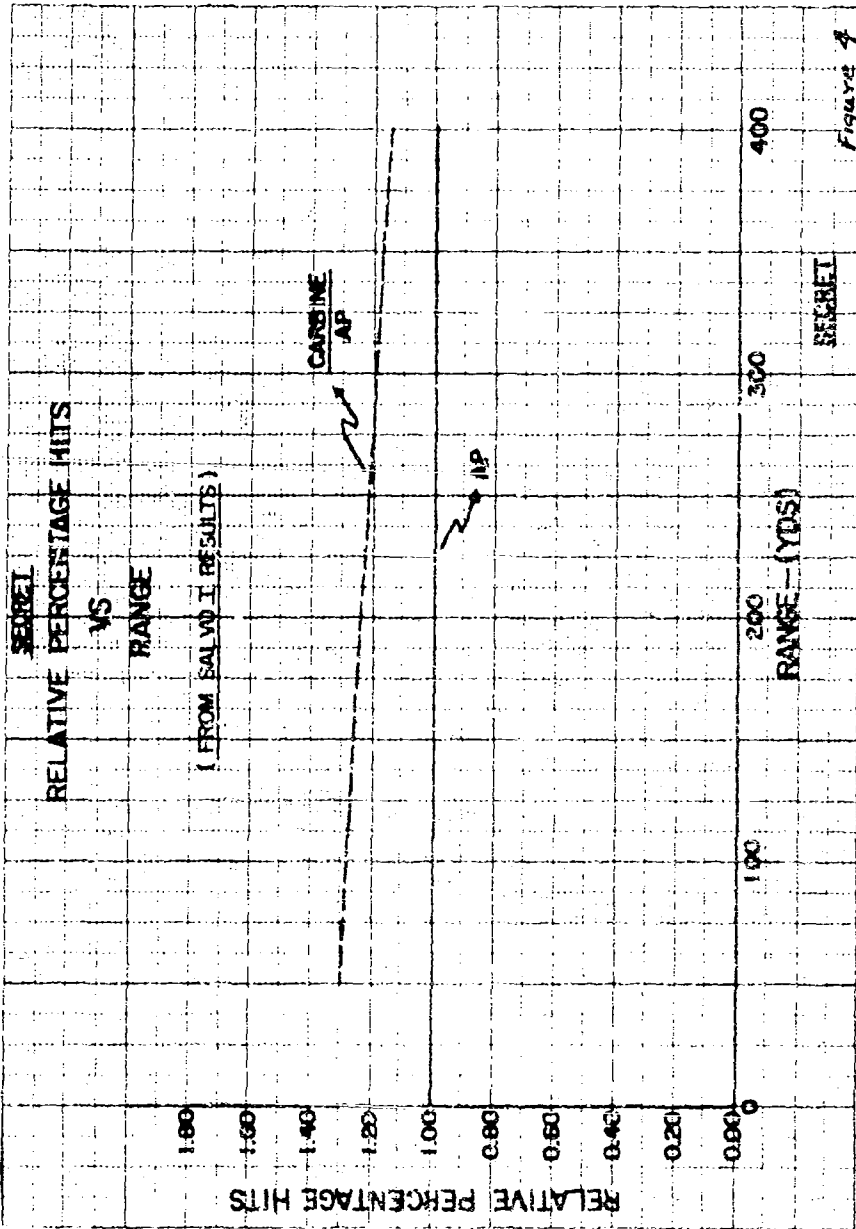
● CAL. 32 CARBINE

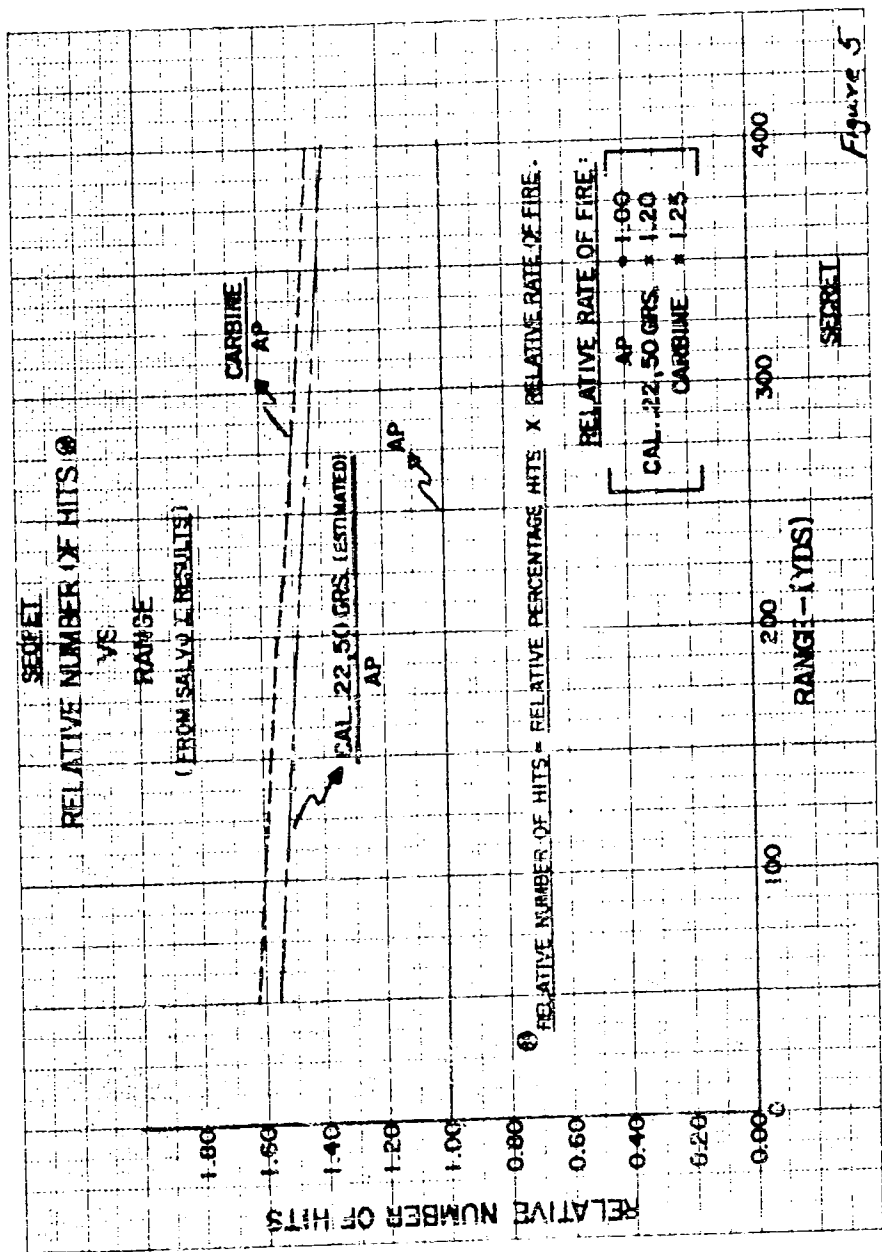
○ RANGE (TARGET LOCATIONS)



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Figure 3





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0 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 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

* PROBABILITY, P_{HK} , THAT A RANDOM HIT BY A BULLET

INCAPACITATES

CASE: ASSAULT SOLDIER - FIVE MINUTES AFTER WOUNDING

NOTE:

1.00
.90
.80
.70
.60
.50
.40
.30
.20
.10
.00

AS YET, UNPUBLISHED DATA
RECEIVED FROM MR. J. SPERRAZZA,
TBL, ORNL.

CAL. 22(50GRS)
B
TRIPLEX
DUPLIX
AP & SIERRA

P_{HK}

20

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* FOR 100% "SURE" KILLS ONLY.

Figure 6

10⁸

10⁷

10⁶

$MV^{3/2}$ (grains x ft/sec^{3/2})

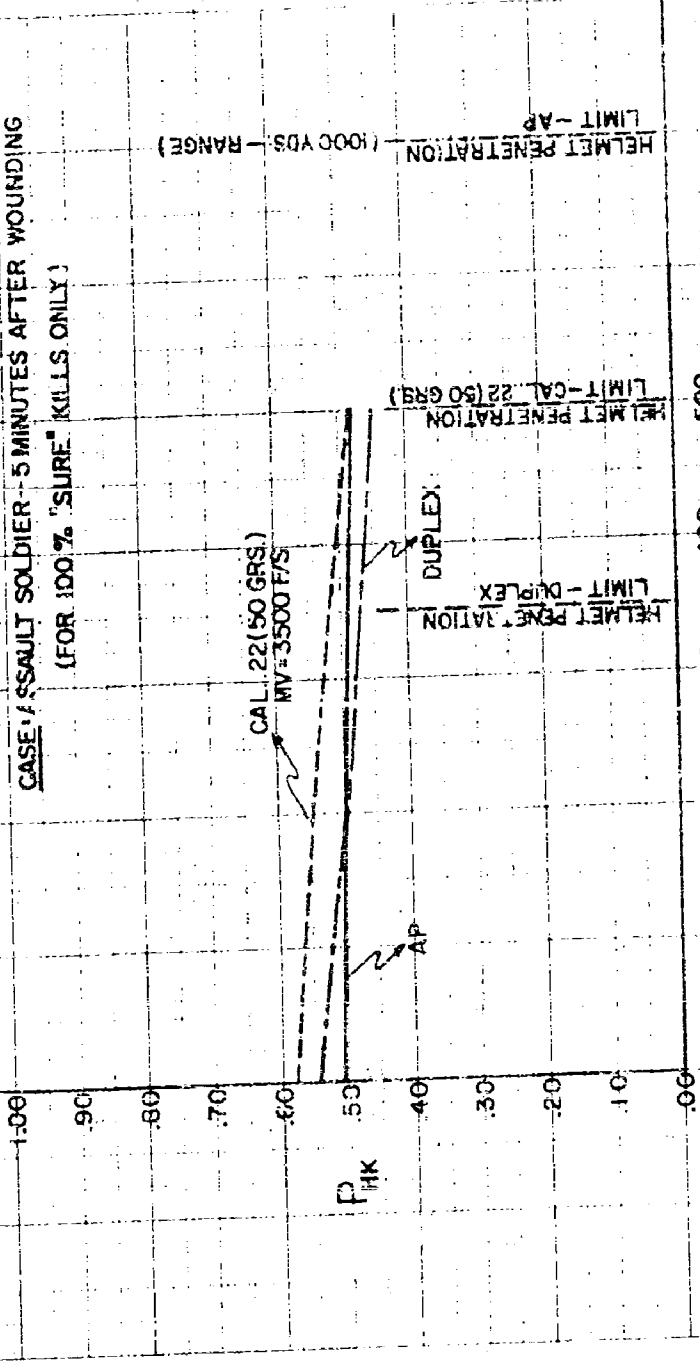
10⁵

10⁴

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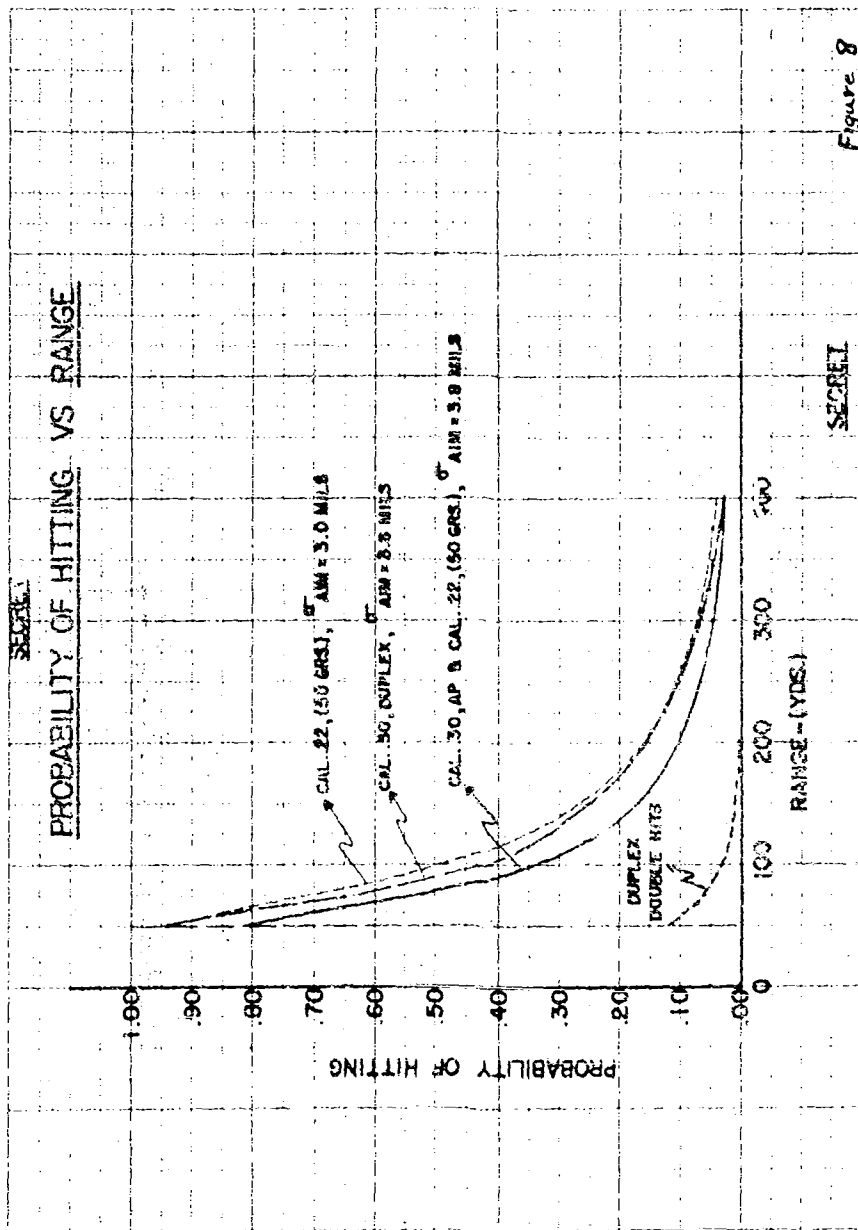
PROBABILITY THAT A RANDOM HIT BY A BULLET INCAPACITATES

CASE: / ASSAULT SOLDIER - 5 MINUTES AFTER WOUNDING
(FOR 100% "SURE" KILLS ONLY)



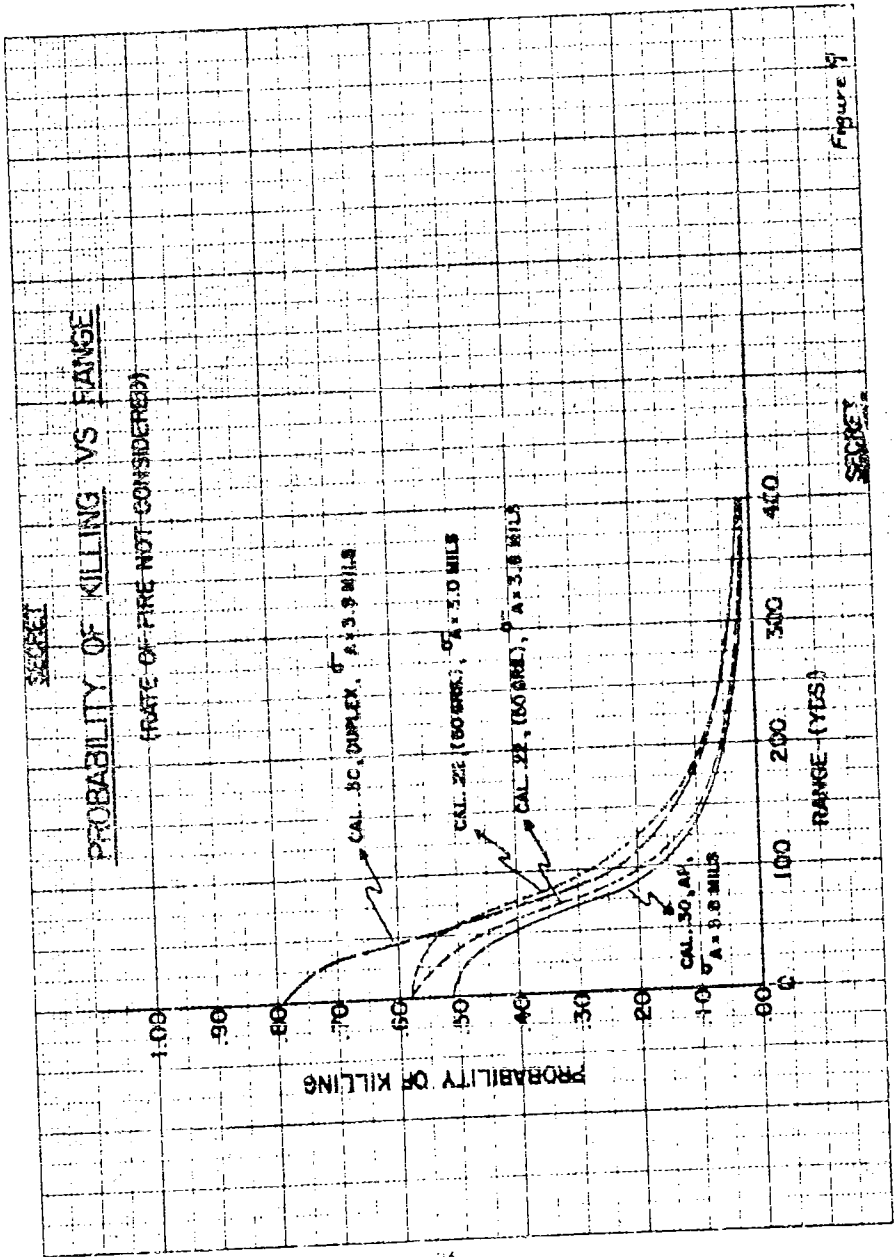
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Figure 7



SECRET

Figure 8



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RELATIVE EFFECTIVENESS VS. RANGE

CAL. 30 DUPLEX (AP)	n 1,000
CAL. 30 (AP)	n 1,205

RELATIVE RATE OF FIRE

RELATIVE EFFECTIVENESS

RANGE (YDS.)

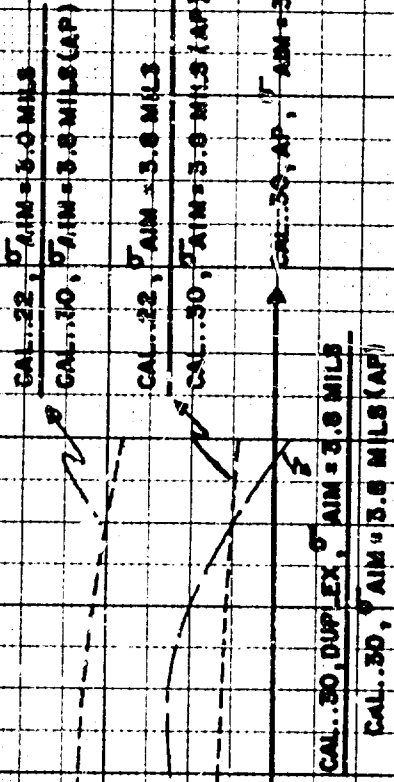
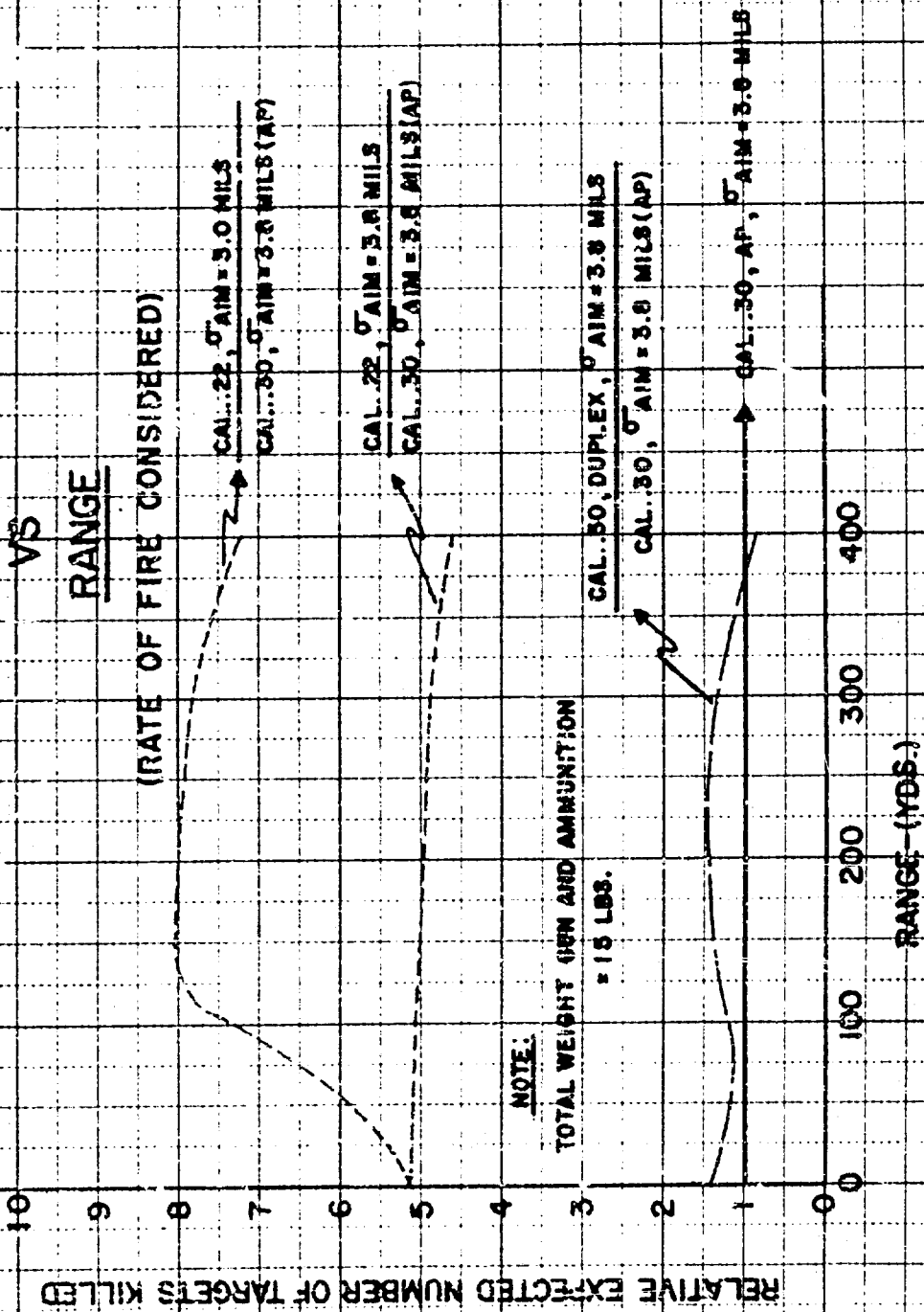


Figure 10

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RELATIVE EXPECTED NUMBER OF TARGETS KILLED



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Figure 11

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