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21005

HUMAN FACTORS EVALUATION OF THREE SPIW PROTOTYPE WEAPONS (U)

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August 1964

DRAFT

~~CONFIDENTIAL~~

ACKNOWLEDGMENT

The assistance given by Robert T. Gschwind and Major R. V. Krogh is greatly appreciated, as is the advise and assistance rendered by other members of the Weapons Branch, Human Engineering Laboratories, in the reduction of the data.

SUMMARY

The aspects of weapon performance considered in the human engineering evaluation are the following:

1. Noise and blast.

2. Pointability.

3. Pseudotactical, that is, Day Defense performance.

4. Particulate Matter hazard.

5. Rapid Grenade fire performance (pilot study).

The conclusions made are as follows:

1. In general, none of the weapons are optimum. It is probably possible to improve all the weapons.

2. Neither the test nor control weapons are optimum from the standpoint of pointability, that is, it is estimated that significantly greater hit probabilities can be achieved by appropriate redesign. In some cases this design is minor and in other cases an extensive redesign may be in order.

3. The SPIW weapons show significant improvements over the conventional weapons only when they are firing multiple rounds per trigger pull.

4. From the standpoint of noise hazards, the AR-15 is acceptable and is the safest of all weapons tested. The M-14 is acceptable and marginally safe. Damage will occur above 4kc, but this is not compensable damage. All SPIW weapons and the M-16-M are unacceptable since they will cause permament hearing losses which are compensable.

5. Preliminary examination of the data indicates that the fiberglas particles originating from disintegrating sabots are probably not a serious hazard to the firer. Tests conducted at Aberdeen Proving Ground did not indicate any potential for damage greater than what was indicated at Fort Benning.

6. It is not possible to make any positive conclusions at this time, based on available data, as to whether a single shot or three shot launcher would be more effective.

7. The rank ordering (in terms of hit capability) of the weapons is as follows:

a. Quick-Fire:

(1) AAI

(2) Springfield

(3) Winchester

(4) M-14

(5) M-16 and M-16-M

b. Day Defense:

(1) AAI

(2) Springfield, Winchester, and M-16-M

(3) M-14 and M-16

RECOMMENDATIONS

1. If a serially fired weapon is developed it will be necessary to devise a muzzle brake compensator which produces a sound characteristic that is no more detrimental than that of the M-14.

2. A weapon development program should include further studies, the purpose of which will be to provide an optimum configuration.

3. Based on the above recommendations, a serially fired weapon will require the inclusion of all the following properties in the muzzle brake:

a. It must be relatively quiet.

b. It must reduce impulse and introduce the appropriate amount of compensation with larger values of h than have been considered to date.

c. It must be a flash hider.

d. It must be relatively lightweight.

It is not known at this time whether such a device could be designed. It is therefore recommended that examination of non-serially fired weapons be continued.

4. In order to determine the appropriate design of a grenade launcher, that is, whether it should be a single or multiple shot launcher, the following questions must be answered:

a. What are the missions of the grenade launcher and their relative importance?

b. What penalties in weight, reliability, ease of maintenance, etc. are associated with multiple shot launchers?

c. What dispersion and rates of fire are associated with firing rapidly?

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INTRODUCTION

The following report is a compilation of reports related to the areas below. These were some of the investigations initiated to evaluate the three SPIW prototype weapons that were fired at Fort Benning and Aberdeen Proving Ground during March and April of 1964. Those aspects of the weapons which were considered of greatest importance to the human engineering evaluation are as follows:

1. Pointability.

2. Auditory damage to the firer.

3. Hazard due to sabot disintegration.

In addition, this report concerns itself with the selection and matching of the firers who were the subjects in the experiments and with comments on certain aspects of the Day Defense and Mean Extreme Spread Tests.

Appendix A contains a description of a pilot study conducted to attempt to examine the utility of 3-shot grenade launchers.

POINTABILITY

An ORO study[1] has indicated that in all probability a very large percentage of rounds expended by riflemen are not aimed, but rather are pointed. A study performed by HEL in conjunction with the Infantry Board indicated that the behavior of a firer when he is shooting very rapidly is quite different from the well known case where he is taking careful aim. The relationships involved are discussed in HEL TM 6-64, "Effects of Configuration on Quick Fire Accuracy."[2] The conclusions arrived at from that study are that configuration is very important and that extremes of performance on the order of 4 to 1 may occur between good and bad pointing weapons. It further concluded that an overall configuration similar to a shotgun was probably optimum.

Briefly, pointability is associated with what has been termed "quick-fire." Quick-fire is characterized by rapid target engagement, that is, on the order of 1 to 1½ seconds to fire the first round and from ½ to 3/4 second to fire the succeeding rounds. In addition, the weapon is not aimed, that is, the sights are not carefully aligned with the target.

As would be expected, aiming errors are considerably larger than those associated with even poorly aimed fire. Under these circumstances the firer's performance is very much affected by certain details of weapon design, such as, the length of the stock, weapon recoil, sight configuration, location of the right hand grip, etc.

PROCEDURE

In order to examine the pointability of a weapon a quick-fire course which contains the following elements is required:

1. A range between 20 and 80 meters. Forty meters appears to be about optimum for the purposes of data gathering.

2. Approximately eight targets at each range to be examined.

3. Target exposure times on the order of 2 to 3 seconds.

4. Thirty or more firers.

The actual range layout used in these studies is indicated in figure 1. The four 8 X 8 panels located behind the even numbered targets were used to witness the location of the shots that penetrated these targets (see Appendix C for a discussion of the instrumentation details) in order to get estimates of offsets and variability about the offsets. All eight silhouettes were instrumented to record hits. The firer did not know where a target would come up, when it was going to come up, or for how long it would stay up. Because of the location of the cameras and the light boxes the targets were not dug in, but rather were placed behind sandbags on top of the ground. This procedure eliminated most of the ricochets and explains why some of the hit percentages noted in this study are less than those measured in other studies[3].

The firers were grouped into six independent matched groups of nominally 30 firers each. They were matched as is indicated in Appendix B. They would also have been matched by their quick-fire test scores, however, that data was not available in time to be useful for matching purposes. The quick-fire test scores indicate that the groups were reasonably equal and, as indicated in Appendix B, the correlation between the test score and their actual performance indicates that the quick-fire test is not always a good indicator of performance on the course.

For those weapons which fired both controlled bursts and semi-automatically, that is all except the M-14 and the M-16, the odd

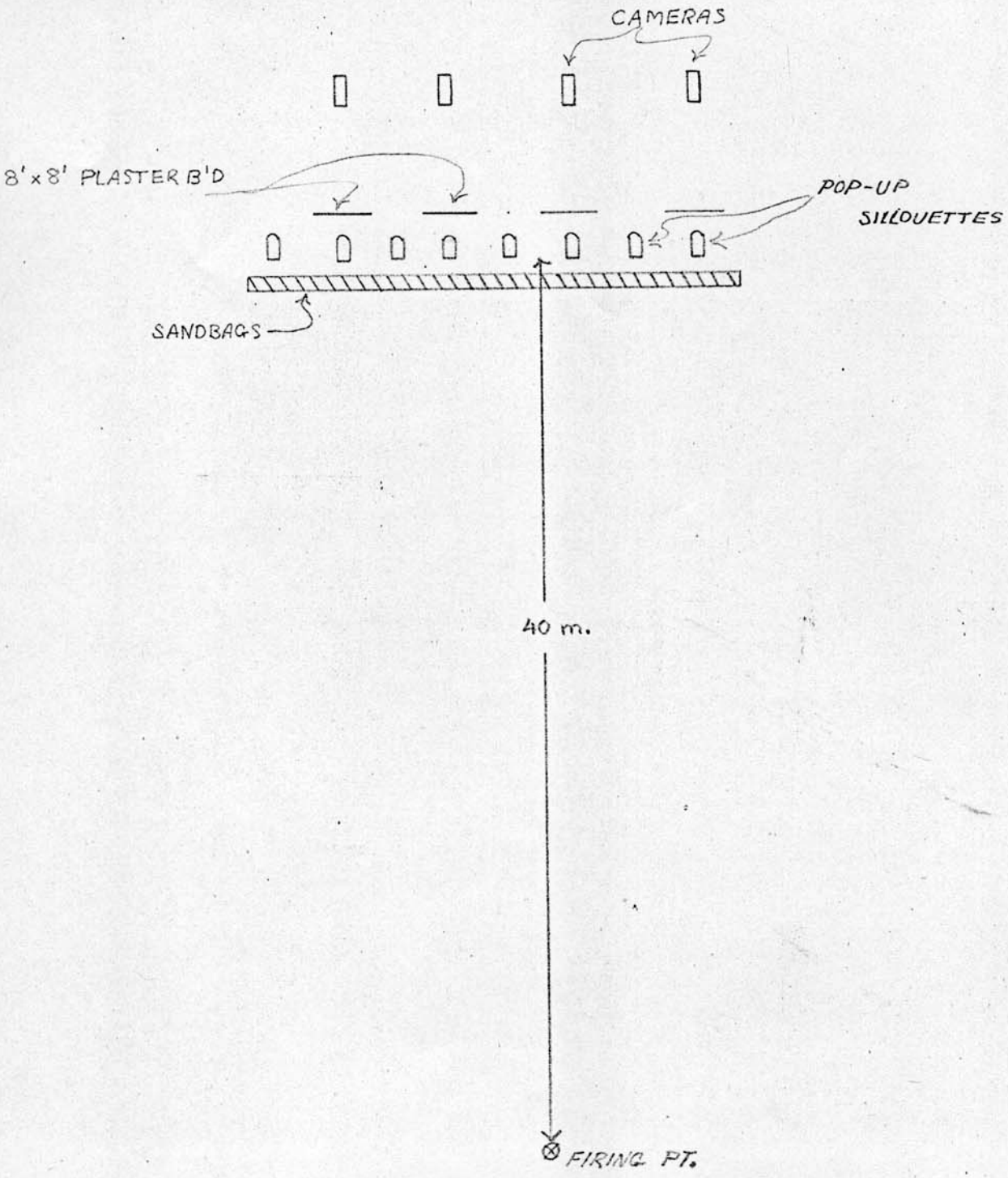


Fig. 1. QUICK-FIRE RANGE LAYOUT

numbered firers fired semi-automatic for their first pass through the course while the even numbered firers fired controlled bursts. This was reversed for the second trial and reversed again for the third trial. Two target sequences were used; the second sequence, used for the second trial, being the reverse of the first sequence. The third trial utilized the first sequence.

The data that was recorded consisted of the following:

1. The firer's number.

2. Mode of fire.

3. Weapon type.

4. Order of target presentation.

5. Time of appearance of each target.

6. Time of occurrence of each shot and hit. Note that for controlled burst firing all three shots were distinguishable on the record as were multiple hits.

7. The point of impact of each round that hit the 8 X 8 witness panel.

This information was recorded on film and on an oscillograph as outlined in Appendix C.

The firers were trained and matched around the middle of March; that is, shortly before the test firings commenced at Fort Benning. The training consisted of a briefing on the pointing technique and practice with M-14 rifles at tin cans at 25 meters. The firers were then given firing practice during the quick-fire phase at the end of April.

DESCRIPTION OF THE WEAPONS

A detailed description of each weapon can be found elsewhere[4]. The notable features affecting pointability of each weapon are as follows:

1. AAI: The weapon has a pistol grip, small drop at the comb, a reasonably smooth sight line, and sights which are not excessively bulky.

2. Springfield: This weapon has a pistol grip, a high sight line with a straight, flat carrying handle comprising most of the sight line, and a straight stock.

3. Winchester: This weapon is characterized by having a design which is almost that which is considered optimum except that the rear sight is quite high and the stock is short.

4. M-14: This weapon is again near optimum except that the sight line is slightly cluttered, the rear sight is bulky, and the stock is short.

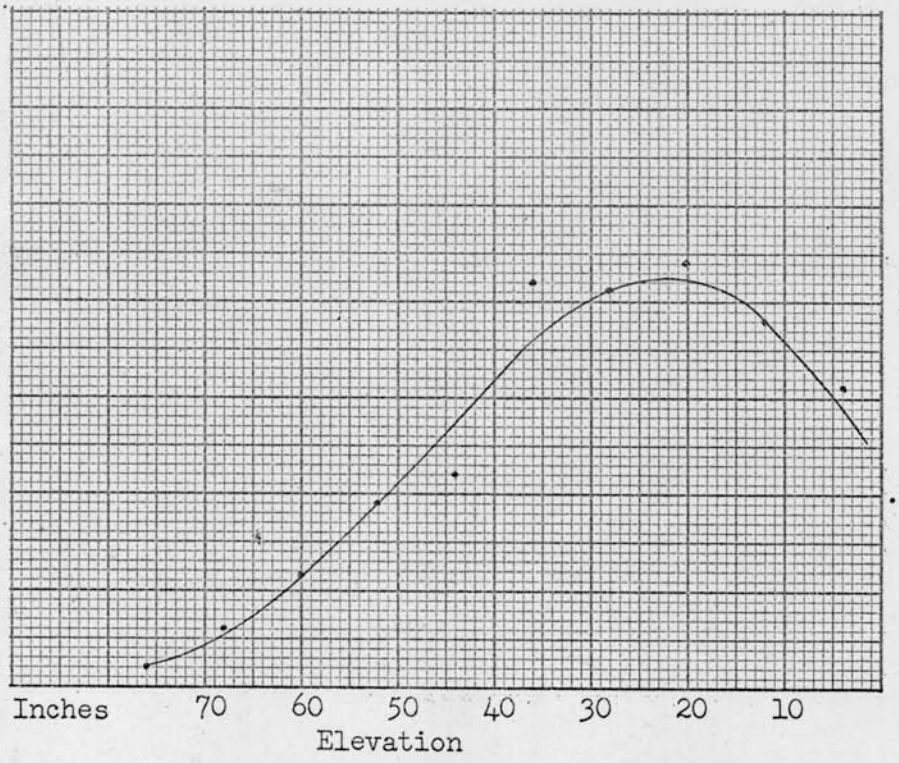
5. M-16: This weapon is characterized by the same features as the Springfield weapon with the exception that the carrying handle and the front hand grip are sloped.

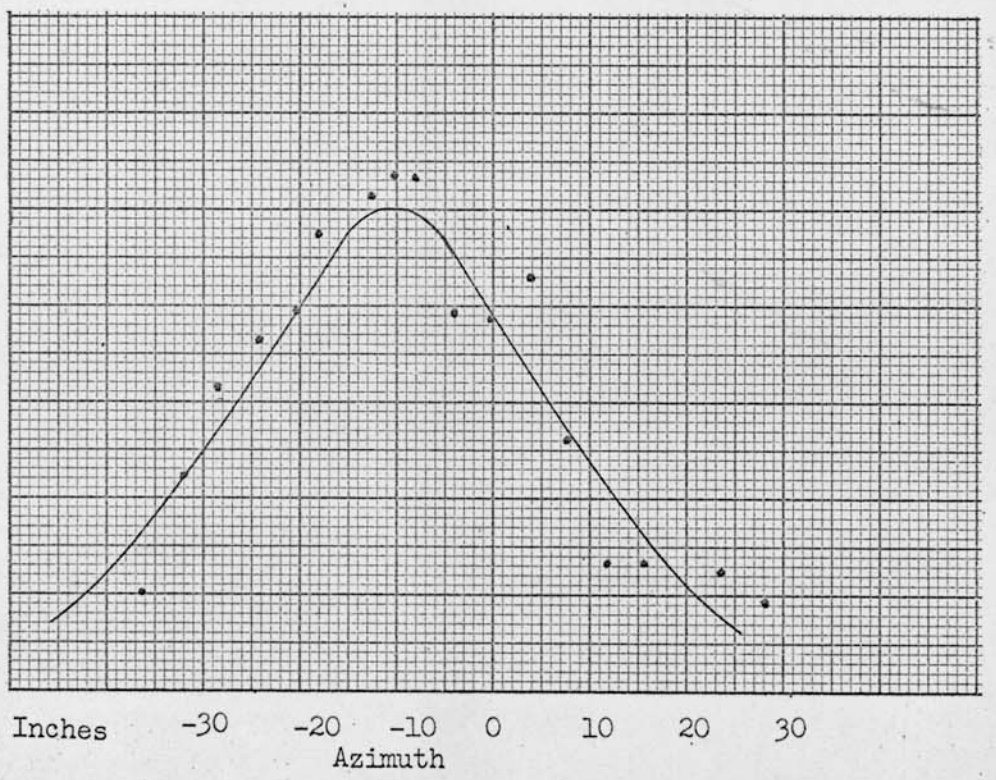
6. M-16-M: This weapon has the same features as the M-16 with the addition of a muzzle brake compensator which has a large down and to the left compensation.

DISCUSSION OF RESULTS

The curves presented in Figures 2 - 7 represent azimuth and elevation distributions of shots as recorded by the cameras behind the witness panels. The azimuth curves are normal curves that are the best fit to the data. The elevation curves are smooth lines that appear to be a reasonable fit to the data and are markedly non-gaussian.

Certain unusual features appear in the data which are not readily explainable. For example, the azimuth curves indicate a fixed bias to the left and, in addition, the data points themselves indicate a certain similiarity from one weapon to the other in their deviation from the normal curve. That is, a curve drawn to the data points would indicate a more peaked curve than the normal distribution predicts, with a certain degree of bimodality indicated at $x = \bar{x}$ and $x - 0$ (the center of the target silhouette). It is possible that this is caused by "left eyed" firing although one would certainly not expect to find a population with more left eyed firers than right eyed firers when the population is of this size. It should also be noted that with the exception of the Winchester and the M-14, the azimuth error is essentially the same for all weapons, that is, about 16 to 17 inches. The larger M-14 dispersion can probably be explained by the fact that the large recoil (2.65 lb/sec) causes considerable jump of the weapon. A conceivable explanation for the large Winchester azimuth dispersion is that the rear sight obscures right eyed vision for a lot of the shooters and besides looking over the sight, they look around it.



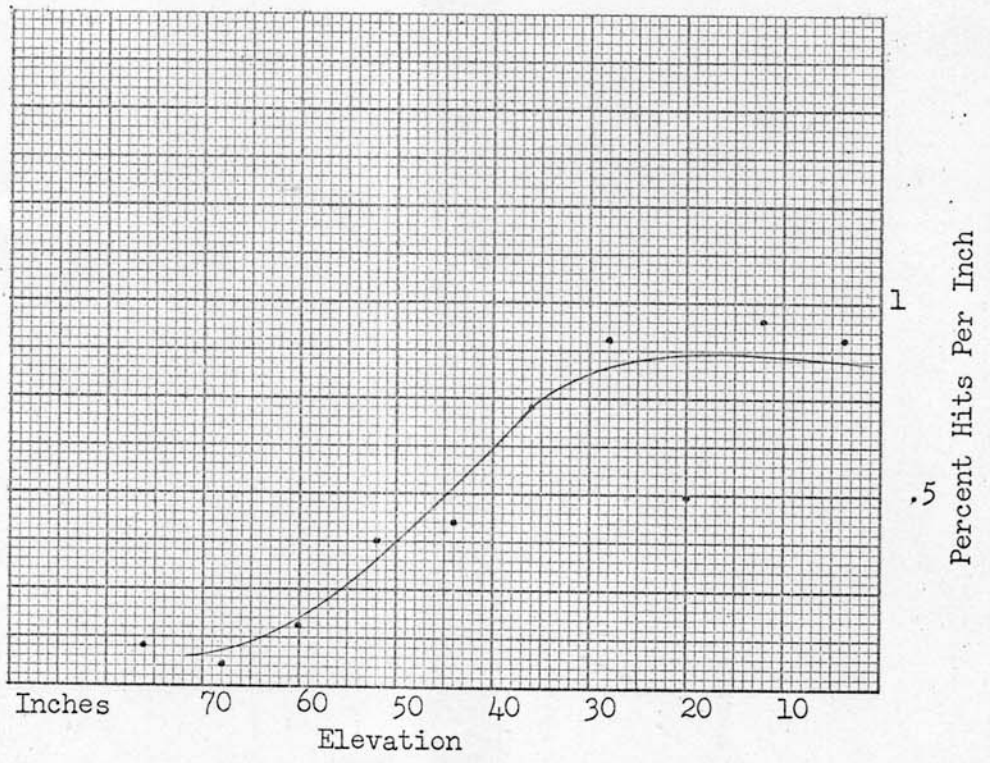


$\bar{X} = -10$

$\sigma = 16$

Fig. 2.(c) AZIMUTH AND ELEVATION DISPERSION (u)

Springfield



$\bar{X}$ = -9

σ = .17

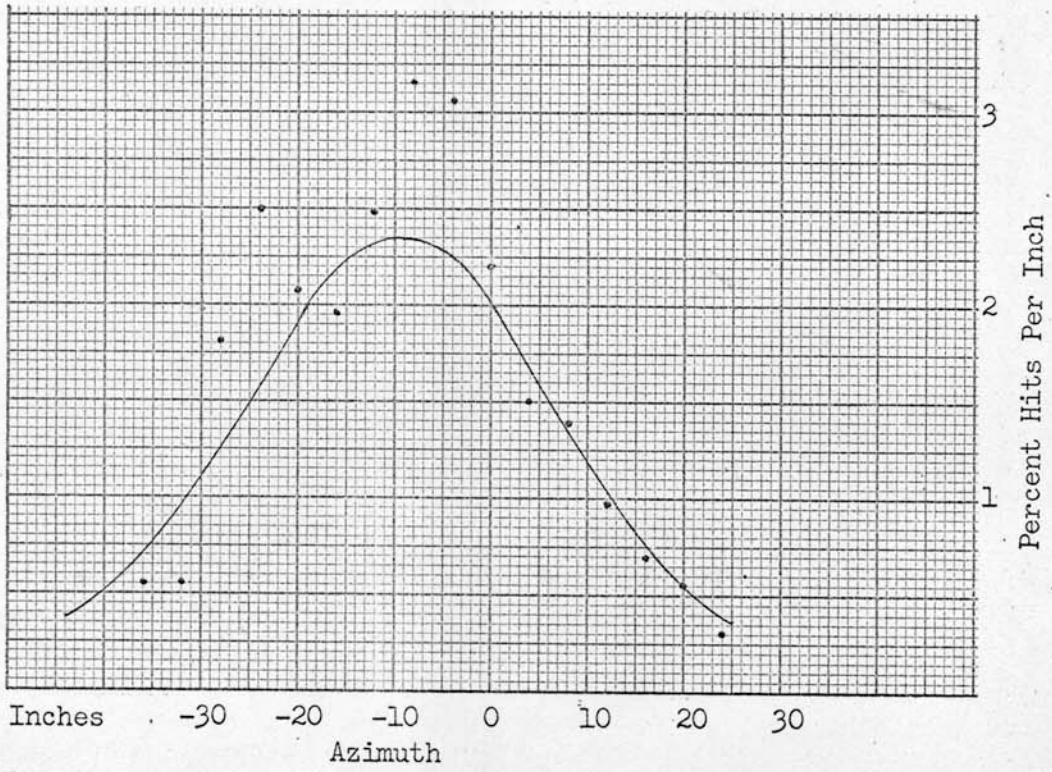
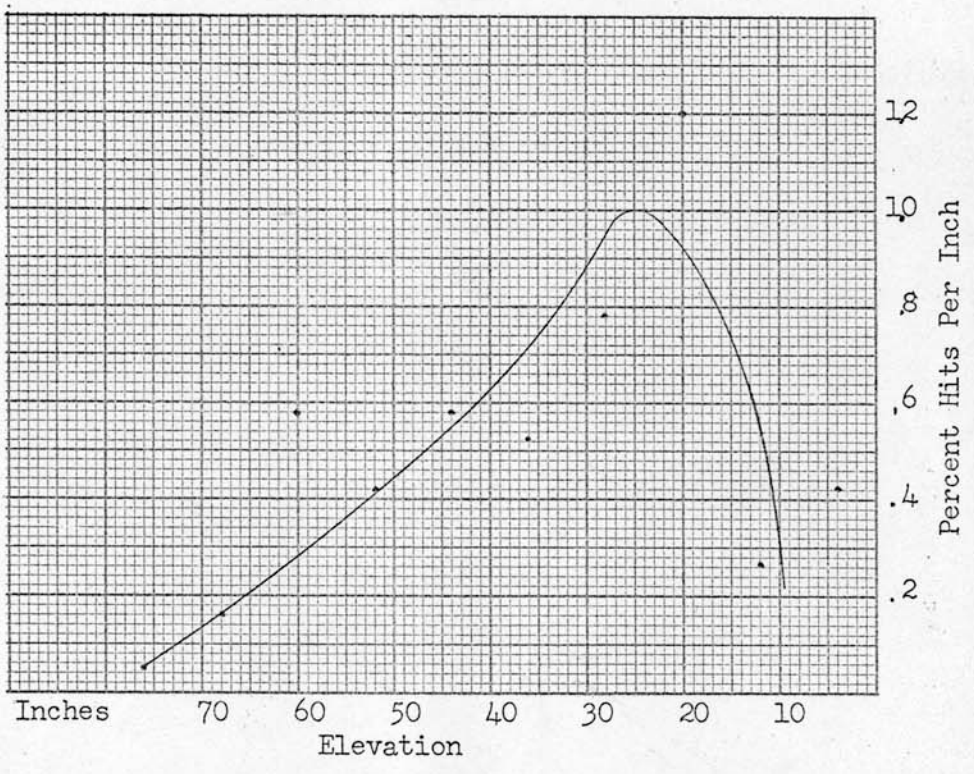
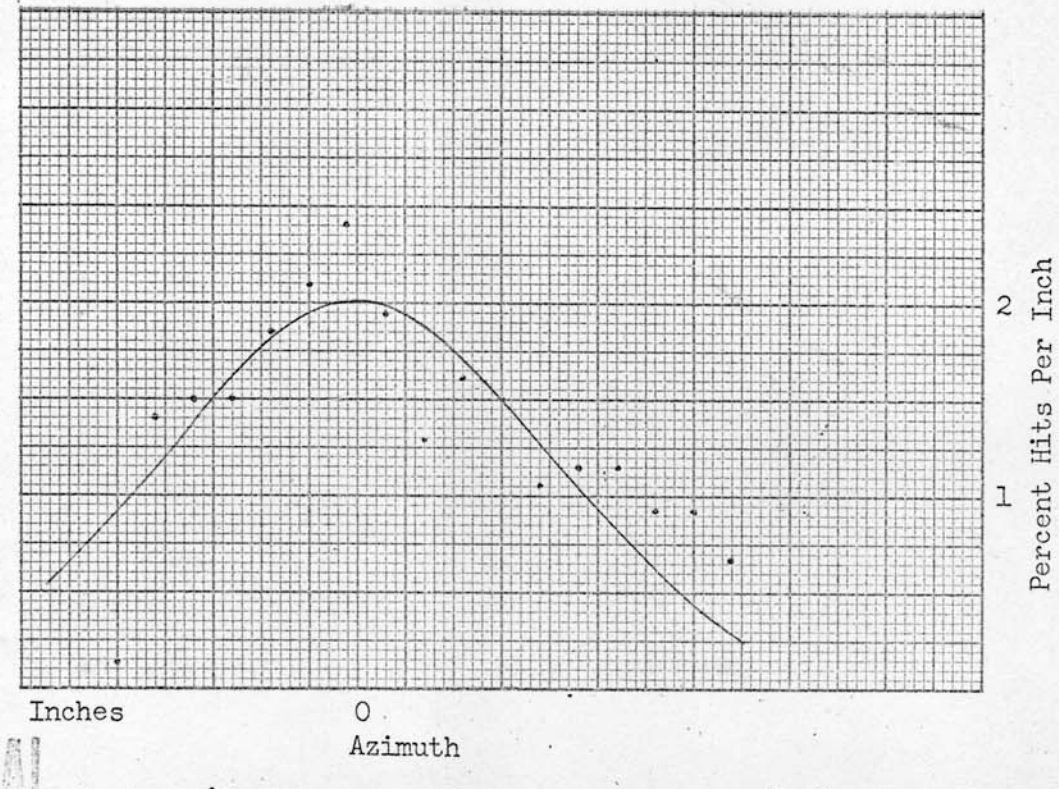


Fig. 3. (c) AZIMUTH AND ELEVATION DISPERSION (U)

Winchester

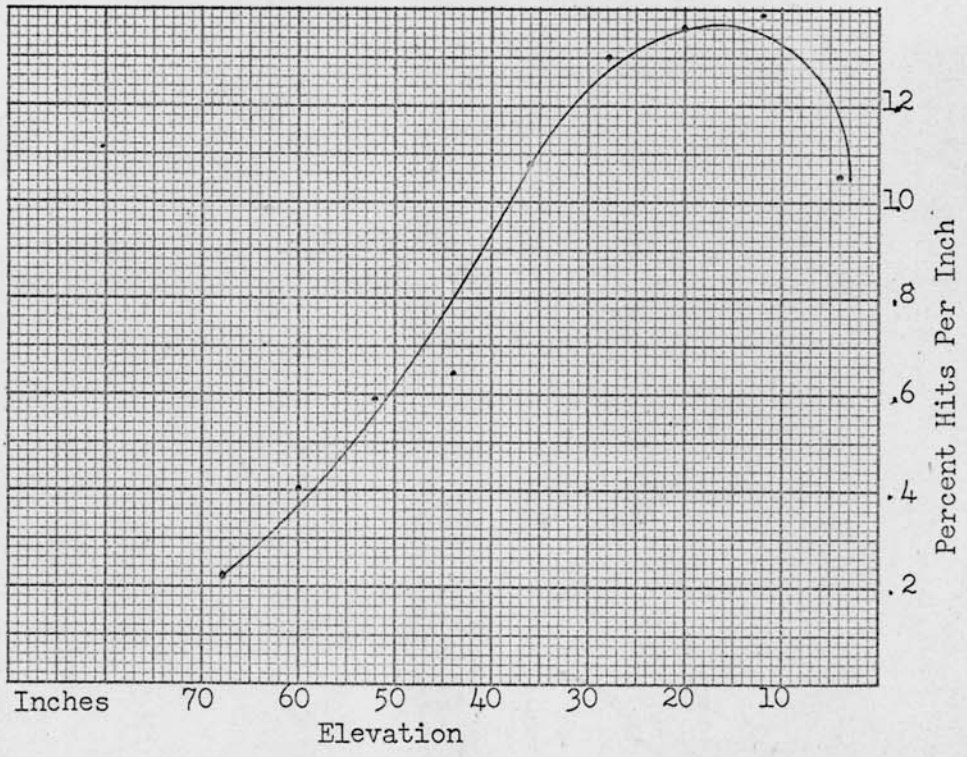




$\bar{X} = 14$

$\sigma = 20$

Fig. 4. (C) AZIMUTH AND ELEVATION DISPERSION (U)



$\bar{X} = -5$

$\sigma = 20$

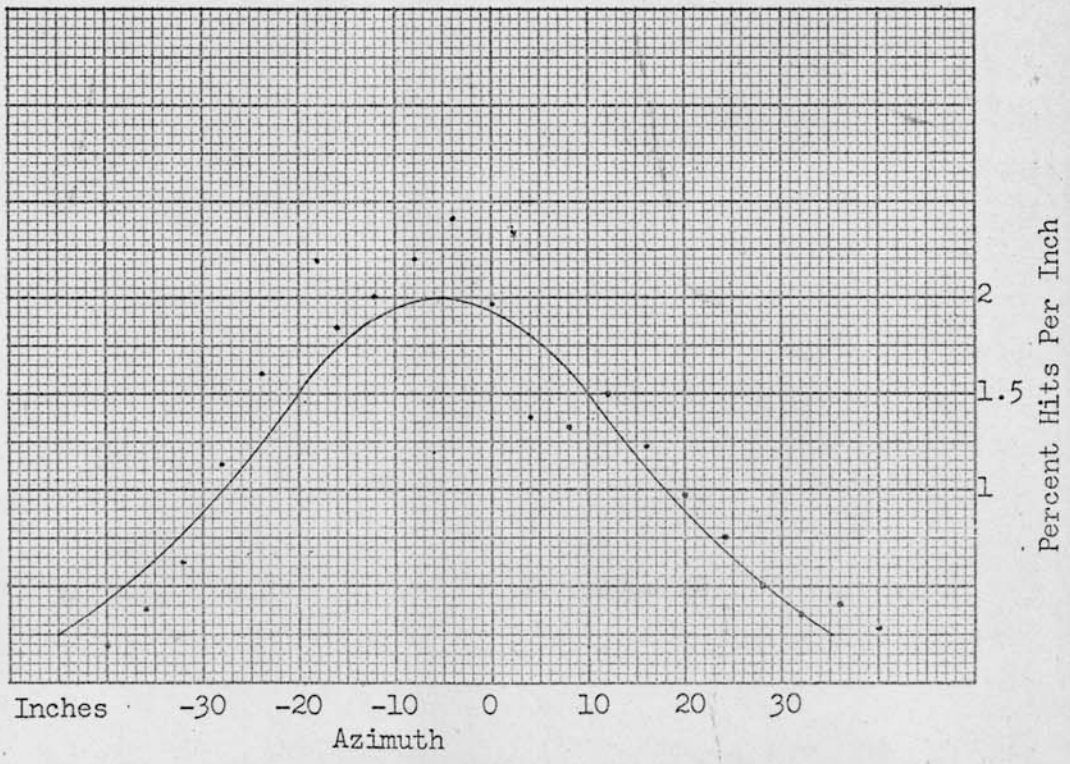
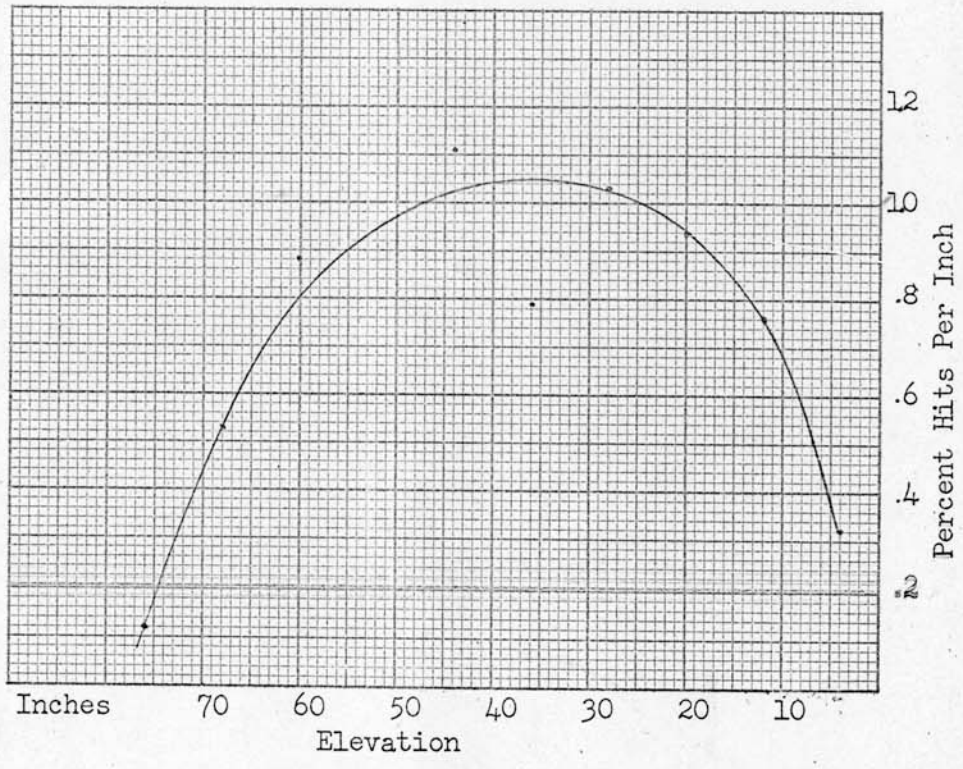


Fig. 5. (c) AZIMUTH AND ELEVATION DISPERSION (u)



$\bar{X} = -10$

$\sigma = 17$

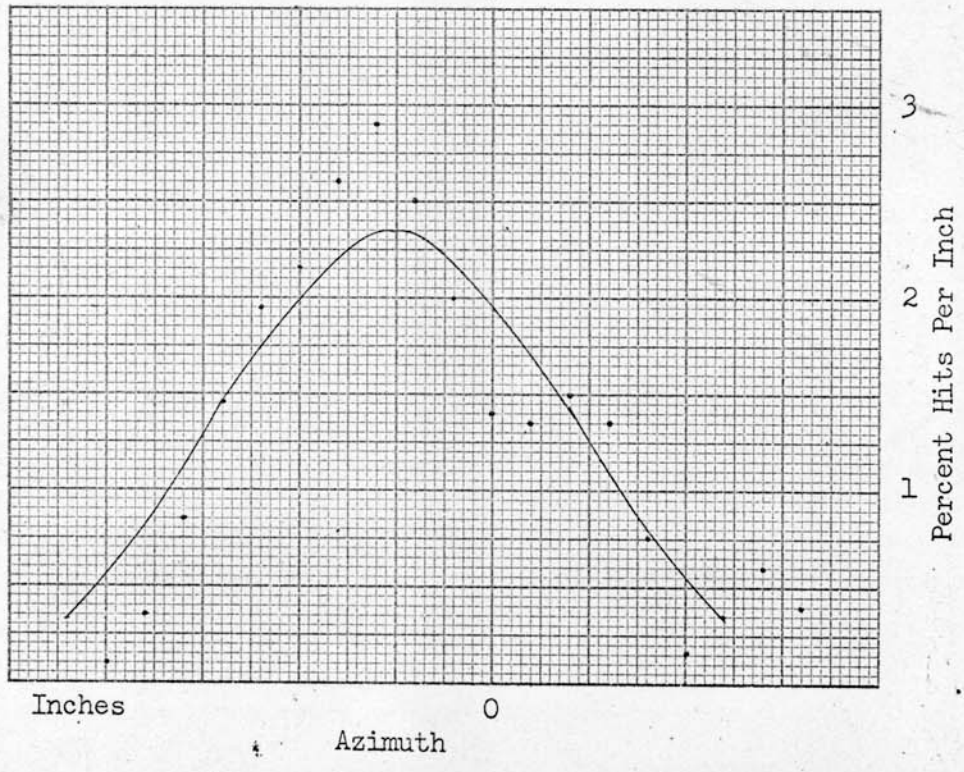
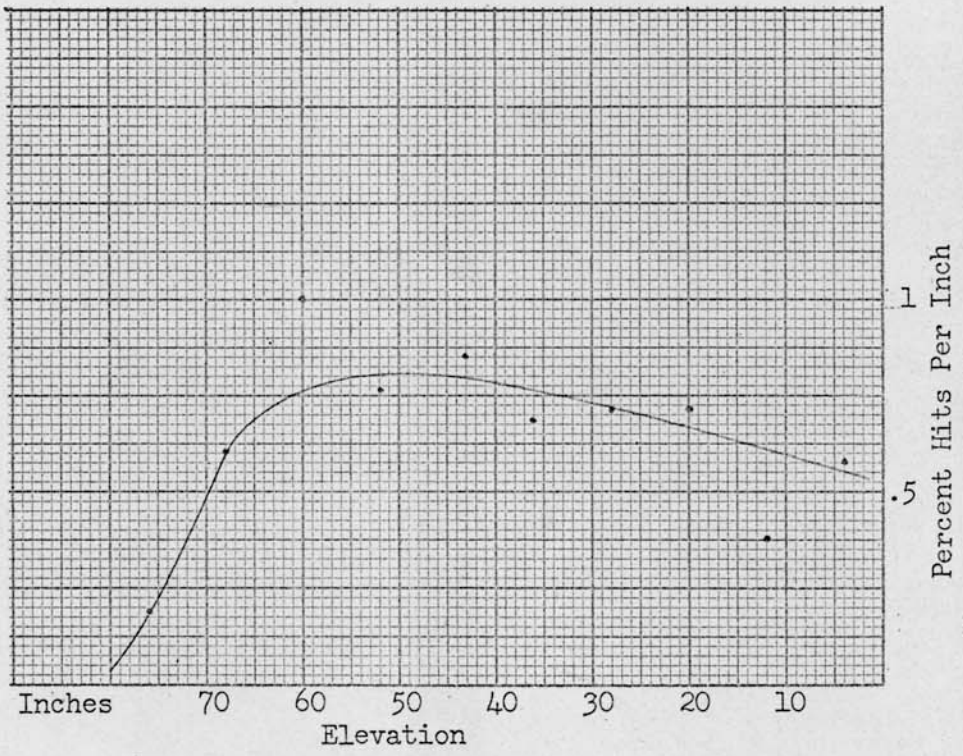


Fig. 6.(c) AZIMUTH AND ELEVATION DISPERSION (U)

M-16 Modified



$\bar{X}$ = -5

σ = 16

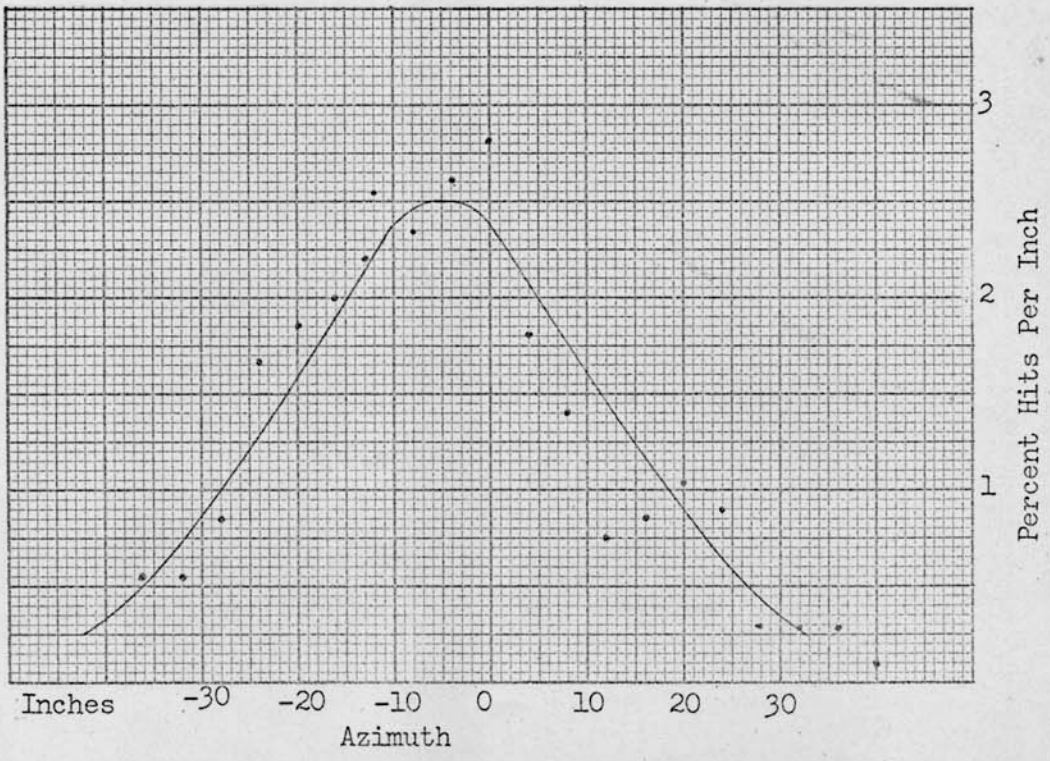


Fig. 7. (C) AZIMUTH AND ELEVATION DISPERSION (U)

The data points indicated on the elevation curves appear to be much noisier than those of the azimuth curves. In addition, examination of the data indicates that essentially all the rounds are within the confines of the azimuth field of view; that is, the curves taper off to essentially zero before the limits of the camera system have been reached. This is not the case with the elevation data. Approximately half the rounds fired hit the panels, but extrapolation of the elevation curves in the downward direction does not account for the missing rounds in most cases. This affect cannot be readily explained.

Table 1 is a summary of the quick-fire data. The numbers represent overall differences between the weapons. At this time the confidence intervals for the means have not been calculated, but based on previous work, differences on the order of 10 to 20 percent between weapons should be significant at about the .10 level.

Figure 8 represents estimated cumulative hit probabilities for at least one hit per trigger pull which is equivalent to percent successful trigger pulls. The times are estimated times from other studies[2, 3] since at this writing this data has not yet been reduced. There is little reason to believe these estimated times are significantly in error. The data represented in this figure are taken from Table 2 and only selected curves have been shown.

The data shown in Figure 9 and Table 3 indicate the estimated hit probabilities as a function of trigger pull. Notice that the M-14 performance is degraded by the large recoil impulse, that is, the first and second rounds have higher P_h associated with them than do the succeeding rounds. This is not the case with the lower recoil weapons. Notice also that the first round P_h of the M-14 is higher than any of the other weapons firing semi-automatically which indicates that the M-14 has fundamentally better pointability than the other weapons. One would expect that a weapon could be designed which would have a pointability for all rounds at least as good as that of the M-14. One can conclude from this that none of the weapons are optimum from a pointability standpoint. In fact, other tests have indicated that a hit probability as high as 50 percent could be achieved for three-round bursts at 40 meters.

Table 4 represented targets hit, that is, the percent of the targets that were hit by at least one round. This figure is similar in meaning to cumulative percent successful trigger pulls. One difference is that the "targets hit" figure does not compensate for malfunctions. Another difference is that it represents a cumulative P_{h_1} averaged over the target exposure times and a weapon with a sharply changing slope may give a false average.

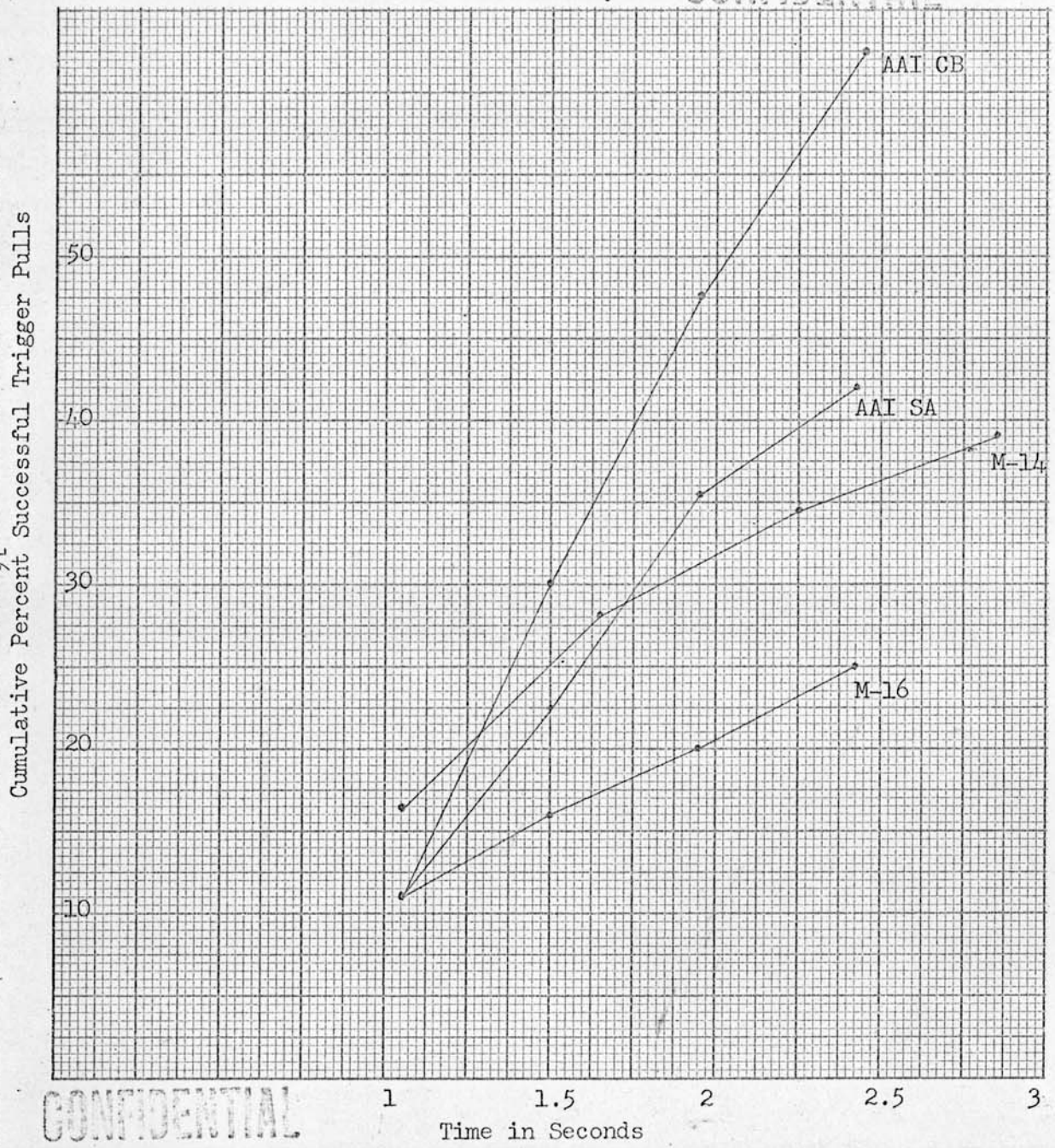


Fig. 8 (C) P_{h_2} VS. TIME FOR SELECTED WEAPONS (U)

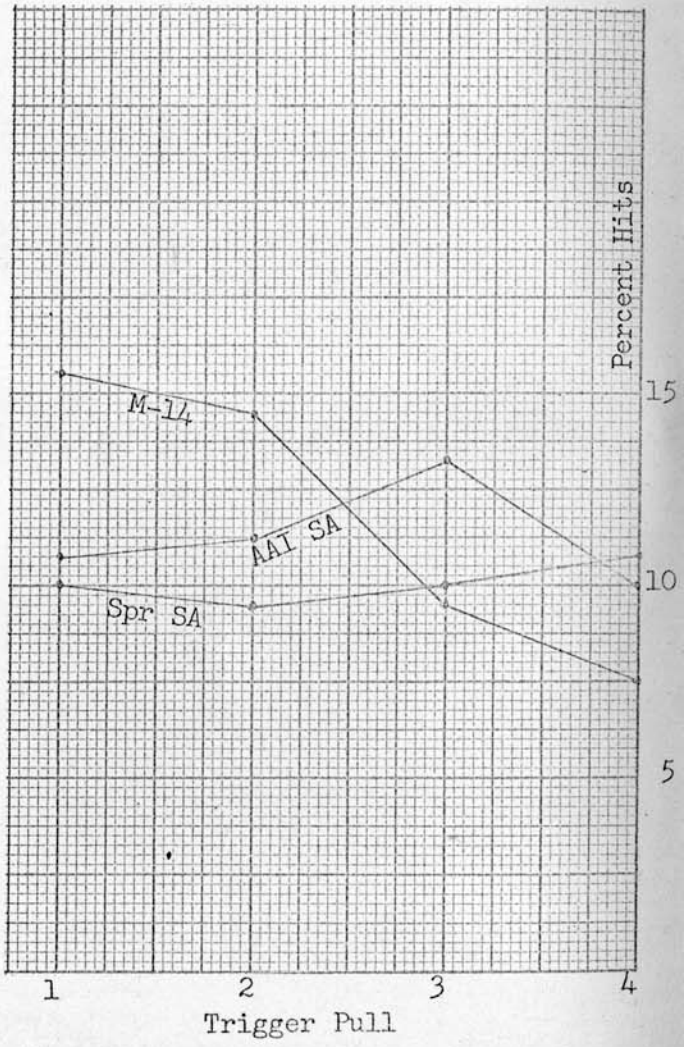


Fig 9 (C) PERCENT HITS VS. TRIGGER PULL NO. (U)

TABLE 1 (C)

Overall Percent Successful Trigger Pulls (U)

Weapon	SA	CB
AAI	13	23
Springfield	10	17
Winchester	6	15
M-14	14	
M-16	8	
M-16-M	5	8

TABLE 2 (C)

P_{h_1} VS. TIME (U)

Time of Trigger Pull (Secs. after Target Appearance)	Mode	AAI	Spring-field	Win-chester	M-14	M-16	M-16-M
1.1	SA	11.6	10.4	5.0	16.2	11.7	8.3
	CB	11.9	13.2	12.5			6.2
1.5	SA	22.6	18.9	12.8	25.0	16.0	13.4
	CB	30.3	28.2	27.1			
1.9	SA	35.5	27.2	16.9	31.2	20.2	17.9
	CB	47.4	41.1	39.2			
2.3	SA	41.9	35.6	19.6	36.2	24.9	22.5
	CB	62.7	48.4	51.4			

TABLE 3 (C)

Percent Successful Trigger Pulls vs. Trigger Pull (U)

Trigger Pull	Mode	AAI	Springfield	Winchester	M-14	M-16	M-16-M
1	SA	11.6	10.4	5.0	16.2	11.7	8.3
	CB	11.9	13.2	12.5			6.2
2	SA	12.5	9.3	8.5	14.2	4.9	5.5
	CB	21.0	17.2	16.6			8.5
3	SA	16.7	10.1	5.0	8.9	4.9	5.1
	CB	24.5	17.9	16.5			4.8
4	SA	9.9	11.5	3.2	7.4	5.7	5.5
	CB	28.9	12.4	20.0			2.1

TABLE 4 (C)

Percent Targets Hit (U)

Mode	AAI	Springfield	Winchester	M-14	M-16	M-16-M
SA	35.3	28.0	19.8	36.7	22.6	19.9
CB	46.1	34.4	25.1			19.8

CONCLUSIONS

1. For those weapons where the recoil is low, that is 1.2 lb/sec or less*, there is no significant difference in the azimuth aiming errors between weapons with the exception of the Winchester weapon.

2. There are, on the other hand, great differences in the elevation errors. They are characterized by distributions which are markedly non-normal.

3. The effect of recoil moments is significant, that is, the M-14 has an azimuth aiming error which is large compared to that for lower recoil weapons, and a comparison between the M-16-M and the M-16 indicates that the firers are probably overcompensating for the down and left compensation of the muzzle brake compensator on the M-16-M.

RECOMMENDATIONS

None of the weapons are optimum. The Aircraft Armaments weapon can probably be improved by removing the pistol grip, increasing the drop of the comb and by modifying the sights in accordance with HEL TM 6-64. It is not easy to see how the Springfield weapon could be improved without a major redesign which would, in effect, make it look like any other good pointing weapon. A program to investigate methods for increasing the effectiveness of the Springfield weapon would involve looking at details peculiar to this weapon which have not been examined elsewhere.

The Winchester could be greatly improved by modification of the sights and by an increase in the length of the stock. This weapon offers the greatest potential for improvement with the least amount of modification.

The muzzle brake compensator on the M-16-M is far from optimum and a significant improvement can be made by concentrating on that aspect of the weapon.

Recommendations relevant to the M-14 and the M-16 may be found in HEL TM 7-64[3] and an unpublished report to the AR-15 project manager.

It may become apparent that the marriage of good pointing characteristics and good three-round dispersion features may not be possible. This is due primarily to one cause; namely, that a good pointing weapon requires a large value of h which corresponds to a drop in the comb of about $2\frac{1}{4}$ to $2\frac{1}{2}$ inches. On the other hand, the design of a muzzle brake compensator that will produce the useful

* Recoil impulses are: M-14 - 2.65 lb/sec; M-16 - 1.2 lb/sec; SPIW weapons fired[5,4] .4 to .5 lb/sec

mean extreme spread values is facilitated by a small h. It would appear then that a solution to this problem (and also the blast problem) would be to develop a weapon cartridge system which fired the three projectiles simultaneously, thus, eliminating the muzzle brake.

CONCLUSIONS

1. For those weapons where the recoil is low, that is 1.2 lb/sec or less*, there is no significant difference in the azimuth aiming errors between weapons with the exception of the Winchester weapon.

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4. The M-14 has the best pointing characteristics although it does not necessarily achieve the highest hit capabilities when compared to weapons firing multiple rounds per trigger pull.

RECOMMENDATIONS

None of the weapons are optimum. The Aircraft Armaments weapon can probably be improved by removing the pistol grip, increasing the drop of the comb and by modifying the sights in accordance with HEL TM 6-64. It is not easy to see how the Springfield weapon could be improved without a major redesign which would, in effect, make it look like any other good pointing weapon. A program to investigate methods for increasing the effectiveness of the Springfield weapon would involve looking at details peculiar to this weapon which have not been examined elsewhere.

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