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(U) SIDEARM AND SHOTGUN AMMUNITION FOR COIN AND RAC

Report No. BAT-171-24

Prepared Under Contract SD-171

August 20, 1965

RACIC report

NO 53746

By

J. R. Thorson, G. R. Riley, and D. W. Frink

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August 20, 1965

Director
Advanced Research Projects Agency
Office of the Secretary of Defense
Washington, D. C. 20301

Attn: Project AGILE

Dear Sir:

We are enclosing two copies of our report titled (U) "Sidearm and Shotgun Ammunition for COIN and RAC" (Report No. BAT-171-24).

Any comments or suggestions you may have concerning this study will be most welcome.

Sincerely,

John W. Murdock

John W. Murdock
Project Director
RACIC

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(U) SIDEARM AND SHOTGUN AMMUNITION FOR COIN AND RAC

by

J. R. Thorson, G. [illegible] Riley, and D. W. Frink

INTRODUCTION AND OBJECTIVES

(U) This report summarizes the results of studies conducted on sidearm- and shotgun-ammunition effectiveness, in response to requests of the Research and Development Field Unit - Vietnam as outlined in:

(1) RDFU-V Memo 65, dated 23 January 1965 to RACIC

(2) RACIC work statement for "Study of Sidearms Ammunition for COIN and RAC", dated 19 February 1965

(3) RDFU-V Memo 278, dated 31 March 1965 to RACIC.

(U) The objectives of these studies were to provide, from the viewpoint of both sidearm- and shotgun-ammunition effectiveness:

(1) A summary of what has been tried in the past to accomplish improvements

(2) A summary of current U. S. Government, private industry, and foreign activity bearing on the problem

(3) Suggestions for future work which might form a base for an SDR or QMDO.

(U) In the performance of these studies, a number of papers, letters, reports, and books were examined, and visits were made to three Government

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arsenals and one commercial firm. No contact with foreign small-arms researchers was made, primarily because of the limited time available.

SUMMARY

(U) Although history records scattered instances of concern with the effectiveness of sidearm and shotgun ammunition, it has only been within the recent past that the unique problems of ammunition effectiveness in COIN and RAC situations have received any systematic investigation. The efforts for each type of ammunition are summarized briefly below.

Sidearm Ammunition

[redacted] The standard sidearms are primarily ineffective except at extremely short range. For example, a stationary target 2 ft in diameter must be within a range of 23 ft before the average shooter has a 50:50 chance of scoring a single-round hit with a pistol. Aiming error is the major single factor causing the low probability of obtaining a hit.

(U) The major sidearm-ammunition research projects have been directed toward creating ammunition which inherently compensates for excessive aiming error. These projects have been concerned for the most part with three types of concepts: (1) the multiple-flechette cartridge, (2) the shot cartridge, and (3) the strip-bullet cartridge. Each of these approaches provides a burst of many projectiles in a dispersed pattern.

Shotgun Ammunition

[redacted] A shotgun is more often aimed by "pointing" than by the use of sights. The light weight desirable for "quick pointing" fire and the high impulse of shotgun ammunition combine to give a standard (12 gage) shotgun a recoil energy

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which is 50 per cent greater than that of a full-power military rifle. Because greater recoil appears undesirable, most research projects on shotgun ammunition have been concerned with obtaining more optimum dispersion of present shot types and increasing the lethality of the individual shot. Essentially, these efforts have been concerned with reducing dispersion, increasing sectional density, changing the configuration of the individual projectiles, and charging the individual projectiles with explosive.

RECOMMENDATIONS

(U) Although many basic limitations confront the improvement of sidearm and shotgun ammunition, it appears that significant increases in effectiveness can be attained for COIN and RAC operations. The recommended approaches for achieving improvements in each type of ammunition are described in the body of the report.

GENERAL DISCUSSION OF SIDEARM AND SHOTGUN EFFECTIVENESS

(U) This general discussion is presented to provide basic background related directly to the subject of sidearm- and shotgun-ammunition effectiveness.

[redacted] The mathematical measure of the effectiveness of small arms is the probability that a "trigger-pull" will result in a "kill". A "trigger-pull" represents a decision to discharge a weapon; a "kill" represents one man rendered ineffective, whether actually dead or not. The "kill" probability, for semiautomatic fire with single-projectile rounds, P_k, is the product of P_h, the probability that a "trigger-pull" will result in a hit on the target, and P_{hk}, the probability that a hit will be a kill:

$$P_k = P_h \times P_{hk}.$$

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The hitting ability, or "accuracy", P_h, is influenced by three factors directly and one factor indirectly. The three factors which directly influence P_h are aiming error, bias, and dispersion. The indirect factor in hitting ability is rate-of-fire (the number of projectiles fired at the target within a given period of time). The rate-of-fire factor is applicable mainly to automatic weapons and is not considered in this report.

The "lethality" of a projectile, P_{hk}, is determined by the Military Stress Situation and the Terminal Ballistics of the projectile.

Accuracy

The accuracy, P_h, is determined by the projectile dispersion (the spread of hits), bias (the distance from the center of the hit pattern to the center of the target), and the aiming error (round-to-round variations in alignment of gun barrel). These variables are almost universally dealt with by the methods of Probability Mathematics.

Dispersion

Unless specifically stated, dispersion is assumed to have circular normal distribution, such as is shown in Figure 1. With reference to Figure 1, the axes x-y lie in the plane of the target. The center of a group of shots (+) is at o (not necessarily the center of the target). In the y-z and the x-z planes are shown curves representing the hit density, z, as a function of radius, r, from the group center, o. Assuming the hits to have circular normal distribution, and integrating the hit density curve revolved about the z axis, the expression for hit probability is:

$$P_h = 1 - e^{\frac{-r^2}{2\sigma^2}},$$

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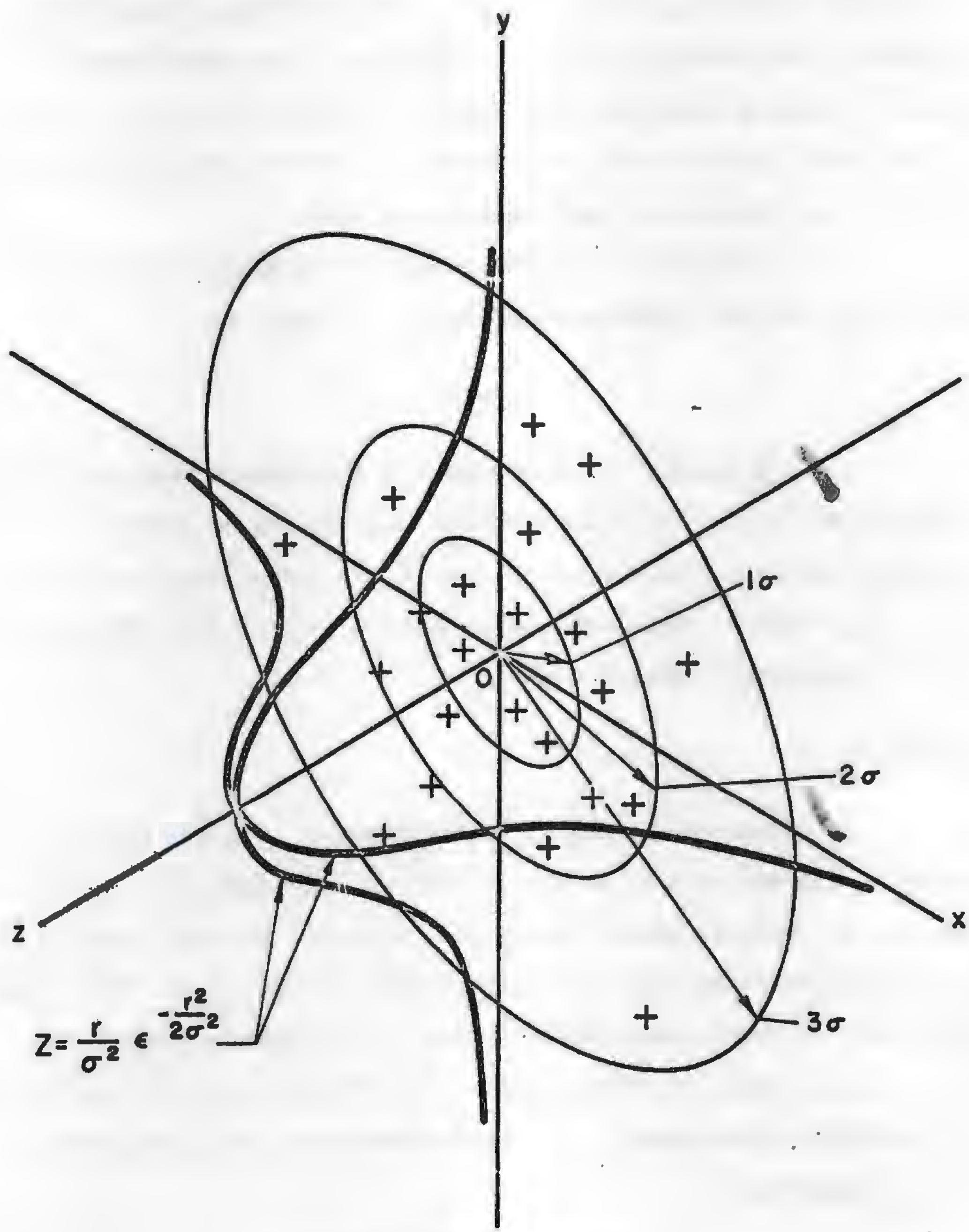

FIGURE 1. NORMAL DISPERSION

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where:

σ = the radius, from the center of the group, of a circle enclosing 39.33 per cent of all shots fired

r = the radius, from the center of the group, of the target (assuming that the target and group centers coincide, i.e., that aiming error = 0).

([redacted] This formula is valid only if the bias is zero and the dispersion and aiming errors in fact are "circular normal". While a group of single shots from a rifle or pistol will exhibit circular normal distribution, a burst from an automatic rifle will often exhibit a strong vertical dispersion resulting from weapon "climb".

[redacted] Although dispersion is usually expressed as σ_p (distribution of the projectiles) either in inches at the target or in mils, other measures frequently used are: (a) C.E.P. (circular error, probable - sometimes abbreviated c.p.e.), which is the radius of the circle about the group center enclosing 50 per cent of all shots fired, (b) "dispersion", δ, which is the diameter of a circle enclosing 75 per cent of all shots fired, and (c) m.r.e. (mean radial error), which is the mean radial distance from the group center to the individual shots. The various expressions can be related by:

$$\text{C.E.P.} = 1.1774\ \sigma_p$$

$$\delta = 3.330\ \sigma_p$$

$$\text{m.r.e.} = 1.2533\ \sigma_p.$$

[redacted] These terms are employed in discussions of dispersion whether a series of individual shots or a salvo of many projectiles is under consideration.

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Except for factors (such as automatic fire) which result in non-normal distribution, the two cases are mathematically the same.

<u>Aiming Error</u>

Aiming error, is the round-to round variation in the aligment of the alignment of the gun barrel. The aiming error arises because of inability to hold the weapon stationary and imperfect estimation and allowance for the effects of range and wind. When only a little time is available for the combined operations of coming on target and aiming, the aiming error will be large; when ample time is available for coming on target and aiming, the aiming error will be smaller (1)*.

The measure of aiming error will be σ_A, either in inches at the target, or in mils (which is the ratio of the offset on the target, in inches, to the distance to the target in thousands of inches).

Aiming error is also assumed to exhibit circular normal distribution about the group center. It is known(2), however, that in competition pistol shooting, various flaws in technique produce characteristic aiming errors which are definitely not normally distributed.. In Reference 1, it was noted that for both proficient and ordinary shooters firing the cal. .45 M1911 pistol at targets exposed for periods between 1 and 8 seconds, aiming error showed an elliptical distribution having a vertical minor axis of 0.86 times the horizontal major axis. However, in light of the assumptions concerning target size, range, psychological factors, etc., the use of circular normal distribution for computational convenience does not create serious inaccuracies.

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*Superscript numbers in parentheses refer to items listed in the Bibliography.
**A "group" may consist of a single projectile also.

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Bias

(U) Bias or offset is an error resulting from an improper sight setting, i.e., the weapon sights are not aligned with the center of the group of hits. As can be seen in Figure 2, the presence of bias greatly changes the distribution of hits on the target.

(U) The introduction of bias makes the mathematical expression for P_h very complex. Consequently, solutions for the equation for P_h are usually generated by a high-speed computer in terms of target radius, aiming error, and dispersion[3].

Lethality

[redacted] The second aspect of weapon effectiveness is lethality or wounding ability. Wounding ability of an individual projectile is expressed as P_{hk}, the probability that a hit will result in a "kill". A "kill" is defined as the cessation of military activity. The P_{hk} for a particular projectile, therefore, depends not only on the terminal ballistics of the projectile, but also on the Military Stress Situation.

Military Stress Situation

[redacted] Because a "kill" is defined as the cessation of a military activity by the person hit, the combat situation, in part, determines the "wounding ability" of a particular wound. For example, a leg wound that would incapacitate an assault soldier would not necessarily incapacitate a soldier employed in defense. Further, a wound which incapacitated fully only after several hours would not be considered a "kill" in an assault or defense situation lasting only 30 minutes.

[redacted] The Military Stress Situation, as defined in Reference 4, that is considered appropriate to guerrilla/ambush situations is "Defense, 100 per cent

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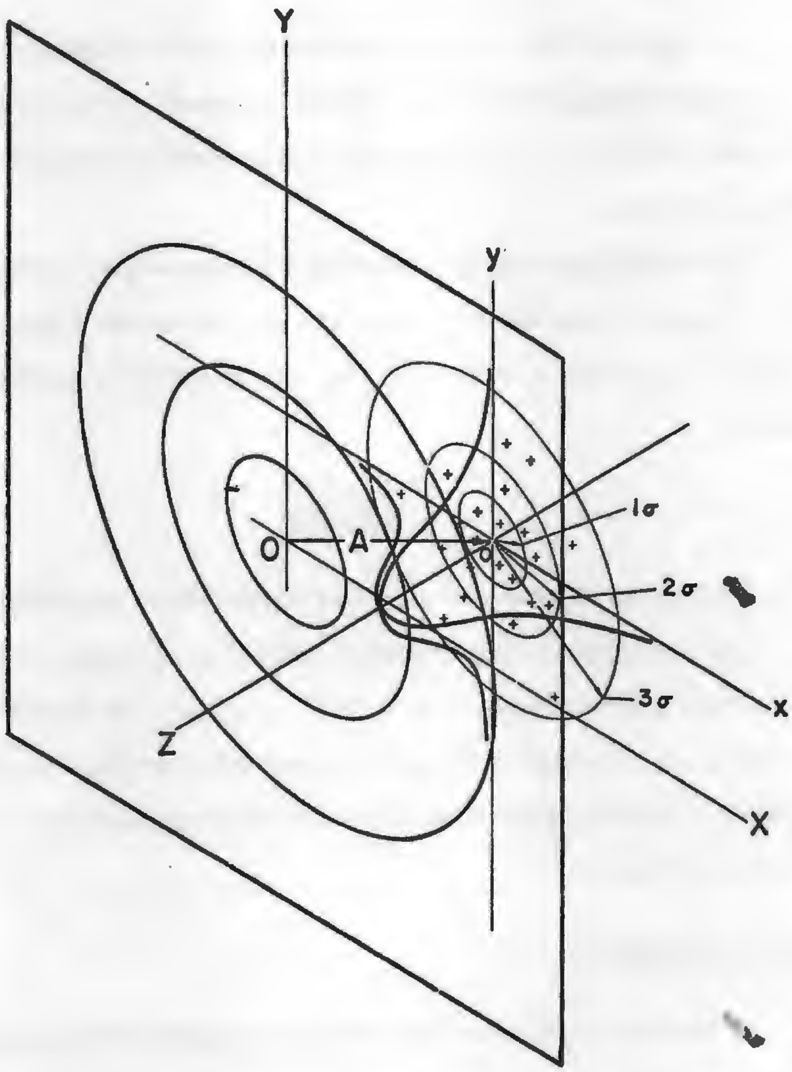

FIGURE 2. BIAS OR OFFSET

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incapacitation in 30 seconds". This stress situation, which is the most demanding of the situations, is applicable even though the "target" personnel are attacking, because of the necessity for quick, decisive action at close range, where a side-arm or shotgun would normally be utilized.

Terminal Ballistics

(U) Attempts to define the wounding ability of small projectiles in terms of projectile properties date from approximately 1760. The great bulk of work in this field has concerned itself with round balls and roughly cubical fragments, such as are appropriate to artillery practice(4).

(U) The Army, in 1867, defined wounding capability of round balls according to their ability to penetrate pine boards. There were three classifications: "slight", "dangerous", and "very dangerous" wounds, corresponding to 0.31 in., 0.63 in., and 1.2 in. of penetration(4). A common rule of thumb, found in a German military textbook(4) and accepted until quite recently, defines 58 ft-lb as the minimum striking energy for fragments to be considered incapacitating(4). In 1944, Gurney(4), on the basis of the hydrodynamic shock produced by high-speed fragments and bullets, suggested mV^3 (where m = mass and V = velocity) as a measure of the wound-producing ability of a projectile.

(U) Studies by McMillen and Gregg(4) of the Princeton Department of Biology in 1945, however, disclosed that there was no abrupt change in the wounding ability of balls at energy levels near 58 ft-lb. Their conclusion was that wounding ability did not correspond to fragment (or ball) energy (i.e., mV^2), but rather to velocity alone. They suggested that a minimum velocity of 250 $ft \cdot sec^{-1}$ was required for incapacitation, provided that the hit was in a "vulnerable" area of the (human) target. The average human target presents 4-1/2 sq ft of area, of which 2 sq ft is considered vulnerable. Sterne(4), based on experimental results,

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proposed the use of mV/A (where A = the cross-sectional area of the projectile) as a wounding criterion. Shortly afterward(5), he stated that 2.5×10^7 ergs (1.843 ft-lb) rather than 250 ft-sec^{-1} was the threshold of incapacitation.

[redacted] The following paragraphs from Reference 5 summarize the present status:

> "In general, the experiences of the U. S. Army in the Philippines as well as in WW I indicate that a large (.45 caliber), heavy (230 grains), and low-velocity pistol bullet is much more effective at close quarters as a manstopper than any of smaller caliber(52)*. The implication is that a vital area of the body must be penetrated for rapid incapacitation, and given this, it is the size of the hole that counts. Therefore, the mass, and consequently the cross-sectional area, becomes of prime importance. (It is assumed that the bullets are of the nonexpanding type, and also that they are bluff shaped (i.e., do not tumble).) Interestingly enough, the same conclusion has been reached by a noted big-game hunter, John Taylor,(53)* for close-quarter situations where vital-organ shots are again a necessity. He has estimated the knockout (KO) value of a comprehensive list of hunting weapons varying from small bore (< .30 caliber) to large bore (< .45 caliber). In general, his findings are that for non-magnum weapons (<2500 fps), the KO value varies directly with the mass to the two-thirds power and is relatively independent of velocity. This is equivalent to making the KO value proportional to cross-sectional area and therefore wound diameter.
>
> "The above suggests that for vital area shots, the distinction to be made between high- and low-velocity impacts is even more fundamental than has hitherto been realized. It would appear that if the velocity is sufficient for a penetration but low enough so that cavitation of the tissue does not take place, the wounding criterion should depend on $m^{2/3}$ and not on velocity. It therefore seems possible that for rapid and total incapacitation, two completely separate wounding regimes exist, as speculated in Eq.(6):

$$P_{hk} = f(mV^{3/2}), \qquad V > 2{,}500 \text{ fps}$$

$$P_{hk} = g(m^{2/3}), \qquad 400 \leq V \leq 2{,}500 \text{ fps}$$

$$P_{hk} = 0, \qquad V \leq 400 \text{ fps."}$$

*References 52 and 53 referred to in this quotation are References 6 and 7 of this report.

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[redacted] Extensive experimental work in recent years with gelatin, live goats, and human cadavers[2,4,5] indicates that for projectiles having striking velocities above 2,500 fps, the function of $mV^{3/2}$ is:

$$P_{hk} = 1 - e^{-a(mV^{3/2} - b)^n} ,$$

where:

e = 2.718, the base of natural logarithms

m = weight of projectile, grains

V = velocity of projectile, ft-sec^{-1}

a, b, and n = experimentally determined constants as given in Table 1[4].

Weapon Effectiveness

[redacted] In the use of these mathematical tools, it is well to observe that should either P_h or P_{hk} be below, say, 0.20, no increase in the other parameter will provide a significant gain in system effectiveness, that is, once the P_h and P_{hk} for any particular weapon are determined, the parameter having the lower value represents the area in which improvement will yield the greatest gain in weapon effectiveness. For example, consider a cal. .45 ball projectile and a 20-in. target at 28 yards; these would result in the following:

$$\text{Cal. .45 ball} \begin{cases} P_h = 0.01 \\ P_{hk} = 0.09 \\ P_k = 0.0009. \end{cases}$$

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Table 1. Recommended Values of Constants*
a, b, n in Law:
$P_{hk} = 1 - e^{-a\,(mV^{3/2} - b)^{n}}$ [redacted]

Military Stress Situation	Time After Wounding	a	b	n
Assault	1/2 Min.	0.0001472	55,000	0.5805
	5 Min.	0.0003253	55,000	0.5575
	30 Min.	0.0006725	45,000	0.5342
Defense	1/2 Min.	0.00003262	54,000	0.6547
	5 Min.	0.0001527	57,500	0.5751
	30 Min.	0.0002244	47,500	0.5814
	1/2 Day	0.001020	57,500	0.4848
	1 Day	0.002447	61,000	0.4270
Reserve	30 Min	0.001047	42,500	0.5231
	1/2 Day	0.007453	62,000	0.4028
	1 Day	0.01388	64,000	0.3621
Supply	1/2 Day	0.001010	57,500	0.5021
	1 Day	0.002335	61,000	0.4463
	5 Days	0.0001653	42,500	0.6444

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If five projectiles are utilized and their total mass is 1/2 that of the cal. .45 ball so that the muzzle velocity is doubled for the same impulse, the following results, which indicate a marked improvement, are obtained:

$$\text{5-shot pellet cartridge}\begin{cases} P_h = 0.50 \\ P_{hk} = 0.04 \\ P_k = 0.020. \end{cases}$$

(U) In a weapon system whose wounding ability arises from the kinetic energy of one or more projectiles, there are presently two ways of imparting velocity to the projectile(s): (1) firearms utilizing gas pressure in the gun tube, and (2) systems utilizing propellant in the projectile as in the case of a rocket projectile. Given the requirement that the weapon must be hand held and holster carried, there is a limit placed on the energy level of each shot, burst, or salvo. Recoil energy is proportional to the square of the projectile muzzle velocity and inversely proportional to the weight ratio of the gun to projectile. For a fixed sidearm weight and a fixed level of recoil energy, projectile energy (muzzle) can be increased by increasing projectile velocity and reducing projectile weight. For example, the cal. .45 M1911 pistol and ball ammunition has the following performance characteristics:

Pistol weight	= 2.5 lb
Projectile weight	= 230 grains (= 0.0329 lb)
Muzzle velocity	= 860 ft-sec^{-1}
Muzzle energy	= 378 ft-lb
Recoil energy	= 4.97 ft-lb.

[redacted] A hypothetical sidearm of the same weight and having the same recoil energy could fire a 50-grain projectile at a velocity of 3,955 ft-sec^{-1}; this

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would have a muzzle energy of 1,740 ft-lb, an increase of more than 350 per cent. Presumably this projectile would have greater lethality than the 230-grain bullet.

[redacted] Two factors limit this approach to increased sidearm effectiveness. First is the extreme difficulty in achieving anything like 3,955 ft-sec^{-1} in a pistol-length barrel. A <u>mean</u> gas pressure of 70,000 psi is required, which represents a peak pressure of perhaps 300,000 psi. This is beyond the state of the art in gun design (in a 2.5-lb semiautomatic pistol). Second, a fourfold increase in muzzle energy would require a fourfold increase in weight of propellant, assuming that the increased amount of propellant could be burned as efficiently. The size, weight (possibly), and cost of ammunition would necessarily increase. It might be added that such a weapon would have an awesome muzzle blast.

EFFECTIVENESS OF SIDEARM AMMUNITION FOR COIN AND RAC

(U) On January 23, 1965, a request was received to summarize efforts to improve sidearm-ammunition effectiveness. Such a summary is needed as part of a staff study by ARPA that is to form the basis for recommendations concerning possible means of increasing the effectiveness of sidearms, particularly those used by U. S. advisor personnel. This complete staff study is to include consideration of different types of weapons, holsters, and other weapon auxiliaries.

(U) The information that forms the basis for the following section was obtained from two sources: (1) the published literature, and (2) discussions with technical personnel. The literature was obtained from the RACIC file, the Battelle Main Library, and from some of the personnel contacted. The most pertinent information is referenced in the Bibliography, Items 1 through 80. The

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personnel interviewed, all active in the field of small arms and ammunition, included the following:

(1) Mr. Robert E. Carn, Weapon Systems Laboratory, Ballistic Research Laboratories, Aberdeen Proving Ground, Aberdeen, Maryland.

(2) Messrs. C. M. Dickey, B. Podolsky, and H. Rosenberg, Frankford Arsenal, Philadelphia, Pennsylvania.

(3) Messrs. T. G. Lorenzen, D. Wagner, and R. C. Maguire, Directorate of R&D, Weapons Command, Rock Island Arsenal, Illinois.

Past Development Activity

[redacted] Although history records scattered instances of concern with pistol effectiveness, it has only been within the last half-dozen years that the unique problems of pistol effectiveness in COIN and RAC situations have received any systematic investigation. Three sidearm-ammunition concepts have been studied in various independent development efforts: (1) the multiple-flechette cartridge, (2) shot cartridges, and (3) the strip-bullet cartridge.

[redacted] Each of these concepts is embodied in a round that is interchangeable with the cal. .45 ball cartridge with regard to feeding, sight setting, and functioning in the M1911 pistol and the M-3 SMG. Each provides a salvo of many projectiles in a dispersed pattern. Since aiming error is the major single factor in pistol <u>in</u>effectiveness, the dispersion of the projectiles offers an opportunity to increase the probability of hitting a briefly exposed target. By careful design of a multiprojectile round, the corresponding reduction of lethality of the individual missile can be held to a level that will yield an

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over-all increase in weapon effectiveness. These three concepts have represented attempts to make the most advantageous compromise within practical limits.

Multiple-Flechette Cartridge

[redacted] The wounding ability, or lethality (P_{hk}), of flechettes has been investigated by several groups[5-8], using live goats as well as gelatin block targets. Lethality was calculated both from the $mV^{3/2}$ criterion and from the kinetic-energy criterion (based upon gelatin-block-target experiments).

[redacted] The multiple-flechette cartridge for the cal. .45 pistol was proposed by Frankford Arsenal in 1961, and sample lots, made by Aircraft Armaments, Inc., were tested at Army Chemical Center, Maryland, during that year. The cartridge tested had the following characteristics[6]:

Muzzle velocity: 1,650 $ft\text{-}sec^{-1}$

Projectile: 49 1-grain steel flechettes.

To briefly summarize the results of this test program, 18 goats were shot with multiple-flechette cartridges and 12 with ball cartridges, all at a range of 16.7 yards (50 ft). Of these, 50 per cent of the goats shot with the ball cartridge died within 48 hours; 41.7 per cent collapsed permanently within 30 seconds. Of those shot with the flechette cartridge, 33.3 per cent died within 48 hours; 33.3 per cent collapsed permanently within 30 seconds. (The average number of flechette hits per goat was 10.8.) Assuming that goats are equivalent to soldiers, this test indicates that the ball round is superior to the flechette round by a factor of 41.7/33.3 = 1.25. On the basis of calculated hit probability and lethality, the .45 ball cartridge is superior to the multiple-flechette cartridge by a factor of 0.095/0.070 = 1.35.

[redacted] Additional firings of the multiple-flechette cartridge at standing-man paper ... ve high calculated P_k values, but it is felt that the results on the animal targets are more trustworthy. It should be noted that the dispersion of the multiple-flechette salvos does not appear to follow circular normal distribution, presumably because of aerodynamic interaction between the individual flechettes in flight.

([redacted]) In an investigation of pistol effectiveness, Carn[9] found the proposed flechette cartridge to have an average effectiveness 3 per cent greater than the cal. .45 ball round in an analysis which covered all ranges up to 50 meters and a target radius of 1.25 ft. On the basis of tests with both pistol and shotgun flechette ammunition, it was concluded that, in the case of the pistol, the dispersion obtained with flechettes would result in an increase in effectiveness as shown in Figure 3. Figure 4 shows the effectiveness of five different pistol-ammunition concepts, for the D-30-100% Stress Situation and a σ_A of 20 mils. Figure 5 compares the 49 1-grain flechette cartridge, a proposed 64 1-grain flechette round, and .45 ball ammunition.

([redacted]) In addition, Carn calculated the effectiveness of several hypothetical flechette cartridges[9], with the common restriction that each must be capable of functioning in the cal. .45 M1911 pistol. On the basis of this study, Table 2 was prepared which indicated that a better flechette cartridge could be hypothesized. The use of 66 2-grain flechettes having a muzzle velocity of 1,000 ft-sec^{-1} was found to be markedly more effective than the proposed multiple-flechette round.

([redacted]) At Frankford Arsenal, Dickey and Podolsky have done extensive work in the development of multi-ball and multi-flechette cartridges for the M1911 pistol and the M-3 SMG. There have been two aspects to their work. The first has been the experimental development of a cartridge design having acceptable ballistics (dispersion and terminal energy) and the proper impulse for operating

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INITIAL PROJECTILE VELOCITY = 1000 FPS PAYLOAD WT. = 133 GRAINS
INDIVIDUAL FLECHETTE WEIGHT = 2 GRAINS
30 SECOND DEFENSE 100% KILL CASUALTY CRITERION
PROJECTILES STABLE WITHIN TARGET MEDIUM
TARGET RADIUS = 1.25 FT. AIMING ERROR (σ_A) = 20 MILS

NOTE: A PROJECTILE DISPERSION OF 22 MILS IS OBTAINED WITH THE PROPOSED CAL. 45 MULTIPLE FLECHETTE PISTOL ROUND

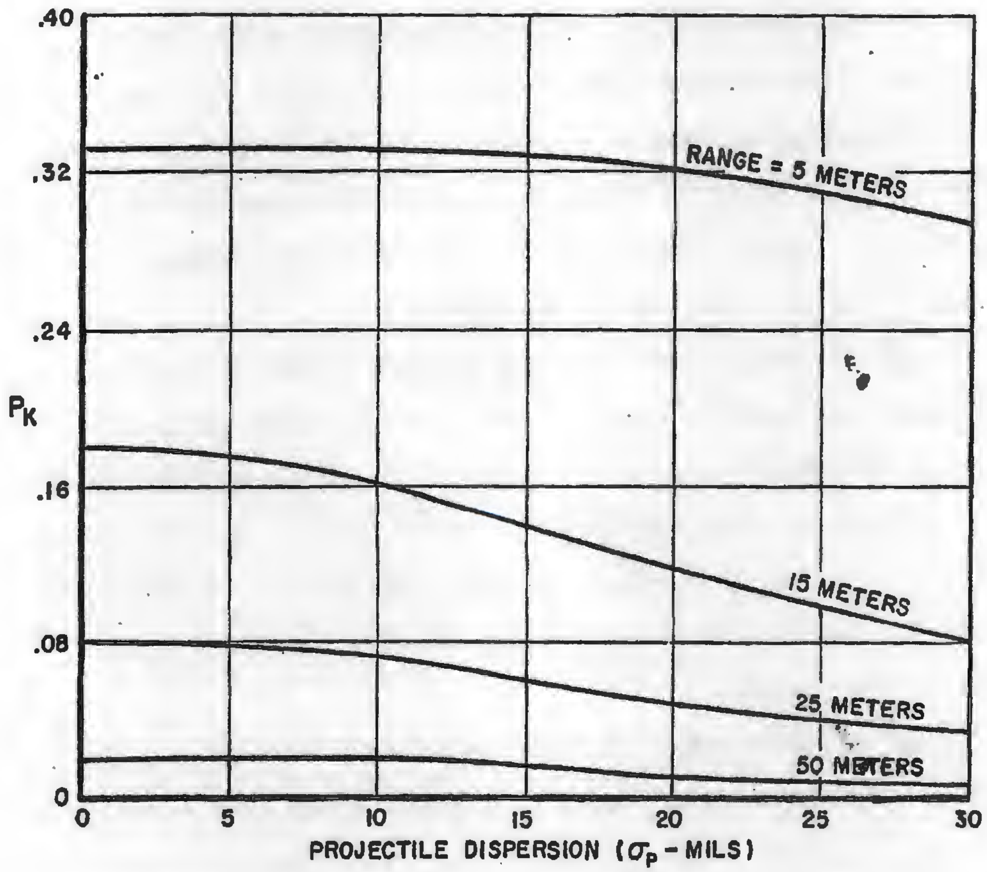

FIGURE 3. PISTOL EFFECTIVENESS STUDY — HYPOTHETICAL MULTIPLE-FLECHETTE ROUND (U)

Probability of Incapacitation (P_K) Versus Projectile Dispersion About the Pattern Center (σ_P)

Extracted from Reference 9.

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30 SECOND DEFENSE 100% KILL CASAULTY CRITERION

TARGET RADIUS = 1.25 FT. AIMING ERROR = 20 MILS

RANDOM TARGET HITS

ROUND	LEGEND	NO. PROJECTILES PER ROUND	INDIVIDUAL PROJECTILE WEIGHT (GRAINS)	PROJECTILE DISPERSION (MILS)	INITIAL PROJECTILE VELOCITY (FPS)
BALL M1911	×	1	234	N/A	830
MULTIPLE FLECHETTE	□	49	1	22	1650
#4 LEAD SHOT	→→	20	3.6	22	1650
#4 MALLORY SHOT	●—●—●	13	5.4	22	1650
#4 MALLORY SHOT	△	13	5.4	7	1650

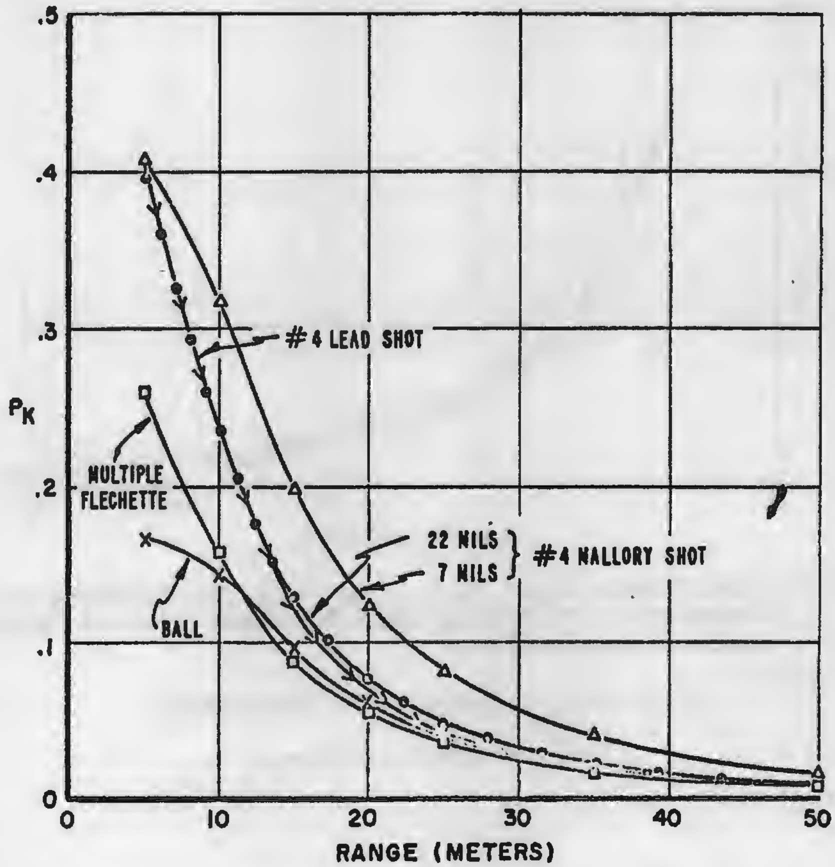

FIGURE 4. CAL .45 PISTOL M1911 EFFECTIVENESS (U)

Probability of Incapacitation (P_K) Versus Range

Extracted from Reference 9.

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[redacted]

PROJECTILE DISPERSION ABOUT PATTERN CENTER (σ_p) = 22 MILS
30 SECOND DEFENSE 100% KILL CASUALTY CRITERION
PROJECTILES STABLE WITHIN TARGET MEDIUM
TARGET RADIUS = 1.25 FT. AIMING ERROR (σ_A) = 20 MILS

LEGEND: □ PROPOSED ROUND i.e. 49-1 GRAIN FLECHETTES
○ MODIFIED ROUND i.e. 64-1 GRAIN FLECHETTES
x BALL M1911

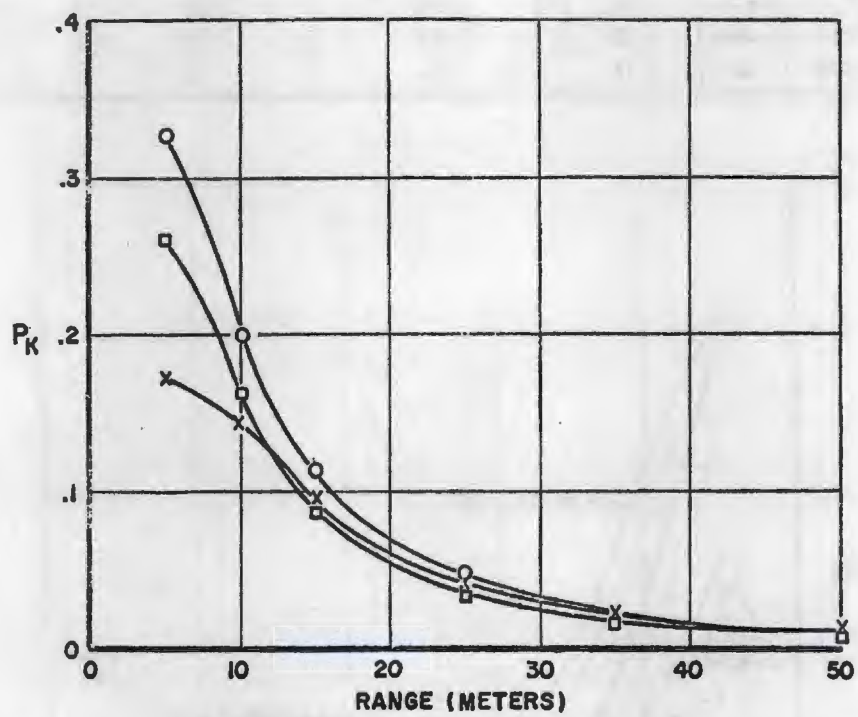

FIGURE 5. PISTOL EFFECTIVENESS STUDY — CAL .45 MULTIPLE-FLECHETTE ROUNDS — COMPARISON OF PROPOSED AND MODIFIED VERSION OF CAL .45 MULTIPLE-FLECHETTE PISTOL ROUNDS (U)

Probability of Incapacitation Versus Range

Extracted from Reference 9.

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Table 2. Comparison of Proposed Multiple-Flechette Round With Hypothetical Multiple-Flechette Rounds[9] (U)

Initial Velocity, fps	Incapacitation Probability					
	At 5 Meters		At 15 Meters		At 25 Meters	
	P_k	Relative Effectiveness	P_k	Relative Effectiveness	P_k	Relative Effectiveness
Hypothetical - 1,000	0.32	1.23	0.11	1.25	0.045	1.32
Hypothetical - 1,500	0.27	1.04	0.091	1.03	0.036	1.06
Proposed - 1,650	0.26	1.00	0.088	1.00	0.034	1.00
Hypothetical - 2,000	0.24	0.92	0.080	0.91	0.032	0.94
Hypothetical - 3,000	0.17	0.65	0.050	0.66	0.024	0.71

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the pistol mechanism. The second has been the theoretical determination of kill probability for various types and sizes of projectiles, dispersions, energies, etc.

[redacted] The cartridge development on both the flechette and the ball was carried to the point where production designs having specific characteristics can readily be provided. The effectiveness study, being entirely theoretical, is still subject to verification. Some of their conclusions about flechette and/or pellet number, size, and effectiveness do not agree exactly with those of similar studies carried out by BRL. The disagreements are not radical, but do influence the choice of the "most effective" pistol cartridge.

[redacted] The Special Devices Division at Frankford, under Rosenberg, has done work in microballistic devices (1 to 4-mm rifled-barrel, high-velocity projectiles). These are applicable to a lightweight multibarrel pistol, but nothing has been done to develop this concept further.

[redacted] Dickey is of the opinion that pistol effectiveness can be increased by:

(1) A multiple-flechette cartridge employing CB-tipped flechettes.

(2) Barring Item 1 for political reasons, a multiple-flechette cartridge employing explosive flechettes (FLEX).

(3) Barring Items 1 and 2, a multi-ball cartridge employing dense-metal shot.

Shot Cartridges

[redacted] In a pistol-effectiveness study conducted by BRL(9) in 1961, two hypothetical cal. .45 shot cartridges were examined. The cartridges were similar

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[redacted]

except that lead shot was assumed in one case and "Mallory"* shot in the other. They each had an assumed total projectile weight of 80 grains, of which 72 grains was actual "payload" (i.e., shot). The muzzle velocity in each case was assumed to be 1,650 ft-sec^{-1}. These assumed values result in a lower impulse, but a slightly higher muzzle energy than for the .45 ball round. On the basis of test firings of other cal. .45 pistol shot cartridges, it was assumed that the dispersion was 22 mils. For the sake of thoroughness, it was also assumed that a choke could reduce the dispersion to 7 mils, and the effectiveness for this value was calculated also.

[redacted] It was concluded(9) that for an aiming error of 20 mils, for 2.5-ft-diameter targets at all ranges up to 50 meters, the lead-shot round would be 19 per cent more effective, and the Mallory-shot round 33 per cent more effective than the cal. .45 ball. The optimum pellet weight for all ranges up to 50 meters is 4 grains each.

[redacted] Subsequent conversation(10) with Carn disclosed that continued work in this field shows that optimum values of dispersion and pellet weight are 5 mils and 20 grains (at 1,300 ft-sec^{-1}), respectively. These values are relatively independent of aiming error and range.

[redacted] In 1963, the design of a cal. .45 dense-metal shot cartridge was subjected to a computer study at Frankford Arsenal(11). For a cartridge having the same impulse as .45 ball ammunition, maximum effectiveness was obtained with 16 7-grain pellets of Mallory metal. As a result, a quantity of these cartridges was manufactured by Aircraft Armaments, Inc., and tested at Frankford. This first-design ammunition had a dispersion of 25 to 30 mils. Refinements in the design

*"Mallory 1000", an alloy made by P. R. Mallory & Co. Inc., Indianapolis, Indiana. Density = 16.8 g-cm^{-3}.

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by Frankford personnel resulted in a dispersion of 10 to 12 mils for either rifled- or smooth-bore pistol-length barrels. These rounds have a muzzle velocity of 900 to 950 ft-sec^{-1} and will function in the unmodified cal. .45 pistol or the M-3 SMG. No numerical values of lethality (P_{hk}) or effectiveness (P_k) were available; the statement was made that the Mallory-shot cartridge is 6.3 times as "effective" as the cal. .45 ball. It was also stated, however, that additional work is necessary to determine the lethality of "small" projectiles, such as shot and flechettes.

Strip Bullet

[redacted] The strip-bullet concept originated with NOTS early in 1962[12]. This bullet is a projectile made up of two or more wires or prismatical strips of lead having long axes parallel to the barrel axis. These strips are swaged into a "bullet" and loaded into ordinary cartridges. When this is fired, the spin of the "bullet" causes it to disperse after leaving the bore, thus, presumably, increasing hit probability. This concept was tested in cal. 7.62 NATO as well as cal. .45 (M-3 SMG) weapons. It is not known that it was ever tested in the cal. .45 pistol.

[redacted] When tested in the SMG, lead-wire strip-bullet ammunition functioned properly, but caused severe bore leading, which resulted in reduced dispersion. The bore leading in no way interfered with the use of ball ammunition[13]. Reference 13 states that the concept was abandoned because other devices seemed to be more effective. Reference 30 indicates that the strip-bullet concept, discontinued in FY 64 for lack of funding, was "proven lethal and controllable". Frankford is able to produce this kind of ammunition in quantity.

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Analytical Lightweight Pistol Study

[redacted] An analytical study of a lightweight pistol system has just been completed at BRL under the direction of Carn. The purpose of this investigation was to determine the feasibility of a lightweight pistol system having effectiveness similar to that of the cal. .45 M1911 pistol system. Four types of cartridges were considered: single ball, single flechette, multiple ball (shot), and multiple flechette. In addition, four levels of muzzle energy were considered: 75, 100, 125, and 150 per cent of that of the cal. .45 ball cartridge. Anthropomorphic targets, divided into six zones of varying values of [redacted]$_{hk}$, and also circular targets were used; measures of "effectiveness" on both types of targets were found to be in reasonable agreement.

[redacted] The conclusion reached by BRL, according to Carn's tentative analysis, was that a single ball of 50-grain weight at a muzzle velocity of 2,500 ft-sec^{-1} will be slightly more effective than the .45 ball now in use. The other projectile types are considered inferior to the single ball. Multiple-projectile bursts all suffer from too much dispersion, reducing their effectiveness except at very short range.

[redacted] It was also determined that the most significant variable in the effectiveness equation is aiming error. This "offset" cannot be practically compensated for by increasing the dispersion of a multiple-projectile burst. Increased dispersion may increase the number of hits, but the energy of the individual projectiles is then, necessarily, too low to be sufficiently lethal, because the total energy available in a hand-held weapon is limited by recoil-energy limitations.

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Current Development Activity

(U) Work in the field of pistol ammunition is being done at a low rate-of-effort (generally as in-house funds permit) by both BRL and Frankford. Current activity by private firms is a closely guarded secret. No attempt was made to determine the existence of current programs within organizations like Aircraft Armaments, Inc., Smith and Wesson, MB Associates, etc., but it is probable that at least some attention is being given to the subject of pistol-ammunition effectiveness by these and other interested firms.

[redacted] In conversation with Carn[10], he expressed the intention of performing some simple experimental work to determine the effect of recoil on aiming error. This work, which is to be done with the assistance of Springfield Armory, will employ a small camera attached to a M1911 pistol. The camera tripped by the hammer fall, will provide a record of aiming error in three modes of operation: (1) dry fire, (2) firing with the cal. .22 conversion, and (3) firing of issue (ball) ammunition.

(U) Lorenzen of Rock Island Arsenal[14] stated that in the Army Weapons Command there is "no official requirement" for a new pistol.

Possible Future Development Activity

(U) On the basis of the information obtained during the course of this program, it appears that development work should be undertaken in the two areas described briefly below. The first could be the subject of an SDR, while the second would probably be the subject of a QMDO.

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Dense-Metal Shot Cartridge

[redacted] This concept has been carried to a high degree of development and appears to offer a significant increase in effectiveness. The cartridge design is ready for production(11). It is believed that a quantity of this ammunition should be manufactured and subjected to user testing as soon as possible. Consideration should be given to the use of spent uranium in addition to the tungsten alloy (Mallory 1000) which has been tested; this suggestion is made because the availability of Mallory metal might become a problem, should this cartridge prove attractive.

Reduction of Dispersion

[redacted] In each of the multiple-projectile concepts explored, it is evident that the projectile dispersion was greater than the optimum defined by mathematical theory. It is recommended, therefore, that a program of research in projectile dispersion be implemented. The objective of this research would be to gain knowledge which would permit the control of dispersion (pattern shape as well as size) in the design of any multiple-projectile weapon-ammunition system.

EFFECTIVENESS OF SHOTGUN AMMUNITION FOR
COIN AND RAC

(U) On March 31, 1965, a request was received to expand the study described above, to include shot-gun-ammunition effectiveness, and three agencies were suggested as possible sources of valuable information: Ballistics Research Laboratory and Human Engineering Laboratory, Aberdeen Proving Ground, Maryland, and Bio Physics Laboratory, Edgewood Arsenal, Maryland. Unfortunately, this request was received after two of the three scheduled project months had passed, and it was decided that the effort on shotgun ammunition had to be confined

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primarily to the documents at hand. The items which provided useful information are listed in the Bibliography. Additional information had been obtained before March 31 in a meeting with Mr. Carn, BRL, in regard to the sidearm-ammunition-effectiveness study; and some was available from Mr. Robert Raddatz of Winchester-Western on May 12.

(U) In hunting and sport, the shotgun has been used against moving or briefly exposed targets at ranges between 10 and 60 yards. It is more often aimed by "pointing" than by using the sights. In police and guard work, it is employed in substantially the same way. The light weight desirable for "quick pointing" fire and the high impulse of shotgun ammunition combine to give a standard (12 gage) shotgun a recoil energy which is 50 per cent greater than that of a full-power military rifle. Because of recoil, it is impractical to increase the effectiveness by means of more projectiles driven at higher velocities. In theory, impulse can be reduced without reducing muzzle energy, by the use of a lighter total missile weight and higher muzzle velocity, but at the cost of higher breech pressure and increased barrel length, as well as heavier, bulkier ammunition. However, such a complete redesign of gun and ammunition has not yet been undertaken.

Past Development Activity

(U) More than a century ago, proprietary ammunition components were made that reduced the dispersion of a shot charge(15). Their purpose was to increase the effective range of the shotgun. Various means for delaying the separation of the shot charge to a point well beyond the muzzle were marketed up to the advent of choke-boring. From about 1900 to about 1960, there appears to have been little development of military shotgun ammunition. In about 1960, work was initiated on shotgun ammunition for use in special military operations. This effort has been concerned for the most part with analyzing the effects of different types of ammunition, reducing pellet dispersion, and increasing the killing effect of the pellets.

General Analytical Studies

([redacted]) In 1961, BRL conducted an analytical study of actual and hypothetical shotgun weapons in "special and guerrilla" fire roles(9). A Defense 30-second, 100 per cent incapacitation criterion was used and circular normal distribution of aiming error and projectile dispersion was assumed. The effectiveness of various weapon systems was compared for aiming errors between 5 and 10 mils. Table 3 presents a summary of the parameters considered for selected rounds.

([redacted]) Figures 6 and 7 show the results of this comparison. The curves indicate the general superiority of the No. 4 Mallory (dense metal) shot in comparison with the other types of rounds, and the superiority of the shotgun to the M-14 rifle at distances less than 50 meters. Beyond 50 meters the M-14 was found to be superior, even with "shotgun role" aiming errors.

Evaluation of Shot Size

([redacted]) In the above analytical study at BRL(9), consideration was also given to the effect of individual pellet weight (constant payload weight) in the 12-gage Mallory round on kill probability. This computation was made for aiming errors of 5 and 10 mils, and a pattern dispersion of 7 mils. The results are shown in Figure 8. The effect of dispersion on P_k was determined as shown in Figure 9. This curve substantiates the statement by Carn(10) that all multiple-projectile systems require an optimized dispersion.

([redacted]) In 1963, NOTS conducted a mathematical analysis of shotgun effectiveness(16). In this analysis, the effectiveness of eight different loads having

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Table 3. Shotgun-Ammunition Types Considered by BRL[(9)] (U)

Round	No. of Projectiles	Wt. of Individual Proj., grains	Payload Wt, grains	Initial Proj. Velocity fps
Proposed multiple flechette (shotgun)	32	12	384	1,260
Brassie-40-mm (M-79 launcher) multiple flechette	150	2	300	2,000
40-mm No. 4 Mallory shot (hypothetical)	100	5.4	540	2,000
No. 00 lead shot (12-gage shotgun) (existing)	9	60	540	1,260
No. 4 lead shot (12-gage shotgun) (existing)	150	3.6	540	1,260
No. 4 Mallory shot (shotgun) (hypothetical)	100	5.4	540	1,260
7.62-mm NATO (M14 rifle)	1	147	147	2,800

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30 SECOND DEFENSE 100% KILL CASUALTY CRITERION
TARGET RADIUS = 1.25 FT. AIMING ERROR = 5 MILS
RANDOM TARGET HITS

CARTRIDGE	NUMBER OF PROJECTILES	PROJECTILE WEIGHT (GRAINS)	PROJECTILE DISPERSION (MILS)	LAUNCH VELOCITY (FPS)
#00 LEAD SHOTGUN	9	60.0	7	1260
#4 LEAD SHOTGUN	150	3.6	7	1260
#4 MALLORY SHOTGUN-HYPOTHETICAL	100	5.4	7	1260
#4 MALLORY-40 MM-HYPOTHETICAL	100	5.4	17	2000
MULTIPLE FLECHETTE-SHOTGUN-PROPOSED	32	12.0	17	1260
MULTIPLE FLECHETTE-40 MM-BRASSIE	150	2.0	17	2000

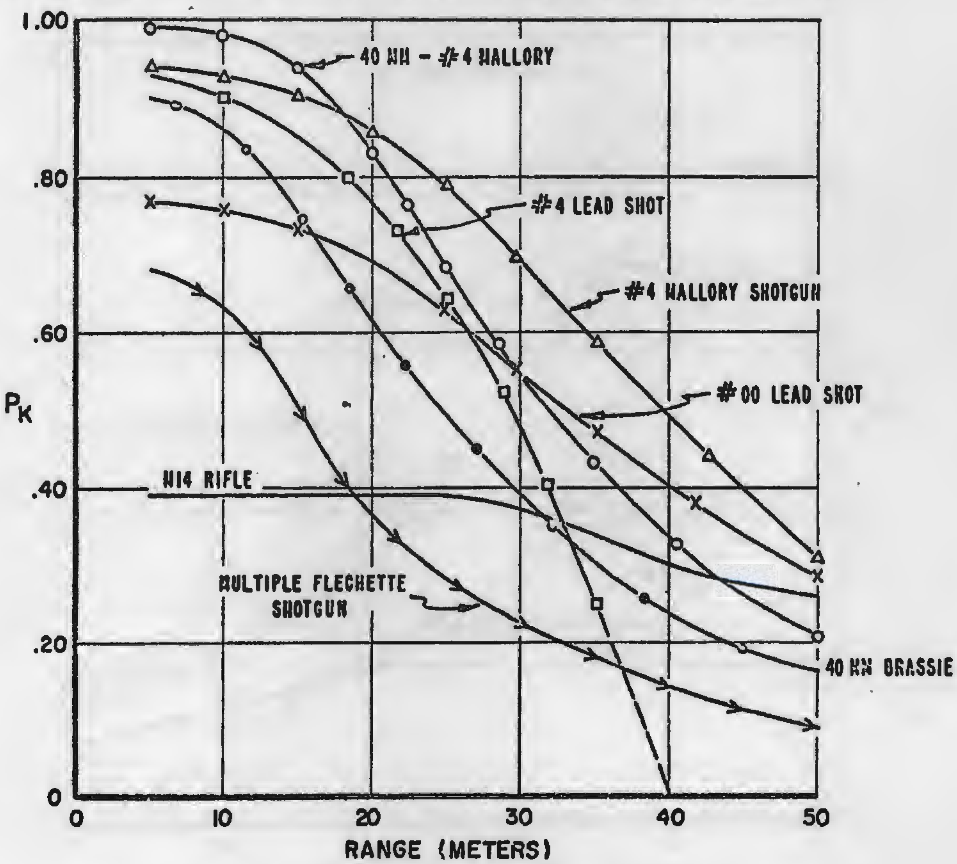

FIGURE 6. SHOTGUN EFFECTIVENESS STUDY (U)

Probability of Incapacitation (P_K) Versus Range

Extracted from Reference 9.

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[redacted]

30 SECOND DEFENSE 100% KILL CASUALTY CRITERION

TARGET RADIUS = 1.25 FT. AIMING ERROR = 10 MILS

RANDOM TARGET HITS

CARTRIDGE	NUMBER OF PROJECTILES	PROJECTILE WEIGHT (GRAINS)	PROJECTILE DISPERSION (MILS)	LAUNCH VELOCITY (FPS)
#00 LEAD SHOTGUN	9	60.0	7	1260
#4 LEAD SHOTGUN	150	3.6	7	1260
#4 MALLORY SHOTGUN-HYPOTHETICAL	100	5.4	7	1260
#4 MALLORY-40 MM-HYPOTHETICAL	100	5.4	17	2000
MULTIPLE FLECHETTE-SHOTGUN-PROPOSED	32	12.0	17	1260
MULTIPLE FLECHETTE-40 MM-BRASSIE	150	2.0	17	2000

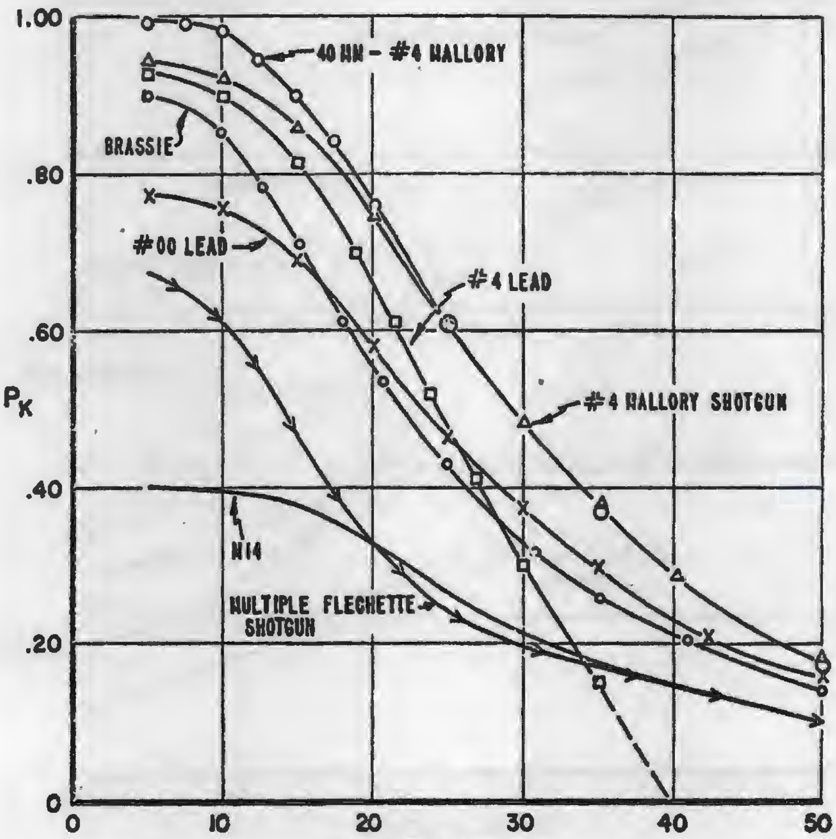

FIGURE 7. SHOTGUN EFFECTIVENESS STUDY (U)

Probability of Incapacitation (P_K) Versus Range

Extracted from Reference 9.

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30 SECOND DEFENSE 100% KILL CASUALTY CRITERION-FRAGMENT LETHALITY
MALLORY SHOT-PROJECTILE DISPERSION ABOUT THE PATTERN CENTER = 7 MILS
TARGET RADIUS = 1.25 FT. PAYLOAD WT. = 540 GRAINS
LAUNCH VELOCITY = 1260 FPS

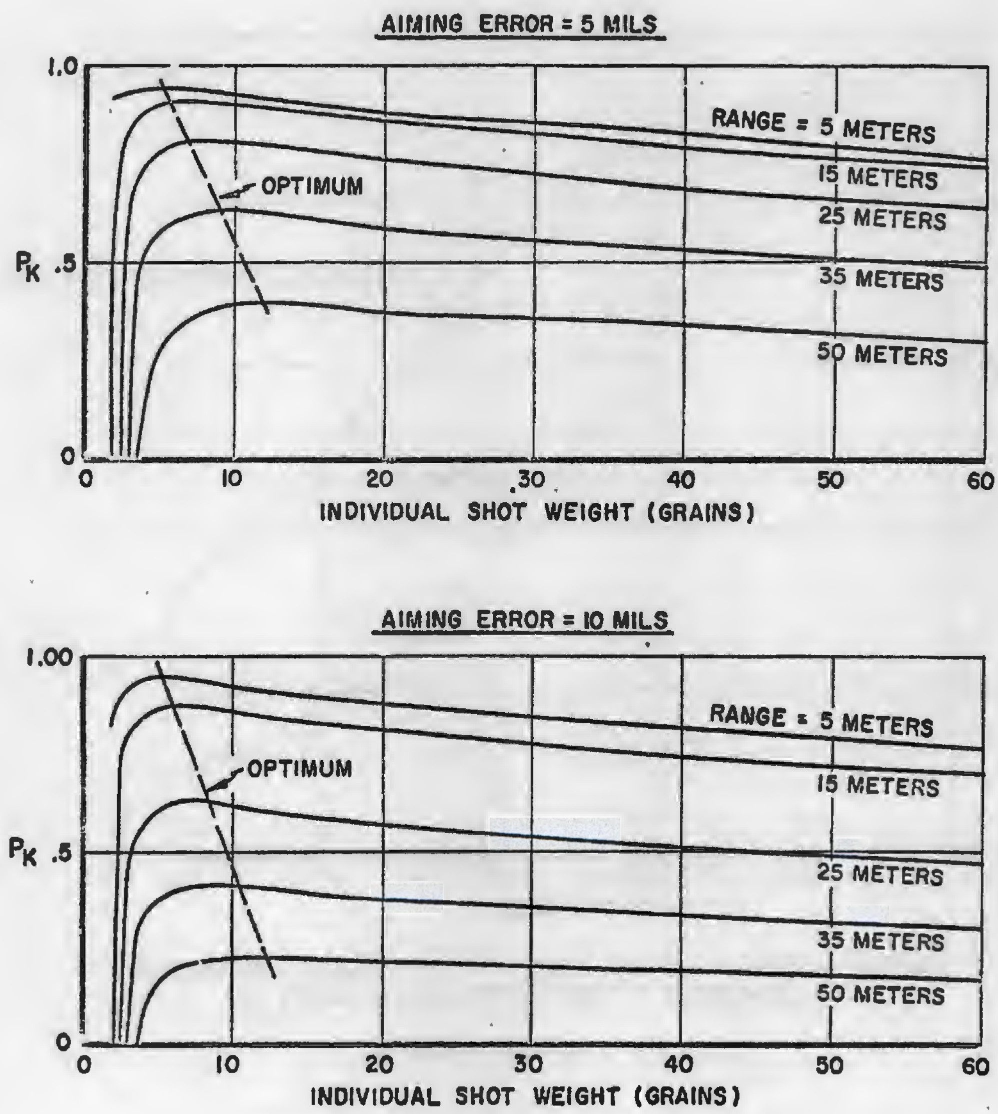

FIGURE 8. SHOTGUN EFFECTIVENESS STUDY (U)

Probability of Incapacitation (P_K) Versus Individual Shot Weight

Extracted from Reference 9.

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#MALLORY SHOTGUN ROUND WITH 100 SHOT WEIGHING 5.4 GRAIN EACH
INITIAL PROJECTILE VELOCITY = 1260 FT/SEC
TARGET RADIUS = 1.25 FT. AIMING ERROR (σ_A) = 5 MILS

30 SECOND DEFENSE - 100% KILLS - FRAGMENT LETHALITY

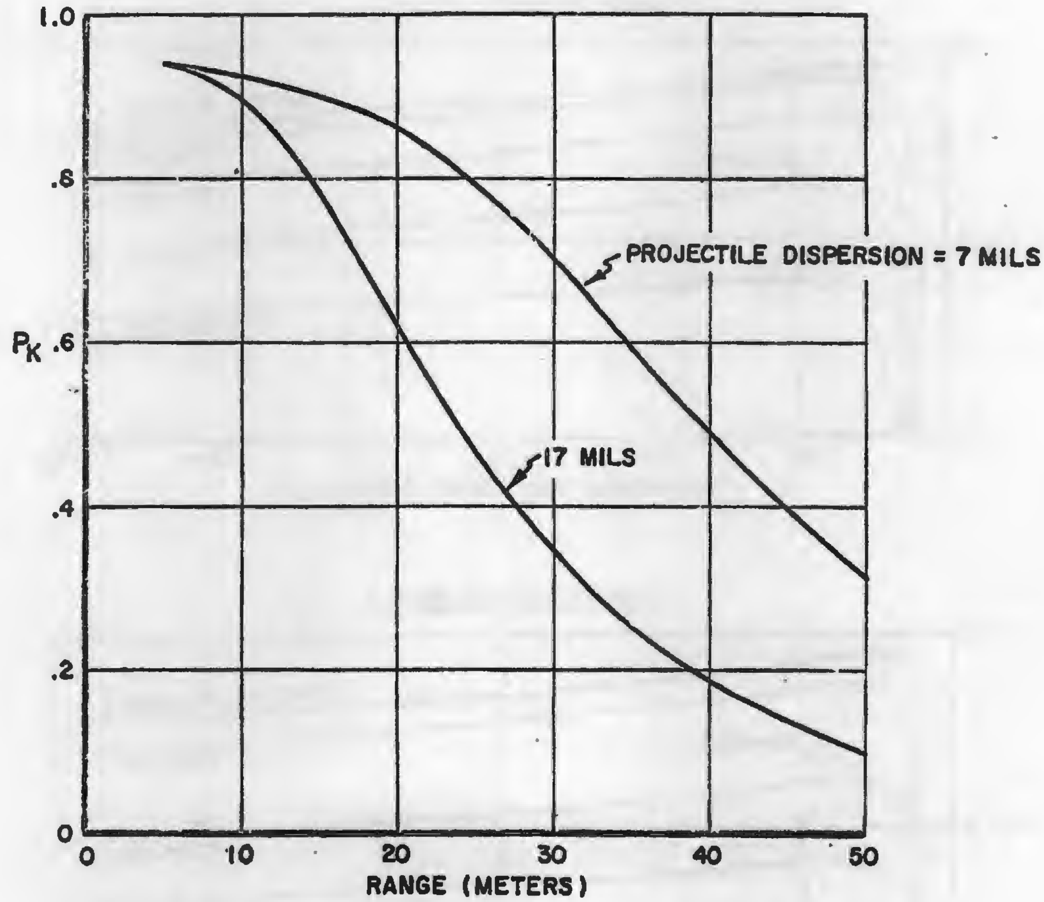

FIGURE 9. SHOTGUN EFFECTIVENESS STUDY — EFFECT OF PROJECTILE DISPERSION ON INCAPACITATION PROBABILITY (U)

Extracted from Reference 9.

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a constant impulse (namely, 770×10^3 grain-ft-sec^{-1}) was examined for various ranges. A D-30-100 per cent incapacitation criterion and a rectangular target, 1.8 x 2.7 ft, were used, and the customary circular normal distribution of aiming error and dispersion was assumed. The conclusions from this work are quoted:

> "From the study of shotguns thus far, some general conclusions can be summarized, as follows:
>
> 1. Shotguns are generally ineffective beyond 40 meters. Even at 40 meters, small aiming errors and shot dispersions are required.
>
> 2. When maximum recoil energy is the limiting factor on loading, large-size shot and high muzzle velocity are not especially desirable. Variations of speed, number, and size of shot such that the recoil energy is the same do not change the effectiveness significantly, provided none of the quantities are too small.
>
> 3. 'Chokes' for reducing shot dispersion are not advisable, unless the rather marginal effectiveness at longer ranges is important. For shorter ranges and larger aiming errors, large shot dispersions are helpful."

(U) These conclusions are somewhat at variance with those of Reference 9. This may be caused in part by the slightly heavier payload and higher muzzle velocity of the hypothetical loads considered in Reference 16.

Reduced Dispersion

(U) In early 1962, the Chief of Ordnance requested BRL to look at the subject of shotgun effectiveness. Shortly thereafter, ARPA made a similar request, having particular interest in weapons for COIN. In November (1962) under ARPA Order No. 329, an Army Weapons Command-managed program began, with tasks performed by BRL, Frankford, and Springfield Armory. The program was composed of three parts. The first was to determine the most appropriate (for COIN) commercial shotguns and simple modifications required to increase their suitability. The second was a study of the requirements of a village-defense shotgun system. The third part was the determination of the characteristics of an optimum military shotgun system and development of its components.

([redacted]) In connection with the three-part program, three minor developments were mentioned[17] concerning a reduction of dispersion. In July, 1962, Remington Arms Company began the development of a dense-metal 12-gage shotshell (No. 4 buck equivalent) that resulted in an experimental round giving 3-mil dispersion at 100 yards.

([redacted]) Research in shotshell construction resulted in designs of greatly reduced length, having standard 12-gage performance. Wax- or rubber-encapsulated shot columns were found to greatly reduce dispersion in cylinder-bored (riot gun) shotguns.

([redacted]) Development work was performed on multiple-flechette shotgun rounds with muzzle velocities up to 3,500 ft-sec^{-1}. Rubber-encapsulated 8-flechette rounds were prepared which had an average dispersion of 7 mils - not previously achieved.

(U) Further information regarding these efforts was not available during the study of shotgun ammunition.

<u>Multiple Flechettes</u>

([redacted]) In the SALVO I program[10], tests were performed on a 12-gage shotgun round whose payload was 32 steel flechettes weighing 13 grains each. The muzzle velocity was 1,423 ft-sec^{-1}, which gave a recoil energy of 15.4 ft-lb. A full-scale evaluation was considered desirable, and some 3,000 rounds were procured for the SALVO II program.

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([redacted]) In the SALVO II program(18), the 12-gage weapon-ammunition combination was of "such poor technical quality that no useful data concerning [its] combat potential was collected". The technical problems were: (1) the shotgun (a modified commercial auto-loading model) frequently failed to eject and/or feed, so that it was simply single-loaded; (2) the shotshell closure, a frangible plastic "card", frequently broke in handling, thus allowing the flechettes to move forward; and (3) the separation of the flechettes and sabot was not reliable.

([redacted]) The mean dispersion was 17 mils. The data obtained indicated that the flechette round produced 0.387 the casualties per trigger-pull and 0.201 the casualties per lb of ammunition as compared with M-1 rifle-fired ball ammunition. However, the limited amount of testing done in this program does not provide conclusive results.

Explosive-Charged Shot Pellets

([redacted]) In July, 1963, Remington Arms began a special shotgun-ammunition development program for the Army Material Command(19). The objective was to develop and test 12-gage shotshells employing explosive-charged shot which would detonate on impact with human tissue. Tests were made with both No. 4 buck pellets (0.240-in. diameter) and No. 4 shot pellets (0.130-in. diameter) having diametral cylindrical holes charged with explosive. The explosive charges used were composed of PY-62, PY-55, PY-164, lead azide (dextrinated), and lead styphnate, either singly or in combination. The No. 4 buck pellets required a velocity of at least 650-ft-sec^{-1} to penetrate the six-layer G.I. winter uniform. At this velocity 60 per cent of the charged pellets (best charge composition and form) detonated; at an impact velocity of 1,100 ft-sec^{-1} 95 per cent detonated.

([redacted]) In an effort to fire a load of 22 explosive-charged No. 4 buckshot at 1,300 ft-sec^{-1} without premature (bore) detonation, a polyethylene shot cup

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was used and the shot column was impregnated with polyethylene powder. However, premature explosions still occurred at a rate which was not acceptable even in experimental ammunition.

Proposed Rocket-Boosted Round

([redacted]) In June, 1963, the Armour Research Foundation (now the Illinois Institute of Technology Research Institute) submitted a proposal, at the request of ARPA, to develop a rocket-boosted 12-gage buckshot round. The projectile was to be a plastic rocket motor integrated into a cup-type sabot containing nine each No. 1 buckshot. The muzzle velocity of 760 ft-sec^{-1} was to be achieved essentially by a conventional propellant charge, which was presumed to ignite the rocket propellant. Folding fins were provided to give stability during the rocket flight. At burnout, aerodynamic drag was to strip the sabot-cum-rocket from the charge of shot and allow the latter to disperse. Thus, the start of dispersion was to be moved out to a point 50 to 150 yards from the muzzle, and effectively reduce dispersion.

([redacted]) This proposal was evaluated by the Army Weapons Command, and found to have serious shortcomings. Briefly, the conclusions were:

(1) In the zone between muzzle and burnout there would be no dispersion, thus reducing hit probability for near targets.

(2) Only cylinder-bore weapons could be used, precluding the best utilization of other shotgun rounds.

(3) The payload (9 each No. 1 buck) should be heavier

(4) The proposed rocket propellant is one which tends to be difficult to ignite. Reliability of the round would be in question.

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(5) The estimated specific impulse of the rocket motor (190 seconds) is unrealistically optimistic.

(6) The proposed frangible closure disc has not proved feasible in other shotshell designs.

(7) The cost would be excessive.

(8) The folding-fin construction did not appear reliable.

Winchester-Western Flechette Round

(U) Recently, Winchester-Western has developed a 12-gage load containing 20 flechettes weighing 7.3 grains each. The muzzle velocity of these flechettes is 1,750 ft-sec^{-1} and at 100 yards the velocity is 1,200 ft-sec^{-1}. This load is of interest because of its low dispersion. At 150 yards, 50 per cent of the flechettes will hit within a circle 6 ft in diameter. This would result in a value of 6 mils for σ_p. On May 12, 1965, Winchester-Western demonstrated this load to representatives of the Army, Marine Corps, and RACIC.

(U) At 100 yards, the flechettes completely penetrated a 1/8-inch-thick mild-steel plate and at 200 yards completely penetrated 1-3/4 inches of pine. More detailed information as to the effectiveness (P_k) of the individual flechettes was not available. The work of Winchester-Western was done without Government funding, and they consider their developments proprietary.

Current Development Activity

M-79 Grenade Launcher,
12-Gage Adapter

(U) Winchester-Western has developed an experimental adapter to permit the firing of 12-gage shotshells in the M-79 grenade launcher. This adapter is

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currently undergoing evaluation at the Limited War Laboratory at Aberdeen Proving Ground, Maryland.

Possible Future Development Activity

Dense-Metal, Reduced-Dispersion Shot Cartridge

[redacted] A development program on this subject would have two primary objectives: (1) to determine the best type and size of shot, and (2) to determine the best means of reducing dispersion for the shot selected. The selection of the type and size of shot should be relatively straightforward because of the past work on these general subjects. A primary decision would be involved in the selection of cartridge size. The second objective would require considerable experimental work to evaluate the effectiveness of different means of reducing shot dispersion. However, on the basis of the results of past work, it should be possible to achieve a significant reduction in dispersion within a reasonably short time. The inclusion of these two features, dense metal and reduced dispersion, in a standard cartridge would appear to be extremely desirable for COIN and RAC operations.

Winchester-Western Flechette

[redacted] Because of the low dispersion reported for the Winchester-Western flechette and its relatively long-range effectiveness, a program to determine the effectiveness of the cartridge in terms of P_h, P_{hk}, and P_k as related to COIN and RAC operations would appear to be extremely desirable.

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Explosive-Charged Shot

([redacted]) The development of a satisfactory cartridge using explosive-charged shot would be a major undertaking. However, in view of the greatly increased effect per round, it is believed that the potential of this approach should be explored further. The primary problem appears to be premature (bore) detonation. Therefore, a Phase I program appears desirable, to investigate premature detonation in relation to important factors such as shot size, explosive type, and velocity. If this study were successful, follow-on work could be initiated to optimize the parameters in a standard cartridge.

OTHER SIDEARM CONSIDERATIONS

(U) In addition to the ammunition aspects discussed previously, the study described here disclosed a limited number of concepts related to non-ammunition improvements of systems effectiveness. Generally, these items fall into two categories: (1) aiming-error reduction methods, and (2) special weapons systems.

Aiming-Error Reduction Methods

(U) The most important facet of pistol effectiveness under field conditions is aiming error. Systems employing dispersion to compensate for aiming error are not guaranteed an increase in effectiveness when the net energy of the weapon system is limited, either by recoil, in the case of conventional arms, or by logistic considerations, as in the case of rocket weapons. Generally, aiming error is considered to be a fixed quantity which cannot be reduced. On the other hand, the whole sport of pistol target shooting presupposes that aiming error *can* be reduced. The means employed in the sport to reduce aiming error fall

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into four categories: training, special weapons, special sights, and special stocks (grips).

(U) Training encompasses more than simply "practice". It is a well-developed and orderly science as practiced by serious target-pistol enthusiasts. Special weapons include modifications (apart from those intended to reduce projectile dispersion) such as sensitive, repeatable triggers, balance weights, and muzzle brakes. An example of a rather radical and highly successful special weapon is the U.S.S.R. "Record" cal. .22 short pistol[20] which was used in winning the Olympic matches during the first year that it was available and was subsequently barred as "unfair".

([redacted]) One special-weapons possibility might be a fully automatic pistol, carefully compensated and firing a .22 rimfire cartridge. At the ranges where a pistol is used (i.e., under 50 meters), the lethality of the .22 long rifle cartridge is similar to that of one pellet of No. 1 buck from a shotgun. A burst of 13 .22's has the same energy as the shotgun round. One 12-gage shotshell weighs 800 grains, while 13 .22 long rifle cartridges weigh 667 grains. In addition, the spin-stabilized .22 bullet maintains a relatively high velocity at ranges greatly in excess of shotgun range and the P_k value for even a low-power .22 should be superior to that of an individual shot pellet.

(U) Special sights are primarily made to be rigidly attached to the barrel, to provide a long sight radius, and to be capable of fine adjustment. The chief virtue of the common (Patridge) pistol sights is their low profile, which is convenient when the pistol is used with a holster. They are, however, not well suited to "quick fire" situations.

([redacted]) Special stocks are made to fit the hand of the firer, to provide a comfortable position, and to relieve the muscles of the hand from a large part of the job of holding the pistol. A large portion of aiming error is due to the

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flexibility of the shoulder-arm-hand structure. A simple shoulder-stock, as applied to pistols in the past, does much to reduce this flexibility, but at the cost of some speed in pointing. A type of stock which bypassed just the wrist joint (as the shoulder-stock bypasses the wrist and elbow joints) may offer an advantageous compromise. With this type of stock, the forearm, rather than the hand, is "pointed", with a small sacrifice in speed in return for a rather substantial gain in rigidity. For close coupling between the eye and the gun, as necessary in "quick fire" situations, a helmet-mounted weapon system might be a possibility.

Special Systems

(U) Four special systems are described below which are not concerned with sidearm ammunition since they are over-all weapon systems, but may be of interest as total system concepts: (1) Gyrojet, (2) multiple-rocket pistol, (3) RICA Model 16 machine pistol, and (4) salvo-squeezebore cal. 45-9 mm.

Gyrojet

(U) The Gyrojet concept relates to an entire weapon system composed, basically, of a spin-stabilized rocket which is, in its entirety, the inert projectile. The rockets are launched from a short (6-inch long) tubular launcher of "pistol" configuration having provision for aiming and firing as a conventional pistol. Launchers can be made in single-barrel/single-shot, multiple-barrel/single-shot, or single-barrel/semiautomatic form. The launcher is generally light in weight and inexpensive.

(U) Miniature rockets have been under development by MB Associates, San Ramon, California, since the Spring of 1960. Gyrojet types have been made principally in .49, .50, and 13-mm (0.512 in.) "caliber".

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(U) In comparison with conventional weapons the Gyrojet has several unique properties. Since the launcher does not have to sustain any pressure or recoil, it can be of lightweight, inexpensive construction. The Gyrojet does not achieve peak velocity until it has travelled approximately 40 ft. Therefore, maximum lethality is not attained when the target is nearer than this distance. The low velocity of the Gyrojet as it leaves the launcher, the initial low rate of spin, and the fact that the individual rocket does not tightly fit the "barrel" of the launcher are characteristics detrimental to accuracy. In addition, the dynamic balance is affected by the initial balance of the propellant and the manner in which it burns. It must be pointed out, however, that the dominant factor in handgun accuracy (P_h) is not ammunition accuracy (dispersion), but rather aiming error.

[redacted] Early interest in the Gyrojet(22-24) related to a low-cost pistol of reduced accuracy for village defense by indigenous personnel. This concept used a plastic "pistol" (launcher) of double-barrel form that was manually loaded. The estimated cost of the pistol was $0.50, and of ammunition $0.50 per round. The rockets, at burnout, would have approximately the same kinetic energy as the cal. .45 pistol bullet. Dispersion, when the unit was hand held, was also comparable to that of the cal. .45 pistol. The concept later changed to that of a semiautomatic, single "barrel" pistol with a seven-round magazine within the grip. This pistol was of die-cast aluminum construction having an estimated production cost of $2.00 per item. Reliability problems were concerned with hangfires, misfires, rocket blow-ups, and improper feeding; the dispersions, on the order of 10 mils, were also considered high. With a burnout weight of 190 grains and a velocity of 860 to 1,200 $ft \cdot sec^{-1}$, the rockets had burnout energies of 400 to 600 ft-lb.

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(U) ARPA has funded continued research[25-27] "to determine the optimum spin-stabilized microrocket for hand weapon use". Under this program work has been concentrated on the 13-mm (0.512 in.) "caliber" Gyrojet. The target of this research has been 90 per cent reliability and a dispersion of not more than 7 mils C.E.P. at 100 ft. The final results of the program are not yet available.

(U) In an independent effort[28], Ford Aeronutronic proposed a modified revolver firing a 5-1/2-in.-long, cal. .50 spin-stabilized (by barrel rifling only) rocket. Burnout weight was to be 230 grains and velocity 860 ft-sec^{-1}. They also proposed a 160-grain, 1,500-ft-sec^{-1} fin-stabilized rocket of similar proportion and also launched from a modified (long cylinder) revolver. No further work on this concept has been uncovered.

Multiple-Rocket Pistol

([redacted]) A hand-held weapon firing a salvo of fin-stabilized rocket missiles was proposed in September, 1960, by ORDTECH Corporation (presently MB Associates), Walnut Creek, California[29]. This concept involved a honeycomb array of 24 0.10-in.-diameter rockets within a short tubular launcher of perhaps 1-1/2-inch diameter, with a firing button, but no conventional "grip". This weapon was intended as a throw-away device to be airdropped to indigenous personnel having no training and very little education. It was evidently not developed or investigated further.

([redacted]) In 1962, in connection with development work in the field of microrockets, MB Associates submitted a concept of fin-stabilized microrockets fired in salvo from a pistol-type launcher[30]. The performance of two sizes of fin-stabilized rockets, 1/8- and 1/4-in. diameter, in various hypothetical salvo sizes was examined on the basis of the ballistic properties of single rockets and the wounding abilities of stable flechettes. Initially proposed were: (1) a salvo

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of 24 1/8-in., 2-1/2-grain rockets having a burnout velocity of 3,600 ft-sec^{-1} at 8 ft, and (2) a salvo of 9 1/4-in., 20-grain rockets having a burnout velocity of 3,600 ft-sec^{-1} at 17 ft.

([redacted]) The dispersion of both the 1/8- and 1/4-in. rockets was 58 mils (6-in. launcher length). With such a high value of dispersion, a salvo of 48 1/8-in. rockets was required to yield an effectiveness equal to that of the cal. .45 ball cartridge at 25 meters. A comparison of the 1/8-in. rocket system ("pistol" plus 50 48-round salvos) with the M1911 pistol and 50 rounds of ball ammunition showed that the weights of the two systems were comparable, but that the volume (bulk) of the rocket weapon system was 50 times that of the .45 pistol system(30).

([redacted]) The 1/4-in. rocket system, which required a salvo of 27 rockets to match the effectiveness of the cal. .45 sidearm, was even less competitive in weight than is the 1/8-in. rocket system. [redacted]

(U) On the basis of this evaluation by BRL(30), no further work was recommended on this concept.

<u>RICA Model 16 Machine Pistol</u>

(U) The RICA "Constant Reaction" machine pistol was developed during World War II by Shepard Robinson Arms Development Co., Woolwich, N.S.W. It was tested after the war in England. Development was continued in the U. S. by the RICA Co. of Costa Mesa, California, up to 1952 when the work stoppe[redacted] all of the development costs having been borne by private individuals. In early 1962, Robinson of the RICA Co. offered test samples of the Model 16 machine pistol to ARPA for evaluation. This offer was declined because there was "no immediate need" for such a weapon(31).

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(U) The pistol proposed was a one-hand-held, holster-carried pistol similar in size and weight to the cal. .45 M1911 pistol. It fired 9-mm Parabellum ammunition (cal. .45 being offered as an option), either semi- or full-automatic (cyclic rate, 600 rpm), from a 16-round magazine in the grip. The magazine was expendable and self-ejecting, allowing sustained high rates of fire. The average reaction force was 7.5 lb.

(U) In this "constant reaction" system, the reciprocating elements of the gun mechanism were grounded to the weapon frame only by the friction of the sliding members and the reaction of the main (actuating) spring. Thus, the pulsations of automatic fire (both rearward and forward impulses) were largely damped and the frame was subjected to a steady, average recoil force. This principle applied to a pistol is said(31) to permit very accurate full-automatic fire.

(U) No further information regarding this concept has been uncovered.

Salvo-Squeezebore Cal. .45-9 mm

(/) The salvo-squeezebore (SSB) concept, in which multiple projectiles in a single cartridge are fired through a converging barrel, has been primarily applied to the cal. .50 machine gun. This concept, a development of the RICA Co., was also proposed in cal. .45-9 mm "size" for use in the pistol and submachine gun. The salvo-squeezebore concept is one in which SSB ammunition could be used in conventional, existing weapons, but conventional (ball) ammunition could not be used in SSB weapons.

(/) At the request of MUCOM, a quantity of cal. .45-9 mm ammunition and a "squeezebore" modified M-3 SMG were evaluated by Frankford Arsenal(11). The dispersion, of the order of 7 mils, was caused largely by the loss of symmetry (balance) of the projectiles as they were deformed in the conical portion of the

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bore. The use of steel projectiles resulted in severe barrel erosion, which is intolerable in a Service weapon.

([redacted]) The effectiveness of this device, on the basis of stable projectile properties, was higher than that of ball ammunition, but lower than that of the dense-metal shot cartridge. Assuming "fragment" projectile characteristics, the SSB system is somewhat more effective, but still inferior to the Mallory-shot cartridge. It was the opinion of Dickey[11] that further studies should be made regarding the lethality of this weapon. The problem of bore erosion must in any case be resolved before this system can be considered for adoption. It has apparently never been tested in actual pistol form.

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13. ABSTRACT

This report discusses the effectiveness of sodearm and shotgun ammunition for use in counterinsurgency and remote area conflict (U)

Range, dispersion, aiming bias, recoil, military stress and projectile velocity are discussed with regard to their effect on accuracy, lethality, and effectiveness.

The use and effectiveness of multiple flechettes, explosive-charged shot pellets, and rocket-boosted rounds as shotgun ammunition as well as the effect of dispersion reduction are discussed. (U)

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Range	6					
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Aiming	9,6					
Bias	6					
Recoil	6					
Military Stress	6					
Projectile Velocity	6					
Accuracy	7					
Lethality	7					
Multiple-Flechette Cartridges	8,9,10					
Shot Cartridges	8,9,10					
Strip-Bullet Cartridges	8,9,10					
Multiple Flechettes	8,9,10					
Explosive-Charged Shot Pellets	8,9,10					
Rocket-Boosted Rounds	8,9,10					
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