UNCLASSIFIED

63-3-1



BRL

MEMORANDUM REPORT NO. 1452
JANUARY 1963

# EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

Arthur D. Groves





Department of the Army Project No. 503-05-005
BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 1452

JANUARY 1963

# EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

Arthur D. Groves

Weapons Systems Laboratory

Department of the Army Project No. 503-05-005

ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

MEMORANDUM REPORT NO. 1452

ADGroves/jdk
Aberdeen Proving Ground, Md.
January 1963

# EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

ABSTRACT

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

## INTRODUCTION

Small arms are frequently employed in an unaimed fire rolè. That is, they are fired into a target area, but not at a particular target element within that area. It is therefore of interest to devise mathematical techniques for evaluating the effectiveness of small arms weapons when employed in this manner. Two measures of effectiveness will be considered in this report, and mathematical formulae will be generated allowing computations of each of these measures to be made. The concept of the lethal area of a round of small arms ammunition was introduced in BRL Memorandum Report 998, "The Lethal Areas of Small Arms", by Theodore E. Sterne. The discussion there suggested the first effectiveness measure to be discussed, a lethal area model applicable to a small arms round. The second model to be devised is one which allows for the computation of the probability of incapacitating a target element (usually a soldier) when a round is fired into the target area.

## ASSUMPTIONS AND DEFINITIONS

For both models it will be assumed that the target consists of soldiers uniformly but randomly distributed throughout the target area with density $\delta$ men per unit area. The target is of depth D measured parallel to the line of fire, and is of sufficient width that a round cannot miss the target to the side. The soldiers are assumed to be in such a posture and on such a terrain that each presents area $A_p$ to a bullet falling into the target area with angle of fall $\theta$. In this posture the height of each soldier is H. Thus the target can be thought of as a volume having depth D, height H, and essentially infinite width. While the round is not aimed at any individual soldier, it is aimed at some point in relation to the entire target volume. Let this point be on the front of this target at a height Y above the ground. Let $\sigma$ be the standard deviation of total vertical delivery error at the front of the target, and assume that, within the target volume, all trajectories are straight lines and are parallel to the line defined by the angle of fall $\theta$. Let y indicate the height above the ground at which the bullet passes the front of the target. This height, of course, will be variable, having a normal distribution with mean Y and standard deviation $\sigma$. Let d(y) denote the horizontal distance traveled <u>within the target volume</u> by a bullet passing the front of the target at height y. Now define the "endangered area" to be $\frac{A_p d(y)}{H}$, where $\frac{A_p}{H}$ is an approximation to the average width of a soldier in the posture assumed. Let the density function for the distribution of y be given by

$$f(y) = \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(y-Y)^2}{2\sigma^2}}$$

## DERIVATION OF MODELS

The desired lethal area, $A_L$, will be the average value of the product of the probability that a soldier becomes a casualty when hit ($P_{H_K}$), and the endangered area, the average being taken over the distribution of y. It is assumed that $P_{H_K}$ is a constant throughout the target volume. Actually, $P_{H_K}$ varies slightly as the projectile passes through the target due to velocity fall off. This change in $P_{H_K}$ is small, however, for target sizes of interest, and can be ignored without introducing significant error. Thus

$$A_L = \int_{y=-\infty}^{\infty} \frac{P_{H_K} A_p d(y)}{H} f(y)\, dy$$

$$= \frac{P_{H_K} A_p}{H} \int_{y=-\infty}^{\infty} d(y)\, f(y)\, dy$$

$$= \frac{P_{H_K} A_p}{H} \bar{d} ,$$

where $\bar{d} = \int_{y=-\infty}^{\infty} d(y)\, f(y)\, dy$ is recognized as the average value of d(y), the horizontal distance traversed by the bullet within the target volume.

In deriving the model for computing the probability of incapacitating a soldier under the assumed conditions, the following reasoning was followed: The probability of hitting a soldier given a particular y and hence a particular "endangered area" is simply the probability that at least one soldier is found within that "endangered area." (Here it is assumed that if the bullet hits a soldier, it completely spends itself and cannot pass through that soldier and hit a second behind him.) According to Poisson probability theory, the probability of exactly i soldiers being in the "endangered area" is

$$p_i = \frac{e^{-E(y)}\left[E(y)\right]^i}{i!} ,$$

where E(y) is the expected number of soldiers in that area. Then the probability of at least one soldier being there is

$$1-p_o = 1-e^{-E(y)} .$$

Of course, E(y) is simply the product of the "endangered area" and the density of troops within the target area. Thus

$$E(y) = \frac{\delta A_p \, d(y)}{H} .$$

Since $1-e^{-E(y)}$ is the probability of hitting a soldier as a function of y, the probability of incapacitating a soldier as a function of y is

$$P_K(y) = P_{H_K}\left[1-e^{-E(y)}\right],$$

where $P_{H_K}$ is, as before, the probability that a soldier will be incapacitated if he is hit. The desired result is then the average value of $P_K(y)$ taken over the distribution of y. Thus $P_K$, the desired result, is given by

$$P_K = \int_{y=-\infty}^{\infty} P_K(y)\ f(y)\ dy.$$

Before either this integral or the one defining $\bar{d}$ in the derivation of the lethal area can be evaluated a specific definition of the function d(y) must be given. Initially two cases will be given, although it will be shown that these can be combined into a single result. The two cases are defined by the following inequalities:

| | |
|---|---|
| Case 1 | $D \tan \theta \geq H$ |
| Case 2 | $D \tan \theta < H$ |

Figures 1 and 2 illustrate the conditions represented by these cases. As can be seen, Case 1 applies when no bullet can enter the target so as to traverse the full depth D within the target, while Case 2 applies when the full depth D can be traversed by a bullet. In either case, a falling bullet may enter the target through any one of three zones, with the zones being defined according to how the distance d(y) is computed for a bullet entering through that zone. The following defines the zones and specifies d(y) for each zone.

Case 1 $(D \tan \theta \geq H)$

| | | |
|---|---|---|
| Zone 1 | $0 \leq y < H$ | $d(y) = y \cot \theta$ |
| Zone 2 | $H \leq y < D \tan \theta$ | $d(y) = H \cot \theta$ |
| Zone 3 | $D \tan \theta \leq y < H + D \tan \theta$ | $d(y) = D + (H-y) \cot \theta$ |

Case 2 $(D \tan \theta < H)$

| | | |
|---|---|---|
| Zone 1 | $0 \leq y < D \tan \theta$ | $d(y) = y \cot \theta$ |
| Zone 2 | $D \tan \theta \leq y < H$ | $d(y) = D$ |
| Zone 3 | $H \leq y \leq H + D \tan \theta$ | $d(y) = D + (H-y) \cot \theta$ |

In both cases, $d(y) = 0$ if $y < 0$ or if $y > H + D \tan \theta$. Now notice that a single definition of the three zones and distance functions suffices for both cases, as follows:

Zone 1 $0 \leq y < \min(H, D \tan \theta)$

$$d(y) = y \cot \theta$$

Zone 2 $\min(H, D \tan \theta) \leq y < \max(H, D \tan \theta)$

$$d(y) = \min(D, H \cot \theta)$$

Zone 3 $\max(H, D \tan \theta) \leq y \leq H + D \tan \theta$

$$d(y) = D + (H-y) \cot \theta,$$

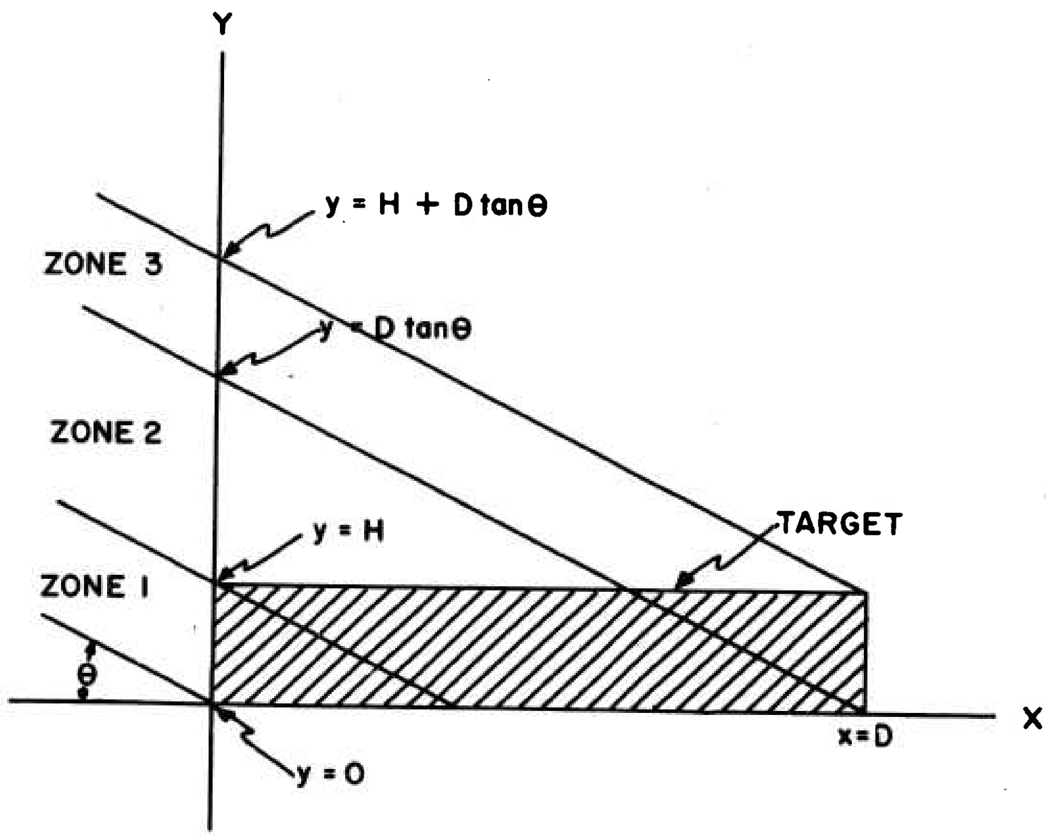


FIGURE I CASE I D tanθ ≥ H

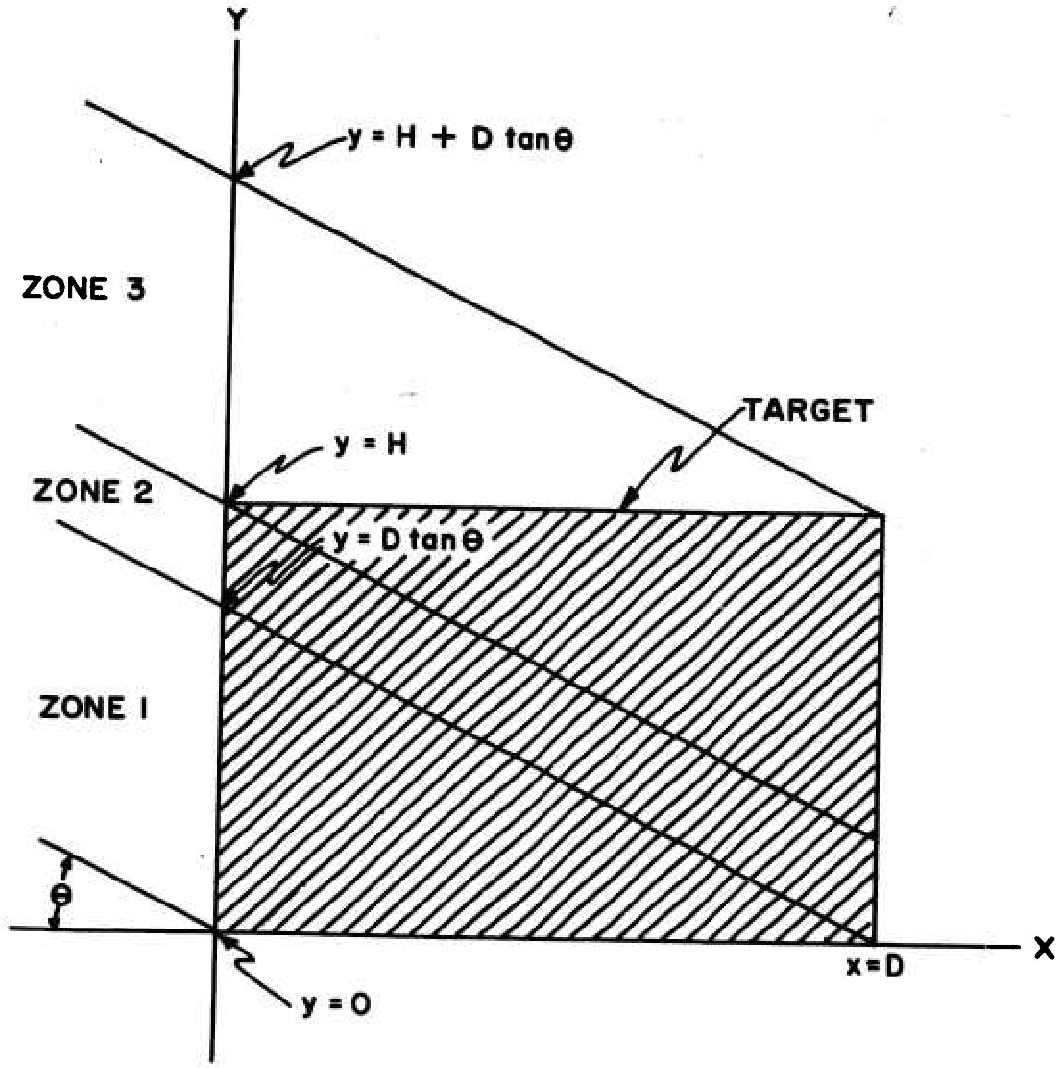


FIGURE 2 CASE 2 D tanθ < H

where min (H, D tan θ) means the smaller of the two quantities H and D tan θ, and max (H,D tan θ) means the larger of those two quantities. Based on this composite definition, the general definition of d(y) can be given. For simplicity, denote

$$a = \min(H, D\tan\theta),$$

and

$$b = \max(H, D\tan\theta).$$

Note that

$$H + D\tan\theta = a+b,$$

$$\min(D, H\cot\theta) = a\cot\theta,$$

and

$$D + (H-y)\cot\theta = (a+b-y)\cot\theta.$$

Thus

$$d(y) = \begin{cases} 0 & \text{if } y < 0 \\ y\cot\theta & \text{if } 0 \leq y < a \\ a\cot\theta & \text{if } a \leq y < b \\ (a+b-y)\cot\theta & \text{if } b \leq y \leq a+b \\ 0 & \text{if } y > a+b \end{cases}$$

Applying this definition in the lethal area model,

$$\bar{d} = \int_{y=-\infty}^{\infty} d(y)f(y)dy = \cot\theta\left[\int_0^a yf(y)dy + a\int_a^b f(y)dy + \int_b^{a+b} (a+b-y)f(y)dy\right].$$

In the model for computing the probability of incapacitating a soldier, the further simplification

$$M = \frac{\sigma A_p \cot\theta}{H} \qquad \text{is introduced.}$$

Then

$$P_K = P_{H_K}\left\{\int_0^a f(y)\left[1-e^{-\frac{\delta My}{\sigma}}\right]dy + \int_a^b f(y)\left[1-e^{-\frac{\delta Ma}{\sigma}}\right]dy + \int_b^{a+b} f(y)\left[1-e^{-\frac{\delta M}{\sigma}(a+b-y)}\right]dy\right\}.$$

## EVALUATION OF LETHAL AREA INTEGRALS

It has been shown that in the lethal area model

$$\bar{d} = \cot\theta\left[\int_0^a yf(y)dy + a\int_a^b f(y)dy + \int_b^{a+b}(a+b-y)f(y)dy\right].$$

This can be rewritten

$$\bar{d} = \cot\theta\left[\int_0^a yf(y)dy - \int_b^{a+b} yf(y)dy + a\int_a^b f(y)dy + (a+b)\int_b^{a+b} f(y)dy\right].$$

Now, in general, for any A and B

$$\int_A^B f(y)dy = \Phi\left(\frac{B-Y}{\sigma}\right) - \Phi\left(\frac{A-Y}{\sigma}\right),$$

where $$\Phi(X) = \int_{-\infty}^{X} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} dt,$$

the cumulative normal probability function. In Appendix A it is shown that

$$\int_A^B yf(y)dy = \sigma\left[\phi\left(\frac{A-Y}{\sigma}\right) - \phi\left(\frac{B-Y}{\sigma}\right)\right] + Y\left[\Phi\left(\frac{B-Y}{\sigma}\right) - \Phi\left(\frac{A-Y}{\sigma}\right)\right]$$

where $$\phi(X) = \frac{1}{\sqrt{2\pi}} e^{-\frac{X^2}{2}},$$

the normal density function. Thus

$$\int_{0}^{a} yf(y)dy = \sigma\left[\phi\left(\frac{-Y}{\sigma}\right) - \phi\left(\frac{a-Y}{\sigma}\right)\right] + Y\left[\Phi\left(\frac{a-Y}{\sigma}\right) - \Phi\left(\frac{-Y}{\sigma}\right)\right],$$

$$\int_{b}^{a+b} yf(y)dy = \sigma\left[\phi\left(\frac{b-Y}{\sigma}\right) - \phi\left(\frac{a+b-Y}{\sigma}\right)\right] + Y\left[\Phi\left(\frac{a+b-Y}{\sigma}\right) - \Phi\left(\frac{b-Y}{\sigma}\right)\right],$$

$$a\int_{a}^{b} f(y)dy = a\left[\Phi\left(\frac{b-Y}{\sigma}\right) - \Phi\left(\frac{a-Y}{\sigma}\right)\right], \text{ and}$$

$$(a+b)\int_{b}^{a+b} f(y)dy = (a+b)\left[\Phi\left(\frac{a+b-Y}{\sigma}\right) - \Phi\left(\frac{b-Y}{\sigma}\right)\right].$$

Combining these,

$$\overline{d} = \cot\theta\left[\sigma\left\{\phi\left(\frac{-Y}{\sigma}\right) - \phi\left(\frac{a-Y}{\sigma}\right) - \phi\left(\frac{b-Y}{\sigma}\right) + \phi\left(\frac{a+b-Y}{\sigma}\right)\right\}\right.$$
$$\left. -Y\Phi\left(\frac{-Y}{\sigma}\right) - (a-Y)\,\Phi\left(\frac{a-Y}{\sigma}\right) - (b-Y)\,\Phi\left(\frac{b-Y}{\sigma}\right) + (a+b-Y)\,\Phi\left(\frac{a+b-Y}{\sigma}\right)\right]$$

and thus

$$A_L = \frac{P_{H_K} A_p \cot\theta}{H}\left[\sigma\left\{\phi\left(\frac{-Y}{\sigma}\right) - \phi\left(\frac{a-Y}{\sigma}\right) - \phi\left(\frac{b-Y}{\sigma}\right) + \phi\left(\frac{a+b-Y}{\sigma}\right)\right\}\right.$$
$$\left. -Y\Phi\left(\frac{-Y}{\sigma}\right) - (a-Y)\,\Phi\left(\frac{a-Y}{\sigma}\right) - (b-Y)\Phi\left(\frac{b-Y}{\sigma}\right) + (a+b-Y)\,\Phi\left(\frac{a+b-Y}{\sigma}\right)\right]$$

EVALUATION OF INCAPACITATION PROBABILITY INTEGRALS

It has been shown that the probability of incapacitation is given by

$$P_K = P_{H_K}\left\{\int_0^a f(y)\left[1-e^{-\frac{\delta M y}{\sigma}}\right]dy + \int_a^b f(y)\left[1-e^{-\frac{\delta M a}{\sigma}}\right]dy + \int_b^{a+b} f(y)\left[1-e^{-\frac{\delta M(a+b-y)}{\sigma}}\right]dy\right\}$$

$$= P_{H_K}\left\{\int_0^{a+b} f(y)dy - I_1 - I_2 - I_3\right\},$$

where $I_1 = \int_0^a f(y)e^{-\frac{\delta M y}{\sigma}} dy$ ,

$$I_2 = \int_a^b f(y)e^{-\frac{\delta M a}{\sigma}} dy,$$ and

$$I_3 = \int_b^{a+b} f(y)e^{-\frac{\delta M}{\sigma}(a+b-y)} dy.$$

But $\int_0^{a+b} f(y)dy = \Phi\left(\frac{a+b-Y}{\sigma}\right) - \Phi\left(\frac{-Y}{\sigma}\right)$

and $I_2 = e^{-\frac{\delta M a}{\sigma}} \int_a^b f(y)dy = e^{-\frac{\delta M a}{\sigma}} \left\{\Phi\left(\frac{b-Y}{\sigma}\right) - \Phi\left(\frac{a-Y}{\sigma}\right)\right\}.$

Now if a function F(A,B,R) is defined to be

$$F(A,B,R) = \int_A^B e^{Ry} f(y)dy, \qquad \text{then}$$

$$I_1 = F\left(a, b, -\frac{\delta M}{\sigma}\right) \qquad \text{and}$$

$$I_3 = e^{-\frac{\delta M}{\sigma}(a+b)} F\left(b, a+b, \frac{\delta M}{\sigma}\right)$$

In Appendix B it is shown that

$$F(A,B,R) = e^{R\left(\frac{R\sigma^2}{2} + Y\right)} \left\{\Phi\left(\frac{B-Y-R\sigma^2}{\sigma}\right) - \Phi\left(\frac{A-Y-R\sigma^2}{\sigma}\right)\right\}$$

Thus

$$I_1 = e^{\delta M\left(\frac{\delta M}{2} - \frac{Y}{\sigma}\right)} \left\{\Phi\left(\frac{a-Y+\delta M\sigma}{\sigma}\right) - \Phi\left(\frac{-Y+\delta M\sigma}{\sigma}\right)\right\}$$

and

$$I_3 = e^{-\delta M\left(\frac{a+b-Y}{\sigma} - \frac{\delta M}{2}\right)} \left\{\Phi\left(\frac{a+b-Y-\delta M\sigma}{\sigma}\right) - \Phi\left(\frac{b-Y-\delta M\sigma}{\sigma}\right)\right\}.$$

Thus

$$P_K = P_{H_K}\Bigg[\Phi\left(\frac{a+b-Y}{\sigma}\right) - \Phi\left(\frac{-Y}{\sigma}\right) - e^{\delta M\left(\frac{\delta M}{2} - \frac{Y}{\sigma}\right)}\left\{\Phi\left(\frac{a-Y+\delta M\sigma}{\sigma}\right) - \Phi\left(\frac{-Y+\delta M\sigma}{\sigma}\right)\right\}$$

$$e^{-\frac{\delta M a}{\sigma}}\left\{\Phi\left(\frac{b-Y}{\sigma}\right) - \Phi\left(\frac{a-Y}{\sigma}\right)\right\} -$$

$$e^{-\delta M\left(\frac{a+b-Y}{\sigma} - \frac{\delta M}{2}\right)}\left\{\Phi\left(\frac{a+b-Y-\delta M\sigma}{\sigma}\right) - \Phi\left(\frac{b-Y-\delta M\sigma}{\sigma}\right)\right\}\Bigg] .$$

COMPUTATIONAL FORMS

These expressions for the probability of incapacitation and for the lethal area can be simplified somewhat for computational purposes. Let

$$\alpha = \frac{a}{\sigma} = \frac{1}{\sigma} \min (H, D \tan \theta)$$

$$\beta = \frac{b}{\sigma} = \frac{1}{\sigma} \max (H, D \tan \theta)$$

$$\gamma = \frac{Y}{\sigma}$$

$$M = \frac{\sigma A_p \cot \theta}{H}$$

Then

$$A_L = P_{H_K} M\Big[\Phi(-\gamma) - \Phi(\alpha-\gamma) - \Phi(\beta-\gamma) + \Phi(\alpha+\beta-\gamma) - \gamma\Phi(-\gamma) -$$

$$(\alpha-\gamma)\Phi(\alpha-\gamma) - (\beta-\gamma)\Phi(\beta-\gamma) + (\alpha+\beta-\gamma)\Phi(\alpha+\beta-\gamma)\Big]$$

and

$$P_K = P_{H_K}\left[\Phi(\alpha+\beta-\gamma) - \Phi(-\gamma) - e^{\delta M\left(\frac{\delta M}{2} - \gamma\right)}\left\{\Phi(\alpha-\gamma+\delta M) - \Phi(-\gamma+\delta M)\right\} - \right.$$

$$\left. e^{-\delta M\alpha}\left\{\Phi(\beta-\gamma)-\Phi(\alpha-\gamma)\right\} - e^{-\delta M\left(\alpha+\beta-\gamma - \frac{\delta M}{2}\right)}\left\{\Phi(\alpha+\beta-\gamma-\delta M)-\Phi(\beta-\gamma-\delta M)\right\}\right]$$

If $\theta = 0$, these formulae cannot be used, since $\cot\theta = \infty$, making $M = \infty$. However, following the same logical development, but restricting $\theta$ to be zero, it can be shown that

$$A_L = \frac{P_{H_K} A_p D}{H}\left\{\Phi\left(\frac{H-Y}{\sigma}\right) - \Phi\left(\frac{-Y}{\sigma}\right)\right\}.$$

In determining the probability of incapacitating a solider, if $\theta = 0$, it can be shown that

$$P_K = P_{H_K}\left[1 - e^{-\frac{\delta D A_p}{H}}\right]\left[\Phi\left(\frac{H-Y}{\sigma}\right) - \Phi\left(\frac{-Y}{\sigma}\right)\right].$$

Arthur D Groves

ARTHUR D. GROVES

APPENDIX A

$$\int_A^B y f(y)\,dy = \int_A^B \frac{y}{\sqrt{2\pi}\sigma} e^{-\frac{(y-Y)^2}{2\sigma^2}}\,dy$$

Let $t = \frac{y-Y}{\sigma}$ so that $y = \sigma t + Y$ and $dy = \sigma dt$

Then $\displaystyle\int_A^B y f(y)\,dy = \int_{\frac{A-Y}{\sigma}}^{\frac{B-Y}{\sigma}} \frac{\sigma t + Y}{\sqrt{2\pi}} e^{-\frac{t^2}{2}}\,dt$

$$= \sigma \int_{\frac{A-Y}{\sigma}}^{\frac{B-Y}{\sigma}} \frac{t}{\sqrt{2\pi}} e^{-\frac{t^2}{2}}\,dt + Y \int_{\frac{A-Y}{\sigma}}^{\frac{B-Y}{\sigma}} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}}\,dt$$

$$= -\sigma \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} \Bigg|_{\frac{A-Y}{\sigma}}^{\frac{B-Y}{\sigma}} + Y \left\{\Phi\left(\frac{B-Y}{\sigma}\right) - \Phi\left(\frac{A-Y}{\sigma}\right)\right\}$$

$$= \sigma \left\{\phi\left(\frac{A-Y}{\sigma}\right) - \phi\left(\frac{B-Y}{\sigma}\right)\right\} + Y \left\{\Phi\left(\frac{B-Y}{\sigma}\right) - \Phi\left(\frac{A-Y}{\sigma}\right)\right\}$$

## APPENDIX B

$$F(A,B,R) = \int_A^B e^{Ry} f(y)dy = \int_A^B e^{Ry} \frac{1}{\sqrt{2\pi}\sigma} e^{-\frac{(y-Y)^2}{2\sigma^2}} dy$$

Let $y = \sigma t + R\sigma^2 + Y$ so that $t = \frac{y-Y-R\sigma^2}{\sigma}$

and $dy = \sigma dt$. Then

$$F(A,B,R) = \int_{\frac{A-Y-R\sigma^2}{\sigma}}^{\frac{B-Y-R\sigma^2}{\sigma}} e^{R(\sigma t+R\sigma^2+Y)} \frac{1}{\sqrt{2\pi}} e^{-\left(\frac{t+R\sigma}{2}\right)^2} dt$$

$$= e^{\left(R^2\sigma^2 + RY - \frac{R^2\sigma^2}{2}\right)} \int_{\frac{A-Y-R\sigma^2}{\sigma}}^{\frac{B-Y-R\sigma^2}{\sigma}} \frac{1}{\sqrt{2\pi}} e^{-\frac{t^2}{2}} dt$$

$$= e^{R\left(\frac{R\sigma^2}{2} + Y\right)} \left\{\Phi\left(\frac{B-Y-R\sigma^2}{\sigma}\right) - \Phi\left(\frac{A-Y-R\sigma^2}{\sigma}\right)\right\}$$

DISTRIBUTION LIST

| No. of Copies | Organization |
|---|---|
| 10 | Commander<br>Armed Services Technical Information Agency<br>ATTN: TIPCR<br>Arlington Hall Station<br>Arlington 12, Virginia |
| 2 | Director<br>IDA/Weapon Systems Evaluation Group<br>Room 1E875, The Pentagon<br>Washington 25, D. C. |
| 2 | Director<br>Advanced Research Projects Agency<br>ATTN: Technical Information Officer<br>Mr. Fred Koether<br>The Pentagon<br>Washington 25, D. C. |
| 2 | Commanding General<br>U. S. Army Materiel Command<br>ATTN: AMCRD-RS-PE-Bal<br>AMCRD-DE-W<br>Research and Development Directorate<br>Washington 25, D. C. |
| 1 | Commanding Officer<br>Harry Diamond Laboratories<br>ATTN: Technical Information Office, Branch 012<br>Washington 25, D. C. |
| 6 | Commanding General<br>Frankford Arsenal<br>ATTN: Pitman-Dunn Laboratories<br>Mr. S. Kucson<br>Mr. C. Dickey<br>Mr. H. Rosenberg<br>Mr. J. Mitchell<br>Ballistic Division<br>Mr. Malinowski<br>Philadelphia 37, Pennsylvania |
| 3 | Commanding Officer<br>Picatinny Arsenal<br>ATTN: Feltman Research and Engineering Laboratories<br>Mr. Thomas Norton, ORDBB, D-W-9<br>Mr. S. Einbinder<br>Dover, New Jersey |
| 2 | Commanding Officer<br>Munition Command<br>ATTN: M. S. Spaulding<br>Picatinny Arsenal<br>Dover, New Jersey |
| 2 | Commanding General<br>U. S. Army Weapons Command<br>ATTN: Research Branch<br>Rock Island, Illinois |
| 2 | Foreign Science Technology Center<br>Arlington Hall Station<br>Washington 25, D. C. |
| 5 | Commanding Officer<br>Springfield Armory<br>ATTN: Mr. Carl Harvey<br>Mr. Herman Hawthorne<br>Mr. Otto Von Lossnitzer<br>R & D Division<br>AMSWE-PRD, Mr. Moberg<br>Springfield 1, Massachusetts |
| 2 | Research Analysis Corporation<br>6935 Arlington Road<br>Bethesda, Maryland<br>Washington 14, D. C. |
| 1 | Commanding Officer<br>U. S. Army Chemical Warfare Laboratories<br>ATTN: Medical Laboratory<br>Edgewood Arsenal, Maryland |
| 1 | Commanding General<br>U. S. Continental Army Command<br>Fort Monroe, Virginia |

DISTRIBUTION LIST

| No. of Copies | Organization |
|---|---|
| 3 | Commanding General<br>U. S. Army Combat Developments Command<br>ATTN: CDCMR-W<br>CDCRE-C<br>Fort Belvoir, Virginia |
| 2 | President<br>U. S. Army Infantry Board<br>Fort Benning, Georgia |
| 2 | Commandant<br>The Infantry School<br>Fort Benning, Georgia |
| 1 | Commanding Officer<br>U. S. Army Infantry CD Agency<br>Fort Benning, Georgia |
| 1 | President<br>U. S. Army Airborne Air Director and Special Warfare Board<br>Fort Bragg, North Carolina |
| 2 | Commanding General<br>Special Doctrine and Equipment Group<br>ATTN: SDEG-MA<br>Fort Belvoir, Virginia |
| 1 | Commandant<br>U. S. Army Special Warfare School<br>Fort Bragg, North Carolina |
| 1 | Army Research Office<br>3045 Columbia Pike<br>Arlington, Virginia |
| 1 | Commanding Officer<br>U. S. Army Strategy and Tactics Group<br>ATTN: STAG-LW<br>8120 Woodmont Avenue<br>Bethesda 14, Maryland |
| 2 | Chief, Research and Development<br>ATTN: Combat Materiel Division<br>Department of the Army<br>Washington 25, D. C. |
| 1 | Supervisor<br>U. S. Military Academy<br>ATTN: Professor of Ordnance<br>West Point, New York |
| 3 | Chief, Bureau of Naval Weapons<br>ATTN: DIS-33<br>Department of the Navy<br>Washington 25, D. C. |
| 1 | Chief of Naval Research<br>ATTN: Code 463<br>Department of the Navy<br>Washington 25, D. C. |
| 2 | Commander<br>U. S. Naval Weapons Laboratory<br>ATTN: Mr. M. Mussenden<br>Oper. Res. Group KBO-2<br>Dahlgren, Virginia |
| 5 | Commander<br>U. S. Naval Ordnance Test Station<br>ATTN: Gray 121<br>Code 4573<br>Code 4501<br>Code 4005<br>Code P-80<br>China Lake, California |
| 1 | Commander<br>U. S. Naval Ordnance Laboratory<br>ATTN: Mrs. Eva Liberman<br>White Oak<br>Silver Spring 19, Maryland |
| 1 | Commander<br>U. S. Naval Weapons Laboratory<br>ATTN: Technical Library<br>Dahlgren, Virginia |

## DISTRIBUTION LIST

| No. of Copies | Organization |
|---|---|
| 1 | AFSC (SCSA)<br>Andrews Air Force Base<br>Washington 25, D. C. |
| 1 | APGC (PGAPI)<br>Eglin Air Force Base<br>Florida |
| 2 | Commandant<br>U. S. Marine Corps<br>Washington 25, D. C. |
| 1 | Commandant<br>Marine Corps School<br>Quantico, Virginia |
| 1 | Institute for Defense Analyses<br>ATTN: Mr. DeDuff<br>1825 Connecticut Avenue, N. W.<br>Washington 25, D. C. |
| 1 | Aircraft Armaments, Inc.<br>ATTN: Eng. Library<br>Cockeysville, Maryland |
| 10 | The Scientific Information Officer<br>Defence Research Staff<br>British Embassy<br>3100 Massachusetts Avenue, N. W.<br>Washington 8, D. C. |
| 4 | Defence Research Member<br>Canadian Joint Staff<br>2450 Massachusetts Avenue, N. W.<br>Washington 8, D. C. |

AD ________ Accession No. ________

UNCLASSIFIED

Ballistic Research Laboratories, APG
EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE
A. D. Groves

Small arms -
Effectiveness
Area fire - small arms

BRL Memorandum Report No. 1452

DA Project No. 503-05-005
UNCLASSIFIED Report

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ________ Accession No. ________

UNCLASSIFIED

Ballistic Research Laboratories, APG
EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE
A. D. Groves

Small arms -
Effectiveness
Area fire -small arms

BRL Memorandum Report No. 1452

DA Project No. 503-05-005
UNCLASSIFIED Report

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ________ Accession No. ________

UNCLASSIFIED

Ballistic Research Laboratories, APG
EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE
A. D. Groves

Small arms -
Effectiveness
Area fire - small arms

BRL Memorandum Report No. 1452

DA Project No. 503-05-005
UNCLASSIFIED Report

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ________ Accession No. ________

UNCLASSIFIED

Ballistic Research Laboratories, APG
EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE
A. D. Groves

Small arms -
Effectiveness
Area fire - small arms

BRL Memorandum Report No. 1452

DA Project No. 503-05-005
UNCLASSIFIED Report

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ______ Accession No. ______

Ballistic Research Laboratories, APG

EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

A. D. Groves

BRL Memorandum Report No. 1452

DA Project No. 503-05-005

UNCLASSIFIED Report

UNCLASSIFIED

Small arms -
Effectiveness
Area fire - small arms

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ______ Accession No. ______

Ballistic Research Laboratories, APG

EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

A. D. Groves

BRL Memorandum Report No. 1452

DA Project No. 503-05-005

UNCLASSIFIED Report

UNCLASSIFIED

Small arms -
Effectiveness
Area fire - small arms

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ______ Accession No. ______

Ballistic Research Laboratories, APG

EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

A. D. Groves

BRL Memorandum Report No. 1452

DA Project No. 503-05-005

UNCLASSIFIED Report

UNCLASSIFIED

Small arms -
Effectiveness
Area fire - small arms

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.

AD ______ Accession No. ______

Ballistic Research Laboratories, APG

EFFECTIVENESS OF UNAIMED SMALL ARMS FIRE

A. D. Groves

BRL Memorandum Report No. 1452

DA Project No. 503-05-005

UNCLASSIFIED Report

UNCLASSIFIED

Small arms -
Effectiveness
Area fire - small arms

Mathematical models are presented for computing the lethal area and the probability of incapacitating a soldier when a round of small arms ammunition is fired into a target area but not at a particular soldier in that area. It is assumed that soldiers are uniformly but randomly distributed throughout the target area, and provision is made for varying the terrain and troop posture.