MEMORANDUM REPORT
M63-8-1

HIT PROBABILITY OF T114 BAT VEHICLE SYSTEM

by

D. E. WALTERS

OMS Code 5520.11.434 (TS4-4024)
DA Project 5S02-01-008

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FRANKFORD ARSENAL
RESEARCH AND DEVELOPMENT GROUP
PITMAN - DUNN LABORATORIES
PHILADELPHIA 37, PA.

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ABSTRACT

An estimate is made of the multiple fire hitting performance of the repeating T114 BAT Vehicle System against a passive tank target. Its probability of hitting with at least one hit in 4 shots is computed from a set of error assumptions representing quasi-combat conditions on a 7.5 ft. by 7.5 ft. target at 800, 1000, and 1200 yards.

INTRODUCTION

The 106 mm M40 BAT weapon was initiated and authorized in 1950 for the express purpose of dealing with the Soviet tank threat in Europe. After three years of development, it was standardized in 1953, and produced in quantity and issued to troops on a large scale in 1955.

Today, the M40, even with intense competition from AT wire-guided missiles, is still the most important member of the infantry's family of antitank weapons. In fact, it constitutes the backbone of the Army's current antitank defense.

The 106 mm M40 BAT System is a direct fire, 1000-yard, single shot, air-cooled, tripod-mounted, recoilless weapon, which can be fired from the ground or on a jeep. Its fire control equipment is a caliber .50 spotting rifle whose spotting ammunition matches that of the armor defeating 106 mm HEAT round. The basic rifle fires a 17.5 lb. hollow, charged projectile at 1650 fps. The entire weapon weights 485 lb and is manned by a three-man crew. The ground-mounted M40 is shown in Figure 1; Figure 2 shows the jeep-mounted M40.

In 1958, the infantry believed that a powerful and mobile antitank weapon could evolve from the M40 by making it automatic and mobile. The basic idea was to give the M40 an automatic firing capability and to place this armament on an armored vehicle. Other weapon specifications were that it be loaded and fired from inside the vehicle, its fire control was not to be altered, and its round-to-round accuracy was not to be hindered by going to burst fire. So, in accordance with the wish of the user, a hardware study was started to modify the breech of the 106 mm M40 rifle so it could accept a feed mechanism for producing automatic fire.

The present version of the modified M40 rifle utilizes a three-round magazine which enables the weapon to dispense four rounds, without reloading, at a rate of 6 rounds/minute. This repeating rifle was mounted on the lightly armored, track laying T114 carrier. The systems consists of the modified 106 mm M40 rifle, the 106 mm M344 HEAT cartridge, the caliber .50 M8 spotting rifle, the caliber .50 spotting-tracing M48 cartridge, and a pod turret assembly. The weapon and its carrier are shown in Figures 3 and 4.

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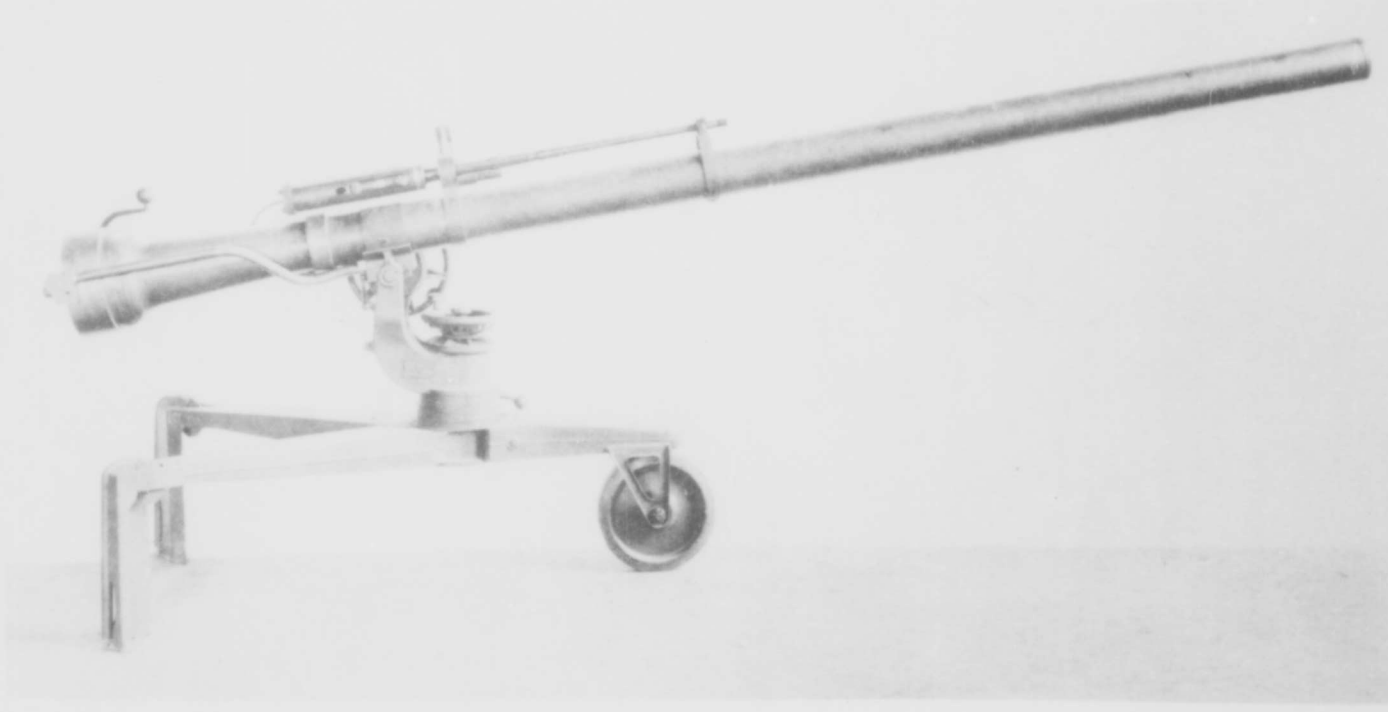

Figure 1. 106 mm M40 Rifle, ground mounted

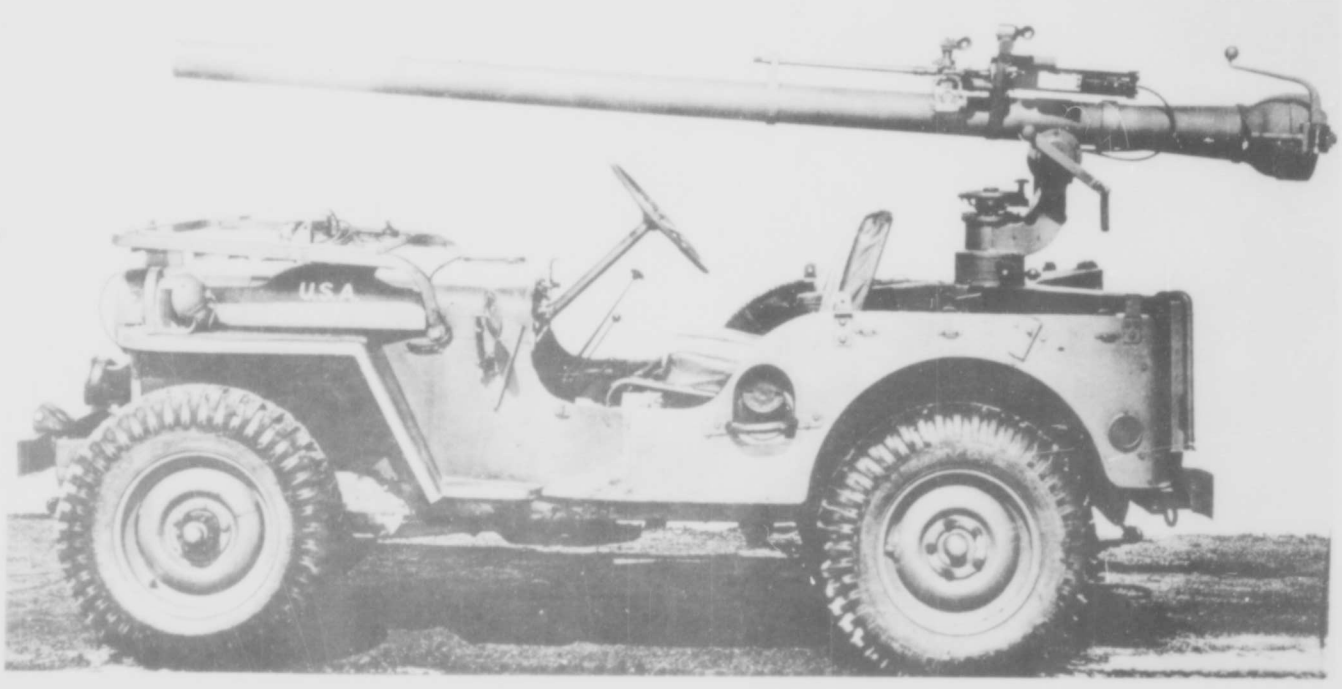

Figure 2. 106 mm M40 Rifle, mounted on M38 Truck

Figure 3. Vehicle, Armored, Full-tracked, BAT, T114, left side view - general

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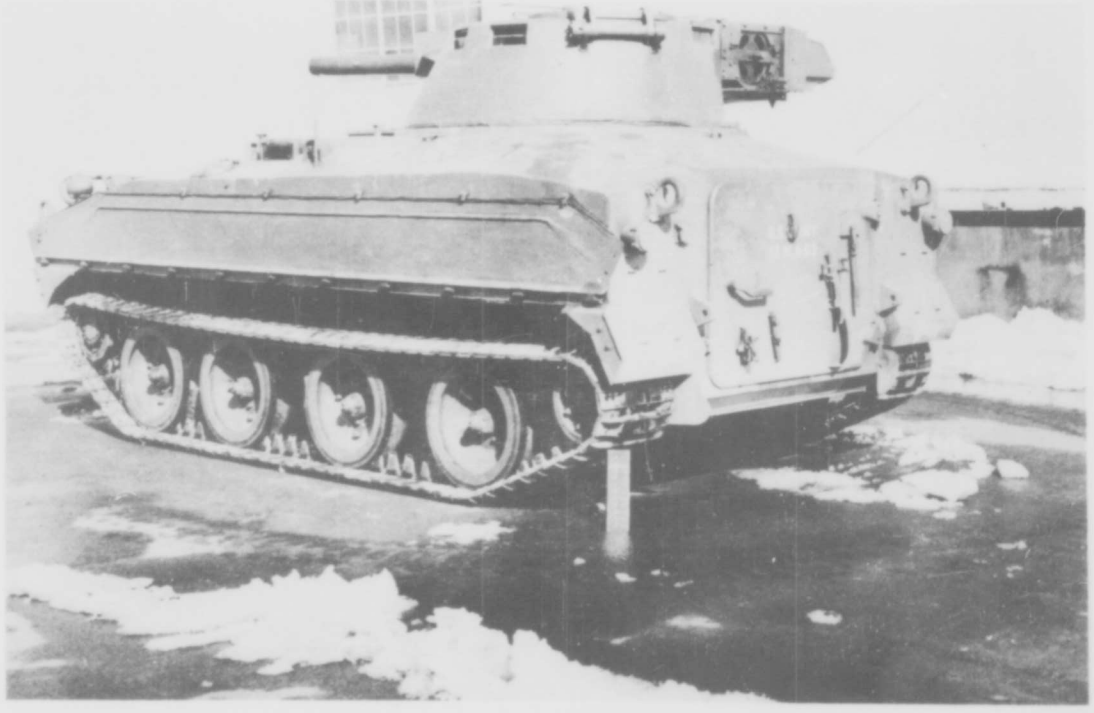

Figure 4. Vehicle, Armored, Full-tracked, BAT, T114, right rear view - general

PROBLEM STATEMENT

Although comprehensive studies involving the estimation of single shot first round accuracy have been made for the M40 BAT System, little consideration has been given to the assessment of its multiple fire performance. It is the object of this report to compute the probability of one or more hits of the T114 BAT Vehicle System in a burst of fire released against a co-operating tank target. No consideration is given to over-all effectiveness, such as time to hit, terrain, target vulnerability, warhead lethality, etc. Our purpose is simply to evaluate the hitting magnitude of the T114 BAT system under realistic error assumptions at target ranges of 800, 1000, and 1200 yards.

HITTING PROBABILITY WITH MULTIPLE SHOTS

The prediction of the probability of at least one hit in a burst fired at a given target depends on target area, range, number of shots, distribution of shots within the burst, and the accuracy of placing the burst in the vicinity of the target.

We are concerned with the over-all accuracy of the T114 BAT Vehicle System and we desire to estimate its chance of hitting a tank target once it dispenses its ammunition after the target is sensed with a caliber .50 M8 spotting round. The probability of one or more hits on a 7.5 ft. by 7.5 ft. vertical target (which is stationary and normal to the line of fire) with a burst from the T114 BAT system is computed by numerically evaluating the integral, assuming no trajectory mismatch.

$$\frac{1}{2\pi\,\sigma_{xb}\,\sigma_{yb}} \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \exp -\frac{1}{2}\left(\frac{x^2_b}{\sigma_{xb}^2} + \frac{y^2_b}{\sigma_{yb}^2}\right) \cdot$$

$$\cdot\left[1 - \left\{1 - \frac{1}{2\pi\,\sigma_x\,\sigma_y}\int_{-a}^{a}\int_{-a}^{a} \exp -\frac{1}{2}\left(\frac{(x-x_b)^2}{\sigma_x^2} \quad \frac{(y-y_b)^2}{\sigma_y^2}\right) dxdy\right\}^N\right] dx_b\; dy_b$$

(See Appendix for derivation.)

where $a = 3.75$ ft

N = number of rounds in burst

$x - x_b$ = horizontal deviation of impact point from burst center

$x - y_b$ = vertical deviation of impact point from burst center

x_b = horizontal deviation of burst center from target center

y_b = vertical deviation of burst center from target center.

σ_x = horizontal standard deviation of "x"

σ_y = vertical standard deviation of "y"

σ_{xb} = horizontal standard deviation of "x_b"

σ_{yb} = vertical standard deviation of "y_b"

The hitting performance of the T114 BAT system is dependent on the accuracy of putting the burst near the target center and on the distribution of shots within the burst. It is necessary to specify all the component errors which make up the accuracy of the burst center, as well as those errors which cause deviations from a fixed burst center.

With regard to the precision of delivering the burst on the target, the bivariate distribution of burst centers on the target plane is compounded from the errors caused by jump, cant, cross wind, aimpoint, muzzle velocity level, and zeroing. Specifically, the breakdown of the over-all burst center error into its components follows:

Source	Standard Deviation	
	Horizontal Components	Vertical Components
M8 jump	0.3 mil	0.3 mil
M40 jump	0.3 mil	0.3 mil
M8-M40 cant	88 mil	
M8 muzzle velocity		10 fps
M8-M40 cross wind	11 fps	
M40 muzzle velocity		10 fps
M8 aimpoint	1.25 ft	1.25 ft
M8 round to round	0.5 mil	0.5 mil
Zeroing		
M8 CI	0.22 mil	0.22 mil
M40 CI	0.22 mil	0.22 mil
M8 jump	0.3 mil	0.3 mil
M40 jump	0.3 mil	0.3 mil
M8 OCI	0.07 mil	0.07 mil
M40 OCI	0.07 mil	0.07 mil
M8-M40 cant	44 mil	
Muzzle velocity		10 fps
M8-M40 cross wind	11 fps	

As for the distribution of shots within the burst, it is assumed that this is made up solely of the M344 round-to-round variation. Given a burst center in the target plane, the distribution of M344 shots is measured from that point with a standard deviation of 0.5 mil in the horizontal and vertical directions.

Under these error suppositions, the probability of at least one hit with a burst from the T114 BAT Vehicle System was computed at 800, 1000, and 1200 yards on a passive tank target. The hitting probability attainable with the T114 BAT system under a set of quasi-combat errors is presented in graphical form in Figures 5 and 6 as a function of the number of rounds in a burst. Figure 5 contains the hitting levels achievable with the BAT zeroed at 1000 yards; Figure 6 shows its hitting probability without zeroing errors. Five rounds from each weapon are used in zeroing the system at 1000 yards.

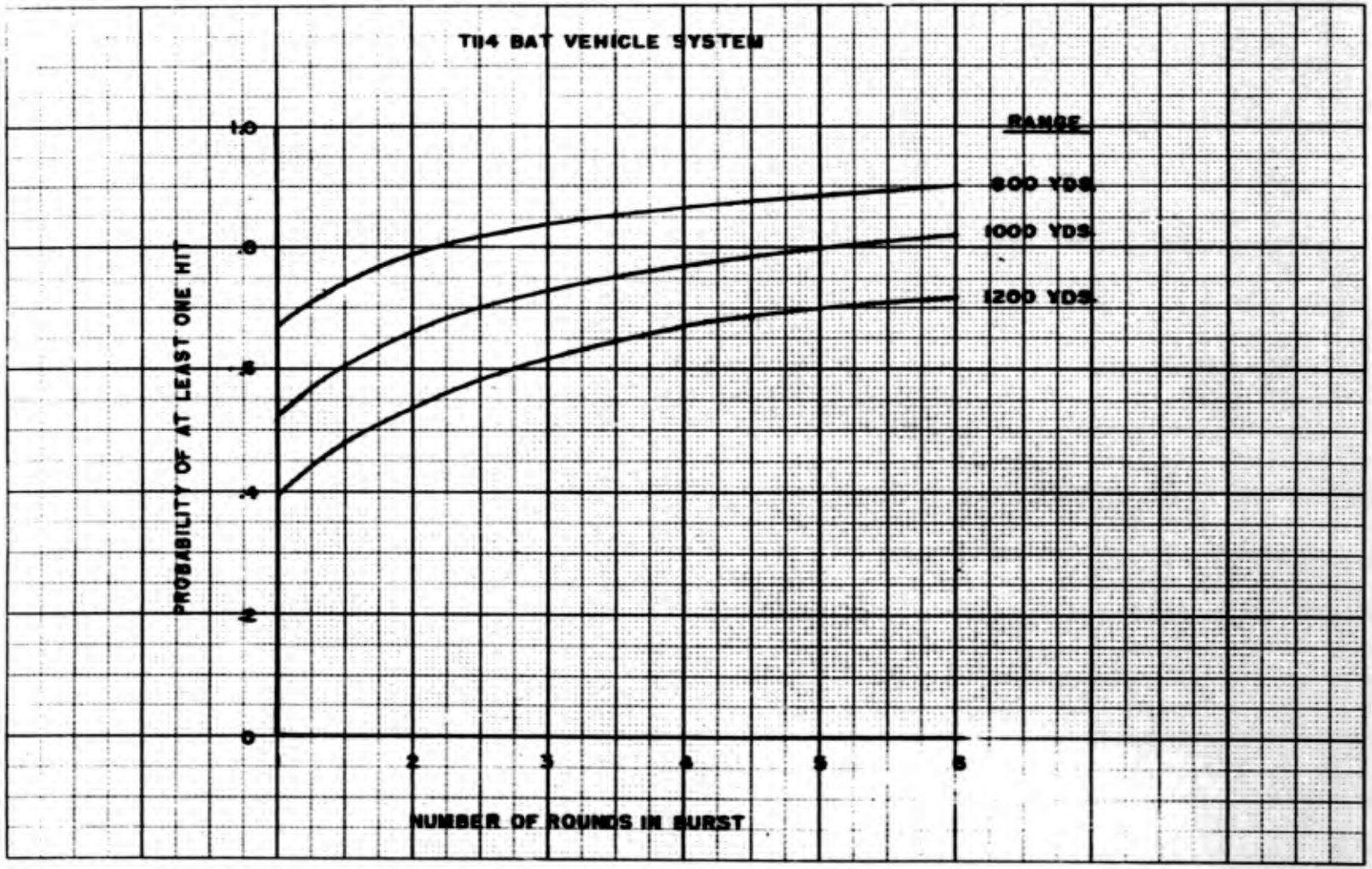

Figure 5. Probability of at least One Hit against a Tank Target at 800, 1000, and 1200 yards with the T114 BAT Vehicle System, zeroed at 1000 yards

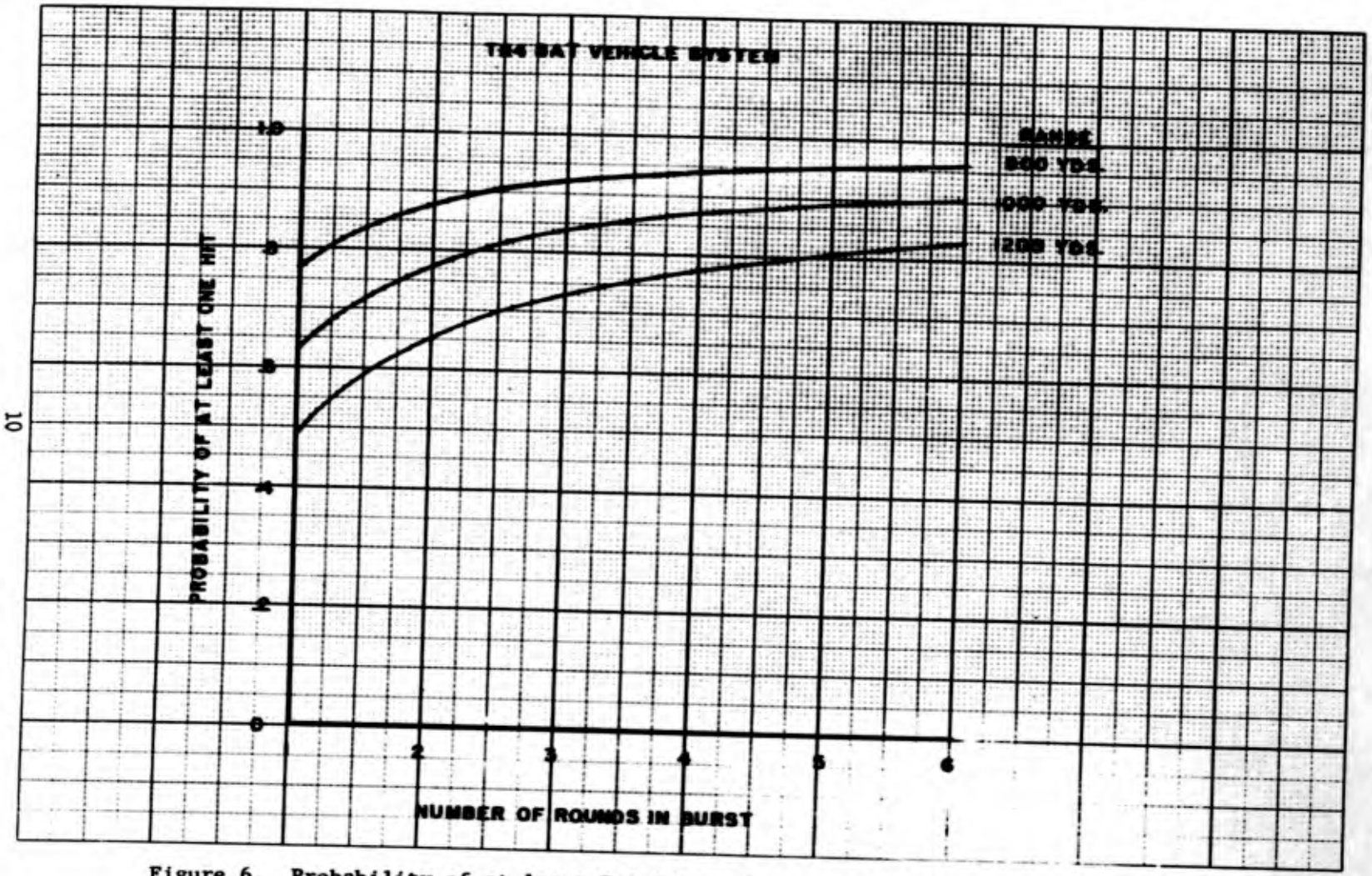

Figure 6. Probability of at least One Hit against a Tank Target at 800, 1000, and 1200 yards with the T114 BAT Vehicle System, not zeroed

CONCLUSIONS

The hitting performance of the multi-firing T114 BAT system was computed, taking into account range, number of rounds in burst, and firing errors. If the T114 BAT system is not zeroed, it has a good chance of hitting a stationary 7.5 ft by 7.5 ft target with at least one round at between 800 and 1200 yards in four shots. Actually, it can engage a tank-sized target with the following probabilities as a function of range and number of shots in burst.

Range (yd)	Probability of Hitting (Not Zeroed)			
	N = 1	N = 2	N = 3	N = 4
800	.77	.88	.92	.94
1000	.63	.78	.84	.87
1200	.49	.65	.73	.78

If the T114 BAT is zeroed at 1000 yards with five round from the M40 and M8 rifles prior to engaging a target, its chances of hitting with at least one shot is lower than that achievable in the nonzeroed case at the same range and for the same number of shots. Under the zeroed or calibrated situation, the T114 BAT chances of hitting vary with range and number of rounds as follows.

Range (yd)	Probability of Hitting (Zeroed)			
	N = 1	N = 2	N = 3	N = 4
800	.66	.78	.84	.87
1000	.52	.66	.74	.77
1200	.39	.54	.61	.66

Inasmuch as the BAT weapon will be zeroed in the field, it is concluded that the T114 BAT system with a 3-round burst can hit a tank target at least once with a probability of approximately 75% at 1000 yards.

APPENDIX

PROBABILITY OF HITTING WITH BURST FIRE

The position of the burst center of the T114 BAT system on the target plane is a random variable with density function $\rho(x_b, y_b)$. The probability of a burst center lying in a small rectangle $dx_b dy_b$ is

$$\rho(x_b, y_b)\, dx_b\, dy_b$$

A burst of N rounds from the 106 mm repeating rifle is fired at the target. The probability that a round in the burst drawn at random from its round-to-round distribution centered at (x_b, y_b) will hit the target is

$$p(x_b, y_b)$$

The probability that the target is not hit in N rounds if all the rounds have the same burst center (x_b, y_b) is

$$q(x_b, y_b) = \left[1 - p(x_b, y_b)\right]^N$$

and the probability that the target is hit at least once from this fixed burst center is

$$1 - q(x_b, y_b)$$

The probability of there being a burst center at (x_b, y_b) and that at least one round from the burst hits the target is

$$\rho(x_b, y_b)\left[1 - q(x_b, y_b)\right] dx_b\, dy_b$$

and the average probability of making an error in the burst center and of obtaining at least one hit from the burst is

$$\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \rho(x_b, y_b)\left[1 - q(x_b, y_b)\right] dx_b\, dy_b$$

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J. S. Zitz, "Report on Preliminary Engineering Tests of T114 BAT Vehicle System (Weapon Dispersion)," Aberdeen Proving Ground, D&PS, Report No. DPS-218, May 1961.

F. E. Grubbs and H. J. Coon, "On Estimating Probabilities of Hitting for the Battalion Anti-Tank Weapon," Aberdeen Proving Ground, BRL, Memorandum Report 636, January 1953.

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