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TECHNICAL REPORT

AD NO. 309124

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MEMORANDUM REPORT No. M59-22-1

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AN ANTIMISSILE SMALL ARMS WEAPON (U)

By

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D. E. WALTERS

February 1959

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FA Subproject No. R183
OCO Project No. TS4-4024
DA Project No. 5504-01-008

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MEMORANDUM REPORT
No. M59-22-1



FRANKFORD ARSENAL
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AN ANTIMISSILE SMALL ARMS WEAPON (U)

February 1959

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FA Subproject No. R183
OCO Project No. TSL-2024
EA Project No. 5S04-01-008

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FRANKFORD ARSENAL
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OBJECT

To develop the characteristics of a very lightweight weapon for defeating missiles in the prelaunch stage

SUMMARY

~~This report proposes~~ a lightweight, hand-held recoilless weapon firing contact-fuzed HE projectiles for attacking large missiles in the prelaunch stage *as described.*

The weapon will weigh between 5 and 10 lb and should be able to attack and defeat a missile of the Corporal and Redstone class from a distance of one mile with the expenditure of a few shots.

AUTHORIZATION⁴⁹

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INTRODUCTION

Antimissile Discussion

Antimissile weapons are designed to intercept and destroy long range ballistic missiles on the incoming leg of their trajectories, in the upper atmosphere, that is, from about 70,000 to 500,000 ft altitude. These defensive weapons are in the form of elaborate and expensive missiles, and necessarily so because of the power, guidance, control, and time requirement for reaching the region of interception. This problem of actively engaging an incoming ballistic missile is very important to the strategic protection of the continental United States and it is also important to the security of the tactical field army.

The Army recognizes that the field army faces a threat posed by ballistic missiles; accordingly, efforts are being made for developing a defensive capability against such attacks, as evidenced by the characteristics of the Plato missile. It would be interesting to counter the short range ballistic missiles that would be used against the field army by other than active measures such as the Plato. Although it is feasible and practical to use a missile to shoot down an incoming missile, another approach to the problem is proposed. It would be fundamentally easier to attack and damage a missile in the prelaunching stage, during its emplacement and assembly, rather than during its flight.

The proposed weapon is intended to deal with mobile, field type, tactical, long range missiles whose principal target is the field army. Enemy missiles of about the size and capability of Corporal, Sergeant, and Redstone, with maximum ranges varying from 80 to 200 miles, are of chief concern. These missiles require many hours for assembly, emplacement, fueling, and checkout. Enemy missiles will be operating relatively close to the front in support of their corps or army, and will be fairly accessible for detection by low flying high performance aircraft now organic to the U. S. Army. The objective is to take advantage of the long time that it takes to prepare these missiles for launching so that an army aircraft, operating over enemy lines in its routine missions of reconnaissance and combat surveillance, could deliver a lightweight weapon for killing missiles before lift-off.

Three probabilities are important in the employment of the proposed weapon, each of which are time dependent. These are:

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- (1) Probability of detecting enemy missile during preparation.
- (2) Probability of penetrating the enemy defense to within the effective range of the weapon.
- (3) Probability of killing the missile.

This report deals with only one aspect of the over-all problem, that of estimating the probability of killing the missile with the proposed weapon.

Weapon Characteristics

In the effort to preliminarily explore the problem regarding a small caliber antimissile weapon for attacking missiles before lift-off, a 20 mm recoilless rifle was selected because of its reasonable capacity for carrying HE and because of its over-all lightweight. For concreteness, projectile weights of 2000, 2500, and 3000 grains and muzzle velocities of 1500, 2000, and 2500 fps were chosen so that the relative importance of these basic parameters could be determined in respect to system weight and chances of hitting. The weapon is hand-held, with support from the ground, and fires projectiles filled with HE and equipped with impact fuzes. The fire control for the weapon consists of a telescope, featuring a level vial, with reliance on adjustment of aim based on observation of misses.

MISSILE VULNERABILITY AND PRESENTED AREA

Vulnerability

A missile consists basically of airframe, power plant, guidance, and pay load. None of these primary components of a missile is protected from blast or fragmentation effects. Each component appears to be vulnerable to a small bursting charge, and missiles themselves, are not deliberately shielded against damage caused by blast or incoming fragments. In fact, their performance would be drastically curtailed if ballistic protection were necessary.

Projectiles intended for use in the antimissile, hand-held weapon are armed with contact fuzes and, on missile impingement, it is assumed that they explode on the missile surface or enter the missile skin and explode. A burst outside or inside the missile skin will kill by blast and fragmentation. A well designed 20 mm

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projectile can carry about 20 per cent HE. The 20 mm rounds chosen in this study, those weighing 2000, 2500, and 3000 grains, could hold 400, 500, and 600 grains of HE. Damage-wise, it is hypothesized that

(1) A HE bullet of this size, mass, and terminal velocity is easily able to penetrate the ballistic skin of current missiles and, so, is able to enter the compartments housing vital parts;

(2) A hit on the power plant with a small HE charge will ignite the fuel or damage the engine, whether it uses liquid or solid propellant, and prevent lift-off;

(3) An impact on the guidance package thwarts the missile from accomplishing its mission by disruption of its accuracy; and

(4) A burst on or in the vicinity of the warhead is sufficient to prevent its functioning.

This problem of the vulnerability of missiles to small bursting charges requires study. No work has been done concerning the passive resistance of missiles to counterfire. Considering the structural and component composition of current long range missiles with their high motor-to-pay load ratios, it is assumed that a hit anywhere on the missile will result in sufficient damage to prevent the missile from doing its job.

Presented Area

Long range missiles are positioned vertically upward for firing for strength reasons, because of their high propellant-to-vehicle weight ratios. It is assumed that the missile is upright on its pad and, for convenience of computation, configuration of the missile is approximated by a right circular cylinder, so that its area presented to the weapon is given by a slender rectangle. For estimation purposes, two target sizes were chosen, representing two classes of missile - the Corporal-Sergeant and the Redstone. Although the Corporal is longer than the Sergeant, they are considered as one target and a 30 ft x 3 ft rectangle is used to represent their areas. A 70 ft x 6 ft rectangle is used for the Redstone missile. Hence, two target sizes - 30 x 3 ft² and 70 x 6 ft² - with their longer dimensions vertical, characterize the missile targets.

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PRINCIPAL WEAPON ASSUMPTIONS

Exterior Ballistics

It is assumed that the family of projectiles will travel along their trajectories with a form factor of 1.1 on drag law 7, independent of sectional density and initial velocity. The family consists of 20 mm projectiles weighing 2000, 2500, and 3000 grains and having initial velocities of 1500, 2000, and 2500 fps. For each projectile and velocity level, calculations were made of the angle of departure, angle of fall, time of flight, and terminal velocity at distances of 500, 1000, 1500, 2000, 2500, and 3000 yards.

Interior Ballistics

In order to give some idea of the general proportions and performance of a small arms recoilless rifle in 20 mm, calculations were made of the propellant weight, chamber volume, and peak pressure of a rifle which fires a 2500-grain projectile at 2000 fps. Using a loading density of 0.5 gm/cc and a 2.5 expansion ratio, the following quantities are obtained:

Propellant weight	1750 gr
Chamber volume	14.5 in ³
Travel	45.5 in.
Peak pressure	17,500 psi.

Muzzle Energy and Weapon Weight

In recoilless weaponry, when muzzle energy is doubled, the mass of the system tends to double regardless of caliber, tube length, chamber capacity, etc. Because rifle weight (which consists of tube, chamber, and nozzle) varies directly with muzzle energy, it is assumed that rifle weight for the proposed weapon is given, to a first approximation, by

$$W_R = KE_o = \frac{KW_p V_o^2}{2g}$$

where W_p = projectile weight

V_o = initial velocity

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When muzzle energy, solely, is used for establishing an estimate of system weight, the choice of the proportionality constant is fundamental. Estimates are predicated on $K = 5000^{-1}$ lb/ft-lb, since that value is descriptive of the capability of current recoilless rifles.

The prediction of system weight based on energy consideration is convenient and is preferred to establishment of the weight from a detailed design engineering study. Present trends in metallurgy and recoilless weapon design indicate that K can be reduced so that these estimates of weight are on the conservative side. Evaluation of the above rifle weight-kinetic energy equation for projectile masses of 2000, 2500, and 3000 grains and velocities of 1500, 2000, and 2500 fps leads to the following rifle weights.

Initial Velocity (fps)	Rifle Weight (lb)		
	$W_p = 2000$ gr	$W_p = 2500$ gr	$W_p = 3000$ gr
1500	2.0	2.5	3.0
2000	3.5	4.4	5.3
2500	5.5	6.9	8.3

PROBABILITY OF HITTING

General

The probability estimates apply to a man firing the weapon from the ground. One visualizes a hand-held weapon supported on the ground through an "A" frame attached to the muzzle end. The weapon could also be aimed and fired from the air, but the error assumptions are intended for describing the over-all accuracy of the system when operated from the ground.

Killing Chances with First Round

Let individual intersections of the weapons' trajectories on a vertical plane be measured from the origin of a rectangular coordinate system, the axes of which form a vertical plane orthogonal to the line of fire. The coordinate system X-Y is positioned at the center of gravity of the target/missile and oriented so that its X axis is along the horizontal direction. Impacts fall on this vertical plane, and they are assumed to obey a Gaussian law as follows.

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$$\rho(x,y) = \frac{1}{2\pi \alpha_x \alpha_y} \exp \left[-\frac{x^2}{2\alpha_x^2} - \frac{y^2}{2\alpha_y^2} \right]$$

where α_x = total standard deviation in horizontal direction

α_y = total standard deviation in vertical direction

The single shot kill probability (p_{ssk}) against the missile presented area (A) is

$$P_{ssk} = \int \int_A P_c(x,y) \rho(x,y) dx dy$$

where P_c is the conditional probability that a hit is a kill. Considering the vulnerability of missiles, suppose that $P_c = 1$.

Errors cause impacts to deviate from the target center. Assume that each error takes place at random from shot to shot and is normally distributed. Suppose the following sources of errors are responsible for producing the first round distribution on the missile.

<u>Source</u>	<u>Random Errors, First Round</u>	
	<u>Horizontal Std Dev</u>	<u>Vertical Std Dev</u>
Muzzle velocity		10 fps
Angular orientation	.1 mil	.1 mil
Aim point	.1 mil	.1 mil
Cross wind	10 fps	
Cant	5 mils	
Range estimation		20% R

Use of the above errors allows the calculation of the hitting chances on the first shot as a function of range, initial velocity, projectile weight, and missile presented area. The results of the computation are plotted in Figures 1 through 6. Information presented in these figures indicates that it is very difficult to attack missiles of the Corporal-Sergeant and Redstone classes at long ranges with the first shot. In order to increase the level of hitting it is mandatory to fire more than one round. Accordingly, computations

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involving multifire capability are carried out to show what gains are possible with a few rounds.

Killing Chances with N Rounds

When the first round probability at a given distance from the missile is not sufficiently high, more than one weapon could be placed against the missile or more than one shot could be fired from the same weapon. If more than one try is attempted from the same weapon, it is desirable to adjust aim.

If allowance is made for sensing burst positions in approaching the target, then it is possible to make angular corrections to the weapon. Since the projectile is equipped with a ground contact fuze and a tracing element, one takes the liberty of assuming that burst positions can be seen and that adjustments can be made based on them. However, once the trajectory of the weapon reaches the target vicinity, it is assumed that no more reductions in the errors are possible. The errors that can be changed by the sequence of spotting the target are cross wind and range estimation. Reasonable magnitudes are taken for these reduced errors and the magnitudes of all other errors are preserved.

It will take at least one shot to get in the proximity of the target. In fact, shots bursting on ground impact may be lost because of background contrast, terrain features, soil conditions, etc., so it may require a few shots before one approaches the conditions defined by the following error assumptions. Let the following errors hold, after the fire of the weapon is placed near the target, each of which is random from shot to shot and is normally distributed.

<u>Source</u>	<u>Random Errors, N Rounds</u>	
	<u>Horizontal Std Dev</u>	<u>Vertical Std Dev</u>
Muzzle velocity		10 fps
Angular orientation	.1 mil	.1 mil
Aim point	.1 mil	.1 mil
Cross wind	1 fps	
Cant	5 mil	
Range estimation		4% R

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In the computations involving multifire, once the target is zeroed in, one uses the relation $P_K = 1 - (1 - P_{SSK})^n$ which gives the probability of at least one kill in n independent tries, assuming no cumulative damage. P_{SSK} is determined by the random errors tabulated above, by the target size, and by the assumption that P_c is unity. To appraise the effect of a reasonable number of shots, after getting near the target with a prior shot or shots, $n = 5$ is chosen and the probability of one or more kills on the missile targets is calculated. These results are given in Figures 7 through 12 as a function of range, initial velocity, and projectile weight.

In summary, the following is a tabulation of the distance to which the weapon is effective with at least one kill in five rounds, assuming that the target is spotted in as a function of projectile weight, initial velocity, and missile type.

Projectile Weight (gr)	Initial Velocity (fps)	Effective Range (miles)*	
		Corporal-Sergeant	Redstone
2000	1500	0.9	1.4
	2500	1.2	1.7
3000	1500	1.0	1.5
	2500	1.4	2

*Distance at which $P_K \leq .80$

CONCLUSIONS

If only first round accuracy is considered, the effective range of the weapon is less than 1/2 mile. Once most of the initial range estimation and initial cross wind errors are taken out, missiles of the Corporal-Sergeant and Redstone class can be hit repeatedly from substantial distances. If five rounds are used against these missiles after the target is spotted in, the distance to which they can successfully attack extends over 1 mile, depending on specific initial velocity and projectile weight combinations. Under the assumptions of this report, the biggest pay-off in increasing the effective range of the weapon is to fire high-sectional density projectiles at high initial velocities.

It is concluded that a weapon of the general proportions described herein, if delivered by air to an advantageous position

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within a 1-to 2-mile radius from missiles of the Corporal-Sergeant and Redstone types, can destroy such missiles with the expenditure of a few shots.

RECOMMENDATIONS

It is recommended that thought be given to the tactical feasibility of deploying a lightweight, hand-held, recoilless weapon for defeating ballistic missiles in their pretake-off phase.

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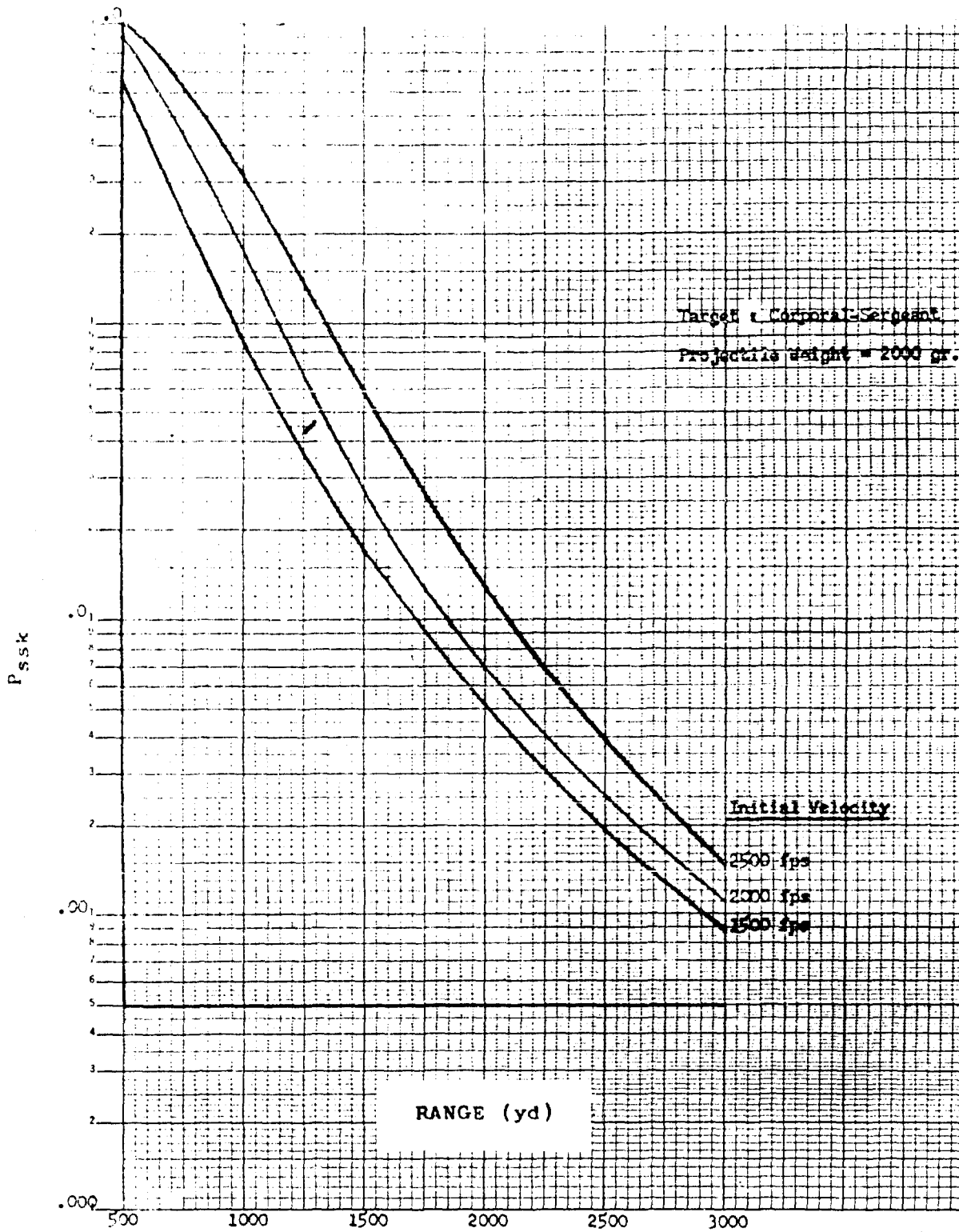


Figure 1. Single shot kill probability with first round vs range
(Target - Corporal-Sergeant; Projectile Weight - 2000 gr)

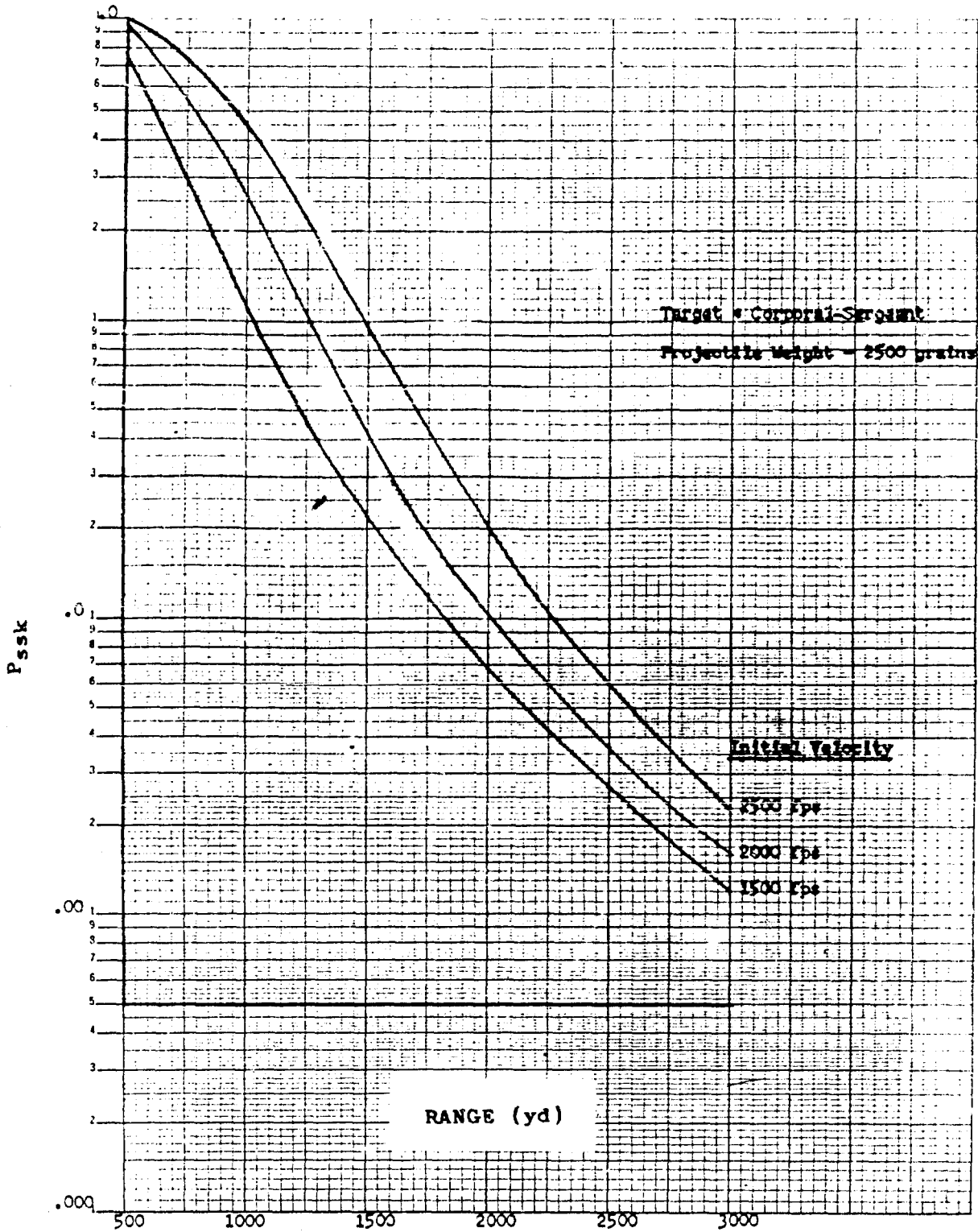


Figure 2. Single shot kill probability with first round vs range
(Target - Corporal-Sergeant; Projectile Weight - 2500 gr)

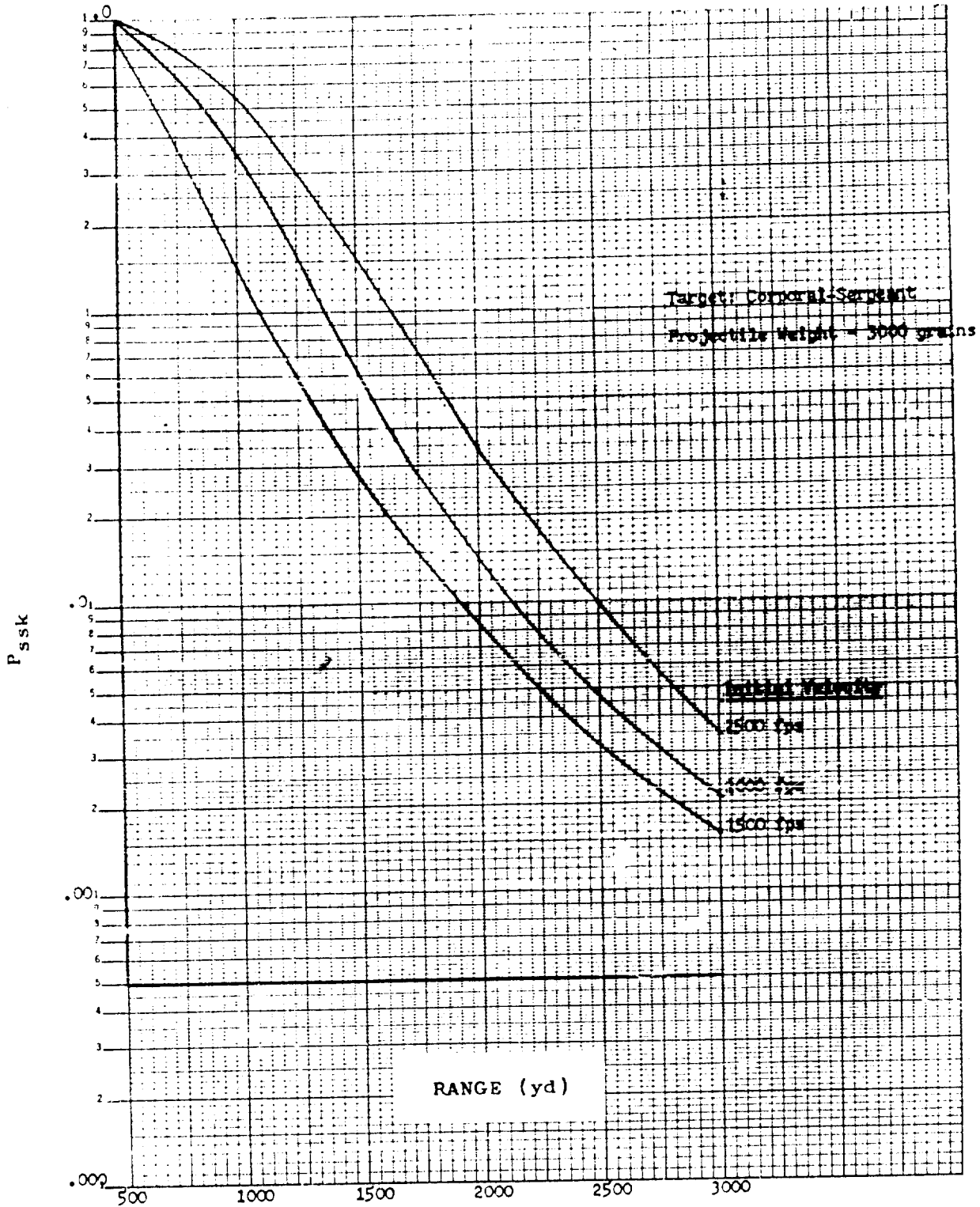


Figure 3. Single shot kill probability with first round vs range
(Target - Corporal-Sergeant; Projectile Weight - 3000 gr)

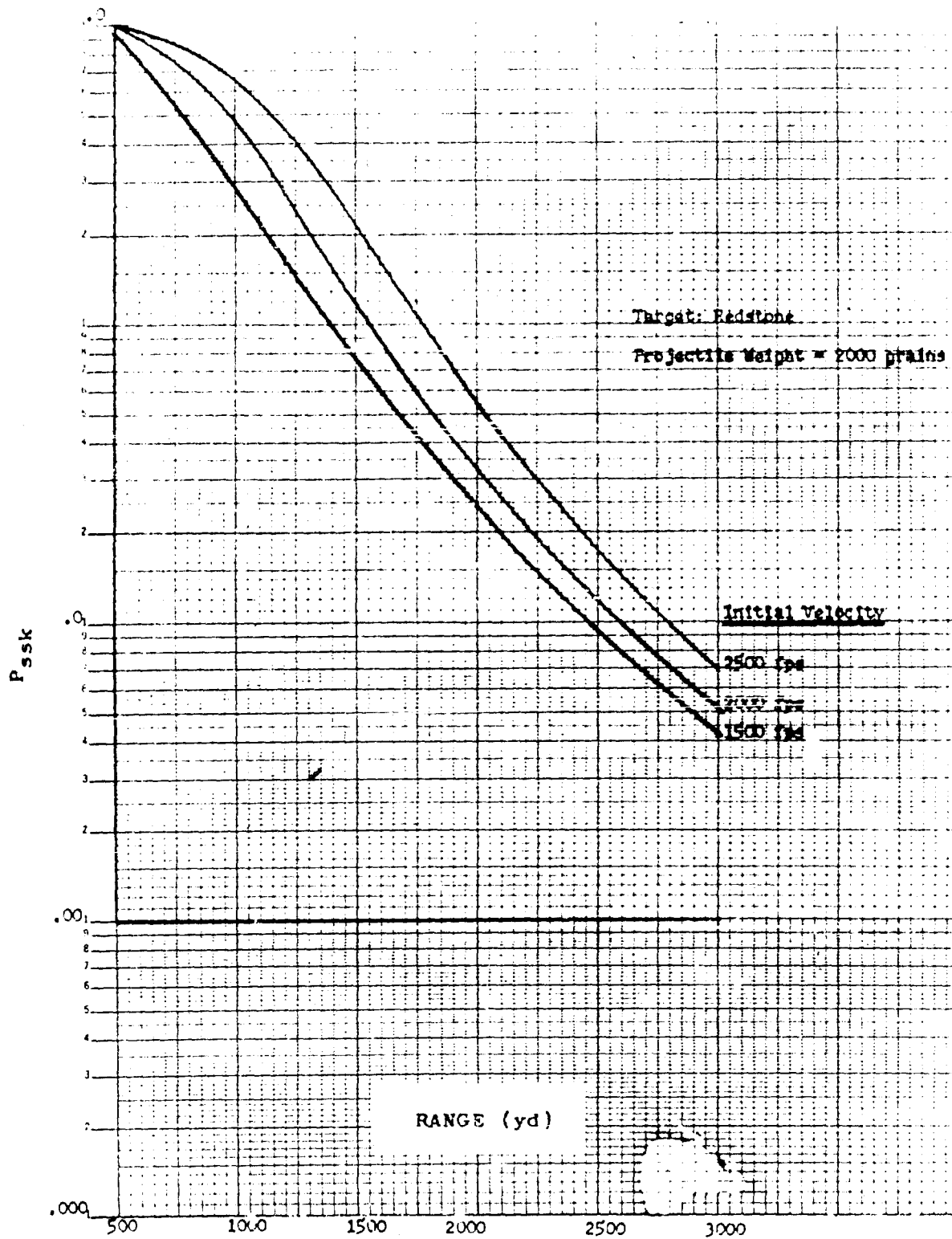


Figure 4. Single shot kill probability with first round vs range
(Target - Redstone; Projectile Weight - 2000 gr)

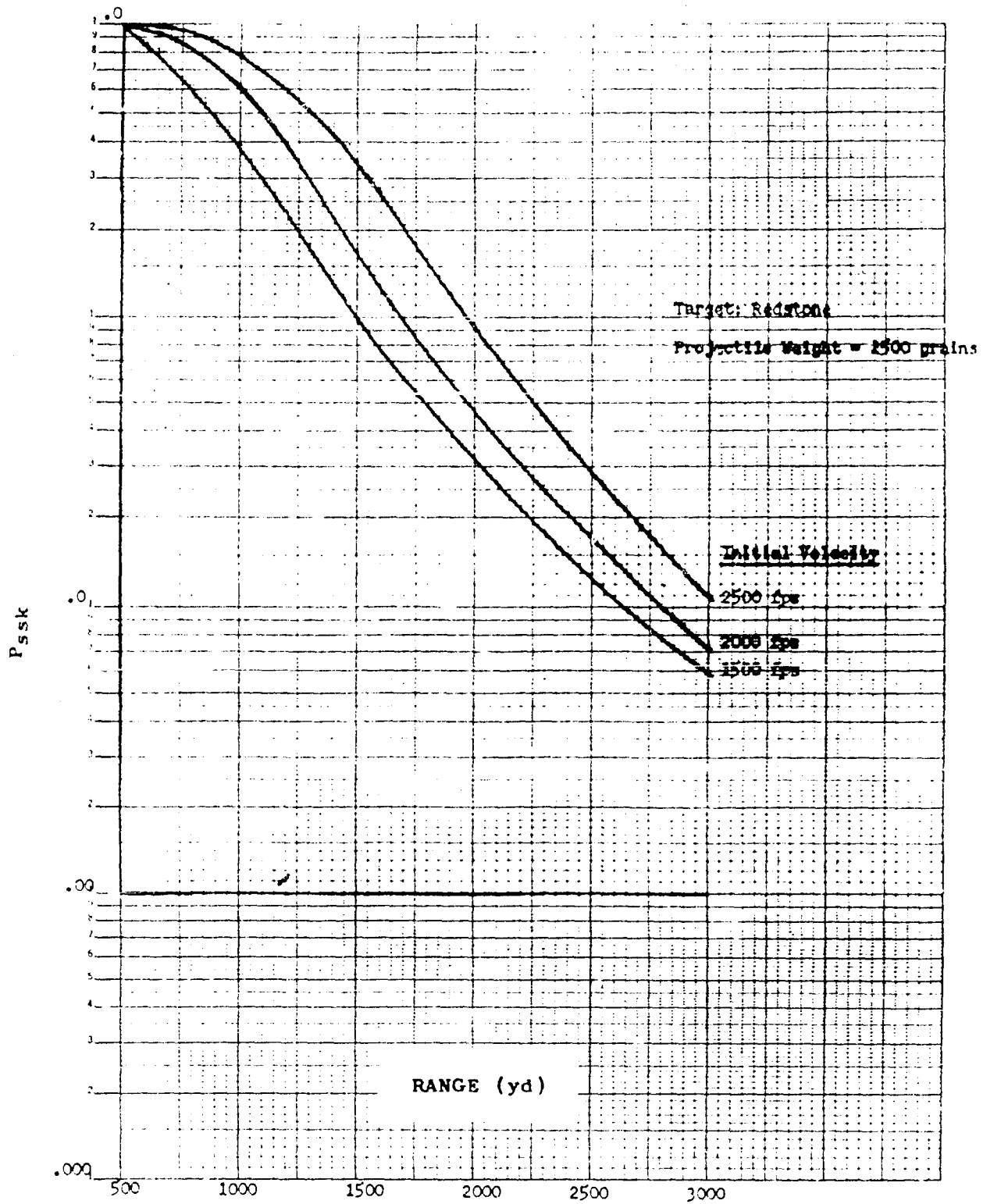


Figure 5. Single shot kill probability with first round vs range
(Target - Redstone; Projectile Weight - 2500 gr)

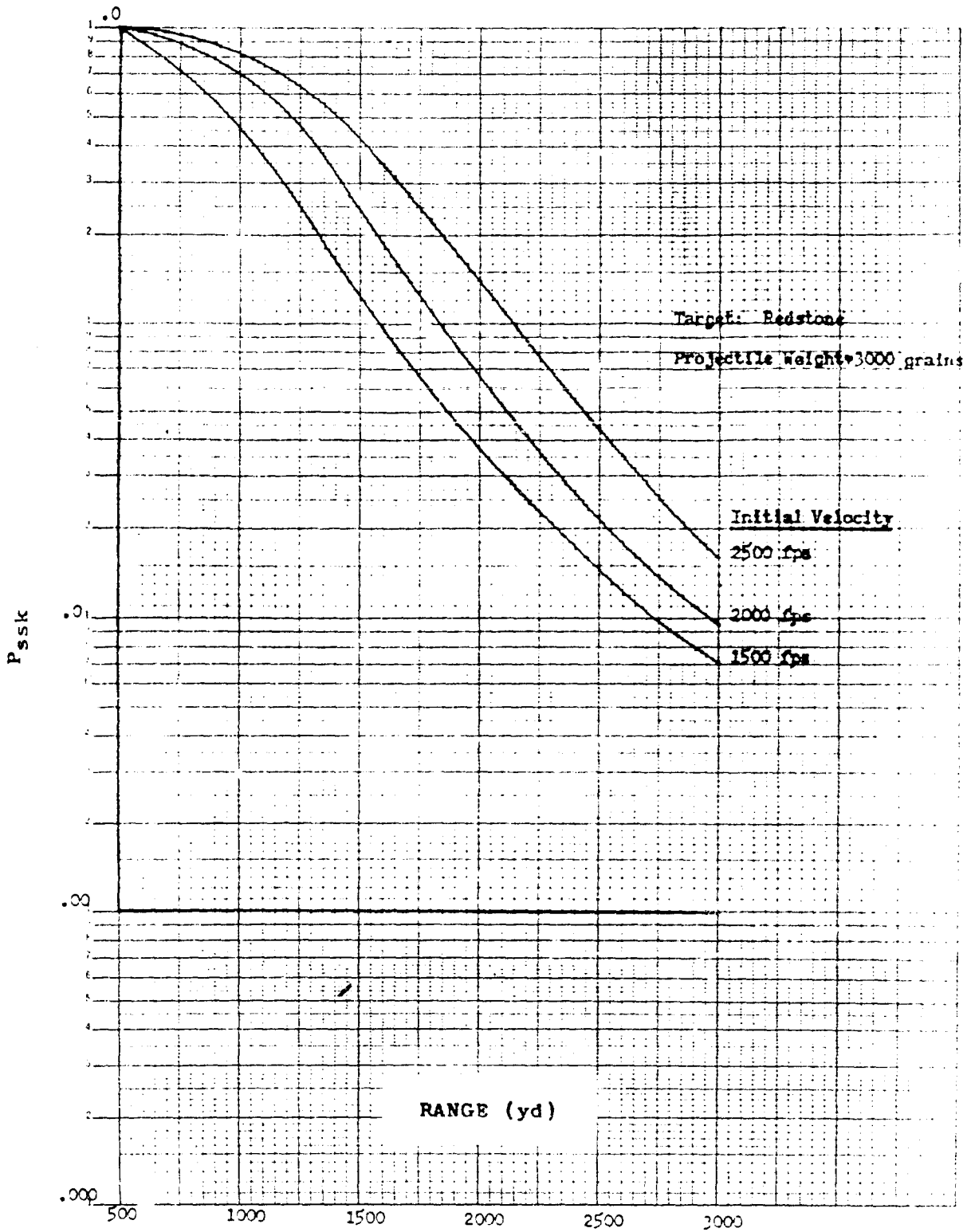


Figure 6. Single shot kill probability with first round vs range
(Target - Redstone; Projectile Weight - 3000 gr)

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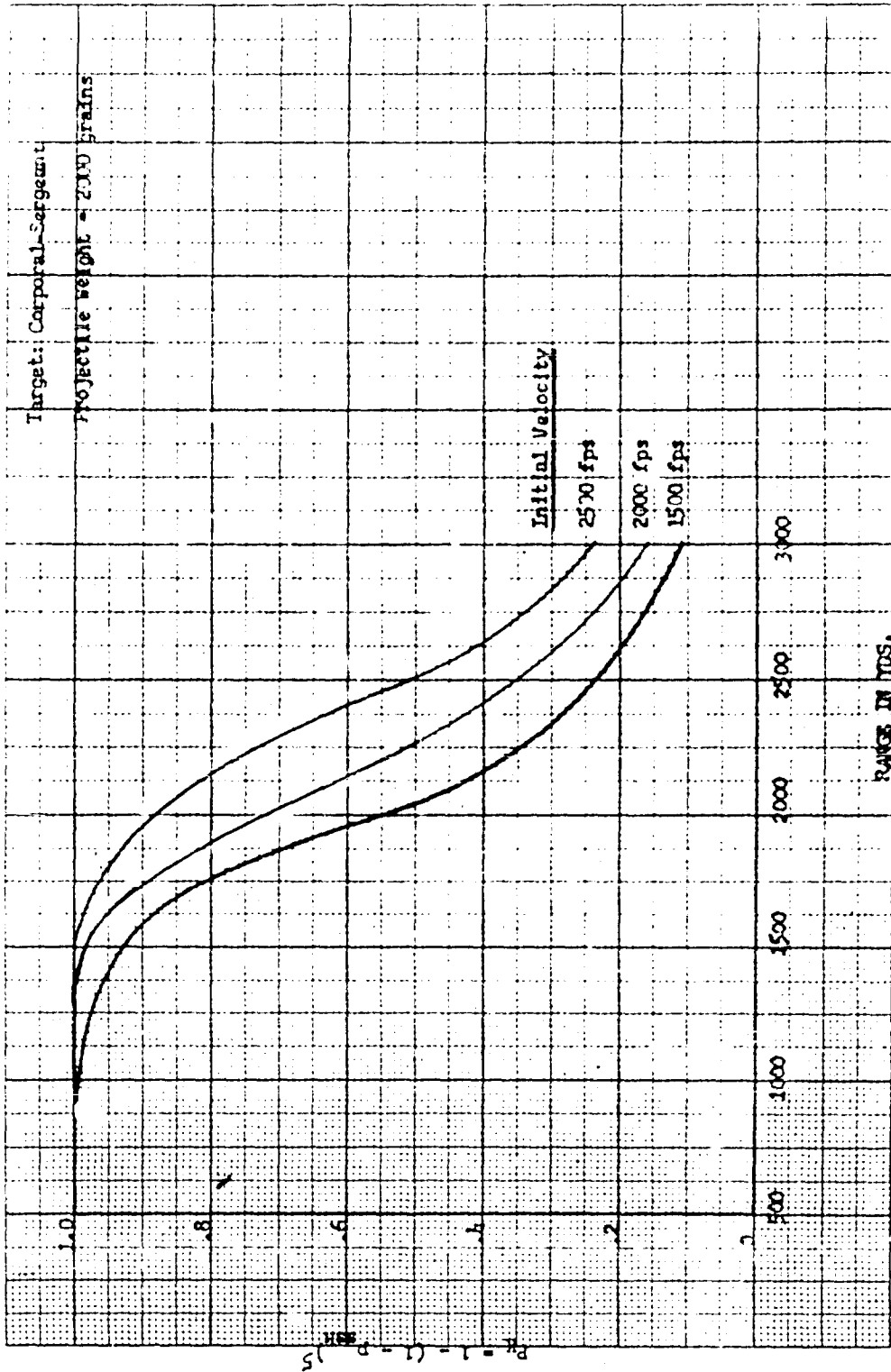


Figure 7. Probability of at least one kill in 5 rounds vs range
(Target - Corporal-Sergeant; Projectile Weight - 2000 Gr)

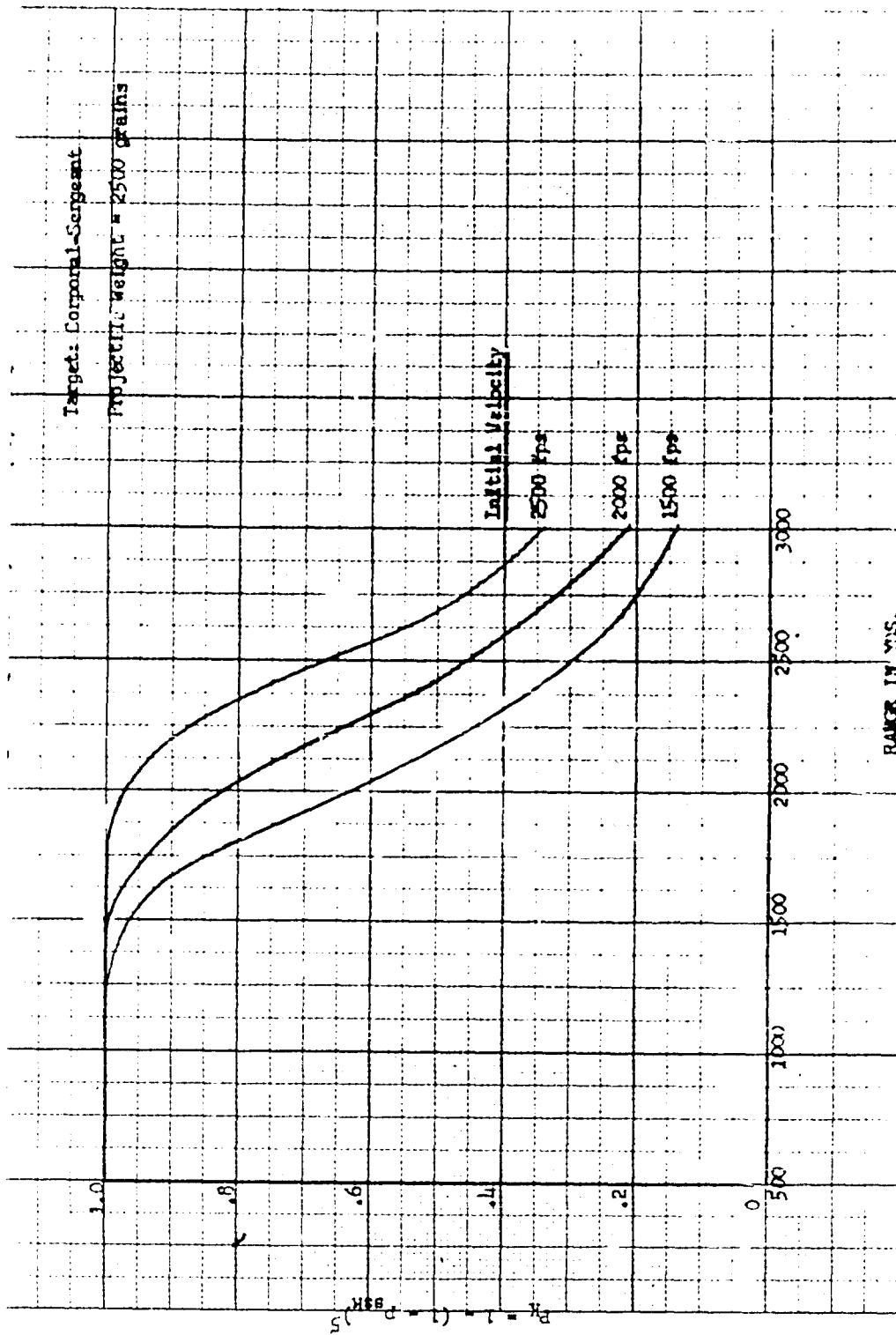


Figure 8. Probability of at least one kill in 5 rounds vs range
(Target - Corporal-Sergeant; Projectile Weight - 2500 gr)

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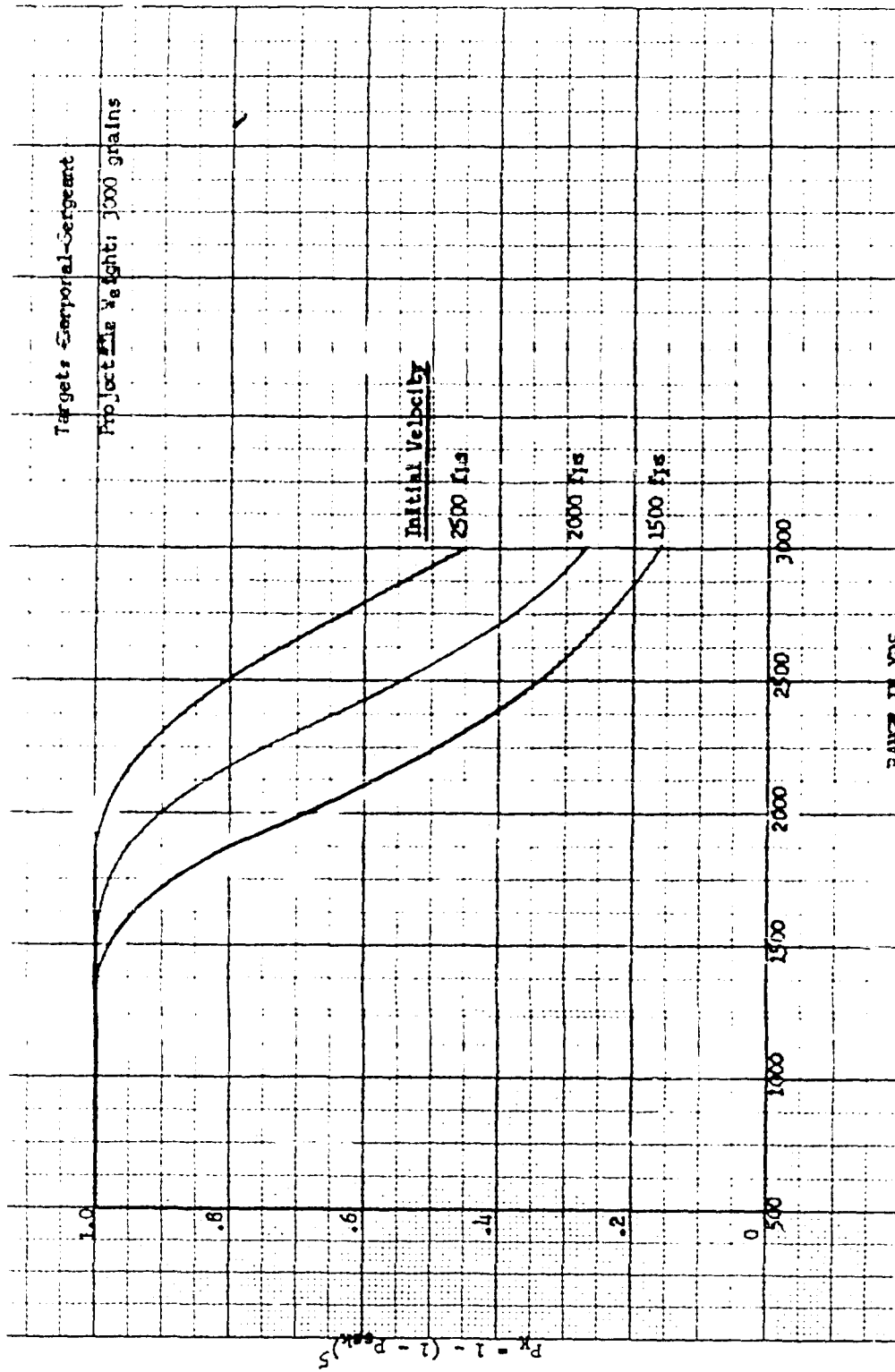


Figure 9. Probability of at least one kill in 5 rounds v. range
(Target - Corporal-Sergeant; Projectile Weight - 3000 gr)

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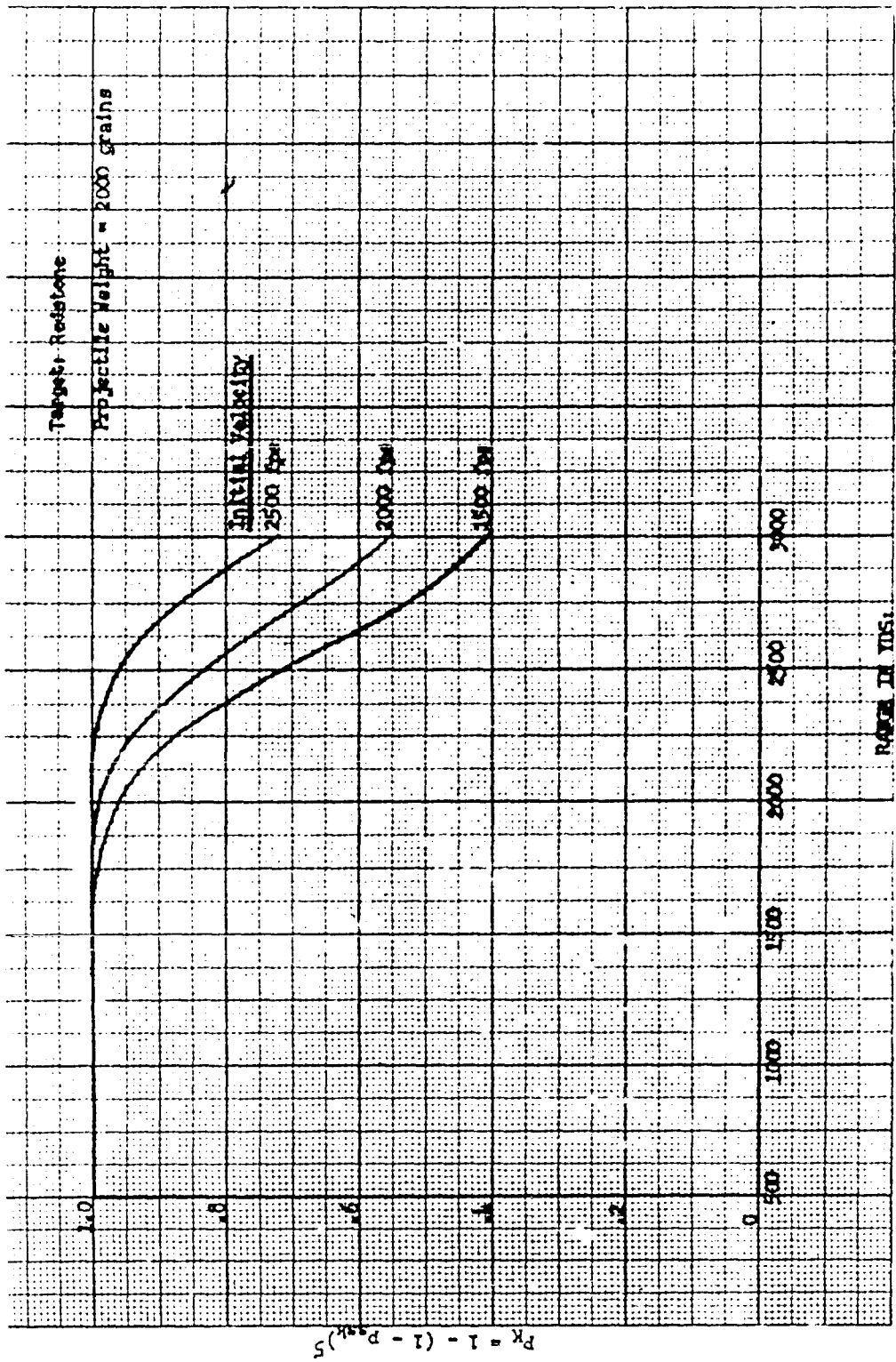


Figure 10. Probability of at least one kill in 5 rounds vs range
 (Target - Redstone; Projectile Weight - 2000 gr)

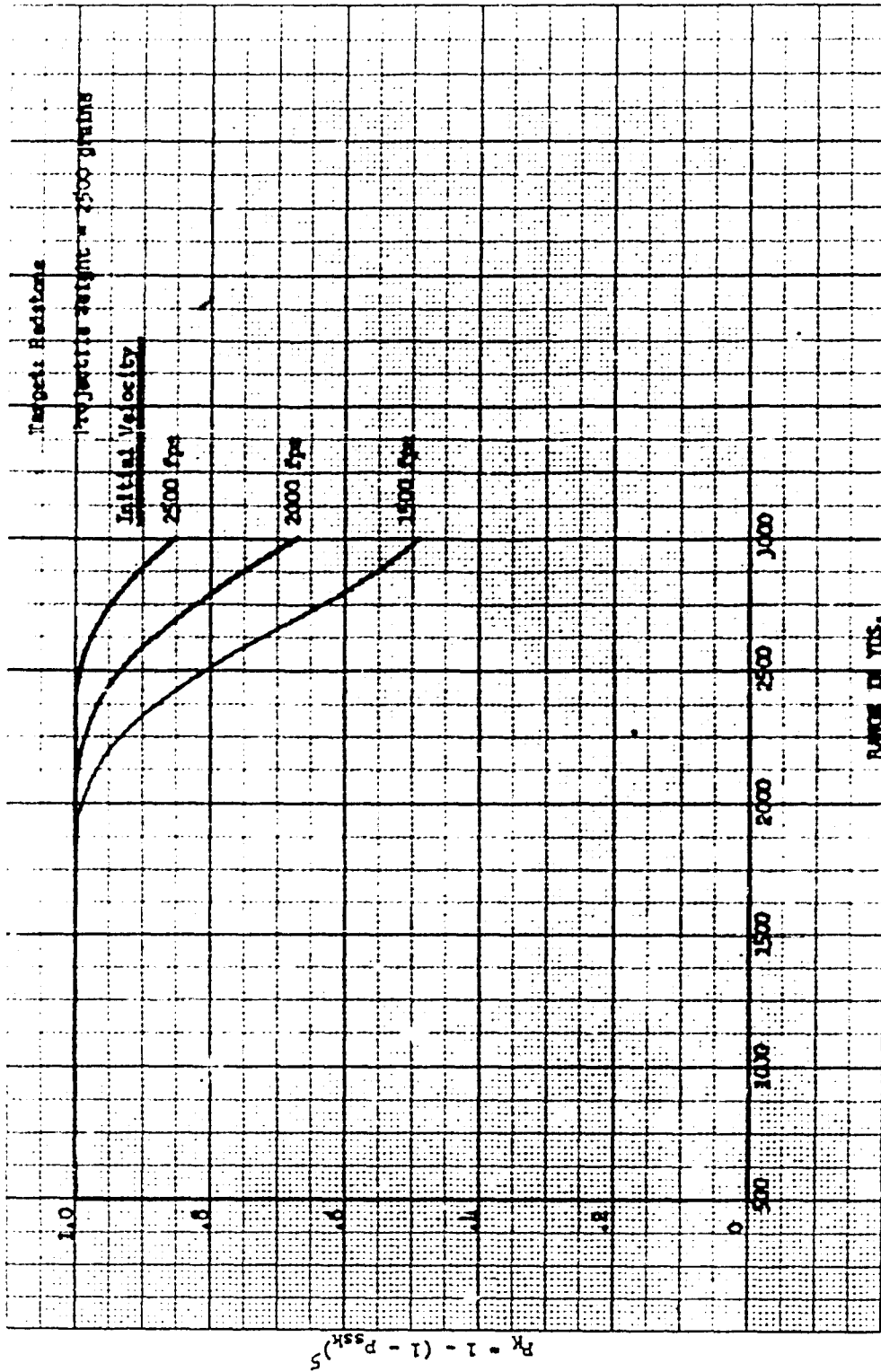


Figure 11. Probability of at least one kill in 5 rounds vs range
(Target - Redstone; Projectile Weight - 2500 Gr)

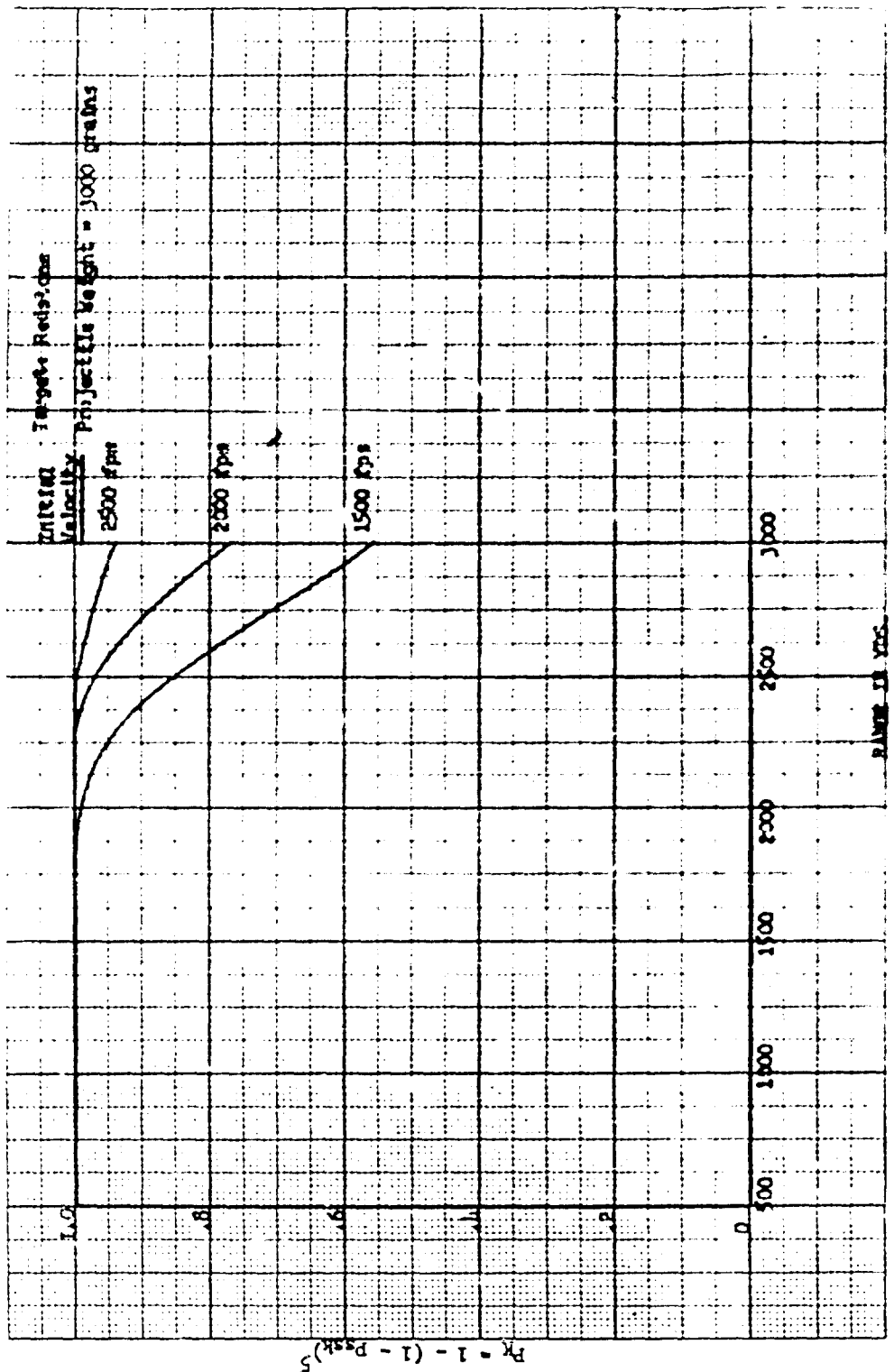


Figure 12. Probability of at least one kill in 5 rounds vs range
(Target - Redstone; Projectile Weight - 3000 gr)