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MEMORANDUM REPORT No. 827

Distribution Of Armor Of The M48 Medium Tank

HOWARD R. GOLDMAN

GILBERT H. KEMPINGER

DEPARTMENT OF THE ARMY PROJECT No. 503-04-004
ORDNANCE RESEARCH AND DEVELOPMENT PROJECT No. TB3-1224B

BALLISTIC RESEARCH LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

FEB 11 1955

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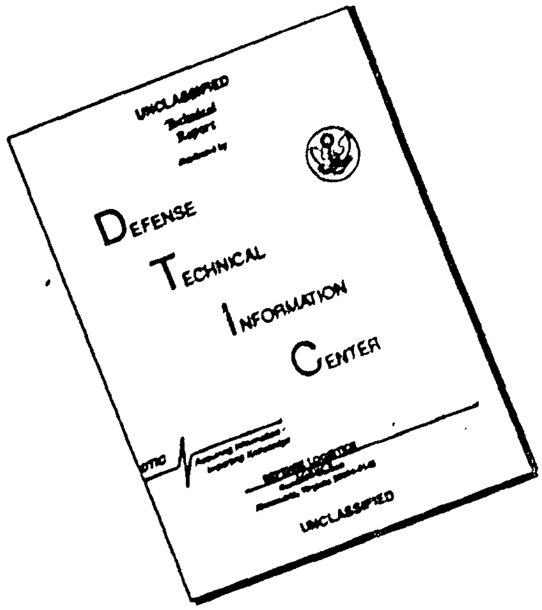

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BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 827

SEPTEMBER 1954

DISTRIBUTION OF ARMOR OF THE M48 MEDIUM TANK

Howard R. Goldman

Gilbert H. Kempinger

Department of the Army Project No. 503-04-004
Ordnance Research and Development Project No. TB3-1224B

ABERDEEN PROVING GROUND, MARYLAND

[redacted]

TABLE OF CONTENTS

BALLISTIC RESEARCH LABORATORIES

MEMORANDUM REPORT NO. 827

HRGoldman/GHKempinger/jmc
Aberdeen Proving Ground, Md.
September 1954

DISTRIBUTION OF ARMOR OF THE M48 MEDIUM TANK

ABSTRACT

The probabilities of perforating the M48 Tank with 76mm to 120mm AP, HVAP, HEAT and HEP projectiles are given. Data are given which permit one to determine this probability for any size of the four types of ammunition. In addition to determining the effectiveness of these types of projectiles against this tank, the protection afforded by external components is also investigated. The latter effect was found to decrease the probability of penetrating with HEP projectiles by about 0.2 and with HEAT, AP and HVAP by about 0.1.

The distribution of armor obliquities found on the M48 and its presented areas as a function of azimuth attack angle are also given.

INTRODUCTION

The main purposes of this study are to determine the distribution of armor thicknesses of 90mm Gun Tank, M48, and to determine the additional protection afforded by the suspension and other exterior components.

The methods used to determine the distribution of armor thicknesses are similar to those discussed in BRL Memorandum Reports 612 and 727.

DESCRIPTION OF TANK

The M48 tank is a fifty-ton medium tank with a 90mm gun for its main armament. It has a one-piece, cast homogeneous steel armor hull and a one-piece, cast homogeneous steel armor turret. The hull and turret are elliptically shaped presenting highly curved surfaces to most angles of sight. When viewed from the front, the turret is asymmetric and slopes 12° and 35° away from the normal on the right and left sides respectively.

The vehicle has a torsion bar type suspension and individually sprung wheels. The exterior stowed components consist of storage boxes, sand shields, headlights, lifting eyes, water cans, tools, etc.

A complete description of the M48 medium tank can be found in TM-9-718B, 90mm Gun Tank T-48.

DETERMINATION OF EQUIVALENT THICKNESS

The penetration that will result from firing HEAT, AP, HVAP, and HEP rounds at armor plate is dependent on the angle at which they strike armor of a given thickness. Ballistic limit (BL) data for AP and HVAP projectiles in the range from 37mm to 155mm against rolled homogeneous steel armor of various hardnesses, were plotted against the t/d ratio $\left(\frac{\text{thickness of armor}}{\text{projectile diameter}}\right)$ for obliquity angles between 0° and 65°. In the case of HVAP rounds, the core diameter is used. The curves of BL vs t/d for AP and HVAP rounds are shown in Figs. 1 and 2 respectively with some of the BL data extrapolated.

These curves indicate that for armor at any angle (obliquity) from a plane normal to the line of fire, $BL = C_{\theta}(t/d)^n$ where C_{θ} is a constant characteristic of obliquity and projectile type, and 'n' is a characteristic of each projectile type constant for all obliquities. Then for a constant Ballistic Limit, $t_o/t_{\theta} = (C_{\theta}/C_o)^{1/n} = K_{\theta}$ where t_o is a thickness at 0° obliquity and t_{θ} is a thickness at θ° obliquity. Thus the thickness t_e at 0° obliquity is equivalent in protection to a thickness t at θ° obliquity or

$$t_e = K_{\theta}t, \tag{1}$$

where K_{θ} is dependent on the type of projectile. Figure 3 shows K plotted

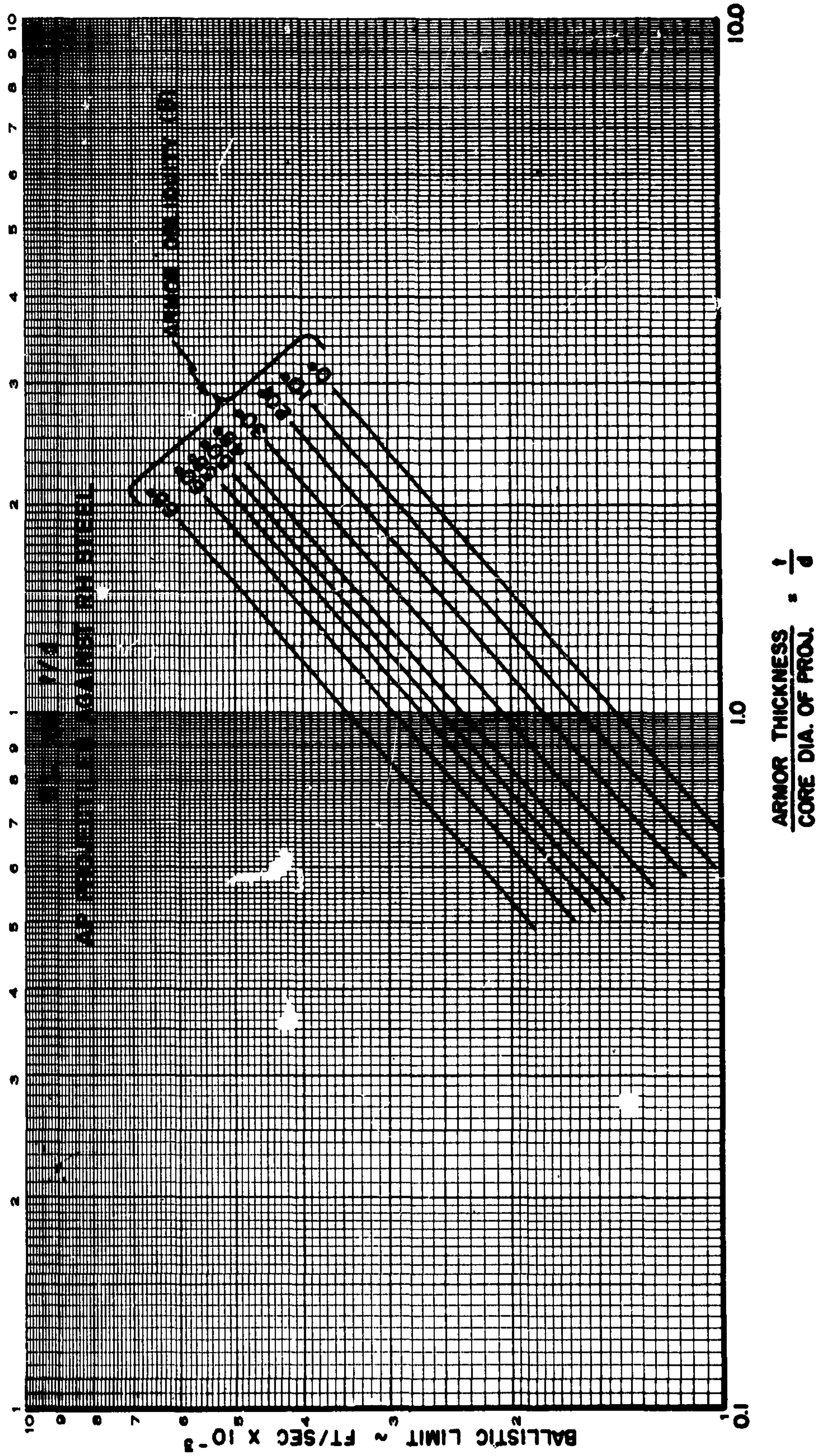

ARMOR OBLIQUITY (θ)
BALLISTIC LIMIT ~ FT/SEC X 10^-3
ARMOR THICKNESS / CORE DIA. OF PROJ. = t/d
0.1
1.0
10.0

FIG. I

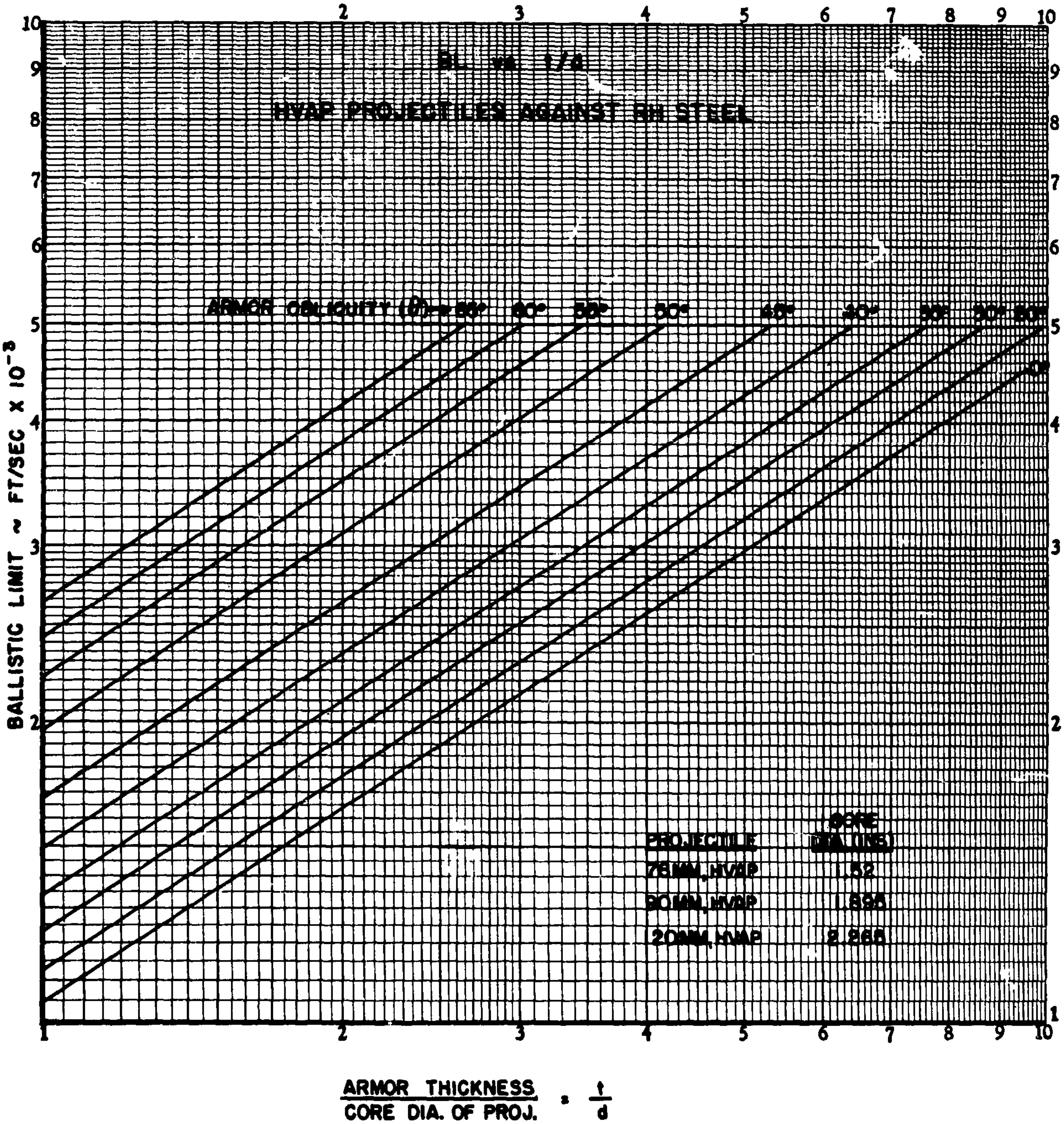

BL vs. t/d
HVAP PROJECTILES AGAINST RH STEEL
ARMOR OBLIQUITY (θ) = 65° 60° 55° 50° 45° 40° 35° 30° 20°
0°
BALLISTIC LIMIT ~ FT/SEC X 10⁻³
PROJECTILE
CORE DIA.(INS.)
76MM. HVAP 1.52
90MM. HVAP 1.895
120MM. HVAP 2.265
ARMOR THICKNESS / CORE DIA. OF PROJ. = t/d

FIG. 2

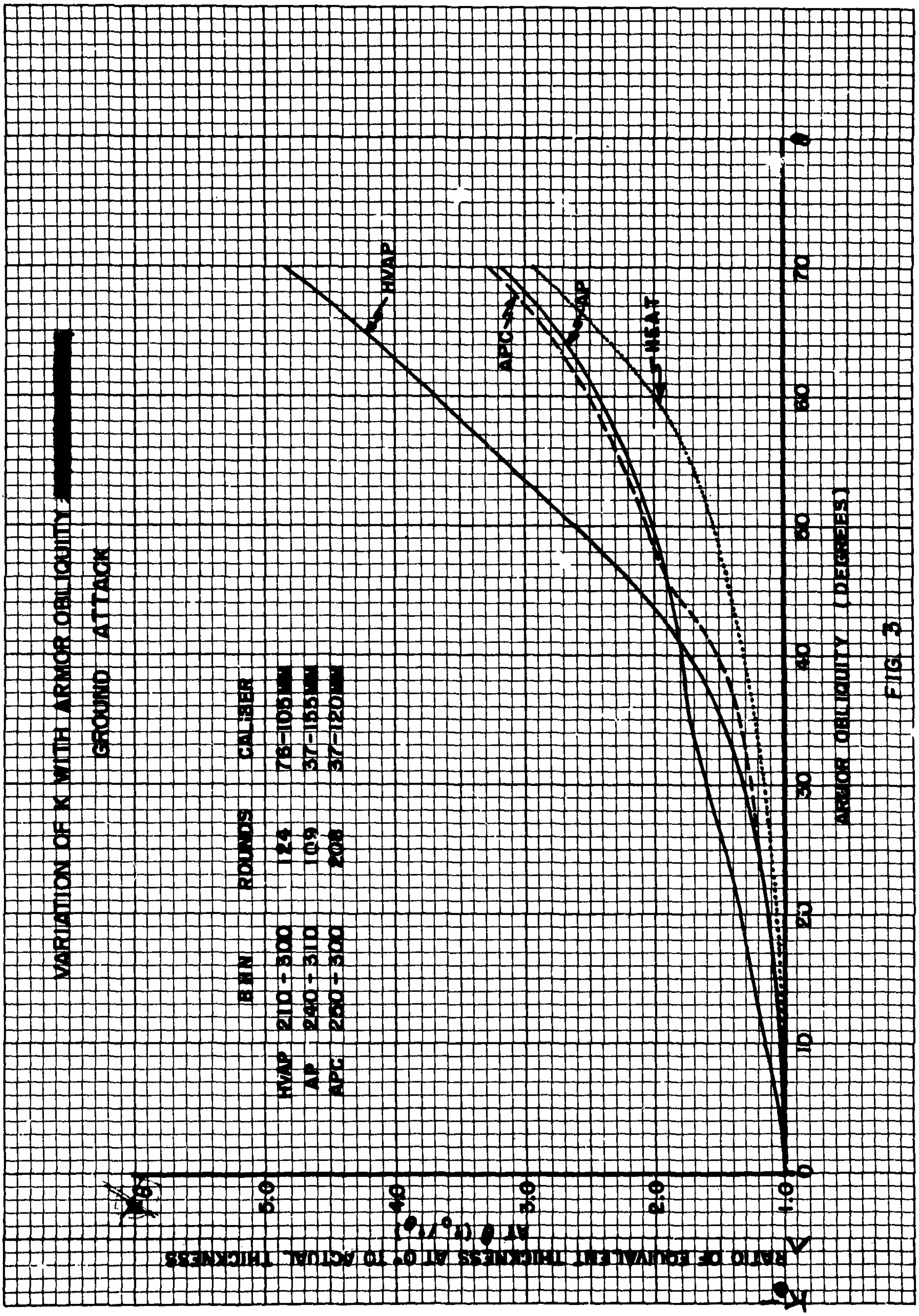

VARIATION OF K WITH ARMOR OBLIQUITY [redacted]
GROUND ATTACK
BHN ROUNDS CALIBER
HVAP 210 - 300 124 76-105[redacted]
AP 240 - 310 109 37-155[redacted]
APC 250 - 300 208 37-120[redacted]
HVAP
APC
AP
HEAT
0 10 20 30 40 50 60 70
ARMOR OBLIQUITY (DEGREES)
1.0 2.0 3.0 4.0 5.0
RATIO OF EQUIVALENT THICKNESS AT 0° TO ACTUAL THICKNESS

FIG. 3

as a function of obliquity for the various projectile types. For HEP rounds, it is assumed that t_e is not dependent on obliquity*, hence $t_e = t_o$. For HEAT rounds, it is assumed that t_e is simply the length of the projectile path through the armor. Thus, K_θ for HEAT projectiles is sec θ and $t_e = t \sec \theta$.

ANGULAR FREQUENCY OF ATTACK

A previous study[1] has shown that the angular frequency of attack on tanks by AP projectiles during World War II could be represented by a cardioid of the form $f(\gamma) = 1/2\pi\ (1 + \cos \gamma)$, where γ is the azimuth angle of attack. In this study the cardioid is used as the distribution of attack angles from tank-fired and high velocity AT weapons. In the case of shoulder fired weapons (rocket launcher) the distribution of attack angles is assumed to be circular.

DETERMINATION OF THE PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS t_e OR LESS AND OBLIQUITY θ OR LESS

To determine the expected armor thickness to be encountered by random hits of fire from ground attack (0° elevation) on the presented area of a tank, the following procedure was used. The presented area at each attack angle, $A(\gamma)$, was divided into sections, $a(\gamma, t, \theta)$, such that each section represented a plate of constant thickness t, and constant angle of obliquity θ at attack angle γ. Obliquity is the angle between the normal to the area of armor and the line of fire. The thickness t at obliquity θ is converted to its equivalent thickness, t_e, at 0° obliquity by equation (1) which is $t_e = K_\theta t$. From this the armor distribution curves are drawn. These curves for the M48 from specific angles of attack are shown in the appendix.

The frequency of encountering a section $a(\gamma, t_e)$ is $f(\gamma)a(\gamma, t_e)/A(\gamma)$, and the probability, P_{t_e}, of encountering an equivalent thickness t_e or less for a random hit on the presented area of the armored shell averaged over all angles of attack is,

$$P_{t_e} = \int_0^{2\pi} \int_0^{t_e} f(\gamma) \frac{a(\gamma, t_e)}{A(\gamma)} dt_e\, d\gamma. \tag{2}$$

The suspension and other exteriorly stowed components were considered to be armor, and their thicknesses at various angles of attack were determined. These thicknesses were than converted to equivalent thicknesses and added to the thicknesses of the sections, $a(\gamma, t_e)$, that they shielded.

*Very recent firings at Aberdeen Proving Ground now indicate that this assumption may not be completely valid.

[1] BRLM 590 "The Range and Angular Distribution of AP Hits on Tanks", R. H. Peterson, Dec. 1951.

Values of P_{t_e} were obtained for the different projectiles first ignoring external components and then considering them.

The HEP rounds do damage by causing a shock wave in the armor which in turn causes a spall to come off the back of the armor. It is assumed that this shock wave is broken up by the suspension and exterior components, thereby defeating the round. It is further assumed that all armor over 70° obliquity is impenetrable to all rounds.

The distribution of the angles of obliquity of the armor can be useful in the design of projectiles and fuzes. The computations are similar to those used to determine the distribution of armor thicknesses. Hence, the probability of a random hit on the presented area of the hull and turret encountering an obliquity of θ° or less, averaged over all angles of attack, is

$$P_\theta = \int_0^{2\pi} \int_0^{\theta} f(\gamma) \frac{a(\gamma,\theta)}{A(\gamma)} d\theta \, d\gamma \tag{3}$$

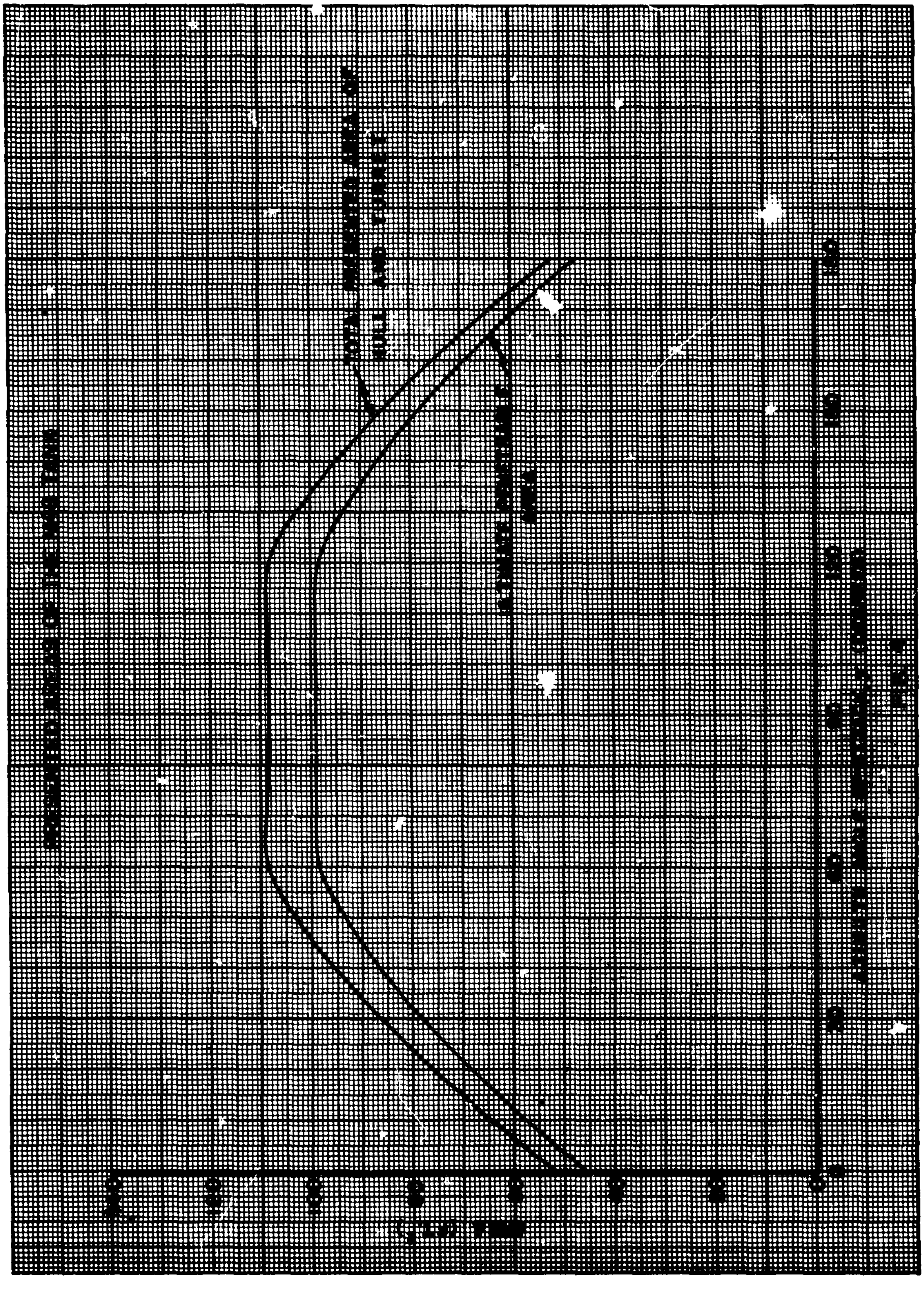
DISCUSSION OF RESULTS

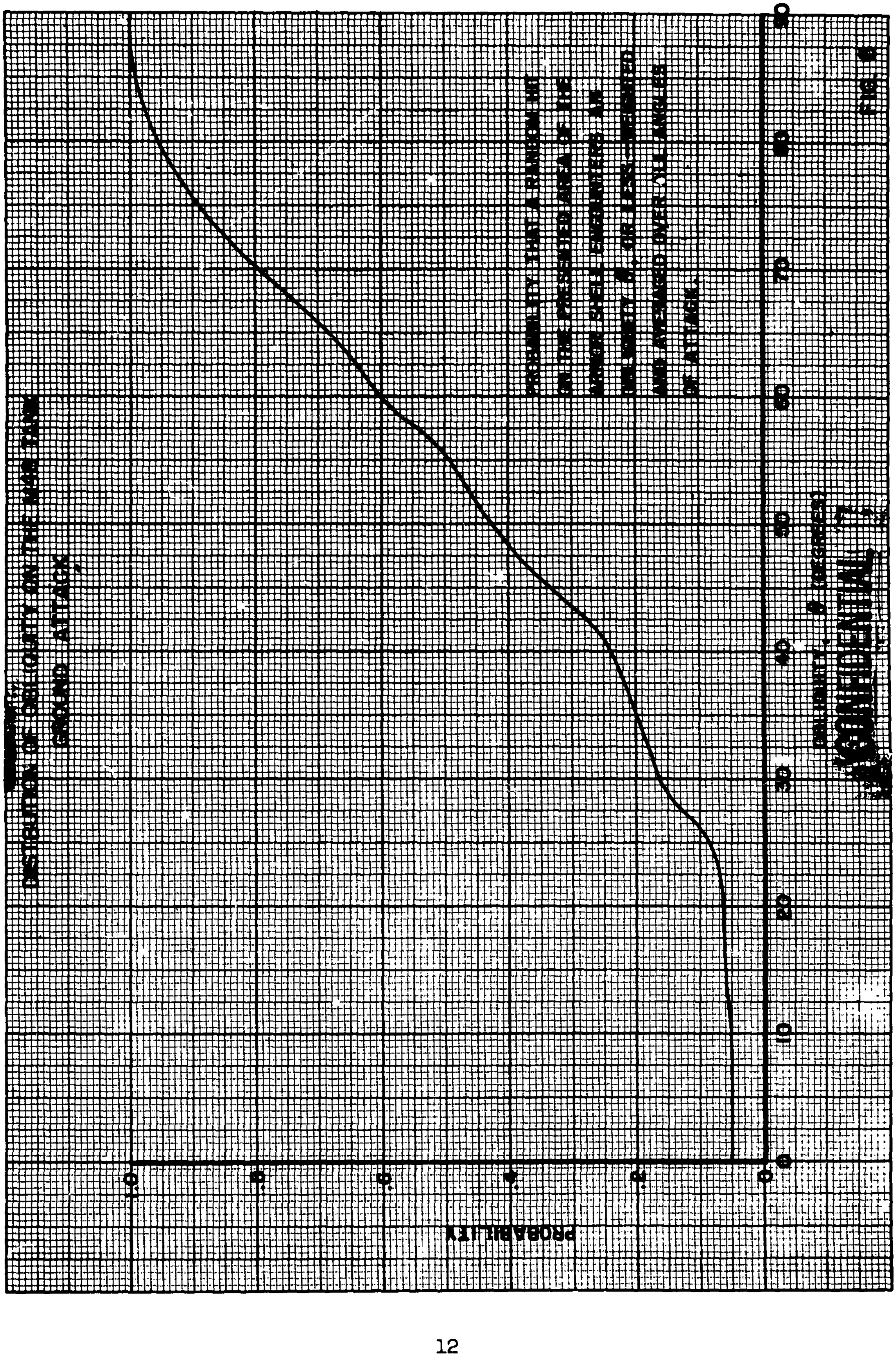
At each attack angle there is (1) the total presented area of the hull and turret, A_t, (2) the total ultimate penetrable area or the presented area of the internal volume, A_μ, and (3) the total presented area of the tank (including suspension), A_E. These areas are functions of the attack angle, γ, and in this study the area (1) is used in evaluating equations (2) and (3) above. The values of P_{t_e} based on A_t can be changed to values based on A_μ by multiplying them by A_t/A_u. Figure 4 shows the presented areas of the M48 medium tank for 0° elevation.

The function P_θ as given by equation (3) above is plotted in Fig. 5. It shows that 50% of the time a random hit encounters an obliquity of 56° or more. Furthermore, since it is assumed that all armor over 70° obliquity is impenetrable to all rounds, 20% of the time a random hit will have no penetration effect.

The probability that a random hit encounters an equivalent thickness t_e or less, averaged over all angles of attack, as given by equation (2) is

$$P_{t_e} = \int_0^{2\pi} \int_0^{t_e} f(\gamma) \frac{a}{A} \, dt_e \, d\gamma .$$




DISTBUTION OF OBLIQUITY ON THE M48 TANK
GROUND ATTACK
PROBABILITY
1.0
.8
.6
.4
.2
0
0
10
20
30
40
50
60
70
80
90
OBLIQUITY, θ (DEGREES)
PROBABILITY THAT A RANDOM HIT ON THE PRESENTED AREA OF THE ARMOR SHELL ENCOUNTERS AN OBLIQUITY θ, OR LESS—WEIGHTED AND AVERAGED OVER ALL ANGLES OF ATTACK.
CONFIDENTIAL
FIG. 6

Curves of this function taking into consideration (1) the armor plate only, and (2) the effect of the suspension and other exterior components, are plotted in Figs. 6 and 7 respectively for HEP, HEAT, AP and HVAP projectiles. There are two distributions for HEAT--one weighted for attack by hand fired weapons and the other for attack by tank fired or other high velocity AT weapons.

Since it is assumed that $t_e = t$ for HEP rounds, its curve is simply the distribution of actual armor thicknesses and disregards obliquity altogether. From Fig. 3 it can be seen that large obliquities affect the K values for HVAP rounds more than the other rounds. Therefore, because of the large obliquities encountered, the HVAP curve in Fig. 6 is lowest for almost the entire range of thicknesses. Since the large obliquities do not as greatly affect the K values for HEAT and AP rounds, their curves consequently lie between those of HVAP and HEP.

The curves in Fig. 6 (exterior components not considered) reach a probability limit of approximately 0.77 indicating that 23% of the presented area is impenetrable to a random hit by all types of rounds. The curves for AP, HVAP and HEAT rounds in Fig. 7 (exterior components considered) are similar in shape to those of Fig. 6 but are shifted to the right showing a lower P_{t_e} for the entire range of t_e considered. Since all exteriorly stowed components are considered to defeat HEP rounds, the curve for this projectile has changed considerably. The HEP curve in Fig. 7 reaches a probability limit of 0.56 indicating that 44% of the presented area is impenetrable to a random hit by this type of projectile.

A comparison of the curves in Figs. 6 and 7 gives no indication of the merits of specific projectiles. Although the HVAP round has a lower probability of encountering a particular t_e than the other rounds over the range of thicknesses considered, this does not necessarily mean that HVAP rounds are less effective against armor.

In order to compare specific AP and HVAP projectiles, it is necessary to enter Figs. 1 and 2, respectively, to find their t/d values at 0° obliquity and then multiply them by the diameters of the rounds to obtain their penetration capabilities. At this value of t_e Fig. 6 or 7 is entered to obtain the probability of encountering this t_e or less which is the probability of perforating, P_p, for the given projectile.

The probability (P_p) of a random hit perforating the M48 tank averaged over all attack angles was obtained for the projectiles listed in Table I. Table II lists these probabilities for the cases where external components are not included and included. Before determining P_p for the HEAT projectiles 2.5" was subtracted from their penetration capabilities. Thus the probabilities of Table II for HEAT projectiles are probabilities of penetrating and having at least 2.5" of residual penetration. This residual penetration was introduced to allow for damage after perforation. The data of Table II on kinetic energy projectiles are plotted as a function of range in Figs. 8 and 9.

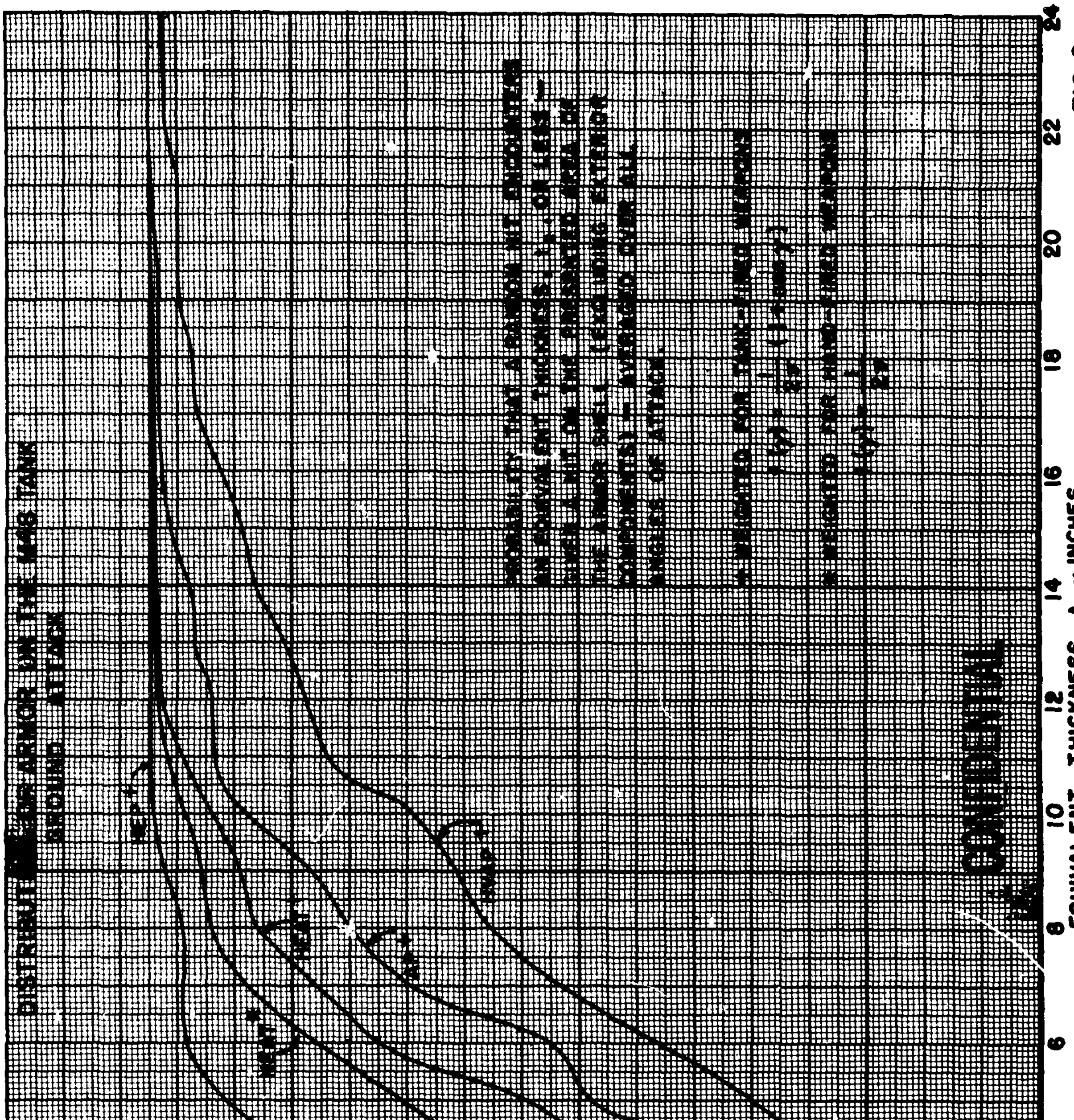

GROUND ATTACK
HEP*
HEAT*
HEAT+
AP*
HVAP*
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL (EXCLUDING EXTERIOR COMPONENTS) — AVERAGED OVER ALL ANGLES OF ATTACK.
* WEIGHTED FOR TANK-FIRED WEAPONS
+ WEIGHTED FOR HAND-FIRED WEAPONS
CONFIDENTIAL
0
2
4
6
8
10
12
14
16
18
20
22
24
EQUIVALENT THICKNESS, t_e ~ INCHES

FIG. 6

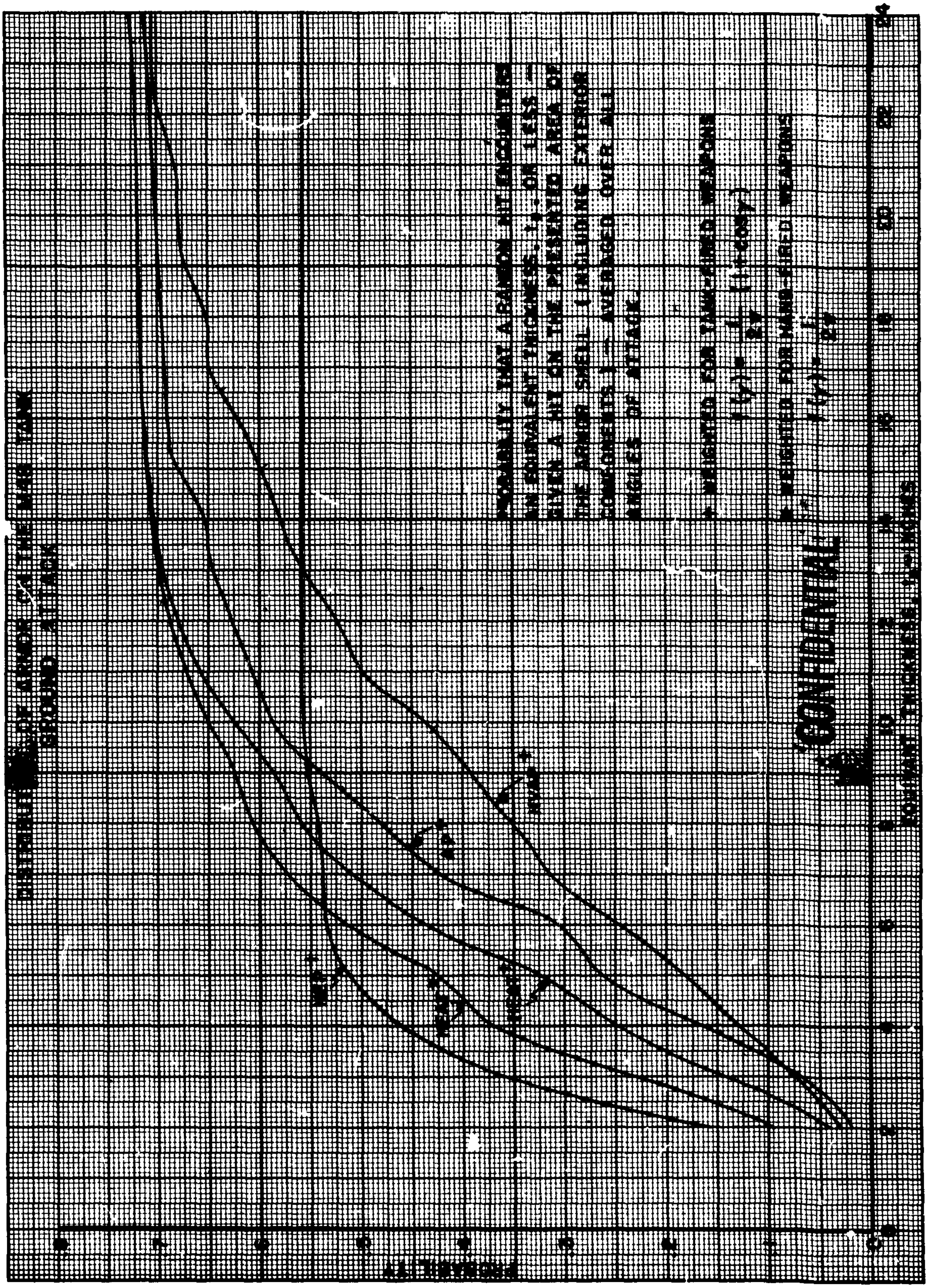

OF ARMOR ON THE M48 TANK
GROUND ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL (INCLUDING EXTERIOR COMPONENTS) — AVERAGED OVER ALL ANGLES OF ATTACK.
* WEIGHTED FOR TANK-FIRED WEAPONS
$f(\gamma) = \frac{1}{2\pi}(1-\cos\gamma)$
* WEIGHTED FOR HAND-FIRED WEAPONS
$f(\gamma) = \frac{1}{2\pi}$
CONFIDENTIAL
EQUIVALENT THICKNESS, t_e — INCHES
PROBABILITY
0
2
4
6
8
10
12
14
16
18
20
22
24

FIG. 7

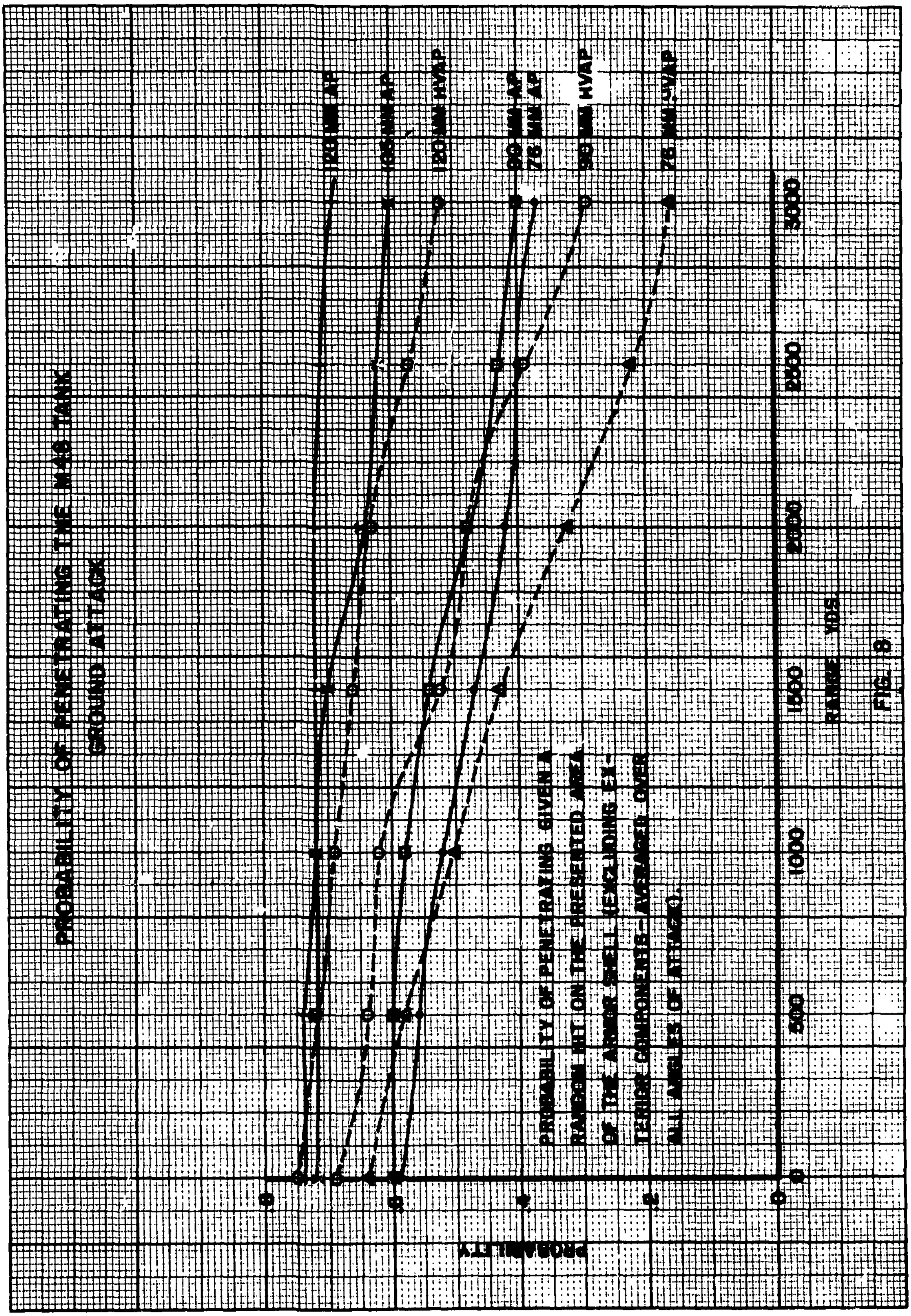

PROBABILITY OF PENETRATING THE M46 TANK
GROUND ATTACK
120MM AP
105MM AP
120MM HVAP
90 MM AP
76 MM AP
90 MM HVAP
76 MM HVAP
PROBABILITY OF PENETRATING GIVEN A RANDOM HIT ON THE PRESENTED AREA OF THE ARMOR SHELL (EXCLUDING EXTERIOR COMPONENTS) AVERAGED OVER ALL ANGLES OF ATTACK.
.8
.6
.4
.2
0
500
1000
1500
2000
2500
3000
RANGE YDS
PROBABILITY

FIG. 8

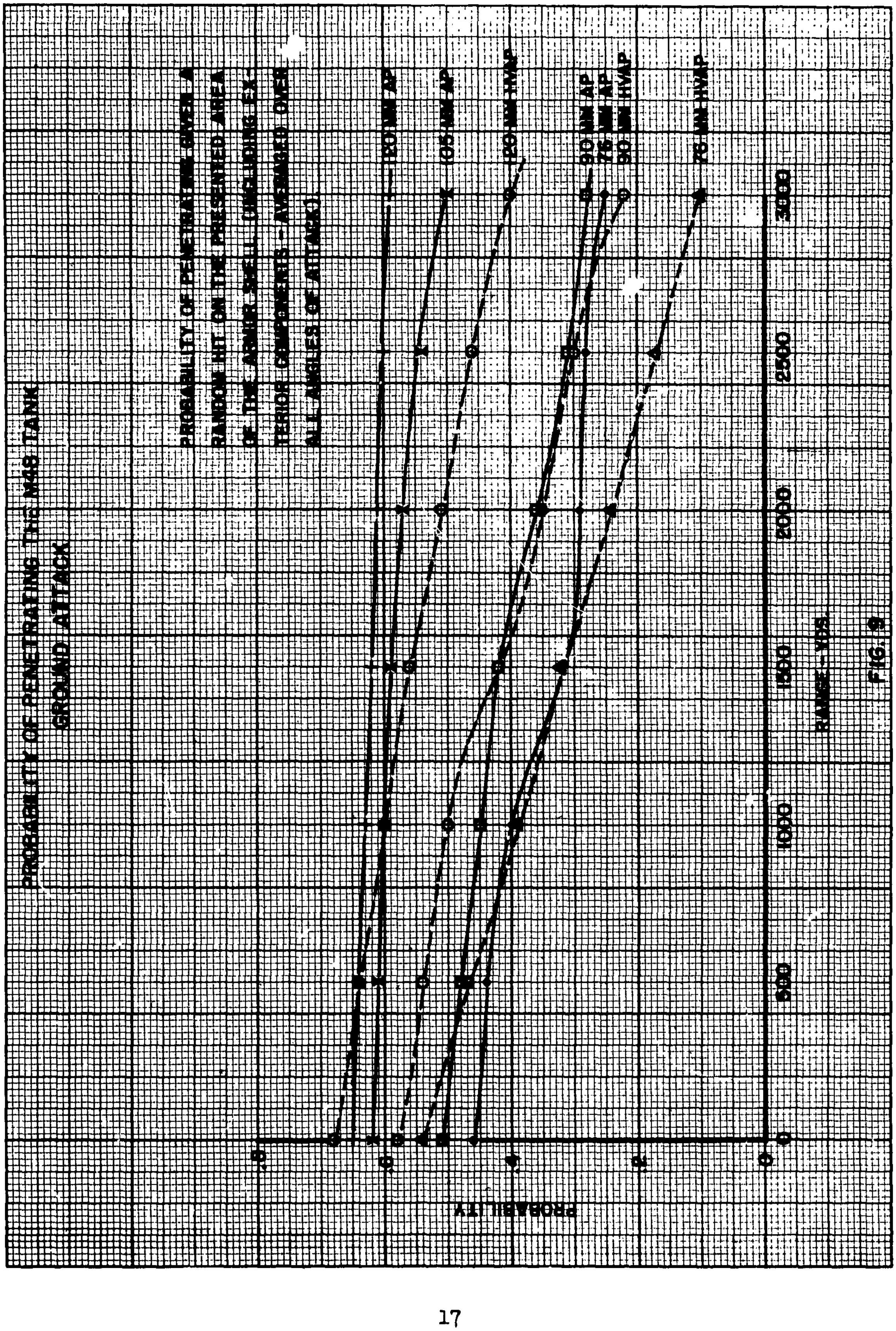

PROBABILITY OF PENETRATING THE M48 TANK
GROUND ATTACK
PROBABILITY OF PENETRATING GIVEN A RANDOM HIT ON THE PRESENTED AREA OF THE ARMOR SHELL (INCLUDING EX-TERIOR COMPONENTS - AVERAGED OVER ALL ANGLES OF ATTACK).
120 MM AP
105 MM AP
120 MM HVAP
90 MM AP
76 MM AP
90 MM HVAP
76 MM HVAP
.8
.6
.4
.2
0
PROBABILITY
0
500
1000
1500
2000
2500
3000
RANGE - YDS.

FIG. 9

TABLE I

Gun	Projectile	Muzzle Velocity ft/sec.
76mm T91	T180 HEAT	2800 E
	7128E6 AP	3200
	T66E4 HVAP	4135
	T170E3 HEP	2600
90mm T119	T108E40 HEAT	2800
	T33E7 AP	3000
	T67E7 HVAP	3900
	T142E5 HEP	2600
105mm T140	T298 HEAT	2800 E
	T182 AP	3500
	T297 HEP	2600 E
120mm T123	T153 HEAT	3600 E
	T116E5 AP	3420 E
	T17E1 HVAP	4150
	T143 HEP	2600 E

NOTE: "E" indicates estimated muzzle velocity.

TABLE II

Probability of a Random Hit Penetrating the M48 Averaged Over All Attack Angles

A. External components not included

Range (Yds.)	76mm AP	76mm HVAP	76mm HEAT	76mm HEP	90mm AP	90mm HVAP	90mm HEAT	90mm HEP	105mm AP	105mm HEAT	105mm HEP	120mm AP	120mm HVAP	120mm HEAT	120mm HEP
0	.59	.64	.68	.52	.60	.69	.70	.64	.72	.76	.71	.74	.75	.76	.74
500	.56	.58			.60	.64			.72			.73	.72		
1000	.52	.50			.58	.62			.72			.72	.69		
1500	.47	.43			.54	.52			.70			.72	.66		
2000	.42	.32			.47	.48			.64			.72	.63		
2500	.40	.22			.43	.39			.62			.71	.57		

B. External components included

Range (Yds.)	76mm AP	76mm HVAP	76mm HEAT	76mm HEP	90mm AP	90mm HVAP	90mm HEAT	90mm HEP	105mm AP	105mm HEAT	105mm HEP	120mm AP	120mm HVAP	120mm HEAT	120mm HEP
0	.46	.54	.56	.36	.51	.58	.61	.46	.62	.69	.51	.65	.67	.69	.54
500	.44	.47			.48	.54			.61			.64	.64		
1000	.40	.39			.45	.50			.60			.63	.60		
1500	.32	.32			.42	.42			.59			.62	.56		
2000	.29	.24			.36	.35			.57			.61	.51		
2500	.27	.17			.31	.30			.54			.60	.46		
Average decrease in P_p due to presence of external components.	.13	.10	.12	.16	.10	.11	.09	.18	.10	.07	.20	.10	.10	.07	.20

Comparing parts A and B of Table II it is seen that the presence of the exterior components decreases P_p by approximately the same amount at all ranges for a given projectile type and size. At the bottom of Table II is given the average decrease in P_p for each projectile type and size. An average decrease of approximately .1 is observed for AP, HVAP and HEAT projectiles with a tendency to be slightly greater than .1 for the smaller projectiles and slightly lower than .1 for the larger projectiles.

For HEP projectiles the average decrease in P_p due to the presence of external components ranges from .16 for the 76mm projectile to a maximum of .20 for the 105 and 120mm projectiles.

Considering, now, only part B of Table II (part A is of interest only insofar as it indicates the protective qualities of external components) it is noteworthy that the greater gains in P_p are obtained at all ranges in going from the 90mm to the 105mm for all types of projectile except the HEP, the greatest increase for this type being obtained in going from 76 to 90mm. Only a small increase in P_p is obtained in going from 105mm to 120mm. Thus, it seems hardly worthwhile to consider a gun for the defeat of the M48 larger than the 105mm.

Table II and Figs. 8 and 9 indicate the superiority of the AP projectile over the HVAP at the larger ranges and the superiority of HVAP projectile over the AP at shorter ranges. Considering ranges from 0 to 2000 yds. it appears that there is no particular advantage gained on the basis of penetrating ability by selecting HVAP over AP or AP over HVAP.

Table II also indicates that the least desirable projectile type, on the basis of penetrating ability, is probably HEP, the most desirable is HEAT, and kinetic energy projectiles are in between.

Howard R. Goldman

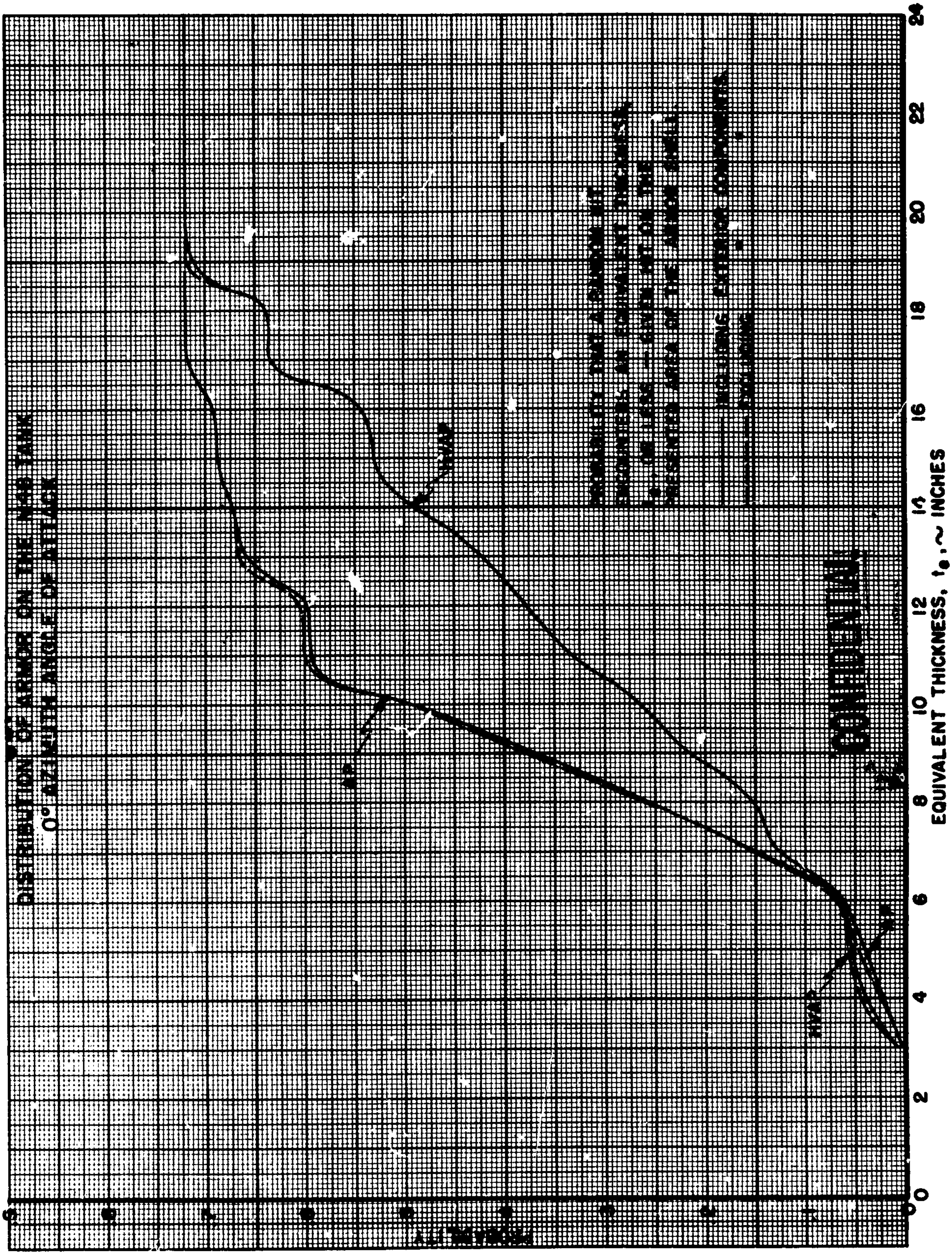
HOWARD R. GOLDMAN

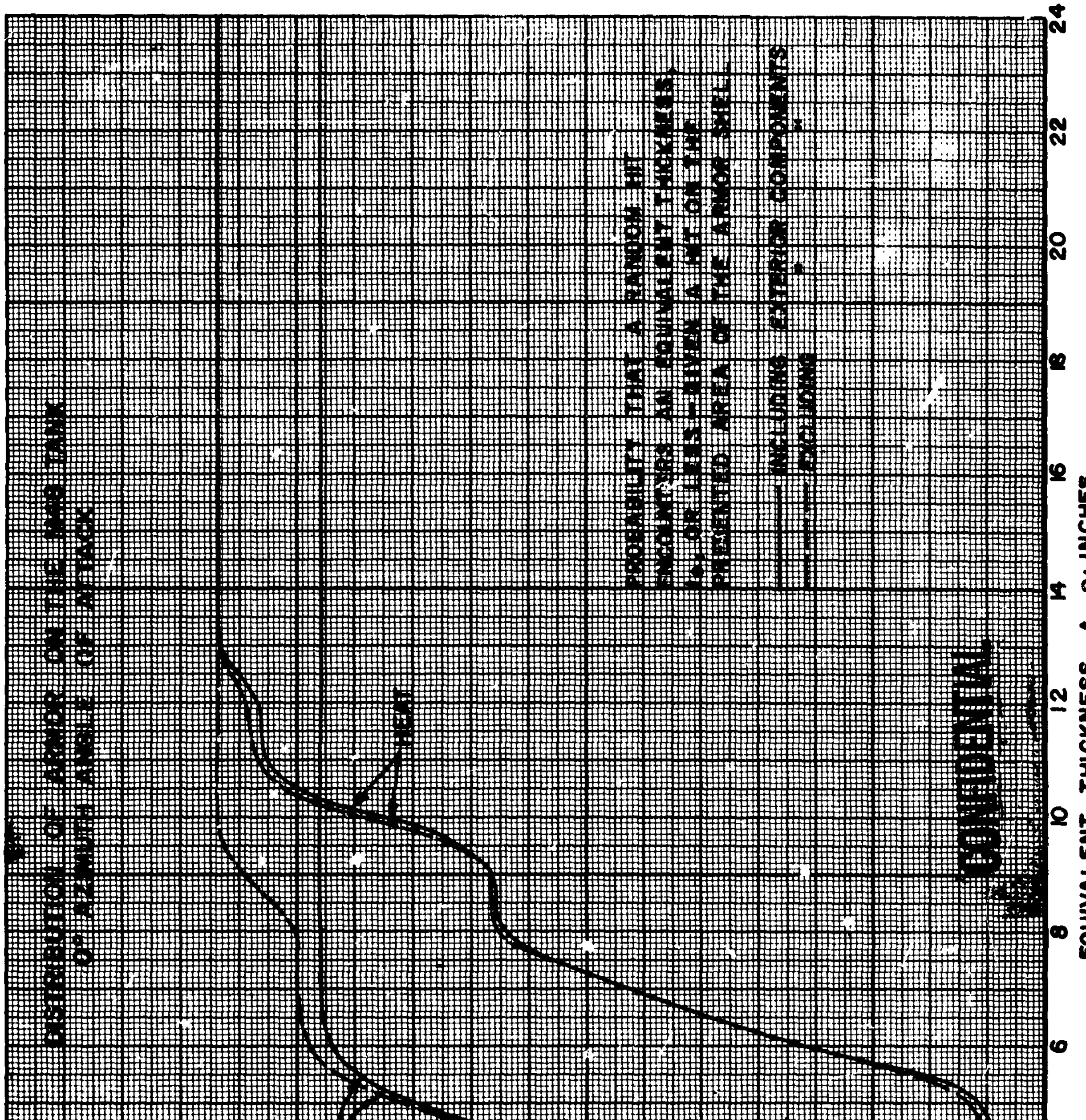
Gilbert H. Kempinger

GILBERT H. KEMPINGER

APPENDIX

Distribution of Armor Thickness and Obliquity Curves for Specific Angles of Attack.


DISTRIBUTION OF ARMOR ON THE M48 TANK
0° AZIMUTH ANGLE OF ATTACK
PROBABILITY
AP
HVAP
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN HIT ON THE PRESENTED AREA OF THE ARMOR SHELL.
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
CONFIDENTIAL
0 2 4 6 8 10 12 14 16 18 20 22 24
EQUIVALENT THICKNESS, t_e, ~ INCHES


0° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS - GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL.
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
HE
HEAT
PROBABILITY
0
2
4
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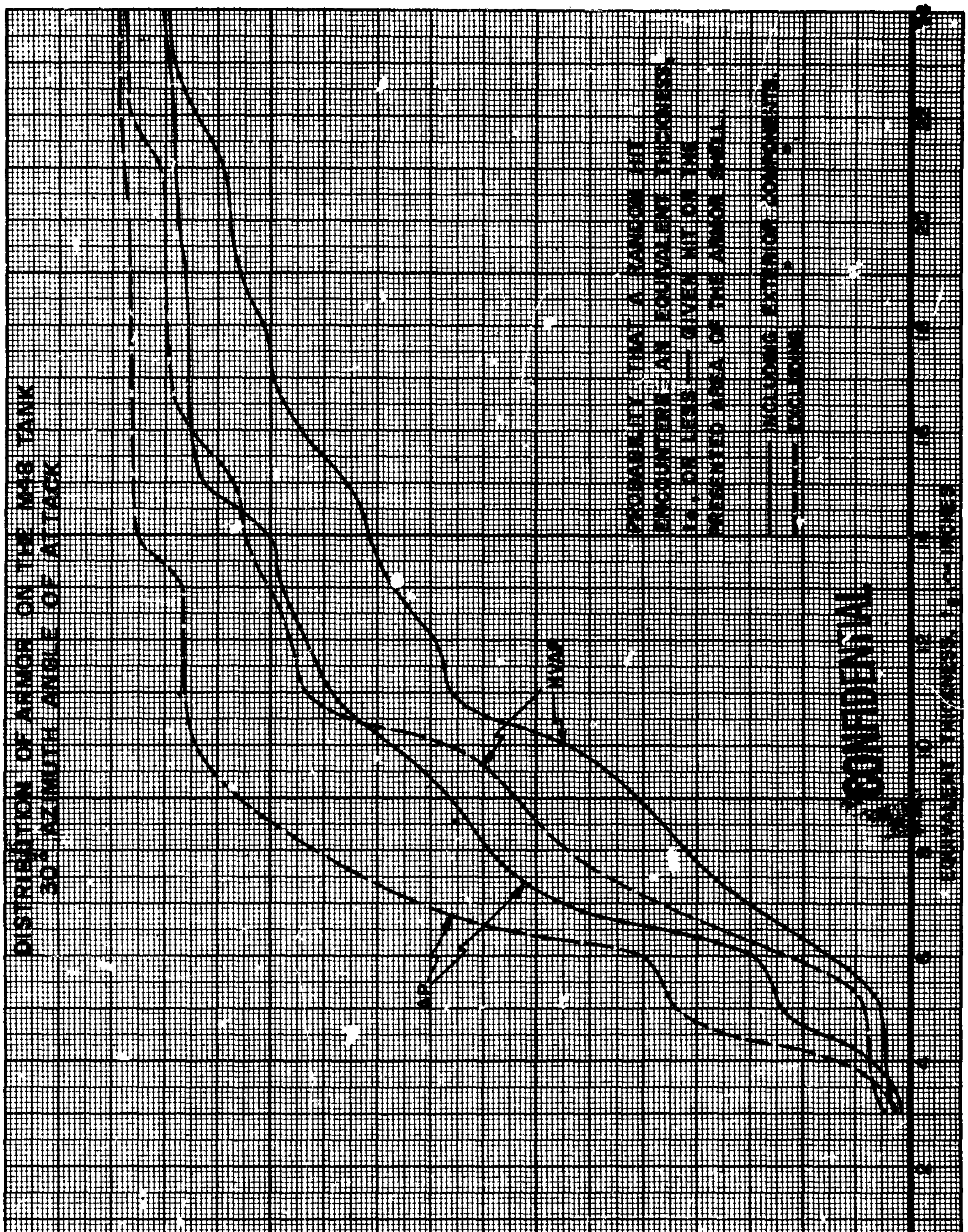
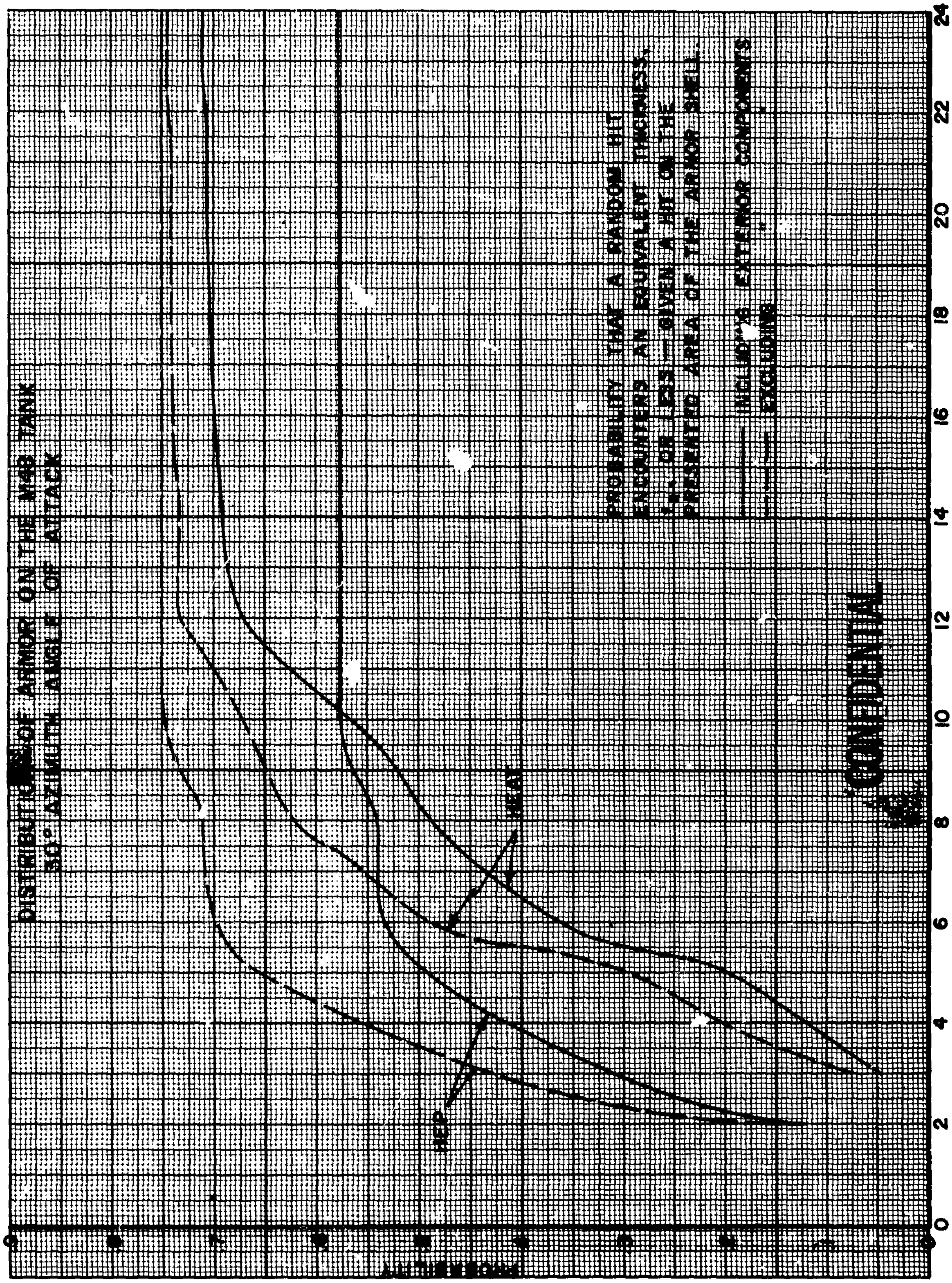
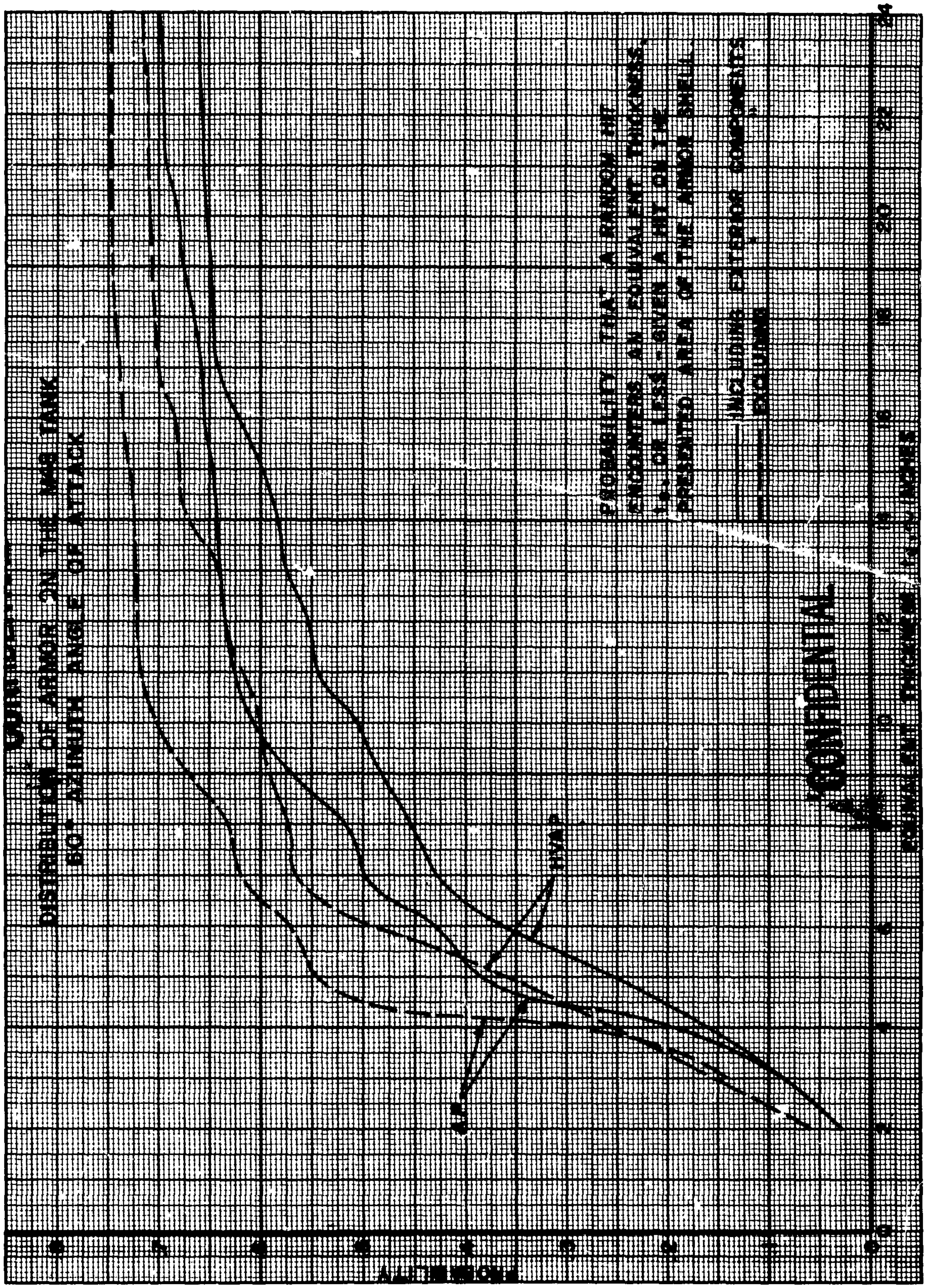
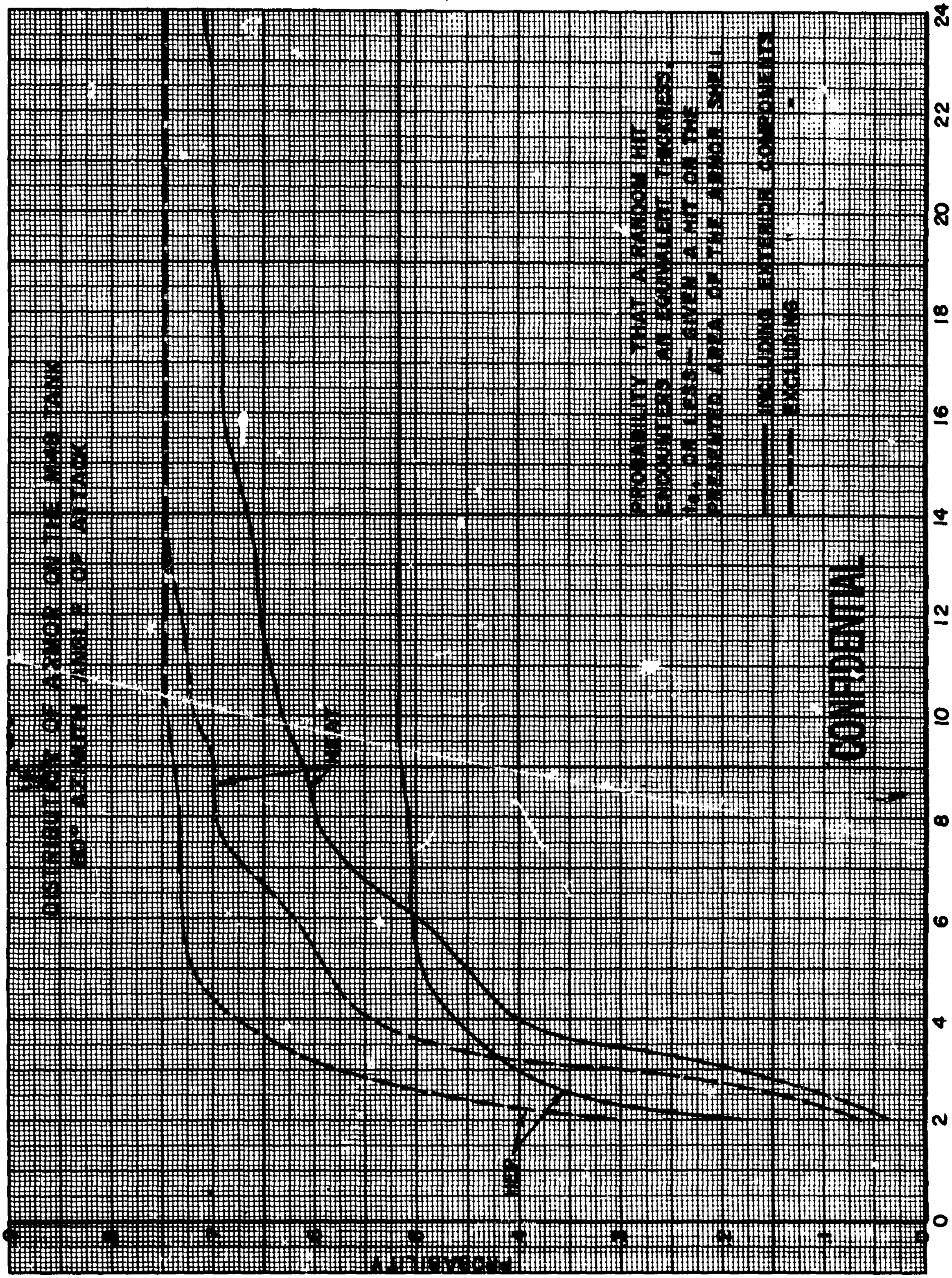
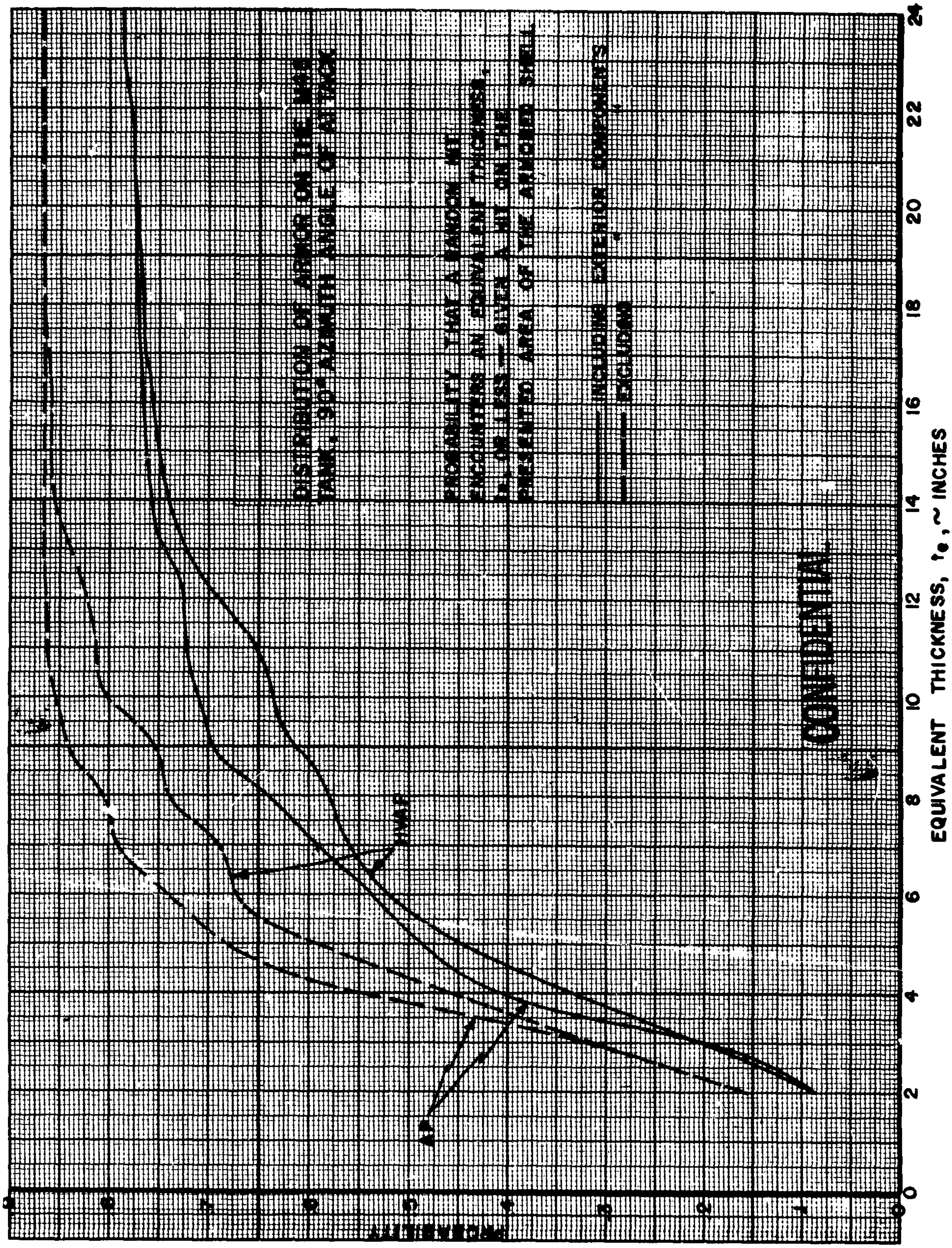
12
14
16
18
20
22
24
EQUIVALENT THICKNESS, t_e, ~ INCHES
CONFIDENTIAL

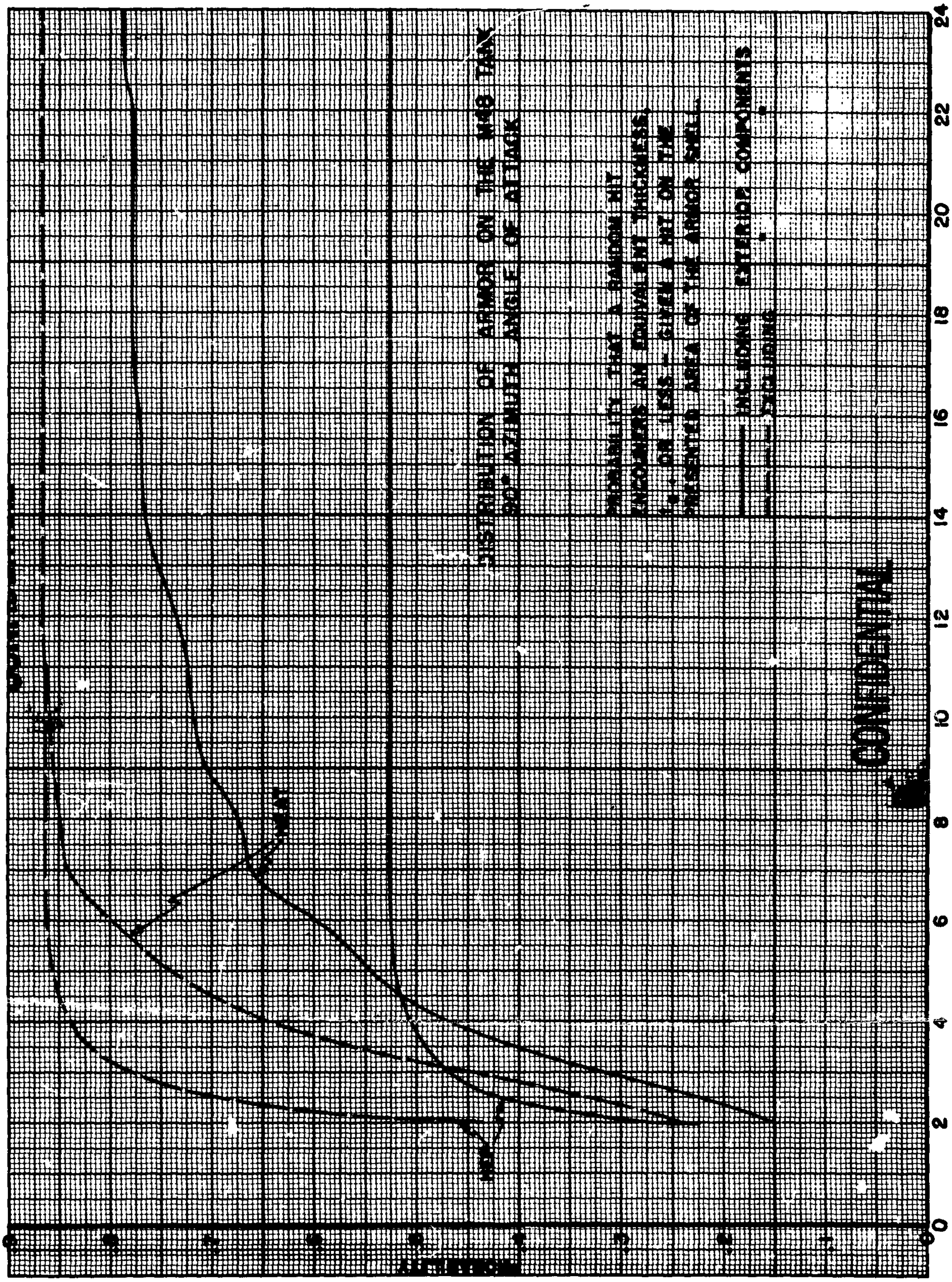

DISTRIBUTION OF ARMOR ON THE M48 TANK
30° AZIMUTH ANGLE OF ATTACK
AP
HVAP
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN HIT ON THE PRESENTED AREA OF THE ARMOR SHELL.
INCLUDING EXTERIOR COMPONENTS.
EXCLUDING
CONFIDENTIAL
PROBABILITY
EQUIVALENT THICKNESS, t_e — INCHES
0
.1
.2
.3
.4
.5
.6
.7
.8
2
4
6
8
10
12
14
16
18
20
22

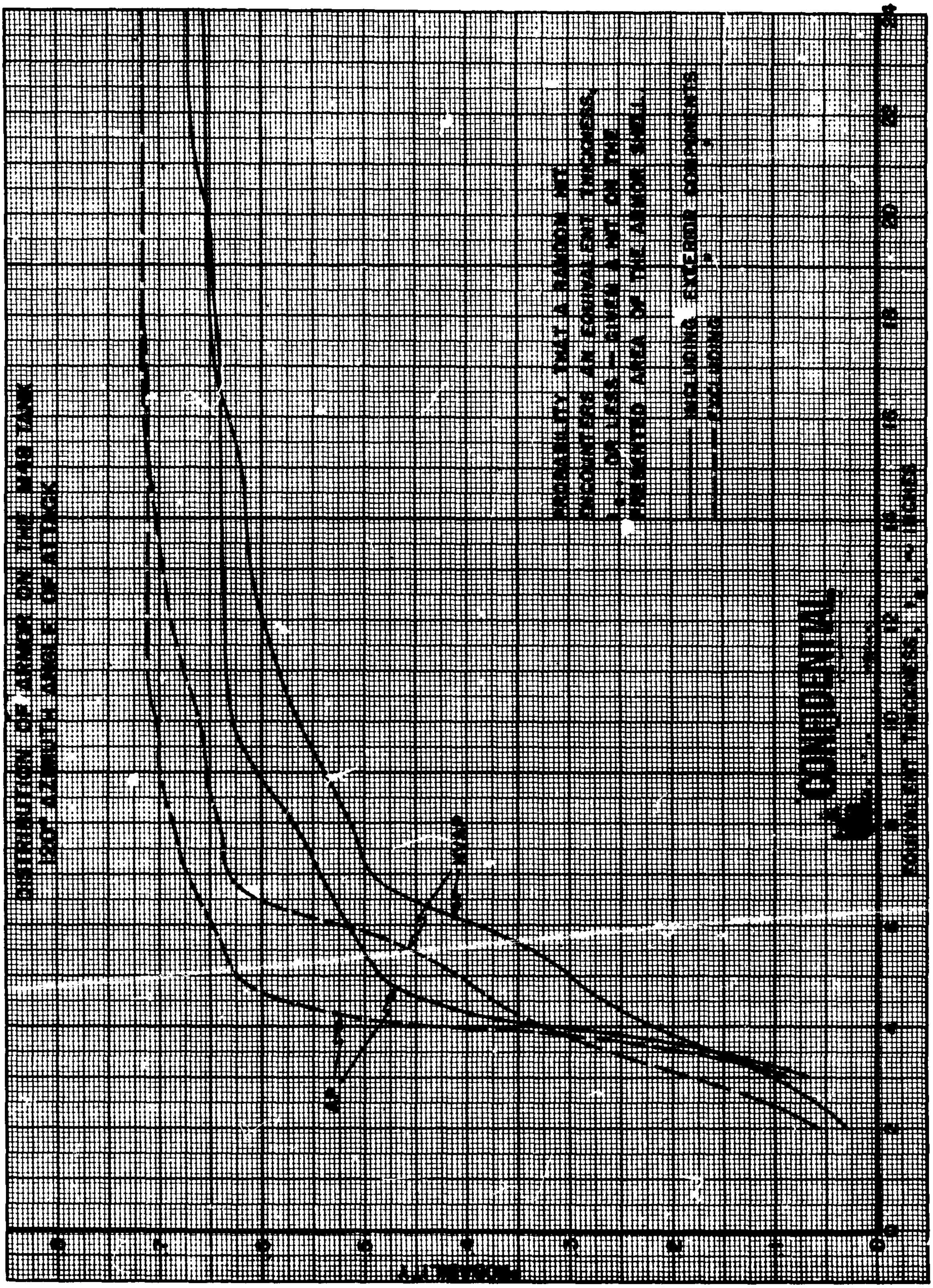

DISTRIBUTION OF ARMOR ON THE M48 TANK
30° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
HEAT
HEP
CONFIDENTIAL
PROBABILITY
EQUIVALENT THICKNESS, t_e, ~ INCHES
0
2
4
6
8
10
12
14
16
18
20
22
24

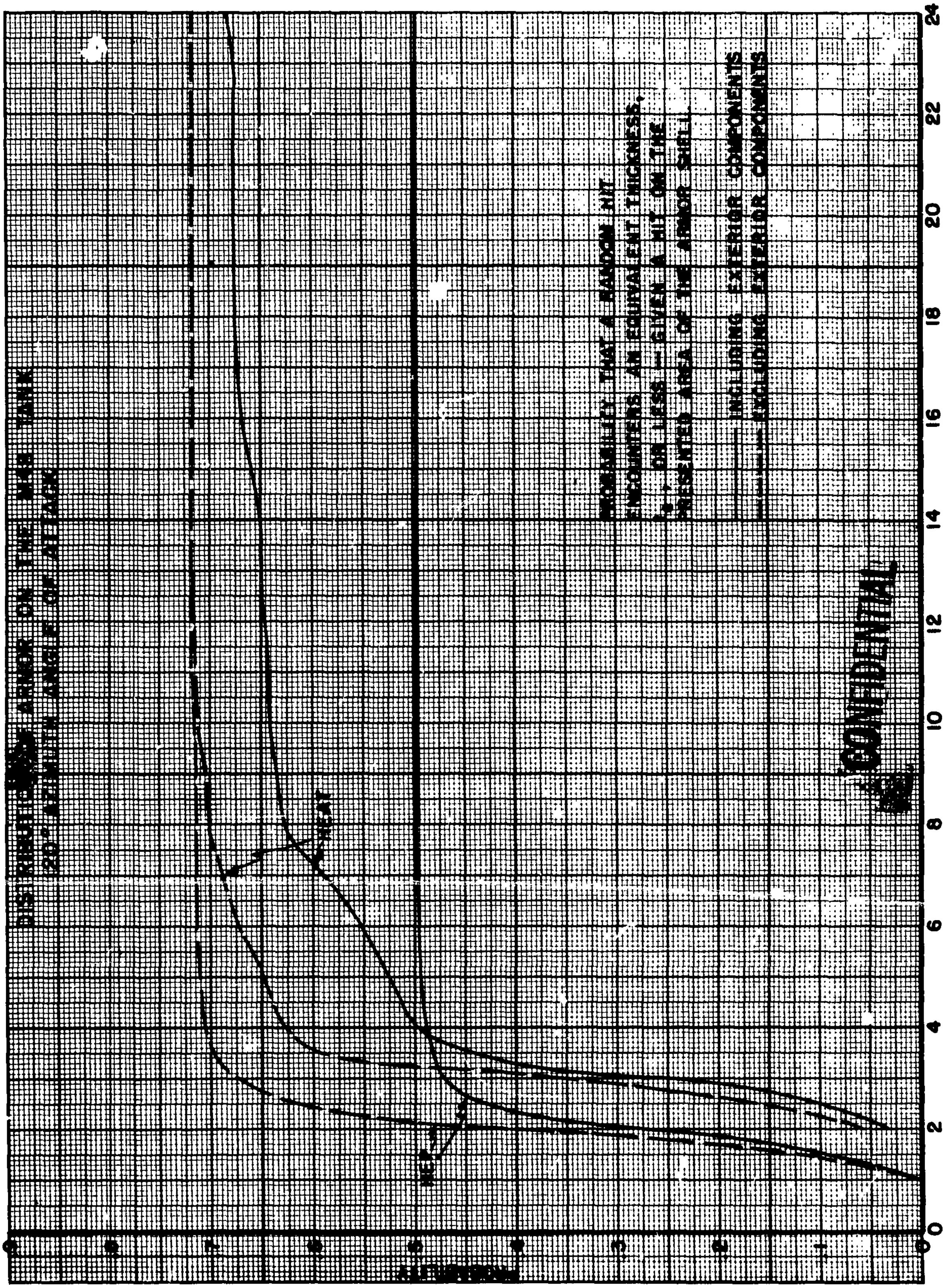

DISTRIBUTION OF ARMOR ON THE M48 TANK
60° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t, OR LESS - GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
CONFIDENTIAL
PROBABILITY


DISTRIBUTION OF ARMOR ON THE M48 TANK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS—GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
MEAN
MED
CONFIDENTIAL
PROBABILITY
EQUIVALENT THICKNESS, t_e, INCHES
0
2
4
6
8
10
12
14
16
18
20
22
24


DISTRIBUTION OF ARMOR ON THE M48 TANK, 30° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMORED SHELL
—— INCLUDING EXTERIOR COMPONENTS
— — EXCLUDING
HVAP
AP
CONFIDENTIAL
PROBABILITY
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
0
2
4
6
8
10
12
14
16
18
20
22
24
EQUIVALENT THICKNESS, t_e, ~ INCHES


DISTRIBUTION OF ARMOR ON THE M48 TANK
90° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS - GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL.
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
PROBABILITY
0
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
0
2
4
6
8
10
12
14
16
18
20
22
24
EQUIVALENT THICKNESS, t_e, ~ INCHES
CONFIDENTIAL


DISTRIBUTION OF ARMOR ON THE
AZIMUTH ANGLE OF ATTACK
INCLUDING EXTERIOR COMPONENTS
EXCLUDING
CONFIDENTIAL
AP
HEAT
PROBABILITY
EQUIVALENT THICKNESS
0
2
4
6
8
10
12
14
16
18
20
22
24



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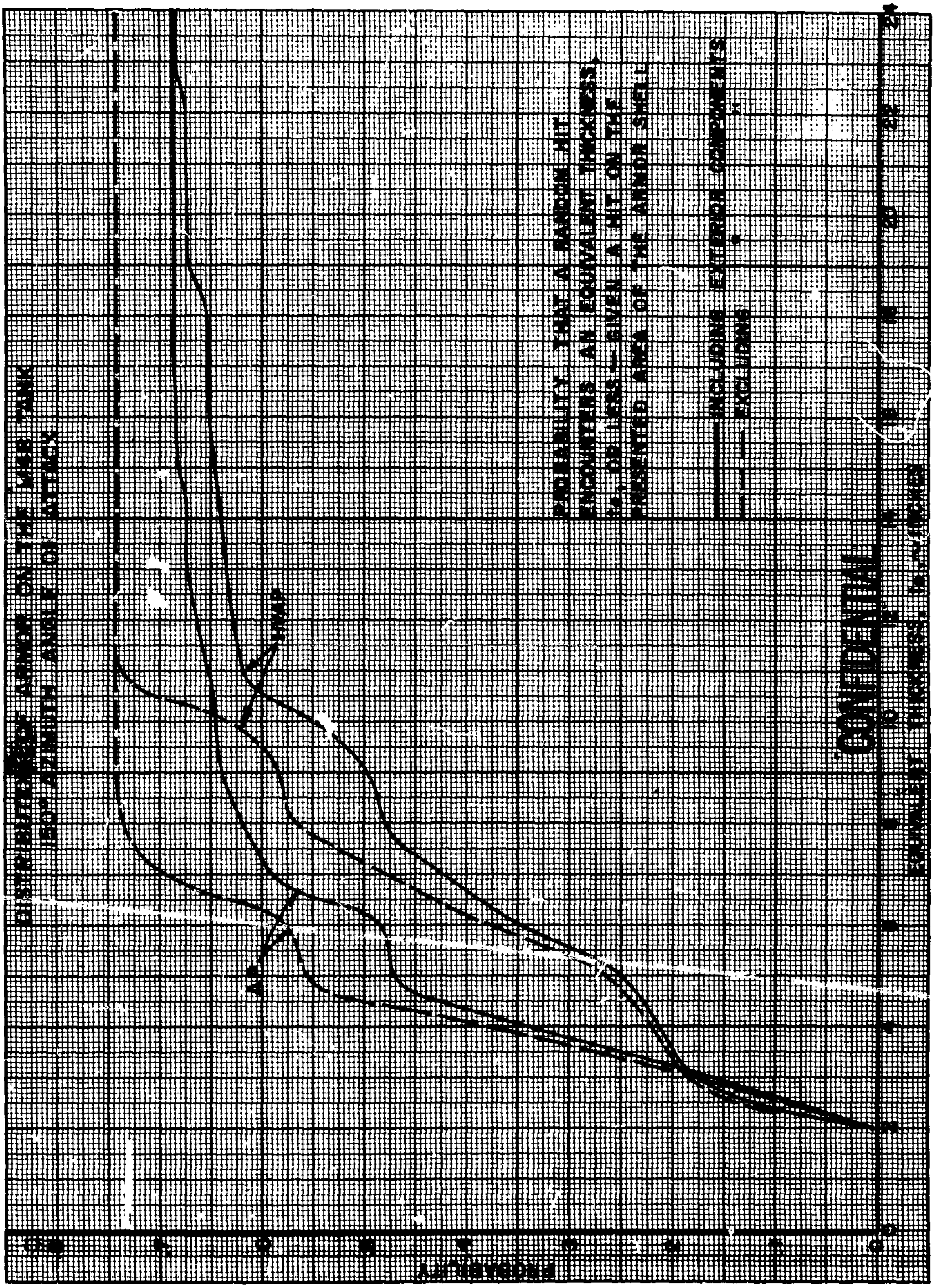
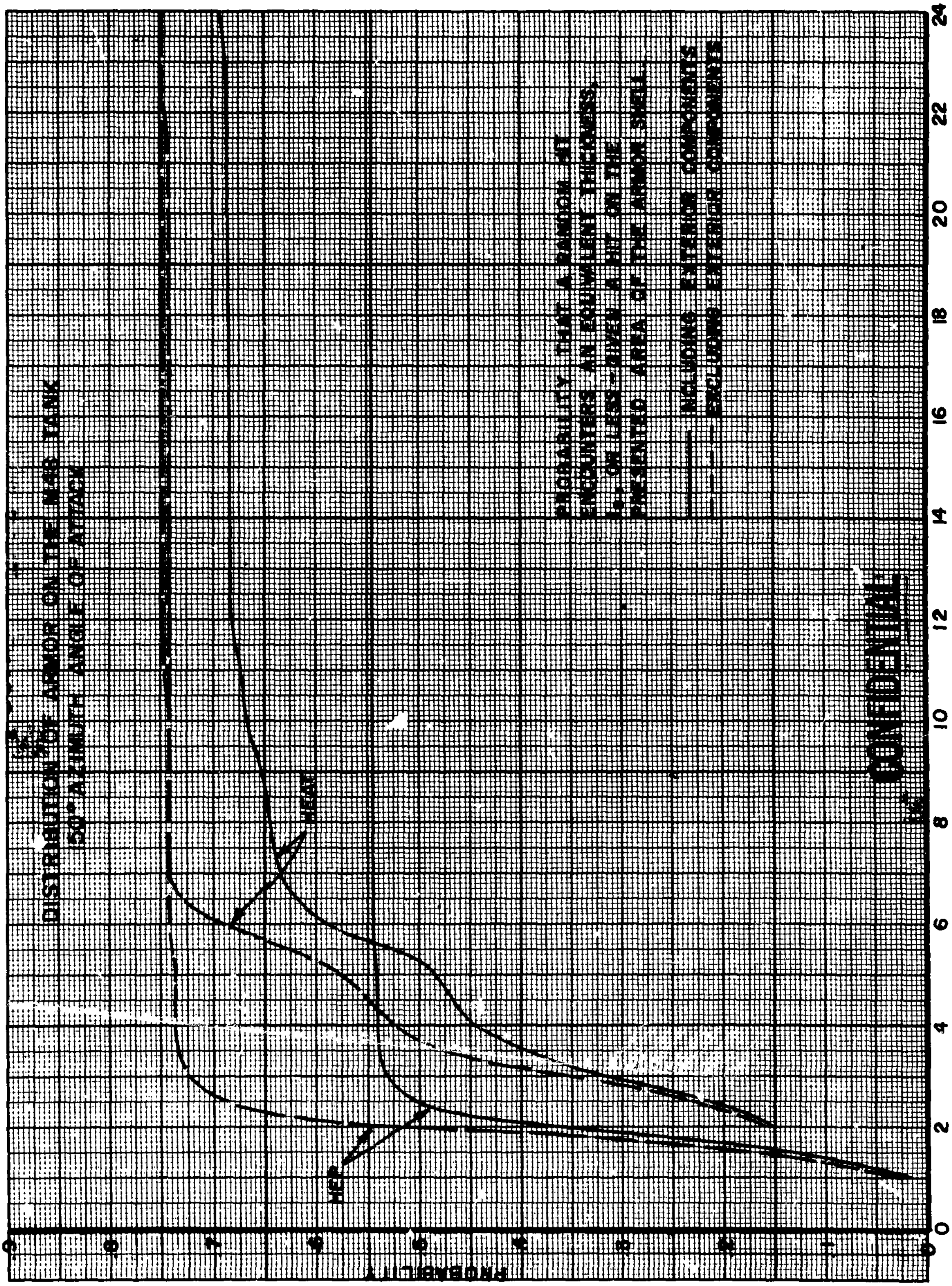
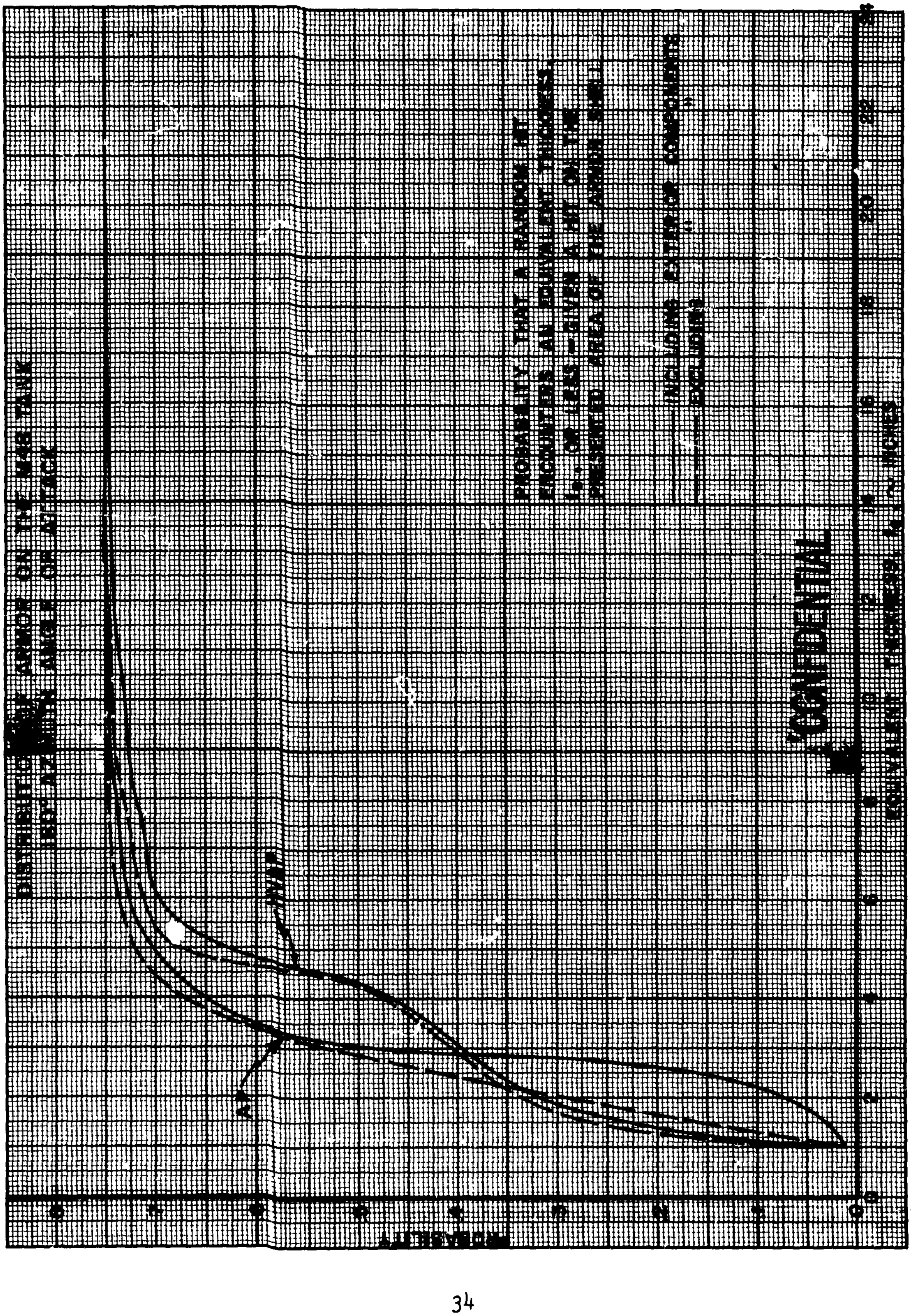
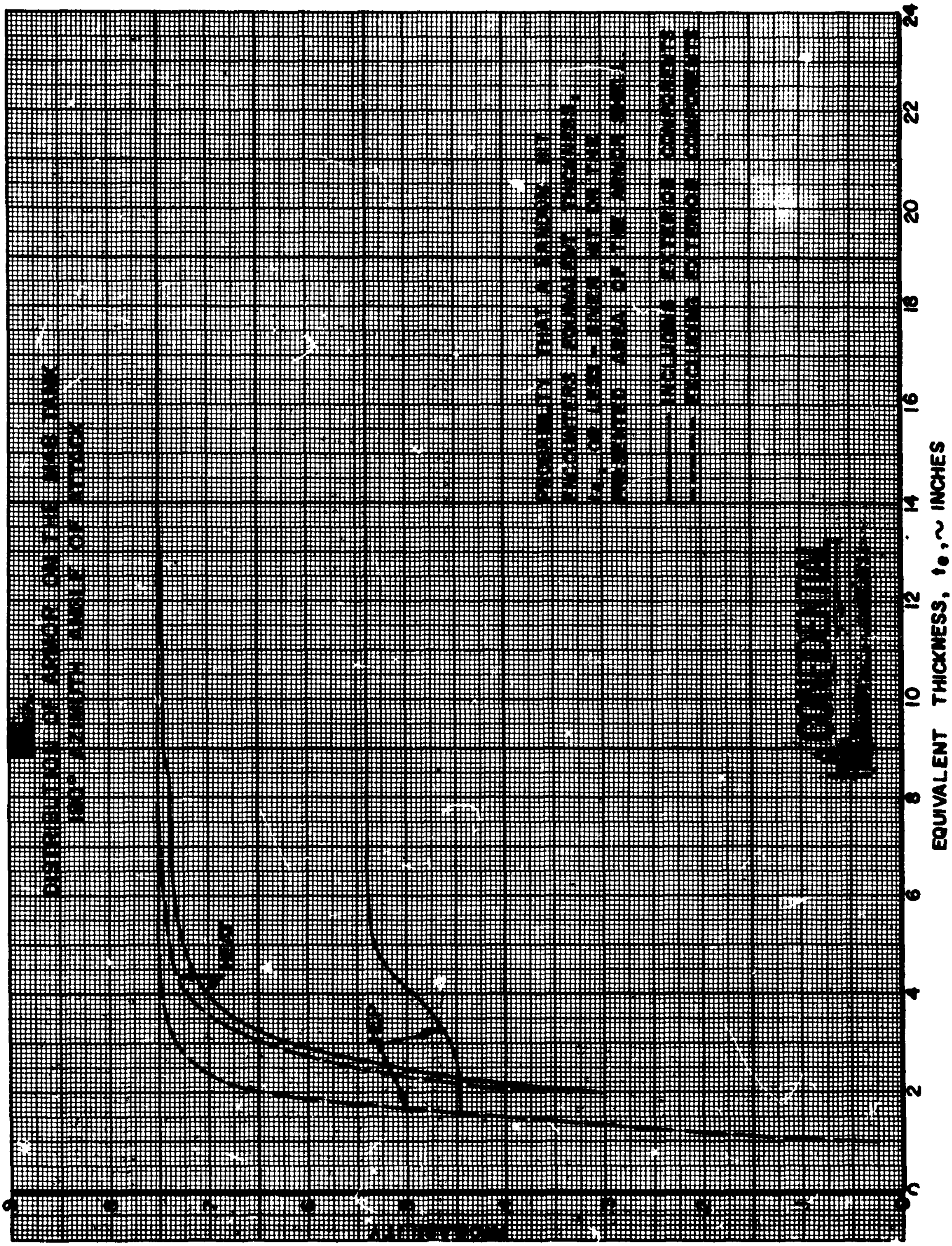
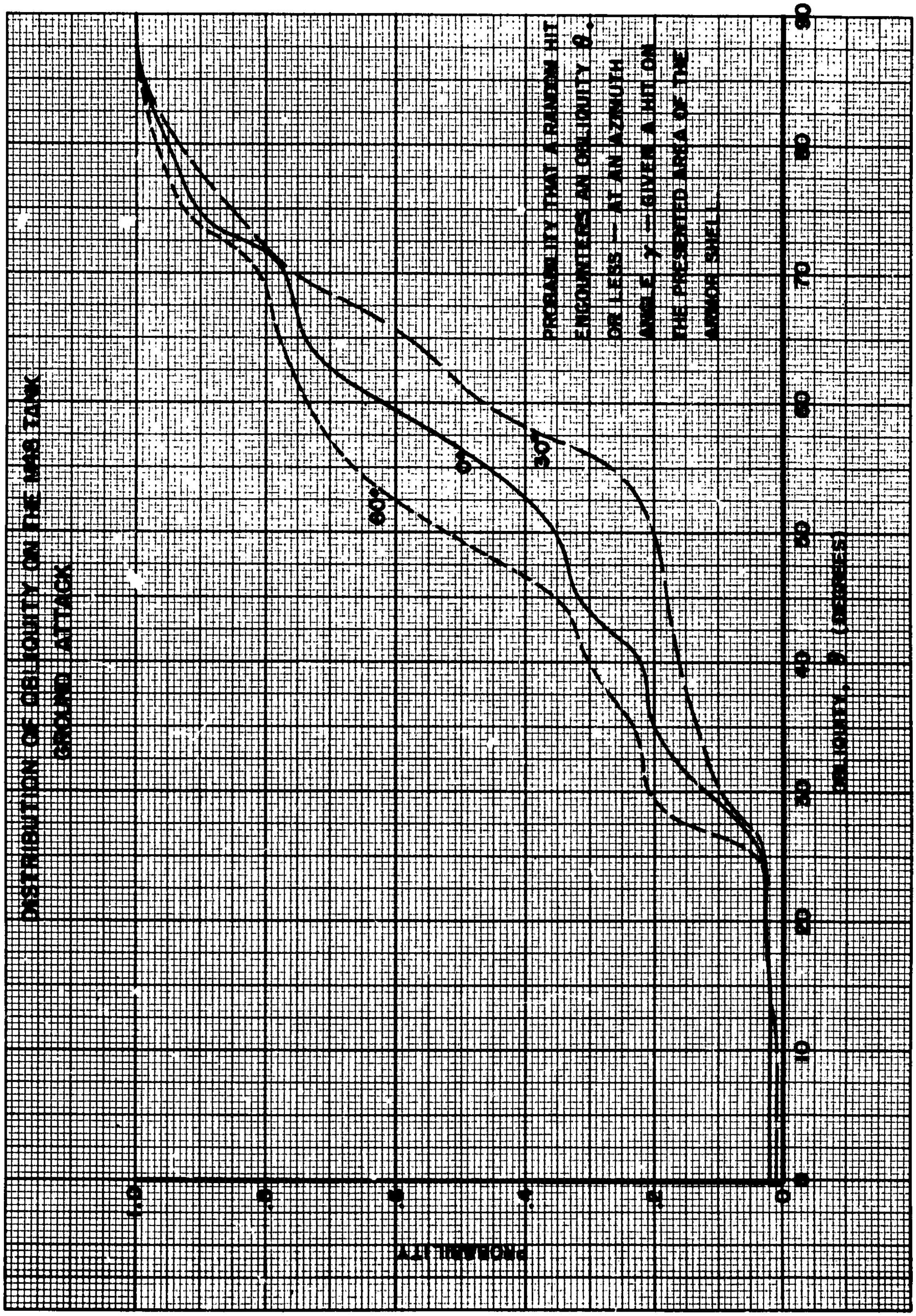

DISTRIBUTION OF ARMOR ON THE M48 TANK
150° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM HIT
ENCOUNTERS AN EQUIVALENT THICKNESS
t, OR LESS—GIVEN A HIT ON THE
PRESENTED AREA OF THE ARMOR SHELL
—— INCLUDING EXTERIOR COMPONENTS
— — EXCLUDING
HVAP
AP
CONFIDENTIAL
EQUIVALENT THICKNESS, t, INCHES
PROBABILITY

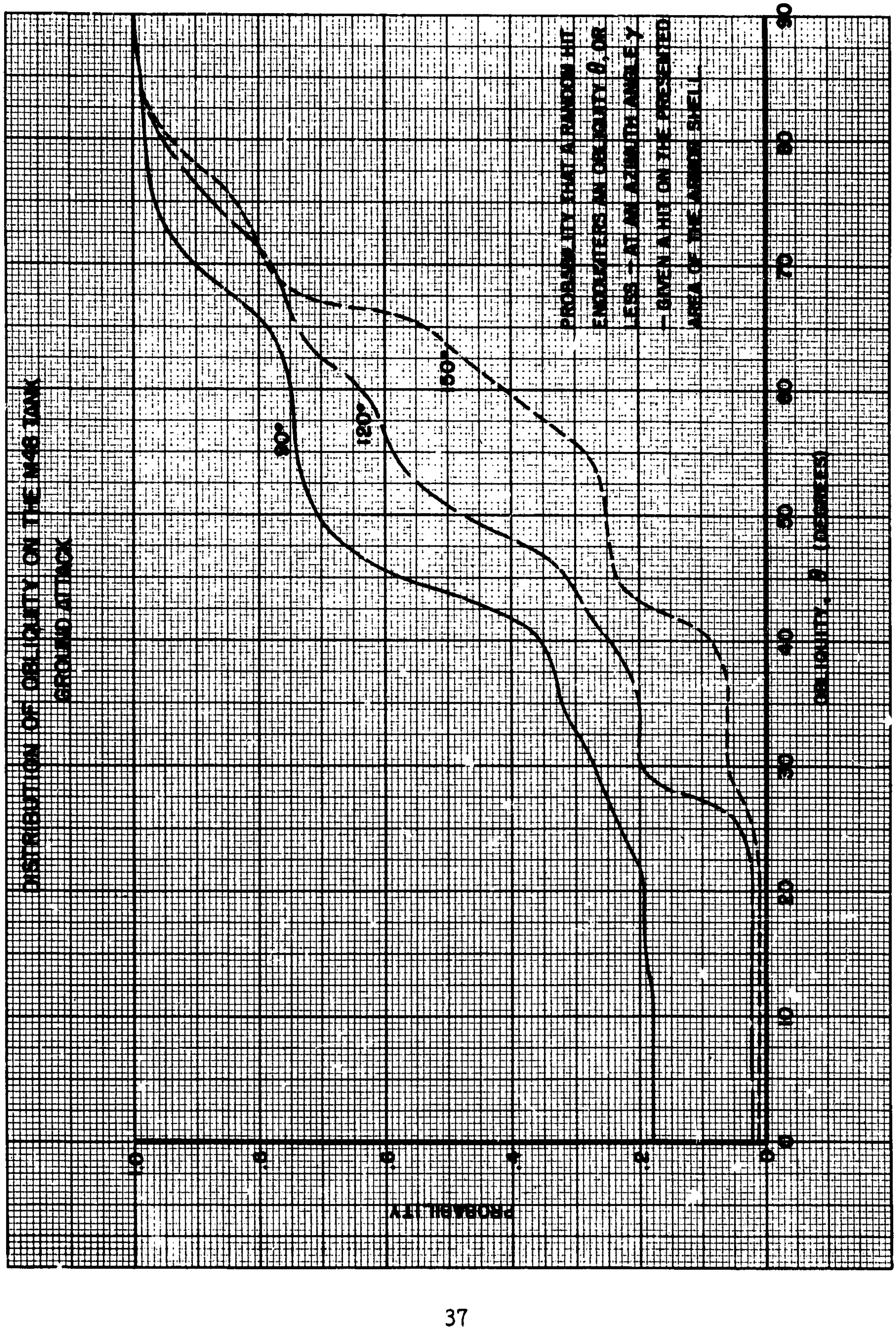

DISTRIBUTION OF ARMOR ON THE M48 TANK
50° AZIMUTH ANGLE OF ATTACK
PROBABILITY THAT A RANDOM JET ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS—GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
INCLUDING EXTERIOR COMPONENTS
EXCLUDING EXTERIOR COMPONENTS
HEAT
HEP
CONFIDENTIAL
EQIVALENT THICKNESS, t_e ~ INCHES
PROBABILITY
0
2
4
6
8
10
12
14
16
18
20
22
24

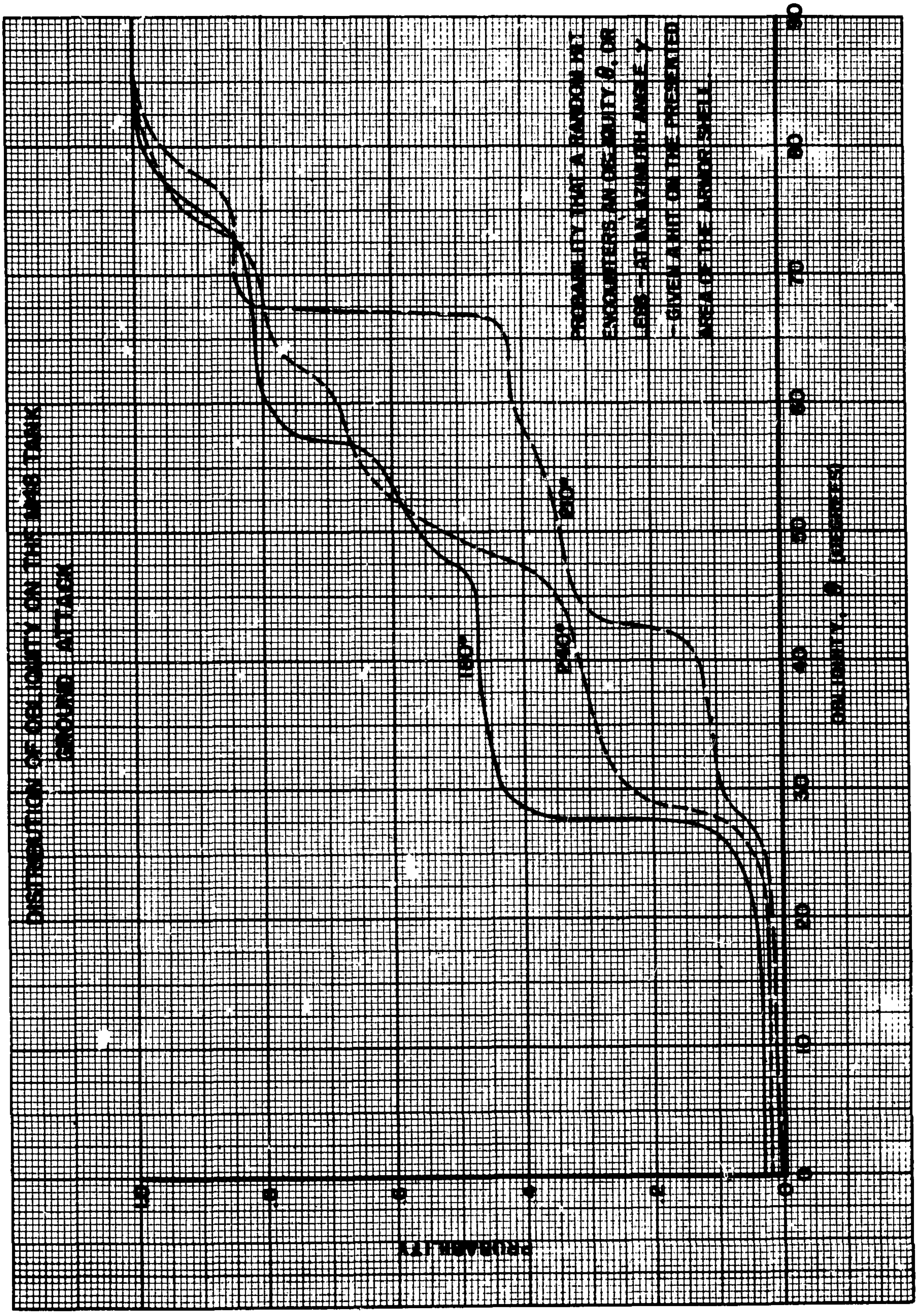

DISTRIBUTION OF ARMOR ON THE M48 TANK
180° AZIMUTH ANGLE OF ATTACK
AP
HVAP
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN EQUIVALENT THICKNESS, t_e, OR LESS — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
INCLUDING EXTERIOR COMPONENTS
EXCLUDING " "
CONFIDENTIAL
0
2
4
6
8
10
12
14
16
18
20
22
24
EQUIVALENT THICKNESS, t_e, ~ INCHES
PROBABILITY

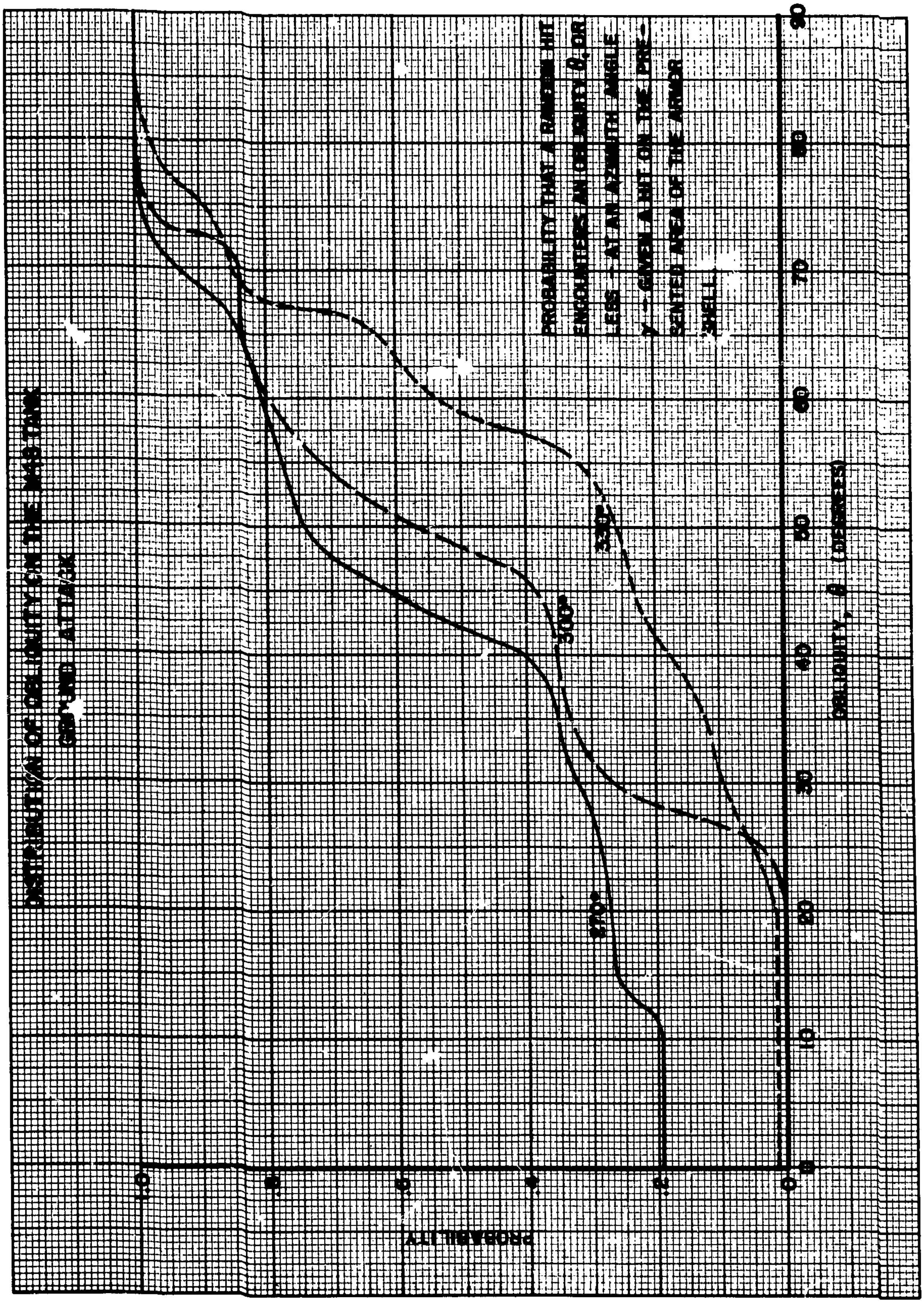


0
2
4
6
8
10
12
14
16
18
20
22
24
EQUIVALENT THICKNESS, t_e, ~ INCHES


DISTRIBUTION OF OBLIQUITY ON THE M48 TANK
GROUND ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN OBLIQUITY θ OR LESS — AT AN AZIMUTH ANGLE γ — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
60°
0°
30°
PROBABILITY
1.0
.8
.6
.4
.2
0
0
10
20
30
40
50
60
70
80
90
OBLIQUITY, θ (DEGREES)


DISTRIBUTION OF OBLIQUITY ON THE M48 TANK
GROUND ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN OBLIQUITY θ, OR LESS - AT AN AZIMUTH ANGLE γ - GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
90°
120°
150°
PROBABILITY
1.0
.8
.6
.4
.2
0
0
10
20
30
40
50
60
70
80
90
OBLIQUITY, θ (DEGREES)


DISTRIBUTION OF OBLIQUITY ON THE M48 TANK
GROUND ATTACK
PROBABILITY THAT A RANDOM HIT ENCOUNTERS AN OBLIQUITY θ, OR LESS — AT AN AZIMUTH ANGLE γ — GIVEN A HIT ON THE PRESENTED AREA OF THE ARMOR SHELL
180°
OBLIQUITY, θ (DEGREES)
PROBABILITY
0
10
20
30
40
50
60
70
80
90
0
.2
.4
.6
.8
1.0



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