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710/607-1 WAL

WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT

NO. WAL 710/607-1

PRINCIPLES OF ARMOR PROTECTION

Second Partial Report

BY

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DATE 2 June 1944

WATERTOWN ARSENAL
WATERTOWN, MASS.

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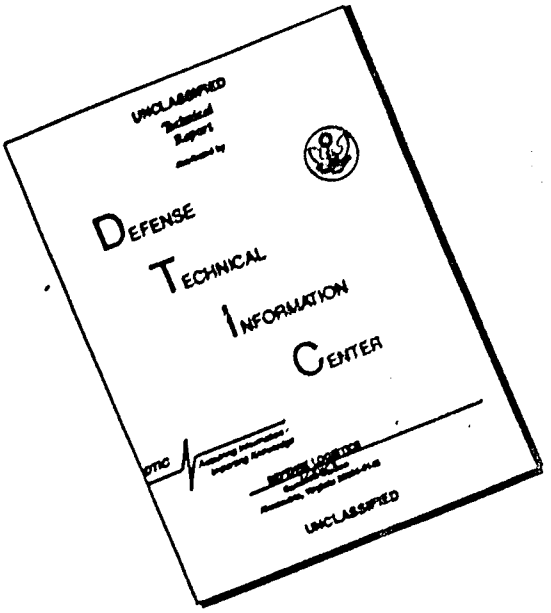

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2 June 1944

PRINCIPLES OF ARMOR PROTECTION

Second Partial Report

To determine, for artillery style projectiles, the detailed relations of Navy Ballistic Limit (V) to plate thickness (e) and obliquity (θ), at high velocities for one hardness level.

1. In the design of armor protection one must have available some source of information concerning the performance, under combat conditions, of armor against the projectiles liable to be encountered in the field. Due to the technical difficulties encountered in firing large caliber guns against thick plate at high obliquities, there is a dearth of information on the penetration of major caliber projectiles. This report is an attempt to establish as accurately as possible the effects of plate thickness and obliquity on penetration at a given hardness level with modern combat velocities.

2. The firing was done with cal. .30 model German 75 mm. APC projectiles. The projectiles, developed at this Arsenal for a previous report,[1] do not deform even at the extreme velocities and obliquities encountered in the present program.

1. C. Zener: "Principles of Armor Protection, First Partial Report", Report Number WAL 710/607.

ground down to represent 2", 2 1/2", 3", 3 1/2" and 4" plate opposed to a 3" projectile. All plates were cut from the same 1/2" x 36 x 36 plate to insure uniform resistance.

3. Attention was confined primarily to angles above 30° and velocities of 2000 to 3000 feet per second. These conditions are thought to be those most liable to be encountered in combat. All velocities were measured and the Navy ballistic limits were found within ±20 Ft./Sec.. Since the projectiles were undeformed and unbroken there was no ambiguity as to limits. All projectiles were recovered and penetration was considered complete when a projectile was recovered in the rear of the plate. The method of orientation of the plate and gun are described in a separate report.[1] The obliquity was determined to ±0.5 degrees.

4. The data are presented in tabular form as Table I and are plotted in Figures 1 and 2. Two separate plots are made, one to show the dependence of Ballistic limit on obliquity, the other to show the dependence of ballistic limit on plate thickness. In both cases the solid lines connecting experimental points are drawn parallel and lie within ±20 Ft./Sec. of the points obtained in firing.

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1. D. Van Winkle: "Principles of Projectile Design, Third Partial Report", Report Number WAL 762/23-3.

straight lines correspond to the following two equations:

$$V \sim 1/\cos^{\beta} \theta \qquad (1)$$

$$V \sim e^{\alpha} \qquad (2)$$

The lines are parallel so that the exponents α and β are constant and are equal to the slopes of the corresponding lines. Combining equations (1) and (2) gives

$$V \sim \frac{e^{\alpha}}{\cos^{\beta} \theta} \qquad (3)$$

Inspection of the graph gives $\alpha = .63$ and $\beta = 1.0$ in the range of $v \simeq 2000$-2300 Ft./Sec., $e \simeq .2"$-$.4"$ and $\theta > 30^{\circ}$. The range of e from .2" to .4" is for a cal. .30 projectile ($d = .30"$) and e/d extends from .67 to 1.33. Thus for major caliber capped projectiles of equivalent design and quality one can write

$$V \sim \frac{e^{.63}}{\cos \theta}$$

$V \simeq 2000$-2300

$e/d \simeq .67$-1.33

$\theta > 30^{\circ}$

6. Only two sources[1,2] are known which contain information which can be used to check this relationship. The data for these are tabulated in Tables II and III and plotted

1. Aberdeen Proving Ground Report Number BD 542.
2. C. Zener: Op. Cit. Table III.

was drawn to correspond to equation (2) with a = 0.63. The solid lines were drawn parallel to it. The Aberdeen report, although of small scope, was done with full scale 3" projectiles and shows a striking agreement. The other was done with the same projectiles as used in the present report but is interesting for its startling conformance over a wide range.

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APPROVED:

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JECTILES AGAINST 260 BHN PLATE AT VARIOUS OBLIQUITIES.

Thickness (inches)	V (Ft/sec) 0°	30°	40°	45°	50°	55°	60°
.20	----	----	----	<2000	2030	2300	>3000
.25	----	<2000	2015	2170	2430	>3000	
.30	1975	2015	2283	2500	2720	>3000	
.35	2115	2270	2455	2760	>3000		
.40	2300	2500	2680	>3000			

TABLE II

BALLISTIC LIMITS FROM LITERATURE WITH RESPECT TO 260 BHN PLATE - 2" AMC PROJECTILE.

Thickness (inches)	V(Ft/sec) 45°	50°	55°
2.25	2120	2270	2500
2.50	2300	2430	2670

TABLE III

BALLISTIC LIMITS FROM LITERATURE WITH RESPECT TO 260 BHN PLATE - CAL. .30 PROJECTILE.

Thickness (inches)	V(Ft/sec)
.30	1920
.35	2100
.40	2270
.45	2405

FIGURE 1

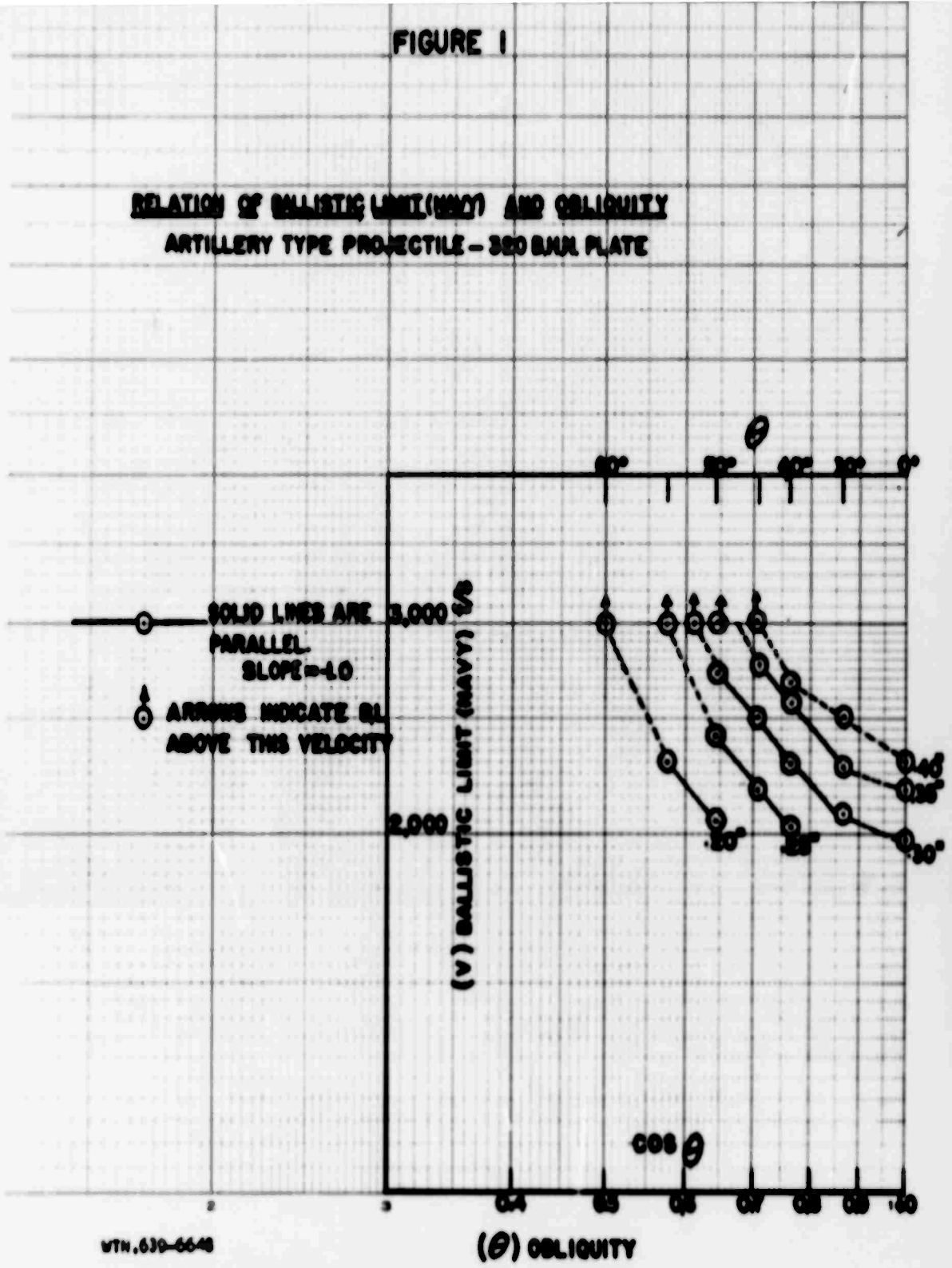

RELATION OF BALLISTIC LIMIT(NAVY) AND OBLIQUITY
ARTILLERY TYPE PROJECTILE – 320 BHN PLATE
θ
SOLID LINES ARE PARALLEL
SLOPE=-4.0
ARROWS INDICATE BL ABOVE THIS VELOCITY
3,000
2,000
(v) BALLISTIC LIMIT (NAVY) f/s
.46"
.26"
.30"
.30"
.35"
cos θ
.4
.5
.6
.7
.8
.9
1.0
WTN.630-6648
(θ) OBLIQUITY

FIGURE 2

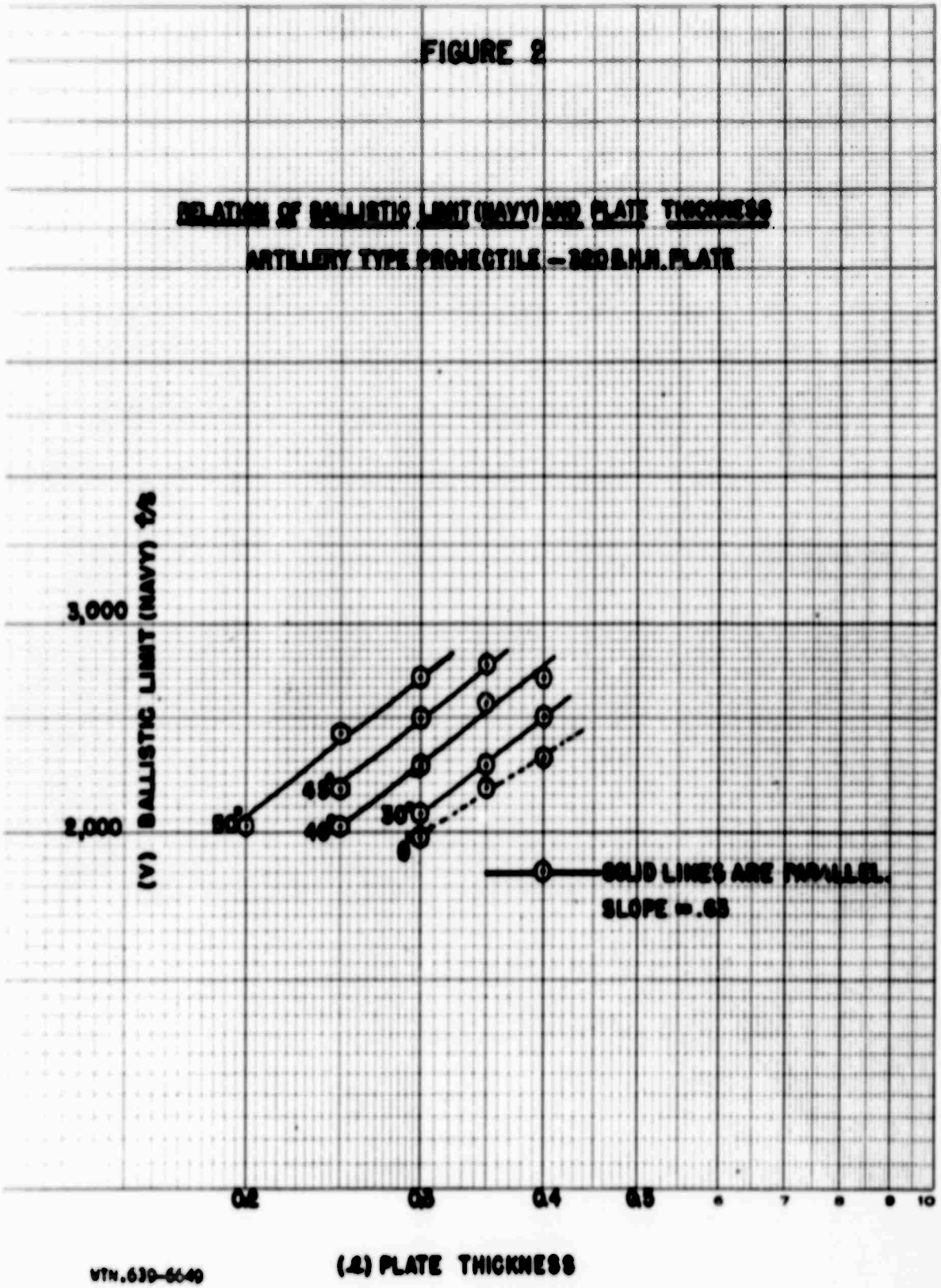
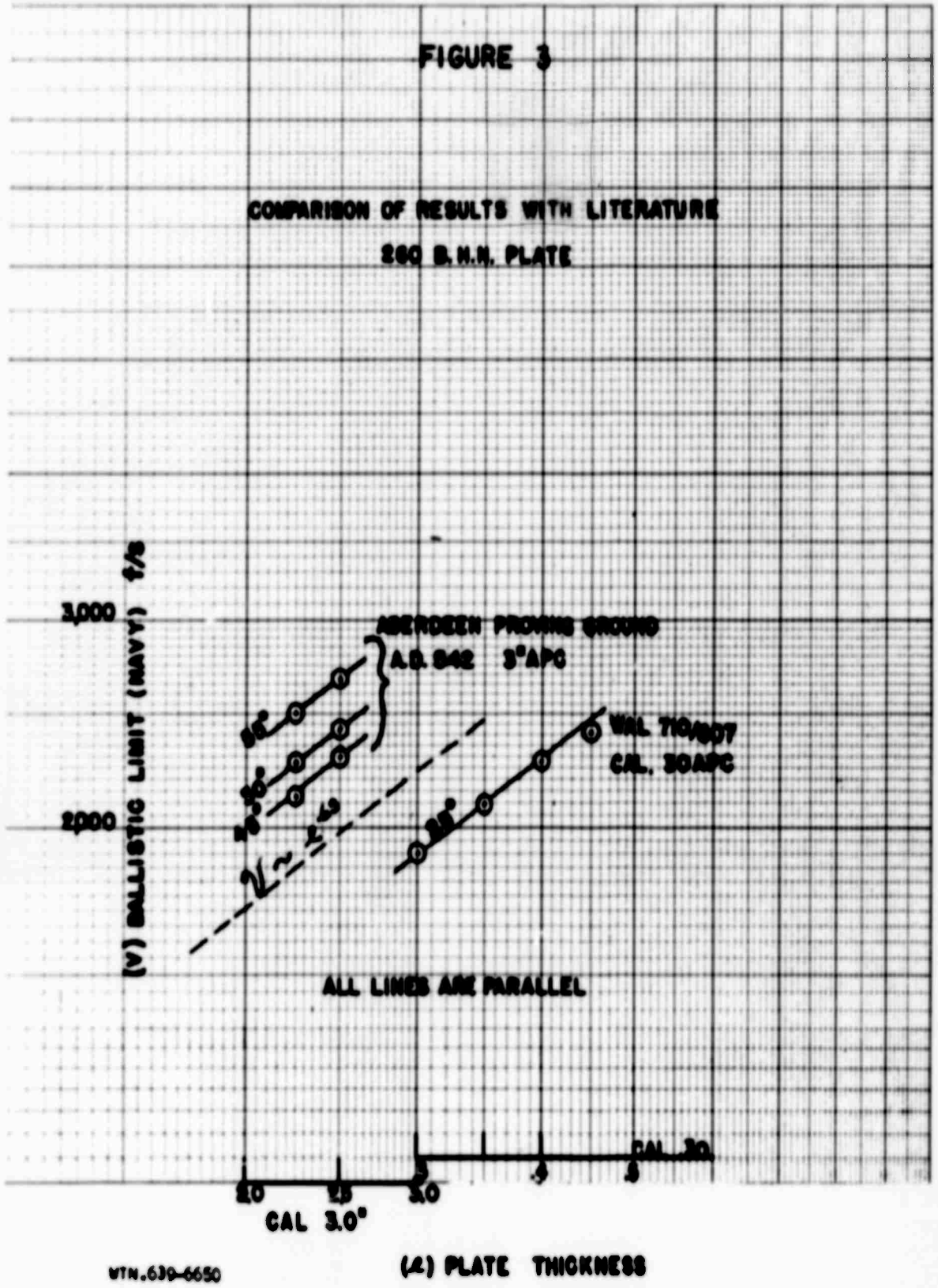

RELATION OF BALLISTIC LIMIT (NAVY) AND PLATE THICKNESS
ARTILLERY TYPE PROJECTILE — 300 B.H.N. PLATE
(V) BALLISTIC LIMIT (NAVY) f/s
3,000
2,000
60°
45°
40°
30°
0°
SOLID LINES ARE PARALLEL.
SLOPE = .65
0.2
0.3
0.4
0.5
6
7
8
9
10
(t) PLATE THICKNESS
WTN.639-6649

FIGURE 3



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