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**WATERTOWN ARSENAL  
LABORATORY**

**MEMORANDUM REPORT**

NO. WAL 710/607-1

PRINCIPLES OF ARMOR PROTECTION

Second Partial Report

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BY

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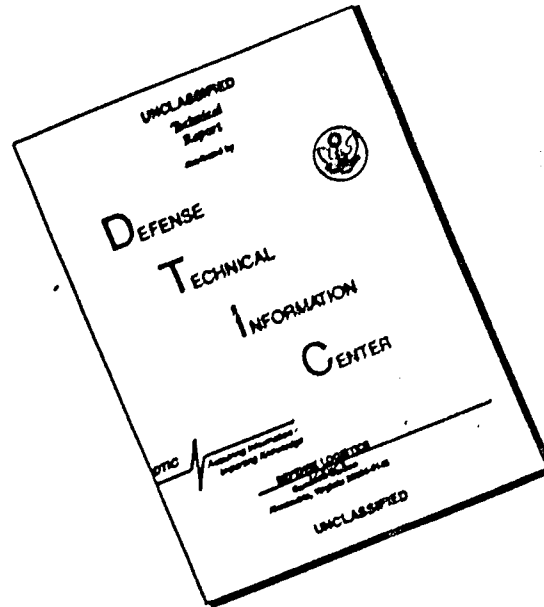
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PRINCIPLES OF ARMOR PROTECTION

Second Partial Report

This report discusses how

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

armor

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,<sup>1</sup> 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 exposed 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.<sup>1</sup> 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 762/231-3.

straight lines correspond to the following two equations:

$$V \sim 1/\cos^\beta \theta \quad (1)$$

$$V \sim e^\alpha \quad (2)$$

The lines are parallel so that the exponents  $\alpha$  and  $\beta$  are constant and are equal to the slopes of the corresponding lines. Combining equations (1) and (2) gives

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

Inspection of the graph gives  $\alpha = .63$  and  $\beta = 1.0$  in the range of  $v \pm 2000-2800$  Ft./Sec.,  $e \pm .2"-.4"$  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

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

$$V \sim 2000-2800$$

$$e/d \sim .67-1.33$$

$$\theta > 30^\circ$$

6. Only two sources<sup>1,2</sup> 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

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1. Aberdeen Proving Ground Report Number AD 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 con-  
formance over a wide range.

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APPROVED:

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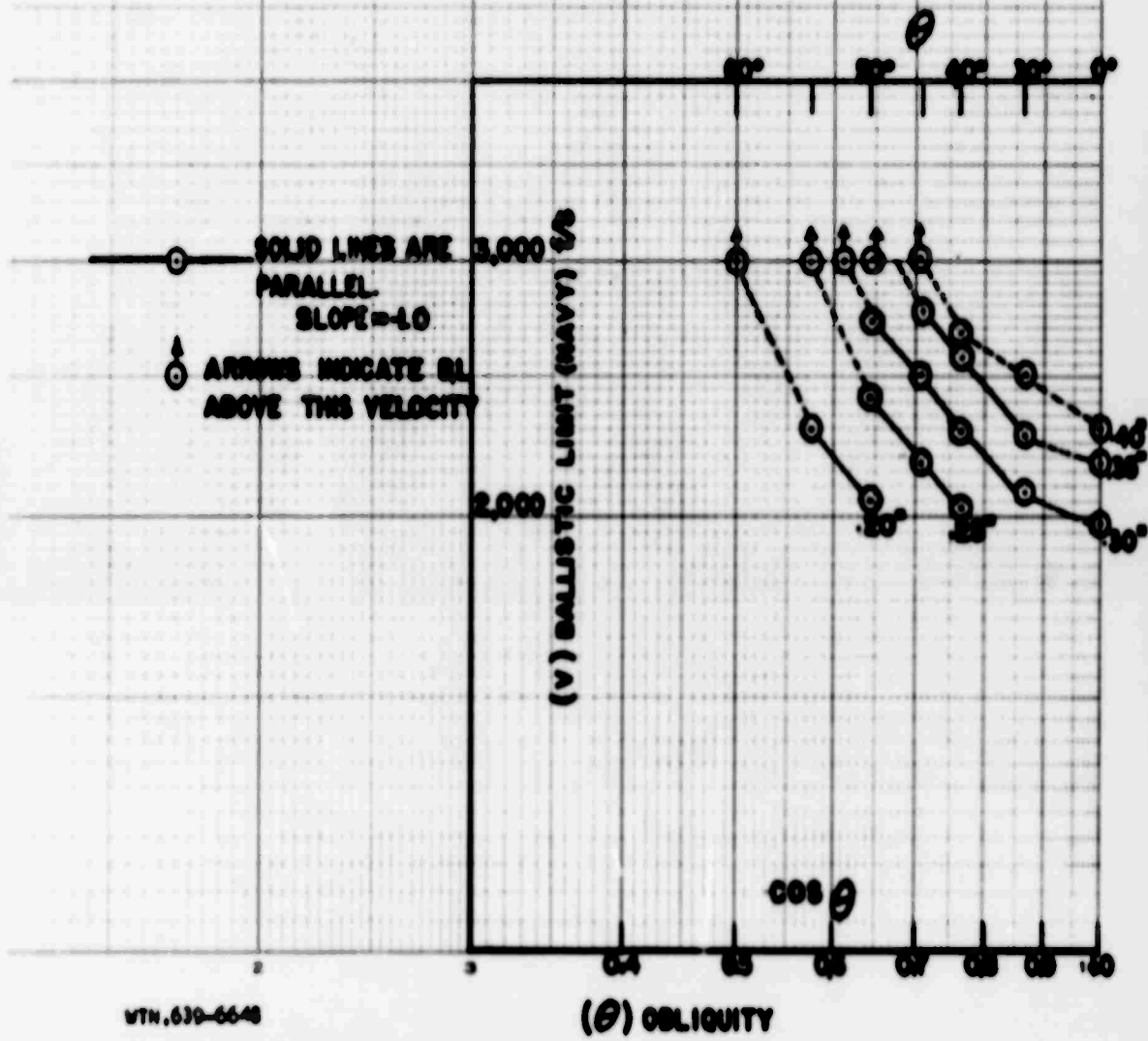


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FIGURE 1

**RELATION OF BALLISTIC LIMIT (MM) AND OBLIQUITY  
ARTILLERY TYPE PROJECTILE - 320 BXL PLATE**

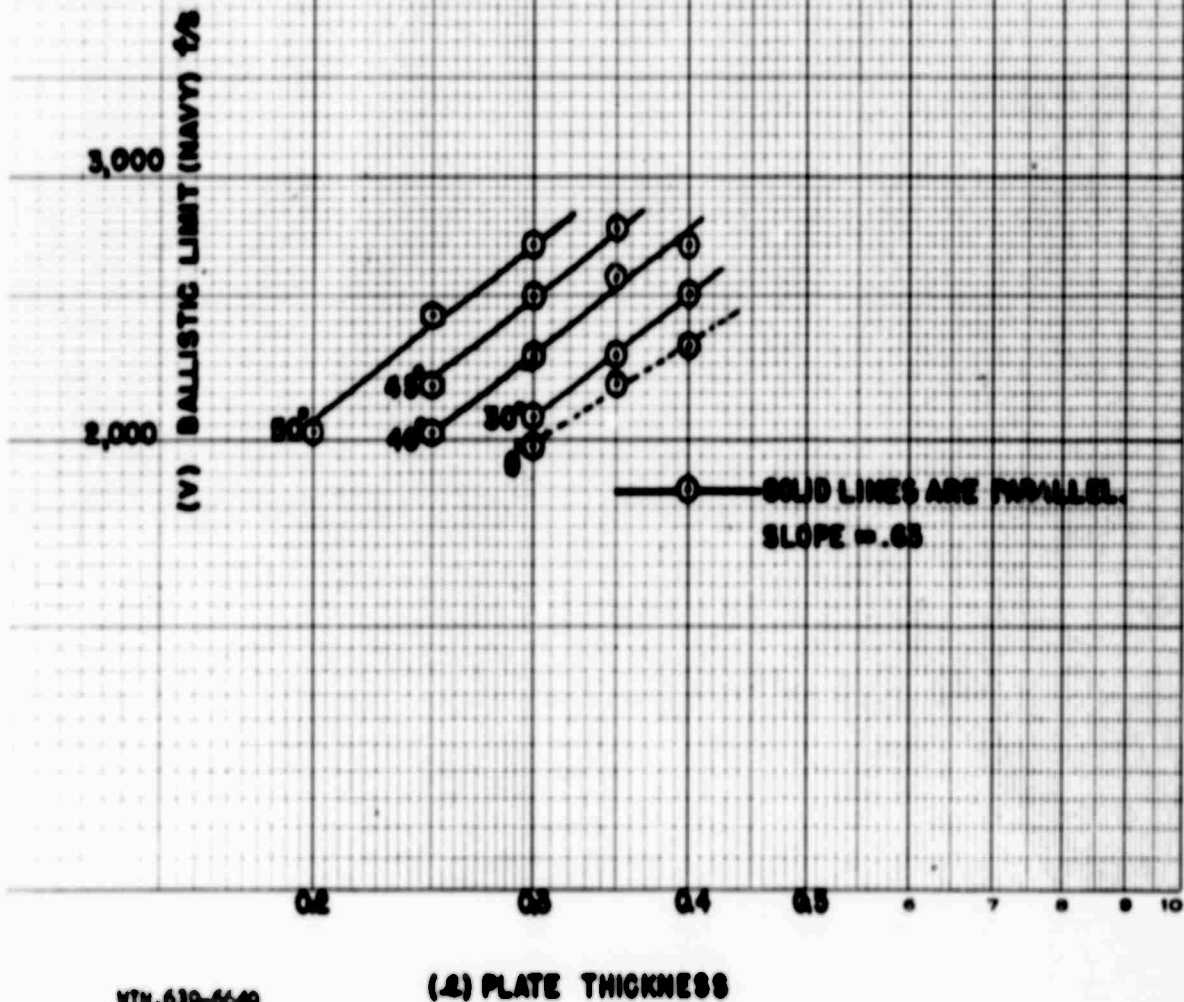


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FIGURE 2

RELATION OF BALLISTIC LIMIT (NAVY) AND PLATE THICKNESS  
ARTILLERY TYPE PROJECTILE - 300 B.M. PLATE

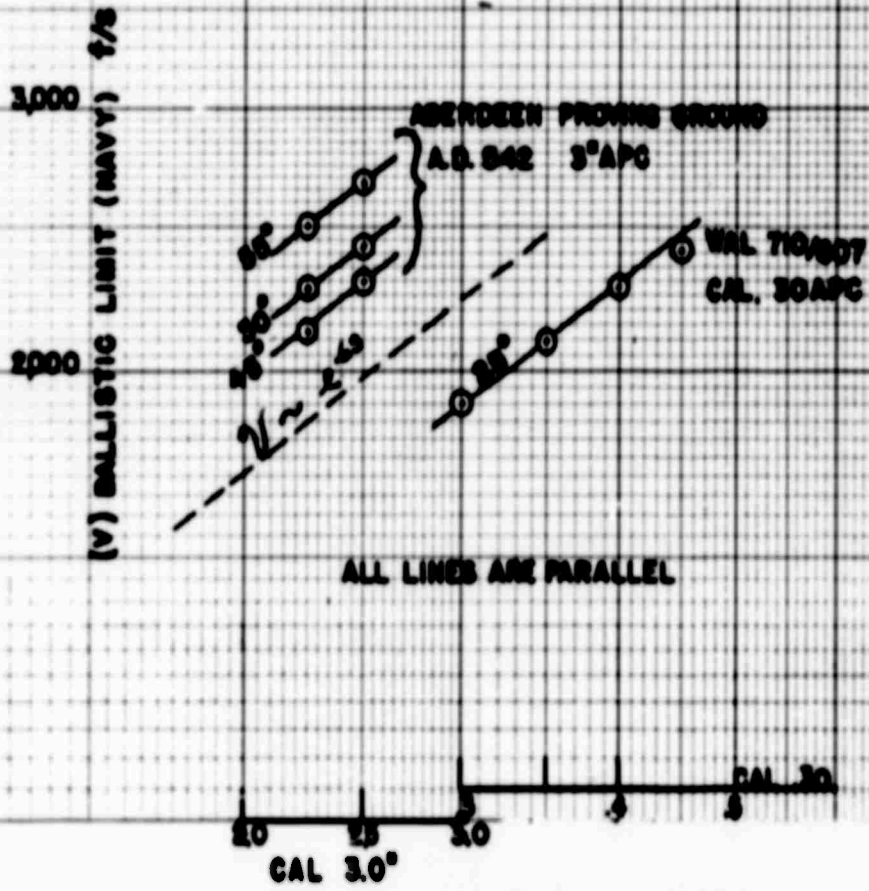


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(L) PLATE THICKNESS

FIGURE 3

COMPARISON OF RESULTS WITH LITERATURE  
200 B.H.N. PLATE



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(2) PLATE THICKNESS