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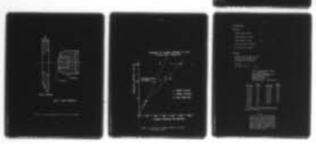

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EFFECTIVENESS OF ALUMINA ARMOR PLATE AGAINST HIGH VELOCITY PROJECTILES

Lawrence Livermore Laboratory
University of California
Livermore, CA 94550

February 1977

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Air Force Systems Command
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Rudy L. Van Hemert

RUDY L. VAN HEMERT
Lt Colonel, USAF
Project Officer

FOR THE COMMANDER

HAROLD E. WAKITSCH
Lt Colonel USAF
Chief, Weapons Section

HERBERT M. FERNANDEZ
Chief, Nuclear Systems Division

JOHN M. LEDERER
Technical Adviser

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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EFFECTIVENESS OF ALUMINA ARMOR PLATE AGAINST HIGH VELOCITY PROJECTILES*

B. L. Hord

Lawrence Livermore Laboratory
University of California, Livermore, Ca.

ABSTRACT

The thickness of alumina armor plate is determined which will stop a 10 gram steel projectile traveling at 2.1 km/sec and 3.0 km/sec.

INTRODUCTION

Studies have shown that sintered alumina can be an effective armor against projectiles with velocities of 1 km/sec and less. The alumina thickness required to stop 10 gm steel projectiles was shown roughly to be linear with projectile velocity below 1 km/sec.(1) The present study was undertaken for the Air Force to determine the stopping thickness of alumina armor plate for 10 gm steel projectiles with velocities of 2 and 3 km/sec.

A 10gm steel slug was imbedded in a polycarbonate sabot to form the projectile which would be accelerated in the LLL two-stage gas gun. The slug was about 13 mm diameter by 10 mm long, and therefore a different aspect ratio from the 30 calibre slug used in the lower velocity studies.(1) The polycarbonate sabot was required to be stripped from the steel slug prior to the impact test.

*Prepared for U. S. Energy Research and Development Administration under contract No. W-7405-Eng-48.

EXPERIMENT DIAGNOSTICS

The projectile impact velocity was measured between two flash x-ray ports for most of these tests. The projectile passes through the stripper before arriving at the first port, and the x-ray photo taken at this point gives a clear indication of the effectiveness of the stripper. A second x-ray photo was taken down range about 300 mm. The time between the two x-ray flashes was recorded on a nanosecond counter, and distance was measured between the two images on the x-ray photos.

On the 2 km/sec tests, the velocity was measured over the interval between the stripper and the first x-ray port, a distance of about 100 mm. In this case, electrical shock-pins were set in the stripper. The shock-pin closure signal due to the sabot impact produced a start pulse for the counter and the x-ray detector signal stopped the count.

The effectiveness of the alumina as an armor against the high velocity steel slug was measured by a 6.35 mm (1/4 inch) thick aluminum witness plate glued to the back side of the alumina. The recovered aluminum plate for each shot was observed to be penetrated or not.

The stipping of the polycarbonate sabot traveling at 3 km/sec was accomplished by allowing the 29 mm diameter projectile to impact around the edge of a 19 mm hole in a 6 mm thick steel plate.[2] The slug was slightly distorted from the resulting shock wave, but the sabot was removed quite adequately (see Fig. 1). Two intermediate baffles were set between the stripper and armor plate to intercept most of the shrapnel; the first at 215 mm from the stripper, the second about 300 mm further down range. The armor was centered about 40 mm past the second baffle.

Three successful tests were made with the above configuration, but the fourth test resulted in a partial break up of the slug after passing through the first baffle. This was observed in the second x-ray photo and the impact depressions in the second baffle. The 19 mm hole in the stripper was opened up to 23 mm, and the slug was stripped cleanly with somewhat less distortion.

A preliminary shot testing the 23 mm restriction on a 2 km/sec projectile resulted in only partially stripping the plastic sabot. Four more tests of modifications of the stripper were required to obtain a successful design. The hole in the steel plate was reemed out to a conical section and the front of the sabot was machined to match (see Fig. 2). This configuration stripped the sabot adequately, but the trajectory of the steel slug was affected to such an extent that it struck the second baffle about one diameter off center. To correct this, the armor was moved in closer to the stripper and the first baffle was eliminated. The single baffle was placed about 190 mm from the stripper with the armor 40 mm further down range.

TESTS OF ARMOR EFFECTIVENESS

Two tests were made in 1974 by impacting a 10 gm steel slug and the 12 gm sabot onto 25 mm thick armor. The 9.5 mm aluminum witness plates were penetrated in both cases. This present series of tests require the sabot to be stripped, and the x-ray photo taken for each shot indicates that the sabot has been stripped. There is the possibility that some parts of the sabot may be following the stripped slug. The mass involved should, however, be $\leq$ 10% of the slug mass. Baffles have been placed between target and stripper as previously indicated to intercept steel shrapnel from the stripper and plastic debris from the sabot. The holes through the baffles were 15 mm diameter so that a minimum of particles could reach the armor.

Table 1 is a list of all tests and experiments conducted for this armor testing program. The first two listings are those initial tests done in 1974. Shots three to eight were armor piercing tests for the 3 km/sec slug impact, and nine to nineteen were shots developing the stripper for the 2 km/sec projectiles and the armor piercing tests at that velocity.

RESULTS

The control of the projectile velocity was quite good for the 3 km/sec slug impact. For the tests bracketing the armor thickness for witness plate failure (shots 6, 7, & 8), the velocity varied only 1%. At 2 km/sec the projectile velocity could not be controlled so well. The bracketing tests (shots 16-19) were as much as 13% too high. THe variation, however, was only ±4% around the velocity 2.18 km/sec.

Table 1 indicates the condition of the 6.35 mm (1/4 inch) thick aluminum witness plate recovered after each shot. The observed penetration was quite evident for all shots reported here. Witness plates indicated as "penetrated" all had large torn through holes. Those plates indicated as "not penetrated" were bowed, but no cracking or breaking was evident.

Some 76 mm diameter ceramic and some 152 mm diameter ceramic samples were tested to check on the possibility of edge proximity affecting the results. The results were the same for both diameters.

TABLE 1

SHOT	PROJECTILE VELOCITY		ARMOR THICKNESS	DIAMETER	WITNESS PLATE CONDITION
1	~3.0 km/sec	Not stripped	25.4 mm (1 in)	76.2 mm	Penetrated
2	~3.0 km/sec	Not stripped	25.4 mm (1 in)	76.2 mm	Penetrated
3	~3.0	Mod. 1 stripper test	--	--	--
4	3.12	Mod. 1	25.4 mm (1 in)	76.2 mm	Penetrated
5	2.88	Mod. 1	63.5 mm (2.5 in)	152.4 mm	Not Penetrated
6	2.98	Mod. 1 partial break-up of projectile	50.8 mm (2.0 in)	152.4 mm	Not Penetrated
7	3.01	Mod. 1 partial break-up of projectile	38.1 mm (1.5 in)	152.4 mm	Penetrated
8	2.95	Mod. 2 23 mm diameter stripper	50.8 mm (2.0 in)	152.4 mm	Not Penetrated
9	~2.0	Mod. 3 stripper failed	--	--	--
10	2.24	Projectile velocity measurement	--	--	--
11	1.92	Mod. 4 stripper failed	--	--	--
12	2.7	Mod. 5 stripper test - partial success	--	--	--
13	1.80	Projectile velocity measurement	--	--	--
14	2.24	Mod. 6 stripper failed	--	--	--
15	2.05	Mod. 7 stripper	25.4 mm (1.0 in)	76.2 mm	Penetrated
16	2.18	Mod. 7 partial break up of projectile	38.1 mm (1.5 in)	76.2 mm	Not penetrated
17	2.12	Mod. 7 projectile off center	31.8 mm (1.25 in)	76.2 mm	Penetrated
18	2.10	Mod. 7 armor moved closer to stripper	38.1 mm (1.5 in)	152.4 mm	Not Penetrated
19	2.26	Mod. 7	31.8 mm (1.25 in)	152.4 mm	Penetrated

CONCLUSIONS

Figure 3 is a plot of projectile velocity versus the alumina armor thickness required to stop a 10 gram steel slug. The solid line is an extrapolation of the low velocity data reported by Wilkins et al.[1] The data points bracketing the armor failure thickness found in the above tests are indicated. The crosses indicate penetration of the witness plate and the circles indicate no penetration. These results show that a considerably greater thickness of armor is required to stop the 10 gram iron slug than the extrapolated curve would suggest. It should be noted, however, that even with no alumina, a non-zero velocity is required to penetrate 6 mm of aluminum. The experimental curve should not pass through the origin.

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1. M. L. Wilkins, C. F. Cline, and C. A. Honodel
   Light Armor, UCRL-71817 (1969).

2. B. L. Hord in H-Division Quarterly Progress Report,
   January through March 1976. UCRL-50028-76-1.

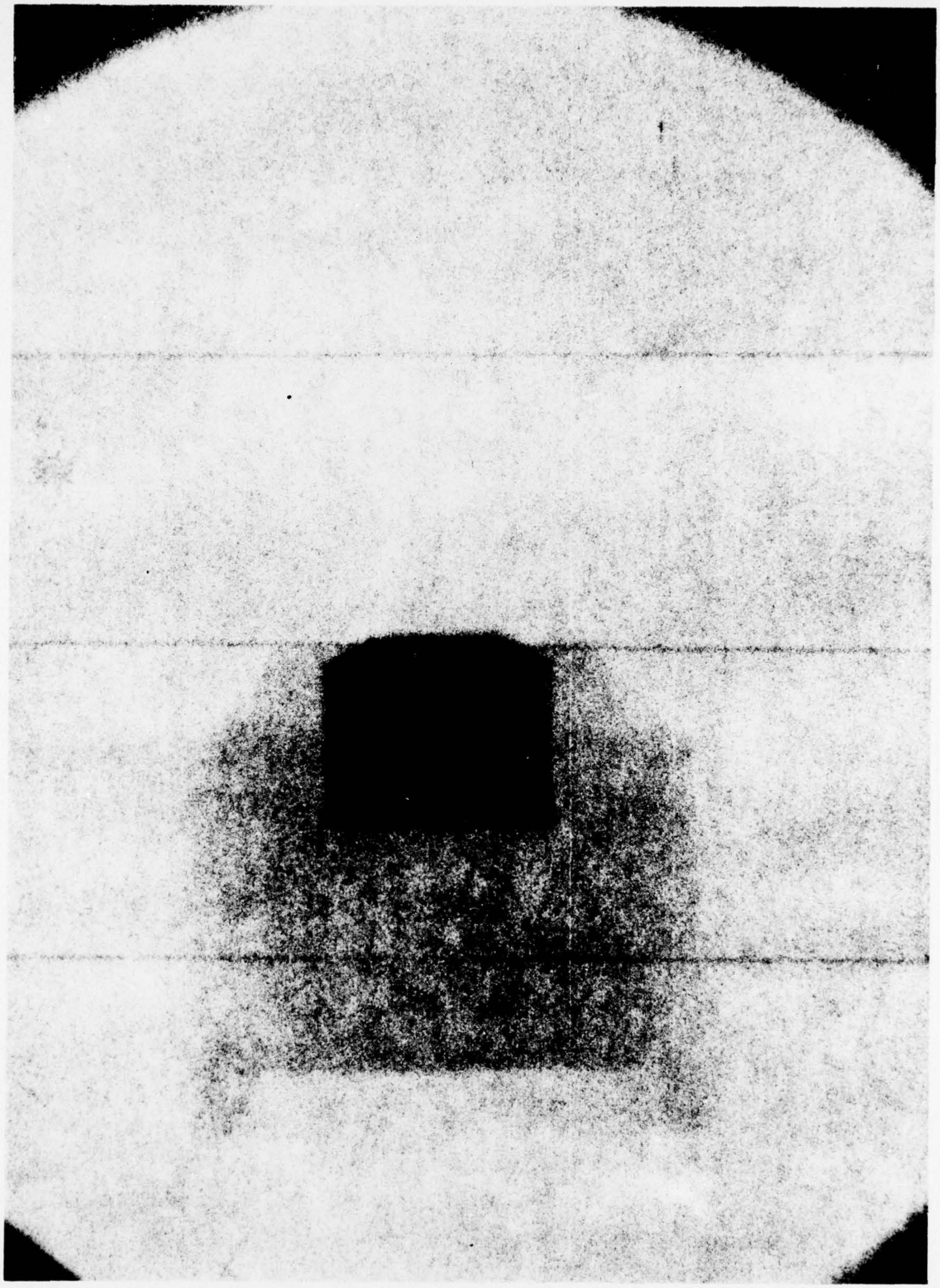


FIGURE 1a -
Sabot and steel slug before stripping.

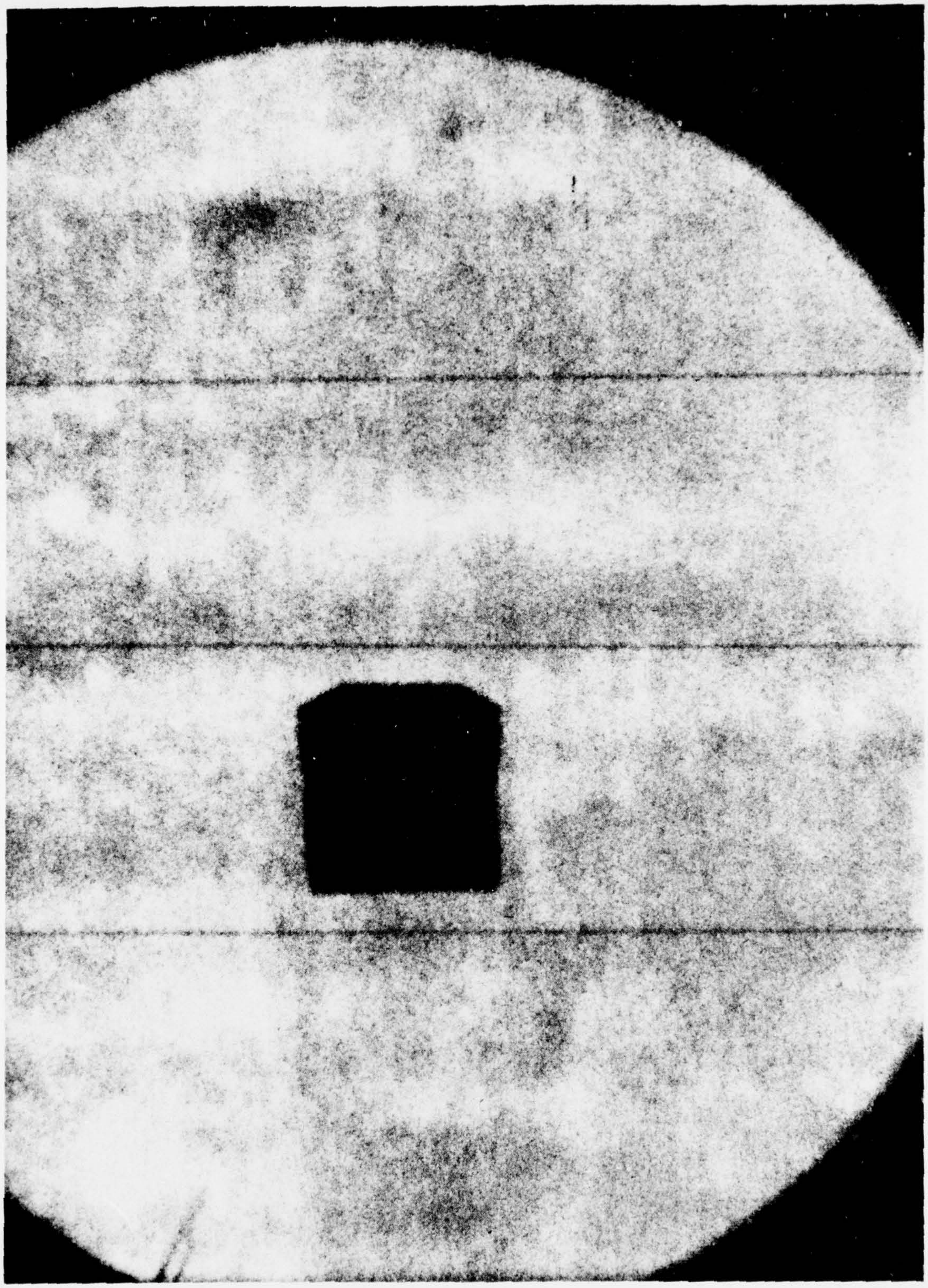
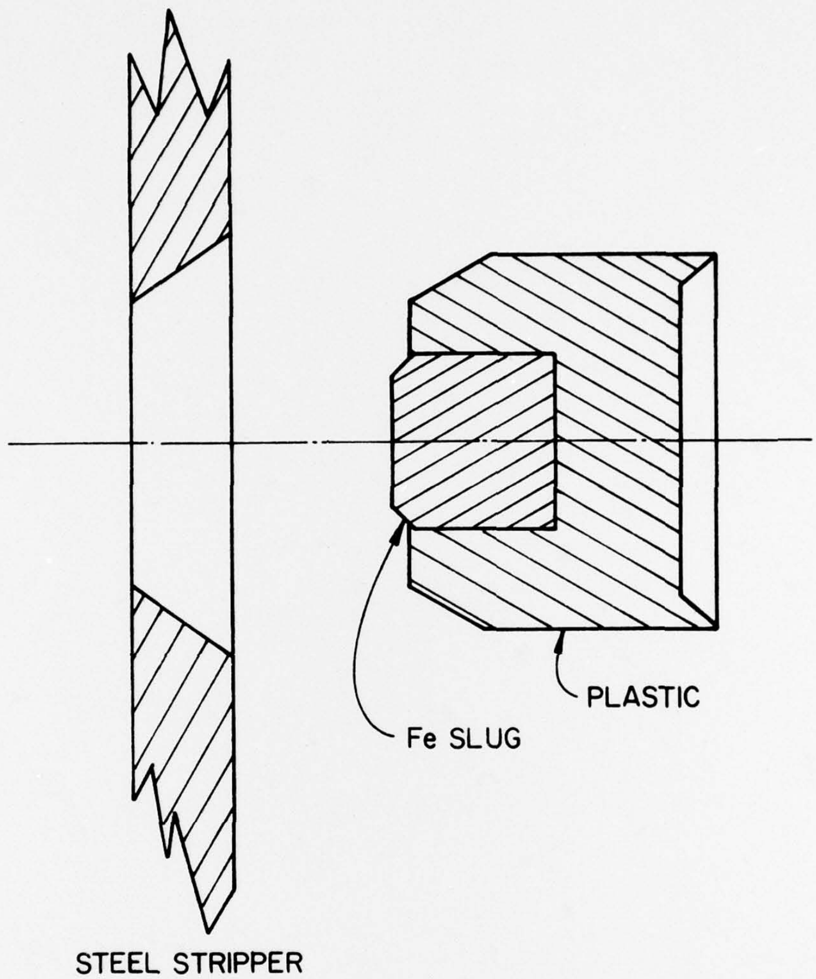


FIGURE 1b -
Steel slug in flight after
sabot has been stripped.



MOD. 7 SABOT STRIPPER

FIGURE 2. Configuration to strip sabot at 2 km/sec.

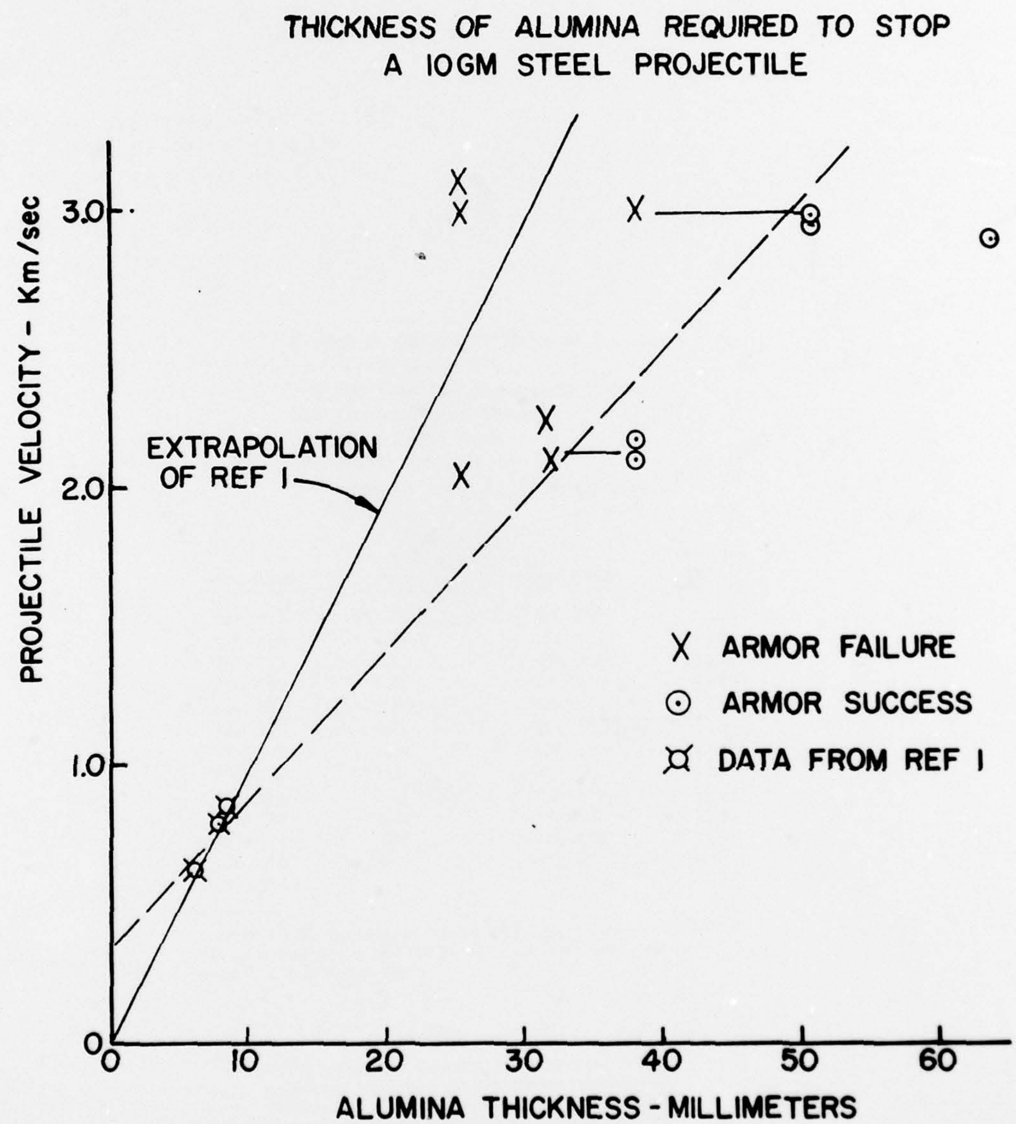


FIGURE 3. Thickness of alumina required to stop a 10 gm steel slug.

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