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EVALUATION OF COMPOSITE ARMOR FOR COAST GUARD VESSELS

JAMES R. OSBORN

E. I. DuPont de Nemours & Co.
Textile Fibers Dept. /F&CDC
P. O. Box 80702
Wilmington, DE 19880-702

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SAMUEL F. POWEL, III
Technical Director
U.S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340-6096

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16. Abstract

The vulnerability of personnel and vital equipment inside Island Class cutters to penetrating small caliber gun fire from maritime drug smugglers was assessed. Four threats from a list of weapons commonly used by drug smugglers were selected for use in this study. It was found that existing materials of construction were readily penetrated by three of the four threats. Composite armor made up of plies of KEVLAR* woven fabric and vinyl ester resin was found to be a weight effective protection against the threats. The effect of the armor on a cutter's cost and weight was estimated. SHIPS, GUNS, WOUNDS

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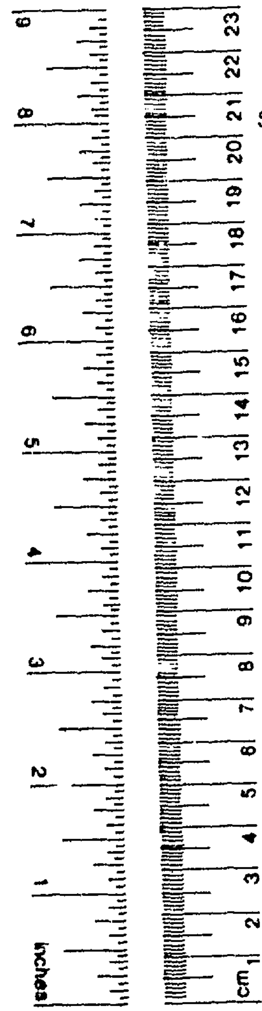
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

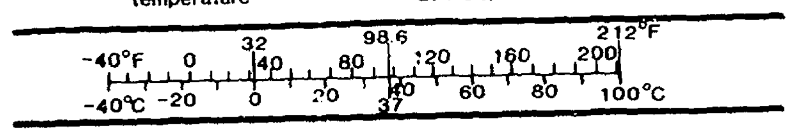
Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (WEIGHT)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (EXACT)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply By	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (WEIGHT)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	0.125	cups	c
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (EXACT)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1. INTRODUCTION. USCG vessels engaged in drug interdiction may be exposed to gun fire. Measurement of the protection level afforded by current construction materials against common firearms is necessary to assess vulnerability of personnel to bullets or fragments penetrating the hull and superstructure. Based upon US Navy experience, vulnerability can be reduced by using fiber reinforced plastic, FRP, composite panels behind the exterior structure. KEVLAR* has been used for this application because of its light weight and ballistic penetration resistance.

The objectives of this study were to: 1) define the threats likely to be encountered in drug interdiction duty; 2) assess the vulnerability of personnel inside Island class cutters fired upon by the threats; 3) evaluate the protection afforded by FRP composite armor used in conjunction with current construction materials.

2. THREAT DEFINITION. The definition of the threat is the cornerstone of this program. At the beginning we evaluated FBI records and interviewed knowledgeable individuals with regards to the type of weapon and ammunition most likely used by maritime drug smugglers. We found that the types of weapons were 1) centerfire, auto-loading and automatic rifles; 2) modern, high-tech submachine guns; 3) high energy personal handguns; 4) shotguns. Although armor piercing (AP) ammunition may be used by some drug smugglers, previous experience with Navy armor show that armor designed to resist AP rounds is neither cost nor weight effective. As a consequence, AP ammunition was not considered in this study.

The scope of this study called for evaluating four weapon/ammunition combinations from the above types that would represent common as well as most lethal threats. We selected the ones listed in TABLE 1 because they are the most likely to penetrate the vessel and still have enough energy to be lethal.

TABLE 1. THREATS

WEAPON	AMMUNITION	MUZZLE VELOCITY
semi-automatic rifle (AR-15) automatic rifle (M-16)	5.56mm, M-193, Ball "	3185 fps "
.308 cal rifle (M14)	7.62mm,M-80,Ball	2750 fps
.30 cal carbine (M1)	.30 cal,M-1,Ball	1950 fps
semi-automatic rifle (UZI)	9mm,FMJ	1400 fps

Although the 3 military projectiles are classified as "Ball" and the 9mm as "Full Metal Jacketed (FMJ)", all these rounds are encased in metal which increase their penetrating ability. These are not armor piercing rounds, however.

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3. VULNERABILITY ASSESSMENT. For the purpose of this study, vulnerability assessment is the determination of whether the above munitions will penetrate the cutter construction materials. Also affecting the assessment are fragments, called spall, that may be formed by the impact of the bullet. The spall can be lethal even though the bullet doesn't fully penetrate.

a. Construction Materials. The superstructure of the Island Class Cutter is constructed from aluminum alloy 5086H-116. The hull is constructed from steel manufactured to British Standard 4360. This information was provided by USCG, Residence Inspectors Office (RIO), Bollinger Shipyard, Lockport, LA. Both materials are standard marine structural grade and not hardened for ballistic protection.

Bollinger provided plates of the above materials for the vulnerability assessment. Our characterization of the plates is listed in TABLE 2.

TABLE 2. CONSTRUCTION MATERIAL

ITEM	THICKNESS (inches)	WEIGHT (lbs/sq ft)	HARDNESS	
			Rockwell B	Brinell
1/8" Al	0.123	1.74	48	81
5# Steel	0.110	4.57	83	160
7# Steel	0.161	6.66	79	146

The values in this table are an average of the measurements for 14 plates received in each item. The hardness values were measured by Du Pont.

b. Assessment Procedure.

(1). Test Facility. Du Pont maintains a ballistic test facility that was used for this study. A layout of the facility is shown in FIGURE 1.

The target plate was mounted in a rigid frame fixture so 10 feet from the muzzle of the gun. The bullet speed was measured by a chronograph connected to a computer so that there is a record of every shot. Located 6 inches behind the target was a 0.02 inch thick, 2024-T3 aluminum plate called a witness plate.

To insure that the data base we generated was for the case where the center line of the bullet was perpendicular to the face of the target at impact we placed a paper card in front of the target. A round hole left in the card by the bullet means that the bullet impacted at essentially normal incidence. The tolerance placed upon impact angle measured in this manner is 5 degrees so all the data reported here is for normal incidence within that tolerance. The reason for doing this is that normal impact is the most conservative case. Oblique impact would require a greater bullet speed to penetrate the target.

(2). Lethality. The witness plate has been adopted by the Navy as the means of determining penetration. If light could be seen through the witness plate following a shot at the target, then the shot was recorded as a penetration. For this study, any particle causing a hole in the witness plate is considered lethal and so penetration of the witness plate is equivalent to lethality.

(3). Test Scheme. Each of the four threats was fired once at each of the three material test panels. For the first round of tests the bullet velocity was the muzzle velocity listed in TABLE 1. A second test was conducted using a new set of targets and reducing the bullet speed to simulate a target to gun range of 100 yards. A new witness plate was installed after each round was fired and a photograph was taken of each target and witness plate.

c. Results. As mentioned above, visual examination of the witness plate after a shot is fired at a target determines for the purposes of this study if the target has been penetrated. The results for the vulnerability assessment are summarized in TABLE 3.

The results show that personnel behind the aluminum superstructure are vulnerable to lethal injury from all the threats tested. The steel hull material offers some protection to those below deck depending upon the threat and range. Photographs of the impact face of the six target plates shot in the evaluation are shown in FIGURES 2 - 7. The backsides of the plates showed no spall which is normally the case when the plate thickness is less than the bullet diameter. An indication of the extent of the envelope of lethal particles generated by the penetration of the target is given by the hole size and distribution in the witness plate. Photographs of several witness plates are shown in FIGURES 8 - 16. The remaining ones are in Appendix A. The envelope of the perforations in each plate was circled on the photographs to distinguish them from dents. Generally, the perforations in the witness plates behind the aluminum targets were limited to a single hole about the diameter of the bullet. In the plates behind the steel targets, however, the envelope and hole size was larger. This is evidence that the bullet passes through the aluminum intact while it fragments as it penetrates the steel.

TABLE 3. BALLISTIC TEST OF HULL/SUPERSTRUCTURE

THREAT	TARGET MATERIAL			RANGE
	1/8" Aluminum	5# Steel	7# Steel	(yard)
5.56mm,M193	X	X	X	0
7.62mm,M80	X	X	X	0
.30cal,M1	X	X	X	0
9mm,FMJ	X	-	-	0
5.56mm,M193	X	X	X	100
7.62mm,M80	X	X	X	100
.30cal,M1	X	X	-	100

- stopped

X penetrated

Along with hole size and distribution, the speed of the bullet after it penetrates the target is also indicative of lethality. A chronograph located behind the witness plate measured the residual speed of the bullet. The results are tabulated in TABLE 4 showing both the impact and residual speed. The 9mm threat was not evaluated at 100 yards range because we didn't have reliable data for the FMJ's speed as a function of range. Since it is the least serious of the threats, it wouldn't have influenced the recommendation anyhow.

TABLE 4. IMPACT AND RESIDUAL BULLET SPEED

THREAT	IMPACT/RESIDUAL (ft./sec.)			RANGE
	1/8" Aluminum	5# Steel	7# Steel	(yards)
5.56mm,M193	3171/3064	3178/2727	3178/2508	0
7.62mm,M80	2760/2685	2887/2553	2780/2304	0
.30cal,M1	1988/1808	1993/1366	1984/1044	0
9mm,FMJ	1421/1191	1434/0	1427/0	0
5.56mm,M193	2844/2700	2780/2186	2791/1967	100
7.62mm,M80	2540/2457	2588/2230	2540/2049	100
.30cal,M1	1550/1363	1535/534	1551/0	100

With the exception of the 9mm against steel and the .30cal against steel at a range of 100 yards, the bullet retains enough speed after passing through the ship's outer shell to be potentially fatal. The required thickness to stop the first two threats are shown in TABLE 5 for muzzle velocity. These results were constructed from a compendium of ballistic data by Mascianica (ref.1). The charts from which this table was constructed are included in Appendix B.

1. Mascianica,F.S., Ballistic Technology of Lightweight Armor-1981, AMMRC TR 81-20, May 1981.

TABLE 5. REQUIRED THICKNESS OF CONSTRUCTION MATERIAL

	ALUMINUM (5083)*		STEEL #	
	Thickness (inch)	Weight (lbs/sq ft)	Thickness (inch)	Weight (lbs/sq ft)
5.56mm,M193	0.86	12.0	0.36	14.5
7.62mm,M80	1.00	14.0	0.40	16.5

* MIL-A-46027 # MIL-A-12560

Both materials are armor grade. For structural grade material, such as the type used on the Coast Guard vessels, the required thickness would be upwards of 25% greater. A more weight effective solution to reduce the vessel's vulnerability is composite armor.

4. COMPOSITE ARMOR. Fiber reinforced plastic (FRP) is a composite made up of a fiber in a resin matrix. At the beginning of this study, the only composite FRP armor qualified by the U.S. Navy was constructed from KEVLAR. Therefore, this was the fiber used in most of the armor panels that were tested in this study. However, at the end of this study, S-2 GLASS** was also qualified by the USN so one glass FRP panel was manufactured and tested.

a. Objective. We wanted to determine the ability of FRP armor to stop the threats from penetrating the ship's hull and superstructure. We also wanted to determine the weight of the FRP armor required.

b. Armor Construction. The KEVLAR reinforced plastic (KRP) armor panels were 11"x 14" and were made in three constructions, 17, 26 and 35 ply. The constituents were 80% by weight of 16.5 oz/sq. yd. KEVLAR 29 fabric in a 3000 denier, 4x4 basket weave construction and 20% by weight DERAKANE# 510A-40 vinyl ester resin. Figure 17 is a photograph of a typical KRP panel. The areal densities corresponding to the three thicknessess were 2.3, 3.5 and 4.8 lbs/ sq. ft. (psf) respectively. The S-2 GLASS reinforced plastic (GRP) armor panel was constructed from 24 oz/sq. yd. fabric and 29% DERAKANE and weighed 5.2 psf. Both panels will meet the Navy requirements regarding flammability.

c. Test Procedure. The preferred application of FRP armor panel in a ship is behind the metal outer structure. This is the way the panels were mounted in the ballistic test facility for the majority of the tests. FIGURE 18 shows a KRP panel spaced 2" behind the metal plate and 6" in front of the witness plate. The 2" stand-off was selected to provide space for running utilities between the outer structure and the armor panels in an actual application.

**Trademark of the Owens-Corning Co.
#Trademark of the Dow Chemical Co.

Several panels were tested in front of the metal plates, however, to evaluate the effectiveness of this configuration in case a retrofit installation was required on short notice that did not permit mounting the armor on the inside. In this application, the stand-off distance was increased to 3" to provide adequate room for the KRP panel to deflect when impacted by a bullet.

The threats used for the FRP armor evaluation were the 5.56mm, M193; 7.62mm, M80; .30 cal, M1. They were fired at their muzzle velocity which was measured and recorded as before. One round was fired at each metal plate/FRP panel combination starting with the 17 ply panels. If penetration occurred, as determined by examining the witness plate, we went to the 26 ply panel, and so on until the bullet was stopped. When it was necessary to test panels thicker than 35 plies, two panels were clamped together.

d. Results. All the results given here are for the 0 yard range data which is the worst case. The results for KRP behind steel are shown in FIGURE 19. For protection against all three threats behind 7 psf steel, 26 plies of KRP armor are an upper limit, and behind 5 psf steel, 35 plies are an upper limit. The results for KRP behind of and in front of aluminum are shown in FIGURE 20. In this case, 61 plies provide an upper limit to the number of plies required to stop the worst threat, the 7.62mm, M80.

The above results have been replotted in FIGURE 21 for the M80 bullet with total areal density of the KRP plus metal as the dependent variable. The areal density for the required thickness of metal alone to stop the M80, obtained from TABLE 5, is also plotted for comparison. It can be seen that KRP added to the existing material of construction is more weight effective than increasing the thickness of the existing hull and superstructure. The weight differential is even greater than shown here for several reasons. First, the aluminum and steel used in combination with KRP was not armor grade. Second, the test we ran did not determine the minimum amount of KRP that would stop the threat. That would be part of a Phase II program to be done in the future.

It should be noted that even if the metal thickness was increased to stop the bullet, there is always the possibility that lethal metal fragments will spall off the back side of the metal when it is impacted by a bullet. This is a common occurrence in thick metal armors which necessitates the addition of FRP panels, called spall liners.

A comparison of KRP and GRP panels behind steel is shown in FIGURE 22. For approximately the same weight, the KRP armor panel stopped the bullet and the GRP did not.

5. SUMMARY.

a. Conclusion. Up to a firing range of 100 yards, which was the limit of this study, personnel inside Island Class cutters are vulnerable to lethal rifle fire coming from drug smugglers. Test results showed that unconditional protection for personnel inside can be obtained by adding KRP armor panels to the cutter. This is also a more weight effective solution than increasing the thickness of the hull and superstructure. Although it was found that placing the KRP either in front of or behind the 1/8" aluminum was equally effective, it should be noted that the aluminum by itself was overmatched by the threats. In general, it is more efficient to place the KRP behind metal.

b. Implementation. The USCG R&D Center defined three areas of the Island Class cutter that required protection in order to allow it to continue its mission if it came under fire. These were the bridge and the communications room, both behind 1/8" aluminum, and the magazine behind 5# steel. A visit was made to the USCGC Matinicus to take measurements and assess the feasibility of retrofitting KRP armor in those areas. Retrofitting them inside the bridge and communications room could be done by placing them in the space between the exterior aluminum skin and the interior trim panels. This might require some fit and trim but KRP panels can be cut and drilled so there should be no particular difficulty. Another option is to place the panels on the exterior of the bridge and communications room. This would appear to be an easier task but would present a different set of considerations. Since the KRP panels would have to be spaced 3" infront of the aluminum, the panel supports would have to be designed to withstand green water loading. Environmental effects on these panels caused by exposure to seawater and UV radiation is not a problem for adequately sealed KRP. For the remaining area requiring armor, the magazine, mounting the panels against the steel hull inside the vessel did not appear to be difficult.

The amount of material and weight added in each of the critical areas is summarized in TABLE 6 for the worst case threat, the 7.62mm, M80 at point blank range.

TABLE 6. KRP ARMOR REQUIRED

LOCATION	AREA COVERED (sq ft)	ARMOR DENSITY (psf)	TOTAL WEIGHT (lbs)
Bridge	33' x 4' = 132	8	1056
Communication rm.	14' x 6' = 84	8	672
Magazine	6' x 6' = 36	5	180
Total	252		1908

These numbers are guidelines because the minimum armor density required was not determined in this study. Nevertheless, realizing these numbers are on the high side, the material cost from a commercial panel manufacturer for a KRP panel weighing 8 psf with 20% resin would be about $40,000. This is based upon a panel cost in the $20 to $24 per pound range.

Another factor when considering adding armor is it's ability to take a hit from a bullet and still function effectively. The 11" x 14" panels evaluated in this study were still intact after three shots. It would be prudent, however, to replace a panel after it had taken four shots in a foot square area. Repairing a panel shot full of holes, however, is not an alternative to replacing it. The only instance in which a repair is feasible and justified is if a mounting hole is misdrilled and the alternative is to scrap the panel. The U.S. Army's Material Technology Lab has funded a DuPont study to evaluate hole plugging repair techniques.

c. Recommendation. As a final step we recommend that compromises between armor protection, cost, weight and patrol boat performance be addressed in a unified approach involving all appropriate Coast Guard functions. We view these activities as part of the Phase II program when it is funded.

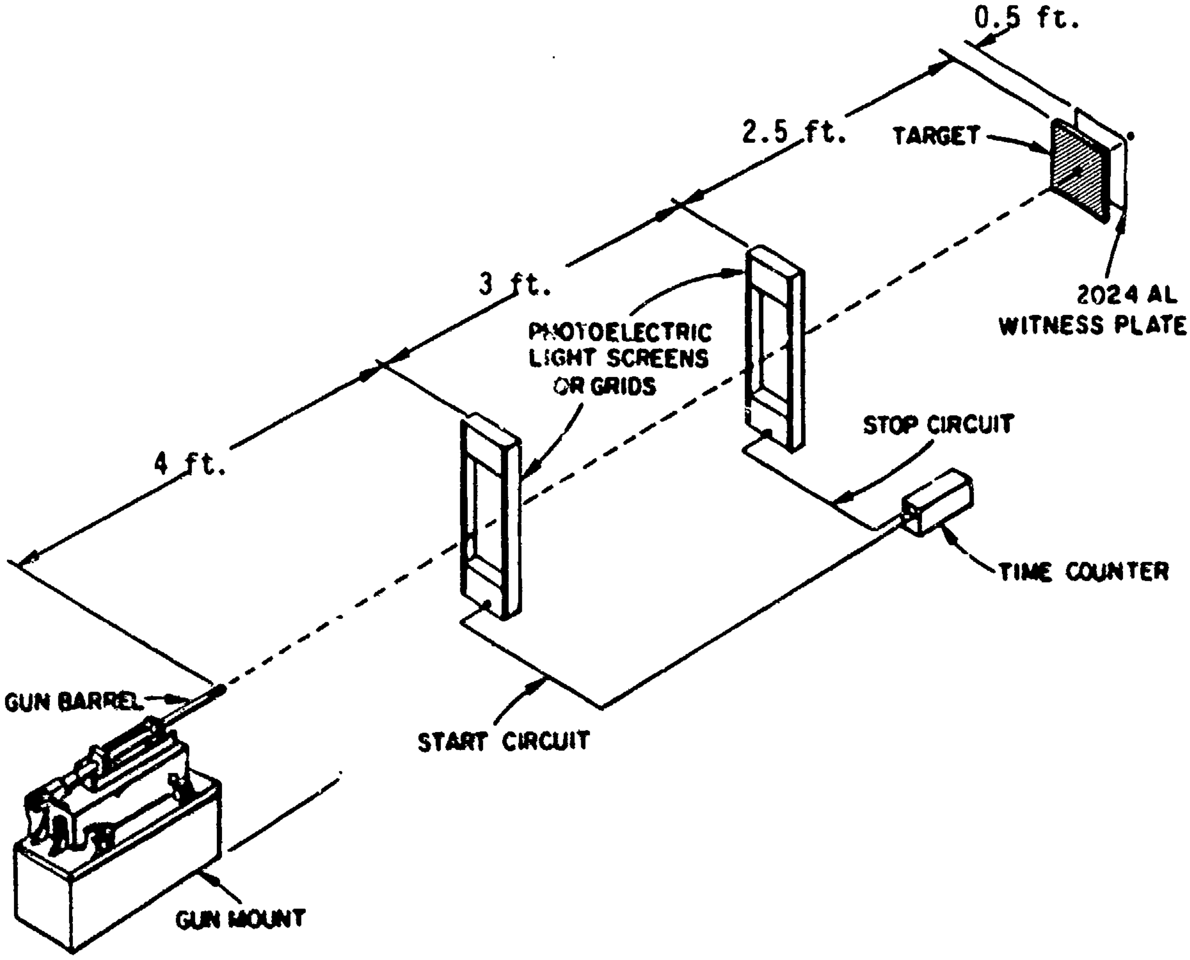


Figure 1. Ballistic Test Facility

Legend	Threat
1-20-88 -1	5.56mm,M193
-4	.30 cal,M1
-7	9mm,FMJ
-10	7.62mm,M80

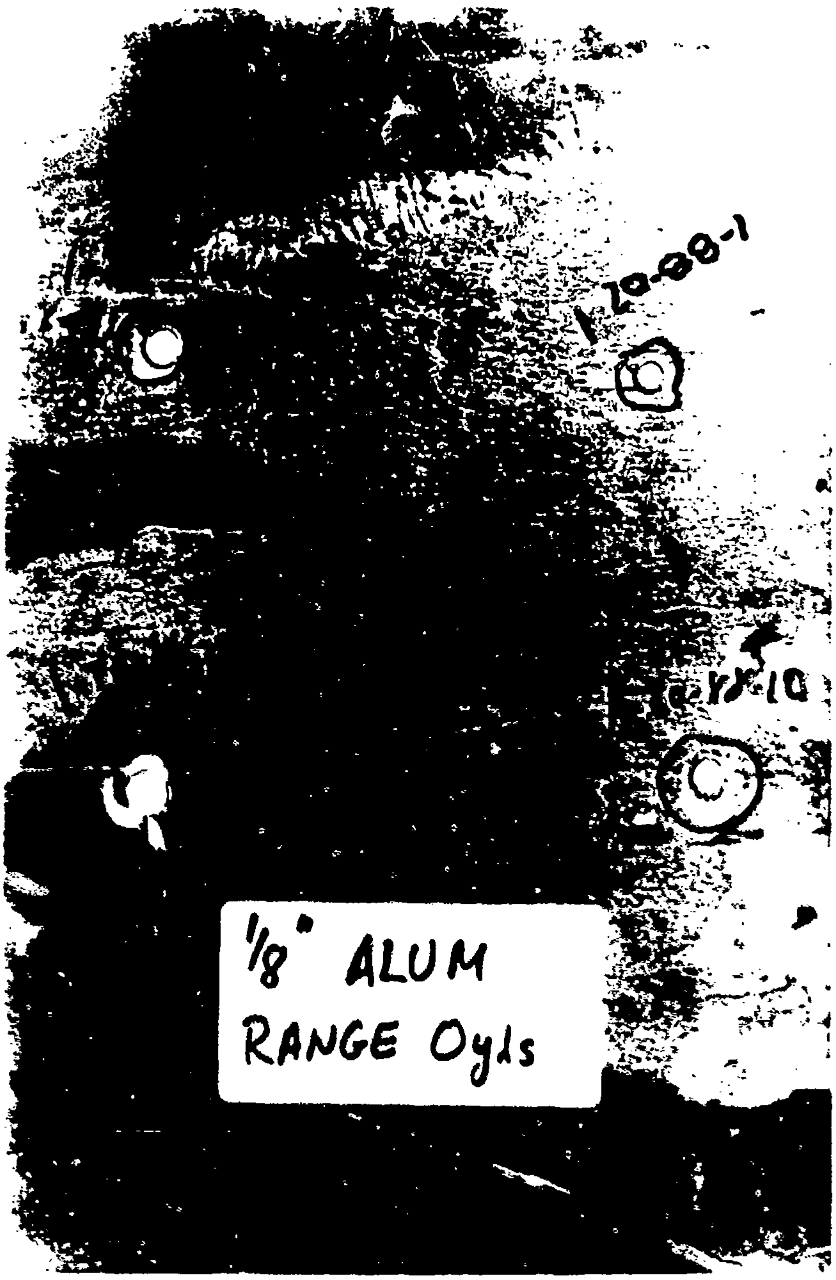


Figure 2. Impact Face of Aluminum Target at Close-in Range

Legend	Threat
1-20-88 -2	5.56mm,M193
-5	.30 cal,M1
-8	9mm,FMJ
-11	7.62mm,M80

Figure 3. Impact Face of 5# Steel Target at Close-in Range

Legend	Threat
1-20-88 -3	5.56mm,M193
-6	.30 cal,M1
-9	9mm,FMJ
-12	7.62mm,M80

Figure 4. Impact Face of 7# Steel Target at Close-in Range

Legend	Threat
1-21-88 -1	7.62mm,M80
-4	5.56mm,M193
-7	.30 cal,M1

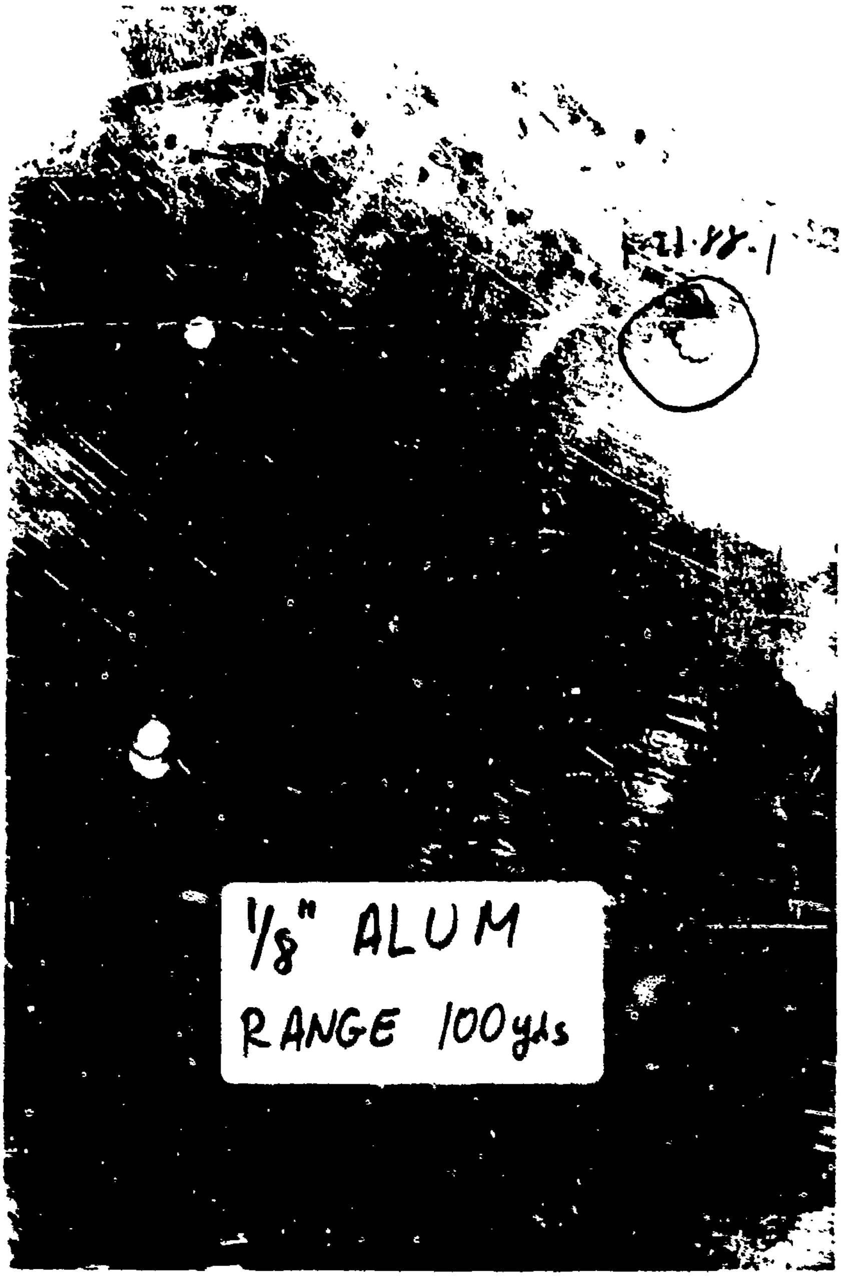


Figure 5. Impact Face of Aluminum Target at 100 Yard Range.

Legend	Threat
1-21-88 -2	7.62mm,M80
-5	5.56mm,M193
-8	.30 cal,M1

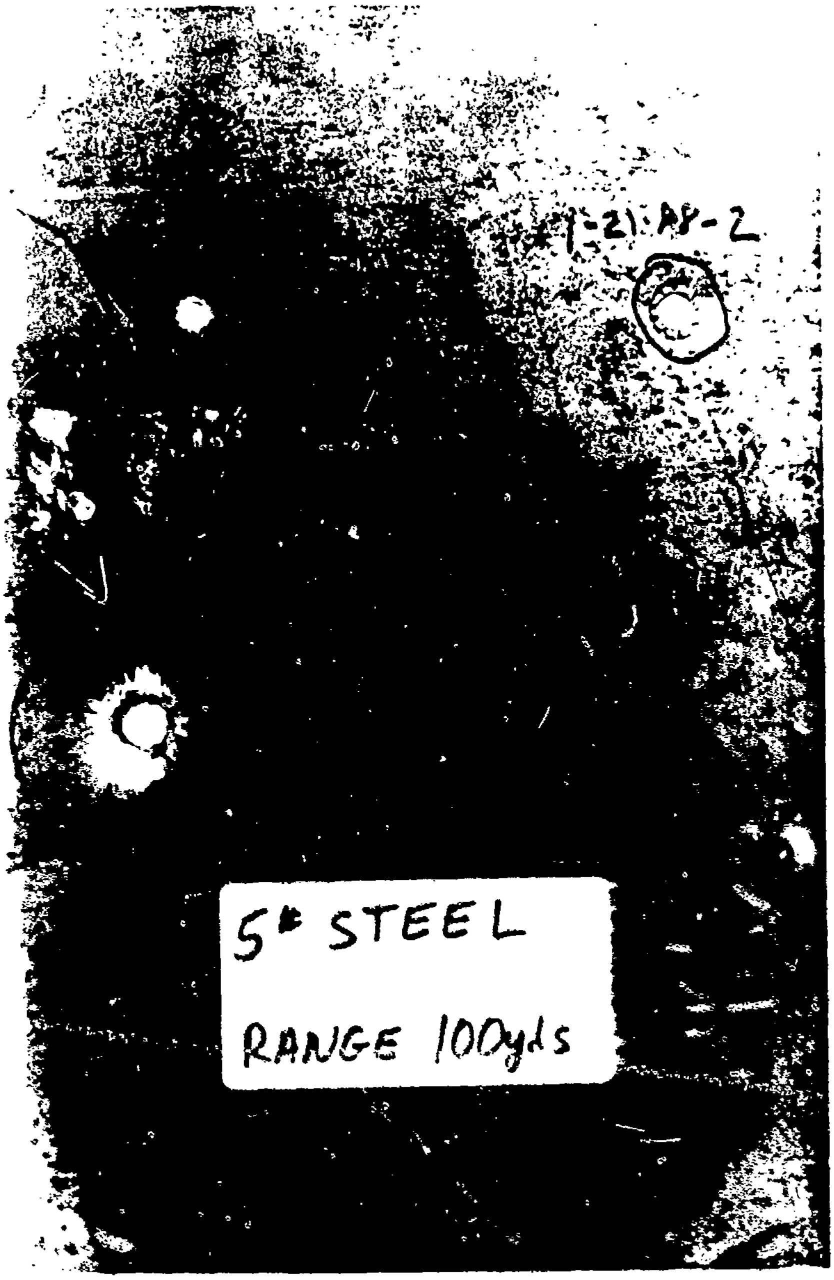


Figure 6. Impact Face of 5# Steel Target at 100 Yard Range.

Legend	Threat
1-21-88 -3	7.62mm,M80
1-21-88-6	5.56mm,M193
1-21-88-9	.30 cal,M1
1-21-88-10	.30 cal,M1

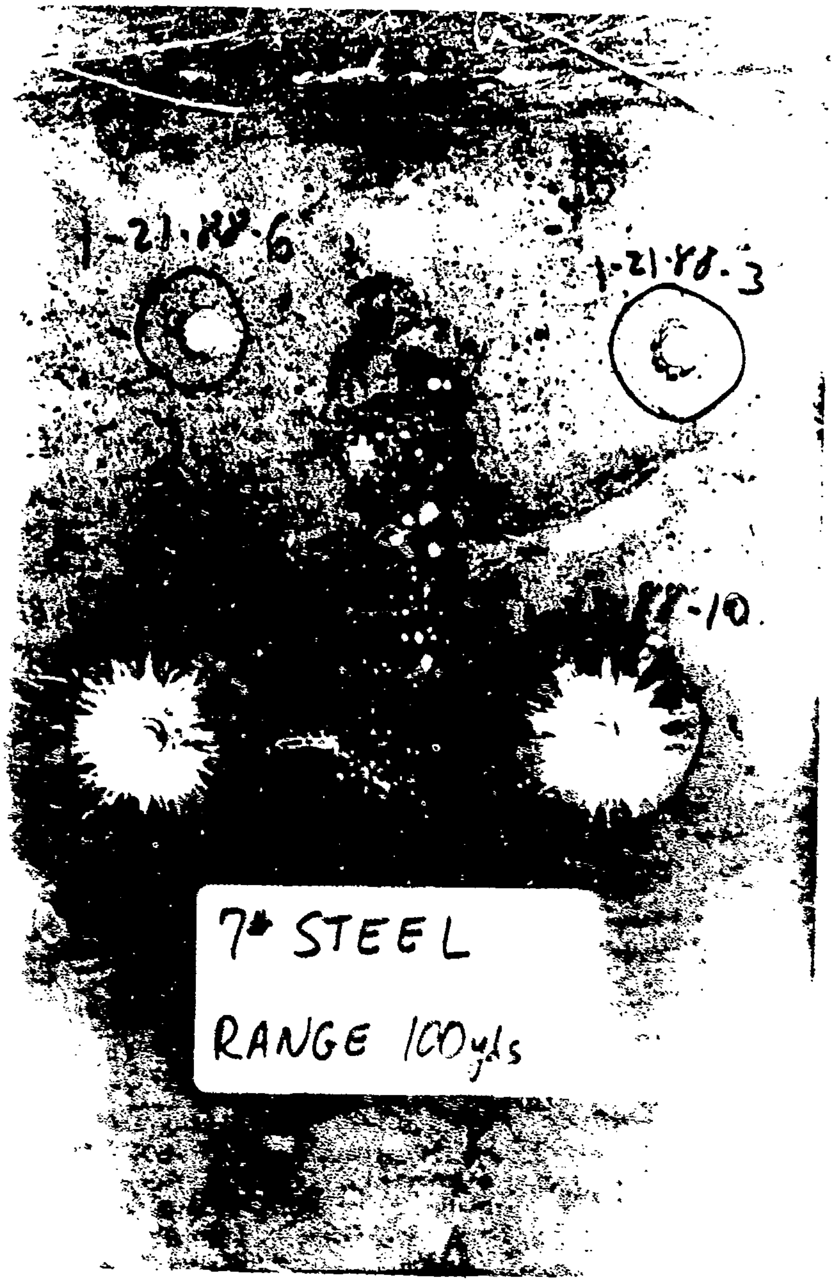


Figure 7. Impact Face of 7# Steel Target at 100 Yard Range

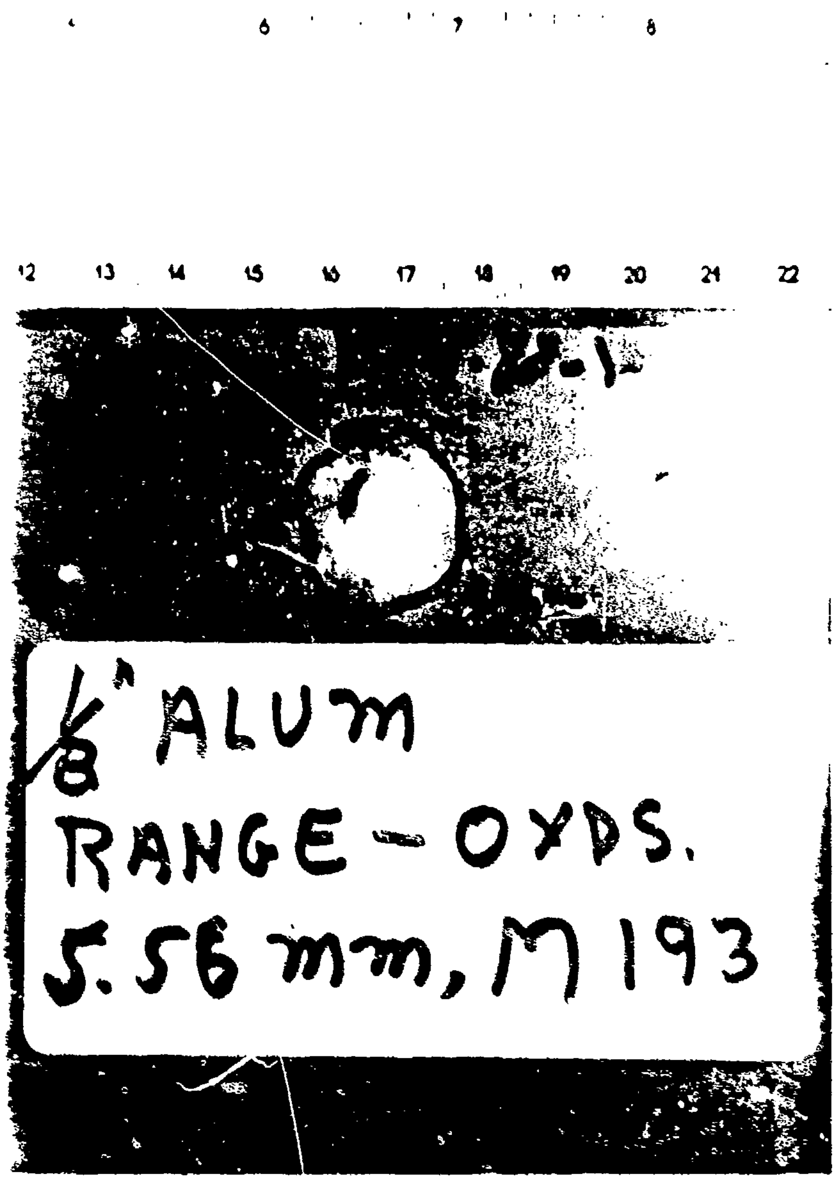


Figure 8. Witness Plate Behind Aluminum

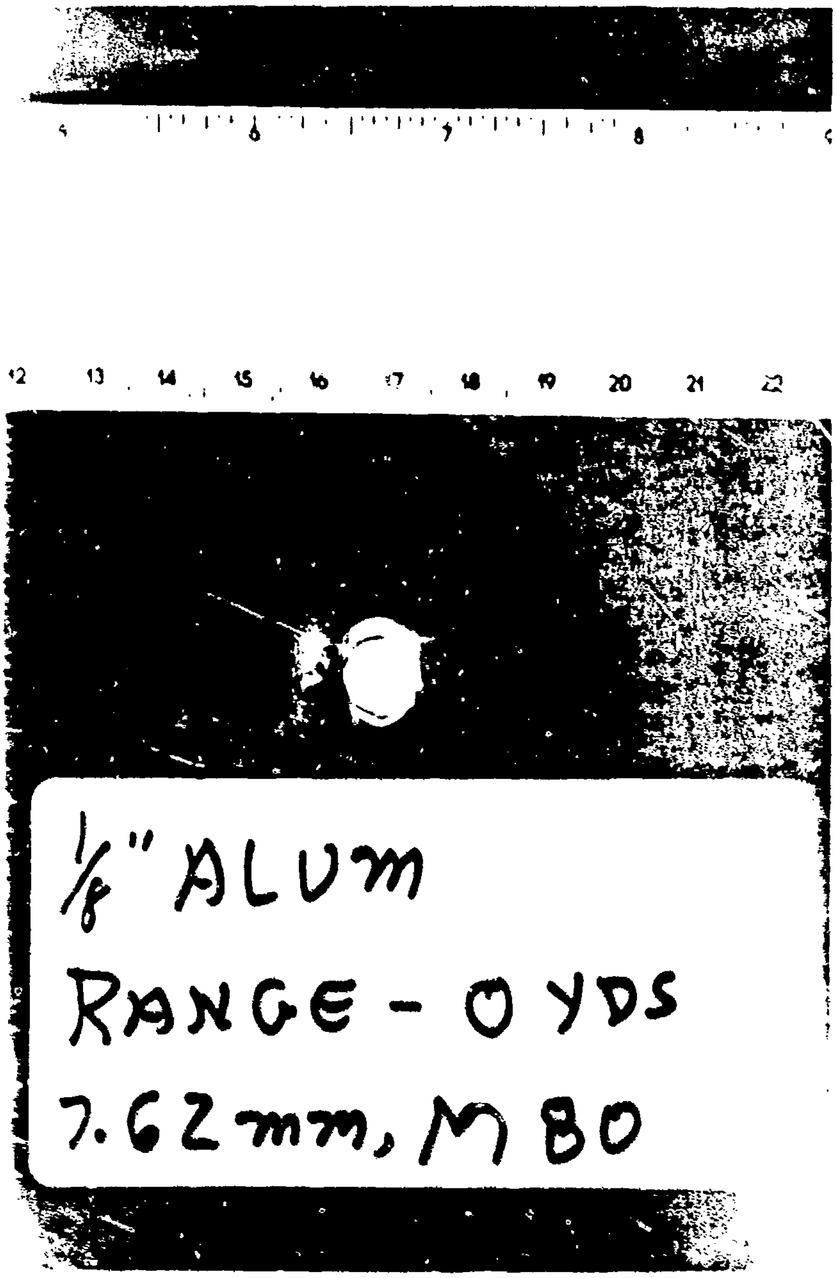
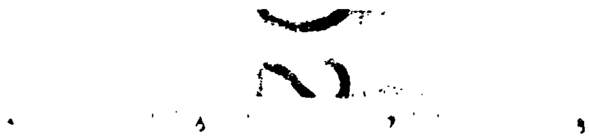


Figure 9. Witness Plate Behind Aluminum



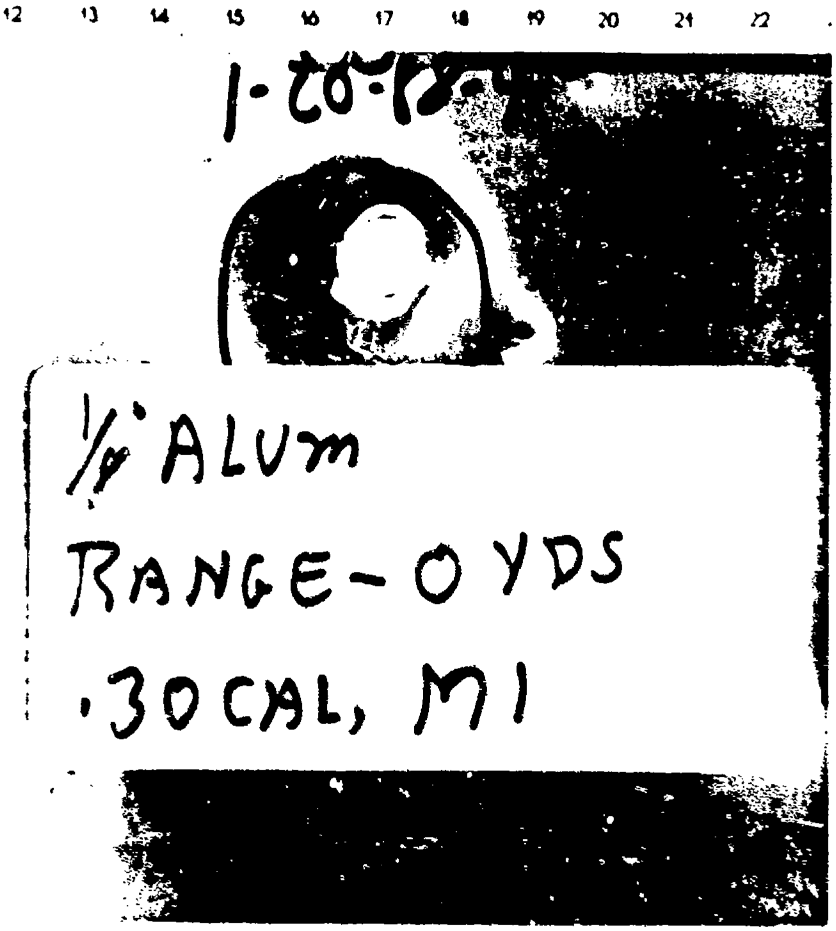


Figure 10. Witness Plate Behind Aluminum

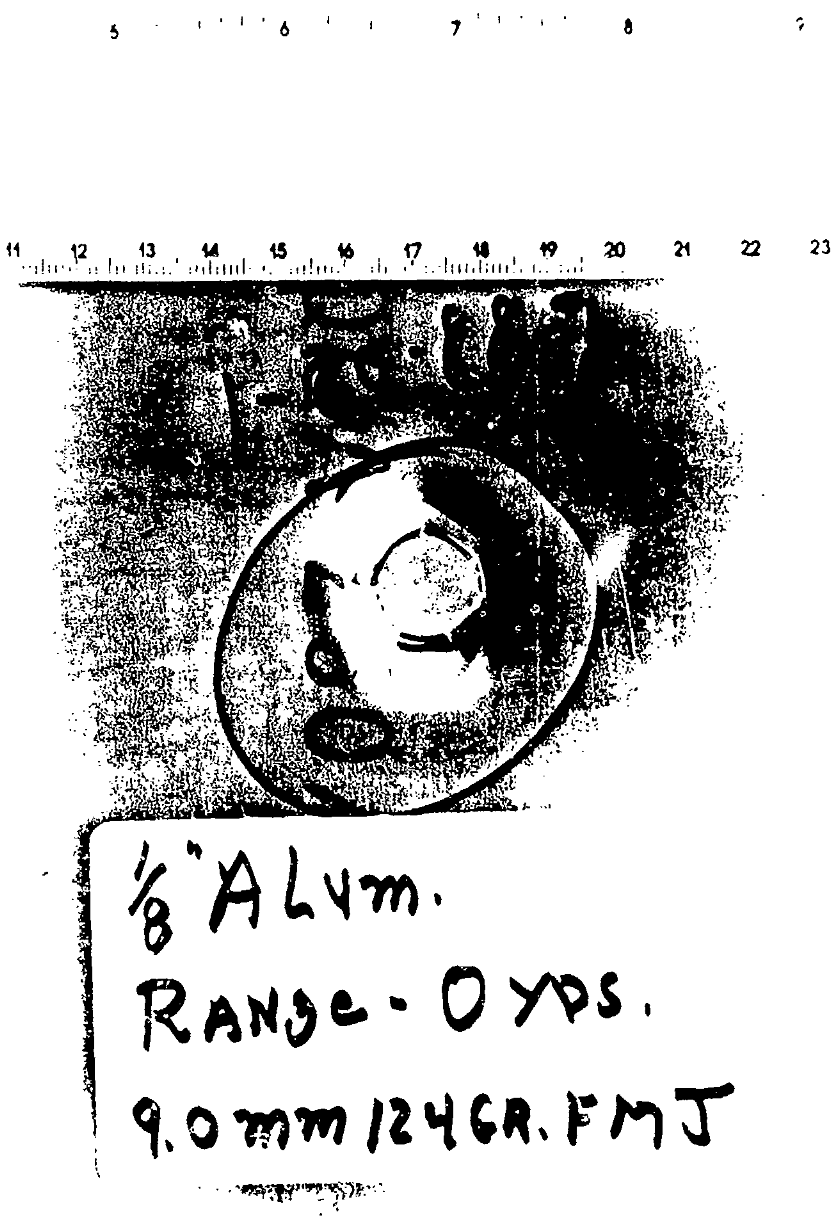


Figure 11. Witness Plate behind Aluminum

Figure 12. Witness Plate Behind 5# Steel

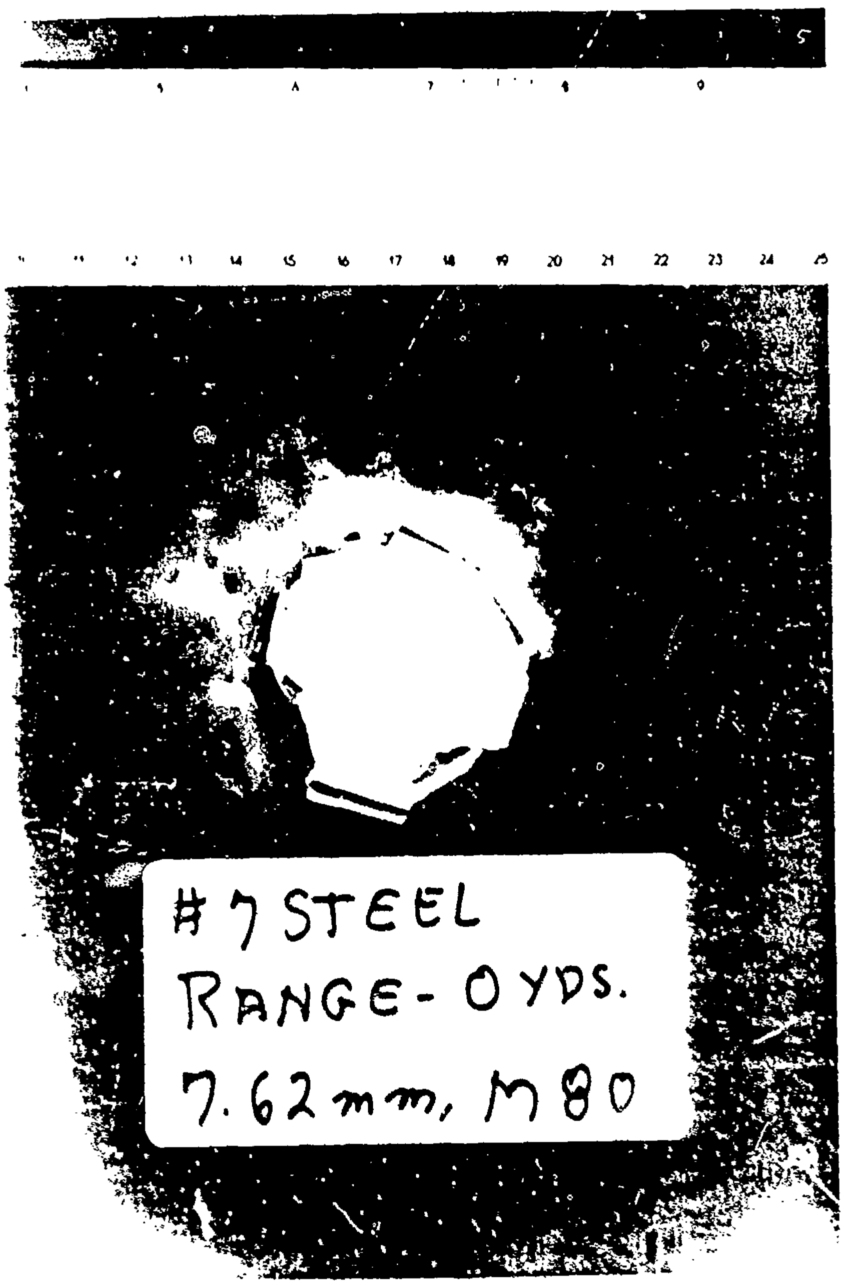


Figure 13. Witness Plate Behind 7# Steel

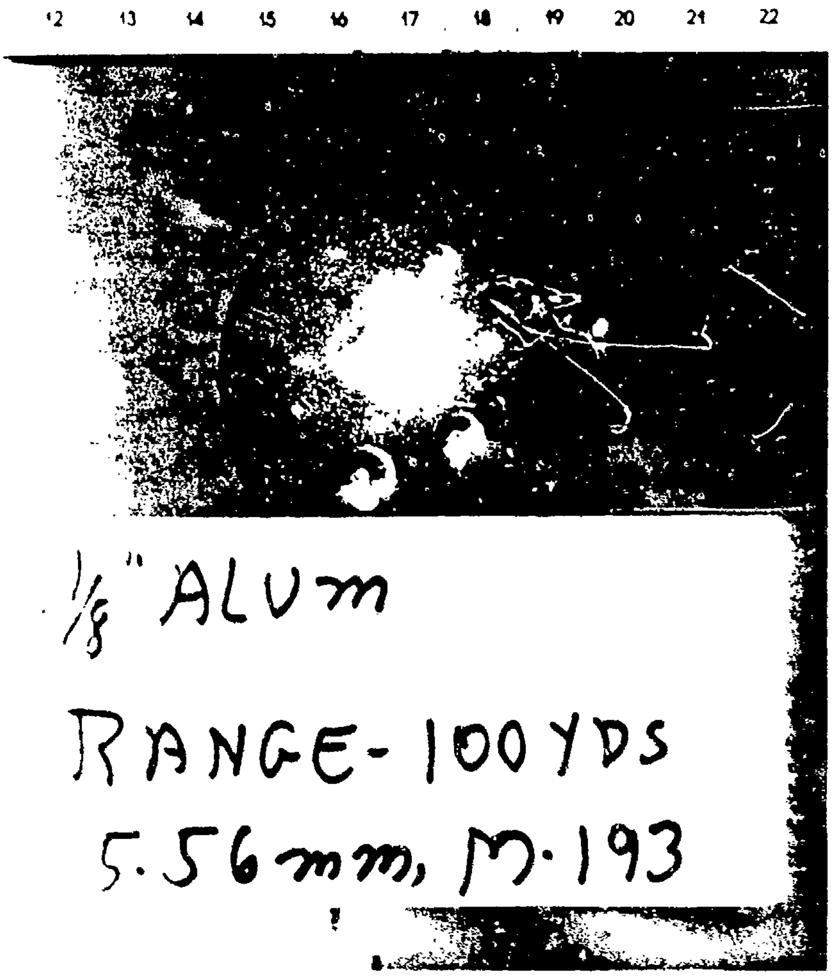


Figure 14. Witness Plate Behind Aluminum

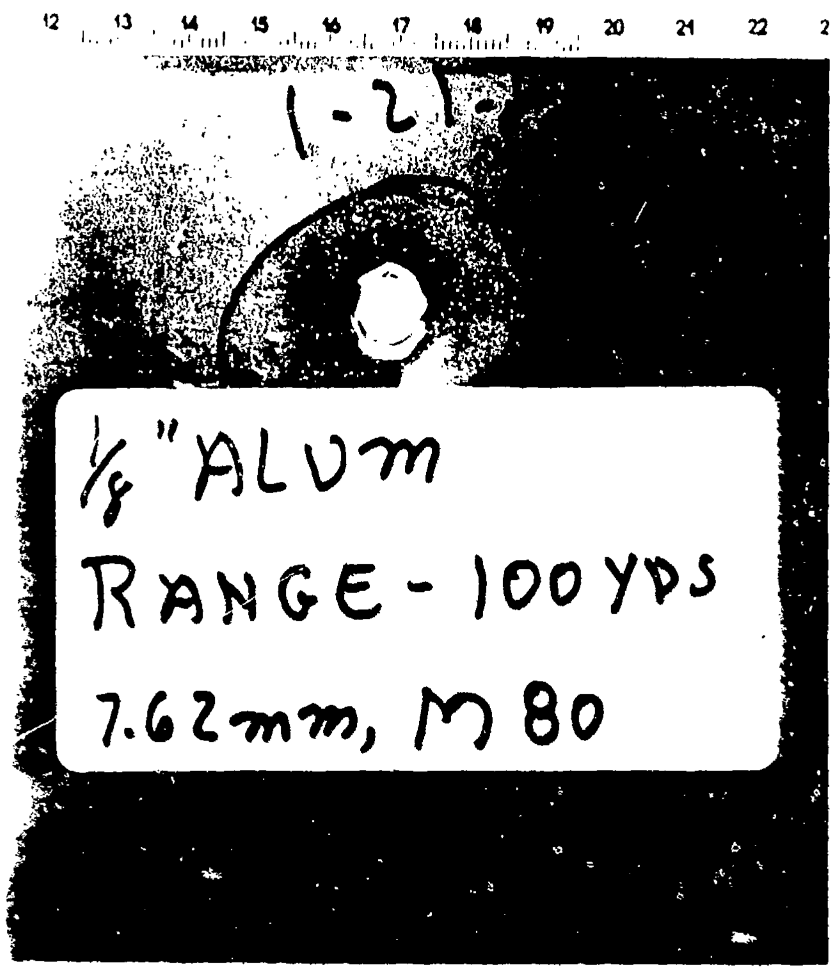


Figure 15. Witness Plate Behind Aluminum

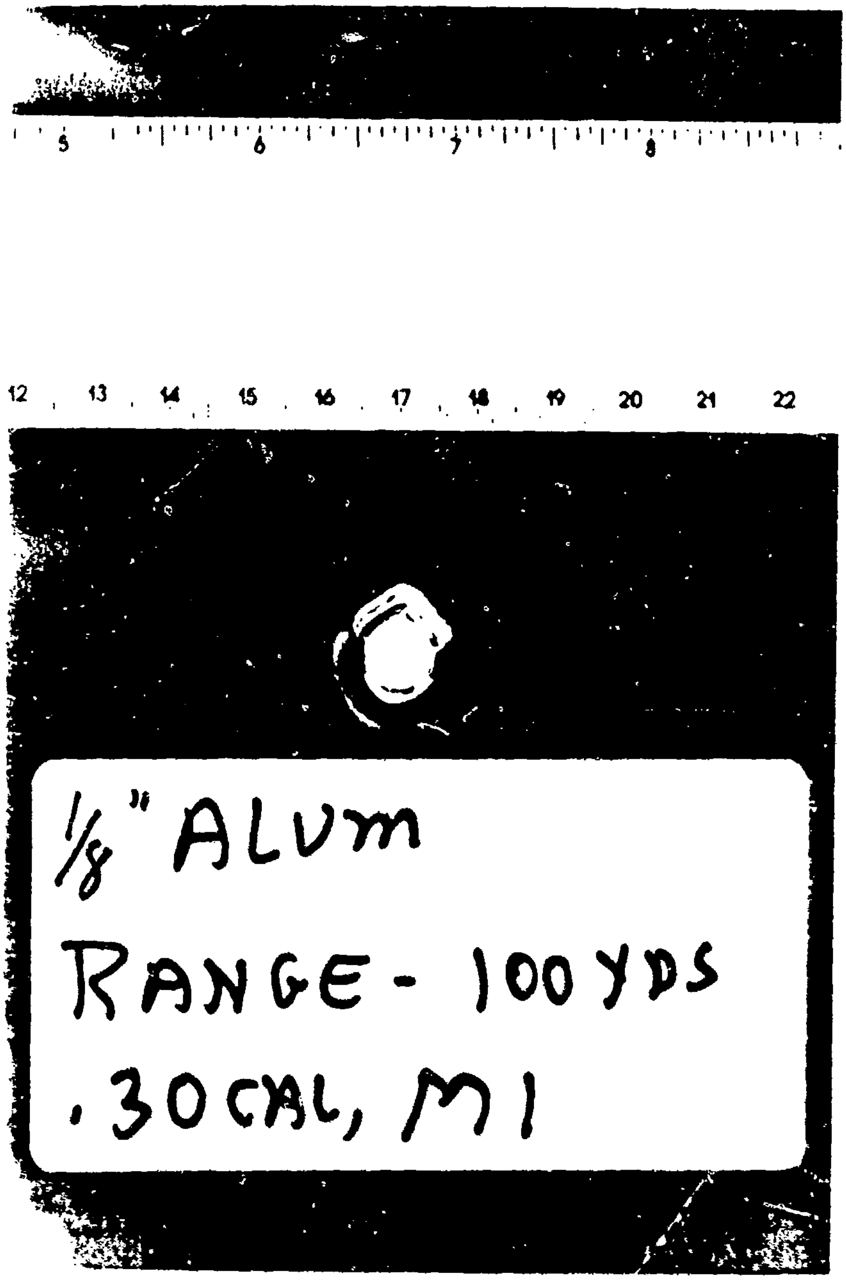


Figure 16. Witness Plate Behind Aluminum

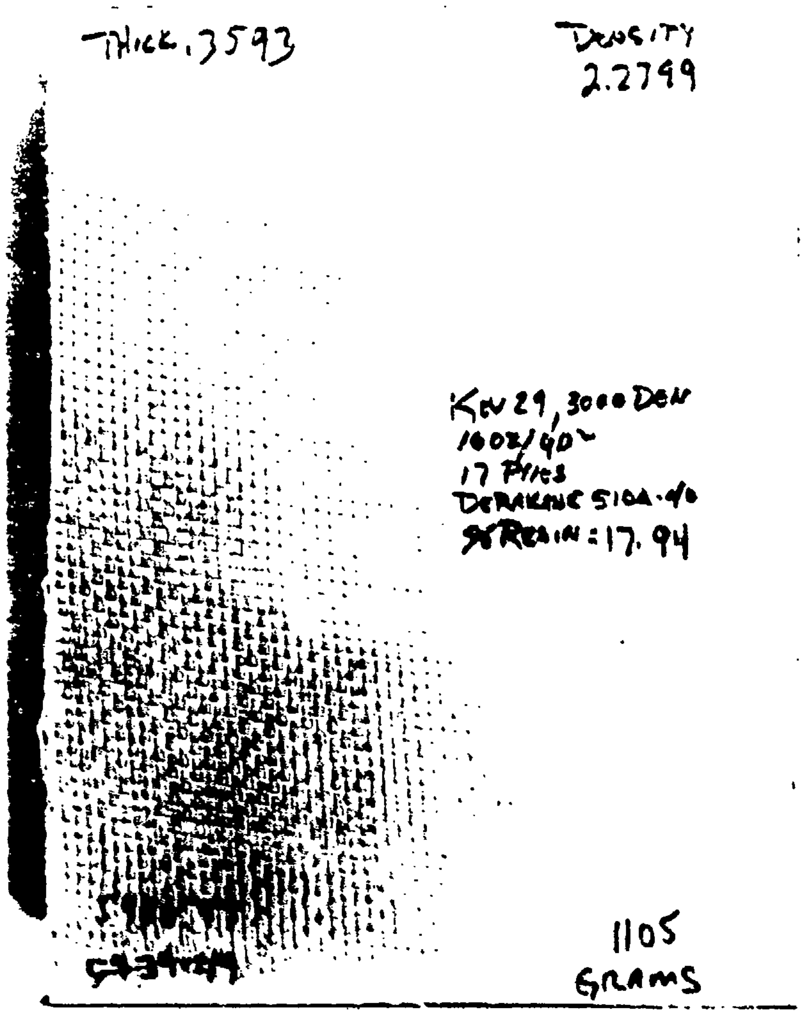
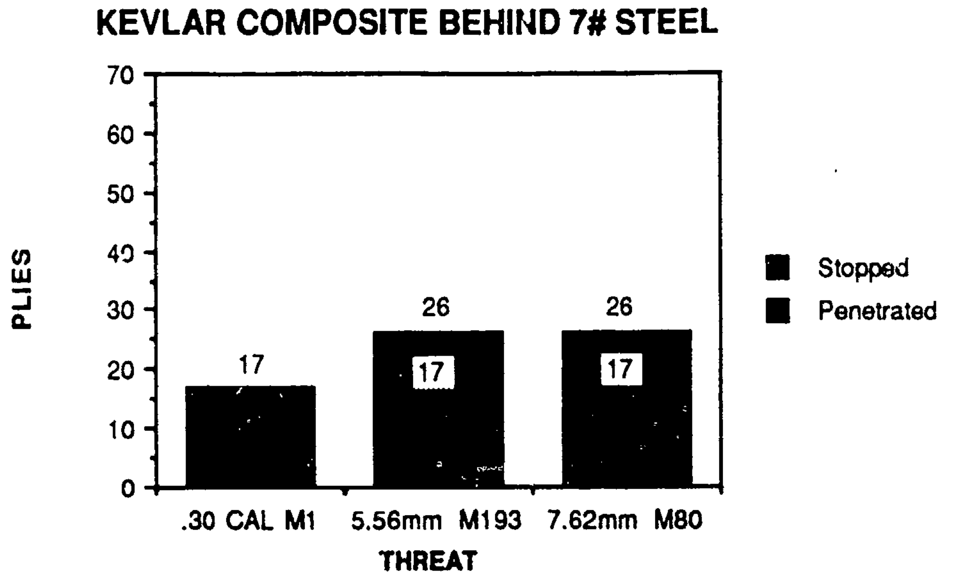


Figure 17. KRP Armor Panel

Figure 18. KRP Armor Test Arrangement



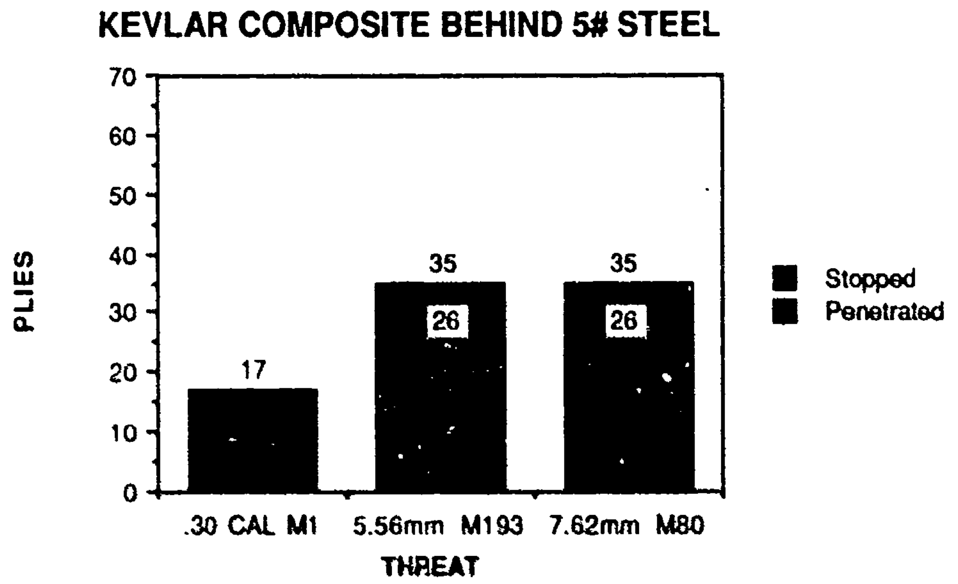
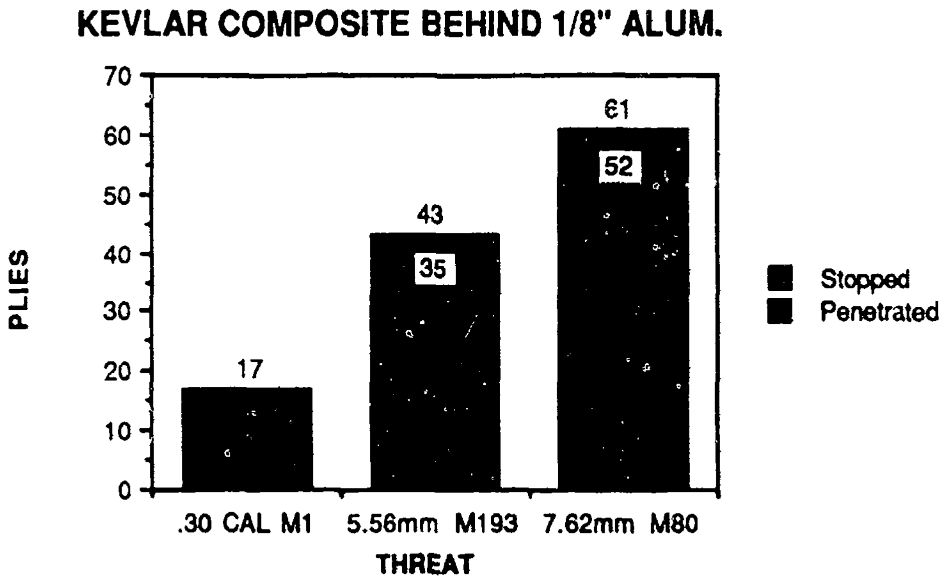


FIGURE 19. EFFECT ON NUMBER OF PLIES OF KRP ARMOR BEHIND DIFFERENT THICKNESS STEEL.



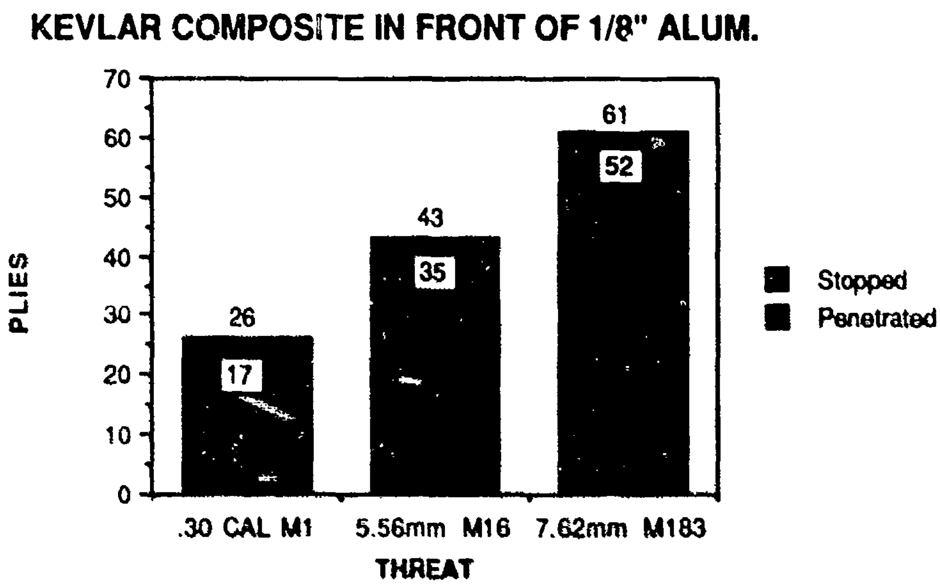


FIGURE 20. EFFECT ON NUMBER OF PLIES OF PLACING KRP ARMOR INSIDE OR OUTSIDE VESSEL.

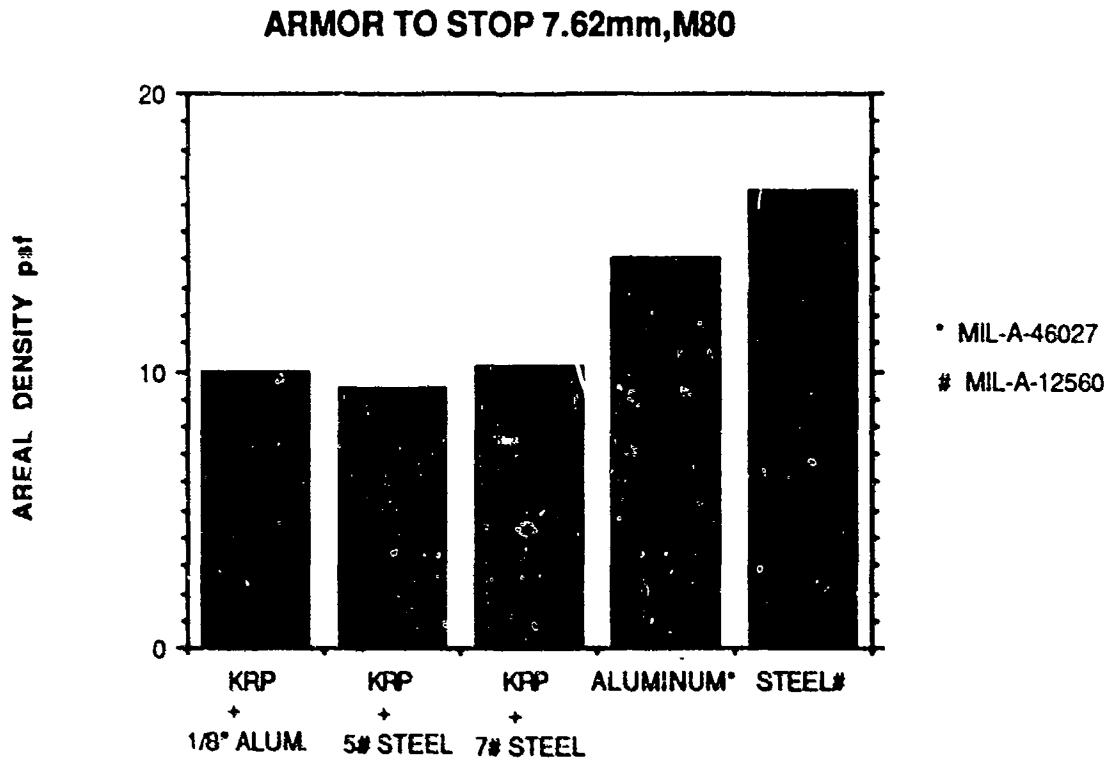


FIGURE 21. WEIGHT EFFECTIVENESS OF KRP VS. ALL METAL ARMOR.

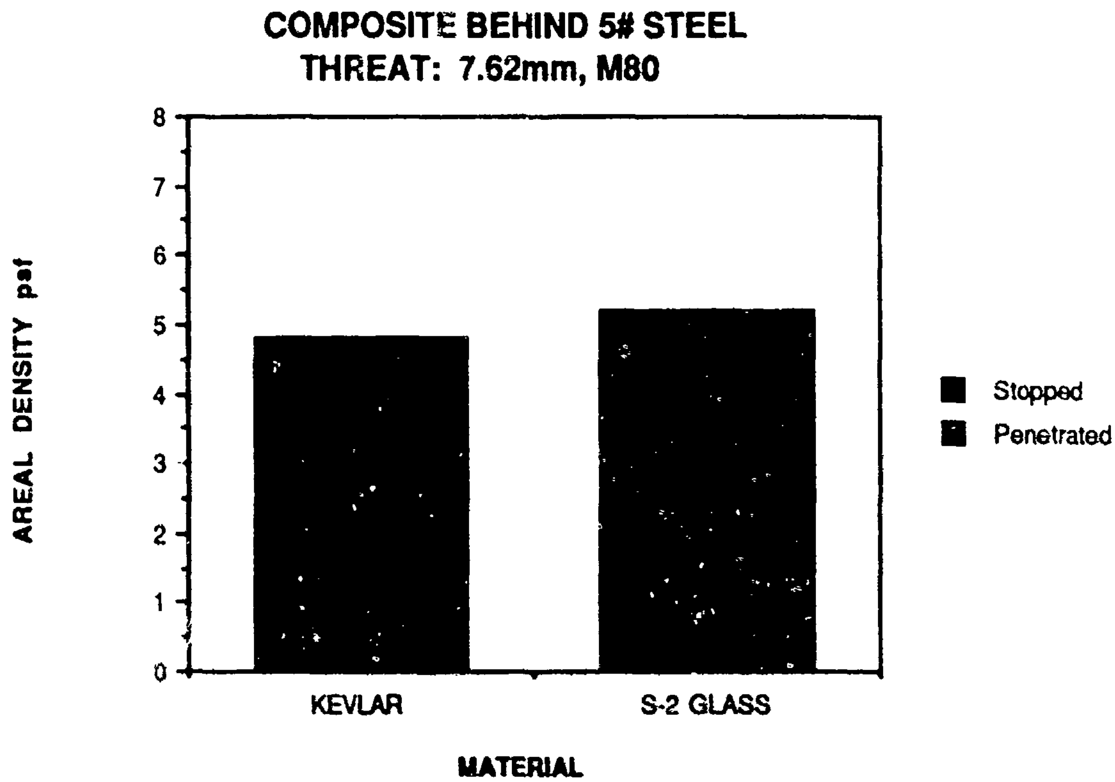
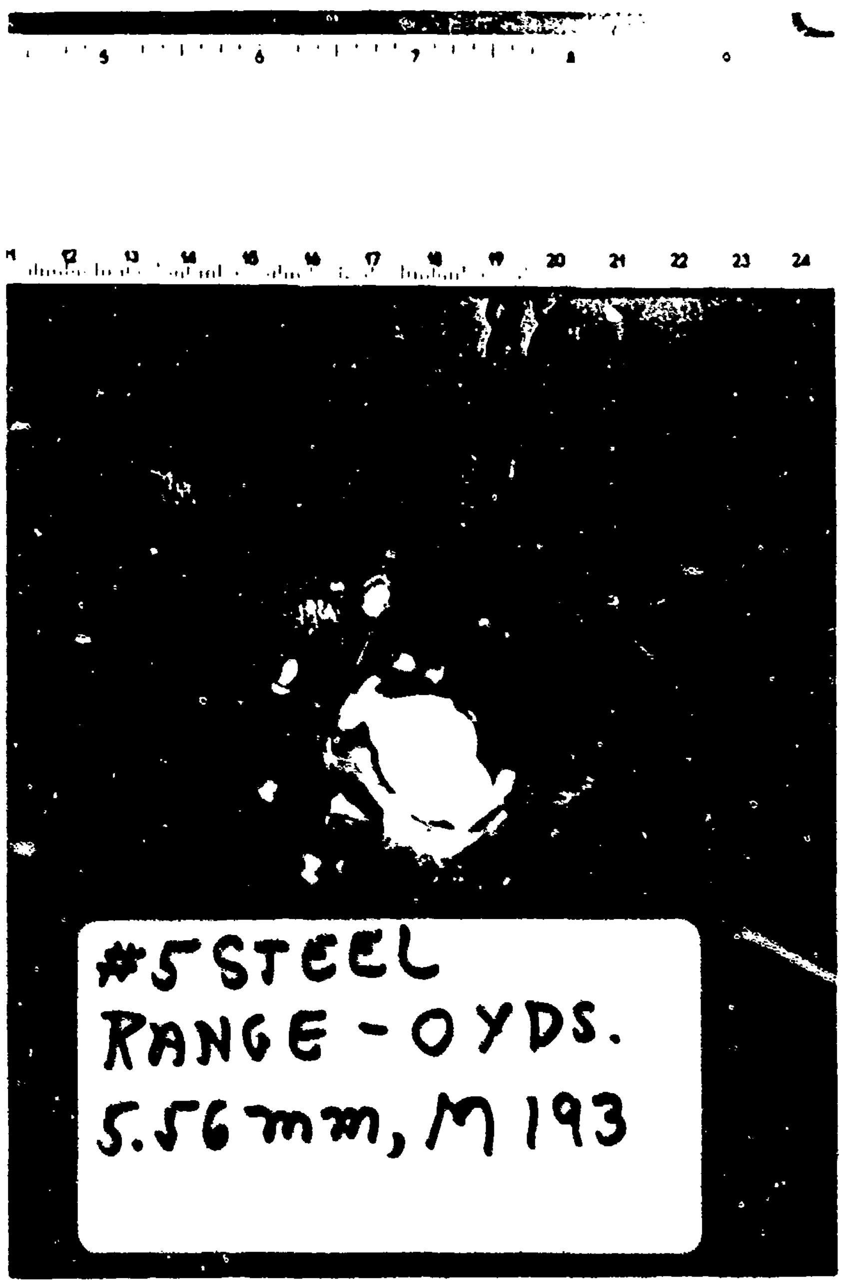
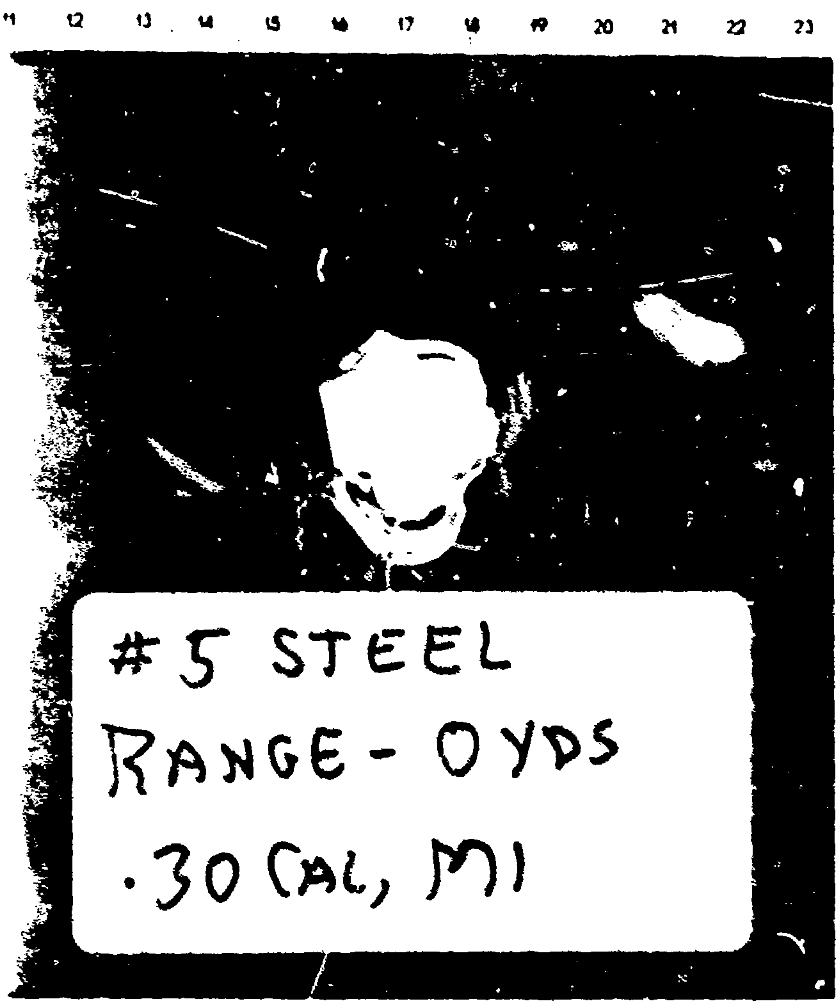
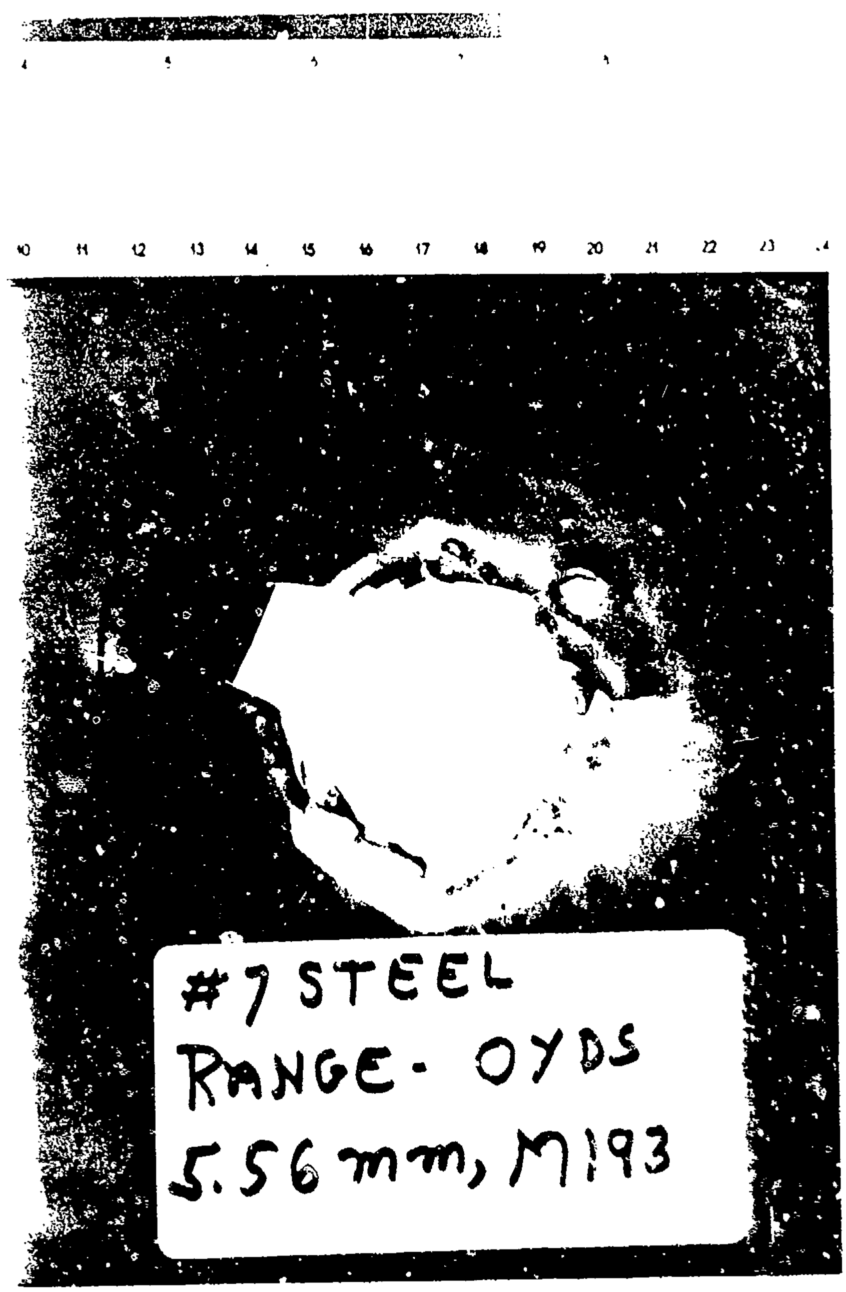


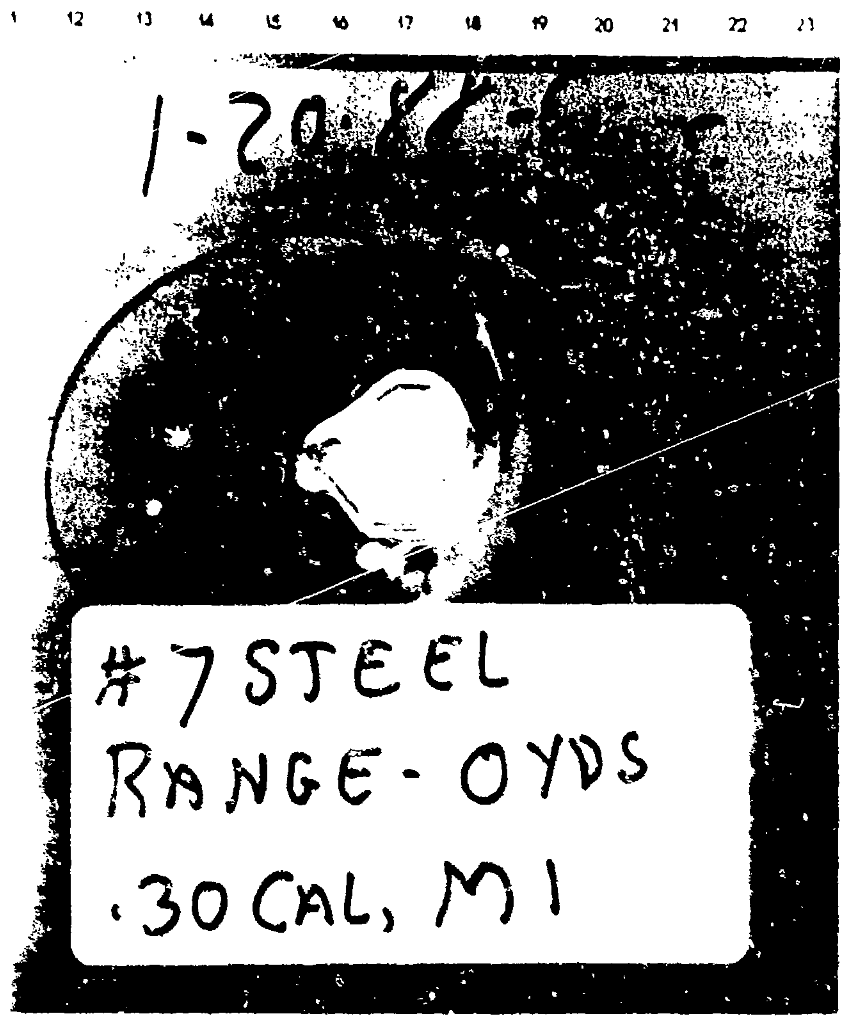
FIGURE 22. COMPARISON OF KRP AND GRP BEHIND 5# STEEL

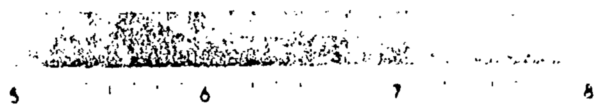
APPENDIX A WITNESS PLATES

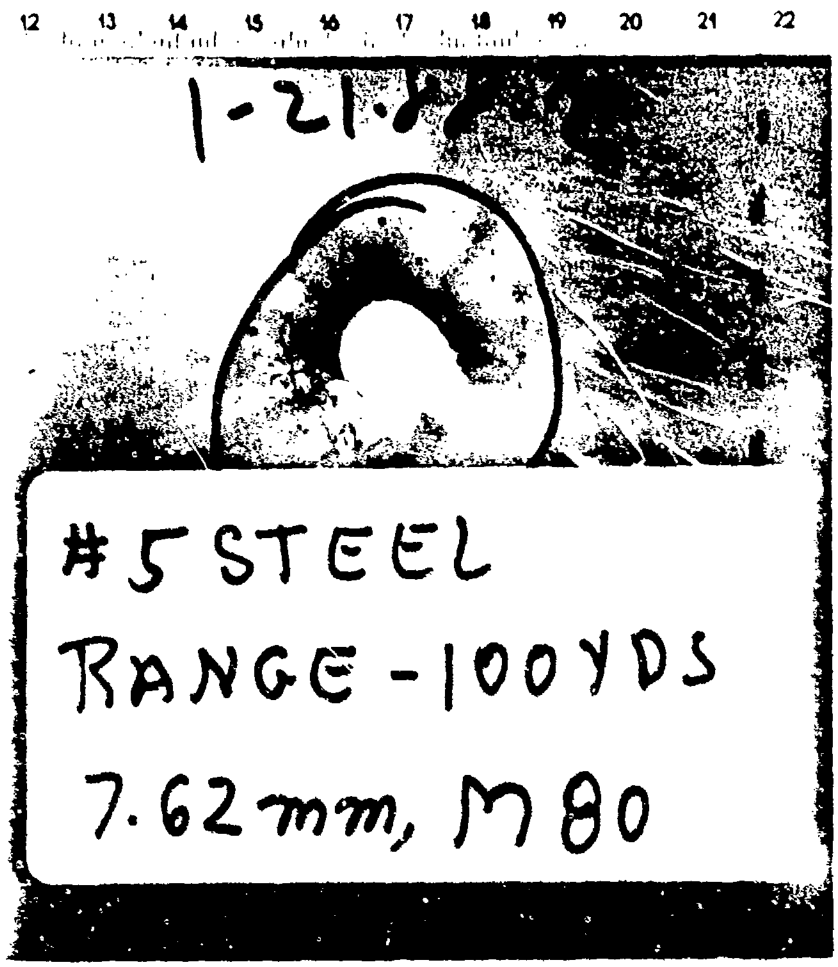


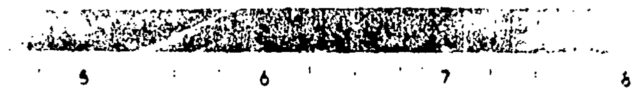

11 12 13 14 15 16 17 18 19 20 21 22 23
#5 STEEL
RANGE - 0 YDS
.30 CAL, M1

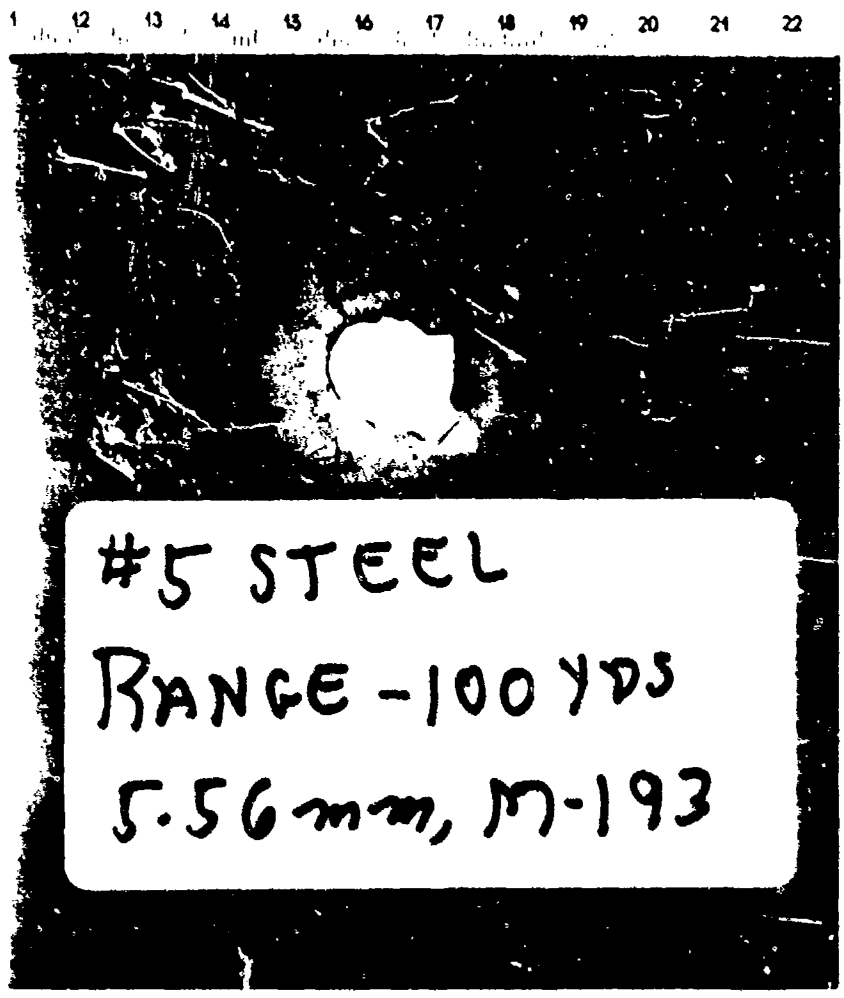

#7 STEEL
RANGE- 0YDS
5.56mm, M193

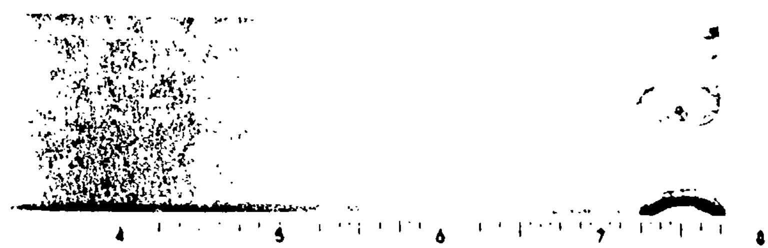

#7 STEEL
RANGE - 0 YDS
.30 CAL, M1


5
6
7
8

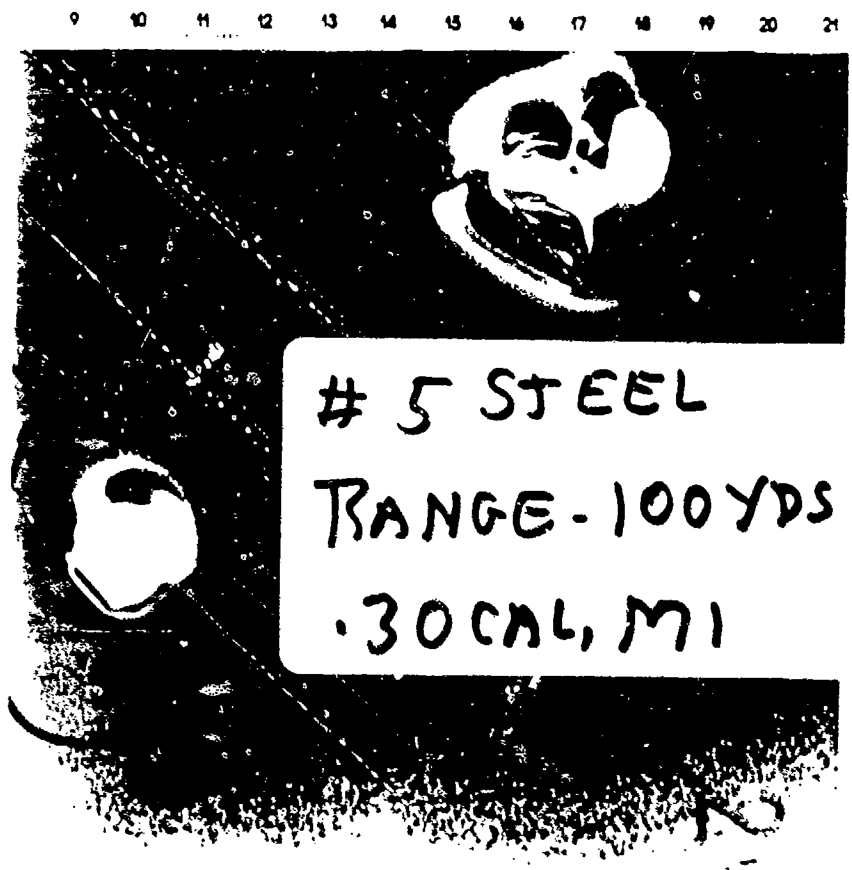

12 13 14 15 16 17 18 19 20 21 22
1-21-8
#5 STEEL
RANGE - 100 YDS
7.62 mm, M80


5
6
7
8

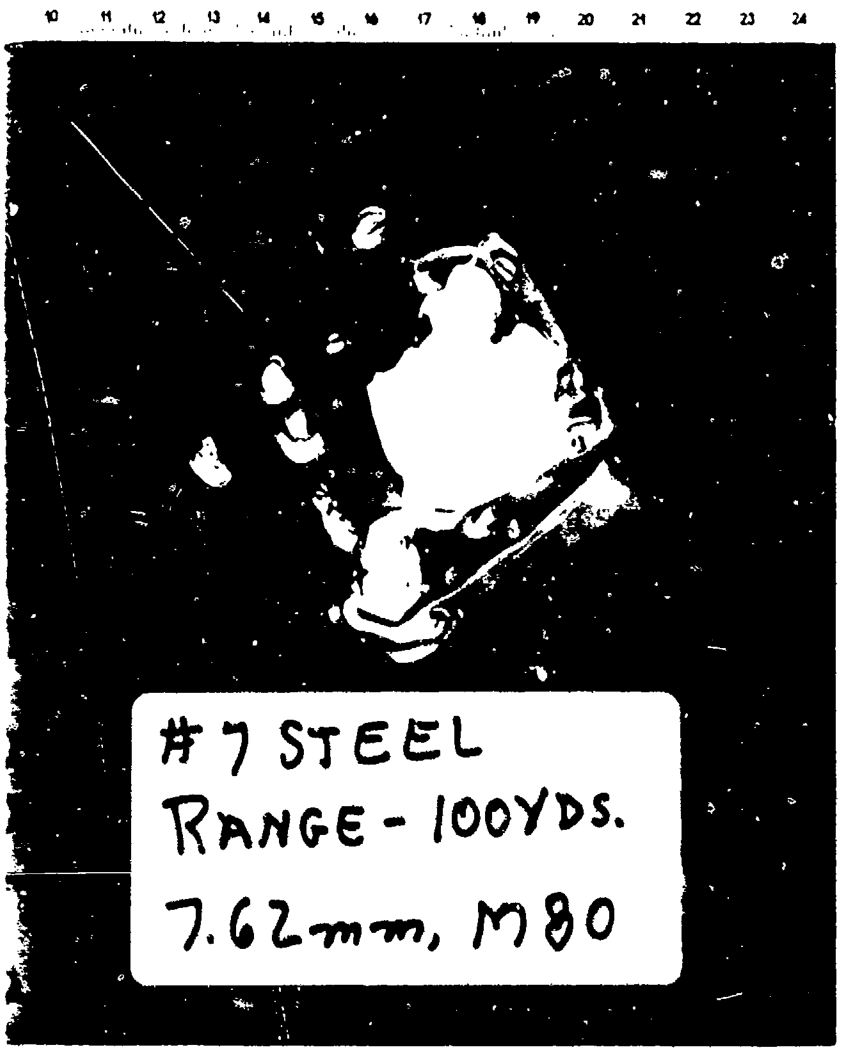

#5 STEEL
RANGE - 100 YDS
5.56 mm, M-193

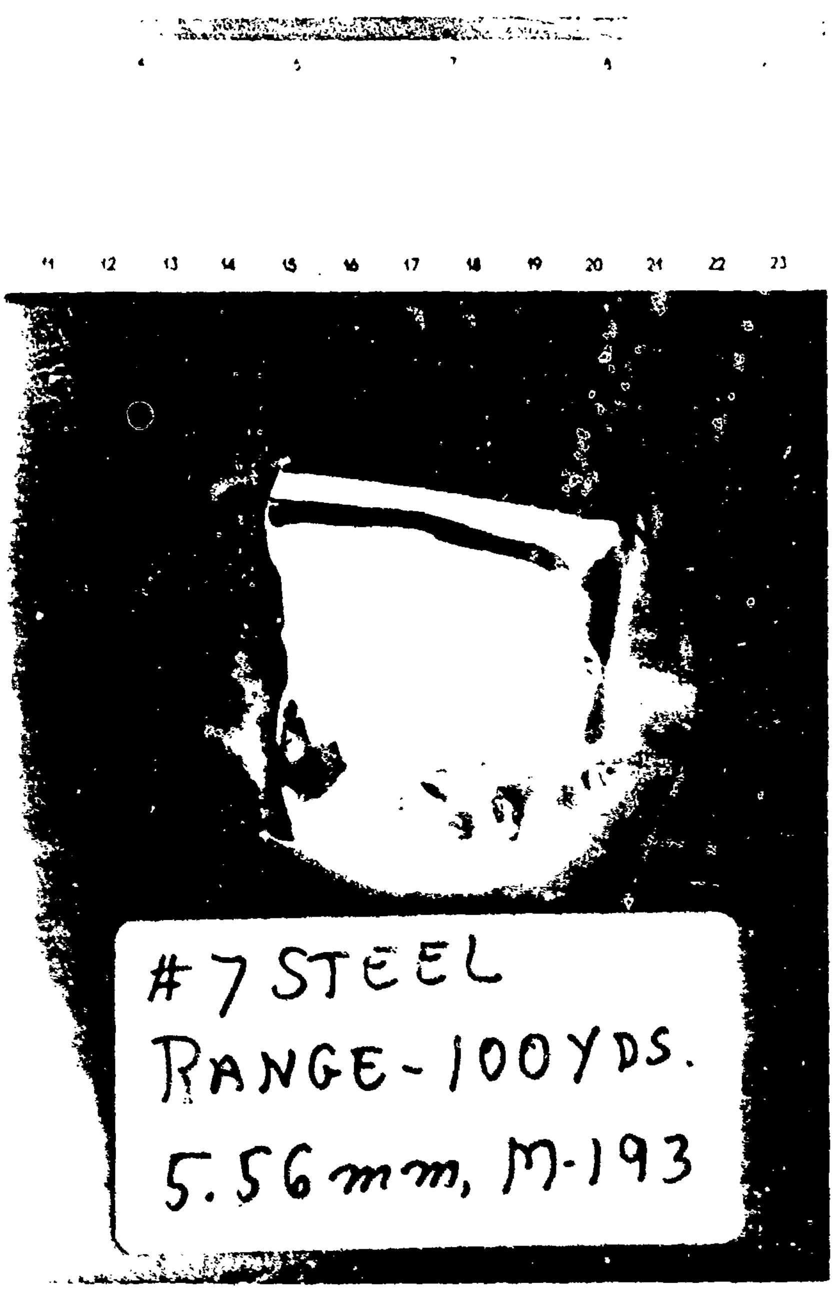


4
5
6
7
8



9
10
11
12
13
14
15
16
17
18
19
20
21
5 STEEL
RANGE - 100 YDS
.30 CAL, M1


#7 STEEL
RANGE - 100YDS.
7.62mm, M80


#7 STEEL
RANGE-100YDS.
5.56mm, M-193

[BLANK]

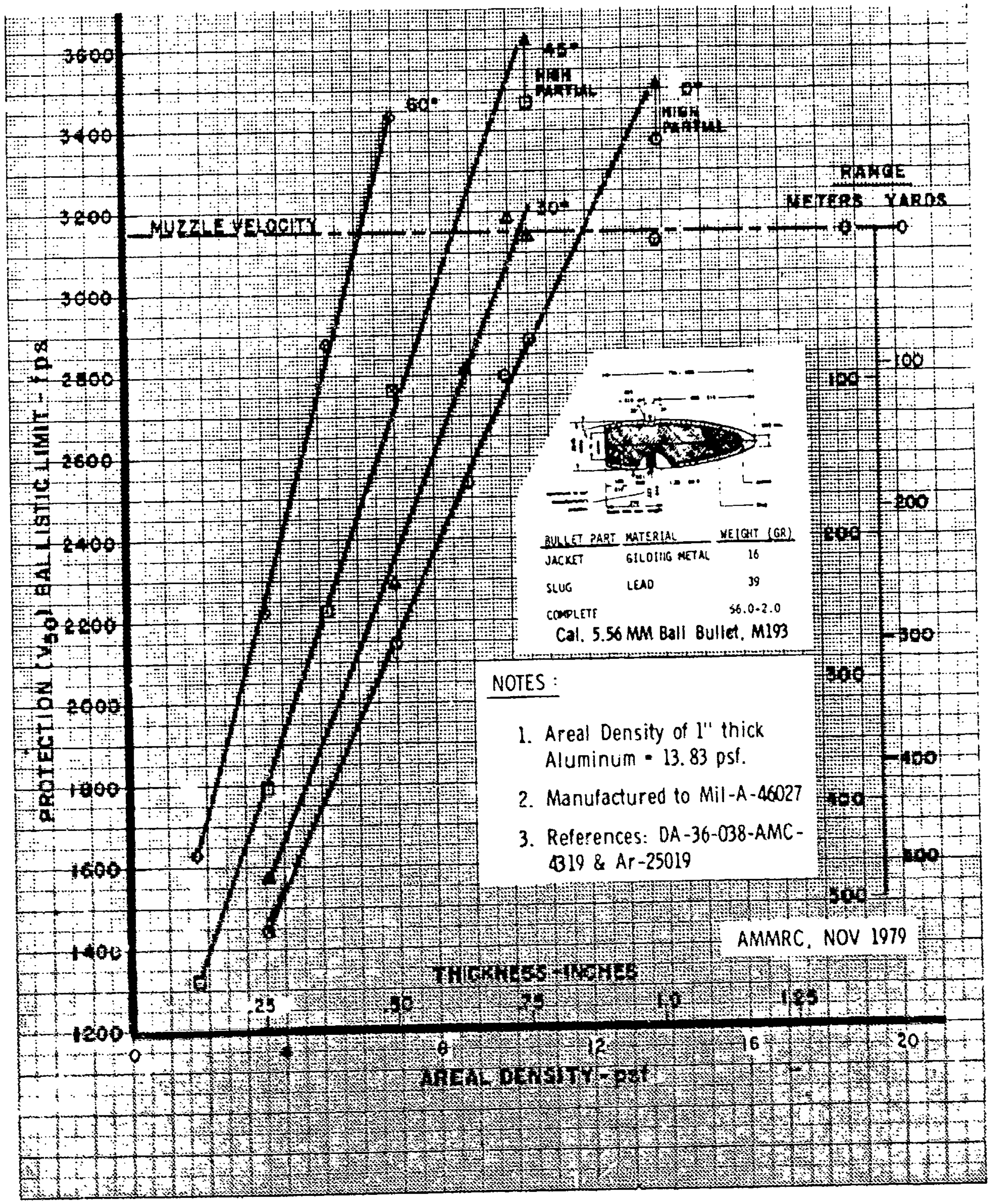


FIGURE 45 PROTECTION PROVIDED BY 5083 ALUMINUM ARMOR AGAINST 5.56MM BALL, M193 AT VARIOUS OBLIQUITIES

ARMY MATERIALS AND MECHANICS RESEARCH CENTER

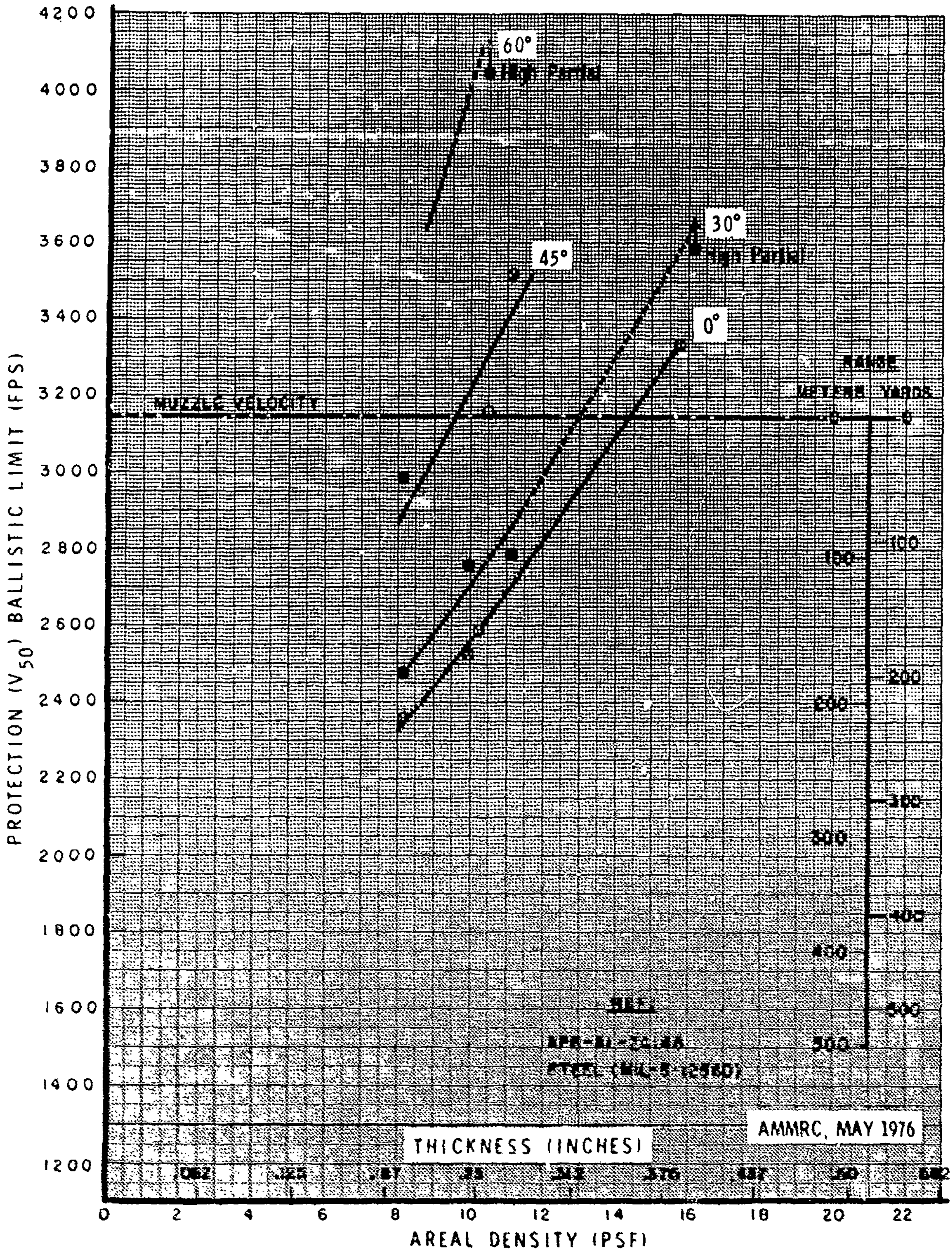


FIGURE 436 PROTECTION PROVIDED BY STEEL ARMOR AGAINST 5.56MM BALL M193 PROJECTILES

ARMY MATERIALS AND MECHANICS RESEARCH CENTER

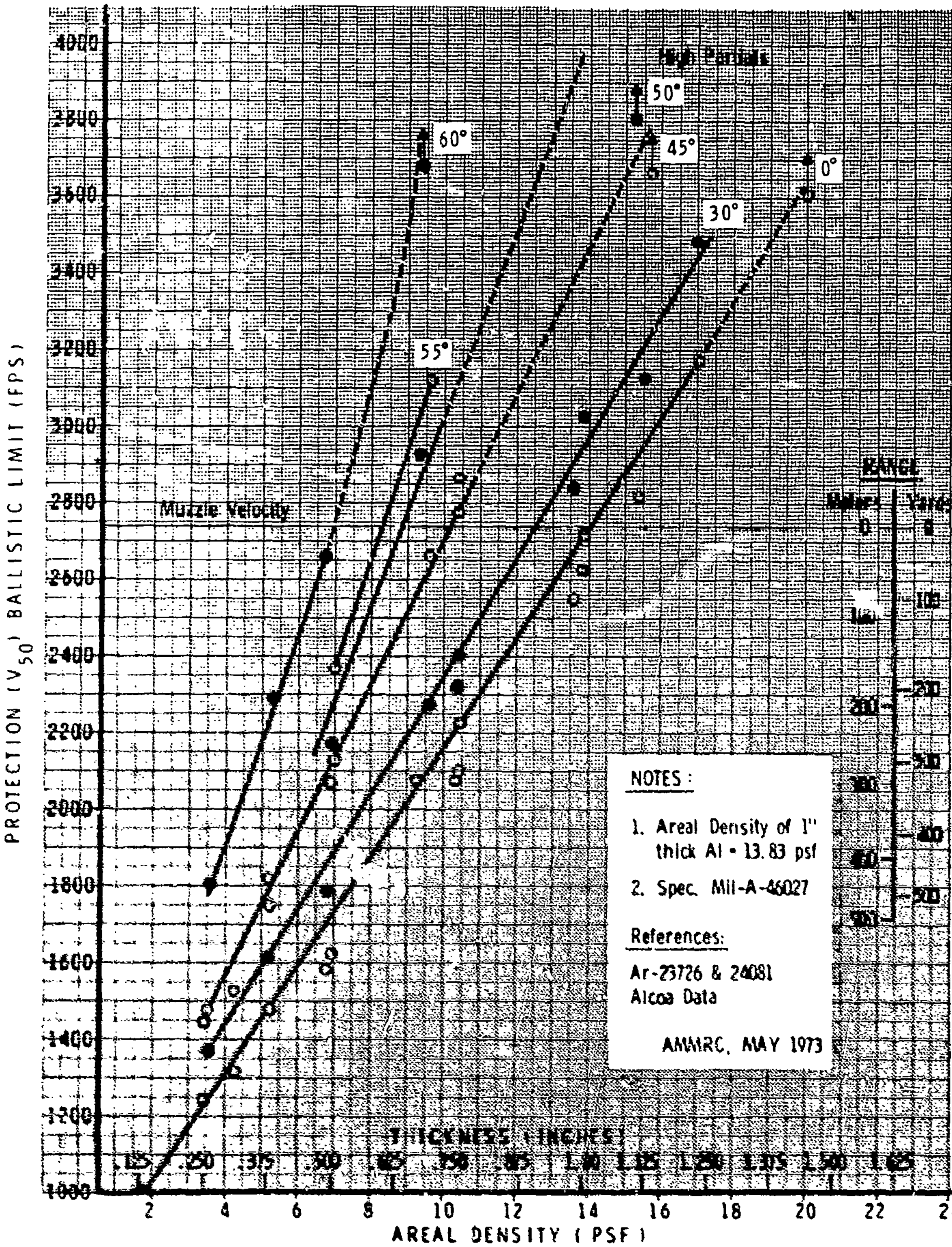


FIGURE 48. PROTECTION PROVIDED BY ALUMINUM ALLOY ARMOR (5083) AGAINST 7.62MM M80 BALL PROJECTILES AT VARIOUS OBLIQUITIES

ARMY MATERIALS AND MECHANICS RESEARCH CENTER

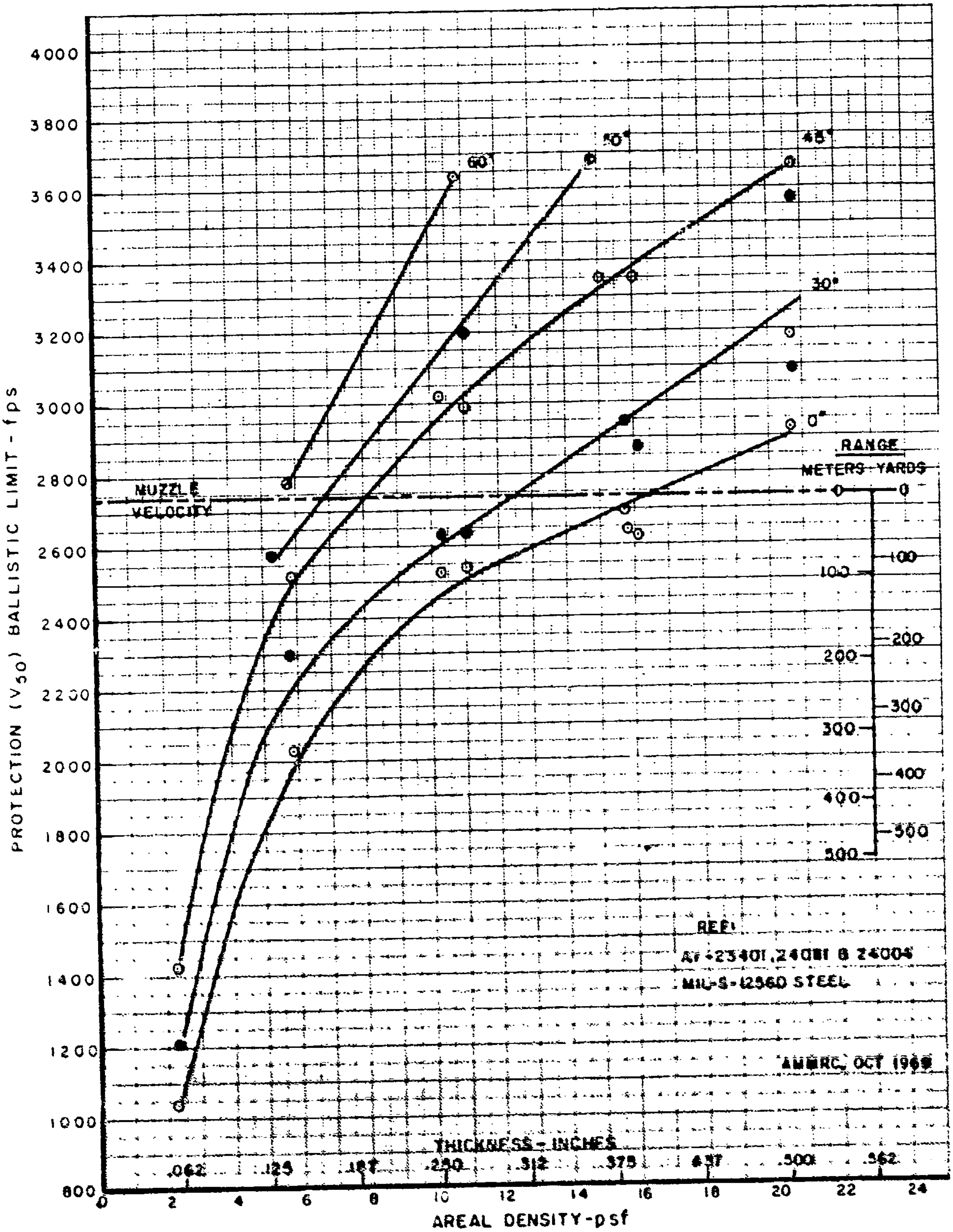


FIGURE 439 PROTECTION PROVIDED BY STEEL ARMOR AGAINST 7.62MM BALL M80 PROJECTILES AT VARIOUS OBLIQUITIES

ARMY MATERIALS AND MECHANICS RESEARCH CENTER

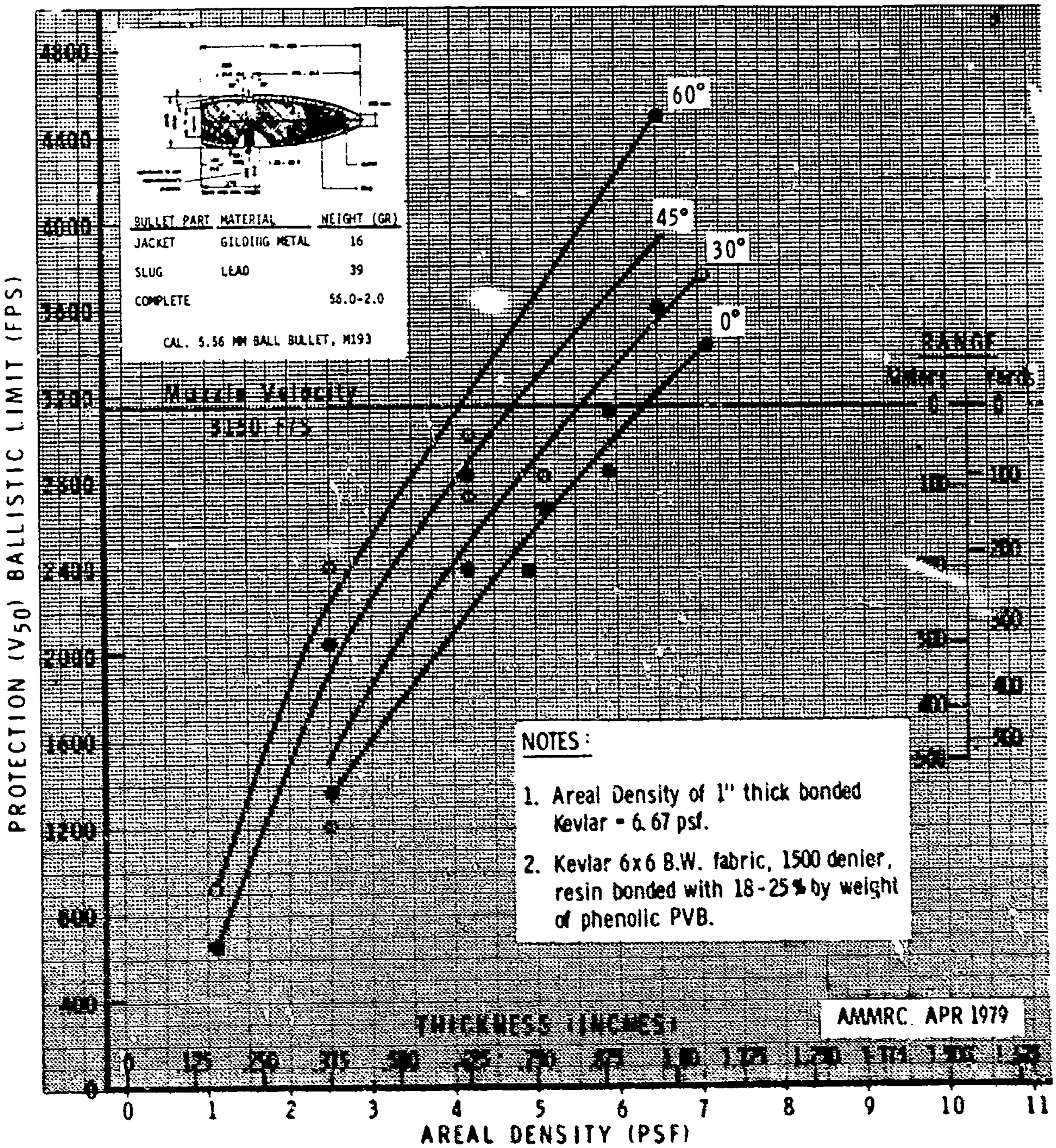


FIGURE 40C PROTECTION PROVIDED BY BONDED KEVLAR FABRIC AGAINST 5.56 MM BALL M193 AMMUNITION

ARMY MATERIALS AND MECHANICS RESEARCH CENTER

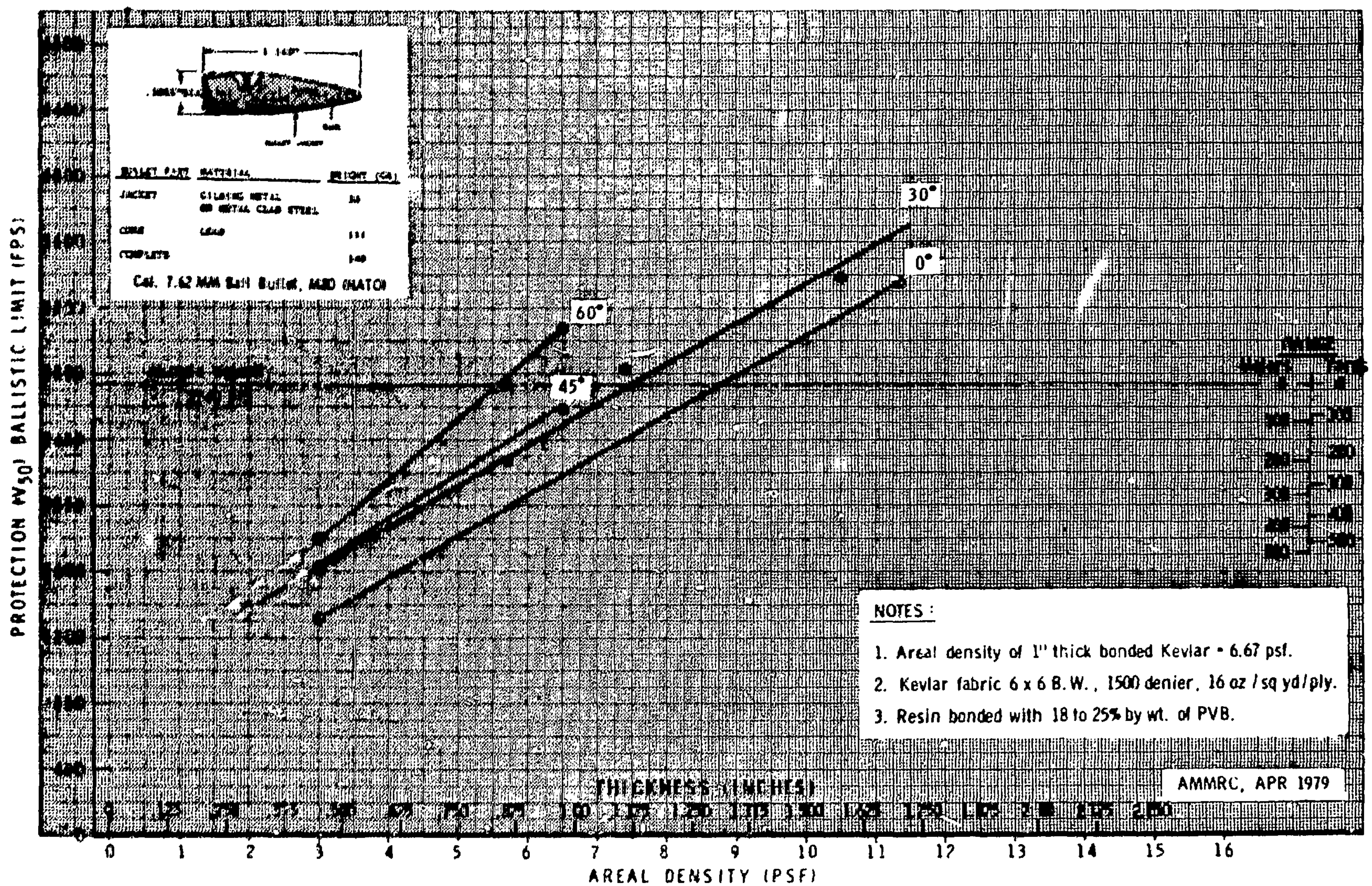


FIGURE 403 PROTECTION PROVIDED BY BONDED KEVLAR FABRIC ARMOR AGAINST 7.62 MM BALL M80 AMMUNITION
ARMY MATERIALS AND MECHANICS RESEARCH CENTER