Report No. 710/435

ARMOR PLATE

Metallurgical Examination of German Armor from a Pz. Kw. III Tank

by

P. V. Riffin
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March 15, 1943

WATERTOWN ARSENAL
WATERTOWN, MASS.

REPRODUCED AT GOVERNMENT EXPENSE

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Report No. 710/485
Watertown Arsenal
Problem No. B-31

March 15, 1943

ARMOR PLATE

Metallurgical Examination of German Armor from a Pz. Kw. 111 Tank

The object of this study was to conduct a metallurgical examination of three face-hardened and two homogeneous sections of German armor which had been previously subjected to ballistic tests at the Proving Center, Aberdeen Proving Ground.

SUMMARY OF RESULTS

1. The five armor plates were composed of steel of two distinct types: (1) flame hardened, medium carbon, chrome-molybdenum-vanadium type deoxidized with aluminum; and (2) a flame hardened and homogeneous medium carbon, chrome-molybdenum type deoxidized with aluminum and titanium.

2. The five plates were heat treated as homogeneous armor to the following hardness levels:

1 plate	-	5/8" homogeneous armor	- 375 Brinell
1 plate	-	1-1/4" homogeneous armor	- 331 Brinell
3 plates	-	1-1/4" flame hardened armor	- 363 and 388 Brinell

A subsequent operation, probably flame hardening, was employed on the three face hardened plates to form a hardened face of 600 Brinell. The thickness of this zone was .090"-.110" on one plate, .140"-.200" on a second, and .210"-.230" on the third plate.

3. The armor was composed of good quality cross-rolled steel in which no undesirable nonmetallic segregations were observed. Considerable banding was present in the microstructure indicating the prevalence of the carbon and alloy segregations.

4. A splash shield on the back of the homogeneous armor escape door was composed of a 1/8" thick mild steel strip attached with an intermittent weld deposit analyzing approximately 5% manganese, 1½% chromium, and 1% nickel.

5. A flange section attached to one of the face hardened plates was a .25% carbon manganese-chrome-molybdenum steel which had been forged, carburized, and heat treated.

6. Comparatively poor penetration resistance of one of the flame hardened plates when impacted with 37 MM M80 A.P. projectiles is traceable to the relatively thin face hardened zone which was inadequate to break up the projectiles.

P. V. Riffin,
Assistant Metallurgist.

APPROVED:

H. H. ZORNIG
Colonel, Ordnance Dept.
Director of Laboratory

INTRODUCTION

Upon request of the Chief of Ordnance[1], Aberdeen Proving Ground submitted five armor plate sections[2] from a German Pz. Kw. III tank. The plates were subjected to extensive ballistic tests[3] at the Proving Center before being sent to this station. The individual sections were listed as follows:

a. One homogeneous plate from beneath the engine (3/4"x14"x31").

b. One face hardened plate (1-1/4"x23"x71").

c. One face hardened plate (1-1/4"x15"x75").

d. One face hardened plate (1-1/4"x14"x48").

e. One homogeneous armor escape door 1-1/4" thick (from the left side of the tank).

Photographs showing the effect of the ballistic tests on the five plates, which were included in the ballistic report[3] are omitted in this report.

Since plates b, c, and d were similar to the face hardened armor investigated previously[4], a detailed metallurgical investigation was not made on the subject plates.

TEST PROCEDURE

The plates were sectioned in the longitudinal and transverse directions for hardness surveys, macroscopic, and microscopic examination. Chemical analyses of the base metal of the five plates and the flange on plate c were obtained. A partial analysis of the weld metal on plate e was obtained. A carbon analysis of the outer .020" layer and the next .020" layer of the flange forging was made in order to confirm that this section was carburized.

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[1] O.O. 470.5/12636, A.P.G. 470.5/4492, see Ballistic Report, Appendix A.

[2] W.A. 470.5/5631, A.P.G. 470.5/4492A, see Appendix A.

[3] Ballistic Report No. AD-121 by Aberdeen Proving Ground, see Appendix A.

[4] Watertown Arsenal Report No. 710/458 - Metallurgical Examination of Section of German Face Hardened Armor from the Front of a Pz. Kw. III Tank.

RESULTS AND DISCUSSION

1. Visual Examination

The plates were painted overall with a dull red (iron-oxide type) paint. On the back of plate a this paint was covered with a greenish-grey paint which flaked off under ballistic impacts. The remaining four plates were painted on the face with a light tan paint, a major portion of which had already been worn off when the plates were received.

Some of the markings on the plates were lost during the ballistic tests, but those remaining were as follows:

Plate a

2HP66216
6741 012 E02517

Plate b

K 2512
388612
60087
144
12 3
21161

Plate c

1241 325 6000 3 "Brinell Mark"
- - - - -6207

Plate d

No distinguishable markings were observed.

Plate e

66217 AMP "Brinell Mark"
34879 289 41 34

The five sections contained rivet and bolt holes, many of which were countersunk. A 1/8" thick splash shield was welded on the back of the escape door (plate e). The steel strip was tacked to the armor with an intermittent weld whose sections were 2" to 4" long. In several of the sections the steel strip had separated from the base plate as a result of the weld failure which occurred in the weld metal directly adjacent to the mild steel and in the heat affected zone of the armor plate. In one area a welding crack was observed extending into the base metal perpendicular to the plate surface. Although this is a very undesirable condition, the extensive ballistic tests did not enlarge this crack unduly.

2. Thickness Measurements

Micrometer measurements, which showed a variation of as much as .013" in thickness along a transverse section of one of the plates, are

given below for the five plates and flange section.

Plate	Thickness of Plate in Inches Left Edge	Center	Right Edge	Converted to MM.
a	.622	.622	.622	16
b	1.232	1.245	1.240	31+
c	1.235	1.238	1.235	31+
d	1.232	1.237	1.233	31+
e	1.200	1.210	1.200	31-
Flange on b	1.185-1.190			30

3. Chemical Analyses

Complete analyses of the five plates, the flange and stud on plate c, and the mild steel splash shield and weld on plate e were obtained and the results are as follows:

Section	C	Mn	Si	S	P	Ni	Cr	Mo	V	Cu	Ti	Al
H. Plate a	.52	.70	.58	.029	.018	trace	1.39	.20	trace	.03	.065	.03
F.H. Plate b	.44	.97	.21	.026	.008	"	1.28	.38	.25	.19	nil	.02
F.H. Plate c	.53	.71	.49	.025	.015	"	1.47	.18	trace	.03	.07	.04
F.H. Plate d	.48	1.03	.64	.031	.007	"	.83	.23	.23	.17	nil	.04
H. Plate e	.54	.69	.49	.027	.016	"	1.25	.49	trace	.09	.07	.02
Carb. Flange	.25	1.01	.63	.028	.007	.18	1.27	.26	"	.09	nil	.01
Stud	.35	.79	.29	.029	.007	trace	.99	.15	.18	.25	nil	.02
Splash Shield	.07	.41	trace	.077	.049	"	.09	nil	nil	.10	nil	.02
Weld on Splash Shield		5.19				.99	11.46					

Carbon analysis of the outer .020" of the flange is .90%, and the next .020" layer analyses .83% carbon.

The 5/8" plate a and two of the 1-1/4" plates c and e are of approximately the same composition, a chrome-molybdenum type similar to S.A.E. 6150 with chromium and manganese on the high side. The 1-1/4" face

hardened plates b and d are a medium carbon chrome-molybdenum-vanadium type composition which is not equivalent to any of the S.A.E. or the new N.E. type compositions. The flange was the only section having a composition similar to that used at the present time in American armored vehicles, but even this section differed in that its chrome content is higher. With regard to the other sections the most important difference is the carbon content, for in our practice a maximum of .30% carbon is desired to simplify the welding procedure.

The analysis of the stud was similar to two German armor attachment bolts studied previously[5]. The alloy content is unusually high for a steel used in the given application.

The weld metal is similar to that observed in a previous study[5].

4. Hardness Surveys

Rockwell "C" and Brinell hardness surveys were made across the thickness of sections of the plates and flange. Then Rockwell "C" hardness surveys were taken on transverse sections, 1/16" from the edge of the hardened face of the face hardened plates. The readings were taken every 1/8". Since the results were fairly consistent and varied cyclically, only every fourth reading was tabulated in the diagrams of Figure 1 which show the results of the hardness surveys. Where the hardened zone was very thin as in plate b, the hardness impressions extended into the unhardened area, resulting in a low reading, i.e.: values of 45 and 53 on this plate.

A summary of the results are given in Table I.

TABLE I

Summary of Hardness Tests

Section	Core Hardness BHN	Core Hardness Rockwell "C"	Hardened Zone Rockwell "C"
5/8" Homo. Plate a	375	38-39	--
1-1/4" F.H. Plate b	388	38-40	55-60
1-1/4" F.H. Plate c	352/363	37-40	55-58
1-1/4" F.H. Plate d	352/363	36-38	57-61
1-1/4" Homo. Plate e	331/341	34-36	--
1-1/4" Carb. Flange	363	35-38	57-62

The results show that plate c possessed a lower face hardness than the other two flame hardened plates, and its hardened zone was not as deep. In the ballistic tests, the 37 MM M80 A.P. uncapped projectiles were broken up by plate b with the formation of face spalls, whereas the projectiles did not break up against plate c. Thus the ballistic limit was 500 f/s lower[3].

[5] Watertown Arsenal Report 710/472 - Metallurgical Examination of Armored Vehicle Components from a German Pz. Kw. III Tank.

The core hardnesses of the 1-1/4" flame hardened plates and the 1-1, 4" homogeneous plate are somewhat higher than those desired in American armor of the same thickness, for the subject armor probably would not have satisfactory shock properties against overmatching projectiles.

The 5/8" homogeneous plate a possessed a slightly higher hardness level than that desired in material exposed to overmatching projectiles. This fact is borne out in the tests with 20 MM A.P. projectiles which showed up the lack of ductility of this plate.

The hardness of the stud used to fasten the flange to plate c varied from Rockwell "C" 31 in the threaded zone to 42 in the head. The only explanation for this variation is the attempt to prevent failure of the threaded area of the bolts during a ballistic impact, because failure of this type is quite prevalent.

Hardness of the weld metal attached to the escape door, plate e, was found to be 380-400 Vickers. The heat affected zone hardness was 542 Vickers, and the mild steel was 154 Vickers hardness.

5. Macroscopic Examination

Results of macroetching longitudinal and transverse sections are shown in Figures 2-5. No undesirable nonmetallic segregations were observed in any of the sections examined. Since there was very little difference in etching characteristics between the longitudinal and transverse sections, it is felt that the steel was cross-rolled. Previous studies of German armor have shown that the Germans strive for extremely fine quality steel for use in armor plate[4,5].

The flange was forged from good quality steel, and as has been shown, was carburized.

The macroetching sharply delineated the hardened zone on the face hardened plates. The contour and formation of this hardened zone confirms the fact that it was made by a flame hardening operation. The heating element or elements were aligned parallel to the transverse direction of the plate and travelled at a uniform rate along the longitudinal direction. The hardened zone was greater on plates b and d than on plate c indicating that either the rate of travel of the heating element was greater or the heating was less intense in the preparation of plate c.

Measurements of the face hardened zone made on the macroetched section are as follows:

Section	Thickness in Inches
Plate b	.210-.230
Plate c	.090-.110
Plate d	.140-.200

7. Microscopic Examination

An examination of the steel in the unetched condition indicated that the plate was made at two different facilities. Plates a, c, and e contained both a sulfide type stringer and a titanium nitride type. Plates b and d contained a polyphase globular type inclusion as well as short stringers. All five plates were made from relatively clean steel free from nonmetallic segregations. There was very little difference in the nonmetallic condition between the longitudinal and transverse direction.

Plate a possessed an acicular tempered martensitic structure having a severe degree of banding. (Figures6A and B)

Plates b, d, and e were similar in structure, a sorbite having undissolved carbides in the banded areas. (Figures 6D and 7B.) The flame hardened zone of plates b and d was a martensitic structure as shown in Figure 7C. Since the structure of plate d was similar to b no photographs were obtained from this plate.

Plate c was similar to plate a and a plate investigated in a previous report[4] in which extensive photographs were taken and, therefore, no photographs of its microstructure are contained here.

The flange is composed of a low carbon martensite in the core (Figure 7E) and a high carbon martensite in the case (Figure 7F).

The weld metal used in securing the mild steel strip to the back of the door was completely austenitic, indicating that the Germans are successful in forming an austenitic weld deposit using a manganese-chrome-nickel steel. However, as was noted under the hardness test results, this structure is much harder than the ductile 18-8 austenitic deposits found in domestic welds.

8. General Considerations

a. Homogeneous Armor

The 5/8" homogeneous plate examined was made of good quality steel which was heat treated to a uniform hardness of 375 Brinell. The hardness is slightly higher than that desired in homogeneous armor of this thickness. Although it exceeds our resistance to penetration requirement by 60 f/s (Specification AXS-711), it did not withstand the shock test of overmatching projectiles in that excessive back spalling developed on complete penetrations.

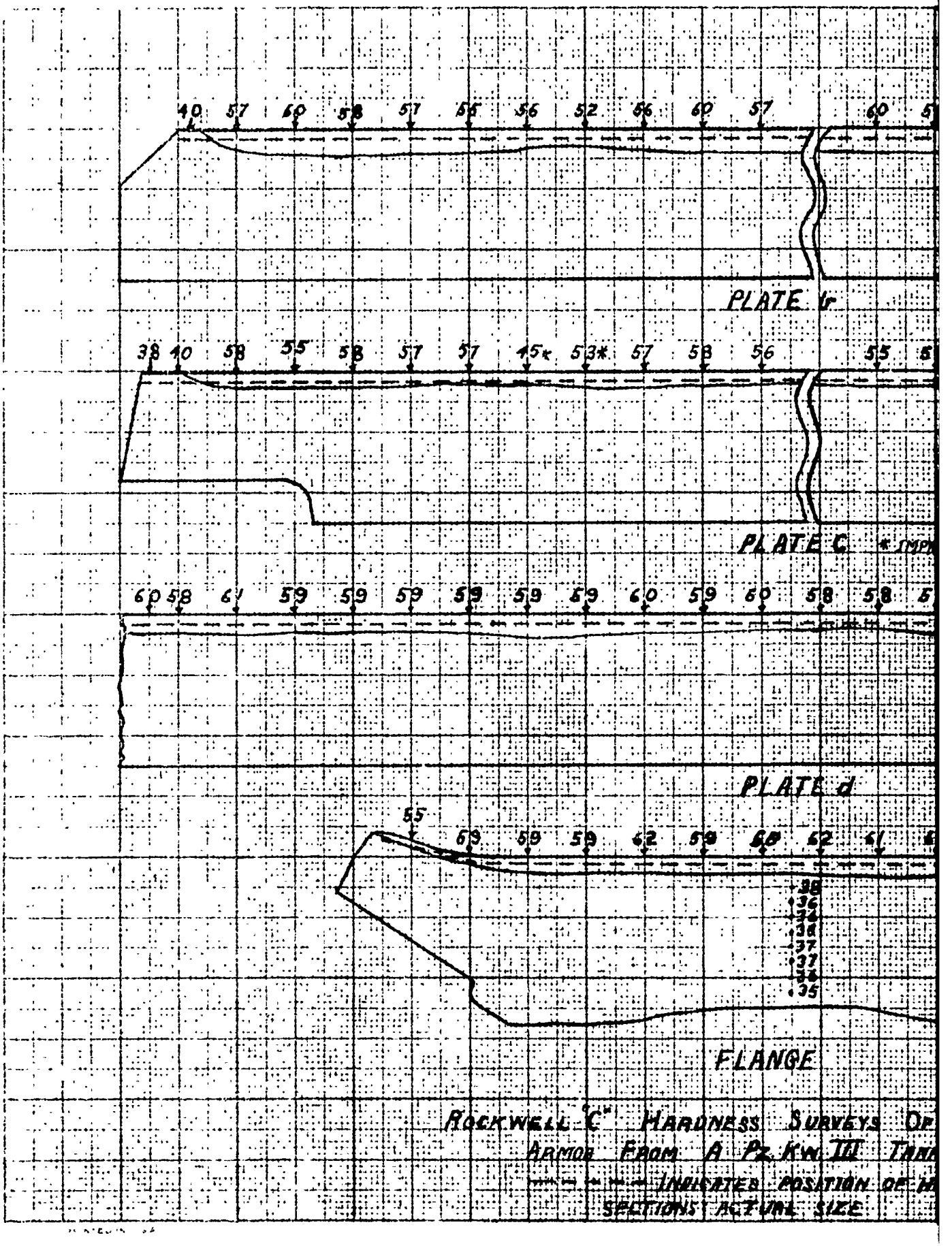
The 1-1/4" homogeneous plate was made of good quality steel which was heat treated to 331/341 Brinell. It passed the penetration requirement of Specification AXS-488 by about 40 f/s. Its hardness is higher than desired if plate is to have good shock properties against overmatching projectiles.

b. Flame Hardened Armor

Two of the plates (b and d) were similar in composition and flame hardening depth. Against capped projectiles they behaved similarly; the 37 MM M51 A.P.C. projectile penetrated plate b somewhat more successfully than the M59 did against plate d at normal incidence.

A marked difference in ballistic efficiency was observed between plates b and c when tested with the M80 uncapped projectile. Plate b which possessed a hardened zone of 15-20% of the thickness broke up the projectiles. Plate c, which possessed a hardened zone of under 10% of the thickness as well as a slightly lower core hardness, did not break up the projectiles, and the result was a ballistic limit 500 f/s. lower than in plate b. The ballistic efficiency of the two plates probably would not be markedly different against capped 37 MM M51 projectiles.

Overmatching projectiles would be expected to show up the poor ductility of all three flame hardened plates.



ROCKWELL "C" HARDNESS SURVEYS OF
ARMOR FROM A Pz. Kw. III TANK
---- INDICATES POSITION OF H
SECTIONS: ACTUAL SIZE

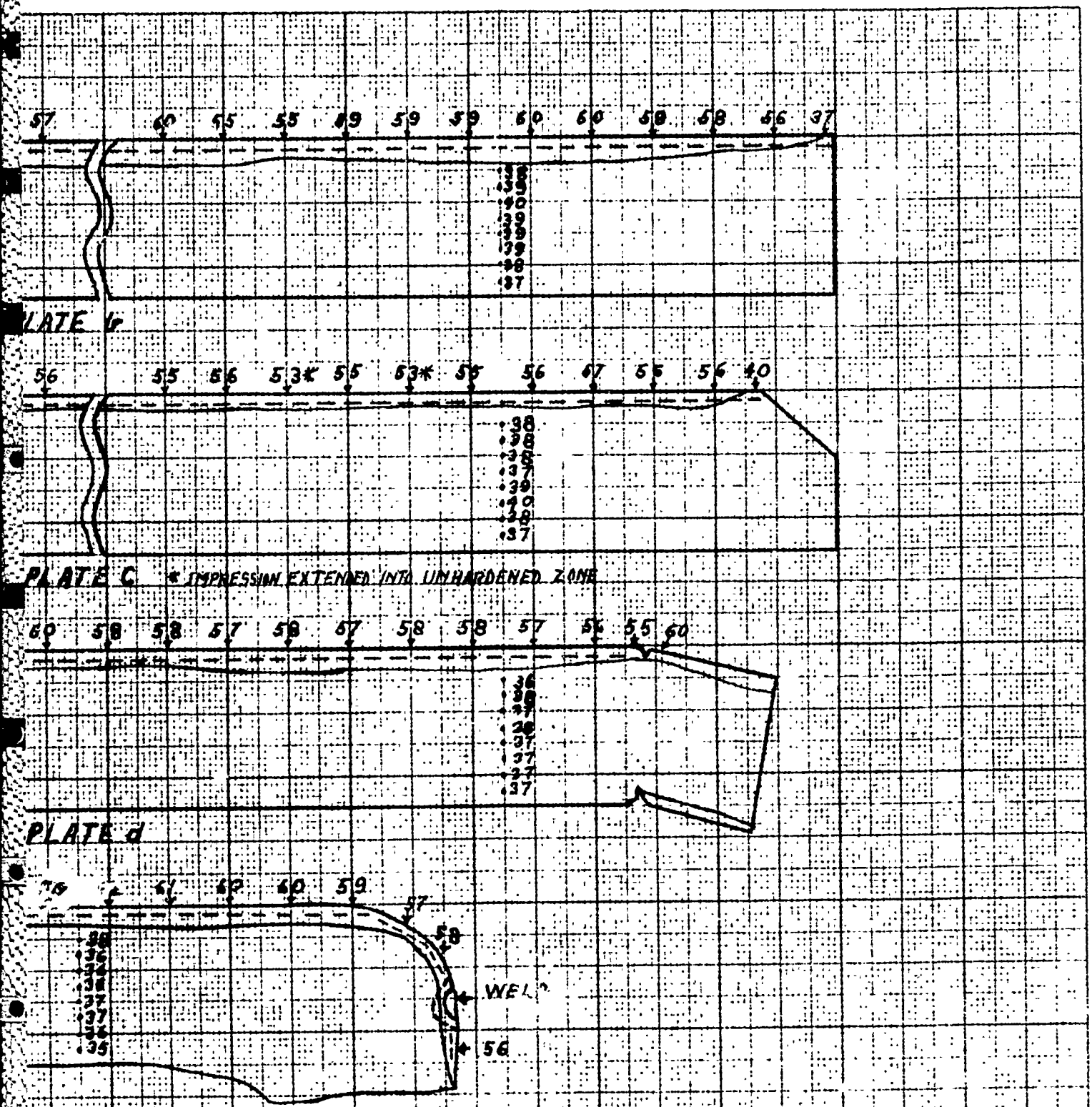


FIGURE 1

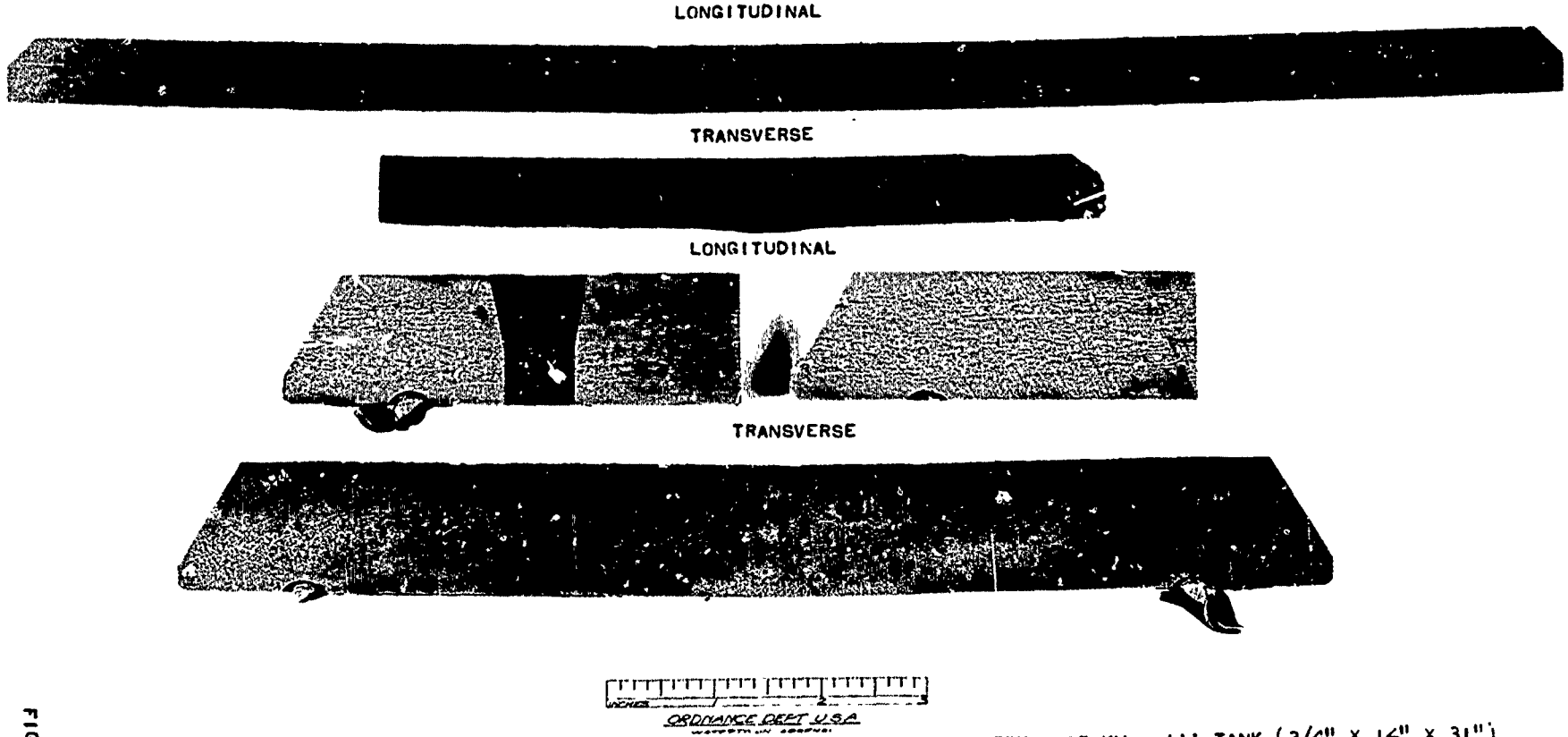


FIGURE 2

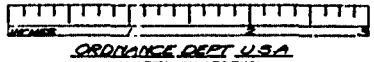
(TOP) MACROETCHED SECTIONS OF ARMOR PLATE FROM BENEATH THE ENGINE OF GERMAN PZ.KW. III TANK (3/4" X 14" X 31")
(BOTTOM) MACROETCHED SECTIONS OF ARMOR PLATE ESCAPE DOOR FROM LEFT SIDE OF GERMAN PZ.KW. III TANK. 1 1/4" THICK
JANUARY 22 1943

WTN.710-2006

LONGITUDINAL

TRANSVERSE

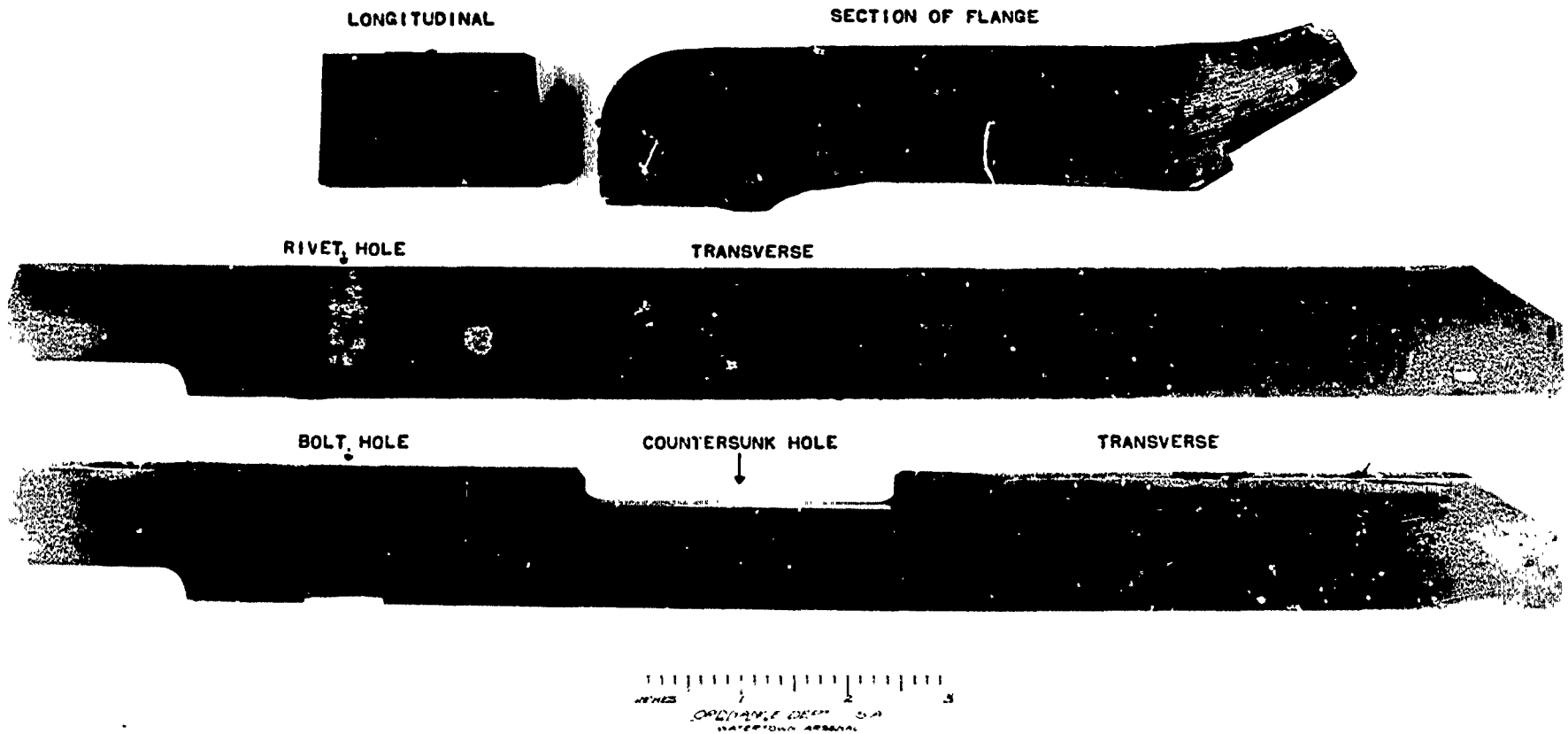
TRANSVERSE



ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

MACROETCHED SECTIONS OF ARMOR PLATE FROM GERMAN PZ.KW. III TANK (1 1/4" X 71" X 23")
JANUARY 22 1943 WTN.710-2007

FIGURE 3



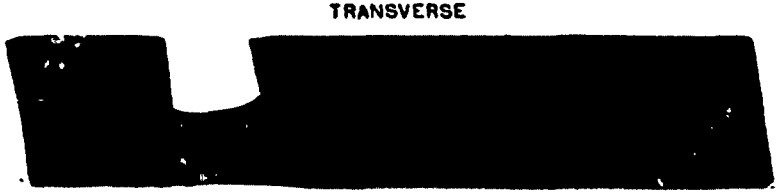
MACRO-ETCHED SECTIONS OF ARMOR PLATE FROM GERMAN PZ.KW. III TANK (1 1/4" X 75" X 15")
JANUARY 22 1943
WTN.710-2008

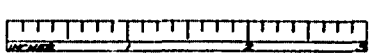
FIGURE 4

TRANSVERSE

LONGITUDINAL

TRANSVERSE



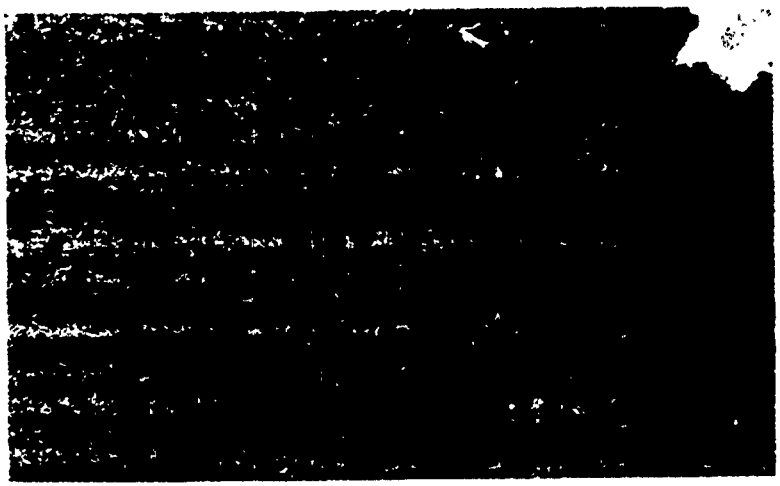


ORDNANCE DEPT U.S.A.
WATERTOWN ARSENAL

MACROETCHED SECTIONS OF ARMOR PLATE FROM GERMAN PZ.KW. III TANK (1 1/4" X 1-4" X 48")
JANUARY 22 1943 WTN.7[illegible]-2009

FIGURE 5

WTN.639-5001

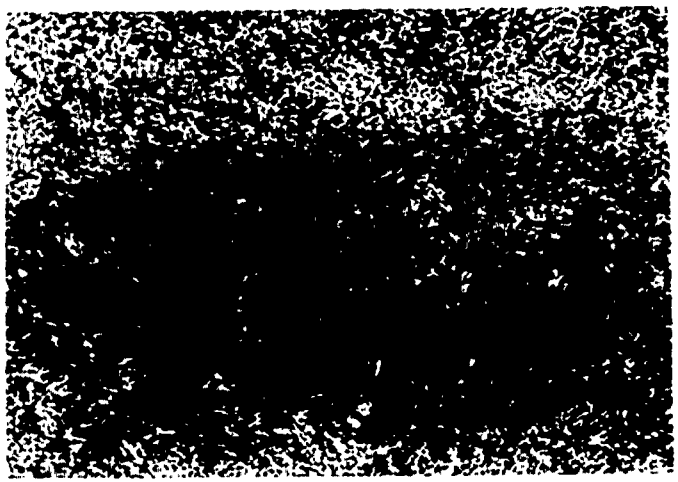


X100 -A- Picral-Nital
Banded Structure

X1000 -B- Picral-Nital
Tempered Martensite

Microstructure of Plate (a)

X100 -C- Picral-Nital
Banded Structure

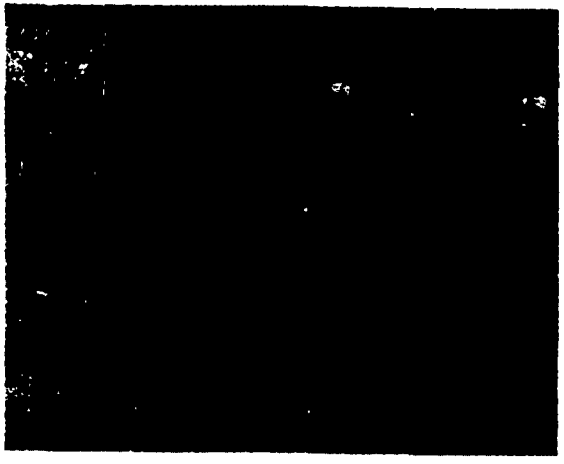


X1000 -D- Picral-Nital
Carbides in Tempered Martensite

Microstructure of Plate (e)

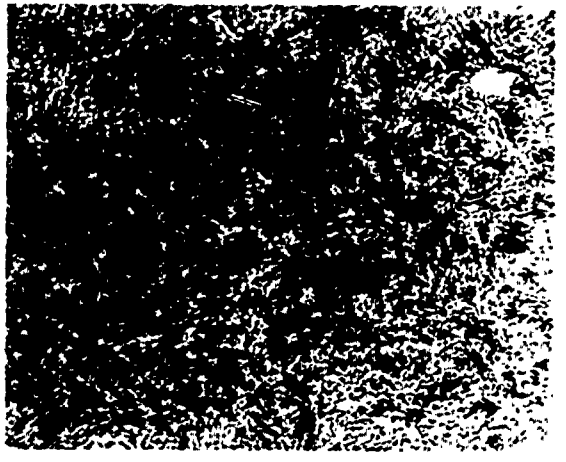
FIGURE 6

WTN.639-5002



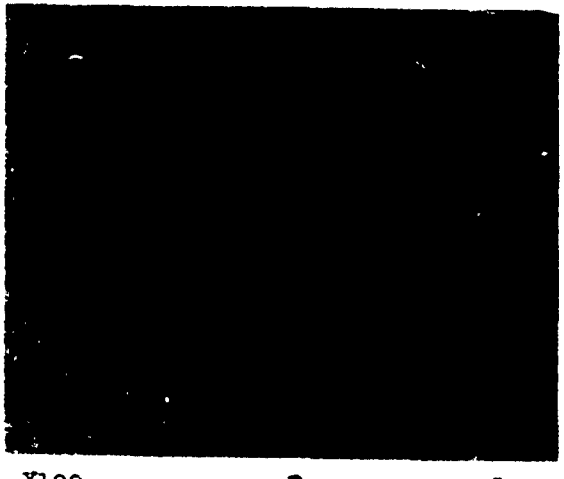
X100 -A- Core
Banded Structure

X1000 -B- Core
Carbides in Tempered Martensite



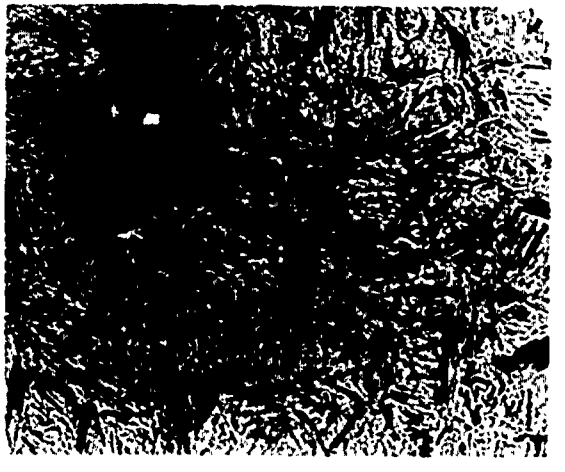
X1000 -C- Flame Hardened Zone
Martensite

Microstructure of Plate (d) - Etched in Picral Nital



X100 -D- Core
Absence of banding

X1000 -E- Core
Low Carbon Martensite



X1000 -F- Carburized Case
High Carbon Martensite

Microstructure of the Flange - Etched in Picral-Nital

FIGURE 7

APPENDIX A

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WAR DEPARTMENT
THE PROVING CENTER
ABERDEEN PROVING GROUND

MARYLAND

Armor Division
GA/beh

APG 470.5/4492A
WA. 470.5/5631

December 10, 1942

Subject: Metallurgical Investigation of German Armor

To: The Commanding Officer
Watertown Arsenal
Watertown, Mass.

1. By order of the Chief of Ordnance, letter of November 27, 1942, O.O. 470.5/12636. A.P.G. 470.5/4492, we are forwardi to your station via express, Shipping Order 7260, the following plat

1 Plate from beneath engine of German tank PZ111, 14" x 31" x 5/8" (Act. thickness 3/4")

1 Door escape, from left side of German Tank PZKW111 - 1-1/4" thick.

1 Plate from PZKW111 German tank - 1-1/4" x 71" x 23"

1 Plate from PZKW111 German tank - 1-1/4" x 75" x 15"

1 Plate from PZKW111 German Tank - 1-1/4" x 14" x 48" (two pieces, small piece broke off during ballistic test).

2. A copy of the results of your investigations is requested by this station.

3. A copy of the ballistic results obtained on these plates is being forwarded to your station at an early date.

For the Commanding General:

(S) H. J. ROUSE

(T) G. G. Eddy
Col., Ord. Dept.
Assistant

COPY

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THE PROVING CENTER
ABERDEEN PROVING GROUND, MARYLAND
ARMOR TEST REPORT

OBJECT: Ballistic Investigation of German Pz. Kw. 111 Armor

Report No.: AD-121
Sheet 1 of: 5
Date of test: Dec. 3 & 4, 1942

SUBMITTED BY:

Project No.: P-2-2
References: O.O. 470.5/12636
APG. 470.5/4492
Photo. Nos.: 74656, 74657, 74655
74658, 74659

MATERIAL TESTED:

1. The following armor from the German Pz. Kw. 111 Tank was tested:

a. One plate from beneath the engine 3/4" x 14" x 31"
b. One face hardened plate - 1-1/4" x 23" x 71"
c. " " " " 1-1/4" x 15" x 75"
d. " " " " 1-1/4" x 14" x 48"
e. " " " escape door 1-1/4" thick (from left side of tank)

CONCLUSIONS AND RECOMMENDATIONS:

1. From the data obtained in this firing it is indicated that German armor of this type is inferior to American homogeneous armor of corresponding thickness.

2. The face hardened plates were inconsistent in their resistance to penetration qualities. They cannot be compared to domestic armor since no American face hardened armor of this thickness is manufactured.

3. In order to obtain more accurate information regarding the ballistic qualities of this armor against domestic models of armor piercing projectiles it is necessary to test more samples.

4. This station is of the opinion that some domestic armor should be tested with armor piercing projectiles of German design fired from German anti-tank guns. By changing the components of these tests as stated complete results of this type of testing could be obtained.

APPROVED: BY:

W. B. HARDING (S/T) G. G. EDDY (S/T) G. C. AUMENT
Col., Ord. Dept. Col., Ord. Dept. Asst. Eng. Aide
Director Officer in Charge Proof Officer
Proof Department

THE PROVING CENTER
ABERDEEN PROVING GROUND, MARYLAND

OUTLINE OF TEST:

1. The plates were tested as follows:

a. Army and Navy ballistic limits on the 3/4" x 14" x 31" at 0° and 30° and Army B.L. only at 20° with 20 mm. M75 A.P. projectiles. An army ballistic at normal impact with cal. .50 M2, A.P.

b. Army and Navy ballistic limits at normal with 37 mm. M74 A.P., 37 mm. M51 A.P.C. and 37 mm. M80 A.P. projectiles on the 1-1/4" x 23" x 71" plate.

c. Army and Navy ballistic limits with the M80, A.P. at normal and at 20° with M51, A.P.C. against 1-1/4" x 15" x 71" plate.

d. Army and Navy ballistic limits with 37 mm. M59 A.P.C. at normal only on the 1-1/4" x 14" x 48".

e. Army ballistic limit with 37 mm. M51 A.P.C. projectiles at normal on the small escape door 1-1/4" thick.

RESULTS OF TESTS:

PLATE	THICKNESS	BHN	AMMUNITION	OBLIQUITY	BALLISTIC LIMITS ARMY	BALLISTIC LIMITS NAVY
14"x31"	3/4"	Face-418	Cal..50 M2 A.P.	0°	1666.5	
		Back-364	20 mm. M75, A.P.	0°	1026	1155
				20°	1679	-
				30°	1694	2044.5
23"x71"	1-1/4"	Face-600	37 mm. M74, A.P.	0°	1735	1865
		Back-320	37 mm. M51, A.P.C.	0°	1368.5	1395
			37 mm. M80, A.P.	0°	1611	1896
15"x75"	1-1/4"	Face-578	37 mm. M80, A.P.	0°	1052	1353.5
		Back-418	37 mm. M51, A.P.C.	20°	1646	1646
14"x48"	1-1/4"	Face-600	37 mm. M59 A.P.C.	0°	1443	1469.5
		Back-402				-
Escape Door 1-1/4"		-	37 mm. M51 A.P.C.	0°	1340	-

DETAILED RESULTS OF TEST:

1. The 3/4" x 14" x 31" plate had all the characteristics of hard homogeneous plate, of approximately 400 BHN. The Army ballistic limit at normal with cal..50 M2, A.P. was 213 f/s. lower than the applicable specification AXS 711. On the 20 mm. firing excessive back spalling occurred at normal impact when the striking velocities were 1088 f/s., 1090 f/s., 1120 f/s., and 1122 f/s. The resulting exit diameters of penetration ranged from 1-3/4" x 1-3/4" to 1-7/8" x 2"; this indicates lack of ductility of the plate.

2. The results of the firing on one German 1-1/4" x 23" x 71" face hardened plate (BHN, face-600, back-320) with the 37 mm. M51 A.P.C. projectile at normal impact show the Army ballistic limit to be 323 f/s. below an average army ballistic limit of eight (8) 1-1/2" face hardened domestic plates at normal impact. No existing specifications apply to American armor of this type and thickness. The Navy ballistic limit was only 27 f/s. higher than the Army ballistic limit, which that after the face hardening is penetrated very little additional velocity is required to enable the projectile to pass through the plate. Back spalling occurred at normal impact with the M51, A.P.C. but was not excessive, according to existing American Specifications. The 37 mm. M74, A.P. projectile was much less effective than the M51, A.P.C. against this armor due to its face-hardening. Neither the M74 A.P. nor M80 A.P. projectiles are designed for face-hardened armor, however, the M80, A.P. proved to be more effective against this armor than did the M74, A.P.

3. The 1-1/4" x 15" x 75" face-hardened plate had a very low ballistic limit with the M80 projectile at normal. This plate had a BHN of 578 on the face and 418 on the back. The ballistic limit, being 1052 f/s. with the M80, could not have been obtained with the M51 A.P.C. assuming that the difference, of 242 f/s., between ballistic limits with the two projectiles on the same plate, is fairly constant. The difference, of 242 f/s. between the M80, A.P. ballistic limit and the M51, A.P.C. ballistic limit, was found on the 1-1/4" x 23" x 71" plate. The Army and Navy ballistic limit of the 1-1/4" x 15" x 75" plate at 20° obliquity with the M51 A.P.C. was the same - 1646 f/s. which compares closely with the average ballistic limit (1692 f/s.) of the eight (8) 1-1/2", face hardened American plates previously mentioned, which were fired at normal.

4. Since the M59 projectile is capped it should be as effective as the M51 against this plate. The M59 ballistic cap contains more metal than the ballistic cap on the M51 because the M51 cap is threaded so a windshield can

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DETAILED RESULTS OF TEST (CONT'D)

be attached. This threading also weakens the ballistic cap of the M51. The Army ballistic limit with the M59 against the 1-1/4" x 14" x 48", face hardened plate was 1443 f/s. and the Navy ballistic limit was 1470 f/s. at normal, showing a difference of 27 f/s. as was the case with the M51 A.P.C. at normal against the 1-1/4" x 23" x 71" plate. Assuming that the M59 is as effective as the M51 against this type of plate, this particular plate would have better resistance to penetration qualities than any of the other German plates. This plate was the driver's door on the German Pz. Kw. III Tank and had a BHN of 600 on the face and 364 on the back.

5. The remaining piece of 1-1/4" face hardened armor was the escape door on the left side of the German Tank and had an Army ballistic limit of 1340 f/s. with the M51 A.P.C. at normal. This ballistic limit is 29 f/s. lower than the Army ballistic limit of the 1-1/4" x 23" x 71" piece at normal.

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Report No.: AP-121
Sheet No. 5 of 5

WAR DEPARTMENT

C.O. 470.5/12636
APG. 470.5/4492

OFFICE OF THE CHIEF OF ORDNANCE

WASHINGTON

SPORT Intel.

November 27, 1942

Subject: Tests on Armor Plate

To: The Director
The Proving Center
Aberdeen Proving Ground, Md.

ATTN: Major G. B. Speir - Foreign Materiel Section

1. In reference to the miscellaneous pieces of armor plate from a German Pz. Kw. III which are now at Aberdeen Proving Ground, it is requested that the following tests be made:

(a) Obtain the ballistic limit on the four (4) large pieces of 1-1/4" armor plate with Shot, A.P., 37 mm M80; Shot, A.P., 37 mm M74; and Shot A.P.C., 37 mm M51.

(b) Obtain the ballistic limit on the 14" x 31" piece of 5/8" armor plate with Shot, A.P., 20 mm, M75.

2. At the completion of the firing tests, the samples should be sent to Watertown Arsenal for metallurgical, physical and chemical tests.

By Order of the Chief of Ordnance:

/s/ E. S. DAVIS
Capt., Ord. Dept.
Assistant

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THE PROVING CENTER
ABERDEEN PROVING GROUND, MARYLAND
ARMOR TEST REPORT

OBJECT: Ballistic Investigation of German Pz. Kw. III Armor

Report No.: AD-121
Sheet 1 of: 5
Date of test: Dec. 3 & 4, 1942

SUBMITTED BY:

Project No.: P-2-2
References: O.C. 470.5/12636
APG. 470.5/4492
Photo. Nos.: 74656, 74657, 74655
74658, 74659

MATERIAL TESTED:

1. The following armor from the German Pz. Kw. III Tank was tested:

a. One plate from beneath the engine 3/4" x 14" x 31"
b. One face hardened plate - 1-1/4" x 23" x 71"
c. " " " " 1-1/4" x 15" x 75"
d. " " " " 1-1/4" x 14" x 48"
e. " " " escape door 1-1/4" thick (from left side of tank.)

CONCLUSIONS AND RECOMMENDATIONS:

1. From the data obtained in this firing it is indicated that German armor of this type is inferior to American homogeneous armor of corresponding thickness.

2. The face hardened plates were inconsistent in their resistince to penetration qualities. They cannot be compared to domestic armor since no American face hardened armor of this thickness is manufactured.

3. In order to obtain more accurate information regarding the ballistic qualities of this armor against domestic models of armor piercing projectiles it is necessary to test more samples.

4. This station is of the opinion that some domestic armor should be tested with armor piercing projectiles of German design fired from German anti-tank guns. By changing the components of these tests as stated complete results of this type of testing could be obtained.

APPROVED:

W. P. HARDIGG
Col., Ord. Dept.
Director

BY:

G. G. EDDY
Col., Ord. Dept.
Officer in Charge
Proof Department

G. C. AUMENT
Asst. Eng. Aide
Proof Officer

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ABERDEEN PROVING GROUND, MARYLAND

OUTLINE OF TEST:

1. The plates were tested as follows:

a. Army and Navy ballistic limits on the 3/4" x 14" x 31" at 0° and 30° and Army B.L. only at 20° with 20 mm. M75 A.P. projectiles. An army ballistic at normal impact with cal. .50 M2, A.P.

b. Army and Navy ballistic limits at normal with 37 mm. M74 A.P., 37 mm. M51 A.P.C. and 37 mm. M80 A.P. projectiles on the 1-1/4" x 23" x 71" plate.

c. Army and Navy ballistic limits with the M60, A.P. at normal and at 20° with M51, A.P.C. against 1-1/4" x 15" x 71" plate.

d. Army and Navy ballistic limits with 37 mm. M59 A.P.C. at normal only on the 1-1/4" x 14" x 48".

e. Army ballistic limit with 37 mm. M51 A.P.C. projectiles at normal on the small escape door 1-1/4" thick.

RESULTS OF TESTS:

PLATE	THICKNESS	BHN	AMMUNITION	OBLIQUITY	BALLISTIC LIMITS ARMY	BALLISTIC LIMITS NAVY
14"x31	3/4"	Face-418	Cal..50 M2 A.P.	0°	1666.5	
		Back-364	20 mm. M75, A.P.	0°	1026	1155
				20°	1679	-
				30°	1694	2044.5
23"x71"	1-1/4"	Face-600	37 mm. M74, A.P.	0°	1735	1865
		Back-320	37 mm. M51, A.P.C.	0°	1368.5	1395
			37 mm. M80, A.P.	0°	1611	1896
15"x75"	1-1/4"	Face-578	37 mm. M60, A.P.	0°	1052	1353.5
		Back-418	37 mm. M51, A.P.C.	20°	1646	1646
14"x48"	1-1/4"	Face-600	37 mm. M59 A.P.C.	0°	1443	1469.5
		Back-402				-
Escape Door	1-1/4"	-	37 mm. M51 A.P.C.	0°	1340	-

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DETAILED RESULTS OF TEST:

1. The 3/4" x 14" x 31" plate had all the characteristics of hard homogeneous plate, of approximately 400 BHN. The Army ballistic limit at normal with cal..50 M2, A.P. was 213 f/s. lower than the applicable specification AXS 711. On the 20 mm. firing excessive back spalling occurred at normal impact when the striking velocities were 1088 f/s., 1090 f/s., 1120 f/s., and 1122 f/s. The resulting exit diameters of penetration ranged from 1-3/4" x 1-3/4" to 1-7/8" x 2"; this indicates lack of ductility of the plate.

2.. The results of the firing on one German 1-1/4" x 23" x 71" face hardened plate (BHN, face-600, back-320) with the 37 mm. M51 A.P.C. projectile at normal impact show the Army ballistic limit to be 323 f/s. below an average army ballistic limit of eight (8) 1-1/2" face hardened domestic plates at normal impact. No existing specifications apply to American armor of this type and thickness. The Navy ballistic limit was only 27 f/s. higher than the Army ballistic limit, which that after the face hardening is penetrated very little additional velocity is required to enable the projectile to pass through the plate. Back spalling occurred at normal impact with the M51, A.P.C. but was not excessive, according to existing American Specifications. The 37 mm. M74, A.P. projectile was much less effective than the M51, A.P.C. against this armor due to its face-hardening. Neither the M74 A.P. nor M80 A.P. projectiles are designed for face-hardened armor, however, the M80, A.P. proved to be more effective against this armor than did the M74, A.P.

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DETAILED RESULTS OF TEST (CONT'D)

5. The remaining piece of 1-1/4" face hardened armor was the escape door on the left side of the German Tank and had an Army ballistic limit of 1340 f/s. with the M51 A.P.C. at normal. This ballistic limit is 29 f/s. lower than the Army ballistic limit of the 1-1/4" x 23" x 71" piece at normal.

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Report No.: AD-121
Sheet No. 5 of 5

WAR DEPARTMENT

O.O. 470.5/12636
APG. 470.5/4492

OFFICE OF THE CHIEF OF ORDNANCE

WASHINGTON

SPOBT Intel.

November 27, 1942

Subject: Tests on Armor Plate

To : The Director
The Proving Center
Aberdeen Proving Ground, Md.

ATTN: Major G.B. Speir - Foreign Materiel Section

1. In reference to the miscellaneous pieces of armor plate from a German Pz.Kw. III which are now at Aberdeen Proving Ground, it is requested that the following tests be made:

(a) Obtain the ballistic limit on the four (4) large pieces of 1½" armor plate with Shot, A.P., 37 mm M80; Shot, A.P., 37 mm M74; and Shot A.P.C., 37mm M51.

(b) Obtain the ballistic limit on the 14" x 31" piece of 5/8" armor plate with Shot, A.P., 20mm, M75.

2. At the completion of the firing tests, the samples should be sent to Watertown Arsenal for metallurgical, physical and chemical tests.

By Order of the Chief of Ordnance:

/s/ E. B. DAVIS
Capt., Ord. Dept.
Assistant

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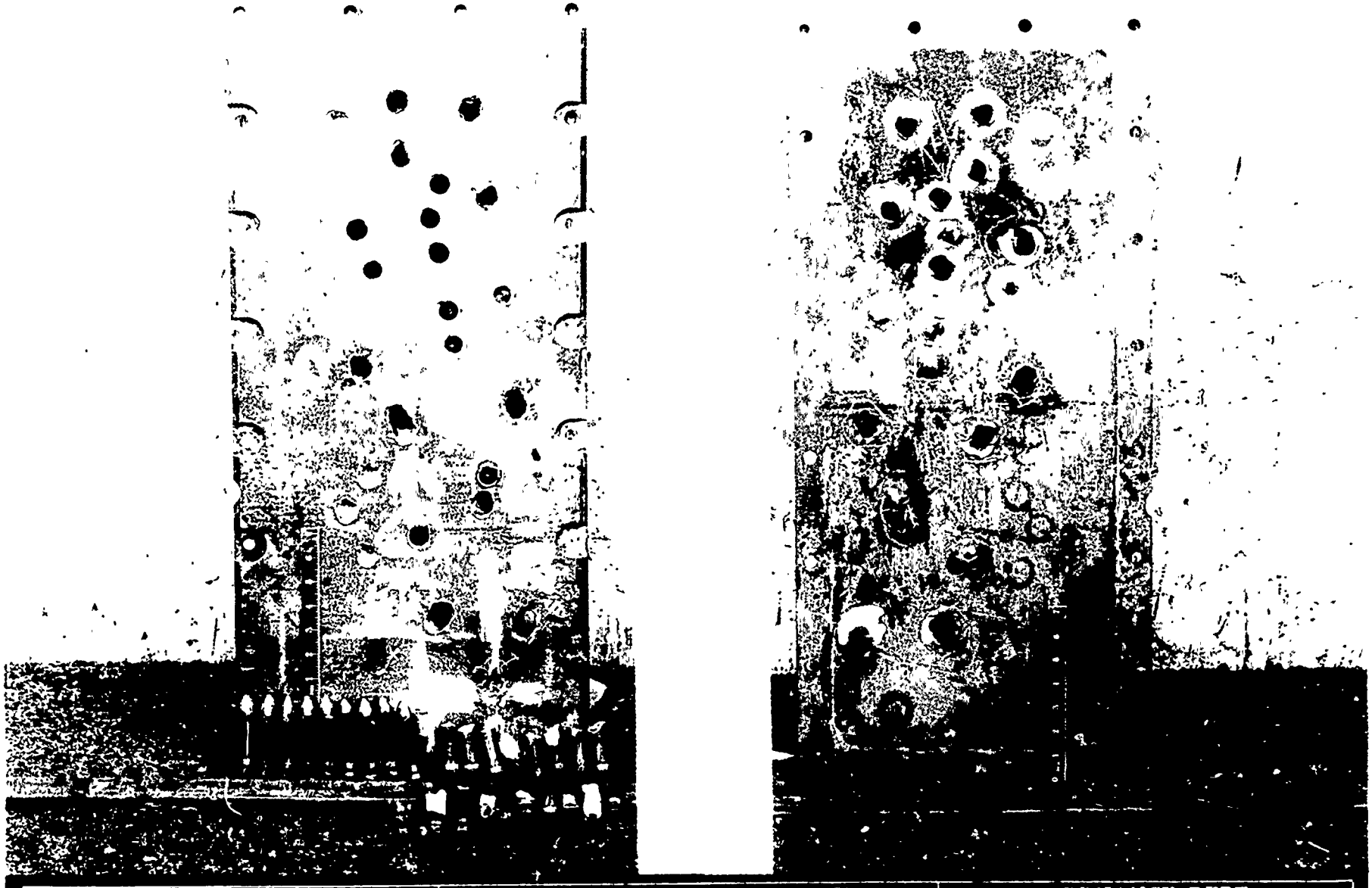
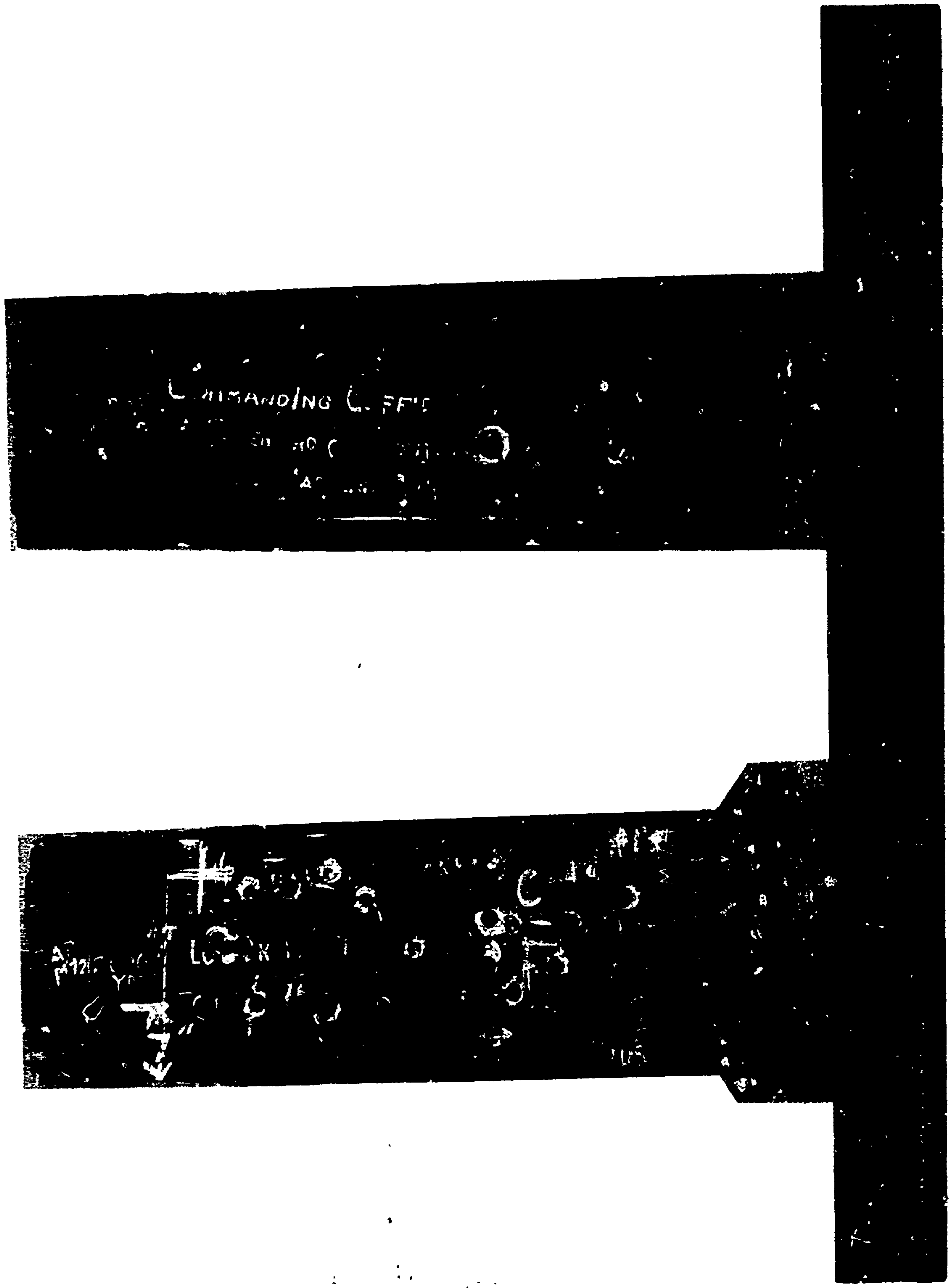
74655 12-4-42 ABERDEEN PROVING GROUND ORDNANCE DEPT.

Armor Plate Escape Door, from left side of German Pz. Kw. III Tank, fired with 37 mm M51 A. P. C. at normal.



74656 12-4-42 | ABERDEEN PROVING GROUND | ORDNANCE DEPT.

Armor plate from beneath the engine of Pz. Kw. III German Tank (3/4"x1½"x31") fired with 20 mm M75 A. P. at normal, 20° and 30°.




P.Z.III
74659 12-4-42 ABERDEEN PROVING GROUND ORDNANCE DEPT.
Armor plate from German Pz. Kw. III Tank (1½"x14"x48") fired for Army and Navy B. L.'s with 37 mm M59 A.P.C.