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BALLISTIC TESTS AND METALLURGICAL EXAMINATION OF JAPANESE HEAVY ARMOR PLATE

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BALLISTIC TESTS AND METALLURGICAL EXAMINATION OF JAPANESE HEAVY ARMOR PLATE

1. The U. S. Naval Technical Mission to Japan obtained a number of armor plates from the Japanese and forwarded them to the U. S. Naval Proving Ground, Dahlgren, Virginia. A representative number of these plates were tested ballistically and were subsequently given a metallurgical examination. The results of these tests are presented herein.

2. The ballistic tests were performed by the Plate Battery of the U. S. Naval Proving Ground, Dahlgren, Virginia, and the metallurgical examination was conducted at the Armor and Projectile Laboratory of the U. S. Naval Proving Ground, Dahlgren, Virginia, as part of the general program of investigation on foreign ordnance.

C. T. Joy

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Rear Admiral, USN
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PREFACE

AUTHORIZATION

Authorization for testing the Japanese armor plates was given by BuOrd Ltr. EF37(Re3a-G3) dated 15 August 1946.

OBJECT

This investigation was conducted to obtain ballistic and metallurgical information on Japanese Armor and to verify where possible the Japanese manufacturing methods reported by the U. S. Naval Technical Mission to Japan.

SUMMARY

Twelve Japanese heavy armor plates from 3" to 26" in gauge were tested ballistically in accordance with standard U. S. testing procedures. Where the plates were of the same gauge as U. S. armor the same test conditions were used. Following the ballistic test a complete metallurgical examination was made on each plate, including the following: chemical analysis, tensile data, Charpy V-notch data, normal tensile data, hardness distribution (Class A only) macrostructure, and microstructure.

Ten of the 12 Japanese heavy armor plates were found to be inferior to average quality U. S. armor. One plate, 7" Class A Plate No. 3133, was equal to the best U. S. armor of the same gauge. The 26" Japanese Turret Face plate could not be compared as no U. S. armor of this gauge has been manufactured. Experience with heavy U. S. armor, however, indicates this plate to be inferior also.

The metallurgical investigation revealed the Japanese plates to have inferior Charpy V-notch impact properties and to contain a greater amount of dirt than U. S. armor. The four Class A plates were found to have light chills and low face hardness. None of the metallurgical characteristics were found to be superior to those of U. S. armor.

Only those metallurgical data obtained by the Naval Proving Ground are contained in this report at present. Data obtained by the several U. S. Armor Manufacturers, Appendix (B) to this report, will be forwarded when received by the Naval Proving Ground.

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(b) NPG ltr A8-2(3)EF37(BPO 97993) dated 25 June 1946.

(c) BuOrd ltr EF37(Re3a-G3) dated 15 August 1946.

(d) U. S. Naval Technical Mission to Japan Report "Japanese Heavy Armor" dated January 1946.

(e) Hardness Conversion Chart for Hardened Steels H. Scott and T. H. Gray.

(f) NPG ltr A8-2(3)EF30(P 70245) dated 25 February 1947.

I. INTRODUCTION

The U. S. Naval Technical Mission to Japan located a number of plates at the Japanese Naval Proving Ground, Kamegakubi, Kurahashishima and at the Kure Naval Arsenal, Kure Navy Yard, Japan. Eighteen (18) of these plates of various thickness and compositions, both Class A and Class B armor, were forwarded to the U. S. Naval Proving Ground, Dahlgren, Virginia. A portion of this armor, as listed in reference (a), was forwarded to the United Kingdom for test and examination. A ballistic test for a representative group of 12 plates was proposed in reference (b). Further testing on the remaining plates was to be dependent upon the ballistic and metallurgical results on the first 12 plates. The list of plates and the conditions of test proposed by reference (b) and authorized by reference (c) is given below. The ballistic tests on the Japanese armor plate were conducted at the Naval Proving Ground during September and October 1946.

List of Japanese Heavy Armor Plates
Tested at the U. S. Naval Proving Ground

Plate No.	Gauge	Class	Test Condition	% of Ord. Sk. 78841 Est.B.L.	U.S.Average
JE-50-3133	7-1/4"	A	8" AP Mk. 21-3 at 30°	118±1	112.8
			8" AP Mk. 21-5 at 30°	110-111	109.7
JE-50-3124	13"	A	14" AP Mk. 16-8 at 30°	87±1	89.7
JE-50-3113	15"	A	14" AP Mk. 16-8 at 30°	82±1	89.6
Turret Face Plate	26"	A	16" AP Mk. 8-6 at 0°	90±3	--
JE-50-3114	3-1/4"	B	6" AP Mk. 35-5 at 30°	104-105	111.8
JE-50-3116	3"	B	6" AP Mk. 35-5 at 30°	107±1	110.6
JE-50-3120	3-1/4"	B	6" AP Mk. 35-5 at 30°	101-102	111.8
JE-50-3122	6"	B	8" AP Mk. 21-3 at 35°	98±1	107.2
JE-50-3123	6"	B	8" AP Mk. 21-3 at 35°	98±1	107.2
JE-50-3128	7"	B	8" AP Mk. 21-3 at 35°	94±1	105.4
JE-50-3118	9"	B	12" AP Mk. 18-1 at 35°	94-95	96.3
JE-50-3108	12"	B	14" AP Mk. 16-8 at 30°	91±1	95.1

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II. THE BALLISTIC TEST

1. METHODS

The testing of the plates was conducted in accordance with the standard testing procedure used for U. S. armor. Briefly this procedure was as follows: The plate to be tested was secured in butts approximately 400 feet from the gun. The plate was blocked to the desired degree of obliquity by means of wooden blocks which were backed by heavy steel supports set securely in the ground. Sand was piled behind the plate to stop the projectile and fragments. Obliquity was measured from the plane normal to the plate thickness. Velocity was measured by firing the magnetized projectile through coils of wire connected to recording oscillographs. The disturbance in the field of the coils caused by the passage of the projectile was recorded on photographic paper. Counter chronographs were also used as an added check. The limits are given herein in terms of percent of Ordnance Sketch 78841. The ballistic limits are estimated from the percentage figures for the striking velocities of the complete and incomplete penetrations on each plate. The striking velocity percentage is based on a 100% velocity obtained from the sketch. The 100% velocity can also be calculated from the following formula:

$$VL = \frac{F \times \sqrt{e} \times d}{41.57 \times \sqrt{m} \times \cos \theta}$$

Where VL = 100% velocity
e = plate thickness in inches
d = projectile diameter in inches
m = mass of the projectile in pounds
θ = angle of obliquity, degrees
F = Navy F coefficient, calculated thus:
$6\,(e/d - .45)(\theta^2 + 2000) + 40{,}000$

No attempt should be made to compare a limit at one set of conditions with a limit at another set of conditions on the basis of a lower or higher percent. The sketch is based on an empirical formula, consequently if average quality at one condition is below 100% there is no basis on which to consider this armor inferior to armor at another condition showing an average over 100%. The sketch does, however, furnish a convenient method of expressing limits in figures which are independent of minor gauge and obliquity variations and also facilitates corrections for variations of this type during the ballistic test.

2. TEST CONDITIONS AND RESULTS

The details of the ballistic test are summarized and the photographs of the ballistic test plates are presented in Figures 1 to 25. The results on each plate are discussed briefly below. In order to evaluate the data correctly certain U. S. armor and German armor limits are cited for comparison.

(a) 7".25 Class A Plate No. 3133 (Figures 1 and 2)

Versus the 8" AP Proj. Mk. 21-3 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3133	118±1
Average Quality U. S. Armor	112.8
U. S. Plate No. 1G469A1 (7.6" non cemented)	116-117
U. S. Plate No. RR324 (7"/3" cemented)	117±1
Versus the 8" AP Proj. Mk. 21-5 at 30° Obl.	
Japanese Plate No. 3133	110-111
Average Quality U. S. Armor	109.7
Highest U.S. Plate No. 1G469A1 (7.6" non cemented)	112±1
German Plate No. 33032 (8-1/2")	113±1

It can be seen from the above that plate No. 3133 is slightly superior to the highest U. S. plates when tested with the 8" AP projectile Mk. 21-3 but is slightly inferior when tested with the Mark 21-5 projectile. This plate is considered equal in quality to the best U. S. armor. It is the only one of the 12 plates tested to have a limit above the U. S. average.

(b) 13" Class A Plate No. 3124 (Figures 3 and 4)

Versus the 14" AP Proj. Mk. 16-8 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3133	87±1
Average Quality U. S. Armor	89.7

Plate No. 3124 is approximately 3% of Ordnance Sketch 78841 inferior to average quality U. S. armor tested under the same test conditions.

(c) 15" Class A Plate No. 3113 (Figures 5 and 6)

Versus the 14" AP Proj. Mk. 16-8 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3113	82±1
Average Quality U. S. Armor	89.6
German Plate No. 34563 (15")	97-98

Plate No. 3113 is approximately 7.5% of Ordnance Sketch 78841 inferior to Average Quality U. S. Armor tested under the same test conditions.

(d) 26" Class A Turret Face Plate (Figures 7, 8, and 9)

The estimated limit of the subject plate versus the 16" AP projectile Mark 8-6 at 0° obliquity is 90±3% of Ordnance Sketch 78841. No U. S. plate of similar gauge has ever been manufactured so no direct comparison of ballistic limits is possible. Early ballistic tests conducted on heavy Class A and B armor at low obliquity indicated that the limit of U. S. armor under similar conditions would approach 100%. It is interesting to note that, assuming the turret face plate was mounted at approximately 45° to the vertical, calculation indicates the inability of the modern 16" U. S. projectiles to penetrate a plate of this gauge at any range. However, as can be seen from Figure 7, the plate broke in half on both the complete and incomplete penetrations, and a failure of this type in service would partially, and perhaps completely, disable the turret.

(e) 3"25 Class B Plate No. 3114 (Figures 10 and 11)

Versus the 6" AP Proj. Mk. 35-5 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3114	104-105
Average Quality U. S. Armor	111.8

Plate No. 3114 is approxiamtely 7% of Ordnance Sketch 78841 inferior to average quality U. S. armor tested under same conditions.

(f) 3" Class B Plate No. 3116 (Figures 12 and 13)

Versus the 6" AP Proj. Mk. 35-5 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3116	107±1
Average Quality U. S. Armor	110.6
Highest U. S. Plate No. 051664	114±1
Lowest U. S. Plate No. 54E424133	106-107

Plate No. 3116 is comparable to the lowest quality 3" Class B plate tested under the same conditions at the Naval Proving Ground. It is approximately 4% of Ordnance Sketch 78841 inferior to U. S. Average Quality.

(g) 3.25" Class B Plate No. 3120 (Figures 14 and 15)

Versus the 6" AP Proj. Mk. 35-5 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3120	101-102
Average Quality U. S. Armor	111.8

Plate No. 3120 is approximately 10% of Ordnance Sketch 78841 inferior to average quality U. S. armor tested under the same conditions.

(h) 6" Class B Plate No. 3122 (Figures 16 and 17)

Versus the 8" AP Proj. Mk. 21-3 at 35° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3122	98±1
Average Quality U. S. Armor	107.2

Plate No. 3122 is approximately 9% of Ordnance Sketch 78841 inferior to average quality U. S. armor tested under the same conditions.

(i) 6" Class B Plate No. 3123 (Figures 18 and 19)

Versus the 8" AP Proj. Mk. 21-3 at 35° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3123	98±1
Average Quality U. S. Armor	107.2

Plate No. 3123 is approximately 9% of Ordnance Sketch 78841 inferior to average quality U. S. armor tested under the same conditions.

(j) 7" Class B Plate No. 3128 (Figures 20 and 21)

Versus the 8" AP Proj. Mk. 21-3 at 35° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3128	94±1
Average Quality U. S. Armor	105.4
German Plate No. 42711	105±1

Plate No. 3128 is approximately 11% of Ordnance Sketch 78841 inferior to both U. S. average quality and to 7" Class B German Plate No. 42711 tested under the same conditions.

(k) 9.75" Class B Plate No. 3118 (Figures 22 and 23)

Versus the 12" AP Proj. Mk. 18-1 at 35° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3118	94-95
Average Quality U. S. Armor	96.3

Plate No. 3118 is approximately 2% of Ordnance Sketch 78841 inferior to average quality U. S. armor tested under the same conditions.

(l) 12" Class B Plate No. 3108 (Figures 24 and 25)

Versus the 14" AP Proj. Mk. 16-8 at 30° Obl.	% of Ord. Sk. 78841
Japanese Plate No. 3108	91±1
Highest U. S. Plate No. TT200 (13.5")	96-97
Lowest U. S. Plate No. 9535 (13.5")	93.5-94.5
Highest U. S. Plate No. 10882 (10.5")	95-96
Lowest U. S. Plate No. 35E130A1 (10.5")	95±1
Average Quality U. S. Armor (13.5")	95.1
German Plate No. 42940 (12")	90±1

No U. S. 12" Class B plate has been tested at the Naval Proving Ground at these conditions. A comparison is made with 10.5" and 13.5" armor. The two 10.5" Class A plates listed above are the only plates of this gauge tested at the above conditions. Plate No. 3108 is approximately 4% of Ordnance Sketch 78841 inferior to average quality U. S. armor of similar gauge tested under the same conditions. Although the 14" AP projectile Mark 16-8 was broken up upon the incomplete penetration (see Figure 24), nc great significance is attached since several U. S. plates have rendered the same projectile ineffective on both complete and incomplete penetrations.

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III. SAMPLING PROCEDURE

1. Selection of Coupons

Upon completion of the ballistic test a metallurgical sample approximately 7" x 18" x the plate thickness was flame cut from each plate. Water was used to keep the samples cool during the cutting. In addition to the metallurgical sample for the Naval Proving Ground three 2' x 2' square sections were removed from each plate and one each forwarded to the following companies:

The Bethlehem Steel Corporation
The Carnegie-Illinois Steel Corporation
The Midvale Co.

It is understood that the coupons forwarded to these companies are to be metallurgically examined and the results of the examinations made available at a later date. When available, the results of these examinations by the companies will be forwarded under separate cover as Appendix (B) to this report.

Also samples from each of the following plates were forwarded to the British for examination and ballistic tests:

JE-50-3123	6" B	2 foot x 2 foot square
3116	3" B	2 foot x 2 foot square
3122	6" B	2 foot x 2 foot square
3128	7" B	2 foot x 2 foot square
3118	9-3/4"B	2 foot x 2 foot square
3133	7-1/4"A	2 foot x 2 foot square
3124	13" A	2 foot x 2 foot square
3113	15" A	2 foot x 2 foot square
JE-50-3108		One half of plate
3111		One half of plate
3114		One half of plate
3119		One half of plate
3120		One half of plate

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2. <u>Sectioning</u>

The 7" x 18" x plate thickness samples were sectioned in the laboratory on a water cooled abrasive cut off wheel. All tensile, normal tensile, and Charpy impact test specimens were cut from the 1/4 point, that is they were taken as nearly as possible in the area half way between the surface and center of the plate. This was done to permit comparison with U. S. armor physical tests which are taken from this area. Two hardness strips the full cross-section of the plate were taken from the center of the Class A plate samples. These strips were cut and surface ground carefully to prevent any burning in order that the true hardness pattern would be obtained.

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IV. METALLURGICAL TEST RESULTS

The detailed metallurgical test results are given in the tables and figures at the end of the report and are referred to in the summary of the metallurgical data given below.

1. Chemical Analysis

The analysis was determined for each of the 12 Japanese plates and is listed in Table II. Spectrographic analysis was used for all the elements except carbon and sulfur which were determined gravimetrically and phosphorus which was determined volumetrically. In addition to the elements reported in the table the spectrograph revealed no trace of Va, W, Sn, Pb, Zr and Ti.

Reference (d) gives the seven analysis types used by the Japanese and the specified chemical ranges for each type. From reference (c) and from comparing the chemical analysis determined in the laboratory with the specified ranges given in reference (d) the analysis type was established for each of the Japanese plates and is listed in Table II. With only a few minor exceptions the analyses fell within the specified ranges. The three analysis types not represented in Table II are as follows:

VC = Vicker's Cemented
CNC = Copper alloy, non-cemented
CNC_2 = Copper alloy, non-cemented

Types VC, VH and NVNC differed only in application and not in alloy content, all three being a nickel chrome composition similar to U. S. armor. Types MNC, CNC, CNC_2 were the result of experiments conducted to reduce the nickel and chrome by the substitution of molybdenum and copper.

It should be noted that the carbon content is much higher in the Japanese plates than in U. S. armor. This would tend to make the plates more difficult to treat and still maintain the desired ductility, but should aid in obtaining a higher face hardness in the non-cemented Class A armor. This was not accomplished, however, as can be seen from the hardness data presented in Figures 38 to 41. With the exception of the high carbon and the substitution of copper for nickel, the Japanese armor can be considered very similar in analysis to U. S. armor. From a hardenability standpoint the analyses appear to be sufficient for every gauge except the 26" turret face plate. With an oil quench as reported in reference (d) it seems unlikely that the center of this plate would quench out properly.

Although the plates were reported to be type VH (non-carburized) and the macroetched sections (discussed later) did not reveal a carburized zone, a check was made on the carbon in the face of one of the Japanese plates. The results given below show the lack of carburization and indicate some decarburization.

	Distance from the Surface in Inches							
	1/16	1/8	3/16	1/4	5/16	3/8	7/16	1/2
	Percent Carbon							
Plate 3133	0.37	0.46	0.49	0.50	0.51	0.51	0.51	0.51

2. Tensile Properties

The tensile properties of the 12 Japanese plates as determined by the U. S. Naval Proving Ground are listed in Table III. The first three Class A plates have tensile strengths very close to the U. S. average for each particular gauge although plate No. 3133 is slightly higher than average 7" U. S. armor. The low tensile strength of the 26" Turret face plate probably resulted from the inability of the Japanese to fiber such a heavy plate at higher tensile strength.

The tensile properties of the Class B plates fall well within the range expected for U. S. armor of similar gauge. The 9" and 12" plates have somewhat lower properties than recent U. S. plates of the same approximate gauges. The tensile results of the other plates however, fall within 4000 or 5000 psi of the U. S. average.

3. Charpy V-notch Properties

The Charpy V-notch impact data are given in Table IV and are plotted in Figures 26 to 37. In every case the Japanese plates had impact values below the average for U. S. plates of the same gauge. In some cases the values were the lowest yet determined at that gauge. On Class A armor they were only slightly inferior to the U. S. average but on the lighter gauge Class B armor they were very much lower. A few U. S. plates of 3" gauge have given impact values of better than 100 F* at -78°C and 80 FG# at -100°C in contrast to the Japanese plates which show about 45 FG at -50°C.

* F = Fibrous fracture
\# FG = Mostly fibrous, some grain

4. <u>Normal Tensile Properties</u>

The normal tensile properties given in Table V are the lowest of any group of plates yet tested. In almost every gauge category the Japanese armor was found to be lower than any previous plate tested. It should also be noted that for most of the plates the tensile strength found on the normal tensile test was considerably lower than that found on the standard tensile test. Coupled with the low elongation and reduction of area this lack of ductility indicates an excessive amount of dirt. A brittle granular fracture with considerable shelving was shown by all the Japanese plates on this test.

5. <u>Macrostructure</u>

Figures 42 to 53 present the results of the macro-etch test. In the photographs it can be seen that most of the Japanese plates were very dirty. It was also noted during the etching that the Japanese plates appeared to be much more porous and less resistant to acid attack. While the normal time of etching on U. S. armor has been found to be about one hour at 70°C the Japanese plates were heavily attacked in about one half hour.

The absence of carburization can also be observed in the macroetch tests on the Class A plates since there is no change in color at the face of the plate. The Class A etch specimens were annealed at 1200°F for 2 hours before etching and consequently no hardened zone would be revealed. However, a persulfate macroetch which is presented along with the hardness curves in Figures 38 to 41 does reveal the structural changes through the plate thickness and this shows that the plates were not carburized.

It was reported in reference (d) that plate No. 3124 and plate No. 3113 were forged, while the balance of the plates were rolled. Most of the plates show very straight flow lines and were undoubtedly rolled. Plates 3124 and 3113 do not show pronounced curved flow lines, and it is impossible to determine definitely from the macro-etch whether the plates were rolled or forged. The flow lines of the 26" Class A Japanese Turret face plate show some curvature indicating that is was probably forged.

6. <u>Hardness Distribution</u>

The hardness data for the Class A plates are presented in Figures 38 to 41 and in Table VI. All four of the plates have very light chills ranging from 20.5 to 26% which is very low when compared to U. S. standards. The hardness curves however, verify the Japanese practice as reported by reference (d). According to reference (d) the Japanese tried to obtain from 30 to 33% chill at 42 Shore hardness. Using a hardness conversion table (reference (e)) 42 Shore converts to 27 Rockwell "C". The hardness curves reveal the percentage over 27 Rockwell "C" to be slightly lower than 30% in each case. It is possible that the Japanese attempted to obtain 30%-33% chill on these plates but were unable to control the hardening process well enough.

Since reference (d) reports that the plates were heated to 850°C or above at the face it is hard to understand why the face hardness is so low. With the high base carbon of the plates and with no face carburization to cause retained austenite, the face should have attained a hardness of at least 60 Rockwell "C". On the final drawback the Japanese were reported to heat their plates to 150°C only, but the low face hardness makes this appear unlikely.

It is interesting to note that the 7" plate which performed well ballistically has the highest face hardness and deepest chill of the 4 Japanese Class A plates tested. Cross section hardness surveys were made on all the Class B plates. The hardness was fairly uniform across the section of each plate and the strength obtained in tensile tests adequately shows the relative hardness of each plate.

7. <u>Microstructure</u>

Typical microstructures are presented in Figures 54 to 57. The faces of the four Class A plates were all very similar, and consisted essentially of a martensite matrix with numerous undissolved carbides. The amount of undissolved carbides decrease near the plate surface but a large number remain, indicating that the plates were not heated to a temperature higher than that reported. No evidence of retained austenite was noted. The microstructure of the face of plate No. 3113 is shown in Figure 54(A).

The backs of the Class A plates and the Class B plates had similar microstructures. The structure showed a ferrite matrix with many spheroidized carbides (see Figure 54 (B) for the microstructure of Class A plate No. 3124 and Figure 55 for the microstructure of Class B plate No. 3128). Some of the carbides were quite large and apparently were undissolved carbides remaining from the austenitizing treatment. In certain of the Class B plates these undissolved carbides seem to be more numerous in bands indicating alloy segregation. An example of this is shown in Figure 56. The photomicrographs of plate No. 3128 were taken with a lens having a low resolving power in order that the carbide distribution could be more readily seen. From a spheroidized structure of this nature it is difficult to determine what prior quench structure existed, but since the Japanese gave their plates a timed quench in oil the structure before tempering was undoubtedly lower bainite.

The plates were all examined at 100X for dirt and were found to contain a number of long stringers of which Figure 57A is a typical case. Examination at higher magnification revealed these stringers to be complex sulfide silicate stringers (see Figure 57B). Examination at higher magnification of the unetched specimens also revealed clusters of what appeared to be alumina inclusions.

V. MANUFACTURING PROCESS

The manufacturing procedures followed by the Japanese are given in full detail in reference (d). In every case where this metallurgical investigation furnished information as to the manufacturing methods, the data given in reference (d) were verified with the possible exception of the final drawback temperature. Comparison of the U. S. practice with the Japanese practice shows that they are similar in many respects but differ significantly in the following:

1. The carbon content of Japanese armor is higher than U. S. armor.

2. The substitution of copper for nickel was made by the Japanese, as the result of a nickel shortage.

3. The acid open hearth was used by the Japanese instead of the basic open hearth.

4. Ingot to plate reduction was accomplished by forging and then rolling, whereas almost all American plates above 4" gauge are reduced entirely by forging.

5. The quench after austenitizing was in oil instead of in a water spray as used in U. S. practice.

6. The Japanese produced non-cemented armor for use on their ships while non-cemented U. S. armor has been used only for experimental and projectile test plates.

7. The Japanese attempted to obtain a much lower percent of chill in their face hardened plates.

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VI. DISCUSSION

On the basis of the 12 plates tested ballistically, Japanese armor is definitely inferior to U. S. armor. Only one plate, (7" Class A Plate No. 3133) was better than the U. S. average, being equal to the highest quality U. S. plate. This was also the only plate able to damage the projectiles significantly. The balance of the plates showed limits below the U. S. average, in some cases as much as 9 or 10%.

From a metallurgical standpoint the Charpy V-notch impact test revealed the plates to have poor impact properties and the normal tensile test, macroetch test, and microexamination showed the plates to have excessive dirt. This undoubtedly explains the poor performance of the homogeneous plates.

Since the above conditions also existed in the Class A plates and since all four plates showed a low face hardness and light chill it is hard to explain the performance of plate No. 3133. The amount of dirt necessary to affect the limit of a Class A plate is often greater than that for a homogeneous plate and perhaps the effect of dirt may be discounted in this instance. The impact ductility of plate No. 3133, while not high, was the best of the four Class A plates and as has already been pointed out plate No. 3133 had the hardest face and the deepest chill. In addition its back had the highest tensile strength. This combination of factors might account for the superiority of plate No. 3133 over the other three plates but seems insufficient to account for the very high limits found on this plate.

Prior to the testing of the 15" Class A German plate No. 34563 (reported in reference (f)), it was thought that a superior plate should have a high face hardness with the greatest depth of hardness that could be obtained consistant with at least 40% or more ductile, high strength back. Plate 34563 showed that it was possible to have a superior plate with all the above attributes except the high face hardness. It was felt that by drawing the face of their plates at a higher temperature than U. S. practice the Germans lost hardness but gained some impact ductility in the face.

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Plate No. 3133 judged from either of the above criteria has only a large amount of high tensile back to recommend it. The ballistic test shows that the high limit undoubtedly resulted from the ability of the plate to damage the projectile. Since this plate's chill characteristics differ so radically from those judged desirable and still performed well, it seems that a great amount of work must still be done in this field before optimum chill properties can be definitely stated.

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VII. RECOMMENDATIONS

1. In view of the above results, it is believed that no further ballistic testing is necessary and it is recommended that the ballistic tests of Japanese heavy armor be considered complete.

2. It is further recommended that an investigation of optimum chill characteristics be conducted on Class A armor.

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APPENDIX (A) TABLES AND FIGURES

TABLE I

List of Japanese Heavy Armor Plates Tested at the U. S. Naval Proving Ground

Plate No.	Gauge	Class	Test Condition	% of Ord. Sk. 78841 Est.B.L.	U.S.Average
JE-50-3133	7-1/4"	A	8" AP Mk. 21-3 at 30°	118±1	112.8
			8" AP Mk. 21-5 at 30°	110-111	109.7
JE-50-3124	13"	A	14" AP Mk. 16-8 at 30°	87±1	89.7
JE-50-3113	15"	A	14" AP Mk. 16-8 at 30°	82±1	89.6
Turret Face Plate	26"	A	16" AP Mk. 8-6 at 0°	90±3	-
JE-50-3114	3-1/4"	B	6" AP Mk. 35-5 at 30°	104-105	111.8
JE-50-3116	3"	B	6" AP Mk. 35-5 at 30°	107±1	110.6
JE-50-3120	3-1/4"	B	6" AP Mk. 35-5 at 30°	101-102	111.8
JE-50-3122	6"	B	8" AP Mk. 21-3 at 35°	98±1	107.2
JE-50-3123	6"	B	8" AP Mk. 21-3 at 35°	98±1	107.2
JE-50-3128	7"	B	8" AP Mk. 21-3 at 35°	94±1	105.4
JE-50-3118	9"	B	12" AP Mk. 18-1 at 35°	94-95	96.3
JE-50-3108	12"	B	14" AP Mk. 16-8 at 30°	91±1	95.1

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TABLE II

Chemical Analyses
Japanese Heavy Armor

Class A

Plate No.	Gauge	Analysis Type	C	Mn	P	S	Si	Ni	Cr	Mo	Cu
3133	7-1/4"	VH	.52	.39	.026	.036	.21	3.82	2.12	.04	.11
3124	13"	VH	.46	.43	.029	.031	.17	3.65	2.19	.06	.10
3113	15"	VH	.51	.37	.027	.037	.14	3.65	1.96	.06	.11
Turret Face	26"	VH	.48	.39	.016	.026	.18	3.67	2.13	.06	.12

Class B

Plate No.	Gauge	Analysis Type	C	Mn	P	S	Si	Ni	Cr	Mo	Cu
3114	3-1/4"	CNC_1	.50	.39	.021	.037	.16	2.25	2.25	.21	.79
3116	3"	CNC_1*	.41	.42	.029	.019	.27	2.22	1.81	.26	.85
3120	3-1/4"	NVNC	.47	.35	.021	.038	.18	3.36	2.02	-	.10
3122	6"	MNC	.36	.38	.022	.028	.11	3.25	1.93	.30	.11
3123	6"	NVNC	.54	.35	.023	.031	.17	3.72	2.01	-	.12
3128	7"	MNC	.38	.36	.025	.036	.12	3.30	2.00	.37	.10
3118	9"	MNC	.42	.41	.011	.031	.15	3.85	2.10	.42	.10
3108	12"	NVNC	.50	.38	.014	.034	.18	3.53	2.05	.06	.11

* All the above steel was made in the acid open hearth except plate No. 3116 which was made in the basic open hearth, (from reference (2)).

VH = Vickers hardened

CNC_1 = Copper non cemented

NVNC = New Vickers non cemented

MNC = Molybdenum non cemented

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TABLE III

Tensile Data
Japanese Heavy Armor

Class A

Plate No.	Gauge	Location	Y.S. (.2% Offset)	T.S.	% El.	% R.A.
3133	7-1/4"	Longitudinal	80,050	108,970	24.2	64.8
		Transverse	70,160	108,000	22.5	55.4
3124	13"	Longitudinal	81,700	102,500	25.5	64.6
		Transverse	63,780	100,250	26.0	57.5
3113	15"	Longitudinal	71,470	103,430	25.0	63.3
		Transverse	71,450	103,990	23.8	58.0
Turret Face	26"	Longitudinal	68,500	99,400	22.3	45.6
		Transverse	70,100	98,200	25.5	62.2

Class B

Plate No.	Gauge	Location	Y.S. (.2% Offset)	T.S.	% El.	% R.A.
3114	3-1/4"	Longitudinal	99,350	121,120	23.5	60.1
		Transverse	99,400	120,780	20.2	49.2
3116	3"	Longitudinal	92,830	121,160	22.5	60.2
		Transverse	86,120	119,160	22.8	54.4
3120	3-1/4"	Longitudinal	86,620	113,300	25.0	64.0
		Transverse	71,890	109,080	24.5	57.8
3122	6"	Longitudinal	96,000	119,200	22.8	63.5
		Transverse	93,800	118,900	21.2	57.0
3123	6"	Longitudinal	73,890	107,340	26.0	57.3
		Transverse	73,390	107,260	27.3	59.6
3128	7"	Longitudinal	87,500	114,600	22.8	60.1
		Transverse	89,800	114,650	19.8	50.9
3118	9"	Longitudinal	71,900	101,350	24.8	61.5
		Transverse	81,300	102,500	22.8	56.0
3108	12"	Longitudinal	87,050	102,400	23.3	64.2
		Transverse	80,400	101,200	19.5	48.2

Note: Each value listed here is the average obtained from two test specimens.

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TABLE IV

Charpy V-Notch Impact Data
Japanese Heavy Armor

Class A

Plate No.	Gauge	Location	-105	-78	-50	0	50	100
3133	7-1/4"	Longitudinal	30G	32G	60FG	74F	76F	88F
			28G	38G	63FG	70F	75F	94F
		Transverse	15G	27G	53GF	68F	60F	80F
			22G	32G	55GF	66F	60F	82F
3124	13"	Longitudinal	17G	26G	36FG	80F	74F	98F
			14G	27G	30FG	80F	78F	95F
		Transverse	10G	25G	27G	74F	54F	70F
			10G	14G	27G	75F	54F	82F
3113	15"	Longitudinal	20G	20G	38G	69FG	64F	88F(L)
			15G	19G	25G	56FG	70F	78F
		Transverse	15G	18G	23G	56FG	53F	72F
			15G	28G	23G	56FG	52F	68F
Turret Face	26"	Longitudinal	10G	23G	35G	73FG	75F	95F
			14G	20G	31G	77FG	94F	80F
		Transverse	8G	20G	30G	56FG	73F	70F
			9G	20G	26G	48FG	71F	69F

Class B

Plate No.	Gauge	Location	-105	-78	-50	0	50	100
3114	3-1/4"	Longitudinal	25G*	28GF*	28GF*	62F*	54F*	60F(L)
			20G*	30GF*	48GF*	52F*	56F*	64F(L)
		Transverse	15G	20G	28G	40F	52F	35F
			17G	20G	30G	38F	52F	34F
3116	3"	Longitudinal	24G*	49FG(L)	61F*	68F*	58F	82F(L)
			25G*	47FG(L)	65F*	70F*	60F	72F
		Transverse	25G	35GF	48FG	56F	56F	75F
			26G	31GF	47FG	52F	55F	76F
3120	3-1/4"	Longitudinal	20G	45GF	48FG	68F	65F	70F
			20G		50FG	62F	64F	74F
		Transverse	20G	39FG*	44FG*	55F	70F	64F
			17G	32GF*	48FG	55F	68F	62F

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TABLE IV
(Continued)

Charpy V-Notch Impact Data
Japanese Heavy Armor

Plate No.	Gauge	Location	-105	-78	-50	0	50	100
3122	6"	Longitudinal	19G	34G(L)	54FG	80F	68F(L)	70F(L)
			20G	30G	57FG	95F	75F	92F
		Transverse	15G	22G	46GF	67FG	62F	70F
			20G	22G	51GF	71FG	62F	60F
3123	6"	Longitudinal	30G(L)	46FG*	53FG*	53F*	54F	74F
			7G	48FG*	46FG*	54F	53F	64F
		Transverse	18G	40GF	55FG*	60F	58F	68F
			20F	45GF	58F	60F	66F	64F
3128	7"	Longitudinal	20G	34G	50GF	65F	68F	85F
			30G	37G	62GF	70F	70F	60F(L)
		Transverse	10G	26G	48FG	48F	44F	45F
			18G	26G	47FG	62F	45F	54F
3118	9".75	Longitudinal	7G	9G	25G	60FG	64F	74F
			7G	17G	22G	60FG	68F	73F
		Transverse	7G	18G	30G	80FG(L)	58F	60F
			7G	15G	25G	60FG	66F	70F
3108	12"	Longitudinal	20G	46G	47G	71FG	105F	110F
			20G	42G	32G	66FG	98F	110F
		Transverse	9G	48G	25G	65FG	58F(L)	68F
			21G	20G	25G	65FG	68F(L)	64F

Note:
- G = Grain
- GF = Mostly grain some fiber
- FG = Mostly fiber some grain
- F = Fiber
- L = Laminated
- * = Small splits

TABLE V

Normal Tensile Data
Japanese Heavy Armor

Class A

Plate No.	Gauge	Specimen No.	T.S.	% El.	% RA
3133	7-1/4"	1	96,190	6	20.2
		2	92,640	2	11.5
		3	98,220	5	15.3
		4	97,200	4	11.5
		5	106,700	9	18.9
		Average	98,200	5.2	15.5
		Variation High	106,700	9	20.2
		Low	92,640	2	11.5
3124	13"	1	101,810	20	42.6
		2	103,360	19	43.3
		3	102,420	21	45.7
		4	105,600	18	44.0
		5	102,220	19	45.7
		6	103,250	19	41.0
		Average	103,110	19.4	43.7
		Variation High	103,110	21	45.7
		Low	101,810	18	41.0
3113	15"	1	104,670	19	37.6
		2	104,970	22	52.7
		3	104,970	21	46.5
		4	104,970	21	48.3
		5	104,240	18	36.1
		6	104,870	22	50.5
		Average	104,780	20.5	45.2
		Variation High	104,970	22	52.7
		Low	104,240	18	36.1
Turret Face	26"	1	89,280	Broke outside of gage length	
		2	94,980	Broke outside of gage length	
		3	92,200	10.0	13.7
		4	95,100	9.0	3.2
		5	89,670	Broke outside of gage length	
		6	97,800	2.1	43.7
		Average	93,157	7.0	20.3

TABLE V
(Continued)

Normal Tensile Data
Japanese Heavy Armor

Class B

Plate No.	Gauge	Specimen No.	T.S.	% El.	% RA
3114	3-1/4"	1	111,600	3.0	9.4
		2	102,850	3.0	10.2
		3	104,700	2.0	11.0
		4	99,400	1.0	5.5
		5	100,200	2.0	8.6
		6	100,600	2.0	7.8
		Average	103,250	2.5	8.8
	Variation	High	111,600	3.0	11.0
		Low	99,400	1.0	5.5
3116	3"	1	112,400	5.0	10.2
		2	110,000	2.0	7.1
		3	116,100	4.0	7.8
		4	109,500	3.0	7.9
		5	116,500	5.0	6.3
		6	116,100	Broke outside of gage length	
		Average	113,450	3.8	7.9
	Variation	High	116,500	5.0	10.2
		Low	109,500	2.0	6.3
3120	3-1/4"	1	80,850	2.0	7.1
		2	69,650	2.0	4.1
		3	84,750	Broke outside of gage length	
		4	93,700	2.0	11.6
		5	90,850	1.0	7.8
		6	86,050	1.0	7.8
		Average	84,300	1.5	7.7
	Variation	High	93,700	2.0	11.6
		Low	69,650	1.0	4.1

TABLE V
(Continued)

Normal Tensile Data
Japanese Heavy Armor

Class B

Plate No.	Gauge	Specimen No.	T.S.	% El.	% RA
3122	6"	1	95,120	2	5.6
		2	105,560	3	12.3
		3	102,680	3	13.7
		4	97,140	5	11.9
		5	94,570	1	11.9
		6	107,010	4	10.8
		Average	100,350	3.0	11.0
	Variation	High	107,010	5	13.7
		Low	94,570	1	5.6
3123	6"	1	91,350	5	18.3
		2	104,400	10	7.8
		3	107,050	15	30.8
		4	106,800	11	9.4
		5	101,650	7	12.4
		6	93,400	3	9.4
		Average	100,800	8.5	14.7
	Variation	High	107,050	15	30.8
		Low	91,350	3	7.8
3128	7"	1	105,800	4.0	10.8
		2	91,000	1.0	4.8
		3	101,700	2.0	5.6
		4	92,800	2.0	9.4
		5	94,750	2.0	9.3
		6	93,200	2.0	7.0
		Average	96,550	2.5	7.7
	Variation	High	105,800	4.0	10.8
		Low	91,000	1.0	4.8

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TABLE V
(Continued)

Normal Tensile Data
Japanese Heavy Armor

Class B

Plate No.	Gauge	Specimen No.	T.S.	% El.	% RA
3118	9"	1	103,400	10.0	21.6
		2	104,400	19.0	33.3
		3	104,500	18.0	38.9
		4	103,200	15.0	30.7
		5	103,600	16.0	37.7
		6	103,700	15.0	32.5
		Average	103,800	15.5	32.5
	Variation	High	104,500	19.0	38.9
		Low	103,200	10.0	21.6
3108	12"	1	100,200	9.0	17.4
		2	103,200	12.0	21.6
		3	100,400	8.0	16.8
		4	102,200	8.0	14.6
		Average	101,500	9.3	17.6
	Variation	High	100,200	12.0	21.6
		Low	103,200	8.0	14.6

TABLE VI

Hardness Data

Japanese 7" Class A Plate No. 3133

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
Inches	Percent	1	2	Inches	Percent	1	2
	.8	51.0	50.5		36.2	20.0	19.5
1/8	1.7	53.0	50.5	3/4	37.9	20.0	19.0
	2.6	52.5	53.5		39.6	18.0	20.0
1/4	3.4	53.0	53.5	3"	41.4	19.0	19.0
	4.3	51.5	53.0		43.1	17.5	18.0
3/8	5.2	51.5	52.5	1/4	44.8	18.5	19.5
	6.0	51.5	52.0		46.5	18.5	18.0
1/2	6.9	51.5	52.0	1/2	48.3	18.0	19.5
	7.8	51.5	54.0		50.0	17.5	18.0
5/8	8.6	50.5	51.0	3/4	51.7	18.5	18.0
	9.5	49.5	50.0		53.4	18.5	19.0
3/4	10.3	49.5	49.5	4"	55.2	17.5	20.0
	11.2	48.5	48.0		56.9	21.5	15.5
7/8	12.1	47.0	47.0	1/4	58.6	20.0	18.5
	12.9	47.0	46.5		60.3	19.0	19.5
1"	13.8	45.5	46.5	1/2	62.1	18.5	16.5
	15.5	44.5	44.0		63.8	16.0	16.5
1/4	17.2	43.5	43.0	3/4	65.5	15.5	13.0
	19.0	42.5	41.5		67.2	16.5	17.5
1/2	20.7	40.5	41.5	5"	69.0	17.0	16.5
	22.4	39.5	40.0		72.4	16.0	16.0
3/4	24.1	35.0	39.5	1/2	75.8	17.0	16.0
	25.9	34.0	33.5		79.3	18.0	16.5
2"	27.6	31.0	31.0	6"	82.7	17.0	16.5
	29.3	29.0	29.0		86.2	17.5	18.0
1/4	31.0	26.0	25.5	1/2	89.6	18.5	18.5
	32.8	23.0	22.0		93.1	18.0	16.0
1/2	34.5	21.0	21.0	7"	96.5	18.0	15.5
					7-1/4" Back		

TABLE VI
(Continued)

Hardness Data

Japanese 13" Class A Plate No. 3124

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
Inches	Percent	1	2	Inches	Percent	1	2
	.5	49.0	50.5		31.4	19.0	19.5
1/8	1.0	50.5	51.5	1/4	32.4	20.5	20.5
	1.4	50.0	51.0		33.3	18.5	17.5
1/4	1.9	50.5	52.0	1/2	34.3	17.0	17.5
	2.4	50.5	51.0		35.2	16.5	18.0
3/8	2.9	50.5	51.0	3/4	36.2	17.0	17.5
	3.3	51.0	51.5		37.1	17.0	17.0
1/2	3.8	51.0	51.5	5"	38.1	16.0	19.0
	4.3	51.0	52.0		39.0	18.0	19.0
5/8	4.8	51.0	52.0	1/4	40.0	18.0	15.0
	5.2	48.5	52.5		41.0	15.0	16.0
3/4	5.7	52.0	52.5	1/2	41.9	16.5	15.5
	6.2	52.0	52.0		42.9	17.0	18.5
7/8	6.7	52.5	52.5	3/4	43.8	17.5	17.0
	7.1	52.5	52.0		44.8	16.0	17.0
1"	7.6	52.5	34.0	6"	45.7	16.0	17.0
	8.6	50.0	49.0		46.7	17.5	17.5
1/4	9.5	48.5	49.5	1/4	47.6	18.0	18.0
	10.5	47.0	47.0		48.6	20.0	16.0
1/2	11.4	45.5	45.0	1/2	49.5	16.0	15.5
	12.4	43.0	43.0		50.5	17.0	16.0
3/4	13.3	43.0	42.0	3/4	51.4	16.0	17.0
	14.3	41.5	41.5		52.4	17.0	16.0
2"	15.2	41.0	40.0	7"	53.3	16.5	17.5
	16.2	39.5	39.0		54.3	18.0	19.0
1/4	17.1	39.0	39.0	1/4	55.2	16.0	17.0
	18.1	40.0	39.0		56.2	14.5	18.0
1/2	19.0	37.5	38.0	1/2	57.1	15.0	15.0
	20.0	38.0	38.5		58.1	16.5	15.0
3/4	21.0	37.0	37.0	3/4	59.0	15.5	17.0
	21.9	37.0	34.0		60.0	14.5	14.5
3"	22.9	34.5	33.0	8"	61.0	16.0	14.5
	23.8	34.5	31.5		61.9	13.0	16.5
1/4	24.8	30.5	32.0	1/4	62.9	13.0	16.0
	25.7	28.0	29.0		63.8	17.5	17.5
1/2	26.7	26.0	25.5	1/2	64.8	17.5	17.0
	27.6	23.0	24.5		65.7	17.0	16.0
3/4	28.6	22.5	21.5	3/4	66.7	17.5	16.0
	29.5	24.0	24.0		67.6	18.0	15.5
4"	30.5	21.5	20.0	9"	68.6	17.0	17.0

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TABLE VI
(Continued)

Hardness Data

Japanese 13" Class A Plate No. 3124

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
Inches	Percent	1	2	Inches	Percent	1	2
	70.5	14.0	14.0		85.7	16.0	16.5
1/2	72.4	13.5	13.0	1/2	87.6	16.5	16.5
	74.3	15.0	14.5		89.5	16.0	18.0
10"	76.2	15.0	14.5	12"	91.4	16.0	18.5
	78.1	15.0	16.0		93.3	17.5	17.5
1/2	80.0	15.0	15.0	1/2	95.2	16.5	17.5
	81.9	15.5	16.0		97.1	16.5	18.0
11"	83.8	17.0	16.5	13"	99.0	16.5	
					13-1/8" Back		

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TABLE VI
(Continued)

Hardness Data

Japanese 15" Class A Plate No. 3113

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
Inches	Percent	1	2	Inches	Percent	1	2
	.4	37.5	33.5		27.7	25.5	26.5
1/8	.8	40.0	36.0	1/4	28.6	25.5	24.0
	1.3	41.5	37.5		29.4	22.0	21.5
1/4	1.7	42.0	38.0	1/2	30.3	20.5	20.5
	2.1	42.0	39.5		31.3	18.5	19.0
3/8	2.5	44.0	40.5	3/4	31.9	24.0	18.5
	2.9	42.0	41.0		32.8	19.5	17.5
1/2	3.4	43.5	42.0	5"	33.6	20.0	19.0
	3.8	45.0	43.0		34.5	19.0	18.0
5/8	4.2	47.5	43.0	1/4	35.3	19.5	17.5
	4.6	44.0	44.0		36.2	20.0	19.0
3/4	5.0	44.5	44.0	1/2	37.0	18.0	16.5
	5.5	46.0	44.5		37.8	17.0	16.0
7/8	5.9	45.0	44.0	3/4	38.7	21.0	17.5
	6.3	45.5	44.5		39.5	18.0	16.5
1"	6.7	46.0	45.0	6"	40.4	17.5	16.0
	7.6	46.0	46.0		41.2	10.0	16.0
1/4	8.4	46.0	45.5	1/4	42.0	15.0	16.0
	9.2	46.0	46.0		42.9	16.0	15.0
1/2	10.1	45.0	44.0	1/2	43.7	15.5	15.5
	10.9	44.0	43.5		44.6	16.0	16.0
3/4	11.8	43.5	43.0	3/4	45.4	12.5	16.5
	12.6	42.5	43.0		46.2	11.5	15.0
2"	13.5	41.5	41.5	7"	47.1	14.0	15.0
	14.3	41.0	42.0		47.9	-	-
1/4	15.1	42.0	39.5	1/4	48.8	-	-
	16.0	39.0	42.0		49.6	13.0	15.0
1/2	16.8	40.0	38.0	1/2	50.4	12.5	16.5
	17.7	39.0	37.5		51.3	16.0	16.0
3/4	18.5	38.0	37.5	3/4	52.1	16.0	16.0
	19.3	38.5	38.0		53.0	16.0	16.0
3"	20.2	37.5	29.5	8"	53.8	15.0	16.0
	21.0	37.0	36.5		54.6	15.0	16.0
1/4	21.9	37.0	36.0	1/4	55.5	14.0	15.5
	22.7	37.0	36.0		56.3	15.0	15.5
1/2	23.2	35.0	36.0	1/2	57.2	19.0	15.5
	24.4	35.0	34.0		58.0	15.5	16.0
3/4	25.2	33.0	33.0	3/4	58.9	15.0	15.5
	26.1	32.0	31.0		59.7	15.5	15.5
4"	26.9	29.0	29.0	9"	60.5	15.0	15.0

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TABLE VI
(Continued)

Hardness Data

Japanese 15" Class A Plate No. 3113

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
Inches	Percent	1	2	Inches	Percent	1	2
	61.4	13.0	14.5		79.0	17.0	16.0
1/4	62.2	15.0	15.0	12"	80.7	16.0	16.0
	63.1	15.0	17.5		82.4	16.0	17.0
1/2	63.9	15.0	16.0	1/2	84.1	16.0	17.0
	64.7	15.0	15.0		85.8	16.0	18.5
3/4	65.6	15.5	14.0	13"	87.4	15.5	17.0
	66.4	14.0	13.0		89.1	16.0	16.5
10"	67.3	15.0	15.5	1/2	90.8	17.0	16.5
	68.9	15.0	15.0		92.5	16.0	16.5
1/2	70.6	15.0	15.5	14"	94.2	15.5	16.0
	72.3	15.5	16.5		95.8	15.0	16.0
11"	74.0	15.5	16.0	1/2	97.5	15.5	16.0
	75.7	15.0	17.0		99.2	13.0	13.5
1/2	77.3	15.5	16.5		14-7/8" Back		

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TABLE VI
(Continued)

Hardness Data

Japanese 26" Turret Face Plate

Distance from Face: Inches	Distance from Face: Percent	Rockwell C Hardness: 1	Rockwell C Hardness: 2	Distance from Face: Inches	Distance from Face: Percent	Rockwell C Hardness: 1	Rockwell C Hardness: 2
	.3	46.5	46.5	3/4	14.4	38.5	38.5
1/8	.5	47.0	48.0		14.9	38.5	39.0
	.8	48.0	48.5	4"	15.4	38.5	39.0
1/4	1.0	48.0	47.0		15.9	38.5	41.5
	1.2	47.0	48.0	1/4	16.3	39.0	37.5
3/8	1.4	47.5	47.5		16.8	40.5	39.0
	1.7	47.5	48.5	1/2	17.3	38.5	39.0
1/2	1.9	47.0	47.5		17.8	38.5	38.5
	2.2	48.5	48.5	3/4	18.3	37.5	38.0
5/8	2.4	47.0	49.5		18.8	38.5	38.5
	2.7	47.5	47.5	5"	19.2	40.0	37.5
3/4	2.9	47.5	48.0		19.7	40.0	38.5
	3.2	47.0	48.0	1/4	20.2	36.5	36.0
7/8	3.4	48.0	47.5		20.7	34.5	33.0
	3.6	47.5	47.5	1/2	21.2	33.0	31.5
1"0	3.8	47.5	48.0		21.7	32.5	32.5
	4.3	47.5	48.0	3/4	22.1	31.5	30.5
1/4	4.8	47.5	48.5		22.6	31.5	30.5
	5.3	48.0	48.5	6"	23.1	29.5	29.5
1/2	5.8	48.0	49.0		23.6	25.5	23.5
	6.3	48.0	49.0	1/4	24.0	24.5	24.0
3/4	6.7	51.0	49.0		24.5	27.0	25.5
	7.2	50.0	48.5	1/2	25.0	25.0	25.0
2"	7.7	49.0	48.0		25.5	25.0	24.5
	8.2	48.5	47.0	3/4	26.0	23.5	23.5
1/4	8.7	46.0	46.0		26.5	22.5	22.5
	9.2	44.0	46.0	7"	26.9	22.5	21.5
1/2	9.6	43.5	44.5		27.4	20.5	21.5
	10.1	42.5	45.0	1/4	27.9	21.0	19.5
3/4	10.6	41.5	42.5		28.4	21.0	19.5
	11.1	41.0	41.5	1/2	28.8	19.0	19.5
3"	11.5	40.5	40.5		29.3	20.0	18.5
	12.0	40.5	40.0	3/4	29.8	17.5	18.5
1/4	12.5	40.5	39.5		30.3	18.0	17.5
	13.0	40.5	40.0	8"	30.7	17.5	17.0
1/2	13.4	39.0	39.0		31.2	16.0	17.0
	13.9	38.5	38.5	1/4	31.7	18.0	16.0
					32.2	16.0	16.5

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TABLE VI
(Continued)

Hardness Data

Japanese 26" Turret Face Plate

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
Inches	Percent	1	2	Inches	Percent	1	2
1/2	32.7	16.5	17.0	1/4	50.9	14.0	13.0
	33.2	17.0	17.5		51.4	14.0	13.0
3/4	33.7	17.0	17.5	1/2	51.9	14.5	14.5
	34.2	17.5	17.5		52.3	14.0	14.0
9"	34.6	17.5	16.5	3/4	-	-	-
	35.0	14.5	13.5		-	-	-
1/4	35.6	15.0	15.5	14"	53.8	11.5	11.5
	36.1	14.5	14.5		54.8	15.0	15.0
1/2	36.5	14.0	14.5	1/2	55.8	15.0	14.0
	37.0	15.0	15.0		56.8	15.5	14.0
3/4	37.5	14.0	14.5	15"	57.7	15.0	14.0
	38.0	13.5	14.5		58.7	15.5	14.0
10"	38.5	14.5	14.0	1/2	59.7	13.5	13.5
	39.2	13.0	13.0		60.6	14.5	13.5
1/4	39.4	13.5	13.5	16"	61.5	14.5	12.5
	40.0	12.5	15.0		62.5	14.5	13.0
1/2	40.4	13.5	16.5	1/2	63.5	13.0	14.0
	40.9	13.0	15.5		64.4	15.0	12.5
3/4	41.3	15.0	14.5	17"	65.3	13.0	12.0
	41.8	14.0	14.5		66.3	14.5	12.0
11"	42.3	13.5	14.5	1/2	67.3	12.5	13.5
	42.8	13.0	15.5		68.3	12.5	14.5
1/4	43.3	12.0	14.5	18"	69.2	14.5	13.5
	43.8	12.5	14.0		70.2	15.5	14.0
1/2	44.2	13.5	15.5	1/2	71.2	15.5	13.0
	44.7	13.5	15.0		72.2	14.0	11.0
3/4	45.2	14.5	15.0	19"	73.1	13.0	11.0
	45.7	14.0	15.5		74.1	13.5	11.0
12"	46.2	13.5	14.0	1/2	75.0	12.5	10.0
	46.9	13.5	15.0		76.0	13.5	13.0
1/4	47.1	12.5	14.5	20"	76.9	13.5	13.5
	47.3	12.5	14.0		77.4	13.0	13.5
1/2	48.1	14.5	14.5	1/2	77.9	13.5	10.5
	48.6	14.0	13.5		79.4	12.0	12.0
3/4	49.0	14.0	14.5	21"	80.8	10.5	12.0
	49.5	14.5	13.5		81.8	12.0	10.0
13"	50.0	14.0	13.5	1/2	82.7	11.5	11.5
	50.5	14.0	14.0		83.7	14.5	11.0

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TABLE VI
(Continued)

Hardness Data

Japanese 26" Turret Face Plate

Distance from Face		Rockwell C Hardness		Distance from Face		Rockwell C Hardness	
22"	84.6	11.5	11.5	24"	92.3	13.5	12.5
	85.6	11.5	11.5		93.3	11.5	12.5
1/2	86.5	14.0	11.0	1/2	94.2	12.5	12.5
	87.5	12.5	12.5		95.2	14.0	13.0
23"	88.5	13.0	13.0	25"	96.2	14.5	14.0
	89.5	11.5	12.5		97.2	13.0	14.5
1/2	90.4	13.5	12.5	1/2	98.1	14.5	14.5
	91.4	12.5	13.0		99.0	12.5	17.0

26" Back

[redacted]

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NP9-33777 - Ballistic Experimental Test and Limit Determination of 7"25 Class A Japanese Plate No. JE-50-3133 vs. 8" AP Projectile Mark 21 Mods. 3 and 5. 26 September 1946. [redacted]

View: Face of plate and sides of projectiles.

Proj. Mk.-Mod.	Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
21-5	33396	29-40	7.22	1627	Inc.	104.6	Proj. effective - nose chewed off - base slapped.
21-5	33398	29-30	7.21	1787	Comp.	115.4	Proj. effective with side slightly gouged.
21-5	33399	30-00	7.22	1706	Inc.	109.3	Proj. effective - nose chewed off - 1/3 base ring off.
21-5	33401	30-20	7.21	1748	Comp.	111.6	Proj. effective with side gouged and nose cracked.
21-3	33402	29-40	7.21	1808	Inc.	116.4	Proj. effective - nose chewed off - base slapped and body upset.
21-3	33403	29-30	7.21	1867	Comp.	120.5	Proj. not effective. Nose chewed off - body extruded - 3/4 base off from forward edge of band score back.

Estimated Ballistic Limit versus 8" AP Projectile Mk. 21-3 at 30° 118±1%

Estimated Ballistic Limit versus 8" AP Projectile Mk. 21-5 at 30° 110-111%

FIGURE 1

NP9-33778 - Ballistic Experimental Test and Limit Determination of 7.25" Class A Japanese Plate No. JE-50-3133 vs. 8" AP Projectile Mark 21 Mods. 3 and 5.
26 September 1946 - [redacted]

View: Back of plate.

Proj. Mk.-Mod.	Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
21-5	33396	29-40	7.22	1627	Inc.	104.6	Proj. effective - nose chewed off - base slapped.
21-5	33398	29-30	7.21	1787	Comp.	115.4	Proj. effective with side slightly gouged.
21-5	33399	30-00	7.22	1706	Inc.	109.3	Proj. effective - nose chewed off - 1/3 base ring off.
21-5	33401	30-20	7.21	1748	Comp.	111.6	Proj. effective with side gouged and nose cracked.
21-3	33402	29-40	7.21	1308	Inc.	116.4	Proj. effective - nose chewed off - base slapped and body upset.
21-3	33403	29-30	7.21	1367	Comp.	120.5	Proj. not effective - nose chewed off - body extruded - 3/4 base off from forward edge of band score back.

Estimated Ballistic Limit versus 8" AP Projectile Mk. 21-3 at 30° 118±1%

Estimated Ballistic Limit versus 8" AP Projectile Mk. 21-5 at 30° 110-111%

FIGURE 2

NP9-33783 - Ballistic Experimental Test and Limit Determination of 13" Class A Japanese Plate No. JE-50-3124 vs. 14" AP Projectile Mark 16-8. 3 October 1946 - [redacted]

View: Face of plate and sides of two projectiles.

Impact	Cbl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33413	29-40	13.22	1580	Comp.	89.4	Proj. effective with side gouged. Nose cracked after recovery.
33414	30-20	13.10	1512	Inc.	85.5	Proj. effective with side slightly gouged.

Estimated Ballistic Limit versus 14" AP Projectile Mk. 16-8 at 30° 87±1%

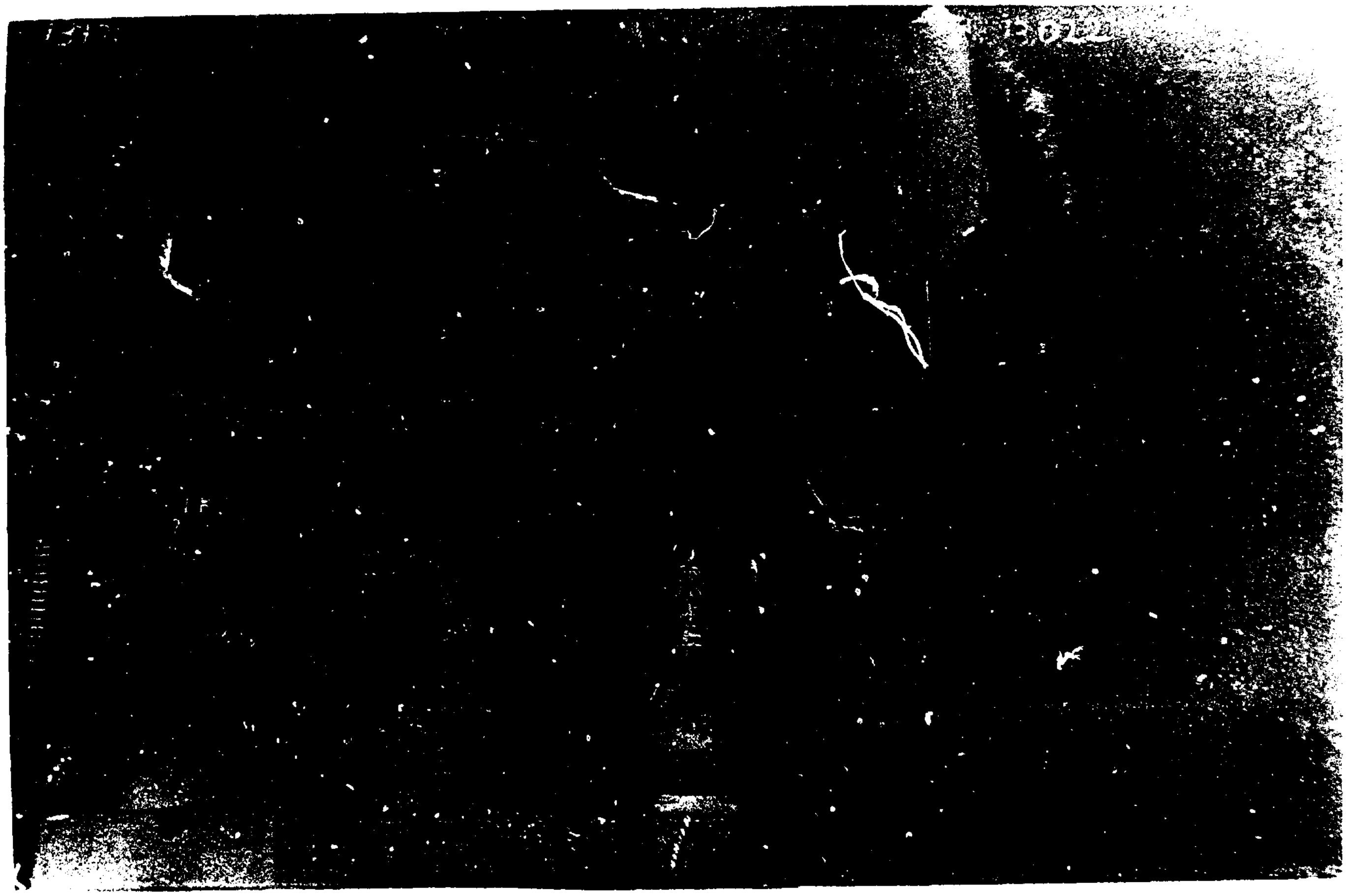

FIGURE 3

NP9-33784 - Ballistic Experimental Test and Limit Determination of 13" Class A Japanese Plate No. JE-50-3124 vs. 14" AP Projectile Mark 16-8. 3 October 1946 - [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33413	29-40	13.22	1590	Comp.	89.4	Proj. effective with side gouged - nose cracked off after recovery.
33414	30-20	13.10	1512	Inc.	85.5	Proj. effective with side slightly gouged.

Estimated Ballistic Limit versus 14" AP Projectile Mk. 16-8 at 30° 87±1%

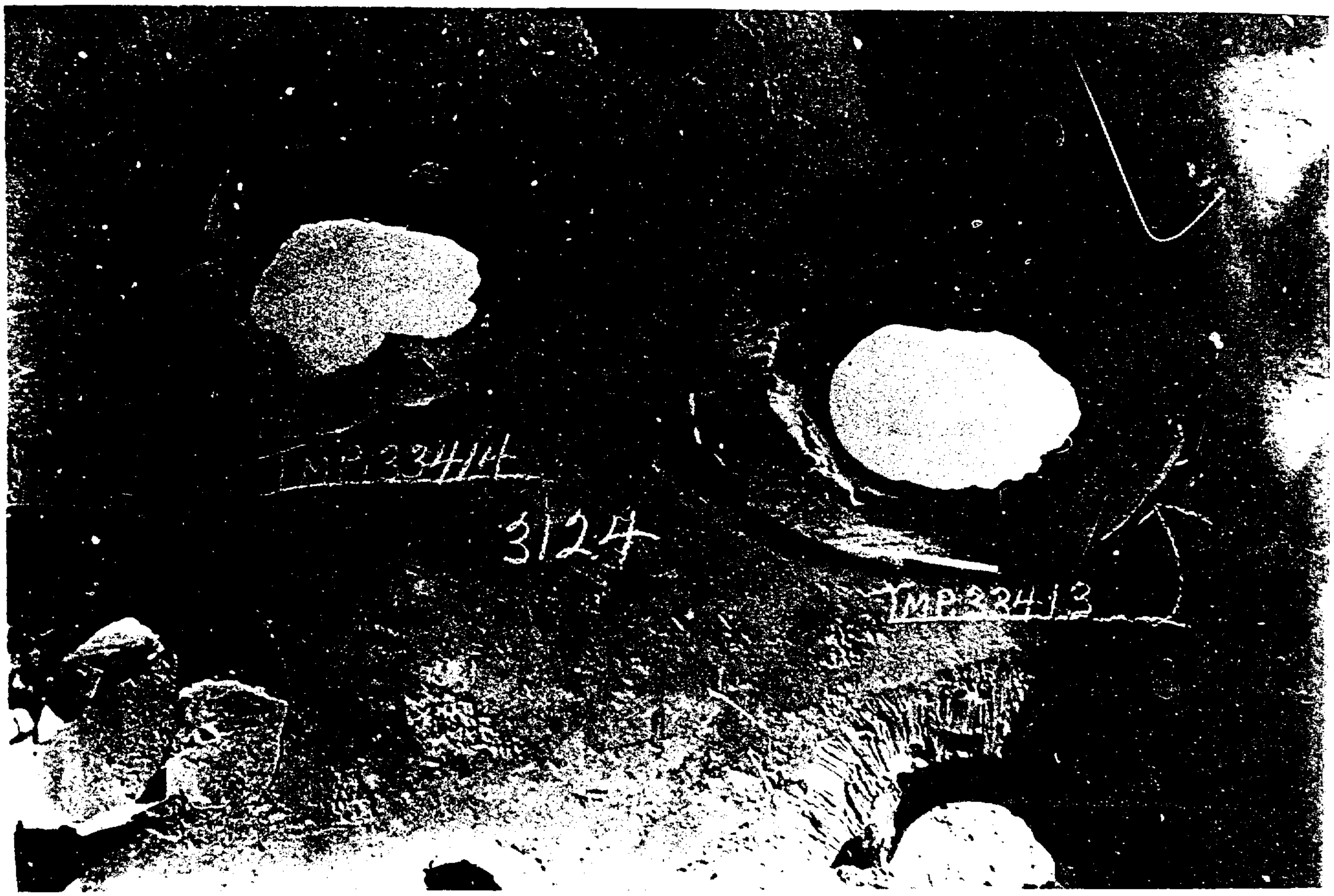

FIGURE 4

NPG-33978 - Ballistic Experimental Test and Limit Determination of 15" Class A Japanese Plate No. JE-50-3113 vs. 14" AP Projectile Mark 16-8. 9 October 1946 - [redacted]

View: Face of plate and sides of three projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33423	30-00	14.94	1739	Comp.	88.7	Proj. effective - nose cracked off.
33424	29-30	14.95	1555	Inc.	79.8	Proj. not effective - nose chewed off - body split longitudinally from nose to base.
33426	30-20	14.95	1657	Comp.	84.1	Proj. effective with side gouged and nose cracked.

Estimated Ballistic Limit versus 14" AP Projectile Mk. 16-8 at 30° 82±1%

FIGURE 5

TMB-33979 - Ballistic Experimental Test and Limit Determination of 15" Class A Japanese Plate No. JE-50-3113 vs. 14" AP Projectile Mark 16-8. 9 October 1946 - [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33423	30-00	14.94	1739	Comp.	88.7	Proj. effective - nose cracked off.
33424	29-30	14.95	1555	Inc.	79.8	Proj. not effective - nose chewed off. Body split longitudinally from nose to base.
33426	30-20	14.95	1657	Comp.	84.1	Proj. effective with side gouged and nose cracked.

Estimated Ballistic Limit versus 14" AP Projectile Mk. 16-8 at 30° 82±1%

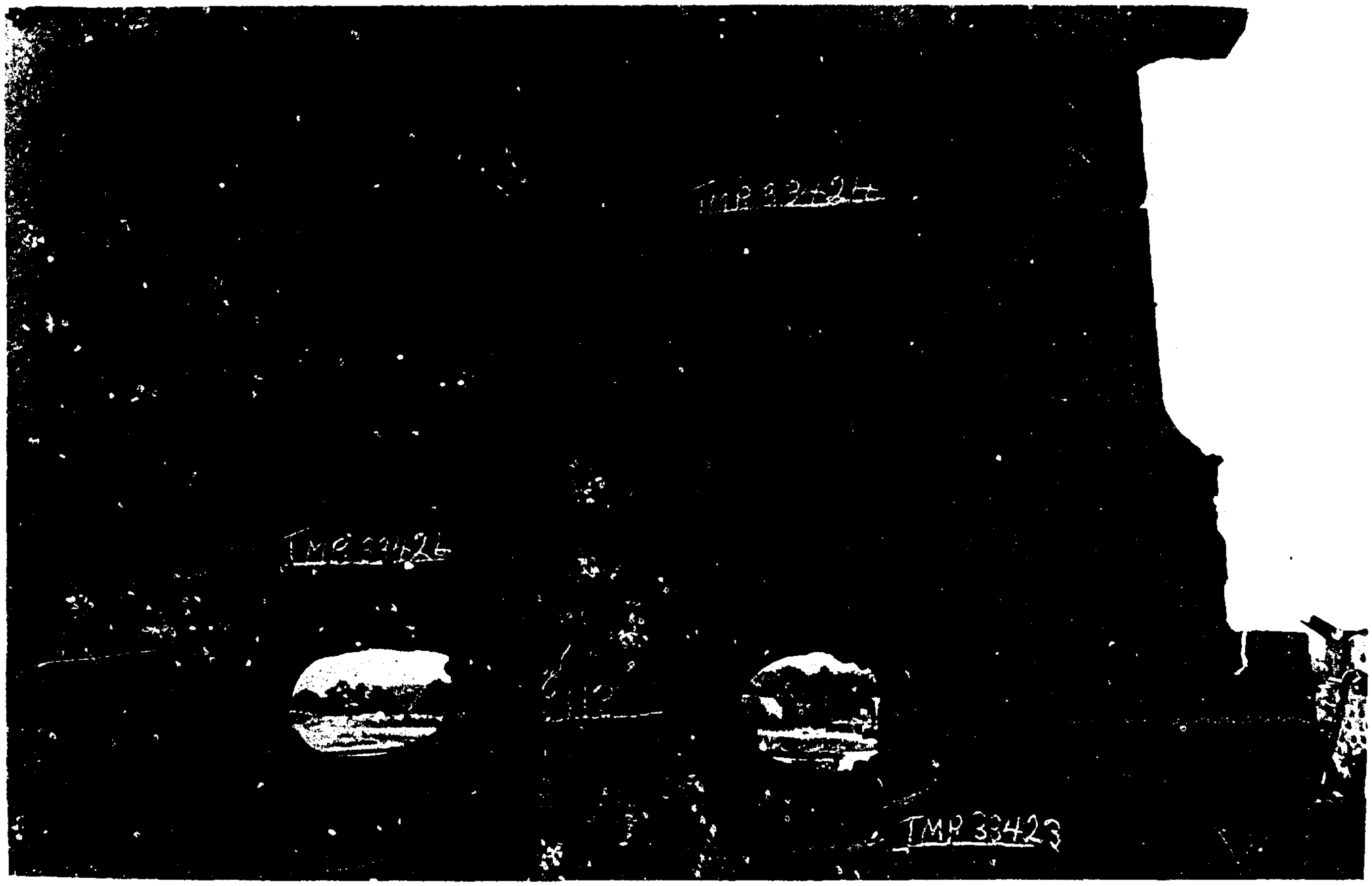

FIGURE 6

[illegible]-34246 - Ballistic Experimental Test and Limit Determination of 26" Class A Japanese Turret Face Plate vs. 16" AP Projectile Mark 8-6 at 0° Obl. 16 and 23 October 1946. [redacted]

View: Face of plate and side of one projectile.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33443	0-20	25.99	1992	Comp.	97.5	Proj. not recovered - plate broke into two pieces at impact point.
33459	0-30	25.99	1707	20"	83.6	Proj. effective and intact. Body slightly bent - plate broke into two pieces at impact point.

Estimated Ballistic Limit versus 16" AP Projectile Mk. 8-6 at 0° 90_30

FIGURE 7

NP9-34247 - Ballistic Experimental Test and Limit Determination of 26" Class A Japanese Turret Face Plate vs. 16" AP Projectile Mark 8-6 at 0° Obl. 16 October 1946. [redacted]

View: Face of plate.

Impact	Obl.	Thick.	B.V.(f.s.)	Pene.	%VL	Remarks
33443	0-20	25.99	1992	Comp.	97.5	Proj. not recovered. Plate broke into two pieces at impact point.

Estimated Ballistic Limit versus 16" AP Projectile Mk. 8-6 at 0° 90±3%

FIGURE 8

[illegible] - Ballistic Experimental Test and Limit Determination of 26" Class A Japanese Turret Face Plate vs. 16" AP Projectile Mark 8-6 at 0° Obl. 23 October 1946 [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33443	0-20	25.99	1992	Comp.	97.5	Proj. not recovered. Plate broke into two pieces at impact point.

Estimated Ballistic Limit versus 16" AP Projectile Mk. 8-6 at 0° 96.3%

FIGURE 9

NP9-33775 - Ballistic Experimental Test and Limit Determination of 3725 Class B [redacted]
Plate No. JE-50-3114 vs. 6" AP Projectile Mark 35-5. 26 September 1946 - [redacted]

View: Face of plate and sides of projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33395	29-40	3.18	1109	Inc.	103.5	Proj. effective and intact
33397	29-40	3.17	1163	Comp.	108.7	Proj. effective and intact
33400	29-40	3.16	1138	Comp.	106.6	Proj. effective and intact

Estimated Ballistic Limit versus 6" AP Projectile Mk. 35-5 at 30° 104-105%

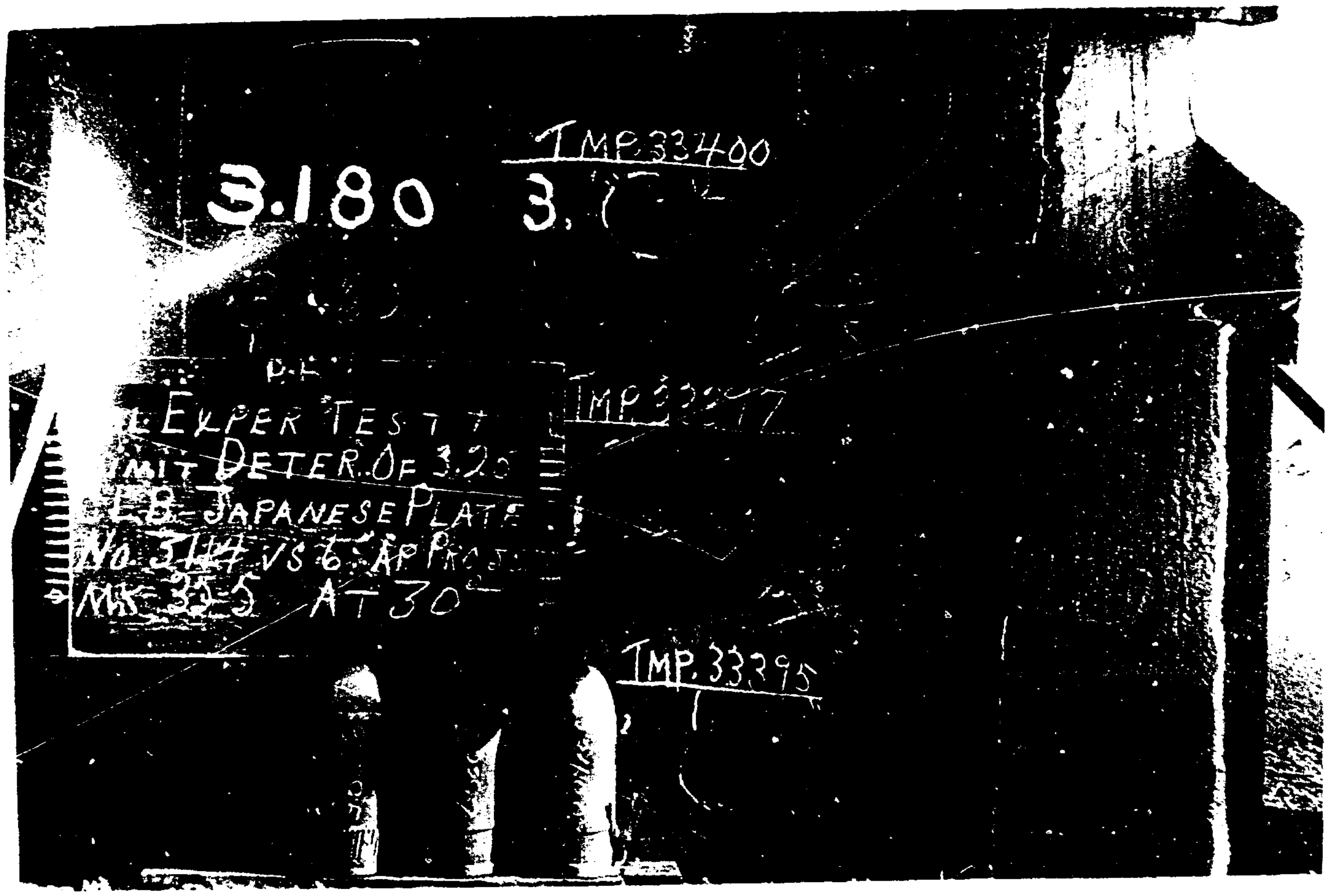

FIGURE 10

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NP9-33776 - Ballistic Experimental Test and Limit Determination of 3"25 Class B Japanese Plate No. JE-50-3114 vs. 6" AP Projectile Mark 35-5. 26 September 1946 - [redacted]

View: Back of plate.

Impact	Cbl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33395	29-40	3.18	1109	Inc.	103.5	Proj. effective and intact
33397	29-40	3.17	1163	Comp.	108.7	Proj. effective and intact
33400	29-40	3.16	1138	Comp.	106.6	Proj. effective and intact

Estimated Ballistic Limit versus 6" AP Projectile Mk. 35-5 at 30° 104-105%

FIGURE 11

UNCLASSIFIED

NP9-33661 - Ballistic Experimental Test and Limit Determination of 3" Class B Japanese Plate No. JE-50-3116 vs. 6" AP Projectile Mark 35-5. 12 September 1946 - [redacted]

View: Front of plate and sides of projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33373	29-00	2.96	1112	Comp.	109.8	Proj. effective and intact
33375	29-10	2.99	1075	Inc.	105.1	Proj. effective and intact

Estimated Ballistic Limit versus 6" AP Projectile Mk. 35-5 at 30° 107±1%

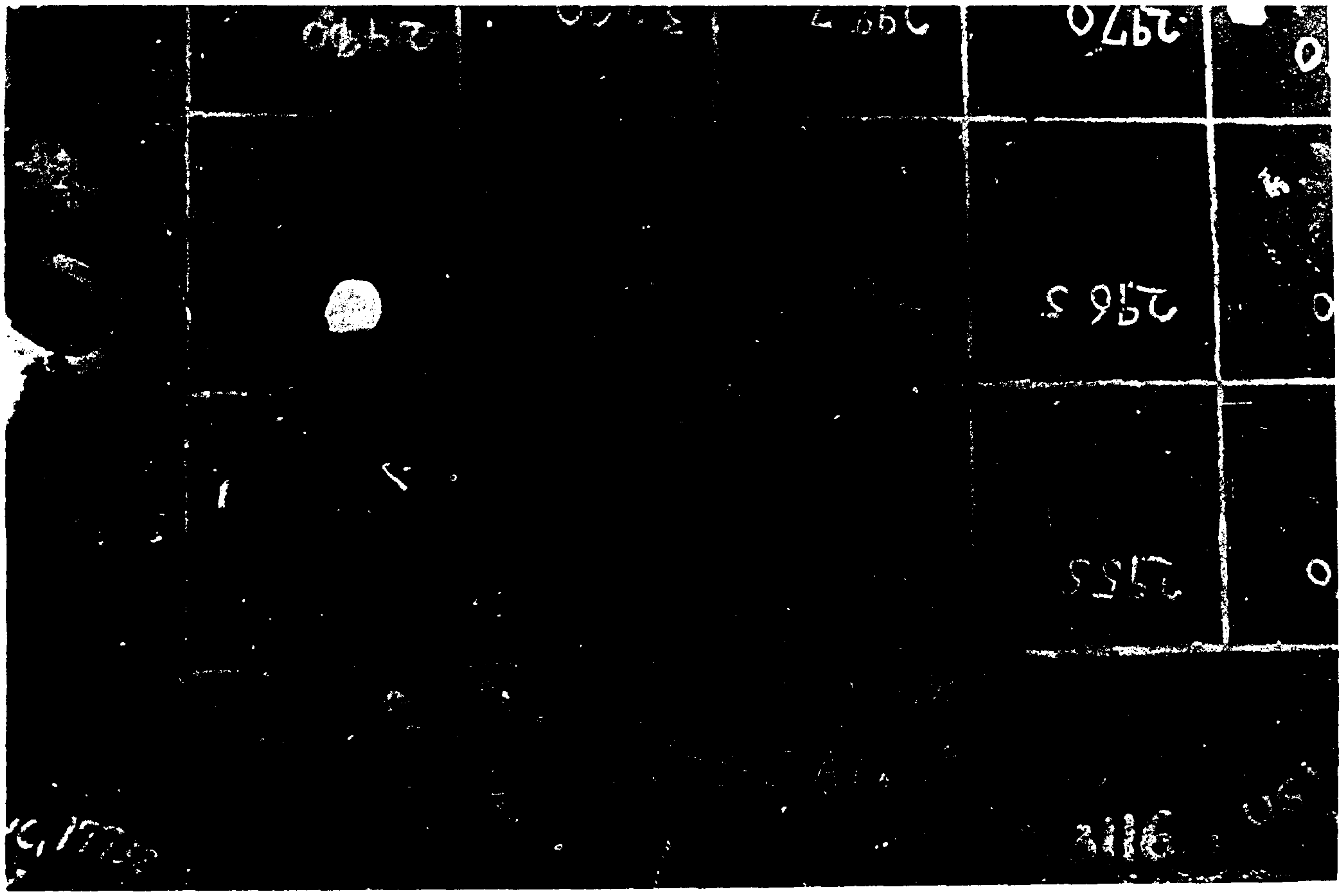


FIGURE 12

NP9-33662 - Ballistic Experimental Test and Limit Determination of 3" Class B Japanese Plate No. JE-50-3116 vs. 6" AP Projectile Mark 35-5. 12 September 1946 [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33373	29-00	2.96	1112	Comp.	109.8	Proj. effective and intact
33375	29-10	2.99	1075	Inc.	105.1	Proj. effective and intact

Estimated Ballistic Limit versus 6" AP Projectile Mk. 35-5 at 30° 107±1%

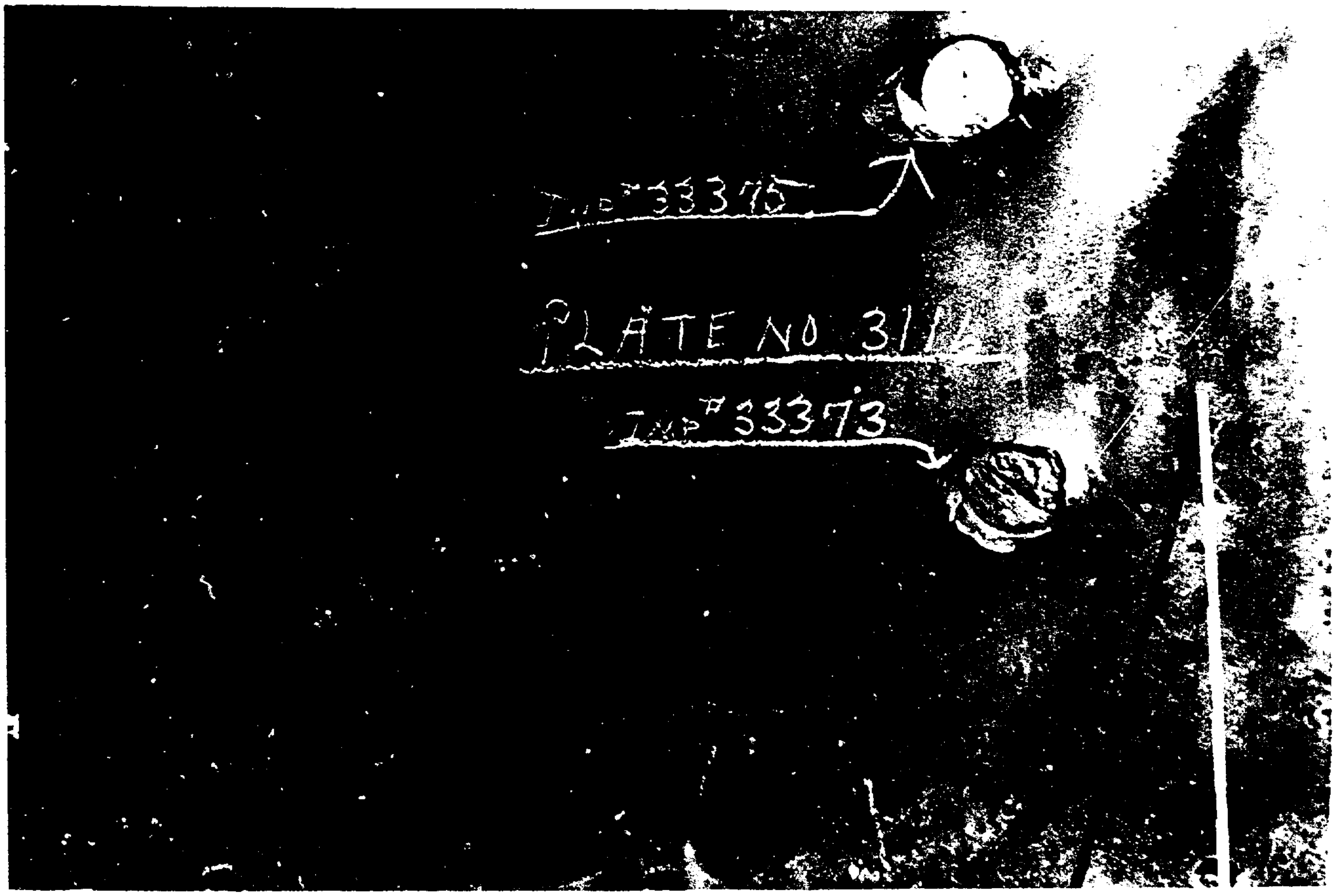


FIGURE 13

UNCLASSIFIED

[illegible]-3006 - Ballistic Experimental Test and Limit Determination of 3725 Class B Japanese Plate No. CE-50-3120 vs. 6" AP Projectile Mark 35-5. 19 September 1946 - [redacted]

View: Front of plate and sides of four projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33381	29-40	3.18	1175	Comp.	109.6	Proj. effective and intact
33383	30-00	3.19	1117	Comp.	103.6	Proj. effective and intact
33385	30-00	3.18	1046	Inc.	97.2	Proj. effective and intact - cap stuck in plate.
33387	30-40	3.17	1087	Inc.	100.5	Proj. effective and intact

Estimated Ballistic Limit versus 6" AP Projectiles Mk. 35-5 at 30°   101-1025

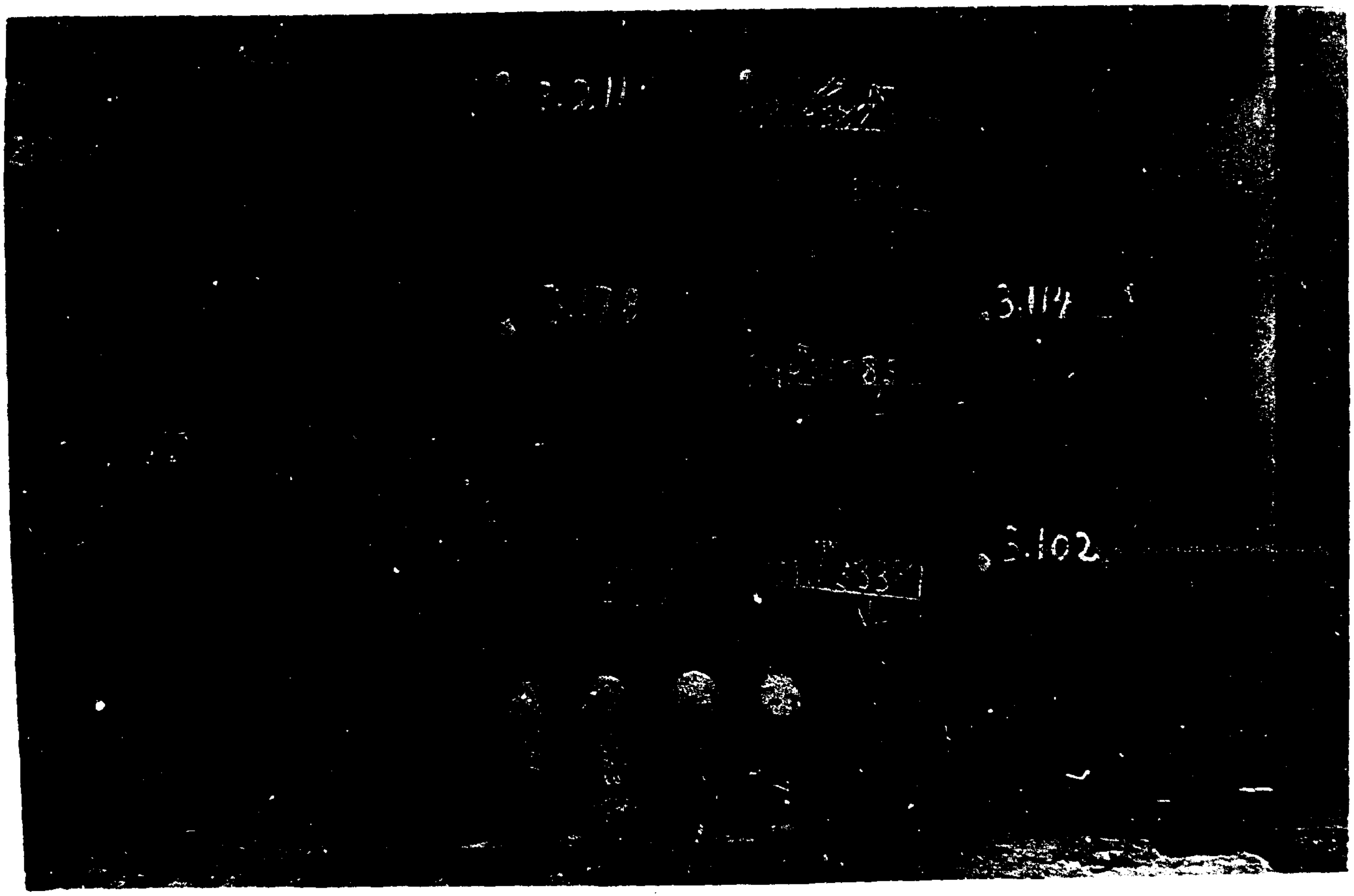


FIGURE 14

FP9-33667 - Ballistic Experimental Test and Limit Determination of 3.25 Class B Japanese Plate No. JE-50-3120 vs. 6" AP Projectile Mark 35-5. 19 September 1946 - [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33381	29-40	3.18	1175	Comp.	109.6	Proj. effective and intact
33383	30-00	3.19	1117	Comp.	103.6	Proj. effective and intact
33385	30-00	3.18	1046	Inc.	97.2	Proj. effective and intact - cap stuck in plate.
33387	30-40	3.17	1087	Inc.	100.5	Proj. effective and intact

Estimated Ballistic Limit versus 6" AP Projectiles Mk. 35-5 at 30° 101-102%

FIGURE 15

NP9-33779 - Ballistic Experimental Test and Limit Determination of 6" Class B Japanese Plate No. JE-50-3122 vs. 8" AP Projectile Mark 21-3. 15 October 1946 [redacted]

View: Face of plate and sides of two projectiles.

Impact	Obl.	Thick.	B.V.(f.s.)	Pene.	%VL	Remarks
33442	35-00	5.94	1452	Comp.	101.5	Proj. effective and intact.
33444	34-40	5.95	1366	Inc.	95.8	Proj. effective and intact.

Estimated Ballistic Limit versus 8" AP Projectiles Mk. 21-3 at 35° 981[illegible]

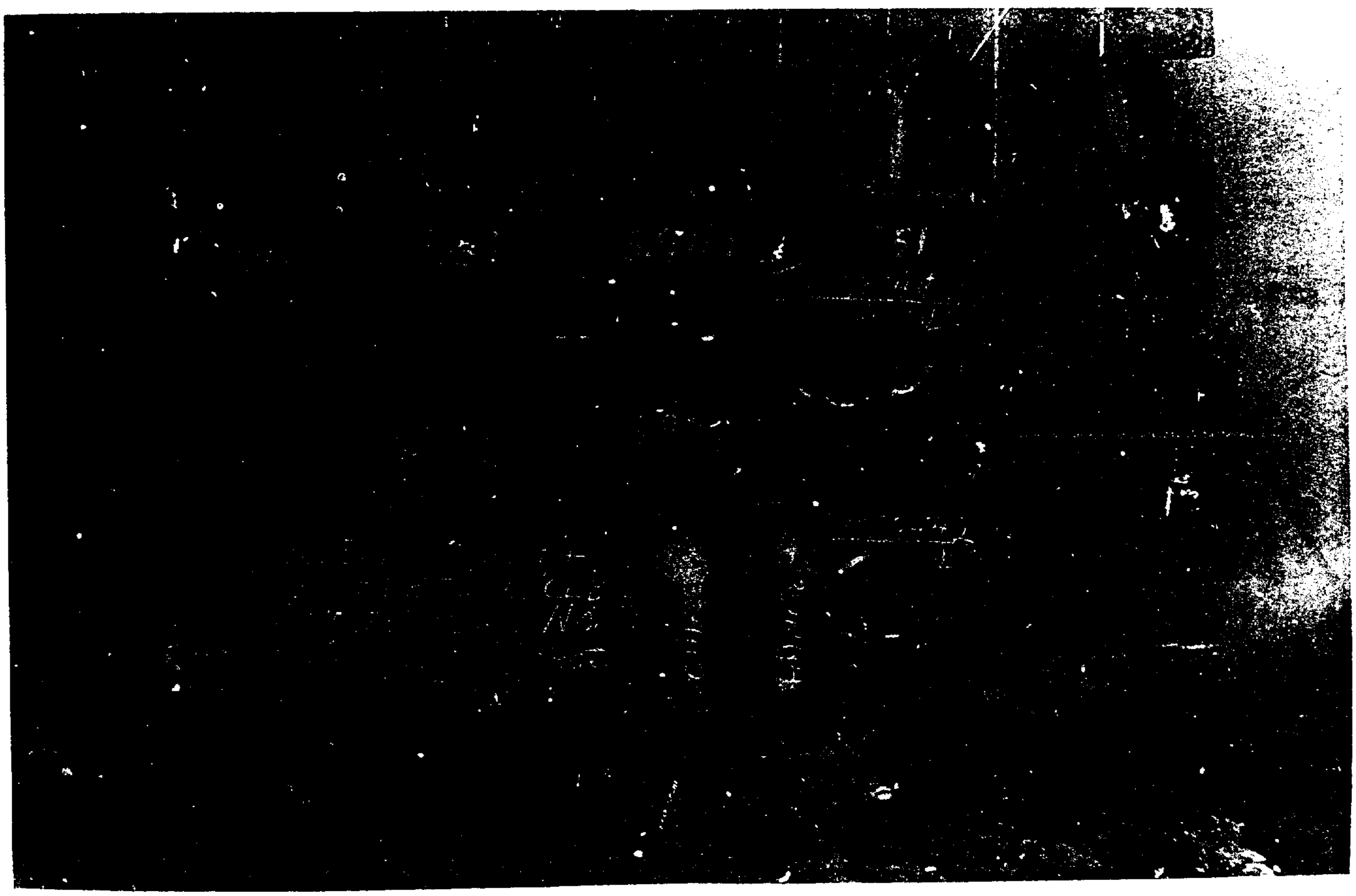


FIGURE 16

NP9-33780 - Ballistic Experimental Test and Limit Determination of 6" Class B Japanese Plate No. JE-50-3122 vs. 8" AP Projectile Mark 21-3. 15 October 1946 - [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33442	35-00	5.94	1452	Comp.	101.5	Proj. effective and intact
33444	34-40	5.94	1366	Inc.	95.8	Proj. effective and intact

Estimated Ballistic Limit versus 8" AP Projectiles Mk. 21-3 at 35° 98±1%

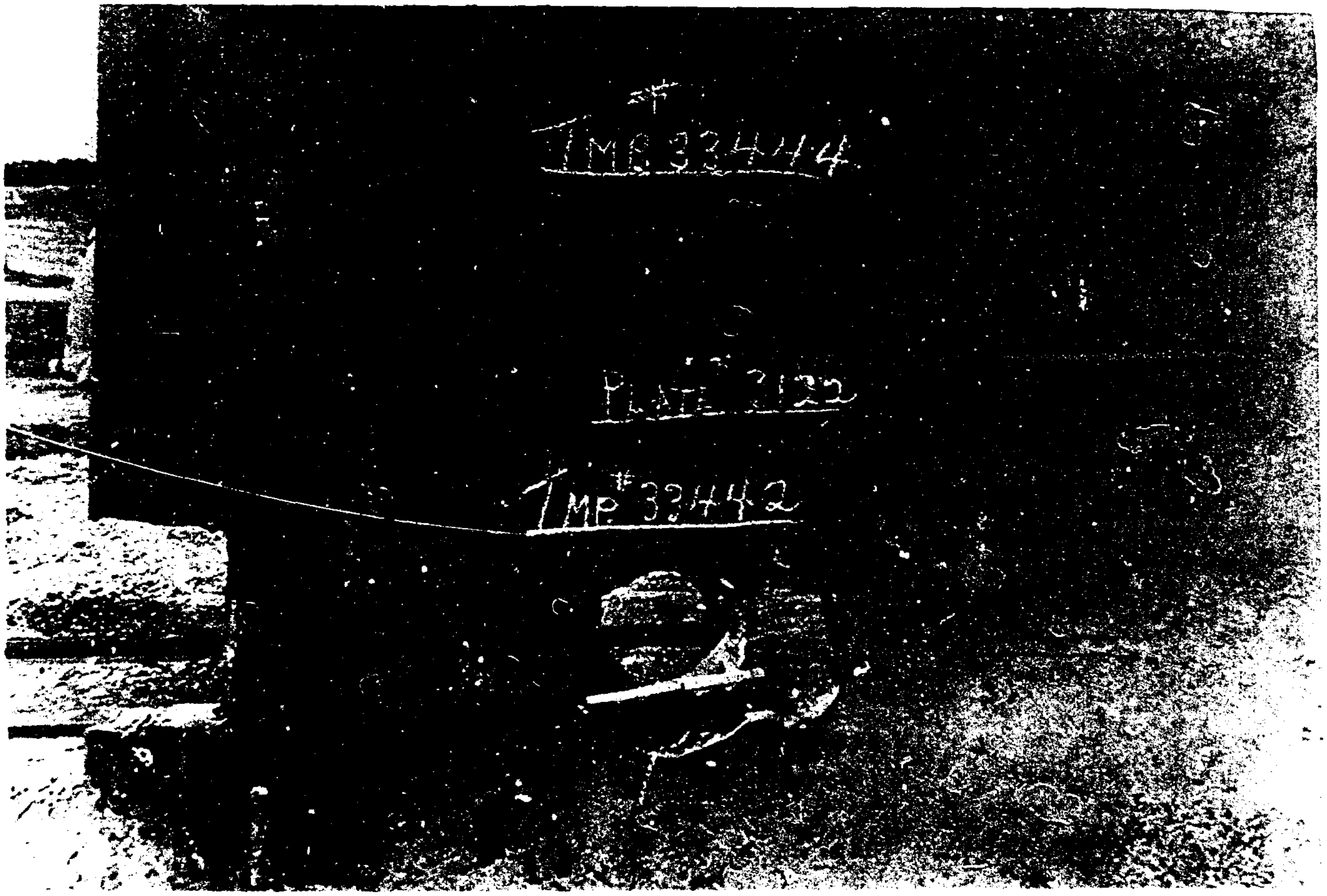


FIGURE 17

NP9-33650 - Ballistic Experimental Test and Limit Determination of 6" Class B Japanese Plate No. JE-50-3123 vs. 8" AP Projectile Mark 21-3. 19 September 1946 - [redacted]

View: Face of plate and sides of three projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33382	35-30	5.86	1502	Comp.	105.4	Proj. effective and intact
33384	35-30	5.87	1439	Comp.	100.8	Proj. effective and intact
33386	34-40	5.88	1365	Inc.	95.7	Proj. effective and intact

Estimated Ballistic Limit versus 8" AP Projectiles Mk. 21-3 at 35° 98.1%

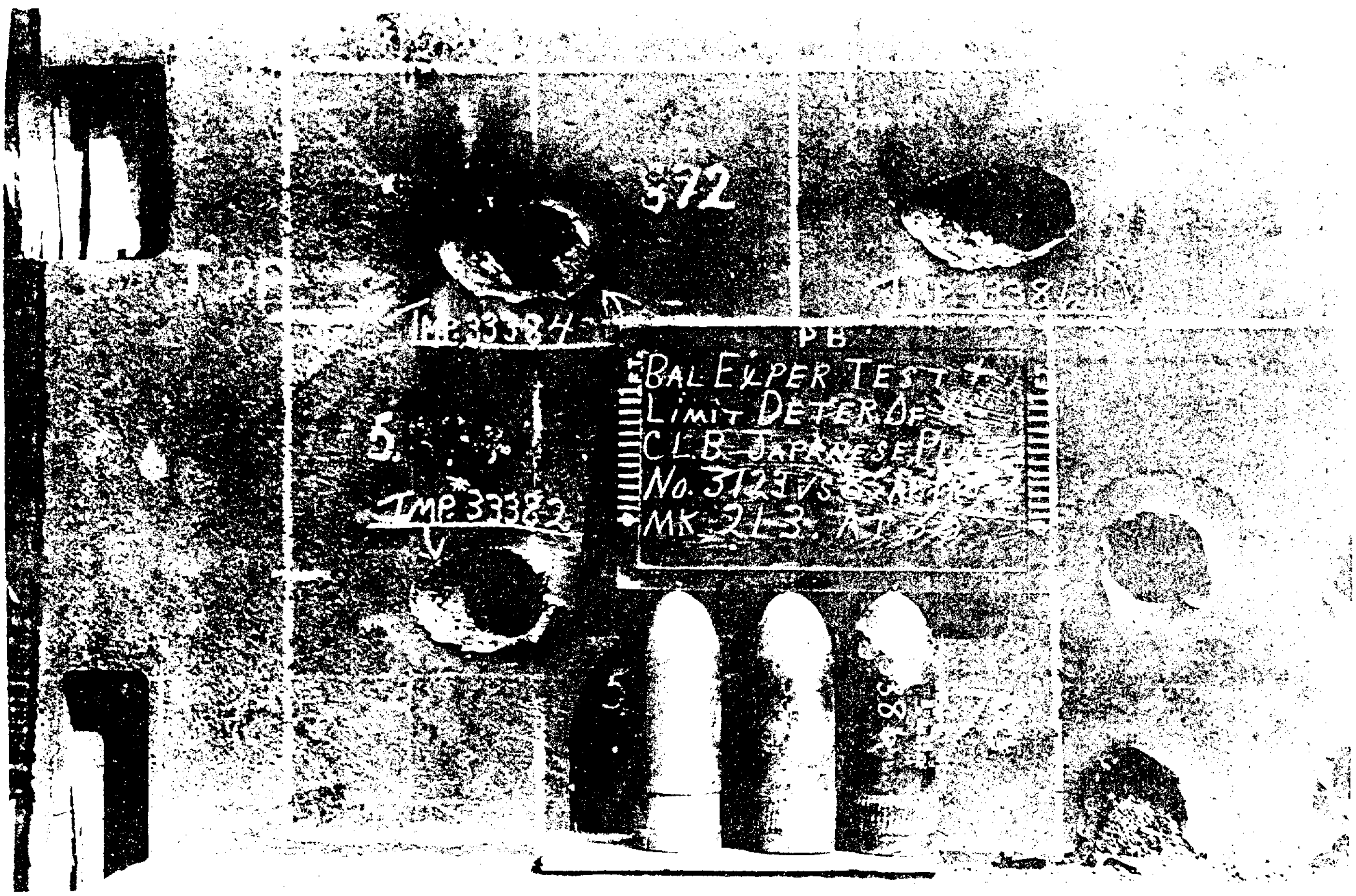


FIGURE 18

NP9-33663 - Ballistic Experimental Test and Limit Determination of 6" Class B Japanese Plate No. JE-50-3123 vs. 8" AP Projectile Mark 21-3. 19 September 1946 - [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33382	35-30	5.86	1502	Comp.	105.4	Proj. effective and intact
33384	35-30	5.87	1439	Comp.	100.8	Proj. effective and intact
33386	34-40	5.88	1365	Inc.	96.7	Proj. effective and intact

Estimated Ballistic Limit versus 8" AP Projectiles Mk. 21-3 at 35° 98.1%

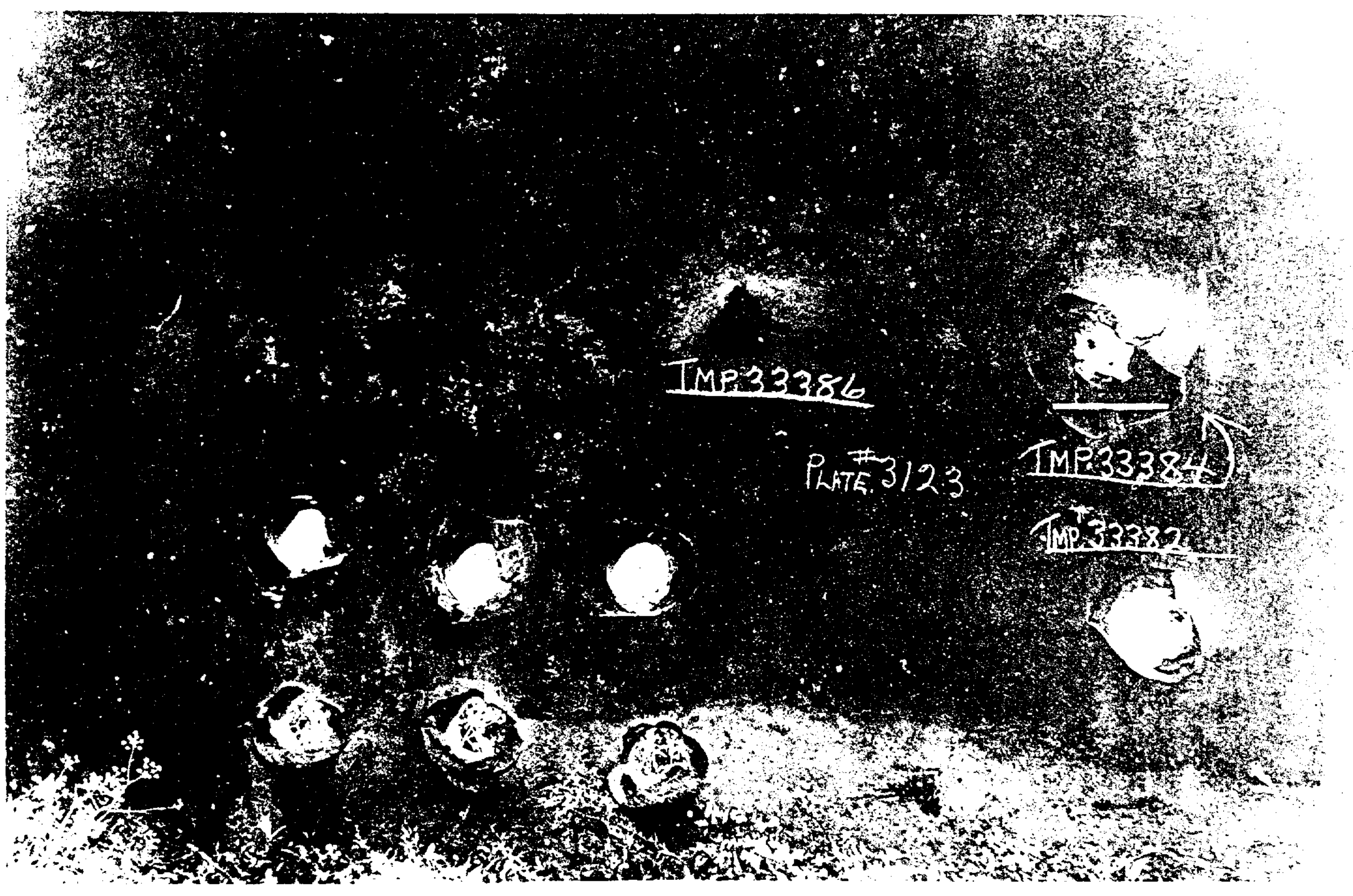


FIGURE 19

NP9-33781 - Ballistic Experimental Test and Limit Determination of 7" Class B Japanese Plate No. JE-50-3128 vs. 8" AP Projectile Mark 21-3. 9 October 1946 - [redacted]

View: Face of plate and sides of two projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33422	34-50	6.99	1659	Comp.	101.7	Proj. not recovered
33425	34-40	7.00	1572	Comp.	96.4	Proj. effective and intact
33427	34-40	6.99	1497	Inc.	92.0	Proj. effective - base slapped

Estimated Ballistic Limit versus 8" AP Projectile Mk. 21-3 at 35° 94±1%

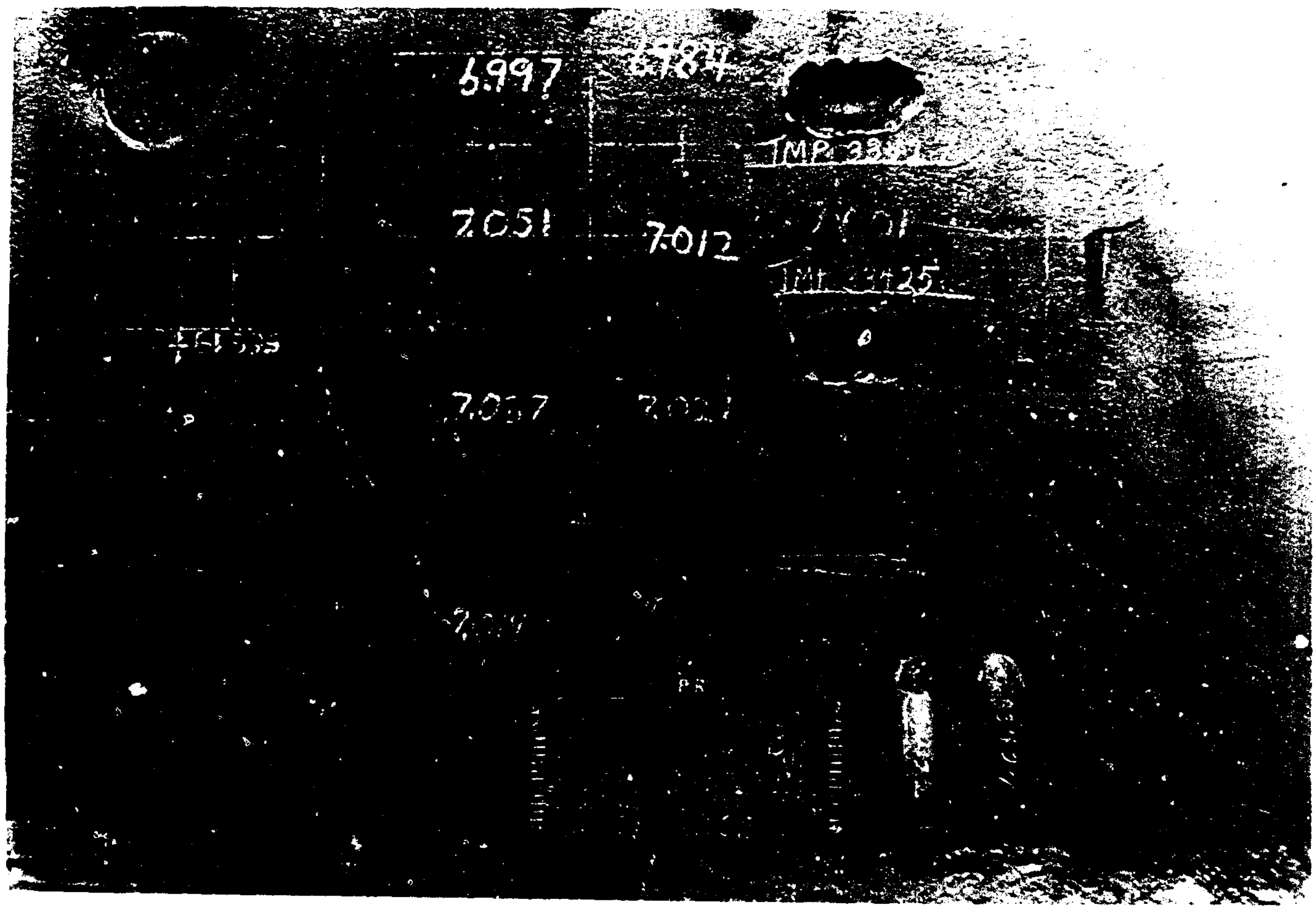


FIGURE 20

NP9-33782 - Ballistic Experimental Test and Limit Determination of 7" Class B Japanese Plate No. JE-5C-3128 vs. 8" AP Projectile Mark 21-3. 9 October 1946. -[redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33422	34-50	6.99	1659	Comp.	101.7	Proj. not recovered.
33425	34-40	7.00	1572	Comp.	96.4	Proj. effective and intact.
33427	34-40	6.99	1497	Inc.	92.0	Proj. effective - base slapped.

Estimated Ballistic Limit versus 8" AP Projectile Mk. 21-3 at 35° 94±1%

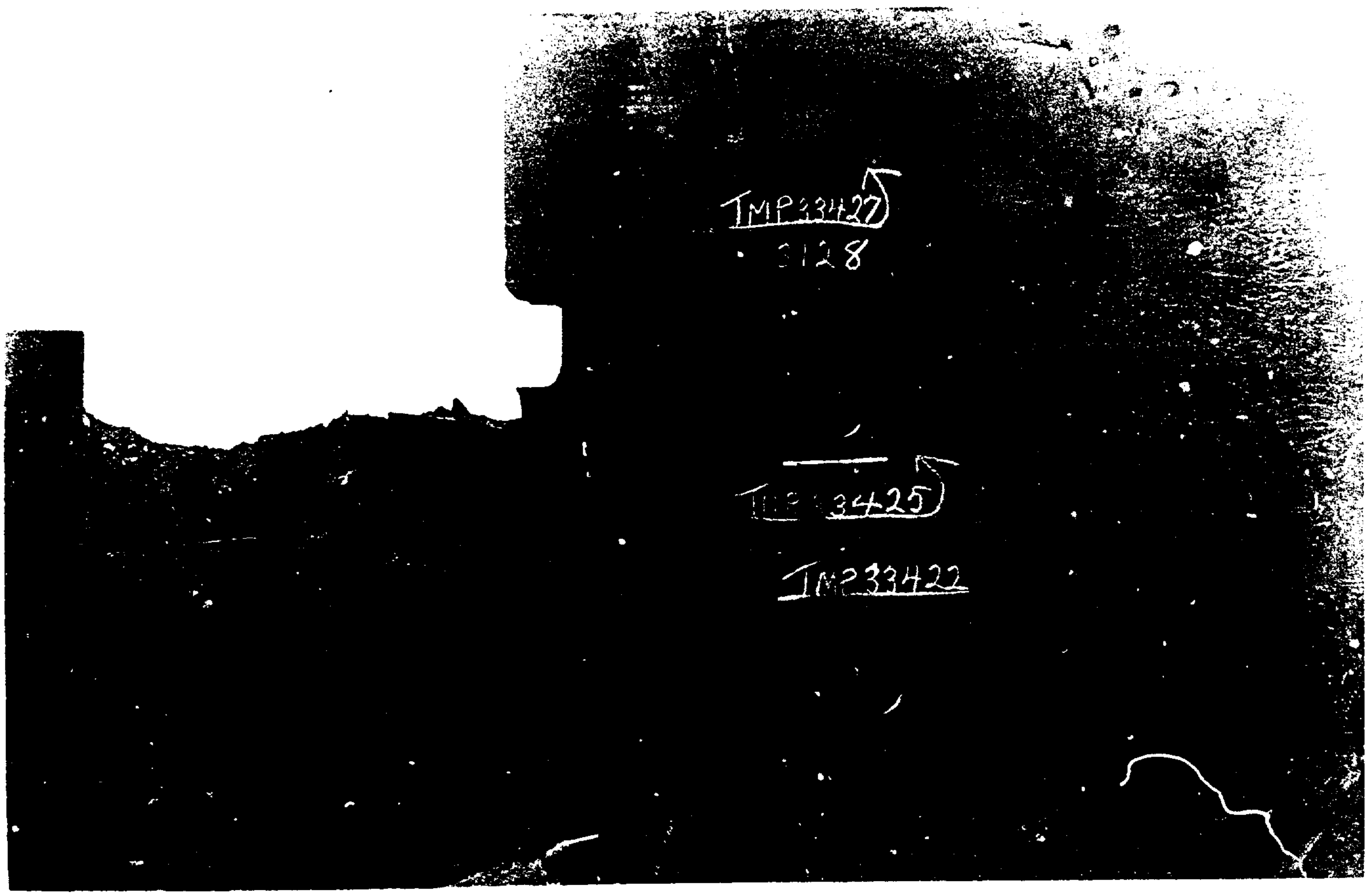


FIGURE 21.

NP9-33787 - Ballistic Experimental Test and Limit Determination of 9"75 Japanese Class B Plate No. JE-56-3118 vs. 12" AP Projectile Mark 18-1. 3 October 1946.

[redacted]

View: Face of plate and base of projectile stuck in plate.

Impact	Cbl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33412	34-2	9.75	1420	SIP	93.6	Proj. effective and intact. Base of projectile flush with face of plate.

Estimated Ballistic Limit versus 12" AP Projectile Mk. 18-1 at 35° 94-95%

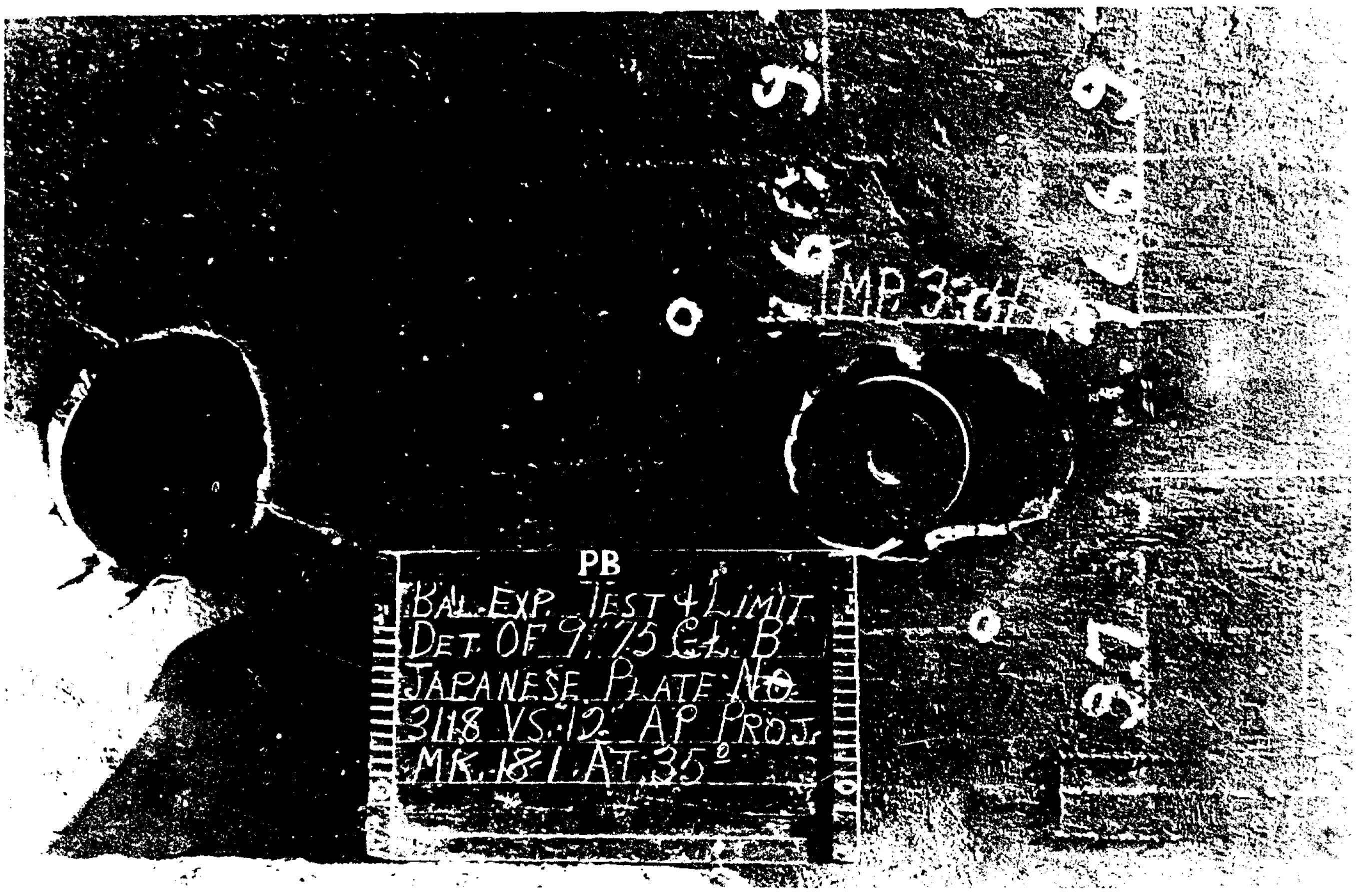


FIGURE 22

UNCLASS

NPG-33786 - Ballistic Experimental Test and Limit Determination of 9.75 Japanese Class B Plate No. JE-50-3118 vs. 12" AP Projectile Mark 18-1. 3 October 1945.

[redacted]

View: Back of plate and nose of projectile stuck in plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33412	34-20	9.75	1420	SIP	93.6	Proj. effective and intact. Base of projectile flush with face of plate.

Estimated Ballistic Limit versus 12" AP Projectile Mk. 18-1 at 35° 94-95%

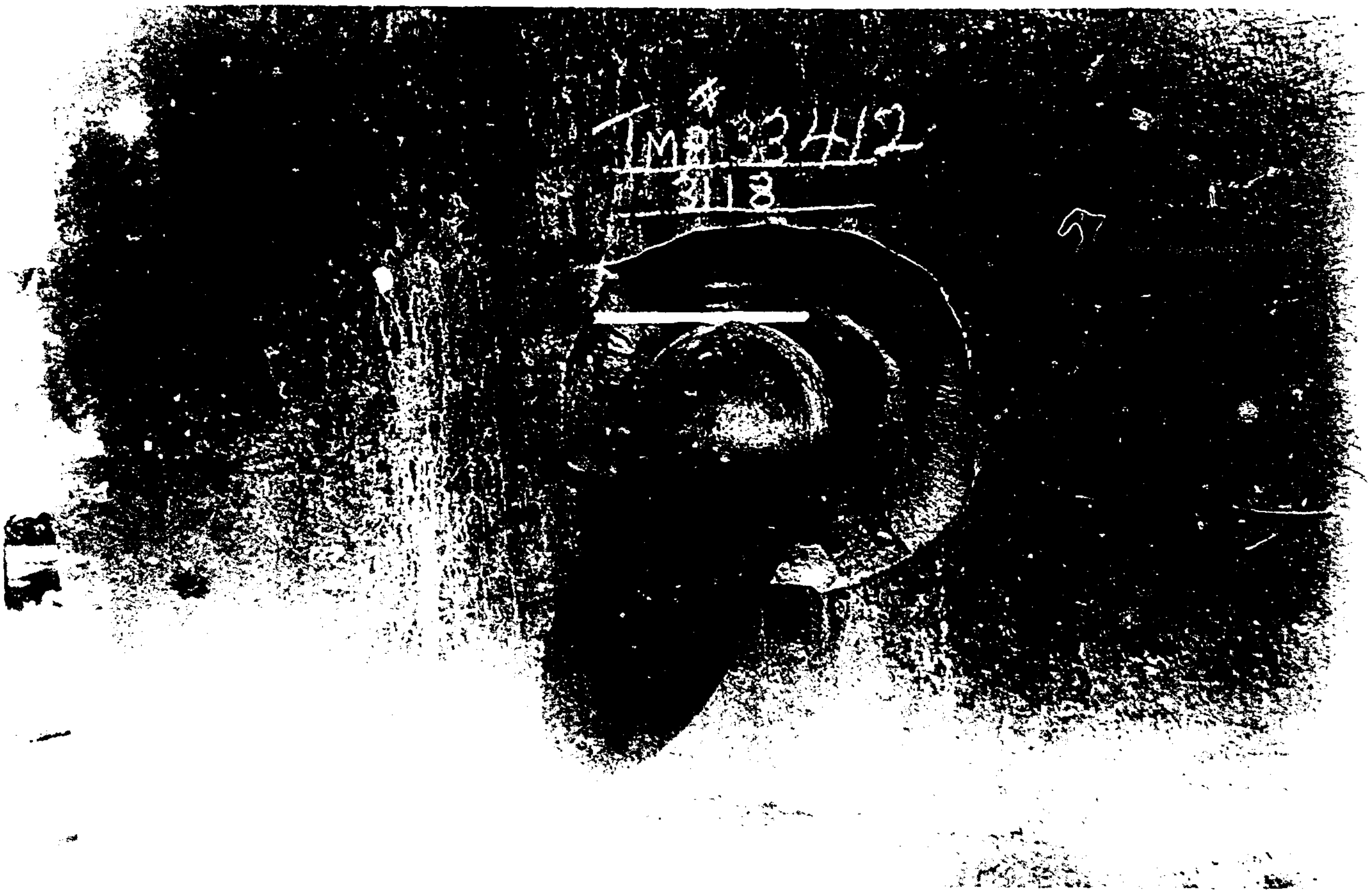


FIGURE 23

NPG-3648 - Ballistic Experimental Test and Limit Determination of 12" Class B Japanese Plate No. JE-50-3168 vs. 14" AP Projectile Mark 16-8. 12 September 1946.

[redacted]

View: Face of plate and sides of projectiles.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
3374	30-00	12.10	1533	Comp.	93.0	Proj. effective and intact.
3375	30-00	12.10	1459	Inc.	88.5	Proj. not effective, broken into three pieces.

Estimated Ballistic Limit versus 14" AP Projectile Mk. 16-8 at 30° [illegible]

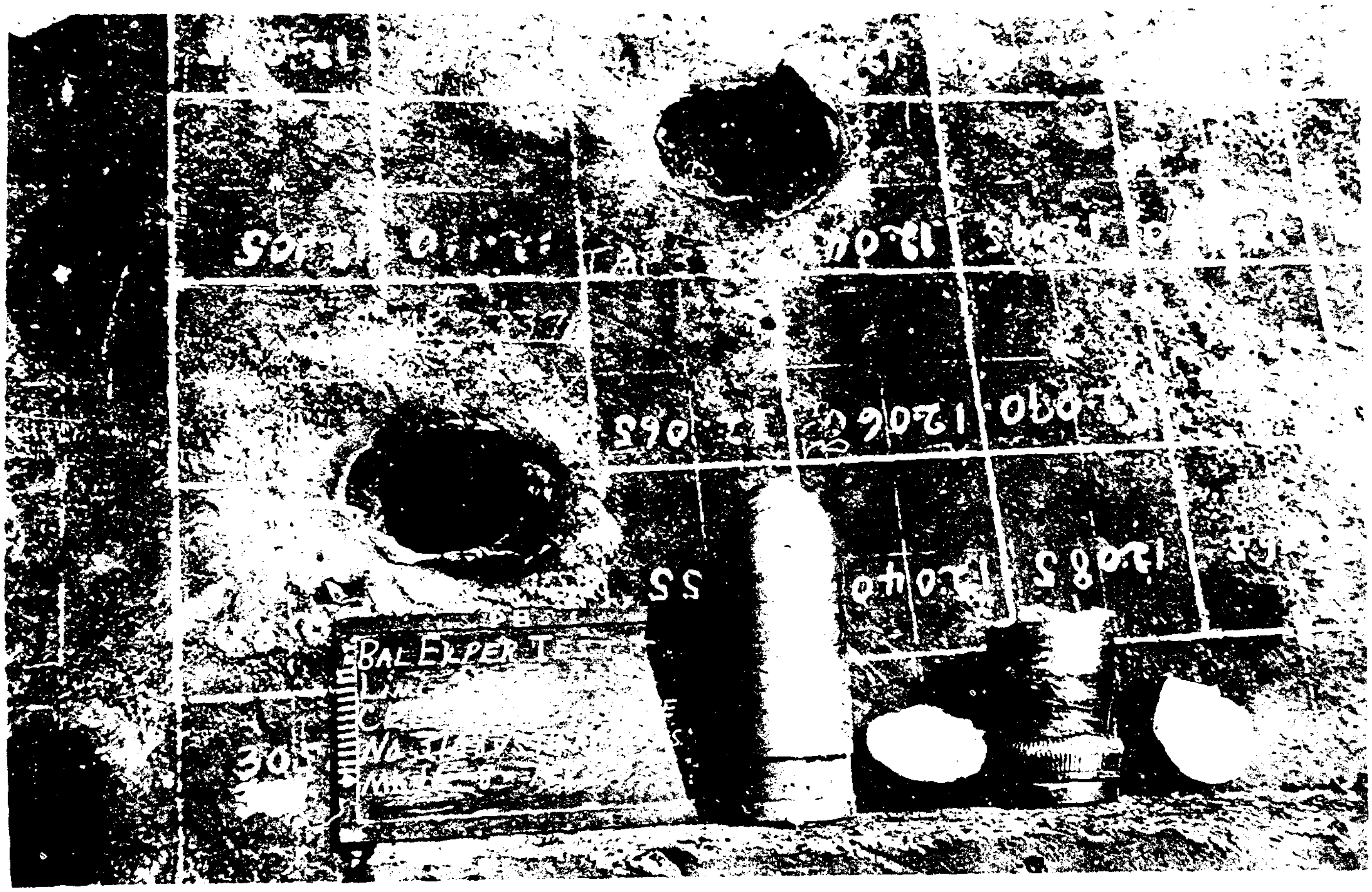


FIGURE 24

UNCLASSIFIED

NP9-33649 - Ballistic Experimental Test and Limit Determination of 12" Class B Japanese Plate No. JE-50-3108 vs. 14" AP Projectile Mark 16-8. 12 September 1946 - [redacted]

View: Back of plate.

Impact	Obl.	Thick.	S.V.(f.s.)	Pene.	%VL	Remarks
33374	30-00	12.10	1533	Comp.	93.0	Proj. effective and intact.
33376	30-00	12.10	1459	Inc.	88.5	Proj. not effective, broken into three pieces.

Estimated Ballistic Limit versus 14" AP Projectile Mk. 16-8 at 30° 91±1%

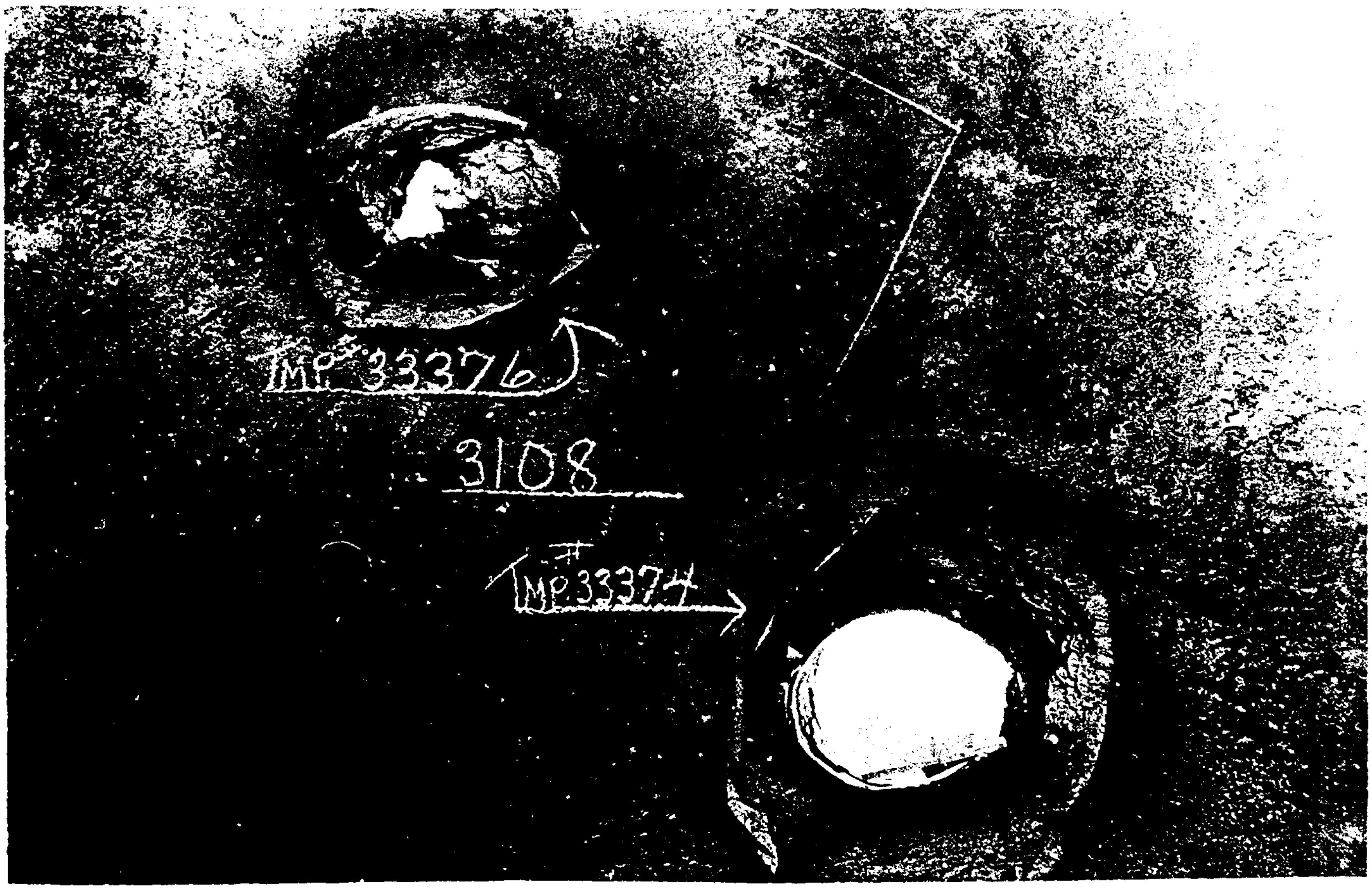


FIGURE 25

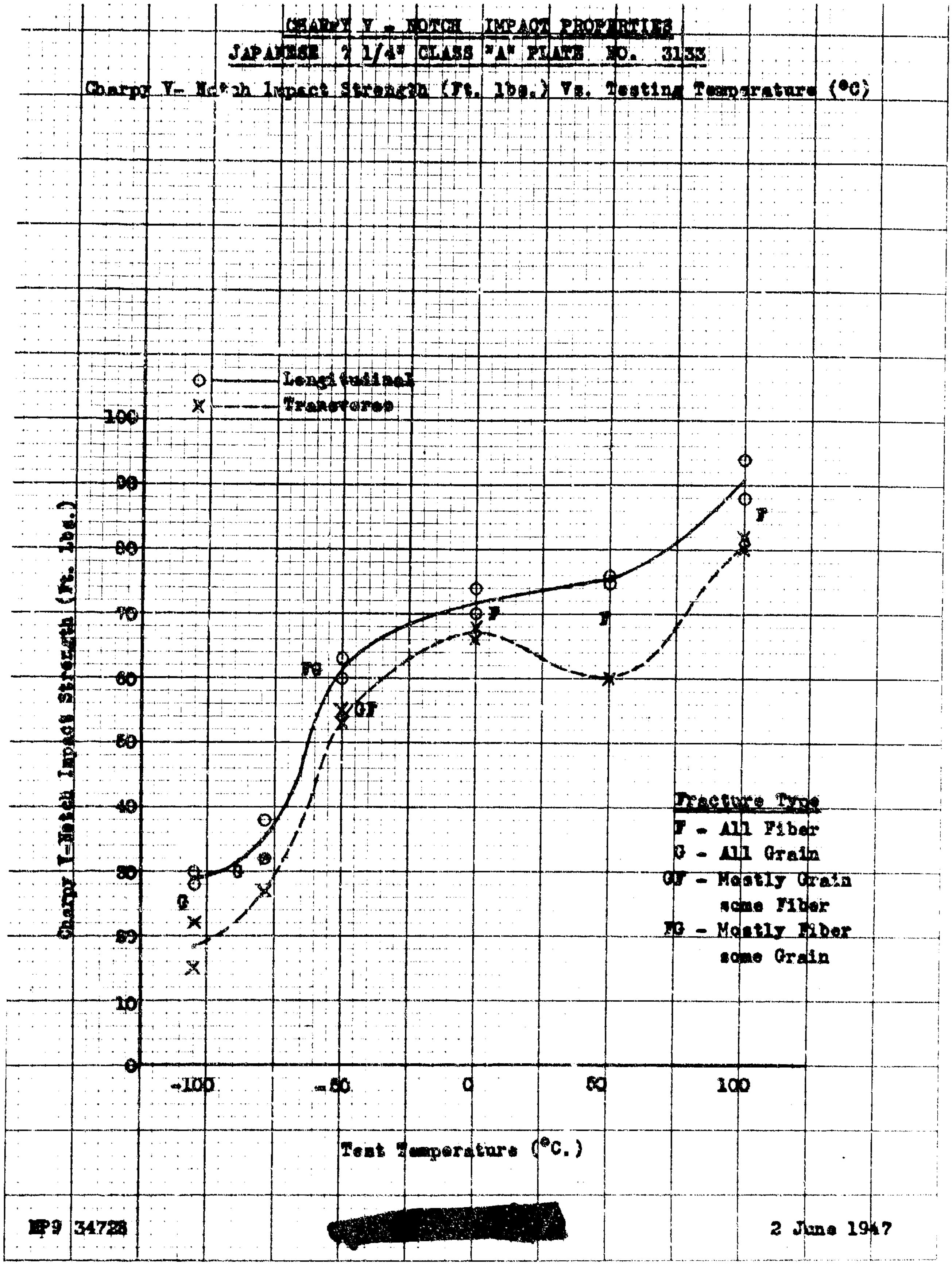
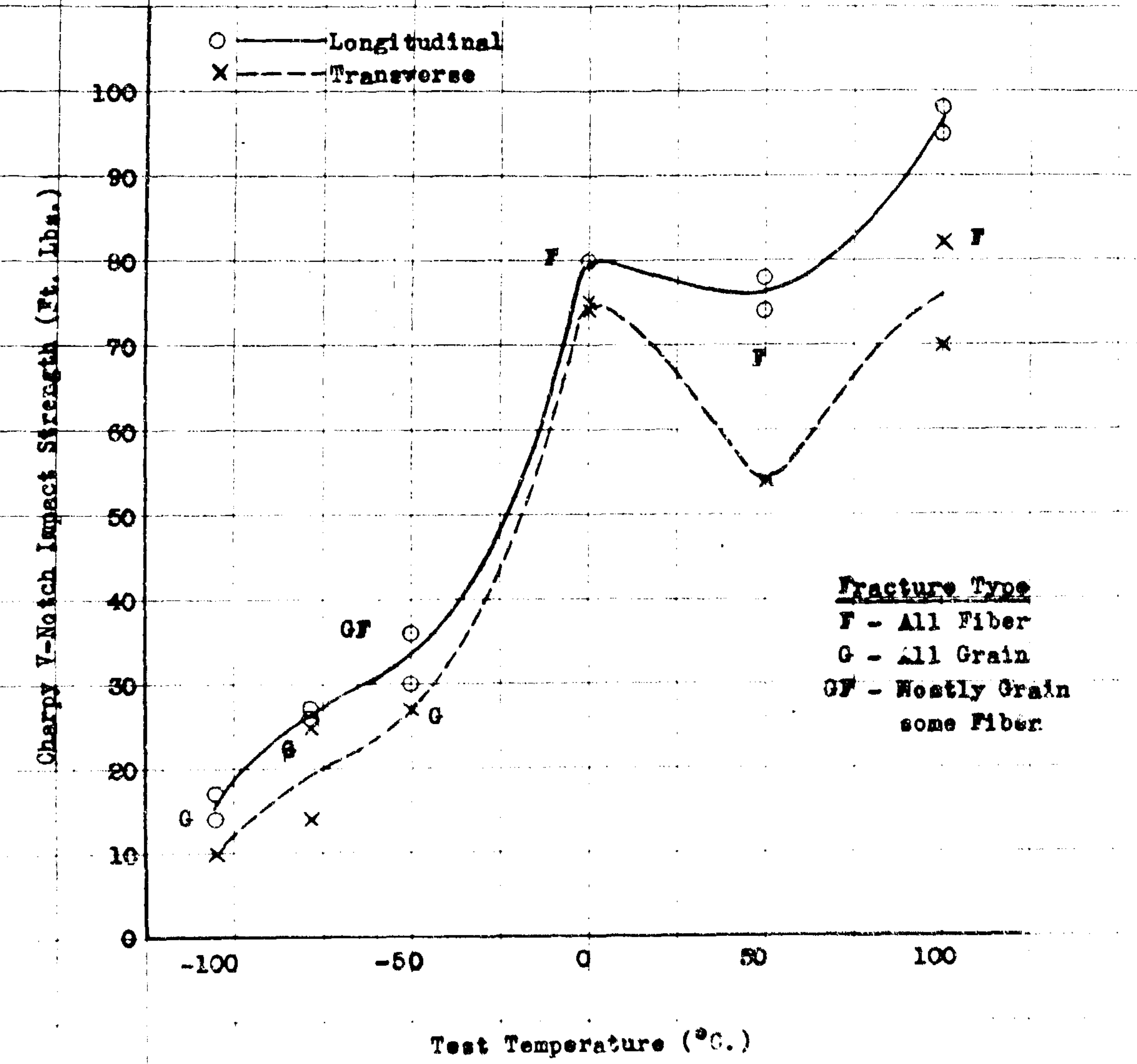

CHARPY V - NOTCH IMPACT PROPERTIES
JAPANESE 7 1/4" CLASS "A" PLATE NO. 3133
Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)
Longitudinal
Transverse
Charpy V-Notch Impact Strength (Ft. lbs.)
0
10
20
30
40
50
60
70
80
90
100
-100
-50
0
50
100
Test Temperature (°C.)
G
FG
GF
F
F
F
Fracture Type
F - All Fiber
G - All Grain
GF - Mostly Grain some Fiber
FG - Mostly Fiber some Grain
MP9 34728
[redacted]
2 June 1947

FIGURE 26

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 13" CLASS "A" PLATE NO. 3124

Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



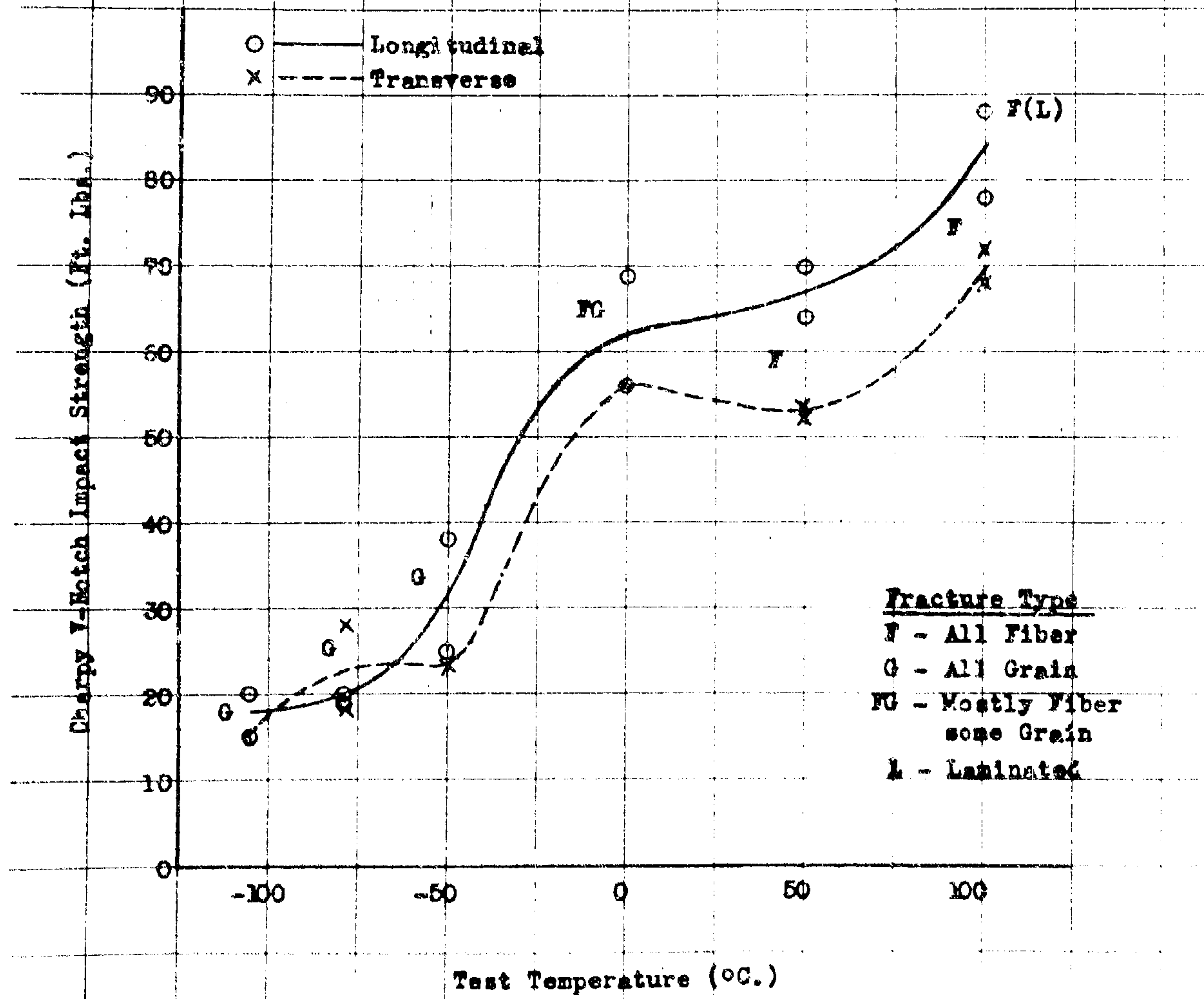
NP9 34729 [redacted] 2 June 1947

FIGURE 27

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 15" CLASS "A" PLATE NO. 3113

Charpy V- Notch Impact Strength (Ft. Lbs.) Vs. Testing Temperature (°C)



NP9 34730 -- [redacted] -- 4 June 1947

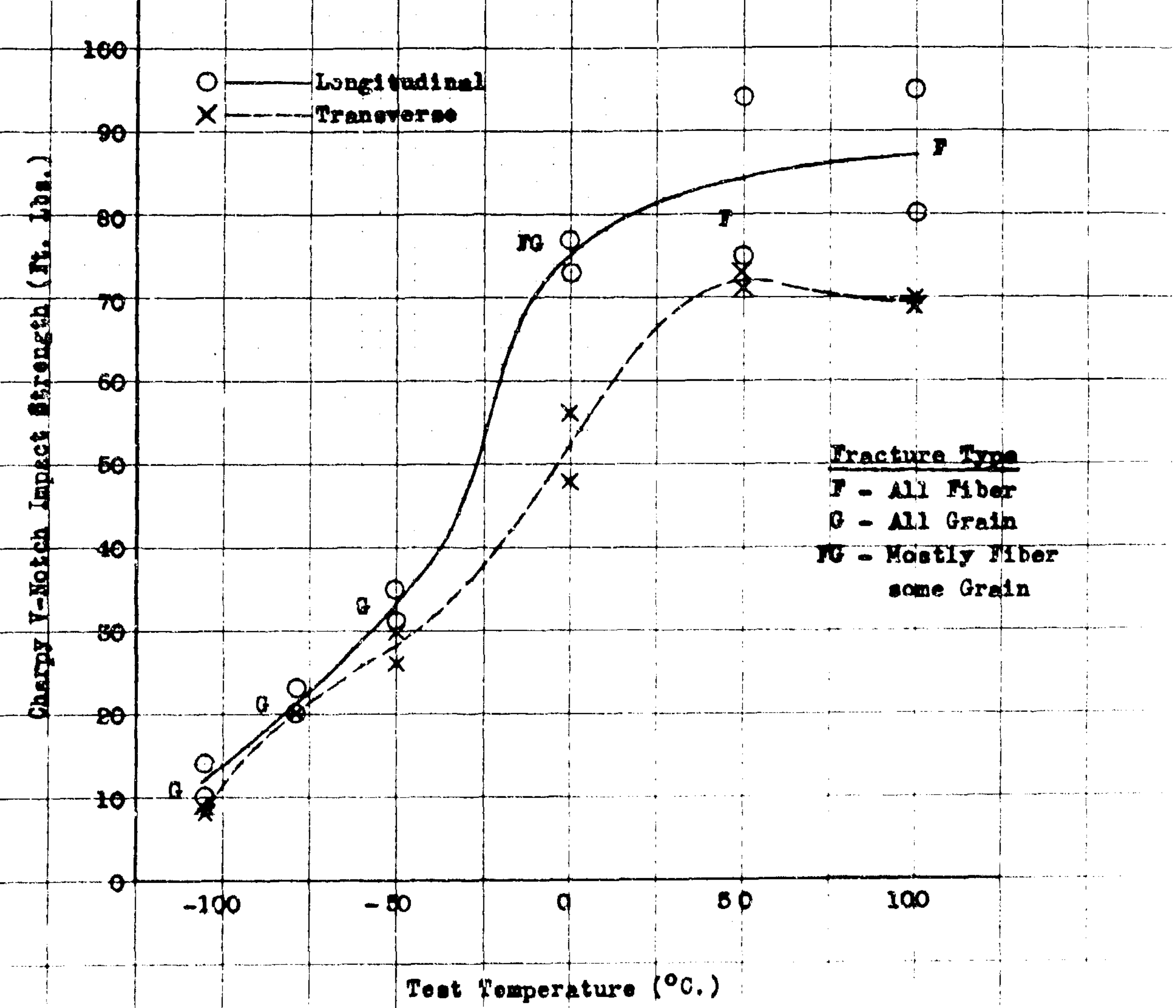
FIGURE 28

CLASSIFIED

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 26" CLASS "A" TURRET FACE PLATE

Charpy V- Notch Impact Strength (Ft.lbs.) Vs. Testing Temperature (°C)



MP9 34973 -- [redacted] -- 4 June 1947

FIGURE 29 UNCLASSIFIED

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 3 1/4" CLASS "B" PLATE NO.3114

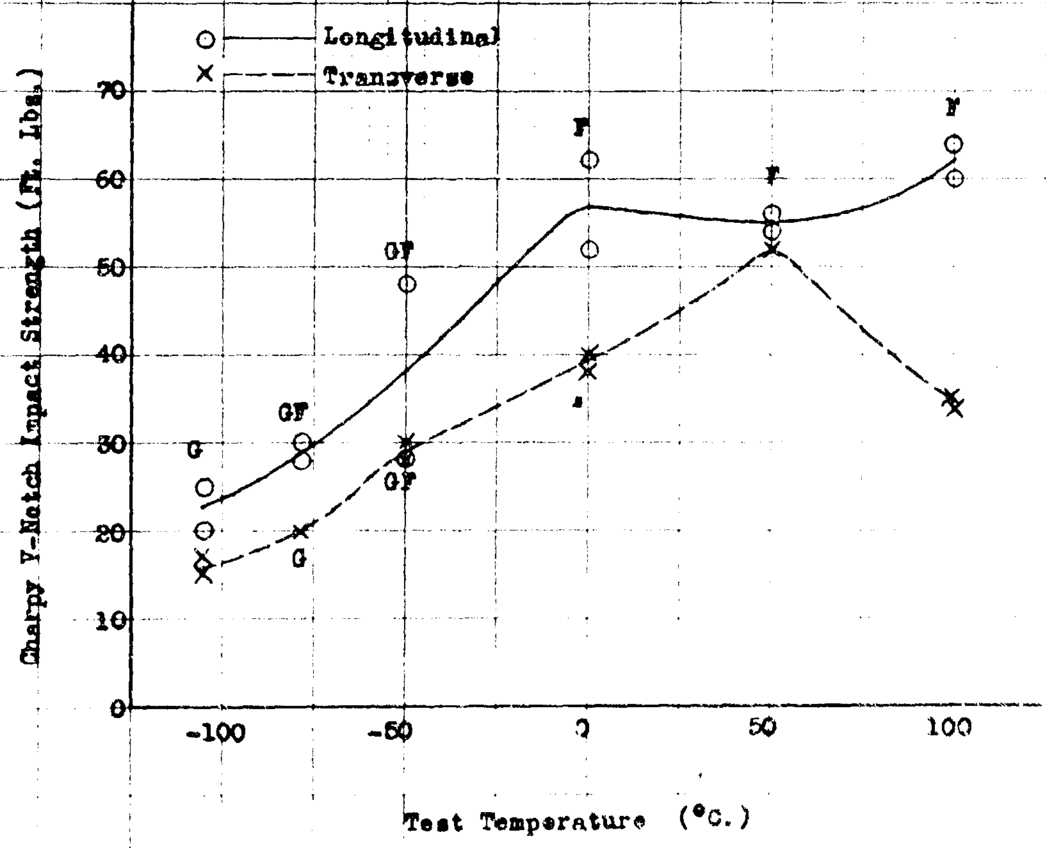
Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)

Fracture Type

F - All Fiber

GF - Mostly Grain some Fiber

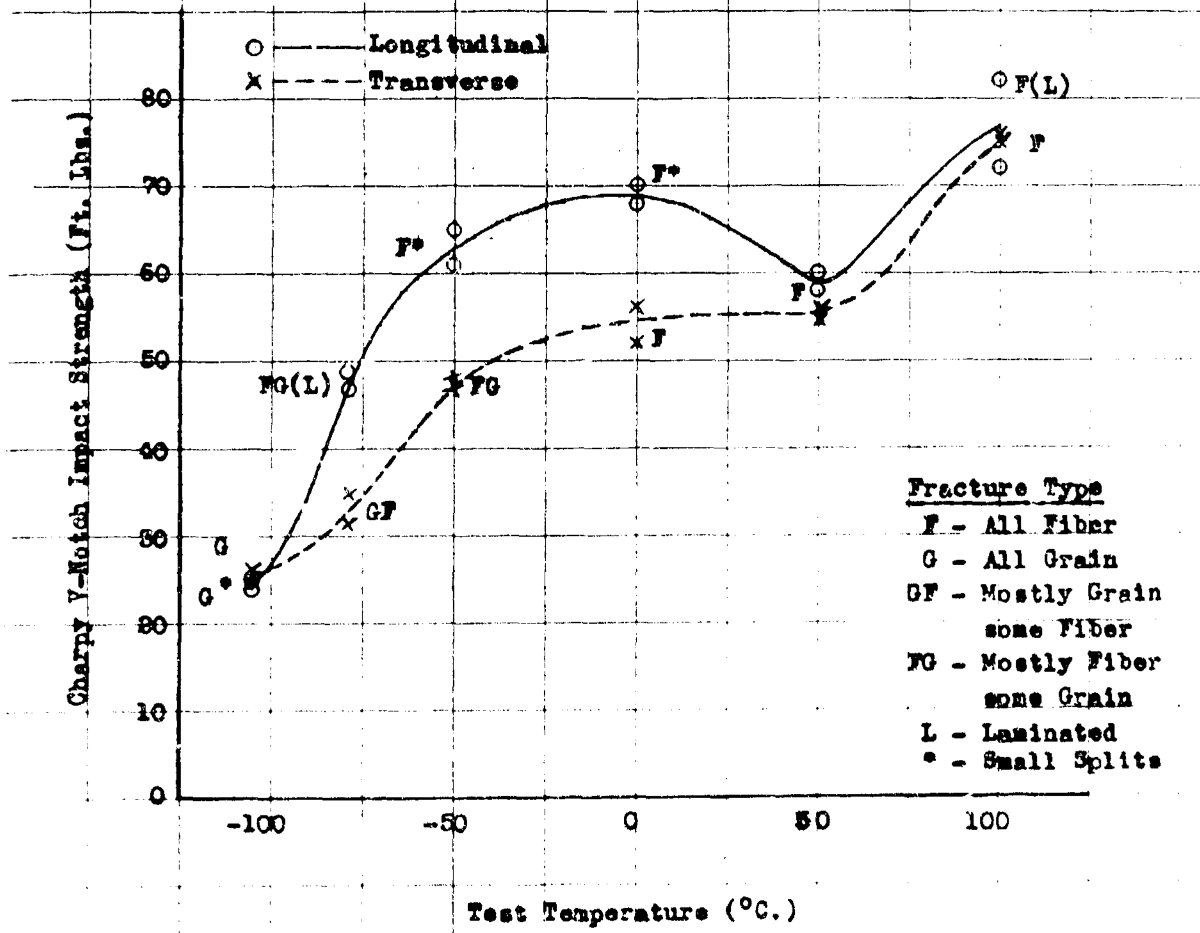
G - All Grain



CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 3" CLASS "B" PLATE NO. 3116

Charpy V-Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



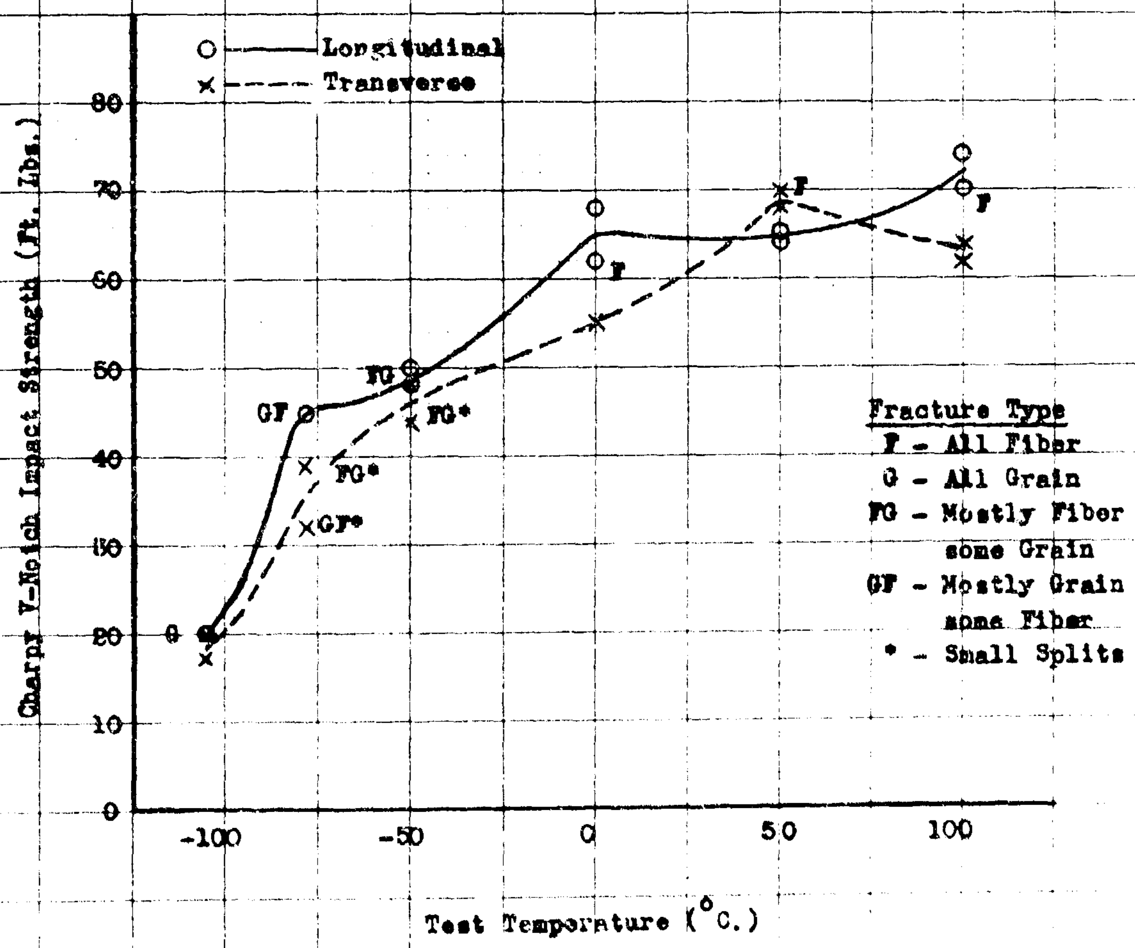
NP9 34977 -- [redacted] -- 10 June 1947

FIGURE 31

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 3 1/4" CLASS "B" PLATE NO. 3120

Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



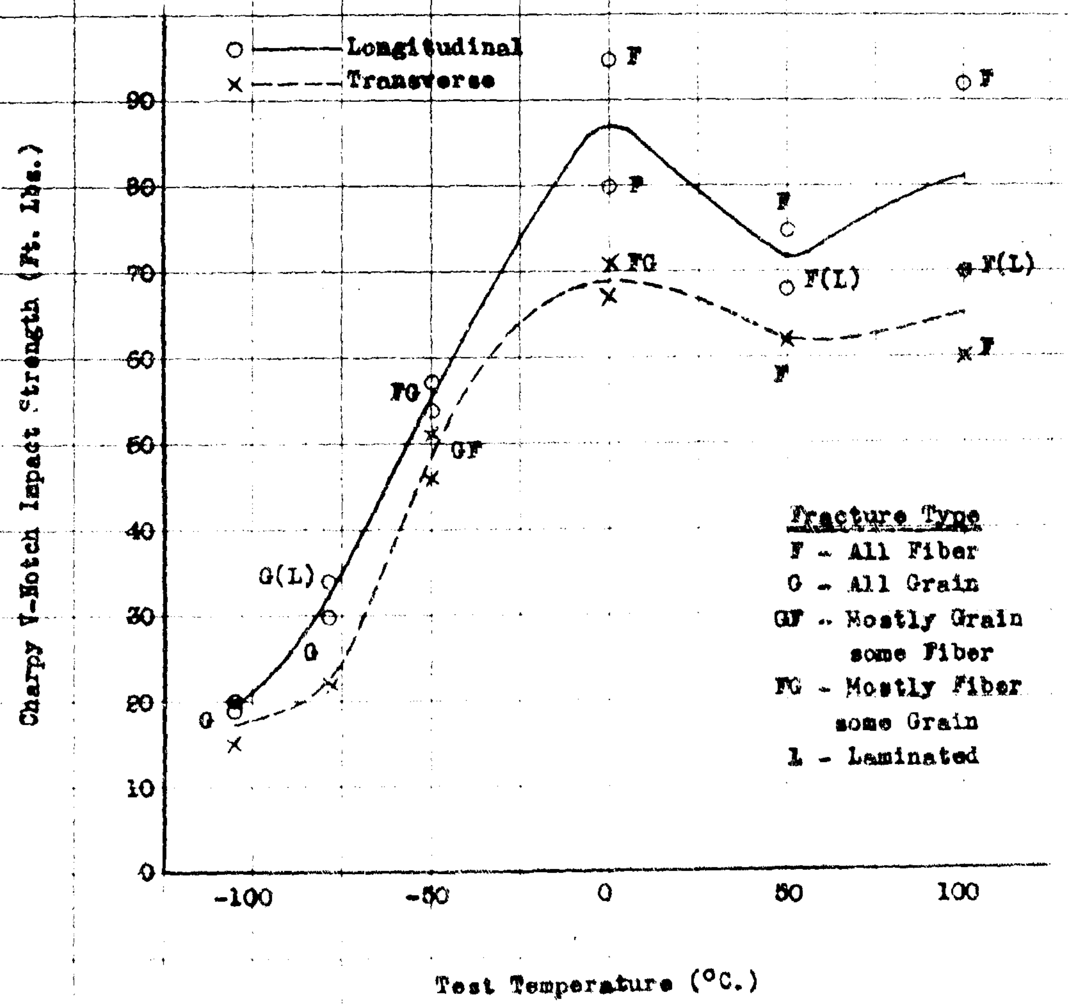
NPG 34976 -- [redacted] -- 10 June 1947

FIGURE 32

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 6" CLASS "B" PLATE NO. 3222

Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



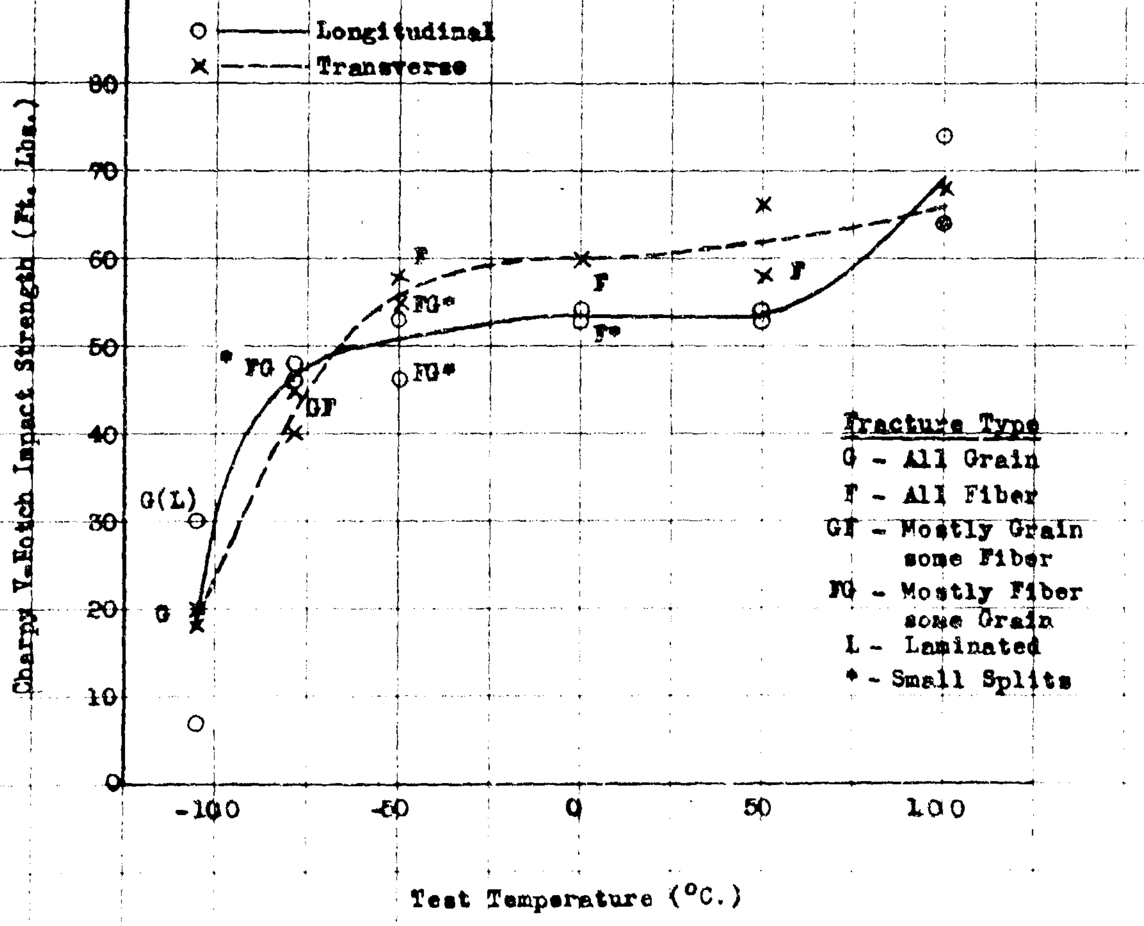
NP9 34978 -- [redacted] -- 11 June 1947

FIGURE 35

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 6" CLASS "B" PLATE NO. 3123

Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



HP9 34731 -- [redacted] -- 4 June 1947

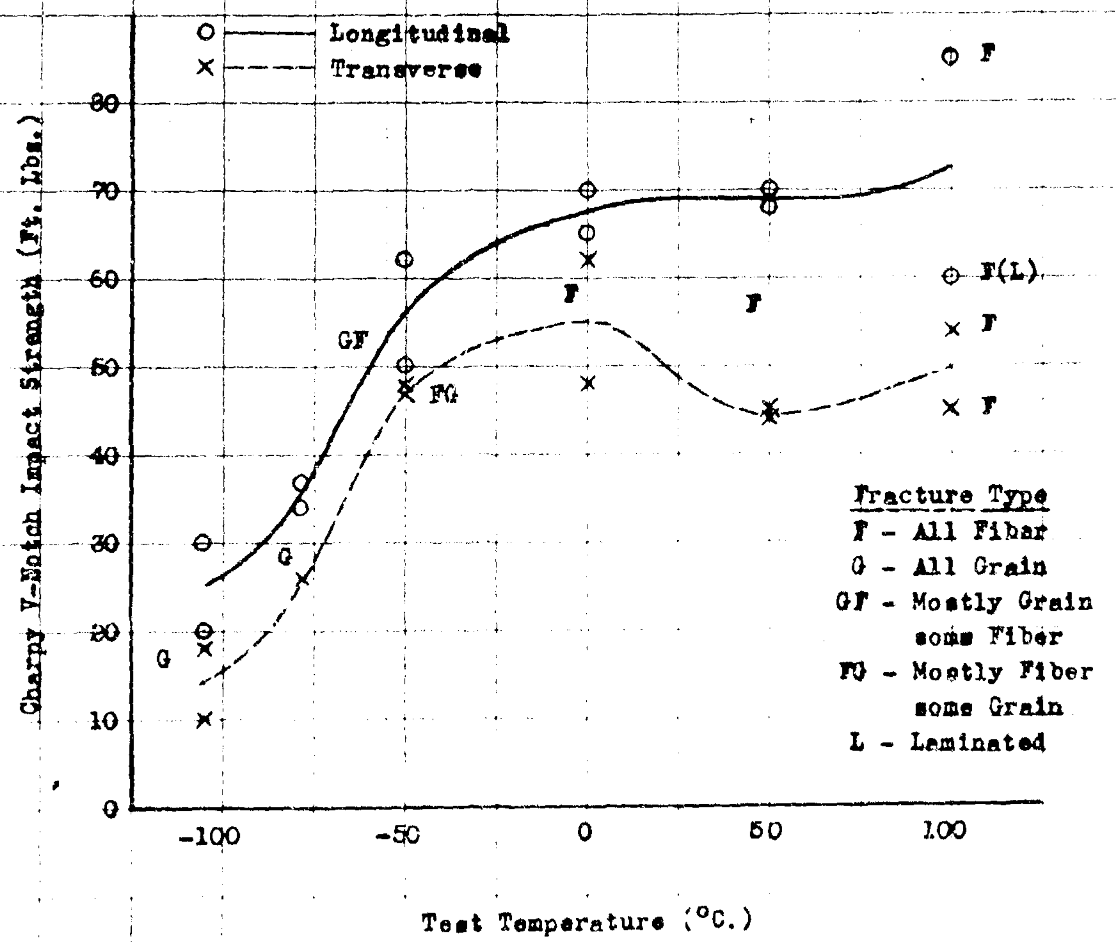
FIGURE 34

UNCLASSIFIED

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 7" CLASS "B" PLATE NO. 3128

Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



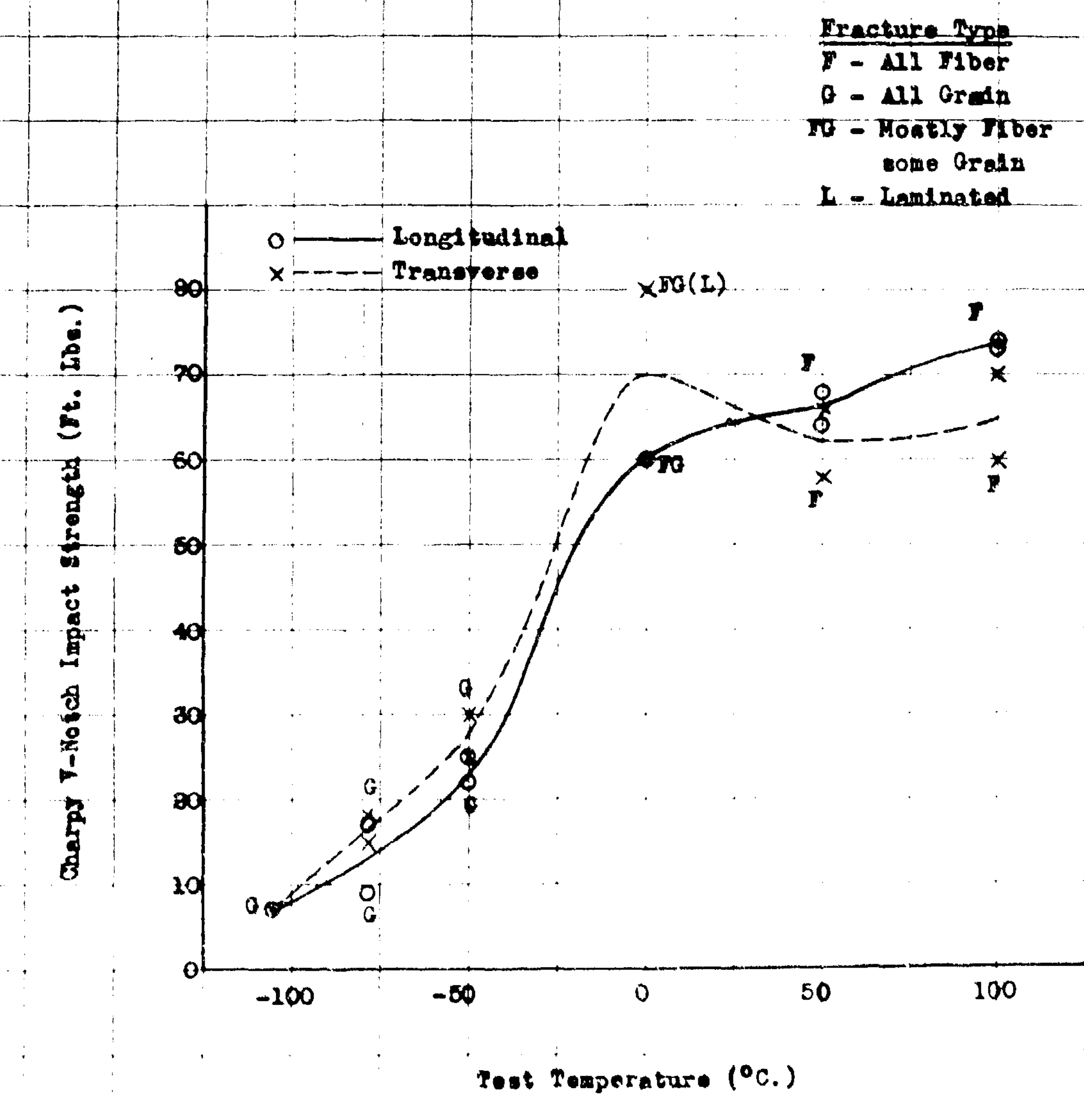
NP9 34975 -- [redacted] -- 10 June 1947

FIGURE 35

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 9!75 CLASS "B" PLATE NO. 3118

Charpy V- Notch Impact Strength (Ft. lbs.) Vs. Testing Temperature (°C)



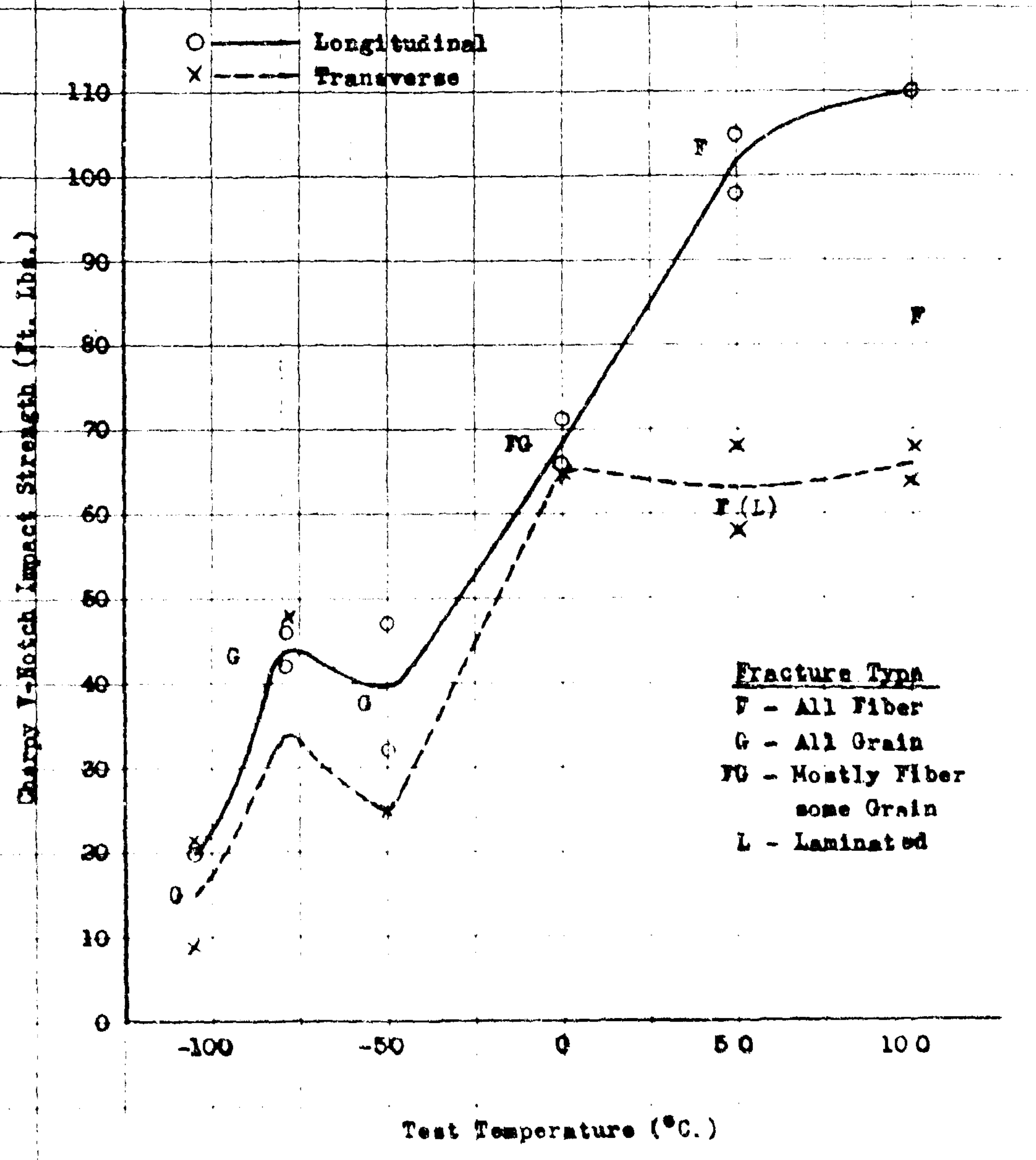
NPS 34979 -[redacted] 11 June 1947

FIGURE 36

CHARPY V - NOTCH IMPACT PROPERTIES

JAPANESE 12" CLASS "B" PLATE NO. 3108

Charpy V- Notch Impact Strength (Ft.lbs.) Vs. Testing Temperature (°C)



NP9 34974 [redacted] 10 June 1947

FIGURE 37

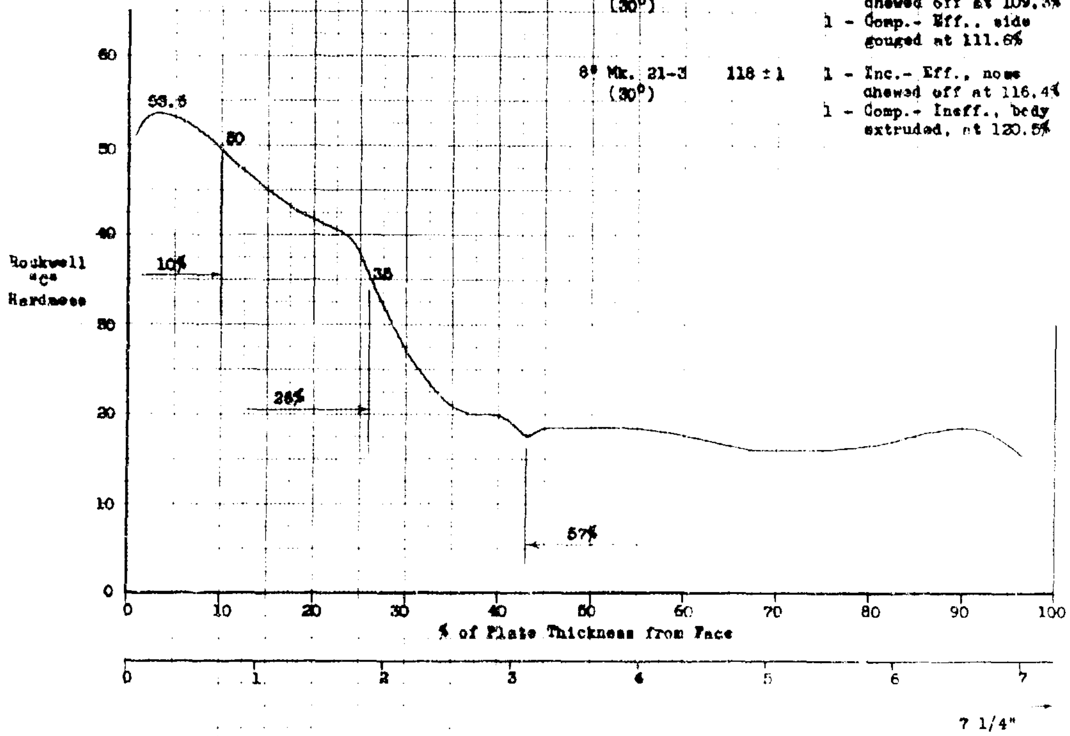
HARDNESS DISTRIBUTION THROUGH CROSS SECTION OF

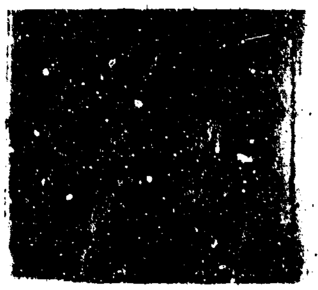
JAPANESE 7" CLASS "A" ARMOR PLATE

No. 2133

ESTIMATED LIMITS

Projectile	θ	Projectile Condition
8" Mk. 21-5 (30°)	110-111	1 - Inc.- Eff., nose chewed off at 109.3% 1 - Comp.- Eff., side gouged at 111.6%
8" Mk. 21-3 (30°)	118 ± 1	1 - Inc.- Eff., nose chewed off at 116.4% 1 - Comp.- Ineff., body extruded, at 120.5%





MACROETCHED SECTION

Etch: 10% Ammonium persulphate - 1 minute

NP9 34621 [redacted] 27 March 1947

FIGURE 38

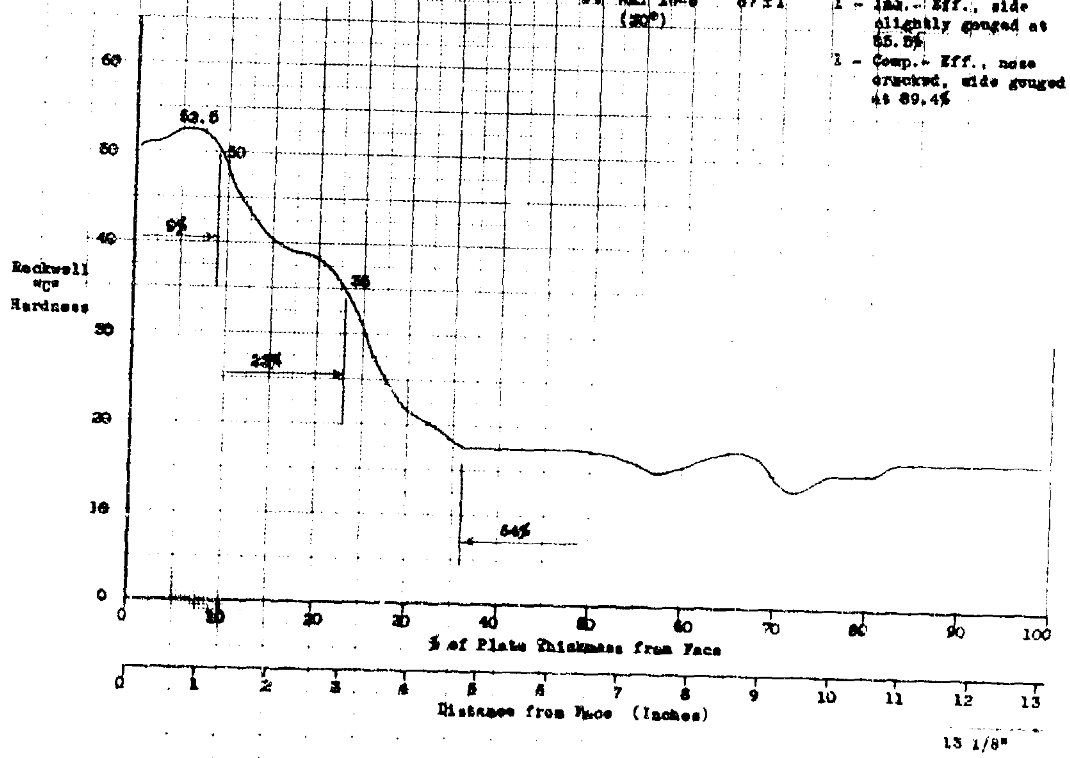
HARDNESS DISTRIBUTION THROUGH CROSS SECTION OF

JAPANESE 13" CLASS "A" ARMOR PLATE

No. 3134

ESTIMATED LIMIT

Projectile	SNL	Projectile Condition
14" Mk. 16-8 (30°)	87 ± 1	1 - Imp.- Eff., side slightly gouged at 85.5%
		1 - Comp.- Eff., nose cracked, side gouged at 89.4%

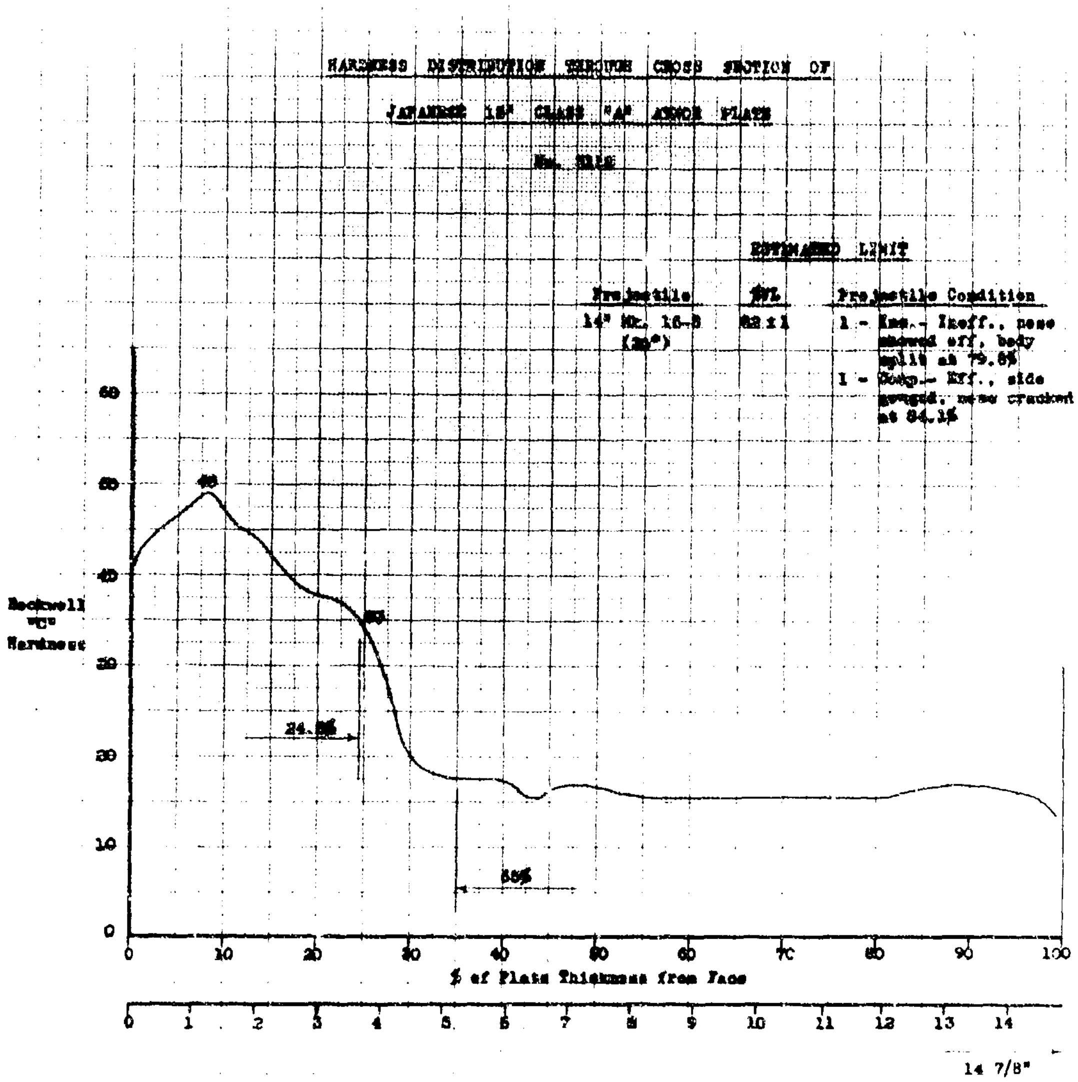


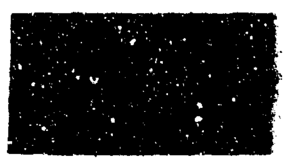
MACROETCHED SECTION

Etch: 10% Ammonium persulphate - 1 minute

NP9 34622 [redacted] 10 April 1947

FIGURE 39





MACROETCHED SECTION

Etch: 10% Ammonium persulphate - 1 minute

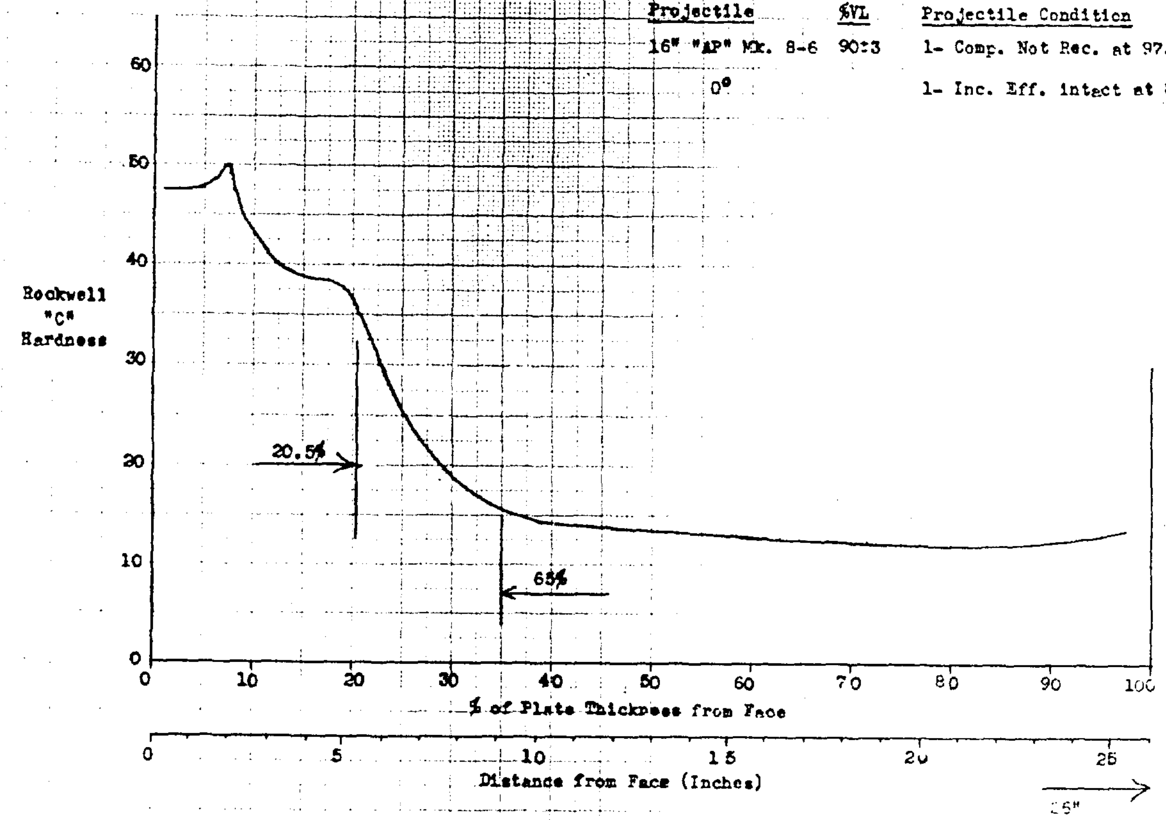
NP9 34623 [redacted] 10 April 1947

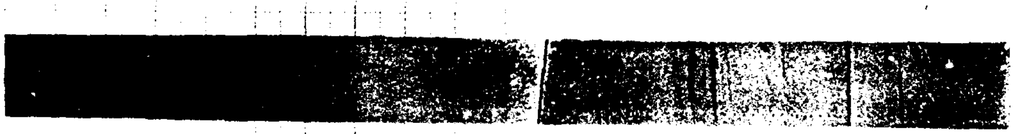
FIGURE 40

HARDNESS DISTRIBUTION THROUGH CROSS SECTION OF JAPANESE 26" CLASS "A" TURRET FACE PLATE

ESTIMATED LIMIT

Projectile	%VL	Projectile Condition
16" "AP" Mk. 8-6	90.3	1- Comp. Not Rec. at 97.5
0°		1- Inc. Eff. intact at 86.3





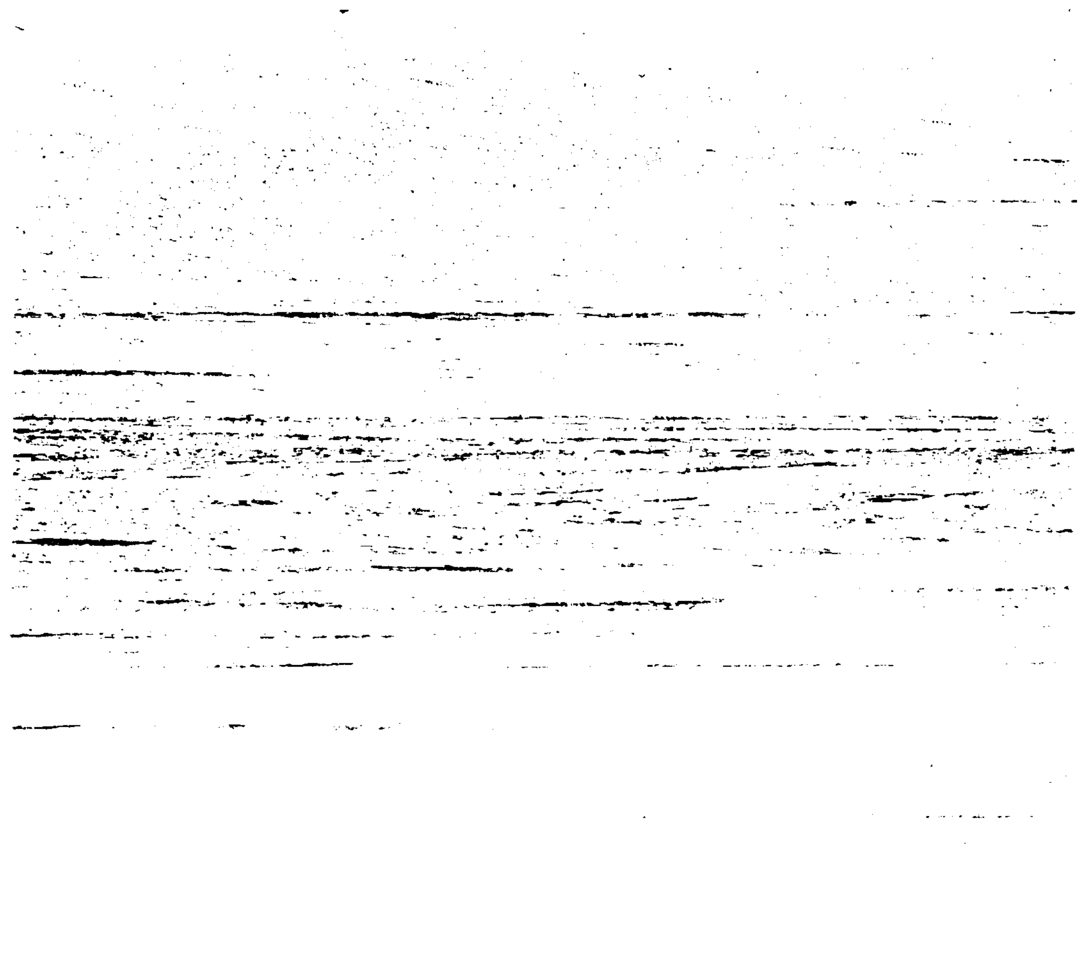
MACROETCHED SECTION

Etch: 10% Ammonium persulphate - 1 minute

NP9 34722 [redacted] 9 May 1947

UNCLASSIFIED

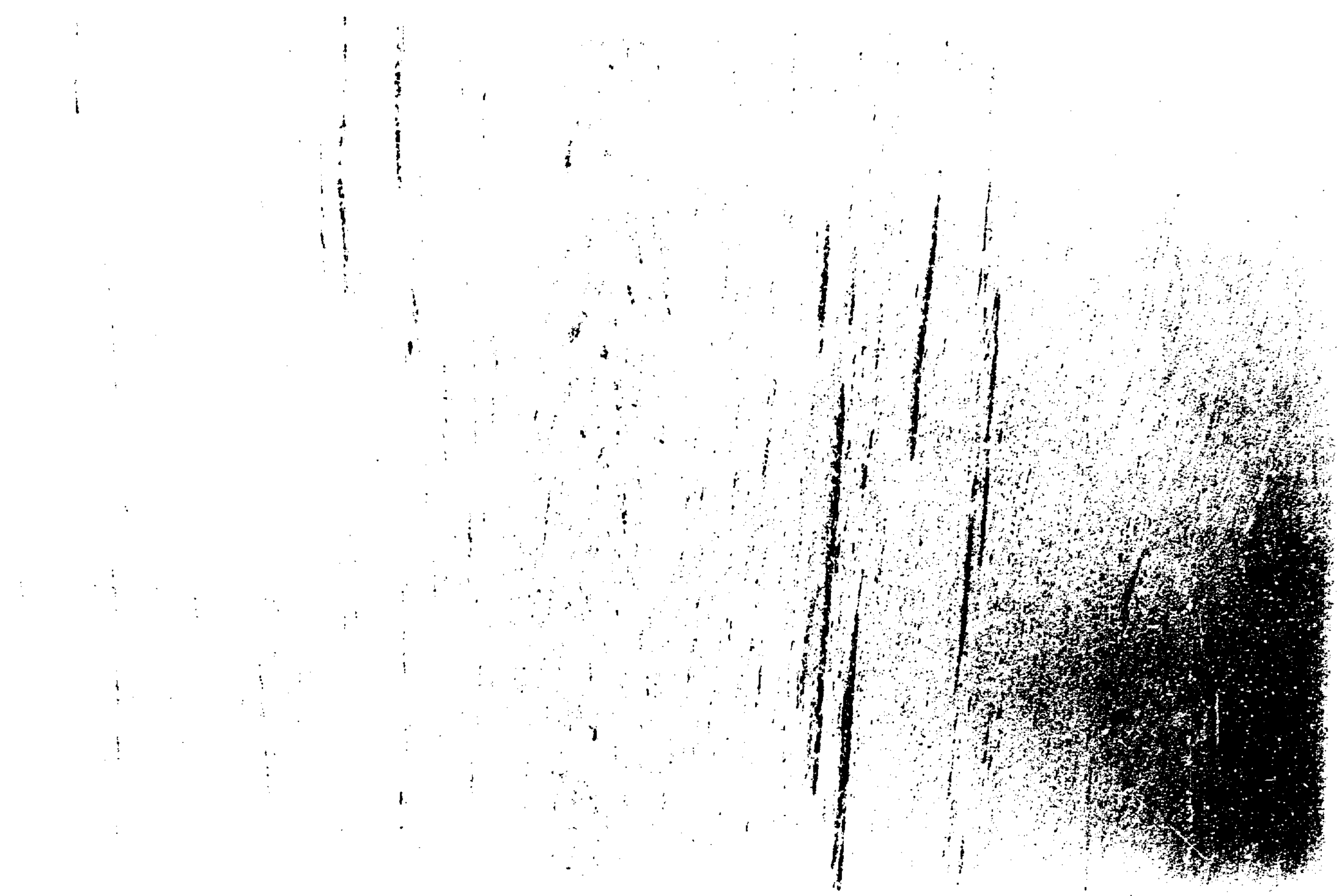
FIGURE 41



NP9 34987 Macroetch Longitudinal Section
Japanese 7-1/4" Class "A" Plate 3133
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 30 mins.
Magnification: Approximately 3/4
[redacted] 15 Aug. 1947

FIGURE 42

UNCLASSIFIED



NPG 35184
Japanese 13" Class "A" Plate 3124
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 22 mins.
Magnification: Approximately 3/4
[redacted]

Macroetch Longitudinal Section

15 Aug. 1947

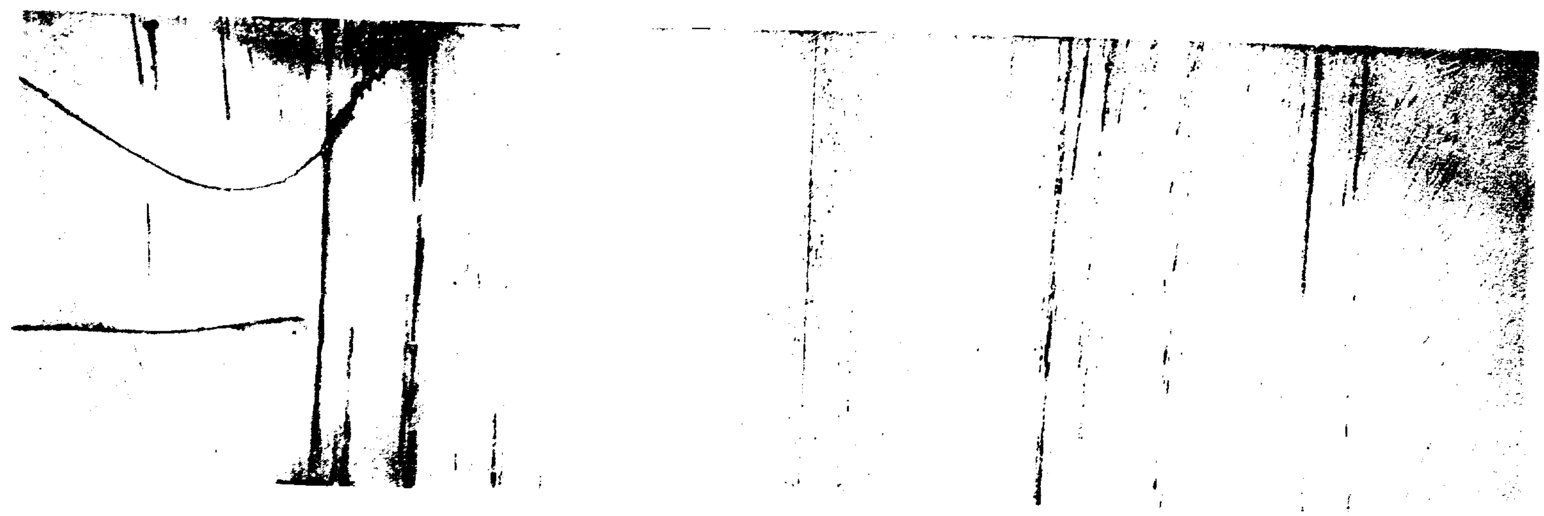
FIGURE 4[illegible]

NP9 35185 Macroetch Longitudinal Section
Japanese 15" Class "A" Plate 3113
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 30 mins.
Magnification: Approximately 1/2

[redacted] 15 Aug. 1947

UNCLASSIFIED

FIGURE 44

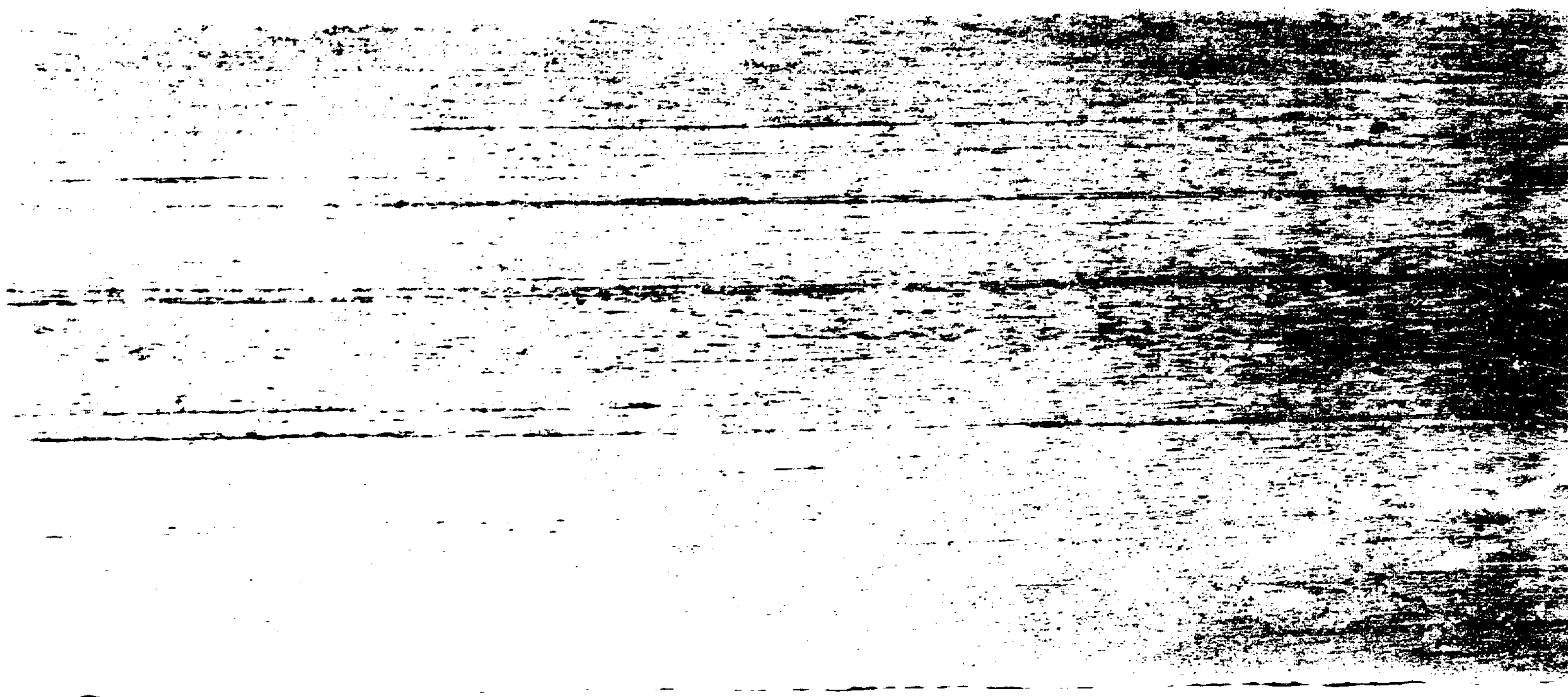


WD9 35186
Japanese 26" Turret Face Plate
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 30 mins.
Magnification: Approximately 1/3
[redacted]

Macroetch Longitudinal Section

15 Aug. 1947

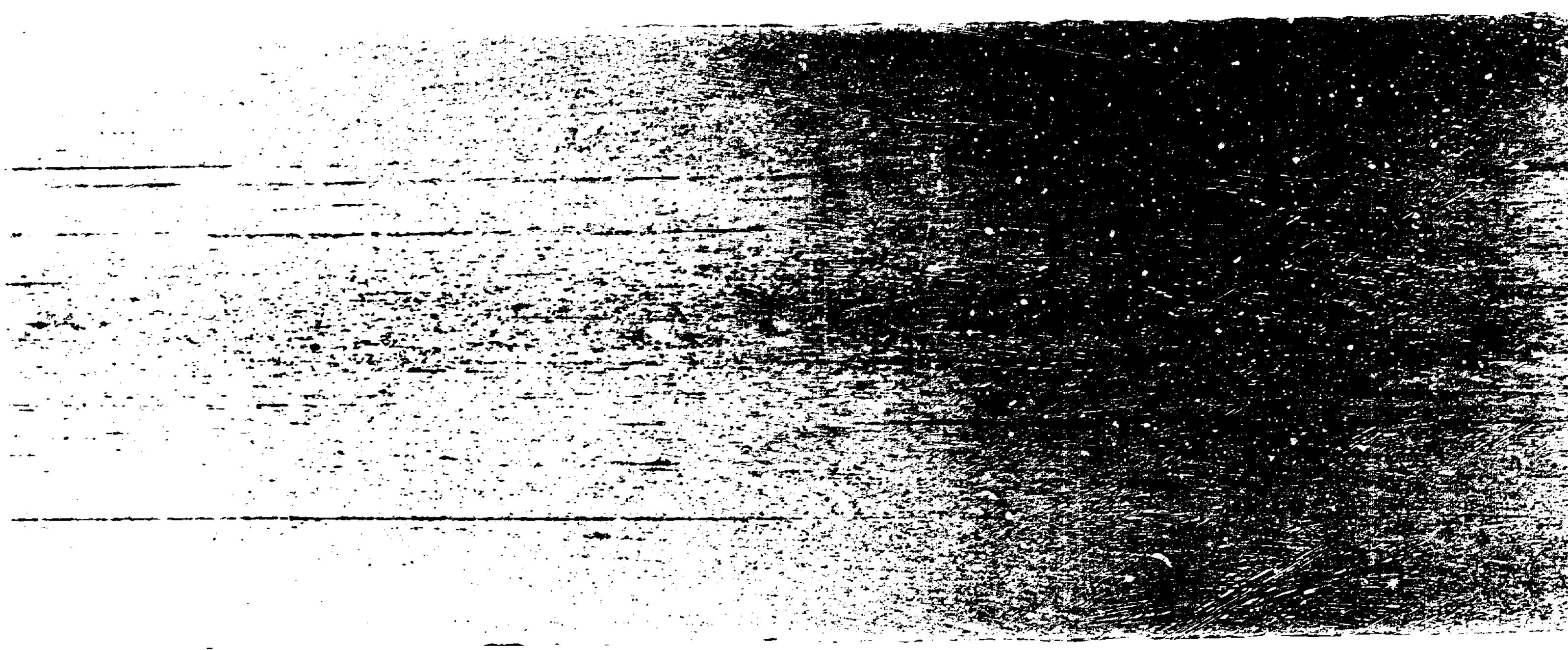
UNCLASSIFIED



NP9-34982 Macroetched Longitudinal Section
Japanese 3" Class B Plate No. 3114
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 25 mins.
Magnification: Approximately Actual Size

[redacted] 10 July 1947

FIGURE 46



NP9-34983

Japanese 3" Class B Plate No. 3116

Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 1 hour

Magnification: Approximately Actual Size

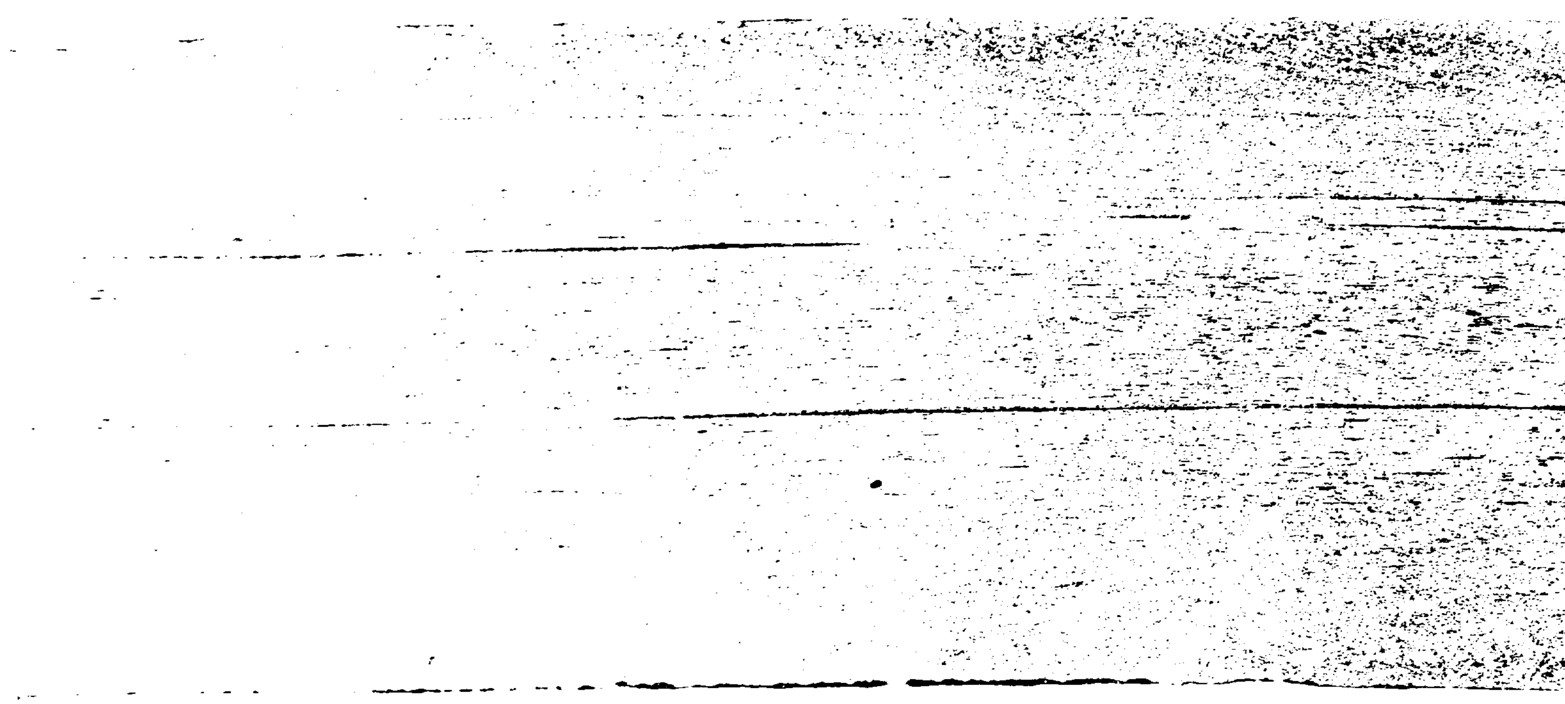
Macroetched Longitudinal Section

10 July 1947

[redacted]

UNCLASSIFIED

FIGURE 47



NP9-34984
Japanese 3" Class B Plate No. 3120
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 30 mins.
Magnification: Approximately Actual Size

Macroetched Longitudinal Section

10 July 1947

[redacted]

FIGURE 48

NPS-34986

Macroetched Longitudinal Section

Japanese 6" Class B Plate No. 3122

Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 45 minutes

Magnification: Approximately actual size

[redacted]

FIGURE 49

21 July 1947

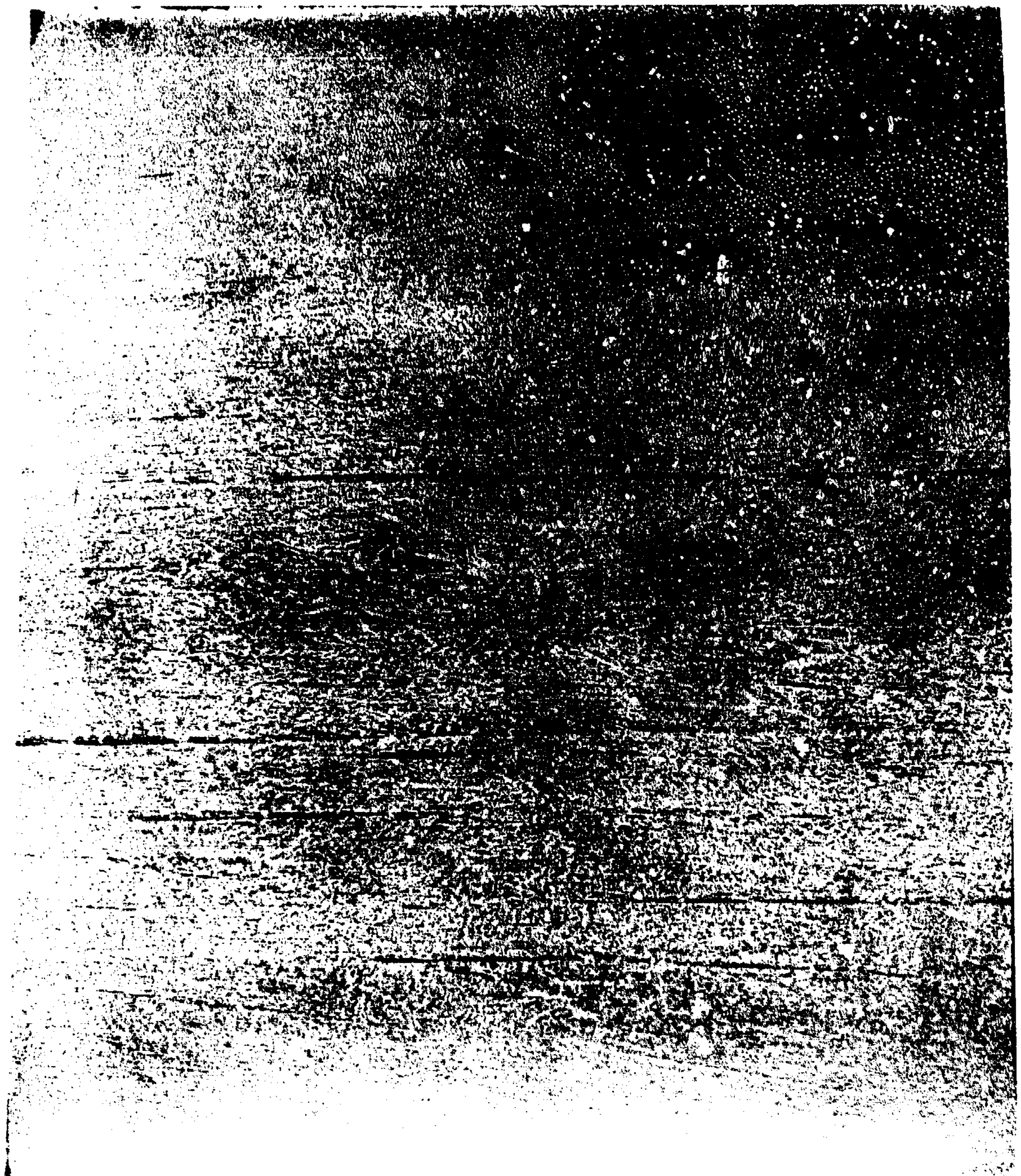
NP9-34985 Macroetched Longitudinal Section
Japanese 6" Class B Plate No. 3123
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 30 minutes
Magnification: Approximately 5/6
[redacted]
21 July 1947

FIGURE 50

NP9 35187 Macroetch Longitudinal Section
Japanese 7" Class B Plate 3128
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - [illegible] - [illegible] min.
Magnification: Approximately [illegible]

[redacted]

UNCLASSIFIED



NP9 35188 Macroetch Longitudinal Section
Japanese 9" Class "B" Plate 3118
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 25 mins.
Magnification: Approximately Actual Size
[redacted]
15 Aug. 1947

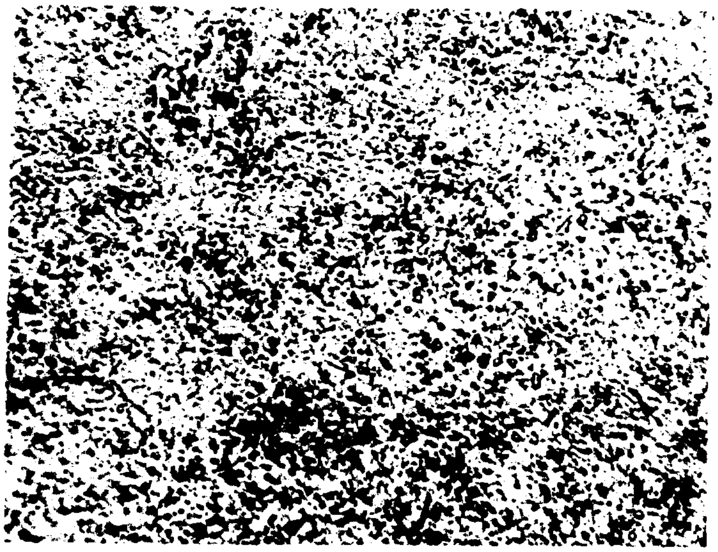
UNCLASSIFIED

NP9 35189 Macroetch Longitudinal Section
Japanese 12" Class "B" Plate 3108
Etch: 12% H_2SO_4, 38% HCl, 50% H_2O - 70°C - 30 mins.
Magnification: Approximately 2/3
[redacted]
15 Aug. 1947

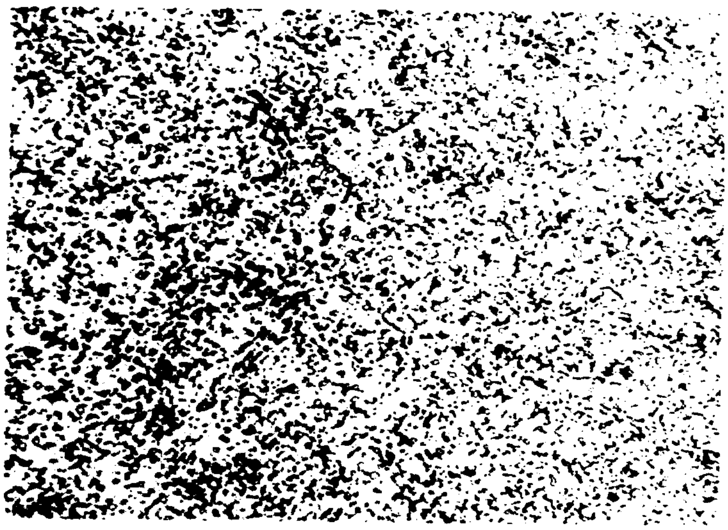
FIGURE [illegible]

UNCLASSIFIED

NP9 35195 28 Aug. 1947-[redacted]



(A) Picral Nital Etch 1500X
Structure 1-1/4" From Face of
15" Class A Plate No. 3113
Undissolved Carbides in Marten-
sitic Matrix

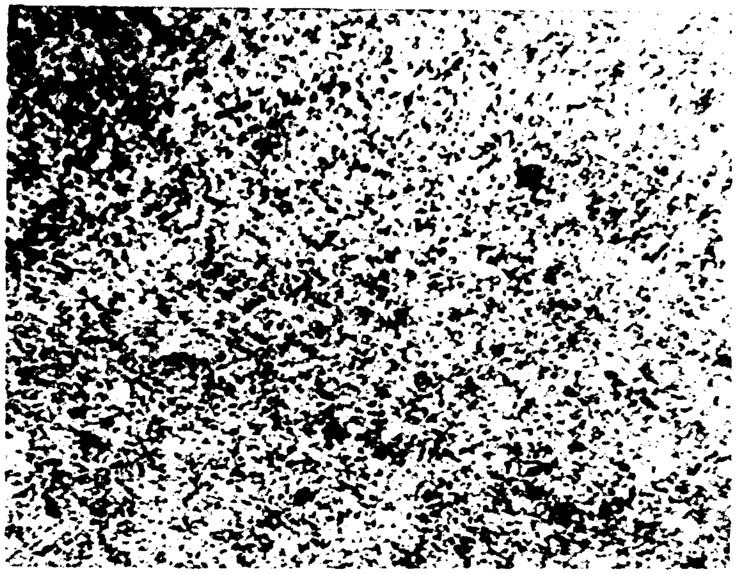


(B) Picral Nital Etch 1000X
Structure at 1/4 Point of
13" Class A Plate No. 3124
Spheroidized Carbides in
Ferritic Matrix

FIGURE 54

UNCLASSIFIED

NP9 35196 28 Aug. 1947-[redacted]

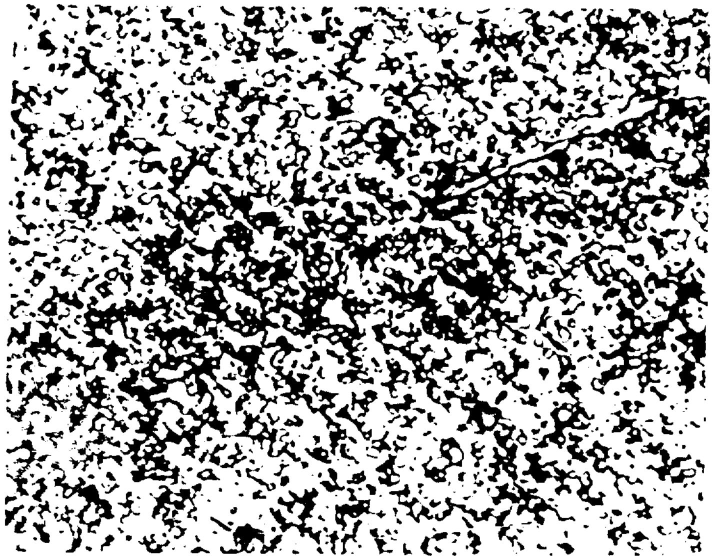


(A) Picral Nital Etch 1000X
Spheroidized Carbides in Ferritic Matrix
1/4 Point 7" Class B Plate No. 3128

FIGURE 55

UNCLASSIFIED

NP9 35197 28 Aug. 1947-[redacted]



(A) Picral Nital Etch 1000X
Spheroidized Carbides in
Ferritic Matrix

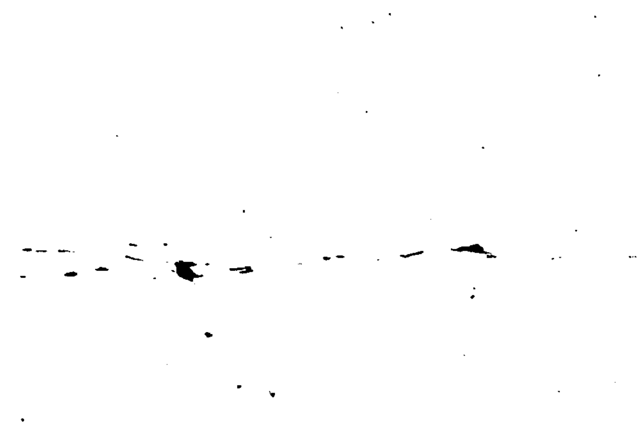
(B) Picral Nital Etch 1000X
Spheroidized Carbides in
Ferritic Matrix

Microstructures at the 1/4 point of 7" Class B Plate No. 3128 showing the banded distribution of carbides. Note the difference in carbide distribution between (A) and (B) which were taken at adjacent locations.

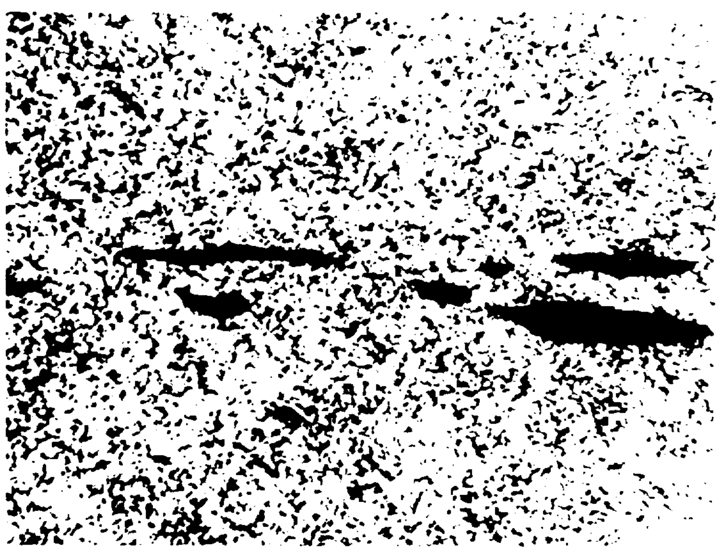
FIGURE 56

UNCLASSIFIED

NP9 35342 28 Aug. 1947-[redacted]



(A) Unetched 100X



(B) Picral Nital Etch 1000X

Inclusions at the 1/4 point of 6" Class B Plate No. 3122
Stringers typical of Japanese Armor Plate

FIGURE 57