UNCLASSIFIED

DTIC FILE COPY

(1)

U. S. NAVAL PROVING GROUND

DAHLGREN, VIRGINIA

AD-A955 276

DTIC
ELECTE
SEP 2 1 1987
S D
D

564120
NPG 3-47

[redacted]

Reproduced From
Best Available Copy

REPORT NO. 3-47

METALLURGICAL EXAMINATION OF STANDARD U. S. NAVY
ARMOR-PIERCING PROJECTILES

8" AP PROJECTILE MARK 21-5
12" AP PROJECTILE MARK 18-1
14" AP PROJECTILE MARK 16-8
16" AP PROJECTILE MARK 8-8

APPROVED FOR PUBLIC RELEASE,
DISTRIBUTION UNLIMITED.

JUNE 1947

UNCLASSIFIED

COPY NO.

[redacted]

INDEXED	✓
DESCRIPTIVE	✓ Encl. (19)

87 9 1 166

NOTICE OF CHANGE IN CLASSIFICATION
S/N 0107-735-1000

Commander
Naval Surface Weapons Center
Dahlgren, Virginia 22448

DATE
25 Aug 1981

ADDRESSES OF ORIGINAL DISTRIBUTION (Use Standard Navy Distribution List numbers if applicable. Additional sheets may be attached if more space is necessary.)

The material described below has been changed in classification as indicated. Addressees shall change the classification of copies held.

☐ REGRADED TO ______ ☐ DOWNGRADED TO ______ ☒ DECLASSIFIED

DATE AND DESCRIPTION OF MATERIAL (Avoid identification which would cause this form to be classified.)

NPG Report 3-47, Metallurgical Examination of Standard U. S. Navy Armor-piercing projectiles, 8" AP Projectile Mark 21-5, 12" AP Projectile MARK 18-1, 14" AP Projectile MARK 16-8 and 16" AP Projectile MARK 8-6

The following distribution statement should be applied: Approved for public release; distribution unlimited.

SIGNATURE OF AUTHORIZING OFFICIAL W. L. PARSELL
By direction

U. S. NAVAL PROVING GROUND

DAHLGREN, VIRGINIA

NPG REPORT NO. 3-47

METALLURGICAL EXAMINATION OF STANDARD U. S. NAVY ARMOR-PIERCING PROJECTILES

8" AP PROJECTILE MARK 21-5
12" AP PROJECTILE MARK 18-1
14" AP PROJECTILE MARK 16-8
16" AP PROJECTILE MARK 8-6

Submitted by: RH Lyddane
R. H. LYDDANE
Senior Physicist
Head of Armor &
Projectile Laboratory

Prepared by: Gerrit DeVries
G. DeVRIES
Associate
Metallurgist

Reviewed by: W.C. Bryson
W. C. BRYSON
Capt., USN
Experimental Officer

Reviewed by: J G Franklin
J. G. FRANKLIN
Comdr., USN
Armor Officer

Approved by: C.T. Joy
C. T. JOY
Rear Admiral, USN
Commanding Officer

Reviewed by: W.H. Benson
W. H. BENSON
Capt., USN
Ordnance Officer

APPROVED FOR PUBLIC RELEASE,
DISTRIBUTION UNLIMITED.

[redacted]

METALLURGICAL EXAMINATION OF STANDARD U. S. NAVY
ARMOR-PIERCING PROJECTILES

8" AP PROJECTILE MARK 21-5
12" AP PROJECTILE MARK 18-1
14" AP PROJECTILE MARK 16-8
16" AP PROJECTILE MARK 8-6

1. The results presented in this report are a part of the general program of development of armor-piercing projectiles being carried out by the Armor and Projectile Laboratory at the Naval Proving Ground.

2. The projectiles were sectioned and the surfaces ground at the Naval Gun Factory. The metallurgical examination was performed by the author and other staff members of the Armor and Projectile Laboratory.

C. T. Joy
C. T. JOY
Rear Admiral, USN
Commanding Officer

 [redacted]

PREFACE

AUTHORIZATION

Specific directives for this investigation were issued in BuOrd ltr. NP7/S78 (Re3) of 29 November 1945.

OBJECT

This investigation was conducted to obtain metallurgical information on the present standard 8", 12", 14", and 16" AP projectiles.

SUMMARY

The examination of the projectiles included the determination of the hardness distribution, the Charpy V-notch properties, the macro- and mirco-structures, and the chemical composition. Results are given and discussed. The projectiles are in general quite similar.

CONTENTS

Accesion For
NTIS CRA&I
DTIC TAB
Dist
A-1

QUALITY INSPECTED 2

UNANNOUNCED

 [redacted]

LIST OF FIGURES

LIST OF TABLES

[redacted]

I. INTRODUCTION

It is usual to subject one representative from each group of experimental projectiles to a metallurgical examination, which includes the determination of the hardness distribution, the Charpy V-notch properties, the macro- and micro-structures, and the chemical analysis. In the past, such examinations have been limited to projectiles smaller than 8", but the acquisition of new hardness testing equipment has made possible the application to projectiles of any size in use. The present standard 8", 12", 14", and 16" AP projectiles have therefore been subjected to examination, in order to provide a comparison for future work with experimental projectiles.

A brief discussion of the significance of the various tests follows.

1. Hardness and Hardness Distribution

The hardness of a projectile cap and also of the nose of the projectile influences its ability to cause damage to the face of Class A armor. The extreme hardness of the cap is instrumental in starting damage to the surface. After the cap has been shattered the nose of the projectile is able to complete the damage started by the cap. The hardness alone is not a measure of the quality of the projectile. The high hardness necessary to cause the plate to fail must be backed up by a more ductile material capable of absorbing shock without failure. The hardness pattern or hardness distribution gives a measure of the contour of the hardened zone.

Work done at the Naval Proving Ground on AP projectiles equipped with caps of hardness greater than 600 Brinell (carbide ball) led to the development by the projectile manufacturers of 6" and 8" AP projectiles with considerably improved penetrative performance against Class A plate over standard projectiles. As a result of this work 6" and 8" AP projectiles are now equipped with caps of approximately 680 Brinell (carbide ball) as contrasted with the old production projectiles which had a cap hardness of 550 (carbide ball) Brinell.

Deeper hardness patterns and higher nose hardnesses for the bodies of AP and Common projectiles have been advocated by the Proving Ground for several years. It appears that the nose hardness should be as high as

CONFIDENTIAL

possible while the body hardness should be that which gives the maximum bend strength.

2. Impact Test

The Charpy V-notch impact test is a measure of the ability of the material to absorb shock without fracture. The test is usually applied to a sample from the body of the projectile rather than from the cap or nose. The principal property required of the cap and nose is hardness while the body of the projectile must withstand stresses without failure in order to carry the projectile through the plate.

3. Macroetch

It is well-known that by macroetching important structural features of the material are developed. Any dendritic segregation which may have been retained from the original ingot will be shown. The fiber of the metal which indicates the method of forging will be shown, though this may not be clear in a fine grained well hardened alloy steel. An added feature of the macroetch is its ability to develop the pattern of the hardened zone. Hardened steels show a darker color than unhardened steels when etched with ammonium persulfate.

4. Microstructure

The microstructure shows the general quality of the steel and also the effect of heat treatment. Physical properties may be predicted with reasonable accuracy by studying the structure revealed under the microscope. Unetched specimens are usually used in order to determine the number and size of inclusions. This latter feature is usually of minor importance in well made alloy steels.

5. Chemical Analysis

By chemical analysis the type of material is determined. This information gives a reasonable indication of hardenability and indication of probable physical properties. Certain features such as susceptibility to temper brittleness and possibility of cracking on quenching are also predictable. By determining the amount and kind of alloying elements present it is possible to predict the results obtainable by tempering at various temperatures.

By examining a projectile with all of the above methods it is usually possible to determine the effectiveness of heat treatment and also to discover if the proper heat treatment has been applied.

II. DESIGN FEATURES

Outline drawings of the projectiles are shown in Figure 1 and a tabulation of some of their major design features is given in Table I.

TABLE I

Design Data on Armor-piercing Projectiles

	8" AP Mk. 21-5	12" AP Mk. 18-1	14" AP Mk. 16-8	16" AP Mk. 8-6
Diameter (in.)	8	12	14	16
Overall length (in)	36	54	56	72
Body length (in)	23.2	37.7	36.5	49.8
Cap length (in)	5.1	5.5	6.0	6.8
Loaded wt. (lbs.)	335	1140	1500	2700
Body wt. (lbs.)	245	925	1203	2191
Cap wt. (lbs.)	58	124	153	312
% Cap by wt.	17.3	10.9	10.2	11.6
% Bursting charge by wt.	1.5	1.5	1.5	1.5
Maximum cap hardness (BHN)	683	578	578	555
% Windshield by wt.	1.3	1.2	2.3	1.2
Length of windshield	9.9	15.1	23.7	19.65

The 8" AP projectile has a greater percentage of cap and a harder cap than the other projectiles. The 14" AP projectile is only 4 calibers long, while the other projectiles are 4-1/2 calibers long. The 14" projectile has the windshield threads cut in the soft part of the skirt of the cap rather than in the hard upper part of the cap, which causes it to have a longer and heavier windshield than the other projectiles. Variations in the contours of the cap, the nose, and the cavity are apparent in Figure 1.

III. HEAT TREATMENT

According to the manufacturer's data the body of the 8" AP Mark 21-5 was hardened decrementally, after the conditioning treatment, by dipping nose downwards into lead at 1650°F and then water quenching; followed by an overall temper at 475°F. The triple alloy cap was hardened in the same way except that the overall temper was at 325°F. The 16" AP Mark 8-6 was given the same hardening treatment except that the cap was tempered at 450°F. The data available at the Proving Ground indicate that the 12" and 14" AP projectiles were heat treated similarly to the 16" AP projectile.

IV. EXPERIMENTAL

1. Chemical Analyses

The results of chemical analysis of specimens from the caps and bodies of the projectiles are given in Table II. The values reported were obtained spectrochemically with the exception of those of carbon, phosphorus and sulfur which were determined by standard chemical procedures.

TABLE II

Chemical Compositions of Armor-piercing Projectiles

Bodies

	C	Mn	P	S	Si	Ni	Cr	Mo	Cu
8" Mk. 21-5	.64	.38	.018	.018	.43	3.38	2.22	.08	.09
12" Mk. 18-1	.59	.38	.023	.015	.37	3.20	2.16	.08	.10
14" Mk. 16-8	.58	.41	.022	.015	.43	3.00	2.22	.06	.11
16" Mk. 8-6	.60	.34	.025	.017	.26	3.33	2.30	.09	.10

Caps

	C	Mn	P	S	Si	Ni	Cr	Mo	Cu
8" Mk. 21-5	.81	.80	.021	.022	.27	1.65	.96	.33	.15
12" Mk. 18-1	.60	.39	.023	.014	.31	3.15	2.23	.08	.09
14" Mk. 16-8	.60	.46	.023	.020	.43	3.05	2.21	.06	.14
16" Mk. 8-6	.60	.35	.031	.018	.39	3.60	2.49	.06	.10

The caps and bodies of all the projectiles were made of the same type of nickel chromium steel except the 8" AP projectile which had a high carbon triple alloy steel cap.

2. Macroetch and Hardness Patterns

One projectile of each type was sent to the Naval Gun Factory for sectioning and surface grinding. The results of the macroetch and hardness survey of the ground halves are shown in Figures 2, 3, 4, 5 and 6.

The macroetch patterns of all projectiles were generally similar. The 12" AP body had the dark etching area extending all the way to the end of the base instead of ending above the bandscore, as for the other projectiles. The dark etching area at the base was about 7 points Rc greater in hardness than the light etching area. The 14" AP cap had a greater amount of light etching area than the caps of the other projectiles. The cracks visible in the hardened part of some of the projectiles are believed to have been caused by the splitting process.

All projectiles had similar hardness patterns except the 8" AP projectile which had a much harder cap than the others. Both Vickers and Brinell hardness tests were made on the same 8" AP projectile so that the values could be compared. As would be expected the Vickers values were somewhat higher than the Brinell numbers in the higher ranges but otherwise the hardness patterns obtained by either method were similar.

3. Impact Properties of the Base

Specimens for impact tests were taken from the base of the unground half of each projectile. The results of these tests are shown in Table III.

TABLE III

Results of Charpy V-notch Impact Tests

	8" AP	12" AP	14" AP	16" AP
Temp. °C	Ft. lbs.	Ft. lbs.	Ft. lbs.	Ft. lbs.
+100	55 F	45 F	69 F	65 F
+ 50	57 F	48 F	57 F	58 F
0	45 F	48 F	47 G10%	56 F
- 50	26 G50%	24 G80%	21 G100%	39 G40%
- 78	17 G100%	20 G100%	17 G100%	20 G100%

F = All fibrous fracture.
G = Grainy fracture, percent.

All the projectiles have about the same impact properties. The hardness of the impact specimens varied between 23 and 27 Rc. Impact specimens were taken from the light etching part of the base of the 12" AP projectile.

CONFIDENTIAL

4. Microstructure

Photomicrographs were made of samples taken from the nose and skirt of the caps and from the base and nose of the bodies of all the projectiles. These are shown in Figures 7, 8, 9 and 10. The microstructure in the nose of the caps and in the nose of the bodies consisted of slightly tempered martensite while the microstructure of the skirt of the caps and base of the bodies consisted of spheroidized carbides in a ferritic matrix.

V. DISCUSSION

1. Cap Hardness

The present standard 12", 14" and 16" AP projectiles have caps of relatively low hardness 550 Brinell (carbide ball). As was pointed out in the introduction the penetrative ability of the 8" AP was increased by increasing the cap hardness, so that increasing the cap hardness of the 12", 14" and 16" AP projectiles might increase their penetrative ability.

2. Body Hardness

Higher nose and body hardness for the subject projectiles might be desirable. With many steels the breaking strength on impact is greater when the steel is tempered at 350°F than when the steel is tempered at 450°F even though the steel is harder when tempered at 350°F. Therefore, if the bodies of the subject projectiles were given a final tempering at 350°F instead of 450-475°F as at present, the ballistic performance might be improved. Tempering at 350°F would give harder steel that is likely to have greater impact strength.

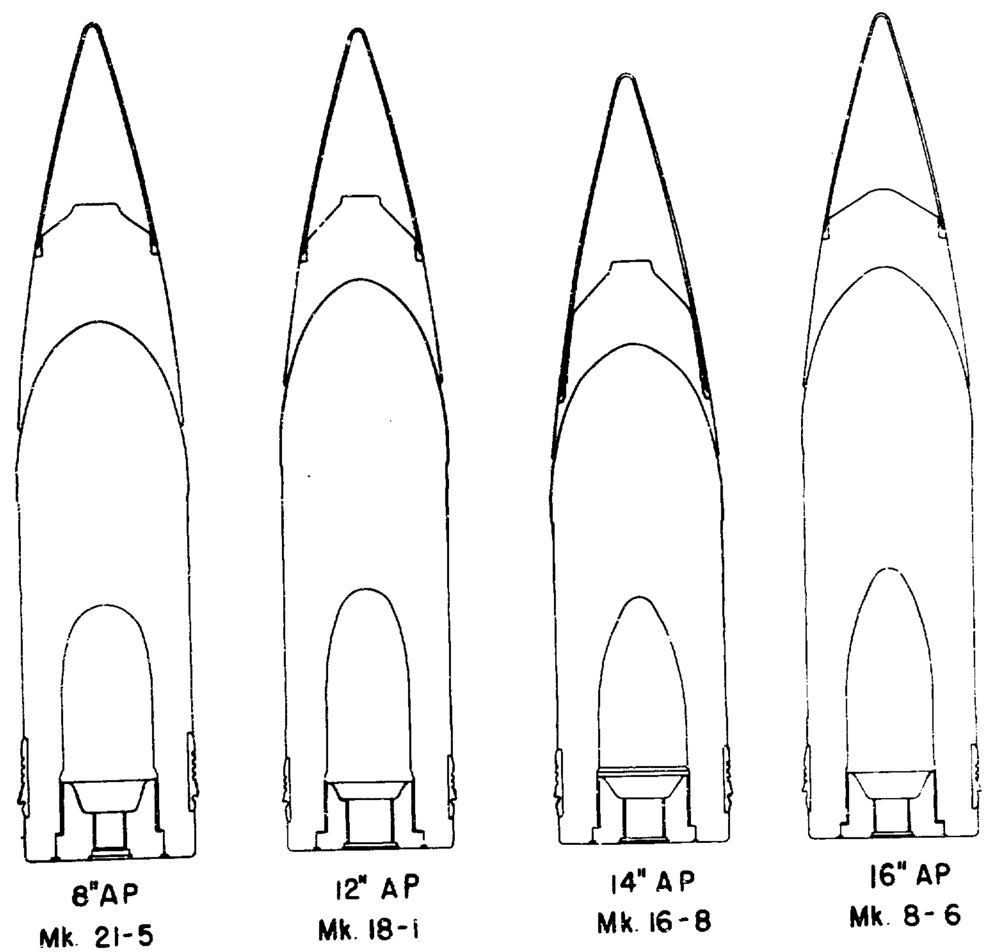
3. Composition

Most Navy projectiles regardless of size are made of steel of the same analysis (.60C, 2.2 Cr and 3.2 Ni). Considering hardenability only, it may be that a more highly alloyed steel would produce better properties in the larger projectiles (12", 14" and 16").

NP9-34736

Figure 1

17 Apr. 1947



OUTLINES OF PROJECTILES

NP9 33983

SEPT 16, 1946

HARDNESS DISTRIBUTION AND MACROSECTION OF CRUCIBLE 8" AP PROJECTILE MK 21-5 LOT 1

Hardness Values Vickers Pyramid (50 Kg)

Etch Ammonium Persulfate

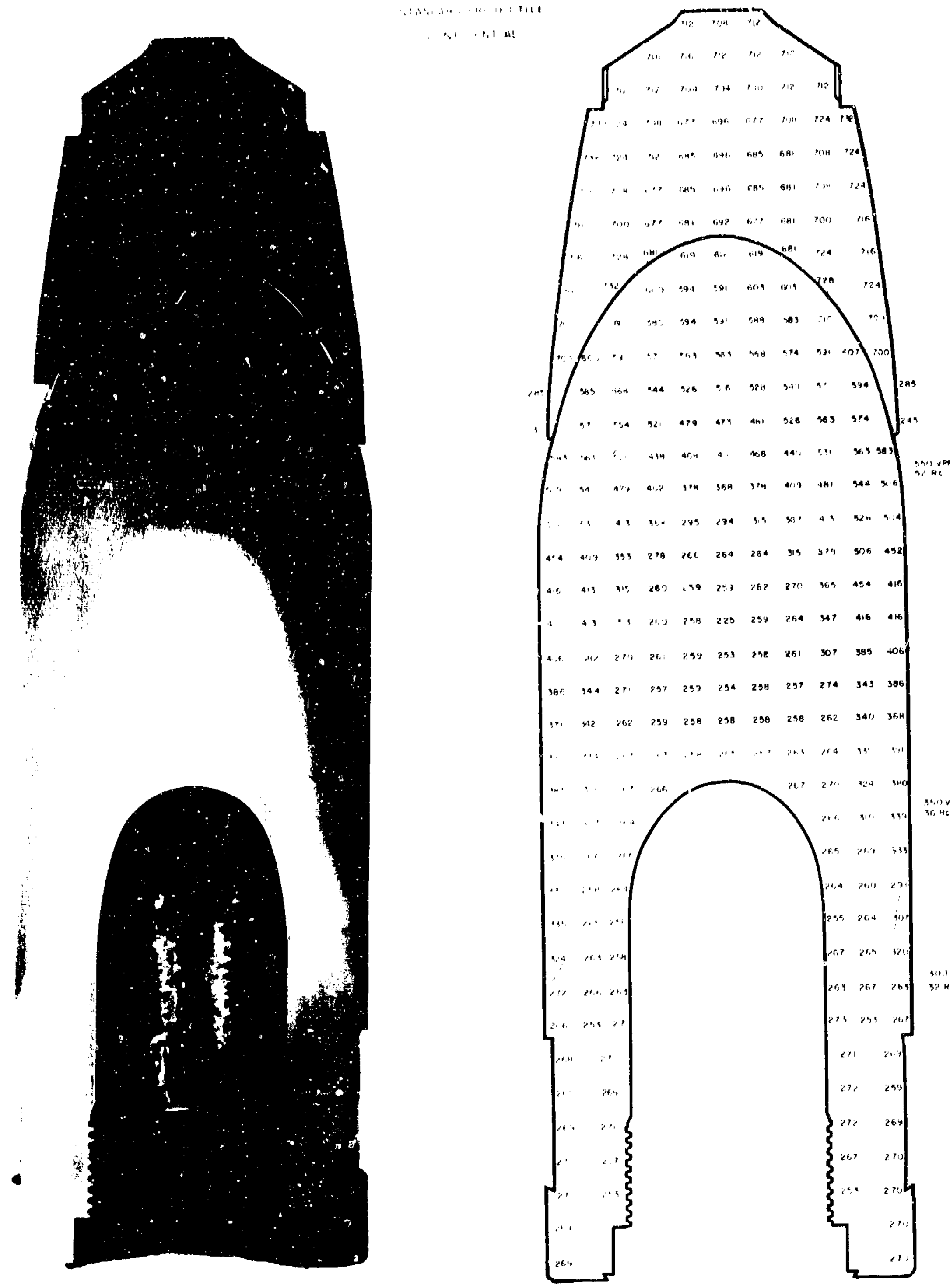


FIGURE 2

HARDNESS DISTRIBUTION AND MACROSECTION

PROJECT-LF MK 21-5 LOT 1 NO F 5333

10 Seconds

Ammonium Persulphate

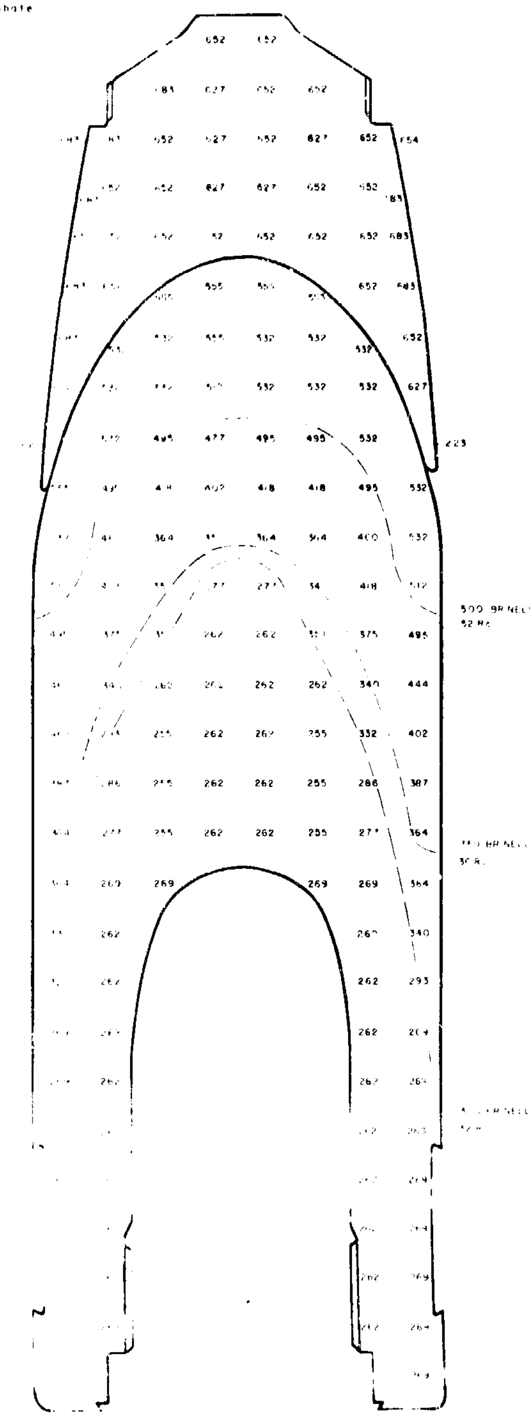


FIGURE 3

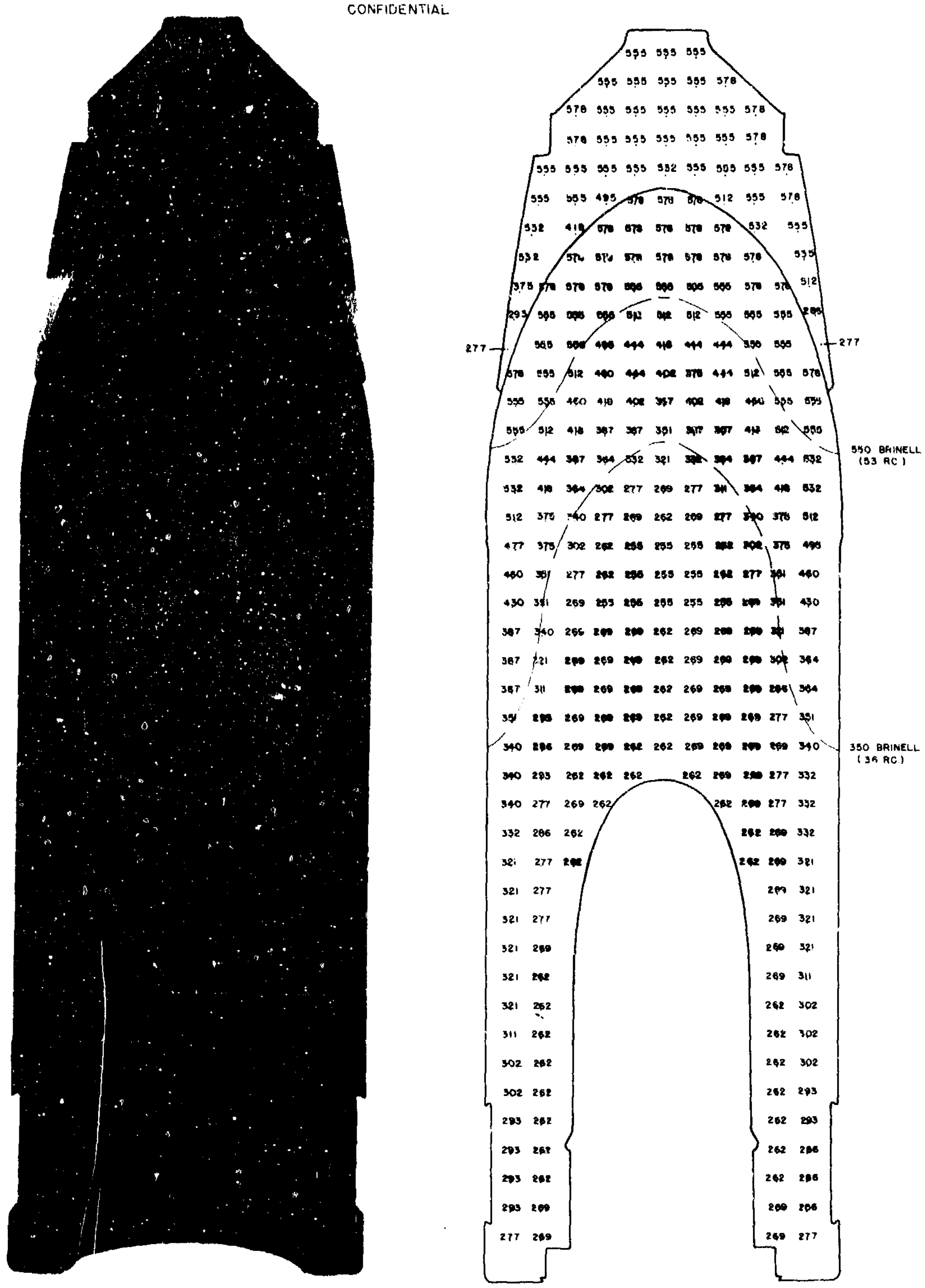
NPS - 34004 Nov. 13, 1946

HARDNESS DISTRIBUTION AND MACROSECTION OF CRUCIBLE 12" A.P. PROJECTILE MK. 18-1 LOT 21

Brinell Hardness Values: 10 mm. Carbide Ball - (3000 kg) - 10 Seconds

Etch: Ammonium Persulfate

CONFIDENTIAL



3507

FIGURE 4

HARDNESS DISTRIBUTION AND MACROSECTION OF CRUCIBLE 14" AP PROJECTILE MK. 16-8

Brinell Hardness Values: 10mm. Carbide Ball -(3000 kg.)- 10 seconds

Etch: Ammonium Persulfate

Standard Projectile

CONFIDENTIAL

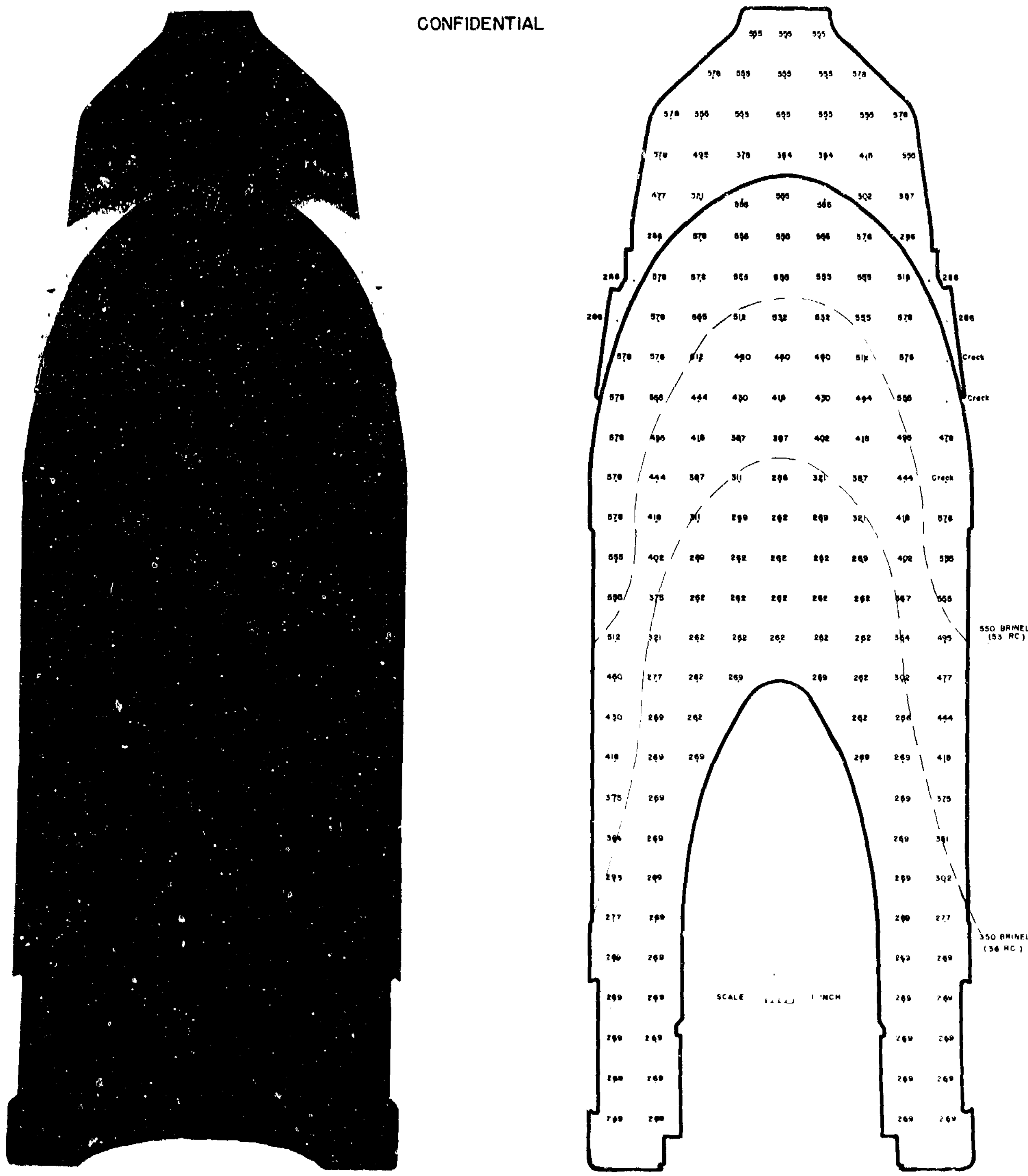


FIGURE 5

N°9 34012 Nov 18, 1946

HARDNESS DISTRIBUTION AND MACROSECTION OF BETHLEHEM 16" AP PROJECTILE MK. 8-6 LOT 5 NO. 6E9B

Brinell Hardness Values: 10mm Carbide Ball -(3000 kg)-10 seconds

Etch: Ammonium Persulfate

Standard Projectile

CONFIDENTIAL

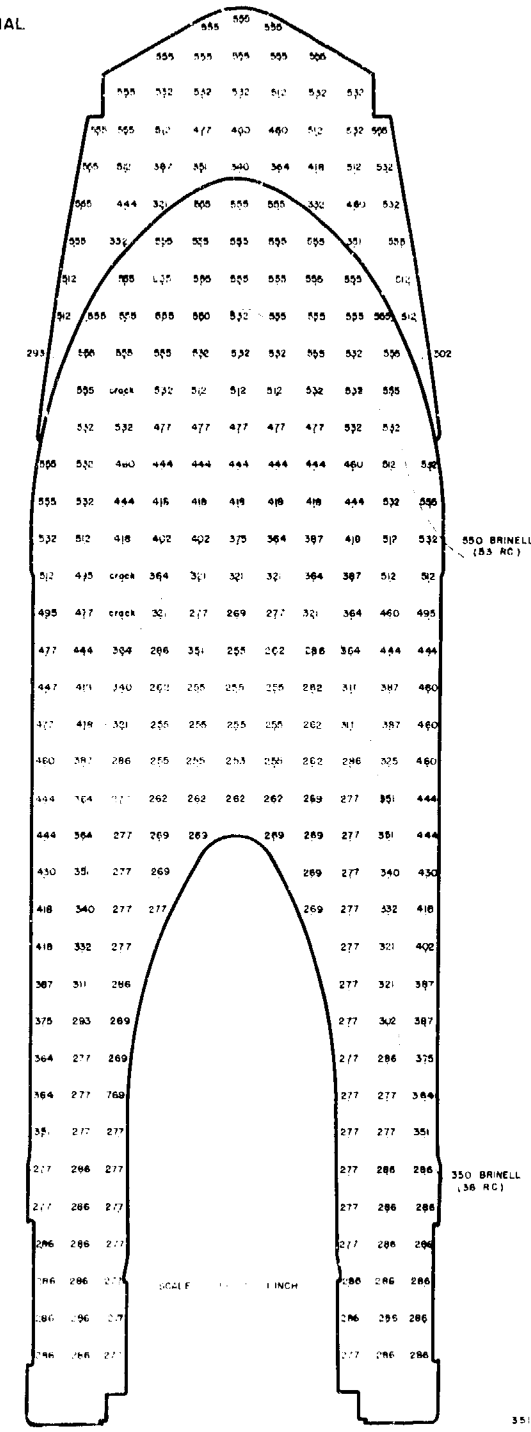
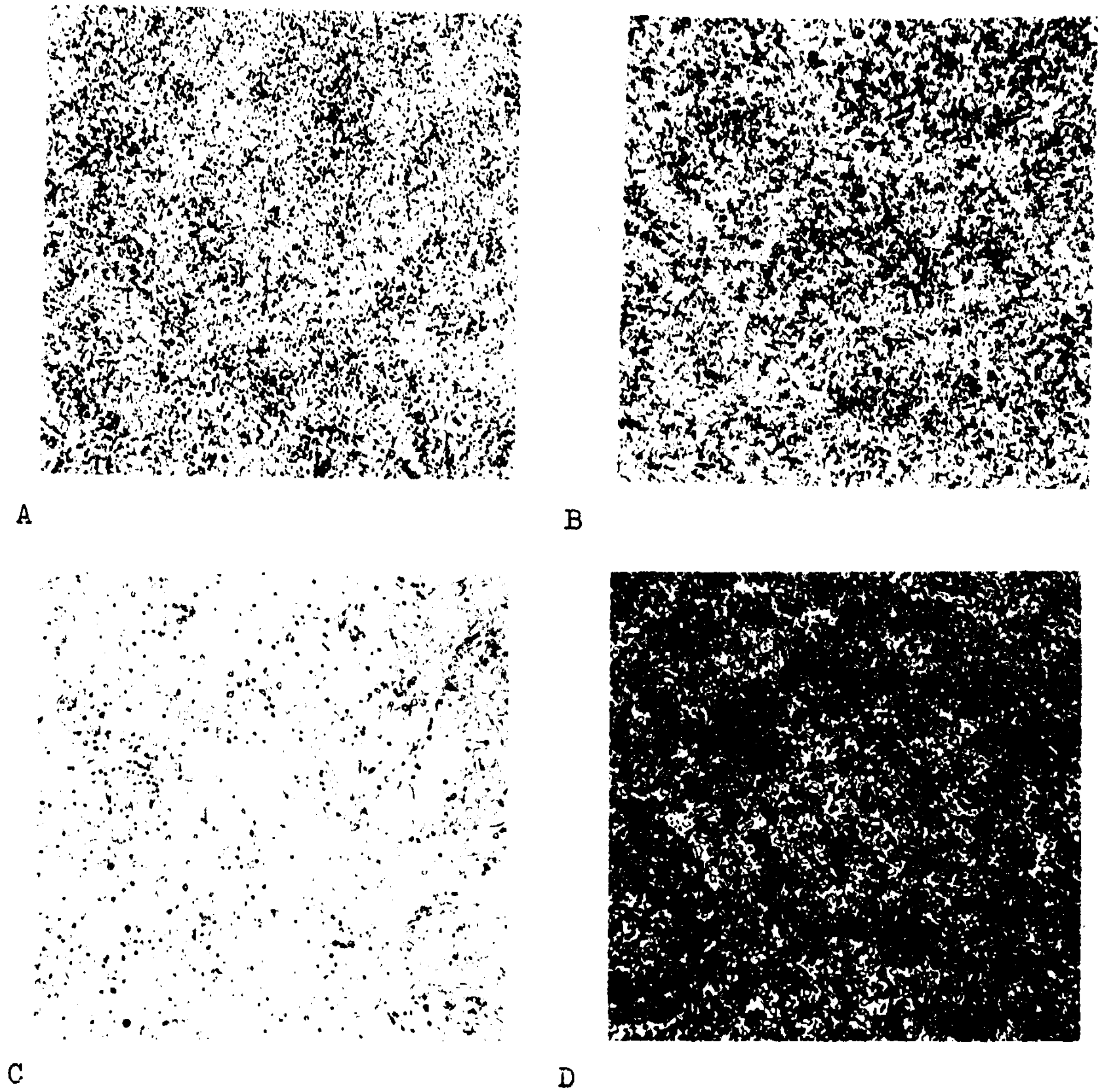


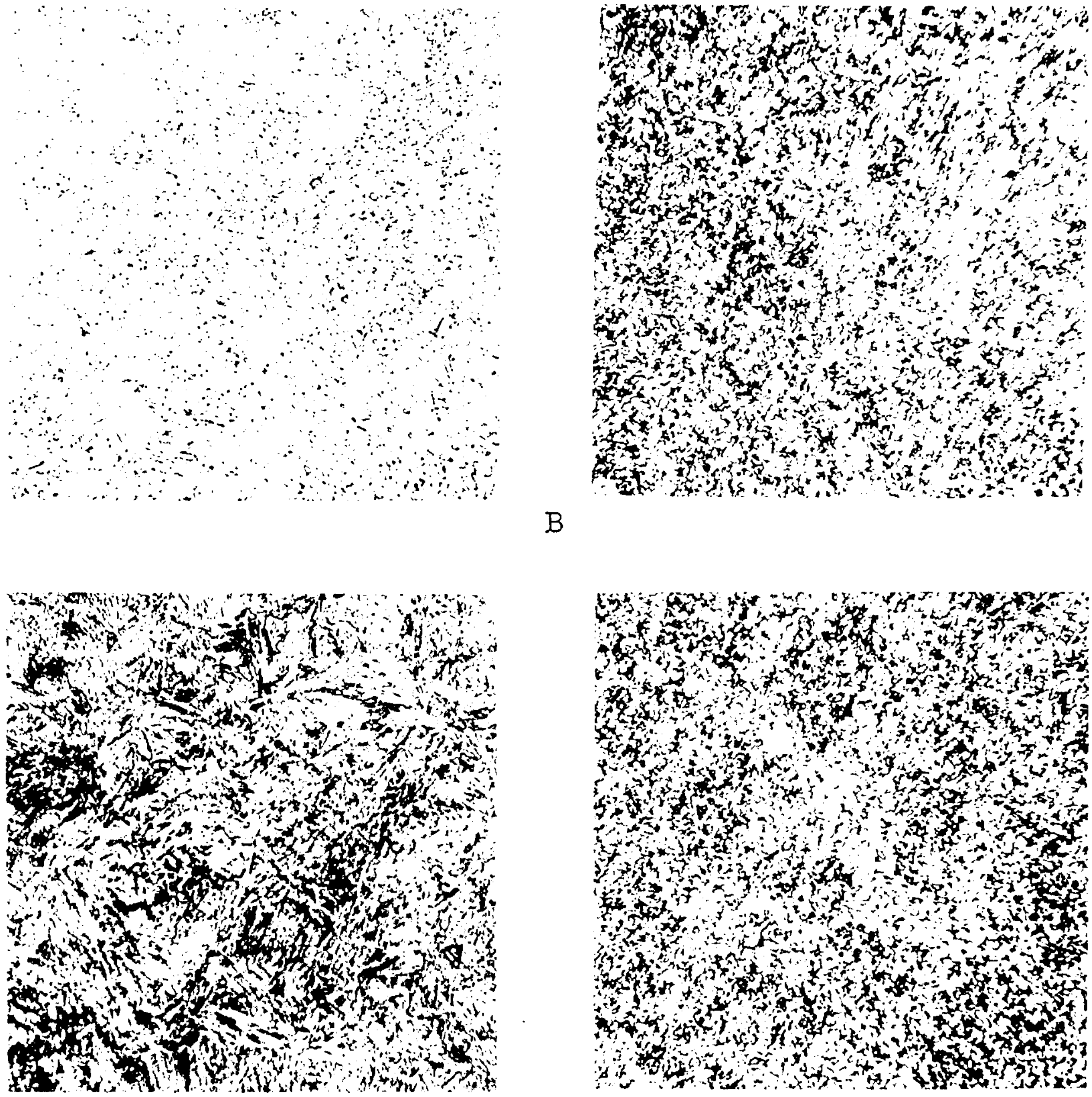
FIGURE 6



Photomicrographs of the 8" AP projectile Mk. 21-5. Picral Etch, 750X

		Hardness
A.	NP9 34465 - Nose of body, tempered martensite	555 BHN
B.	NP9 34196 - Base of body, spheroidized structure	269 BHN
C.	NP9 34211 - Nose of cap, tempered martensite	652 BHN
D.	NP9 34203 - Skirt of cap, spheroidized structure	269 BHN

Figure 7



A B C D

Photomicrographs of the 14" AP projectile Mk. 16-8. Picral Etch, 750X

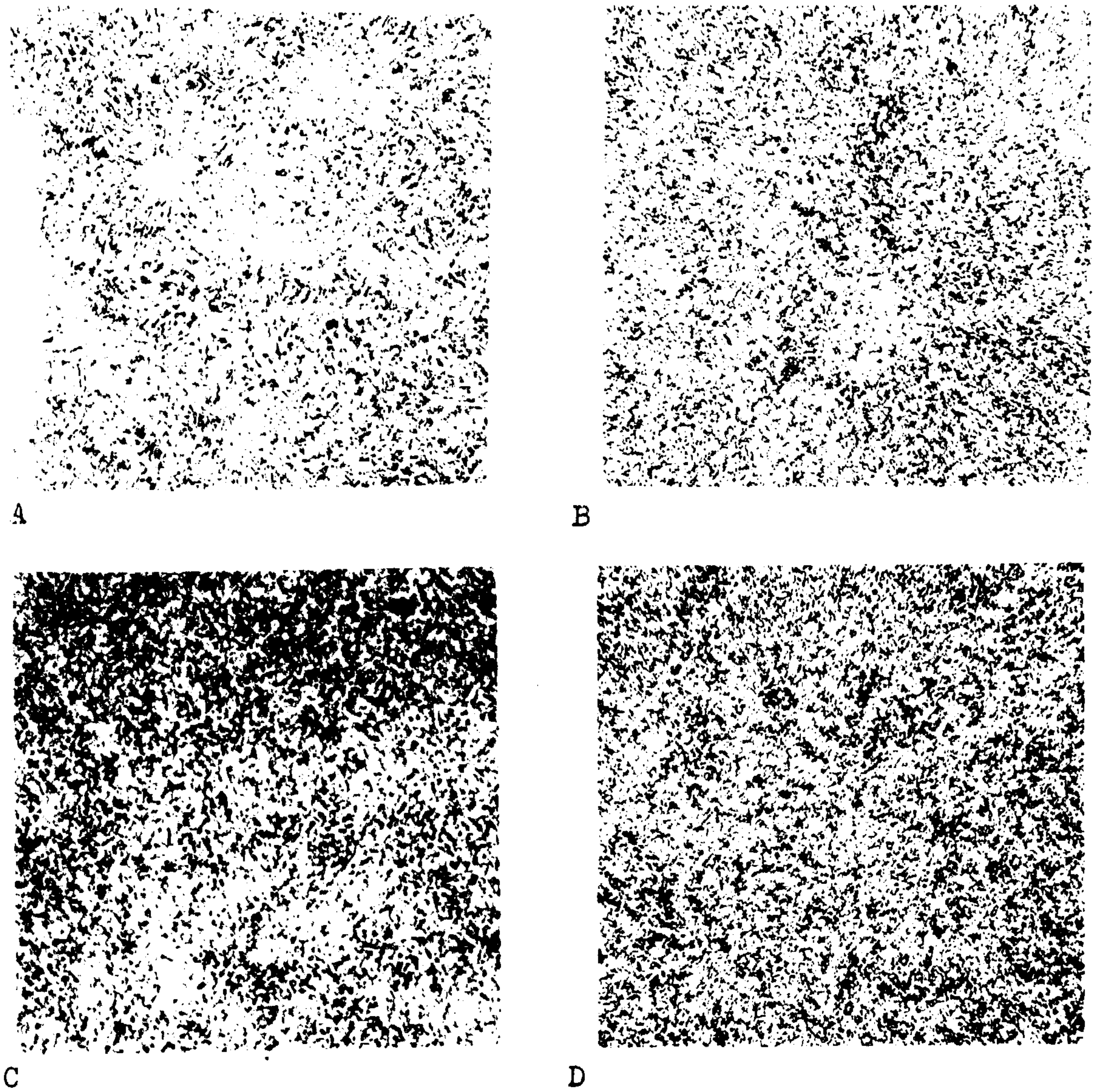
	Hardness
A. NP9 34435 - Nose of body, tempered martensite	555 BHN
B. NP9 34214 - Base of body, spheroidized structure	269 BHN
C. NP9 34200 - Nose of cap, tempered martensite	555 BHN
D. NP9 34215 - Skirt of cap, spheroidized structure	286 BHN

Figure 9

716.8

CONFIDENTIAL

This Document Contains Missing Page/s That Are Unavailable In The Original Document



Photomicrographs of the 16" AP projectile Mk. 8-6. Picral Etch 750X

	Hardness
A. NP9 34437 - Nose of body, tempered martensite	555 BHN
B. NP9 34219 - Base of body, spheroidized structure	286 BHN
C. NP9 34195 - Nose of cap, tempered martensite	555 BHN
D. NP9 34218 - Skirt of cap, spheroidized structure	293 BHN

Figure 10