

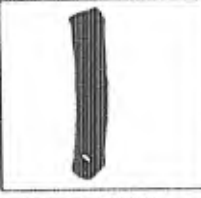
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AD-A953 818

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REPORT NO. 710/80

AD-A953 818

HARDNESS SURVEYS OF PENETRATIONS IN HOMO-
GENEOUS ARMOR PLATE OF HIGH, MEDIUM, AND POOR
BALLISTIC PROPERTIES

OFFICIAL USE ONLY
NOT TO BE RELEASED WITHOUT PRIOR
APPROVAL OF THE COMMANDING OFFICER
WATERTOWN ARSENAL, WATERTOWN, MASS.

WATERTOWN ARSENAL
WATERTOWN, MASS.

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Report presented on the

Hardness Surveys of Penetrations in Homogeneous Armor Plate of High, Medium, and Poor Ballistic Properties.

PLATE NO. 614 - 5.

DISSTON - Homogeneous Armor Plate.

18 x 18 x $\frac{1}{2}$ ".

Actual Thickness - .506".

Brinell - 430-444.

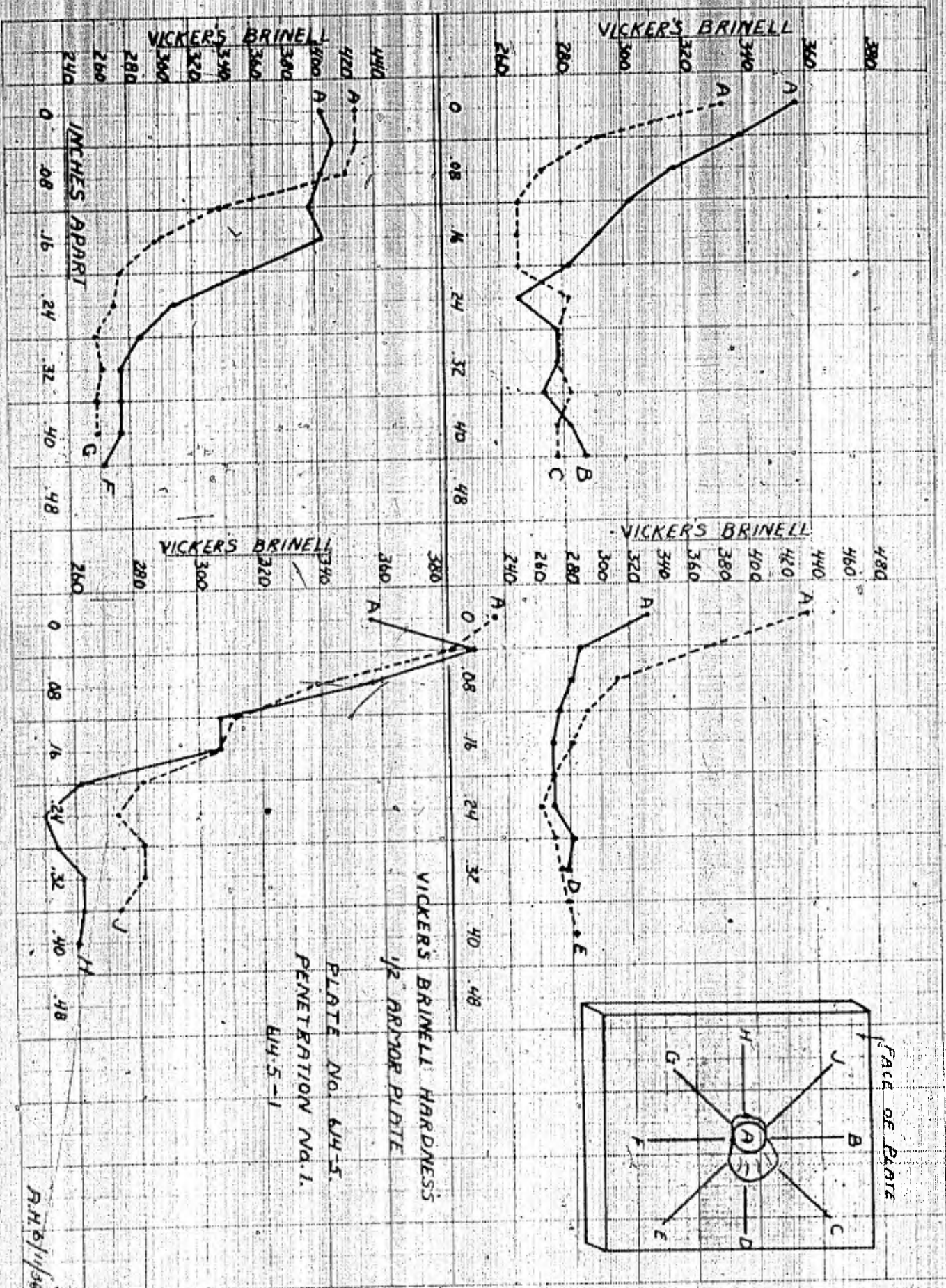
<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Ni</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>
.51	.42	.14	.013	.016	.09	1.21	.56	.29

Ammunition - .30 cal. 165 gr. M1922. A.P.

Range - 100 yards.

Specification - AXS - 54.

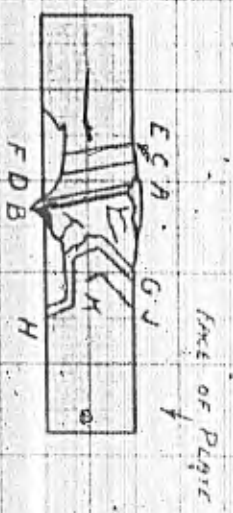
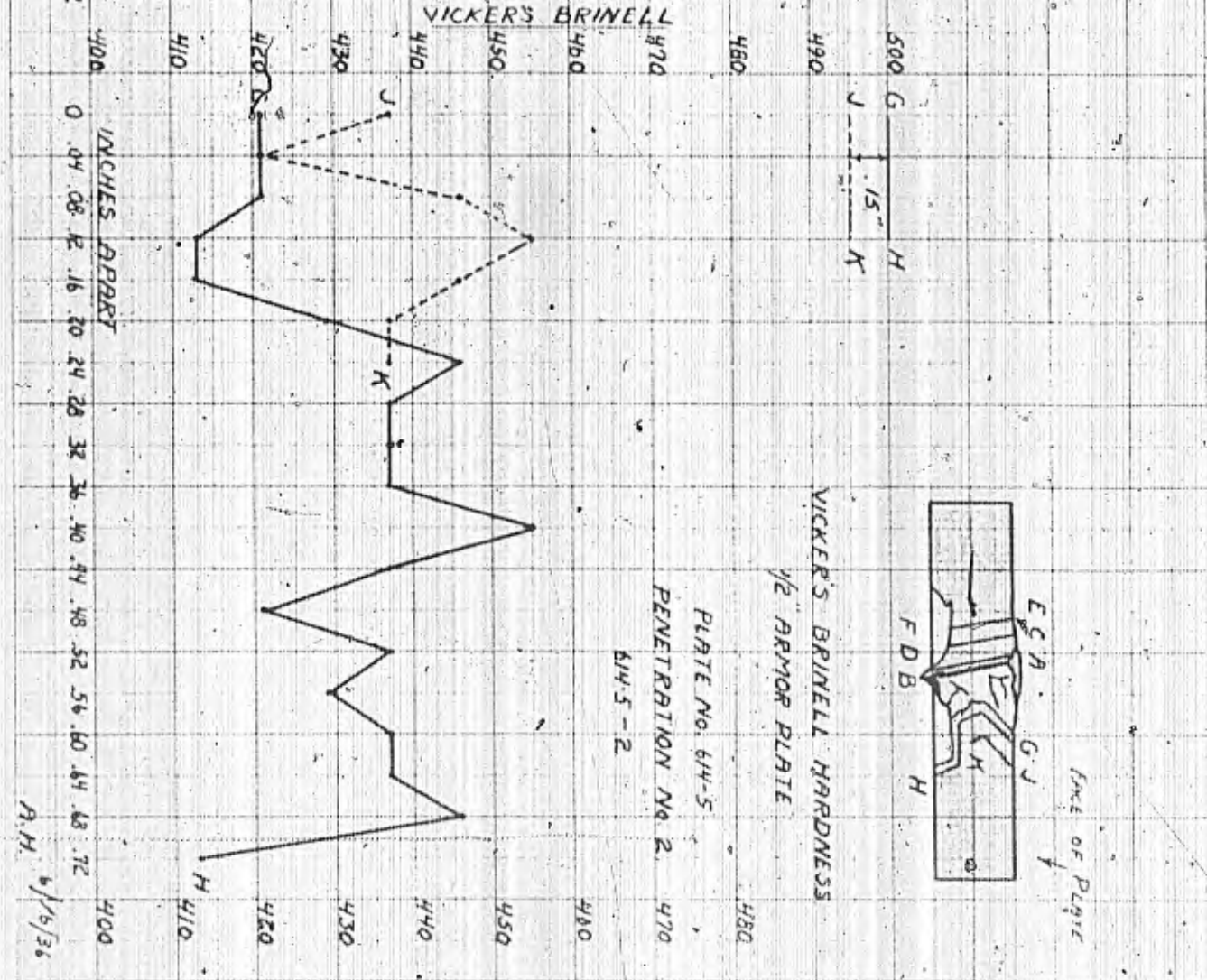
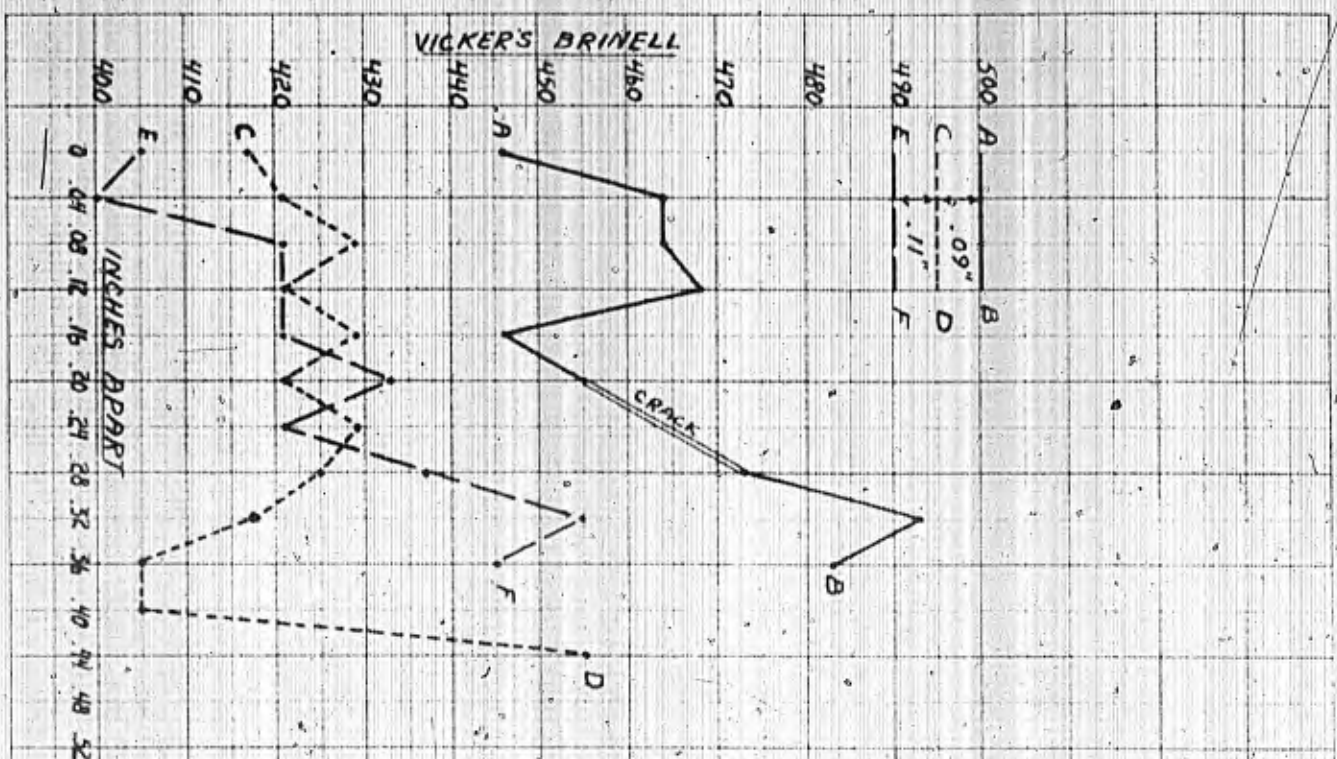
- Round 1. Str. Vel. 2696 f/s. Complete Penetration.
Diam. of Hole in Back - .70".
- Round 2. Str. Vel. 2656 f/s. Complete Penetration. G.I.P.
- Round 4. Str. Vel. 2459 f/s. Partial Penetration.
Diam. of Hole in Back - .005".
- Round 5. Str. Vel. 2495 f/s. Partial Penetration.
Diam. of Hole in Back - .01".
- Round 9. Str. Vel. 2409 f/s. Partial Penetration.
Height of Bulge on Back - .05".
- Round 10. Str. Vel. 2446 f/s. Partial Penetration.
Height of Bulge on Back - .06".



VICKERS BRINELL HARDNESS
 1/2" ARMOR PLATE

PLATE NO. 644-5.
 PENETRATION NO. 1.
 E44.5-1

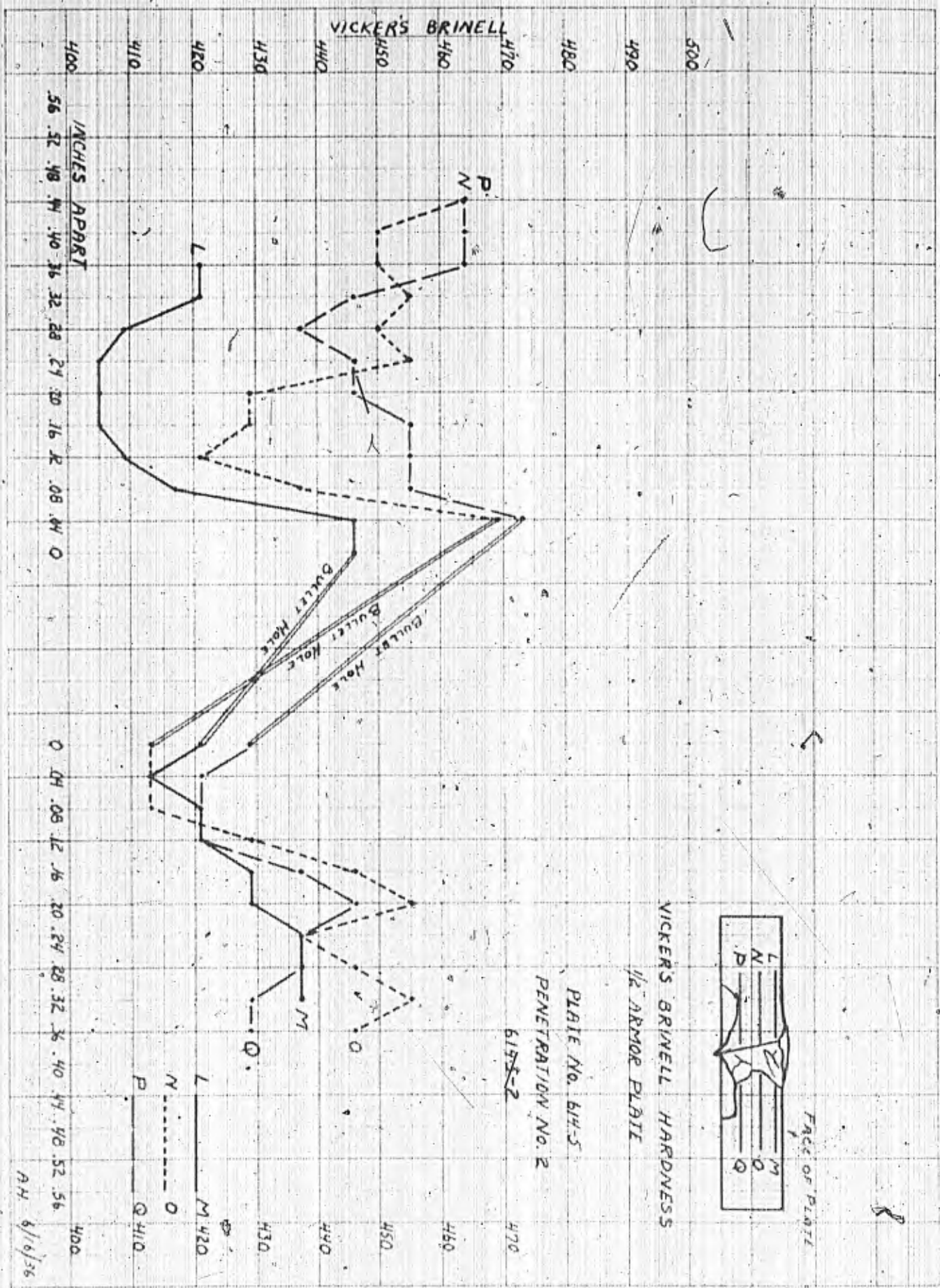
R.H. 5/11/36

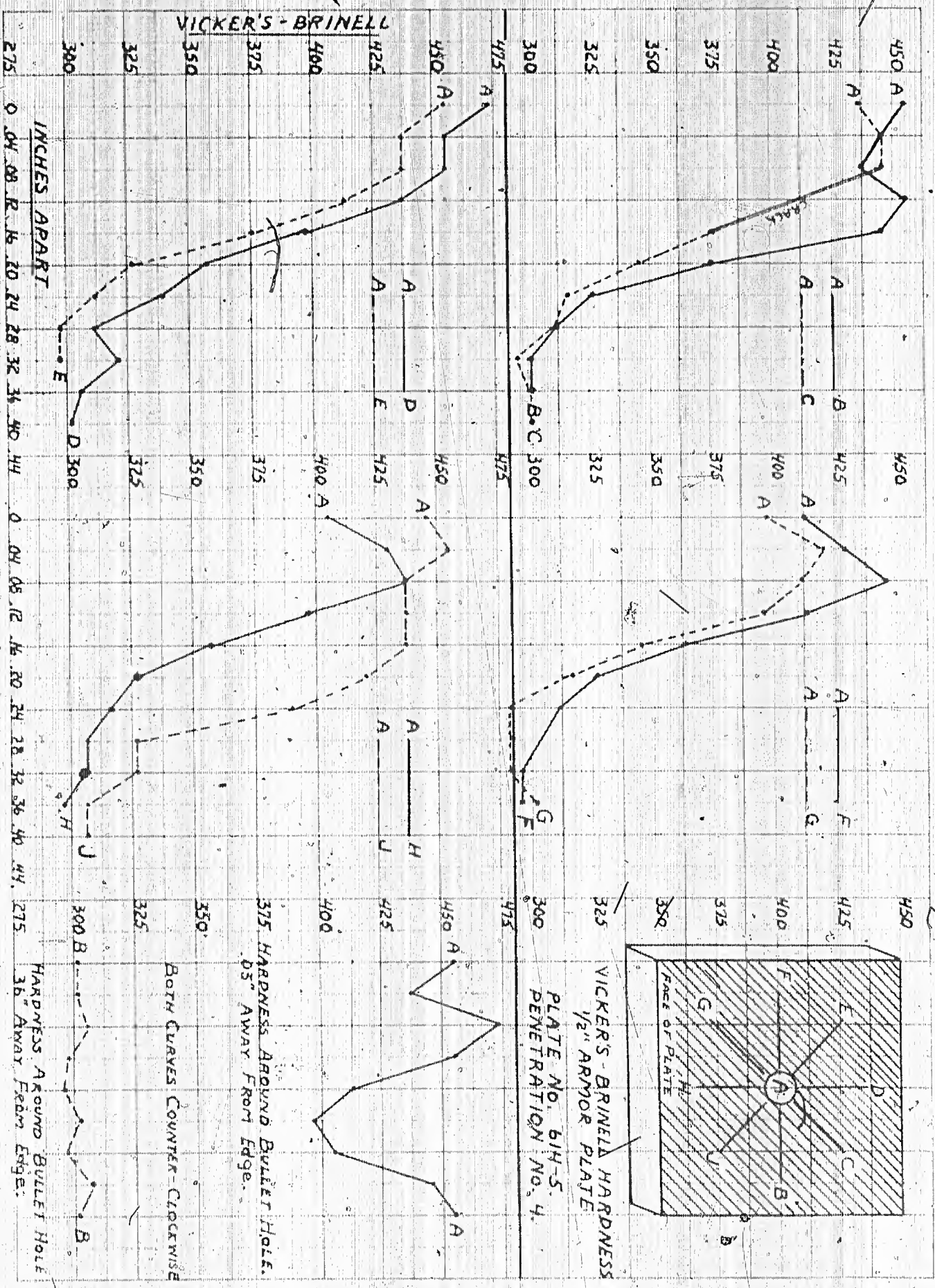


VICKERS BRINELL HARDNESS
1/2 ARMOR PLATE

PLATE NO. 614-5
PENETRATION NO. 2, 470
614-5-2

A.H. 6/16/36





VICKERS-BRINELL

INCHES APART

HARDNESS AROUND BULLET HOLE
36" AWAY FROM EDGE:

450 A

425 A

400 A

375 A

350 A

325 A

300 A

275 A

0 04 08 12 16 20 24 28 32 36 40 44

450 A

425 A

400 A

375 A

350 A

325 A

300 B

275

450 A

425 A

400 A

375 A

350 A

325 A

300 B

275

450 A

425 A

400 A

375 A

350 A

325 A

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375 A

350 A

325 A

300 B

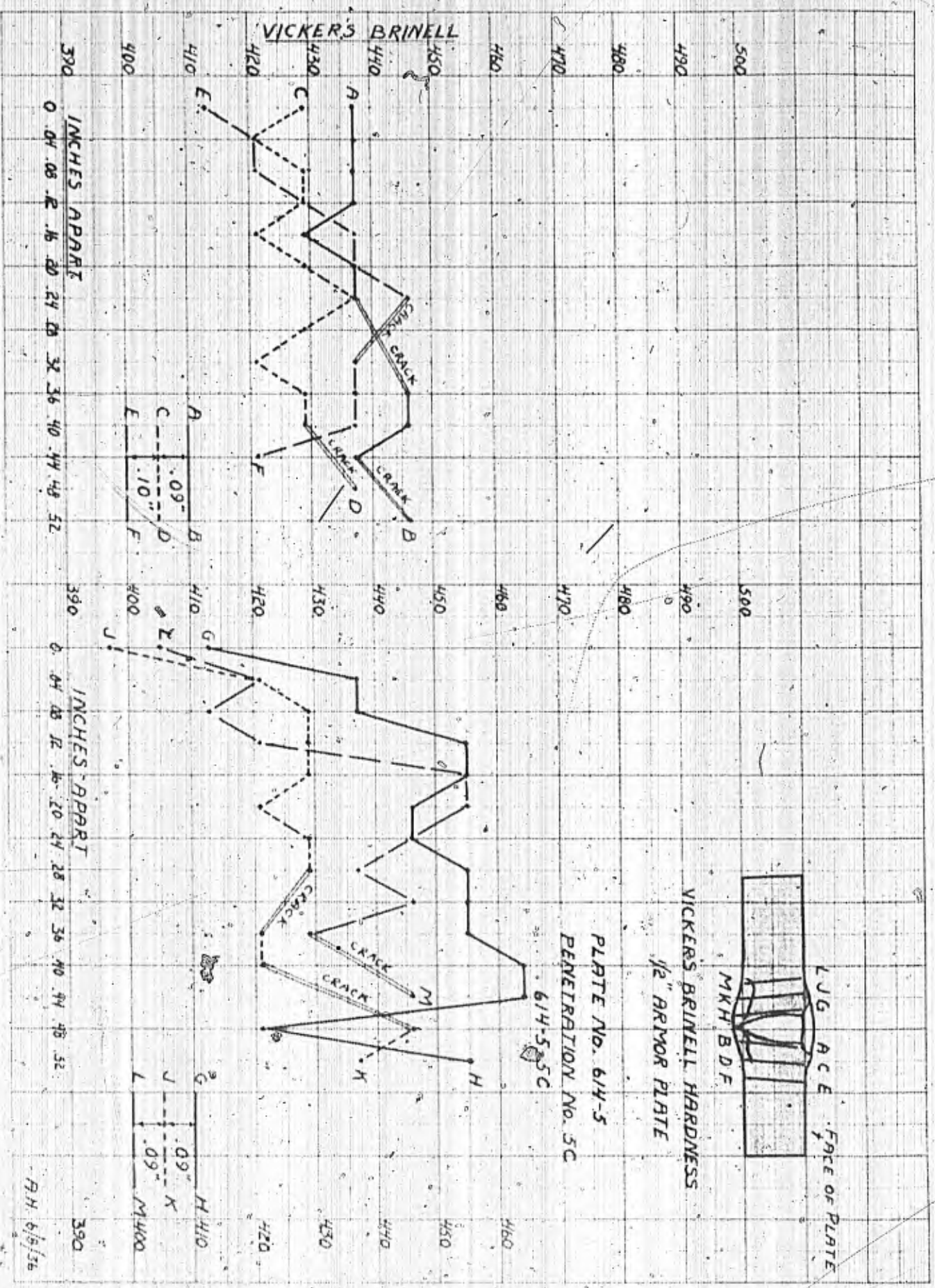
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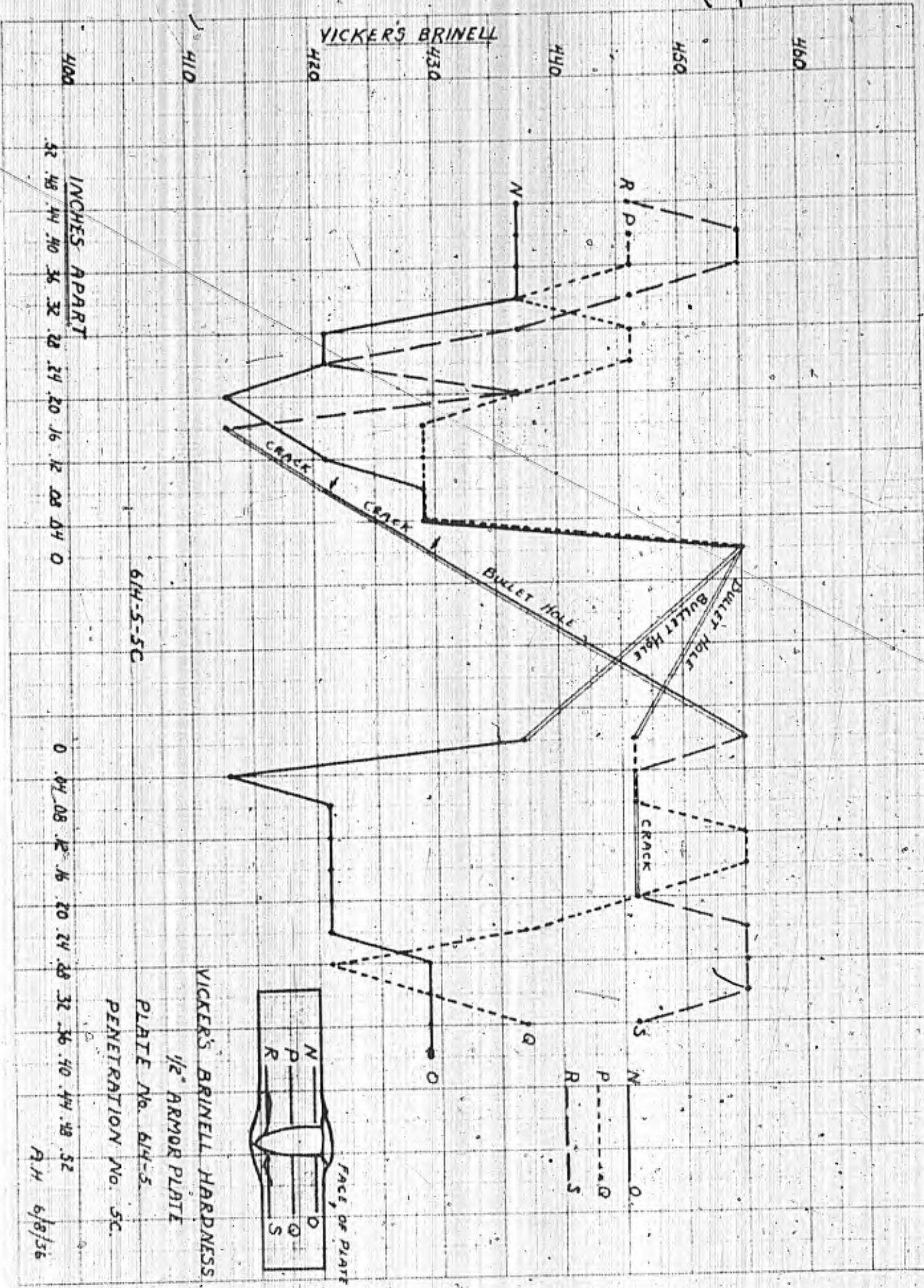
VICKERS BRINELL HARDNESS
1/2" ARMOR PLATE

PLATE No. 614-5
PENETRATION No. 5C

614-55C



PH 6/5/56



VICKERS BRINELL

400 410 420 430 440 450 460

INCHES APART

0 4 8 12 16 20 24 28 32 36 40 44 48

614-S-5C

VICKERS BRINELL HARDNESS
 1/2" ARMOR PLATE
 PLATE No. 614-S
 PENETRATION No. 5C.



RH 6/8/56



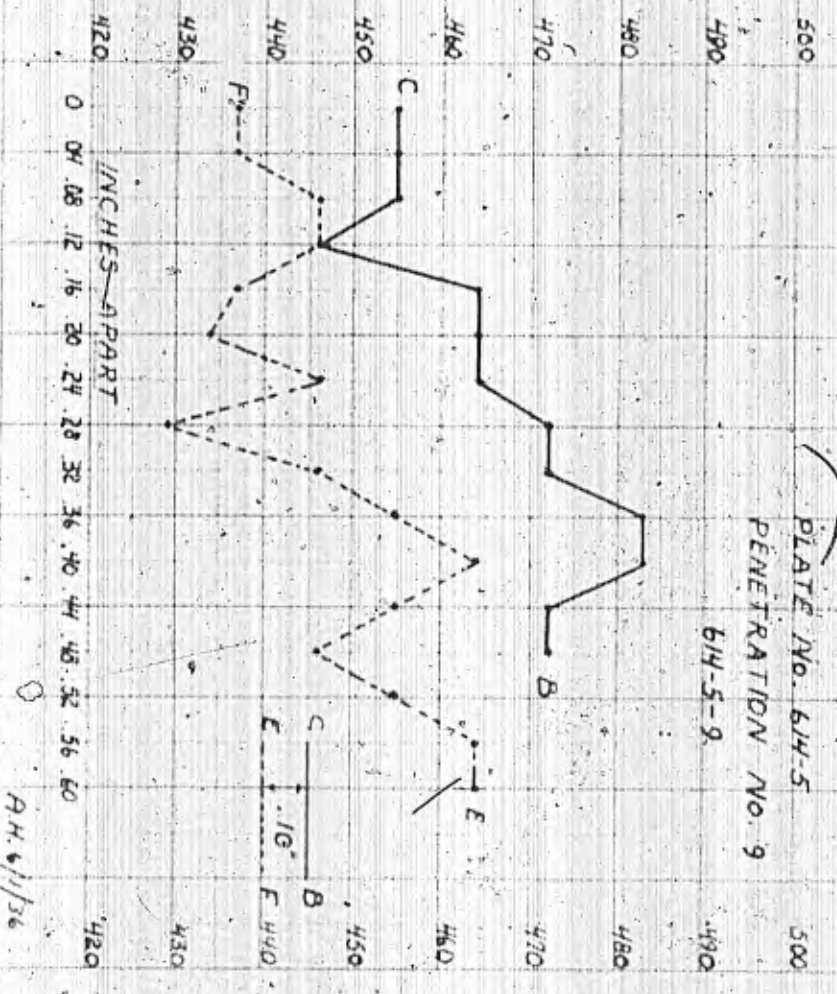
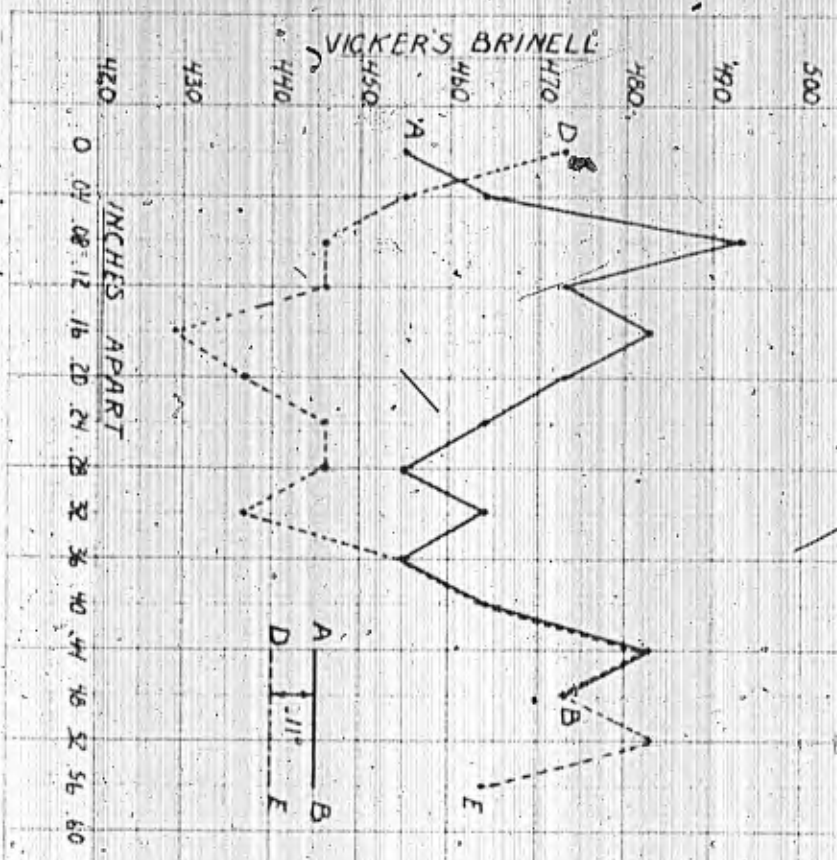
WICKERS BRINELL HARDNESS

1/2" ARMOR PLATE

PLATE No. 6H-5

PENETRATION No. 9

6H-5-9



A.H. 6/1/36



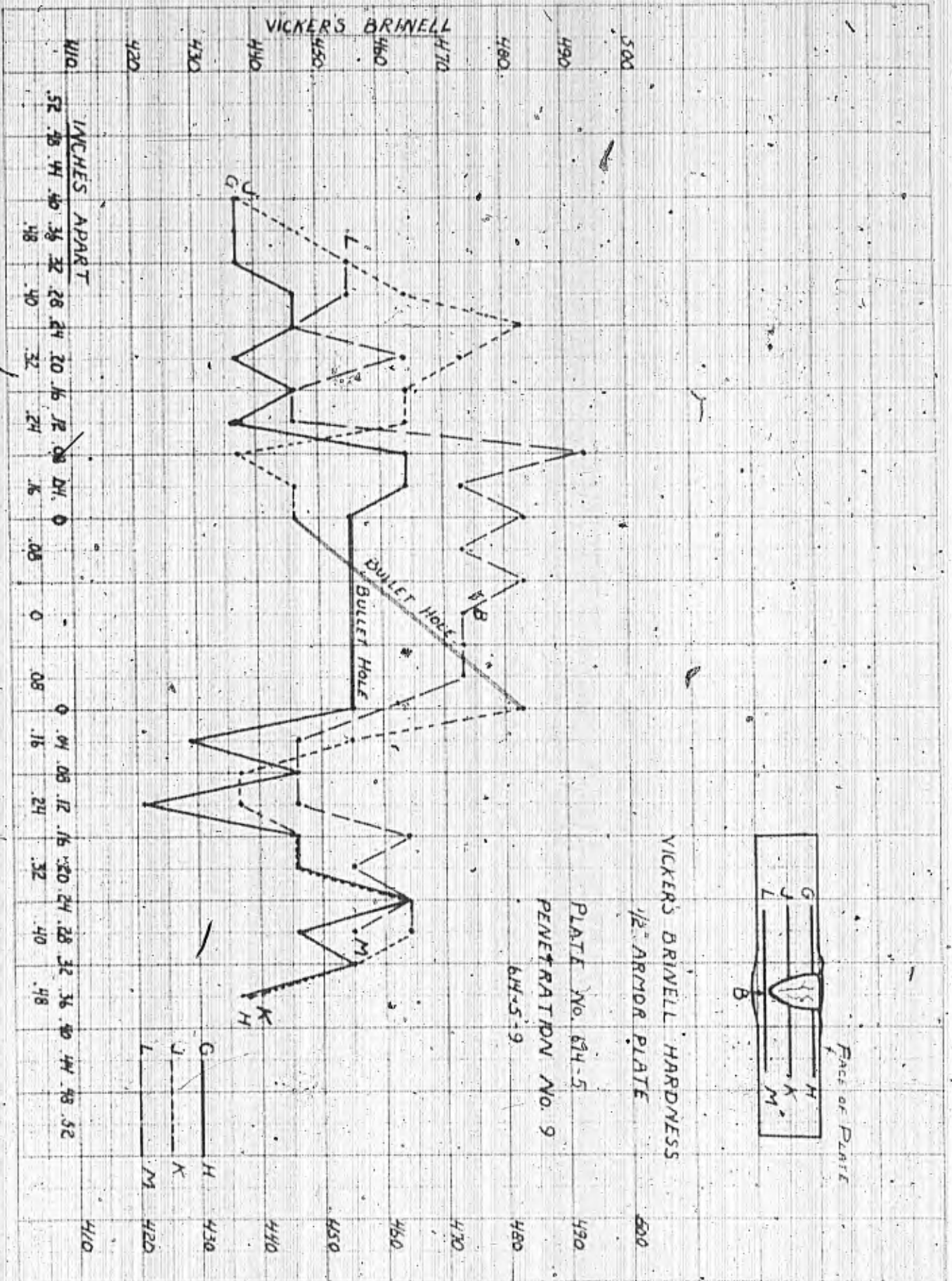
VICKERS BRINELL HARDNESS

1/2" ARMOR PLATE

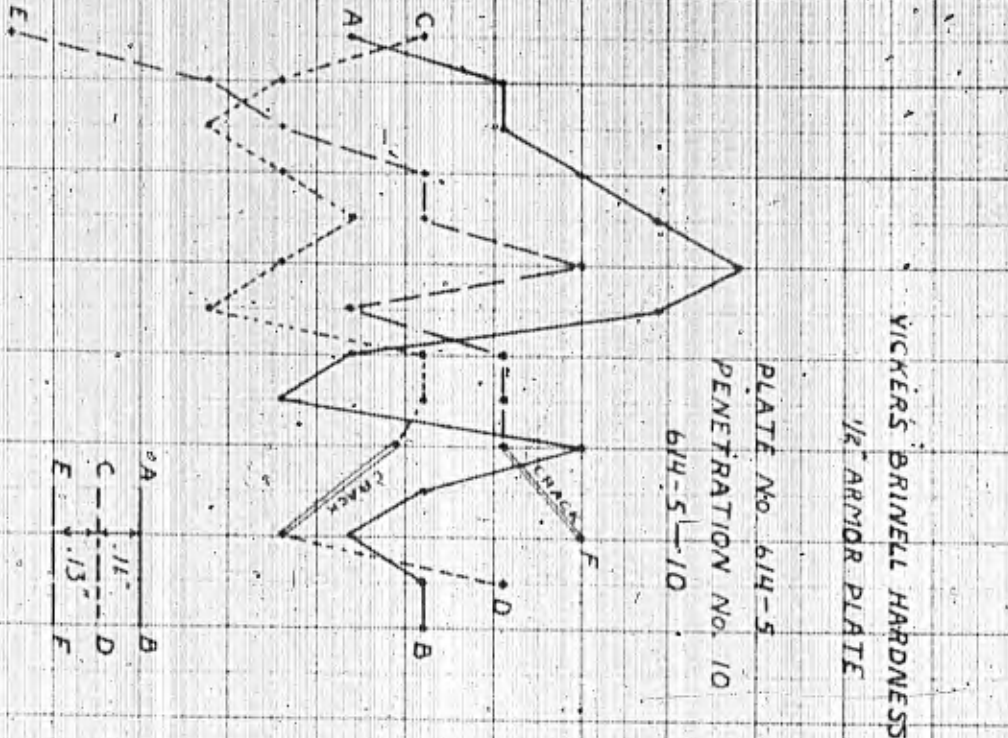
PLATE NO. 6H-5

PENETRATION NO. 9

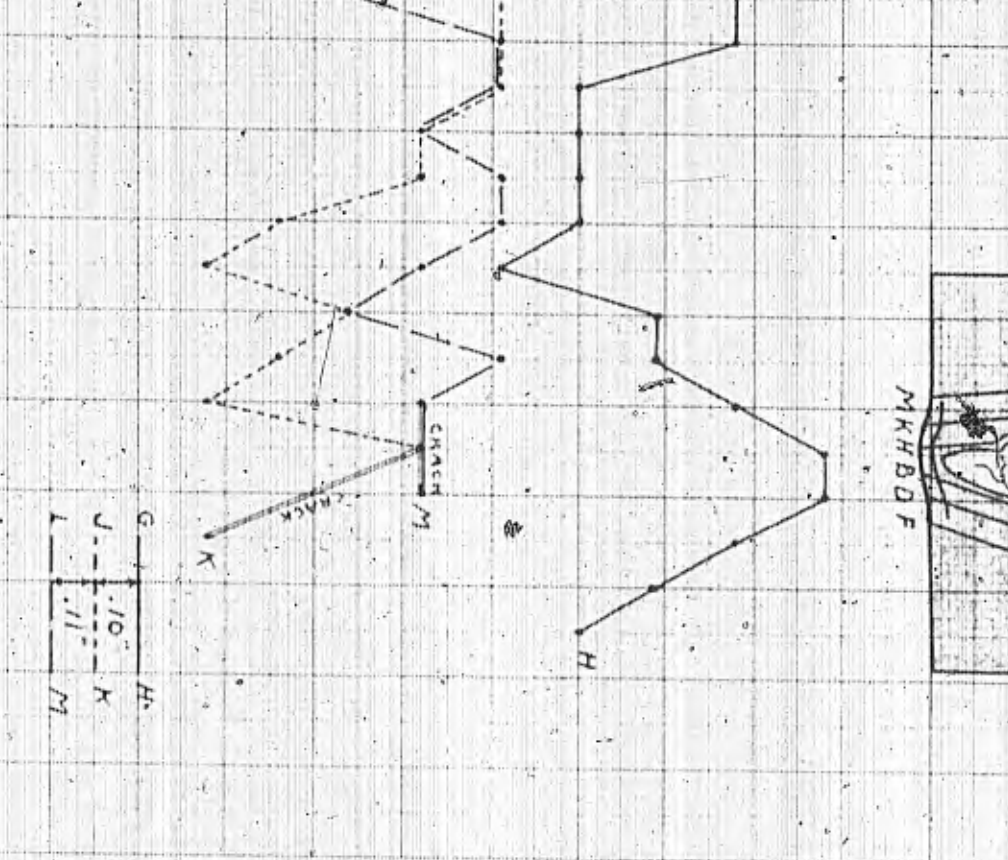
6H-5-9



VICKERS BRINELL



VICKERS BRINELL



A.H. 5/29/56

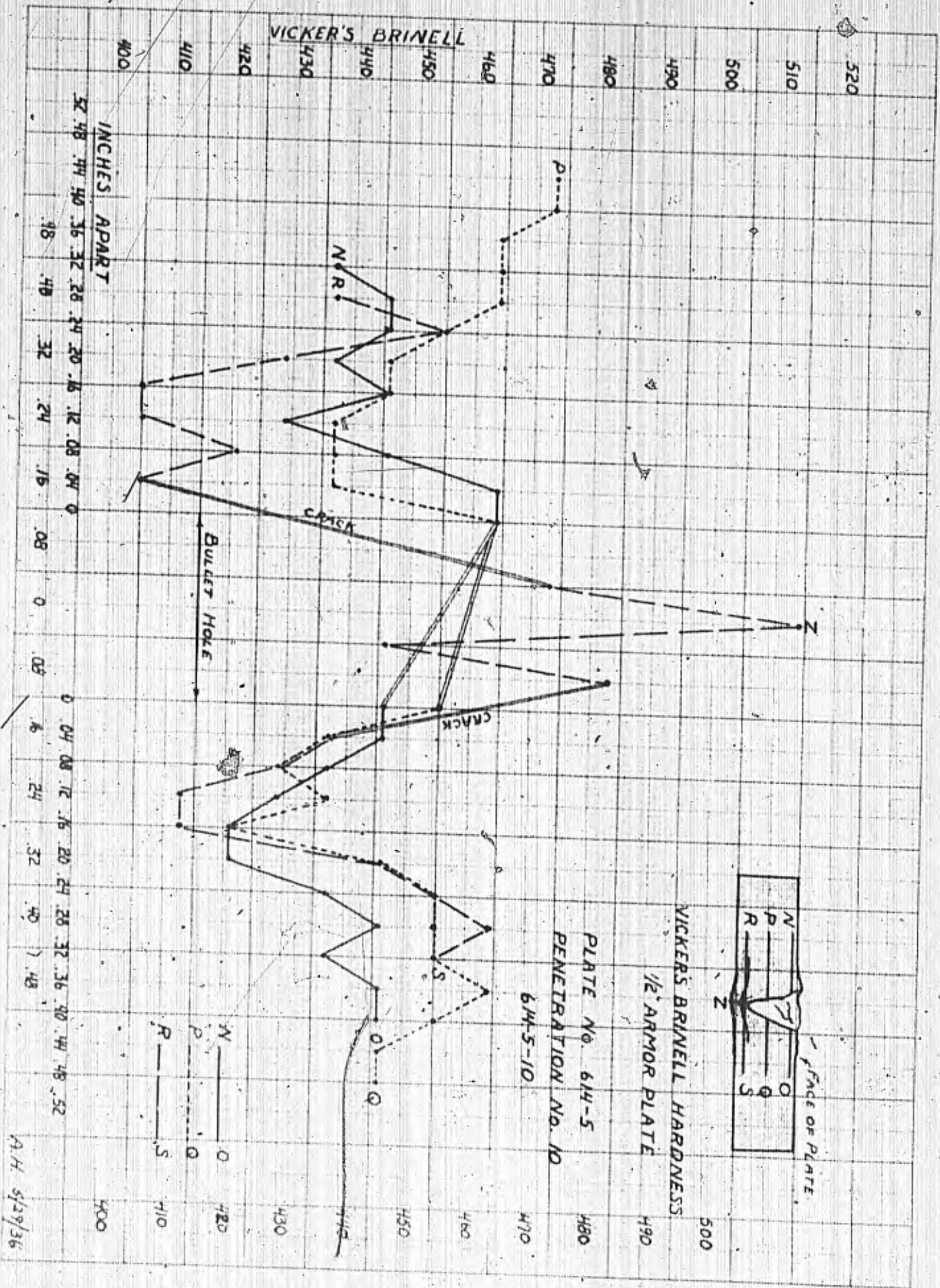


PLATE NO. EX 26.

DISSTON - Homogeneous Armor Plate.

18 x 18 x $\frac{1}{2}$ "
Actual thickness - .502"

Brinell - 402-418.

<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>
.38	.69	.17			1.14	.65	.30

Ammunition - .30 cal. 165 gr. M1922 A.P.

Range - 100 yards.

Specifications - 31. AXB.- 54, Rev. 1.

Round 1. Str. Vel. 2672 f/s. Complete Penetration. C.I.P.

Round 4. Str. Vel. 2704 f/s. Complete Penetration.

Diam. of Hole in Back. - .41".

Round 5. Str. Vel. 2696 f/s. Complete Penetration. C.I.P.

Round 6. Str. Vel. 2385 f/s. Complete Penetration.

Diam. of Hole in Back - .01".

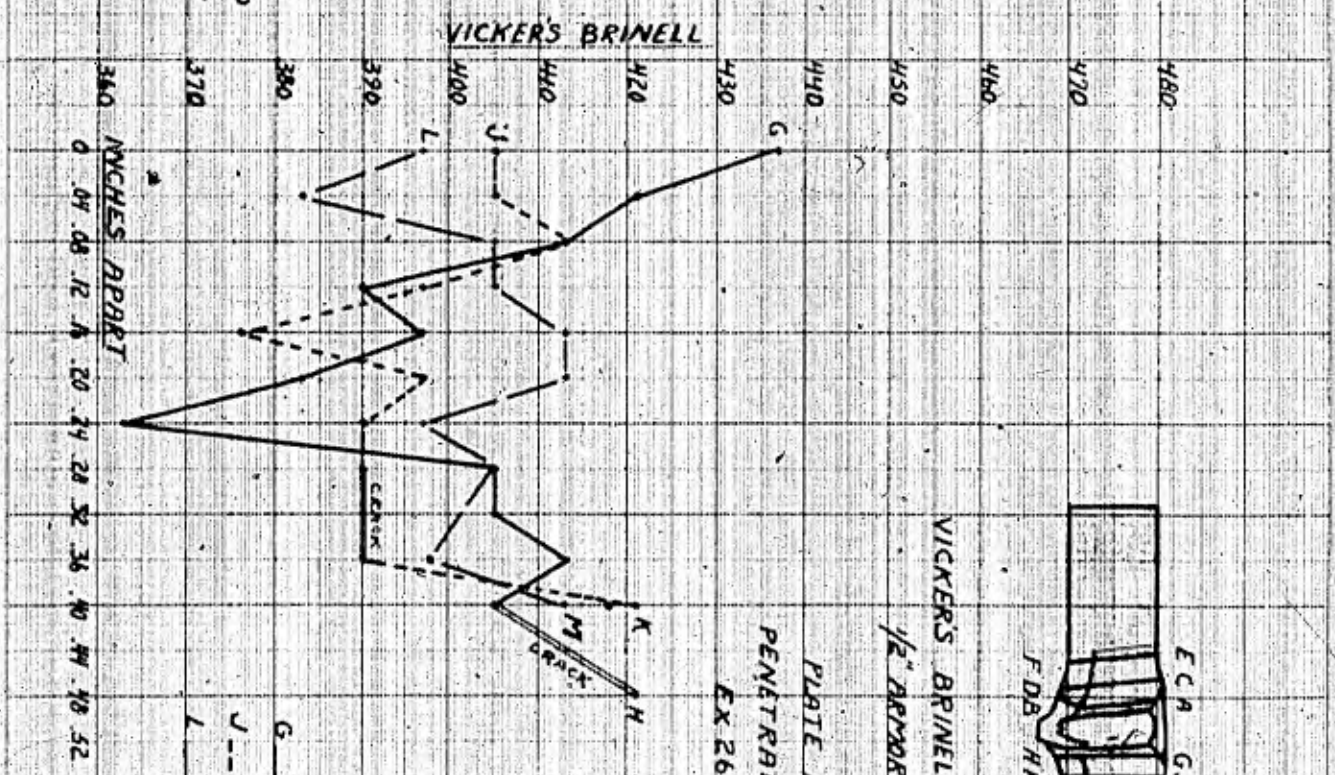
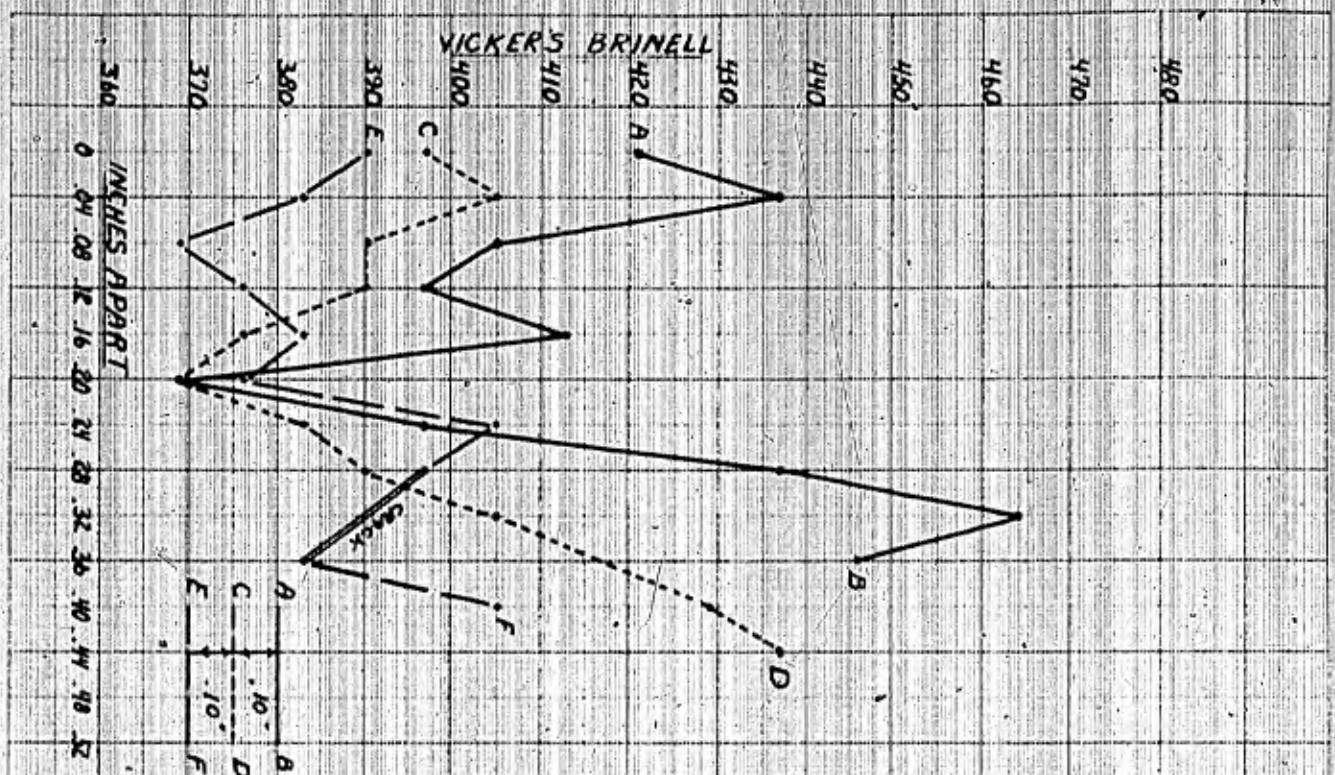
Height of Bulge on Back - .06".

Round 7. Str. Vel. 2286 f/s. Partial Penetration.

Height of Bulge on Back - .03".

Round 8. Str. Vel. 2371 f/s. Partial Penetration.

Height of Bulge on Back - .05".



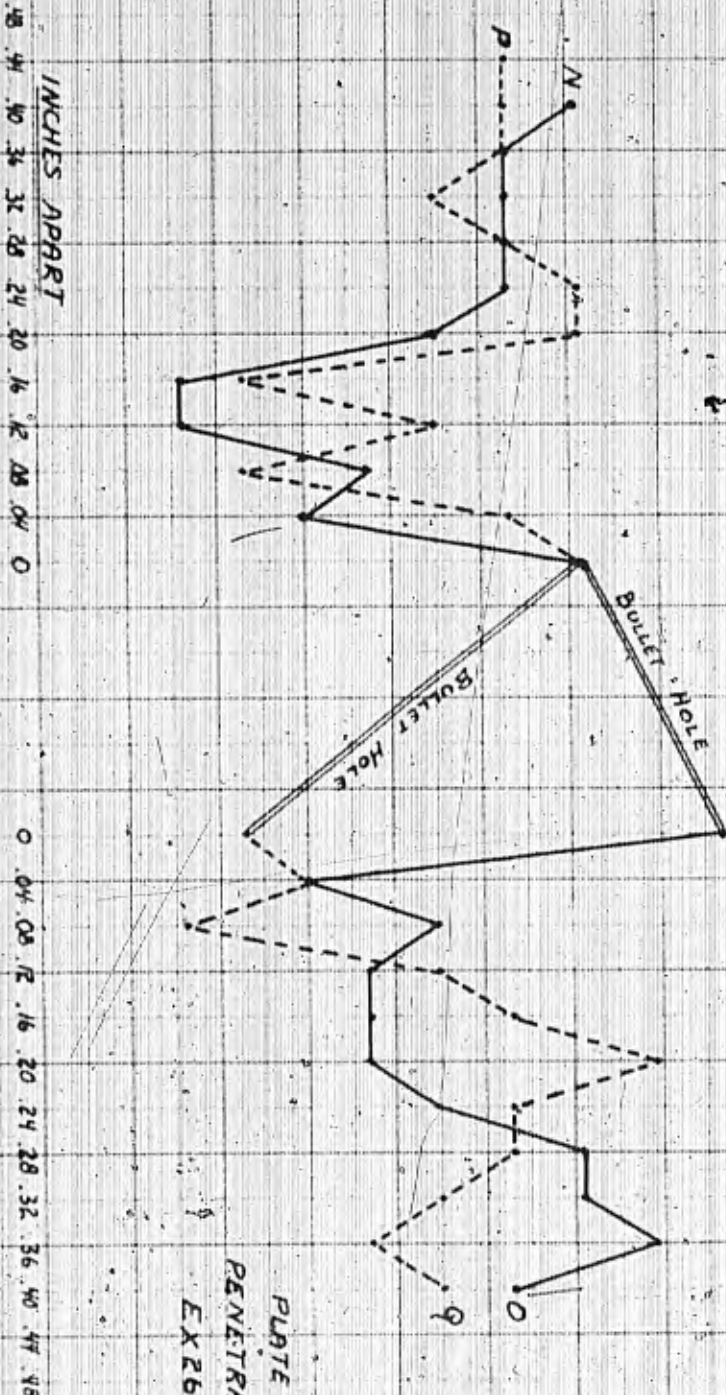
VICKERS BRINELL HARDNESS
1/2" ARMOR PLATE

PLATE No. 26
PENETRATION NO. 1
EX 26-1

AM 6/16/36

VICKERS BRINELL

480
470
460
450
440
430
420
410
400
390
380
370
360



INCHES APART

48 44 40 36 32 28 24 20 16 12 08 04 0

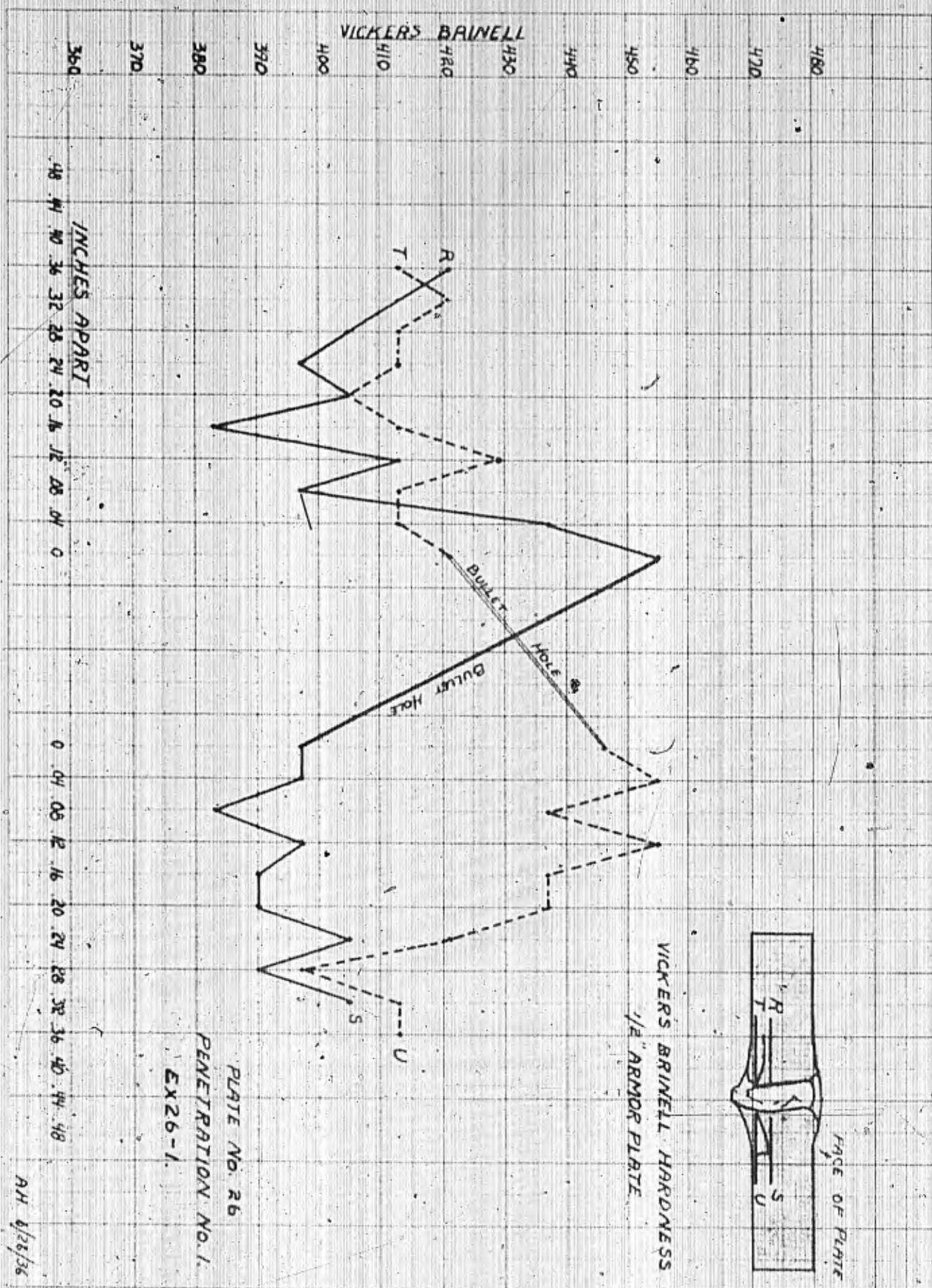
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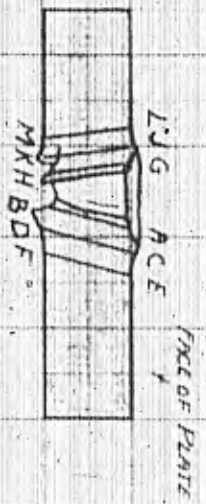


VICKERS BRINELL HARDNESS
1/2" ARMOR PLATE

PLATE No. 26
PENETRATION No. 1
EX 26-1

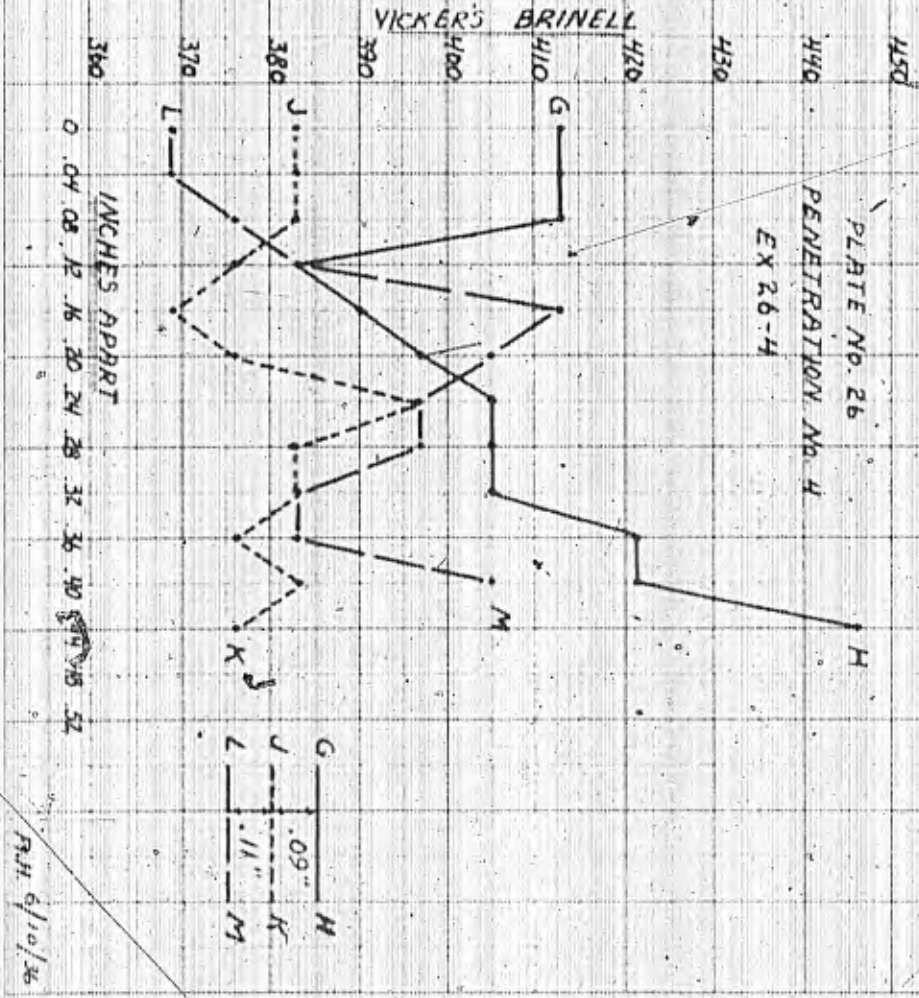
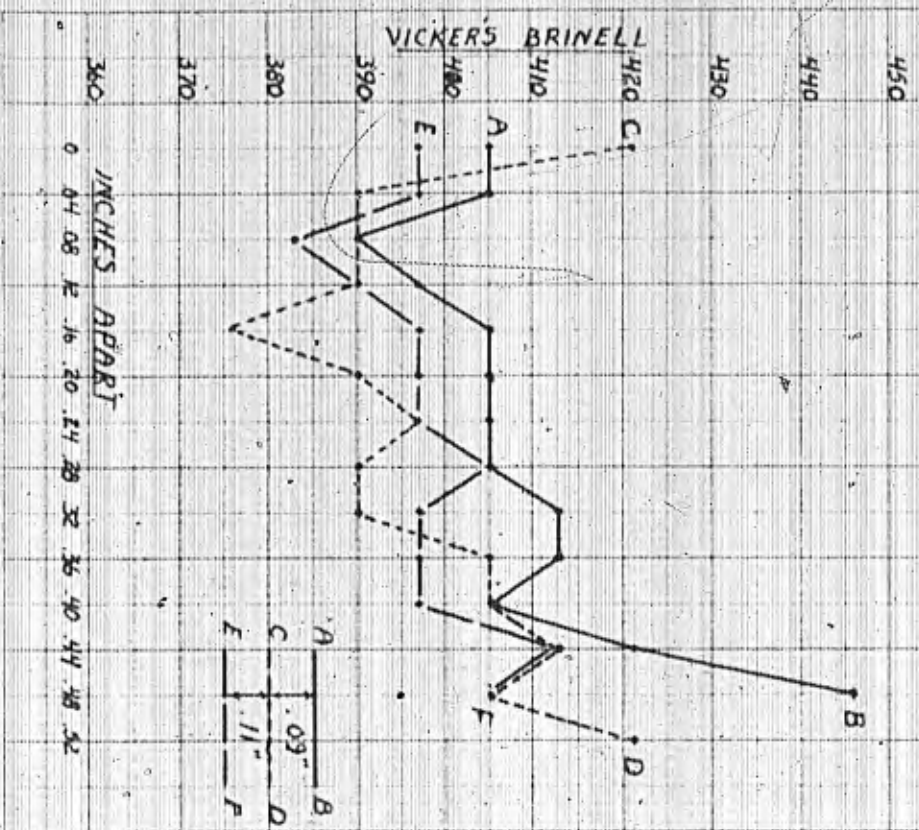
6/16/36





VICKERS BRINELL HARDNESS
1/2" ARMOR PLATE

PLATE No. 26
PENETRATION No. 4
EX 26-4

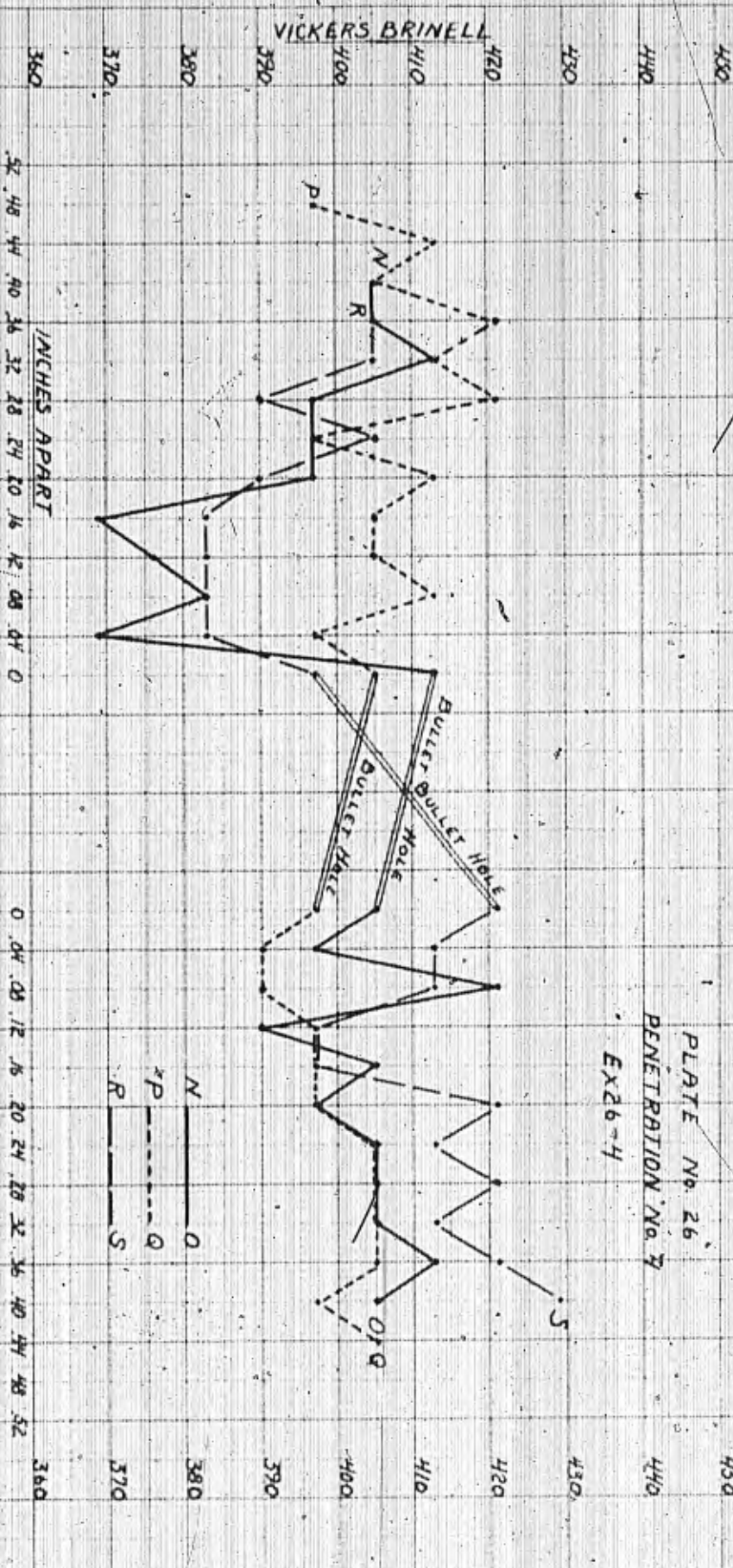


R.H. 6/10/36

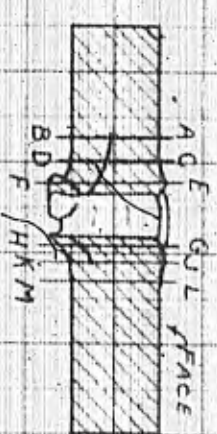
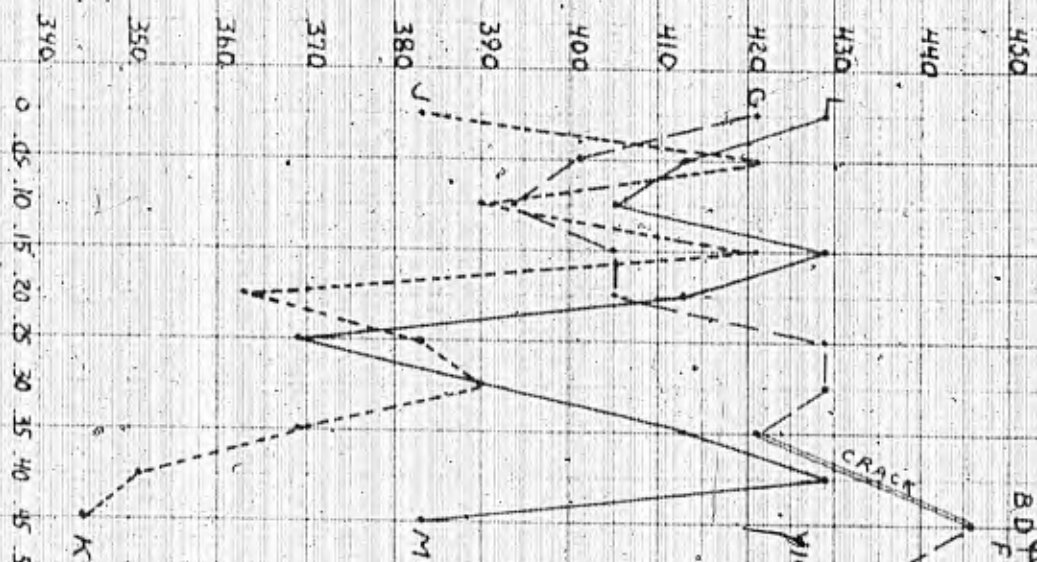
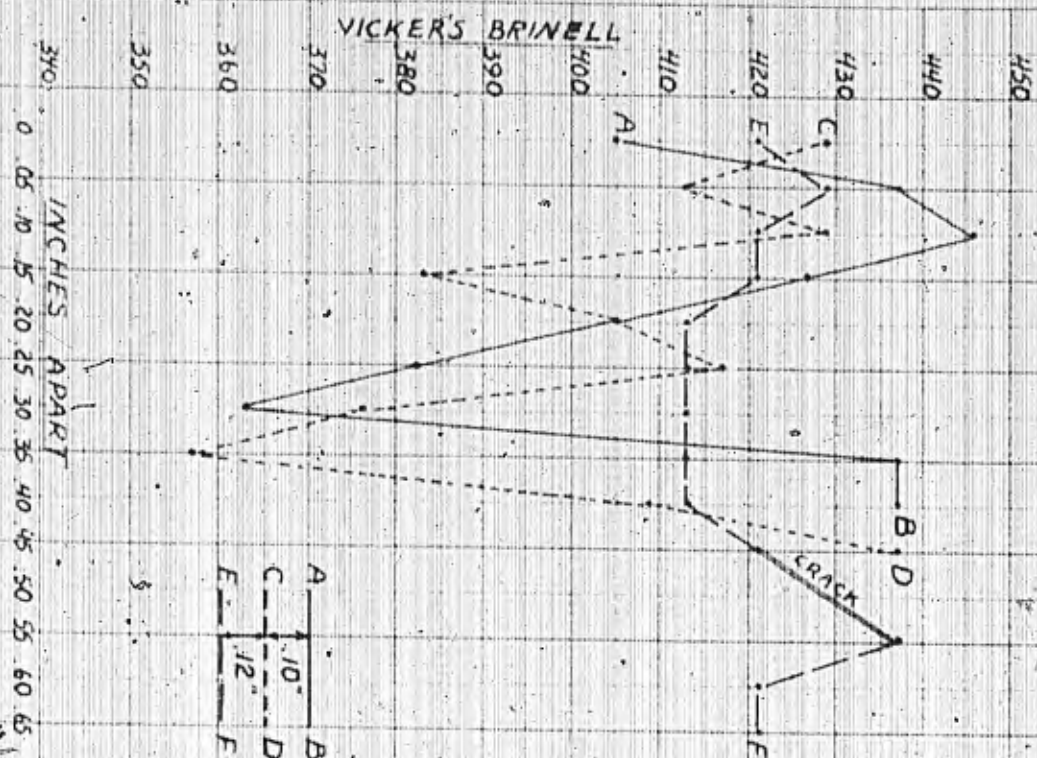


VICKERS BRINELL HARDNESS
1/2" ARMOR PLATE

PLATE No. 26
PENETRATION No. 7
EX26-4

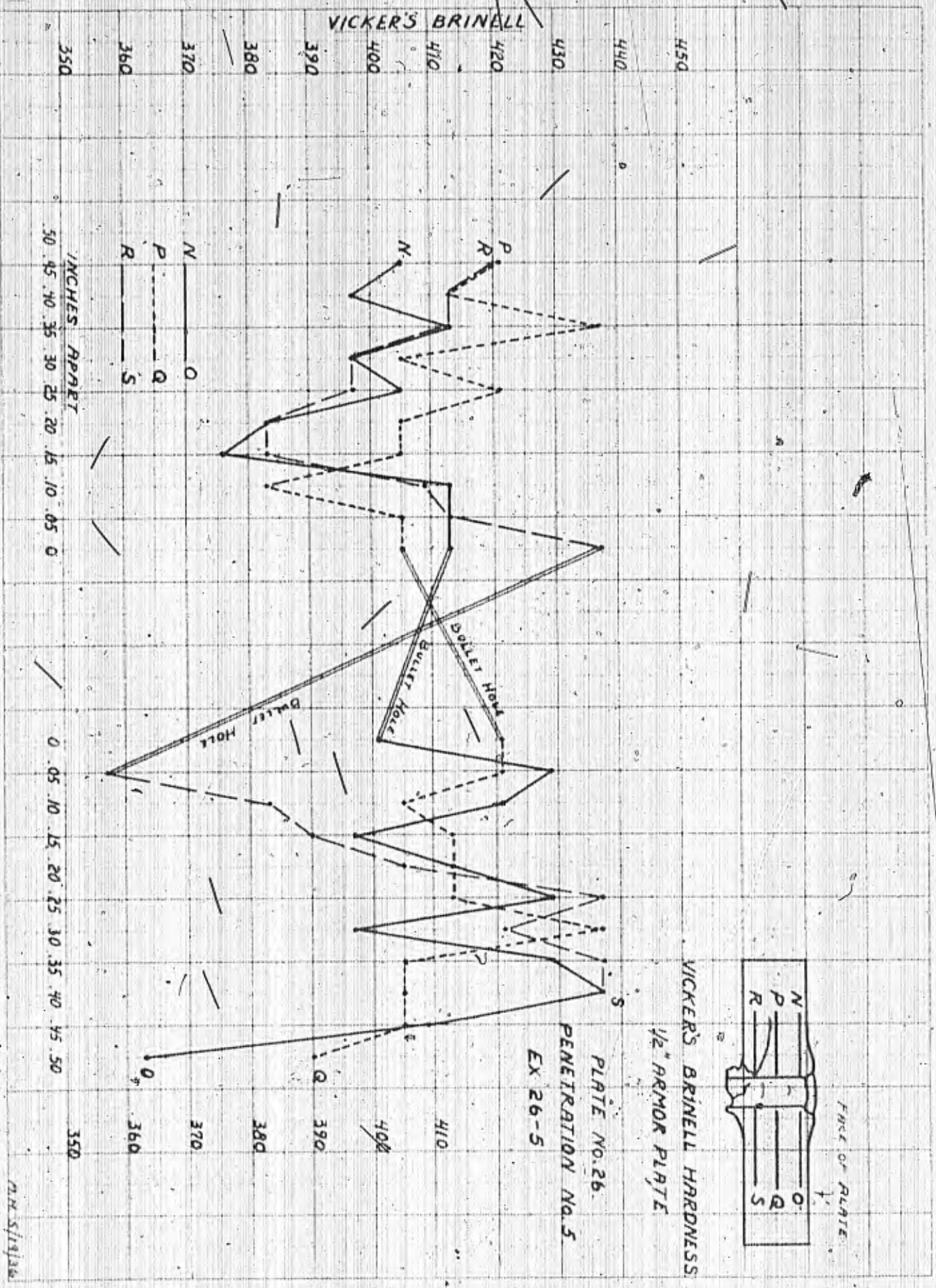


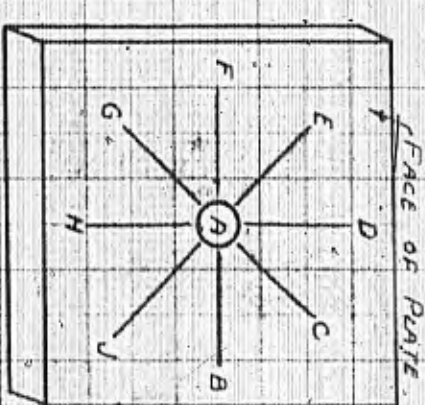
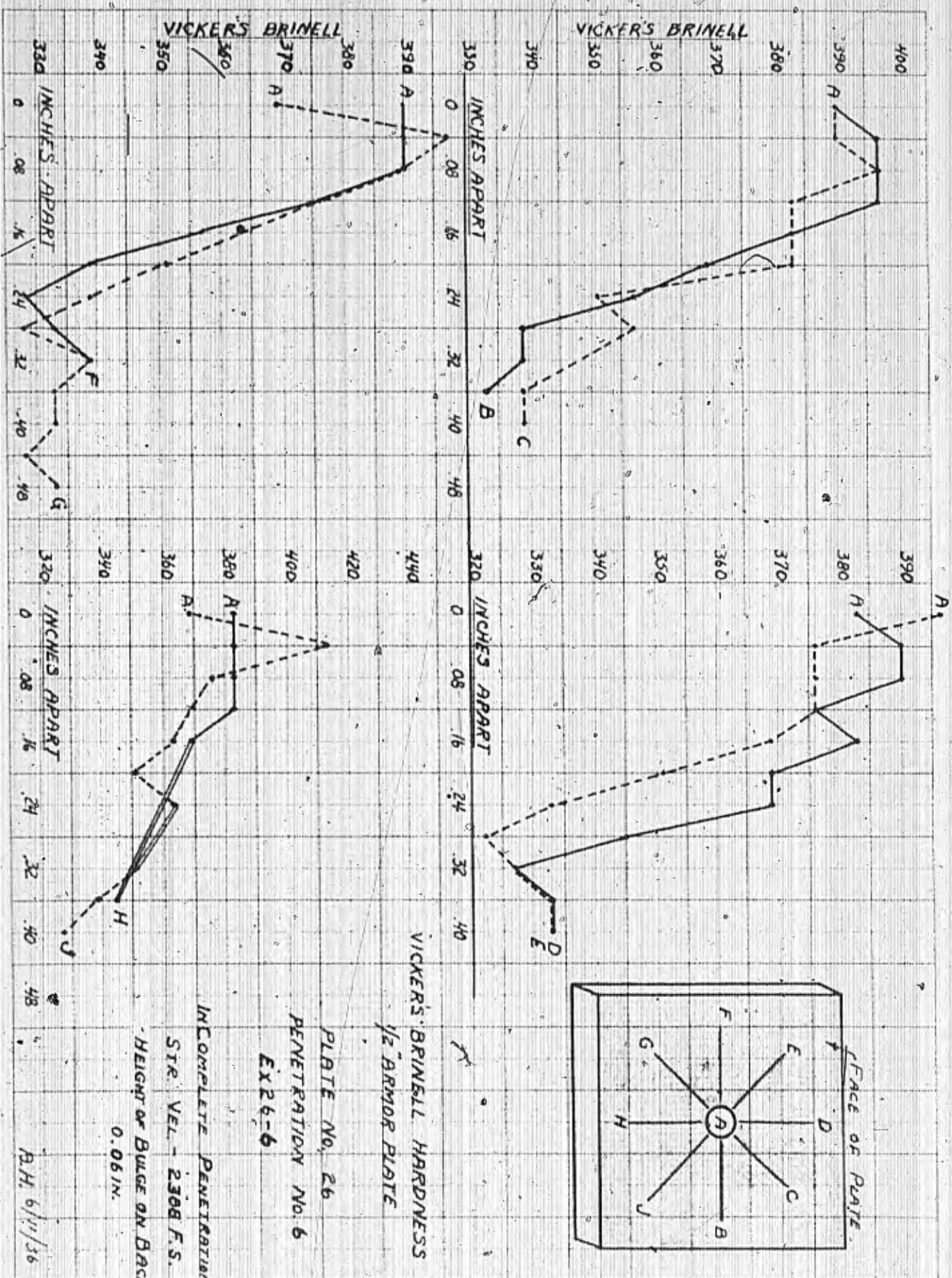
A.M. 6/11/51



VICKER'S BRINELL HARDNESS
 1/2" ARMOR PLATE
 PLATE NO. 26,
 PENETRATION NO. 5.
 EX 26-5.

AH
 8/11/16



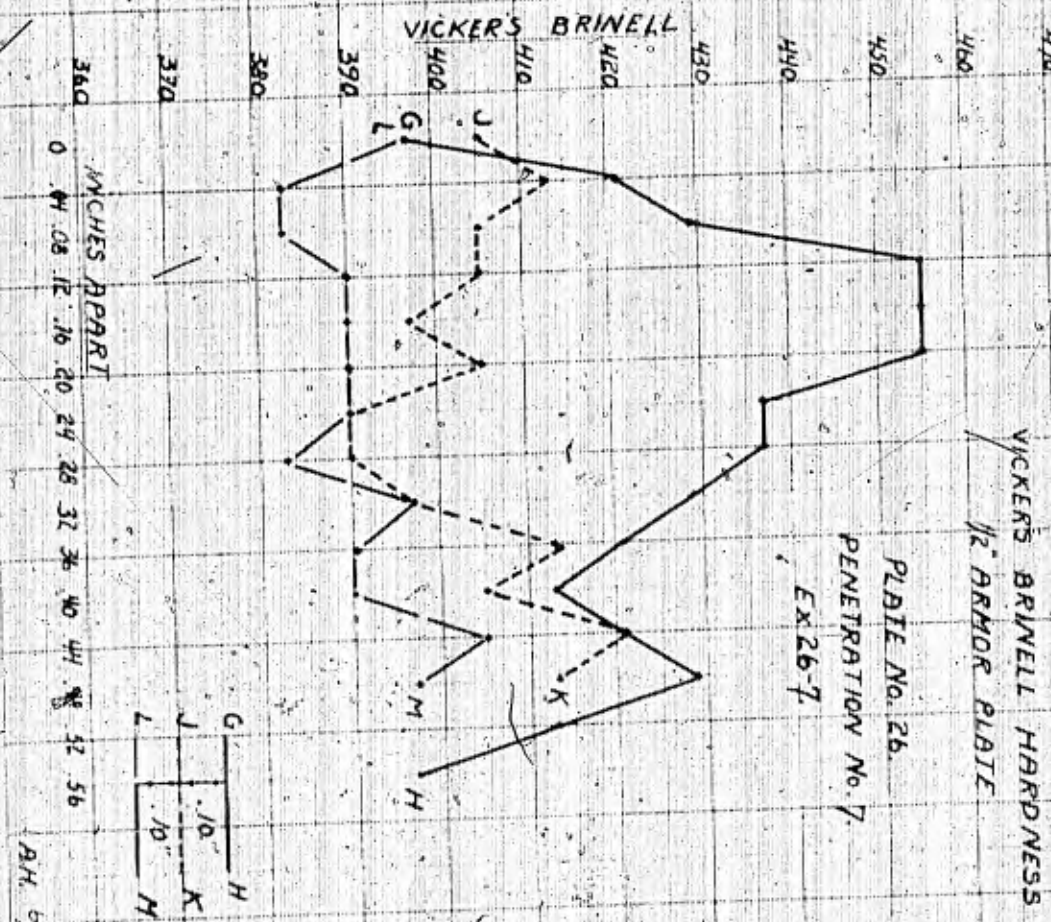
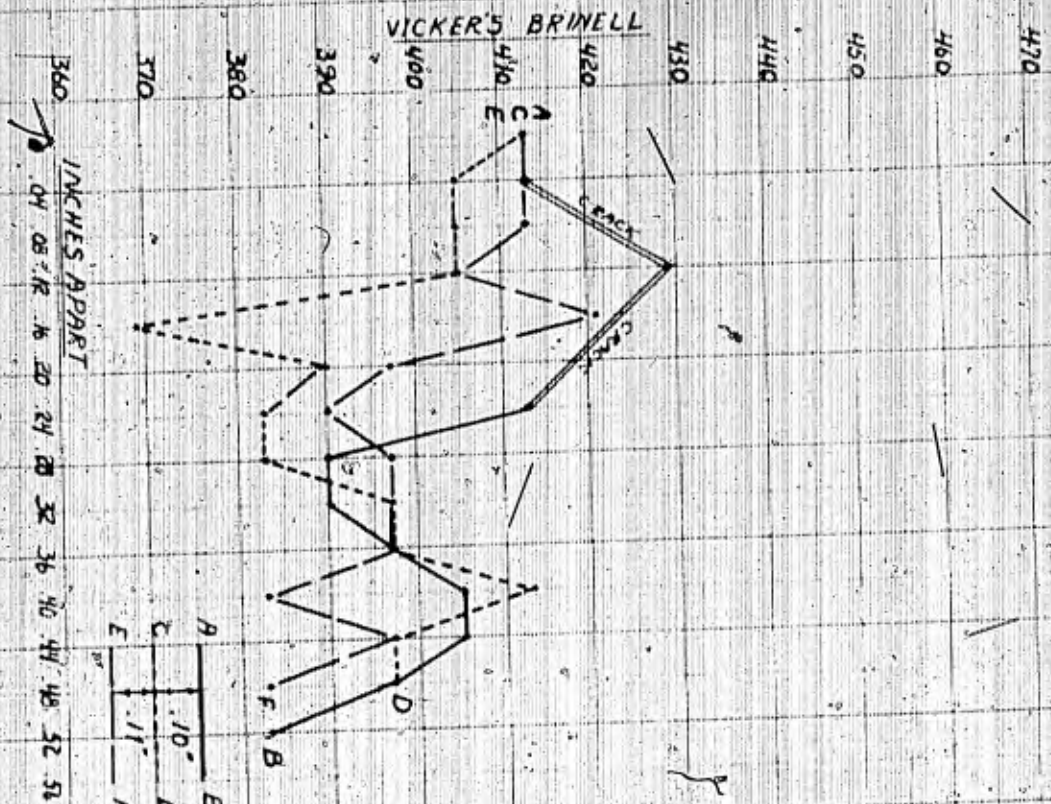


VICKERS BRINELL HARDNESS
 1/2" ARMOR PLATE

PLATE No. 26
 PENETRATION No. 6
 EX 26-6

INCOMPLETE PENETRATION
 STR. VEL. - 2300 F.S.
 HEIGHT OF BULGE ON BACK
 0.06 IN.

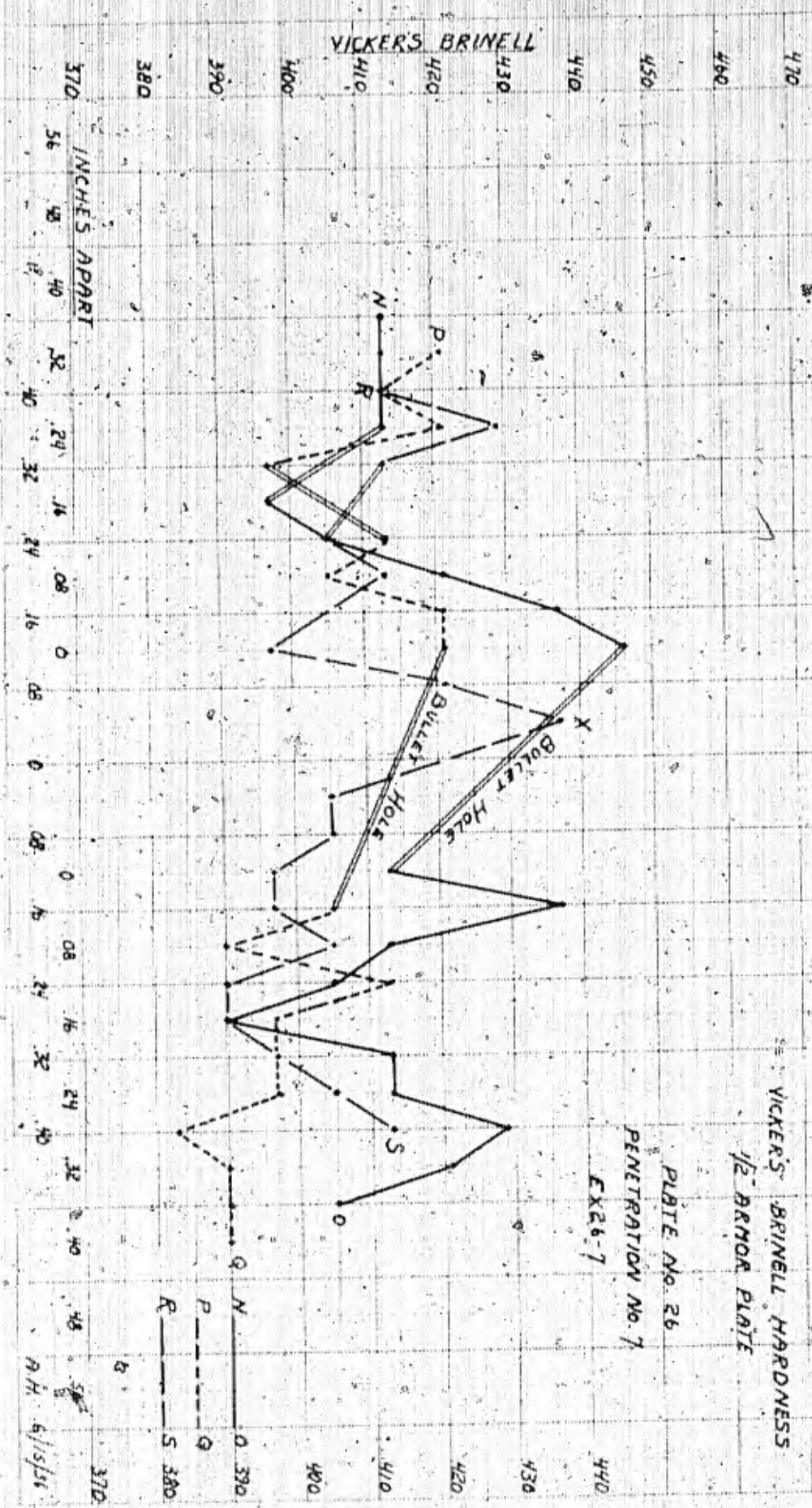
B.H. 6/11/36



VICKERS BRINELL HARDNESS
 1/2" ARMOR PLATE
 PLATE No. 26.
 PENETRATION No. 7



PH. 6/5/36



N.H. 4/15/56



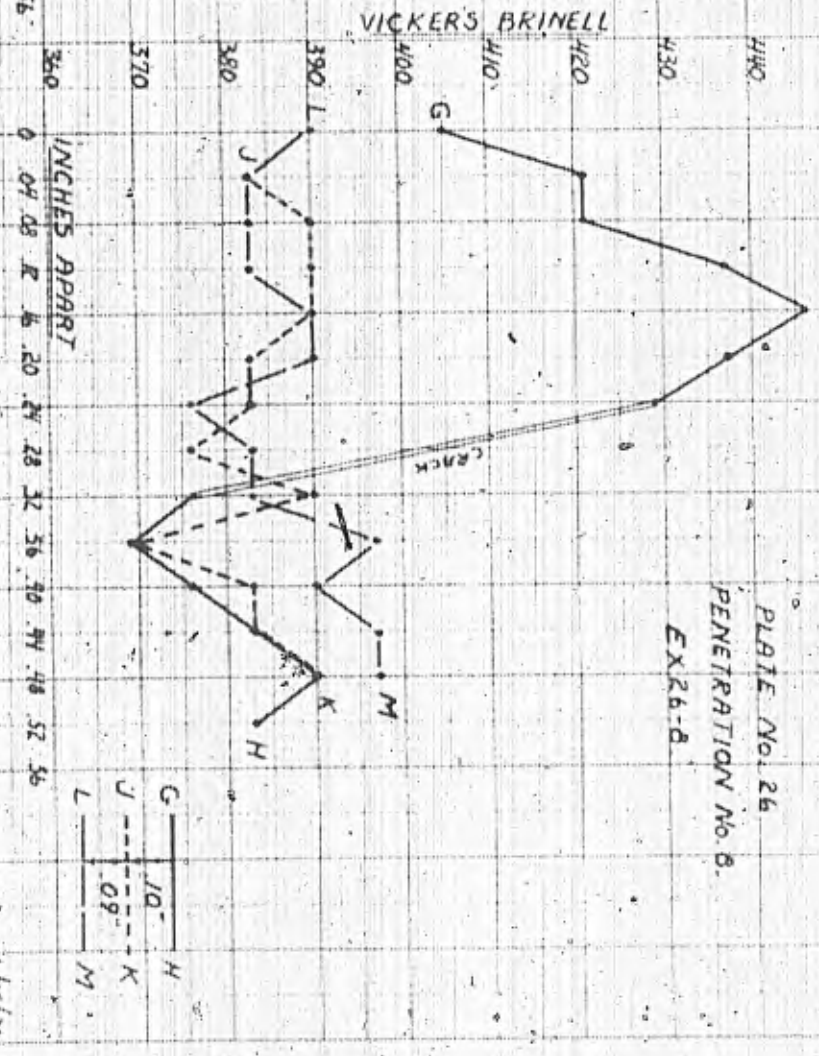
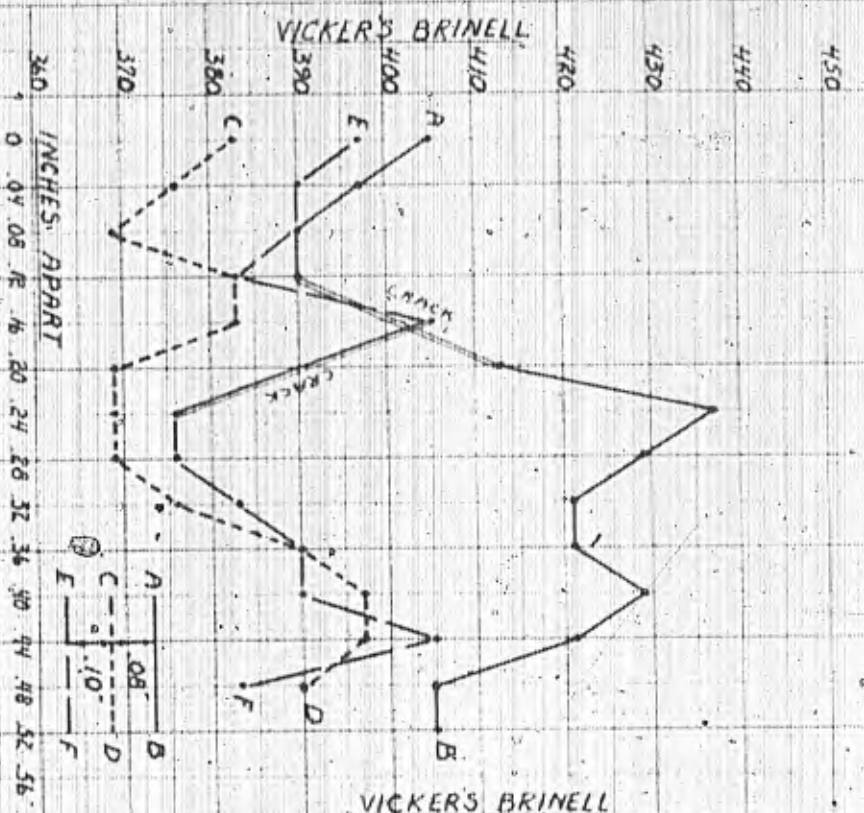
VICKERS BRINELL HARDNESS

1/2" ARMOR PLATE

PLATE No. 26

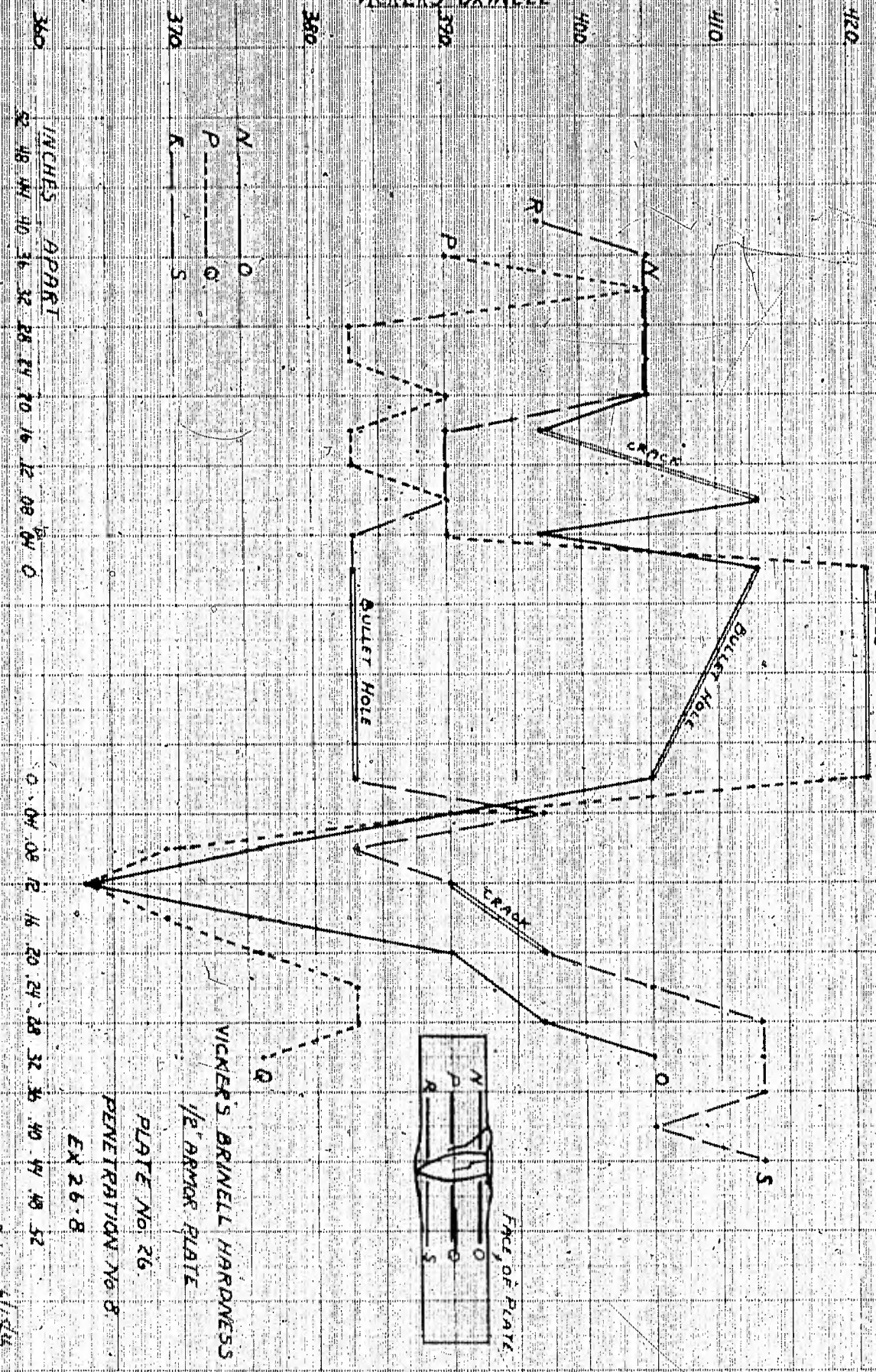
PENETRATION No. 8.

EX 26-A



R.H. 6/15/36

VICKERS BRINELL



INCHES APPRT
 0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52

VICKERS BRINELL HARDNESS
 1/2" ARMOR PLATE
 PLATE No. 26.
 PENETRATION No. 8
 EX 26-B

A.H. 6/15/44

PLATE NO. 29.

DIBSTON - Homogeneous Armor Plate.

12 x 12 x 1".
Actual thickness - 1.0165".

Brinell - 418.

<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>
.50	.70	.25	.020	.023	1.12	.65	.25

Ammunition - .50 cal. 750 gr. M-1. A.P.

Range - 100 yards.

Specification - 31.

Round 1. Str. Vel. 2499 f/s. Partial Penetration.

Height of Bulge on Back - .01"

Depth of Penetration - .77".

Round 2. Str. Vel. 2568 f/s. Partial Penetration.

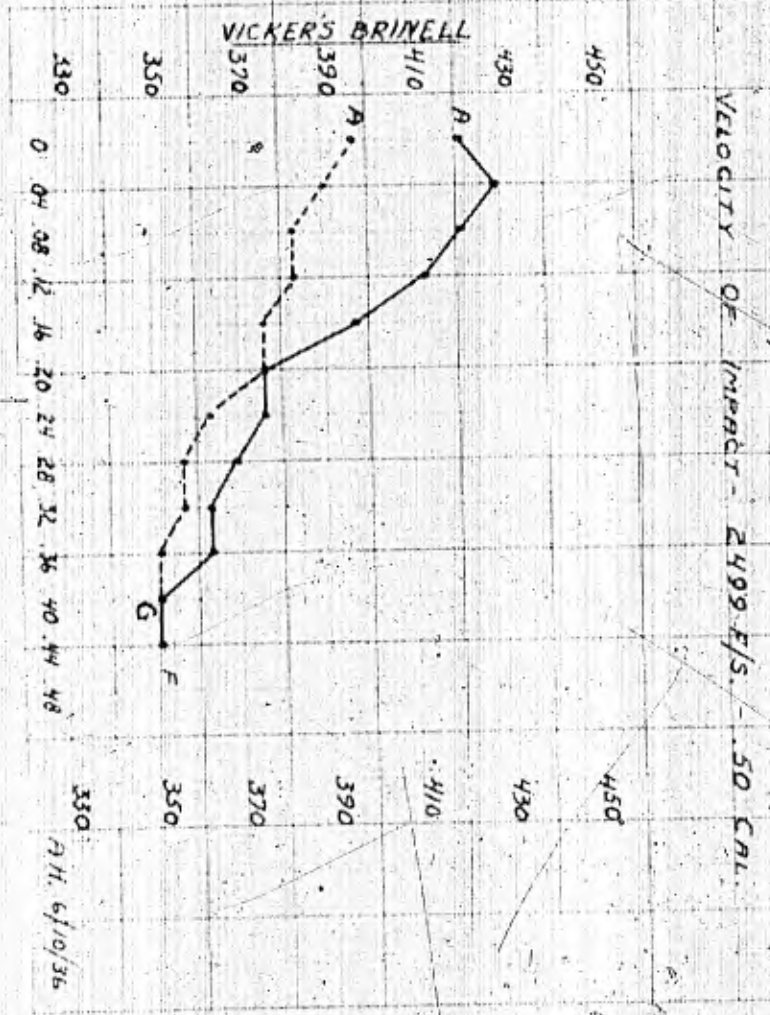
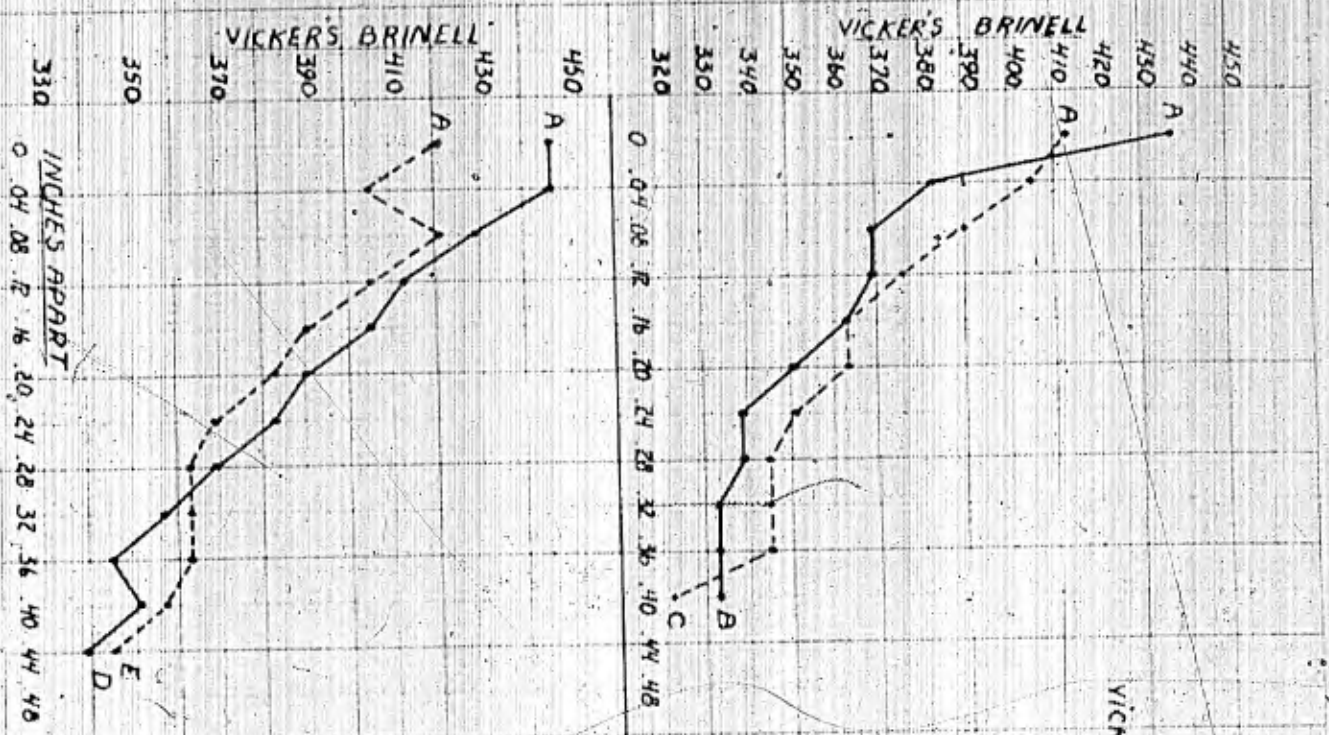
Height of Bulge on Back - .06".

Depth of Penetration - .98".

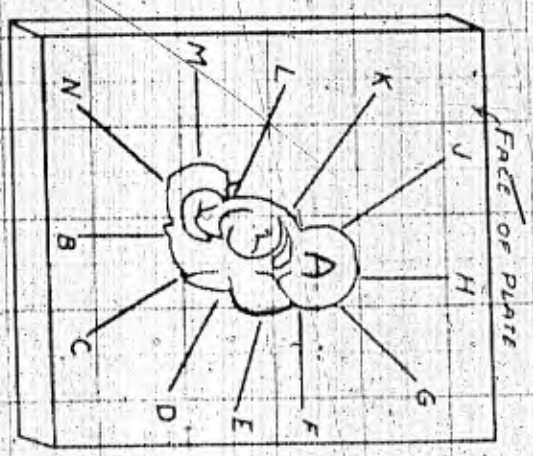
Round 3. Str. Vel. 2540 f/s. Partial Penetration.

Height of Bulge on Back - .06".

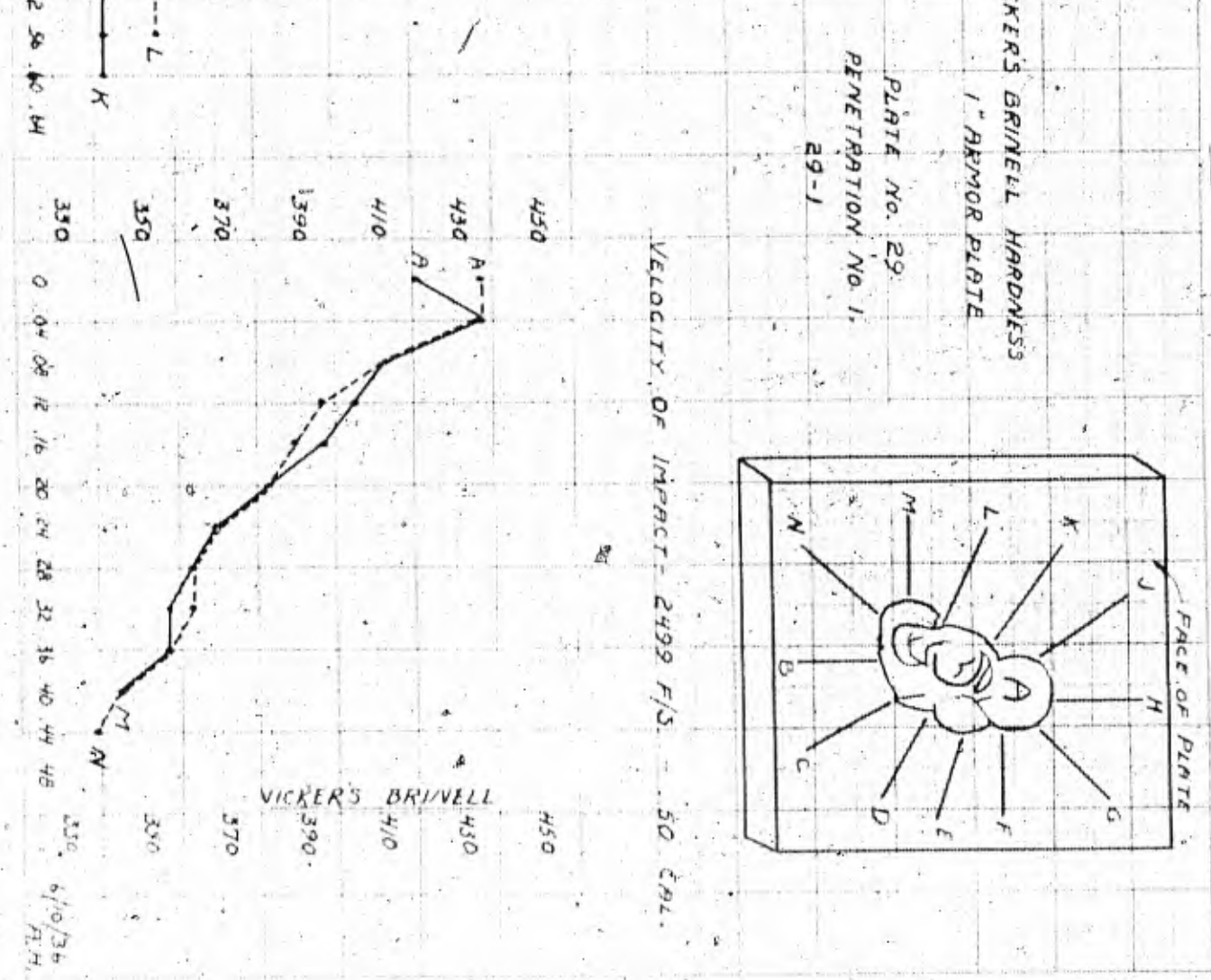
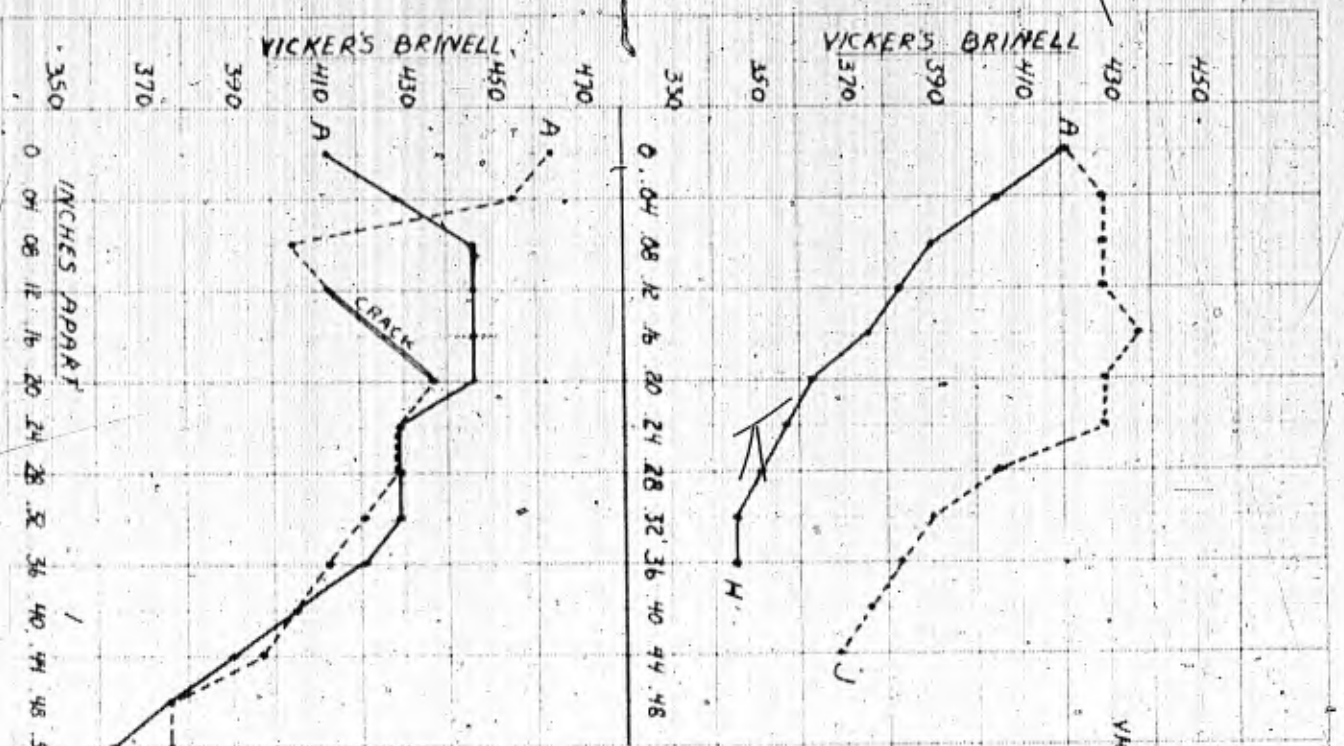
Depth of Penetration - .96".



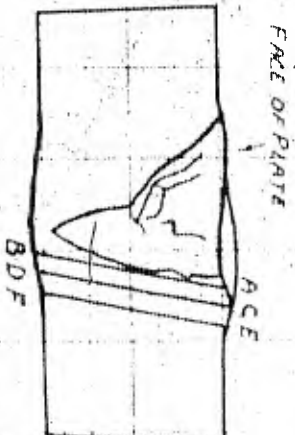
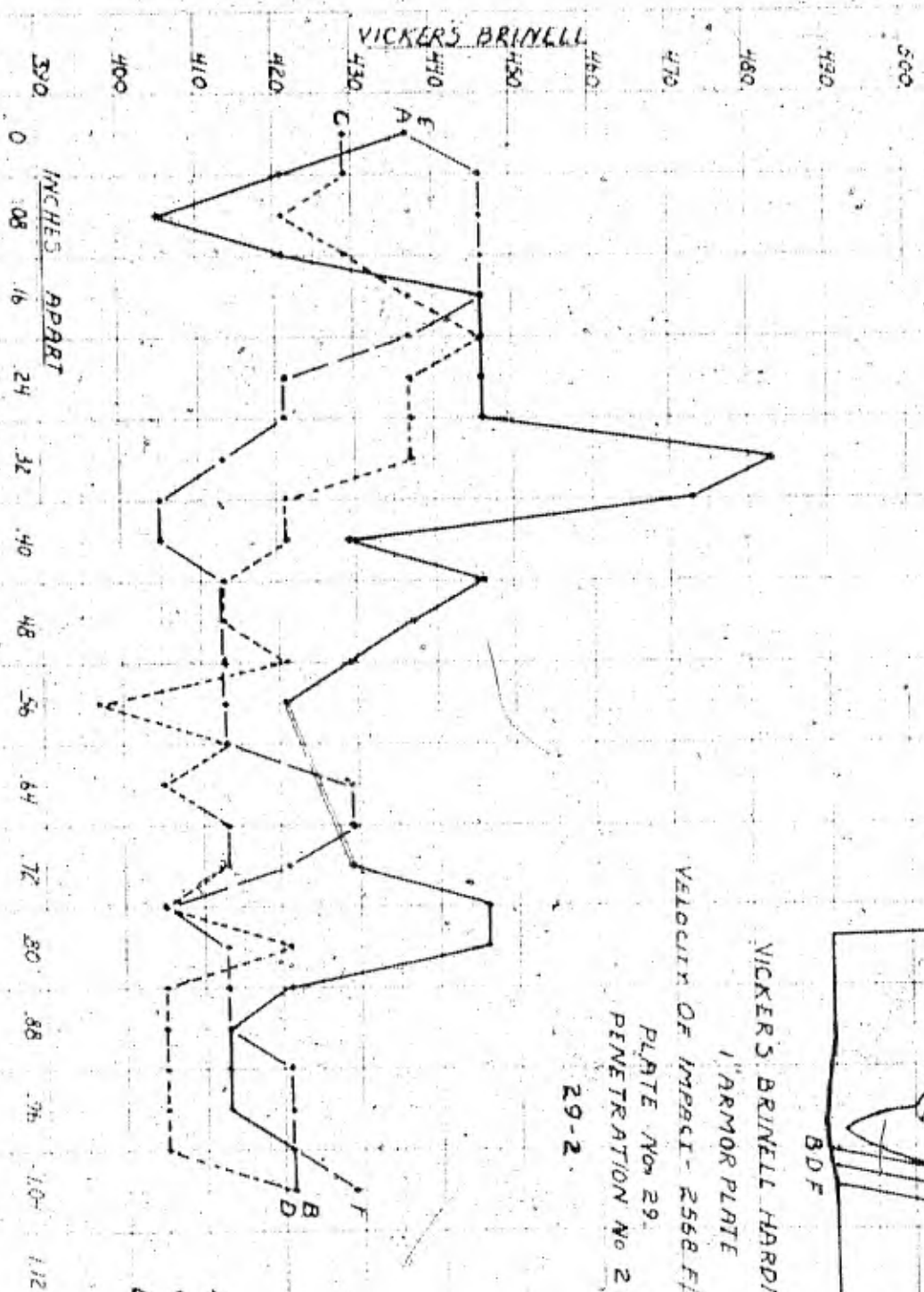
VICKERS BRINELL HARDNESS
1" ARMOR PLATE
PLATE No. 29.
PENETRATION No. 1.
29-1



330
A.H. 6/10/36



6/10/34
A.H.



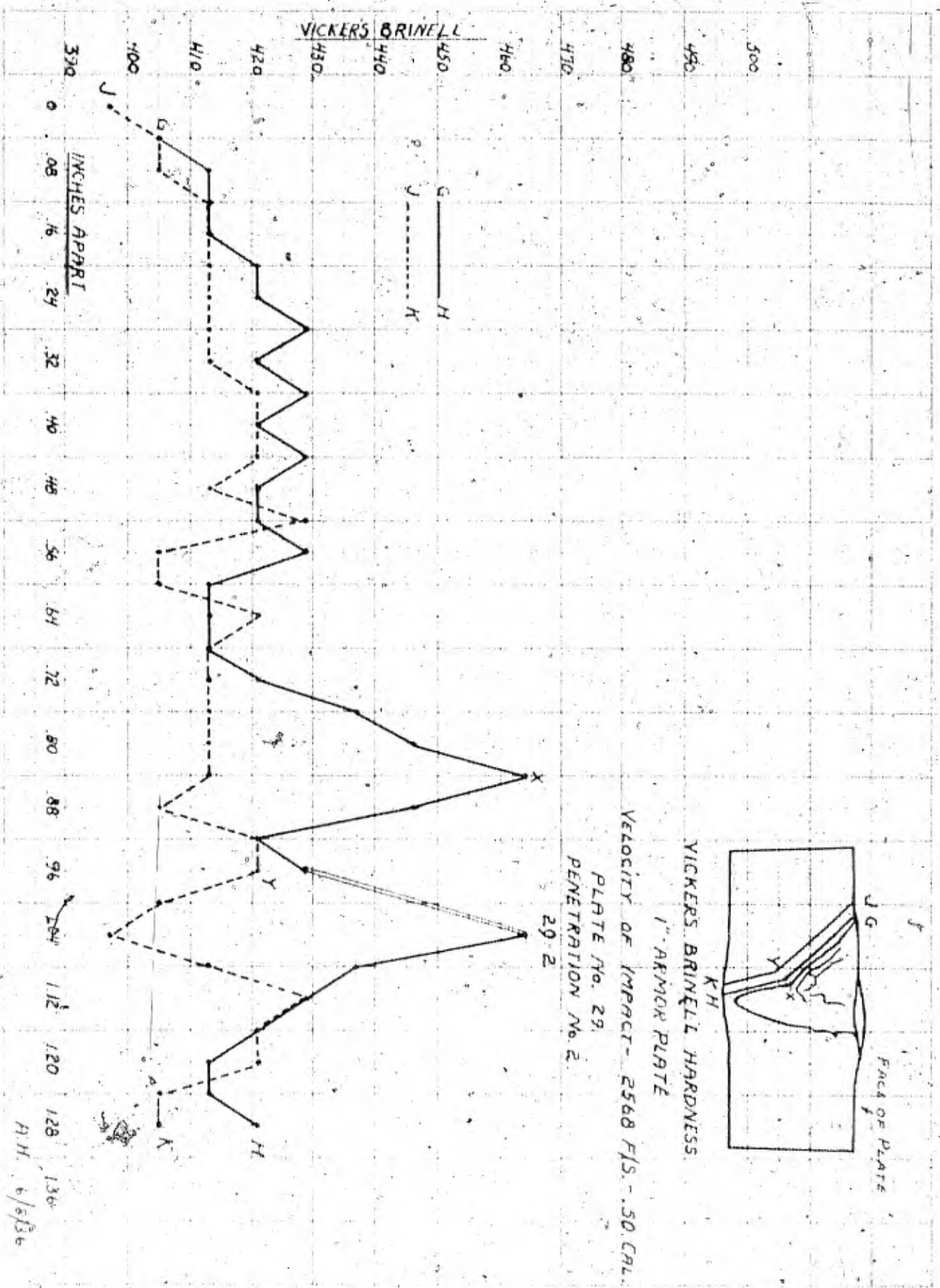
VICKERS BRINELL HARDNESS
1" ARMOR PLATE

VELOCITY OF IMPACT - 2558 F/S. - .50 CAL. #70
PLATE No. 29
PENETRATION No. 2

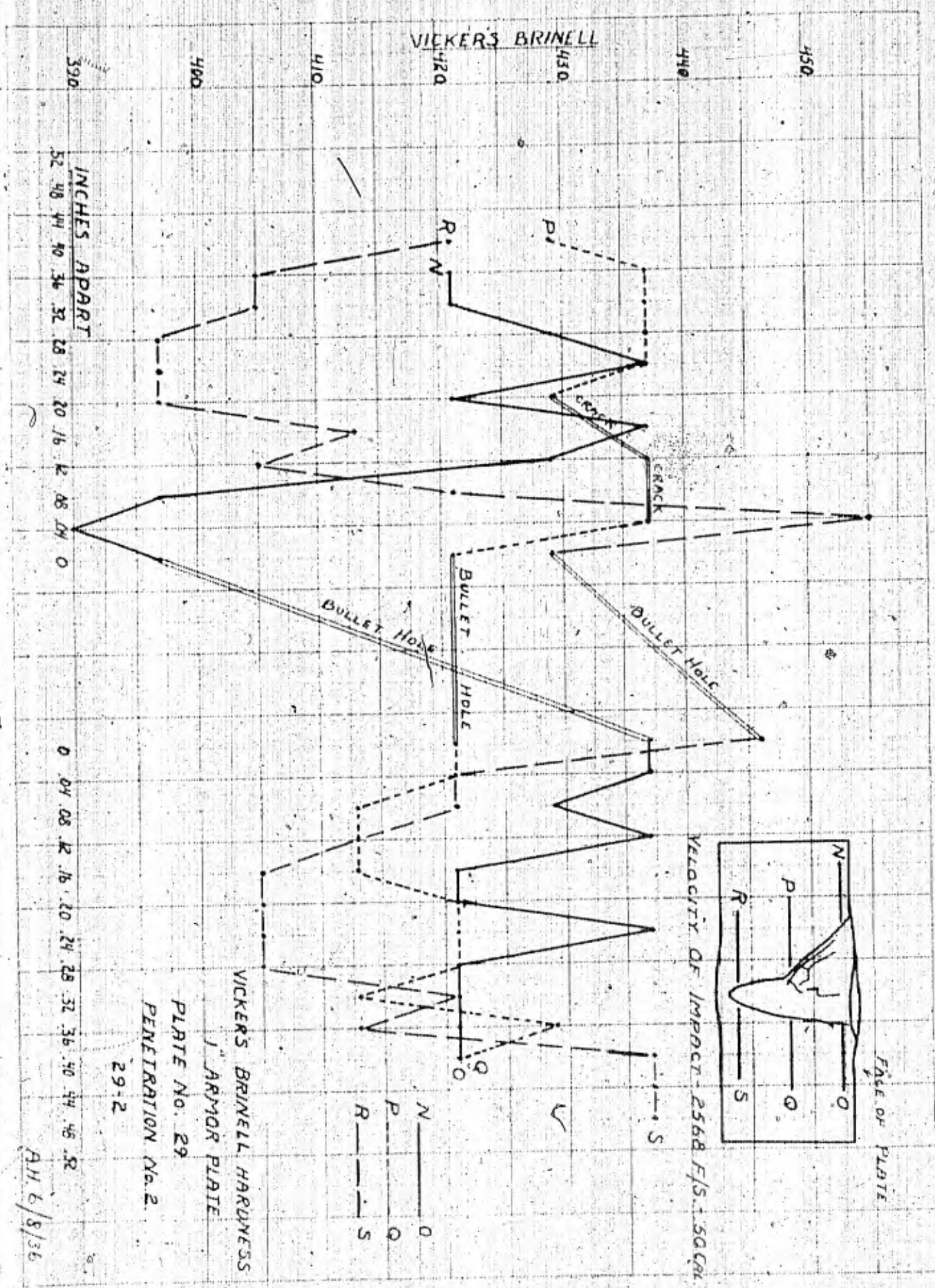
29-2

A ——— B 410
C ——— D
E ——— F 410

370
6/8/36



A.M. 6/5/36



VICKERS BRINELL

450
440
430
420
410
400
390

INCHES APART

52 48 44 40 36 32 28 24 20 16 12 08 04 0

0 04 08 12 16 20 24 28 32 36 40 44 48 52

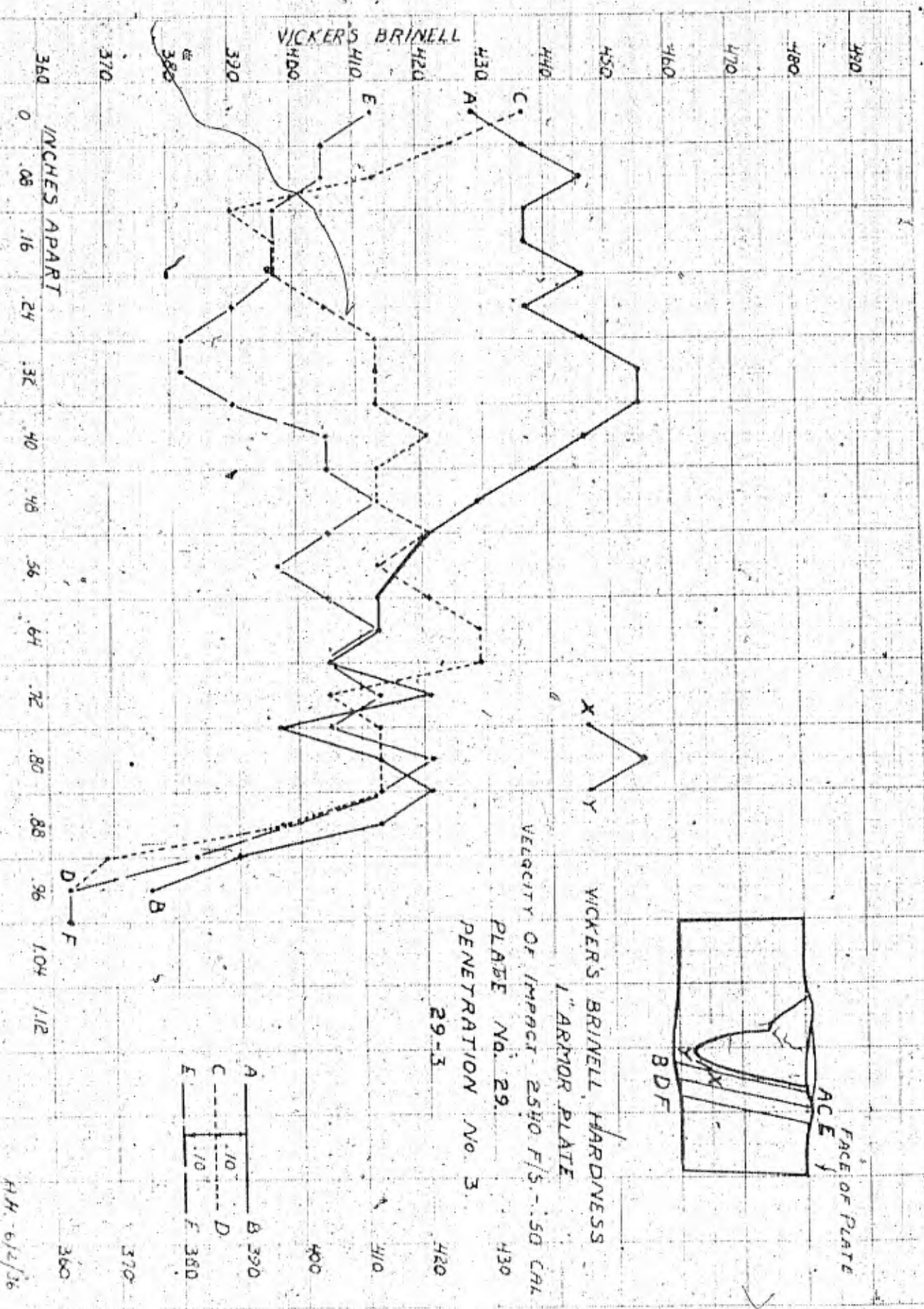
VICKERS BRINELL HARDNESS
1" ARMOR PLATE
PLATE No. 29
PENETRATION No. 2
29-2

AM 6/8/36



VELOCITY OF IMPACT - 2568 F/S. - 50 GR

N — 0
P — 0
R — S



450

480

470

460

450

440

430

420

410

400

360

370

380

0

.08

.16

.24

.32

.40

.48

.56

.64

.72

.80

.88

.96

1.04

1.12

HH. 6/2/36

360

370

380

390

400

410

420

430

29-3

PENETRATION No. 3.

PLATE No. 29.

VELOCITY OF IMPACT 2500 F/S. .50 CAL

1" ARMOR PLATE

VICKERS BRINELL HARDNESS

FACE OF PLATE

BDF

ACE

X

Y

VICKERS BRINELL

450

440

430

420

410

400

390

380

370

360

HH. 6/2/36

360

370

380

390

400

410

420

430

29-3

PENETRATION No. 3.

PLATE No. 29.

VELOCITY OF IMPACT 2500 F/S. .50 CAL

1" ARMOR PLATE

VICKERS BRINELL HARDNESS

FACE OF PLATE

BDF

ACE

X

Y

VICKERS BRINELL

450

440

430

420

410

400

390

380

370

360

HH. 6/2/36

360

370

380

390

400

410

420

430

29-3

PENETRATION No. 3.

PLATE No. 29.

VELOCITY OF IMPACT 2500 F/S. .50 CAL

1" ARMOR PLATE

VICKERS BRINELL HARDNESS

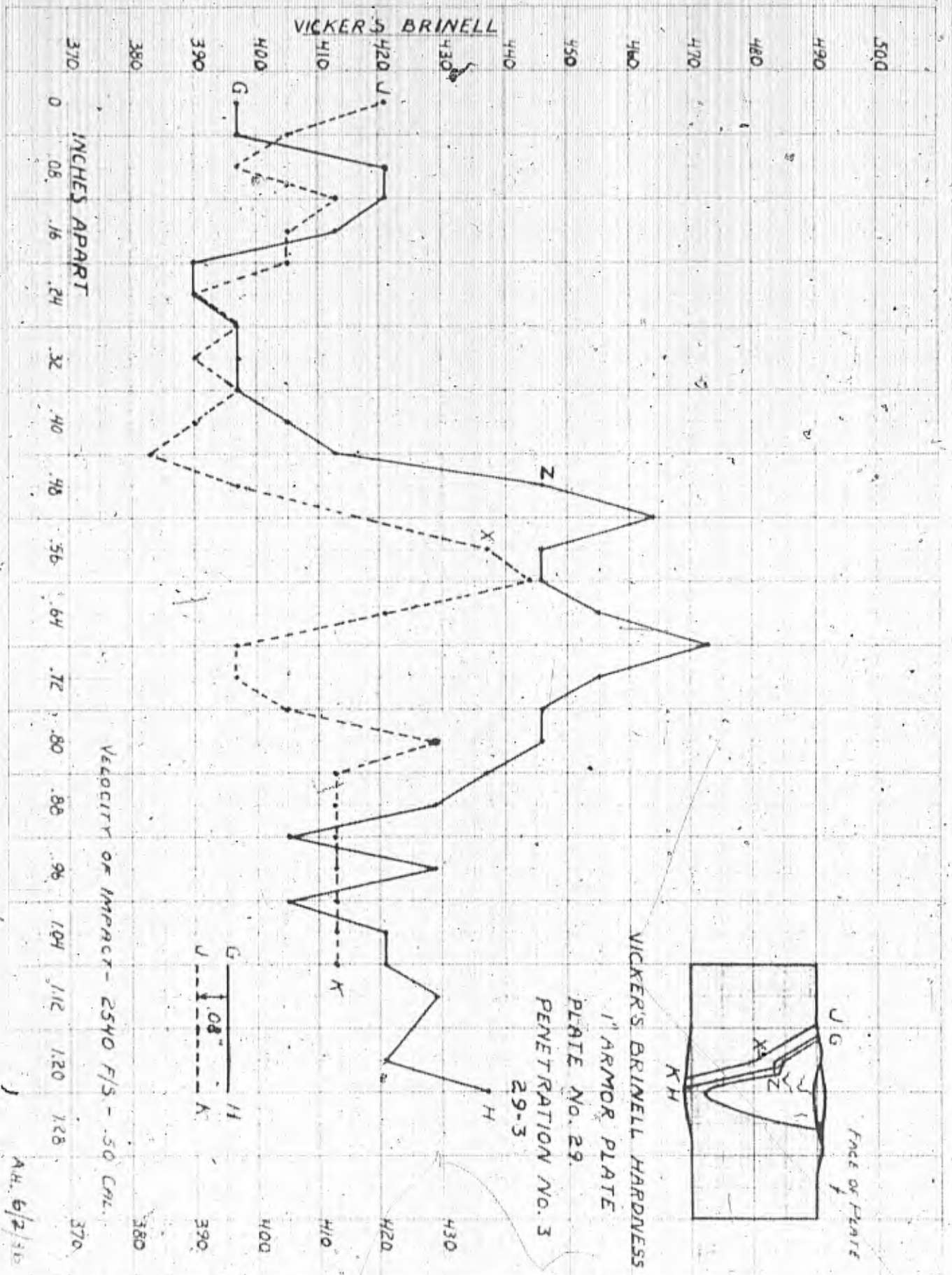
FACE OF PLATE

BDF

ACE

X

Y



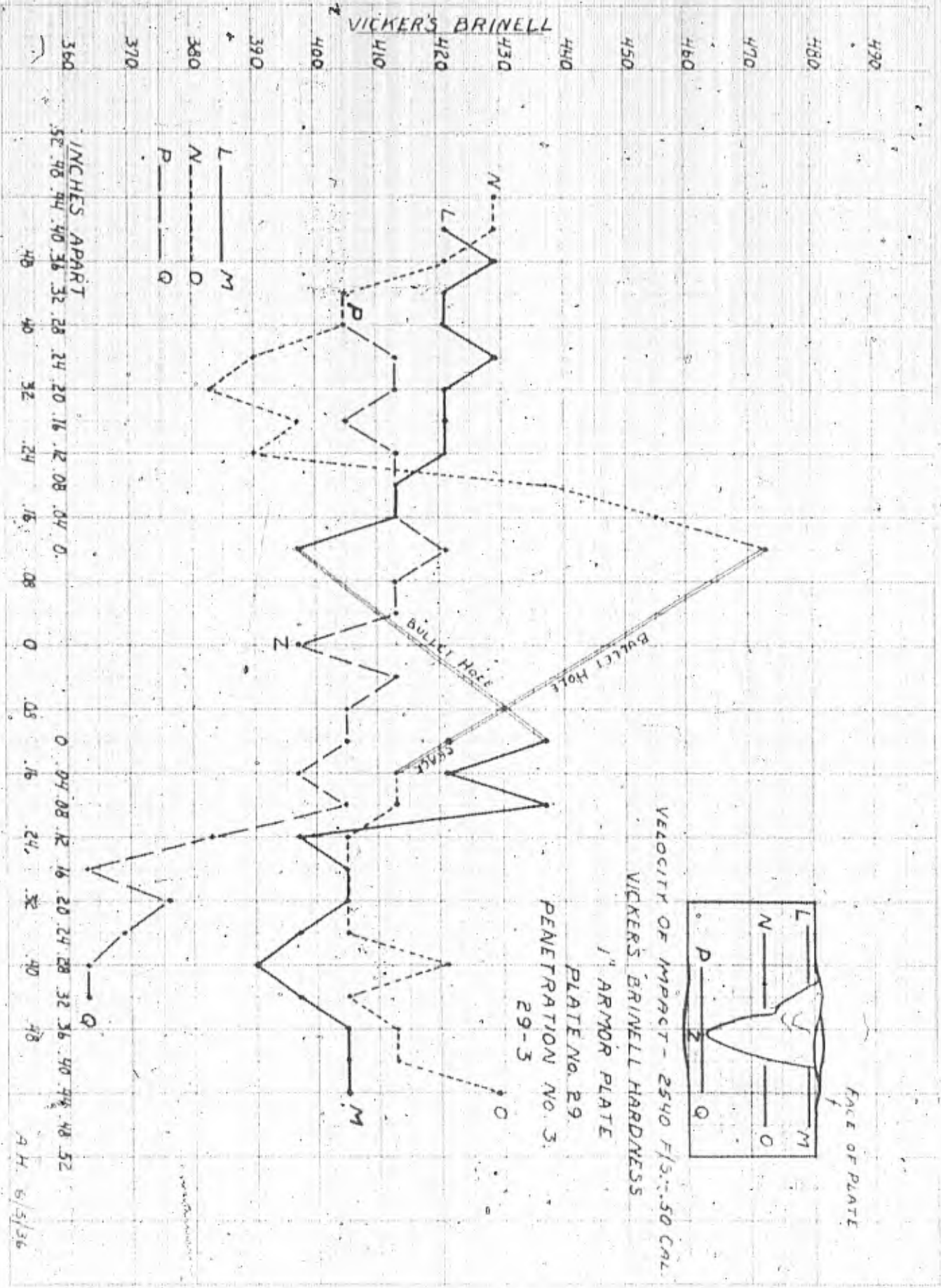


PLATE NO. 2.

TAYLOR - WHARTON - Homogeneous Armor Plate

12 x 12 x $\frac{1}{2}$ "
Actual thickness - .491 - .493"

Brinell - 255

<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>
1.17	11.40	.405	.018	.057

Hadfield Manganese Steel, chromium plated on
front side.

Ammunition - .30 cal. 165 gr. M1922. A.P.

Range - 150 feet.

Round C. Str. Vel. 2215 f/s. Complete Penetration.

C.I.P.

Round D. Str. Vel. 2357 f/s. Complete Penetration.

Height of Bulge on Back - .14"

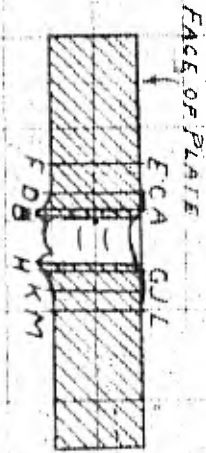
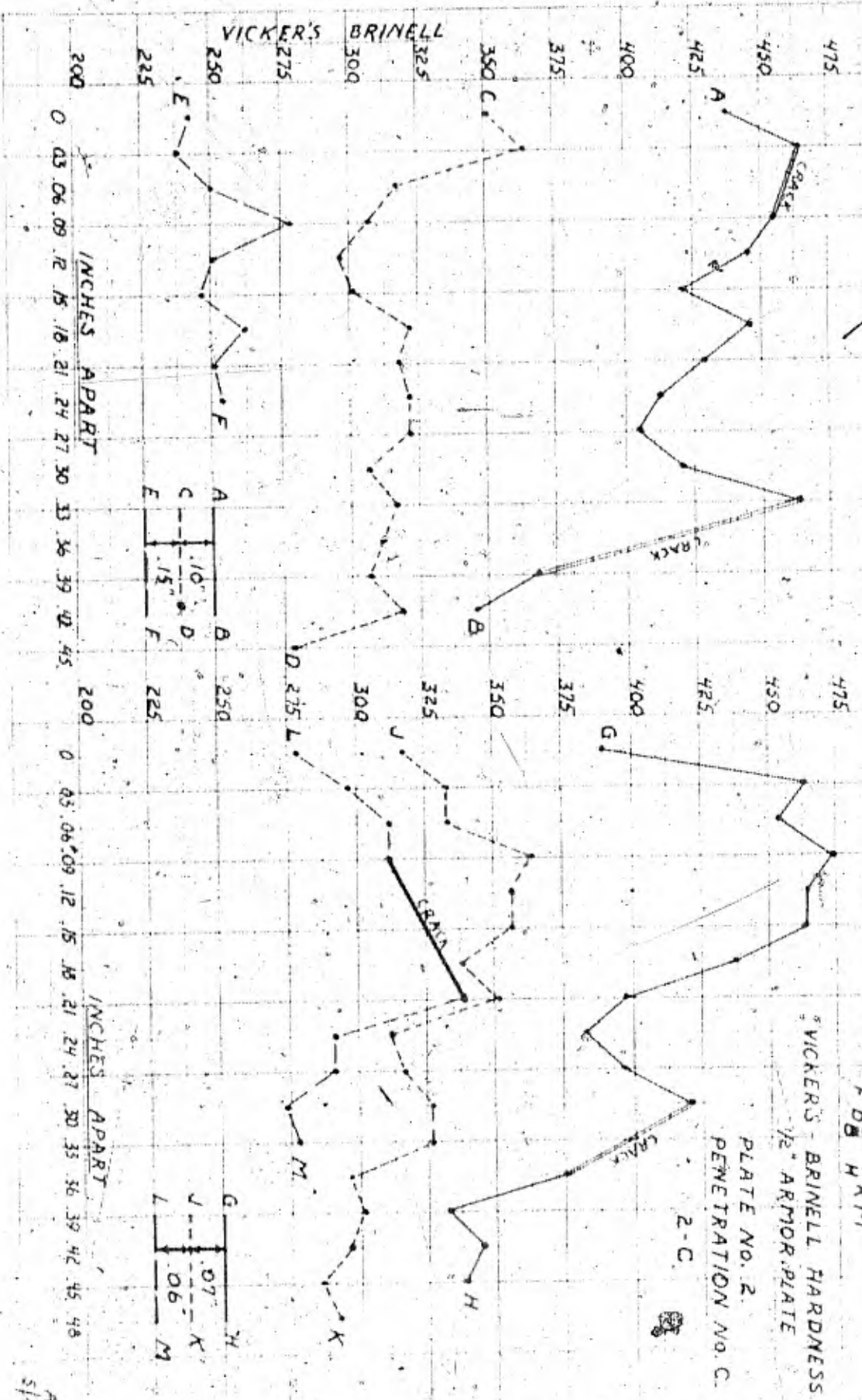
Diam. of Hole in Back - .25"

Round E. Str. Vel. 2283 f/s. Complete Penetration.

Height of Bulge on Back - .17"

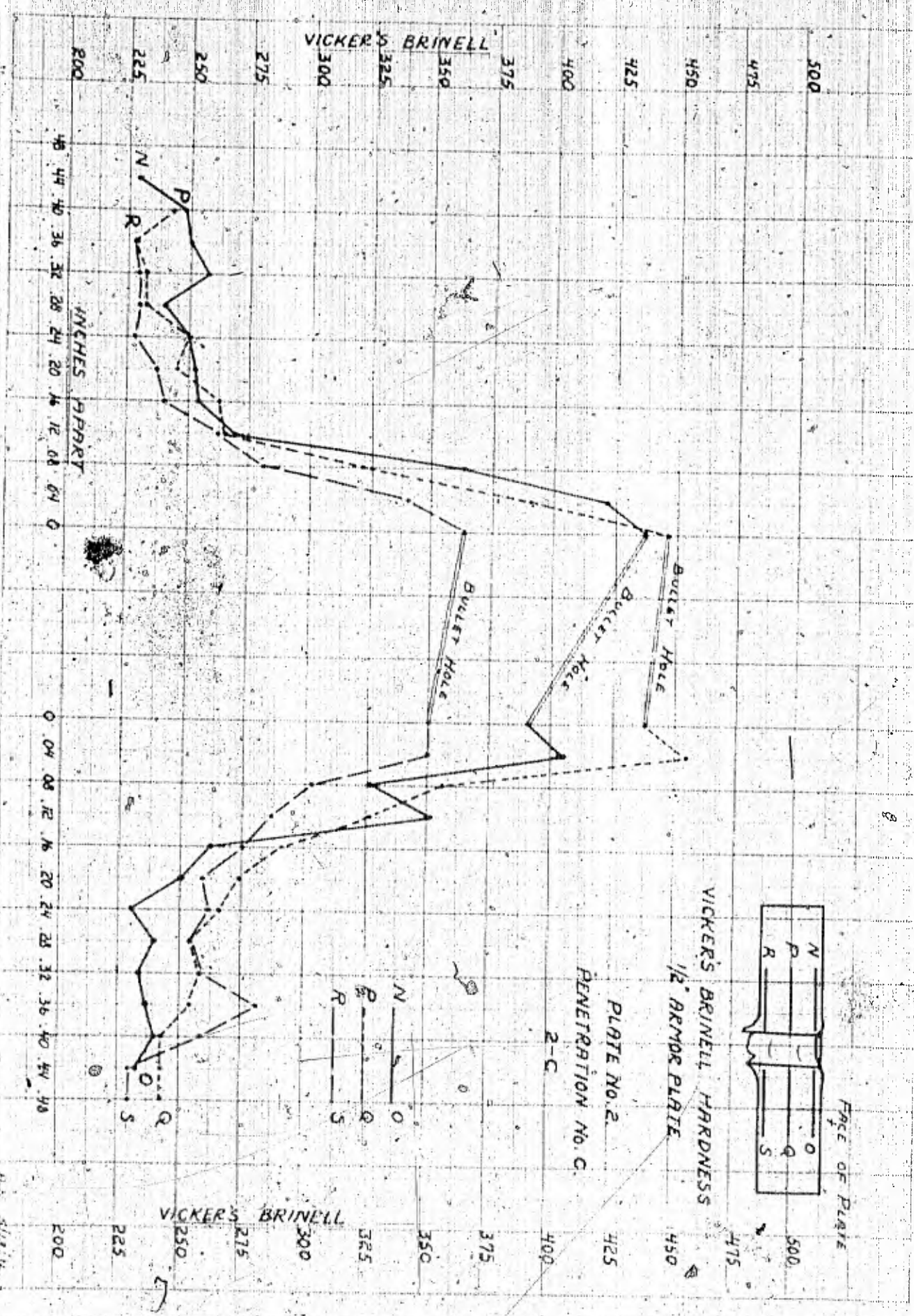
Diam. of Hole in Back - .25"

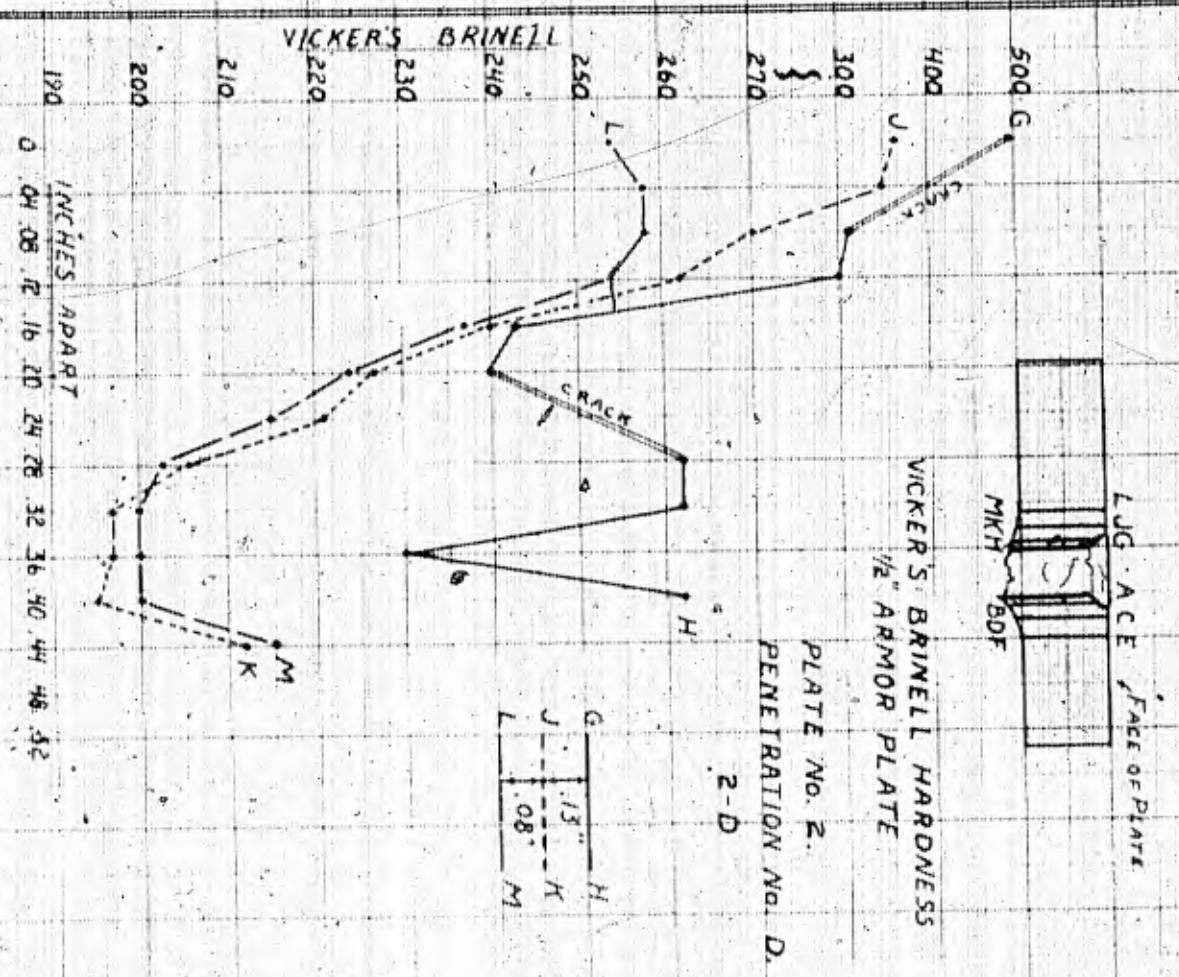
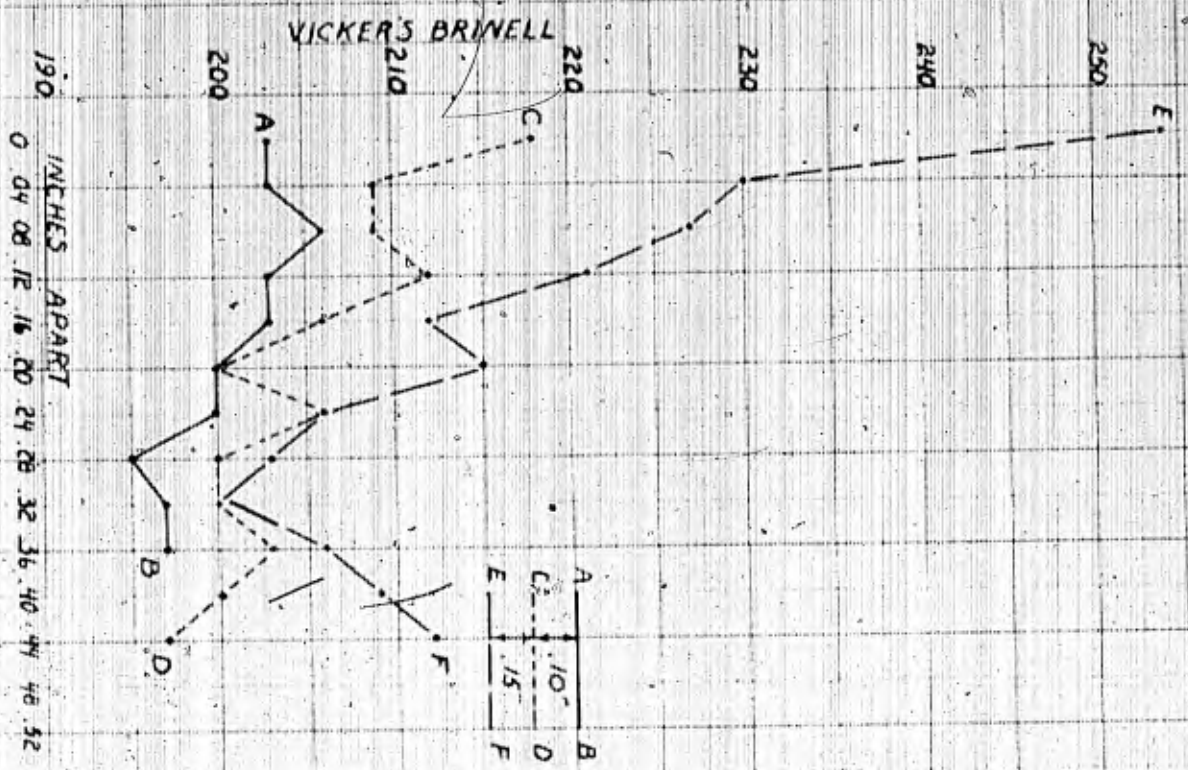
Partial Penetration - Str. Vel. 1800 f/s.



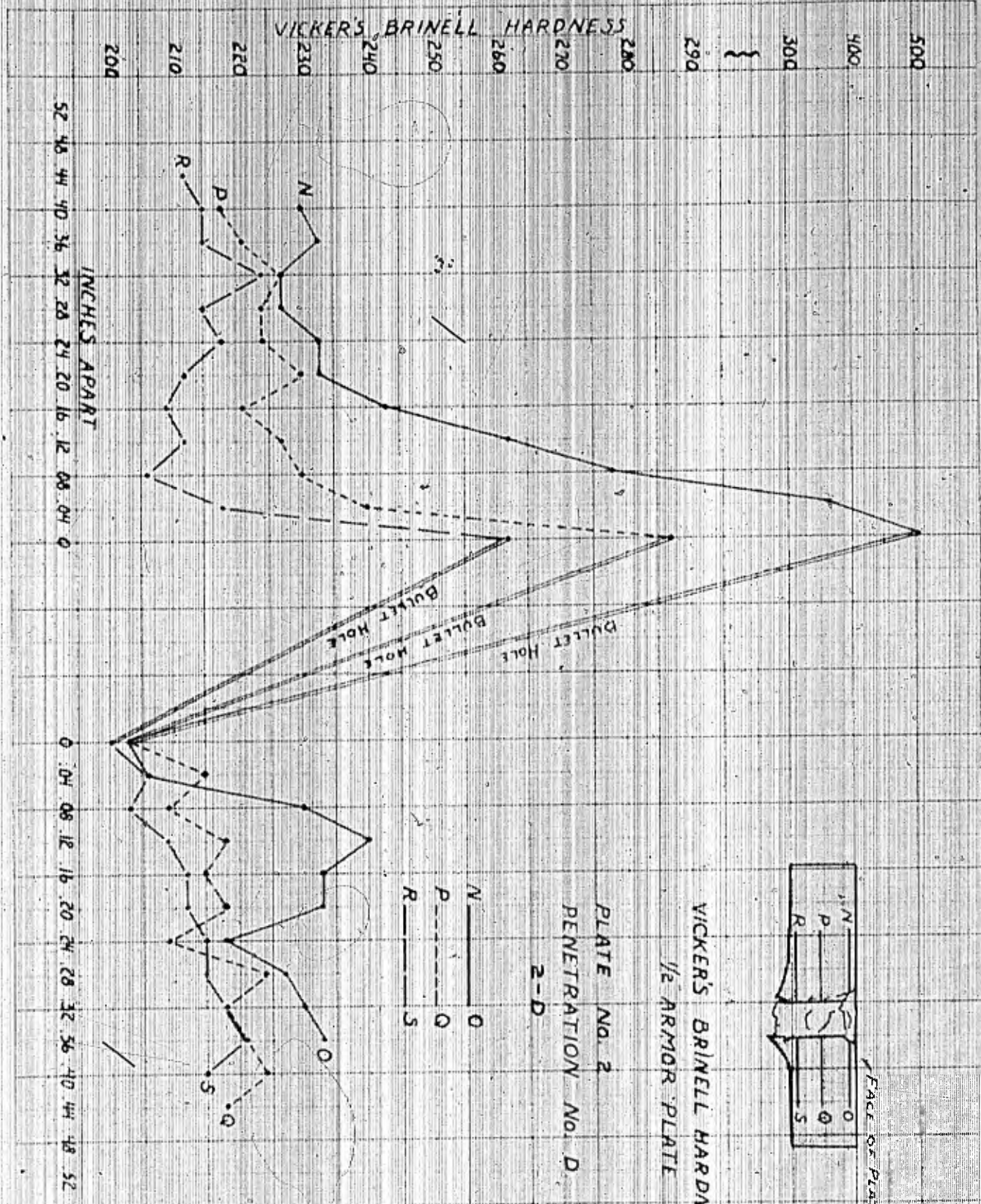
VICKER'S BRINELL HARDNESS
 1/2" ARMOR PLATE
 PLATE NO. 2.
 PENETRATION NO. C.
 2-C.

A.M.
 5/1/56





A.H. 9/28/35



A.H. 5/28/34

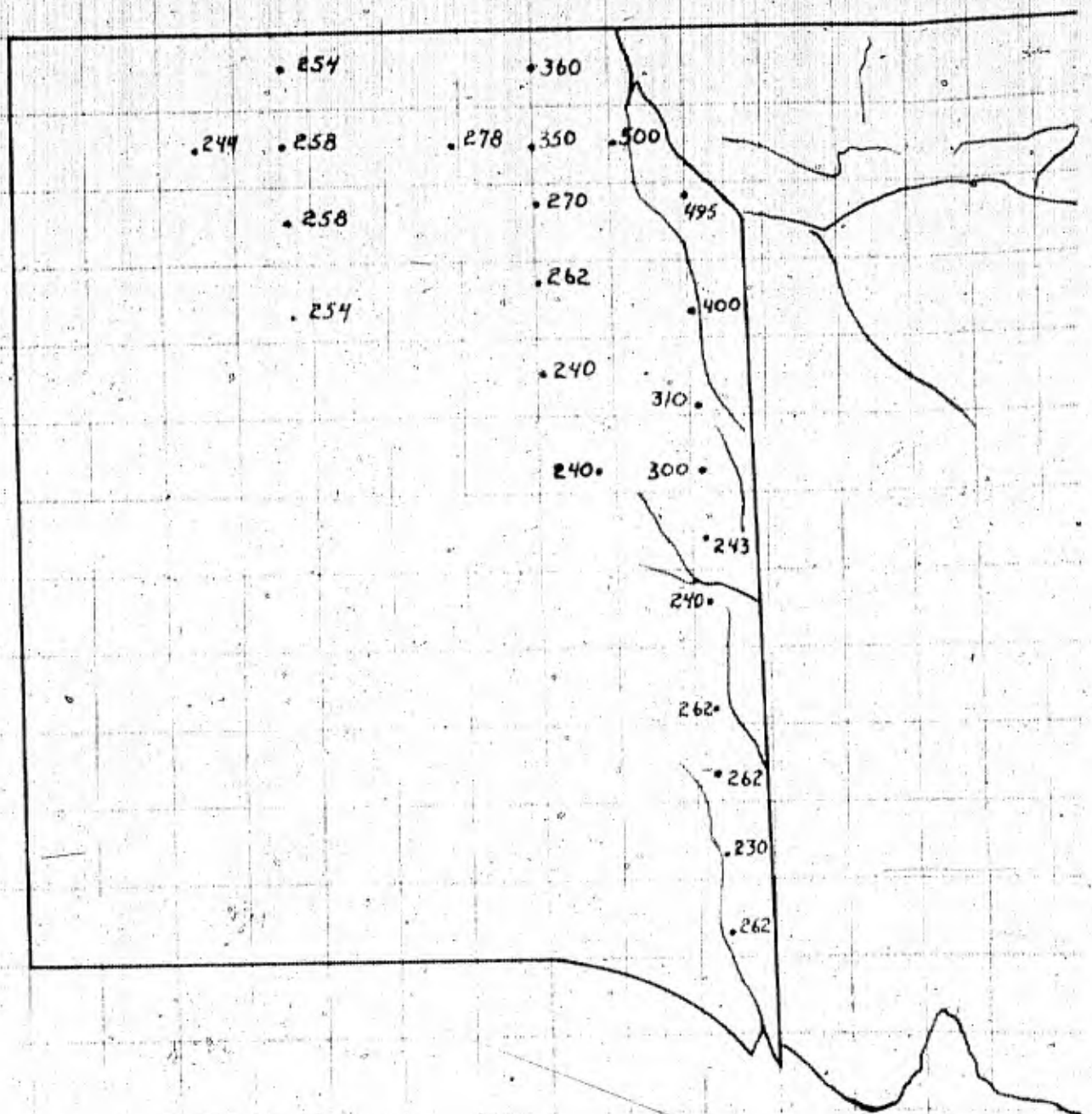


PLATE No. 2.
PENETRATION No.

SHOWING AREAS HAVING A HARDNESS IN EXCESS

7NE

FACE OF PLATE

• 256

• 240

SCALE: 12 TO 1

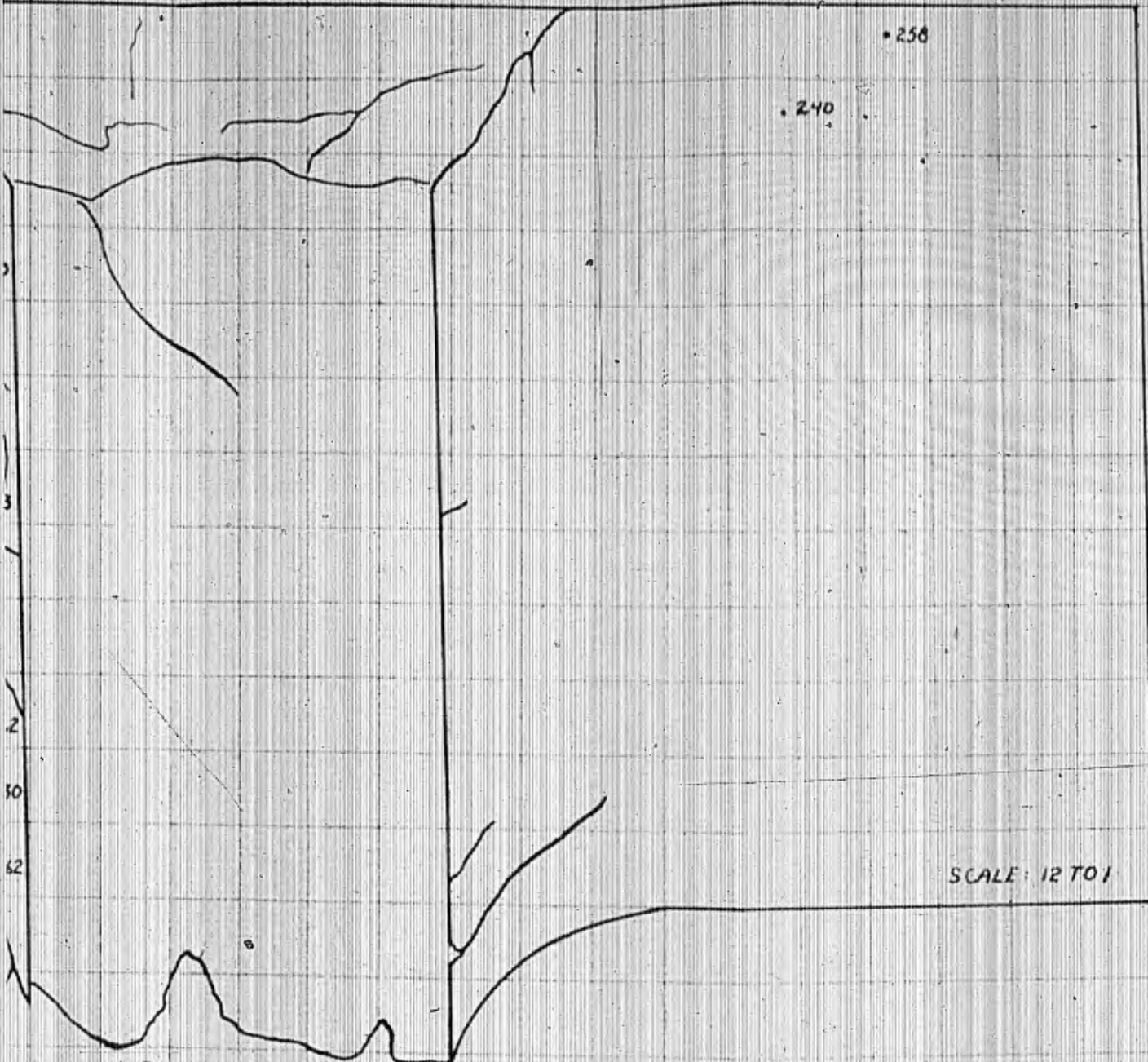
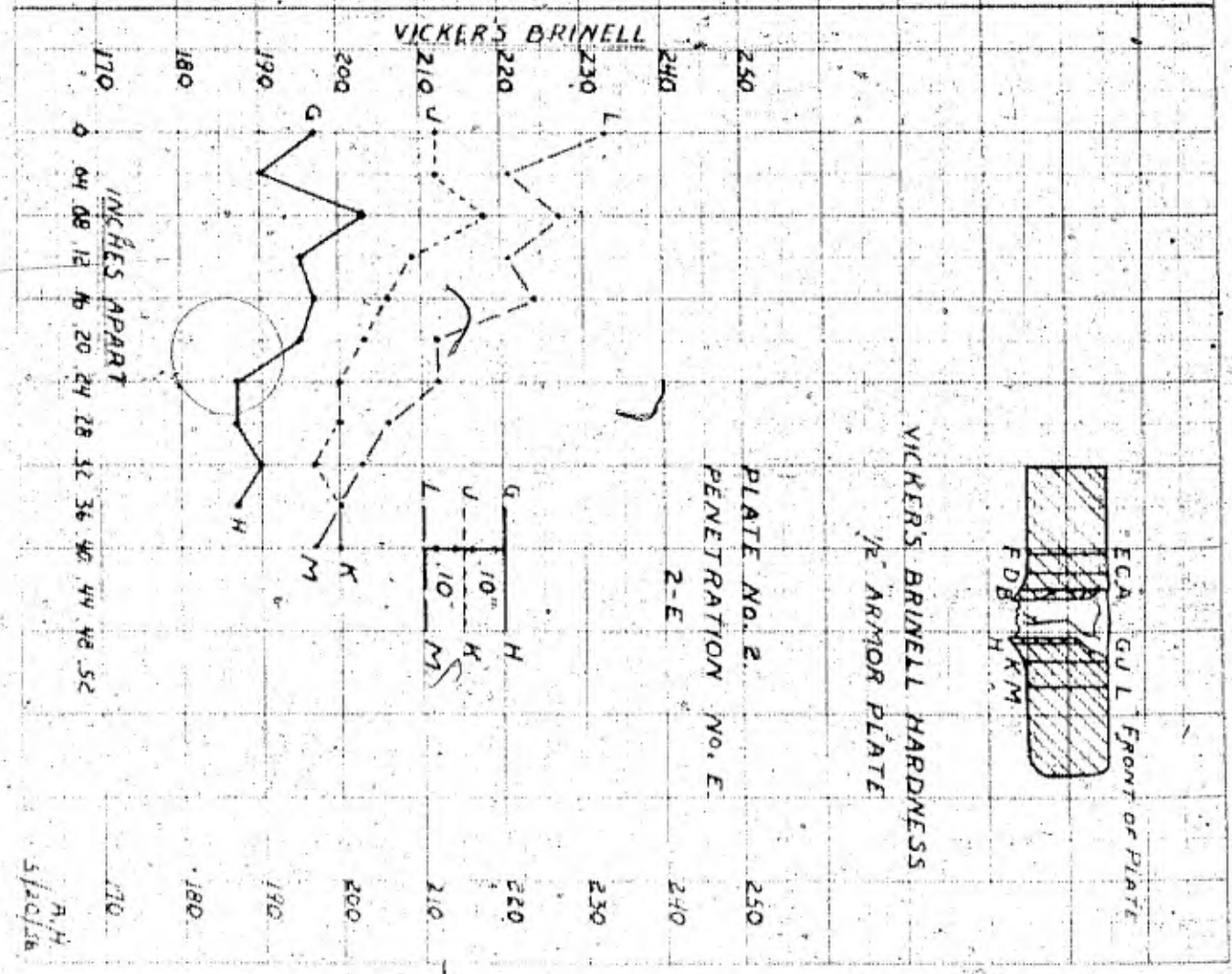
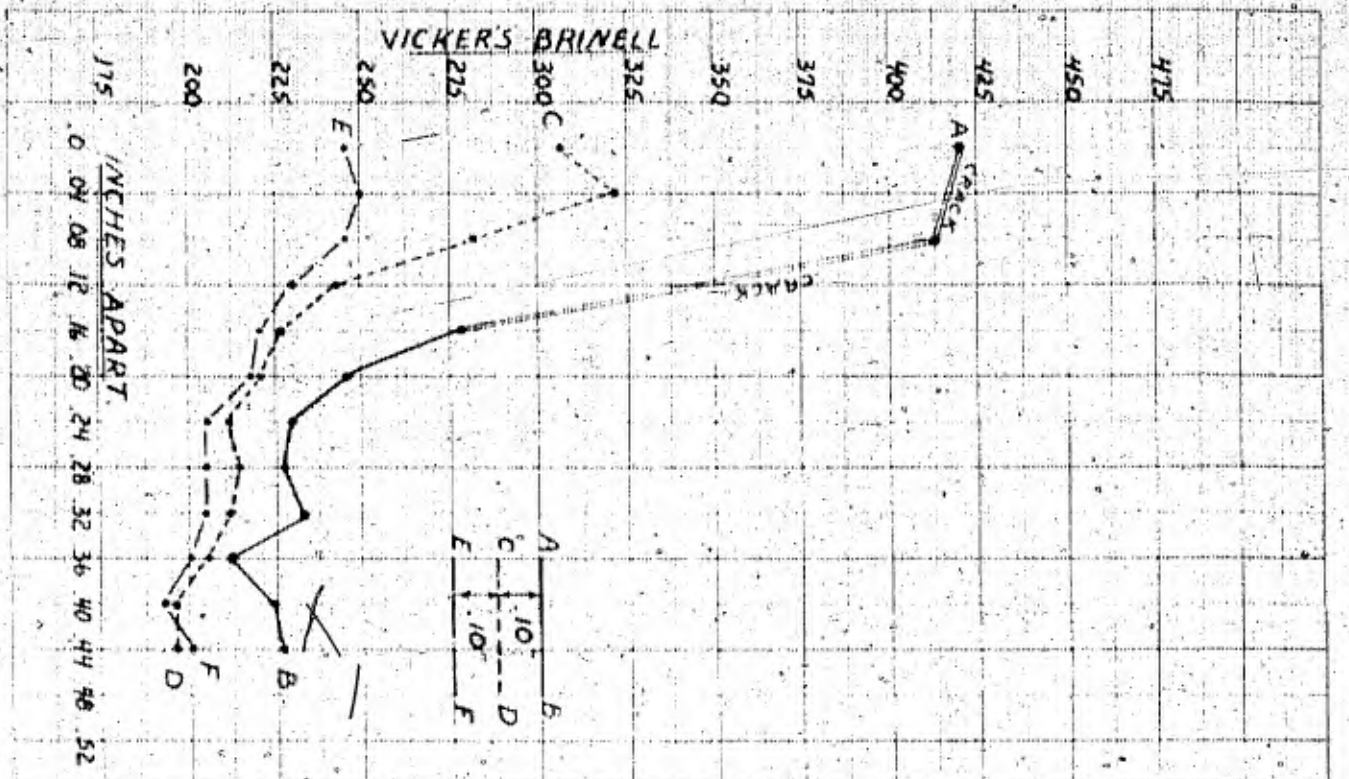


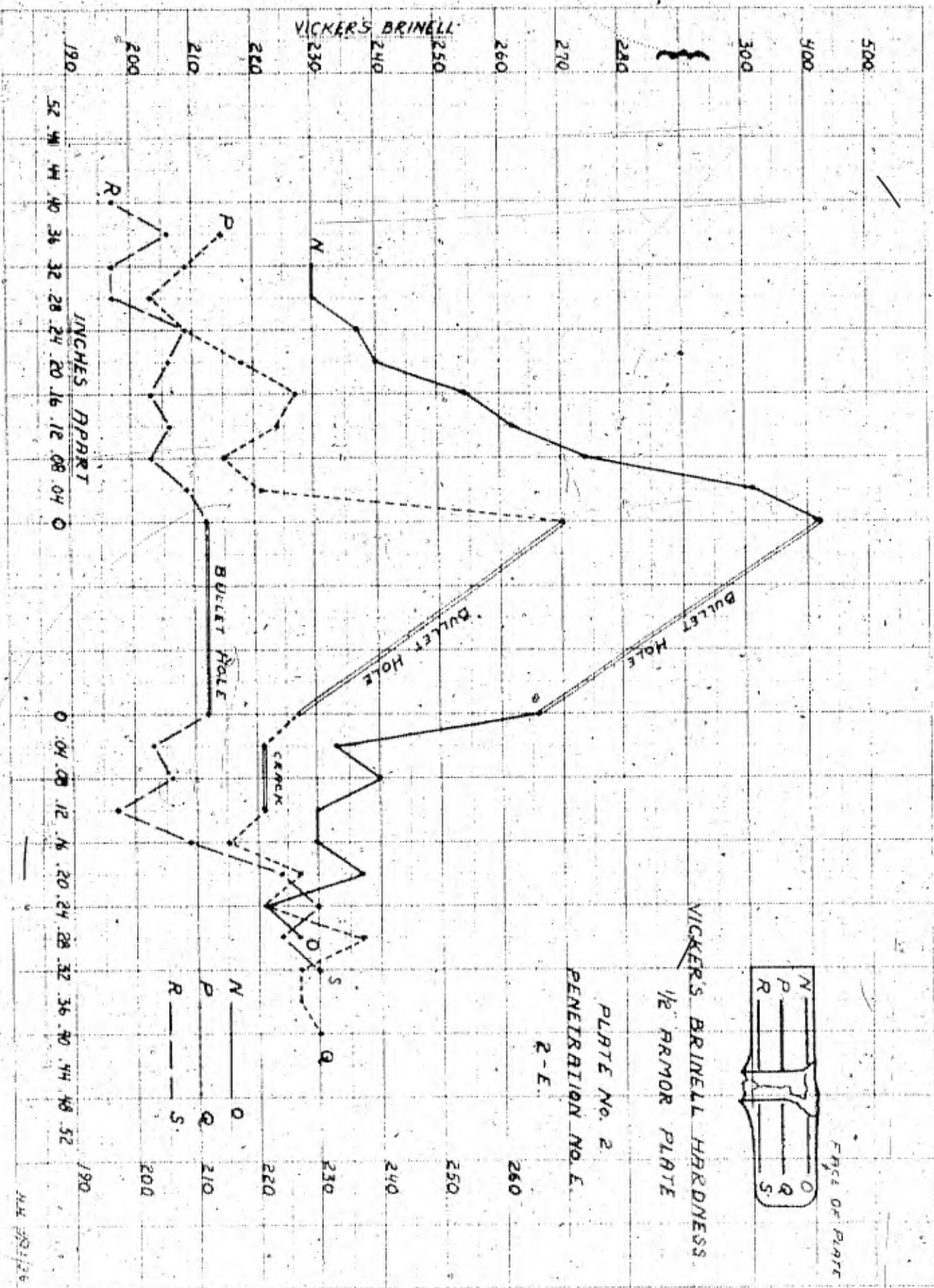
PLATE No. 2.
PENETRATION No. D.

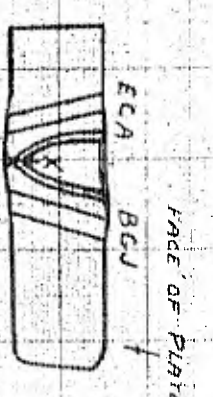
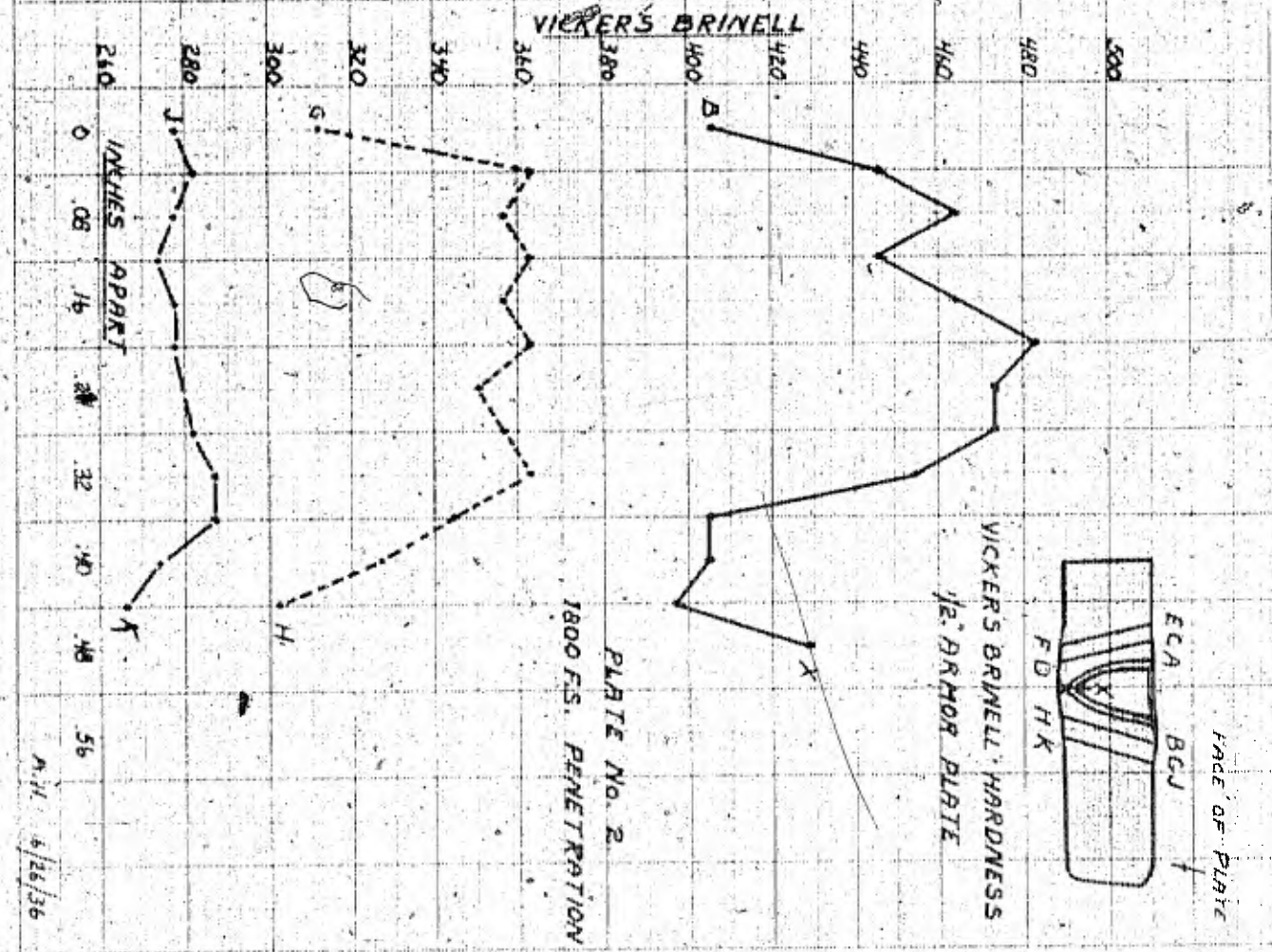
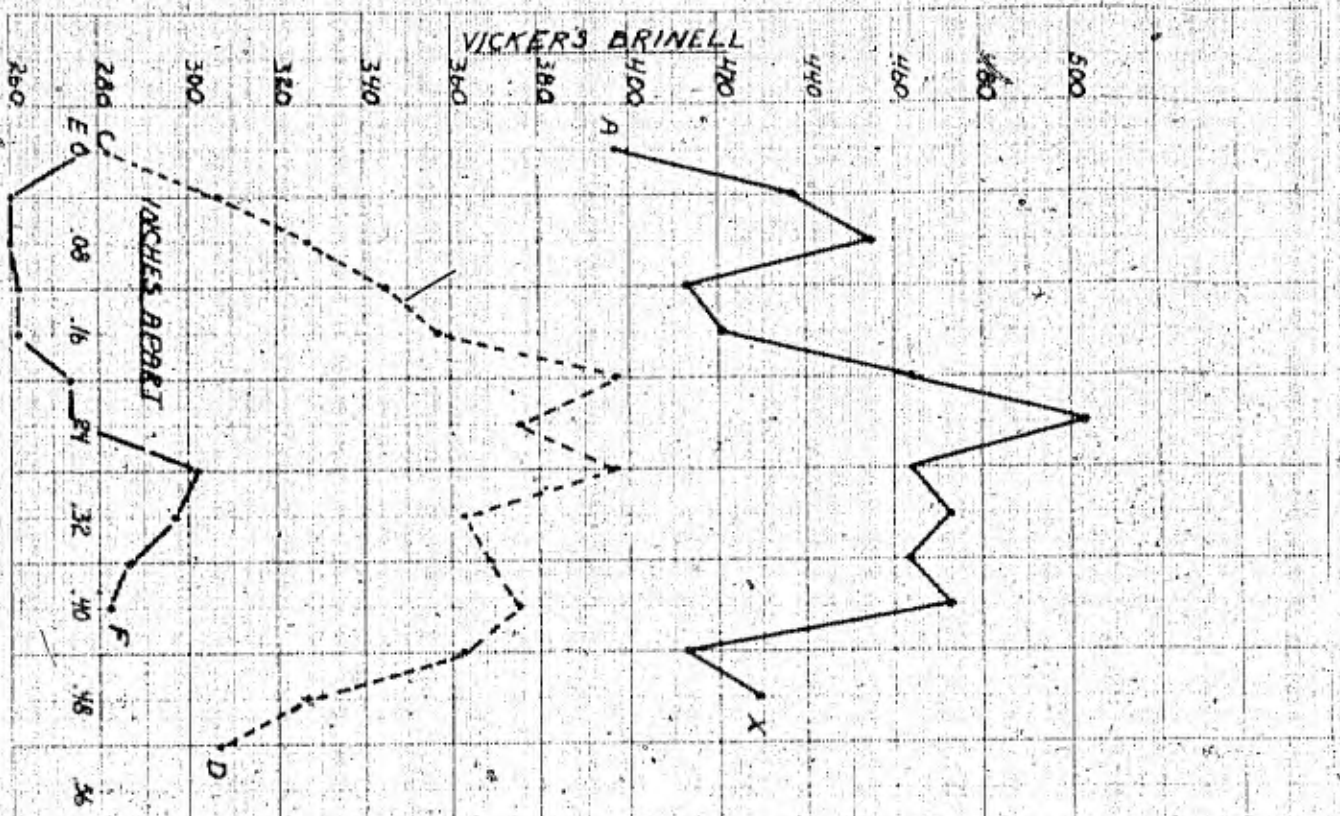
AVERAGE HARDNESS OF PLATE • 220 VICKERS

HARDNESS IN EXCESS OF 240 VICKERS BRINELL

A.H. 6/5/56



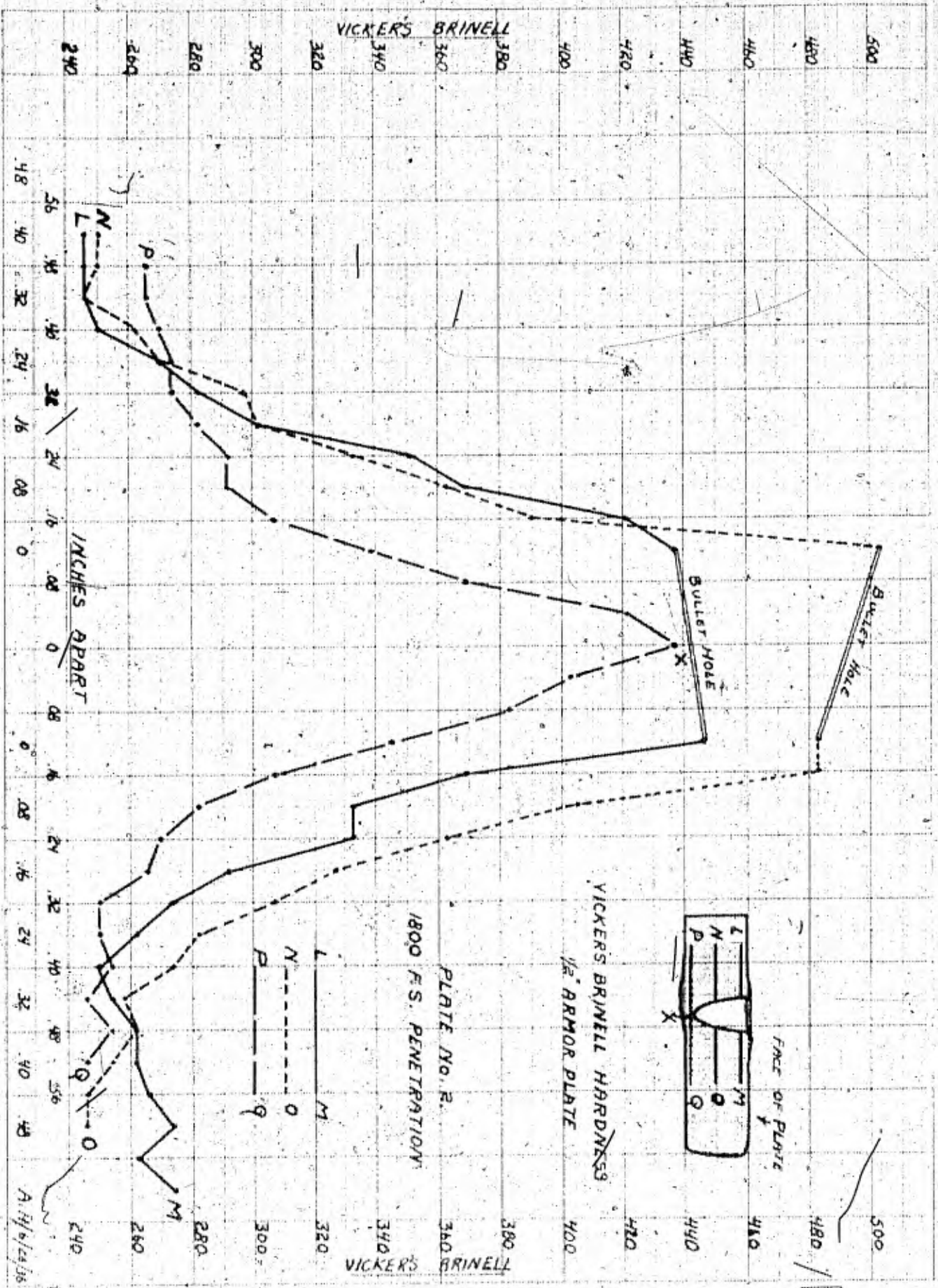




VICKERS BRINELL HARDNESS
1/2" ARMOR PLATE

PLATE No. 2
1800 F.S. PENETRATION

M.M. 6/26/36



CARBON STEEL PLATE.

Homogeneous Carbon Steel Plate.

12 x 12 x $\frac{1}{2}$ "

Brinell - 120.

<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Cr</u>
.19	.42	.025	.034	.012	.05

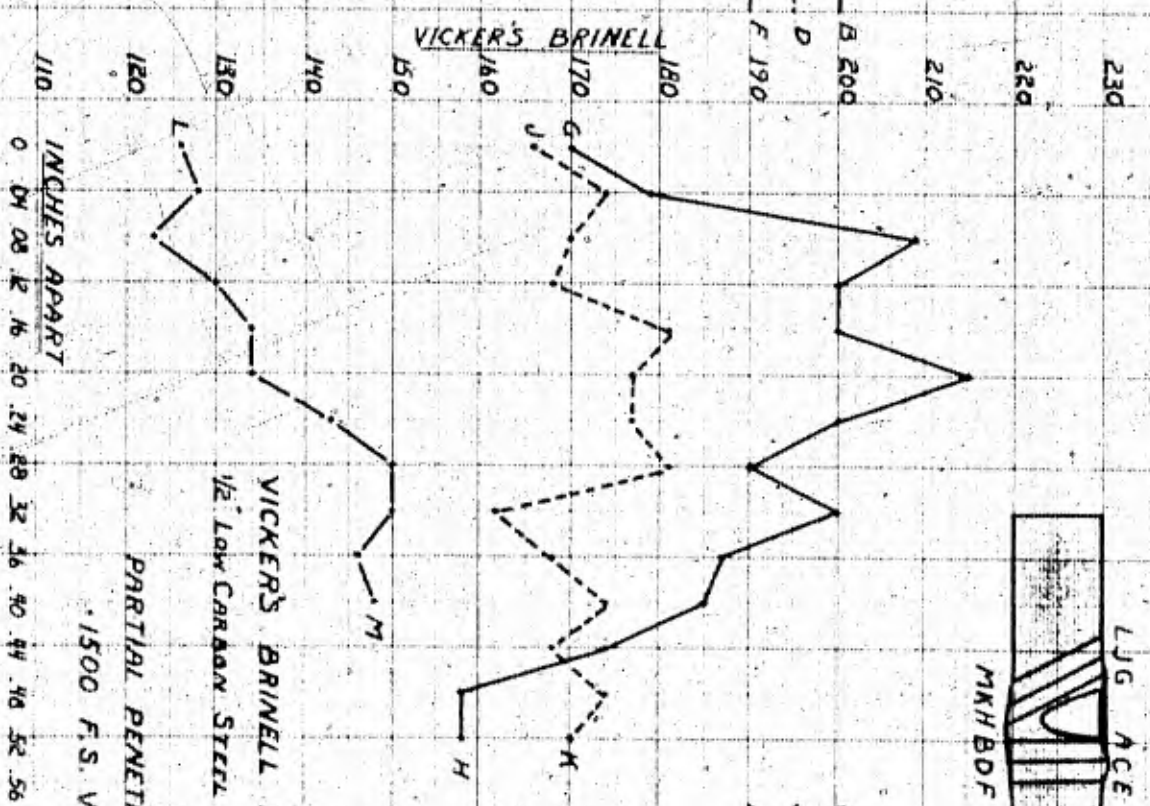
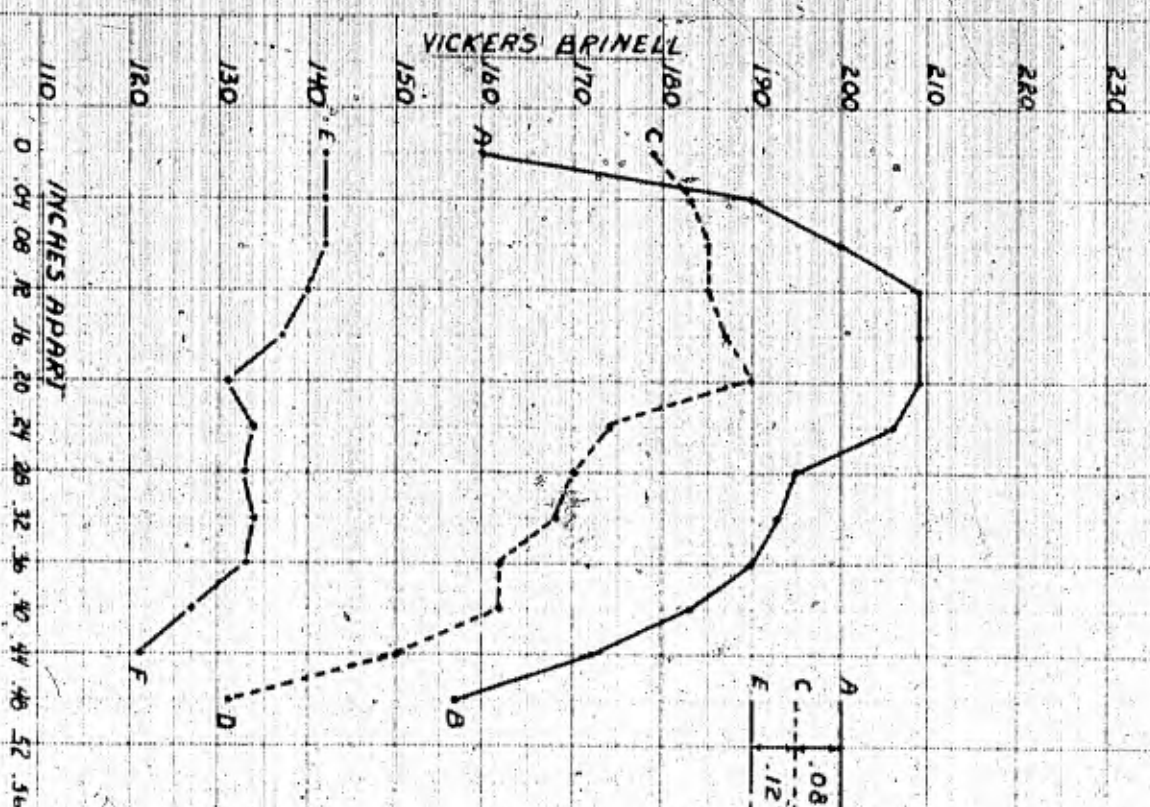
Ammunition - .30 cal. 165 gr. M1922. A.P.

Range - 100 yards.

Specification - AXS.- 54. Rev. 2.

Partial Penetration - Str. Vel. 1500 f/s.

Complete Penetration - Str. Vel. 2300 f/s.

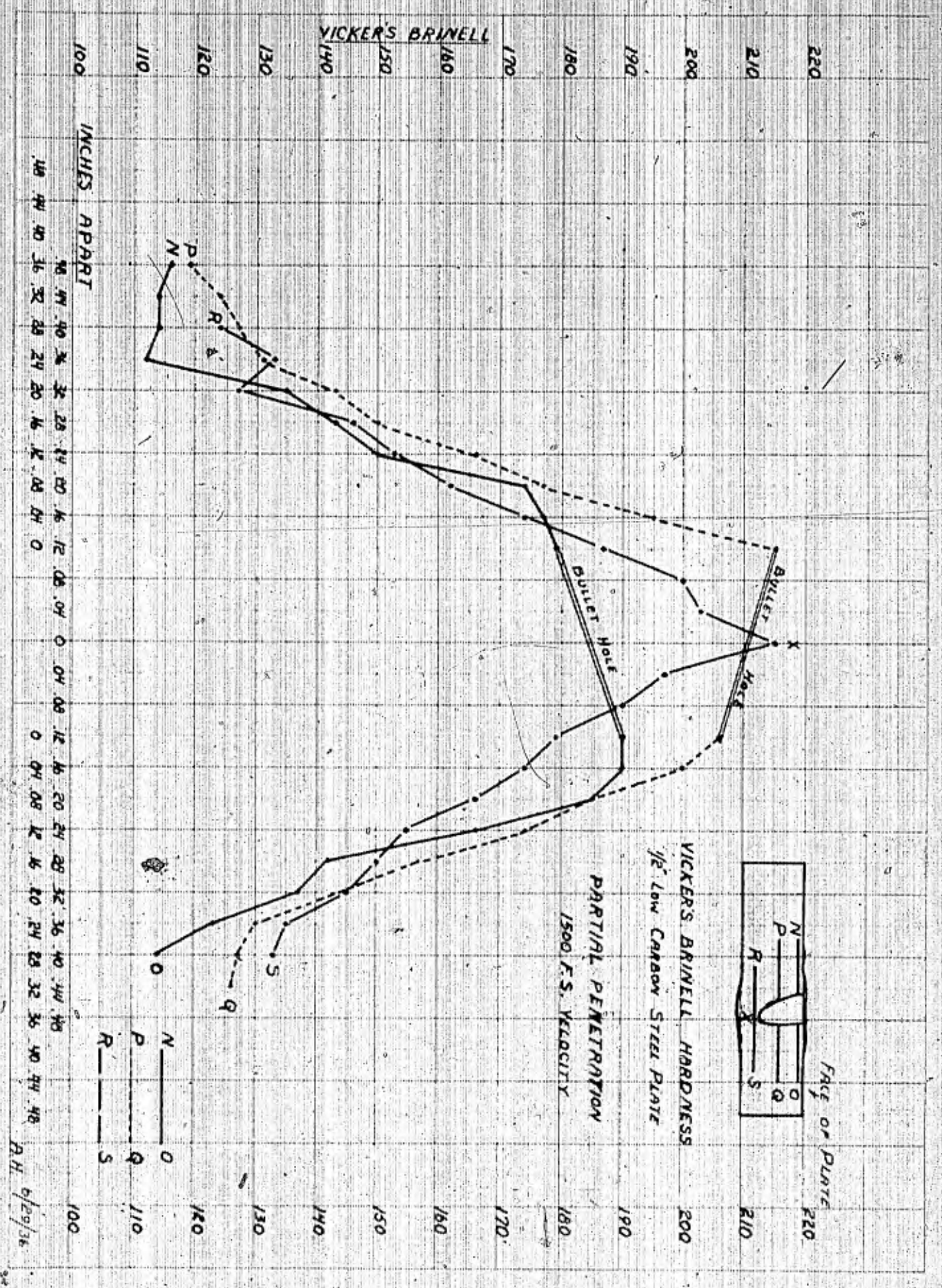


VICKERS BRINELL HARDNESS
1/2 LOW CARBON STEEL PLATE

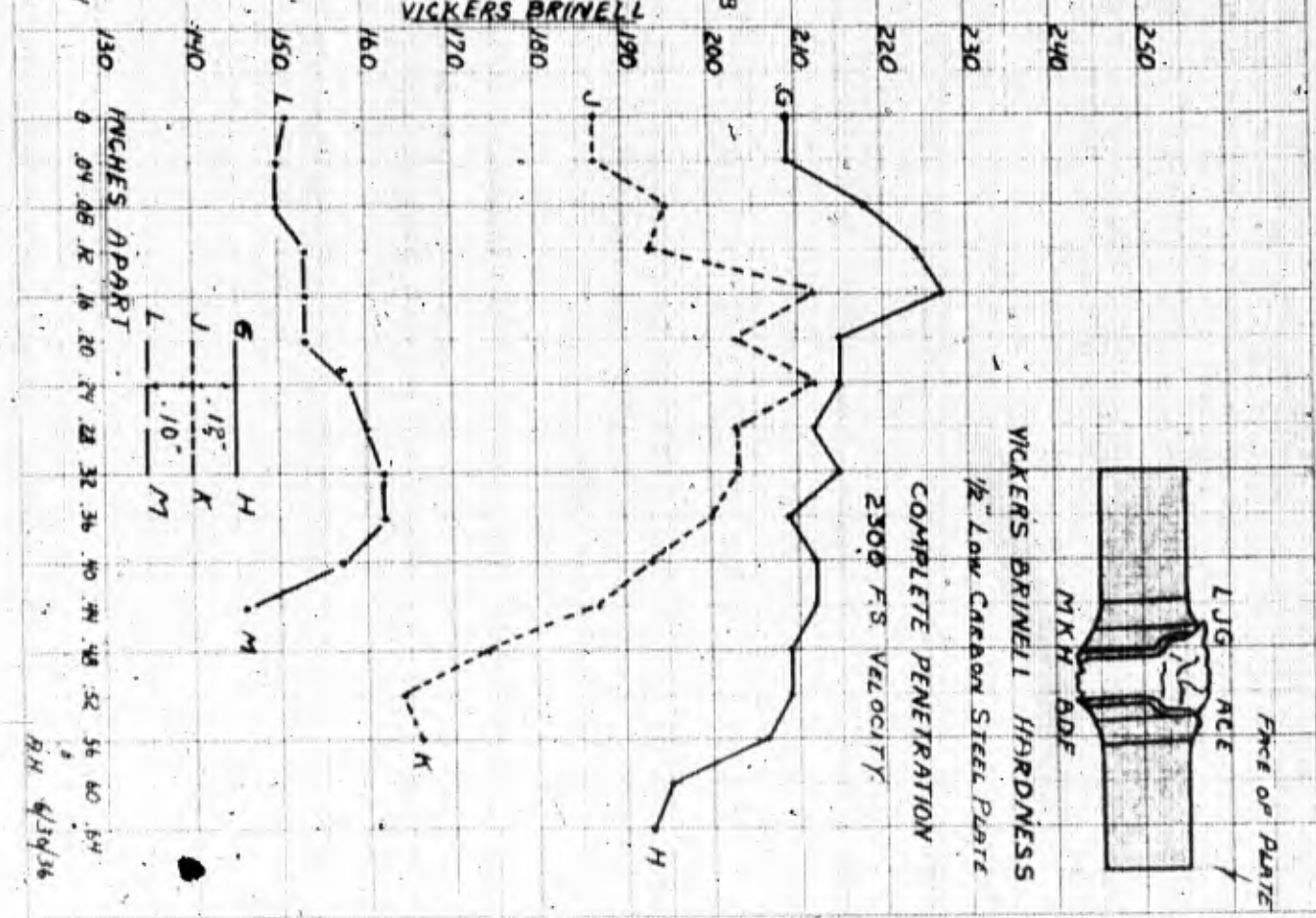
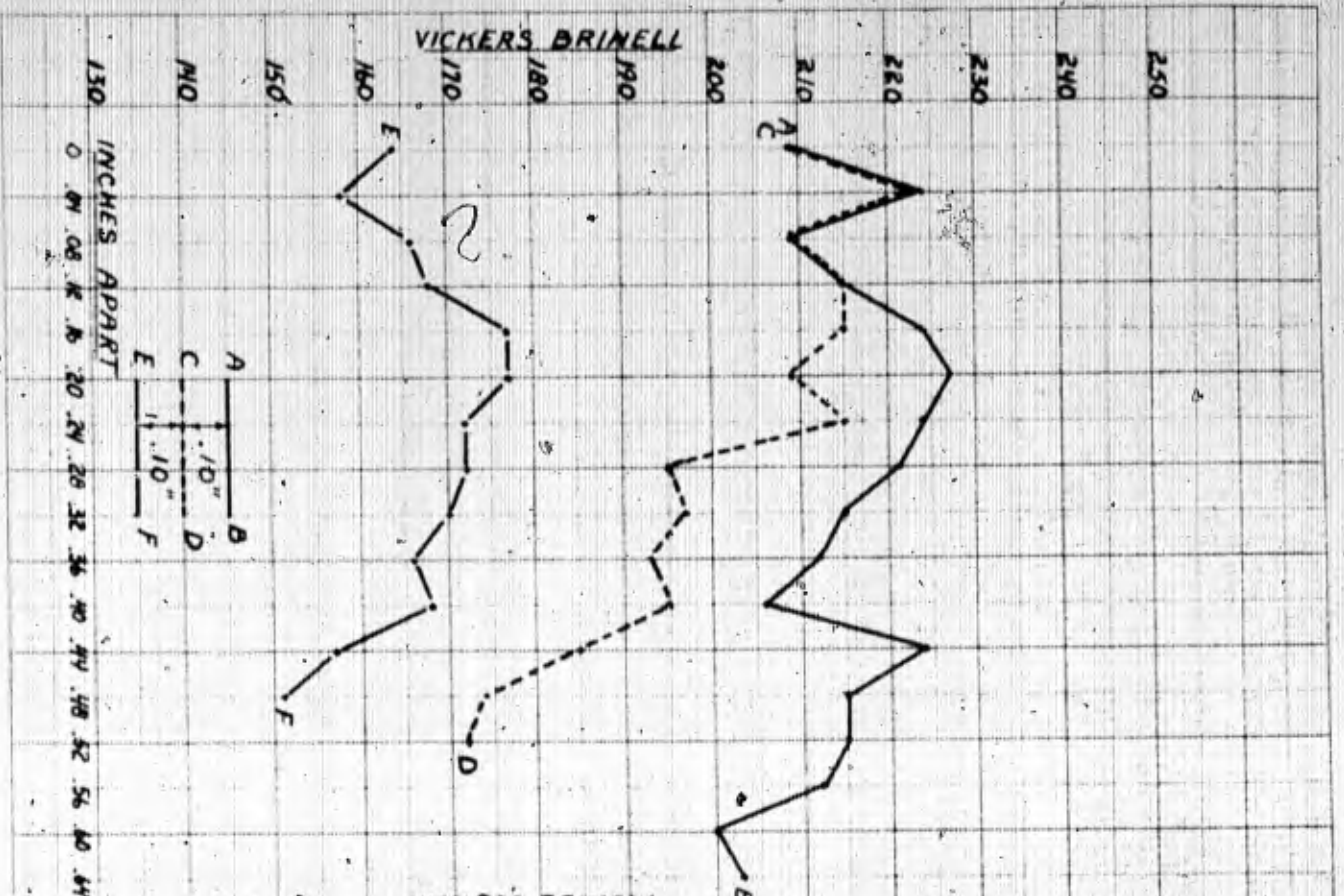
PARTIAL PENETRATION

.1500 F.S. VET.

R.H. 6/29/36



R.H. 6/29/36



RH 4/29/36

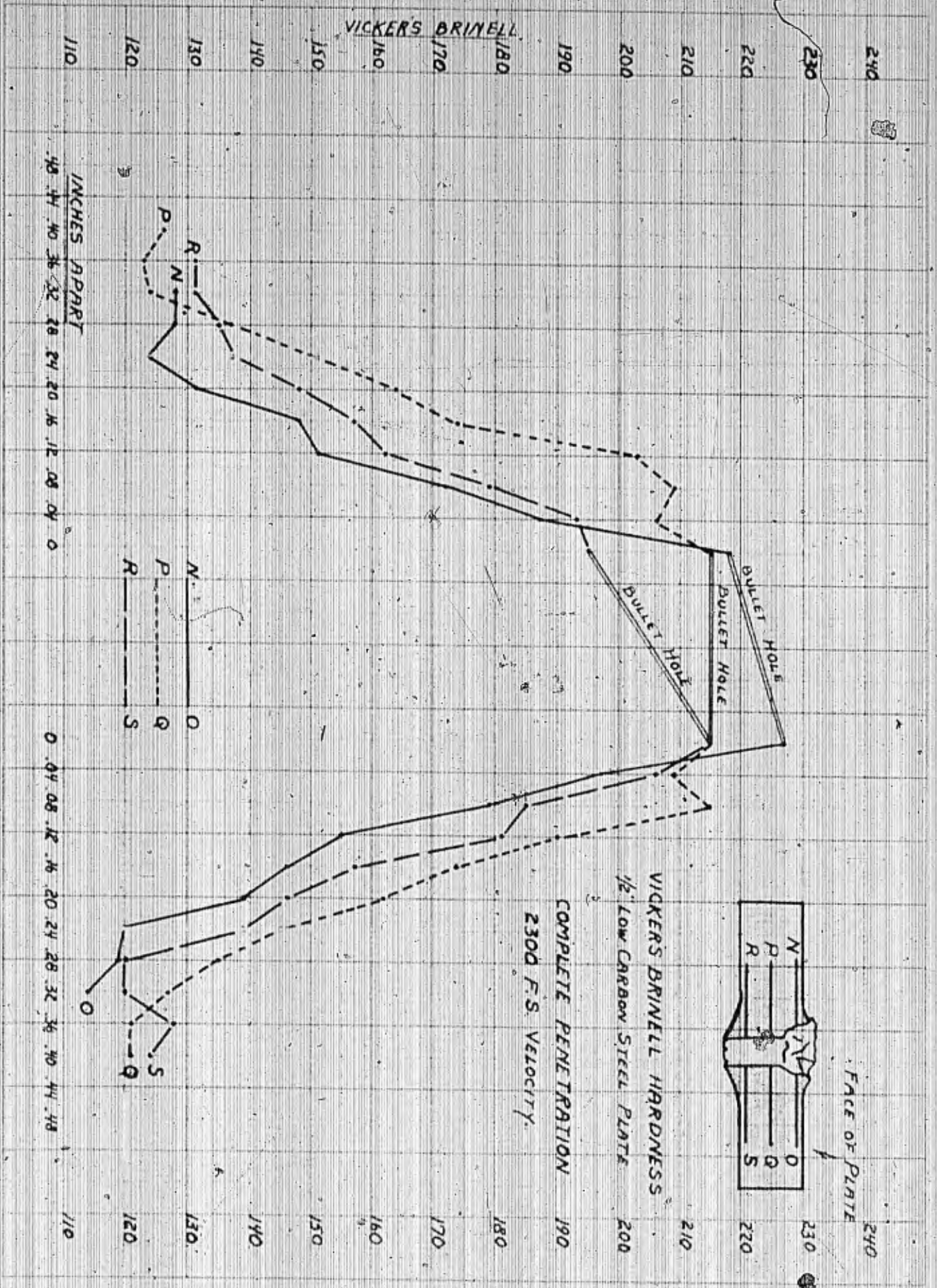


PLATE NO. WJ2

JESSOP - Homogeneous Armor Plate.

12 x 12 x $\frac{1}{2}$ ".

Actual thickness - .496"

Brinell - 555.

C	Mn	Si	S	P	Ni	Cr
.425	.66	2.01	.018	.024	3.58	0.24

Ammunition - .30 cal. 165 gr. M1922. A.P.

Range - 100 yards.

Specification - 31.

Round 3. Str. Vel. 2599 F./S. Partial Penetration.

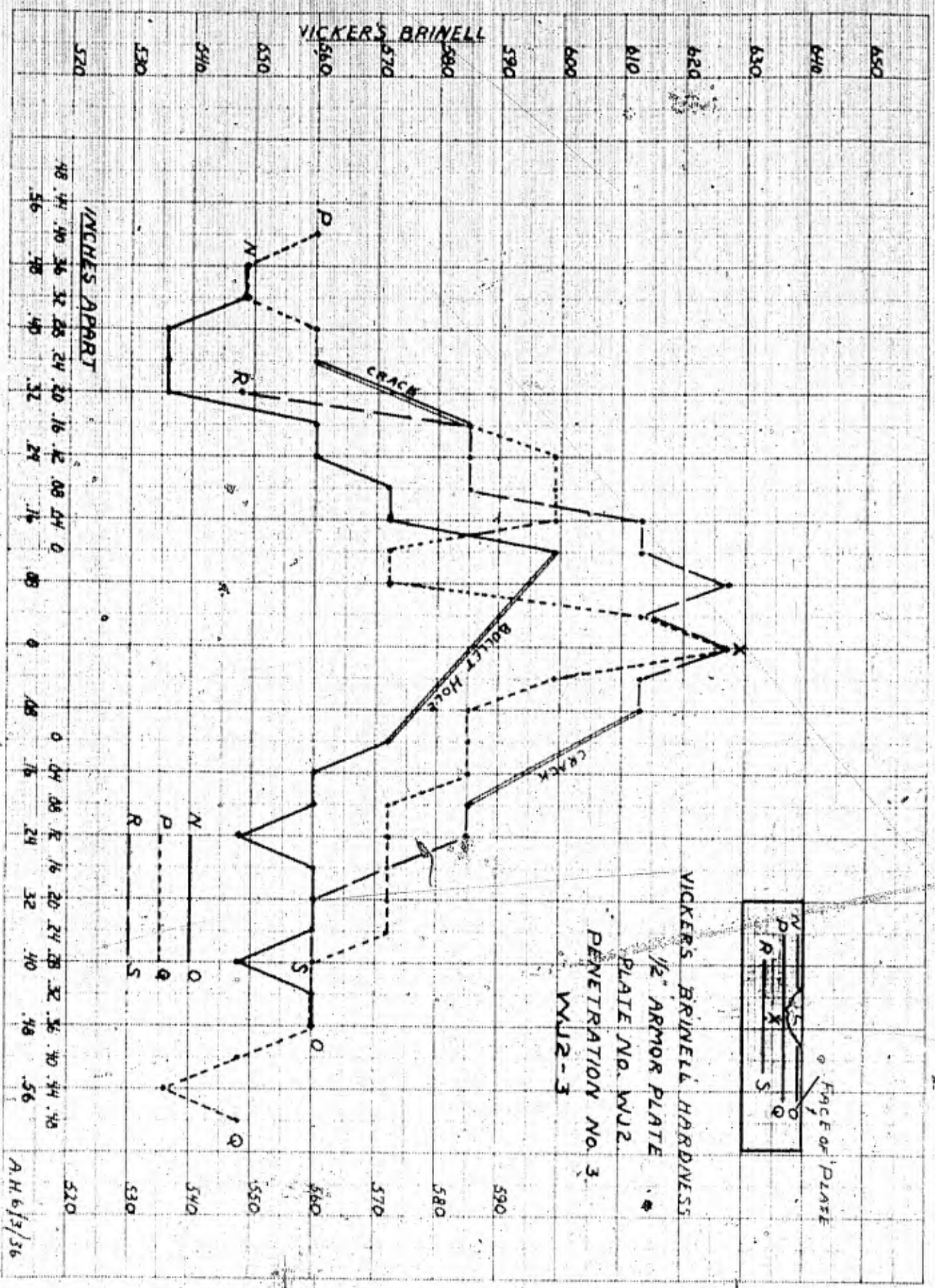
Height of Bulge on Back - .01".

Round 4. Str. Vel. 2682 F /S. Partial Penetration.

Height of Bulge on Back - .01".

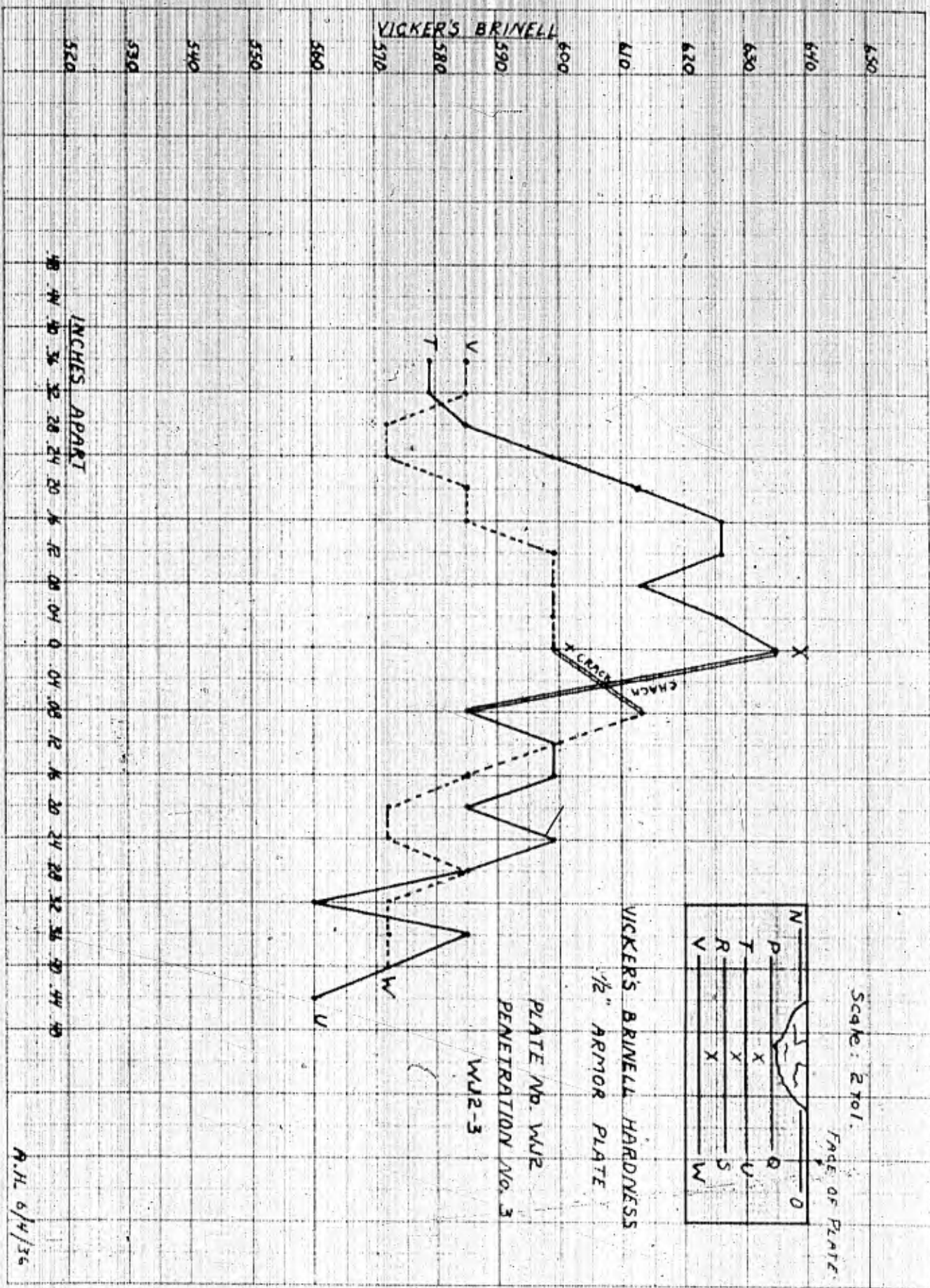
Round 9. Str. Vel. 2945 F./S. Partial Penetration.

Height of Bulge on Back - .01".



A.H. 6/3/36

VICKERS BRINELL



SCALE: 2701.

FACE OF PLATE.



VICKERS BRINELL HARDNESS

1/2" ARMOR PLATE

PLATE NO. WJ2

PENETRATION NO. 3

WJ2-3

INCHES APART

0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40

R.H. 6/4/36

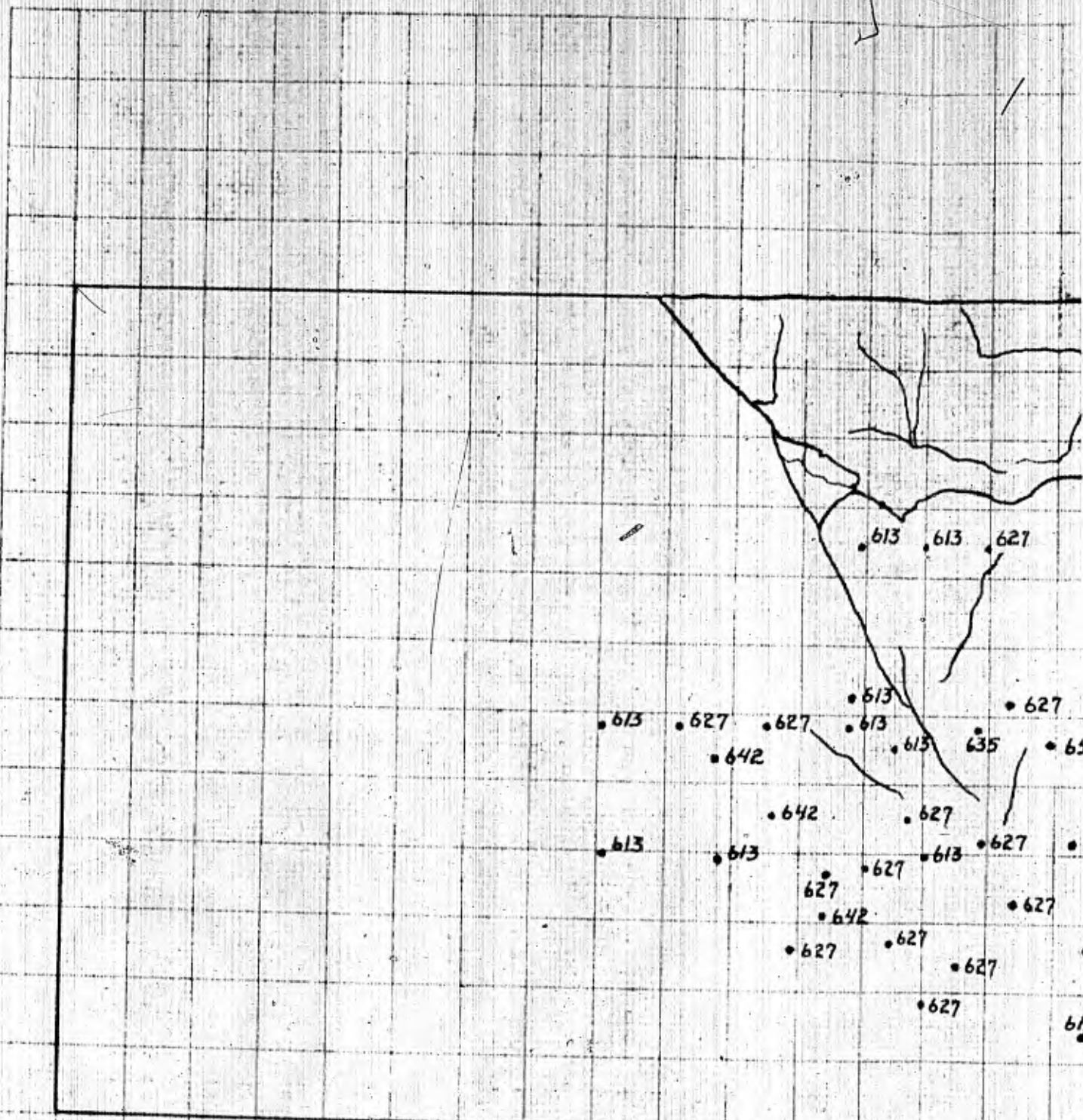
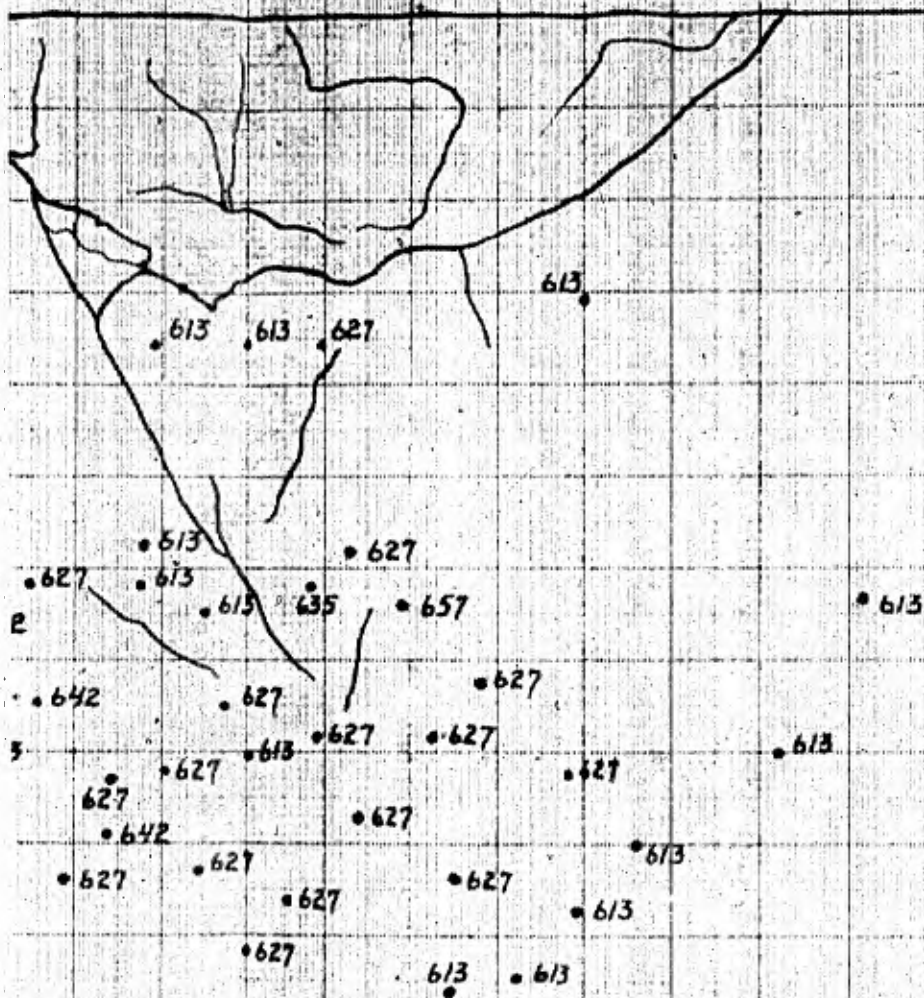


PLATE No. WJ2
PENETRATION No. 3.

SHOWING AREAS HAVING A HARDNESS IN EXCESS OF

FACE OF PLATE



SCALE: 12 TO 1.

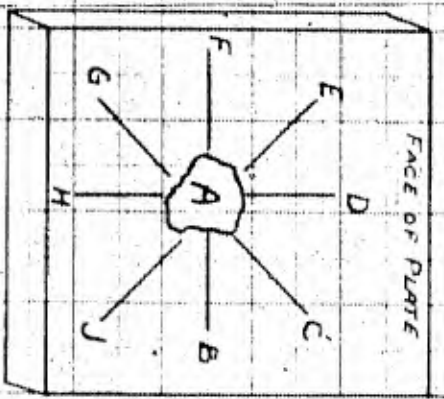
PLATE No. WJ2
PENETRATION No. 3.

AVERAGE HARDNESS OF PLATE = 570 VICKER'S

HARDNESS IN EXCESS OF 600 VICKER'S BRINELL.

A.H. 6/4/56

6/2/36 A.H.

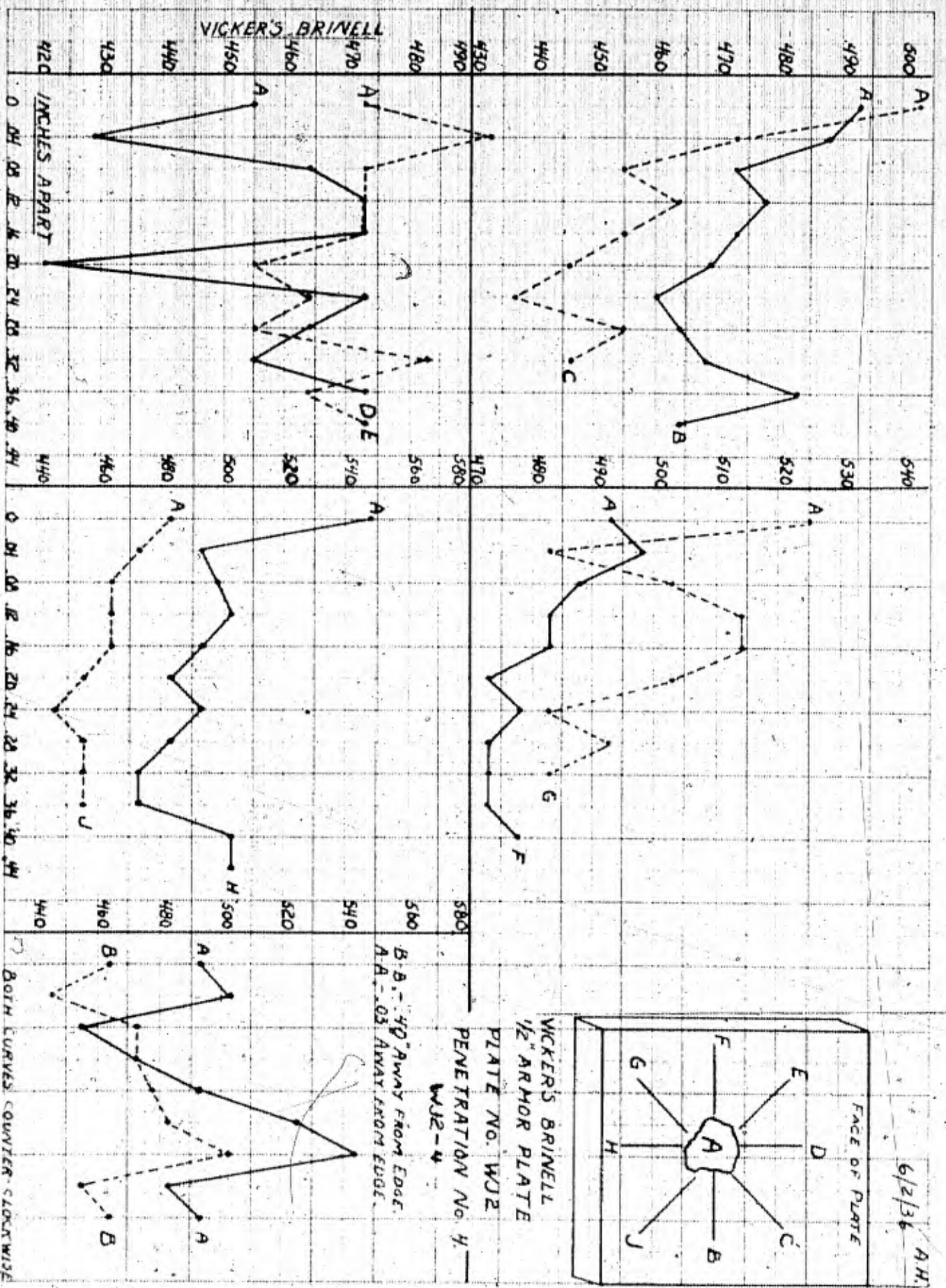


WICKERS BRINELL
1/2" ARMOR PLATE

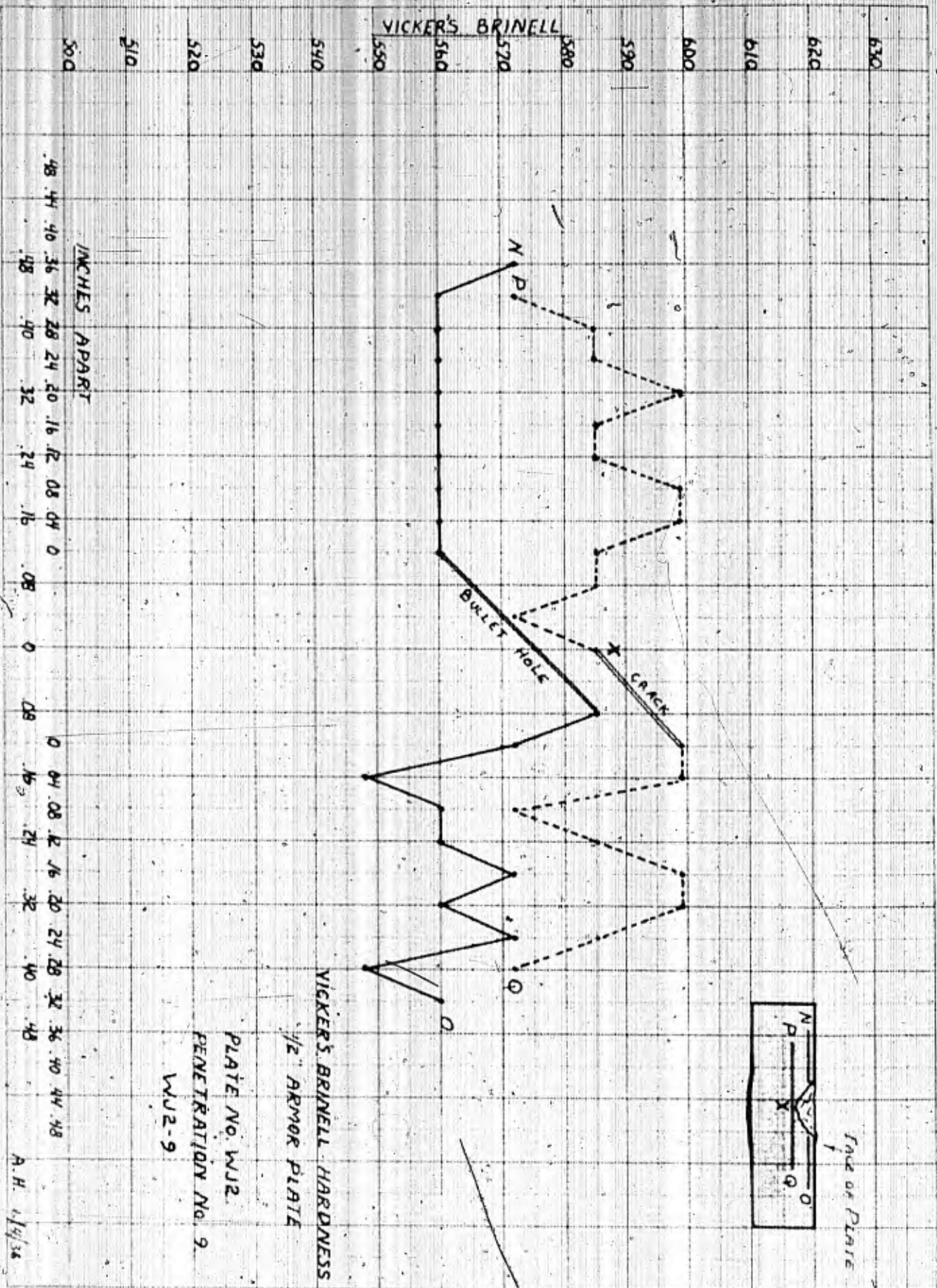
PLATE NO. WJ2
PENETRATION NO. 4

WJ2-4

B. A. - 40" AWAY FROM EDGE.
A. A. - 0.5" AWAY FROM EDGE.



BOTH CURVES COUNTER-CLOCKWISE

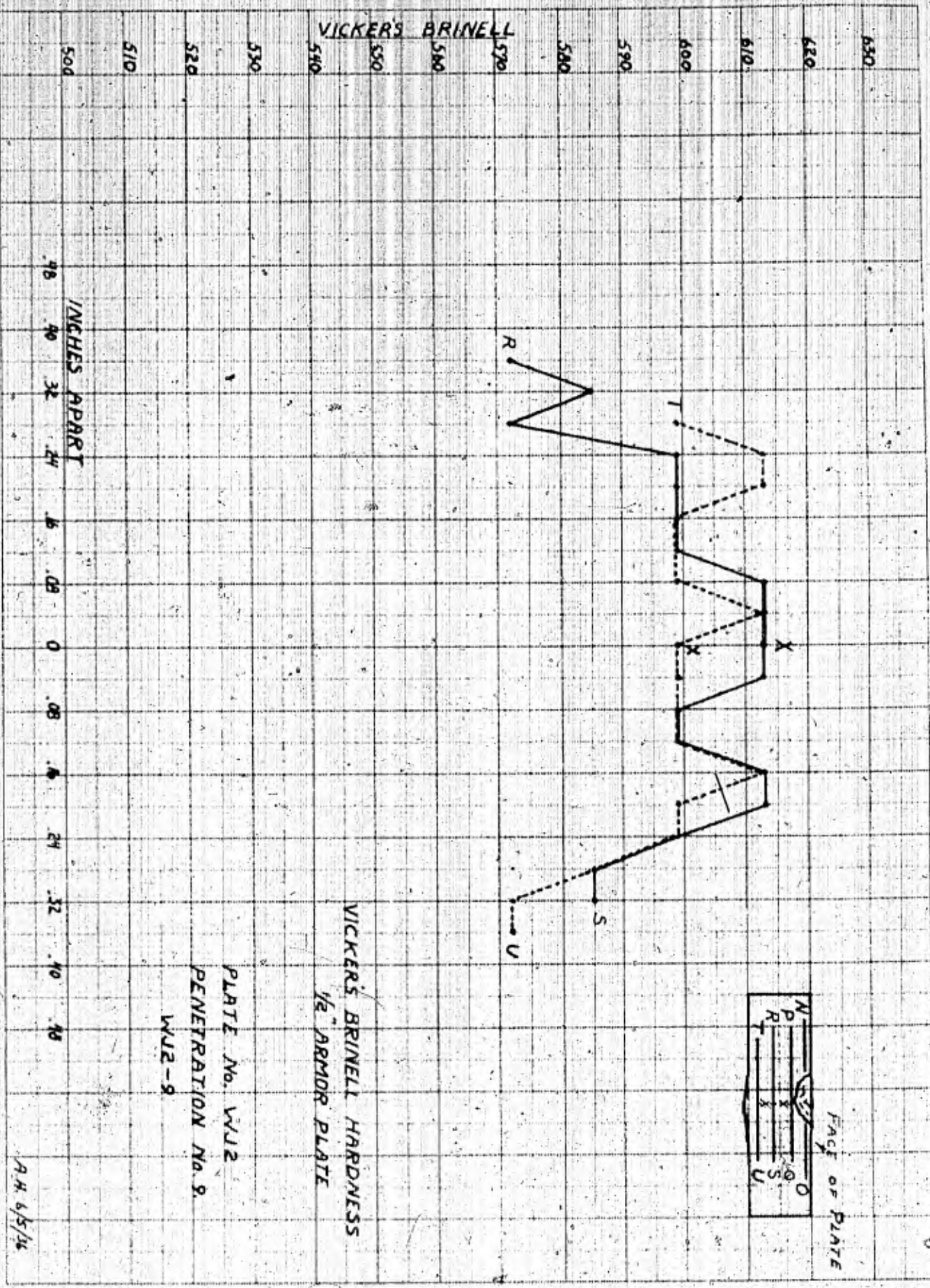


INCHES APART

48	44	40	36	32	28	24	20	16	12	08	04	0	08	0	08	0	16	08	12	16	20	24	28	32	36	40	44	48
----	----	----	----	----	----	----	----	----	----	----	----	---	----	---	----	---	----	----	----	----	----	----	----	----	----	----	----	----

VICKERS BRINELL HARDNESS
 1/2" ARMOR PLATE
 PLATE No. WJ2
 PENETRATION No. 9
 WJ2-9

A.H. 1/4/34



A.H. 6/5/36

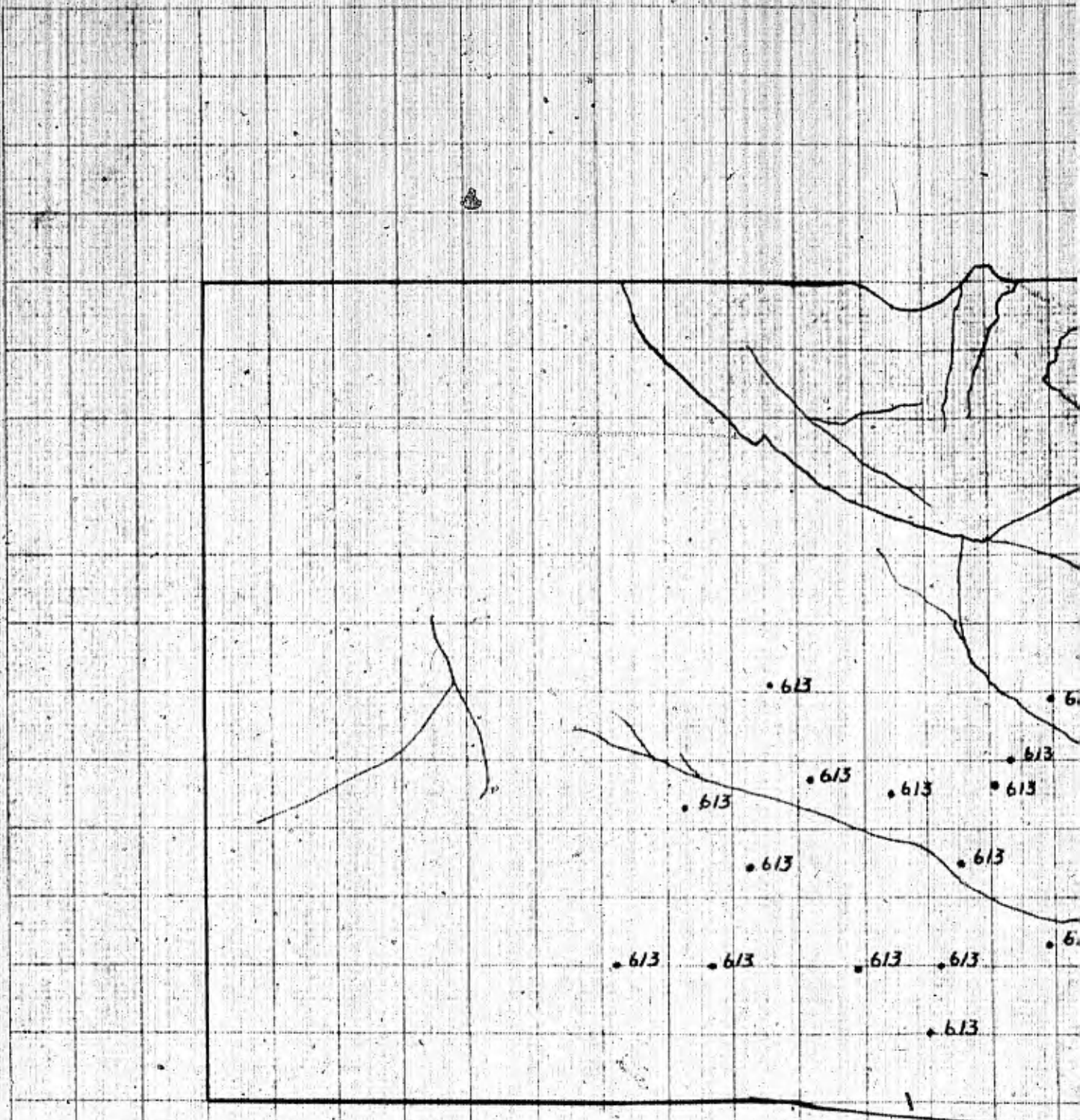
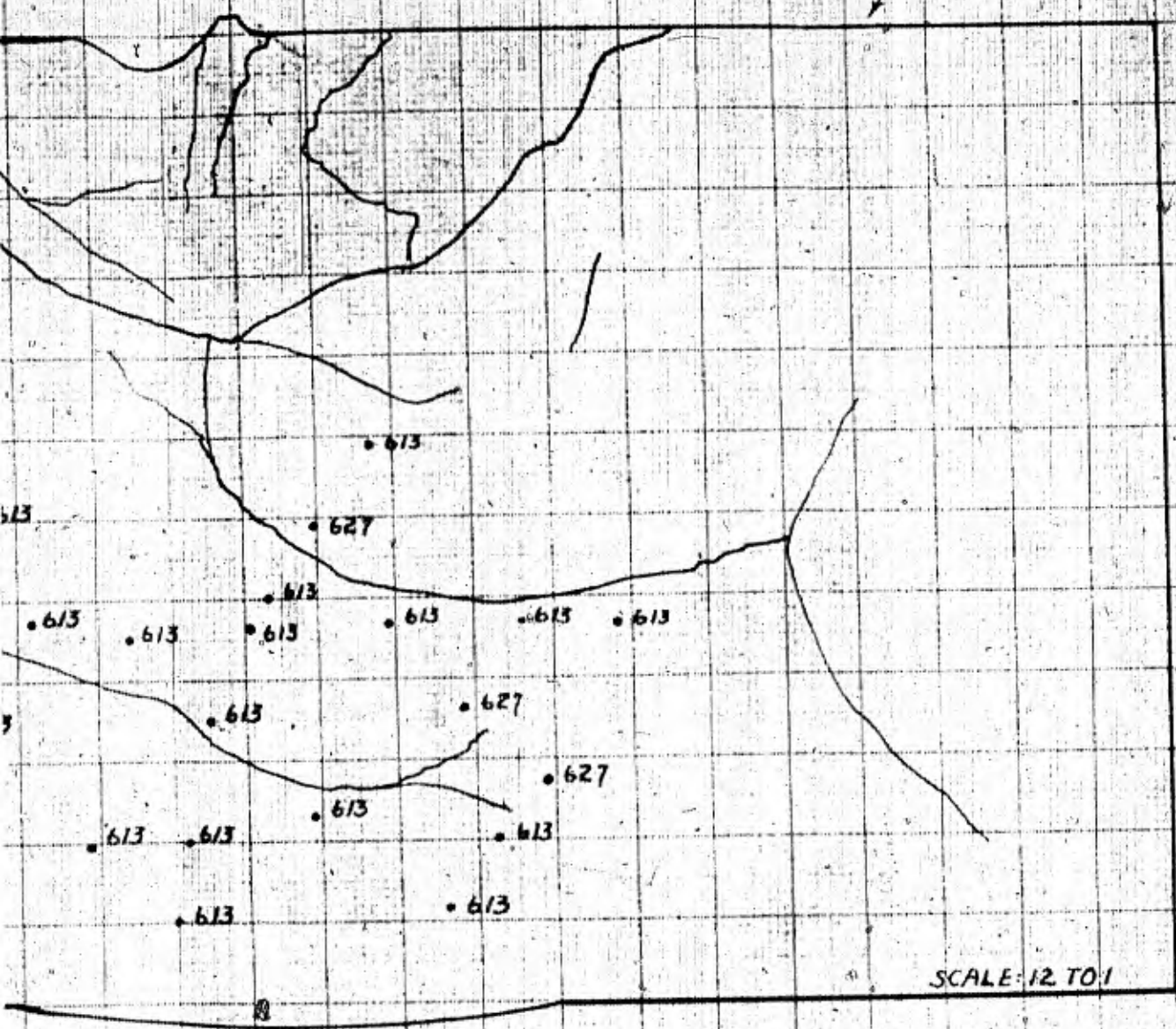


PLATE No. 1
PENETRATION

SHOWING AREAS HAVING A HARDNESS IN EXCESS

FACE OF PLATE



SCALE: 12 TO 1

PLATE No. WJ2
PENETRATION No. 9

AVERAGE HARDNESS OF PLATE = 570 VICKER'S

HARDNESS IN EXCESS OF 600 VICKER'S BRINELL

A.H. 6/5/36

CASTING NO. A.

Carburetor Cover

WATERTOWN ARSENAL Casting.

21 $\frac{1}{2}$ x 15 x $\frac{1}{2}$ "

Brinell - 418.

<u>C</u>	<u>Mn</u>	<u>Si</u>	<u>S</u>	<u>P</u>	<u>Cr</u>	<u>Mo</u>	<u>Va</u>
.19	.54	.165	.018	.010	1.13	.82	.21

Ammunition - .30 cal. 165 gr. M1922 A.P.

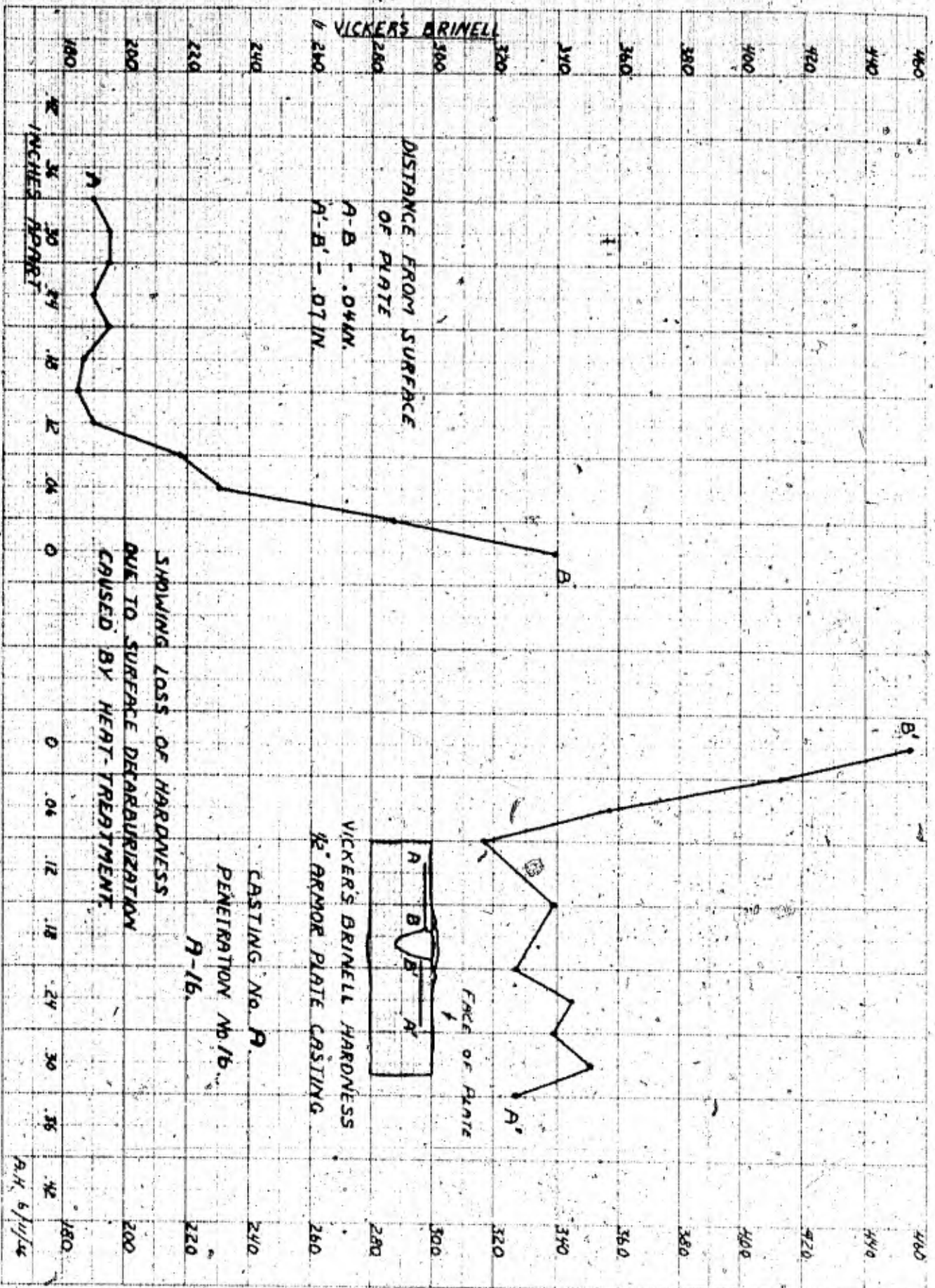
Range - 100 yards.

Specification - AXS - 54. Rev. 2.

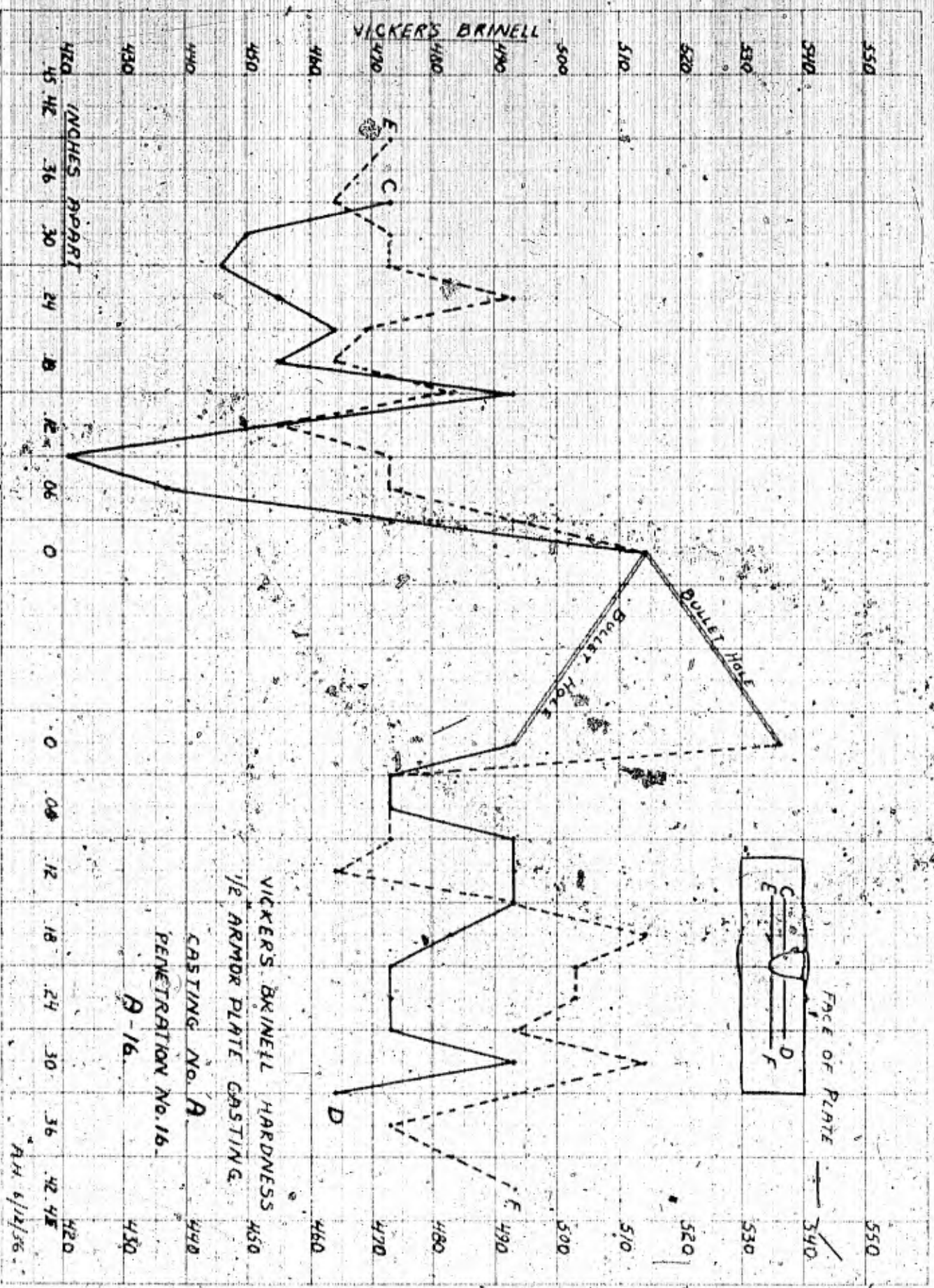
Round 16. Str. Vel. 1571 f/s. Partial Penetration.

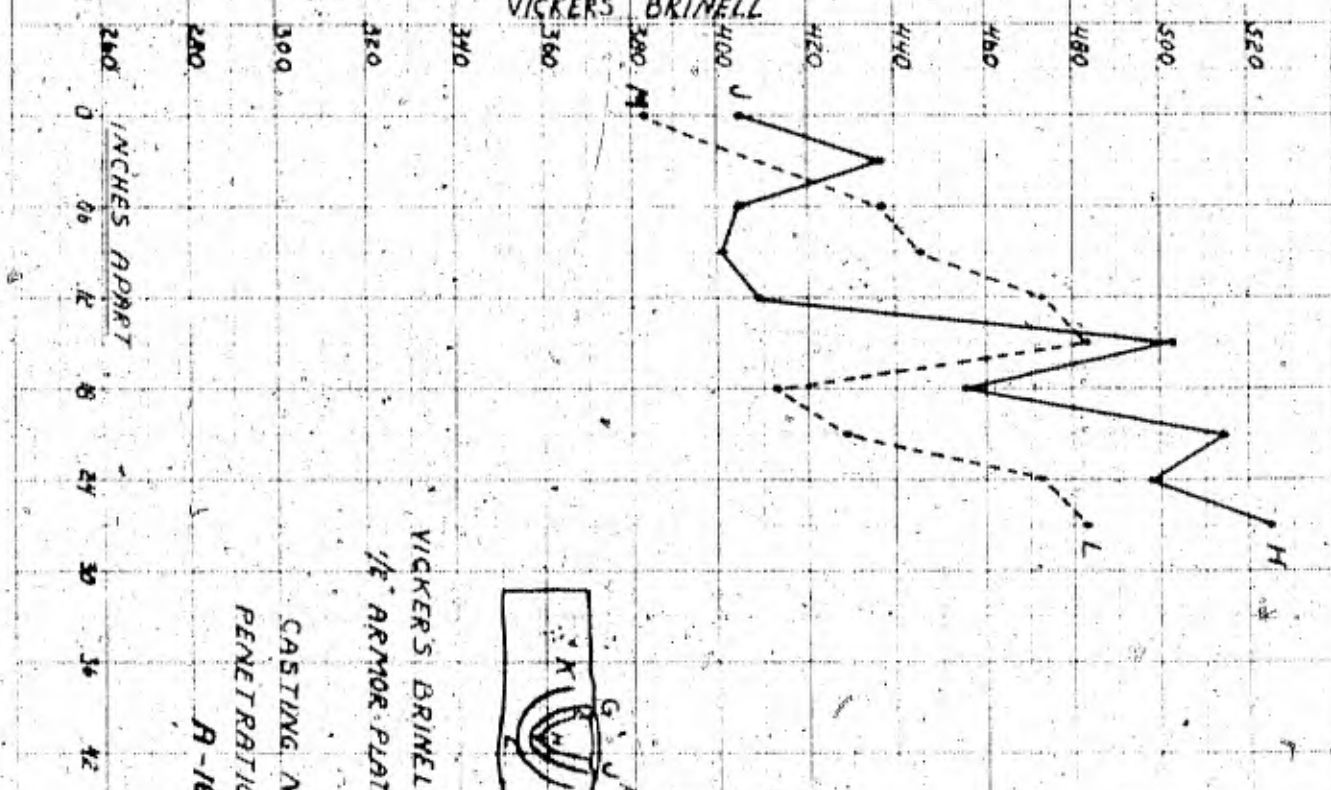
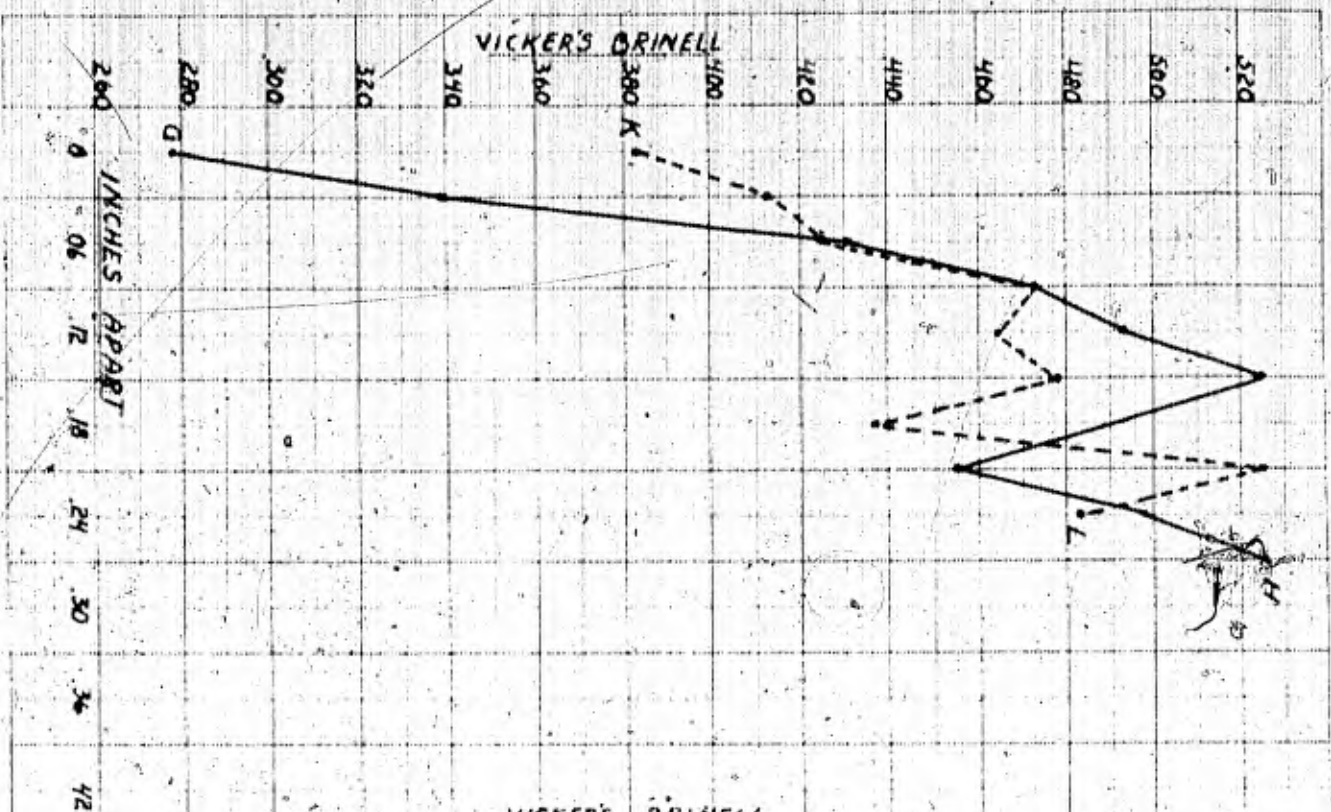
Height of Bulge on Back - .02".

Depth of Penetration - .46".



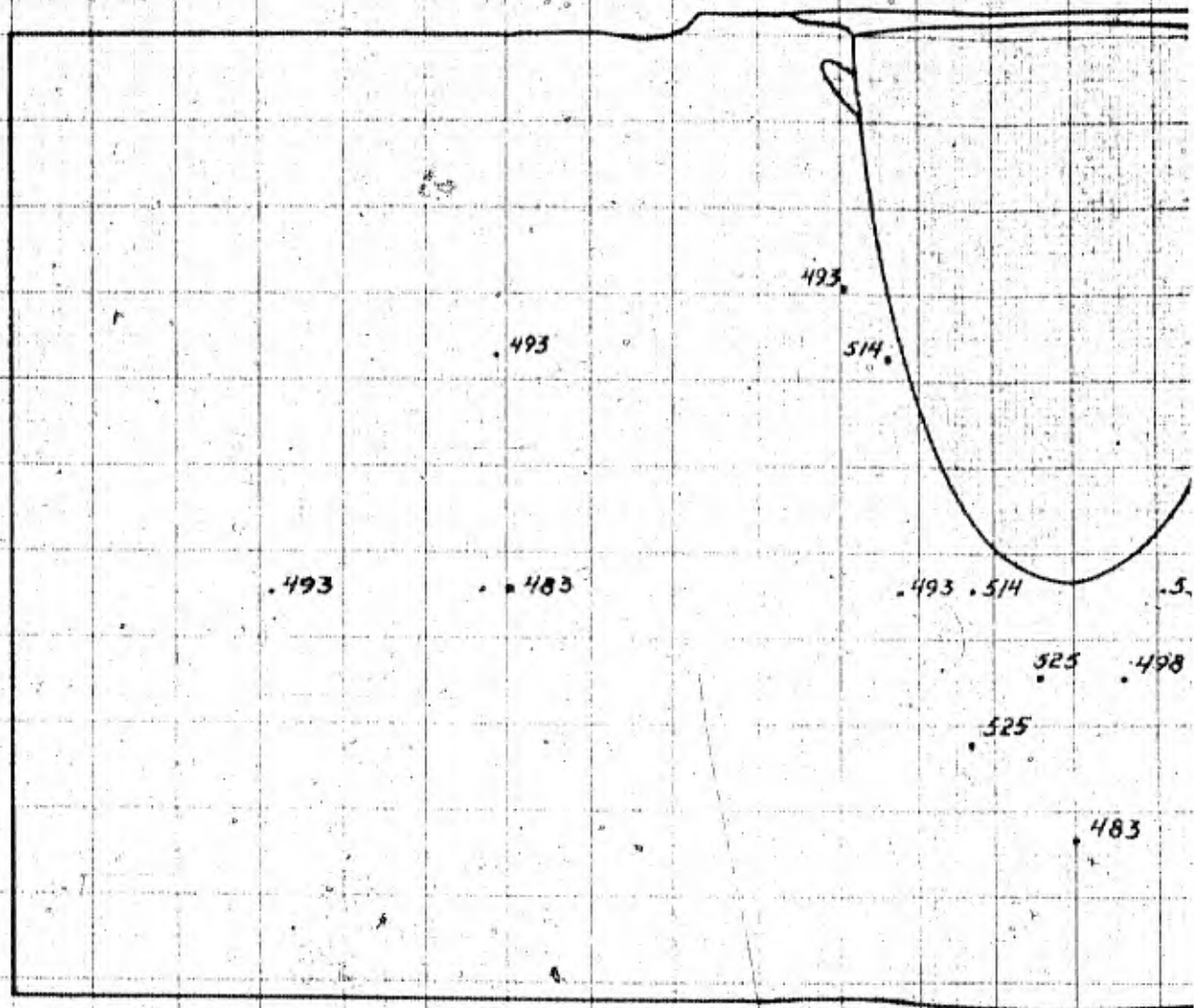
A.H. 6/19/44





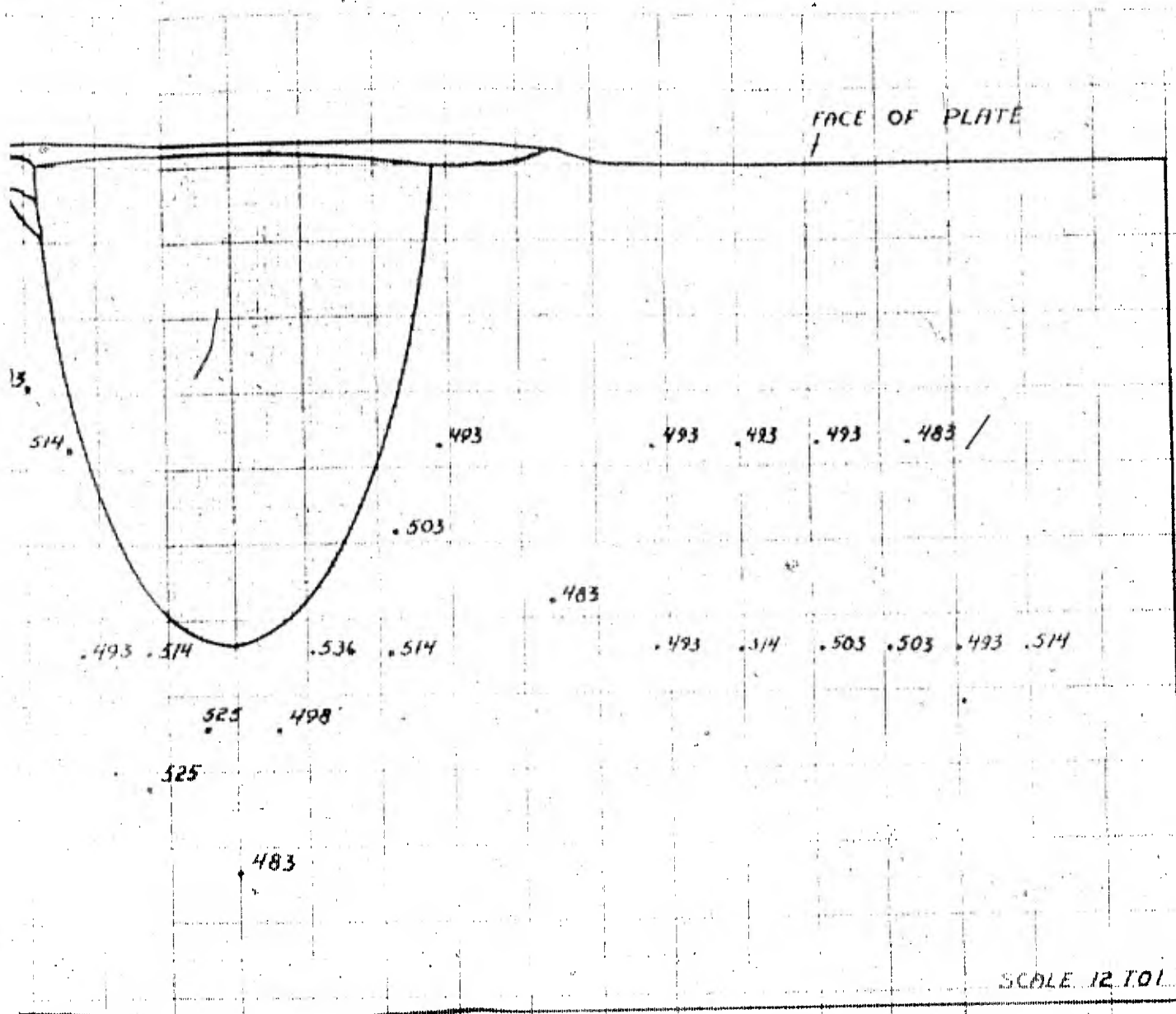
VICKER'S BRINELL HARDNESS
 1/8" ARMOR PLATE CASTING
 CASTING No. A
 PENETRATION No. 16
 R-16

AM 6/15/36



CASTING No. A.
PENETRATION No. 16
A-16

SHOWING AREAS HAVING A HARDNESS IN EXCESS OF



ASTING No. A.
 ETRATION No. 16
 9-16

AVERAGE HARDNESS OF PLATE 470 VICKER'S

LESS IN EXCESS OF 480 VICKER'S BRINELL

A.H. 4/15/36