AD-781 841

INVESTIGATION OF THE HOOD EFFECT OF THE 6" COMM. MK. 27-7 PROJECTILE AT VARIOUS OBLIQUITIES

A. V. Hershey

Naval Proving Ground
Dahlgren, Virginia

21 April 1947

NAVAL PROVING GROUND
DAHLGREEN, VIRGINIA

EXPERIMENTAL DEPARTMENT MEMORANDUM

No. 1238-47

INVESTIGATION OF THE HOOD EFFECT OF THE 6" COMM. MK. 27-7 PROJECTILE AT VARIOUS OBLIQUITIES.

Authorized in
BuOrd letter NP9/A9(Re3)
dated 9 January 1943.

Prepared: A V Hershey
A. V. Hershey
Senior Physicist

Downgraded. [illegible]
at 31 Dec [illegible]

Submitted: R H Lyddane
R. H. Lyddane
Senior Physicist

APPROVED: ____________
F. C. BRYSON
Captain, U.S. Navy
Experimental Officer

[redacted]

21 April 1947.

18

Subject: Investigation of the Hood Effect of the 6" Comm. Mk. 27-7 Projectile at Various Obliquities.

Reference: (a) Armor Officer's Memo to Experimental Officer (undated).

Enclosures: (A) NPG Photos. No. NP9 34054, 34055, 35059, 35060, 35061, 35062, 35057, 35058, 34056, 34290.
(B) Summary of Plate Penetration Coefficients.
(C) Schematic Diagram of Apparatus for Shock Loading of Tensile Specimens.

1. Reference (a) reports the results of tests at the Plate Fuze Battery which were conducted to obtain a comparison between plate ballistic limits using 6" Comm. Mk. 27-7 projectiles, in the standard condition and also with the windshield and hood removed, versus STS and Class B armor plates at various obliquities. The conditions and results of test are summarized in the NPG Photos. of Enclosure (A), and a summary of plate penetration coefficients is given in Enclosure (B).

2. One projectile in the subject tests was fired at 0° obliquity versus a plate of STS with an arrangement for capturing the fragments of the hood and windshield. The arrangement is shown in the photos. of Enclosure (A). The parts consisted of a nine foot armor tube, an eighteen inch culvert pipe, and two cover plates with round holes large enough to admit the culvert pipe. The annular space between the culvert pipe and the armor tube was filled with sawdust, the annular space was covered, and the assembled apparatus was placed against the target plate. The projectile traveled a distance of 16 feet down the culvert pipe to the point of impact.

The fragments were recovered without evidence of any secondary damage. The windshield and the crown of the hood were splintered into many small pieces, but the skirt of the hood was recovered in three equal pieces. The crown of the hood appeared to have fractured by shear after severe plastic deformation, as illustrated by lamellar blocks of the metal which have slipped over each other without becoming separated. The skirt of the hood experienced several brittle fractures on planes normal to the prevailing axis of tension in the region free from severe cold work, but each normal fracture shifted to the shear type of fracture when it ran into the severely worked region. Three of these brittle fractures were initiated by three minute punched indentations on the shoulder of the hood, but a fourth crack was also observed which did not originate from any obvious imperfection. The fourth crack did not pass into the plastically deformed region, as revealed by microsections of the recovered fragment. The fourth crack probably failed to reach completion because of a release of stress by the prior completion of the other three fractures. Measurements of the fragments show that the reduction of area at the brittle fractures was not more than 2%, whereas the material of the hood would undergo a reduction of area of more than 65% in a standard tensile test. The full elongation was, in fact, obtained in the region of severe plastic deformation.

3. Two hypotheses have been considered which might explain this anomalous behavior.

The stress in a dynamic deformation is known to be greater than the stress in a static deformation, and mild steel, such as the material of the hood, is known to have an upper yield point. If, therefore, the upper yield point were able to reach the fracture stress during a rapid loading of the metal, then the fracture would be brittle.

To test this hypothesis, apparatus was constructed at the Light Armor Battery. The apparatus consisted of a gate, which was made of BP3 plate 1" thick by 7" high by 18" wide. The gate was pivoted at one side where it bore against a gate post. The gate and gate post at the other side were notched to receive a special tensile specimen 3/8" diameter by 3.5" gage length. A shield was mounted over the specimen to protect it from fragments. Clearance was arranged between the head of the tensile specimen and the gate, so that the gate would have time to pick up speed before impact on the specimen. The specimen was carefully aligned with the face of the gate, so that the impact between gate and specimen would be as sudden as possible.

The first specimen was machined from a 37mm T21 mild steel projectile. Another 37mm T21 projectile was fired at the center of the gate with a striking velocity of the order of 700 (ft.)/(sec.). The specimen was necked down and not broken.

The second specimen was machined from a piece of annealed mild steel bar stock with a BHN of 120. A 37mm T21 projectile was fired at the gate with a striking velocity of the order of 1800 (ft.)/(sec.). The gate was broken in half at the point of impact, and the projectile was demolished from the nose to the rotating band. The gate was also broken at the point where it came into contact with the head of the specimen. The specimen itself was necked down to fracture with the full reduction of area in a static tensile test.

Although the gate was a casualty in the above test, it is nevertheless possible to estimate the minimum velocity with which the gate must have struck the head of the specimen. The work required to break the specimen can be estimated from its known tensile strength and its measured dimensions. This energy was necessarily available in the piece of gate which struck the specimen.* The specimen was elongated .9" and the work of deformation is estimated to have been 630 (ft.)(lb.). The piece of gate weighed 16 (lb.), and its velocity is therefore estimated to have been at least 80 (ft.)/(sec.). While stretching the specimen the piece of gate turned through an angle of 13°.

If the gate had remained intact, its average velocity would probably have been greater than 100 (ft.)/(sec.). The velocity at the point of contact with the specimen is uncertain by ±25 (ft.)/(sec.) because of vibrations in the plate.

If the specimen had remained elastic, a stress of 140,000 (lb.)/(in.)^2 would have been created in it at an impact velocity of 80 (ft.)/(sec.), whereas the same specimen would break at a true stress of 115,000 (lb.)/(in.)^2 during a conventional tensile test. The specimen would break at a greater stress in the absence of plastic deformation. The specimen was brought up to full loading while the gate moved at 80 (ft.)/(sec.) through a distance of less than a sixteenth of an inch. An elastic wave would have had time to make three transverses of the specimen in this time interval. The hood of the projectile was brought up to full loading while the projectile moved at 1000 (ft.)/(sec.) through a distance of more than an inch. The rate of loading in the tensile specimen was therefore at least as great as the rate of loading in the hood.

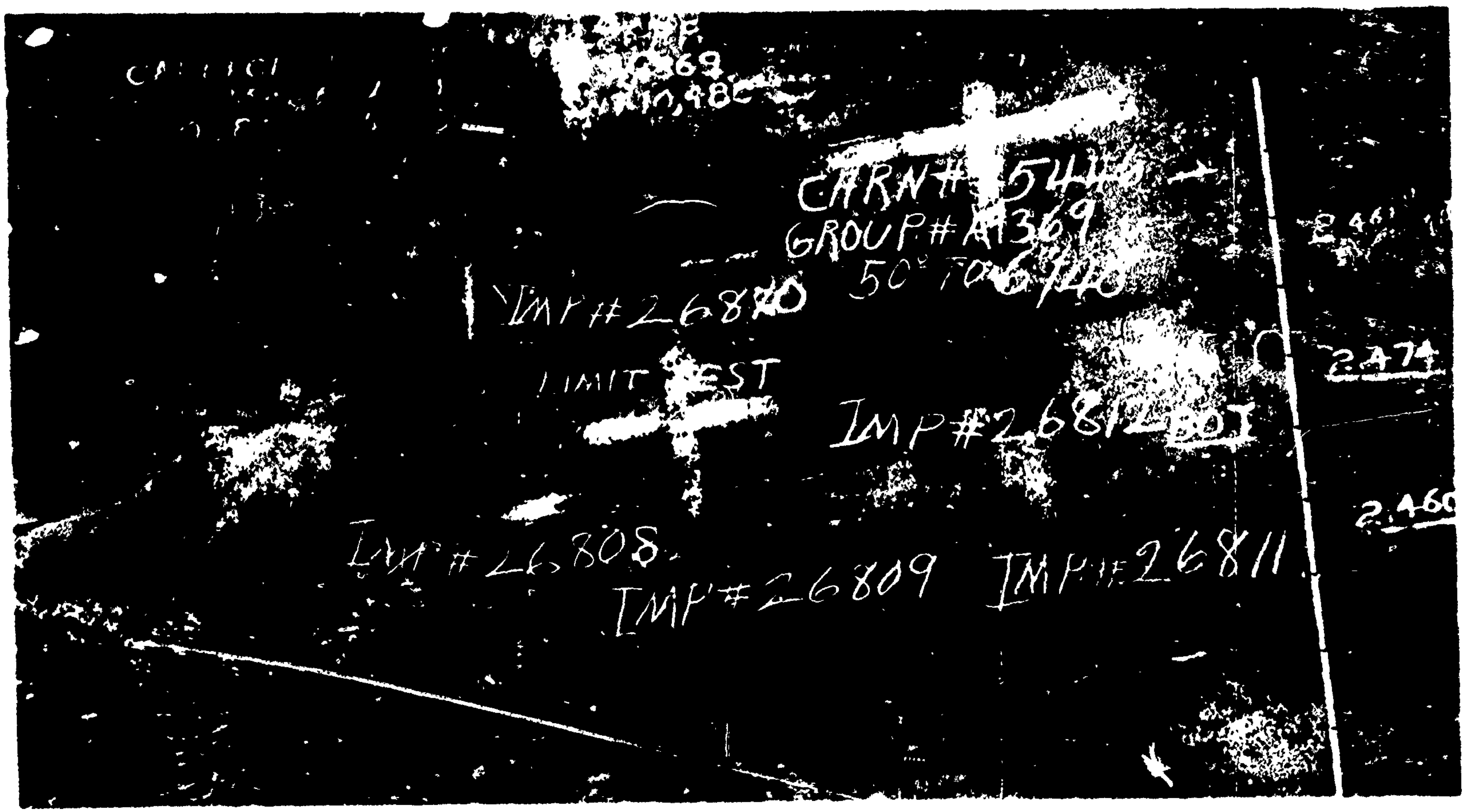
* A square plate, against which a steady force is applied at a point on a diagonal midway between the center and a corner, would expend on that force two fifths of its kinetic energy before it came to rest at the point of application of force. The plate would be turned through an angle equal to three fifths of the ratio between the displacement at the point of application of force and the distance of the point of application from the center of the plate.

4. On the basis of the results so far obtained it appears that the first hypothesis is unlikely.

According to the second hypothesis, fracture in a ductile material can only occur after a severe plastic deformation. The zone in which the plastic deformation occurs may be concentrated at the very tip of a crack where the stress is most intense, and thus be concealed from superficial measurements of strain. The concentration of plastic flow may not be stable in narrow sections where yielding may occur parallel to the edge of a possible crack. The conditions under which the zone of plastic deformation may become so concentrated are the subject of further analytical work.

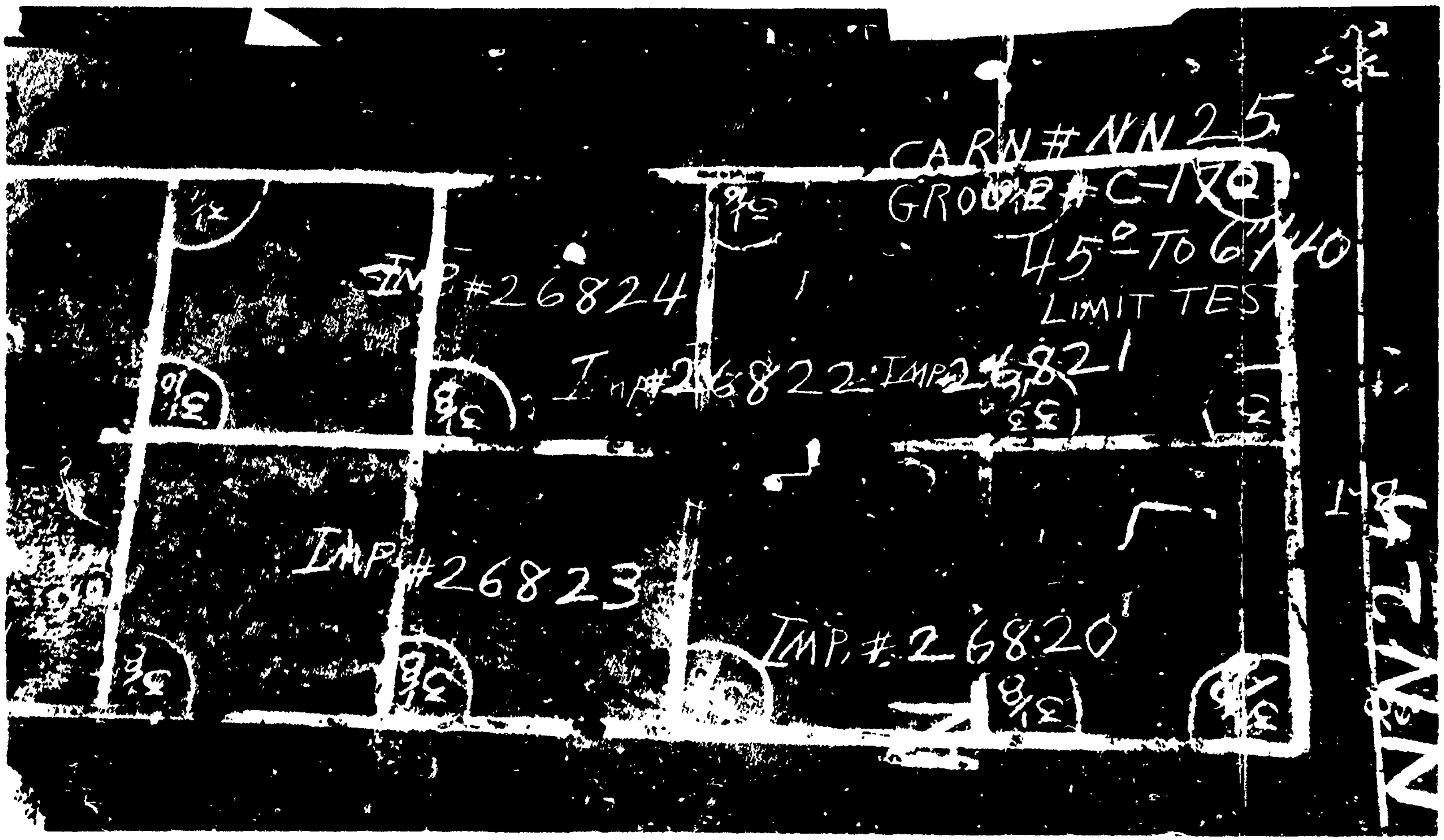
NPG 32654 - Bal. Limit Test of 2.45" STS Plate No. 75446 Mfd. by Carnegie Illinois Steel Co. vs. 5" Common Mk. 27-7 Proj. IL&P with and without [redacted] windshield and hood. View: Front of Plate.

Impact	Cbl.	S.V.	% Ck. 73341	Pene.	Thru Open	Projectile
26808	50°30'	1339	103.7	1-5/8"	None	With windshield and hood
26809	49°20'	1442	107.9	Corp.	8" x 9"	" " " "
26810	50°10'	1405	105.3	3"	9" x 1/2"	" " " "
26811	48°40'	1339	95.3	3"	6" x 3/8"	Without windshield and hood
26812	49°30'	1385	9[illegible].1	Corp.	6" x 9"	" " " "



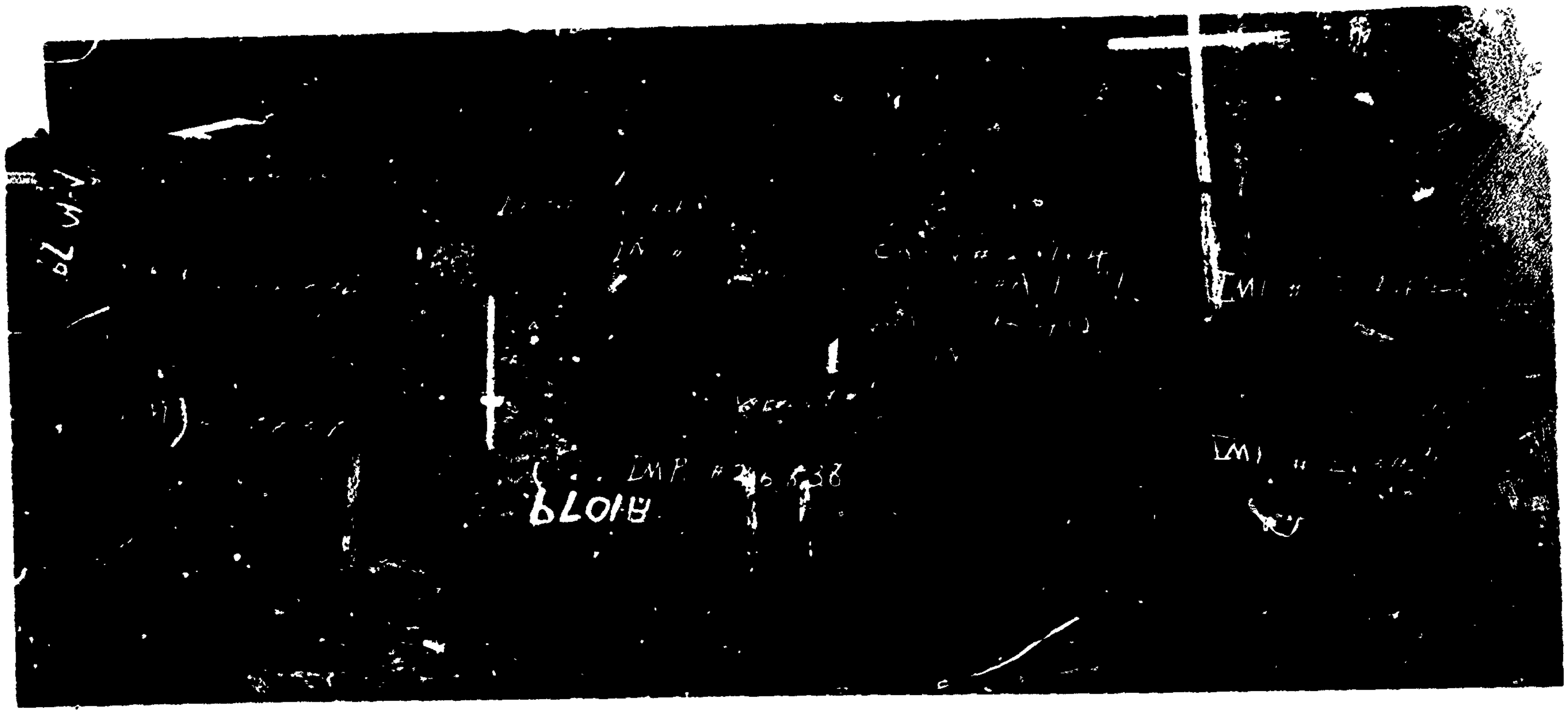
NP9 34055 - Bal. Limit Test of 3"13 STS Plate No. NN-25 Mfd. by Carnegie Illinois Steel Co. vs. 6" Common Mk. 27-7 Proj. IL&P with and without windshield and hood. View: Front of Plate. [redacted]

Impact	Obl.	S.V.	% Sk. 78841	Pene.	Thru Open	Projectile
26820	45°00'	1438	97.6	2-3/4"	None	With windshield and hood
26821	45°40'	1507	100.9	2-1/4"	None	" " " "
26822	44°30'	1543	105.7	Comp.	6" x 7"	" " " "
26823	44°20'	1413	92.3	2-1/2"	None	Without windshield and hood
26824	45°00'	[illegible]	97.4	Comp.	6" x 7"	" " " "



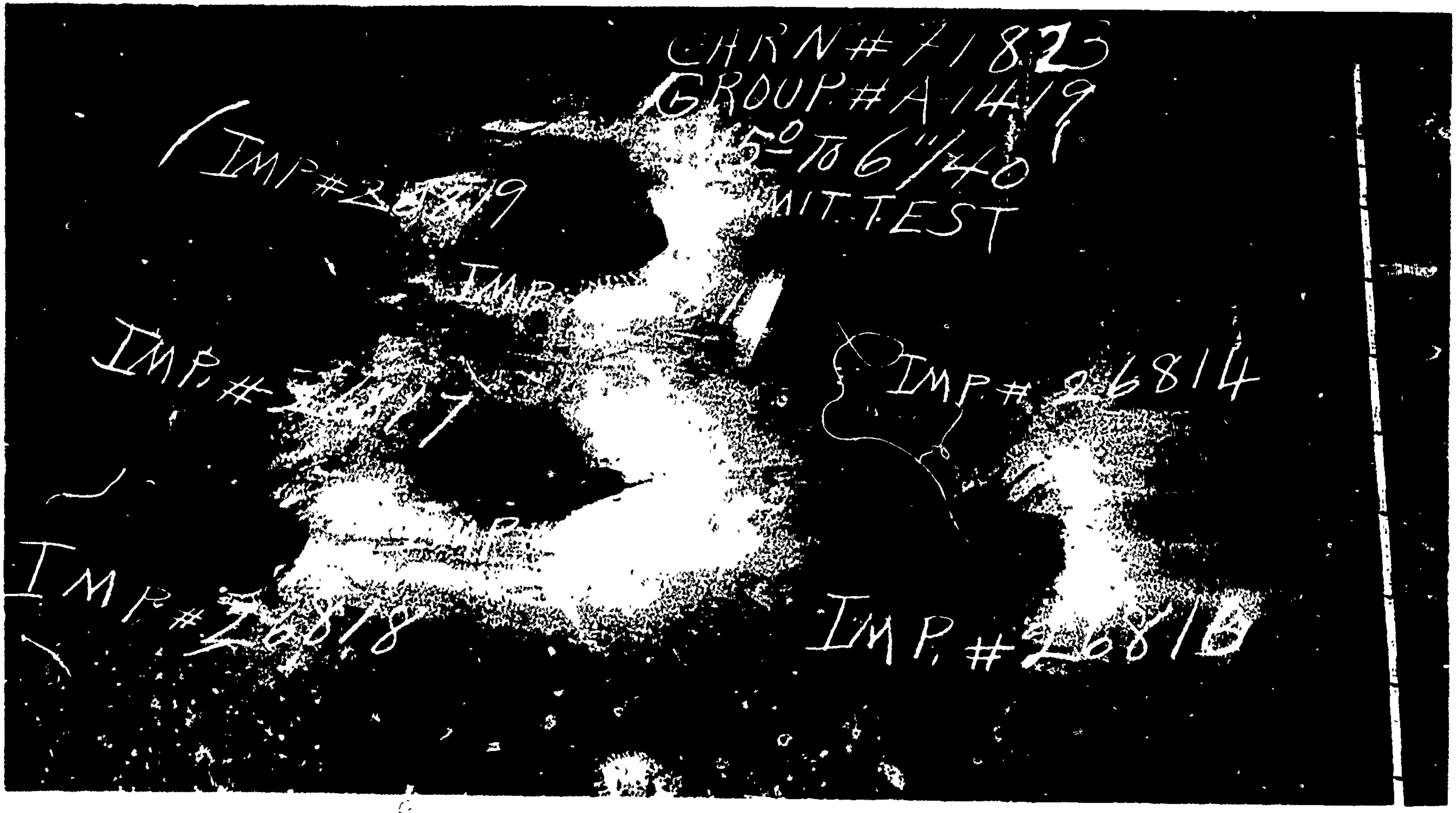
NP9 35059 - Bal. Limit Test of 0"764 STS Plate No. 23164 Mfd. by Carnegie Illinois Steel Co. vs. 6" Common Mk. 27-7 Proj. IL&P with and without [redacted] windshield and hood. View: Front of Plate.

Impact	Obl.	S.V.	% Sk. 78841	Pene.	Thru Open	Projectile
26835	60°00'	840	117.0	1"	5-1/2" x 39"	With windshield and hood
26836	60°00'	869	121.0	1"	1" x 19"	" " " "
26837	60°30'	910	126.0	Comp.	6" x 56"	" " " "
26838	60°00'	900	120.5	Comp.	6" x 10"	Without windshield and hood
26839	60°00'	860	115.1	Comp.	6" x 10"	" " " "
26840	60°00'	826	110.6	Comp.	6" x 15"	" " " "
26841	60°00'	819	109.6	Comp.	6" x 13"	" " " "
26842	60°00'	764	102.3	1-1/4"	4-1/2" x 36"	" " " "



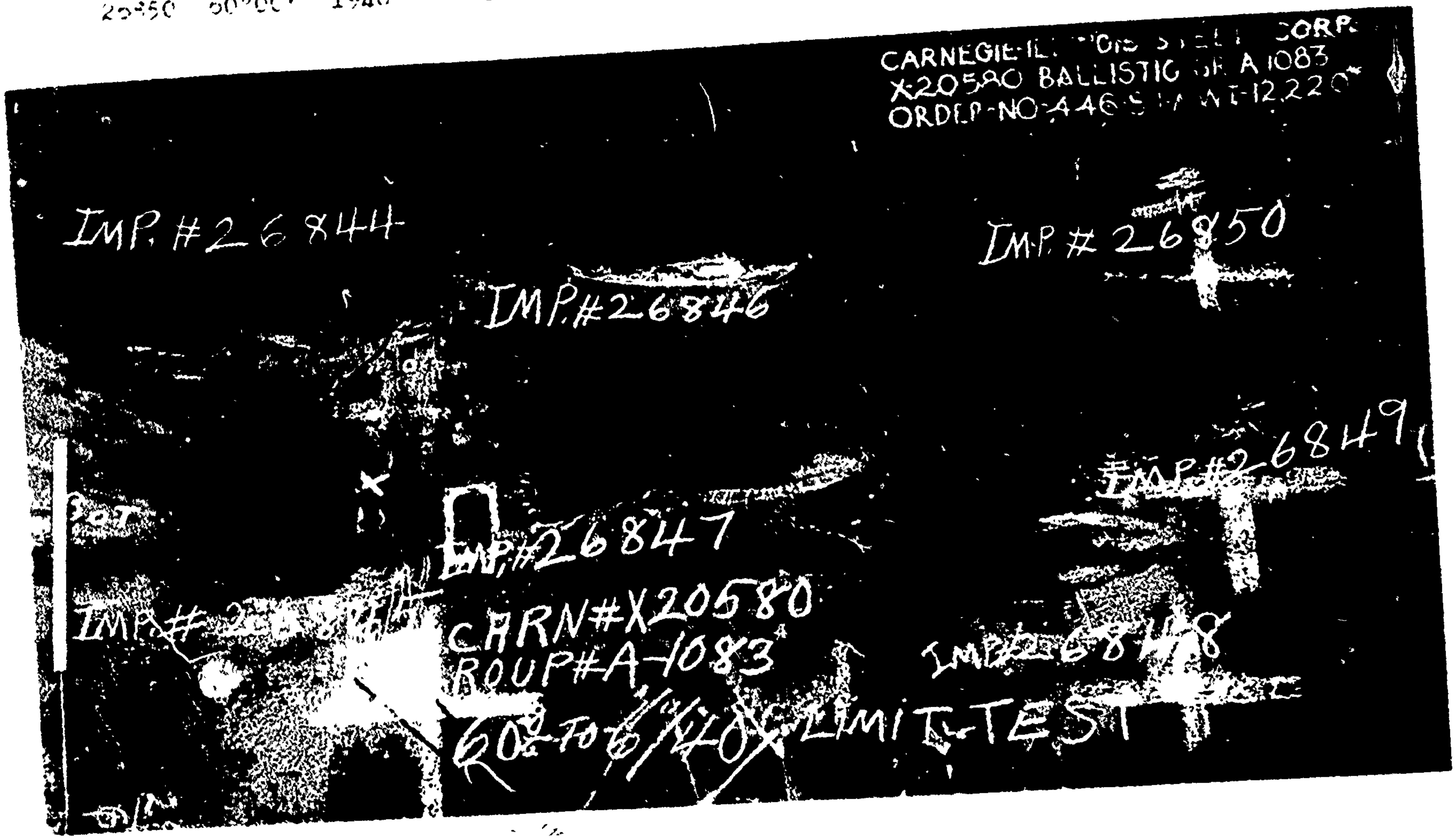
NPG 35060 - Bal. Limit of 1945 (T) Plate No. F-1323 Mfd. by Carnegie Illinois Steel Co. vs. 6" Common Mk. 27-7 Projectiles IIAP with and without windshield and hood. View: Front of Plate. [redacted]

Impact	Obl.	S.V.	% Bk. 7841	Pene.	Thru Open	Projectile
26813	45°10'	856	95.3	Comp.	6" x 7"	Without windshield and hood
26814	45°00'	733	87.4	Comp.	6" x 6-1/4"	" " " "
26815	46°00'	716	78.7	1-1/2"	1/2"x 5-1/2"	" " " "
26816	45°40'	746	82.9	3"	6-1/2"x4-1/2"	" " " "
26817	44°40'	897	109.0	Comp.	6" x 7"	With windshield and hood
26818	44°00'	854	103.8	Comp.	6" x 7"	" " " "
26819	44°00'	795	96.6	3"	3-1/2" x 8"	" " " "



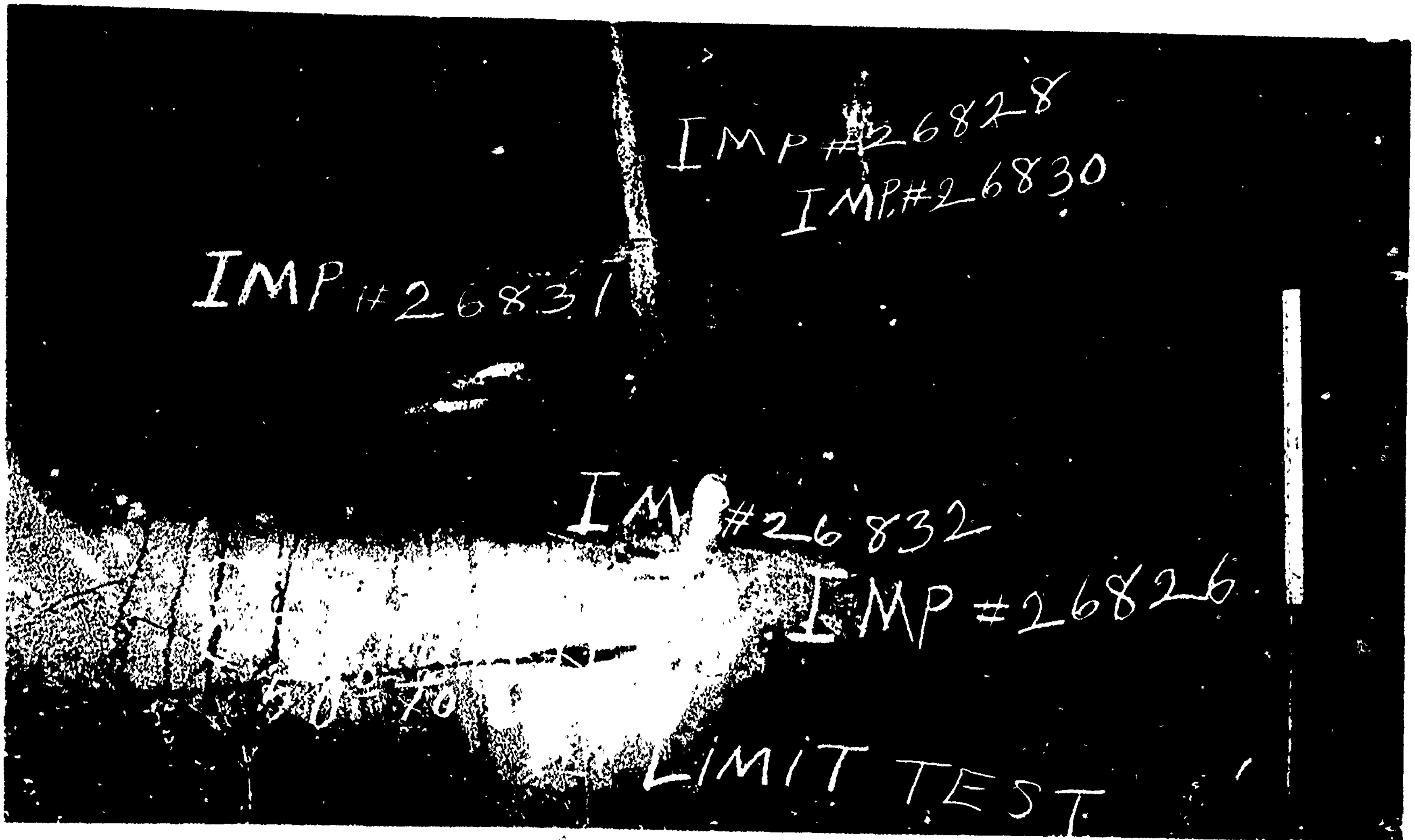
NPG 35061 - Bal. Limit Test of 1"973 STS Plate No. X20580 Mfd. by Carnegie Illinois Steel Co. vs. 6" Common Mk. 27-7 Proj. IL&P with and without wind- [redacted] shield and hood. View: Front of Plate.

Impact	Obl.	S.V.	% Ck. 78841	Pene.	Thru Open	Projectile
26844	60°00'	1779	124.6	1-3/4"	4-1/2" x 20"	With windshield and hood
26845	60°00'	1816	127.2	Comp.	6" x 17"	" " " "
26846	60°40'	1666	109.5	1-1/2"	1-1/2" x 12"	Without windshield and hood
26847	60°00'	1772	117.5	2"	7" x 26"	" " " "
26848	60°40'	1812	119.1	3"	10" x 30"	" " " "
26849	60°00'	1862	123.5	2-5/8"	8-1/2" x 28"	" " " "
26850	60°00'	1948	129.2	Comp.	6" x 9"	"



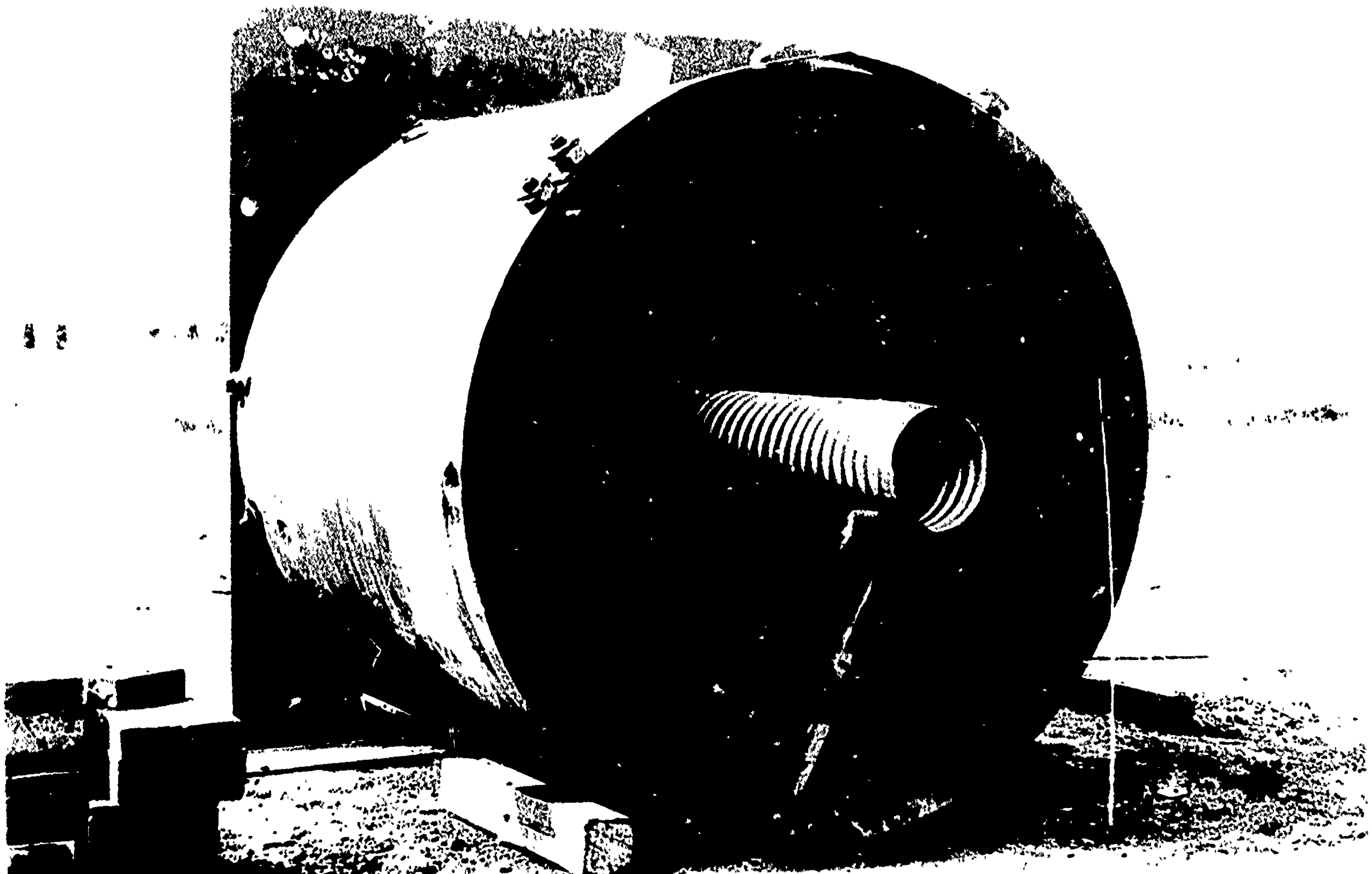
NP9 35062 - Bal. Limit Test of C797 STS Plate No. 634580 Mfd. by Carnegie Illinois Steel Co. vs. 6" Common Mk. 27-7 Proj. IL&P with and without windshield and hood. View: Front of Plate. [redacted].

Impact	Obl.	S.V.	% Sk. 78841	Pene.	Thru Open	Projectile
26826	50°50'	724	101.7	Comp.	6" x 17"	With windshield and hood
26828	51°00'	695	96.8	5/8"	None	" " " "
26830	50°00'	662	89.3	Comp.	6" x 8"	Without windshield and hood
26831	50°00'	597	80.7	1-1/4"	3/4" x 10"	" " " "
26832	51°00'	628	84.6	Comp.	6" x 11"	" " " "



[illegible] - Neg. 4[illegible]. Test of 1.[illegible]" STS Plate No. [illegible] Mfd. by Carnegie Illinois Steel Corp. vs. 3" [illegible] Mk. 27-7 Proj. [illegible], fired for recovery of fragments of the windshield and hood. View: Back of the Fragment [redacted] Recovery Tube.

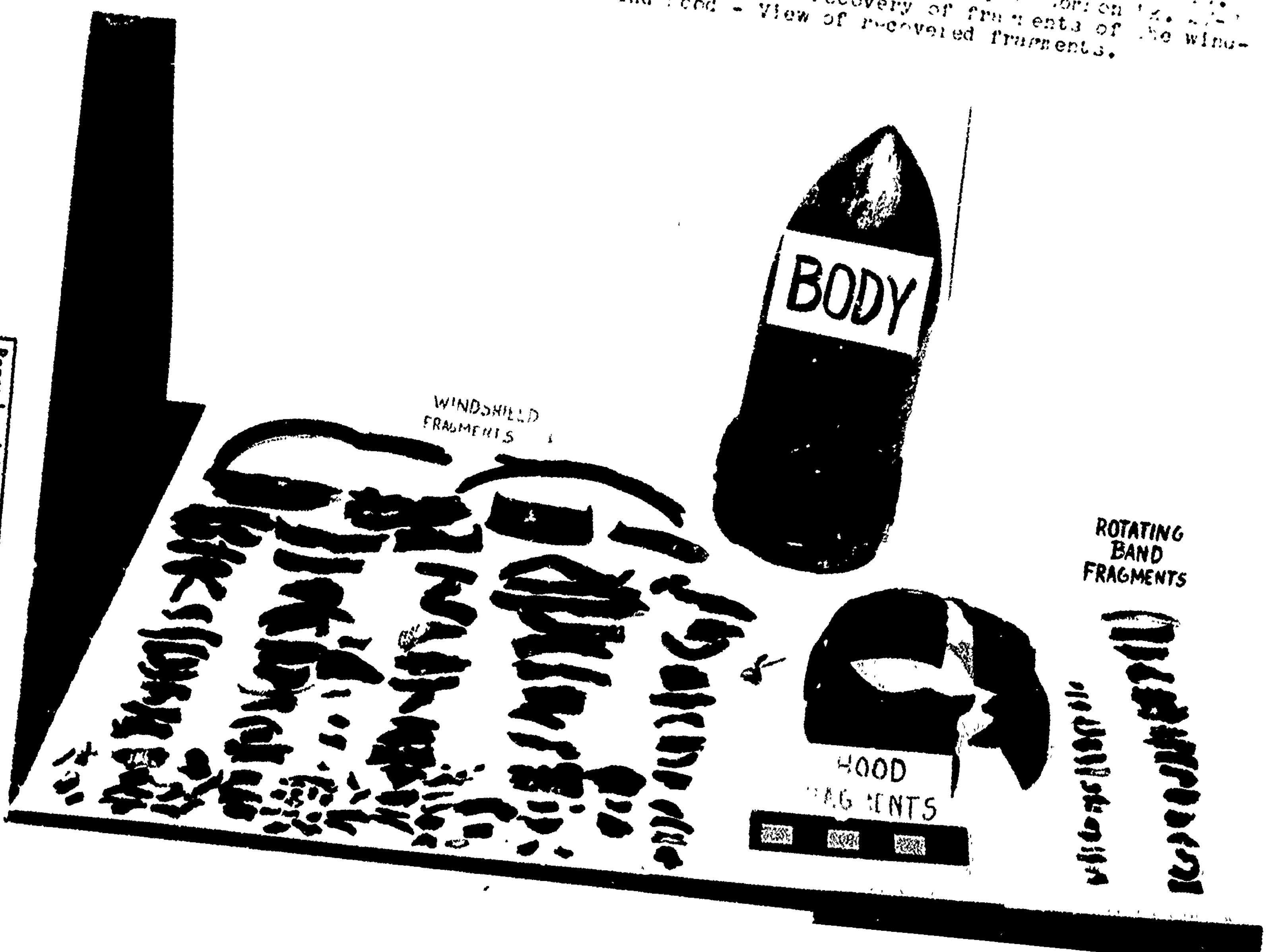
NPG 35658 - Bal. Exp. Test of 1.908 STS Plate No. 98503 Mfd. by Carnegie Illinois Steel Corp. vs. 6" Common Mk. 27-7 Proj. IL&P fired for recovery of fragments of the windshield and hood. View: Front of fragment recovery tube with cover plate removed to show concentric arrangement of culvert pipe and armor tube. [redacted]



NP9 34056 - Bal. Exp. Test of 1.908 STS Plate No. 98503 Mfd. by Carnegie Illinois Steel Corp. vs. 6" Common Mk. 27-7 Proj. IL&P fired for recovery of fragments of the windshield and hood. View: Front of Plate. [redacted]

Impact	Obl.	S.V.	% Sk. 78841	Pene.	Thru Open
26851	0°	957	127.9	Comp.	6-3/4" x 7"

179 38290 - Ballistic [illegible] of 1.9[illegible]" [illegible] plate [illegible]
by Carnegie-Illinois Steel Corp. vs. [illegible]
[illegible] fired for recovery of fragments of the windshield and hood - View of recovered fragments.

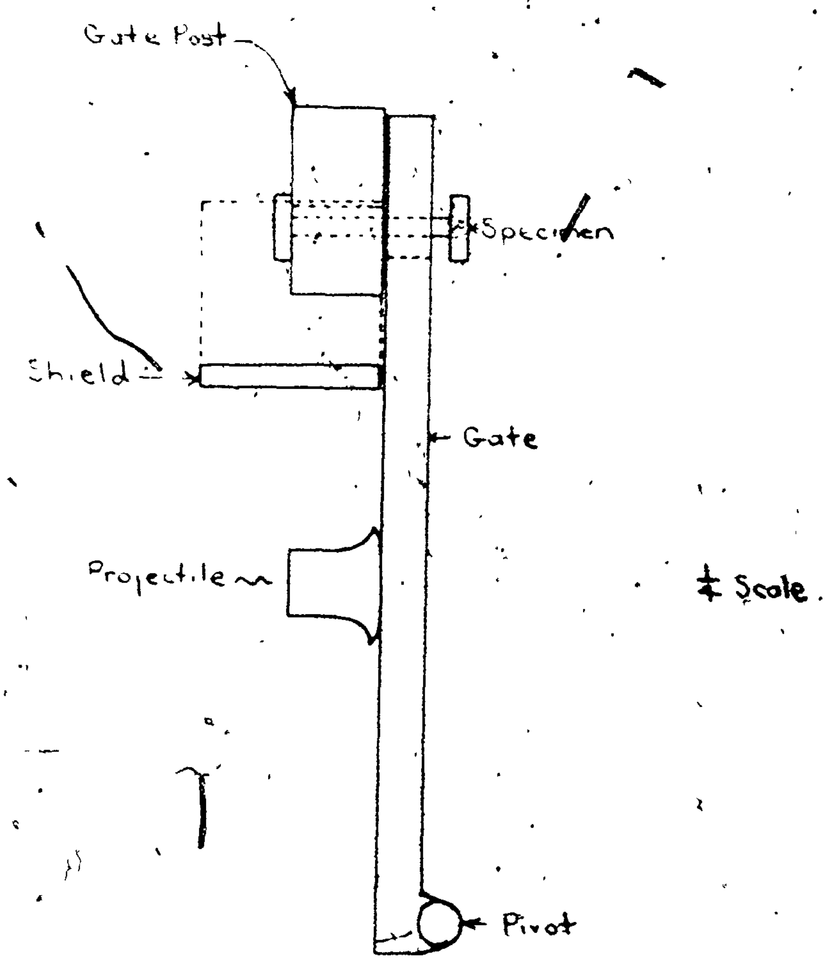


ENCLOSURE (B)

TABLE I

Comparison Between Plate Penetration Coefficients for 6" Comm. Mk. 27-7 Projectiles, With Windshields and Hoods, and Without Windshields or Hoods.

Plate Number	Plate Tensile Strength	θ	$\frac{e}{d}$	$F(\frac{e}{d}, \theta)$ With Ws. and Hood	$F(\frac{e}{d}, \theta)$ Without Ws. or Hood
F1823	128,000	45°	.242	35,600 ± 600	30,100 ± 900
NN25	119,000	45°	.522	43,300 ± 900	39,600 ±1100
634580	124,000	51°	.162	32,200 ± 700	26,600 ± 400
75446	121,000	50°	.408	41,700 ± 900	38,300 ± 400
23164	124,000	60°	.127	35,800 ± 500	30,500 ± 900
X20580	123,000	60°	.329	45,500 ± 400	45,700 ±1000



SCHEMATIC DIAGRAM OF APPARATUS FOR SHOCK LOADING OF TENSILE SPECIMENS