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U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

REPORT NO. 953

WARHEAD CHARACTERISTICS

5th Partial Report

TERMINAL BALLISTICS OF ROD-LIKE FRAGMENTS

1st Partial Report

Task Assignment NPG-Re3d-442-1-52

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Terminal Ballistics of Rod-Like Fragments

PART A

SYNOPSIS

1. A program to determine the terminal ballistics of rod-like fragments was initiated by the Bureau of Ordnance on the basis of calculations and tests which indicated that such fragments might be more effective in producing structural damage to aircraft than conventional fragments. The aims of this program were to achieve controlled firings of single rods, and subsequently to carry out ballistic tests on representative targets to determine damage under various conditions of attack.

2. This report covers the development of methods and attendant instrumentation to project rods in a reproducible fashion and over a range of sizes and velocities.

3. As a result of this work, a background of information has been acquired regarding the controlled flight of single rods. Specifically, configurations have been developed that have projected given rods at given velocities from 1500 ft./sec. to over 2000 ft./sec. Using these configurations preliminary structural damage data have been obtained by making shots against 1/4" and 3/8" mild steel and STS plates, and 1/2" 24S-T4 aluminum plates positioned face on and edge on.

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Terminal Ballistics of Rod-Like Fragments

PART B

INTRODUCTION

1. AUTHORITY:

This test was authorized by references (a), (b), and (c).

2. REFERENCES:

a. BUORD conf ltr 05124-Re3d-AM:bc of 29 Jun 1950
b. Task Assignment No. NPG-Re3d-442-2 of 22 May 1950
c. Task Assignment No. NPG-Re3d-442-1-51 of 22 Dec 1950
d. NPG Report 662, of 18 Oct 1950

3. BACKGROUND:

In aircraft damage tests at the New Mexico School of Mines, the results appeared to indicate that the structural damage caused by rod-like fragments could be considerably greater than that due to conventional fragments. Preliminary studies in warhead design also indicated that a rod-expelling configuration might be highly effective. Therefore, in order that the various warhead needs of the Navy might be considered with regard to this type of fragment, the Bureau of Ordnance requested the Naval Proving Ground to investigate the characteristics of rod-like fragments and fragment producers to obtain pertinent information required in making type and design choices.

The first phase of the program was to be the determination of methods for expelling single rods under controlled conditions, considering such problems as reproducibility of path, orientation and velocity. The next phase of the investigation was to be the determination of damage to suitable targets, using well-controlled single rods. With a number of configurations giving standard velocities and trajectories of rods, the velocity and penetration laws, limit velocities, and mechanics of rod fragments are now being determined as a function of initial velocity, path, geometry of the systems, physical properties, and the like for various structure types and materials.

4. PERIOD OF TEST:

This report covers the period from July 1950 up to April 1951.

5. REPRESENTATIVES PRESENT:

During the period reported upon, representative tests were witnessed and discussed by Dr. Abraham Miller of the Bureau of Ordnance and Dr. L. F. Wolanetz of The Johns Hopkins University, Applied Physics Laboratory.

PART C

DETAILS OF TEST

6. DESCRIPTION OF TEST EQUIPMENT AND PROCEDURE:

The first tests were conducted in order that the nature of rod flight might be determined, and utilized methods that set the basic form for the subsequent work. In them the rod was set up horizontally at a convenient height and projected broadside by a layer of explosive backing the rod. As explosive only Composition C-3 was used. Screens of 3/16" cardboard were set up in definite positions, and the flight of the rod was then determined by the rod cuts on the screens and the recovered fragments.

The first rods were 1/2" square, 15" long, of carbon steel (AISI 1090). The explosive was loaded to depths of 1/4" and 1/2" to the proper density in an aluminum foil channel. The channel had such a depth as to accommodate both the rod and explosive. In assembly a 1/2" wide strip of blotting paper was placed in the channel between the rod and the explosive, for the purpose of reducing rod spalling. The whole assembly was tightly held together with paper tape.

Engineer's special electric blasting caps were used in detonating the charge. The method employed was to insert the cap parallel to the rod into a booster charge placed at one end of the explosive column. Detonations attempted from the middle of the column resulted in low order explosions. See Figure 1, Appendix (B) for set up, and Figure 34, Appendix (D) for recovered rods.

For velocity determinations two aluminum foil sandwich contact screens operating two 100 kilocycle electronic counter chronographs in parallel, were substituted for the plain cardboard screens. Average velocities were calculated by determining the time of flight over a ten foot base line. Figure 2, Appendix (B) shows a schematic diagram of screen details.

This set up was used with little change other than refinements being made and firing configurations being varied, the latter so that methods of propelling the rod and flight characteristics could be investigated. Initially the rods were backed with either 1/4" or 1/2" deep by 1/2" wide columns of explosive, 15" long, plus a small booster charge at one end. By lengthening the column to 20" a 5" booster beyond the rod was obtained which was also increased in thickness for these narrow columns. Detailed data referring to the tests performed make up Table II to Table VIII in Appendix (A).

Other modifications made in the rod and explosive configuration in an attempt to obtain controlled flight are listed in Table I, Appendix (A).

These changes resulted in a design which is referred to as the "free plate rod gun". In the rod gun the explosive is confined between 1/2" steel top and bottom plates and a 1/2" square backing rod. In one type of set up the rod is backed by the explosive and lies between the two plates. In another the explosive column alone is confined between the plates with the rod outside the plates and between two rods. A diagram of a rod gun is included as Figure 3, Appendix (B).

One half inch square rods 7" and 15" long, and 3/4" square rods 15" long were shot by means of one or the other of these methods. In all the designs so far treated, detonation was achieved by end initiation and a 5" booster charge.

Despite the success attained in projecting rods, velocity measurements gave inconsistent values. It was thought that outer rod and plate fragments were causing the screens to trigger erratically. To solve this problem, first, more ductile steel was substituted for rod and plate material since the harder steels seemed to fragment excessively, (Figure 35, Appendix (D)). Secondly, a contact screen was designed that would not be triggered readily except by rods. This resulted in the grid contact screen, where the circuit was closed by the rod coming into contact with neighboring aluminum foil strips.

However, it appeared that the softer steel solved the fragmentation problem, and that the flight of a rod could be controlled, with the 1-1/2" explosive depth giving a reproducible velocity.

A change was now made in the velocity screen set up. Two sets of screens (each set with a separate counter) were employed. The distance between the start and stop screens of a set was 5' while the charge to screen distances were varied. The two sets could be used either to check one another by being placed across the same distance or to show velocity change by covering separate base lines.

The exact weight of the explosive loading was now obtained so velocity dependence upon this factor would be better known and so more definite results could be predicted for a given system. 0.06 lb./in.^{3} was the usual density for a loading.

Using the rod gun configuration and sandwich contact screens for velocity checking, shooting of rods against steel and aluminum plates was commenced. Seven inch rods of 3/4" and 1/2" square cross section were tried but difficulty was encountered in projecting them so that the plates would be hit broadside. Final results showed that end hits predominated. Shots were made against plates of 1/8", 1/4", and 3/8" mild steel and STS: and 1/2" 24S-T4 aluminum with the plates placed both face on and on edge. Fragments were recovered in a 4 foot by 6 foot by 4 foot sawdust filled box. Plates were rigidly supported and velocity screens on a five foot base line were placed before the plates.

After a series of shots against these plates it became evident that the correct values of rod velocities were not being obtained. Plate damage was greater than that to be expected for the measured velocities. To determine the source of error, shots were made using larger columns of explosive. Velocities did not vary greatly over the range of explosive weights, but varied erratically beyond inaccuracies of geometry. It was first suspected that screen triggering by the blast wave was the cause of these inconsistent values of velocity. Blast shields were utilized but seemed to do little toward correcting the observed discrepancies.

In reference (d) velocities measured by the high-speed camera method for rods from a flat plate configuration were found that could be taken as the basis along with the Gurney formula for further checking. These values are summarized in Appendix (A), Table V. These plates consisted of 6" rods held in a plywood frame and backed with Composition C-3. For checking purposes,

three 7" rods held in the same sized plywood frame and backed by a smaller amount of explosive corresponding to the reduced rod area were constructed, (Figure 4, Appendix (B)). These were shot under different conditions in that contact screens were used for velocity measurement and the base line was shorter. 1/2" and 3/4" layers of explosive backed the rods. Felt was placed between the rods and the explosive to prevent spalling in some of the 1/2" layer rounds. Velocities failed to check with reference (d). (Compare Table IV with Tables V and VI, Appendix (A)).

The results indicated that the inconsistent velocities were primarily due to the velocity measuring instrumentation rather than fragment and blast triggering or inaccuracies of loading and geometry. Since the counters and input leads responded accurately to check tests, it seemed that the sandwich contact screens were responsible for the unsatisfactory performance. Further tests were made to verify this assumption, conducted in a 30' arena with both contact screens and cameras to measure rod velocities (Figure 5, Appendix (B)).

The results indicated that the contact screens were not effective or reliable triggering devices. The screen velocities obtained varied erratically and were much lower than the correct values measured by the camera.

One other test was conducted as a final check. Camera and screens were employed for velocity measurements. The plate shots reported in reference (d) were duplicated with more precision being followed in the construction and loading of the charge and plate, and in the velocity measuring scheme. The values measured by the contact screens were definitely incorrect while those obtained with the camera checked with reference (d) and Gurney's formula.

With the problems of rod projection investigated and solved except for the velocity measuring difficulties, attention was primarily directed toward developing a convenient and accurate method of checking velocities. Two lines of attack were followed; adaption of camera techniques so that film records might be taken at existing laboratory firing facilities, and development of new screens for counter triggering.

The first of these was accomplished with little difficulty, thus enabling the absolute checking of screen measurements. For the second, it was necessary that a screen be designed taking into account the geometry of the rod as well as the desirability of a sharp, positive triggering action upon rod contact with the screen. Break screens were first investigated, as well as wire-and-foil contact screens. Neither was satisfactory.

Concurrently with these a modified type of grid screen was tested. This design turned out to be more accurate and dependable, with the secondary advantage that triggering by blast wave or extraneous fragments was more difficult, and it was considered that the screen problem was solved.

In the grid screen, triggering depends upon electrical contact between two parallel aluminum foil strips being made through the rod. The first screens of this type had been designed around fragment control specifications. With fragmentation no longer a problem the new factors determining the geometry of the screen were blast effects and the necessity that the rod come into positive contact with a set of triggering strips. The requirements posed by these factors were satisfied by using narrow strips close together and stapled down firmly. Subsequent use indicated that this screen was quite adequate. (See Figure 3, Appendix (B)).

From these investigations standard procedures and methods giving reproducible performance evolved. Variations make use of these basic components and involve only slight change or repositioning of the elements.

A description of the standard rod gun and instrumentation follows: The charge consists of a 1/2" thick column of Composition C-3 in a 20" long welded channel of 1/2" steel stock. Various depths (1-1/2" and less) cover the velocity range from 1000 ft./sec. to over 2000 ft./sec. A 1/2" square, 15" long steel rod is inserted into the channel. Both hardened 1090 and soft 1020 rods, with identifying marks punched on the surface, have been used. For velocity measurements, two sets of grid screens are positioned either both before, or one set before and one set after the target. Conditions determine the desired distances between screens, target, and charge. Velocities measured by the 16mm high speed camera method serve as a check on the values measured by the screen method for new rod gun configurations. The path and orientation of the rod may be checked by cuts on velocity screens or by the

positioning of additional cardboard. Fragment collection is accomplished by the use of a sawdust filled box. Targets are of aluminum and steel, both in plate form and of such shapes and so supported as to represent structural members. Shots are made so as to hit specific portions of the target at various points along the rod. Secondary targets of lighter steel plate are put up as the test demands.

More specifically, channels with 1/2", 3/4", 1", and 1-1/2" depths of Composition C-3 are being shot. Targets have consisted of 1/4", and 3/8" mild steel and STS plates, and 1/2" 24S-T4 aluminum plates. Additional terminal ballistics data are obtained by studying the rod fragments collected in the sawdust box after impact.

New configurations are being investigated for obtaining higher velocities. In one such, the rod gun is set up vertically and surrounded by heavy steel blocks on the back and sides. In another, shorter rods and shorter and wider explosive columns are to be shot in the welded channel configuration.

7. RESULTS AND DISCUSSION:

The main problems connected with the work reported upon were determination of the methods of firing a single rod, and investigation into the terminal ballistics of a given rod against a given target. The first may be further resolved into the characteristics of firing, the effect of firing upon the rod, velocities which a given system will produce consistently, and the trajectory to be expected. The results obtained serve to supply information on these points.

The shots for which velocities were measured by the sandwich contact screen method alone and which therefore, owing to screen failure to trigger properly under the circumstances encountered, did not give the required data are listed in Tables I to III, Appendix (A), together with the characteristics peculiar to them. These representative values show the performance of a given system, but also indicate the inconsistencies in velocities for a given assembly and between different assemblies due to the use of the contact screens. Note that the prevailing velocity is in the 1000-1500 ft./sec. range due to shock wave or slower fragment triggering after the passage of the rod.

Target shots are given in more detail with reference to photographs of plates and with the apparent velocity measured which may be compared with that of subsequent tests. Pictures of these target plates appear in Appendix (C) and include Figures 6 to 25.

Short rod penetration of these plates may be explained by the greater tendency for these rods to revolve horizontally and thus hit the plate end on. Indications on the plates and rods show that such hits occurred most often. Also the measured velocities recorded here are below the true velocities and thus give incorrect information concerning limit velocities for broadside penetration of plates. Consequently higher actual velocities as well as end-on hitting on the plates account for the penetrations observed.

Following these shots come the tests concerned with determining the sources of error in the velocity measurement instrumentation and with their removal. These data make up Tables IV to VI in Appendix (A) and overlap with the data obtained in development of new charge configurations, Table VII, Appendix (A).

The most recent shots reported upon are the most significant. Reproducible velocities under controlled conditions have been obtained, and may be correlated with the damage data of plates. An empirical formula has been suggested as a basis for calculating the velocities to be expected from a given thickness of explosive in the welded steel rod gun, that is $v = 1835 \sqrt[4]{t}$, where t is the thickness in inches. (See Figure 38, Appendix (E)).

Data have been obtained using these rod guns to project rods against mild steel, STS, and aluminum plate. The first initial shots are included in this report and corresponding information is found in Appendix (A), Table VIII, and Appendix (C), Figures 16 to 25.

Additional remarks concerning certain tests are included in the appendices when necessary and complete the discussion and the presentation of the results of this program for the period covered by this report.

A report now in preparation will cover the more recent phases of this program. An evaluation of the terminal ballistics results will not be attempted here, owing to the preliminary nature of the tests.

PART D

CONCLUSIONS

8. It is concluded that as a result of this work a background of information has been acquired regarding the controlled flight of single rods. Specifically, configurations have been developed that have projected given rods at given velocities from 1500 ft./sec to over 2000 ft./sec. Using these configurations preliminary structural damage data have been obtained by making shots against 1/4" and 3/8" mild steel and STS plates, and 1/2" 24S-T4 aluminum plates positioned face on and edge on.

Terminal Ballistics of Rod-Like Fragments

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NPG REPORT NO. 953

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

Fifth Partial Report

on

Warhead Characteristics

- -

First Partial Report

on

Terminal Ballistics of Rod-Like Fragments

NAVY RESEARCH SECTION
SCIENCE DIVISION
REFERENCE DEPARTMENT

APR 28 1952

Project No.: NPG-Re3d-442-1-52
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TABLE I

List of Preliminary Charge and Rod Modifications Investigated

1. Single rod backed by 1-1/2" Composition C-3. Rod fragmented.

2. Single rod backed by 1-1/4" Composition C-3 all in sheet steel channel. Outside rods on either side of center rod. Good flight.

3. Slotted pipe 1.1" I.D., 1.89" O.D., 15" long, containing approximately .8 pound Composition C-3. 15" rod in the slot and flush with the outer surface. Excessive fragmentation.

4. One (1") inch or 1-1/4" thick charge and single 1020 or 1090 steel rod contained in .020" sheet aluminum channel. Confinement by 1/2" square wooden rods around back of charge and 1/2" square steel rods around front. Widely varying velocities.

5. Single rod backed by 1" Composition C-3 all in aluminum channel. Top and bottom confinement by 2" by 6" by 20" steel plates, back confinement by 1/2" thick plate filling in remaining space between the 2" plates. Plates and rod fragmented. See Figure 34, Appendix (D).

6. Rods strapped to blocks of explosive (explosive confinement depended upon). Rods badly broken up. Velocities listed in Table II, Appendix (A). Recovered fragments included in Figure 35, Appendix (D).

   a. Single rod backed by 1-1/2" wide block all supported on 3/4" pine backing.

   b. Same with 1/2" to 1" thicknesses of explosive and with or without tetryl boosters.

   c. Rod set flush in 1/2" by 1" block of Composition C-3.

7. Three (3) rods all backed by explosive in aluminum channel. Explosive depth ranging from 1/4" to 2-1/2", width constant at 1-1/2". Rods marked for determination of trajectories. Outside rods project at angles to the horizontal, center rod's flight horizontal with ballistics satisfactory. Confining of charge by 3/4" thick pine box investigated. See Table II, Appendix (A) and Figures 35 and 36, Appendix (D).

TABLE I (Continued)

8. Single rod backed by 1/2" thickness of explosive, 3/4", 1" and 1-1/2" deep. Confinement top and bottom by 1/2" plates, in the rear by 1/2" rod. Designated as free plate rod gun. Front edge of top and bottom plates spalled giving undesirable fragments. See Table II, Appendix (A); Figure 32, Appendix (D).

TABLE II

Preliminary Investigations into Rod Flight

Representative shots: Sandwich contact screens, 10' distance between screens.
Explosive in Aluminum channel; 1/2" square, 15" long rods; 5' charge to screen distance.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod and Fragment Data
A-1	2" confining plates, 1/2" x 1" x 20" Comp. C-3 column	4.86	2060		Rod broke up, plates fragmented. (App. (D), Fig. 34).
A-2	1/2" plates, 1/2" x 3/4" x 20" column, single front rod	7.73	1290	Rod tilted	Rod intact, curved. (Shown by screen cuts).
A-3	Same, 1/2" x 1" x 20" column	5.81	1720	Rod rotated in horizontal plane	Rod intact, curved.
A-4	Same, 1/2" x 1-1/2" x 20"	6.58	1520	Broadside, level	Rod intact, curved.
A-5	1/2" plates, 1/2" x 1-1/2" x 20" column, 3 frontal rods	6.65	1500	Broadside, tilted	Rod intact, curved. (App. (D) Fig. 33)
A-6	Same	7.18	1390	Broadside, tilted	Rods bent or broken on hitting backstop. Rod intact, curved.
A-7	Same, 2 sets of screens 0-10', 3-13'	1) 5.93 2) 7.03	1690 1420	Broadside, straight, level	Rod intact, straight.
A-8	Same	1) 2.78 2) 75.12	3600 133	Broadside flight, dropping	Rod intact, straight.
A-9	Same, 1/2" x 2-1/2" x 20" column, 2 sets of screens	1) 5.90 2) 7.83	1700 1280	No rod hits on stopping screens	Rod intact, straight.
A-10	Same	1) 5.21 2) 5.92 5.86	1920 1690 1710	Broadside flight, slight tilting over 13'	Rod intact, straight.

TABLE II (Continued)

Representative shots: Sandwich contact screens, 10' distance between screens.
Explosive in Aluminum channel; 1/2" square, 15" long rods; 5' charge to screen distance, 3/4" pine backing.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data
B-1	Rod backed by 1" x 1-1/2" x 20" block Comp. C-3	6.65	1500		Fragmented. (App. (D), Fig. 35).
B-2	Same, 1/2" x 1-1/2" x 20" block	5.83	1720	Fragments spread	Fragmented.
B-3	Same, tetryl booster	6.39	1570		Fragmented.
B-4	Rod set flush in 1" x 1-1/2" x 20" block (1/2" explosive surrounding rod), tetryl booster	6.91	1450		Fragmented. (App. (D), Fig. 35)
B-5	Rod between two rods, all backed by 1/4" x 1-1/2" x 20" block	Recorded velocities range from 500-800		Center rod is rotating, top & bottom rods go off at an angle	Intact, curved. (App. (D), Figs. 35 and 36).
B-6	Same, 1/2" depth	8.42	1190	Tilting, broadside	Intact, straight.
B-7	Same, 3/4" depth	8.17	1220	Tilting, broadside	Intact, straight.
B-8	Same, 3/4" depth, confined by 3/4" pine box	Approximately	1300	Tilting, broadside	Intact, straight.
B-9	Same, 1" depth	8.41	1190	Stop screen not hit	Intact.
B-10	Same, 3/8" depth (Note Velocity Variation)	(a) 10.80	930	Tilting, dropping, broadside	Intact.
		(b) 5.38	1860	Same as above	Intact.
		(c) 18.39	540	Tilted, broadside	Intact.
		(d) 14.19	710	Tilted, dropping, broadside	Intact.
		(e) 7.60	1320	Rotating horizontally	Intact.
		(f) 11.09	900	Level, broadside	Intact, split on hitting wooden backstop.

TABLE III

Attempt at Standardization of Rod Velocities, Target Shots

Rod gun 1/2" wide, 20" long; three 1/2" x 1/2" x 15" rods.
Sandwich contact screens; 10' base line (except as noted).

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
A-1	1-1/2" depth Comp. C-3; 2 sets of screens	1) 7.73 7.74 2) 6.35	1290 1580	Rotating horizontally	Intact, curved	5" rocket motor, 1/4" shell, approx. 25' from charge; cut half through; rod broken up. (App. (D), Fig. 33)
A-2	1-1/2" depth; 5' base line	4.19 4.16	1190 1200	Broadside	Intact, straight, broke upon hitting plate	1/2" x 18" x 30" 24S-T4 aluminum plate on edge, marked 11/16 1/2" cut. (App. (C) Figs. 6 & 7)
A-3	1-1/2" depth	7.19 7.16	1390 1400	Broadside, rotating	Intact, curved	----
A-4	1-1/2" depth; 2 sets of screens, 8' screen distance, 11' base line	1) 6.19 6.20 2) 4.65	1290 1720	Broadside, rotating, level	Intact, curved	Same, end hit, 11/17; 1" cut.
A-5	1-1/2" depth	7.94 7.98	1260 1250	Broadside, rotating	Intact, curved	----
A-6	1-1/2" depth	7.04 7.06	1420	Broadside, level	Intact, curved	Same, 11/21; 1-1/2" deep
A-7	1-1/2" depth	6.68 6.71	1500 1490	Rotating	Intact, bent	----
A-8	1" depth	7.78 7.80	1290 1280	Rotating	Intact, curved	----
A-9	1" depth	6.44 6.45	1550	Rotating	Intact, curved	Same, clipped; 11/22.

TABLE III (Continued)

Rod guns: 5/8" wide, 1-1/2" deep, 20" long, and 1/2" wide, 1-5/8" deep, 20" long, explosive columns; three 1/2" x 1/2" x 15" rods.
Sandwich contact screens; 10' base line.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
B-1	5/8" x 1-1/2" 1 lb. Comp. C-3	6.78 6.79	1470	Rotating	Marked (B), straight, (App. (D), Figs. 26 & 27.)	1/2" x 18" x 30" 24S-T4 aluminum plate, on edge, marked 11/28-1, end hit, 3/4" wide, 1" deep. (Charge target distance 15') (App. (C) Figs. 6 & 7.)
B-2	Same. .95 lb.	7.15	1400	Rotating	(K), straight	----
B-3	Same. 1 lb.	6.29 6.32	1590 1580	Rotating	(H), straight	Same, 11/29-1, rod hit at angle 5" from end, 3/4" wide, 1-1/4" deep.
B-4	Same. 1.15 lb.	6.92 6.65	1450 1500	Broadside, rotating	(C), intact, bent	Same, 12/6, face cut.
B-5	Same. 1.15 lb.	6.36 6.37	1570	Broadside, rotating	(D), intact, bent	----
B-6	1/2" x 1-5/8" 1 lb. Comp. C-3	7.10 7.13	1410 1400	Broadside, rotating	(E), curved intact	Same, 11/28-2, hit at center of rod, 3/4" deep, 5/8" wide.
B-7	Same. .9 lb.	6.66 6.69	1500	Broadside	(N)	Same, 11/29-2, hit at angle at center of rod. Cut 1-1/2" wide, 1" deep.
B-8	Same. .95 lb.	6.50	1540	Broadside, rotating	Intact, bent	Same, 11/30, rod hit 5" from end. Cut 3/4" wide, 1-1/4" deep.
B-9	Same. .95 lb.	6.71	1490	Rotating	(B_1)	Same, 11/30, face out.

TABLE III (Continued)

Rod gun, 7/8" wide, 1-1/2" deep, 12" long, explosive column, three 3/4" x 3/4" x 7" rods. Sandwich contact screens.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
C-1	10' base line .9 lb.	8.65	1160	Rotating	Rod marked (A) (App. (D) Fig. 26 & 27)	3/8" x 36" x 36" STS plate, marked Plate I, 12/7-2, on edge, 3/4" wide, 1/4" deep. (App. (C) Figs. 8 & 9).
C-2	10' base line .9 lb.	--	--	Rotating	(B)	Same, 12/7-3, on edge, 1-1/4" wide, 3/4" deep.
C-3	10' base line .95 lb.	8.03 8.04	1250 1240	Rotating	(BO)	Same, 12/8-1.
C-4	10' base line .95 lb.	8.71 8.89	1150 1130	Broadside, rotating		Same, 12/8-2.
C-5	5' base line .95 lb.	4.58	(1090)	Rotating, did not hit stop screen	(K)	Same, 12/8-3.
C-6	5' base line	3.85	1300	Dropping, horizontal rotation	(M)	Same, 12/8-4, end on hit.

TABLE III (Continued)

Rod gun, 5/8" wide, 1-1/2" deep, 12" long explosive column; 7" backing rod; three 1/2" x 1/2" x 7" rods. Sandwich contact screens, 5' base line.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
D-1	.75 lb. Comp. C-3	4.39 4.40	1140	Rotating	(App. (D) Fig.28)	----
D-2	.75 lb.	2.68	1870	Rotating, hit end on	All intact before hitting	3/8" x 36" x 36" STS plate, marked Plate I, 12/8-5, (App. (C) Figs. 8 & 9).
D-3	.75 lb.	3.96	1260	Broadside, rotating		3/8" x 36" mild steel, marked Plate II, 12/14-1, (App. (C) Figs. 10 & 11).
D-4	.7 lb.	4.29 4.31	1170 1160	Broadside, rotating		Same, 12/15-2, clipped plate.
D-5	.7 lb.	4.34 4.35	1150	End on		Same, 12/15-3.
D-6	.7 lb.	3.85 3.86	1300	Broadside, rotating		Same, 12/15-4.
D-7	.7 lb.	4.54 4.57	1100 1090	Broadside, rotating		Same, 12/15-5.
D-8	.7 lb.	4.03	1240	Rotating		Same, 12/16-6.
D-9	.7 lb.	3.91	1280	Rotating		Same, 12/16-7, end on hit.
D-10	.7 lb.	3.47 3.48	1440	Bad hit on screens		Same, 12/16-8.
D-11	.7 lb.	3.69	1360	Rotating		Same, 12/18-9.
D-12	.73 lb.	--	--	Rotating		Same, 12/18-10, end on hit.
D-13	.73 lb.	3.96 3.97	1260	Rotating		Same, 12/19-11.

TABLE III (Continued)

Rod guns, 5/8" wide, 1/2" deep, 12" long, explosive column and 5/8" wide, 1" deep, 12" long explosive column; 12" backing rod; three 1/2" x 7" rods.
Sandwich contact screens; 5' base line.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
E-1	5/8" x 1"; .5 lb. Comp. C-3	3.26	1530	Straight path, rotating	End hit, rod bent. (App. (D) Fig. 28)	1/4" x 36" x 36" mild steel marked Plate III, 12/19-1 (App. (C) Figs. 12 & 13).
E-2	.5 lb.	4.49	1110	Rotating		Same, 12/19-2.
E-3	.5 lb.	3.31	1510	Straight path, rotating	Intact, curved	Same, 12/20-3.
E-4	.48 lb.	4.38 4.37	1140	End on		Same, 12/20-4.
E-5	.45 lb.	4.43	1130	Straight path, rotating	7" backing rod in addition	Same, 12/20-5.
E-6	5/8" x 1/2", .23 lb. Comp. C-3	5.90	850	Broadside, rotating	Marked (Z), 2 backing rods, straight (App. (D) Fig. 29)	Same, 12/20-6.
E-7	.23 lb.	6.45 6.44	780	Rotating	2 backing rods	Same, 12/21-7.

TABLE III (Continued)

Rod guns, 5/8" wide, 1-3/4" deep, 12" long explosive column and 5/8" wide, 1-5/8" deep, 12" long explosive column, 12" backing rod; three 1/2" x 1/2" x 7" rods.
Sandwich contact screens; 5' base line.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
F-1	5/8" x 1-5/8" .8 lb. Comp. C-3	3.67	1360	Rotating	(App. (D) Fig. 28)	1/4" x 36" x 36" mild steel; marked Plate III, 12/21-8, (App. (C), Figs. 12 & 13).
F-2	.8 lb.	4.12 4.13	1210	Dropping		Same, 12/21-9.
F-3	.8 lb.	3.75	1330	Rotating		Same, 12/21-10.
F-4	.8 lb.	3.89	1290	Rotation in vertical plane	Curved, intact	3/8" x 36" x 36" mild steel, marked Plate IV, 12/22-1 (App. (C), Figs. 14 & 15).
F-5	.8 lb.	4.05 4.14	1240 1210	Rotation in vertical plane	Curved, intact	Same, 12/22-2.
F-6	5/8" x 1-3/4"	3.54 3.57	1410 1400	Straight, rotation in horizontal plane	End hit, curved intact	Same, 12/30-3.
F-7	Same as above	4.62 4.64	1080	No rod hits on screen II, rod rose		Same, 12/30-4.
F-8	Same as above	3.68 3.69	1360 1350	Rotating in horizontal plane		Same, 12/30-5.
F-9	Same as above	3.65 3.67	1370 1360	Rotating in horizontal plane	Straight	Same, 12/30-6.
F-10	Same as above	3.58 3.60	1400 1390	Rotating in horizontal plane		Same, 12/30-7.

TABLE IV

Investigation of Sandwich Contact Screen Failure

Rods in plywood frame backed by Composition C-3, approximately .8 lb. explosive, 1/2" thick.
Three 1/2" x 1/2" x 7" rods; sandwich contact screens, 5' screen distance, 2 sets of screens over base line.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data
A-1	1/16" felt between explosive and rods	1) 5.84 5.85 2) --	860	Top and bottom rods off at angle, rods revolve in vertical plane, center rod rising	Intact and straight. (App. (D), Figs. 31 and 36).
A-2	No felt	6.12 1) 6.14 2) 6.44	820 780	Top and bottom rods off at angle, rods revolve in vertical plane, center rod dropping	Intact and straight.

TABLE IV (Continued)

Rods in plywood frame backed by Composition C-3; approximately 1-1/4 lb. explosive 3/4" thick. Three 1/2" x 1/2" x 7" rods.

Rd. No.	Charge & Rod Configuration	Time Millisec.		Apparent Velocity Ft./Sec.	Flight	Rod & Fragment Data
B-1	Sandwich contact screens, 5' screen distance over approx. 10' base line	0-5')	3.78 3.79	1320	Straight, level flight, rod rotating in vertical plane	Rods intact and straight (App. (D) Fig. 31 and 36).
		6-11')	2.36 2.39	2120 2090		
B-2	Same as above, cardboard shield before first screen	0-5')	3.08 3.09	1620	Same	Rod intact and straight.
		6-11')	2.58 3.52	1940 1420		
B-3	Same as above, no shield 1/16" felt between explosive and rod	1)	3.69 3.70	1360 1350	Same	Rods intact and straight.
		2)	3.77	1330		

TABLE V

Velocities Compared with Sandwich Contact Screen Values

Rods in plywood frame backed by Composition C-3.
Velocity values taken from NPG Report 662, of 18 Oct. 1950.

	Velocity
1/4" Comp. C-3, 16" felt between explosive and rod	Less than 1100 ft./sec.
1/2" Comp. C-3	Maximum 1700 ft./sec. Median 1640 ft./sec. Average 1580 ft./sec.
1" Comp. C-3	Maximum 2440 ft./sec. Median 2270 ft./sec. Average 2210 ft./sec.

TABLE VI

Camera Velocities for Comparison with Sandwich Contact Screen Values

Rods in plywood frame backed by Composition C-3, approximately 3 lbs. explosive, 1" thick.
Ten 1/2" x 1/2" x 6" rods.
Sandwich contact screens 5' base line and 35mm camera, 30' velocity arena.

Rd. No.	Charge & Rod Configuration	Time Milliseo.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
1	Counter velocity	4.13	1210	7 rod group rose and went to one side. Random orientation. Indication that rest dropped.	Rods intact and curved (App. (D), Fig. 31 and 36).
	Camera velocity	Highest	2480		
		Average	2370		
2	Counter velocity	3.95	1270	Similar results	
	Camera velocity	Highest	2680		
		Average	2440		
3	Counter velocity	2.30	2170	Similar results	
		2.34	2140		
	Camera velocity	Highest	2510		
		Average	2430		

TABLE VII

Development of Velocity Screens and Higher Velocity Rod Guns

Welded and free plate rod guns; 1-1/2" wide, 1-1/2" deep, 20" long explosive column; 1/2" x 1/2" x 15" rods.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
A-1	Sandwich contact screens; 5' base line, 8' charge to screen distance; 2.6 - 2.7 lb. Comp. C-3; free plates	3.36	1490	Three rod group spreads & travels to one side, rotating in horizontal plane mostly	Intact, curved slightly. (App. (D), Fig. 31).
A-2	Same as above	2.87	1740	No rod hits on stop screen	
A-3	Same as above	2.72	1840	Good screen cuts. Similar results to first round	
A-4	Sandwich contact screens, approx. 5' base line, 35mm camera; 30' arena; 2.75 lb. Comp. C-3 welded plates	3.75 4.19 (Camera) Center rod " Top rod " Bottom rod	1330 1190 2960 2780 2420	Center rod dropped approx. 2' and went to the left 4' over 30' distance; rod rotating; stop screen missed by rod; start screen 12' from charge. Rods missed sec. screen	Intact, curved (App. (D), Figs. 31 and 36).
A-5	Same as above. 2.6 lb. Comp. C-3	" Center rod " Top rod " Bottom rod	 2890 2730	Rods missed second screen. Similar results as above.	
A-6	Same as above. 2.75 lb. Comp. C-3	2.41 2.44 " Center rod " Top rod " Bottom rod	2080 2050 2980 2890 2450	Similar results	

TABLE VII (Continued)

Free plate rod gun, 1/2" wide, 1-1/2" deep, 12" long explosive column; 12" backing rod; three 1/2" x 1/2" x 7" rods.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
B-1	Piano wire break screens, approx. 5' screen distance, 2 sets of screens; 3/4 lb. Comp. C-3	1) 2.90 2) 2.71	1720 1850		(See App. (D), Fig. 31) Note wire markings on rod surface.
B-2	Same as above	1) 2.96 2) 2.65	1660 1860		
B-3	Same as above with grid contact screens	1) -- 2) 2.74 2.78	-- 1800 1770	Slight tilting causing deviation from horizontal-broadside flight at 12' from charge; dropping	Intact, straight.
B-4	Same as above with copper wire break screens	1) 4.25 2) 4.17	1180 1200		
B-5	Same as above	1) 3.15 2) 4.31	1590 1160		
B-6	Same as above	1) 2.96 2) --	1690 --		
B-7	Same as above	1) 3.86 2) 2.59	1300 1930		
B-8	Piano wire break screens	1) 2.81 2) .69	1780 ?	Screens have high retardation effect	
B-9	Grid screens	1) 2.72 2.74 2) 2.99	1840 1830 1670	Straight, level, broadside	Straight and intact.
	6000 ft./sec. 16mm, camera, 24' base line		1710		

TABLE VII (Continued)

Welded steel rod gun; 1/2" wide, 1-1/2" deep, 20" long explosive column, 1/2" x 1/2" x 15" rod. Approximately 5' screen distance, 2 sets of screens; 16mm camera, 30' base line.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
C-1	.96 lb. Comp. C-3, grid screens	1) 2.58 2.62 2) 2.68 Camera approx.	1970 1940 1960 1800	Straight, level, broadside	Straight, intact (App. (D), Fig. 29).
C-2	.96 lb., break screens	1) 2.88 2) 4.08 Camera approx.	1740 1230 1800	Vertical rotation over 30' base line, broadside	Straight.
C-3	Wire & foil contact screens	1) -- 2) 2.61 2.60 Camera	-- 1920 1910	Straight, level, broadside (vertical rotation over 30')	Straight, intact.
C-4	Grid screens	1) -- 2) 2.58 Camera	-- 1940 1825	Straight, level, broadside	Intact.
C-5	Grid screens (shielded) Wire & foil contact screens	1) 2.53 2.55 2) 2.76 Camera	1980 1960 1810 1835	Straight, level, broadside	1-1/2" broke off one end.
C-6	Wire & foil contact screens Grid screens	1) 3.02 3.04 2) 2.73 2.72 Camera	1660 1650 1830 1840 1795	Straight, level, broadside (for center piece 11" long)	1 piece 1" broke off one end, 2 pieces 1-1/2" long broke off the other end.
C-7	.95 lb. Comp. C-3, Grid Wire & foil	1) 2.44 2) 3.46 3.50 Camera (28' 10" baseline)	2050 1450 1430 1910	Broadside, rotating vertically	Slightly curved. (App. (D), Fig. 30) Marked 3/15

TABLE VII (Continued)

Welded steel rod gun, 1/2" wide, 20" long explosive column, 1/2" x 1/2" x 15" rod. Approximately 5' screen distance, 2 sets of screens; 16mm camera, 30' base line.

Rd. No.	Charge & Rod Configuration		Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
C-8	.95 lb. Comp. C-3, 1-1/2" depth.	Grid 1)	2.43 2.44	2060 2050	Broadside, rotating vertically	Slightly curved.
		Wire & foil 2)	2.92 2.91	1710		
		Camera (28' 9" baseline)		1935		
C-9	.95 lb., 1-1/2" depth	Wire & foil 1)	2.88 2.89	1740 1730	Broadside, rotating	Slightly curved.
		Grid 2)	2.54 2.55	1970 1960		
		Camera (28' 8" baseline)		1905		
C-10	.6 lb. 1" depth	Grid 1)	2.74 2.76	1830 1810	Broadside, rotating vertically slowly	Intact, curved slightly (App. (D), Fig. 30) Marked 3/14
		Wire & foil 2)	2.71	1850		
		Camera (28' 8" baseline)		1720		
C-11	.58 lb. 1" depth	Grid 1)	--	--	Broadside, rotating vertically	
		Wire & foil 2)	2.94 2.93	1680 1690		
		Camera (28' 9" baseline)		1655		
C-12	.65 lb. 1" depth	Grid 1)	2.72 2.73	1850	Broadside, rotating vertically	
		Wire & foil 2)	2.70	1880		
		Camera (28' 7" baseline)		1740		

TABLE VII (Continued)

Welded steel rod gun, 1/2" wide, 3/4" deep, 20" long explosive column, 1/2" x 1/2" x 15" rod. Approximately 5' screen distance; 2 sets of screens, 16mm camera.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
D-1	.4 lb. Comp. C-3	Grid 1) 2.92	1710	Broadside rotating in vertical plane	Curved, intact (App. (D), Fig. 30), marked 3/17.
		2.95	1700		
		Wire & foil 2) 2.98			
		2.97	1680		
		Camera (28' 10" baseline)	1665		
D-2	.38 lb.	Grid 1) 2.95	1700	Broadside rotating in vertical plane	Curved, intact.
		2.97	1680		
		Wire & foil 2) 3.01	1660		
		Camera (28' 11" baseline)	1560		
D-3	.4 lb.	Grid 1) 2.95	1700	Broadside rotating in vertical plane	Curved, intact.
		2.97	1680		
		Wire & foil 2) 3.03	1650		
		Camera (28' 11" baseline)	1580		

TABLE VII (Continued)

Welded steel rod gun, 1/2" wide, 1/2" deep, 20" long explosive column, 1/2" x 1/2" x 15" rods. Approximately 5' screen distance; 2 sets of screens, 16mm camera.

Rd. No.	Charge & Rod Configuration		Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data
E-1	.3 lb. Comp. C-3	Grid 1)	3.39	1480	Broadside rotating in vertical plane	Slightly curved, intact. (App. (D), Fig. 30). Marked 3/20.
			3.40	1470		
		Wire & foil 2)	3.46	1450		
			3.47	1440		
		Camera (28' 8")		1400		
E-2	Same as above	Grid 1)	--	--	Broadside rotating in vertical plane	Slightly curved, intact.
		Wire & foil 2)	3.38	1480		
			3.37			
		Camera (28' 8")		1395		
E-3	Same as above	Grid 1)	3.22	1550	Broadside rotating in vertical plane	Slightly curved, intact.
			3.26	1530		
		Wire & foil 2)	3.32	1510		
		Camera (28' 7")		1560		
E-4	.29 lb.	Grid 1)	3.42	1460	Broadside rotating in vertical plane	Slightly curved, intact. Marked 3/21.
			3.45	1450		
		Wire & foil 2)	4.04	--		
		Camera (28' 7")		1370		
E-5	.3 lb.	Grid 1)	--	--	Broadside rotating in vertical plane	Slightly curved, intact.
		Wire & foil 2)	3.44	1450		
			3.45			
		Camera (28' 8")		1400		
E-6	.3 lb.	Grid 1)	3.45	1450	Broadside rotating in vertical plane	Slightly curved, intact.
		Wire & foil 2)	3.37	1480		

TABLE VIII

Target Shots with Standard Velocity Rod Guns

Welded steel rod gun, 1/2" wide, 20" long explosive column, 1/2" x 1/2" x 15" rods.
5' screen distance, grid contact screens.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
A-1	1/2" depth, .29 lb. Comp. C-3	1) 3.50 3.53 2) 4.55 4.56	1430 1420 --	Broadside, rotating vertically	1020 steel; curved. (App. (D), Fig. 30). Marked 3/22-A	1/4" x 36" x 36" mild steel plate, marked 3/22-1 (App. (C), Fig. 18).
A-2	3/4" depth, .43 lb. Comp. C-3	1) 2.92 2.94 2) 3.01 3.02	1710 1700 1660	Broadside, rotating in vertical plane	1020 steel; slightly curved. Marked 3/22-B	Same, 3/22-2.

TABLE VIII (Continued)

Welded steel rod gun, 1/2" wide, 1-1/2" deep, 20" long explosive column, 1/2" x 1/2" x 15" rods, 5' screen distance.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod Data	Target Data
B-1	.87 lb. Comp. C-3, grid screens	1) 2.48 2.46 2.50 2) 2.51	2020 2030 2000 1990	Consistently broadside	1020 steel; slightly curved. (App. (D), Fig. 30) Marked 3/23-C.	1/4" x 36" x 36" mild steel plate, marked 3/23-3 (App. (C), Fig. 18).
B-2	.92 lb.	1) -- 2.56 2) 2.55	-- 1950 1960		Intact, straight (App. (D), Fig. 37) Marked 3/28-1	1/4" x 36" x 36" STS plate, marked 3/28-1 (App. (C), Fig. 21).
B-3	.87 lb.	2.39 1) 2.43 2) 2.51	2090 2060 1990		Marked 3/28-2	3/8" x 36" x 36" mild steel plate, marked 3/28-2 (App. (C), Fig. 22).
B-4	.9 lb.	1) -- 2) 2.45	-- 2040		Slightly curved, tilted.	1/4" x 36" x 36" mild steel on edge, end hit by rod 1" wide, 5/8" deep, marked 3/31-1 (App. (C), Fig. 18).
B-5	.92 lb.	1) -- 2) 2.61	-- 1920		Slightly curved tilted	3/8" x 36" x 36" mild steel on edge, center hit 1" wide, 3/8" deep, marked 3/31-2 (App. (C), Fig. 23 and 24).
B-6	.91 lb.		1980±50		Slightly curved, tilted	1/4" x 36" x 36" STS (rod hit 5" from end) 1/2" wide 1/2" deep.
B-7	.93 lb.	1) 2.52 2.54 2) 2.56	1980 1970 1950		Straight, tilted	3/8" x 36" x 36" STS (end hit by rod) 1/2" wide, 1/4" deep.

TABLE VIII (Continued)

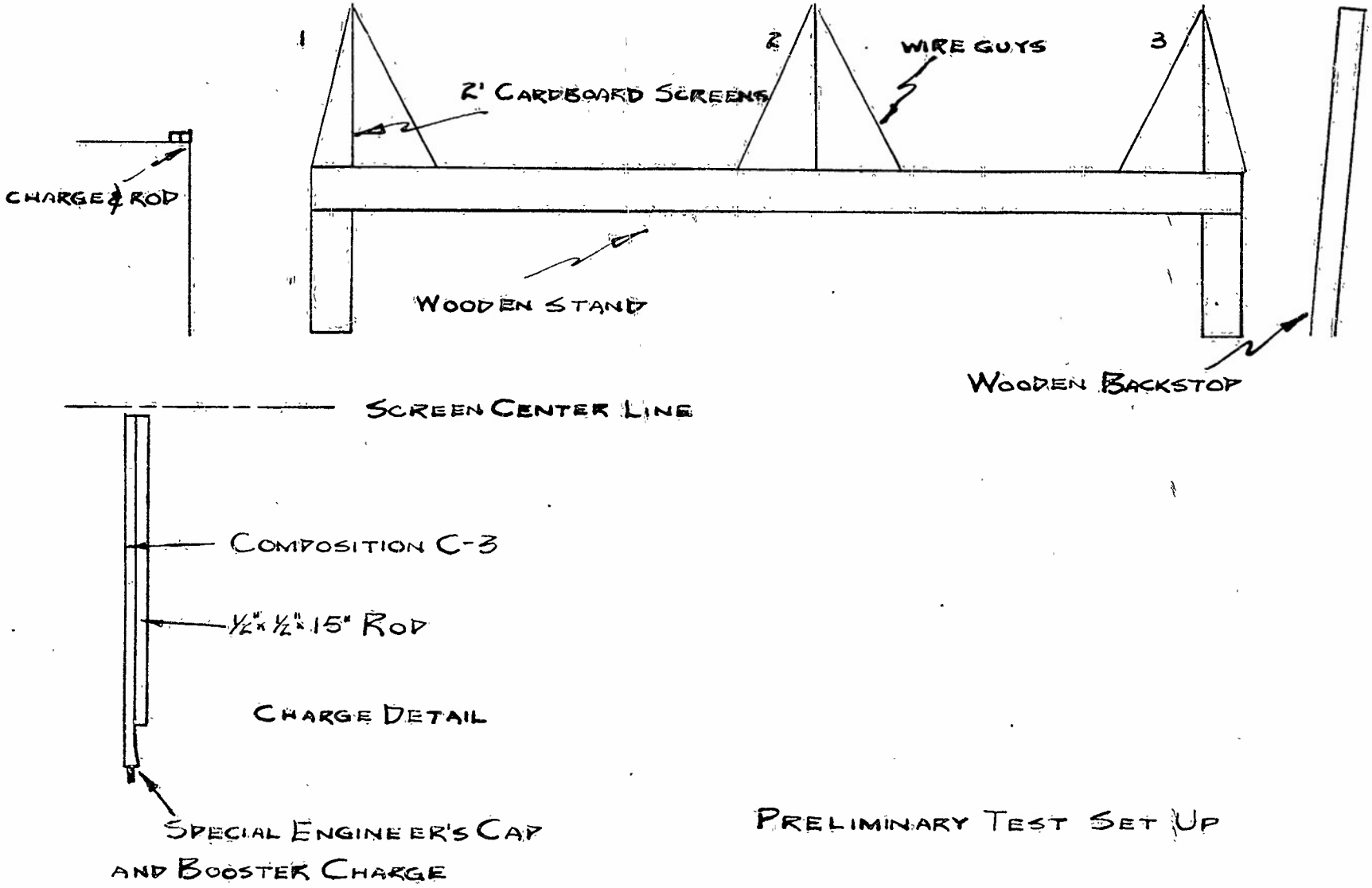
Welded steel rod gun, 1/2" wide, 1" deep, 20" long explosive column, 1/2"x 1/2"x 15" rods.
5' screen distance, grid contact screens.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod & Fragment Data	Target Data
C-1	.6 lb. Comp. C-3	Approximately	1850	Broadside		1/4" x 36" x 36" mild steel plate, marked 3/28-3, (App. (C), Figs. 19 & 20).
C-2	.58 lb.	2.74	1830	Broadside		Same. Marked 3/29-4.
C-3	.63 lb.	Approximately	1850	Broadside	(App. (D), Fig. 37) Marked 4/4-1	3 plates 1' apart. 1/4" mild steel plate and 1/8" mild steel plate, penetrated, 1/8" mild steel plate not penetrated. Marked 4/4-1 (App. (C), Figs. 16 and 17).

TABLE VIII (Continued)

Welded steel rod gun 1/2" wide, 1-1/2" deep, 20" long explosive column, 1/2" x 1/2" x 15" rods, 5' screen distance.

Rd. No.	Charge & Rod Configuration	Time Millisec.	Velocity Ft./Sec.	Flight	Rod Data	Target Data
D-1	.9 lb. Comp. C-3 (longer charge to screen distance.)	approx.	1900	Turning	1085 rod as rec'd Rockwell B-78	3/8" x 36" x 36" mild steel plate on edge, 3/8" deep, 5/8" wide, marked 4/7-1 (App. (C), Figs. 23 & 24).
D-2	.9 lb.	1) 2.76 2.69 2) 2.72 2.71	1870 1860 1840 1850	Broadside	Oil quenched from 1500°F, no draw, Rockwell C-36, straight (broke on hitting)	Same. 1" deep, 3/4" wide marked 4/7-2 (App. (C), Figs. 22, 23 and 24).
D-3	.9 lb.	1) 2.66 2.69 2) 2.65	1880 1860 1890	Broadside, rotating	Oil quenched from 1500°F, no draw. Rockwell C-40	Same. 5/8" deep, 3/4" wide, marked 4/7-3 (App. (C), Figs. 22, 23 and 24).
D-4	.89 lb.	1) 2.66 2.67 2) 2.69	1880 1870 1860	Broadside, rotating	Oil quenched, 1085 rod, center hit. (App. (D), Fig. 37) Marked 4/10-1.	1/2" x 18" x 30" 24S-T4 aluminum plate on edge, 1-1/8" wide, 2" deep, marked 4/10-1 (App. (C), Fig. 25).
D-5	.89 lb.	1) 2.64 2.67 2) 2.71	1900 1870 1850	Broadside, rotating	Oil quenched, 1085 rod, end hit	Same. 1/2" wide, 1/2" deep, marked 4/10-2.

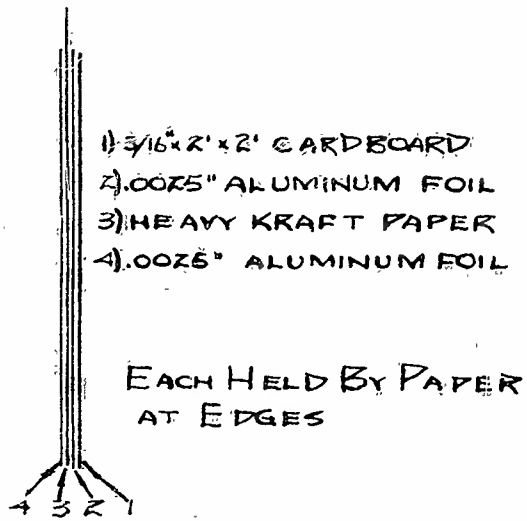


PRELIMINARY TEST SET UP

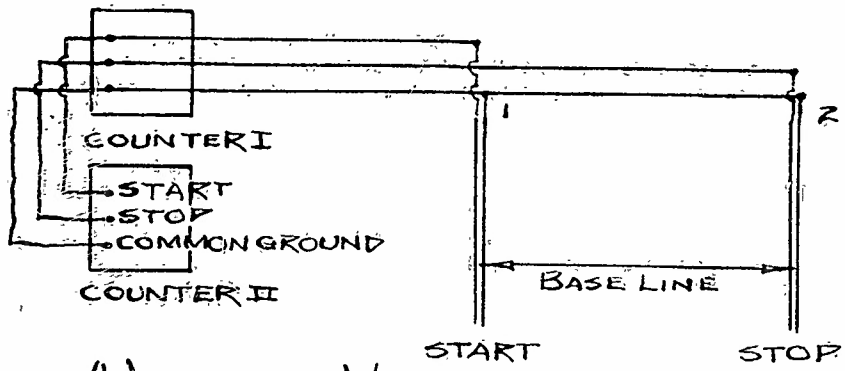
APPENDIX B

FIGURE 1

CONFIDENTIAL



(a) SCHEMATIC OF SANDWICH CONTACT SCREEN



(b) COUNTER & VELOCITY SCREEN SCHEMATIC

APPENDIX B

FIGURE 2

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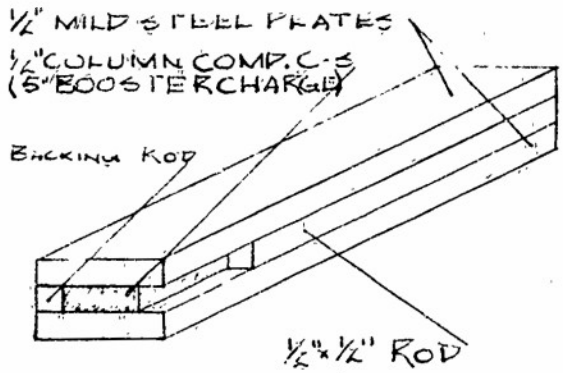
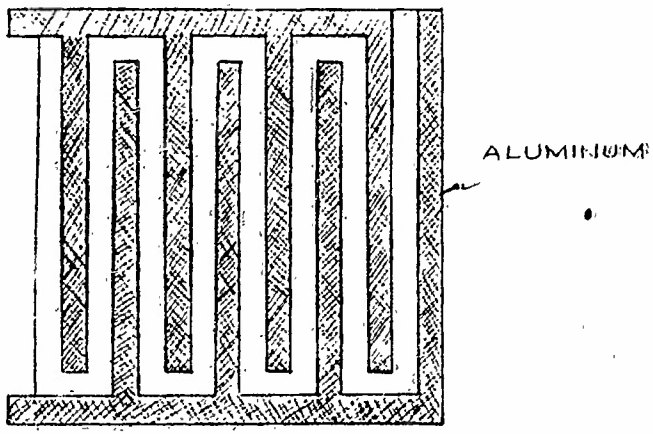
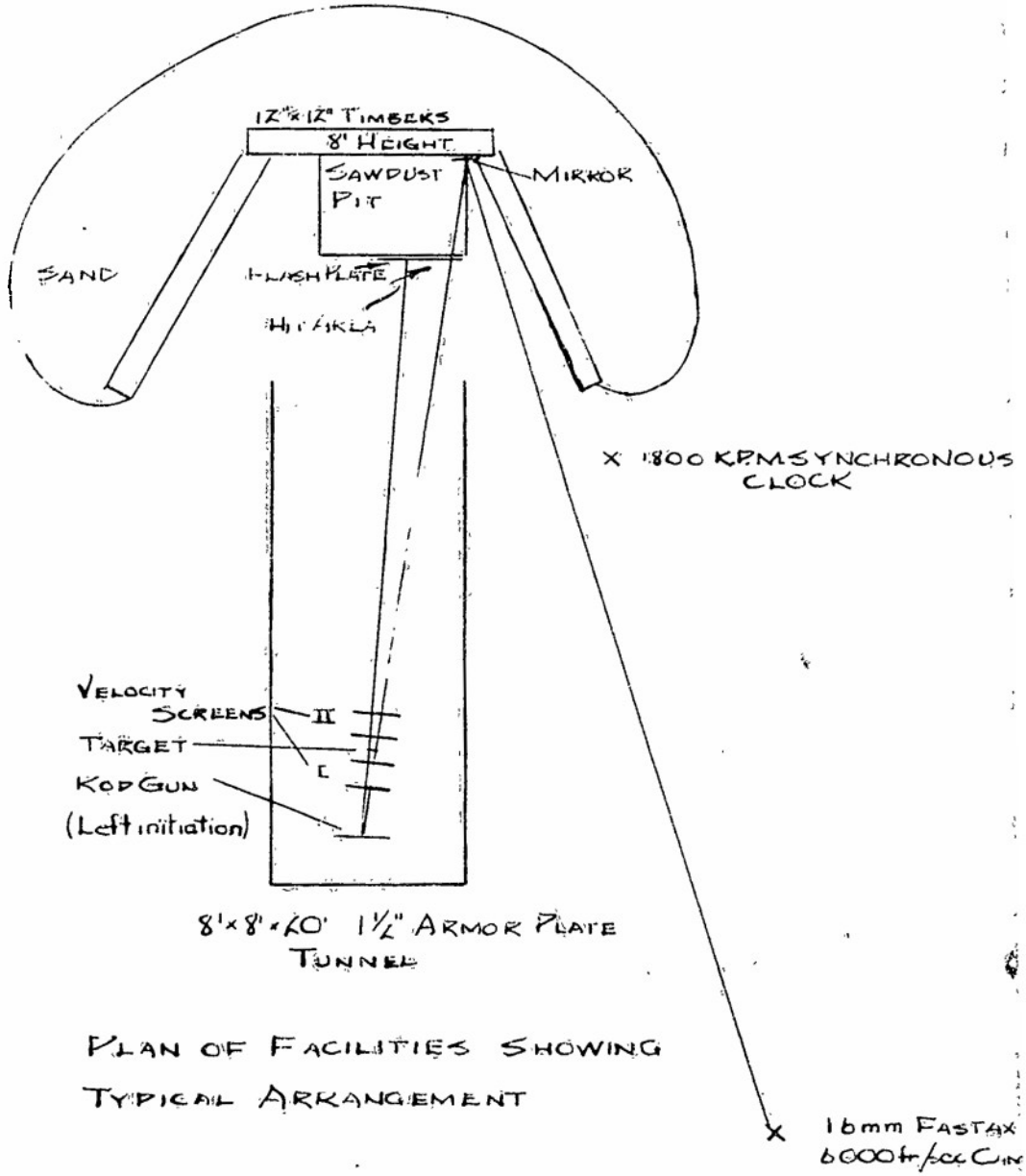


ROD GUN



GRID CONTACT SCREEN
ALUMINUM FOIL STRIPS
STAPLED ON 3/16" CARDBOARD
SHEET MOUNTED ON WOODEN
REINFORCING FRAME



PLAN OF FACILITIES SHOWING
TYPICAL ARRANGEMENT

APPENDIX B

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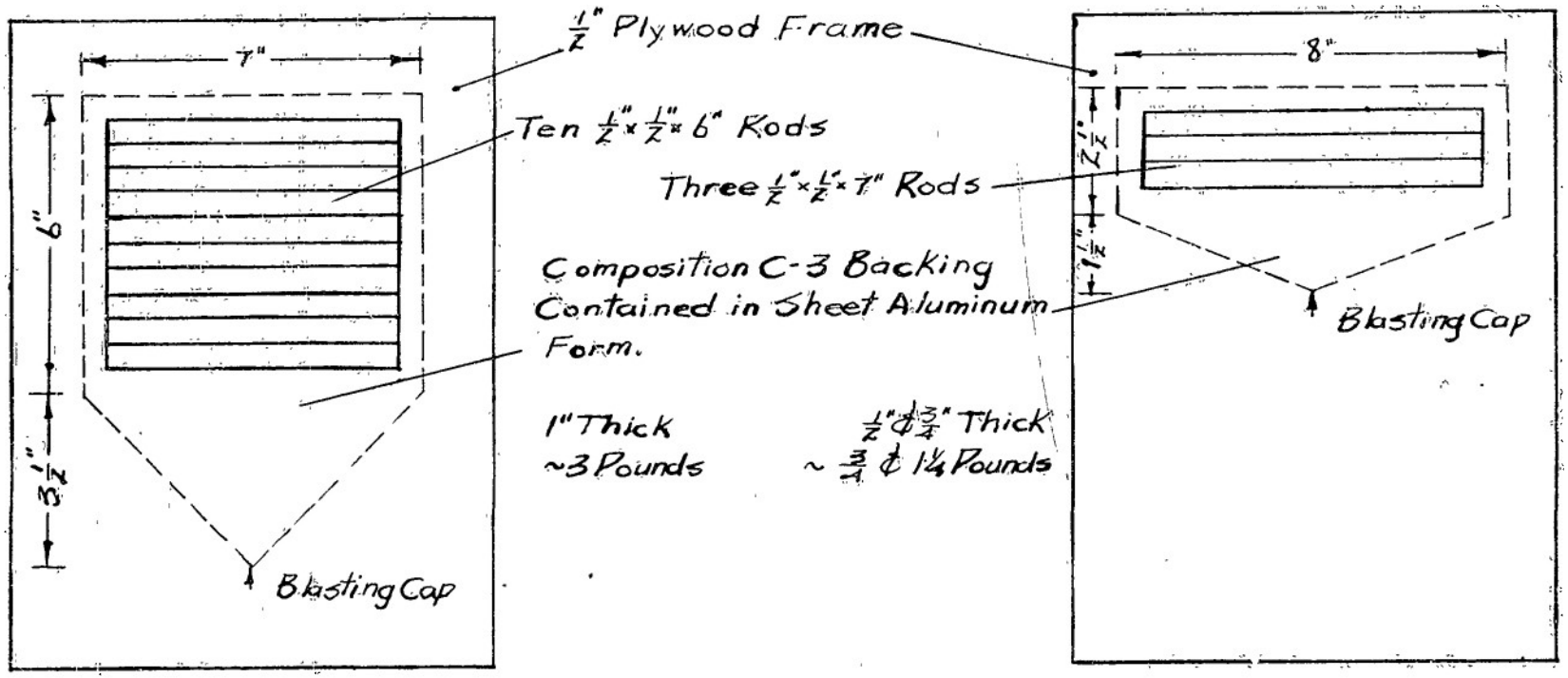
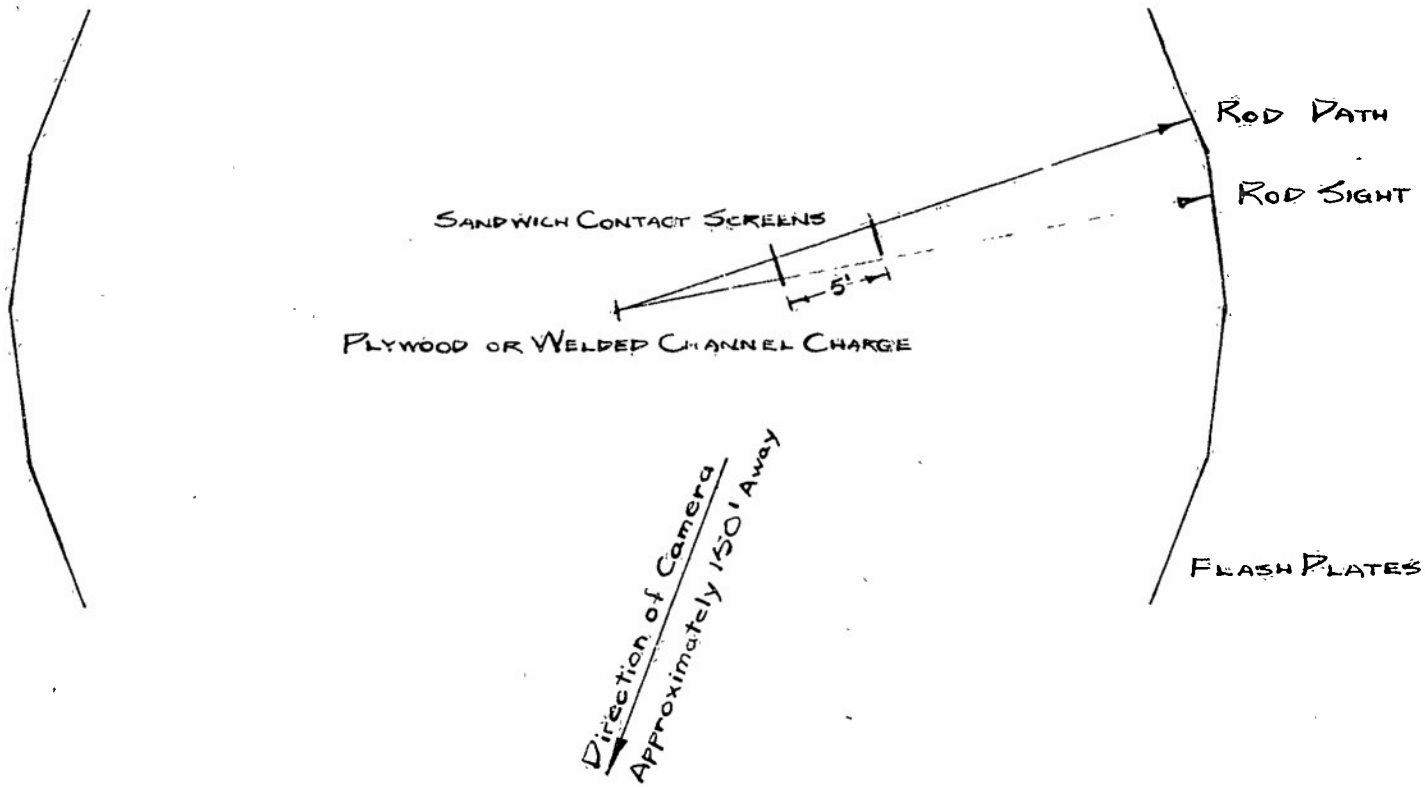
FIGURE 3



RODS IN FLAT PLATE CONFIGURATION

TEST ARRANGEMENT 30' ARENA



APPENDIX B

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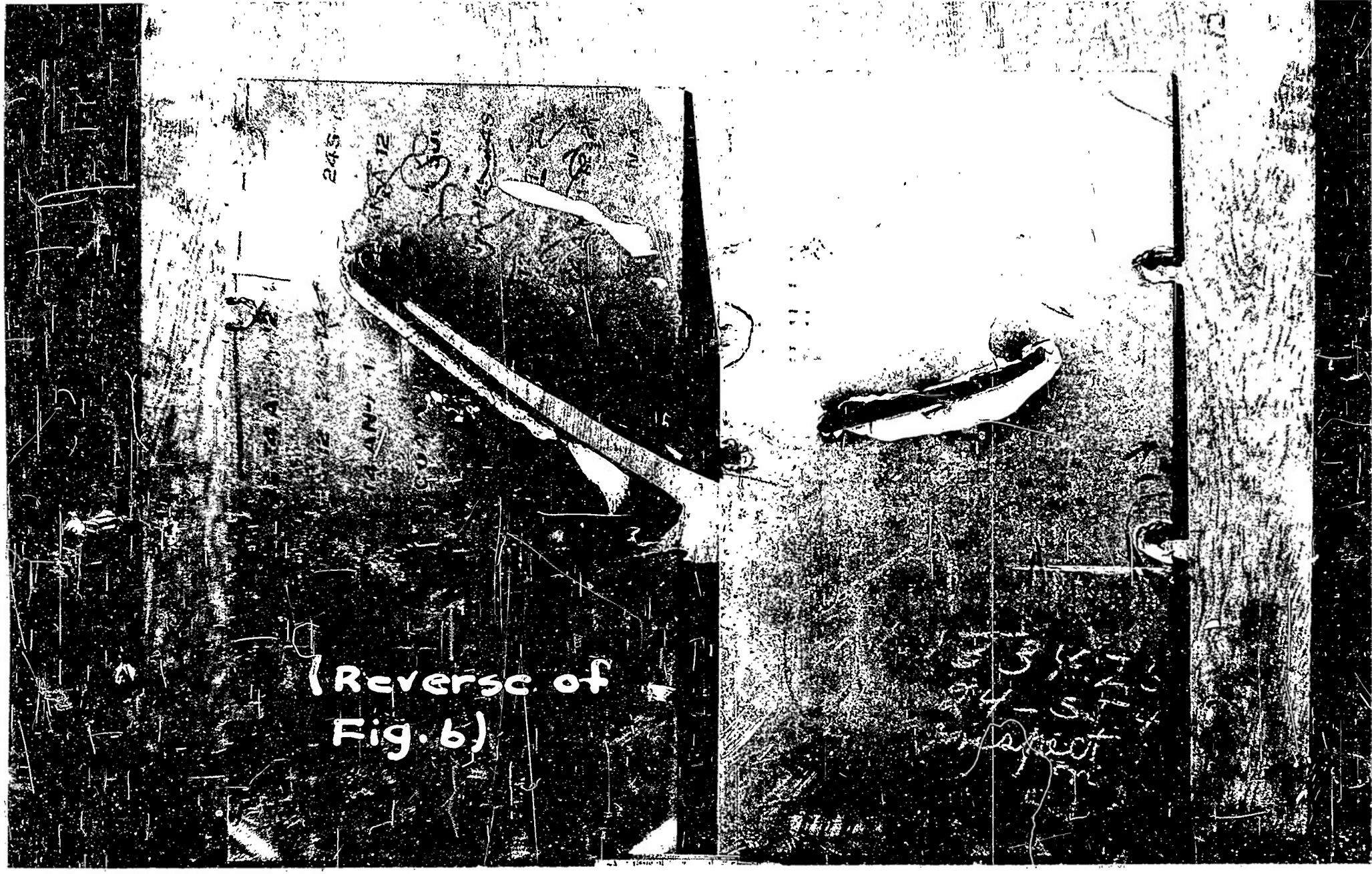
FIGURE 5

NP9-45571

24 September 1951
1/2" 24S-T4 Aluminum Plate.
Figure 6

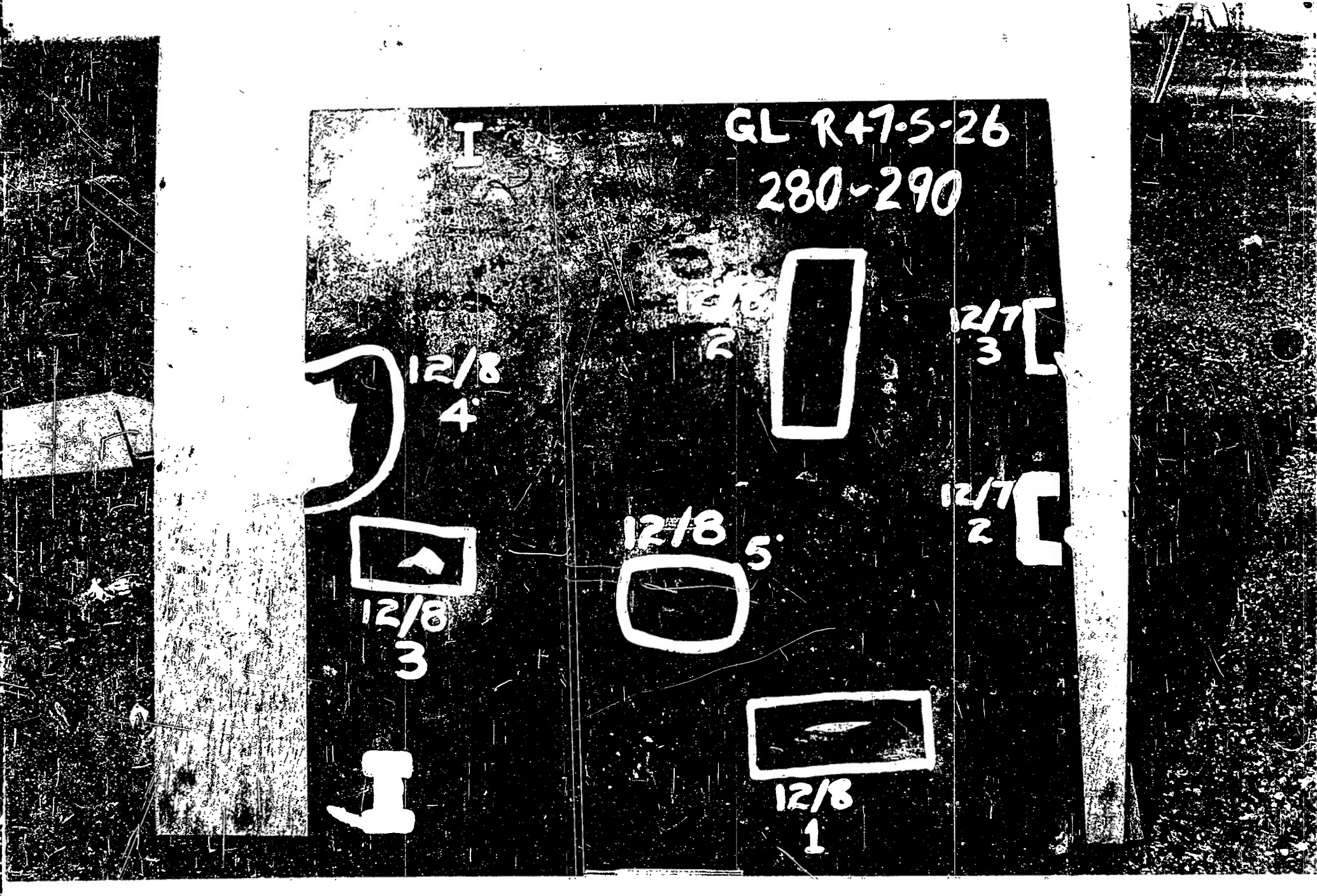
CONFIDENTIAL



NP9-45572

24 September 1951
1/2" 24S-T4 Aluminum Plate.
Figure 7

CONFIDENTIAL



NP9-45573

24 September 1951
3/8" STS Plate.
Figure 8

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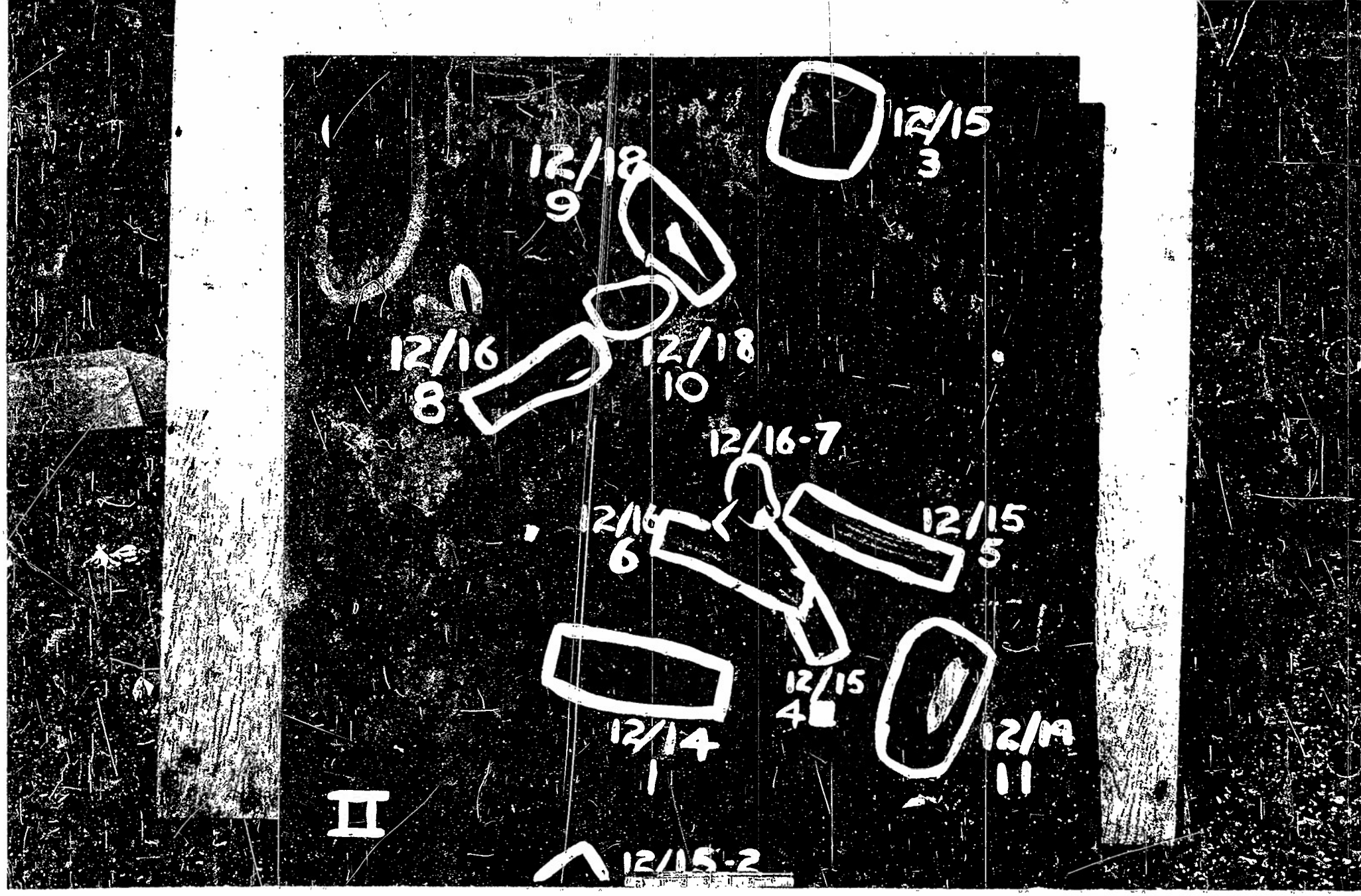
NP9-45574

24 September 1951
3/8" STS Plate.
Figure 9

CONFIDENTIAL



NP9-45575

24 September 1951
3/8" Mild Steel Plate.
Figure 10

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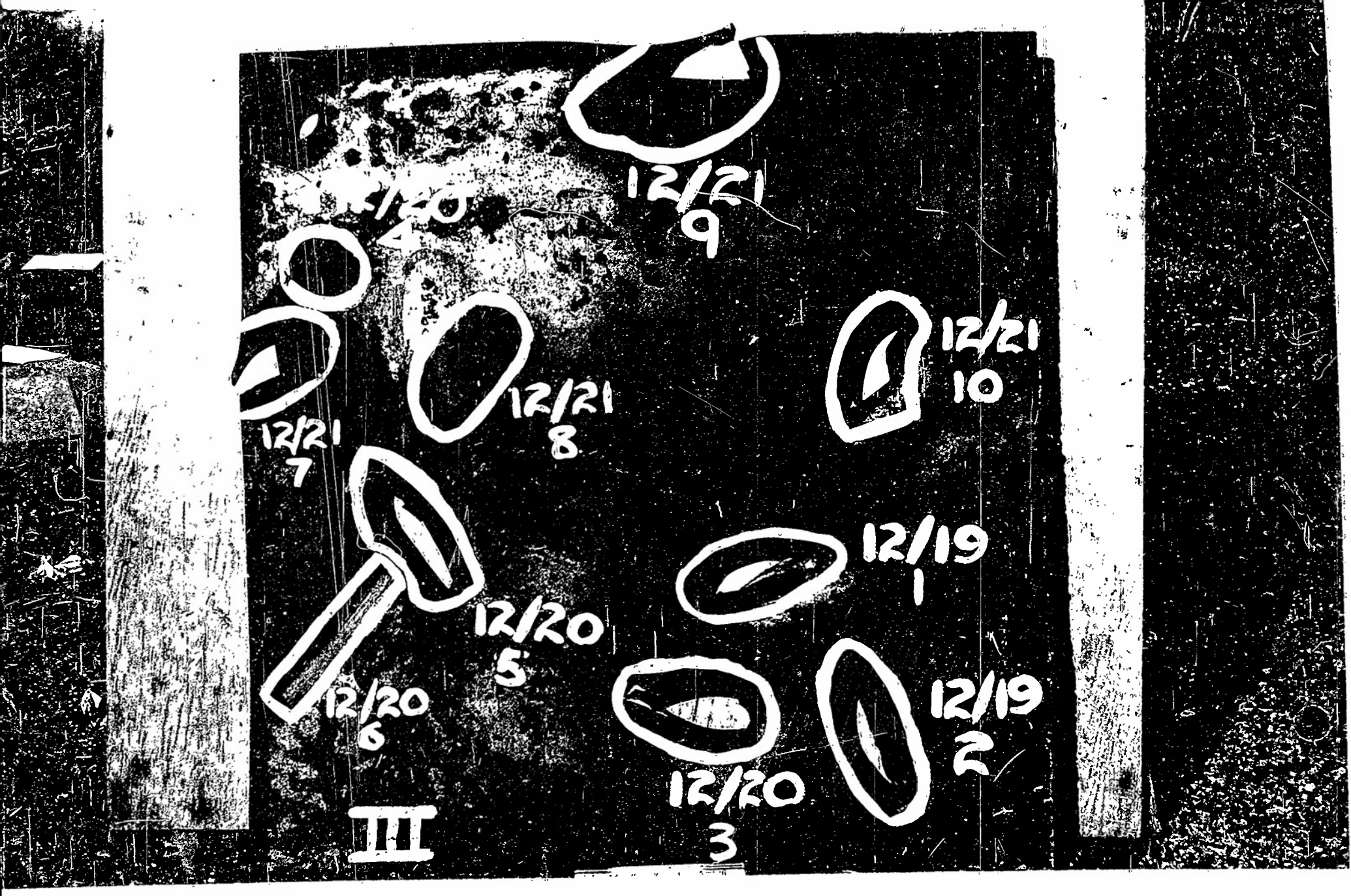
NP9-45576

24 September 1951
3/8" Mild Steel Plate.
Figure 11

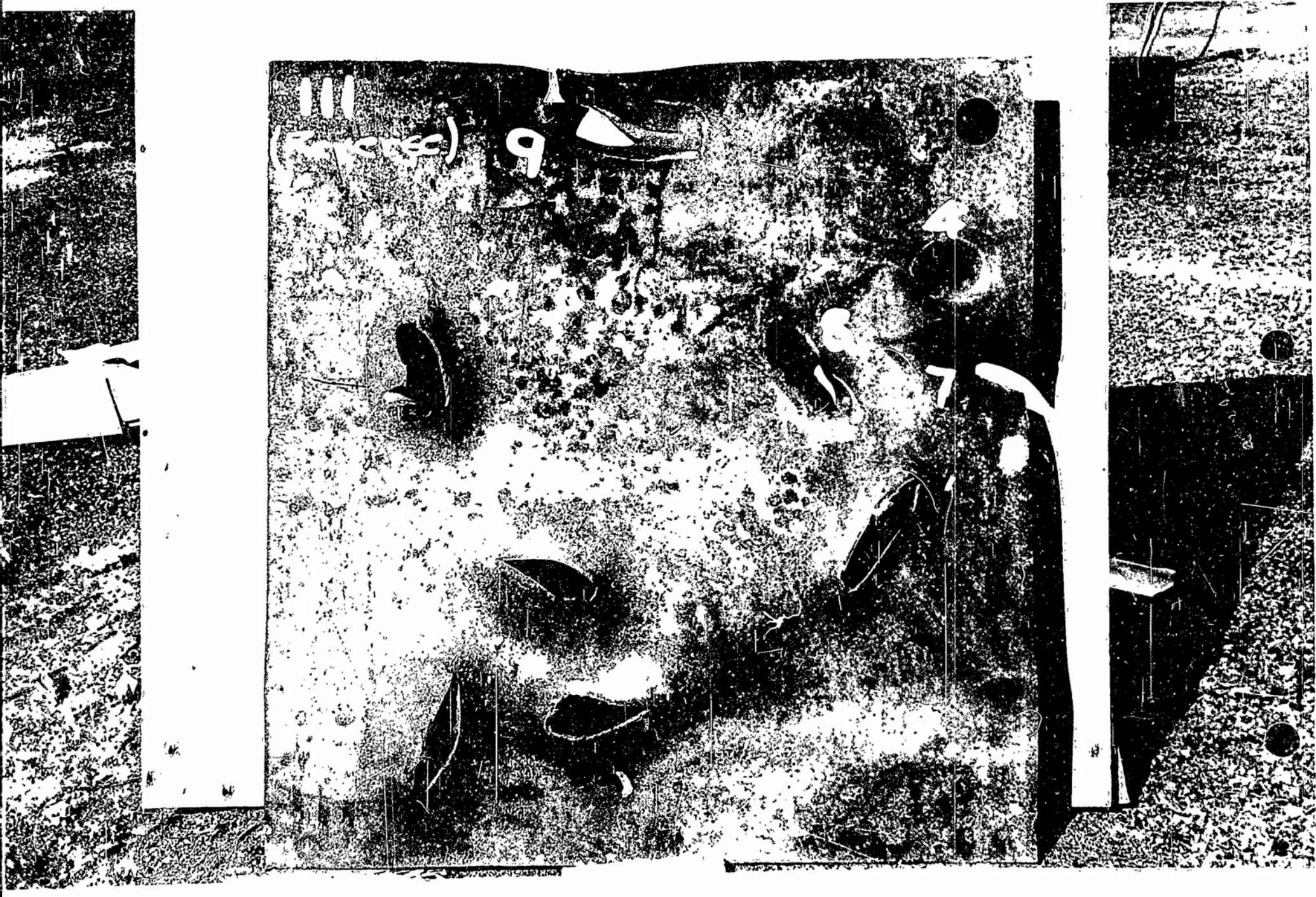
CONFIDENTIAL



NP9-45577

24 September 1951
1/4" Mild Steel Plate.
Figure 12

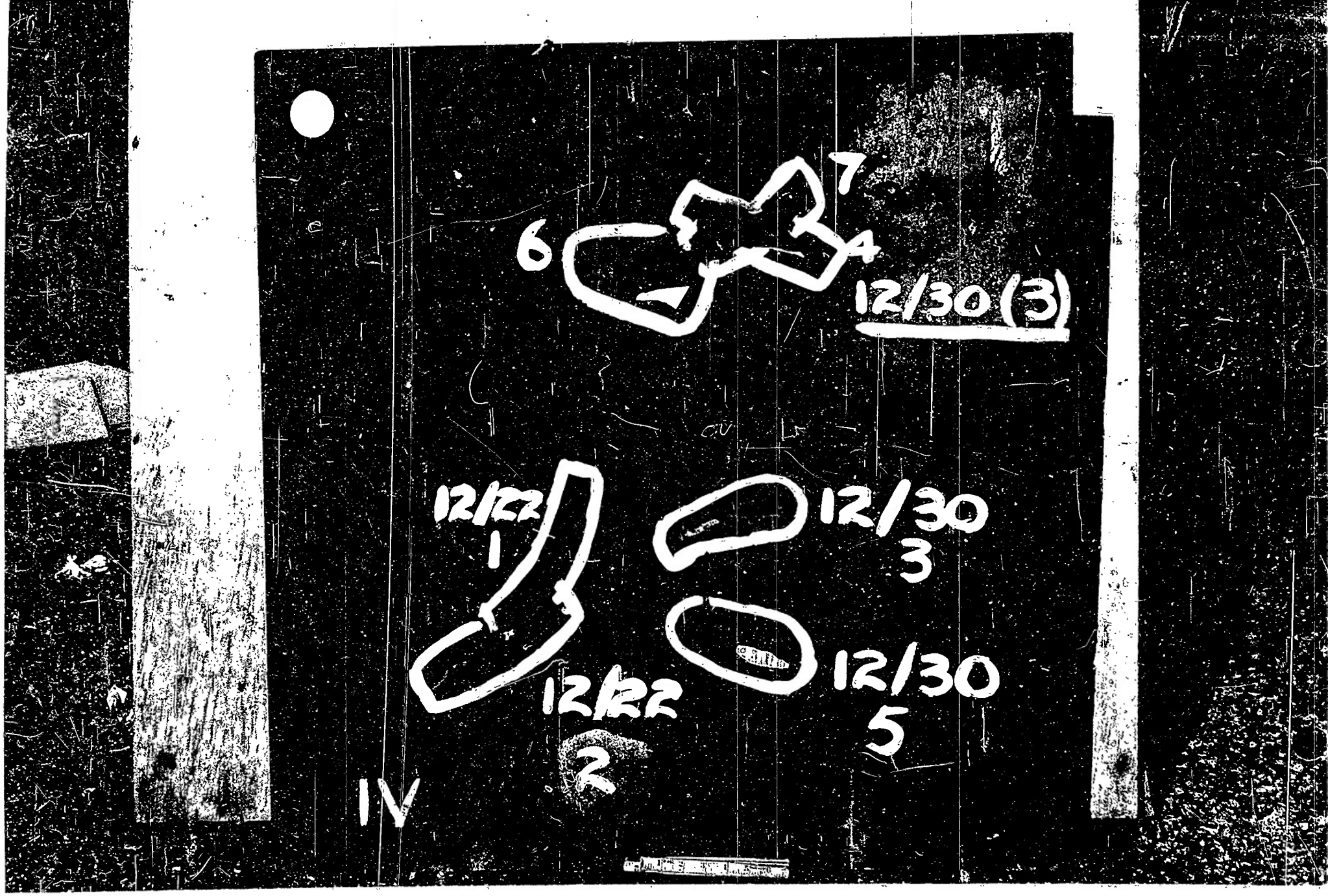
CONFIDENTIAL



NP9-45578

24 September 1951
1/4" Mild Steel Plate.
Figure 13

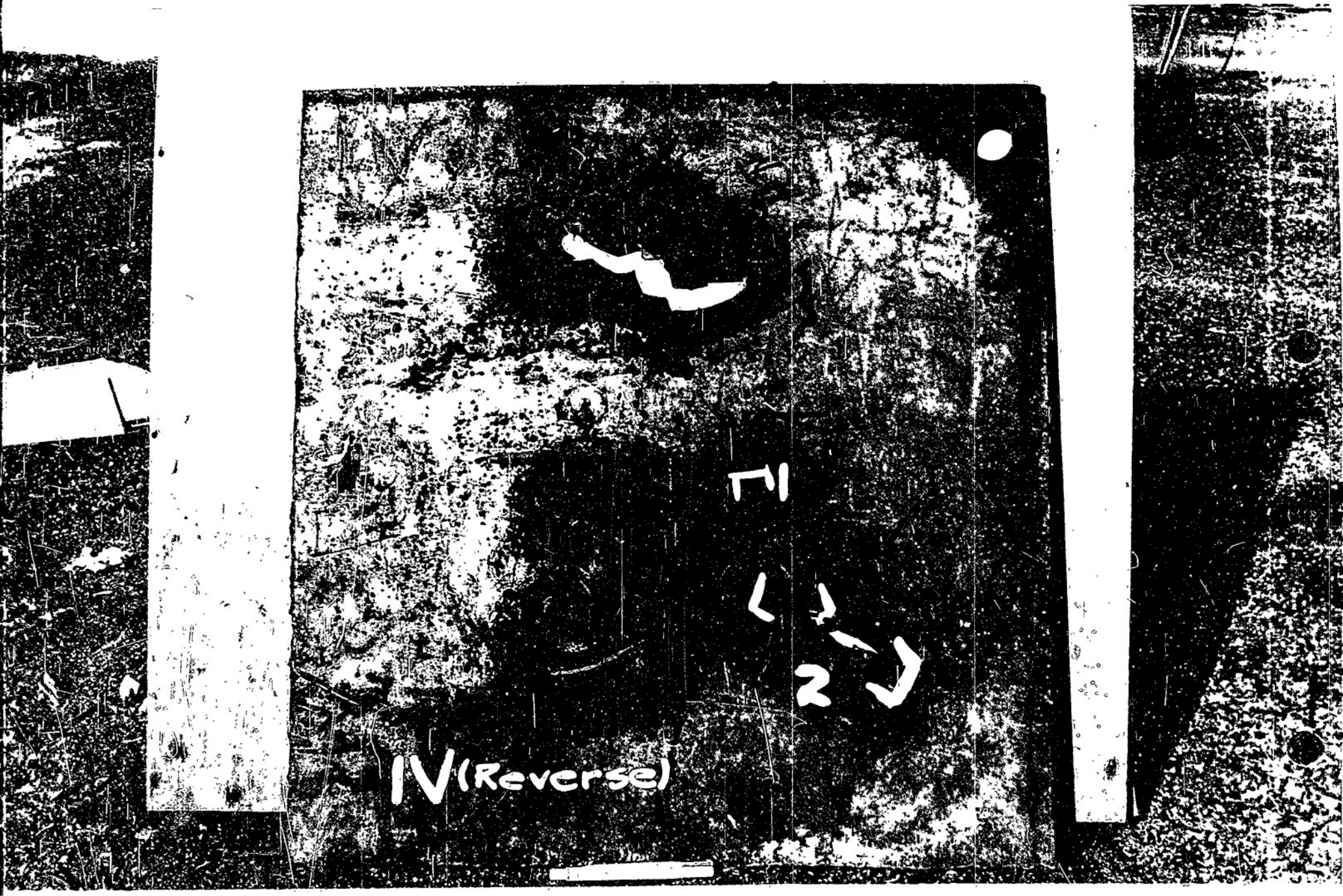
CONFIDENTIAL



NP9-45579

24 September 1951
3/8" Mild Steel Plate.
Figure 14

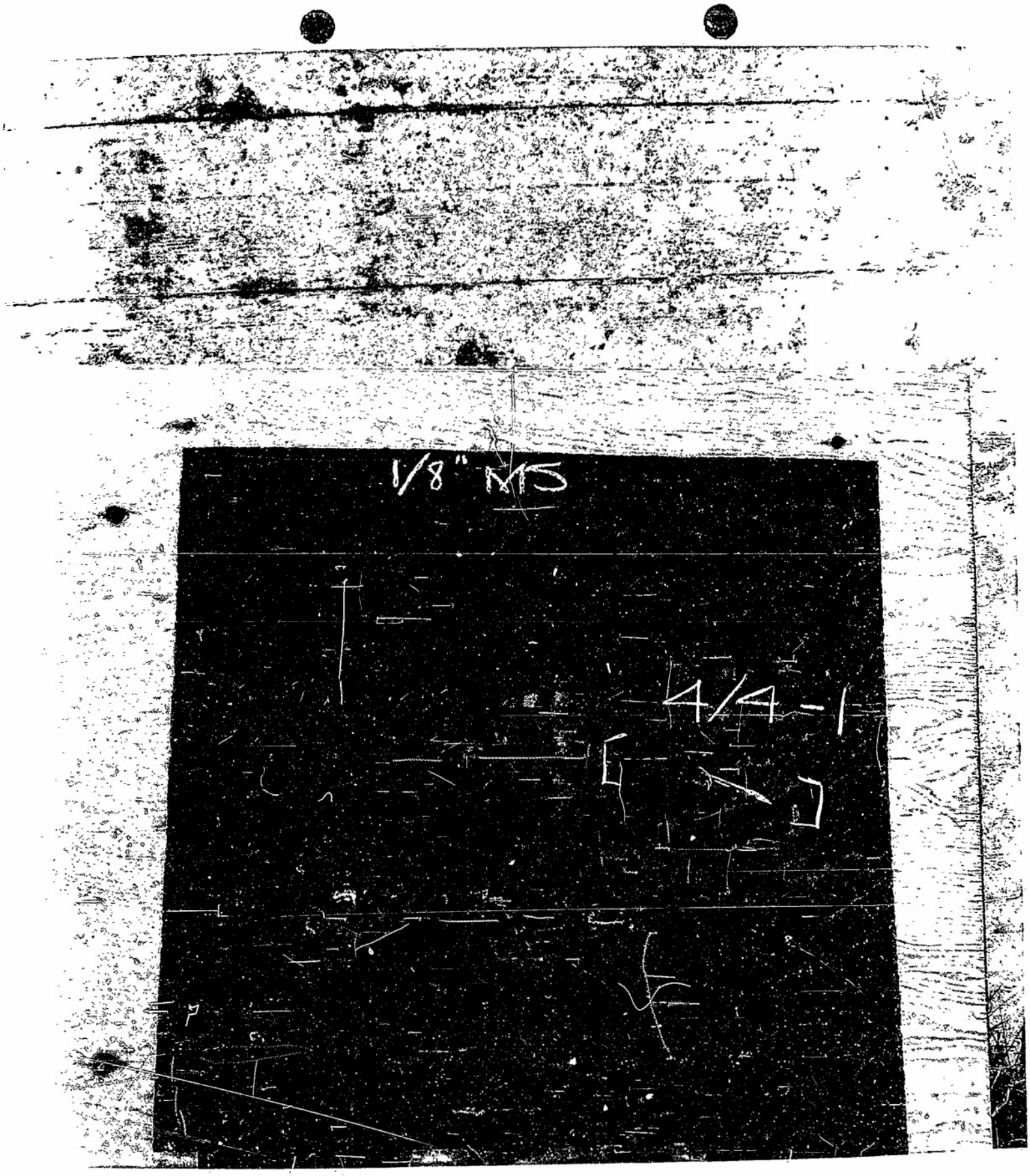
CONFIDENTIAL



NP9-45580

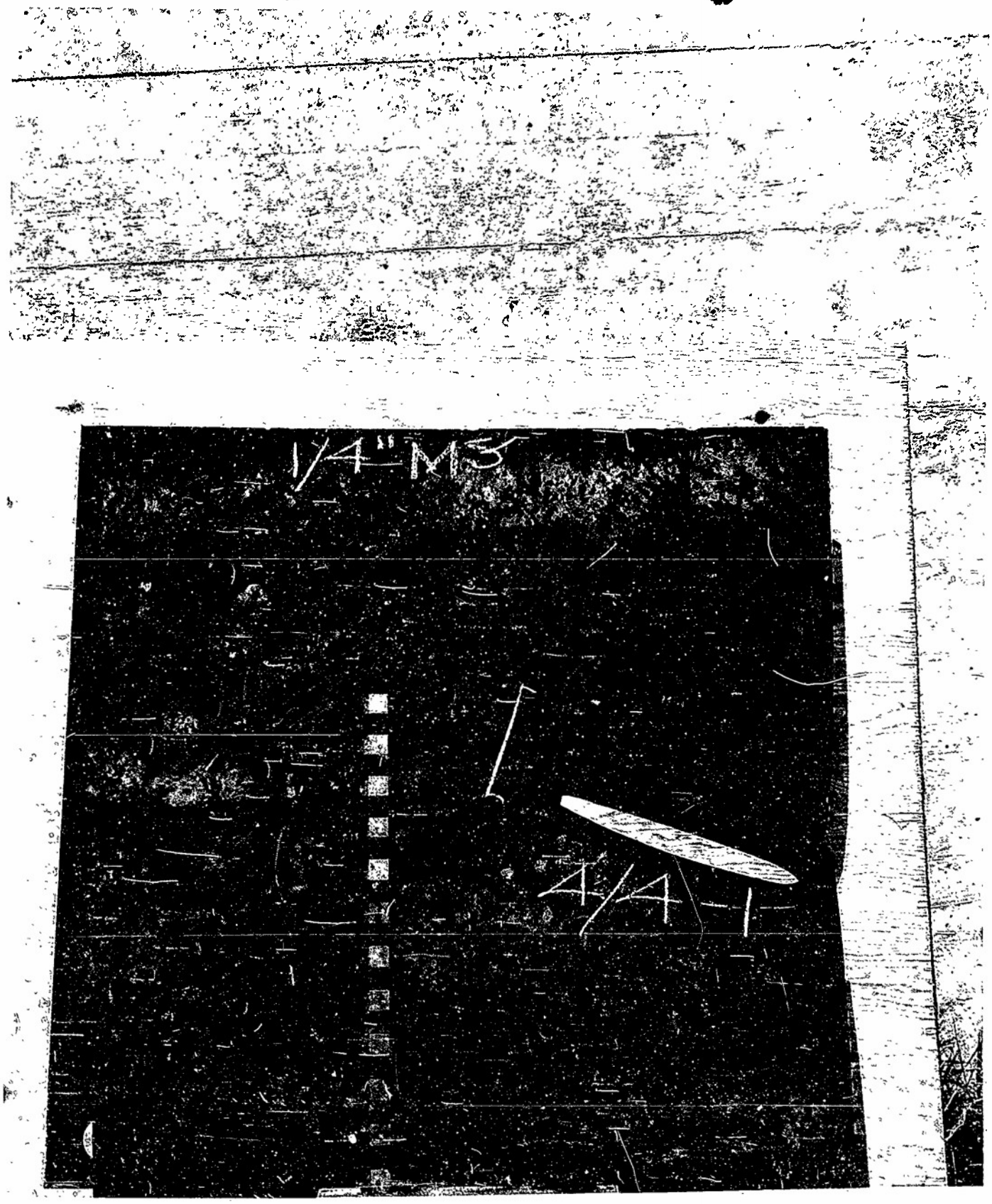
24 September 1951
3/8" Mild Steel Plate.
Figure 15

CONFIDENTIAL



NP9-45581 24 September 1951 CONFIDENTIAL

Figure 16

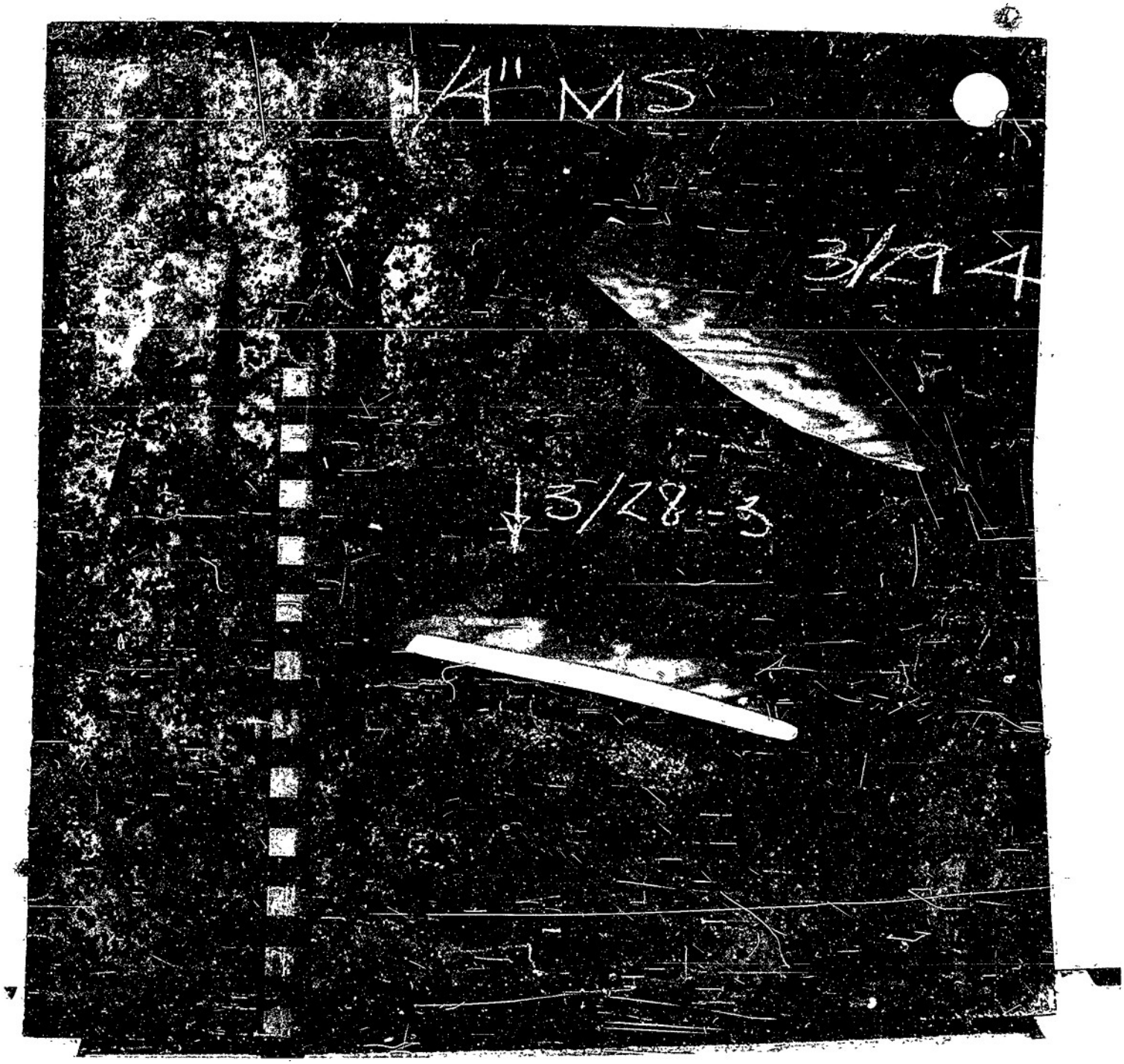


NP9-45582 24 September 1951 CONFIDENTIAL

Figure 17

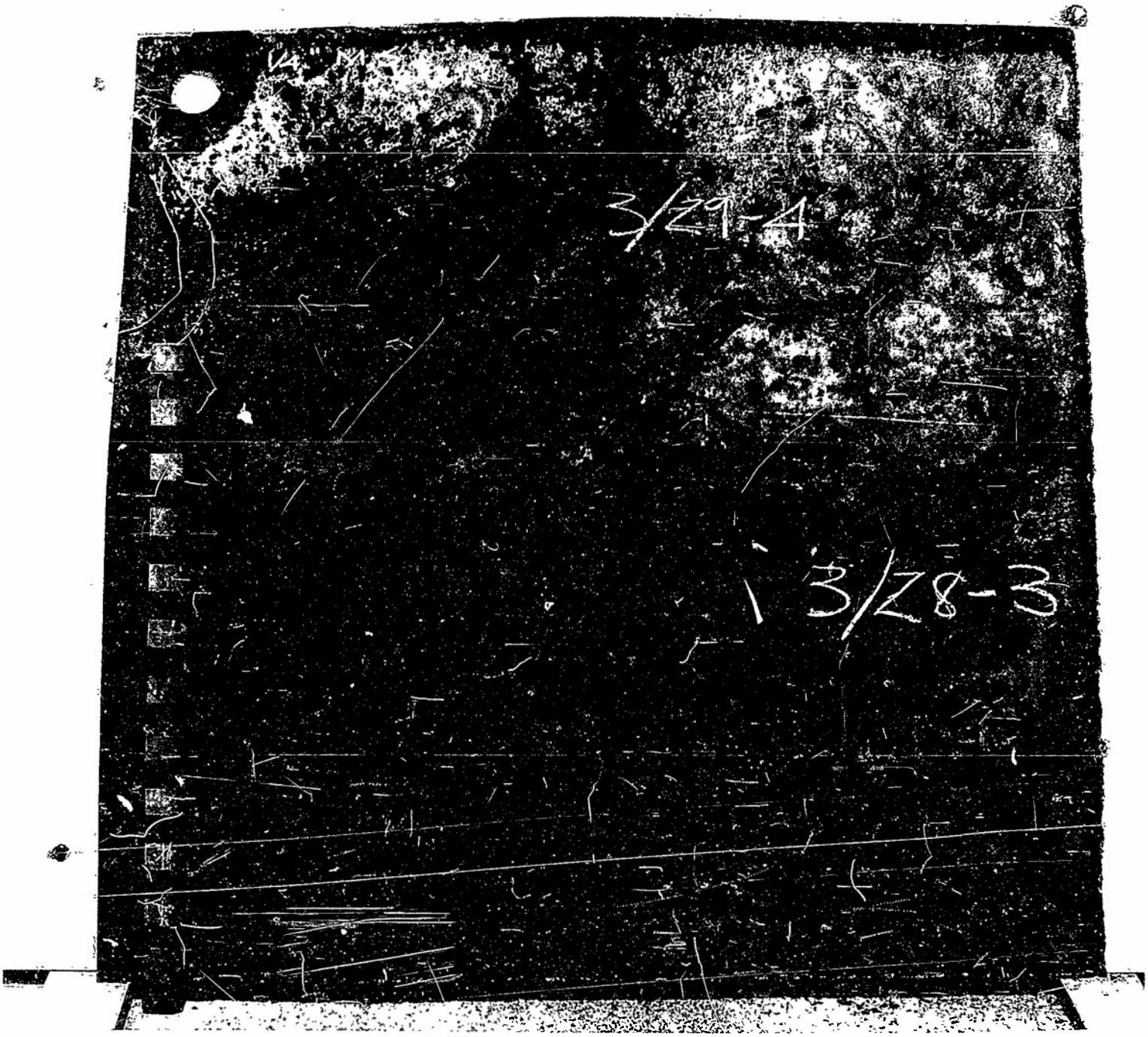
NP9-45583 24 September 1951 CONFIDENTIAL

Figure 18



NP9-45584 24 September 1951 CONFIDENTIAL

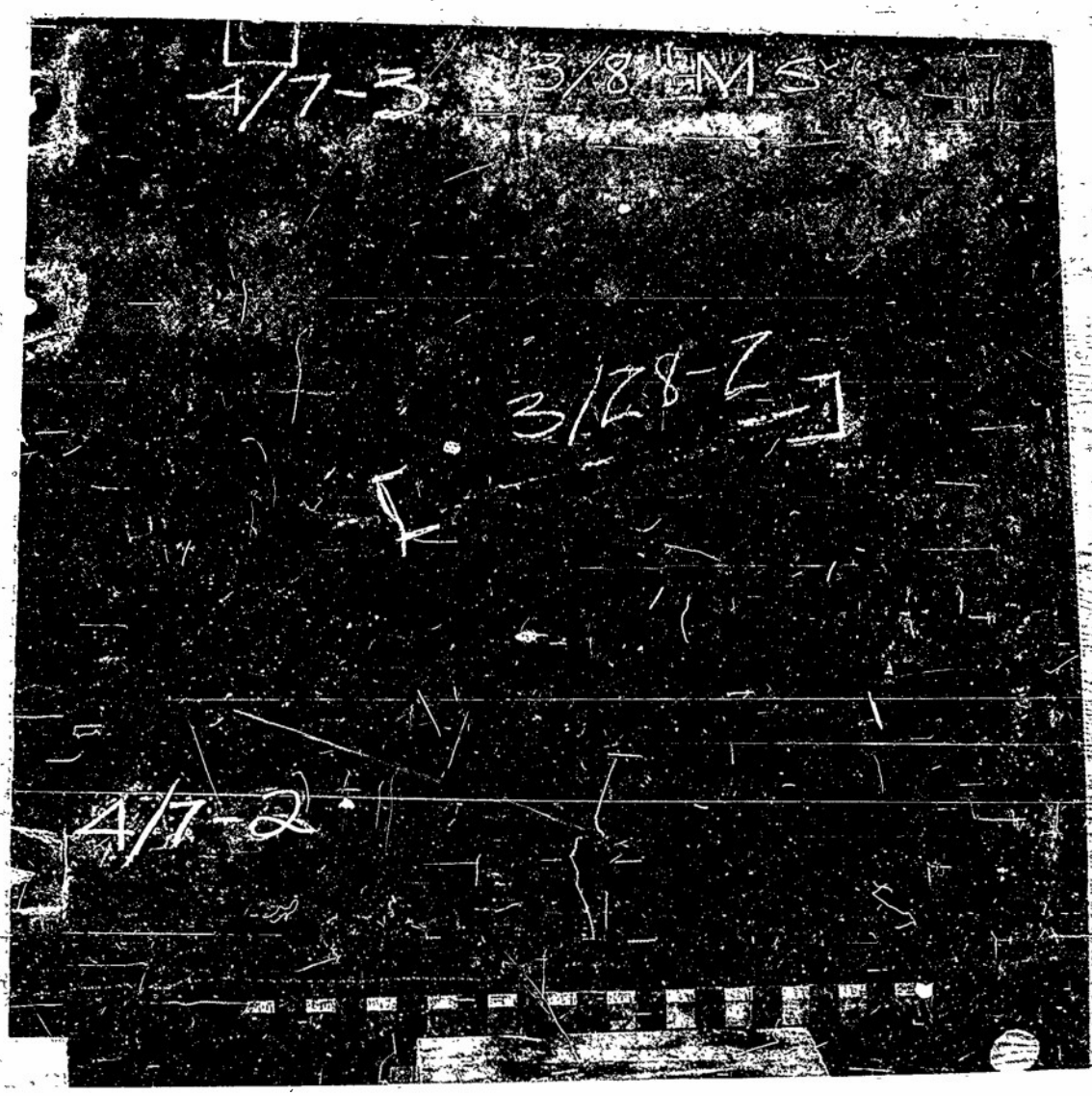
Figure 19



NP9-45585 24 September 1951 CONFIDENTIAL

Figure 20

Figure 21



NP9-45587 24 September 1951 CONFIDENTIAL

Figure 22

NP9-45588 24 September 1951 CONFIDENTIAL

Figure 23

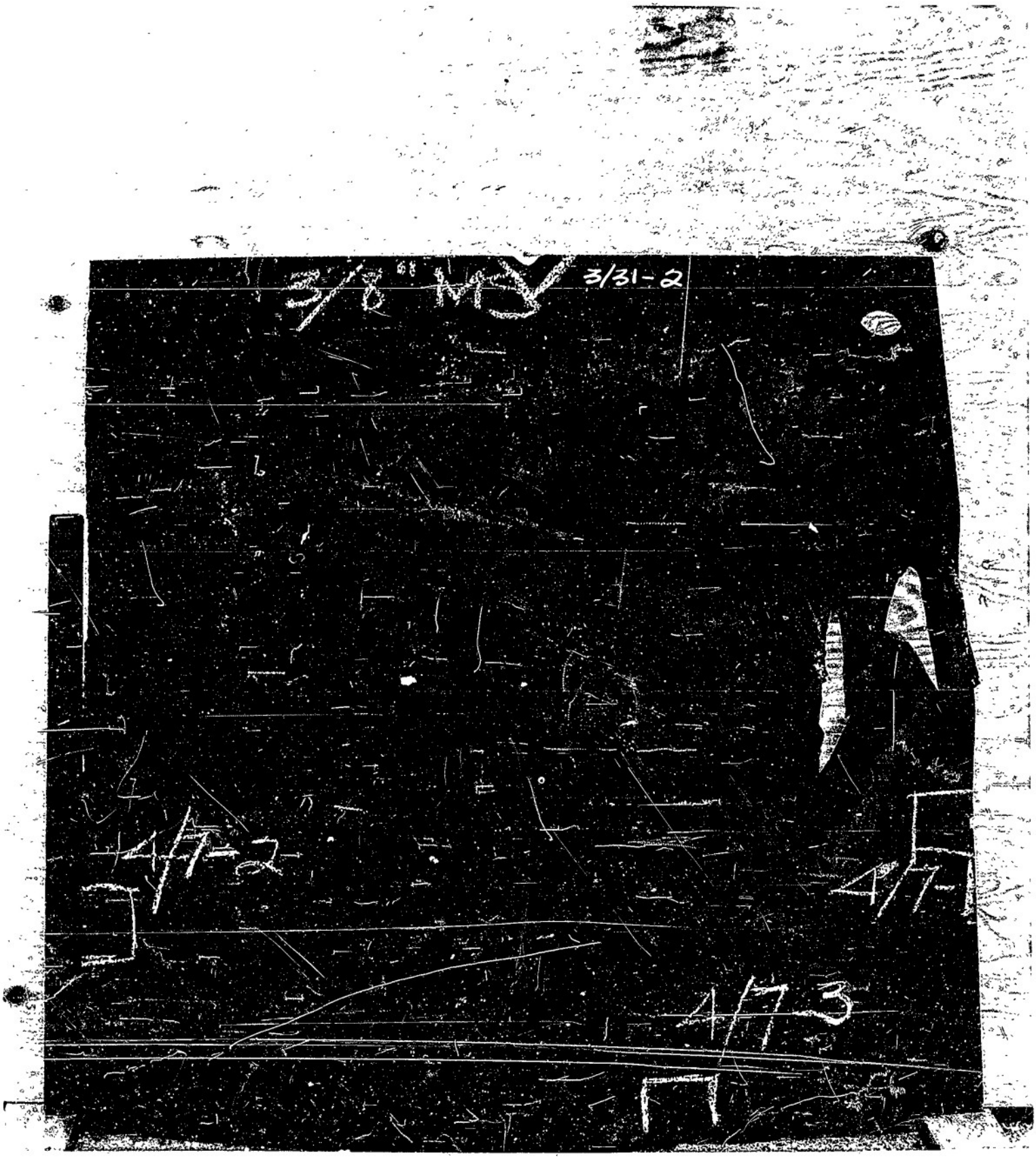
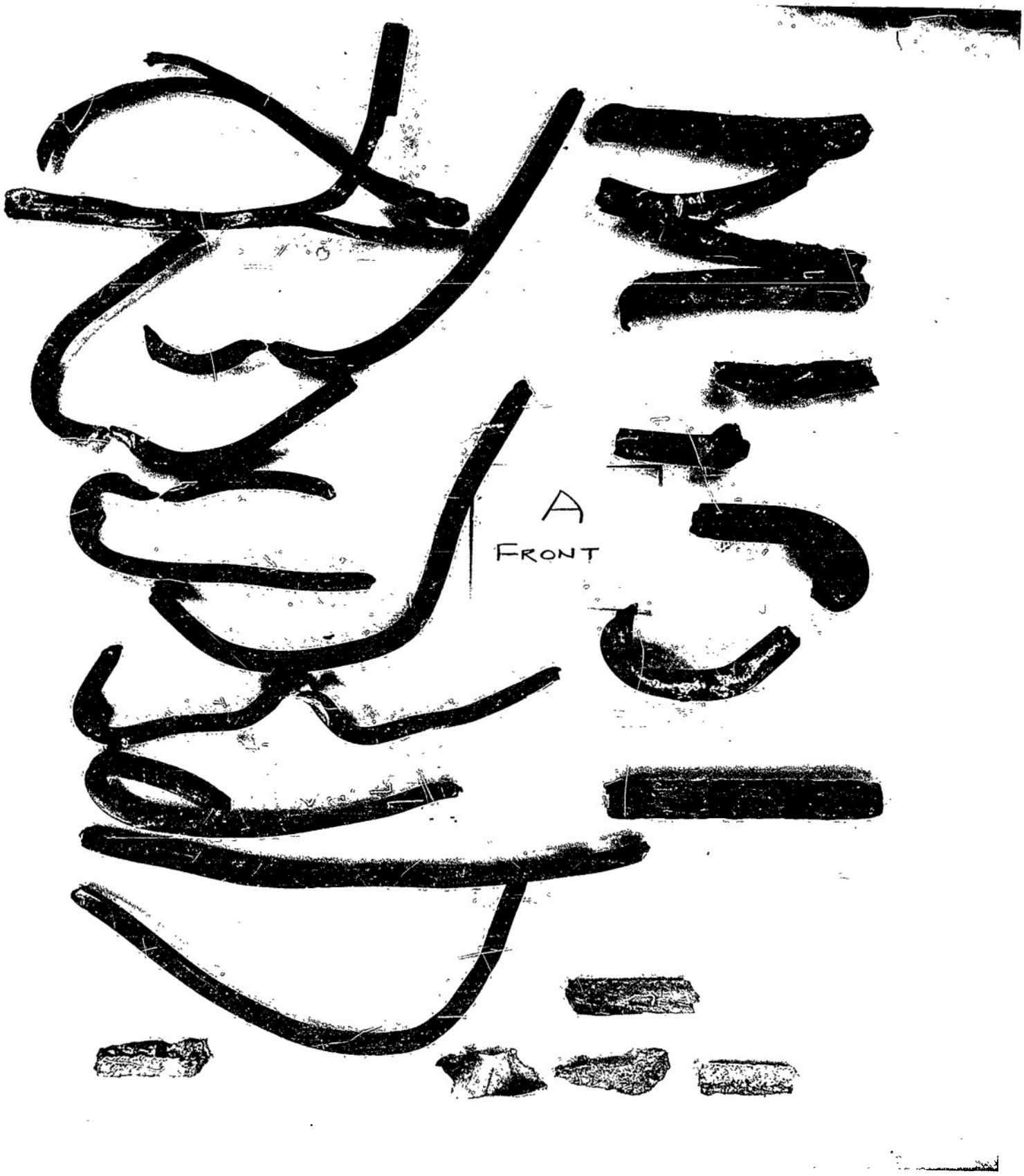


Figure 24

NP9-45590 24 September 1951 CONFIDENTIAL

Figure 25



NP9-45591

24 September 1951

CONFIDENTIAL

Figure 26

Figure 27

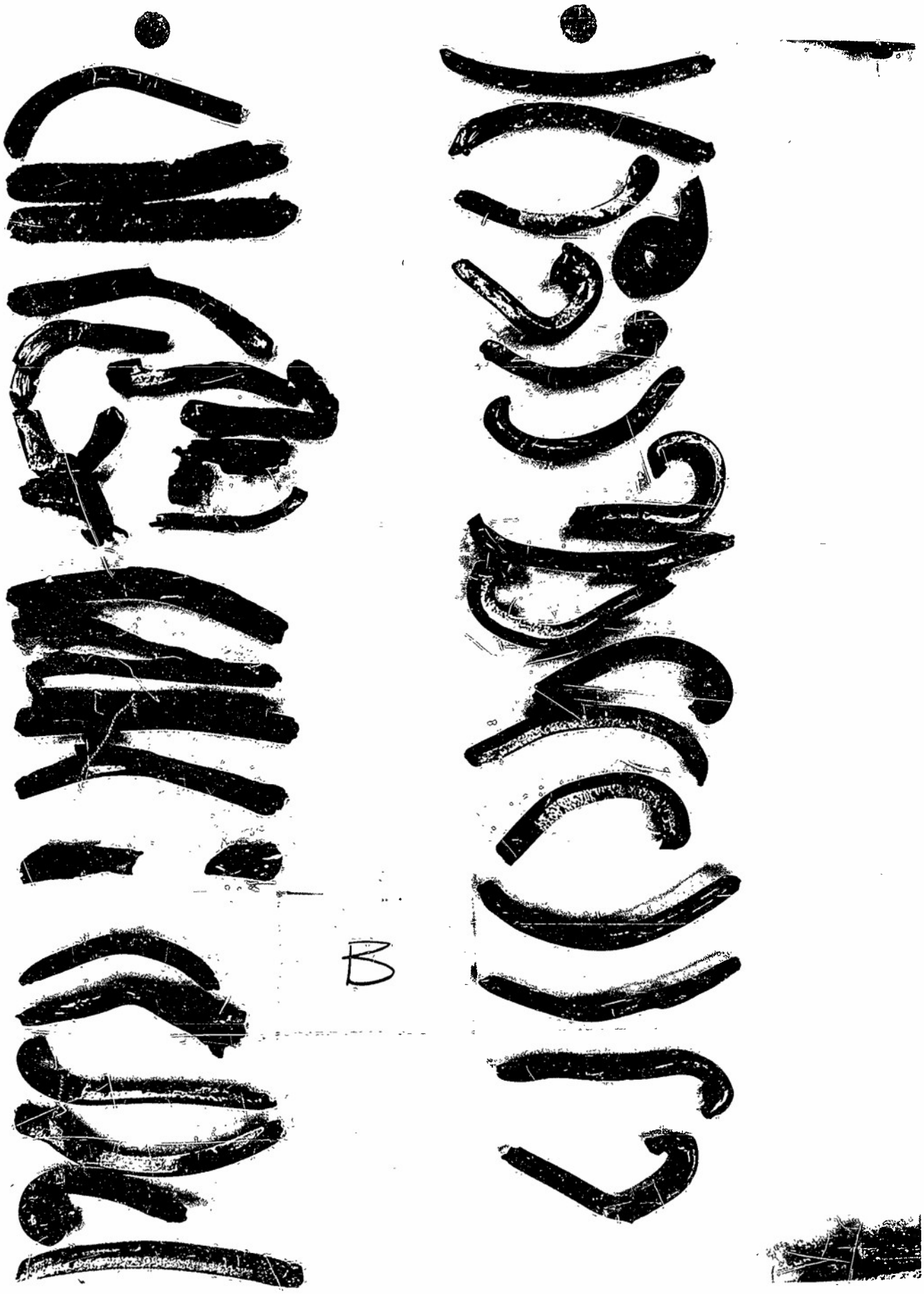


Figure 28

NP9-45594 24 September 1951 CONFIDENTIAL

Figure 29

NP9-45595 24 September 1951 CONFIDENTIAL

Figure 30

NP9-45596 24 September 1951 CONFIDENTIAL

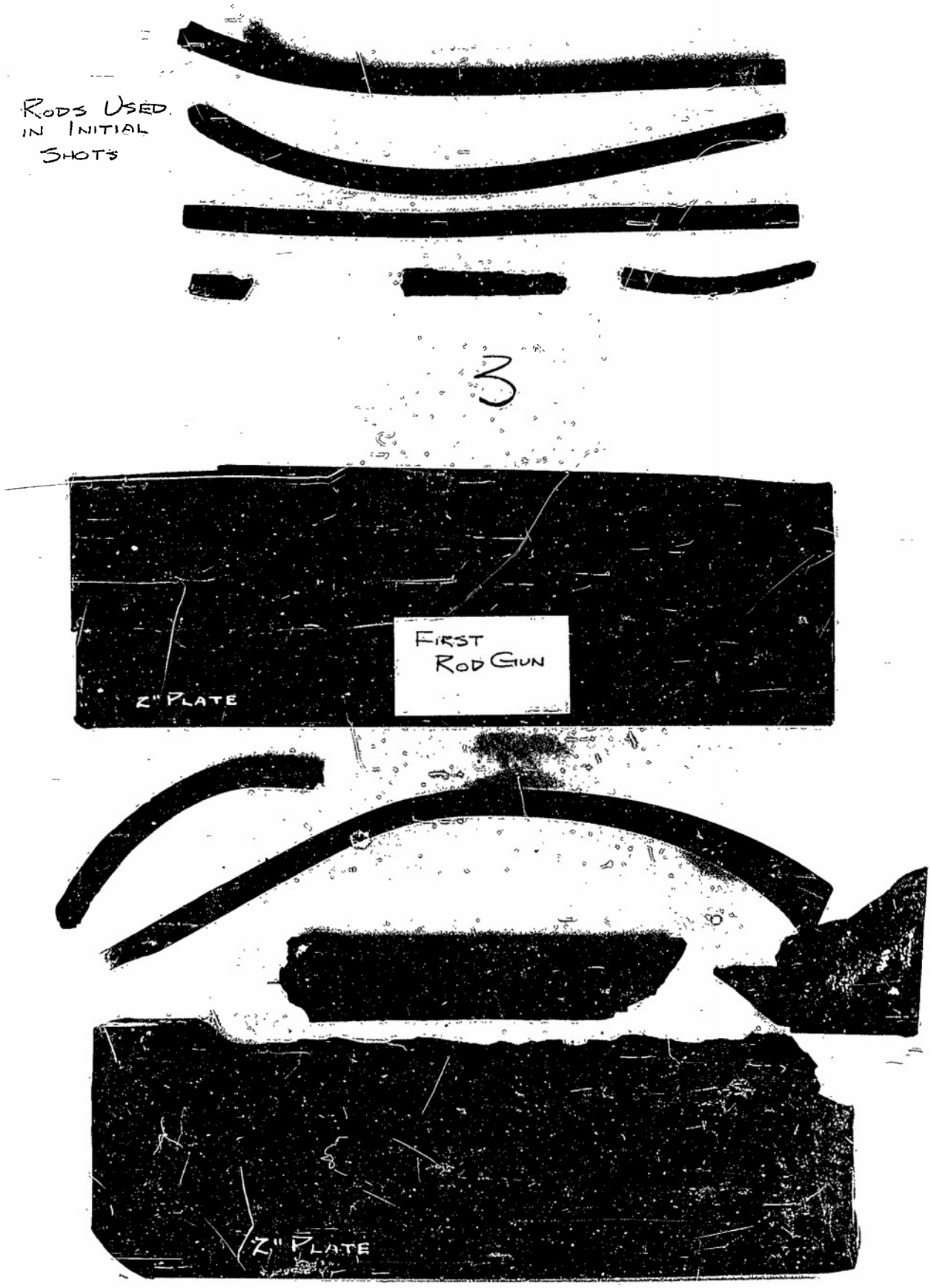
Figure 31

NP9-45597 24 September 1951 CONFIDENTIAL

Typical Free Plate Rod Gun Fragments.

Figure 32

Figure 33



NP9-45599 24 September 1951 CONFIDENTIAL

Figure 34

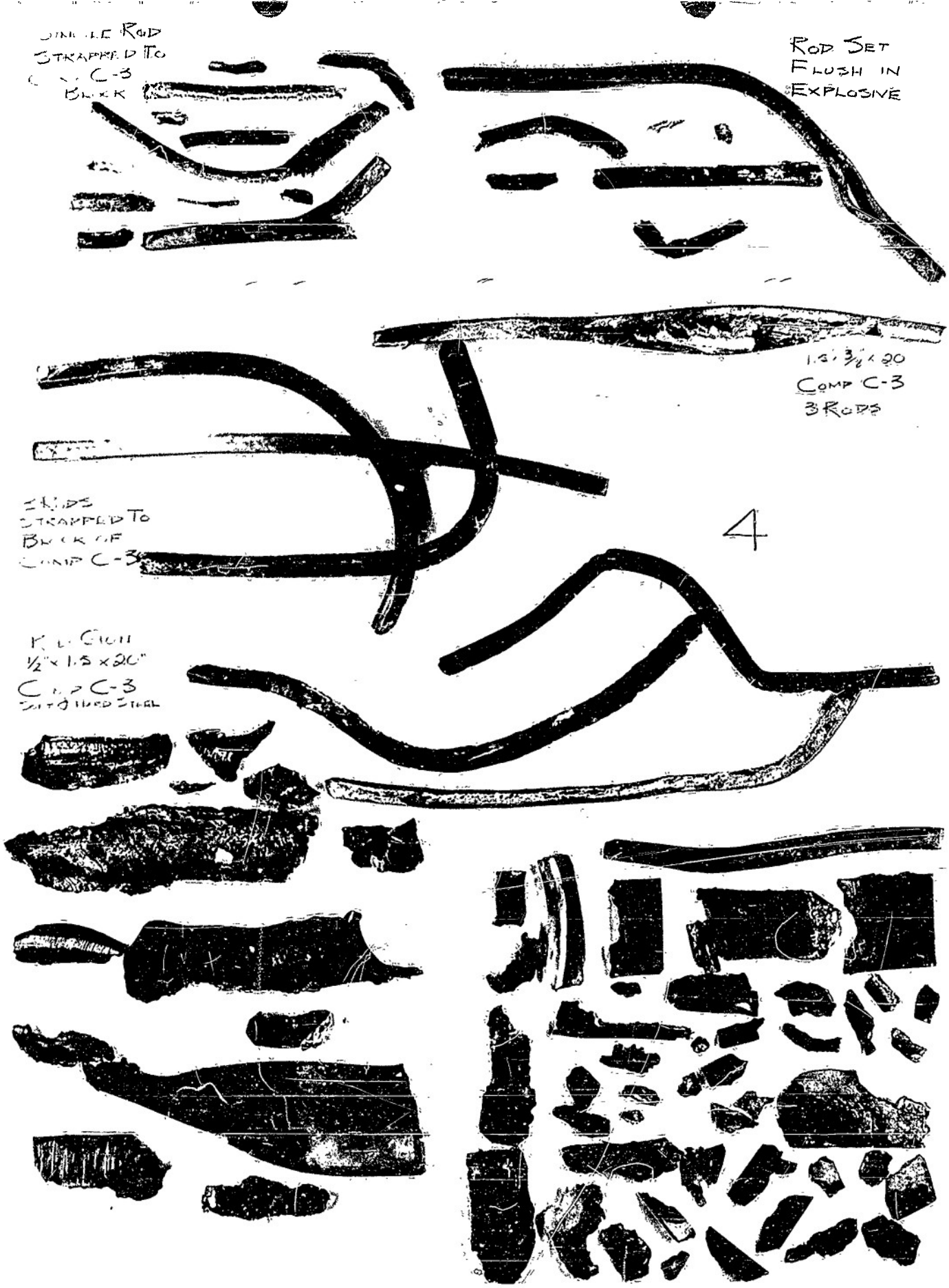
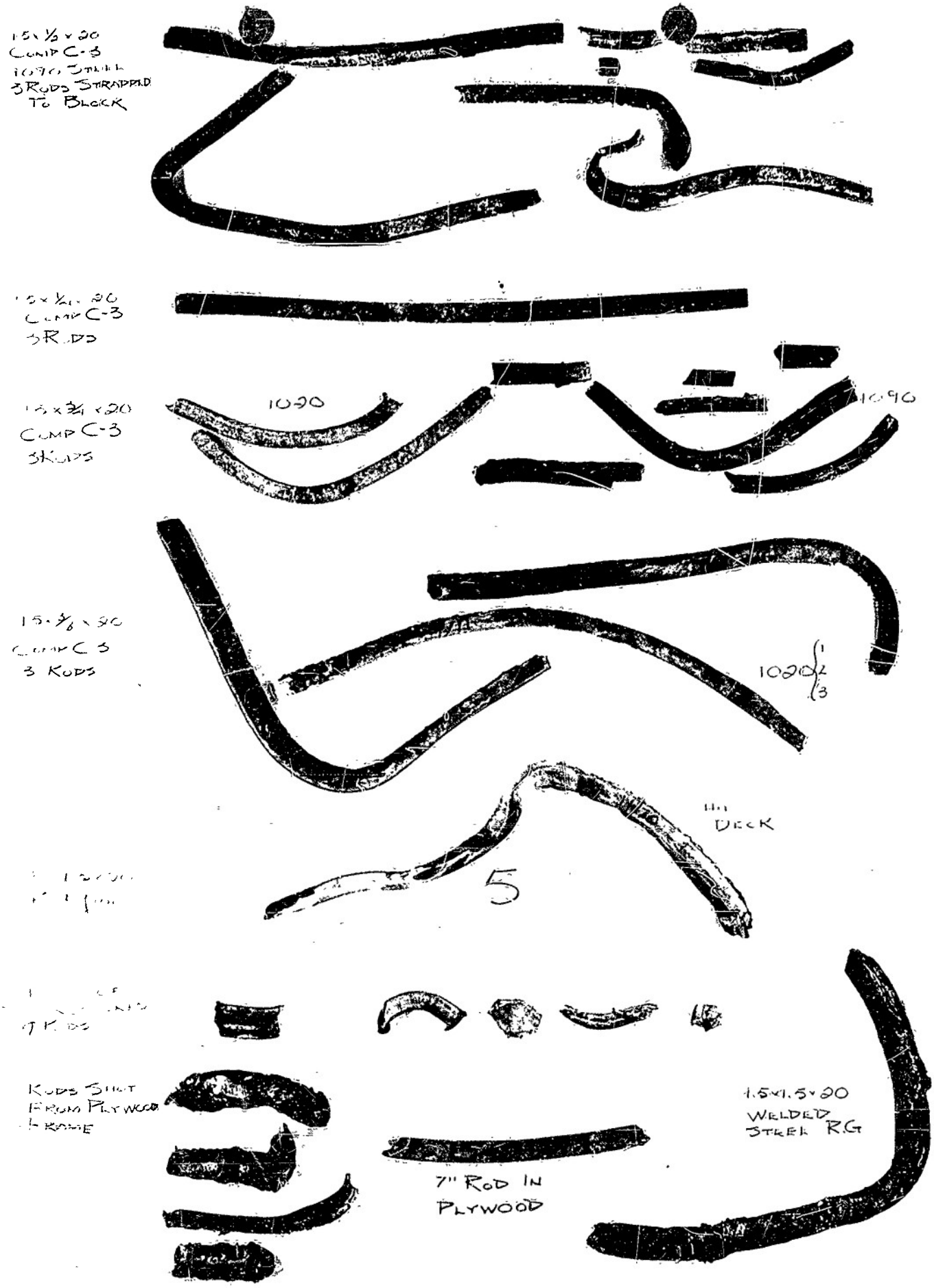


Figure 35

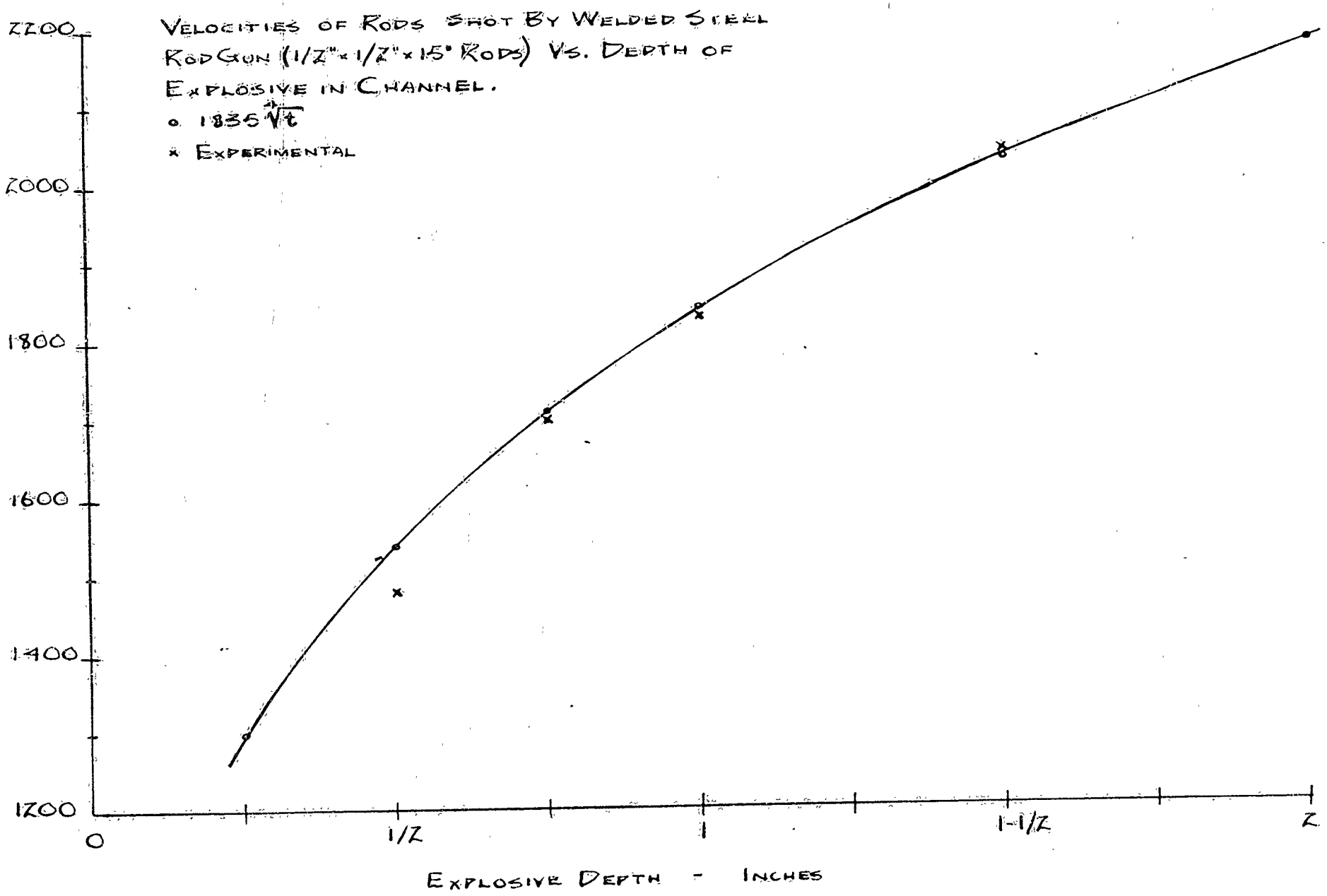


NP9-45601 24 September 1951 CONFIDENTIAL

Figure 36

NP9-45602 24 September 1951

Figure 37



APPENDIX E

FIGURE 38