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U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

REPORT NO. 950

BOMBS AND ASSOCIATED COMPONENTS

32nd Partial Report

- - - - - - - - - - - - - - - - - -

PLATE PENETRATION TESTS OF THE 2000 LB. BOMB, G. P. (LOW DRAG), TYPE EX-11, MOD. 0

FINAL Report

Copy No. 4

Task Assignment NPG-Re3c-321-1-52

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Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod 0

PART A

SYNOPSIS

1. The tests reported herein were conducted to determine (a) the maximum armor (STS) plate thickness which the 2000 lb. G.P. Low Drag Type EX 11 Mod 0 bomb body will penetrate and remain in an effective bursting condition, (b) the degree of acceptable deformation of the bomb body resulting from impact, and (c) the conditions under which the bomb will fail. Further, a metallurgical study was made of the recovered bomb bodies in order to determine any points of weakness or causes of failure and to suggest any corrective measures that should be taken to improve the bomb performance or facilitate production.

2. It is concluded that:

a. The maximum STS armor plate thickness the inert loaded 2000 lb. G.P. Low Drag Type EX 11 Mod 0 bomb will penetrate and remain in effective bursting condition when fired at 1000 ft./sec. velocity at 20° obliquity is 1-7/8".

b. The firing condition which caused failure of the 2000 lb. G.P. Low Drag Type EX 11 Mod 0 bomb occurred when the bomb was fired at 20° obliquity against 2".0 STS armor using a striking velocity of 1000 ft./sec.

c. No quantitative figures can be given for the amount of acceptable deformation resulting from impact. Deflagration tests were not conducted and thus it cannot be estimated what conditions would be critical as far as deflagration is concerned. From the manner in which the bomb broke up when fired against 2".35 STS armor at 20° obliquity at 1000 ft./sec. it may be reasonable to assume that deflagration would occur at these conditions. The bomb becomes ineffective when cracking occurs which takes place when bomb is fired at 2".0 STS armor at 20° obliquity at 1000 ft./sec. velocity.

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

d. The primary cause for the failure of Bomb #20 was the segregated condition of the steel in the area 180° from the weld. The other two bombs examined, #3 and #7, were satisfactory metallurgically with the possible exception that the ductility was somewhat low.

3. The A. O. Smith Co. is experimenting with a boron steel for the manufacture of this type of bomb. Also, the National Tube Co. is redesigning the nose section and is modifying its N-80 steel by substituting a small percentage of chromium for the molybdenum content, both of these changes being made for strengthening purposes. Consequently, no recommendation will be made at present pending the outcome of the above mentioned experiments.

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

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Plate Penetration Tests of the 2000 lb. Bomb, G.P. (Low Drag), Type EX-11, Mod 0

PART B

INTRODUCTION

1. AUTHORITY:

This test was conducted by authority of references (a) and (b). The test was conducted in accordance with enclosure (2) of reference (a).

2. REFERENCES:

a. BUORD Conf ltr Re3c-REN:mt, NP9/ Serial 18721 of 28 March 1951
b. Task Assignment NPG-25-Re3c-321-3
c. NPG Report No. 646 of 21 September 1950
d. NPG Report No. 694 of 29 December 1950
e. NPG Report No. 748 of 3 April 1951
f. NPG Report No. 878 of 20 October 1951

3. BACKGROUND:

Presently existing AN standard G.P. bombs, because of excessive drag, materially reduce the maximum performance of high speed aircraft when these bombs are suspended externally. The Bureau of Ordnance, therefore, has developed a new family of bombs designed to reduce the drag when they are suspended externally from aircraft. This new family of bombs is called collectively the Low Drag bomb. The first test of this family involved the 1000 lb. Low Drag bomb, Type EX-10. The results of this test were reported in reference (c). The second test was of the 250 lb. Low Drag, G.P. Bomb, Types EX-1 Mod 0, EX-1 Mod 1, and EX-2 Mod 0. The results of this test were reported in reference (d). The third test involved the 1000 lb. Low Drag G.P. bomb, Type EX-10 Mod 3. The results of this test were reported in reference (e). The fourth test was a further study of the 250 lb. Low Drag G.P. bomb, Type EX-2 Mod 0. Results of this test were reported in reference (f). The present test is the first investigation of the 2000 lb. Low Drag G.P. bomb group. The bomb Type is EX-11 Mod 0.

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

4. OBJECT OF TEST:

The tests were conducted (a) to obtain the maximum STS armor plate thickness the 2000 lb. (Low Drag) G.P. bomb, Type EX-11 Mod 0 will penetrate and remain in an effective condition, (b) to determine the conditions which will cause bomb failure, (c) to determine the degree of acceptable deformation resulting from impact and, (d) to determine by metallurgical study any causes of failure in design and suggest any corrective measures pertaining thereto.

5. PERIOD OF TEST:

a.	Date Project Letter	28 March 1951
b.	Date Material Received	27 June 1951
c.	Date Commenced Tests	27 July 1951
d.	Date Tests Completed	17 August 1951

PART C

DETAILS OF TEST

7. DESCRIPTION OF ITEM UNDER TEST:

a. A. O. Smith Corp. Dr. MV-9048-A shows the experimental 2000 lb. Low Drag G.P. bomb, Type EX-11 Mod 0, as modified for gun firing. The bomb bodies were inert loaded with vermiculite cement having a specific gravity of 1.55.

8. DESCRIPTION OF TEST EQUIPMENT:

a. Gun: 18"/47 Rifled Gun Mk A Mod 0 No. 1 L

b. Charge: 60 lbs. of SPDN-3369 powder used with 3 - 5 lb. powder boosters

c. Targets: Various thickness of STS armor plate.

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

9. PROCEDURE:

a. Eleven (11) EX-11 Mod 0, 2000 lb. Low Drag G.P. bombs were inert loaded with vermiculite cement of specific gravity 1.55. These bombs were fired against various thickness (1"5 through 2"35) of STS armor plate at a velocity of approximately 1000 ft./sec. The targets were set at 20° obliquity to the line of fire. The armor plate targets were backed up by a large sandpile which was used as the recovery medium. The back half of the sandpile was covered with large steel plates to assist in holding the fired bombs in the sandpile. Each bomb was recovered and examined prior to firing the next round. Velocities were measured by using coils and counter chronographs.

b. Method of Metallurgical Sampling

Samples for metallurgical examination were cut from the fractured side walls of Bomb #20, (impact No. 39181) which broke up and from the least deformed side walls of bombs #3 (impact #39196) and #7 (impact #39204) which were intact and only moderately flattened when recovered after firing.

10. RESULTS AND DISCUSSION:

a. Table I, Appendix (A), summarizes the firing conditions and test results. Appendix (B), Tables II through XII, includes the butt impact records. Figures 1 through 10, Appendix (C), show the condition of the bombs after firing.

b. Metallurgical Examination

Metallurgical examination consisted of chemical and spectrographic analyses, tensile, Brinell hardness, Charpy impact, hot acid etch tests and microscopic examination.

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

The results of chemical and spectrographic analyses were as follows:

	C	Mn	P	S	Si	Cu	Ni	Cr
Bomb #20	.29	1.32	.012	.034	None	.10	None	None
Bomb #3	.31	1.17	.020	.031	Trace	.07	.06	.07
Bomb #7	.32	1.07	.022	.031	Trace	.07	.06	.07

These analyses represent a medium high manganese carbon steel. The copper, nickel and chromium contents are incidental.

Due to the bent and fractured condition of Bomb #20 no tensile test specimens were taken. The results of triplicate longitudinal tensile tests of Bombs 3 and 7 and of transverse Brinell hardness tests are shown below:

	Yld. Str. .2% p.s.i.	Ult. Str. p.s.i.	Elong. % 2"	R.A. %	Brinell 3000 Kg.
Bomb #20	-	-	-	-	303
Bomb #3	104000	126300	10.0	44.1	271
	99000	123500	11.4	43.6	
	104000	127400	11.4	42.8	
Bomb #7	97100	120300	14.3	50.8	255
	94000	118000	15.0	48.6	
	100000	121200	14.3	49.1	

Transverse sections of the three bombs were etched in 50% HCl - 50% H_2O solution at 160°F for twenty minutes and the results are shown in Figures 11 and 12, Appendix (D). Two sections of Bomb No. 20 are shown in Figure 12. At the top is the area of the electric butt weld showing sound steel and a good weld. At the bottom is shown a section 180° from the weld, showing a highly segregated condition in the fractured area. Figure 11 shows sections of Bombs 3 and 7 which are satisfactory although Bomb 3 shows considerable segregation and slight laminations.

Figures 13 through 18 show photomicrographs of the three bombs taken at magnifications of 250X and 1000X, and are indicative of quenched and drawn heat treatment. Figures 13 and 14 were taken near the fracture in Bomb #20 and show oxides and other indications of segregation.

Table XIII and Figures 19 and 20, Appendix (E) show the values of impact tests obtained from standard V-notch Charpy specimens. On Bomb #20 the impact values obtained from the specimens cut away from the fracture area compare with values obtained on Bombs 3 and 7 at room temperature while the impacts from the fracture area show somewhat more brittleness. On Bombs #3 and #7 impacts were made at temperatures ranging from 100°C to minus 78°C and the results were plotted as shown in Figures 19 and 20. On the basis that the transition from toughness to brittleness is taken to be the point on the curve where the fracture is 50% granular and 50% fibrous, the transition temperatures for Bombs #3 and #7 are +30°C and +25°C respectively which is approximately room temperature or slightly above. This is rather a high temperature for the transition but it may be accounted for in part by the fact that the steel was tested after firing which may have caused some work hardening.

PART D

CONCLUSIONS

11. It is concluded that:

a. The maximum STS armor plate thickness that the inert loaded 2000 lb. Low Drag G.P. bomb Type EX-11, Mod 0 will penetrate and remain in effective bursting condition when fired at 1000 ft./sec. velocity with target set at 20° obliquity is 1-7/8".

b. The firing condition which will cause failure of the 2000 lb. Low Drag G.P. bomb Type EX-11, Mod 0 occurs when the bomb is fired at 20° obliquity against 2"0 STS armor plate using a velocity of 1000 ft./sec.

c. No quantitative figures can be given for the amount of acceptable deformation resulting from impact. It is conclusive that when cracking occurs the bomb becomes ineffective but the amount of deformation which will cause a bomb to become ineffective has not been determined.

d. The primary cause for the failure of Bomb #20 was the segregated condition of the steel in the area 180° from the weld. The other two bombs examined, No. 3 and No. 7, were satisfactory metallurgically with the possible exception that the ductility was somewhat low.

PART E

RECOMMENDATIONS

12. The A. O. Smith Co. is experimenting with a boron steel for the manufacture of this type of bomb. Also the National Tube Co. is redesigning the nose section and is modifying its N-80 steel by substituting a small percentage of chromium for the molybdenum content, both of these changes being made for strengthening purposes. Consequently, no recommendations will be made at present pending the outcome of the above mentioned experiments.

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

The tests upon which this report is based were conducted by:
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CONFIDENTIAL

NPG REPORT NO. 950

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

Thirty-Second Partial Report

on

Bombs and Associated Components

Final Report

on

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

NAVY RESEARCH SECTION
SCIENCE DIVISION
REFERENCE DEPARTMENT

APR 28 1952

Project No.: NPG-Re3c-321-1-52
Copy No.: 4
No. of Pages: 10

Date: APR 7 1952

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TABLE I

SUMMARY OF FIRING CONDITIONS AND TEST RESULTS

Impact No.	Date Fired 1951	Type	No of Bomb	Weight lbs.	Target Thickness	Through Opening	Obl.	Powder Charge	Striking Velocity	Tons/in^2 Chamber Pressure	Gun	Remarks
39176	7/27	EX-11 Mod 0	5	1919	1"42	18"x19"	20°	70 lbs. SPDN 3369 15 lbs. black powder booster	1123	1.7	18"/47 Mk A Mod 0	Bomb in river - appeared to be intact and in good shape.
39177	7/31	EX-11 Mod 0	18	1998	1"79	18"x18-3/4"	20°	55 lbs. SPDN 3369 15 lbs. black powder booster	943	1.4	18"/47 Mk A Mod 0	Bomb effective and intact - Moderate to severe flattening - Nose plug sheared off.
39181	8/3	EX-11 Mod C	20	1950	2"35	19"x20"	20°	70 lbs. SPDN 3369 15 lbs. black powder booster	1120	1.6	18"/47 Mk A Mod 0	Bomb completely broken up.
39182	8/6	EX-11 Mod 0	6	1963	2"15	18"x19"	20°	60 lbs. SPDN 3369 15 lbs. black powder booster	823	1.3	18"/47 Mk A Mod 0	Bomb cracked open on nose section - Severely flattened and bent.
39183	8/7	EX-11 Mod 0	15	1954	2"0	15"x19"	20°	55 lbs. SPDN 3369 15 lbs. black powder booster	817	1.1	18"/47 Mk A Mod 0	Bomb effective and intact - Moderate to severe flattening on sides.
39184	8/7	EX-11 Mod 0	12	1959	2"0	17-1/2"x19"	20°	60 lbs. SPDN 3369 15 lbs. black powder booster	980	1.4	18"/47 Mk A Mod 0	Bomb cracked open around fuze hole - Severely flattened.
39196	8/10	EX-11 Mod 0	3	1937	1"84	18-1/2"x 18-1/2"	20°	60 lbs. SPDN 3369 15 lbs. black powder booster	914	1.5	18"/47 Mk A Mod 0	Bomb effective and intact - Moderate flattening.

File No.

Butt Firing

U.S. Naval Proving Ground

Dahlgren, Va. 7-27-51 ~~194~~

IMPACT NO. 39176

IMPACT DATE 27 JUL 1951

BUTT NO. F

OBJECT BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB TYPE EX 11 MOD 0 VS. 1½" STS PLATE AT 0° OBL.

REFERENCE N.P.G. ~~LETTER~~ Report No. 950 DATED

PLATE		G.P. BOMB PROJECTILE	
Gauge	1."50	Caliber	2000 LB.
Class	STS	Maker	A. O. SMITH
Maker	CARNEGIE	Type	LOW DRAG G.P.
No.	022 615 Group d-526-223	Lot No.	– Year of Specification 1951
Contract		Mark	EX 11 Mod. 0 No. 5
Date received	4-11-51	Date received	–
Dimensions	2.50" X 95"	~~Capped~~ or uncapped	
No. of impact on plate		~~Weight (capped)~~	
Thickness at impact	1."42	Weight (uncapped)	1919.0#
OBLIQUITY	20°	~~Length (uncapped)~~	
Impact dimensions	19" X 20"	Fuze	NONE
PENETRATION	COMPLETE	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	31"	EFFECTIVE or INEFFECTIVE	
Dist. from ~~right~~, left	64"	Bomb in river - Appeared to be intact and in good shape	
Dist. from nearest impact	11.5"		
Dish	3"		
Spur	10"		
Cracks - Bulge	0		
Button (Thrown) ~~(Started)~~			
Through Opening	18" X 19"		

BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, estimated for this thickness of impact.	-5- Actual, adjusted to nominal gauge.	-6- Limit, for nominal gauge, based on this impact only. (Adjusted from column 4)	-7- Limit, for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		1123					

REMARKS PRESS = 1.7 tons/in²

70 LBS. OF SPDN-3369 POWDER USED W/3.5# BLACK PDR. BOOSTERS.

Limit shots only

e/d

F(e/d, θ)

N.P.G. Photo. No.

Table II

~~Acceptance or Rejection recommended~~

~~U. S. Navy~~

GUN: 18"/47 MK. A MOD 0 #1L

Appendix B

File No.

Butt Firing

U.S. Naval Proving Ground

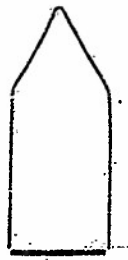
Dahlgren, Va. 7-31-51 ~~194~~

IMPACT NO. 39177
IMPACT DATE 7-31-51
BUTT NO. F.

OBJECT EXPERIMENTAL BALLISTIC TEST OF 2000 LB. G.P. LOW DRAG BOMB VS. 2"0 PLATE AT 20° OBLIQUITY

REFERENCE N.P.G. ~~LETTER~~ Report No 950 DATED

PLATE		G.P. BOMB ~~PROJECTILE~~	
Gauge	2"0	Caliber	17"95
Class	STS	Maker	A.O. SMITH
Maker	U.S. STEEL	Type	LOW DRAG
No.	016358 Group U-526-780	Lot No.	– Year of Specification –
Contract	N600-1555-9928	Mark	EX 11 Mod. – No. 18
Date received	5-3-51	Date received	–
Dimensions	93" X 250"	~~Capped or~~ uncapped	
No. of impact on plate	4	~~Weight (capped)~~	
Thickness at impact	1"97	Weight (uncapped)	1998.2#
OBLIQUITY	20°	~~Length (uncapped)~~	
Impact dimensions	21" X 23"	Fuze	NONE
PENETRATION	COMPLETE	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	33"	EFFECTIVE ~~or INEFFECTIVE~~	
Dist. from right, ~~left~~	63"	Intact – Moderate to Severe	
Dist. from nearest impact	170"	Flattening - Nose plug sheared	
Dish	4"	off	
Spur	10"		
Cracks - Bulge	0		
Button (Thrown) ~~(Started)~~			
Through Opening	18" X 18 3/4"		



BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, estimated for this thickness of impact.	-5- Actual, adjusted to nominal gauge.	-6- Limit, for nominal gauge, based on this impact only. (Adjusted from column 4)	-7- Limit, for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		943					

REMARKS PRESS – 1.4 Tons/IN²

USED 55.0# SPOX-3369 WITH 3-5# B.C. FOR BOOSTERS.

Limit shots only

e/d

F(e/d, Θ)

N.P.G. Photo. No.

Confidential

Table III

~~Acceptance or Rejection recommended~~

W W Harper
Ord. Eng.
~~U.S. Navy~~

Appendix B

GUN: 18"/47 MK 1 MOD 0 #1L

File No.

Butt Firing

U.S. Naval Proving Ground

Dahlgren, Va. 6-3-51 ~~194~~

Impact No. 37151

Impact Date 3 Aug. 1951

Butt No. F

Object EXPERIMENTAL BALLISTIC TEST OF 2000 LB. G.P. LEAD WALLED BOMB VS. 2 1/2" PLATE AT 20° OBL.

Reference N.P.G. ~~LETTER~~ Report 3 Jan. 1950 Dated

PLATE		PROJECTILE	
Gauge	2.048	Caliber	17.99
Class	CTS	Maker	[illegible]
Maker	[illegible]	Type	[illegible]
No.	[illegible] Group H-1191	Lot No.	— Year of Specification —
Contract	[illegible]	Mark	EX 1 Mod. — No. [illegible]
Date received	[illegible]	Date received	
Dimensions	92 1/2" x 199 1/2"	~~Capped or~~ uncapped	
No. of impact on plate	9	~~Weight (capped)~~	
Thickness at impact	[illegible]	Weight (uncapped)	[illegible]
OBLIQUITY	[illegible]	Length (uncapped)	102.65"
Impact dimensions	31 x 25	Fuze	NONE
PENETRATION	[illegible]	Filler	[illegible]
Flaking front		Flight by screen	
Flaking back		Condition after firing:-	
Dist. from top, ~~bottom~~		~~EFFECTIVE or~~ INEFFECTIVE	
Dist. from ~~right~~, left		Bomb broken up	
Dist. from nearest impact	54"		
Dish	4"		
Spur	[illegible]		
Cracks - Bulge			
Button (Thrown) ~~(Started)~~			
Through Opening	19" x [illegible]		

BALLISTIC DATA

NOTE: All limits are for this plate and the obliquity only.	-1-	-2- Chronograph	-3- Crusher	-4- Limit, calculated for this thickness & obliquity	-5- Actual limit for this velocity	-6- Limit for nominal gauge, based on the plate only (Adjusted from col. 4)	-7- Limit, for nominal gauge, established from previous impacts.
		MEA					
Striking velocity (f/s)		1120					

Remarks 1.6 TSI over pressure

60 lbs IMR-3360 Powder - 15 lbs Black Powder Tracer

Limit shots only Confidential ~~Acceptance or Rejection recommended~~

c/d

F/c/d/(c)

N.P.G. Photo. No.

Table IV

Not Required

Ord Eng

~~Lt. Navy~~

[illegible] #12

Appendix B

File No.

Butt Firing

U.S. Naval Proving Ground

Dahlgren, Va. 8-6-51 ~~194~~

IMPACT NO. 39182

IMPACT DATE 8-6-51

BUTT NO. 7

OBJECT BALLISTIC TEST OF INERT LOADED 2000 LB. LOW DRAG G.P. BOMB TYPE EX11 MOD 0 VS. 2 1/4" STS PLATE

REFERENCE N.P.G. ~~LETTER~~ Report No. 950 DATED

G.P. BOMB

PLATE

Gauge 2"15

~~Class~~ STS

Maker CARNEGIE

No. 0110864 Group C-526-522

~~Contract~~ H-447

Date received 25 JAN. '45

Dimensions 89 15/16" X 202 9/8"

No. of impact on plate 2

Thickness at impact 2"15

OBLIQUITY 20°

~~Impact dimensions~~ 20" X 21"

PENETRATION Complete

Flaking front 0

Flaking back 0

Dist. from top, ~~bottom~~ 59"

Dist. from ~~right,~~ left 61"

Dist. from nearest impact 50"

Dish 5"

Spur 7"

Cracks - Bulge 0

Button (Thrown) ~~(Started)~~

Through Opening 18" X 19"

PROJECTILE

Caliber 17"99

Maker A.O. SMITH

Type LOW DRAG

Lot No. – Year of Specification –

Mark EX 11 Mod. – No. #6

Date received –

~~Capped or~~ uncapped

~~Weight (capped)~~

Weight (uncapped) 1963.0#

Length (uncapped) 103"65

Fuze NONE

Filler VERMICULITE

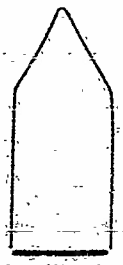
Flight by screen –

Condition after firing:-

~~EFFECTIVE or~~ INEFFECTIVE

Cracked open on nose section

Severely flattened and bent



BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, calculated for this thickness of impact	-5- Actual, adjusted to nominal gauge	-6- Limit, for nominal gauge, based on this impact only. (Adjusted from Column 4)	-7- Limit, for nominal gauge, established from column 6 and previous impacts.
		Inert					
Striking velocity (f.s.)		823					

REMARKS Pressure - 1.3 tons/in²

55 lbs SPDN-3369 Powder - 15 lbs. Black Powder Booster

Limit shots only Confidential ~~Acceptance or Rejection recommended~~

c/d

F(c/d, e) Table V Nonmenclature Ord Tag ~~U.S. Navy~~

N.P.G. Photo. No. Appendix B

GUN: 18"/47 MK 6 MOD. 0 #14

File No.

Butt Firing

U.S. Naval Proving Ground

Dahlgren, Va. 8-7-51 ~~194~~

IMPACT No. 39183
IMPACT DATE 8-7-51
BUTT No. F

OBJECT BALL TEST OF INERT LOADED 2000 LB. LOW DRAG G.P. BOMB TYPE EX 11 MOD 0 VS 2" STS PLATE

REFERENCE N.P.G. ~~LETTER~~ Report No. 950 DATED

G.P. BOMB

PLATE

Gauge 2"0
Class STS
Maker CARNEGIE
No. 081221 Group —
Contract NORD 10280
~~Date received~~ —
Dimensions 98" X 288"
No. of impact on plate 14
Thickness at impact 2"
OBLIQUITY 20°
Impact dimensions 17" X 22"
PENETRATION COMPLETE
Flaking front 0
Flaking back 0
Dist. from top, ~~bottom~~ 34"
Dist. from right, ~~left~~ 59"
Dist. from nearest impact 36"
Dish 4"
Spur 8"
Cracks - Bulge 0
Button (Thrown)(~~Started~~)
Through Opening 15" X 19"

PROJECTILE

Caliber 17"99
Maker A. O. SMITH
Type G.P. LOW DRAG
Lot No. — Year of Specification —
Mark EX 11 Mod. — No. 15
Date received —
~~Capped or~~ uncapped
~~Weight (capped)~~
Weight (uncapped) 1954 #
Length (uncapped) 103"65
Fuze NONE
Filler VERMICULITE
Flight by screen
Condition after firing:-
EFFECTIVE ~~or INEFFECTIVE~~
Intact = Moderate to severe flattening on sides

BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, estimated for this thickness of impact.	-5- Actual, adjusted to nominal gauge.	-6- Limit, for nominal gauge, based on this impact only. (Adjusted from column 4)	-7- Limit, for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		817					

REMARKS Press 1.1 tons/in²

55 lbs SPDN - 3369 Powder - 15 lbs Black Powder Booster

Limit shots only Confidential

~~Acceptance or Rejection recommended~~

e/d

F(e/d, θ) Table VI

N.P.G. Photo. No.

W W Meyers
Ord Eng ~~U.S. Navy~~

Appendix B

File No.

Butt Firing

U. S. Naval Proving Ground

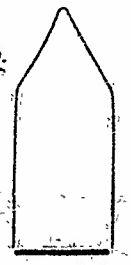
Dahlgren, Va. 8-7-51 ~~194~~

IMPACT No. 39184
IMPACT DATE 8-7-51
BUTT No. F

OBJECT BALL TEST OF 2000 LB. G.P. LOW DRAG BOMB VS. 2" STS PLATE AT 20° OBL.

REFERENCE N.P.G. ~~LETTER~~ Report No. 950 DATED

PLATE		G.P. BOMB PROJECTILE	
Gauge	2"0	Caliber	17"99
Class	STS	Maker	A. O. SMITH
Maker	CARNEGIE	Type	G.P. LOW DRAG
No.	081221 Group —	Lot No.	— Year of Specification —
Contract	NORD 10280	Mark	EX11 Mod. — No. 12
Date received	—	Date received	—
Dimensions	98" X 288"	~~Capped or~~ uncapped	
No. of impact on plate	15	~~Weight (capped)~~	
Thickness at impact	2"	Weight (uncapped)	1959 #
OBLIQUITY	20°	Length (uncapped)	103"65
Impact dimensions	19" X 22"	Fuze	NONE
PENETRATION	COMPLETE	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	68"	~~EFFECTIVE or~~ INEFFECTIVE	
Dist. from ~~right~~, left	65"	Cracked open around Fuze hole - Severely flattened	
Dist. from nearest impact	64"		
Dish	5"		
Spur	7"		
Cracks - Bulge	0		
Button (Thrown)(~~Started~~)			
Through Opening	17½" X 19"		



BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, estimated for this thickness of impact.	-5- Actual, adjusted to nominal gauge.	-6- Limit, for nominal gauge, based on this impact only. (Adjusted from column 4)	-7- Limit, for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		950					

REMARKS Press 1.4 tons/in²

60 lbs. SPDN 3369 Powder - 15 lbs Black Powder Booster

Limit shots only

e/d

F(e/d, θ)

N.P.G. Photo. No.

Confidential

Table VII

~~Acceptance or Rejection recommended~~

W W Meyers
Ord. Eng. ~~U. S. Navy~~
Appendix B

File No.

Butt Firing

U.S. Naval Proving Ground

Dahlgren, Va. 8-10-51 ~~191~~

IMPACT No. 39196
IMPACT DATE 8-10-51
BUTT No. G

OBJECT BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB Vs. 1-3/4" PLATE AT 20° OBLIQUITY

REFERENCE N.P.G. ~~LETTER~~ Report No. 950 DATED

PLATE		G.P. BOMB ~~PROJECTILE~~	
Gauge	1."849	Caliber	17."983
Class	STS	Maker	A. O. SMITH
Maker	CARNEGIE	Type	LOW DRAG G.P. BOMB
No.	091460 Group C-526-736	Lot No.	— Year of Specification —
Contract	C-N600S-S-5615	Mark	EX 11 Mod. 0 No. 3
Date received	8-16-50	Date received	—
Dimensions	95" X 250"	~~Capped or~~ uncapped	
No. of impact on plate	3	~~Weight (capped)~~	
Thickness at impact	1."84	Weight (uncapped)	1937#
OBLIQUITY	20°	Length (uncapped)	103.65"
Impact dimensions	19" X 21"	Fuze	NONE
PENETRATION	Complete	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	63"	EFFECTIVE ~~or INEFFECTIVE~~	
Dist. from ~~right~~, left	90"	Intact - Moderate	
Dist. from nearest impact	42"	Flattening	
Dish	4"		
Spur	8"		
Cracks - Bulge	0		
Button (Thrown)(~~Started~~)			
Through Opening	18½" X 18½"		

BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, estimated for this thickness of impact.	-5- Actual adjusted to nominal gauge.	-6- Limit, for nominal gauge, based on this impact only. (Adjusted from column 4)	-7- Limit, for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		914					

REMARKS Press 15 tons/in²

60 lbs SPDN 3369 Powder & 15 lbs Black Powder Booster

Limit shots only

~~Acceptance or Rejection recommended~~

e/d

F(e/d, θ)

N.P.G. Photo. No.

Confidential

Table VIII

W W Meyers
Ord. Eng.
Appendix B

~~U.S. Navy~~

File No.

Butt Firing

U. S. Naval Proving Ground

Dahlgren, Va. 8-10-51 ~~194~~

IMPACT No. 37197

IMPACT DATE 8-10-51

BUTT No. 6

OBJECT BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB VS. 1-3/4" PLATE AT 20° OBLIQUITY

REFERENCE N.P.G. ~~LETTER~~ Report No. 950 DATED

PLATE		G.P. BOMB ~~PROJECTILE~~	
Gauge	1.849"	Caliber	17.960"
Class	STS	Maker	A.O. SMITH
Maker	CARNEGIE	Type	LOW DRAG G.P. BOMB
No.	091460 Group C-526-736	Lot No.	— Year of Specification
Contract	C-N600S-5-5615	Mark	EX 11 Mod. — No. 11
~~Date received~~	8-14-51	Date received	
Dimensions	95" x 250"	~~Capped or~~ uncapped	
No. of impact on plate	4	~~Weight (capped)~~	
Thickness at impact	1.84	Weight (uncapped)	1946.#
OBLIQUITY	20°	Length (uncapped)	103.65"
Impact dimensions	20" x 22"	Fuze	NONE.
PENETRATION	Complete	Filler	VERMICULITE
~~Flaking front~~	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	34"	EFFECTIVE ~~or INEFFECTIVE~~	
Dist. from right, ~~left~~	62"	Intact - Moderate	
Dist. from nearest impact	96"	Flattening	
Dish	4"		
Spur	7"		
Cracks - Bulge	0		
Button (Thrown)(~~Started~~)			
Through Opening	18" x 18½"		

BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Desired	-2- Oscillograph	-3- Chronograph	-4- Limit, estimated for this thickness of impact.	-5- Actual adjust. to nominal gauge.	-6- Limit for nominal gauge, based on this impact only. (Adjusted from column 4).	-7- Limit for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		928					

REMARKS Press - 1.5 tons/in²

60 lbs SPDN 3369 Powder & 15 lbs Black Powder Booster

Limit shots only

e/d

F(e/d, θ)

N.P.G. Photo. No.

Confidential

Table IX

~~Acceptance or Rejection recommended~~

C. Fewell

Lt., U.S. Navy

Appendix B

File No.

Butt Firing

U. S. Naval Proving Ground

Dahlgren, Va. 8-17-51 194

IMPACT No. 39202

IMPACT DATE 8-17-51

BUTT No. F

OBJECT BALLIS TC TEST OF 2000 LB. LOW DRAG G.P. BOMB EX 11 VERMICULITE LOADED VS. 1-3/4" PLATE

REFERENCE N.P.G. ~~LETTER~~ Report 70.950 DATED

PLATE		G.P. BOMB ~~PROJECTILE~~	
Gauge	1.849	Caliber	17.966
Class	STS	Maker	A.O. SMITH
Maker	CARNEGIE	Type	LOW DRAG BOMB
No.	091460 Group C-526-736	Lot No.	— Year of Specification —
Contract	C-N6005-S-5615	Mark	EX 11 Mod. - No. 10
Date received	8-16-50	Date received	—
Dimensions	95" X 250"	~~Capped or~~ uncapped	
No. of impact on plate	5	~~Weight (capped)~~	
Thickness at impact	1.84	Weight (uncapped)	1956.00#
OBLIQUITY	30°	Length (uncapped)	103.65
Impact dimensions	18" X 19"	Fuze	NONE
PENETRATION	COMPLETE	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	32"	EFFECTIVE ~~or INEFFECTIVE~~	
Dist. from ~~right~~, left	86"	Intact - Moderate Flattening	
Dist. from nearest impact	40"		
Dish	2"		
Spur	8"		
Cracks - Bulge	0		
Button (Thrown)(~~Started~~)			
Through Opening	16" X 18"		

BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	-1- Timed	-2- Oscillograph MEAN	-3- Chronograph	-4- Limit, expected for this thickness of impact	-5- Actual w/p, f.d. to nominal range	-6- Limit, for nominal range, based on this impact only. (Adjusted from column 4)	-7- Limit, for nominal range, established from column 6 and previous impacts
Striking velocity (f/s)		932					

REMARKS: Three - 1.5 Lbs Tonite

60 lbs SPDN 3369 Powder & 15 lbs Black Powder Booster

Limit shots only

e/d

F(e/d, θ)

N.P.G. Photo. No.

~~Acceptance or Rejection recommended~~

Confidential

Table X

E. Lenette

Lt.

U. S. Navy

GUN: 18"/47 MK A MOD 0 #1L

appendix B

File No.

Butt Firing

U. S. Naval Proving Ground

Dahlgren, Va. 8-17-51 194

IMPACT No. 39203

IMPACT DATE 8-17-51

BUTT No. F

OBJECT BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB EX 11 VERMICULITE LOADED VS. 1-3/4" PLATE

REFERENCE N.P.G. ~~LETTER~~ Report No. 959 DATED

PLATE		G.P. BOMB ~~PROJECTILE~~	
Gauge	1."849	Caliber	17."987
Class	STS	Maker	A.O. SMITH
Maker	CARNEGIE	Type	LOW DRAG BOMB
No.	091460 Group C-526-736	Lot No.	— Year of Specification —
Contract	C-N600S-5-5615	Mark	EX 11 Mod. — No. 19
Date received	8-16-50	Date received	—
Dimensions	95" X 250"	~~Capped or~~ uncapped	
No. of impact on plate	6	~~Weight (capped)~~	
Thickness at impact	1."84	Weight (uncapped)	1975.00#
OBLIQUITY	20°	Length (uncapped)	103."65
Impact dimensions	19" X 21"	Fuze	NONE
PENETRATION	COMPLETE	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:-	
Dist. from top, ~~bottom~~	32"	EFFECTIVE ~~or INEFFECTIVE~~	
Dist. from ~~right,~~ left	140"	Intact - Moderate	
Dist. from nearest impact	46"	Flattening	
Dish	2"		
Spur	4"		
Cracks - Bulge	0		
Button (Thrown) ~~(Started)~~			
Through Opening	17" X 24"		

BALLISTIC DATA

NOTE: All limits are for this plate and this obliquity only.	1 Desired	2 Oscillograph	3 Chronograph	4 Limit, calculated for this thickness of impact.	5 Actual adjusted to nominal gauge	6 Limit for nominal gauge based on this impact only. (Adjusted from column 4)	7 Limit for nominal gauge, established from column 6 and previous impacts.
	—	MEAN					
Striking velocity (f.s.)		848					

REMARKS Press - 1.7 [illegible]

60 lbs SPDN - 3369 Powder & 15 lbs Black Powder Booster

Limit shots only Confidential ~~Acceptance or Rejection recommended~~

e/d

F(e/d, θ) Table II E. Lenfest

N.P.G. Photo. No. U.S. Navy

GUN: 18"/47 MK A MOD 0 #11 Appendix B

File No.

Butt Firing

U.S. Naval Proving Ground
Dahlgren, Va. 8-17-51 ~~INT~~

IMPACT No. 39204
IMPACT DATE 8-17-51
BUTT No. F

SUBJECT BALLISTIC TEST OF 2000 LB. LOW DRAG G.P. BOMB EX 11 VERMICULITE LOADED VS. 1 3/4" PLATE

~~REFERENCE~~ N.P.G. ~~LETTER~~ Report No. 950 DATED

PLATE G.P. BOMB ~~PROJECTILE~~

Gauge	1.849"	Caliber	17.981"
Class	STS	Maker	A.O. SMITH
Maker	CARNEGIE	Type	LOW DRAG BOMB
No.	091460	Group C-526-736	Lot No. — Year of Specification —
Contract	C-46005-S-5615	Mark	EX 11 Mod. — No. 7
Date received	8-16-50	Date received	—
Dimensions	95" X 250"	~~Capped or~~ uncapped	
No. of impact on plate	7	~~Weight (capped)~~	
Thickness at impact	1.84"	Weight (uncapped)	1968.0#
OBLIQUITY	20°	Length (uncapped)	130.65"
Impact dimensions	19" X 20"	Fuze	NONE
PENETRATION	COMPLETE	Filler	VERMICULITE
Flaking front	0	Flight by screen	
Flaking back	0	Condition after firing:	
Dist. from top, ~~bottom~~	70"	EFFECTIVE ~~or INEFFECTIVE~~	
Dist. from ~~right~~, left	110"	Intact - Moderate	
Dist. from nearest impact	46"	Flattening	
Dish	2"	0	
Spur	9"		
Cracks - Bulge	0		
Button (Thrown) ~~(Started)~~			
Through Opening	18" X 26"		

BALLISTIC DATA

Note: All limits are for this plate and this obliquity only.	1 Desired	2 Oscillograph	3 Chronograph	4 Limit, estimated for this thickness of impact.	5 Actual adjusted to nominal gauge.	6 Limit, for nominal gauge, based on this impact only. (Adjusted from column 4).	7 Limit, for nominal gauge, established from column 6 and previous impacts.
		MEAN					
Striking velocity (f.s.)		1013					

REMARKS Press. - 15 Tons/in²

Cotton SPDL-3369 Powder & 15 lbs Black Powder Booster

Limit shots only Confidential ~~Recommendations Recommended~~

e/d Table XII C. Levitt

F(e/d, θ) Lt.

N.P.G. Photo. No. U.S. Navy

GUN: 18"/47 MK A MOD 0 #11 Appendix B

NP9-48450

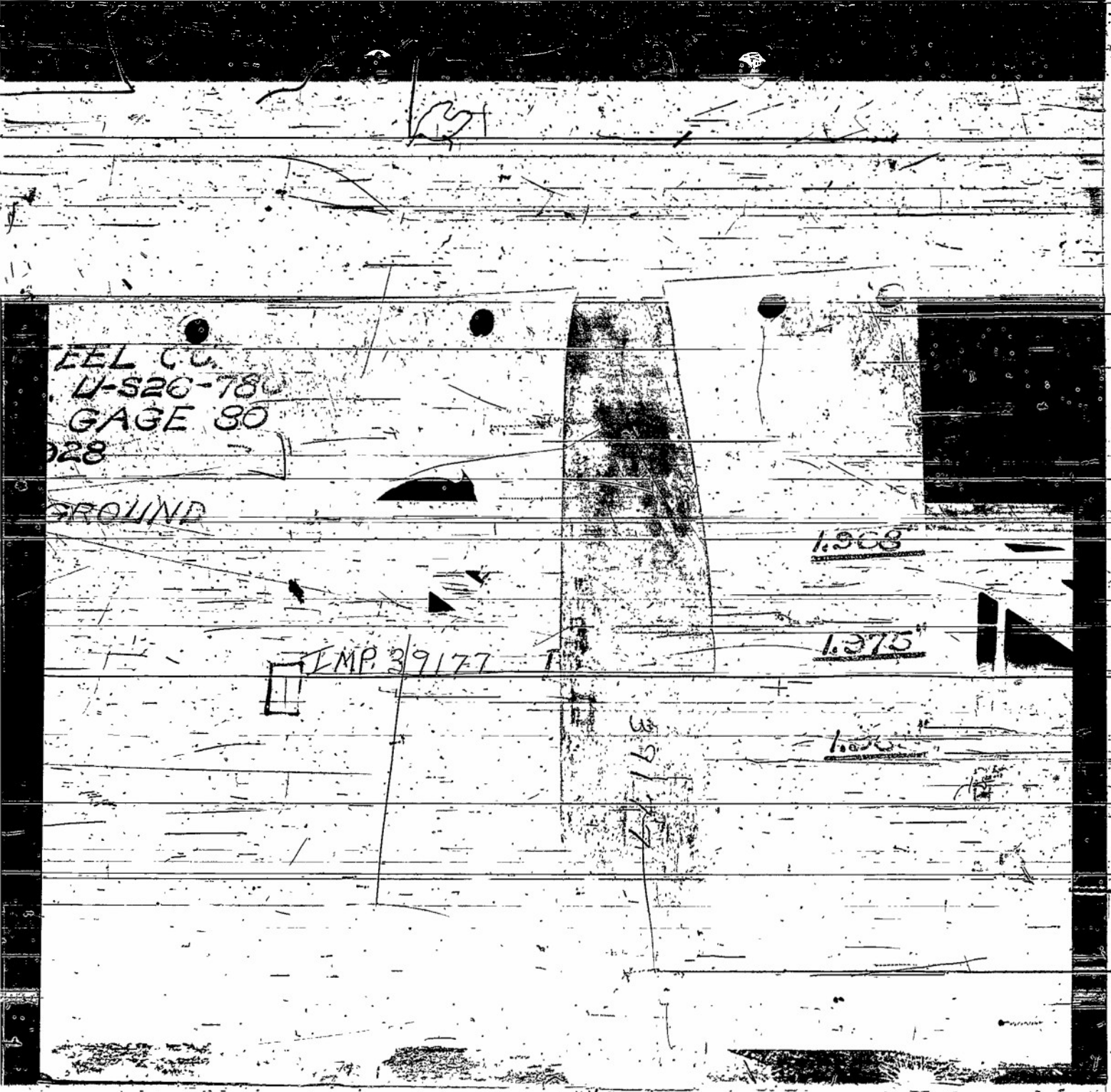
Figure 1

CONFIDENTIAL
SECURITY INFORMATION

Impact 39176, 2000 lb. G.P. bomb (low drag) EX-11 Mod 0 went down river after impact against [illegible] at 0° obliquity. Striking velocity was 1[illegible]23 f.s.

Appendix C

IMP. 39176



[illegible] C[illegible]ITY, I[illegible]ATION

I[illegible]pact 39177, [illegible] (low [illegible]) [illegible]-11 od C after imp against 1.9[illegible] plate at [illegible]° obliquity. [illegible] striking velocity was [illegible] f.s.

Appendix C

Figure 3

Impact [illegible]9181, [illegible] lb. [illegible] bomb (low drag) [illegible]-11 [illegible] after impact [illegible]
[illegible] plate at [illegible] Striking velocity [illegible]

CONFIDENTIAL
SECURITY INFORMATION

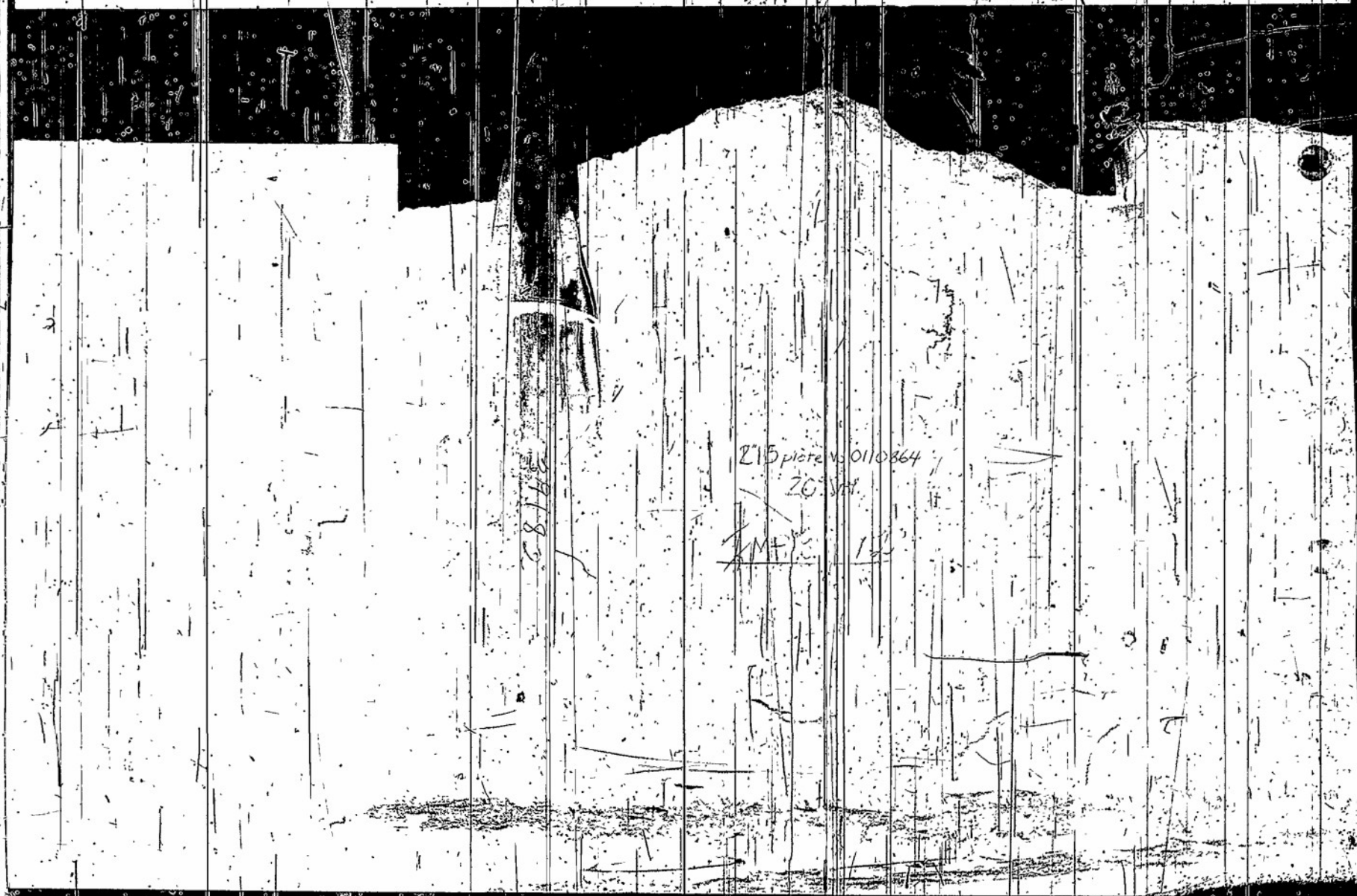
NPG-48447

Figure 4

Impact 39182, 2000 lb. G.P. bomb (low drag) EX-11 Mod 0 after impact against 2"15 SPS plate at 20° obliquity. Striking velocity was 823 f.s.

CONFIDENTIAL
SECURITY INFORMATION

Appendix C



NP9-48446 Figure 5 CONFIDENTIAL
SECURITY INFORMATION

Impact 39183, 2000 lb. G.P. bomb (low drag) EX-11 Mod 0 after impact with 2.0 SP plate at 20° obliquity. Striking velocity was 817 f.s.

Appendix C

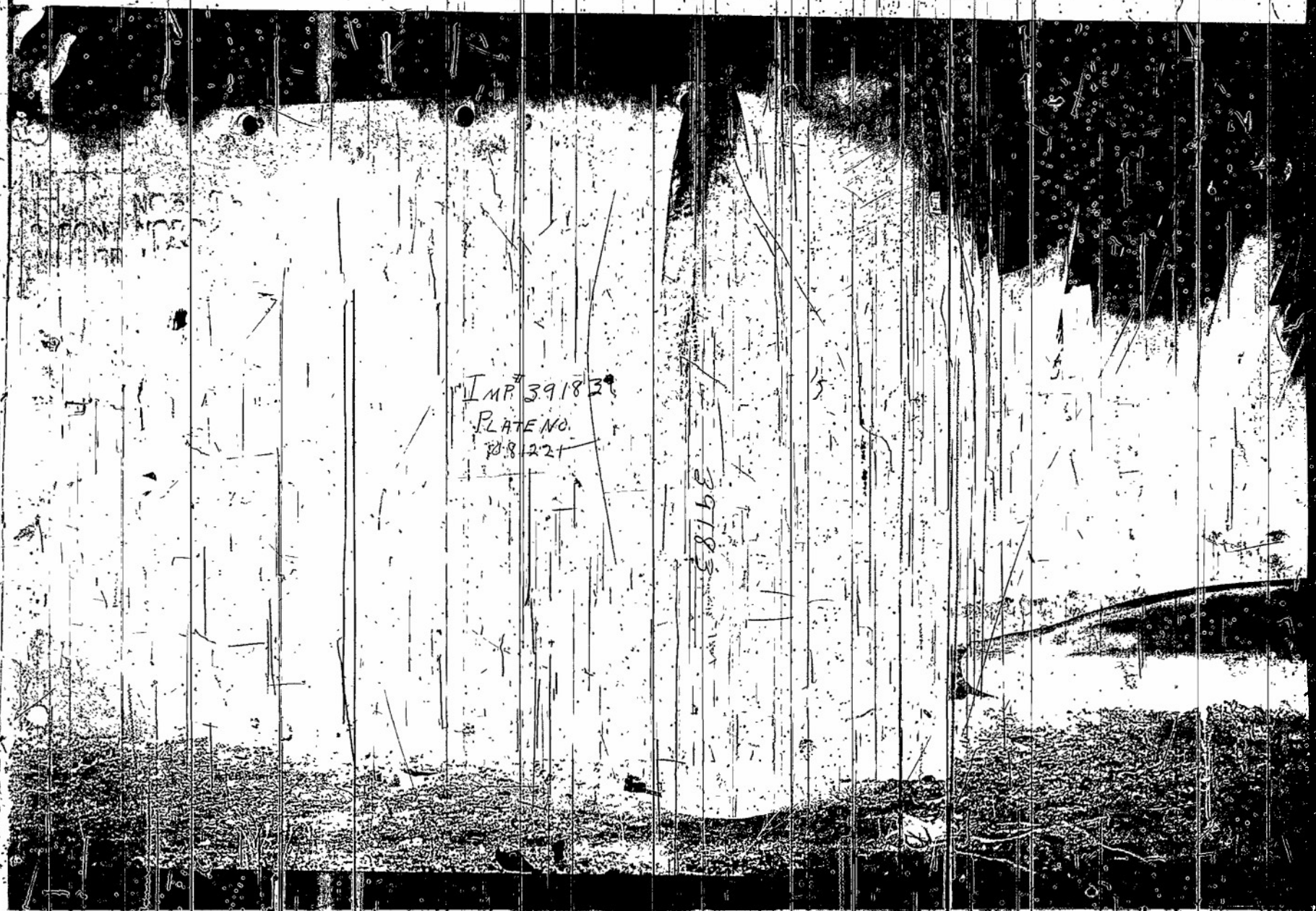
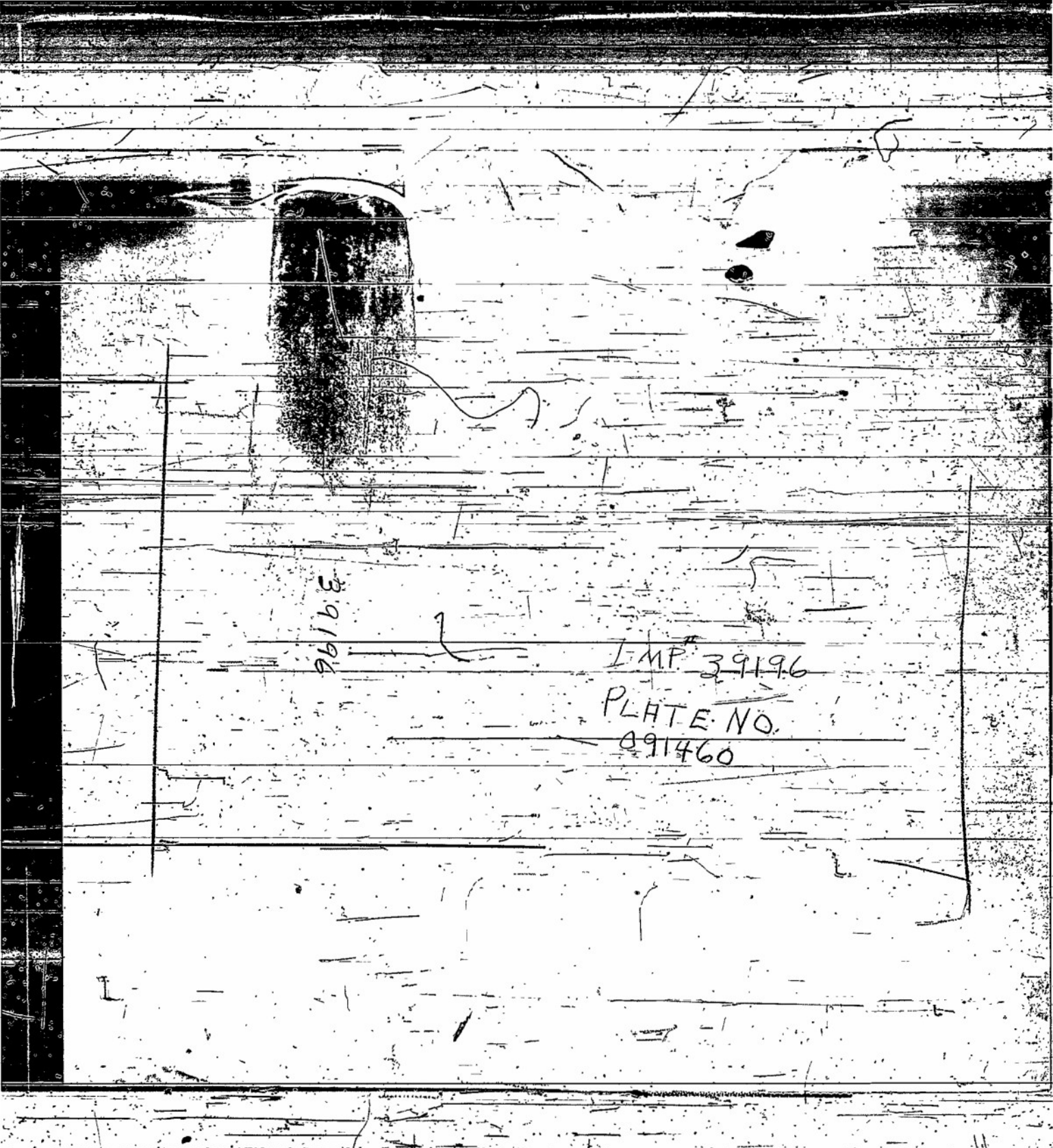


Figure 6

Impact 39184, 2000 lb. G.P. bomb (low drag) D.-11 6d 0 after impact against 2.0 STS plate at 20° obliquity. Striking velocity was 920 f.s.



NP9-48444 Figure 7 CONFIDENTIAL
SECURITY INFORMATION

Impact 39196, 2000 lb. G.P. bomb (low drag) EX-11 Mod 0 after impact against 1.84 STS plate at 20° obliquity. Striking velocity was 914 f.s.

Appendix C

NP9-48443 Figure 8 CONFIDENTIAL SECURITY INFORMATION

Impact 39197, 2000 lb. G.P. bomb (low drag) LA-11 Mod 0 after impact against 1"84 STS plate at 0° obliquity. Striking velocity was [illegible] f.s.

Appendix C

NP9-48442

Figure 9

Impacts 39202 and 39203, 2000 lb. G.P. bomb (low drag) EX-11 Mod 0 after impact against 1184 STS plate at 20° obliquity. Striking velocity of impact 39202 was 932 f.s. and 848 f.s. for impact 39203.

CONFIDENTIAL
SECURITY INFORMATION

Appendix C

Figure 10

Impact 39204, 2000 lb. G.P. bomb (low drag) EX-11 Mod 0 after impact against 1"84 STS plate at 20° obliquity. Striking velocity was 1013 f.s.

Transverse Section of 2000# Low Drag G.P. Bomb, Type Ex-11, Mod. 0.
Etched in 50% HCl-50% H_2O for 20 Min. at 160°F. Magn. 1X.

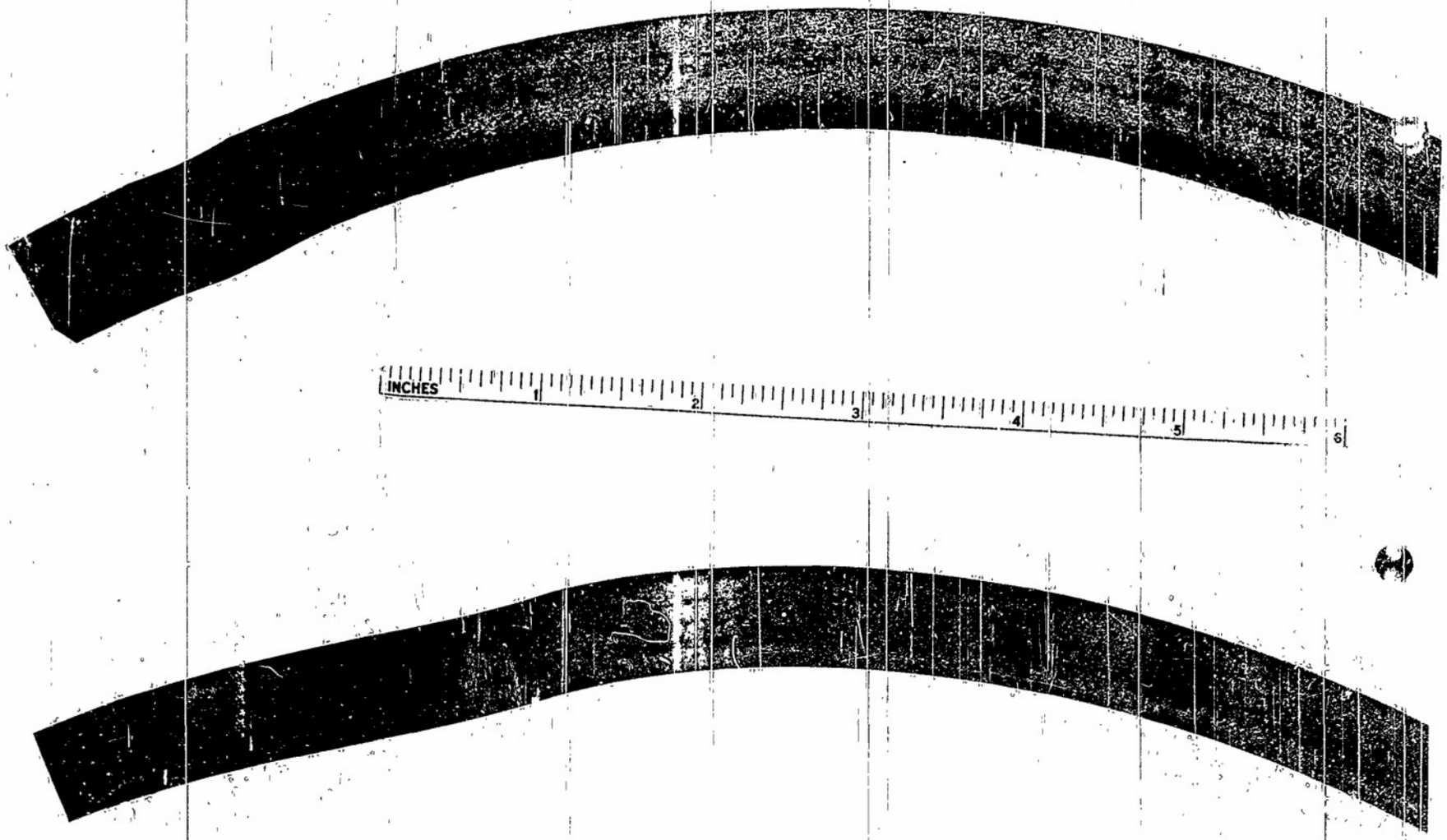
Top:- Bomb No. 3, Impact No. 39196.
Bottom:- Bomb No. 7, Impact No. 39204.

NP9-45700

Figure 11.

APPENDIX D.

CONFIDENTIAL



Transverse Section of 2000# Low Drag G.P. Bomb, Type Ex-11, Mod.O.
Etched in 50% HCl-50% H_2O for 20 Min. at 160°F. Magn. 1X.

Top:- Weld Area - Sound Steel - Good Weld.
Bottom:- 180° from weld showing fracture in segregated area.

NP9-45699 Figure 12. APPENDIX D.

CONFIDENTIAL

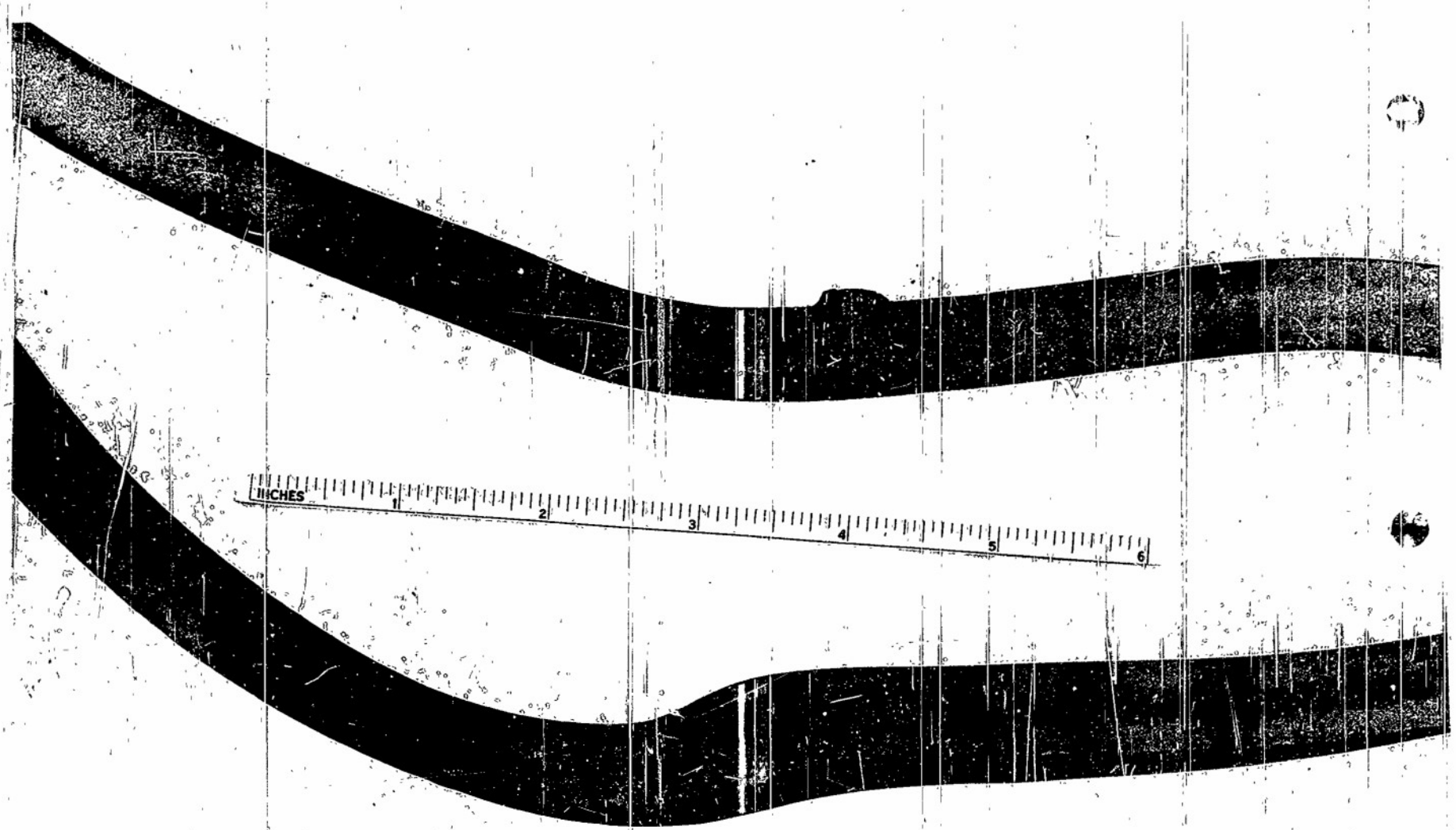


Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod. 0

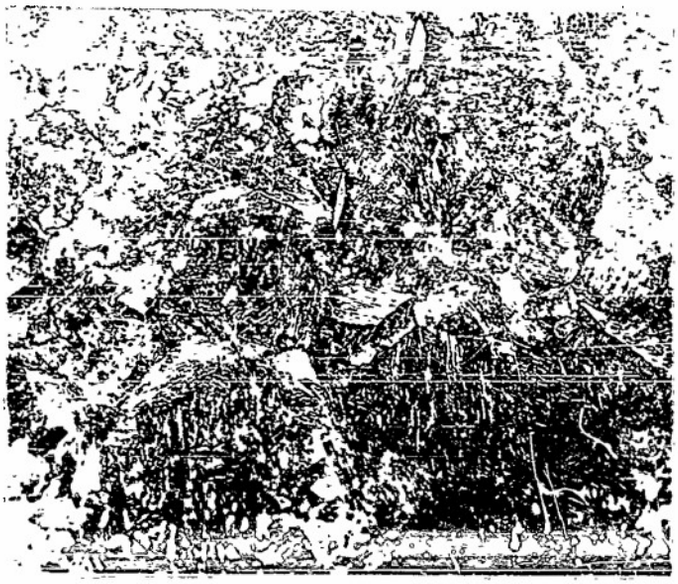


Figure 13 250X

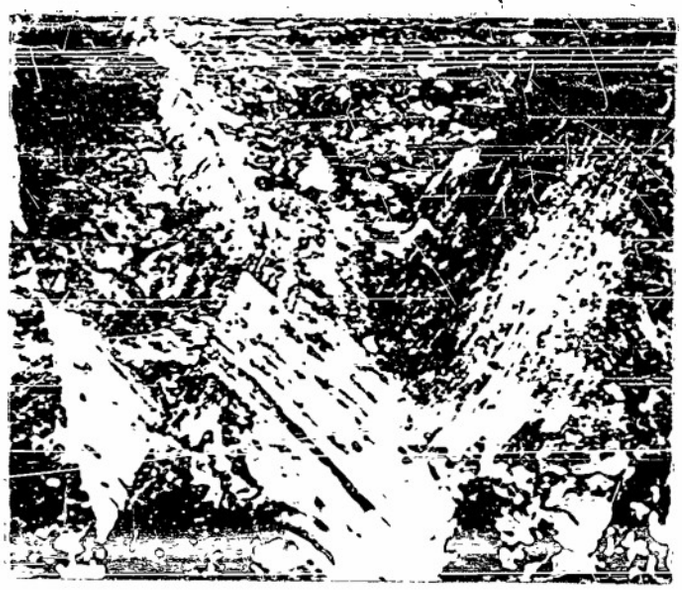


Figure 14 1000X

Bomb No. 20 - Impact No. 39181 - Nital-Picral Etch.

Figure 15 250X

Figure 16 1000X

Bomb No. 3 - Impact No. 39196 - Nital-Picral Etch.

NP9-45701

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod. 0

Figure 17 250X Figure 18 1000X
Bomb No. 7 - Impact No. 39204 - Nital-Picral Etch.

NP9-45702

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

TABLE XIII

CHARPY IMPACT TESTS AT VARIOUS TEMPERATURES

Testing Temp. °C	Bomb No. 20 Charpy Ft.Lbs.	Bomb No. 20 Fracture *	Bomb No. 3 Charpy Ft.Lbs.	Bomb No. 3 Fracture *	Bomb No. 7 Charpy Ft.Lbs.	Bomb No. 7 Fracture *
-78	See Note No. 1		10	G	11	G
"			15	G	10	G
			13	G		
-40			14	G	15	G
"			13	G	16	G
0			20	10F	18	20F
"			18	20F	23	30F
+25	30	60F	25	50F	27	50F
"	32	60F	22	40F	29	50F
"	28	50F				
"	27	50F				
"	19	10F				
"	13	30F				
+100			47	F	51	F
"			45	F	50	97F

Note 1: On Bomb No. 20 Charpy impact tests were made only at room temperature (25°C). The first four values shown were from an area away from the fracture in the bomb. The last two values were from specimens taken near the fracture.

* F denotes 100% Fibrous Fracture.
60F " 60% " " and 40% Granular.
G " 100% Granular Fracture.

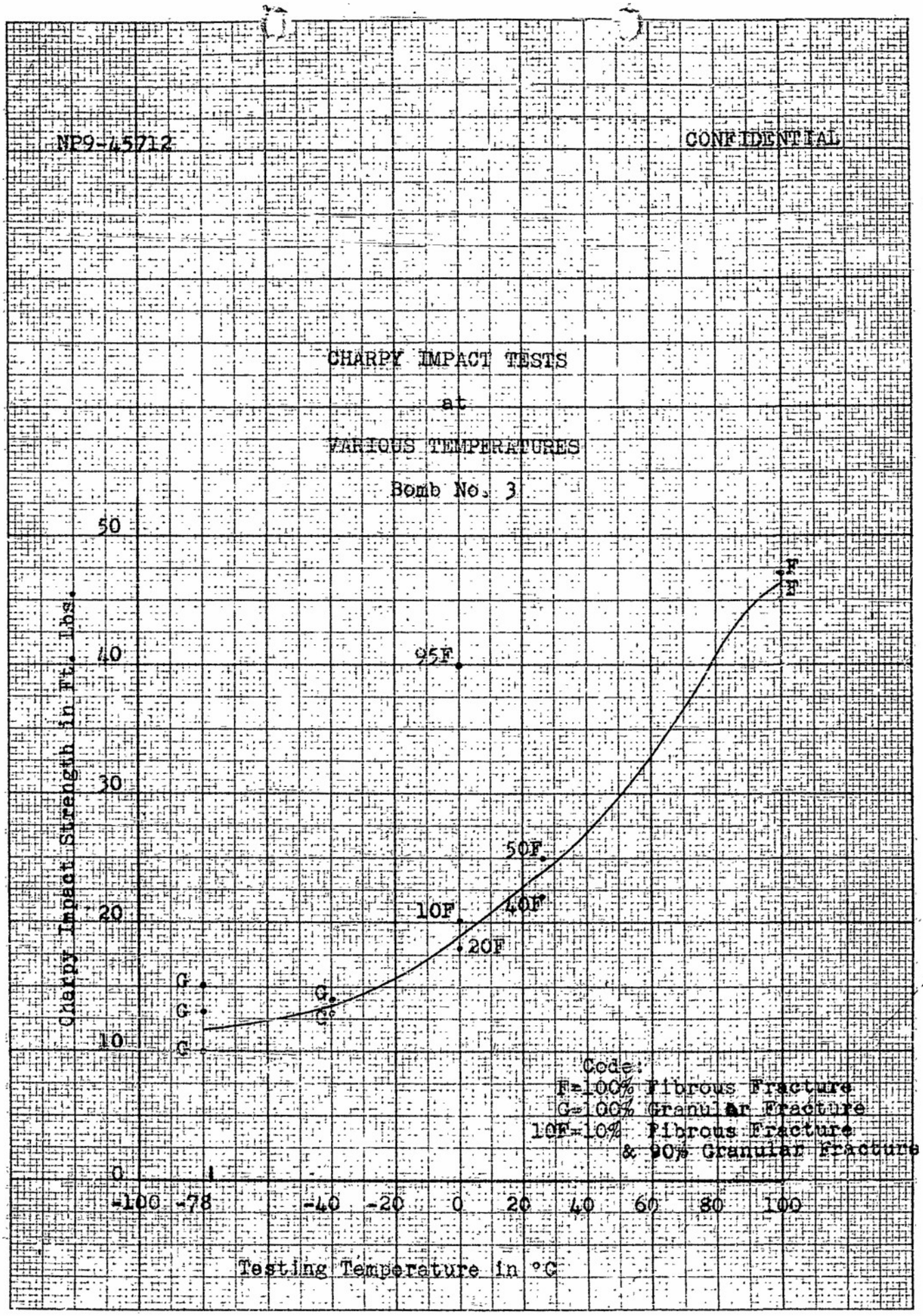

CHARPY IMPACT TESTS
at
VARIOUS TEMPERATURES
Bomb No. 3
Charpy Impact Strength in Ft. Lbs.
50
40
30
20
10
0
95F
50F
40F
10F
20F
G
G
G
G
G
F
F
F
Code:
F=100% Fibrous Fracture
G=100% Granular Fracture
10F=10% Fibrous Fracture
& 90% Granular Fracture
-100 -78 -40 -20 0 20 40 60 80 100
Testing Temperature in °C

FIGURE 19

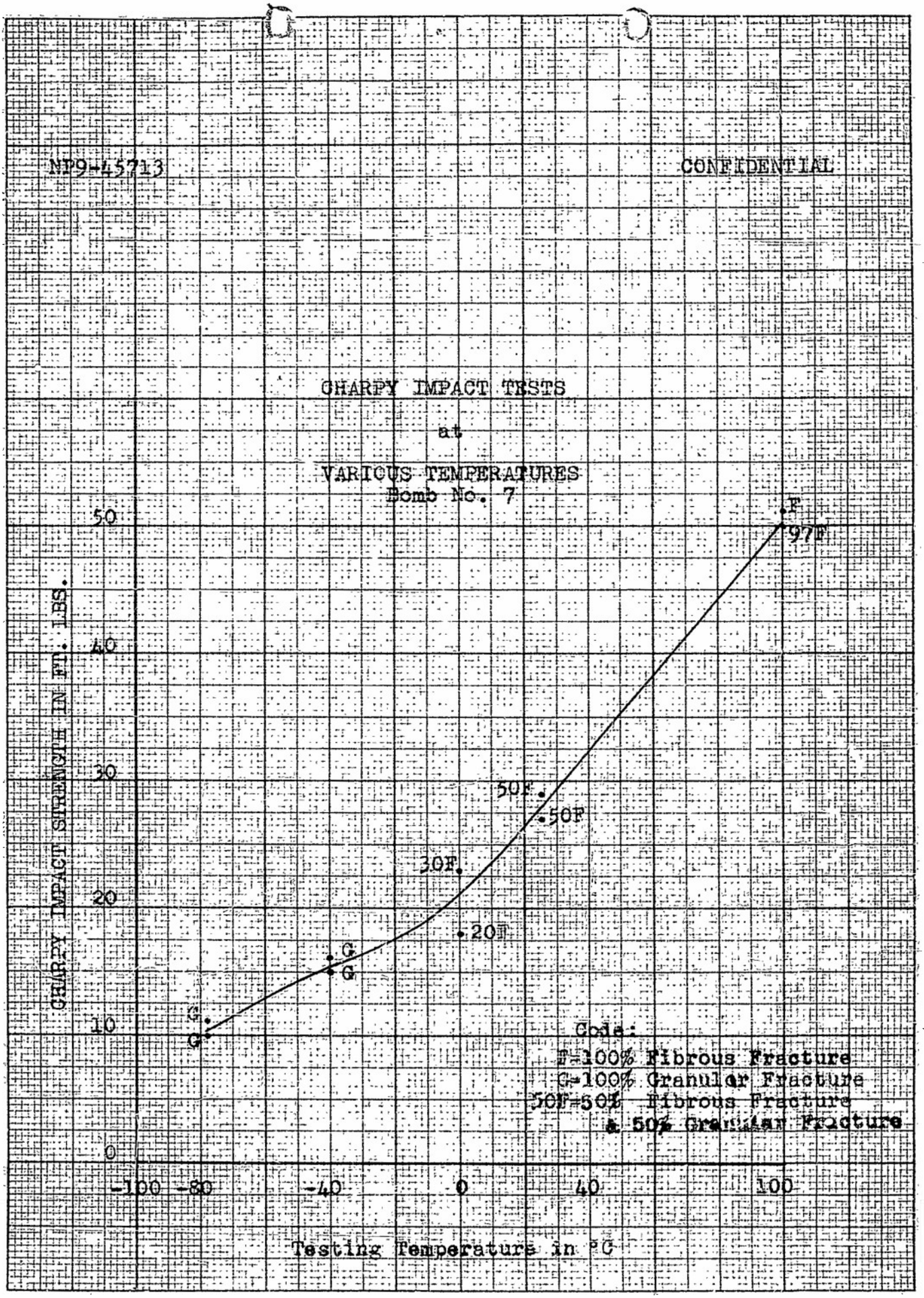

CHARPY IMPACT TESTS
at
VARIOUS TEMPERATURES
Bomb No. 7
CHARPY IMPACT STRENGTH IN FT. LBS.
50
40
30
20
10
0
-100
-80
-40
0
40
100
Testing Temperature in °C
F
97F
50F
50F
30F
20F
G
G
G
G
Code:
F-100% Fibrous Fracture
G-100% Granular Fracture
50F-50% Fibrous Fracture
& 50% Granular Fracture

FIGURE 20

Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

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Plate Penetration Tests of the 2000 lb. Bomb,
G.P. (Low Drag), Type EX-11, Mod 0

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