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NPG Report No. 1449

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HIGH VELOCITY IMPACTS OF

250 LB. G. P. BOMB MK 81

U. S. NAVAL PROVING GROUND
DAHLGREN, VIRGINIA

APR 13 1956

56 14098

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Date- 29 MARCH 1956

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U. S. Naval Proving Ground
Dahlgren, Virginia

High Velocity Impacts of 250 lb. G. P. Bomb Mk 81

by

F. W. Kasdorf
Terminal Ballistics Department

NPG REPORT NO. 1449

Task Assignment No.
NPG-S3-3d-442-1-56

29 March 1956

APPROVED: J. F. BYRNE
Captain, USN
Commander, Naval Proving Ground

R. D. RISSER
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ABSTRACT

The air-to-ground, rocket propelled, optically guided missile Bullpup is now under development by the Glenn L. Martin Company for the Bureau of Aeronautics. The existing 250 lb. G. P. bombs Mk 81 and AN-M-57A1, as well as the 220 lb. M81 fragmentation bomb, are all being considered as possible warheads for this missile. Inasmuch as its impact velocity is expected to fall in the range of 1100 to 1900 ft./sec. the question has arisen as to whether the bomb's ability to penetrate targets in effective bursting conditions will be seriously impaired by the high striking velocities. This information is of particular importance since a fuze delay would be tactically desirable, and a delay fuze is useless if the bomb does not remain intact after penetrating its target. Normally these bombs are not tested at impact velocities greater than 1000 ft./sec., since this is the maximum velocity that would be expected from a free fall. Therefore, a limited program has been conducted on the 250 lb. G. P. Mk 81 bomb to find the effect of higher striking velocities on bomb break-up.

The results indicate that the inert loaded 250 lb. G. P. bomb Mk 81:

a. Will penetrate 7/8" STS armor plate at 20° obliquity at 1470 ft./sec. but will break up in penetrating this target at 1735 ft./sec. or higher velocities.

b. Will penetrate sand or normal earth (free of rocks, stones, etc.) and remain in effective condition at 1700 ft./sec. and 20° obliquity but will break up at 1900 ft./sec.

FOREWORD

This is the final report on high velocity impact tests of the 250 lb. G. P. Mk 81 Low Drag Bomb, which is being considered for use as a warhead for the Bullpup missile. The program was conducted under Task Assignment NPG-S3-3d-442-1-56 as authorized by reference (a). The bombs were received under reference (b), tested during the period 14 December 1955 to 3 January 1956, and a preliminary report submitted as reference (c).

Lieutenant (jg) G. J. Miskho of the Terminal Ballistics Department conducted the firings.

This report was reviewed by:

C. B. GREEN, Director of Terminal Ballistics Research
J. R. WELSH, Commander, USN
Terminal Ballistics Officer
R. H. LYDDANE, Director of Research

INTRODUCTION

The air-to-ground, rocket propelled, optically guided missile Bullpup is now under development by the Glenn L. Martin Company for the Bureau of Aeronautics. The existing 250 lb. G. P. bombs Mk 81 and AN-M57A1, as well as the 220 lb. M81 fragmentation bomb, are all being considered as possible warheads for this missile. Inasmuch as its impact velocity is expected to fall in the range of 1100 to 1900 ft./sec. the question has arisen as to whether the bomb's ability to penetrate targets in effective bursting condition will be seriously impaired by the high striking velocities. This information is of particular importance since it would be desirable to use a delay fuze with the G. P. bombs. Such a fuze is useless if the bomb does not remain intact after penetrating its target. Normally these bombs are not tested at impact velocities greater than 1000 ft./sec. since this is the maximum velocity that would be expected from a free fall. Therefore, a limited program has been conducted on the 250 lb. G. P. Mk 81 bomb to obtain preliminary data on the effect of higher striking velocities on bomb break-up.

DESCRIPTION OF MATERIAL

Five 250 lb. G. P. Mk 81 bombs were inert loaded with a perlite-cement-water mixture to a weight of 250^{+0}_{-10} lbs. The flat-faced nose fuze being developed by the Elgin National Watch Company for use in the missile warhead, was simulated by 4" diameter flat base plugs, removed from other 250 lb. bombs, inserted in the nose of these bombs. The fuze wells were left empty.

DESCRIPTION OF TEST EQUIPMENT

The following equipment and materials were used in conducting this program:

a. Gun: 9"12/31.5 Smoothbore Gun No. 1

b. Propellant: NPFR-241(6"/47) powder
56.0# for 1470 ft./sec.
67.0# for 1710 ft./sec.
78.0# for 1920 ft./sec.
with bomb rammed 74¾5 from breech end

c. Targets: Sand and 7/8" STS armor plate

d. Velocity Measurements: Solenoid coils and oscilloscope

e. Cameras: 35mm Fastax, Speed Graphic

PROCEDURE

Since the major diameter of the Mk 81 bomb is 9¾0 and the gun employed was a 9¾1 diameter smoothbore, it was unnecessary to provide any forward bourrelet on the bomb. A 1-5/8" thick x 9¾097 diameter steel base plate was attached to the base of the bomb by means of four set screws which engaged in the V-notch at the base of the bomb. This design permitted the base plate to tear loose from the bomb upon plate impact without damaging the base of the bomb. Only one inert Bullpup fuze was available, Figure (2), so bomb base plugs (the most readily available item with the proper thread) were used to simulate the fuzes. The Mk 8[illegible] bomb had consistently penetrated 7/8" STS plate and [illegible] plate a large percentage of the time at 1000 ft./sec., in effective condition. Therefore, 7/8" STS at 20° obliquity was chosen as the initial high velocity (1900 ft./sec.) target. Earth or sand are also conceived of as being sible impact materials for this missile so the break velocity was determined for sand. A 3/4" thickness plywood faced the front of the sand pile with the [illegible]d piled up in contact with the wood.

A 16mm Fastax camera, operated at 2500 [illegible]es/sec., was used on round 2 to photograph the bomb bet[illegible] the gun muzzle and target and provide information [illegible] its flight stability. A Ballistic Synchrocamera w[illegible]sed to photograph round 3 to obtain more detailed inform[illegible]on on the base plate, simulated nose fuze and alti[illegible] of the bomb immediately before impact.

Velocities were measured in the conventional manner by solenoids and oscilloscopes.

RESULTS AND DISCUSSION

Table 1, Appendix (A), gives the test conditions and results for the five bombs fired in this program. These data are supplemented by butt impact records of each round (Appendix (B)) and photographs of the recovered bombs (Appendix (C)).

The results are summarized as follows:

Target*	Velocity ft./sec.	Condition of Recovered Bomb
7/8" STS	1919	Broken up
	1735	Broken up
	1470	Effective-intact, deformed
Sand	1933	Broken up
	1704	Effective-intact, good condition

*One impact at each condition. All impacts at 20° obliquity.

Round 1

The first round was fired at the highest impact velocity this missile is expected to attain, 1919 ft./sec. The velocity of the launching aircraft would be at least 500 knots, it would have a steep dive angle and release the missile somewhere below 15,000 ft., reference (d), to enable the missile to reach such a striking velocity. The 7/8" STS target, which might represent some armored type of vessel, was perforated by the bomb but served to break it up into numerous pieces, thus preventing the operation of any delay fuze and destroying the effectiveness of the missile, Figure (3).

Round 2

The least severe target material available, sand, was utilized for the next round in order to determine whether the bomb could withstand any type of impact at this high a velocity. The forward section of the bomb had broken into

numerous pieces but the base section had held together, Figure (4). This indicated that at some slightly lower velocity the bomb might hold together in penetrating sand or earth. High speed photography of the round from the gun muzzle to the target indicated that the bomb was flighting well and was intact upon impacting the target, Figure (5).

Round 3

Inasmuch as this missile might be fired into earth or sand at such an angle that it would detonate below a surface structure, it was deemed advisable to continue with the investigation of sand targets at a lower impact velocity. At a 500 knot launching speed and 70° dive angle, the missile would have an impact velocity of 1700 ft./sec. when released between 15,000 and 20,000 ft. altitude. Therefore round 3 was impacted against sand at 1700 ft./sec. and 20° obliquity to simulate these conditions. Under these conditions the bomb remained in good condition after penetrating a sand target fronted by 3/4" plywood, Figure (6). The nose plug was pushed in as a result of the impact. A ballistic synchrocamera picture of the round just before target impact indicated that the round was intact and in stable flight condition, Figure (7) (the bomb is shortened in this picture because the film speed was too high).

Round 4

Since 1700 ft./sec. is an impact velocity that might be anticipated under numerous high speed launching conditions, it was used against another 7/8" STS target. The bomb was again found to be broken up after penetrating the armor plate target at 20° obliquity but not as badly as it had been at the 1919 ft./sec. striking velocity. The forward part of the bomb was split open but the base had held together, Figure (8).

Round 5

This round was fired to obtain a penetration velocity limit on the 7/8" STS target at 20° obliquity. The condition of the previous round had indicated that this limit might be in the neighborhood of 1500 ft./sec. At an actual impact velocity of 1470 ft./sec the bomb penetrated

the target and remained intact, although deformed in the nose section. It is conceivable that the deformation would have been sufficient to prevent a nose fuze from functioning or cause a nose booster charge to deflagrate, Figure (9). This is an impact velocity that in all probability would be obtained with a launching speed lower than 500 knots; more likely at 250 knots.

CONCLUSIONS

It is concluded that the inert loaded 250 lb. G. P. Bomb Mk 81:

a. Will penetrate 7/8" STS armor plate at 20° obliquity at 1470 ft./sec. but will break up in penetrating this target at 1735 ft./sec. or higher velocities.

b. Will penetrate sand or normal earth (free of rocks, stones, etc.) and remain in effective condition at 1700 ft./sec. and 20° obliquity but will break up at 1900 ft./sec.

REFERENCES

(a) BUORD Conf ltr Re3d-ANB:bjk Ser 11691 of 15 Nov 1955
(b) AM30 565542
(c) NPG Conf Preliminary Report 25 Jan 1956
(d) Glenn L. Martin Company Conf Report ER 6460 - Model XASM-N-7 Guided Missile Weapon System

APPENDIX A

TABLE 1

FIRING CONDITIONS AND RESULTS

1955 Date Fired	Impact No.	Rd. No.	Bomb Wt. lbs.	Target Conditions Material	Obl.	Strik. Vel. ft./sec.	Pene.	Through Opening	Remarks
12/14	43470	1	243	7/8" STS	20°	1919	Comp.	9-1/2"x10-1/2"	Ineffective-Bomb shattered.
12/16	43477	2	240	Sand	20°	1933	Comp.	—	Ineffective-forward section of bomb broke up, base held together.
12/20	43490	3	245	Sand	20°	1704	Comp.	—	Effective-intact, bomb in good condition.
12/22	43493	4	240	7/8" STS	20°	1735	Comp.	10-1/2"x12"	Ineffective-forward section split open, base held together.
1956									
1/3	43514	5	240	7/8" STS	20°	1470	Comp.	10"x12"	Effective-intact, except for deformation of nose section.

Note: Bombs fired from 9"12/31.5 Smoothbore Gun No. 1

APPENDIX B

BUTT IMPACT RECORD

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

REF: [illegible]

TEST OBJECT: [illegible]	IMPACT NUMBER: 43470
	DATE OF IMPACT: 12-14-55
	BUTT NO: R

PLATE		BOMB PROJECTILE	
GAUGE: .87"	CLASS: STS	CALIBER: 250 Lb. G. P.	TYPE: Low Drag
MANUFACTURER: Lukens	CONTRACT: N600-1555-30292	MANUFACTURER: A. O. Smith	LOT NO: 2
GROUP: --	NO: 65	MARK: 31	MOD: 1
DIMENSIONS: 96" x 300"		PROJECTILE NO: 1	YEAR OF SPECIFICATION: --
IMPACT DATA		CAPPED: ☐ YES ☒ NO	LENGTH (Uncapped): --
OBLIQUITY: 20°	PENETRATION: Comp.	WEIGHT (Capped): --	WEIGHT (Uncapped): 243.00
THICKNESS AT IMPACT: .87"	NO OF IMPACT ON PLATE: 1	FUZE: None - Flat base plate in use	FILLER: Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 55"	THROUGH OPENING: 9-1/2" x 10-1/2"	CONDITION AFTER FIRING: ☐ EFFECTIVE ☒ INEFFECTIVE	
DISTANCE FROM: ☒ TOP ☐ BOTTOM 54"	DISTANCE FROM: ☐ RIGHT ☐ LEFT 149"	Bomb broke up; completely shattered	
FLAKING FRONT: 0"	FLAKING BACK: 0"		
SPUR: 8"	DISH: 2"		
CRACKS: 0"	BULGE: [illegible]		
BUTTON: ☒ THROWN ☐ STARTED			

VELOCITY (F.S.)

DESIRED	OBTAINED			
		☐ MUZZLE	☐ STRIKING	☒ MEAN 1919

REMARKS

GUN: [illegible]

[illegible]	[illegible]	[illegible]
SIGNATURE: [illegible]		[illegible], U.S.N., WEAPONS OFFICER

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[illegible]

NAVY-DPPO PRESS, WASH., D.C.

BUTT IMPACT RECORD

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

TEST OBJECT	IMPACT NUMBER
	DATE OF IMPACT
	BUTT NO

PLATE		SOT PROJECTILE	
GAUGE	CLASS	CALIBER	TYPE
MANUFACTURER	CONTRACT	MANUFACTURER	LOT NO
GROUP	NO	MARK	MOD
DIMENSIONS		PROJECTILE NO	YEAR OF SPECIFICATION
IMPACT DATA		CAPPED ☐ YES ☒ NO	LENGTH (Uncapped)
OBLIQUITY	PENETRATION	WEIGHT (Capped)	WEIGHT (Uncapped)
THICKNESS AT IMPACT	NO OF IMPACT ON PLATE	FUZE	FILLER
DISTANCE FROM NEAREST IMPACT	THROUGH OPENING	CONDITION AFTER FIRING ☐ EFFECTIVE ☐ INEFFECTIVE	
DISTANCE FROM ☐ TOP ☐ BOTTOM	DISTANCE FROM ☐ RIGHT ☐ LEFT		
FLAKING FRONT	FLAKING BACK		
SPUR	DISH		
CRACKS	BULGE		
BUTTON ☐ THROWN ☐ STARTED			

VELOCITY (F.S.)

DESIRED	OBTAINED			
		☐ MUZZLE	☐ STRIKING	☒ MEAN

REMARKS

SIGNATURE		DATE	

GPO-DPPD PRNT., WASH., D.C.

BUTT IMPACT RECORD

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

REF: [illegible]

IMPACT NUMBER	43490
DATE OF IMPACT	12-20-55
BUTT NO	P

TEST OBJECT: Bomb Impact at High Velocity

PLATE

(NO PLATE)
3/4" PLYBOARD BACKED BY SAND

GAUGE:	CLASS:
MANUFACTURER:	CONTRACT:
GROUP:	NO:
DIMENSIONS: 3/4" PLYBOARD BACKED BY SAND	

IMPACT DATA

OBLIQUITY:	PENETRATION:
THICKNESS AT IMPACT:	NO. OF IMPACT ON PLATE:
DISTANCE FROM NEAREST IMPACT:	THROUGH OPENING:
DISTANCE FROM: ☐ TOP ☐ BOTTOM	DISTANCE FROM: ☐ RIGHT ☐ LEFT
FLAKING FRONT:	FLAKING BACK:
SPUR:	DISH:
CRACKS:	BULGE:
BUTTON: ☐ THROWN ☐ STARTED	

BOMB ~~PROJECTILE~~

CALIBER: 250 lb. G. P.	TYPE: Low Drag
MANUFACTURER: A. O. Smith	LOT NO: 2
MARK: 81	MOD: 1
PROJECTILE NO: 4	YEAR OF SPECIFICATION: --
CAPPED: ☐ YES ☒ NO	LENGTH *(Uncapped)*: --
WEIGHT *(Capped)*: --	WEIGHT *(Uncapped)*: 245.00#
FUZE: None - flat base plate in nose	FILLER: Perlite-Cement-Water

CONDITION AFTER FIRING: ☒ EFFECTIVE ☐ INEFFECTIVE

Intact, bomb in good condition

VELOCITY *(F.S.)*

DESIRED	OBTAINED	
		☐ MUZZLE ☐ STRIKING ☒ MEAN 1704

REMARKS

GUN: [illegible] No. 1 Mk A Mod [illegible]

		☐ ACCEPT ☐ REJECT

SIGNATURE: [illegible] MISKHO, LTJG, USNR, TEST OFFICER

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TABLE 4

NAVY-DPPO PRNC, WASH., D.C.

BUTT IMPACT RECORD
NPG-NPG-314

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

REF: (a) [illegible]

IMPACT NUMBER	43493
DATE OF IMPACT	12-22-55
BUTT NO	3

TEST OBJECT: Bomb Impacts at High Velocity

PLATE		BOMB	
GAUGE: .87"	CLASS: STS	CALIBER: 250 lb. G. P.	TYPE: Low Drag
MANUFACTURER: Lukens	CONTRACT: N600-1553-30292	MANUFACTURER: A. O. Smith	LOT: 2
GROUP: --	NO: 65	MARK: 81	MOD: 1
DIMENSIONS: 96" x 300"		PROJECTILE NO: 5	YEAR OF SPECIFICATION: --
IMPACT DATA		CAPPED: [ ] YES [X] NO	LENGTH *(Uncapped)*: --
OBLIQUITY: 20°	PENETRATION: Comp.	WEIGHT *(Capped)*: --	WEIGHT *(Uncapped)*: 240.00#
THICKNESS AT IMPACT: .87"	NO. OF IMPACT ON PLATE: --	FUZE: None - flat base plate in nose	FILLER: Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 36"	THROUGH OPENING: 10-1/2" x 12"	CONDITION AFTER FIRING: [ ] EFFECTIVE	[X] INEFFECTIVE
DISTANCE FROM: [X] TOP [ ] BOTTOM 66"	DISTANCE FROM: [ ] RIGHT [ ] LEFT 115"	Forward section split open, base	
FLAKING FRONT: 0"	FLAKING BACK: 0"	held together	
SPUR: 5"	DISH: 3"		
CRACKS: 0"	BULGE: 0"		
BUTTON: [X] THROWN [ ] STARTED			

Impact Dim. 11" x 12-1/2"

VELOCITY (F.S.)				
DESIRED	OBTAINED	[ ] MUZZLE	[ ] STRIKING	[X] MEAN 1735

REMARKS

GUN; 9912 No. 1 Mk A Mod 0

		[ ] ACCEPT [ ] REJECT
SIGNATURE: G. J. MISKHO		LTJG, USN, TEST OFFICER

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TABLE 5

BUTT IMPACT RECORD
PRNC-NPG-114

U. S. NAVAL PROVING GROUND
DAHLGREN, VA.

REF: (a) [illegible]

IMPACT NUMBER	DATE OF IMPACT	BUTT NO
43514	1-3-56	3

TEST OBJECT

Bomb Impacts at High Velocity

PLATE		BOMB ~~PROJECTILE~~	
GAUGE: .87"	CLASS: STS	CALIBER: 250 lb. G. P.	TYPE: Low Drag
MANUFACTURER: Lukens	CONTRACT: N600-1555-30292	MANUFACTURER: F. E. Crane	LOT: 2
GROUP: —	NO: 65	MARK: 81	MOD: 1
DIMENSIONS: 96" x 300"		PROJECTILE NO: 1	YEAR OF SPECIFICATION: —
IMPACT DATA		CAPPED: ☐ YES ☒ NO	LENGTH (Uncapped): —
OBLIQUITY: 20°	PENETRATION: Comp.	WEIGHT (Capped): —	WEIGHT (Uncapped): 239.50#
THICKNESS AT IMPACT: .87"	NO. OF IMPACT ON PLATE: 3	FUZE: —	FILLER: Perlite-Cement-Water
DISTANCE FROM NEAREST IMPACT: 26"	THROUGH OPENING: 10" x 12"	CONDITION AFTER FIRING: ☒ EFFECTIVE	☐ INEFFECTIVE
DISTANCE FROM: ☒ TOP ☐ BOTTOM 35"	DISTANCE FROM: ☐ RIGHT ☒ LEFT 208"	Intact except for deformation of	
FLAKING FRONT: 0"	FLAKING BACK: 0"	nose section	
SPUR: 5"	DISH: 3"		
CRACKS: 0"	BULGE: 0"		
BUTTON: ☒ THROWN ☐ STARTED			

VELOCITY (F.S.)				
DESIRED:	OBTAINED:	☐ MUZZLE	☐ STRIKING	☒ MEAN 1470

REMARKS

GUN: 9912 No. 1 Mk A Mod [illegible]

GUN	SPEED	RECOMMENDATION: ☐ ACCEPT ☐ REJECT
SIGNATURE: G. J. SISKRO		TITLE: LTJG, USNR, TEST OFFICER

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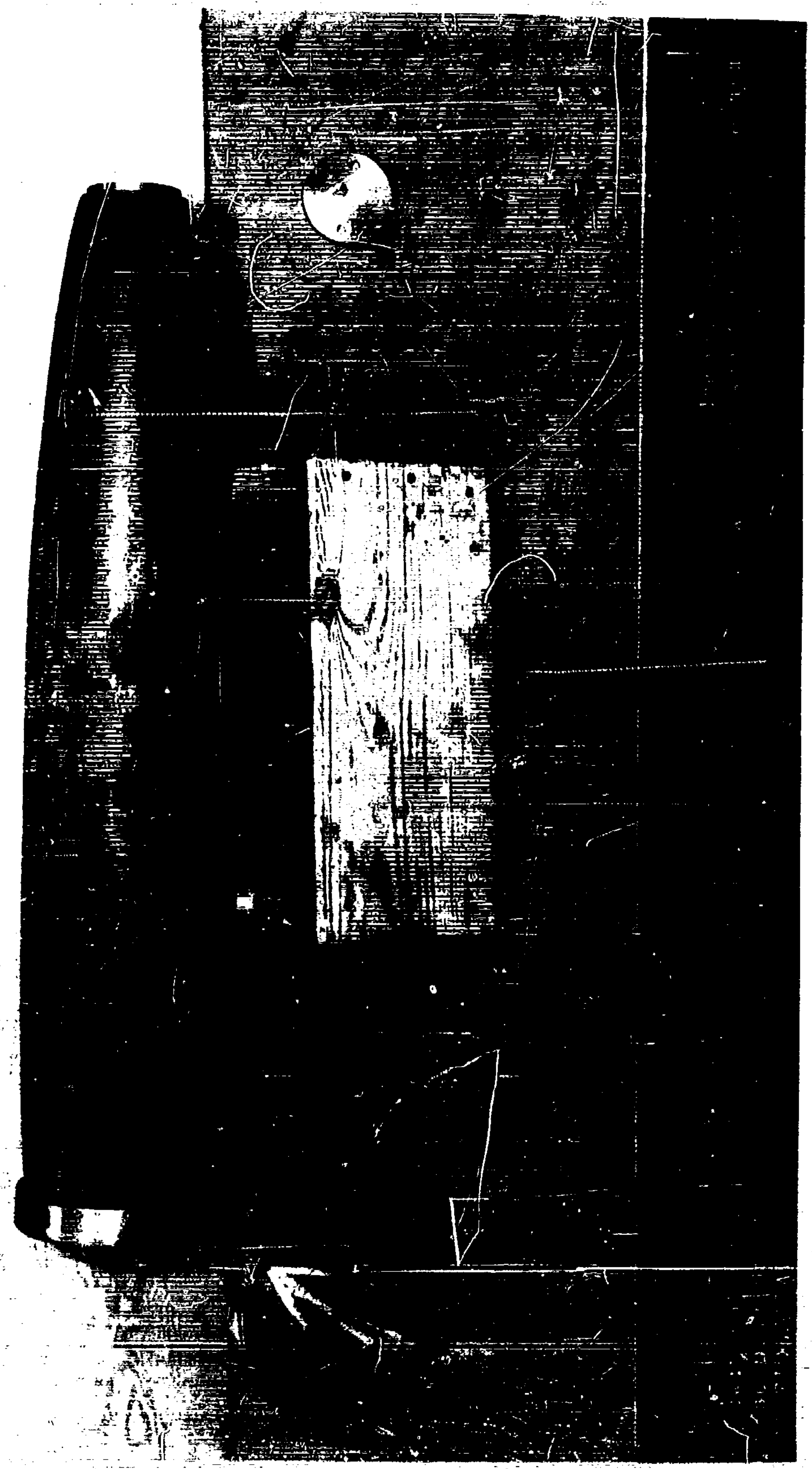
NAVY-DPPO [illegible]

APPENDIX C



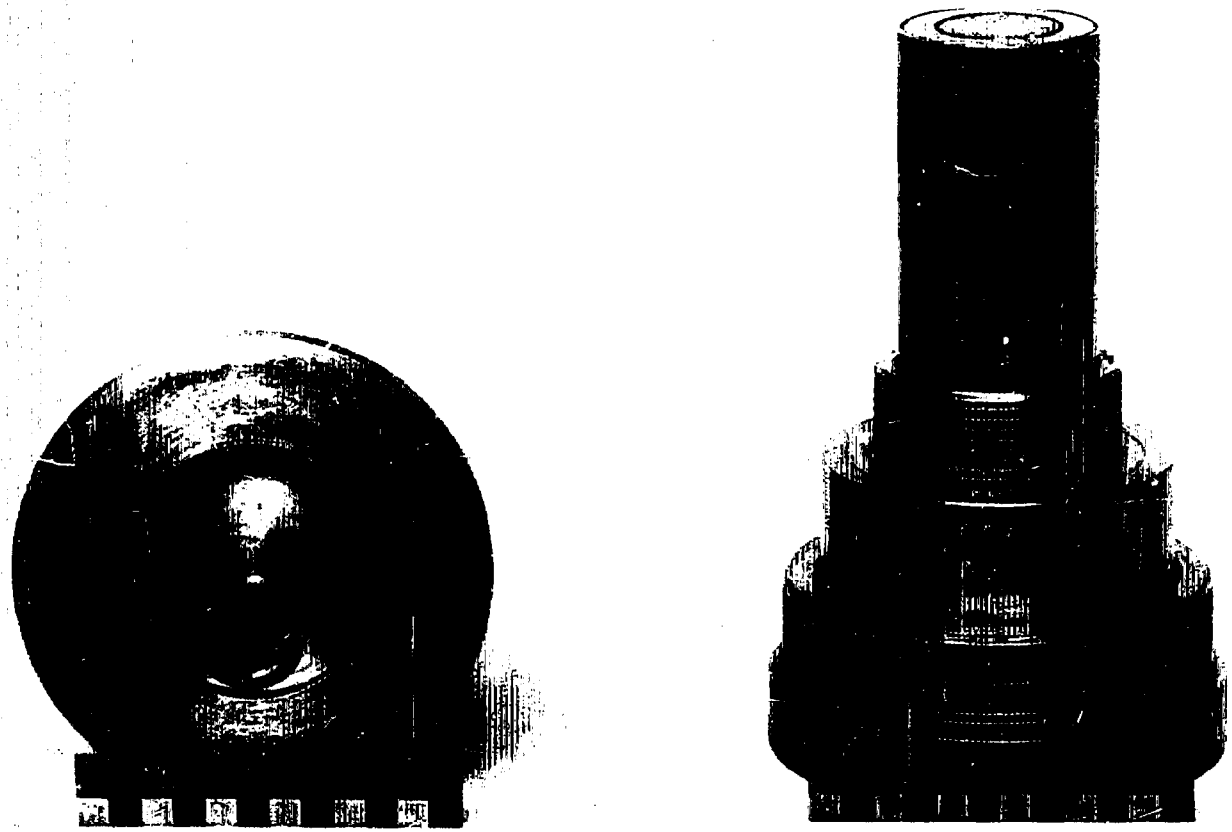


Figure 2

AP4-70573 - 250 lb. G. P. Low Drag Bomb MK 81 Mod 2, High Velocity Impact Tests.
View: Fuze developed by Alvin National Watch Company for Bullpup Missile Warhead.
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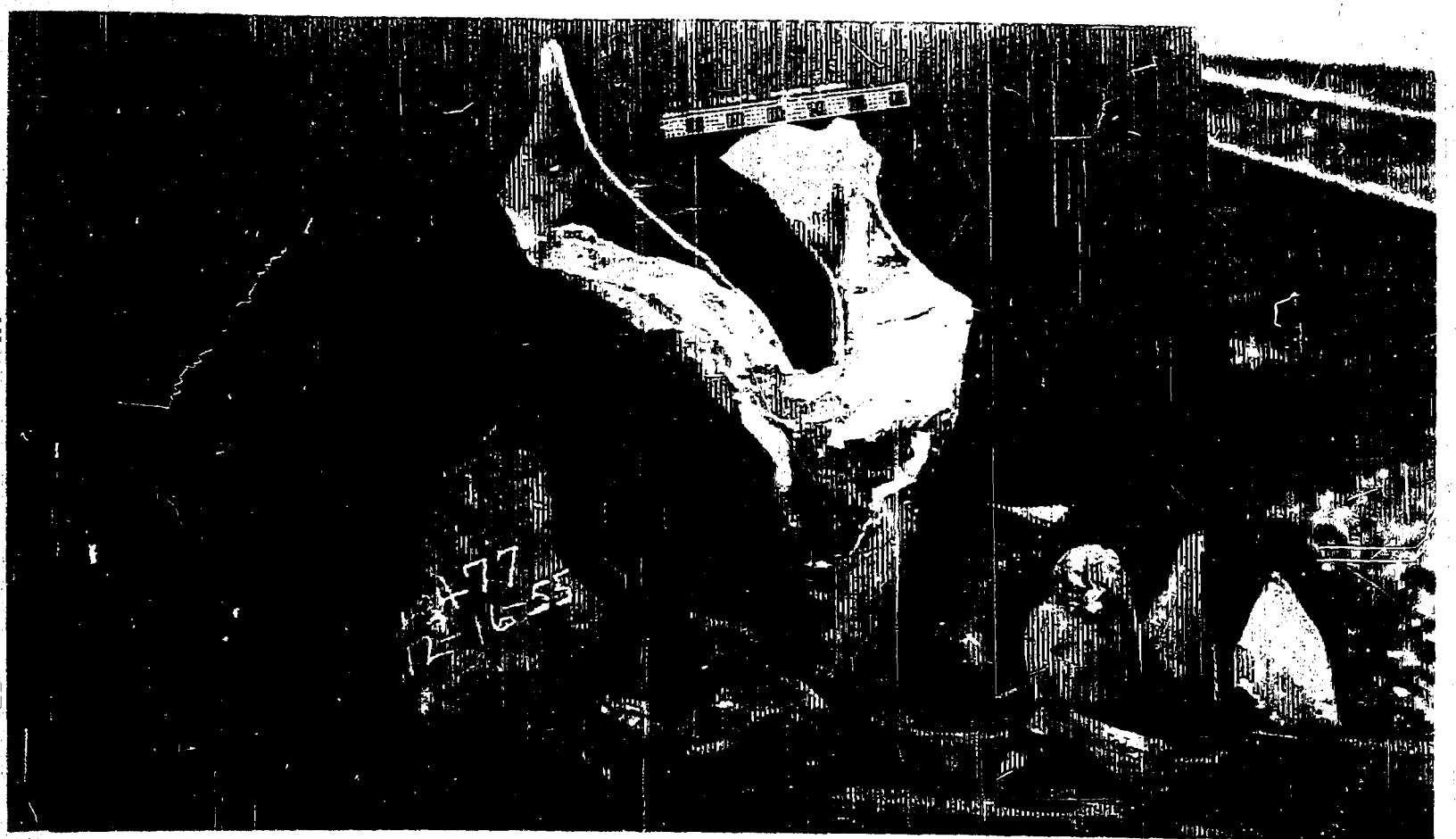
LUKENS STEEL COMPANY



NP9-70574 — 250 lb. G. P. Low Drag Bomb Mk 61 Vol 0, High Velocity Impact Tests:

Impact No.	Date Fired	Rd. No.	Target	Ft.	Velocity	Att.	Bomb Bene.	Thrown Opening	Remarks
3477	12/16/55	2	Sand	2'	1135 f/s	24°	Comp.	--	Ineffective-forward section of bomb broke up, base held together.

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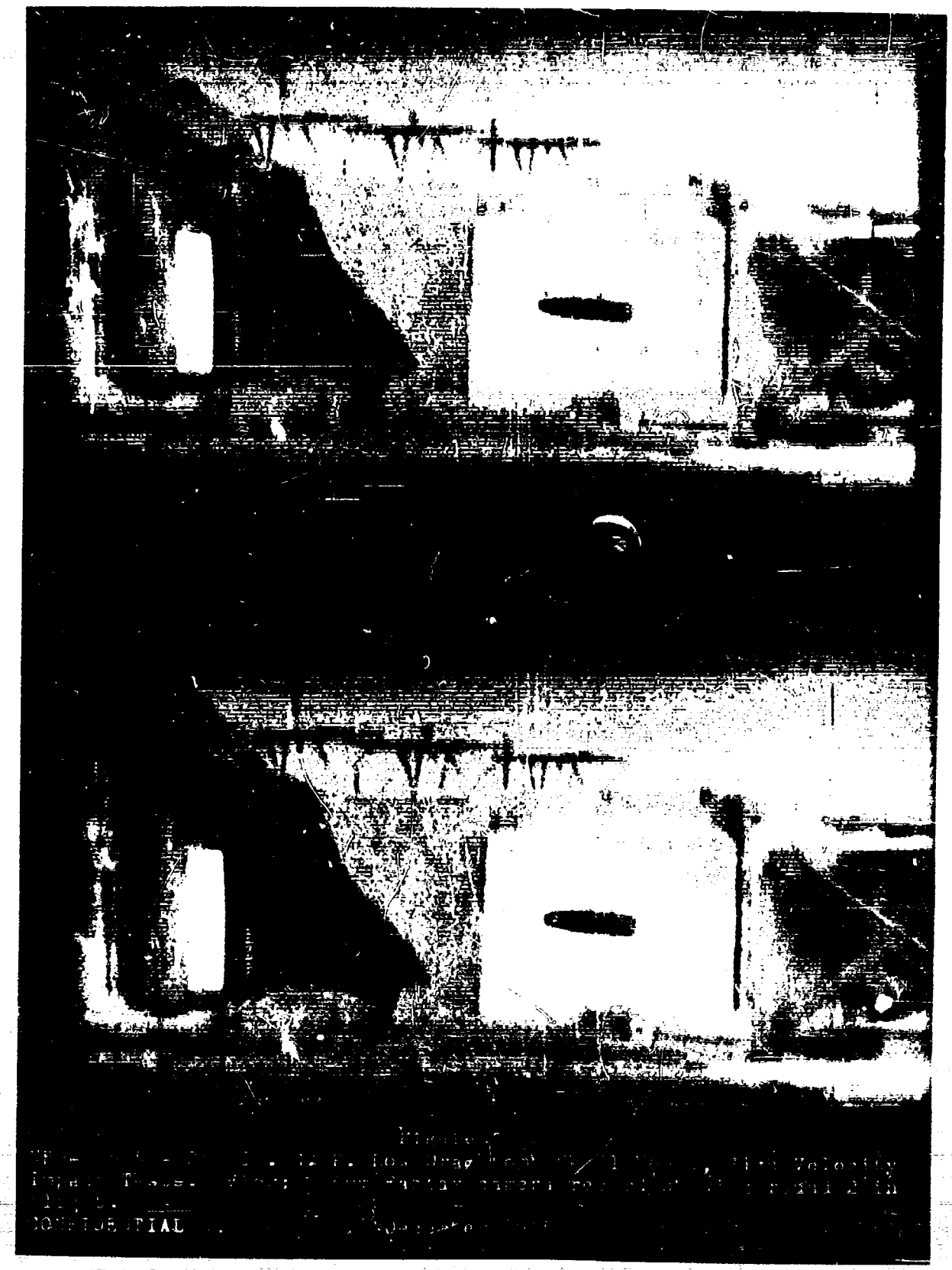
27 December 1955



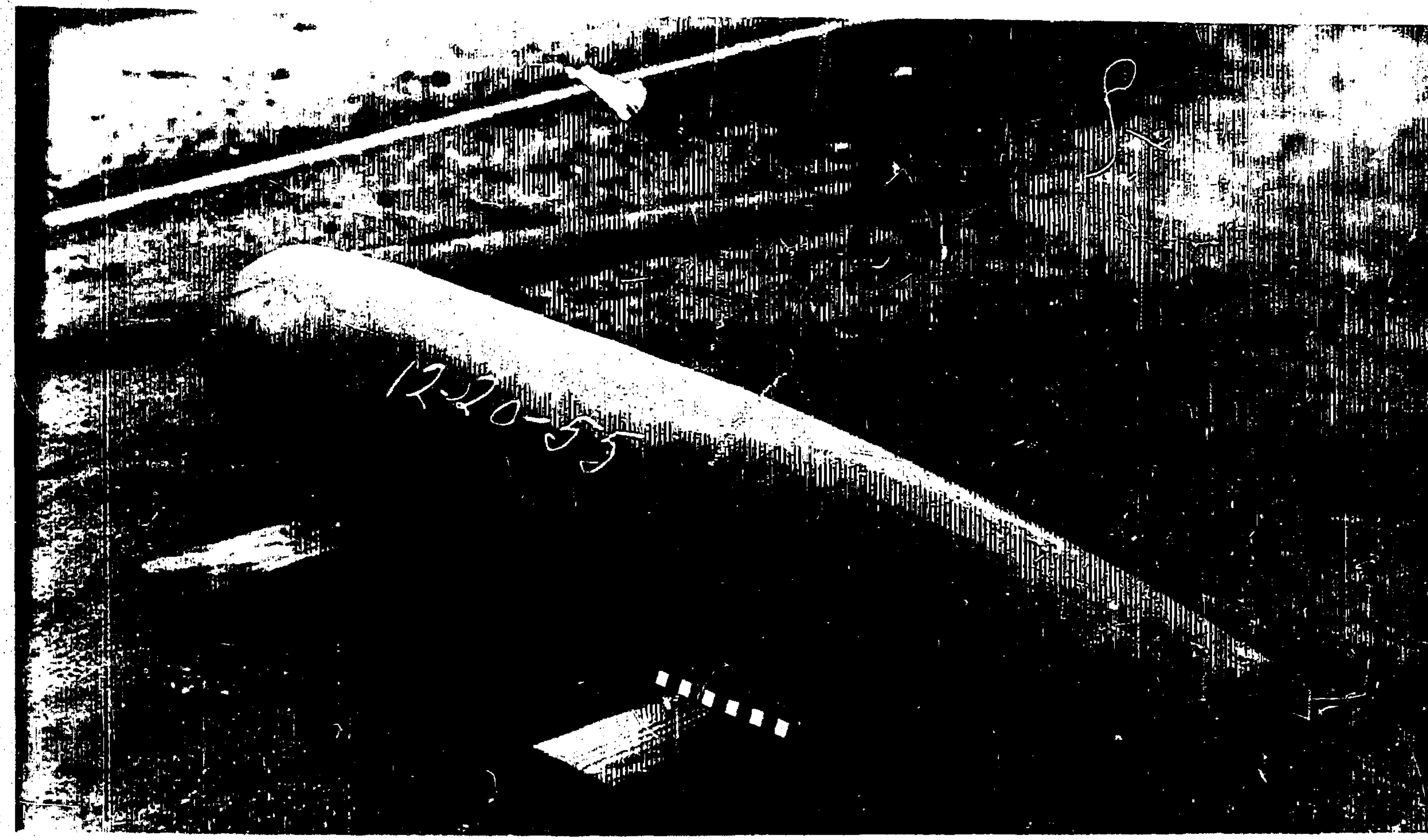


Figure [illegible]

NPG-70576 - 250 [illegible] Low Drag [illegible] Velocity Impact Test:

Impact No.	Date Fired	El. [illegible]	Target	[illegible]	Velocity	[illegible] Wt.	Fuze Comp.	Chronograph Reading	Remarks
[illegible]	12/20/55	3	Sand	[illegible]	[illegible] f/s	[illegible]	Comp.	--	Effective-intact, bomb in good condition

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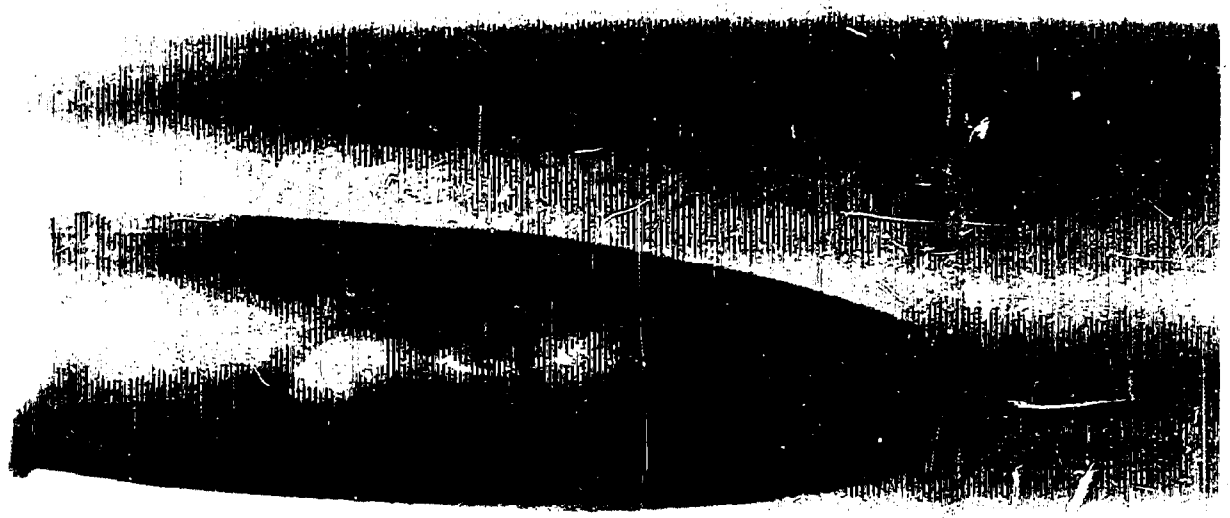
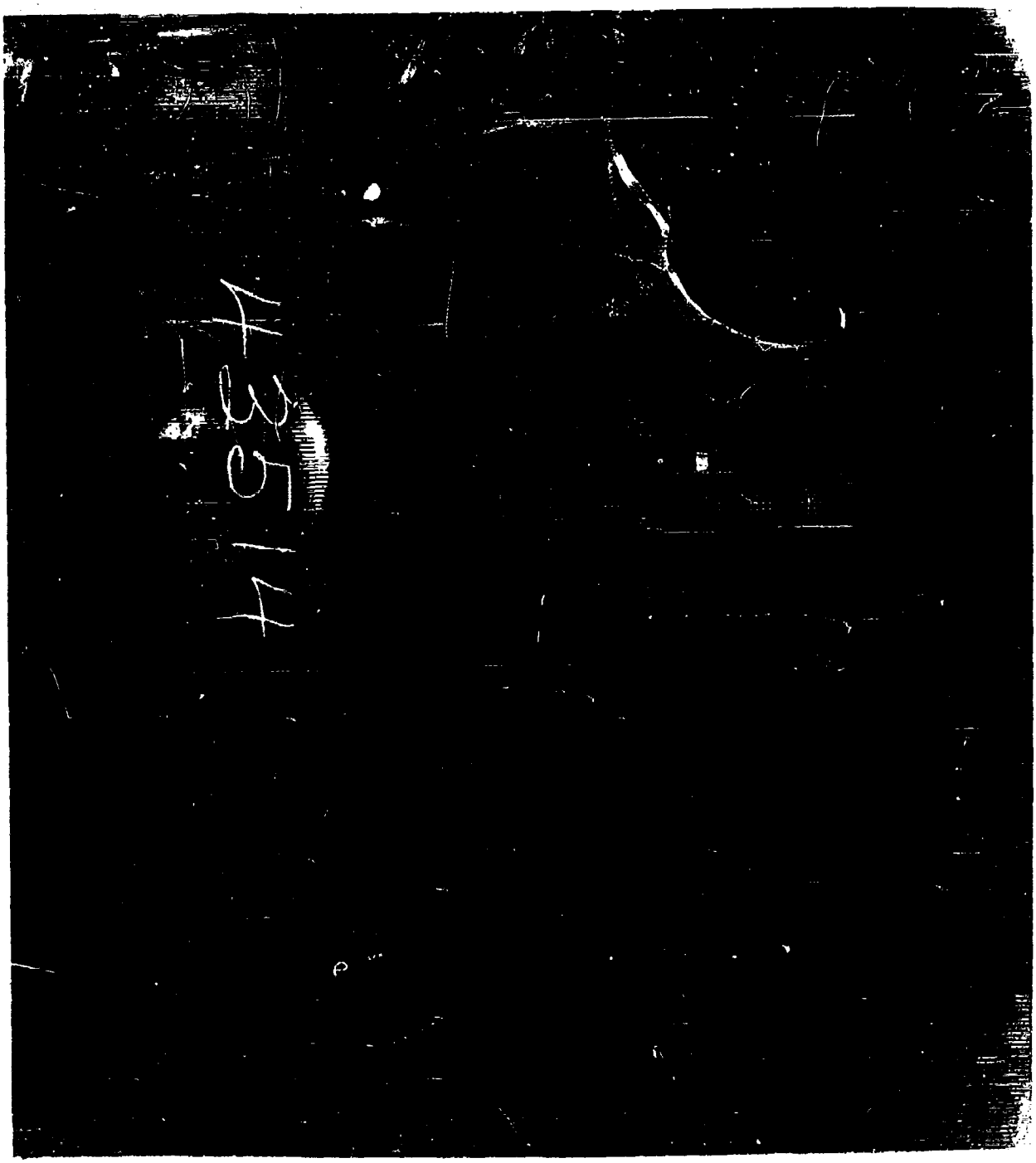
[illegible] December 1955




EMP 43493



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Naval Proving Ground. NPG Report No. 1449
HIGH VELOCITY IMPACTS OF 250 LB. G. P. BOMB MK 81,
by F. W. Kasdorf. 29 Mar 1956. 5 p. 6 tables,
9 figs. CONFIDENTIAL

Inasmuch as the impact velocity of the 250-lb. G. P. bomb Mk 81 is expected to fall in the range of 1100 to 1900 ft./sec. the question has arisen as to whether the bomb's ability to penetrate targets in effective bursting conditions will be seriously impaired by the high striking velocities. Results indicate that it will:
(a) Penetrate 7/8" STS armor plate at 20° obliquity at 1470 ft./sec. but will break up in penetrating this target at 1735 ft./sec. or higher velocities.
(b) Penetrate sand or normal earth (free of rocks, stones, etc.) and remain in effective condition at 1700 ft./sec. and 20° obliquity but will break up at 1900 ft./sec.

I. General purpose bombs - Terminal ballistics

2. Bombs - 250 lb. - Mark 81

I. Kasdorf, F. W.

II. Title

III. NPG-S3-3d-442-1-56

CONFIDENTIAL

Naval Proving Ground. NPG Report No. 1449
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by F. W. Kasdorf. 29 Mar 1956. 5 p. 6 tables,
9 figs. CONFIDENTIAL

Inasmuch as the impact velocity of the 250-lb. G. P. bomb Mk 81 is expected to fall in the range of 1100 to 1900 ft./sec. the question has arisen as to whether the bomb's ability to penetrate targets in effective bursting conditions will be seriously impaired by the high striking velocities. Results indicate that it will:
(a) Penetrate 7/8" STS armor plate at 20° obliquity at 1470 ft./sec. but will break up in penetrating this target at 1735 ft./sec. or higher velocities.
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