

AD/A-003 221

LESS LETHAL LIQUID BALL

John W. Sarvis

Army Land Warfare Laboratory
Aberdeen Proving Ground, Maryland

May 1974

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Three sizes of liquid-filled balls were tested for various ballistic characteristics to determine the best size for potential use as a less lethal munition. Test results and drawings or photographs are presented. Previous attempts have been made to employ supposedly nonlethal weapons in quelling civil disturbance. The use of fire hoses has been tried but has led to injury and to an			

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BLOCK 20. ABSTRACT CONT

unfavorable image cast on firefighters. The Army undertook to study the use of both water cannon (not identifiable with firefighting units) and water-filled launched containers for the purpose of finding an acceptable less-lethal munition. This report describes the genesis, development, and testing of liquid-filled breakable spherical munitions in 12-gauge, 40mm and 3-inch diameter sizes.

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INTRODUCTION

In responding to a domestic confrontation situation, Army personnel armed with conventional munitions incur a certain risk that their intended restrained response may, through either happenstance or isolated malevolence, be uncontrollably escalated. There is, therefore, the necessity to have a less drastic response capability (one purposefully less-than-lethal) for those situations for which death would not be an appropriate deterrent.

The objective of this program was to develop spherical projectiles containing water or other liquids for less lethal applications. Additional effort on the less lethal area was also conducted under LWL Task 01-F-72, Less Lethal Ammunition for Small Arms. This development effort is described in LWL Technical Report No. 74-17.

DEVELOPMENT

In the beginning of the US Army Land Warfare Laboratory's (USALWL) study to find an acceptable means of quelling civil disturbance, personnel of Mobility Branch, USALWL, envisioned the use of discrete encapsulated slugs of water launched at moderate velocity to accomplish a relatively noninjurious desirable effect.

3-Inch Diameter Liquid Ball

Both Government and contractor personnel pursued the concept of discrete slugs of water in frangible spheres. A child's toy ball, the "Blue Bird" ball, available locally, was chosen for the candidate sphere. Under funding from USALWL Task 10-M-71, the contractor, AAI Corporation, Cockeysville, MD, prosecuted development of a less-lethal projectile using the 3-inch diameter toy ball as a basis. The ball material was ethylene vinyl acetate. The ball, having a skin thickness of from 0.030 inch to approximately 0.090 inch at the seam, was scored to a depth of 0.025 inch, filled with water, and glued to a cupped cylindrical styrofoam and homosote sabot for retention purposes (See Figure 1).

This assemblage was designed to be fired from an existing launching system vended by the service contractor for firing their 3-inch diameter riot agent dispensing grenade (See Figure 2). This existing system is composed of a standard 12-gauge riot gun, an L-110 launcher, and a tangent sight mounted on the riot gun. The launch is powered by a C-200 blank cartridge, also vended by AAI Corporation.

In 1971 USALWL requested the then-operational US Army Small Arms Systems Agency (SASA) to have the Biophysics Laboratory at Edgewood Arsenal perform comparative hazards studies to assess the probable worth of further effort on the 3-inch diameter Liquid Ball (at that time referred to as the Water Ball). The Edgewood Arsenal study consisted of a series of shots at gelatin filled skulls and liver and lung organs of goats and baboons. Test projectiles were the Rubber Bullet, a device used by the United Kingdom; the Stun Bag; and the USALWL Water Ball. The UK Rubber Bullet appeared hazardous to a range of approximately 63 feet (difficult to pinpoint exactly due to erratic velocities). The MBA Stun Bag appeared hazardous to a range of 85 feet. The results from the USALWL Water Ball, however, were more encouraging and indicated hazard to only about 7 feet. (Refer to Edgewood Arsenal Biophysics Laboratory Report EB-TR 73056, by Heieck and others.) SASA recommended further work on the liquid-filled frangible sphere due to its relatively low hazard.

The concept was pursued further by Munitions Branch, USALWL, which was then engaged in evaluation of salient commercial less-lethal munitions and certain other new concept items. To determine quickly that optimum size of Liquid Ball which was most effective and least damaging, it was decided to investigate the tactical, flight, and impact characteristics of three different sizes. The sizes, corresponding



Figure 1. Less-Lethal Liquid Ball, 3-inch Diameter



Figure 2. 3-inch Diameter Less-Lethal Liquid Ball,
Launch System Components, and Commercial Grenade

to available launch mechanisms, were those which would fit 12-gauge, 40mm and 3-inch guns or launchers. Because of the environmental considerations associated with military items, the filler material (100% water) had to be replaced by a liquid which would not become solid (and lethal or unusable) when stored at extremely low temperature prior to use in a northern CONUS location. Of the various candidate fillers, a mixture of glycerine and water appeared best to permit low temperature storage and tactical employment, to insure a minimum of public objection, to prevent harmful physiological effects to user and target, and to minimize certain risks if the munition were a candidate for adoption into the Army inventory.

A work assignment under an existing contract with AAI Corporation was executed for fabrication of 500 of the 3-inch diameter Liquid Balls having the improved filler. The contractor provided a 60% glycerine and 40% water filling for the serrated balls. Specific gravity of the mix was about 1.2. The weight of the filled ball was 265 grams \pm 3 grams. The contractor also provided drawings (see Appendix A). The depth of the two normal diametral serrations was kept at 0.025 inch. The burst energy of sample projectiles was about 3.5 foot-pounds. Because of the large variation in skin thickness in the balls, this burst energy figure was variable.

Loading and firing the launch system for the 3-inch diameter is clumsy and time-consuming--a tactical disadvantage. The sequence is as follows:

1. Place the butt of the gun on the ground and, grasping the L-110 Launcher or the riot gun barrel to steady it with one hand, insert a Liquid Ball into the mouth of the launcher with the other hand. Press firmly down on the Liquid Ball forcing the sabot to engrave into the rifling of the launcher bore.
2. After raising the gun to waist height and holding the gun horizontal at the balance with the left hand, place a blank cartridge into the chamber with the right hand. (The short blank C-200 cartridge must be manually loaded for reliable operation.)
3. Shoulder the loaded and charged launcher and riot gun and then sight and fire.

Because of the care required to avoid rupturing the ball while forcing the sabot to engrave into the rifling, a rate of fire of only about 3 shots per minute was experienced.

40mm Liquid Ball

Another work assignment under the same R & D contract provided for development of a 40mm version of the Liquid Ball. The final design is shown as an assembled cartridge (see Figure 3). The ball itself is a serrated glycerin and water-filled ping-pong ball. This celluloid type ball material is 0.015-inch thick and is serrated on two normal diameters to a depth of 0.010-inch for easy fracture upon

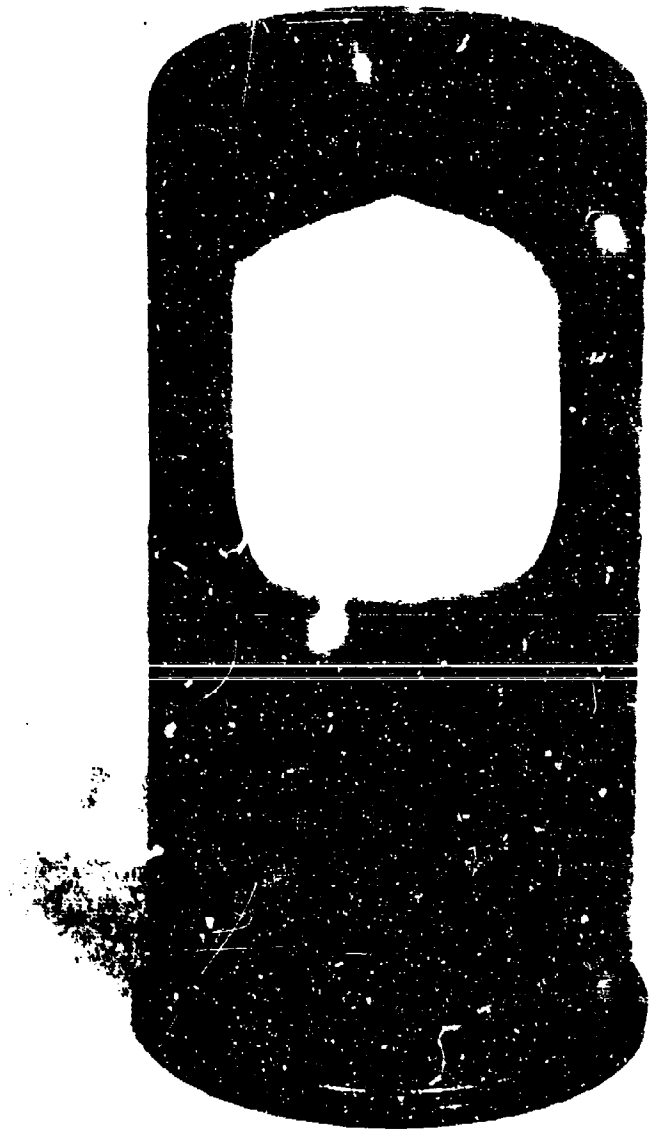


Figure 3. 40-mm Liquid Ball Cartridge (cutaway)

target impact. Impact fracture consumes about 0.7 foot-pounds of energy. (Refer to drawings in Appendix B.)

12-Gauge Liquid Ball

A 12-gauge Liquid Ball was designed, fabricated, and tested by USALWL. The projectile had the following characteristics:

length	-	1.08 inch
diameter	-	0.67 inch
ogive	-	spherical
jacket thickness	-	0.063 inch
base plug length	-	0.25 inch
jacket material	-	silicone elastomere RTV-602
filling	-	glycerin & water
weight	-	5.5 grams

Following preliminary tests, it was determined that a commercially-available marking pellet could be used to economically provide 12-gauge test data. These pellets had a thin skin composed of gelatin and glycerine and they were filled with a lead-free oil-based paint. The specific gravity of the paint was 1.2, virtually identical to that of the 60/40 glycerine/water mix used in the other liquid balls. These pellets were procured from the Nelson Paint Company, Iron Mountain, Michigan 49801. These "Nelson Marking Pellets" were fired from a 12-gauge Hi200 riot gun and from a "Nel-Spot 007" CO₂ marking pistol.

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WEAPON SYSTEM FIRING TESTS

Firing tests by the H. P. White Laboratory, Belair, MD performed under contract DAAD05-73-C-0532 yielded information on the following:

1. accuracy at ranges of 6.4, 20, 35, 50 and 70 meters
2. stress-condition accuracy at 35 meters
3. cold temperature storage and firing characteristics
4. gross effect of cross-wind
5. maximum range

Contractor reports on results of firing tests of the 3-inch diameter, 40mm, and 12-gauge Liquid Balls are located in Appendixes C, D and E.

IMPACT TESTS

Munitions Branch, USALWL, funded physiological testing of the three Liquid Balls through Biological Sciences Branch, USALWL to AAI Corporation. Physiological testing was completed in September 1973. Refer to LWL Technical Report No. 74-79 "The Effects of Less Lethal Projectiles." This report, which is in preparation at this time, will provide information on impact damage done by various projectiles.

RESULTS & CONCLUSIONS

1. Weapon systems firing tests indicate that the accuracy characteristics of the Liquid Balls in existing launchers would permit consistent hits on a designated individual at a range no greater than about 20 meters.

2. Poor accuracy appeared to be in part due to viscous shear of the liquid filler in the larger balls. At low temperature when the filler became relatively inviscid, the accuracy improved.

3. Maximum range for employment in volley fire against crowds would be slightly over 100 meters for the 40mm and 3-inch diameter Liquid Ball systems as tested. Maximum range for the 12-gauge Liquid Ball system tested was about 65 meters.

4. The present launch system for the 3-inch diameter Liquid Ball is operationally unacceptable due to its low reloading rate. Use of a more rapidly reloadable launcher, several preloaded throwaway launchers, or use of the balls in a multiple-shot launcher (possible vehicle mounted) could overcome this problem; however its utility would still be limited by aiming and accuracy considerations.

5. The present hard nylon sabot for the 40mm Liquid Ball makes this particular configuration hazardous.

6. Impact test results available to date indicate the 3-inch Liquid Ball exhibits less hazard to test targets than the smaller sizes of balls for the same level of energy.

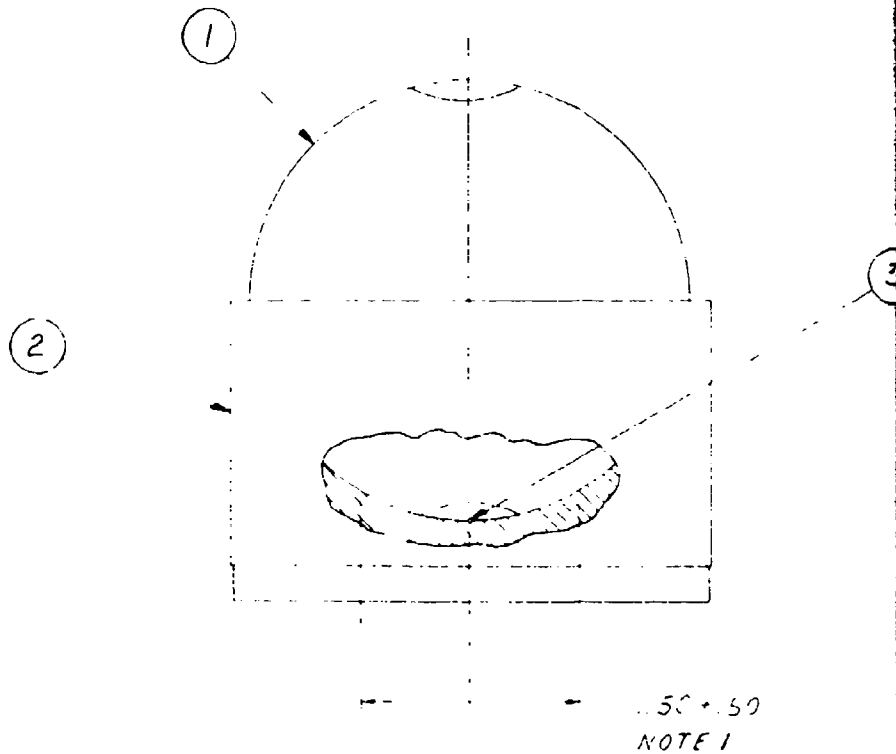
RECOMMENDATIONS

1. When additional evaluated information on damage phenomena associated with blunt trauma for the Liquid Balls and certain other items developed under Task 01-F-72 becomes available, it is recommended that the Parent Agency (ARMCOM) consider this and other data and develop a program to provide the US Army with a less lethal munition system which will maximize desired safe effects (possibly those associated with the 3-inch ball) and minimize those undesirable tactical, safety, and physical characteristics (some noted in this report) which preclude successful system use.

2. Should the parent agency determine (upon availability of this evaluated information) that a 3-inch liquid-filled sphere would present the best combination of desirable effects and minimum undesirable characteristics, it is recommended that a projectile be designed with internal ribbing to immobilize the liquid and thereby provide better accuracy.

3. Use of a softer ball material such as silicone elastomer RTV-602 (or other inert frangible elastomer having hardness of around Shore A20) is recommended to preclude unnecessary laceration of sensitive tissue.

APPENDIX A
3-Inch Liquid Ball
(Drawings)



NOTES:

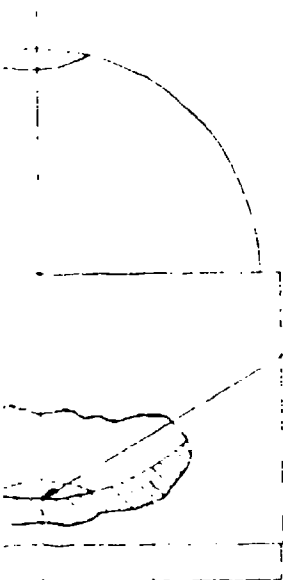
1. COAT ITEM 1 & 2 WITH RUBBER CEMENT TO DIAMETER SHOWN. ALLOW TO CURE PER MANUFACTURE'S INSTRUCTIONS. THEN ASSEMBLE, ALIGNING THE BALL'S TRADE MARK ON THE CENTER LINE AS SHOWN.
2. SUGGESTED SOURCE: BEST TEST - RUBBER CEMENT NO. 500 UNION RUBBER & ASBESTOS Co., TRENTON, N.J.

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1	04.102004	PROJECTILE	
	-10	ASSEMBLY	

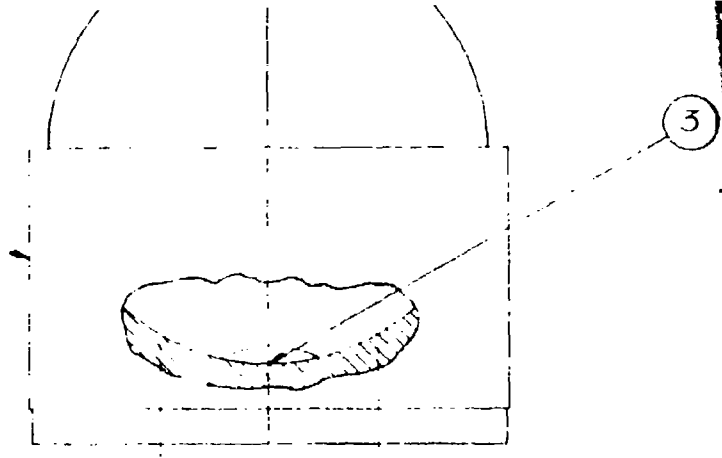
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1. COAT ITEM 1 & 2 WITH RUBBER CEMENT TO DIAMETER SHOWN. ALLOW TO CURE PER MANUFACTURE'S INSTRUCTIONS. THEN ASSEMBLE, ALIGNING THE BALL'S TRADE MARK ON THE CENTER LINE AS SHOWN.
2. SUGGESTED SOURCE: BEST TEST - RUBBER CEMENT NO. 500 UNION RUBBER & ASBESTOS Co., TRENTON, N.J.

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Figure 1. Three-Inch Less Lethal Launcher

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NOTE 1

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AR		RUBBER CEMENT			
1	040102003	BAROT ASSEMBLY			
1	040102004	PROJECTILE			
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		DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES	OCTOBER 16, 1972		
		MATERIAL	DRAFTSMAN	SA. Hiett 10-16-72	U. S. ARMY PROJECT LESS LETHAL
			CHECKER	R. STEINER 10-16-72	
			PROJECT ENG	R. STEINER 10-16-72	
			PROJECT NO	02-F-73	
1		FINISH	APPROVED	DATE	SIZE
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		HEAT TREATMENT	COCKEYSVILLE, MD.		C 97384
APPLICATION					SCALE 1/1

Figure 1. Three-Inch Less Lethal Liquid Ball Projectile Assembly

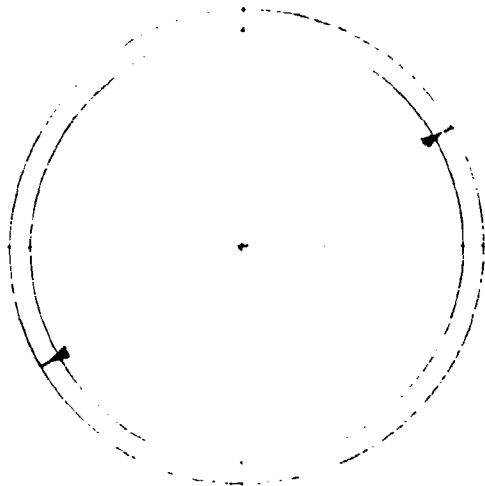
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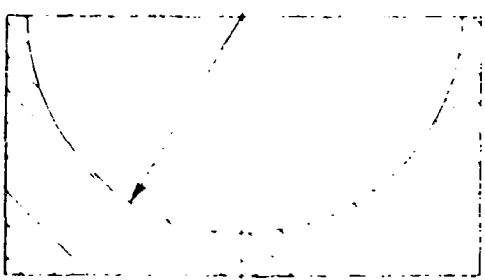
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IN INCHES	OCTOBER 16, 1972	U. S. ARMY LAND WARFARE LABORATORY		
EQUALS ANGLES	DRAFTSMAN SA 11/10/72	PROJECTILE ASSEMBLY		
	CHECKER P. STREHLIN 10-16-72	LESS LETHAL LIQUID BALL (3" DIA.)		
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AAI CORPORATION COCKEYSVILLE, MD.		SCALE 1/1	DAAD 05-72-C-209	SHEET 1 OF 1

all Projectile Assembly

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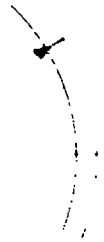
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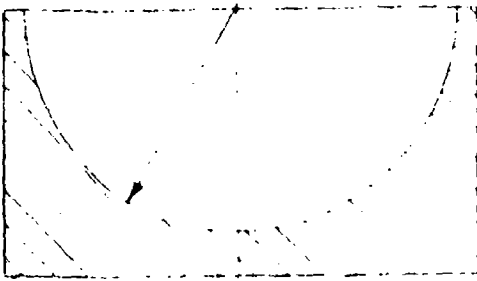


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		MATERIAL	DRAFTSMAN
		STYROFOAM - FR PER FED SPEC H-11-I-524 A TYPE 2, CLASS B	R. STAMM 10-16
			CHECKER
			P. 224 10-16
			PROJECT ENG
			PROJECT NO.
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APPLICATION			AAI CORPORATION COCKEYSVILLE, MD.

Figure 2. Sabot, 3-Inch Liquid Ball

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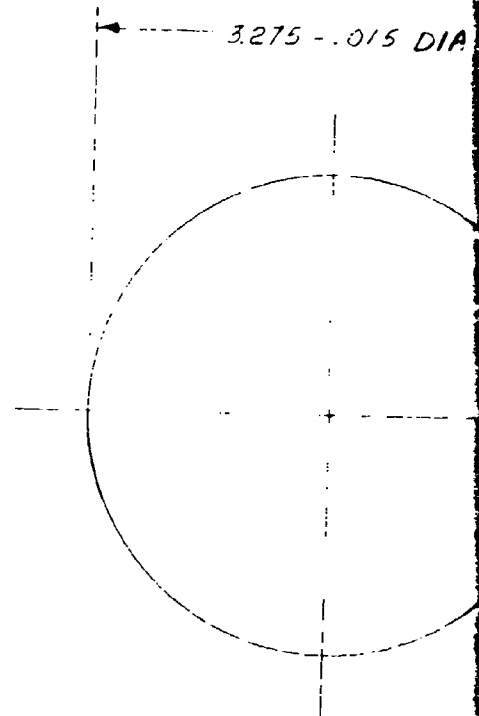
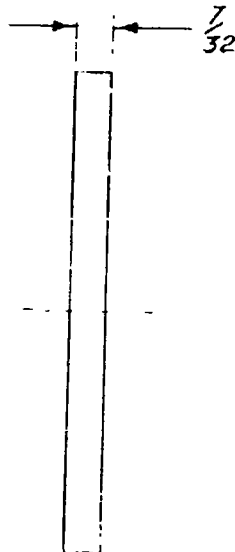
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		UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING
		DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES	OCTOBER 16, 1972
		MATERIAL	DRAFTSMAN
		STYROFOAM-FR PER FED SPEC H-H-I-524 A TYPE 2, CLASS B	J. J. ... 10-16
			CHECKER
			R. STAMM ... 10-16
			PROJECT ENG
			P. ... 10-17
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APPLICATION			AAI CORPORATION COCKEYSVILLE, MD.
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Figure 2. Sabot, 3-Inch Liquid Ball

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ARE IN INCHES AS ON DECIMALS ANGLES = .010 —		OCTOBER 16, 1972				
FOAM-FR PER SPEC H-11-I-524 A , CLASS B		DRAFTSMAN	JSA/11/11	10-16-72		
		CHECKER	R. STAENL	10-16-72		
		PROJECT ENG	P. L. H.	10-17-72		
		PROJECT NO				
		02-F-73				
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			C	97384	040102001	
AGENT		AAI CORPORATION				
		COCKEYSVILLE, MD.		SCALE 1/1	DAAD05-72-C-0209	SHEET 1 OF 1

Liquid Ball



NOTES:

- 1. MATERIAL: HOMASOTE COMP INSULATING BOARD
HOMASOTE COMPANY, TRENTON, N.J.*

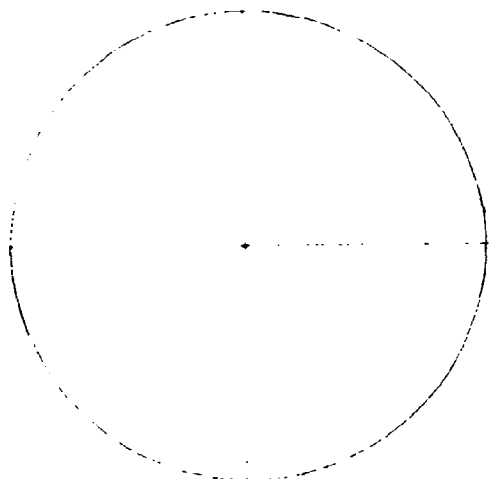
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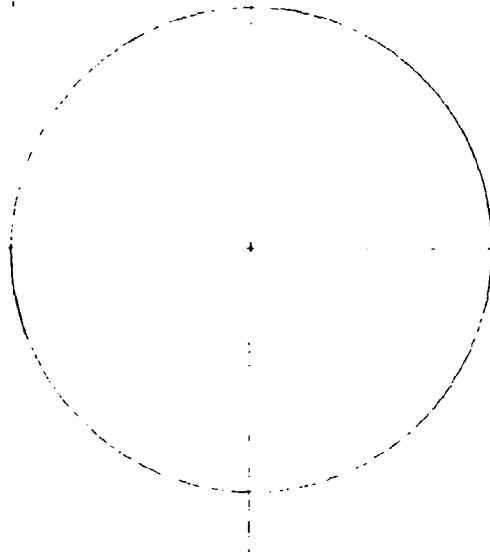
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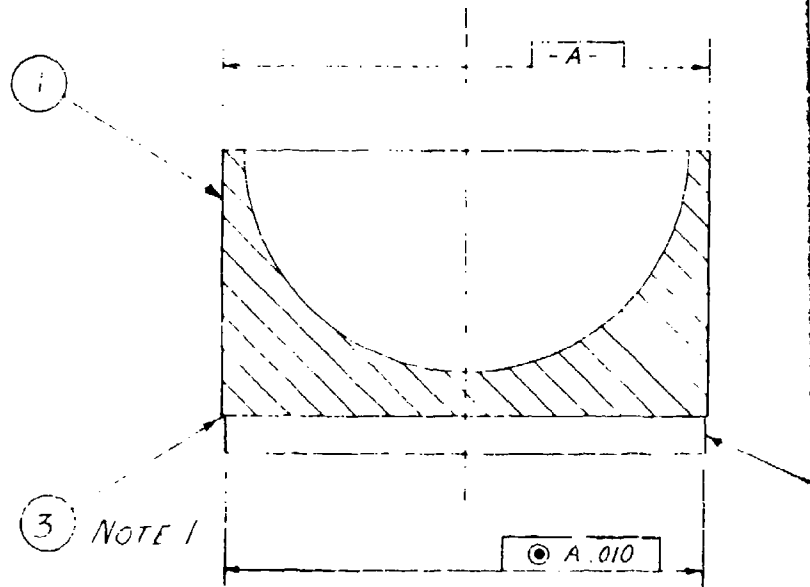
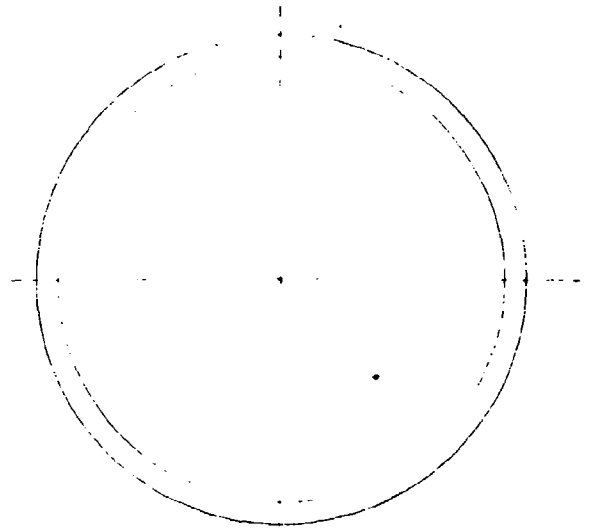
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			DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS = 1/32 DECIMALS = .010 ANGLES ± —	OCTOBER 16, 1972
			MATERIAL	DRAFTSMAN
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				CHECKER
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APPLICATION				AAI CORPORATION COCKEYSVILLE MD.

Figure 3. Pusher, 3-Inch Liquid Ball

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PART NAME		STOCK SIZE		MATERIAL		SPEC		ITEM	
TYPE SPECIFIED		ORIGINAL DATE OF DRAWING		[REDACTED]					
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DRAFTSMAN		10-16-72		U. S. ARMY LAND WARFARE LABORATORY PUSHER					
CHECKER		P. STANLEY 10-16-72							
PROJECT ENG		E. J. H. 10-17-72							
PROJECT NO.		02-F-73							
APPROVED		DATE		SIZE	CODE IDENT. NO.	REV.			
				C	97384	040102002			
AAI CORPORATION		COCKEYSVILLE MD.		SCALE	1/1	DAAD 05-72-G-0209	SHEET 1 OF 1		

Ball



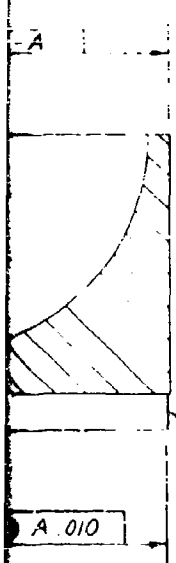
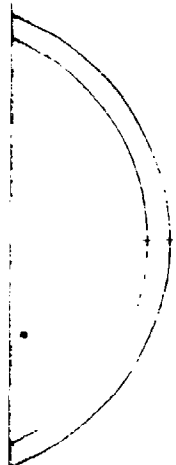
1. COAT BOTH PIECES WITH CEMENT AND ALLOW TO CURE PER MANUFACTURE'S INSTRUCTIONS PRIOR TO ASSEMBLY.
2. SUGGESTED SOURCE: BEST TEST - RUBBER CEMENT No. 500, UNION RUBBER & ASBESTOS Co., TRENTON, N.J.

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SABOT

- 10

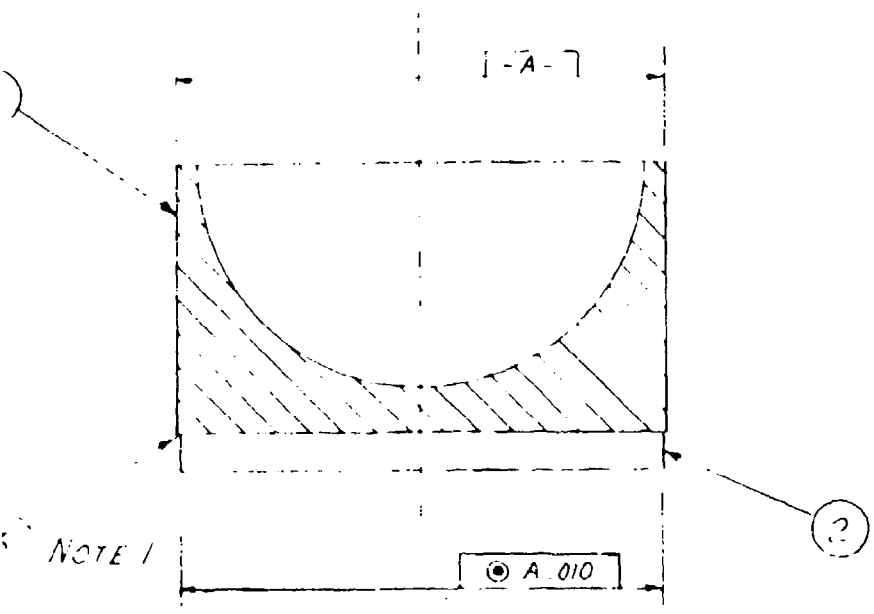
ASSEMBLY

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED

040102003

CEMENT		NOTE 2		3
				2
				1
PLY				X
PART NAME	STOCK SIZE	MATERIAL	SPEC	ITEM



NOTE 1
 CEMENT AND
 MANUFACTURE'S
 ASSEMBLY.
 TEST - RUBBER
 RUBBER & ASBESTOS

AR		RUBBER CEMENT	
1	040102002	PUSHER	
1	040102001	SABOT	
X		-10 ASSEMBLY	
QTY	PART NO	PART NAME	STOCK #
		UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING
		DIMENSIONS ARE IN INCHES	OCTOBER 16, 1972
		TOLERANCES ON	
		FRACTIONS DECIMALS ANGLES	
		± .010	
		MATERIAL	DRAFTSMAN
			O.S.H. 11/11 10-16-72
			CHECKER
			R. SPANGLER 10-16-72
			PROJECT ENG
			e.l.h. 10-17-72
			PROJECT NO
			02-F-73
		FINISH	APPROVED
1	040102000	040102000	DATE
QTY	NEXT ASSY	USED ON	
APPLICATION		HEAT TREATMENT	HAT CORPORATION SOCKEYSVILLE, MD.

Figure 4. Sabot Assembly, 3-Inch Liquid Ba .

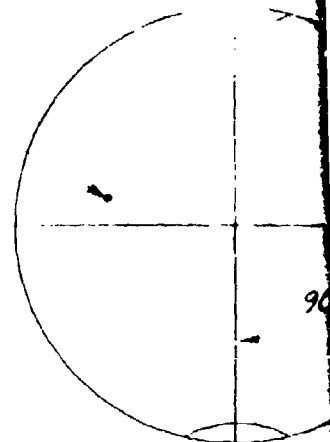
040102003

CEMENT		NOTE 2		3
				2
				1
PLY				X
PART NAME	STOCK SIZE	MATERIAL	SPEC	ITEM

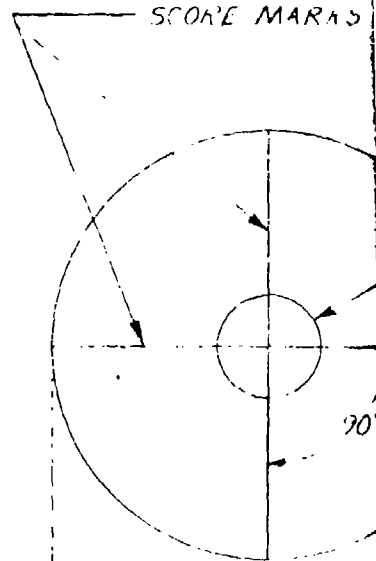
UNLESS OTHERWISE SPECIFIED DIMENSIONS IN INCHES DECIMALS ANGLES = .010	ORIGINAL DATE OF DRAWING OCTOBER 16, 1972		[REDACTED]	
			ABERDEEN PROVING GROUND, MARYLAND 21005	
DRAFTSMAN <i>O. S. HARRIS</i>		DATE <i>10-15-72</i>	U. S. ARMY LAND WARFARE LABORATORY SABOT ASSEMBLY	
CHECKER <i>R. STEWART</i>		DATE <i>10-16-72</i>		
PROJECT ENG <i>R. L. L.</i>		DATE <i>10-17-72</i>		
PROJECT NO 02-F-73				
APPROVED	DATE	SIZE C	CODE IDENT. NO 97384	REV.
HAT CORPORATION COCKEYSVILLE, MD.		SCALE 1/1	040102003	
		DAAD05-72-C-0209	SHEET 1	OF 1

Liquid Ball

FILL HOLE
NOTE 3



SCORE MARKS

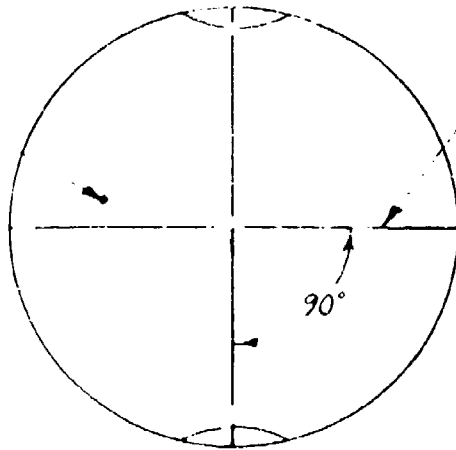


NOTES:

1. MAKE FROM PIN 10003#17, SUGGESTED SOURCE, THE NATIONAL LATEX PRODUCTS CO. 246 EAST 4TH STREET, ASHLAND, OHIO, 44805.
2. SCORE DEPTH TO BE .025.
3. FILL BALL WITH LIQUID CONSISTING OF:
COMMERCIAL GLYCERIN (60% BY WT)
WATER (40% BY WT)
ADJUST WEIGHT OF FILLED BALL TO
265.0 ± 3.0 GRAMS TOTAL, THEN HEAT SEAL.
4. FILLED BALL MUST WITHSTAND A
3 FOOT DROP TEST ON HARD CONCRETE
WITHOUT RUPTURING. (POINT OF IMPACT
TO BE AT INTERSECTION OF SCORE MARKS.)

QTY	

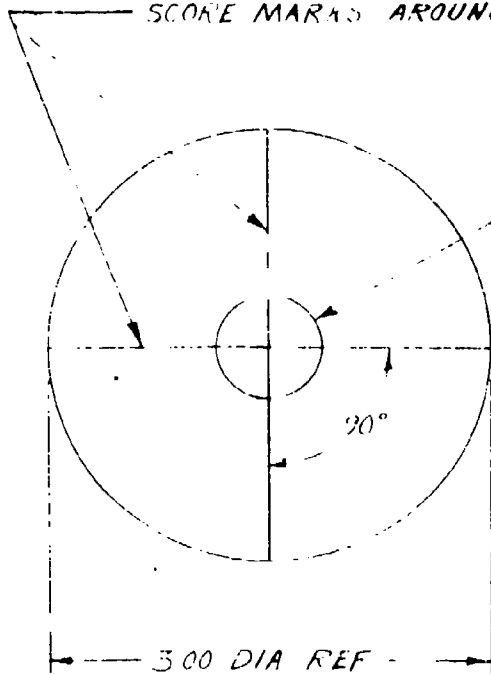
FILL HOLE
NOTE 3



SLAM

90°

SCORE MARKS AROUND CIRCUMFERENCE



TRADE MARK
(EACH END)

90°

300 DIA REF

SUGGESTED
LATEX PRODUCTS
EET, ASHLAND.

025.

CONSISTING OF:
(60% BY WT)
(40% BY WT)

D BALL TO
L, THEN HEAT SEAL.
STAND .1
YARD CONCRETE
POINT OF IMPACT
(OF SCORE MARKS)

QTY	PART NO	PART NAME	

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED

4M

REFERENCE

TRADE MARK
(EACH END)

04010200

PART NAME	STOCK SIZE	MATERIAL	SPEC	ITEM
-----------	------------	----------	------	------

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED

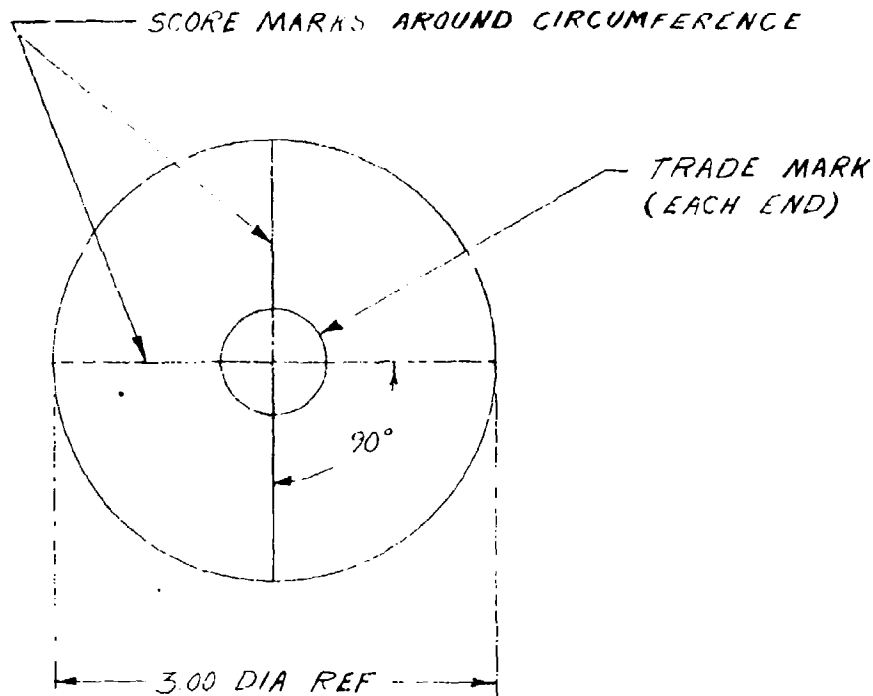
M

REFERENCE

TRADE MARK
(EACH END)

010102004

PART NAME	STOCK SIZE	MATERIAL	SPEC	ITEM
OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING			



SUGGESTED
 ATEX PRODUCTS
 TET, ASHLAND.

25.
 CONSISTING OF:
 (60% BY WT)
 (40% BY WT)
 BALL TO
 THEN HEAT SEAL.
 STAND A
 HARD CONCRETE
 POINT OF IMPACT
 (F SCORE MARKS.)

QTY	PART NO.		PART NAME			ORIGINAL DATE OF DRAWING	
			UNLESS OTHERWISE SPECIFIED			OCTOBER 16, 1971	
			DIMENSIONS ARE IN INCHES				
			TOLERANCES ON				
			FRACTIONS	DECIMALS	ANGLES		
			=	=	= 15°		
			MATERIAL:			DRAFTSMAN	J. S. TITTE 10-11
			NOTE 1			CHECKER	P. STAENLIN 10-11
						PROJECT ENG.	E. Schreff 10-11
						PROJECT NO.	
						02-F-73	
			FINISH: _____			APPROVED	
1	040102000	040102000					
QTY	NEXT ASSY	USED ON	HEAT TREATMENT: _____			AAI CORPORATION	
APPLICATION						COCKEYSVILLE, MD.	

Figure 5. Projectile, 3-Inch Liquid Ball

REFERENCE

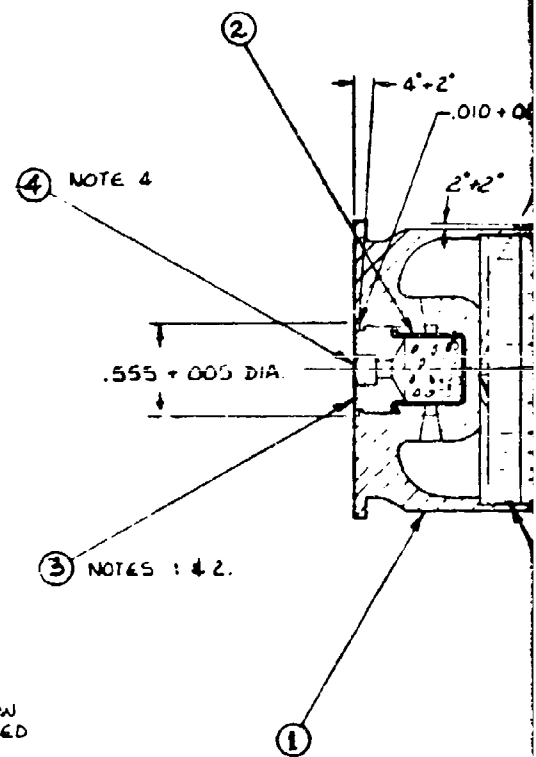
TRADE MARK
(EACH ENL)

040102004

PART NAME		STOCK SIZE		MATERIAL	SPEC	ITEM
OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING OCTOBER 16, 1972		[REDACTED]		
DIMENSIONS ARE IN INCHES DIMENSIONS ON DIMENSIONS DECIMALS ANGLES = — : 15°		DRAFTSMAN [REDACTED] 10-16-72		ABERDEEN PROVING GROUND, MARYLAND 21005		
NOTE 1		CHECKER P. STAHLIN 10-16-72		U. S. ARMY LAND WARFARE LABORATORY		
		PROJECT ENG R. [REDACTED] 10-17-72		PROJECTILE		
		PROJECT NO. 02-F-73				
APPROVED		DATE	SIZE C	CODE IDENT. NO. 97384	040102004	
FURNISHING AGENCY: AAI CORPORATION COCKEYSVILLE, MD.			SCALE 1/1	DAAD05-72-C-0209	SHEET 1 OF 1	

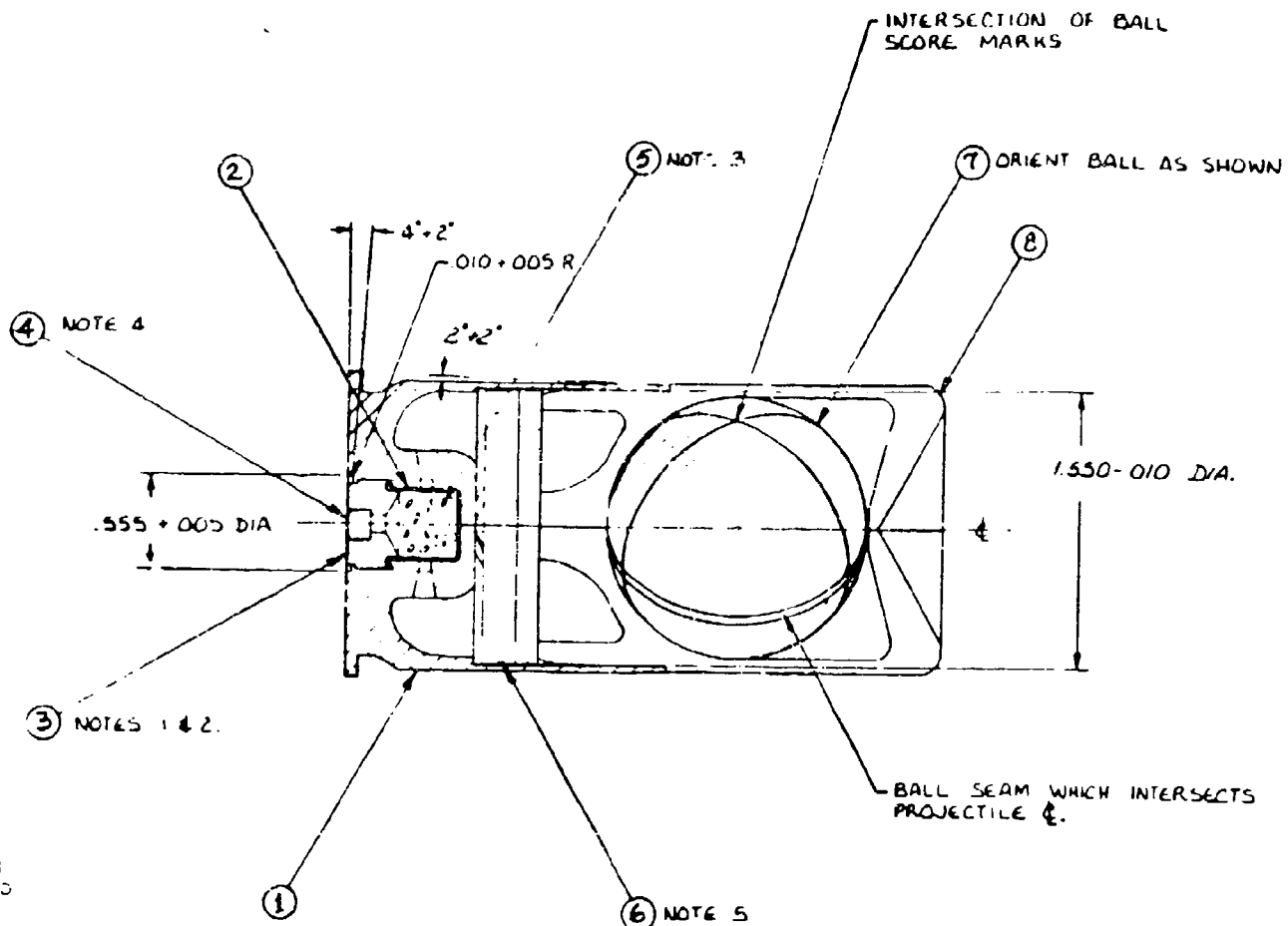
1/2 Inch Liquid Ball

APPENDIX B
Semi-Liquid Ball
(Drawings)



NOTES:

- 1- BASE PLUG TO BE FLUSH TO .005 MAX. BELOW REAR OF CASE. ADVISORY- DEAD LOAD REQUIRED 7000 LB. MIN.
- 2- CRIMP BASE PLUG 360° AVERAGE UNSEATING FORCE TO BE 3500 LBS. OR MORE WITH NO VALUES BELOW 2000 LBS. CRIMP FORCE 11000 TO 13000 LBS. USING A CRIMPING PUNCH .555 ± .005 OUTSIDE DIA AND $4^\circ \pm 2^\circ$ FACE ANGLE.
- 3- LOAD WITH M9 PROPELLANT TO MEET THE MEAN VELOCITY OF 245 FEET PER SECOND. (2.2 GRAINS ± .01 GRAINS)
- 4- PRIMER TO BE FLUSH TO .003 MAX. BELOW BASE PLUG.
- 5- OBTURATOR INSERTION TO BE ACCOMPLISHED BY TEMPORARILY DEFORMING A POINT ON THE OBTURATING SURFACE WHICH PROVIDES A VENT TO PREVENT PROPELLANT CUP DEFORMATION.



MAX. BELOW
 REQUIRED

SEATING FORCE
 RANGES
 10 TO 13000 LBS
 05 OUTSIDE DIA

THE MEAN
 (2.2 GRAINS

BELOW BASE PLUG.
 LISHED BY
 THE OBTURATING
 D PREVENT

4	040103004	AROT	
1	040103003	ASSEMBLY	
1	040103002	EXTRACTOR	
NOTE 3		BASE PLUG	
1	8799925	BRASS, M42	M
1	8844611	PLUG, BASE	M
1	8844612	CUP, HOUSER CHANGE	
1	040103001	CASE 40MM (MODIFIED)	
1	040103000	ASSEMBLY	
QTY	PART NO	PART NAME	
		UNLESS OTHERWISE SPECIFIED	OR JOURNAL DATE OF DRAWING
		DIMENSIONS IN INCHES	8
		FRACTIONS DECIMALS ANGLES	
		MATERIAL	DRAFTSMAN
			CHECKER
			PROJECT ENG
			PROJECT NO
			0
			APPROVED
FINAL			
QTY	REVISION	USED ON	HEAT TREATMENT
		APPLICATION	
			BAI CORP COCKEYS

Figure 1. 40mm Less Lethal Liquid Ball Projectile Assembly

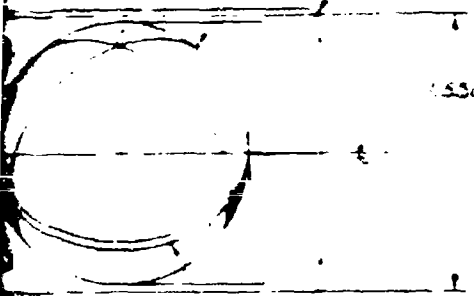
REVISIONS			
NO.	DESCRIPTION	DATE	APPROVED

- INTERSECTION OF BALL
SECRET MARKS

NOTE 3

③ ORIENT BALL AS SHOWN

③



1530-010 DIA.

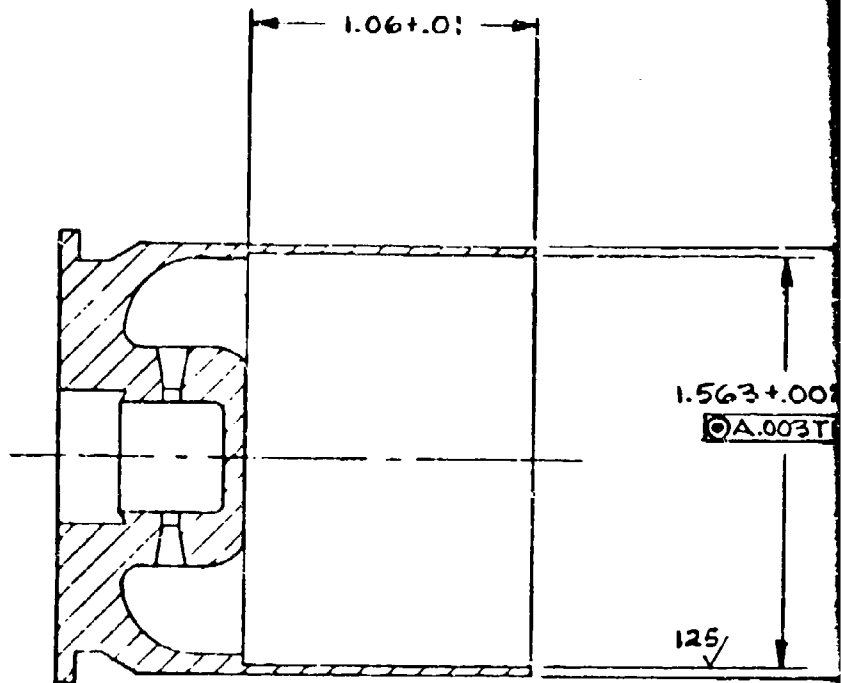
- BALL LEAM WHICH INTERSECTS
PROJECT NO. 2

NOTE 2

040103000

1530-010-01	ASSEMBLY				8
1530-010-02	ASSEMBLY				7
1530-010-03	ASSEMBLY				6
1530-010-04	ASSEMBLY				5
1530-010-05	ASSEMBLY				4
1530-010-06	ASSEMBLY				3
1530-010-07	ASSEMBLY				2
1530-010-08	ASSEMBLY				1
1530-010-09	ASSEMBLY				0

UNLESS OTHERWISE SPECIFIED	OR LOCAL DATE OF DRAWING	
DATE	8-31-73	
PROJECT NO.	02-F-73	
PROJECT NAME	COMM CIRCULAR BALL PROJECTILE	
PROJECT NO.	02-F-73	
PROJECT NAME	U.S. ARMY LAND WARFARE LABORATORY	
PROJECT NO.	02-F-73	
PROJECT NAME	ABERDEEN PROVING GROUND, MARYLAND 21005	
PROJECT NO.	02-F-73	
PROJECT NAME	ASSEMBLY	
APPROVED	DATE	SEE COMB. BOMBS NO.
		D 97384 040103000
APPLICATOR	AAI CORPORATION	SCALE
	COCKEYSVILLE, MD	DAARD3-72-C-0205 SHEET 1 OF 1



NOTES:

1. MODIFY STANDARD 40MM: M118 CARTRIDGE CASE. ORDNANCE PART NUMBER 8844610.

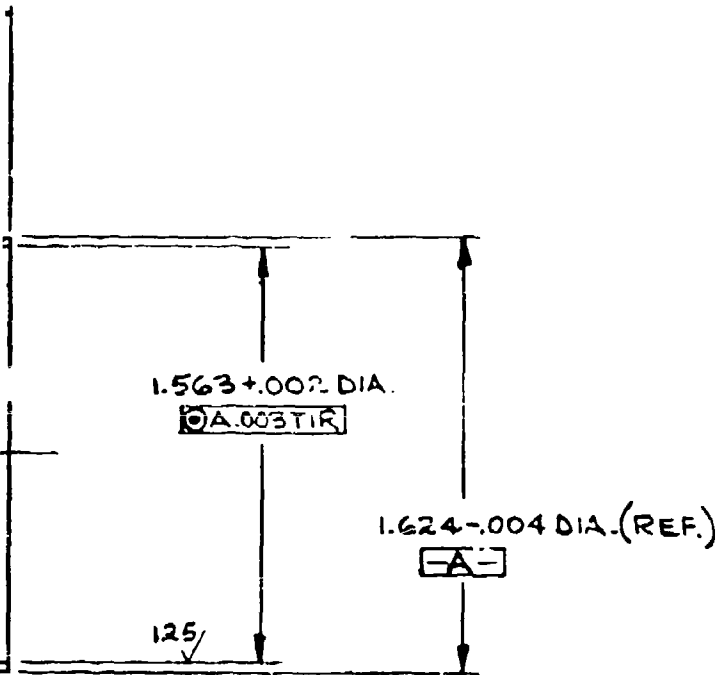
QTY	PART NO	PART
		UNLESS OTHERWISE
		DIMENSIONS ARE IN INCH
		TOLERANCES ON
		FRACTIONS DECIMALS
		MATERIAL
		SEE NOTE 1
		FINISH
1	040103000	---
QTY	NEXT ASSY	USED ON
		HEAT TREATMENT

		APPLICATION

Figure 2. Cartridge Case, 40mm Liquid Ball

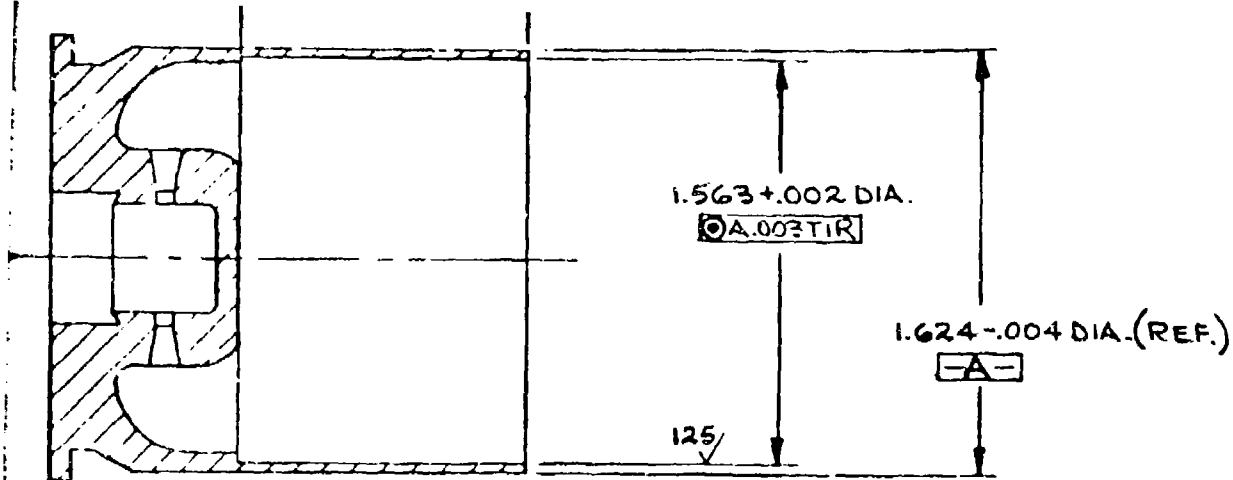
REVISIONS

LTR	DESCRIPTION	DATE	APPROVED



040103001

NO	PART NAME	STOCK SIZE	MATERIAL	SPEC	ITEM
	UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING	U.S. ARMY LAND WARFARE LABORATORY ABERDEEN PROVING GROUND MARYLAND 21005		
	DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES	8-31-73	CASE, CARTRIDGE 40 MM: M118,		
	MATERIAL	DRAFTSMAN			
	SEE NOTE 1	CHECKER			
		PROJECT ENG			
		PROJECT NO			



M118
R 8844610.

QTY	PART NO	PART NAME	STOCK SIZE	
		UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING	U.S. ARMY LAB ABERDEEN PROVE
		DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES	8-31-73	
		MATERIAL	DRAFTSMAN <i>R. Melsted</i> 8/15/73	CASE, CA 40 MM: MODIFIED
		SEE NOTE 1	CHECKER <i>LOWE</i> 8/21/73	
			PROJECT ENG <i>Schuff</i> 8/23/73	
			PROJECT NO 02-F-73	
		FINISH	APPROVED	DATE
1	040105000	—		
QTY	NEXT ASSY	USED ON		SIZE
				CODE IDENT
		HEAT TREATMENT	AAI CORPORATION	C 97384
			COCKEYSVILLE, MD.	SCALE 2/1
				DAAD

Figure 2. Cartridge Case, 40mm Liquid Ball (Modified M118)

563+.002 DIA.

QA.003TIR

1.624-.004 DIA.(REF.)

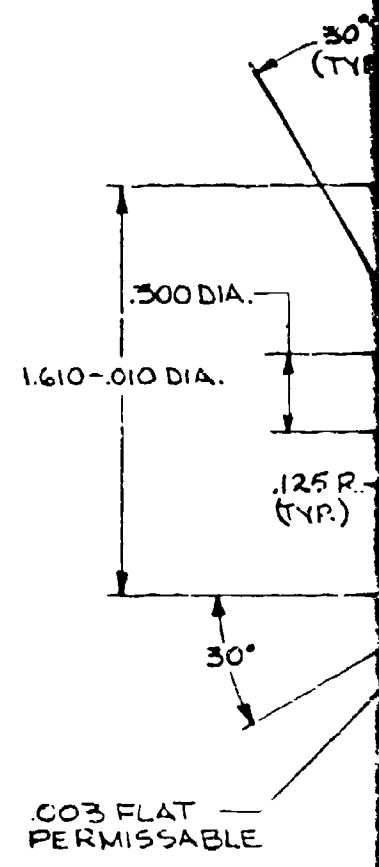
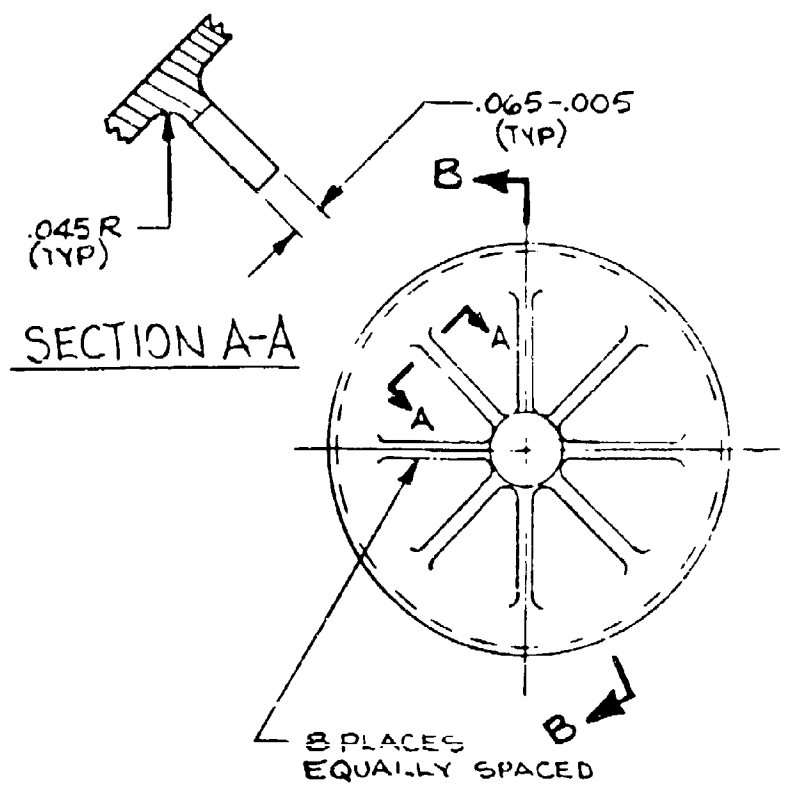
-A-

5/

040103001

PART NAME		STOCK SIZE		MATERIAL	SPEC	ITEM
OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING		U. S. ARMY LAND WARFARE LABORATORY		
UNITS: INCHES DECIMALS ANGLES		8-31-73		ABERDEEN PROVING GROUND MARYLAND 21005		
NOTE 1	DRAFTER	8/15/73		CASE, CARTRIDGE 40 MM: M118, MODIFIED		
	CHECKER	LOWE 8/21/73				
	PROJECT ENG	Schiff 8/23/73				
	PROJECT NO	02-F-73				
	APPROVED	DATE	SIZE	CONTROL NO	REV	
			C	97384	040103001	
	AAI CORPORATION COCKEYSVILLE, MD.		SCALE 2/1	DAAD05-72-60209 SHEET 1 OF 1		

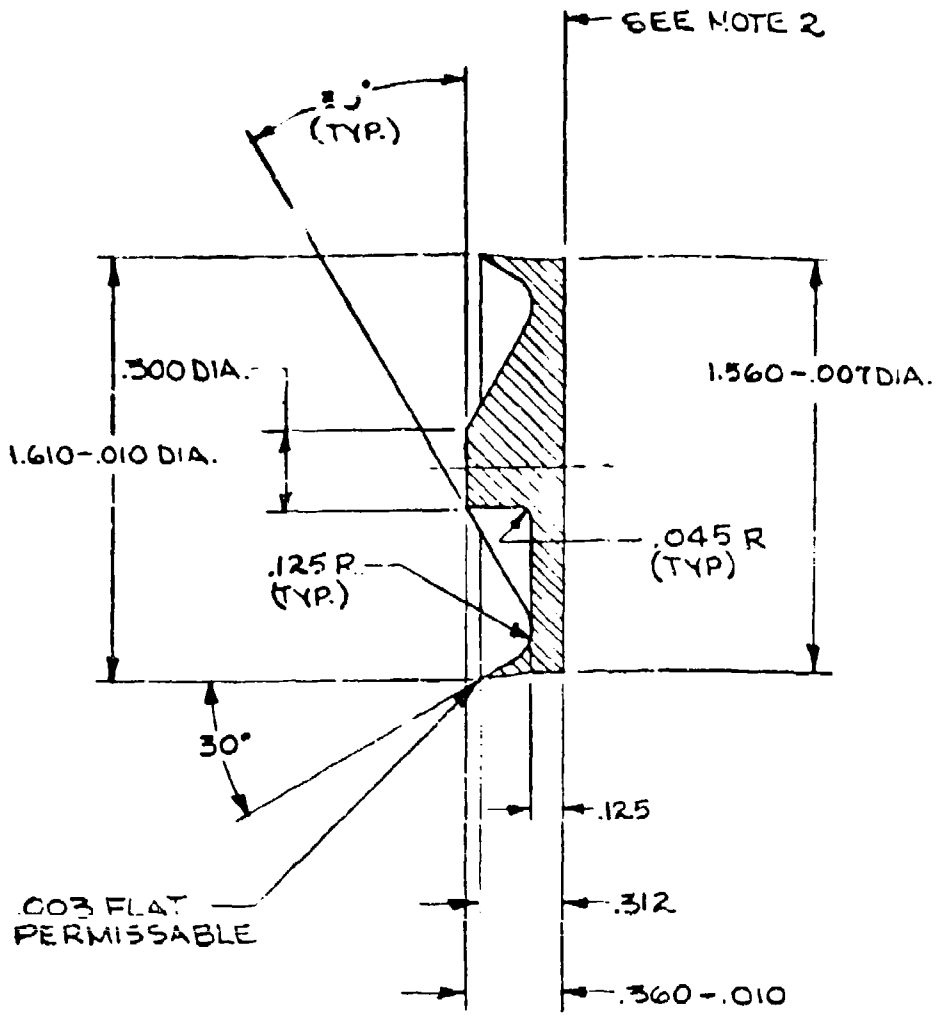
Grid Ball (Modified M118)



- NOTES:
1. CORNER AND FILLET RADII .005 MAX. UNLESS OTHERWISE NOTED
 2. THIS SURFACE TO BE FLAT WITHIN .005 AND FREE FROM FLASH AND EJECTION PIN MARKS.

QTY	PART NO	UNLES
		DIMEN
		TOLER
		FRACT
		MATER
		PLA
		HI
		POL
		FINISH
1	040103000	
QTY	NEXT ASSY	USED ON
APPLICATION		
		HEAT T

05

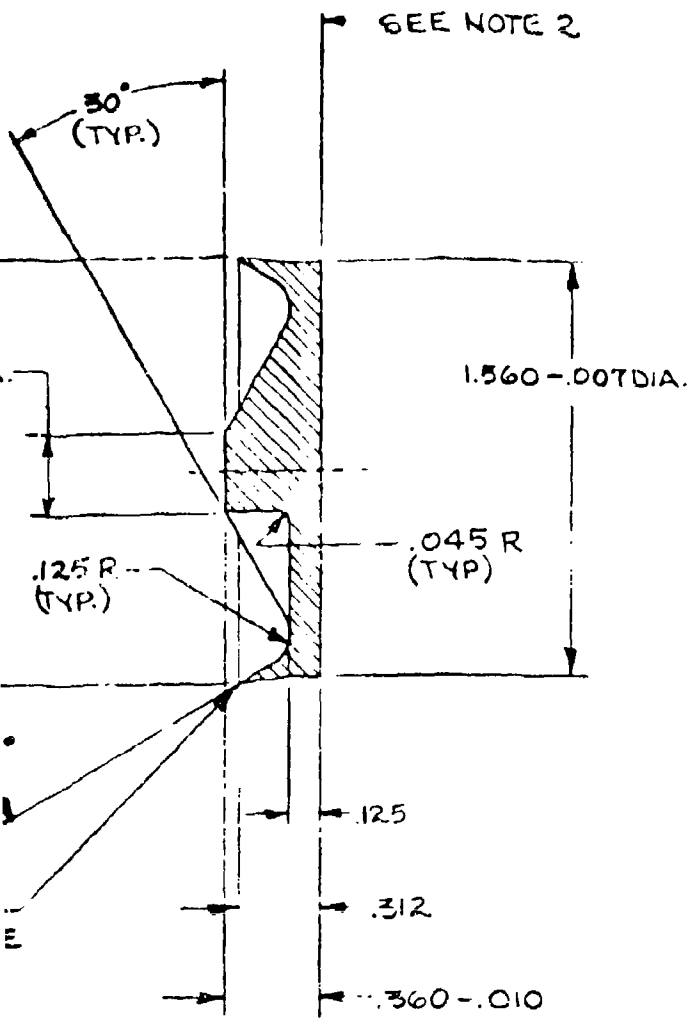


SECTION B-B

15 MAX.
WITHIN .005
EJECTION

QTY	PART NO	PART NAME	STOCK SIZE
		UNLESS OTHERWISE SPECIFIED	ORIGINAL DATE OF DRAWING
		DIMENSIONS ARE IN INCHES	8-31-73
		TOLERANCES ON FRACTIONS DECIMALS ANGLES	
		± .010 ± 1°	
		MATERIAL	DRAFTSMAN
		PLASTIC HI-DENSITY POLYETHYLENE	12-2-72
			CHECKER
			LOWE 3/22/73
			PROJECT ENG
			8/22/73
			PROJECT NO.
			02-F-73
		FINISH	APPROVED
			DATE
1	040103000		
QTY	NEXT ASSY	USED ON	SIZE
			CODE IDENT. NO.
			C 9738
		HEAT TREATMENT	SCALE 2/1
			AAI CORPORATION COCKEYSVILLE, MD.

Figure 3. Obturator, 40mm Liquid Ball

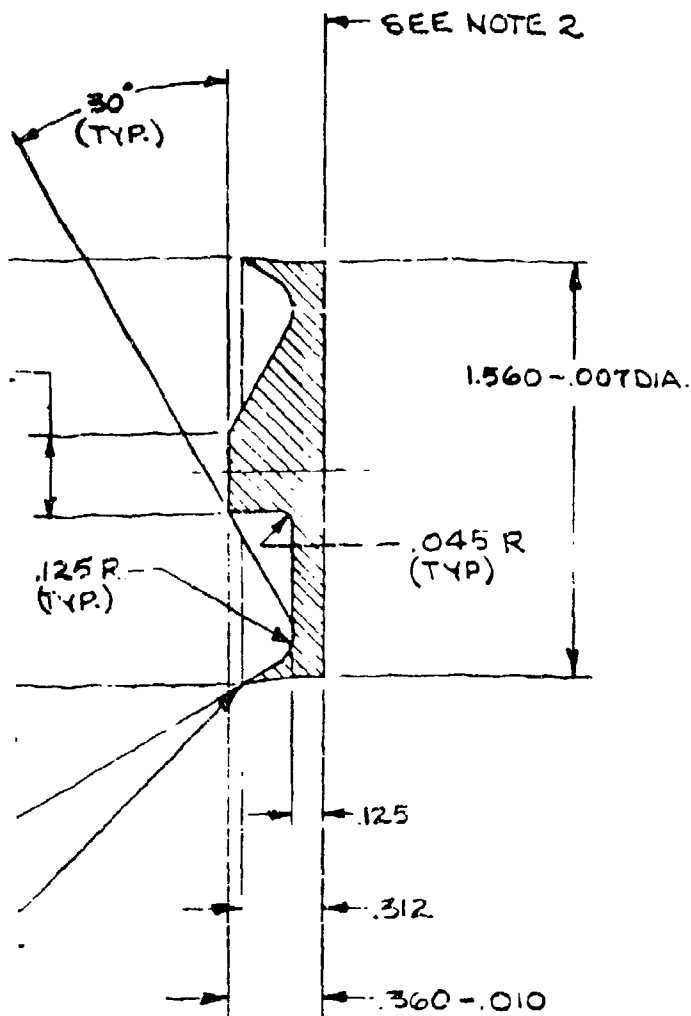


SECTION B-B

20050103002

PART NAME		STOCK SIZE		MATERIAL	SPEC	ITEM
UNLESS OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING		[REDACTED]		
DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± .010 ± .001 ± .1°		8-31-73		ABERDEEN PROVING GROUND, MARYLAND 21005		
MATERIAL		DRAFTSMAN	12-3-72	U. S. ARMY LAND WARFARE LABORATORY OBTURATOR		
PLASTIC HI-DENSITY POLYETHYLENE		CHECKER	LOWE 8/22/73			
FINISH		PROJECT ENG	8/22/73			
HEAT TREATMENT		PROJECT NO	02-F-73			
APPROVED		DATE	SIZE	CODE IDENT. NO.	REV.	
				C 97384	040103002	
AAI CORPORATION COCKEYSVILLE, MD		SCALE 2/1		DAAD05-72-G-0209	SHEET 1 OF 1	

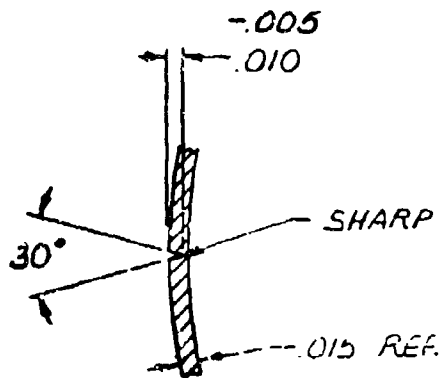
urator, 40mm Liquid Ball



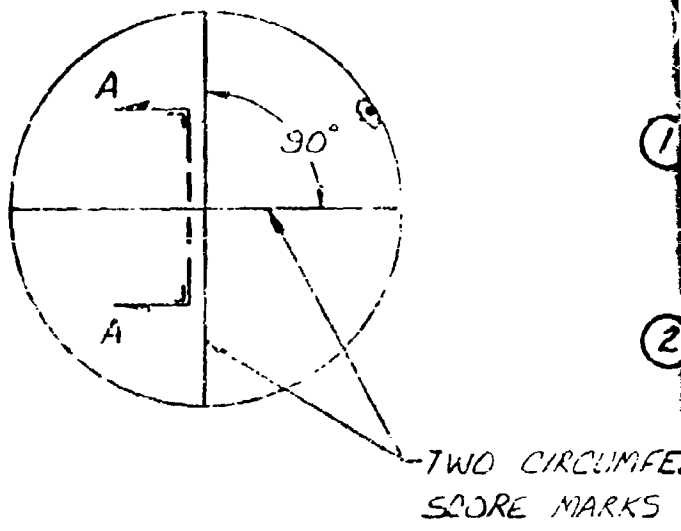
SECTION B-B

040103002

PART NAME		STOCK SIZE		MATERIAL	SPEC	ITEM
UNLESS OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING		[REDACTED]		
DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLES ± .010 ± .1°		8-31-73		ABERDEEN PROVING GROUND, MARYLAND 21005		
MATERIAL		DRAFTSMAN	DATE	U. S. ARMY LAND WARFARE LABORATORY		
PLASTIC HI-DENSITY POLYETHYLENE.		CHECKER	8/22/73	OBTURATOR		
		PROJECT ENG	8/22/73			
		PROJECT NO	02-F-73			
FINISH	APPROVED	DATE	SIZE	CODE IDENT. NO.	REV.	
			C	97384	040103002	
HEAT TREATMENT	AAI CORPORATION		SCALE 2/1		DAAD05-72-C-0209 SHEET 1 OF 1	
	COCKEYSVILLE, MD.					



SECTION A-A
 SCALE 10/1
 (TYP. BALL SCORE MARK)



NOTES:

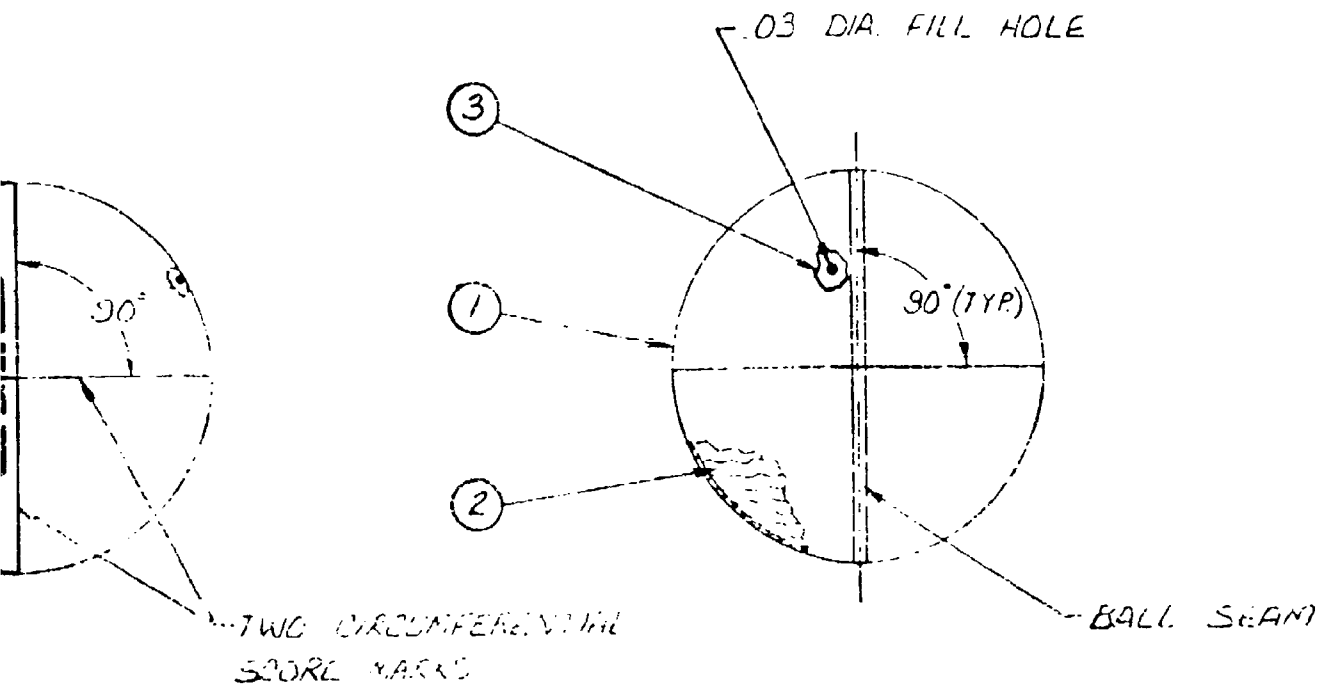
- 1- BALL MUST BE -HALOX (3 STAR) TABLE TENNIS BALLS (MADE IN U.S.A.)
- 2- LIQUID TO BE A MIXTURE OF 60% GLYCERIN AND 40% WATER BY WEIGHT.
- 3- SEAL WITH DUCO® CEMENT E.I. DU PONT DE NEMOURS & CO. (INC.) WILMINGTON, DEL. 19898 OR EQUIVALENT.
- 4- FILL BALL COMPLETELY WITH A HYPODERMIC NEEDLE AND SYRINGE OR EQUIVALENT. AFTER FILLING, CLEAN SURFACE AROUND HOLE THOROUGHLY WITH WATER AND LET AIR DRY. SEAL FILL HOLE WITH MINIMUM AMOUNT OF SEALANT AND LET AIR DRY PER MANUFACTURERS INSTRUCTIONS.

AR.		SE
AR.		LI
1	-1	BA
1	-10	BI
QTY	PART NO	
		UNL
		DIMS
		TOL
		FRAC
		5
		MATER

REVISIONS

LTR

DESCRIPTION

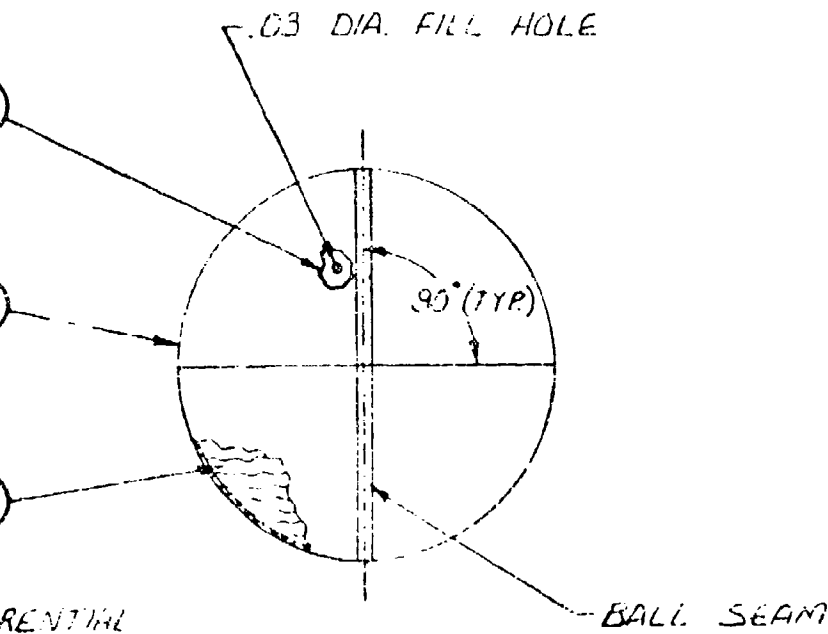


AR.		SEALANT	NOTE 3
AR.		LIQUID	NOTE 2
1	-1	BALL	NOTE 1
1	-10	BALL ASSEMBLY	
QTY	PART NO.	PART NAME	STOCK SIZE
		UNLESS OTHERWISE SPECIFIED	ISSUAL DATE
		DIMENSIONS ARE IN INCHES	DRAWING
		FRACTIONS DECIMALS ANGLES	8-31-73
		= — .01 5°	U S ARMY LAND WARFARE
			ABERDEEN PROVING GROUND MA
			LOWE 18/2/73

(C.)
02
NT

REVISIONS

LYR	DESCRIPTION	DATE	APPROVED



040103003

SEALANT	NOTE 3			3
LIQUID	NOTE 2			2
ALL	NOTE 1			1
ALL ASSEMBLY				X

LESS OTHERWISE SPECIFIED

DIMENSIONS ARE IN INCHES
 FRACTIONS DECIMALS ANGLES

01 5°

DATE OF DRAWING: 8-31-73

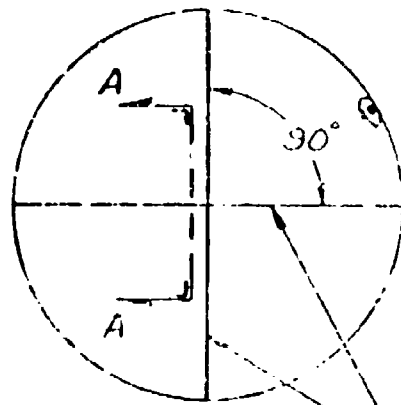
DRAFTSMAN: LOWE 8/21/73

CHECKER: [Signature] 8/21/73

NOTE 1

U.S. ARMY LAND WARFARE LABORATORY
 ABERDEEN PROVING GROUND MARYLAND 21005

MARK)



1
2

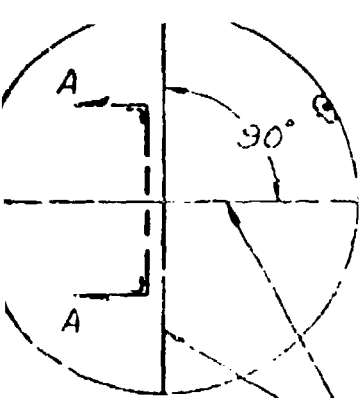
-TWO CIRCUMFERE
SCORE MARKS

NOTES:

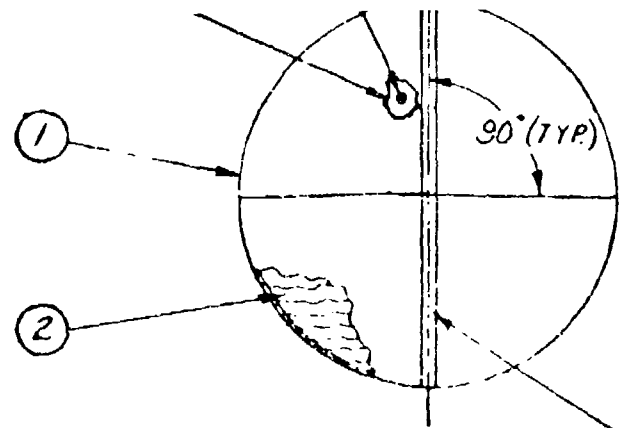
- 1-BALL MUST BE HALOX (3 STAR)
TABLE TENNIS BALL (MADE IN
E.I. DU PONT)
- 2-LIQUID TO BE A MIXTURE OF
60% GLYCERIN AND 40%
WATER BY WEIGHT.
- 3- SEAL WITH DUCO® CEMENT
E.I. DU PONT DE NEMOURS & CO. (INC.)
WILMINGTON, DEL. 19898
OR EQUIVALENT.
- 4- FILL BALL COMPLETELY WITH A
HYPODERMIC NEEDLE AND SYRINGE OR
EQUIVALENT. AFTER FILLING, CLEAN
SURFACE AROUND HOLE THOROUGHLY
WITH WATER AND LET AIR DRY.
SEAL FILL HOLE WITH MINIMUM AMOUNT
OF SEALANT AND LET AIR DRY PER
MANUFACTURERS INSTRUCTIONS.

AR.		SEA
AR.		LIO
!		-1 BAL
X		-10 BAL
QTY	PART NO	UNLESS
		GENERAL
		FRAC
		MATERIAL
		NU
		FINISH
!	0A0103000	
QTY	NEAR ASST	USED ON
		HEAT TRE
	APPLICATION	

Figure 4. ball Assembly,



TWO CIRCUMFERENTIAL SCORE MARKS



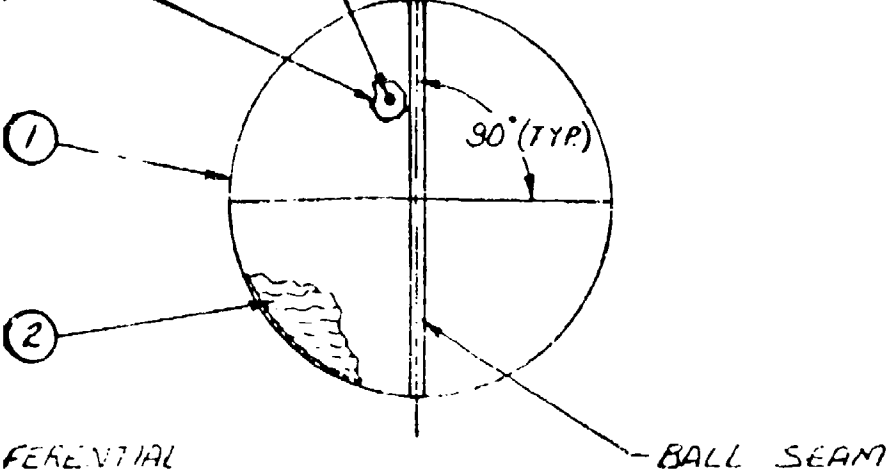
BALL SEAM

CO (INC.)

WITH A SYRINGE OR CLEAN ROUGHLY DRY. USE SMALL AMOUNT DRY PER USE.

AR.	SEALANT	NOTE 3	
AR.	LIQUID	NOTE 2	
!	-1 BALL	NOTE 1	
X	-10 BALL ASSEMBLY		
QTY	PART NO	PART NAME	STOCK SIZE
	UNLESS OTHERWISE SPECIFIED		
	TOLERANCES UNLESS OTHERWISE SPECIFIED		
	FRACTIONS DECIMALS ANGLES		
	= .01 5°		
	MATERIAL	DATE	U S ARMY LAND
	NOTE 1	8-31-73	ABERDEEN PROVING
		DESIGNED BY LOWE 8/21/73	
		CHECKER [Signature] 8/21/73	BALL A
		PROJECT ENG [Signature] 8/23/73	
		PROJECT NO 02-F-73	
	FINISH	APPROVED	DATE
1	040103000		
QTY	NEEDED	USE BY	HEAT TREATMENT
	APPLICATION	AAI CORPORATION	SCALE 2/1
		COCKEYSVILLE, MD.	DAAD05-
			CODE IDENT NO C 97384 04

Figure 4. Ball Assembly, 40mm Liquid Ball



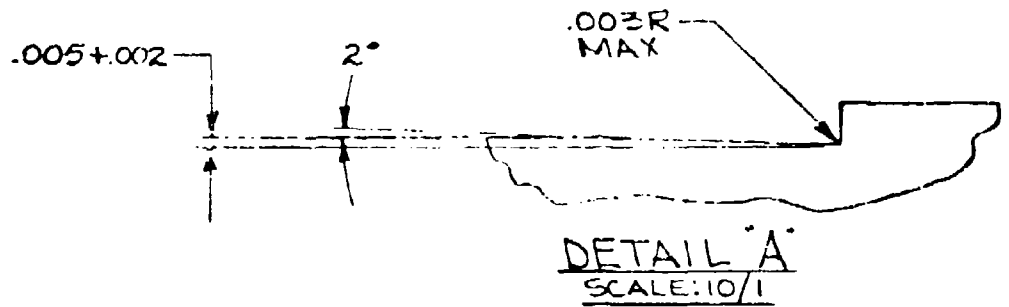
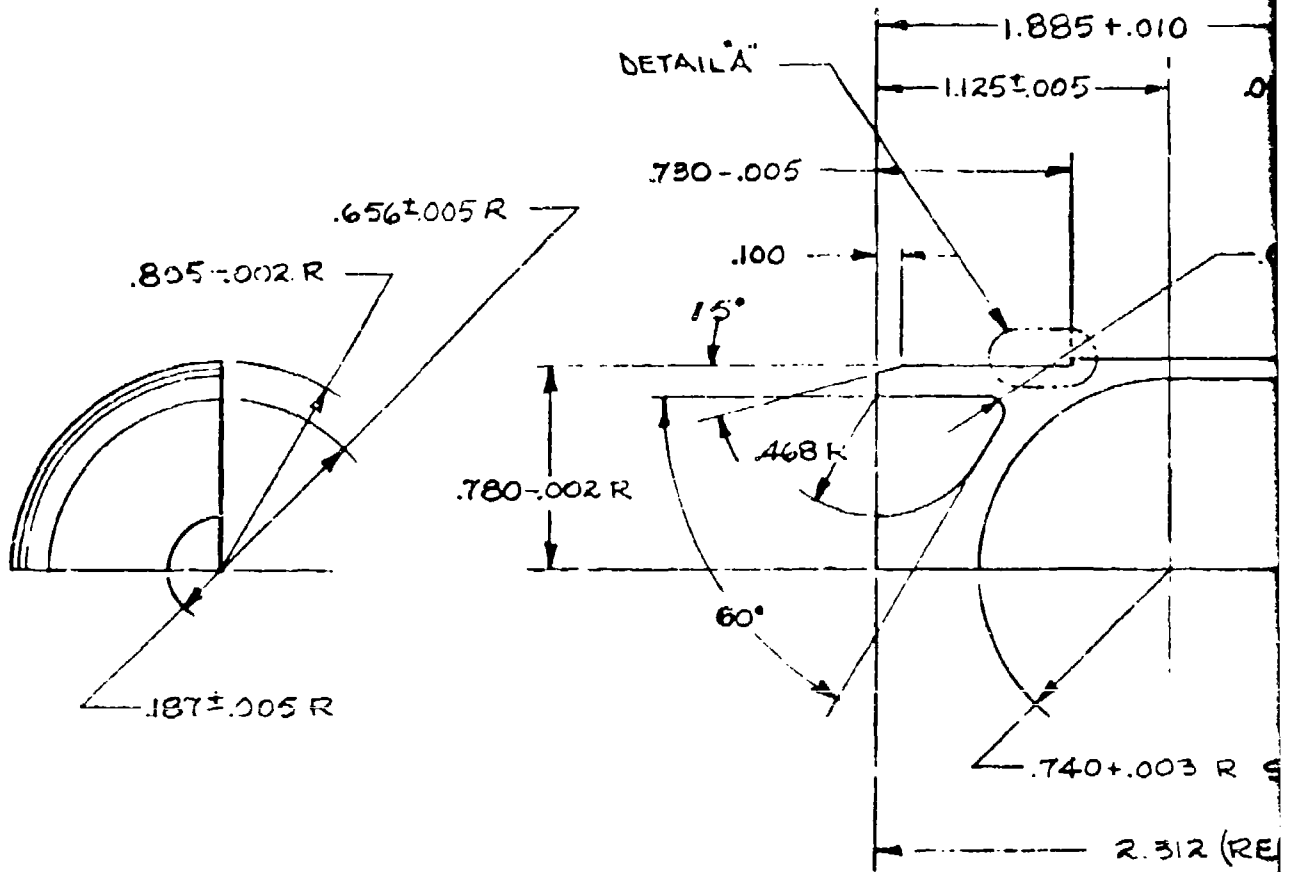
FERENTIAL
S

040103003

SEALANT	NOTE 3			3
LIQUID	NOTE 2			2
BALL	NOTE 1			1
BALL ASSEMBLY				X

UNLESS OTHERWISE SPECIFIED		STOCK SIZE		MATERIAL	SPEC	ITEM
DIMENSIONS ARE IN INCHES FRACTIONS DECIMALS ANGLES		8-31-73		U S ARMY LAND WARFARE LABORATORY ABERDEEN PROVING GROUND MARYLAND 21005		
MATERIAL		DRAFTSMAN		BALL ASSEMBLY		
NOTE :		LOWE 8/21/73				
		CHECKER				
		PROJECT ENG				
		PROJECT NG				
		02-F-73				
FINISH	APPROVED	DATE	FILE CODE IDENT	REV		
			C 97384	040103003		
HEAT TREATMENT	AAI CORPORATION C KEYSVILLE, MD.		SCALE 2/1 DAAD05-72-C-0209 SHEET 1 OF 1			

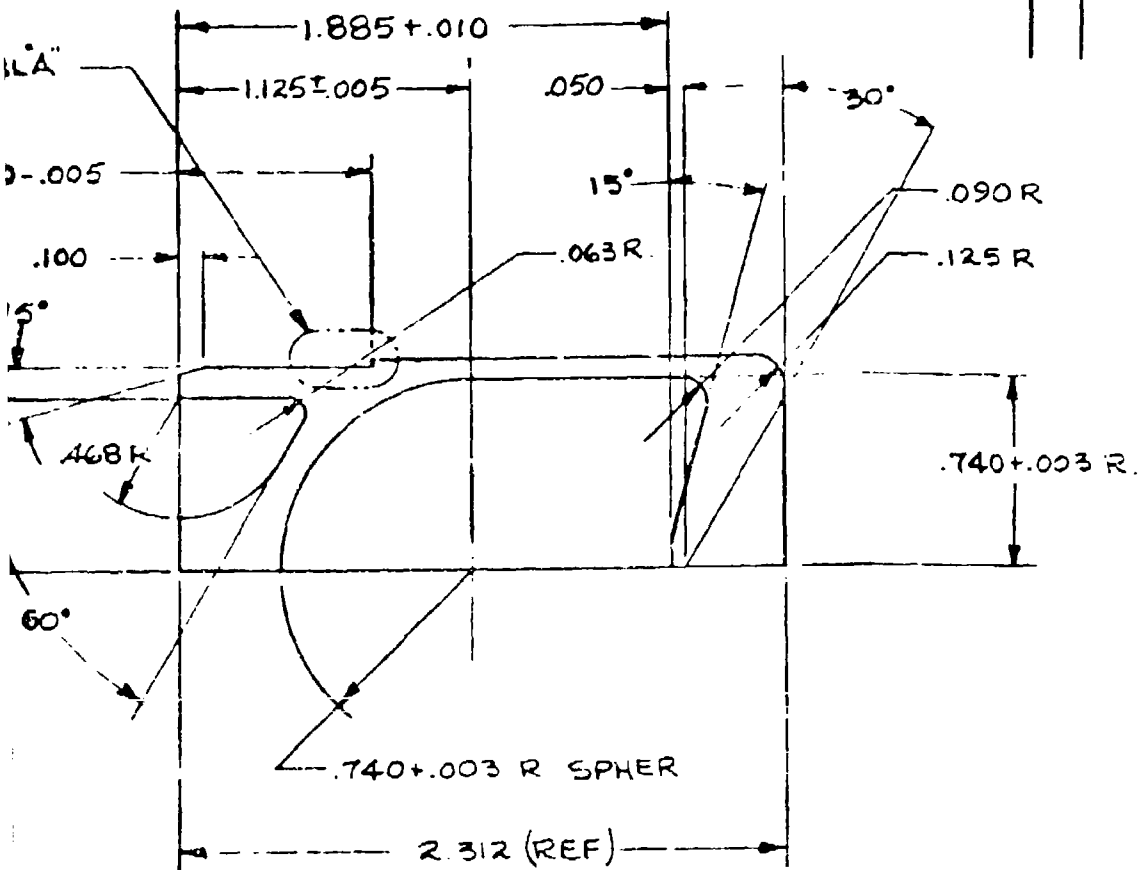
Assembly, 4mm Liquid Ball



QTY	PART NO	UNLESS I
		DIMENSION
		TOLEFRAN
		FRACTION
		=
		MATERIAL

REVISIONS

LTR	DESCRIPTION



.003R
MAX

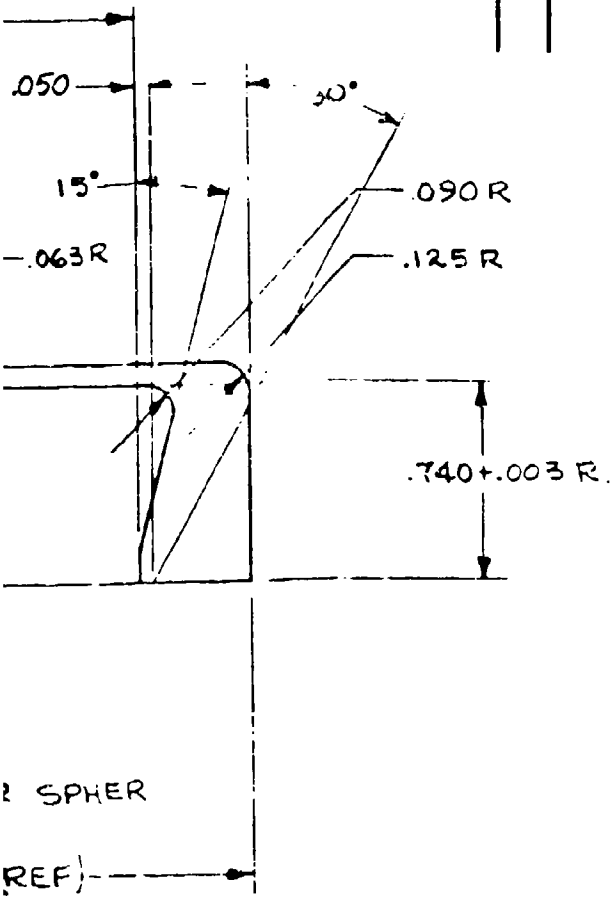
DETAIL A
SCALE: 10/1

QTY	PART NO	PART NAME	STOCK SIZE	MATERIAL
		UNLESS OTHERWISE SPECIFIED		
		DIMENSIONS ARE IN INCHES	SIGNAL DATE DRAWING	
		TOLERANCES ON	8-31-73	
		FRACTIONS DECIMALS ANGLES		
		.010 1°	CRAFTSMAN	
		MATERIAL		
			12-3-72	

ABERDEEN PROVING GROUND, I
U. S. ARMY LAND WAFAR

REVISIONS

LTR	DESCRIPTION	DATE	APPROVED



040103004

PART NAME		STOCK SIZE		MATERIAL		SPEC		ITEM	
LESS OTHERWISE SPECIFIED		ORIGINAL DATE DRAWING		[REDACTED]		[REDACTED]		[REDACTED]	
DIMENSIONS ARE IN INCHES		8-31-73		ABERDEEN PROVING GROUND, MARYLAND 21005		U. S. ARMY LAND WARFARE LABORATORY		[REDACTED]	
TOLERANCES IN DECIMALS ANGLES		DRAFTSMAN		DATE		[REDACTED]		[REDACTED]	
.010 1°		[REDACTED]		12-3-72		[REDACTED]		[REDACTED]	

0.005 R

60°

.740+.003 R SPHER

2.312 (REF)

.005+.002

2°

.003R
MAX

DETAIL A
SCALE: 10/1

QTY	PART NO	PART NAME	ORIGINAL DATE OF DRAWING
		UNLESS OTHERWISE SPECIFIED	8-31-73
		DIMENSIONS ARE IN INCHES TOLERANCES ON FRACTIONS DECIMALS ANGLE = = .010 = 1°	DRAFTSMAN <i>J. H. H.</i>
		MATERIAL NYLON FOAM 15% FIBERGLAS FIBERFIL F3-15 NYLAFIL / FOAM	CHECKER <i>LOWE</i>
		FINISH _____	PROJECT ENG <i>Schiff</i>
4	040103000	HEAT TREATMENT _____	PROJECT NO. 02-F-7
QTY	NEXT ASSY	USED CN	APPROVED
APPLICATION			AAI CORPORATION COCKEYSVILLE, M

Figure 5. Sabot Segment, 40mm Liquid Ball

R SPHER

(REF) →

040103004

PART NAME		STOCK SIZE		MATERIAL	SPEC	ITEM
LESS OTHERWISE SPECIFIED		ORIGINAL DATE OF DRAWING		[REDACTED]		
DIMENSIONS ARE IN INCHES DIMENSIONS IN FRACTIONS DECIMALS ANGLES - - - - - °		8-31-73		ABERDEEN PROVING GROUND MARYLAND 21005		
MATERIAL		CRAFTSMAN	DATE	U S ARMY LAND WARFARE LABORATORY		
POLYURETHANE FOAM		LOWE	8/22/73	SABOT SEGMENT		
FIBERGLAS		PROJECT ENG	8/23/73			
SERFIL F3-15		PROJECT NO	02-F-73			
LAFIL/ FOAM		APPROVED	DATE	SIZE	CODE IDENT NO	REV.
				C	97384 040103004	
TREATMENT		JAI CORPORATION COCKEYSVILLE, MD.		SCALE	DAADG5-72-C-0209	SHEET 1 OF 1

40mm Liquid Ball

APPENDIX C
3-Inch Liquid Ball
(Test Firing)

TEST REPORT
LESS LETHAL 3-INCH LIQUID BALL - 1

(Task 02-F-73, Contract
NO. DAA005-73-C-0552
WORK ORDER NO. 11)

Prepared For
United States Army
Land Warfare Laboratory
Aberdeen Proving Ground, Maryland

By
H.P. White Laboratory
Bel Air, Maryland 21014

January 1974

v. 5

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ABSTRACT

This report presents the results of tests on less lethal 5-Inch Liquid Ball munitions in accordance with the provisions of Contract No. DAA05-75-C-0532, Task 02-1-73 (in agreement between the U.S. Army, Land Warfare Laboratory and H.P. White Laboratory).

ABSTRACT

This report presents the results of tests of less lethal 3-Inch Liquid Ball munitions in accordance with the provisions of Contract No. DAMD05-75-C-0552, Task 02-1-75 (an agreement between the U.S. Army, Land Warfare Laboratory and H.P. White Laboratory).

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SECTION I. SCOPE OF WORK

1. OBJECTIVE

The objective of these tests was to provide the external ballistic data necessary to assess the ballistic performance of the 5-Inch Liquid Ball less lethal ammunition.

2. MATERIALS

The following materials were used in the conduct of this test program:

- a) 5-Inch Liquid Ball less lethal projectiles (see Figure 1).
- b) Blank Propelling cartridges (Model C200) (see Appendix D and Figure 1).
- c) M1200 12 Gauge riot gun (Serial No. 1571489).
- d) Launcher, Model L-110.
- e) Miscellaneous range and photographic equipment (see Appendix C).

3. SCOPE OF TESTS

Twenty-four (24) rounds of 5-Inch Liquid Ball ammunition were fired on an instrumented indoor range to determine velocity, accuracy, muzzle exit phenomena, relative impact characteristics and the effect of shooter stress on accuracy. Ten (10) rounds were fired on an outdoor range to determine maximum range and maximum effective hitting range when the projectiles are subjected to environmental variables such as wind. Three (3) rounds were fired to determine the effect of cold temperature firing. (see Table 1)

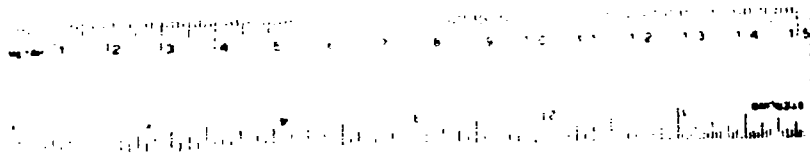
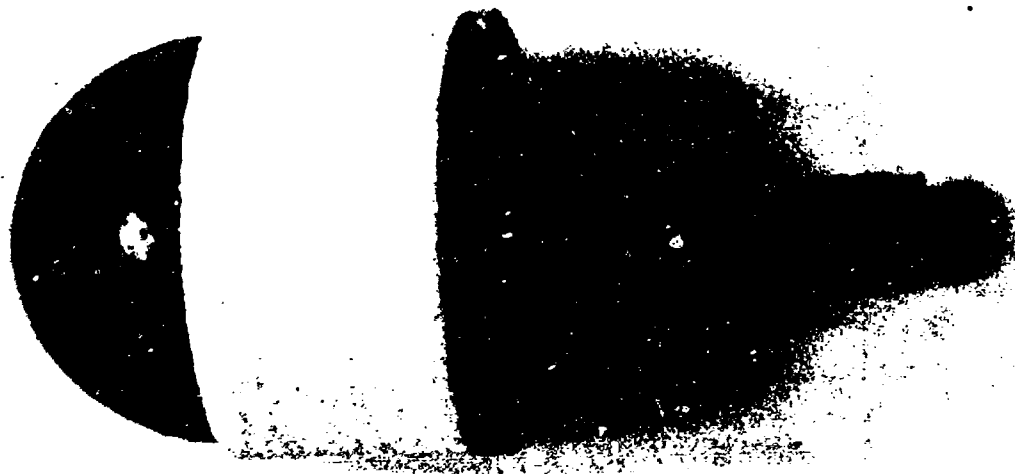


Figure 1. 3-Inch Liquid Ball and Model C-200 Blank Propelling Cartridge.

TABLE I. SCOPE OF TESTS

Round No.	Velocity		Energy		Impact Coordinates	Muzzle Exit Phenomena	Impact Phenomena & Indentation	Cold Test	Maximum Range	Maximum Effective Hitting Range	Shooter Stress
	Mr-1c	2m	Mr-1c	2m							
1-24	LS	LS	C	C	A		A				
25					A	MF	A				
26, 27	HS		C		A	HS	A				T, A
28-42					A				A		
45-48					A		A	A			
49-55					A					A, E	

HS - High Speed Motion Picture
 LS - Lumiline Screens/Time Interval Counter
 MF - Micro Flash
 C - Calculated
 A - Measured
 T - Timed
 E - Estimated

SECTION 11. PROCEDURE

1. VELOCITY

- a) The velocity of twenty-four (24) rounds of the 3-Inch Liquid Ball projectiles was derived from data collected by erecting lumiline screens 5.06, 8.06, 14.9 and 17.9 feet (1.54, 2.46, 4.54, and 5.46 meters respectively) from the muzzle of an M1200 riot gun (with launcher attachment) fired from the prone/rest position. The outputs of these screens activated time interval counters from which the velocities at 2 and 5 meters from the muzzle were calculated.
- b) Velocity of two (2) of the 3-Inch Liquid Ball projectiles was calculated from data extracted from high speed motion pictures of the muzzle and initial few feet of projectile flight recorded by 16mm Fastax motion picture cameras positioned 4 feet 8 inches to the right of the line of fire and 9 inches in front of the muzzle. The film speed, used to compute the projectile velocity, was determined from timing marks on the film created by a time pulse generator.

2. PROJECTILE ENERGY

Projectile energy of the 3-Inch Liquid Ball projectile was calculated by applying the unfired projectile weight and the velocity data derived per 1, above, to the standard energy formula--

$$\text{Kinetic Energy} = (1/2) MV^2$$

3. ACCURACY

The accuracy of the 3-Inch Liquid Ball ammunition was determined from impact data on a target constructed of 2" x 4" wood backing, 1/2-inch thick Homasote and faced with paper. The accuracy of the ammunition was determined by measuring the horizontal and vertical dispersion from the aiming point on the target. Standard deviations in the x and y directions and the mean radius were calculated.

4. IMPACT CHARACTERISTICS

Indentations in the Homasote, produced by each projectile impact, were measured using a depth micrometer and the average indentation was calculated. Indications of projectile attitude at impact were observed and noted. These data were collected from the target when positioned 6.4, 20, 35, and 50 meters from the muzzle of the prone/rest fired M1200 riot gun and launcher.

5. EFFECT OF SHOOTER STRESS ON ACCURACY

Three (3) shooters fired five (5) rounds each at an anthropometric silhouette target positioned 35 meters from the shooter. In order to induce stress, each shooter was told that he would have an average of 4 seconds (varying from 3 seconds to 5 seconds) to shoulder the M1200, sight and fire at the target. This timing was accomplished by utilizing a cardboard shield which obscured the shooter's view of the target before and after each shot. No warning was given before the shield was raised and the time interval started. The coordinates of each shot in relation to the center of the chest area of the silhouette were recorded. Whether or not a hit had been scored on the man-size silhouette was recorded and any hits in critical areas (groin and eyes) were noted. Standard deviation of the x and y coordinates and the mean radius were calculated from these data.

6. MAXIMUM RANGE

The M1200, with its barrel elevated 30° from horizontal, was fired from a bench rest on a 400-meter outdoor range. After each shot, the distance the projectile traveled before its initial impact with the ground was measured as well as the deflection right or left of the line of sight.

7. MAXIMUM EFFECTIVE HITTING RANGE

The launcher equipped M1200 was bench rest fired at an anthropometric silhouette target positioned 35 meters from the muzzle. After four (4) firings without scoring a hit on the silhouette, the target was moved to 20 meters from the muzzle for the remaining 3 firings. Wind velocity at each firing was measured using a Dwyer "Wind Meter." Silhouette target hits and misses, impact coordinates, and flight time from muzzle to target (timed by stop watch) were recorded. Estimate of maximum effective hitting range was the average of three (3) observers opinion of range at which tactical hits could be expected under test conditions.

8. COLD TEMPERATURE FIRING

Three (3) of the 5-Inch Liquid Ball and three (3) power charges were stored at -45°F for 24 hours. They were then stored for one additional hour at 0° immediately before being fired from the machine rest mounted M1200 riot gun and launcher. Each shot was remotely fired. The fired cartridge case, M1200, and launcher were examined for damage after each shot. Impact coordinates and the indentation in the "blomasote" faced target were measured and recorded.

9. MUZZLE EXIT PHENOMENA

Three (3) 3-Inch Liquid Ball projectiles were photographed as they exited the muzzle of the launcher. Two (2) rounds were photographed using two (2) 16mm Fastax High Speed Motion Picture cameras simultaneously. One Fastax camera was positioned perpendicular to and 4 feet 8 inches from the line of fire, 9 inches forward of the muzzle. The other Fastax camera was positioned 38.3 feet forward of the muzzle, 3 feet to the left of the line of fire and focused on the muzzle. Both cameras ran at a nominal 4000 frames per second. The third round was photographed using a Linhof 4" x 5" camera positioned 4 feet to the right and 1 foot in front of the muzzle. Four (4) General Radio "Stroboslave" recycling flash units were pulsed at .0013 second intervals for a flash duration of .000005 seconds each. These strobes provided four (4) exposures of the projectile within 17 inches of the muzzle. Projectile muzzle exit was studied by examining the 16mm high speed motion picture film and enlargements of the 4" x 5" microflash photography (see Figure 2).

10. SAFETY

In addition to normal safety procedures followed during firing, personnel were required to wear respiratory protection during conduct of the test to preclude inhalation of any small droplets of the glycerin and water mix in the projectile which might have been aerosolized upon target impact.

SECTION III. RESULTS

1. VELOCITY

Table II is a summary of the velocity data contained on the data sheets of Appendix A.

TABLE II. RESULTS OF VELOCITY TESTS (f.p.s.)
3-INCH LIQUID BALL

	Muzzle** (2 rds)	2m* (21 rds)	5m* (21 rds)
Maximum	116.0	145.8	143.6
Minimum	108.0	110.7	95.2
Average	112.0	129.8	125.6

*Lumiline screens/time interval counter
(accuracy \pm 3 f.p.s.)
**High Speed Motion Pictures
(accuracy \pm 20 f.p.s.)

2. PROJECTILE ENERGY

Table III is a summary of calculations based on the data contained in Appendix A.

TABLE III. PROJECTILE ENERGY (ft-lbs)
3-INCH LIQUID BALL

	Muzzle (2 rds)	2m (21 rds)	5m (21 rds)
Maximum	127.2	200.9	194.9
Minimum	110.5	115.9	82.1
Average	118.8	160.5	150.7

3. ACCURACY

Table IV is a summary of calculations based on the data contained in Appendix A.

TABLE IV. RESULTS OF ACCURACY TESTS
3-INCH LIQUID BALL

Target Distance (meters)	Group Center (from point of aim) (in.)		Extreme Spread (in.)		Standard Deviation (in.)		Mean Radius (in.)
	x	y	x	y	x	y	
6.4	-0.2	-1.5	3.8	12.1	27.0	24.3	3.0
20	-8.1	-62.0	27.0	24.3	9.9	8.6	11.1
55	Trajectory would not permit hits on 8'x8' target.						

4. IMPACT CHARACTERISTICS

Table V is a summary of calculations based on the data contained in Appendix A.

TABLE V. INDENTATIONS OF HOMASOTE
3-INCH LIQUID BALL

Target Distance (meters)	Average Indentation (in.)	Minimum Indentation (in.)	Maximum Indentation (in.)
6.4	.014	0	.059
20	0	0	0
55	Trajectory would not permit hits on 8'x8' target.		

5. EFFECT OF SHOOTER STRESS ON ACCURACY

Table VI is a summary of the calculations based on the data contained in Appendix A.

NOTE: The elevation required of the M1200 in conjunction with the large diameter of the launcher attachment obscured the target from the shooter. Therefore, all subsequent firing at ranges of 20 meters or more were conducted by using a point of aim well above the target.

TABLE VI. SUMMARY OF STRESS TEST RESULTS
5-INCH LIQUID BALL, TARGET 35 METERS

Shooter	Group Center (from point of aim) (in.)		Extreme Spread (in.)		Standard Deviation (in.)		Mean Radius (in.)	Total Hits on Silhouette	Hits in Critical Area
	x	y	x	y	x	y			
A	-9.8	-45.4	34.4	5.8	13.6	2.4	9.6	0	0
B	+2.5	-24.0	50.0	96.1	20.5	41.6	54.8	1	0
C	+28.3	-47.0	70.8	30.0	28.5	12.9	24.2	0	0

6. MAXIMUM RANGE

Table VII is a summary of the data contained in Appendix A.

TABLE VII. MAXIMUM RANGE
5-INCH LIQUID BALL

	distance (meters)	deflection (meters)
Maximum	117.5	16-right
Minimum	91.0	2-left
Average	105.5	6.7-right

7. MAXIMUM EFFECTIVE HITTING RANGE

Table VIII is a summary of the data contained in Appendix A.

TABLE VIII. MAXIMUM EFFECTIVE HITTING RANGE.
3-INCH LIQUID BALL.

Impact Coordinates (in.)		Hits	Wind Velocity (m.p.h.)	Average Flight Time (sec.)	Remarks
x	y				
TARGET DISTANCE: 55 METERS (4 ROUNDS)					
+14.6*	-46.9*	0	9.0-10.5	0.9*	3 of 4 projectiles impacted ground at 50-51 meters.
TARGET DISTANCE: 20 METERS (5 ROUNDS)					
0	-45.9**	2	10.0-11.0	0.5**	1 projectile impacted ground at 18.5 meters.
*One round on'y.					
**Two rounds only.					

It was the opinion of the three (5) observers that the maximum range at which tactical hits on a man could be expected was approximately 20 meters.

8. COLD TEMPERATURE FIRING

The launcher equipped M1200 was machine mounted and aimed at a point 100 inches above the floor at 55 meters from the muzzle. All three (5) rounds impacted the floor before reaching the target at 55 meters. No abnormalities were observed regarding the launcher, M1200 Riot Gun, or the fired cartridge cases.

Projectile filler (60% glycerin, 40% water) appeared to be in a solid state at impact. Dispersal characteristics appeared to be approximately 55% smaller than those of projectiles at room temperature. Due to the poor accuracy at 55 meters, no appreciable difference could be detected between the projectiles at room temperature and those at reduced temperatures.

9. MUZZLE EXIT PHENOMENA

The muzzle exit of three (3) rounds was recorded photographically--two (2) with 10mm high speed motion pictures and one (1) with recycling microflash. Analysis of the high speed motion pictures revealed:

- a) The projectile of Round No. 26 assumed a 9° yaw attitude immediately after clearing the muzzle.
- b) The projectile of Round No. 27 was distorted throughout the field of view of the camera (approximately 18 inches of linear travel).
- c) The velocities of the projectiles from Round Nos. 26 and 27 were 116.0 and 108.0 feet per second, respectively.

The projectile from Round No. 25 which was photographed with microflash equipment is obscured in what appears to be a combination of muzzle gas and particles of the styrofoam portion of the projectile. The degree of distortion and/or yaw (if any) is, therefore, not discernable (see Figure 2). (Note: Extending the interval between the strobes of the microflash system and increasing the field of view of the camera in any subsequent firings of this projectile at this velocity should result in one (1) or more exposures of the projectile after it has cleared this muzzle opacity.)

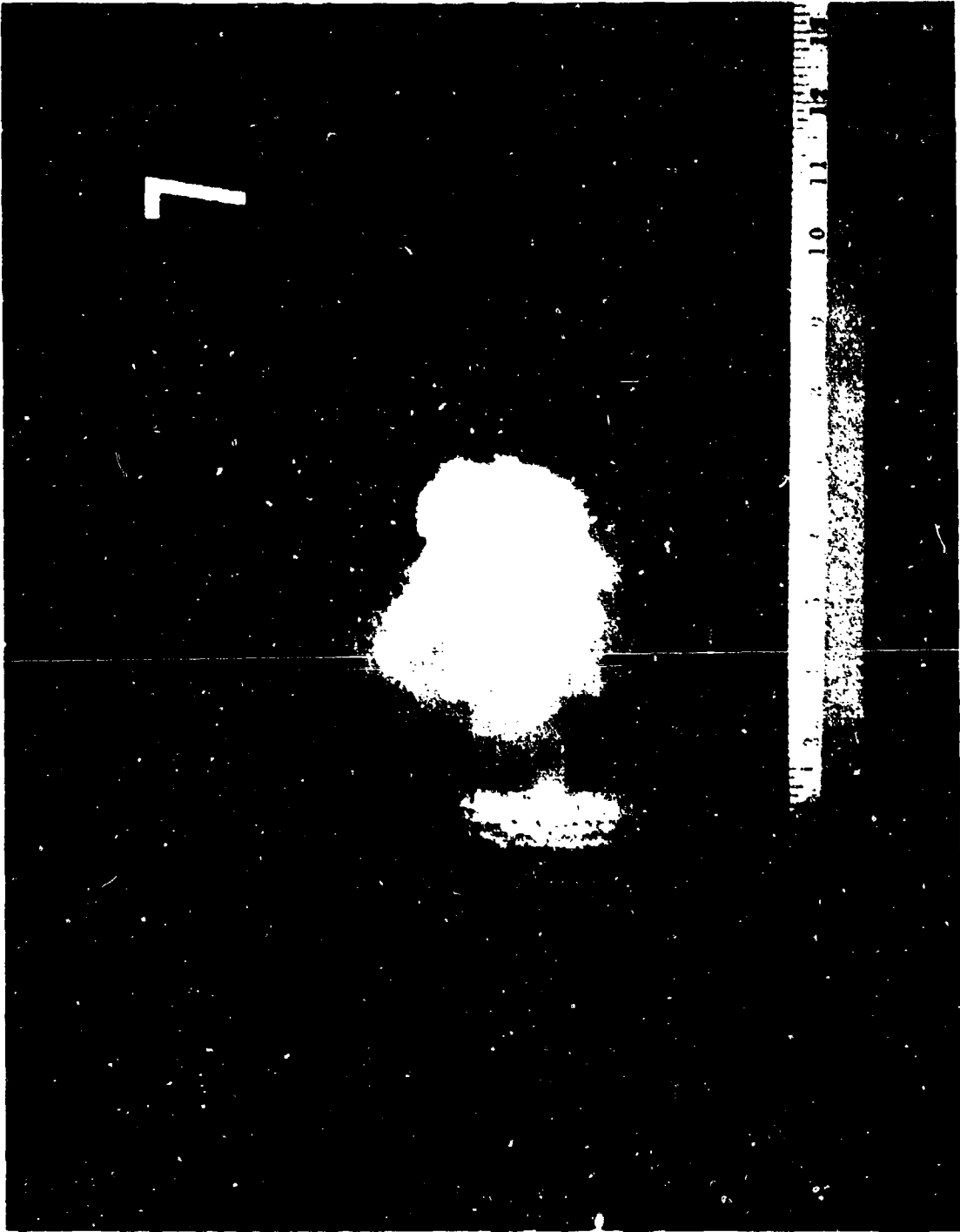


Figure 2. Muzzle Exit of Round No. 25.

APPENDIX A

Date 4 October 1975

Shooter Poole

Job No. 1883-11

Temperature 70°F ; Humidity 8.5

Recorder Summit

Page

2-Meter Screens 5.06' and 8.06' (over 5')

Chronograph Dehler

Weapon M1200 #1571489

5-Meter Screens 14.90' and 17.90' (over 5')

Ammunition 3" Liquid Ball

Type --- Lot ---

Target 6.4 meters

Shot No.	2-Meter		S-Meter		Coord. nates			Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	x (in.)			
1	25770	126.2	4241.7	24014	124.9	4241	-1.5	-6.5	.059	Front of flask shield wet from projectile All screens soaked
2	26193	114.5	4271.0	27757	108.2	4271.0	-2.5	-5.4	.052	
3	24563	122.1	4238.6	28401	105.6	4238.6	0	-5.8	.038	
4	22461	135.6	4264.8	22777	131.7	4264.8	+0.8	+5.6	0	
5	22600	132.7	4359.0	22942	130.8	4359.0	-0.8	0	0	
6	20580	145.8	4255.6	20898	143.6	4255.6	-1.2	-1.1	0	
7	23101	129.9	4264.8	25559	128.4	4264.8	+0.2	-1.5	0	

Date 2 October 1975Shooter PeckleJob No. 1883-11Temperature 70°F; humidity 83%Recorder Sumalt

Page _____

2-Meter Screens 5.06' and 8.06' (over 3')Chronograph L.C.Weapon M1200 #15714895-Meter Screens 14.90' and 17.90' (over 3')Chronograph UehlerAmmunition 3" Liquid Ball

Type _____ Lot _____

Target 20 meters

Shot No.	2-Meter			5-Meter			Coordinates			Aiming Data	Indent. in Holesote (in.)	Results
	Time (sec)	Vel. (ft./sec)	Proj. Wt.* (gn.)	Time (sec)	Vel. (ft./sec)	Proj. Wt.* (gn.)	X (in.)	Y (in.)	Z (in.)			
8	No reading											
9	24214	135.9	4257.1	24460	122.6	4257.1	-2.0	-57.0	5° Elevation	0		
10	21476	139.7	4257.1	21830	137.4	4257.1	-7.6	-57.6		0		
11	21467	139.7	4257.1	21768	137.8	4257.1	+1.7	-59.0		0		
12	22580	132.9	4257.1	22854	131.4	4257.1	-17.8	-58.6		0		
13	24425	122.8	4257.1	24887	120.5	4257.1	-25.3	-61.0		0		
14	No reading											
15	22728	132.0	4257.1	22986	130.5	4257.1	0	-59.6		0		
16	25537	127.4	4257.1	32197	93.2	4257.1	-6.0	-81.3		0		

*Average weight.

Date 1 October 1975

Shooter Evdey

Job No. 1883-11

Temperature 68°F; Humidity 80%

Recorder Summitt

Page

2-Meter Screens 5.00' and 8.00' (over 3')

Chronograph Chlier

Weapon M200 #1571489

5-Meter Screens 14.90' and 17.90' (over 3')

Chronograph L.C.

Ammunition 5" Liquid Ball

Type _____ Lot _____

Target 55 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Hairs (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gr.)	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gr.)	x (in.)			
17	22507	153.3	4257.1	23168	129.5	4257.1			level 25 1/4"	Hit floor prior to hitting target.
18	22785	151.7	4257.1	25049	130.2	4257.1			5° Elevation	Hit floor prior to hitting target.
19	27092	110.7	4257.1	27505	109.1	4257.1			5° Elevation	Hit floor prior to hitting target.
20	22095	155.8	4257.1	22546	134.3	4257.1			5° Elevation	Hit floor prior to hitting target.
21	24473	122.6	4257.1	24830	120.8	4257.1			4° Elevation	Hit floor prior to hitting target.
22	No reading									
23	21740	138.0	4257.1	2194	136.7	4257.1				Hit floor prior to hitting target.
24	22765	151.8	4257.1	25060	150.1	4257.1				Hit floor prior to hitting target.
	All projectiles hit the floor prior to hitting the target.									
	*Average weight.									

Date 25 September 1975

Shooter Poole

Job No. 1883-11

Temperature 62°F; Humidity 51%

Recorder Usell

Page

2-Meter Screens and (over)

Chronograph

Weapon 12 Ga. M200 #1571489

5-Meter Screens and (over)

Ammunition 5" Liquid Ball

Type Lot

Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)			
25	Micro flash		425.1				Aiming point of 14" up from floor		Projectile hit approximately 6' to left of center line and behind target.
	*Average weight								

Date 19 September 1975 Job No. 1883-11
 Temperature 60 F; Humidity 71 Shooter Paul
 Recorder U. Star
 2-Meter Screens and (over)
 Chronograph
 5-Meter Screens and (over)
 Chronograph
 Type Lot
 Target 50 meters

Job No. 1883-11

Page

Weapon 1.6 in. M200 #1571489

Ammunition 30 Liquid Ball

Type Lot

Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr.)			
20	Black and White High Speed Movie		High Speed Movie	425.			Aiming point of 1/4"		Ball hit at 45m on left wall approximately 5' to left of center. No impact on 8'x8' target. Base found at 52m.
	Average weight.								

Date 25 November 1975 Shooter Pyper, R. J. Job No. 1583-1
 Temperature 57.1 Humidity 60 Recorder analog Page _____
 2-Meter Screens _____ and _____ (over _____) Chronograph _____
 5-Meter Screens _____ and _____ (over _____) Chronograph _____
 Type _____ Lot _____
 Target 53 meters

1151111111

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr)	X (in.)			
28							-13.3	-11.1	Miss, Point only	Missed
29							-20.7	-10.1	Miss, Point only	Missed
30							-17.0	-11.3	Miss, Point only	Missed
31							-13.3	-11.5	Miss, Point only	Missed
32							+15.7	-11.7	Miss, Point only	Missed

Date 25 November 1975

Shooter 1 July 1975

Job No. 1883-11

Temperature 57 F, humidity to

Recorder Summit

Page

2-Meter Screens and (over)

Chronograph

Weapon 1. Cal. M1200 #157149

3-Meter Screens and (over)

Chronograph

Ammunition 3" Liquid Ball

Type Lot

Target 35 meters

1134 D FIRE

Shot No.	Z-Meter		S-Meter		Coordinates			Aiming Data	Indent. in Homasote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr.)	x (in.)			
33							+19.0	-41.0	Miss. Point only	Missed
34							- 9.5	-45.5	Miss. Point only	Missed
35							-25.5	-46.1	Miss. Point only	Missed
36							+24.5	+50.0	Miss. Point only	Missed
37							+ 2.9	-51.8	Miss. Point only	Missed

Date 25 November 1975 Shooter Sam Hill Job No. 1883-11
 Teperature 57.1; Humidity 66 Recorder Flow Page
 2-Meter Screens and (over) Chronograph Section 12 Cal. 5.200 # 15-1489
 5-Meter Screens and (over) Chronograph Ammunition 5" Liquid Ball
 Type Lot
 Target 55 meters

1130 HR

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in (in.)	Results
	Time (sec)	Proj. Wt. (gn)	Time (sec)	Proj. Wt. (gn)	X (in.)	Y (in.)			
38					-20.5	-42.0	Miss. Point only		Missed
39					+27.1	-41.1	Miss. Point only		Missed
40					+41.5	-40.0	Miss. Point only		Missed
41					+40.0	-70.0*	Miss. Point only		Missed. Broke in flight. Hit floor at approx 52m.
42					+50.5	-41.0	Miss. Point only		Missed

*Approximately

OBSERVED DATA

MAXIMUM RANGE
M1200-Launcher 3-Inch Liquid Ball
Barrel Elevated 30°

Date: 5 February 1974

Temperature: 30°F, variable
cross wind (left to right)

Round No.	Range (meters)	Deflection (meters)	Remarks
43	91.0	0.0-right	Broke on impact with ground.
44	117.5	2.0-left	Broke on impact with ground.
45	108.0	16.0-right	Broke on impact with ground.

OBSERVED DATA

COLD TEST

M1200 Launcher 3-Inch Liquid Ball

Date: 12 February 1974

Ammunition: Stored at -45°F for 24 hours.

Stored at 0°F for 1 hour immediately before firing.

Machine rest, lanyard fired

Target: 35 meters

Aiming point: 100 inches high

Round No.	(in.)	(in.)	Indentation (in.)	Remarks
46	--	--	--	Hit floor at 25 meters.
47	--	--	--	Hit floor at 32 meters.
48	--	--	--	Hit floor at 35 meters, bounced to target.

OBSERVED DATA

MAXIMUM EFFECTIVE HITTING RANGE
M1200 Launcher - 5-Inch Liquid Ball

Date: 1 March 1974

Temperature: 45°F, variable cross wind
right to left

Round No.	Impact Coordinates (in.)		Silhouette Hit/ Missed	wind Velocity (m.p.h.)	Flight Time (sec.)	Projectile Weight (gt.)	Remarks
	x	y					
TARGET DISTANCE: 55 METERS							
49	-	-	Missed	9.0	-	4275.1	hit ground at 31m
50	-	-	Missed	10.0	-	4256.1	hit ground at 30m
51	+14.0	-46.9	Missed	10.0	0.9	4245.8	
52	-	-	Missed	10.5	-	4559.5	hit ground at 31m
TARGET DISTANCE: 20 METERS							
53	0	-46.5	hit	10.0	0.5	4559.5	
54	0	-45.5	hit	10.0	0.5	4590.4	
55	-	-	Missed	11.0	-	4556.4	hit ground at 18.5m

APPENDIX B

CALCULATED DATA

ACCURACY

3-Inch Liquid Ball
6.4 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	(x - \bar{x})	(y - \bar{y})	
1	+1.5	-6.5	2.89	25.0	5.3
2	-2.3	-5.4	4.41	3.61	2.8
3	0	-5.8	0.04	5.29	2.5
4	+0.8	+5.0	1.0	50.41	7.2
5	-0.8	0	0.36	2.25	1.6
6	-1.2	-1.1	1.0	0.16	1.1
-	+0.2	-1.5	0.16	0	0.4

<div style="display: flex; justify-content: space-around;"> \bar{x} \bar{y} σ_x σ_y </div>					

Standard deviation	---	---	1.6	5.8	---
Mean	$\bar{x} = -0.2$	$\bar{y} = -1.5$	---	---	3.0
Extreme Spread	5.8	12.1	---	---	---

CALCULATED DATA

ACCURACY
3-Inch Liquid Ball
20 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
9	-2.0	-57.0	37.21	25.0	7.9
10	-7.6	-57.6	0.25	19.36	4.4
11	+1.7	-59.0	96.04	9.0	10.2
12	-17.8	-58.6	94.09	11.56	10.3
13	-25.3	-61.0	295.84	1.0	17.2
15	0	-59.6	65.61	5.76	8.4
16	-6.0	-81.3	4.41	372.49	19.4
			\bar{x} (in.)	\bar{y} (in.)	
Standard Deviation	---	---	9.9	8.6	---
Mean	$\bar{x} = -8.1$	$\bar{y} = -62.0$	---	---	11.1
Extreme Spread	27.0	24.3	---	---	---

CALCULATED DATA

ACCURACY Timed Fire 3-Inch Liquid Ball

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
28	-12.3	-44.5	6.25	1.21	2.7
29	-20.7	-46.1	118.81	7.29	11.2
30	-17.0	-40.3	51.84	9.61	7.8
31	-12.5	-44.5	7.29	1.21	2.9
32	+13.7	-41.7	552.25	2.89	23.6

			x (in.)	y (in.)	
Standard Deviation	---	---	13.6	2.4	---
Mean	$\bar{x} = -9.8$	$\bar{y} = -43.4$	---	---	9.6
Extreme Spread	34.4	5.8	---	---	---

CALCULATED DATA

ACCURACY Timed Fire 3-inch Liquid Ball

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
33	+19.0	-44.0	278.89	400.00	26.1
34	-9.5	-45.3	134.56	453.69	24.3
35	-25.5	-46.1	772.84	488.41	35.5
36	+24.5	+50.0	492.84	5476.00	77.3
37	+2.9	-34.8	0.36	116.64	10.8
Standard Deviation	---	---	20.5	41.6	---
Mean	$\bar{x} = +2.3$	$\bar{y} = -24.0$	---	---	34.8
Extreme Spread	50.0	96.1	---	---	---

CALCULATED DATA

ACCURACY Timed Fire 3-Inch Liquid Ball

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
38	-20.3	-42.0	2361.96	25.00	48.9
39	+27.1	-41.1	1.44	34.81	6.0
40	+44.3	-40.0	256.00	49.00	17.5
41	+40.0	-70.0*	136.89	529.00	25.8
42	+50.5	-41.9	492.84	26.01	22.8
*Approximately					
			x (in.)	y (in.)	
Standard Deviation	---	---	28.5	12.9	---
Mean	$\bar{x} = +28.3$	$\bar{y} = -47.0$	---	---	24.2
Extreme Spread	70.8	30.0	---	---	---

APPENDIX C

TEST INSTRUMENTATION
EQUIPMENT AND MATERIALS

- 1 - Oehler Model 41B Chronotach, calibrated at factory in May 1973
- 1 - Electronic Counters, Inc. Model 4010 Velocity Computing Chronograph, calibrated at factory in June 1973
- 4 - Oehler Model 35 Lumiline Screens
- 2 - Fastax 16mm High Speed Motion Picture Cameras
- 1 - Wollensak Model 3106 Time Pulse Generator
- 2 - Colortran 1000 Watt Lights
- 2 - Wollensak 1000 Watt Lights
- 2 - 100-foot Rolls Kodak Ektachrome (7242) 16mm High Speed Film (GFE)
- 2 - 100-foot Rolls Eastman Double-X Negative (722) 16mm High Speed Film
- 1 - Vanguard Model 16C Motion Analyzer
- 4 - General Radio Type 1539 "Stroboflash" Microflash
- 1 - General Radio Model 1541 Multi-Flash Generator
- 1 - Linhof 4x5 Camera with Kodak f4.5, 135mm Lens
- 1 - Royal Pan 4" x 5" Cut Film, Type 4141
- Various darkroom and photographic equipment
- 100-meter indoor range having ceiling height of 12 feet
- 400-meter outdoor range
- Miscellaneous range supplies and equipment
- 1 - Specially constructed target (Homasote faced), Homasote Company, Lower Ferry Road, Trenton, N.J.
- 1 - Dry Ice Freezer Unit
- 1 - Rochester Thermometer
- 1 - Plywood Anthropometric Silhouette Target based on 1960 Dreyfus data
- 1 - Dwyer Wind Meter, F.W. Dwyer Mfg Co., Michigan City, Indiana

APPENDIX D

AAI CORP. — MODEL C-200

Blank Propelling
Cartridges

FOR USE WITH
MPG SERIES GRENADES
AFO
MODEL L-110 LAUNCHERS

APPENDIX D
40mm Liquid Ball
(Test Firing)

TEST REPORT
LESS LETHAL 40MM LIQUID BALL-1

(TASK 02-F-73, CONTRACT
NO. DAAD05-73-C-0532
WORK ORDER NO. 10)

Prepared For
United States Army
Land Warfare Laboratory
Aberdeen Proving Ground, Maryland

By
H.P. White Laboratory
Bel Air, Maryland

February 1974

D-3

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ABSTRACT

This report presents the results of initial tests of less lethal 40mm Liquid Ball rounds in accordance with the provisions of Contract No. DAMD03-75-C-0552, Task 02-F-75 (an agreement between the U.S. Army Land Warfare Laboratory and H.P. White Laboratory).

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SECTION I. SCOPE OF WORK

1. OBJECTIVE

The objective of these tests was to provide the external ballistic data necessary to assess the ballistic performance of the 40mm Liquid Ball less lethal ammunition.

2. MATERIALS

The following materials were used in the conduct of this test program:

- a) 40mm Liquid Ball less lethal projectiles (see Figure 1).
- b) Grenade launcher, 40mm, M79, Serial No. 47637.
- c) Miscellaneous range and photographic equipment (see Appendix C).

3. SCOPE OF TESTS

Seventy-eight (78) rounds of 40mm Liquid Ball ammunition were fired on an instrumented indoor range to determine velocity, accuracy, muzzle exit phenomena, relative impact characteristics and the effect of shooter stress on accuracy. Ten (10) rounds were fired on an outdoor range to determine maximum range and maximum effective hitting range when the projectiles are subjected to environmental variables such as wind. Seven (7) rounds were fired to determine the effect of cold temperature firing. (see Table I)

TABLE I. SCOPE OF TESTS

Round No.	Velocity		Energy		Impact Coordinates	Muzzle Exit Phenomena	Impact Phenomena & Indentation	Cold Test	Maximum Range	Maximum Effective Hitting Range	Shooter Stress
	Muzzle	5m	Muzzle	5m							
1-21	LS	LS		C	A		A				
22	HS		C		A		A				
23-26					A		A				
27-30					A	MF	A				
31-37	HS		C		A	HS	A				
38-48					A		A				
49-78					A		A				T,A
79-81					A		A		A		
82-88								A			
89-95					A		A			A,E	

HS - High Speed Motion Picture
 LS - Lumiline Screens/Time Interval Counter
 MF - Micro Flash
 C - Calculated
 A - Measured
 T - Timed
 E - Estimated

SECTION II. PROCEDURE

1. VELOCITY

- a) The velocity of twenty-one (21) rounds of the 40mm Liquid Ball projectiles was derived from data collected by erecting lumiline screens 5.06, 8.06, 14.9 and 17.9 feet (1.54, 2.46, 4.54 and 5.46 meters, respectively) from the muzzle of an M79 Grenade Launcher fired from the prone/rest position. The outputs of these screens activated time interval counters from which the velocities at 2 and 5 meters from the muzzle were calculated.
- b) Velocity of eight (8) of the 40mm Liquid Ball projectiles was calculated from data extracted from high speed motion pictures of the muzzle and initial few feet of projectile flight recorded by 16mm Fastax motion picture cameras positioned 4 feet 8 inches to the right of the line of fire and 9 inches in front of the muzzle. The film speed, used to compute the projectile velocity, was determined from timing marks on the film created by a time pulse generator.

2. PROJECTILE ENERGY

Projectile energy of the 40mm Liquid Ball projectile was calculated by applying the unfired projectile weight and the velocity data derived per 1, above, to the standard energy formula--

$$\text{Kinetic Energy} - (1/2) MV^2$$

3. ACCURACY

The accuracy of the 40mm Liquid Ball ammunition was determined from the impact data on a target constructed of 2" x 4" wood backing, 1/2-inch thick Homasote and faced with paper. The accuracy of the ammunition was determined by measuring the horizontal and vertical dispersion from the aiming point on the target. Standard deviations in the x and y directions and the mean radius were calculated.

4. IMPACT CHARACTERISTICS

Indentations in the Homasote, produced by each projectile impact, were measured using a depth micrometer and the average indentation was calculated. Indications of projectile attitude at impact were observed and noted. These data were collected from the target when positioned 6.4, 20, 35, 50 and 70 meters from the muzzle of the prone/rest fired M79 Grenade Launcher.

5. EFFECT OF SHOOTER STRESS ON ACCURACY

Three (3) shooters fired ten (10) rounds each at an anthropometric silhouette target positioned 35 meters from the shooter. In order to induce stress, each shooter was told that he would have an average of 4 seconds (varying from 3 seconds to 5 seconds) to shoulder the M79, sight and fire at the target. This timing was accomplished by utilizing a cardboard shield which obscured the shooter's view of the target before and after each shot. No warning was given before the shield was raised and the time interval started. The coordinates of each shot in relation to the crotch area of the silhouette were recorded. Whether or not a hit had been scored on the man-size silhouette was recorded and any hits in critical areas (groin and eyes) were noted. Standard deviation of the x and y coordinates and the mean radius were calculated from these data.

6. MAXIMUM RANGE

The M79, with its barrel elevated 30° from horizontal, was fired from a bench rest on a 400-meter outdoor range. After each shot, the distance the projectile traveled before its initial impact with the ground was measured as well as the deflection right or left of the line of sight.

7. MAXIMUM EFFECTIVE HITTING RANGE

The M79 Grenade Launcher was bench rest fired at an anthropometric silhouette target positioned 50 meters from the muzzle. After two (2) firings without scoring a hit on the silhouette, the target was moved to 35 meters. After three (3) firings without scoring a hit on the silhouette, the target was moved to 20 meters for the remaining two (2) firings. Wind velocity at each firing was measured using a Dwyer Wind Meter. Silhouette target hits and misses, impact coordinates, and flight time from muzzle to target (timed by stop watch) were recorded. Estimate of the maximum effective hitting range was the average of three (3) observers opinion of range at which tactical hits could be expected under test conditions.

8. COLD TEMPERATURE FIRING

Seven (7) of the 40mm Liquid Ball projectiles were stored at -45°F for 24 hours. They were then stored for one additional hour at 0°F immediately before being fired from the machine rest mounted M79 Grenade Launcher. Each shot was fired remotely. The fired cartridge case and the M79 Grenade Launcher were examined for damage after each shot. Impact coordinates and the indentation in the Homasote faced target were measured and recorded.

9. MUZZLE EXIT PHENOMENA

Twelve (12) 40mm Liquid Ball projectiles were photographed as they exited the muzzle of the launcher. Eight (8) rounds were photographed using two (2) 16mm Fastax high speed motion picture cameras simultaneously. One Fastax camera was positioned perpendicular to and 4 feet 8 inches from the line of fire, 9 inches forward of the muzzle. The other Fastax camera was positioned 38.3 feet forward of the muzzle, 3 feet to the left of the line of fire and focused on the muzzle. Both cameras ran at a nominal 4000 frames per second. Four (4) rounds were photographed using a Linhof 4" x 5" camera positioned 4 feet to the right and 1 foot in front of the muzzle. Four (4) General Radio "Stroboslave" recycling flash units were pulsed at .0013 second intervals for a flash duration of .000003 seconds each. These strobes provided four (4) exposures of the projectile within 14 inches of the muzzle. Projectile muzzle exit was studied by examining the 16mm high speed motion picture film and enlargements of the 4" x 5" microflash photographs (see Figures 2 thru 5).

10. SAFETY

In addition to normal safety procedures followed during firing, personnel were required to wear respiratory protection during conduct of the test to preclude inhalation of any small droplets of the glycerin and water mix in the projectile which might have been aerosolized upon target impact.

SECTION III. RESULTS

1. VELOCITY

Table II is a summary of the velocity data contained on the data sheets of Appendix A.

TABLE II. RESULTS OF VELOCITY TESTS (f.p.s.)
40mm Liquid Ball

	Muzzle** (8 rds)	2m* (21 rds)	5m* (21 rds)
Maximum	305.5	270.1	262.0
Minimum	255.9	225.8	220.2
Average	275.4	245.9	259.2
*Lumiline screens/time interval counter (accuracy : 5 f.p.s.)			
**High Speed Motion Pictures (accuracy : 20 f.p.s.)			

2. PROJECTILE ENERGY

Table III is a summary of calculations based on the data contained in Appendix A.

TABLE III. PROJECTILE ENERGY (ft-lbs)
40mm Liquid Ball

	Muzzle	2m	5m
Maximum	95.2	74.5	70.5
Minimum	65.9	51.2	49.5
Average	77.9	62.0	58.6

3. ACCURACY

Table IV is a summary of calculations based on the data contained in Appendix A.

TABLE IV. RESULTS OF ACCURACY TESTS
40mm Liquid Ball

Target Distance (meters)	Group Center (from point of aim) (in.)		Extreme Spread (in.)		Standard Deviation (in.)		Mean Radius (in.)
	x	y	x	y	x	y	
6.4	-0.2	+8.0	3.2	5.6	1.5	2.0	1.9
20	+0.5	+10.2	52.8	64.9	33.7	22.2	31.9
55	-21.3	+10.6	56.5	75.8	18.4	22.5	21.8
50	+39.3	-10.0	59.4	85.5	21.0	29.0	25.6
70	+14.8	-5.4	25.8	48.4	8.6	15.4	12.8

4. IMPACT CHARACTERISTICS

Table V is a summary of calculations based on the data contained in Appendix A.

TABLE V. INDENTATIONS OF TOMASOTE
40mm Liquid Ball

Target Distance (meters)	Average Indentation (in.)	Minimum Indentation (in.)	Maximum Indentation (in.)
6.4	.160	.070	.196
20	.019	0	.051
55	.038	.031	.044
50	.012	0	.040

5. EFFECT OF SHOOTER STRESS ON ACCURACY

Table VI is a summary of the calculations based on the data contained in Appendix A.

TABLE VI. SUMMARY OF STRESS TEST RESULTS
40mm Liquid Ball, Target 35 Meters

Shooter	Group Center (from point of aim) (in.)		Extreme Spread (in.)		Standard Deviation (in.)		Mean Radius (in.)	Total Hits on Silhouette	Hits in Critical Area
	x	y	x	y	x	y			
A	-4.2	+7.9	104.9	152.0	34.0	40.0	44.2	0	0
B	+17.8	+8.5	64.1	73.7	20.2	25.6	25.2	1	1
C	+10.6	+8.9	58.9	41.2	16.2	15.2	19.2	2	2

6. MAXIMUM RANGE:

Table VII is a summary of the data contained in Appendix A.

TABLE VII. MAXIMUM RANGE
40mm Liquid Ball

	Distance (meters)	Deflection (meters)
Maximum	122.0	5.0-right
Minimum	108.0	On line of sight
Average	115.7	4.0-right

7. MAXIMUM EFFECTIVE HITTING RANGE

Table VIII is a summary of the data contained in Appendix A.

TABLE VIII. MAXIMUM EFFECTIVE HITTING RANGE.
40mm Liquid Ball

Group Center (from point of aim) (in.)		Standard Deviation (in.)		Mean Radius (in.)	Hits	Wind Velocity (m.p.h.)	Average Flight Time (sec.)	Remarks
x	y	x	y					
-	-	-	-	-	0	6.0-9.5	-	One round broke in flight
TARGET DISTANCE 50 METERS								
-79.9	+8.8*	56.8	12.4*	41.2*	0	9.5-12.0	0.5*	
TARGET DISTANCE 35 METERS								
TARGET DISTANCE 20 METERS								
-1.2	-12.8	9.5	2.1	6.8	2	11.0-12.0	0.2	
*2 rounds								

It was the opinion of the three (3) observers that the maximum effective range at which tactical hits on a man could be expected was approximately 20 meters.

8. COLD TEMPERATURE FIRING

Table IX is a summary of the data contained in Appendix A.

TABLE IX. COLD TEMPERATURE FIRING
(7 ROUNDS)
40mm Liquid Ball

Group Center (from point of aim) (in.)		Standard Deviation (in.)		Mean Radius (in.)	Indentation in Homasote (in.)	Remarks
x	y	x	y			
+5.1	+10.5*	20.0	14.4*	20.4*	.025*	
*5 rounds only						

Projectile filler (60% glycerin, 40% water) appeared to be in a solid state at impact. Dispersal characteristics appeared to be reduced to approximately

1/3 the size of those fired at room temperature. Two (2) of the seven (7) rounds did not reach the target--one was observed to break in flight and we were unable to account for the other. The mean radius of the five (5) measureable impacts (20.4 inches) cannot be directly compared to the mean radius of 21.8 inches from the room temperature firing.

9. MUZZLE EXIT PHENOMENA

The muzzle exit of twelve (12) rounds were recorded photographically--eight (8) with high speed motion pictures and four (4) with multistrobed microflash.

Analysis of the film revealed:

- a) Rounds number 34 and 36 show the projectile spilling its liquid filling near the muzzle.
- b) Ten (10) of the films show the sabot opening and no apparent abnormalities.
- c) Four (4) of the films were ruined in development.
- d) One of the four microflash (Figure 4) shows the projectile spilling liquid.

APPENDIX A

Date 4 October 1973

Shooter Poolie

Job No. 1883-10

Temperature 70°F; Humidity 85%

Recorder Sumwalt

Page

2-Meter Screens 5.06' and 8.06' (over 3')

Chronograph Oehler

Weapon M79 #47637

5-Meter Screens 14.90' and 17.90' (over 3')

Chronograph L.C.

Ammunition 40mm Liquid Ball

Type -- Lot --

Target 6.4 meters

Shot No.	2-Meter		5-Meter			Coordinates		Aiming Data	Incident. in Homasote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	x (in.)			
1	13238	226.6	460.0	13603	220.5	460.0	-0.3	+7.0	.070	Sabots penetrated flash shield homasote.
							obturator -3.2	+2.5		
2	11068	270.1	460.0	11424	262.6	460.0	0.0	+8.9	.171	Sabot imbedded in flash shield all broke/wet screens
							obturator -2.0	-5.4		
3	12807	234.2	460.0	13181	227.6	460.0	+1.5	+10.4	.170	Sabot +0.4 x y Sabot -6.0 0.0 +9.1
							obturator +5.5	+7.1		
4	12204	245.8	460.0	12597	238.2	460.0	+1.3	+7.4	.151	
5	12069	248.6	460.0	12460	240.8	460.0	-1.7	+6.1	.171	
6	11755	255.2	460.0	12004	249.9	460.0	-1.3	+8.8	.196	
7	11493	261.0	460.0	11809	254.0	460.0	-1.1	+11.7	.190	

*Average weight.

Date 1 October 1975

Temperature 68°F; Humidity 80

2-Meter Screens 5.00' and 8.00' (over 3')

5-Meter Screens 14.90' and 17.90' (over 3')

Shooter Pooler

Recorder Summitt

Chronograph Behler

Chronograph E.C.

Job No. 1883-10

Page

Weapon M79 #47657

Ammunition 40mm Liquid Ball

Type -- Lot --

Target 20 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Blotzote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	X (in.)			
8	11574	259.2	460.0	11910	251.9	460.0	+24.5	-55.9	0	Sabot broke. Photographed/sec Figure 6.
9	12128	247.5	460.0	12492	240.2	460.0	+9.5	+15.7	.040	
10	13203	227.2	460.0	13498	222.5	460.0	-10.9	+23.6	.045	
11	11143	269.2	460.0	11782	254.6	460.0	+17.2	+24.9	0	Hit top of 17.9' screen
12	11736	255.6	460.0	11975	250.5	460.0	+39.5	+29.0	0	Sabot broke
13	12361	242.7	460.0	12584	238.4	460.0	-15.3	+10.4	.051	Sabot broke
14	13404	225.8	460.0	13625	220.2	460.0	-63.0	+5.3	0	
*Average weight.										

Date 1 October 1973

Shooter Poole

Job No. 1883-10

Temperature 68°F; Humidity 80%Recorder Sumwalt

Page

2-Meter Screens 5.06' and 8.06' (over 3')Chronograph OehlerWeapon M79 #476375-Meter Screens 14.90' and 17.90' (over 3')Ammunition 40mm Liquid BallType -- Lot --Target 35 meters

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in Homasote (in.)	Results		
	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)				X (in.)	Y (in.)
15	12137	247.2	460.0	12512	239.8	460.0	-26.2	+5.9	Muzzle 3° Elevation .042	One sabot completely penetrated homasote 3' in front of muzzle.	
16	12360	242.7	460.0	12615	237.8	460.0	-41.7	-54.5	Muzzle 3° Elevation .031	Sabot - interior wet and one penetrated homasote 3' in front of muzzle	
17	12693	236.4	460.0	13046	230.0	460.0	+14.8	+24.2	Muzzle 3° Elevation .032	Sabot penetrated flash shield 3' in front of muzzle. Broken sabot.	
18	12709	249.8	460.0	12393	242.1	460.0	-17.4	+8.7	Muzzle 3° Elevation .044	Sabot penetrated flash shield	
19	12722	235.8	460.0	13130	228.5	460.0	-37.5	+17.1	Muzzle 3° Elevation .033	Sabot penetrated flash shield	
20	11749	255.3	460.0	12105	247.8	460.0	-19.0	+17.1	Muzzle 3° Elevation .042	Broken sabot	
21	12992	230.9	460.0	13251	276.4	460.0	-22.4	-21.3	Muzzle 3° Elevation .039		
											*Average weight.

Date 7 September 1973Shooter PooleJob No. 1883-10Temperature 65°F; Humidity --Recorder FlohrPage --2-Meter Screens -- and -- (over --)Chronograph --Weapon N79 -470375-Meter Screens -- and -- (over --)Chronograph --Ammunition 40mm Liquid BallType -- Lot --Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in Honasote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)			
22	Color	Flight Speed Movic			+81.0*	-20.0*	Level 25 1/4"		Did not impact 8'x 8' target.
23					+23.4	-2.2	Level 25 1/4"	.150	Bounced prior to impacting 8'x 8' target
24					+72.0*	-63.0*	Barrel 4° Elevation aiming point 66 1/4"		Ball hit floor 3' in front of target and missed 8'x 8' target. Ball found cracked but not broken. Wet spots on floor at 33m, inside of sabot wet.
25					+35.1	-7.5	Barrel 4° Elevation aiming point 66 1/4"	.050	
26					+32.4	-15.6	Barrel 4° Elevation aiming point 66 1/4"	0	
									*Approximately

Date 25 September 1973 Shooter Poole Job No. 1883-10
 Temperature 62°F; Humidity 81% Recorder Flohr Page _____
 2-Meter Screens -- and -- (over --) Chronograph -- Weapon M79 #47637
 5-Meter Screens -- and -- (over --) Chronograph -- Ammunition 40mm Liquid Bail
 Type -- Lot --
 Target 50 meters

Shot No.	2-Meter		5-Meter			Coordinates		Aiming Data	Indent. in Homasote (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	X (in.)				Y (in.)
27	Micro	Flash					+54.9	-5.5	Aiming point 61 1/4" up from floor	.040	

Date 1 November 1973

Shooter Pocle

Job No. 1883-10

Temperature 54°F; Humidity 66%

Recorder Sunwalt

Page

2-Meter Screens -- and -- (over --)

Chronograph --

Weapon M79 #47057

5-Meter Screens -- and -- (over --)

Chronograph --

Ammunition 40mm Liquid Ball

Type -- Lot --

Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	x (in.)			
28	Micro flash						-	-	-	Hit left wall 25' in front of target at a height of 5'.
29	Micro flash						+10.7	-14.4	0	Hit pipe on left side of range approximately 5' behind target and 19" above floor. Ball passed target approximately 6' to left of center.
50	Micro flash									

Date 19 September 1973 Shooter Poolc Job No. 1883-10
 Temperature 60°F; Humidity 74% Recorder Flohr Page _____
 2-Meter Screens -- and -- (over --) Chronograph -- Weapon M79 #47657
 5-Meter Screens -- and -- (over --) Chronograph -- Ammunition 40mm Liquid Ball
 Type -- Lot -- Target 50 meters

Date 19 September 1973 Shooter Poolc Job No. 1883-10
 Temperature 60°F; Humidity 74% Recorder Flohr Page _____
 2-Meter Screens -- and -- (over --) Chronograph -- Weapon M79 #47657
 5-Meter Screens -- and -- (over --) Chronograph -- Ammunition 40mm Liquid Ball
 Type -- Lot -- Target 50 meters

Shot No.	2-Meter		5-Meter			Coordinates		Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	X (in.)			
51	Black and White	High	Speed	Novic						Projectile did not impact 8' x 8' target - apparently went over top of target sabots found at 22m, 25m, 27m, and 7m

Date 13 November 1975 Shooter Pooler Job No. 1883-10
 Temperature 50° Humidity 65% Recorder Sumwalt Page _____
 2-Meter Screens -- and -- (over --) Chronograph -- Weapon M79 # 47657
 5-Meter Screens -- and -- (over --) Chronograph -- Ammunition 40mm Liquid Ball
 Type -- Lot --
 Target N/A meters _____

Shot No.	2-Meter		5-Meter			Coordinates			Ident. in Homasote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	x (in.)	y (in.)		
32	16mm	Color High Speed Make up					Not taken			
33	16mm	Color High Speed Make up					Not taken			

Date 30 October 1975 Shooter Boole
 Temperature 50°F; Humidity 68% Recorder Sumwalt
 2-Meter Screens -- and -- (over --) Chronograph --
 5-Meter Screens -- and -- (over --) Chronograph --
 Job No. 1883-10
 Page
 Weapon M7 17037
 Ammunition 40mm Liquid Ball
 Type -- Lot --
 Target 50 meters

Date 30 October 1975 Shooter Boole
 Temperature 50°F; Humidity 68% Recorder Sumwalt
 2-Meter Screens -- and -- (over --) Chronograph --
 5-Meter Screens -- and -- (over --) Chronograph --
 Job No. 1883-10
 Page
 Weapon M7 17037
 Ammunition 40mm Liquid Ball
 Type -- Lot --
 Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in film/sote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)			
34	16mm Color High Speed	High Speed	Movids				-	-	Broke open 5m from muzzle.
35	16mm Color High Speed	High Speed	Movids				-	-	Hit pipe on left side of range 54m from muzzle.
36	16mm Color High Speed	High Speed	Movids				-37.8	-	Hit floor 54m from muzzle and rolled to target and hit base at x coordinate.
37	16mm Color High Speed	High Speed	Movids				-15.5	+14.2	

Date 10 October 1973

Shooter Poole

Job No. 1893-10

Temperature 68°F ; Humidity 81%

Recorder Burwell

Page

2-Meter Screens -- and -- (over --)

Chronograph

Weapon M79 #17637

5-Meter Screens -- and -- (over --)

Ammunition 40mm Liquid Kill

Type -- Lot --

Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Holesote (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gm.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gm.)	x (in.)				y (in.)
38							+12.6	+22.5	4° Elevation	0	Broke open in flight.
39							+81.0*		4° Elevation		Missed 8' x 8' target.
40							-	+96.0*	4° Elevation		Missed 8' x 8' target.
41							+28.6	+7.0	4° Elevation	0	Broke open in flight.

*Approximately

Date 10 October 1975

Shooter Poole

Job No. 1885-10

Temperature 68°F; Humidity 81%

Recorder Stewart

Page

2-Meter Screens -- and -- (over --)
 5-Meter Screens -- and -- (over --)

Chronograph --
 Chronograph --

Weapon M79 #1765
 Ammunition 4.7m Liquid Ball

Type -- Lot --

Target 70 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	x (in.)				y (in.)
42							+55.3	-5.1	7° Elevation on barrel	0	Ball broke open in flight approximately 50m from muzzle.
43							-48.2	+6.3	7° Elevation on barrel	0	Ball broke open in flight approximately 50m from muzzle.
44							-25.0	-8.4	7° Elevation on barrel	0	Ball hit floor 35m in front of target.
45									7° Elevation on barrel	0	Ball broke open and spiraled in flight. Point of impact was 35m in front of target.
46									7° Elevation on barrel	0	Ball impacted floor 10m in front of target.
47									7° Elevation on barrel	0	
48							-42.5	+8.6	7° Elevation on barrel	0	

Date 21 November 1975

Shooter Sumwalt " "

Job No. 1883-10

Temperature 58°F ; humidity 65%

Recorder Flohr

Page

2-Meter Screens -- and -- (over --)

Chronograph

Weapon M79

5-Meter Screens -- and -- (over --)

Chronograph

Ammunition 40mm Liquid Ball

Type -- Lot --

Target 35 meters

TIMED FIRE

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gr.)				X (in.)
49							+12.6	+19.5	38 1/2" from floor	Missed.
50							+10.6	-0.6	38 1/2" from floor	Missed.
51							0	+28.5	38 1/2" from floor	Hit vital.
52							+21.0	+27.9	38 1/2" from floor	Missed.
53							+16.9	-6.7	38 1/2" from floor	Missed.
54							-25.8	-6.6	38 1/2" from floor	Missed.
55							+35.1	+20.5	38 1/2" from floor	Missed.
56							-0.5	+5.9	38 1/2" from floor	Hit.
57							+19.4	-12.7	38 1/2" from floor	Missed.
58							+18.8	+14.8	38 1/2" from floor	Missed.

Date 21 November 1975

Shooter Flohr "B"

Job No. 1883-10

Temperature 58°F ; Humidity 65%

Recorder Sumwalt

Page

2-Meter Screens -- and -- (over --)

Chronograph --

Weapon M79 # 47657

5-Meter Screens -- and -- (over --)

Chronograph --

Ammunition 40mm Liquid Kill

Type -- Lot --

Target SS meters

TIMED FIRE

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Homesite (in.)	Result
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	x (in.)			
59							+55.0	-25.0	10" up from floor	Missed
60							-11.1	+40.8	40" up from floor	Missed
61							+11.6	+28.4	40" up from floor	Missed
62							+12.2	+7.7	40" up from floor	Missed
63							+27.5	+16.5	40" up from floor	Missed
64							+27.1	+10.1	40" up from floor	Missed
65							-	-	40" up from floor	Broke in flight. Never reached target.
66							+55.6	+18.5	40" up from floor	Missed
67							-8.2	+10.6	40" up from floor	Hit
68							+15.0	-32.9	40" up from floor	Missed

Date 21 November 1973

Shooter Poole "V"

Job No. 1883-10

Temperature 58°F; Humidity 65%

Recorder Stewart

Page

2-Meter Screens -- and -- (over --)

Chronograph

Weapon M79 44033

5-Meter Screens -- and -- (over --)

Chronograph --

Ammunition 40gr. Liquid Ball

Type -- Lot --

Target 55 meters

TIMED FIRE

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)				x (in.)
69							+11.8	+17.4	48" up from floor	Missed
70							+4.2	-30.6	48" up from floor	Hit
71							+17.4	-6.7	48" up from floor	Missed
72							+27.9	+9.1	48" up from floor	Missed. Broke open in flight.
73							-24.0	+84.0	48" up from floor	Missed.
74							+19.5	+34.4	48" up from floor	Missed.
75							+15.9	-37.5	48" up from floor	Missed.
76							-47.1	+35.7	48" up from floor	Missed.
77							+11.8	+21.4	48" up from floor	Missed.
78							-77.0	-48.0	48" up from floor	Missed. Broke open in flight.

OBSERVED DATA

MAXIMUM RANGE
M79-40mm Liquid Ball
Barrel Elevated 30°

Date: 5 February 1974

Temperature: 30°F, variable wind
(left to right)

Round No.	Range (meters)	Deflection (meters)	Remarks
79	108	5.0-right	
80	122	4.0-right	
81	111	On line	

OBSERVED DATA

COLD TEST

40mm Liquid Ball

Date: 12 February 1974

Ammunition: Stored at -45°F for 24 hours.
 Stored at 0°F for 1 hour immediately before firing.

Machine rest, lanyard fired
 Target: 35 meters
 Aiming Point: 47 1/2 inches high

Round No.	x (in.)	y (in.)	Indentation (in.)	Remarks
82	+12.2	+26.7	.025	Even spray on target.
85	+7.2	+5.3	.050	Even spray on target.
84	+29.6	-7.5	.013	Little spray on target.
85	-19.3	+4.3	.016	No spray on target. Round impact mark.
86	-14.1	+23.7	.043	No spray on target. Round impact mark.
87	Unk	Unk	Unk	
88	-	-	-	Ball broke in flight at approx 35 meters, sabot found wet inside and out.

OBSERVED DATA

MAXIMUM EFFECTIVE HITTING RANGE

40mm Liquid Ball

Date: 1 March 1974

Temperature: 45°F, variable cross wind
right to left

Round No.	Impact Coordinates (in.)		Silhouette Hit/ Missed	Wind Velocity (m.p.h.)	Flight Time (sec.)	Remarks
	x	y				
TARGET DISTANCE 50 METERS						
89	-	-	Missed	6.0	-	Broke in flight. Hit ground at 30m.
90	-	-	Missed	9.5	-	Hit ground at 40m.
TARGET DISTANCE 35 METERS						
91	-	-	Missed	9.5	-	Hit ground at 28m.
92	-39.7	+17.6	Missed	11.0	0.3	
93	approx -120.0	0	Missed	12.0	0.3	
TARGET DISTANCE 20 METERS						
94	-7.8	-14.2	Hit	11.0	0.2	
95	+5.4	-11.3	Hit	12.0	0.2	

APPENDIX B

CALCULATED DATA

ACCURACY
40mm Liquid Ball
6.4 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
1	-0.3	+7.0	0.01	2.56	1.6
2	0	+8.9	0.04	0.09	0.4
3	+1.5	+10.4	2.89	3.24	2.5
4	+1.3	+7.4	2.25	1.44	1.9
5	-1.7	+6.1	2.25	6.25	2.9
6	-1.3	+8.8	1.21	0.04	1.1
7	-1.1	+11.7	0.81	9.61	3.2
			x (in.)	y (in.)	
Standard Deviation	---	---	1.3	2.0	---
Mean	$\bar{x} = -0.2$	$\bar{y} = +8.6$	---	---	1.9
Extreme Spread	3.2	5.6	---	---	---

CALCULATED DATA

ACCURACY
40mm Liquid Ball
20 Meters

Round No.	Coordinates (in.)		Calculations		Krus (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
8	+24.5	-35.9	576.00	2125.21	52.0
9	+9.5	+15.7	81.00	30.25	10.5
10	-10.9	+23.6	129.96	179.56	17.6
11	+17.2	+24.9	278.89	216.09	22.2
12	+59.5	+29.0	1521.00	353.44	44.3
15	-15.3	+10.4	190.44	0.04	13.8
14	-65.0	+3.8	4032.25	40.96	63.8
			x (in.)	y (in.)	
Standard Deviation	---	---	35.7	22.2	---
Mean	$\bar{x} = +0.5$	$\bar{y} = +10.2$	---	---	31.9
Extreme Spread	52.8	64.9	---	---	---

CALCULATED DATA

ACCURACY
40mm Liquid Ball
35 Meters

Round No.	Coordinates (in.)		Calculations		radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
15	-26.2	+5.9	24.01	114.49	11.8
16	-41.7	+54.5	415.16	1436.41	43.0
17	+14.8	+24.2	1303.21	57.76	36.9
18	-17.4	+18.7	15.21	4.41	4.4
19	-37.5	+17.1	262.44	0.25	16.2
20	-19.0	+17.1	5.29	0.25	2.4
21	-22.4	-21.3	1.21	1436.41	37.9
			x (in.)	y (in.)	
Standard Deviation	---	---	18.4	22.5	---
Mean	$\bar{x} = -21.3$	$\bar{y} = +16.6$	---	---	21.8
Extreme Spread	56.5	75.8	---	---	---

CALCULATED DATA

ACCURACY
40mm Liquid Ball
50 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
24	+72.0	-63.0	1069.29	2809.00	62.3
25	+35.1	-7.3	17.64	7.29	5.0
26	+32.4	-13.6	47.61	12.96	7.8
27	+54.9	-5.5	243.36	20.25	16.2
38	+12.6	+22.5	712.89	1056.25	42.1
41	+28.6	+7.0	114.49	289.00	20.1
			x (in.)	y (in.)	
Standard Deviation	---	---	21.0	29.0	---
Mean	$\bar{x} = +39.5$	$\bar{y} = -10.0$	---	---	25.6
Extreme Spread	59.4	85.5	---	---	---

CALCULATED DATA

ACCURACY
TIMED FIRE
40mm Liquid Ball

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
59	+53.0	-25.0	1239.04	1108.89	48.5
60	-11.1	+40.8	835.21	1056.25	43.5
61	+11.6	+28.4	38.44	404.01	21.0
62	+12.2	+7.7	31.36	0.36	5.6
63	+27.3	+16.5	90.25	67.24	12.5
64	+27.1	+10.1	86.49	3.24	9.5
65	--	--	--	--	--
66	+33.6	+18.5	249.64	104.04	18.8
67	-8.2	+10.6	676.00	5.29	26.1
68	+15.0	-32.9	7.84	1697.44	41.3
			x (in.)	y (in.)	
Standard Deviation	---	---	20.2	23.6	---
Mean	$\bar{x} = +17.8$	$\bar{y} = +8.3$	---	---	25.2
Extreme Spread	64.1	73.7	---	---	--

CALCULATED DATA

ACCURACY
TIMED FIRE
40mm Liquid Ball

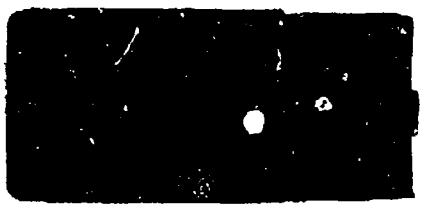
Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
69	+11.8	+17.4	256.00	90.25	18.6
70	+4.2	-30.6	0	1482.25	38.5
71	+17.4	-6.7	466.56	213.16	26.1
72	+27.9	+9.1	1050.41	1.44	32.1
73	-24.0	+84.0	392.64	5791.21	78.6
74	+19.5	+34.4	561.69	702.25	35.6
75	+13.9	-37.5	327.61	2061.16	48.9
76	-47.1	+35.7	1840.41	772.84	51.1
77	+11.8	+21.4	256.00	182.25	20.9
78	-77.0	-48.0	5299.84	3124.81	91.8
			x (in.)	y (in.)	
Standard Deviation	---	---	34.0	40.0	---
Mean	$\bar{x} = -4.2$	$\bar{y} = +7.9$	---	---	44.2
Extreme Spread	104.9	132.0	---	---	---

APPENDIX C

TEST INSTRUMENTATION
EQUIPMENT AND MATERIALS

- 1 - Oehler Model 41B Chronotach, calibrated at factory in May 1973
- 1 - Electronic Counters, Inc. Model 4010 Velocity Computing Chronograph, calibrated at factory in June 1973
- 4 - Oehler Model 35 Lumiline Screens
- 2 - Eastax 16mm High Speed Motion Picture Cameras
- 1 - Wollensak Model 3106 Time Pulse Generator
- 2 - Colortran 1000 Watt Lights
- 2 - Wollensak 1000 Watt Lights
- 14 - 100-foot Rolls Kodak Ektachrome (7242) 16mm High Speed Film (GFE)
- 2 - 100-foot Rolls Eastman Double-X Negative (722) 16mm High Speed Film
- 1 - Vanguard Model 16C Motion Analyzer
- 4 - General Radio Type 1539 "Stroboflash" Microflash
- 1 - General Radio Model 1541 Multi-Flash Generator
- 1 - Linhof 4x5 Camera with Kodak f4.5, 135mm Lens
- 5 - Royal Pan 4" x 5" Cut Film, Type 4141
- Various darkroom and photographic equipment
- 100-meter indoor range having ceiling height of 12 feet
- 400-meter outdoor range
- Miscellaneous range supplies and equipment
- 1 - Specially constructed target (Homasote faced), Homasote Company, Lower Ferry Road, Trenton, N.J.
- 1 - Dry Ice Freezer Unit
- 1 - Rochester Thermometer
- 1 - Plywood Anthropometric Silhouette Target based on 1960 Dreyfus data
- 1 - Dwyer Wind Meter (F.W. Dwyer Mfg. Co., Michigan City, Indiana)

APPENDIX D



1 2 3 4 5 6

1 2 3 4 5 6

Figure 1. Recovered Components from a 40mm Liquid Round.

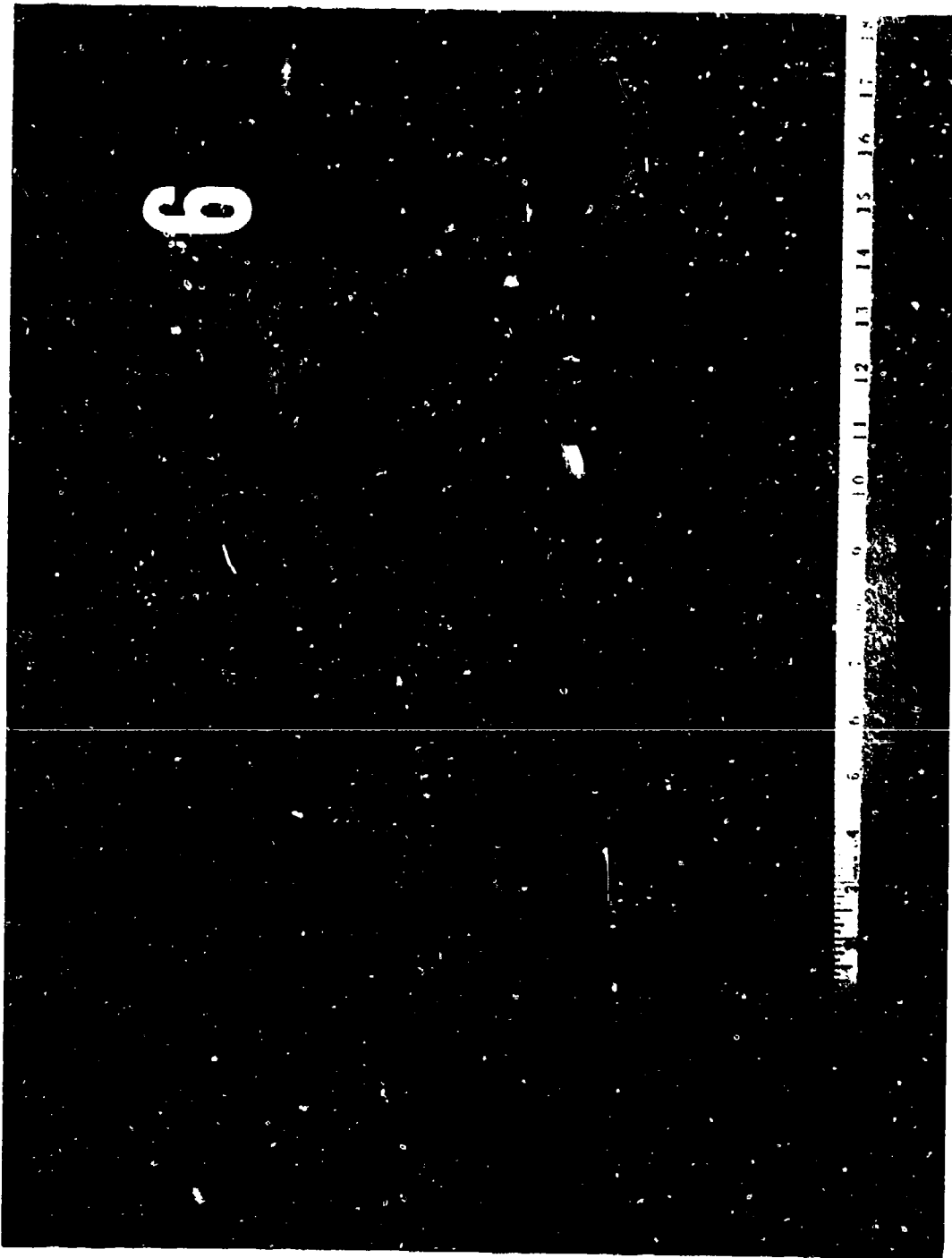


Figure 2. Round Number 27. Microflash, 40mm Liquid Ball Round.

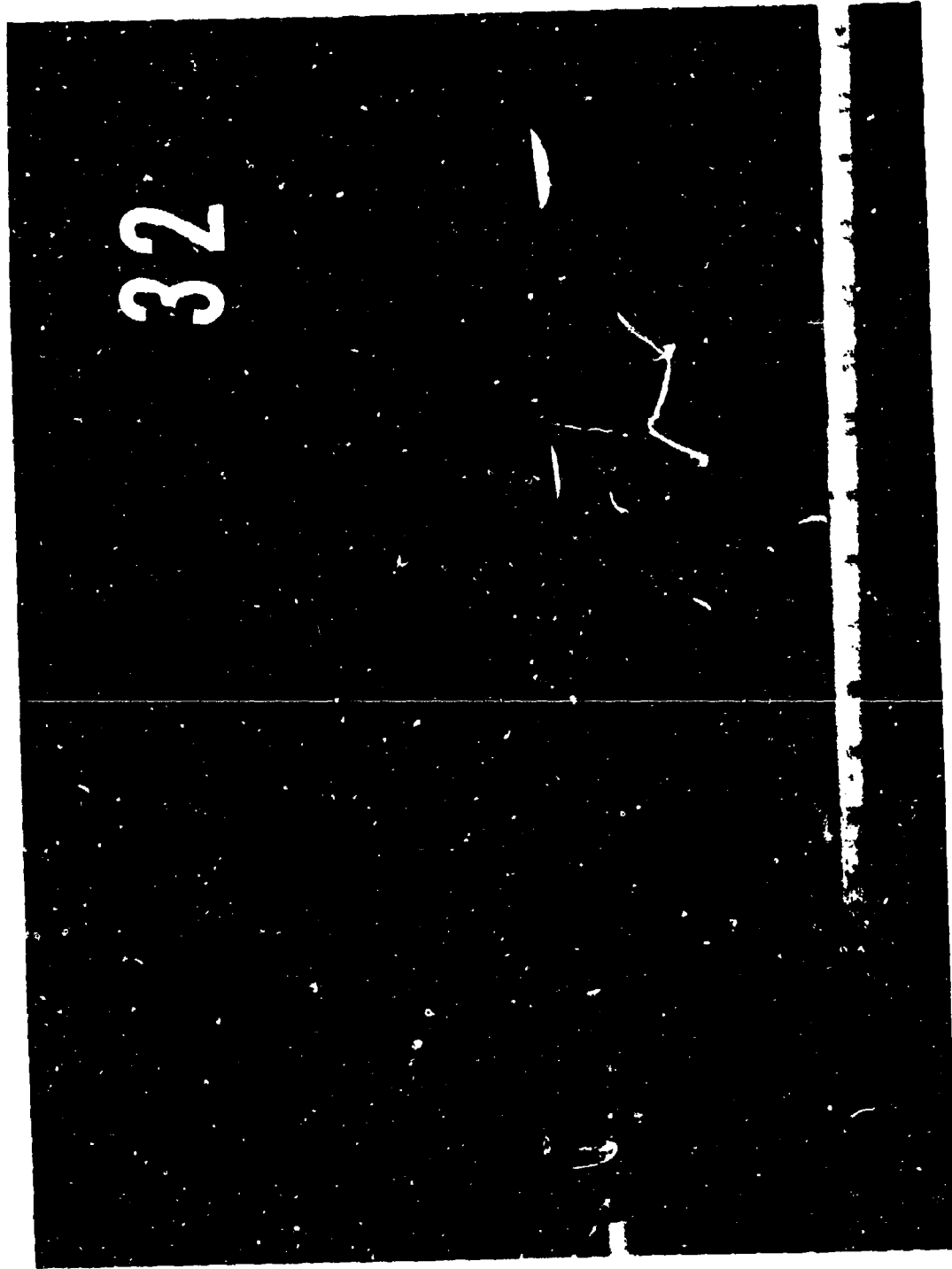


Figure 3. Round Number 28. Microflash, 40mm Liquid Ball Round.

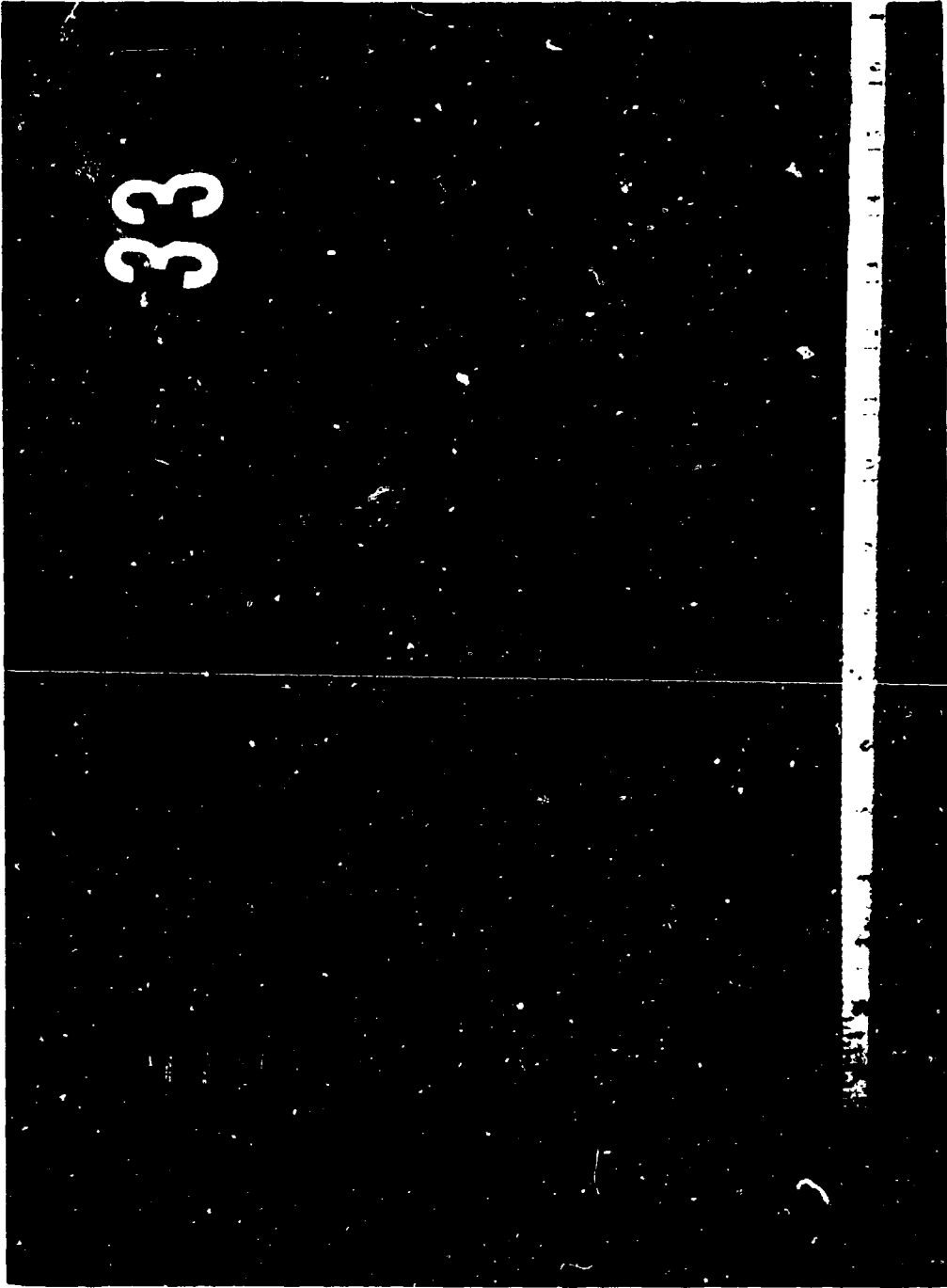


Figure 4. Round Number 29. Microflash, 40mm Liquid Ball Round.

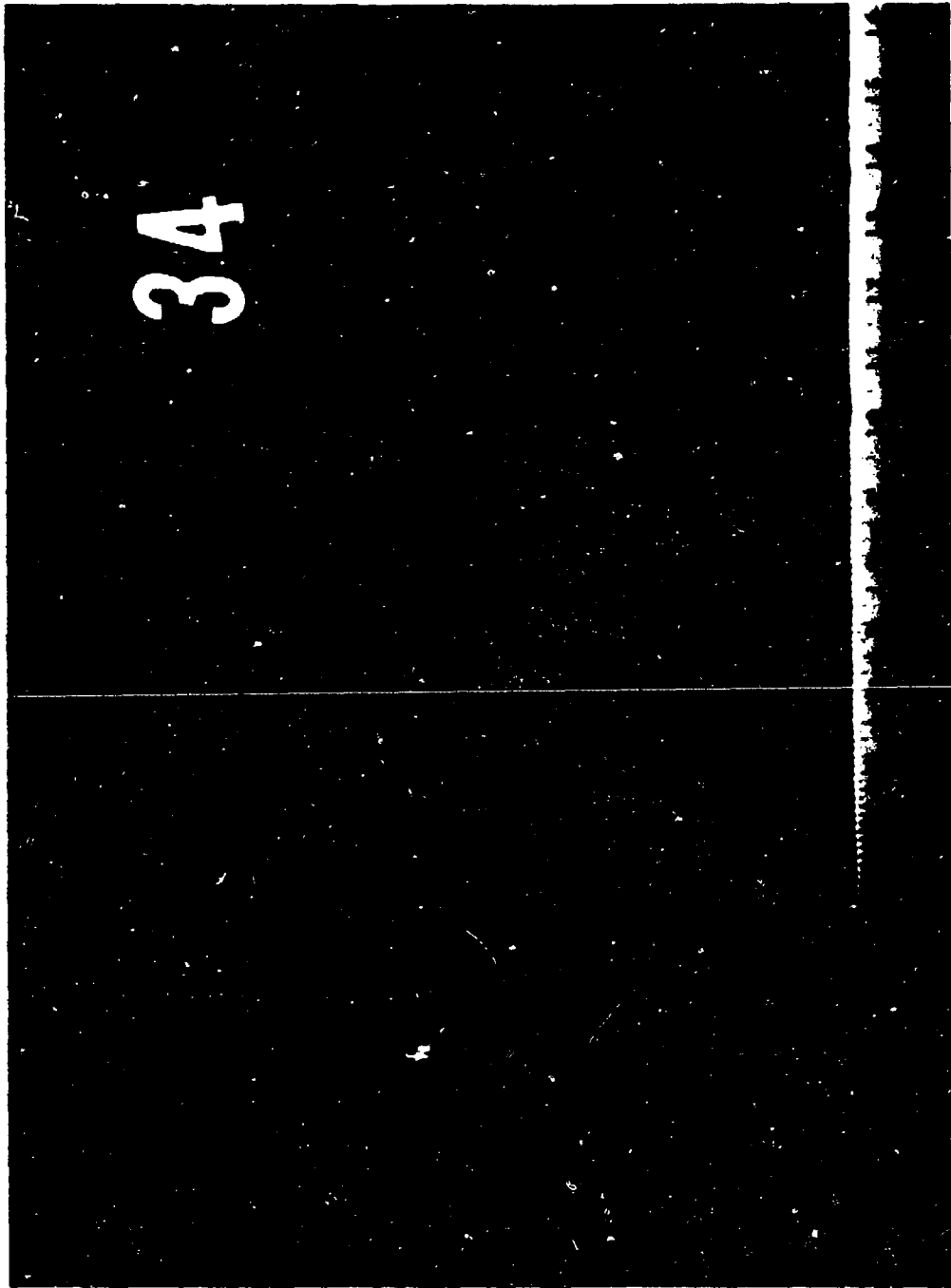


Figure 5. Round Number 30. Microflash, 40mm Liquid Ball Round.



Figure 6. Round Number 8. Photo of Broken Sabot.

APPENDIX E
12-Gauge Liquid Ball
(Test Firing)

TEST REPORT
LESS LETHAL 12-GAUGE LIQUID BALL-I

(TASK 02-F-73, CONTRACT
NO. DAAD05-73-C-0532
WORK ORDER NO. 12)

Prepared For
United States Army
Land Warfare Laboratory
Aberdeen Proving Ground, Maryland

By
H.P. White Laboratory
Bel Air, Maryland

February 1974

1 5

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ABSTRACT

This report presents the results of initial tests of less lethal 12-Gauge Liquid Ball munitions in accordance with the provisions of Contract No. DAAD05-73-C-0532, Task 02-F-73 (an agreement between the U.S. Army Land Warfare Laboratory and H.P. White Laboratory).

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SECTION 1. SCOPE OF WORK

1. OBJECTIVE

The objective of these tests was to provide the external ballistic data necessary to assess the ballistic performance of the "Nelson Marking Pellet" when fired from a 12 Gauge M1200 riot gun and also from a CO₂ powered Marking Pistol.

2. MATERIALS

The following materials were used in the conduct of this test program:

- a) 12 Gauge Liquid Ball (Nelson Marking Pellets) less lethal projectiles (see Figure 1).
- b) 12 gauge shot shell cases specially loaded.
- c) M1200 12 Gauge riot gun (Serial No. L571489).
- d) "Nel-Spot 007" CO₂ pistol and CO₂ power charges. (See Figure 2)
- e) Miscellaneous range and photographic equipment (see Appendix C).

3. SCOPE OF TESTS

Eighteen (18) rounds of 12 Gauge Liquid Ball ammunition were fired on an instrumented indoor range to determine velocity, accuracy, muzzle exit phenomena, and impact characteristics.

Forty-five (45) "Nelson Marking Pellets" were fired from a "Nel-Spot 007" marking pistol (CO₂) on an instrumented indoor range to determine velocity, accuracy, muzzle exit phenomena, impact characteristics, and the effect of shooter stress on accuracy. Ten rounds were fired on an outdoor range to determine maximum range and maximum effective hitting range when the projectiles are subject to environmental variables such as wind. Three (3) rounds were tested to determine the effect of cold temperature. (see Table 1)

TABLE I. SCOPE OF TESTS

Round No.	Velocity		Energy		Impact Coordinates	Muzzle Exit Phenomena	Weapon	Cold Test	Maximum Range	Maximum Effective Hitting Range	Shooter Stress
	Muzzle	2m	5m	Muzzle							
1-15		LS	LS				12 gauge Shotgun				
16					A	MF	12 gauge				
17-18	HS			C	A	HS	12 gauge				
19-39		LS	LS		A		CO ₂ pistol				
40-41	HS			C	A		CO ₂ pistol				
42-45					A	MF	CO ₂ pistol				T,A
46-60					A		CO ₂ pistol				
61-63					A		CO ₂ pistol		A		
64-70										A,E	
71-73					A						

HS - High Speed Motion Picture
 LS - Lumiline Screens/Time Interval Counter
 MF - Micro Flash
 C - Calculated
 A - Measured
 T - Timed
 E - Estimated

SECTION II. PROCEDURE

1. VELOCITY

- a) The velocity of fifteen (15) rounds of the 12 Gauge Liquid Ball ammunition fired from an M1200 riot gun and twenty-one (21) Nel-Spot Marking Pellets fired from a "Nel-Spot 007" pistol was derived from data collected by erecting lumiline screens 5.06, 8.06, 14.9 and 17.9 feet (1.54, 2.46, 4.54, and 5.46 meters respectively) from the muzzle of the prone/rest fired test weapon. The outputs of these screens activated time interval counters from which the velocities at 2 and 5 meters from the muzzle were calculated.
- b) Velocity of two (2) each of the 12 Gauge Liquid Ball and Nel-Spot Marking Pellets was calculated from data extracted from high speed motion pictures of the muzzle and initial few feet of projectile flight recorded by 10mm Eastax motion picture cameras positioned 4 feet 8 inches to the right of the line of fire and 9 inches in front of the muzzle. The film speed, used to compute the projectile velocity, was determined from timing marks on the film created by a time pulse generator.

2. PROJECTILE ENERGY

Projectile energy was calculated by applying the unfired projectile weight and the velocity data derived per 1, above, to the standard energy formula--

$$\text{Kinetic Energy} = (1/2) MV^2$$

3. ACCURACY

The accuracy of the 12 Gauge Liquid Ball ammunition was determined from impact data on a target constructed of 2" x 4" wood backing, 1/2-inch thick Homasote and faced with paper. The accuracy of the ammunition was determined by measuring the horizontal and vertical dispersion from the aiming point on the target. Standard deviations in the x and y directions and the mean radius were calculated.

4. IMPACT CHARACTERISTICS

Indentations in the Homasote, produced by each projectile impact, were measured using a depth micrometer and the average indentation was calculated. Indications of projectile attitude at impact were observed and noted. These data were collected from the target when positioned 6.4, 20, 35, and 50 meters from the muzzle of the prone/rest fired test weapon.

5. EFFECT OF SHOOTER STRESS ON ACCURACY

Three (3) shooters fired five (5) "Nel Spot Marking Pellets" each at an anthropometric silhouette target positioned 35 meters from the shooter. In order to induce stress, each shooter was told that he would have an average of 4 seconds (varying from 3 seconds to 5 seconds) to raise the pistol, sight and fire at the target. This timing was accomplished by utilizing a cardboard shield which obscured the shooter's view of the target before and after each shot. No warning was given before the shield was raised and the time interval started. The coordinates of each shot in relation to the center of the chest area of the silhouette were recorded. Whether or not a hit had been scored on the man-size silhouette was recorded and any hits in critical areas (groin and eyes) were noted. Standard deviation in the x and y directions and the mean radius were calculated from these data.

6. MAXIMUM RANGE

The "Nel-Spot 007" Gas Pistol with its barrel elevated 30° from horizontal, was fired from a bench rest on a 400-meter outdoor range. After each shot, the distance the projectile traveled before its initial impact with the ground was measured as well as the deflection right or left of the line of sight.

7. MAXIMUM EFFECTIVE HITTING RANGE

The "Nel-Spot 007" Gas Pistol was bench rest fired at an anthropometric silhouette target positioned 35 meters from the muzzle. After three (3) firings without scoring a hit on the silhouette, the target was moved to 20 meters from the muzzle for the remaining four (4) firings. Wind velocity at each firing was measured using a Dwyer "Wind Meter." Silhouette target hits and misses, impact coordinates, and flight time from muzzle to target (timed by stop watch) were recorded. Estimate of maximum effective hitting range was the average of three (3) observers opinion of range at which tactical hits could be expected under test conditions.

8. COLD TEMPERATURE FIRING

Three (3) of the "Nel-Spot Marking Pellets" were stored at -45°F for 24 hours. They were then stored for one additional hour at 0°F before being loaded into the machine rest mounted "Nel-Spot 007" CO₂ pistol. It was planned that each shot was to be remotely fire and that impact coordinates and the indentation in the "Homasote" faced target were to be measured and recorded. This procedure was altered during testing. (See SECTION 11. RESULTS)

9. MUZZLE EXIT PHENOMENA

Three (3) 12 Gauge Liquid Balls were photographed as they exited the muzzle of the M1200 riot gun. Two (2) rounds were photographed using two (2) 16mm Fastax High Speed Motion Picture cameras simultaneously. One Fastax camera was positioned perpendicular to and 4 feet 8 inches from the line of fire, 9 inches forward of the muzzle. The other Fastax camera was positioned 38.5 feet forward of the muzzle, 5 feet to the left of the line of fire and focused on the muzzle. Both cameras ran at a nominal 4000 frames per second. The third round was photographed using a Linhof 4" x 5" camera positioned 4 feet to the right and 1 foot in front of the muzzle. Four (4) General Radio "Stroboslave" recycling flash units were pulsed at .0015 second intervals for a flash duration of .000005 seconds each. These strobes provided four (4) exposures of the projectile within 17 inches of the muzzle. Six (6) "Xel-Spot Marking Pellets" were photographed as they exited the muzzle of the "Xel-Spot 007" CO₂ pistol. Two (2) rounds were photographed using the 16mm Fastax equipment as described above. Four (4) rounds were photographed using the recycling flash units described above. Projectile muzzle exit was studied by examining the 16mm high speed motion picture film and enlargements of the 4" x 5" microflash photography (See Figures 5 thru 7).

10. SAFETY

Normal safety procedures were used during the conduct of these tests.

SECTION III. RESULTS

1. VELOCITY

Table II is a summary of the velocity data contained on the data sheets of Appendix A.

TABLE II. RESULTS OF VELOCITY TESTS (f.p.s.)
12-Gauge Liquid Ball

12 Gauge Liquid Ball, (Nel-Spot Marking Pellets) M1200 12 Gauge Riot Gun			
	Muzzle** (2 rds)	2m* (15 rds)	5m* (15 rds)
Maximum	471.5	404.9	351.6
Minimum	390.5	271.6	157.0
Average	451.0	352.8	276.3
Nel-Spot Marking Pellets Nel-Spot 007 CO, Pistol			
	Muzzle** (2 rds)	2m* (21 rds)	5m* (21 rds)
Maximum	356.5	288.9	265.8
Minimum	335.8	244.4	226.4
Average	346.2	260.1	240.8
*Lumiline screens/time interval counter (accuracy \pm 3 f.p.s.)			
**High Speed Motion Pictures (accuracy \pm 20 f.p.s.)			

2. PROJECTILE ENERGY

Table III is a summary of calculations based on the data contained in Appendix A.

TABLE III. PROJECTILE ENERGY (ft-lbs)
12 Gauge Liquid Ball

<u>12 Gauge Liquid Ball (No1-Spot)/12 Gauge Shotgun</u>			
	Muzzle (2 rds)	2m (15 rds)	5m (15 rds)
Maximum	20.3	15.0	11.5
Minimum	14.0	6.8	2.3
Average	17.2	11.5	7.3
<u>No1-Spot Marking Pellets (No1-Spot 007 CO₂ Pistol)</u>			
	Muzzle (2 rds)	2m (21 rds)	5m (21 rds)
Maximum	11.6	7.6	6.5
Minimum	10.3	5.5	4.7
Average	11.0	6.2	5.3

3. ACCURACY

Table IV is a summary of calculations based on the data contained in Appendix A.

TABLE IV. RESULTS OF ACCURACY TESTS
12 Gauge Liquid Ball

Target Distance (meters)	Group Center (from point of aim) (in.)		Extreme Spread (in.)		Standard Deviation (in.)		Mean Radius (in.)
	x	y	x	y	x	y	
12 Gauge Liquid Ball (Nel-Spot Marking Pellets) M1200 12 Gauge Riot Gun							
6.4	+0.4	+0.2	12.3	13.8	4.2	5.1	5.4
20	Projectiles broke in flight. 2 of 7 reached target.						
Nel-Spot Marking Pellet Nel-Spot 007 CO ₂ Pistol							
6.4	-1.2	+0.9	9.2	6.2	2.9	2.3	2.9
20	-5.4	+5.7	14.0	40.7	6.1	14.2	12.8
35	-22.7	-5.1	47.5	54.7	13.2	19.8	19.5

4. IMPACT CHARACTERISTICS

None of the 12 Gauge Liquid Balls or Nel-Spot Marking Pellets produced a measurable impact on the Homasote faced target.

5. EFFECT OF SHOOTER STRESS ON ACCURACY

Table V is a summary of the calculations based on the data contained in Appendix A.

TABLE V. SUMMARY OF STRESS TEST RESULTS
 Nel-Spot Marking Pellets - Nel-Spot 007 CO₂ Pistol

Shooter	Group Center (from point of aim) (in.)		Extreme Spread (in.)		Standard Deviation (in.)		Mean Radius (in.)	Total Hits on Silhouette	Hits in Critical Area
	x	y	x	y	x	y			
A	+10.1	-33.4	22.1	12.6	8.3	4.9	7.1	1	0
B	+22.1	-13.3	51.8	30.7	19.2	12.7	19.1	1	0
C	-24.2	-29.1	29.9	31.0	12.7	11.3	14.3	0	0

6. MAXIMUM RANGE

Table VI. is a summary of the data contained in Appendix A.

TABLE VI MAXIMUM RANGE
 Nel-Spot Marking Pellets -
 Nel-Spot 007 CO₂ Pistol

	Distance (meters)	Deflection (meters)
Maximum	67.0	21.0-right
Minimum	62.0	4.0-right
Average	64.7	12.5-right

7. MAXIMUM EFFECTIVE HITTING RANGE

Table VII is a summary of the data contained in Appendix A.

TABLE VII MAXIMUM EFFECTIVE HITTING RANGE
Nel-Spot Marking Pellets - Nel-Spot 007 CO₂ Pistol

Impact Coordinates (in.)		Hits	Wind Velocity (m.p.h.)	Average Flight Time (sec.)	Remarks
x	y				
TARGET DISTANCE 35 METERS (3 ROUNDS)					
-70.5	-31.0	0	9.0-9.5	0.8*	2 projectiles impacted ground at 25 and 30 meters.
TARGET DISTANCE 20 METERS (4 ROUNDS)					
-7.9**	-1.6**	1	10.0-11.5	0.5**	1 projectile broke in bore at firing
*One round only.					
**Three rounds only.					

It was the opinion of the three (3) observers that the maximum range at which tactical hits on a man could be expected was approximately 10 meters.

8. COLD TEMPERATURE FIRING

The Nel-Spot Marking Pellets expanded during the cold storage conditioning so that they would fit into the magazine of the Nel-Spot 007 CO₂ pistol but would not enter the chamber. No shots could be fired.

9. MUZZLE EXIT PHENOMENA

The muzzle exit of three (3) rounds of 12 Gauge Liquid Ball was recorded photographically--two (2) with 16mm high speed motion pictures and one (1) with recycling microflash. Analysis of the film revealed:

- a) Round No. 17 shows projectile filler (paint) exiting projectile beginning approximately 10 inches from muzzle.

- b) Round No. 18 shows gas exiting the muzzle before the projectile and projectile spilling filler (paint).
- c) Round No. 16 (microflash) shows projectile filler (paint) exiting projectile. (See Figure 3)

The muzzle exit of six (6) rounds of Nel-Spot Marking Pellets was recorded photographically--two (2) with 16mm high speed motion pictures and four (4) with recycling microflash.

- a) Round 40 projectile obscured in gas (CO_2) during first 8 inches of flight--no abnormalities observed.
- b) Round 41 shows gas (CO_2) exiting muzzle before projectile--no other abnormalities.
- c) Rounds No. 38, 39, and 40 the projectile is obscured by gas (CO_2) for approximately 16 inches of flight.
- d) Round No. 20 is obscured by gas (CO_2) for approximately 20 inches.

APPENDIX A

Date 19 October 1975

Shooter Poole

Job No. 1883-12

Temperature 52°F; Humidity 64%

Recorder Sumwalt

Page

2-Meter Screens 5.0m' and 8.06' (over 3')

Weapon 12 Ga. M1200 #L571489

5-Meter Screens 14.90' and 17.90' (over 3')

Ammunition 12 Ga. Liquid Ball

Type -- Lot --

Target 6.4 meters

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in Homasote (in.)	Results		
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)				X (in.)	Y (in.)
1	08987	535.8	41.2	14017	214.0	41.2	+4.0	+4.9	Level 25 1/4"	0	Projectile appeared to break at first screen. Base was found between first and second and was covered with paint
2	09429	318.1	41.2	15558	224.9	41.2	+2.0	+0.5	Level 25 1/4"	0	Projectile broke in barrel
3	07482	401.0	41.2	09526	521.7	41.2	-0.9	+7.5	Level 23 1/4"	0	
4	09255	502.0	41.2	12554	258.9	41.2	+5.4	-2.0	Level 25 1/4"	0	Broke in flight
5	07410	404.9	41.2	14434	209.1	41.2	-2.7	-6.5	Level 25 1/4"	0	Broke in flight
6	08021	374.5	41.2	08785	341.5	41.2	+0.5	-5.3	Level 25 1/4"	0	Broke in flight
7	09040	331.9	41.2	10156	295.9	41.2			Level 25 1/4"	0	Broke in flight. Hit second screen shield
8	07758	386.7	41.2	08547	351.0	41.2	+0.4	+0.2	Level 25 1/4"	0	Broke in flight
	Heavy deposits of unburned powder found in barrel after each shot.										
	*Average weight.										

Date 25 October 1973

Shooter: Poole

Job No. 1883-12

Temperature 60°F ; Humidity 65%

Recorder Sumwalt

Page

2-Meter Screens 5.06' and 8.06' (over 3')

Chronograph B.C.

Weapon 12 Ga. M1200 #L571489

5-Meter Screens 14.90' and 17.90' (over 3')

Ammunition 12 Ga. Liquid Ball

Type -- Lot --

Target 20 meters

Shot No.	2-Meter		5-Meter			Coordinates		Aiming Data	Indent. in Homasote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gn.)	x (in.)			
9	11045	271.6	41.2	13999	214.3	41.2			0	Round broke in flight and never reached target.
10	08237	364.2	41.2	10011	299.6	41.2			0	Round broke in flight and never reached target.
11	08070	371.7	41.2	08870	338.2	41.2	+15.8	-2.3	0	Round broke in flight.
12	08251	363.6	41.2	10274	292.0	41.2			0	Round broke in flight and never reached target.
13	08097	370.5	41.2	09487	316.2	41.2			0	Round broke in flight and never reached target.
14	08742	343.2	41.2	19106	157.0	41.2			0	Round broke in flight and never reached target.
15	08483	353.6	41.2	13869	216.3	41.2	+50.7	-5.7	0	Round broke in flight and never reached target.
										*Average weight.

Date 26 October 1973 Shooter Poole Job No. 1883-12
 Temperature 54°F; Humidity 70% Recorder Sumwalt Page
 2-Meter Screens --- and --- (over ---) Chronograph ---
 5-Meter Screens --- and --- (over ---) Chronograph ---
 Type --- Lot ---
 Target 50 meters

Weapon 12 Ga. M1200 #L571489
 Ammunition 12 Ga. Liquid Ball

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Incident. in Monasote (in.)	Results		
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gm.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gm.)				x (in.)	y (in.)
16	Micro Flash						-	-	Level 23 1/4"	-	Could not find point of impact on target
17	16mm Black and White		High Speed Movies				-	-	Level 23 1/4"	-	Could not find point of impact on target.
					29 October 1973		54°F		75% R.H.		
18	16mm Color High Speed Movies						-	-		-	Could find no indication of impact on target.

Date 8 November 1973

Shooter Peole

Job No. 1883-12

Temperature 52°F; Humidity 65%

Recorder Sumwalt

Page

2-Meter Screens 5.06' and 8.06' (over 3')

Chronograph I.C.

Weapon M1-S1M1 007

5-Meter Screens 14.90' and 17.90' (over 3')

Chronograph Dehler

Ammunition Nelson Marking Pellets

Type -- Lot 2636

Target 5.4 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Homasote (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	x (in.)				y (in.)
19	11892	252.5	41.2	12899	252.5	41.2	-6.4	-2.4	Level 25 1/4"	0	Paint ball broke on impact.
20	11510	260.6	41.2	12461	249.7	41.2	-1.4	+2.6	Level 25 1/4"	0	Paint ball broke on impact.
21	11589	258.9	41.2	12571	238.6	41.2	+1.1	+0.7	Level 25 1/4"	0	Paint ball broke on impact.
22	11560	259.5	41.2	12513	259.7	41.2	-0.3	+1.0	Level 25 1/4"	0	Paint ball broke on impact.
23	11720	256.0	41.2	12636	257.4	41.2	+2.8	-1.7	Level 25 1/4"	0	Paint ball broke on impact.
24	12243	245.0	41.2	13157	238.0	41.2	-1.9	+3.8	Level 25 1/4"	0	Paint ball broke on impact.
25	11213	267.5	41.2	12107	247.7	41.2	-2.2	+2.3	Level 25 1/4"	0	Paint ball broke on impact.
One CO ₂ cylinder used for entire test.											
*Average weight.											

Date 8 November 1973

Shooter Poole

Job No. 1883-12

Temperature 52°F; Humidity 65%

Recorder Sumwalt

Page 1 of 1

2-Meter Screens 5.06' and 8.06' (over 3')

Chronograph E.C.

Weapon MIL-SPOF 007

5-Meter Screens 14.90' and 17.90' (over 3')

Chronograph Oehler

Ammunition Nelson Marking Pellet

Type -- Lot --

Target 20 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Monasore (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gm.)	Time (sec)	Vel. (ft/sec)	Proj. Wt.* (gm.)	x (in.)				y (in.)
26	10385	288.9	41.2	11287	265.8	41.2	-9.1	-25.0	Level 23 1/4"	0	Ball did break on impact.
27	11083	270.7	41.2	12030	249.3	41.2	-6.4	-5.6	Level 23 1/4"	0	Ball did break on impact.
28	10872	275.9	41.2	11784	254.5	41.2	+1.6	+10.2	Level 23 1/4"	0	Ball did not break on impact.
29	11173	268.5	41.2	12013	249.7	41.2	-0.9	+1.2	Level 23 1/4"	0	Ball did not break on impact.
30	11392	263.3	41.2	12307	245.7	41.2	+1.6	+11.0	Level 23 1/4"	0	Ball did not break on impact.
31	11398	263.2	41.2	12290	244.1	41.2	+11.8	+14.3	Level 23 1/4"	0	Ball did break on impact.
32	11719	256.0	41.2	12641	257.3	41.2	+12.4	+17.7	Level 23 1/4"	0	Ball did break on impact.
*Average weight.											

Date 8 November 1973 Shooter Pooler
 Temperature 49°F; Humidity 63% Recorder Sumwalt
 2-Meter Screens 5.06' and 8.06' (over 3') Chronograph E.C.
 5-Meter Screens 14.90' and 17.90' (over 3') Chronograph Oehler
 Job No. 1883-12
 Page 1 of 1
 Weapon NLL-SPOT 007
 Ammunition Nelson Marking Pellet
 Type -- Lot --
 Target 35 meters

Date 8 November 1973 Shooter Pooler
 Recorder Sumwalt
 Chronograph E.C.
 Chronograph Oehler

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)			
33	12121	247.5	41.2	13016	230.4	41.2	-39.0	-9.7	Level 23 1/4" Ball broke on impact.
34	11947	251.1	41.2	12852	233.4	41.2	-17.8	-15.4	Level 23 1/4" Ball did not break on impact.
35 *	11620	258.2	41.2	12548	239.0	41.2	-43.7	+7.1	Level 23 1/4" Ball did not break on impact.
36 *	11452	262.0	41.2	12345	243.0	41.2	-15.8	-15.9	Level 23 1/4" Ball broke on impact.
37 *	12276	244.4	41.2	13248	226.4	41.2	-16.9	-16.6	Level 23 1/4" Ball did not break on impact.
38 **	11736	255.6	41.2	12655	257.4	41.2	-17.0	-19.8	Level 23 1/4" Ball broke on impact. It appeared to hit floor prior to impacting target.
39 *	11703	256.3	41.2	12647	237.2	41.2	-8.5	+34.9	Level 23 1/4" Ball did not break on impact.

* Lipstick used to find impact point.
 ** New CO₂ cylinder used.
 *** Average weight.

Date 26 October 1975 Shooter Poole Job No. 1883-12
 Temperature 54°F; Humidity 70% Recorder Sumwalt Page
 2-Meter Screens --- and --- (over ---) Chronograph ---
 3-Meter Screens --- and --- (over ---) Chronograph ---
 Weapon NEL-SPN (07)
 Ammunition Nelson Super Spot Marking Pellet
 Type --- Lot ---
 Target 50 meters

Shot No.	2-Meter		5-Meter		Coordinates			Aiming Data	Indent. in Homasote (in.)	Results
	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gm.)	X (in.)	Y (in.)			
40	16mm Black and White High Speed Movies							Level 25 1/4"	-	Could not find point of impact on target.
				29 October	1975	54°F	75% R.H.			
41	16mm Color High Speed Movies							Level 25 1/4"	-	Could not find point of impact on target.

Date 31 October 1973 Shooter Boole Job No. 1883-12
 Temperature 50°F; Humidity 67% Recorder Sumwalt Page _____
 2-Meter Screens --- and --- (over ---) Chronograph --- Weapon NEL-SPOT 007
 5-Meter Screens --- and --- (over ---) Chronograph --- Ammunition Nelson Super Spot Marking Pellets
 Type --- Lot --- meters
 Target 50

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in Homasote (in.)	Results		
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)				x (in.)	y (in.)
42	Micro	Flash					-	-	Level 23 1/4"	-	Could find no indication of impact.
43	Micro	Flash			1 November		1973	54°F	66% R.H.	-	Could find no indication of impact.
44	Micro	Flash					-	-	Level 23 1/4"	-	Could find no indication of impact.
45	Micro	Flash					-	-	Level 23 1/4"	-	Could find no indication of impact.

Date 23 November 1973

Shooter Poole - "A"

Job No. 1883-12

Temperature 57°F; Humidity 66%

Recorder Flohr

Page

2-Meter Screens --- and --- (over ---)

Chronograph

Weapon M.L.-SPOT 007

5-Meter Screens --- and --- (over ---)

Chronograph ---

Ammunition Nelson Super Spot Marking Pellet

Type --- Lot ---

Target 35 meters

TIMED FIRE

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Ident. in Homasote (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)				x (in.)
46							+7.0	-36.6	Mass	Missed
47							+11.2	-33.4	Mass	Missed
48							+23.7	-27.5	Mass	Missed
49							+7.0	-30.1	Mass	Missed
50							+1.6	-40.1	Mass	Hit

Date 23 November 1973 Recorder Flohr - "B" Job No. 1883-12
 Temperature 57°F; Humidity 66% Recorder Sumwalt Page _____
 2-Meter Screens --- and --- (over ---) Chronograph --- Weapon NEL-SPOT 007
 5-Meter Screens --- and --- (over ---) Chronograph --- Ammunition Nelson Super Spot Marking Pellet
 Type --- Lot ---
 Target 35 meters

TIMED FIRE

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in Homasote (in.)	Results	
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)				x (in.)
51							-1.8	+2.2	Mass	Hit
52							+24.0	-28.5	Mass	Missed
53							+50.0	-12.0	Mass	Missed. Did not break.
54							+26.3	-23.4	Mass	Missed
55							+12.0	-5.0	Mass	Missed

Date 23 November 1973

Shooter Sumwalt - 'C'

Job No. 1883-12

Temperature 57°F; Humidity 66%

Recorder Flohr

Page _____

2-Meter Screens --- and --- (over ---)

Chronograph ---

Weapon NEL-SIXT 007

5-Meter Screens --- and --- (over ---)

Chronograph ---

Ammunition Nelson Super Spot Marking Pellet

Type -- Lot --

Target 35 meters

TIMED FIRE

Shot No.	2-Meter		5-Meter		Coordinates		Aiming Data	Indent. in Homasote (in.)	Results
	Time (sec)	Vel. (ft/sec)	Proj. Wt. (gn.)	Time (sec)	X (in.)	Y (in.)			
56					-13.5	-11.1	Mass		Missed
57					-13.6	-30.1	Mass		Missed
58					-43.4	-29.3	Mass		Missed
59					-20.3	-42.1	Mass		Missed
60					-30.1	-32.7	Mass		Missed

OBSERVED DATA

MAXIMUM RANGE

Nel-Spot Marking Pellets - Nel-Spot 007 CO₂ Pistol
Barrel Elevated 30°

Date: 5 February 1974

Temperature: 30°F, variable
cross wind (left to right)

Round No.	Range (meters)	Deflection (meters)	Remarks
01	62.0	4.0-right	Did not break on impact with ground.
02	65.0	12.0-right	Did not break on impact with ground.
03	67.0	21.0-right	Did not break on impact with ground.

OBSERVED DATA

MAXIMUM EFFECTIVE HITTING RANGE

Nel-Spot Marking Pellets - Nel-Spot 007 CO₂ Pistol

Date: 1 March 1974

Temperature: 45°F, variable cross wind
right to left

Round No.	Impact Coordinates (in.)		Silhouette Hit/ Missed	Wind Velocity (m.p.h.)	Flight Time (sec.)	Remarks
	x	y				
			TARGET DISTANCE 35 METERS			
64	-70.5	-31.0	Missed	9.0	0.8	
65	-	-	Missed	9.5	-	Hit ground at 25m.
66	-	-	Missed	9.0	-	Hit ground at 23m.
			TARGET DISTANCE 20 METERS			
67	-13.5	+29.7	Missed	10.0	0.5	
68	-18.7	-22.4	Missed	10.0	0.5	
69	+8.6	-12.0	Hit	11.0	0.4	
70	-	-	Missed	11.5	-	Broke in barrel.

OBSERVED DATA

COLD TEST

Nel-Spot Marking Pellets - Nel-Spot 007 CO₂ Pistol

Date: 12 February 1974

Ammunition: Stored at -45°F for 24 hours.
Stored at 0°F for 1 hour immediately before firing.

Machine rest, lanyard fired

Target: 35 meters

Aiming point: 47 1/2 inches high

Round No.	x (in.)	y (in.)	Indentation (in)	Remarks
71	-	-		Paint balls, when subjected to cold temperature, expanded and would not fit into the bore of the pistol.
72	-	-		
73	-	-		

APPENDIX B

CALCULATED DATA

ACCURACY
12 Gauge Liquid Ball
6.4 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
1	+4.0	+4.9	12.96	22.09	5.9
2	+2.0	+0.5	2.56	0.09	1.6
3	-6.9	+7.5	53.29	53.29	10.3
4	+5.4	-2.0	25.00	3.24	5.3
5	-2.7	-6.3	9.61	42.25	7.2
6	+0.5	-5.2	0.01	29.16	5.4
7	+0.4	+2.0	0	3.24	1.8

			x	y	
			(in.)	(in.)	
Standard Deviation	---	---	4.2	5.1	---
Mean	$\bar{x} = +0.4$	$\bar{y} = +0.2$	---	---	5.4
Extreme Spread	12.3	13.8	---	---	---

CALCULATED DATA

ACCURACY
Nelson Marking Pellet
6.4 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	(x - \bar{x})	(y - \bar{y})	
19	-6.4	-2.4	27.04	10.89	6.2
20	1.4	+2.6	0.04	2.89	1.7
21	+1.1	+0.7	5.29	0.04	2.3
22	-0.3	+1.0	0.81	0.01	0.9
23	+2.8	-1.7	16.00	6.76	4.8
24	-1.9	+3.8	0.49	8.41	3.0
25	-2.2	+2.3	1.00	1.96	1.7
			\bar{x} (in.)	\bar{y} (in.)	
Standard Deviation	---	---	2.9	2.5	---
Mean	$\bar{x} = -1.2$	$\bar{y} = +0.9$	---	---	2.9
Extreme Spread	9.2	6.2	---	---	---

CALCULATED DATA

ACCURACY
Nelson Marking Pellet
20 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
26	-9.1	-23.0	13.69	712.89	27.0
27	-6.4	-5.6	1.00	86.49	9.4
28	+1.6	+10.2	49.00	42.25	9.6
29	-0.9	+1.2	20.25	6.25	5.1
30	+1.6	+11.0	49.00	53.29	10.1
31	-11.8	+14.3	40.96	112.36	12.4
32	-12.4	+17.7	49.00	196.00	15.7
Standard Deviation	---	---	6.1	14.2	---
Mean	$\bar{x} = -5.4$	$\bar{y} = +3.7$	---	---	12.8
Extreme Spread	14.0	40.7	---	---	---

CALCULATED DATA

ACCURACY
Nelson Marking Pellet
35 Meters

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	(x - x)	(y - y)	
53	-39.0	-9.7	265.69	21.16	16.9
54	-17.8	-15.4	24.01	106.09	11.4
55	-43.7	+7.1	441.00	148.84	24.3
56	-15.8	-15.9	47.61	116.64	12.8
57	-16.9	-16.6	33.64	132.25	12.9
58	-17.0	-19.8	32.49	216.09	15.8
59	-8.5	+34.9	201.64	1600.00	42.5
			x (in.)	y (in.)	
Standard Deviation	---	---	3.2	19.8	---
Mean	$\bar{x} = -22.7$	$\bar{y} = -5.1$	---	---	19.5
Extreme Spread	47.5	54.7	--	---	---

CALCULATED DATA

ACCURACY
Timed Fire
Nelson Super Spot
Marking Pellet

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
46	+7.0	-36.0	9.61	6.76	4.1
47	+11.2	-33.4	1.21	0	1.1
48	+23.7	-27.5	184.96	34.81	14.8
49	+7.0	-30.1	9.61	10.89	4.5
50	+1.6	-40.1	72.25	44.89	10.8

			x (in.)	y (in.)	
Standard Deviation	---	---	8.53	4.93	---
Mean	$\bar{x} = +10.1$	$\bar{y} = -35.4$	---	---	7.1
Extreme Spread	22.1	12.6	---	---	---

CALCULATED DATA

ACCURACY
Timed Fire
Nelson Super Spot
Marking Pellet

Round No.	Coordinates (in.)		Calculations		Radius (in.)
	x	y	$(x - \bar{x})^2$	$(y - \bar{y})^2$	
51	-1.8	+2.2	571.21	240.25	28.5
52	+24.0	-28.5	3.61	251.04	15.3
53	+50.0	-12.0	778.41	1.69	27.9
54	+20.3	-23.4	17.64	102.01	10.9
55	+12.0	-5.0	102.01	68.89	13.1
			x	y	
			(in.)	(in.)	
Standard Deviation	---	---	19.2	12.7	---
Mean	$\bar{x} = +22.1$	$\bar{y} = -13.5$	---	---	19.1
Extreme Spread	51.8	30.7	---	---	---

APPENDIX C

TEST INSTRUMENTATION
EQUIPMENT AND MATERIALS

- 1 - Oehler Model 41B Chronotach, calibrated at factory in May 1973
- 1 - Electronic Counters, Inc. Model 4010 Velocity Computing Chronograph, calibrated at factory in June 1973
- 4 - Oehler Model 35 Lumiline Screens
- 2 - Fastax 16mm High Speed Motion Picture Cameras
- 1 - Wollensak Model 3106 Time Pulse Generator
- 2 - Colortran 1000 Watt Lights
- 2 - Wollensak 1000 Watt Lights
- 4 - 100-foot Rolls Kodak Ektachrome (7242) 16mm High Speed Film (GFE)
- 4 - 100-foot Rolls Eastman Double-X Negative (722) 16mm High Speed Film
- 1 - Vanguard Model 16C Motion Analyzer
- 4 - General Radio Type 1539 "Stroboflash" Microflash
- 1 - General Radio Model 1541 Multi-Flash Generator
- 1 - Linhof 4x5 Camera with Kodak f1.5, 135mm Lens
- 6 - Royal Pan 4" x 5" Cut Film, Type 4141
- Various darkroom and photographic equipment
- 100-meter indoor range having ceiling height of 12 feet
- 400-meter outdoor range
- Miscellaneous range supplies and equipment
- 1 - Specially constructed target (Homasote faced), Homasote Company, Lower Ferry Road, Trenton, N.J.
- 1 - Dry Ice Freezer Unit
- 1 - Rochester Thermometer
- 1 - Plywood Anthropometric Silhouette Target based on 1960 Dreyfus data
- 1 - Dwyer Wind Meter, F.W. Dwyer Mfg Co., Michigan City, Indiana

APPENDIX D

NEL SPOT MARKING PELLETS
(Band indicates color)

FOR REMOTE MARKING OF ANIMALS, TREES, OR AL-
MOST ANYTHING. USE WITH NEL SPOT "007" OR "707"
MARKING GUN. REMOVE COLORED END CAP FROM TUBE
AND ROLL CONTENTS INTO MAGAZINE.

LIMITED STORAGE LIFE—KEEP COOL & DRY. AVOID
FREEZING. FLAMMABLE. KEEP AWAY FROM CHILDREN
—HARMFUL IF EATEN.

CONTENTS: 12-14 UNIT TUBES
(168 NET COUNT) - MADE IN U.S.A.

BOLITAS MARCADORAS NEL-SPOT
(La franja indica el color)

PARA MARCAR A DISTANCIA ANIMALES, ARBOLES Y
CASI TODA CLASE DE SUPERFICIES. USENSE CON LA
PISTOLA NEL SPOT "007" O "707". QUITESE LA TAPA
PINTADA E INSERTENSE LAS GOLITAS EN EL MAGAZIN.

DURACION DE ALMACENAJE LIMITADA—GUARDENSE
EN UN LUGAR FRESCO SIN HUMEDAD. EVITE QUE SE
CONGELEN. NO LAS ACEPQUE AL FUEGO. TENGANSE
ALEJADO DE LOS NIÑOS. PELIGROSO A COMER.

CONTENIDO: 12 CILINDROS CON 14 BOLITAS
CADA UNO (168 BOLITAS EN TOTAL)
PRODUCTO DE E.U.A.

PLOMBS MARQUEURS NEL-SPOT
(La bande indique la couleur)

POUR MARQUER A DISTANCE LES ANIMAUX, LES ARBRES
ET LA PLUPART DES SURFACES. UTILISER AVEC LE
PISTOLET A PLOMBS NEL SPOT "007" OU "707". ENLEVER
LE COUVERCLE COLORE ET INTRODUIRE LES PLOMBS
DANS LE MAGASIN DU PISTOLET.

EMMACASINAGE LIMITE—CONSERVER DANS UN
ENDROIT FRAIS ET SEC. EVITER LE GEL. NE PAS APPRO-
CHER DU FEU. TENIR ELOIGNE DES ENFANTS—DANGER-
EUX A MANGER.

CONTENU: 12 TUBES AVEC 14 PLOMBS CHACUN
(TOTAL DE 168 PLOMBS)
FABRIQUE AUX ETATS-UNIS.

NEL SPOT MARKIERUNGSPLATZCHEN
(Des Streifen zeigt die Farbe an)

MIT DER NEL SPOT "007" ODER "707" MARKIERUNGS-
PISTOLE ZUM FERNMARKIEREN VON TIEREN, BAUMEN,
UND DIE MEISTEN OBERFLACHEN ZU GEBRAUCHEN. DEN
GEFARBTE DECKEL ABZUNEHMEN UND DIE PLATZCHEN
INS MAGAZIN EINZUSETZEN.

BEGRENZTE LAGERZEIT—KÜHL UND TROCKEN ZU
LAGERN—VOR FROST ZU SCHÜTZEN. UMGANG BEI OF-
FENER FLAMME VERMEIDEN. SICH VON KINDER FERN-
ZUHALTEN—GEFÄHRLICH ZU ESSEN.

GEHALT: 12 TUBE JEDE MIT 14 PLATZCHEN
(168-ER PACKUNG) U.S.A.—ERZEUGNIS.

THE NELSON PAINT COMPANY
IRON MOUNTAIN, MI. 49841
MONTGOMERY, AL. 36108 - McMinnville, OR. 97128

Nelson



MARKING PELLETS

BAND INDICATES COLOR

APPENDIX E

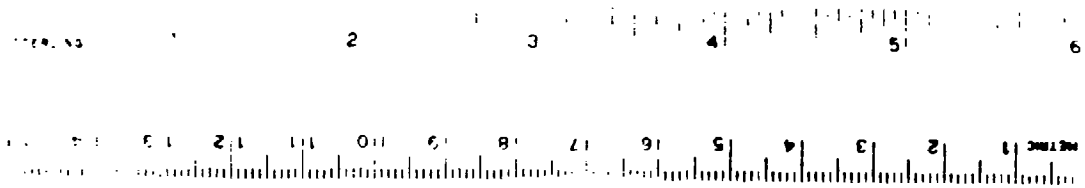


Figure 1. 12 Gauge Liquid Ball, Round and Components.



Figure 2. Nel Spot 007 CO₂ Pistol Power Charge
and Nelson Marking Pellet Projectile.

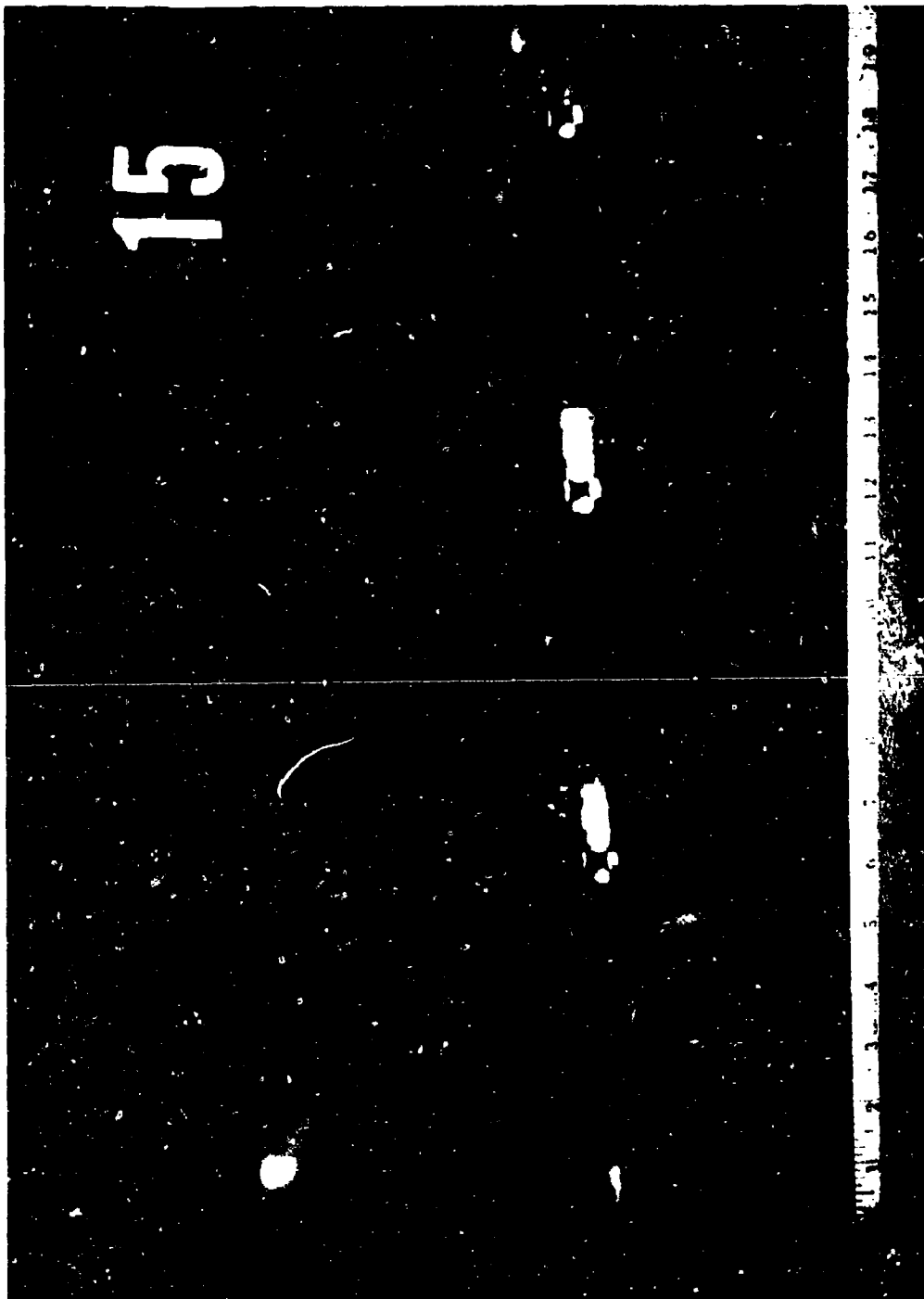


Figure 3. Round Number 16. Microflash, 12 Gauge Liquid Ball Projectile & Wad.

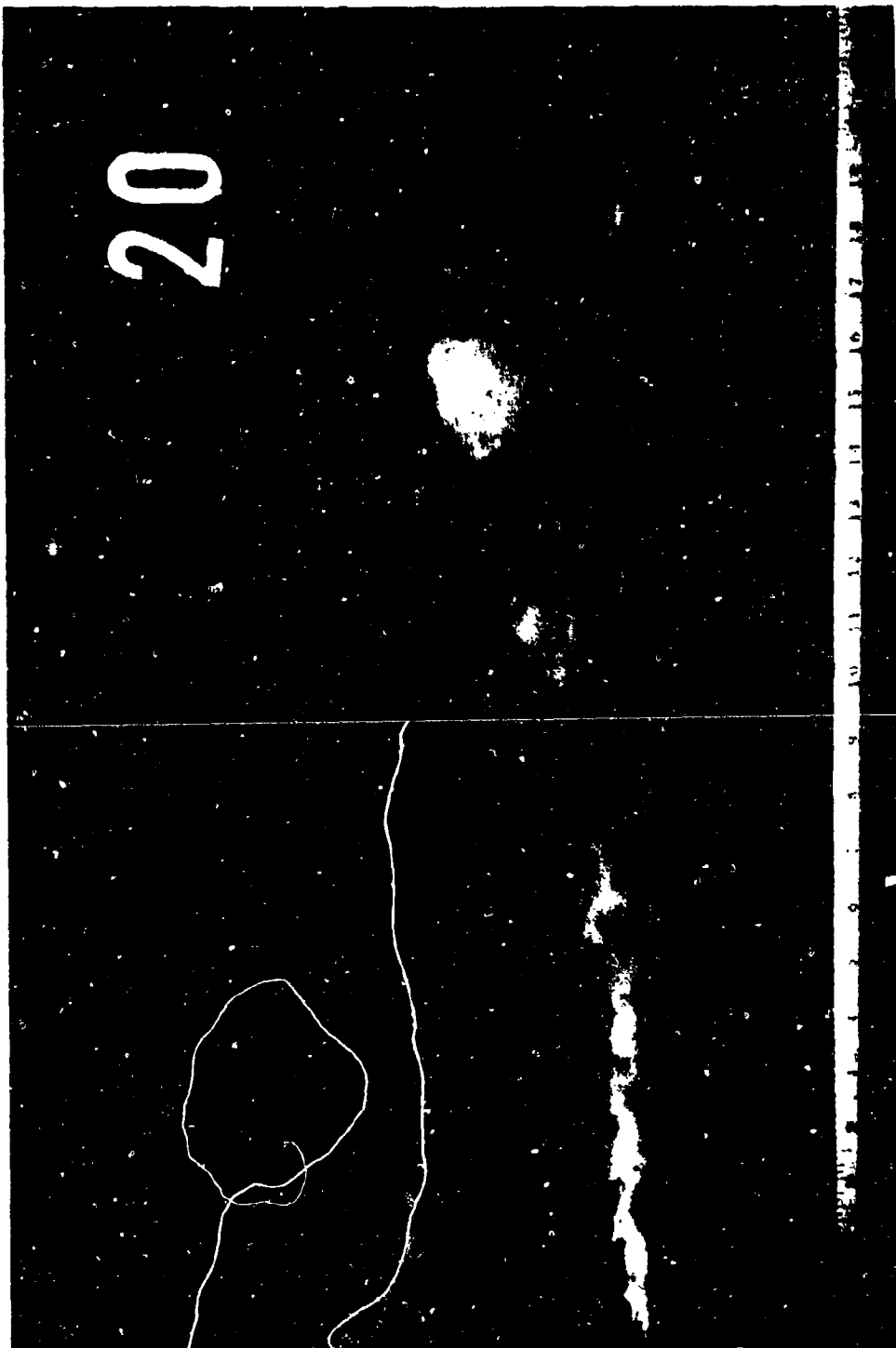


Figure 4. Round Number 42. Microflash, Nelson Marking Pellet Fired from a "Nel-Spot" 007 CO₂ Pistol.

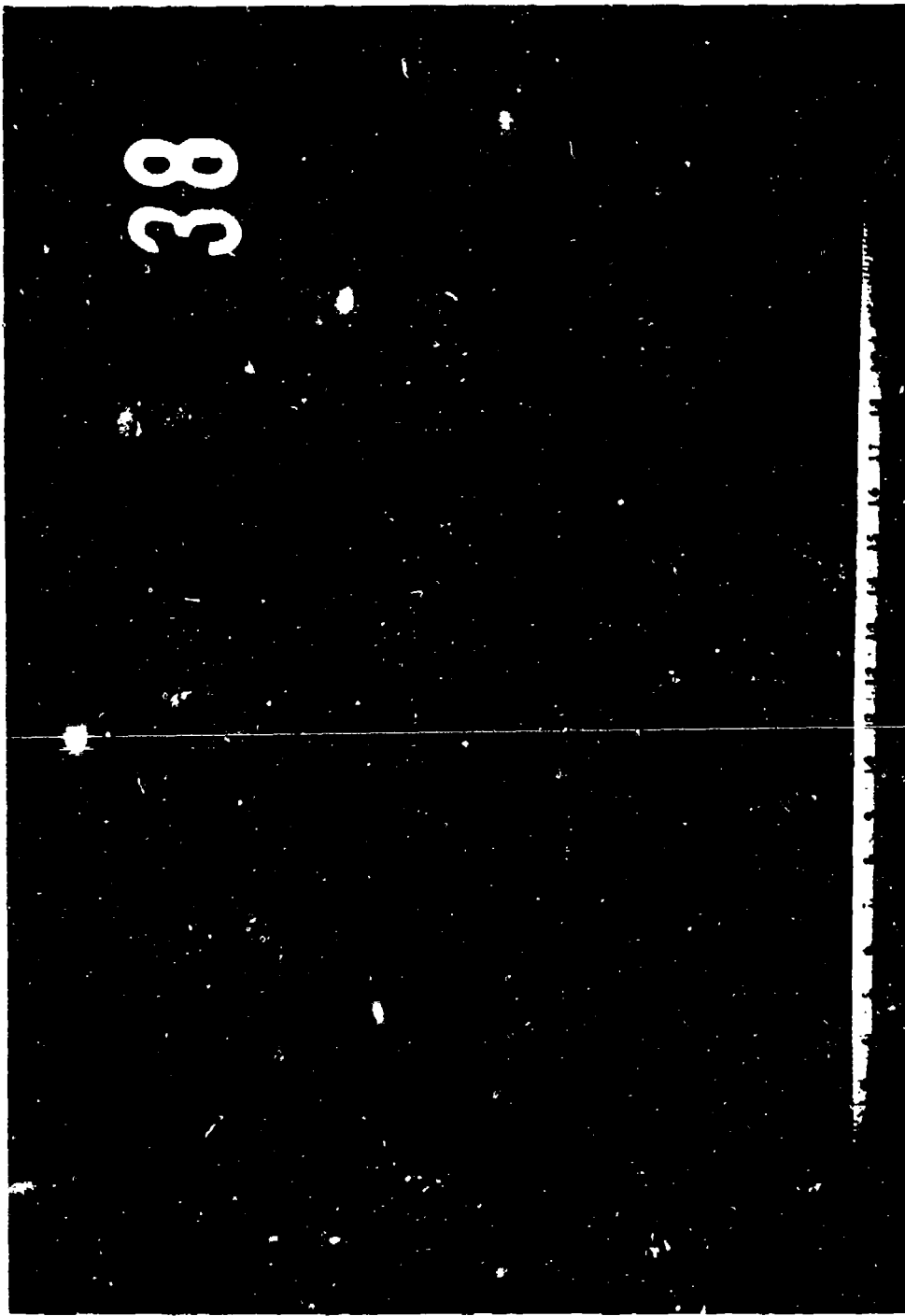


Figure 5. Round Number 43. Microflash, Nelson Marking Pellet Fired from a "Nel-Spot" 007 CO₂ Pistol.

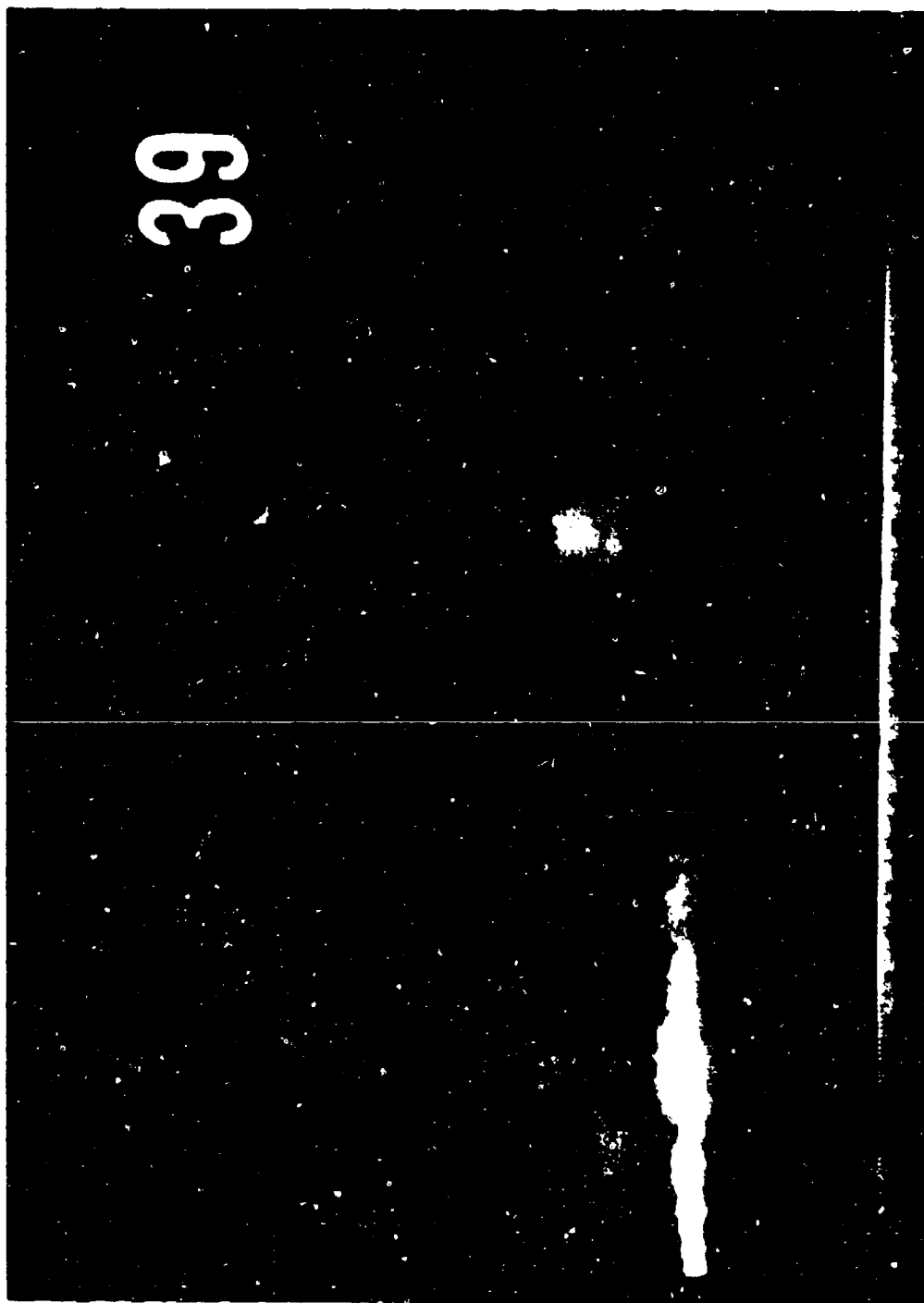


Figure 6. Round Number 44. Microflash, Nelson Marking Pellet Fired from a "Nel-Spot" 007 CO₂ Pistol.

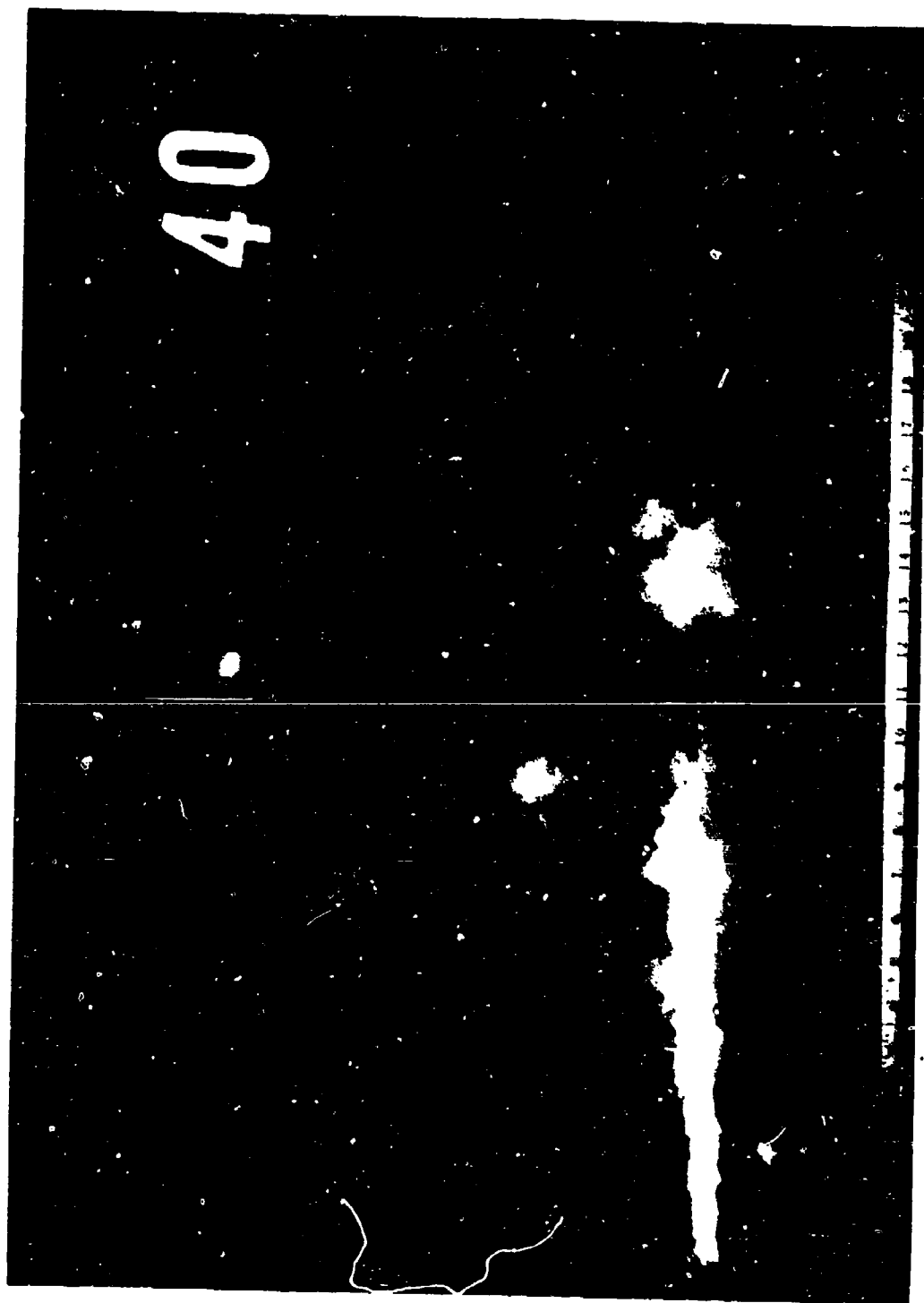


Figure 7. Round Number 45. Microflasi, Nelson Marking Pellet Fired from a "Nel-Spot" 007 CO₂ Pistol.