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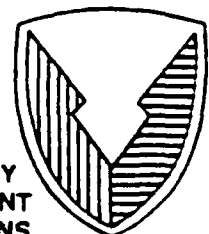
UNIVERSAL AIR GUN LAUNCHER SYSTEM

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RESEARCH DIRECTORATE

April 1992

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PREFACE

The work described in this report was authorized under Project No. 1C162706A553, CB Defense and General Investigation. This work was started in September 1987 and completed in January 1990.

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The authors acknowledge the efforts of Paul C. Zurkowski, Donald N. Olsen, and Miles C. Miller, Aerodynamics Research and Concepts Assistance Branch, Physics Division, Research Directorate, CRDEC. Paul Zurkowski developed the computer program, which performs a trade-off analysis of air gun design parameters. He also performed much of the initial design work leading to the fabrication contract specifications. Donald Olsen originated the concept and design of the Spigot Sabot, which is used to launch certain payloads from the Universal Air Gun Launcher. Miles Miller's supervision, comments, and suggestions aided in establishing the final launcher configuration.

The authors are also grateful to Mark Ward and Jim Ryan, Test and Evaluation Office, CRDEC, for their support and assistance during the field testing of the Universal Air Gun Launcher.



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CONTENTS

	Page
1. INTRODUCTION	7
2. PERFORMANCE REQUIREMENTS	7
3. GENERAL DESIGN REQUIREMENTS	8
4. PRELIMINARY DESIGN ANALYSIS	8
4.1 Design Concept	9
4.2 Air Gun Design Analysis	9
4.3 Detailed Design Characteristics	10
4.4 Spigot Sabot Design	11
5. FINAL DESIGN AND FABRICATION	14
6. ASSEMBLY PROCEDURES	14
6.1 General	14
6.2 Base Support Mounting Procedure	14
6.3 Tank Mounting Procedure	14
6.4 Barrel Mounting Procedure	19
6.5 Launcher Controls Installation	19
7. FIRING PROCEDURE	20
8. FLIGHT OF SPIGOT SABOT AND SLUG	22
9. MISCELLANEOUS INFORMATION	22

LIST OF FIGURES

1	UGAL Concept and Performance Requirements	8
2	Launch Conditions and Computed Trajectory to Meet Requirements	9
3	Air Gun Barrel Diameter Comparison	11
4	Spigot Sabot Components and Payload	12
5	Spigot Sabot Engineering Drawing	13
6	Completed UAGL System (Spigot Sabot not Shown) . .	15
7	Disassembled UAGL	16
8	UAGL Component Size and Portability Demonstration	17
9	Photograph of Actual Test Firing	18
10	Four Major Components of UAGL	19
11	Operating Curve for Launcher Control Unit	20
12	Plot of Muzzle Velocity as a Function of Plenum Tank Pressure	21
13	Typical Flight Trajectories	21

UNIVERSAL AIR GUN LAUNCHER SYSTEM

1. INTRODUCTION

This report is a brief overview documenting the design concept, operational capabilities, and testing process for the Universal Air Gun Launcher (UAGL) System.

A special air gun launching system is required to launch obscurant type payloads of various sizes and weights for research and development test purposes. A nonpyrotechnic launcher was desired to avoid the extensive development and safety certification required of a pyrotechnic launcher for shipboard use. The basic concept is to use a small, transportable, air gun capable of launching various sized obscurant type payloads to specified altitudes. The various sized payloads are launched using a special spigot sabot, which allows the payload to be positioned externally on the air gun.* The spigot sabot is recovered after each use. The actual propelling medium can be any inert gas; typically, nitrogen is used. Because of its eventual application to both shipboard and land use, the air gun is referred to as the Universal Air Gun Launcher (UAGL).

The Aerodynamics Research and Concepts Assistance Branch (ARCA Br), Physics Division, Research Directorate, U.S. Army Chemical Research, Development and Engineering Center (CRDEC), performed the predesign layout of the launcher for the Smoke Division, Munitions Directorate, CRDEC. The launcher's detailed final design and fabrication were completed in CRDEC-CR-103** under Contract No. DAAA15-87-D-0019, Task 44, with MRC Chamberlain Corporation, Hunt Valley, MD.

2. PERFORMANCE REQUIREMENTS

The major performance requirement for the UAGL was that it be able to launch a 12-in. or smaller diameter payload weighing up to 30 lb on a trajectory that would carry the payload through a point 450 ft out from and 450 ft above the launcher. This trajectory is illustrated in Figure 1.

*The term "air gun" is used generically in this report.

**Broady, James P., Universal Launcher System, CRDEC-CR-103, U.S. Army Chemical Research, Development and Engineering Center, Aberdeen Proving Ground, MD, May 1991, UNCLASSIFIED Report.

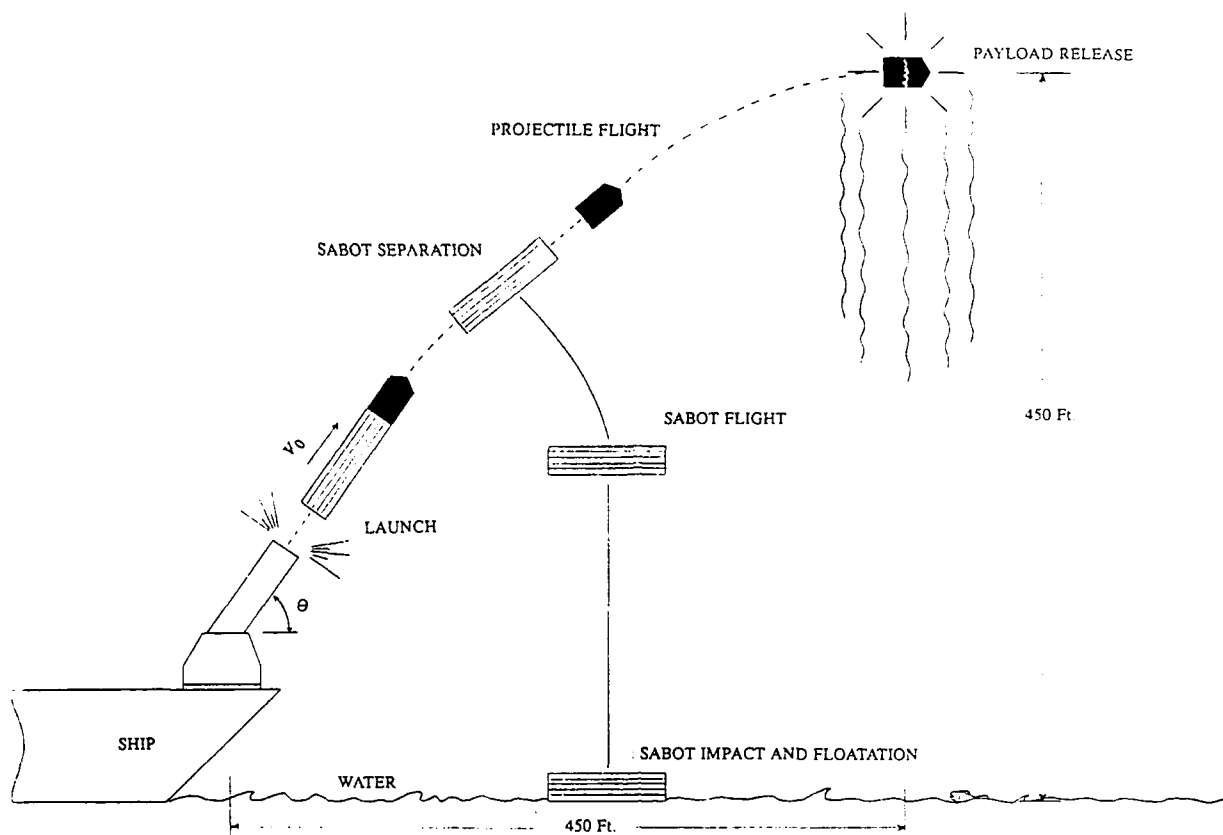


Figure 1. UAGL Concept and Performance Requirements

3. GENERAL DESIGN REQUIREMENTS

The launch system was designed in consideration of several constraints. First, for transportation, the launcher must be capable of being easily disassembled into its various components. Second, each launcher component must be transportable by two men and be compact enough to fit through a 4 ft. by 4 ft. ship hatch. The design analysis resulted in the following detailed design parameters: a spigot sabot will be used to launch projectiles larger than the barrel diameter, also, the gun orientation will be adjustable from 0-90° in elevation and have an azimuth range of $\pm 60^\circ$.

4. PRELIMINARY DESIGN ANALYSIS

The ARCA Br's contribution to the UAGL development consisted of the following four primary functions:

- establish the design concept

- determine the operational and design specifications
- design and fabricate the special spigot sabot required for launching large payloads
- provide field test support to demonstrate the sabot and launcher capabilities.

4.1 Design Concept.

The design concept for the UAGL evolved from the ARCA Br's past experience with its 3 and 6-in. Spinning Barrel Air Gun facilities. These guns are very similar in function to the UAGL. An air gun works on the principal of a high pressure inert gas rapidly filling the gun barrel containing the projectile. Air guns use a gas storage (plenum) tank connected to the launch tube or barrel through a quick acting valve. The plenum tank is pressurized by a bank of storage cylinders. When the gun is fired, the quick acting valve opens and allows the gun tube to be pressurized. Thus, a launch force is applied to the projectile or sabot contained in the tube.

4.2 Air Gun Design Analysis.

The ARCA Br developed a computer program that performs ballistic trajectory analysis to evaluate the performance requirement that a launched payload must travel through a point in space 450 ft out from and 450 ft above the launcher. This analysis determined that the requirement could be met with a muzzle velocity of 250 ft/s and a launch elevation of 55° to the horizontal. The results from this analysis are shown in Figure 2.

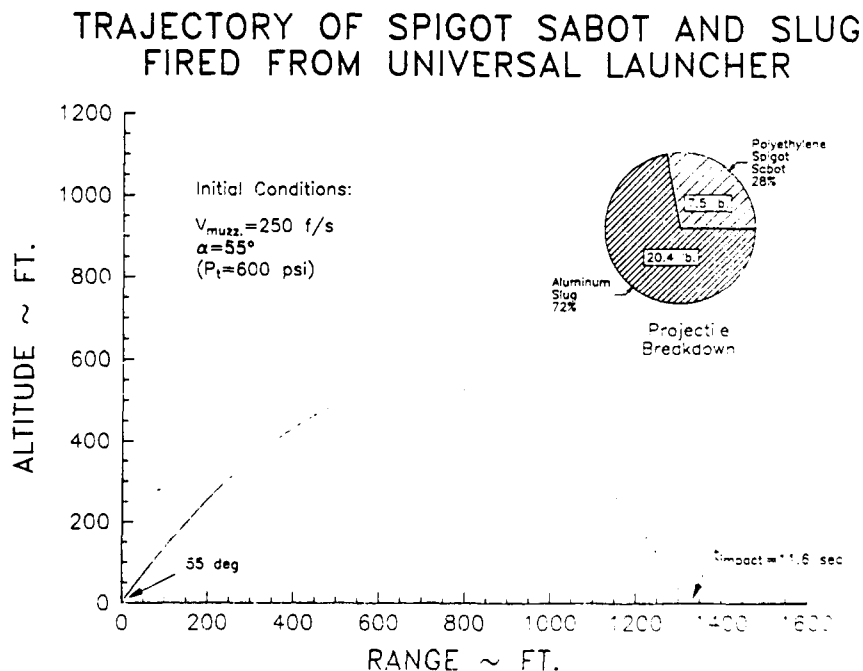


Figure 2. Launch Conditions and Computed Trajectory to Meet Requirements

The ARCA Br developed another computer program to simulate the air gun internal operation. This computer program aided in designing the lightest, smallest, air gun configuration that would provide the muzzle velocity desired using a conventional, bottled gas supply. This program allowed a parametric analysis of the air gun's internal operation and established a design consistent with the various performance requirements. The program allowed five parameters to be varied and trade-off studies to be conducted. These five variables follow:

- Barrel Diameter
- Barrel Length
- Plenum Tank Pressure
- Plenum Tank Volume
- Projectile Weight

These five inputs were varied, and the resulting performance in terms of muzzle velocity was predicted. An example of the results is shown in Figure 3, which depicts muzzle velocity as a function of plenum pressure for various barrel diameters. To meet the hatch portability requirements, the investigators determined that a 4-ft barrel represented the maximum length. As can be seen from Figure 3, the 6-in. diameter, 4-ft barrel requires a supply pressure of about 350 psi to achieve a muzzle velocity of 250 ft/s (the velocity dictated by the contract trajectory requirements). The 8- and 10-in. diameter barrels require 300 and 275 psi, respectively, to achieve the 250-f/s muzzle velocity. No significant increase in muzzle velocity is obtained through using barrel diameters larger than 6 in. at high operating pressures. However, the larger diameter barrels represent an increased weight penalty. Successive iterations on this trade-off of barrel diameter, barrel weight, and muzzle velocity resulted in the decision to use a 6-in. diameter barrel. The 6-in. barrel is approximately half the weight of a 10-in. diameter barrel and offers the lightest configuration that meets the performance requirement with reasonable storage tank pressures. Similar trade-off studies were performed to determine the supply tank volume and operating pressures necessary to obtain the required performance while maintaining transportability and size restrictions.

4.3 Detailed Design Characteristics.

The resulting detailed design characteristics follow:

- The launcher will use a 1500 in.³, high pressure supply tank that can be filled by standard nitrogen bottles.
- The barrel will be 43 in. long with a 5.75 in. i.d., fabricated from stainless steel, and removable from the plenum tank.
- The UAGL will operate at a nominal operating pressure of 500 psi and a maximum operating pressure of 1000 psi.

0.1 s.

- The valve operating time of the UAGL will be less than
- The UAGL must be remotely fired on command.

Air Launcher Design Tradeoff Study Example

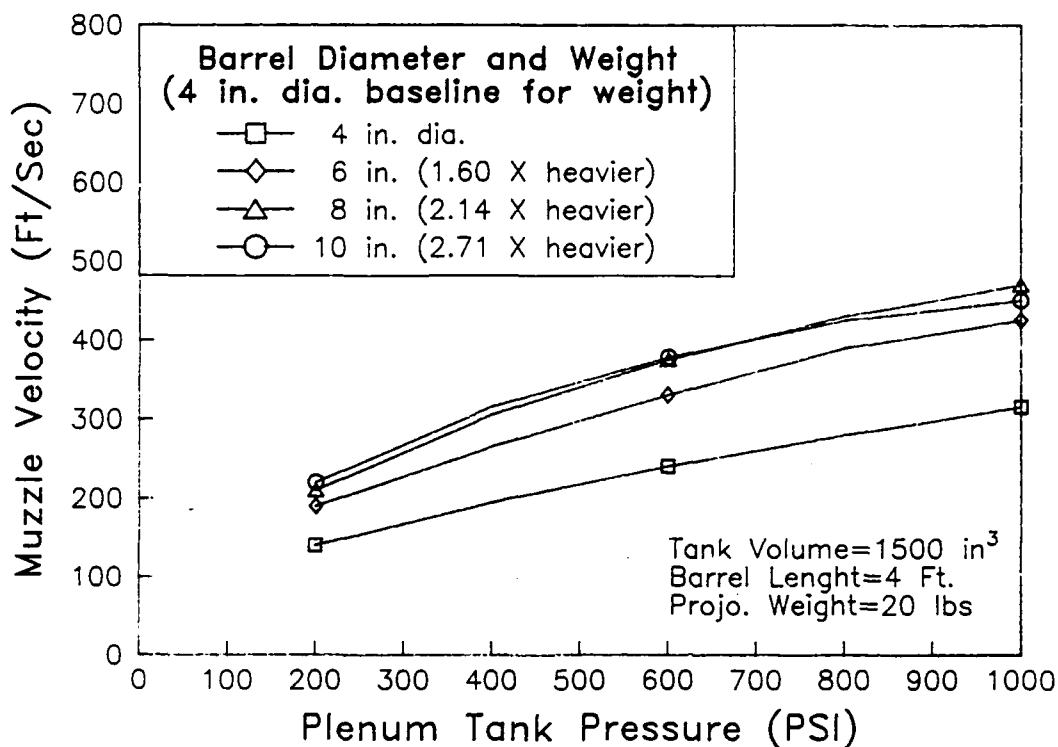


Figure 3. Air Gun Barrel Diameter Comparison

4.4 Spigot Sabot Design.

A spigot sabot, slug, and spring separation mechanism were designed by the ARCA Br to satisfy the requirement to fire a payload described as the size of a bowling ball and still keep the air gun launcher's size manageable. A spigot sabot is an interface component used to transmit energy to accelerate the payload, which is located outside the barrel. The spigot sabot fits down inside the barrel opening and completely fills the barrel volume. The payload is attached to the end of the sabot and is located external to the barrel. The design of the spigot sabot can be described as an externally ribbed column with bore riding endcaps. This design was chosen to achieve the strength and rigidity necessary to withstand launch and impact forces. The design also had

to be lightweight to not degrade the UAGL System maximum muzzle velocity performance. The spigot sabot is fabricated from high density polyethylene. The material choice was based on the requirement that the sabot must float in water so that it can be recovered and reused after a shipboard test. The high density polyethylene offers excellent strength in addition to buoyancy.

The payload is secured to the spigot sabot by a shear pin. A recess area between the sabot and payload contains a compressed coil spring. Upon launch setback, the shear pin is severed. The compressed coil spring then separates the payload from the sabot. The major components of the spigot sabot and slug are depicted in Figure 4. Figure 5 is an engineering drawing of the spigot sabot.

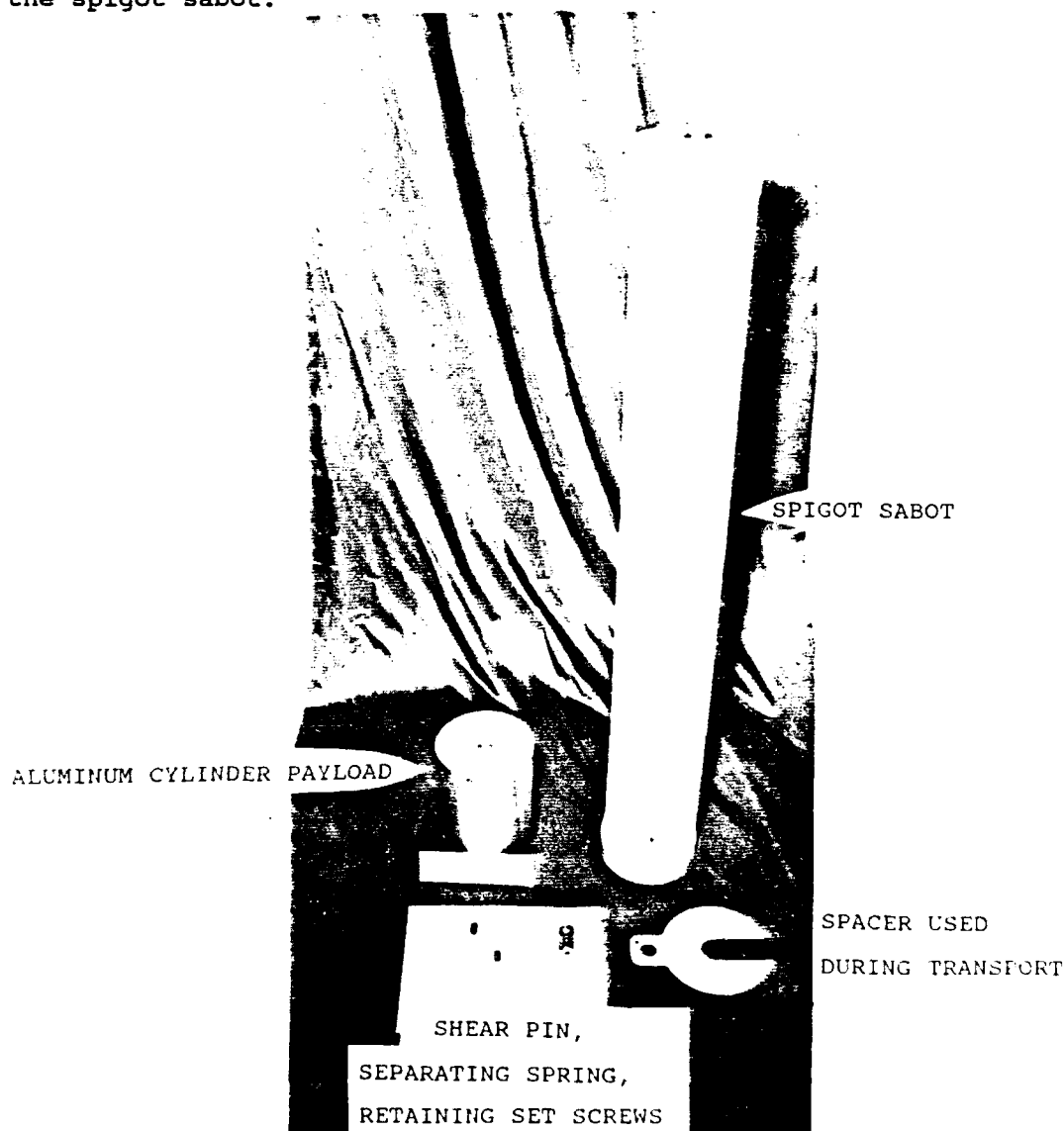
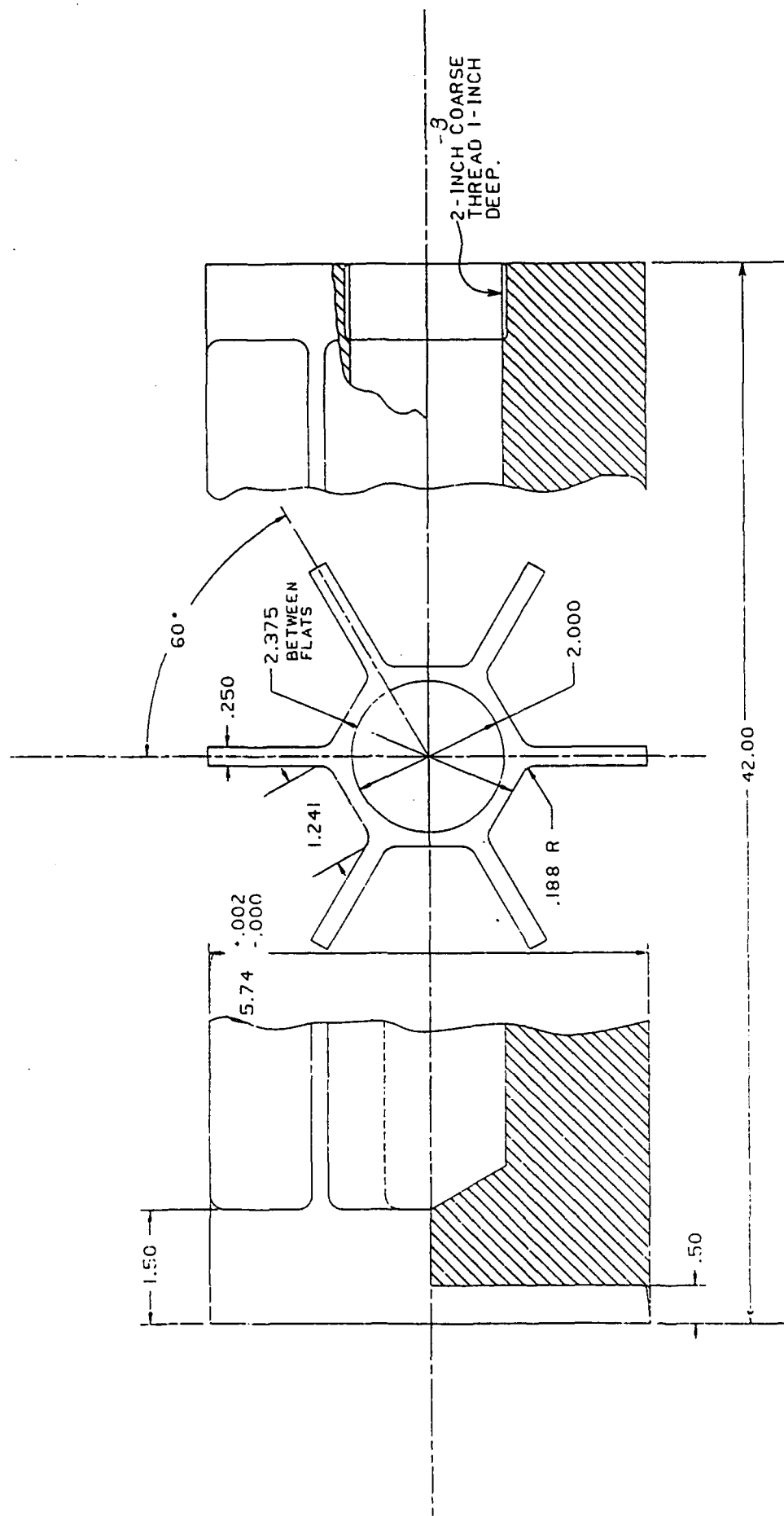


Figure 4. Spigot Sabot Components and Payload



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FRACTIONS 1/16	ANGLES 10° 30'	SUBMITTED			
MATERIAL HIGH DENSITY POLYETHYLENE		APPROVED			
SIZE C		MARK MITCHELL ARCA BR EXT 2158/3055			
SCALE 3/4		SHEET 01			

Figure 5. Spigot Sabot Engineering Drawing

5. FINAL DESIGN AND FABRICATION

Based on the computer-aided analysis and initial design performed by the ARCA Br, the UAGL was built through a CRDEC task order contract with MRC Chamberlain Corporation, Hunt Valley, MD. MRC performed the detailed design, acquired the necessary hardware, fabricated, assembled, and performed the necessary reliability tests to meet the contract's requirements. The completed UAGL System is shown in Figure 6. Figure 7 illustrates the two major portable components of the UAGL. Figure 8 demonstrates the two-man transportability of these components.

On 10 January 1990, the UAGL was successfully demonstrated at the Edgewood Area, Aberdeen Proving Ground, MD, meeting all contractual requirements. For these tests, a 20-lb aluminum cylinder was used as the payload. A photograph of a firing is shown in Figure 9. A final report, CRDEC-CR-103, (MRC Project No. 1119), was written and describes the completed system.

6. ASSEMBLY PROCEDURES

6.1 General.

The four primary components needed for assembling the UAGL System follow:

- Base Support
- Tank Assembly
- Gun Barrel
- Launch Control Unit

These components are displayed in Figure 10. The following sections provide a summary of the detailed procedures found in CRDEC-CR-103 (MRC Project No. 1119).

6.2 Base Support Mounting Procedure.

Mount the base support to the desired mounting surface using four, grade 3, 1/2-16 UNC hex bolts, nuts, and washers in the four-bolt hole locations around the perimeter of the base support.

6.3 Tank Mounting Procedure.

Mount the tank to the base support by aligning the bearing blocks with the mounting surface of the base support. Insert four 3/8-16 UNC by 2.5-in. long bolts and 3/8-in. lock washers into the bearing blocks. Thread all four bolts completely down, then tighten.

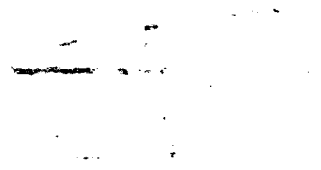
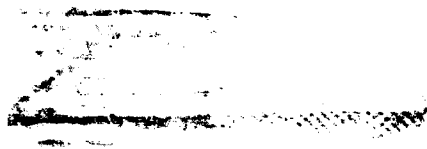
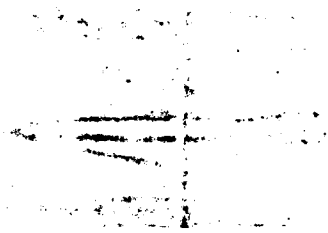


Figure 6. Completed UAGL System (Spigot Sabot not Shown)



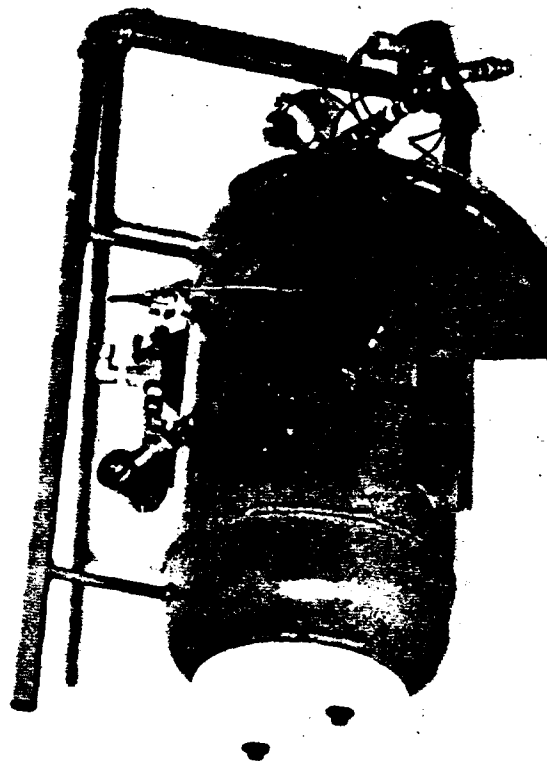
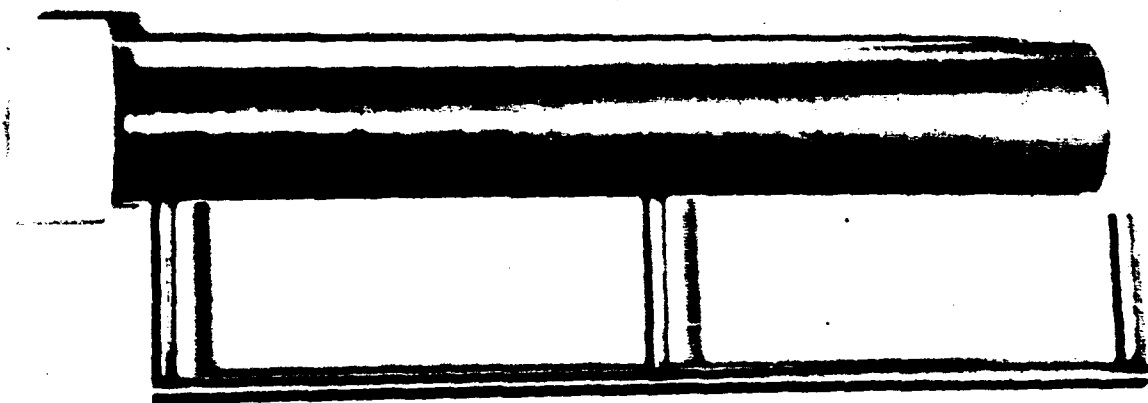


Figure 7. Disassembled UAGL

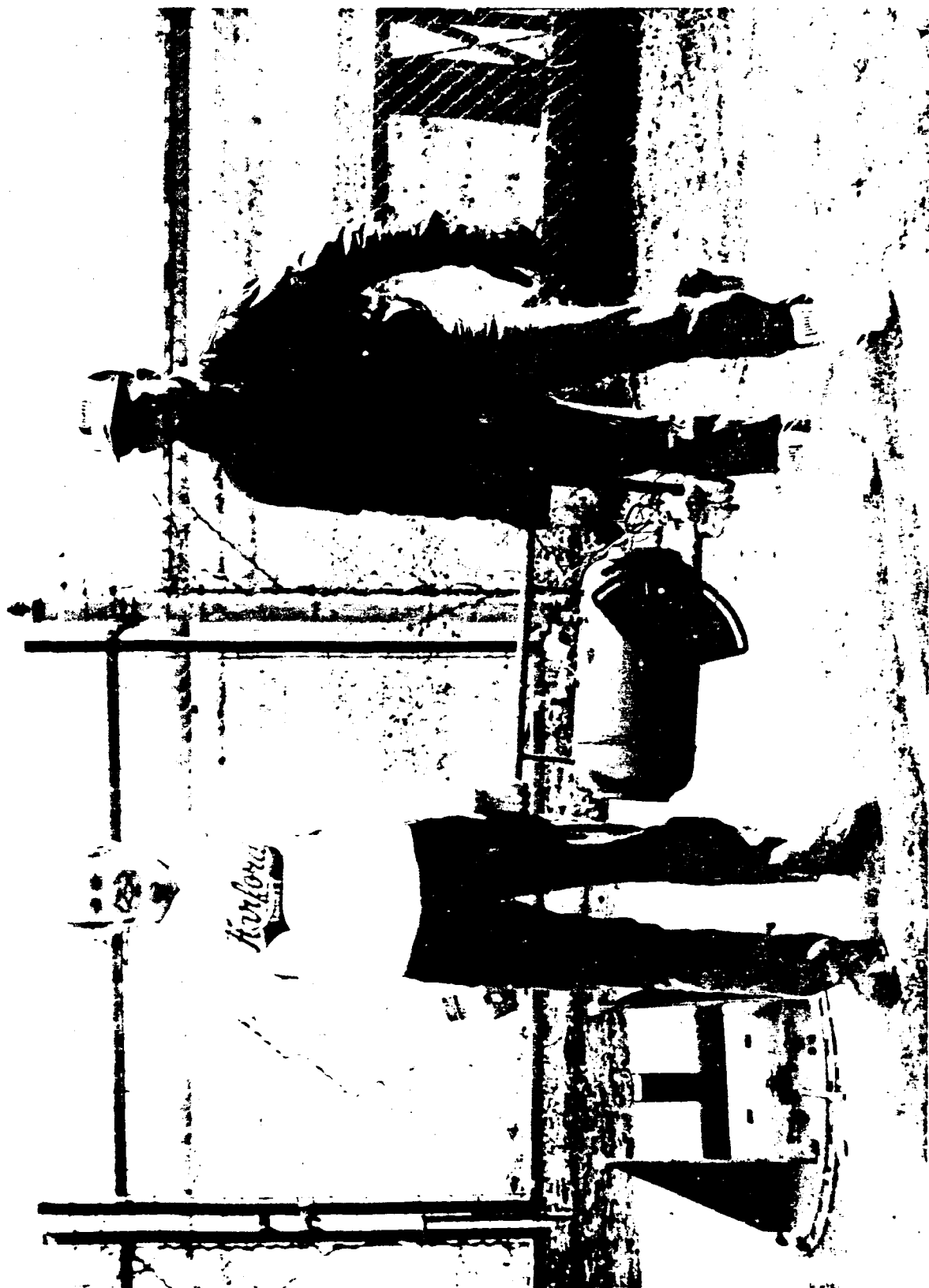


Figure 8. UAGL Component Size and Portability Demonstration

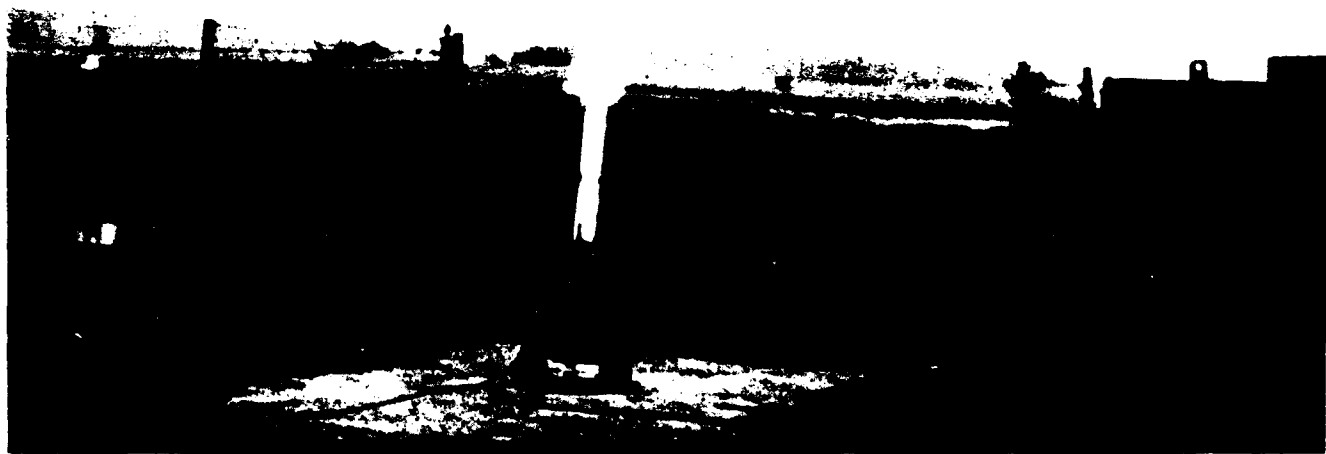


Figure 9. Photograph of Actual Test Firing

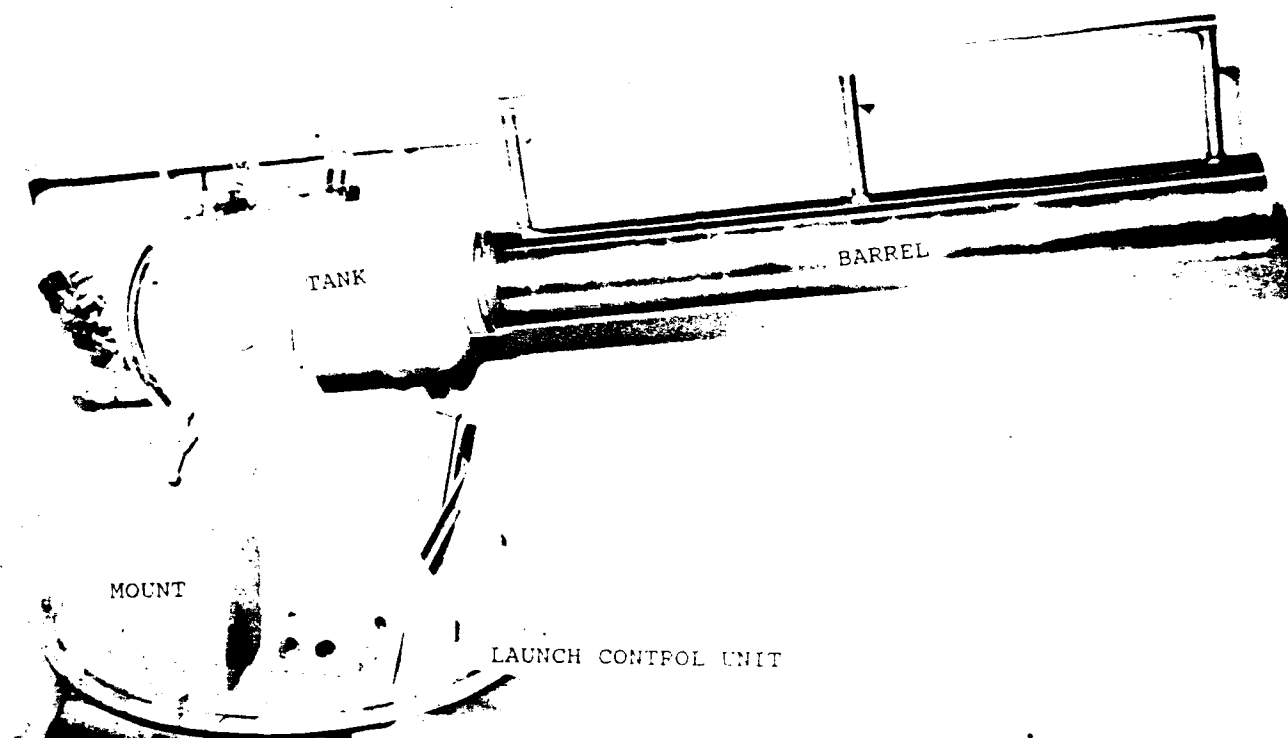


Figure 10. Four Major Components of UAGL

6.4 Barrel Mounting Procedure.

With the tank in a vertical position, place the barrel on top of the charging tank and rotate it clockwise by hand until the barrel's o-ring flange is flush against the tank's o-ring surface. The barrel handle can be used as leverage to tighten the barrel. The barrel handle should align with the supply tank handle as seen in Figure 10.

6.5 Launcher Controls Installation.

Connect the white, 9-pin female connector to the 9-pin male connector located on the charging tank. Connect the black, female, 10-pin connector to the control box. Connect the remaining black and white leads to any convenient 24 vdc supply or battery source. When power is applied, the launch control unit should display 1.2 mV, indicating a zero pressure reading. In addition, the UAGL System requires a supply of nitrogen gas for tank pressurization. A 1/4-NPT female fitting, rated at 1000 psig, is required on

the nitrogen supply to connect it to the UGAL's quick disconnect charging port. The UAGL System should now be fully operational!

7. FIRING PROCEDURE

To fire the UAGL System, first open the purge solenoid, which will allow the air in the barrel to be displaced while the spigot sabot is being loaded into the barrel. Next, load the spigot sabot and payload into the barrel. Elevate the barrel to the desired angle and lock it into place. Turn the key switch on the control box to the off position. Press the red (fill) switch on the control box until the desired pressure is displayed. A graph of pressure versus pressure transducer voltage (which is displayed on the launch control unit) is shown in Figure 11. The launch pressure is dictated by the desired launch velocity and can be estimated from Figure 12. After it is pressurized, the launcher is ready to be fired. To fire the launcher, turn the key clockwise, which will activate the firing solenoid, launching the spigot sabot and payload. Flight trajectories for a 30-lb projectile (typically, this would be a 20-lb projectile affixed to the 10-lb spigot sabot) are illustrated in Figure 13 for various launch angles.

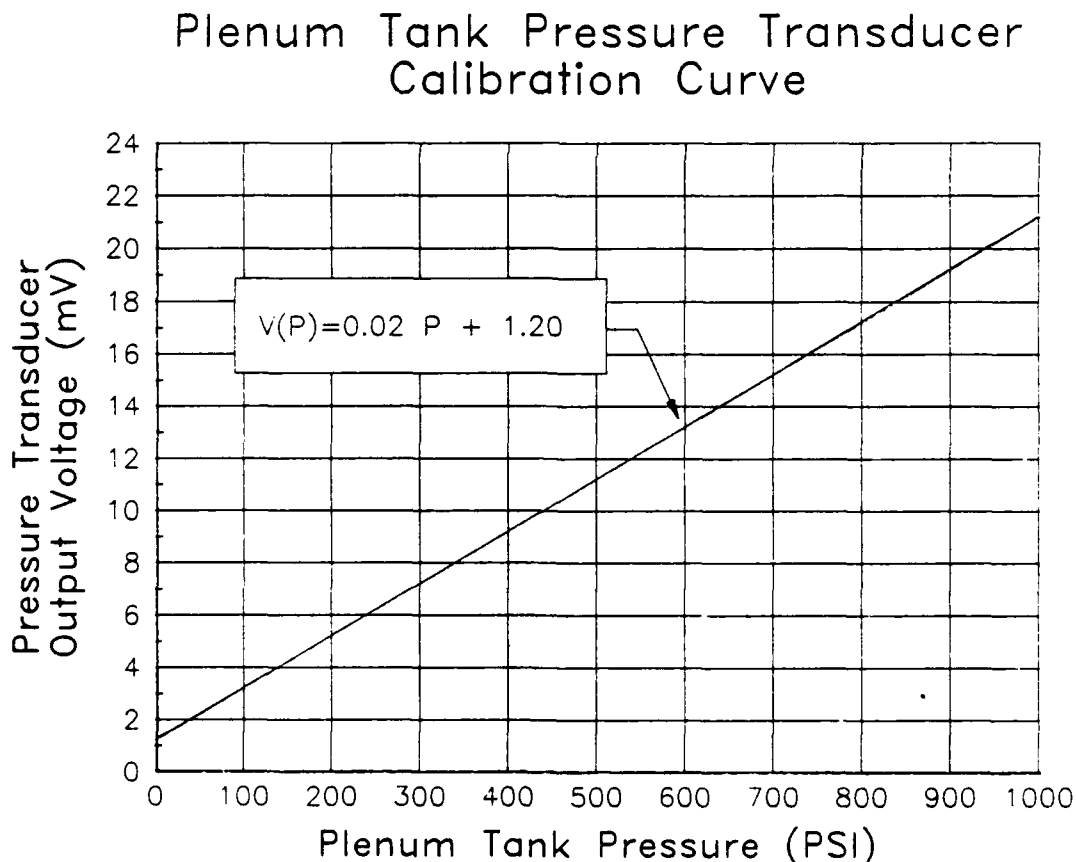


Figure 11. Operating Curve for Launcher Control Unit

UNIVERSAL AIRGUN TANK PRESSURE vs MUZZLE VELOCITY

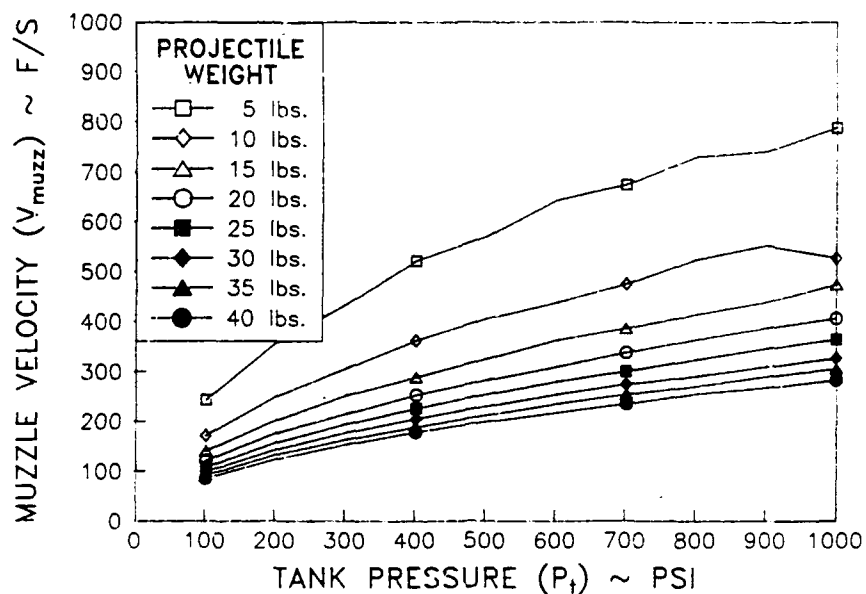


Figure 12. Plot of Muzzle Velocity as a Function of Plenum Tank Pressure

FLIGHT TRAJECTORIES 30 lb. PAYLOAD/SPIGOT SABOT COMBINATION

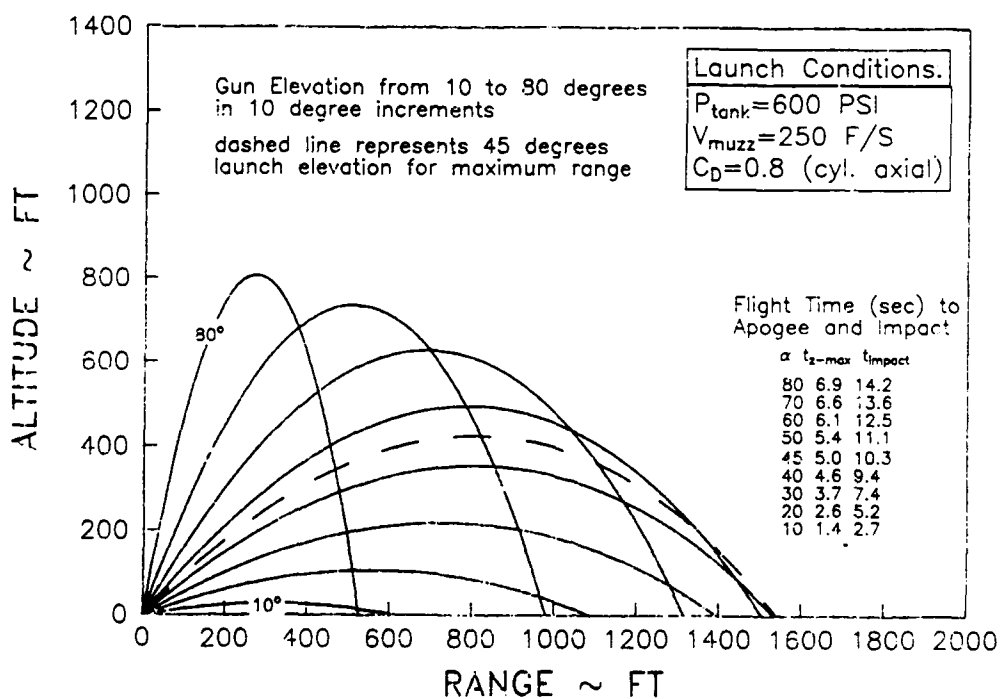


Figure 13. Typical Flight Trajectories

8. FLIGHT OF SPIGOT SABOT AND SLUG

After the UAGL is fired, the spigot sabot and slug travel up and out of the barrel. The shear pin is severed by the acceleration force. While in flight, the spigot sabot follows the payload until the spring, released by the severed shear pin, separates them. The spigot sabot then falls to the ground while the payload travels to its destination. This process is illustrated in Figure 1.

9. MISCELLANEOUS INFORMATION

Recently, the ARCA Br designed protective barrel end caps, a barrel handle, and a protective valve cover for the UAGL. The protective caps will keep the launcher components from getting dirty and being damaged. The handle will help a two-man personnel team to easily carry the barrel and will facilitate assembling and disassembling the barrel from the charging tank.