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STUDY TO DETERMINE THE FEASIBILITY OF USING SABOTS FOR LAUNCHING DEPLETED URANIUM PROJECTILES

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TECHNICAL REPORT AFATL-TR-69-53

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AIR FORCE ARMAMENT LABORATORY

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STUDY TO DETERMINE THE FEASIBILITY OF USING SABOTS FOR LAUNCHING DEPLETED URANIUM PROJECTILES

Mark Rottenberg

ABSTRACT

The feasibility model 7.62 MM Flechette Cartridge developed under this program consists of a depleted uranium flechette assembled within a lightweight plastic sabot and loaded within a standard 7.62 MM NATO Cartridge case. The final configuration evolved in this program was capable of launching depleted uranium flechettes from a conventional rifled barrel at velocities in the order of 4100-4200 fps. Velocities as high as 4545 fps were achieved during the course of the program. Further development effort is required in order to reduce round dispersion and achieve a flechette geometry which will be compatible with system requirements.

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SECTION I

INTRODUCTION

The purpose of this program was to design, develop, fabricate, and demonstrate the feasibility of using sabots for launching depleted uranium flechettes. The friction grip puller type discarding sabot principle was utilized for the purpose of achieving the objectives of this program. In the friction grip principle, a fin stabilized subcaliber flechette is launched through the medium of a pressure transmitting sabot. Because of the sabot's conical shape, the same gas pressure that provides the propelling energy acts as the "clamping" force between sabot and flechette. On barrel exit, the sabot with its seal is disintegrated and discarded by the centrifugal forces introduced by the rifling spin.

Friction grip discarding sabot launched depleted uranium flechettes should provide a level of effectiveness, against both hard and soft type targets considerably beyond that which may be achieved with conventional spin stabilized projectiles loaded within the same cartridge case. These advantages are achieved through the combination of high impact energy per unit frontal area, high length to diameter, and high residual down range velocity. These physical characteristics provide significant advantages primarily in the ability to penetrate increased thicknesses of armor, the ability to penetrate armor at high obliquities and the ability to defeat targets at increased ranges. Since armor penetration is a function of the penetrator mass per unit frontal area, depleted uranium enhances the effectiveness of the flechette as depleted uranium is two and one half times as dense as steel. Furthermore, since depleted uranium has a strong affinity for oxygen, substantial pyrophoric effects can be expected at the target.

The primary objective of the program - "To determine the feasibility of using sabots for launching depleted uranium projectiles" was satisfied early in the program when depleted uranium flechettes were sabot launched at velocities as high as 4545 fps. Thus the majority of the effort subsequent to these early tests was directed towards refining the round so as to achieve a consistent dispersion compatible with the overall program objectives.

Included in this report is a brief description of the design evolution for each of the round components, interior and exterior ballistics characteristics of the finalized round configuration, conclusions and recommendations, and appendixes which include firing data on the finalized round configuration.

SECTION II

DESIGN EVOLUTION

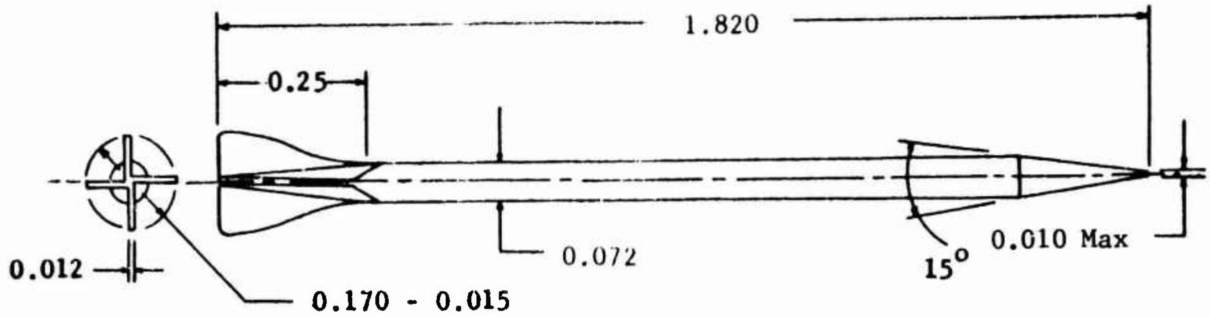
1. FLECHETTE

The geometric characteristics of the flechette were specified by the sponsor. The flechette should be of a low drag configuration and have an L/D (length to diameter ratio) of 24 to 26 and a weight of 28-31 grains. These requirements indicated that the flechette shank diameter would be 0.072 inches, and its length approximately 1.85 inches. Past experience with single fired high velocity flechettes indicated that a canted fin having a span of two to three times the shank diameter would be desirable for stability purposes. Factors influencing point cone geometry include drag and friction grip surface area requirements as well as ultimate terminal ballistic requirements.

Initial effort on the program began with the determination of the feasibility of cold swaging fins on 0.072 diameter depleted uranium shafts. Conventional fin swaging tools were utilized. These tools consist of four dies which are cammed into the uranium rod thus dividing the rod into four equal elements. The ultimate fin span achieved is determined by the depth of die penetration into the rod, the hardness of the rod, the ductility of the uranium as well as its work hardening characteristics.

Two types of depleted uranium were considered, unalloyed and an eight percent molybdenum content alloy (U-8 w/o MO). The depleted unalloyed uranium was found unsuitable for forming due to excessive peen failure caused by the rapid work hardening characteristics of the uranium. Single hits with the forming dies did not produce sufficient fin span and multiple hits caused die failure.

Fabrication of fins by cold swaging proved quite feasible in the case of the U-8 w/o MO alloy. Depleted U-8 w/o MO is a gamma stabilized alloy not subject to as much work hardening as unalloyed uranium. In order to improve die life with the U-8 w/o MO alloy, forming of the fins required three successive hits. The final fin span was approximately 0.165 inch, which is 2.3 times the shank diameter. This fin span has proved to be effective and firing tests during the program indicated it was sufficient to dampen out high yaw launches (over 10°) to less than 3° within 100 yards of flight. Throughout the program there was no evidence of fin failure on the 0.072-inch rod attributable to the stress corrosion cracking phenomenon associated with depleted U-8 w/o MO alloys. It was observed, however, that a small percentage of fins did flake off the rod during the fin forming operations. These failures can be attributed to work hardening and can probably be reduced or eliminated with further refinements in the die design and forming techniques.



Weight - 28.5 Grains

Material - Depleted Uranium Alloyed with 8% Molybdenum

Figure 1. 7.62 MM DU Flechette

It has been recommended that some effort be directed towards determining the feasibility of plating depleted uranium. Plating may eventually be necessary to avoid in-flight ignition of the uranium flechette due to aerodynamic heating. It should be pointed out that crude experiments utilizing a welding torch indicate that for the flight times involved (approximately two seconds to 6000 feet range), the chances of in-flight ignition appear to be nil. However, only actual night firing tests at extended ranges can establish the flechette ignition characteristics.

Depleted uranium and its alloys can be plated. Most of these coatings are applied over a nickel base. Because of the affinity of the uranium for oxygen, it is necessary to acid etch the uranium prior to plating in order to assure adhesion of the nickel coating. Care must be taken to avoid over-etching as was the case with some of the flechettes nickel-plated in this program. Firing tests with these nickel-plated flechettes indicated that they can be pulled with friction grip discarding sabots. Figure 1 illustrates the flechette design as established in this program. It was necessary to use a 15° point so as to have a maximum amount of flechette surface area available to the sabot pressure cone. Total zero yaw drag coefficients for the flechette have been computed and are illustrated in figure 2.

The C_{D_0} of the depleted uranium flechette was determined analytically by modifying the nose drag of a similar 0.072 diameter steel projectile. The drag data for the steel flechette had been experimentally determined by Ballistics Research Laboratory, Aberdeen Proving Ground, Aberdeen, Maryland. The nose drag for the DU flechette contributed approximately 18 percent with the remaining drag being developed by the shank and fins. A plot of velocity decay versus range, assuming zero yaw and using these drag coefficients, is included as figure 3.

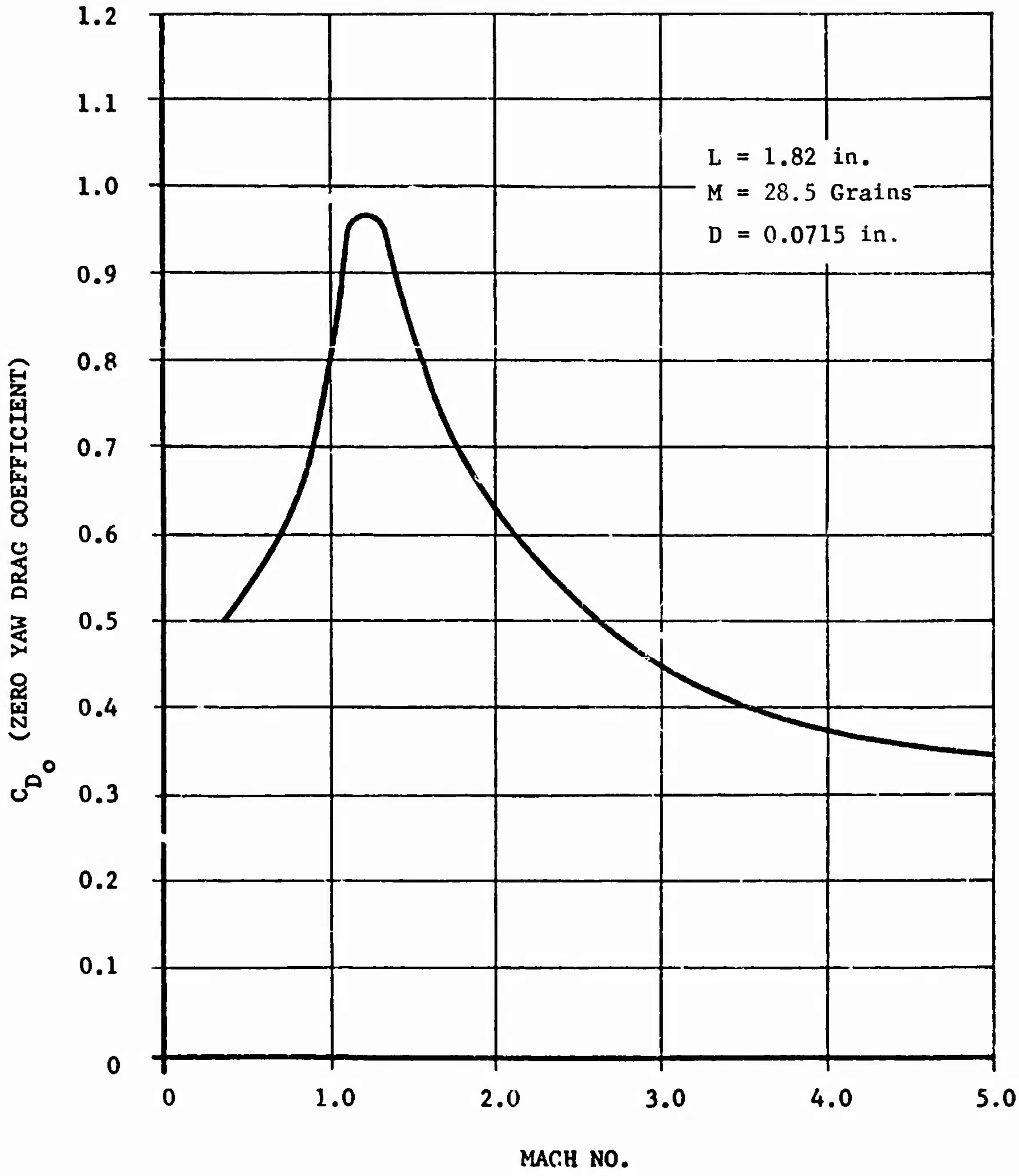


Figure 2. Zero Yaw Drag Coefficient Versus Mach No.

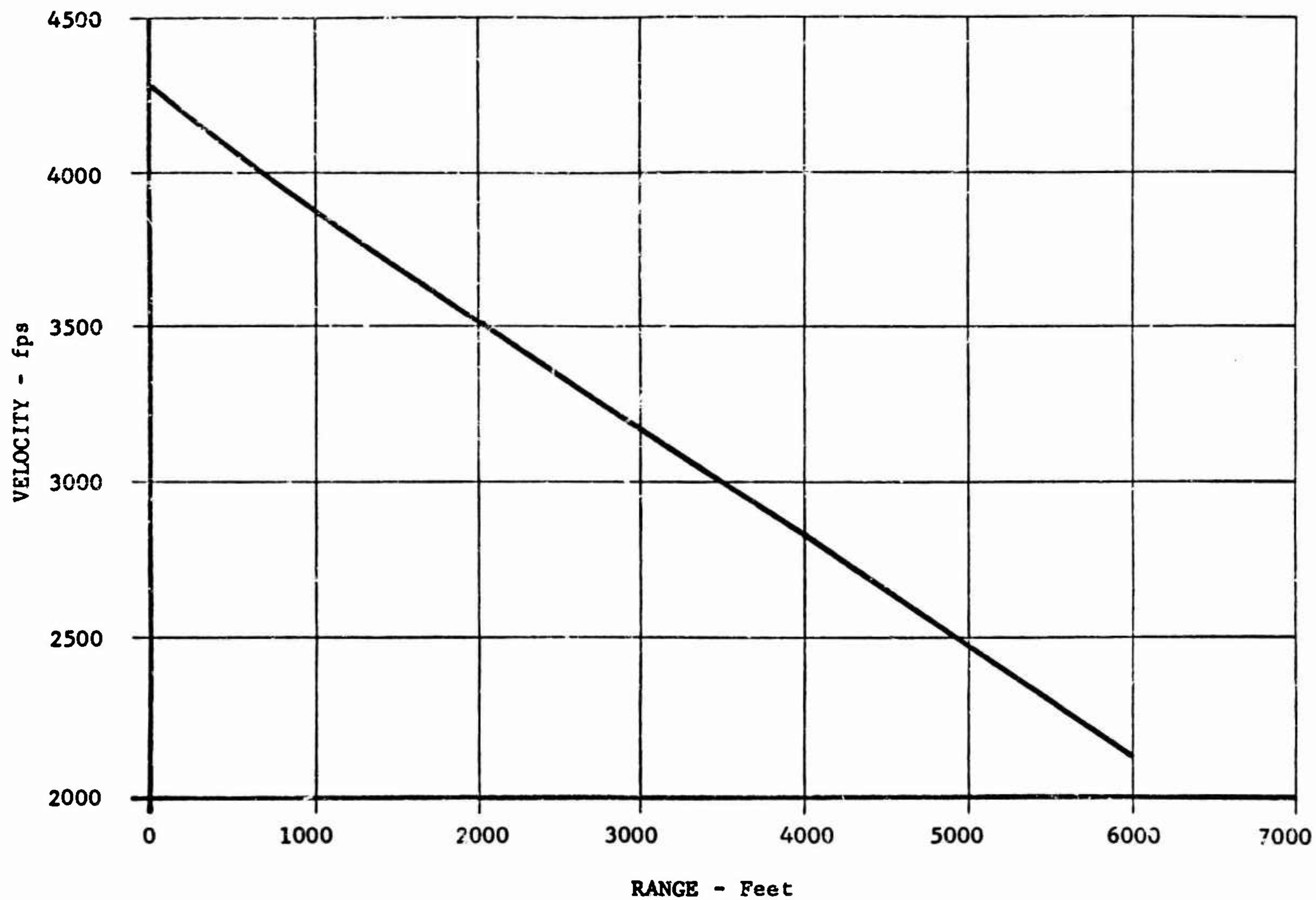


Figure 3. Velocity Versus Range

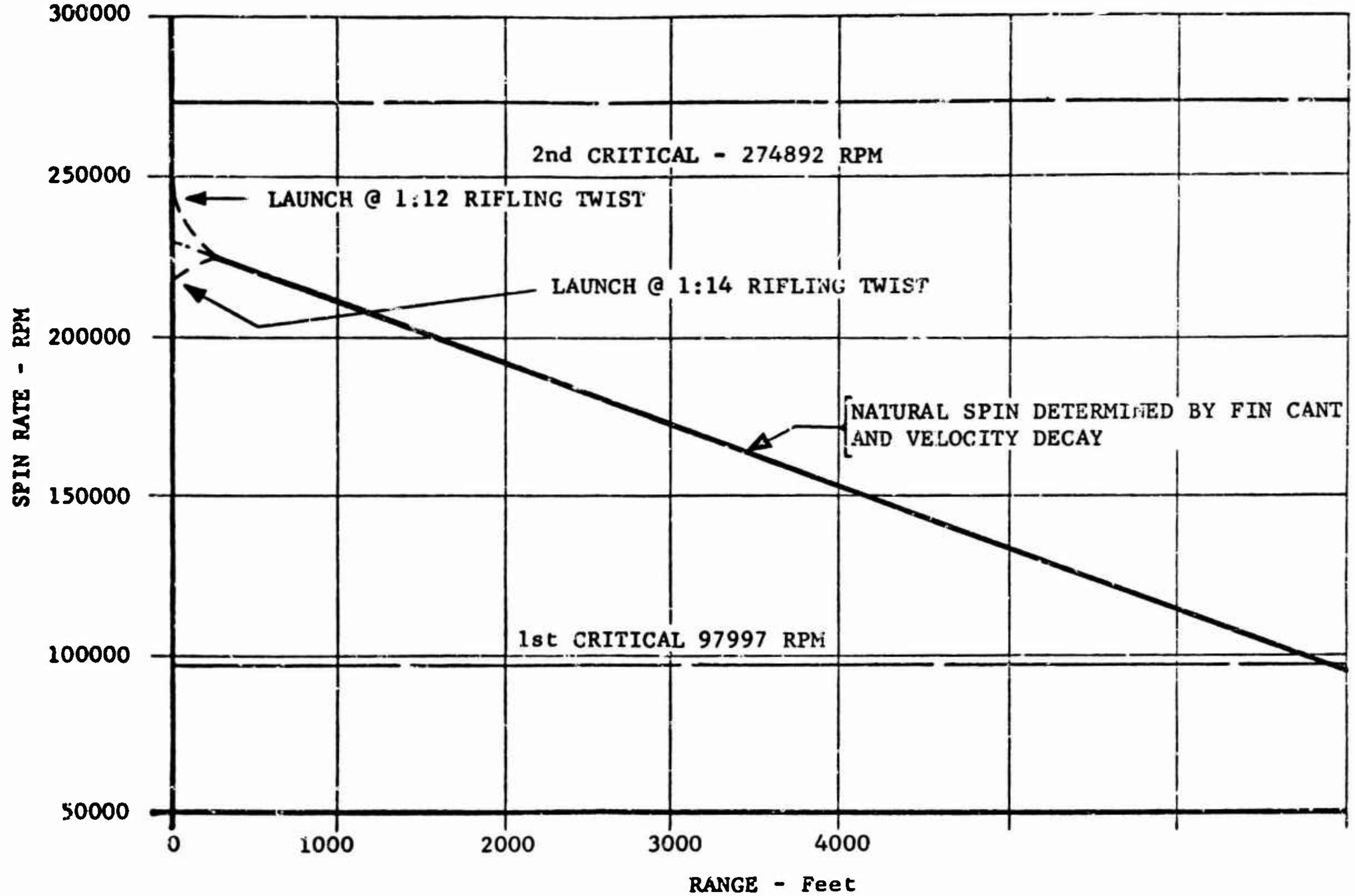


Figure 4. Spin Rate Versus Range

A plot of spin rate versus range for the DU flechette is included as figure 4. Note that the launch and natural spin as determined by fin cant and velocity decay lies between the two critical spin rates. Some bending of the flechettes has been observed in the X rays and on the targets. It is believed at this time that this bending is due to eccentricities of the assembly within the barrel. These eccentricities can be reduced with the further refinement of the manufacturing tooling.

2. SABOT

The primary design consideration for the sabot was to achieve the proper balance between the tensile and shear forces so as to avoid sabot failure and projectile slippage. Thus the sabot must be designed to grip the flechette upon the initial application of ballistic gas pressure and to maintain its grip throughout the travel down the barrel without failing structurally. At barrel exit the sabot must disintegrate and separate itself from the flechette without disturbing the flight of the flechette.

In order to satisfy these requirements, a conventional one-piece puller type sabot was designed. The sabot gripping cone was designed to grip over as much of the flechette cylindrical length as would be feasible in order to assure maximum pulling reliability. The outside diameter of the sabot was established at 0.299-0.001 so as to assure minimum clearance without engagement of the 0.300 diameter rifling lands. The sabot was machined in one piece from unidirectional glass filled polyester, and razor slit fore and aft to facilitate breakup or disintegration at barrel exit. The hole for accommodating the flechette was drilled. At a late stage in the program, a shallow circumferential crimp groove was added to facilitate assembly.

3. SEAL

The seal serves the function of sealing the ballistic gas pressure and also provides some support to the assembly during barrel travel. At muzzle exit, the seal must separate cleanly from the assembly so as not to impede sabot separation. Initially, a short nylon obturator seal was utilized, but as the program progressed it was apparent that a number of changes would be required. It was thus necessary to modify the seal so as to:

a. Increase the volume available for propellant.

b. Improve the separation characteristics.

c. Provide additional support for the sabot during barrel travel.

d. Increase the assembled round length to that of the standard NATO round.

At the completion of the program, the final seal configuration evolved consisted of a semi-obturator hi density polyethylene seal which was razor slit in four places for separation purposes. The outside diameter of the seal was cylindrical with a diameter of 0.307-0.002 which will engage the barrel rifling.

4. CARTRIDGE ASSEMBLY

Figure 5 illustrates the cartridge assembly ultimately evolved in this program. The initial configuration tested in this program consisted of essentially the same sabot as illustrated but assembled with a short nylon obturator type seal. This assembly was inserted within the case and the case crimped directly on the forward part of the sabot nose section. Though the rounds pulled, this design was objectionable as the cartridge assembly was substantially shorter than the standard NATO cartridge.

Thus in order to assure compatibility with existing weapons, magazines, and feed systems, it was necessary to lengthen the assembly by either increasing the length of the sabot nose or moving the sabot out of the cartridge case and crimping on the seal. Lengthening the sabot nose proved to be unsatisfactory for obvious reasons, thus it was necessary to change the seal configuration to provide for a crimping surface. Thus the configuration illustrated in figure 5 was evolved. Using this assembly and loading with 40 grains of WC 665 double based ball propellant, muzzle velocities of 4100-4200[1] fps could be achieved from a 30 inch barrel at an average pressure of 55,000 psi. The loading density for this charge was approximately 90 percent. Figure 6 illustrates pressure travel and velocity versus time for the final configuration.

Two hundred rounds were then fabricated to this configuration and then delivered to the Government for evaluation.

5. DISPERSION

The use of sabots to pull depleted uranium flechettes was proven feasible early in the program. Thus the majority of the effort subsequent to these early tests was directed towards refining the round so as to achieve a consistent dispersion compatible with the overall program objectives. The results of these tests indicate that for this high performance sabot configuration in a rifled barrel that there were two design parameters which were the primary factors affecting accuracy. These were sabot and seal separation at muzzle exit and the geometry of the assembly within the barrel.

Sabot and seal separation was achieved by preslitting the sabot and seal. This also assured breakup of the sabot and seal into lightweight fragments. The geometry of the round was of major concern because of the spin effects within the rifled barrel. These effects indicated a requirement for close tolerances for the hardware as is required in conventional ammunition. Thus, effort in the latter part of the program was directed toward establishing manufacturing and quality control techniques for assuring the maintenance of the close tolerances required for this round. It should be pointed out that this effort was limited because of the funding limitations of the program.

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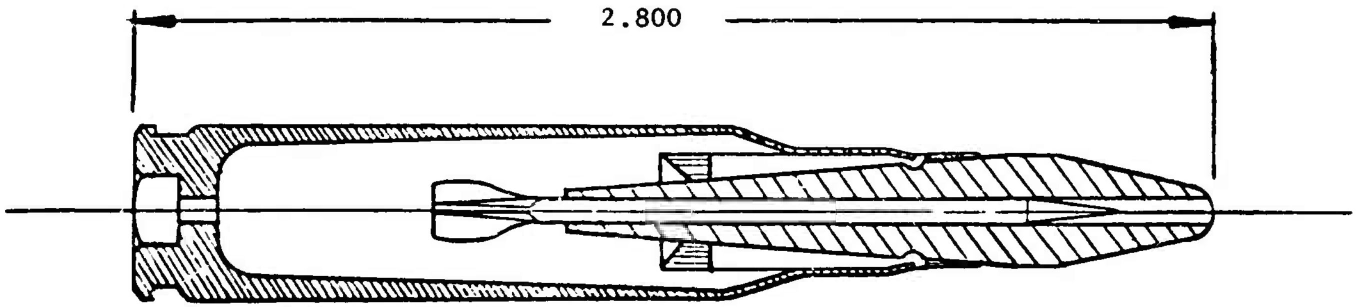
[1] See note in appendix III.



FLECHETTE

Weight - 28.5 Grains

Material - Depleted Uranium Alloyed with 8% Molybdenum

Length - 1.82 inches

Diameter - 0.072 inch

SEAL

Weight - 7.0 Grains

Material - High Density Polyethylene

SABOT

Weight - 23.4 Grains

Material - Glass Reinforced Polyester

Muzzle Velocity - 4200 fps

Propellant - 40 Grains

Figure 5. 7.62 MM NATO Cartridge (DU Flechette)

Charge - 40 Grains - WC 665
Total Propelled Mass - 58.9 Grs.

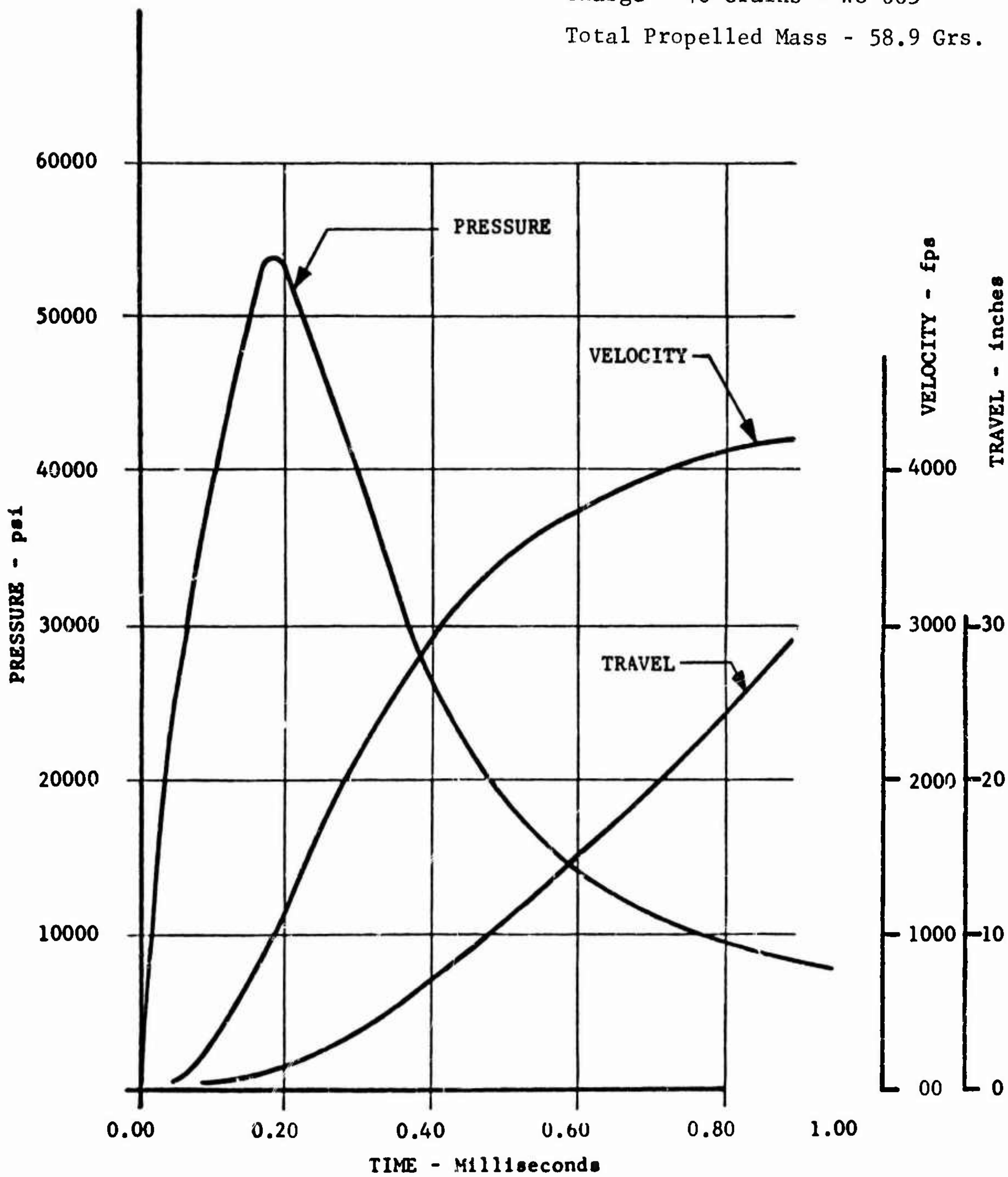


Figure 6. Pressure, Travel Velocity Versus Time

The dispersions achieved in this program, over 4 mils, should not be considered indicative of the ultimate performance of this round. Such parameters which affect dispersion such as component and assembly eccentricities, separation techniques, and flechette mass and geometry could only be investigated superficially because of the limited scope of the program. For comparison purposes, a 20 MM DU flechette round of essentially the same configuration in which the design has been substantially completed has produced dispersions as low as 0.7 mils standard deviation for a 20 round group.

SECTION III

CONCLUSIONS AND RECOMMENDATIONS

The results of this program indicate that it is feasible to use sabots for launching depleted uranium flechettes. Launch velocities as high as 4545 fps were achieved. The velocity of the configuration ultimately evolved in this program was between 4100 and 4200 fps.

Efforts expended on this program indicate the feasibility of swaging fins directly onto depleted uranium alloy (U-8 w/o MO) projectile rods. Flechettes fabricated from this alloy when fired from a standard 7.62 MM barrel were aerodynamically stable. Calculations indicate that these flechettes should exhibit low drag characteristics and should have a residual velocity of at least 2000 fps at 6000 feet when fired at a muzzle velocity of slightly over 4200 fps.

Limited firing tests with this round have indicated that a substantial degree of terminal effectiveness can be achieved. It is thus recommended that efforts be directed towards continuing this program so that the design of the round may be refined. The first area of investigation should be a comprehensive evaluation to insure that the optimum flechette geometry is selected for refinement. Design fabrication and testing effort should then be directed towards obtaining a low dispersion round configuration having the maximum degree of muzzle energy without exceeding the pressure limitations of the system. A suggested goal for dispersion would be 1 mil standard deviation in the x and y axis, and for muzzle velocity 4400 fps from a 20 inch barrel for a 28 grain flechette. Following the completion of the design, a substantial number of rounds should then be fabricated and evaluated for weapon compatibility and effectiveness.

APPENDIX I

FINAL DEVELOPMENT TESTS

ROUND NUMBER	VELOCITY (FPS)	ROUND NUMBER	VELOCITY (FPS)
12-23-68-1	3731	12-23-68-9	---
12-23-68-2	4098	12-23-68-10	4202
12-23-68-3	4098	12-23-68-11	---
12-23-68-4	4065	12-23-68-12	4237
12-23-68-5	4132	12-23-68-13	4098
12-23-68-6	4202	12-23-68-14	4098
12-23-68-7	4198	12-23-68-15	---
12-23-68-8	4065		

CONFIGURATION - AS ILLUSTRATED IN FIGURE 5
CHARGE - 40 GRAINS WC 665 LOT NO. 43
BARREL LENGTH - 30 INCHES
VELOCITY AVERAGE - 4102 FPS
DISPERSION MEASURED @ 50' IN MILS

	MEAN RADIUS	σ x	σ y	(σ = sigma)
100%	4.9	3.25	4.9	
80%	3.6	3.15	2.8	

(3 Rounds Discarded)

These results should not be considered indicative of the ultimate capability of the round as only a comparatively limited effort could be directed towards achieving a low dispersion round in this program. For comparison purposes dispersion data for a 20 MM DU flechette round in which the design has been substantially completed is listed below.

DATE FIRED - 3/17/69

RANGE FIRED - 100 Ft.

NUMBER OF ROUND - 20

MEAN RADIUS - 0.9 Mils

σ x - 0.74 Mils

σ y - 0.67 Mils

APPENDIX II

PRESSURE TEST RESULTS

ROUND NUMBER	VELOCITY	PEAK PRESSURE
12-30-68-1	4274 FPS	54524
12-30-68-2	4310 FPS	55830
12-30-68-3	4310 FPS	55830
12-30-68-4	INSTRUMENTATION FAILURE	54524
12-30-68-5	4000 FPS	52000

CONFIGURATION - AS ILLUSTRATED IN FIGURE 5

CHARGE - 40 GRAINS WC 665 LOW NO. 43

BARREL LENGTH - 30 INCHES

VELOCITY AVERAGE - 4235 FPS

PRESSURE AVERAGE - 54542 PSI

APPENDIX III

ACCEPTANCE TEST RESULTS

ROUND NUMBER	VELOCITY (FPS)
2-24-68-1	3846
2-24-68-2	4202
2-24-68-3	3754
2-24-68-4	4125
2-24-68-5	4202
2-24-68-6	4125
2-24-68-7	4202
2-24-68-8	4125
2-24-68-9	4125
2-24-68-10	4202

CONFIGURATION - AS ILLUSTRATED IN FIGURE 5

CHARGE - 40 GRAINS WC 665 LOT NO. 43

BARREL LENGTH - 30 INCHES

AVERAGE VELOCITY LESS ROUNDS 1 AND 3 = 4164

DISPERSION @ 100' IN MILS

	MEAN RADIUS	σ x	σ y
90% (1 Round Discarded)	5.49	5.94	2.53

NOTE: During the program occasional partial slippage of the sabot with respect to the flechette was noted. When this partial slippage occurred the launch velocity fell to approximately 3700-3800 fps. Experience in similar programs has indicated that these partial slips will disappear as the round design and associated fabrication tooling and techniques are refined.

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13. ABSTRACT

The feasibility model 7.62 MM Flechette Cartridge developed under this program consists of a depleted uranium flechette assembled within a lightweight plastic sabot and loaded within a standard 7.62 MM NATO Cartridge case. The final configuration evolved in this program was capable of launching depleted uranium flechettes from a conventional rifled barrel at velocities in the order of 4100-4200 fps. Velocities as high as 4545 fps were achieved during the course of the program. Further development effort is required in order to reduce round dispersion and achieve a flechette geometry which will be compatible with system requirements.

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Sabot						
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Depleted Uranium (DU)						
Round Dispersion						

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