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A PRELIMINARY DESIGN STUDY OF THE ADAPTABILITY OF FIN STABILIZED DISCARDING SABOT PROJECTILES TO THE 5"/38 GUN

21 AUGUST 1956

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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A PRELIMINARY DESIGN STUDY OF THE ADAPTABILITY OF FIN STABILIZED DISCARDING SABOT PROJECTILES TO THE 5"/38 GUN

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ABSTRACT: A study has been made of the adaptability of fin stabilized, discarding sabot projectiles to the 5"/38 gun. Such a projectile has a definite time-to-target and range advantage over spin stabilized projectiles. Preliminary design details of fixed and semi-fixed 5-inch rounds incorporating an FSDS projectile are presented. The designs are patterned after similar type projectiles which have been developed at NOL(WO). These projectiles could be fired through rifled barrels interchangeably with standard spin stabilized ammunition but modifications to ammunition handling and fire control equipment would be required for compatibility with the FSDS round. The magnitude of the alterations involved would depend upon the efficiency desired in the overall system. The fixed round, one-piece ammunition offers several advantages in respect to stowing, handling and increased cyclic rate. Relative merits of utilizing the British 127/59 mm round in the 5"/38 gun are also discussed.

U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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The investigation documented in this report was performed at the request of the Bureau of Ordnance under Task NOL-B3b-211-1-54. The purpose of this study was to determine the feasibility of adapting fin stabilized ammunition to the service 5-inch rifled gun. This report is intended for information only and is not to be used as the basis for official action.

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By direction

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A PRELIMINARY DESIGN STUDY OF THE ADAPTABILITY OF FIN STABILIZED DISCARDING SABOT PROJECTILES TO THE 5"/38 GUN

INTRODUCTION

1. The Naval Ordnance Laboratory was directed by reference (a) to study the fin stabilized discarding sabot projectile as adapted to the 5-inch rifled gun. A desired feature of such a round would be interchangeability with standard projectiles. Such a feature would permit firing fin stabilized antiaircraft projectiles and spin stabilized bombardment projectiles from the same gun, depending upon the tactical situation.

2. Subcaliber projectiles offer a means of improving the antiaircraft effectiveness of conventional guns due to higher muzzle velocity, reduced drag, and increased rate of fire. These projectiles are usually relatively slow spinning, aerodynamic stability being furnished by fins. Such a projectile consists of an arrowshell centered in the gun barrel by means of the sabot which also serves as an obturator for the propellant gases. Upon emergence from the muzzle, the sabot discards, allowing the arrowshell to proceed along its trajectory. Fin stabilized subcaliber projectiles may be classified into two general categories, center drive and base drive, according to the point of application of the sabot applied driving force. A typical center drive projectile is shown in Figure 2 and a typical base drive projectile is shown in Figure 7.

3. Preliminary design studies of both projectile types for the 5"/38 gun have been made by NOL. Details of the proposed projectiles are presented in later sections. Consequences of utilizing the British 127/59 mm projectile in the 5"/38 gun are also discussed in subsequent sections.

4. This report is concerned with fin stabilized discarding sabot projectiles in the 5"/38 gun and the conclusions to be drawn will apply to that gun only.

PRELIMINARY DESIGN OF A CENTER DRIVE FIN STABILIZED PROJECTILE FOR THE 5"/38 RIFLED GUN

5. Navy arrowshell development of this type has been concerned primarily with the 3"/50 and 3"/70 guns, references (b) and (c). Considerable success has been obtained by firing from smoothbore guns, the preferable weapon for this type of projectile. About a dozen rounds have also been fired from rifled guns. Enough experience has been gained to indicate that subcaliber projectiles can be successfully adapted to 5"/38 rifled barrels.

6. The initial design of the 5"/38 fin stabilized projectile is patterned after the 3-inch versions. The round is designed as fixed ammunition with

the projectile crimped into the cartridge case (Figure 1). The term projectile refers to an assembly of an arrowshell plus discarding sabot (Figure 2). Arrowshell details are shown in Figure 3 and sabot details in Figures 4 and 5. A brief summary of data is presented in Table I followed by a description of the individual components. For brevity the NOL design center drive FSDS projectile will be referred to as the 5/2.5-inch projectile.

TABLE I

PRINCIPLE WEIGHTS AND DIMENSIONS OF 5/2.5-INCH FSDS (CENTER DRIVE) PROJECTILE

WEIGHT (lb)	
1. High Explosive	3.0
2. Arrowshell (including HE)	18.7
3. Sabot	6.3
4. Projectile (2 + 3)	25.0
5. Cartridge (including propellant)	54.0
DIMENSIONS (in.)	
Cartridge length	43.1
Projectile length	32.0
Arrowshell body diameter	2.5
Fin Span	5.0
Center of gravity (from base)	15.0 (46.9%)

7. The arrowshell consists of a nose, tail, body and high explosive (see Figure 3). For the arrowshell to possess satisfactory aerodynamic characteristics with the HE capacity considered, the arrowshell body diameter should be approximately 1/2 caliber. Several factors entered into the selection of projectile length. Any intrusion into the cartridge case will decrease the space available for propellant and a compromise has to be made. A practical length limit is also imposed due to the stresses involved in accelerating the projectile in the gun. Taking these factors into consideration, a tentative over-all length of 32 inches was selected.

8. In order to obtain a maximum ratio of high explosive to metal parts weight, the tail and nose of the arrowshell are made of aluminum alloy and the body is made of high strength alloy steel having a yield point of approximately 170,000 psi under static conditions. Annular grooves are machined on the outside of the body to provide for sabot attachment. The body wall is thickened under the grooves to obtain the necessary strength in this section. To gain better aerodynamic characteristics, the aft end of the body is boattailed and the nose is streamlined. An asymmetrical bevel is provided on the fins to produce a slow spin of about 30-35 rps as an aid to trajectory accuracy. Shoes are machined on the fins to span the rifling grooves in the gun barrel. The tail has a protective oxide coating, but steel shoes or a shroud may be required on the bore riding surfaces of the fins since rifled barrel tests of the 3"/70 arrowshell have shown the fins to be subject to damage. The internal shape of the nose and the tail will be largely dependent on the location of the fuze.

9. The sabot assembly consists of four identical heat-treated alloy steel segments held together on the arrowshell by a molded nylon obturating band (see Figures 4 and 5). The annular groves on the arrowshell body engage corresponding projections on the internal surface of the sabot leaving the sabot free to rotate. Only a slight amount of spin is imparted to the arrowshell as a result of rifling. The sabot will be rotating at approximately 300 rps at the muzzle. Centrifugal force plus the effect of muzzle blast will break the nylon band allowing the sabot to separate. When the cartridge is rammed into the chamber there is a high lip at the breech face which must be cleared. To aid in clearing this lip, a large sloped surface is provided on the forward surface of the sabot. An alternate proposal is to attach a plastic or metal sleeve to the front of the sabot as shown in Figure 5. Such a sleeve would have the advantages of decreasing weight and providing a smaller slope angle.

10. Several modifications are necessary to the cartridge case, (see figure 1). It is desirable to crimp the cartridge case to the steel part of the sabot. Since the steel portion of the sabot must be very slightly under bore size, it is necessary to neck down the inside diameter of the front end of the case from 5.31" to approximately 5.0". To assist in centering the projectile in the cartridge case and prevent excessive sidewise movement during firing, it is advisable to spot weld a sleeve of 5" i.d. in the cartridge case. This sleeve is perforated to allow free flow of gas. A loading hole is provided in the base of the cartridge case to permit loading of propellant after the projectile is crimped in place. An alternate centering device to the sleeve mentioned above is the use of four rails to guide the fins during travel in the cartridge case. This is the method used for the 3"/50 and 3"/70 rounds.

11. Theoretical performance calculations have been made to compare the 5-inch arrowshell with the standard 5"/38 projectile. Since no firings or wind tunnel tests have been performed on the 5/2.5-inch projectile it was necessary to make several assumptions. A theoretical muzzle velocity was

obtained using the method given in reference (d) as modified by reference (e). Assumptions were made and a solution determined for the completely burned powder condition. Using this value of muzzle velocity, a partial trajectory was plotted for a QE of 45° (see figure 8). Due to lack of information regarding the drag coefficient, the C_D vs Mach number curve of the 3"/70 arrowshell (reference (b)) was assumed to apply since the two arrowshells are dimensionally similar. As can be noted from Figure 9, between the ranges of 2,000-10,000 yards slant range, the time of flight to a particular range is considerably less for the arrowshell than for a standard 5"/38 projectile. A theoretical performance comparison between the standard 5"/38 projectile and the 5/2.5-inch arrowshell is presented in Table II. This study has not attempted to optimize the interior and exterior ballistics for the 5/2.5-inch round but the values presented are believed to be a good approximation to the performance attainable.

TABLE II

A Comparison Between The 5/2.5 Inch FSDS (Center Drive) Projectile and the 5"/38 AA Projectile Mk 35

	5"/2".5 Projectile	5"/38 AA Projectile
Breech Pressure (long tons copper)	18	18
Gun Fired Weight (lb)	25	55
Maximum Acceleration (g's)	*30,000	14,000
Chamber Volume (in^3)	522	551
Charge Weight (lb)	15	17
Muzzle Velocity (fps)	*3,800	2,600
Flight Weight (lb)	18.7	55
Total Round Weight (lb)	54	85
High Explosive Weight (lb)	3	8
Time of Flight (sec) to 10,000 yds. slant range (QE = 45°)	* 12.1	23
Maximum Altitude QE = 85° (ft)	*19,000	35,200

*Theoretical

POSSIBLE DEVIATION OF 5/2.5 INCH FSDS ROUND FROM PRESENT DESIGN

12. Since the 5/2.5-inch round is only in the preliminary design stage, most of its features are copied from the 3-inch FSDS designs. By deviating from the 3-inch version in the design of some components, it may be possible to improve the performance of the 5"/38 FSDS projectile.

13. It would be desirable to decrease sabot weight by using a lighter material such as aluminum. An aluminum sabot is used on the British 127/59 mm projectile. Feasibility of aluminum sabots has been established in limited firings in the 3"/50 smoothbore gun (reference (c)).

14. To provide minimum time of flight to a given slant range, a heavier arrowshell, of greater ballistic density, may be preferred. Such a heavier projectile could be obtained by substituting a steel nose or tail for the aluminum components of the present design. It may also be feasible to increase the body diameter slightly (on the order of .10 inches).

15. The chamber diameter at the forward end of the Mk 5 or Mk 8 cartridge case is 5.4 inches. The maximum sabot diameter is slightly greater than the 5.1 inches across the grooves of the rifling. This clearance could cause sabot separation while still in the chamber resulting in improper sabot operation. Such a condition existed in the 3"/70 gun and difficulty was experienced in obtaining proper rifled barrel operability. If similar problems are encountered in the 5"/38 gun, it may be necessary to lengthen the cartridge case as shown in Figure 6. The increased length would locate the sabot where the chamber and sabot band are nearly the same diameter.

PRELIMINARY DESIGN OF A BASE DRIVE FIN STABILIZED PROJECTILE FOR THE 5"/38 RIFLED GUN

16. Several hundred rounds of base drive fin stabilized projectiles were fired from the 8-inch gun in conjunction with the AAP program (Task NOL-Re3f-614-1). The majority of these rounds were fired in a smoothbore gun but several rounds were also fired from a rifled barrel In view of the excellent results obtained with these projectiles, it was considered advisable to investigate a projectile of this type for the 5-inch gun.

17. A preliminary design of a round based on an arrowshell of 3.5-inch diameter and 30-inch length is shown in Figure 7. The arrowshell is retained in the sabot by means of a brazed stud and flexible diaphragm assembly. Upon firing, gas pressure deforms the diaphragm and breaks the brazed point, thereby freeing the arrowshell from the sabot. When the projectile emerges from the muzzle, air pressure causes the sabot petals to peel back. The sabot then discards and the arrowshell continues along its trajectory. Table III is a comparison of this projectile to the standard 5"/38 MK 35 AA Projectile.

A COMPARISON BETWEEN THE 5/3.5 INCH FSDS (BASE DRIVE) PROJECTILE AND THE 5"/38 AA PROJECTILE MK 35

	FSDS Projectile	Projectile MK 35
Arrowshell Weight (lb)	43	
Sabot Weight (lb)	10.4	
Projectile Weight (lb)	53.4	55
Muzzle Velocity (fps)	2630	2600
High Explosive (lb)	8	8
Overall Length (in.)	31.5	20.82
Arrowshell Length (in.)	30	
Arrowshell Body Diameter (in.)	3.5	
Total Round Length (in.)	60.0	49.3

18. The overall length of the two-piece 5/3.5-inch base drive round is incompatible with the present rammer. It is not practical to insert the 5/3.5-inch projectile into the cartridge case to decrease the overall round length since too much propellant would be displaced. The ramming operation would have to be performed in two steps, thereby reducing the rate of fire.

19. Since the 5/3.5-inch round is not adapted to the rammer, complete performance computations were not performed. Relative merits of the 5/2.5-inch center drive and the 5/3.5-inch base drive projectiles were therefore not determined. The center drive projectile offers the advantage of higher muzzle velocity whereas the base drive projectile has a greater high explosive capacity.

CONSEQUENCES OF ADOPTING THE BRITISH 127/59 mm CARTRIDGE

20. If possible, it would be preferable to use an existing operable round. Such a course would make it unnecessary to go into the development and testing program which a new projectile design would require. Some success has been experienced with the British 127/59 mm projectile

(reference (f)) which is designed for a 5-inch gun. Although this round is intended for smoothbore firing, it was considered worthwhile to investigate its usefulness to the Navy.

21. The 127/59 mm cartridge case is larger than the Mk 5 or Mk 8 cases, making it necessary to re-chamber the barrel if this round is adopted. Such an alteration would appear to pose no problem since the operation could be performed at the same time the barrel is smoothbored. Calculations indicated that the yield strength of the barrel would not be exceeded. However, investigation revealed several points of possible interference existing in the ramming and breech mechanisms which would, as presently designed, be incompatible with the British cartridge case. These difficulties, all due to the larger diameter of the British case, are as follows:

a. Top of breechblock too high in the lowered position resulting in improper alignment for the cartridge to be rammed into the gun.

b. Insufficient clearance between the cartridge case extractors.

c. The ramming trough in the housing too narrow to accomodate the larger case.

The amount of interference involved is very small being less than 1/2 inch. When it is considered that alterations would be required to smoothbore and re-chamber the barrel for this round, the additional revisions to the housing may not be objectionable.

22. To eliminate the interference which the larger British cartridge case would produce, the possibility of fitting the 127/59 mm projectile into a new or modified Navy case was examined. It was concluded that developing a new smaller case similar to the British cartridge case would be impractical due to the expense involved. Some alterations to the projectile would be required to adapt a modified Mk 5 or Mk 8 case to the 127/59 mm projectile.

23. It is obvious that several revisions, either to the gun or the cartridge, would be required to permit firing of the 127/59 mm projectile from the 5"/38 gun. Even then the projectile would still be restricted to smoothbore barrel use unless additional alterations were made to the tail and the sabot to permit rifled barrel operation.

MODIFICATIONS REQUIRED TO EXISTING SHIPBOARD EQUIPMENT FOR CENTER DRIVE FIN STABILIZED AMMUNITION

Gun Mount and Associated Components.

24. An initial objective of this study was to attempt to design a projectile compatible with existing handling equipment and interchangeable with standard 5"/38 ammunition. Examination of the present ammunition hoisting and ready service equipment indicates that it would be difficult if not impossible to handle the FSDS cartridge under rapid fire conditions due to the overall length of the one-piece round. The hoists and ready service racks are

virtually integral components of the ship. Therefore, any modification will prove to be a major alteration amounting essentially to a redesign of the [illegible]. However, if the necessary alterations were made to permit handling of the longer FSDS cartridge, interchangeability would be no problem.

25. Since the total cartridge length of the 5/2.5-inch round is less than the cartridge case plus projectile length of the standard 5"/38 round the rammer has sufficient stroke to handle the round. There appear to be no problems once the cartridge is delivered to the gun platform.

Fire Control

26. Due to the large difference in trajectories between the arrowshell and the standard 5"/38 projectile it would be necessary to alter the fire control equipment to provide for interchangeable ammunition. There are several alternate methods to accomplish this modification depending on the degree of precision desired and space available for additional equipment. The present fire control system could probably be adapted to arrowshells exclusively by changing the ballistics of the computer. Altering the computer to handle both arrowshells and spin stabilized ammunition would be much more complicated since two different trajectories would be involved. It is felt that a detailed analysis of the fire control system is not justified at this time.

DISCUSSION

27. Although the feature of interchangeability has been heavily stressed, smoothbore guns remain the preferred means of launching fin stabilized discarding sabot projectiles. Rifled barrel operability offers the distinct advantage of the same gun being able to fire both fin and spin stabilized projectiles. However, the rifling may have some adverse effect on initial launching, as a result possibly increasing the projectile dispersion. The effect of rifling should be compared with the desirability of interchangeable ammunition in making a choice between rifled and smoothbore guns. Only slight modifications would be required to the 5/2.5-inch projectile as presently designed to permit its use in smoothbore guns.

28. Multi-purpose guns also complicate the fire control situation since the equipment must then be adaptable to two different projectile trajectories. Modifications to the fire control facilities for interchangeable ammunition would be somewhat more extensive than would be required to convert from the present system to one adapted to the higher velocity arrowshell only.

CONCLUSIONS

29. The following conclusions are drawn regarding adaption of fin stabilized discarding sabot projectiles to the 5"/38 gun.

a. Center drive FSDS projectiles offer a promising means of increasing the antiaircraft effectiveness of the 5"/38 gun. The major advantages of these projectiles are shorter time to target and probable faster firing rate of the integral round design.

b. Development of a round similar to the 5/2.5-inch center drive version appears to offer the most feasible method of adapting FSDS projectiles to the 5"/38 gun. Other projectiles investigated have the disadvantage of greater incompatibility with existing facilities.

c. The 5/2.5-inch projectile can be fired interchangeably with standard spin stabilized projectiles from the present 5"/38 gun but smoothbore barrels are preferable for firing sub-caliber projectiles.

d. Performance of the 5/2.5-inch round could possibly be improved by use of a lightweight sabot, improved propellant, or a longer cartridge case.

e. Although the 5/2.5-inch projectile can be successfully adapted to the present 5"/38 gun, considerable alterations would be required to other shipboard equipment, such as ammunition handling and fire control systems.

f. Should further investigation of 5-inch FSDS projectiles be warranted, a design study of a 5"/54 round would probably be in order.

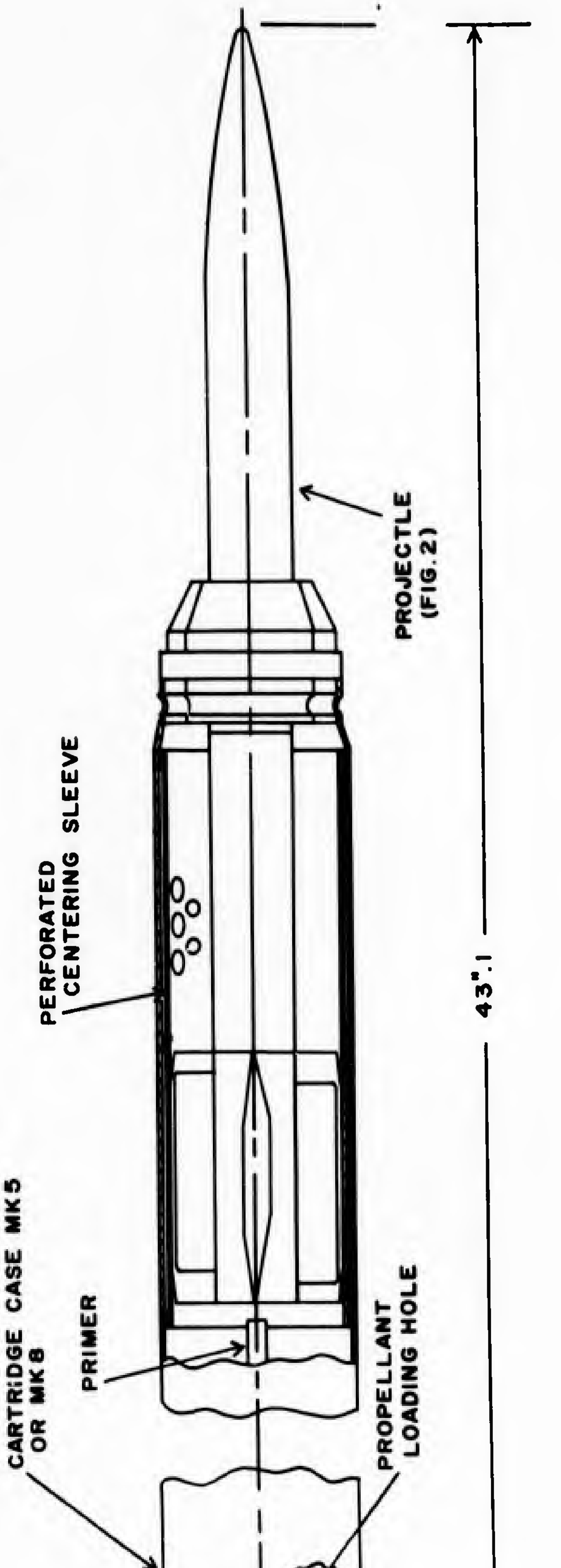

FIG. 1 5"/38 FSDS (CENTER DRIVE) CARTRIDGE

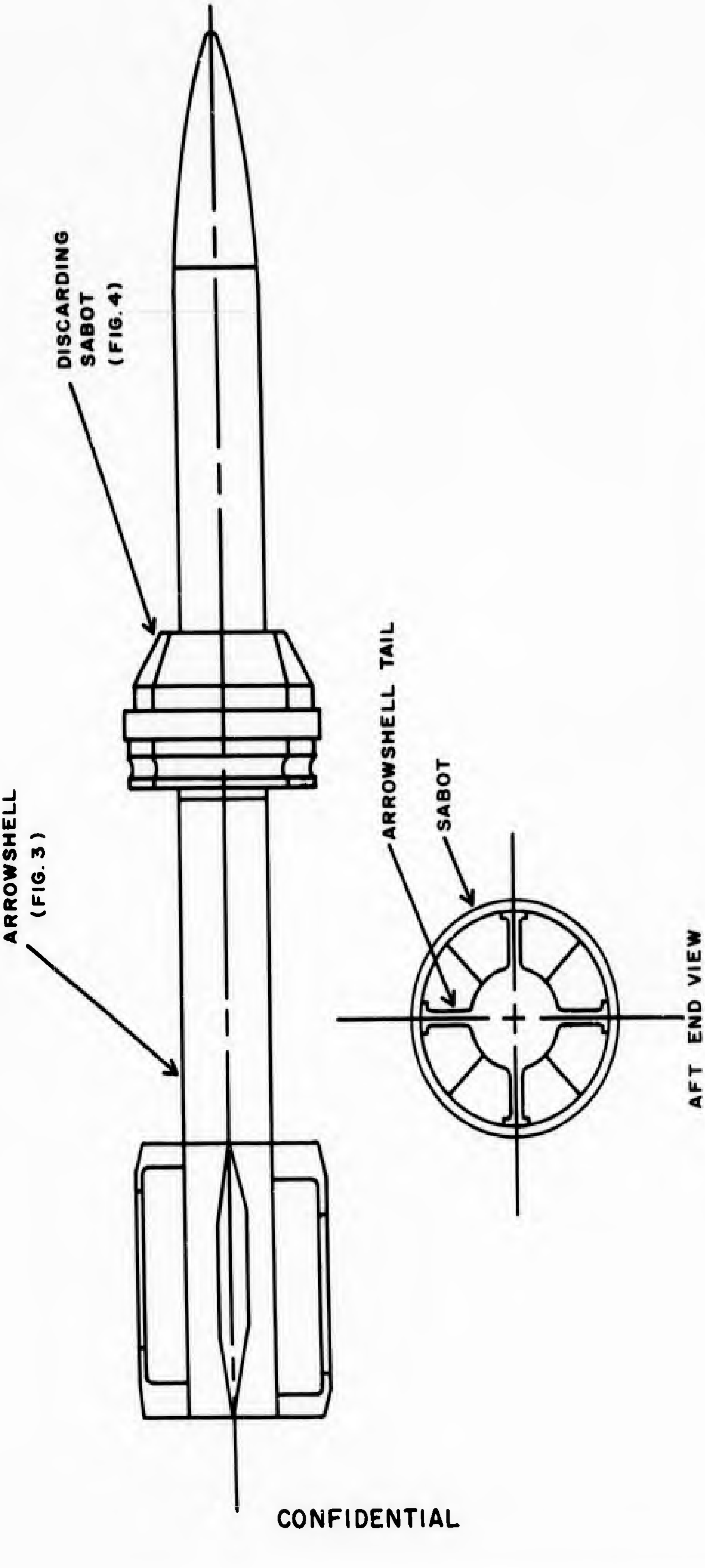

FIG. 2 5/2.5-INCH FSDS (CENTER DRIVE) PROJECTILE

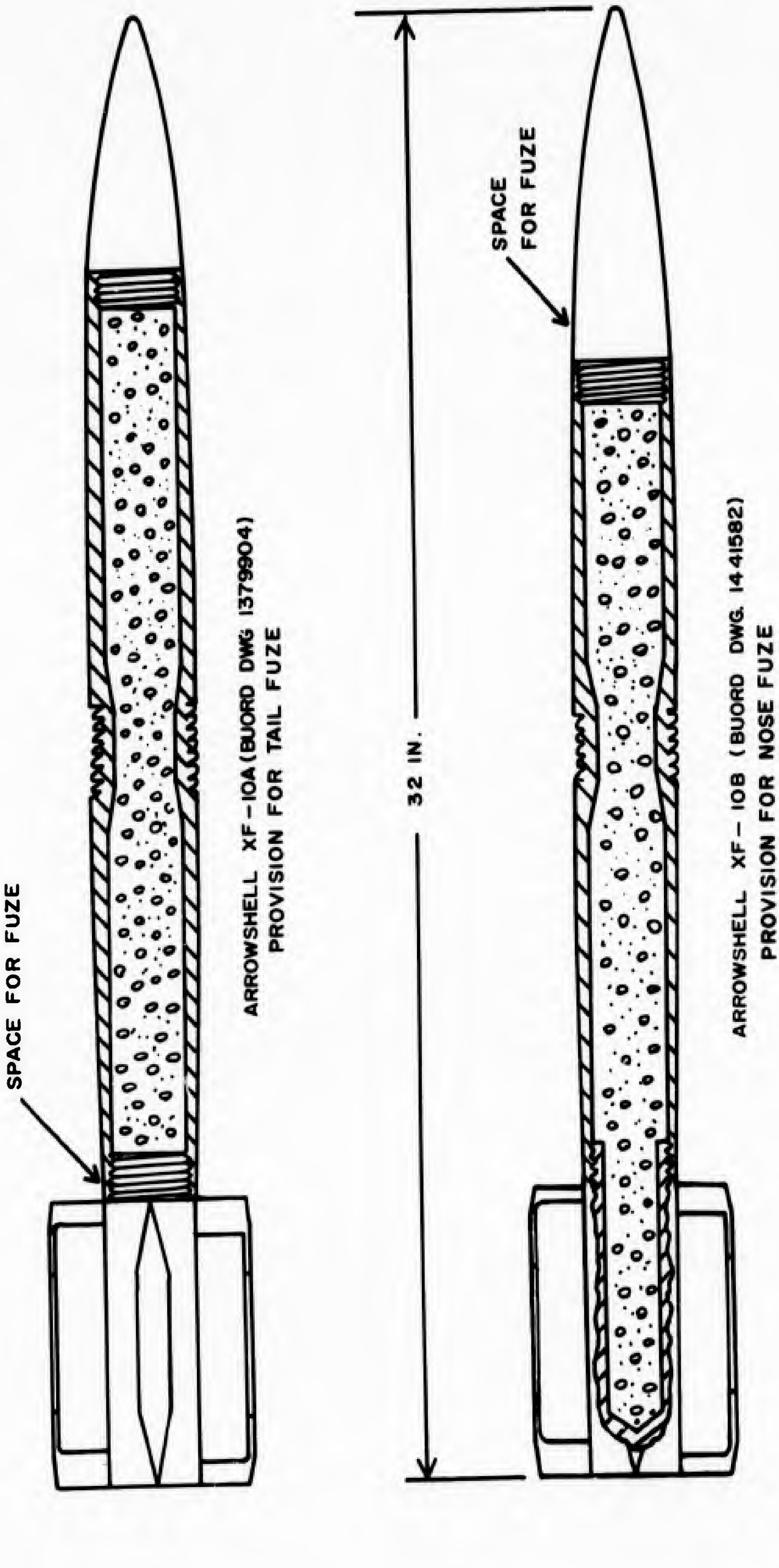

FIG.3 5/2.5-INCH ARROWSHELL

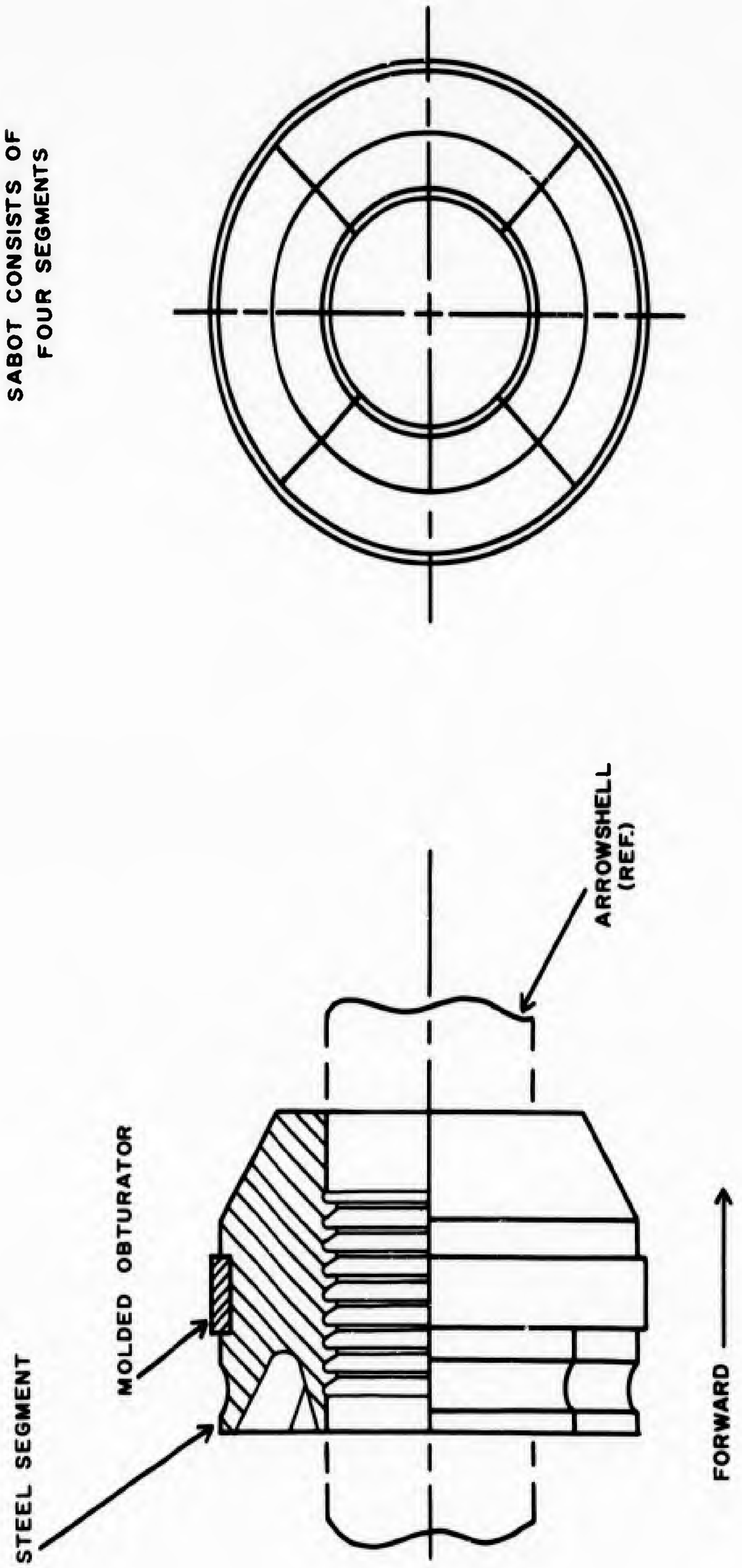

FIG. 4 SABOT FOR 5/2.5 INCH FSDS (CENTER DRIVE) PROJECTILE

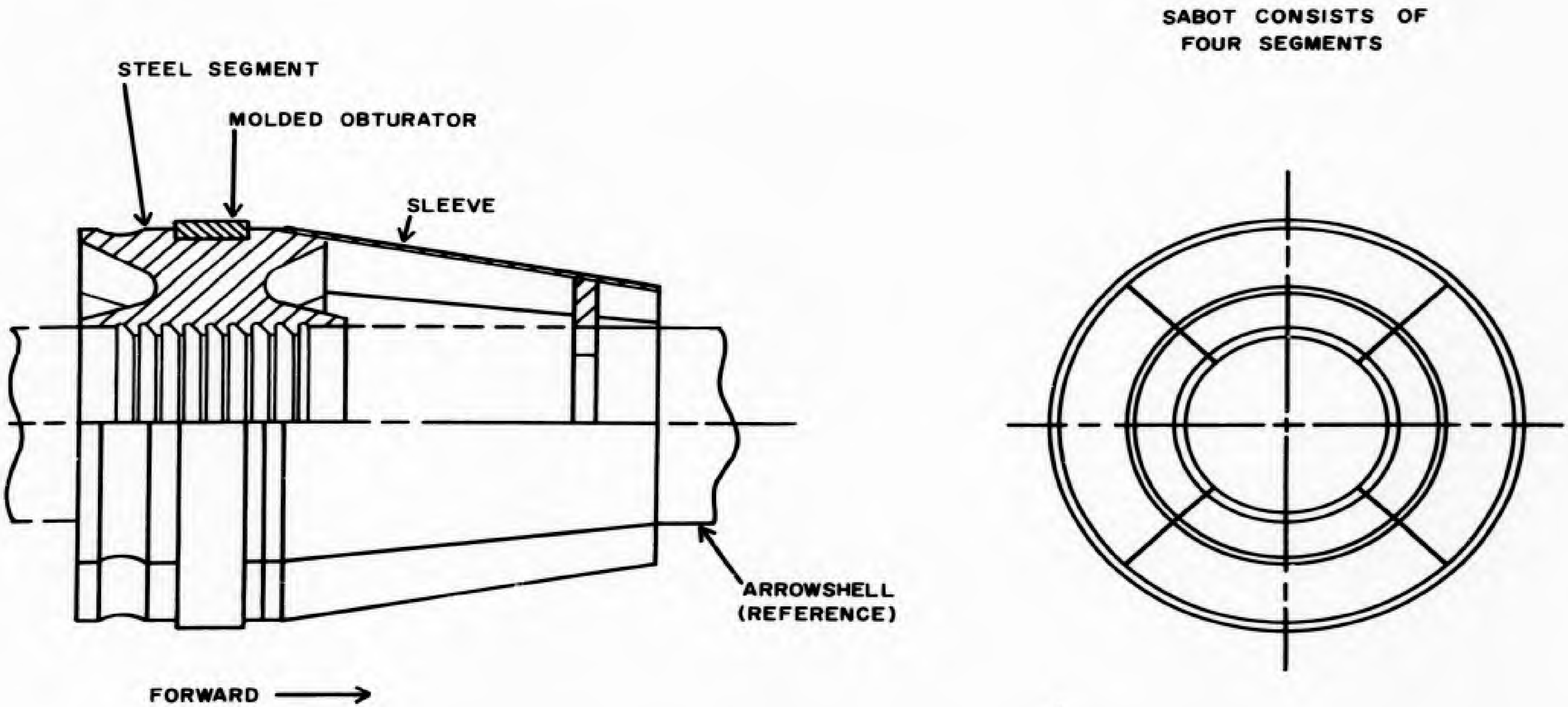

FIG. 5 SABOT FOR 5/2.5 INCH FSDS (CENTER DRIVE) PROJECTILE, ALTERNATE PROPOSAL

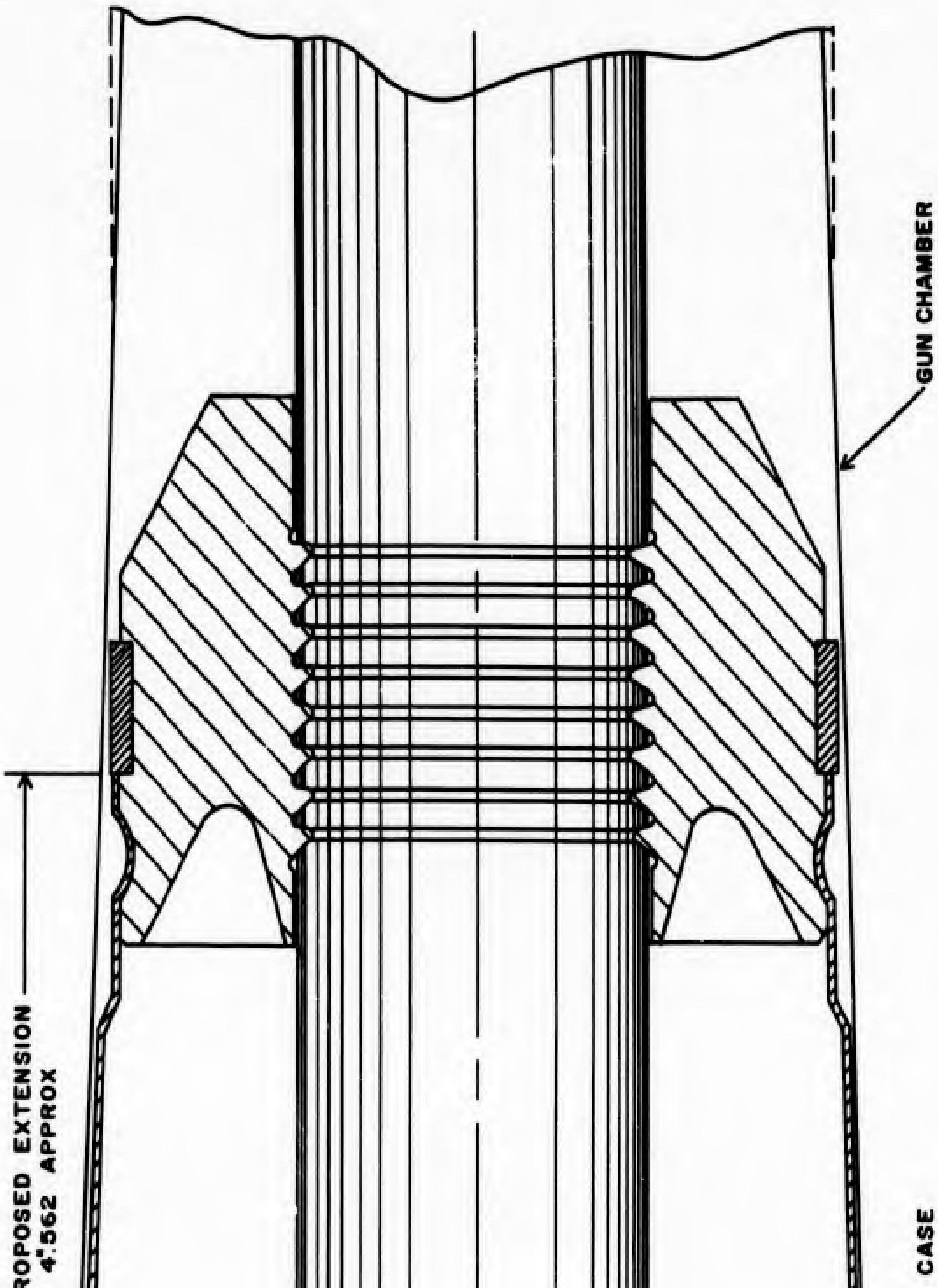

FIG.6 5/2.5 INCH FSDS CARTRIDGE, CHAMBER DETAIL

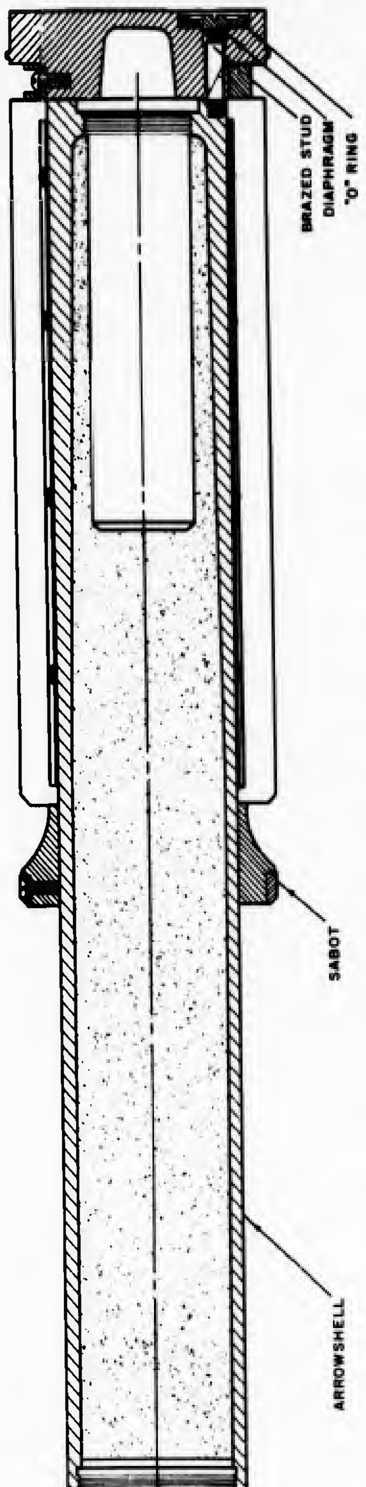

FIG. 7 5"/38 FSDS (BASE DRIVE) PROJECTILE
(BUORD DWG. 1379658)

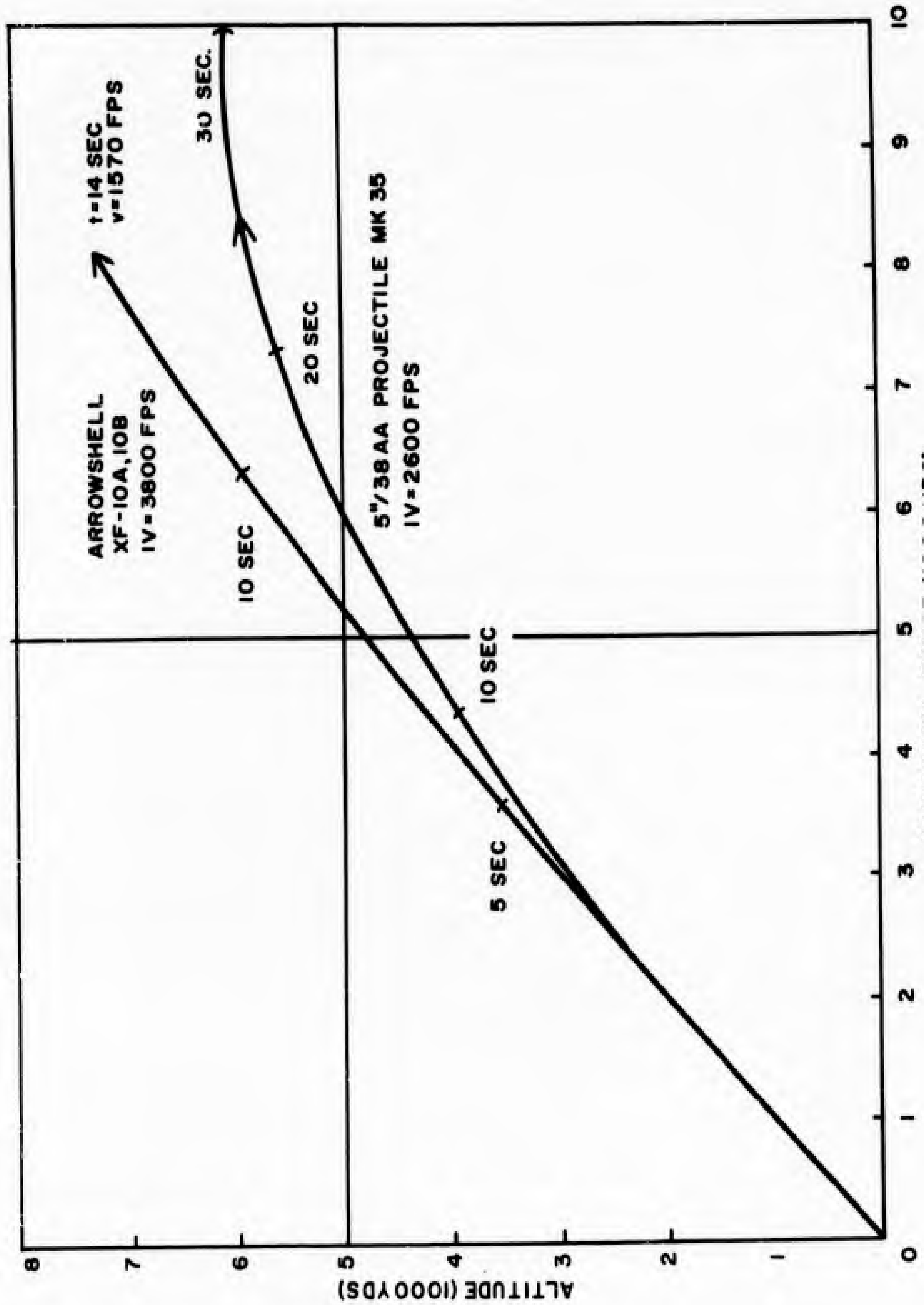

FIG. 8 COMPARATIVE TRAJECTORIES, QE = 45°; ARROWSHELL XF 10A,10B AND 5"/38 AA PROJECTILE MK 35

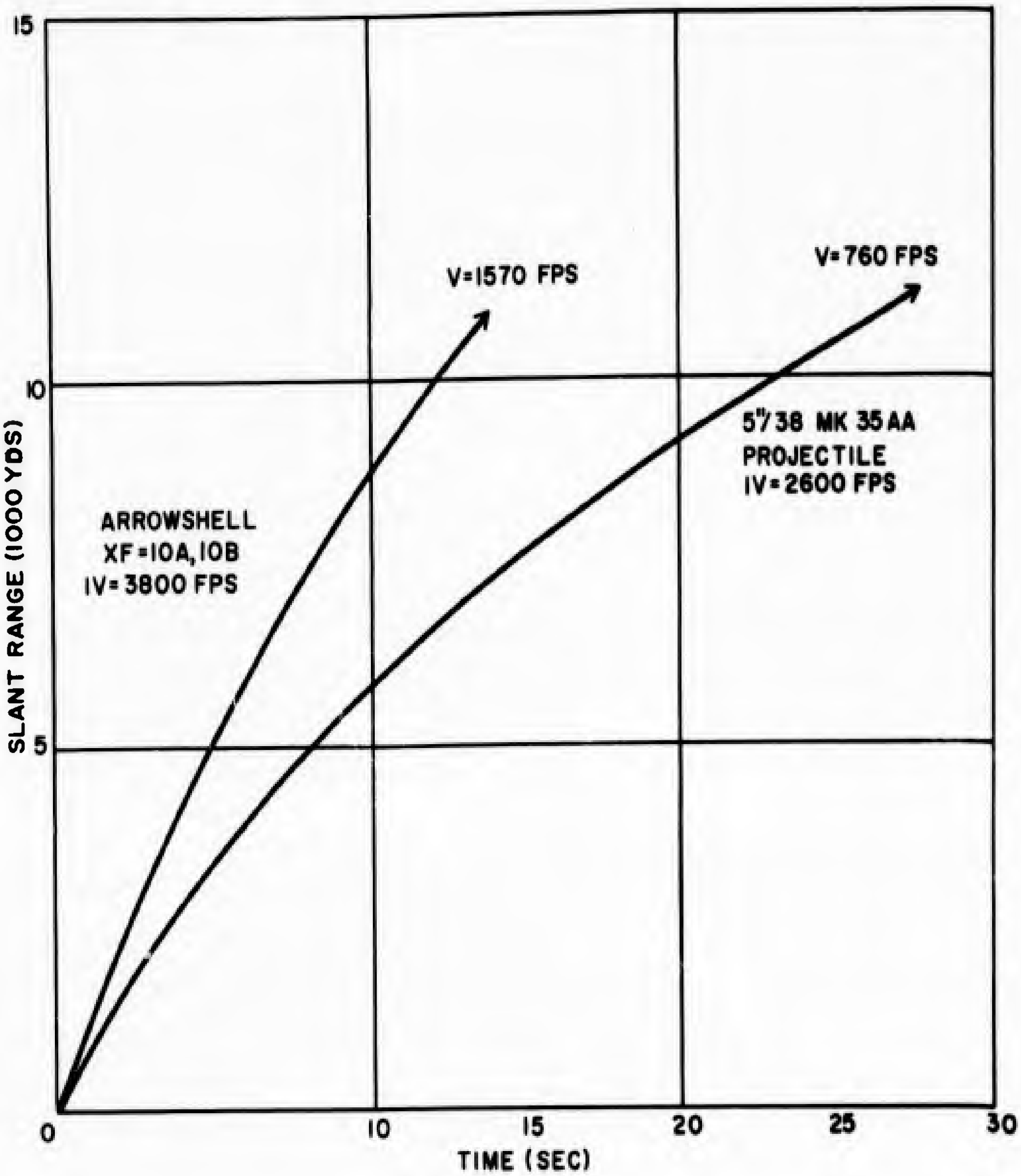

FIG. 9 SLANT RANGE VS TIME OF FLIGHT, QE = 45°; ARROWSHELL XF10A,10B, AND 5"/38 AA PROJECTILE MK 35

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