Sept. 5, 1961 L. G. MOSIER 2,998,771

PROJECTILES

Filed April 1, 1955

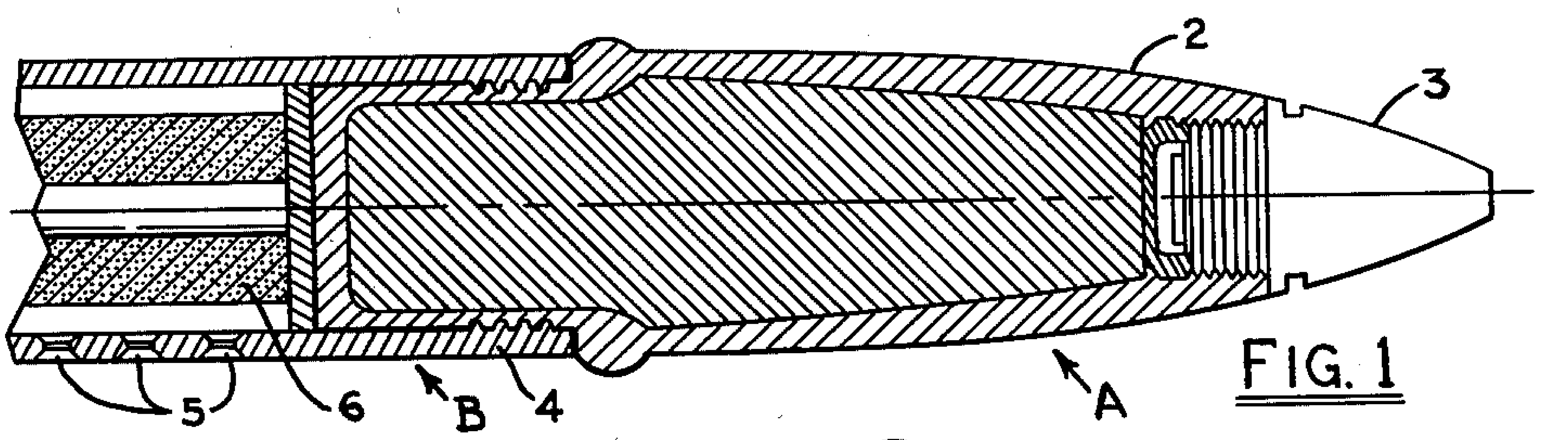

FIG. 1

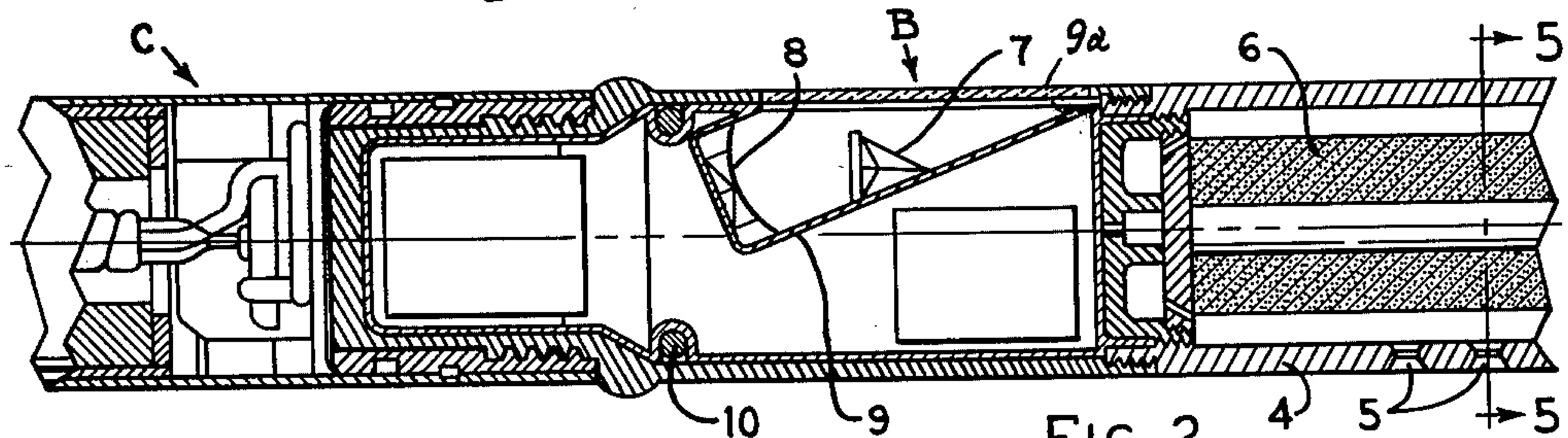

FIG. 2

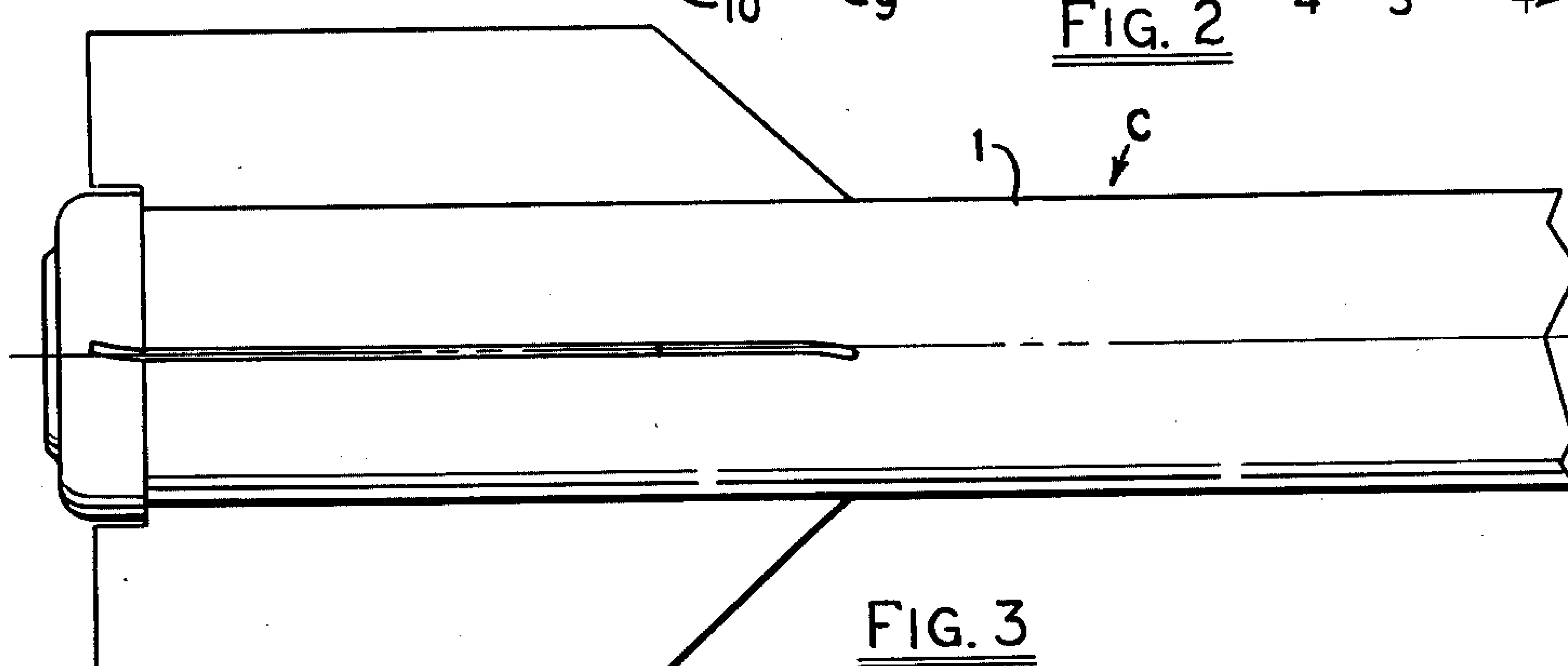

FIG. 3

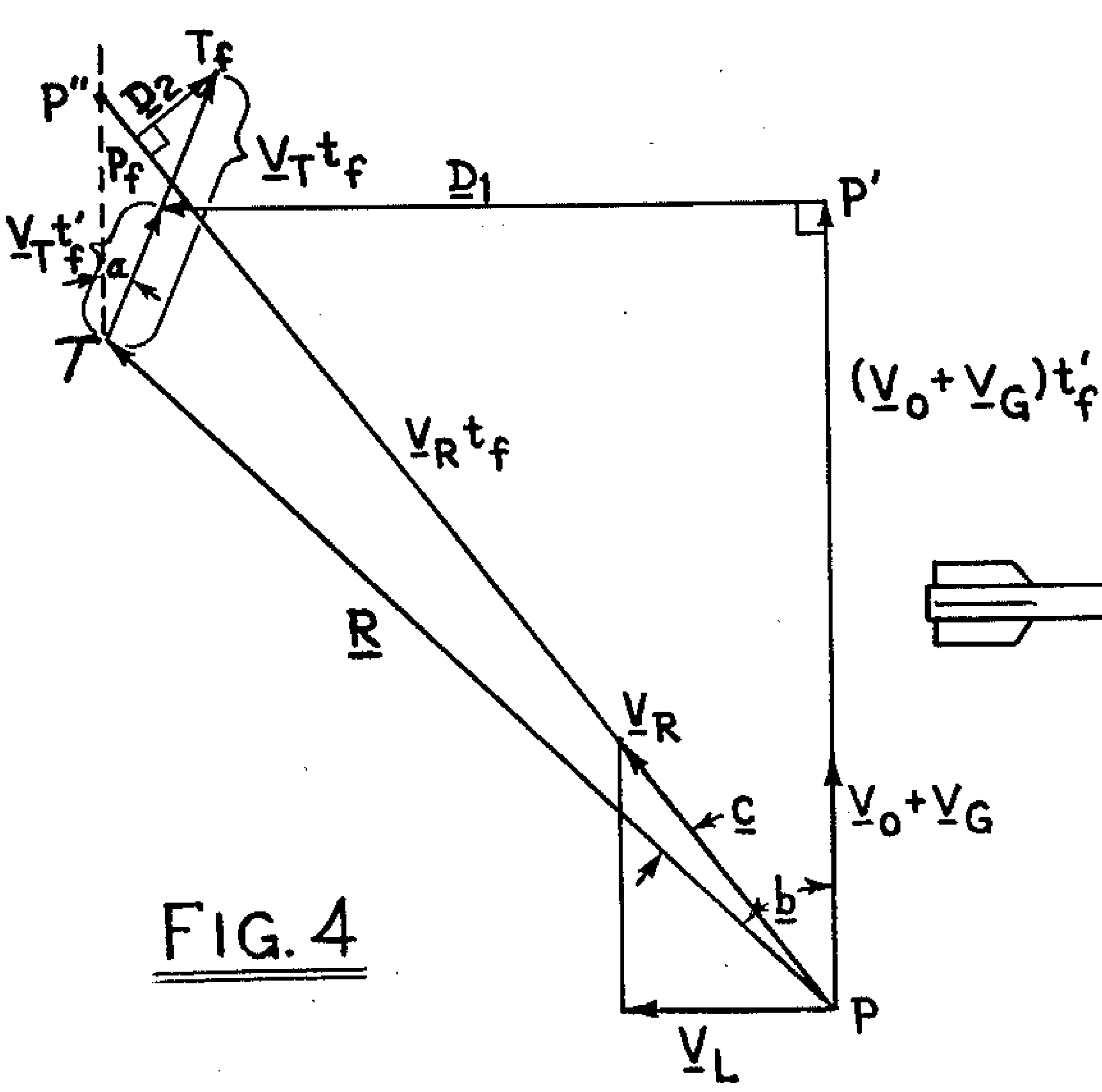

FIG. 4

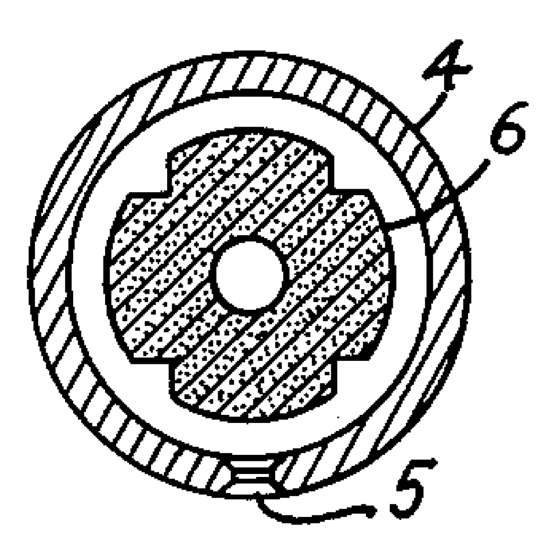

FIG. 5

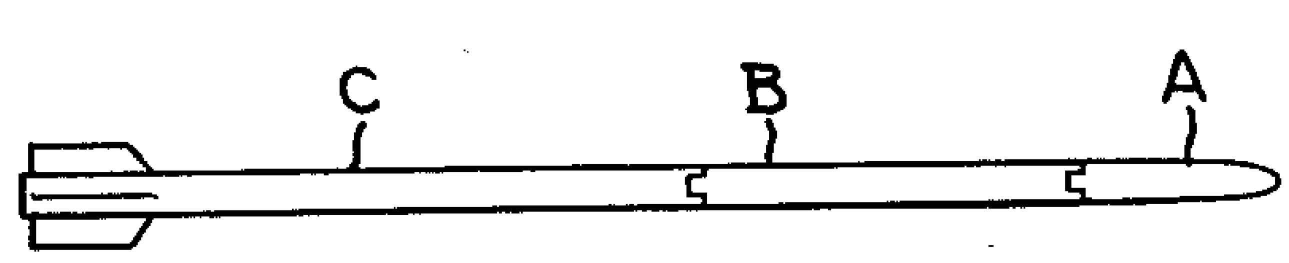

FIG. 6

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PROJECTILES

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

My invention relates to projectiles and is particularly directed to means for increasing the hit probability of the projectile with its target.

It is possible to compute the launching lead angles of a projectile with considerable accuracy. Hit probabilities, however, are found in practice to be less than the theoretical values because of the unpredictable variations of forces that act upon the projectile after launching. Homing devices on the projectile, and radio controls at the launcher are partially effective in increasing hit probability but the vastly increased complexity of equipment reduces the reliability and value of the equipment.

The proximity fuses on explosive bullets or rockets were adopted to increase the kill probability of the projectile with a fixed dispersion pattern.

The object of my invention is to increase hit probability of projectiles by reducing the size of the dispersion pattern of the projectile at its target.

The object of my invention is attained by imparting to the projectile a strong lateral thrust to suddenly redirect the projectile on a collision course just before the projectile reaches the target. The projectile is provided with a light sensitive cell which can "see" any target within an acute forward angle from the projectile center line. The light to which the cell is sensitive is preferably in the infrared range and the lateral thrust is provided by a gas jet-producing rocket grain exhausting through ports in the side of the projectile, as contemplated in the preferred embodiment of my invention. The miss distance of one of my improved two-stage rockets is reduced to zero with the target path parallel to the original trajectory and to about one-third with an angle of intercept of ±10 degrees.

Other features and objects of my invention will become apparent by referring to the specific embodiment described in the following specification and shown in the accompanying drawing in which:

FIGS. 1, 2 and 3 are elevational views, partly in section, of the components A, B and C, respectively, of a rocket, shown assembled in FIG. 6.

FIG. 4 is a vector diagram of the principal target and rocket velocity vectors typically involved in a fire control problem employing the rocket of my invention,

FIG. 5 is a section of the rocket taken on line 5—5 of FIG. 2, and

FIG. 6 is an elevation of the assembled rocket of my invention.

The particular projectile chosen here for illustrating the principles of my invention is a rocket, although the principles could be applied to a gun propelled bullet. In FIG. 6 is shown a rocket with end-to-end sections A, B and C. The rear end section C contains a propulsion rocket grain for exhausting a high velocity jet of gas from the rear (left end) of the tube 1, FIG. 3. The particular rocket shown may be of the 2.75" FFAR-type used extensively in air-to-air combat. After launching, the rocket is given fairly high speed rotation about its longitudinal axis by either canting the exhaust ports at a slight screw-thread angle with respect to the axes or by trimming the stabilizing fins as shown so as to produce,

aerodynamically, the desired rotation. At the right, or front, section A of the rocket is the warhead with casing 2 and fuse nose 3, preferably with a proximity fuse mechanism for detonating the warhead when the warhead arrives at a point nearest the target. Intermediate the rocket motor tube 1 and the warhead 2 is the auxiliary motor 4, section B, comprising a tube of the same diameter as the other sections and provided with exhaust ports 5 drilled, preferably, in a straight line along the side of tube 4 and adapted to exhaust high velocity gas perpendicular to the longitudinal axis of the rocket. The propulsion material 6 may comprise a grain similar in composition to the primary motor grain but is so constituted as to have very short burning time and may be so fused as to be simultaneously ignited at all points throughout its length. Details of the igniting mechanism form no part of this invention and will not be described in detail; it is sufficient that the igniting mechanism be fast acting and adapted to ignite the auxiliary motor with little or no dead time after receipt of the actuating impulse.

The actuating impulse for the auxiliary motor is obtained from the light sensitive cell 7, which cell is arranged through an optical system to "see" forwardly and laterally of the rocket at an acute angle hereinafter to be more fully described. The optical system depicted in FIG. 2 may comprise the reflector 8 set in the bottom of the telescope tube 9. The forward end of the telescope is closed by a clear light-transmitting window *9a* shaped and fitted to the rocket tube so as to not disturb the stream-lined outer surface of the rocket. The reflector and the light shielding about the light sensitive cell are so arranged that the cell will respond to radiation received only along the said forward acute angle. The electrical pulses produced by the cell are amplified and applied to a trigger circuit (not shown) for actuating the secondary rocket grain 6. The size of the cavity surrounding the telescope 9 is ample to receive the amplifier and triggering circuits of the cell as well as the battery power supplies for these circuits. Since such amplifier circuits may be conventional and may embody many features not important to the basic characteristics of my invention, they are not described.

In one embodiment of my invention the primary motor portion of the rocket is separated from the forward portion after the primary motor is burned out. Separation may be affected by the explosive gasket 10 of a material known in the art as "Primacord." Ignition of the primacord may be timed either with the completion of the burning of the primary motor grain or with the ignition of the secondary motor grain.

The ports or nozzles 5 of the secondary motor are in the side of tube 4 preferably diametrically opposite the window and line of sight of cell 7. Where the burning time of grain 6 is finite and where dead time between receipt of the actuating ray of light and the middle point of the burning time is finite, the ports of the secondary motor will be displaced from said diametrically opposite portion a few degrees in the direction of the rotation. Such an angular displacement of the nozzles with respect to the window is to insure lateral propulsion of the rocket in a plane containing the longitudinal axis and the line of sight of the cell.

In the design of the rocket of my invention the following parameters of the system become important. First, the rocket closing velocity and the sight angle of the system determines the required lateral velocity. Second, the rocket closing velocity plus the target length, as seen by the cell, determines the required spin velocity of the rocket. Third, the spin velocity plus the loss of thrust allowable from finite burning time determines the maximum allowable burning time.

Let it be assumed that a rocket of the 2.75" FFAR type has a closing velocity of 1300 ft./sec., and that a change-of-direction of rocket flight of 20° is desired. Then the lateral velocity, V_L, is

$$(1)\qquad V_L=(1300\text{ ft./sec.})\tan 20°=474\text{ ft./sec.}$$

The necessary spin velocity is, obviously, a function of the rocket closing velocity and the length of target which can be seen by the cell. Assume that the exhaust trail made by the target airplane is 40 feet, then the spin rate, S, required is

$$(2)\qquad S=\frac{1300\text{ ft./sec.}}{40\text{ ft.}}=33\text{ revolutions per second}$$

to insure that the target will be scanned at least once by the light sensitive cell.

The maximum burning time allowable from the secondary rocket motor is seen to be a function of the spin parameter and the maximum rotational angle through which the thrust must be applied without appreciable loss in lateral velocity. The thrust of the motor acting during 60° of rotation of the rocket is chosen as a compromise to allow maximum thrust with a minimum sacrifice of lateral thrust. The maximum time, T, allowable is thus:

$$(3)\qquad T=\frac{60}{360}\times\text{spin period}=5\text{ milliseconds}$$

The firing system of the side thrust rocket requires that the original lead angle must be less than 20° to avoid premature blast of the secondary rocket motor. However, present day fire control systems, which might be employed for determining the initial lead angles, do not provide leads greater than about 14°; therefore, the rocket with my secondary motor imposes no restrictions in tactics. Also, momentary yaw following launching may be counteracted by inserting a time delay in the activation of the cell detection system.

When the attacking and target aircraft are flying nonparallel courses an error is introduced in the correction system. This error is an error in kinematic lead since the two-stage rocket is a fixed lead device calibrated for parallel courses. In FIG. 4, let P and T represent the projectile and target, respectively, at the time the second rocket motor is fired which is at the time the optical system "sees" the target at angle b from the line of flight. The projectile velocity at that time is V_o+V_g along the miss trajectory of the rocket, where V_o is own ship velocity, and V_g is acquired rocket velocity at point P. Let t'_f be the time required if the projectile were to continue with this velocity until the target and projectile would be in he same plane normal to the initial projectile path. At the computed future positions T' and P' of the target and projectile, respectively, the miss distance is D_1. Now, due to firing of the secondary motor, the projectile will acquire lateral velocity V_L normal to (V_o+V_g) in the plane of (V_o+V_g) and T resulting in a total velocity V_R. Now, let t_f be the time until the projectile, on its new path, and the target lie in the same plane normal to the new projectile path at P_f and T_f, respectively. The new miss distance is now D_2. According to my invention V_L is so chosen with relation to (V_o+V_g) and the cell sighting angle b, that for a target path with velocity V_t parallel to (V_o+V_g) and under the assumed speed conditions that $V_o+V_g-V_T=1340$ ft./sec., D_2 would be zero, that is, projectile and target would coincide at point P".

It follows that this value of V_L may be written

$$(4)\qquad V_L=(V_o+V_g)\times\tan b$$

In order to find the miss distance D_2 when V_T makes an angle a with the original projectile path and for an arbitrary target speed, the following vector relations may be written from FIG. 2.

$$(5)\qquad R+V_Tt_f-D_2-V_Rt_f=0$$

$$(6)\qquad R+V_Tt'_f-D_1-(V_o+V_g)t'_f=0$$

where R is the initial projectile-to-target range.

Resolving Equation 4 into components parallel and perpendicular to V_R and resolve Equation 5 into components parallel and perpendicular to (V_o+V_g) gives

$$(7)\qquad D_2=-R\sin c+V_Tt_f\sin(a+b-c)$$

$$(8)\qquad O=R\cos c+V_Tt_f\cos(a+b-c)-V_Rt_f$$

$$(9)\qquad D_1=+R\sin b-V_Tt'_f\sin a$$

$$(10)\qquad O=R\cos b+V_Tt'_f\cos a-(V_o+V_g)t'f$$

Equations 7, 8, 9 and 10 are four equations for the four unknowns, D_2, R, t_f, t'_f. Where D_1 is assumed to be equal to 60 feet and b equal to 20°, and c equal to 7.3°, $V_o+V_g=2100$ ft./sec., $V_T=800$ ft./sec., $V_L=474$ ft./sec., $V_o=1300$ ft./sec. and $a=+10°$ and $-10°$, then calculations indicate that the new miss distance $D_2=21$ ft. and 13.5 ft., respectively for the $a=\pm10°$.

It is apparent that the magnitude of the required correction angle applied to the first trajectory will vary with the change in the rocket closing velocity. Therefore, as a first step in determining the magnitude of the residual error imposed by variations in closing time, the extent of the velocity variations must be evaluated. Since the firing aircraft will close to only a relatively long range when employing a weapon of this type, a low closing rate at the time of fire of the first rocket may be assumed. For the purpose of this invention a possible variation of ±25 knots for an assumed aircraft closing rate of 25 knots will be used. This yields a variation of projectile closure velocity of ±42 ft./sec. from an average value of approximately 1340 ft./sec. Since the weapon of my invention will be used at long ranges, it is reasonable to assume that the second stage motor will be activated only after the burning time of the first stage. Under these conditions, interpolation from firing tables yields a possible variation, from an assumed average for temperatures of −30° F. to +130° F., of ±23 ft./sec. Further, since both the first and second stages will be similarly affected by density variations, variations in closure velocity due to altitude may be ignored. Finally, variations of range, at the time of rocket launching, of ±300 yards may be assumed. For rocket velocities in the region of interest, this yields a possible variation in closure velocity of ±100 ft./sec. for an assumed average for the 2.75" FFAR. Under these conditions variations in projectile closure velocity of approximately 165 ft./sec. from the assumed value are possible. An average variation is about 110 ft./sec.

The maximum miss distance from the target center due to the maximum variation of target closing rate at the assumed maximum firing range of the second target may now be calculated. From the above considerations at the time of launching we may conclude that the maximum percentage change of rocket closing rate is approximately ±10%. Where the rocket closing velocity is 10% too high, the angular error due to the variation of rocket closing velocity is 1.7°. This results in a maximum miss distance of 5.2'. In case the rocket velocity is 10% to low the correspondent miss distance from the point of aim is 6.5'.

The mechanical arrangement of the rocket may be substantially as shown in FIG. 1, it being merely necessary to select the light sensitive cell and its optical system to be sensitive to the anticipated exhaust trail of the enemy target. Secondly, a very fast burning rocket grain must be selected for the secondary motor 4.

Many modifications may be made in the rocket of FIG. 1 without departing from the scope of the invention defined in the following claims. By imparting a lateral velocity to the projectile in a plane containing the target and the line of sight of the rocket, the miss distance can also be reduced as to increase the percentage kill a considerable amount. Most of the advantages of homing devices and of radio directional control are attained with none of the complexity of either. This two-stage rocket is remarkably simple in construction and can reduce the error of a given rocket to approximately one-third of its original value and can increase the kill probability by approximately 60%, assuming no bias error.

What is claimed is:

A two-stage rocket comprising an elongated cylinder, a primary motor occupying the rearward portion of said cylinder for propelling said cylinder along a line of flight, a window in the side wall of the middle portion of said cylinder, at least one exhaust port in the middle portion of said cylinder diametrically opposite said window, a secondary motor occupying a middle portion of said cylinder for applying a propelling force through said at least one exhaust port, a single radiant energy sensitive cell in said cylinder behind said window for producing an electrical pulse in response to energy radiated from a

target, an igniting mechanism for igniting said secondary motor, and means for rotating said cylinder about the longitudinal axis of said cylinder whereby said window and said single radiant energy sensitive cell are revolved in a spiral pattern.

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