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M. L. RICE ET AL
ROCKET PROJECTILE

2,977,879

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3 Sheets-Sheet 1

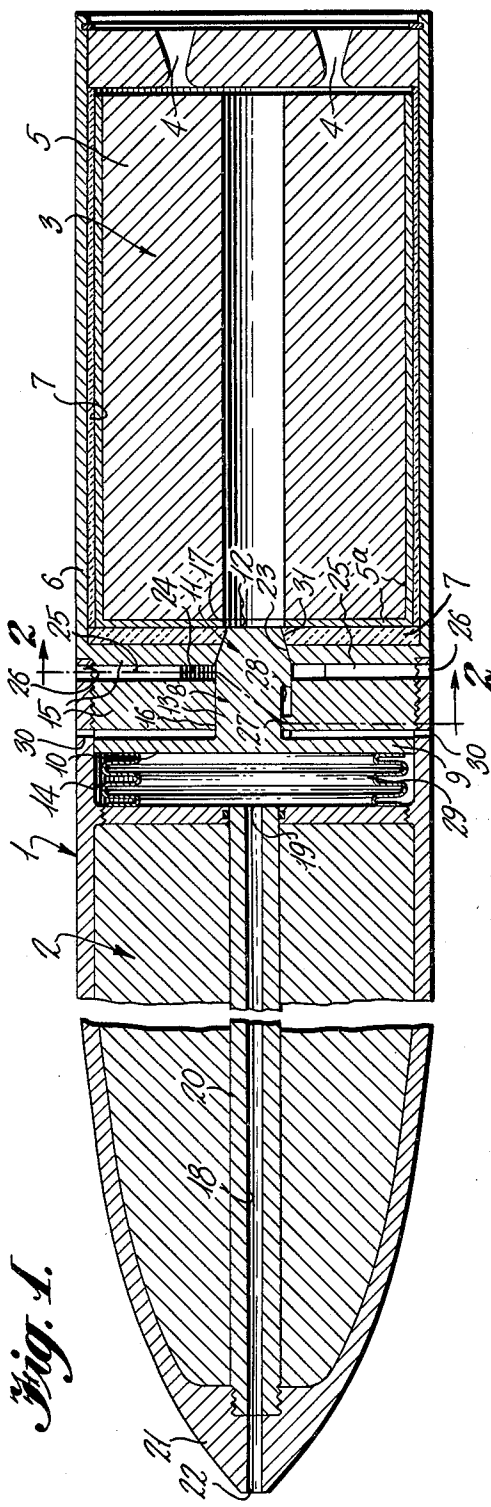


Fig. 1.

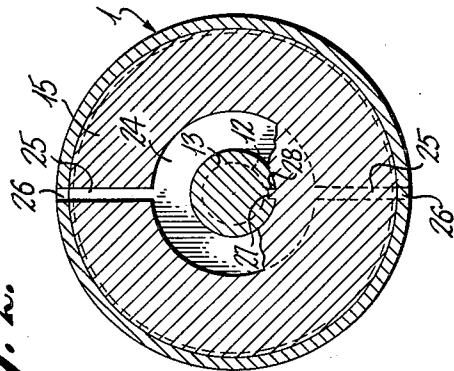


Fig. 2.

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3 Sheets-Sheet 2

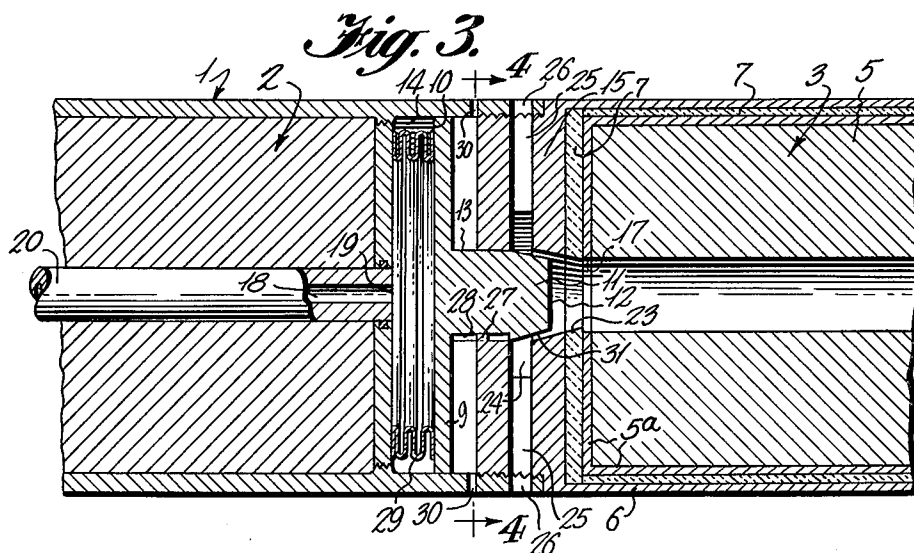


Fig. 4.

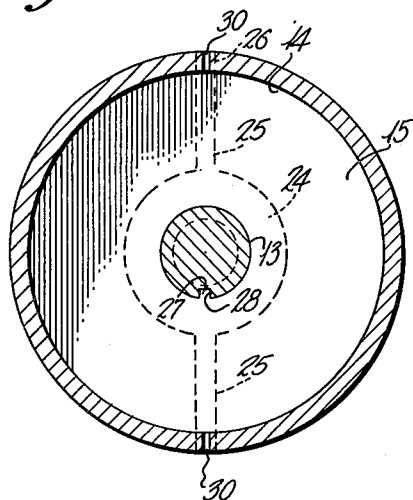
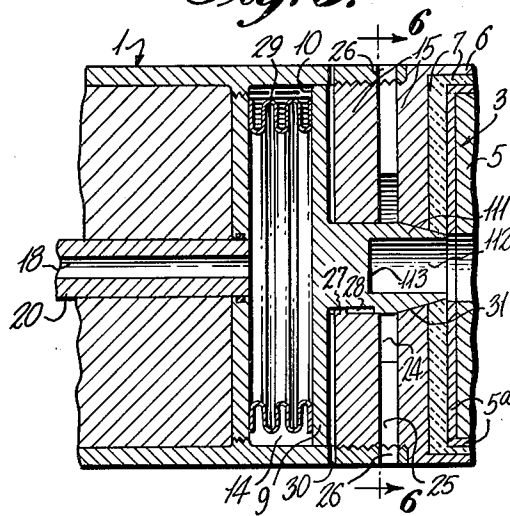


Fig. 5.



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3 Sheets-Sheet 3

Fig. 6.

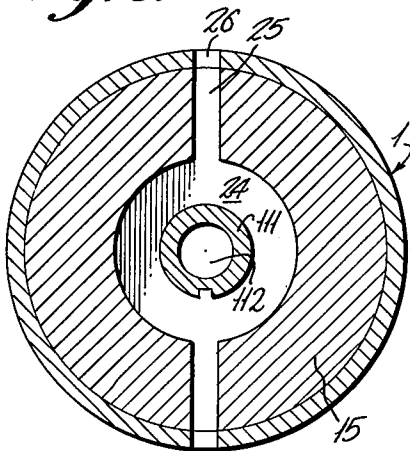


Fig. 8.

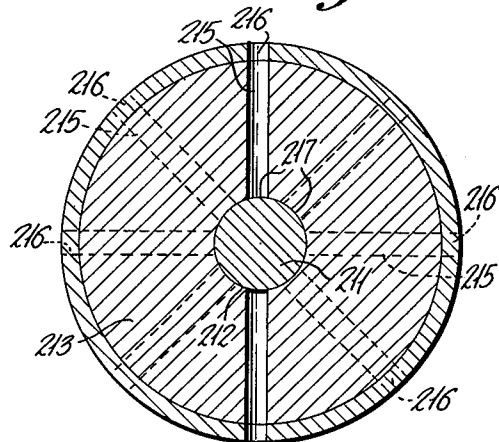
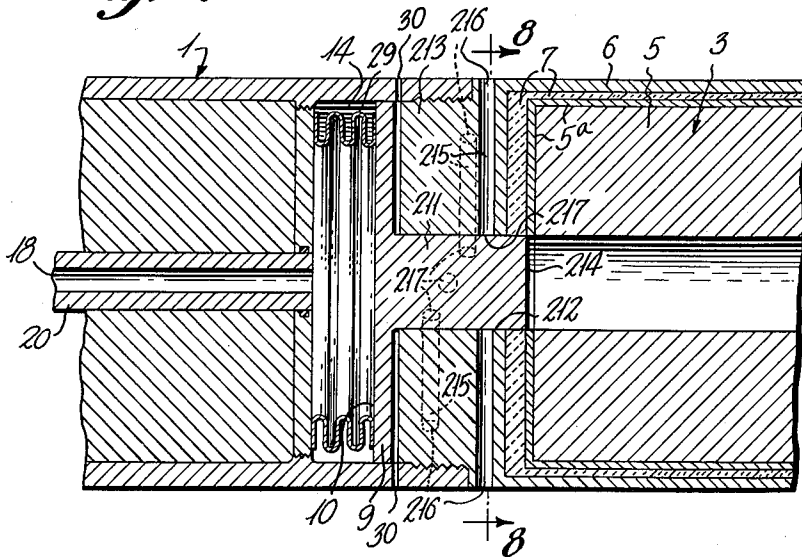


Fig. 7.



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1

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ROCKET PROJECTILE

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9 Claims. (Cl. 102-49)

This invention relates to rocket-assisted projectiles.

The object of this invention is to provide rocket projectiles employing solid propellant fuel, which, when launched at Mach number velocities above 2, automatically compensate for changes in aerodynamic drag to which the projectile is subjected during flight, thereby making possible maintenance of desired constant velocity by the projectile rocket motor.

In the accompanying drawings:

Fig. 1 is a vertical longitudinal sectional view through a rocket projectile showing an embodiment of the invention.

Fig. 2 is a vertical transverse sectional view along line 2-2 of Fig. 1.

Fig. 3 is a fragmentary vertical, longitudinal, sectional view showing the valve of Fig. 1 in forward position.

Fig. 4 is a vertical transverse sectional view along line 4-4 of Fig. 3.

Fig. 5 is a fragmentary vertical longitudinal sectional view illustrating a modified valve structure.

Fig. 6 is a vertical transverse sectional view taken along line 6-6 of Fig. 5.

Fig. 7 is a fragmentary vertical sectional view showing another modification of the valve and port venting means.

Fig. 8 is a vertical transverse sectional view taken along line 8-8 of Fig. 7.

The maintenance of constant projectile velocity is frequently of great importance, as, for example, in the case of air to air missiles where variation in velocity introduces inaccuracies in the missile trajectory which may cause the missile to miss its target. Such projectiles are generally fired from rapidly moving aircraft so that the requisite launching velocity is imparted to the projectile both by the velocity of the plane and the propulsive effect of an external thrust-producing device, such as a gun. If the projectile is launched from a stationary propulsive mechanism, as, for example, if fired from the ground, the external thrust produced by the firing device must be sufficient to launch the projectile at the necessary high velocity.

Variation in aerodynamic drag on a projectile launched from a stationary device is primarily produced by changing altitude. In the case of projectiles launched from moving aircraft, variation in drag is also caused by variations in aircraft velocity relative to the atmosphere, where the launching velocity of the projectile relative to the launching craft is fixed. To maintain the moving projectile at a constant velocity, the thrust or velocity-producing force engendered by the rocket motor must vary with changes in aerodynamic drag. In other words, it must increase with increasing drag and decrease with decreasing drag.

This invention comprises a solid-propellant rocket projectile which automatically compensates for variation in aerodynamic drag by varying the thrust produced by the rocket motor with the air pressure on the nose of the high velocity projectile. Air pressure at the nose of the

2

moving projectile, namely ram pressure, is approximately proportional to the ambient pressure, e.g. the air pressure at the given altitude, times the square of the projectile Mach number. At the usual velocities of air-launched rocket projectiles, namely at velocities above a Mach number of 2, the ram pressure is proportional to the aerodynamic drag, so that the device of this invention, by providing means for making the thrust responsive to ram pressure, thereby automatically overcomes the effect of changes in aerodynamic drag on projectile velocity.

Broadly speaking, the propulsive mechanism of the projectile comprises a rearwardly positioned rocket motor comprising a combustion chamber venting rearwardly through a nozzle or nozzles of fixed diameter, a floating differential piston axially positioned in the projectile forward of the combustion chamber, the smaller end of which functions rearwardly as a slidable valve member controlling the cross-sectional venting area of a port in the forward end of the combustion chamber, and side vents forward of the combustion chamber opening in the side wall of the projectile and communicating with said port to permit the escape of combustion gases in amounts determined by the position of the aforementioned piston valve. The forward larger face of the differential piston is responsive to ram pressure on the nose of the projectile, which is communicated to the piston through an open longitudinal channel extending from the nose to a chamber in which the larger, forward end of the piston is slidably seated. The smaller, rear face of the differential piston, which is in the port opening into the forward end of the combustion chamber, is responsive to combustion gas pressure in the combustion chamber. The port and/or this valve end of the piston are designed in such manner that forward motion of the piston, namely motion toward the nose of the projectile, increases the gas-venting area of the port and vice versa. The gas discharge channels communicating with the port and exterior apertures are positioned in such fashion that the gases issuing from the forward end of the combustion chamber through the port vent out the side of the projectile at an angle normal to the rear, forward-thrust-producing jet. The side venting gases thus introduce a thrust component which is in a plane normal to the forward thrust component and, therefore does not affect the latter. This is of importance since it is desirable not to introduce counter-thrust which would affect response of the mechanism to variations in the ram pressure. The side thrust component can be balanced or off-set by venting the gases perpendicularly to the side of the projectile through oppositely positioned side vents or its can be employed to impart a desired spin to the projectile, as, for example, by venting the gases in a plane normal to the forward-thrust component but at a predetermined angle inclined to the normal with respect to the side wall.

The floating differential piston acts as a balancing means between ram pressure and the pressure in the combustion chamber. When ram pressure on the forward face of the piston increases, the piston moves rearwardly and decreases the gas-venting cross-sectional area of the port opening into the combustion chamber. The pressure in the combustion chamber rises, thereby increasing the burning rate of the solid propellant and increasing the forward thrust produced by the high velocity gas stream issuing from the rear nozzle of the rocket motor. Since, as aforementioned, ram pressure is proportional to aerodynamic drag, the increased thrust produced by the motor overcomes the increase in drag and maintains the projectile at constant velocity.

Conversely, when ram pressure decreases, as with increasing altitude, the pressure in the combustion cham-

ber overbalances the force exerted by ram pressure, the piston moves forward, the gas-venting cross-sectional area of the forward combustion chamber port is increased in size, permitting the escape of a larger amount of combustion gases through the side vents, combustion chamber pressure drops and thrust on the projectile decreases in an amount compensating for the decrease in aerodynamic drag and the projectile is maintained at constant velocity.

An important advantage of the thrust-adjusting mechanism stems from the fact that the system automatically corrects to the proper thrust for different propellant temperatures. Such automatic thrust correction regardless of propellant temperature takes place because thrust adjustment is achieved by the balance between ram pressure, which is independent of propellant temperature, and actual combustion chamber pressure. Thus, despite the fact that the pressure in the combustion chamber is influenced by propellant temperature, the size and variation in the side venting port cross-sectional area are determined by and proportionately compensate for the particular opposing ram and combustion chamber pressures acting on the differential piston.

Figures 1, 2, 3 and 4 illustrate a device embodying the principles of the invention. The projectile 1 contains a war head 2 at its forward end and a rocket motor comprising a combustion chamber 3 and rearwardly venting nozzles 4 of predetermined, fixed size. The combustion chamber contains a solid propellant grain 5 of suitable composition and properly designed to give the requisite burning surface area. 5a is an inhibitor coating on the grain. The metal motor wall 6 and 15 of the combustion chamber is insulated interiorly by a layer of insulation 7. Axially positioned forward of the combustion chamber is a floating differential piston 8 oriented in such manner that end 9 of the piston having the larger surface 10 faces forwardly and the smaller valve end 11 of the piston having the smaller surface 12 faces rearwardly. The large and small ends of the differential piston are joined by cylindrical piston stem 13. Rotation of the floating piston is prevented by a fixed restraining member 27 which extends into longitudinal groove 28 in the side of the piston stem. The groove is sufficiently long to permit the desired degree of longitudinal motion of the piston but terminates rearwardly at a point which checks forward movement of the piston valve out of the gas discharge port 23 at the most open position desired. End 9 of the piston, which is a disc rearwardly attached to piston stem 13, is slidably seated in piston chamber 14. The piston chamber is separated from the insulated combustion chamber by transverse metal wall 15, which also forms the rear wall of the rocket motor. The piston stem traverses wall 15 through an axial bore which fits closely around the piston stem at 16, expands into wider annulus 24 and is again reduced to form a portion of the flaring port 23.

Channel 18, which extends longitudinally and axially from the piston chamber at 19 through cylindrical tube 20 and the forward end wall 21 of the projectile and opens to the atmosphere in the nose at 22, provides an open channel for entry of air at the high compressional pressure incident at the nose into the piston chamber so that the ram pressure on the nose of the projectile is duplicated on the forward face 10 of the piston. The piston chamber is sealed against gas leakage by peripheral bellows seal 29. Vents 30 at the rear of the piston chamber provide for ambient air pressures behind the piston so that pressures cannot build up back of the forward piston head which would counteract the effective ram pressure.

In the device as shown, a forwardly flaring port 23 extends from the aperture 17 in the forward wall of the combustion chamber, through the insulation layer and part way into wall 15 where it opens into a wider sec-

tion of the bore, which, with the inserted piston stem, forms annulus 24. Two oppositely disposed channels 25 radiate outwardly from annulus 24 and open to the atmosphere through side vents 26. The rear portion of the differential piston forming piston valve 11, which is tapered rearwardly at an angle substantially complementary to that of the forwardly flaring port, extends axially into port 23 so that its rear face 12 is acted on by the pressure in the combustion chamber. Conical face 31 of the piston valve member is also acted on by the pressure of the gases in the combustion chamber but this force is generally small unless the degree of taper is large.

The device functions as follows: The high pressure combustion gases produced by the burning propellant grain in the combustion chamber vent rearwardly through rear nozzles 4 as high velocity gas streams which produce a forward thrust on the projectile. The combustion gases also exert pressure on rear face 12 and conical face 31 of the piston valve in port 23 opening into the forward end of the combustion chamber. The force exerted on the piston valve is equal to the combustion chamber pressure times the maximum cross-sectional area of the piston valve exposed to combustion gas pressure. The ram pressure at the nose of the rapidly moving projectile is communicated through open channel 18 and exerts an opposing force on forward face 10 of the larger end of the piston equal to the ram pressure times the area of face 10. When the opposing forces balance, the piston remains stationary. When the force produced by ram pressure exceeds the force produced by combustion chamber pressure on the rear piston valve, the floating piston moves rearwardly to reduce the venting throat area of the port, thereby reducing forward discharge of combustion gases from the combustion chamber. If ram pressure is sufficiently high, the piston valve will completely close the port against gas discharge, as shown in Figure 1. Reduction or stoppage of forward gas discharge increases pressure in the combustion chamber with resulting increase in propellant burning rate, which produces the desired increase in thrust to overcome the high aerodynamic drag.

Reduction in ram pressure reduces the force exerted on forward face 10 of the piston. The opposing combustion chamber pressure on the rear valve end pushes the piston forward as shown in Figure 3, thereby increasing the venting throat area of the port and permitting increased discharge of gases from the combustion chamber which vent through communicating annulus 24, channels 25 and side vents 26. The increased port venting throat area is made possible by the increasing clearance between the tapered valve and the outwardly flaring walls of the port as the piston valve moves forward. Since the venting channels 25 are at an angle normal to the forward component of thrust, the thrust produced by the gases discharged from the forward end of the combustion chamber is a sidewise component, which, in this case, is balanced by oppositely positioning the channels and side vents. Pressure in the combustion chamber drops until the force on piston face 12 is balanced by the ram force on piston face 10 and forward thrust is concomitantly reduced.

Variation in cross-sectional venting area of the gas-release port opening into the forward end of combustion chamber by movement of the piston valve can be accomplished in a number of different ways by modifying the configuration of the port and the piston valve. Preferably the piston valve is so designed that the surface area acted on by combustion chamber pressure is maintained substantially constant throughout the motion of the piston. The maximum venting port area should be sufficiently large to reduce the combustion chamber pressure to the level required to produce the minimum forward thrust desired.

Figures 5 and 6 show a modification in which piston

5

valve 111 is provided with a cylindrical axial recess 112 opening posteriorly into the forward end of the combustion chamber. This modification operates similarly to that shown in Figure 1 except that combustion chamber pressure exerted on the bottom surface 113 of the recess in the piston valve is static, thereby eliminating the effect of the high velocity exhausting gases streaming out around the valve on combustion chamber pressure on the major portion of the rear valve face.

The modification shown in Figures 7 and 8 illustrates a somewhat different method for varying the cross-sectional venting area of the gas-release port. The reduced portion of the floating differential piston forming valve 211 is cylindrical and is slidably seated in cylindrical port 212 which is an axial bore extending through transverse wall or disc 213 forming the rear wall of the rocket motor, and insulation layer 7 and opening into the forward end of the combustion chamber 3. Combustion chamber pressure is exerted on rear face 214 of the piston valve. A plurality of channels 215 in spaced transverse axial planes relative to the cylindrical port of sufficient number and size to provide substantially uniform variation in venting area and to permit the maximum requisite degree of opening connect port 212 with side vents 216. The side-wise thrust component imparted by the side venting gases is balanced, as shown, by providing oppositely paired channels in each of the transverse axial planes.

When aerodynamic drag decreases, with concomitant decrease in ram pressure, combustion chamber pressure acting on valve face 214 forces the piston forward, thereby uncovering port orifices 217 communicating with venting channels 215. The further the valve is pushed forward, the larger is the number of port venting orifices exposed in successive transverse axial planes, thereby increasing the cross-sectional venting area of the port and permitting higher combustion gas exhaust until combustion chamber pressure and ram pressure are balanced. The converse occurs when ram pressure overbalances combustion chamber pressure on the opposing faces of the differential piston.

In general, the type of solid propellant most suitable for use is one with a pressure exponent of about 0.5 to 0.6. Although the device can be designed for use with any propellants having a pressure exponent less than 1, exponents closely approaching 1, such as 0.9, tend to be oversensitive to slight changes in pressure caused, for example, by combustion instability or minor irregularities in the propellant grain. Propellants having very low pressure exponents, such as 0.2 or 0.3, are relatively insensitive to changes in combustion chamber pressure and would, therefore, require a large degree of variation in venting port area.

The specific design of a given projectile in terms, for example, of the particular surface area ratio of the differential piston, the degree of variation in port cross-sectional venting area, the size and number of the gas-venting channels, the design and composition of the rocket grain, the size and number of the rear jet nozzles and the like, is of course, determined by the particular requirements, such as the weight, size and shape of the projectile, the desired velocity and the particular launching conditions. These are factors which can readily be calculated by anyone versed in the art.

Although this invention has been described with reference to illustrative embodiments thereof, it will be apparent to those skilled in the art that the principles of this invention may be embodied in other forms but within the scope of the claims.

We claim:

1. In a rocket-assisted projectile designed to travel at substantially constant velocity, a posteriorly positioned combustion chamber adapted to contain a solid propellant charge and having at least one rear nozzle for producing forward thrust by rearward discharge of high-

6

velocity combustion gases, and a floating differential piston axially positioned anteriorly of said combustion chamber, the forward larger face of said differential piston being in open communication with and responsive to ram pressure on the nose of the projectile, and the smaller, rear portion of said differential piston serving as a valve axially and slidably positioned in a port opening posteriorly into the forward end of the combustion chamber, whereby the smaller rear end of the differential piston is acted on and responsive to combustion chamber pressure, said port being of variable cross-sectional venting area and being provided with means for permitting exhaust of combustion gases from said port out the side of the projectile, variation in the cross-sectional venting area of said port and, thereby, the amount of combustion gases venting out the forward end of the combustion chamber through said port, being controlled by the forward or rearward motion of the differential piston in response to variation in ram pressure on the nose of the projectile relative to combustion chamber pressure.

2. The projectile of claim 1 in which the forward, larger end of the floating differential piston is slidably seated in a chamber which is in open communication with the nose of the projectile.

3. The projectile of claim 2 in which the port is provided with means for permitting exhaust of combustion gases out of the side of the projectile comprising a plurality of laterally disposed open channels communicating with said port and with apertures in the side of the projectile and so oriented that the exhausting gases are discharged out the side of the projectile in a plane normal to the rear forward-thrust producing jet.

4. The projectile of claim 2 in which the port, which opens posteriorly into the forward end of the combustion chamber, flares forwardly and the valve end of the floating differential piston is substantially complementarily tapered rearwardly.

5. The projectile of claim 3 in which the port, which opens posteriorly into the forward end of the combustion chamber, flares forwardly and the valve end of the floating differential piston is substantially complementarily tapered rearwardly.

6. The projectile of claim 4 in which the rear end of the valve is provided with an axial recess open to the combustion chamber, the bottom of said recess forming a face responsive to combustion chamber pressure.

7. The projectile of claim 5 in which the rear end of the valve is provided with an axial recess open to the combustion chamber, the bottom of said recess forming a face responsive to combustion chamber pressure.

8. In a rocket-assisted projectile designed to travel at substantially constant velocity having a posteriorly positioned combustion chamber adapted to contain a solid propellant charge and having at least one rear nozzle for producing forward thrust by rearward discharge of high velocity combustion gases, a floating differential piston axially positioned anteriorly of said combustion chamber, the forward larger face of said differential piston being in open communication with and responsive to ram pressure on the nose of the projectile, and the smaller, rear portion of said differential piston being a cylindrical member serving as a valve axially and slidably positioned in an axial cylindrical port opening posteriorly into the forward end of the combustion chamber, whereby the smaller rear face of the differential piston is acted on and responsive to combustion chamber pressure, said port being provided forward of the combustion chamber with a plurality of laterally disposed channels in spaced transverse axial planes relative to said cylindrical port, said channels communicating with said port and with apertures in the side of the projectile and being so oriented that combustion gases venting from the forward end of the combustion chamber through the port are discharged out the side of the projectile in a plane normal to the rear forward-thrust producing jet, the number of said channels open to combustion gas discharge and, thereby,

7

the amount of combustion gases venting out the forward end of the combustion chamber through said port, being controlled by the forward or rearward motion of the differential piston in response to variation in ram pressure on the nose of the projectile relative to combustion chamber pressure. 5

9. The projectile of claim 8 in which the forward, larger end of the floating differential piston is slidably seated

8

in a chamber which is in open communication with the nose of the projectile.

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