Sept. 24, 1963 M. L. RICE ETAL 3,104,613

ROCKET PROJECTILE

Filed Sept. 18, 1957 2 Sheets-Sheet 1

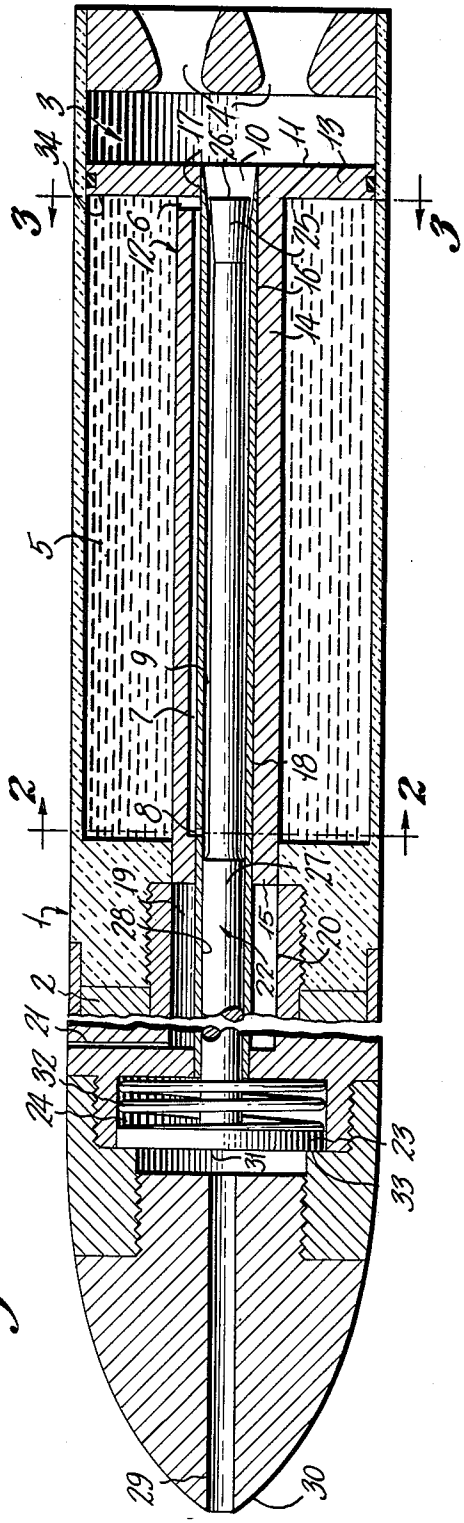


Fig. 1.

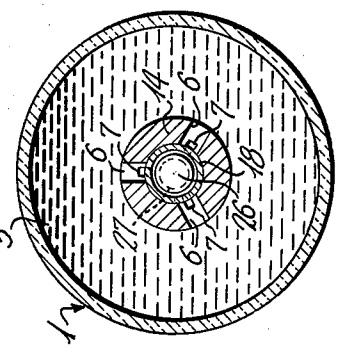


Fig. 3.

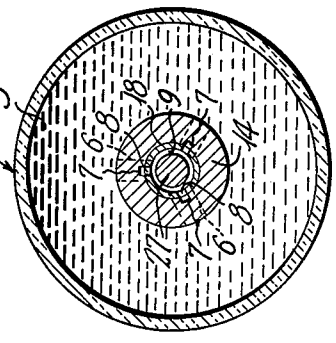


Fig. 2.

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ROCKET PROJECTILE

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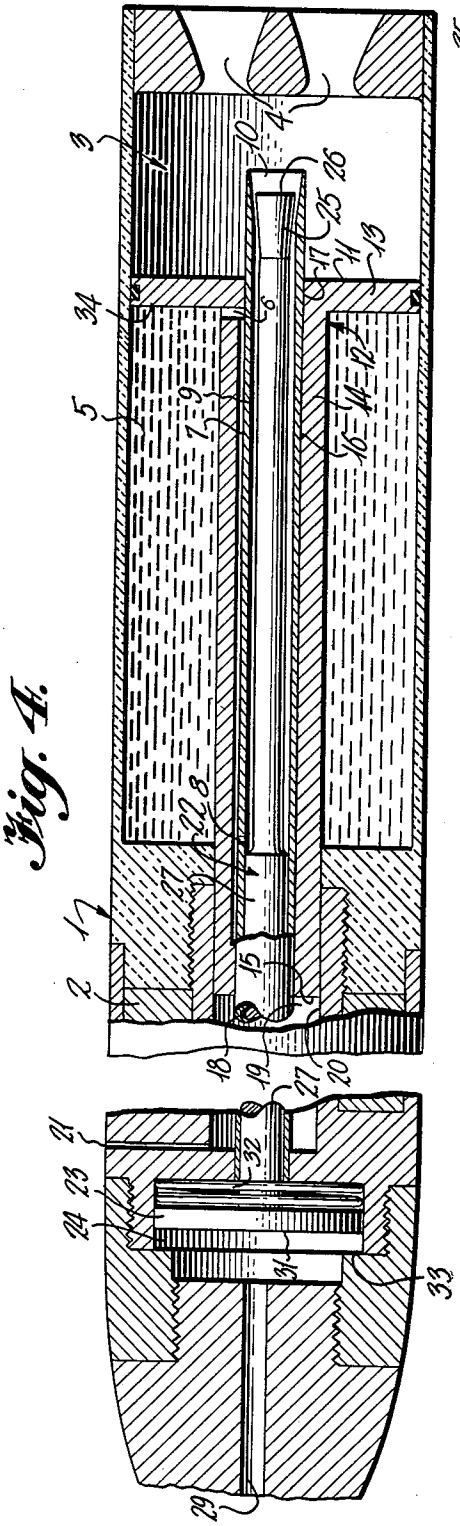


Fig. 4.

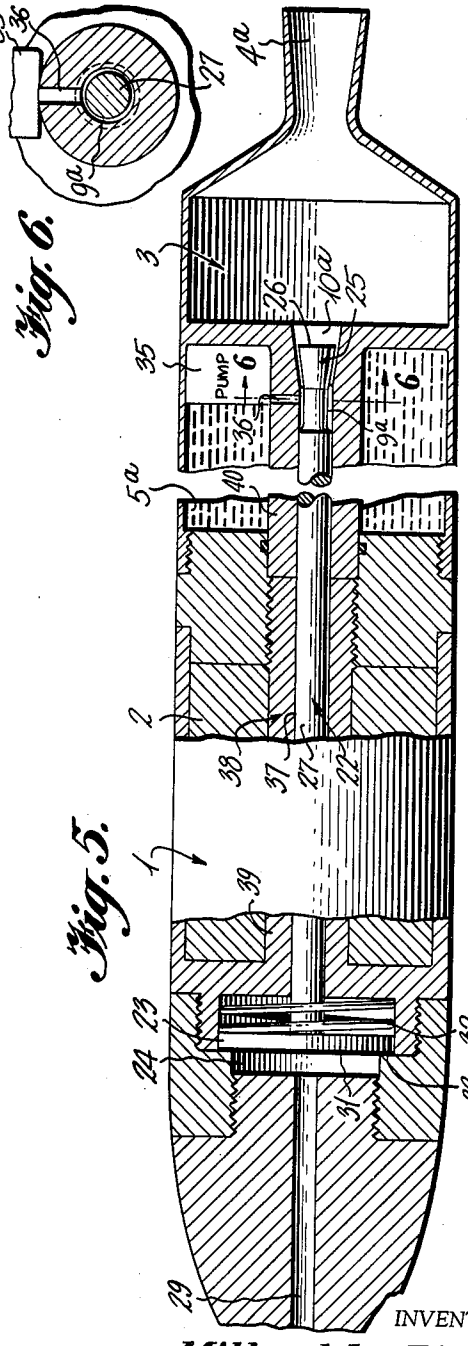



Fig. 6.

Fig. 5.

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3,104,613

# ROCKET PROJECTILE

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10 Claims. (Cl. 102—49)

This invention relates to rocket-assisted projectiles.

The object of this invention is to provide rocket projectiles employing a liquid monopropellant, 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 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, cross-sectional view taken along line 2—2 of FIG. 1.

FIG. 3 is a vertical, transverse cross-sectional view taken along line 3—3 of FIG. 1.

FIG. 4 is a vertical, longitudinal, sectional view, with certain parts shown in elevation, showing the effect of increased ram pressure on the ram pressure piston with concomitant increased injection valve opening and also showing the position of the regenerative pumping piston after depletion of some of the liquid monopropellant in the reservoir.

FIG. 5 is a vertical, longitudinal sectional view through a modification of the device.

FIG. 6 is a fragmentary cross-sectional view taken along line 6—6 of FIG. 5.

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 or 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 liquid-monopropellant 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 moving projectile, namely ram pressure, is approximately proportional to the ambient pressure, namely atmospheric 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.

The liquid monopropellant employed in the projectile rocket motor can comprise a single compound, such as hydrogen peroxide, nitromethane or tetranitromethane, which contains molecularly-combined oxygen in sufficient amount for internal combustion of other components of the compound, or a mixture comprising a fuel and an oxidizing agent, such as a mixture of hydrazine, nitric acid and water or a slurry of kerosene and ammonium perchlorate.

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 liquid monopropellant reservoir forward of the combustion chamber communicating with the combustion chamber through a valve port of variable cross-sectional throat area opening into the forward end of the combustion chamber for injection of the liquid propellant, means for forcing flow of the propellant into the combustion chamber and a floating differential piston axially positioned in the projectile forward of the combustion chamber, the forward larger face of which is responsive to ram pressure at the nose of the projectile and the reduced rearward end of which is responsive to combustion chamber pressure and functions as a slidable valve member seated in and controlling the effective cross-sectional throat area of the propellant injection valve port and, thereby, the mass flow rate of the propellant.

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, by proper design of the rear valve end, increases the size of the injection port opening into the combustion chamber to a controlled degree, thus increasing the amount of propellant injected into the combustion chamber in an amount proportional to the increase in ram pressure. The pressure in the combustion chamber rises, thereby 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 chamber overbalances the force exerted by ram pressure, the differential piston moves forward, the cross-sectional throat area of the propellant-injection valve port is decreased in size, reducing the amount of propellant introduced into the combustion chamber, combustion chamber pressure drops, thrust on the projectile decreases in an amount compensating for the reduction in aerodynamic drag and the projectile is maintained at constant velocity.

In a liquid monopropellant rocket the mass flow rate of the propellant into the combustion chamber determines the combustion chamber pressure and consequently the rocket thrust. Under equilibrium conditions the mass flow rate of the propellant into the chamber is proportional to the chamber pressure and the rocket thrust.

The propellant injection valve, therefore, must be so designed that change in the mass flow rate of propellant is proportional to the change in ram pressure. The mass

flow rate Q of the propellant into the combustion chamber is substantially given by the following equation:

$$Q=\sqrt{2\rho_p \Delta P A^2}$$

where $\rho_p$ is propellant density, $\Delta P$ is the pumping pressure, namely the difference in pressure between that on the liquid forcing it out of the reservoir and combustion chamber pressure, and A is the valve orifice area. By calculating these factors on the basis of particular conditions, the injection valve can then readily be designed so that for a given motion of the piston produced by variation in ram pressure, the size of the injection valve port throat area will be change to the requisite extent to provide for the proportional change in propellant flow rate necessary to adjust combustion chamber pressure and, thereby, thrust, to the change in aerodynamic drag.

FIGURES 1 through 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 liquid monopropellant is stored in reservoir **5** and feeds into the combustion chamber through orifice **6** in the propellant reservoir, communicating channel **7**, aperture **8** and annular channel **9** from which it is injected into the forward end of the combustion chamber through the rearwardly flaring valve port **10** of variable cross-sectional throat area.

In the device shown, the pumping pressure for injection of the liquid propellant into the combustion chamber is provided by a regenerative system in which the combustion chamber pressure acting on the rear larger face **11** of floating differential piston **12**, which will hereafter be characterized as the pumping piston, is employed as the injecting force. The differential pumping piston comprises a rearward annular disc **13** which functions as the insulated separating wall between the reservoir and the combustion chamber. Cylindrical hollow piston stem **14**, of considerably reduced diameter, extends forward longitudinally from piston disc **13** the entire length of the propellant reservoir, forming the interior wall of the annular reservoir chamber and terminating at its forward end **15** at a point beyond the forward end of the reservoir chamber when the chamber is at maximum size. The forward face **34** of piston disc **13**, which is acted on by the pressure of the liquid in the reservoir, has a smaller surface area than rear face **11** because of piston stem **14**. Bore **16** in the hollow piston stem is continuous with bore **17** in the large disc end of the pumping piston, which opens into the combustion chamber. Orifice **6** providing for fluid flow from the reservoir is located in the rear end of the pumping piston stem and opens into channel **7**, which is a longitudinal groove in the interior wall of the hollow stem terminating at a point rearward of the forward end of the stem. Fixed cylindrical tube **18**, having an outer diameter substantially equal to the diameter of the pumping piston stem bore, extends longitudinally from the rear face of the differential pumping piston at its rearwardmost position through the pumping piston stem and extends forward of the anterior end **15** of the pumping piston for a distance at least equal to the greatest length of the reservoir, namely the length of the reservoir when filled with the maximum amount of the liquid propellant. The forward end of the hollow pumping piston stem extends into and is free to move forward in annular channel **19** defined interiorly by the outer wall of tube **18** and exteriorly by the interior wall **20** of the cylindrical annular war head. Annular channel **19** extends forward from face **15** of the pumping piston stem for a distance at least equal to the greatest length of the propellant reservoir when the pumping piston is at its rearwardmost position. The channel is open to the atmosphere through side vent **21** so that the pressure within it is ambient.

Axially positioned anteriorly of the combustion chamber, is a second floating differential piston **22**, which will be characterized hereafter as the ram pressure piston, oriented in such manner that the larger end **23** of the piston, which is a disc slidably seated in piston chamber **24** in the forward end of the projectile, faces forwardly, and the smaller valve end **25** of the piston, having the smaller face **26**, faces rearwardly. The large disc end and smaller valve end of the differential ram pressure piston are joined by cylindrical piston stem **27** which extends axially and longitudinally through axial bore **28** in fixed tube **18**. The piston stem, which fits closely in the anterior portion of bore **28**, is narrowed to a smaller diameter at a point slightly forward of aperture **8** in tube **18** to form annular channel **9** for flow of the liquid propellant. The inner wall at the rear end of tube **18** flares rearwardly to form valve port **10** of variable cross-sectional throat area for injection of the propellent liquid into the combustion chamber. The rear end of the ram pressure piston forms a rearwardly flaring valve member **25** which is slidably positioned in similarly flaring valve port **10**, so that face **26** of the ram pressure piston is exposed to the pressure of the gases in the combustion chamber. As the ram pressure piston moves forward or backward, the cross-sectional venting throat area of injection valve port **10** becomes respectively larger or smaller with corresponding increase or decrease in the mass flow rate of the propellant into the combustion chamber.

Channel **29**, which extends forward longitudinally and axially from piston chamber **24** and opens to the atmosphere in the nose **30** of the projectile, provides an open passage 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 **31** of the piston. Spring **32** of predetermined design and tensional characteristics is positioned back of piston disc **23**. Shoulder **33** in the piston chamber prevents forward motion of the piston to the point where the rear valve end completely closes injection port **10**. Gas seals are provided at the necessary points throughout the system to prevent gas leakage.

The device functions as follows: The pumping pressure requisite for propellant injection into the combustion chamber is produced by combustion gas pressure on the rear face **11** of the pumping piston. The total force exerted by the piston on the propellant liquid in the reservoir equals the pressure in the combustion chamber ($P_c$) times the surface area of face **11** ($A_c$) minus ambient atmospheric pressure ($P_A$) times the area of the forward face **15** ($A_A$) of the pumping piston, the latter force being substantially negligible. The pressure in the reservoir ($P_R$) is given by the following equation:

$$P_R=P_cA_c/A_R-P_AA_A/A_R$$

where $A_R$ is the area of piston face **34**. Since $A_R$ is smaller than $A_c$ and $P_AA_A$ is quite small, the pressure in the reservoir is higher than that in the combustion chamber and provides a positive pumping pressure P, which is equal to $P_R-P_c$. As the liquid propellant is depleted in the reservoir, the floating differential pumping piston is moved forward by combustion chamber pressure and the pumping pressure in the reservoir is maintained. The position of the pumping piston after depletion of some of the propellant in the reservoir is shown in FIGURE 4.

The combustion gases produced by burning of the liquid monopropellant in the combustion chamber vent rearwardly through the restricted nozzles **4** as high velocity gas streams which produce a forward thrust on the projectile. The combustion gases also exert pressure on rear face **26** of the ram pressure piston, the total force on the piston equaling the combustion chamber pressure times the area of the piston valve face. The ram pressure at the nose of the rapidly moving projectile is communicated through passage **29** and exerts an opposing force on forward face **31** of the ram pressure piston equal to

the ram pressure times the area of face 31. Since combustion chamber pressures in a liquid propellant system are relatively low, rarely exceeding about 200 to 300 p.s.i., and the valve end of the ram pressure piston is relatively small the high ram pressures normally incident on the high velocity projectile are likely to push the piston rearwardly to such an extent as to keep the valve wide open at all times. Spring 32 functions to reduce the effect of ram pressure in an amount which, being proportional to variations in ram pressure, does not counteract the over-all counterbalancing of ram and combustion chamber pressures.

When the opposing forces on the ends of the spring-retarded floating differential ram pressure piston balance, the piston remains stationary. When ram pressure increases the piston moves rearwardly, as shown in FIGURE 4, to increase venting throat area of injection valve 10 to the extent required to increase the mass flow rate of the propellant, thereby increasing combustion chamber pressure, which produces the desired increase in thrust to overcome the higher aerodynamic drag.

Reduction in ram pressure reduces the force exerted on forward face 31 of the piston. The opposing combustion chamber pressure pushes the piston forward, thereby reducing venting throat area of injection valve 10, reducing combustion chamber pressure and reducing thrust in a proportional amount.

The number of fluid feeding orifices in the reservoir can be varied as desired. The design of the ram pressure piston valve and injection port can also be modified so long as they are properly designed to proportionate the desired increase and decrease in mass flow rate with change in ram pressure as aforediscussed.

Although the specific embodiment shows a regenerative fluid injection system employing a differential piston to provide pumping pressure, conventional pumping means can also be used, as shown in FIGURES 5 and 6.

The modification shown in FIG. 5 is substantially similar to the device shown in FIG. 1 in many respects, including the floating differential ram pressure piston and its mode of functioning in the device, the chief difference being that a conventional pump 35 replaces the regenerative pumping piston system. Similar elements are designated by corresponding reference numerals.

The projectile 1 contains a war head 2 at its forward end and a rocket motor comprising a combustion chamber 3 and rearwardly venting nozzle 4*a* of predetermined, fixed size. The liquid monopropellant is stored in reservoir 5*a* and is fed into the combustion chamber by means of pump 35, shown diagrammatically, through orifice 36 into annular channel 9*a* from which it exits through the rearwardly flaring valve port 10*a* of variable cross-sectional throat area.

Floating differential piston 22 is axially positioned anteriorly of the combustion chamber, with its forward, larger spring retarded disc end 23 slidably seated in piston chamber 24, its stem 27 extending rearwardly and axially through longitudinal axial bore 37 within fixed tube 38, formed in part by the interior wall 39 of the annular casing containing the war head and in part by the interior wall 40 of the annular reservoir chamber, and its rear, flaring valve end 25 extending into flaring port 10*a* opening into the forward end of the combustion chamber. The rear, smaller face 26 of the differential piston is thereby exposed to and responsive to the pressure of the gases in the combustion chamber. The piston stem fits closely in bore 37 until a point just forward of propellant-feeding orifice 36 in the reservoir, where it narrows in diameter to form an annular channel 9*a* for passage of the liquid propellant into the injection valve. As the differential piston moves forward or backward under the opposing ram and combustion chamber pressures, the cross-sectional venting throat area of injection valve port 10*a* becomes respectively larger or smaller with corresponding increase or decrease in the mass flow rate of the propellant into the combustion chamber.

Forward piston chamber 24 is open to the atmosphere through channel 29 which opens into the nose of the projectile, so that the forward larger face 31 of the differential piston is acted on and is responsive to ram pressure on the nose of the rapidly moving projectile. Spring 32 functions similarly to that in the device of FIG. 1 and shoulder 33 similarly prevents total closure of the injection valve port.

The differential piston functions in the same way as the ram pressure piston of the device of FIG. 1 in compensating for variation in aerodynamic drag and thereby maintaining the projectile at constant velocity. Increase in ram pressure, which, as aforedescribed, is substantially proportional to increase in aerodynamic drag at the high projectile velocities, forces the piston rearwardly with resulting increase in valve aperture and increase in mass flow rate of the propellant, thereby increasing combustion chamber pressure, which produces the increased thrust necessary to compensate for the increased drag. When aerodynamic drag and ram pressure drop, the piston moves forward, reducing the rate of propellant injection and combustion chamber pressure, thereby reducing thrust to a compensating degree.

The specific design of a given projectile in terms, for example, of the particular surface area ratio of the differential ram pressure piston, the degree of variation in the propellant injection valve throat area, the particular monopropellant used, 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, a posteriorly positioned combustion chamber adapted to burn a liquid monopropellant and having at least one rear nozzle for producing forward thrust by rearward discharge of high velocity combustion gases, an annular reservoir chamber forward of said combustion chamber adapted to contain liquid monopropellant, pumping means for forcing said monopropellant out of the reservoir and into the combustion chamber, 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 directly responsive to ram pressure on the nose of the projectile, and the smaller rear portion of said differential piston forming a valve member axially and slidably positioned in a port of variable cross-sectional throat area opening posteriorly into the forward end of the combustion chamber, whereby the smaller rear face of the differential piston is acted on and is directly responsive to combustion chamber pressure, said port being in communication with the liquid venting orifice of the monopropellant reservoir and forming an exit passage into the combustion chamber for the liquid monopropellant flowing therefrom, the rear piston valve member having a configuration relative to that of the port such that rearward motion of the piston valve member increases the cross-sectional throat area of said port for increased passage of monopropellant into the combustion chamber and forward motion decreases the cross-sectional throat area, the mass flow rate of the monopropellant being injected into the combustion chamber, thereby 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 and in which said piston is associated with means for reducing to a predetermined and proportionate degree its rearward motion in response to ram pressure.

3. In a rocket-assisted projectile, a posteriorly positioned combustion chamber adapted to burn a liquid monopropellant and having at least one rear nozzle for producing forward thrust by rearward discharge of high velocity combustion gases; an annular reservoir chamber forward of said combustion chamber and adapted to contain liquid monopropellant, pumping means for forcing said liquid monopropellant out of the reservoir and into the combustion chamber, and a floating differential piston axially positioned anteriorly of said combustion chamber, said piston comprising a forward larger disc end slidably positioned in a chamber which is in open communication with the nose of the projectile, whereby the forward, larger face of the piston is acted on and is directly responsive to ram pressure on the nose of the projectile, said forward end of the piston being associated with means for reducing to a predetermined and proportionate degree rearward motion of said piston in response to ram pressure, a piston stem of reduced diameter extending axially and longitudinally through an axial bore within a fixed longitudinal tube opening rearwardly into the forward end of the combustion chamber, said bore being in communication with the liquid-venting orifice in the reservoir, the rear portion of said bore flaring rearwardly posteriorly of the entrance of propellant liquid into the bore, thereby forming an exit passage port of variable cross-sectional throat area into the combustion chamber for the liquid monopropellant, and a rear portion of reduced diameter relative to the forward piston disc, said rear portion flaring rearwardly and being slidably seated in said port, whereby the rear face of the differential piston is acted on and is directly responsive to combustion chamber pressure, variation in the cross-sectional throat area of said port and, thereby, the mass flow rate of the monopropellant liquid being injected into the combustion chamber, 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.

4. The projectile of claim 3 in which the means for reducing rearward motion of the differential piston in response to ram pressure is a spring urging the differential piston in a direction opposite to the ram pressure force.

5. The projectile of claim 1 in which the pumping means for forcing the liquid monopropellant out of the reservoir is a second floating differential piston comprising a centrally perforated, annular disc forming a slidable wall between the combustion chamber and the monopropellant reservoir forward thereof, the rear face of the disc being responsive to combustion chamber pressure and the forward face being responsive to the pressure of the liquid monopropellant in the reservoir, and a hollow tube, of substantially reduced exterior diameter relative to the diameter of said disc, attached to and reducing the area of the forward face of said disc and extending forward longitudinally to the axis of the projectile, the bore of the tube and the perforation in the disc being in registry, said hollow tube member of the pumping differential piston forming the interior wall of the annular monopropellant reservoir chamber and terminating forward of the reservoir chamber within an annular channel in which it is slidably positioned, which extends forward of said hollow tube pumping-piston member for the desired distance of forward travel of the pumping piston and which is in communication with the atmosphere through a side venting channel whereby pressure on the forward annular face of the reduced end of the pumping differential piston is ambient.



6. The projectile of claim 2 in which the pumping means for forcing the liquid monopropellant out of the reservoir is a second floating differential piston comprising a centrally perforated, annular disc forming a slidable wall between the combustion chamber and the monopropellant reservoir forward thereof, the rear face of the disc being responsive to combustion chamber pressure and the forward face being responsive to the pressure of the liquid monopropellant in the reservoir, and a hollow tube, of substantially reduced exterior diameter relative to the diameter of said disc, attached to and reducing the area of the forward face of said disc and extending forward longitudinally to the axis of the projectile, the bore of the tube and the perforation in the disc being in registry, said hollow tube member of the pumping differential piston forming the interior wall of the annular monopropellant reservoir chamber and terminating forward of the reservoir chamber within an annular channel in which it is slidably positioned, said annular channel extending forward of said hollow tube pumping-piston member for the desired distance of forward travel of the pumping piston and being in communication with the atmosphere through a side venting channel whereby pressure on the forward annular face of the reduced end of the pumping differential piston is ambient.

7. The projectile of claim 3 in which the pumping means for forcing the liquid monopropellant out of the reservoir is a second floating differential piston comprising a centrally perforated, annular disc forming a slidable wall between the combustion chamber and the monopropellant reservoir forward thereof, the rear face of the disc being responsive to combustion chamber pressure and the forward face being responsive to the pressure of the liquid monopropellant in the reservoir, and a hollow tube, of substantially reduced exterior diameter relative to the diameter of said disc, attached to and reducing the area of the forward face of said disc and extending forward longitudinally to the axis of the projectile, the bore of the tube and the perforation in the disc being in registry, said hollow tube member of the pumping differential piston forming the interior wall of the annular monopropellant reservoir chamber and terminating forward of the reservoir chamber within an annular channel in which it is slidably positioned, which extends forward of said hollow tube pumping-piston member for the desired distance of forward travel of the pumping piston and which is in communication with the atmosphere through a side venting channel whereby pressure on the forward annular face of the reduced end of the pumping differential piston is ambient.

8. The projectile of claim 4 in which the pumping means for forcing the liquid monopropellant out of the reservoir is a second floating differential piston comprising a centrally perforated, annular disc forming a slidable wall between the combustion chamber and the monopropellant reservoir forward thereof, the rear face of the disc being responsive to combustion chamber pressure and the forward face being responsive to the pressure of the liquid monopropellant in the reservoir, and a hollow tube, of substantially reduced exterior diameter relative to the diameter of said disc, attached to and reducing the area of the forward face of said disc and extending forward longitudinally to the axis of the projectile, the bore of the tube and the perforation in the disc being in registry, said hollow tube member of the pumping differential piston forming the interior wall of the annular monopropellant reservoir chamber and terminating forward of the reservoir chamber within an annular channel in which it is slidably positioned, which extends forward of said hollow tube pumping-piston member for the desired distance of forward travel of the pumping piston and which is in communication with the atmosphere through a side venting channel whereby pressure on the forward annular face of the reduced end of the pumping differential piston is ambient.

9. The projectile of claim 7 in which the slidable hollow tube member of the pumping differential piston forming the interior wall of the annular reservoir chamber has at least one rearwardly positioned orifice for venting of the monopropellant liquid feeding into a channel extending forward longitudinally from said orifice and defined by a longitudinal groove in the interior wall of said hollow tube member, said groove terminating rearwardly of the forward end of said hollow tube, and the exterior wall of the fixed longitudinal tube housing the axial bore in which the axial piston stem of the differential piston responsive to ram pressure is slidably seated, said channel communicating with an orifice in said fixed longitudinal tube positioned in a transverse plane substantially adjacent the forward end of the monopropellant reservoir, the orifice in said fixed longitudinal tube in turn feeding the monopropellant liquid into an annular channel within the axial bore defined by the interior wall of the fixed longitudinal tube and the axial piston stem, the axial piston stem being of reduced diameter relative to the diameter of the axial bore rearwardly from a point forward of the orifice in the fixed longitudinal tube until the piston stem flares rearwardly to form the valve member seated in the monopropellant injection port which forms the exit passage of the monopropellant liquid from said annular channel within the axial bore into the combustion chamber.

10. The projectile of claim 8 in which the slidable hollow tube member of the pumping differential piston forming the interior wall of the annular reservoir chamber has at least one rearwardly positioned orifice for venting of the monopropellant liquid feeding into a channel extending forward longitudinally from said orifice and defined by a longitudinal groove in the interior wall of said hollow tube member, said groove terminating rearwardly of the forward end of said hollow tube, and the exterior wall of the fixed longitudinal tube housing the axial bore in which the axial piston stem of the differential piston responsive to ram pressure is slidably seated, said channel communicating with an orifice in said fixed longitudinal tube positioned in a transverse plane substantially adjacent the forward end of the monopropellant reservoir, the orifice in said fixed longitudinal tube in turn feeding the monopropellant liquid into an annular channel within the axial bore defined by the interior wall of the fixed longitudinal tube and the axial piston stem, the axial piston stem being of reduced diameter relative to the diameter of the axial bore rearwardly from a point forward of the orifice in the fixed longitudinal tube until the piston stem flares rearwardly to form the valve member seated in the monopropellant injection port which forms the exit passage of the monopropellant liquid from said annular channel within the axial bore into the combustion chamber.




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