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METHOD AND MEANS FOR AUGMENTING HYPERVELOCITY FLIGHT

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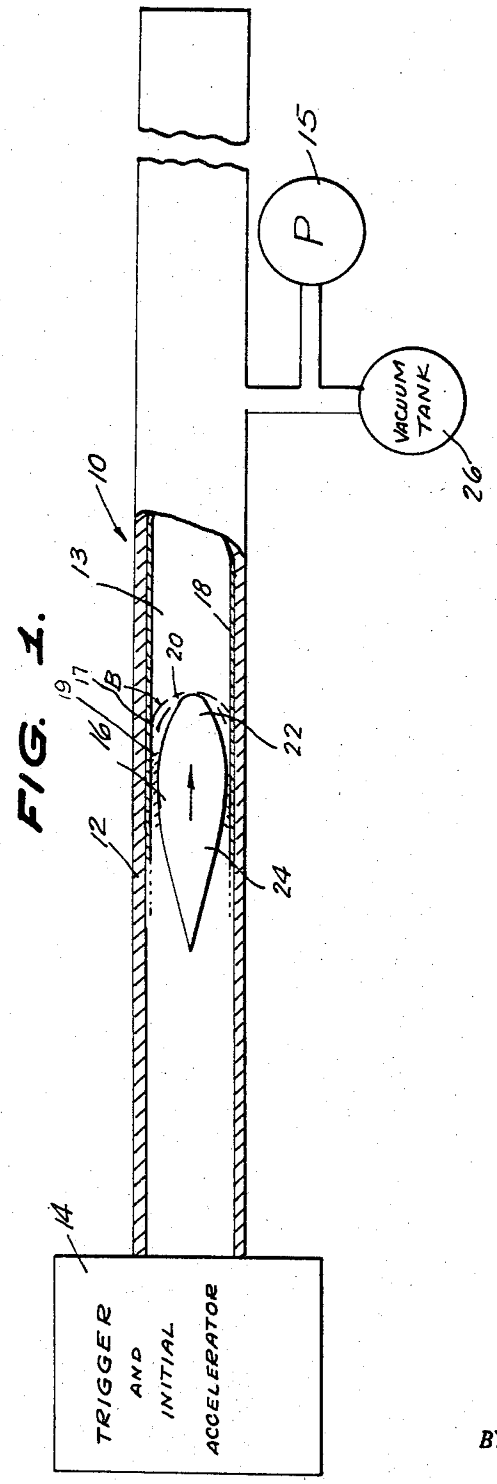

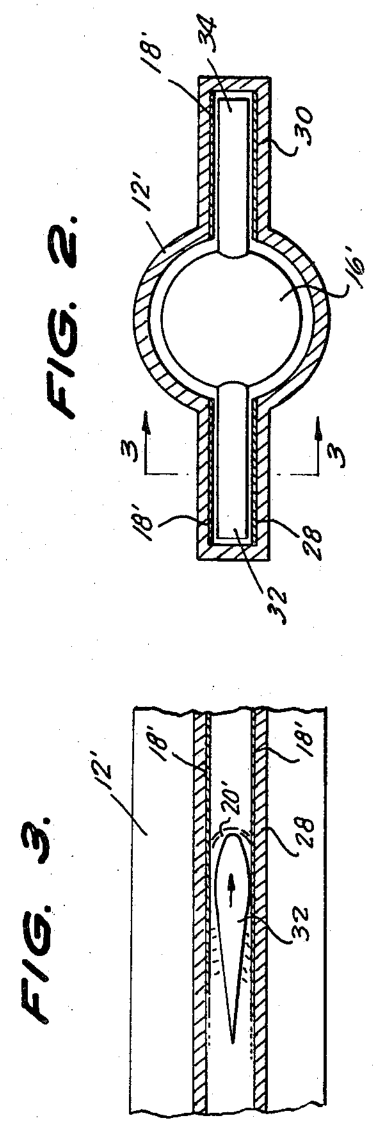

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3,418,878 METHOD AND MEANS FOR AUGMENTING HYPERVELOCITY FLIGHT

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ABSTRACT OF THE DISCLOSURE

A process and means for augmenting hypervelocity flight of a projectile. A projectile is initially propelled at supersonic velocities through a tube containing a gaseous medium and lined with a chemically explosive propellant responsive to high temperatures and pressures. Movement of the projectile produces a high temperature and pressure shock wave in the gaseous medium which is reflected off the propellant lining beside the projectile and detonates the lining. Detonation of the propellant will generate a high pressure gas impinged upon the aft portion of the projectile to accelerate it. As the projectile is moved down the tube, this process is continuously repeated to continuously accelerate the projectile.

This invention relates to a process and a device for accelerating a mass to high velocities.

With the advent of space exploration, the physics and dynamics of hypervelocity flight, as well as impact reactions, must be studied under simulated conditions. One mode of study devised for this purpose is to propel a projectile or mass in a barrel or launch tube to great speeds.

Current devices propel the projectile or mass by driving it with a high pressure gas forced into the barrel. As the projectile velocity exceeds the speed of sound in the driver gas, the pressure on it begins to reduce rapidly and consequently the acceleration of the projectile is reduced, limiting its maximum attainable velocity.

Accordingly, it is an object of this invention to propel a projectile or mass in a barrel to greater velocities than have been attainable heretofore.

Another object of this invention is to provide an acceleration tube or barrel lined with a chemically explosive propellant, which is adapted to be ignited by a high temperature and pressure shock wave generated by the projectile as it is accelerated in the barrel, the consequent explosion of the propellant generating a driving gas for exerting pressure on the aft portion of the projectile for uniformly and continuously accelerating it.

A still further object of this invention is to provide a process for accelerating a projectile or mass, where the projectile or mass is accelerated by flying it down the barrel enclosing it, by causing a series of high pressure gas generating continuous explosions to occur beside it, thereby preventing the projectile or mass from out-distancing the driver gas, which would result in a consequent reduction of gas pressure on it, limiting its acceleration.

Further objects and advantages of the invention will become apparent from the following description and claims, and from the accompanying drawing, wherein:

FIGURE 1 is a fragmentary, side view in elevation of the hypervelocity augmentation apparatus used in the present invention partly in section, and including portions illustrated schematically;

FIGURE 2 is a cross-sectional view of a slightly modified form of the apparatus; and

FIGURE 3 is a fragmentary cross-sectional view taken substantially along the plane indicated by line 3—3 of FIGURE 2.

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Referring now to the drawing in detail, wherein like numerals indicate like elements throughout the several views, a hypervelocity augmentation apparatus is generally indicated in FIGURE 1 by the numeral **10**.

The apparatus **10** includes a launch tube or barrel **12** filled with a gaseous medium **13**, a standard ignition device **14**, and a vacuum pump **15** for reducing friction or gas resistance in the barrel.

The ignition device **14** could be an ordnance type device to initiate a high temperature and pressure of gas **13** and consequent motion of a projectile or mass **16** in barrel **12**, or preferably, could constitute a complete first stage acceleration assembly to have accelerated the projectile **16** to a predetermined supersonic velocity before entering barrel **12**.

The ignition device **14** is of standard construction and forms no part of the instant invention. For examples of suitable ignition devices, see U.S. Patent Nos. 3,126,789 and 3,148,587.

In order to increase the velocity of the projectile **16** as it moves through barrel **12**, the barrel is lined with a chemically explosive propellant **18**, ignitable by heat and pressure. The propellant to be used can be made from any material rated as a low or secondary chemical explosive or a high chemical explosive that can be formed into a plastic-adhesive mass, as more fully discussed hereinafter, and is capable of generating a driver gas at a high rate.

As the projectile **16** is propelled at supersonic velocities down barrel **12**, it generates a shock wave or disturbance **20** in gaseous medium **13** about its nose portion **22**.

Any small disturbance in a gaseous medium is propagated with the speed of sound in that medium. For example, a disturbance in still air travels outward from the source of disturbance at the speed of sound, as a spherical pressure wave. When the source of the disturbance moves with a subsonic velocity, a wave is generated which travels ahead of the disturbing body and gives the fluid a chance to adjust itself to the oncoming body. However, when the disturbing body is moving at supersonic velocities, the body moves faster than the spherical waves emitted from it, yielding a curved or cone-shaped wave front with a vertex at the body. The pressure front extends out beside the body and is called a shock wave. There is a sudden change in velocity and presure intensity across a shock wave, with a coresponding increase in temperature.

As shown in FIGURE 1, the projectile **16** has a maximum cross-section which is smaller than the diameter of barrel **12**. Consequently, shock wave **20** extends out beside the nose **22** of projectile **16**, which serves as the vertex of the wave, and is reflected off lining **18** beside the nose.

The temperature and pressure across shock wave **20** is ideal for igniting propellant **16**. Neglecting real gas effects, the temperature and pressure across the shock wave beside nose **22**, at very high speeds, can be expressed as:

$$T_1 = \frac{T_o 2\gamma(\gamma-1)V^2 \sin^2 B}{(\gamma+1)^2 A_o^2}$$

$$P_1 = \frac{P_o 2\gamma}{\gamma+1} \frac{V^2}{A_o^2} \sin^2 B$$

where:

T_1=temperature behind the shock wave
P_1=pressure behind the shock wave
T_o=temperature of the gaseous medium ahead of the projectile
P_o=pressure of the gaseous medium ahead of the projectile
V=velocity of the projectile

A_0=speed of sound in the gaseous medium ahead of the projectile

B=angle of the shock wave (see FIG. 1)

γ=ratio of specific heat of the gaseous medium at constant pressure to its specific heat at constant volume, or the adiabatic constant for the gaseous medium

Asuming sea level conditions, and that the gaseous medium is air:

$A_0=1116.9$ ft./sec.
$T_0=59°$ F.
$\gamma=1.4$

Taking $B=30°$ and the value of V as 20,000 ft./sec. and multiplying by 2. to account for the reflection of the shock wave:

$T_1=15{,}640°$ F.
$P_1=186.4P_0$

This shows that the temperature and pressure rise across shock wave **20** is sufficient to trigger almost any type of chemically explosive propellant.

As the shock wave **20** is reflected off propellant lining **18**, it will cause the propellant to explode adjacent the aft portion **24** of projectile **16**. Explosion of the propellant **18** will generate a high pressure gas impinged upon the aft portion **24** of projectile **16**, to accelerate it.

As the projectile **16** moves down the barrel **12**, the shock wave **20** causes the lining **18** to continuously explode beside the projectile to continuously accelerate it and fly it down barrel **12**. The projectile **16** is streamlined in shape, as shown in FIGURE 1, so as to enable the generated high pressure gas to drive it with maximum forward thrust. The projectile **16** cannot outrun the driving gas, and its maximum attainable velocity is limited only by the length of barrel **12**, and the reaction time of the explosive lining.

To insure detonation of the propellant lining **18** at the proper time so that the gas generated by the explosion acts on the aft portion **24** of projectile **16**, and not behind it or in front of it, the time lapse or delay time between the triggering of the propellant and the time it explodes should be calibrated along the length of barrel **12**.

For example, if a linear distance of .2 inch between the shock and the reaction of the explosive (points **17** and **19** on FIG. 1) is required to obtain proper pressure on the aft portion of the projectile, and the velocity of the projectile is 100,000 ft./sec., the reaction time must be of the order of 2×10^{-7} sec. The materials which react this fast are high explosives such as TNT. At lower speeds a less active propellant, such as gunpowder could be used. Therefore the propellant lining **18** should be varied along the barrel **12** to compensate for the increasing velocity of the projectile **16**.

On the other hand, it may be possible to use a secondary explosive or less active propellant throughout the length of the barrel, as long as the propellant is responsive to the heat radiated ahead of the shock wave. The explosive, due to its reaction time, would explode beside the projectile and thereby exert a force on the aft portion thereof. Often, this may be desirable because high explosives such as TNT are difficult and dangerous to work with.

As an alternative or additional method for controlling the time and place of the detonation, the barrel **12** could have different size cross-sections at the various stages of travel of the projectile **16**. These different size barrel sections would serve the purpose of allowing the shock wave **20** to pass around the projectile nose **22** at different speeds and would compensate for the fact that the mass rate of flow of the gaseous medium of the wave will increase with the speed of the projectile.

In lieu of varying the diameter or cross-section of barrel **12**, a vacuum tank **26** can be connected to the barrel **12** for varying the density of the gaseous medium **13** in the barrel, in timed reaction to the firing of the projectile. This will also control the mass rate of flow of wave **20** past the projectile nose **22**.

FIGURES 2 and 3 illustrate a slightly modified form of the invention, which is used when it is desired to change the shape or configuration of the projectile for experimentation purposes.

As shown in FIGURES 2 and 3, the cylindrical barrel **12'** has enclosed lateral extensions **28** and **30**. A projectile **16'** is provided of any desirable shape. Attached to the sides of the projectile are wing-like elements **32** and **34**, corresponding in design to projectile **16**, and which extend into lateral extensions **28** and **30**, respectively, of barrel **12'**.

The top and bottom interior surfaces of lateral extensions **28** and **30** are coated with a chemically explosive propellant **18'**, corresponding to propellant lining **18** in FIGURE 1.

Movement of projectile **16'** through barrel **12'** at supersonic velocities will generate a shock wave **20'** about wing-like elements **32** and **34**. The shock waves **20'** will detonate propellant **18'** in the same manner as in FIGURE 1, adjacent the aft portions of wing-like elements **32** and **34**, for continuously accelerating projectile **16'** down barrel **12'**.

With the process and means of the present invention, the problem of a shock wave building in front of the projectile with the possibility of premature detonation of the lining if the temperature and pressure of the wave is sufficiently high, is also eliminated, because the projectile does not contact the sides of the barrel, but is flown down the barrel. This enables the generated wave to be disposed behind the projectile nose.

Barrel **12** or **12'** may be made from a recoverable material of high structural strength to resist internal pressure, or it may be made expendable.

The process and means disclosed also has ordnance capabilities. A weapon with a propellant lined barrel as disclosed, will be capable of shooting projectiles with increased range.

While specific embodiments of my invention have been disclosed in the foregoing description, it will be understood that various modifications within the spirit of the invention may occur to those skilled in the art. Therefore, it is intended that no limitations be placed on the invention except as defined by the scope of the appended claims.

I claim:

1. A process for accelerating a mass having a streamlined-shaped portion comprising the steps of initially propelling said mass at supersonic velocities through a tube lined with an explosive propellant and filled with a gaseous medium, said mass when passing through said gaseous medium in said lined tube generating a shock wave of sufficient temperature and pressure to initiate detonation of said propellant lining, and causing said generated shock wave to detonate said lining adjacent the aft portion of said streamlined mass, thereby providing a force on the mass to accelerate it.

2. A process in accordance with claim **1** wherein said shock wave is reflected off said propellant lining in said tube to detonate said lining adjacent the aft portion of said streamlined mass.

3. A process in accordance with claim **1** wherein said shock wave is continuously generated adjacent said mass as it moves through said tube, causing said propellant to continuously explode adjacent the aft portion of said mass to continuously accelerate it.

4. A process in accordance with claim **1** including the step of varying the mass rate of flow of said shock wave in said tube.

5. Apparatus comprising an elongated barrel having an explosive propellant lining and filled with a gaseous medium, projectile means disposed within said barrel and having a streamlined portion adjacent said barrel lining, the maximum cross-section of said streamlined portion of said projectile means being less than the inside diameter of said barrel lining, means connected to one end of said barrel for initially propelling said projectile means through the gaseous medium in said barrel at supersonic velocities, the passage of said streamlined portion of said projectile means through said gaseous medium generating a shock wave for detonating said lining, said explosive lining having a reaction time so that its detonation occurs adjacent the aft portion of the projectile, whereby said explosion will exert a force acting on the projectile means to accelerate it down said barrel.

6. Apparatus in accordance with claim **5** wherein said barrel includes a pair of opposed lateral extensions, said propellant lining coating only the interior surfaces of said extensions.

7. Apparatus in accordance with claim **6** including vacuum tank means operatively connected to said barrel for varying the density of the gaseous medium within said barrel.

8. Apparatus in accordance with claim **6** including pump means operatively connected to said barrel for partially evacuating said barrel to minimize frictional resistance to propulsion of said projectile means.

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42—76; 89—14