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Fletcher et al.

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[54] **TWO STAGE LIGHT GAS-PLASMA PROJECTILE ACCELERATOR**

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[51] **Int. Cl.²** **F41F 1/04**

[58] **Field of Search** 89/7, 8; 73/12; 315/111, 315/111.5, 111.6

[56] **References Cited**

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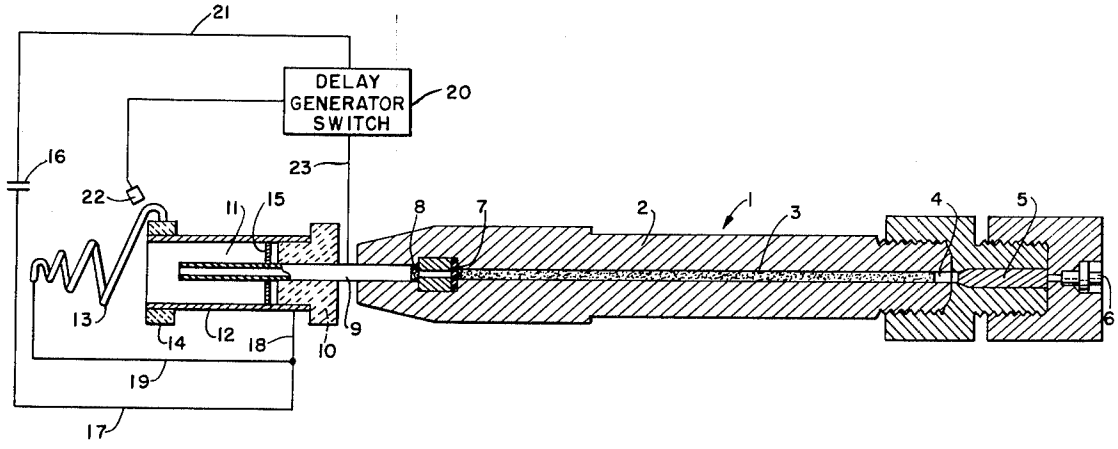
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[57] **ABSTRACT**

A device for accelerating a projectile to extremely high velocities includes a light gas accelerator to impart an initial high velocity to the projectile and a plasma accelerator and compressor receiving the moving projectile and accelerating it to higher velocities. A capacitor bank is discharged into a plasma generator in timed relationship to the position of the projectile so that the moving plasma drags the projectile along with it. Projectile velocities in the order of 20 kilometers per second, the average meteoroid velocity, can be attained, whereby the accelerator finds particular utility in the field of meteoroid simulation.

8 Claims, 2 Drawing Figures



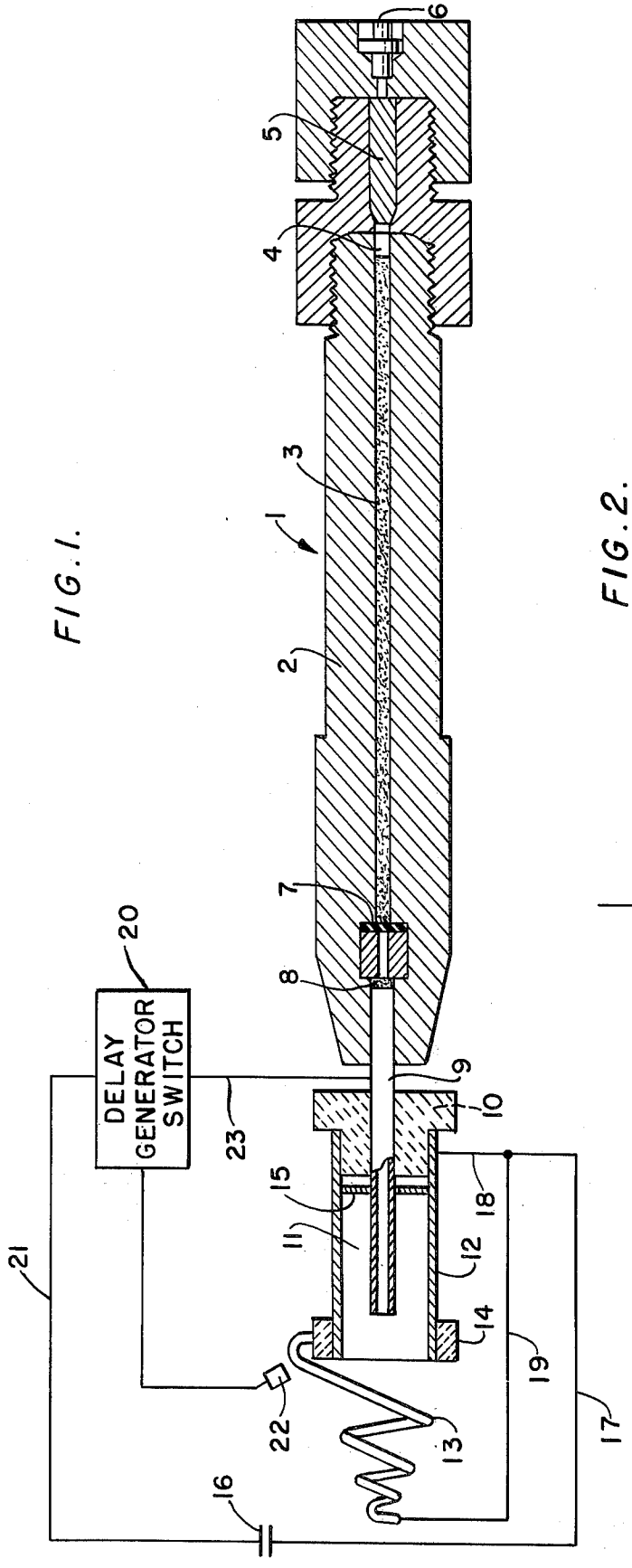

DELAY GENERATOR SWITCH
20
23
21
16
22
13
17
19
14
12
11
15
18
10
9
8
7
2
3
1
4
5
6

FIG. 1.

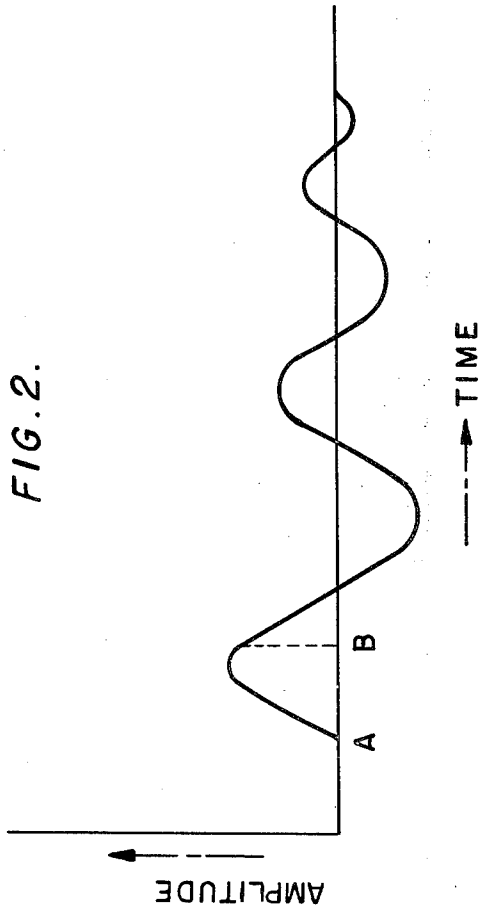

AMPLITUDE
TIME
A
B

FIG. 2.

TWO STAGE LIGHT GAS-PLASMA PROJECTILE ACCELERATOR

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 USC 2457).

BACKGROUND OF THE INVENTION

The present invention relates generally to the field of projectile acceleration, and more particularly to apparatus including a light gas accelerator for causing a projectile to attain extremely high velocities.

Many techniques have been used in the attempt to achieve a high projectile velocity. Many of these efforts have been directed toward the achievement of average meteoroid velocity with a relatively small projectile. Projectiles traveling at such a velocity are very useful in the testing of meteorite damage to space vehicles and in the simulation of orbital velocity re-entry problems.

One prior art technique for projectile acceleration is a light gas accelerator utilizing the compression of a light gas to drive the projectile by driving a piston through an enclosed pump tube containing the light gas with a diaphragm at the other end of the tube. When the diaphragm bursts, the compressed gas accelerates the projectile down a barrel. While this is a useful technique, the performance of such a device is fundamentally limited by the finite velocity of sound in a gas. Thus, at any given time, the gas pressure near the projectile is only a fraction of the pressure near the piston, resulting in lower acceleration to limit terminal velocity of the projectile.

Other methods of projectile acceleration include the use of gases from chemical explosions, electrostatic potential accelerators, electrically exploded wires, high velocity plasmas, and combinations thereof. Some of these methods do achieve the desired projectile velocity, but are restrictive in the size of the projectile which can be accelerated. Other of the methods can be used for a wide range of projectile sizes, but the projectiles cannot achieve the 20 kilometer per second velocities needed.

SUMMARY OF THE INVENTION

The general purpose of the present invention is to provide a projectile accelerator that cannot only be used for a wide range of projectile sizes, but can also provide the projectile with velocities of 20 kilometers per second or more. To attain this result, the accelerator of the present invention combines a light gas accelerator with a high velocity plasma generator in such a manner that the velocities imparted to the projectile by each are additive.

The device can be considered as consisting of three component parts. They are: a light gas accelerator, a plasma accelerator, and a self-energized plasma compressor. These components are combined in a manner which allows each component to contribute its unique capabilities to the overall system performance in accelerating projectiles.

The light gas accelerator provides the projectile with an initial velocity. As the projectile leaves the barrel of the light gas accelerator, a plasma is generated in the region around the barrel. This plasma is caused to move at high velocity in the same direction as the projectile is moving. The moving plasma drags the projectile along with it, accelerating the projectile to higher velocities. The generation and movement of the plasma is synchronized with the projectile position.

Therefore, it is an object of the present invention to provide apparatus capable of accelerating projectiles of a wide range of sizes to velocities of 20 kilometers per second or more.

Another object of the present invention is to provide a projectile accelerator which can provide projectile velocities at least as high as the average meteoroid velocity.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings, wherein:

FIG. 1 shows a preferred embodiment of the present invention; and,

FIG. 2 illustrates the timing relationship between the plasma generation and projectile position.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a light gas accelerator 1 comprises a cylindrical pump tube 2 filled with a light gas 3, such as hydrogen or helium. At one end of the tube is a deformable polyethylene piston 4. Behind the piston is an explosive charge carrying device 5, such as a conventional 30 caliber rifle cartridge loaded with gun powder. A firing pin 6 for firing the cartridge is disposed adjacent the cartridge base.

At the other end of tube 2, a stationary retaining diaphragm 7 seals the tube. The projectile 8 is disposed on the other side of diaphragm 7 within metal barrel 9, which extends through insulating member 10 into plasma chamber 11. A tubular conductive member 12 is mounted on insulating member 10 and is coaxial with barrel 9. A thin foil 15, of aluminum or some other metal, connects member 12 to barrel 9 within the plasma chamber 11. A conical compressor coil 13 is disposed at the open end of plasma chamber 11 coaxial with the barrel 9. The coil is of copper wire and is partially insulated to prevent arc over between windings, but uninsulated on the inner diameter of the coil. The large end of coil 13 faces the plasma generator, as shown in FIG. 1, and is separated therefrom by a dielectric mounting block 14 which holds the coil 13 in a position coaxial with the plasma generator. The opposite, narrow end of coil 13 is held in position by another dielectric block (not shown) attached to the plasma generator.

A capacitor bank 16 has one terminal connected via electrical conductors 17 and 18 to conductive member 12 and to the narrow end of coil 13 via conductors 17 and 19. The other terminal of the capacitor bank 16 is connected to a delay generator switch 20, the function of which will be described below, by electrical conductor 21. Also connected to switch 20 is a photosensitive detector 22, which can be any one of a variety of photosensitive devices, such as photomultipliers, phototransistors, etc. The detector 22 is so disposed that the

photosensitive area views the end of barrel **9.** Switch **20** is connected to conductive barrel **9** by conductor **23.**

The operation of the device will now be described. The cartridge **5** is fired by firing pin **6** and the expanding gas from the fired cartridge forces piston **4** to move down the center of pump tube **2,** thereby compressing the gas **3** between piston **4** and stationary diaphragm **7.** The trapped gas increases in pressure until a pressure is reached which causes the retaining diaphragm **7** to burst. The pressure is a function of the thickness of the diaphragm. After the retaining diaphragm has burst, the escaping, high pressure, hot gas accelerates projectile **8** down barrel **9.** The barrel serves a multipurpose in this device. It serves to confine the escaping gas and accelerate the projectile, it serves to aim or direct the projectile toward the target, and, as will be described below, it serves as one electrode of the coaxial plasma generator.

The projectile exits from barrel **9** at some initial velocity in a direction coaxial with the plasma generator and with the compressor coil **13,** and in the direction of the target which is to be impacted with the projectile. When the projectile is free of the barrel, and at a time appropriate for the plasma generator and compressor coil to exert their maximum effect upon the projectile, the electrical energy stored in capacitor bank **16** is discharged into the coaxial plasma generator. As described above, one terminal of the capacitor is connected to conductive member **12** while the other terminal is connected to conductive barrel **9** through switch **20.** When switch **20** is closed, a very large current flows through metal foil **15,** evaporating the metal and creating a metal plasma. The plasma so produced is acted upon by the forces arising from the interaction of the current in the metal plasma with the magnetic field of center electrode **9.** This force causes the plasma to be accelerated out of the plasma generator **11** and into the plasma compressor coil **13.** When the expanding metal plasma contacts the uninsulated inner portions of compressor coil **13,** a current is established in the coil which creates a time changing magnetic field in the longitudinal direction. The current generated in the plasma by the time varying magnetic field flows perpendicular to the field. The force on the plasma is, then, radially inwards. A dynamic balance is attained between the current in the coil **13** giving rise to the magnetic field and the force on the plasma so that the plasma is contained within the coil during the increasing current phase of the discharge. When the current from the capacitor bank **16** starts to decrease, the magnetic field in the coil maintains its direction but starts to decrease. This causes the current induced in the plasma to change direction, forcing the plasma out of the coil. At the time the magnetic field starts to decrease, the projectile is at the narrow end of the coil and is accelerated to a higher velocity by the expanding plasma.

The use of a proper time delay between the firing of the light gas accelerator and the discharge of the capacitor bank is important to the attainment of average meteoroid velocities by the projectile. For maximum velocities to be attained, the plasma generation must be synchronized with projectile position. Since the characteristics of the light gas accelerator are known, a time delay measured from the cartridge ignition time could conceivably be utilized. However, it has been found in practice that such a method is not satisfactory due to the fact that the time between cartridge ignition and projectile exit from the barrel varies over too wide a range. It has also been found in practice that the light gas accelerator emits from barrel **9** a flash of hot gas a predictable length of time prior to the exit of the projectile from the barrel. The phenomenon is utilized to synchronize the plasma with the projectile by means of photosensitive device **22** and delay generator switch **20.** The photosensitive device **22** detects the emission of hot gas from the barrel and initiates the operation of a time delay circuit. At the conclusion of the delay period, switch **20** closes and applies the energy in the capacitor bank **16** to the plasma generator.

FIG. **2** illustrates the desired relationship between the projectile position and the capacitor bank discharge current, which is shown as a damped sine wave. At point A, the switch **20** has just closed and the capacitor bank **16** has just begun to discharge. At this time the projectile should have just left the barrel **9** and entered the plasma generator. At point B, the first half cycle of the sine wave capacitor discharge current has peaked and is starting to decrease in amplitude, although the polarity is still positive. This is the time mentioned above when the plasma current changes direction and the plasma expands out of the coil. At point B, the projectile should be near the narrow end of the coil **13** so as to be accelerated out of the coil by the expanding plasma.

Obviously, the period of the capacitor bank discharge sine wave, the dimensions of the plasma accelerator and compressor coil, the initial velocity imparted to the projectile, the size, shape and weight of the projectile, as well as many other factors, are variable and under control of the designer. Therefore, it is clear that many modifications and variations of the present invention are possible in light of the above teachings. It is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

We claim:

1. A device for accelerating a projectile to a high velocity, comprising:

a light gas accelerator, including a barrel, for imparting an initial velocity to said projectile;

a plasma generator adapted to receive said projectile from said barrel, said plasma generator being of the type having a pair of coaxial electrodes, said barrel extending into said generator so as to constitute the center electrode thereof;

means for initiating the generation of said plasma when said projectile is in a preselected location in said generator; and,

means for controlling the flow of said plasma in a manner so as to accelerate said projectile to velocities higher than the initial velocity.

2. The device of claim **1** wherein said plasma generator comprises:

a capacitor bank switchably connected to the electrodes; and,

a thin metal foil disposed between and electrically connecting the electrodes.

3. The device of claim **1** wherein said plasma flow controlling means includes a plasma compressor coil of conical shape mounted with the cone axis coaxial with said barrel with the large end of the cone adjacent said plasma generator, whereby said projectile travels along the cone axis from the large to the narrow end thereof.

4. The device of claim 3 further including a dielectric block mounted on the outer electrode of said plasma generator, and wherein:

the large end of said coil is affixed to said block; and,

the narrow end of said coil is electrically connected to said outer electrode.

5. The device of claim 2 wherein said plasma generation initiating means includes:

a photosensitive device mounted such that the sensitive area views the exit end of said barrel; and,

switching means for connecting said capacitor bank to said electrodes in response to a signal from said photosensitive device.

6. The device of claim 5 wherein said switching means includes means for delaying the connection of said capacitor bank to said electrodes for a preselected time following the receipt of the signal from said photosensitive device.

7. The device of claim 3 wherein said plasma generator comprises:

a capacitor bank switchably connected to said electrodes; and,

a thin metal foil disposed between and electrically connecting said electrodes.

8. The device of claim 7 wherein:

the capacitor bank discharge voltage waveform is a damped sine wave; and,

the parameters of said plasma generator and plasma flow controlling means are so related to each other and to the projectile dynamics that the projectile is in the narrow end of the compressor coil when the discharge voltage begins to decrease.

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