Oct. 2, 1962 P. L. TAILER 3,056,336

HIGH VELOCITY ACCELERATOR FOR PROJECTILES

Filed Nov. 3, 1959 2 Sheets-Sheet 1

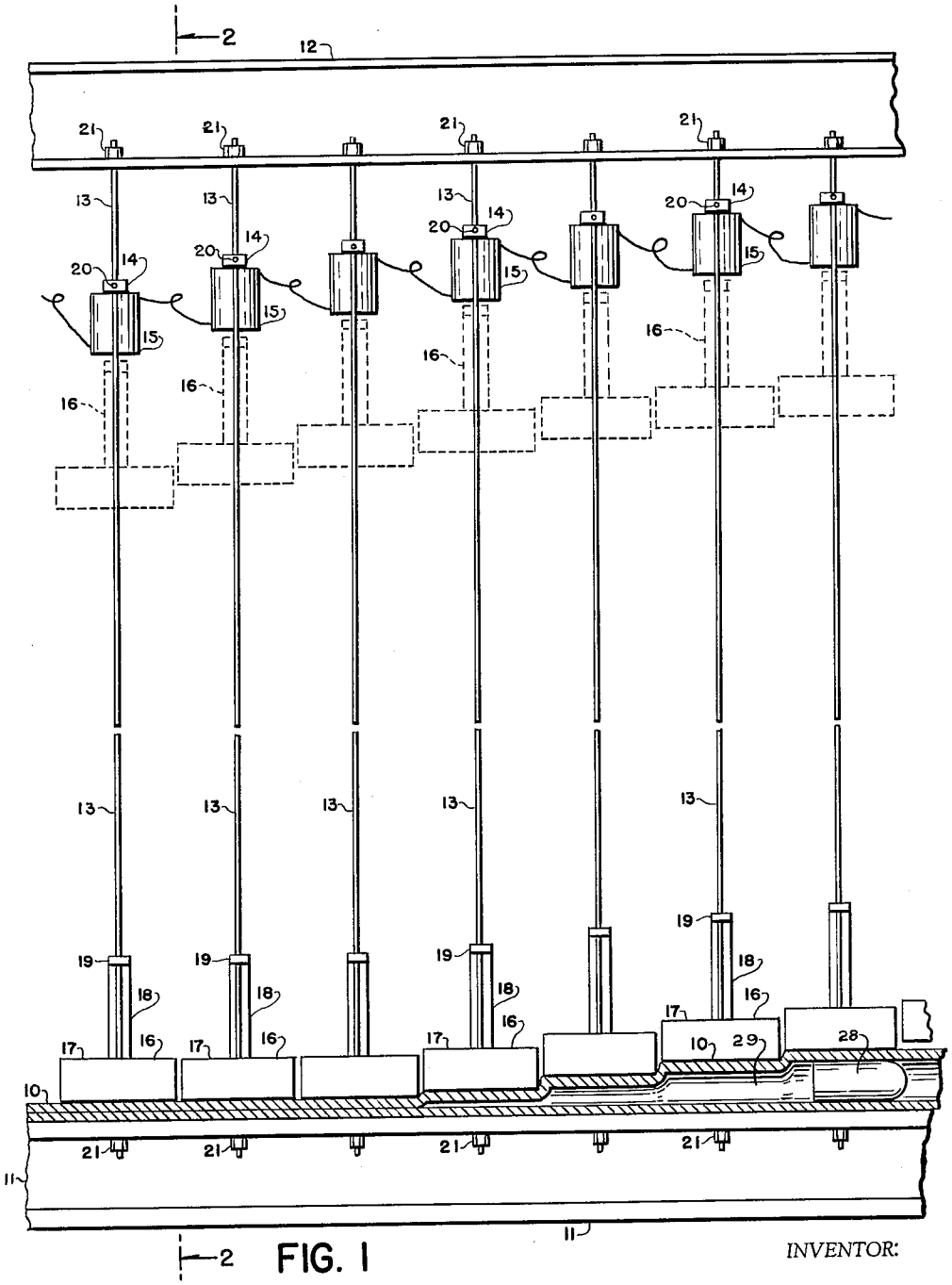

FIG. 1

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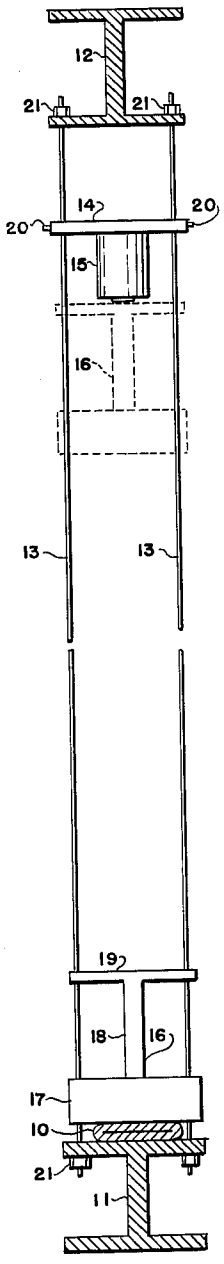

FIG. 2

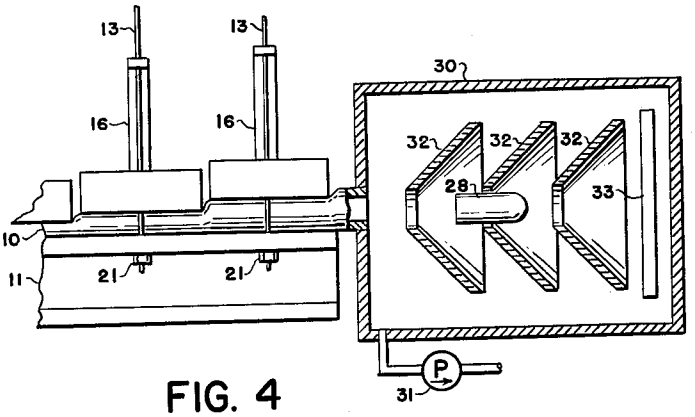

FIG. 4

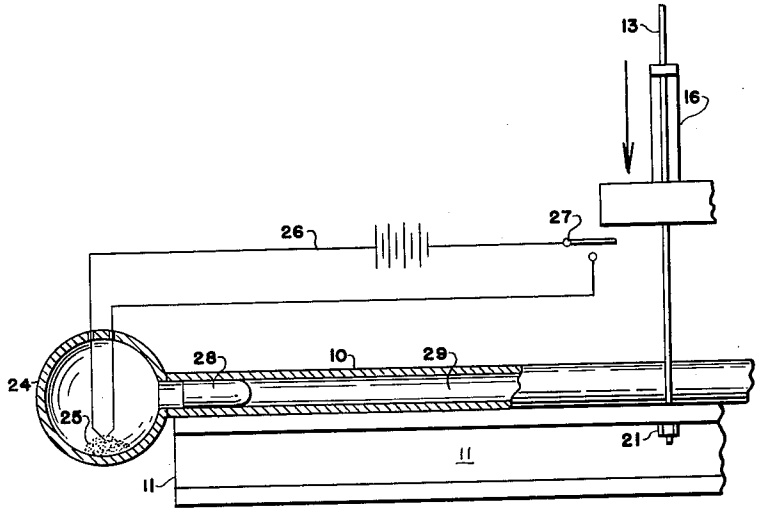

FIG. 3

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HIGH VELOCITY ACCELERATOR FOR PROJECTILES

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3 Claims. (Cl. 89—8)

This invention relates in general to firearms, and, more particularly, to a test device to accelerate a projectile to a high velocity.

Although this invention requires considerable apparatus to accelerate a very small projectile to a velocity up to five miles per second or more, there is a need for such apparatus to test the result of the impact of small particles at high speeds. Now that orbiting satellites have become a reality and man's space flight is being planned and considered, many questions are raised which are at present unanswered. If a particle weighing two or three grams strikes a space vehicle with a relative speed of three or more miles per second, what will be the result? Is the skin of the space vehicle any protection against such particles? In the unfortunate event of a war, could a dispersed bag of sand or a released cloud of small shot on an orbit of interception destroy an enemy satellite or space vehicle? These questions and many others can be answered with a test apparatus which can accelerate particles to velocities of over three miles per second in the laboratory.

The British patent to Tumber, No. 679,296, which was published September 17, 1952, describes the limitations of conventional firearms for achieving high velocities. As Tumber explains, the ultimate limiting factors are the mean molecular velocities of the propellent gas. Thus in conventional firearms, the greatest possible exhaust velocity of the propelling gases is limited in the last analysis by the temperature and the molecular weight of these gases.

The reason the molecular weight of the propelling gas is a limiting factor is that a given amount of energy in a molecule of the propelling gas will result in a greater molecular velocity in a lighter gas. The temperature of the propelling gas is the other determining factor in that a hotter propelling gas at a given pressure will be less dense and, therefore, less massive. As a projectile is accelerated down a long bore, the propelling gas must flow from a static position down the bore to exert a force on the projectile. If this propelling gas is dense and comparatively heavy, its weight will soon exceed that of the projectile. Thus the greatest amount of the energy released by the propelling gas will be wasted accelerating itself from a position of rest to flowing down the bore. In an infinitely long hypothetical frictionless bore, it is only these two factors, the molecular weight and the temperature, which ultimately determine the exhaust velocity of a given propelling gas. In practice, of course, pressure plays a large part in that a higher breech pressure will more rapidly accelerate a given projectile and allow a shorter barrel.

If a long barrelled test firearm is built and the best possible propelling gases are generated by an explosion, the effective limit of the velocity to which a test projectile may be accelerated is on the order of about 10,000 feet per second. Bore friction, gaseous friction, heat losses in the propelling gases as they expand, and many other complex factors seem to set these limits. However, to anticipate in a laboratory the result on the skin of a space vehicle in orbit of the effect of the impact of a particle of sand also in orbit but in the opposite direction, velocities up to 10 miles per second must be produced. The apparatus which is the subject of this invention may theoretically accelerate particles to such velocities under laboratory conditions.

The main object of my invention is to provide apparatus to accelerate projectiles in a laboratory to heretofore unattainably high velocities.

Another object of my invention is to provide an apparatus which accelerates projectiles to high velocities which bear little relation to the energy stored in the propelling gases or to the mean molecular velocities of the propelling gases.

A further object of my invention is to provide an apparatus which accelerates a given weight of a propelling gas and a projectile down a long bore by adding energy from an external source to accelerate the gas and the projectile as they travel down the bore.

A still further object of my invention is to provide a high velocity accelerator for projectiles which may be less costly to build when considered in relation to comparable research projects.

A feature of my invention is to provide a long bore within a barrel of deformable material which is constricted or crushed after the passage of a projectile to accelerate a given quantity of propelling gases and the projectile over a longer distance and to a higher velocity than was heretofore possible.

Additional objects, advantages and features of invention reside in the particular construction, combination and arrangements of parts involved in the embodiment of my invention and its practice otherwise as will be understood from the following description and the accompanying drawing wherein:

FIG. 1 is a side view of a fragment of my invention with the central portions of the vertical guide rods broken away, with the deformable bore shown in longitudinal section, and with the bore crushing elements shown in their uppermost positions in dotted lines;

FIG. 2 is a vertical cross section taken on line 2—2 of FIG. 1;

FIG. 3 is a side view of the breech end of my invention with the chamber and a part of the bore broken away in section; and

FIG. 4 is a side view of a fragment of the muzzle end of my invention with the target chamber and the gas baffles shown in section.

Referring to the drawings in detail, FIGS. 1, 2, 3 and 4 show a barrel 10 of deformable material such as soft brass, mild steel, or the like, which is laid on a heavy I-beam 11. A considerable height above the beam 11 thereis supported the upper I-beam 12. On either side of the barrel 10, vertical guide rods 13 extend between the beams 11 and 12. These guide rods 13 may be thin rods which are threaded at the ends to be secured between the beams 11 and 12 with the nuts 21.

As shown in FIGS. 1 and 2, each pair of vertical guide rods has a horizontal support 14 fixed across them by means of the set screws 20. Each horizontal support 14 holds an electromagnet 15 in position between a pair of the guide rods 13. Slidably secured by each pair of the guide rods 13, are the barrel crushing elements 16, each of which consists of a heavy rectangular weight 17, a vertical upward extension 18 and a cross arm 19. As shown, the guide rods 13 pass with a small clearance through apertures in the cross guide arms 19 and the weights 17.

This invention is used as follows. An uncollapsed barrel 10 is placed on the I-beam 11 which acts as an anvil. The barrel crushing elements 16 are raised upward and held in position by the electromagnets 15 which are either connected in series as shown or are all connected through one switch to a current source. The horizontal supports 14 are carefully pre-positioned, each one slightly above the one before it, in a calculated manner that will be described. As shown in FIG. 3, a chamber 24 contains the explosive 25 which is ignited by the elec-

trical system 26. This chamber 24 is connected to the barrel 10 in any suitable manner with a suitable breech opening mechanism so that the projectile 28 may be placed in the barrel. Conventional screw threads joining the chamber 24 to the barrel 10 would be satisfactory.

By opening a single switch, all the electromagnets 15 are simultaneously disconnected allowing the barrel crushing elements 16 to start to fall from their uppermost positions. Allowing for slight differences due to barometric pressure and humidity variations which would affect air resistance, these elements could fall well over 100 feet and maintain their positions relative to each other with a high degree of accuracy and predictability. This accuracy could be achieved as all the elements 16 would be in free fall from the moment of release until their impacts. As shown in FIG. 3, the weight 16 nearest the chamber 24 can make an electrical contact 27 at some time during its fall to ignite the explosive 25 in the chamber 24. This explosion would generate a propelling gas of high pressure and high temperature and preferably consisting mostly of hydrogen gas which would start to drive the projectile 28 down the bore 29 of the barrel 10. After the projectile 28 passed the first barrel crushing element 16, this barrel crushing element 16 would reach the barrel 10 rapidly followed by the next barrel crushing element 16. Thus the barrel 10 would be progressively and precisely crushed behind the moving projectile 28 trapping the propelling gases in a finite volume as shown in FIG. 1. Since this volume is effectively moved forward and accelerated as the barrel 10 is progressively crushed, the projectile is continually accelerated down the length of a long bore by the same given mass of propelling gases with no loss of force due to pressure drop on the back of the projectile 28.

At the muzzle end of the apparatus as shown in FIG. 4, there is a target chamber 30 which is evacuated by means of the pump 31. The pump 31 evacuates the target chamber 30 and the bore 29 to lessen resistance and prevent any build up of air in front of the projectile 28 which would effectively increase the total mass being accelerated within the bore. For test purposes, baffles 32 may deflect the propelling gases leaving the bore so the effect of the projectile alone striking a target element 33 may be observed. Although a solid type projectile is shown, a sabot type projectile could be used to accelerate any desired test material or even test materials of small grain size. In such a case, the sabot projectile would have to be slowed down by a peripheral impact or otherwise deflected so the impact of the test material alone could be observed on the target 33. For some projects, gas alone could be accelerated in this apparatus. Naturally, the proportions in the drawings are greatly distorted as the drawings are purely exemplary of the general principles involved.

The results which this invention make possible may be best shown by giving some approximate calculations for a hypothetical apparatus. Let us assume that the bore of this apparatus is ½ inch in diameter and the guide rods are long enough to allow the last bore crushing element to fall 128 feet. In such a case, this bore crushing element will reach the bore moving downward with a velocity of about 90 feet per second. Thus it will crush the bore completely in $\frac{1}{160}$ second. If this particular hypothetical apparatus is designed to produce a velocity of about four and one-half miles per second or 23,700 feet per second at the muzzle, after a bore crushing element near the muzzle starts to crush the bore after the passage of the projectile, the projectile will have moved 23,700 feet per second times $\frac{1}{160}$ second or about 11 feet. Therefore the volume of the propelling gas which will have to be trapped behind the projectile will have to be 13 cubic inches.

$$V=\frac{1}{2}\cdot\pi R^2 h$$

$$V=\frac{1}{2}\cdot\pi\cdot\frac{1^2}{4}\cdot 11\cdot 12''$$

$$V=13 \text{ cu. in.}$$

Since the weights cannot be timed to fall and crush the bore exactly behind the projectile, we can allow another 26 cubic inches of propelling gas to be trapped behind the projectile so that the weights could start to crush the bore in a given spot after the projectile had passed this spot by 11 feet. Thus there would be a total of 39 cubic inches of the propelling gas.

If this propelling gas was hot hydrogen gas at 2102 degrees F. and 7,680 pounds per square inch, it would weight .0151 pound. The forward component of force exerted on this gas by the bore which is being progressively crushed and the force which this gas then exerts on the projectile would amount to 7,680 pounds per square inch times the area of the bore. The force is then about 1,500 pounds.

$A=\pi R^2$	$F=P\cdot A$
$A=\pi(\frac{1}{4})^2$	$F=7680\cdot .195$
$A=.195$ sq. in.	$F=1{,}500$ lbs.

If the projectile weighs .066 pound or slightly more than an ounce, the total weight of propelling gases and the projectile being accelerated would amount to .081 pound. This force of acceleration, 1,500 pounds, would result in an acceleration of 593,000 feet per second per second.

$$a=\frac{F}{m}$$

$$a=1500\cdot\frac{1}{.081/32}$$

$$a=593{,}000 \text{ ft./sec.}^2$$

If the initial velocity of the projectile and the propelling gas were 2,500 feet per second before the bore was crushed together behind them, an additional 470 feet of bore length would result in a velocity of four and one-half miles per second.

$$V_1^2+V_0^2=2ad$$

$$d=\frac{23{,}500^2+2500^2}{2\cdot 593{,}000}$$

$$d=470 \text{ feet}$$

Thus a 500 foot length of barrel with 128 feet of fall for the weights will produce this heretofore unattained high velocity of four and one-half miles per second. While these foregoing approximate calculations have not taken into account certain factors such as the effect of bore friction on the projectile or the possible cooling of the propelling gas as it flows down the unheated bore, the detrimental aspects of these factors may be overcome in several ways. A slightly lighter projectile could be used to compensate for the bore friction which is usually considered as a constant. If there is any appreciable cooling of the propelling gas, slightly more could be used to compensate for its contraction. It would even be possible to attach slow burning grains of powder to the rear of the projectile to generate propelling gases as the projectile moved down the bore. These additional propelling gases could compensate for any cooling and contraction of the original propelling gases. It is also possible, however, that the friction generated by the flow of the propelling gases along the bore may raise their temperature after they exceed certain velocities.

As for the construction of the apparatus, there are many existing research buildings, hangars for aircraft, and other structures that could house this apparatus along one wall at relatively little cost as only the upper and lower beams would have to be attached to the inside of the existing structure. Higher velocities may be obtained by increasing the proportions of the apparatus. Once a given apparatus was set up and designed, it would be a

simple matter to calculate the estimated position of the projectile along the bore at any given time. Then the weights over this estimated position would be set at a height above the barrel to reach the barrel at the appropriate time after the projectile started to move along the bore.

While I believe that falling weights can be most inexpensively used with the greatest accuracy to progressively crush the barrel, other methods may be used such as metal rams driven by explosings set off in a rapid sequence. In the case of the falling weights, it takes a long time for a given weight to fall the entire distance and then crush the barrel, yet the sequence of the impacts of the weights striking the barrel occupies a fraction of a second and the instants between the striking of adjacent weights is very small. In a like manner, the cycle of an explosion and its driving a metal ram to crush the barrel may occupy a large fraction of a second, yet such explosions could be set off almost simultaneously to accomplish the progressive crushing of the bore behind the projectile.

Special materials and techniques may be developed to practice this invention. Since the barrel must be deformable and yet should withstand high pressure, softer, deformable materials may be wrapped with fine wire of high tensile strength to contain the pressure and yet deform easily. Also, the lower beam may contain a groove in which the barrel lies so that the falling weights may only crush it to a desired degree or only to the extent that the bore is closed off. Although I have shown an explosion generating the propelling gases, these may be generated otherwise as shown in the forementioned patent to Tumber. In such a case, the falling of the weights would have to be synchronized to the release of the projectile.

Although I have described my invention in the best form known to me, it will nevertheless be understood that this is purely exemplary and that modifications may be made without departing from the spirit of the invention except as it may be more particularly limited in the appended claims wherein I claim:

1. Apparatus for accelerating a projectile to a high velocity comprising, in combination, a long deformable barrel containing a bore, a projectile within said bore, a propelling gas, means to introduce said propelling gas into the bore of said barrel to accelerate said projectile along said barrel, weights suspended above said barrel, means to release said weights to fall and progressively crush said barrel at an increasing rate after the passage of said projectile further accelerating said propelling gas and thereby said projectile.

2. Apparatus for accelerating a projectile to a high velocity comprising, in combination, a long deformable barrel containing a bore, a projectile within said bore, a propelling gas, means to introduce said propelling gas into the bore of said barrel accelerating said projectile along said barrel, electromagnets suspended above said barrel at increasing heights, weights held by said electromagnets, switch means to disconnect said electromagnets releasing said weights to fall and progressively crush said barrel at an increasing rate after the passage of said projectile further accelerating said propelling gas and thereby said projectile.

3. Apparatus for accelerating a projectile to a high velocity comprising, in combination, a long deformable barrel containing a bore, a projectile within said bore, a propelling gas, means to introduce said propelling gas into said bore of said barrel to accelerate said projectile along said barrel, and a number of falling weights positioned along said barrel progressively crushing and barrel at an increasing rate after the passage of said projectile further accelerating said propelling gas and thereby said projectile.

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