May 1, 1962 W. K. KERN ETAL 3,031,933

EXPLOSIVE LINEAR ACCELERATION

Filed Nov. 4, 1960 2 Sheets-Sheet 1

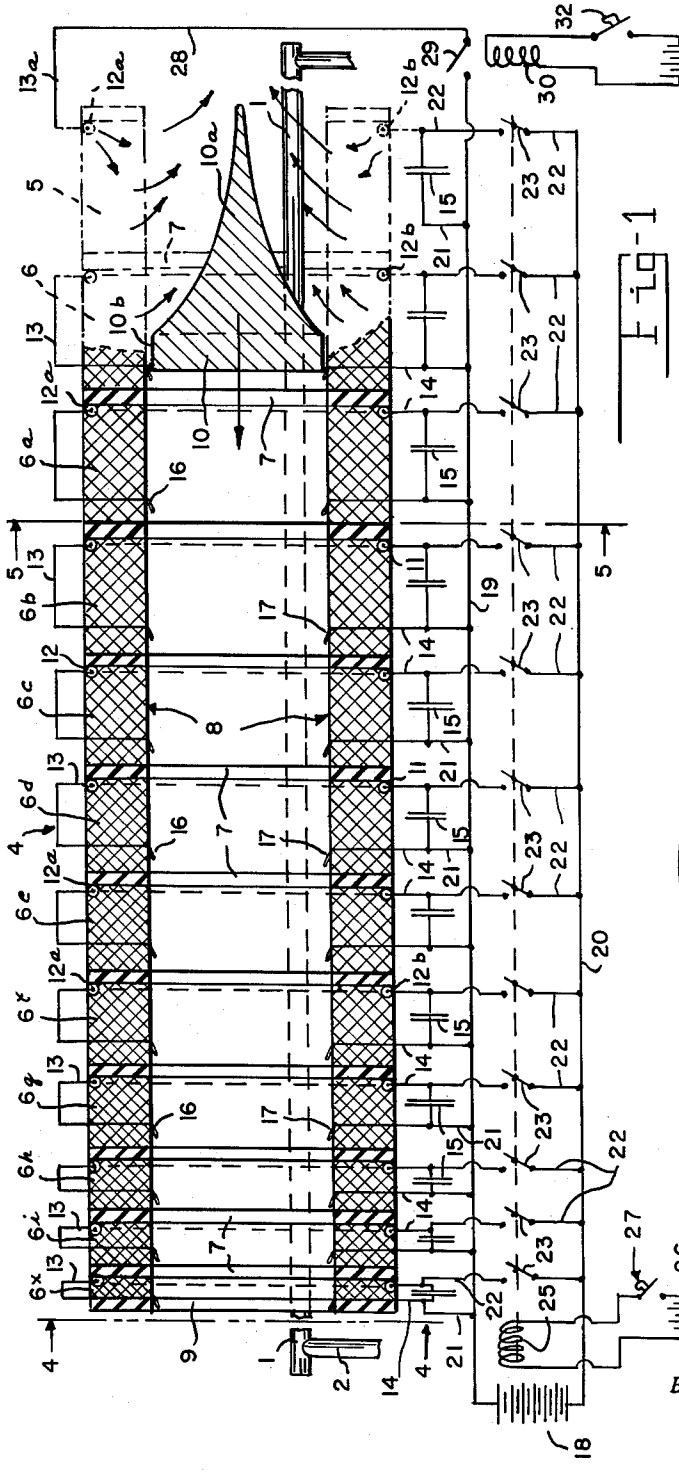


Fig-1

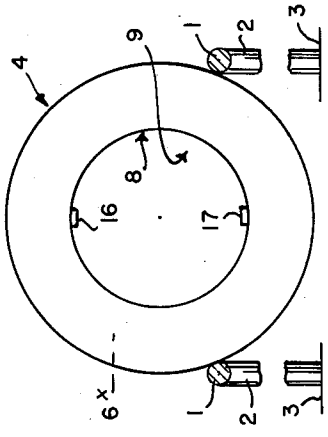


Fig-4

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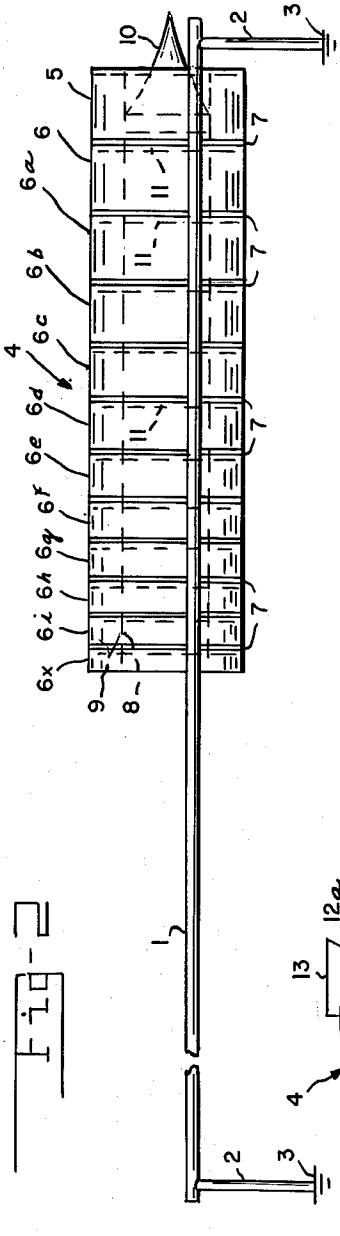


Fig. 2

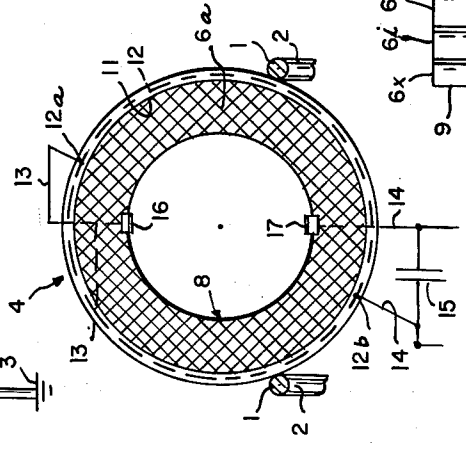


Fig. 5

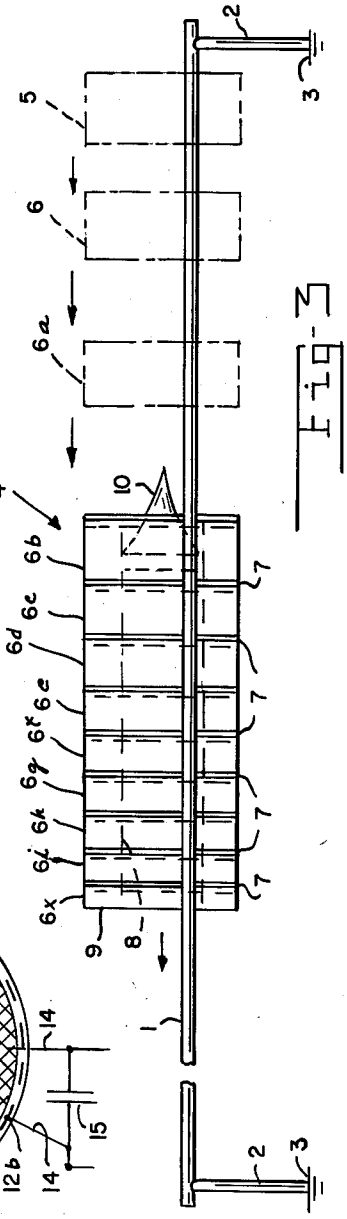


Fig. 3

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EXPLOSIVE LINEAR ACCELERATION

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The invention described herein may be manufactured and used by or for the United States Government for governmental purposes without the payment to us of any royalty thereon.

This invention relates to projectile explosive accelerators and, more particularly to research apparatus for true hypervelocity study.

Past difficulties in high explosive reproducibility and initiation plus projectile disintegration and inability of combustion gases to exert pressure on the projectile, especially at the higher velocities, prevented significant increase in accelerations.

An object of the present invention is to eliminate these difficulties by employing a plurality of ring or hollow cylinder shaped explosive elements through which the projectile is driven by the force of the explosion and shock wave therefrom, utilizing condenser means to explode each of the rings successively as the projectile passes centrally through the rings, a further object being the use of the projectile to successively discharge the condenser for exploding each ring as the projectile passes through each ring.

Another object is the provision of a projectile having its rear end or trailing portion shaped or tapered inwardly for impingement thereon of the implosion and shock wave travelling radially inward from the exploded propulsion ring to accelerate the projectile to hypersonic speeds or velocities.

A further object utilizes the hollow detonation wave symmetrically directed toward the geometric center of the implosion where it will come in contact with a specially designed boat tail of the projectile for imparting an acceleration pulse to the projectile, in which the projectile boat tail is constructed of sufficiently durable material to withstand the crushing effect of the successive hollow detonation waves and, is curved in such a manner that the detonation gases are rotated in the direction opposite to the direction of travel, which imparts successive driving impulses to the projectile as it passes through the exploding rings.

A further object is the provision of support means for supporting the ring shaped explosives in adjacent axial alignment and, the provision of elastic packing or spacing means between the explosive ring cartridges, to prevent detonation of the succeeding rings, in which the explosive material of the rings will have low brisance characteristics.

A further object is the provision of an explosive linear accelerator device for a projectile employing hollow ring shaped explosive cylinders, in which the lengths of the hollow cylinders decrease toward the muzzle in order that, at the higher projectile velocities, the explosions can occur while the projectile is quite close in or to the ring, so that the combustion products and shock waves will have no difficulty in reaching the boat tail and less explosive energy is wasted.

A further object is the stacking of the detonating cylinders in a column, in the desired direction of projection of the projectile, so that the pressure between each detonating hollow cylinder or ring and those remaining in the stack or column will propel and accelerate the column in the direction of movement of the projectile, in order to impart further initial incremental velocity to the projectile as it is accelerated by the exploded rings,

thereby utilizing the implosion principles plus the acceleration of the remaining column of the explosive cylinders to obtain maximum energy for impulse acceleration of the projectile, thus also preventing destruction of the succeeding explosive cylinders in the column due to compression by the preceding exploding rings or cylinders in the column.

Other objects and advantages of the invention will become apparent from the following description and accompanying drawings in which like reference characters refer to like parts in the several figures.

FIG. 1 is a longitudinal vertical sectional view taken through an explosive linear accelerator, incorporating the invention, showing the construction somewhat schematically and including a wiring diagram therefor, the dot and dash lines in the right hand end of the figure indicating the exploded or partly detonated ring shaped explosive cylinders;

FIG. 2 is a somewhat diagrammatic view, in side elevation, showing the explosive linear accelerator before firing and with the wiring diagram shown in FIG. 1 omitted;

FIG. 3 is a view similar to FIG. 2 but schematically illustrating the apparatus in the process of successive firing of the explosive rings, dot and dash lines representing the positions of the explosive acceleration rings which have been detonated and disintegrated, showing the acceleration movement of the column of the succeeding explosive rings forwardly toward the muzzle end of the device to increase the rate of acceleration of the projectile;

FIG. 4 is a transverse sectional view taken about in the plane indicated by line 4—4 in FIG. 1, looking toward the muzzle end of the device, showing one form of support; and

FIG. 5 is a transverse section taken about on the plane indicated by line 5—5 in FIG. 1, showing the condenser discharging circuit and the peripheral detonator ring, capacitor and circuit closing contact for the boat tail projectile.

Referring to the drawings the improved explosive linear decelerator apparatus is suitably supported, as shown, in a trough-like support; for instance, by spaced longitudinal supports or rods 1—1 carried by suitable standards 2 which extend upwardly from a fixed supporting surface 3.

The linear accelerator is indicated generally at 4 and comprises a plurality of ring or disk-shaped hollow explosive cylinders 5, 6, 6^a, 6^b, 6^c, 6^d, 6^e, 6^f, 6^g, 6^h, 6^i–6^x etc., depending upon the desired number of cylindrical accelerators desired.

These explosive cylindrical accelerators are substantially of the same or similar construction except for their axial length or thickness and therefore only one will be later described in detail.

Interposed between each of the accelerators 5 and 6 to 6^x is an insulating elastic or cushion-packing ring or washer-like separator 7. These separator members or cushion washers are not limited to any specific type of insulating material. Any type of packing material such as foam or semi-hard rubber may be used to prevent premature or sympathetic detonation of the succeeding explosive cylinders or rings 6, 6^a, etc.

Each of the explosive rings 5, 6 etc. may be made of a suitable detonable explosive material from trinitrotoluene to compressed black powder, dependent on the end velocity desired, projectile material, and length of assembled accelerator. The "TNT" may be alloyed with inert materials such as barium nitrate to the extent that the projectile or slug will not be damaged in its travel through the accelerator. Suitable experimental metallic alloy

percentages can be found for each type of projectile material desired.

The explosive cylinders 5, 6 to 6^x are in cake washer-like form, all having similar outer and inner diameters and, as shown, the separating resilient cushion members 7 have similar outer and inner diameters to those of the explosive hollow cylinders 5, 6 etc., so that when they are positioned on the supports 1 in juxtaposed or stacked relation a straight cylindrical bore 8 extends through the explosive cylinders and the washers 7 from the rear end of the accelerators to the muzzle end 9, to accommodate the passage of the boat tail projectile 10 therethrough.

The individual cylindrical, washer-like cakes of explosive material, as seen in FIGS. 1 and 5, do not necessarily have a hard outer coating to direct the detonation wave inwardly toward the axis, since the detonation forms spherical shock waves directed inwardly toward the curved boat tail 10^a or the projectile 10, and most of the shock is lost whether contained or not. The explosive material should have comparatively low brisance.

Each of the explosive, hollow cylinders is provided with an outer peripheral detonator ring 11 preferably located adjacent the rear face of the cylinder and includes an electric firing conductor or capacitor wire 12 for instantaneously detonating the annular ring 11, which in turn explodes the hollow explosive cylinder. The firing conductor 12 is connected at diametrically opposite points 12^a and 12^b to conductors 13 and 14, with the exception of the hollow explosive cylinder 5 which has the initial detonating circuit wire connected to the firing circuit conductors 13^a and 14^a.

The conductors 14 and 14^a, as seen in the drawings have a high intensity electrical condensers 15 interposed therein.

Suitable diametrically opposite electrical contacts 16—17 are preferably disposed in the bore 9 at or adjacent the forward end of each of the hollow explosive cylinders 6 to 6^x and the conductors 13 are connected to the contacts 16 while each of the conductors 14 is connected to one of the contacts 17. The contacts 16 and 17 may be contact springs projecting into the bore 8 as seen in FIGS. 1, 4 and 5 for contacting and circuit closing engagement with the periphery of the boat tail projectile 10 as it passes through the respective explosive cylinders. The projectile 10 is therefore of metallic construction, or is provided with a metallic peripheral rim 10^b, for establishing electrical circuit closing contact between the contacts 16 and 17 to discharge the condensers 15 for firing the detonating rings 12 successively as the projectile 10 passes through the cylinders 6 to 6^a etc.

Any suitable means for simultaneously charging all of the condensers may be provided, for instance, a suitable electrical source or battery 18 having its terminals connected to parallel conductor wires 19 and 20, wire 19 being connected to one terminal of all of the condensers 15 through the conductors 21, while the connector wires 22 connect the conductor 20 to the other terminals of the condensers 15, the wires 22 each having a switch 23 therein which is normally "open." The switches are connected for simultaneous opening and closing movement by a common actuator rod 24 which is suitably stressed for opening the switches (simultaneously) by any suitable means, such as a spring (not shown).

Means are provided for moving the actuator 24 to close the switches 23, such as a solenoid or relay 25 which is supplied with electric current by a battery 26 under the control of the condenser charging switch 27, normally open. Closing of the switch 27, as seen in FIG. 1, energizes the relay 25 which pulls the actuator 24 to the left connecting all of the condensers 15 to the battery 18 so that they will be charged to capacity.

Since the spring contact terminals 16 and 17 are open during this condenser charging cycle (because the rim 10^b of the projectile 10 is not in contact with them) the condensers can be charged without firing any of the explosive ring cartridges 6, 6^x.

After sufficient time has elapsed to fully charge the condensers 15 the switch 27 is released, or opened, which deenergizes the relay 25 which allows the actuator 24 to move to the right to open all of the switches 23.

It should be noted that the first or rear explosive ring member 5 does not have circuit closing contacts 16 and 17 therein for exploding the detonator ring or wire 12^a therein, but it includes a firing circuit 28 connected to the wire 13^a at one end and at its other end to the condenser wire 21 for the condenser for this rear or initial explosive ring 5, a normally open switch 29 being provided in the conductor 28 which is closed by the relay 30, energized by the battery 31 under control of a normally open firing switch 32.

In the operation, assuming that the explosive ring shaped cakes are stacked on or along the cradle or supporting rods 1, as seen in FIGS. 1 and 2, and the detonating wires are all connected to the condensers 15, as seen in the schematic wiring arrangement in FIG. 1, the boat tail projectile 10 is inserted in the rear or right hand end of the bore 8 with its head and contact ring 10^b disposed in the forward end of the ring 5 in medium close relation to the resilient washer 7 between the explosive ring 5 and the next explosive ring 6, the condenser charging switch is now closed, charging all of the condensers 15 from the battery or source of electrical energy 18. The supporting rods 1 may extend forwardly a considerable distance beyond the last or muzzle end explosive ring cartridge 6^x as seen in FIGS. 2 and 3, if desired, and the rear curved boat tail portion 10^a of the projectile 10 extending rearwardly (to the right) as shown.

When the condensers 15 are fully charged the switch 27 is opened deenergizing the relay 25 to allow the actuator 24 to move to the right and open the switches 23 in the charging circuits to the condensers 15.

When ready for firing the firing switch 32 is closed to energize the firing relay 30, which closes the detonating switch 29, which allows current from the first condenser 15 to the right to discharge at opposite points 12^a and 12^b into the detonating wire 12 and explodes the peripheral detonator ring 11, which, in turn, explodes the ring shaped explosive cake or cartridge 5, the explosive traveling from the rear forwardly and inwardly the inward (implosion) force and the inwardly moving, shock wave impinging on the rearwardly and inwardly curved boat tail portion projects the projectile 10 forwardly into the next explosive ring cartridge 6, isolated from the exploding ring cartridge 5 by the insulating cushion ring or washer 7 therebetween.

As the projectile 10 is projected forwardly toward the forward end of the second explosive ring 6 the contact ring portion 10^b of the projectile strikes and closes the contacts 16 and 17 near the forward end of the cartridge 6, closing the condenser discharging circuit for the second condenser 15 from the rear end, and the second detonator ring 12^a in the explosive cylinder 6 is exploded, detonating the explosive cake 6 (from its rear end forwardly), the inward explosive pressure and shock wave therefrom further impinges on the boat tail 10^a, further increasing the acceleration of the projectile 10 through the bore 8 toward the muzzle end 9.

The successive automatic dentonations of the explosive ring shaped cakes 6^a, 6^b, 6^c . . . 6^x continues, each one providing inward explosive forces and shock waves on the boat tail 10^a to accelerate the projectile faster and faster until it emerges at the muzzle end 9 at its maximum velocity.

Since the column of the explosive cakes or cylinders is resting on the cradle-like rods 1, the column is substantially free to move longitudinally forward, or in the direction from the rear end to the muzzle end as the ring cylinders are successively exploded from the rear end

toward the muzzle end, as shown schematically on FIGS. 2 and 3.

FIG. 2 shows the column at rest before firing, and FIG. 3 illustrates the column of unexploded ring moving forward under the influence of the exploded rings **5**, **6**, **6a** (shown in dot and dash lines). This action further provides additional acceleration in the projectile **10**.

Since the projectile is moving faster and faster as its velocity is increased by the exploding cylinders it may be desirable to increase the rate of occurrence of the accelerating impulses, thus, as seen in FIGS. 1, 2 and 3, the longitudinal or axial thickness of the ring shaped cylindrical cartridges or cakes decreases from the rear end to the forward or muzzle end; those at the rear end where the rate of movement of the projectile is lower being thicker, while those at the forward end where the rate of movement of the projectile is greater being thinner.

As before mentioned the ring shaped explosive cakes are each separated by a soft resilient washer-shaped separator **7** which insulates the succeeding explosive cake or ring from the exploding ring and thus cushions or prevents the explosive and shock wave of the exploding ring from detonating the next ring, and the next ring is thus detonated by the projectile as it passes thereinto closing the contacts **16** and **17** which discharge the firing condenser **15** for that ring.

Once the condensers **15** are "fully charged" the charging circuit wires **19** and **20** can be disconnected from all of the condensers if desired since they are no longer necessary and would then not in any way obstruct or resist the forward movement of the column of the explosive rings as they move forwardly on the support or cradle **1**.

Having thus described the invention it is realized that it is susceptible to various changes and modifications, and it is not therefore desired to limit the invention to the precise form herein shown and described but only by the scope of the appended claims.

The invention set forth in the foregoing specification is hereby claimed as follows:

We claim:

1. In a linear explosive actuator for projectiles having a rear end and a forward end, an elongated longitudinal support, a plurality of annular ring shaped explosives stacked on said support in aligned relation having an axial bore therethrough from said rear end to said forward end, electrical detonating means in each of said ring shaped explosives for independently exploding the same, separate electrical condenser means for detonating each of said detonating means having an open firing circuit therefrom, connected to each detonator means, a projectile disposed in said bore and movable therein from said rear end through said bore and said forward end for closing said open firing circuits for said condensers successively as it passes through said ring shaped explosives to successively explode the same, said projectile having a rearwardly and inwardly curved boat tail disposed axially in said bore in the ring shaped explosives as they are exploded to receive the explosion and shock wave thereon for accelerating the projectile through said ring shaped explosives.

2. In a linear explosive actuator for projectiles, an elongated longitudinal cradle support, a plurality of ring shaped explosives stacked on said support in aligned relation having an axial bore therethrough from a rear end to a muzzle end, annular electrical detonating means in each of said ring shaped explosives for exploding each of said ring shaped explosives separately, electrical condenser means connected to each of said annular electrical detonating means for detonating said detonator means when said condenser means is discharged and each including an open detonating circuit therefor having spaced circuit closing contacts extending into said bore between the ends of each of the ring-like explosives, and a circuit closing projectile disposed in said bore in the rear end thereof, having a rearwardly and inwardly curved boat tail disposed axially in said bore within the rear of one of said ring shaped explosives for receiving the impingement and shock wave of said last ring shaped explosive when the same is exploded for projecting said projectile forwardly through the remaining ring shaped explosives to progressively engage said circuit closing contacts to successively discharge said separate condenser means for progressively exploding the remainder of said ring shaped explosives for acceleration of said projectile as the projectile passes through said ring shaped explosives by the explosive impact and shock waves therefrom on said rearwardly tapering boat tail.

3. In a linear explosive actuator for projectiles having a muzzle end and a rear end, a plurality of ring shaped explosive cakes stacked in aligned relation from said rear end to said muzzle end having an axial bore therethrough, detonating means in each of said ring shaped explosive cakes for exploding each of said ring shaped explosive cakes, separate electrical condenser means for each of said detonator means having a detonating circuit therefrom connected to one of said detonator means, circuit closing contact means in the bore of each of said ring shaped explosive cakes for closing each of said detonator circuits to discharge each condenser means for detonating each of said detonating means for firing each of said ring shaped explosive cakes as a projectile passes therethrough, and a projectile disposed in said bore at the rear end thereof, said projectile having a rearwardly and inwardly curved boat tail disposed axially within the ring shaped explosive cake at the rear end of said bore for impingement of the explosion and shock wave thereon from that ring shaped explosive cake incident to the detonation thereof, for projecting the projectile forwardly through the remaining ring shaped explosive cakes for successively discharging said condensers therefor progressively exploding the explosive cakes as the projectile is projected through said bore by the explosive and shock waves from the progressively exploding ring shaped cakes.

4. In a linear explosive actuator for projectiles, an elongated longitudinal support, a plurality of ring shaped explosives stacked on said support from a rear end to a muzzle end in aligned relation having an axial bore therethrough, electrical detonating means in each of said ring shaped explosives for exploding each of said ring shaped explosives, electrical condenser means for firing each of said detonating means each having a firing circuit connected to each one of said detonating means, contact means in the bore of each of said explosives for closing said firing circuit disposed to discharge said condenser means for exploding said detonator means, a projectile disposed in said bore having means for circuit closing engagement with each of said contact means incident to movement through each ring shaped explosive, said projectile having a rearwardly and inwardly curved boat tail disposed axially in said bore within the rear end of one of said ring shaped explosives for impingement of the explosion and shock wave thereon from said end ring shaped explosion for projecting the projectile forwardly through the remaining ring shaped explosives to explode the same progressively as the same is projected through said bore and receive the explosion and shock wave therefrom for acceleration of said projectile.

5. In a linear explosive actuator for projectiles, an elongated longitudinal support, a plurality of ring shaped explosives stacked on said support in closely spaced aligned relation having an axial bore therethrough, having a rear end and a forward end, detonating means in the rear end of each of said ring shaped explosives for exploding the same independently of the other ring shaped explosives, individual electrical condenser means having an electrical firing circuit connected to each of said detonating means for firing the same to explode said ring shaped explosives individually incident to discharge of

said condenser means, spaced electrical contact means in each of said firing circuits disposed in each of said ring shaped explosives in the forward end of said bore thereof for circuit closing engagement with a projectile moving through said bore from said rear end to said forward end, and a projectile disposed in said bore having a forward end for successive circuit closing engagement with said contact means in said ring shaped explosives during the passage of said explosive through the bore thereof, said projectile having a rearwardly and inwardly curved boat tail portion disposed axially within said bore for impingement thereon of the inward explosive forces and shock waves from said ring shaped explosives during the explosion thereof for accelerating said projectile through the exploding ring shaped explosives.

6. Apparatus as set forth in claim 5 in which the explosive detonating means for each ring shaped explosive comprises an annular detonating ring extended around the outer portion of the ring shaped explosive adjacent the rear end thereof to start the combustion thereof annularly around the same from the outside and rear end thereof for travel forwardly and inwardly.

7. Apparatus as claimed in claim 5 including a resilient cushion separator ring between each pair of said ring shaped explosives for cushioning the explosion of each of the exploding ring shaped explosive from the succeeding adjacent ring shaped explosive prior to the detonation thereof.

8. Apparatus as claimed in claim 5 in which said elongated longitudinal support extends forwardly beyond the forward ring shaped explosive and supports the plurality of ring shaped explosives in aligned relation for longitudinal movement thereon in a direction from the rear end of the stack toward the forward end, whereby the unexploded ring shaped explosives are free to move forwardly under the influence of the preceding exploding ring shaped explosives as the projectile is projected forwardly thereby.

9. Apparatus as claimed in claim 8 in which the ring shaped explosives are form sustaining and are progressively thinner in the axial direction from the rear forwardly to increase the rate of detonation of the ring shaped explosives as the projectile is accelerated therethrough for increasing the rate of shock wave and explosive impacts therefrom on the boat tail of the projectile in predetermined ratio to the rate of acceleration of the projectile.

10. A ring shaped explosive for a linear explosive accelerator, comprising a ring shaped explosive cake having a forward end face and a rear substantially parallel end face disposed normal to the axis of said ring shaped explosive, and a central bore therethrough, spaced opposite electrical contacts disposed in said bore of said ring shaped explosive cake for circuit closing contact with a projectile projected through said bore, annular electrical detonating means imbedded around the rear end of said ring shaped explosive cake adjacent its outer periphery and rear end, electrical detonator wire means connecting each of said electrical contact means to said electrical detonator means at substantially oppositely spaced points therein at opposite sides of said ring shaped explosive cake, an electrical condenser interposed in one of said detonating wire means for detonating said detonating means for exploding said ring shaped explosive cake inwardly from the outside and forwardly from the rear end thereof when said contacts in said bore are closed to discharge said electrical condenser, and means for charging said electrical condenser means while said contacts in said bore are open.

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