March 11, 1969 J. R. DALE 3,431,816

MOBILE GAS-OPERATED ELECTRICALLY-ACTUATED PROJECTILE FIRING SYSTEM

Filed July 21, 1967

Fig. 1

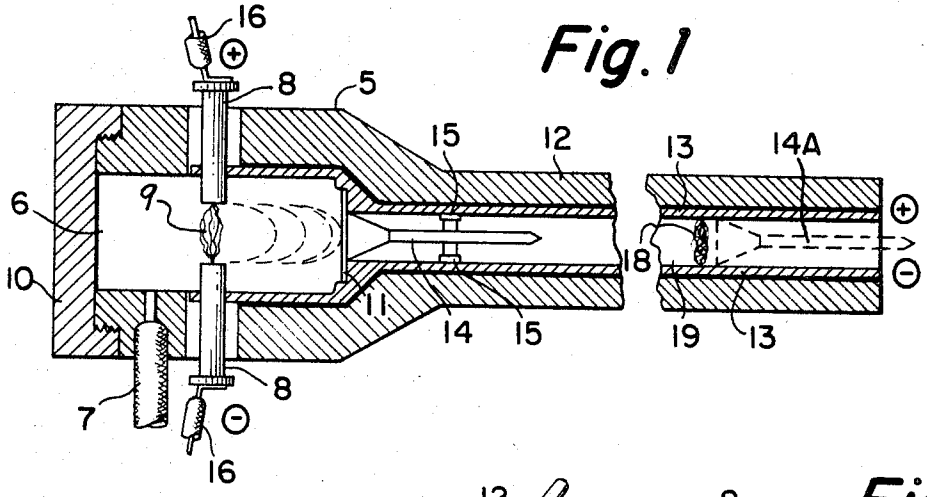


Fig. 2

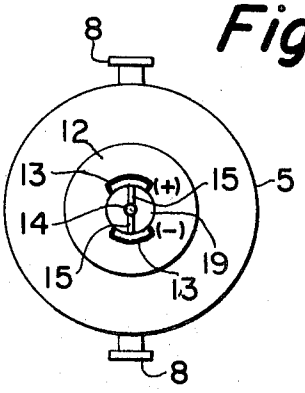


Fig. 3

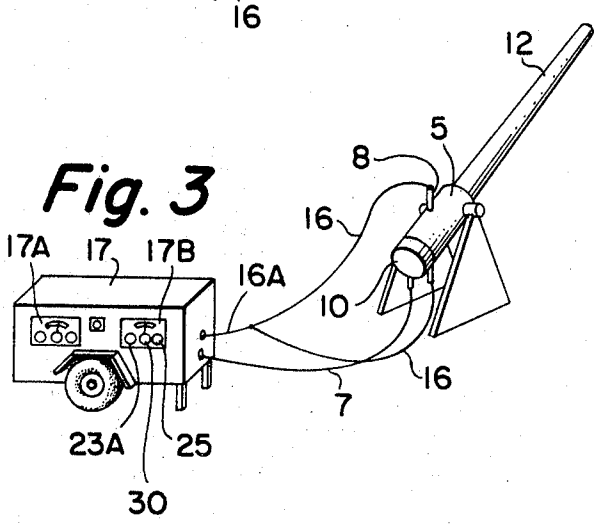
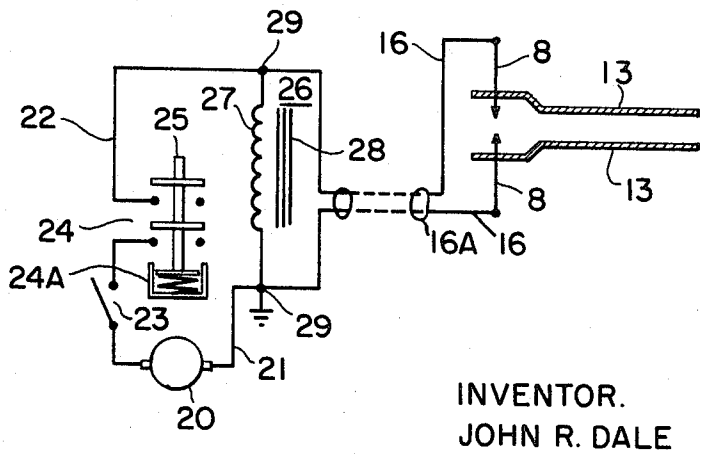


Fig. 4



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MOBILE GAS-OPERATED ELECTRICALLY-ACTUATED PROJECTILE FIRING SYSTEM

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ABSTRACT OF THE DISCLOSURE

A small arms weapon is provided with a gun barrel having a loading or firing chamber at the rear end thereof. Projectiles are propelled through the bore of the gun barrel and into freeflight by electro-thermionic energy. An electrical energy discharge through a light gas load in the chamber behind the projectile provides an explosive force to effect initial projectile movement and acceleration. A second electrical energy discharge travels through the bore with the expanding gas and provides additional force to overcome system losses and enhance projectile acceleration.

The subject invention relates to a mobile type projectile firing system that may be electrically actuated or fired. More particularly the invention relates to a mobile small-arms weapon or gun in a system of the above type the projectile of which is propelled by electro-thermionic energy derived from explosive gas and the combination of both an initiating and a following traveling wave of electrical energy discharge therethrough.

Due to its many advantages, it is desirable to utilize electric power for firing the projectiles of small arms military weapons and the like. However, it has been found that there are many problems involved in utilizing this power, many of which are not readily or have not been successfully solved. For example, although prior research has determined that about 1 megajoule of energy is required to cause propulsion of a normal small arms projectile seated in the bore of a military gun or like weapon and capacitive and/or inductive techniques have been employed to produce a 1 millisecond pulse having the above mentioned energy level, present known power supply means capable of producing 1 megajoule in 1 millisecond would be extremely massive in size and weight and accordingly would be considerably limited for use with military weapons of this type.

However, in modern warfare, the demand appears to be for more electrically-initiated mobile small arms weapons which may effectively be utilized in the field and readily transported or moved from place to place as the need may arise. As noted, the use of such weapons is presently limited due to power supply and other problems. The projectile firing system of the present invention is provided to solve the power supply problem and many others related thereto and to make effective use of electric energy or power in conjunction with the firing of mobile small arms weapons of the type referred to. In accordance with the invention, a relatively low-power sustained electrical discharge of seconds duration is utilized to realize the same total energy level of 1 megajoule. The power level required for propulsion is then found to be on the order of 100 kw., a wattage readily producible by mobile power supply means. In addition to utilizing such a power supply, the present invention provides an entirely mobile and possible portable, new and improved weapons system suitable for in-the-field operation for military purposes.

It is therefore a primary object of this invention to

provide an electrically-initiated mobile small-arms weapon system.

It is a further object of the invention to provide a mobile small-arms weapon system which may operate in response to electro-thermionic energy transfer and with simplified energy supply and storage means.

Another object of the invention is to provide an electrically-initiated, gas-operated mobile-type small arms weapon system of the gun type capable of higher projectile muzzle velocities than are now available with conventional weapons of that type.

Still another aspect and object of the invention is to provide an electrically-initiated small arms weapon system which is readily adapted to be transported by existing military vehicles and which has increased range, accuracy, and penetration capabilities over conventional weapons.

The above and still further objects, features and advantages of the present invention will become apparent upon consideration of the following detailed description of a preferred embodiment thereof in conjunction with and reference to the accompanying drawing, the scope of the invention being pointed out in the appended claims.

In the drawing, FIG. 1 is a longitudinal cross-sectional view partially-diagrammatic in form, of an electrically-initiated, gas-operated mobile type small arms weapon of the gun type, representing a presently-preferred embodiment of the invention.

FIG. 2 is a front end view of the small arms weapon or gun of FIG. 1, showing further details thereof in accordance with the invention,

FIG. 3 is a view in perspective of a field set up of the complete system of the present invention showing the weapon and supply means therefor, and

FIG. 4 is a schematic circuit diagram of one form of electrical energy supply means for the weapon and the electrical operating connections therewith.

Referring to the drawings wherein like elements throughout the various figures and designated by like reference numerals, and referring particularly to FIG. 1, the small arms weapon or gun shown includes a rear end housing **5** for a sustained-arc electrical discharge or firing chamber **6** which receives light gas through a flexible supply or intake hose **7** connected with the housing as indicated. Projecting into the chamber through the housing wall are two opposed electrical discharge electrodes **8**, both of which are insulated from the housing, as indicated, and securely mounted to withstand explosive forces incident to the firing of the weapon which follows a sustained electrical arc discharge **9** between them as will hereinafter be described.

The discharge chamber **6** is closed at its rear end or breech by a suitably releasable breech block for loading the weapon, such as a screw-type cap of block **10**. The chamber is temporarily sealed off or closed at its forward or bore end by a diaphragm or chamber seal **11**. The diaphragm or chamber seal **11** is designed to rupture at a predetermined point in the firing cycle as will hereinafter be explained and is replaced after each projectile has been fired during the reloading operation.

The barrel **2** of the small arms weapon or gun may be relatively long as indicated, and extends forward from and is integral with the housing **5**. The dual track electrodes **13** extend the entire length of the barrel in diametrically opposite relation to each other through the bore **19** of the barrel at the top and bottom thereof. The electrodes **13** are extended along the wall of the bore **19** and into connection with the electrodes **8**. This allows a moving arc **18** to follow and accelerate the projectile as it advances through the bore as will later be described. The projectile **14** is shown seated in the bore

19 supported by the projectile guides 15. The guides may be constructed of a light plastic material which, upon firing of the weapon, are either burned up by the heat or drop out of the front end of bore when the projectile begins its free flight trajectory.

Referring to FIG. 2, it can be seen that the dual track electrodes 13 do not completely circumscribe the bore 19 but rather are preferably relatively-narrow and occupy positions only along the top and bottom portions thereof.

Referring also to FIG. 3 along with FIGS. 1 and 2, it will be seen that the electrodes 8 are provided with flexible, electrical supply conductors 16 which may be included in a common cable connection 16A and, with the flexible gas intake hose 7, provide extended supply connections whereby electrical energy and the light gas may respectively be fed to the arc chamber 6. A utility-type small mobile carrier or van 17 may be provided to house the electrical power and light gas supply means for the system. Control panels 17A and 17B for the gas and electric power supplies, respectively, may be provided as indicated in FIG. 3. It is thus noted that the entire system is mobile and may be moved by any of a plurality of readily available military transport means (not shown).

Referring now to FIG. 4, along with FIG. 3 and the preceding figures of the drawing, the source of electrical energy may be a generator 20, connected through output leads 21 and 22 with the supply conductors 16 for the electrodes 8. The one conductor 21 may be grounded, as indicated, while the other, or high side of the generator, may be provided with control switch means, such as a power or main switch 23 and a firing switch 24 in series relation therewith as shown. The firing switch 24 may be of the push button type with an operating button 25, as indicated, and may provide a high-voltage multiple break in the circuit by the use of series multiple switch elements as shown. It may be of delayed opening type also, as by dash-pot or like control means 24A.

At the same time that the supply leads 16 are energized by the generator 20 upon closing the main switch 23 and pushing the firing button 25, a relatively large inductor 26 is energized through its winding 27 which is wound on the core 28 and connected at terminals 29 between the generator output leads 21 and 22. This provides a simple inductive energy storage means as the inductor 26 builds up a heavy field so long as the circuit remains closed. When the firing button 25 is released and the switch 24 is opened, the inductor 26 releases a relatively heavy current pulse.

The firing button 25 and control means 23A for the main switch 23 are indicated on the control panel 17B of FIG. 3 along with a generator output control element 30. Likewise the panel 17A for the gas supply in the unit 17 is provided with control elements for turning the gas supply ON and OFF and for adjusting the output gas pressure. As such means do not, per se, form part of the invention, no further description thereof is believed to be necessary. The operation of the system will now be described.

Opening the chamber 6 by unscrewing or releasing the breech block or cap 8 at the rear end of the gun, in the present example, permits the projectile 14 to be seated in the rear or chamber end of the bore 19 as shown in FIG. 1. The diaphragm or chamber seal 11 and the projectile guides 15 are seated, as shown, concurrently with the seating of the projectile 14. Loading of the weapon in the manner above indicated seals the sustained arc discharge chamber 6 from the bore 19. The chamber seal 11 may be designed to rupture at about 20,000 p.s.i.a. and thereby release the projectile. A 2500 p.s.i.a. light gas supply means housed in the utility van or supply unit 17, as described with reference to FIG. 3, is used to charge the sustained arc discharge chamber 6, through the flexible hose 7, to a moderate pressure level of from 100 p.s.i.a. to 2,000 p.s.i.a. At this point it will be seen that the gun is fully primed and ready to be fired.

Just prior to firing, the electric power source, such as the generator 20, is put into operation, being driven by any suitable means such as an internal combustion engine, for example (not shown).

In firing, the power switch 23 is closed and a high-voltage low-power discharge pulse from the generator is then applied between the sustained discharge electrodes 8 through the firing switch 24, as above described. The discharge pulse thus derived causes electrical breakdown of the gas in the chamber 6 and initiates the high-current, high-power sustained arc discharge 9 which may take as much power as 100 kw. for example.

The electrical energy in the arc thus produced is transferred to the gas as thermal energy with a resulting ramp function gas pressure increase. The pressure continues to increase until the energy losses balance the energy supplied. Since the major energy loss is in the form of radiant heat transfer through the housing walls around the arc discharge chamber 6, one method for minimizing this loss is to impregnate the chamber 6 with a sodium salt which, when excited by the resultant heat energy, becomes opaque to the radiant heat flux and thereby acts as a heat radiation shield.

Just prior to reaching the balanced or equilibrium state heretofore referred to, a chamber pressure of about 20,000 p.s.i.a. is achieved which breaks the diaphragm or projectile seal 11 and causes the projectile to move and start to accelerate.

As the projectile 14 moves through the bore 19, a high power pulsed electrical discharge 18 from the inductor 26 follows the projectile 14 by advancing along the dual track electrodes 13. This travelling wave of energy results in a slug of gas behind the projectile 14, the static pressure of such gas being higher than the internal ambient. This gas slug functions to negate the reduction of gas pressure which normally accompanies the expanding volume, thereby resulting in a more efficient weapon having a higher muzzle velocity. This phenomena may be explained as follows.

In order to negate the gas pressure decrease during the acceleration phase of the projectile 14, internal ballistics theory dictates the necessity of a high-energy electrical pulse automatically discharged and forced to follow directly behind the projectile 12. The duration of the pulse need generally be equivalent to the time of acceleration of the projectile 14, i.e., time within the bore 19. To accomplish this result, the inductive circuit as heretofore described is incorporated into the main power supply unit.

When the projectile starts to move, the resulting expanding gas flow bends the sustained arc column 9 toward the projectile 14 thereby causing the anode and cathode arc spots of electrodes 8 to automatically transplant to their respective dual track electrodes 13. This transplant or "arc jump" momentarily interrupts the power circuit thereby causing the inductive circuit to release its stored energy as a high voltage, high power pulse 18 appearing across the dual track electrodes 13. It is noted that the initial electrical energy supplied to electrodes 8 is of seconds duration and that at the instant the diaphragm 11 ruptures, the dash pot or like device 24A serves to open the firing switch 24. The opening of this switch is predetermined to occur exactly upon the transplanting of the arc, thereby further insuring deenergization of the inductor 26 across the dual track electrodes 13. The resultant power pulse or arc appearing across electrodes 13, as above described, is then electromagnetically accelerated behind the projectile 14 by virtue of the added electrical pulse energy from the inductor. A positive column of gas is also forced to follow the projectile 14 by virtue of both the dynamic gas pressure gradient thus produced and the self induced electromagnetic force. Accordingly, a high rate of power is released which results in a pressure wave following directly behind the accelerating projectile until the muzzle exit station is reached.

At this point, the projectile **14** begins its free flight trajectory and the moving arc **18** extinguishes.

It may also be pointed out that the accompanying pressure wave is thus enhanced and amplified by the continuous release of latent energy from the excited gas during the expansion process. The driving gas comes into thermal equilibrium well within the dynamic pressure range so that as the pressure drops during expansion, fractions of the energy expended for ionization and dissociation of the gas are then released to supplement the energy derived from the moving electrical arc.

Variable range capability may be provided by controlling and varying the inductive build-up in the main power circuit as by varying the generator output control element **30**. For example, as the circuit inductance is increased, more electrical energy may be stored for exchange to the gas directly behind the projectile **14**. Upon discharge, this results in a lower pressure drop as the gas expands, thereby yielding a corresponding increase in muzzle velocity and, hence, increase in range capability and penetration. Similarly, reducing the amount of stored inductive energy tends to reduce the muzzle velocity and hence lessen the range of the weapon.

I claim:

1. A mobile projectile firing system comprising in combination, an elongated gun barrel having an axially-extending bore of predetermined diameter for receiving a projectile and guiding said projectile from a seated position at the base into flight through the open forward end thereof, means providing a firing chamber of relatively larger diameter than said bore and of sufficient axial length to receive and contain a charge of explosive gas of predetermined magnitude as the main propellant for said projectile, means for charging said chamber with said gas including a supply conduit connected with said chamber means, a high-pressure rupturable diaphragm element sealing said chamber from the bore, an electric generator providing a source of electrical energy, a series firing switch, a pair of insulated electrodes connected with said generator through said switch and extending into said chamber in spaced relation to each other for producing a sustained electrical discharge therebetween to fire said gas charge upon application of electrical energy

thereto from said generator by closure of said switch, thereby to provide a propelling force at the rearward end of said projectile, a relatively-large inductor connected between said electrodes for receiving and storing electrical energy during closure of said switch and the sustained discharge between said electrodes, and means including a pair of spaced electrodal elements extending longitudinally along the bore in diametrically opposite relation to each other and connected each with one of said electrodes for maintaining and enhancing the propelling force on said projectile through the creation of a moving high power electrical arc discharge directly behind the accelerating projectile upon opening of said switch and receipt of stored electrical energy from said inductor.

2. The invention as defined in claim **1** wherein the walls of said firing chamber are impregnated with a sodium salt substantially opaque to radiant heat flux thereby effecting a reduction in thermal loss through the walls of the weapon.

3. The invention as defined in claim **1**, wherein said electrical discharge is of seconds duration and is applied through said charge of gas until a predetermined gas pressure is attained to rupture said diaphragm element, and wherein said moving electrical arc discharge travels the length of the bore from the ruptured diaphragm element and is applied upon the opening of said switch and a resultant arc jump from said electrodes to said electrodal elements due to the stored energy from said inductor.

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U.S. Cl. X.R.

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