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ELECTROMAGNETICALLY OPERATED GUN

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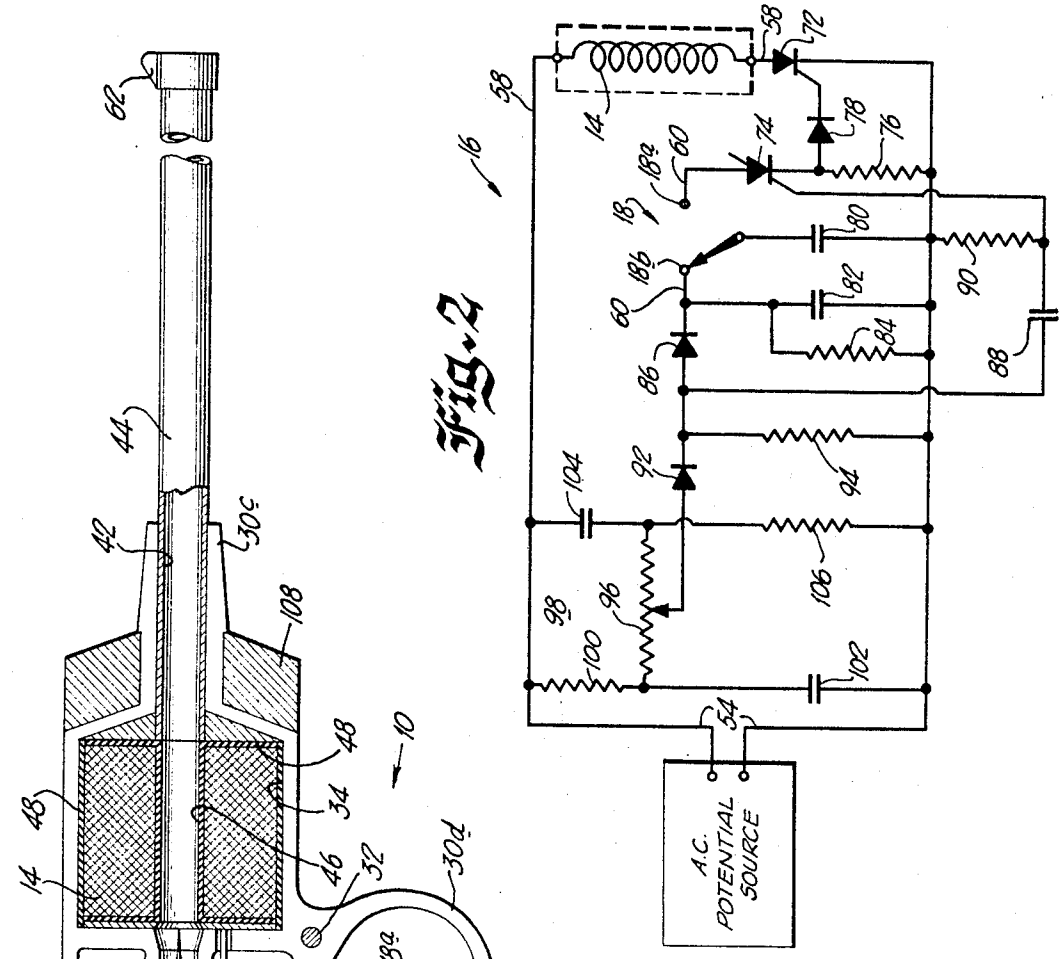

Fig. 2

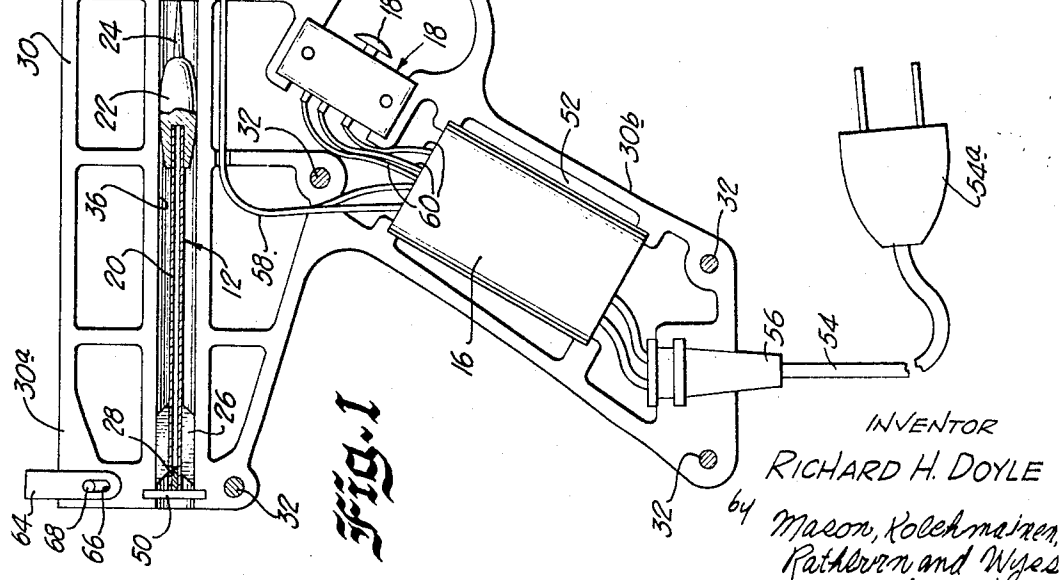

Fig. 1

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ELECTROMAGNETICALLY OPERATED GUN

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This invention relates to an electric gun for projectiles and, more particularly, to an electrically operated gun for shooting darts or other projectiles formed at least in part of magnetic material.

The types of guns that are now generally available are not well suited for use in the home. Conventional firearms require the installation of indoor range facilities, create excessive noise, and can become rather expensive because of both the cost of ammunition and the initial capital investment required. Guns using spring motors and pneumatic motors are also available and generally do not require extensive indoor range facilities. However, with the possible exception of the more expensive air powered units, these types of guns frequently lack accuracy.

Accordingly, one object of the present invention is to provide a new and improved electrically operated gun.

Another object is to provide an electrically operated gun shooting darts formed at least in part of a magnetic material.

Another object is to provide a gun that is economically manufactured and operated and which possesses the accuracy desired for target shooting.

A further object is to provide an electrically operated gun for use with magnetic projectiles including an operating winding and means for accurately positioning the projectile relative to the operating winding.

In accordance with these and many other objects, an embodiment of the invention comprises an electrically operated hand gun for shooting darts or other projectiles formed at least in part of magnetic material. One projectile that can be used with the gun comprises a dart having a generally elongated body formed of nonmagnetic material to the leading end of which is secured a mass of magnetic material having a point structure. The trailing end of the nonmagnetic body is provided with a plurality of vanes and carries an additional magnetic element.

The gun comprises a housing having both a chamber and an elongated opening adapted to receive the dart. An operating winding is disposed in the chamber with its axial opening aligned at one end with the elongated opening for receiving the dart and at its other end with a barrel structure carried on the housing. A power supply disposed in a hollow handle on the housing is connected between a source of alternating current potential and the operating winding and is selectively controlled by a switch to energize the winding when the gun is to be fired.

To provide means for accurately locating the dart in a desired position within the gun, a permanent magnet disposed adjacent one end of the elongated opening acts on the magnetic element carried on the vaned end of the dart to releasably secure the dart in a predetermined position. This holding means permits the gun barrel to be tipped downwardly and insures that the magnetic mass on the leading end of the dart is properly located relative to the winding means. In addition, the magnetic holding means assists in imparting high velocity to the dart when the gun is operated by retarding movement of the dart under the influence of the energized winding until the flux field developed thereby increases in value to the desired magnitude.

Many other objects and advantages of the present invention will become apparent from considering the following detailed description in conjunction with the drawings in which:

FIG. 1 is a fragmentary sectional view of an electric gun embodying the present invention; and

FIG. 2 is a schematic diagram of a control and operating circuit for the gun shown in FIG. 1.

FIG. 1 of the drawings illustrates an electrically operated gun **10** which embodies the present invention and which is adapted to shoot a projectile, such as a dart, indicated generally as **12**. The gun **10** shoots the dart **12** with uniform high velocity by selectively energizing a winding **14** under the control of a power supply circuit **16** which is carried on the gun **10** and which is actuated by a manually controlled switch assembly **18**.

The dart **12** comprises an elongated tubular or cylindrical shaft or body **20** formed of nonmagnetic material. The leading end of the shaft **20** is provided with a mass of magnetic material **22** formed generally in the configuration of a prolate spheroid and carrying a point structure **24**. The trailing or rear end of the shaft **20** is provided with a plurality of peripherally spaced vanes **26** made of feather or plastic material. A second element **28** of magnetic material is also carried on the rear end of the shaft **20**.

The gun **10** includes a housing **30** made of nonmagnetic or plastic material and formed with a somewhat cylindrical head portion **30***a* and a handle portion **30***b*. Although the housing **30** can be formed as a single integral construction, it preferably is formed as two matching halves which are secured in face-to-face relationship by a plurality of fastening means **32**. The head portion **30***a* of the housing **30** defines a chamber or cavity **34** and an elongated cylindrical opening **36** for receiving the dart **12**. A forwardly projecting nose portion **30***c* of the head portion **30***a* of the housing **30** is provided with an opening **42** aligned with the opening **36** for receiving a cylindrical barrel structure **44**.

The gun **10** is operated by the operating winding **14**. This winding comprises a plurality of convolutions of copper wire formed in a cylindrical configuration with an axially extending center opening **46**. If desired, the winding **14** can be "potted" in a metal filled epoxy material to provide both electrical insulation and also good heat transmitting characteristics for dissipating heat generated during operation of the gun **10**. The winding **14** is disposed within the chamber or opening **34** in the housing **30** with the axially extending opening **46** aligned at its inner end with the opening **36** in the housing and at its outer end with the opening in the barrel structure **44**. If desired, an additional layer of dielectric material **48** can be interposed between the winding **14** and the adjacent walls of the housing **30**.

To provide means for releasably retaining the dart **12** in a predetermined position relative to the operating winding **14**, a permanent magnet **50** is mounted on the housing **30** in a position adjacent or closing the end of the opening **36** that is spaced from the winding **14**. When a dart **12** is placed in the gun by dropping it into the open end of the barrel structure **44**, vaned end first, the dart slides rearwardly relative to the gun **10** through the barrel **44** and the axial opening **46** in the operating winding **14** into the elongated opening **36**. When the vaned end of the dart **12** moves into proximity to the permanent magnet **50**, the flux field of this magnet acts on the magnetic element **28** to hold the trailing or rear end of the dart **12** in engagement with this magnet. This releasably retains the dart **12** within the elongated opening or chamber **36** in the gun **10** and permits the outer end of the barrel **44** to be moved downwardly without causing displacement of the dart **12**. In the normal or retained position illustrated in the drawing, the mass of magnetic material **22** is held within the elongated opening **36** spaced from the axial opening **46** in the operating winding **14**. However, the mass of magnetic material **22** is within the

effective electromagnetic field developed by the winding **14** when this winding is energized.

The power supply circuit **16** provides means for selectively energizing the winding **14**. Although this circuit can comprise any suitable circuit for applying a unidirectional potential to the winding **14**, this circuit preferably comprises one of the type shown in FIG. 2 of the drawings. In general, this circuit comprises a gated silicon rectifier supplied with a 110 volt, 60 cycle alternating current potential and operable to connect the winding **14** directly across the potential source for a single selected half cycle of the potential. Since the direct current resistance of the winding **14** is on the order of .5 to 5 ohms, the winding **14** draws a very large current during the brief period in which it is energized to develop a large electromagnetic field acting on the mass of magnetic material **22** on the dart **12** to propel this dart outwardly through the opening **46** and the barrel **44**.

The power supply circuit **16** preferably is "potted" in a dielectric material and is secured or mounted within a cavity **52** in the handle portion **30***b* of the housing **30**. The circuit **16** is supplied with energy from a conventional line cord **54** terminating in a strain relief insulator **56** that is secured to the handle **30***b* of the housing **30**. The circuit **16** is connected to the winding **14** by a plurality of flexible leads **58** and is also connected to the manually actuated switch assembly **18** by a plurality of flexible leads **60**. The switch assembly **18**, which can be of any suitable type, is mounted at the junction of the head portion **30***a* and handle portion **30***b* of the housing **30** and includes a manually actuated switch operating element **18***a*, the outer end of which is disposed within a space defined by a trigger guard portion **30***d* of the housing **30**.

To aid in sighting the gun **10**, a front sight **62** is secured to the forward end of the barrel **44**, and a rear sight **64** is mounted adjacent the rear end of the head portion **30***a*. The rear sight **64** is provided with a longitudinally extending slot **66** through which a threaded fastener **68** extends. By releasing the fastener **68**, the vertical position of the rear sight **64** can be adjusted. This sight is clamped between the halves of the housing **30** by tightening the fastener **68**.

Referring now more specifically to FIG. 2 of the drawings, therein is illustrated a suitable or representative load control or power supply circuit **16**. The circuit **16** connects the winding **14** to an alternating current potential source for all or a selected part of a single half cycle of the alternating current potential. The circuit **16** includes a set of input terminals connected to the alternating current potential source, such as a conventional 60 cycle, 120 volt, single phase source by the line cord **54** and a set of output terminals which are connected to the terminals of the winding **14** by the leads **58**.

The circuit **16** includes a gated unidirectional controlled conduction device **72**, such as a silicon controlled rectifier. The anode of the gated rectifier **72** is connected to one terminal of the winding **14** by one of the leads **58**, and the cathode of the unit **16** is directly connected to one terminal of the potential source over one of the leads **58** and the line cord **54**, although the relative polarities of the unidirectional conducting components in the circuit **16** can be reversed, if desired. When a positive potential is applied to the anode of the gated rectifier **72** and a trigger signal is applied to the control or gate electrode thereof, the winding **14** is directly connected across the potential source to develop a magnetic field for actuating the dart **12**.

The gate electrode of the gated rectifier **72** is provided with an operating or trigger signal under the control of a second controlled conduction device **74**, such as a silicon controlled switch. The cathode of the switch **74** is connected to one side of the potential source through a resistance element **76** and is coupled to the control electrode of the gated rectifier **16** through a blocking diode **78**. The anode of the switch **74** is connected to a pair of normally open contacts **18***a* on the manually actuated switch **18** over one of the leads **60**. The switch is actuated to close the normally open contacts **18***a* and to open a pair of normally closed contacts **18***b* when the control circuit **16** is to connect the winding **14** to the potential source.

The normally closed contacts **18***b* connect an energy storing means or storage capacitor **80** to a charging circuit including a capacitor **82** that is shunted by a resistance element **84**. Positive-going half cycles of the alternating current potential from the source are continuously supplied through a diode **86** to charge the capacitors **80** and **82**. When the gun **10** is to be operated, the switch **18** is actuated to open the contacts **18***b* and to close the contacts **18***a*. This disconnects the storage capacitor **80** from its charging circuit and connects it to the anode of the second controlled conduction device **74** so as to provide an operating potential therefor. The energy stored in the capacitor **80** is such as to maintain the device **74** in a conductive condition for a period of time no longer than one cycle of the potential supplied by the source.

Inasmuch as the switch **18** can be operated to prepare the device **74** and, thus, the device **72** for conduction at random times relative to the alternations in the potential supplied by the source, it is desirable to synchronize the periods of conduction through the device **74** with the potential supplied by the source so as to insure that the potential applied across the device **72** is of a proper polarity and to insure that the rectifier is fired early enough in the cycle to permit the necessary power to be obtained. To accomplish this, one of the gate or control electrodes of the silicon controlled switch **74** is connected to a differentiating network including a capacitor **88** and a resistance element **90**. The capacitor **88** is connected to the cathode of a diode **92**, which cathode is also returned to one side of the potential source through a resistance element **94**. The anode of the diode **92** is connected to an adjustable tap on a potentiometer **96** that is connected across two legs of a phase shifting network **98** which is connected across the potential source. The positive-going alternations in the potential supplied by the source are differentiated in the network including the resistance element **90** and the capacitor **88** to provide positive-going pulses at the gate electrode of the silicon controlled switch **74**.

These positive-going pulses are continuously applied to the controlled conduction device **74** so long as the circuit **16** is energized by the source. However, the device **74** normally is not placed in a conductive condition because of the absence of an operating potential for this device. During the first properly poled half cycle following the time at which the switch **18** is operated to close the contacts **18***a*, the positive-going pulse supplied to the control electrode of the device **74** places this device in a conductive state so that the storage capacitor **80** is discharged through the resistance element **76**. This provides a positive-going pulse that is forwarded through the diode **78** to the gate electrode of the silicon controlled rectifier **72**. Since the trigger pulse for the device **74** occurs only during positive-going alternations in the potential supplied by the source, the anode of the device **72** is also at a positive potential with respect to its cathode, and the trigger pulse supplied through the diode **78** places the silicon controlled rectifier **72** in a conductive condition to connect the winding directly across the potential source.

Since the storage capacitor **80** provides sufficient energy for maintaining the device **18** in a conductive condition for no longer than one cycle of the potential supplied by the source and since the silicon controlled rectifier **72** is placed in a nonconductive condition as soon as the potential on its anode swings negative relative to its cathode, the winding **14** can be energized only once in

response to the actuation of the switch **18**. When the trigger or other controlling means for the switch **18** is released, the switch **18** returns to its normal position to open the contacts **18***a* and to close the contacts **18***b*. The opening of the contacts **18***a* disconnects the storage capacitor **80** from the anode of the silicon controlled switch **74**, and the closure of the contacts **18***b* connects the capacitor **80** in parallel with the capacitor **82** in the charging circuit. The potential supplied by the capacitor **82** as well as that forwarded through the diode **86** rapidly recharges the storage capacitor **80** to again condition the power supply circuit **16** for controlling the next cycle of energization of the winding **14**.

Since the power delivered to the winding **14** during any cycle of operation is determined by the portion of the alternating potential half cycle in which the silicon controlled rectifier **72** is in a conductive condition and since the firing of the gated rectifier **72** is dependent on the time at which the silicon controlled switch **74** is rendered conductive, the circuit **16** includes means for controlling the output power developed in the winding **14** by controlling the relative phase relationship between the alternating current potential supplied by the source and the pulses provided by the differentiating network including the capacitor **88** and the resistance element **90**. This control is exerted by the phase shift network **98** which comprises a first leg including a resistance element **100** and a capacitor **102** and a second leg including a capacitor **104** and a resistance element **106**, both of which legs are connected in parallel across the potential source. The potentiometer **96** is connected between the two legs at the point of common connection of the elements **100**, **102** and **104**, **106**. The network **98** shifts the phase of the alternating current potential applied to the diode **92** relative to the phase of the potential supplied by the source.

By adjusting the position on the tap of the potentiometer **96**, the phase of the signal coupled through the diode **92** can be made to substantially coincide with the beginning of the positive-going half cycle of the potential from the source so that all of the power available in the half cycle can be used by triggering the silicon controlled rectifier **72** at the beginning of the selected positive-going half cycle. Alternatively, the tap on the potentiometer **96** can be adjusted to provide a delay approaching one-half of the positive-going half cycle so that the differentiating network triggers the controlled conduction devices **72** and **74** after substantially half of the half cycle has passed. This reduces the power available for use by the winding **14** by a factor approaching two. In this manner, the phase shift network **98** permits the power supplied by the circuit **16** to be easily adjusted without requiring the use of components connected in series between the potential source and the winding **14**.

When the gun **10** is to be operated, the vaned end of the dart **12** is placed in the open end of the barrel **44**, and the dart **12** is released to permit it to fall downwardly through the barrel **44** and the axial opening **46** into the elongated opening or chamber **36**. When the magnetic element **28** on the dart **12** moves into proximity to the permanent magnet **50**, it is attracted into engagement with this magnet so that the dart **12** is releasably retained in a proper position within the opening **36** with the mass of magnetic material **22** disposed in proximity to but spaced from the operating winding or coil **14**. The dart **12**, by virtue of its magnetic retention within the opening **36**, will not be displaced from its proper position even when the end of the barrel **44** is pointed downwardly. This permits the gun **10** to be aimed at objects or targets disposed below the level at which the gun is held.

The gun **10** is fired by depressing the operator element **18***a* on the switch assembly **18**. The operation of the switch assembly **18**, controls the power supply circuit **16** so that the next complete positive-going cycle of alternating current input potential supplied by the line cord **54** is applied directly across the winding **14**. In response to energization, the winding **14** develops an electromagnetic field which acts on the mass of magnetic material **22** and attempts to move this mass inwardly toward the magnetic center of the operating winding **14** to reduce the reluctance of the external air gap. The initial movement of the mass of material **22** and thus of the dart **12** is retarded by the magnetic attraction between the permanent magnet **50** and the magnetic element **28**. This permits the field produced by the energization of the winding **14** to develop to a high enough value that when the dart **12** begins to move, a fairly high rate of acceleration is achieved. The electromagnetic forces acting on the mass of magnetic material **22** propels this material and the dart **12** through the axial opening **46** and into the barrel **44** with enough velocity that it passes the magnetic center of the winding **14** and is propelled outwardly through the open end of the barrel **44**. It is desirable that the permanent magnet **50** only partially closes the rear end of the opening **36** or that other means, such as a vent passage in the housing **30** communicating with the opening **36**, be provided to prevent the formation of a vacuum behind the dart **12** when it is propelled. The formation of a vacuum tends to retard the acceleration of the dart **12**.

The propulsion of the dart **12** is also enhanced by an annular ring of electrically conductive material **108** that is disposed on the nose portion **30***c* of the housing **30** adjacent or directly against one end of the winding **14**. The annular element **108** provides a "shorted turn" or bucking coil to delay the collapse of the field developed by the winding **14** and thus extends the duration of the electromagnetic field for propelling the dart **12**. In effect, the element **108** provides a single turn coil linked by the flux field of the winding **14** in which a relatively large current is induced when the winding **14** is energized. This induced current tends to retard the collapse of the flux field developed by the winding **14** when the power supply circuit **16** terminates the energization of this winding.

The power supply circuit **16** is capable of delivering only a single pulse of energy through the winding **14** each time that the switch assembly **18** is actuated. Thus, the winding **14** will be energized only once in response to each manual actuation of the operator element **18***a*. The gun **10** is restored to a normal condition by releasing the switch assembly **18**. Since the winding **14** is energized for only one positive-going or negative-going cycle of the input potential, the heat generated by the winding **14** is not excessive and does not cause heating of the gun **10**.

In one gun **10** constructed in accordance with the present invention, the control circuit **16** applies 8–10,000 watts of power to the winding **14** for a part of one cycle of the 110 volt, 60 cycle input potential. This energization of the winding **14** produces acceleration of the dart **12** on the order of 30,000 feet/sec./sec. with this dart attaining terminal velocities in excess of 100 feet per second. The gun **10** is completely silent in operation, lacks any moving parts that might result in malfunction or require replacement, and can be operated to provide over 10,000 shots at a cost of less than one cent for the electrical power consumed.

The control circuit **16** can also be of the type in which a capacitor charged by a direct current potential supplied from the alternating current potential source through a rectifying network or supplied by a battery is discharged through the winding **14** in a short time interval under the control of the switch means **18**. With this type of control circuit **16**, the resistance of the winding can be reduced to a value less than one ohm with an inductance on the order of .002 henry to permit a peak driving current of around 300 amperes. This applies from 200 to 300 watt-seconds of energy to the winding **14** to obtain rates of acceleration and terminal velocities as well as ranges of operation greater than those obtained with the control circuit **16** previously described.

Although the present invention has been described with reference to a single illustrative embodiment thereof, it should be understood that numerous other modifications and embodiments can be devised by those skilled in the art that will fall within the spirit and scope of the principles of the present invention.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An electric gun for use with projectiles having a magnetic end part and a magnetic portion comprising a housing having a depending hollow handle and an elongated opening, said housing also having an enlarged chamber adjacent one end of the elongated opening, winding means mounted in the chamber and having an axial opening disposed in alignment with the elongated opening, a barrel mounted on the housing in alignment with the elongated opening and the axial opening, permanent magnet means carried on the housing adjacent the other end of the elongated opening and cooperating with the magnetic end part on the projectile to releasably secure the projectile in the elongated opening with the magnetic portion disposed adjacent the winding means, said permanent magnet means being spaced from the winding means by substantially the full length of the projectile to separate the permanent magnet means from the field of the winding means, power supply means mounted within the hollow handle and connceted to the winding means, said power supply means comprising a control circuit means connected between a cycling potential source and said winding means for connecting the winding means to the potential source for a period of time no greater than one cycle in the potential supplied by the source, and manually operable means carried on the housing for controlling the operation of the control circuit means.

2. An electric gun energized by an undulating potential source for propelling a projectile having a magnetic portion comprising a housing having a barrel structure, winding means on the housing including an axial opening aligned with the barrel for receiving the projectile, control circuit means connected between the undulating potential source and the winding means for connecting the winding means to the potential source for a period of time no greater than one undulation in the potential supplied by the source, and manually operable means carried on the housing for controlling the operation of the control circuit means.

3. An electric gun adapted to be energized by an alternating current potential source to propel a projectile formed at least in part of magnetic material comprising a housing including a barrel structure communicating with an elongated opening in the housing adapted to receive the projectile, winding means on the housing and encircling at least a portion of the opening at a position disposed in proximity to the magnetic part of a projectile in the opening, control circuit means connected between the alternating current potential source and the winding means and operable to connect the winding means to the potential source for a period of time no greater than one cycle of the potential, and manually operable means on the housing for controlling the operation of the control circuit means.

4. A gun energized by an alternating current potential source for propelling a projectile having a magnetic portion comprising a housing having an elongated body portion and a handle portion extending generally transverse to the body portion, the handle portion having a first cavity and the body portion having an elongated opening closed at one end and extending in the direction of elongation of the body portion, the body portion also having a second cavity surrounding the elongated opening and disposed intermediate the ends thereof, winding means disposed in the second cavity and having an axial opening aligned with and forming a part of the elongated opening, retaining means for releasably retaining a projectile in the portion of the elongated opening disposed between its closed end and the winding means, a power supply circuit mounted in the first cavity in the handle portion and operable to control the connection of the winding means to the potential source, first flexible electrically conductive means connected to the power supply circuit for coupling the power supply circuit to the potential source, second electrically conductive means for connecting the power supply circuit to the winding means and extending from the first cavity in the handle portion of the housing to the second cavity in the body portion of the housing, and manually operable switch means connected to the power supply circuit and mounted on the housing adjacent to the junction of the body portion and the handle portion.

5. The gun set forth in claim 4 including an annular means of electrically conductive material mounted on the body portion of the housing in a portion immediately adjacent to the end of the winding means spaced away from the closed end of the elongated opening.

6. The gun set forth in claim 5 in which the body portion of the housing includes a forwardly extending projection surrounding the elongated opening on which the annular means is mounted.

7. The gun set forth in claim 4 including a barrel carried on the housing at the end of the body portion spaced from the closed end of the elongated opening and forming a part thereof.

8. The gun set forth in claim 4 in which the switch means is mounted within the housing and includes an operator means projecting outwardly from the housing.

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