Aug. 31, 1943. O. T. FRANCIS 2,328,444

IGNITION SYSTEM

Filed Nov. 17, 1941

Fig. 1

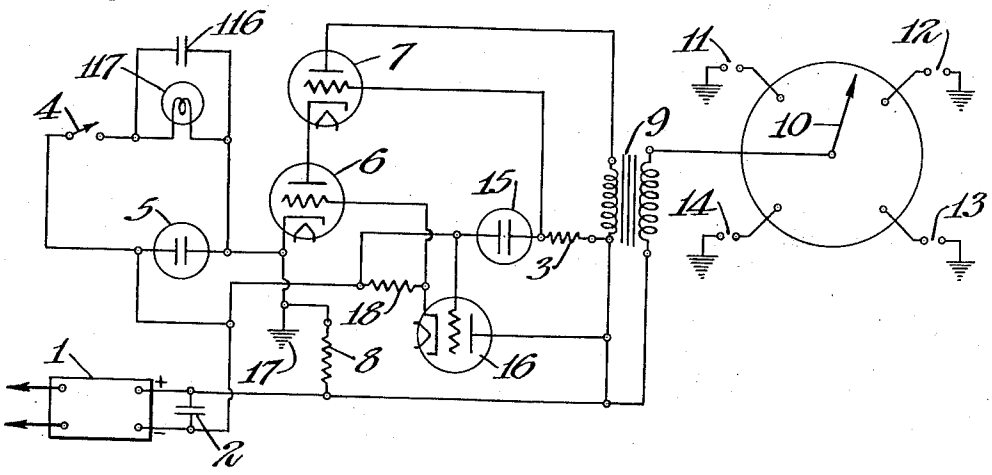
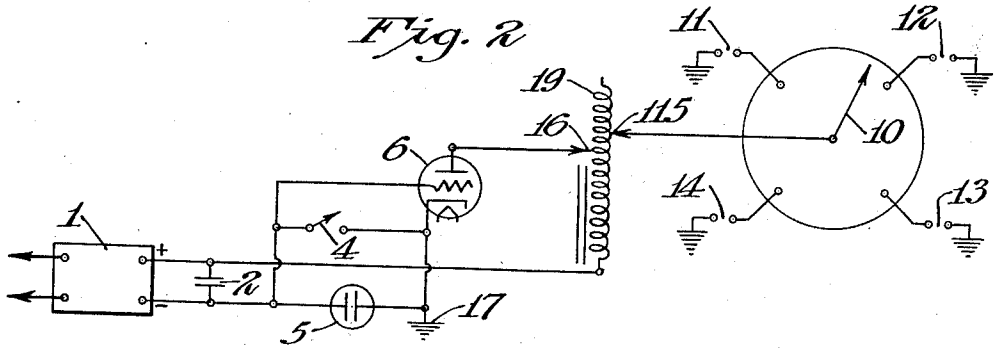


Fig. 2



Inventor

Oliver T. Francis

Patented Aug. 31, 1943 2,328,444

UNITED STATES PATENT OFFICE

2,328,444

IGNITION SYSTEM

Oliver T. Francis, Renville, Minn.

Application November 17, 1941, Serial No. 419,400

11 Claims. (Cl. 123—148)

This invention relates to ignition systems and more particularly to means for producing sparks for gas engines with a plurality of cylinders.

To produce a good spark in the secondary of ignition coils, considerable electrical energy must be changed into magnetic energy in the core during the period that the primary circuit is closed. The magnitude of the energy is of the order of .01 watt second, or 100,000 ergs. In order that this energy should not be reconverted into electrical energy in the primary circuit, it is mandatory that the primary circuit be broken as near instantaneously as possible. Present mechanical interrupters are shunted by large capacity condensers to prevent sparking contacts which sparks would permit all this magnetic energy to be dissipated in the primary circuit. Even with these condensers shunting the interrupter a considerable portion of the energy of magnetization of the core is dissipated in the primary circuit, often amounting to several thousand ergs.

While mechanical interrupter ignition systems have proved fairly satisfactory for present day gas motors, with the trends of increasing speed and number of cylinders, such ignition systems have about reached the limit of their capacity to produce sparks at high speeds. It is impossible with mechanical interrupters to interrupt large currents at frequencies above two or three hundred times per second due to the fact that the gases in the vicinity of the interrupter become ionized and produce a continuous arc, instead of sharply defined sparks. The RC time elements of low voltage primary circuits also become limiting factors. Even when low voltage primary circuits are kept of as low a resistance as possible, it is a problem to change large amounts of electrical energy into magnetic energy in the thousandth of a second that primary contacts may be closed.

It is an object of this invention to illustrate a vacuum tube interrupter of the primary of an ignition coil, thereby permitting the use of higher primary voltages with primary ignition coil windings of higher inductances and resistances, to produce secondary sparks at spark plugs at higher frequencies, than are possible with present day ignition systems.

In order to produce good sparks with a vacuum tube interrupter it is essential, as brought out above, that the primary circuit be broken as nearly instantaneously as possible. The problem is further complicated by the fact that at the instant of breaking the primary circuit the self inductance of the primary may impress a voltage on the vacuum tube interrupter several times as great as the ordinary direct current voltage rating of the tube. If 100,000 ergs of magnetic energy has been stored in the core, and at the time of interrupting the primary circuit the primary self inductance builds up an electromotive force of 5,000 volts, two milliamperes flowing in the primary circuit for .001 of a second would completely dissipate this magnetic energy without producing any spark in the secondary. If only a small fraction of this 100,000 ergs of energy were dissipated in the primary circuit, the remaining energy would not be sufficient to produce a good spark in the secondary. The importance of instantaneously breaking the primary circuit therefore becomes apparent.

The grid-filament capacities of tubes capable of carrying a hundred milliamperes of current is so large that their grids cannot be thrown highly negative substantially instantaneously by conventional circuits, which instantaneous action is essential for producing excellent secondary sparks. It is an object of this invention to illustrate a vacuum tube circuit breaker whereby these capacities shall have as small a deleterious effect as possible.

In U. S. Patent No. 1,886,386, issued to me November 8, 1932, I disclosed a plurality of vacuum tubes each having an anode, a cathode, and a control electrode, an input and an output circuit, the anode and cathode of a first of said tubes being connected in the input and output circuit of a second of said tubes, and means for controlling the potential on said control electrode of said first of said tubes. In U. S. Patent No. 1,913,588, I disclosed means for substantially eliminating arcing of contacts across the key of a radio transmitter by placing a gas discharge device across said key. It is an object of this invention to utilize the principles illustrated in these two patents for interrupting the current in the primary of an ignition coil.

Another object is to illustrate a vacuum tube ignition circuit, wherein, the anode voltage supply shall be connected in series with the secondary high voltage source to produce higher voltages across the spark plug.

It is an object of this invention to illustrate a primary protective device comprising a positive coefficient resistance in the input and output circuit of a vacuum tube.

The length of time of continuation of the arc at a circuit breaker is dependent on the voltage

across said circuit breaker. It is an object to produce a vacuum tube amplification of said voltage across said circuit breaker to thereby reduce the time of breaking said circuit. Another object is to illustrate a vacuum tube interrupter in connection with an auto-transformer for spark production.

Other objects of the invention will become evident from the claims, drawing, and following description, wherein:

Fig. 1 illustrates an ignition system in which vacuum tubes are used to interrupt primary inductance coil circuits.

Fig. 2 illustrates a variation of Fig. 1, wherein an autotransformer is used in place of the conventional ignition coil.

In the following description and claims the term "vacuum tube" is used as conventionally used in radio receiver and transmitter art, that is a tube of such high vacuum that space currents are streams of electrons as differentiated from the term gas discharge device where condition is principally by ionization of gases.

In the figures the same numbers are assigned elements performing the same function.

Referring to Fig. 1, 1 is a power supply such as ordinarily used in amateur radio transmitters, and may be capable of furnishing one hundred milliamperes at a thousand volts, although I have found my device to function satisfactorily on power supplies as low as 500 volts. The higher the voltage of supply 1 the better the spark produced. The voltage of power supply should not however greatly exceed the D. C. voltage rating prescribed for tube 7 by its manufacturers. Across the output of power supply 1 is condenser 2, in parallel with two voltage dividers, one comprising a resistance 3 in series with gas discharge device 15, and the other comprising vacuum tube 16 having a resistance 18 connected in its input and output circuit. Since resistance 18 is in the input and output circuit of tube 16, the voltage drop across 18 remains substantially constant regardless of current drawn from the positive terminal of reistance 18. Resistance 8 is connected from the positive terminal of source 1 to cathode of tube 6 to maintain gas discharge device 5 conductive as long as interrupter 4 is open.

The positive terminal of power supply 1 is connected through primary of ignition coil 9 to the anode of vacuum tube 7, the cathode of which is connected to anode of vacuum tube 6. The cathode of tube 6 is connected to ground 17 and through gas discharge device 5 in parallel with interrupter 4 to negative terminal of power supply 1. In series with interrupter 4 is an incandescent light 117 in parallel with a condenser 116. As is well known an incandescent light with a tungsten filament has a high temperature coefficient of resistance. This light 117 is in the input and output circuit of tube 6 when interrupter 4 is closed and limits the current flowing through primary of transformer 9 to prevent same from overheating and burning out if interrupter 4 is allowed to remain closed over long periods of time. Interrupter 4 may be the interrupter used in conventional ignition systems today, with contact shunting condenser removed.

One terminal of secondary of ignition coil 9 is connected to the positive terminal of power supply 1. The other terminal is connected to arm 10 of a conventional ignition distributer, making contact successively with leads going to one terminal of spark plugs 11, 12, 13, and 14. The other terminal of each of these spark plugs is grounded as is conventional in present day ignition systems.

Fig. 2 illustrates a modification of Fig. 1 wherein an auto-transformer 19 is used in place of ignition coil 9. Distributor arm 10 is connected to auto-transformer 19 at a point 115 to place the desired voltage thereon. The anode of vacuum tube 6 is connected to auto-transformer 19 at point 16. The cathode of tube 6 is connected through interrupter 4 in parallel with gas discharge device 5 to negative terminal of power supply 1. The functioning of the circuit is similar to that described for Fig. 1.

To illustrate the operation of my invention the circuit elements of an ignition circuit constructed for operation of a conventional six cylinder automobile engine are given. Referring to Fig. 1, power supply 1 consisted of a conventional direct current 500 volt power supply, which derived its energy from being plugged into a 110 volt A. C. electric light socket. Condenser 2 was of 4 microfarad capacity. As its only function is that of a filter condenser it may be eliminated if batteries are used. Vacuum tube 6 was a 2A3, having an amplification factor of 4.2 and a plate current rating of 60 milliamperes. Vacuum tube 7, was an 809, having an amplification factor of 50, a plate voltage rating of 1000 volts D. C., and a power rating of 30 watts. Vacuum tube 16 was a 2A6. As the maximum plate voltage rating of a 2A6 is 250 volts, its plate was connected to a 250 volt tap on power supply 1. Gas discharge device 15 was an 874, with an anode to cathode conductive voltage drop of 90 volts. Resistance 3 was a 10,000 ohm ten watt resistor, and was connected to the center tap of power supply 1. Resistor 18 was a 100,000 ohm, two watt resistor. Resistor 8 was a 500,000 ohm, two watt resistor. Gas discharge device 5 was a half watt neon lamp, which had a conductive anode to cathode voltage drop of 70 volts. Light 117 was a 40 watt tungsten filament electric light having a resistance when incandescent of 300 ohms and a cold resistance of 40 ohms. Condenser 116 was of 8 microfarad capacity. Interrupter 4 was the conventional interrupter on a six cylinder automobile engine with conventional contact shunting condenser removed. Distributor arm 10 was that of a conventional six cylinder automobile engine. Ignition coil 9 was a conventional ignition coil constructed for a Ford automobile engine, and was connected as an auto-transformer. The secondary of said coil acted as primary of transformer 9 of my Fig. 1. It had a resistance of 4000 ohms and an impedance of 30 henrys. The combined primary and secondary of said coil acted as the secondary of transformer 9 of my Fig. 1.

In operation the following currents and voltages were found to exist in this circuit. With interrupter 4 closed, fifty milliamperes flowed from positive terminal of power supply 1, through primary of coil 9, anode to cathode of vacuum tube 7, anode to cathode of vacuum tube 6, light 117, to negative terminal of power supply 1. The filament of light 117 became slightly luminous and the voltage drop thereacross was approximately 15 volts. The voltage drop across resistance 18 was approximately 5 volts, which left the grid of tube 6 approximately 10 volts negative with respect to its filament. The plate of tube 6 was approximately 75 volts positive with respect to negative terminal of power supply 1. The voltage drop across gas discharge device 15 was 90 volts, leaving the grid of vacuum tube

7 fifteen volts positive with respect to its filament. When interrupter 4 was suddenly opened, gas discharge device 5 became conductive making the cathode of vacuum tube 6 seventy volts positive with respect to negative of power supply 1. Since the grid of tube 6 remained approximately 5 volts positive with respect to negative of power supply 1, by reason of the IR drop across resistance 18, the grid of tube 6 was 65 volts negative with respect to the cathode of tube 6. The plate of tube 6 assumed its cut-off value of 230 volts positive with respect to its cathode, or 300 volts positive with respect to negative of power supply 1. The cathode of vacuum tube 7 was then 300 volts positive with respect to negative of power supply. The grid of tube 7 was 90 volts positive with respect to negative of power supply 1, by reason of the drop across discharge device 15. This resulted in the grid of vacuum tube 7 being 210 volts negative with respect to the cathode of tube 7. Since the amplification factor of an 809 (tube 7 of my Fig. 1) was 50, the plate current cut-off of tube 7 was 10,000 volts, and a half inch spark was observed across the secondary of coil 9.

When light 117 was short circuited and interrupter 4 closed, 65 milliamperes flowed from positive of power supply 1, through the primary of coil 9, anode to cathode of tube 7, anode to cathode of tube 6, to negative power supply 1. When interrupter 4 was opened under that condition a three-quarter inch spark was observed across the secondary of coil 9. With light 117 short circuited and interrupter 4 closed, the I squared R heat losses in the primary of coil 9 was 17 watts, and the coil tended to heat up if interrupter 4 remained closed for long periods of time. A protective device such as light 117 is therefore regarded as desirable in practice, to prevent the primary of coil 9 from overheating.

When gas discharge devices 5 and 15 were removed from their sockets, with light 117 short circuited, a somewhat longer spark was observed across the secondary of coil 9 when interrupter 4 was suddenly opened. Internal arcing on the inside of vacuum tube 6 was occasionally observed under that condition, together with increased arcing at contacts 4. These latter deleterious effects were attributed to the fact that with grid of tube 7 connected to positive midpoint terminal of 500 volt power supply 1, through 10,000 ohm resistance 3, the plate potential of vacuum tube 6 assumed a very high potential upon opening interrupter 4, and tube 6 would eventually have been injured thereby.

While the above specific values were found highly satisfactory, it is desired to emphasize that they are only suggested values, and I do not desire to limit my invention to such or even to values of the order of those listed.

Many variations of the apparatus above described will occur to those skilled in electronic, television, and gas engine ignition art. It is therefore not desired to limit my invention to the forms described. The invention is to be limited in scope only as necessitated by prior art and as described in the following claims.

What I claim is:

1. An ignition system, comprising: an ignition coil having a primary and secondary winding, a vacuum tube having an input and an output circuit, a source of current, and said primary winding connected in said output circuit, an interrupter connected in said input and said output circuit, a spark gap connected across said secondary winding, and means for rendering said interrupter nonconductive, to produce a spark at said spark gap.

2. An ignition system comprising: an ignition coil having a primary and a secondary winding, a spark gap connected across said secondary winding, a vacuum tube having an input and an output circuit, a source of current and said primary winding connected in said output circuit, an interrupter connected in said input and said output circuit, means for rendering said interrupter non-conductive to produce a spark at said spark gap, and a gas discharge device connected across said interrupter to reduce arcing in said interrupter, when said interrupter is rendered nonconductive.

3. An ignition system comprising: an ignition coil having a primary and a secondary winding, a spark gap connected across said secondary winding, a plurality of vacuum tubes each having an anode, a cathode, and a grid, an input and an output circuit, said anode and said cathode of a first of said tubes being connected in the common input and output circuits of a second of said tubes, a source of voltage and said primary winding connected in the common output circuits of both of said tubes, and means for impressing a negative potential on said grid of said first tube to produce a spark across said spark gap.

4. An ignition system comprising: an ignition coil having a primary and a secondary winding, a spark gap connected across said secondary winding, a first vacuum tube having an input and an output circuit, a second vacuum tube having an anode, a cathode, and a grid, said anode and said cathode of said second tube being connected in said input and said output circuit, an interrupter in parallel with a gas discharge device connected in the common circuits of said anode and said grid, a source of voltage and said primary winding connected in said output circuit, and means for rendering said interrupter nonconductive to produce a spark at said spark gap.

5. An ignition system comprising: an ignition coil having a primary and a secondary winding, a vacuum tube having an input and an output circuit, a source of voltage and said primary winding connected in said output circuit, a spark gap connected across said secondary winding and said source of voltage, an interrupter connected in said input and said output circuit, and means for rendering said interrupter non-conductive to produce a spark across said gap.

6. An ignition system comprising: an ignition coil having a primary and a secondary winding, a spark gap connected across said secondary winding, a vacuum tube having an anode, a cathode, and a control electrode, an input and an output circuit, a source of voltage and said primary winding connected in said output circuit, an interrupter connected in said input and said output circuit, a thermionic tube having a plate, filament and grid, means for impressing a positive potential on said control electrode when said interrupter is conductive, said last means comprising a resistance common to the circuits of said plate and said grid of said thermionic tube and to the circuit of said control electrode, means for connecting said plate to said source of voltage, and means for rendering said interrupter non-conductive to produce a spark at said gap.

7. In an ignition system, an ignition coil having a primary and secondary winding, a spark gap connected across said secondary winding, a

vacuum tube having an input and an output circuit, a source of current and said primary winding connected in said output circuit, an interrupter and a resistance having a positive temperature coefficient connected in series, in said input and said output circuit, to prevent excessive current flowing through said primary winding when said interrupter is closed, and means for rendering said interrupter non-conductive to produce a spark across said gap.

8. An interrupter for an ignition system comprising a vacuum tube having an input and an output circuit, a circuit breaker in parallel with a gas discharge device connected in said input and said output circuit, and means for rendering said circuit breaker non-conductive to impress a negative potential on said input circuit.

9. An interrupter for an ignition system comprising a vacuum tube having an input and an output circuit, a second vacuum tube having an anode, a cathode, and a control electrode, said anode and said cathode being connected in said input and said output circuit, and means for varying the potential of said control electrode to impress a varying voltage on said input circuit.

10. An interrupter for an ignition system comprising a vacuum tube having an input and an output circuit, means for impressing a varying potential on said input circuit, a resistance with a positive temperature coefficient connected in said input and said output circuit to limit the current flowing in said output circuit to a desired value.

11. An ignition system for producing sparks, comprising: a vacuum tube having an input and an output circuit, a source of voltage and a coil having a core connected in said output circuit, means for passing a current from said source through said coil to change electrical energy from said source into magnetic energy in said core, an interrupter connected in said input and said output circuit for interrupting said current to produce said sparks with said magnetic energy, means for limiting said current to a predetermined value, said last means comprising a resistance in parallel with a condenser connected in series with said interrupter in said input and said output circuit.

OLIVER T. FRANCIS.