

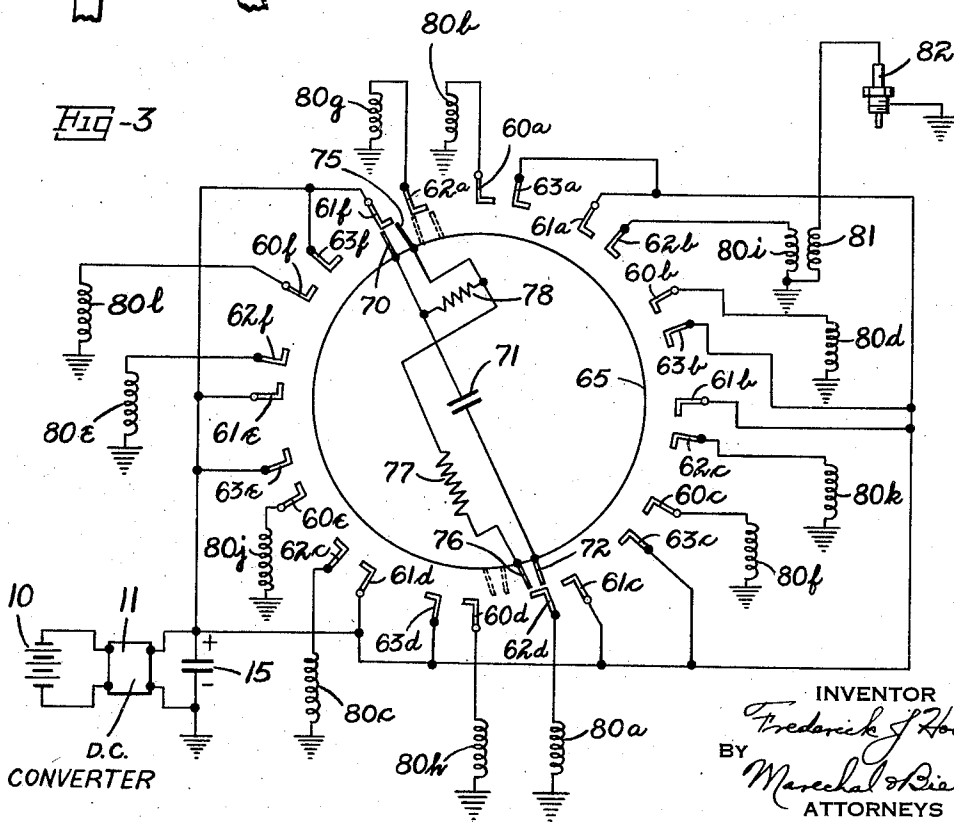
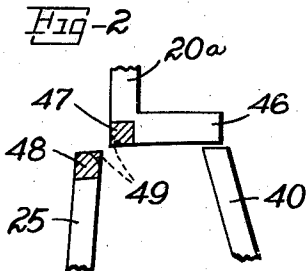
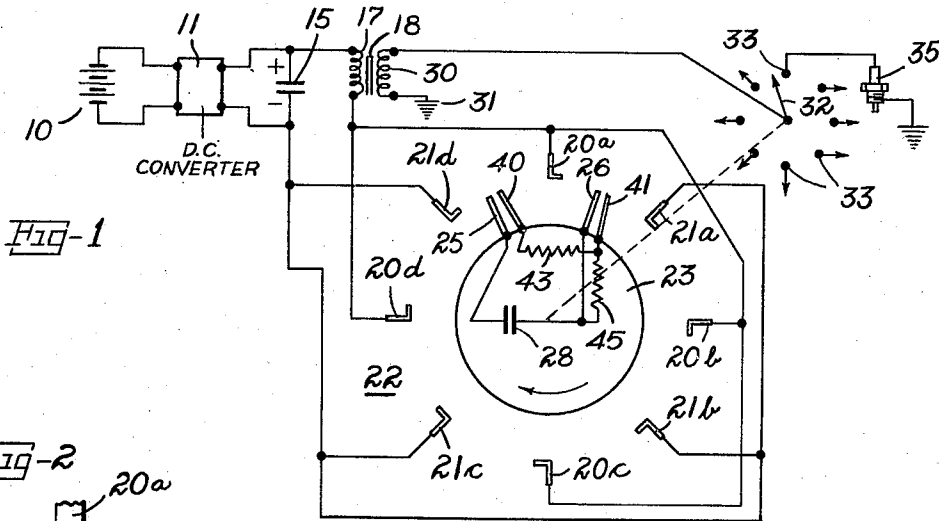
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TIMING SYSTEM FOR IGNITIONS AND THE LIKE

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TIMING SYSTEM FOR IGNITION AND THE
LIKE

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19 Claims. (Cl. 315—211)

1

2

This invention relates to an electrical system for producing timed electrical impulses, and more particularly to an ignition system.

It is the principal object of the invention to provide a timed impulse generating system in which the impulses are produced in accurately timed relation, at any desired speed over a wide range of speeds, and by means which is reliable and which maintains its accuracy over long periods of use.

It is a further object to provide a timer, particularly adapted for ignition systems, which produces accurate timing over a wide range of speeds, which conserves electrical energy, and which is capable of producing large amounts of energy for each spark.

It is also an object to produce such a timer which operates without cams, springs, or rubbing surfaces and in which control over the timing conditions can be accurately maintained at all times.

It is also an object to provide a timer for an ignition system in which a high degree of accuracy of the sparking intervals is obtained.

It is also an object to provide a timer including relatively fixed and movable electrodes and in which the gap between the electrodes is ionized in order to assure prompt and accurately timed breakdown of the gap.

Other objects and advantages will be apparent from the following description, the accompanying drawing and the appended claims.

In the drawing:

Fig. 1 is a schematic view of a system constructed in accordance with the present invention and shown as applicable to an eight cylinder engine, or for producing eight timed impulses per revolution;

Fig. 2 is a detail view on an enlarged scale showing the relationship of the timing and ionizing electrodes; and

Fig. 3 is a schematic view showing an arrangement suitable for use with a twelve cylinder engine or for producing twelve timed impulses per revolution.

The present invention relates to the production of accurately timed impulses, and is particularly advantageous in providing timed sparking impulses for use in the operation of multi-cylinder internal combustion engines. The following description will illustrate the principles of the invention by reference primarily to the production and application of such timed impulses to load impedance means which in an

ignition circuit may be a spark or ignition coil or a high tension transformer.

Ignition sparking voltage for internal combustion engines is commonly supplied by induction coil means. It is well known that the induction coil is limited in its ability to maintain suitable voltage across a spark plug where there is a shunt leakage conductance across the gap, as for example when carbon or metallic salts are deposited on the insulator, which is a condition commonly found in the engine. Numerous efforts have been made to improve the operation of ignition systems and toward this end circuits including condensers adapted to discharge through a spark or ignition coil have been provided, an example of such circuit being that shown in applicant's prior Patent No. 2,180,358, issued November 21, 1939, the present invention utilizing different means which are advantageous in a system of this character.

An embodiment of the invention is shown schematically in Fig. 1 which employs as a load impedance means a single spark coil for supplying the sparking energy to the eight cylinders of the engine. Referring to the drawing, battery 10 connected to a direct current converter 11 provides a source of direct current energy having a potential of about 1500 volts. The converter 11 may be any suitable or well known means such as a transformer and rectifier, a synchronous vibrator, motor generator, or the like.

The voltage source is connected directly to a reservoir condenser 15 which is of substantial capacity, for example of the order of about .5 microfarad. The positive side of the condenser 15 is connected through the primary winding 17 of induction coil 18 to the four electrodes 20a, 20b, 20c and 20d which are spaced equally around the circumference of the timer indicated generally at 22. The negative side of the condenser 15 is connected to the four electrodes 21a, 21b, 21c and 21d which are likewise equally spaced and in alternating relation with the other series of electrodes. The eight fixed electrodes are thus arranged equally about the circumference of a circle whose center is on the axis of rotation of the rotor 23 which is driven at half crank shaft speed from the engine.

The rotor carries a pair of relatively movable electrodes 25 and 26 which are spaced apart at an angle of 45° and of such length that their outer ends approach closely the inner ends of the fixed electrodes 20 and 21. The arrangement is such that when movable electrode 25 is

3

opposite fixed electrode 20a, movable electrode 26 will be directly opposite fixed electrode 21a. It will be equally evident that upon rotation of the movable electrodes through an angle of 45°, movable electrode 25 will be opposite the fixed electrode 21a, while movable electrode 26 will be opposite fixed electrode 20b, this relationship continuing throughout the entire circumference. A relatively smaller capacity condenser 28 is connected directly between electrodes 25 and 26 and is carried on the rotor. Since relative movement between the electrodes is the important factor, it is evident that either group of electrodes may move, either in a rectilinear or a circular path with respect to the other group, and the references to fixed and movable electrodes are for relative purposes only.

The spark coil or transformer 18 has a high voltage secondary winding 30, and is grounded on one side at 31, the high tension line being connected to the distributor shown diagrammatically at 32 from which the high voltage impulses are distributed through contacts 33 to the several spark plugs 35, in the proper sequence.

Referring now to the operation of the system, assuming the existence of a direct current voltage charge upon condenser 15, and that electrodes 25 and 26 are approaching fixed electrodes 20a and 21a, respectively, continuation of movement of the rotor in a clockwise direction as indicated will result in sparks jumping between each fixed electrode and the moving electrode which is approaching it.

It is found that it is not necessary for the electrodes to actually touch each other, and it is preferred that there be a small gap of the order of .003 inch so that there is no rubbing or wiping contact, and no frictional drag which might change the timing relationship.

Upon the occurrence of the spark, current will flow from condenser 15, through the primary winding 17 of the induction coil means, electrode 20a to electrode 25, through condenser 28, from electrode 26 to electrode 21a, and back to the negative side of the condenser 15. This current flow takes place in a low resistance circuit, producing a rapid build-up of flux in the spark coil, and resulting in a strong spark which is produced in the secondary winding 30, and which is distributed to the proper spark plug 35.

Such flow of current also results in producing a charge upon condenser 28. Electrode 25 assumes substantially the potential of electrode 20a which is positive while electrode 26 assumes substantially the potential of negative electrode 21a. This charge remains upon condenser 28 during the interval in which rotor 23 is moving the electrodes 25, 26 to their next sparking engagement with the fixed electrodes and it will be evident at that time that the negative electrode 26 approaches the positively charged electrode 20b while positively charged electrode 25 approaches the negatively charged electrode 21a. The actual charge on condenser 28 is a considerable portion of the initial voltage on condenser 15, and thus the total potential difference between the sparking electrodes is substantially in excess of the voltage supplied by condenser 15, and approaches almost twice that amount. This causes prompt and reliable sparking conditions, and results in the occurrence of another pulse of energy through the primary winding 17 of the induction coil, which is transferred into the high voltage spark in the manner described above. It will likewise be evident that this same discharge

4

results in reversing the charge upon condenser 28, so that there is always a substantial voltage on the condenser which is of the proper polarity to be additive with the voltage of condenser 15 in preparation for the next sparking engagement.

From the above it will be evident that there is thus produced a strong spark impulse at each sparking engagement of the relatively fixed and movable electrodes, the voltage available for producing such spark being substantially more than and approaching twice the value of the voltage supplied by the reservoir condenser. At the occurrence of each spark, this increased voltage is available to cause the spark accurately and with certainty, and the smaller capacity condenser on the rotor is left with a charge of such polarity as will be additive with that of the reservoir condenser in preparation for the next sparking engagement.

Although the condenser 28 serves to meter the amount of energy withdrawn from the source and reservoir at each spark, no more than one quarter of this amount of energy remains in condenser 28 at any time. The energy dissipated per spark may be expressed by—

$$W_s = \frac{(E)^2 C}{2}$$

where

E is the change of voltage across condenser 28

C is the capacity of condenser 28 in mf.

W_s is the spark energy in joules

while the maximum charge residing in condenser 28 will be:

$$W_c = \frac{E_s^2 C}{2}$$

E_s is the supply voltage

W_c is the charge on condenser 28.

Since, assuming that condenser 15 is very large compared with condenser 28,

$$E = 2E_s$$

it follows that

$$W_s = 4W_c$$

In actual practice, condenser 15 is made of such size that the charging current for condenser 28 causes a relatively small, but not negligible drop in the voltage across condenser 15 so that the above relation does not hold precisely, and the actual spark energy is accordingly somewhat less than four times the value of W_c.

Suitable values for the windings of the spark coil 18 are .75 millihenry for coil 17 and 200 millihenrys for coil 30, with a coupling coefficient of 10%, the core being either high-frequency powdered iron or air. This gives a natural frequency of about 50,000 cycles for the secondary circuit when connected to an average unshielded high-tension circuit and plug. The primary circuit will have a natural frequency of the same value but is highly damped and the flow of current through it drops below the value necessary to sustain the arc in the moving gap after about 50 microseconds. This is about the length of time required for the rotor 22 to move through 1° when rotating at 3500 R. P. M., corresponding to an engine speed of 7,000 R. P. M.; it will accordingly be evident that the time required for the actual flow of current during sparking is short, and not appreciable with reference to the time required for the operation of the engine itself.

Such a system having the values described is capable of developing a voltage of over 50,000

5

volts when connected to an ordinary ignition circuit, and a similar system using only one-third as much energy per spark is capable of developing of the order of 30,000 volts. Likewise, such a system is capable of impressing half its maximum voltage across a leak of 100,000 ohms while a conventional induction coil system is able to develop only about 16,000 volts across a leak of 1,000,000 ohms however high its voltage may be. By using smaller spark coils of higher natural frequency it is possible to reduce the value of shunt resistance for half voltage output down to as little as 3,000 ohms, and the system is thus additionally advantageous where it is necessary or desirable to use coils of small dimensions, as for example where the coils are to be mounted within a shielded spark plug. However the use of such high frequencies for ordinary purposes is not necessary and may result in some loss in efficiency because of the heavy discharge currents, sometimes requiring higher voltages for reliable sparking.

It is desirable to assure that the spark will occur with a high degree of accuracy and uniformity, and that the gap will not break down at varying spacings of the electrodes due to varying conditions in the atmosphere immediately surrounding the electrodes. For this purpose it has been found that improved uniformity and accuracy of the gap breakdown can be obtained by producing an ionization of the air gap immediately in advance of the sparking engagement of the electrodes. Where the gap is ionized just prior to the approach of the moving and fixed electrodes, the final breakdown of the gap is found to occur with a high degree of uniformity and precision, thus contributing to the desired overall reliability of the system.

To accomplish such ionization, a pair of ionizing electrodes 40, 41 are mounted upon the rotor 23 immediately adjacent and somewhat in advance of movable electrodes 25 and 26 respectively. The amount of this advance is somewhat exaggerated in the drawing, satisfactory results having been found where the extent of the advance was about 3° between each ionizing electrode and its corresponding sparking electrode. A resistance 43 is connected between the two ionizing electrodes 40 and 41 and is of a sufficiently high value, for example of the order of 10 megohms, that only a small current will flow through the circuit, such as of the order of 150 microamperes. A second resistance or leak 45 is provided between ionizing electrode 41 and sparking electrode 26 in order to cause this sparking electrode to assume the same potential as the fixed electrode which it is approaching. This has the effect of causing substantially the entire potential difference to appear between electrode 25 and the fixed electrode which it is approaching, electrode 20a in this case. Thus there is a potential difference between one of the fixed electrodes and its related movable electrode of practically the full 3,000 volts and thus complete assurance is provided that the spark will occur with certainty, and with precision in timing. After the spark occurs between such fixed electrode 20a and movable electrode 25, the full potential differences then appear between electrodes 21a and 26, so that this spark also occurs immediately and with precision. Thus by establishing this relationship for the potential of the movable electrodes, a greater potential difference is produced across the gaps in this manner than would be the case if the potential were divided between

6

the two gaps in series. The system is thus able to continue in operation even after the sparking electrodes are considerably eroded, the only change being a slight and gradual retarding of the sparking time as the erosion progresses.

Referring to Fig. 2, one of the fixed electrodes 20a is shown in relation to the movable ionizing electrode 40 and sparking electrode 25. As shown the fixed electrode has an arcuate foot 46 which is of a length approximately sufficient to span the gap between each ionizing electrode and its associated sparking electrode. Also as shown the sparking electrode 20a preferably has an insert 47 of highly refractory conducting metal, such for example as tungsten, which is adapted to cooperate with a similar insert 48 in sparking electrode 25, it being understood that similar inserts are provided in each of the fixed and movable sparking electrodes.

The purpose of such inserts is to provide for the spark occurring therebetween, the sharp edges and the microscopic roughness of the metal producing a concentration of the electric field around the sharp points of the inserts as they approach each other. After prolonged service, the corners may be worn away and rounded as indicated by dotted lines 49 but the axial extent of all of the electrodes and of the respective inserts 47 and 48 may be increased as desired to provide an adequate area to reduce such wear to the minimum.

It is well known that delay in the breakdown of a gap may result from the absence of ions in the gap, and that suitable ionization may be provided by illuminating the gap with ultra-violet light. The function of the ionizing electrodes 40 and 41 is to provide a low current discharge which occurs immediately prior to the sparking engagement of the sparking electrodes 25, 26, with the respective fixed electrodes. This discharge begins when electrodes 40 and 41 are opposite the forward edges of a pair of the fixed electrodes, the voltage difference between each adjacent pair of the fixed electrodes being such as to result in such discharge which continues across the gap and along the foot 46 of each of the fixed electrodes. Although the resistance 43 limits the current flow to a negligibly small value, it leaves behind a train of ions and provides a source of ultra-violet light in the immediate vicinity of the gap so that the gap becomes suitably ionized and there is no delay in the breakdown of the gap to produce the desired spark when the sparking electrodes approach the stationary electrodes. There is no substantial wear or erosion of the ionizing electrodes because of the small energy of the discharge which they carry, and accuracy of timing of the discharge through these ionizing electrodes is unimportant so long as it occurs before the sparking electrodes are in position to spark.

Referring now to Fig. 3, a system suitable for producing 12 timed impulses per cycle, such as for a twelve cylinder engine, is diagrammatically illustrated. In this system there are two fixed electrodes for producing each impulse or two such electrodes for each cylinder, instead of the single fixed electrode per impulse or cylinder as shown in the system described in connection with Fig. 1. The fixed electrodes marked 60a to 60f are evenly spaced around the circumference of the circle at even multiples of 30°, and the alternate fixed electrodes 61a to 61f are evenly spaced around the circumference of the circle at odd multiples of 30°. Two additional series of fixed electrodes

are likewise provided, the series 62a to 62f being spaced at angles 20° less than the corresponding electrodes 60a to 60f while the electrodes 63a to 63f are spaced at angles 20° less than electrodes 61a to 61f.

The rotor is shown at 65, and comprises a sparking electrode 70 connected through condenser 71 with a cooperating sparking electrode 72, these electrodes being so related that when sparking electrode 70 is opposite fixed electrode 61f, sparking electrode 72 is directly opposite fixed electrode 62d.

Ionizing electrode 75 is located immediately in advance of sparking electrode 70 while ionizing electrode 76 is located immediately in advance of sparking electrode 72, similarly to ionizing electrodes 40 and 41. Resistors 77 and 78 corresponding to resistors 43 and 45 respectively are provided for the same purposes.

It will be seen that when the rotor 65 advances through an angle of 10° from the position shown in full lines to the position shown in dotted lines, the sparking and ionizing electrodes 70 and 75 will have shifted from their relation with fixed electrode 61f to fixed electrode 62a. However the movable sparking electrode 72 and its associated ionizing electrode 76 will have shifted to the dotted line position shown in which there is a gap, between fixed electrodes 62d and 60d, and it is evident therefore that under these circumstances no sparking will take place. It will be seen therefore that electrodes 70 and 75 cooperate only with fixed electrodes 60 and 61 while electrodes 72 and 76 cooperate only with fixed electrodes 62 and 63. Fixed electrodes 61 and 63 are all connected to the positive side of the reservoir condenser 15 while electrodes 60 and 62 are connected through the respective primary windings 80 of spark coil means, shown as a series of separate coils forming the load impedance means, the opposite side of which is grounded and thus connected to the negative side of the reservoir condenser. It will be understood that each of these coils or transformers is provided with a secondary winding, only one of which has been indicated at 81, and this may be connected to supply the pulse as desired, such for example as to spark plug 82. The system as illustrated, therefore, provides separate coils for each spark plug, and the coils may if desired be incorporated directly in the spark plugs themselves.

With the parts as shown in Fig. 3, a circuit is completed from the positive side of the reservoir condenser 15 through fixed electrode 61f to movable electrode 70, through condenser 71 to movable electrode 72 and across the gap to electrode 62d which produces a pulse of current through the particular primary winding 80 connected thereto and which is referred to as 80a. When the rotor has advanced through an angle of 30°, it will be in position for a flow of current from the positive side of the reservoir condenser through fixed electrode 63d, movable electrode 72, condenser 71 in the reverse direction, movable electrode 70, fixed electrode 60a, and coil 80b. It will be understood without further detailed analysis that this operation continues throughout the entire revolution, the ionizing electrodes 75 and 76 functioning in the manner described above, and with a charge being produced in condenser 71 of reverse polarity so that there is available for each successive sparking engagement of the movable and fixed electrodes a potential difference substantially in excess of that of the source

itself. The several primary windings of the coils 80 have been lettered 80a through 80l to show the sequence in which the firing occurs. While all the electrodes are shown in Fig. 3 as rotating about a common locus, it is evident that rotation of the sparking electrode 70, its ionizing electrode 75 and the series of fixed electrodes with which they cooperate, namely, electrodes 60 and 61 may be arranged to rotate in one plane while the sparking electrode 72, the ionizing electrodes 76 and the series of fixed electrodes with which they cooperate, namely, electrodes 62 and 63, may rotate in another plane axially displaced relative thereto.

From the above it will be understood that the system is one which operates without mechanical limitations of speed because it does not employ cams, springs, or rubbing surfaces, and hence may operate accurately and reliably for long periods without adjustment. It operates economically from a supply of direct current energy, and is capable of supplying large amounts of energy per spark and is especially suitable for operation with automatic controls for controlling the timing of the pulses. The moving electrodes are subject only to uniform angular motion, and there is no friction except for that in the bearing supporting the rotor, nor is there any intermittent torque such as that produced by a cam operating spring loaded contacts. It is therefore practicable to employ sensitive and accurate controls for the timing of the impulses and to avoid those variable factors which have been encountered heretofore in connection with conventional timing systems.

While the forms of apparatus herein described constitute preferred embodiments of the invention, it is to be understood that the invention is not limited to these precise forms of apparatus, and that changes may be made therein without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. In an ignition system of the character described adapted to be energized from a source of direct current energy, the combination of a timer having a series of relatively fixed and relatively movable electrodes, ignition coil means, a condenser connected to one series of said fixed electrodes, means for connecting said ignition coil means in circuit with said source and said condenser and with another series of said fixed electrodes, said electrodes being arranged to provide for reversal of the charge upon said condenser at each successive sparking engagement between said fixed and said movable electrodes to provide for substantially increasing the potential difference between said electrodes above that of said source.

2. In an ignition system of the character described adapted to be supplied from a source of direct current voltage, the combination of a timer having a series of relatively fixed and of relatively movable electrodes, means connecting one side of said source to a portion of said fixed electrodes, ignition coil means, means connecting the other side of said source through said ignition coil means to another portion of said fixed electrodes interrelated with the first said portion, a condenser connected between said relatively movable electrodes and arranged to complete a sparking circuit from an electrode of said first portion to an electrode of said second portion, and means providing for relative motion between said two series of electrodes to cause reversal of the charge

upon said condenser at each successive sparking engagement between said electrodes.

3. In an ignition system of the character described adapted to be supplied from a source of direct current voltage, the combination of a timer having a series of relatively fixed and of relatively movable electrodes, means connecting one side of said source to a portion of said fixed electrodes, ignition coil means, means connecting the other side of said source through said ignition coil means to another portion of said fixed electrodes interrelated with the first said portion, a condenser connected between said relatively movable electrodes and arranged to complete a sparking circuit from an electrode of said first portion to an electrode of said second portion, means providing for relative motion between said two series of electrodes to cause reversal of the charge upon said condenser at each successive sparking engagement between said electrodes, and means to cause substantially the full potential difference to occur between a single pair of said fixed and said movable electrodes.

4. In an ignition system of the character described adapted to be supplied from a source of direct current voltage, the combination of a timer having relatively fixed and relatively movable electrodes adapted to have sparking engagement therewith, means connecting one side of said source to a portion of said relatively fixed electrodes, load impedance means, means connecting said load impedance means to the other side of said source and to another portion of said relatively fixed electrodes, a condenser connected between a pair of said relatively movable electrodes, said pair of relatively movable electrodes having predetermined spaced relation with respect to said relatively fixed electrodes providing for completing a circuit through said relatively fixed electrodes and said condenser in opposite directions at each successive sparking engagement of said electrodes.

5. In an ignition system of the character described adapted to be energized from a source of direct current potential, the combination of two series of electrodes arranged in predetermined relation with each other, a reservoir condenser having one side thereof connected to the electrodes of one of said series, load impedance means connected to the other side of said reservoir condenser and to the other series of said electrodes, a pair of electrodes movable relative to the electrodes of both said series and spaced in predetermined relation thereto to bridge from an electrode of one of said series to an electrode of the other said series, a smaller capacity condenser connected to said pair of relatively movable electrodes, and means providing for relative movement between said pair of electrodes and the electrodes of said series to produce a flow of energy through said smaller capacity condenser in opposite directions at each successive sparking relation of said electrodes.

6. In an ignition system of the character described adapted to be energized from a source of direct current potential, the combination of two series of electrodes arranged in predetermined relation with each other, a reservoir condenser having one side thereof connected to the electrodes of one of said series, load impedance means connected to the other side of said reservoir condenser and to the other series of said electrodes, a pair of electrodes movable relative to the electrodes of both said series and spaced in predetermined relation thereto to bridge from an electrode of one of said series to an electrode of the

other said series, a smaller capacity condenser connected to said pair of relatively movable electrodes, and means providing for relative movement between said pair of electrodes and the electrodes of said series to produce a flow of energy through said smaller capacity condenser and said induction coil means in opposite directions at each successive sparking relation of said electrodes.

7. In an ignition system of the character described adapted to be energized from a source of direct current potential, the combination of two series of electrodes arranged in predetermined relation with each other, a reservoir condenser having one side thereof connected to the electrodes of one of said series, spark coil means connected to the other side of said reservoir condenser and to the other series of said electrodes, a pair of electrodes movable relative to the electrodes of both said series and spaced in predetermined relation thereto to have sparking engagement from an electrode of one of said series to an electrode of the other said series, a smaller capacity condenser connected to said pair of relatively movable electrodes, and means providing for relative movement between said pair of electrodes and the electrodes of said series to produce a flow of energy through said pair of electrodes in opposite directions at each successive sparking relation of said electrodes.

8. In an ignition system of the character described adapted to be energized from a source of direct current potential, the combination of two series of electrodes arranged in predetermined relation with each other, a reservoir condenser having one side thereof connected to the electrodes of one of said series, spark coil means connected to the other side of said reservoir condenser and to the other series of said electrodes, a pair of electrodes movable relative to the electrodes of both said series and spaced in predetermined relation thereto to have sparking engagement from an electrode of one of said series to an electrode of the other said series, a smaller capacity condenser connected to said pair of relatively movable electrodes, means providing for relative movement between said pair of electrodes and the electrodes of said series to produce a flow of energy through said pair of electrodes in opposite directions at each successive sparking relation of said electrodes, and means for ionizing the air gap between said electrodes at each engagement thereof.

9. In an ignition system of the character described adapted to be energized from a source of direct current potential, the combination of two series of electrodes arranged in predetermined relation with each other, a reservoir condenser having one side thereof connected to the electrodes of one of said series, load impedance means connected to the other side of said reservoir condenser and to the other series of said electrodes, a pair of electrodes movable relative to the electrodes of both said series and spaced in predetermined relation thereto to bridge from an electrode of one of said series to an electrode of the other said series, a smaller capacity condenser connected to a pair of relatively movable electrodes, means providing for relative movement between said pair of electrodes of said series to produce a flow of energy in opposite directions at each successive sparking relation of said electrodes, and ionizing electrodes deriving their potential from said series of electrodes for causing ionization of the air gap immediately in advance of said pair of electrodes.

10. In an ignition system of the character de-

scribed adapted to be energized from a source of direct current potential, the combination of two series of electrodes arranged in predetermined relation with each other, a reservoir condenser having one side thereof connected to the electrodes of one of said series, load impedance means connected to the other side of said reservoir condenser and to the other series of said electrodes, a pair of electrodes movable relative to the electrode of both said series and spaced in predetermined relation thereto to bridge from an electrode of one of said series to an electrode of the other said series, a smaller capacity condenser connected to a pair of relatively movable electrodes, means providing for relative movement between said pair of electrodes of said series to produce a flow of energy in opposite directions at each successive sparking relation of said electrodes, ionizing electrodes deriving their potential from said series of electrodes for causing ionization of the air gap immediately in advance of said pair of electrodes and means for maintaining substantially the full potential difference between one of said ionizing electrodes and the electrode of said series which it approaches to secure effective ionization of the gap therebetween.

11. A timed pulse generating system adapted to be supplied from a direct current source of power comprising a reservoir condenser supplied from said power source, load impedance means having one side thereof connected to one side of said reservoir condenser and having its other side connected to a series of relatively fixed electrodes, means connecting the other side of said reservoir condenser to another series of relatively fixed electrodes in predetermined spaced relation with those of said first series, a pair of relatively movable electrodes adapted to have sparking relation with an electrode of one said series and an electrode of the other said series, a condenser of smaller capacity connected to said movable electrodes, and means providing for relative movement of said movable electrodes with respect to said fixed electrodes to cause alternate sparking engagements with the electrodes of both said series with the current flowing in alternate directions through said movable electrodes to effect successive reversals of the charge upon said smaller capacity condenser.

12. In an ignition system of the character described the combination of a timer including a series of relatively fixed and relatively movable electrodes, means for causing ionization of the air gap between said fixed and movable electrodes, and means for controlling said ionizing means to be effective in said air gap immediately prior to the approach of said electrodes to each other.

13. In an ignition system of the character described the combination of a timer including a series of relatively fixed and relatively movable electrodes, means for causing ionization of the air gap between said fixed and movable electrodes, means for controlling said ionizing means to be effective in said air gap immediately prior to the approach of said electrodes to each other, and means for limiting the current flow through said ionizing means.

14. In a timed pulse generating system, a series of relatively fixed electrodes, a relatively movable sparking electrode, and means for ionizing the gap between said movable electrode and said fixed electrodes.

15. In a timed pulse generating system, a series of relatively fixed electrodes, a series of relatively

movable sparking electrodes, and means movable with said sparking electrodes and located adjacent thereto for ionizing the gap between said sparking electrodes and each successive one of said series of fixed electrodes.

16. A timed pulse generating system adapted to be supplied from a direct current source of power comprising a reservoir condenser supplied from said power source, load impedance means having one side thereof connected to one side of said reservoir condenser and having its other side connected to a series of relatively fixed electrodes, means connecting the other side of said reservoir condenser to another series of relatively fixed electrodes in predetermined spaced relation with those of said first series, a pair of relatively movable electrodes adapted to have sparking relation with an electrode of one said series and an electrode of the other said series, a condenser of smaller capacity connected to said movable electrodes, means providing for relative movement of said movable electrodes with respect to said fixed electrodes to cause alternate sparking engagements with the electrodes of both said series with the current flowing in alternate directions through said movable electrodes to effect successive reversals of the charge upon said smaller capacity condenser, and means for ionizing the gap immediately prior to the approach of said pair of movable electrodes toward each successive pair of fixed electrodes.

17. A timed pulse generating system adapted to be supplied from a direct current source of power comprising a reservoir condenser supplied from said power source, load impedance means having one side thereof connected to one side of said reservoir condenser and having its other side connected to a series of relatively fixed electrodes, means connecting the other side of said reservoir condenser to another series of relatively fixed electrodes in predetermined spaced relation with those of said first series, a pair of movable sparking electrodes adapted to have sparking relation with an electrode of one said series and an electrode of the other said series, a condenser of smaller capacity connected to said movable electrodes, means providing for relative movement of said movable electrodes with respect to said fixed electrodes to cause successive sparking engagements with the electrodes of both said series with the current flowing in alternate directions to effect successive reversals of the charge upon said smaller capacity condenser, and an additional pair of movable ionizing electrodes located in advance of said pair of movable electrodes respectively providing for ionizing the air gap in the presence of said movable electrodes to facilitate the sparking engagement thereof with said fixed electrodes.

18. In a timed pulse generating system, the combination of a series of relatively fixed electrodes, another series of relatively fixed electrodes in predetermined interspaced relation with those of said first series, a pair of relatively movable electrodes adapted to have sparking engagement with an electrode of one said series and an electrode of the other said series, a condenser connected to said movable electrodes, means providing for relative movement of said movable electrodes with respect to said fixed electrodes to cause successive sparking engagements with the electrodes of both said series with the current flowing in alternate directions through said movable electrodes to effect successive reversals of the charge upon said condenser, and ionizing elec-

13

trodes located in advance of said movable electrodes providing for ionizing the air gap between said movable electrodes and said fixed electrodes to facilitate the sparking engagement thereof.

19. In a timed pulse generating system, the combination of a series of relatively fixed electrodes, another series of relatively fixed electrodes in predetermined interspaced relation with those of said first series, a pair of relatively movable electrodes adapted to have sparking engagement with an electrode of one said series and an electrode of the other said series, a condenser connected to said movable electrodes, means providing for relative movement of said movable electrodes with respect to said fixed electrodes to cause successive sparking engagements with the electrodes of both said series with the current flowing in alternate directions through said movable electrodes to effect successive reversals of the charge upon said condenser, ionizing electrodes

14

located in advance of said movable electrodes providing for ionizing the air gap between said movable electrodes and said fixed electrodes to facilitate the sparking engagement thereof, and means for controlling the potential of said ionizing electrodes to maintain one of them at substantially the potential of the fixed electrode it approaches providing for a high voltage difference between the other ionizing electrode and the fixed electrode it approaches.

FREDERICK J. HOOVEN.

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The following references are of record in the file of this patent:

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