

April 16, 1940.

H. RABEZZANA ET AL

2,197,114

IGNITION SYSTEM

Filed Feb. 27, 1939

3 Sheets-Sheet 1

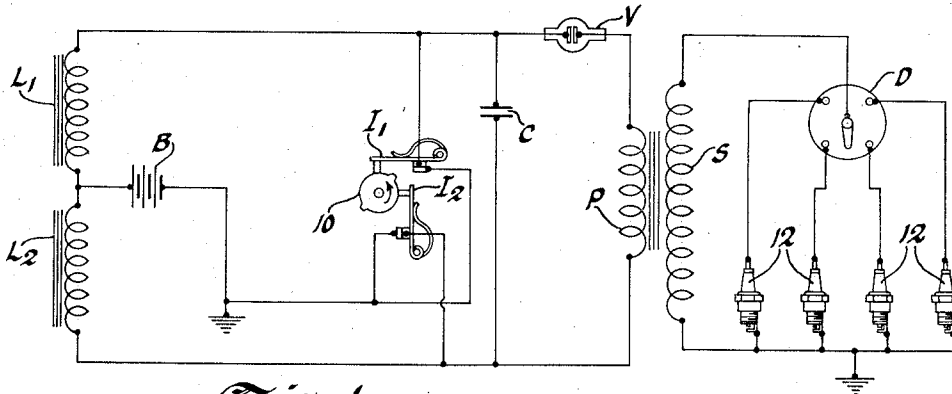


Fig. 1

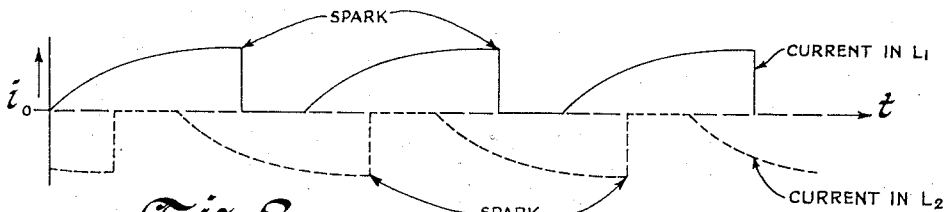


Fig. 2

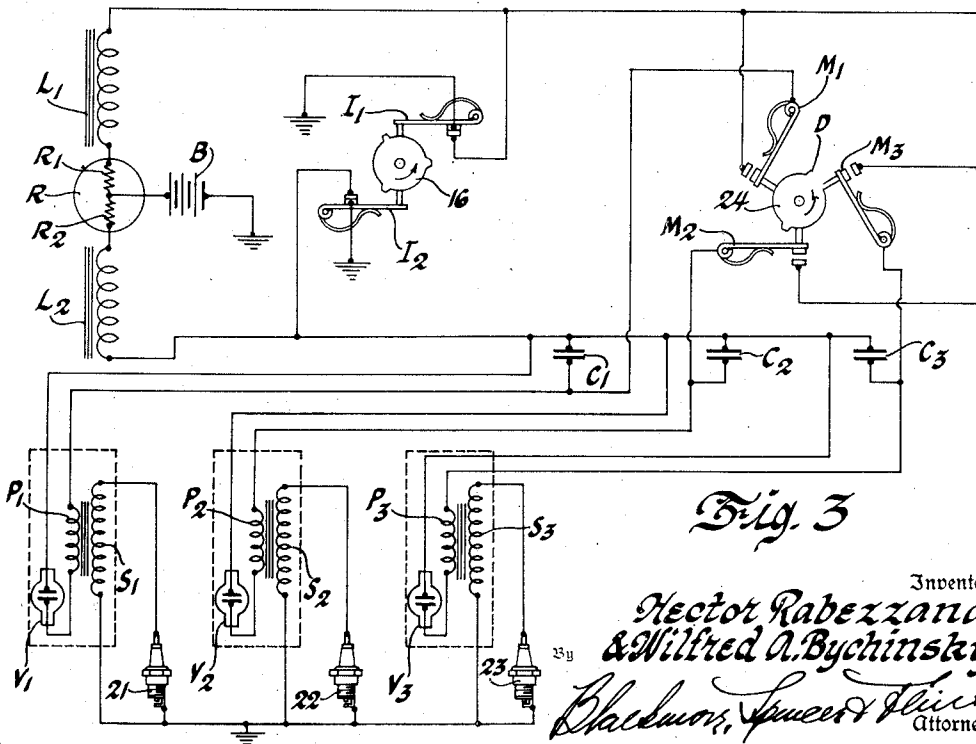


Fig. 3

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3 Sheets-Sheet 2

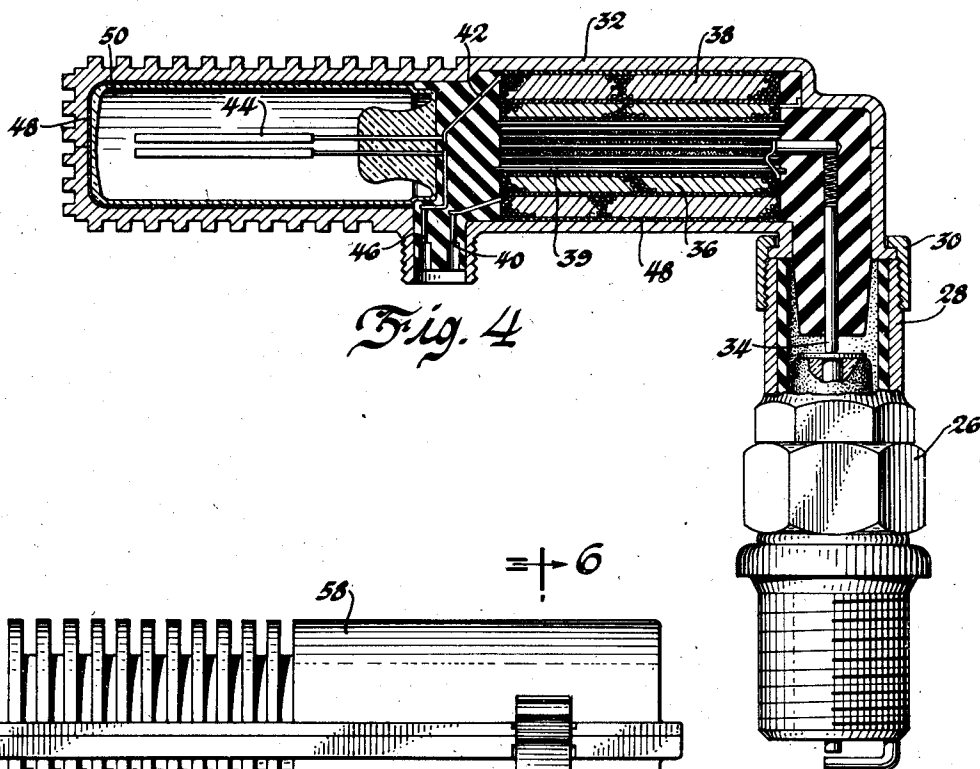


Fig. 4

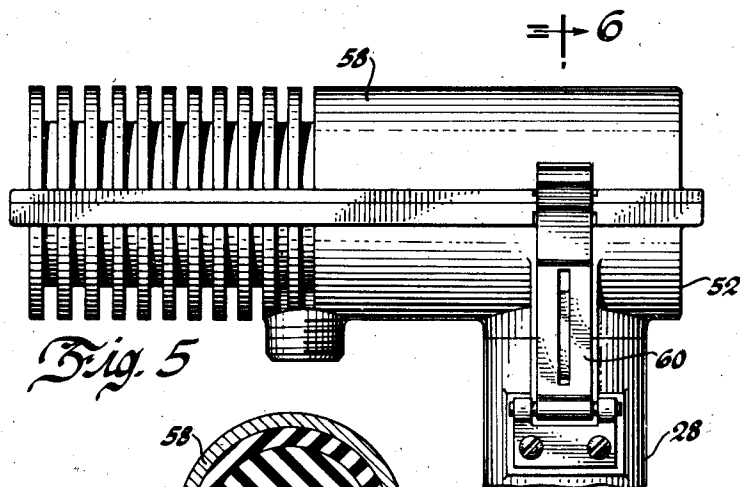


Fig. 5

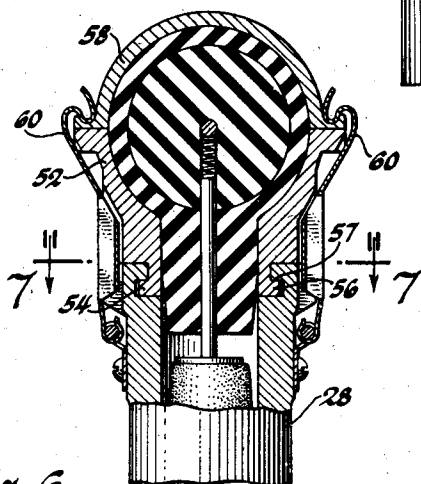


Fig. 6

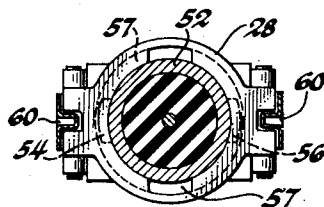


Fig. 7

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3 Sheets-Sheet 3

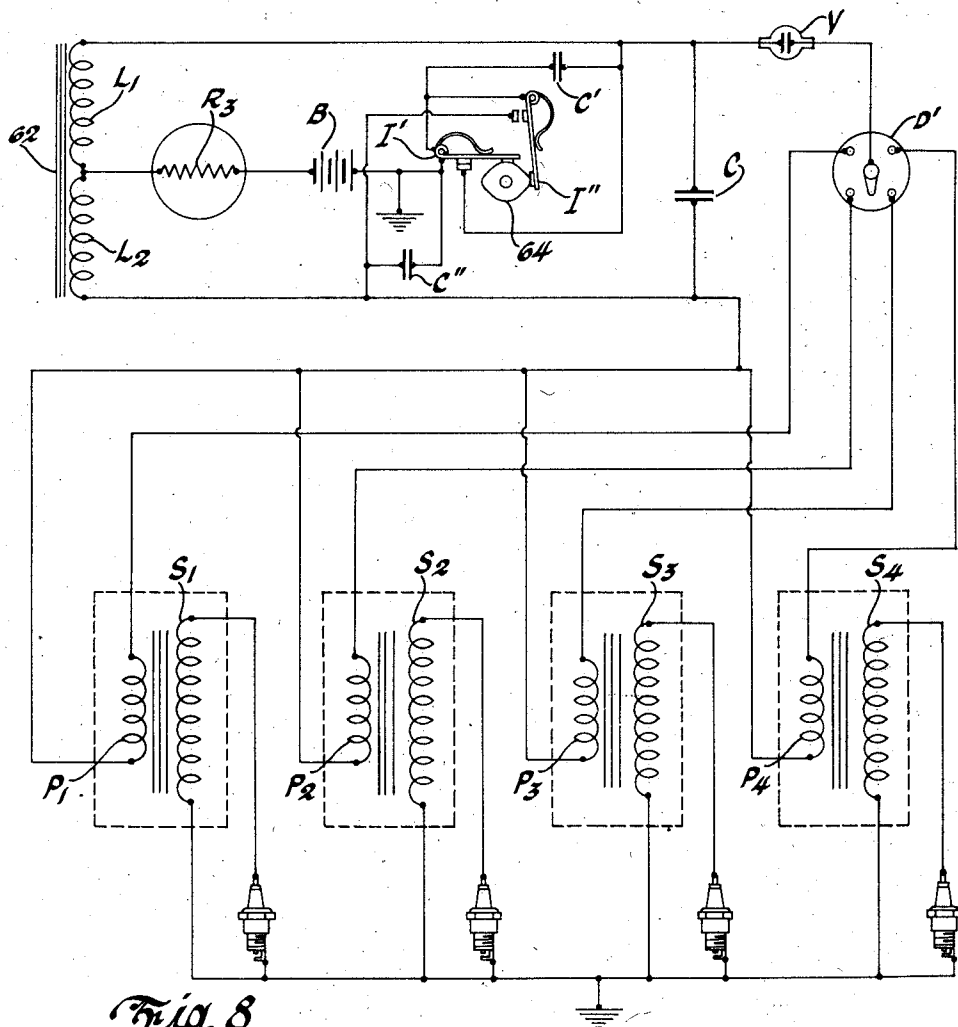


Fig. 8

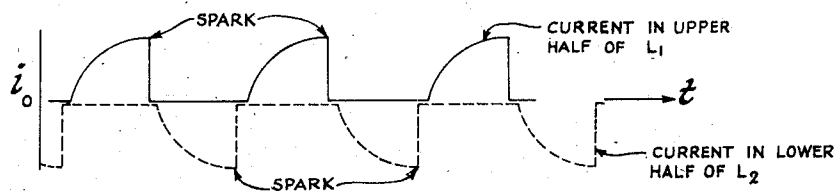


Fig. 9

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UNITED STATES PATENT OFFICE

2,197,114

IGNITION SYSTEM

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Application February 27, 1939, Serial No. 258,652

17 Claims. (Cl. 123—148)

This invention is an improvement on the ignition system described and claimed in Patent No. 2,047,431 granted to Donald W. Randolph on July 14, 1936. In that application there is disclosed an impulse operated system especially adapted for use as an ignition system for automobiles in which a plurality of impulse producing circuits, each preferably consisting of a source of energy, an inductance and an interrupter in series, are timed to alternately discharge into a common circuit containing a device, preferably a two electrode electrical valve, adapted to break down on application of sufficient voltage so as to permit passage of a surge of current. This flow of current is preferably utilized to produce a high voltage discharge in a circuit containing an ignition device. This is accomplished by coupling the tube circuit with the ignition circuit by means of a step-up transformer. To increase the instantaneous energy of the discharge and at the same time obtain a high frequency impulse a condenser is provided across each of the impulse producing circuits, the condensers being arranged in series with each other and with the electrical valve.

According to one feature of the present invention Randolph's circuit is simplified by eliminating one of the condensers, and so arranging the other as to alternately store the energy of the impulses from the discharge circuits. This is accomplished by simply connecting a condenser of sufficient capacity across the inductances and in series with the tube and the primary of the step-up transformer. With this change the circuit is simplified, the impedance of the tube circuit is reduced, and the cost of the system is lowered.

According to another feature of the invention a separate condenser, tube and transformer is provided for each of the spark plugs and a distributor is provided, preferably between the impulse producing circuits and the condensers, to distribute the charges to them in proper sequence.

An advantage of this arrangement is that the transformers may be mounted on the plugs and the length of the secondary leads may be reduced to a minimum. In present day ignition systems long secondary leads are employed. These must be well shielded to prevent interference with radio transmission and reception and because of their length, together with shielding, their capacity is very considerable and affords a path for leakage of a considerable amount of the energy of the system. At the same time the high tension leads are subject to rapid deterioration

in service. With secondary leads of minimum length, as provided for by the present invention, their capacity is greatly reduced thereby reducing the energy losses and insuring appreciably higher voltage at the spark plug terminals enabling the plugs to function where otherwise they would be disabled due to fouling or other causes. Radio shielding is also more readily accomplished with short leads.

The use of a separate tube for each spark plug greatly increases the life of the tubes for each tube is functioning a much smaller part of the time.

Other objects and advantages of the invention will be pointed out in the course of the following description taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view showing one form of the improved circuit.

Figure 2 is a graph showing the variation of current with time in the operation of the ignition system of Figure 1.

Figure 3 is a diagrammatic view showing the preferred form of improved circuit as applied to a three cylinder engine.

Figure 4 is a longitudinal section through one form of tube-transformer unit mounted on a spark plug.

Figure 5 is a side elevation of a similar but slightly modified tube-transformer unit.

Figure 6 is a section on line 6—6 of Figure 5.

Figure 7 is a section on line 7—7 of Figure 6.

Figure 8 is a diagrammatic view showing a modified form of circuit.

Figure 9 is a graph showing the current-time relations in the operation of the circuit of Figure 8.

The ignition circuit shown in Figure 1 is designed for use with a four cylinder internal combustion engine but may be readily adapted by those skilled in the art for service with engines having any number of cylinders.

L_1 and L_2 indicate inductances, having magnetizable cores, fed with current from a common connection to a suitable battery B or other source of electrical energy. In series with inductance L_1 is the interrupter I_1 , and in series with the inductance L_2 is interrupter I_2 . The interrupters are preferably operated by a common engine-driven cam 10 preferably provided with two lobes as shown and operated at one-half engine speed.

The interrupters are timed so that their closing periods overlap as hereinafter explained.

The impulse producing circuits L_1I_1B and L_2I_2B

are connected to discharge into a condenser C in series with electrical valve V and the primary P of a step-up transformer. The condenser C is connected across the interrupters $I_1 I_2$ as shown.

5 The valve V is preferably of the type disclosed in the prior Duffendack and Wolfe Patent No. 2,122,932, granted July 5, 1938, and consists of two electrodes, one or both of which are preferably made of a durable alloy containing low work
10 function material, preferably barium in a nickel-copper-barium alloy, the electrodes being surrounded by an atmosphere of inert gas at sufficient pressure to support arc discharge. Since the voltage available is low the valve must have a
15 relatively low break-down voltage and at the same time be durable and capable of resisting arcing over long periods of time.

The secondary S of the step-up transformer is connected in series with the distributor D arranged to direct current to the spark plugs 12 in succession in well known manner. Transformer
20 P-S is preferably provided with an iron core which may consist of thin sheets of iron or of particles of iron powder suitably insulated from each other to reduce losses due to eddy currents, etc.

Operation.—With the parts in the position shown in Figure 1 with the interrupters closed, battery B stores energy in the inductances L_1 and
30 L_2 . This condition is indicated in the graph, Figure 2, by the increasing ordinates of the curves at the left of the graph. This charging is continued until the interrupter I_1 suddenly opens, causing the inductance L_1 to discharge
35 into the condenser C through a path including battery B and closed interrupter I_2 . The suddenness of the collapse of the magnetic field of the inductance results in the development of a considerable voltage in the circuit. When the voltage across the terminals of the condenser C reaches the break down voltage of the valve V, the valve breaks down and a high frequency surge of current takes place in the tube circuit. This surge is converted by the transformer P-S
40 into a high voltage, high frequency surge in the secondary circuit and the distributor is so timed with respect to the interrupter that this surge takes place when the distributor is in position to carry the current to one of the spark plugs thereby producing ignition in one of the cylinders. Following the discharge, interrupter I_1
50 closes.

In the meantime the current builds up in the circuit containing inductance L_2 as indicated by the dotted line curve in Figure 2 until interrupter
55 I_2 is suddenly opened, causing discharge of energy from the inductance L_2 to the condenser C through a path including battery B and closed interrupter I_1 , thereby charging the condenser to the opposite polarity, and upon attaining the necessary voltage, discharge takes place from the condenser through the valve V and transformer P-S to another one of the plugs in the same manner as described above. Thereafter interrupter I_2 closes, beginning another cycle which is a repetition of that described above.

It will be noted that the condenser C is first charged to one polarity and then to the other. This correspondingly reverses the direction of
70 discharge through the valve V preventing the building up of metal on one electrode and the pitting of the other, with consequent eventual short-circuiting of the electrodes as is often the case where the discharge through the valve is always in one direction. The circuit also possesses

the advantage that but one condenser is required in the tube circuit, thus reducing cost.

The preferred form of circuit shown in Figure 3 embodies the same principle as the circuit of Figure 1, but is modified to make possible the location of the transformer close to the plugs so as to reduce the length of the secondary leads to a minimum. The circuit of Figure 1 is further modified to require the use of an electric valve for each spark plug, thus reducing the period of time during which each valve is in operation and so greatly increasing valve life. The provision of independent valves makes it necessary to employ a separate condenser for each valve.

Another improvement consists in the use of ballast resistances to hold the current in the impulse producing circuits within desirable limits. The circuit of Figure 3 is designed to provide ignition for a three cylinder four cycle engine. This application has been selected to simplify illustration of the system but obviously the invention can be applied to an engine of any number of cylinders.

Referring now to Figure 3, B indicates the battery, L_1 and L_2 the inductances, and I_1 and I_2 the interrupters actuated by cam 16 which is driven at one-fourth crankshaft speed and is provided with three lobes as shown.

Between the battery B and the inductances L_1 and L_2 is preferably arranged a tube R containing constant current type ballast resistances R_1 and R_2 . These resistances each preferably consist of a filament of substantially pure iron in an atmosphere of hydrogen, but other known types of such resistances may be used. The resistances are designed to maintain the current passing through them fairly constant over a wide range of applied voltages and act in the following manner: As the current increases, the resistance of the iron wire increases thereby reducing the flow of current and tending to return it to its original value. Conversely as the current decreases the resistance of the wire decreases thereby increasing the flow of current and tending to enable it to regain its original value.

The use of a ballast resistance insures a sufficient supply of current under substantially all operating conditions. It also prevents injury to the coils in case the ignition is left on with the engine not running or in the similar case of very low speed operation.

The ballast resistance also improves high speed performance of the system for at such speeds the ignition voltage tends to fall off because of reduction in time during which the inductances receive energy from the battery. This reduction is offset by corresponding reduction in effectiveness of the ballast resistance.

The impulse producing circuits, just described, supply energy to condensers C_1 , C_2 and C_3 which in turn discharge into independent circuits each containing in series an electric valve V_1 , V_2 or V_3 and the primary coil P_1 , P_2 or P_3 of a step-up transformer. The corresponding secondaries S_1 , S_2 and S_3 supply ignition current to plugs 21, 22 and 23 respectively.

A distributor D is provided to supply energy to the condensers in proper sequence. This distributor preferably takes the form of circuit makers M_1 , M_2 and M_3 actuated by cam 24 provided with two lobes as shown and driven at one-fourth crankshaft speed.

With the construction shown applied to a four cycle engine having three cylinders, it will be apparent that during a complete engine cycle,

that is, during two revolutions of the crankshaft, the circuit breaker cam 16 will have rotated 180° and will have effected three successive breaks of the impulse producing circuits, one circuit being broken once while the other is broken twice, alternating with the first circuit. Distributor D likewise makes one-half a revolution for every two revolutions of the crankshaft and in so doing operates circuit makers M₁, M₂ and M₃ in sequence.

The parts are so timed that one of the circuit makers is closed just before and during the time that one of the interrupters I₁ or I₂ is being opened thereby closing the circuit to the corresponding condenser. This permits the condenser to be charged by the surge of current, and upon attaining sufficient voltage, to discharge through the corresponding electric valve and through the primary of the transformer, thus producing a spark at the plug.

It will be noted that the arrangement is such that each condenser is first charged to one polarity and then to the other, thereby reversing the direction of discharge through the valves and prolonging their life. This is made clear in the following description in which the convention is adopted that when the upper plate of the condensers as illustrated on Figure 3 are given a positive charge the condensers are said to have positive polarity and vice versa. It will be understood that charging of the condenser is in every case followed immediately by its discharge through the tube circuit to produce ignition. To avoid repetition no further mention will be made of condenser discharge in the following description. Beginning with the parts in the position shown in Figure 3 in which both interrupters I₁ and I₂ are closed and all of the circuit makers are open, and assuming that the cams 16 and 24 rotate in the direction indicated by the arrows, circuit maker M₂ closes, then interrupter I₂ opens, thereby charging condenser C₂ to positive polarity. Next circuit maker M₁ closes and interrupter I₁ opens, thereby charging condenser C₁ to negative polarity. Circuit maker M₃ now closes and interrupter I₂ opens, thereby charging condenser C₃ to positive polarity. Next circuit maker M₂ again closes, and interrupter I₁ opens thereby again charging condenser C₂ but to negative polarity. Circuit maker M₁ again closes, and interrupter I₂ opens thereby again charging condenser C₁ to positive polarity. Circuit maker M₃ again closes, interrupter I₁ opens, thereby charging condenser C₃ to negative polarity. Thereafter the cycle is repeated, charging each condenser alternately to opposite polarities.

An important advantage of the system just described is the fact that cams for the circuit interrupters and circuit makers may be designed to give any desired spacing of the sparks.

The improved ignition system is preferably so constructed in practice that the transformer and preferably the electric valve as well are mounted as close to the spark plug as possible. In Figure 4 there is shown a suitable design of valve-transformer assembly. Here 26 indicates a conventional type of spark plug provided with radio shielding indicated at 28. To the shield 28 is secured by a suitable screw-threaded coupling 30, a die cast housing 32 containing in one end an insulated conductor 34 in series with the secondary 36 of the transformer, the primary of which is indicated at 38, and the core, consisting of thin laminations or wires, at 39. One end of the primary 38 is connected to insulated lead 40 which may be connected by a suitable conductor (not

shown) to one side of the corresponding condenser. The other end of the primary is connected by lead 42 to one of the electrodes of electric valve 44, the other electrode being connected to insulated terminal 46 which is connected by a suitable conductor (not shown) to the other side of the condenser. 48 indicates a layer of compressible cement, such as asbestos cement, which may be applied to the glass envelope 50 of the electric valve. The purpose of this is to protect the envelope against the heat of die casting should it be found desirable to cast the housing 32 about the assembly as shown.

In Figures 5, 6 and 7 there is shown a slightly modified form of valve-transformer assembly. Here 28 indicates the shielding of the plug. 52 indicates the lower half of a longitudinally split housing for the tube and transformer. The part 52 is provided with lugs 54 and 56 adapted to have a bayonet or other type of quick detachable connection indicated at 57 with the upper end of the plug shield 28. The upper portion 58 of the housing is held to the lower portion by means of suitable spring clips 60 of the type commonly used to hold distributor caps in place.

In the modification shown in Figure 8 the inductances L₁ and L₂ have a common core as indicated at 62, this necessitating a somewhat different cycle of operations as pointed out hereinafter. The inductances are illustrated as fed from the battery B through a single ballast resistance R₃ functioning the same as ballast resistances R₁ and R₂ previously described. Cam 64, driven at one-half engine speed, operates interrupters I' and I'' so as to give four interruptions per revolution. C' and C'' indicate auxiliary condensers which may be connected across the interrupters to reduce sparking but are not essential.

The impulse producing circuits just described discharge alternately as before into condenser C which, upon attaining the necessary voltage, discharges through valve V into the primary P₁ P₂ P₃ or P₄ in the sequence determined by the distributor D', producing a surge in the corresponding secondary circuit S₁ S₂ S₃ or S₄ and sparking at the corresponding plug.

In Figure 9 is illustrated the current-time relations obtaining with the circuit of Figure 8 with proper timing of the interrupters. Owing to the employment of a common core for the inductances it is necessary that but one of the interrupters be closed at a time. Otherwise opening of one of the impulse producing circuits at its interrupter would result in discharge of the energy of the impulse through the closed impulse producing circuit which, because of the common core, would act as a short-circuited secondary. Consequently the time during which energy can be stored in either of the inductances must be somewhat less than the time between sparks.

In common with the form of circuit shown in Figure 1, the circuit of Figure 9 possesses the advantage that but a single main condenser is employed. The distributor D' could, if desired, be arranged in the secondary circuit but the illustrated arrangement has the advantage that the transformers may be mounted on the spark plugs with the advantages pointed out in connection with the circuit of Figure 3.

Our improved ignition system is susceptible of a great deal of modification. It may, of course, be designed for engines of any number of cylinders. It may likewise be adapted for double ignition systems in which two spark plugs are pro-

vided for each cylinder. The usual arrangements for obtaining manual or automatic spark advance may be applied to the new system. In the case of the circuit of Figure 3 it will be found convenient to provide a common drive for the interrupter cam 16 and the distributor D and to provide a common mounting for the interrupters I₁ and I₂ and the circuit makers M₁, M₂ and M₃ so that the spark advance mechanism, whether manual or automatic, may simultaneously adjust the position of the interrupters and circuit makers with respect to their respective cams for the circuit makers should always close prior to the opening of the interrupters to permit efficient charging of the corresponding condensers, and reduce sparking at the interrupters. Other modifications will occur to those skilled in the art.

We claim:

1. The combination of a source of direct current, impulse producing circuits arranged in parallel and including said source, means for timing said impulse producing circuits to cause them to alternately produce electrical impulses, a condenser connected to said circuits so as to be charged to one polarity by one of said circuits and then to the opposite polarity by the other of said circuits and so on alternately, and a discharge circuit for said condenser comprising a device adapted to normally prevent passage of current therethrough but to break down and permit passage of a surge of current upon application of predetermined voltage.

2. In the combination as defined in claim 1, a work circuit coupled to said discharge circuit.

3. In the combination as defined in claim 1, a work circuit including an ignition device inductively coupled to said discharge circuit.

4. In an ignition system the combination of a plurality of impulse producing circuits, each circuit consisting of an inductance and an interrupter in series, means for supplying current to said circuits, said interrupters being timed to alternately produce impulses in said circuits, a condenser connected to said circuits so as to be charged first to one polarity by one of said circuits and then to opposite polarity by the other circuit upon actuation of said interrupters, a discharge circuit for said condenser comprising an electric valve adapted to break down upon application of sufficient voltage in series with the primary of a step up transformer, and an ignition device in series with the secondary of said transformer.

5. In an ignition system the combination of an electrical impulse producing circuit, a plurality of condensers, means for connecting each of said condensers in succession to said circuit to receive a charge therefrom, and a discharge circuit for each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage and an ignition device inductively coupled to said discharge circuit.

6. In an ignition circuit the combination of a plurality of electrical impulse producing circuits, means for alternately producing impulses in said circuits, a plurality of condensers, means for connecting each of said condensers in succession to each of said circuits, and a discharge circuit connected to each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage and an ignition device inductively coupled to said circuit.

7. In an ignition system the combination of

an electrical impulse producing circuit comprising an inductance and an interrupter in series, and means for supplying current to said circuit, a plurality of condensers, means for connecting each of said condensers in succession to said circuit to receive a charge therefrom, and a discharge circuit for each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage, and an ignition device inductively coupled to said discharge circuit.

8. In an ignition circuit the combination of a plurality of electrical impulse producing circuits each comprising an inductance and an interrupter in series, and means for supplying current to said circuits, said interrupters being timed to alternately produce impulses in said circuits, a plurality of condensers, means for periodically connecting each of said condensers in succession to each of said circuits to receive charges therefrom, and a discharge circuit for each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage, and an ignition device inductively coupled to said discharge circuit.

9. In an ignition circuit the combination of a plurality of electrical impulse producing circuits each comprising an inductance, an interrupter and a source of current in series, said source being common to said circuits, said interrupters being timed to alternately produce impulses in said circuits, a plurality of condensers, means for periodically connecting each of said condensers across said interrupters with the interrupters in series with such condenser so that when one of the interrupters is opened the condenser in series therewith is charged to one polarity and with the other interrupter opened the condenser in series therewith is charged to opposite polarity, and a discharge circuit for each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage, and an ignition device coupled to said discharge circuit.

10. In an ignition circuit the combination of a plurality of electrical impulse producing circuits each comprising an inductance, an interrupter and a source of current in series, said source being common to said circuits, said interrupters being timed to alternately produce impulses in said circuits, a plurality of condensers, means for periodically connecting each of said condensers across said interrupters with the interrupters in series with such condenser so that when one of the interrupters is opened the condenser in series therewith is charged to one polarity and with the other interrupter opened the condenser in series therewith is charged to opposite polarity, and a discharge circuit for each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage, and the primary of a step up transformer in series therewith, and an ignition device in series with the secondary of said transformer.

11. In an ignition circuit the combination of a plurality of electrical impulse producing circuits each comprising an inductance, an interrupter, a ballast resistance, and a source of current in series, said source being common to said circuits, said interrupters being timed to alternately produce impulses in said circuits, a plurality of condensers, means for periodically connecting each of said condensers across said interrupters with the interrupters in series with such condenser so

that when one of the interrupters is opened the condenser in series therewith is charged to one polarity and with the other interrupter opened the condenser in series therewith is charged to opposite polarity, and a discharge circuit for each of said condensers comprising an electrical valve adapted to become conducting upon application of sufficient voltage, and an ignition device coupled to said discharge circuit.

12. In an ignition system the combination of a spark plug and a housing mounted thereon containing a transformer having one side of its secondary in conducting relation with the insulated electrode of the plug and the other in conducting relation with the spark plug shell, and an electrical valve in said housing having a plurality of spaced electrodes, one of said electrodes being connected to one side of the primary of said transformer, a pair of insulated terminals mounted on said housing, one connected to the other electrode of said valve and the other to the other side of said primary coil.

13. In the combination as defined in claim 12, said housing and shell forming a substantially complete enclosure for said parts preventing the transmission of radio waves.

14. The combination of a plurality of impulse producing circuits arranged in parallel, means for timing said impulse producing circuits to cause them to alternately produce current impulses, a condenser connected to said circuits so as to be charged to one polarity by one of said circuits and then to the opposite polarity by the other of said circuits and so on alternately, and means in series with said condenser adapted to normally prevent discharge thereof but to break down and permit discharge when the charges thereon build up to a sufficient voltage.

15. The combination of a plurality of impulse producing circuits arranged in parallel, means for timing said impulse producing circuits to cause them to alternately produce current impulses, a condenser connected to said circuits so as to be charged to one polarity by one of said circuits

and then to the opposite polarity by the other of said circuits and so on alternately, and means in series with said condenser adapted to normally prevent discharge thereof but to break down and permit discharge when the charges thereon build up to a sufficient voltage, and a circuit including an ignition device inductively coupled to said last-named circuit.

16. In an ignition system the combination of a source of electrical energy and a plurality of circuits connected to said source in parallel, each circuit comprising an inductance and a circuit breaker in series with said source, means for timing said circuit breakers to cause the circuits to alternately produce current impulses, a condenser in parallel with both of said circuit breakers and in series with said inductances so as to be charged first to one polarity by one of said circuits and then to the opposite polarity by the other of said circuits and so on alternately, and a discharge circuit for said condenser including an electric valve adapted to break down when the charges on said condenser build up to a sufficient voltage.

17. In an ignition system the combination of a source of electrical energy and a plurality of circuits connected to said source in parallel, each circuit comprising an inductance and a circuit breaker in series with said source, means for timing said circuit breakers to cause the circuits to alternately produce current impulses, a condenser in parallel with both of said circuit breakers and in series with said inductances so as to be charged first to one polarity by one of said circuits and then to the opposite polarity by the other of said circuits and so on alternately, and a discharge circuit for said condenser including an electric valve adapted to break down when the charges on said condenser build up to a sufficient voltage, and a circuit including an igniting device coupled to said discharge circuit.

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