

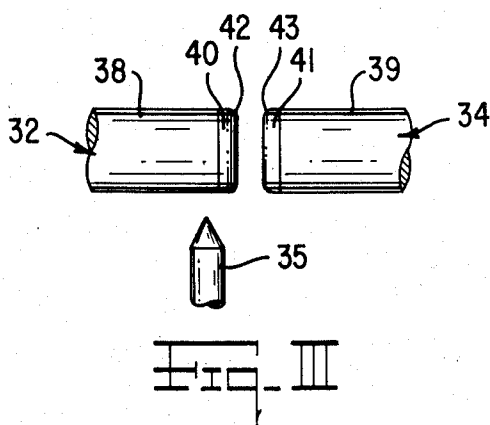
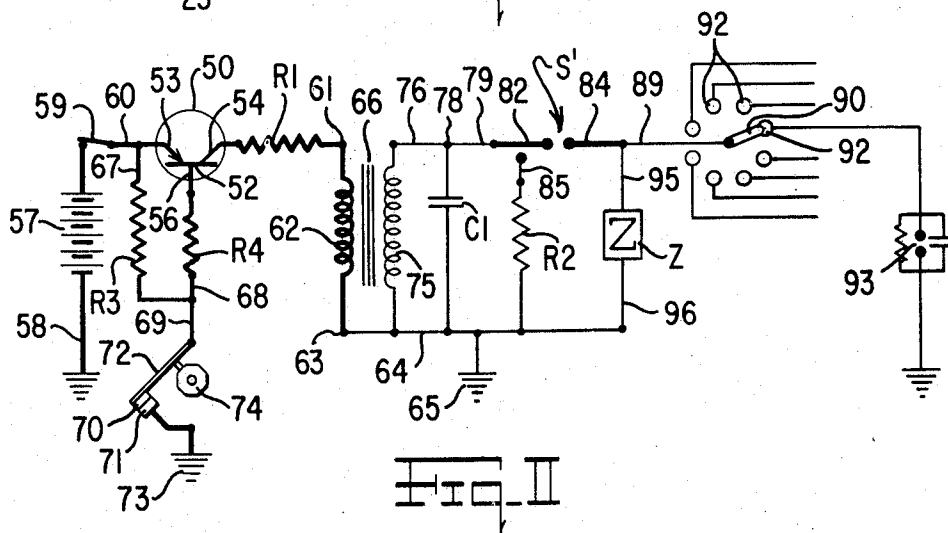
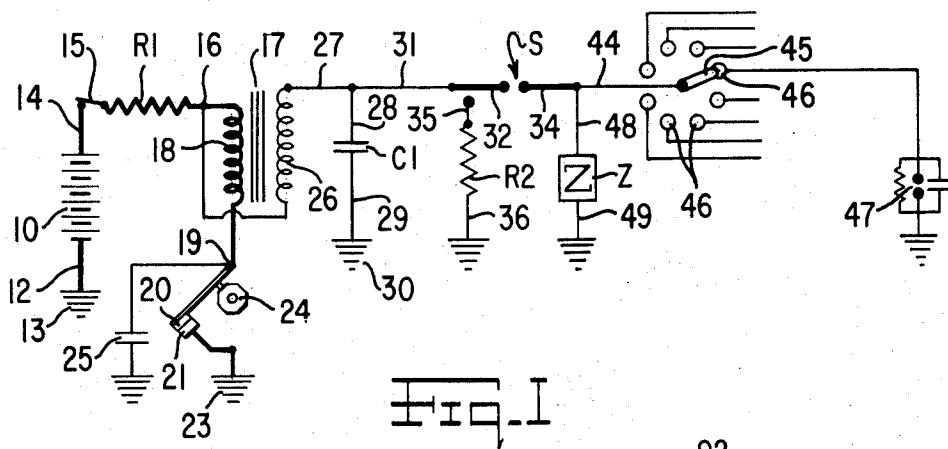
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IGNITION SYSTEMS

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IGNITION SYSTEMS

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This invention relates to electrical systems for igniting combustible mixtures in prime movers with particular reference to the apparatus and the method for securing and effectively controlling the voltage required to produce a spark of sufficient power to ignite an explosive mixture.

The invention comprehends novel electrical circuits for an ignition system for multi-cylinder engines, whereby the life of the expendable parts is materially increased and the danger of failure of producing an electrical igniting discharge across the electrodes firing gap in the engine combustion chamber is substantially eliminated.

The invention comprises an ignition system for internal combustion engines which is extremely insensitive to spark plug fouling, utilizing a condenser charged by an electrical current of relatively low voltage and discharged across the spark plug firing gap in proper timed relation with the engine.

The invention contemplates a low voltage condenser discharge type ignition system of very stable characteristics incorporating a very consistent series spark gap for producing electrical spark discharges of sufficient power to ignite the combustible mixtures of high compression engines.

The invention embraces an ignition system of the low voltage direct condenser discharge type incorporating means for effectively establishing and interrupting currents of high magnitude in the primary or input circuit of the ignition system wherein the useful life of the timing mechanism is not only long lasting but the possibilities of performance failure are greatly minimized.

The invention includes an ignition system of the low voltage condenser discharge type utilizing an extremely stable series gap and an impedance in the output circuit to produce an effective, high-energy discharge across the spark plug firing gap which is extremely insensitive to the deleterious effect caused by the fouling of the firing gap or by the presence of a comparatively low resistance path shunting the firing gap caused by carbon deposits or other deleterious matter.

According to the foregoing summary of the invention indicating the general nature and substance, its main objective is to provide an electrical system including a novel step-up transformer, in which current of high value is used to consistently produce a high incendivity discharge at the firing gap of a spark plug and wherein the voltage induced in the primary does not rise to such a value as to cause objectionable arcing across the timing contacts upon the interruption of the primary current whereby their effective life is materially prolonged and performance failures are substantially minimized.

Conventional electrical systems for igniting combustible charges in high compression engines have been unsatisfactory for prolonged service due to lack of consistency of the electrical discharge produced and on account of the exceedingly short life of the timing contacts. The attainment of consistent discharge characteristics and the prolongation of the useful life of the timing contacts present

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many problems including many complex and variable factors, so that many attempts to solve these problems have been unsuccessful and present day systems have not overcome the drawbacks before enumerated.

One of the principal objects of the invention is to avoid the foregoing drawbacks and produce a very stable, high-energy input ignition system of extremely reliable characteristics and long-lasting life for use with high compression, multi-cylinder engines subjected to variable operating conditions of load and speed.

Another object of the invention is to provide an electrical system in which a current of high magnitude supplied by an electric source for energizing a current-consuming device is established or interrupted by a transistor which performs the energizing current on or off switching function by a simple controlling circuit utilizing said electric source as its voltage bias.

Another object of this invention is to provide an electrical system in which extremely small currents are used for controlling and timing the high electrical energy input used in a condenser discharge ignition system for securing a very high incendivity spark at the spark plug electrodes.

Another object of the invention is to provide an ignition system in which a current of comparatively high value is used to produce a high-energy discharge without detrimental effects in the circuit make and break timing contacts, as well as avoiding objectionable decrease in the energization of the ignition coil at high engine speeds.

Another object of the invention is to provide an ignition timing mechanism wherein a transistor is used for effectively establishing and interrupting a relatively high current in the primary circuit of an ignition coil without producing objectionable arcing or limiting high speed operation of the engine.

Another object of the invention is to provide an ignition system in which objectionable arcing at the timing contact is materially reduced by the utilization of an ignition coil having very close coupled primary and secondary windings and wherein correlation of the windings and the magnetizable core is such that the induced voltage in the primary winding does not rise to such a value as to cause objectionable arcing across the timing contacts upon the interruption of the primary current whereby their effective life is materially prolonged and performance failures are substantially decreased.

A further object of the invention is to provide an electrical system in which a transistor is used to establish and interrupt currents of high magnitude without impairing its characteristics or decreasing its effective operating useful life.

Other objects and advantages of this invention relating to the arrangement, operation and function of the related elements of the structure, to various details of construction, to combinations of parts and to economies of manufacture, will be apparent to those skilled in the art upon consideration of the following description and appended claims, reference being had to the accompanying drawings forming a part of this specification wherein like reference characters designate corresponding parts in the several views.

Referring to the drawings:

Fig. I is a schematic circuit diagram of an ignition system embodying the principles of the invention;

Fig. II is a schematic circuit diagram of another form of the invention utilizing the principles of the invention; and

Fig. III is a fragmentary elevational view illustrating the spark gap means of the invention.

The present invention may be incorporated in any suitable electrical system and devices used for producing electrical discharges to ignite combustible mixtures and,

for practical application of its principles, the same is shown in the drawings as embodied in ignition systems for use with internal combustion engines subjected to variable conditions of load and speed. However, it is to be understood that the invention is not limited in its application to the particular embodiment shown but that it is contemplated that its principles may be used whenever the same may be found to have utility.

Referring particularly to Fig. I of the drawings, a suitable source of electrical energy may be utilized to provide the energization of the step-up transformer or ignition coil used as a potential source for charging the condenser and producing the voltage required for firing each of the spark plugs. In the form shown, the source of electrical energy is shown in the form of an electric storage battery 10 preferably having its negative terminal grounded to thereby provide a common return for the components of the ignition system of the invention. It is also contemplated that other uni-directional sources of electrical energy, such as a D.C. generator driven by the engine with which the ignition system is intended to be used, may be utilized.

In Fig. I, the uni-directional electric source of substantially constant low voltage is shown as storage battery 10 with its negative terminal connected by lead 12 to ground or common return connection 13. The positive terminal of the storage battery 10 is connected by conductor 14 to the main controlling switch 15 which may be of any suitable construction, preferably adapted to be manually actuated to open or close the main circuit of the system. The movable element of the switch 15 is connected to a terminal of a ballast or main current-limiting resistor R1, which has its other end suitably connected to the terminal 16 of the primary winding 18 of the step-up transformer or ignition coil operable to periodically induce the step-up electro-motive force required to fire the spark plugs. The other end or terminal 19 of the primary winding 18 is connected to the movable contact 20 of a conventional type primary circuit make and break timing mechanism. As shown, the timing mechanism comprises the movable contact 20 normally in engagement with the stationary contact 21 grounded as at 23. The contact 20 is carried by a breaker arm which is arranged to cause its separation from the contact 21 by being engaged by the lobes of the eight lobed cam 24 and thereby periodically interrupt the flow of energizing current in the primary winding 18 of the ignition coil. A condenser 25 is connected across the contacts 20 and 21 in the conventional manner. The circuit hereinbefore described constitutes the low voltage circuit of the system or the input circuit of the ignition coil or step-up transformer which is used to periodically produce the step-up electro-motive force utilized to charge a condenser for firing the spark plugs.

The output circuit of the transformer or step-up voltage circuit of the system includes the secondary winding 26 which is connected at one end to the terminal 16 of the primary winding 18 and has its opposite end connected by lead 27 and conductor 28 to one terminal of the condenser C1 connected at its other end by lead 29 to ground as at 30, whereby the condenser C1 is shunted across the secondary winding 26. The end of the secondary winding is also connected through lead 27 and conductor 31 to the isolating or spark gap means, generally designated as S.

The isolating spark gap means S are provided to effect the charge of the condenser C1 to a voltage not exceeding a predetermined peak value of the step-up voltage produced by the ignition coil and, in turn, permit the proper discharge of the ignition condenser for firing the low voltage type spark plugs. The spark gap means comprise a main discharge gap and a teaser or triggering discharge gap. The main gap is produced by axially-aligned, spaced electrodes 32 and 34, while the teaser gap is formed by a right-angle-positioned, secondary

spaced electrode 35 located rearwardly of the discharge face of the main electrode 32. The secondary electrode 35 is connected to a terminal of the current-limiting impedance R2, which has its opposite end connected by lead 36 to ground.

The electrodes 32 and 34, arranged to provide the main gap, are shown in Fig. III as duplicate composite structures, each formed by cylindrical metallic members 38 and 39 respectively capped by conducting discs 40 and 41 slightly rounded at their peripheries as at 42 and 43 in order to minimize sharp edges discharge effects. The members 38 and 39 are dimensioned to provide relatively large mass in order to enhance cooling of the electrode by conduction, and are preferably made of a base metal suitably coated or plated to withstand oxidation or corrosion, and may be also made of materials having good thermal and electric conductivity not readily oxidizable by electrical discharges. The discs 40 and 41, which may be termed the vulnerable components of the main electrodes, are preferably made of good erosion-resistant conducting materials, or of metals having high melting point fixed at the ends of the cylindrical members 38 and 39 by being brazed or welded thereto and are preferably arranged, so that their discharge faces are uni-planar providing flat spaced surfaces located in substantially parallel relation. It has been found highly advantageous to form each of the discs 40 and 41 of either tungsten, molybdenum, tantalum, or alloys of such metals. However, it is contemplated that other materials having the characteristics before mentioned may be used.

The teaser gap, utilized herein as means to stabilize the break-down voltage of the main gap, is shown in Fig. III as a cylindrical secondary electrode 35 located at right angles to the axis of the main electrode rearwardly of the flat end and properly spaced from the outer wall of the main electrode 32. The electrode 35 is preferably of a smaller diameter than the main electrodes and has a conical end section having an included angle between 50° and 90°. In practice, a metal rod, having a diameter about one-third of the diameter of the main electrodes and terminating in the form of a 60° cone, serves very effectively as the secondary electrode 35. Moreover, its tip should be positioned about 0.060" to 0.080" behind or rearwardly of the planar face of the electrode 32, as a closer placement than 0.060" increases the possibility of the discharge across the main gap sparking over the end of the conical section and eroding it.

The three electrodes 32, 34, and 35 are suitably held by conventional insulating means providing gaps having the proper spacing to satisfy the voltage requirements of the system. Comparative tests indicate that the main gap or spacing between the axially disposed electrodes may satisfy the requirements of a system having a 2700 volt rating when such spacing is approximately 0.027". and that the spacing between the secondary electrode 35 and the side of the main electrode 32 or width of the teaser gap should be of such value as to cause its break-down voltage requirement to be satisfied before that of the main gap. Therefore, the spacing between electrodes 35 and 32 can range from being of very small value to a predetermined safe maximum which will allow the teaser gap to fire before a discharge occurs between the electrodes 32 and 34 of the main gap. Comparative tests indicate that a maximum safe spacing of 0.025" for the teaser gap will effectively stabilize the break-down potential of the main or series gap when the latter is arranged for a 2700 volt rating. Moreover, that the teaser-limiting impedance R2 finds its counterpart in a large resistance or a small capacitance as its function is to limit the teaser gap discharge current, conserving energy and minimizing electrical erosion of the tip of electrode 35. In practice, its value may range anywhere from 100,000 ohms to 1 megohm. In view of the fact that an impedance of a too high resistance value will cause the teaser gap to

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become ineffective, a 500,000 ohms resistor has been found very effective in aiding the stabilization of the break-down potential of the main gap when the latter is arranged for a 2700 volt rating. The values hereinbefore set forth with respect to the spacing of the main series and teaser gaps, as well as for the impedance of the current-limiting resistor associated therewith, are given, by way of example only, as the teachings of the invention are not intended to be restricted thereby.

The gap means of the invention, inclusive of the electrodes 32, 34, and 35 and the impedance R2, which are utilized to effect the periodic charge of the condenser to a predetermined value and thereafter permit its discharge through the spark gap means, whereby a high frequency voltage is applied to the firing gap of the spark plug, are directly connected to the spark plugs so as to provide a substantially non-inductive connection between the ignition condenser C1 and the spark plugs. The substantially non-inductive connection between the output side of the spark gap means is preferably secured by a low resistance conductor 44 directly connected at one end to the main electrode 34 and at its other end to the rotor 45 of a commutator type distributor. The rotor 45 provides, in proper timed relation with the engine by a mechanical connection with cam 24, a direct non-inductive wiping engagement with the stationary contacts 46 suitably connected to each of the low voltage spark plugs 47 of the creeping discharge firing gap which has one of its firing electrodes grounded. The stationary contacts 46 may take the form of flush inserts preferably molded in an insulating distributor cap providing, with the rotor 45, a low resistance connection for the application of the high frequency discharge voltage applied to each of the creeping firing gaps of the spark plugs 47. In order to control and stabilize, to a predetermined value, the voltage requirements of the system, avoiding the additive effect of the break-down voltage requirements of the main series gap and of the gap of the spark plugs, a load-stabilizing impedance Z is used. As shown in Fig. I, the load-stabilizing impedance Z is connected to the terminal of the main electrode 34 by conductor 48 and has its other end grounded by lead 49, thereby forming a circuit in parallel with the spark plugs 47. The presence and function of the impedance Z may be better understood when it is considered that the series gap and the spark plugs gap, prior to their firing or break-down discharge, act like two condensers in series, and, therefore, the voltage applied will divide across each condenser inversely proportional to their capacity. Thus, while the series gap, which has the smaller capacity, and consequently the largest impedance, will have the largest share of the available voltage across it, the firing gap of the spark plugs will still have a significant voltage across it which must be furnished by the voltage source and cannot be used until the main gap fires. In order to eliminate the useless additive effect of these break-down voltages, the load-stabilizing impedance Z is inserted in parallel with the spark plugs. The value of this impedance is made low enough, so that it is the controlling element in the two parallel circuits. With the impedance of the firing gap of the spark plugs effectively reduced, the applied voltage is now virtually all across the main gap. When the main gap breaks down, its impedance becomes very low and, therefore, the voltage drop across it is very low, and almost all the voltage is then applied across the firing gap of the spark plugs. There is practically no energy lost through the stabilizing impedance Z because of the high frequency of the voltage applied to it after the main series gap breaks down. In practice, impedance Z may be of a composite type, but, consistent with economical manufacture, may take the form of a 5000-ohm carbon resistor having a 4 watt rating. This value is set forth as typical and should not be considered as limiting the teachings of the invention as other values have been found satisfactory.

Another feature of this embodiment of the invention

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resides in the provision of a step-up transformer or ignition coil wherein the basic components are so arranged as to provide a very close coupled coefficient between the primary and secondary windings and wherein its magnetizable core and the windings characteristics are such that the induced voltage in the primary winding is materially decreased so as to substantially reduce the duration of the objectionable arcing across the timing contacts when the energizing current is interrupted. It is contemplated that the ignition coil should include a laminated, high-permeability, low-loss core having a substantially close magnetic path, preferably of a C-shaped configuration, with an air gap of very small width so as to minimize flux leakage and effectively contribute to decrease the induced voltage in the primary winding 18 to a substantially low value to thereby reduce objectionable arcing across the timing contacts when the circuit of the primary winding 18 is open.

It has been found very effective to make the core 17 of high permeability electrical steel, or magnetically soft material capable of carrying a very high magnetic flux per unit of cross-sectional area and that a core produced by a winding of grain-oriented, high percentage silicon steel ribbon serves the purpose very successfully. Moreover, we have found that an air gap in the magnetizable circuit ranging between 0.005" to 0.030" serves the purpose very effectively, and that very efficient performance is secured when such gap in the magnetizable circuit is substantially 0.010".

The windings 18 and 26 of the ignition coil are preferably arranged in concentric relation and positioned surrounding the air gap provided in the substantially closed magnetic core 17. It is also contemplated that the ignition coil should include a primary winding having low inductance and adapted to receive a high input energizing current, which amplitude may be governed by the speed requirements of the engine in order that the size and inertia of the movable contact 20 will not cause objectionable bounce at high engine speeds.

In applying the teachings of the invention to a 12 volt ignition system for use with spark plugs of the low voltage firing gap, we have found that an ignition coil provided with a primary winding, which may be energized by a current ranging up to 6 amps. under normal conditions, preferably having the primary winding of 75 turns of No. 20 wire, while the secondary winding has approximately 2600 turns of No. 30 wire and both windings mounted in concentric relation and with the secondary winding over the primary, preferably on the leg of the core having the controlled air gap, serves the purpose very efficiently. The ignition coil, following the teachings of the invention with respect to its electrical characteristics, relationship of windings and location on the substantially closed core, as well as the number of turns hereinbefore set forth, is particularly adaptable for effectively charging a 0.004 microfarad condenser which finds its counterpart in the ignition condenser C1. The values given, relationship and position of the windings are set forth only as typical examples for the power supply of an ignition system having a 2700 volt rating, and should not be considered as restricting the teachings of the invention as other values, relationship and position have been found satisfactory.

In Fig. II there is shown a schematic wiring diagram of another form of the invention in which a transistor 50, such as, by way of example, one of the P-N-P junction type, is utilized to control the flow of current in the circuit of the current-consuming device, finding its counterpart in the energizing winding of the ignition coil utilized for producing the electrical potential required for charging the condenser and thereby fire the gap of the spark plugs. The transistor shown comprises a semi-conductor body 52 having three conventional electrodes such as the emitter 53, collector 54, and base electrode 56 cooperatively associated therewith which is used to perform the

energizing current on or off switching function in the primary circuit of the ignition coil directly secured in the embodiment of the invention shown in Fig. I by the conventional make and break timing mechanism.

A suitable source of electrical energy, such as the storage battery 57, supplies the current to the primary winding of the step-up transformer or ignition coil, as well as the proper voltage bias to control the transistor 50. The battery 57, as shown, has its negative terminal connected by lead 58 to ground to provide a common conducting path for the return of the current used in the components of the ignition system while its positive terminal is connected to a switch 59 which opens and closes the main circuit of the system. The movable element of the switch 59 is connected by lead 60 to the emitter electrode 53 of the transistor 50, while the collector electrode 54 is connected to one end of a ballast or main current-controlling resistor R1 connected at its other end to the terminal 61 of the primary winding 62 of the ignition coil which has its other terminal 63 connected by common lead 64 to ground as at 65. Thus it can be seen that the emitter and collector electrodes of the transistor 50, the resistor R1, and the primary winding are connected in series constituting the current input circuit of the ignition coil operable to periodically induce the step-up electromotive force required to charge the ignition condenser and thereby fire the gap of the spark plugs.

In accordance with the principles of the invention, the transistor 50 functions as the energizing current on or off switch means to periodically establish and interrupt the flow of the energizing current in the primary winding 62 from the battery 57 and thus, by the collapse of the magnetic flux, produces the voltage required to charge the condenser and thereby fire the spark plugs. The energizing current on or off switching function of the transistor is accomplished in this form of the invention by periodically applying proper voltage bias to render the transistor 50 conductive or nonconductive by a control circuit inclusive of a make and break contact mechanism of the conventional ignition system, which periodically connects and disconnects the control circuit across the battery 57.

The control circuit for the transistor 50 is provided by connecting the emitter 53 with the base 56 through conductor 67, high resistance unit R3, lead 68, and current-limiting resistor R4 and, in turn, by connecting this circuit through lead 69 to the movable contact 70 of a conventional timing mechanism. The timing mechanism comprises the contact 70 normally in engagement with the stationary contact 71 grounded as at 73. The contact 70 carried by breaker arm 72, is separated from contact 71 by its engagement with the 8 lobe cam 74 and thereby periodically interrupts the connection with the negative terminal of the battery 57 constituting the voltage bias for controlling transistor 50. The cam 74 is rotated in timed relation with the engine and thus the energizing current on or off switching function of the transistor occurs in timed relation with the engine. The control circuit of the transistor 50 comprises, in effect, two parallel paths, across the battery 57, both including the timing contacts 70—71. One is external of the transistor and comprises from the positive terminal of the battery the conductor 67, resistance R3, lead 69, timing contacts 70 and 71, and ground 73. The other path comprises the emitter 53, semi-conductor body 52, base 56, resistor R4, leads 68 and 69, contacts 70 and 71, and ground 73. When the contacts 70 and 71 are closed or in engagement, the base 56 is placed at a negative potential with respect to the emitter 53 and, therefore, forward current flows in the emitter to the base. When this condition occurs, the battery current flows from the emitter 53 to the collector 54, hence through resistance R1 to the primary winding 62 in series therewith. However, when the contacts 70 and 71 are opened, or out of

engagement, the base 56 is placed at the same voltage potential as the emitter 53, rendering the transistor 50 non-conductive, thereby cutting off the battery current to the primary winding 62 and causing collapse of the magnetic flux, thereby producing in the output circuit of the ignition coil the required voltage for charging the condenser to fire the gaps of the spark plugs.

Applying the principles of the invention to an ignition system for use with a 12 volt storage battery as its source of energy, we found that a 100,000 ohm resistor functions satisfactorily as the resistance unit R3 in the transistor control circuit, and that resistors ranging from 15 to 40 ohms satisfy the requirements of the base current-limiting resistor R4. Moreover, that resistors ranging from 0.5 to 3 ohms resistance give acceptable performance as the current-limiting ballast resistor R1, used in the input or primary circuit of the system, designed to produce a high incandescence electrical discharge at the firing gap of the low voltage spark plugs.

The output circuit of the ignition coil or the step-up voltage circuit of the system includes the secondary winding 75 connected at one end to the grounded terminal 63 of the primary winding 62 and has its other terminal connected by lead 76 to the terminal 78 of the ignition condenser C1. This condenser, in turn, has its other terminal grounded as at 65 by its connection with the common connector 64, thereby the condenser is shunted across the secondary winding 75. The non-grounded terminal of the secondary winding 75 is also connected by leads 76 and 79 to the isolating spark gap means of the invention, generally designated as S'.

In this embodiment, the isolating spark gap means S' are also provided to effect and control the charge of the ignition condenser C1 to a voltage not exceeding a predetermined peak value of the step-up voltage produced by the secondary winding 75 and, in turn, are used to permit the proper discharge of the condenser C1 for firing the low voltage type spark plugs of the system. The spark gap means comprise a main gap and a teaser or triggering gap. The main or series gap is produced by axially aligned spaced electrodes 82 and 84, while the teaser gap is formed by a secondary right-angle positioned electrode 85 located rearwardly of the discharge face of the main electrode 82. The electrode 85 is connected to a terminal of a current-limiting impedance R2 which has its opposite end grounded as at 65 by its connection with connector 64.

It is contemplated that the spark gap means S' should be arranged to duplicate the constructional features and functional characteristics present in the spark gap means used with the form shown in Fig. I. Therefore, the electrodes 82 and 84 comprise duplicate structures formed by cylindrical metallic members, which, as particularly shown in Fig. III, are dimensioned to provide proper cooling, and are arranged to withstand oxidation or corrosion by the means particularly set forth in connection with the other form of the invention. In addition, the vulnerable discharge faces of the electrodes 82 and 84 are uni-planar, providing flat, spaced, end surfaces located in substantially parallel relation, preferably formed of good corrosion-resisting conducting materials or metals having high melting point of the type hereinbefore referred to in connection with the embodiment shown in Fig. I. Furthermore, it is also contemplated that the secondary electrode 85 should have the same constructional features, size, and relationship with respect to the outer surface of the main electrode as those indicated in connection with the secondary electrode used in the other embodiment of the invention to produce the teaser gap in view of the fact that in this form of the invention, the teaser gap is also used as means to stabilize the breakdown voltage of the main gap.

In the form of the invention shown in Fig II, the three electrodes 82, 84, and 85 are suitably held by insulating means providing a spark gap having proper

spacing to satisfy the voltage requirements of the system. Comparative tests indicated that a 0.027" spacing between the electrodes 82 and 84 satisfies the requirements of a system having a 2700 volt rating, and that the separation between the secondary electrode 85 and the side of the main electrode 82 constituting the width of the teaser gap should be of such a value as to cause its break-down voltage requirement to be satisfied before that of the main gap. Thus, the spacing of the teaser gap can range from a very small value to a predetermined safe maximum which will allow the teaser gap to fire before an electrical discharge occurs in the main gap. Comparative tests indicate that a maximum safe spacing of 0.0025" for the teaser gap will effectively stabilize the break-down potential of the main gap when the spacing of the latter is arranged for a 2700 volt rating. Moreover, that a large resistance or a small capacitance will satisfactorily perform the functions of the current-limiting impedance R2 with respect to conserving energy and minimizing erosion of the tip of the secondary electrode 85. In practice, the resistors, ranging anywhere from 100,000 ohms to 1 megohm, have been found satisfactory. However, in view of the fact that an impedance of a too high resistance value will cause the teaser gap to become ineffective, a 500,000 ohm resistor has been found effective in aiding the stabilization of the break-down potential of the main gap when the latter is arranged for a 2700 volt rating. The values heretofore set forth with respect to the spacing of the main series gap and teaser gap, as well as for the resistance of the current-limiting resistor associated therewith, are given, by way of example, as the teachings of the invention, and are not intended to be restricted thereby.

The step-up voltage circuit of the system in the second form of the invention also includes the provision of a substantially non-inductive connection between the ignition condenser and the spark plugs, including the gap means of the invention which are utilized to effect the periodic charge of the condenser to a predetermined value and thereafter permit its discharge through the spark gap means S', whereby a high frequency voltage is applied to the firing gap of the spark plugs. The substantially non-inductive connection between the output side of the spark gap means is preferably secured by low resistance conductor 89 directly connected at one end to the main electrode 84 and at its other end to the rotor 90 of a commutator type distributor. The rotor 90 provides, in proper timed relation with the engine, by mechanical connection with the cam 74, a direct non-inductive wiping engagement with each of the stationary contacts 92 suitably connected to each of the low voltage spark plugs 93 of the creeping discharge firing gap, each of which has one of its firing electrodes grounded. The stationary contacts 92 may take the form of flush inserts, preferably milled in an insulating distributor gap providing, with the rotor 90, a low resistance non-inductive connection with each one of the spark plugs for the application of the high frequency discharge voltage supplied by the condenser C1 for firing the gaps of the spark plugs.

As shown in Fig. II, the load-stabilizing impedance Z is connected to the terminal of the main electrode 84 by conductor 95 and has its other end grounded as at 65 by lead 96 through conductor 64, thereby forming a circuit in parallel with the spark plugs 93 on the output side of the spark gap S'. The load-stabilizing impedance Z is also used in the second form of the invention as means to stabilize to a predetermined value the voltage requirements of the system avoiding the additive effect of the break-down voltage requirements of the main series gap and of the firing gap of the spark plugs. In practice, in this form of the invention satisfactory performance has been secured when the impedance is of a composite type. However, consistent with economical manufacture, a 5000 ohm carbon resistor having about a 4 watt rating has been found very effective to control and stabilize to

a predetermined value the voltage requirements of the system. The value set forth for the load-stabilizing impedance must be considered as typical and not as limiting the teachings of the invention as other values have been found to provide acceptable performance.

In order to effectively fulfill the objects of the invention in the form shown in Fig. II, a step-up transformer or ignition coil is used wherein the basic components are constructed and arranged, so that the induced voltage in the primary winding does not rise to such a value as to cause objectionable arcing across the timing contact upon the interruption of a comparatively high energizing current, therefore, the induced voltage is of such low value that a transistor can be used for establishing and interrupting the flow of a relatively high primary current without impairing its characteristics.

It is contemplated, in the second form of the invention, that the step-up transformer or ignition coil should include a magnetizable core 66 having a substantially closed magnetic path, preferably of C-shaped configuration, with an air gap of very small width so as to minimize magnetic flux leakage and, in addition, effectively contribute to the decrease of the induced voltage in the primary winding 62. In order to carry out this purpose, the magnetizable core should be made of high permeability electrical steel or of magnetically soft materials capable of carrying a very high magnetic flux per unit of cross-sectional area. The core 66 is preferably formed of a multi-turn winding of a ribbon of grain-oriented, high percentage silicon steel coated to separate and hold in position its turns and fashioned to accommodate the close coupled primary and secondary windings 62 and 75 of the ignition coil providing an air gap of extremely small width. We have found that an air gap in the magnetic circuit of the C-shaped core ranging between 0.005" to 0.030" provides acceptable performance, and that very efficient operation is secured with a controlled air gap in the magnetic circuit of 0.010". Thus, the core provided is characterized by having a very low magnetic flux leakage, as well as a very low induced voltage in the primary winding, and is, in effect, a laminated, high permeability, low-loss core having a substantially closed magnetic path.

The primary and secondary windings 62 and 75 are arranged in concentric relation and preferably positioned over the air gap provided in the substantially magnetic core 65. It is contemplated that the ignition coil should include a primary winding made for high input energizing current having relatively low inductance and utilizing comparatively few turns with a very high turn ratio between its primary and secondary windings.

In applying the principles of the invention to an ignition system adapted to be energized by a 12 volt battery, we have found that ignition coils provided with primary windings adapted to be energized by currents ranging from 8 to 12 amps. and utilizing less than 70 turns with a turn ratio with respect to the secondary winding at least higher than 60 to 1. Ignition coils, including such features, serve very effectively to satisfy the voltage requirements of low output voltage ignition systems in which high input current is used to consistently produce high incandescence discharge at the firing gap of the spark plugs and wherein the voltage induced in the primary is of a very low value, so that the ignition timing is secured by the use of a transistor. Comparative tests indicate that a very efficient performance for a 2700 volt system is obtained when the primary winding 62 of the ignition coil is made for an energizing current of 8 to 10 amps. with 30 turns of No. 16 wire, while the secondary winding 75 has approximately 3300 turns of No. 30 wire, the windings being very close coupled and mounted in concentric relation on the core 66 with the primary being surrounded by the secondary. However, this relationship can be reversed without material interference with successful performance. Moreover, the tests indicate that such ignition coil is particularly adaptable for effectively

charging the condenser C1 when its value is approximately 0.004 microfarad. The values are set forth as typical examples for an ignition coil used to satisfy the voltage requirements in an ignition system of the condenser discharge type having a 2700 volt rating and should not be considered as restricting the teachings of the invention as other values have been found to produce acceptable performance.

It is to be understood that the above detailed description of the present invention is intended to disclose an embodiment thereof to those skilled in the art, but that the invention is not to be construed as limited in its application to the details of construction and arrangement of parts illustrated in the accompanying drawings, since the invention is capable of being practiced and carried out in various ways without departing from the spirit of the invention. The language used in the specification relating to the operation and function of the elements of the invention is employed for purposes of description and not of limitation, and it is not intended to limit the scope of the following claims beyond the requirements of the prior art.

What is claimed:

1. An ignition system for internal combustion engines comprising a plurality of low voltage discharge spark plugs, a step-up ignition transformer having close coupled primary and secondary windings, an ignition condenser forming a circuit connected across said secondary winding, a primary circuit for periodically supplying electromotive force to said primary winding to cause the condenser to be charged by said secondary winding, spark gap means comprising two main spaced electrodes and a secondary spaced electrode, a discharge circuit for said condenser including said two main spaced electrodes, the secondary spaced electrode of said spark gap means forming a parallel branch circuit across said condenser for applying the voltage of said condenser to said spark gap means for stabilizing the break-down potential of the two main spaced electrodes, a constant load impedance forming another parallel branch circuit across said condenser on the discharge side of said two main electrodes, and a non-inductive connection including switching means for successively connecting said condenser through said two main electrodes to the spark plugs.

2. An ignition system for internal combustion engines comprising a plurality of spark plugs, a step-up ignition transformer having a high coupling coefficient between its primary and secondary windings directly mounted in concentric relation on a magnetizable core of high permeability grain-oriented material, an ignition condenser shunted across said secondary winding, a primary circuit for periodically supplying electromotive force to said primary winding to cause said condenser to be charged by said secondary winding, three electrodes spark gap means forming main and secondary air gaps, a circuit connecting said secondary winding said condenser and said spark gap means to effect the charge of said condenser by said secondary winding to a predetermined voltage, a current-limiting impedance, a discharge circuit for said condenser including the main air gap of said spark gap means, the said secondary air gap and the said current-limiting impedance forming a circuit across said condenser for stabilizing the break-down voltage of the main air gap of said spark gap means, a constant load impedance forming a branch circuit across said condenser on the discharge side of said spark gap means, and means including distributor contacts having direct non-inductive wiping engagement for connecting in proper timed relation with the engine said condenser discharge circuit with said spark plugs.

3. An ignition system for engines comprising a plurality of spark plugs, three spaced electrodes, an ignition condenser, means for periodically supplying electromotive force to charge said condenser, means connecting

two of said electrodes to provide a main gap in series with said condenser, the third electrode and one of the other electrodes forming a secondary gap connected across said condenser for applying the voltage of the condenser to said secondary gap for stabilizing the break-down potential of the main gap, a constant load impedance connected on a branch circuit across said condenser on the discharge side of said main gap, and distributor contacts having non-inductive wiping engagement for connecting in timed relation with the engine said condenser through said main gap to the spark plugs.

4. An ignition system for engines comprising a plurality of spark plugs, spark gap means comprising three spaced electrodes providing a main air spark gap and a secondary air spark gap, an ignition condenser, means for periodically supplying electromotive force to cause the condenser to be charged to a predetermined value limited by said spark gap means, a non-inductive discharge circuit for said condenser including said condenser in series with said main air gap, a current-limiting resistor, a main branch circuit including said current-limiting resistor and said secondary air gap connected to said discharge circuit across said condenser for stabilizing the break-down voltage of the said main air gap, a constant load impedance forming a secondary branch circuit connected to said discharge circuit across said condenser on the discharge side of said main gap, and distributor contacts having direct non-inductive wiping engagement for connecting in timed relation with the engine said discharge circuit to the spark plugs.

5. An ignition device for charging a condenser for firing the gap of low voltage spark plugs comprising a magnetizable core of grain-oriented silicon steel having a substantially closed magnetic path, primary and secondary windings arranged in concentric relation directly mounted on said core, the turn ratio between said primary and secondary windings being at least 60 to 1, and the primary winding having comparatively low inductance and a very low primary induced voltage.

6. An ignition device for charging a condenser for firing the gap of low voltage spark plugs comprising a magnetizable core of high permeability grain-oriented material, said core having a C-shaped configuration with an air gap of a width ranging between .005" to 0.030", close coupled primary and secondary windings mounted on said core surrounding said air gap, the turn ratio between said primary and secondary windings being at least 60 to 1, the primary winding having a low inductance, and said primary and secondary windings being constructed and arranged with respect to said magnetizable core whereby the induced voltage in the primary winding does not rise to a value as to cause objectionable arcing across the timing contacts used for the interruption of its energizing current to produce the voltage required for charging a condenser for firing the gap of the low voltage spark plugs.

7. A low voltage ignition system of the condenser direct discharge type for variable speed combustion engines comprising a source of current, an ignition condenser, a transistor, a step-up transformer having close coupled primary and secondary windings for charging said ignition condenser, the turn ratio between the primary and secondary windings being at least 60 to 1, the primary winding having comparatively low inductance and a very low primary induced voltage, series connections for the flow of electrical current from said source through said transistor to said primary winding, and a control circuit for said transistor including make and break contacts functioning in timed relation with the engine for periodically connecting said control circuit to said source of current causing the operation of said transistor as means for establishing and interrupting the flow of electrical current to said winding.

8. A low voltage ignition system of the direct condenser discharge type for engines utilizing at least a low

voltage firing gap spark plug comprising an ignition condenser, spark gap means including three electrodes forming a main air gap and a teaser air gap, means connecting said condenser and said spark gap means to a source of electromotive force to effect the charge of said condenser to a predetermined voltage controlled by said spark gap means, a circuit to permit the discharge of said condenser to the said spark plug including said spark gap means, said circuit providing a substantially non-inductive connection between said condenser and said spark plug, and a constant load impedance connected across said condenser on the air side of said main discharge gap to avoid the additive effect of the break-down voltage requirements of the main air gap and of the firing gap of the spark plug.

9. A low voltage ignition system of the condenser discharge type for variable speed engines comprising a source of direct electric current, a transistor, an ignition condenser, an ignition coil having a high coupling coefficient and a high turn ratio between its primary and secondary windings which are mounted in concentric relation on a magnetizable core of high permeability grain-oriented material for charging said condenser, spark plugs having a surface spark gap of the low voltage firing type, connections for the flow of current through said transistor to said primary winding, a control circuit for the transistor including means functioning in timed relation with the engine for periodically connecting said control circuit across said source of direct electric current causing the transistor to periodically permit the flow of current to said primary winding to effect the periodic charge of said condenser, and non-inductive circuit connections for transferring the charge of said condenser to the spark plugs for firing their gap.

10. A low voltage ignition system of the condenser discharge type for variable speed combustion engines comprising a source of current, a transistor, an ignition condenser, an ignition coil having a high coupling co-

efficient and high turn ratio between the primary and secondary windings for charging said condenser, the primary winding of said ignition coil having a very low primary induced voltage, spark plugs having creepage gaps of the low voltage firing type, circuit connections for the flow of electric current from said source through said transistor to the primary winding of said ignition coil, a control circuit including make and break contacts functioning in timed relation with the engine for successively connecting and disconnecting said control circuit to said source of current causing the operation of said transistor as energizing current on or off means for controlling the flow of electric current to the primary winding of said ignition coil to effect thereby the periodic charge of said condenser, and a non-inductive circuit including distributor contacts having direct non-inductive wiping engagement for transferring the charge of said condenser to the spark plugs for firing their gaps.

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UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,963,624

December 6, 1960

Earl W. Meyer, Jr., et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 9, line 14, for "0.0025" read -- 0.025" --;
line 55, for "moled" read -- molded --; column 12, line 57,
before "condenser" insert -- direct --; line 58, strike out
"direct"; column 13, line 12, for "air" read -- discharge --;
same line, strike out "dis-"; line 13, for "charge" read
-- air --.

Signed and sealed this 23rd day of May 1961.

(SEAL)

Attest:

ERNEST W. SWIDER

Attesting Officer

DAVID L. LADD

Commissioner of Patents

UNITED STATES PATENT OFFICE
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