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ELECTRICAL IGNITION SYSTEM

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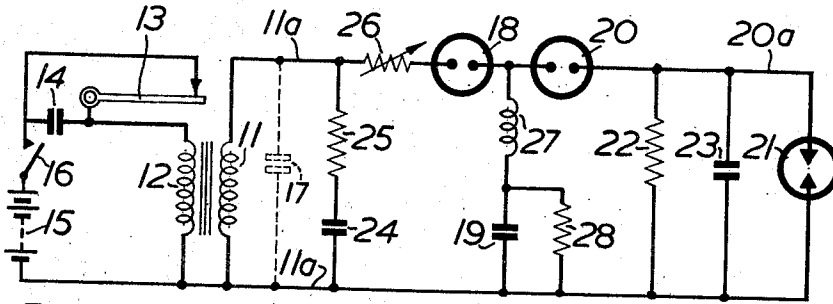


Fig. 1

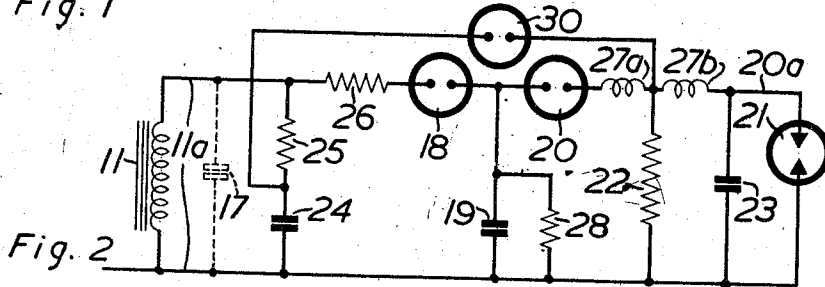


Fig. 2

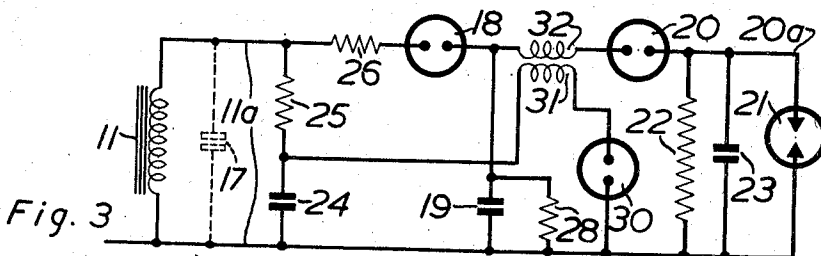


Fig. 3

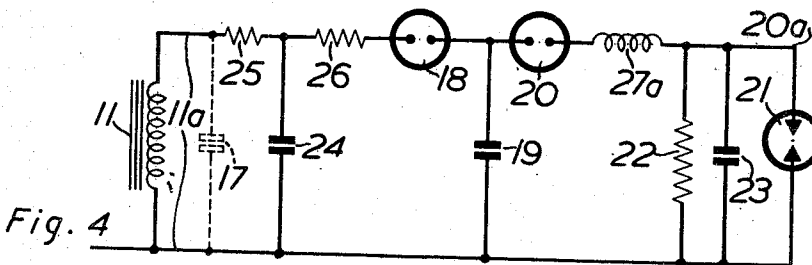
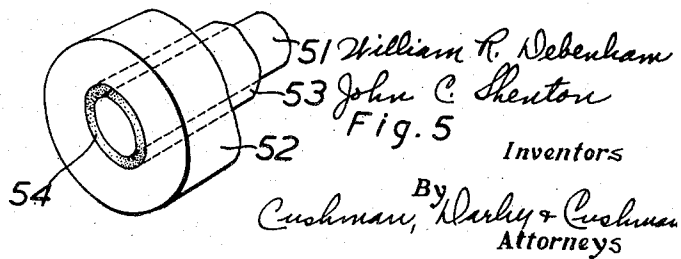


Fig. 4



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UNITED STATES PATENT OFFICE

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ELECTRICAL IGNITION SYSTEM

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This invention relates to electrical ignition systems. Various high frequency ignition systems for piston engines are already known in which a condenser is charged from a low frequency source such as a magneto until a predetermined charge voltage has been reached when a spark gap or other circuit closing device functions automatically to allow the condenser to discharge into a high frequency circuit via which energy is transmitted to a spark plug, a single discharge taking place at the latter for each operation of the contact breaker at the low frequency source.

High intensity ignition apparatus for use where precise timing, as for a piston engine, is unnecessary, is also known in which a charge accumulating condenser is connected to receive via a relatively high voltage charging spark gap repeated unidirectional charges from an induction coil and to discharge via a relatively low voltage discharging spark gap when the voltage of the accumulated charge thereon reaches a predetermined value to supply energy to a spark plug.

The present invention has for an object to provide improvements in such high intensity ignition apparatus for use, for example, for turbine or jet type engine ignition, cabin heaters, flame warfare apparatus and fog disposal apparatus, apparatus in accordance with the invention having been evolved in the first place for use for starting and restarting turbine or jet type aircraft engines at any altitude.

According to the invention, in high intensity ignition apparatus in which a charge accumulating condenser is connected to receive via a relatively high voltage "charging" spark gap repeated unidirectional charges from an induction coil and to discharge, when the voltage of the accumulated charge thereon is sufficiently high, via a relatively low voltage discharging spark gap and a spark plug lead, means are provided to reduce the interelectrode voltage of said gap, and ensure its rapid extinction or suppression, each time the induction coil voltage declines and/or changes polarity and thus prevent or reduce the opportunity for any discharge of the charge accumulating condenser reversely through the charging gap.

Preferably, the interelectrode voltage reducing means comprise a small auxiliary condenser connected via series resistance across the induction

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coil connections at that side of the charging gap remote from the charge accumulating condenser. The values of such auxiliary condenser and its series resistance are not critical for any particular induction coil and are so chosen that they have the effect that extinction of the charging gap is ensured each time the induction coil voltage declines and then changes polarity and that the value of the changed polarity voltage is reduced so that no appreciable reverse voltage is developed across the charging gap at any time adding to the voltage across the charge accumulating condenser, whereby opportunity for discharge of the charge accumulating condenser reversely through the charging gap is reduced.

The provision of such interelectrode voltage reducing means according to the invention enables the use, for a given maximum charge voltage of the charge accumulating condenser, of a charging gap of substantially lower break down voltage and an induction coil of correspondingly lower output voltage than would otherwise be possible, and thus substantially increases the efficiency of the apparatus.

According to a feature of the invention there is connected in series with the charge accumulating condenser in the charging and discharging circuits thereof a small inductance across which, each time the charging gap breaks down, a transient high frequency voltage is developed, by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil and any added shunt capacity, which reduces the accumulated charge voltage required to break down the discharging spark gap by the effective amount of the transient high frequency voltage and reduces pre-break-down corona and brush discharge losses in said gap.

The transient high frequency voltage developed in this way will depend on the characteristics of the series inductance employed and also on the self-capacity of the induction coil and any added capacity, but preferably, series resistance, which may be variable, is provided in the charging circuit of the charge accumulating condenser to control the transient high frequency voltage as required. Being in series in the discharging circuit of the charge accumulating condenser, this small series inductance, besides effectively reduc-

ing the accumulated charge voltage required to break down the discharging gap, has the effect of limiting the peak discharge current through the discharging gap and also acts, in conjunction with capacity associated with the spark plug lead, to increase the voltage produced at a plug with which the latter is connected.

In order to obtain a high ratio of output energy, i. e. spark plug discharge energy to input energy, to minimise the value of the high voltages developed and to prolong the useful life of the spark plugs used with high intensity ignition apparatus according to the invention, it is preferable that the latter should be of low voltage type in which the discharge takes place over the surface of the insulation between electrodes which are preferably of substantial size to minimise the effects of erosion of the material thereof. The break down voltage of such a plug under normal ground level conditions may, for example, be of the same order as that of the discharging gap. It is also desirable from the point of view of minimising high voltage values that the spark plug lead should have such leakage or insulation resistance as will, by being in shunt across a spark plug, substantially reduce the voltage required to break down, or initiate a discharge in, the discharging gap. Such shunt resistance may be comprised as to a substantial proportion thereof by a resistor provided for the purpose, but where a low voltage spark plug of the type referred to is employed, this may present a semi-conductive discharge path. Thus a deposit applied to, and/or formed during use on, the insulating material over which the discharge takes place can afford some or all of the desirable leakage resistance. Where mica is used as the insulating material, colloidal graphite may be burned, as by an applied flame, on to the mica surface before the plug is connected for use. A resistor is, however, desirable to protect the apparatus, for example, should it be operated with no spark plug.

In some cases, however, for example, when it is required to employ conventional high voltage type spark plugs of which the break down voltage under normal ground level conditions may be several times that of the discharging gap, a considerably higher voltage is required to initiate a discharge at a spark plug than is required to maintain such discharge, but such high discharge-initiating voltage may, in general be of very brief duration compared with the duration of the discharge as a whole so that the greater part of the energy transmitted to a spark plug may be at the lower voltage which need be only just sufficient to maintain the discharge.

The auxiliary or suppressor condenser employed as above set forth to ensure rapid extinction of the charging gap may be utilised, with or without a small series inductance as above set forth, for providing a high discharge-initiating voltage, and according to a further feature of the invention the auxiliary or suppressor condenser is connected to supply energy to the spark plug lead via a third spark gap, whereby the discharge at a spark plug is initiated at relatively high voltage by energy from the small suppressor condenser, to be maintained by energy from the charge accumulating condenser at a lower voltage corresponding to that required to break down the discharging gap when there is already a discharge at the plug. Some series inductance in the discharging circuit is, however, desirable if only to limit the peak value of the discharge through the discharging gap.

In such a case, particularly when a surface discharge plug as above set forth is used, energy may be fed from the auxiliary or suppressor condenser via the third gap directly to the spark plug lead. Alternatively, however, particularly when a conventional high voltage plug is used, a third spark gap of which the break down voltage is not substantially less than that of the charging gap may be connected in series with the primary winding of a high frequency transformer across the auxiliary condenser, the secondary winding of the transformer being connected in series with the discharging gap between the latter and the charge accumulating condenser, so that when the voltage of the charge on the auxiliary condenser becomes instantaneously high enough the third spark gap breaks down and the resulting high frequency voltage induced in the transformer secondary winding is effectively added to the voltage of the charge on the charge accumulating condenser.

Figures 1, 2, 3 and 4 of the accompanying drawings are circuit diagrams showing components and connection of four typical high intensity ignition arrangements according to the invention, a spark plug and an induction coil being shown connected therewith in each case;

Figure 5 being a fragmentary view showing the arrangement of the electrodes and insulation of a spark plug.

In each of the four arrangements shown, a conventional vibrator operated induction coil is employed of the type commonly used for starting aircraft engines. The secondary winding 11 only of this coil is shown in Figures 2, 3 and 4; the primary winding being shown at 12; the vibrating reed at 13, contact shunting condenser at 14, an exciting battery at 15 and a manual "on-off" switch at 16 only in Figure 1. In each case, the self-capacity of the secondary winding 11 is indicated by broken lines as a condenser 17, "input" leads at 11a, a relatively high voltage charging spark gap at 18, a charge accumulating condenser at 19, a relatively low voltage discharging spark gap at 20, a spark plug lead at 20a, a spark plug at 21, shunt resistance and capacity associated with the plug lead 20a at 22 and 23, respectively, an auxiliary condenser and series resistance connected across the induction coil 11 at 24 and 25, respectively, and a resistance connected in series in the charging circuit of the charge accumulating condenser 19 at 26, whilst in Figure 1, a small inductance connected in series in both said charging circuit and in the discharging circuit of the condenser 19 is indicated at 27. Both the spark gaps 18 and 20 are of known enclosed and sealed type for aircraft use, the charging gap 18 at least preferably comprising electrodes composed of sintered nickel and alumina enclosed in hydrogen gas.

The arrangement of Figure 1 is intended for use with a low voltage spark plug 21 of a type comprising substantial inner and outer electrodes, which by virtue of their size are more resistant to the effects of erosion than the wire-like electrodes of conventional high voltage type plugs, which define between them an annular space filled with insulating material presenting an annular surface, substantially flush with the "ends" of the electrodes, over which surface the discharge occurs, the voltage required to initiate a discharge across this plug when operating, with a carbon deposit bridging the annular insulation surface, under normal ground level conditions, being of the order of two kilovolts or less. It

is found that where the insulating material of such a plug is mica and is tightly compressed between the inner and outer electrodes and where there is a deposit of carbon over the annular mica surface, the mica becomes eroded in use to a less extent than the metal of the electrodes, so that the plug has a long useful life.

The relatively high voltage charging gap 18 is such as to break down when the voltage across it is two or more times the voltage required to break down the discharging gap 20 and the break down voltage of the latter is of the same order as that required to initiate a discharge at the plug 21 under normal operating conditions.

It will be observed that the effective or charging impulses induced in the coil 11 are all of the same polarity corresponding to the "breaking" of the vibrator contacts and that the intervening impulses corresponding to "making" of said contacts are of opposite polarity and at a much lower voltage. The voltage of each effective or charging impulse is applied across the charging gap 18 by way of the charge accumulating condenser 19 and the small series inductance 27.

Each time the voltage across the charging gap 18 reaches a given value dependent upon the characteristics of the latter, said gap 18 breaks down and the charge accumulating condenser 19 receives a charging impulse. Owing to the self-capacity 17 of the coil 11 there is a transient flow of high frequency current through the charging gap 18 as the energy stored by said self-capacity 17 discharges. The capacity of the charge accumulating condenser 19 is so great as to constitute virtually a short-circuit at the high frequencies involved but the characteristics of the small series inductance 27 are such that the latter offers substantial impedance at said high frequencies, and thus, during the brief duration of each discharge of the self-capacity 17, there is developed across the inductance 27 a transient voltage which is effectively added to the voltage of the accumulated charge of the condenser 19.

The voltage developed across the series connected inductance 27 and the charge accumulating condenser 19 is applied, via the shunt resistance and condenser 22 and 23 and the spark plug 21, across the discharging gap 20, but only when the accumulated charge voltage of the condenser 19 has been built-up (as a result of a series of successive charging impulses from the coil 11, each breaking down the charging gap 18 and adding its quota to the charge of the condenser) to a value which plus the effectively added transient high frequency voltage developed (each time the charging gap 18 is broken down) across the small series inductance 27, reaches a sufficiently high value, will the discharging gap 20 break down, whereupon the charge accumulating condenser 19 discharges via the discharge gap 20 and the spark plug 21. The resistance 22 effectively shunts the spark plug 21 and thus reduces the maximum voltage required to a value much nearer the break down voltage of the discharge gap 20 than to the arithmetical sum of the break down voltages of said gap 20 and of the plug 21.

Although it is desirable for reasons of safety, e. g. in case the apparatus should be operated without a spark plug connected, that the resistance 22 should be comprised, in part at least, by an actual resistor connected as shown, this resistance can be comprised by a semi-conductive surface or discharge path between the spark plug electrodes. The plug illustrated by Figure 5 of

the drawings has a substantial solid cylindrical central electrode 51 between which and a substantial hollow cylindrical outer electrode 52 is compressed tightly an annular insulating body 53 of mica, the end faces of said electrodes 51 and 52 and of the mica insulating body 53 being substantially flush with one another. With such a spark plug the semi-conductive surface or discharge path can be comprised by a deposit applied to, or formed during operation, upon the end face of the mica insulating body 53 as indicated at 54. Such a deposit may be formed by burning colloidal graphite, as by an applied flame, on to the end surface of the mica insulating body 53.

The amount of transient high frequency current which flows in the inductance 27 each time the charging gap 18 breaks down is dependent on the characteristics of said inductance 27 and on the value of the self-capacity 17, and additional capacity may, if desired, be connected in shunt across the coil 11. The high frequency current is also dependent on the resistance of the circuit in which it flows. In Figure 1 the variable resistor 26 serves for final adjustment of the high frequency current and, therefore, of the transient high frequency voltage across the inductance 27 as required.

It will be observed that, in use, the voltage applied across the input leads 11a by the coil 11 will decline and may even, due to the subsequent "make" operation of the reed 13, change polarity before the charging gap 18 is extinguished, and before the charge period of the charge-discharge cycle of the condenser 19 is complete, and that the reverse voltage so produced across the charging gap 18 may be sufficient to maintain the latter broken down (i. e. conductive) and allow substantial discharge of the condenser 19 to take place reversely through the charging gap 18. The values of the auxiliary condenser and its series resistance 25 connected across the coil 11, which are not critical in any particular case, are such, however, that the voltage at the coil side or electrode of the charging gap 18 will be maintained long enough after each effective impulse from the coil 11 to ensure the rapid extinction of the gap 18 as the coil voltage declines and then changes polarity and that the opposite polarity "make" voltage of the coil 11 will be decreased so that said gap 18 will not have any appreciable voltage developed across it at any time adding to the voltage across the charge accumulating condenser, and thus opportunity for discharge of the charge accumulating condenser reversely through the charging gap 18 is greatly reduced or eliminated.

Although the efficiency of the arrangement of Figure 1 is increased by the transient high frequency voltage developed across the small series inductance 27 due to the prevention or reduction thereby of corona and/or brush discharge in the gap 20, this inductance is not essential and may be omitted. In that case, however, the inclusion of a small series inductance in the discharging circuit alone is desirable, if only to limit the peak value of the discharge current, and so protect the discharging gap 20. A series inductance in the discharging circuit alone will act in conjunction with the capacity 23 associated with the spark plug lead to augment the voltage developed at the plug 21. An appropriate small series inductance at 27, however, is clearly preferable because in this position it will serve all three purposes.

The arrangement of Figure 1 will operate satisfactorily with relatively large values of capacity at 23 so that it is quite practicable to include a switch in the plug lead so that a single arrangement may be used, for example, for starting or restarting a number of engines in succession, the capacity at 23 being dependent upon the lengths of the leads and upon the switch employed.

The arrangement of Figure 2 is intended for use where it is desired that each discharge at the plug should be initiated at high voltage and then maintained by energy at a lower voltage from the charge accumulating condenser 19. As transient high frequency voltages superimposed upon the charge voltage of the charge accumulating condenser 19 are not now required the small inductance 27 is omitted and two small series inductances 27a and 27b in the discharging circuit alone are employed. Otherwise the arrangement is the same as that of Figure 1 except that a third spark gap 30 is connected between the junction of the auxiliary condenser 24 with the series resistance 25 and the junction of the two small inductances 27a and 27b. The break down voltage of this third gap 30 is of the same order as that of the charging gap 18 and the latter and also the break down voltage of the gap 20 may be of the same order as in Figure 1. In operation, the voltage of the charge on the auxiliary condenser 24 reaches a value high enough to break down the third gap 30 before the voltage of the accumulated charge on the condenser 19 is high enough to break down the discharging gap 20. The breaking down of the third gap 30 is accompanied by a discharge of energy from the auxiliary condenser 24 at the plug 21 and approximately at the same time the discharging gap 20 is also broken down, whereupon the discharge at the plug 21 is maintained by energy from the charge accumulating condenser 19 at the lower voltage than that at which said discharge is initiated by energy from the auxiliary condenser 24. The maximum voltage of the charge on the auxiliary condenser 24, and, therefore, the plug discharge-initiating voltage are dependent inter alia on the value of the series resistor 25 which is chosen appropriately in each particular case.

The arrangement of Figure 3 is also intended for use where it is desired that each plug discharge should be initiated at a higher voltage than the maximum voltage of the accumulated charge of the condenser 19. In this case the third gap 30 has a similar or higher break down voltage than the charging gap 18 and is connected in series with the primary winding 31 of a step-up high frequency transformer across the auxiliary condenser 24, and the secondary winding 32 of the transformer is connected in the discharging circuit of the charge accumulating condenser 19 (e. g., as shown), between the latter and the discharging gap 20. The secondary winding 32, incidentally, performs the same functions in the discharge circuit as the inductances 27 of Figure 1, 27a of Figure 4, and 27a and 27b of Figure 2, which, as such, are omitted from the Figure 3 arrangement. In operation, the third gap 30 breaks down under the voltage of the charge on the auxiliary condenser 24 (which in this case is of somewhat greater capacity than in the case of Figure 1) before the voltage of the accumulated charge on the condenser 19 is sufficient, of itself, to cause the discharging gap 20 to break down. The stepped up voltage con-

sequently induced in the high frequency transformer secondary winding 32 is applied to the discharging gap 20 and plug 21 and breaks down both the latter and the discharge therethrough is continued by energy from the charge accumulating condenser 19 after the energy from the auxiliary condenser 24 has been dissipated.

In both Figures 2 and 3 the third gap 30 is of known enclosed and sealed type, preferably like the charging gap 18.

Arrangements such as that of Figure 2 are intended for use with low voltage spark plugs and arrangements such as that of Figure 3 are intended for use with high voltage spark plugs, at 21, but the arrangement of Figure 3 may be used for high or low voltage spark plugs.

It will be understood that the utilisation of the auxiliary condenser 24 to obtain a high plug discharge-initiating voltage, as in Figures 2 and 3, does not appreciably, or at all, impair its operation to reduce the interelectrode voltage of the charging gap 18, provided that the capacity of the auxiliary condenser 24 is chosen appropriately in each particular case. The capacity of the condenser 24 will in all cases, be many times less than that of the charge accumulating condenser 19.

The arrangement of Figure 4 is a modification of Figure 1 in which the series resistance 25 via which the auxiliary condenser 24 is connected across the induction coil 11 is in series with the charging circuit of the charge accumulating condenser 19. For satisfactory operation the value of the resistance 25 of Figure 4 must be many times less but the resistance 26 of Figure 4 must be many times greater than in Figs. 1, 2 or 3. In view of the inclusion of relatively high resistance at 26 the use of series inductance (such as 17, Figure 1) to afford transient high frequency voltages is not feasible and series inductance 27a as in Figure 2 is employed instead. Also the charge received by the charge accumulating condenser 19 at each effective impulse from the induction coil 11 is reduced and an arrangement such as Figure 4 cannot, therefore, provide so many spark plug discharges, having the same energy, per second as arrangements such as Figure 1. Moreover, due to the absence of an inductance as at 27 Figure 1, pre-break down corona and brush discharges may occur across the discharging gap 20. Arrangements such as Figure 4 are intended for use where high efficiency is not required.

In all the arrangements shown a resistance 28 of which the value is so high that it has negligible effect upon the performance is connected across the charge accumulating condenser 19 to ensure that the latter becomes discharged when the apparatus is not in use. In some cases two or more coils 11 and corresponding charging gaps 18 may be connected in parallel to charge a single charge accumulating condenser 19.

Using a conventional vibrator operated "booster coil" as illustrated, such as is commonly employed to provide a continuous series of sparks, one per operation of the vibrator, for starting piston type aircraft engines, the following values for the various circuit components have been found to give satisfactory operation of the four arrangements illustrated, an output of some 12 Joules once per second (i. e. 12 watts) having been obtained from the condenser 19 for an input of 1.8 amperes at 24 volts in the case of Figure 1 when the booster coil vibrator operates about 500 times per minute.

	Fig. 1	Fig. 2	Fig. 3	Fig. 4
Inductance of coil 11 in Henries.....	4 to 6	4 to 6	4 to 6	4 to 6
Capacity 17 in Picofarads.....	50 to 100	50 to 100	50 to 100	50 to 100
Break down potential of gap 18 in Kilovolts.....	5.4 to 5.8	5.4 to 5.8	5.4 to 5.8	5.4 to 5.8
Capacity of condenser 19 in Microfarads.....	5.5 to 6	5.5 to 6	5.5 to 6	5.5 to 6
Break down potential of gap 20 in Kilovolts.....	2.4	2	2	2
Capacity of condenser 24 in Picofarads.....	1000	1000	2000	1000
Resistance 25 in Kilohms.....	85 to 95	30 to 40	20	1 to 4
Resistance 26 in Kilohms.....	1 to 2	1 to 2	1 to 2	10 to 20
Inductance 27 in Microhenries.....	5-7			
Resistor at 22, Kilohms.....	50 to 60	100	100	50 to 60
Permissible capacity at 23 in Picofarads.....	100 to 1000	100 to 500	100 to 300	100 to 1000
Maximum output, Kilovolts.....	3	6	10	3
Break down potential of gap 30 in Kilovolts.....		5.5	7.0	
Inductance 27a in Microhenries.....		5		5 to 7
Inductance 27b in Microhenries.....		5		
Inductance ratio of transformer 31.32.....			5 to 10 greater than 0.6	
Coupling of transformer 31.32.....				

Whilst a spark plug, such as that illustrated by Figure 5, having electrodes spaced by insulation presenting a semi-conductive discharge path between said electrodes, and especially one having a substantial electrodes between which mica insulation is tightly compressed and presents a treated surface, or a deposit thereon, as a semi-conductive discharge path, is beneficial for use with or as part of ignition apparatus according to the invention, it has been found that such a plug is beneficial in other applications.

It is, therefore, a feature of the invention to provide electrical ignition apparatus comprising a condenser, such as 19, a charging circuit for connection with a source of charging voltage and from which dependent upon the voltage source employed in any particular case, any or all of the gap 18, the condenser 24, the resistances 25 and 26 and inductance 27 of Figure 1 may be omitted, and a discharging circuit comprising a spark gap and a condenser, such as 20 and 21 Figure 1, connected in series with one another, the spark plug having electrodes, such as 51 and 52 Figure 5, spaced by insulation, such as 53 Figure 5, presenting between said electrodes a semi-conductive discharge path, such as 54 Figure 5, which may be comprised by a carbon or other deposit.

It is also a feature of the invention to provide for use in electrical ignition apparatus a spark plug comprising substantial inner and outer electrodes, such as 51 and 52 Figure 5, and mica insulation, such as 53 Figure 5, which is compressed tightly between said electrodes and has a deposit, such as 54 Figure 5, of carbon or other material on an exposed surface thereof providing a semi-conductive discharge path between the electrodes.

The semi-conductive discharge path, such as 54 Figure 5, may be formed by burning colloidal graphite on to an exposed surface of the insulation.

The compression of mica insulation, such as 53 Figure 5, between inner and outer electrodes, such as 51 and 52 Figure 5, may be effected in any known or convenient manner, for example, by placing the mica, such as 53, within an internally slightly tapering external electrode, such as 52, and then driving an externally slightly tapering internal electrode, such as 51, into position within it. It is found that by having mica insulation tightly compressed between substantial electrodes the mica becomes eroded by repeated discharge via the semi-conductive path over the surface of the mica in use, to a less extent than do the electrodes so that the improved spark plug has a long useful life.

We claim:

1. Electrical ignition apparatus for use with an induction coil comprising a charge accumulating condenser, a charging circuit connected therewith including a relatively high voltage charging spark gap and input leads for connection with an induction coil, and, a discharging circuit connected with the charge accumulating condenser including a spark plug lead and a relatively low voltage-discharging spark gap, whereby in operation the charge accumulating condenser receives from an induction coil with which the input leads are connected and via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulated charge thus built up on the condenser becomes sufficiently high said condenser discharges via the discharging gap, means being provided for reducing the potential difference obtaining between the electrodes of the charging gap whereby it is ensured that said gap is extinguished each time the induction coil voltage declines and then changes polarity and opportunity for discharge of the charge accumulating condenser reversely through the charging gap is reduced.

2. Electrical ignition apparatus for use with an induction coil comprising a charge accumulating condenser, a charging circuit connected therewith including a relatively high voltage charging spark gap and input leads for connection with an induction coil, and, a discharging circuit connected with the charge accumulating condenser including a spark plug lead and a relatively low voltage-discharging spark gap, whereby in operation the charge accumulating condenser receives from an induction coil with which the input leads are connected and via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulated charge thus built up on the condenser becomes sufficiently high said condenser discharges via the discharging gap, there being connected in the charging and discharging circuits in series with the charge accumulating condenser a small inductance of such uncritical value in any particular case that in operation each time the charging gap breaks down a transient high frequency voltage is developed across said small inductance by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil connected to the input leads and any added shunt capacity, whereby the accumulated charge voltage required to break down the discharging

gap is made smaller and pre-break down corona and brush discharge losses in said gap are reduced, said small inductance also having the effect of limiting the peak discharge current through the discharging gap and acting in conjunction with capacity associated with the spark plug lead to augment the voltage produced at a spark plug with which the latter is connected.

3. Electrical ignition apparatus as claimed in claim 2, wherein series resistance is included in the charging circuit for the purpose of controlling the value of the transient high frequency current and so also of the transient high frequency voltage developed across the small series inductance.

4. Electrical ignition apparatus as claimed in claim 1, wherein there is connected in the charging and discharging circuits in series with the charge accumulating condenser a small inductance of such uncritical value in any particular case that in operation each time the charging gap breaks down a transient high frequency voltage is developed across said small inductance by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil connected to the input leads and any added shunt capacity, whereby the accumulated charge voltage required to break down the discharging gap is made smaller and pre-break down corona and brush discharge losses in said gap are reduced, said small inductance also having the effect of limiting the peak discharge current through the discharging gap and acting in conjunction with capacity associated with the spark plug lead to augment the voltage produced at a spark plug with which the latter is connected.

5. Electrical ignition apparatus as claimed in claim 4, wherein series resistance is included in the charging circuit for the purpose of controlling the value of the transient high frequency current and so also of the transient high frequency voltage developed across the small series inductance.

6. Electrical ignition apparatus for use with induction coil comprising a charge accumulating condenser, a charging circuit connected therewith including a relatively high voltage charging spark gap and input leads for connection with an induction coil, and a discharging circuit connected with the charge accumulating condenser including a spark plug lead and a relatively low voltage discharging spark gap, whereby in operation the charge accumulating condenser receives from an induction coil with which the input leads are connected and via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulated charge thus built up on the condenser becomes sufficiently high said condenser discharges via the discharging gap, there being connected across the input leads via a series resistance a small auxiliary condenser, of which latter and said series resistance the values are uncritical, whereby it is ensured that the discharging spark gap is extinguished each time the induction coil voltage declines and then changes polarity and opportunity for the charge accumulating condenser to discharge reversely through the charging gap is reduced.

7. Electrical ignition apparatus as claimed in claim 6, wherein there is connected in the charging and discharging circuits in series with the charge accumulating condenser a small inductance of such uncritical value in any particular

case that in operation each time the charging gap breaks down a transient high frequency voltage is developed across said small inductance by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil connected to the input leads and any added shunt capacity, whereby the accumulated charge voltage required to break down the discharging gap is made smaller and pre-break down corona and brush discharge losses in said gap are reduced, said small inductance also having the effect of limiting the peak discharge current through the discharging gap and acting in conjunction with capacity associated with the spark plug lead to augment the voltage produced at a spark plug with which the latter is connected.

8. Electrical ignition apparatus as claimed in claim 7, wherein series resistance is included in the charging circuit for the purpose of controlling the value of the transient high frequency current and so also of the transient high frequency voltage developed across the small series inductance.

9. Electrical ignition apparatus as claimed in claim 6, wherein a small inductance is connected in series in the discharging circuit and a third spark gap, of which the break down voltage is of the same order as that of the charging gap, is connected between the small auxiliary condenser and the spark plug lead at that side of said small inductance remote from the charge accumulating condenser, whereby in operation each discharge at a spark plug connected to the spark plug lead is initiated at relatively high voltage by energy from the small auxiliary condenser and break down of the discharging gap and discharge of the charge accumulating condenser follow.

10. Electrical ignition apparatus as claimed in claim 6, wherein a high frequency transformer having primary and secondary windings and a third spark gap of which the break down voltage is not substantially less than that of the charging gap are connected with said third gap and the transformer primary winding in series with one another across the small auxiliary condenser and the transformer secondary winding in series with the discharging spark gap between the latter and the charge accumulating condenser.

11. Electrical ignition apparatus comprising an induction coil, a spark plug having electrodes spaced by insulation presenting a semi-conductive surface as a discharge path between said electrodes, a charge accumulating condenser, a charging circuit connected with said condenser including a relatively high voltage charging spark gap and input leads connected with the induction coil, and, a discharging circuit connected with the charge accumulating condenser including a relatively low voltage discharging spark gap and a spark plug lead connected with the spark plug, whereby in operation the charge accumulating condenser receives from the induction coil via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulated charge thus built up on the condenser becomes sufficiently high said condenser discharges via the discharging gap and the spark plug, means being provided for reducing the potential difference obtaining between the electrodes of the charging gap whereby it is ensured that said gap is extinguished each time the induction coil voltage declines and then charges polarity and opportunity for discharge

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of the charge accumulating condenser reversely through the charging gap is reduced.

12. Electrical ignition apparatus as claimed in claim 11, wherein there is connected in the charging and discharging circuits in series with the charge accumulating condenser a small inductance of such uncritical value in any particular case that in operation each time the charging gap breaks down a transient high frequency voltage is developed across said small inductance by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil connected to the input leads and any added shunt capacity, whereby the accumulated charge voltage required to break down the discharging gap is made smaller and pre-break down corona and brush discharge losses in said gap are reduced, said small inductance also having the effect of limiting the peak discharge current through the discharging gap and acting in conjunction with capacity associated with the spark plug lead to augment the voltage produced between the spark plug electrodes.

13. Electrical ignition apparatus comprising an induction coil, a spark plug having electrodes spaced by insulation presenting a semi-conductive surface as a discharge path between said electrodes, a charge accumulating condenser, a charging circuit connected with said condenser including a relatively high voltage charging spark gap and input leads connected with the induction coil, and, a discharging circuit connected with the charge accumulating condenser including a relatively low voltage discharging spark gap and a spark plug lead connected with the spark plug, whereby in operation the charge accumulating condenser receives from the induction coil via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulated charge thus built up on the condenser becomes sufficiently high said condenser discharge via the discharging gap and the spark plug, there being connected across the input leads via a series resistance a small auxiliary condenser, of which latter and said series resistance the values are uncritical, whereby it is ensured that the discharging spark gap is extinguished each time the induction coil voltage declines and then changes polarity and opportunity for the charge accumulating condenser to discharge reversely through the charging gap is reduced.

14. Electrical ignition apparatus as claimed in claim 13, wherein there is connected in the charging and discharging circuits in series with the charge accumulating condenser a small inductance of such uncritical value in any particular case that in operation each time the charging gap breaks down a transient high frequency voltage is developed across said small inductance by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil connected to the input leads and any added shunt capacity, whereby the accumulated charge voltage required to break down the discharging gap is made smaller and pre-break down corona and brush discharge losses in said gap are reduced, said small inductance also having the effect of limiting the peak discharge current through the discharging gap and acting in conjunction with capacity associated with the spark plug lead to augment the voltage produced between the spark plug electrodes.

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15. Electrical ignition apparatus as claimed in claim 14, wherein series resistance is included in the charging circuit for the purpose of controlling the value of the transient high frequency current and so also of the transient high frequency voltage developed across the small series inductance.

16. Electrical ignition apparatus as claimed in claim 13, wherein a small inductance is connected in series in the discharging circuit and a third spark gap, of which the break down voltage is of the same order as that of the charging gap, is connected between the small auxiliary condenser and the spark plug lead at that side of said small inductance remote from the charge accumulating condenser, whereby in operation each discharge at the spark plug is initiated at relatively high voltage by energy from the small auxiliary condenser and break down of the discharging gap and discharge of the charge accumulating condenser follow.

17. Electrical ignition apparatus as claimed in claim 13, wherein high frequency transformer having primary and secondary windings and a third spark gap of which the break down voltage is not substantially less than that of the charging gap are connected with said third gap and the transformer primary winding in series with one another across the small auxiliary condenser and the transformer secondary winding in series with the discharging spark gap between the latter and the charge accumulating condenser.

18. Electrical ignition apparatus as claimed in claim 11, wherein the spark plug has substantial inner and outer electrodes and mica insulation compressed tightly between said electrodes to prevent erosion of the mica, the exposed surface of the mica being treated to provide a semi-conductive discharge path between the electrodes.

19. Electrical ignition apparatus as claimed in claim 13, wherein the spark plug has substantial inner and outer electrodes and mica insulation comprised tightly between said electrodes to prevent erosion of the mica, the exposed surface of the mica being treated to provide a semi-conductive discharge path between the electrodes.

20. Electrical ignition apparatus as claimed in claim 19, wherein there is connected in the charging and discharging circuits in series with the charge accumulating condenser a small inductance of such uncritical value in any particular case that in operation each time the charging gap breaks down a transient high frequency voltage is developed across said small inductance by the transient high frequency current which then flows in the charging circuit due to the self-capacity of the induction coil connected to the input leads and any added shunt capacity, whereby the accumulated charge voltage required to break down the discharging gap is made smaller and pre-break down corona and brush discharge losses in said gap are reduced, said small inductance also having the effect of limiting the peak discharge current through the discharging gap and acting in conjunction with capacity associated with the spark plug lead to augment the voltage produced at a spark plug with which the latter is connected.

21. Electrical ignition apparatus as claimed in claim 20, wherein series resistance is included in the charging circuit for the purpose of controlling the value of the transient high frequency current and so also of the transient high fre-

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quency-voltage developed across the small series inductance.

22. Electrical ignition apparatus comprising a condenser, a charging circuit connected with said condenser, and a discharging circuit connected with said condenser, said discharging circuit including an enclosed and sealed type spark gap and a spark plug connected in series with one another, and the spark plug having electrodes spaced by insulation presenting a semi-conductive discharge path between said electrodes.

23. Electrical ignition apparatus as claimed in claim 22, wherein the spark plug has substantial inner and outer electrodes and mica insulation which is compressed tightly between said electrodes and is treated at an exposed surface thereof to present the semi-conductive discharge path.

24. Electrical ignition apparatus as claimed in claim 23, wherein the semi-conductive discharge path is comprised by carbon on an exposed surface of the mica insulation of the spark plug.

25. Electrical ignition apparatus as claimed in claim 24, wherein the semi-conductive discharge path is formed by burning colloidal graphite on to an exposed surface of the mica insulation of the spark plug.

26. Electrical ignition apparatus for use with an induction coil arranged to have current impulses flow therethrough, said apparatus comprising a charge accumulating condenser, a charging circuit containing a charging spark gap, and means comprising resistance and capacitance for reducing the potential difference obtaining between the electrodes of the charging gap, whereby it is ensured that said gap is extinguished each time the induction coil voltage declines and then changes polarity, and a discharging circuit comprising an ignition device and including an inductance and associated sparking gap arrangement for controlling discharge through the discharge circuit.

27. Electrical ignition apparatus for use with an induction coil arranged to have current impulses flow therethrough, said apparatus comprising a charge accumulating condenser, a charging circuit containing a charging spark gap, and a discharging circuit comprising an ignition device and including an inductance and associated sparking gap arrangement for controlling discharge through the discharge circuit.

28. Electrical ignition apparatus for use with an induction coil arranged to have current impulses flow therethrough, said apparatus comprising a charge accumulating condenser, an induction coil, a charging circuit comprising a relatively high voltage charging spark gap connected in series relation to the coil and condenser, a discharging circuit connected across the charge accumulating condenser including a spark plug lead, a spark gap means and inductive means therein for controlling discharge through the discharge circuit, the charging spark gap permitting successive impulses from the coil to build up a charge in the accumulating condenser before the said discharge is established, and means comprising resistance and capacitance in the charging circuit for reducing the potential difference obtaining between the electrodes of the charging gap whereby it is ensured that said gap is extinguished each time the induction coil voltage declines and then changes polarity and opportunity for discharge of the charge accumulating condenser reversely through the charging gap is reduced.

29. Electrical ignition apparatus comprising an

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induction coil, a spark plug having electrodes spaced by insulation presenting a semi-conductive surface as a discharge path between said electrodes, a charge accumulating condenser, a charging circuit connected with said condenser including a relatively high voltage charging spark gap and input leads connected with the induction coil, and, a discharging circuit connected with the charge accumulating condenser including a relatively low voltage discharging spark gap and a spark plug lead connected with the spark plug, whereby in operation the charge accumulating condenser receives from the induction coil via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulated charge thus built up on the condenser becomes sufficiently high said condenser discharge via the discharging gap and the spark plug, there being connected across the input leads via a series resistance a small auxiliary condenser, of which latter and said series resistance the values are uncritical, whereby it is ensured that the discharging spark gap is extinguished each time the induction coil voltage declines and then changes polarity and opportunity for the charge accumulating condenser to discharge reversely through the charging gap is reduced, the spark plug having substantially inner and outer electrodes and mica insulation comprised tightly between said electrodes to prevent erosion of the mica, the exposed surface of the mica being treated to provide a semi-conductive discharge path between the electrodes, a small inductance connected in series in the discharging circuit and a third spark gap, of which the breakdown voltage is not substantially less than that of the charging gap, connected between the small auxiliary condenser and the spark plug lead at that side of said small inductance remote from the charge accumulating condenser, whereby in operation each discharge at a spark plug connected to the spark plug lead is initiated at relatively high voltage by energy from the small auxiliary condenser and break down of the discharging gap and discharge of the charge accumulating condenser follow.

30. Electrical ignition apparatus comprising an induction coil, a spark plug having electrodes spaced by insulation presenting a semi-conductive surface as a discharge path between said electrodes, a charge accumulating condenser, a charging circuit connected with said condenser including a relatively high voltage charging spark gap and input leads connected with the induction coil, and, a discharging circuit connected with the charge accumulating condenser including a relatively low voltage discharging spark gap and a spark plug lead connected with the spark plug, whereby in operation the charge accumulating condenser receives from the induction coil via the charging spark gap repeated unidirectional charging impulses corresponding to successive interruptions of the induction coil primary circuit and when the voltage of the accumulator charge thus built up on the condenser becomes sufficiently high said condenser discharge via the discharging gap and the spark plug, there being connected across the input leads via a series resistance a small auxiliary condenser, of which latter and said series resistance the values are uncritical, whereby it is ensured that the discharging spark gap is extinguished each time the induction coil voltage declines and then

changes polarity and opportunity for the charge accumulating condenser to discharge reversely through the charging gap is reduced, the spark plug having substantial inner and outer electrodes and mica insulation comprised tightly between said electrodes to prevent erosion of the mica, the exposed surface of the mica being treated to provide a semi-conductive discharge path between the electrodes, and a high frequency transformer having primary and secondary windings and a third spark gap of which the breakdown voltage is not substantially less than that of the charging gap being connected with said third gap and the transformer primary winding in series with one another across the small auxiliary condenser and the transformer secondary winding in series with the discharging spark gap between the latter and the charge accumulating condenser.

31. Electrical ignition apparatus comprising a condenser, a charging circuit connected with said condenser, and a discharging circuit connected with said condenser, said discharging circuit including an enclosed and sealed type spark gap and a spark plug connected in series with one

another, and the spark plug having electrodes spaced by insulation presenting a semi-conductive discharge path between said electrodes, the semi-conductive discharge path being comprised by a deposit upon the exposed surface of the insulation of the spark plug.

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