June 25, 1940. H. B. HOLTHOUSE 2,205,561

IGNITION SYSTEM AND MAGNETO THEREFOR

Original Filed Nov. 2, 1936 3 Sheets-Sheet 1

Fig. 1.

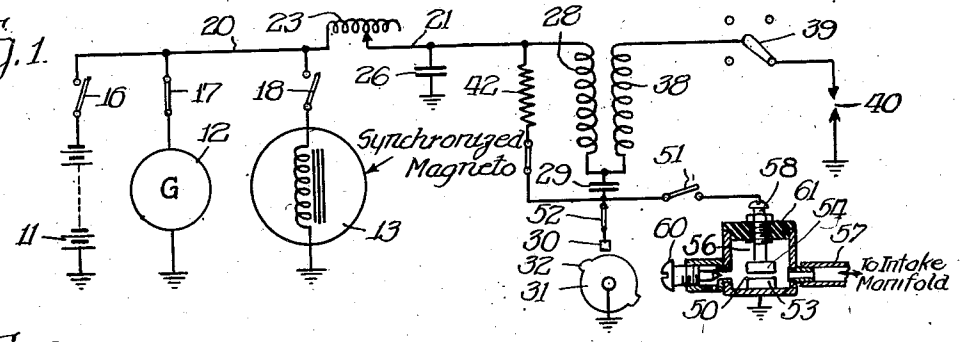
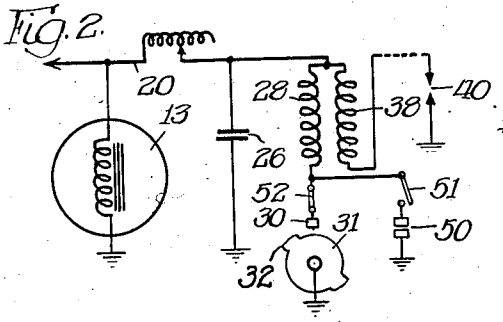


Fig. 2.



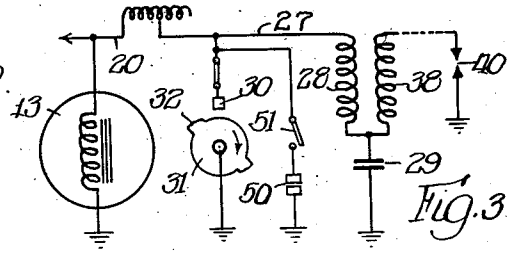
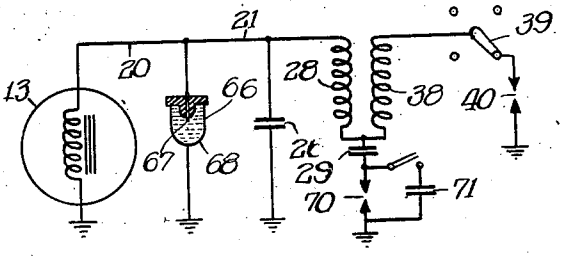


Fig. 3

Fig. 4



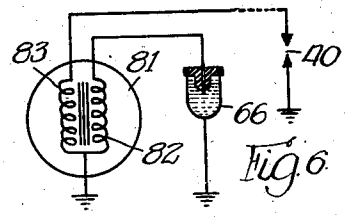
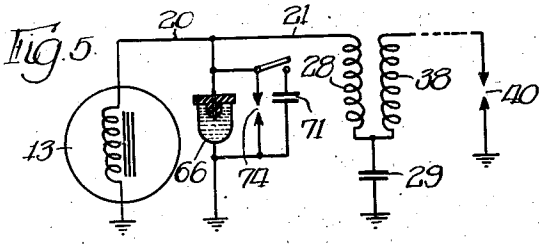


Fig. 6

Fig. 5



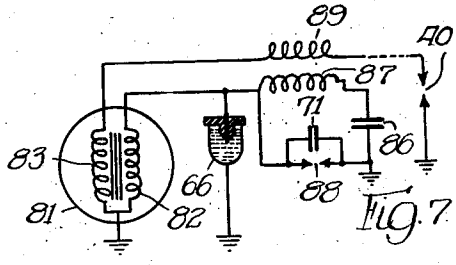


Fig. 7

Fig. 8

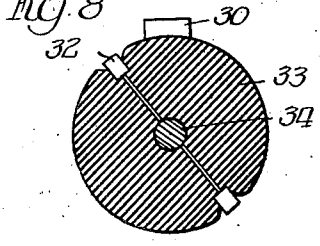


Fig. 9

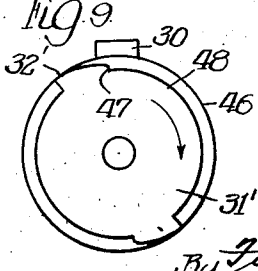


Fig. 10

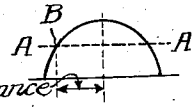
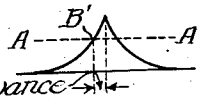


Fig. 11



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Fig. 12.

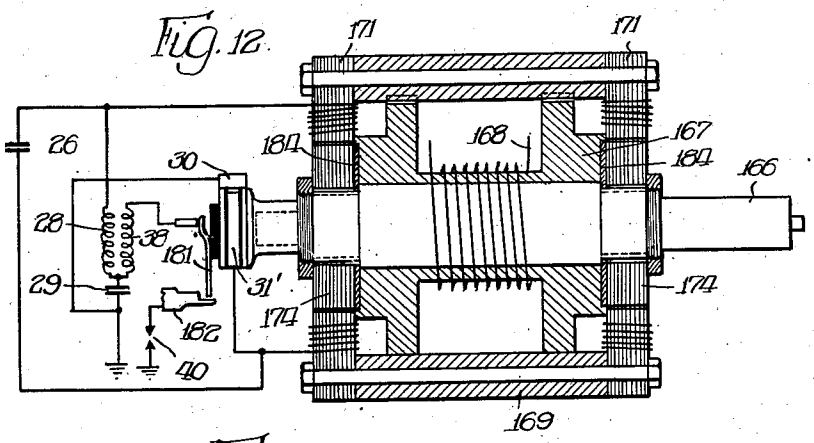


Fig. 13.

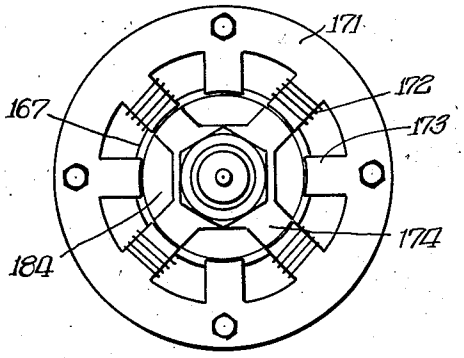


Fig. 14.

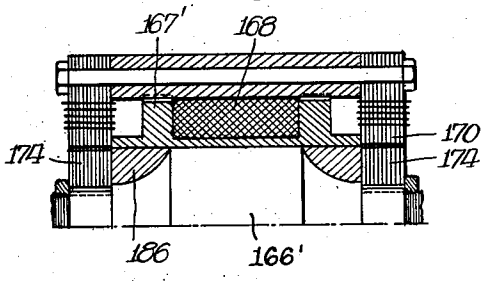
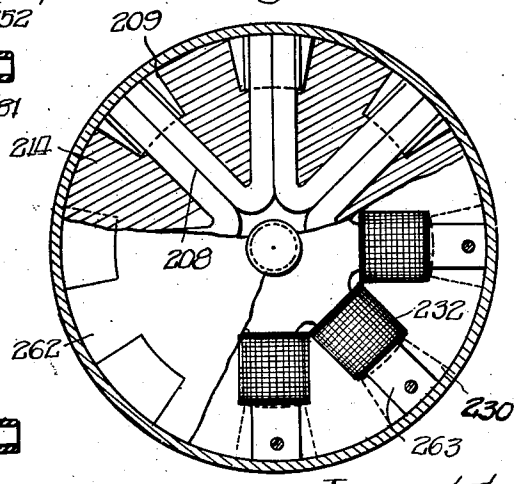


Fig. 21.



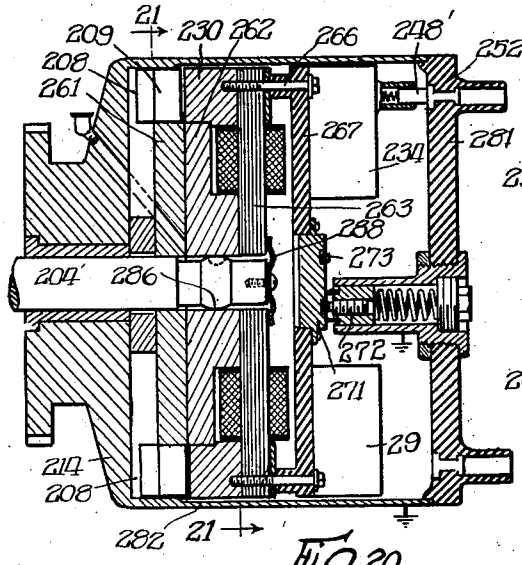


Fig. 20.

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Fig. 15.

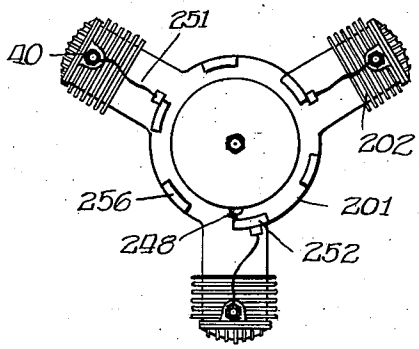


Fig. 16.

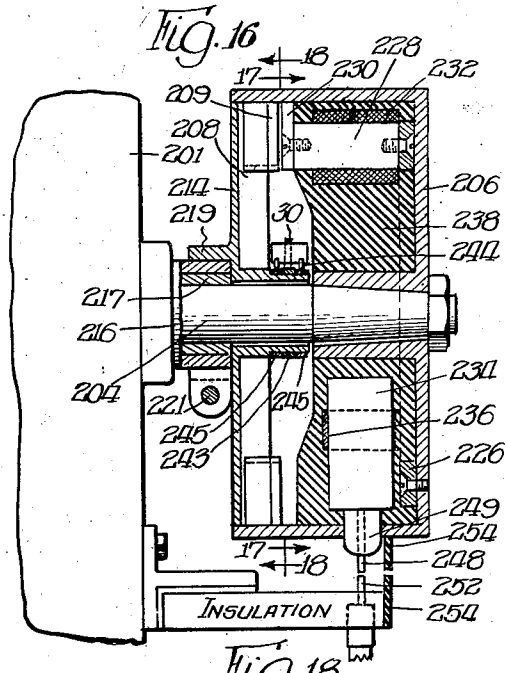


Fig. 17.

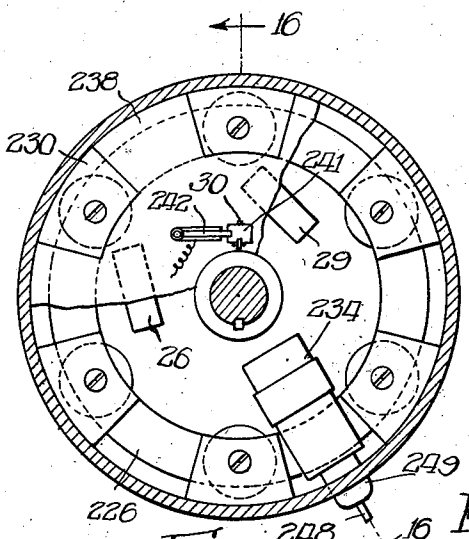


Fig. 18.

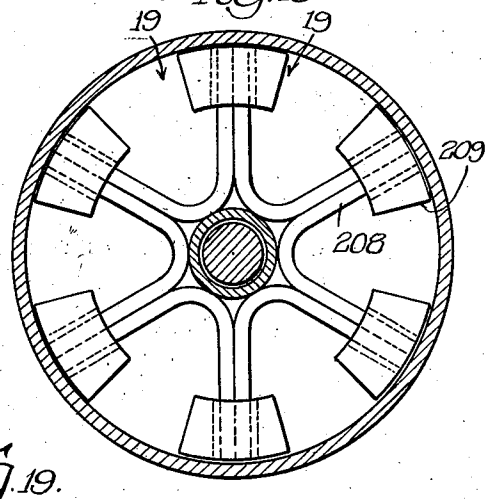


Fig. 19.

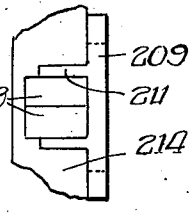
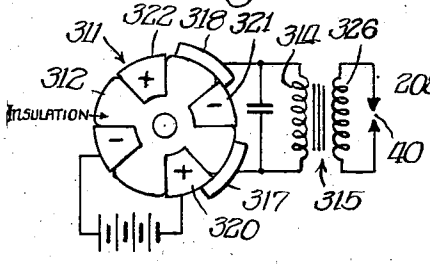


Fig. 22.



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Patented June 25, 1940 2,205,561

UNITED STATES PATENT OFFICE

2,205,561

IGNITION SYSTEM AND MAGNETO THEREFOR

Harry B. Holthouse, Chicago, Ill.

Application November 2, 1936, Serial No. 108,756
Renewed April 7, 1939

28 Claims. (Cl. 123—148)

This application relates to ignition systems and in some of its aspects it relates particularly to magnetos especially suitable for use in ignition systems. The invention is illustrated as embodying a number of modifications both as to the circuit and as to the magneto.

In nearly all instances the circuits illustrated are designed to produce a spark of high frequency oscillation as well as very high potential, both the high frequency oscillations and high potential being very advantageous in ignition systems. In one form of the invention which is illustrated in Fig. 1, the system may be operated from a magneto, a direct current generator or a high voltage battery. This system as well as those illustrated in Figs. 2 and 3 produces the ignition spark upon closing of a contact and continues to spark as long as the contact is closed. The continuing spark is, of course, very advantageous in starting and under any other conditions which make firing at the time of the initial spark uncertain.

The circuits here disclosed embody some of the features covered by my prior Patents Nos. 1,710,541 and 2,059,237, and application Serial No. 741,610, with the last two of which this application is copending.

When a magneto is used which is synchronized with the pistons, the circuits of Figs. 1, 2 and 3 may be used to produce automatic timing, that is, they may be used to cause the spark to occur earlier in the cycle of the engine as the speed of the engine increases, the advance being due to the fact that the voltage of the magneto increases as its speed increases.

The circuits of Figs. 4 to 7 are circuits involving a trip device such as an electrolytic interrupter. These circuits also include the feature of automatic timing in that the spark occurs whenever the current produced by the magneto reaches a predetermined value for which the electrolytic interrupter has been designed. As soon as the current exceeds this value, the electrolytic interrupter acts in a manner similar to the breaker contacts of a conventional ignition system to produce a high voltage for firing. The voltage may be either a kick (self-induced) voltage, or a voltage induced in a secondary coil, and this high voltage may be conducted directly to the spark plug or it may actuate a high frequency oscillating circuit which in turn produces a high frequency spark at the spark plug.

All forms of the magneto illustrated are designed to permit an extremely close clearance between the armature and field poles while avoiding the danger of trouble, which might be expected when rotating parts are used having such small clearance, by a bearing arrangement which has a diameter commensurate with the diameter between the poles of the rotor so that there will not be any material wear on the bearing. The magneto assembly also includes enough other parts of the ignition system so that the magneto rotor may act as a distributor, thus eliminating the separate distributor. In some instances the rotor includes enough parts of the ignition system to eliminate numerous connections between the rotor of the magneto and other parts of the ignition system.

The objects of the invention are to a large extent apparent from the foregoing brief discussion of the nature of the invention, but they may be summarized by stating that one object of the invention is to provide a better ignition system than any ignition systems heretofore known, except applicant's prior systems mentioned; and another object of the invention is to provide a better magneto than those heretofore known.

Additional objects and advantages will be apparent from the following description and from the drawings, in which:

Figs. 1 to 3 are various forms of ignition circuits involving a mechanical timer which either closes a circuit or narrows a gap to produce firing.

Fig. 1 shows a plurality of forms of sources of power, and a vacuum spark gap which may be in the other figures as well.

Figs. 4 to 7 are circuit diagrams showing a plurality of ignition systems each involving an electrolytic interrupter.

Fig. 8 is a sectional view showing one form of commutator or timer which may be used in the circuits of Figs. 1 to 3.

Fig. 9 illustrates a modified form of timer for use in Figs. 1 to 3, at least under certain conditions.

Figs. 10 and 11 are diagrams illustrating respectively a broad wave-form and a narrow wave-form.

Figs. 12 and 13 are sectional and end views of a rotating field magneto.

Fig. 14 is a fragmentary sectional view corresponding to Fig. 12, but showing a modified form of magneto.

Fig. 15 is an end view of an internal combustion engine, showing a flywheel magneto applied thereto.

Fig. 16 is a fragmentary view of the structure shown in Fig. 15, showing the magneto in section,

the section being substantially along the line 16—16 of Fig. 17.

Fig. 17 is a sectional view taken substantially along the line 17—17 of Fig. 16 partially broken away to show the internal arrangement of the parts.

Fig. 18 is a sectional view taken substantially along the line 18—18 of Fig. 16 to show the arrangement of field magnets.

Fig. 19 is a fragmentary view showing primarily the relationship of the pole faces to the permanent magnets. It is a view taken substantially along the line 19—19 of Fig. 18.

Fig. 20 is a sectional view through another form of magneto.

Fig. 21 is a sectional view taken at right angles thereto, approximately along the irregular line 21—21, successive portions being broken away for clarity; and

Fig. 22 is a diagrammatic representation of another ignition circuit and controller therefor.

Although this invention has been shown in numerous forms, it should be understood that it could also take many additional forms within the broad principles here disclosed. For the sake of clarity different aspects of the invention may first be considered separately even though they are all interrelated.

Circuits including timer contacts

Figs. 1 to 3 show three circuits involving timer contacts, although under certain circumstances the timer contacts may be replaced by a spark gap of constant width. However, when a timer is used involving contacts which close upon one another, a plurality of different sources of power may be used optionally. Thus Fig. 1 shows a high voltage battery 11, a direct current generator 12, and a magneto 13. Ordinarily only one of these would be supplied in a given ignition system, but they could all be provided for optional use in the same system, in which case switches 16, 17 and 18 would be provided to disconnect two of these sources of power while leaving the other one connected. Whichever one of these sources of power 11, 12 or 13 is connected to the ignition system will be connected to a wire 20 which is connected to wire 21 either directly or through a choke coil 23. It will be understood that each of the sources of power 11, 12 and 13 is also connected to ground as illustrated.

A condenser 26 is connected across the source of power (which we may assume to be the generator 12) by virtue of being connected between the wire 21 and ground. This condenser will be charged with whatever voltage is produced by generator 12. This condenser 26 also forms part of a primary high frequency oscillating circuit which is completed by wire 21, primary winding 28 of a high frequency transformer, condenser 29, contact or electrode 30, rotor 31, and ground. The rotor 31 may include raised contacts 32 or segments thereon which at the proper time for ignition engage the brush 30, being driven in synchronism with the motor. If there is to be no special provision for wave-form timing, the contacts 30 and 32 may comprise ordinary breaker points operated by a cam to close the points when a spark is desired, or they may comprise a commutator such as that illustrated in Fig. 8, in which the contact 30 rides on insulating segment 33 until a spark is desired, at which time the segment 32, connected to ground through the shaft 34, comes into contact with the contact 30.

In any event, when the contacts 30 and 32 close, the primary oscillating circuit already traced is formed. The high frequency oscillations flowing through primary coil 28 induce a high voltage in a secondary coil 38 which is connected through a distributor 39 to one point of an ignition spark gap 40 (the spark plug of a motor), which is connected to ground as shown. Thus the secondary oscillating circuit includes the secondary coil 38, the spark plug 40, and the condenser 29. The contacts 30 and 32 are in this circuit too, but they may be disregarded since they are assumed to be closed.

It will be observed that the condenser 29 is a condenser common to both the primary and the secondary oscillating circuits. This is an important feature in obtaining a very hot spark and is covered by one or more of my prior patents previously mentioned. Although it is preferred that this high frequency arrangement be used, it should be understood that other portions of the circuit are independent of it and may be used with other arrangements for transmitting a suitable voltage to the spark plug 40.

As long as the contacts 30 and 32 are in contact or so close that a spark will jump across them, the sparking at the spark plug 40 will continue, providing that the voltage supplied by the source of power remains sufficiently high. Thus with the direct current generator 12 or with the high voltage battery 11, the sparking could be of long duration. With the magneto 13, the voltage, being in wave-form, would die down, but nevertheless the magneto could be designed to supply an adequate voltage as long as may be desired.

As soon as the contacts 30 and 32 have separated enough to prevent sparking therebetween, the sparking at the plug 40 will cease. It should be observed, however, that should the condenser 29 be charged, it may not become fully discharged across the gap 40 or the contacts 30 and 32. A high charge on the condenser 29 when the contacts 30 and 32 next close might prevent the condenser 26 from discharging therethrough to start the oscillations. It is, therefore, desirable to provide an inductive resistance 42 or other suitable impedance connected as shown to serve as a drain for the condenser 29. The impedance should be high enough so as not to divert much of the oscillating current from the primary coil 28.

The sparking produced at the spark plug 40 is extremely hot. In fact, if the source of power supplies too much power, the points of the spark plug 40 may be melted. It may, therefore, be desirable to insert a choke 23 between the source of power and the wire 21, since such a choke coil, whether having an iron core or an air core, tends to decrease the heat of sustained sparking at the plug 40. This is apparently because the sustained sparking is not actually a continuous spark but rather a series of successive trains of sparks, each train resulting from a discharge of the condenser 26 after which it must be again charged. The choke coil 23 apparently retards the recharging of condenser 26. Whether this theory is sound or not, choke coil 23 does decrease the heat of a sustained spark at the plug 40. This apparently does not affect the voltage available for starting the spark since between successive closings of the contacts 30 and 32 there is adequate time for the condenser 26 to become fully charged in spite of the presence of choke 23.

No mention has been made at this time of the spark gap which may be connected into the circuit by the switch 51 since this switch is shown

open, and that gap is not necessary to the operation of the circuit.

The circuit of Fig. 2 is somewhat similar to the circuit of Fig. 1. Though it is probably very inferior thereto, it is capable of producing prolongated sparking. The magneto 13 has been shown, but the possible presence of the other source of power has been indicated by the arrow at the end of wire 20. The condenser 29 has been omitted and the condenser 26 is connected in both the primary and secondary oscillating circuits as well as being connected across the source of power. In this circuit the source of power charges the condenser 26, and when the contacts 30 and 32 close, the condenser 26 discharges through the primary coil 28 which induces voltages in the secondary coil 38, thus setting up oscillations in the secondary oscillating circuit including the secondary coil 38, the spark plug 40, ground, and the condenser 26.

It will be noted that in nearly all of the figures, the secondary circuit has been shown with a dotted line portion. This is merely a simplification to indicate that the distributor would ordinarily be included in the circuit.

Fig. 3 is also similar to Fig. 1, showing a magneto but indicating that there may be other sources of power. In this instance the condenser 29 is included, but the condenser 26 is omitted. The condenser 29 is permanently connected across the magneto 13 but has no primary oscillating circuit available until the contact 32 approaches the contact 30. When these contacts are closed, the primary oscillating circuit is completed and includes besides the condenser 29 the primary winding 28 of a high frequency transformer, the wire 27, contacts 30 and 32 and ground. The secondary circuit includes the condenser 29, the secondary winding 38, the spark plug 40 and ground. It will be observed that, since the condenser 29 is always included in a circuit through the magneto 13, the polarity of which reverses, the impedance 42 need not be provided for draining the condenser 29. Of course, if it were found that the impedance of the magneto was too high to drain the condenser 29, the impedance 42 could be added.

Wave-form timing

If in Figs. 1 to 3 the contacts 30 and 32 either instead of closing or before closing form a spark gap of the proper length for wave-form timing, wave-form timing may be provided when the magneto 13 is used, assuming that the wave-form of the magneto voltage is synchronized with the pistons. As each piston approaches or reaches the top of its cycle at the time when explosion is desired, the voltage produced by the magneto 13 will reach its maximum. The contacts 30 and 32 may be so adjusted that when the piston is at the top of its stroke, i. e. when the voltage is at its maximum, this voltage will be just enough at slow speeds to cause the condenser 26 to discharge across the contacts 30 and 32. As the engine speeds up, however, and the magneto with it, the voltage is increased so that a voltage adequate for discharge is reached earlier in the cycle. The result is that the discharge takes place before the piston reaches the top of its stroke, and the ignition is therefore advanced. This automatic wave-form timing is covered by my prior patents above mentioned. With some magnetos the wave-form might be quite broad as illustrated by Fig. 10 so that, if the line A—A represents the firing voltage, this voltage will be reached at the speed for which the diagrams are drawn at the point B which may be advanced by as much as sixty degrees. With a two-pole magneto this would represent sixty degrees in the revolution of the crank shaft. This would, of course, be too great an advance and even thirty degrees might be too great an advance ordinarily.

The advance can be controlled to that desired in several ways. One way is by changing the wave-form to that shown in Fig. 11 or to some other suitable wave-form. In Fig. 11 it is seen that the point B' at which the wave reaches the firing voltage is advanced only about twenty degrees.

Another manner of controlling the amount of advance due to increased voltage upon increased speed is by accurately varying the length of the gap. This can probably best be done by a gap including some such rotating element as shown in Fig. 9, in which the contact 30 rides on an insulating rim 46 and the rotor 31' has a specially shaped sparking or contact portion 32'. The shape is such that with the leading end 47 under the contact (or electrode) 30, the sparking distance is relatively wide, whereas as the rotor 31' advances, the shape of the portion 32' reduces the length of the sparking gap. It is obvious that, if a voltage sufficient to jump the narrow portion of the gap were reached at say thirty degrees advance, it would not be able to jump the gap because the gap at this time is wider. By carefully shaping the sparking portion 32' any desired advance may be provided for any given wave shape. It should also be observed that the spark portion 32' may be terminated at its front and rear edge by a sharp break so that beyond that portion the surface 48 of the rotor will be so far removed from the contact 30 that sparking will be prevented even with excessive motor speeds. This will positively limit the ignition to whatever maximum advance or maximum duration of spark may be desired.

Vacuum timing correction

With automatic timing, whether it be of the wave-form type above discussed or of the conventional governor type, there are some situations that are not fully provided for simply on the basis of engine speed. For example, if the timing is so regulated that at a given speed and with the throttle only moderately opened, the spark occurs at exactly the right time, it is likely to follow that if the throttle is fully opened and other conditions are maintained the same, the timing will appear to be advanced to the extent that the ignition will take place too quickly and knocking will result. This may be due to the fact that with the throttle fully opened more gas is taken into the cylinder and the compression is higher. In the past, attempts have been made to overcome this fault by moving the timer in a spark advancing direction in response to the vacuum of the intake manifold so that when the throttle is opened wide, the decreased vacuum retards the spark.

According to the present invention, this same effect of advancing the spark when the vacuum is high, and retarding it when the vacuum is low, is accomplished in a more simple manner. If the switch 51 in Fig. 1 is left closed and the switch 52 opened, or the controller 31 disregarded, the spark will occur whenever the voltage across gap 50 between a grounded electrode 53 and an adjustable electrode 54 is sufficient to cause a spark to jump the gap therebetween. In other words, disregarding other considerations, this gap will provide automatic wave-form timing. Accord-

ing to the present invention, however, this gap is enclosed in a vacuum chamber 56 which is connected by conduit 57 to the intake manifold. When the vacuum of the intake manifold is high, there will be a corresponding high vacuum within the chamber 56 which lowers the resistance of the gap 50, with the result that a spark will jump said gap more easily or at an earlier point on the wave of the magneto and hence an earlier time in the cycle of the engine.

The electrode 54 may be adjusted by turning the screw 58 to give proper timing under these conditions, and, if the wave-form of the magneto is proper for the particular engine, this timing will be correct for all speeds of the engine, assuming say an average throttle position at all speeds. If the throttle is opened wide, the tendency toward a quicker ignition is compensated for by a reduction of vacuum in the intake manifold and consequently in the chamber 56 which increases the resistance of the gap between electrodes 53 and 54, and hence retards the spark.

It is desirable that a spark gap have a more or less constant change of air and chiefly for this purpose the bleeder valve 60 may be provided so that the suction of the intake manifold will continually draw fresh air into the chamber 56. The bleeder valve 60 will also tend to regulate the vacuum in the chamber 56, especially if the conduit 57 should be somewhat constricted. Of course, in place of the bleeder valve 60 there may be a fixed small aperture or one or more of the walls of the chamber 56 may be formed of a porous material which will permit air to seep therethrough. Since the wall 61 is formed of an insulating material to insulate the electrode 54 from the metal portions of chamber 56, this wall 61 could very suitably be made of a porous material.

One advantage of the provision of a vacuum chamber 56 around the gap 50 is that the gap may be longer, and hence less subject to fouling. The vacuum will permit the spark to jump over a much longer gap than if the gap were in atmospheric pressure. Of course, the rotary gap formed by the electrodes 30 and 32' is hardly subject to fouling, but, if a fixed gap were to be used, it would be very desirable for it to be a vacuum gap. It should be explained that in the circuits of Figs. 1, 2 and 3 whenever wave-form automatic timing is provided (i. e., when a synchronized magneto is used), the controller 31' and the vacuum chamber 56 may both be used, normally being connected in parallel. This is especially true if the wave form is of such a desirable shape that compensation for it by shaping the contact 32' is unnecessary. In this case the contact 32' will be of uniform radius except for an enlargement at the end for insuring a spark if one does not occur earlier. During starting, when the voltage of the magneto 13 is extremely low, the vacuum spark gap will be ineffective and the spark will occur when the primary oscillating circuit is closed by contact of the contact 32' with the contact 30. As the motor speeds up, the voltage of the magneto 13 will increase so that it is able to cause a spark to jump either between electrodes 30 and 32' or between electrodes 54 and 53. The electrode 32' may be so designed that with the throttle wide open the sparking will take place between the electrode 30 and the electrode 32', while with the throttle closed or nearly closed, the vacuum in vacuum spark chamber 56 will be high enough so that the spark will more easily jump between electrodes 54 and 53 and hence advance the timing somewhat.

Of course, if desired, the switch 52 may be opened after starting, so that during running the timing will be entirely by the spark gaps 54 and 53 to give straight wave-form timing as modified by the vacuum correction. This might be particularly advantageous on a long trip when the wave-form timing would be less subject to variation due to atmospheric conditions if the timing spark gap were included in the vacuum chamber 56. However, the rotor 31' and its electrode or contact 30 could be included within a vacuum chamber.

Wave-form timing with electrolytic interrupter

In Figs. 4 to 7, I have shown circuits for providing wave-form timing in a somewhat different manner. In these circuits a device is used for interrupting a short circuit across a magneto so as to send a surge of current into the effective portion of the ignition circuit.

In its preferred form this trip device is an electrolytic interrupter illustrated diagrammatically in these figures and indicated as a whole by the reference numeral 66. These interrupters are already well known in other connections and include an electrode 67 which is insulated except for a small tip, which tip is submerged in an electrolyte in container 68, which may form the other electrode. This electrolytic interrupter 66 is connected across the magneto 13 which, as in Figs. 1 to 3, is synchronized with the pistons. The operation of such electrolytic interrupter is that they will carry current up to a certain amperage and will then interrupt the current, closing it almost instantaneously, and interrupting it again and again in very rapid succession. These interrupters are very accurate and the current rate at which they will interrupt may be controlled by the amount of the electrode 67 which is exposed to the electrolyte. Furthermore, if a plurality of these interrupters are connected in parallel to carry a heavier amperage than one will alone, they will operate in synchronism, even though the rate of successive interruptions is extremely high.

The immediate effect of these interrupters on each interruption is very similar to the effect of timers in conventional automobiles. While the circuit is completed through the interrupter, a relatively heavy current will flow through the coil of the magneto 13. This coil is wound on an iron core and hence a heavy magnetic field is built up. When the interrupter interrupts the current, the collapse of this magnetic field induces a very high voltage. In the circuit of Fig. 4, this high voltage is applied across the condenser 26, which bears the same relation to the ignition circuit therebeyond as the condenser 26 in Fig. 1. Thus in Fig. 4, the condenser 26 is part of a primary oscillating circuit including primary winding 28 of the high frequency transformer, the condenser 29, a spark gap 70, and ground. The spark gap 70 may be of any form and may be by-passed by condenser 71, since it has been found that such a by-pass condenser will often improve the spark. The second oscillating circuit includes the coil 38, the distributor 39, spark plug 40, ground, the gap 70, and the condenser 29.

Fig. 5 includes the interrupter features of Fig. 4 with its wave-form timing, but in its high frequency aspects corresponds to Fig. 3. Thus, in

both figures, the magneto 13 charges the condenser 29, which is permanently connected across the magneto. Of course, in Fig. 5 the charge on condenser 29 is insignificant until the interrupter 66 functions, at which time a high kick voltage is impressed on condenser 29. In case the electrolytic interrupter 66 will not serve as a spark gap immediately after interruption of the current, a separate spark gap 74 may be provided in parallel therewith, a by-pass condenser 71 being optionally provided as well, though the interrupter 66 may serve as such a condenser. It will thus be seen that the primary oscillating circuit includes besides the condenser 29, the primary winding 28 of the high frequency transformer, the wire 21, the spark gap 74, and ground. The secondary circuit is the same as in Fig. 3, including condenser 29, secondary winding 38, and spark plug 40.

Fig. 6 shows the electrolytic interrupter feature with its wave-form timing applied to a low frequency or unidirectional ignition circuit. In this instance the magneto 81 may be a conventional type of magneto, including both a primary armature winding 82 and a secondary armature winding 83 wound on the same core so as to function as a spark coil. The magneto is preferably designed to have the wave-form in the coil 82 synchronized with the pistons. The primary winding 82 is normally short circuited by the electrolytic interrupter 66, but when the magneto reaches the point on its wave-form which yields sufficient current, the interrupter 66 will function to break the circuit of primary winding 82, thus causing a break down in the magnetism of its core, which induces a high voltage in the secondary winding 83. This induced voltage is cumulative with the normal voltage in the winding 83 due to rotation of the magneto and the result is therefore a very high voltage.

As shown in Fig. 6, the secondary winding 83 may simply be connected directly to the spark plug 40 with the return circuit from the spark plug 40 through ground. The usual distributor would, of course, be included, as in all of the other circuits.

Fig. 7 shows a circuit substantially identical with that of Fig. 6, except for the inclusion therewith of a high frequency boosting circuit disclosed in my prior application, Serial No. 741,610, as applied to conventional ignition circuits. It will be understood that when the short circuit of primary wniding 82 is interrupted by interrupter 66, a high kick voltage will be developed. In the circuits of Figs. 4 and 5 this kick voltage was used as the main voltage supplied to the ignition system. In Fig. 7 it is utilized for the booster circuit. A condenser 86 is connected in a circuit in parallel with the interrupter 66 (unless interrupter 66 has adequate capacity after interruption to serve its purpose), so that it is charged by the kick voltage. A primary oscillating circuit is provided for this condenser which includes a primary winding 87 of a high frequency transformer, and a spark gap 88 which may be provided with a by-pass condenser 71. The secondary winding 89 of the high frequency transformer is connected in boosting relationship between secondary winding 83 of the magneto and spark plug 40.

Although these circuits have been illustrated with a trip device comprising an electrolytic interrupter, it should be understood that any other voltage or current controlled trip device may be used to provide the feature of wave-form timing. Of course, a mechanically driven interrupter may be used when wave-form timing is not desired. Interrupters which could give wave-form timing are magnetic interrupters which operate either with a predetermined current or with a predetermined voltage.

Rotating field magneto

Although any form of magneto may be used, subject to the requirements of the different circuits already mentioned, several forms of magnetos are illustrated in the drawings which are especially suitable for use in some of these circuits.

The magneto of Figs. 12 and 13 may be used in all of the circuits except in those of Figs. 6 and 7 (and could be used there if another winding were provided). This magneto is a rotating field magneto. It includes a shaft 166 which throughout the central portion is of quite large diameter and revolves in bearing 167. The bearing 167 is of H-shape in cross section to form an annular chamber for the field coil 168. After the coil is wound thereon, it is enclosed within the magneto shell 169. This shell 169 forms part of the stationary armature of the magneto, which is completed by the face members 171, which are shaped as shown in Fig. 13, and have armature windings 172 on alternate poles 170. The intervening poles 173 may be left blank for the purpose described in the next paragraph.

It will be observed that the coil 168 will magnetize the shaft 166, making one end thereof always north and the other always south. At the ends of this shaft are provided field pole pieces 174 having half as many poles as are provided on the armature face members 171. It will be observed that with the field poles 174 alined with the armature coils 172, a magnetic circuit will be formed passing through each of the armature coils 172. However, as the field poles 174 rotate to alinement with the blank pole pieces 173, the magnetic flux will be carried almost entirely by said pole pieces 173, with the result that there will be practically no flux passing through the coils 172. This change of flux passing through the coils 172 induces a voltage therein according to well known principles. The various coils 172 may therefore be connected in series and connected in any of the circuits of Figs. 1 to 7. They have been illustrated as connected in a circuit similar to Fig. 1, but with the secondary circuit independent of contact 30 and controller 31 (or 31').

If this magneto is to be used with wave-form timing, it may be rotated synchronously with the engine and, of course, it should have the proper number of poles so that one voltage wave will reach its maximum as each piston reaches the top of its compression stroke. Of course, there may be intervening waves which may be disregarded for the present. The form of magneto illustrated in Figs. 12 and 13 will serve for a four-cylinder engine, or for an eight-cylinder engine if the two halves of the voltage cycles are sufficiently alike in wave-form.

When the magneto makes one revolution for each one or two revolutions of the engine, its shaft may be used as a distributor shaft, as illustrated diagrammatically at the left of Fig. 12, in which a distributor arm 181 is carried by the shaft 166 and engages or comes into sparking relation with the distributor terminals 182, each of which is connected to a spark plug. The rotor 31 or 31' may also be mounted on the dis-

tributor shaft and engaged by brush or electrode 30. The rotor and brush have been illustrated as structurally similar to one in my Patent No. 2,059,037, though the controller 31' is preferably shaped as shown in Fig. 9, though with additional contacts 32'.

One of the main advantages of the form of magneto shown in Fig. 12 is the extremely large bearing which it provides, namely the entire engaging surfaces of shaft 166 and bearing 167. This bearing surface is so large that it will be substantially free from wear. The result is that the clearance between the poles 124 and 171 may be extremely small without danger of trouble due to slight wear in the bearings. Since the effectiveness of magnetos is largely dependent upon the smallness of the clearance in the magnetic circuit, other factors being the same, this is an extremely important consideration. End plates 184 may be provided inside of the laminated pole portion 174 to bear against the bearing 167 to prevent end play. It should be understood, of course, that the bearing 167 is of a non-magnetic bearing metal, and the end plate 184 will also be of a non-magnetic metal.

In Fig. 14 there has been illustrated a modified form of magneto which operates on the same theory. In this form it is not necessary to remove either of the pole members 174 from the shaft 166' in order to insert the shaft 166' into the magneto. The bearing 167' is flush with the inner ends of the poles 170 and the shaft 166' is so greatly enlarged at its central portion as to fit said bearing. The enlarged portion of the shaft 166' must not come too close to the armature poles 170 and hence the intervening space 186 may be filled with bearing metal. It will be observed that this form of the invention has an even larger bearing surface than that of Figs. 12 and 13, being just as long, but considerably larger in diameter. Because of this large bearing surface, which substantially eliminates wear, and because the poles 174 are permanently secured in place and may be machined with extreme accuracy, the magnetic clearance in this form may be extremely small with safety. The rotating portion of the magneto including the shaft 166 and poles 174 may be held in centered position by the magnetic attraction of the poles 174 for the poles 170. Of course, if required, suitable end play bearings may be provided, being preferably of an external nature which will not require removal of the pole pieces 174.

Flywheel magneto

Figs. 15 to 19 illustrate a novel form of flywheel magneto and its application to a motor which in this instance is a motor 201 having radially disposed cylinders 202, as seen in Fig. 15. The magneto is carried by the crank shaft 204 of the motor, the rotating portion of the magneto being carried in a flywheel 206 which is non-magnetic, at least in its rim.

The magneto field may desirably comprise permanent magnets 208 radially disposed, as seen in Fig. 18, and provided with pole faces 209 which, as seen in Fig. 19, may preferably include clamping legs 211 which squeeze together adjacent poles of two magnets 208. It will be understood, of course, that the two poles thus squeezed together will be like poles so that successive pole faces 209 will be opposed to one another in polarity. The permanent magnets 208 may be secured to a non-magnetic base 214 in any desired manner, as by having the base cast around the magnets. This base may be secured to the housing 216 of crank shaft bearing 217 in any desired manner, as by the split collar 219 which may be tightened by bolt 221. Such a manner of securing will permit adjustment of the field magnets 208 to provide very small clearances between these magnets and the armature. The magnets 208 instead of being made in separate members may be cast as a single integral structure, in which case the pole faces 209 may be cast integrally with them.

As seen best in Fig. 16, the armature magnetic circuit may include a heavy iron ring 226 secured to the flywheel 206, cores 228 secured to the ring 226, and pole faces 230 secured to the cores 228. It will be seen that the magnetic flux from one pole of the field magnet will flow through the core 228, through the ring 226 to adjacent cores 228, and back to opposed poles of the field magnet. As the armature rotates, the polarity in the cores 228 will be reversed and hence these cores and also the ring 226 and the pole faces 230 may be laminated or may be made of some material such as Swedish iron which has relatively high electrical resistance and also relatively high magnetic permeability.

The armature coils 232 are carried by the cores 228 and hence have a voltage induced therein due to the changing magnetic flux in the cores 228. The magneto should be so designed, especially in the number and positions of the poles, that the voltage of the coils will reach its maximum as each of the pistons reaches the end of its compression stroke (or slightly later). In the illustrated form there are twice as many poles as there are cylinders.

This magneto may be used with any of the circuits of Figs. 1 to 5 (or the circuit of Figs. 6 and 7 if a secondary armature winding is provided). However, because of features not yet described, it is especially suitable with the circuits of Figs. 1 to 3 when these circuits include the wave-form timing features. It may, therefore, be described as used in the circuit of Fig. 1. The condensers 26 and 29 and a high frequency transformer 234 including coils 28 and 38 may be positioned on the inside of the flywheel, as seen in Fig. 17, and secured in any desired manner. For example, they may be set on cradles 236 and secured in place by straps, if desired. In any event, they may desirably be completely sealed within the flywheel by some suitable insulating compound 238, such as that known commercially as "Bakelite." The condenser 26 will be connected directly across the armature winding comprising the coils 232 and for convenience the flywheel 206 may serve as the ground connection. Primary winding 28 of high frequency transformer 234 will be connected at one end to the condenser 26 and at the other end to the condenser 29. The other side of this condenser 29 will be connected to a sparking electrode 30 which may be carried in the manner illustrated in Figs. 16 and 17. In these figures an insulating block 241 is carried by a spring urged arm 242 pivotally supported on the flywheel and is spaced from a contact ring 243 in any suitable manner, as by spacing legs 244 bearing on rings 245. The rings 243 and 245 may comprise a single ring unless it is desired to have the ring 243 of irregular contour. It will usually be preferred that this ring be provided with raised portions corresponding to the electrodes 32' of Fig. 9. The ring 243 will be grounded to complete the primary oscillating circuit to condenser 26.

Suitable arrangements should be made for holding the arm 242 swung to an out of the way position while the flywheel is being applied to the shaft 204 and releasing it thereafter to engage the rings 243 and 245.

The secondary coil 38 will be connected between condenser 29 and a terminal 248 which may conveniently be carried by the transformer 234 and project through the flywheel 206, as seen best in Fig. 16, being insulated from the flywheel by an insulator 249. The terminal 248 may thus be used as a distributer. Each spark plug 40 will, therefore, be connected by a wire 251 with an arcuately elongated terminal 252 positioned to have the terminal 248 pass in close proximity thereto. Thus, the secondary circuit oscillations will be distributed to the successive spark plugs in properly timed relationship by the terminal 248. The return circuit from the spark plugs is, of course, by way of ground through the ring 243 and contact 30, though it may be independent of the gap between ring 243 and contact 30 if the modified circuit of Fig. 12 is used.

The condenser-draining impedance 42 has not been shown in these figures because it is not necessary inasmuch as successive voltages applied to the condenser 29 by the magneto 13 and condenser 26 will be reversed in polarity (assuming at least that condenser 26 discharges into condenser 29 each time) so that any charge remaining on the condenser 29 will be helpful rather than harmful. Likewise the choke 23 has not been shown since the magneto cannot give a continuous spark on a single spark plug and so there probably is no danger of melting the points of the spark plug.

Since it may be desirable under some circumstances that the ignition system function on each voltage rise, a plurality of grounded terminals 256 may be provided between the terminals 252 which are connected to the spark plugs. It will be understood, of course, that all of these terminals and the terminal 248 may be concealed by an insulating ring 254 so that there will be no unnecessary shock hazard involved. It is desirable, however, that a slit be left between the rings so that the spark between the terminals 248 and 252 may be observed. The position of this spark will indicate the timing of the ignition spark. If the timing is too advanced, the electrode 30 may be unscrewed slightly to elongate the gap between it and the ring 243, thus retarding the timing. It would, of course, be desirable to provide a hole through which access could be had to the adjustable electrode 30. For this reason the electrode 30 will probably not be positioned in alinement with armature poles 230, although this position was chosen for the purpose of simplicity of illustration in Fig. 16.

It should be understood that the terminals 252 will be elongated through an arc corresponding to the maximum advance in timing desired. With the magneto illustrated having six poles there would be six current surges in each revolution and, since the wave-form timing ordinarily uses only half of each current surge, it follows that the maximum advance timing available is something less than 1/12 of a revolution, perhaps about 20 degrees. This, however, is adequate for most motors unless they run at very high speeds and, of course, if greater advance is desired, a magneto could be designed with a smaller number of poles.

It should be understood, of course, that the flywheel should be properly balanced so that its rotation will not produce vibration. The condensers 26 and 29 and the arm 243 with its associated parts may ordinarily be so located as to balance the high frequency transformer 234, and of course any correcting weights needed may be added.

It will be understood that the pole faces 209 and 230 and also the pole faces of the other magnetos may be given any shapes necessary to produce the particular wave shape which will give proper timing. The general principles of changing the wave shape by shaping the poles are sufficiently well known to enable the skilled designers to produce satisfactory wave shapes without special instructions. However, where the whole wave is very narrow as in magnetos having as many as say six surges a revolution, it will not usually be necessary to give the wave a narrow shape, or to provide a changing gap, except that when the piston reaches dead center it is desirable for the gap to close to utilize any weak voltage in slow speed cranking.

Radial bearing magneto

In Figs. 20 and 21 another magneto is illustrated which is quite similar to the flywheel magneto of Figs. 15 to 18 especially in that it incorporates the important feature of having the condensers and transformer rotate with the coils so that all external connections except the spark gap and the self contained distributor can be eliminated. In these Figs. 20 and 21 the same reference characters have been used as in Figs. 15 to 18 as far as possible. The shaft 204' may be an engine crank shaft or a separate shaft geared thereto. The permanent magnets 208 are secured to the base 214 in any suitable manner and are provided with pole faces 209. The interstices between legs of magnets 208 are preferably filled with a metal of which the base 214 is cast. On the front side of this a layer of non-magnetic bearing metal 261 is provided with its outer surface lying in a plane approximately flush with the faces of the pole pieces 209. The rotor is carried by a bearing plate 262 which is of a non-magnetic metal suitable for engaging the bearing metal 261. To the bearing plate 262 are secured core laminations 263 which may desirably be stamped out in one piece spiders, as seen best at the lower right hand portion of Fig. 21. The armature coils 232 are slipped over these spiders, after which the armature pole faces 230 are secured to the legs of the spider 236. If desired, the coils 232 may fill the radial space between the cores 263.

The pole faces 230 may be secured by screws 266, which also secure a table 267 of some such suitable insulating material as "Bakelite". On this table are carried the condensers 26 and 29 and the transformer 234. There may also be carried on this table a controller 271 corresponding to the rotor 31. In this instance it may be more desirable to ground the stationary sparking contact 272 than the rotating controller 271. In any event, the controller 271 may desirably include a ring 273 having raised portions corresponding to the specially shaped contacts 32'. These raised portions may be shaped to alter the wave-form timing or not, as desired, but it is preferred that they at least be shaped to engage the contact 272 just after the dead center position of the piston so as to insure a spark when the voltage is low due to low cranking speed.

In all instances where a magneto and a con-

troller such as 31 or 31' is used with the illustrated circuits, it will probably be desirable, when practical, to make provision for discharge of the primary circuit on every voltage surge of the generator. This will probably make the provision of the drain impedance for the condenser 29 (Fig. 1) unnecessary. If there is more than one idle surge between ignition surges, it will probably be sufficient to provide for the discharge of the last one only. When there is a fixed gap either stationary or rotating so that the spark may occur at any time, special provision will not be necessary, but when there are raised portions 32' or segments 32 it will probably be desirable to provide one such segment for each pole of the magneto or for every current surge.

It will be seen from Fig. 20 that the transformer 234 again in this instance carries a distributor terminal 248'. In this figure it has been shown as a contacting terminal rather than as a sparking terminal, being spring urged against the terminals 252' connected to the spark plugs. The terminals 252' are, of course, flush with the cover 281 which may desirably be removably secured to the extension 282 of the base 214. Although this extension has been shown integral with the base, that of course is not necessary.

Although the electrode 272 has been shown carried by the cover 281 and grounded through its holder and carrying tube (which would, of course, have a special connection with ground), it should be obvious that the positions of the parts could be reversed. In this case the electrode 272 might be connected to the condenser 29 and be positioned opposite a control element secured to the cover 281. As a matter of fact, the electrode 272 could be positioned directly adjacent the rim 282 instead of providing a special disc-shaped controller.

If the circuit of Fig. 1 is used, the secondary circuit will normally have two spark gaps therein, namely the spark plug and the gap between electrode 272 and ring 273 (contacts 30 and 32 of Fig. 1). There may be a very slight loss from including the gap of contact 272 in this secondary circuit. However, that can be avoided in this instance by the circuit modification of Fig. 12, in which the armature instead of being grounded is wired to the gap formed by the contact 30 so that ground may be used for the secondary circuit alone. The only disadvantage of this modification is that it makes something in the nature of a slip ring necessary in order for the magneto armature winding to be connected to both the stationary contact and the rotating contact. In some systems there would be a further inconvenience in not allowing the generator armature winding to be grounded, but that would not be an inconvenience in this instance except that neither electrode 272 nor ring 273 could be grounded.

Although the plate 262 could be a support plate secured firmly to the shaft 204 and not resting on the bearing 261, it is preferred that it serve instead as a bearing plate to facilitate the provision of extremely close clearances between pole faces 209 and 230. It should be understood that either the stationary magnet element or the rotating magnet element may be ground flush with its associated bearing, while the pole faces on the other element may be ground or otherwise machined so as to be countersunk with respect to the associated bearing member. The amount that the pole faces are thus countersunk will be the clearance between the respective pole faces and it is obvious that it may be an extremely small clearance. This is partly because of the fact that the bearing surfaces are so large that the wear will be extremely slight. A suitable oiling vent may be provided as shown or the bearings may be of the self-lubricating type.

The rotating element will be drawn firmly against the stationary element by the magnetism of the permanent magnets 208 and it is preferred that nothing other than the lubricating film should interfere with their coming into close contact and true parallelism so that full advantage of the small clearance above referred to may be had. To this end the rotating element is carried on the shaft 204' by a ball joint, the ball section 286 being formed on the shaft 204', enough clearance being provided elsewhere along the shaft to permit a very slight swivel action which is the most that would be necessary. A spring retaining member 288 on the end of the shaft 204' may be provided as an additional safeguard in holding the rotating element in place. Of course, the rotating element would be keyed to the shaft 204'. Since there will be practically no swiveling action, a large bearing surface engaging the ball 286 probably will not be necessary, but, if it should be, it could be provided by a collar socket shaped internally for engaging the ball 286 and on which the bearing plate 262 is slidable.

It should be understood that the form of magneto shown in Figs. 15 to 18 could very easily be provided with a radial bearing similar to that shown in Figs. 20 and 21. In this case the stationary member including the magnets 208 might well be slidably and swivelly mounted on the shaft 204 and urged against the rotating element. The controller unit including the arm 242 could be moved radially outwardly so as to be positioned approximately between the pole faces of the armature and it could engage a ring on the outer edge of the fixed radial bearing which would extend approximately to the pole faces.

Polarity reversing ignition circuit

In Fig. 2 I have illustrated a low frequency or unidirectional ignition circuit similar to conventional ignition circuits except that the current in the primary winding of the spark coil is reversed instead of merely being interrupted. A commutator 311 is provided which includes a plurality of segments 312 of insulation separating segments which are alternately connected to opposite sides of a battery as indicated by the "+" and "—" signs on said segments. The primary winding 314 of a conventional spark coil is connected across a pair of brushes 317 and 318 which engage segments of opposite polarity to cause a current to pass through primary coil 314, as the commutator 311 rotates, the conductive sections 320 and 321 will pass out from under the brushes 317 and 318, thus breaking the circuit for primary coil 314. If desired, a condenser may be connected across this coil as illustrated to prevent arcing at the brushes 317 and 318, and this condenser may be connected in a high frequency boosting circuit similar to that shown in Fig. 7.

The brushes 317 and 318 are of sufficient arcuate extent so that almost immediately after one pair of live segments 320 and 321 leaves these brushes, another pair 321 and 322 will engage them applying the battery in reversed polarity to the primary coil 314. The initial interruption of the current in coil 314 will induce a high voltage in coil 326 which will be increased or prolonged

by supplying current of reversed polarity to coil 314.

Refinements

Although the foregoing description is sufficient to give a good understanding of the invention, the following additional comments may be helpful to anyone who makes use of the invention.

All of the drawings are more or less diagrammatic. In Figs. 8 and 22, however, there is one detail which is quite important. This is the provision of an air gap at the edge of each live segment, the air gap preferably being formed by a slight groove in the insulation. The primary purpose of this air gap is to prevent the wiping of a film of conductive material from the live segment onto the insulating segment with the result that there would be a sharp break as the brush left the live segment. A secondary purpose is to facilitate sparking between the electrode and the live segment when the circuit is designed for such sparking. This sparking is aided both by the clean break resulting from the recess in the insulating material and also by the absence of any insulating material from the normal path of the spark. This feature is covered by my Patent No. 2,059,237. It should be observed that the structure of Fig. 9 carries the recess to the extreme, since the recess extends from one contact or electrode to the other.

Under some circumstances it may be desirable to use two of the sources of current in Figs. 1 to 3 simultaneously. This would be particularly true in starting when the voltage of the magneto might be undesirably low and a special generator or high voltage battery could be used momentarily. Ordinarily it would be desirable to switch off one when the other is switched on, but this would not always be necessary.

In connection with the vacuum gap it should be noted that the vacuum chamber could be connected with the intake manifold on either side of the throttle valve. The description contemplates that it would be connected on the engine side of the throttle valve and if it were connected on the opposite side the effect would be somewhat reversed, but under certain circumstances that might be desirable for it might be desirable to connect it to both sides with a check valve in line to each side. With this double connection the spark would be advanced whenever there was suction on either side of the throttle. Thus the retard of the open throttle would be relatively less at higher speeds than at lower speeds. Even with only one connection to the intake manifold, a check valve in this connection might be desirable so as to sustain a vacuum at the vacuum gap for a short time and so as to positively prevent combustible gas from getting into the vacuum spark chamber. As a matter of fact, however, the vent would prevent this by keeping the connecting line filled with fresh air.

If it be desired to use the vacuum gap and another controller as well, the controller shown in Fig. 8 would be very suitable (assuming the wave shape of the magneto to be proper for automatic timing) because the controller of Fig. 8 would simply close the gap at the dead center position leaving the timing control otherwise to the vacuum gap.

The desirability of changing the air in a spark gap was mentioned in connection with a vacuum gap. This would also be true of the rotating gaps, although the mere fact of rotation would insure a constant change of air whenever new air is available. Where these gaps are enclosed within a housing as within the flywheel in Figs. 15 to 18 and within the housing in Fig. 20, it may be desirable to provide some means for insuring a gradual change of air within the chamber. This could be accomplished simply by providing vents, preferably one near the axis of rotation and one or more at the periphery of the housing in line with some rotating part whereby centrifugal force will insure a proper circulation.

One advantage of the electrolytic interrupters which has not been brought out clearly is their high frequency of operation, which would result in a large number of successive kick voltages being applied to the ignition circuit during the ignition in a single cylinder. This would be very valuable in starting or under adverse conditions when the charge in the cylinder might not ignite on the first spark.

The large bearings of Figs. 12 to 14 and the large radial bearings of Figs. 20 and 21 (and of Figs. 15 to 18 if optionally included therein) permit an amazing reduction in the length of the magnetic gap with safety. It is entirely possible to make a commercially satisfactory magneto which will run more or less indefinitely with a gap of 1/1000 of an inch or as heretofore commercially practical magnetos have had to have a gap of about 6 to 8/1000. Those which had a smaller gap than this had a life say in the neighborhood of fifty hours.

The disclosures of this application are illustrative and the invention is not to be limited by them. In fact, if modifications or improvements are not at once obvious, they may be devised in the course of time to make additional use of the broad ideas taught and covered by this application. The claims are intended to point out novel features and not to limit the invention except as may be required by prior art.

I claim:

1. A spark producing system capable of prolonged sparking comprising a source of substantially continuous, high voltage, direct current; a condenser charged by said current and included in a primary high frequency oscillating circuit; a controller in said circuit for rendering said circuit effective when desired; and a secondary oscillating circuit in inductive relation to said primary oscillating circuit and including a condenser in common therewith, and an ignition spark gap all connected in series.

2. An ignition system including a primary oscillating circuit including a primary winding of a high frequency transformer, a condenser in series therewith and a grounded spark gap in series with said winding and said condenser; and a secondary oscillating circuit including a secondary winding of said transformer, said condenser and an ignition spark gap in series therewith, and a return through said ground and said first mentioned spark gap but independent of said primary winding.

3. An ignition system including a source of high voltage current; a primary oscillating circuit including a condenser and the primary winding of a high frequency transformer; a controller for normally keeping said primary circuit open and for rendering said primary circuit effective by substantially closing it when ignition is desired, said condenser being connected to be energized by said source of power when said controller makes said primary circuit effective; and a secondary circuit including the secondary winding of said high frequency transformer.

4. An ignition system including a source of high

voltage current; a condenser connected to be charged by said source; a primary oscillating circuit including said condenser, the primary winding of a high frequency transformer and control means effective to substantially close said primary circuit when ignition is desired; and a secondary circuit including a secondary winding of said transformer and a common condenser in series with each of said windings.

5. An ignition system for a combustion engine having a piston and an ignition spark gap, including a magneto synchronized with said piston; an interrupter normally forming a short circuit for said magneto whereby a heavy current is built up in said magneto having a wave-form synchronized with the piston, said interrupter being effective at a given current value to interrupt said short circuit whereby a kick voltage is produced in the winding in said magneto; and means for rendering said kick voltage effective to produce a spark at the ignition spark gap of said engine.

6. An ignition system for a combustion engine having a piston and an ignition spark gap, including a magneto synchronized with said piston; an electrolytic interrupter normally forming a short circuit for said magneto whereby a heavy current is built up in said magneto having a wave-form synchronized with the piston, said interrupter being effective at a given current value to interrupt said short circuit whereby a kick voltage is produced in the winding of said magneto; and means for rendering said kick voltage effective to produce a spark at the ignition spark gap of said engine.

7. An ignition system for a combustion engine having a piston and an ignition spark gap, including a magneto synchronized with said piston; an interrupter normally forming a short circuit for said magneto whereby a heavy current is built up in said magneto having a wave-form synchronized with the piston, said interrupter being effective at a given current value to interrupt said short circuit whereby a kick voltage is produced in the winding in said magneto; and means for rendering said kick voltage effective to produce a spark at the ignition spark gap of said engine, said means including a high frequency transformer having primary and secondary windings, a primary oscillating circuit including said primary winding and a condenser in series therewith and a secondary oscillating circuit including said secondary winding and said condenser and the ignition spark gap all in series.

8. An ignition system for a combustion engine having a piston and an ignition spark gap, including a magneto synchronized with said piston; an electrolytic interrupter normally forming a short circuit for said magneto whereby a heavy current is built up in said magneto having a wave-form synchronized with the piston, said interrupter being effective at a given current value to interrupt said short circuit whereby a kick voltage is produced in the winding in said magneto; and means for rendering said kick voltage effective to produce a spark at the ignition spark gap of said engine, said means including a high frequency transformer having primary and secondary windings, a primary oscillating circuit including said primary winding and a condenser in series therewith and a secondary oscillating circuit including said secondary winding and said condenser and the ignition spark gap all in series.

9. Apparatus for producing successive long trains of sparks comprising a source of high direct voltage, a high frequency transformer having primary and secondary windings, a primary oscillating circuit including said primary winding and a condenser, means to discharge said condenser between trains of sparks and to apply said high voltage to it while it is discharged to set up oscillations in said circuit, and a secondary circuit including said secondary winding.

10. Apparatus for producing successive long trains of sparks comprising a source of high direct voltage, a high frequency transformer having primary and secondary windings, a primary oscillating circuit including said primary winding and a condenser, means to discharge said condenser between trains of sparks and to apply said high voltage to it while it is discharged to set up oscillations in said circuit, and a secondary circuit including said secondary winding, and a condenser also included in said primary oscillating circuit.

11. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage wave having its peak synchronized substantially with the dead center firing position of each piston; an oscillating circuit including a condenser and a timing spark gap; means to cause an ignition spark in response to oscillations in said circuit; and means to discharge said condenser between ignition sparks to permit the timing to be controlled solely by said generator and said gap.

12. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage wave having its peak synchronized substantially with the dead center firing position of each piston; an oscillating circuit including a condenser and a timing spark gap; and means to cause an ignition spark in response to oscillations in said circuit, said gap including a stationary electrode and a rotor separated therefrom during the production of each of said voltage waves approximately until the dead center position is reached, but being shaped to reduce the length of the gap micrometrically before that time.

13. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage wave having its peak synchronized substantially with the dead center firing position of each piston; an oscillating circuit including a condenser and a timing spark gap; and means to cause an ignition spark in response to oscillations in said circuit, said gap including a stationary electrode and a rotor separated therefrom during the production of each of said voltage waves approximately until the dead center position is reached, and then engaging said electrode to insure oscillations even though the voltage be weak.

14. An ignition system including a generator having a rotating armature winding; a high frequency transformer rotating therewith and including primary and secondary windings, a primary oscillating circuit including said primary winding and a condenser rotating therewith and energized by the armature winding; and a secondary oscillating circuit including said secondary winding and an ignition spark gap.

15. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage

wave having its peak synchronized with a predetermined position of the piston, an oscillating circuit including a condenser and a timing spark gap, and means to cause an ignition spark in response to oscillations in said circuit, said gap and said magneto being so constructed as to reduce the advance in timing of the spark upon speeding up of the engine and generator below the advance which would be produced with a sine-wave wave shape and a constant spark gap.

16. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage wave having its peak synchronized with a predetermined position of the piston, an oscillating circuit including a condenser and a timing spark gap, and means to cause an ignition spark in response to oscillations in said circuit, said generator being so constructed as to produce a wave form substantially different in shape from a sine wave.

17. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage wave having its peak synchronized with a predetermined position of the piston, an oscillating circuit including a condenser and a timing spark gap, means to cause an ignition spark in response to oscillations in said circuit, and means for causing an advance in ignition timing by reducing the air pressure within the spark gap in response to certain motor conditions.

18. The combination of a combustion engine having a piston and a wave-form timing ignition system including a generator producing a voltage wave having its peak synchronized with a predetermined position of the piston, an oscillating circuit including a condenser and a timing spark gap, means to cause an ignition spark in response to oscillations in said circuit, and means for causing an advance in ignition timing by reducing the air pressure within the spark gap in response to certain motor conditions, said means including a housing about said spark gap, and a conduit connecting said spark gap with the intake manifold of the engine for drawing air from said housing; said housing having a restricted air inlet therein to provide a change of air in the air gap even with constant manifold suction.

19. A high frequency oscillating system including a spark gap, a housing around said spark gap, and means for drawing air from said housing to cause said spark gap to function in a partial vacuum, said housing being provided with a restricted air inlet to cause a change of air within said spark gap.

20. An ignition system for a combustion engine having a piston, an intake manifold, and an ignition spark gap, including means for producing a rising voltage at approximately the time an ignition spark is desired, including a spark gap for producing such ignition spark when the voltage reaches a value sufficient to jump said gap, a housing for said spark gap, and means connecting said housing with the intake manifold whereby the timing of the ignition spark is varied by the degree of vacuum in the intake manifold.

21. An ignition system for a combustion engine having a piston and an ignition gap, including a generator whose voltage wave form is synchronized with said piston, said system including a transformer of which the primary winding carries the generator current, and electrical means responsive to a predetermined voltage output of the generator and adapted to control the primary winding to induce a high voltage in the secondary winding of the transformer, thereby producing a spark at the ignition gap, said means providing for an automatic advance in the timing of the spark upon speeding up of the engine.

22. An ignition system for a combustion engine having a piston and an ignition spark gap, including a generator whose voltage wave form is synchronized with said piston, electrolytic means for normally short-circuiting said generator whereby a heavy current is built up in the winding thereof having its wave form synchronized with the piston, said means being effective at a given current value to interrupt said short circuit to produce a sudden change in the magnetic field thereof, and means responsive to said sudden change to produce a spark at said ignition spark gap.

23. An ignition system for a combustion engine having a piston and an ignition spark gap, including a generator whose voltage wave form is synchronized with said piston, electrolytic means for normally short-circuiting said generator whereby a heavy current is built up in the winding thereof having its wave form synchronized with the piston, said means being effective at a given current value to interrupt said short circuit to produce a sudden change in the magnetic field thereof, including a secondary coil having a high voltage induced therein as a result of said sudden change for producing a spark at the ignition spark gap.

24. An ignition system for a combustion engine having a piston and an ignition gap, including a generator having a primary and secondary winding, the secondary winding being connected to the ignition gap, the wave form of said primary winding being synchronized with said piston, and electrical means for normally short-circuiting said primary winding whereby a heavy current is built up in said primary winding having its wave form synchronized with the piston, said means being effective at a given current value to interrupt said short circuit to energize the secondary winding and produce a spark at the ignition gap of said engine.

25. Apparatus for producing successive long trains of sparks, comprising a source of high direct voltage, a high frequency transformer having primary and secondary windings, a primary oscillating circuit including said primary winding and a condenser, and means to connect said source across said circuit successively in opposite polarity for successive trains of sparks whereby any charge which the source leaves on the condenser in producing one train of sparks will be discharged by the source as it is next connected to the condenser.

26. An ignition system for an internal combustion engine having a piston, including a generator producing a wave having its peak synchronized with a predetermined position of the engine piston, and electrical means for effecting an ignition spark at a predetermined value of the generator output, said generator being so constructed as to produce a wave form substantially different in shape from a sine wave.

27. An ignition system for an internal combustion engine having a piston, including an engine spark gap and a generator which produces a wave having its peak synchronized with a predetermined position of the engine piston, and

a spark gap of variable resistance for automatically regulating the timing of the ignition spark in response to engine load and throttle conditions.

28. An ignition system for an internal combustion engine having a piston, including an ignition spark gap and a generator which produces a voltage wave having its peak synchronized with a predetermined position of the engine piston, and a spark gap of variable resistance for automatically regulating the timing of the ignition spark in response to engine load and throttle conditions, said generator being so constructed as to produce a wave form substantially different in shape from a sine wave.

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