

April 23, 1963

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3,087,000

IGNITION SYSTEM FOR COMBUSTION ENGINES

Filed May 29, 1961

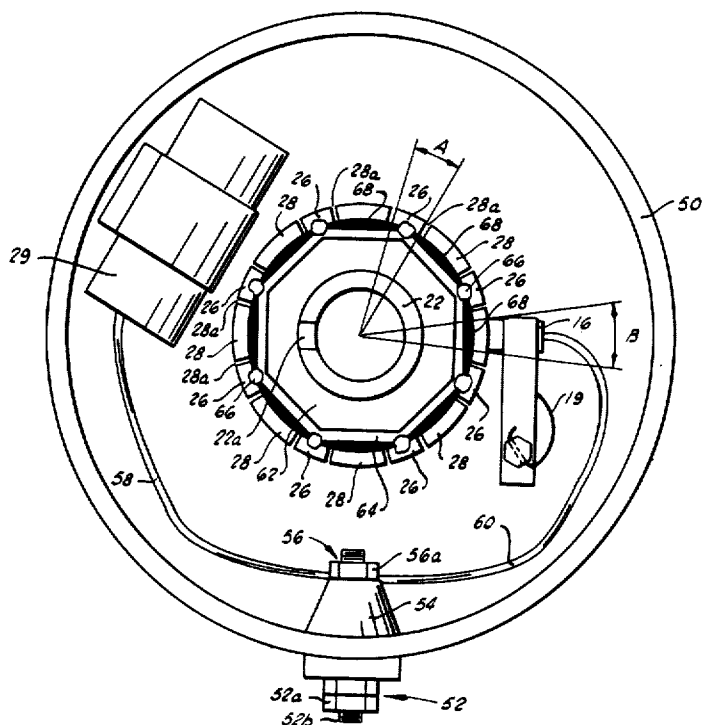


FIG. 2

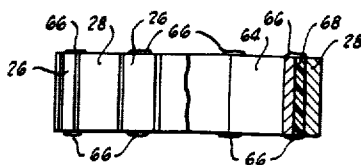


FIG. 3

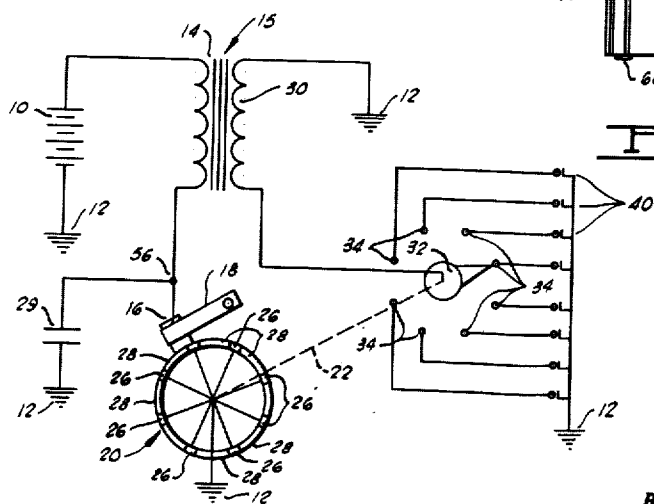


FIG. 1

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IGNITION SYSTEM FOR COMBUSTION ENGINES
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Filed May 29, 1961, Ser. No. 113,450
1 Claim. (Cl. 123—146.5)

The present invention relates to electrical ignition systems for internal combustion engines.

Ignition systems currently used for almost all automotive internal combustion engines have a primary or low voltage circuit in which an electrical power source, such as a battery, is connected in series with the primary winding of a transformer, usually referred to as a coil. A circuit breaker device, known as the points, closes and opens the primary circuit to alternately build and collapse the magnetic field of the coil. A capacitor, known in the art as the condenser, is provided primarily to reduce arcing and burning of the points. A secondary, high voltage winding is inductively coupled to the primary winding of the coil transformer and the high voltage induced in the secondary winding is sequentially distributed to the cylinder spark plugs by a rotating distributor switch. The distributor switch is rotated by a timing shaft in synchronism with the engine at half the engine speed for a four-cycle engine.

When the primary, low voltage circuit is completed by the points closing, the current builds in the primary winding of the coil or transformer and establishes a flux field around both the primary and secondary windings. When the points are open, the primary circuit is broken and the magnetic field instantly collapses, inducing a high voltage in the secondary winding. The high voltage increases to a maximum almost instantaneously and then quickly decreases. A pulse of current is also counter-induced in the primary windings, but the capacitor absorbs the pulse of current as the points open to prevent arcing across the points and then discharges while the points are still open.

Both the buildup and collapse of the currents in both the primary and secondary windings are retarded by the impedance of the inductively coupled circuits. However, the time required for the buildup of current in the primary circuit is much longer than the time for the complete dissipation of the induced pulses in the two circuits. If the current in the primary winding does not reach a maximum before the points open, the voltage induced in the secondary winding when the magnetic flux collapses will not be a maximum. If the period during which the points are open is too short, the capacitor will not have time to discharge all resonant harmonics inherent in the circuit and the points will close while the capacitor is still discharging. The discharge of the capacitor will cause arcing across the points, but, more importantly, the discharging oscillations in the resonant, inductively coupled primary and secondary circuits will interfere with the buildup of the current in the primary circuit the next time the points are closed, so that the current cannot build to a maximum within the same time period.

At low engine r.p.m., the period of time during which the circuit is completed and opened by the points is sufficiently long that no appreciable problem exists. However, as the engine r.p.m. increases, the period of time between each opening of the primary circuit and firing of a spark plug greatly decreases and is quickly inadequate for complete buildup and discharge of the two inductively coupled

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circuits as previously mentioned. Of course, as the period during which the points are opened increases, the period during which the points are closed decreases. Therefore, the most efficient or optimum compromise must be chosen which will actually produce the best operating results for the particular ignition system. This optimum condition is determined by all automotive engine and ignition system manufacturers experimentally for the particular electrical and mechanical components employed in each particular standard ignition system. This optimum condition is defined in the art in terms of the angle through which the timing shaft (which drives the distributor switch arm and operates the breaker points) rotates during which it is desired to close the primary circuit to permit current buildup. This period corresponds roughly to the period when the points are closed to complete the primary circuit. This angle is commonly referred to as the "dwell angle." It will be appreciated that the dwell angle will vary considerably for the various standard ignition systems, depending upon the size and structure of the coil, the condenser, the spark plugs, and the resistance of the wires, and even the compression within the engine cylinders. Almost all present-day dwell angles are in the range from twenty-two degrees to forty-two degrees, the larger angles being that related to six-cylinder engines.

It is extremely important that the dwell angle be adjusted and maintained with precision. For example, if the dwell angle is increased six degrees, the angle during which the primary circuit is opened will be decreased six degrees. In an eight-cylinder engine, each ignition cycle is allotted only forty-five degrees of timing shaft rotation. Since the period of time required for maximum buildup is much greater than the time required for dissipation of the secondary current, the period during which the primary circuit is open is normally a relatively small percentage of the forty-five degrees of allotted rotation. Therefore, six degrees reduction in the time the points are open may change the period the points are open as much as fifty percent at higher r.p.m., this figure obviously being a conservative estimate.

Furthermore, in order to obtain optimum engine operation, the points must be "timed" to open at precisely the right instant of piston travel, usually just before the piston reaches top dead center. Also, if the primary circuit is opened out of time with the rotary distributor switch, the maximum voltage induced in the secondary winding will not be applied to the particular spark plug by the rotating distributor switch. If the points open too late, the distributor switch may open before the maximum voltage buildup and only partial voltage will be delivered to the particular spark plug. If the points open too soon, the distributor switch may not close until the secondary circuit voltage has dissipated to a value lower than the maximum, so that again a lower voltage is delivered to the spark plug.

The type of breaker points universally adopted by the automotive ignition industry for opening the primary circuit to induce a high voltage in the secondary winding comprises two contacts, one stationary contact and one contact mounted on a pivoted arm. The pivoted arm is disposed adjacent a polygon-shaped cam which is mounted on the timing shaft. The timing shaft is synchronously driven by the engine, as previously mentioned, and drives both the cam and the rotating distributor

switch. The pivoted arm is spring-biased so that the two contacts are normally closed. The pivoted arm is provided with a small projection which rides on the cam as the cam is rotated. As the projection rides over the corners of the cam, the pivoted arm contact is raised from the stationary contact to open the circuit. As the projection passes the sides of the polygon-shaped cam, the contacts are closed. Of course, the number of sides of the polygon-shaped cam corresponds to the number of cylinders of the particular engine.

The dwell angle, or angle of rotation of the timing shaft during which the contact points are closed, is adjusted by varying the position of the stationary contact relative to the cam. Adjustment of the dwell angle is made either with the assistance of special electronic timing equipment or is approximated by measuring with a feeler gauge the maximum spacing between the two contacts when the projection is resting on a corner of the polygon-shaped cam. When the projection wears as much as 0.001 inch, the dwell angle will increase as much as six degrees, closing three degrees sooner and opening three degrees later. This amount of wear of the projection normally occurs after only a few thousand miles of driving. Conversely, the angle of rotation of the timing shaft during which the breaker points are opened is decreased six degrees. The shortened discharge period normally causes arcing across the points and frequently the points are quickly burned beyond use. Also, the oscillations in the resonant circuits do not have time to dissipate completely during the shortened period the points are open and will retard the buildup of current in the primary circuit so that the voltage applied to the spark plugs will be materially decreased. As a result, at high compression conditions in the cylinder, the spark plugs may not fire. Probably the most significantly detrimental effect is that the instant at which each plug fires is delayed by three degrees, which results in reduced efficiency of the engine and increased gas consumption. Therefore, it can generally be said that maintenance of the dwell angle is of utmost importance in maintaining proper operation of the ignition system. The breaker-type points presently in use require frequent readjustment of the dwell angle for efficient operation and have a very short useful life so as to require frequent replacement.

Modern electronic equipment used to analyze ignition systems reveals that the pivoted arm type breaker points are highly inefficient and erratic at higher engine r.p.m. corresponding to normal highway driving. Although the exact cause of this erratic behavior of the points is not known, the natural frequency of the spring biasing the pivoted arm of the points appears to be the primary cause of malfunction at higher r.p.m. For example, the firing of each spark plug in the system is periodically and rather systematically skipped so that for each spark plug a definite delayed pattern of ignition will occur at an angle fifteen to twenty degrees behind the desired firing angle. For some reason, this delayed firing occurs at substantially the same point with relation to the rotation of the timing shaft and with sufficient rapidity that, in the flashing light type electronic analysis system, the secondary firing point is readily evident. Of course, when installed on an automobile engine, the fifteen to twenty-degree delay in firing occurs after the distributor switch has passed the contact for that particular spark plug so that no firing results for that stroke of the piston. Also, as the r.p.m. is increased, the exact angle at which each spark plug fires is progressively retarded as much as five degrees. It is well known in the automotive art that for most efficient operation at high speeds, the spark timing should be advanced rather than retarded as the r.p.m. is increased. All of these malfunctions directly decrease the efficiency of operation of the engine and therefore increase gas consumption. These malfunctions can be reduced by increasing the force

of the spring, but the increased force greatly accelerates wear of the projection which rides on the cam.

Many attempts have heretofore been made to utilize rotary-type switches in automotive ignition systems. However, except for the use of a rotary switch arm to sequentially connect a potential to each of the spark plugs, rotary switches have not been accepted by the automotive industry.

Therefore, in accordance with the present invention, an ignition system for an internal combustion engine having a plurality of cylinders and a sparking fuel igniter means for each cylinder is provided. The ignition system comprises a first low voltage circuit having an electrical source, a primary winding and a rotary circuit breaker means connected in series, and a second high voltage igniter circuit having a secondary high tension winding inductively coupled to the primary winding and connected to deliver high voltage induced in the winding to a rotary distributor switch. The rotary distributor switch is connected to sequentially complete, in the proper sequence, a high tension circuit to each of the fuel igniter means. The rotary circuit breaker means in the primary circuit is comprised of a cylindrical member rotated in synchronism with the rotary distributor switch, preferably by the same timing shaft. The cylindrical member has alternately disposed conducting and nonconducting segments around the periphery thereof with the number of conducting segments being equal to the number of cylinders of the combustion engine. The conducting segments have equal arc lengths, each arc length being defined by an angle projected from the axis of the cylindrical member. A brush means is disposed in contact with the periphery of the cylindrical member and is connected to complete the first low voltage circuit when in contact with the conductive segments of the cylindrical member. The brush means has an arc length also defined by an angle projected from the axis of the cylindrical member, and the sum of the angle defining the arc length of each of the individual conducting segments and the angle defining the arc length of the brush means is equal to the optimum dwell angle for the particular combination of physical components of the ignition system. In this ignition system, the low voltage of the primary circuit is alternately closed and opened in perfectly timed sequence with the distributor switch which handles the high voltage circuit. The distributor switch has contact points which are sufficiently spaced to handle the high voltage, and the rotary circuit breaker controls with great accuracy the buildup and collapse of current in the low voltage, primary circuit. In a preferred embodiment, it is also contemplated by the present invention to provide a specially constructed rotary circuit breaker device for application to the polygon-shaped cam of conventional combustion engine timing shafts to thereby readily install the ignition system on existing automobiles.

Therefore, the primary object of the present invention is to provide an improved electrical ignition system for a reciprocating internal combustion engine.

Another important object of the present invention is to provide an ignition system of the type described in which the optimum dwell angle can be accurately and continually maintained for the life of the ignition system.

Another important object of the present invention is to provide an improved ignition system of the type described in which the optimum dwell angle is fixed for the life of the circuit breaker device by manufacture and therefore does not require manual adjustment.

Another object of the present invention is to provide an ignition system in which the point of piston travel at which the respective spark plug fires does not change as a result of wear of the circuit breaker device.

Another object of the present invention is to provide an ignition system of the type described having a greatly increased efficiency at high engine r.p.m.

Another object of the present invention is to provide

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breaker points for an ignition system of the type described which have an extremely long life and which are therefore economical of operation.

Another object of the present invention is to provide an ignition system of the type described in which the angle at which each spark plug fires remains constant for the full range of engine r.p.m.

Another object of the present invention is to increase the contact area of breaker points to provide better and easier starting of the engine at low operating temperatures.

Another object of the present invention is to provide a rotary circuit breaker of the type described which can be used in combination with the distributor and timing shaft mechanism of almost all standard automotive ignition systems.

Another object of the present invention is to provide a rotary circuit breaker of the type described which can be economically manufactured.

Another object of the present invention is to provide a rotary circuit breaker of the type described which will not become fouled after prolonged use.

Additional objects and advantages will be evident from the following detailed description and drawings in which:

FIGURE 1 is a schematic drawing of an electrical and mechanical ignition system in accordance with the present invention.

FIGURE 2 is a top view of a mechanical circuit breaker in accordance with the present invention.

FIGURE 3 is a side view, partially in section, of a part of the device of FIG. 2.

Referring now to FIG. 1, the negative pole of an automotive battery 10 is connected to the automobile chassis which is represented by the conventional electrical ground symbol 12. The positive terminal of the battery 10 is connected to a primary winding 14 of a transformer 15, known as a coil, and to an electrical brush 16. The brush 16 is mounted on a pivoted arm 18 which is suitably spring-biased by a spring 19 (shown only in FIG. 2) to cause the brush 16 to ride against the periphery of a cylindrical rotary member indicated generally by the reference numeral 20. The cylindrical rotary member 20 is schematically illustrated in FIG. 1 and is rotated by the timing shaft 22 which is driven synchronously by the internal combustion engine.

The cylindrical rotary member 20 has alternately disposed conducting segments 26 and nonconducting segments 28 around the periphery thereof. The conducting segments 26 are electrically connected to the timing shaft 22 which is in electrical contact with the remainder of the automobile chassis, as represented by the electrical ground symbol 12. The nonconducting segments 28 are electrically insulated from the conducting segments 26 and from the conductive timing shaft 22. A capacitor 29 is connected in parallel with the circuit breaker device comprised of the brush 16 and rotary member 20. When the brush 16 contacts any one of the conducting segments 26, a circuit is completed from the battery through the primary winding 14 and to the timing shaft 22, and also charges the capacitor 29. This circuit is hereafter referred to as the primary circuit. When the brush 16 is in contact only with the nonconducting segments 28, the primary circuit is broken.

A secondary winding 30 of the transformer coil 15 is inductively coupled to the primary winding 14. The secondary winding 30 is connected to a rotary distributor switch arm 32. The rotary distributor switch arm 32 is rotated by the timing shaft 22 and sequentially completes the secondary circuit to each of the contacts 34. Each of the contacts 34 is connected to an appropriate fuel igniter means known as the spark plugs and indicated collectively by the reference numeral 40. The spark plugs 40 are electrically connected to the engine block represented by the symbol 12 to complete the circuit hereafter referred to as the secondary circuit. The contacts

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34 are relatively small and spaced a substantial distance apart, and the rotary arm 32 is well insulated from the timing shaft 22. Therefore, the distributor switch mechanism is well adapted to handle a high potential current induced in the secondary windings 30.

A preferred embodiment of the rotary circuit breaker device is shown in detail in FIGS. 2 and 3. Referring now to FIG. 2, the housing 50 of a conventional distributor device has a suitable conventional electrical connection 52 comprised of a nut 52a and threaded terminal post 52b which is insulated from the housing by insulation 54. The terminal post 52b extends through the housing 50 and provides a second connection 56 comprised of nut 56a and the terminal post 52b. The electrical connection 52 is connected to the lead from the primary winding 14 of the coil transformer by a suitable conductor (not shown). The connection 56 corresponds to the junction 56 on FIG. 1 and is connected to the capacitor 29 by a conductor 58. The connection 56 is also connected to the brush 16 by a conductor 60. The vertically disposed timing shaft 22 is geared at its remote end to the engine drive shaft and has a suitable notch 22a in the adjacent end which is adapted to be coupled to the rotary distributor switch 32 (not shown in FIG. 2). The rotary distributor switch is positioned directly over the housing shown in FIG. 2 when the device is completely assembled for operation. An octagonally shaped cam 62 is connected to the timing shaft 22. The octagonally shaped cam 62 is normally used in conjunction with an eight-cylinder engine, it being understood that a polygonal-shaped cam having a number of sides corresponding to the number of cylinders would normally be used. So much of the distributor device as is described above is conventional and is used on substantially all existing automotive vehicles.

In a preferred embodiment, an octagonal inner ring member 64 is sized and shaped to fit closely over the octagonal cam 62. The inner ring member 64 is preferably fabricated from a conductive metal such as brass or copper and can readily be slipped over the cam 62 and will be rotated therewith. The conducting segments 26 are each located adjacent the corners of the octagonal inner ring 64 and are electrically and structurally bonded to the inner ring 64 by a suitable bonding agent such as a spot of solder 66 at each end of the segment 26. The conducting segments 26 are conveniently fabricated from the same metal as the inner ring 64. The nonconducting segments 28 are each separated from the conducting segments 26 by spaces 28a on each side thereof and are bonded to the sides of the octagonal inner ring 64 by a suitable nonconductive bonding agent 68 (shown in solid coloring), such as a synthetic resin. The nonconducting segments 28 are preferably fabricated from the same metal as the conducting segments 26, or some other conductive material, for purposes hereafter described and are termed nonconducting because they are electrically insulated from the segments 26 and from the timing shaft 22 and therefore open the primary circuit when in contact with the brush 16. It is to be understood that, in the broader aspects of this invention, the conducting segments 26 can be structurally and electrically connected to the inner octagonal ring 64 in any suitable manner.

The arc length of each conducting segment 26 is defined by an angle A which is projected from the axis of the timing shaft 22. Each of the arc lengths of the conducting segments 26 should be equal. Similarly, the brush 16 has an arc length defined by an angle B projected from the axis of the timing shaft 22. The primary circuit is completed from the instant one of the conducting segments 26 first contacts the brush 16 until the segment 26 has completely passed the other edge of the brush 16. Therefore, the sum of the angles A and B should equal the optimum angle during which the primary circuit should be completed to permit the current in the primary circuit to build to a maximum. Therefore, it

can be said that the sum of the angles A and B should equal the optimum "dwell angle" of the particular ignition system.

In operation, the rotary member 20 and the rotary distributor switch 32 are connected to the timing shaft which is synchronously driven by the engine at half the engine r.p.m. As a particular conducting segment 26 first contacts the brush 16, current begins to flow in the primary circuit and builds to a maximum, which, due to the impedance of the inductively coupled circuits, requires a relatively long period of time but, nevertheless, is measured in fractions of a second. As the particular conducting segment passes the brush 16, the primary circuit is instantly opened and the magnetic field in the transformer coil 15 collapses with great speed, thereby inducing a very high voltage current in the secondary circuit. The rotary member 20 and the distributor switch 32 are so related on the timing shaft 22 that at the instant the primary circuit is opened by each conducting segment 26 passing by the brush 16, the distributor switch arm 32 will be in contact with one of the contacts 34 and the high voltage current will be applied to the corresponding spark plug 40 to ignite the fuel in the cylinder. Of course, the firing is also "timed" with the piston travel so that the spark plug ignites the fuel just before top-dead-center, as desired.

A counter-e.m.f. is induced in the primary winding of the primary circuit, but this current is absorbed by the capacitor 29, which prevents arcing between the conducting segment and the brush 16. The current and voltage in the inductively coupled primary and secondary circuits continues to resonate for some relatively short period of time due to the combination of the capacitor and the transformer windings which constitute, in effect, a resonating circuit. Except at higher engine r.p.m., the resonating pulses are all dissipated while the primary circuit is open due to the brush 16 being in contact with the next conducting segment 28. Therefore, each time that the distributor switch contacts one of the contacts 34, the primary circuit will be opened by a conducting segment 26 passing the brush 16, and a high voltage pulse will be induced in the secondary circuit and supplied to the appropriate spark plug at the proper instant of piston travel.

The dwell angle is manufactured into the rotary circuit breaker device by construction of the arc width of the conducting segments 26 and the arc width of the brush 16, the sum of the two arc widths being equal to the dwell angle or angle of rotation of the timing shaft during which it is desired that the primary circuit be completed. Once the rotating cylindrical member 20 is properly positioned on the timing shaft 22, and/or the brush member 16 is located relative thereto to cause the primary circuit to open at the exact desired instant to produce firing of the spark plugs, neither the dwell angle nor the point of firing will change due either to wear of the device or to increased engine r.p.m. This is because wear of either the brush 16 or the periphery of the cylindrical member 20 will not change the arc widths of the brush 16 or the conducting segments 26. Therefore, the dwell angle will remain constant. Similarly, wear of either the brush 16 or the segments 26 cannot alter the instant at which the primary circuit is opened to cause the spark plugs to fire. Opening and closing of the primary circuit is not dependent upon the action of a spring, as was previously the case in most ignition systems, so that operation of the circuit breaker device is completely independent of engine r.p.m. Therefore, as the engine r.p.m. is increased, the instant or angle at which the primary circuit is both opened and closed remains constant. This permits the ultimate in timed control and dwell angle control to produce the maximum engine efficiency. The ignition system of the present invention is particularly well suited for racing engines of all types.

The preferred construction of the rotary member 20, described in detail, provides a means for converting al-

most all existing ignition systems to ignition systems utilizing the principles and advantages of the ignition system herein described. The polygon-shaped inner ring 64 is easily slipped over the timing cam 62 of the distributor mechanism in use on almost all automobiles. The cylindrical member 20 is easily and economically manufactured by inserting the polygon-shaped inner ring 64 in a tubular ring member and joining the two rings by the spots of solder 66. The nonconductive synthetic resin 68 can then be injected in the space between the two rings and cured. Then the outer ring can be cut by sawing, or some other suitable method, to form the spaces 28a which separate the conducting segments 26 from the nonconducting segments 28. The synthetic resin 68 then serves as both an insulating means and a bonding means. The outer periphery of the segments 26 and 28 is assured of being perfectly cylindrical. The dwell angle for various ignition systems can be varied as desired either by varying the arc width of the brush 16 for a standard arc width segment 26 or by varying the arc width of the segments 26. Therefore, by the simple installation of the brush arm 18 and brush 16 which requires but one screw, by slipping the polygon-shaped inner ring over the timing cam, and by adjusting the position of the brush 16 to produce the proper timing or instant at which the primary circuit is opened to fire the spark plugs, almost any ignition system previously in use may be converted to an ignition system in accordance with the present invention. The timing of the circuit breaker device need not again be adjusted for the life of the device.

Although the nonconducting segments 28 could be fabricated entirely of a nonconductive material, it is desirable to fabricate the segments 28 from the same conductive material as the conducting segments 26 because, in addition to simplifying the method of construction, a longer operating life is produced. The wear rate of the segments 26 and 28 will be the same if the same metal is used so as not to produce an uneven periphery which would wear the brush at an accelerated rate. But, more importantly, most nonconductive materials presently in use tend to "wipe" off on the brush 16 to form a nonconductive film which fouls the operation of the brush when in contact with the conducting segments 26.

Although a preferred embodiment of the rotary circuit breaker means has been described in detail, it is to be understood that, in its broader aspects, the present invention contemplates the novel combination of a rotary circuit breaker means in an ignition system having inductively coupled primary and secondary circuits. Therefore, it is to be understood that various changes and substitutions can be made in the preferred embodiments above described without departing from the spirit and scope of my invention as defined in the appended claim.

I claim:

55 A circuit breaker device for an internal combustion engine ignition system of the type having primary and secondary circuits inductively coupled and having a timing shaft synchronously rotated by the engine, the shaft having a polygonally shaped cam thereon, the circuit breaker

60 device comprising:
a polygonally shaped inner ring fabricated of an electrically conductive material and sized to be fitted on the cam and rotated thereby;

65 a cylindrical surface around the inner ring formed by an equal number of spaced segments each fabricated of an electrically conductive material;

electrically conductive bonding means mechanically and electrically connecting alternate segments to the inner rings;

70 and electrically non-conductive bonding means mechanically connecting and electrically insulating the other alternate segments from the inner ring, said nonconductive bonding means being positioned inwardly of the outer faces of said segments;

electrically conductive brush means in sliding contact with the outer faces of said segments for connection in the ignition system to complete the primary circuit when in contact with one of the segments electrically connected to the inner ring, and to break the primary circuit when in contact with one of the other segments and thereby induce a voltage in the secondary winding for igniting fuel in a piston of the engine.

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