Feb. 14, 1967 J. R. RICHARDS 3,303,835

FUEL IGNITION SYSTEM PREVENTING RADIO FREQUENCY INTERFERENCE

Filed Oct. 22, 1965 3 Sheets-Sheet 1

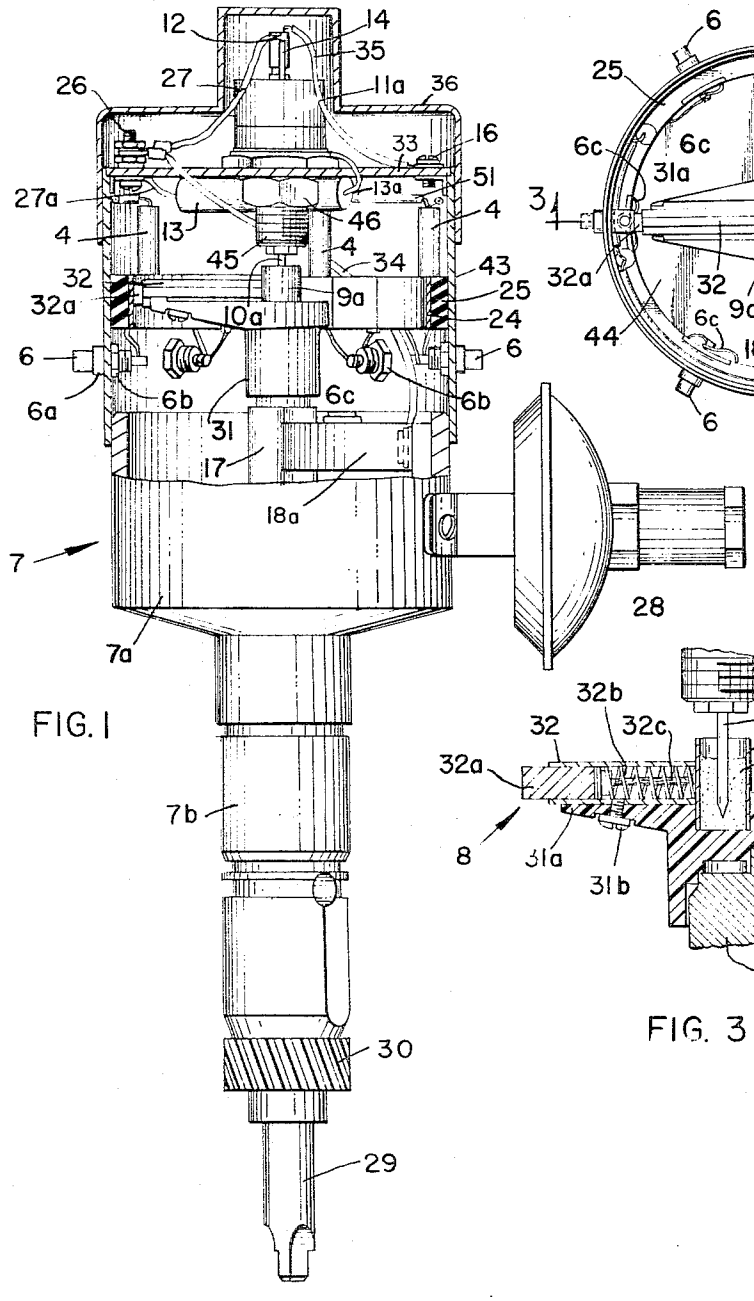



FIG. 1

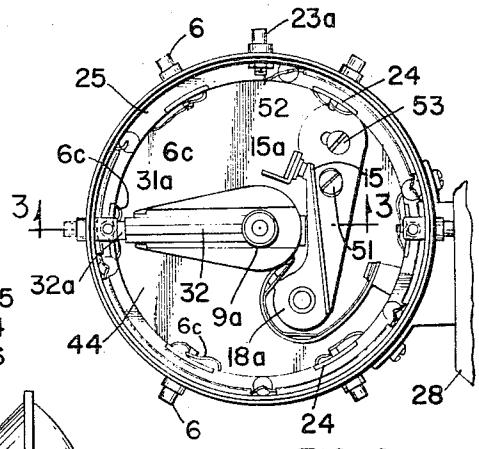



FIG. 2




FIG. 3

7b

30

29

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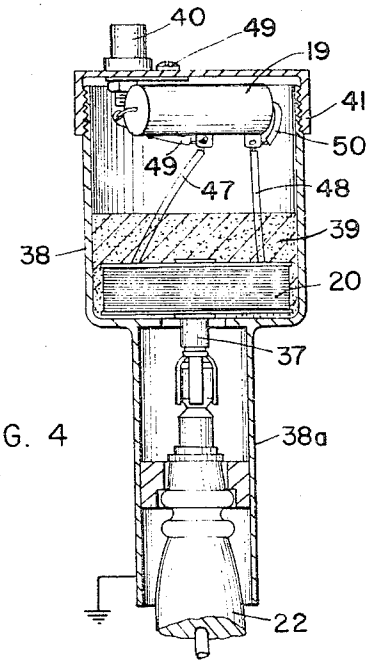



FIG. 4

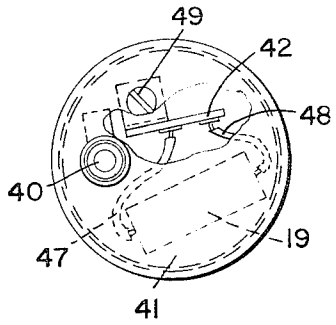



FIG. 5

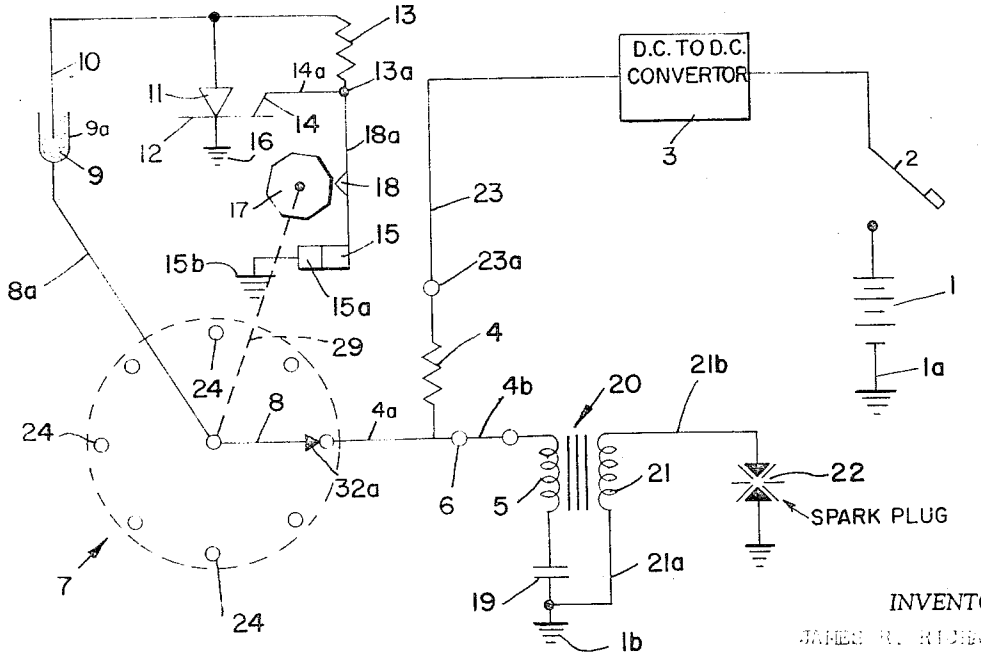



FIG. 6

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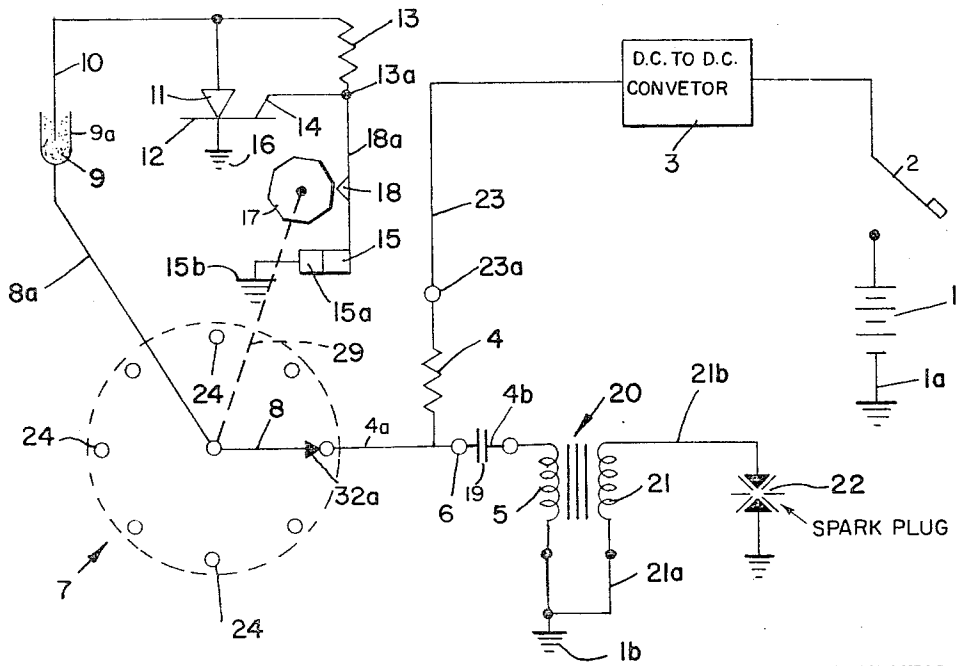



FIG. 7

INVENTOR.

BY

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# 3,303,835
# FUEL IGNITION SYSTEM PREVENTING RADIO FREQUENCY INTERFERENCE

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6 Claims. (Cl. 123—148)

This invention relates to an ignition system for internal combustion engines and which eliminates radio frequency interference radiation. More particularly, the invention relates to an ignition system for engines for automotive vehicles, which includes a low voltage metal shielded distribution system incorporating a solid state silicon controlled rectifier which does the switching and automatically controls the time duration of the ignition arc, to produce arc oscillations of relatively long duration at slow engine speeds and which automatically decrease in duration with increase in engine speeds.

Among the chief objects of the invention are:

(1) To provide a low voltage distribution system which is easily shielded to curtail emission of radiation causing radio frequency interference;

(2) To provide a system in which the high voltage necessary to fire each spark plug is located at and is a substantially integral part of the plug itself so that the distributor and leads therefrom are required to handle only relatively low voltages;

(3) To provide means for continuously charging a condenser in series with the primary winding of a high voltage, high frequency transformer and discharging the stored current in the condenser through the primary winding of the transformer by means of a commutating carbon brush and a silicon controlled rectifier triggered by conventional breaker points opened in correctly timed relation with the positions of the engine pistons, by a multilobed cam;

(4) To provide means for causing the arc which occurs across the gap of the spark plugs to oscillate at a frequency of several hundred pulses per second for each explosion, instead of a single pulse arc produced by present or prior art ignition system;

(5) To provde a method and apparatus which enables engines having high compression ratios to operate at high efficiency on relatively low octane rated fuels, without knocking, bucking or stalling, over the entire speed range of the engine;

(6) To provide an ignition system as aforesaid which substantially reduces cost of operation per brake horsepower hour;

(7) To provide an ignition system that is exceptionally reliable and efficient, which can be manufactured at relatively low cost and which has a life in use equal to that of the engine.

Other objects and advantages of my invention will become clear to those skilled in the art, after a study of the following detailed description, in connection with the accompanying drawing.

In the drawing:

FIGURE 1 is an elevational view, partly in section, of an assembled distributor embodying components of the invention;

FIGURE 2 is a top plan view of the distributor of FIG. 1 with dust cap and cover plate removed to illustrate details of the rotary distributor arm and breaker points;

FIGURE 3 is an axial sectional view in a plane identified by line 3—3, FIG. 2, showing to an enlarged scale the distributor arm assembly and the manner in which this arm is electrically connected with the rectifier and breaker points;

FIGURE 4 is an axial section through the transformer assembly forming a component of the invention and showing the manner in which the assembly is directly mechanically and electrically connected with a spark plug;

FIGURE 5 is a plan view looking down on FIG. 4, with a part of the cover cap broken away to disclose the capacitor terminal board beneath; and

FIGURE 6 is a schematic wiring diagram to facilitate explanation of the principle of operation of the invention.

FIGURE 7 is a variation of FIG. 6, showing an alternative method for mounting the capacitor.



*The invention in general*

Referring first to the wiring diagram of FIG. 6, 1 identifies a battery or other source of low voltage direct current having one terminal grounded at 1*a*. The remaining terminal is connected through switch 2 to D.C. to D.C. converter 3, which steps up the output over line 23, to about 250 volts. Line 23 is connected through resistors 4 and leads 4*a* with each respective terminal 6 of the distributor generally identified at 7. FIG. 6 shows the distributor adapted for an eight-cylinder engine; but for simplicity and clarity of illustration all but one of the connections to these terminals with terminal 23*a* have been omitted, it being understood that this terminal is connected with one terminal of each of a number of resistors 4, corresponding to the number of cylinders of the engine, and that the other terminal of each resistor is connected with a respective one of terminals 6 at the distributor.

A lead 4*b* also extends from terminal 6 to one terminal of the primary 5 of a transformer 20. The remaining terminal of this primary is connected to ground at 1*b*, through capacitor 19. One terminal of secondary 21 of transformer 20 is likewise grounded over lead 21*a*, while its other terminal is connected by lead 21*b* with a conventional spark plug 22 associated with a cylinder of the engine in the conventional manner.

As subsequently described in detail, distributor arm 8 is connected with the crankshaft of the engine, not shown, to rotate in synchronism therewith at one-half the engine speed for a 4-cycle engine, and to make successive electrical contact in the proper firing order, with the distributor terminals. FIG. 6 shows this arm as making temporary contact in its continued rotation, with one distributor terminal 6.

Although, as subsequently described, arm 8 is in permanent contact with a mercury pool connection generally identified at 9, and located within the distributor housing, this connection is for clarity of illustration, shown upon FIG. 6 as apart from distributor 7 and connected with arm 8 by a lead 8*a*. From connection 9, a lead 10 extends to anode 11 of a silicon controlled rectifier whose cathode is grounded at 16. Lead 10 is also connected to gate 14 of the rectifier, through a resistor 13, whose terminal 13*a* is also connected with breaker arm 18*a* having an integral cam follower 18 of the usual dielectric material and in continuous engagement with breaker cam 17. The cam, in the well-known way, is mechanically connected by means schematically indicated at 29, with distributor arm 8 and hence rotates in synchronism with the engine's crankshaft, at one-half the speed thereof. One breaker point 15 is carried by arm 18*a* and the other 15*a*, adjustably fixed with the distributor base in the usual way, is grounded at 15*b*.

*The distributor*

The distributor shown in detail upon FIGS. 1, 2 and 3, and generally identified at 7, includes a generally cylindrical housing 7*a* having a downward integral tubular extension 7*b* fitting and removably secured within an opening in the engine crankcase, not shown. A shaft 29 having a driving gear 30 keyed or otherwise fixed thereto at

its lower projecting end, is journaled for rotation in the housing. This gear is engaged by a like gear connected, for example, with the valve cam shaft, not shown, of the engine, so that shaft 29 is positively driven in the correctly timed relation with the engine's crankshaft.

The shaft extends upwardly into housing 7*a* and has the distributor arm assembly keyed to its upper end, by means indicated at 29*a*, FIG. 3. The arm includes a cap 31 of dielectric material which fits down over the upper end of shaft 29 and is shaped to receive key 29*a* with a snug fit, so that the arm is constrained to rotate as a unit with the shaft. A short metal tube 9*a* is secured within a central bore in cap 31, to form a reservoir for a small quantity of mercury 9.

Cap 31 has an integral radially extending arm 31*a* to which there is secured, as by a machine screw 31*b*, a metal tube or brush holder 32. The holder extends radially of shaft 29 and at its inner end may abut tube 9*a*. Arm 8 includes a carbon brush 32*a* which has a smooth sliding fit within the radially outward end of tube 32 and is urged outwardly of this end by a compression coil spring 32*b* abutting at one end against tube 9*a* and at its other end against brush 32*a*. The inner end of the brush has a reduced portion snugly fitting the contiguous end of the spring so that while the brush is urged outwardly in and along tube 32, it is yieldingly held against complete removal, except in response to an appreciable pull thereon. Tube 32 and brush element 32*a* may be of square or other non-circular shape in cross section so that the brush is held against rotation in and relatively to the tube, about the axis thereof. A flexible copper lead 32*c* electrically connects brush 32*a* and tube 9*a*.

A cylindrical extension or terminal support 43 is shown with its lower end fitting over and about, and secured to, the upper end of housing 7*a*. A ring 25 of insulating material fits within and is secured to extension 43 at the level of distributor arm assembly 8. A number of equi-angularly spaced metallic arcuate contacts or commutator segments, 24 are fixed within respective recesses in the inner surface of ring 25. In the model shown upon FIG. 1 there are six of these segments each with its surface flush with the inner surface of the ring. These contacts are essentially coplanar with the plane in which brush 32*a* rotates, so that the latter in its rotation successively makes electrical contact with each segment. The angles subtended at the axis of shaft 29 by the segments are the same. This angle is so selected as to afford the desired maximum period of ignition at the respective spark plugs, over the entire range of engine speeds, as subsequently explained. The mechanical connections and arrangements are such that at the instant cam 17 acts to separate contacts 15, 15*a*, brush 32*a* will be in contact with a segment 24.

Plate 44, FIG. 2, mounts breaker points 15, 15*a* and, in a known manner, is rotatable through limited angles about the axis of shaft 29, (1) by means 28 connected with the engine's intake manifold and embodying a diaphragm deflected in response to absolute pressure within the manifold and (2) means not shown, in the base of housing 7*a*, responsive to rotational speed of the shaft. The purposes are the usual ones of advancing the time of ignition in each cylinder directly with engine speed and retarding the time in accordance with absolute manifold pressure.

Each of the segments 24 is electrically connected to a respective one of a like number of electrically insulated terminals 6 extending through the wall of support 43. Referring particularly to FIG. 1 terminal 6 at the left of the figure is shown to include an externally and internally threaded bushing 6*a* of insulating material, extending radially through and fitting a hole in support 43 and clamped in place by a nut 6*b*. The metallic terminal includes an external head having a reduced shank extending axially through and threadedly engaging the bushing and connected at its end inside the support, with its respective segment 24. The model shown upon FIGS. 1 and 2 is for a six-cylinder engine, so that there are shown six terminals 6, each connected with its segment by a respective one of an equal number of leads, such as 6*c*, FIGURE 2. Each of these distributor terminals is electrically connected by leads or cables such as 4*a*, 4*b*, FIG. 6, with a respective one of the transformer assemblies 20, etc., subsequently described in detail.

The upper edge of extension 43 is recessed to form an annular shoulder receiving an insulated circular cover plate 33. Means not shown prevent rotation of the plate with respect to its support. Resistor 13 is attached to the under side of this plate. The plate has a central aperture to receive an insulating bushing 45. An enlarged hexagonal head integral with the bushing contacts the upper surface of plate and is held thereto by a nut 46 threaded on the bushing into contact with the lower face of the plate. An electrode 10*a* is fixed in bushing 45 to extend axially therealong and at its lower end dips into the pool of mercury 9 to thus make continuous electrical contact with brush 32*a*.

In correspondence with FIG. 6, electrode 10*a* is connected with the anode 11 of the rectifier within casing 11*a*. From this electrode a lead also extends by way of conductor 27 to a binding post 26 fixed in plate 33 and from this post over conductor 27*a* to one terminal of resistor 13. A third conductor 34 extends from the other terminal 13*a* of resistor 13, downwardly within the distributor housing, to breaker arm 18*a*. A cable or conductor 35 connects cathode 12 of the rectifier to ground at 16. Gate 14 is connected by lead 14*a* with terminal 13*a* of resistor 13, in the manner clearly shown upon FIGURE 6. A protective shield can or cap 36 fits down exteriorly over and about support 43 and is removably held in place by means not shown. At 23*a*, FIGURES 1 and 6, there is identified a common terminal which, in a way clear from the preceding description, is connected by a common lead with one terminal of each of the resistors 4, of which there is one for each cylinder of the engine. These resistors 4 are conveniently mounted in circumferentially spaced relation on the inner wall of support 43. A plurality of leads extend, one from each of the other terminals of resistors 4, to a respective terminal 6.

*The transformer assembly*

This assembly has been previously generally described in connection with FIG. 6, and is shown in greater detail upon FIGS. 4 and 5. It will be understood that one of these assemblies is provided for each spark plug. Referring particularly to FIG. 4, the assembly is mounted in a metallic housing or container 38 having a central depending integral tubular extension 38*a* adapted to be releasably secured over the top end of the plug 22 and extending down over the base of the plug to effect a good ground. Transformer 20, is mounted contiguous to the base of container 38 and is encapsulated by a potting compound 39 which may be of epoxy resin. One terminal of the secondary 21 of transformer 20, is in the form of a clip 37 insulated from can 38 and having resilient arms to snap over and about the central electrode terminal of the plug as the assembly is moved down thereover. The other terminal is grounded to container 38.

A cover 41 for container 38 mounts capacitor 19 on its under side. An insulating terminal board or base 42 is also fixed by a screw 49 to the under side of cover 41 and carries a pair of terminals one of which is grounded to can 38 and connected by conductor 48 to one terminal of secondary 21 of transformer 20. The other terminal of board 42 is connected by lead 47 to one terminal of the primary 5, of transformer 20. The two terminals of the board are also connected to the respective terminals of capacitor 19, by leads 49 and 50. The remaining terminal of transformer primary 5 is connected to a terminal 40 carried by cover 41, externally there-

of. This terminal **40** at each spark plug is connected by a respective one of a plurality of leads only one of which, **4***b*, is shown upon FIG. 6, to a terminal of a corresponding one of resistors **4** clearly shown upon FIG. 1 as mounted vertically to and in equiangularly spaced relation about terminal support **43**.

For simplicity of illustration, but one resistor **4** is shown upon FIG. 6. In actual practice, there will be a resistor for each cylinder, mounted as aforesaid. One terminal of each resistor is connected, as by conductor **51**, FIG. 1, to a common terminal **23***a*, FIG. 2, fixed in the wall of support **43** and insulated therefrom in the manner previously described for terminals **6**. This terminal **23***a* is connected by a lead **23**, shown only upon FIG. 6, to converter **3**, located at a convenient location on or adjacent the engine. Within the distributor the load end or terminal of each resistor **4** is connected to a respective one of the terminals **6**, as by leads **6***c*.

In FIGURE 7 a variation on the schematic wiring diagram of FIGURE 6 is shown. The capacitor **19** is inserted between the distributor terminal **6** and the primary **5** of the transformer **20** with the end of the primary **5** connected to ground **1***b*. In this instance the capacitor **19** is mounted inside the distributor **7** and the transformer **20** only is mounted within the transformer assembly container **38**.

*Operation*

The tendency in modern automotive engineering practice is to design engines with relatively high compression ratios. Ratios as high as **11** or **12** are common and are used, principally to give greater thermodynamic efficiency and reduced fuel consumption per brake horsepower hour. However such high compression ratios have heretofore required a fuel having a correspondingly high octane rating, or number, in order to eliminate knocking and ping at low engine speeds.

Actually the higher the octane number of a fuel, the slower it burns. This is of decided advantage at low engine speeds and hard pulls, over fuels with lower octane numbers because the slower burning rate, at lower engine speeds affords more complete combustion and a more even and prolonged thrust on the pistons and hence reduces or eliminates knocking produced by a fuel of relatively low octane number, which burns at a higher rate.

In practice the explosive charge in the engine is ignited a few degrees before the piston reaches top dead center on its compression stroke, in order that the charge may have time to develop its maximum thrust as the piston starts down on its power stroke. This is the initial timing for the fuel-air mixture, which burns at a fixed rate for any given fuel. When the engine speed increases the explosive mixture must be ignited at an earlier point in the upward compression stroke of the piston in order to give the mixture time to develop its maximum thrust as the piston reaches top dead center and starts downwardly on its power stroke. This earlier ignition is effected automatically by the speed-responsive mechanism in the engine's distributor.

I have found that at higher engine speeds, fuels with lower octane numbers, which burn and deliver their power at a high rate, work very efficiently and without knock. Thus the advantages of fuels of higher octane numbers, which are present at slower engine speeds and hard pulls, are non-existent at higher engine speeds, where fuels from low to high octane numbers cause equally satisfactory engine operation. I have also found that in an engine of relatively high compression ratio and at relatively low engine speeds and heavy loads, fuels of lower octane numbers give satisfactory operation without knock provided the spark at the plug can be controlled so as to prolong the time duration thereof inversely with engine speed. Or, in other words, satisfactory operation of a high-compression engine at low speeds and heavy loads can be effected with fuels of lower octane numbers provided the time duration of the spark is prolonged in proportion to decrease in engine speed. This result follows from the fact that the prolonged spark effects a more complete combustion or burning and hence produces a more even, uniform and prolonged pressure upon the piston. This is in contradistinction to a conventional ignition system wherein the practically instantaneous spark produces an explosion which causes the pressure to rise immediately to a peak value and thus results in knock and ping at lower engine speeds, where fuel of low octane number is used.

In operation, my invention effects the foregoing highly useful result as well as producing numerous other advantages thermodynamically and mechanically. With switch **2** closed and the engine in operation the output of D.C. to D.C. converter **3** is approximately 250 volts at 75 ma., and supplies power to all resistors **4** over common lead **23** to charge each capacitor **19** at the respective plugs, through the leads or conductors such as **4***b*, FIG. 6, connecting each distributor terminal **6** with the primary **5** of its transformer **20**. Distributor arm assembly is rotating at one-half the crankshaft speed and as brush **32***a* thereof makes contact with a commutator segment **24** power is supplied through mercury pool **9** and electrode **10***a*, to anode **11** of the rectifier, and to one terminal of resistor **13** whose other terminal is connected with gate **14** and presently closed breaker points **15**, **15***a*. Thereafter cam **17** in its synchronous rotation with distributor arm assembly **8**, separates points **15**, **15***a* to thereby remove ground at **15***b* from gate **14** and resistor **13**, thus allowing the voltage at the gate to rise from 0 to 250 volts. This rise, in turn, effects conduction between anode **11** and cathode **12** which reaches a very low resistance and effects discharge of capacitor **19** of the corresponding plug and which, as shown, is in series with primary winding **5** of transformer **20** from anode to cathode of the rectifier. The resulting discharge induces a high voltage in secondary **21** of the corresponding transformer **20**, and fires plug **22**.

At this point the voltage at anode **11** has dropped to near zero and the rectifier stops conduction and develops a high resistance between anode **11** and cathode **12**. Capacitor **19** in series with primary **5** starts to recharge through the corresponding resistor **4** and when the voltage rises high enough and points **15**, **15***a* remain open, the rectifier again conducts, going to a low resistance from anode to cathode and discharging capacitor **19** to thus cause another arc across the gap of plug **22**. As long as points **15**, **15***a* remain separated, the arcs across plug **22** continue in very rapid succession and occur at a rate determined by the time constant of resistors **4** and capacitor **19**, as in a relaxation oscillator. Since with proper setting, points **15**, **15***a* remain separated for each cylinder, a time directly proportioned to engine speed, it follows that the time duration of the arcs across the gap of plug **22** will be inversely proportional to engine speed; and as the result, the prolonged spark period at lower engine speeds results in more even, complete and smooth combustion and enables the use of fuel of lower octane number in engines of high compression ratios, without knocking, bucking, or stalling at low engine speeds and under heavy loads. It will be understood that the maximum separation of points **15**, **15***a*, and thus for any given engine speed, the time during which they are separated, is adjustable by the usual eccentric **51**, FIG. 2, connected with the support **52** of arm **18***a*, and that the adjustment is fixed by tightening screw **53** in the conventional manner.

A number of other advantages result from the invention. Since only low voltages are produced in the distributor, this is easily shielded to curtail emission of radio frequency interference. All high voltages are produced at each plug by means which in effect form an integral part of the plug itself. All high-tension wiring is thus reduced to a minimum length, reducing cost of wiring and further reducing radio frequency interference. The high tension oscillations in secondary **21** are shielded by

the metal of container 38 which is effectively grounded to the cylinder block itself.

Numerous modifications, re-arrangements and substitutions of equivalents will readily occur to those skilled in the art, after a study of the foregoing disclosure. Hence the disclosure should be considered in an illustrative rather than a limiting sense. All modifications within the scope of the subjoined claims, are reserved.

I claim:

1. In an ignition system for a multi-cylinder internal combustion engine, a distributor housing for connection with the crankcase of the engine, a shaft journaled in said housing and connectable with the camshaft of the engine for rotation in unison therewith, a breaker cam and a distributor arm fixed with said shaft for rotation as a unit therewith, normally-closed breaker points in said housing and periodically opened by and in response to rotation of said cam, a plurality of terminal segments carried by said housing in angularly-spaced relation about the axis of said shaft for contact in succession by said arm, a solid state switching device comprising an anode, grounded cathode, and control gate, a resistor connected between said anode and gate, a ground connection between said gate, through said points, a first circuit connection between said anode and said arm, a plurality of resistors carried by said housing, an electrical connection between one terminal of each of said plurality of resistors and a respective one of said terminal segments, a common terminal fixed to said housing, and an electrical connection between the remaining terminals of all said plurality of resistors and said common terminal.

2. The ignition system of claim 1, said first circuit connection including a mercury reservoir carried by said arm axially of said shaft, a fixed electrode carried by said housing and extending into said reservoir, and a conductor from said electrode to said anode.

3. The system of claim 1, a source of D.C., a D.C. to D.C. converter, and a series connection between said source, converter and common terminal.

4. The system of claim 1, a plurality of transformer units each adapted for mechanical and electrical connection to a respective one of the spark plugs of the engine, each said unit comprising a container, a step-up transformer and a capacitor fixed in said container, one terminal of the primary of said transformer being connected to ground, through said capacitor, one terminal of the secondary of said transformer being grounded, a clip fixed with said container for detachable connection with the electrode of a spark plug, an exposed terminal carried by said container, for electrical connection with a respective one of said terminal segments of said distributor, and an electrical connection between said exposed terminal and the remaining terminal of said primary.

5. The system of claim 4, each said container including a tubular extension adapted to fit down over and about a spark plug for grounding to the base thereof, said clip being fixed within and insulated from said extension, for automatic securement to the electrode terminal of the plug, by and in response to movement of the extension over and about the plug.

6. In an ignition system for an internal combustion engine having a cylinder, a spark plug connected with said cylinder for igniting a combustible charge compressed therein, a lobed cam connected for rotation in timed relation with the crankshaft of the engine, a pair of normally contacting breaker points separated by and in response to rotation of said cam, a source of D.C., a first resistor, a terminal, first circuit connections connecting said source to said terminal, through said first resistor, a capacitor, a step-up transformer, a converter, a second resistor, a fixed contact segment, a distributor arm fixed with said cam for rotation about an axis as a unit with said cam, and periodically engaging said segment, a reservoir of mercury fixed with said arm on said axis, a fixed electrode dipping into said reservoir, second circuit connections connecting said capacitor, the primary of said transformer, said segment, distributor arm, reservoir, electrode, converter, second resistor and breaker points in series through said terminal, and means adapted to electrically connect the secondary of said transformer to said spark plug.

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