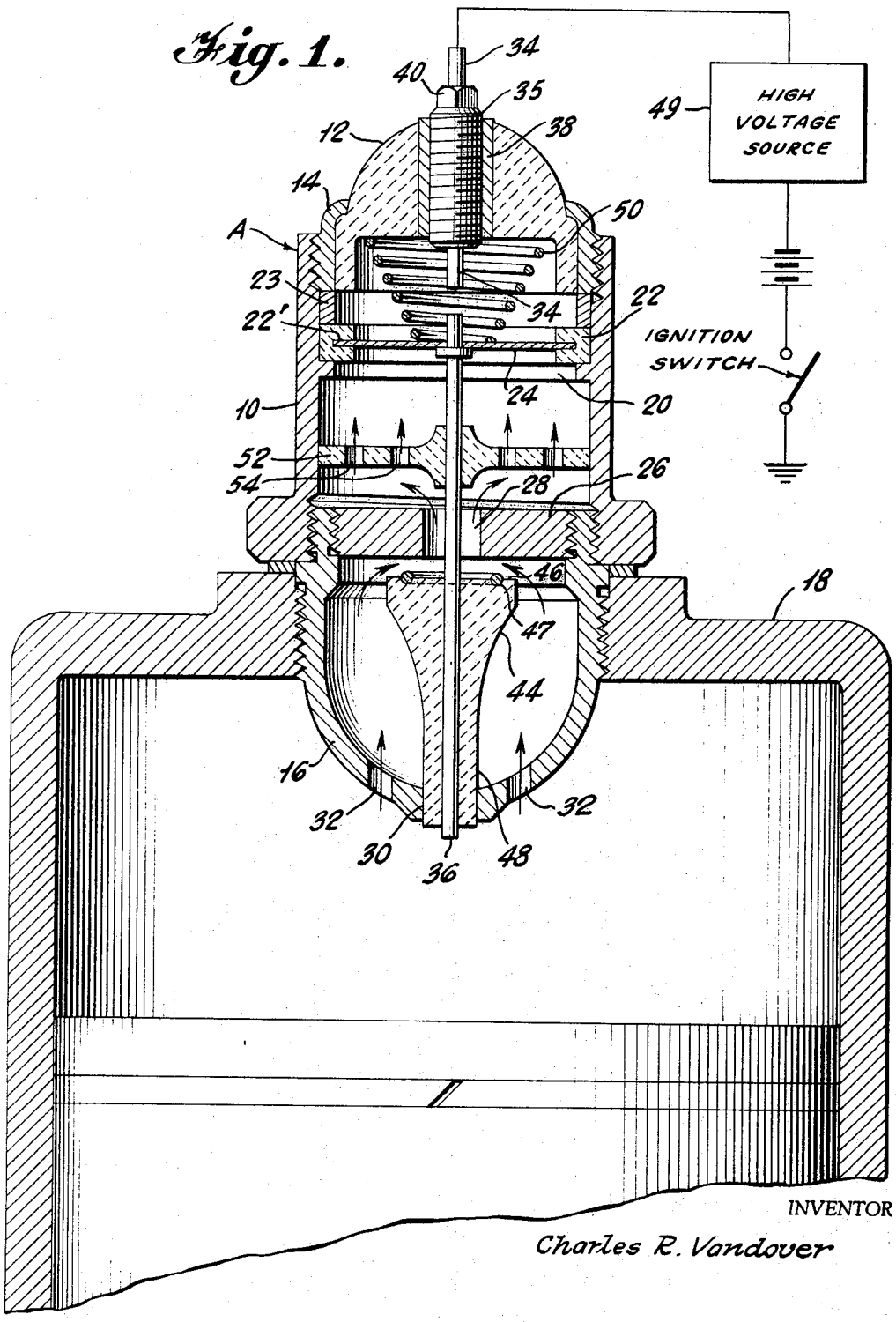
Jan. 2, 1968 C. R. VANDOVER 3,361,929

SPARK PLUG HAVING FLEXIBLE DIAPHRAGM WHICH PROVIDES ELECTRICAL ENERGY AT THE SPARK GAP

Filed Oct. 5, 1966 3 Sheets-Sheet 1

Fig. 1.



INVENTOR

Charles R. Vandover

Fig. 2.

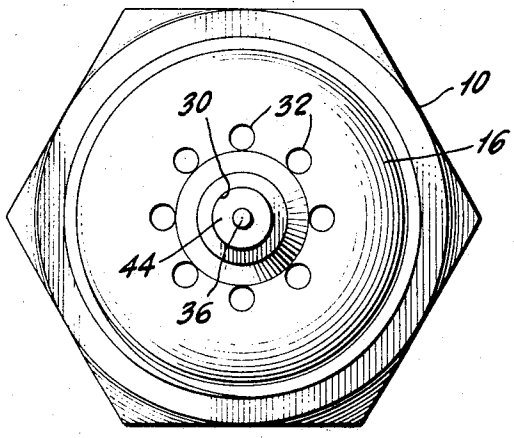
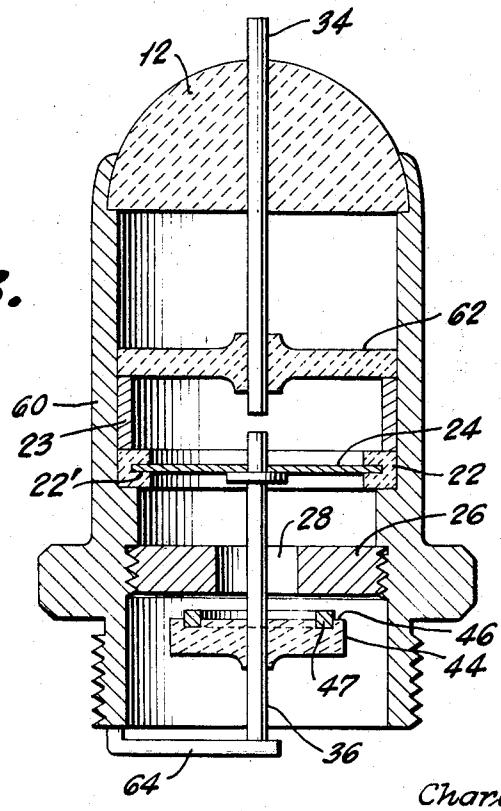


Fig. 3.



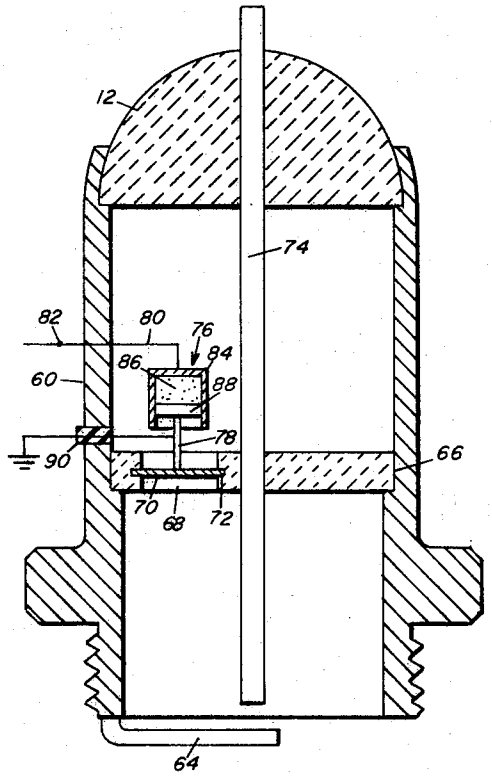
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FIG. 4



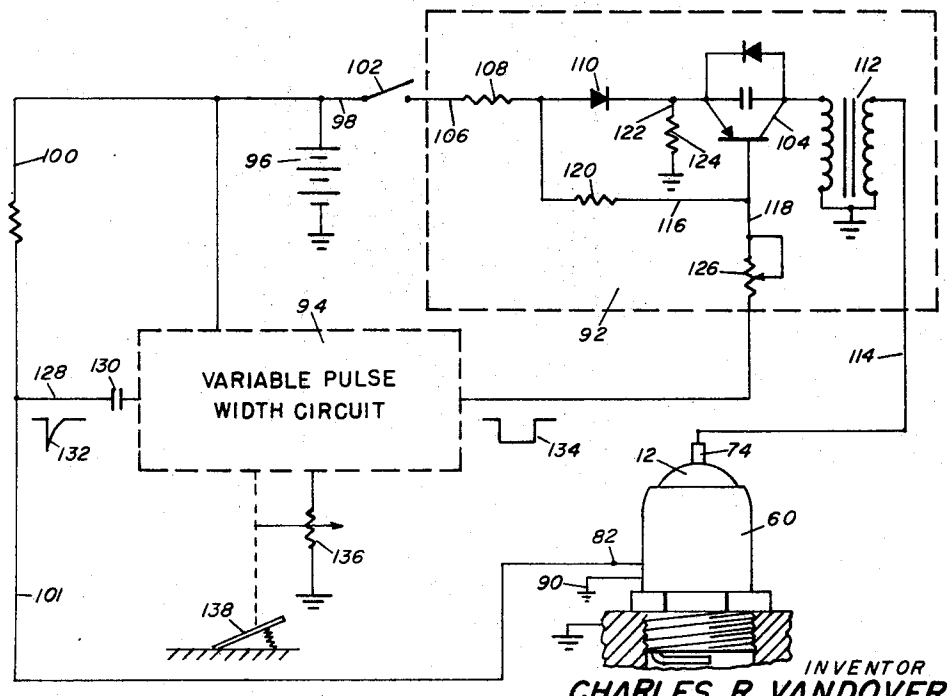


FIG. 5

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3,361,929

SPARK PLUG HAVING FLEXIBLE DIAPHRAGM WHICH PROVIDES ELECTRICAL ENERGY AT THE SPARK GAP

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Filed Oct. 5, 1966, Ser. No. 599,331
7 Claims. (Cl. 315—55)

ABSTRACT OF THE DISCLOSURE

A spark plug having a body member divided into upper and lower chambers by an insulating disk and flexible diaphragm which carries a transducer in order to generate electricity upon deflection of the diaphragm.

This application is a continuation-in-part of copending application Ser. No. 277,342, filed May 1, 1963, now abandoned.

The invention disclosed herein relates to ignition systems and more specifically to an ignition system particularly adapted for use with high voltages.

As is well known, prior art ignition systems incorporate timing mechanisms which, through mechanical connection to a rotating portion of the engine, send properly timed pulses of electrical energy to spark plugs for ignition of a combustible mixture in the cylinders thereof. The prior art timing mechanisms are complicated and expensive, and because of wear require continual readjustment and replacement of parts thereof.

It has been found that, by providing a pressure responsive means in the structure of the spark plug to trigger or complete the circuit to the voltage source for energization of the plug, the timing mechanism may be eliminated altogether.

It is possible to accomplish the foregoing by providing a pressure responsive means in a spark plug which, at the proper time in the pressure sequence of the cylinder in which the plug is disposed, signals the voltage source to cause firing of the plug.

It is also possible to accomplish the foregoing by providing a plug having a two-member electrode or spindle and wherein one electrode has high voltage continuously impressed thereon, and the other electrode is moved at the proper time, by pressure responsive means in the plug into and out of circuit completing engagement with the first electrode to causing firing of the plug.

It is an object of this invention to provide an ignition system wherein the system is energized by a pressure responsive means located in the spark plug.

It is another object of this invention to provide a spark plug for use in the ignition system described wherein the pressure responsive means comprises a pressure transducer disposed within the plug.

Applicant recognizes that two-part electrodes have previously been used in spark plugs, as exemplified by Berkey Patent No. 2,604,510 and pressure responsive means for moving an electrode, as disclosed in the above patent and also in Seibert 1,525,415.

The foregoing and other objects and advantages will be apparent from the description of the invention when read in view of the accompanying drawings, wherein:

FIGURE 1 is a sectional view through a spark plug incorporating the invention herein;

FIGURE 2 is an end view as seen from the bottom of the spark plug;

FIGURE 3 is a vertical sectional view of another embodiment of the spark plug;

FIGURE 4 is an elevational view in section of yet another embodiment in accordance with the invention; and

FIGURE 5 is a schematic view of an ignition system incorporating the plug of FIGURE 4.

Referring to the drawings, an embodiment is shown in FIGURE 1. Therein a three-piece tubular metal body A has a center member **10** with interior threads at each end. The upper end of member **10** is closed by a cap comprising a hemispherical insulator **12** fixed within a ring member **14**, the ring member having exterior threads for securing it to the upper end of the center member **10**. The lower end of the body comprises a substantially hemispherical member **16** having exterior threads at its upper end for securing it to the center member **10**. The bottom member **16** is further provided with a second set of exterior threads for mounting and grounding the plug in an engine block diagrammatically indicated at **18**.

Between the center member **10** and bottom member **16**, there is provided a cylindrical partition member **26** having exterior threads for securing it to the interior threads on the upper end of the bottom closure **16**. A central opening **28** is provided in member **26** which defines a gas passage for reasons hereinafter apparent.

The lower end of the bottom closure **16** has a central opening **30** in axial alignment with the partition member opening **28**, and circumferentially spaced around the central opening **30** are a plurality of smaller gas entry openings **32**.

Adjacent the top of the center member **10** and below ring member **14**, the center member **10** has an integral interior circumferential shoulder **20**, supporting a circumferential ring **22** of non-conducting insulating material. The ring **22** has an inner facing circumferential groove **21** supporting a flexing disk **24** of steel or other suitable material. The ring **22** is held in place by a spacing ring **23** of non-conducting material.

The spark plug includes a centrally positioned stationary, but adjustable, first electrode member **34** having an enlarged threaded portion **35** rotatably mounting it in a threaded sleeve **38** fixedly secured in the insulator cap **12**. The upper end of portion **35** has a non-cylindrical head portion **40** for receiving a suitable tool to rotate member **34** and thereby vertically adjust the electrode member. The upper electrode member **34** projects below the insulator cap **12** and terminates above the flexible disk **24**.

Additionally, there is provided a second electrode member **36**, in axial alignment with first member **34**. The second electrode member is fixed to the member **24** and projects above the disk but terminates short of the end of member **34**, and also projects downwardly from the disk through the passage **28** and the end opening **30**.

The portion of the second electrode or spindle member **36**, within the bottom member, fixedly supports a valve **44** of insulating material for closing the gas passage **28**. To accomplish this, valve **44** has a flat or disk top **46** of greater diameter than the passage **28**, and has a suitable O-ring **47** therein which seats on the bottom face of the ring **26** to close the gas passage **28**. The valve **44** tapers down and inwardly to a lower cylindrical end **48**, which slidably fits within the body bottom opening **30**, the end of the valve normally projecting below the end of the plug, but terminating short of the lower end of the second electrode member **36**.

In operation the first electrode member **34** is connected to a high voltage power source, here diagrammatically indicated at **49** which may be a multi-vibrator-pulse coil, or any other type to impress a continuing voltage on the plug.

Normally, the plug parts are in the position shown in FIGURE 1, and upon the compression stroke of the piston, the gases will be forced through the bottom openings **32**, into what may be termed the valve chamber of the plug, then through the open valve defined by valve member **44**, and partition member **26**, and into the center or pressure chamber of the plug defined between flexing member **24** and partition member **26**.

The disk **24** will flex upon a predetermined pressure, which will vary with the engine and compression stroke but is readily determined, and move the second electrode member **36** into circuit completing engagement with the first electrode, in what may be termed the arc or contact chamber defined by the flexing member **24** and the bottom of the top insulating member **12**. As high voltage is being used, it is not necessary that the spindle actually make physical contact for power flow, but the adjustment must be such as to prevent an arc which will cause power loss.

Upon the moving electrode member **36** being raised, the valve closes off the gas chamber and the lower end thereof is lifted to position the bottom of the second electrode centrally of the lower body opening **30** which functions as the third electrode, whereupon the plug will fire through the entire circumferential space between the spindle and the body end. It is thus seen that the second electrode is not only moved into and out of circuit completing position, but the firing end is moved into and out of firing position.

The closing of the valve means prevents damage to the flexing member **24** upon explosion of the new mixture in the piston chamber. The rapid drop of pressure in the cylinder thereafter results in the higher pressure in the gas chamber acting on the valve to open the latter and release the pressure in the plug, whereupon the parts return to the position shown in FIGURE 1.

From the foregoing, it can be seen that the plug comprises in general, a stationary and movable spindle, spaced a required amount in the arc chamber, a pressure responsive means for moving the movable spindle to close the circuit, that is, said means herein being responsive to a pressure increase in the pressure chamber, and valve means responsive to movement of the lower spindle from non-firing to firing position to close off the pressure chamber.

In order to assure quick action of the plug, a suitable compression spring **50** may be positioned in the arc chamber, the spring respectively engaging the bottom of insulator **12** and the top of flexing member **24**.

Additionally, there may be fixed to the electrode **36**, within the pressure chamber, a centering disk **52** of suitable insulating material having openings **54** therethrough to permit passage of the gas. The disk is of slightly less diameter than the inside diameter of the body to permit it to raise and lower with the spindle.

Referring to FIGURE 3 there is shown a second embodiment of the plug, this embodiment being less expensive to manufacture than that of FIGURE 1. In FIGURE 3 the parts corresponding to FIGURE 1 have been similarly numbered. Herein the body **60** is a cylindrical member **60** threaded at its lower exterior to mount and ground it in a cylinder head. The insulator **12** is fixed in the upper end of body **60**, and electrode **34** is fixed centrally of the insulator. Additionally, the lower end of spindle **34** is centrally held by an insulator disk **62** secured to the body member **60**. The plug further carries an electrode **64** extending laterally and inwardly from body member **60** and terminating adjacent the lower end of the movable spindle **36**, this electrode being adjusted to fix the gap as in most plugs.

It is obvious the operation is the same as that of FIGURE 1. Upon the compression stroke the gases will flow past valve means **44** into the pressure chamber until member **24** flexes to close the electrode members whereupon firing will occur. Again valve **44** will remain closed during the explosion, and upon release of pressure the parts will return to the position shown in FIGURE 3.

Although in the particular embodiments illustrated, the plug fires in response to pressure conditions within the cylinder, the gases flowing directly into the plug, thus simplifying construction; indirect feeding of the gases, or even supplemental pressure producing means could be used, such as an air pump responsive to operation of the crank shaft. In such an embodiment, the partition member **26** would be closed, except for a sealed opening through which the electrode member **36** would pass. Additionally, the valve member **44** would be eliminated.

In FIGURE 4 a further variation in accordance with the above-mentioned principles is illustrated. In the embodiment of FIGURE 4, the responsive means actuates a transducer which, in turn, signals the source of electrical energy to conduct a pulse of current to the electrodes of the device and produce a spark thereby. As in the embodiment of FIGURE 3, the plug comprises a body **60** having a hemispherical insulator **12** closing off the upper portion thereof and an electrode **64** extending from the lower face toward the center thereof. A disk **66**, of some suitable insulating material, is mounted intermediate the ends of the body **60** and has a bore **68** disposed therethrough at a point spaced from the centerline thereof. A flexible disk **70** is mounted in a groove **72** disposed around the periphery of the bore **68**. A central electrode **74** extends through the insulator **12** and the disk **66** to a point proximate but spaced from the electrode **64** to provide a spark gap therebetween. A transducer **76**, comprising in the embodiment shown a carbon granule variable resistance switch, is mounted in the chamber formed by a disk **66**, body **60** and the hemispherical insulator **12** and is connected to the flexible diaphragm **70** by connecting member **78**. The transducer **76** is connected, by an insulated conductor **80**, to a terminal **82** at the exterior of the body **60**.

The switch **76** comprises a container member **84** filled with loose carbon granules **86** and having a movable piston-like member **88** closing the open end thereof and insulated therefrom in such a way that electric current passing between the member **88** and the conductor **80** must pass through the carbon granules **86**. The member **88** is connected by a conductor **90** to a ground. The above-described structure is typical of the well-known variable resistance carbon granule type switch. As the diaphragm **70** is deflected upwardly under the influence of pressure from the piston in which the spark plug is located, the member **88** moves upwardly with the connecting member **78** thereby compressing the carbon granules **86** and decreasing resistance to the passage of electrical current therethrough.

It should be obvious that, as a substitute for the carbon granule transducer **76**, other types of transducers can be utilized to accomplish the same function and mechanical switches, operated either by the diaphragm directly, by a spring-loaded snap-action switch operated by the diaphragm, an eccentric snap-action switch or a mercury switch.

Turning now to FIGURE 5, of the drawings, a plug, incorporating the teachings of this invention, is shown in schematic connected to a circuit adapted to fire the plug at the proper time during the cycling of the engine. The circuitry includes an ignition circuit **92** and a time delay circuit **94** connected to a storage battery **96** or other suitable source of electrical energy through leads **98** and **100** respectively.

The ignition circuit **92** is connected to the conductor **98** through an ignition switch **102** and includes a PNP transistor **104**, the emitter side thereof being connected to a lead in conductor **106** which is in turn connected to the switch **102** through a resistor **108** and blocking and biasing diode **110**. The collector side of the transistor **104** is connected to an ignition coil or step up transformer **112**. The coil is preferably of 400 to 1 ratio

and is connected, on the high voltage side thereof, to the electrode 74 of the spark plug through a lead out conductor 114. A by-pass conductor 116 connects the lead in conductor 106 to a base conductor 118 which is connected to the base of the transistor 104. The conductor 116 includes a base cut off resistor 120. A bias conductor 122 connects the conductor 106 between the transistor 104 and the diode 110 to ground through a resistor 124. A variable resistor 126 is interposed in the base conductor 118 and serves as an adjustment for the point or potential at which the transistor 104 will conduct.

The ignition circuit 92 operates as follows: With no potential on the base conductor 118, current flows from the storage battery 96 through the closed ignition switch 102 and into a closed loop consisting of the resistor 124, conductor 122, diode 110, resistor 108 through the battery 96 and back to the resistor 124. This produces a positive voltage at the junction of conductors 106 and 122 which junction is tied to the emitter of the transistor 104. A more positive voltage is produced across the diode 110 and is applied to the base of the transistor 104 through conductor 116 and resistor 120. Since the voltage applied through the conductor 116 is more positive than the voltage applied to the emitter by the voltage drop across a diode 110, the transistor 104 is nonconducting in the absence of other voltage applied to the conductor 118.

With application of a voltage through the conductor 118 to reduce the base bias, the transistor 104 suddenly breaks into conduction since, for all practical purposes, a short appears across the collector to emitter junction of the transistor. The heavy current flow through the primary coil of the transformer 112 produces a high flux field in the core thereof. When the voltage applied through the conductor 118 is terminated, conductivity through the transistor 104 is also terminated through the return of the bias on the base of the transistor 104 to the original condition and the flux field in the transformer 112 rapidly collapses producing a voltage in the secondary core of the transformer high enough to fire the spark plug.

It should be noted that normally open points in the conductor 118 connected to the ground could produce the above result. When the points close or the voltage applied to the conductor 118 amounts to a pulse going from negative to ground and back to a positive voltage, the same result would be produced in the ignition circuit 92.

Referring now to the delay circuit 94, a circuitry is connected to the battery conductor 100 and a plug switch conductor 126 through an inlet lead 128 and an input coupling capacitor 130. The plug switch conductor 126 is connected to the terminal 82. The variable pulse width circuit incorporated in the timing device 94 may be of any of the types commonly known in the art, such, for example, as the silicon controlled time delay switch described in the General Electric Transistor Manual, sixth edition, at page 326, or the one-shot multi-vibrator described in Technical Data Sheet, TD/4/T105, revision B, of the Engineered Electronics Company of Santa Ana, Calif. Devices of the above-described type are triggered by a negative gate pulse such as that shown at 132 in FIGURE 5 and produce a negative going square wave, indicated at 134 in FIGURE 5, the trailing edge of which is delayed to the required point in time with reference to the occurrence of top dead center in the cylinder in which the spark plug is installed. The width of the wave 134 is controlled by a delay resistor 136, coupled to some acceleration indicating mechanism such, for example, as a linkage to the throttle 138. This mechanism acts in such a way that opening the throttle decreases the width of the pulse 134 thus advancing the time of firing of the plug. As a substitute for the throttle linkage controlling the delay resistor 136, the linkage could be connected to the vacuum from the engine in such a way that increasing engine speed decreases the output pulse 134 so that the spark is advanced as required. If a different circuit than that shown or a different type of delay device which produces an output pulse of different polarity than an inverter could be installed in the circuit or in line of the conductor 118 between the delay circuit 94 and the ignition circuit 92 to produce the required polarity in the output pulse.

In operation the upward compression stroke of the piston in the cylinder in which the plug is located induces an upward deflection of the diaphragm 70 increasing the current flow through the variable resistance switch 76 thereby sending a negative gate pulse through the conductor 126 to the variable pulse width or time delay circuit 94. The spring constant of the diaphragm 70 is such that the signal to the time delay circuit 96 is well in advance of the top dead center position of the piston in that cylinder and is also in advance of the maximum advance or earliest firing time required, so that the leading edge of the square wave 134 occurs in advance of the maximum advance required. The trailing edge of the square wave 134 may, because of the capability of the circuitry of the variable pulse or time delay circuit 92, be varied from a time nearly coincident of top dead center to a time coincident with the maximum advance required in the system. By suitable connecting linkage into the spark advancing mechanism the spark may then be advanced from the point of time proximate the occurrence currents of top dead center to the maximum advance time required as the engine is accelerated.

It should be understood that the electrodes may be any suitable type, such as those disclosed in Paulson Patent No. 1,719,948. As a substantial part of the electrode is exposed to combustion gases, it is preferable to manufacture it of a metal which will resist erosion. In like manner, the interior of the plug body may be covered with a suitable material to prevent erosion.

What has been set forth above has been intended to be exemplary of an embodiment incorporating features in accordance with the invention to enable those skilled in the art in the understanding thereof. It should therefore be understood that, within the scope of the appended claims, the invention may be practiced other than as specifically described.

What is new and therefore desired to be protected by Letters Patent of the United States is:

1. A spark plug comprising:
a body member;
an insulating closure for the upper end of the body member;
an insulating disk mounted in said body member below the top closure and defining therewith upper and lower chambers;
said disk having first and second bores therethrough;
a flexible diaphragm mounted in said first bore;
an electrode in said body member passing through said second bore with its lower end terminating adjacent the lower end of said lower chamber;
a source of electric current;
and transducer means carried by said diaphragm to periodically connect said electrode to said source of electric current upon a deflection thereof.

2. A spark plug comprising:
a body member;
an insulating closure for the upper end of the body member;
a flexible diaphragm mounted in said body member below the top closure and defining therewith upper and lower chambers;
an electrode in said body member with its lower end terminating adjacent the lower end of said lower chamber;
a source of electric current;

a transducer to generate an electrical signal upon deflection of said diaphragm; and

a normally passive element in the circuit to the source of electrical current activated by said signal for conducting a pulse of current to said electrode.

3. A device in accordance with claim 2 wherein said transducer comprises a variable resistance carbon granule switch connected to said diaphragm so that the resistance thereof is varied when said diaphragm is deflected.

4. A device in accordance with claim 3 wherein said plug is installed in an engine and wherein means are provided to vary the length of said electrical signal in accordance with the speed condition of said engine.

5. A device in accordance with claim 2 wherein said normally passive element comprises a transformer, said electrode being connected to the secondary coil of said transformer, a PNP transistor, the collector of said transistor being connected to the primary coil of said transformer, said source of electric current being connected to the emitter of said transistor,

means to bias the base of said transistor in a normally non-conductive state, said base being connected to said transducer, the signal from said transducer being of sufficient magnitude to reduce the bias of said base to a degree to render said transistor conductive to said primary coil for the duration of said signal, the termination of conduction of said transistor causing generation of current in said secondary coil on collapse of the field around said primary coil of sufficient magnitude to fire a spark across the gap of said spark plug.

6. A spark plug of the character described including:

(a) a body member;

(b) an insulating closure for the upper end of the body member;

(c) a pressure responsive means movable from a lower to an upper position in said body and disposed below the top closure and defining therewith a contact chamber;

(d) a first electrode extending through the closure and terminating in said contact chamber;

(e) a second electrode carried by and movable with the pressure responsive means and having its upper

end in said contact chamber and spaced from the lower end of the first electrode, and its lower end terminating adjacent the bottom of the body member;

(f) a partition member in the body member positioned below the movable member, said member having an opening through which the second electrode passes;

(g) a bottom body member having an opening therein through which the second electrode passes;

(h) and a valve member carried by the second electrode for closing said first-mentioned opening upon upward movement of the electrode; and

(i) a plurality of openings circumferentially spaced about said second-mentioned opening;

wherein said valve member closes said second-mentioned opening when the electrode is in a lower position.

7. A spark plug of the character described including:

(a) a body member;

(b) an insulating closure for the upper end of the body member;

(c) a pressure responsive flexing disk movable from a lower to an upper position in said body and disposed below the top closure and defining therewith a contact chamber;

(d) a first electrode extending through the closure and terminating in said contact chamber;

(e) a second electrode carried by and movable with the pressure responsive disk and having its upper end in the contact chamber and spaced from the lower end of the first electrode, and its lower end terminating adjacent the bottom of the body member.

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