

May 26, 1942.

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2,284,068

IGNITION SYSTEM OF INTERNAL COMBUSTION ENGINES AND METHOD  
OF CONTROLLING THE SPARK  
Filed March 8, 1941

Fig. 1.

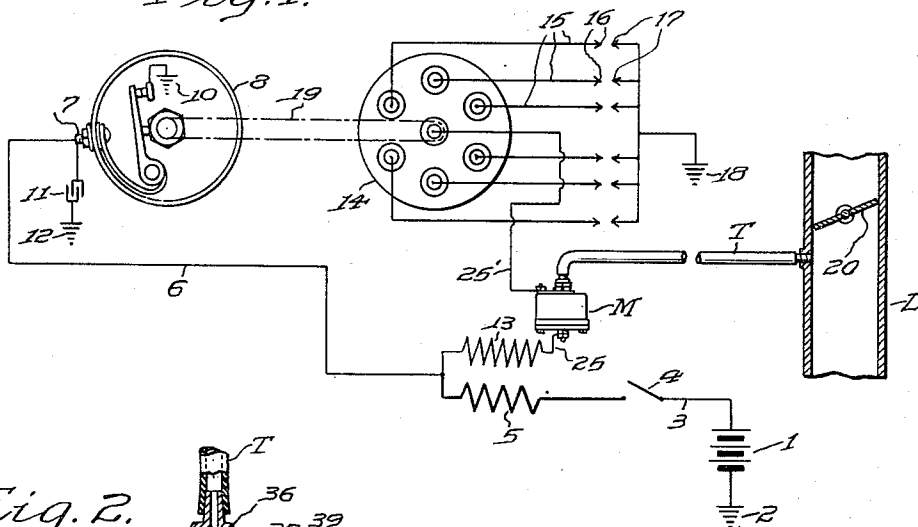


Fig. 2.

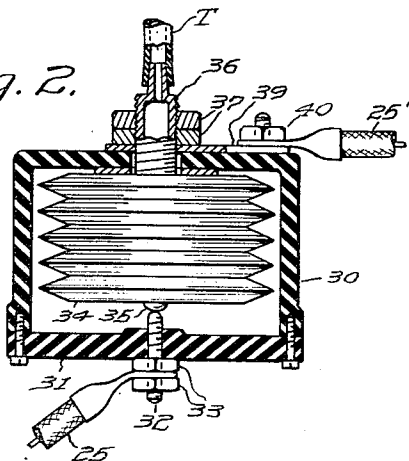


Fig. 3.

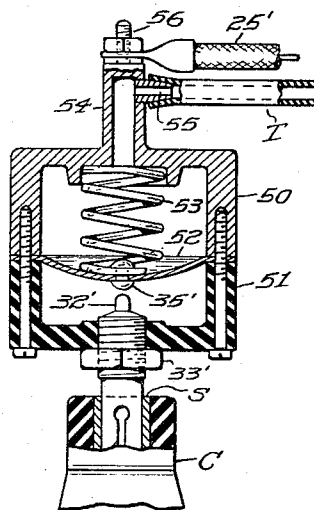
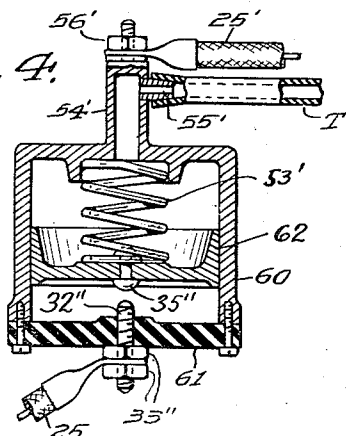


Fig. 4.



WITNESS

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## UNITED STATES PATENT OFFICE

2,284,068

## IGNITION SYSTEM OF INTERNAL COMBUSTION ENGINES AND METHOD OF CONTROLLING THE SPARK

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Application March 8, 1941, Serial No. 382,296

10 Claims. (Cl. 123-148)

This invention relates to internal combustion engines and more particularly to the ignition systems thereof.

It is recognized that the electrodes of the spark plugs in the ignition system of an internal combustion engine should be closely spaced if maximum power and speed are to be obtained for when the engine throttle is wide open the compression in the cylinders is high and the resistance across the gap between the electrodes correspondingly so while, in addition, most ignition systems decrease somewhat in efficiency at very high engine speeds with consequent weakening of the spark. Similar close adjustment of the electrodes is also an aid to the easy starting of the engine since the drain of the starting motor on the battery momentarily decreases its voltage and consequently that of the spark.

On the other hand, entirely different conditions prevail when the engine is idling or running under a very light load for the compression in the cylinders is then low and the resistance of the gap between the spark plug electrodes likewise so; thus if the latter are set sufficiently close to attain optimum performance under heavy loads and at high speeds, the lessened resistance of the gap when the compression is low permits the spark to jump at too low a voltage and also adversely alters the character of the spark itself. The charge is thus not only improperly fired but the weakened spark frequently fails to burn the carbon from the electrodes as rapidly as it is formed thereon, so that for best performance under minimum load-speed conditions a materially wider gap between the electrodes is required.

Between these two extremes, that is, when the engine is being operated with a partially opened throttle for medium load and/or medium speed, the compression pressures in the cylinders are such that the engine will function efficiently if the spark plug electrodes are set to form a gap intermediate those respectively desirable for the best performance under the extremes to which I have referred, but any such setting is necessarily a compromise designed to bring about the best average performance of the engine over its entire load-speed range. Thus, for example, if in a given engine most efficient operation under maximum load-speed is obtainable with the spark plug electrodes set to a gap of .015" and under minimum load-speed when set to a gap of .04", it is customary to set them to a gap of about .025".

Moreover, setting the electrodes initially to a relatively wide gap is objectionable in that under

maximum load-speed a greater strain is imposed on the ignition coil than when the electrodes are set more closely, with resulting tendency of the coil to break down in service, a tendency which gradually increases as the gap widens by the burning away of the electrodes under the intense heat to which they are subjected in service.

Attempts therefore have been made to improve the operation of internal combustion engines by incorporating in the secondary circuits of their ignition systems one or more spark gaps of fixed width and if the spark plug electrodes are set relatively close, such gaps do sometimes better the running of the engine at low speeds and/or light loads but result in a weakened spark under maximum load and/or speed; consequently, though quite commonly used with the relatively low compression, low speed engines of earlier days, they are seldom if ever employed with modern high speed automotive marine, airplane and similar internal combustion motors.

It is therefore a principal object of my invention to provide means adapted to create in the secondary circuit of the ignition system of an internal combustion engine a spark gap the width of which is automatically controlled in correspondence to engine operating conditions with resulting production in the engine cylinders of a spark of a character to properly fire the charge whatever may be its then state of compression although the spark plug electrodes are set for most efficient engine performance under maximum load-speed conditions.

A further object of the invention is the provision of means for controlling the operation of the ignition system of an internal combustion engine in accordance with variations in the suction in the inlet line through which the explosive mixture is drawn from the throttle to the cylinders so as to insure an efficiently operative spark throughout the entire permissive load-speed range of the engine.

Another object is the provision of means suitable for the attainment of the aforesaid objects which are of simple character and readily installable on automobile, marine and other internal combustion engines without the necessity for material changes therein and which, when so installed, are effective to form a spark gap in the secondary circuit of the ignition system when desirable for optimum engine performance and to vary the width of that gap automatically in correspondence to changes in the load-speed conditions under which the engine is operating.

Still another object is the provision of a novel

vacuum-actuated variable spark gap mechanism adapted for interposition in the secondary circuit of an internal combustion engine ignition system.

The invention further comprehends a novel method of controlling the operation of the ignition system of an internal combustion engine in accordance with changes in the vacuum in the intake line through which the explosive mixture is drawn in its passage between the throttle and the engine cylinders.

Other objects, advantages and novel features of design, construction and operation incident to the invention are hereafter more fully pointed out or will be apparent to those skilled in the art from the following specification, reference being had to the accompanying drawing.

In the said drawing Fig. 1 is a substantially diagrammatic view showing my invention incorporated in a typical internal combustion engine ignition system, a portion of the inlet pipe of the engine also being shown;

Fig. 2 is an enlarged central vertical section, with some parts shown in elevation, of one form of my variable spark gap mechanism;

Fig. 3 is a similar view of another form of said mechanism, and

Fig. 4 is a similar view of still another form.

It is primarily to be understood that I accomplish the objects of my invention by including in the secondary circuit of the ignition system a mechanism having relatively movable electrodes through which the current must pass as it flows from the secondary of the ignition coil to the spark plugs and connecting this mechanism with some suitable point in that part of the inlet line through which the explosive mixture is drawn into the cylinders after passing the throttle, said mechanism being effective upon variations in the vacuum in the said line to move the electrodes relatively to each other and thereby form a spark gap in the secondary or, under certain conditions, to close the gap entirely. Since, as hitherto pointed out, when the engine is operating at maximum load-speed the suction or vacuum in the inlet line is at a minimum while when operating at minimum load-speed the suction is generally at a maximum, creation and/or variation in width of the spark gap in the secondary circuit is thus controlled with the utmost nicety in accordance with the momentary requirements for most effective sparking, as my variable spark gap mechanism under the influence of variations in the said suction is automatically operative to maintain the gap closed or nearly so when the suction is low and compression in the cylinders high at the time the charge is fired and to gradually increase the width of the gap as the suction increases and the cylinder compression decreases with corresponding decrease in the resistance to the passage of the spark between the spark plug electrodes.

Referring now more especially to Fig. 1 of the drawing, 1 indicates a battery or other current source having a ground connection 2 and a lead 3, in which is interposed an ignition switch 4, extending to the primary winding 5 of the coil of the ignition system. From this coil a lead 6 goes to a terminal 7 of an interrupter mechanism 8 having a fixed contact 9 grounded at 10, a condenser 11 by-passing the interrupter with a ground at 12. Connected with primary winding 5 of the coil is a secondary winding 13 and in the usual ignition system of this character a lead extends directly therefrom to the central contact of a distributor mechanism 14 which dis-

tributes the current through leads 15 to the spark plug terminals 16 which are respectively spaced from the other plug terminals 17 in turn grounded at 18. The interrupter and distributor mechanism are usually driven by a common shaft 19 from the cam shaft of the engine and the latter of course comprises an inlet line L extending from the carburetor and including the inlet manifold and in which a movable throttle 20 is interposed. Such an ignition system is typical of those generally employed in the art and is well understood by those familiar therewith.

In accordance with my invention I interpose at some convenient point in the secondary circuit between the windings of secondary coil 13 and spark plug terminals 16 one or more mechanisms for creating the variable spark gap to which reference has been made. Normally but one of these mechanisms, generally designated as M in the drawing, is employed and may be placed between coil 13 and distributor 14, as at some convenient point in lead 25, 25' running between these parts, or, as hereinafter explained, the mechanism may be so constructed as to be capable of direct attachment to the coil or the distributor and is then connected by a lead running from it to the other of these parts. In still other cases, a plurality of the mechanisms may be employed and respectively disposed in leads 15 between the distributor and the spark plugs, but irrespective of whether but one or a plurality of the mechanisms is used, each is also connected to some suitable point in inlet line L of the engine between throttle 20 and the cylinders by flexible rubber tubing T or the like; in installations on automobiles it therefore will frequently be found convenient to connect tube T with the vacuum operated windshield wiper or some other vacuum operated part instead of directly with the inlet pipe or intake manifold. It will consequently be understood that the number of the mechanisms M employed in a given installation and the manner of effecting their electrical and vacuum connections is largely a matter of choice and will generally be dictated by the construction of the engine and its auxiliary apparatus.

More particular reference may now be made to the construction and operation of the variable spark gap device M itself and I have shown in Figs. 2, 3 and 4 various forms thereof without, however, in any way intending to restrict or confine myself thereto as the principles of the device may be embodied in many other constructions equally satisfactory for the performance of their intended functions. Thus, in Fig. 2 I have shown the device as including a casing comprising a hollow cup-shaped portion 30 closed at its end by a removable plate 31 at the center of which is disposed a fixed electrode 32 preferably threaded through the plate and carrying one or more lock nuts 33 outwardly of the latter; consequently the electrode may be adjusted axially and then secured in adjusted position relatively to the plate. The outwardly projecting end of the electrode together with the nuts forms a terminal for convenient attachment of lead 25 extending to the secondary coil 13 and I have shown both the plate and the casing as made of non-conductive material such as Bakelite but the casing may be made of metal or other electro-conductive material and the plate of insulating material or vice versa if desired. Within the casing is positioned a metallic bellows or sylphon 34 the face of which adjacent electrode 32 is provided at its center with an electrode 35 in juxtaposed re-

lation thereto, while from the opposite face of the Sylphon and communicating with its interior is extended a hollow stem 36 which may be constricted at its free end for convenient attachment of the tube T forming the connection with the inlet line. The Sylphon is supported in the casing in any suitable way, desirably by threading the exterior of tube 36 for the reception of lock nuts 37 bearing against the upper face of the casing or, as shown, against a metal plate 39 perforated for the passage of the tube, extending radially therefrom and near its outer extremity carrying a terminal, generally designated as 40, for the reception of lead 25' running to the distributor.

In Fig. 2 electrodes 32 and 35 are shown as in contact which is normally their preferred position when the vacuum in the inlet line is low and the engine thus operating under maximum load-speed conditions. When the vacuum in the line increases as the throttle is gradually moved from fully opened toward fully closed position, corresponding increase of vacuum occurs within Sylphon 34 which causes it to contract, thus moving electrode 35 away from the fixed electrode 32 so as to first separate them and then to progressively widen the space between them. As the electrodes thus move apart the current flowing in leads 25, 25' must necessarily jump the air gap thus created and the firing efficiency of the spark between the spark plug points is thus maintained as the engine load and/or speed decrease even though the gap between those points is that best suited for maximum load-speed operation and starting and thus relatively small.

The spark gap mechanism shown in Fig. 3 comprises a casing formed of hollow complementary cup-shaped sections 50, 51, that which holds the stationary electrode 32' preferably being of insulating material and the other section of electro-conductive material such as metal. Between the sections is clamped the peripheral margin of a diaphragm 52 which supports the movable electrode 35' at its center, this electrode being in electrical connection with a spring 53 biasing the diaphragm toward the fixed electrode, the opposite end of the spring seating against the inner face of the metal portion 50 of the casing. From the latter a hollow neck 54 extends and is provided with a nipple 55 for attachment of tube T while at the extremity of the neck is a terminal 56 to which lead 25' may be connected. It will be apparent that as there is free communication between the interior of tube T and the interior of the casing on the adjacent side of the diaphragm, the latter will move away from the stationary electrode against the bias of spring 52 upon an increase of the vacuum in the inlet line to which the tube is connected thereby separating the electrodes if they are in contact when said vacuum is at a minimum, and that the greater the increase in the vacuum the farther will the electrodes be moved apart as in the case of the device shown in Fig. 2 and with like results. Electrode 32' may be arranged to form a terminal for reception of the lead 25 as shown in Fig. 2 or it may be enlarged where it passes through and exteriorly of the casing and provided with a resilient extremity so that it may be pushed directly into the usual metallic socket S in the center of the cap C of the distributor or into a similar socket at the end of secondary coil, thus dispensing with use of a wire or the like between

electrode 32 and the distributor or coil as the case may be, a construction which frequently facilitates installation of the device and of course may be utilized if desired in either of the mechanisms shown in Figs. 2 or 4.

In the latter, that part 60 of the casing corresponding to part 50 in Fig. 3 is of generally similar construction to the latter save that it is made longer and is closed by a removable plate 61 as in Fig. 2, this plate being formed of insulating material, and a piston 62 movable in the casing is substituted for diaphragm 52. The piston carries a movable electrode 35'' in juxtaposition to the fixed electrode 32'' and is biased toward the latter by a spring 53'. Consequently, upon an increase in the vacuum on that side of the piston adjacent the spring the former will move against the bias of the latter in a direction to separate the electrodes and vice versa.

In Fig. 4 the electrodes are shown as more widely separated than in Fig. 3 while in Fig. 2 they are shown in contact so that their relative positions in these three figures correspond generally to those assumed when operating under minimum load-speed, intermediate load-speed and maximum load-speed conditions.

It will now be apparent that the various forms of variable spark gap mechanism which I have illustrated are adapted, when suitably installed on internal combustion engines as heretofore described, to automatically form a spark gap in the secondary circuit under certain operating conditions and to proportion the width of that gap to changes in those conditions, a gap of greatest width being created when the engine is running under minimum load or idling and progressively decreased in width as it approaches maximum loads or speeds at which, normally, the gap is closed entirely. It results that even though the spark plug electrodes are spaced very closely together, for example .015", as is desirable for operation at maximum load or speed, efficient ignition of the charge is secured at all lower loads and/or speeds because of the creation and progressive widening of the spark gap in the secondary circuit as the load and/or speed decrease; thus satisfactory firing of the charge throughout the entire load-speed range of the engine as well as increased intensity of the spark at the plugs when the engine is being started is secured while overloading of the coil is avoided.

While I have shown and described certain forms of the said mechanism with considerable particularity since they are well adapted for effecting the objects of the invention, I do not thereby desire or intend to restrict or limit myself specifically to the use thereto, as the said mechanism may partake of other forms and is susceptible of numerous changes and modifications in details of design, construction and arrangement and in the manner of its installation without departing from the spirit and scope of the invention as defined in the appended claims.

Having thus described my invention, I claim and desire to protect by Letters Patent of the United States:

1. The combination with an internal combustion engine comprising means through which the explosive mixture is drawn to the cylinders and an ignition circuit, of spark gap forming means having relatively movable electrodes interposed in the secondary of said circuit and means for varying the spacing of said electrodes

in correspondence with variations in the vacuum induced in said first mentioned means.

2. The combination with an internal combustion engine including a throttle, means through which the explosive mixture is drawn from the throttle to the engine cylinders and an ignition circuit, of relatively movable electrodes interposed in the secondary of said circuit and means for controlling the spacing of said electrodes in accordance with variations in the vacuum induced in said first mentioned means when the engine is in operation.

3. The combination with an internal combustion engine comprising a throttle, means for conducting the explosive mixture from the throttle to the engine cylinders and an ignition circuit, of relatively movable electrodes in the secondary of said circuit and pressure responsive means operative to move said electrodes apart upon increase of the vacuum in said conducting means, and means to move said electrodes toward each other upon a decrease of said vacuum.

4. A variable spark gap mechanism adapted for incorporation in the secondary circuit of the ignition system of an internal combustion engine comprising a casing, an electrode supported thereby, means responsive to negative pressure disposed within the casing and an electrode supported by said means in juxtaposed relation to the first electrode, said means tending to separate the electrodes upon an increase in their negative operating pressure, and means biasing the electrodes toward each other in opposition to the action of the negative pressure responsive means.

5. A variable spark gap mechanism adapted for incorporation in the secondary circuit of the ignition system of an internal combustion engine comprising a relatively stationary electrode, a movable electrode in juxtaposition to the first electrode, vacuum operated means adapted to separate the electrodes upon increase in their operating vacuum, and means operative to yieldingly move the electrodes together upon a decrease in said vacuum.

6. A variable spark gap mechanism adapted for incorporation in the secondary circuit of the ignition system of an internal combustion engine comprising a pair of relatively movable electrodes, metallic bellows supporting one of said electrodes

and means supporting the other electrode, said bellows being adapted for connection with the intake line of the engine whereby an increase in the vacuum therein is operative to contract the bellows and progressively separate the electrodes.

7. A variable spark gap mechanism adapted for incorporation in the secondary circuit of the ignition system of an internal combustion engine comprising a casing, an electrode supported therefrom, another electrode in juxtaposed relation to the first electrode, a diaphragm within the casing supporting said second electrode, means biasing the diaphragm in a direction to move the electrodes together, and means for connecting the interior of the casing on one side of the diaphragm with the intake line of the engine whereby increase in negative pressure therein is operative to move the diaphragm in opposition to said biasing means and thereby separate the electrodes.

8. A variable spark gap mechanism adapted for incorporation in the secondary circuit of the ignition system of an internal combustion engine comprising a casing, a piston movable in the casing, an electrode carried thereby, another electrode in juxtaposed relation to the first electrode, means biasing the piston in a direction to move the electrodes together and means for connecting the interior of the casing on one side of the piston with the inlet line of the engine whereby increase in negative pressure therein is operative to move the piston in opposition to said biasing means and thereby separate the electrodes.

9. That method of controlling the ignition circuit of an internal combustion engine which comprises varying the width of a spark gap in the secondary circuit of said system in accordance with changes in the vacuum in the intake line of the engine.

10. That method of controlling the intensity of the spark between the electrodes of a spark plug in the ignition system of an internal combustion engine which consists in progressively increasing the width of a spark gap in the secondary circuit of said system in correspondence to increase in the vacuum in the intake line of the engine and progressively decreasing the width of said gap in correspondence to decrease in said vacuum.

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