May 29, 1928. 1,671,740

W. L. PHILLIPS

SPARK PLUG

Filed March 1, 1922

Fig. 5

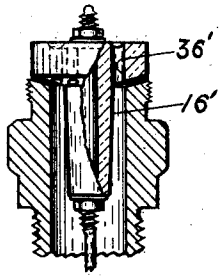


Fig. 1

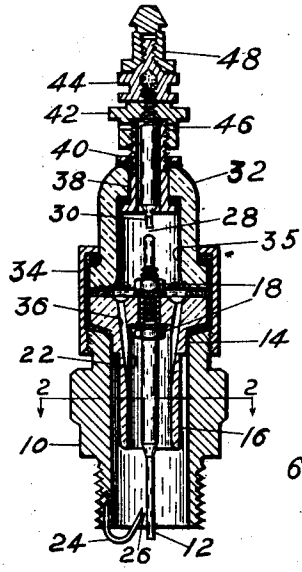


Fig. 8

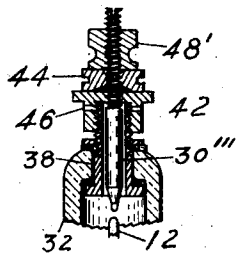


Fig. 4

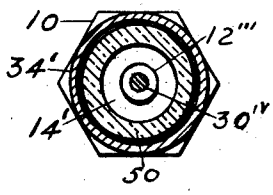
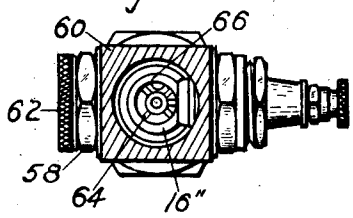


Fig. 7



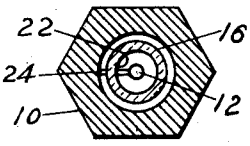


Fig. 2

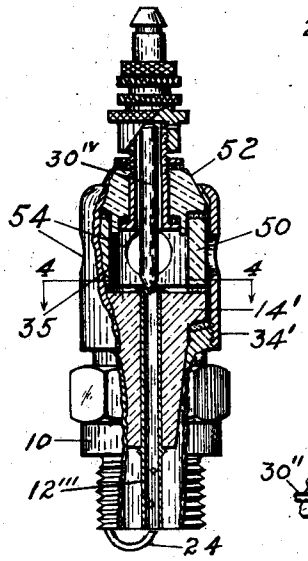
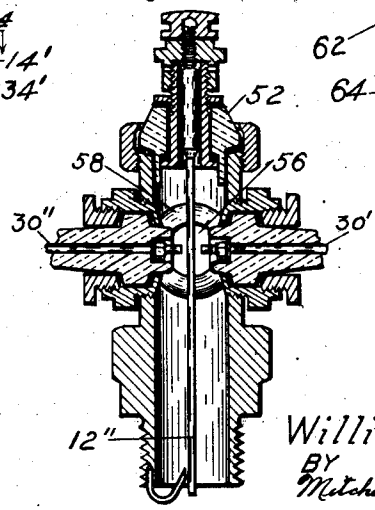


Fig. 3

Fig. 9



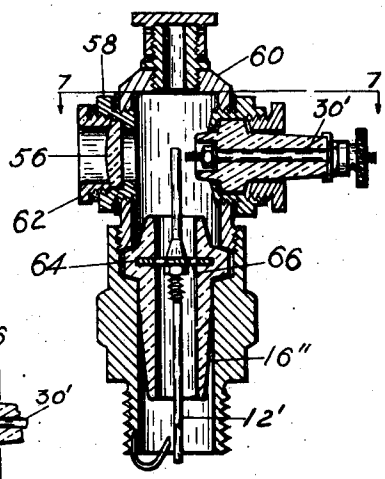


Fig. 6

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Patented May 29, 1928. 1,671,740

UNITED STATES PATENT OFFICE.

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SPARK PLUG.

Application filed March 1, 1922. Serial No. 540,317.

This invention relates to improvements in spark plugs. More especially it relates to spark plugs of the type comprising an auxiliary or subsidiary gap in the ignition circuit. The main purpose of all spark plugs is the transmission of a current to a place where it can be caused to ignite a charge of explosive gases within an engine adapted to utilize the power developed by such explosion. To this end, the spark plugs now in use have supplied the means whereby the current from a magneto or coil is conducted along an insulated electrode into the chamber of the cylinder, there caused to jump a gap to the wall of the plug from which the current may pass off, usually into the engine walls which act as a ground circuit back to the source of potential. The important function of the spark plug is to conduct the current so that it will positively jump the gap, and not become short circuited in any manner before doing so. To insure this result the incoming electrode is usually encased in a substantial insulator, for practically its entire length. This insulator or core is usually made large and heavy in order to withstand both the pressure of the electrode, due to the latter's expansion when heated, and the severe strains imposed by compression in assembling the parts of the plug; and as a result, the core occupies nearly all the space within the plug, almost to the end of the electrode. It thus furnishes a convenient surface for the deposition of solid products of combustion, which in a short time bridge across the small open space left between the insulator and the plug walls and thereby short circuit the current. This immediately diminishes the action across the gap, and as the depositing continues, being rapidly enhanced by the already impaired firing of the explosive charge, its formation becomes more compact and its resistance falls so low that the current will follow this convenient path instead of discharging across the gap, thus failing to cause an explosion in the cylinder and seriously affecting the performance of the engine. It has, however, been found under these conditions, that if the energy of the current is increased at the instant the spark would ordinarily jump, that it actually will jump the gap in spite of the fouling effect already described. As a means for increasing the energy available for ignition to overcome the fouling effect, a second or subsidiary gap has been interposed between the principal gap and the source of energy, with some satisfactory results; but, so far as I am aware, this subsidiary gap has never been utilized to its greatest capacity. It is usually found in one of three places; integral with the plug; at the plug, but not integral with it; or removed from the plug at a point within or near the distributor. The first of these locations is undoubtedly the most desirable from the viewpoint of electrical efficiency, inasmuch as its action with respect to the principal gap is so near the latter that the evil of dissipation is reduced to its minimum. But when placed integral with the plug it has been the practice to leave the subsidiary gap either open to the air, or inclosed in an air-tight container; and its purpose and effect have been to overcome the short-circuiting effect of deposit and thus enable a spark to jump the principal gap. The action of the subsidiary gap, however, has in no way been utilized either to prevent the creation of such deposit or to break it up and eliminate it after its formation has begun. In contrast with this mere effort to surmount the evil conditions due to fouling and to operate more or less effectively in spite of them, it is an important purpose of the present invention to get rid of or to prevent the fouling.

It is among the objects of the invention to so construct a spark plug that both the principal and subsidiary gaps are within the explosive mixture, whereby the spark across each gap may be utilized to fire the charge, thus at least doubling the igniting effectiveness of the plug. Other objects of the invention are, to intensify the principal spark by the use of the subsidiary gap in the circuit; to augment the intensifying effect of the subsidiary gap by placing it in a medium which is under compression and thus of increased density corresponding to a greater break-down voltage; to provide means by which the subsidiary gap may be adjusted both when the engine is idle and while running; to utilize the explosion caused by the auxiliary spark to clean an internal electrode and prevent deposit thereon of carbon or oil and, if desired, to clean an electrode directly connected with the outside conductor; to provide means permitting the auxiliary spark and its resultant explosion to be visible, thus signalling the

actual firing of the explosive charge; to provide an insulated support for the internal electrode which shall be easily molded, light and self-cooling; to so position this insulator within the plug that it will be subjected to substantially equal degrees of heat and pressure on its opposite surfaces; and to so arrange and dispose the several parts of the plug as to provide a closed passage through the plug which may be opened when desired to permit priming of the plug, the testing of the compression, or the utilization of the latter for tire inflation or other purposes.

These various objects are attained by supporting within a hollow of a spark plug a separate insulated internal electrode to which the current may jump from the external electrode across the subsidiary gap and from which it may jump across the principal gap, the said hollow constituting a part of the explosive chamber of the engine in which both gaps are filled by the gaseous mixture under compression. The support for this isolated electrode is provided with a passage through which the gases are forced during the compression and expansion strokes of the piston, the passage being so arranged as to cause the moving gases to act as a cleaning agent on the internal electrode, the inner portion of the external electrode and on the support itself, thereby preventing any undue deposit of the products of combustion and eliminating any fouling or short circuiting of the plug. The walls of the plug surrounding the region in which the subsidiary gap is located may be made non-transparent, or transparent or provided with windows, through which the igniting of the charge may be seen. The terminal of the plug to which the outside conductor is attached comprises clamping means for holding an upper or external electrode in adjustable relation to the internal electrode, and is so arranged that it may be withdrawn slightly on the plug to open a restricted passage therethrough from the cylinder chamber to the atmosphere, or may be wholly removed to allow a compression gauge or air pump to be attached. In the embodiments shown in the accompanying drawings, various applications of the invention are shown, but it is to be understood that these adaptations are merely illustrative. It is intended that the patent shall cover by suitable expression in the appended claims whatever features of patentable novelty exist in the invention disclosed.

Referring to the drawings:

Figure 1 is an elevation in medial section showing one form of plug embodying the invention;

Figure 2 is a plan in section on line 2—2 of Figure 1;

Figure 3 is an elevation, partly cut away to a medial section, showing a modification;

Figure 4 is a horizontal section on line 4—4 of Figure 3;

Figure 5 is an elevation of a detail of another modification;

Figure 6 is an elevation in medial section of a plug showing other modifications in the design and arrangement of the parts;

Figure 7 is a plan of Figure 6 in section on line 6—6;

Figure 8 is an elevation in section showing a modified form of the plug terminal; and

Figure 9 is an axial section of a further modification of the invention.

In the drawings, a spark plug base 10, threaded exteriorly at one end for engagement with an engine casing (not shown) is bored throughout its length to permit an internal conductor or electrode 12, to be supported axially therein by a tubular insulating element 14, hereinafter called a core, having a flange head and holding portion seating on the upper edge of the base, and a thin walled tubular body portion 16 projecting within the base to form an insulating sleeve about the electrode for a considerable portion of its length. This internal conductor is secured to its support by clamping nuts 18, one of which presses upon the top surface of the head of the said holding and insulating element, and the other of which rests against the under surface of the same, in the deep recess 22 within the body portion 16, which has the aspect of an annular chamber about the electrode 12. The lower end of the latter is near a sparking terminal 24, extending radially inward from the wall of the base being separated therefrom by a gap 26, hereinafter called the principal gap, across which a spark may be caused to jump to ignite the explosive gases in the cylinder. This gap may be varied by bending the curved terminal 24 in the ordinary way either toward or away from the electrode, which is relatively fixed in position at the axis.

The upper end of this internal electrode is separated by another gap 28 hereinafter called the auxiliary or subsidiary gap, from another electrode 30 called the external electrode, which is adjustably supported axially in alignment with the internal electrode by a hollow, non-conducting cap or cover 32 held tightly in register with the insulated core 14 by a collar 34 threaded on the upper exterior surface of the base 10. This collar is flanged inward at its top to engage an external flange around the bottom of the cap, so that upon the collar being turned on its threads it will clamp the cap 32, the insulated support 14, and the base 10 firmly together, there being suitable gaskets or washers between the abutting surfaces to make the joints leak-proof under the working pressures in the cylinder. The chamber 35 of

the cap 32, is connected with the annular chamber 22 by a series of holes 36 through the head of the insulating core, constituting passages for the admission of gas from the engine cylinder to the chamber 35 in the top of the plug, and for its expulsion.

The upper or external electrode 30 is held in axial alignment within a sleeve 38 which passes through the top of the cap and is securely clamped thereto by a nut 40 threaded exteriorly on the sleeve, the threaded portion of the latter extending upward to form a stem for a supporting nut 42 whose body portion engages the stem, and through which the electrode projects and to which it is locked by the locking nut 44 on the protruding end of the electrode. The hole through the sleeve 38 is larger in cross section than the electrode 30, so that the latter is surrounded by a small annular space which opens into the chamber 35 at one end, and at the other is closed by the tight fit of the stem in the supporting nut when the latter is screwed down to its limit on the sleeve 38. This space, however, may be vented to the atmosphere, upon the supporting nut being unscrewed a short distance, there being radial holes 46 through the body of the nut close to its head which will connect with the space left above the end of the sleeve 38 when the nut 42 is backed a thread or two. If it is desired to prime the cylinder, the supporting nut, and with it the upper electrode, may be entirely removed from the sleeve 38. The liquid gasoline, ether or other priming substance may then be poured into the top of the plug, whence it will pass through the chamber 35, passages 36, chamber 22 and the bore of the plug into the engine cylinder. This mode of priming is very useful in that the liquid in passing through the plug dampens surfaces in the immediate vicinity of the gaps whereby upon occurrence of the sparks across the gaps an explosion will of certainty occur. The removal of the supporting nut and electrode also enables a gauge to be attached to the stem for testing the compression of the cylinder; or if a pump is attached, instead of a gauge, the pressure of the cylinder may be utilized to operate the pump for blowing up tires or doing other useful work.

The terminal of the outside conductor from the source of electric energy may be slipped around a neck portion of the locking nut 44, or may be clamped between this nut and a binding nut 48 screwed thereon, or may be clipped over the top end of the binding nut itself.

When the plug has been placed in the engine cylinder head, and the compression stroke takes place the explosive mixture is forced into the bore of the spark plug base and thence through the passages 36 into the chamber 35 until the engine piston reaches its top dead center, at which time the plug will be internally charged with the compressed ignitible gases of the explosive mixture. By means of any usual or suitable timing device and distributor the electro-motive force of the ignition system is directed to this particular plug at a favorable time for the igniting of the charge. At the inner terminus of the external electrode it builds up, momentarily, until its voltage is great enough to overcome the high resistance of the gap, when a spark jumps across to the internal electrode, and another spark jumps the principal gap between the terminal of the internal electrode 12 and the terminal 24. The action is so rapid that the sparks are almost simultaneous; and even though the gases in the upper chamber are actually ignited first the second spark occurs before the burning has been transmitted to the gases about the second gap, so that the latter spark also sets fire to the explosive mixture. Thus two separate igniting sparks are provided by one circuit through the plug, one of which, the principal, is intensified by the other. This is particularly so in a plug embodying the present invention because of the fact that the auxiliary gap is through a mixture of gases under compression of the cylinder. As the density of a gas is directly proportional to its pressure, and its resistance is directly proportional to its density, it follows that the energy required to overcome the resistance of a gap thus under compression is substantially larger than if the gap were in free air or merely incased in an air-tight chamber. When the increased energy required to overcome the resistance of the subsidiary gap is built up and the current leaps across this gap, practically all of this energy is then available for intensifying the spark across the principal gap, and as a result the principal spark is highly energized and its effectiveness increased for ignition of the engine charge.

The expansion of the burning gases in the chamber 35 causes them to pass down rapidly through the passageways 36 into the chamber 22 and thence along past the electrode 12 into the engine cylinder. This high speed of flow of the gas through the plug acts with marked cleaning effect upon the walls of the chamber 22 of the insulating core, as well as upon the surface of the electrode, thus preventing ab initio any incipient deposit thereon of the products of combustion, and effectively doing away with any possibility of fouling. In the event of any deposit forming in the space surrounding the upper electrode within the sleeve 38, it may easily be removed by unscrewing the nut 42 until the radial holes 46 vent the space to the atmosphere. The degree of

longitudinal movement of this nut is so slight that even though the gap 28 be increased by the unscrewing of the nut 42 and the consequent movement of the upper electrode, the spark will continue to jump and the explosion to occur; and the pressure resulting from the explosion in the chamber 35 will force any solid matter in the space about the electrode out through the holes 46.

In order that the operator may see that the plug is properly functioning, transparent means is provided in the top of the plug through which the sparking across the subsidiary gap and the flash of the resulting explosion are visible. The cap or cover 32 shown in Figure 1 may be made of any suitable transparent material such as glass especially made to withstand heat and pressure changes. In Figure 3, a modified form of a top is illustrated in which a cylindrical transparent shell 50 is interposed between the support 14′ of the lower electrode and an insulated support 52 of the upper electrode, the aligning collar 34′ being perforated as at 54 to provide peep holes to the chamber 35. In Figures 6 and 9 a still different method is shown whereby a glass window 56 is held against an annular seat in a sleeve 58 threaded into the side wall of the plug casing 60, by a hollow nut 62 bottoming upon the edge of the glass.

In addition to determining if the plug itself is working, another advantage is gained by means of the explosion chamber 35 and windows 54 thereof in that the nature of the combustion in the cylinder can be ascertained by the color of the flame seen in the chamber of the plug. It has been found in practice that the color of this flame varies in accordance with the kind of explosion taking place in the cylinder. If a very rich mixture is used the flame will be of one color; if a thin or poor mixture is employed the flame will be of a different color; and if kerosene or other substances are added to the gasoline, this also causes changes in the flame color. Accordingly, by a series of experiments a color chart may be developed, based upon the flame colors of different explosive mixtures which will show the relative efficiency of various fuels; and thereafter a comparison of the colors of the flames produced in the plug with the listings on the chart, will enable the user of the plug to know the conditions existing in the cylinder at the time the explosion therein takes place.

A further modification is illustrated in Figures 3 and 4, wherein the lower electrode 12‴ is made in the form of a hollow stem or tube fitting tightly within the central bore of the insulating element 14′. The upper end of this electrode is preferably substantially flush with the top surface of the core, while its lower extremity extends below the core close to the sparking terminal 24. The opening through this tube constitutes the transfer passage for unfired gases from the engine cylinder to the upper chamber of the plug, and for the burning gases from the upper chamber back to the cylinder. In consequence of the latter transfer and because of its proximity to the lower spark gap, the protruding end of the tube becomes hot and serves to heat the unburned gases as they pass upward through it into the chamber 35, thus aiding their ignition, and by so doing, permitting poorer grades of fuel to be used than has heretofore been possible because of inability to fire them under normal temperatures existing in the cylinder. In a plug equipped with this particular type of lower electrode the passage to the upper chamber may be restricted by moving the upper electrode 30ᴵᵛ toward the hollow conductor 12‴ thus reducing the effective opening of the latter and at the same time varying the spark gap. By this means, the amount of gas entering the upper chamber can be regulated to any desired amount and may in fact be entirely cut off by screwing down the upper electrode 30 until its conical end seats tightly on the rim of the tubular conductor. This, of course, will also do away with the auxiliary spark gap and would not be the most desired manner of using the plug, but such setting could be adopted advantageously in case the transparent cylinder 50 should become accidentally shattered and could not be conveniently replaced at the time of such accident. By thus closing the passage to the upper chamber the plug could then function as the ordinary single gap spark plug.

In the type of plug shown in Figure 1, and in the various modifications hereinafter described, the upper spark gap may be closed by bringing the adjacent ends of the electrodes together and making them electrically integral. This would make the upper chamber a mere flash chamber in which the gases would be fired by the single spark occurring within the cylinder but even when thus used, the plug would serve, as already described, to indicate by the color of the flame the nature of the explosion occurring in the cylinders.

In Figure 5 a modification of the support for the internal electrode is shown in which the sleeve portion 16′ is reduced in diameter and set close to the electrode, and the passages 36′ are provided through the flange portion communicating with the lower chamber on the outside of the sleeve 16′. In Figure 6 a still different form of support 16″ is shown, in which the support has an axial passage throughout its length, in the midst of which the electrode is supported by a perforated disk member 64 set into the walls of the insulator, through the perfora-

tions 66 of which the gases may pass inward or outward through the plug.

All of the forms of support shown may be easily molded, being simple, light and compact. It is a feature of the invention that such cores may be used, in that they are not subjected to any excessive unbalanced pressures, nor are they under high temperature at one end and relatively low temperature at the other. The cores are held in place by direct clamping pressures on opposite sides of their flanged portions; and the pressure on the nuts or other means which support the electrode in place are equal and opposite in effect. Since the explosion occurs above and below and around the core at practically the same instant, the pressure changes upon and the temperature changes of the insulator are substantially uniform. When the cylinder is being charged the movement of the fresh gases through the plug and passageways of the support into the upper chamber, tend to uniformly cool the porcelain and prevent its ever becoming overheated though entirely located within the exploding chamber.

In Figure 6 the upper or external electrode 30′ is shown arranged at the side of the plug casing 60 instead of at the top. Figure 9 also embodies this arrangement but shows a further modification of the invention wherein the internal electrode 12″ is supported at the top of the plug so that it projects longitudinally through the bore which is substantially unobstructed by any supporting means, except where tightly closed at its upper end. The current is brought into the plug from the side through the external electrode 30′, or if a duplex system of ignition is used, another electrode 30″ may conduct the second current to the internal electrode. If it were desired to use a system wherein the ignition circuit was to be entirely insulated from the engine, and not use the latter as a ground, the form of plug shown in Figure 9 would lend itself most conveniently to such an arrangement, in that the internal electrode 12″ could be entirely removed, the current conducted through the plug by the external electrodes 30′ and 30″, the spark occurring across the gap between their ends located in the bore of the plug.

Figure 8 shows a modification of the upper electrode and its connections, wherein the electrode extends upward so that its external end may be engaged by a screwdriver or other tool and the electrode moved for adjustment while the engine is running. The external conductor would be attached to the lock nut 44 or between this nut and the binding nut 48′, both of which would be removed on the electrode away from the supporting nut 46, so that the electrode could be withdrawn or inserted until the proper gap was ascertained under running conditions, after which the lock nut could be seated against the supporting nut to fix the electrode in the adjusted position, and then the binding nut turned down to clamp the conductor.

Although referred to as being in a vertical position, it is evident that the plug of the invention may be set otherwise, at pleasure. If for any reason the current is momentarily cut off from a spark plug of type hitherto known, and the engine allowed to run awhile without a spark occurring, such a plug may become foul by having its gap filled with lubricating oil that has leaked by the piston rings, and it is usually necessary to remove and clean the plug before it will again properly function. But with a plug of the type herein described the upper gap, being protected from such oil leakage would fire the charge as soon as the circuit was restored. Upon the first firing, the lower gap would be cleaned and the normal double-fire condition restored.

I claim as my invention:

1. A spark plug for the cylinder of an internal combustion engine, having spark gap electrodes in combination with a chamber into which explosive mixture of the engine cylinder may be forced past said electrodes; and other spark gap electrodes within said chamber, in series with the first mentioned electrodes, the spark of which is adapted to ignite said mixture within said chamber.

2. A spark plug for the cylinder of an internal combustion engine, having spark gap electrodes in combination with a chamber into which explosive mixture of the engine cylinder may be forced to be ignited by the spark of said electrodes; and means for regulating the quantity of explosive mixture forced into said chamber.

3. A spark plug for the cylinder of an internal combustion engine, having spark gap electrodes in combination with a chamber into which explosive mixture of the engine cylinder may be forced past said electrodes; and other spark gap electrodes within said chamber, in series with the first mentioned electrodes, the spark of which is adapted to ignite said mixture within said chamber, there being a partition separating the spaces where the two gaps are, supporting the conductor which runs between the gaps, and having an opening for passage of gases to and from the second mentioned spark gap.

4. A spark plug for the cylinder of an internal combustion engine having conductors arranged to form two spark gaps in series, both being set in space accessible to mixture of the engine cylinder, and one of them being between the other and the engine cylinder, whereby the ignition of

mixture by that which is more remote from the cylinder causes a rush of gases past the other into the cylinder.

5. A spark plug for the cylinder of an internal combustion engine having conductors arranged to form two spark gaps in series, both being set in space accessible to mixture of the engine cylinder, and one of them being between the other and the engine cylinder, whereby the ignition of mixture by that which is more remote from the cylinder causes a rush of gases past the other into the cylinder, there being a partition arranged between the spaces wherein the two gaps are located, penetrated by a passage for transfer of the gases from one space to the other.

6. A spark plug, adapted to have one end inserted in the wall of the cylinder of an internal combustion engine, having spark gap electrodes; and a chamber, within the plug, outside of the engine cylinder, having communication with the engine cylinder through one of said electrodes for passage of gases; said chamber containing said spark gap electrodes.

7. A spark plug for the cylinder of an internal combustion engine having a plurality of chambers accessible to explosive mixture from the engine cylinder, and having spark gap electrodes in each chamber whose spark ignites the explosive mixture therein.

8. A spark plug for the cylinder of an internal combustion engine having conductors arranged to form two spark gaps in series lengthwise of the plug, both gaps being set in spaces accessible to mixture of the engine cylinder; one of said spaces being outside of the engine cylinder.

9. A spark plug for the cylinder of an internal combustion engine having conductors arranged to form two spark gaps in series, both being set in space accessible to mixture of the engine cylinder and one of the conductors which constitutes a spark electrode being mounted movably in the plug, toward and from the other electrode of the same gap; and external means to move and to fasten said movable conductor.

10. A spark plug for the cylinder of an internal combustion engine having a plurality of intercommunicating chambers in the same plug, each accessible to explosive mixture from the engine cylinder; and spark gap electrodes arranged for ignition of the mixture in each of said chambers.

11. A spark plug for the cylinder of an internal combustion engine, having spark gap electrodes arranged to cause ignition of the explosive mixture in the cylinder, combined with means comprising a chamber in said plug connecting with said cylinder and with the outside of said plug, and a closure for said outside connection adapted to be opened to vent said chamber.

12. A spark plug for the cylinder of an internal combustion engine, having spark gap electrodes arranged to cause ignition of the explosive mixture in the cylinder, combined with a chamber in said plug, a passage connecting said chamber with the engine cylinder wherein gases may pass to and from said chamber, and means for regulating the flow of gases through said passage.

13. A spark plug for the cylinder of an internal combustion engine comprising conductors arranged to form multiple spark gaps, a chamber in the plug removed from the cylinder and having communication therewith through the hollow of one of said conductors, whereby gases may pass to and from the cylinder to the chamber; a gap in said chamber between the end of the hollow conductor and another conductor; the said other conductor being adjustable whereby the gap and the opening of the hollow conductor into the chamber may be varied simultaneously.

14. A spark plug for the cylinder of an internal combustion engine, comprising conductors arranged to form multiple spark gaps; a chamber in said plug removed from the cylinder and having communication therewith through the hollow of one of said conductors whereby gases may pass to and from the cylinder; a gap arranged in said chamber, across which the current jumps to ignite the gases therein, thereby causing a rush of burning gases through the hollow conductor to the cylinder; the said burning gases heating said hollow conductor which in turn gives up heat to the unburned gases forced therethrough to the chamber.

15. A spark plug for the cylinder of an internal combustion engine, having an internal chamber; spark gap electrodes arranged to form a spark gap therein; a passage connecting said chamber with the engine cylinder for transfer of gases from one to the other; one of said electrodes being arranged in said passage whereby it is cleaned by the gases passing to and from said chamber.

16. A spark plug for the cylinder of an internal combustion engine, having an internal chamber; spark gap electrodes arranged to form a spark gap therein; a passage connecting said chamber with the engine cylinder for transfer of gases from one to the other; another passage connecting said chamber with the atmosphere; and means for regulating the opening of the last mentioned passage.

17. A spark plug having a hollow body portion adapted to be inserted in the wall of an internal combustion engine; insulating members secured to said body portion, form-

ing a chamber; spark gap electrodes supported by said members providing a spark gap in said chamber; and a passage through one of said members connecting said chamber with the engine cylinder for transfer of gases from one to the other.

18. A spark plug having a hollow body portion adapted to be inserted in the wall of an internal combustion engine; insulating members secured to said body portion forming a chamber; spark gap electrodes supported by said members providing a spark gap in said chamber; a passage through one of said members connecting said chamber with the engine cylinder for transfer of gases from one to the other, and a passage through another of said members communicating with the atmosphere; the said passages and chamber affording an outlet for the gases; and means externally on said plug for closing said outlet.

19. A spark plug, adapted to have one end inserted in the wall of the cylinder of an internal combustion engine, having spark gap electrodes; and a chamber, within the plug, outside of the engine cylinder, having communication with the engine cylinder; one of said electrodes being hollow and having side openings through which the gases are jetted against an internal wall of the plug to clean it.

20. A spark plug for an internal combustion engine having hollow insulating members whose hollows constitute a passage between the engine cylinder and the atmosphere; a sleeve through one of said members; an electrode movably supported on said sleeve and adapted to be moved to close said passage; and another electrode in the plug forming with said movable electrode a spark gap.

21. A spark plug, adapted to have one end inserted in the wall of the cylinder of an internal combustion engine, having spark gap electrodes in combination with a chamber, within the plug, outside of the engine cylinder, and having connection with the engine cylinder; one of said electrodes having a passage through it for transfer of fluid to said chamber.

22. A spark plug having a body portion adapted for insertion in the wall of the cylinder of an internal combustion engine; a chamber in said plug beyond said body portion and outside of said cylinder; electrodes forming a spark gap in said chamber for ignition of gases therein; and a passage through said body portion connecting said chamber with the cylinder for transfer of gases from one to the other; said passage having a metallic wall constituting one of said electrodes.

23. A spark plug having a body portion adapted for insertion in the wall of the cylinder of an internal combustion engine; a chamber in said plug beyond said body portion and outside of said cylinder; electrodes forming a spark gap in said chamber for ignition of gases therein; and a passage through said body portion connecting said chamber with the cylinder for transfer of gases from one to the other; said passage having a wall adapted to absorb heat from the hot gases passing from the chamber to the cylinder, and to give up heat to the cooler gases passing from the cylinder to the chamber.

24. A spark plug for the cylinder of an internal combustion engine, having a chamber therein outside of the engine cylinder; electrodes forming a spark gap in said chamber for ignition of gases therein; and a relatively long passage through said plug connecting said chamber with said cylinder for transfer of explosive mixture to said chamber and for transfer of burning gases from said chamber to the cylinder; the walls of said passage being of such length as to permit transfer of heat thereto during passage of the burning gases and to permit transfer of heat therefrom during passage of the explosive mixture.

25. A spark plug, adapted to have one end inserted in the wall of the cylinder of an internal combustion engine, having spark gap electrodes in combination with a chamber, within the plug, having connection with the engine cylinder; one of said electrodes being hollow to permit entrance therein of hot gases whereby the electrode is heated and cleaned.

26. A spark plug, adapted to have one end inserted in the wall of the cylinder of an internal combustion engine, having spark gap electrodes; and a chamber, within the plug, having communication with the engine cylinder; one of said electrodes being hollow and having an opening into said chamber whereby gases may pass through the electrode to and from said chamber.

27. The combination with an internal combustion engine, of a spark plug extending through a wall and into the combustion space thereof, said plug being provided with spark gaps positioned one on each side of said wall and further provided with a chamber adjacent the outer gap, a restricted opening leading from said chamber and into the combustion space of said engine adjacent the inner gap, whereby the gases exploding in the outer chamber are forced through said opening with high velocity and caused to contact the electrodes of the inner gap and purge the same, substantially as described.

28. The combination with an internal combustion engine having a combustion space, a spark plug formed outside of said space with a combustion chamber having a restricted opening communicating with said space, and a pair of spark gaps arranged in series and

disposed one on each side of said restricted opening, substantially as described.

29. A spark plug for internal combustion engines comprising a body formed with a restricted chamber adapted to communicate with the combustion space thereof, a grounded terminal carried thereby, an electrode insulated from and extending through said body into said chamber, and a neutral electrode insulated from said body and interposed between said grounded terminal and said electrode.

30. A spark plug for internal combustion engines comprising a body formed with a restricted chamber adapted to communicate with the combustion space thereof, a grounded terminal carried thereby, an electrode insulated from and extending through said body into said chamber, and a neutral electrode mounted within said chamber adjacent said electrode extending through said restricted chamber adjacent said grounded terminal.

31. A spark plug for internal combustion engines comprising a body formed with a restricted chamber adapted to communicate with the combustion space thereof, and electrodes arranged in series and insulated from said body providing a plurality of spark gaps.

32. A spark plug for internal combustion engines comprising a body formed with a combustion chamber adapted to communicate with the combustion space thereof and electrodes mounted in said combustion chamber and arranged in series providing a plurality of spark gaps.

33. A spark plug, adapted to have one end inserted in the wall of the cylinder of an internal combustion engine, having an insulator with a chamber, within the plug, having communication with the engine cylinder; electrodes forming a spark gap in said chamber, one of said electrodes being hollow and having an opening into said chamber whereby gases may pass through the electrode to and from said chamber.

34. A spark plug having a body portion adapted for insertion in the wall of the cylinder of an internal combustion engine, and having spark gap electrodes; a chamber within said plug, beyond said body portion and outside of said cylinder having communication with the cylinder; and other spark gap electrodes, within said chamber, in series with the first mentioned electrodes.

35. A spark plug having a body portion adapted for insertion in the wall of the cylinder of an internal combustion engine, and having conductors arranged to form two spark gaps in series lengthwise of the plug, both gaps being set in spaces accessible to explosive mixture of the engine cylinder; one of said spaces being outside of the engine cylinder and beyond said body portion.

36. A spark plug having, in combination, an inner conducting jacket adapted for insertion in the wall of the cylinder of an internal combustion engine and having a spark gap terminal; an outer casing adapted to be positioned outside of the cylinder and having a chamber; an insulating element extending into the jacket and disposed between the jacket and the outer casing and having a passage communicating with the chamber and with the cylinder for transfer of gases between the chamber and the cylinder; an electrode carried by the outer casing having a spark gap terminal in the chamber; a second electrode, insulated from the first mentioned electrode and mounted in the insulating element and having a spark gap terminal cooperating with the first mentioned terminal to form a spark gap in the chamber; the second electrode being insulated by the insulating element from the jacket, and having a second spark gap terminal cooperating with the jacket terminal to form a spark gap in the cylinder; whereby the said spark gaps are disposed in series.

Signed at Boston, Massachusetts, this twentieth day of February, 1922.

WILLIAM L. PHILLIPS.