

June 26, 1945.

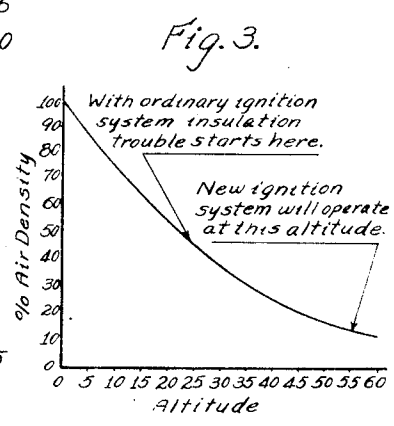
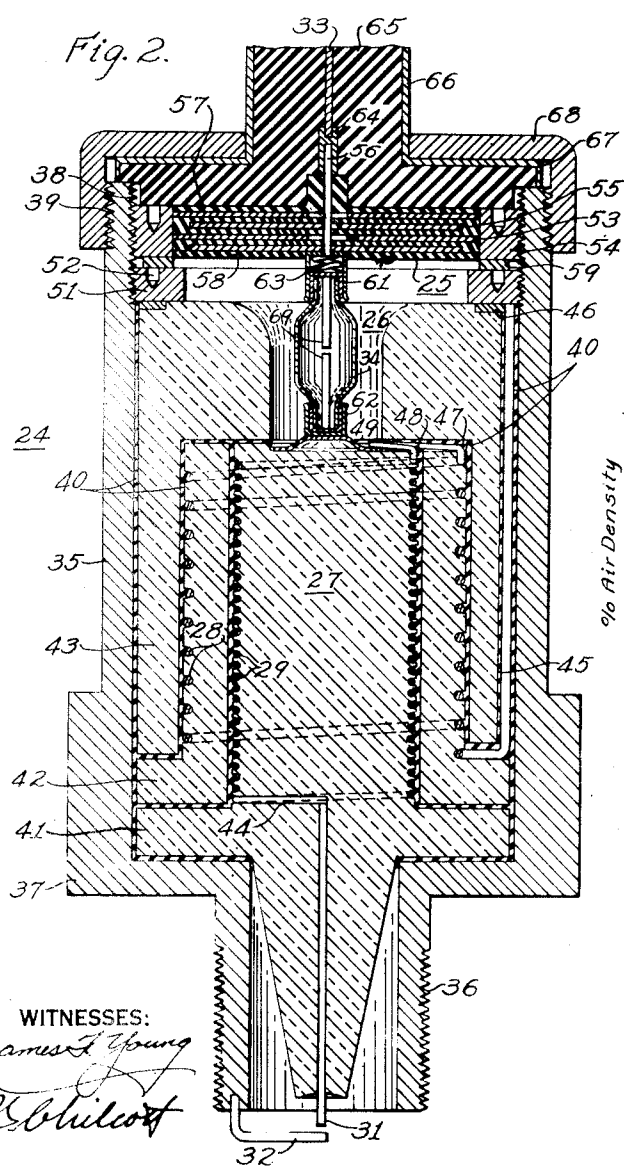
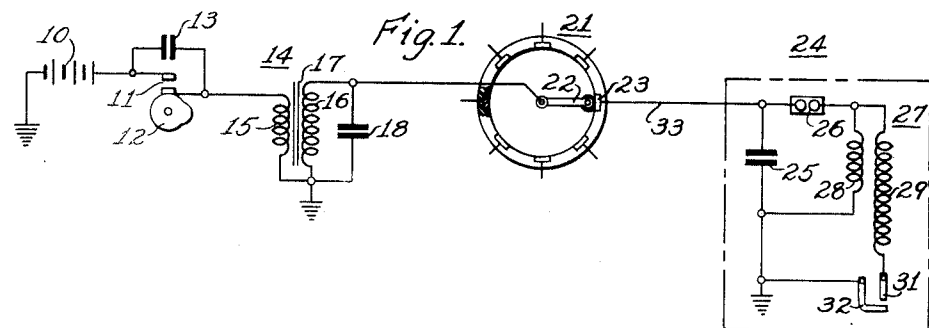
W. E. BERKEY ET AL

2,378,893

IGNITION SYSTEM

Filed March 10, 1942

2 Sheets-Sheet 1



WITNESSES:

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Fig. 4.

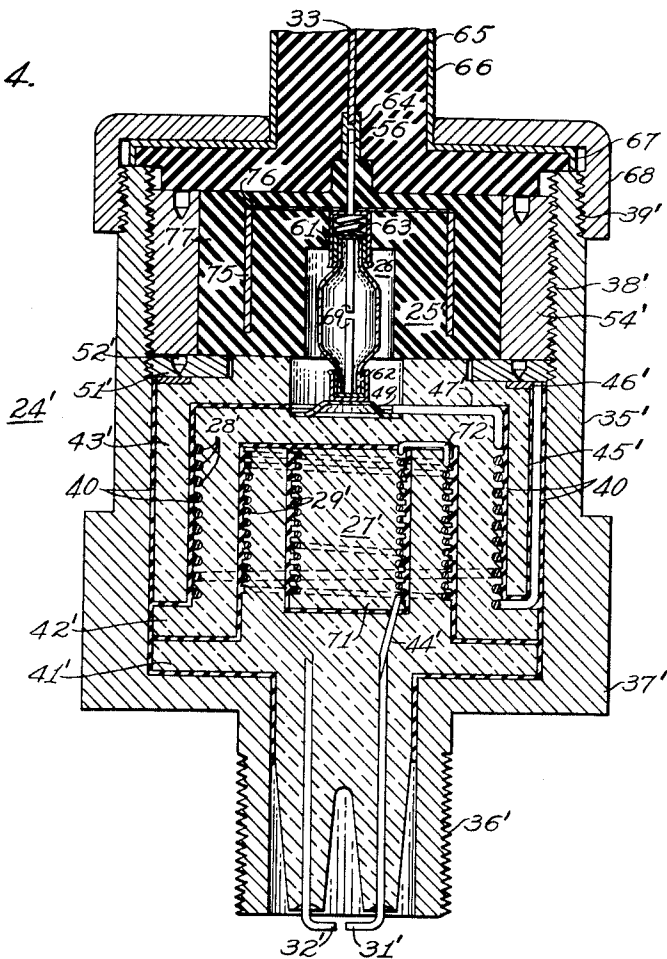


Fig. 5.

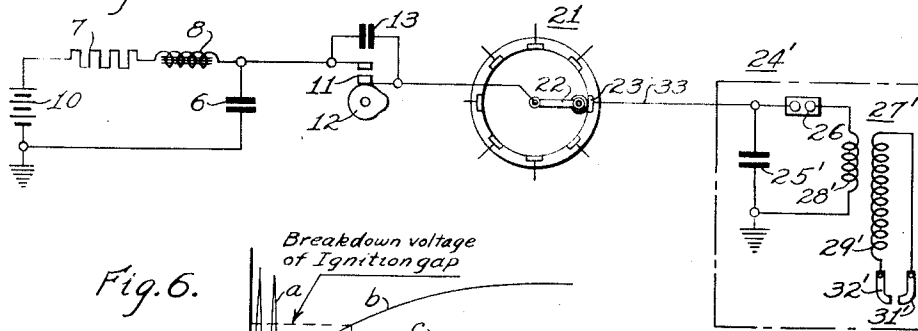
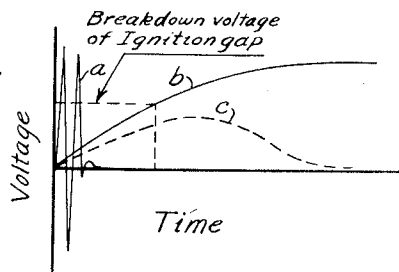


Fig. 6.



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2,378,893

IGNITION SYSTEM

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Application March 10, 1942, Serial No. 434,030

14 Claims. (Cl. 315—57)

Our invention relates, generally, to ignition systems for internal combustion engines and, more particularly, to ignition systems for engines adapted for aeronautical use.

At the present time practically all airplanes are equipped with an ignition system which is essentially the same as that utilized in automobiles. A high voltage is generated in a spark coil by making and breaking the primary circuit, which is energized from a battery. A distributor is provided in the high voltage part of the system, and consequently, the distributor as well as the wires connecting the distributor to the individual spark plugs must be insulated for the high voltage.

The foregoing system is not satisfactory at altitudes over 25,000 feet because of decreased air density which causes a proportional decrease in air dielectric strength. The decreased dielectric strength causes the distributor and spark plug insulation to fail by external flashover. Recent attempts to improve the insulation of the spark plugs and the distributor against external flashover have not been very successful. A ceiling of around 35,000 feet has been reported for planes equipped with the improved insulation. However, present motors are capable of carrying the planes to 55,000 feet if provided with a satisfactory ignition system.

An object of our invention, generally stated, is to provide an improved ignition system for internal combustion engines.

A more specific object of our invention is to provide a relatively low voltage ignition system.

Another object of our invention is to provide an ignition system which may be readily adapted to present systems with only minor changes in the present systems.

A further object of our invention is to provide a high frequency spark plug suitable for use in our improved ignition system.

Other objects of our invention will be explained fully hereinafter or will be apparent to those skilled in the art.

In accordance with our invention, the distributor is connected in the low voltage part of the ignition system and a high frequency spark plug having a primary winding of a relatively low voltage and a secondary winding of a high voltage is provided. The spark plug also contains a condenser and a spark gap so connected in the ignition circuit that an oscillating current of a high frequency is produced in the plug. Thus, the high voltage is generated within the plug itself and is not exposed to atmospheric pressure.

For a fuller understanding of the nature and objects of our invention, reference may be had to the following detailed description, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of an ignition system embodying our invention;

Fig. 2 is a view, in vertical section, of a spark plug suitable for use in the system shown in Fig. 1;

Fig. 3 is a curve showing the relation between altitude and air density;

Fig. 4 is a view, in vertical section, of a modified plug structure;

Fig. 5 is a diagrammatic view of a modification of the ignition system shown in Fig. 1; and

Fig. 6 is a view of curves illustrating differences in characteristics of our ignition system and the usual system.

As indicated in the curve shown in Fig. 3, in which air density is plotted against altitude, airplanes equipped with the usual ignition system develop ignition trouble at altitudes of approximately 25,000 feet. As explained hereinbefore, the decreased air density causes a proportional decrease in air dielectric strength. Because of the relatively high voltage impressed upon the distributor and spark plugs, the decreased dielectric strength permits the distributor and spark plug insulators to flashover. Thus, a limitation is placed upon the altitude reached by the planes which otherwise would be capable of flying at much higher altitudes.

In our ignition system, flashover of insulation is not a limitation because a relatively low voltage is utilized throughout the system up to the spark plugs which are of a special construction, as fully described hereinafter. Moreover, our system may be readily adapted to present ignition systems with only minor changes.

Referring to the schematic diagram in Fig. 1, the system shown therein comprises a battery 10, breaker points 11 which are closed in the usual manner by a cam 12 driven by the engine (not shown), the usual condenser 13, which bridges the breaker points 11, and a spark coil 14, which may be of the usual type having a primary winding 15 and a secondary winding 16 disposed upon an iron core 17. The spark coil 14 may be similar to the coils now used in automotive ignition systems with the exception that the coil will deliver a relatively low voltage as compared with the voltage of the present ignition systems. A small condenser 18 may or may not be connected

across the secondary winding 16, depending upon the construction of the coil.

A distributor 21, which may be of the usual type having a rotor 22 for successively engaging contact members 23, is provided. Each one of the contact members 23 is connected to a spark plug 24 located in each cylinder of the engine. The distributor 21 may be of a standard design and driven by the engine in the usual manner.

As indicated schematically in Fig. 1, the spark plug 24 is provided with a condenser 25, which may be of a relatively small capacity of the order of .002 microfarad, an enclosed spark gap 26 and an air core transformer 27 having a primary winding 28 and a secondary winding 29. The plug 24 is provided with the usual igniting electrodes 31 and 32.

As shown, the electrode 31 is connected to one terminal of the secondary winding 29. The other terminal of the secondary winding 29 and one terminal of the primary winding 28 are connected to one terminal of the enclosed spark gap 26. The other terminal of the spark gap 26 and one terminal of the condenser 25 are connected to the usual conductor 33 leading from the distributor. The other terminal of the condenser 25 and the other terminal of the primary winding 28, as well as the electrode 32, are connected to ground through the engine frame in the usual manner.

The dimensions of the enclosed spark gap 26 may be made similar to those of a cartridge fuse of the automotive type. It may be sealed in an air-tight transparent case 34 and should be set to break down at about half the voltage which the coil 14 is capable of supplying. It will be understood that the breakdown voltage of the gap may be varied by changing the pressure of the gas in the tube which encloses the gap. Thus, the gap may be made to break down at any desired voltage by creating a partial vacuum in the tube when the gap is constructed. The breakdown voltage of the gap may be stabilized to breakdown with a very short time lag by introducing a small quantity of radio-active material inside the tube or by pre-ionizing the gap by other known methods.

Since the discharge through the spark gap is intermittent, high frequency and the effective current is small, there should be practically no burning of the electrodes. However, as explained hereinafter, the enclosed gap is readily accessible for removal and replacement.

The air core transformer 27 should have a relatively few turns, approximately 10, in the primary winding 28 and approximately 10 times as many turns of fine wire in the secondary winding 29. It has been determined that good coupling can be obtained with a coil of relatively small dimensions and having the foregoing turn ratio.

Referring to Fig. 2, which illustrates the mechanical structure of a spark plug suitable for use in our ignition system, the plug shown comprises a metal casing 35 having a threaded portion 36 for insertion in the engine in the usual manner and a shoulder 37 which may be hexagonal in shape to permit a wrench to be utilized for screwing the plug in the engine. The upper end of the casing 35 is threaded both internally at 38 and externally at 39, as shown.

Three insulating tubes 41, 42 and 43, which may be composed of porcelain or other suitable ceramic material, are disposed within the metal casing 35. The tubes 41, 42 and 43 are so sized and shaped as to telescope into each other, as shown, and the tubes 41 and 42 are provided with

spiral grooves for receiving the secondary winding 29 and the primary winding 28, respectively, of the transformer 27.

The transformer wires are sealed air-tight by means of a cement 40 which may be made of a mixture of water glass and powdered quartz or any other suitable inorganic powder or sealing paste. The cement 40 fills the space between the tubes and may also be utilized to hold the electrode 31 in place. The cement 40 also seals the insulating tubes to the metal casing 35.

A hole 44 is provided in the tube 41 for connecting the secondary winding 29 to the electrode 31. It will be understood that the end of the winding 29 may be inserted in the hole 44 and electrically welded to the electrode 31. A groove 45 may be provided in the side of the tube 43 for a portion of the primary winding 28, one end of which may be welded to a metal ring 46 inserted in the top of the tube 43. The other terminal of the primary winding 28 and the other terminal of the secondary winding 29 are brought out through grooves 47 and 48 in the tubes 42 and 41, respectively, and electrically connected to a spring terminal 49 of the spark gap 26.

After the windings are in place and the proper electrical connections made, the assembled insulators 41, 42 and 43, may be inserted in the casing 35 and sealed with cement, as hereinbefore described. A retaining nut 51 may be screwed into the casing 35 to hold the insulators firmly in place. It will be noted that the nut 51 engages the ring 46, thereby connecting one terminal of the primary winding 28 to the casing 35 which completes the ground connection for the primary winding when the plug is inserted in the engine. The nut 51 may be provided with sockets 52 for receiving a suitable wrench for tightening the nut.

The condenser 25 comprises plates 53 which are connected to a metal ring 54 threaded into the casing 35, thereby constituting the ground electrode of the condenser and plates 55 which are connected to a center electrode 56. The condenser 25 may be filled with a suitable insulating compound which is retained therein by means of insulating washers 57 and 58 disposed at the top and bottom, respectively, of the condenser.

A soft metal ring or washer 59 may be provided between the nut 51 and the ring 54 to seal the top chamber of the plug against moisture and also against a decrease in air pressure. A cup-shaped terminal 61 is provided in the lower side of the condenser 25 and a similar cup-shaped terminal 62 is provided on the spring terminal 49 for receiving the spark gap 26. A spring 63 may be provided in the cup terminal 61 for insuring good electrical contact between the upper terminal of the spark gap 26 and the electrode 56 of the condenser.

The distributor conductor 33 may be electrically connected to the electrode 56 by means of a suitable connector 64 which is embedded in suitable insulation 65 surrounding the conductor 33. A metal sheath 66 having a flanged cap 67 may be provided for the insulation 65 and the cap retained on the casing 35 by means of a flanged nut 68 threaded onto the outside of the casing.

It will be seen that the spark gap 26 may be readily removed from the plug 24 by removing the nut 68 and the distributor cable 66. After these are removed, the condenser 25 and the spark gap 26 may be removed from the plug. If it is determined by inspection that the dis-

tance between the electrodes 69 of the spark gap has become too great, a new spark gap tube 34 may be installed in the plug and the condenser and distributor cable reassembled in the manner hereinbefore described. As explained hereinbefore, it is not expected that the spark gaps will have to be replaced except after long periods of operation. However, it is recommended that they be inspected during each time that the engine is being overhauled.

Referring again to Fig. 1, the operation of our ignition system is as follows: At the proper instant, as determined by the operation of the breaker points 11 and the distributor 21, the voltage produced by the coil 14 is applied across the condenser 25 which charges until its potential equals the breakdown voltage of the enclosed spark gap 26. The gap 26 breaks down and allows the accumulated charge to surge through the primary winding 28 of the transformer 27. The discharge is an oscillating current of a very high frequency. In this manner a voltage is induced in the secondary winding 29, which, added to the primary voltage, breaks down the combustion gap across the electrodes 31 and 32 and ignites the fuel mixture in the cylinder. Ordinarily, there will be several of these high frequency surges during each firing cycle depending upon the natural frequency of the plug circuit and the characteristics of the voltage-supplied by the distributor.

As illustrated by the curves in Fig. 6, a spark of high frequency is not affected by the accumulation of oil on the spark plug which has a tendency to short-circuit the plug. In Fig. 6, in which voltage is plotted against time, curve *a* is a high frequency voltage wave, such as produced by our system, curve *b* is the voltage wave for a standard system and curve *c* illustrates how fouling of the plug affects the voltage of a standard system by lowering the voltage at the plug. It will be seen that the voltage of the high frequency wave reaches the breakdown voltage of the gap and causes the plug to fire before the fouling can appreciably lower the voltage. With a standard system, the fouling lowers the resistance to such an extent that the voltage never reaches the breakdown point.

From the foregoing description it will be seen that only a relatively low voltage is impressed upon the distributor and the conductors leading to the spark plugs of an internal combustion engine. The high voltage required for igniting the fuel is produced entirely within the plug itself, thereby eliminating the danger of flashover through the insulation on the conductors and the distributor of the ignition system. Furthermore, the spark plug is incorporated in a grounded metal casing, thereby reducing radio interference.

In order to reduce the length of the plug 24, the secondary winding 29 may be disposed in two layers which are concentrically wound, as shown in Fig. 4. The outer layer is disposed on the insulating member 41' and the inner layer is disposed on an insulating spool 71 which telescopes in the insulating member 41'; the two layers are electrically connected by a jumper 72 and wound cumulatively, thereby obtaining the same electrical effect as with a single layer.

As shown in Fig. 4 and illustrated schematically in Fig. 5, the electrode 31' is connected to one terminal of the secondary winding 29' and the electrode 32' is connected to the other terminal instead of being grounded, as in the system hereinbefore described. However, if desired, the one

terminal of the secondary winding 29' may be connected to the one terminal of the primary winding 28', as illustrated in Figs. 1 and 2. In this case, the electrode 32' would be disposed in the casing 35' and the electrode 31' disposed in the center of the insulating member 41' in a manner similar to that illustrated in Fig. 2.

With a view to still further decreasing the length of the plug, the condenser 25' may be of a cylindrical construction instead of a plate construction, as illustrated in Fig. 2. In the structure shown in Fig. 4, the metal ring 54' constitutes one plate of the condenser 25' and a cylindrical metal sleeve 75 constitutes the other plate of the condenser. The sleeve 75 may be supported by a metal disc 76 which is electrically connected to the electrode 56' of the condenser. The sleeve 75 may be insulated from the ring 54' by suitable insulation 77 which may be of a molded construction or, if desired, the condenser may be compound filled, the insulating compound being retained in the ring 54 by suitable retaining members, as illustrated in the structure shown in Fig. 2. It will be understood that the capacity of the condenser may be increased by increasing the number of plates.

With the exception of the foregoing features, the plug illustrated in Fig. 4 is of substantially the same construction as the one illustrated in Fig. 2 and hereinbefore described. It will be seen that the overall length of the plug may be materially reduced by constructing it in the manner shown in Fig. 4. Furthermore, it will be understood that a cylindrical condenser in which the spark gap 26' is disposed inside the condenser may be utilized with the transformer structure shown in Fig. 2, thereby somewhat decreasing the length of the plug.

As illustrated in Fig. 5, a spark plug of the type herein described may be utilized in an ignition system which is not provided with an ignition coil of the type now used in automotive ignition systems. In the system shown in Fig. 5, a condenser 6 is charged from the battery 10' through a resistance 7 and an inductance 8. The charging time for the condenser 6 is determined by the constants of the resistor 7 and the inductance 8.

The condenser 6 discharges through the breaker points 11 and the distributor 21, thereby charging the condenser 25' which, in turn, is discharged through the spark gap 26' and the primary winding 28' of the transformer 27' in the manner hereinbefore described. In this manner, the usual ignition coil may be omitted from the system.

If desired, the system illustrated in Fig. 5 may be utilized with a spark plug in which the primary winding 28 and the secondary winding 29 of the transformer 27 have two terminals connected together, as illustrated in Fig. 1. As explained hereinbefore, the electrode 32 would then be grounded, as shown in Fig. 1, instead of being connected to the winding 29.

In addition to the sources of electromotive force herein illustrated, it is also possible to supply a potential to the distributor by means of a magnet of a type well known in the art. In fact, almost any kind of voltage wave may be utilized. For example, a constant potential direct voltage from a rectifier has been satisfactorily utilized. An alternating voltage may be utilized, the only restriction being that the frequency should be high enough to allow at least one half cycle to be impressed on the plug circuit before the timing circuit has removed voltage from the distributor. On the other hand, this frequency must not be

sufficiently high to allow the condenser 25 to short-circuit the supply.

From the foregoing description it is apparent that we have provided an ignition system suitable for internal combustion engines of all types which eliminates the danger of insulation failure at any point in the system, thereby making the system particularly suitable for utilization in aircraft which operates at high altitudes. Furthermore, the metal enclosed spark plug which we have provided is structurally capable of withstanding the severe vibration to which airplane spark plugs are subjected, it is completely shielded from lightning surges, etc., and is moisture proof, thereby eliminating trouble caused by wet weather shorting the plug. It is also apparent that the dimensions of the spark plug are such that it may be utilized in any of the airplane motors now being manufactured, and, therefore, does not require motors of special construction. Furthermore, our ignition system may be readily incorporated in ignition systems of the type now known.

Since numerous changes may be made in the above described constructions and different embodiments of the invention may be made without departing from the spirit and scope thereof, it is intended that all matter contained in the foregoing description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

We claim as our invention:

1. A unitary spark plug for an internal combustion engine comprising a casing having one end reduced in size for insertion into the engine, a transformer having a primary winding and a secondary winding disposed within the casing, a spark gap and a condenser also disposed within the casing, said spark gap being disposed between said condenser and said transformer in close proximity thereto, and a pair of igniting electrodes at least one of which is connected to the secondary winding of said transformer.

2. A unitary spark plug for an internal combustion engine comprising a casing having one end reduced in size for insertion into the engine, a transformer having a primary winding and a secondary winding disposed within the casing, a spark gap and a condenser removably disposed within the casing, said spark gap being disposed between said condenser and said transformer in close proximity thereto, and a pair of igniting electrodes at least one of which is connected to rated in ignition systems of the type now known.

3. A unitary spark plug for an internal combustion engine comprising a casing having one end reduced in size for insertion into the engine, a transformer having a primary winding and a secondary winding disposed within the casing, a spark gap and a condenser removably disposed within the casing, said spark gap being disposed between said condenser and said transformer in close proximity thereto, and a pair of igniting electrodes at least one of which is connected to the secondary winding of the transformer, said primary winding being connected to one terminal of the spark gap.

4. A unitary spark plug for an internal combustion engine comprising a cylindrical casing having one end reduced in diameter for insertion into the engine, a transformer having a primary winding and a secondary winding disposed within the casing, a spark gap and a condenser removably disposed within the casing, said spark gap being disposed between said condenser and said transformer in close proximity thereto, and

a pair of igniting electrodes at least one of which is connected to the secondary winding of the transformer, said primary winding being connected to one terminal of the spark gap, the other terminal of the spark gap being connected to one terminal of the condenser.

5. A unitary spark plug for an internal combustion engine comprising a cylindrical casing having one end reduced in diameter for insertion into the engine, a transformer having a primary winding and a second winding disposed within the casing, a spark gap and a condenser removably disposed within the casing, said spark gap being disposed between said condenser and said transformer in close proximity thereto, and a pair of igniting electrodes at least one of which is connected to the secondary winding of the transformer, said primary winding being connected to one terminal of the spark gap, the other terminal of the spark gap being connected to one terminal of the condenser, and the other terminal of the condenser being connected to said primary winding.

6. A unitary spark plug for an internal combustion engine comprising a casing having one end reduced in size for insertion into the engine, telescoping insulating members disposed within the casing, a transformer having a primary winding and a secondary winding concentrically disposed on the insulating members, an enclosed spark gap removably disposed within the casing, a condenser removably disposed within the casing, and a pair of igniting electrodes at least one of which is connected to the secondary winding of the transformer and substantially totally embedded in the innermost one of said insulating members.

7. A unitary spark plug for an internal combustion engine comprising a metal casing having a threaded portion for insertion into the engine, telescoping insulating members disposed within the casing, a transformer having a primary winding and a secondary winding concentrically disposed on the insulating members, an enclosed spark gap removably disposed within the casing, a condenser removably disposed within the casing, and a pair of igniting electrodes, one of which is connected to said secondary winding and substantially totally embedded in the innermost one of said insulating members and the other of which is connected to said casing.

8. A unitary spark plug for an internal combustion engine comprising a metal casing having a threaded portion for insertion into the engine, telescoping insulating members disposed within the casing, a transformer having a primary winding and a secondary winding concentrically disposed on the insulating members, an enclosed spark gap removably disposed within the casing, a condenser removably disposed within the casing, and a pair of igniting electrodes, each one of which is connected to a terminal of said secondary winding and substantially totally embedded in the innermost one of said insulating members.

9. A spark plug for an internal combustion engine comprising a casing having a threaded portion for insertion into the engine, insulating members disposed within the casing, a transformer having a primary winding and a secondary winding concentrically disposed on the insulating members, a cylindrical condenser removably disposed within the casing, and a spark gap disposed within the casing.

10. A spark plug for an internal combustion engine comprising a casing having a threaded portion for insertion into the engine, insulating members disposed within the casing, a transformer

having a primary winding and a secondary winding concentrically disposed on the insulating members, a cylindrical condenser removably disposed within the casing, and an enclosed spark gap removably disposed within the casing.

11. A spark plug for an internal combustion engine comprising a metal casing having a threaded portion for insertion into the engine, insulating members disposed within the casing, a transformer having a primary winding and a multi-layer secondary winding concentrically disposed on the insulating members, an enclosed spark gap removably disposed within the casing, a cylindrical condenser surrounding the spark gap, and a pair of igniting electrodes at least one of which is connected to the secondary winding of the transformer.

12. In an ignition system for an internal combustion engine, the combination with a source of electromotive force and a distributor therefor, of a unitary spark plug having one end constructed for insertion into the engine and comprising a transformer having a primary winding and a secondary winding, a condenser and a spark gap all disposed within the plug, said condenser being connected to discharge across the spark gap through the primary winding of the transformer, said spark gap being disposed between the condenser and the transformer in close proximity thereto.

13. In an ignition system for an internal com-

bustion engine, the combination with a source of electromotive force and a distributor therefor, of a unitary spark plug having one end constructed for insertion into the engine and comprising a transformer having a primary winding and a secondary winding, a condenser and a spark gap all disposed within the plug, said condenser being connected to discharge across the spark gap through the primary winding of the transformer, said spark gap being disposed between the condenser and the transformer in close proximity thereto and a pair of igniting electrodes, at least one of which is connected to the secondary winding of the transformer.

14. In an ignition system for an internal combustion engine, the combination with a source of electromotive force and a distributor therefor, of a unitary spark plug having one end constructed for insertion into the engine and comprising a transformer having a primary winding and a secondary winding, a condenser and a spark gap all disposed within the plug, said condenser being connected to discharge across the spark gap through the primary winding of the transformer, said spark gap being disposed between the condenser and the transformer in close proximity thereto and a pair of igniting electrodes connected across the secondary winding of the transformer.

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