June 24, 1941. K. J. R. WILKINSON 2,247,075

ELECTRIC IGNITION SYSTEM

Filed Nov. 4, 1939

Fig. 1.

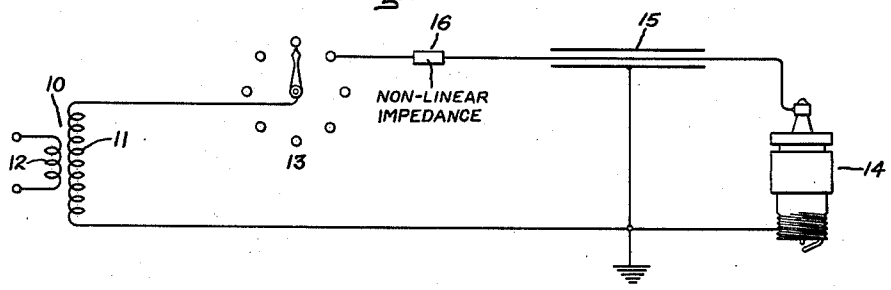



Fig. 2.

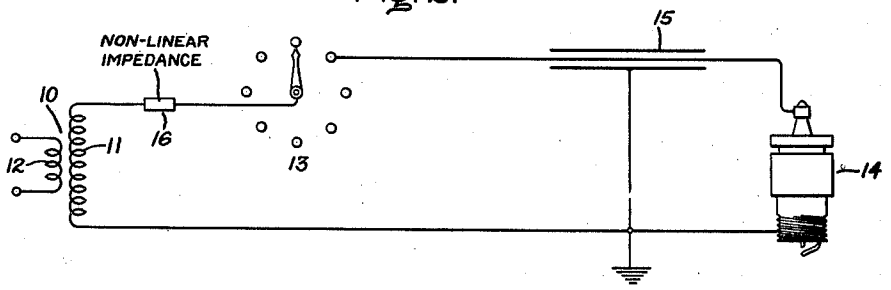
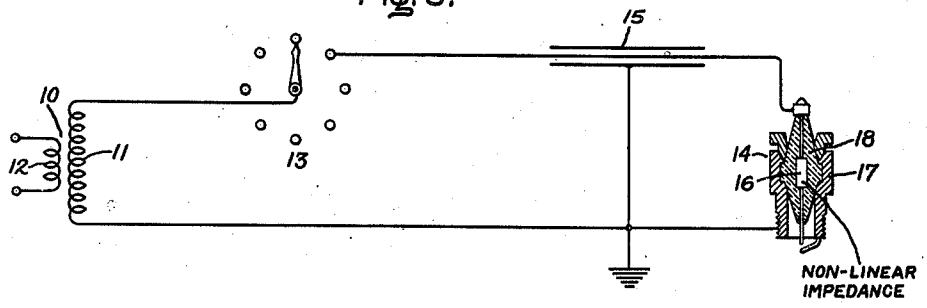



Fig. 3.




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## ELECTRIC IGNITION SYSTEM

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6 Claims. (Cl. 123—148)

This invention relates to electric ignition systems and more particularly to an arrangement for substantially limiting an appreciable flow of current in the high tension circuit thereof to that time when an ignition spark is desired.

When electric ignition systems are used on aircraft the problem of preventing excessive after-current which results from ionization in the distributor chamber at high altitudes presents itself. Heretofore, in order to meet this problem it has been proposed to provide a series resistor of material with a relatively high resistivity, such as carbon, or a series condenser in the high tension circuit of electrical ignition systems. However, a series resistor to be effective would dissipate a large amount of energy and would in combination with external lead capacitance reduce the available output voltage, and a series condenser may require additional resistors to remove residual charges which it otherwise acquires.

An object of my invention is to provide an improved ignition system for internal combustion engines.

Another object of my invention is to provide an improved ignition system which will operate effectively in rarefied atmospheres.

I accomplish these objects by providing a suitable element having a non-linear impedance characteristic with respect to current in the high tension circuit of an ignition system.

Further objects and advantages of my invention will become apparent from the following description referring to the accompanying drawing, and the features of novelty which characterize my invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

In the drawing, Fig. 1 diagrammatically illustrates an electric ignition system provided with an embodiment of my invention; Fig. 2 is a modification of the ignition system shown in Fig. 1 and Fig. 3 is a further modification of the ignition system shown in Fig. 1.

Referring to the drawing, in Fig. 1 I have illustrated diagrammatically a conventional electric ignition system having a step-up transformer 10 for providing the desired high voltage across a secondary winding 11. A primary winding 12 of the transformer may be connected to any suitable source of low voltage. For example, the transformer may have reference to a conventional magneto, wherein a current is induced in the primary thereof and upon interruption of the primary circuit a voltage will be induced across the secondary. In order to distribute properly the high voltage from the secondary of the transformer to spark plugs at the proper time the secondary winding of the transformer may be connected to a suitable distributor 13. This distributor may be of the conventional type and, of course, has a series of stationary contacts and a rotating electrode which may be rotated by the camshaft of the internal combustion engine directly or by the crankshaft through suitable gears. Each of the stationary contacts of the distributor 13 has connection with a spark plug 14 through a shielded conductor 15, the connection between the distributor and the spark plug including an element having a non-linear impedance-ampere characteristic whose function will be hereinafter described.

It is known that spark plug erosion is largely dependent upon the initial portion or "head" of each spark, and that the "tail," or after-current, can undergo frequent interruptions of current under engine conditions, which leads to a multiplicity of "heads" at each ignition. It is therefore apparent that any arrangement which tends to curtail the duration of this after-current will tend to reduce erosion by lessening the number of interruptions which are possible following the initial spark. In order to curtail the duration of this after-current I provide in the high tension circuit of any electric ignition system an element having the general property that its impedance is a direct but non-linear function of voltage, or an inverse non-linear function of current. An example of a suitable non-linear impedance for use according to my invention is Thyrite, and is described in U. S. Patent 1,822,742 issued to McEachron. No attempt will be made herein to completely discuss all the characteristics of this material. However, this material is somewhat similar to dry process porcelain throughout the mass of which appear minute particles of conducting material. This material has a non-linear or substantially hyperbolic resistance-ampere characteristic. As described in the above mentioned McEachron patent the characteristic of this material can be expressed by the equation $V=cI^a$, where V is the voltage applied, I the current flowing, $c$ a constant dependent upon the shape of the resistor material, and $a$ a constant dependent upon the material itself. This constant $a$ is appreciably less than unity. Before breakdown of the spark plug gap, the resistance of this gap is very high. At this same time, current is flowing through the non-linear element to charge the distributor capacity of the leads as the voltage builds up. The re-

sistance value of the non-linear element is relatively low as compared to that of the gap due to this flow of charging current. The voltage from the coil divides up proportionally to the resistances in its path and thus the major portion is applied to the spark plug. At breakdown, the resistance of the gap becomes, and remains, low due to the presence of hot gasses at the spark plug. When this occurs, a relatively large current flows since the circuit resistance has been lowered and the coil or secondary winding begins to discharge its energy and the voltage and current begin to drop. Due to the non-linear characteristic of the element, as the current decreases, the resistance of this element increases. Thus the voltage in the circuit is transferred from the spark plug to the element. At a certain point, insufficient voltage will be available across the spark plug to maintain the arc and the current will cease. At the time of zero current, the resistance of the non-linear element becomes very high and thus any subsequent attempt of the coil to build up voltage again across the plug is defeated, because the major portion of any such voltage will appear across the now high resistance non-linear element and not across the plug.

I have found that a desirable value of the non-linear resistance lies between 20,000 and 60,000 ohms at a current of 60 milliamperes. This is equivalent to a constant $c$ of between 2200 and 6500, if $a$ equals .02.

In Fig. 2 I have illustrated an electric ignition system similar to that shown in Fig. 1, except that the non-linear impedance is placed between the distributor and the source of high voltage.

In Fig. 3 I have shown an electric ignition system similar to that shown in Fig. 1 except that the non-linear impedance is incorporated into the spark plug itself. The spark plug includes a metallic casing 17 and an insulating mass 18 of any suitable material, such as porcelain, within the shell. The shell also carries an electrode which co-operates with another electrode which is electrically connected with the high tension circuit and is mechanically held by the porcelain. Within the porcelain I also place the non-linear impedance so that it is mechanically held by the porcelain and electrically connected in series with the high tension electrode. The non-linear impedance may also be mounted on top of the spark plug. If the non-linear impedance is placed in the plug the effective impedance of this non-linear impedance to the "head" of the spark can be taken as about 10,000 to 20,000 ohms. There is also an added advantage in placing the non-linear impedance at the plug inasmuch as chopping or interruption of after-current can be eliminated entirely if the rate of discharge of the high tension lead capacitance is made sufficiently small. I have found that this rate is small enough if an impedance in excess of 5000 ohms is placed at the plug.

In view of the foregoing it will be seen that I have provided a new and improved ignition arrangement which may be used on aircraft or under conditions where the distributor chamber is subject to rarefied atmospheres, since an appreciable flow of current is substantially limited in the high tension circuit to that time when the ignition spark is desired.

Modifications of the particular arrangements which I have disclosed embodying my invention will occur to those skilled in the art, so that I do not desire my invention to be limited to the particular arrangements set forth and I intend in the appended claims to cover all modifications which do not depart from the spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. An ignition system for an internal combustion engine including a spark plug and a high tension circuit connected to said spark plug and having a resistor with a non-linear resistance-ampere characteristic therein.

2. An ignition system for an internal combustion engine having a spark plug and a high tension circuit electrically connected with said spark plug and including an impedance, said impedance having a hyperbolic resistance-ampere characteristic.

3. An ignition system for an internal combustion engine having a spark plug and a high tension circuit electrically connected with said spark plug and including a resistor, said resistor having a relatively low value when the current is high and a relatively high value when the current is low.

4. An ignition system for an internal combustion engine having a spark plug and a high tension circuit electrically connected with said spark plug and including a source of potential, a distributor, a resistor, said resistor having a non-linear resistance-ampere characteristic, and an electrical connection between said distributor and said spark plug.

5. An ignition system for an internal combustion engine having a spark plug and a high tension circuit electrically connected with said spark plug and including a source of potential, a distributor, a resistor, said resistor having a non-linear resistance-ampere characteristic, and an electrical connection between said source of potential and said distributor.

6. A spark plug for an internal combustion engine including an insulating mass, a high tension electrode, a grounded electrode, and an impedance having a non-linear resistance-ampere characteristic, said impedance being electrically connected in series with said high tension electrode and mechanically supported within said insulating mass.

KENNETH J. R. WILKINSON.