Aug. 8, 1961

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2,995,685

IGNITION SYSTEM

Filed May 1, 1958

Fig. 1.

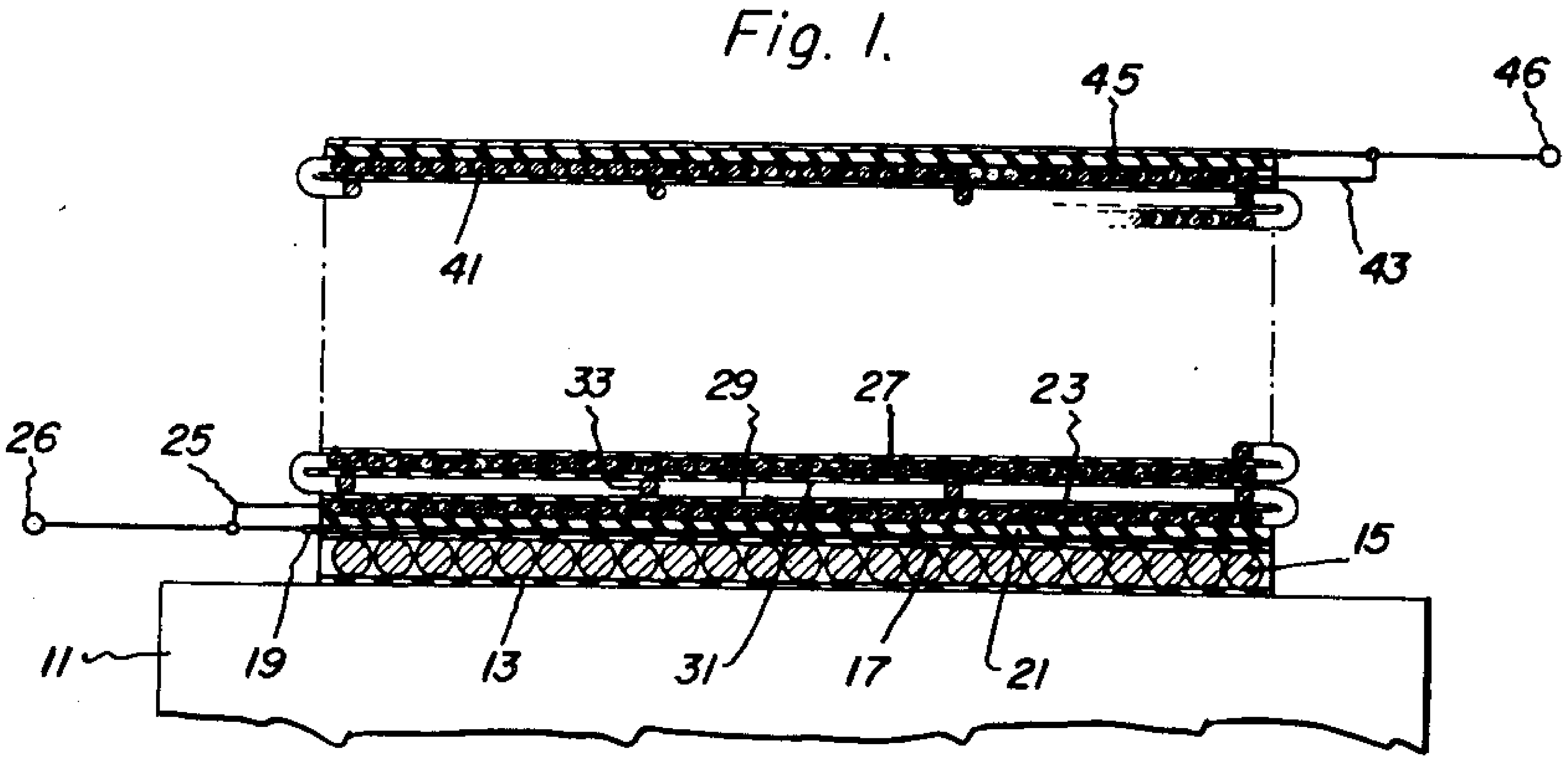


Fig. 2.

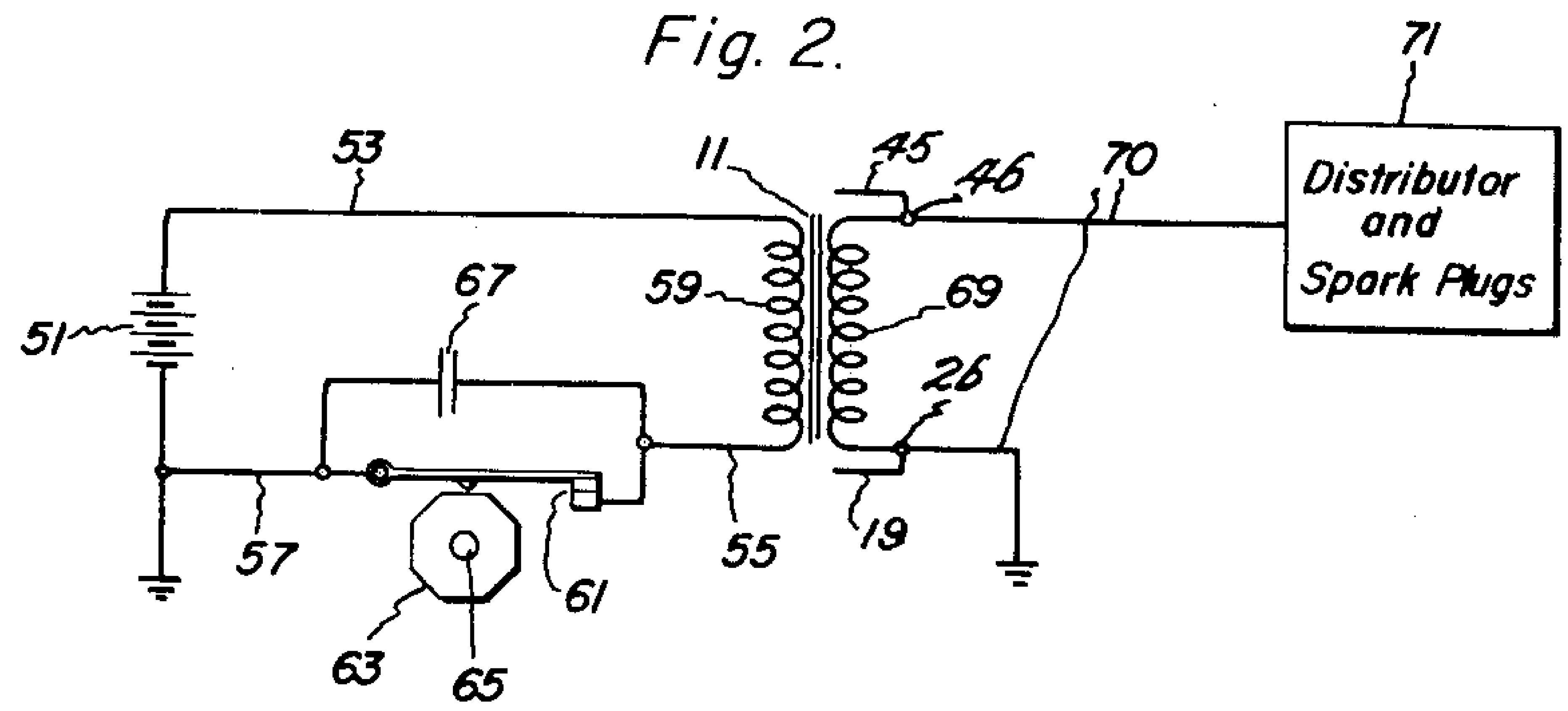
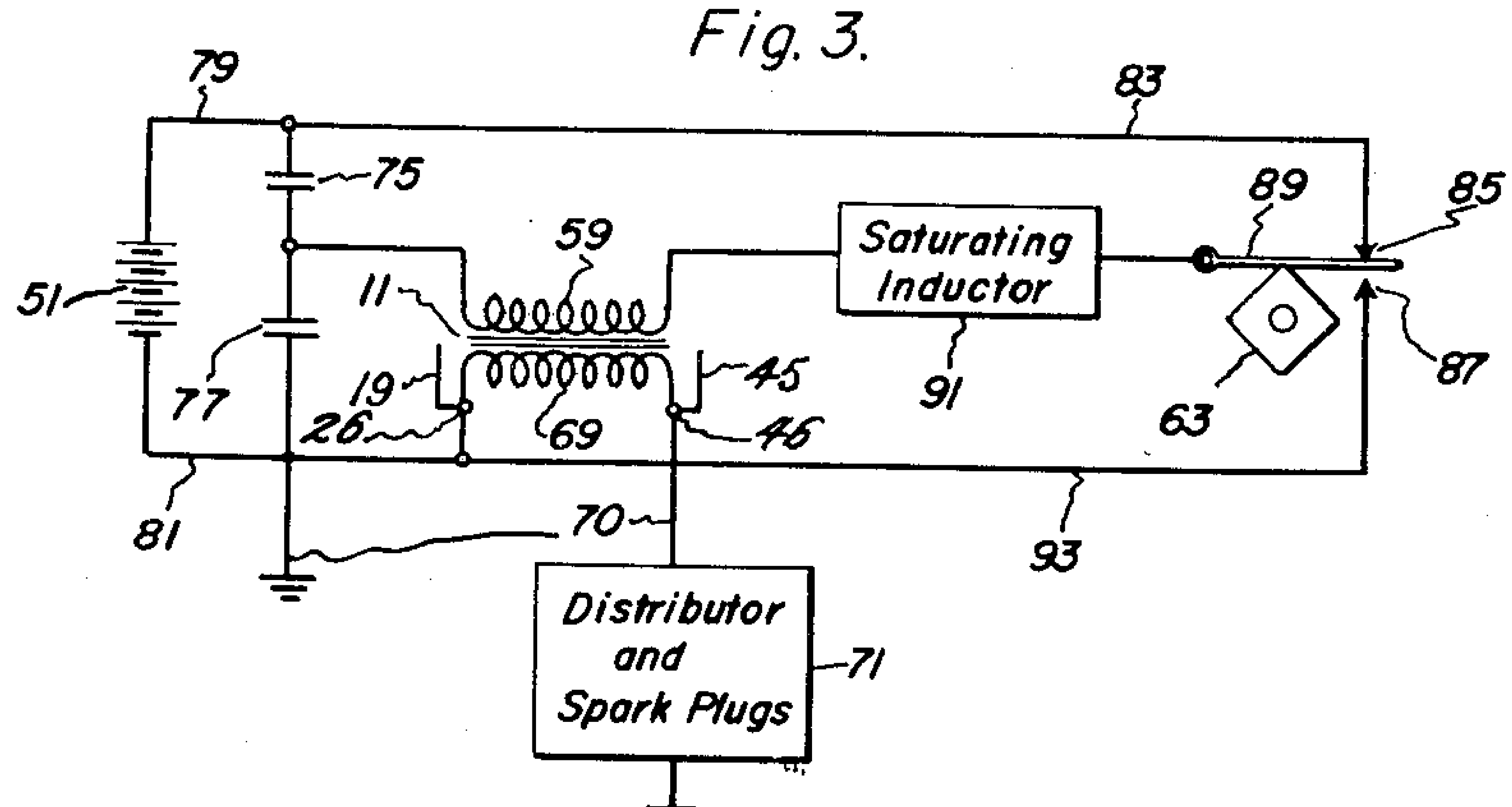


Fig. 3.



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IGNITION SYSTEM

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5 Claims. (Cl. 317—79)

The present invention relates to an improved ignition system, and more particularly to an ignition system in which electrostatic energy is stored.

In many ignition systems, such as are used in automotive, jet-engine, and oil-burner applications, ignition is obtained by the discharge of electrostatic energy stored in capacitance elements arranged effectively in parallel circuit with the load and the secondary winding of the ignition coil. These capacitance elements are usually provided by the capacitance to ground of the high-voltage leads between the secondary winding of the ignition coil and the spark plug, plus that of the spark plug bushing or by a capacitor placed between the terminals of the secondary winding of the ignition coil.

A large portion of the energy stored in the distributed capacitance of the secondary winding of the ignition coil of a prior ignition system is unavailable to the spark plug at the instant of "break-down" or "firing" of the plug, when a large magnitude of energy is desired. This energy which discharges through the inter-layer leakage inductance and resistance of the secondary winding turns is so delayed by the inductance and attenuated by the resistance that the resulting current does not reach the arc at the spark plug until after the initial firing. The current which does reach the arc is of so much lower magnitude than that from the external shunt capacitance as to be of little significance in producing ignition of the fuel and air mixture.

Accordingly, an object of the present invention is to provide a more efficient ignition system.

Another object is to provide an improved ignition system in which substantially all of the electrostatic energy stored in the ignition coil is utilized to produce ignition.

These and other objects are achieved in one ignition system embodying my invention by the utilization of an ignition coil wound to render the electrostatic energy stored per unit volume of insulation in the coil substantially uniform. Electrostatic shields associated with the coil are connected to produce discharge of this electrostatic energy without a substantial flow of current along the coil windings.

The novel features that I believe are characteristic of my invention are set forth in the appended claims. My invention itself, together with further objects and advantages thereof, may best be understood by reference to the following description, taken in connection with the accompanying drawing in which:

FIG. 1 is a partial cross-sectional view of a preferred ignition coil for use in the ignition system of my invention,

FIG. 2 is a schematic diagram of an ignition system of my invention in which an ignition induction coil is used, and

FIG. 3 is a schematic circuit diagram of an ignition system of my invention in which an ignition transformer is used.

Referring now to FIG. 1, I have illustrated a cross-sectional view of the upper half of an ignition coil embodying winding arrangement and shielding features of the high voltage coil, further disclosed and claimed in my copending concurrently filed application S.N. 732,301, filed May 1, 1958, and assigned to the assignee of the present invention. This coil comprises a bar-shaped magnetic core 11, that alternatively, may be in the form of a closed loop

or some other configuration, and may or may not have an air gap, depending upon whether the coil is an ignition induction coil or an ignition transformer. Some insulators 13 and 17 insulate a primary winding 15 from the core 11 and an electrostatic shield 19, respectively. Shield 19 is also insulated by an insulator pad 21 from the first secondary winding layer 23, the low voltage turn of which is connected by a lead 25 to shield 19 and to an output terminal 26. This layer 23 is insulated from the next layer 27 by an insulation pad provided in two sections 29 and 31 so that a lead 33 from the high voltage turn of layer 23 may be passed between these sections to the low voltage turn of layer 27. For convenience of manufacture, the lead preferably follows a spiral path, but as regards functionality, the lead can as well follow a straight line or may be placed outside the coil.

The secondary winding layers between layer 27 and the outer layer 41 are not shown because they have the same number of turns and width of traverse as illustrated layers 23 and 27, the start of each layer (low voltage end) is on the same side of the coil as for layers 23 and 27, and also, the high voltage end of each layer is connected to the low voltage end of the following layer as is illustrated for layers 23 and 27. The high voltage turn of the last secondary winding layer 41 is connected by a lead 43 to an electrostatic shield 45 surrounding the coil and also to an output terminal 46.

With this winding arrangement, the voltage distribution between winding layers and portions of adjacent winding layers lying in the same radial plane is substantially uniform. If, in addition, the insulation pads are selected as regards thickness and dielectric constant to make the electrostatic energy stored per unit volume of insulation between layers uniform througout each layer and the same for all of the layers, the electrostatic shields 19 and 45 couple practically all of this stored electrostatic energy into a spark plug or into any device which places an arc-discharge across output terminals 26 and 46.

If shield 19 is eliminated and core 11 used for the inner shield, the primary winding layer 15, which will be between shields, will adversely affect the voltage distribution. However, if winding layer 15 is wound about shield 45, core 11 may be used for the inner shield without introducing significant adverse effects.

The utilization of an ignition induction coil of the FIG. 1 type is illustrated in the ignition system of FIG. 2 in which a source of D.C. (direct current) energy, such as a battery 51, is connected in series relationship by leads 53, 55, and 57 with the primary winding 59 of an ignition coil and with points 61. As is conventional, points 61 are opened and closed by a cam 63 mounted on a cam shaft 65. Also, points 61 are shunted by a capacitor 67 which facilitates their interruption of the direct current and thereby reduces their burning while improving the system efficiency.

The secondary winding 69 of the ignition coil has electrostatic shields 19 and 45, such as are disclosed in FIG. 1, which are connected in a conventional manner to output terminals 26 and 46 and by leads 70 across the distributor and spark plugs 71.

In the operation of the illustrated embodiment, the closing of points 61 by cam 63 causes a direct current flow from battery 51 through the primary winding 59 and a resulting electromagnetic energy storage in the air gap of core 11. Upon opening of points 61, the interruption of the primary current induces a high voltage in the secondary winding 69 thereby transferring some of the stored electromagnetic energy into electrostatic energy that is stored in the capacitance in shunt with the terminals 46 and 26 of the secondary winding. This shunt capacitance includes the high tension leads 70, the bushings (not shown), including the spark plug bushings, and the capacitance between the winding layers of the secondary winding **69**.

Without shields **45** and **19**, the energy supplied to the spark plugs would be mainly due to the electrostatic energy stored only in the high tension leads **70** and the bushings. But with them, practically all of the electrostatic energy stored in the secondary winding **69** aids in the spark plug firing when the voltage across terminals **46** and **26** is sufficient to cause the spark plug to fire. This increase in electrostatic energy, which is almost twice that of a conventional ignition system, permits the design of an ignition system requiring less current for the ignition coil and thus less current flow through points **61**.

The present invention is equally applicable to an ignition system utilizing an ignition transformer such as is illustrated in FIG. 3. In this system, two equal capacitors **75** and **77** which are connected in series with battery **51** by leads **79** and **81** are each connected in series with a different circuit. The series circuit for capacitor **75** includes a lead **83** connecting one plate of capacitor **75** to a terminal **85** of a single-pole, double-throw switch which also has another terminal **87** and a movable arm **89** operated by a cam **63**. This series circuit also includes arm **89**, a saturating inductor **91**, and the primary winding **59** of an ignition transformer. The series circuit for capacitor **77** comprises a lead **93**, terminal **87**, arm **89**, inductor **91**, and primary winding **59**. The secondary winding **69** of the ignition transformer is connected by high tension leads **70** to the distributor and spark plugs **71**.

Each time arm **89** makes contact with one of the terminals **85** or **87**, the capacitor **75** or **77**, whose series circuit is then completed, discharges and the other capacitor charges. Since arm **89** alternately moves between terminals **85** and **87**, the total discharge current of each capacitor alternately flows through primary winding **59** producing low voltage pulses therein which are transformed by the high step-up ratio of the ignition transformer into voltage pulses in secondary winding **69** for firing the spark plugs. To be more specific, the high secondary voltage pulses cause the storage of electrostatic energy in the shunt capacitance elements until the pulses reach sufficient magnitude to fire the spark plugs.

Without shields **19** and **45**, very little of the electrostatic energy stored in the secondary winding would be available for firing the spark plugs. But with these shields, substantially all of this energy is used in the firing. Consequently, more firing energy can be obtained in the present ignition system as compared to a conventional system with the same energy drain on battery **51**. Or, the same firing energy can be obtained with much less energy drain and much less current flow between the terminals **85**, **87**, and arm **89**. With less drain on the system, the system components last longer, and in particular, with less current flow between terminals **85**, **87**, and arm **89**, the single-pole, double-throw switch lasts longer.

The saturating inductor **91** delays the increase of current through terminals **85**, **87**, and arm **89** until several microseconds after each contact is made. This allows time for the contact pressure to increase to provide a low contact resistance before high peak currents flow.

In an alternative embodiment, arm **89** may be eliminated and two separate arms connected together at one end and disposed in relation to the cam **63** such that each arm alternately closes its contacts during the middle of the open period of the other arm.

The advantages of my ignition system are best obtained when an ignition coil such as is shown in FIG. 1 is used wherein substantially all of the electrostatic energy stored in the secondary winding is used. However, the utilization of electrostatic shields **19** and **45** with the secondary winding of a conventional configuration improves the availability of the electrostatic energy in the distributed capacitance of the secondary winding to the spark. But not as much of it is available as in the ignition coil of FIG. 1 since the voltage between adjacent layers in a conventionally wound multilayer coil is zero at one end and twice layer voltage (volts per layer) at the other end of adjacent layers. This voltage increase from left to right and right to left between successive layers, forces some of the electrostatic energy to flow through some of the layer turns, thereby introducing a certain amount of series inductance and resistance. However, considerable electrostatic energy is obtained from the electrostatic shields, which, of course, increases the firing energy.

From the above it is seen that an ignition system has been disclosed in which a large amount of electrostatic energy stored in the secondary winding of the ignition coil is made available to the firing system. This is accomplished by placing electrostatic shields on both sides of the secondary winding, which are connected respectively to the high voltage and low voltage turns of this winding. Although a conventionally wound ignition coil may be used, most efficient operation is obtained when an ignition coil of the type disclosed in the above-mentioned application is employed.

While the invention has been described with respect to certain specific embodiments, it will be appreciated that many modifications and changes may be made by those skilled in the art without departing from the spirit of the invention. I intend, therefore, by the appended claims, to cover all such modifications and changes as fall within the true spirit and scope of the invention.

What I claim is:

1. An ignition system comprising an ignition coil including a primary winding and a secondary winding, having inter-turn capacitance, two electrostatic shields respectively positioned on opposite sides of and capacitively interrelated with said secondary winding, leads for connecting the high voltage turn of said secondary winding to one of said shields and the low voltage turn of said secondary winding to the other of said shields, means for interrupting the current flow through said primary winding, and circuit coupling means for completing a secondary circuit to a load including said secondary winding, whereby the energy stored in the inter-turn capacitance of said secondary winding is released to said secondary circuit through said shields when said current is interrupted.

2. The ignition system as defined in claim 1 wherein said secondary winding is in the form of winding layers wound and inter-connected such that when said coil is energized, the voltage distribution between said secondary winding layers is substantially uniform.

3. The ignition system as defined in claim 2 and insulation pads between said secondary winding layers of such thicknesses and dielectric constants that the electrostatic energy stored per unit volume of insulation pads is substantially uniform throughout the coil.

4. An ignition system comprising an ignition coil including a primary winding and a secondary winding with a high voltage terminal, an electrostatic shield around said ignition coil having a capacitive interrelation with said secondary winding, means for interrupting the current flow to said primary winding, and a lead for connecting said electrostatic shield to said high voltage terminal so that a capacitively coupled current flows in said lead when said current is interrupted.

5. A system for energizing a spark plug system comprising an ignition coil including a primary winding and a secondary winding with a high voltage terminal and a low voltage terminal, a first electrostatic shield around said secondary winding, a lead for connecting said high voltage terminal to said first electrostatic shield, a second electrostatic shield on the interior of said secondary winding, a lead for connecting said low voltage terminal to said second electrostatic shield, means for connecting said high voltage and low voltage terminals to the input of said spark plug system, and means for causing an in-

termittent current flow through said primary winding at the ignition rate desired for said spark plug system.

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