Dec. 11, 1951 J. R. MILLER 2,578,145

APPARATUS FOR HANDLING LIQUIDS

Filed Oct. 17, 1946 3 Sheets-Sheet 1

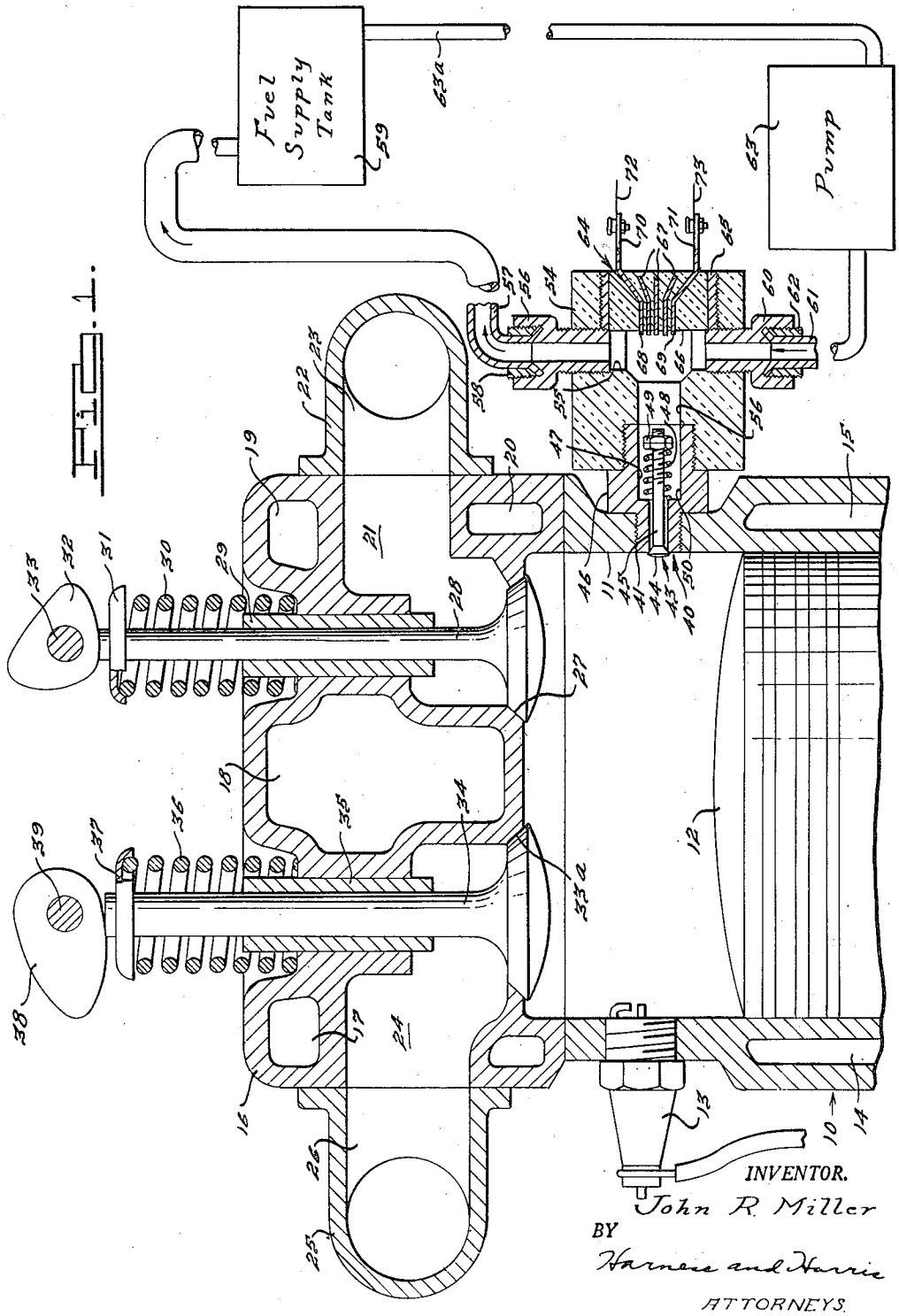


Fig. 1.

INVENTOR.
John R. Miller
BY
Harness and Harris
ATTORNEYS.

Dec. 11, 1951 J. R. MILLER 2,578,145

APPARATUS FOR HANDLING LIQUIDS

Filed Oct. 17, 1946 3 Sheets-Sheet 2

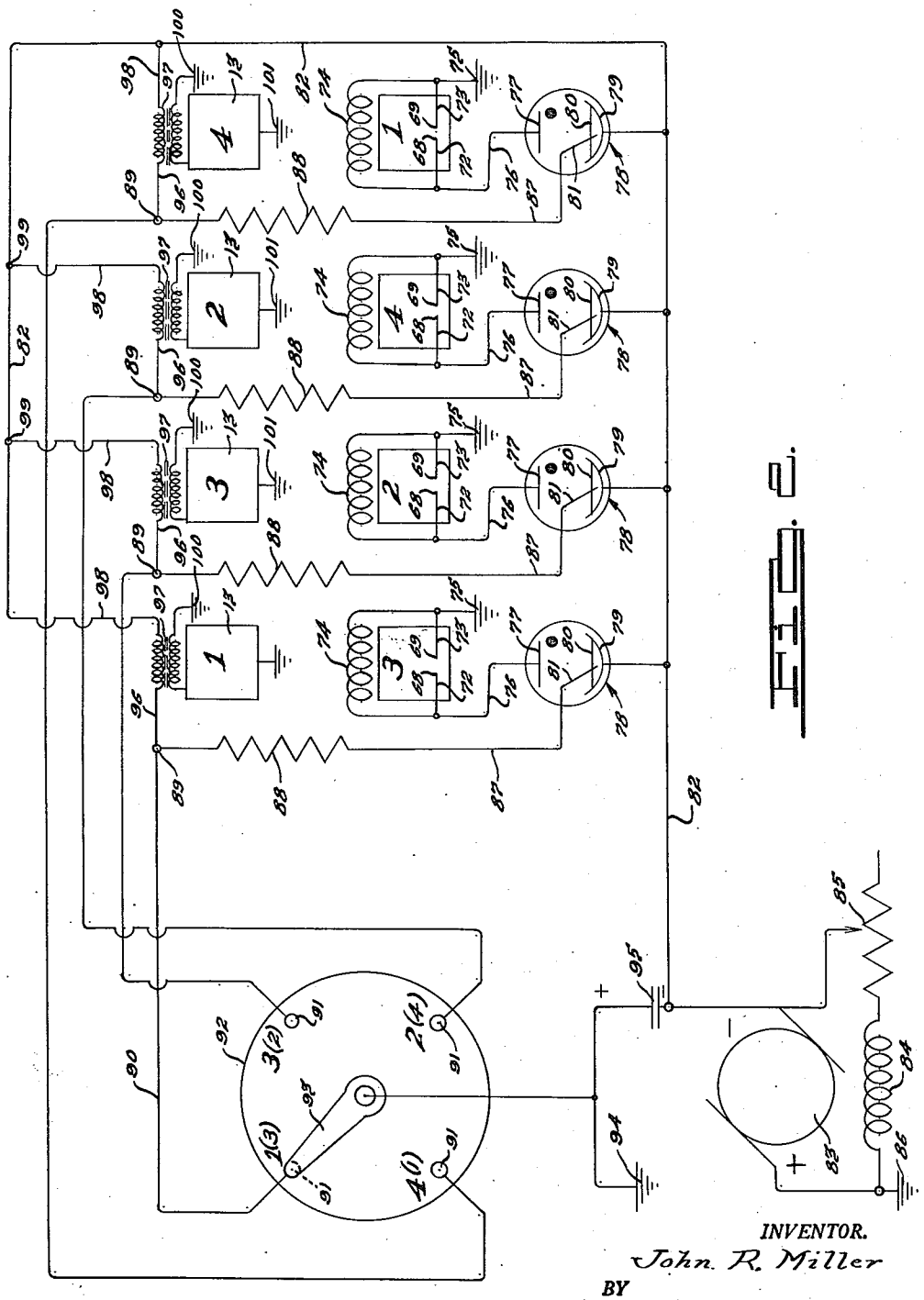


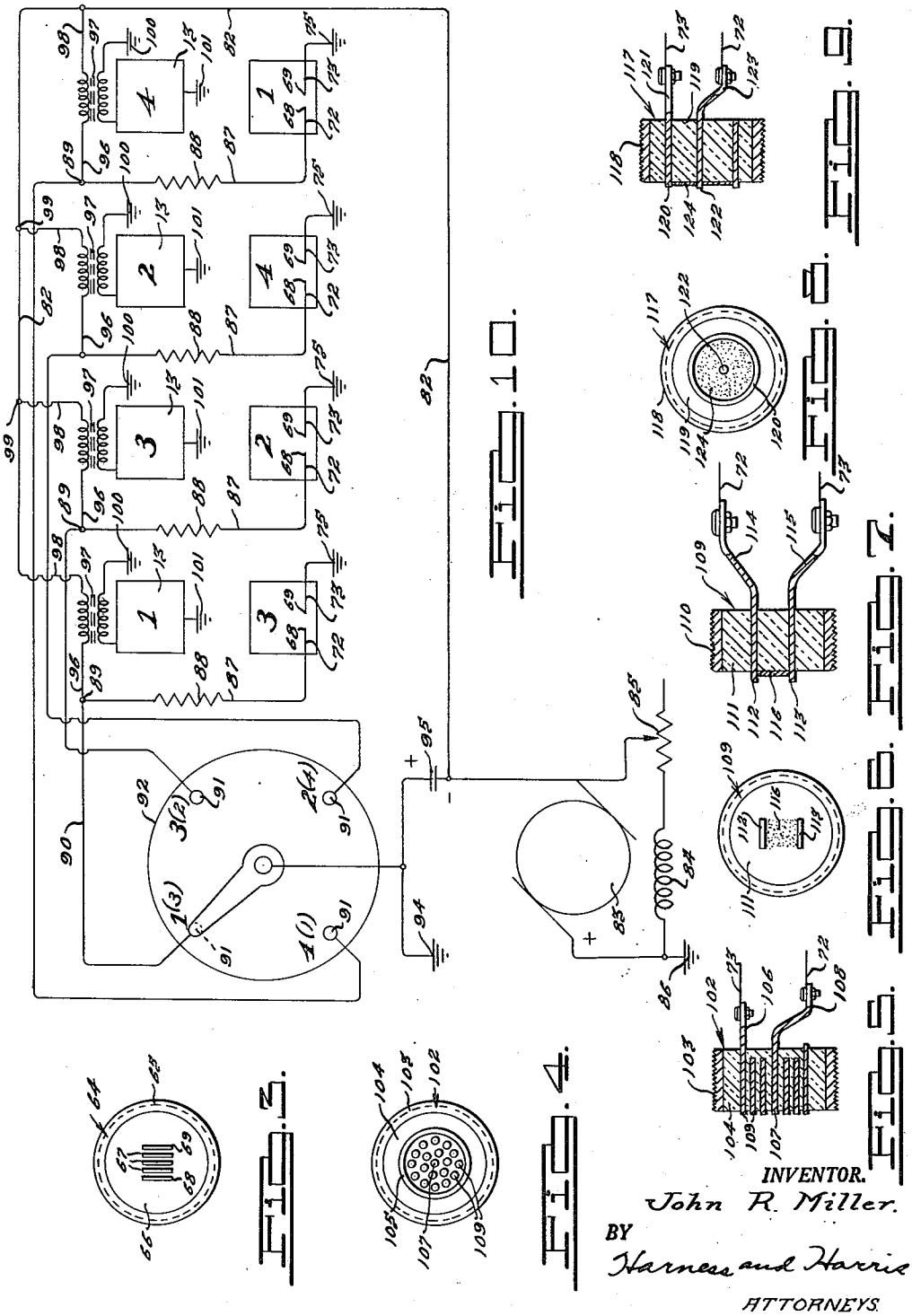
Fig. 1

INVENTOR.
John R. Miller
BY
Harness and Harris
ATTORNEYS

Dec. 11, 1951 J. R. MILLER 2,578,145

APPARATUS FOR HANDLING LIQUIDS

Filed Oct. 17, 1946 3 Sheets-Sheet 3



INVENTOR.
John R. Miller.
BY
Harness and Harris
ATTORNEYS

Patented Dec. 11, 1951

2,578,145

UNITED STATES PATENT OFFICE

2,578,145

APPARATUS FOR HANDLING LIQUIDS

John R. Miller, Royal Oak, Mich., assignor to Chrysler Corporation, Highland Park, Mich., a corporation of Delaware

Application October 17, 1946, Serial No. 703,862

11 Claims. (Cl. 315—11)

1

This invention relates to an apparatus for producing electrical discharges in contained bodies of liquids for the purpose of increasing the pressures within the liquids. More specifically, it relates to the use of such an apparatus for injecting fuel in an engine.

An object of the present invention is to provide improvements in a device for creating an electrical discharge between spaced electrodes in a liquid such as a fuel, whereby the production of the electrical discharge is facilitated. According to the present invention, appropriate means are provided between the electrodes for insuring the creation of an electrical discharge thereacross. The interposed means facilitates the electrical discharge through an initiation procedure involving the creation of minor electrical discharges across the smaller spaces between the electrodes and the interposed means.

A further object is to associate the aforesaid spaced electrodes and interposed means facilitating electrical discharge, with an engine and a valve leading from a passage where the electrodes are positioned, whereby fuel is injected into the engine.

Another object is the use of the aforesaid spaced electrodes and interposed means facilitating electrical discharge, with a system comprising a closed path for fuel and pumping means advancing the fuel about the closed path, whereby the passage containing the electrodes and leading from the path to an engine is appropriately cleansed of any undesirable products of the fuel produced by the electrical discharge such as should not be injected in the engine.

Other objects will appear from the disclosure.

In the drawings:

Fig. 1 is a sectional view through an engine showing the novel fuel injection apparatus of the present invention:

Fig. 2 is a diagrammatic view of parts of the fuel injection apparatus and includes a showing of the electrical system connected therewith;

Fig. 3 is an end view of an electrode unit employed with the apparatus of Fig. 1, the unit being shown in section in Fig. 1;

Figs. 4 and 5 are an end view and a sectional view, respectively, of a first modified form of unit;

Figs. 6 and 7 are an end view and a sectional view, respectively, of a second modified form of unit;

Figs. 8 and 9 are an end view and a sectional view, respectively, of a third modified form of unit; and

2

Fig. 10 shows a modified form of electrical system used with the injection apparatus of the present invention.

As seen in Fig. 1 the engine includes a cylinder block 10 in which is formed a cylinder 11. The piston 12 is slidably mounted in the cylinder 11. A spark plug 13 extends through one side of the cylinder wall. Passages 14 and 15 are formed in the block for circulation of a cooling fluid. A head 16 is suitably attached to the block 10 and has passages 17, 18, 19, and 20 formed therein for circulation of the cooling fluid. An air intake passage 21 is formed in the head 16, and an air intake manifold 22 is attached to the head with the passage 23 formed therein communicating with the passage 21 in the head. An exhaust passage 24 is formed in the head 16, and an exhaust manifold 25 is attached to the head with a passage 26 therein in communication with the passage 24. At the top of the cylinder 11 a seat 27 is formed, which is engaged by an inlet valve 28 opening and closing the air intake passage 21. The inlet valve 28 is slidable in a sleeve 29 suitably mounted in the head 16. A coil spring 30 acting between a recess formed in the top of the head 16 and a collar 31 on the valve 28 acts to maintain the valve against the seat 27. The end of the valve 10 is engaged by a cam 32 secured to a shaft 33. A seat 33a is formed in the end of the exhaust passage 24 adjacent the end of the cylinder 11. An exhaust valve 34 engages the seat and is slidable in a sleeve 35 suitably mounted in the head 16. A coil spring 36 acting between a recess formed in the head 16 and a collar 37 attached to the valve 34 urges the valve 34 against the seat 33a. The end of the stem of the valve 34 is engaged by a cam 38 secured to a shaft 39.

An injection nozzle 40 includes a sleeve 41 having an external thread engaging the wall of the cylinder 10, and a valve 43 having a head 44 engaging the inner end of the sleeve 41 and a stem portion 45. The outer end of the sleeve 41 is enlarged as indicated at 48, and the bore at this portion is enlarged as indicated at 47. A coil spring 48 is held on the valve 45 by means of a pair of nuts 49, the coil spring acting between the nuts and a shoulder 50 formed in the bore in the nozzle sleeve 41. The enlarged portion 46 on the sleeve 41 limits the inward adjustment of the sleeve in the cylinder wall by engaging the cylinder wall. A threaded extension on the nozzle sleeve 41 connects the nozzle sleeve with a fibre block 54. A through passage 55 is formed in the block 54. A side passage 56 is also formed in the block and intersects the through passage 55 at a

central region thereof, the side passage 56 being in communication with the enlarged portion 47 of the nozzle sleeve bore. As will contribute toward the provision of a free discharge passage for block 54, a smooth bore fitting 56 may be threaded straight into the upper end of the through passage 55 and receives the flared end of a tube 57. A fitting 58 clamps the flared end of the tube 57 on the fitting 56. The tube 57 leads, as may be observed, directly and unobstructed to a fuel tank 59. A fitting 60 is threaded in the lower end of the through passage 55 and the flared end of a tube 61 is clamped in the fitting 60 by a fitting 62. The tube 61 extends to the discharge side of a pump 63. A tube 63a extends from the fuel supply tank 58 to the intake side of the pump 63.

An electrical discharge unit 64 is threaded into the block 54 as shown in Fig. 1. Fig. 3 is an end view of the unit. The unit comprises a threaded tubular section 65, by which threaded engagement of the unit 64 with the block 54 is effected. Within the tubular section 65 is a mass of insulating material 66, in which are embedded a plurality of plate-like or strip-like conductive inserts 67 in parallel spaced relation. The inner ends of the inserts 67 project beyond the insulating mass 66, and the outer ends of the two outer inserts 67 are bent so that the spacing between the inserts is increased at this region. A pair of plate-like or strip-like electrodes 68 and 69 are positioned in the insulating mass on the outer sides of the inserts 67 in parallel spaced relation thereto. Portions of the electrodes 68 and 69 near the outer side of the insulating mass 66 are bent so as to diverge and present end connecting portions 70 and 71 in widely spaced relation. These portions 70 and 71 are appropriately connected as shown to conductors 72 and 73.

The electrodes 68 and 69 and the conductors 72 and 73 are shown in a complete electrical circuit for a four-cylinder engine in Fig. 2. There are four sets of electrodes 68 and 69, one for each of the four cylinders. Each set of electrodes is shown within a box designated by an engine-cylinder number. An impedance 74, which may include inductance, is connected across each set of electrodes 68 and 69. Each electrode 73 is connected through the associate conductor 69 with a ground 75. Each electrode 68 is connected by the associated conductor 72 and an electrical connector 76 with an anode 77 of a gas-filled rectifier 78 of the cold-cathode type. Each rectifier has a cathode 79 containing a pool of mercury 80 and an igniter rod 81 dipping into the mercury. Each cathode 79 is connected by a line 82 with the negative side of a D. C. generator 83 having a field 84 controlled by a variable resistance 85. The positive side of the generator is connected to a ground 86. The igniter rod 81 of each rectifier 79 is connected by a line 87 containing an impedance 88 with a connection point 89 from which a line 90 leads to one of a plurality of contacts 91 of a distributor 92 having a rotating arm 93. The distributor arm 93 is connected with a ground 94, and a capacitor 95 is connected between the ground 94 and the negative side of the generator 89.

A line 96 leads from each connection point 89 to the primary side of a powdered iron core transformer 97, which is connected by a line 98 to the line 82 at a connection point 99. The secondary side of the transformer 97 is connected at one end to a ground 100 and at the other end to the spark plug 13 for cylinder No. 1, which is in turn connected to a ground 101.

In Fig. 2 the distributor arm 93 is shown to be passing over the contact 91 for the spark plug 13 of engine cylinder No. 1, and for set of electrodes 68 and 69 associated with the spark plug engine cylinder No. 3 (the next in firing order after cylinder No. 1) which electrodes are connected by the rectifier 78, conductor 87, and impedance 88 with the spark plug 13 for engine cylinder No. 1. At each contact 91 the numeral not in parenthesis indicates the number of the engine cylinder for the spark plug connected with the contact, and the numeral in parenthesis, the number of engine cylinders for the set of electrodes connected with the contact.

At the instant the distributor arm 93 passes over the contact 91, as shown in Fig. 2, a portion of the energy stored in the capacitor 95 is discharged in the spark plug 13 for cylinder No. 1, and current flows through line 87 and from the ignitor rod 81 into the mercury pool 80 causing ionization of the mercury, which results in current flow between anode 77 and cathode 79, which establishes a sufficient difference in potential between electrodes 68 and 69 to cause an electrical discharge therebetween, derived from the balance of the energy stored in the capacitor 95. This electrical discharge acts on the supply of fuel passing continuously from the fuel supply tank 59 through the conduit 63a, the pump 63, the conduit 61, the passage 55 in the fibre block 54, and the conduit 57 back to the fuel supply tank 59. The action of the electrical discharge is, perhaps because of a partial cracking thereof into gaseous or other products, to increase the pressure of the fuel very considerably.

If the coil spring 48 causing the nozzle valve 44 to hold the nozzle sleeve 41 closed is appropriately regulated, the increased pressure, constrained locally by inherent fluid inertia acting on an increment of relatively unresisting fuel will be sufficient to make the nozzle valve open the valve sleeve and discharge fluid through the nozzle into cylinder No. 3. The spacing between the electrode tips 68 and 69 and the rate of discharge across these electrodes as determined by the adjustment of the field resistance 85 determines the amount of fuel discharged, probably by governing the duration of increase in pressure of the liquid fuel or the magnitude of the increase in pressure. The evanescent increase in pressure lasts only long enough for the required injection of fuel through the nozzle 40 into the engine cylinder. A great portion of any gaseous products formed by the electrical discharge are injected into the engine cylinder with great advantage for these gaseous products are very satisfactory as a fuel. The continuous circulation of the fuel from the supply tank through the pump and through the block 54 and back to the supply tank causes any gaseous products not injected into the engine cylinder and solid residue to be carried off through the conduit 57 and thereby scavenges the space between the electrodes for conditioning for the next electrical discharge.

The electrical discharge between the electrodes 68 and 69 is initiated and facilitated by the ends of the members 67 projecting from the mass of insulating material 66 between the projecting ends of electrodes 68 and 69. These are small electrical discharges, for example, from electrode 68 to the adjacent member 67, from one member 67 to another, and finally from the last member

67 to the electrode 69. This small discharge from electrode to member, from member to member, and from member to electrode, make possible the large electrical discharge between electrodes. The members 67 intervening between the electrodes 68 and 69 constitute what may be considered a semi-conducting path between the electrodes.

The impedance of the armature of the generator 63 must be appropriately regulated so as to be high enough to prevent continuous discharge across the electrodes 68 and 69 and low enough for adequate charges of the capacitor 95 between discharges across the electrodes.

The impedance 88 between the igniter rod 81 of the rectifier 78 and the connection point 89 prevents the potential across the spark plug 13 from approaching too low a value during firing of the rectifier 78. Similarly the impedance of the transformer 97 prevents the potential applied across the rectifier 78 from approaching too low a value during firing of the spark plug 13. The impedance 88 should be high enough so as to pass just enough current to cause the igniter rod 81 to make the rectifier 78 conductive. The current flowing through the igniter rod is small in comparison with the current passing between anode 77 and cathode 79.

The purpose of the impedance 74 is to prevent the cathode 79 and anode 77 of the rectifier 73 from approaching the same potential between discharges across the electrode tips 68 and 69 and thus to prevent failure of the rectifier to conduct when fired by the igniter rod 81, because of insufficient difference of potential between anode and cathode. The impedance 74 should conduct as little current as possible during electrical discharge between the electrodes 68 and 69, thus insuring a maximum current flow across the electrode tips during discharge.

Let it be assumed that the engine of which one cylinder and its associated parts are shown in Fig. 1 has four cylinders, and that their firing order is 1—3—2—4 as indicated by the row of spark plugs 13 illustrated diagrammatically in Fig. 3. This firing order for the spark plugs is insured by the distributor 92, the contacts 91 thereof being connected with the appropriate spark plugs. The numeral 1, 2, 3, or 4 associated with each contact 91 and not in parenthesis designates the contact for the spark plug of the cylinder of that numeral, the spark plug itself carrying the same numeral. The numeral 1, 2, 3, or 4 in parenthesis at each contact 91 designates the contact for the set of electrodes 68 and 69 for the cylinder of that numeral, the box surrounding the set of electrodes carrying the same numeral.

As previously stated, spark plug No. 1 is fired at the same time as the electrical discharge is effected in the No. 3 fuel injection discharger. Discharge of the No. 3 apparatus produces injection of fuel in the No. 3 cylinder and thereafter the No. 3 spark plug is fired. At this time, as indicated by Fig. 3, the No. 2 fuel injection discharger is being fired and causes the injection of fuel in No. 2 cylinder. Thereafter the No. 2 spark plug fires and at this time the No. 4 fuel injector operates. Thereafter the No. 4 spark plug fires and at this time the No. 1 fuel injector operates. Then the cycle is repeated. The fuel injection system of the present invention has been shown as applied to an engine of the type in which ignition is effected by spark plugs. The present fuel injection system is of great advantage when employed with spark plug ignition because the electrical systems of the two may be combined and common parts may be used, for example, the distributor and the magneto. However, it is to be understood that a fuel injection system of the present invention is not limited to use with engines having spark plug ignition, but may be just as well applied to engines, for example, of the diesel type having compression-ignition. The invention may also be applied to the injection of fuel in an engine manifold. It is also to be stated at this point that the present invention is not limited in its use to fuel injection for an engine, but is particularly applicable to other installations wherever discharge of a liquid may be employed.

As previously stated, one result of the injection by electrical discharge in a liquid fuel is the cracking of the fuel. If the fuel is gasoline, the gaseous products along with the liquid products are injected in the engine. Both liquid and gaseous products may have higher octane rating, because the residue formed as the result of the cracking is carbon. Thus it is clear that the gasoline resulting from the cracking has had some of its carbon removed and, in effect, its hydrogen increased. This may mean a higher octane rating. With the cracking and injecting of the fuel carried on together, there is no substantial loss of gaseous products normally resulting from cracking.

Figs. 4 and 5 show a modified form of electrical discharge unit 102, comprising a threaded ring 102 containing a mass of insulating material 104. In the insulating mass is positioned an outer electrode 105 in the form of a ring having an extension 106, to which the conductor 73 is connected. In the ring electrode 105 is an inner electrode 107 in the form of a rod having an offset end 108, to which the conductor 72 is connected. A plurality of metallic rod-like members 109 are positioned within the ring electrode 105, being embedded in the insulating mass 104 so as to be insulated from the ring electrode 105, from the central electrode 107, and from one another. The unit 102 may be substituted for the unit 64 so as to have threaded engagement with the block 54, the projecting ends at the left side of unit 102 of Fig. 5 being within the chamber in the block 54 so as to be in the fuel as it flows through the block 54. When sufficient potential is applied across the electrodes 105 and 107 by the conductors 72 and 73, small discharges occur from the inner electrode 107 to adjacent interposed rods 109, then across individual rods 109, and then from the outer rods 109 to the outer rim, electrode 105, thereby initiating a large discharge between electrodes 105 and 107. This latter discharge will act as the discharge previously described as taking place between electrodes 68 and 69 in Fig. 1, to raise the pressure of fuel in the block 54 sufficiently to open the valve 43 and thereby to inject fuel into the engine cylinder.

Figs. 6 and 7 show a modified electrical discharge unit 109, comprising an outer threaded ring 110, a mass of insulating material 111, and two electrodes 112 and 113 having offset ends 114 and 115 to which conductors 72 and 73 are connected, respectively. All these parts are very similar to corresponding parts of the unit 64 of Fig. 3. However, the present unit 109 carries a layer 116 of semi-conducting material affixed to the surface of the mass of insulating material 111 between the projecting ends of the electrodes 112 and 113. The semi-conducting layer 116 may be

formed of a finely divided carbon product embedded in the insulating mass 111 when in a softened condition from heating by a pounding process or the like. Penetration to a mixed layer depth as desired may thus be achieved whereby the working-surface parts can withstand pitting and other evidences of sustained operation without requiring frequent attention or re-surfacing. Within the broader aspects of the invention, the insulating mass 111 may alternatively be a phenolic fibre board and the semi-conducting layer 116 may be formed of an appropriate metal sprayed on the board. In another form, the insulating mass 111 may be quartz, and the semi-conducting layer 116 may be tungsten applied on the quartz in small particles by a so-called evaporation process, involving placing the quartz near a tungsten wire in a high vacuum and applying a high heating current to the tungsten wire. The unit 109 is threaded into the block 54 in place of the unit 64, the projecting ends of the electrodes 112 and 113 and the semi-conducting layer 116 being within the block 54 and in the liquid fuel flowing therethrough.

When an appropriate electric potential is applied across the electrodes 112 and 113 by the conductors 72 and 73, there are small electrical discharges from the electrode 112 to an adjacent point on the semi-conducting layer 116, then from one point on the semi-conducting layer 116 to another and so on, and finally to the other electrode 113. This facilitates the creation of a large electrical discharge between electrodes, which increases the pressure of the liquid fuel in the block 54 sufficiently to open the valve 43 and thereby to inject fuel into the engine cylinder.

Figs. 8 and 9 show a modified electrical discharge unit 117, which represents a combination of the unit 102 of Figs. 4 and 5 and the unit 109 of Figs. 6 and 7. The unit 117 comprises a threaded ring 118, a mass of insulating material 119, an outer ring electrode 120 having an extension 121 to which the conductor 72 is connected, a central rod electrode 122 having an offset end 123 to which the conductor 73 is connected, and a semi-conducting layer 124 applied to the surface of the insulating mass 119 between the projecting ends of the outer ring electrode 120 and the inner rod electrode 122. The semi-conducting layer 124 may be applied to the insulating mass 119 in the same way that the semi-conducting layer 116 of the unit 109 of Figs. 6 and 7 is applied to the insulating mass 111. The unit 117 is adapted to replace the unit 64, the ring 118 having threaded engagement with the block 54, the projecting ends of the electrodes 120 and 122 and the semi-conducting layer 124 being wtihin the block 54 and in the liquid fuel passing therethrough.

When an appropriate electric potential is applied across the electrodes 120 and 122 by the conductors 72 and 73, there are small electrical discharges, for example, from the inner rod electrode 122 to an adjacent point on the semi-conducting layer 124, then across successive points of the semi-conducting layer 124, and finally from an outer point on the layer 124 to the outer ring electrode 120. This action facilitates a large electrical discharge between electrodes 120 and 122, which increases the pressure of the liquid fuel in the block 54 sufficiently to open the valve 43 and thereby to inject fuel into the engine cylinder.

The advantage in the use of outer ring electrodes and inner rod electrodes in the unit 102 of Figs. 4 and 5 and the unit 117 of Figs. 8 and 9 is that, no matter in which direction small discharges start from the inner electrode across the semi-conducting layer 124 or the spaced rod inserts 109, the outer ring electrode will be reached.

Fig. 10 shows an electrical system for use with the sets of electrodes 68 and 69 of Figs. 1, 2, and 3 or the alternative devices of Figs. 4–9, inclusive, which differs from that of Fig. 2 in that the rectifiers 78 of Fig. 2 are eliminated. Thus for each set of electrodes the conductor 72 connected to one electrode is connected directly to the conductor 87, impedance 88, and connection point 89, rather than by way of the rectifier 78. Otherwise, the electrical system of Fig. 10 is the same as that of Fig. 2, as the use of the same numerals to designate like parts indicates.

The intention is to limit the invention only within the scope of the appended claims.

I claim:

1. Apparatus for discharging liquid from a chamber into the combustion chamber of an internal combustion engine, said apparatus including a mass of insulating material forming a wall of the chamber, a plurality of electrodes provided with relatively diverging electrode terminals and having each an end projecting through and held by the insulating mass such as to dip into the liquid in spaced relation to any other electrode end, and conductor means embedded in the mass of insulating material and exposed to the liquid between the electrodes and in spaced relation thereto.

2. Apparatus for discharging liquid from a chamber into the combustion chamber of an internal combustion engine, said apparatus including a mass of insulating material forming a wall of the chamber, a plurality of electrodes provided with relatively diverging electrode terminals and having each an end projecting internally through and held by the insulating mass such as to dip into the liquid in spaced relation to any other electrode end, a condenser having a continuously charging source of electric potential and a switch between the condenser and electrodes closable to apply a difference in potential across the latter, and means for causing the difference in electric potential to create an electrical discharge between the electrodes in the liquid, said last mentioned means comprising a plurality of conductive inserts embedded in the mass of insulative material and exposed to the liquid between the electrodes and in spaced relation to one another and to the electrodes and between them.

3. Apparatus for discharging from a chamber a liquid not readily ionizable into the combustion chamber of an internal combustion engine, said apparatus including a mass of insulating material forming a wall of the chamber, a plurality of electrodes provided with relatively diverging electrode terminals and having each an end projecting internally through and held by the insulating mass such as to dip into the liquid in spaced relation to any other electrode end, a condenser having a continuously charging source of electric potential and an interconnecting switch between the condenser and electrodes closable to apply a difference in potential across the latter, and means for causing the difference in electric potential to create an electrical discharge between the electrodes in the liquid, said last mentioned means comprising a layer of semi-conducting particles impregnated in and below the

face layer of the insulating mass and exposed to the liquid.

4. Apparatus for discharging liquid from a chamber into the combustion chamber of an internal combustion engine, said apparatus including a mass of insulating material forming a wall of the chamber, a plurality of electrodes provided with relatively diverging electrode terminals and having each an end projecting internally through and held by the insulating mass such as to dip into the liquid in spaced relation to any other electrode end, a condenser having a continuously charging source of electric potential and circuit means including a switch between the condenser and electrodes closable to apply a difference in potential across the latter, and means for causing the difference in electric potential to create an electrical discharge between the electrodes in the liquid, said last mentioned means comprising a plurality of conductive plates inserted in the insulating mass and insulated from one another and from the electrodes and protruding therefrom in spaced relation to one another and to the electrodes and between them.

5. Apparatus for discharging liquid from a chamber into the combustion chamber of an internal combustion engine, said apparatus including a mass of insulating material forming a wall of the chamber, a plurality of electrodes provided with relatively diverging electrode terminals and having each an end projecting internally through and held by the insulating mass such as to dip into the liquid in spaced relation to any other electrode end, a condenser having a continuously charging source of electric potential and a connecting switch between the condenser and electrodes closable to apply a difference in potential across the latter, and means for causing the difference in electric potential to create an electrical discharge between the electrodes in the liquid, said last mentioned means comprising a plurality of parallel rod-like conductors interposed substantially coextensively between the electrodes in spaced relation to one another and to the electrodes, said conductors having each a substantial portion thereof insulated mutually and from said electrodes, and a minor portion thereof exposed mutually and to said electrodes, the minor portions aforesaid dipping into the liquid in the manner of said electrode ends.

6. Apparatus for discharging from a chamber a liquid not readily ionizable including, in combination, an electrical discharge unit comprising a mass of insulating material forming a wall of the chamber, a pair of electrodes provided with diverging energizing terminals and spaced parallel plate portions generally embedded in the mass of insulating material and each having an end emerging from the insulating material and dipping into the liquid in spaced relation to the end of any other parallel plate portion, a condenser having a constantly charging source of electric potential for the electrode terminals and having a switch in series therebetween closable to make available a difference in electrical potential from the source across the electrodes, and semi-conducting means of a substance containing randomly spaced crystalline particles generally embedded in the insulating mass and being partially exposed at the surface thereof to the liquid between ends of the parallel plate portions of the electrodes, for causing the difference in electric potential to create an electrical discharge in the liquid between the electrodes through a series of electrical discharges taking place between each electrode and the semi-conducting means and between points representing crystalline particles of the semi-conducting means spaced apart less than the electrodes.

7. Apparatus for discharging liquid from a chamber, including an electrical discharge unit comprising a mass of insulating material forming a wall of the chamber, an inner electrode having an energizing terminal and an end extending through the mass of insulating material and dipping into the liquid, an outer electrode surrounding the inner electrode and having an energizing terminal at relatively divergent angles to the first energizing terminal and an end extending through the mass of insulating material and dipping into the liquid in spaced parallel relation to the inner electrode end, a condenser having a source of electrode potential under constant charge and having a switch in series therewith closable to subject the electrodes to a potential difference, and conductive means at least partially embedded in said mass of insulating material in surrounding relation to the inner electrode and in surrounded relation by the outer electrode, said conductive means being exposed to the liquid and to the electrodes and defining conducting points intermediate the electrode ends for causing the difference in electric potential to create an electrical discharge between the electrodes through a series of electrical discharges taking place between each electrode and said interposed means, and between conducting points of said interposed means spaced apart less than the electrodes.

8. Apparatus for discharging liquid from a chamber, comprising a mass of insulating material forming a wall of the chamber, a first electrode having an energizing terminal and an end extending through the mass of insulating material and dipping into the liquid, a second electrode having an energizing terminal at relatively divergent angles to the first energizing terminal and an end extending through the mass of insulating material and dipping into the liquid in spaced parallel relation to the first electrode end, a condenser under constant charge and having a switch in series therewith closable to subject the electrodes to a potential difference, and a plurality of parallel plate conductive means at least partially embedded in said mass of insulating material, said parallel plate conductive means having ends exposed to the liquid and to the electrodes and defining transverse conducting strips intermediate the electrode ends for causing the difference in electric potential to create an electrical discharge between the electrodes through a series of electrical discharges taking place between each electrode and the strips formed by said interposed means, and between conducting strips of said interposed means spaced apart less than the electrodes.

9. Apparatus for discharging from a chamber a liquid not readily ionizable including, in combination, a mass of insulating material forming a wall of the chamber, a pair of electrodes provided with diverging energizing terminals and spaced parallel plate portions generally embedded in the mass of insulating material and each having an end emerging from the insulating material and dipping into the liquid in spaced relation to the end of any other parallel plate portion, a condenser having a constantly charging source of electric potential for the electrode terminals and having a switch in series therebetween closable to make available a difference in electrical potential from the source across the

electrodes, and a plurality of intervening conductor elements in the mass between the electrodes comprising spaced parallel plate portions extending coextensively with the electrode parallel plate portions and having each an end emerging from the mass dipping into the liquid, for causing the difference in electric potential to create an electrical discharge in the liquid between electrodes through a series of electrical discharges taking place between each electrode and the intervening elements and between the intervening elements spaced apart less than the electrodes.

10. In a device of the character described, a spark discharge unit comprising a chamber-wall forming portion of insulating material adapted to be impervious to and confine liquid at one side thereof, a set of strip-like main electrodes provided with relatively diverging electrode terminals and each having a substantial portion thereof projecting internally through and held by the insulating material so as to protrude in part from the said one side thereof and dip into the liquid, the electrodes being in parallel spaced relation within the material to one another at all points and being energizable to different electrical potentials, and means for causing the difference of electric potential to create an electrical discharge between the electrodes in the liquid, the just-named means comprising a plurality of metallic plates embedded in the insulating material in parallel spaced relation to one another and to each main electrode and having a minor portion thereof protruding from said one side of the material so as to dip into the liquid in the manner of the main electrodes.

11. In a device of the character described, a spark discharge unit comprising a chamber-wall forming portion of insulating material adapted to be impervious to and confine a contained liquid at one side thereof, a concentric set of main electrodes provided with relatively diverging electrode terminals and each having a substantial portion thereof projecting internally through and held by the insulating material so as to protrude in part from the said one side thereof and dip into the liquid, the electrodes being in parallel spaced relation within the material to one another at all points and being energizable to different electrical potentials, and means for causing the difference in electric potential to create an electrical discharge between the electrodes in the liquid, the just-named means comprising a plurality of metallic rods embedded in the insulating material in parallel spaced relation to one another and to each main electrode and having a minor portion thereof protruding from said one side of the material so as to dip into the liquid in the manner of the main electrodes.

JOHN R. MILLER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,333,612	Fisher	Mar. 16, 1920
2,436,090	Bodine	Feb. 17, 1948