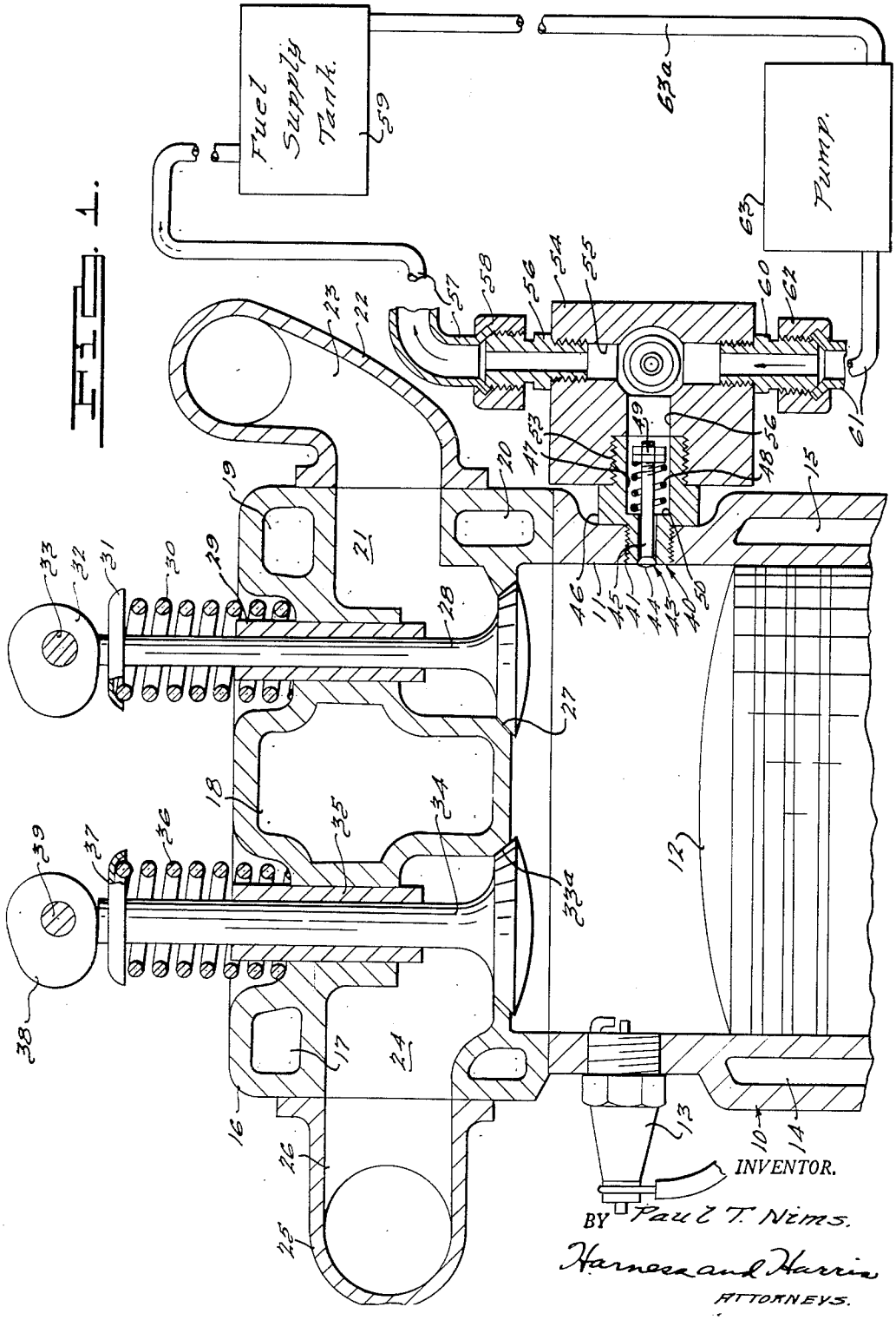
Nov. 4, 1952 P. T. NIMS 2,617,080

APPARATUS FOR HANDLING LIQUID

Filed July 11, 1946 3 Sheets-Sheet 1

Fig. 1.



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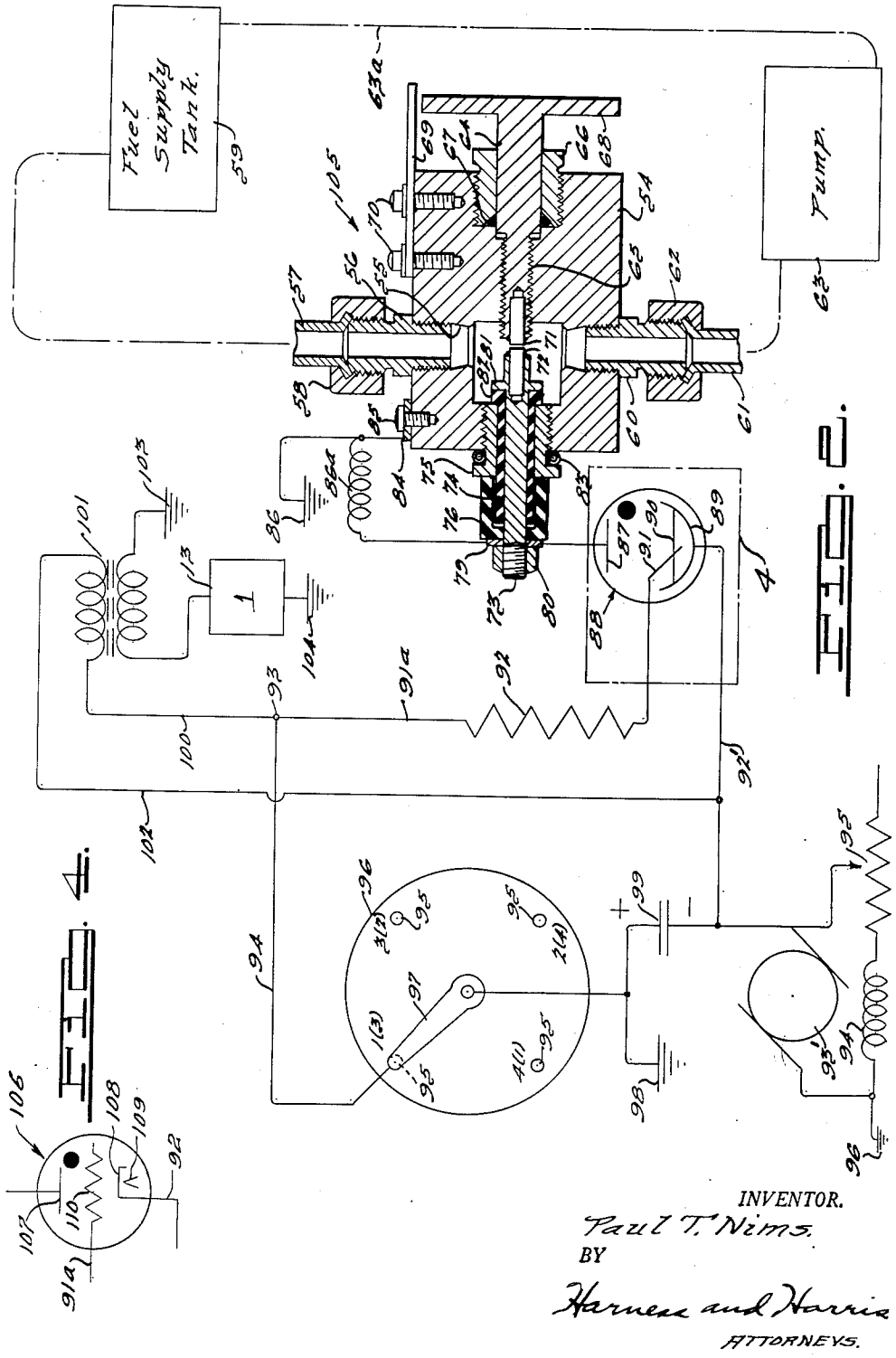
Filed July 11, 1946 3 Sheets-Sheet 2



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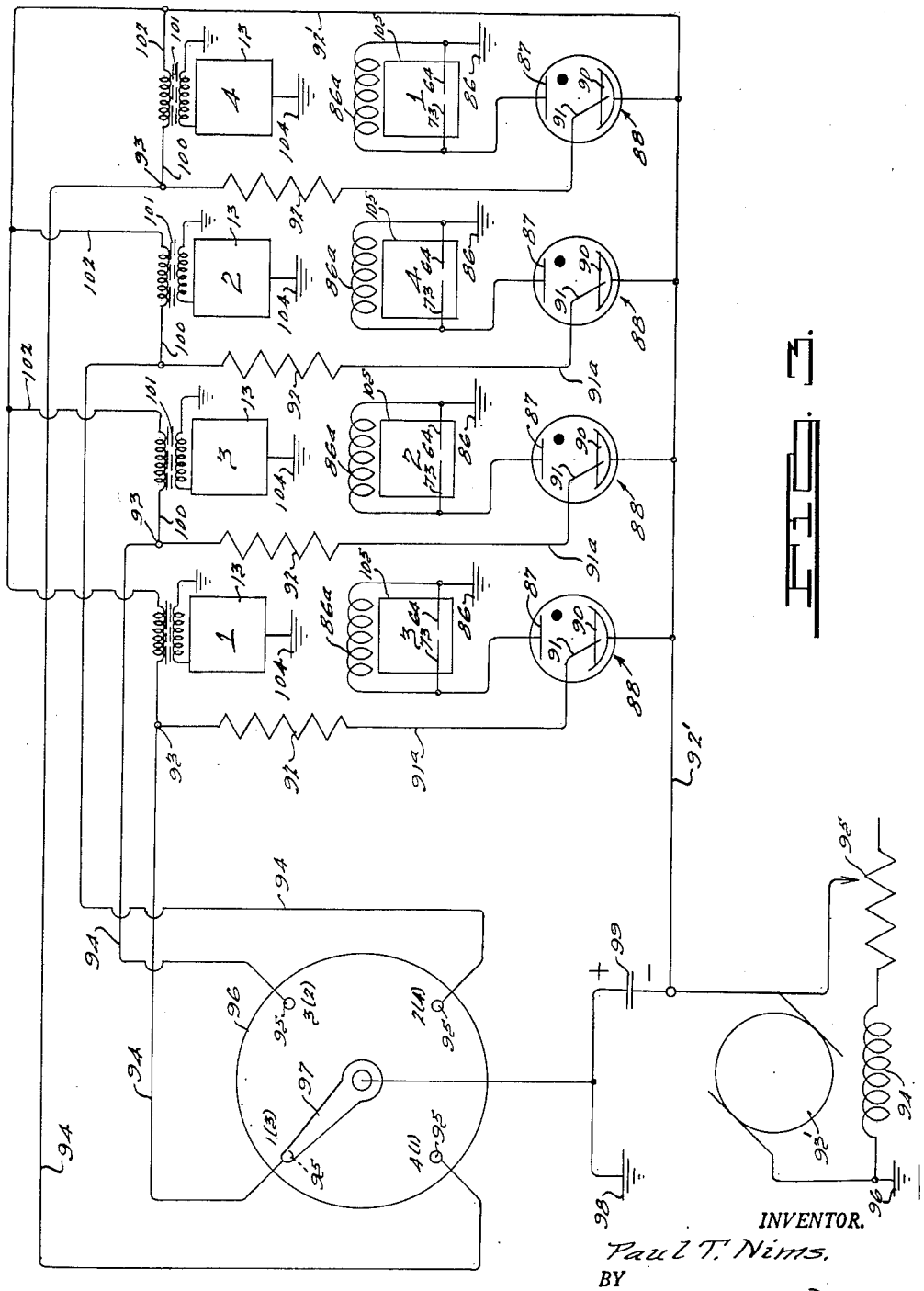

Fig. 7

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APPARATUS FOR HANDLING LIQUID

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Application July 11, 1946, Serial No. 682,953

8 Claims. (Cl. 315—180)

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This invention relates to an apparatus for producing electrical discharges in liquids for the purpose of increasing their pressures. 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 in liquid such as fuel and more particularly in a device employing two electrodes for the electrical discharge. The use of two electrodes has the advantage of simplicity.

A further object is the provision of a novel arrangement of switching means and an electrode system for creating spark discharge in liquid. This novel arrangement is of special advantage when the electrode system is of the two electrode type, for with two electrodes the current capacity of the switching means must be very high.

Another object of the invention is to provide improvements in a system for injection of fuel in an engine by spark discharge in the liquid fuel and the interconnection of such a system with the ignition system for 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 sectional view through a portion of the injection apparatus and includes the electrical circuit connected therewith;

Fig. 3 is a diagrammatic view of parts of the fuel injection apparatus and includes a showing of the electrical system connected therewith; and

Fig. 4 is a partial view of a modified form of the invention, which is completely illustrated by the substitution of the parts shown in Fig. 4 for the parts within the dash-dot rectangle in Fig. 2 designated by the reference character 4.

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

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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 33^a 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 33^a. 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 46, and the bore at this portion is enlarged as indicated at 47. A coil spring 48 is held on the valve 43 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 53 on the nozzle sleeve 41 connects the nozzle sleeve with a metallic 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 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 63^a extends from the fuel supply tank 59 to the inside of the pump 63.

As seen in Fig. 2, an electrode 64 is threaded in the metallic block 54 as indicated at 65 for longitudinal adjustment into and out of the metallic block. A locking nut 66 threaded in the metallic block 54 fixes the electrode 64 in any desired position. A gasket 67 between a conical end face of the nut 66, the block 54, and the electrode 64 provides a seal. The electrode 64 has an enlarged end 68 facilitating adjustment of the electrode. The enlarged end may carry indicia, not shown, the position of which with respect to a strip 69 fastened by screws 70 to the metallic block 54 indicate the longitudinal position of the electrode 64 with respect to the block 54. The electrode 64 is provided at its inner end with a tip 71 preferably formed of refractory material, for example tungsten, and inserted in the electrode 64 and welded, brazed, or soldered thereto. An electrode tip 72 similar to the tip 71 is in directly opposed, facing, and closely spaced relation to the tip 71 and is brazed, soldered, or welded in the inner end of an electrode 73. The electrode 73 is surrounded by an insulating sleeve 74 in turn surrounded by a fitting 75 threaded in the metallic block 54. An insulating member 76 has a base embracing the outer end of the electrode 73 and surrounds the insulating sleeve 74 and abuts the fitting 75. There is clearance between the left end of the member 74 and the inner side of the base of the member 76.

An electrical connector 79 closely fits the outer end of the electrode 73 and is clamped between the base of the insulating member 76 and a retaining nut 80 threaded on the outer end of the electrode 73. The inner ends of the electrode 73 and the insulating sleeve 74 have flanges 81 and 82, respectively. The flange 82 on the insulating sleeve 74 is clamped between the electrode flange 81 and the fitting 75, pressure being applied to the fitting 75 by the insulating member 76 and the nut 80. This is the only stress to which the sleeve 74 is subjected. A seal 83 is clamped between the fitting 75 and the outer side of the metallic block 54.

An electrical connector 84 secured to the metallic block 54 by a screw 85 is connected to a ground 86 and thereby grounds the metallic block 54 and the electrode 64. An impedance 86a, which may include inductance, is connected between the electrodes 64 and 75. The electrode 73 is connected by the electrical connector 79 with an anode 87 of a gas-filled rectifier 88 of the cold-cathode type. This rectifier has a cathode 89 containing a pool of mercury 90 and an igniter rod 91 dipping into the mercury. The cathode 89 is connected by a line 92' with the negative side of a D. C. generator 93' having a field 94 controlled by a variable resistance 95. The positive side of the generator is connected to the ground 96. The igniter rod 91 of the rectifier 88 is connected by a line 91a containing an impedance 92 with a connection point 93 from which a line 94 leads to one of a plurality of contacts 95 of a distributor 96 having a rotating arm 97. The distributor arm 97 is connected with a ground 98, and a capacitor 99 is connected between the ground 98 and the negative side of the generator 93'.

A line 100 leads to the primary side of a powdered iron core transformer 101, which is connected by a line 102 to the line 92'. The secondary side of the transformer 101 is connected at one end to a ground 103 and at the other end to the spark plug 13 for cylinder No. 1, which is in turn connected to a ground 104.

The metallic block 54 and the electrodes 64 and 73 mounted therein and associated parts will be hereafter referred to as an electrode device 105. In Fig. 2 the distributor arm 97 is shown to be passing over the contact 95 for the spark plug 13 of engine cylinder No. 1. This is shown by the reference character 1 adjacent the upper left hand contact 95. The electrode device 105 shown in Fig. 2 is the one associated with engine cylinder No. 3 (the next in firing order after cylinder No. 1), and this is indicated by the reference character 3 in parentheses adjacent the upper left hand contact 95.

At the instant the distributor arm 97 passes over the contact 95, as shown in Fig. 2, a portion of the energy stored in the capacitor 99 is discharged in the spark plug 13 for cylinder No. 1, and in addition produces a current flow through line 91a and from the igniter rod 91 into the mercury pool, causing ionization of the mercury, which results in current flow between the plate 87 and cathode 89, which establishes a sufficient difference in potential between electrode tips 71 and 72 to cause an electrical discharge therebetween, derived from the balance of the energy stored in the capacitor 99. 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 metallic 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 close the inner end of the bore 50 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 71 and 72 and the rate of discharge across these electrodes as determined by the adjustment of the field resistance 95 determines the amount of fuel discharged, probably by governing the evanescent duration of increase in pressure of the liquid fuel or the magnitude of the increase in pressure. The 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 impedance of the armature of the generator 93' must be appropriately regulated so as to be high enough to prevent continuous discharge across the electrode tips 71 and 72 and low enough for adequate charges of the capacitor 99 between discharges across the electrodes.

The impedance 92 between the igniter rod 91 of the rectifier 88 and the connection point 93

prevents the potential across the spark plug 13 from approaching too low a value during firing of the rectifier 88. Similarly the impedance of the transformer 101 prevents the potential applied across the rectifier 88 from approaching too low a value during firing of the spark plug 13. The impedance 92 should be high enough so as to pass just enough current to cause the igniter rod 91 to make the rectifier 88 conductive. The current flowing through the igniter rod is small in comparison with the current passing between anode 87 and cathode 89.

The purpose of the impedance 86a is to prevent the cathode 89 and anode 87 of the rectifier 88 from approaching the same potential between discharges across the electrode tips 71 and 72 and thus to prevent failure of the rectifier to conduct when fired by the igniter rod 91, because of insufficient difference of potential between anode and cathode. The impedance 86a should conduct as little current as possible during electrical discharge between the electrode tips 71 and 72, 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 96, the contacts 95 thereof being connected with the appropriate spark plugs. The numeral 1, 2, 3, or 4 associated with each contact 95 and not in parenthesis is the contact for the spark plug designated by the numeral. The numerals in parenthesis at the contacts 95 designate the structures shown in detail in Fig. 2 and associated with the various cylinders.

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 in 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.

Fig. 4 illustrates a gas-filled rectifier 106 of the hot cathode type, which may be substituted for the rectifier 88. The various parts of Fig. 4 are substituted directly for the dash-dot rectangle 4 of Fig. 2 surrounding the rectifier 88. The rectifier 106 comprises an anode 107 adapted to be connected to the electrical connector 79 in the manner of the anode 87 in Fig. 2, a cathode 108 connected to the line 92', a heating element 109 for the cathode 108 adapted to be separately electrically energized, and a grid 110 connected through the line 91a and the impedance 92 with the connection point 93 in the manner of the igniter rod 91 in Fig. 2.

The rectifier 106 functions in the manner of the rectifier 88. At the instant the distributor arm 97 passes over the contact 95, as shown in Fig. 2, a portion of the energy stored in the capacitor 99 is discharged in the spark plug for cylinder No. 1, and the grid 110 of the rectifier 106, which was previously of the same potential as that of the cathode 108, is made positive, thereby causing electrons to flow between said cathode 108 and anode 107. Thus a sufficient difference in potential is established between electrode tips 71 and 72 to cause an electrical discharge therebetween. This results in an increase in pressure on the fuel into which the electrode tips 71 and 72 project and a consequent injection of fuel into the engine cylinder, all as previously described.

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

I claim:

1. An electrode device including a metallic block having a space within the central portion and an opening extending from the outside of the block to the space therein, a first electrode mounted in the block in conducting relation thereto and projecting into the space at the side thereof opposite the opening and a second electrode assembly comprising a pipe fitting threadedly extending through the opening, an insulating sleeve positioned in the fitting and having an outwardly extending flange at one end within the space in the block, a second electrode positioned in the insulating sleeve and having an inner end in the space in the block in operative proximity to the first electrode, a flange engaging the flange on the insulating sleeve, both of said flanges being of a limited girth adapted to clear said opening in transit therethrough and an outer threaded end projecting outwardly of the block beyond the fitting and the insulating sleeve, an insulating cup having an opening in its base receiving the outer end of the second electrode and a wall portion surrounding the insulating sleeve and engaging the fitting, and a nut on the outer end of the second electrode and backed against the insulating cup and in turn against the fitting for clamping the insulating sleeve flange between the second electrode flange and the fitting, the balance of the insulating sleeve being free of lengthwise pressure

because of clearance between the outer end of the insulating sleeve and the base of the insulating cup, the component parts of said second electrode assembly being cooperatively adapted to be unsecrewed and replaced in said block as a unit.

2. Apparatus for periodically increasing pressure in a container of fluid comprising in combination, spaced electrodes projecting into the container, a switch connected in series with the electrodes, a capacitor connected in parallel with the electrodes and the switch, a continuously charging source of D. C. electric power adapted to be connected with the electrodes through the switch and having an impedance sufficiently high to prevent continuous discharge across the electrodes and sufficiently low for continuous adequate charging of the capacitor between discharges across the electrodes, and electrical means connected in parallel with the electrodes and the switch for periodically closing the switch.

3. Apparatus for periodically increasing pressure in a container of fluid comprising in combination, spaced electrodes projecting into the container, a switch connected in series with the electrodes and comprising a gas-filled rectifier having a mercury-containing cathode and an igniter rod dipping in the mercury, a capacitor connected in parallel with the electrodes and the switch, a continuously charging source of D. C. electric power adapted to be connected with the electrodes through the switch and having an impedance sufficiently high to prevent continuous discharge across the electrodes and sufficiently low for continuous adequate charging of the capacitor, and means for periodically connecting the igniter rod with the source of power to condition the mercury contained in the cathode for rendering the rectifier conductive periodically to connect the source of power with the electrodes.

4. An electrode device including a metallic block having a space within the central portion and an opening extending from the outside of the block to the space therein, a first electrode threadably mounted in the block in conducting relation thereto and positionably projecting into the space at one side thereof opposite the opening, indicating means mounted exteriorly of the block for determining the extent of penetration of said positionable electrode, and a second electrode assembly comprising a metal fitting threadably extending through the opening, an insulating sleeve positioned in the fitting and having a portion within the space engaging the fitting, a second electrode positioned in the insulating sleeve and having an inner end portion in operative proximity to the positionable first electrode and engaging said sleeve portion, and an outer threaded end projecting outwardly of the block beyond the fitting and the insulating sleeve, an insulating cup having an opening in its base receiving the outer end of the second electrode and a wall portion surrounding the insulating sleeve and engaging the fitting, and a nut on the outer end of the second electrode and backed against the insulating cup and in turn against the fitting for clamping the insulating sleeve portion between the engaging inner end portion of the second electrode and the fitting, the balance of the insulating sleeve being free of lengthwise pressure because of clearance between the outer end of the insulating sleeve and the base of the insulating cup, said opening being of a size to exceed the transverse extent of said portions thereby affording unobstructed passage for the second electrode assembly as a unit.

5. Apparatus for discharging fluid from a chamber comprising a pair of electrodes extending into said chamber, and means including an electric valve connecting the electrodes with a source of power, said electric valve comprising spaced elements of relatively large current carrying capacity, and an intervening igniter element having circuit means including a mechanically recurrently actuated switch for connecting the intervening igniter element and power source to condition the space between the spaced elements for the flow of current therebetween for applying an electric potential derived from the source of power across the electrodes to create a relatively large energy discharge thereacross, said circuit means including an impedance limiting the current through the intervening element and switch to a relatively low value.

6. Apparatus for discharging fluid from a chamber comprising a pair of electrodes extending into said chamber, means including an electric valve connecting the electrodes with a source of power, said electric valve comprising spaced elements and an intervening igniter element, means including a current limiting impedance for connecting the power source and intervening igniter element to condition the space between the spaced elements for the flow of current therebetween for applying an electric potential derived from the source of power across the electrodes to create an electric discharge thereacross, and an inductive impedance connected in parallel with the electrodes for preventing the spaced elements of the electric valve from approaching the same potential prior to the time for discharge across the electrodes.

7. Apparatus for discharging fluid from a chamber comprising a set of spaced electrodes projecting into the chamber, a mercury type rectifier providing an anode-cathode path of large current-carrying capacity in series with spaced electrodes of the electrode set and including a mercury-containing cathode and an igniter rod associated with the mercury, a capacitor in parallel with the mercury type rectifier and electrodes aforesaid and a continuously charging source of A. C. electric power adapted to be connected with the electrodes through the mercury type rectifier, said source of power having an impedance sufficiently high to prevent continuous discharge across the electrodes and sufficiently low for continuous adequate charging of the capacitor, said igniter rod having circuit means including a recurrently-closing switch for intermittently connecting the source of power and igniter rod to condition the mercury contained in the cathode for rendering the rectifier conductive to apply an electric potential across the electrodes for obtaining a discharge thereacross through the fluid.

8. Apparatus for discharging fluid from a chamber comprising a set of spaced electrodes projecting into the chamber, a mercury type rectifier providing an anode-cathode of large current-carrying capacity in series with spaced electrodes of the electrode set and including a mercury-containing cathode and an igniter rod associated with the mercury, a capacitor in parallel with the rectifier and electrodes aforesaid, and a continuously charging source of D. C. electric power adapted to be connected with the electrodes through the rectifier and having an impedance sufficiently high to prevent continuous

discharge across the electrodes and sufficiently low for continuous adequate charging of the capacitor, said igniter rod having circuit means including a recurrently-closing switch for intermittently connecting the source of power and igniter rod to condition the mercury contained in the cathode for rendering the rectifier conductive to apply an electric potential across the electrodes for obtaining intermittent discharges thereacross through the fluid, said circuit means further including an impedance for limiting to a relatively low value the magnitude of energy transmitted through said igniter rod and switch.

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