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METHOD AND APPARATUS FOR INJECTION OF LIQUID FUELS

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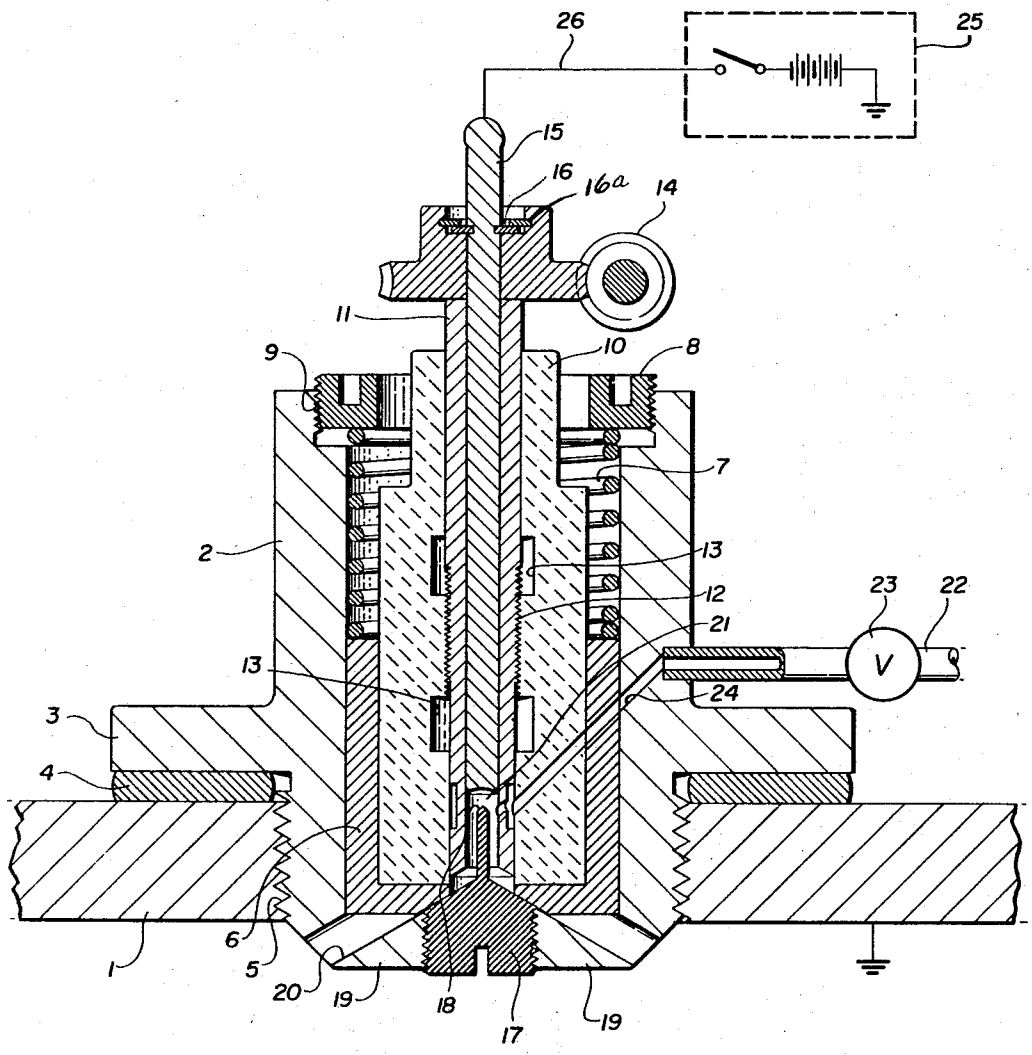

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METHOD AND APPARATUS FOR INJECTION OF LIQUID FUELS

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ABSTRACT OF THE DISCLOSURE

This is an apparatus and method for atomizing and vaporizing liquids by use of an electric arc discharge or plasma within the liquid to be vaporized. It is especially adapted for use in connection with hydrocarbon and similar liquid fuels for use in internal combustion engines. Essentially it involves introduction of a suitable hydrocarbon fuel into a confined chamber and there subjecting it to an arc discharge or plasma. The extreme pressures thus produced are utilized to eject the fuel through suitable nozzles, thus producing an extremely fine degree of atomization. This process further produces high temperatures which vaporize part of the fuel and thus render it ready for immediate combustion. An additional phenomenon resulting is that of "voltolysis" which comprises a decomposition or dissociation of the fuels into basic elements or compounds such as hydrogen and various hydrocarbon radicals.

This invention relates to the atomization and vaporization of liquids by use of an electric arc discharge or plasma. More particularly it relates to the conditioning of hydrocarbon liquids and their injection into an internal combustion engine for propulsion purposes, although it is not limited to the latter application.

Present methods of introducing hydrocarbon fuels into a burner or engine when the fuel is initially in a liquid state is attended by many problems. Usually a high pressure is required to force the liquid fuel into the conditioning apparatus and consequently the pumping problems are considerable. A suitable apparatus for conditioning the fuel, be it through atomization or vaporization, presents a number of difficult problems. A great number of nozzles, carburetors and related devices have been made to perform this operation but the are all accompanied by many disadvantages. One of the greatest of these is that existing devices are all quite inflexible and require frequent adjustment and replacement with changes in fuel and operating conditions. It is, moreover, exceedingly difficult to obtain a fine degree of atomization, such as that required for efficient combustion without resorting to extremely high pressures and very complicated nozzle mechanisms, the latter being subject to frequent clogging, etc.

Attempts have been made to overcome the foregoing objections by utilization of an auxiliary atomizing fluid such as steam or air. In addition to being quite cumbersome and expensive to operate, such systems have a definite tendency to decrease the overall efficiency of the process, both thermodynamically and mechanically.

Another very troublesome phenomenon associated with all existing forms of solid fuel injection is what is known to those skilled in the art as "ignition lag." The latter may be defined as the time of injection of the fuel and the time when the fuel starts burning. In a high speed engine this lag must be overcome by a complicated design of combustion chamber which increases the cost of the engine and reduces its efficiency.

A primary object of my invention is therefore to provide a method and apparatus for efficiently and economically conditioning hydrocarbon fuels for most efficient combustion.

Another object of my invention is to provide a method and apparatus for atomizing hydrocarbon fuels which would be more efficient and economical to operate than those now in use.

A still further object of my invention is to provide a method and apparatus which will simultaneously atomize and vaporize hydrocarbon fuels and overcome the problem of "ignition lag."

A more specific object of my invention is to provide a method and apparatus which utilizes a high voltage arc discharge or plasma upon a hydrocarbon fuel in a manner to produce unusually effective and efficient atomization and vaporization.

These and other objects will become apparent to those skilled in the art from the specification, drawings, and the claims which follow.

I have discovered that if a suitable hydrocarbon fuel is introduced into a confined chamber and there subjected to an arc discharge or plasma, the extreme pressures which are produced may be utilized to eject the fuel through suitable nozzles, producing an extremely fine degree of atomization. I have discovered further that the action on the fluid as described above produces high temperatures which vaporize part of the fuel and thus are ready for immediate combustion.

I have discovered still further that passage of an arc in the manner described above causes decomposition or dissociation of the hydrocarbon fuels into basic elements or compounds, such as H_2, CH_4, C_2H_2, etc.

This phenomenon is what has sometimes been described as "voltolysis" by those skilled in the art. (See "Voltolysis of Hexane in the Liquid Phase," A. Maillard—Bulletin Soc. Chem., France, 1963, "Arc Action on Some Liquid Insulating Compounds"; C. J. Rodman, Trans. Am. Electrochem. Soc., 1922.) Its effect, together with the vaporization effect described above eliminates the problem of "ignition lag" and will permit combustion to start at once upon injection even at low temperatures existing in the combustion chamber. The latter eliminates the use of elaborate combustion chambers and permits attainment of high efficiency at low compression ratio. I have discovered this to be especially advantageous in connection with the starting up of solid fuel injection engines.

References should now be had to the drawing which represents a preferred embodiment of my invention shown in longitudinal section as applied to the cylinder head of an internal combustion engine.

A part of a cylinder head is shown at 1 into which is inserted the main body of my device 2. In this embodiment my device is equipped with a flange section 3 which makes tight contact against the cylinder head 1 through gasket 4 by means of a screwed section 5. These parts may be made from steel, cast iron, or other materials known to those skilled in the art.

The interior of the body of my device 2 is equipped with a hollow cylindrical section as shown. A cup shaped cylindrical bushing 6 which may also be of steel or cast iron is slideably positioned inside the cylindrical opening in 2. A helical spring 7 is positioned above and in contact with the top edge of bushing 6. A spring tension adjusting screw 8, having a screwed portion 9 engages with the body 2 and provides means for adjusting the tension on spring 7.

An external insulating bushing 10 is tightly positioned inside of cup shaped bushing 6 and may be constrained against relative movement in bushing 6 by any convenient manner not shown. Bushing 10 may be made of any electrical insulating material capable of being machined or have threads otherwise formed therein, such as hard rubber, "Pyroceram," etc. Internal insulating bushing 11 is positioned inside external insulating bushing 10 and engages with the latter through a threaded or screwed sec-

tion 12. The fit between the cylindrical portions of bushings 10 and 11 is such as to permit relative motion between the bushings when bushing 11 is turned. Recessed portions 13 provide suitable clearance required for mechanical and fabricating reasons as is known to those skilled in the art. Bushing 11 is likewise made from any well known electrical resisting material which has sufficiently strong mechanical properties. A worm and wheel mechanism 14 has its wheel fixedly positioned on bushing 11 so that turning of the worm causes bushing 11 to revolve and move either upwards or downwards in relation to bushing 10.

An upper electrode 15 which is an electrical conductor fabricated from any conducting material such as copper is slideably inserted into bushing 11. Electrode 15 may employ a thrust washer 16 with thrust collars 16*a*, the former being fixedly positioned on electrode 15 and the latter being fixedly positioned on the face of the worm wheel 14. With this embodiment movement of bushing 11 up and down will cause corresponding movement of the electrode 15. I may, however, equip electrode 15 with independent moving mechanism and positioning means not shown where this appears to be preferable.

A lower electrode 17 may be screwed into the bottom of the body 2*a*, part of which is shown at 19. Ports are formed in the body 2 at this point by the drilling of a plurality of outlet nozzles 20 through the body at that angle as shown. These may be four or more in number and have a diameter of about .010". Lower electrode 17 is also, of course, manufactured of an electrical conducting material and is equipped with an elongated or tipped portion 18.

As thus assembled it will be evident that the parts form a fuel chamber or compartment 21, the operation and function of which will become apparent from the further description.

A fuel inlet line 22 connects with a source of fuel from a fuel pump not shown. The latter need not be of a high pressure type as will be evident from a study of the operation of my method and apparatus. In some applications, however, it may be desirable to maintain a high pressure fuel supply, as pointed out below. A check valve 23 is inserted between the fuel inlet line and an inlet port 24 which leads to the fuel chamber 21.

A high voltage intermittent source of supply of direct current is shown diagrammatically at 25. This may consist of a battery, generator, spark coil, capacitor, etc., equipped with a distributor spark interrupter, as is well known to those skilled in the art.

Operation

To start my operation, worm and wheel 14 are first adjusted to move bushing 11, together with electrode 15 up or down and thus provide the proper volume in fuel chamber 21, depending on the amount of fuel it is desired to condition at each pulse. Fuel is then admitted through fuel line 22 and check valve 23 to the chamber 21. A pulse of current from 25 to connecting wire 26 causes an arc to jump between electrodes 15 and 17 and hence through the fuel chamber and the fuel which it contains. This arc creates a high temperature and a high pressure wave, the combined effect of which vaporizes a large portion of the fluid, shuts off the check valve 23, and pushes against electrode 15 causing an upward thrust. This causes an upper portion of the entire assembly comprising bushing 11 and electrode 15, as well as insulating bushing 10. Also moving upwards in bushing 6 which acts against the tension of spring 7. This motion of bushing 6 may be utilized as a pumping action to aid injection of the fuel. The upper motion of bushing 6 brings it out of contact with the face of lower electrode 17 and thus permits the fuel chamber to communicate with ports 20 and thence to the combustion chamber. The contacting surfaces of 6 and 17 may be ground and lapped for tight contact. The remaining fuel which may still be in liquid or finely divided

liquid form is completely vaporized in passing through the nozzles. At the same time it absorbs heat from the voltolysis reaction previously described as a result of the action of the arc so that combustion may be instantaneous with no "ignition lag." The latter action may be regulated by adjustment of screw 8 which in effect determines at what pressure the fuel in the chamber which is now in a combined liquid and vapor phase will discharge through the nozzles. This in turn will, of course, be governed by the type of fuel, temperature, nature of the cycle or process in which the hydrocarbon fuel will be utilized. The rate of combustion or the speed and power of the process will in turn be governed also by the amount of fuel admitted to the chamber during each firing which is regulated by adjustment of worm and wheel 14 which determines the volume of the fuel chamber, and hence the quantity of fuel.

It should be evident that my method and apparatus are adaptable also to the continuous burning of fuel as in a furnace. In this case I supply my fuel through 24 at a considerably higher pressure and adjust my electrodes 15 and 17 and adjusting screw 8 accordingly. This is continued until an equilibrium is reached between the rate of fuel supplied to chamber 21 and at the rate of ejection through apertures 20 thereby providing for continuous combustion.

While I have described a preferred embodiment of my invention and while this particular embodiment appears to be especially adapted for use with an internal combustion engine, my invention is not so limited, but may be applied also to various types of fuel oil burners, combustion processes, and similar applications which will now be apparent to those skilled in the art. I therefore do not limit myself to the embodiment disclosed herein, except as I do so in the claims which follow.

I claim:

1. A method of treating fluid fuel to achieve improved combustion thereof comprising the steps of:
   - intermittently introducing said fuel to a closed chamber at a relatively low pressure;
   - intermittently discharging an electric arc through the fuel in said chamber while simultaneously shutting off the supply of said fuel;
   - automatically releasing the pressure in said chamber to a predetermined value by opening an aperture communicating therewith;
   - permitting said fuel to escape from said chamber through said aperture and into a combustion space.

2. A method of treating fluid fuel to achieve improved combustion thereof comprising the steps of:
   - continuously introducing said fuel to a closed chamber at a relatively high pressure;
   - continuously discharging an electric arc through the fuel in said chamber;
   - automatically adjusting the pressure in said chamber to a predetermined amount by opening an aperture communicating therewith;
   - causing said fuel to escape from said chamber through said aperture and into a combustion space.

3. A method of treating liquid hydrocarbon fuel to achieve improved combustion thereof comprising the steps of:
   - adjusting the volume of a closed chamber to a predetermined value;
   - introducing said fuel into said chamber;
   - discharging an electric arc of predetermined magnitude across said chamber and through said fuel thereby effecting a shock and pressure wave in said fuel and simultaneously effecting a voltolysis of hydrocarbons in said fuel;
   - adjusting the pressure on the resultant fuel so formed to a predetermined value by regulating the opening in an aperture communicating between said chamber and a combustion space, thereby permitting said fuel

to flow from said chamber and into said combustion space.

4. An apparatus for treating liquid fuel to achieve improved combustion thereof comprising:

a closed chamber;

means for carying the volume of said chamber;

means for supplying said fuel to said chamber;

electrodes positioned within said chamber;

means for varying the space between said electrodes;

a source of electrical potential;

means for applying said potential across said electrodes to produce an arc therebetween and through said fuel in said chamber, thereby creating an increased pressure in said fuel;

means for releasing said fuel of increased pressure from said chamber into a combustion space while simultaneously cutting off the supply of said fuel to said chamber.

5. An apparatus for injection of fuel into a combustion space comprising:

a housing of generally cylindrical configuration having a hollow cylindrical center section and one blind end;

means for tightly positioning said blind end onto a combustion space;

a first bushing, having one blind end, slideably mounted within said hollow cylindrical section with its blind end adjacent to the blind end of said hollow section;

a second bushing concentrically mounted within said first bushing;

a third bushing concentrically mounted within said second bushing so as to define a chamber within said second bushing between one end of said third bushing and the blind end of said first bushing;

said second and third bushings being fixedly positioned with respect to said first bushing;

adjustable spring means positioned against the end of said first bushing opposite its blind end whereby said first bushing is forced down against the blind end of said hollow cylindrical section of said housing;

a first electrode tightly positioned within said third bushing;

a second electrode tightly positioned within the blind end of said housing and protruding through the blind end of said third bushing into said chamber in said second bushing;

ports communicating from said chamber through the blind ends of said first bushing and said housing and into said combustion space;

said ports being so positioned as to be uncovered by the movement of said first bushing against said spring means;

a port communicating from said chamber through said second and first bushings and through said housing to a source of fuel supply;

a difference of electrical potential connected across said first and second electrodes.

6. The apparatus of claim 5 including means for adjusting the axial position of said third bushing with relation to said second bushing thereby varying the volume of said chamber in said second bushing.

7. The apparatus of claim 5 including independent means for varying the axial position of said first electrode with relation to said third bushing.

8. The apparatus of claim 6 including independent means for varying the axial position of said first electrode with relation to said third bushing.

References Cited

UNITED STATES PATENTS

2,950,867 8/1960 Hawley et al. ---------- 239—85

FOREIGN PATENTS

111,446 9/1940 Australia.

EVERETT W. KIRBY, *Primary Examiner.*