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FUEL INJECTION NOZZLE AND METHOD OF INJECTING
FUEL FOR INTERNAL COMBUSTION ENGINES

Filed Dec. 19, 1957

2 Sheets-Sheet 1

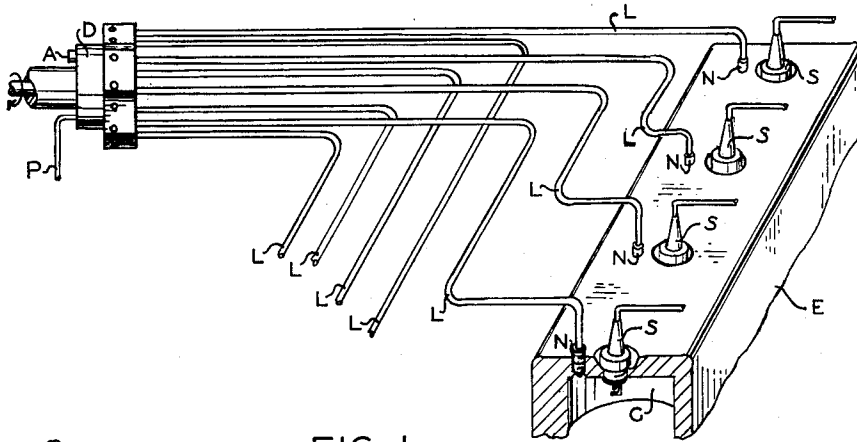


FIG. 1

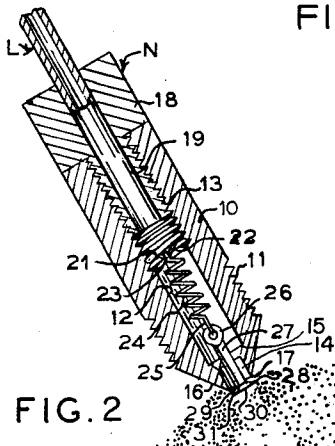


FIG. 2

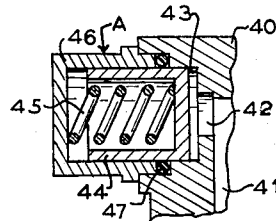
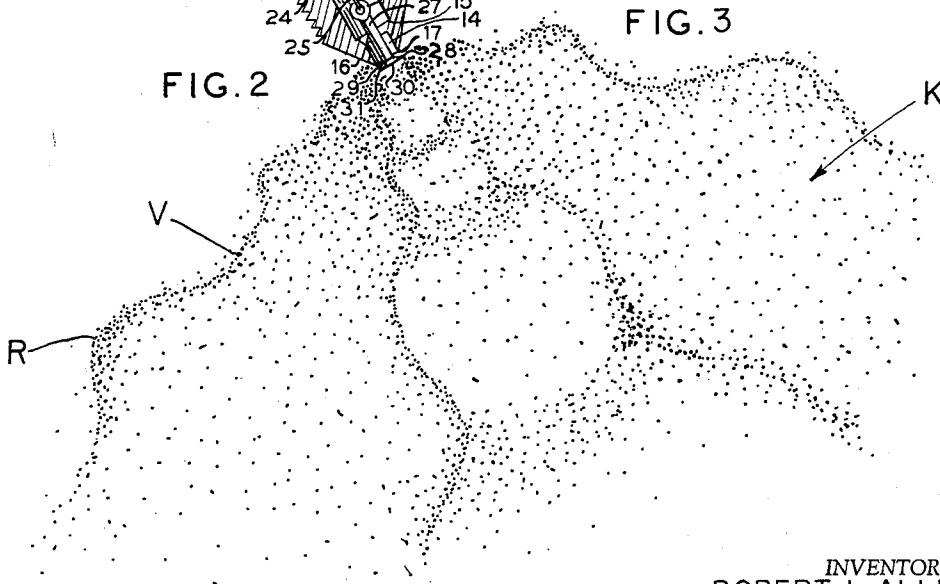


FIG. 3



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May 8, 1962 R. L. ALLEN 3,033,182
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Filed Dec. 19, 1957 2 Sheets-Sheet 2

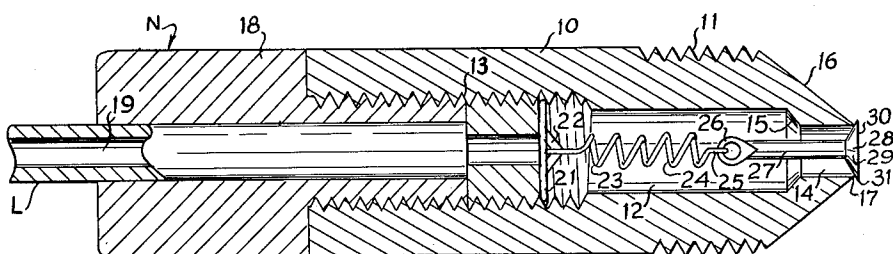
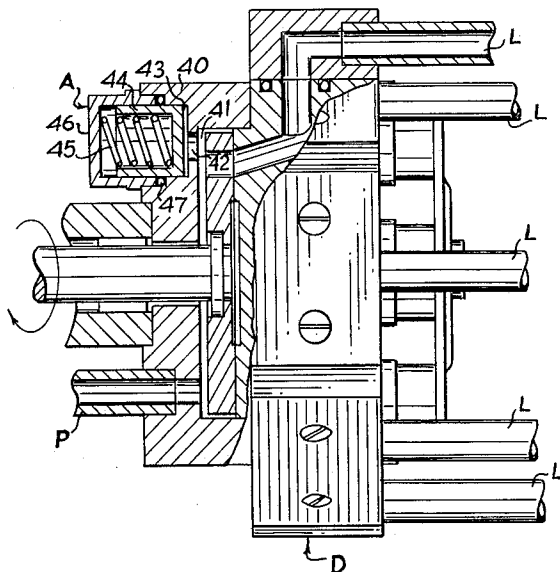
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2 Sheets-Sheet 2



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1

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FUEL INJECTION NOZZLE AND METHOD OF INJECTING FUEL FOR INTERNAL COMBUSTION ENGINES

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This invention relates to a nozzle and method of injecting fuel for internal combustion engines, and is particularly concerned with fuel injection for high speed, multiple cylinder, spark ignition engines.

Fuel injection had its inception in low speed, compression ignition engines; however, recent developments have made material advances toward the achievement of the successful application of the principle of fuel injection to the field of high speed, spark ignition, multiple cylinder, internal combustion engines. Originally the application of such systems was limited to the injection of fuel into the intake manifold from which the combustible mixture passed to the individual cylinders. It is, of course, recognized that many advantages are inherent in the individual injection of appropriately metered increments of fuel to the individual cylinders either directly or adjacent the individual inlet ports. One of the prime obstacles to successful individual injection of the fuel to the separate cylinders has been failure to achieve an adequate method or an appropriate nozzle by which a faithfully responsive, accurately metered, fuel increment may be injected at proper pressure and in precise time intervals into the cylinder and with an effectively uniform atomization and diffusion characteristic.

In order to overcome these and other problems, the present invention includes, as a novel and improved method, the steps of supplying fuel under pressure at a rate of flow commensurate with the engine demands for fuel, subjecting said fuel to the action of a distributor by which such supply is divided into successive incremental pulsations and delivering said individual increments directly into, or adjacent the inlet port of, the individual cylinders through diffusion nozzles.

Thus, broadly stated, the method partakes of the general procedure of some contemporary injection systems. The present method, however, is characteristically distinguished in that the fuel upon final discharge into the combustion supporting medium is in a highly miscible state, preferably as a hollow conical cloud of increasing wall thickness. By virtue of the nozzle of the present invention, the discharge pattern may be vibratory in character presenting progressively undulating features, and/or the method includes the control of pressures such as to avoid wide fluctuations or pressure peaks. Such pressure is preferably maintained substantially approximate that of the yieldable resistance of a diffusion element of the nozzle so that there may be a vibration like hunting action between pressures to facilitate the undulating character of discharge as well as insuring a comparatively low overall pressure thus precluding locks, binds, turbulence, pounding or undue fluid friction in the system.

The nozzle of the present invention is such as to limit the injection to accurately responsive bursts of the individual fuel increments, discharged at a predetermined pressure value, which are abruptly terminated and cut off after the full accurately metered increment has been injected. The nozzle is further such as to provide the conical discharge pattern of diffused and/or atomized fuel which rapidly loses density from the point of origin and which will develop a pulsation type of discharge characterized by outwardly traveling annular pulsation rings or migrating undulations of increasing amplitude.

Structurally, the nozzle may be generally defined as

2

including a hollow body presenting an orifice cooperating with a free floating diffusing element preferably urged to seating position by flexible means. This element provides a frusto-conical surface facing the direction of fluid flow, terminating in a sharp peripheral edge, characterized by a radius slightly exceeding, but closely approaching, that of the radius of the flow surface with which it is associated to minimize the length of travel of fluid in a restricted zone. The body is formed with a uniformly cylindrical outlet bore insuring free direct passage of liquid, terminating in a circular flow orifice forming a seat for the diffusion element. The outer wall of the body adjoining the seat is formed as a frusto-conical surface meeting the orifice at a sharp, acute angle, the apex of which defines the seat as a sharp circular edge. Since the acute angles between inner and outer body walls at the orifice provide a sharp edge confronting the smooth tip edge surface of the inwardly facing conical surface of the diffusion head, a sharp circular line contact between the element and its seat is insured. A spring suspends the diffusion element for free floating movement, and a simple wire ring adjustably supports the spring by selective engagement with internal threads of the body. The same threads provide for the securement of a closure plug and mounting for a fluid inlet tube communicating with the nozzle cavity. In carrying out this design, a simple cylindrical body is utilized which, while providing easily adjustable supporting means for the free floating support of the diffusion element, is rugged, and durable, and well designed to meet the demands of economic manufacture.

It will therefore be seen that it is among the more general objects of the invention to provide a novel and improved method of, and means for, fuel injection for multi-cylinder high speed, spark ignition, internal combustion engines.

More specifically, it is an object of the invention to provide a fuel injection method and apparatus for the effective and efficient injection of individual increments of fuel to the individual cylinders or inlet parts of a high speed multi-cylinder, spark ignition type, internal combustion engine.

The method includes as one of its objectives the injection of fuel in such manner as to accomplish rapid and thorough dispersion of fuel particles and for clearly defined flow intervals, characterized by abrupt and positive cut off at the termination of full discharge of the individual increments.

Another object of the method is to provide a diffusion pattern for injected fuel which is substantially of hollow conical formation characterized by a progressively increasing diameter and consequent decreasing density as the fluid progresses from the discharge nozzle. This vapor sheath is observable as including outwardly progressing undulations of increasing amplitude and decreasing frequency as the cloud expands.

It is also an important object of the present method to provide pressure relationships such that excessive pressure peaks are avoided and to provide a supply pressure so related to the flow resistance of the injection nozzle that a discharge pattern of maximum effectiveness and efficiency is achieved.

As to structure, it is also an object to provide a nozzle for fuel injection which provides for the full discharge of fuel increments with minimum friction drag or adherence and to insure rapid pressure drop upon separation of the fuel from the nozzle to enhance the rapidity of complete co-mingling of minute fuel particles with combustion supporting gases.

Another object is to provide a nozzle having a pressure responsive diffusion element adjustably mounted in such manner that flow resistance may be substantially similar to applied pressure in order to avoid difficulties due to wide pressure discrepancies and to utilize such

similar pressures in the achievement of effective and efficient atomization.

Other objects include that of providing a device of the character described which is simple in construction and operation, requiring minimum maintenance and adjustment and one which may be economically manufactured without sacrifice of strength, durability, or effective and efficient operation over long periods of time.

Numerous other objects, features and advantages of the present invention will be apparent from consideration of the following specification taken in conjunction with the accompanying drawing, in which:

FIG. 1 is a schematic illustration of one arrangement of apparatus for carrying out the method of the present invention.

FIG. 2 is a cross sectional view of a nozzle formed in accordance with the present invention illustrating a preferred type of fluid diffusion pattern emanating therefrom.

FIG. 3 is a cross sectional view of the accumulator D of FIG. 1.

FIG. 4 is a cross sectional view of the nozzle on an enlarged scale.

FIG. 5 is a side elevation of the distributor, with parts broken away, showing the accumulator mounted therein.

In FIG. 1 of the drawings, the apparatus of the present invention is depicted as including a distributor D to which liquid fuel is supplied under appropriate pressure through pipe P at an ample rate of flow to insure an adequate supply. The distributor D is constructed and arranged to deliver accurately metered increments, as successive fuel pulses, to the individual lines L each of which delivers to a different nozzle N. As here illustrated, each nozzle N is set into one of the cylinders C of a multiple cylinder, high speed, spark ignition type, internal combustion engine E. Each cylinder C of the engine is provided with a conventional spark plug S in proximity to the injection nozzle N. One of the important elements of this arrangement is the inclusion in the fluid line of a pressure compensator, here shown as an accumulator A, constructed, arranged and so located, here shown communicating with the inlet side of the distributor D, whereby the fluid of pressure surges may be accommodated to insure a peak-free, controlled pressure of fluid delivered to the nozzles.

The primary structural element of the present invention is the nozzle N, the detailed structure of one preferred embodiment of which is presented in FIG. 2 of the drawings. In this present form of the nozzle, the body 10 may be readily and inexpensively formed from a generally cylindrical tube blank. For mounting the nozzle in operative position with respect to associated equipment, the lower end of the upper cylindrical portion of the outer surface of the body 10 may be formed with external threads indicated at 11. Internally, the body is formed with a central longitudinally extending axial bore forming a central cavity 12 having internal threads 13. The lower end of the body below the threads 13 is formed with an axial reduced fluid outlet bore 14 which is open to the cavity 12 by merging therewith through the intermediary of a short internal frusto-conical wall 15. The opposite outer end of the bore 14 terminates in an orifice formed as a sharp knife-edge circular seat 17 at the apex between the inner perpendicular walls of the bore 14 and the outer downwardly and inwardly tapering frusto-conical walls 16 of the body below the threads 11.

As here shown, the walls of the bore 14 are concentric with the walls 15 of the cylindrical cavity 12, and thus axial with respect to the body. The inward and downward taper of the frusto-conical outer surface 16 of the body meets the wall of the base at an acute angle to form the sharp smooth circular seat 17. While the angularity between the walls of the bore 14 and the outer frusto-conical surface 16 may not be critical, it is nevertheless

desirable that this angle be such as to insure a thin circular line contact between the seat 17 and the diffusion head. At the opposite end of the body 10, the cavity 12 is capped by a threaded plug 18 having a central fluid supply duct 19 to which is applied the fluid supply line L.

Mounted within the cavity and adjustably engaging a selected turn of the threads 13 below the plug 18, there is located the annulus 21 of a spring supporting ring. A generally V-shaped cross bar 22, formed integrally with and depending from the annulus 21, receives the upper terminal end 23 of a coil spring 24. Axial adjustment of the ring within the cavity may be conveniently obtained by rotation of the annulus 21 for thread-like adjustment in the body 10. The lower end 25 of the spring 24 engages the ring 26 of the shank 27 of the diffusion element to suspend the element from within the body.

At the lower end of the shank 27 a diffusion head 28 is formed integrally with the shank 27. The head 28 comprises a disc-like member having an upper frusto-conical fluid contact surface 29. The head 28 is of minimum radius capable of providing sealing contact with the sharp circular seat 17. The under or outer side of the head 28 is here shown as a flat circular surface 30 disposed in a plane normal to the axis of the head and joining the outer periphery of the frusto-conical surface 29 at an acute angle to provide a short thin and acutely angled lip 31. The sharp lip 31, when seated, will contact the sharp seat 17 to provide a thin circular line contact. While, as indicated with respect to angularity forming the seat 17, the angle between the surfaces 29 and 30 is not critical; however, it is preferable that this angle be acute to insure a sharp edge for the lip 31 to effect a quick and complete discharge of fluid eliminating the danger of fluid drag and insuring rapid drop in fluid pressure.

It will be noted that the substantially equal diameter of the body 28 with respect to the diameter of the seat 17 at the end of the fluid outlet passage 14 provides a minimum marginal lip 31 extending outwardly and downwardly from the seat 17. The frusto-conical surface including the lip will insure a radial spread of fluid discharged, providing the desired degree of atomization and diffusion. It will further be noted that since the diffusion element is retained in position merely by the spring 24 which is fully flexible, both laterally as well as longitudinally, the element is free floating and may move rapidly and fully from its seat 17 to be floatingly suspended by the spring. It will also be noted that the conical configuration of the surface will insure a proper seating of the element against the seat, such conical formation providing a guiding action for the seating of the element under spring tension when fluid pressure permits.

In the operation of the nozzle, as the fluid fuel increments are admitted periodically through the fuel lines L, a discharge of the fluid into the cylinders will be restrained until such pressure is achieved sufficient to flex spring 24 longitudinally to permit the head 28 to move outwardly from the seat 17. In the normal operation it will be understood that the supply line L and the nozzle cavity are filled with the fuel liquid, and thus the opening of the nozzle by displacement of the diffusion head against the tension of the spring will be substantially instantaneous in response to the supply of the fuel increment to the line L from the distributor D. As the fuel increment emerges from the nozzle port, it is guided or diverted outwardly along the frusto-conical surface of the diffusing element to form a generally hollow conical spray pattern. Due to the sharp annular edge 17 from which the body of the nozzle recedes along the surface 16, it will be seen that the fluid fuel pressure drops almost instantly to the pressure of the environment into which the fuel is injected, the sharp annular edge 17 in conjunction with the sharp edge 31 of the diffusion head precluding adhesion and clinging of fuel particles. It will

5

be noted that in the discharge of the liquid, since the diffusion element is freely suspended from spring 24 through the ring 26, the diffusion element is free as a floating element to move in such lateral direction as may be imposed thereon by minute variations and/or in response to such deviations from the straight flow as may inadvertently appear in the flow of fluid from the bore 14, the arrangement being such that the diffusion head is free to permit a flow of the fuel increment responsive to any lateral lack of uniformity.

It will also be noted that since the diffusion head is freely suspended from the spring, the pressure will tend to build up behind the head to force it from its seat, and that as the fluid flows and the pressure immediately drops the diffusion head will tend to move inwardly under the tension of the spring. There is therefore the possibility of a vibratory type of hunting action whereby the diffusion head may flutter as the fuel increment is discharged therefrom. As a consequence of such fluttering, whether responsive to the fuel pressure in the nozzle as opposed to the spring pressure of the spring 24 or from other sources, such fluttering will produce undulations and expanding ringlets within the hollow conical spray formations emitted by the nozzle. Such vibratory and undulating spray pattern will of course materially aid in the co-mingling of the fuel particles in the combustion supporting medium so that a high degree of atomization is achieved and the charge is readily combustible in its entirety without delayed burning due to the chain ignition of one particle with another. In FIG. 2, the hollow conical discharge pattern is shown generally as a cloud K, the cross section of the wall of which continually expands to emerge with the expanding cross section of an opposed wall, the rings R being spaced by the valleys V. Since the vibratory characteristic is produced at the original propagation of the cloud, such rings R will move outwardly as the cross section of the wall expands and they will gain amplitude while the frequency or distance between the rings increases.

While the above described type of spray pattern may emanate from the nozzle regardless of the pressure conditions under which the fuel is supplied thereto, an effective, efficient and uniform spray pattern best suited to the production of a desirable combustible mixture for the cylinders of an internal combustion engine is achieved by the delivery of the increments of fuel to the nozzle at a uniform and controlled pressure. Where high pressures are employed in order to overcome some of the difficulties involved in supply and distribution of fuel, such high pressures may frequently produce vapor locks, pounding and turbulence, militating against the discharge of the uniform spray pattern from the nozzle of the type herein set forth. The present invention therefore seeks to provide a fuel delivery of constant pressure, and since uniformity of pressure is best achieved by the maintenance of a system devoid of pressure peaks and disturbances inherent in high pressure systems, the present invention contemplates the use of relatively low pressures throughout the entire system.

In order to further avoid any possibility of undesirable pressure fluctuations, there is provided a pressure responsive means of variable volume type, so as to accommodate varying rates of fluid flow without jeopardizing the uniformity of operation. Thus there is provided in the fluid line and preferably on the intake side of the distributor D the accumulator A which may be of the form shown in detail in FIG. 3. In this figure, the distributor casing is indicated by the numeral 40, the casing defining an inlet fluid chamber 41 which may be directly supplied by fuel through the fuel pipe P. It will be understood that other than for the provision of the accumulator here shown, the distributor may be of generally conventional form comprising a rotating apertured disc through which the fuel fluid passes to the successive lines L as the plate is rotated, fluid

6

being supplied to the aperture of the plate from the chamber 41 and thence to the individual lines L as the aperture of the plate progressively registers therewith. For accommodating excess fluid as the fluid supply may vary in response to engine demands for fuel, there is provided an accumulator duct 42 in the wall defining the fluid chamber 41. Concentrically formed about the port 42, there is a recess 43 adapted to slidably receive the cup shaped accumulator piston 44 which is urged inwardly by an accumulator spring 45, the spring 45 and the outer portions of the walls of the piston 44 being housed within an accumulator shell 46 secured in any manner as desired to the outer wall of the distributor 40 and sealed in conventional manner by suitable O rings 47.

By this arrangement it will be seen that as the supply of liquid fuel through pipe P may vary in response to varying demands for fuel by the engine and while there may be momentary instances wherein the passage of fuel from the chamber 41 to the individual line is blocked as the aperture of the disc passes from one line aperture to another, such fuel may be accommodated within the accumulator. For such accommodation the piston may move rearwardly against the pressure of its spring 45 to accommodate such volumes, but in a manner such as to avoid any substantial pressure increase since the spring 45 acts as an upward pressure limiting element. Such excess fluid will of course be discharged as the increased quantity of fuel is supplied to the engine and/or when the disc aperture registers with the next successive line opening.

An important feature of the present invention is the provision of a spring 45 which is commensurate in tension with that of the spring 24 of the nozzle. In one successful operative embodiment of the present invention, the tension of the accumulator spring 45 is set at substantially 90 p.s.i. while the tension of spring 24 of the nozzle tending to close the nozzle by a seating of the head may be approximately 60 p.s.i. Under these circumstances not only will the accumulator preclude the buildup of excess pressure in the system, but since the pressure maintained by the spring 45 is commensurate with that of the spring 24 tending to close the nozzle, a hunting action will take place between the accumulator and the nozzle. It will of course be understood that pressure builds up in the nozzle to overcome the tension of the spring 24 and since such pressure is quickly reduced when the diffusion head leaves the nozzle port there is a tendency to decrease the entire pressure of the line associated with that particular nozzle, and consequently there will be a tendency for the accumulator piston to surge forward under the influence of its spring 45 to compensate for the reduced pressure in the line. However, at such time the reduced pressure in the line will tend to relieve the pressure in the nozzle chamber, and thus the spring 24 will tend to move the diffusion head toward the closing position, and this cycle of operation will be rapidly repeated to provide for an effective vibration of the diffusion head so as to assist in the promotion of the undulating character of the spray pattern as hereinbefore discussed.

From the foregoing, it will be seen that the present invention provides a novel and improved method by which fuel will be discharged in a highly atomized condition into the combustion supporting medium of a high speed, spark ignition type, internal combustion engine. It will be further seen that in connection therewith there is here provided a nozzle structure for accomplishing the desirable characteristics of operation herein set forth. In the practice of the invention it will be understood that numerous changes, modifications and the full use of equivalents may be resorted to without departing from the spirit or scope of the invention, as defined in the appended claims.

I claim:

1. An injection nozzle for intermittent injection of fuel to a multi-cylinder, high speed, spark ignition type, internal combustion engine including a body defining a circular discharge orifice surrounded by a narrow peripheral seat from which the outer wall of said body is sharply swept back, a diffusion element having a sloping surface directed toward said orifice, said surface being bounded by a sharp circular edge the diameter of which closely approaches the diameter of said seat, adjustable means normally urging said element toward said seat and a fluid supply for said nozzle including a pressure responsive fluid reception chamber means for maintaining substantially constant pressure on said fuel between successive injections.

2. An injection nozzle for intermittent injection of fuel to a multi-cylinder, high speed, spark ignition type, internal combustion engine, including a body defining a fluid cavity, having an axial bore communicating therewith to form a discharge orifice, a seat at the discharge orifice of said bore, the outer wall of said body being tapered inwardly to said seat to provide a sharp circular meeting edge, a diffusion head, resilient means suspending said head from within said body for free universal vibratory movement of said head upon discharge of fluid through said nozzle, said head having a sloping surface directed toward said orifice, said suspending means providing yieldable contact of said sloping surface with said seat.

3. An injection nozzle for intermittent injection of fuel to a multicylinder, high speed, spark ignition type, internal combustion engine including a body defining a threaded bore, a fluid cavity in axial alignment with said bore, an axial outer bore communicating therewith and forming a discharge orifice, the outer wall of said body being tapered to said orifice to provide a sharp circular seat at said discharge orifice, a diffusion head, resilient means suspending said head from within said body for free universal movement with respect thereto, said head having an inner sloping surface facing said orifice, the diameter of said surface closely approaching the diameter of said orifice, the opposite outer surface adjacent the periphery of said head presenting a flat face lying in a plane normal to the axis of said inner surface, said suspending means providing yieldable contact of said inner surface with said seat and being threadedly adjustable in the threads of said threaded bore, a fluid supply for said nozzle, and an accumulator communicating with said fluid supply, for storing fluid between successive injections, said accumulator being biased for substantially constant pressure above a predetermined minimum and for discharging the accumulated fluid during the next injection.

4. A fuel injection system for intermittently injecting fuel to the cylinders of a high speed spark ignition type internal combustion engine including a fuel supply, an accumulator for storing fuel between one injection and the next in constant communication with said fuel supply, and a spray nozzle for discharging fuel from said fuel supply, said accumulator being biased for substantially constant pressure above a predetermined minimum and for discharging the accumulated fuel during said next injection.

5. A fuel injection system for intermittently injecting fuel for the cylinder of a high speed spark ignition type internal combustion engine including a fuel supply, an accumulator having a chamber for storing fuel between one injection and the next, the chamber being in constant communication with said fuel supply and having a movable wall for forcing fuel out of the chamber, a spring biasing said wall to force fuel out of the chamber at a predetermined accumulator discharge pressure, a nozzle for discharging fuel from said fuel supply, said accumulator

discharge pressure being greater than the release pressure of the nozzle, and a distributor connected between said nozzle and said accumulator chamber for periodically releasing fuel to the nozzle so that the nozzle will open and the accumulator chamber will discharge the fuel stored therein.

6. A fuel injection system for intermittently injecting fuel for the cylinder of a high speed spark ignition type internal combustion engine including a fuel supply, an accumulator having a chamber for storing fuel between one injection and the next with the chamber being in constant communication with said fuel supply and having a spring biased movable wall exposed to the chamber for forcing fuel out of the chamber, a nozzle for discharging fuel from said fuel supply, and a distributor connected between said nozzle and said accumulator chamber for periodically releasing fuel to the nozzle with said accumulator wall being biased for pressure above a predetermined minimum and for discharging the accumulated fuel during the next injection when connected to the nozzle by the distributor.

7. A fuel injection system for intermittently injecting fuel for the cylinder of a high speed spark ignition type internal combustion engine including a fuel supply, an accumulator having a chamber for storing fuel between one injection and the next with the chamber being in constant communication with said fuel supply and having a spring biased movable wall exposed to the chamber for forcing fuel out of the chamber, a nozzle for discharging fuel from said fuel supply, and a distributor to be driven by the engine connected between said nozzle and said accumulator for releasing fuel from the accumulator for each fuel intake stroke of the engine with said accumulator wall being biased for substantially constant pressure above a predetermined minimum and for discharging the accumulated fuel during the next injection when connected to the nozzle through the distributor.

8. A fuel injection system for intermittently injecting fuel for the cylinder of a high speed spark ignition type internal combustion engine including a fuel supply, an accumulator having a chamber for storing fuel between one injection and the next being in constant communication with said fuel supply and having a movable wall for forcing fuel out of the chamber, spring means biasing said wall to force fuel out of the chamber, a stop in the chamber limiting the movement of the wall at a discharged position so that the spring means will have a biasing force above a predetermined minimum at said stop to maintain a pressure in the fuel above said minimum pressure for the full discharge of the accumulated fuel during said next injection, a nozzle for discharging fuel from said fuel supply, and a distributor connected between said nozzle and said accumulator chamber for periodically releasing said fuel to said nozzle.

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