Dec. 14, 1937. O. L. A. RIEGELS 2,102,485

FUEL INJECTION MEANS FOR MOTORS

Filed April 26, 1935 2 Sheets-Sheet 1

FIG. 1.

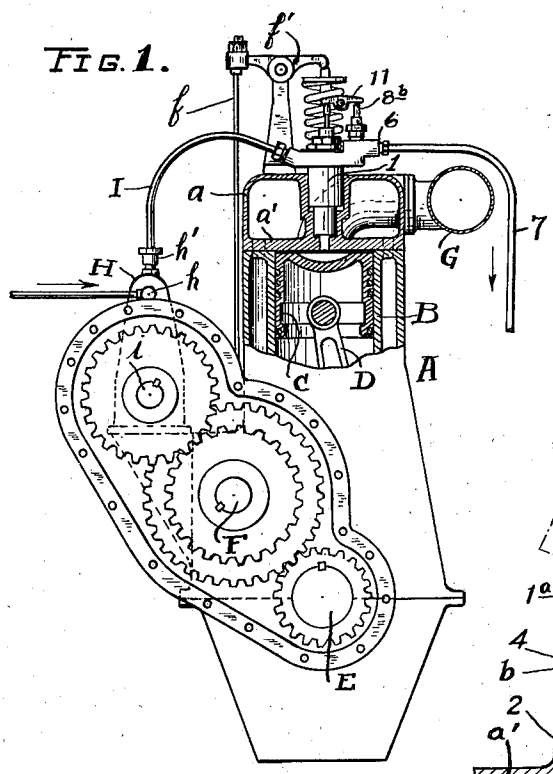

FIG. 4.

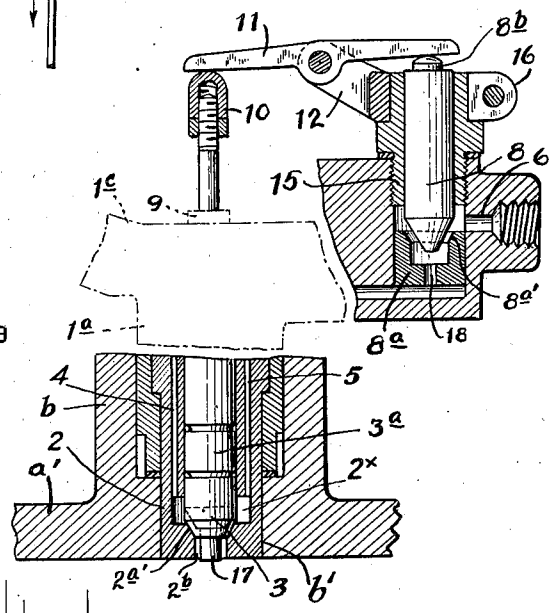

FIG. 5.

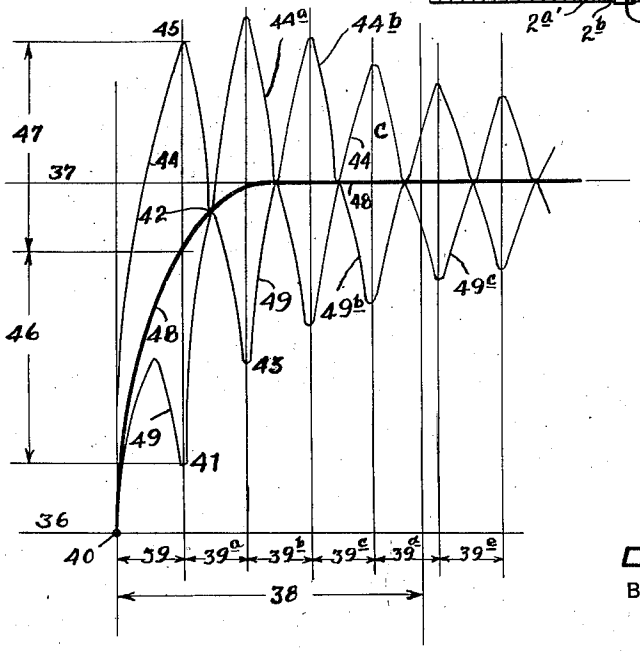

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FIG. 2.

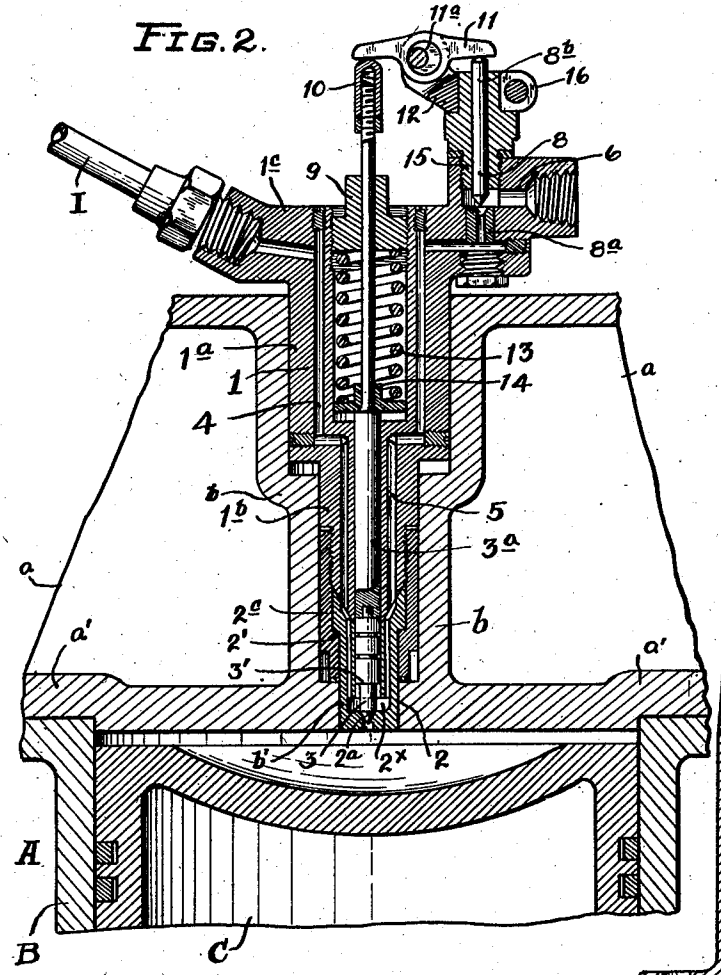
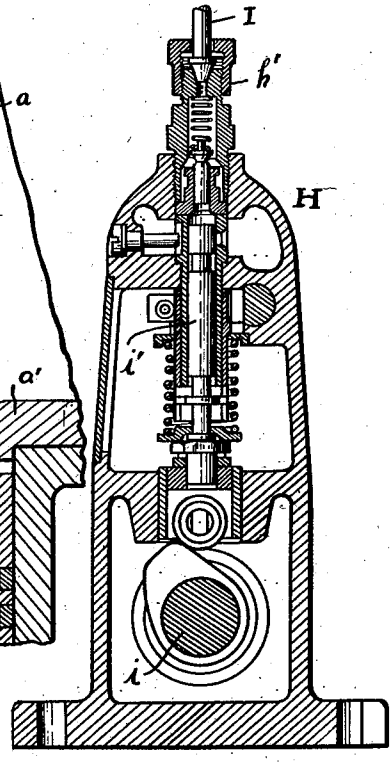


FIG. 3.



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FUEL INJECTION MEANS FOR MOTORS

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5 Claims. (Cl. 123—32)

This invention relates to fuel oil injection means for direct injection oil engines or motors, and has particularly reference to those of the Diesel type.

Because of very pronounced pressure fluctuations occurring in the fuel line during fuel injection, a constant and gradual injection of fuel oil cannot be obtained under present practice in this art; and because of the extremely low compressibility of the fuel oil and the high rigidity of the enclosing structure, the time-interval of the pressure fluctuations is very short, and accordingly a number of such fluctuations take place in the time necessary for and during a single gradual injection of the fuel. One object of this invention is to reduce or eliminate these fluctuations.

In an injection apparatus or nozzle and in the fuel line of a Diesel engine, two kinds of fluctuations or waves are ordinarily observed and known to exist. One kind originates at the fuel pump, due to the compression of the fuel and exists in the fuel line and in the injection nozzle, when the latter is closed by the nozzle valve. These fluctuations are known as and have the character of pressure waves, but they are not important as they have a relatively low frequency and their elimination is not the subject of the present invention.

The other kind of fluctuations, little known and far more difficult to control, originate at the injection nozzle or discharge opening and are produced at the very moment the nozzle valve opens and the hitherto compressed fuel tends to again regain its original or normal density. By this release of pressure upon opening of the injection valve, fluctuations or waves are built up, which travel from the nozzle tip to the end of fuel supply pipe or pump plunger and back and forth again. These waves have the character of rarefaction or tension waves and are very violent and cause at their maximum amplitude a considerable pressure drop, which reduces the pressure to an amount much less than is necessary to sustain a continuous and gradual injection.

If said tension waves are damped out or balanced by pressure waves of equivalent frequency and intensity and opposite phase, a continuous and gradual fuel injection results. This action is, according to the present embodiment, accomplished by a stop or bypass valve placed in a bypass opening and operated by elements co-acting with the nozzle valve, to move oppositely with respect thereto, so as to effect a closure of the one as the other is opening. Accordingly, another object of the invention is to provide improved means for insuring the presence of pressure waves of substantially equal intensity and frequency and of opposite phase relationship to balance out the tension waves.

Another object of the invention is to provide improved means for insuring that exactly the same volume of the fuel shall pass through the stop valve when fully open as passes through the injection valve when open, during equal time intervals.

Another object of the invention is to construct an improved fuel injection nozzle having a stop valve provided with a removable valve seat.

A further object of this invention is to provide an improved fuel injection means having an injection valve and a stop valve the openings of which are of predetermined correlated size to insure a balanced wave re-action during fuel injection.

Other objects of the invention will be apparent to those skilled in the art to which my invention relates from the following description taken in connection with the accompanying drawings, wherein

Fig. 1 is a view, partly in elevation and partly in section, of an engine embodying my invention.

Fig. 2 is a fragmentary section of parts shown in Fig. 1, enlarged.

Fig. 3 is a sectional view of the fuel pump, enlarged.

Fig. 4 is a view of parts shown in Figs. 1 and 2, slightly modified and partly diagrammatic.

Fig. 5 is a diagram.

In the drawings, A indicates as an entirety an engine of the Diesel type, showing one cylinder B and a piston C therein. The engine may be constructed to provide any number of cylinders, as desired, but as my improved injection means is applied to each cylinder, only one thereof need be illustrated and referred to. D indicates a piston rod, which drives a crank shaft E. The shaft E is drivingly connected to a cam shaft F which, through the rod *f* and rocker *f'*, time controls the usual exhaust valve to the exhaust manifold G. H indicates the fuel pump having a fuel inlet *h* connected with a pipe leading from a suitable source of supply and a fuel outlet *h'* connected to a conduit I. The shaft *i* of the pump is suitably driven, for example by the gearing shown in Fig. 1, to rotate a cam which in turn, in cooperation with a spring, operates the pump plunger *i'*. The pump H serves to supply the fuel to the injection nozzle, as hereinafter set forth, at relatively high pressure. Any desired construction of pump for this purpose may be used, that shown being for illustrative purposes only. *a* indicates a casing formed integrally with the cylinder head *a'* and shaped to form axially of the cylinder B a tubular wall *b*, enlarged at its upper end, to receive and support the injection valve nozzle structure, the head *a'* being formed with an opening *b'* axially of the cylinder to receive a portion of the structure, as later described.

1 indicates a hollow body member of the injection valve having a main portion 1*a*, an integral neck portion 1*b* at its lower end (these portions being seated in the wall *b*) and an integral head 1*c* at its upper end. The lower end of the neck portion 1*b* is preferably of conical shape to which is axially related a removable, tubular tip member 2 removably fitting at its lower end into the opening *b'*, and having at such end an end wall formed with a nozzle opening 2*a*. The inner wall of the tip member adjacent its end wall is cut away to form a chamber 2*x*. The upper end of the opening 2*a* is of conical shape to form the valve seat 2*a'* of the movable injection valve element 3 to be later referred to. The tip member 2 is reduced in diameter throughout a portion of its length to form a shoulder 2', which is engaged by a shoulder on a sleeve 2*c*, the upper end of which is threaded on the lower end of the neck portion 1*b* to removably secure the tip member in position. The head 1*c*, main body portion 1*a*, neck portion 1*b* and tip member 2 are formed with ducts in connected relation to provide a fuel supply conduit 4 suitably connected at its upper end with the conduit I and leading to the chamber 2*x*; also these parts are formed with ducts in connected relation to provide a fuel conduit 5 leading from the chamber 2*x* to an outlet 6, connected to a pipe 7, which leads to the fuel supply or storage tank (not shown). A stop valve 8 is provided in the conduit 5, forming a valve controlled bypass, for a purpose later set forth.

The injection opening through the tip member 2, located between the valve seat 2*a'* and the engine cylinder, is accurately sized to permit the passage therethrough of exactly the desired amount of fuel required by the particular engine to which the injection valve is applied when the valve element 3 is moved from its seat to give free flow of fuel from the pressure feed line I to the engine cylinder.

The shank 3*a* of the injection valve 3 slidably extends through the neck 1*b* and an opening in a plug 9 threaded in the upper end of the main portion 1*a*, the upper end of the shank 3*a* being threaded to adjustably support a cap 10, which is engaged by one arm of a rocker 11 suitably fulcrumed on a standard 12. The plug 9 serves as an abutment for one end of an expansion spring 13 coiled around the shank 3*a*, the other end of the spring engaging a collar 14 fixed to the shank and normally acting to seat the valve 3 against its seat. The plug 9 is positioned in the body portion 1*a* so as to adjust the tension of the spring to the predetermined pressure desired to effect or permit opening of the injection valve 3. The lower end portion of the shank 3*a* is reduced to form an annular shoulder 3' against which the fuel pressure acts to unseat the valve 3.

The stop valve 8 comprises a seat member 8*a* removably mounted in an opening formed in the head 1*c* and a plunger 8*b*, the lower end of which forms the valve element to engage the seat member. The opening through the seat member communicates with the adjacent ducts of the conduit 5. The upper end of the opening in the seat member 8*a* is of conical shape to form the seat for the similarly shaped lower end of the plunger 8*b*. The plunger slidably fits an opening formed in a plug 15 threaded into an opening formed in the head 1*c*, the upper end of the plunger 8*b* being arranged to be engaged by the other arm of the rocker 11. The upper end of the plug 15 is provided with a boss to which a split collar 16, which is connected to the standard 12, is suitably clamped. As the rocker 11 engages the plunger 8*b* and shank 3*a*, the injection valve 3 is closed when the stop valve 8 is opened, and when the valve 3 is opened, valve 8 is closed.

Fuel supplied under pressure by the pump H flows through the conduit 4 to the injection valve 3 and if the latter is closed, the fuel flows through the conduit 5 to the return pipe 7, the pressure of fuel serving to lift the plunger 8*b* and permit such fuel flow to the pipe 7. This fuel flow permits air contained in the fuel line to escape and those pressure waves originating at the pump and caused thereby during this stage of operation to be eliminated so long as the injection nozzle valve remains closed. As soon as the pressure of the fuel rises to a point sufficient to overcome the pressure of the spring 13 (which spring pressure is adjusted to a predetermined tension dependent upon the area of the valve 3), the resulting fuel pressure acting on the shoulder 3', which has an area larger than that of the valve element 3, will lift the valve element 3 from its seat, permitting the injection of the fuel into the combustion chamber or cylinder.

Because of the low pressure in this chamber, compared with the high pressure of the fuel, the fuel will tend to regain its original or normal density and volume, in proportion to said pressure difference, resulting in a sudden pressure drop in the injection nozzle, and as the compressibility of fuel oil is very low, and said pressure difference is very high, this sudden drop in pressure creates a tension or rarefaction wave, which travels from the injection nozzle tip to the pump or pressure source and back and forth. As the time period of these waves is very short compared with the time of injection for Diesel-cycle operations, these waves or fluctuations, of which a plurality occur during each injection, prevent gradual fuel injection.

When the injection valve 3 lifts, it operates the rocker which in turn closes the stop valve to stop the flow of fuel through the conduit 5, the effect of which, due to the sudden check in the velocity of the fuel, is to cause a pressure wave of equal frequency and of opposite phase to that of the tension wave and traveling from the stop valve to the pump and back and forth. These tension and pressure waves just referred to have practically the same period (the difference between them in this respect being so slight as to be immeasurable and hence may be disregarded) and if their amplitudes be the same they may be caused to neutralize or damp out each other so that they have no practical effect in the injection nozzle, with the result that a gradual and continuous injection of fuel into the combustion chamber takes place.

To secure this wave balancing effect in order to insure a smooth flow of fuel into the engine cylinder it is especially important that the waves of force of opposite phase,—the tension waves originating at the injection valve and the pressure waves originating at the by-pass or stop valve,—shall accurately oppose each other, as distinguished from being in more or less staggered or out of step relationship, as has been the case in earlier attempts to obliterate these waves of force which interfere with proper fuel feed. I have discovered that this accurate harmonic opposing of these waves of opposite phase may be accomplished by properly operating the injection and the by-pass or stop valves with relation one to the other. Thus the injection valve is so operated that its discharge passage 2*b* into

the engine cylinder is fully opened or exposed to the full flow of fuel from the pressure line I almost instantly upon the starting of the simultaneous movements of the two valves; for an exceedingly short movement of the valve stem 3 at the beginning of the movement of the valves insures this full fuel feed opening,—further movement of the valve stem 3 not affecting the opening or size of the fuel passage 2b. On the other hand the movement of the stop or by-pass valve must be gradual in its control of the flow of fuel through passage 18, this being insured by operating this valve so as to much prolong its flow-restricting or accelerating movements; for, as will be seen by reference to Figure 4 when the valve stem 8 moves with reference to the seat 8a' the flow passage to the port 18 is gradually varied in size by reason of the relatively long taper at the end of the stem.

I not only secure this accurate positioning in harmonic opposition of the waves of opposite phase, but I cause such opposing waves to be of equal force so they counter-balance each other, thus losing their interfering effects upon the flow of fuel which passes on into the engine cylinder as a smooth, steady stream. To insure this latter result I co-ordinate the discharge apertures in the two valves as to their sizes or areas in proportion to the differences in pressure on the delivery sides of the two valves.

It is evident that the flow of fuel through the injection valve is from the fuel line where the pressure is high,—let it be assumed 4000 lbs. per sq. in.,—into the engine cylinder where the pressure is much lower,—perhaps 500 lbs.; and that at the stop valve the flow is from the high pressure fuel line into the return pipe where the pressure may be atmospheric or thereabouts. Thus there is a very considerable difference in the pressures of the fluid passing the two valves respectively; and, since the volume of fuel passing the port or opening of a valve is governed both by the difference in the pressure of the fuel on the two sides of the valve, and the size of the port through which it is flowing, it becomes necessary, in order to secure the desired results in the counterbalancing and neutralizing of the effects of the waves of force traveling through the pressure column of liquid when the valves are operated, as has been described, that there be uniform volumetric flow through the two valves when they are operated. I have discovered that due to the facts just stated the fuel passage through the stop valve must be slightly smaller than the corresponding passage through the fuel injection valve, as they are simultaneously operated, to effect this desired result and insure a uniform delivery of fuel to the injection nozzle.

To insure accuracy, the mounting for the rocker 11 may be adjusted laterally the effect of which is to change the length of the rocker arms relative to the points of contact with the shanks of the valve elements. This adjustment is preferably provided for by an eccentric 11' having an extended end (not shown) to permit its operation and suitable means for securing it in operated position. In connection with such adjustment, the cap 10 may be adjusted to provide the accurate relationship between the valves; also the plunger for valve 8 may be provided with an adjustable cap, similar to cap 10, if found to be desirable.

If a wider seat for valve 3 is needed, for example where a multiple hole nozzle tip or a pintle type of nozzle valve is used I can either provide the proper size seat openings by the use of correspondingly different valve seat angles, or by a combination with different rocker arm lengths as described, or I can use equal valve seat diameters in combination with equal discharge openings.

Fig. 4 shows a valve head arrangement embodying the several features of my invention. Referring to this view it will be seen that the injection valve 3 is provided with a pintle 17 which is concentric with the discharge opening 2b through the valve seat member 2 and extending into or through the same so as to reduce the effective area for the flow of fuel through said passage. The area of the closing seat 2a' with which the tapering end of the valve stem cooperates is much greater than is the area of the discharge opening 2b, and its shape is such that a very slight lift or movement of the valve stem 3 operates to effect a full opening of the engine cylinder injection passage, while a further movement of the valve stem has no effect on the size of such passage. On the other hand the taper of the by-pass valve stem 8 is longer and more gradual than that of the stem 3 with the result that the change in the size of passage between the seat 8a' and the taper of the valve stem 8 takes place throughout the full movement of the stem,—from full open to completely closed position and vice versa,—so that the starting of the operation of the by-pass valve,—either to open or to close—is synchronous with the simultaneous movements of the two valves.

From the foregoing description it also will be understood, that a change of type of the injection valve 3, or the slightest change of the amount of discharge through said valve, will call for an equivalent change of the character of the stop valve 8 and its discharge opening. To permit of change in the seat of the stop valve, I provide its seat in an insert member 8a, which is readily accessible and removable and is constructed to have the discharge passage 18, of the proper size such as has been described, located at such distance from the seat 8a' with which the tapering valve stem 8 cooperates as permits the gradual closing and opening movements of the valve as has been pointed out.

The importance of an accurate balance of the waves of pressure, when the injection valve 3 is suddenly opened, and when the stop valve 8 is closed, is shown diagrammatically in Fig. 6. The line 36 represents atmospheric pressure and the line 37 represents the pressure at full fuel flow. The line 38 represents the length of time or duration of each injection, and the line lengths indicated at 39, 39a, 39b, etc. represent the time period of the tension waves and pressure waves.

When the injection nozzle 3 starts to unseat at point 40, the compressed fuel rushes out, represented by line 49, trying to accelerate to a velocity of full flow at line 37, but before it reaches this point it expands to its normal density which results in a sudden pressure drop, which maximum at point 41 will occur in the time interval represented by 39, and immediately surge up again to a maximum pressure at 42, followed by a maximum drop again to point 43, which action will be repeated in the character of tension waves, and having a constant time period from point 40 to 41, from 41 to 43, etc. represented by the constant equal length of lines 39, 39a, 39b, etc.

As these fluctuations under practical conditions are repeated several times in the duration of each injection, represented by the length of line 38, a gradual or uniformly smooth injection has hitherto been impossible. But, when the injection valve

3 starts to unseat the stop valve 8 simultaneously starts to close, and as the momentum of the suddenly stopped fuel column in conduit 5 is equal to the momentum of the fuel column in conduit 4 suddenly released by valve 3, a pressure wave 44 is originated, which maximum pressure is reached at point 45 having precisely the same frequency and intensity and of opposite phase as the tension wave 49, and thus the forces are balanced as described. The pressure rise represented by the length of the line 47, will precisely balance the pressure drop represented by the line 46. As all of the following pairs of pressure and tension waves will likewise become balanced, an effective pressure, represented by the line 48, will result in a controlled constant and gradual injection practically free from fluctuations.

It will be observed that the tip or valve seat member 2 of the injection valve, and the seat member 8a of the stop valve, are both relatively simple parts and are arranged and mounted so as to be easily removable and replaceable without disturbing the other parts of the entire valve assemblies. The purpose of this arrangement is this: in practice the two valve assemblies—the injection valve and the stop valve—are standardized so as to be fitted to engines of varying sizes and operating conditions. But for each different size of engine and for engines of the same size where operating conditions are widely different, the flow of fuel past the two valves must be determined and the flow in the separate valves accurately related one to the other in order that the discharge of fuel into the engine cylinder shall be steady and uninfluenced by the periodically recurring fluctuations in pressure which take place in the vicinity of both of the valves, and due to their movements, whenever they are operated. This adjustment of the valves to suit special sizes and conditions of engines is determined by theoretical calculation, or trial and test for the particular engine in question, or by a combination of these methods of determination as to the proper parts to be used. These latter being determined upon may be easily inserted into their proper positions in the engine without disturbing the other parts of the valve assemblies.

To those skilled in the art to which my invention relates, many changes in construction and widely differing embodiments and applications of the invention will suggest themselves without departing from the spirit and scope of the invention. My disclosures and the description herein are purely illustrative and not intended to be in any sense limiting.

What I claim is:

1. A fuel injection apparatus for internal combustion engines, which includes a source of fuel supply under high pressure, a normally closed spring-controlled injection means comprising a valve seat having a discharge opening of predetermined size governed by the desired discharges into the engine cylinder, and a movable element co-operating with such valve seat, a by-pass means for periodically by-passing fuel to said source of supply and comprising a valve seat having a discharge opening and a movable valve element cooperating with said seat, the related surfaces of said last mentioned valve seat and valve element serving gradually to open or close the discharge opening through the valve seat during the movement of said valve element, the discharge opening through said last mentioned valve seat being smaller than the discharge opening through said injection means valve seat and said openings being proportioned to the relative pressures respectively beyond the same, the higher pressure being beyond the injection valve where it discharges into the engine cylinder, and means for operating said movable valve elements for effecting the opening of one valve simultaneously with the closing of the other, said means being co-ordinated with the relative sizes of said discharge openings to insure equal volumetric flow through said openings.

2. An apparatus such as described in claim 1, wherein the valve operating means comprise a rocker engaging the valve elements of said valves arranged to close one valve when the other is opened, the arms of said rocker being related to the relative sizes of the openings for said valves to provide for the same volumetric discharge of fuel through one when open as through the other when the latter is open.

3. An apparatus such as described in claim 1, wherein the valve operating means comprise a rocker engaging the valve elements of said valves arranged to close one valve when the other is opened, the arms of said rocker being related to the relative sizes of the openings for said valves to provide for the same volumetric discharge of fuel through one when open as through the other when the latter is open, and means for adjusting the fulcrum for said rocker.

4. An apparatus as claimed in claim 1 wherein the movement of the valve element of the injection valve away from its seat by the operating means terminates when the valve element of the by-pass valve closes its valve, and the movement of the valve element of the by-pass valve away from its seat by the operating means terminates when the valve element of the injection valve closes its valve.

5. The herein described method of operating an internal combustion engine of the Diesel type, wherein is employed a feed system of fuel under pressure, including a source of supply, a fuel line to an engine cylinder, a return line to the source of supply and a normally closed injection valve in the fuel supply line, which method consists in operating the injection valve, in synchronized relation to the compression stroke of the engine piston, through a predetermined cycle and causing an opening of its injection port to provide a pre-determined volume flow of fuel in the initial portion of the cycle, maintaining such opening through an intermediate portion of the cycle and finally closing the injection port in the latter portion of the cycle whereby tension waves are set up in the fuel, and simultaneously in the return line beyond the injection valve and during and throughout the complete cycle of movement of the latter valve, checking the flow of fuel through a port of smaller area than the port of the injection valve to set up pressure waves which are of opposite phase to the tension waves and controlling the pressure waves so that they start at the time the injection valve starts to open and are stopped at the time the injection valve closes.

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