

[54] **FUEL INJECTING DEVICE FOR AN INTERNAL COMBUSTION ENGINE**

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[56] **References Cited**

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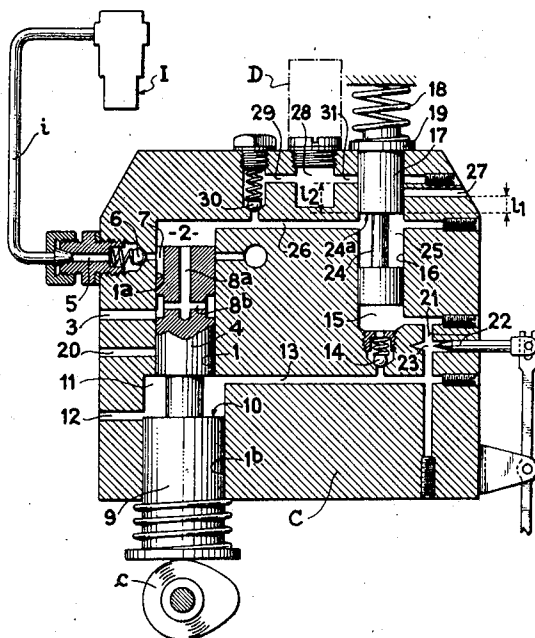
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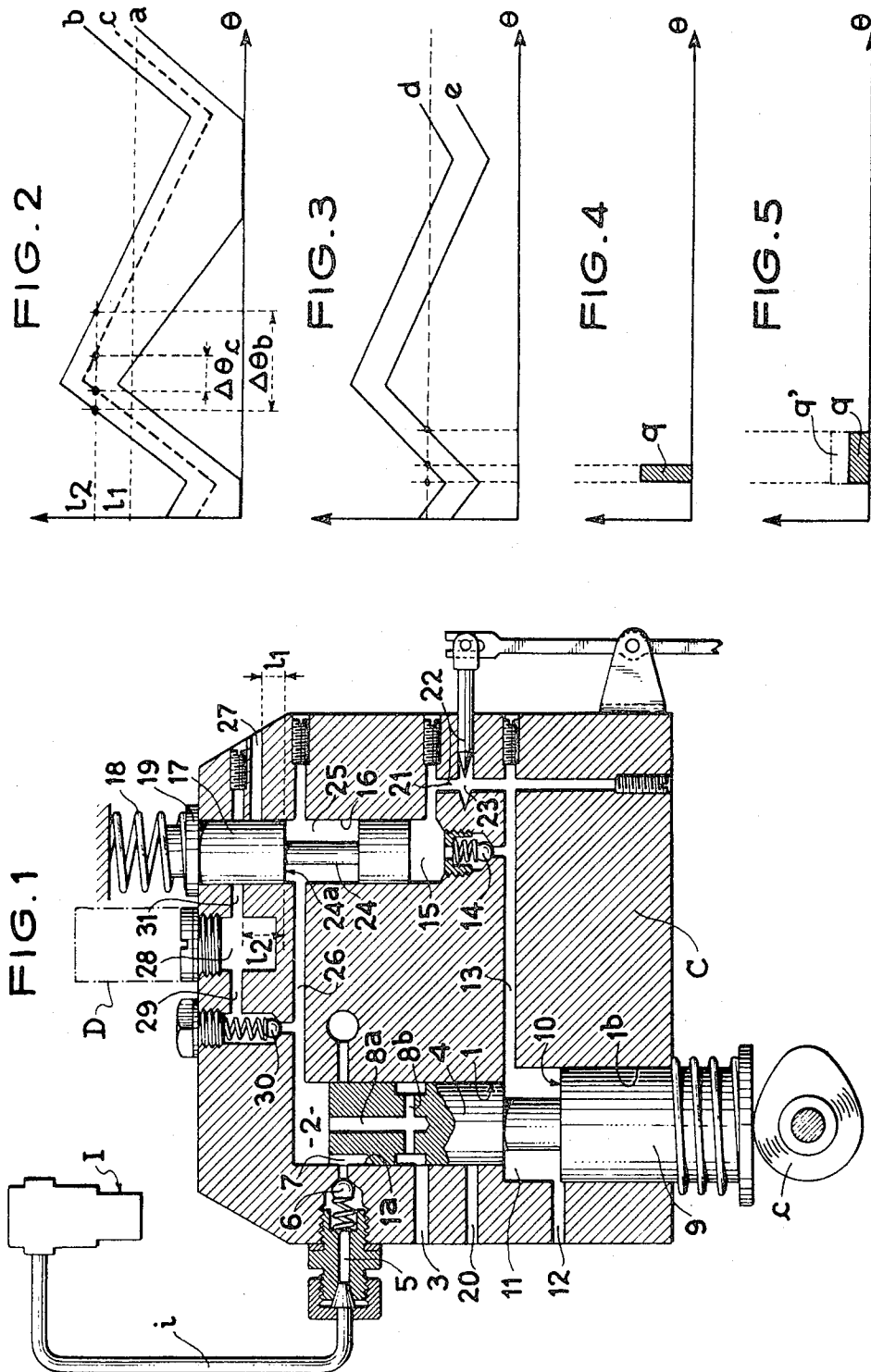
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[57] **ABSTRACT**

Fuel injecting device for an internal combustion engine comprising at least one injection pump connected to at least one injector and a regulating system of the liquid abutment type formed by a fuel relief or discharge passageway for the injection pump in which is interposed a movable closing member whose movement is controlled by a fluid pressure regulated by an acceleration control of the engine so that the amount of fuel delivered for each stroke of the pump is determined by the movement of the closing member. The characteristic of the injecting device is that a fuel deducting chamber having an inlet constituted by a throttling orifice is connected in parallel with the discharge passageway upstream of the closing member.

4 Claims, 5 Drawing Figures





FUEL INJECTING DEVICE FOR AN INTERNAL COMBUSTION ENGINE

The present invention relates to fuel injection devices for pressure-ignited internal combustion engines.

Devices have been described in the U.S. Pat. No. 3,456,629 and U.S. application Ser. No. 801,961 filed by the Applicant whereby it is possible to modify the law of injection of the fuel under given conditions of operation of the engine so as to improve the conditions of combustion and render operation of the engine much less noisy.

These devices may be adapted to conventional injection systems and comprise a fuel deduction chamber having a variable volume and connected to the delivery chamber of the injection pump by way of a restricted or throttling orifice, and neutralizing means for holding the movable wall of the delivery chamber stationary or closing the passage interconnecting the delivery chamber and fuel deducting chamber, said neutralizing means being so arranged that the injection law is modified only under given conditions for which this modification is necessary.

Injection systems are also known in which the regulation of the amount of fuel injected is effected by a "liquid abutment" device.

An example of such a system is described in French Pat. No. 1,452,638.

The object of the invention is to provide a device for effecting a modification of the injection law under predetermined conditions of operation of the engine in the case where the injection system for the engine comprises a liquid abutment regulating device.

The invention provides an injection device for an internal combustion engine comprising at least one injection pump connected to at least one injector and a regulating system of the "liquid abutment" type comprising a discharge passageway of the injection pump in which is interposed a closing member whose travel is controlled by a fluid pressure regulated by the acceleration control of the engine, whereby the amount of fuel delivered to the injector for each delivery stroke of the pump is determined by the travel of said closing member, wherein there is branch-connected to said discharge passageway, upstream of said closing member, a fuel deducting chamber having an inlet constituted by a throttling orifice.

According to one embodiment of the invention, the throttling or constricted orifice of said fuel deducting chamber has a check valve and said chamber has an outlet connected to said discharge passageway under the control of said closing member.

By means of this arrangement and under certain conditions of operation of the engine, there is superimposed on the regulation afforded in the usual manner by the liquid abutment system, a supplementary modification of the injection law for avoiding brutal combustion and undesirable engine noise. This modification of the injection law has for effect to distribute the injection of the fuel in an improved manner with respect to time without however modifying the total amount of fuel injected, which is determined by the conditions of load and speed of operation of the engine. Further, apart from its usual function, the liquid abutment regulating system performs a further function of neutralizing the deduction of the fuel as soon as said conditions of operation are no longer satisfied.

Further features and advantages of the invention will be apparent from the ensuing description with reference to the accompanying drawings.

In the drawings:

FIG. 1 is a partial diagrammatic sectional view, partly in elevation, of an injection device according to the invention;

FIGS. 2, 3, 4 and 5 are graphs representing the results obtained with the device shown in FIG. 1.

FIG. 1 shows a body C containing an injection pump and a part of the regulating system, injection conduits, such as conduit *i*, connecting the injection pump to injectors, such as I.

The injection pump comprises a cylinder 1a which is a part of a stepped bore 1 and defines a delivery chamber 2 con-

nected to a fuel pump (not shown) by way of a supply orifice 3. The chamber 2 receives a piston 4 which pumps the fuel, by way of passage 5 and a check valve 6, to the injector I. The piston 4 has a lateral recess 7 and passageways 8a, 8b. The recess 7 communicates with the injection conduits *i* and the passageways 8a, 8b put the supply passageway 3 in communication with the delivery chamber 2. The piston 4 is shifted by a mechanism of which only a cam *c* has been shown. The latter operates in synchronism with the engine and causes the piston to undergo an axial reciprocating motion and a rotary motion which are so combined as to deliver the fuel and distribute it to the various injectors. Such a unit constitutes a distributor pump. However, it must be understood that the invention is also applicable to a system having pumps in line, in which the distribution function is omitted.

The regulating system comprises a differential piston 9 which is integral with the piston 4 and located in a part 1b of the bore 1. The two pistons are separated by an annular recess 10. The differential piston 9 and the bore 1 define a chamber 11 which is connected, by way of a passageway 12, to the supply pump and, by way of a passageway 13 and a check valve 14, to a chamber 15 defined by a bore 16 and a slide valve 17 which is slidably mounted in the bore and biased to its lower position by a spring 18. The lower position of the valve 17 is determined by the abutment of a flange 19 against the body C.

The recess 10 between the pistons 4 and 9 permits a discharge of fuel from the chamber 11 by way of an orifice 20 for an axial movement or rise of the piston which is slightly less than its maximum travel, this discharge being, for example, to the supply pump.

A pipe 21, which is in parallel with the check valve 14, has a needle valve 22 which is shifted by the accelerator through a suitable mechanism and constitutes a variable throttling means 23.

The slide valve 17 has an annular recess or groove 24 which is located between two lands and defines with the bore 16 a chamber 25 permanently communicating with the delivery chamber 2 of the injection pump by way of a passageway 26. An orifice 27 serves as a discharge orifice for the chamber 25 when the slide valve 17 has been shifted or raised an extent exceeding l_1 . This orifice can be, for example, connected to the fuel supply pump.

According to the invention, the device is completed by a fuel deducting chamber 28 which communicates, on one hand, with the passageway 26 by way of a constricted or throttling orifice 29 and a check valve 30 and, on the other hand, with the bore 16 by way of a passageway 31 which is suitably positioned with respect to the upper face 24a of the recess 24 of the slide valve. In the presently described embodiment, the face 24a un.masks or uncovers the orifice 31 for a movement or rise l_2 of the slide valve 17 which exceeds l_1 .

Operation of such a device will first be rapidly described, assuming that the fuel deducting means according to the invention designated by the reference numerals 28 to 31, are not included.

During a delivery travel or stroke of the piston 4, 9, there is produced simultaneously, on one hand, a delivery of fuel to the injector I by the piston 4 as soon as the latter has closed the supply passage way 3 and, on the other hand, a delivery of fuel by the differential piston 9 to the chamber 15, by way of the passageway 13 and the check valve 14, which causes the slide valve 17 to move or rise. When this rise has reached the value l_1 there is created a fuel discharge path 26, 25, 27 for the fuel contained in the chamber 2 and the injection ceases. Just before the extreme upper position of the piston is reached as soon as the recess 10 uncovers the orifice 20 and during the descending phase of the cam and piston, the slide valve 17 biased by the spring 18 descends and urges the fuel contained in the chamber 15 through the passageway 21 and the throttling orifice 23.

The slide valve 17 therefore descends at a speed depending on the section of passage of the throttling means 23, which are controlled by the accelerator.

Two cases may arise :

1. Before the following injection, the slide valve 17 has sufficient time to return to its lower position determined by the abutment of the flange 19 against the body C. In this case, the quantity injected is maximum. This corresponds to full-load conditions.

The law of movement of the slide valve 17 corresponding to this case is represented graphically in FIG. 2 by the curve a.

2. If the section of passage of the throttling means 23 is small enough, and/or if the speed of operation of the engine is high enough, between two injections, the slide valve has no longer time enough to redescend to its extreme position determined by the abutment of the flange 19 against the body C. When the differential piston 9 once more discharges fuel at the start of the following cycle, the slide valve starts from a higher point of departure. In its extreme lower position, the slide valve 17 has what might be called a "liquid abutment."

In this case, the quantity of fuel injected is less than before since the slide valve 17, in starting from a higher position, reaches the level 11 sooner and uncovers the discharge orifice 27 which results in the injection being stopped sooner.

This case corresponds to "regulation" or "partial load" conditions of operation.

The law of the movement of the slide valve corresponding in this case is represented graphically in FIG. 2 by the curve b.

Depending on the conditions of operation, the lower extreme position of the slide valve, determined by the liquid abutment, is more or less high and the quantity of fuel injected can therefore be of any value between zero and the maximum quantity corresponding to full load.

If the improvement according to the invention is now taken into account, the operation of the device is modified in the following manner.

During a fuel injecting travel or stroke of the piston 4, fuel is deducted in chamber 28 and acts on the law of injection in a manner similar to the procedure described in the aforementioned U.S. Pat. No. 3,456,629 and U.S. application Ser. No. 801,961. At the end of the injection, the check valve 14 closes and prevents the fuel deducted from being restored to the delivery chamber 2.

As the discharge of fuel from the deducting chamber 28 can only occur by way of the passageway 31, the chamber 25 and the orifice 27, two situations are possible :

1. Under full-load conditions, the total rise or travel of the slide valve 17 is insufficient to uncover the passageway 31. Consequently, the chamber 28 cannot be emptied and remains of fuel at the maximum injection pressure. Thus, in the following injections, there is no deduction of fuel. The system operates as though there were no fuel deducting device.
2. Under partial load conditions, the slide valve 17 has a liquid abutment and is shifted from a higher extreme lower position and displaced to such a level that, after deduction of fuel, the orifice 31 is uncovered and put in communication with the discharge orifice 27. Under these conditions, the fuel deducting device is operative for each injection and the law of injection is modified as follows :

For a partial load close to full load, that is, for a liquid abutment close to the solid abutment of the slide valve 17, the chamber 28 communicates with the discharge orifice 27 for a very short period of time. This situation is represented by the curve c shown in FIG. 2. The angle of rotation $\Delta\theta c$ of the cam during which the fuel discharged is small. The corresponding very short period of time combined with the throttling of the passageway 31 by the face 24a of the slide valve 17, in this case allows only a partial discharge of fuel from the chamber 28 and the fuel deduction is incomplete. Indeed, the fuel deducting chamber 28 has practically no time to discharge fuel and a pressure p_c remains in the chamber after discharge and the fuel deduction in the course of the following injection of fuel corresponds to the variation in the volume of fuel due

to the pressure variation ($p_{max} - p_c$); p_{max} being the maximum injection pressure.

- 5 On the other hand, at very low loads, the discharge lasts longer and consequently the fuel deduction is greater. This case is represented by the curve b shown in FIG. 2. The discharge in this case takes place during an angle of rotation $\Delta\theta b$ of the cam which is greater than $\Delta\theta c$.

The pressure p_b at the end of the discharge is therefore lower than p_c since the relief of pressure lasts longer. Consequently, the quantity of fuel deducted for each injection in this case corresponds to a greater pressure variation ($p_{max} - p_b$). Consequently, a larger quantity of fuel is deducted than in the preceding case.

- 15 Owing to the combination of the liquid abutment regulating system and the supplementary fuel deducting means according to the invention, there is therefore achieved, for a given speed of operation of the engine, a deduction of fuel which varies with the load and which can be zero at full load and increase progressively as the load decreases.

Further, for a given partial load, that is, for a given height or level of the liquid abutment for the slide valve 17, the device has less and less effect as the speed of operation of the engine increases. Indeed, the higher the speed of operation, the shorter the time between two cycles and the shorter the time for discharging fuel from the deducting chamber 28 and the smaller the quantity of fuel deducted.

The effect of the deduction of fuel in accordance with the invention is more clearly brought out by a comparison of the injection laws under identical conditions, low load and low speed of operation (for example an idling engine), obtained with a conventional injection device having a liquid abutment regulation and with the improved device according to the invention.

- 35 In both cases, the quantities of fuel injected q must be the same, assuming that the associated engines are identical. These two cases of operation are shown in FIGS. 3, 4, and 5. The curve d shown in FIG. 3 and FIG. 4 respectively illustrates the law of the rise of the slide valve 17 and the law of the flow of fuel delivered by the injection pump in the case of fuel injection without deduction of fuel. As there is no fuel deduction, the quantities of fuel delivered and injected are identical and the curve shown in FIG. 4 therefore also represents the injection law.

The curve e shown in FIG. 3 and FIG. 5 respectively corresponds to the curve d shown in FIG. 3 and FIG. 4 in the case of the injection device having fuel deducting means. The pump must then deliver for each injection a quantity $Q = q + q'$ in which q' is the quantity deducted by the chamber 28.

As the beginning of the delivery of fuel in both cases occurs at the same moment (when the piston 4 closes the supply orifice 3), the end of the delivery with deduction of fuel therefore occurs later for a given injected quantity q . The law of movement of the slide valve 17 is therefore different, since the slide valve must open the discharge of the end of injection later (curve e shown in FIG. 3). It corresponds to a throttling orifice 23 having a fuel passage section which is slightly larger than in the preceding case and therefore corresponding to a slightly different position of the accelerator. The regulation rate in both cases is the same, the means rate of descent of the slide valve 17 being unchanged. An increase in the section of the fuel passage of the throttling orifice 23 which would have a tendency to cause the slide valve 17 to descend more rapidly, is compensated by a decrease in the mean force of the return spring of the slide valve, the liquid abutment in the second case being lower and the mean compression of the spring being less.

As the characteristics of the fuel deducting system are chosen in such a manner as to result in a simultaneous injection and deduction of fuel, there is obtained an injection law such as that shown in FIG. 5. It will be understood that it is possible to obtain injection laws which are different from that shown. Indeed, it is possible to obtain, according to the characteristics of the fuel deducting system, injection laws

which are similar to those described in the aforementioned patents. For this purpose it is sufficient to replace the constant volume chamber 28 by a variable volume chamber, for example in accordance with the various embodiments disclosed in the aforementioned patents. These various possible modifications have been represented in dot-dash line in FIG. 1 in the form of a device D for varying the volume of the fuel deducting chamber 28.

Thus, it is clear that with this simple device, approximately combined with the regulating system of a fuel injection device of the liquid abutment type, it is possible while retaining under some conditions of operation the same injection characteristics, to automatically modify the injection law in other conditions of operation and in particular at low speeds of operation and low loads, the neutralization of the fuel deducting means outside these conditions being effected by the regulating system itself.

It must be understood that in addition to the means cancelling or neutralizing the fuel deducting device constituted by the slide valve 17, another cancelling or neutralizing means could be provided. For example the passageway 29 may be closed by a closing or valve member connected to the accelerator lever of the engine as described in the aforementioned U.S. application Ser. No. 801,961.

Alternatively, the movable wall of the device D may be held stationary as described in the aforementioned U.S. Pat. No. 3,456,629.

Having now described our invention what We claim and desire to secure by Letters Patent is:

1. In a fuel injecting device for an internal combustion engine comprising at least one injection pump connected to at least one injector and a regulating system of the liquid abut-

ment type formed by a fuel relief or discharge passageway for the injection pump in which is interposed a movable closing member whose movement is controlled by a fluid pressure adapted to be regulated by an acceleration control of the engine whereby the amount of fuel delivered to the injector for each delivery stroke of the pump is determined by the movement of said closing member, the feature that there is provided, connected in parallel with said discharge passageway upstream of said closing member, a fuel deducting chamber having an inlet constituted by a throttling orifice combined with a check valve and an outlet which communicates with said discharge passageway under the control of said closing member.

2. A fuel injecting device as claimed in claim 1, wherein said closing member is a slide valve slidably mounted in a bore and subjected to two opposed forces, namely a fluid pressure and a resiliently yieldable return means, said slide valve having an annular recess between two bearing portions which are in sliding contact with said bore, said recess being a part of said discharge passageway when it puts two orifices opening into said bore in communication with each other, said fuel deducting chamber communicating with said bore by way of a passageway which opens into said bore at a level higher than that of said orifices whereby the fuel is discharged from said fuel deducting chamber upon a travel of said slide valve which is greater than that in respect of which the discharge of the injection pump by way of said discharge passageway occurs.

3. A fuel injecting device as claimed in claim 1, wherein said fuel deduction chamber has a constant volume.

4. A fuel injecting device as claimed in claim 1, wherein said fuel deducting chamber has a variable volume.

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