FUEL INJECTION SYSTEMS FOR INTERNAL COMBUSTION ENGINES
WITH AUTOMATIC VARIATION OF THE ADVANCE
OF FUEL INJECTION

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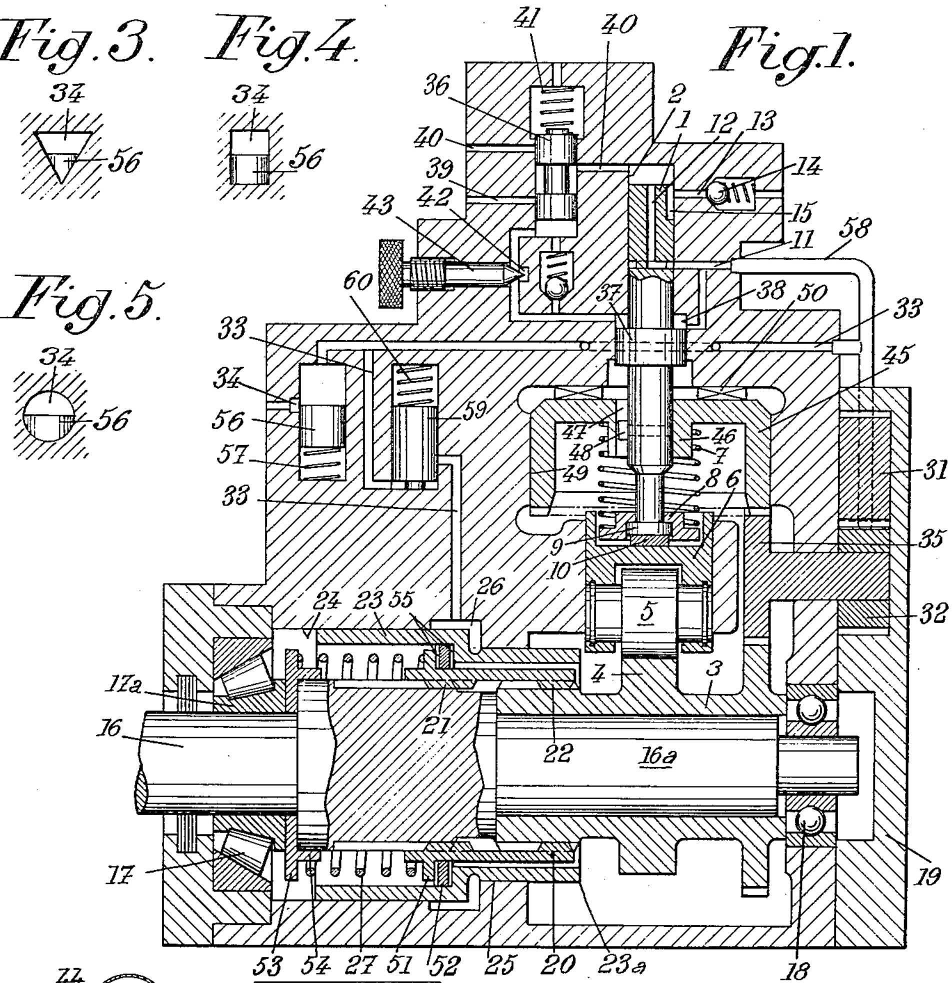
Fig. 3. Fig. 4. Fig. 5. Fig. 1.



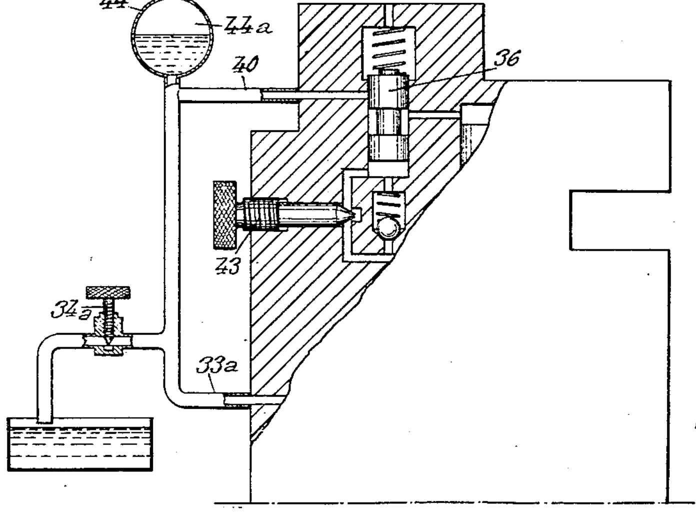


Fig. 2

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FUEL INJECTION SYSTEMS FOR INTERNAL COMBUSTION ENGINES WITH AUTOMATIC VARIATION OF THE ADVANCE OF FUEL INJECTION

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The present invention relates to fuel injection systems for internal combustion engines with automatic variation of the advance of fuel injection.

There are known systems of this kind which include a threaded sleeve adapted to be moved axially and serving to connect the driving shaft, or a shaft driven by said driving shaft at a speed proportional to the speed thereof, to a rotating member which produces, through suitable mechanical means such as cams, connecting rods, links, eccentrics, etc., the axial reciprocating movement of the fuel injection pump piston, at least in one direction.

It is also known to produce the axial displacement of said sleeve by means of a hydraulic ram or jack acting against a return force under the effect of a pressure the value of which varies with the speed of the engine fed with fuel from the injection pump.

The object of my invention is to provide a device of this kind which is better adapted to meet the requirements of practice than those known up to this time.

According to the invention, I make use, to produce the pressure variable with the speed which is to act upon the piston of said hydraulic ram, of a volumetric pump driven at a speed proportional to that of the internal combustion engine and in the delivery circuit of which there is provided a leak through an outlet the area of which increases when the delivery pressure of said volumetric pump increases as a consequence of an increase of the speed of the engine, and vice versa. The variation of area of this outlet as a function of the speed serves to moderate the variation of pressure acting upon the piston of the hydraulic ram. It is thus possible to obtain a variation of the advance of fuel injection over a very wide range of different speeds.

It should be well understood that the term "volumetric" pump designates a pump such that the delivery flow rate thereof is proportional to the speed at which it is driven.

Other features of my invention will become apparent in the course of the following detailed description thereof.

Preferred embodiments of my invention will be hereinafter described with reference to the accompanying drawings, given merely by way of example and in which:

FIG. 1 diagrammatically shows, in axial section, a fuel injection pump made according to the invention and in which the variable pressure acting upon the hydraulic ram is proportional to the speed at which the pump is driven.

FIG. 2 is a partial view diagrammatically showing a modification of the pump of FIG. 1, where the hydraulic ram is operated in accordance with the load of the engine fed with fuel by the injection pump.

FIGS. 3 to 5 inclusive show a detail of FIG. 1 according to three modifications, respectively.

The pump illustrated by way of example in FIG. 1 is a pump the piston of which acts as a distributing valve so as to produce successive fuel injections into the respective cylinders of an internal combustion engine from a single pump working chamber. This is a possible application of the invention but this disclosure has no limitative character.

The reciprocating movement of pump piston 1, which is slidable in cylinder 2, is obtained from a hollow shaft 3 carrying a cam 4 which acts upon the lower end of piston 1 through a roller 5 mounted in a push-piece 6 against which the lower end of piston 1 is applied by a spring 7. The upper end of said spring bears against a fixed piece which will be hereinafter referred to, whereas the lower end of said spring acts upon a cup-shaped member 8 bearing against a shoulder 9 provided at the lower end of piston 1, a plate 10 being interposed between said shoulder 9 and push-piece 6 so as to reduce the friction between the piston and the push-piece when the piston has, in addition to its reciprocating movements, a movement of rotation about its axis, as hereinafter explained.

Fuel is fed to the working chamber of cylinder 2, that is to say the portion of said cylinder located above piston 1, through a feed conduit 11 provided in the side wall of the cylinder and a conduit 12 provided in piston 1, fuel feed taking place when these two conduits 11 and 12 register with each other, which is for instance the case when piston 1 is in its lower dead center position, as illustrated by the drawing. Furthermore, the side wall of cylinder 2 is provided with a plurality of delivery conduits 13 (only one of which is shown by FIG. 1) each provided with a check-valve 14. Each of these delivery conduits is, during one delivery stroke, in communication with the working chamber of cylinder 2 through a groove 15 provided in the side wall of piston 1. Said piston is rotated about its axis through means which will be hereinafter described, so that it acts as a distributing valve. It will be understood that the delivery of fuel through each of said conduits 13 and the feed of fuel to an injector (not shown) to which said delivery conduit leads begins as soon as piston 1, at the beginning of its upward stroke (delivery stroke), has separated conduits 11 and 12 from each other.

Camshaft 3 is rotated through a shaft 16 journalled, for instance through bearings 17 and 18, in the casing 19 of the pump. This shaft 16 is driven in such manner by the shaft of the engine fed with fuel by the injection pump that the instantaneous angular positions of shaft 16 always correspond to the same instantaneous angular positions of the engine driving shaft. Hollow shaft 3 is mounted on an extension 16*a* of shaft 16 so as to be able to rotate about said shaft without however being able to move axially with respect thereto. The coupling connection between shaft 16 and shaft 3 is ensured by a threaded sleeve 20 provided with helical teeth of small obliquity 21, 22, in mesh with corresponding helical teeth carried, respectively, by shaft 16 and shaft 3. Teeth 21, 22 are inclined in opposite directions. It will be understood that said sleeve 21 serves to couple shafts 16 and 3 together, while producing a variation of the angular position of shaft 3 with respect to shaft 16 when it is displaced in the axial direction. Such a variation corresponds to a variation of the advance of fuel injection by the pump.

In order to produce this axial displacement of sleeve 20 in accordance with variations of the speed or of the load of the engine supplied with fuel by the injection pump, I provide an annular hydraulic ram or jack surrounding sleeve 20 and disposed in the casing 19 of the pump. I thus obtain a considerable reduction of the total volume of the pump and I make use only of pieces of revolution which are easy to machine.

The tubular piston 23 of said ram is a stepped piston including two portions which are slidably fitted in two respective bores 24, 25 of different respective diameters of the pump casing. Thus, a free space 26 exists between the shoulder separating the outer surfaces of stepped piston 23 and the shoulder separating the cylindrical walls of bores 24 and 25. This free space 26 constitutes the variable volume working chamber of the hydraulic ram, to which is fed a fluid the pressure of which varies with the speed of the engine and which tends to move stepped piston 23 toward the left, against the action of a return spring 27.

The annular shoulder of piston 23 preferably acts, as illustrated, through a coupling ring or annular plate 52 cooperating with a flange or collar 51 of threaded sleeve 20. Thus the cooperating surfaces of annular plate 52 on the one hand and flange 51 and the annular shoulder of piston 23 on the other hand are in frictional contact with one another respectively over large areas, so that piston 23 is driven in rotation by sleeve 20 with some slipping with respect to ring 52, which increases the sensitivity of response of piston 23 to variations of the forces acting thereon to move it axially.

In order further to facilitate the rotation of piston 23, spring 27 does not bear, at one of its ends, directly against piston 23 but against a flange 51 of sleeve 20. The other end of spring 27 bears against a shoulder 53 of an annular element 54 interposed between the rotating ring 17*a* of bearing 17 and a shoulder of shaft 16. Therefore, both ends of spring 27 bear against rotating pieces in turn together with them about the axis of shaft 16. This further has the advantage of protecting spring 27 against torsional stresses. Friction ring or plate 52 is advantageously provided, on both of its faces, with radial lubricating grooves 55.

When the pressure of the liquid in the working chamber 26 of the hydraulic ram increases, piston 23 and therefore sleeve 20 are moved toward the left, which produces a rotation of shaft 3 with respect to shaft 16 in one direction, whereas the movement of piston 23, and therefore the rotation of shaft 3 with respect to shaft 16, takes place in the opposed direction when the pressure in the working chamber 26 decreases.

Preferably, as shown, the portion of piston 23 which is slidable in bore 25 is so dimensioned that the edge 23*a* of said piston portion is always on the outside of said bore and never enters therein. This prevents any possibility of jamming of the ram.

The pressure variations in the working chamber 26 of the ram are produced by a volumetric pump, as above defined, for instance a gear pump 31, 32 driven at a speed proportional to that of the internal combustion engine and which delivers liquid into a conduit 33 provided with a discharge outlet forming a leak 34, said conduit 33 leading to the working chamber 26 of the ram. It is known that with such an arrangement the pressure in chamber 26 increases when the speed of rotation of pump 31, 32 increases, and inversely. In order to avoid too sudden variations of pressure, the cross-section area of the outlet forming the leak is controlled by a moderating valve. Such a valve is constituted, in the embodiment illustrated, by a piston 56 subjected in one direction to the pressure existing in conduit 33 and, in the other direction, to the action of an opposing spring 57. The whole is arranged in such manner that said moderating valve increases the area of the outlet forming the leak when the pressure in conduit 33 increases and reduces said cross-section area when this pressure in conduit 33 decreases. In order to obtain the best possible variation of the advance of fuel injection for every internal combustion engine, the shape of the outline of the outlet through which liquid can leak out is suitably chosen (circular, rectangular, triangular, or other shape) so that the variation of pressure in chamber 26 takes place according to a law corresponding to the desired variation of the advance of fuel injection.

Gear pump 31, 32 is driven by hollow shaft 3 which drives the gear 32 of said pump through a toothed wheel 35.

In the pump shown by FIG. 1, auxiliary pump 31, 32 serves both to supply the control pressure for the hydraulic ram and to feed fuel to the cylinder of the injection pump through a conduit 58 which connects the feed conduit 11 of the injection pump with the delivery conduit 33 of pump 31, 32.

It should be noted that in a hydraulic ram such as above described, it is impossible to avoid some leakage which reduces the pressure of the fuel supplied in working chamber 26 by volumetric pump 31, 32. For this reason, at low speeds of the internal combustion engine fed with fuel by the injection pump, for instance at idling speeds, say at speeds averaging 500 revolutions/minute, the delivery pressure of said auxiliary volumetric pump 31, 32 may become insufficient, due to the existence of such a leakage, to feed fuel to the injection pump. This danger is particularly great when the engine is being started by cold weather. On the contrary, for higher speeds of the engine, the delivery pressure of the volumetric pump 31, 32 is quite sufficient, despite the above mentioned leakage, and even requires the action of the moderating valve 56. On the other hand, at low speeds of the engine, there is no utility in obtaining a correction of the advance of fuel injection. This may remain constant for speeds of the engine up to for instance 800 revolutions/minute.

In view of these facts, I provide a closing valve 59 in conduit 33 at a point thereof downstream of that where feed conduit 58 branches off from conduit 33 and also downstream of the leak producing means 34. Preferably, this closing valve is controlled in accordance with the delivery pressure of volumetric pump 31, 32, that is to say as a function of the speed of the internal combustion engine. For instance, as shown by the drawing, said valve 59 consists of a piston which, under the effect of the pressure supplied by volumetric pump 31, 32, tends to open conduit 31, whereas a spring 60 tends to close said conduit.

As long as the engine runs at a relatively low speed, for instance below 800 revolutions/minute, valve 59 cuts off the delivery of pump 31, 32 from the working chamber 26 of the ram and any leakage as may exist in this ram can have no effect on the delivery pressure of the pump, which is determined exclusively by the leak producing means 34 controlled by moderator valve 56. It is only when the speed of the engine increases above 800 revolutions/minute that the delivery pressure of pump 31, 32 moves closing valve 59 sufficiently to open the communication between pump 31, 32 and the ram.

The pump illustrated by the drawings comprises self-regulating means for controlling, in accordance with the speed, the flow rate of the pump per cycle thereof. Said means operate on the basis of the so-called "liquid abutment" phenomenon. Such self-regulating means comprise a control member 36 called "shuttle" which, during the delivery stroke of the piston 1 of the pump, moves upwardly under the effect of a liquid delivered by an auxiliary piston 37 which is integral with the main piston 1 and which cooperates with an auxiliary cylinder 38. At the end of its upward stroke, which is determined by the opening of a discharge conduit 39, the shuttle opens another discharge conduit 40 in communication with the working chamber of cylinder 2 so that the opening of said discharge conduit 40 stops injection. During the downward stroke of pistons 1 and 37, shuttle 36 also moves in the downward direction under the action of a return spring 41, but this movement is slowed down due to the fact that the shuttle must force the liquid located under it, through a throttled passage 42, preferably adjustable by means of a screw 43. Consequently, when the speed of the pump exceeds a given value, shuttle 36 has not had time, during its downward strokes, to come back to its lowermost position when a new stream of liquid is supplied into the space below it to produce the next upward stroke thereof. The stroke is therefore shortened, which advances the time when the shuttle opens discharge valve 40 so that the amount of fuel delivered by piston 1 through conduit 13 decreases.

The rotation movement of piston 1 to cause it to act as a distributing valve is obtained through a toothed wheel 35 in mesh with the teeth provided on the edge of a bell-shaped wheel 45. In the hub 46 of said wheel 45 there is provided a longitudinal groove 47 which cooperates with a radial projection 48 carried by piston 1. The whole is arranged in such manner that piston 1 can have its reciprocating movements under the effect of cam 4, while being able to rotate about its axis under the action of elements 3, 35 and 45.

It should also be noted that the bell-shaped wheel 45 rotates in a housing 49 of casing 19 which acts as a guide and bears against a needle bearing 50.

In the pump shown by FIG. 1, the pressure produced in the working chamber 26 of the ram and consequently the advance of fuel injection depend upon the speed of the engine which is fed with fuel from the injection pump. When this speed does not vary or varies a little and when it is desired to vary this advance to fuel injection as a function of the load of the engine, it is advantageous to have recourse to another feature of the invention which is based upon the fact that the load depends upon the amount of fuel that is truly injected into the engine. As already stated, adjustment of this amount takes place in such manner that only a portion of the fuel displaced by the piston 1 of the pump during its delivery stroke is sent toward the injector, whereas another portion is discharged to the outside. Of course, the amount of fuel that is truly injected is the smaller as the discharged amount is greater. Therefore I make use of the variation of the amount of fuel discharged to the outside to control the pressure in the working chamber of the hydraulic ram.

An embodiment of such a system is shown by FIG. 2. This figure shows a modification of the injection pump of FIG. 1, in which the variable pressure in working chamber 26 depends upon the load of the engine.

In this FIG. 2, the discharge conduit 40 through which fuel delivered by the piston 1 of the pump is evacuated after said discharge conduit has been cleared by shuttle 36 is connected to a conduit 33*a* which opens into the working chamber 26 of the hydraulic ram. A discharge leak is provided at 34*a* in this conduit 40, 33*a*. Furthermore, a liquid pressure accumulator 44 is connected with conduit 33*a*. This accumulator constitutes a closed space partly filled with the fuel so that, between the upper level of this fuel and the top of this space, there is produced an air cushion 44*a* the pressure of which depends upon the level of the liquid. It will be readily understood that the pressure in conduits 40 and 33*a*, and consequently also in working chamber 26, is the greater as the amount of fuel evacuated from cylinder 2 through discharge conduit 40 is greater and therefore as the load of the engine is lower.

FIG. 2 diagrammatically shows, in the form of a screw 34*a*, means for varying the section of passage for the leak, but of course said means might be automatically arranged as shown by FIG. 1.

Of course, my invention is not limited to the case where regulation of the fuel injection pump is obtained on the "liquid abutment" principle.

In a general manner, while I have, in the above description, disclosed what I deem to be practical and efficient embodiments of my invention, it should be well understood that I do not wish to be limited thereto as there might be changes made in the arrangement, disposition and form of the parts without departing from the principle of the present invention as comprehended within the scope of the accompanying claims.

What I claim is:

1. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said

engine and in line with said rotating member, a threaded sleeve in mesh both with said shaft and with said rotating member for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being movable axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said internal combustion engine fed by said pump, a volumetric pump, means operatively connected to said driving shaft and to said volumetric pump for driving the latter at the speed proportional to that of said engine, conduit means leading from the output of said volumetric pump to said working chamber of said ram, and means mounted in said conduit means to produce a leak of liquid therefrom the greater as the liquid pressure in said conduit means upstream of said leak producing means is higher, said leak producing means comprising a cylinder in communication at one end with said conduit means, a piston slidable in said cylinder, one wall of said cylinder being provided with a longitudinal outlet slot of a width varying along its length, said slot being partly closed by said piston, and resilient means operatively connected with said last mentioned piston to urge it in the direction tending to reduce the portion of said slot uncovered by said last mentioned piston, the shape of said slot being adapted to produce a predetermined law of variation of the uncovered portion thereof as a function of the liquid pressure in said conduit means.

2. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said engine and in line with said rotating member, a threaded sleeve in mesh both with said shaft and with said rotating member for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being movable axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said inter-

nal combustion engine fed by said pump, a volumetric pump, a conduit for placing the output of said volumetric pump in communication with said injection pump cylinder for feeding fuel thereto, means operatively connected to said driving shaft and to said volumetric pump for driving the latter at a speed proportional to that of said engine, conduit means leading from the output of said volumetric pump to said working chamber of said ram, means mounted in said conduit means to produce a leak of liquid therefrom, said leak being the greater as the liquid pressure in said conduit means upstream of said leak producing means is higher, valve means for opening or closing said conduit means, said valve means being located in said conduit means downstream of said leak producing means and downstream of the place where said conduit leads from said volumetric pump output to said fuel injection pump, said valve means being responsive to the pressure in said conduit means for closing said conduit means when said pressure is below a given value and opening said conduit means when said pressure exceeds said given value.

3. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said engine and in line with said rotating member, a threaded sleeve surrounding adjoining portions of said shaft and said rotating member and in mesh with said portions for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being movable axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said internal combustion engine fed by said pump, means for feeding said working chamber of said ram with liquid at a pressure variable in response to variations of a factor of operation of said pump, and coupling means between said ram piston and said shaft for transmitting by friction a rotary movement about said shaft axis to said ram piston.

4. A system according to claim 3 in which said last mentioned means have annular friction surfaces of a mean diameter approximately equal to the diameter of said piston and said sleeve.

5. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said engine and in line with said rotating member, a threaded sleeve surrounding adjoining portions of said shaft and said rotating member and in mesh with said portions for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being movable axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said internal combustion engine fed by said pump, means for feeding said working chamber of said ram with liquid at a pressure variable in response to variations of a factor of operation of said pump, and coupling means between said ram piston and said sleeve for transmitting by friction a rotary movement about said shaft axis from said sleeve to said ram piston, said casing recess comprising two cylindrical portions of different respective diameters in line with each other and connected together by an annular wall portion transverse to said axis, said ram piston being a tubular stepped piston coaxially surrounding said sleeve and comprising two portions of different diameters adapted to fit slidably in said recess portions respectively and connected together by an annular wall portion transverse to said axis, said working chamber being located between said recess annular wall portion and the face of said ram piston annular wall portion turned toward it, said sleeve carrying a flange on the other side of said ram piston annular wall portion from said working chamber and said coupling means being between said sleeve flange and the face of said ram piston annular wall portion turned toward it.

6. A system according to claim 5 in which said coupling means comprise a flat annular member interposed between said sleeve flange and said ram piston annular wall portion.

7. A system according to claim 5 in which said coupling means comprise a flat annular member interposed between said sleeve flange and said ram piston annular wall portion, said annular member being provided, in both of its faces, with radial lubricating grooves.

8. A system according to claim 5 further including an annular part fixed to said driving shaft to form an outward projection around it, said part being located at a distance from said sleeve flange and on the other side thereof from said working chamber, said resilient means operatively connected with said ram piston consisting of a spring interposed between said annular part and said sleeve flange.

9. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said engine and in line with said rotating member, a threaded sleeve surrounding adjoining portions of said shaft and said rotating member and in mesh with said portions for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being mov-

able axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said internal combustion engine fed by said pump, means for feeding said working chamber of said ram with liquid at a pressure variable in response to variations of a factor of operation of said pump, and coupling means between said ram piston and said shaft for transmitting by friction a rotary movement about said shaft axis from said shaft to said ram piston, said casing recess comprising two cylindrical portions of different respective diameters in line with each other and connected together by an annular wall portion transverse to said axis, said ram piston being a tubular stepped piston coaxially surrounding said sleeve and comprising two portions of different diameters adapted to fit slidably in said recess portions respectively and connected together by an annular wall portion transverse to said axis, said working chamber being located between said recess annular wall portion and the face of said ram piston annular wall portion turned toward it.

10. A system according to claim 9 in which the greatest part of said sleeve is located inside the portion of smaller diameter of said tubular stepped piston.

11. A system according to claim 9 in which the cylindrical portion of said casing recess that is closer to said rotating member is shorter, in the axial direction, than the portion of said stepped piston that is housed therein.

12. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said engine and in line with said rotating member, a threaded sleeve in mesh both with said shaft and with said rotating member for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being movable axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said internal combustion engine fed by said pump, an auxiliary liquid

pump, means operatively connected to said driving shaft and to said volumetric pump for driving the latter at a speed proportional to that of said engine, conduit means leading from the output of said auxiliary pump to said working chamber of said ram, and means in communication with said conduit means for controlling the pressure of the liquid fed to said ram working chamber to give said pressure a value variable in response to variations of a factor of operation of said pump, said pressure controlling means comprising means mounted in said conduit means to produce a leak of liquid therefrom the greater as the liquid pressure in said conduit means upstream of said leak producing means is higher, said leak producing means comprising a cylinder in communication at one end with said conduit means, a piston slidable in said cylinder, one wall of said cylinder being provided with a longitudinal outlet slot of a width varying along its length, said slot being partly closed by said piston and resilient means operatively connected with said last mentioned piston to urge it in the direction tending to reduce the portion of said slot uncovered by said last mentioned piston, the shape of said slot being adapted to produce a predetermined law of variation of the uncovered portion thereof as a function of the liquid pressure in said conduit means.

13. A fuel injection system for an internal combustion engine which comprises, in combination, a fuel injection pump including a cylinder and a piston mounted for reciprocating movement in said cylinder, a rotating member having its axis located in fixed position with respect to said cylinder, said rotating member being operatively connected with said piston for imparting thereto said reciprocating movement, a driving shaft coupled with said engine and in line with said rotating member, a threaded sleeve in mesh both with said shaft and with said rotating member for coupling them in rotation, both said shaft and said member being fixed in the direction of their common axis with respect to said cylinder and said sleeve being movable axially with respect to said shaft and said member so that axial displacement of said sleeve with respect to said shaft and said member varies the angular setting of said rotating member with respect to said shaft, a hydraulic ram comprising on the one hand, a casing fixed with respect to said cylinder and provided with a cylindrical recess coaxial with said shaft and said member and on the other hand a ram piston fitting slidably in said recess, said recess and said ram piston limiting between them a working chamber for liquid under pressure, said ram piston being operatively connected with said sleeve for transmitting thereto the liquid pressure in said working chamber, resilient means operatively connected with said ram piston for yieldingly opposing the action of said liquid pressure on said ram piston, whereby variation of said liquid pressure causes a change in the phase relation between the cycle of operation of said fuel injection pump and the cycle of operation of said internal combustion engine fed by said pump, a volumetric pump, a conduit for placing the output of said volumetric pump in communication with said injection pump cylinder for feeding fuel thereto, means operatively connected to said driving shaft and to said volumetric pump for driving the latter at a speed proportional to that of said engine, conduit means leading from the output of said volumetric pump to said working chamber of said ram, means mounted in said conduit means to produce a leak of liquid therefrom, valve means for opening or closing said conduit means, said valve means being located in said conduit means downstream of said leak producing means and downstream of the place where said conduit leads from said volumetric pump output to said fuel injection pump, said valve means being responsive to the pressure in said conduit means for closing said conduit means when said pressure is below a given

value and opening said conduit means when said pressure exceeds said given value.

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