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REGULATING DEVICES FOR RECIPROCATING ACTION PUMPS AND IN PARTICULAR FUEL INJECTION PUMPS

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Fig. 1.

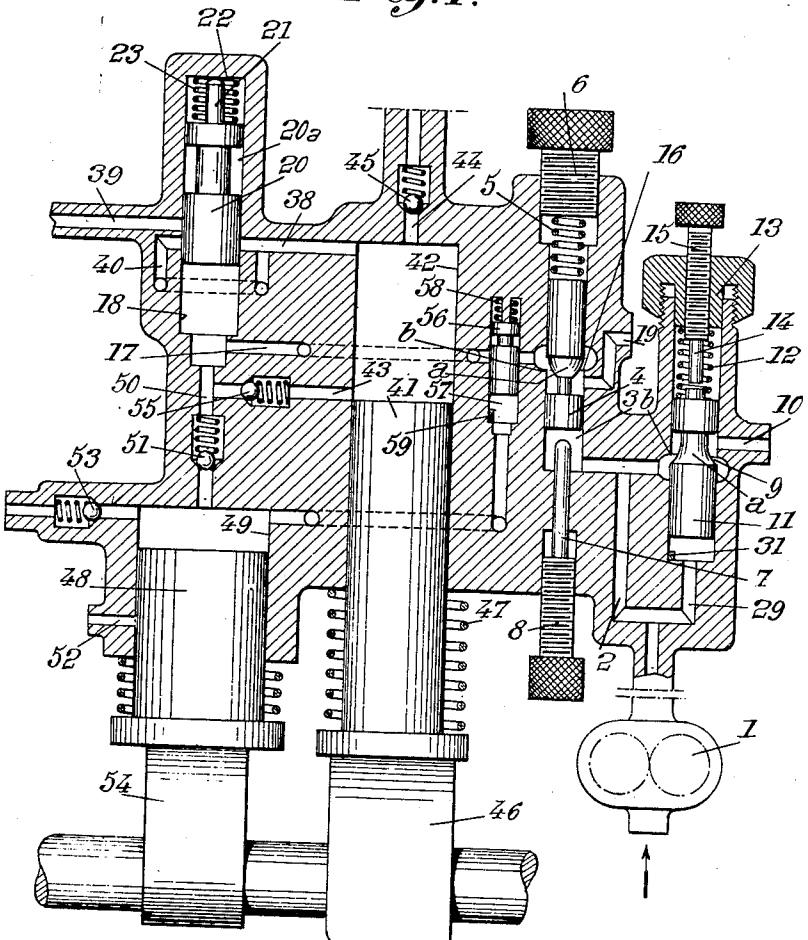
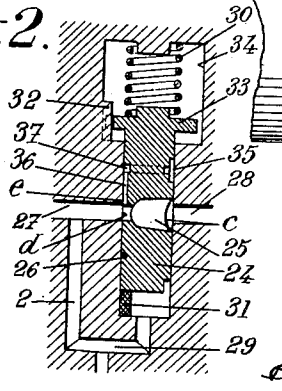


Fig. 2.



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REGULATING DEVICES FOR RECIPROCATING ACTION PUMPS AND IN PARTICULAR FUEL INJECTION PUMPS

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6 Claims. (Cl. 103—41)

The present invention relates to regulating devices for reciprocating action pumps and in particular, but not exclusively, fuel injection pumps.

The regulating device with which the present invention is concerned is of the type including a volumetric pump, hereinafter called "regulation pump," the delivery circuit of which contains a throttled passage, regulation taking place in response to variations of the liquid pressure in the portion of said circuit extending between the regulation pump output and said throttled passage. This liquid pressure increases when the speed of the regulation pump increases, and it is of course the higher as the cross-sectional area of the throttled passage is smaller.

If the cross-sectional area of said throttled passage is caused to decrease when the speed increases, the rise of pressure of the liquid in this delivery circuit portion takes place at an extremely high rate and it would tend to produce an exaggerated regulating effect which will sometimes be hereinafter called "hyper-regulating effect."

The regulating device according to the present invention is of the above mentioned type, including a regulation pump having a throttled passage in its delivery circuit. It is characterized by the combination of means for reducing the cross-sectional area of said throttled passage in response to increases of the speed at which said regulation pump is driven with means operative by variations of the liquid pressure in said delivery circuit upstream of said throttled passage for correcting the operation of the regulation member of the main pump which, in the absence of said correcting means, would tend to have an anti-regulating effect, that is to say to increase the delivery rate of said main pump when said speed increases.

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 is a diagrammatic axial sectional view of a regulation device according to the present invention for use in connection with a fuel injection pump for feeding fuel to an internal combustion engine.

FIG. 2 shows a modification of a portion of the device of FIG. 1.

The fuel injection pump, which will be hereinafter sometimes called "main pump," is a reciprocating action pump including a cylinder 42 and a piston 41. It is fed with liquid (fuel) from an auxiliary pump 49, 48 and delivers this fuel through a delivery pipe 44 (provided with a check-valve 45) leading to the injectors of the internal combustion engine to be supplied with fuel from said main pump.

The hydraulic regulating device for controlling the operation of the main pump includes a regulation pump 1, in particular a continuous flow pump such as a gear pump, driven at a speed proportional to the speed of the engine.

Pump 1 may be a special pump used only for speed regulating purposes or it may be one of the auxiliary pumps of the engine, such as the lubricating oil pump or the cooling water pump.

Regulation pump 1 delivers liquid into a delivery conduit 2 which leads this liquid to a cylinder 3 in which is

slidably mounted a movable part 4 acting as correcting means, the action of which will be hereinafter explained. The pressure existing in delivery conduit 2 tends to move part 4 in one direction, whereas a return force, exerted for instance by an antagonistic spring 5, urges part 4 in the opposed direction. This spring, the compression of which is preferably adjustable by means of a screw 6, tends to apply movable part 4 against an abutment 7 which thus determines the position of rest of part 4, this abutment 7 being adjustable in position, for instance by means of a screw 8.

Delivery conduit 2 communicates, through an adjustable passage 9, with a discharge conduit 10.

The cross-sectional area of throttled passage 9 is controlled by a slide valve 11 which is itself urged in one direction by the pressure in delivery conduit 2, supplied to the underface of this slide valve through a conduit 29, slide valve 11 being urged in the opposed direction by a return spring 12 the compression of which is adjustable by means of a nut 13. The limit position that can be occupied by slide valve 11 under the action of the pressure in delivery conduit 2 is determined by an abutment 14 adjustable by means of a screw 15, whereas the limit position in the opposed direction of this slide valve 11 is determined by an abutment 31. Slide valve 11 is arranged in such manner that an increase of the pressure in delivery conduit 2 produces a reduction of the cross-sectional area of throttled passage 9. Consequently, the delivery pressure in conduit 2, and therefore in cylinder 3, increases very quickly when the speed of pump 1 increases, which gives rise to a hyper-regulating effect.

Part 4, which is subjected to the pressure in cylinder 3, controls a second throttled passage 16 inserted in a conduit 17 which connects a cylinder 18 to a discharge port 19. In cylinder 18, there is slidably mounted a movable regulation member 20 in the form of a slide valve. This regulation member 20 controls a discharge conduit 38—39 leading out from the cylinder 42 of the main pump. Movable member 20 is moved, through hydraulic means which will be hereinafter more explicitly described, in cylinder 18 in the "outward" direction as far as a position which is determined by the contact of an abutment 21, carried by member 20, against the end face 22 of cylinder 18. Member 20 is urged in the opposed direction (return direction) by a spring 23. During every return displacement, regulation member 20 must drive liquid present in cylinder 18 and in conduit 17 past passage 16, to the outside, through discharge port 19. The movement of member 20, under the effect of return spring 23, is more and more braked as the cross-sectional area of throttled passage 16 is being reduced. The speed of the return movement of regulation member 20 is therefore dependent upon the cross-sectional area of throttled passage 16, and this area is, in turn, dependent upon the speed at which pump 1 is being driven. Therefore, finally, the speed of the return movement of member 20 depends upon the speed, which constitutes the factor of regulation. Part 4 is arranged in such manner as to increase the cross-sectional area of throttled passage 16 as the liquid pressure in the delivery circuit 2 of pump 1 increases, that is to say as the speed increases. This arrangement produces an acceleration of the return movement of regulation member 20.

Control elements 4 and 11 which determine, by their position, the free section of throttled passages 16 and 9 advantageously have, in their active portion, the shape of a cone *a* the generatrix of which may be rectilinear, convex or concave, this cone determing, in cooperation with a ridge *b* of the cylinder in which each of these elements 4 and 11 is movable, an annular passage the dimension of

which constitutes the cross-sectional area of each of said throttled passages.

According to the shape of the generatrix of cone *a*, it is possible to obtain very different laws for the variation of the cross-sectional area between cone *a* and ridge *b* when the slide valve (**4** or **11**) is moved axially in its cylinder.

The means for producing the outward and return movements of regulation member **20** are arranged in such manner that the outward movement takes place when the piston **41** of the main pump is moving on its return stroke (downward movement in FIG 1) or, at the latest, when this piston is stopped in its lowermost position shown by FIG. 1 and in which it clears the feed port **43** of cylinder **42** of the main pump. On the other hand, the return movement of element **20**, under the action of spring **23**, starts as soon as piston **41**, moving upwardly in its cylinder, closes the feed port **43** and starts on its delivery stroke. Furthermore, member **20** is arranged in such manner as to close discharge conduit **38—39** at the beginning of its return stroke (downward stroke) and to open this discharge conduit, owing to the provision of a groove **20***a*, after it has already moved over a portion of its downward stroke.

A cam **46**, the speed of revolution of which is proportional to that of the engine, serves to drive piston **41** during its upward stroke, during which it delivers fuel, toward one or several injectors (not shown), through delivery conduit **44** provided with a check-valve **45**, and this as long as discharge conduit **38, 39** is closed by regulation member **20**. The return stroke of piston **41** takes place under the effect of a return spring **47**.

A second piston **48**, working in a cylinder **49**, produces the reciprocating movement of slide valve **20**, that is to say brings this slide valve into the position shown by FIG. 1, from which position the slide valve can start upon its return stroke under the effect of spring **23**. For this purpose, cylinder **49** is connected with cylinder **18**, in which slide valve **20** is reciprocable through a conduit **50** in which is inserted a check-valve **51**. Furthermore, a feed conduit **52** opens into cylinder **49** so as to be cleared by piston **41** when said last mentioned piston is in its lower dead center position. Cylinder **49** is further provided with a safety valve **53**.

Piston **48** is driven, for instance by means of a cam **54** carried by the same shaft as the above mentioned cam **46**, in such manner that piston **48** is in its upper dead center position when piston **41** is in its lower dead center position (as shown by FIG. 1) and vice versa. Consequently, when the piston **41** of the main pump is moving downwardly, the piston **48** of the auxiliary pump is moving upwardly and brings slide valve **20** into its upper position shown by FIG. 1, whereas when piston **41** is running on its delivery stroke (upward stroke), piston **48** is moving downwardly, which enables spring **23** to push slide valve **20** in the downward direction so that the liquid present in the lower portion of cylinder **18** is driven through conduit **17**, past throttled passage **16**, to discharge port **19**, the throttled passage **16** having a braking action upon the downward movement of slide valve **20**.

Advantageously, the auxiliary pump constituted by piston **48** and its cylinder **49** also acts as a feed pump for the main pump **41, 42**. For this purpose, the feed conduit **43** of the cylinder **42** of the main pump is connected with the delivery conduit **50** of the auxiliary pump, with the insertion, in conduit **43**, of a check-valve **55**. The spring of check-valve **55** is loaded to a value higher than that of spring **23** so that slide valve **20** arrives into its upper position, where abutment **21** is applied against the end face **22** of cylinder **18**, before check-valve **55** is opened and permits cylinder **42** to be fed with fuel.

Concerning the loading of safety valve **53**, it must be higher than that of the spring of check-valve **55** but sufficiently low to permit the discharge of an excess of liquid delivered by piston **48** and thus to prevent a parastic injection when cylinder **42** is entirely filled with liquid.

Furthermore, advantageously, a slide valve **56** is interposed across conduit **17**. This slide valve is controlled by liquid delivered by piston **48** during its upward stroke, this liquid pushing slide valve **56** in its cylinder **57** against the action of a spring **58** into a postion where ths slide valve closes conduit **17**. As soon as piston **48** starts on its downward stroke, slide valve **56**, under the action of spring **58**, drops back into its position of rest where it is applied against an abutment **59** and where it clears conduit **17**. The loading of spring **58** is advantageously lower than that of the spring of check-valve **51** so as to ensure the closing of conduit **17** before piston **48** starts delivering fuel through conduit **50**.

It should further be noted that, in order to balance the pressure exerted by the liquid contained in conduit **38** upon member **20** in a direction transverse to the axis thereof, there is provided a conduit **40** which subjects said member **20** to an equal pressure on opposite sides thereof.

The operation of the pump which has been described is as follows:

During the downward stroke of piston **41**, piston **48** is moving upwardly and first brings slide valve **20** into its upper position, shown by FIG. 1, where the cylindrical portion of slide valve **20** located below its groove **20***a* closes discharge conduit **38, 39**. When piston **41** opens the feed conduit **43**, piston **48** keeps moving upwardly in order to feed fuel into cylinder **42**. Piston **48** starts on its downward stroke when piston **41**, at the beginning of its upward stroke (delivery stroke) closes conduit **43**. At this time, discharge conduit **38, 39** is closed by slide valve **20** which is then starting on its downward movement. Consequently, the fuel delivered by piston **41** passes through delivery conduit **44** toward the fuel injectors until the groove **20***a* of slide valve **20** opens discharge conduit **38, 39**. Fuel injection then ceases.

For low speeds of the engine, the braking effect exerted upon the return movement of slide valve **20** and due to the presence of throttled passage **16** is very important. This return movement is therefore very long so that, despite the low speed of the engine, the amount of fuel injected on every stroke of the pump is relatively great. If the speed of the engine increases, the speed of the return movement of slide valve **20**, due to the considerable increase of the cross-sectional area of throttled passage **16**, increases still more quickly so that, despite the increasing speed of the engine, the amount of fuel injected by piston **41** decreases. When a given limit speed is reached, the cross-sectional area of the throttled passage **16** is so great that there is practically no braking action and consequently the opening of discharge conduit **38, 39** takes place practically at the time when piston **41** closes feed conduit **43**, or at least immediately after this closing, so that the amount of fuel that is injected becomes practically zero. This limit speed may be modified by acting upon screw **6** or upon screw **13**. An "all speed" regulation is thus obtained.

It should be noted that, if part **4** which determines the cross-sectional area of throttled passage **16** did not supply an hyper-regulating effect producing a very quick increase of the cross-sectional area of throttle passage **16** when the speed increases, the regulation member **20** could have an anti-regulating result. As a matter of fact, if the cross-sectional area of the throttled passage were of constant dimension, the duration of the downward movement of regulation member **20** would have a constant given value and would produce an opening of the discharge conduits **38, 39** at times when piston **41** has already moved over portions of its delivery stroke the greater as the speed at which this piston is driven is higher, and therefore as the speed of the engine is itself higher. The regulation member would therefore have an anti-regulating effect because it would produce, in response to an increase of the speed, an increase of the

amount of fuel delivered to the injectors on every stroke of the pump, instead of producing a reduction of this amount. This anti-regulating effect is compensated, according to the present invention, by the hyper-regulating action of the hydraulic regulator arrangement **1**, **2**, **3**, **4**, **9**, **10**, **11** which produces an increase of the cross-sectional area of throttled passage **16** such that, for an increase of the speed (which constitutes the factor of regulation), the downward speed of the regulation member **20** increases still more, which produces a reduction of the delivery rate of the pump on every stroke thereof when the speed increases.

Therefore, by the combination of an anti-regulating effect and of an hyper-regulating effect, I obtain a correct regulating action which may be given any desired characteristics by suitably adjusting the laws according to which the reduction of the cross-sectional area of throttled passage **9** and the increase of the cross-sectional area of throttle passage **16** are produced in response to variations of the speed of regulation pump **1**. I may for instance obtain a constant fineness, say of 5% (case of traction engines having a large range of speeds) or a variable but very high fineness (for instance ½%) in the case of engines for generating electricity, the range of speeds of which is very narrow.

On the other hand, with the regulating device which has been above described, I obtain the advantage that the beginning of injection always takes place at the same point of the cycle, that is to say when piston **41** closes the feed conduit **43**, whatever be the amount of fuel that is injected. In other words, the advance to injection is independent of the amount of fuel injected on every stroke.

FIG. 2 shows a modification of the means for controlling the throttled passage **9** of FIG. 1. It should be well understood that such means might also be used for controlling the other throttled passage, to wit **16**.

According to this modification, instead of providing in slide valve **24** (which corresponds to slide valve **11** of FIG. 1), a groove at least a portion of which is constituted by a cone *a*, said slide valve is provided with a transverse conduit **25** the ends of which form ports in the cylindrical surface of the slide valve which cooperate with corresponding ports formed by the ends of conduit elements **27**, **28** opening into cylinder **26**. One of the ends of conduit **25**, constituted for instance by a port *c*, is widened so that this port *c* does not form a substantial throttling when cooperating with the end of the conduit element **28**. Only the other port forming the end of conduit **25**, that is to say port *d*, constitutes a throttled passage in cooperation with the port *e* forming the end of the conduit element **27**. In this case, ports *d* and *e* may be given any suitable shape: circular, rectangular, triangular, ovoid, etc., so as to constitute conjugate ports which determine, under the effect of the axial displacement of slide valve **24**, the variable section of the throttled passage controlled by this slide valve. The fact that only one pair of ports is used to form the throttled passage constitutes an advantage because the law of variation of the cross-sectional area of the passage can be obtained with a high accuracy.

Slide valve **24** is urged in one direction, upwardly, by the delivery pressure of pump **1** fed to the bottom of cylinder **26** through a conduit **29** branching off from the delivery conduit **2** of the pump **1**. In the other direction, the slide valve is urged by a spring **30** which tends to maintain slide valve **24** in the position of rest where it is applied against abutment **31**.

In order to prevent any possibility of rotation of slide valve **24** about its axis, this slide valve is guided axially by a rib **32** engaged in a groove provided in slide valve **24**. This groove is for instance formed in a flange **33** which cooperates with cylinder **34** to act as a dash-pot to make the movement of the slide valve more regular.

In order to balance the transverse forces acting upon the slide valve and which might, otherwise, wedge it against the wall of its cylinder, thus interfering with the axial displacement thereof under the effect of the forces acting thereon in the axial direction, the pressure existing in the conduit element **27** located upstream of the slide valve is caused to act upon the opposite side of the slide valve. For this purpose, the slide valve is provided, on the side opposed to ports *d* and *e*, with a recess **35** which is connected, through a slot **36** and a groove **37**, with conduit element **27**.

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. For use in connection with a reciprocating action main pump, a device for regulating said main pump in accordance with variations of a factor of regulation thereof which comprises, in combination, a regulation member mounted on said main pump to exert a control action on the delivery rate per stroke thereof, means operatively connected with said main pump for actuating said regulation member to increase said delivery rate in response to increase of the reciprocation rate of said pump, a volumetric regulation pump driven at a variable speed proportional to said factor of regulation, said regulation pump having a delivery circuit and a throttled passage in said delivery circuit so as to produce, in the portion of said circuit upstream of said throttled passage, a liquid pressure which is the higher as said speed is higher and as the cross-sectional area of said throttled passage is smaller, means operatively connected with said regulation pump for reducing said cross-sectional area in response to increases of said speed, and means responsive to variations of said liquid pressure and operatively connected with said regulation member for adjusting said regulation member to modify the control action it would have if it were merely actuated by said means operatively connected with said main pump.

2. For use in connection with a main pump including a main cylinder and a main piston reciprocable in said cylinder, a device for regulating said main pump in accordance with variations of a factor of regulation thereof which comprises, in combination, a discharge conduit fixed with respect to said cylinder and leading out therefrom, means fixed with respect to said cylinder forming a cylindrical housing extending across said discharge conduit, a regulation slide valve reciprocable in said housing, resilient means interposed between one end of said housing and said slide valve for urging said regulation slide valve in one direction to produce an active stroke thereof in said direction, an auxiliary pump including a cylinder fixed with respect to said main cylinder and a piston reciprocable in said auxiliary pump cylinder, means interposed between said main pump piston and said auxiliary pump piston for operatively connecting said two pistons with each other so that one of said pistons is moving on its delivery stroke while the other is moving on its return stroke and vice versa, said auxiliary pump cylinder being connected with the other end of said housing so as to move said slide valve in the direction opposed to that of its active stroke during the intervals between the delivery strokes of said main pump piston, a liquid discharge circuit starting at one of its ends from said second mentioned end of said regulation slide valve housing, said liquid discharge circuit having a discharge port at the other end thereof, valve means in said liquid discharge circuit operative by the pressure in said auxiliary pump cylinder for closing said liquid discharge circuit at a point thereof between said last mentioned ends thereof during the delivery strokes of said auxiliary pump piston, first adjustable throttling means forming a throttled passage

of variable cross-sectional area in said liquid discharge circuit, a volumetric regulation liquid pump driven at a variable speed proportional to said factor of regulation, said regulation pump having a delivery circuit, with adjustable throttling means forming in said delivery circuit a throttled passage of variable cross-sectional area, means operatively connected with said delivery circuit throttling means for adjustment thereof in response to variations of the liquid pressure in the portion of said delivery circuit extending between said regulation pump and said delivery circuit throttled passage for reducing the cross-sectional area of said delivery circuit throttled passage when said delivery circuit liquid pressure increases, and means operatively connected with said first mentioned throttling means for adjustment thereof in response to increases of said delivery circuit liquid pressure for increasing the cross-sectional area of said first mentioned throttled passage when said delivery circuit liquid passage increases.

3. A regulating device according to claim 2 in which said auxiliary pump cylinder is connected with said main pump cylinder to feed liquid thereto.

4. A regulating device according to claim 2 in which said valve means in said liquid discharge circuit include means forming a cylindrical housing extending across said liquid discharge circuit, a slide valve in said last mentioned cylindrical housing and means operative by the pressure in said auxiliary pump cylinder for bringing said last mentioned slide valve into liquid circuit closing position during the delivery strokes of said auxiliary pump piston.

5. A regulating device according to claim 2 including a balancing conduit branching off from the portion of said discharge conduit upstream of said regulation slide valve and opening into said slide valve housing at a point opposed to that where said discharge conduit portion opens into said slide valve housing, the portion of said discharge conduit downstream of said regulation slide valve housing being offset with respect to the first mentioned portion of said discharge conduit.

6. A regulating device according to claim 2 wherein said delivery circuit throttling means comprises a valve chamber in said regulation pump delivery circuit, a valve element movable in said valve chamber for varying the cross-sectional area of said delivery circuit; and wherein said means for adjusting said delivery circuit throttling means comprises a spring cooperating with said valve element to increase the cross-sectional area of said delivery circuit, and a fluid conduit from the outlet of said regulation pump cooperating with said valve element whereby pressure in said regulation pump delivery circuit acts on said valve element to decrease the cross-sectional area of said delivery circuit.

No references cited.