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# [54] PUMP POWER GOVERNOR

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[51] **Int. Cl.** ............................................ **F04b 49/00**
[58] **Field of Search** ........... 417/213, 218, 221, 222, 417/212; 60/445, 450, 452, 444

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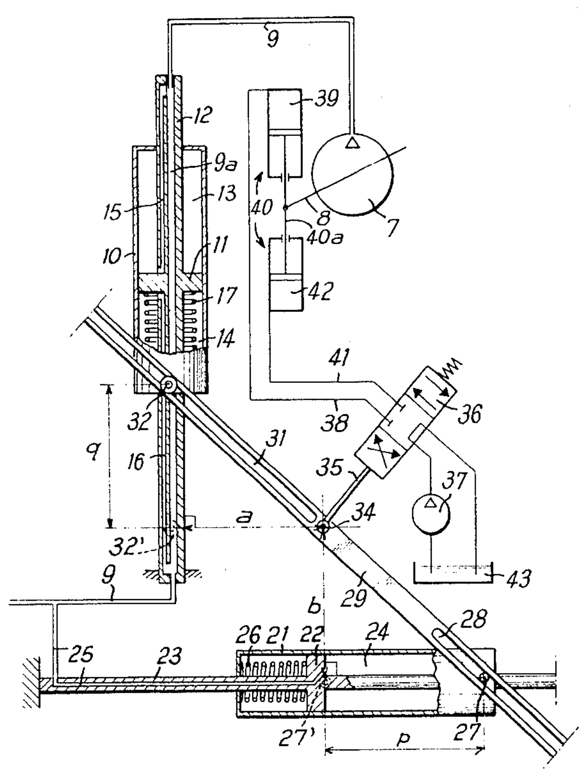
[57] **ABSTRACT**

A device for governing the power of a pump has a conventional system for varying its cylinder capacity and a control arrangement therefor including linked members indicative of the pump delivery rate and the pump output pressure and regulator operable by said linked members to deliver the output of an auxiliary pump to one or the other chamber of a double acting ram of the control system if the linked members indicate that an increase or decrease in power is necessary or to a reservoir if the linked members indicate that the power is correct.

**10 Claims, 5 Drawing Figures**



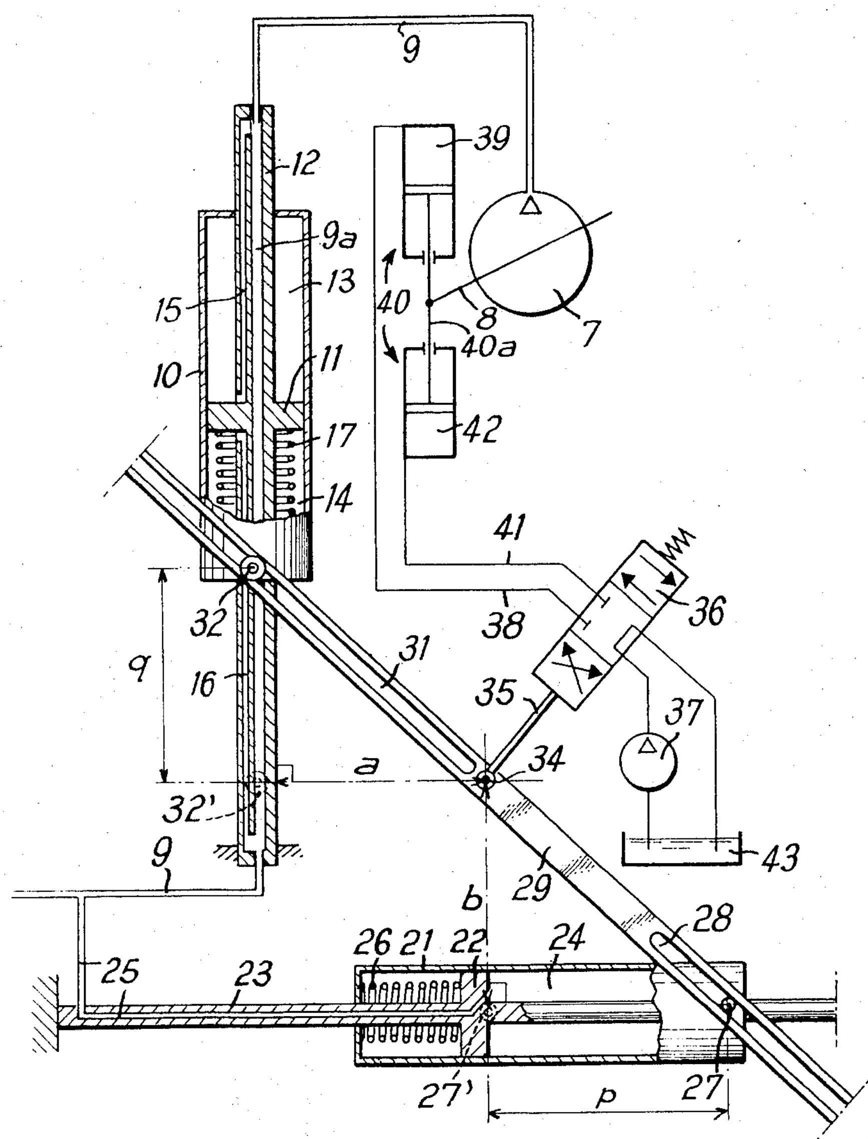

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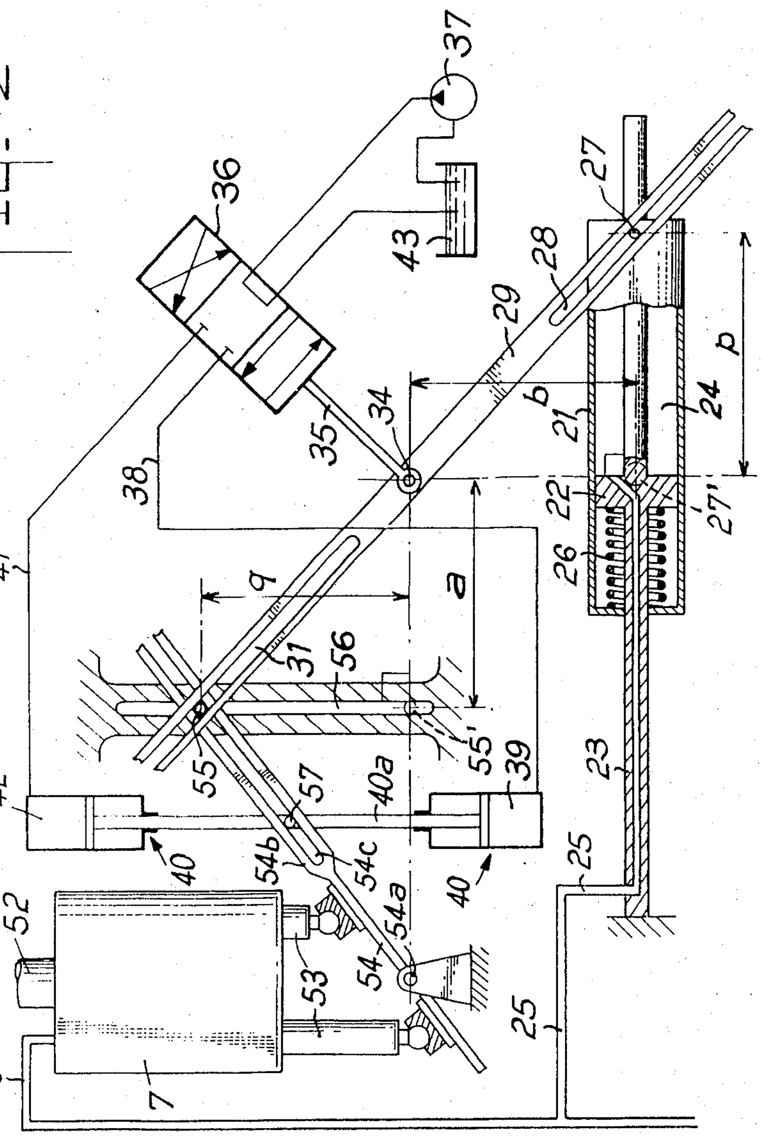
Fig. 1

FIG-2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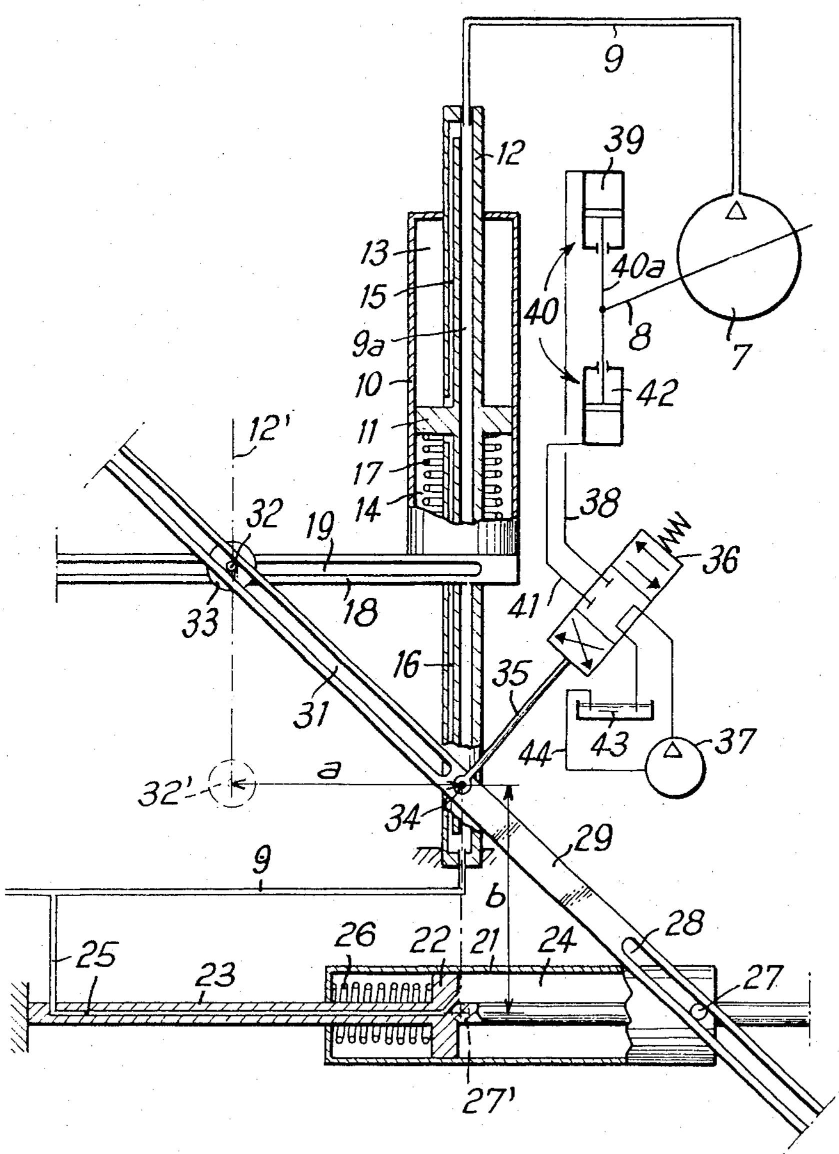
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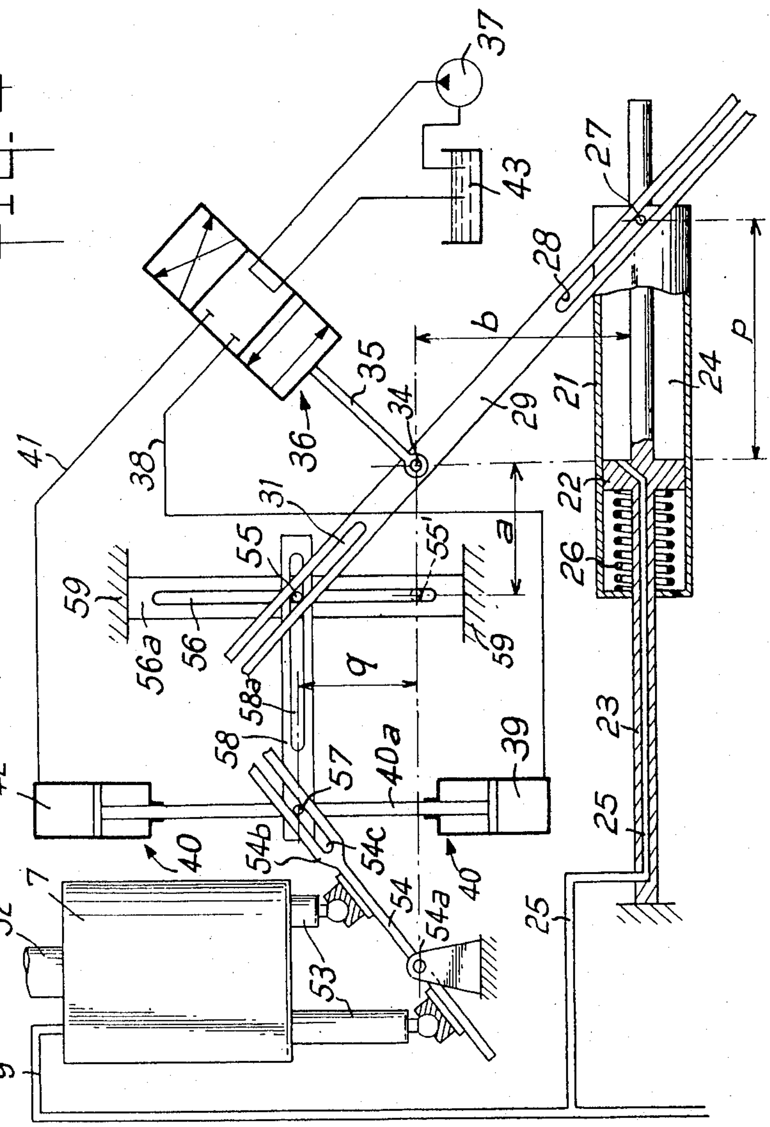
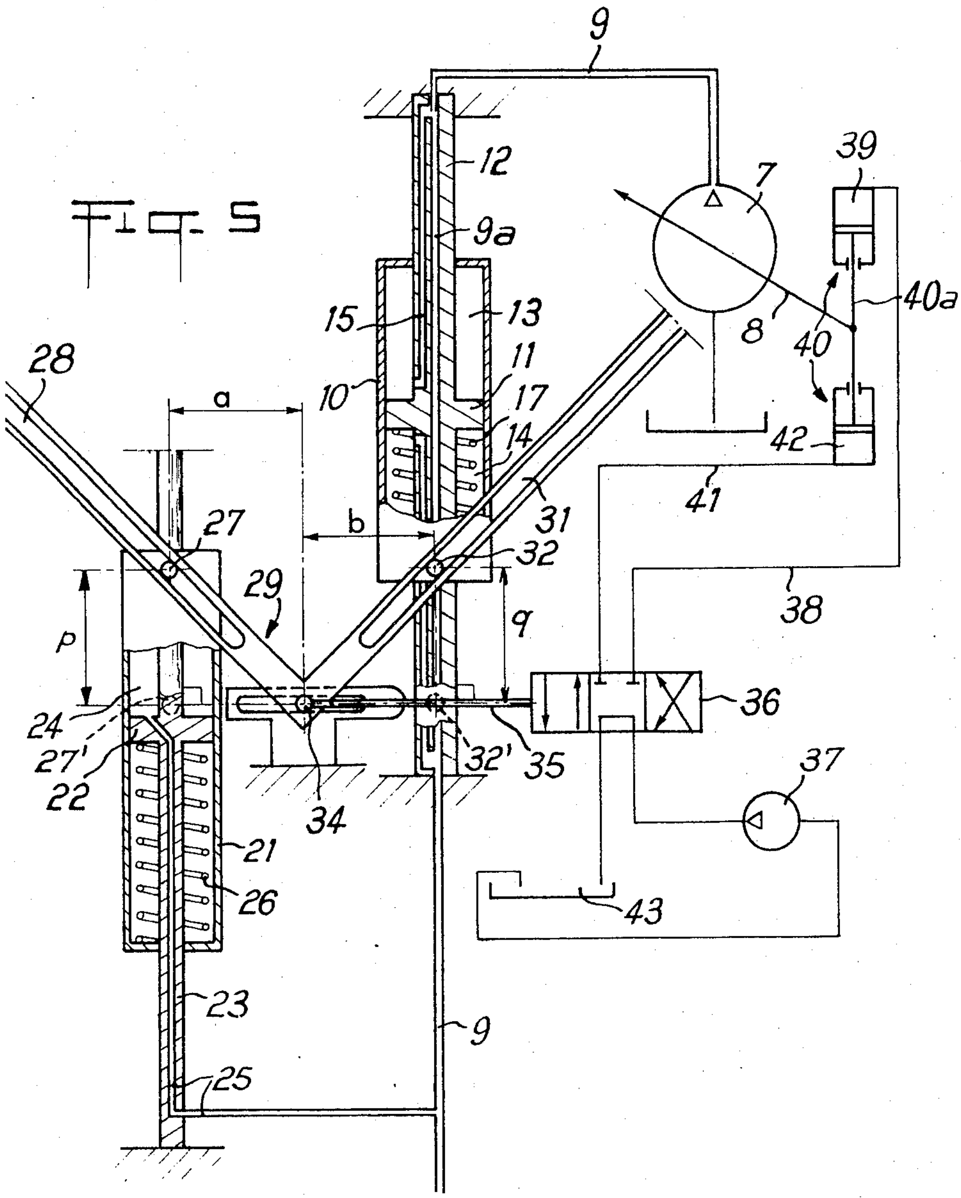
Fig-3

FIG. 4

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40a
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Fig. 5

## PUMP POWER GOVERNOR

The present invention relates to a device for governing the power of a pump of variable cylinder capacity.

The power of a hydraulic or pneumatic pump is determined from the product of the flow delivery rate from the pump and the pressure of the fluid delivered. Once this product has been determined it is necessary to keep it constant by governing the pump operation to follow a hyperbolic curve which determines the variation of one factor as a function of the variation of the other.

In that case operation is generally by approximately by comparison of portions of linearly varying curves which offer disadvantages.

The invention proposes to cure this complexity and these disadvantages by a governor device which is simple to put into effect and precise in its results.

The object of the invention therefore is to provide a device for governing the power of a pump comprising particularly a system for controlling the variation of the cylinder capacity of the pump and a delivery pipe which consists of a first control member movable along a first rectilinear guide, the displacement of which varies in proportion to the value of the flow rate of the fluid conveyed by the delivery pipe, and a second control member movable along a second rectilinear guide, the displacement of which varies in direct ratio with the value of the pressure in the delivery pipe. A connecting rod of variable length links the first and second members and passes through a fixed or predetermined pivot point located at the intersection between two straight lines each of which is drawn perpendicular to each of the rectilinear guides from the position of each of the first and second members signifying zero rate of flow or pressure. This fixed pivot point is connected to the tip of the slide of a regulator valve in its position or rest connected with the connecting rod. When the displacement of the connecting rod with respect to the fixed point is representative of an increase in power the regulator places an auxiliary pump selectively in communication with a first chamber of a double acting piston cylinder unit, the rod of the piston being linked to the control system. When the displacement of the connecting rod with respect to the fixed point is representative of a drop in power the regulator places the auxiliary pump in communication with the second chamber of the piston cylinder unit. When the displacement of the connecting rod is zero with resepct to the fixed point, the auxiliary pump is connected to a fluid reservoir.

In one embodiment the second control member aforesaid consists of a piston-cylinder unit having a fixed piston which constitutes the second rectilinear guide for the cylinder mounted slidingly on this guide and defines, with the said cylinder, a chamber connected to an exhaust pipe. Resilient means linked between the piston and the cylinder tend to make the volume of the chamber a minimum.

The first control member consists of a movable cylinder mounted slidingly on a fixed piston which constitutes the first guide and defines in the cylinder two chambers connected to the delivery pipe for the pump on opposite sides of a restriction in the pipe. A resilient member linked between the piston and the cylinder tends to make the volume of the chamber connected to the delivery pipe between the pump and the restriction a minimum.



Advantageously the restriction in the last mentioned pipe is formed by a hollow conduit in the piston actuator rod of the first control member which has a gauge internal diameter and is arranged in series with the exhaust pipe.

The hollow actuator rod is slidably connected to the delivery pipe of the pump at the end thereof nearer to the pump. The other end of the rod is anchored in a fixed position and the rod is formed from a material which has linear expansion characteristics compatible with the effects of the temperature on the viscosity of the fluid so as to compensate for temperature variations.

In a variant embodiment, the first control member is formed by the tip of the system of control of the variation of the cylinder capacity of the pump retained slidingly in a slide extending parallel with the axis of the pump, onto which tip is linked one of the tips of the connecting rod aforesaid.

Finally the connecting rod is preferably linked to at least one of the first and second control members aforesaid by means of an arm formed integrally with the said member which arm extends perpendicular to the guide of the member and bears an adjustable member which forms the point of attachment of the corresponding tip of the connecting rod.

The invention will be better understood in the course of the description given below by way of purely indicative example which will enable the advantage and secondary characteristics to be made clear:

FIG. **1** is a diagrammatic representation of a first embodiment of a device in accordance with the invention;

FIG. **2** is a diagrammatic representation of a second embodiment of a device in accordance with the invention;

FIGS. **3** and **4** are two respective variants upon the embodiments of FIGS. **1** and **2**;

FIG. **5** is a diagrammatic representation of a third embodiment of the invention.

Referring to FIG. **1**, there is seen a device for governing the power of a pump **7** comprising a device for controlling the variation in its cylinder capacity **8** and a delivery pipe **9**. This device comprises a first control member sensitive to the variations of flow from the pump **7**, consisting of a movable cylinder **10** containing and slidably receiving piston **11** having a rod **12** which constitutes a straight line guide for the cylinder. The piston **11** divides cylinder **10** into two chambers **13** and **14**, respectively connected to pipe **9** by two pipes or conduits **15** and **16** respectively formed on opposite sides of piston **11** in piston rod **12**. The latter also includes a restriction **9*a*** in communication with pipe **9** as seen in FIG. **1** and which is gauged in diameter and length such that the flow of fluid in restriction **9*a*** is always laminar whatever its rate of flow. In the chamber **14** of cylinder **10** a spring **17** is positioned between piston **11** and the end of cylinder **10** in such a way that its effect tends to make the volume of the opposite chamber **13** a minimum.

A second cylinder **21** contains a piston **22** that divides the cylinder into two chambers with the chamber **24** thereof communicating with pipe **9** through a port **25** formed in the fixed piston rod **23**, which acts as a guide for this cylinder. Cylinder **21** is provided with a stud **27**, having a position indicated at **27'** which signifies zero pressure in pipe **9**. This stud is located in one of the slots **28** in a connecting rod **29**, while a second slot 31 is arranged in connecting rod 29 so as to enable a pin 32 carried by the cylinder 10 to slide along the connecting rod 29. The pin 32 adopts at the very least, theoretically when the flow from the pump 7 is zero, the position as indicated at 32'.

Two straight lines drawn perpendicular to the guides 12 and 23 from the points 27' and 32' meet at a predetermined point 34. The connecting rod 29 passes through the point 34 when the device is in equilibrium as shown. At the equilibrium position the tip or free end of the rod 35 which is pivotally connected to rod 29 is located at point 34. The rod 35 controls the position of the slide of a regulator or valve 36 in the neutral position. The end of rod 35 is connected with connecting rod 29 by means of a hingepin or the like in any convenient manner. Regulator 36 is capable of putting an auxiliary pump 37 selectively in communication with: (1) a pipe 38 connecting it to a first chamber 39 of a double-acting piston-cylinder unit 40; (2) with a pipe 42 connecting it to a second chamber 42 of the said unit 40; or (3) with a fluid reservoir 43 by means of pipeline 44. The rod 40*a* of the piston of the unit 40 is linked to the member 8 for controlling the variation of the cylinder capacity of the pump 7.

In operation the cylinders 10 and 21 have divergent movements when the device records an increase of pressure and an increase of flow simultaneously. Recording of the variation in flow is effected by means of a pressure take-off at each end of the restriction or gauge pipe 9*a*. In fact the flow of the fluid being laminar in this pipe 9*a* any variation in the rate of flow brings about a variation in load loss proportional to the variation in the rate of flow. This load loss in the pipe 9*a* creates a drop in pressure in fluid downstream of the pipe 9*a* with respect to the fluid located upstream. The pressure in the fluid upstream of the pipe 9*a* is the pressure in chamber 10 since the latter is connected to the portion of the pipe 9 upstream of the pipe 9*a* through the pipe or port 15.

The pressure in the fluid downstream of the pipe 9*a* is transmitted into chamber 14 of cylinder 10 through pipe 16. During flow of fluid in the pipe 9*a* the pressure in chamber 13 is always higher than the pressure in chamber 14. Equilibrium is achieved because of spring 17 which adds its force to that of the pressure in chamber 14. The result is that the greater the difference in chambers 13 and 14, the greater the compression of the spring 17, hence the greater the displacement of cylinder 10 with respect to the fixed position 11. This difference in pressure is proportional to the rate of flow and hence the position of equilibrium of the cylinder 10 and the compression of the spring 17 are representative of this rate of flow.

Similarly, recording of the pressure in pipe 9 is achieved by means of cylinder 21. The pressure in chamber 24 of that cylinder is the same as that in the pipe 9 to which the chamber is connected through the pipe or conduit 25. The spring 26 balances the effect of the pressure in the chamber 24 and the position of equilibrium attained by the cylinder 21 with respect to the fixed piston 22 results from greater or less compression of the spring 26, proportional to the value of the pressure recorded.

The device described is indeed a governor of the power of a pump. It is known in fact that the power of a pump is equal to the product of its rate of flow and the pressure of the fluid discharged. If the distance 32' – 34 is called $a$, the distance 34 – 27' : $b$, the distance 27' – 27 : $p$ (because it is significant of the pressure reigning in the pipe), and finally the distance 32' – 32 : $q$, one can write from the fact that the device is in equilibrium and hence that the connecting rod 29 passes through the point 34:

$$a/q = p/b$$

by comparing the two triangles 32 – 32' – 34 and 27 – 27' – 34 which are similar whence the power $W$ of the pump: $W = p \times q = a \times b$. Whatever the values of $p$ and $q$ this relationship will always hold if the connecting rod 29 passes through the point 34.

The governing principle therefore rests in the fact that the variation in the cylinder capacity of the pump must be subjected to the variation in the position of the connecting rod with respect to the predetermined point 34 and that this variation in cylinder capacity brings about in return, by the action of the member 10, the location of the connecting rod 29 straight through the point 34. The subjection is then in a closed loop. Any variation of one or both of the values of the pressure and the rate of flow of the fluid delivered by the pump 7 will modify the position of the pin carried by or received in the connecting rod. This variation will be communicated to the slide of the regulator 36 which will establish a communication between the auxiliary pump 37 and one of the chambers 39 or 42 so as to displace the rod 40*a* of the unit 40 and thereby actuate the member 8 for controlling variation of the cylinder capacity of the pump 7 in the direction of a compensation of the variation of the pressures or rate of flow. If, for example, the rate of flow drops the connecting rod will change position and drive the slide of the regulator 36 into its position of putting the pump 37 in communication with the pipe 38 and the chamber 39, bringing about by filling of this chamber, a displacement of the rod 40*a*, and hence of the control member 8, in the direction of increasing the cylinder capacity. Naturally any feeding of a chamber by the pump 37 opens the other chamber to the exhaust in the convention manner.

IN FIG. 2 another embodiment of the invention is illustrated in which certain members described in relation to FIG. 1 are identified with the same references. The pump 7 is represented in the form of a barrel pump capable of being driven in rotation by a shaft 52.

In a manner in itself known the pump includes rotary pistons having piston rods 53 maintained constantly in contact with a tiltable disc or plate 54 which is part of the system of controlling the variation of the pump's cylinder capacity, as by feeding fluid under pressure into pipe 9. The plate 54 is titltable (i.e., pivotable) on the axis or pivot 54*a* and is extended by a connecting rod 54*b* of variable length. This is achieved by use of a telescopic rod, without departing from the scope of the invention.

Pipe 9 is in communication with the pipe 25 of cylinder 21 in order to convey fluid at the discharge pressure from the pump into the chamber 24 of the second member in the manner described above with respect to FIG. 1.

Connecting rod 29 is of variable length, and is linked between cylinder 21 and connecting rod 54*b* by means of an idler stud 55 slidably mounted in the slot 54*c* of the connecting rod 54*b* and the slot 31 of the connecting rod 29 at their point of intersection. The stud is also slidably retained in a fixed slide or slot **56** which extends parallel to the axis of the pump **7.** When the device is in equilibrium the connecting rod **29** passes naturally through the point **34** which corresponds with the intersection between the straight line drawn perpendicular to the guide **23** through the point **27'** and the straight line drawn perpendicular to the slide **56** through the point **55'** representative of the position adopted by the idler stud **55** during zero flow from the pump **7.**

Accordingly, it is apparent that in this embodiment of the invention, the movable member indicating rate of flow is the stud **55** actuated by the plate **54** controlling the variation of the cylinder capacity of the pump **7.** The distance **55** – **55'** likewise called q signifies the theoretical rate of flow from the pump since this rate of flow in contrast to FIG. **1** is not measured but proceeds from the geometrical data of the pump. The principle and the method of subjection of the pump is identical with that of the device described in relation to FIG. **1.** It is seen particularly here that the plate **54** or the system of control **8** is actuated by a lug **57** carried by the rod **40***a* of the jack **40** and engaged in the slot **54***c* in the connecting rod **54***b*.

It will be noted that the device as shown in FIG. **1** governs the output power of the pump since the values that it takes into account are the pressure and rate of flow of the fluid really delivered. On the other hand the device as shown in FIG. **2** governs the input power of a pump because it takes into account a theoretical rate of flow and hence neglects leakages of fluid at the level of the pump.

It is understood likewise that the devices as in FIGS. **1** and **2** enable governing of the power of a pump at its value $W = a \times b$.

It is of interest to be able to select different powers to which the operation of a pump can be restricted. To do this it will be apparent that it is necessary to intervene either in the dimensions $a$ or $b$ or in both at once. FIGS. **3** and **4** show how one can in a simple manner act upon dimension $a$. It is quite obvious that these are only embodiments and that numerous variants can be applied to them.

FIG. **3** takes up again in an arrangement similar to that of FIG. **1** certain members from the latter with the same references. It is to be observed that the cylinder **10** includes an arm **18** having a slot **19** in which is mounted slidingly the pin **32.** The latter through a clamping device **33** or the like is capable of being clamped or fixed in any position along arm **13.** Thus it will be seen that the movements of the cylinder **10** are transmitted to the pin **32** which in turn is displaced along an imaginary rectilinear guide symbolized by the line **12'**. The distance $a$ to be taken into account is hence that which separates the point **34** from this guide **12'**. By displacing the pin **32** along the arm **18** one chooses $a$ and hence the value of the power at which it is desired to govern the operation of the pump.

FIG. **4** shows a governor device similar to that of FIG. **3** with the same reference numerals applied to like ports, and has the possibility of selecting the power of the pump. In order to do this the slide **56** is arranged in a guide **59.** Under the effect of any sort of system of control — a screw-and-nut system, for example — the position of the slide **56** with respect to the guide **57** is acted upon. The dimension $a$ is chosen and hence the power of the pump can be adjusted as described above.

It must however be pointed out that the dimension q is only representative of the theoretical rate of flow from the pump if it is taken at a fixed distance from the axis of tilt **54***a* of the plate **54.** It is therefore necessary to arrange, between the slide **56** and the connecting rod **54***b* linked to the plate **54,** and auxiliary connecting rod **58** furnished with a slot **58***a*. The length q is then measured at the level of the rod **40***a* of the jack **40** fixed with respect to the pump and the connecting rod **58** capable of being displaced parallel to itself under the action of the jack **40** recalls this length q to the level of the movable slide **54.**

In the two embodiments as in FIGS. **3** and **4** it can be imagined that either the part **32** of the slide **56** is subjected in position along its guide to the power of another pump. The device in accordance with the invention, due to this possible subjection, enables governing of the power of a group of pumps comprising for example a constant flow pump and a variable flow pump such as **7.** The power of the constant flow pump being only a function of the pressure of the fluid delivered, it is sufficient to subject the slide **55** or the pin **32** to the pressure in the load circuit by means of a guide member of piston-cylinder type **21–22,** the displacement of which would be made compatible with those of the members described in the device in accordance with the invention.

Finally, FIG. **5** is a variant upon the device described with respect to FIG. **1** with like parts bearing the same reference numerals. In this form the two movable members or cylinders **10** and **21** are arranged along parallel guides or piston rods **12** and **23.** The relationship $W = a \times b = p \times q$ requires that in order to define similar triangles **32, 32', 34** and **27, 27', 34,** described above, the connecting rod **29** at its point coinciding with the point **34** must form a right angle. More generally, if the two guides aforesaid define any angle between them the connecting rod **29** which connects the two movable members must form an angle the complement of the angle between these two guides for the relationship $a \times b \times p \times q$ to hold. The control of the pump is the same as in the cases of preceding figures, that is, in a closed loop between the slope of the control system **8** and the position of the connecting rod **29** with respect to the point **34.**

An advantageous secondary characteristic of the invention will be observed. In fact, if one refers to FIGS. **1, 3** and **5** it is seen that the connection of the portion of pipe contained between the pump **7** and the guide **12** for the movable member **10** to the portion **9***a* of this pipe inside the guide **12** is slidable and enables the two portions to be movable with respect to one another in the direction of their greater dimension. This arrangement therefore enables movement of the guide **12** and in particular allows its expansion in the direction of its length.

Furthermore as previously mentioned, the difference between the pressures in chambers **13** and **14** of the member **10** are representative of the load loss in the fluid in the pipe **9***a* and therefore of its rate of flow and its viscosity, the latter in general becoming lower with temperature. In other words, a given position of equilibrium of the member **10** will signify a greater and greater rate of flow in proportion as the temperature of the fluid flowing in the pipe **9***a* rises.

It is therefore necessary to provide a correction of the position of this member **10** as a function of the temperature of the fluid. This is effected by using the guide **12** of a material having expansion characteristics which are compatible with the effects of the temperature upon the viscosity of the fluid. By this selection a reduction in the viscosity of the fluid and hence in the pressure difference between the chambers **13** and **14**, and therefore a displacement of the point of equilibrium of the member **10** in the direction of a fall in the rate of flow will be compensated by a longitudinal expansion of the guide or piston rod **12**, thus bringing about a modification of the position of the point of equilibrium of the member **10** in the direction of an increase in the rate of flow.

The device in accordance with the invention has the further advantage of offering a simple kinematic device in which the movable members vary linearly with the physical magnitudes which they represent. The result is great ease of execution and easy initial adjustment.

For reasons of simplification in the explanation only one embodiment of the invention has been described above, namely, two cylinders movable respectively on two fixed guide-pistons. It is quite obvious that the invention is not limited to this embodiment but that all the variants which might be applied to it without departing from its scope or spirit of the invention, particularly for example the modification of making the cylinders fixed and pistons mounted slidingly in them movable.

I claim:

**1.** A device for governing the power of a pump having exhaust and delivery pipes, said device including control means for varying the pump's cylinder capacity, said device comprising a first rectilinear guide, a first control member movably mounted on said guide, means operatively connecting said control member to said pump for displacing said control member with respect to said guide distances proportional to the value of the rate of flow of the fluid delivered by the pump; a second rectilinear guide, a second control member movably mounted on said second guide, means operatively connecting said second control member to said pump for displacing said second control member with respect to said second rectilinear guide distances which vary in direct ratio with the value of the pump delivery pressure; a connecting rod of variable length operatively connecting said first and second control members; said connecting rod being located to pass, when the device is in equilibrium, through a predetermined point defined by the intersection between two straight lines respectively drawn perpendicular to each of said guides from the relative position from each of the first and second control members, representative of zero rate of flow and pressure; a regulator valve having a slide including a free end operatively connected to said link at a position located at said predetermined point when the device is in equilibrium, and an auxiliary pump; said regulator valve including means for placing said auxiliary pump in communication with:

a. a first chamber of a double acting piston cylinder unit having a piston rod operatively connected to the control means for varying pump cylinder capacity when the connecting rod is displaced with respect to said predetermined point due to an increase in power of the pump;

b. a second chamber of said piston-cylinder unit, having a piston rod operatively connected to the control means for varying pump displacement capacity when the connecting rod is displaced with respect to said predetermined point due to a drop in power of the pump; and

c. a fluid reservoir when the displacement of the connecting rod is zero with respect to the predetermined point, indicating that constant power is being maintained by the pump.

**2.** A device as defined in claim **1** wherein said second control member consists of a piston-cylinder unit having a fixed piston which defines said second rectilinear guide for the cylinder mounted slidingly thereon, said piston defining in said cylinder a chamber connected to said exhaust pipe; and resilient means in said cylinder connected between the piston and the cylinder for making the volume of the chamber a minimum.

**3.** A device as defined in claim **2** wherein said first control member consists of a movable cylinder mounted slidably on a fixed piston defining said first guide and forming in said last mentioned cylinder two chambers connected by a conduit having a restriction therein; and resilient means connected between the piston and cylinder for making the volume of the chamber connected to said delivery pipe between the pump and the restriction a minimum.

**4.** A device as defined in claim **3** wherein the restriction in said pipe is formed by a conduit formed in the actuator rod of the piston of the first control member, said conduit having a guaged internal diameter and arranged in series with an exhaust pipe.

**5.** A device as defined in claim **4** wherein said conduit is slidably connected to the delivery pipe of the pump, and said conduit is secured in a fixed position at its other end and is formed from a material which has linear expansion characteristics compatible with the effects of temperature on the viscosity of the fluid so as to compensate for temperature.

**6.** A device as in claim **1** wherein said first control member is operatively connected to said control means for varying the cylinder capacity of the pump by means of a slide connection extending parallel to the axis of the pump to which said connecting rod is also operatively connected.

**7.** A device as defined in claim **1** wherein said connecting rod is linked to at least one of the first and second control members by means of an arm formed integrally with its associated control member, which arm extends perpendicularly to the associated guide of the latter and includes means for adjustably securing one end of the connecting rod along the arm.

**8.** A device as defined in claim **6** wherein said slide is slidably mounted in a guide part arranged perpendicularly to its greater dimension and provided with means for fixing the slide in any of its positions; and an intermediate connecting rod of variable length arranged perpendicularly to said slide and capable of being displaced parallel to itself defining the linking of the connecting rod with the control system; and means for connecting the connecting rod and the intermediate connecting rod in the slide, the connection between the intermediate connecting rod and the control system being maintained in a fixed guide extending parallel with the direction of the slide.

**9.** A device as defined in claim **1** wherein said connecting rod is rectilinear and said two guides extend perpendicular to each other.

**10.** A device as defined in claim **1** wherein said cylinders and guides are located at an angle relative to each other and said connecting rod is formed in the shape of a V, the apex of which passes through said predetermined point and the angle of which is the complement of the angle between the two guides.

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