

Sept. 5, 1939.

T. KOTAKI

2,172,103

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Fig. 1

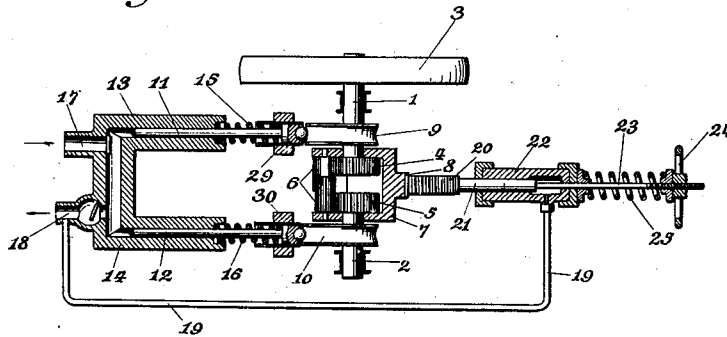


Fig. 2

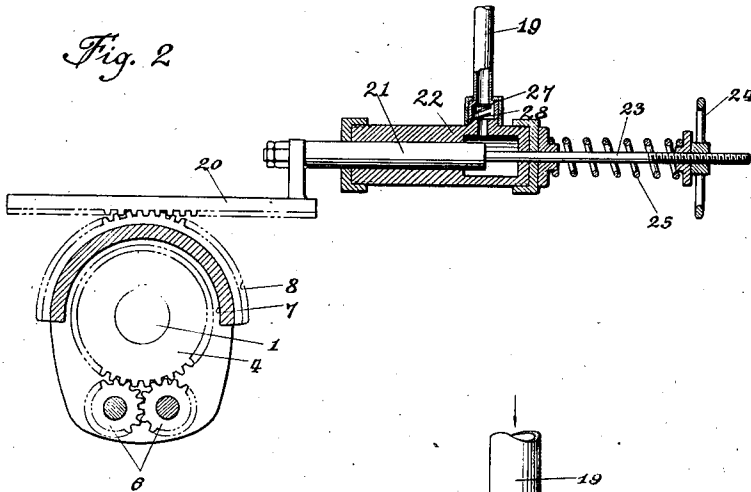
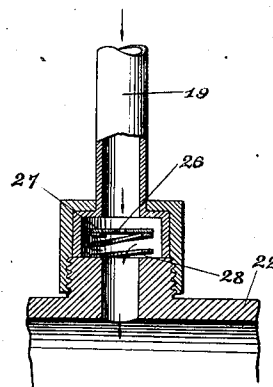


Fig. 3



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Fig. 4

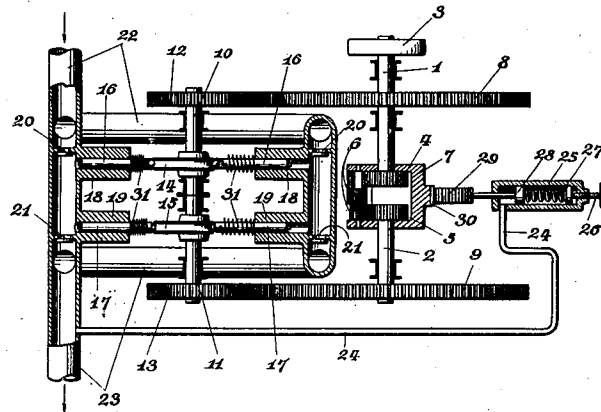
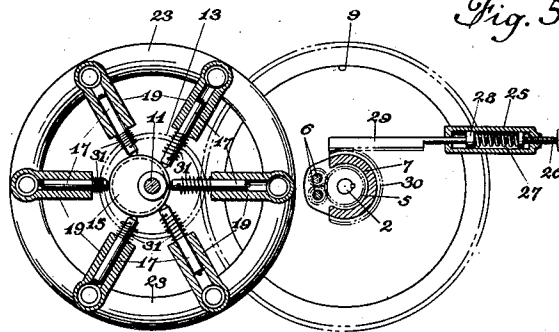


Fig. 5



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2 Claims. (Cl. 103—37)

The present invention relates to a pump such as may generally be used for hydraulic presses or other similar hydraulic (pressure-actuated) machines, and more particularly to a multi-cylinder pump consisting of a plurality of reciprocating pump units of an even number, whose plungers are arranged in a common pump housing, every two of said pump units being cooperatively associated with each other through a differential gear to form one pair.

One object of the present invention is to provide a novel pump of this kind having a pressure balancing device, which, being under the resilience of a spring and subject to the existing discharge pressure of the pump, is operatively associated to a differential gear adapted to permit the relative displacements of two cams, which drive, individually, their own sets consisting of each of paired plungers, in order to keep said relative displacement unvariable. In the present invention, the existing discharge pressure which is transmitted through each plunger, through one of the cams and a shaft to which said cam is fixed to the differential gear, as well as the existing discharge pressure of the fluid delivered from the discharge port of the pump to said balancing device, equal the force exerted by the resilience of the spring of the balance device after effecting the relative displacement of the two cams and, consequently, the differential movement of the differential gear. This equalizing of the existing discharge pressure with the force from the balancing device is maintained continuously, unless it is desired from service reasons to raise or lower the discharge pressure of the pump. During the equalizing period the stroke phases of every paired plungers are made to differ from each other by an amount corresponding to the difference between the existing discharge pressure and the initial, i. e., the lowest discharge pressure of the pump. When from any cause, such as may occur in a hydraulic press whose working pressure is to be varied according to the material to be pressed, the discharge pressure of the pump is required to be raised or lowered, the discharge pressure in the discharge port is raised or lowered by any means, which pressure, after effecting the relative displacement of the cams, equalizes with the force from the balancing device as mentioned above, so that a desired pressure can be imparted very rapidly and sensitively to the fluid discharging from the pump housing, and the pump is thus able to discharge continuously the fluid under the said desired pressure.

It is desirable and of advantage to actuate the pressure-balancing device very rapidly or sensibly when the discharge pressure rises, but very slowly or stolidly when the said pressure falls; for, in general, the rise in the discharge pressure occurs very gradually, so that the differential gear, intermediate gearings etc. are almost never subjected to destructive shocks due to the said pressure rise, whereas the fall in the discharge pressure appears very suddenly, so that shocks due to the said pressure fall are frequently transmitted to the differential gear etc., which shocks may induce damages or eventual destruction of said gear etc.

In the pump due to the present invention, especially in case of each of the cams driving only each one of the plungers, after the differential gear has effected its differential movement the state of said movement is maintained unvaried during the discharge stroke of the plunger, while because during the suction stroke the discharge pressure transmitted through the plunger, cam, etc., to the differential gear vanishes, said gear tends to vary the state of its differential movement by the resilience of the spring acting on said gear so as to diminish the phase difference between the cams. This tendency of the gear is completely removed by actuating the pressure-balancing device sensitively, when the discharge pressure of the pump rises, and stolidly, when said pressure falls. In other words, in such a case as mentioned above the flow-controlling device restrains the fluid in the hermetically sealed body from flowing out therefrom during the half revolution of the cam for the suction stroke and thus the pressure of the fluid in said body is caused to rise so as to balance with the restoring force (resilience) of the spring, with the result that the state of the differential movement is kept substantially unvaried. Considering this respect one cannot help saying the flow-controlling device is of a great importance for the action of the pump due to the present invention.

Another object of the present invention is, therefore, to actuate the pressure-balancing device sensibly, when the discharge pressure of the pump rises, and stolidly, when the said pressure falls, so that the causes underlying the above-mentioned unfavorable occurrences are removed and the pump is able to operate smoothly.

The invention possesses other objects and features of advantage, some of which with the foregoing will be set forth in the following description. In the following description and in the claims, parts will be identified by specific names

for convenience, but they are intended to be as generic in their application to similar parts as the art will permit. In the accompanying drawings the best embodiments of the invention known to the inventor have been illustrated, but such embodiments are to be regarded as typical only of many possible embodiments, and the invention is not to be limited thereto.

The novel features considered characteristics of the present invention are set forth with particularity in the appended claims. The invention itself, however, together with additional objects and advantages thereof will best be understood from the following description of specific embodiments when read in connection with the accompanying drawings, in which:

Fig. 1 is a sectional plan view of an embodiment of the present invention, having only one pair of the pump units;

Fig. 2 is a vertical sectional elevation showing the pressure-balancing device assembly of the embodiment shown in Fig. 1;

Fig. 3 is an enlarged vertical sectional elevation of a flow-controlling arrangement of the pressure-balancing device shown in Fig. 2;

Fig. 4 is a sectional plan view of another embodiment of the invention, having several pairs of pump units and differing constructionally somewhat from the embodiment shown in Fig. 1;

Fig. 5 is a sectional side elevation of the embodiment just referred to.

Now, referring more particularly to the accompanying drawings, a driving shaft 1, to which is transmitted the drive torque through a belt pulley 3 from any power-source, such as an electric motor, is arranged face to and in the same line with a driven shaft 2. Sun toothed wheels 4 and 5 of an epicyclic gear i. e., of a differential gear are keyed to the face ends of the two shafts 1 and 2, respectively, and planet toothed wheels 6, 6 meshing with said sun wheels in the well known manner are supported in a gear case 7 which is, in its turn, loosely mounted on the shafts 1 and 2, and provided with outer teeth 8 on its periphery, that is to say, while the two gears 6 mesh with one another, one of the gears 6 meshes with gear 4 while the other gear 6 meshes with gear 5. Two cams or eccentric wheels 9 and 10 are keyed to the shafts 1 and 2, respectively, and drive plungers 11 and 12 slidably inserted into the pump housings 13 and 14, which constitute the pump housing of the multi-cylinder pump. The outer end of each plunger is in constant contact with the circumference of its cams by means of the action of a helical spring 15 or 16. The pump housing is provided with a common suction pipe 17 and a discharge pipe 18 to which latter is connected a pressure-pipe 19 leading the fluid under discharge pressure to the pressure-balancing device. A rack 20 engages with the outer teeth 8 of the gear case 7 and transmits the differential movement of the differential gear to the pressure-balancing device in such manner as explained hereinafter.

An example of a pressure-balancing device due to the present invention is shown in Fig. 2. It mainly consists of a hermetically sealed body 22 communicating with the discharge side of the pump through pressure-pipe 19, and an actuating rod 21 slidably inserted into said body 22 and subjected to the resilience of a spring 25 and the discharge pressure of the pump. The actuating rod 21 shaped, for example, as a plunger is secured at its one end to the rack 20 and at its other end is formed as a relatively thin rod 23

projecting out of the body 22. An adjusting hand wheel 24 is screwed on the extremity of rod 23, and a helical spring 25 is wound between the body 22 and the hand wheel 24, so that the actuating rod 21 is always subjected to a force tending to pull said rod into the body. In the part of the pressure-pipe 19 where it communicates with the inside of the body 22, is provided a flow-controlling device as shown in Fig. 3, which consists of a throttling disc 27 provided with a center hole 26 and subjected to the force exerted by a helical spring 28. This controlling device works in the following manner: when the fluid under discharge pressure flows into the body 22 the throttling disc 27, owing to pressure exerted thereon by the fluid, is moved against the spring 28, and forms a passage of annular cross-section thereabout, allowing the relative rapid flow of the fluid into the body 22; whereas, when the fluid flows back or out of the body 22, the disc 27 is moved back to close the annular passage, and forces the fluid in the body 22 to flow back through the small center hole 26 only, whereby thus allowing only a comparative slow out-flow of the fluid from the body 22. 29 and 30 are guide members for the plungers 11 and 12, respectively. The rack 20 and the outer teeth 8 of the gear case 7 of the differential gear may be replaced by a link mechanism, without the effectiveness of the actuation of the pressure-balancing device being influenced.

The driving shaft 1 is rotated by the belt pulley 3 driven from any power source, and after the cams 9 and 10 have been positioned so as to rotate synchronously, the rotation of the shaft 1 is transmitted to the driven shaft 2 over the differential gear train 4, 6, 6, 5. The cams 9 and 10 each drive their own plungers 11 and 12 synchronously, i. e., in the same stroke phase. When the discharge pressure of the pump is raised and, consequently, the pressure acting upon the end face of each of the paired plungers 11 and 12 increased, then one of said plungers, i. e., the plunger 12 tends to be displaced from the other, in other words, to move in a stroke phase different from the other, so as to moderate the compression exerted by the plungers. The resisting force against cam 10 exerted by the plunger 12 is thus increased and is transmitted through the driven shaft 2 to the differential gear, which is then correspondingly moved differentially, resulting in the gear case 7 effecting a relative rotary movement in respect to the driving shaft 1, whereby the actuating rod 21 is moved counter to the action of the spring 25. Meanwhile, the discharge fluid under the pressure now existing in the discharge side of the pump has flowed through the pressure-pipe 19 into the body 22, and tends to push the actuating rod 21 out of the body 22 counter to the action of the spring 25. The discharge pressure of the pump is thus balanced with the force exerted by the resilience of the spring 25, unless the said pressure is required to rise or fall from any cause, and the pump continuously discharges the fluid under said pressure. On the other hand, when the discharge pressure of the pump falls from any cause, the resilience of the spring 25 overcomes the said discharge pressure which acts on the end face of the plunger 12 and the actuating rod 21, and, therefore, said spring tends to pull the rod 21 into the body 22, so that the amount of the differential movement of the differential gear is diminished, resulting in a decrease of the difference between the stroke phases of the paired plungers 11 and 12. Thus, when the force due to the resilience of

the spring 25 comes to correspond to the lowered discharge pressure of the pump, the serial movements of the actuating rod, differential gear, etc., are halted and the pressure-balancing device actuates the pump to continuously discharge the fluid under the said lowered pressure. In the present invention, however, because the outflow of the fluid from the body 22 is throttled by the flow-controlling device, as mentioned above, even in the event of the discharge pressure being suddenly lowered, the spring 25, resisted by the fluid still in the body, is not able to pull the actuating rod 21 into the body 22 at the correspondingly sudden rate, but is able to do so only very slowly. Therefore, in the event of use of a throttling device as in the present invention, sudden shocks which would otherwise be imparted to the gearing parts are prevented. The pressure-balancing device in the present invention thus serves also as a shock-absorbing (damping) device for the gearing parts.

As mentioned above, the pump due to the present invention may be operated in accordance with the pressure fluctuation in the discharge side, without imparting any destructive shocks to the gearing parts, but may also always maintain the said pressure at a desired constant value unless fluctuating occurs.

In the foregoing embodiment, the plunger-driving cams are secured directly to the shafts on which the differential gear for the pressure-balancing device is mounted. However, a pump of this type is required to operate at a high revolutionary speed for service reasons, and when the pump is thus operated at high speed, the differential gear, which is furthermore required to move in accordance with the discharge pressure fluctuations, is also compelled to do so. The differential gear, therefore, is subjected to the most unfavorable stresses, which may eventually lead to the utter destruction of said gear. In the embodiment shown in Figs. 4 and 5, in order to remove this defect, besides a pair of the driving and driven shafts between which the differential gear is intercalated another pair of rotating shafts to which are keyed the plunger-driving cams is provided, and speed-changing gear trains are arranged parallel to each other between the two pairs of the shafts, so as to transmit the rotation of the first pair of shafts to the second pair at an increased ratio. This arrangement has the merit that two cams can drive several pairs of plungers, because the pumping assembly and the pressure balancing device can be spaced as far apart as necessary.

In Figs. 4 and 5, the reference numerals 1—7 denote the same or corresponding parts as in Figs. 1 and 2. 8 and 9 denote larger toothed wheels keyed to the driving and driven shafts 1 and 2, respectively, which wheels are in mesh with smaller toothed wheels 12 and 13, which are also keyed to paired rotating shafts 10 and 11, respectively. To said rotating shafts 10 and 11 two cams 14 and 15 are keyed respectively, which drive individually their own sets of radially arranged plungers 16 and 17, which again work in pair and which are inserted into paired housings 18 and 19 respectively. Every housing pair 18 and 19 is provided with an inlet 20 and outlet 21 and connected with a common suction pipe 22 and discharge pipe 23. A pressure-pipe 24 connected to the discharge pipe 23 opens into a body 25 of a pressure-balancing device, in which body 25 is slidably arranged a piston 28 subjected to the discharge pressure of the pump and the force exerted

by the spring 25 which can be adjusted by an adjusting threaded rod 26 screwed in the body 25. An actuating rod rigidly connected to the piston 28 and projecting out of the body 25 is also connected rigidly to a rack 29 which meshes with the teeth 30 arranged on the periphery of the gear case 7 of the differential gear. 31 denotes a helical spring which acts on the plunger 16 or 17 so as to press it against the circumference of the cam 14 or 15.

The operation of the embodiment just referred to is quite the same as that of the embodiment shown in Figs. 1 and 2. However, in the former, the number of the revolutions of the paired shafts 1 and 2 can be greatly reduced by the intercalation of speed-changing gear trains between the said paired shafts and the paired rotating shafts 10 and 11, and, therefore, too high revolutionary speeds of the differential gear train with its consequential unfavorable stresses are completely avoided.

Having now particularly described and ascertained the nature of the present invention, and in what manner the same is to be performed, I declare that what I claim is:

1. A variable delivery type of pump which comprises a pump chamber, a pair of reciprocable volume displacers or plungers to operate in said chamber, primary or driving eccentric means for actuating the one plunger, secondary or driven eccentric means for actuating the other plunger, a differential gear device operatively interconnecting said primary and said secondary plunger actuating means and normally adapted to transmit driving force from the one to the other, said differential gear device having a member which is movable although resiliently restrained and which is responsive to the driving force being transmitted through said gear device, a hydraulic pressure chamber associated with said pressure responsive member to control the same, the movement of said member being adapted to effect a corresponding relative phase shifting between said eccentric actuating means, spring means for resiliently restraining the power transmitting force manifesting itself in said member, hydraulic pressure transmitting pipe connections arranged and effective to cause pump discharge pressure to influence and balance said force responsive member as against the pressure of said spring restraining means and in a manner to effect a positive setting of said member with respect to the amount of phase shifting of the actuating means in response to pump delivery pressure, and a flow throttling device interposed in said pressure transmitting pipe connection, said connection having therein a widened portion designed to provide oppositely disposed annular seating faces extending transversely of the longitudinal axis of the pipe and of the flow of pressure liquid therethrough, one way throttling means disposed in said widened portion and comprising an apertured substantially flat and relatively light and thin disk-like throttling member seatable upon the one of said annular seating faces and a compression coil spring seated upon the other of said annular seating faces and confined between it and said disk-like throttle member, said flow throttling device being instantaneously responsive to the high speed operation of the pump, in that it responds instantaneously and reacts sensitively when the discharge pressure of the pump rises or manifests itself as during the pressure stroke of the pump, but reacts flow throttling when the pressure drops or is checked as during the suc-

tion stroke of the pump, thereby stabilizing the operation of the pressure responsive member with respect to unwanted pressure fluctuations at the pump discharge end.

- 5 2. A variable delivery type pump according to claim 1, in which the pressure transmitting pipe connection has a coupling with said hydraulic

pressure chamber, which coupling comprises a nipple connection between the hydraulic pressure chamber and the pressure transmitting pipe, which nipple connection also constitutes the operating chamber for said throttling device.

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