Jan. 29, 1963 C. M. FINLEY 3,075,473

DIFFERENTIAL PUMP

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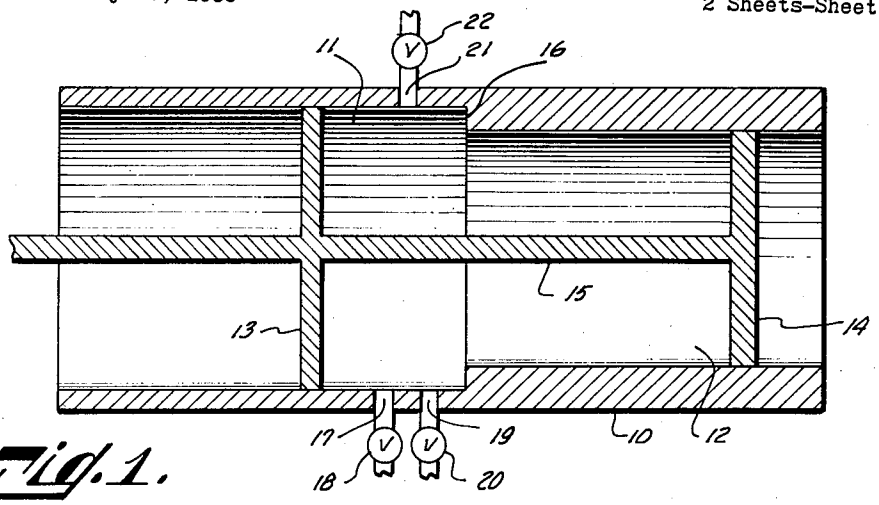


Fig. 1.

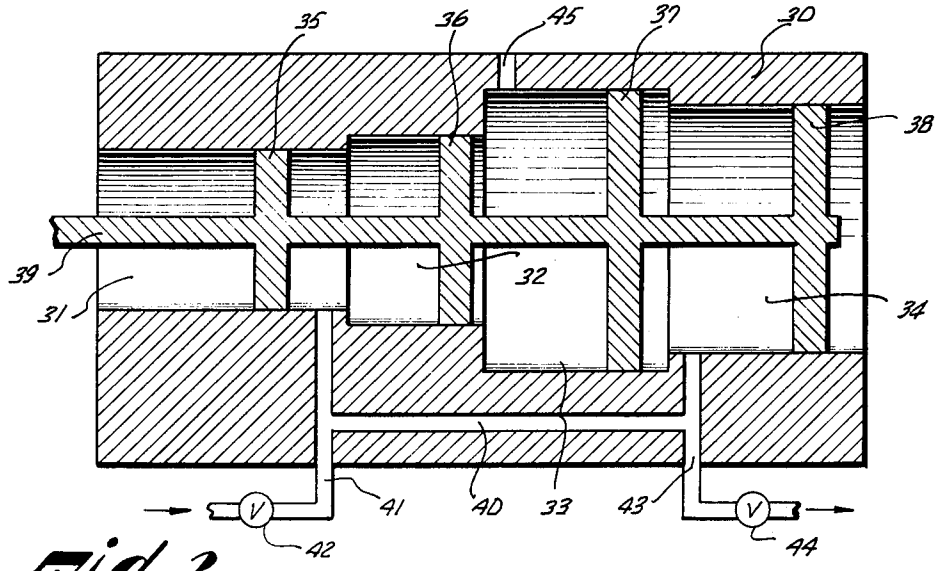


Fig. 2.

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Fig. 3.

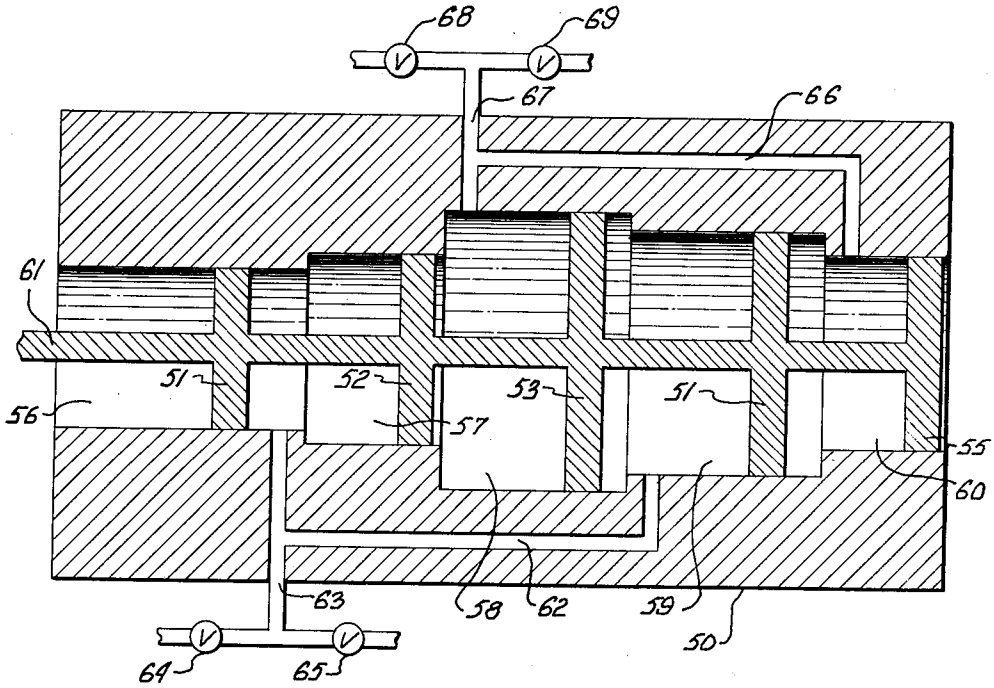
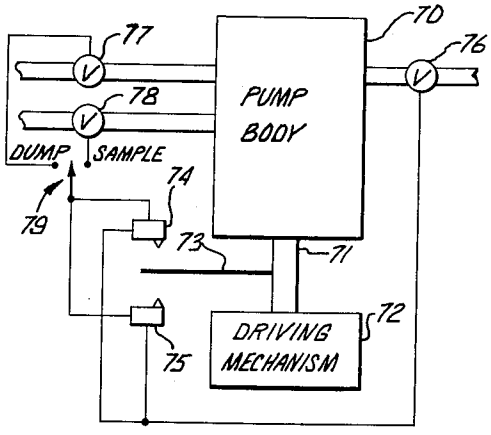


Fig. 4.



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DIFFERENTIAL PUMP

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This invention relates to a differential pump, that is, a pump in which pumping of a hydraulic fluid is achieved by simultaneously changing by different amounts the volumes of two cylinders which contain the fluid so that the resultant over-all change in volume of the cylinders pumps the fluid.

Various types of pumps which are capable of pumping small volumes are well known. Conventionally, such pumps suffer from the comparative disadvantage of lack of precise metering of the quantity of hydraulic fluid pumped. For example, if only a small amount of hydraulic fluid is to be pumped, the conventional pump of the piston and cylinder type may utilize a short stroke of its piston. However, the use of short piston strokes requires that the length of the stroke be precisely measured. Small variations in the length of the stroke result in relatively wide variations in the quantity of fluid pumped. Therefore, it is desirable to have a long stroke in such a pump. Heretofore no such pump has been available.

According to the present invention, the change in the volume available for storing a hydraulic fluid between pistons contained in cylinders of differing diameters is utilized to effectuate precise metering of the hydraulic fluid pumped. The cylinders are connected together, either by opening directly into each other or by a by-pass passage, so as to form a space into which the fluid to be pumped is introduced. Motion of the pistons is such that, as the volume available for the storage of fluid in one of the cylinders decreases, the volume available for the storage of fluid in the cylinder connected thereto increases. If the change in the volume of the space available for the storage of the hydraulic fluid is an over-all increase, fluid is introduced into the space through an inlet. If the change in the volume available for the storage of hydraulic fluid is an over-all decrease, fluid is extracted from the space through an outlet by the compressive force of the diminishing volume. By using a reciprocatory piston motion, hydraulic fluid is alternately introduced into and extracted from the space.

The invention may be more readily understood by reference to the accompanying drawing in which:

FIGURE 1 is a sectional view of a differential pump according to the invention consisting of two adjacent cylinders opening into each other;

FIGURE 2 is a sectional view of a pump according to the invention in which two pumps of the type shown in FIG. 1 are connected together so that the volume pumped is the difference in the pumped volumes of the two pumps;

FIGURE 3 is a sectional view of a pump according to the invention in which three pumps of the type shown in FIG. 1 are connected together so as to produce continuous pumping; and

FIGURE 4 is a block diagram of a control system such as may be utilized to control the differential pump valves.

Referring to FIG. 1, a hollow housing 10 has a configuration such that a first cylindrical portion 11 and a second cylindrical portion 12 are contained therein so as to be axially aligned. A first piston 13 and a second piston 14 are contained within the first and second cylindrical portions respectively. The pistons 13 and 14 are connected together so as to maintain a constant distance therebetween by means of a piston rod 15. The first and

second cylinders open onto each other at a shoulder 16. An inlet 17 and an inlet check valve 18 permit the introduction of hydraulic fluid into the space between the two pistons. A first outlet 19 and first outlet check valve 20 and a second outlet 21 and a second outlet check valve 22 permit the egress of hydraulic fluid from the space between the two pistons.

Movement of the second piston 14 towards the shoulder 16 by means of a reciprocal drive system (not shown) connected to the piston rod 15 causes the volume of the space between the piston 14 and the shoulder 16 to decrease. Simultaneously, the first piston 13 is moved in a direction away from the shoulder 16 and the volume of the space between the first piston 13 and the shoulder 16 increases. The first cylinder 11 has a diameter greater than the second cylinder 12. Therefore, piston movement just described results in an over-all increase in the volume of the space between the two pistons 13 and 14. This increase in volume reduces the hydraulic pressure within the space between the two pistons 13 and 14, causing the inlet check valve 18 to open. Fluid then passes into the space between the two pistons 13 and 14 until the hydraulic pressure within the space is equal to the hydraulic pressure at the inlet check valve 18.

Movement of the second piston 14 by the reciprocatory drive mechanism in the reverse direction of that described in the preceding paragraph causes the first piston 13 to move towards the shoulder 16 and the second piston 14 to move away from the shoulder 16. The movement of the first piston 13 towards the shoulder 16 results in a decrease in the volume of the space between the first piston 13 and the shoulder 16. This decrease in volume is greater than the increase in volume of the space between the shoulder 16 and the second piston 14 caused by the movement of the piston 14 away from the shoulder 16. Therefore, the pressure on the hydraulic fluid contained between the two pistons 13 and 14 increases and the outlet check valves 20 and 22 open.

Preferably, the outlet check valves 20 and 22 are controlled so that either valve may be selected to be operable to permit the egress of fluid therethrough. For example, the outlet 19 and check valve 20 may be connected to a reciprocatory or to a dump system and the outlet 21 and outlet check valve 22 connected to a sampling system. The first outlet check valve 20 would then normally be actuated and the second outlet check valve 22, normally de-actuated. When it is desired to take a sample, the actuation states of the two outlet check valves are reversed and the sample taken through the second outlet check valve 22, the first outlet check valve 20 remaining closed. Thus, a quantity of hydraulic fluid is extracted, the volume of which corresponds to the change in volume of the space between the two pistons for one stroke of the pistons.

By making the cylinders of nearly the same diameter, a relatively long piston stroke may be utilized to extract a small sample volume. In addition, small variations in the length of the stroke of the piston do not appreciably vary the size of the sample extracted. Therefore, the pump is adjusted by changing the length of the stroke to get a precise metered quantity of fluid sample through the second outlet check valve 22.

FIGURE 2 is a sectional view of a differential pump in which two pumps of the type described with respect to FIG. 1 are connected together so as to pump in opposition to each other. The volume pumped is then the difference in the pumping volumes which the two pumps would have if operated separately. Thus, by utilizing two pumps of almost the same pumping volume, extremely small and precisely metered samples of hydraulic fluid can be extracted.

The pump of FIG. 2 consists of a housing 30 with first, second, third and fourth cylindrical spaces 31, 32, 33 and 34, respectively, contained therein and axially aligned so as to be adjacent and open into each other. A first piston 35, a second piston 36, a third piston 37, and a fourth piston 38 are contained within the first, second, third and fourth cylindrical portions 31, 32, 33 and 34 respectively. The pistons 35–38 are connected together by a piston rod 39 so as to maintain a constant distance between each of the pistons. The space between the first and second pistons 35 and 36 and the space between the third and fourth pistons 37 and 38 are connected together by means of a by-pass passage 40. A hydraulic fluid inlet 41 to which is connected an inlet valve 42, opens into the by-pass passage 40 and thereby is connected to the space between the first and second pistons 35 and 36 and the space between the third and fourth pistons 37 and 38. An outlet 43 to which is connected an outlet valve 44 similarly opens onto the by-pass passage 40. The inlet valve 42 and the outlet valve 43 may be check valves, for example. A vent 45 vents the space between the second and third pistons 36 and 37 to prevent the build up of a pressure within this space in response to piston movement.

Movement of the fourth piston 38 towards the by-pass passage 40 by a reciprocatory drive means (not shown) acting on the piston rod 39 causes the space between the third and fourth pistons 37 and 38 to increase. Movement of the first piston 35 away from the by-pass passage 40 causes the space between the first and second pistons 35 and 36 to decrease. As shown in FIG. 2, the increase in volume between the third and fourth pistons 37 and 38 for such movement will be greater than the corresponding decrease in volume between pistons 35 and 36. Therefore, the inlet valve 42 opens. Fluid moves into the space between the third and fourth pistons 37 and 38 both through the inlet 41 and from the space between the first and second pistons 35 and 36 through the by-pass passage 40.

Movement of the pistons in the opposite direction to that described in the preceding paragraph by the reciprocatory drive mechanism results in a decrease in the overall volume available for the hydraulic fluid between the first and second pistons 35 and 36 and the third and fourth pistons 37 and 38. The outlet valve 44 then opens and a sample corresponding to this difference in volume passes through the outlet check valve 44.

As a practical example of the small volume which may be accurately pumped by using the device of FIG. 2, dimensions for such a pump are as follows:

First cylinder 31 diameter—$\frac{55}{64}$ inch
Second cylinder 32 diameter—$\frac{7}{8}$ inch
Third cylinder 33 diameter—1 inch
Fourth cylinder 34 diameter—$\frac{63}{64}$ inch

For a pump having the above dimensions and a one inch stroke, a volume of 0.0386 cubic centimeters of hydaulic fluid is pumped per reciprocatory stroke cycle.

FIGURE 3 is a sectional view of a pump according to the invention which is utilizable for continuous pumping of hydraulic fluid, the pumps illustrated heretofore having required a complete stroke cycle in order to pump one sample volume. The differential pump of FIG. 3 consists of a housing 50 containing first, second, third, fourth and fifth pistons 51, 52, 53, 54 and 55 respectively in axially aligned first, second, third, fourth and fifth cylindrical portions 56, 57, 58, 59 and 60. The pistons 51–55 are connected together by a piston rod 61 so as to maintain a constant distance therebetween. The piston rod 61 and therefore the pistons 51–55 are driven in a reciprocatory motion by a reciprocatory drive means (not shown). A first by-pass passage 62 connects the space between the first and second pistons 51 and 52 and the space between the third and fourth pistons 53 and 54. A first combined hydraulic fluid inlet and outlet 63 opens into the by-pass passage 62 and has connected thereto a first inlet valve 64 and a first outlet valve 65. A second by-pass passage 66 connects the space between the second and third pistons 52 and 53 and the space between the fourth and fifth pistons 54 and 55. A second combined hydraulic fluid inlet and outlet 67 opens into the second by-pass passage 66 and has connected thereto a second inlet check valve 68 and a second outlet check valve 69.

The operation of the differential pump of FIG. 3 is essentially the same as the operation of the pump of FIG. 2 heretofore described. The space between the first and second pistons 51 and 52 and the space between the third and fourth pistons 53 and 54 comprise one pump as described with respect to FIG. 2. The space between the second and third pistons 52 and 53 and the space between the fourth and fifth pistons 54 and 55 comprise a second such pump. Motion of the piston rod 61 causes the hydraulic fluid space of one of the pumps to increase in volume while the hydraulic fluid space of the other pump decreases in volume. The pump whose volume increases has hydraulic fluid introduced thereinto through its inlet valve while the pump whose volume decreases expels hydraulic fluid through its outlet valve. The reciprocatory motion of the pistons thus causes continuous pumping of hydraulic fluid through an outlet passage (not shown) to which the two outlet valves 65 and 69 are connected.

The pump of FIG. 3 differs from the pump of FIG. 2 in that continuous pumping is achieved through the outlet passage connecting the first outlet check valve 65 and the second outlet check valve 69. The device of FIG. 3 has the particular advantage of permitting metered mixing of two quantities by connecting the inlet valves 64 and 68 each to one of two hydraulic fluids. By varying the diameter of any one of the five cylindrical portions 56–60, the exact mixing ratio between the two hydraulic fluids is set. Movement of the piston rod 61 and therefore the pistons 51—55 then alternately pumps the first and then the second hydraulic fluid through this outlet passage in the exact quantity ratios desired.

FIGURE 4 illustrates a system for controlling the actuation states of the inlet and outlet valves for a differential pump. A pump body 70 has a piston rod 71 extending therefrom. The piston rod 71 is connected to a drive mechanism 72 which drives the piston rod 71 in a reciprocatory manner. A contact arm 73 extends from the piston rod 71 and moves therewith. A pair of microswitches 74 and 75 are switched by the action of the contact arm 73. An inlet valve 76, an outlet dump valve 77, and an outlet sample valve 78 control the introduction to and egress from the pump body 70 of fluid. A function switch 79 is operable to select whether the outlet dump valve or the outlet sample valve is actuated.

The driving mechanism 72 drives the piston rod 71, causing the contact arm 73 to approach and contact one of the microswitches 74 and 75. The contacted microswitch causes the actuation states of the valves to change as may be appropriate to either introduce hydraulic fluid into the pump body or permit its egress from the pump body. The contact arm 73 then moves in the opposite direction until contacting the opposite microswitch, whereupon the actuation states of the valves are reversed. Thus, hydraulic fluid is introduced into the pump body or extracted from the pump body as appropriate.

I claim:

1. A hydraulic fluid differential pump comprising a housing containing a plurality of cylinders axially aligned in which adjacent cylinders are of differing diameters, a piston contained in each cylinder, a connecting member connecting said pistons together so as to maintain a constant distance therebetween whereby each piston has two oppositely disposed faces, whereby a space is formed between opposing faces of adjacent pistons, the connecting member between adjacent pistons having a maximum dimension transversely of the cylinders substantially less

than the smaller diameter of the pair of cylinders in which the connecting member is disposed at least one by-pass passage connecting nonadjacent pairs of said spaces, motive means for initiating reciprocal movement of the pistons, and fluid flow means for introducing a hydraulic fluid into said nonadjacent pairs of spaces as the total volume of said pairs of spaces increases in response to piston movement and for extracting said hydraulic fluid from said pairs of spaces as the total volume of said pairs of spaces decreases in response to piston movement.

2. A hydraulic fluid differential pump as defined in claim 1 in which the fluid flow means for introducing and extracting fluid includes a hydraulic fluid passage connected to said nonadjacent pairs of spaces to which are connected inlet and outlet valves.

3. A hydraulic fluid differential pump as defined in claim 1 in which the fluid flow means for introducing and extracting fluid includes an inlet and an inlet valve selectively operable to permit the introduction of fluid into each nonadjacent pair of spaces connected by a second by-pass passage and an outlet and an outlet valve operable to permit the egress of fluid from said pairs of nonadjacent spaces.

4. A hydraulic fluid differential pump as defined in claim 2 in which the inlet and outlet are connected to the by-pass passage.

5. A hydraulic fluid differential pump comprising a housing, at least two cylinders of differing diameters formed therewithin so as to be in axial alignment, a piston positioned in each cylinder, an inlet valve and at least one outlet valve, a connecting member connecting said pistons together so as to maintain a constant distance therebetween, the connecting member between adjacent pistons having a maximum dimension transversely of the axis of the cylinders substantially less than the diameter of the smaller of the pair of cylinders in which said adjacent pistons are positioned whereby spaces are formed between adjacent pistons, motive means for initiating reciprocal movement of the pistons, an inlet opening into the spaces and connected to the inlet valve, an outlet opening from said spaces and connected to the outlet valve, a bypass passage in the housing connecting the inlet and the outlet with two non-adjacent spaces formed by the pistons and cylinders, and fluid flow means for introducing a hydraulic fluid into the spaces between the pistons as the volume of the spaces increases due to piston motion and for extracting fluid from the spaces between the pistons as the volume of the spaces decreases due to piston motion, whereby the change in hydraulic pressure in said spaces resulting from piston motion is utilized to pump hydraulic fluid, the quantity of which is metered by the overall change in the volume of the spaces.

6. A hydraulic fluid differential pump comprising a housing defining first and second cylinders, each cylinder comprising first and second lengths of differing diameters, the difference in the cross-sectional areas of the first and second lengths of the first cylinder being different than said difference for the second cylinder, a piston in each of the first and second lengths of each of the cylinders, a connecting rod between the pistons in the first and second lengths of the first cylinder, a connecting rod between the pistons in the first and second lengths of the second

cylinder, each connecting rod having a diameter less than the diameter of the smallest diameter length of the cylinder in which each connecting rod is disposed, motive means for initiating reciprocal motion of the pistons at equal rates, reciprocation of the pistons causing the volume defined between the pistons of the first cylinder to vary inversely to the change in the volume defined between the pistons of the second cylinder, and fluid flow means for introducing a hydraulic fluid into the cylinders as the total volume between the pistons increases due to the piston motion and for extracting the hydraulic fluid from the cylinders as the volume defined between the pistons decreases due to piston motion.

7. A hydraulic fluid differential pump according to claim 6 including a continuously open passage communicating between the first and second cylinders and opening into said cylinders at the smaller diameter lengths thereof.

8. A hydraulic fluid differential pump according to claim 6 wherein the diameter of the first length of each cylinder is greater than the diameter of the second length of each cylinder, and including a continuously open passage connecting the second lengths of the cylinders.

9. A hydraulic fluid differential pump comprising a plurality of cylinders of differing diameters connected together by a housing so as to be in axial alignment, a piston positioned in each cylinder, each piston having an extent axially of its cylinder less than the axial extent of the respective cylinder whereby a plurality of open spaces are formed between opposing sides of adjacent pistons, a connecting member connecting the pistons together so as to maintain a constant distance therebetween, motive means for initiating reciprocal movement of the pistons, the housing defining passages means for interconnecting at least a pair of said open spaces, fluid flow means for introducing a hydraulic fluid into the interconnected spaces between the pistons as the total volume of the interconnected spaces increases due to piston motion and for extracting fluid from the interconnected spaces as the total volume of the interconnected spaces decreases due to piston motion, whereby the change in volume in the interconnected spaces resulting from piston motion is utilized to pump fluid from the fluid containing spaces, the quantity of fluid pumped being equal to the change in volume of said interconnected spaces.

References Cited in the file of this patent

UNITED STATES PATENTS

159,533	Westinghouse	Feb. 9, 1875
1,322,236	Fish	Nov. 18, 1919
1,513,422	Raymond	Oct. 28, 1924
1,580,973	Rembold	Apr. 13, 1926
2,365,234	Wineman	Dec. 19, 1944
2,755,739	Euwe	July 24, 1956

FOREIGN PATENTS

51,434	Germany	July 11, 1889
66,536	Norway	May 12, 1942
343,599	Germany	Nov. 7, 1921
427,404	Germany	Mar. 31, 1926
575,917	France	Aug. 8, 1924