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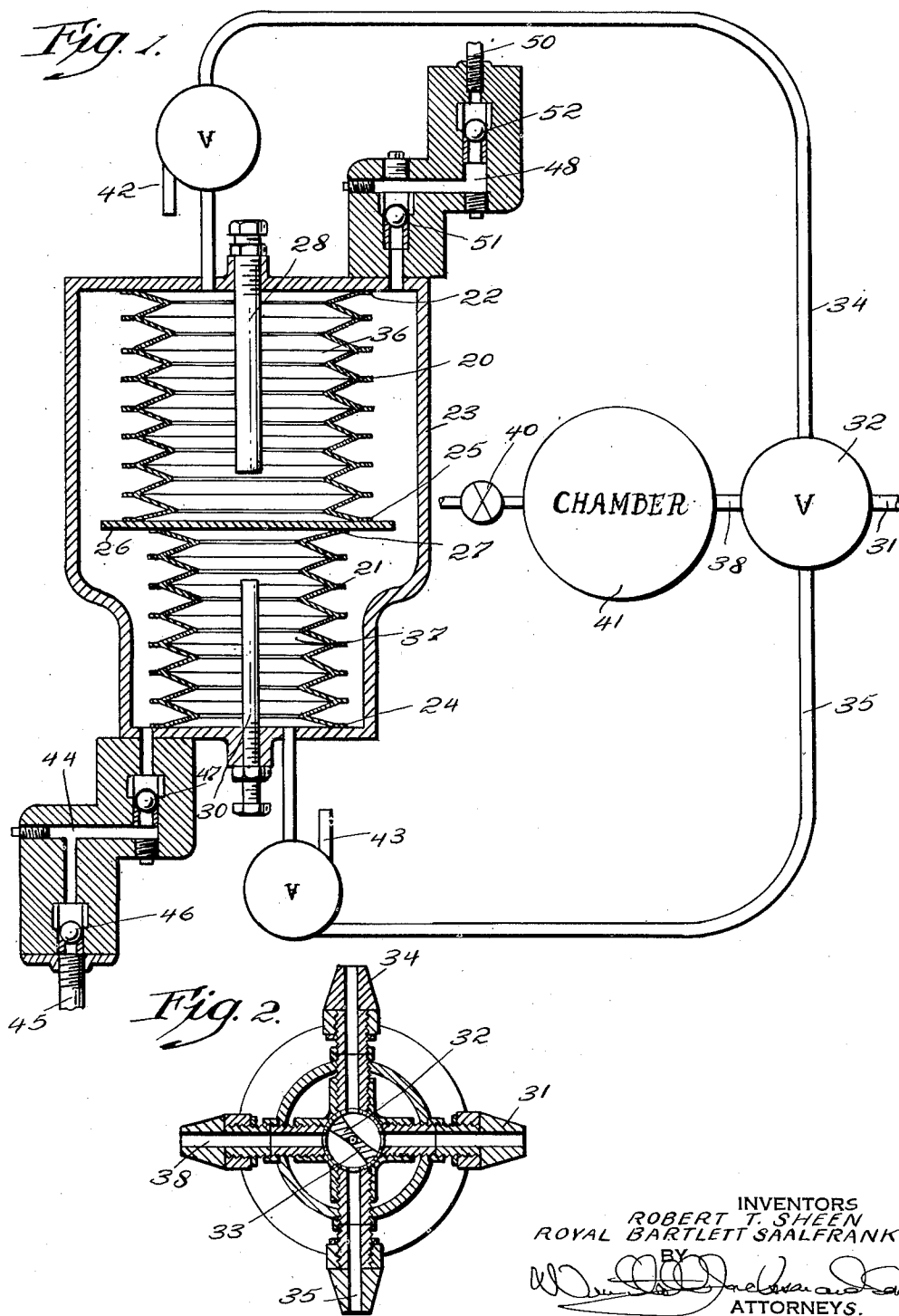
R. T. SHEEN ET AL

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BELLOWS PUMP

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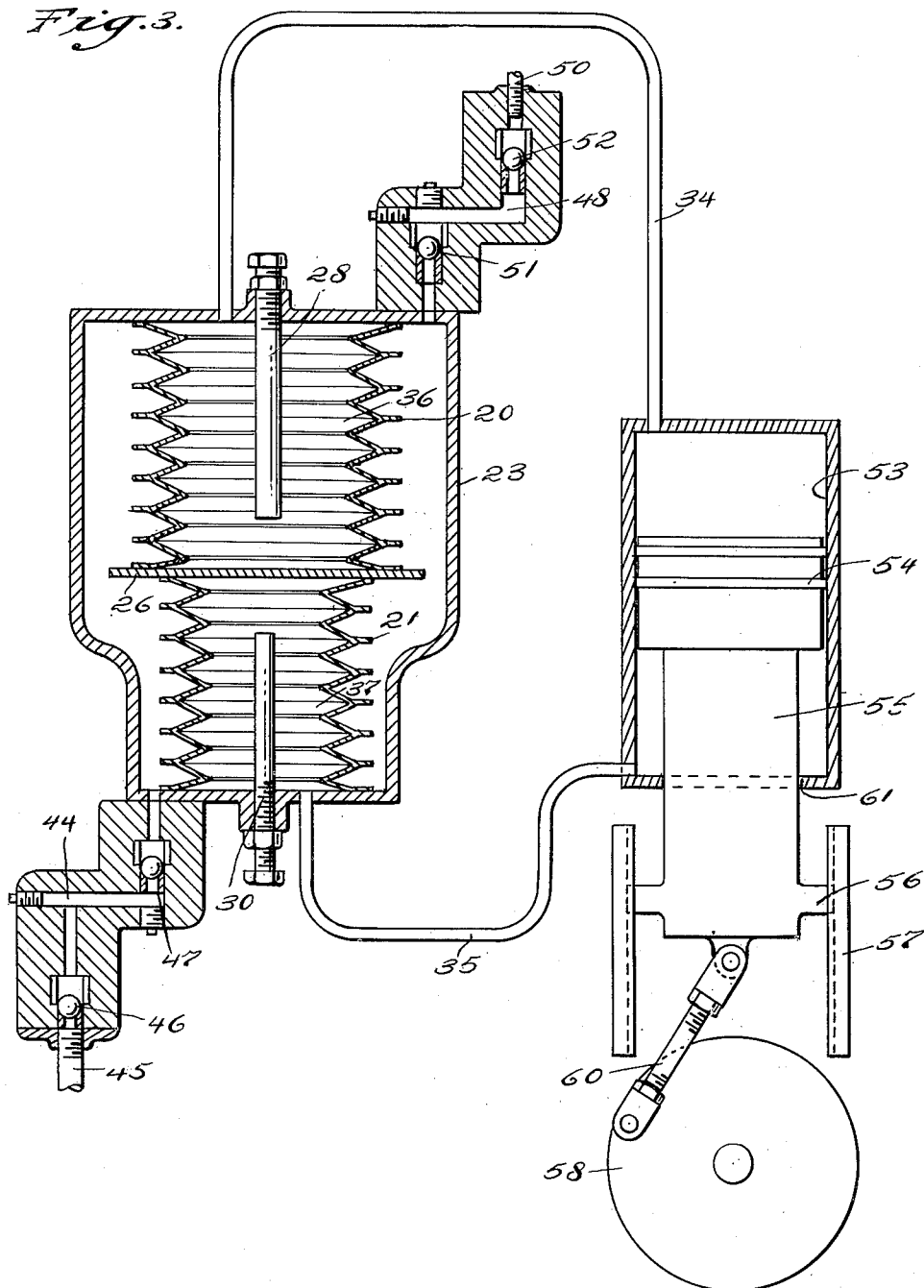
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Fig. 3.



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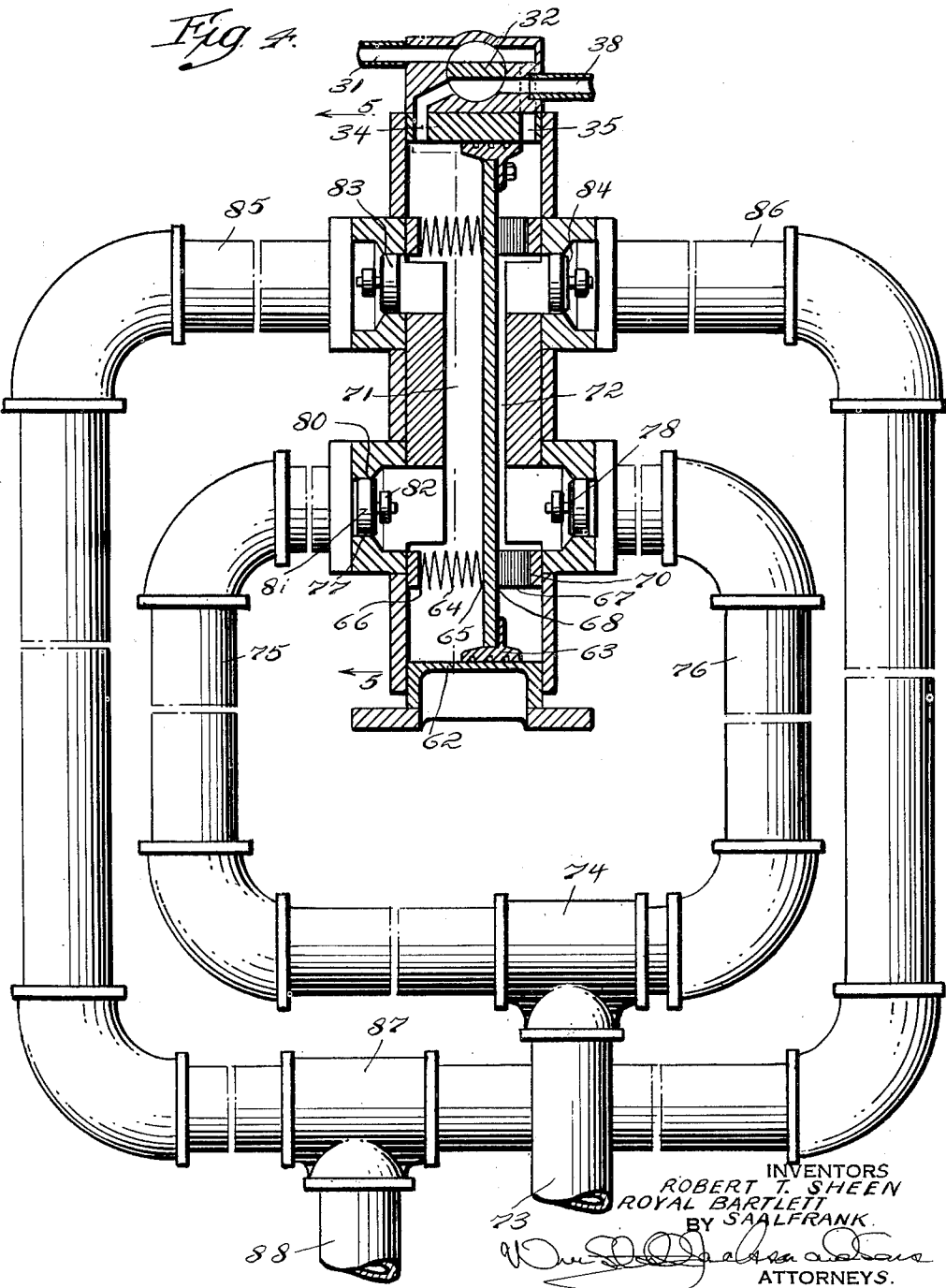
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BELLOWS PUMP

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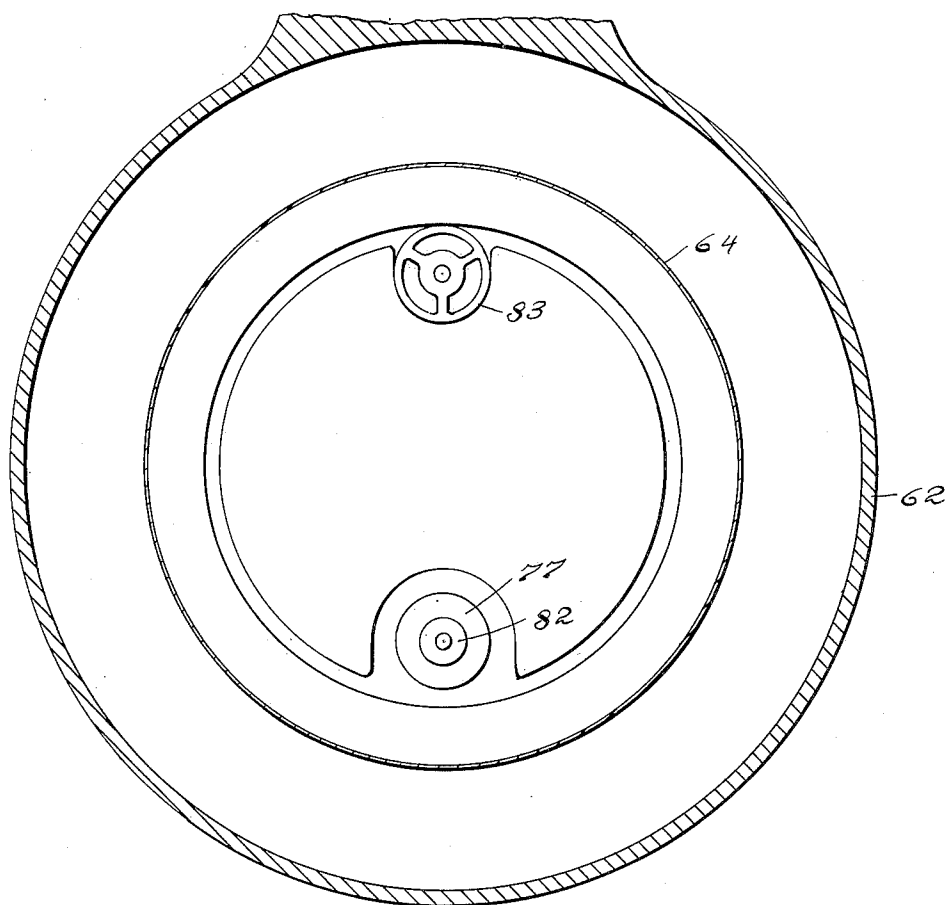
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BELLOWS PUMP

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FIG. 5.



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UNITED STATES PATENT OFFICE

2,613,607

BELLOWS PUMP

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Application October 27, 1949, Serial No. 123,804

23 Claims. (Cl. 103-44)

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The present invention relates to pumps particularly of the character which proportion fluids, especially liquids, but also applicable to general pumping applications.

The purpose of the invention is to improve the accuracy of discharge of bellows pumps by balancing the pressure on a plurality of bellows alternately to back up the bellows against pumping pressure. The balancing pressure may be desirably less than the fluid operating pressure and of the order of magnitude of the pressure developed by the pump.

A further purpose is to operate opposed bellows in a pumping chamber with the pump on one side of the bellows walls and fluid operating means on the other side of the bellows walls, with desirable addition of balancing pressure on the opposite bellows when fluid operating pressure is applied to one bellows.

A further purpose is to provide the fluid operation and balancing on the insides of the bellows and the pumping on the outsides of the bellows.

A further purpose is to use differential bellows and desirably to separate the bellows by a separating wall.

A further purpose is to provide a source of fluid operating pressure and a relief valve, and by a reversing valve to connect the source of fluid operating pressure and the relief valve alternately to the opposite bellows, preferably on the interior thereof.

A further purpose is to limit the stroke of bellows operation by stops acting on the separating wall in the devices above referred to.

A further purpose is to operate differential bellows by a driving cylinder having a piston whose displacement per unit motion corresponds to that of the larger bellows and a piston rod the space around which corresponds in displacement per unit motion with the smaller bellows, and to interconnect the interior of the larger bellows with the pumping cylinder at the end remote from the piston rod and the interior of the smaller bellows with the pumping cylinder at the end adjacent the piston rod, desirably providing a pumping chamber around the bellows.

A further purpose is to position a moving wall, preferably a piston, in a cylinder, to connect opposed bellows between the opposite ends of the cylinder and the moving wall and to fluid operate the moving wall, desirably by interconnecting a source of fluid operating pressure and a source of lower fluid balancing pressure through a reversing valve to the opposite sides of the moving wall on one side of the bellows, preferably

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the outside, and to pump from the other side of the respective bellows, preferably from a common inlet to a common outlet.

Further purposes appear in the specification and in the claims.

In the drawings we have chosen to illustrate a few only of the numerous embodiments in which our invention may appear, selecting the forms shown from the standpoints of convenience in illustration, satisfactory operation and clear demonstration of the principles involved.

Figure 1 is a diagrammatic central vertical section of a pump to which the invention has been applied.

Figure 2 is a diagrammatic transverse section across the axis of the reversing valve of Figure 1, in the plane of the paper of Figure 1.

Figure 3 is a view corresponding to Figure 2 showing a variation.

Figure 4 is a view corresponding to Figure 1 showing a further variation.

Figure 5 is a section of Figure 4 on the line 5-5.

Describing in illustration but not in limitation and referring to the drawings:

For many purposes bellows pumps provide a convenient, simple and reasonably accurate pumping movable wall which is highly satisfactory. In very precise pumping applications, however, as for example when chemical reagents are to be pumped for chemical reactions of high precision, bellows are not of sufficient accuracy because of their tendency to deflect under the difference in pressure applied to the two sides of the bellows wall (the outside and inside).

This condition is greatly aggravated when an effort is made to obtain precise metered pumping at high pressures or high temperatures or both.

A further difficulty develops when bellows are used in high pressure applications. Under such cases the bellows not only causes inaccuracy by its distortion, but suffers in its mechanical properties due to lowering of fatigue strength or endurance limit on account of the distortion caused by the pressure differential on the two sides, resulting in costly failures of bellows, and requiring increased supervision and frequent replacement.

In accordance with the present invention, the accuracy of pumping by bellows pumps is greatly increased, and this is particularly so at very high pressures, or temperatures or both, while at the same time the destructive tendency from distortion of bellows is largely avoided or greatly reduced. The tendency of the fluid to distort the bellows is overcome by balancing pressure. The bellows is also preferably operated by fluid pres-

sure, the differential between the fluid operating pressure and the fluid balancing pressure in many cases being small.

In accordance with the invention, two separate opposed bellows are used. The bellows are preferably but not essentially of different displacements per unit linear motion, due for example to difference in diameter or difference in effective diameter. The operating pressure in the preferred embodiment will usually be applied on the inside of the bellows and the pumping accomplished on the outside, although as shown in one of the embodiments this feature may if desired be reversed.

The fluid operation is preferably accomplished by a source of fluid pressure such as compressed air, compressed gas, or liquid under pressure such as water or oil, admitted alternately to the opposite bellows or the opposite ends of the movable wall, and balanced by fluid balancing pressure of any of the characters mentioned above which is lower than the fluid operating pressure and preferably of the order of magnitude of the pressure attained in the fluid pump. The fluid balancing pressure is desirably determined by the setting of a relief valve which may conveniently operate from a relief chamber.

The bellows are separated by a separating wall, and stroke limiting stops conveniently act on the separating wall to limit the stroke.

In one embodiment, the larger bellows is connected to an operating cylinder on the end remote from the piston rod, the operating cylinder having the same displacement per unit linear motion as the larger bellows. On the other end of the operating piston, the displacement per unit motion around the piston rod is the same as that of the smaller bellows and the smaller bellows is connected to this space around the piston.

In a further embodiment a cylinder of a pump is provided with a movable wall, suitably a piston. Opposed bellows connect from the opposite ends of the cylinder to the opposite ends of the piston. On one side of the respective bellows, pumps are provided at each end of the piston, preferably on the inside of the bellows, and the pumps desirably have common inlet and common outlet. Fluid operating means such as a reversing valve as already described are desirably connected to the opposite ends of the piston on the other side of the respective bellows, suitably the outside.

Figure 1 illustrates a pumping system embodying the invention comprising a bellows 20 having a large displacement per unit linear motion and a bellows 21 opposed thereto and having a smaller displacement per unit linear motion. The bellows as shown are coaxial and this relationship is to be regarded as the simplest, although any other relationship in which one bellows will expand when the other contracts may be employed. In the forms shown the bellows are of metallic construction, suitably of bronze, beryllium copper, stainless steel or other suitable resilient metal, although it will be evident that other materials such as rubber, synthetic rubber and plastic may be employed. The metallic bellows is preferable from the standpoint of accuracy. The bellows 20 is connected at one end 22 to the end wall of a pump cylinder 23, while the opposed bellows 21 is connected by one end 24 to the opposite end wall of the pump cylinder 23. The attachment may be in any suitable manner as by clamping, soldering, or welding.

The adjoining end 25 of bellows 20 to the opposite bellows is connected to a separating wall 26, while the adjoining end 27 of the opposite bellows 21 is similarly connected to the opposite side of the separating wall 26, the connection again being made in any suitable manner as by clamping, welding or soldering. Thus it will be seen that the two bellows and the separating wall act as a unit.

The interiors of the bellows are wholly separate and not interconnected through the separated wall.

Adjustably threaded into the adjoining end of the pump cylinder 23 is a stroke limiting stop 28 which is contacted by the separating wall at one end of the stroke, and similarly adjustably threaded into the opposite end of the pump cylinder 23 is a stroke limiting stop 30 which engages the separating wall 26 at the opposite end of the stroke. The stops 28 and 30 can be moved in and out to vary the stroke manually or automatically as desired.

It will be evident that the two bellows and the separating wall can be made to move axially in either direction by applying a pressure to the interior of either bellows sufficient to overcome any pressure applied to the interior of the opposite bellows and to the fluid being pumped. To achieve this result fluid pressure such as compressed air, gas, water or oil is derived from a source indicated by pipe 31 and enters a reversing valve 32 suitably provided with a separating vane 33 driven in any suitable manner. Most conveniently the vane 33 is driven by interconnection with a variable speed electric motor (not shown) so that the frequency of reversal of the valve can be adjusted by varying the speed of the motor.

The valve connects desirably to pipes 34 and 35 at positions 90° removed from the connection to the source. The respective pipes may be of any suitable length to permit remote operation and connect to the spaces 36 and 37 inside the opposite bellows. At a position opposite to the connection to the source of operating fluid pressure, the reversing valve is connected as by a pipe 38 to a balancing pressure relief valve 40 suitably through a relief pressure chamber 41.

As a precaution against development of abnormal pressures, emergency relief valves set at levels higher than the operating pressures may also be provided at 42 and 43 in the respective pipes 34 and 35.

Each time the opposed bellows move axially in either direction the available volume of the pumping space changes and the pump undergoes an inlet or discharge stroke. The pumping space is provided with an inlet passage 44 connected to an inlet pipe 45 and having check valves 46 and 47 in series with one another and opening toward the pumping space. At the outlet side, the pump is provided with an outlet passage 48 connecting to an outlet pipe 50 and having series check valves 51 and 52 opening away from the pumping space. It normally is not necessary to spring bias the check valves toward closing, gravity closing as shown being sufficient. The check valves are preferably of ball type as shown. The construction of the inlet and outlet passages is desirably progressively upwardly sloping without downwardly directed pockets as described in Milton Roy Sheen U. S. Patent No. 2,263,429, granted November 13, 1941, for Pump and No. 2,367,893, granted January 23, 1945, for Liquid Pump.

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In some cases it is desirable to have the opposed bellows fluid driven from a mechanical drive located at a remote point. A device of this kind is shown in Figure 3. This form includes an actuating cylinder 53 having a piston 54 driven by a piston rod 55 having crossheads 56 which slide in crosshead guides 57. A crank 58 pivotally connects by a connecting rod 60 with the piston. Suitable packing not shown can be provided at 61 where the piston rod passes through the cylinder wall.

The pipe 34 from the end of the actuating cylinder remote from the piston rod connects to the interior of the larger bellows 20 while the pipe 35 from the end of the actuating cylinder adjacent the piston rod connects to the interior of the smaller bellows 21. The space ahead of the piston, in the pipe 34 and in the larger bellows is filled with a suitable fluid and the space behind the piston and around the piston rod, in the pipe 35 and in the smaller bellows is similarly filled with a suitable fluid. The fluid may be compressed air, compressed gas, water, oil or other suitable medium.

The piston diameter is the same as the effective diameter of the larger bellows, so that the displacement per unit linear motion of the piston equals the displacement per unit linear motion of the larger bellows. Likewise the cross sectional area around the piston rod equals the mean cross sectional area of the smaller bellows, so that the displacement per unit axial travel of the piston rod equals the displacement per unit axial travel of the smaller bellows. Thus as the piston moves back and forth the opposed bellows move back and forth without accomplishing any compression or expansion of the actuating fluid in the preferred embodiment. The pumping space around the bellows in the cylinder 23 in Figure 3, and the inlet and outlet connections and valves, are the same as those of Figure 1.

In operation of the form of Figures 1 and 3, whenever the high pressure or actuating medium is applied to the pipe 34, the larger bellows 20 expands, moving the separating wall 26 down and compressing the small bellows 21. Fluid from the interior of the smaller bellows flows out of the bellows through the pipe 35. On this stroke there is a relative decrease in the volume of the pumping space, and the inlet check valves 46 and 47 close, discharging fluid from the pump through the outlet check valves 51 and 52 which open. The pressure inside the bellows sustains the bellows and prevents distortion due to the pumping pressure.

The stroke is limited by the stroke limiting stop 30 engaging the separating wall 26, unless the pump is earlier reversed.

On the next stroke, when the higher pressure fluid enters through the pipe 35, the smaller bellows 21 expands, pushing the separating wall 26 upward as far as permitted by the stroke limiting stop 28 or until the pump is reversed, and compressing the larger bellows 20 and forcing actuating fluid out the pipe 34. There is then a net increase in available space in the pumping chamber, causing the discharge valves 51 and 52 to close and the inlet check valves 46 and 47 to open, and thus producing the suction stroke of the pump.

The ways of producing the pressure of the actuating fluid, and rendering it available to the bellows, and of disposing of excess fluid in the retracting bellows vary in Figures 1 and 3. In

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Figure 1 the reversing valve 32 alternately applies higher pressure actuating fluid to the opposite pipes 34 and 35, and alternately connects the pipe not receiving the higher pressure actuating fluid to the balancing chamber 41 and relief valve 40 which predetermines the balancing pressure maintained in the retracting bellows. The valve element 33 simply continuously rotates in the same direction to reverse the connections as described.

In the form of Figure 3 the pump actuating pressure in one of the pipes 34 or 35 originates from the motion of the piston in that direction, while the motion of the piston in that direction makes available adequate volume on the opposite side of the piston to receive fluid forced out of the interior of the retracting bellows.

In the forms of Figures 1 and 3 we show the actuating fluid applied to the insides of the bellows and the pumping chamber located around the outsides of the bellows. Figures 4 and 5 illustrate a form in which this feature is reversed, the pumping being accomplished on the insides of the bellows and the actuation occurring on the outsides. In this form the separating wall forms a movable wall, preferably a piston, in the chamber.

Whereas in the other forms the bellows shown are differential bellows, the form of Figures 4 and 5 illustrates that the principles of the invention can be applied with equal bellows diameters.

The form of Figures 4 and 5 is especially suited to very high discharge rates in a pump of economical construction and accurate metering. This pump is especially suited to high temperature liquid pumping, as for example, the pumping of the eutectic of diphenyl and diphenyl oxide known as Dowtherm to boilers and heaters at elevated temperatures.

In this form a pumping cylinder 62 contains a wall 63 preferably in the form of a piston, which moves back and forth between the opposite ends of the cylinder. The movable wall 63 performs the function of the separating wall 26 of Figures 1 and 3. One opposed bellows 64 coaxial with the piston is secured to the piston or separating wall at 65 and to the opposite end of the cylinder at 66, while the opposite coaxial bellows 67 is secured at 68 to the opposite side of the piston or separate wall and is secured at 70 to the opposite end of the cylinder. The manner of securing the bellows to the opposite ends of the cylinder and to the piston may be for example by clamping, welding or soldering.

As in the form of Figure 1, reversing valve 32, suitably motor driven, connects from a fluid actuating pipe 31 alternately to opposite ends of the cylinder through pipe 34 and 35. A fluid balancing pressure pipe connection 38 is also provided. Pipe 35 passes behind pipe 33. Just as in Figure 1 the opposite pressures on the insides of the opposed bellows respectively move the bellows back and forth and balance the pressure, so in Figure 4 the actuating pressure alternately applied to the opposite ends of the piston outside the bellows and the balancing pressure alternately applied to the opposite end from the actuating pressure result in moving the piston and the bellows back and forth and balancing the bellows against distortion.

Inside the bellows are duplicate pumping spaces 71 and 72, one of which is always on suction stroke and the other on discharge stroke when the pump is operated. These two spaces pref-

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erably have common inlet and common discharge connection so that the pump will provide a measure of continuous delivery. Thus an inlet pipe 73 branches at 74 into separate inlet connections 75 and 76 to the respective pumping spaces, inlet valves 77 and 78 being provided in the connections. These inlet valves may in this case be disc valves 80 supported by spiders 81 and limited by stops 82. The valves may if required be biased toward closing by springs not shown.

Similarly on the discharge sides of the pumping spaces are outlet valves 83 and 84 suitably similar but reversed with respect to the inlet valves, discharging into outlet pipes 85 and 86 which join at 87 into an outlet connection 88.

Thus as the valve 32 reverses it alternately admits actuating pressure around one bellows and balancing pressure at a lower value around the opposite bellows, causing the piston to move back and forth, first compressing and then expanding each bellows. As the piston moves back and forth a change in the volume inside the bellows causes pumping action in the pumping spaces, one pumping space discharging while the other pumping space is on suction and vice versa. Thus to an extent the delivery is continuous.

In view of our invention and disclosure, variations and modifications to meet individual whim or particular need will doubtless become evident to others skilled in the art, to obtain all or part of the benefits of our invention without copying the structure shown, and we, therefore, claim all such insofar as they fall within the reasonable spirit and scope of our claims.

Having thus described our invention what we claim as new and desire to secure by Letters Patent is:

1. In a pump, a pump chamber including separated opposed bellows having different displacements per unit linear motion, both exposed to contact with fluid in the same pump chamber, inlet and outlet valves to the pump chamber, a source of fluid pressure for balancing the bellows and means to admit the source of fluid pressure for balancing the bellows to the opposite sides of the bellows from that exposed in the pump chamber.

2. In a pump, a pumping chamber including separated opposed bellows having different displacements per unit of linear motion forming a portion of the wall thereof, a source of fluid operating pressure, a source of fluid balancing pressure above atmospheric pressure lower than the fluid operating pressure and comparable to the pressure developed by the pump, means for directing the fluid operating pressure and the balancing pressure alternately to opposite ends of the chamber on one side of each bellows and inlet and outlet valves connecting to the pumping chamber.

3. In a pump, a pumping chamber including separated opposed bellows forming one wall thereof, a source of fluid operating pressure, a balancing chamber, a source of balancing pressure connecting to the balancing chamber, a relief valve from the balancing chamber set at a pressure above atmospheric, valve means alternately connecting the source of fluid operating pressure and the balancing chamber to the opposite bellows on one side thereof and inlet and outlet valves connected to the pumping chamber on the other side of the bellows.

4. In a pump, a pump chamber having opposed separate bellows of different displacements per unit of linear motion forming a por-

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tion of the wall thereof, a source of fluid operating pressure, a source of balancing pressure lower than the fluid operating pressure, pump valves and connections to the pump chamber on one side of the bellows and valve means for alternately connecting the fluid operating pressure and the balancing pressure to the opposite bellows on the other side thereof.

5. In a pump, a pair of opposed bellows having different displacement characteristics per unit of linear motion, a separating wall between the bellows, a chamber surrounding the bellows, inlet and outlet pump connections into the chamber surrounding the bellows, a source of fluid operating pressure, a source of fluid balancing pressure, and valve means for applying the fluid operating pressure and the fluid balancing pressure alternately to the interiors of the opposite bellows.

6. In a pump, a pair of opposed bellows, a separating wall between the bellows, a pump chamber surrounding the bellows, pump inlet valves and connections to the pump chamber around the bellows, pump outlet valves and connections to the pump chamber around the bellows, a source of fluid pressure, a pressure relief valve and valve means for connecting the source of fluid pressure and the pressure relief valve alternately to the interiors of the opposite bellows.

7. In a pump, a pair of opposed bellows, a separating wall between the bellows, stroke limiting stops for controlling the stroke of the separating wall, a pump chamber surrounding the bellows, pump inlet and outlet valves and connections to the pump chamber surrounding the bellows, a source of fluid operating pressure, a relief valve and valve means for alternately connecting the interiors of the respective bellows to the source of fluid pressure and to the relief valve.

8. In a pump, a pair of opposed bellows having different displacements per unit of linear motion, a separation wall between the bellows, a pump chamber surrounding the bellows and having the bellows exposed to fluid in the pump chamber, pump inlet and outlet valves and connections to the pump chamber surrounding the bellows, and fluid operating means alternately connected to the interiors of the opposite bellows.

9. In a pump, a pair of opposed bellows having different displacements per unit of linear motion, a separation wall between the bellows, a pump chamber surrounding the bellows, pump inlet and outlet valves and connections to the pump chamber surrounding the bellows, a source of fluid operating pressure, a relief valve and valve means alternately connecting the interiors of the respective bellows to the source of fluid pressure and to the relief valve.

10. In a pump, a pair of opposed separate bellows having different displacements per unit linear motion, a pumping chamber surrounding the bellows, fluid inlet and outlet valves and connections to the pumping chamber, an actuating cylinder, a piston fitting the actuating cylinder and having a displacement with linear motion corresponding to that of the larger bellows, a piston rod operatively connected to the actuating piston and having a displacement around the piston rod in the actuating cylinder which corresponds to the displacement of the smaller bellows with linear motion, means for reciprocating the piston rod, and fluid connections respectively between the end of the actuating cylinder remote from the piston rod and the interior of the large

bellows and between the end of the actuating cylinder adjacent the piston rod and the interior of the smaller bellows.

11. In a pump, a pair of opposed bellows having different displacements per unit of linear motion, a separating wall between the bellows, stroke limiting stops for the separating wall, a pump cylinder surrounding the bellows, and having the bellows exposed to fluid in the pump chamber, pump inlet and outlet valves and connections to the pump cylinder, an actuating cylinder, a piston in the actuating cylinder and having a displacement corresponding to the displacement of the interior of the larger bellows per unit linear motion, a piston rod in the actuating cylinder connected to the piston and leaving a displacement around the piston rod which corresponds to the displacement of the inside of the smaller bellows per unit linear motion, driving means for the piston rod of the actuating piston, fluid connection from the end of the actuating cylinder remote from the piston rod to the interior of the larger bellows and fluid connection from the end of the actuating cylinder adjacent the piston rod to the interior of the smaller bellows.

12. In a pump, a cylinder, a movable wall in the cylinder, opposed bellows in the cylinder on opposite sides of the movable wall, inlet and outlet pump connections and valves to and from the interiors of the opposite bellows and fluid actuating means connected to the cylinder outside the bellows on the opposite sides of the movable wall.

13. In a pump, a cylinder, a movable wall in the cylinder, opposed bellows in the cylinder on opposite sides of the movable wall, inlet and outlet pump connections and valves to and from the interiors of the opposite bellows, a source of fluid operating pressure, a source of fluid balancing pressure less than the operating pressure and valve means alternately connecting the source of fluid operating pressure and the source of fluid balancing pressure to the cylinder on opposite sides of the movable wall outside the bellows.

14. In a pump, a cylinder, a movable wall in the cylinder, opposed bellows in the cylinder on opposite sides of the movable wall, pump inlet and outlet valves and connections to the cylinder on one side of the bellows and on opposite sides of the movable wall, the inlet connections to both sides of the movable wall being common and the outlet connections to both sides of the movable wall being common, and fluid operating means connected to the cylinder on the opposite sides of the bellows and alternately applied to the opposite sides of the movable wall.

15. In a pump, a cylinder, a movable wall in the cylinder, opposed bellows in the cylinder on opposite sides of the movable wall, pump inlet and outlet valves and inlet and outlet connections to the cylinder on one side of the bellows and on opposite sides of the movable wall, the inlet connections to both sides of the movable wall being common and the outlet connections to both sides of the movable wall being common, a source of fluid operating pressure, a source of fluid balancing pressure and a reversing valve connecting the source of fluid operating pressure and the source of fluid balancing pressure alternately to the cylinder on opposite sides of the movable wall and on the side of the bellows opposite to the side to which the pump inlet and outlet connections lead.

16. In a pump, a cylinder, a movable wall in the cylinder, opposed bellows connected to the

movable wall in the cylinder at opposite sides thereof and connected to the opposite ends of the cylinder, inlet valves and common inlet connections to the interiors of both bellows on opposite sides of the movable wall, outlet valves and common outlet connections to the insides of both bellows on opposite sides of the movable wall, and fluid pressure means alternately connected to the opposite sides of the movable wall around the bellows.

17. In a pump, a cylinder, a movable wall in the cylinder, opposed bellows connected to the movable wall in the cylinder at opposite sides thereof and connected to the opposite ends of the cylinder, inlet valves and inlet connections to the interiors of both bellows on opposite sides of the movable wall, the inlet connections being common, outlet valves and outlet connections to the insides of both bellows on opposite sides of the movable wall, the outlet connections being common, a source of fluid operating pressure, a source of fluid balancing pressure lower than the operating pressure and reversing valve means alternately connecting the cylinder on opposite sides of the movable wall around the bellows to the source of fluid operating pressure and to the source of fluid balancing pressure.

18. In a pump, a cylinder, a piston in the cylinder, opposed bellows connected to the piston on opposite sides thereof and connected to the opposite ends of the cylinder, pump inlet and outlet valves and connections to the cylinder on opposite sides of the piston and on one side of the bellows and fluid operating means alternately connected to the cylinder on opposite sides of the piston on the other side of the bellows.

19. In a pump, a cylinder, a piston in the cylinder, opposed bellows connected to the piston on opposite sides thereof and connected to the opposite ends of the cylinder, pump inlet and outlet valves and connections to the insides of the opposite bellows and fluid operating means alternately connected to the cylinder on the opposite sides of the piston on the outsides of the bellows.

20. In a pump, a cylinder, a piston in the cylinder, opposed bellows connected to the piston on opposite sides thereof and connected to the opposite ends of the cylinder, pump inlet and outlet valves and inlet and outlet connections to the opposite bellows on one side thereof, a source of fluid operating pressure, a source of fluid balancing pressure lower than the source of fluid operating pressure and a reversing valve alternately connecting the source of fluid operating pressure and the source of fluid balancing pressure to the cylinder on the opposite ends of the piston on the side of the bellows opposite to that to which the inlet and outlet connections lead.

21. In a pump, a cylinder, a piston in the cylinder, opposed bellows connected to the piston on opposite sides thereof and connected to the opposite ends of the cylinder, pump inlet and outlet valves and connections to the interiors of the opposite bellows on the opposite sides of the piston, a source of fluid operating pressure, a source of fluid balancing pressure lower than the source of fluid operating pressure, and a reversing valve connecting the source of fluid operating pressure and the source of fluid balancing pressure alternately to the cylinder on the outside of the bellows at the opposite sides of the piston.

22. In a pump, a cylinder, a piston in the cylinder, opposed bellows connected to the piston on opposite sides thereof and connected to the op-

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posite ends of the cylinder, inlet valves and connections to the cylinder on the opposite sides of the piston and on one side of the bellows, the inlet connections being common, outlet valves and connections to the cylinder on opposite sides of the piston and on the same side of the bellows, the outlet connections being common, a source of fluid operating pressure, a source of fluid balancing pressure lower than the source of fluid operating pressure and a reversing valve alternately connecting the source of fluid operating pressure and the source of fluid balancing pressure to the cylinder on the opposite ends of the piston and on the other side of the bellows.

23. In a pump, a cylinder, a piston in the cylinder, opposed bellows connected to the piston on opposite sides thereof and connected to the opposite ends of the cylinder, inlet valves and common inlet connections to the interiors of the bellows on opposite sides of the piston, outlet valves and common outlet connections to the interiors

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of the bellows on opposite sides of the piston, a source of fluid operating pressure, a source of fluid balancing pressure lower than the source of fluid operating pressure, and a reversing valve operatively connecting the source of fluid operating pressure and the source of fluid balancing pressure alternately to the interior of the cylinder on opposite sides of the piston around the outside of the bellows.

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