

May 27, 1958

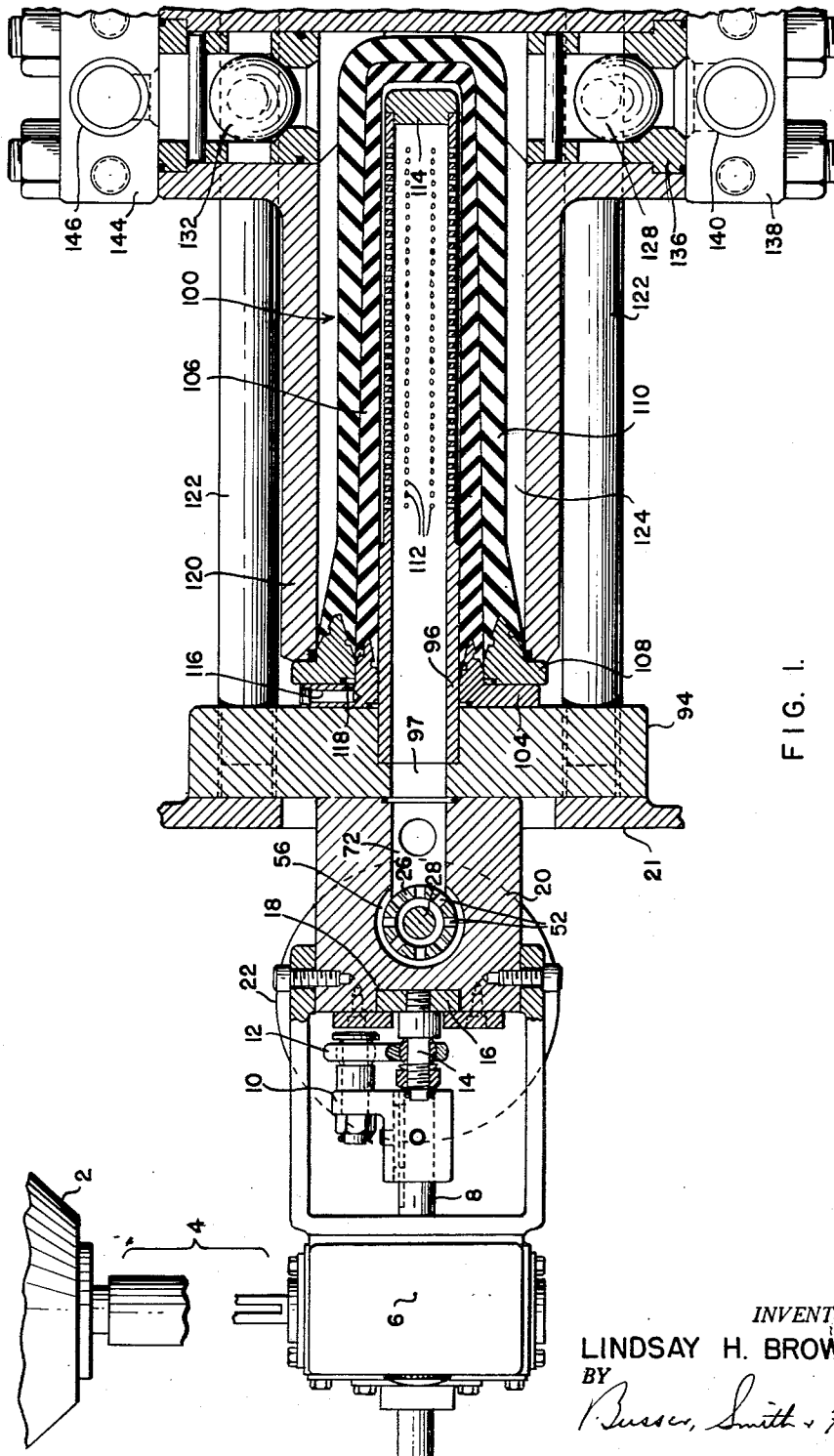
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2,836,121

PUMPS

Filed June 12, 1953

3 Sheets-Sheet 1



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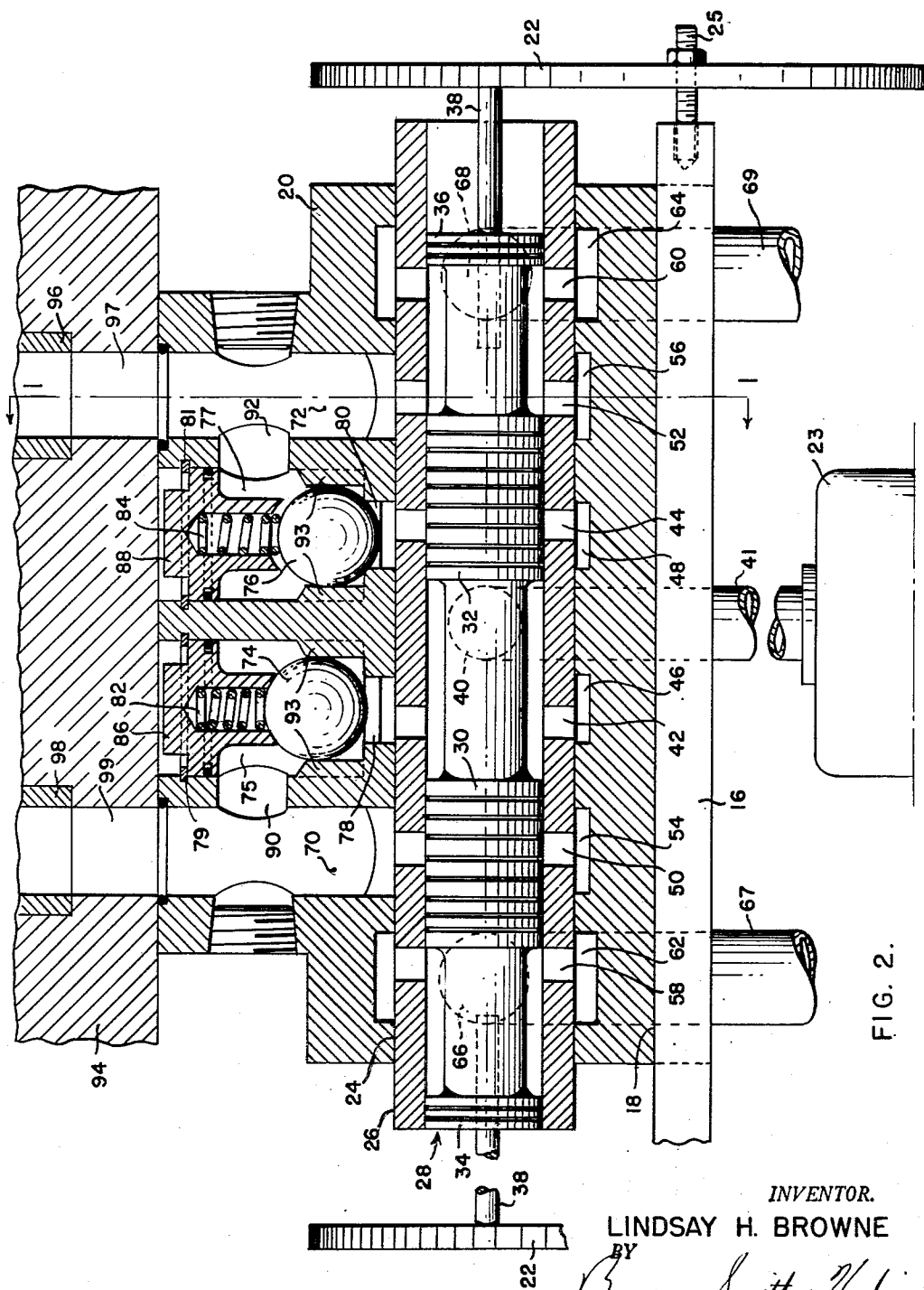


FIG. 2.

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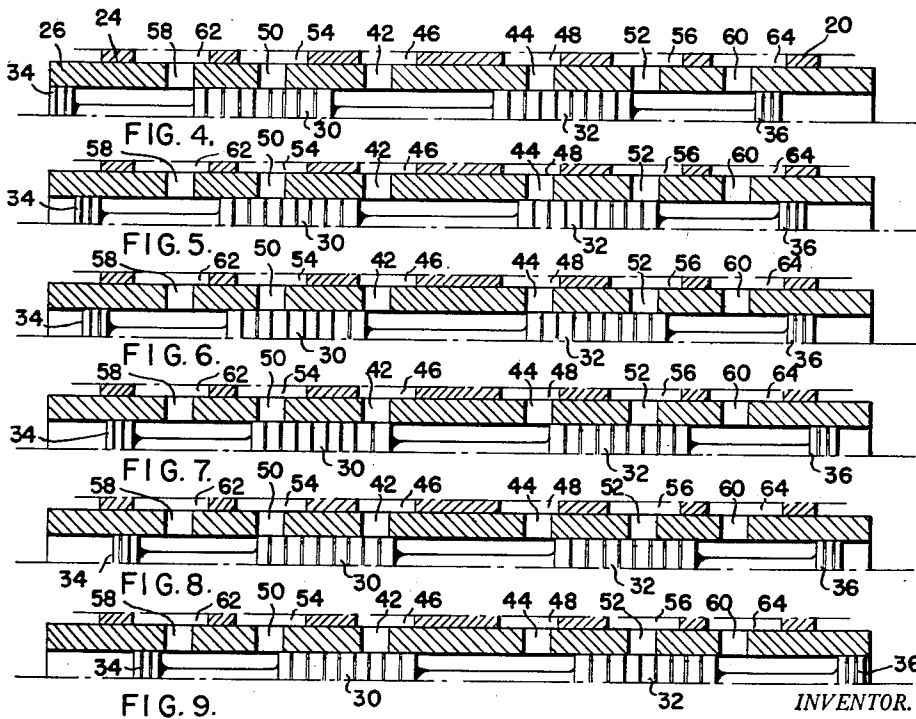
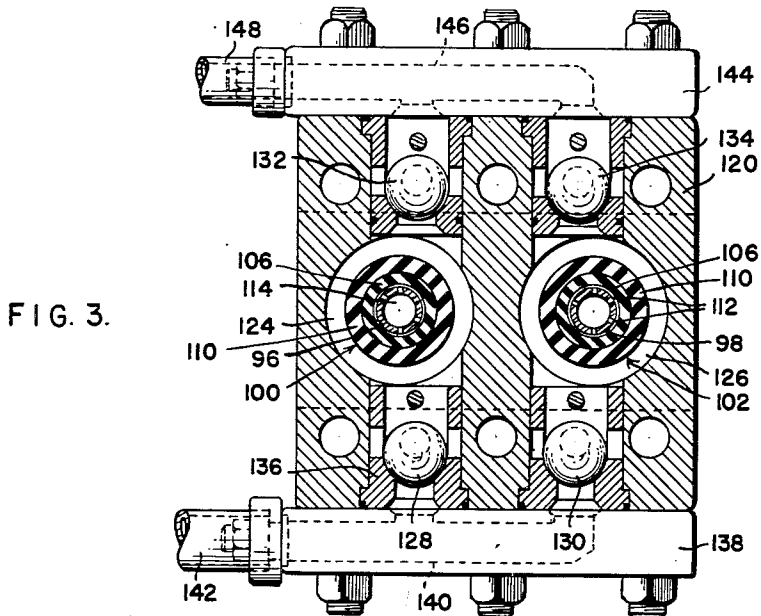
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3 Sheets-Sheet 3



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6 Claims. (Cl. 103—44)

This invention relates to pumps and has particular reference to pumps of the pulsating type in which an operating liquid is completely isolated from the liquid being pumped. Pumps of the types to which the present invention relates are disclosed in my Patent No. 2,738,731 and application Serial No. 265,769, filed, respectively, June 23, 1950, and January 10, 1952.

In particular, the present invention relates to pumps of the type disclosed in the latter of said applications, namely, of the type in which substantially continuous delivery of liquid is achieved despite the use of pulsators. As pointed out in the last mentioned application, a pair of pulsators may be so operated that, when supplied with a continuous flow of driving liquid, they will provide a substantially continuous flow of the liquid being pumped. The statement that the flow is "substantially" continuous does not here imply that there is any appreciable deviation percentagewise from accurately continuous flow. Actually, the only deviation from precise continuity is involved in the occurrence of transient pulses of short duration which are more in the nature of sound waves than measurable deviations of flow rate. These transient shock pulsations, however, have considerable amplitude and give rise to noise and vibration of the pumping system which is objectionable. Several sources of these transient shocks are recognizable. To provide truly continuous flow, it is necessary that both pulsators should have their inlet passages open to receive driving liquid simultaneously for at least short periods. Assuming that one pulsator is substantially expanded while the other is contracted, and that the inlet is opened to the latter before the inlet to the former is closed, the fact that delivery is against high pressure and that the pulsators themselves have, for proper operation, substantial tendencies to collapse, it will be evident that upon the occurrence of the conditions just noted the driving liquid will tend to flow from the expanded pulsator into the collapsed pulsator to fully or partially equalize the expanded conditions of both. When this action takes place, the inlet valve of the liquid being pumped corresponding to the originally expanded pulsator will transiently open. Since any valves which are used have inertia, the result of this condition is to produce a shock in the system. This shock, however, does not involve occurrence, for a continuous supply of pumping liquid to the pulsators, of substantial discontinuity in the flow of liquid being pumped; the transient involved is essentially the result of interaction in the pulsator system between the two pulsators and the chambers interior and exterior to them. The sudden pressure changes accompanying this constitute the cause of the shock.

A second source of shock appears to accompany the beginning of exhaust of the operating liquid from a pulsator. While the liquids involved and the rubber material of the pulsators are substantially incompressible, nevertheless, they involve slight compressibility. The delivery valves for the liquid being pumped also involve very slight lag, and considering the quite high pressures

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which are in practice generally desirably provided by this type of pump, there may be a substantial backward transmission of delivery pressure through the delivery valves before such valves can completely close. Reference is here made to "pressure" because the actual backflow of liquid is very small, and essentially the action primarily involves a transient transmission of pressure. The result is to cause compression-type transient shock waves to be transmitted in the system involving, in particular, a noticeable thrust on the distributing valve for the driving liquid.

The foregoing sources of transient pulsations accompany, particularly, conditions of high pressure of delivery. When the discharge pressure is low, transient pulsations also occur due to the fact that the pulsators are necessarily of such character that they will tend to collapse against a substantial applied internal pressure. For example, in a typical operation, it may require a pressure of fifty pounds per square inch to provide substantial initial expansion of a pulsator. The pulsator spring characteristics will not normally be identical, and shock conditions will here also arise due to the different tendencies of the pulsators to collapse, probably coupled with and aggravated by the lag of the valves in respective closing and opening.

It is the general object of the present invention to provide improved pumps of the type just described in which the transient shock conditions which have been discussed are minimized. Other objects of the invention are concerned with improvements in various structural details of pumps particularly designed for delivery of liquids at high pressures and in continuous flow fashion.

These and other objects of the invention will become apparent from the following description read in conjunction with the accompanying drawings, in which:

Figure 1 is a vertical section through one of the pulsators of the improved pump and its associated elements, the section being taken on the plane the trace of which is indicated at 1—1 in Figure 2;

Figure 2 is a horizontal section taken through the driving liquid distributing valve and associated parts of the pump;

Figure 3 is a vertical section taken through the discharge and inlet valves for the liquid being pumped and through the outer ends of the pulsators; and

Figures 4 to 9, inclusive, are diagrammatic sections showing various successive positions of the driving liquid distributing valve during a half cycle of its operation.

The particular spatial arrangement of the various parts of the pump is not of major consequence and, accordingly, various elements are indicated diagrammatically in rather arbitrary location. A driving motor 2 serves to drive through shaft connections indicated at 4 reduction gearing indicated as located within a housing 6 by which, in turn, there is driven a shaft 8 carrying a crank 10 which through link 12 and pin 14 serves to reciprocate a slide 16 in a guideway 18 provided in a valve block 20. The various elements so far described are desirably located within a pump housing a portion of the wall of which is indicated at 21, this housing also enclosing a primary pump 23 (Figure 2) which is driven by the motor 2. The pump 23 may be of any of a large variety of positive types. It has been found, for example, that one highly satisfactory form of pump is of multiple piston, variable delivery type, which is capable of providing an output reasonably continuous and free from pulsation. In such a pump, for example, variation of displacement from zero to some maximum capacity may be controlled by a manual adjusting device, though the adjustment of the pump may be automatically controlled either pneumatically or electrically. Rotary piston or other types of positive variable delivery pumps may also be

used. The particular driving pump here used does not, in itself, constitute a part of the invention, the invention being concerned only with the use of a positive pump desirably having substantially uniform displacement, and under some circumstances, desirably adjustable as to delivery rate. A constant rate pump may be used where adjustability is not required. Conveniently, the housing which encloses the elements described, including the pump, may provide an oil sump from which oil may be pumped through the system with delivery back to the sump. The oil used may be any suitable lubricating oil and may serve not only as the driving liquid but also for lubrication of the mechanically operating parts.

A valve cylinder 26 is located with a press fit in a bore 24 in the block 20, and arranged to reciprocate in cylinder 26 is a driving liquid distributing valve generally designated 28. This valve comprises the main pistons 30 and 32 and end pistons 34 and 36. The spindle of the valve is bored at its ends to receive rods 38 which are arranged to be engaged by discs 22 threaded on studs 25 secured in the ends of the slide 16, the discs being located in binding condition against the rods 38 and held by lock nuts. The purpose of the arrangement just described is to provide axial adjustability of the valve 28 with respect to the slide 16 to provide for proper phasing of its respective operations as hereafter described. Through the connections from crank 10 the valve is given approximately simple harmonic motion for control of the driving liquid flow. A central port 40 is provided in block 20 and cylinder 26 to serve for the introduction of operating liquid through pipe 41 from the pump 23.

Various ports are provided in axially displaced positions along the cylinder 26 and provide communication between its bore and annular spaces about the cylinder provided in the block 20. Each of these ports desirably consists of a number of radial holes through the cylinder, as indicated in Figure 1, to provide free flow of the driving liquid, but for convenience will be hereafter referred to in the singular.

Ports 42 and 44 provide for delivery of the driving liquid from the central portion of the cylinder 26. These ports communicate with the spaces 46 and 48 in the block 20.

Ports 50 and 52 provide for the exhaust of driving liquid from the pulsators and communicate with the spaces 54 and 56 in the block 20.

Ports 58 and 60 provide for exhaust of the operating liquid from the cylinder and communicate with the spaces 62 and 64 in the block. The spaces 62 and 64 are respectively ported at 66 and 68 to connecting pipes 67 and 69 which serve to return the exhausted driving liquid to the sump.

As will appear hereafter, the valve pistons serve to control flows through the various cylinder ports.

The spaces 54 and 56 are in communication with passages 70 and 72 in the block 20. Spaces 46 and 48 communicate with the openings through valve seats 78 and 80 which are, respectively, controlled by ball check valves 74 and 76 above which, as viewed in Figure 2, are located passages 75 and 77 communicating, respectively, through lateral passages 90 and 92 with the passages 70 and 72. Inwardly directed fins 93 guide the balls and provide for passage of liquid by the balls. Springs 82 and 84 serve to urge the balls 74 and 76 toward seated position, these springs being located within plugs 86 and 88 in the passages 75 and 77 the plugs being provided with packing to provide against leakage from these passages. Snap rings 79 and 81 hold the plugs 86 and 88 in position. The bores 70 and 72 are in communication with bores 99 and 97, respectively, provided in a block 94 which is mounted on the wall 21 of the housing and serves to support, in an opening through this wall, the block 20. Sealing between the block 20 and block 94 at the passages is provided by O rings as illustrated in Figure 2. Communicating with the bores 97 and 99 are tubular fillers 96

and 98 for pulsators which are designated generally at 100 and 102. These pulsators 100 and 102 are of the same construction illustrated most clearly in Figure 1. Each comprises a metal base 104 to which is molded a thimble 106 of rubber, the rubber used being desirably of synthetic type capable of withstanding lubricating oil in its interior and the liquid being pumped on its exterior. Each pulsator also comprises a base 108 of metal bonded to an outer thimble 110 of the same nature as the thimble 106. Desirably, this double arrangement of thimbles is provided for each pulsator so as to avoid disastrous results in the event that one of the thimbles becomes ruptured. Actually, either will suffice for pumping, and while both are in proper condition, they effectively provide a unitary pulsator. The thimbles 106 and 110 are both of such construction as to tend to collapse to normal condition illustrated in Figure 1 against substantial pressure differential in excess of atmospheric pressure. This is of great importance for practical operation since, otherwise, if the inlet valve of a pulsator should stick in closed condition, a thimble incapable of such collapse would remain distended and upon subsequent expansion would engage the walls of its chamber and possibly be extruded into the valve passages with resulting rupture. Collapse of the thimbles is limited by the presence of the metal fillers 96 and 98 which are provided with small radial openings 112 to provide free passage of the operating liquid but which are so small as to prevent extrusion through them of the thimble rubber under the highest pressures encountered in operation. The tubes 96 are closed at their outer ends by plugs 114. To provide indication of possible rupture of one of the thimbles, each of the bases 104 is provided with a radial bore 116 which communicates through an opening 118 with the region of contact of the bases 104 and 108 and of the thimbles 106 and 110. In the event that rupture occurs either the operating liquid or the liquid being pumped will seep out of the opening 116 of the corresponding pulsator and will be detected. The opening 116 is desirably threaded to receive a tube which is not shown but which may serve to deliver leaking liquid to a safe location in the event that the liquid being pumped is of a dangerous character.

A block 120 serves to provide chambers external to the pulsators and mountings for inlet and outlet valves for the liquid being pumped. This block 120 is provided with bores 124 and 126 receiving the pulsators 100 and 102, respectively. The block 120 is clamped by bolts 122 against the thimble bases 108 and 104 and the block 94, there being interposed O rings as indicated in Figure 1 to provide packings between these elements capable of withstanding the high pressures involved in the pumping. The assembly thus provided is particularly desirable for ready dismounting for the purpose of cleaning the various elements which come in contact with the liquid being pumped.

Inlet and outlet valves 128 and 132, respectively, are provided in removable housings in communication with the chamber provided at 124 and similar valves 130 and 134 are provided in association with chamber 126. The valve housings, one of which is designated 136, are readily removable and are suitably packed by O rings.

An inlet header 138 is provided with a passage 140 communicating with both inlet valves 128 and 130 and with external piping 142 through which the liquid being pumped is received. A similar header is provided at 144 for the discharge, this being provided with a passage 146 communicating with the delivery valves 132 and 134 and with piping 148 for delivery of the liquid being pumped. These headers are clamped to the block 120 by suitably arranged bolts, O rings providing the necessary packing.

The operation of the pump may now be described.

Preliminarily, it may be remarked that the rate of rotation of the shaft 8 for the purpose of reciprocating the distributing valve 28 through its cycles is such that,

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considering the maximum delivery of pump 23, if the delivery rate of the pump is adjustable, the pulsators will not be expanded during any cycle to such extent as to cause them to engage the walls of their respective chambers. Variation in delivery rate of the pumping liquid by pump 23 then merely involves less expansion of the pulsators to provide corresponding displacement of the liquid being pumped.

Reference may now be made particularly to Figures 4 to 9, inclusive, with additional reference to Figure 2. There may be first assumed the conditions involved when the valve 28 occupies the position illustrated in Figure 4, i. e. its extreme left hand position, as viewed in the figures. Under such condition, the port 42 is in communication with the supply port 40 for the operating liquid which will then be flowing past valve 74, shown as open in Figure 2, and through passages 90, 70 and 99 to provide expansion of the pulsator 102. As this flow continues, the pulsator 102 reduces the volume in pumping chamber 126 providing outflow of the pumped liquid past check valve 134. The corresponding inlet valve 130 is closed. Outflow port 50 is closed by piston 30. The inlet port 44 for pulsator 100 is closed by piston 32. Ports 52 and 69 are in communication with each other through the space between the pistons 32 and 36 and are also in communication with the outlet port 68. While check valve 76 is now closed, the interior of pulsator 100 is in free communication with the outlet and this pulsator will be in collapsed condition under its own resiliency, the check valve 128 having opened to permit the chamber 124 to receive liquid being pumped. The check valve 132 will be closed under the high pressure of the discharge.

As the valve 28 moves toward the right from its left hand dead center position, there will be attained the position illustrated in Figure 5. The piston 30 continues to close port 50 and will not then have started to close the port 42. Port 44 remains closed by piston 32, but this piston will now have closed the port 52 cutting off communication between the interior of pulsator 100 and the discharge port 68. Actually, at this time, the pulsator 100 will have been fully collapsed and, consequently, flow through the port 52 will have ceased before the piston closes this port. Inasmuch as port 42 is still open for the passage of the operating liquid, the pulsator 102 will continue to expand.

The next event is the location of the valve 28 in the position illustrated in Figure 6, which position is characterized by the beginning of opening of port 44 to the operating liquid. As this port 44 is cracked open, there would occur a tendency for flow to take place from the expanded pulsator 102 to the interior of the collapsed pulsator 100. If such action occurred, there would be produced, in view of the high pressures involved and since the discharge valve 134 is open, a transient shock due to the interchange of liquid from one pulsator to the other. However, in accordance with the present invention, such a transfer of the operating liquid is prevented by the closure of check valve 74 under the action of spring 82. This check valve may close because, even though port 42 is open to the operating liquid supply, the pressure exerted inwardly by the pulsator 102 due to its expanded condition exceeds the inward pressure exerted by the collapsed pulsator 100. This condition continues, in fact, as the pulsator 100 expands due to the flow of operating liquid thereinto, inasmuch as until it receives its full volume of operating liquid it will be less expanded than the pulsator 102. Accordingly, the incoming operating liquid following the attainment of the conditions illustrated in Figure 6 will flow only into the pulsator 100. As pulsator 100 expands, its delivery valve 132 will open providing outflow of the liquid being pumped. Valve 134 corresponding to pulsator 102 will have closed due to the fact that a very small amount of contraction of pulsator 102 will occur as valve 74 closes.

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The condition existing, therefore, is that for a short interval after the attainment of the conditions illustrated in Figure 6, the pulsator 102 will remain essentially in its fully expanded condition.

As further displacement of the valve 28 occurs to the position illustrated in Figure 7, with cut off of port 42 flow continues into pulsator 100 through port 44 and past check valve 76, with no flow (with the exception of possible slight leakage) through port 42 in either direction. If any slight leakage occurs, it would be from pulsator 102 past check valve 74 and through the space between pistons 30 and 32 into the pulsator 100 under a relatively small head due to different extents of expansion of the pulsators. Such slight flow, however, will not produce any noticeable transient in the nature of a shock. When the position of Figure 7 is attained by valve 28, port 50 remains closed. Flow either to or from the pulsator 102 is thus cut off except for possible slight leakage.

When the condition illustrated in Figure 8 is reached, the piston 30 starts to open the port 50. Pulsator 102 is thus brought into communication through passages 99 and 70 and the space between pistons 30 and 34 and port 58 with the outlet passage 66, 67. In the absence of piston 34, the sudden application of pressure at the left of piston 30 would cause the valve 28 to receive a sharp impulse toward the right. However, with piston 34 provided, there is involved an equilization of pressures effective on the valve 28 to avoid the occurrence of a transient at this time. Pulsator 102 now collapses due to its resiliency and produces an opening of its inlet valve 130 to cause flow of the pumped liquid into chamber 126. At this time, port 44 remains open so that flow of operating liquid continues to expand the pulsator 100.

The movement of valve 28 from the position of Figure 8 to that of Figure 9 involves no new operation, the pulsator 102 being completely collapsed before the position of Figure 9 is reached, while the pulsator 100 continues to receive operating liquid through the port 44.

It will be evident that the position of Figure 9 corresponds to that of Figure 4 so that the return of the valve to the position of Figure 4 involves merely a repetition of the phases of the cycle but with inverse respect to the two pulsators.

Despite the intermittent openings and closing of ports, the discharge is continuous. The continuous supply of operating liquid involves necessarily total displacements of the two pulsators, first one, then possibly both, and then the other, in such fashion that the total of the displacements in the two chambers 124 and 126 remains constant. The result is that the flow of pumped liquid is also constant, assuming no leakage which, with suitably viscous operating oil, is actually negligible. In the present apparatus, this constant flow occurs with minimizing of transient shocks at the several changes of phases in the operation. It may be noted that the flow through the inlet connection 142 for the pumped liquid is not constant, and this might be considered a source of pulsations. However, under ordinary conditions of supply at approximately atmospheric pressure, the magnitude of the pressure changes which occur on the intake side of the pump is small and, consequently, pulsations due to the intermittent intake are not of consequence. The pulsations which are to be avoided are those which involve transient changes of pressure of considerable magnitude and, in accordance with the present invention, these are kept down to a satisfactory level.

What is claimed is:

1. Pumping means comprising a plurality of expandible and contractible members, means providing with said members individual chambers of which said members form wall portions, inlet and outlet valves controlling flow to and from said chambers, and means for supplying driving liquid to said members on their sides opposite their chambers

for expanding them and for releasing liquid therefrom for their contraction, the last named means comprising a pump supplying the driving liquid at a substantially constant rate over the period of a plurality of complete cycles of operation of the pumping means, a movable driving liquid distributing valve receiving driving liquid from said pump, driving means for said valve, means providing a plurality of ported passages connected to the respective members and controlled by said distributing valve to receive driving liquid for passage to the respective members, the distributing valve controlling flow of driving liquid into said passages so that, at times, flow occurs simultaneously thereinto, check valves in said passages, and means providing ported passages connected to the respective members and controlled by said distributing valve and through which last mentioned passages driving liquid is released from said members.

2. Pumping means comprising a plurality of expandible and contractible members, means providing with said members individual chambers of which said members form wall portions, inlet and outlet valves controlling flow to and from said chambers, and means for supplying driving liquid to said members on their sides opposite their chambers for expanding them and for releasing liquid therefrom for their contraction, the last named means comprising a pump supplying the driving liquid, a movable driving liquid distributing valve receiving driving liquid from said pump, driving means for said valve, means providing a plurality of ported passages connected to the respective members and controlled by said distributing valve to receive driving liquid for passage to the respective members, the distributing valve controlling flow of driving liquid into said passages so that, at times, flow occurs simultaneously thereinto, check valves in said passages, and means providing ported passages connected to the respective members and controlled by said distributing valve and through which last mentioned passages driving liquid is released from said members.

3. Pumping means comprising a plurality of expandible and contractible members, means providing with said members individual chambers of which said members form wall portions, inlet and outlet valves controlling flow to and from said chambers, means comprising a liquid distributing valve for supplying driving liquid to said members on their sides opposite their chambers for expanding them and for releasing liquid therefrom for their contraction, the last mentioned means at times producing simultaneous expanded conditions of said members, and means for preventing intercommunication between the last mentioned sides of said members during simultaneous expanded conditions thereof.

4. Pumping means comprising a plurality of expandible and contractible members, means providing with said members individual chambers of which said members form wall portions, inlet and outlet valves controlling flow to and from said chambers, and means for supplying liquid to said members on their sides opposite

their chambers for expanding them and for releasing liquid therefrom for their contraction, the last named means supplying the liquid at a substantially constant uninterrupted total rate to said members to effect a total volumetric displacement of said members due to their expansions which is substantially constant throughout a complete cycle of operation, and said last named means at times producing simultaneously expanded conditions of said members, and means for preventing intercommunication between the last mentioned sides of said members during simultaneous expanded conditions thereof.

5. Pumping means comprising a plurality of expandible and contractible members, means providing with said members individual chambers of which said members form wall portions, inlet and outlet valves controlling flow to and from said chambers, and means for supplying liquid to said members on their sides opposite their chambers for expanding them and for releasing liquid therefrom for their contraction, the last named means supplying the liquid at a substantially constant uninterrupted total rate to said members to effect a total volumetric displacement of said members due to their expansions which is substantially constant throughout a complete cycle of operation, said last named means at times producing simultaneously expanded conditions of said members, and the last named means comprising a movable driving liquid distributing valve, driving means for said valve and means for preventing intercommunication between the last mentioned sides of said members during simultaneous expanded conditions thereof.

6. Pumping means comprising a plurality of expandible and contractible members, means providing with said members individual chambers of which said members form wall portions, inlet and outlet valves controlling flow to and from said chambers, means comprising a liquid distributing valve for supplying driving liquid to said members on their sides opposite their chambers for expanding them and for releasing liquid therefrom for their contraction, the last mentioned means at times producing simultaneous expanded conditions of said members, and means for preventing intercommunication between the last mentioned sides of said members during simultaneous expanded conditions thereof, said members being contractible due to their resiliency to a predetermined initial condition despite pressure gradients across them in excess of atmospheric pressure.

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