Dec. 13, 1966 A. S. LIMPERT ETAL 3,291,055

SELF-PURGING PROPORTIONING PUMP FOR CORROSIVE LIQUIDS

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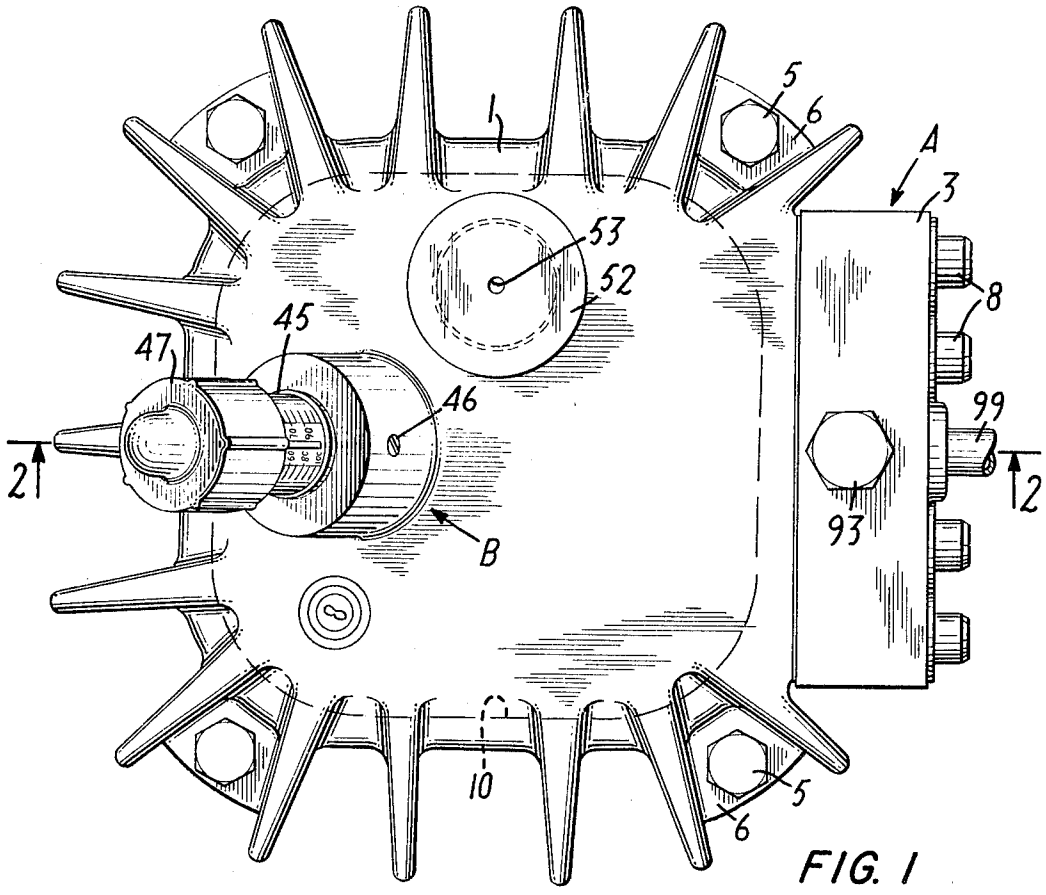


FIG. 1

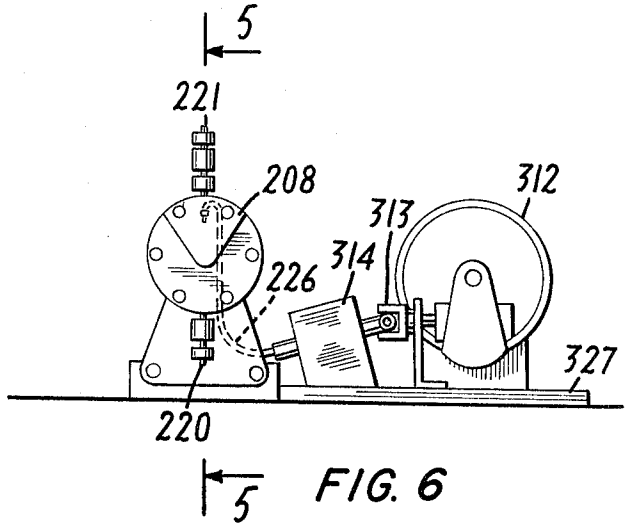


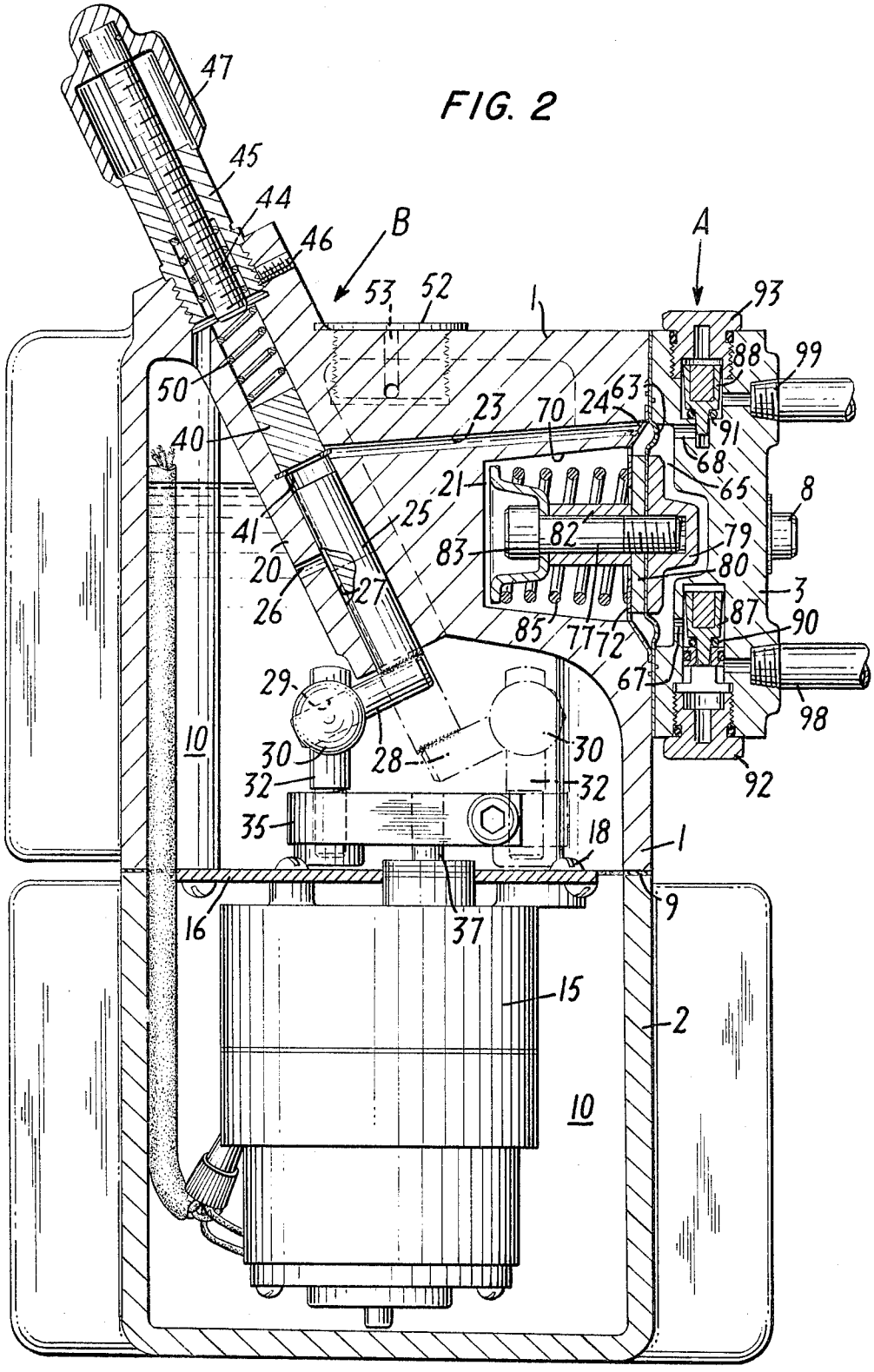
FIG. 6

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SELF-PURGING PROPORTIONING PUMP FOR CORROSIVE LIQUIDS

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FIG. 2



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SELF-PURGING PROPORTIONING PUMP FOR CORROSIVE LIQUIDS

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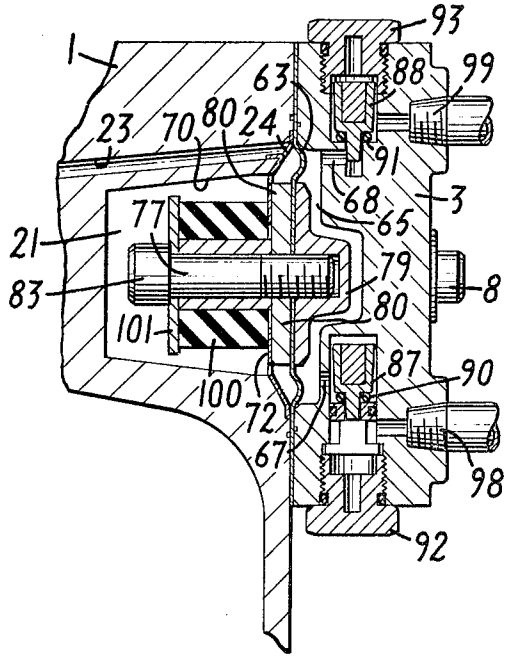


FIG. 3

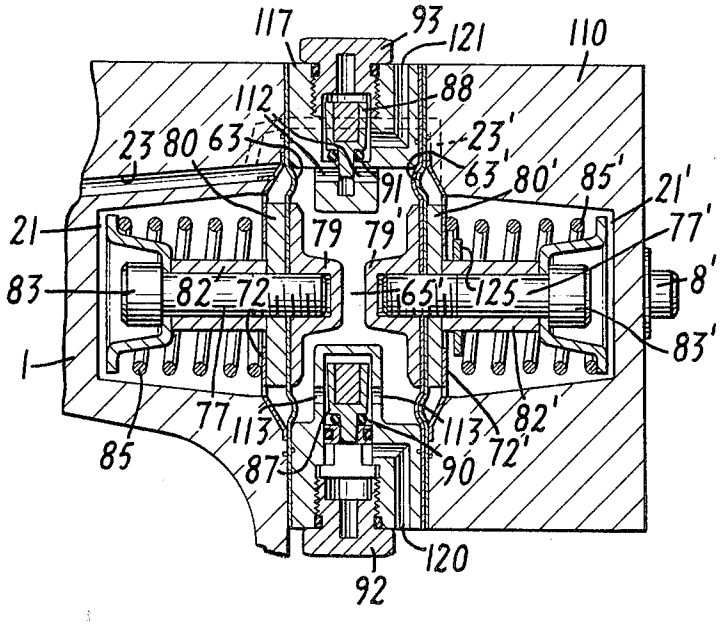


FIG. 4

SELF-PURGING PROPORTIONING PUMP FOR CORROSIVE LIQUIDS

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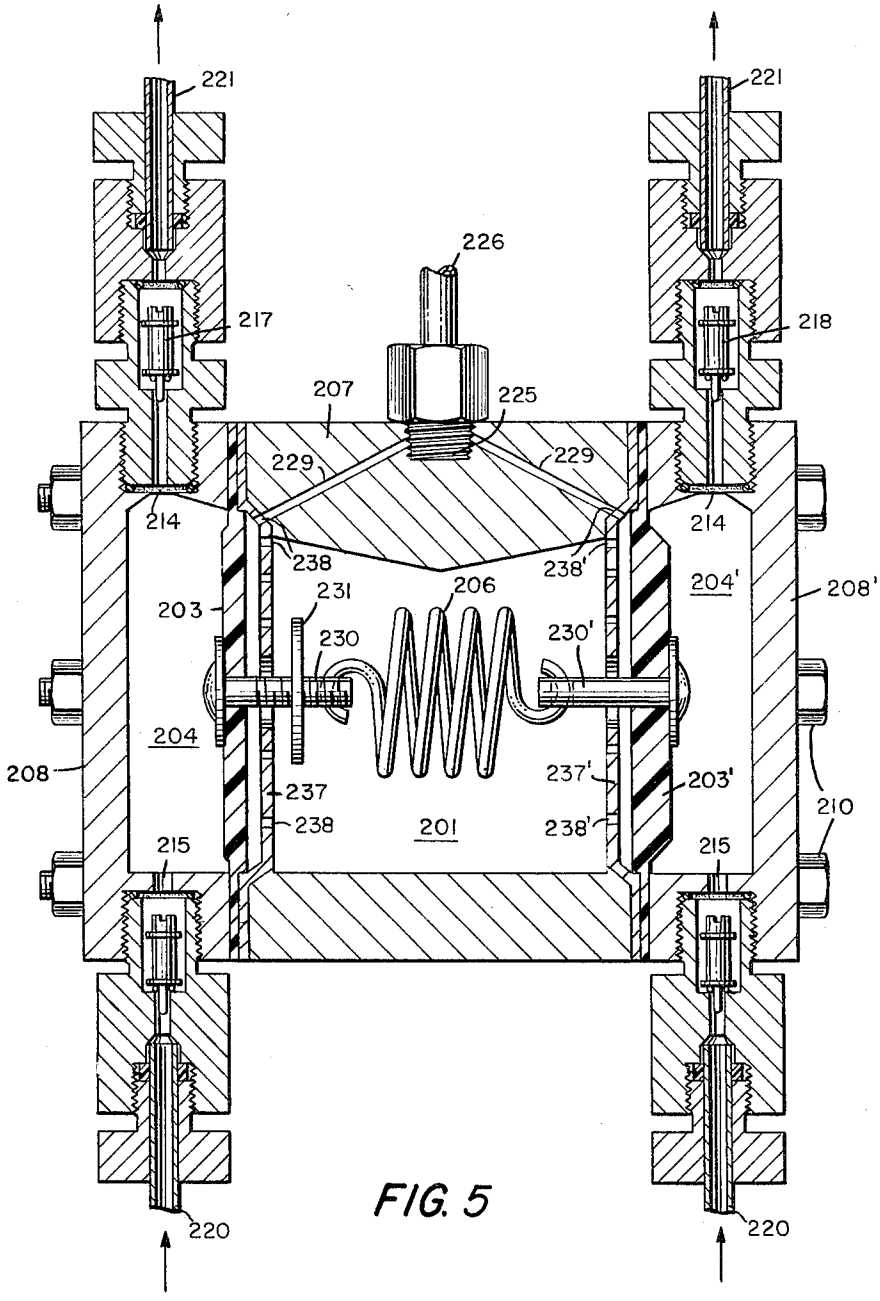


FIG. 5

United States Patent Office 3,291,055 Patented Dec. 13, 1966

3,291,055

SELF-PURGING PROPORTIONING PUMP FOR CORROSIVE LIQUIDS

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Filed Aug. 2, 1965, Ser. No. 478,029
19 Claims. (Cl. 103—44)

This is a continuation-in-part of U.S. application Serial No. 351,719 filed March 13, 1964, now abandoned.

This invention relates to self-purging proportioning or metering feed pumps and more particularly to a hydraulically actuated proportioning feed pump especially designed for the proportioning of corrosive liquids.

Proportioning feed pumps are used to feed and meter liquids of all types. Chemical reactions, for instance, frequently require that small quantities of chemicals be supplied thereto at predetermined rates, and such pumps are used for this purpose. In most cases, the liquids fed are blended with a feed flow or substrate, which blend then serves as the reaction medium.

U.S. Patent No. 2,869,467 describes and claims a proportioning feed pump having a diaphragm actuated by hydraulic pressure, the pressure required for actuation being obtained through the action of a rotating and reciprocating piston operating in a cylinder. On the pressure stroke of the reciprocating piston, a volume of oil is pumped to a diaphragm in an amount determined by the length of the stroke, and this increased volume of oil causes flexing of the diaphragm, due to the increased pressure of the oil on that side. On the return stroke, the pressure is relieved, and the diaphragm can return to its initial position. Thus, reciprocation of the piston induces periodic flexing of the diaphragm. The other side of the diaphragm communicates with a pumping chamber of the proportioning feed pump that forms part of the liquid pumping system, and the flexing action of the diaphragm is used to pump the liquid in that chamber.

The length of the stroke of the reciprocating piston can be adjusted to control the amount of oil fed to the diaphragm, and thereby control the rate of feed of liquid by the pump. A compression spring in the pumping or diaphragm chamber returns the diaphragm to its normal position after each flexing action, when the return stroke of the reciprocating piston exhausts the oil in the hydraulic chamber that causes flexing of the diaphragm.

The piston and cylinder are so arranged that on the return stroke the pressure is relieved by venting the interior of the cylinder to an open reservoir. The cylinder is submerged in a reservoir of oil, which is open to the atmosphere; on the return stroke the piston opens a vent in the cylinder, thereby suddenly decreasing the pressure in the cylinder and in the hydraulic side of the diaphragm to atmosphere. On the pressure stroke, the vent is closed by the piston.

Patent No. 3,100,451 describes an improvement on this type of pump, to make it possible to use a double diaphragm construction with opposed diaphragms having a single compression spring therebetween, to distend the diaphragms in the quiescent condition when a hydraulic pulse is not being applied thereto, and thus assist in filling the pump chamber on the back stroke of the pump, thereby avoiding the need for negative pressure in the hydraulic system. This type of construction has the disadvantage that the compression spring is exposed to the liquids being pumped, and when these liquids are corrosive rapid wear results, as well as contamination of the liquid being pumped with the material corroded away from the spring.

Diaphragm pumps of the above types are usually used where extreme accuracy is required for the metering of liquids. However, the pumps of the prior art have often

been plagued by problems of inaccuracy which have seemed insolvable. Often, the pumps have had to be shut down for repairs after relatively short onstream times due to continued inaccuracy in metering which could not be corrected by the operators while the pumps were in operation.

In accordance with the invention, it has now been determined that one source of such inaccuracy is the accumulation of air or other gases in the hydraulic system or pumping chamber of the pumps. The invention accordingly provides means for purging the hydraulic system as well as the pumping chamber of gas periodically during operation.

The deleterious effect of even a small amount of gas in the system can be illustrated by a unit designed to pump 0.5 cc. per stroke. In this situation, an air bubble with a volume of 0.1 cc. at atmospheric pressure in the hydraulic chamber would have a significant effect on the accuracy of the pump.

In accordance with the present invention, an improved hydraulically actuated proportioning feed pump is provided having means for venting the hydraulic system regularly during operation, comprising, in combination, a housing having therein a pumping chamber, a hydraulic chamber, a flexible diaphragm forming at least a portion of a wall separating the chambers, and adapted to flex from a normal position outwardly into the pumping chamber under pressure of hydraulic fluid in the hydraulic chamber; pulsing means for cyclically supplying hydraulic fluid under pressure to the topmost portion of the hydraulic chamber and for exhausting hydraulic fluid therefrom, valve means for venting the hydraulic system to the atmosphere during the exhaust portion of the cycle, and bias means within the hydraulic chamber for returning the diaphragm after distention by hydraulic fluid to its normal position during the exhaust portion of the cycle.

There are also fluid inlet and outlet connections in the pumping chamber on the other side of the diaphragm, for supplying fluid to be pumped and delivering fluid pumped by pulsation of the diaphragm; the outlet connections preferably are connected at the topmost portion of the pumping chamber so that any gases accumulating in the pumping chamber can migrate thereto and be swept out of the outlet with the pumped fluid.

Preferably, the pulsing means is a piston pump having means to supply on each pressure stroke of the piston a known volume of hydraulic fluid to the hydraulic chamber to distend the diaphragm. The preferred pump is an adjustable reciprocating piston pump of the type shown in U.S. Patent No. 2,869,467, discussed above. In that pump, on each suction stroke of the piston, the cylinder is vented to a reservoir of oil which in turn is vented to the atmosphere. Any air or other gases which may collect in the hydraulic chamber of the diaphragm pump is thereby swept out of the cylinder into the reservoir and then to the atmosphere. The fact that the pumping cylinder is immersed in a reservoir of oil prevents any additional air from entering the hydraulic chamber during the venting. Pulsing systems other than reciprocating piston pumps are also suitable for use in the invention, such as a rotary piston pump. The "hydraulic system" of these pumps includes the hydraulic chamber of the diaphragm, any conduits connecting that chamber to the pulsing means, and usually, the pulsing means itself.

The invention contemplates means for creating turbulence in the hydraulic system, to aid in sweeping out all of the gas bubbles from the hydraulic chamber. For example, the diaphragm bias means can create additional turbulence as it snaps the diaphragm back to its normal position, when the pressure is released in the hydraulic chamber. Accordingly, by combining a diaphragm pump

having a bias means located on the hydraulic side of the pump diaphragm, a hydraulic connection located at the highest part of the hydraulic chamber, and provision for venting the hydraulic system to atmosphere on the exhaust portion of the cycle, a self-purging metering pump with a high degree of accuracy can be obtained. By placing the outlet from the pumping chamber at the highest point in the pumping chamber, that chamber is also effectively kept clear of gases.

To further ensure that all gas is purged from the hydraulic system, the total volume of the fluid connection between the hydraulic chamber and the pulsing means preferably is less than the volume of the pressure pulse provided by the pulsing means.

The proportioning pumps of the invention can include a plurality of diaphragms, in the manner, for example, shown in U.S. Patent No. 3,100,451. The pumping chamber or alternatively, the pulsing or hydraulic chamber, can, for example, be in the form of a cylinder, closed at each end by an impermeable flexible diaphragm, with the bias means always in the pulsing or hydraulic chamber or chambers. In the case of a double diaphragm pumping chamber, the tension bias means is placed outside the diaphragms, and the hydraulic liquid is supplied to the hydraulic chambers outside the diaphragms, as in FIGURE 5. In the case of a double diaphragm hydraulic chamber, the tension bias means is placed between the diaphragms and the hydraulic liquid is supplied to the chamber therebetween for flexing action of the diaphragms in the pumping chambers, as in FIGURE 5. In such a structure, two different liquids could be pumped, and one diaphragm could be stopped (an adjustable stop can be used) so that the other receives a pressure effect of a proportion of the volume of hydraulic fluid supplied, the total amount of this fluid in turn being adjusted by the effective stroke of the piston. If but one liquid is to be pumped, the valves may be manifolded so that a single outlet could be used.

The bias means is of the tension or compression type depending upon the position of the hydraulic chamber and the direction of the bias force required. Any form of bias means can be used. Coil springs, disk springs, also known as Belleville springs or washers, and resilient bushings or plugs are typical, and various embodiments thereof are shown in the drawings. These can be made of any suitable material, usually metal, such as stainless steel, carbon steel, nickel, brass and bronze, or plastic, such as rubber, synthetic rubber, polyamides, polypropylene, polyvinyl butyral, or metal coated with any inert plastic material.

The diaphragms employed in the proportioning pumps of the invention can be made of any sheet material which is sufficiently flexible and resilient to be flexed under fluid pressure, and which can be returned to normal non-flexed position when the fluid pressure is relieved, aided, in accordance with the invention, by bias means. Desirably, the diaphragm can withstand many millions of such flexures without damage.

For additional strength, the sheet diaphragm can be provided with a backing material or plate which will prevent damage due to overpressuring, and can also serve to control the amount of flexure under a given fluid pressure. The backing material can support all or only a part of the diaphragm surface exposed to fluid pressure.

In addition, to increase flexibility, a diaphragm may be formed as a composite or multiple ply structure. Two or more flexible sheets, of the same or different material, may be laminated or clamped together to form the diaphragm. If the sheets are laminated, they may be joined together with an adhesive material, by welding or any other suitable means. The use of a laminated or clamped structure of very thin sheets, increases the flexibility of a diaphragm of a given resiliency, thereby allowing for a greater range of flexing on each stroke of the diaphragm. In the case of plural diaphragms, the diaphragms can all be laminated, or only one can be laminated, as desired. The laminated diaphragm can be designed to have the same or a different resiliency than a single ply diaphragm.

The configuration of the diaphragms can be selected according to the pumping requirements. For instance, the diaphragm can be of uniform thickness throughout its area. It can also be designed to be thicker at the center than at the periphery, so as to increase its resistance to flexing. The shape of the diaphragm is quite immaterial, and the diaphragm can be circular, elliptical, polygonal, rectangular, square or indeed any shape, according to the design of the hydraulic or pulsing and pumping chambers. Thus, for example, the diaphragms can be made of sheet metal, such as stainless steel, Monel metal, aluminum, copper, carbon steel, brass, tin, nickel and zinc, or of a resilient plastic sheet material such as rubber, synthetic rubber, neoprene, Viton A, urea-formaldehyde, melamine-formaldehyde, phenol-formaldehyde, polymethylmethacrylate, nylon, polystyrene, polytetrafluoroethylene, polytrifluorochloroethylene, polypropylene, polyethylene, polyvinyl chloride, polyvinylidene chloride and polycarbonate resins, and epoxy resins; and glass fiber-reinforced laminates of any of these materials.

The back-up plates or other materials used, if desired, for reinforcement can be made of the same or different materials. Thus, for instance, a stainless steel diaphragm can be supported by a stainless steel plate or by a plastic plate, and a rubber diaphragm can be reinforced by a stainless steel plate or by a plate made of polytetrafluoroethylene or nylon. These are merely illustrative examples, and other combinations will be apparent to those skilled in the art from the above description.

The pulsing or hydraulic fluid can be selected as desired, according to the bias means employed, and will be inert to the bias means, the diaphragm and hydraulic chamber walls. Any hydraulic fluid can be used. The hydraulic fluid can, for example, be a lubricating oil or other non-corrosive petroleum liquid, a silicone oil, or a polyalkylene glycol ether.

The drawings show several preferred embodiments of the invention.

FIGURE 1 is a top view of a complete feed pump in accordance with the invention, including in a single unit a diaphragm pump and a hydraulic pulsing unit for supplying hydraulic fluid to the diaphragm for flexing and pumping action thereof.

FIGURE 2 is a cross-sectional view of the pump of FIGURE 1, taken along lines **2—2** and looking in the direction of the arrows.

FIGURE 3 is a cross-sectional view of a modification of the pump of FIGURE 2, showing a rubber plug bias means.

FIGURE 4 is a cross-sectional view of an embodiment of dual diaphragm feed pump in accordance with the invention, showing the hydraulic chambers and the pumping chamber thereof.

FIGURE 5 is a cross-sectional view through an embodiment employing a double diaphragm at opposite ends of a single hydraulic chamber to operate two pumping chambers.

FIGURE 6 is an elevation view of a complete feed pump in accordance with the invention wherein the diaphragm pump and pulsing means are separate units.

Throughout the drawings, like numbers are used for like parts.

The combination pump shown in FIGURES 1 and 2 includes in a single casing a diaphragm pump section A and a reciprocating piston pump section B, or hydraulic pulsing means for providing hydraulic pulses to the diaphragm. The piston pump is an improved embodiment of the pump described in the above mentioned U.S. Patent No. 2,869,467, as shown in FIGURE 8 thereof. The combination pump is enclosed by an outer casing formed in three sections: a pump section **1**, a motor sec-

tion 2, and a diaphragm pump head 3. Sections 1 and 2 are bolted together by bolts 5, passing through the flanges 6. Gasket 9 forms a fluid-tight seal between the two sections. The diaphragm head 3 is bolted to the side of section 1 by bolts 8. Within sections 1 and 2 is a chamber 10 which constitutes a reservoir, for the oil supply for both pumps.

Drive motor 15 is mounted on plate 16 by slot-headed bolts 18. Pump section 1 is a unitary casting in this embodiment, and has formed therein a hydraulic cylinder 20, a hydraulic diaphragm chamber 21 and a fluid connection or passage 23 from the cylinder 20 to the hydraulic chamber 21. A piston 25 is reciprocatingly and rotatably disposed within the cylinder 20, and has a driving arm 28 secured to the end thereof. The arm passes through an aperture 29 in a ball 30, which is mounted between the arms 32 of the coupling 35. Coupling 35 is driven by the motor 15 by means of the shaft 37. A second position of the ball 30, coupling 35, arms 32 and piston 25 is shown by the dotted lines in the drawing. The piston 25 has a longitudinal slot 27 extending a sufficient length to register with the port 26 during the exhaust stroke of the piston. The slot coincides with port 26 through the cylinder 20, serving to vent the hydraulic system as described in U.S. Patent No. 2,869,467.

In order to regulate the volume of hydraulic fluid supplied by the piston on each stroke, the length of the column of oil pumped by the piston is adjusted by means of the slave piston 40, which is reciprocatingly held within the top portion of cylinder 20. Snap ring 41, is held in a groove in cylinder 20 above the fluid connection 23 and below the piston 40, and acts as a stop to limit the downward movement of the piston.

The cylinder has an open end piercing the casing section 1, and closed off by cylinder head 45, inserted in the open end in a press fit and held there by locking screw 46. The head has a threaded central channel, in which is held the bolt 44, which extends into the cylinder into a position to engage the slave piston 40 at the upper limit of its travel. Micrometer head 47 is slip-fitted onto the splined top of bolt 44. By turning micrometer head 47, the bolt 44 is rotated in its threaded socket, and thus moved up or down in the cylinder, to adjust the travel of slave piston 40.

Compression coil spring 50 bears against the upper surface of the piston 40 and against the lower or inner surface of the cylinder head 45, biasing the slave piston 40 against the snap ring 41.

The variable stop means described above as a micrometer screw adjustment is merely one possible type. Other stop adjustments can be used of the continuously variable and discontinuously variable types, as will be evident to anyone skilled in this art.

The oil reservoir 10 for the hydraulic system also serves as a heat sink for the motor 15, which is submerged therein. The cylinder 20 of the hydraulic pump, is also submerged in the reservoir 10. Therefore, any leakage around the piston 25 on either stroke goes into the reservoir and is not lost.

The venting means in accordance with the invention vents the hydraulic system during each exhaust stroke of the piston and comprises a vent plug 52 having central passage 53, opening at one end to the topmost portion of the reservoir chamber 10 and at the other end to the atmosphere, and the port 26, which connects the cylinder 20 with the chamber 10. Thus, any gases vented through port 26 are vented to the atmosphere via chamber 10 and passage 53. Because the port 26 is only indirectly connected to the atmosphere in this way, on the return stroke of the piston, when the piston slot 27 is lined up with port 26, venting is into the oil reservoir 10, thereby preventing any air from entering the port 26, while any gases that bubble up through the reservoir 10 can nonetheless escape to the atmosphere. The aligning of slot 27 with the port 26 is determined by the rotation of the piston as it reciprocates. The piston is reciprocated and rotated by means of the drive arm 28. As the coupling 35 is rotated by the motor 15, the arm 28 is rotated therewith and also slides back and forth within aperture 29. The slot is so arranged that when the piston is on the exhaust stroke, it is aligned with port 26. A fuller explanation of the general principles of operation of the piston pump can be had in Patent No. 2,869,467.

To further ensure that all gas is thoroughly exhausted from the hydraulic system, the conduit 23, connecting the hydraulic chamber 21 of the diaphragm pump to the cylinder 20 has a total volume substantially less than that of the cylinder 20. This is rather simple to arrange in the single unit compact structure shown in FIGURES 1 and 2.

The pumping section A includes the hydraulic or pulsing chamber 21 and a pumping chamber 65 which are separated by a diaphragm 63. The pumping chamber 65 which is defined by the diaphragm 63 and pump head 3, is provided with an inlet 67 and an outlet 68. The hydraulic outlet 68 is located at the highest point of the pumping chamber to ensure that any gas in the chamber will be swept out with the pumped fluid and not be accumulated. The hydraulic chamber 21 defined by the interior walls of the casing 1 and the diaphragm 63 has a port 24 serving as an inlet and an outlet for the pulsing fluid, in this case, hydraulic oil, via the passage 23. The port 24 is at the topmost portion of the hydraulic chamber 21. The top wall 70 of the chamber 21 tapers upwardly towards the port 24 to ensure that no gas bubbles can be trapped at the top of the chamber.

The flexible diaphragm assembly includes the diaphragm 63 which is held between the diaphragm head 3 and the side of casing section 1. The diaphragm is spring-mounted for return to a normal position, after flexure, on the exhaust stroke of the piston 25. The spring-mounting assembly includes a flanged nut 79 on the pumping chamber side of the diaphragm threaded on the end of bolt 77. To prevent leakage through the diaphragm, a sealing nut 80 is threaded on bolt 77 on the hydraulic chamber side of the diaphragm, and nuts 79 and 80 clamp on to the diaphragm 63, to form a leakproof seal. At the far end of bolt 77 is the bolt head 83.

The compression coil spring 85 for diaphragm return is held between a perforated back-up plate 72, also clasped at its periphery between the head 3 and casing section 1, and the spider 82, which is fitted between bolt head 83 and back-up plate 72. One perforation in the back-up plate 72 is aligned with port 24. Thus, whenever the diaphragm 63 is flexed outwardly into the pumping chamber 65, such movement is against the action of the spring 85, which tends to pull the diaphragm back in the direction of the hydraulic chamber. As a result, as soon as the pulsing fluid pressure tending to force the diaphragm outwardly is released, the spring 85 pulls the diaphragm 63 back to the normal nonflexed position shown in FIGURE 1. The spring 50 must be weaker than the bias means in the hydraulic chamber 21, otherwise the diaphragm would be flexed before the slave piston would move.

The inlet and outlet 67, 68, respectively, of the pumping chamber are provided with appropriate check valves 87 and 88, either mechanically or electrically operated, or operated by fluid pressure in the pumping chamber, to control the flow of fluid through the pumping chamber, in the direction from the inlet 67 to the outlet 68. Thus, under increase in pressure in chamber 65, valve 87 is adapted to close and valve 88 to open, and on reduction in pressure, as when diaphragm 63 is returned to normal position by spring 85, valve 87 is adapted to open and valve 88 to close. Annular seal rings 90 and 91, respectively, ensure a leakproof seal when the valves 87 and 88 are closed. Inlet and outlet lines 98 and 99,

respectively, are threadedly attached to pump head 3 in fluid flow connection with valves 87 and 88, respectively.

Valves 87 and 88 are held in valve chambers formed in pump head 3, which are in turn sealed by threaded screws 92 and 93.

In operation, the hydraulic pulsing means B is adjusted to periodically supply a predetermined volume of pulsing liquid or hydraulic fluid, in this case oil, through the line 23 to the hydraulic chamber 21. The increase in fluid volume and hence fluid pressure in the hydraulic chamber 21 causes the diaphragm 63 to flex outwardly into the pumping chamber 65, against the action of the spring 85. This results in a corresponding displacement and increase of pressure of the fluid in the pumping chamber. Valve 87 closes in response to the increase in fluid pressure in the pumping chamber 65, while the valve 88 opens, and thus, the diaphragm forces fluid displaced in the chamber 65 to flow out through the outlet 68.

The operation of the hydraulic pulsing means B is such that each delivery of a volume increment of hydraulic fluid to the line 23 is followed by a period when fluid is withdrawn from the line and cylinder 20 is vented to the reservoir 10 through port 26 and the slot in the piston 25, resulting in a decrease in fluid pressure in the line and in the hydraulic chamber 21 to atmospheric. As soon as the pressure in chamber 21 is reduced sufficiently, the force of the spring 85 can overcome the fluid pressure in the chamber, and retract the diaphragm 63 to the position shown in FIGURE 1. In this position, as is evident from the drawing, the perforated plate 72 serves as a stop and prevents further movement of the diaphragm beyond the limiting position shown. The diaphragm is now ready for the next successive flexing and resultant pumping cycle.

Whenever the diaphragm 63 is withdrawn from its flexed position, upon reduction of pressure in the hydraulic chamber 21, under action of the spring 85, the valve 88 is closed, and the valve 87 is opened, permitting entry of fluid into the pumping chamber 65 past the valve 87 and through the inlet 67. Thus, the volume of fluid in the chamber is now brought up to equal the volume of the chamber, as before, and another pumping cycle can begin.

By adjustment of the volume of fluid delivered to line 23 and of the pulsing period of the hydraulic pulsing means, it will be apparent that a continuous timed pumping and consequent delivery of any desired volume of fluid from the pumping chamber 21 can be assured.

The diaphragm, while sweeping the hydraulic fluid out of the hydraulic fluid chamber also sweeps any air or other compressible gases which may be trapped in the hydraulic chamber out of the port 24 to the hydraulic pump where they are vented through the port 26 to the oil reservoir. In the case of the coil spring as used in the present embodiment, the action of the spring induces an added turbulence in the hydraulic fluid which aids in sweeping out any more bubbles of gas which otherwise could tend to cling to any surface.

The feed pump shown in part in FIGURE 3 is similar in every respect to that of FIGURE 1 with the exception of the bias means; consequently, the following discussion is limited to this feature.

The coil spring is replaced by a resilient rubber plug 100 which is held between a washer 101 attached onto the bolt 83 and the back-up plate 72. Thus, as the diaphragm is moved outwardly under increased fluid pressure in the pulsing chamber 21, the rubber plug 100 is compressed. Accordingly, when the pressure in the pulsing chamber 21 is relieved, the diaphragm is returned to the normal position shown in FIGURE 3, and the pumping cycle can then be repeated, as in the case of the feed pump of FIGURES 1 and 2.

The pump shown in FIGURE 4 is a single unit device similar to that shown in FIGURES 1–3 except that it is provided with a pair of diaphragms 63 and 63′ and a pair of hydraulic chambers 21 and 21′, respectively, both acting on a single pumping chamber 65′.

The pump of FIGURE 4 comprises a casing section 1 forming a first hydraulic chamber identical to that shown in FIGURE 1. An annular plate 117 forms the side walls of the pumping chamber 65′ and is provided with a hydraulic fluid conduit 23′. Outlets 112 are located in the uppermost portion of the plate 117 and inlets 113 in the lowermost part. Passages 120 and 121 leading from the inlet valve 87′ and outlet valve 88′, respectively, are attached to fluid lines not shown. Otherwise, the construction and operation of these valves are the same as in FIGURES 1 and 2.

Hydraulic chamber head 110 defines one end and the side walls of the second hydraulic chamber 21′ and is provided with hydraulic fluid conduit 23″. The two diaphragms 63 and 63′ form the end walls separating the pumping chamber 65′ from the hydraulic chambers 21 and 21′, respectively. The diaphragm 63, plate 117, diaphragm 63′ and head 110 are attached to the casing section 1 by means of bolts 5′. The diaphragms are provided with bias means 85 and 85′ and spiders 82 and 82′, identical to those in FIGURE 1. Diaphragm 63′ is shown in this embodiment as a composite diaphragm formed of two sheets clamped together between flanged nut 79′ and sealing nut 80′.

A stop 125 is provided on spider 82′. As diaphragm 63′ flexes inwardly into the pump chamber 65′, drawing the bolt 77′ and spring 85′ with it, the stop 125 eventually encounters back-up plate 72′, after which further movement of the diaphragm 63′ is prevented. This prevents the diaphragm 63′ from taking more than its share of the pulse volume of hydraulic fluid delivered to the inlet port 23, and insures an appropriate proportional response of the diaphragm 63 to this pulse. Thus, when equal hydraulic oil pressure is applied simultaneously in chambers 21 and 21′, to the faces of the diaphragms 63 and 63′, respectively, the stopped diaphragm 63′ moves towards the stop and then halts, while any additional motion is taken by the diaphragm 63.

It is understood that the spring 85 is heavier than the spring 85′. This ensures that most of the pulsing movement initially will be taken by diaphragm 63′, which has the weaker spring. The heavier spring 85 on diaphragm 63 controls movement of this diaphragm after diaphragm 63′ has reached its stopped or limiting position.

The result is that in this structure the pumping action applied to the fluid in the pumping chamber 65′ is continued over a longer interval by the two diaphragms 63 and 63′ acting more or less in sequence.

Thus, in operation, when hydraulic fluid is supplied under pressure to the hydraulic chambers 21 and 21′, the diaphragms 63 and 63′ are pushed outwardly in that sequence, the diaphragm 63′ moving first to its stop into the pumping chamber 65′ and pulling shaft 83′ with it against the force of spring 85′, up to its stop, and then the second diaphragm 63 moves against the stronger spring 85.

When the pulse is ended, and the pressure in chambers 21 and 21′ is reduced to atmospheric, the diaphragms 63 and 63′ are returned to their normal positions by the springs 85 and 85′. The spring 85 being the heavier, diaphragm 63 is returned to its normal position the first, and diaphragm 63′ follows shortly thereafter.

It will further be noted that this sequential action prevents a hydraulic lock. If the volume of hydraulic oil delivered to the pulsing chambers 21 and 21′ is insufficient to bring the stopped diaphragm 63′ to its locking or limiting position, then the unstopped diaphragm 63 will scarcely move at all. It is only when the hydraulic pulse is of sufficient volume to bring the stopped diaphragm to its stop that the unstopped diaphragm moves on whatever additional hydraulic oil volume remains.

Diaphragms 63 and 63' may also be made of different sizes and hydraulic lock will be avoided because the hydraulic pressure operating on the larger diaphragm will overcome the spring force first, even if the springs themselves are the same size. The same effect can be achieved by using diaphragms of different resiliencies and different thicknesses.

Thus, for instance, the diaphragms can be of different materials, whether the thickness be the same or different. One diaphragm can be made of stainless steel, and the other diaphragm made of polytetrafluoroethylene, or of rubber, both of which are more resilient than stainless steel, and will therefore flex more readily at a lower pressure. The diaphragm which is flexed at the lower pressure is the stopped diaphragm, as in the structure of FIGURE 4, and the diaphragm which flexes only at a higher pressure need not be stopped. Differences in resiliency or flexing pressure can also be obtained or compensated for as desired by using springs of different force, or stressing the springs to different force positions. Similar effects can be obtained by varying the surface areas of the diaphragms exposed to fluid pressure in the hydraulic chamber, the pumping, or both.

A plurality of double diaphragm pumps of the type shown in FIGURE 4 may be used in parallel, with all diaphragms stopped except one, and that one having the least resilient diaphragm or spring, and with a common inlet and outlet line for supplying and delivering the liquid to be pumped, and a common line to the pulsing unit so that all diaphragms are actuated by the same pulse. The diaphragm pumps can also be single, if desired, with all diaphragms stopped except one, and that one having the least resilient diaphragm or spring.

The coupling of a plurality of pumping units to a single delivery line can be employed to supply the same volume of fluid through the outlet line at a greatly increased pressure. Also, a greater total volume can be pumped at a lower pressure. When the total volume is that which would be delivered by one pumping unit, the three units can be made of smaller volume, and therefore much stronger, so that a single pump can be used to pump fluids at extremely high pressures, of the order of several thousand p.s.i. or more.

A plurality of pumps of the type shown in FIGURE 4 can be used in series with a common outlet and inlet valve. In this case no sump valves are needed for the individual pumps, flow being through all pumps from inlet to outlet. A common hydraulic feed line would be provided so that the hydraulic pulsing fluid is supplied to all of the hydraulic pulsing chambers simultaneously.

The pump shown in FIGURE 6 is provided with a pair of diaphragms 203, 203', on each side of a single hydraulic chamber 201, each acting against separate pumping chambers 204 and 204'. Return of the diaphragms to normal position, as shown in FIGURE 6, is assured by use of a single tension coil spring 206.

The pump of FIGURE 6 has an annular central plate 207 defining the side walls of the hydraulic chamber 201, with two diaphragms 203 and 203' defining the end walls thereof. The diaphragm 203 has a lesser thickness than diaphragm 203' and thus is flexed under a lesser pressure in chamber 201 than is diaphragm 203'. A pair of outer back-up plates 208 and 208' are held to the central plate 207 by six bolts 210. A pair of inner back-up plates 237 and 237' are provided in the hydraulic chamber 201 having perforations 238 and 238'. One of the perforations in each of plates 237 and 237' is aligned with conduits 229 and 229', respectively. The back-up plates 208 and 208' are provided with ports 214, 215, check valves 217, 218 and inlet and outlet lines 220, 221. Plate 207 is provided with port 225 connected to line 226 and to conduits 227 leading to the hydraulic or pulsing chamber 201. The tension coil spring 206 is hooked into the shafts 230, 230', which are anchored on diaphragms 203 and 203', respectively. Shaft 230 is provided with a stop 231 to limit movement of the diaphragm 203.

As diaphragm 203 flexes outwardly, drawing the shaft 230 and spring 206 with it, the stop 231 eventually encounters back-up plate 237, after which further movement of the diaphragm 203 is prevented. This prevents the diaphragm 203 from taking more than its share of the pulse volume of hydraulic fluid delivered to the inlet ports 225, and ensures an appropriate proportional response of the diaphragm 203' to this pulse. Thus, when hydraulic oil pressure is applied to chamber 201, to the faces of the diaphragms 203 and 203', simultaneously, the stopped diaphragm 203 moves towards the stop and then halts, while any additional motion is taken by the diaphragm 203'.

The result is that in this structure the pumping action is applied to the fluids in the pumping chamber 204 and 204', the diaphragms acting more or less in sequence.

Thus, in operation, when hydraulic fluid is supplied under pressure to the hydraulic chamber 201, the diaphragms 203 and 203' are pushed outwardly, in that sequence, the thinner diaphragm 203 moving first to its stop 231 into the pumping chamber 204, and pull shafts 230 and 230' with them against the force of spring 206.

When the pulse is ended, and the pressure in chamber 201 is reduced to atmospheric, the diaphragms 203 and 203' are returned to their normal positions by the spring 206. The diaphragm 203' being the heavier, diaphragm 203' is returned to its normal position the first, and diaphragm 203 follows shortly thereafter.

It will further be noted that this sequential action prevents a hydraulic lock. If the volume of hydraulic oil delivered to the pulsing chamber 201 is insufficient to bring the stopped diaphragm 203 to its locking or limiting position, then the unstopped diaphragm 203' will scarcely move at all. It is only when the hydraulic pulse is of sufficient volume to bring the stopped diaphragm to its stop that the unstopped diaphragm moves on whatever additional hydraulic oil volume remains.

It will also be apparent that by this action the same or different volumes of the same or different fluids can be pumped in chambers 204 and 204'. By adjustment of the position of stop 231, and the total volume of oil pulsed to chamber 201, any relative volumes can be delivered, as will be apparent, and the same or different fluids can be supplied to the chambers 204 and 204' for any desired combination of fluids and fluid volumes.

The diaphragm pump of FIGURE 6 is operated by a separate pulsing means of the type shown in FIGURE 5.

The pulsing unit of the proportioning feed pump of FIGURE 5 has a base 327 to which are attached a motor-rotated fly wheel 312, connected by a yoke 313 to an adjustable self-venting hydraulic pulsing mechanism 314 of the type described in U.S. Patent No. 2,869,467. This hydraulic pulsing mechanism supplies pulsations of hydraulic fluid, such as lubricating oil, having a definite and controlled displacement and period to the hydraulic line 226, which in turn conveys them to the diaphragm pumping unit 208.

Having regard to the foregoing disclosure, the following is claimed as the inventive and patentable embodiments thereof:

1. A self-purging proportioning feed pump comprising, in combination, a housing having therein a pumping chamber and a hydraulic chamber, a flexible diaphragm forming at least a portion of a wall separating the chambers and adapted to flex from a normal position outwardly into the pumping chamber under pressure of hydraulic fluid in the hydraulic chamber; a fluid port at the highest point of the hydraulic chamber, pulsing means in fluid connection with the fluid port for cyclically supplying hydraulic fluid under pressure to the hydraulic chamber and for exhausting hydraulic fluid from the hydraulic chamber, vent means for venting the hydraulic system to the atmosphere only during the exhaust portion of the cycle,

diaphragm bias means within the hydraulic chamber for returning the diaphragm to a normal position during the exhaust portion of the cycle, and fluid inlet and outlet connections in the pumping chamber for supplying fluid to be pumped and delivering pumped fluid by flexing pulsation of the diaphragm.

2. The pump of claim 1 wherein the outlet connection to the pumping chamber is connected at the highest point in the pumping chamber.

3. The pump of claim 2 wherein the pulsing means is a reciprocating piston pump.

4. The pump of claim 3 comprising an oil reservoir open to the atmosphere, and wherein the pulsing means comprises a cylinder at least partially immersed therein, and wherein the vent means from said cylinder opens into the oil.

5. A proportioning feed pump according to claim 4 wherein the pulsing means comprises a longitudinally reciprocating and rotating main piston operating within the cylinder, drive means for said piston, and wherein the vent means comprises a port through the cylinder to the oil reservoir and a channel in the piston adapted to connect the port to the cylinder space above the piston only during the suction stroke of the piston.

6. The pump of claim 5 comprising adjusting means to adjust the volume of fluid pulsed by the piston on each stroke.

7. A proportioning feed pump according to claim 6 wherein the adjusting means comprises a slave piston operating within said cylinder in fluid pressure connection with the main piston, piston bias means acting on said slave piston pushing it towards said main piston, the piston bias means having a lower force than the diaphragm bias means, and variable stop means for varying the length of travel of said slave piston; the slave piston being moved away from said main piston by fluid pressure on the compression stroke, a distance determined by the variable stop means, and towards the piston on the suction stroke by the piston bias means.

8. A proportioning feed pump according to claim 3 comprising fluid conduit means between the pulsing means and the hydraulic chamber having a total volume less than the volume of the hydraulic fluid pulses provided by the pulsing means.

9. A feed pump in accordance with claim 1 having a stop associated with the diaphragm for limiting distention of the diaphragm under pressure of hydraulic fluid in the hydraulic chamber.

10. A feed pump in accordance with claim 1 wherein the diaphragm is formed as a multiple ply structure.

11. A feed pump in accordance with claim 1 having a plurality of flexible diaphragms forming walls of the pumping chamber.

12. A feed pump in accordance with claim 11 in which the diaphragms have different distention characteristics.

13. A feed pump in accordance with claim 11 in which at least one of the diaphragms is provided with a stop limiting distention of the diaphragm under pressure of hydraulic fluid in the hydraulic chamber.

14. A feed pump in accordance with claim 1 having a plurality of flexible diaphragms forming walls of the hydraulic chamber.

15. A feed pump in accordance with claim 14 in which the diaphragms have different distention characteristics.

16. A feed pump in accordance with claim 1 having a plurality of pumping chambers and a diaphragm associated with each pumping chamber.

17. A feed pump in accordance with claim 1 in which the bias means is a spring.

18. A feed pump in accordance with claim 17 in which the spring is a coil spring.

19. A feed pump in accordance with claim 17 in which the spring is a resilient plug.

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