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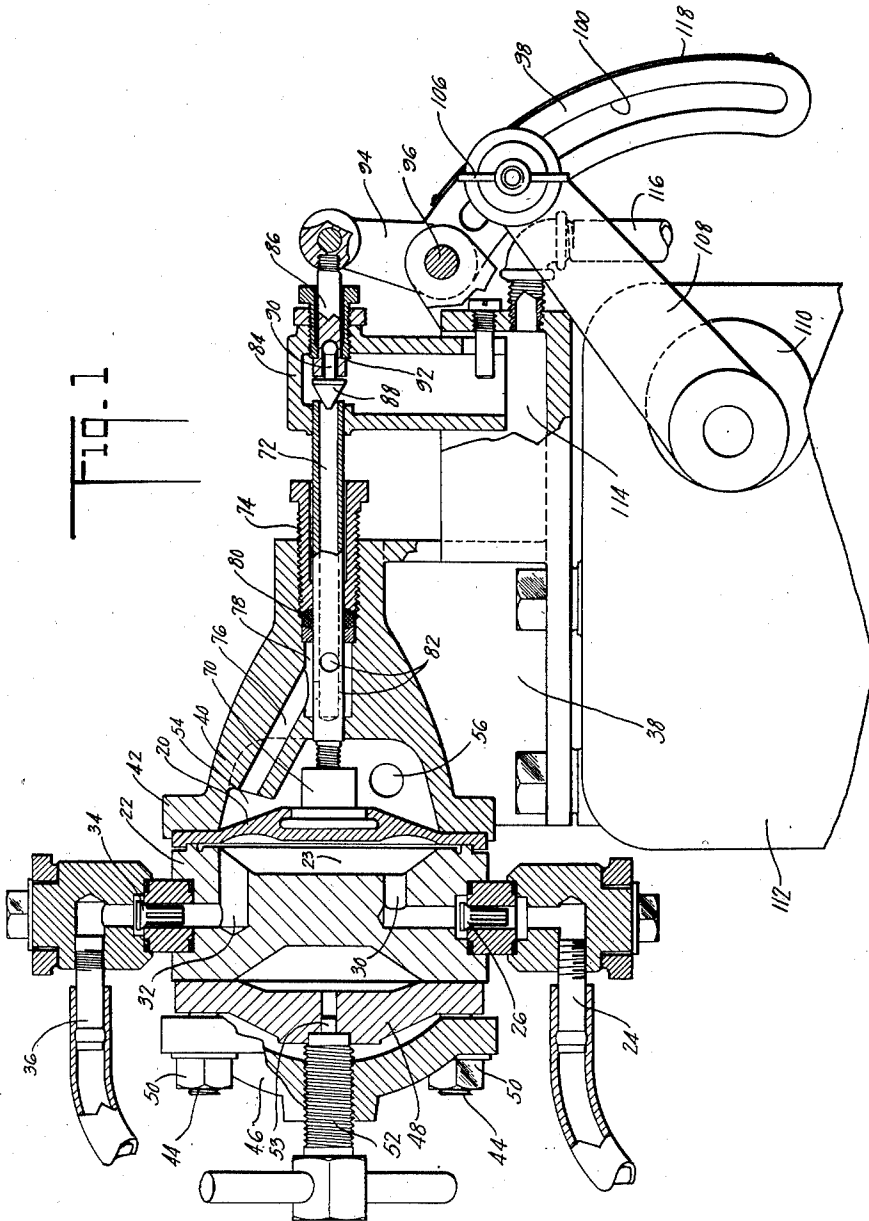
G. M. BOOTH

LIQUID FEEDING APPARATUS

2,229,038

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6 Sheets-Sheet 1



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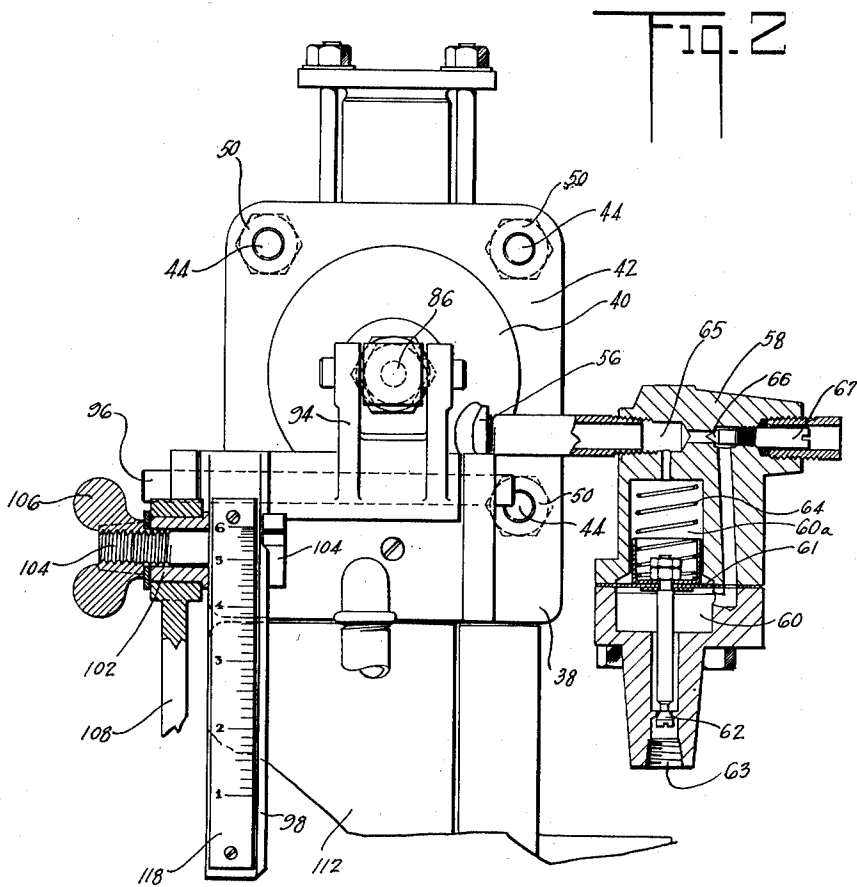
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6 Sheets-Sheet 2



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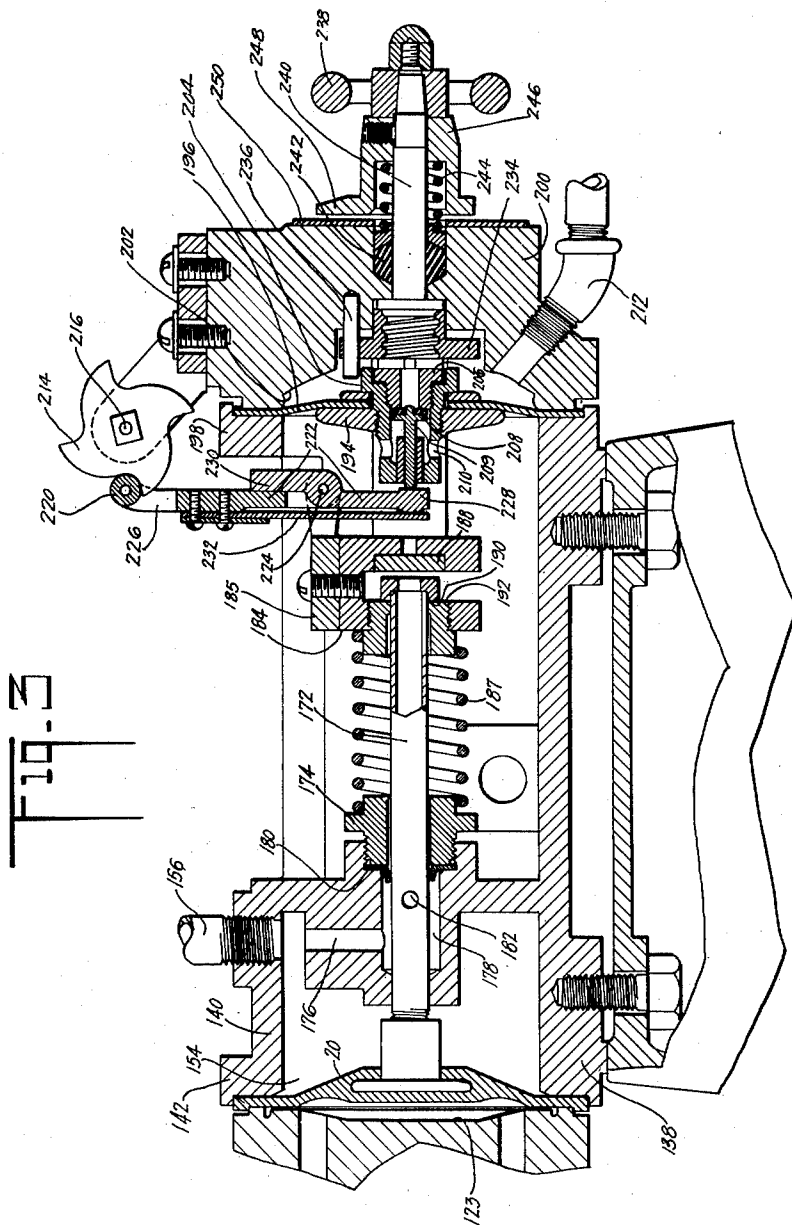
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6 Sheets-Sheet 3



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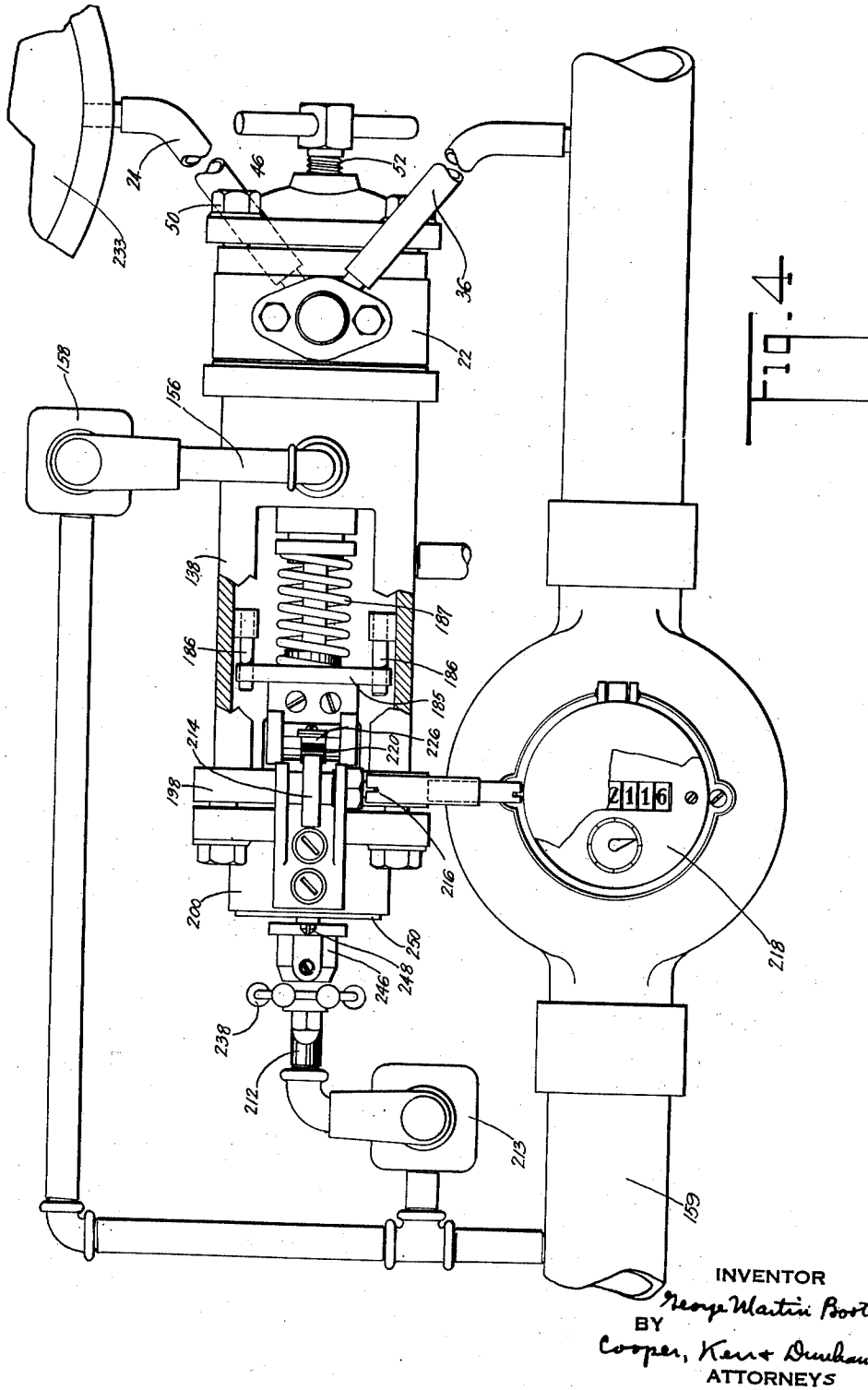
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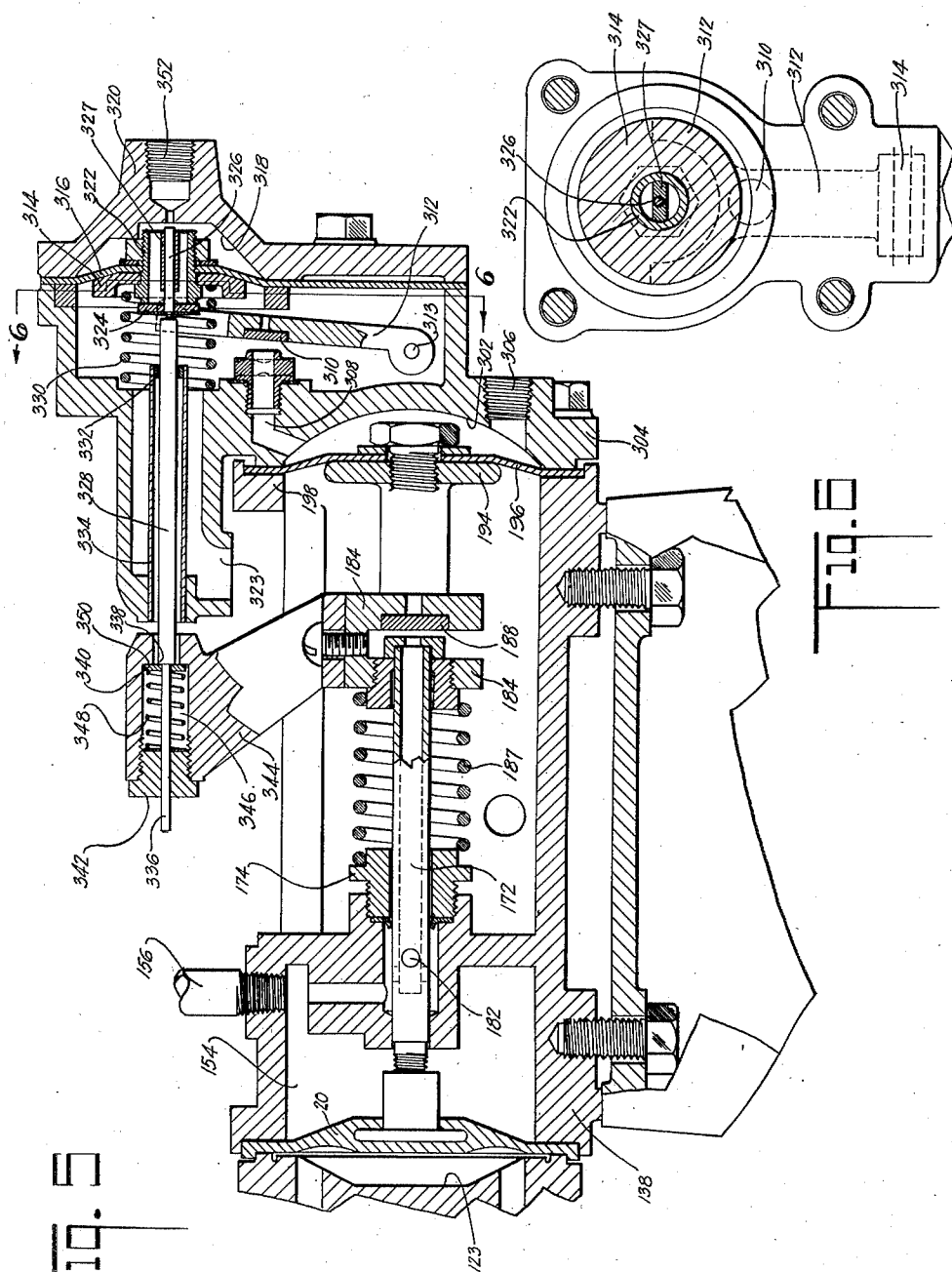
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6 Sheets-Sheet 5



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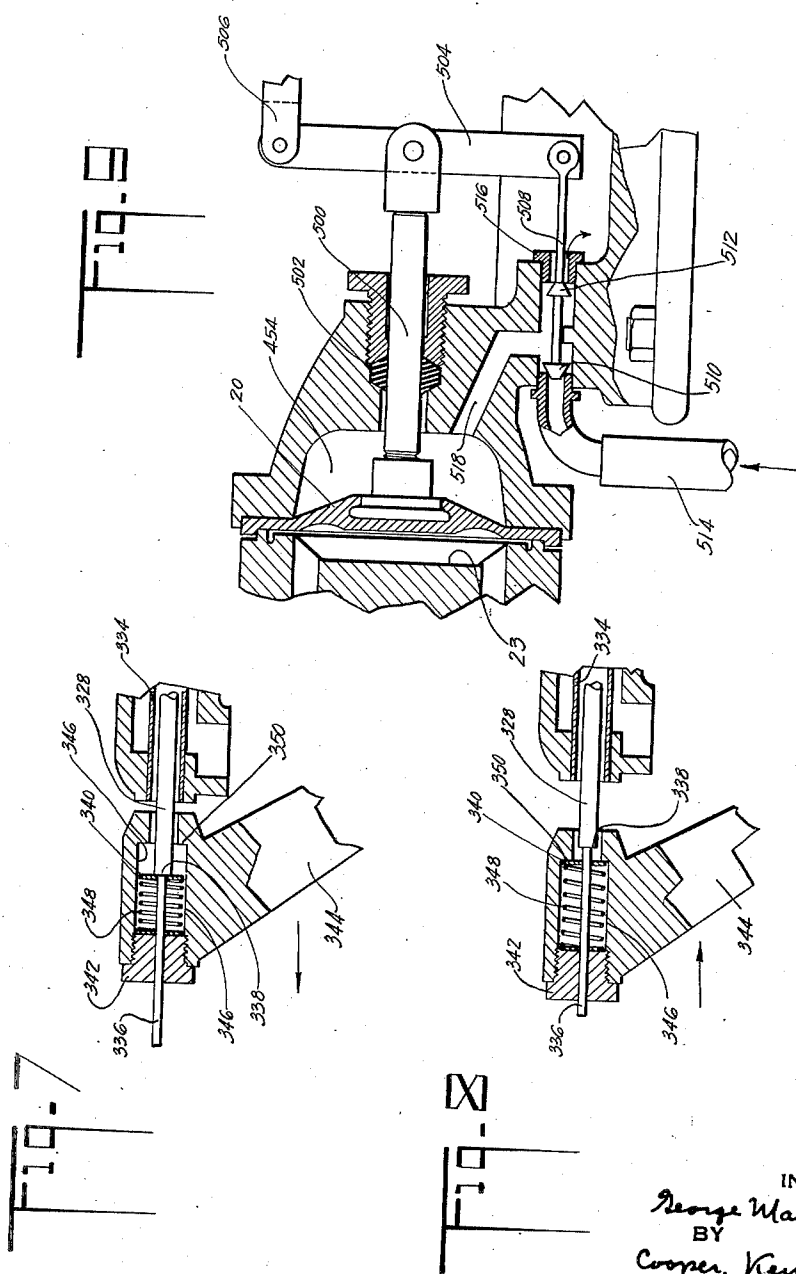
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6 Sheets-Sheet 6



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UNITED STATES PATENT OFFICE

2,229,038

LIQUID FEEDING APPARATUS

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20 Claims. (Cl. 103—150)

This invention relates to hydraulic apparatus, particularly liquid feeding devices, and in one important aspect, relates to apparatus for feeding into a body of liquid under pressure, for example water as contained in a supply main, desired quantities of a treating liquid. In purifying the water of an ordinary supply system, as for towns, villages, hotels, or homes, it has been found that good results are obtained by the regular introduction of small quantities of a chlorinating liquid, such as a suitable hypochlorite solution. A principal object of the present invention, therefore, is to provide simple, efficient, and inexpensive apparatus for effecting such introduction of hypochlorite solution for the purification of water as carried under pressure in a main.

A further object of the invention is to provide improved apparatus of the character described, employing a diaphragm type of pump, but requiring little or no externally supplied power to afford a pump delivery at relatively high pressure; and also to provide such apparatus wherein liquid under pressure is utilized to exert directly on the diaphragm a force substantially equal to that needed for pump delivery.

Another object is to provide liquid feeding apparatus including a pump having a diaphragm of resilient material, wherein wear and tear on the diaphragm is minimized and the life of the latter very greatly increased; and also to provide such apparatus, wherein those results are brought about with a balancing force directly exerted by water which may be taken from the main or like body of liquid under pressure. It has been found, for example, that in using a diaphragm pump to feed liquid into a high pressure main, and particularly a pump having a diaphragm of flexible material secured at its periphery and operated by applying force at its center, tremendous strains are set up in the diaphragm, causing it to bend and bulge rapidly, and to be distorted in a violent and often irregular manner, each time the device reciprocates and in fact, all the time it is in operation. As a result, the diaphragm weakens very soon, and must be frequently replaced in order to have maximum efficiency, and indeed, in order to avoid complete breakdown by permanent distortion or rupture of the diaphragm. With the present invention these disadvantages are obviated, so that the pump will last for a very long time, and thus provide an efficient feeding device for water purification systems or the like, where dependability over long periods is a most important criterion.

It may also be explained that this invention, for these and other reasons, also provides a more efficient and dependable feeding service than is obtained with other pumping arrangements, such as of the plunger or piston type, or of other types wherein continuously rotating valves or sliding valves or the like are employed; for ex-

ample, in systems of that character accuracy of pumping is directly dependent upon the fit or packing of one or more sliding or rotating valves or pistons, which are not only difficult to manufacture with the necessary accuracy, but are apt to leak, or set up friction losses, or become otherwise unreliable.

Other objects are to provide liquid feeding apparatus having new and improved arrangements for the operation or control of reciprocating devices therein; to provide hydraulically operated driving means, suitable for the operation of such devices, and simple and efficient in character; to provide dependable and efficient hydraulically operated driving apparatus which is conveniently free from pistons, rotating valves or like parts requiring a sliding fit under pressure and therefore having disadvantages of the character noted hereinabove; to provide improved liquid feeding apparatus as described, which is adapted to be driven by the force of liquid under pressure, and is conveniently free of elements having the disadvantages of sliding fit as just explained; to provide apparatus improved in the foregoing or other respects, which is adapted to deliver the treating liquid at a rate automatically proportional to the rate of flow of the main body of liquid; and to provide new and improved hydraulic, i. e. liquid-operated, driving apparatus, and new and improved control means for such apparatus.

Other objects and advantages include those hereinafter stated or apparent in connection with the following description of certain presently-preferred embodiments of the invention. These embodiments, which are set forth by way of example, are illustrated in the accompanying drawings, wherein:

Figure 1 is a vertical view, chiefly in section along a central vertical plane, of one form of the apparatus;

Fig. 2 is an end elevation looking toward the right-hand end of Fig. 1, with certain parts in section;

Fig. 3 is a vertical view of another form of the apparatus; chiefly in section along a central vertical plane, with certain parts cut away;

Fig. 4 is a plan view of the apparatus shown in Fig. 3, and including certain cooperating instrumentalities and connections;

Fig. 5 is a vertical view of yet another form of apparatus, chiefly in section along a central vertical plane, with certain parts cut away;

Fig. 6 is a sectional view on line 6—6 of Fig. 5; Figs. 7 and 8 are fragmentary sectional views of a portion of the apparatus in Fig. 5, with certain parts in respectively different positions; and

Fig. 9 is a central vertical section of a modified form of part of the apparatus.

It may be explained that the apparatus shown in these figures is conveniently adapted to with-

draw treating liquid (e. g., hypochlorite solution) from a nearby tank, and to deliver desired quantities thereof into a water main where the pressure may be relatively high, for example, as high as 100 pounds per square inch, or in many cases, considerably higher.

The apparatus of Fig. 1 includes a pumping element comprising a circular flexible diaphragm 20, advantageously made of resilient material, such as rubber. Against this diaphragm there is seated a block 22 having a circular recess 23 disposed toward the diaphragm, to provide a pumping chamber. Treating fluid is admitted to the latter through supply pipe 24, check valve 26, and passage 30 in the block 22. Delivery of treating fluid from the chamber is obtained through an outlet passage 32 in the block 22, a check valve 34 and a discharge pipe 36 which may be connected to the water main (for example, as shown in Fig. 4).

The main supporting structure of the apparatus may comprise a casting 38, having a cup-like portion 40 provided with an annular flange 42 abutting the opposite side of diaphragm 20 from block 22. To secure block 22, and diaphragm 20 in place against the member 40, the latter has a plurality of studs 44, 44, which pass freely through corner portions of the block 22 and through corresponding corner portions of a clamping head 46. Intermediate the head 46 and the block 22, there is a circular aligning member 48, of substantially the same size as the diaphragm 20, and disposed coaxially therewith. The head 46 is preliminarily clamped toward the member 40, so as to engage therebetween the members 48, 22 and 20, by moderately tightening up the nuts 50 on the studs 44. Through the center of the head 46, and threaded therein, there extends a bolt 52 having at its end a projecting pin 53 slidably engaging a corresponding aperture in the aligning member 48, but with a rather loose fit.

In consequence, when the bolt 52 is tightened up, i. e., screwed in, by its handle as shown, the further pressure thereby exerted on member 48 at its center securely clamps this member toward the member 40, so as to lock the diaphragm 20 in place intermediate the block 22 and member 40, and effect a high pressure seal uniformly about the periphery of diaphragm 20 on each side of it. Thus diaphragm 20 is automatically accurately aligned with respect to members 22 and 40, and stress on the diaphragm is evenly distributed about its periphery, preventing distortion, or other irregular strain on the diaphragm, as might otherwise contribute to its wearing out at localized points.

The interior recess of cuplike member 40, facing diaphragm 20, provides what may be conveniently termed a balancing chamber 54 for the pump. Through an inlet port 56, water may be supplied to the chamber 54 from the main into which the treating liquid is to be introduced. The line between the main and the port 56 may conveniently include a suitable strainer (not shown) and a differential valve 58 (See Fig. 2).

The differential valve 58 may be of suitable known construction, adapted to provide a substantially uniform flow of water to the chamber 54 from the main. The valve here shown includes to that end, adjacent chambers 60, 60a, separated by a diaphragm 61 which carries a valve closure 62 for the inlet 63 to the chamber 60 and which is biased toward open position of valve 62 by spring 64. The chamber 60 is connected with the outlet 65 and the chamber 60a through an orifice

66 which is adjustable by means of the threaded member 67. As will now be understood, the pressure differential between chambers 60, 60a, is a function of the force exerted by the spring 64 on the diaphragm and is substantially constant, and in consequence, the flow through orifice 66 is substantially constant for any given setting of member 67, irrespective of variations in pressure at the inlet 63 or the outlet 65.

The diaphragm 20 has at its center a supporting boss 70 secured to a closed end of a tubular member 72. The tube 72 is supported by, and longitudinally slidable in a sleeve 74 mounted in member 40 opposite the diaphragm. Opening near the top of the balancing chamber 54 so as to avoid entrapment of air in the latter, an outlet port 76 extends downwardly from the chamber to a cylindrical recess 78 surrounding the tube 72; suitable packing 80 being provided about the tube, next to the sleeve 74, to prevent leakage of water from the recess 78. The tube 72 has oppositely disposed ports or openings 82, 82, at the portion thereof which is adjacent the recess 78, these ports being so arranged that one or more of them is always open for access to the recess 78 throughout the stroke of the tube 72, as hereinafter explained.

A housing 84 is secured to the outer end of the tube 72, and carries in an appropriate supporting sleeve, a slidable shaft 86, spaced beyond and in axial alignment with the tube 72. Shaft 86, when moved to the left relative to the housing, causes a conical valve member 88 to seat into the adjacent end of tube 72, thus providing a valve closure for the latter. Member 88, by virtue of its supporting pin 90 loosely carried in a cooperating recess in shaft 86, is self-aligned relative to the end of the tube. It will be understood that the shaft 86 is longitudinally slidable relative to the housing 84, but that its displacement to the right (relative to the housing) is limited by the engagement of a shoulder 92, on shaft 86, with the inner face of the supporting sleeve in the housing 84. Thus when the shaft 86 is moved to the right, the valve is permitted to open, but before the apex of valve member 88 can fall clear of the end of tube 72, the shoulder 92 strikes the supporting sleeve, as shown, and further displacement of the shaft 86 to the right will then pull with it the housing 84, tube 72, and the center of diaphragm 20, — the parts being here illustrated in the position so assumed upon movement of shaft 86 to the right.

The outer end of shaft 86 is pivoted to the upper arm 94 of a bell crank lever which rocks about a shaft 96 (carried by the main frame 38, see Fig. 2), and which has a lower arm 98 containing a curved slot 100 extending lengthwise thereof. Adjustably secured at any desired position along this slot, is a bearing 102 (the adjustable securing means comprising the bolt 104 passing through the slot and the cooperating wing nut 106, see Fig. 2) for the outer end of a connecting rod 108, connected to be reciprocated by an eccentric 110. The box or housing 112 contains an electric motor and suitable gearing (of conventional form and hence not shown), arranged to rotate the eccentric 110 at the proper speed for desired operation of the pump, as in the manner now to be described.

Assuming that the parts are in the position shown, and that the stated connections have been made to the water main and to the supply of treating liquid, the apparatus is adapted to operate as follows: Water is constantly flowing in through the port 56 to the balancing chamber 54,

and thence on out through port 76, recess 78, holes 82 and tube 72 (valve 88 being now open) to waste (i. e., dropping into a suitable collecting basin 114 in the lower part of the casting 88, having an outlet 116).

At this point of time, the motor drive, through the eccentric 110, connecting rod 108, and bell crank lever 94—98, is such that the shaft 86 is in its extreme right hand position. Continued operation of the motor drive thereupon commences to displace the shaft 86 to the left. As previously explained, valve 88 first closes, and shaft 86 then pushes the entire assembly, including housing 84, tube 72, and the center of diaphragm 20, to the left. Simultaneously, upon closure of valve 88, water very rapidly backs up in the balancing chamber 54, promptly filling the latter, and for the remaining part, i. e., nearly all, of the leftward stroke of the assembly, force is exerted to the left on the exposed portion of diaphragm 20, by the water flowing constantly into the chamber 54 from the main.

The consequent displacement of the diaphragm 20 to the left will therefore expel into the main, through port 32, check valve 34 and line 36, the charge or slug of treating fluid which will be assumed to have been previously drawn into the pumping chamber 23 from the supply tank for such treating fluid or reagent.

It will now be appreciated that even though the pressure in the main may be relatively high, e. g., 100 pounds per square inch or more, the force which the motor driving mechanism must exert on the reciprocating assembly including tube 72 may at least be very greatly supplemented by the water which backs up in the balancing chamber 54, and which continues to flow into the latter, so as to cooperate directly in displacing the diaphragm 20 to the left. Indeed, beyond mechanical friction in the various elements, the force exerted by the electric motor need only be sufficient, on the leftward or pumping stroke, to hold the valve 88 closed, and to compensate for such inequality of forces on the diaphragm 20 as may be occasioned, for example, by the lesser effective area of the latter on its balancing chamber side (because the tube 72 is connected to that side of the diaphragm). In general, the water is preferably admitted to the balancing chamber at a pressure substantially equal to that of the main, and thus substantially equal to that at which treating liquid must be expelled from the pumping chamber 23; and so far as the above-mentioned difference in effective diaphragm area may cause the water in the balancing chamber to exert less force than is necessary for pumping, it will be at most only a little less. Hence ordinarily, in addition to the mechanical resistances mentioned above, the motor need overcome substantially no more than the little difference in force just mentioned, in order to accomplish the pumping action.

When the leftward stroke is completed, i. e., when the motor driven bell-crank arm 94 has finished rocking to the left and begins its return stroke, its initial return movement withdraws shaft 86 to the right with respect to housing 84, allowing valve 88 to open; shoulder 92 of shaft 86 is then pulled back against the sleeve in the housing 84 and the continued rocking of the arm 94 to the right carries housing 84, tube 72, and the center of diaphragm 20 back to the original right hand position. Throughout this return stroke, valve 88 is open, and the water admitted to the balancing chamber through port 56 merely flows idly through the chamber and out through the

tube 72 to waste, so that no force is exerted from the balancing chamber upon the diaphragm, to impede its free displacement to the right. During displacement of the diaphragm to the right, by the return stroke of the assembly, a fresh charge or slug of treating fluid is sucked into the pumping chamber 23 through line 24, check valve 26 and inlet port 30.

It will be appreciated that on this return stroke, the work of the motor is substantially the same as on the pumping stroke, except that instead of supplying any deficiency of pumping force on the diaphragm 20, the motor must exert the usually slight force necessary to fill the pumping chamber 23 with a fresh slug of treating liquid. Ordinarily, for example, the treating liquid need only be drawn up from a nearby tank or tub, in which it may conveniently be mixed or made up, from time to time.

Following the return stroke to the right, the eccentric 110 and associated instrumentalities thereupon carry the assembly through the pumping stroke to the left, in the manner previously described, and through another return stroke; and the reciprocating pumping action thereafter automatically continues in the same way.

As stated above, the apparatus requires very little power from the electric motor, for example, with an apparatus of the sort here shown, a small 110-volt shaded-pole motor, drawing 25 watts and delivering less than 2 watts, is sufficient to deliver 60 gallons of reagent during 24 hours, at a pressure of 100 pounds per square inch; whereas with diaphragm pumps of other types, lacking the balancing arrangement here shown, a much larger motor, such as a standard $\frac{1}{4}$ H. P. motor drawing 250 to 300 watts and delivering about 180 watts, would be required to obtain the same output of treating liquid. Furthermore, the arrangement provides a tremendous conservation of the life of the diaphragm. As explained hereinabove, when the usual type of diaphragm pump is called upon to operate at high pressures, great strains are set up in the diaphragm, resulting in violent flexing and bulging at every stroke, and usually in irregular fashion or at localized points. The rubber or other diaphragm material rapidly weakens and soon ruptures or stretches, so that frequent replacement is necessary. In the present apparatus, however, by virtue of the balancing chamber 54 and cooperating instrumentalities, strain in the plane of the diaphragm is greatly minimized, and indeed, almost the only strain on the diaphragm is that of pressure exerted transversely thereof, i. e., perpendicular to its surfaces, with the result that there is very little wear of the diaphragm material. At the same time, the clamping arrangement including the aligning member 48 cooperates to keep the sealing and clamping stress uniform throughout the periphery of the diaphragm, avoiding irregular localized strain which has contributed to the aforesaid disadvantages of pumps hitherto available.

The described apparatus, therefore, is both simple in structure and highly dependable in performance. The quantity of reagent delivered through the output line 36 can be varied as desired by adjusting the position of the connecting rod bearing 102 with respect to the lower arm 98 of the bell crank lever, i. e., by moving the supporting bolt up or down in the slot 100 so as to lengthen or shorten the stroke of the pump. For convenience in adjustment, the outer face of the arm 98 may carry a suitable scale 118 relative to which the assembly 102—104—106 may be adjusted, and

which may be calibrated so as to indicate the rate of delivery of the treating fluid by the pump.

The apparatus of Figs. 3 and 4 is identical with that of Figs. 1 and 2 in a number of respects, but differs in that the drive of the pump is here effected by hydraulic means, viz., by an arrangement operating as a water motor in lieu of the electric motor drive of Fig. 1; and the arrangement in Figs. 3 and 4 is also such that the delivery of treating fluid is automatically varied in proportion to variations in the rate of flow through the main to which the treating fluid is supplied and from which the water motor may be driven.

The input and output lines and check valves for the diaphragm pump, and the diaphragm sealing and clamping means, are identical with those of Fig. 1, and hence are not shown in Fig. 3. The supporting frame 138 includes a recessed part 140 identically corresponding in function with the cup-shaped portion 40 of the frame 38 in Fig. 1. That is, portion 140 encloses a balancing chamber 154 on the right-hand side of diaphragm 20, the latter being seated against an annular flange 142 on member 140, as in the previously described apparatus. The water input port 156, and the input differential valve 158 (to which water is supplied from the main 159, Fig. 4), as well as the water output port 176, for the chamber 154, are likewise identical in function with the correspondingly numbered parts in the apparatus of Figs. 1 and 2. Likewise, the output port 176 leads to a cylindrical recess 178, for conducting water to the interior of the tube 172 through the apertures 182 in the latter. The tube 172 is secured at its left-hand end to the center of the diaphragm 20, and is longitudinally slidable through a sleeve 174 having appropriate packing 180 to prevent leakage of water from the recess 178.

A bracket 184 is associated with the outer end of tube 172, to provide a valve arrangement for the end of the tube, as in the case of the housing 84 in Fig. 1. This bracket or frame 184 is carried by a cross member 185, which is horizontally slidable, and supported, upon pins 186, 186, at the sides of the apparatus (see Fig. 4). A coil spring 187, disposed about the tube 172 intermediate frame 184 and sleeve 174, is adapted to urge frame 184 to the right as seen in Fig. 3.

The frame 184 carries on an inner face opposite the end of tube 172, a valve-closing disc 188, conveniently made of resilient material. The tube 172 is slidably supported by frame 184, and has its open end disposed for cooperation with the valve disc 188, so that if the frame 184 is displaced to the left from the position shown (relative to the tube 172), it will bring the disc 188 against the open end of tube 172, closing the latter, as in the case of the valve arrangement 88 in Fig. 1. Thereupon further displacement of the frame 184 to the left will serve to displace the tube 172, and associated parts, in the same direction. Displacement of the frame 184 relative to the tube 172, toward the right, will, of course, open the valve 188, but relative displacement of the parts in this direction is limited by a rearwardly facing shoulder 190, at the end of the tube 172, which engages an inner face 192 of the adjacent portion of bracket 184. Thus after bracket 184 has moved sufficiently to the right to open the valve 188, further displacement of bracket 184 to the right will effect the same displacement of tube 172 and associated parts.

The bracket 184 has a rightwardly extending portion (as seen in Fig. 3), terminating in a circular head 194 which is secured to the center of

a circular diaphragm 196, the latter being peripherally clamped intermediate a supporting rim 198, conveniently integral with the main frame 138, and a head 200 having a cup-shaped recess 202 in its inner face toward the diaphragm, to provide therewith a driving or hydraulic motor chamber, as presently to be explained.

The member 194 is clamped to the diaphragm 196 by a threaded bushing 204, into which there is in turn threaded a bushing 206 having its inner end adapted to provide a seat for a valve disc 208 (comprising a resilient washer backed by a suitable supporting disc, as shown); the valve disc 208 being carried by a pin 209 which is slidably supported in, and extends beyond the portion of bushing 204 that projects on the opposite side of the diaphragm from the motor chamber 202. The interior of bushing 204 is adapted to communicate with the interior of bushing 206, and through the same to the interior of the driving chamber, when the valve 208 is opened (valve pin 209 being then slid to the left), so that water may pass from the chamber 202 through the parts just described, and out to waste, through suitable ports 210 in the outer or left-hand portion of bushing 204.

Water is continuously supplied to chamber 202 through an input port 212, from the water main 159 (Fig. 4), and a differential valve 213, similar to that shown at 58 in Fig. 2, is conveniently provided in this supply line for like reason, i. e., to provide a substantially constant flow of water to the supplied chamber.

Journalled in a suitable bracket carried by the member 200, is a cam 214, which is adapted to be driven by shaft 216 from a water meter 218, of any suitable construction, interposed in the main 159 into which treating fluid is to be injected (see Fig. 4). A cam follower 220 (conveniently a roller) carried by a rocker arm generally designated 222 engages the surface of cam 214, the rocker arm being pivoted at 224 to a portion of the traveling frame 184. The rocker arm 222 is preferably made in two parts separately pivoted at the point 224, and respectively comprising an upper or cam-following part 226 and a lower part 228. The lower part, as shown in Fig. 3, has an upwardly projecting portion 230 which is adapted to engage the right-hand surface of the upper part 226, and upon such engagement (as shown) to prevent any movement of the lower part in a counterclockwise direction relative to the upper part. The upper part 226 carries a flat spring 232 which extends down and engages the lower portion 228 near its lower end, and normally keeps the parts in the position shown, with the portion 230 engaging part 226,—so that the assembly constitutes in effect a unitary member, and the two parts can only be moved relative to each other against the pressure of spring 232.

The lower end of the part 228 of the rocker arm is adapted to abut the outer or left-hand end of the pin 209 which is shiftable to close the valve 208, and it will now be seen that opening or closing of this valve may be controlled by relative displacement of the rocker arm part 228 and the diaphragm 196.

It will now be understood that the operation of the pumping portion of this apparatus is essentially the same as that of the corresponding apparatus in Fig. 1. Assuming that a charge of treating liquid has been drawn into the pumping chamber 123 from a supply tank 233 (Fig. 4), and that the driving mechanism (operated in the manner presently to be described) is commencing to move the

frame 184 to the left (see Fig. 3), the valve 188 is first closed, permitting water from the main to back up in the balancing chamber 154, and thereby setting up balancing force on the diaphragm 20. Further displacement of member or frame 184 to the left carries the diaphragm 20 correspondingly to the left, with the valve 188 closed, until the end of the pumping stroke is reached; the pumping stroke thus serving to expel a slug of treating liquid through outlet 36 (to main 159). Then, at the beginning of the return stroke, the frame 184 is first moved to the right relative to the tube 172, releasing the valve 188, and thereafter the frame 184 carries the entire assembly back to the right-hand position to complete the return stroke. The arrangement here shown differs from that in Fig. 1, however, in that the return stroke is accomplished by the force of spring 187, and in that, in consequence, spring 187 must be compressed during each pumping stroke.

With the apparatus of Fig. 3, the described reciprocation of frame 184 and its associated pumping instrumentalities, is achieved as follows: Assume that the parts are in the position shown, ready to commence a pumping stroke. The diaphragm 196 is in its right-hand position, the follower 220 is on a low spot of the cam 214, which is rotating in a counterclockwise direction as seen in Fig. 3, and the lower end of the rocker arm 222 is therefore in such abutment with the end of pin 209 as to close the valve 208 against its seat in the bushing 206. In consequence, with the outlet to the motor chamber 202 thus closed, the water flowing into the chamber commences to displace the diaphragm 196, and its attendant parts, to the left. This tends to displace the frame 184 correspondingly to the left, similarly tending to move the pivot 224 of the rocker arm 222 and thereby to rotate the latter in a clockwise direction about its pivot 224 (if the upper end of the arm is not moved by the cam), so as to release the lower end of the rocker arm from the pin 209, whereupon valve 208 may open and relieve the displacing force exerted by the water in the motor chamber.

The cam 214, however, is rotating and as its rise tends to move the upper end of the rocker arm 222 counterclockwise, the lower end of the arm correspondingly urges the valve 208 toward closed position, so as to prevent reduction of the diaphragm-displacing force exerted by the water in the chamber 202. In consequence, the diaphragm 196 exactly follows the rise of the cam; i. e., the diaphragm is displaced in exact proportion to the rate at which the cam, as it rotates, moves the follower 220 to the left. The diaphragm 196 cannot be displaced ahead of the cam, so to speak, since the resulting relative movement will rotate the rocker arm 222 clockwise, opening valve 208 and relieving the displacing force on the diaphragm, as previously explained.

It will thus be seen that displacement of the diaphragm 196 to the left, by reason of the force exerted by the water flowing into chamber 202, is exactly controlled by the speed of rotation of the cam 214, and in particular by the rate at which the follower 220 rides up to a high spot of the cam (whereby the rocker arm tends to close the valve 208 all of the time). Indeed, since the work to be done by the diaphragm 196 in moving the frame 184 and associated parts to the left to carry out a pumping stroke is relatively small (as explained above), the flow of water into chamber 202 from the main may always be greater, and is usually considerably greater, than necessary to

displace the diaphragm 196 at the rate prescribed by the cam 214. As a result, in normal operation of the device, the rocker arm 222 only keeps valve 208 sufficiently closed to provide the actually necessary displacing force on the diaphragm 196, so that during the entire pumping stroke, the valve may thus be automatically "cracked" or slightly opened, all the time, to the extent necessary to permit the excess water to flow from chamber 202. It will also now be appreciated that in normal operation during the pumping stroke the position of rocker arm 222 relative to the frame 184 does not change at any time, since the displacement of the upper end of the rocker arm by the cam 214 is exactly paralleled at the lower end of the arm by the resulting or following displacement of diaphragm 196, in the manner previously explained. In effect, moreover, the action of the cam and rocker arm is that of a governor or controlling element, since the only work required of these instrumentalities is the negligible amount necessary to keep the very small valve 208 (which is otherwise freely slidable) closed to the required extent, i. e., against a correspondingly very small proportion of the small force actually needed to be exerted by the liquid in chamber 202.

The diaphragm 196 thus moves to the left at a rate determined by the rotation and characteristics of cam 214, and correspondingly displaces the frame 184, and its attendant pumping instrumentalities, to carry out a pumping stroke of diaphragm 20 in the manner hereinabove described.

When the cam follower 220 reaches a high point of cam 214 and drops suddenly to a low point, travel of the diaphragm 196 to the left is interrupted (since the rocker arm 222 does not then keep the valve 208 closed), and the pumping stroke is thereby terminated. The valve 208 being then open, pressure is relieved in the motor or driving chamber 202 (the water merely passing through the bushings 206—204, and ports 210, to waste), and the spring 187 then carries the traveling frame 184 and its attendant pumping and driving instrumentalities all the way to the right, accomplishing the return stroke and drawing a fresh slug of treating fluid into chamber 123.

Thereafter, as soon as the rise of the cam begins to urge valve 208 closed (the cam here shown being adapted to do so at once, for maximum length of stroke), the cycle of pumping and return strokes is automatically repeated.

In the right-hand wall of chamber 202 there is disposed a member 234 mounted to slide horizontally on a pin or guide 236 and having projecting abutments to serve as a stop for the bushing 206 and in consequence as a stop to limit the travel to the right of the frame 184 and its attendant instrumentalities. The position of this stop may be adjusted, to the left or right, by rotation of a hand-wheel 238 secured to a shaft 240 which is threaded into the member 234. Suitable packing 242 is provided about the shaft 240, to prevent escape of water from the chamber 202, and the outer end of the shaft 240 is appropriately urged to the right (for maintaining it in place relative to the member 234 to be displaced by rotation of the shaft) by spring 244 intermediate the member 200 and a collar 246 which is secured to the shaft 240 and which may carry a pointer 248. It will now be understood that 70 upon rotative adjustment of the wheel 238, the stop 234 is moved to the left or right, thus decreasing or increasing the distance which the frame 184 (carrying the stop-engaging bushing 206) may cover in its travel to the right from the

leftward limit of its pumping stroke (as determined by cam 214), and thus shortening or lengthening the stroke of the pump; means are thus provided for adjusting the pump delivery by altering its length of stroke within the limiting positions dictated by the characteristics of the rotating cam 214. In the drawings, the parts are shown adjusted for maximum length of stroke; adjustment of stop 234 to the left will shorten the stroke and delay the time at which the cam begins to effect leftward displacement of diaphragm 196 after the completion of a return stroke.

A suitable dial 250 may be provided for the pointer 248, and appropriately calibrated for the variations in pump delivery corresponding to various positions of the stop 234 as adjusted by the wheel 238.

It may here be noted that the cam 214, in order to exercise its described control, need exert very little pressure upon the follower 220. Hence a properly flow-responsive water meter (which in the ordinary type of construction employing rotating vanes or buckets, is a device not adapted to develop any substantial amount of power) may be employed to rotate the cam 214, which directly regulates the speed and frequency of the pumping strokes of the apparatus, as explained.

It will now be seen that in view of the control exerted by cam 214 as driven by a water meter or like device which has its speed of rotation necessarily proportional to the flow of water in the main, the delivery of treating liquid by the pumping diaphragm 20, over a given period of time, will be directly proportional to the flow in the main, i. e., will vary in direct proportion to variation in that flow. The amount of treating liquid which is delivered at each stroke of the pump, and thus the rate of delivery over a given period of time, is manually controllable by operation or adjustment of the wheel 238, which shortens or increases the pump stroke. It will also be noted that the cam 214 is preferably so cut as to have a gradual rise to each high spot and a sudden drop therefrom, thus affording a long pumping or delivery stroke and permitting a correspondingly rapid return stroke, and in consequence providing a delivery of treating liquid which very closely approximates a continuous flow,—except in so far as the beginning of the pumping stroke may be delayed in time by adjustment of the wheel 238 so as to shorten the stroke more or less from the maximum limit ordinarily corresponding to the low points of cam 214.

If for any reason the supply of water to chamber 202 should be interrupted, while cam 214 is being rotated by the water meter, the hinged construction of the rocker arm 222 will serve to prevent any damage to the delicate parts of the water meter. The upper part 226 of the rocker arm will then merely be flipped counterclockwise relative to the lower part 228 (against the spring 232), each time the rise of the cam carries the follower 220 to the left. The hinged arrangement of the rocker arm will also avoid damage to the cam or water meter if at any other time, whether the cam is rotating or not, such pressure is exerted on the rocker arm as might otherwise cause the follower 220 to exert excessive force on the cam. It will be understood, of course, that the spring 232 has enough strength to prevent mutual displacement of the rocker arm parts 226, 228, during the intended normal operation of the apparatus as previously described, i. e., normally, there is relatively little force exerted on or by the rocker arm and it acts as a single member.

The apparatus shown in Fig. 3, therefore, provides a simple and convenient hydraulically operated feeding apparatus which is adapted to deliver a flow of treating liquid that automatically varies in direct proportion to variations in the flow of liquid in the main. The power required of the hydraulic driving means is very small, and as in the case of Fig. 1, the diaphragm-balancing means may provide at least the greater part of the liquid-expelling force on the diaphragm 20.

Like the apparatus of Fig. 3, the form of device shown in Fig. 5 is provided with a pumping chamber 123, pump diaphragm 20, inlet and outlet lines for treating liquid, and diaphragm aligning means, identical with those in Fig. 1; and it will be understood that the portion of the apparatus which would extend to the left of the broken line in Fig. 5 is the same as in Fig. 1.

Similarly, the apparatus of Fig. 5 is provided with a balancing chamber 154, traveling frame 184, valve 188, pump-operating tube 172, spring 187, and associated parts constructed and functioning in exactly the same manner as corresponding parts in Fig. 3. Likewise as in the case of Fig. 3, the traveling frame 184 here has a rightwardly-extending portion terminating in a head 194 bolted to the central portion of a driving diaphragm 196, which encloses a driving or motor chamber 302 provided by a corresponding cup-shaped recess in the housing member or frame 304. The chamber 302 has a water inlet port 306, and a water outlet port 308, it being understood that in this form of the apparatus the assembly comprising the diaphragm 196 and its associated head 194 and securing parts is imperforate, there being no outlet for the water through the diaphragm as in the case of the apparatus in Fig. 3.

The outer end of the water outlet 308 is adapted to provide a seat for a valve disc 310 of resilient material carried by a lever 312 which is pivoted at its lower end, at 313, to the frame 304, and which may rock to the right, to open the valve thus provided, or to the left to close the valve disc 310 against the port 308 and prevent escape of water from the chamber 302. Referring also to Fig. 6, the upper end of the lever 312 is forked, and the ends of the fork are adapted to abut (on the other side of the member 312 from the valve disc 310) against an annular plate 314 carried by a diaphragm 316 which encloses a control chamber 318 recessed in the member 320; the diaphragm 316 being peripherally secured between the member 320 and a cooperating annular portion of the frame 304.

The diaphragm 316 is pierced by a bushing or tubular member 322, adapted for passage of water from the chamber 318 to the other side of the diaphragm, and thence to waste through outlet 323. The outer or left-hand end of the bushing 322 is adapted to provide a seat for a resilient valve disc 324 carried by a pin 326 which is slidably mounted and aligned in a transverse block 327 in the bushing. As shown in Fig. 6, this block does not interrupt flow of water through the bushing 322 when the valve (constituted by disc 324 and the end of the bushing) is opened, and the valve pin 326 is freely slidable in the block, to permit opening or closing of the valve. The outer surface of the valve disc 324 is provided with a suitable metal face and the assembly is adapted to be engaged on that side by the end of a controlling rod 328. A spring 330 interposed between the annular member 314 carried by the diaphragm and the frame 304, normally urges the diaphragm 316 to its right hand position shown, so that the

member 312 may then rock back, with its upper forked extremity resting upon the annular member 314, and thus permit the valve 310 to open. The control rod 328 is supported and freely horizontally slidable in a bushing 332 at the end of a tube 334 which is secured to a leftwardly extending portion of the frame 304 as shown in Fig. 5.

The outer left hand end of the rod 328 has a reduced portion 336 so as to provide a leftwardly-facing shoulder 338 which is adapted to abut a washer 340, the latter being freely slidable upon or relative to the reduced portion of the rod. The left hand extremity of the reduced portion of the rod 336 is freely slidable in, and supported by, a bushing 342 carried by an upwardly extending support 344 which is secured to, and displaceable with, the pump-operating frame 184. The bushing 342 is seated partly into a cylindrical recess 346 formed in member 344 and surrounding the operating rod 328—336, and within this recess there is disposed a spring 348 which is seated against the inner face of the bushing 342 and is adapted to urge the washer 340 to the right against the shoulder 338 of the rod 328, or against an inwardly extending shoulder 350 near the right hand end of the recess, depending, as will presently be explained, upon the position of the assembly 184—344, relative to the stationary portion of the apparatus.

Inlet of water to the control chamber 318 is provided through a port 352, conveniently connected to the main through a reducing valve of suitable known construction (not shown), so as to reduce the pressure to no more than that needed for proper rapid action of the control chamber as hereinafter explained, and so that waste of water is avoided, both directly when valve 324 is intended to be open, and by bleeding through this valve at other times.

It will be understood that port 156 is connected with the water main through a suitable differential valve as previously explained in connection with the supply of water to the balancing chamber in Figs. 1 and 3. It will also be understood that the operation of the pumping and diaphragm-balancing instrumentalities, upon reciprocation of frame 184, is the same in the apparatus here shown as in the case of Fig. 3, at the beginning of each pumping stroke valve 188 is closed so as to build up balancing force in the chamber 154, and at the end of each stroke the valve is permitted to open by preliminary movement of the frame 184 to the right, so that as the spring 187 thereafter carries the entire assembly to the right, there is no balancing force exerted by chamber 154 and a rapid return stroke is achieved. The operation of the hydraulic motor of this form of apparatus, whereby the frame 184 is positively driven to the left to provide the pumping strokes, will now be described.

It may be assumed that the pumping apparatus has just completed a return stroke to the right, and the parts are consequently in the position shown in Fig. 5, with the valve 310 open and no displacing force being exerted upon diaphragm 196. At this point of operation, the rightward travel of members 184 and 344 has brought the washer 340 into such engagement with the shoulder 338 of rod 328 that the right hand end of the rod is pushed against the valve disc 324, closing the valve as the shoulder 350 tends to move ahead, and clear, of washer 340. Thereupon the water which is flowing into the small control chamber 318 (and which has previously been escaping through bushing 322) immediately exerts displacing force upon the diaphragm 316 and moves the

latter to the left. This movement of the diaphragm 316, against spring 330,—moving rod 328 to the left against spring 348,—is preferably so rapid as to be almost instantaneous. The effect of so displacing the diaphragm 316, and, in consequence, its ring 314, rocks the arm 312 to the left, closing valve 310 and keeping it closed; the rapid movement of the diaphragm thus providing a snap closing action for the valve 310.

With the valve 310 closed the water flowing into the motor chamber 302 immediately backs up and begins to displace the diaphragm 196 to the left. The left hand end of rod 328—336, and the associated parts carried by member 344, are now in the position shown in Fig. 7, and during the entire pumping stroke which is now proceeding, the spring 348, acting through washer 340 upon the shoulder 338 of the rod 328, keeps the valve 324 closed, so as to maintain the diaphragm 316 in its displaced position, and thereby to keep the valve 310 closed.

The water now flowing into chamber 302 thus continues to displace to the left the diaphragm 196, and the attendant pumping instrumentalities operated by frame 184, for the pumping stroke. At the same time, the member 344 is moving to the left relative to the rod 328, and eventually the washer 340 (urged to the right by the spring 348) comes into engagement with shoulder 350. The pressure exerted upon the rod 328 is thereupon immediately released, and since the closing pressure on valve 324 is consequently and by the same token released, this valve opens itself, and the diaphragm 316 immediately jumps back to its original position (shown in Fig. 5), since no displacing force is now exerted upon it. Likewise the valve 310 opens itself under the pressure of the water in chamber 302, since member 312 is now free to rock to its original right hand position shown in Fig. 5; the force on diaphragm 196 is thus relieved and the water flowing into chamber 302 passes on through ports 308 and 323, to waste.

The force of spring 187, compressed during the pumping stroke, now carries the pump-operating instrumentalities to the right for the return stroke, as in the case of the apparatus shown in Fig. 3. At the same time, the rod 328 is now free and loose, because of the space left in front of it by the return of diaphragm 316, and remains free and loose during the entire return stroke. The positions of the left hand end of the rod and of the parts carried by member 344, just after the commencement of the return stroke, are shown in Fig. 8.

Eventually, however, the washer 340, held by shoulder 350 during the return stroke, again engages the shoulder 338 of the rod 328 and pushes the latter against the valve disc 324. This constitutes the end of the return stroke, since the parts now repeat the operations previously described, i. e., with valve 324 closed, diaphragm 316 jumps to the left, valve 310 is closed, and pressure begins to build up in chamber 302, commencing another pumping stroke. The cycle of pumping operations thereupon proceeds as before.

It will be seen that the arrangement shown in Figs. 5 to 8 inclusive provides a simple and convenient hydraulically operated liquid feeding apparatus, wherein the control of water supply to the driving chamber 302 is automatically positively exercised at the desired points in the travel of frame 184, to initiate the pumping and return strokes respectively, i. e., the control in each direction being exercised in response to arrival of the

member 184 at the position at which the diaphragm 316, rod 328 and associated instrumentalities are adapted to effect such control. It will be noted, moreover, that as in the case of Fig. 3, the apparatus of Fig. 5 is efficiently adapted, because of the relatively very rapid return or suction stroke effected by the spring 187, to approximate closely a continuous feed of treating liquid into the main.

10 A particularly convenient way of controlling the delivery of the pump in this form of the apparatus is by adjustment of the differential valve which may be provided in the supply line between the main and the motor chamber inlet 15 306. It will be understood that such valve, which is adapted to provide a substantially constant flow as in the case of valve 58 (Fig. 2), should preferably have a wide range of adjustment, so that the rate of flow into the motor chamber 20 may be correspondingly adjusted over a wide range and substantial variation of pump delivery obtained as desired. Thus upon increase or decrease of the flow into the motor chamber 302, there will be respectively a decrease or increase 25 in the duration of the pumping stroke, to expel the same unchanged amount of treating liquid, and in consequence, over any period of time, there will be a corresponding increase or decrease of the actual rate of delivery of treating liquid.

30 If desired, the apparatus of Fig. 5 may in many cases be made to deliver treating liquid automatically in proportion to the flow in the main, by creating a minor flow from the latter (for example, by means of the well known arrangement, 35 for setting up a proportional minor flow, which includes a Venturi tube in the main) and by supplying such minor flow to the inlet port 306 of the motor chamber 302, in lieu of the manually adjusted supply just described. Since the pump 40 delivery is adapted to vary automatically in proportion to variations in flow to the motor chamber (as just explained), and the minor flow varies in proportion to variations in the flow of the main, the feed of treating fluid, over a given period of time, will thus automatically vary in proportion to the flow variations of the main. It 45 will be understood that in most cases, since the pressure necessary to operate the hydraulic motor is much less than that to be developed by the pump (because of the balancing chamber arrangement), the pressure in the minor flow will be ample for operation of the motor.

Fig. 9 illustrates a modified controlling arrangement for the diaphragm-balancing chamber. The pumping chamber 23, diaphragm 20 55 and balancing chamber 454 are in general similar to those shown in the other figures and are adapted to operate in the same way. The diaphragm 20 is reciprocated by a rod 500 adapted to slide horizontally through a suitably packed 60 bushing 502, and is pivoted at its outer or right hand end to an intermediate point of a lever 504. The upper end of this lever 504 is pivoted to a connecting member 506, which may be driven by a reciprocating element such as the rod 86 in Fig. 1 or the frame 184 in Figs. 3 and 5. The lower 65 end of lever 504 is pivoted to a rod 508 carrying a pair of valve cones 510, 512, adapted to seat in corresponding orifices, and to be alternately closed as the rod 508 is reciprocated to the left or right. The valve 510 is interposed in the water 70 input line 514 for the balancing chamber, and the valve 512 is adapted to control an output port 516 through which water from the balancing

75 chamber may flow to waste. A port or conduit

518 connects the interior of the balancing chamber 454 with both of these valves 510, 512, as shown.

Assuming that the parts are in the position shown, and that the members 500—506 have just completed a return or suction stroke to the right, displacement of member 506 to the left, for the commencement of a pumping stroke, will first rock lever 504 about its central pivot. So rocked, the lever 504 shifts the valve rod 508 to the left, 1 closing valve 512 (previously opened) and opening valve 510 (previously closed). Thereupon water is admitted through line 514, valve 510, and port 518 to the balancing chamber 454, and immediately builds up balancing force on the diaphragm 20, since the output from the chamber, i. e., through valve 512, is now closed. At the same time, since the cone of valve 512 is now 2 seated against the bushing 516, further drive of the member 506 to the left can only rock lever 504 counterclockwise about its lower pivot, thus displacing member 500 (and in consequence diaphragm 20) to the left for a pumping stroke.

Upon the completion of the pumping stroke, and when member 506 begins to return to the right, the rod 508 is again reciprocated, closing valve 510 and opening valve 512, and thereafter, since the cone of valve 510 is seated against its cooperating bushing, further displacement of member 506 to the right serves to displace likewise the rod 500 and the diaphragm 20. During this return stroke, as will now be seen, no balancing force is exerted on the diaphragm by water in the chamber 454, since the port 518 is connected to the outlet through the valve 512 (now open). At the end of the return stroke, the cycle is repeated in the same manner.

The arrangement shown in Fig. 9 thus affords a positive and effective valve control for the diaphragm-balancing chamber, and serves to cut off the flow of water from the main during the return stroke of the pump, thus minimizing loss of water and particularly avoiding such waste of water as would otherwise result from a continuing flow into and through the balancing chamber at times when load-balancing force is not required.

It will now be appreciated that the present invention, as illustrated by the various embodiments thereof hereinabove described, well attains its stated objects, and affords liquid feeding apparatus which is especially rugged, dependable long-lived and so simple to use that unskilled persons may readily supervise its operation and make any necessary adjustment of its rate of delivery. The efficiency of the apparatus is high throughout, and parts which have a rotating or other necessarily stiff sliding fit and upon which pumping accuracy depends may be, as they are in the described embodiments, satisfactorily eliminated; for example, all of the described control valves in the forms shown are in effect friction-free, and are generally, and to like advantage, self-opening upon release of the associated control element in each instance. The arrangements are also such as to attain a high degree of efficiency, accuracy and reliability with a diaphragm pump in which only a minimum of working parts need be exposed to the treating liquid, and which is in that and other respects so constructed that all elements exposed to such liquid may, if desired, be readily and effectively made of a material resistant to attack by the liquid.

It is to be noted that while the apparatus spe-

ifically illustrated has been described as employing a balancing force on the diaphragm opposite to the pumping surface, which is substantially equal to the force required for pumping, but is in fact slightly less than the latter, it is not essential that it be less; the balancing force may be either greater or less than that required for pumping, depending, for example, upon the specific arrangement of the apparatus. For instance, if the balancing chamber is connected to a separate liquid supply of higher pressure than that of the main into which treating liquid is to be fed, or if an orifice is used in the main to produce a friction loss and the balancing water is taken at a point ahead of the orifice and the treating liquid injected below the orifice, the balancing force may exceed that needed for pumping and no liquid-expelling force may be required of the diaphragm driving or reciprocating instrumentalities which serve to control the balancing chamber valve or the speed, frequency or length of pumping strokes. Of course it will be understood that in some cases satisfactory results may be had when the balancing force is very considerably less than the required pumping force; and also when it is considerably greater.

In accordance with the provisions of the patent statutes, I have herein described the principle of operation of my invention, together with the apparatus which I now consider to represent the best embodiments thereof, but I desire to have it understood that the apparatus disclosed is only illustrative and that the invention can be carried out by other means. Also, while it is designed to use the various features and elements in the combinations and relations described, some of these may be altered and others omitted and some of the features of each modification may be embodied in the others without interfering with the more general results outlined, and the invention extends to such use within the scope of the appended claims.

What I claim is:

1. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a pumping diaphragm, a pumping chamber on one side thereof, a balancing chamber on the other side thereof, a tubular member connected to the diaphragm for displacing the same and adapted to conduct liquid from the balancing chamber, means adapted to conduct liquid to said balancing chamber from the body of liquid under pressure, driving means and means operated thereby and shiftably associated with said tubular member for displacing the same in either direction, said last mentioned means including a valve element shiftable therewith relative to the tubular member for closing the latter against escape of liquid therefrom, whereby upon operation of said last mentioned means to displace the member and diaphragm in pumping direction of the latter, balancing force is exerted by the liquid in the balancing chamber upon the diaphragm.

2. In combination, a diaphragm pump, diaphragm-reciprocating driving means therefor having control means for effecting variation of the quantity of liquid delivered by each delivery stroke of the pump, diaphragm-balancing means for the pump, and means controlled automatically and independently of the delivery-varying control means of the driving means, for bringing the balancing means into operation throughout each delivery stroke.

3. In combination, a pump diaphragm, a pumping chamber on one side thereof, a bal-

ancing chamber on the other side thereof, a conduit member opening into the balancing chamber and secured to the diaphragm at a movable portion of the latter for reciprocating the same, means for supplying liquid to the balancing chamber from a source of liquid under pressure, and a closure member shiftable relative to the conduit and against an end of the latter, for controlling passage of liquid intermediate the chamber and an external point.

4. In combination, a pump diaphragm adapted to be supported at its periphery, and means for reducing strain in the plane of the diaphragm during pumping action thereof, said means including a member adapted to abut peripherally one side of the diaphragm and to enclose a balancing chamber on said side thereof, means for admitting liquid under pressure to said chamber, and means including a self-aligning clamping member for exerting clamping force against the other side of the diaphragm, and uniformly throughout the peripheral portion thereof, to secure the diaphragm peripherally against the first mentioned member.

5. In liquid feeding apparatus, in combination, a pump diaphragm, means for controlling reciprocation of the diaphragm to effect adjustment of its length of stroke, means for admitting liquid under pressure for hydraulically balancing the diaphragm, and means controlled automatically and independently of said adjustment of the first-mentioned means for initiating operation of the balancing means at the beginning of each pumping stroke.

6. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a pump diaphragm, means including diaphragm-balancing and driving means adapted to receive liquid from the body thereof under pressure, for displacing the diaphragm in pumping direction, and a spring disposed to be compressed by operation of said driving means, for displacing the diaphragm in return direction.

7. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a pump diaphragm, a hydraulic driving diaphragm adapted to effect reciprocation of the pump diaphragm, means including a control diaphragm for positively intermittently controlling the displacement of the driving diaphragm, to cause the latter to intermittently displace the pump diaphragm, and means whereby feed of liquid by the pump diaphragm is effected by the liquid under pressure, said last-mentioned means including a balancing chamber for the pump diaphragm and operating chambers for the driving and control diaphragms, each of said chambers being adapted to be supplied with liquid from said body thereof under pressure, for exerting displacing force on the corresponding diaphragm.

8. In combination, a diaphragm pump having a diaphragm and a member associated therewith for operating the diaphragm, said pump including liquid pumping and hydraulic balancing chambers for the diaphragm, driving means for said member settable for selectively adjusting the length of stroke of the member, valve means for effecting supply of balancing liquid to said balancing chamber during pumping strokes of the member, and means controlled in accordance with operation of said member, for operating said valve means at the end of each stroke of the member irrespective of the length of the stroke.

9. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a pump

diaphragm and hydraulically operated means adapted to be supplied from said body of liquid under pressure, for exerting force on the diaphragm substantially throughout one surface thereof, said hydraulically operated means including hydraulic driving means for causing the diaphragm to pump and means for hydraulically exerting balancing force on the diaphragm to reduce the pumping load.

10. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a diaphragm having a pumping surface and adapted to pump liquid from an external supply to said body of liquid, and means for reciprocating the diaphragm, including driving means for exerting force on the diaphragm during pumping strokes, and means admitting liquid under pressure from said body thereof to the opposite diaphragm surface throughout each pumping stroke, for reducing the pumping load on the driving means.

11. Apparatus for feeding liquid to a body of liquid under pressure, comprising a pump diaphragm having an associated pumping chamber for handling the liquid to be fed, and means for reciprocating the diaphragm, including driving means mechanically engaging the diaphragm for exerting force thereon in pumping direction, a balancing chamber opening on the diaphragm, and means for supplying liquid under pressure from said body of same to said balancing chamber, to supplement the pumping force of said driving means during pumping strokes of the diaphragm, and for relieving said chamber of the pressure of said liquid during return strokes of the diaphragm.

12. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a diaphragm, a pumping chamber on one side of the diaphragm, a balancing chamber on the other side of the diaphragm, means for reciprocating the diaphragm for pumping action thereof, said balancing chamber being adapted to receive liquid from the body of same under pressure, and means including a valve controlled in accordance with the operation of said last-mentioned means, for rendering the last-mentioned liquid effective to exert pressure in to the balancing chamber during the pumping stroke of the diaphragm and for relieving said balancing chamber from the pressure of said liquid during the return stroke of the diaphragm.

13. The apparatus of claim 12, which includes means associated with the reciprocating means for preventing displacement of the valve while said reciprocating means is acting to displace the diaphragm in either direction.

14. In combination, a pump diaphragm having a pumping chamber, and means for reciprocating the diaphragm, comprising driving means, hydraulic balancing means for the diaphragm, adapted to be supplied with liquid under pressure, and control means including a liquid-controlling device adapted to render the supplied liquid operatively effective in the hydraulic balancing means, said driving means including means brought into play only upon operation of said control means, for exerting force on the diaphragm in pumping direction.

15. In combination, a diaphragm having a pumping chamber on one side and a balancing chamber on the other side, driving means for reciprocating the diaphragm, valve means shiftable to render a supply of diaphragm-displacing liquid effective to exert pressure in the balancing chamber, and to relieve said balancing chamber

from the pressure of said liquid and associated valve-shifting control means preventing the driving means from changing the direction of diaphragm displacement until the valve means has been shifted from one position to another.

16. In combination, a diaphragm pump, hydraulic means including diaphragm-balancing means and driving means both having connections for receiving liquid under pressure from a common source thereof, for displacing the diaphragm in pumping direction, and pumping stroke control means including valve means for rendering the liquid effective to exert pressure in the diaphragm-balancing means, for initiating diaphragm displacement in pumping direction only upon operation of said valve means.

17. In apparatus for feeding liquid to a body of liquid under pressure, in combination, a pump diaphragm, and means for reciprocating the same, comprising diaphragm-balancing and driving means adapted to receive liquid from the body thereof under pressure, for displacing the diaphragm in pumping direction, and control means including means controlling the operating effectiveness of a supply of liquid to the diaphragm-balancing means, for causing the reciprocating means to initiate pumping and return strokes of the diaphragm at successive times and only upon initiation and interruption, respectively, of operating effectiveness of the supply of liquid to the diaphragm-balancing means at each time.

18. In liquid feeding apparatus, in combination, a diaphragm having pumping and balancing chambers on opposite sides thereof, said balancing chamber having an outlet, means for supplying liquid under pressure to the balancing chamber, including a lifting valve adapted to be closed against the outlet to cause the liquid to build up pressure in the balancing chamber, and driving means for the diaphragm having associated means for operating the valve to close and open the same in accordance with the position of the diaphragm, whereby the liquid supplied to the balancing chamber reduces strains in the diaphragm during pumping strokes of the latter.

19. In liquid feeding apparatus, in combination, a pump diaphragm, hydraulic balancing means therefor adapted to be supplied with liquid and having an outlet, means for reciprocating the diaphragm, and means controlled in accordance with operation of said reciprocating means for controlling operation of the hydraulic balancing means, said last-mentioned means comprising a lifting valve adapted to be closed against the aforesaid outlet to render the supplied liquid effective in the balancing means, and means for alternately closing and opening said valve intermediate successive displacements of the diaphragm in successively opposite directions by the reciprocating means.

20. In apparatus for feeding liquid to a body of liquid under pressure, in combination, means including a pump diaphragm and an associated pump chamber, for delivering liquid to the body of liquid under pressure upon reciprocation of the diaphragm, diaphragm driving means mechanically engaging the diaphragm and adapted to be hydraulically actuated by liquid from the body thereof under pressure, and hydraulic balancing means for causing liquid from said body thereof under pressure, to exert balancing force on the diaphragm to reduce the pumping load on the driving means.

CERTIFICATE OF CORRECTION.

Patent No. 2,229,038.

January 21, 1941.

GEORGE MARTIN BOOTH.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 3, second column, line 44, for "resutling" read --resulting--; page 9, second column, line 14-15, claim 4, for "inclinding" read --including--; line 26, claim 5, for "diagram" read --diaphragm--; page 10, first column, line 47, claim 12, for "in to the" read --in the--; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 18th day of March, A. D. 1941.

(Seal)

Henry Van Arsdale,
Acting Commissioner of Patents.