

E. A. VON SEGGERN
PUMP FOR FLUID AND SEMI-FLUID MATERIAL
SUCH AS PLASTER AND THE LIKE

8 Sheets-Sheet 1

Filed Oct. 5, 1953

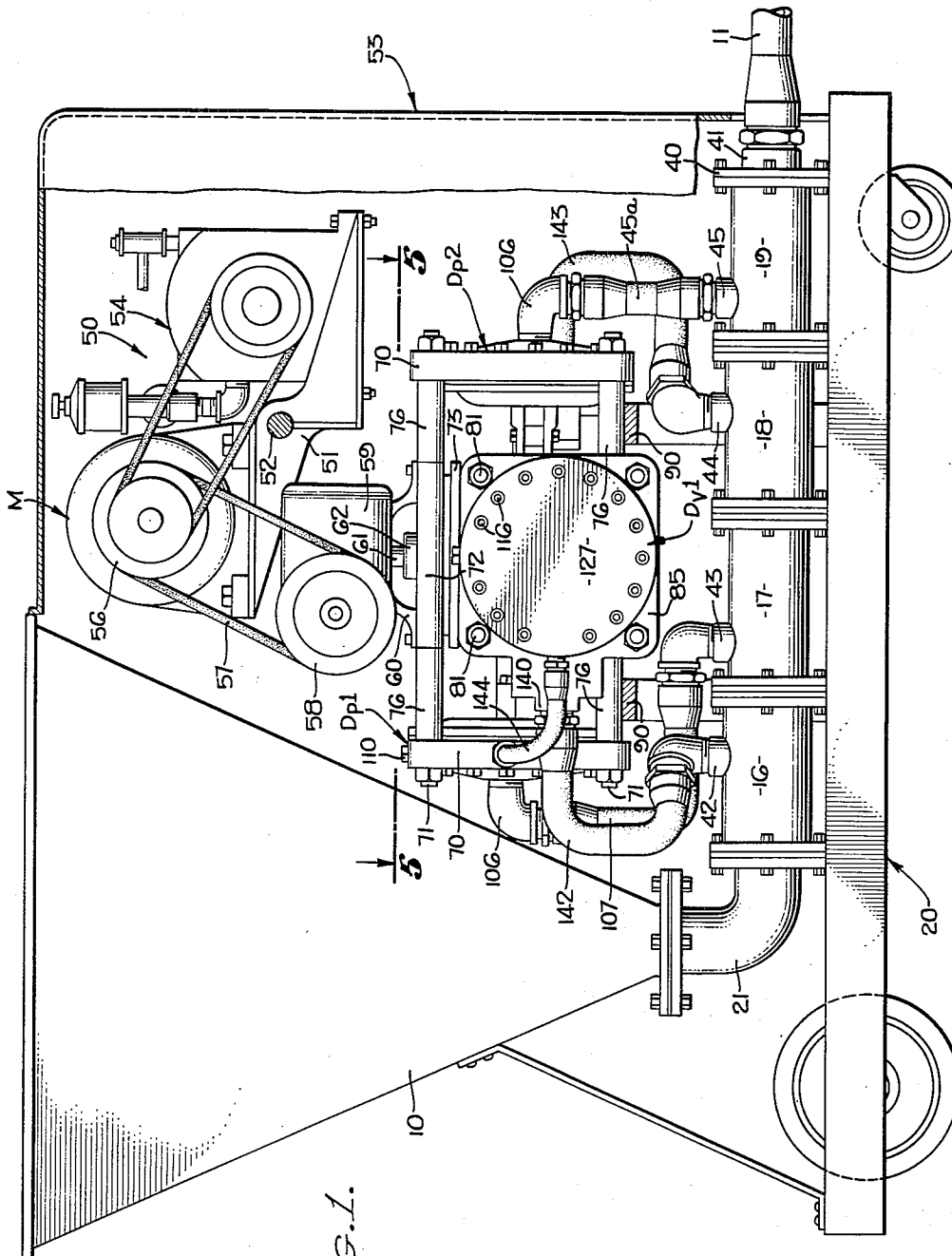


FIG. 1.

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Aug. 28, 1956

E. A. VON SEGGERN
PUMP FOR FLUID AND SEMI-FLUID MATERIAL
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2,760,436

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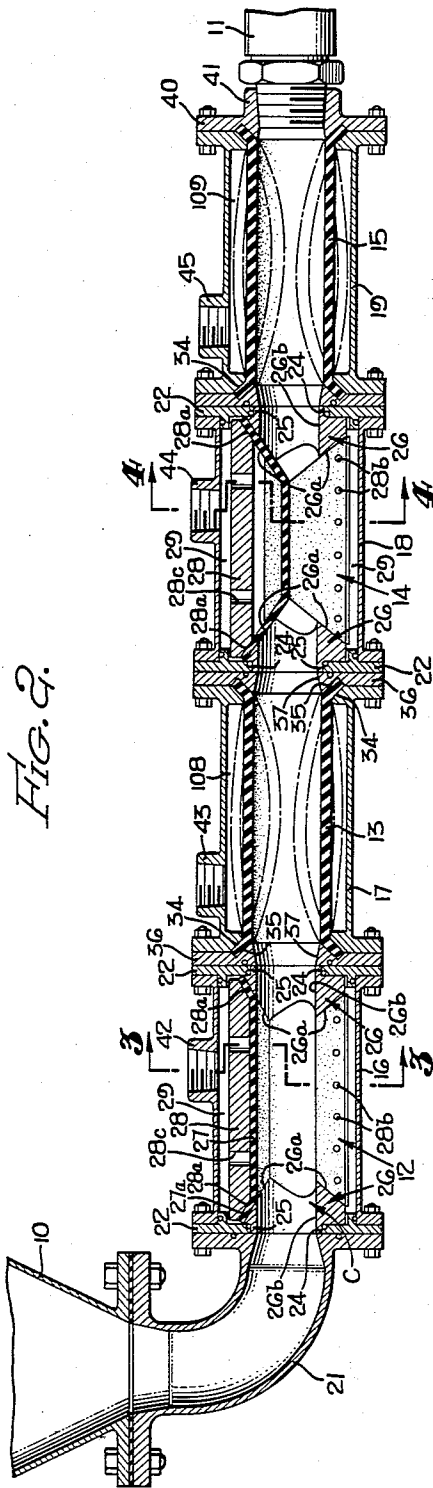


FIG. 4a.

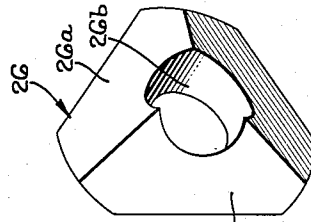


FIG. 4.

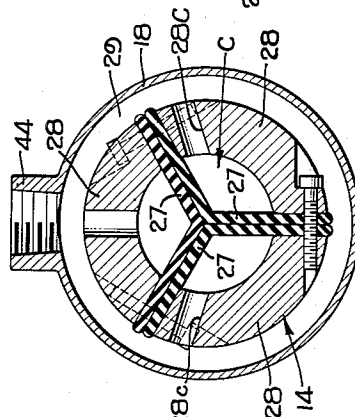
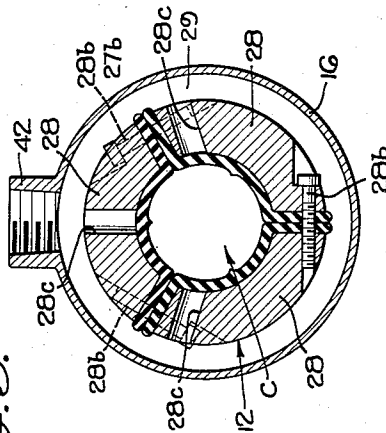


FIG. 3.



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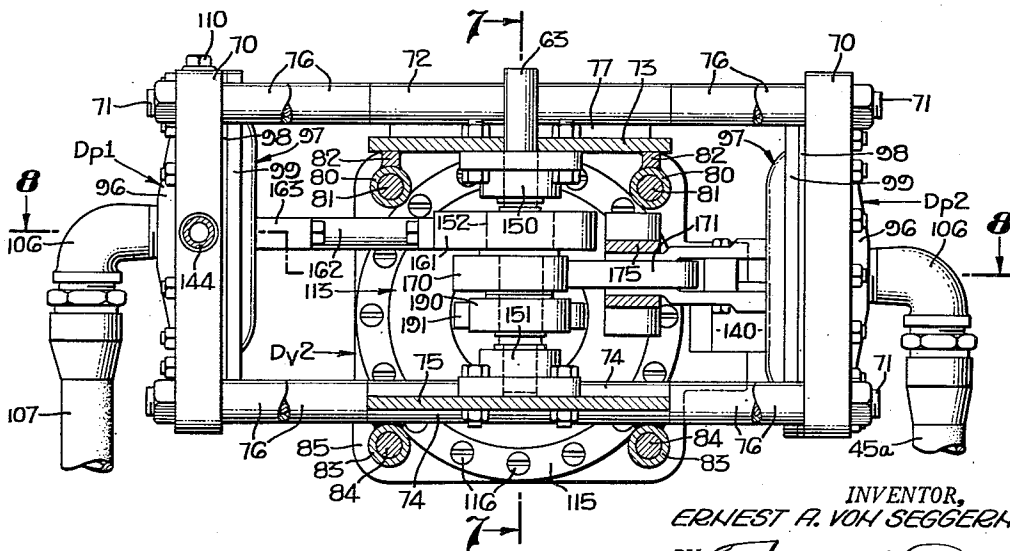
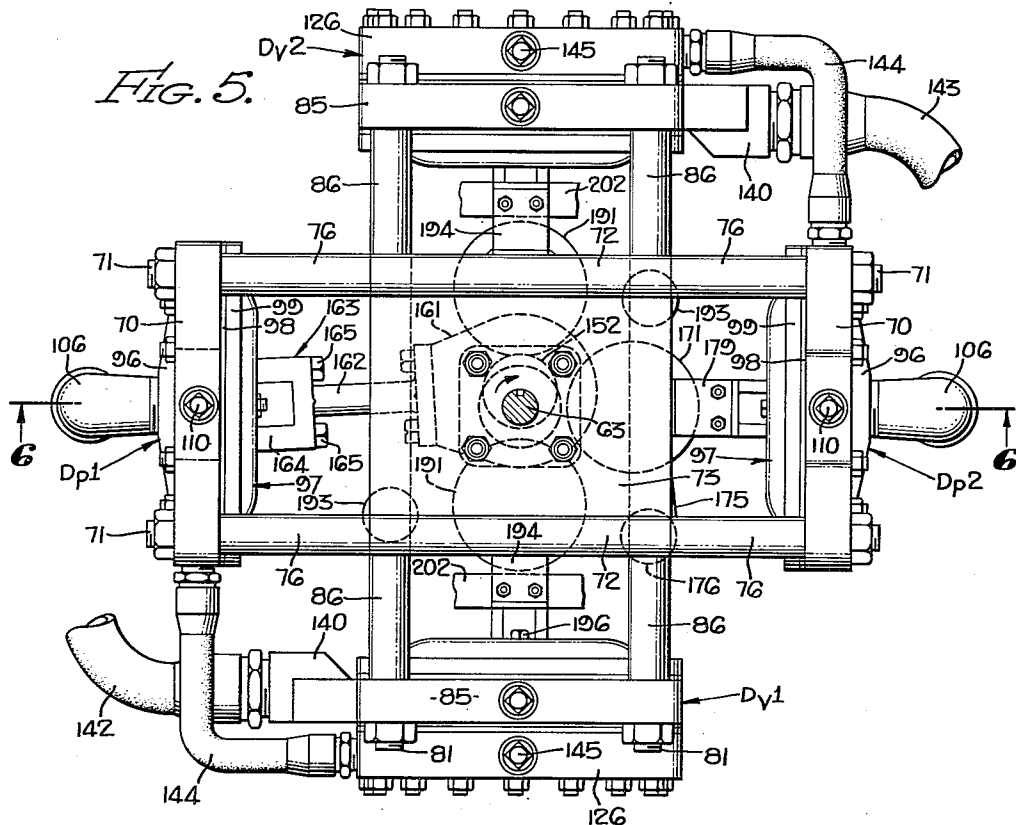
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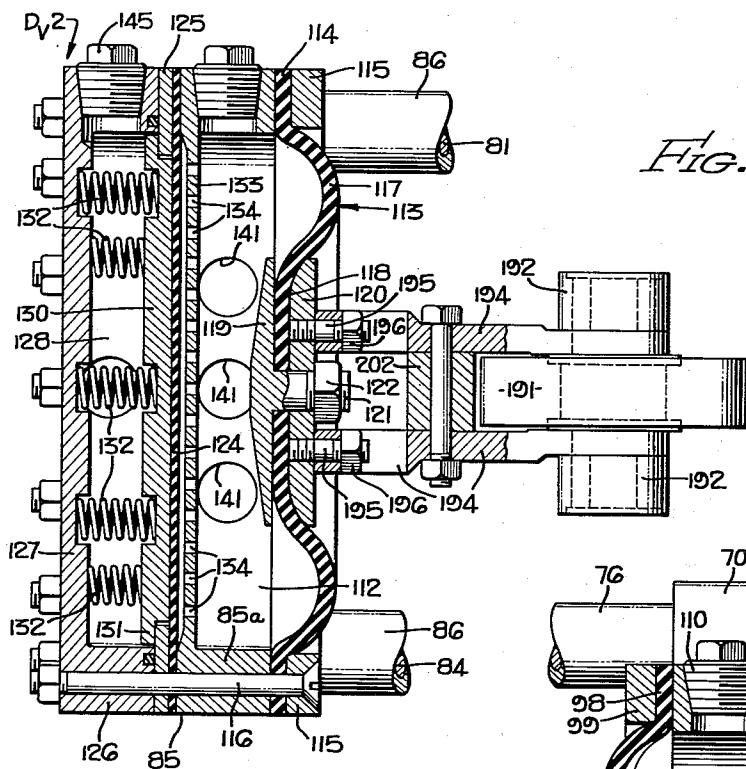


Fig. 9.

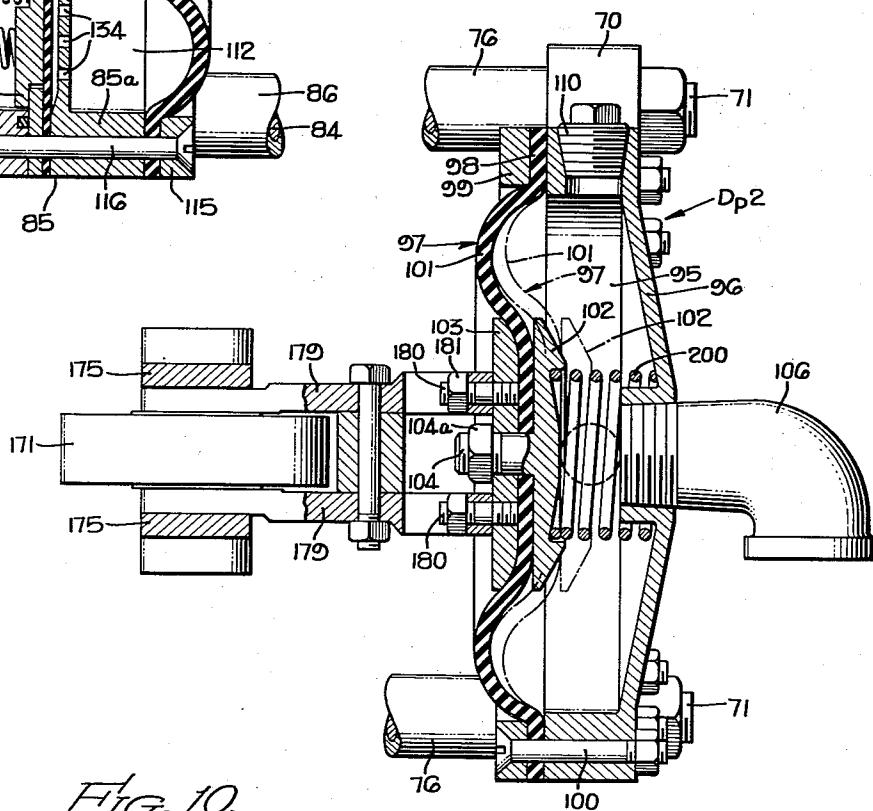


Fig. 10.

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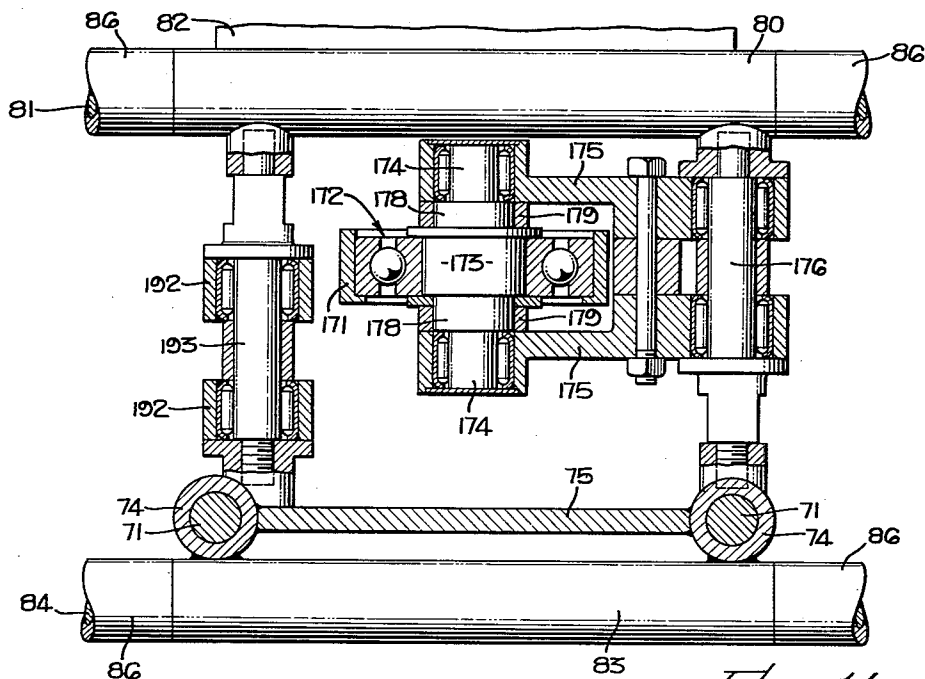


Fig. 11.

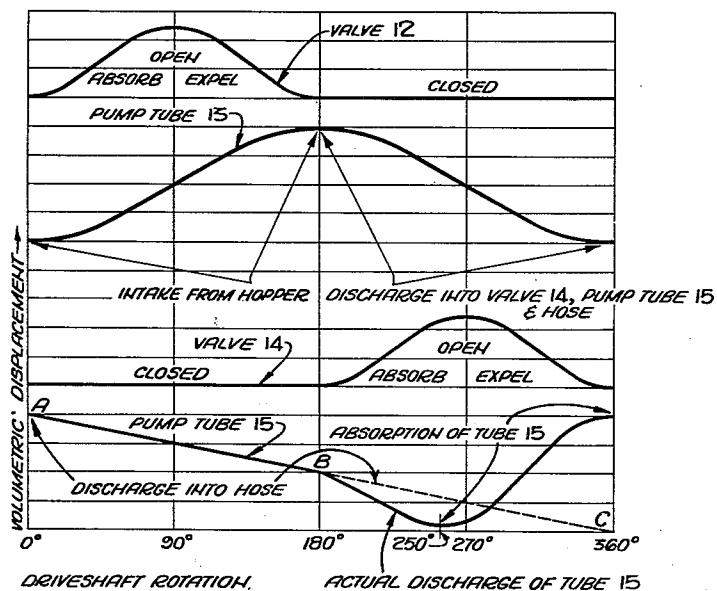


Fig. 15.

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FIG. 12.

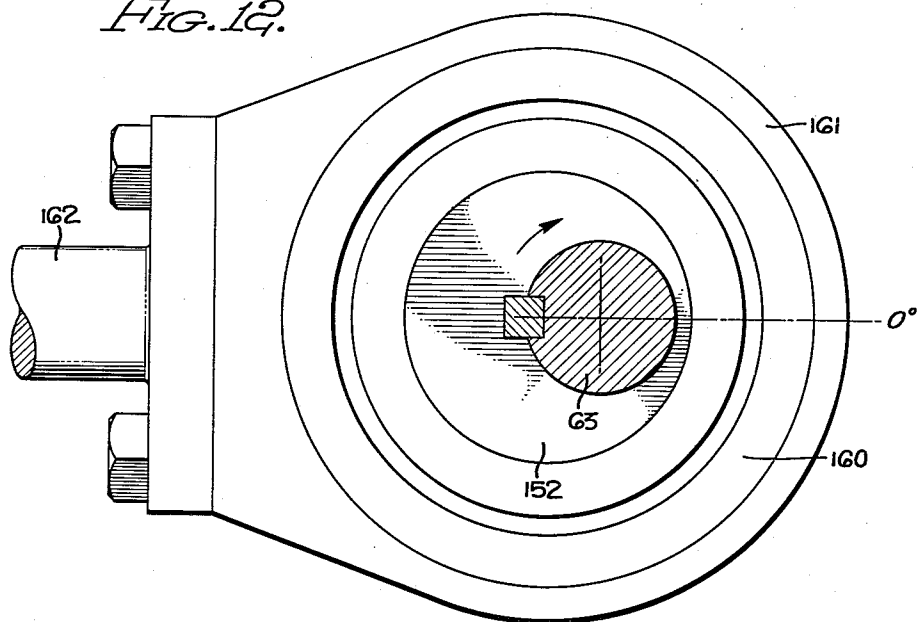


FIG. 13.

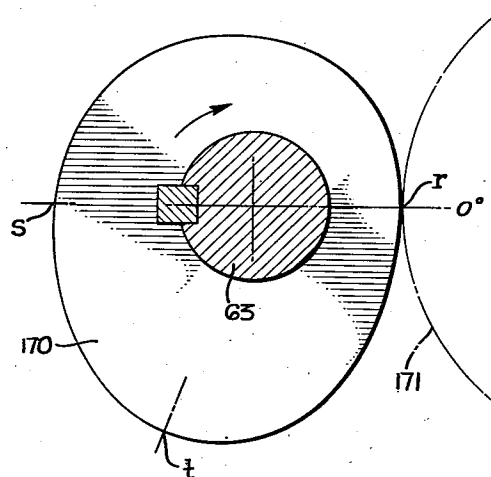
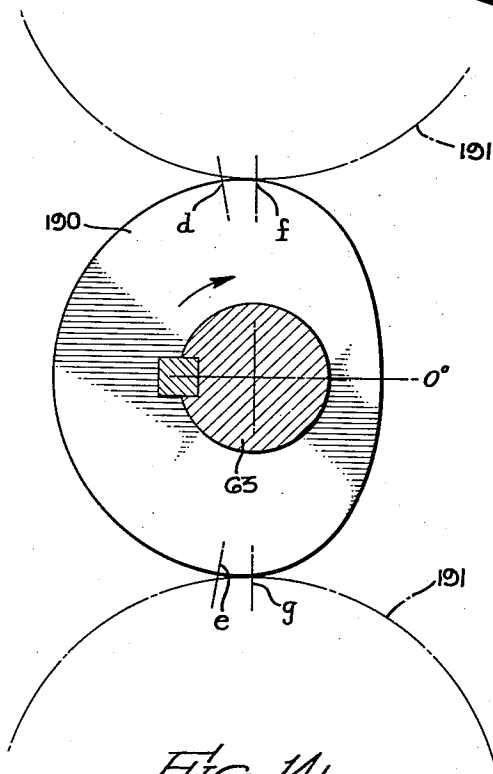


FIG. 14.



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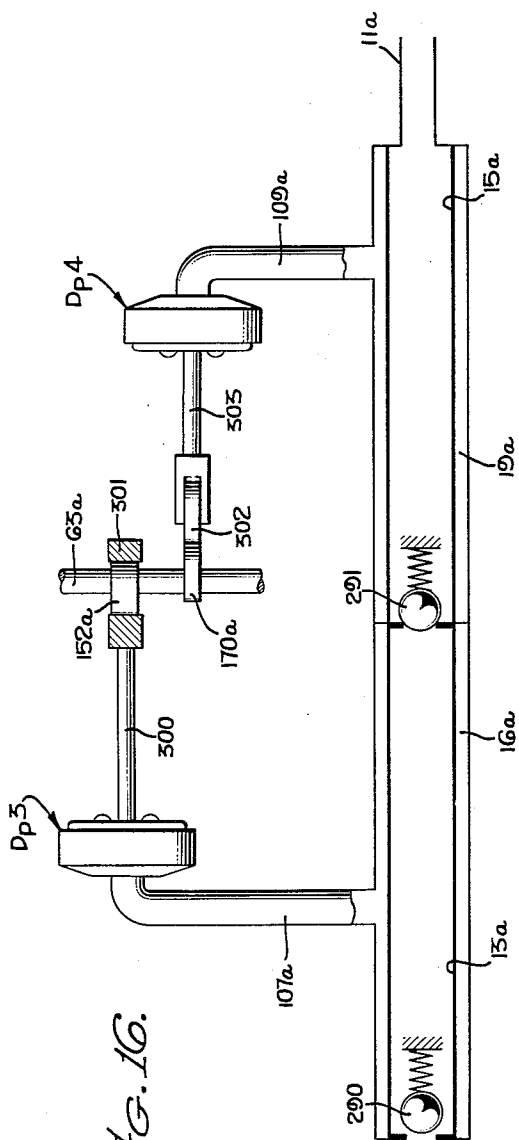


FIG. 16.

FIG. 17.

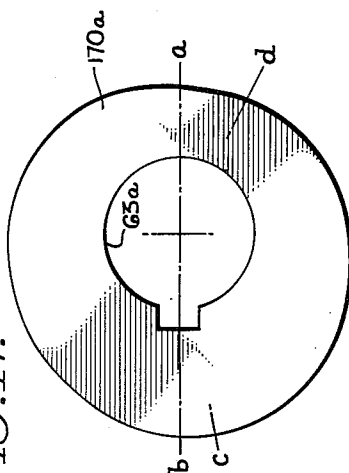
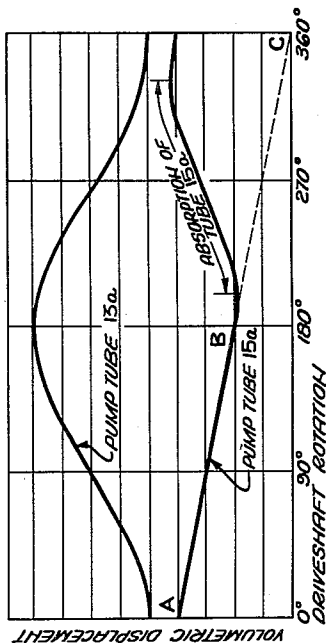


FIG. 18.



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PUMP FOR FLUID AND SEMI-FLUID MATERIAL SUCH AS PLASTER AND THE LIKE

Ernest A. von Seggern, Burbank, Calif.

Application October 5, 1953, Serial No. 384,271

9 Claims. (Cl. 103—44)

This invention relates generally to pumps for pumping liquid and semi-fluid materials, and particularly to pumps for pumping viscous, abrasive materials which solidify with time, also pumps for pumping semi-fluid materials, pulverized solids and liquids which do not remain mixed in uniform proportions but tend to separate while being pumped. Such mixtures may include solid materials in various states of pulverization, or granular materials such as plaster, cement, or concrete containing gravel or rock up to some size. Examples are interior plaster and external stucco, cements and aggregates in suspension in water.

The present invention deals with improvements in a pump disclosed in my prior application entitled Pump for Fluid and Semi-Fluid Material such as Plaster and the Like, filed January 12, 1952, Serial No. 266,226, now Patent No. 2,747,510, and in general the objects of the present invention are those of the invention disclosed in said prior application, with certain additional objects as will appear.

There are certain physical properties possessed by the class of semi-fluids referred to that make them practically impossible to pump by previously known pumps. The material is: (1) viscous, (2) abrasive, (3) non-homogenous, (4) compressible, (5) unstable in mixture, (6) self-hardening with time, and (7) inclusive in some cases of solid particles of substantial size.

Accordingly, a general object of the present invention is to provide a pump which will handle successfully fluids or semi-fluids having the above named properties singly or in combination.

In common with the invention disclosed in my said earlier application, objects of the present invention are:

To provide a positive displacement pump capable of producing high discharge pressures in which the flow of liquid through the pump is slow and non-turbulent;

To provide a pump in which all the parts subjected to the abrasive action of the fluid are either made of rubber or are rubber coated, or are composed of equivalent flexible or elastic material capable of withstanding abrasion;

To provide a pump having a large compression ratio, that is, a large change in displacement during the working cycle relative to the volume of the material being pumped;

To provide a pump in which substantially no pressure gradients or inertia forces are established in the fluid which tend to separate materials having different densities or different size, or different hardness, or different viscosity;

To provide a pump having a small and substantially smooth bore therethrough at all points in which the flow of material is sufficiently fast and uniform so that at no point is the accumulation of static material possible;

To provide a pump of the above class which is simple in design, positive in action, and which will not readily deteriorate or get out of order.

The pump disclosed in my said prior application was

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capable of achieving the above named objects, though was subject to some degree of cyclic flow rate fluctuation or pulsation. Also, the valves used in my prior pump were not of a type capable of handling effectively materials of a granular type, particularly materials containing solid particles of some size.

Accordingly, further objects of the present invention include the provision of improvements by which the discharge flow rate is made to be highly uniform, and by which materials of a granular type, including materials containing rock or other solid particles of substantial size may be effectively pumped.

The invention will be further understood by referring now to the following detailed description of one present illustrative embodiment thereof, reference for this purpose being had to the accompanying drawings, in which:

Figure 1 is a side elevational view of a pump embodying the invention;

Figure 2 is a longitudinal sectional view through the valve and pump cylinders and through a portion of the hopper;

Figures 3 and 4 are transverse sectional views taken on lines 3—3 and 4—4, respectively, of Figure 2;

Figure 4a is a perspective view of an end clamp for the valve diaphragms;

Figure 5 is a horizontal view taken as indicated by the line 5—5 of Figure 1;

Figure 6 is a vertical section taken on the line 6—6 of Figure 5;

Figure 7 is a transverse vertical section taken on the line 7—7 of Figure 6;

Figure 8 is a horizontal broken section taken on line 8—8 of Figure 6;

Figure 9 is a section taken on line 9—9 of Figure 8;

Figure 10 is a section taken on line 10—10 of Figure 8;

Figure 11 is a section taken on broken line 11—11 of Figure 8;

Figures 12, 13 and 14 are plan view diagrams of the pump actuator eccentric, pump actuator cam and valve actuator cam, respectively, shown at the starting point or 0° position of the operating cycle;

Figure 15 is a graph illustrative of the operation of the pump;

Figure 16 is a diagrammatic view of a simplified check-valve form of the pump;

Figure 17 shows a cam used in the pump of Figure 16; and

Figure 18 is a graph illustrating the operation of the pump of Figures 16 and 17.

In the drawings a two-stage pump has been shown for illustrative purposes, having a long, relatively smooth conduit C extending therethrough (see Figure 2), this conduit being fed with material to be pumped from a hopper 10, and discharging to a flexible discharge hose 11, only fragmentarily shown herein, but understood to lead to any suitable discharge nozzle. The first stage comprises a first stage valve 12, of a special type to be described hereinafter, followed by a flexible radially contractive and expansive first stage pump tube or hose 13, and the second stage comprises a second stage valve 14, of the same type as valve 12, followed by a flexible radially contractive and expansive second stage pump tube or hose 15, these four components being arranged in series and forming the above named conduit C. These four components are enclosed within housings comprising four flanged pipes 16, 17, 18 and 19, respectively, secured end to end, and mounted on the bed of a suitable wheeled truck 20 (see also Figure 1). The bottom of hopper 10 is connected by a flanged L-shaped inlet pipe 21 to the flanged housing pipe 16 for first stage valve 12. The two valves 12 and 14 are radially opened and closed between the two positions shown in Figs. 3

and 4, and the flexible sleeves 13 and 15 radially compressed and expanded between the two positions indicated in dot-dash lines in Fig. 2, by hydraulic mechanism later to be described.

The valves 12 and 14 may be identical, and while they may be of various types, the design here shown is of particular advantage in handling granular materials or aggregates, in that it is capable of closing and sealing effectively around granular particles of considerable size. Such a valve is disclosed in my co-pending application entitled Valve, filed December 4, 1951, Serial No. 259,784.

Each valve includes, in addition to its housing, a pair of end plates 22 clamped in position adjacent the flanges at the ends of its housing. The plates 22 have central apertures 24 receiving closely the tubular end portions 25 of centrally bored end clamps 26 (see also Figure 4a) for presently described valve diaphragms. These end clamps 26 are each formed with three flat, angularly disposed surfaces 26a, as seen best in Figure 4a. Engaging these surfaces 26a are the end walls 27a of three generally trough-shaped flexible valve diaphragms 27, made of a flexible elastic substance, preferably rubber or similar material not subject to abrasion by the material to be handled. They may be molded to take normally substantially the form shown in the position of Figure 4.

The end walls 27a of these diaphragms are clamped between the aforementioned surfaces 26a and flat, beveled surfaces 28a on the ends of three arcuate clamping plates 28, the side edges of which engage the side edge portions 27b of the diaphragms, as shown in Figures 3 and 4. The clamp plates 28 are held in assembly with one another and in tight engagement with the side edge portions of the diaphragms by means of screws 28b. A fluid chamber 29 is provided between the clamp plates 28 and the inner surface of the housing 16, and the plates 28 are formed with fluid ports 28c to permit the working fluid in the chamber 29 to act on the diaphragms 27.

When fluid under pressure is introduced into the chamber 29, it compresses the diaphragms tightly against one another in the closed and sealed position of Figure 4, and when fluid is exhausted from chamber 29, the diaphragms expand to the open position shown in Figure 3. If granular particles, even gravel or rock of considerable size, should be within the valve, the diaphragms still close tightly and seal effectively thereabout.

The aforementioned flexible pump tube 13 which is composed of rubber or equivalent flexible material, is flared and tightly clamped at each of its two ends in conical channels, preferably slightly wedge shaped in cross-section for good clamping action, formed in each case between a conical seat 34 formed at the end of the housing tube 17 and a conical seat 35 formed on a mounting plate 36 clamped between the flange on housing 17 and the adjacent valve end plate 22. The plate 36 is apertured as at 37 so as to form a smooth bore between the valve passage and the interior of the flexible tube 13.

As already mentioned, the valve 14 is a duplicate of the valve 12, and the flexible tube 15 and its mounting arrangements are similar to the corresponding parts already described in the case of tube 13. At the discharge end of the pump, however, the exterior clamping member for the end of tube 15 comprises a fitting 40 provided with a threaded nipple 41 to which the discharge hose 11 may be coupled, as clearly shown in Figure 2.

As will be seen from reference to Figure 2, the conduit C is without sharp offsets, shoulders or pockets. The passage inside inlet 21 tapers to join smoothly with the bore 26b of end plate 26, while the bore 26b is continued by the walls of the valve diaphragms when the latter is in open position. In the illustrative embodiment, there is a slight but gradual expansion within the pump units. Thus there are no pockets throughout the length of the

conduit C within which material may become lodged and harden.

Housings 16, 17, 18 and 19 are provided with threaded nipples 42 to 45, respectively, for connection of later described fluid pipes by which hydraulic pressure is transmitted intermittently to the chambers inside the respective housings.

The power unit for the pump is indicated generally at 50 in Figure 1, and includes an electric drive motor M. This drive motor, as here shown, is mounted on a frame work 51, which is in turn mounted on a rock shaft 52 understood to be pivotally mounted at its ends by means of any suitable bearings (not shown) carried by the side walls of the enclosing housing, generally indicated in Figure 1 at 53. In the present embodiment the pump has been equipped with an air compressor, generally indicated at 54, mounted on the same frame 51 that carries the drive motor M, and this air compressor, which is driven by motor M, is provided for use in delivering the plaster or other material pumped by the pump of the invention. The shaft of motor M has a known type of spring actuated, variable diameter V-pulley 56, connected by belt 57 to a pulley 58, which drives reduction gear unit 59. Rocking movement of motor M and its shaft, accomplished by adjustment of rock shaft 52, shifts the belt running in the pulley 56 either toward or away from the axis of the motor shaft, thereby varying the effective diameter of the pulleys and hence the speed of drive in a manner well known and unnecessary to illustrate herein. Such rocking adjustment of shaft 52 may be effected by any suitable mechanism, not necessary to illustrate herein as it forms no part of the present invention. The aforementioned reduction gear unit 59 is mounted, by means of a mounting base indicated at 60, on the top of the pump unit proper, as indicated in Figure 1, and its vertical drive shaft 61 is coupled, as at 62, to the vertical drive shaft 63 of the pump and valve actuating mechanism now to be described in detail.

This mechanism includes a pair of hydraulic pump tube liquid displacers D_{p1} and D_{p2}, and a pair of hydraulic valve liquid displacers D_{v1} and D_{v2}. The former include two diaphragm chamber plates 70, spaced longitudinally of the pump and disposed above the pump conduit C, and connected by upper and lower pairs of longitudinally extending tie rods 71. On the upper rods 71 are supporting sleeves 72 for an upper frame plate 73, and on the lower rods are supporting sleeves 74 for a lower frame plate 75, while between said supporting sleeves and the plates 70 are spacer sleeves 76.

The upper frame plate 73 is spaced below the sleeve 72, and connected thereto by bars 77 welded therebetween. Below the frame plate 73, and at right angles to the sleeves 72, are spaced supporting sleeves 80 receiving tie rods 81, these sleeves 80 being hung from plate 73 by means of bars 82 welded therebetween. Directly welded to the undersides of frame plate 75, and arranged parallel to the sleeves 80, are spaced supporting sleeves 83 receiving tie rods 84. The tie rods 81 and 84 connect diaphragm chamber plates 85 of the aforementioned valve displacers D_{v1} and D_{v2}, spacer sleeves 86 being placed on said tie rods between the sleeves 83 and the plates 85. The assembly is supported on truck 20, in any suitable manner, for instance, by means of any suitable supporting cradle such as that indicated at 90 (Figure 1), supportingly engaging the sleeves 76 on the lower tie rods 71.

The two end plates 70 are identical, though one is inverted top-to-bottom from the other, and the one used for displacer D_{p2} is shown in transverse section in Figure 10, to which reference is now made. As there shown, the plate 70 is hollowed out to define a chamber 95, one side of which is closed by end wall 96, and the other side of which is closed by a flexible but relatively

stiff and strong displacer diaphragm 97, the latter having

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a rim portion 98 sealed to plate 70 by means of clamping ring 99 and screws 100. This diaphragm 97, while subject to considerable modification in practice, is preferably of relatively stiff molded rubber, and to increase its strength, it preferably incorporates layers of nylon cords such as used in tire manufacture. It is formed, just inside rim portion 98, with a convex portion 101, and its inner portion is clamped between inner and outer clamp plates 102 and 103, plate 102 having a central threaded stud 104 projecting through central apertures in the diaphragm and in clamping plate 103, and having on its end a nut 104a set up tightly to assure firm clamping action as well as a good hydraulic seal. The diaphragm has a liquid displacing stroke such as indicated by the dot-dash lines in Figure 10.

Connected into chamber 95 through rearward chamber wall 96 is a hydraulic coupling member 106. As shown in Figure 1, the coupling 106 for the diaphragm chamber of displacer D_{p1} is connected by a pipe 107 to the fluid inlet 43 leading to the chamber 108 surrounding the flexible tube 13 of the first stage of the pump, while the coupling 106 for the diaphragm chamber of displacer D_{p2} is connected by pipe 109 to the fluid inlet 45 leading to the chamber 109 surrounding the flexible tube 15 of the second stage of the pump. The diaphragm chambers 95, pipes 107 and 109, and pump chambers 108 and 109 are fitted with any suitable hydraulic fluid, e. g., water with a suitable rust inhibitor, which is introduced when a plug 110 at the top of the diaphragm chamber is removed.

It has been said that the two diaphragm chamber plates 70 are identical, but inverted top for bottom relatively to one another. It will be noted that the center of the diaphragm chamber 95 of displacer D_{p2} is located somewhat below the level of the half-way point between the upper and lower tie rods (see Figure 10). The center of the diaphragm chamber for the other displacer D_{p1} is then, because of the inverted positioning, somewhat above this same level, so that presently described driving means for the two diaphragms can be located on the single drive shaft 63, one directly below the other.

The diaphragms 97 of the two pump displacers are driven, by mechanism later to be described, to pump liquid alternately to and from each of the two chambers 108 and 109, causing the flexible pump tubes to contract and expand between the two extreme positions shown in dot-dash lines (Figure 2).

The valve displacers D_{v1} and D_{v2} are identical, and the latter is shown in detail in Figure 9. The diaphragm chamber plate 85 will be seen to have a marginal rim portion 85a surrounding the hollowed out diaphragm chamber 112, and this chamber 112 is closed at one side by a flexible displacer diaphragm 113, of the same nature as the previously described diaphragms 97. Thus, diaphragm 113 has rim portion 114 clamped and sealed to plate 95 by clamping ring 115 and screws 116. Inside rim portion 114 the diaphragm has convex section 117 and inside the latter it has inner portion 118 clamped between and sealed between clamping plates 119 and 120, the former having threaded stud 121 projecting through central apertures in the diaphragm and the clamping plate 120 and carrying a nut 122 set up tightly to secure the parts in assembly.

The diaphragm chamber 112 is defined at the other side by a flexible wall 124 of rubber or the like, and a marginal portion of this flexible wall 124 is engaged by a flat ring 125. The ring 125 is in turn engaged by the rim portion 126 of an end closure plate 127, the latter forming a second chamber 128. The previously mentioned screws 116 are utilized to secure the members 124, 125 and 127 in assembly with the diaphragm chamber plate 85.

Within the chamber 128 is positioned a spring pressed closure in the form of a pressure plate 130, normally engaging the surface of flexible wall 124, and provided with a peripheral positioning and seating flange 131 en-

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gageable with an inner marginal portion of ring 125 when the plate 130 is in contact with the flexible wall in the normal position of the latter. Coil compression springs 132 acting between the rearward wall of end plate 127 and the pressure plate 130 yieldingly hold the pressure plate seated against the ring 125, the springs being calculated in strength to exert a pressure on plate 130 equivalent to a fluid pressure of, for example, approximately 15 pounds per square inch.

Preferably the diaphragm plate member 85 includes a rearward wall 113, perforated as indicated at 134, and spaced a short distance from the flexible wall 124.

A hydraulic coupling 140 (Figure 8) is welded to the side of the diaphragm chamber plate 85 of each of displacers D_{v1} and D_{v2}, and its interior communicates with diaphragm chamber 112 via ports 141 (see also Figure 9). The fitting 140 for valve displacer D_{v1} is connected by pipe 142 to the inlet nipple 42 for the valve chamber 29 of the first stage valve, and the fitting 140 for valve displacer D_{v2} is connected by pipe 143 to the inlet nipple 44 for the valve chamber 29 of the second stage valve. The diaphragm chambers, pipes and valve chambers 29 are filled with hydraulic fluid by removing filler hole plugs 85b. Operation of the valve displacers, as later to be described, causes hydraulic liquid to be alternately pumped into and out of the valve chambers 29 to operate the valves 12 and 14 with 180° phase difference.

The diaphragm chambers 95 of pump displacers D_{p1} and D_{p2} are connected to the chambers 128 of valve displacers D_{v1} and D_{v2} respectively, by pipes 144. Filler holes and plugs 145 are used at the tops of chambers 128 to permit filling the system with hydraulic fluid.

There remains for description the mechanism by which the drive shaft 63, driven from the power shaft 61 of reduction gear unit 59, operates the diaphragms of the pump and valve displacers. It should here be stated that, broadly speaking, these several displacers may be driven in various ways and by various mechanisms, by cams or eccentrics serving individual displacers, or with one or more of the cams or eccentrics serving more than one of the displacers. I have found, however, that specially shaped cams facilitate or are necessary to achievement of uniformity in the discharge rate from the pump.

The shaft 63 is journaled near the top in a bearing 150 secured to the underside of frame plate 73, and at the bottom in a bearing 151 mounted on frame plate 75 (see Figure 7). Below bearing 150, the shaft 63 carries a driving element 152, in this case an eccentric, for the drive of the first pump displacer D_{p1}. Surrounding this eccentric 64 is the inner ring of a ball bearing 160, and fitted around the outer ring of said bearing is an eccentric strap 161. To this strap 161 is secured a connecting rod 162 extending from a bifurcated cross head 163, whose two arms 164 are secured by screws 165 to the clamp plate 103 for the diaphragm 97 of pump displacer D_{p1}. It will be appreciated that the flexible nature of the diaphragm accommodates the angular motion of the connecting rod.

Keyed on shaft 63 below eccentric 152 is a cam 170 for driving the diaphragm of the pump displacer D_{p2}. This cam bears on the periphery of a follower roller 171, which is rotatably mounted, by means of bearing 172 (Figure 11) on a cam follower shaft 173. The two reduced extremities 174 of this shaft are journaled in the ends of crank arms 175 whose hubs are mounted for rotation on a vertical shaft 176 mounted in turn between supporting sleeves 80 and 83, respectively, all as clearly shown in Figure 11. Cam follower shaft 173 has bearing sections 178 to which are pivotally connected links 179 (see Figure 10), which are secured by studs 180 and nuts 181 to the diaphragm clamping plate 103 of pump displacer D_{p2}.

Keyed on shaft 63 below cam 170 is a cam 190, utilized to drive both of the valve displacers D_{v1} and D_{v2}. This cam 190 bears at opposite sides on cam follower rollers 191, each of the same nature as, and mounted similarly to, previously described follower roller 171, all as shown

in Figure 11. Thus these follower rollers are pivotally carried by crank arms 192 suitably mounted on stationary mounting shafts 193. The mounting for one of the shafts 193 is shown in Fig. 11 and it will be understood that the mounting for the other is similar. The cam follower rollers 191 are connected by links 194 to the clamping plates 120 for the diaphragms 113 of valve displacers Dv1 and Dv2 by means of studs 195 and nuts 196 (Figure 9).

A coil compression spring 200 is placed inside diaphragm chamber 95 of displacer Dp2 so as to act between wall 96 and a seat formed on diaphragm clamping plate 102, and this spring exerts an expansive force on diaphragm 97 sufficient to maintain the cam follower roller 171 in constant engagement with its cam. The two follower rollers 191 are maintained in engagement with cam by means of a pair of tension springs 201 connected between the ends of bars 202 secured to the links 194 by which the diaphragms 113 are moved.

Operation of the pumping system of the invention is illustrated by the curves of Figure 15, in which volumetric fluid displacement of the first and second valves 12 and 14 and of the expansive and contractive first and second flexible pump tubes 13 and 15 are plotted as ordinates and degrees of rotation of the drive shaft as abscissa. The vertically spaced lines represent equal arbitrary units of fluid displacement. It is to be understood that the valves used in the present preferred embodiment of the pump have a liquid absorption characteristic, absorbing a certain volume of liquid on the opening movement and expelling this volume on the closing movement. This condition is well illustrated in Figure 15, which reveals that, in the present design, each valve has a fluid displacement volume of its own which is somewhat over half the fluid displacement of the pump tube 13.

The slope of the line ABC in Figure 15 represents the rate of discharge into the discharge hose 11, and the uniform slope of this line denotes a uniform discharge rate throughout the cycle. This uniform discharge rate has been accomplished by attention to the design of the driving elements for the pump and valve actuators.

For illustrative purposes, I have here shown an embodiment of the invention in which the displacer diaphragm 97 of the first pump displacer Ap1 is driven sinusoidally, and this has been accomplished by use of the previously described driving eccentric 152. It will become evident hereinafter that this is a perfectly arbitrary choice. The displacer diaphragm is thus retracted and advanced with substantially sinusoidal motion during the full 360° operating cycle, thereby expanding and then contracting the first pump tube 13 in a corresponding manner, as indicated in Figure 15. It will be seen that the rate of volume change of the alternately expanded and contracted pump tube 13, and therefore the material displaced by the pump tube, thus varies sinusoidally over the full 360° operating cycle. The total displacement of the first pump tube 13 is fixed at some predetermined volume.

The valve operating cam 190 (Fig. 14) is so designed as to operate each of valves 12 and 14 substantially sinusoidally, opening and then closing valve 12 during the first 180° of the cycle, and holding it closed during the second 180°, and opening and then closing valve 14 during the second 180° of the cycle, holding it closed during the first 180°, all as represented in Fig. 15.

Accordingly, first pump tube 13 fills at a sinusoidally varying rate through valve 12 during the first 180°, and expels sinusoidally through valve 14 during the second 180°.

Comparison of the curves of Figure 15 will show that the sinusoidal opening and closing of first valve 12 is correlated with the sinusoidal displacement rate of pump tube 13. Thus the valve 12 attains its maximum opening when the displacement rate (absorption) of the pump tube 13 is at its maximum, which occurs at the 90° point

of the cycle. Correspondingly, the second valve 14 is at its maximum opening when the displacement rate (expulsion) of the pump tube 13 is at its maximum.

Turning attention now to the second pump tube 15, it will be seen from Figure 15 that the displacer diaphragm of the displacer Dp2 is so moved by its driving cam 170 through the first 180° of the cycle as to effect a uniformly varying displacement of the pump tube 15 and its contents. Since the second valve 14 is closed at this time, the discharge rate from tube 15 into the discharge hose 11 is uniform, as indicated by the portion AB of the straight line ABC.

As represented in Figure 15, the first half cycle volumetric displacement change (contraction) of the second pump tube 15 is one-half the total liquid displacement change of the first pump tube 12, this being accomplished by giving the eccentric that drives the first pump tube liquid displacer twice the throw of that portion of the cam 170 that drives the second pump tube liquid displacer during the first half of the cycle. This means that while tube 12 is absorbing a predetermined volume of material from 0° to 180°, tube 15 is discharging half that predetermined volume into hose 11.

At the beginning of the second 180° half cycle, first valve 12 is closed, and it remains closed to the end of the cycle. Second valve 14 opens and then closes sinusoidally, as indicated, first absorbing a quantity of material, and then expelling it.

First pump tube 13 is sinusoidally contracted throughout the second 180° half cycle. The volume of the valve 14 varies approximately sinusoidally, so as to match the rate of change of volumetric displacement of the second pump tube 15. It will be seen that the material expelled from the contracting first pump tube will flow into and through second valve 14, some of it filling the expanding valve, some of it passing on into the second pump tube 15, and some of the latter discharging from tube 15 into hose 11.

As appears from Figure 15, the second pump tube 15 is so driven by its liquid displacer Dp2 as to uniformly contract for the first 180° of the cycle, as already indicated, giving uniform discharge into hose 11. Past 180°, the rate of contraction is first increased, then gradually reduced, becoming zero at 250°. From 250° to 360°, tube 15 is expanded, substantially sinusoidally. From 180° to 250° the flow through tube 15 into the discharge hose 11 is that furnished by the contraction of pump tube 13, minus that absorbed by the expansion of valve 14, plus that contributed by the contracting pump tube 15. The contour of the driving cam for the second pump tube actuator is made such that flow contributed by the tube 15 is just that necessary to establish uniform flow into the discharge hose, the accelerated displacement rate of the tube 15 compensating for the material at this time being absorbed by the expanding valve 14.

At 250°, the valve 14 is almost open, and its absorption rate is rapidly approaching zero, which is actually reached at 270°. Beyond 250°, the second pump tube 15 is expanded, substantially sinusoidally, and the expansion is completed at 360°. This expansion of pump tube 15 is so correlated with the completion of expansion of valve 14, and the sinusoidal contraction of valve 14, that the flow rate through the second pump tube into the discharge hose 11 remains constant, as indicated by the straight flow rate line ABC. In other words, the expanding second pump tube absorbs just sufficient material at all times from 250° to 360° that the net or resultant flow rate from the expanding tube 15 into discharge hose 11 remains uniform for the remainder of the cycle. It will be seen that from 180° to 360°, the tube undergoes an "over-all" or net expansion equal to its contraction during the first 180°, i. e., so as to increase its displacement volume by half the aforementioned predetermined displacement volume change of the tube 12.

Figure 13 shows the cam 170 for operating the pump

tube displacer D_{p2} . This cam has a 180° section rs of uniformly increasing radius, followed by a 70° section st which is at first of accelerated increase in radius but terminates in a region of constant radius, and is completed by a 110° section tr of substantially sinusoidally decreasing radius joining with the section rs . This cam gives the characteristics previously discussed, acting first, through the first 180° , to compress the second pump tube 15 at uniform volumetric displacement. It then, for 70° , increases the volumetric displacement rate of the second pump tube to compensate for the "negative" fluid displacement owing to the valve 14 (then opening) absorbing more material than is discharged by the first pump tube (then contracting). At the 250° point of the cycle, the rate of discharge of the first pump tube exceeds the absorption rate of valve 14 by the uniform discharge rate represented by the straight line ABC, and the cam 170 is reduced to constant radius. For the balance of the cycle, the resultant displacement rate of the first pump tube and the second valve exceeds the rate represented by ABC, and the cam 170 expands the second pump tube at a rate to absorb the proper volume of fluid to achieve desired constant discharge rate ABC. Discharge into the hose 11 is thus uniform throughout the cycle. It may here be pointed out the design of the cam 170 is dictated by the choice of driving element for the pump tube displacer D_{p1} , which is in this case an eccentric. The choice might equally as well have been to use an eccentric to drive the displacer D_{p2} , in which case a cam would be used for driving D_{p1} , of shape dictated by the characteristic performance given by the eccentric, and, of course, also by the valves, the over-all result being in all cases correlation of design to achieve uniform discharge from the pump.

Fig. 14 shows the valve actuating cam 190 , and this cam has a constant radius or "dwell" section de of 160° of arc. At the two ends of section de are 10° sections df and eg , which, in simplified forms of the invention, might be included in the constant radius section, giving the latter a full 180° . Between sections df and eg is a 180° section fg of decreasing and then increasing radius and the 10° sections af and eg are of increasing radius to join section fg to de . The section fg is of course of such contour as to operate the valve actuators sinusoidally, giving the sinusoidal displacement characteristics represented in Figure 15. Thus the valves are alternately fully opened and fully closed by the section fg . It will be seen, then, that the cam section df will displace the valve actuator diaphragms a short distance beyond that at which the valve is fully closed. This results (referring to Figure 9) in the fluid inside diaphragm chamber 112 being displaced against flexible wall 124 and spring-seated wall 130 so that the latter is displaced a short distance toward the left, as viewed in the figure. The springs 132 exert a biasing force on plate 130 of some predetermined magnitude, typically so as to give a biasing pressure against wall 130 of 15 pounds per square inch. Once this wall 130 is so unseated from ring 125 , the full fluid pressure existing inside the corresponding pump tube displacer, communicated to chamber 128 via the connecting hose 144 , plus the spring biasing pressure of 15 pounds per square inch, is communicated to the valve actuator chamber 112 , and therefore to the valve diaphragms, to exert this elevated closing pressure thereon. Accordingly, no matter how much compressive pressure may be exerted on the flexible pump tubes, and therefore on the material being pumped, a still greater closing pressure is exerted on the corresponding valve, assuring holding of the valves at all times.

Additionally, in the pumping of fluid materials containing rock or gravel, if the valve diaphragms are unable to close fully due to closing on solid objects, the excess fluid can then be accommodated by any necessary degree of unseating of the pressure plate 130 .

The 10° section eg of the cam 190 will be seen to

function to retract the valve actuator diaphragms by just the amount necessary to permit pressure plate 130 to re-seat on member 125 , after which the section fg of the cam moves the diaphragm outward to open the valve. The perforated plate 133 is preferably used to back up the flexible wall 124 and prevent it from undue distension on this "suction" stroke of the valve actuator in the event the plate 131 fails to make a fluid tight fit with its seat 125 .

Figures 16-18 illustrate somewhat diagrammatically a modified pump in accordance with certain aspects of the invention. This form of pump is equipped with check valves instead of the driven diaphragm type valve of the first embodiment, and is, therefore, not as well adapted for pumping concrete or the like. It is, however, entirely suitable for many fluid substances which do not include solid particles but which still present the problem of self-hardening. The pump of Figures 16-18 retains the advantage of the first embodiment that discharge into the hose is uniform throughout the cycle. Figure 16 shows diagrammatically a pump comprising first and second flexible pump tubes $13a$ and $15a$, provided with liquid jackets $16a$ and $19a$, respectively. At the intake end of tube $13a$ is intake check valve 290 , and between tubes $13a$ and $15a$ is a second check valve 291 . These check valves may be of various types, such as the conventional spring-closed ball type indicated, or a valve developed specifically for this type of pump and described in my copending application entitled Valve, filed December 4, 1951, Serial No. 259,784.

Diaphragm type pump tube liquid displacers D_{p3} and D_{p4} , of the nature fully shown in the earlier described form of pump (see, for instance, Figure 10), are employed to pump liquid into and from jackets $16a$ and $19a$ through hoses $107a$ and $109a$, respectively. These displacers are driven from a suitable combination of driving elements, such as an eccentric and cam, or two cams, designed to give an output characteristic such as represented in Figure 18.

In the present instance, I have chosen illustratively to drive actuator D_{p3} from an eccentric $152a$ on a drive shaft $63a$, and to drive actuator D_{p4} from a cam $170a$ on the shaft $63a$. The eccentric $152a$ is connected to the diaphragm of D_{p3} by a connecting rod 300 and eccentric strap 301 , and the cam $170a$ is connected to the center of the diaphragm of D_{p4} by follower roller 302 and connecting rod 303 .

Referring now to the diagram of Fig. 18, the pump tube $13a$ will be seen to be expanded and then contracted by the operation of displacer D_{p3} in a substantially sinusoidal manner, as results from the use of the driving eccentric $152a$. Thus, at the beginning of the cycle, the pump tube $13a$ is fully contracted. The tube $13a$ is then sinusoidally expanded during the first 180° of the cycle, and sinusoidally contracted during the second 180° of the cycle.

The pump tube $15a$ is so operated by its displacer D_{p4} and the cam $170a$ as to uniformly contract during the first 180° of the cycle, as represented by the portion AB of the straight line ABC representing uniform rate of discharge from the pump into the discharge hose $11a$. The volumetric contraction is made to be half the volumetric expansion of the first tube 12 . For the second half of the cycle, pump tube $15a$ is so manipulated that the resultant flow or discharge into the hose $11a$ remains constant as indicated by the line segment BC. By reference to Fig. 18, it will be seen that the tube $15a$ is further contracted for a few degrees past 180° , and is then expanded, substantially sinusoidally, to approximately the 333° point of the cycle, after which contraction again takes place, all as clearly represented in Fig. 18. The cam $170a$ for accomplishing these functions is shown in Fig. 17, and it will be seen that said cam has a 180° section ab of uniformly increasing radius, followed by a short section bc during which the rate of increase of

radius is reduced to zero. From c to d , at 333° , the radius decreases sinusoidally, and from d to a the radius again increases, as clearly shown.

Operation then is as follows: during the first 180° of the cycle, a predetermined volume of fluid is taken in by pump tube 13a through check valve 290, while check valve 291 remains seated. During this time, pump tube 15a is compressed, and, since valve 291 is closed, fluid is discharged into hose 11a at uniform rate as represented by the straight line AB in Fig. 18, the volume so discharged being half the predetermined volume absorbed by tube 12. During the second 180° of the cycle, tube 13a is sinusoidally compressed, causing check valve 290 to seat and check valve 291 to open. Accordingly, the predetermined volume of material previously absorbed by the expanding tube 13a is discharged past check valve 291 into tube 15a. Half of this material flowing from tube 13a into tube 15a is absorbed by the then expanding tube 15a, and half is discharged into hose 11a. As previously explained, the relative rates of contraction and expansion of the tubes 13a and 15a are so controlled that the resultant discharge from tube 15a into hose 11a during the second half cycle remains constant as represented by the straight line BC in Fig. 18. It will be understood that the invention is not limited to the specific eccentric and cam combination here instanced. Two cams can be employed, or the first tube can be cam driven and the second eccentric driven. In all cases, one driving element is chosen, and the other then correlated therewith to give the uniform discharge characteristic of the invention.

The invention has now been described in two illustrative forms, from which the basic nature and accomplishments of the invention in its various aspects may be readily and fully understood. It is to be further understood, however, that the illustrative embodiments of the invention are not exhaustive of the forms of apparatus which the pump of the invention may take in practice, and that the invention is to be considered as limited only in accordance with the following claims.

I claim:

1. In a pump, the combination of: first and second flexible pump tubes of variable volumetric displacement connected in series, each having intake and discharge ends, a first valve at the intake end of said first tube, a second valve between the discharge end of the first tube and the intake end of the second tube, said first valve being adapted to open and close during expansion of said first tube, and said second valve being adapted to open and close during contraction of said first tube, a jacket for each of said tubes for enclosing a liquid body therearound, a liquid displacer for each tube communicating with the liquid in said jacket for displacing liquid in said jacket to contract or expand the pump tube and thereby vary its volumetric displacement, driving means for the liquid displacer for the first tube for effecting an expansion of said tube by a predetermined volume during a first portion of the operating cycle of the pump, thereby drawing in a corresponding volume of material through said first valve, and for effecting a contraction of said tube by the same volume during a second portion of said operating cycle, thereby discharging such volume of material through said second valve into said second tube, and driving means for the liquid displacer for the second tube correlated with said first mentioned driving means for contracting said second tube by substantially half said predetermined volume at substantially uniform volume change rate during said first portion of said cycle, thereby giving a substantially constant discharge rate from said second tube for said first portion of said cycle, and for effecting a variation in the volumetric displacement of said second tube during said second portion of said cycle in a manner giving a net expansion of said second tube equal to half said predetermined volume, at a variable volume change rate so related to the rate of

flow of material from said second valve into said second tube as to continue said substantially constant rate of discharge from said second tube during said second portion of said cycle.

2. The subject matter of claim 1, wherein said driving means for the liquid displacer for the second pump tube comprises means for first contracting and then expanding said second pump tube during said second portion of the cycle.

3. The subject matter of claim 1, wherein said valves are yieldingly closed check valves.

4. The subject matter of claim 1, wherein the driving means for the first pump tube liquid displacer includes a driving eccentric and the driving means for the second pump tube liquid displacer includes a driving cam whose outline is correlated with said eccentric.

5. The subject matter of claim 1, wherein said valves absorb and expel a volume of liquid during opening and closing movements, and wherein said driving means for the liquid displacer for the second pump tube contracts and then expands the second pump tube during the second portion of the cycle by an amount and at a rate compensating for the material absorbed and then expelled by said second valve.

6. In a pump, the combination of: first and second flexible pump tubes of variable volumetric displacement connected in series, each having intake and discharge ends, a first valve at the intake end of said first tube, a second valve between the discharge end of the first and the intake end of the second tube, said valves embodying conduits including flexible diaphragm means collapsible in response to external pressure to close the passage therethrough and expansive in response to external pressure to open said passage, first and second liquid filled pump housings around said first and second pump tubes and first and second liquid filled valve housings around said valve conduits, first and second pump tube liquid displacers connected to said first and second pump housings, respectively, and first and second valve conduit liquid displacers connected to said first and second valve housings, respectively, driving means for the valve conduit liquid displacers for causing the first valve conduit to expand and collapse during the first 180° of the operating cycle of the pump and for causing the second valve conduit to expand and collapse during the second 180° of the operating cycle of the pump, driving means for the first pump tube liquid displacer for effecting an expansion of said first pump tube by a predetermined volume during the first 180° of the cycle and a contraction of said pump tube by said volume during the second 180° of the cycle, whereby such volume of material is drawn into said pump tube through the first valve conduit during the first 180° and is discharged into the second valve conduit during the second 180° , and driving means for the second pump tube liquid displacer for effecting a contraction of the second pump tube by half said volume at substantially constant rate during the first half cycle, thereby giving substantially constant discharge rate from the pump for the first 180° , and for effecting a further contraction and then an expansion during said second 180° , with a net expansion equivalent to half said predetermined volume during said second 180° , whereby to discharge half said predetermined volume of material received from said first pump tube through said second valve conduit, said driving means for said second pump tube displacer being so correlated with the drive means for the first pump tube displacer and the drive means for the second valve conduit displacer as to effect discharge of said half of said predetermined volume from said second pump tube at substantially constant rate throughout said second 180° .

7. The subject matter of claim 6, wherein said driving means for said valve conduit liquid displacers include harmonic cam means causing said valves to open and

close sinusoidally, said driving means for said first pump tube liquid displacer includes a substantially simple harmonic driving element causing said first pump tube to expand and contract substantially sinusoidally throughout the 360° operating cycle, and wherein the driving means for the second pump tube liquid displacer comprises a cam shaped to give uniform volumetric contraction of the second pump tube during the first 180° of the cycle, and further contraction and then full expansion during the second 180° of the cycle, in such manner as to give substantially constant discharge rate from the second pump tube during said second 180°.

8. In a pump, the combination of: a flexible pump tube having an intake end, a valve communicating with the intake end of said pump, said valve comprising a liquid filled housing and a flexible diaphragm means therein expansive in response to reduction in external liquid pressure to open a passage therethrough and contractive in response to increase in external liquid pressure to close said liquid passage, a liquid filled housing surrounding said flexible pump tube, a reciprocating liquid displacer for said pump tubing communicating with the liquid body in said pump tube housing, a liquid displacer for said valve comprising a first liquid filled chamber having a reciprocating wall, a liquid communication means between said chamber and the liquid filled valve housing, a flexible expansive wall closing a portion of said liquid filled chamber, a spring-pressed closure having one side engageable against the outer surface of said flexible wall, a closure seat engaged by a seating surface extending around said closure in a normal position of said flexible wall and said closure, a second liquid filled chamber in communication with the other side of said closure, a pressure communication between the liquid in the liquid displacer for the pump tube and said second liquid filled chamber, and means for moving said reciprocating wall of said liquid displacer for said valve through a stroke greater than sufficient to fully close said valve diaphragm means, whereby liquid pressure developed inside said first liquid chamber distends said flexible wall and unseats said closure against its housing, a flexible expansive wall closing a portion of said liquid filled chamber, a spring-pressed closure having one side engageable against the outer surface of said flexible wall, a closure seat engaged by a seating surface extending around said closure in a normal position of said flexible wall and said closure, a second liquid filled chamber in communication with the other side of said closure, a pressure communication between the liquid in the liquid displacer for the pump tube and said second liquid-filled chamber, and means for moving said reciprocating wall of said liquid displacer for said valve through a stroke greater than sufficient to fully close said valve diaphragm means, whereby liquid pressure developed inside said first liquid chamber distends said flexible wall and unseats said closure against

its spring pressure, so as to establish a pressure in said first chamber and hence in said valve housing equal to the pressure in the pump tube liquid displacer plus the pressure exerted by said spring pressed closure.

9. In a pump, the combination of: a flexible pump tube having an intake end, a valve communicating with the intake end of said pump, said valve comprising a liquid filled housing and a flexible diaphragm means therein expansive in response to reduction in external liquid pressure to open a passage therethrough and contractive in response to increase in external liquid pressure to close said liquid passage, a liquid filled housing surrounding said flexible pump tube, a reciprocating liquid displacer for said pump tubing communicating with the liquid body in said pump tube housing, a liquid displacer for said valve comprising a first liquid filled chamber having a reciprocating wall, a liquid communication means between said chamber and the liquid filled valve housing, a flexible expansive wall closing a portion of said liquid filled chamber, a spring-pressed closure having one side engageable against the outer surface of said flexible wall, a closure seat engaged by a seating surface extending around said closure in a normal position of said flexible wall and said closure, a second liquid filled chamber in communication with the other side of said closure, a pressure communication between the liquid in the liquid displacer for the pump tube and said second liquid filled chamber, and means for moving said reciprocating wall of said liquid displacer for said valve through a stroke greater than sufficient to fully close said valve diaphragm means, whereby liquid pressure developed inside said first liquid chamber distends said flexible wall and unseats said closure against its housing, a flexible expansive wall closing a portion of said liquid filled chamber, a spring-pressed member having one side engageable against the outer surface of said flexible wall, a second liquid filled chamber in communication with the other side of said member, a pressure communication between the liquid in the liquid displacer for the pump tube and said second liquid filled chamber, and means for moving said reciprocating wall of said liquid displacer for said valve through a stroke greater than sufficient to fully close said valve diaphragm means, whereby liquid pressure developed inside said first liquid chamber distends said flexible wall and moves said member against its spring pressure, so as to establish a pressure in said first chamber and hence in said valve housing equal to the pressure in the pump tube liquid displacer plus the pressure exerted by said spring pressed member.

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