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(54) Hydraulically driven double acting diaphragm pump

(57) A pumping device for liquids or aeriform substances of a double-acting reciprocating type, characterized in that it comprises a first and a second pumping unit provided with a separating element between a working fluid and a pumped fluid, and connected to an oil

control assembly arranged to induce reciprocating motions in said separating elements of said units by means of pressurized oil so as to produce a suction phase in one unit and a delivery phase in the other unit and vice-versa, in a continuous way.

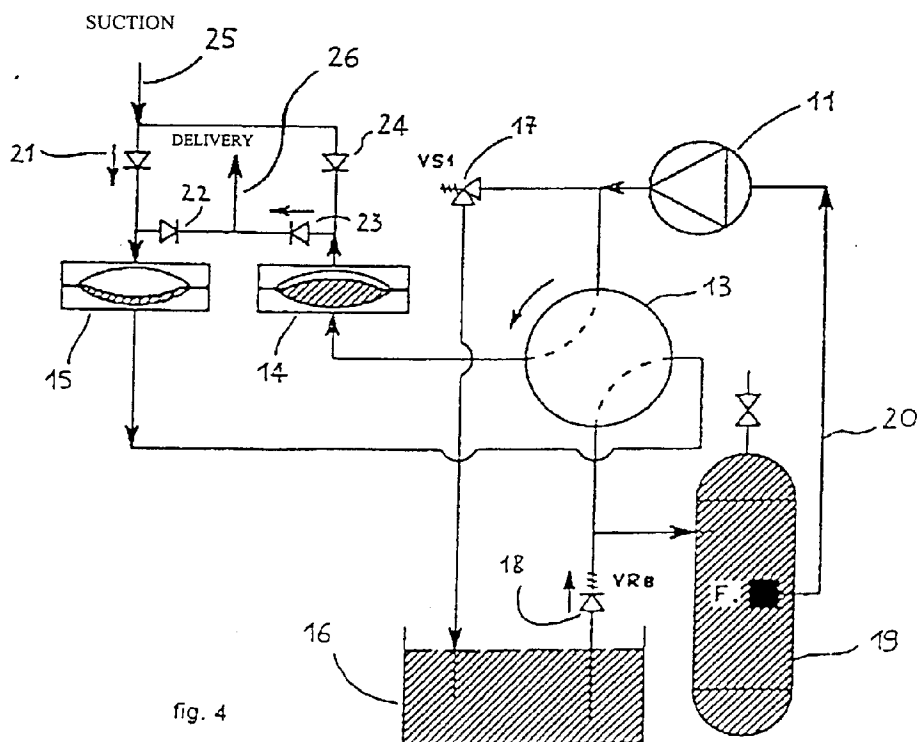


fig. 4

Description

[0001] The present invention relates to a device for pumping liquids or aeriform substances, with double-acting reciprocating motion obtained hydraulically.

[0002] From the state of the art innumerable solutions for pumping liquids or aeriform substances are known. Liquid and aeriform pumping systems can be substantially subdivided into two classes: (a) fluid dynamic action systems, such as for example centrifugal pumps and the like, based on the laws of fluid dynamics and on the transfer between the momentum and the mechanical energy, and (b) positive-displacement systems, based on the variation of the volume enclosed in a pump casing by both direct and indirect mechanical action by means of a working fluid.

[0003] The systems of the group (a) and the group (b) present respective advantages and disadvantages, and the choice between the one or the other system in whatever plant is dictated by the specific applications and the "secondary conditions" which the designer must meet and which are determined by various factors.

[0004] The present invention relates to a device for pumping liquids or aeriform substances of the above-mentioned type, which is included in the system class of the (b) group indicated above.

[0005] In the Italian patent No 1,262,358 in the name of the same Applicant, titled "Device for pumping liquids with a diaphragm pump operated by a hydraulic circuit" a device for pumping liquids, particularly for heat pumps, is illustrated and described, which comprises a diaphragm pump, operated by a hydraulic closed-circuit comprising an hydraulic oil tank, a rotary pump placed between the tank and the lower chamber of the diaphragm pump, and a rotary switching valve whose object is to pump said oil back and forth with a reciprocating motion to said diaphragm pump, in order to induce a pulsating suction and delivery motion in the liquid to be pumped, which flows in the process side of the diaphragm pump.

[0006] Said device is schematized in the annexed figure 1, and it is a reciprocating positive displacement pumping system indirectly operated by a fluid (oil) pressurized in a continuous way by means of a rotary positive displacement pump, in particular a gear pump which cooperates by means of a mechanical transmission of the same driving force which operates the pump, with a rotary valve which reverses the oil flow between the reciprocating pumping unit and a tank.

[0007] Figure 2 shows the behavior, as a function of time, of the flow rate of a pumping system such as the one showed in figure 1 according to the Italian patent No 1,262,358 previously referred to.

[0008] As it can be noted, the pumping action is of a pulsating type, and the flow rate or delivery is similar to a square wave. The pulsation is due to the fact that the diaphragm pumping unit (figure 1) is of the single acting type, and corresponds to the electrical analogy of a sin-

gle half-wave rectifier.

[0009] Such pulsating behavior can suit numerous applications, but, in the case of high flow rates and pressures the pulsation of the pumped fluid, be it a liquid or an aeriform substance, may involve many problems such as periodic stresses in the system fed by the pump, with possible drawbacks due to fatigue stress of the components, noise and flow discontinuity which can prove harmful to refrigerators or heat pumps operating on an absorption cycle, as it is well-known to a man skilled in the art.

[0010] The aim of the present invention is to provide a device for pumping liquids or aeriform substances with a double-acting reciprocating motion or action, with diaphragm pumping units, or the like, of the class described in the above-mentioned Italian patent.

[0011] According to the present invention a pumping system of the type being discussed is provided, which comprises at least two pumping units, provided with a separating element which is formed by a diaphragm or the like, said pumping units being operated by a pressurized hydraulic fluid (oil), and working in a push-pull manner so as to obtain a double-acting pumping action and a substantial elimination of fluctuations in the flow rate and/or pressure at the outlet side of the pumping system, wherein the fluid of said two diaphragm pumping units is combined by means of a valve assembly, in a similar way to what is known in electrotechnics as "Graetz bridge", according to which the outlet flow of the pumping system is practically continuous and free from unwanted pulsations, particularly as regards liquids.

[0012] Other features of the system according to the present invention are defined in the annexed dependent claims.

[0013] The present invention will be now disclosed by presently preferred embodiments, shown as non-limiting examples, on the basis of the figures of the annexed drawings wherein:

figure 1 schematically shows the structure of a single-acting pumping system according to the prior art;

figure 2 schematically shows operating modes of the pumping system according to figure 1, applied to the pumping of liquids;

figure 3 shows a functional diagram of the double-acting pumping system according to the present invention;

figures 4 to 8 show embodiment variants of the double-acting pumping system according to the invention schematized in figure 3; and

figure 9 shows an example of a pumping unit of the free-piston type, which can be utilized in the present invention.

[0014] In the description herebelow, the technical teaching from the Italian patent No 1,262,358 above referred to is to be considered as known, and the relative

description, figures and claims must be considered as included and an integral part of the description herebelow, for the sake of the clarity and simplicity of the description.

[0015] The functional diagram of the present invention will now be illustrated with reference to figure 3. An oil control assembly is provided, which comprises a prime motor consisting of an electric motor 10 which operates a positive displacement rotary pump 11, in particular a gear pump, to move a driving fluid (oil). The transmission of mechanical operation by gear pump 11 through a reduction gear 12 operates a rotary valve 13 which supplies or withdraws oil from a first diaphragm pumping unit 14 and from a second diaphragm pumping unit 15.

[0016] As it can be noted from figure 3, the circuit of the oil which is the working fluid, and the arrangement of the ways of the rotary valve 13 imply a push-pull working of the pumping units 14 and 15, that is a 180° phase shift between the flow rate/pressure pulsations generated in the pumped fluid. In this way the "voids" shown in the schematization of the operative modes of the single-acting pumping system of figure 2 are eliminated.

[0017] In the figure 4 a first practical embodiment of the pumping system according to the functional diagram of figure 3 is shown,

[0018] The components corresponding to those in the diagram of figure 3 are indicated in figure 4 by the same reference numbers.

[0019] In the construction of figure 4 a tank 16, not pressurized, is provided, which, in order to compensate the expansion of the working fluid (oil), operates like an expansion tank, wherein the excess pressure from the pump 11 is discharged by means of a calibrated over-pressure or safety valve 17. Makeup oil can be withdrawn from the tank or expansion tank by means of a valve 18 which can be suitably calibrated, in order to prevent short circuits at the oil side during intake at low pressures. This valve 18 is calibrated at a suitably low pressure to allow the suction of fluids at pressures equal or higher than the calibration pressure. The pipe coming from the valve 18, together with the oil intake line at the side of the diaphragm units 14, 15 leads to tank 19 wherein a filter F is possibly located, which has an outlet 20 connected to the intake side of the gear pump 11.

[0020] An assembly of unidirectional valves 21, 22, 23, 24, in the configuration which is well known in electronics as "Graetz bridge", is located on the process side of the diaphragm pumping units 14, 15. The valves 21, 22, 23, 24 are respectively connected to suction 25 and delivery 26 pipes.

[0021] In this way a "double half-wave rectification" is obtained in the pulsating flow of the single pumping units 14 and 15, which operate in a push-pull manner, i.e. with a 180° phase shift.

[0022] Since the delivery of the single pumping units 14, 15 has a rectangular shape when liquids are involved (figure 2) the output flow in the delivery pipe 26 substan-

tially presents no discontinuity, with the above-mentioned advantages.

[0023] In the figure 5 a second variant of the practical embodiment of figure 4 is shown.

[0024] In figure 5 reference numbers equal to those of figure 4 indicate corresponding components.

[0025] In the variant of figure 5 the expansion tank 16 is eliminated, and the safety valve 17 discharges on the suction side of the gear pump 11, while the thermal expansions of the oil are insured by the diaphragm units 14, 15.

[0026] A further safety valve 27, which is calibrated at a lower pressure than safety valve 17, can be provided on the delivery side of the pump 11. The valve 27 is closed during the normal operation of the system, while, on the contrary, it is used during the first minutes of the system startup only to allow the discharge of the possible excess oil let into the charge, together with the one resulting from the thermal expansion at the normal operating temperature.

[0027] The variant of figure 6 corresponds to the one of figure 5. In the construction of figure 6 the tank is partially full and the free space 28 over the oil mass serves as an expansion space to compensate the thermal expansions of the oil.

[0028] In the construction of figure 6, in order to guarantee operation, the existing pressure in the tank must be kept at a lower value than the pressure of the working fluid on the intake side, controlled by the pumping units 14, 15. Otherwise the diaphragms of the units 14, 15 would be unable to carry out the intake phase.

[0029] It is to be noted that in the embodiments shown in the figures from 3 to 5, the intake pressure of the oil automatically coincides, except for the pressure losses, with the intake pressure on the diaphragm pumping units, while in the case of figure 6 is set on the lower value allowed by the operative conditions.

[0030] A further embodiment is shown in figure 7, corresponding in part to the one in figure 6.

[0031] In the variant of figure 7 a tank 29, simply open at the atmosphere, is provided for the oil. In this case the pressure on the intake side of the diaphragm pumping units will have to be higher than the atmospheric pressure at least by the value required to overcome the elasticity of the diaphragm added to the pressure losses on the oil side. Otherwise, as it is evident, no pumping action would take place.

[0032] In the figure 8 a further variant, similar under many respects to the embodiment shown in figure 4 is shown.

[0033] In the embodiment of figure 8, in the circuit of the working oil, a diaphragm expansion tank 30 is provided, only partially filled with oil. The diaphragm expansion tank 30 allows the thermal expansion of the oil by means of the discharge valve, while the calibrated makeup valve allows the normal pumping with intake of oil from the diaphragm units and, only for makeup, also from the expansion tank. The expansion tank 30 is con-

nected on the side opposite to the oil side, to the intake pipe on the process side, so as to cause the makeup pressure of the makeup valve to adjust automatically to the intake pressure on the process side, hence eliminating the occurrence of short-circuits on the oil side.

[0034] Differently from the diagram of figure 4, the oil circuit remains sealed on the environment side in order to prevent leaks of harmful substances in case of a break of the pumping units' diaphragms.

[0035] Hereinbefore embodiments utilizing diaphragm pumping units have been illustrated. They could be replaced by pumping units of the "free-piston" type, on condition that a separation is kept between the working oil and the pumped fluid.

[0036] Said separation between the oil and the process fluid can be obtained, as it is known to a man skilled in the art, by means of elastic seals between the cylinder and the piston with or without the aid of a so-called "lantern" separating the cylinder on the process side from the cylinder on the oil side.

[0037] As it is shown in figure 9, the free-piston pumping unit comprises a cylinder 40 inside which a piston 41, kept sealed by seals 42, can slide. The piston 41 defines a first control chamber 43 wherein a working fluid (oil) can be forwarded and withdrawn by means of a line 44, and a second working or positive displacement pumping chamber 45, which cooperates with a delivery valve 46 and a suction valve 47. The valves 46, 47 are respectively shown as unidirectional valves of the ball type with a conical seat, however, it is clear that they can be of other shapes.

[0038] Obviously the above-named "lantern" arrangement can be provided.

[0039] The present invention has been described with reference to presently preferred embodiments, however it is to be intended that variants and modifications can be provided in practice without going out of the protective scope of the present industrial patent.

Claims

1. A device for pumping liquids or aeriform substances of a double-acting reciprocating type, characterized in that it comprises a first and a second pumping unit, provided with a separating element between a working fluid and a pumped fluid, which are connected to an oil control assembly arranged to induce reciprocating motions in said separating elements of said units by means of pressurized oil, so as to produce a suction phase in one unit and a delivery phase in the other unit and viceversa, in a continuous way.
2. A device according to claim 1, characterized in that said pumping units are of the diaphragm type.
3. A device according to claim 1 or 2, characterized in

that said oil control assembly produces pulsations of the square-wave type with a 180° phase shift, obtained by cyclically reversing the suction and the delivery of a positive displacement rotary pump.

4. A device according to any of the preceding claims, characterized in that said oil control assembly comprises at least a motor, a positive displacement oil pump, a revolution reduction gear, a four-way connecting rotary valve and a working oil tank for said diaphragm units or the like, operatively interconnected.
5. A device according to claim 4, characterized in that said rotary valve comprises two flat facing disks, the first one being a fixed disk with connecting holes for the oil pipes, the second being a moving disk with slots apt to cyclically invert the holes on the fixed disk two by two, placed in a suitable sealed box which in its turn is pressurized by means of a hole which connects it to a pressurized oil pipe, so as to insure wear clearance between the two disks by means of the hydraulic oil thrust, according to the patent No 1,262,358 in the name of the same Applicant.
6. A device according to claim 5, characterized in that said moving disk is formed directly on the slow gear wheel of the revolution reduction gear.
7. A device according to one or more of claims from 1 to 6, characterized in that said oil control assembly is substantially made as illustrated and claimed in the Italian Patent No 1,262,358 in the name of the same Applicant.
8. A device according to one or more of preceding claims, characterized in that it comprises an external oil expansion tank under atmospheric pressure to which the discharge of a safety valve is connected, located on the delivery side of said rotary positive displacement pump, and from which a makeup valve draws, calibrated at a suitably low pressure to allow the suction of fluids at pressures equal or higher than the calibration pressure (figure 4).
9. A device according to one or more of claims from 1 to 7, characterized in that its size guarantees the thermal expansion of the oil by means of an oversizing of the two pumping units, and in that it comprises an internal by-pass safety valve between the delivery and the suction of the rotary pump (figure 5).
10. A device according to claim 9, characterized in that it comprises a second safety valve, sealed during normal operation, which allows the outside discharge of possible excess oil let in during the charg-

ing phase (figure 5).

11. A device according to one or more of claims from 4 to 7, characterized in that the oil tank is partially filled up and, during the initial charging phase, is set at a sufficiently low pressure to allow the suction of fluids at pressures higher than the pressure existing in said tank (figure 6). 5
12. A device according to one or more of claims from 4 to 7, characterized in that the oil supply tank is of the atmospheric pressure type, hence allowing the suction of fluids at pressures higher than the atmospheric pressure (figure 7). 10
13. A device according to one or more of claims from 1 to 7, characterized in that it comprises a pressurized oil expansion tank having the same intake pressure of the fluid to be pumped, which comprises a diaphragm expansion tank in order to prevent leaks of harmful substances which may have come in contact with the oil and in order to prevent short-circuits in the oil. 15 20
14. A device according to one or more of claims 1 and from 3 to 13, characterized in that said pumping units are of the free-piston type, with or without a separating "lantern" between the cylinder part on the process side and the cylinder part on the oil side. 25 30

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PRIOR ART

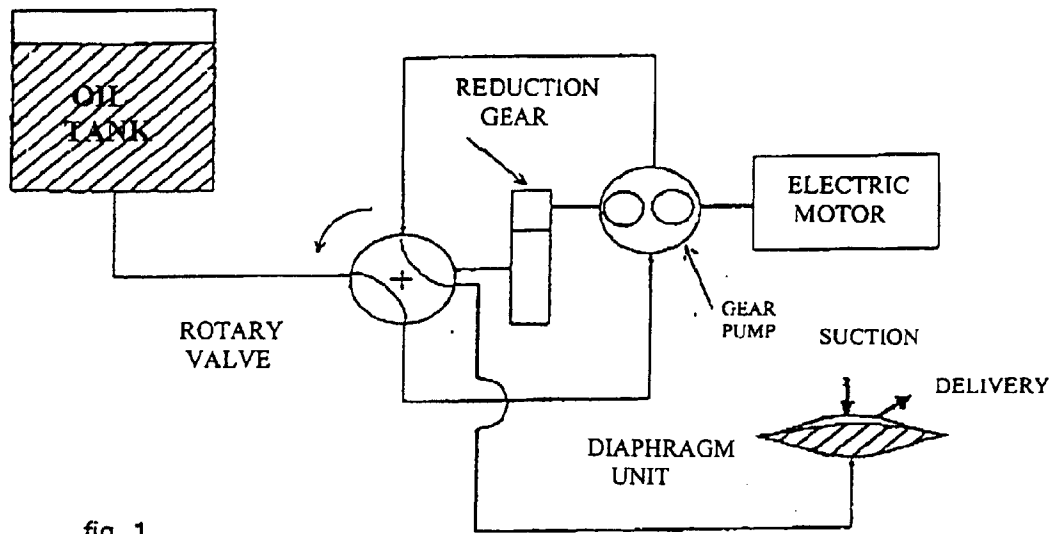


fig. 1

PRIOR ART

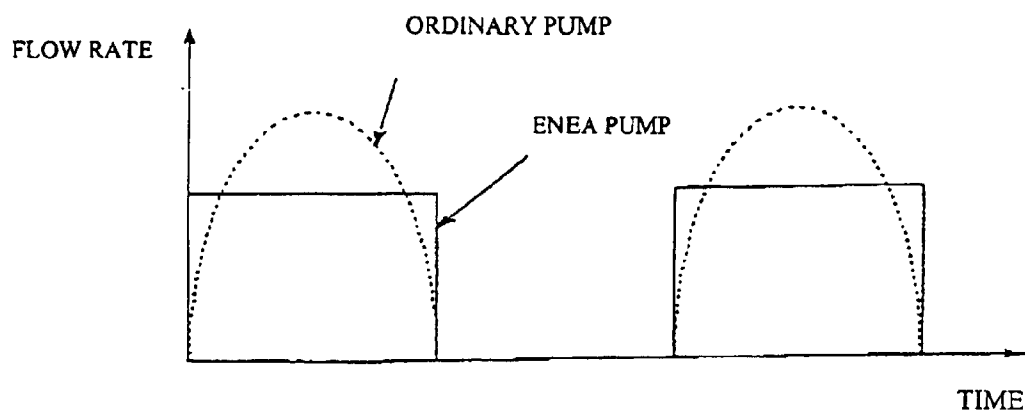


fig. 2

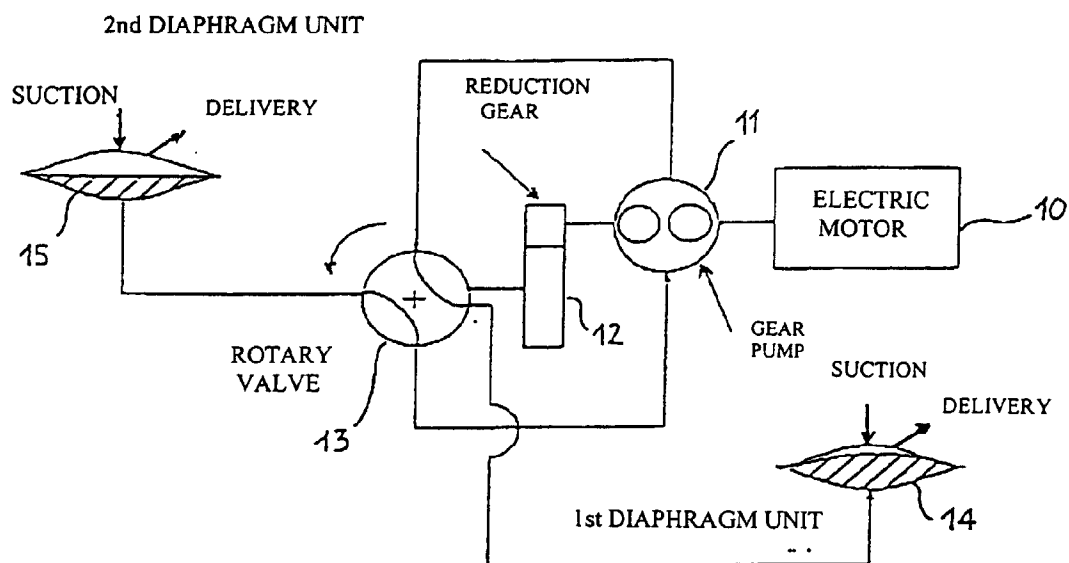


fig. 3

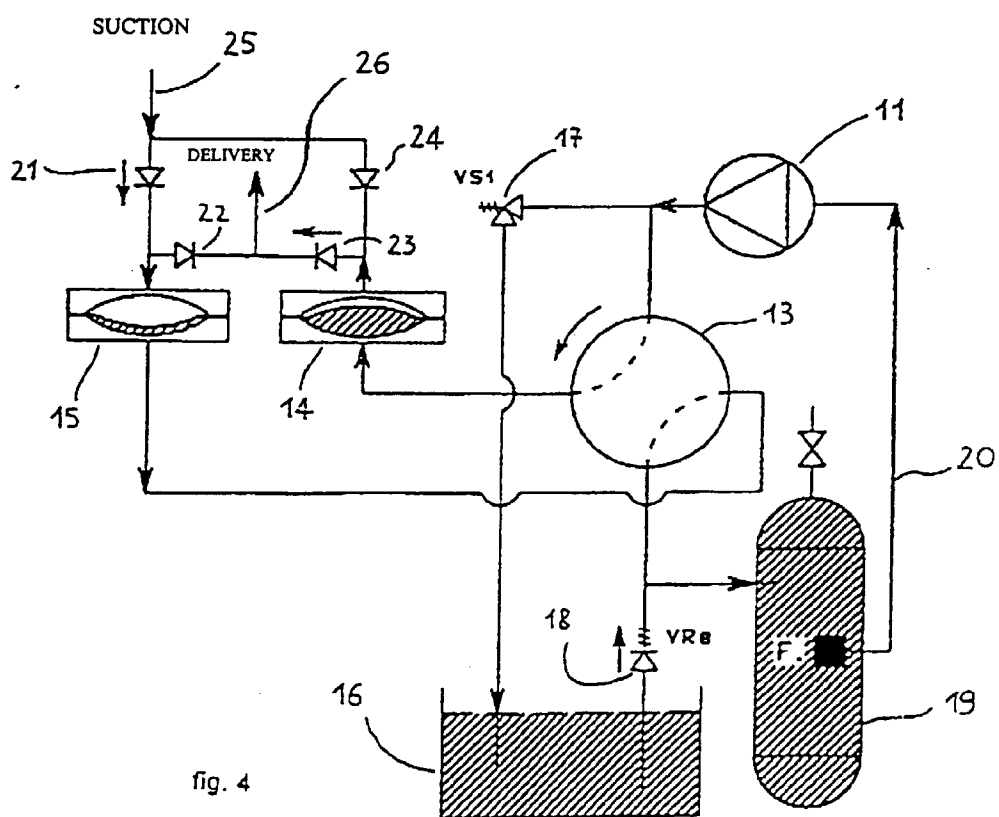


fig. 4

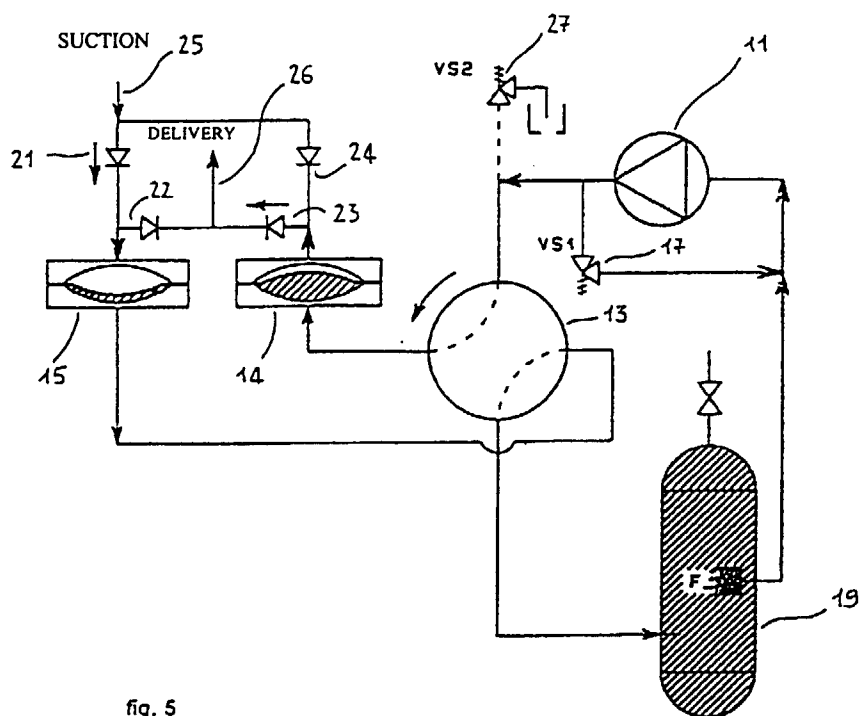


fig. 5

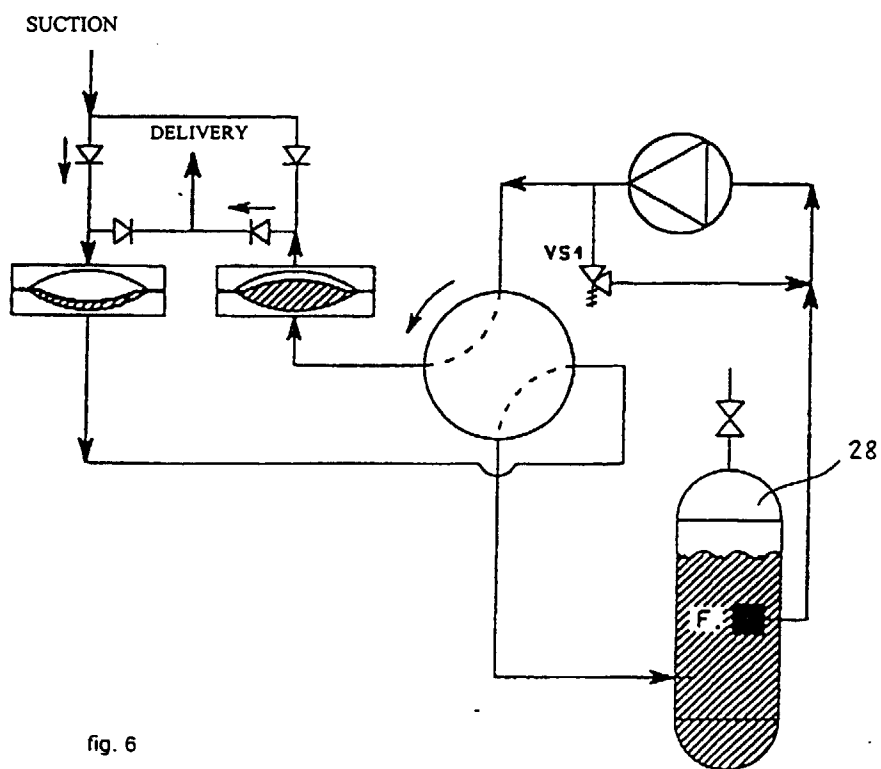


fig. 6

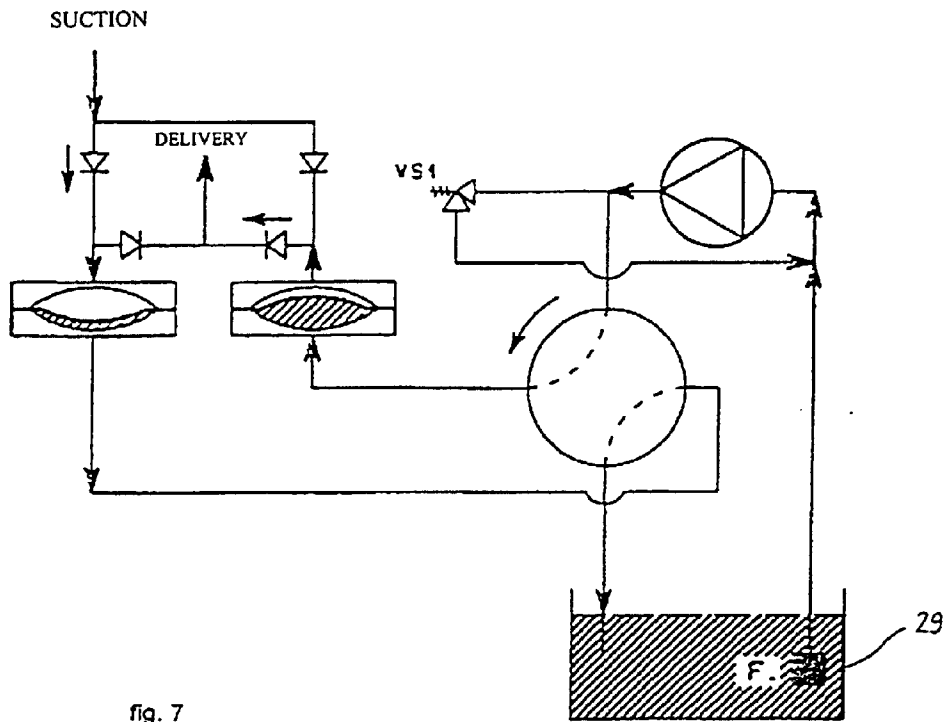


fig. 7

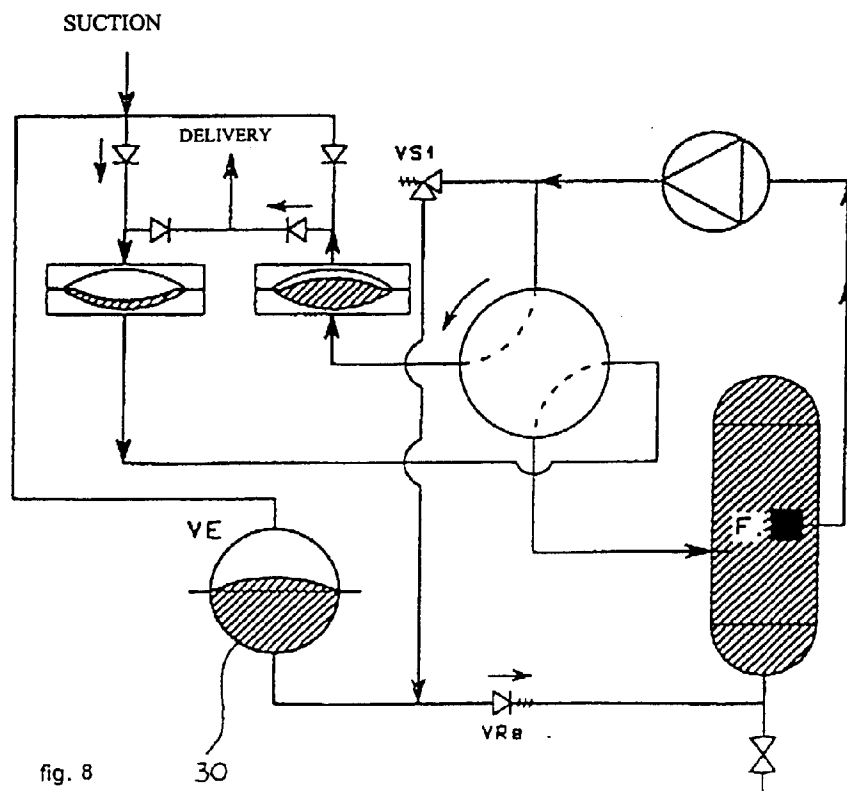


fig. 8

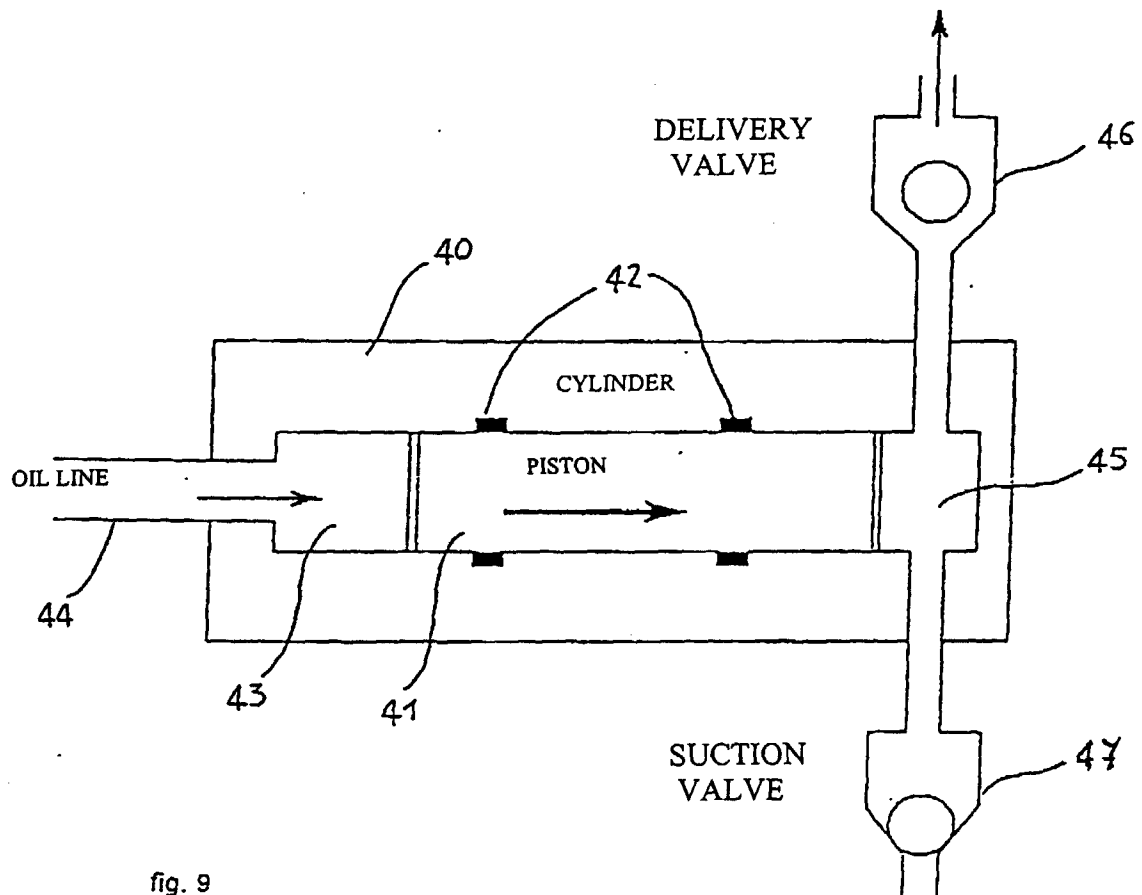


fig. 9