Dec. 6, 1966 E. THIELE 3,289,594

VALVELESS PUMP FOR LIQUIDS

Filed July 8, 1964 4 Sheets-Sheet 1

FIG. 1

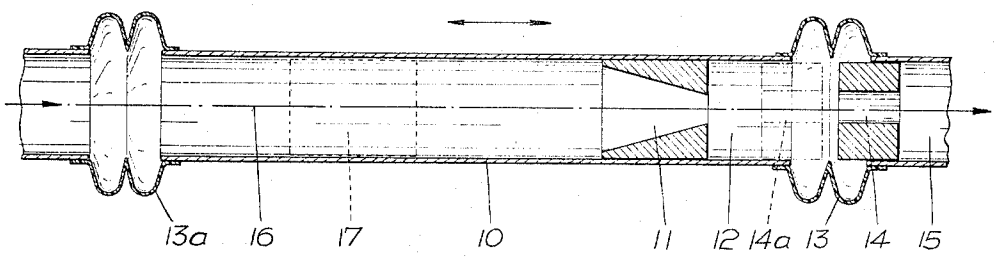
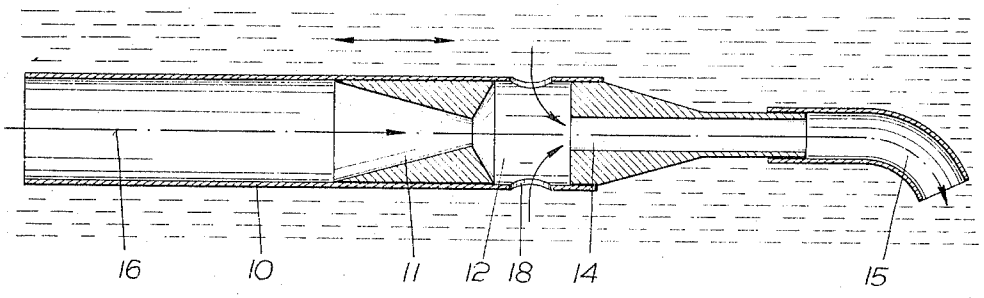


FIG. 2



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VALVELESS PUMP FOR LIQUIDS

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FIG. 3

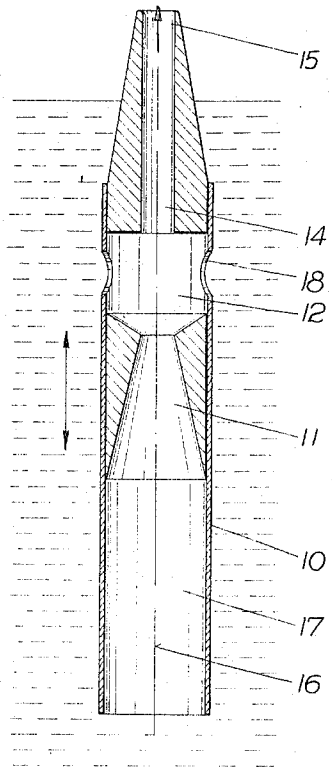
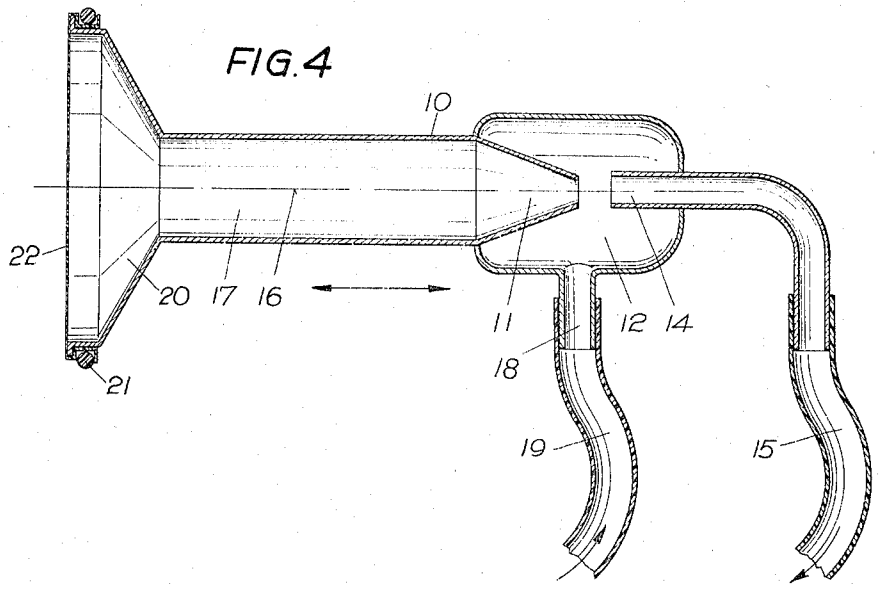


FIG. 4



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FIG. 5

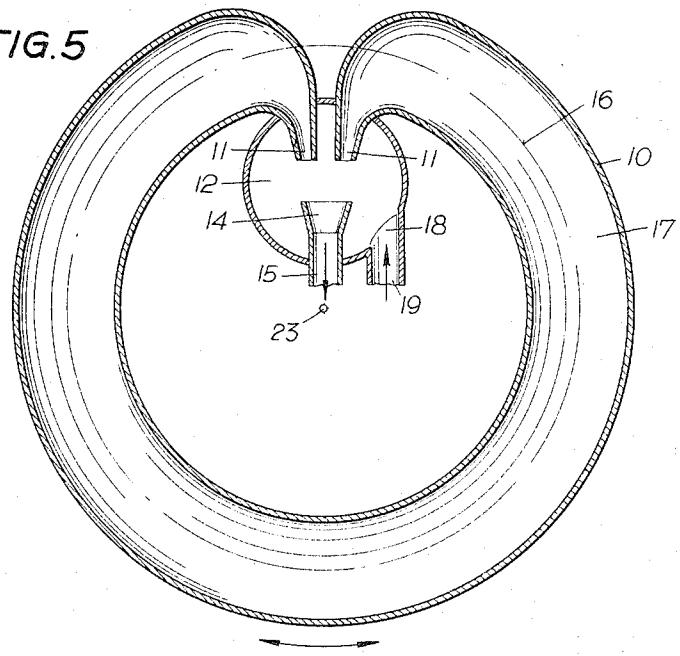
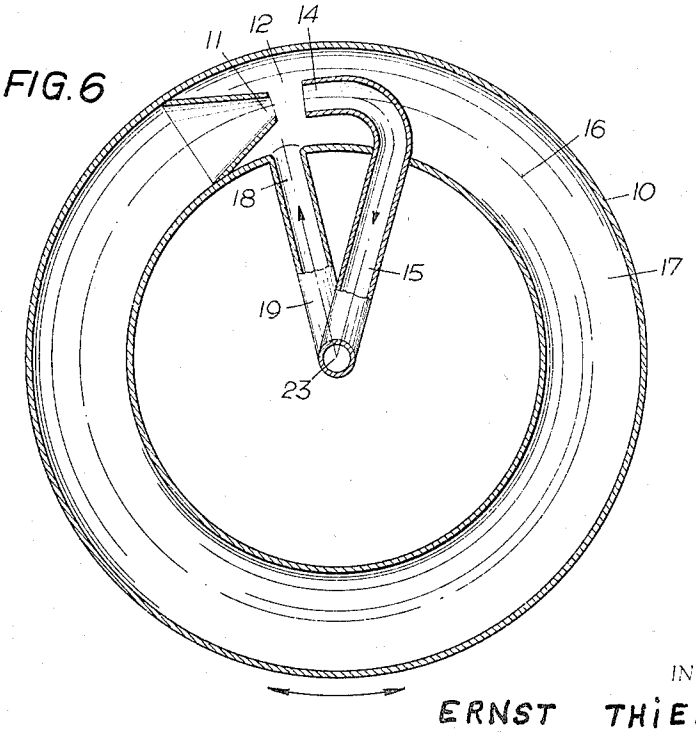


FIG. 6



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FIG. 7

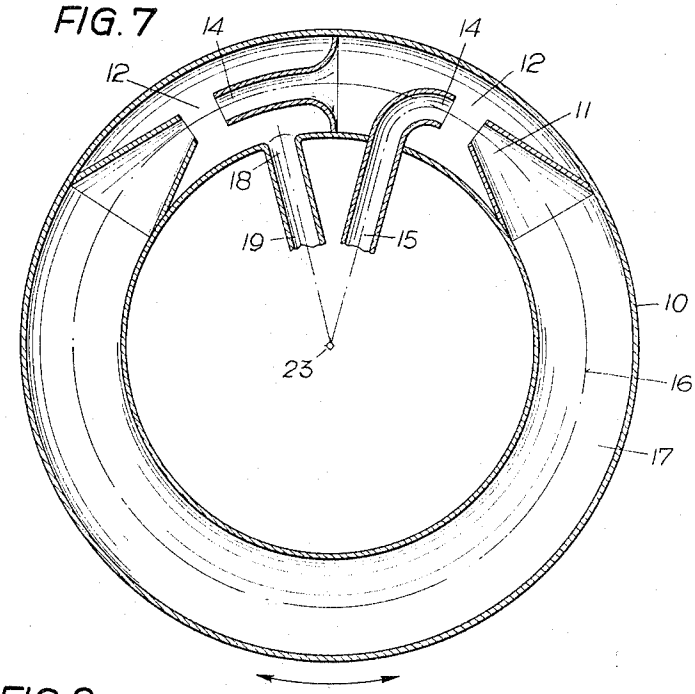


FIG. 8

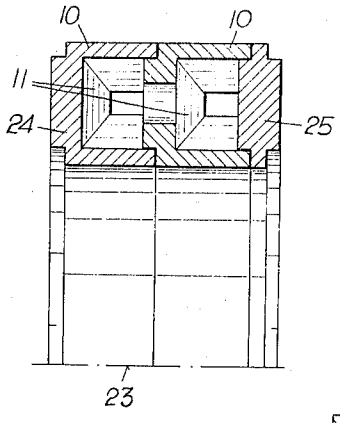


FIG. 9

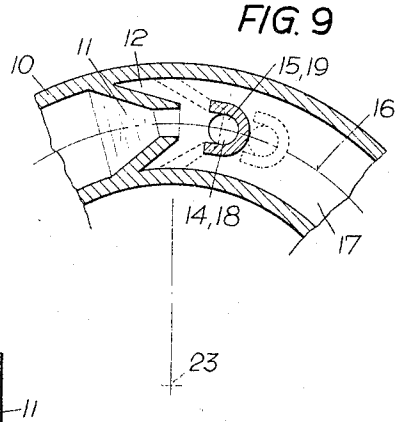
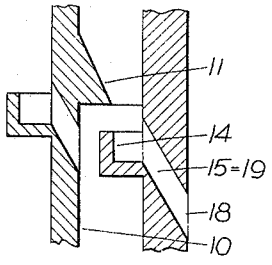


FIG. 10



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3,289,594

VALVELESS PUMP FOR LIQUIDS

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Filed July 8, 1964, Ser. No. 381,157
Claims priority, application Austria, July 11, 1963, A 5,546/63
5 Claims. (Cl. 103—76)

Numerous valveless pumps are known, which have a reciprocating drive including in most cases a diaphragm or a piston which is reciprocated at high speed and forces the liquid to be handled through a nozzle system during a movement of this part at least in one direction. This nozzle system imparts to the liquid a movement in a preferred direction, which is determined by the nozzles. The great disadvantage of all these pump systems resides in that relatively moving parts are required. In a reciprocating piston pump, the piston must be slidably guided in a cylinder and is driven, e.g., by magnetic forces acting through the cylinder wall. For this reason, at least two materials are required, namely, magnetizable materials in the piston and non-magnetizable materials in the cylinder etc. Different materials are also required for the necessary slidable mounting, which involves considerable difficulties. Hence, the two groups of materials must be matched also with a view to their slidability.

The design of such piston pumps does not permit of a free selection of the materials for the members sliding one in the other. Only a highly restricted number of materials, in most cases metals, are available. On the other hand, those members of these pump systems which slide one in or on the other are exposed to the corrosive or otherwise chemically decomposing action of the liquid to be conveyed.

For this reason it has already been attempted to form the pump cylinder and the piston from plastic or to cover them with thin plastic layers. This method also fails to give fully satisfactory results because the manufacture of such members, which are covered, e.g., by injection-molded plastics, involves great difficulties and high costs and because it is not possible in practice to maintain a high resistance to deformation of all plastic parts of these members. For the last-mentioned reason, it is not possible, e.g., to make the pump cylinder entirely of plastic. Because the two relatively moving members must be in slidable engagement, the solution indicated above requires the use of two kinds of plastics, which are compatible in this respect. It is not possible to construct such a pump system from a single kind of plastic, which could be selected with a view to its resistance to the chemical attack by the liquid to be handled. On the other hand, it is hardly possible to select two plastics which meet this requirement because plastics differ greatly in behavior in this respect. The requirement to move the piston only by magnetic forces acting through the cylinder imposes a limitation upon the forces for moving the piston, particularly because the air gaps, which are filled by the plastic layers and the cylinder shell, must be relatively large.

Whereas these disadvantages are only partly encountered in diaphragm pumps, these have still the disadvantage that relatively moving members must be provided, at least one of these members must be reciprocated with substantial deformation and the motive forces act on a point, e.g., at the center of a diaphragm.

Hence, it is a main object of the present invention to provide a pump system, in which the relative movement of the cylinder and the fluid-handling member, which previously consisted of a piston or diaphragm made of solid materials, is entirely eliminated. To accomplish this object, the valveless pump comprises according to

an essential feature of the invention a housing which reciprocates at high speed to impart motion to the liquid contained in this housing so as to handle said liquid, said housing having an inlet and an outlet and being terminated at the outlet end by a nozzle, which is outwardly tapered and ejects a liquid jet during the reciprocating movement of the housing in the direction from the nozzle to the housing, the outlet of said nozzle being adjoined by a cavity, which communicates with a conduit which is opposite to the outlet of said nozzle and receives the liquid jet ejected by the nozzle, said conduit leading to a discharge duct.

According to a further feature of the invention, the housing consists of a pump tube, the conduit for receiving the liquid ejected by the nozzle consists of a jet receiving nozzle, and the pump tube, the ejecting nozzle, the cavity and the jet receiving nozzle have a common system axis.

It is also a feature of the invention that the housing comprises a pump tube bent to form a closed ring and is provided with a supply duct, which discharges laterally into the cavity, and the tubes which form the supply duct and the discharge duct extend to the axis of the ring and are bent to extend in this axis of the ring and form a mounting for the pump system.

Finally, it is a feature of the invention that the inlet duct and the outlet duct are bent to extend in different directions in the axis of the ring and form a torsional suspension for mounting the pump system.

An essential feature of the pump system designed according to the invention resides in that it does not have any relatively movable members and that the motive force can act directly on the outside surface of the pump system. This enables an entirely free selection of the material so that pumps may be made even for most highly aggressive acids or lyes by the selection of a single, suitable plastic for the entire pump system or by forming the entire pump system of glass. This was not possible before and, e.g., chromosulfuric acid was not capable of being pumped at all but only of flowing in glass tubes. The invention does not only afford the above-mentioned functional advantages but the pump systems according to the invention may be made in a single operation in a much simpler manner and at much lower costs than before. Further details of the embodiments of pumps which may be designed within the scope of the invention will become apparent from the following description and from the drawings.

FIG. 1 is a diagrammatic view showing a pump in a section taken along the system axis. This pump causes the liquid to flow through the pump. FIG. 2 is a similar view showing a pump which is open at the rear and entirely disposed within the liquid to be handled. FIG. 3 shows a pump which is similar to the pump shown in FIG. 2 but has a discharge duct which extends into the air and ejects a water jet which is suitable for a fountain. FIG. 4 shows a pump system, which at the tube end remote from hte nozzles is liquid-tightly closed by elastic means. FIG. 5 shows a pump for push-pull operation, both tube ends being terminated by ejecting nozzles. FIG. 6 shows a pump having a tube in the form of a closed ring, which tube contains the nozzle system; just as the pump shown in FIG. 5, this pump performs an angular reciprocation about the axis of the ring. FIG. 7 shows two pump systems arranged in series and comprising a pump tube or the like, which is closed in itself and contains two nozzle systems arranged for push-pull operation. FIG. 8 shows the actual design of a multiple stage pump, in which the several pump elements are formed by interfitting rings, in a sectional view taken on the axis of the ring. FIG. 9 shows the same design in a sectinonal view taken along the system axis and representing only those ring portions which contain the nozzles.

FIG. 10 is a detail view similar to FIG. 8 and shows the design of the transfer ducts leading to the respective adjacent pump element.

In FIG. 1, the pump tube or the like **10** is terminated by an ejecting nozzle **11** extending from the tube. This nozzle opens into cavity **12**. The cavity **12** is preferably formed by an extension of the tube **10** and, in the present case, by a resilient bellows **13**. At the end opposite to the outlet of the nozzle **11**, the cavity is connected to the jet receiving nozzle **14**, which opens into the discharge duct **15**, which is formed by another tube. All pump parts which have been described are symmetric with respect to the system axis **16**. By means not shown, a reciprocation in a direction parallel to the system axis is imparted to the tube **10** and the ejecting nozzle **11**. The liquid column **17** disposed in the tube **10** acts like a reciprocating piston (as is symbolized in dotted lines in FIG. 1). The volume of this column is continuously made up according to FIG. 1 from the inlet side (bellows **13***a*). On the other hand, a part of the volume of this column **17** is ejected through the two nozzles **11** and **14** and the cavity **12** in the direction in which the liquid is to be handled. The handling is effected as a result of the illustrated shape of these nozzles. The fixed nozzle **14** may be replaced by a jet receiving nozzle **14***a*, which follows the reciprocation of the system just as the nozzle **11**.

FIG. 2 shows a pump which is entirely disposed in the liquid to be handled, preferably water, and which has a tube **10** which is open at the end remote from the ejecting nozzle **11**. The remaining parts are designed as in FIG. 1. The bellows **13** and **13***a* are omitted so that the jet receiving nozzle **14** is at a fixed distance from the ejecting nozzle and the cavity **12** is defined by rigid walls (extension of the tube **10**). Inlet openings **18** formed in the tube extension open laterally into the cavity **12**. Hence, the liquid is received through the openings **18** although the tube is open at the rear. During a stroke of the pump system to the right, the inertia of the liquid column defined by the tube **10** causes the liquid entering laterally at **18** to be rearwardly deflected and to flow through the ejecting nozzle **11** into the space enclosed by the tube **10**. During the following stroke of the system to the left, the inertia of the column contained in the tube **10** causes a part of this column to be ejected through the nozzle **11** as a narrow beam jet, which passes through the space **12** and enters the nozzle **14**, from which it is discharged through the duct **15**. In this case the tube **10** serves only to define the liquid column, which has an inertia and which is prevented by the tube from disintegrating by a lateral discharge but acts instead of a piston. The length of the tube must be selected in view of the frequency of reciprocation (shorter tubes are required for higher frequencies than for lower ones). Behind the tube, the liquid can flow freely. There must be a certain fluctuation to the extent of the volume which is displaced by the reciprocating water column. The amount of water or liquid disposed behind the open end of the tube **10** acts only as a resilient buffer for the column contained in the tube and there is no inflow in a handling direction at an appreciable rate through this opening.

The pump shown in FIG. 3 is virtually the same as that of FIG. 2 but discharges in a vertical direction and its discharge duct **15** forms a nozzle for a fountain. This nozzle may be supplemented, e.g., by a multiple nozzle, not shown, which is similar to a showerhead.

FIG. 4 shows an embodiment of the pump system according to the invention in an embodiment in which the only communication to the liquid to be handled is afforded by the supply duct **19**, which feeds the lateral inlet opening **18**. The supply duct **19** and the discharge duct **15** are resilient and consist, e.g., of flexible tubes of rubber or plastic. These tubes are displaced to the right and left to the extent of the amplitude of the reciprocation. The end of the tube **10** remote from the nozzle **11** is closed by resilient means. In the example shown, the tube **10** has an enlarged portion **20** and the open cross-section of this enlarged portion is closed by a diaphragm **22** of sheet rubber or the like. This diaphragm is clamped by a circlip **21**. The length and cross-section of the tube **10** may be selected so that the elasticity of the tube wall is sufficient. In this case the parts **20–22** may be eliminated and the tube itself is capable of taking up the changes in volume which are due to the pulsation.

According to FIG. 5, the tube **10** is curved in the form of a circular ring. Two equal ejecting nozzles **11** are arranged at the two ends of the tube. These two nozzles eject through the cavity **12** into a jet receiving nozzle **14**. Liquid is supplied through the inlet opening **18**, which is connected to the supply duct **19**. Just as in FIG. 4, the supply duct **19** and the discharge duct **15** are connected to flexible tubes, or the like, not shown. The pump system performs an angular reciprocation about its ring axis **23**. The liquid is handled during each stroke through one nozzle during a rotation in one direction and through the other nozzle during a rotation in the other direction so that push-pull operation results. In this embodiment, any movement performed by the system is utilized for handling the liquid, which is sucked from the space **12** through that nozzle **11** which is not ejecting.

FIG. 6 shows a pump system which comprises a tube in the form of a closed ring. In other respects the design is similar to that of the systems described hereinbefore. One difference resides in that the discharge duct **15** connected to the jet receiving nozzle **14** is bent toward the ring axis **23** and extends through the tube **10**, just as the duct **19**. Consisting, e.g., of tubes, both ducts **15** and **19** extend preferably to the ring axis **23** and at this axis are bent to extend in the direction of this axis to opposite sides. These angled tube portions lying in the ring axis have such a length that they can be firmly gripped at their ends and are rotatable through the angles through which the system is reciprocated. The elastic forces of these tube portions may be partly used as restoring forces for the drive means. Alternatively, the angled tube portions may be so short that they can be mounted in rotary bearings and only the subsequent flexible tubes or the like connected to these tube portions take up the torsion or displacement. A different type of rotary mounting may be used for the system so that the ducts **15** and **19** are not utilized for this purpose.

The pump of FIG. 7 is similar to that of FIG. 6. A second nozzle **11**, a second cavity **12** and a second nozzle **14** are provided so that two nozzle systems are obtained, which are connected in series. This enables a higher pressure than a single nozzle system.

FIG. 8 shows a series-connected system composed of individual elements **10** stacked one upon another to form a plurality of coaxial ring-like chambers. Interfitting rings **24**, in which the tubes **10** are formed as annular ducts having, e.g., a rectangular cross-section, may be assembled to form any desired number of pump elements. Each of these elements results in an increase in pressure. The interfitting rings **24** may be made by injection molding from plastic and tightly fit one into the other. They contain also the slot-like nozzles **11** and **14**. Each succeeding interfitting ring **24** forms the cover for the underlying annular duct. FIGS. 9 and 10 show the design of the nozzles **11** and **14** disposed in each ring-like chamber and the layout of the ducts which connect the various stacked chambers. The upwardly inclined ducts **15** and **19** are identical because the discharge duct of one annular duct **10** forms at same time the supply duct for the next annular duct **10**. To avoid the necessity of a right-angled deflection of the jet which enters the respective jet receiving nozzle **14**, because such deflection would generate a high resistance to flow, it is recommended to provide ducts **15** and **19** which extend obliquely through the bottom portions of the interfitting rings **24**. For this reason the individual interfitting rings **24** must be ar-

ranged at a certain angle to each other. This angle is determined by the projection of the oblique ducts. The rings may be assembled without being angularly offset if these ducts are straight. The last ring **24** is tightly closed by a cover member **25** and the stack of rings is connected, e.g., by a screw. The cover member **25** and another member, not shown, contain the discharge duct **15** and the supply duct **19**, respectively. These ducts extend to the ring axis **23** and then extend in this axis, as has been described hereinbefore. It will be readily apparent that in operation of the pump of FIGS. 8–10 the motive and pumped fluids within each ring-like channel move exactly in the manner as in the embodiment of FIG. 6. The liquid jet ejected in one chamber from a nozzle **11** is received in the nozzle **14**, FIGS. 9 and 10, and passes through a duct **15** to the next successive ring-like chamber stacked above. Thus there is a successive pressure build up in the series of ring-like chambers, the system operating with a single inlet duct and single outlet duct connected to the first and last chambers respectively.

The reciprocation of the pump may be effected by any reciprocating motor drive or amplitude-variable electromagnetic drive, which is energized at the frequency of the power supply system and produces a reciprocation at 50 or 100 cycles per second, depending on the design.

It will be understood that the invention is not restricted to the examples which have been mentioned hereinbefore. Within the scope of the invention, other designs of pumps and other materials for the pumps may be used, provided that the entire pump system has the basic form which has been described and is reciprocated at high speed.

What is claimed is:

1. A valveless pump, comprising a pump tube in the form of a closed ring which oscillates about its axis at high speed to impart motion to liquid contained in the tube, said tube having an inlet and an outlet, a nozzle tapered toward said outlet for ejecting a liquid jet during the oscillating movement of the tube in one direction, a cavity adjoining the outlet end of said nozzle, a discharge duct communicating through said outlet with the cavity opposite to the outlet end of said nozzle to receive the liquid jet ejected by the nozzle, a supply duct connected to said inlet to discharge laterally into said cavity, said supply and discharge ducts extending to the axis of the ring and being bent at said axis to extend in the axis and form the mounting for oscillating the ring tube of the pump.

2. A pump for liquid as set forth in claim **1**, wherein said supply and discharge ducts are bent to extend in different directions in the axis of the ring and form a torsional suspension for mounting the pump.

3. A pump as set forth in claim **1** wherein a second nozzle tapered in opposite direction and spaced from the first nozzle is provided in the tube, the space between said first and second nozzles in the tube forming said cavity.

4. A pump as set forth in claim **3** wherein a third nozzle is disposed between said first and second nozzles and arranged to receive is liquid jet from the second nozzle and divert it away from the supply duct and toward the first nozzle.

5. A pump according to claim **1** wherein said tube is formed of a plurality of sections assembled as a stack to form a plurality of coaxial ring-like chambers, a nozzle, a cavity and a jet receiving duct being arranged in each of said chambers, conduits in said sections to convey liquid from each said receiving duct to the adjacent ring-like chamber so as to connect all of the chambers in series, said inlet duct being connected to the cavity of the first chamber and said discharge duct being connected to the receiving duct of the last chamber of said series.

References Cited by the Examiner

UNITED STATES PATENTS

2,508,950	5/1950	Kaplan	103—76
2,829,601	4/1958	Weinfurt et al.	103—76
3,023,708	3/1962	Thiele	103—53
3,103,179	9/1963	Ivanoff	103—76

FOREIGN PATENTS

1,157,507	12/1957	France.

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