Feb. 2, 1971 — B. A. BOYLE — 3,560,114

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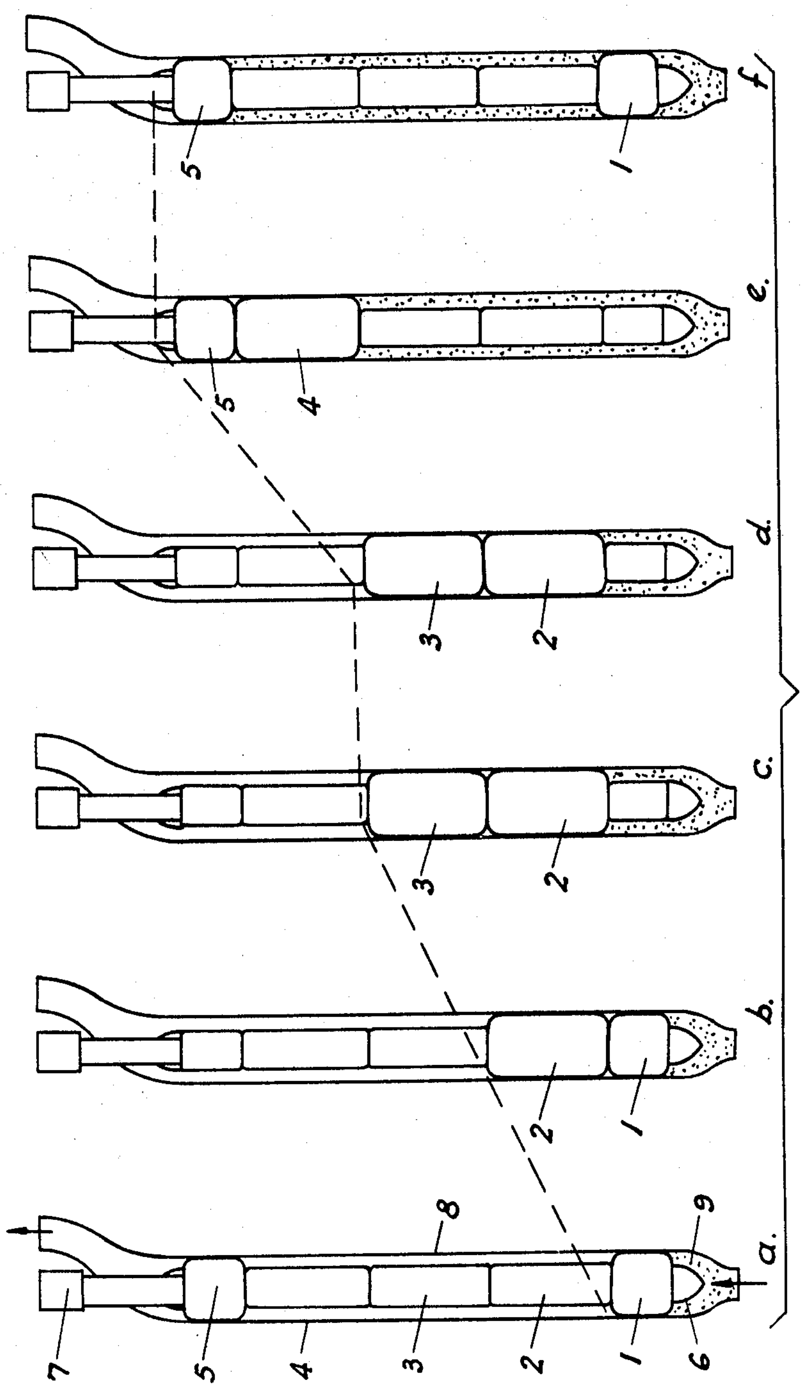

FIG. 1.

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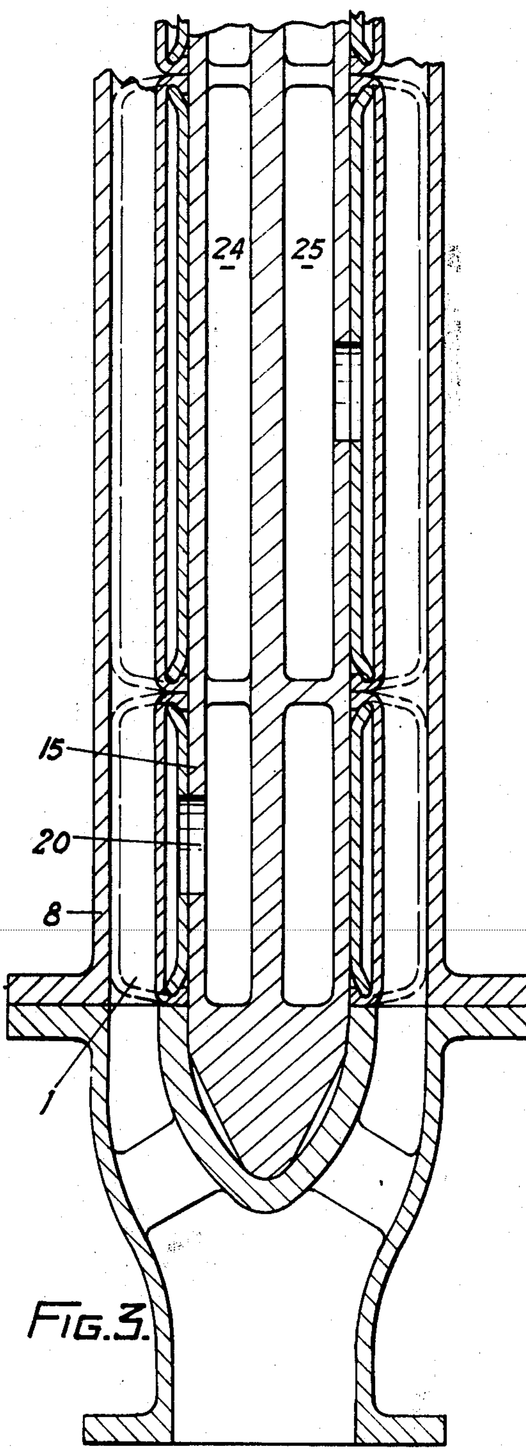


FIG. 3.

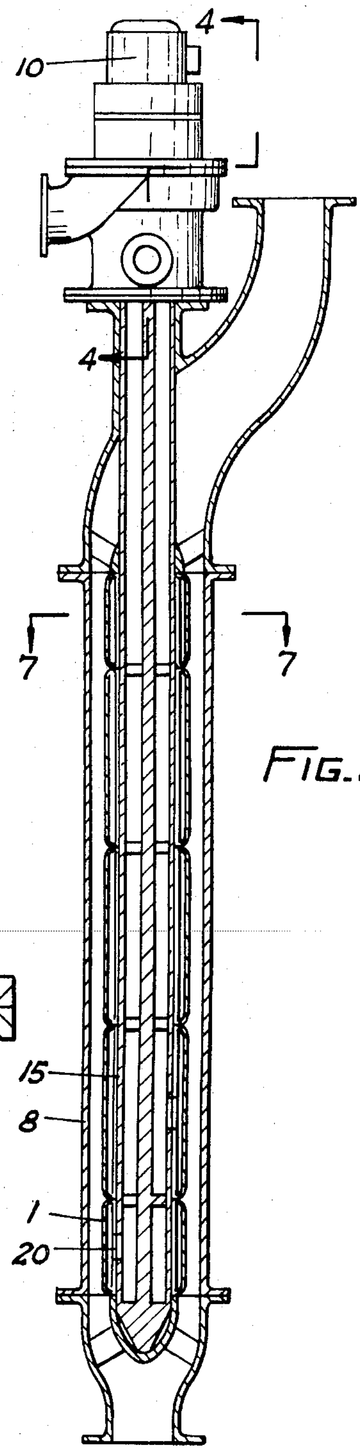


FIG. 2.

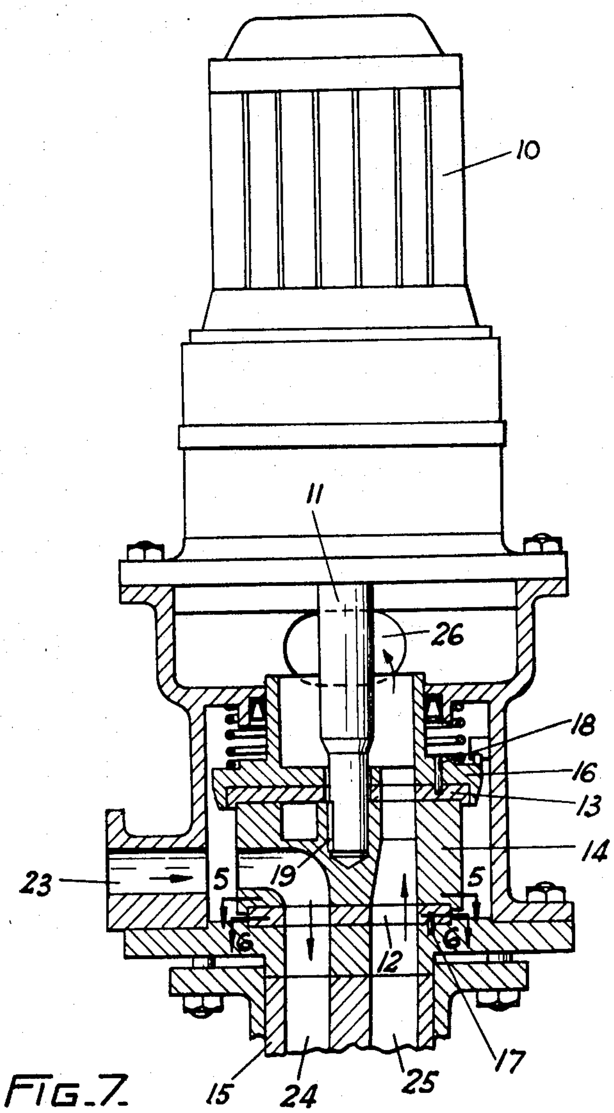


FIG. 4.

FIG. 7.

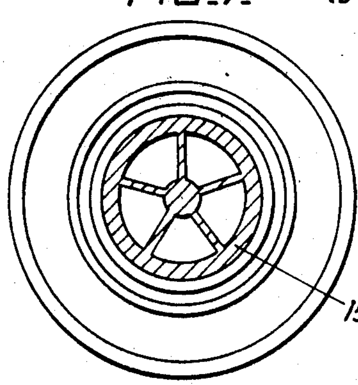


FIG. 6.

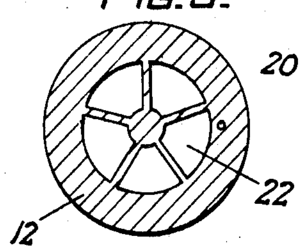
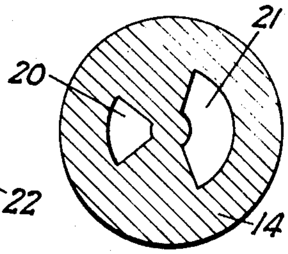


FIG. 5.



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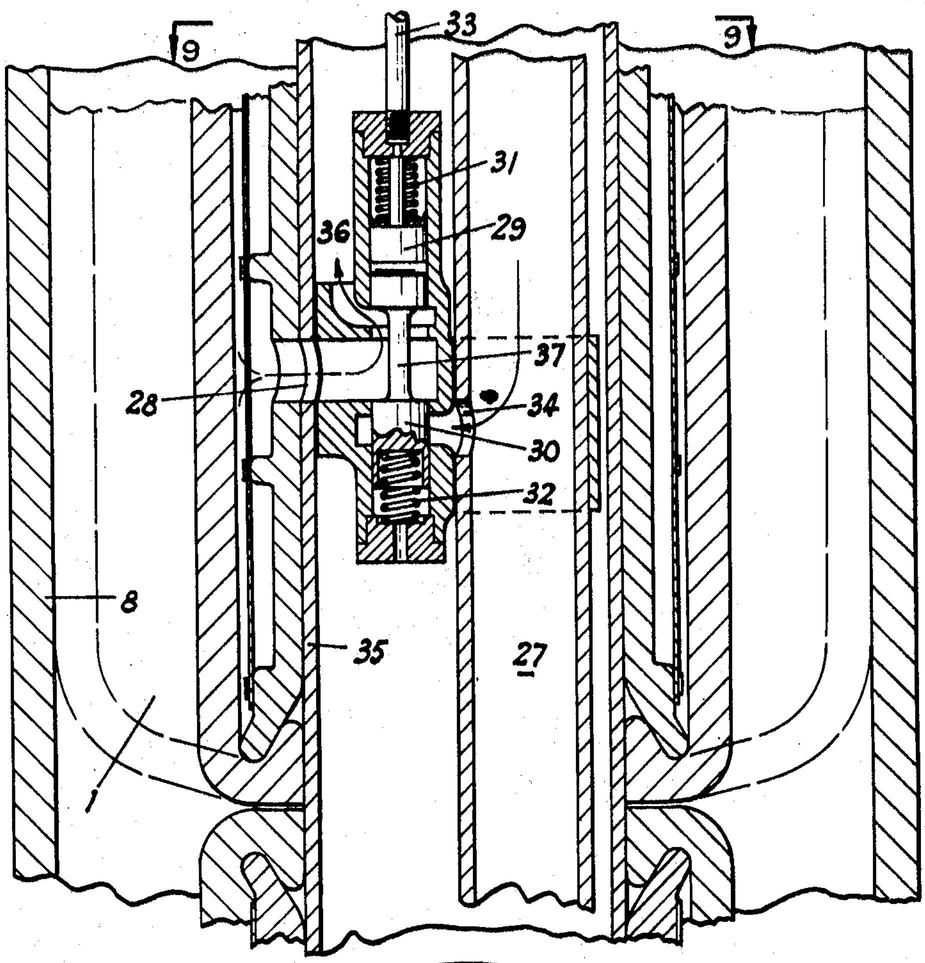

FIG. 8.

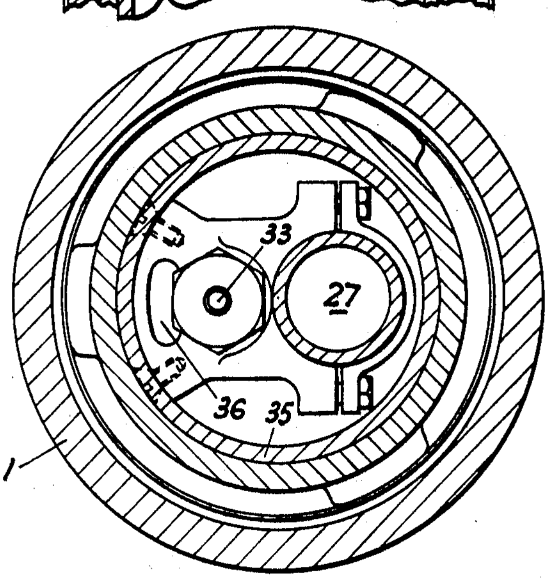

FIG. 9.

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Filed Jan. 28, 1969, Ser. No. 794,744
Claims priority, application Australia, Feb. 6, 1968, 33,166/68
Int. Cl. F04b *17/00*
U.S. Cl. 417—347 7 Claims

ABSTRACT OF THE DISCLOSURE

A pump for pumping slurries or other high viscosity fluids without the use of valves through which the pump fluid is required to pass. The pump has an elongated housing having a plurality of resilient expandible chambers or sacks axially aligned therein. When a chamber is contracted it leaves an annular gap between itself and the interior walls of the housing and when expanded, seals sufficiently tightly against the smooth interior walls so that no valving action is necessary to prevent backflow of the pumped material within the housing.

This invention relates to pumps, and more particularly to so-called slurry pumps adapted for the transmission of high viscosity fluids.

It is known to pump fluids of the above kind by means of centrifugal arrangements but these have suffered from the disadvtnage that there is a limit to the head through which the fluid may be raised, and furthermore, the difficulties of arranging self-priming and positive displacement are increased in the case of high viscosity fluids.

It is an object of the present invention to overcome the above and other disadvantages, and in accordance with the invention therefore, a pump comprises, in combination, at least two expandible pressure chambers enveloped by a close fitting relatively rigid conduit adapted to pass fluid to be pumped through the space between said chambers and the inner walls of said conduit, and a valve arrangement adapted to expand the chambers selectively and sequentially in the direction of the desired flow of said fluid.

Certain particular embodiments of the invention will now be described with reference to the accompanying drawings in which:

FIG. 1 shows, schematically, the sequence of operations in a pump constructed in accordance with the invention,

FIG. 2 shows, in front elevation and partly in section, one particular valve control system for said pump,

FIG. 3 shows, in front elevation and partly in section, a detal of the arrangement of FIG. 2,

FIG. 4 shows, in side elevation and partly in section, a view along the line 4—4 of FIG. 2,

FIG. 5 shows, in plan, a view along the line 5—5 of FIG. 4,

FIG. 6 shows, in plan, a view along the line 6—6 of FIG. 4,

FIG. 7 shows, in plan, a view along the line 7—7 of FIG. 2,

FIG. 8 shows, in front elevation and partly in section, a modified form of the valve control shown in FIGS. 2 and 3, and

FIG. 9 shows, in plan, a view along the line 9—9 of FIG. 8.

Upon referring to the drawings it will be seen that, as best shown in FIG. 1, a number of chambers **1** to **5** is arranged in line so as to terminate in a streamlined protuberance **6** pointing upstream. Said valve arrangement, hereinafter described, comprises a system of tubes

or passages disposed within the chambers so that each tube terminates within a respective chamber and wherein all the tubes lead to a selector unit **7** outside the conduit **8** so that pressure may be applied internally to respective selected chambers from an outside source of pressure as desired.

Alternatively, the control of the chambers may be via a single tube (not shown) adapted to be rotated into register with individual ports each having a different angular disposition about the main axis of the chamber system, in each chamber. Whichever system of control is used, any suitable means may be employed to expand the chambers, for example, compressed air, or oil delivered from a hydraulic accumulator.

In use, the pump commences its operation when, say, the chamber **5** is first expanded by operating the control unit **7** as shown at *a*. The most upstream chamber **1** is then expanded, followed by the expansion of chamber **2** and the simultaneous contraction of chamber **5** as shown at *b*. The chamber **3** is then expanded whilst simultaneously contracting chambers **1** and **5** so that the fluid lying between chambers **1** and **3** tends to move downstream as shown at *c*. This process is repeated sequentially through chambers **1** to **5** in the downstream direction and the continuous flow of at least part of the fluid **9** is ensured by a sufficiency of valve overlap so that one chamber is expanding whilst the next downstream adjacent chamber is contracting and so on. The path of a typical particle of any solid material in said fluid will then be as shown in FIG. 1, in which levels *a* to *f* show the following respective degrees of valve travel:

	Degrees
a	0
b	72
c	144
d	216
e	288
f	0

In the embodiment of the control unit shown in FIGS. 2 to 7, a motor and suitable reduction gear housed within the casing **10** is adapted to rotate the shaft **11** and thus in turn the valve block **14** with respect to the inlet port plate **12** and the exhaust port plate **13**. The two last-mentioned plates are fixed with respect to the casing **15** and the support member **16** by means of the respective dowels **17** and **18**. The shaft **11** is attached to the valve block **14** by means of the key **19**.

Thus, the respective inlet and exhaust ports **20** and **21** in the block **14** are brought into register at appropriate times with apertures such as **22** in the inlet port plate **12**, thereby controlling the flow of a continuously available supply of fluid admitted through the port **23** down through the pipe **24**, up through the pipe **25**, and out through the exhaust port **26**. Thus a selected one of the chambers, such as **1**, may be caused to inflate via a port such as **20** by controlling the admission of control fluid thereto by means of an appropriate pair of pipes such as **24** and **25**. The valve block **14** is, of course, capable of being brought into registration with other apertures in the inlet port plate **12** and also the exhaust port plate **13** so as to bring the control fluid to the ports of other chambers in accordance with the cycle of events dictated by the rotation of said motor.

A modification of the invention is shown in FIGS. 8 and 9 which illustrate an arrangement suitable for use in heavy duty pumps. Here, a supply of control fluid is maintained under pressure in the pipe **27**. Each chamber (in this case chamber **1**) is provided with a port such as **28** which communicates with a pair of piston type valves **29** and **30** under the control of the respective springs **31** and **32**. An additional supply of control fluid may be admitted via the duct **33**. In the position of the piston valves shown, the pipe **27** is cut off from the chamber **1** because the port **34** is closed whilst the port **28** in the wall **35** is in communication with the exhaust exit **36**. Upon now applying fluid under pressure via **33** the valve **29** and **30**, which are connected by the stem **37**, will move down against the influence of the spring **32**, thus closing the exhaust exit **36** and opening the port **34**, so that it communicates with the port **28**, and hence with the interior of the chamber **1**, which begin to inflate. Upon removing the fluid pressure at **33** the spring **32** (which over-rides the spring **31**, which is merely present for the purpose of stability) pushes the valves **29** and **30** upwards again until the port **28** is again open to the exhaust exit **36** whilst also closing the port **34**, and again the chamber **1** commences to deflate.

Thus, in the last-mentioned embodiment of the invention, it is merely necessary to supply an external cyclic device connected to a plurality of ducts such as **33** to enable a set of valves such as **29** and **30** to be sequentially brought into play according to a preset pattern of the kind above described with reference to FIG. 1.

It will be seen that apparatus constructed in accordance with the invention comprises a positive displacement, self-priming, valveless pump of a kind which has a substantially unlimited total lift because individual pumping actions take place only through increments of the total head through which pumping occurs. The increments may be made suitably small, depending upon the rate of flow required and the dimensions of the chambers and their spacing from the enveloping conduit. In this respect it will be seen that it is not necessary for the system of chambers and/or the conduit to be disposed in a straight line, provided that the space between the inner walls of the conduit and the outer walls of the chambers is sufficient to allow unimpeded flow.

It is desirable that the outer walls or surfaces of the chambers and also of the necessary relatively rigid joints therebetween should be given a smooth surface such as a coating of neoprene or other suitable substance which has both self-lubricating properties and is also substantially inert chemically with respect to the material to be pumped.

Among the advantages of the invention are the following:

(1) The discharge head is proportional to the operating pressure of the control fluid less a small amount which is the pressure required to fully expand the chambers which may, for example, be constructed from tough but flexible material such as rubber or the like. The energy required to supply the fluid pressure is recoverable as suction lift as the chambers are opened to exhaust. To increase this suction lift the walls of the chambers may be prestressed on installation to give a higher stress of deformation.

(2) The annular area between the relaxed walls of the chambers and the conduit is sufficient to allow the passage of solids. If, within the cycle of operations, a solid object or particle is trapped by the expanding chambers against the conduit, the rubber or other walls of said chambers tend to form a seal around the object thus enabling the pumping cycle to continue with little or no back flow.

(3) High viscosity fluids and slurries can be pumped effectively even though the walls of the chambers do not completely expand to the region of the conduit when passing such materials. Nevertheless a mass flow effect is achieved with a continuity of action from suction to discharge.

(4) The direction of pumping may be reversed simply by changing the direction of rotation of the valve timing

shaft **11** (in the embodiment of the invention illustrated in FIGS. 2 to 7).

(5) The displacement of the pump can be varied simply by changing the speed of the valve timing means.

(6) The pump may be completely submerged within liquids. For this purpose the construction details of the pump may be varied. For example, the valves may be mounted upon an air supply pipe which passes internally through each membrane, and preferably each valve is located adjacent to its membrane so that pressure losses are minimised. Such valves may be operated by oil columns from a cam shaft timing device mounted above the level of the liquid in which the pump is immersed. This last-mentioned arrangement is especially applicable to large sized pumps where the air losses is distribution passages through the axial region of the pump could otherwise be excessive.

Applications suitable for pumps constructed in accordance with the invention include:

(a) The de-watering or clearing of foundations or sumps where water contains a high percentage of solids.

(b) The pumping of sewerage sludge or the removal of sediments from tanks and reservoirs, drainage channels and irrigation canals.

(c) As a reversible pump in the control or conduct of industrial processes, especially those involving high viscosity liquids or slurries having a high percentage of solids up to 60% by volume or bearing high density particles or in which corrosive liquids must flow.

(d) For the transport of solids by pipeline. In such applications it is merely necessary to add a sufficient proportion of liquid such as water to ensure transport, and the suspended solids are not impeded by mechanical valves or rotating seals.

(e) Dredging operations in which the pump may be mounted in a dredge ladder with the suction inlet of the pump located behind the dredge cuter. As the depth of dredging increases, the output of solids from said pump tends to rise so that the hydrostatic head outside the suction inlet acting in conjunction with the pump's suction head tends to force the solids into the pump. This is in contrast with the action of common centrifugal pumps in which the available suction power gradually falls off with increasing depth.

(f) The exploitation of off-shore mineral deposits wherein the pump may be mounted in a submergible "Sub-Aqueous Miner" such as that which is the subject of our co-pending Australian application No. 37225/68. In this application of the invention the pump, when working at depths below approximately 50 feet of seawater, is able to return its exhaust air to boost the intake of an air compressor which supplies said air to the miner. Thus, nearly the entire static head of immersion of the pump is recoverable as air pressure boost to the suction of said air compressor. This boost represents a saving in compressor intake dimensions together with a lowering of its power requirements.

I claim:

1. A pump for pumping slurries and high viscosity fluids comprising:

(a) an elongated cylindrical housing having smooth interior walls;

(b) at least two expandible pressure chambers axially arranged within said housing, each chamber having flexible resilient walls being sufficiently expandible to sealingly engage said interior walls inflated and sufficiently resilient to leave an annular gap between said chamber and said wall when unpressured;

(c) pressure source means to furnish a fluid under pressure to expand said chambers;

(d) a plurality of internal passages each connecting a chamber with said pressure source means;

(e) control means between said pressure source means and said passages to selectively expand said chamber in a predetermined sequence to pass fluid to be pumped sequentially through said annular gap from one chamber to the next.

2. A pump as claimed in claim **1** wherein said interior walls are coated with neoprene.

3. A pump as claimed in claim **1** wherein said interior walls are coated with a corrosion and abrasion resistent lining.

4. A pump as claimed in claim **1**, wherein said fluid under the influence of said control means comprises compressed air or oil delivered from a hydraulic accumulator.

5. A pump as claimed in claim **1** wherein said chambers are arranged in line so as to terminate in a streamlined protuberance pointing upstream.

6. A pump as claimed in claim **1**, wherein the most downstream of said chambers is adapted to be expanded first by fluid delivered from said control means and wherein the most upstream chamber is then expanded, followed by the expansion of the next downstream chamber and the simultaneous contraction of the most downstream chamber and wherein the next chamber downstream is adapted to be then expanded whilst simultaneously contracting the first or most upstream chamber so that fluid

lying between the first and third chambers tends to move downstream.

7. A pump as claimed in claim **1**, wherein the action of said chambers is adapted to overlap so that one chamber is expanding whilst the next downstream adjacent chamber is contracting.

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U.S. Cl. X.R.

417—395, 474, 486, 900