PNEUMATICALLY ACTUATED PUMP AND SAMPLING SYSTEM

Filed Sept. 13, 1957 5 Sheets-Sheet 1

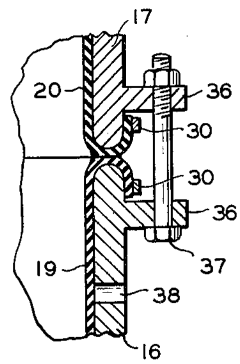

FIG. 3.

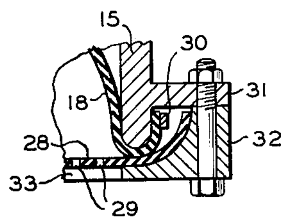

FIG. 2.

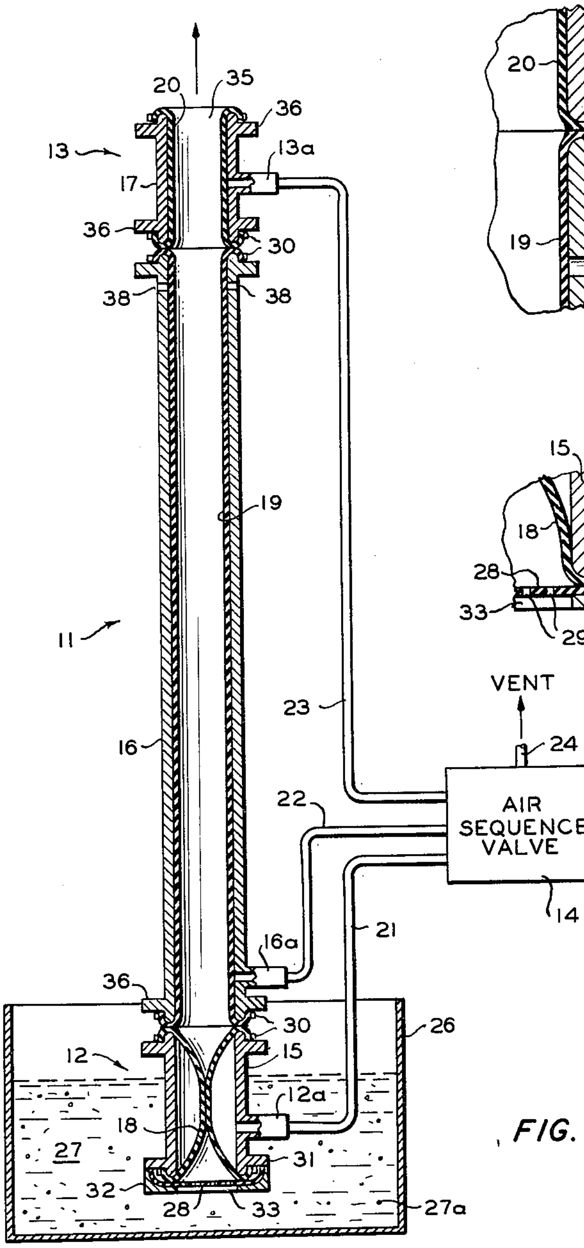

FIG. 1.

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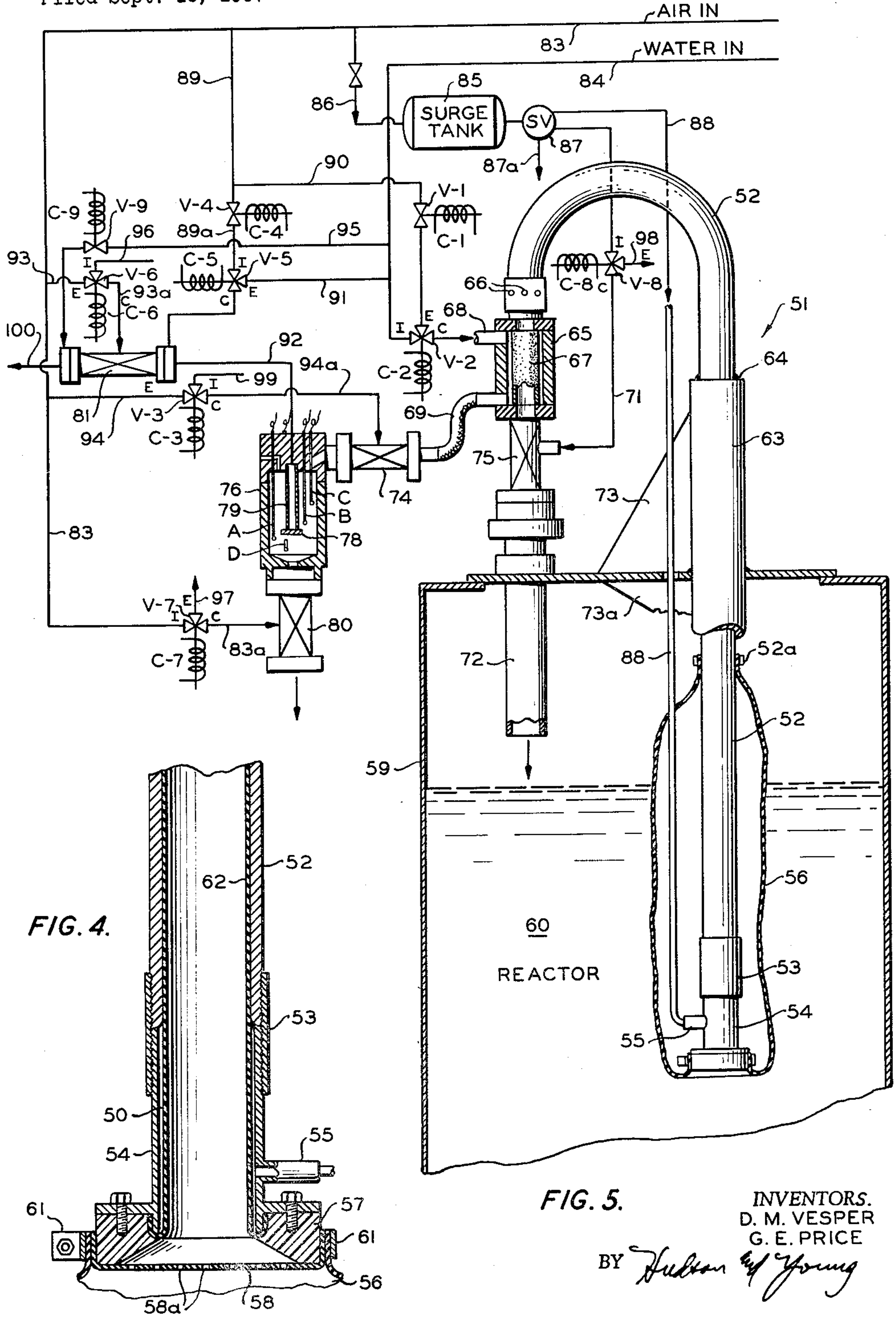

FIG. 4.

FIG. 5.

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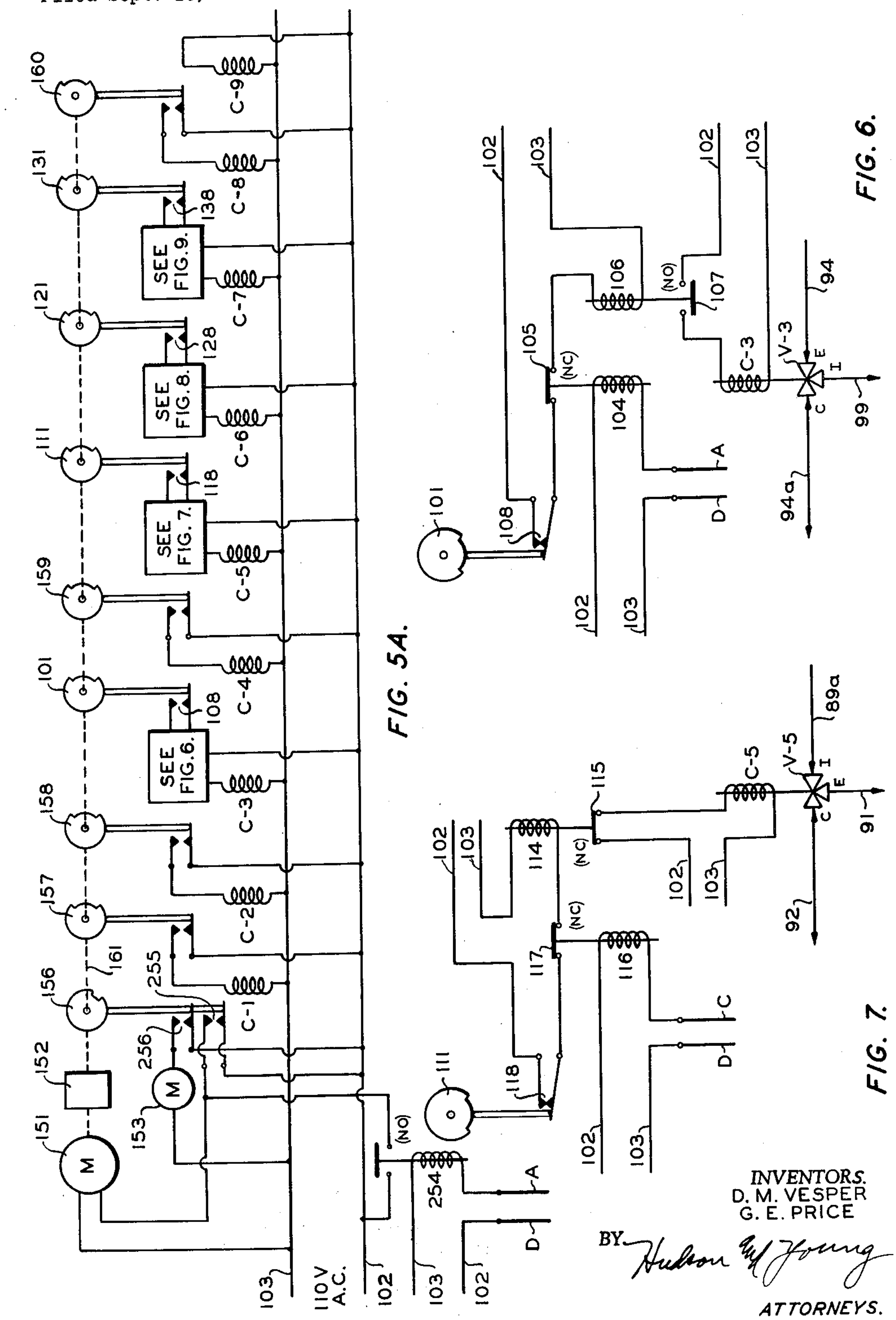

FIG. 5A.

FIG. 6.

FIG. 7.

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PNEUMATICALLY ACTUATED PUMP AND SAMPLING SYSTEM

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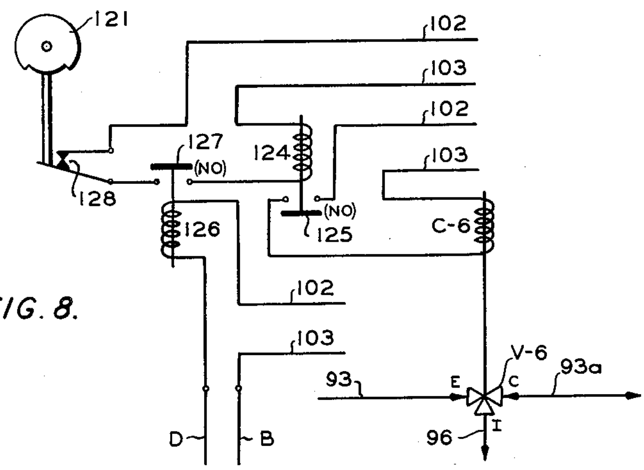

FIG. 8.

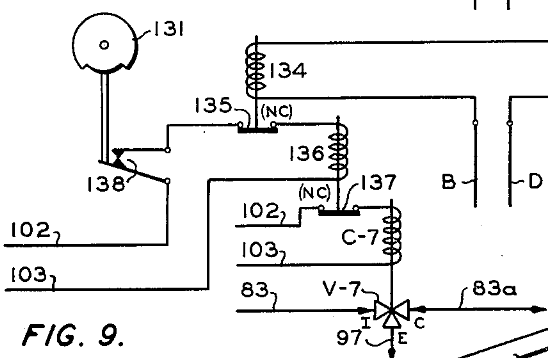

FIG. 9.

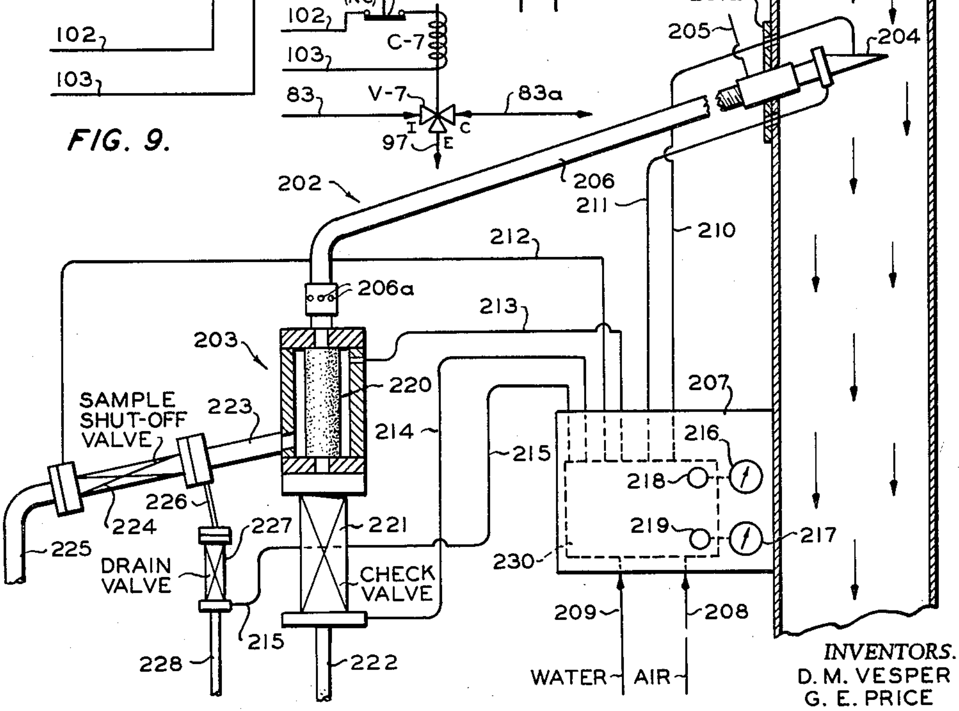

FIG. 10.

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PNEUMATICALLY ACTUATED PUMP AND SAMPLING SYSTEM

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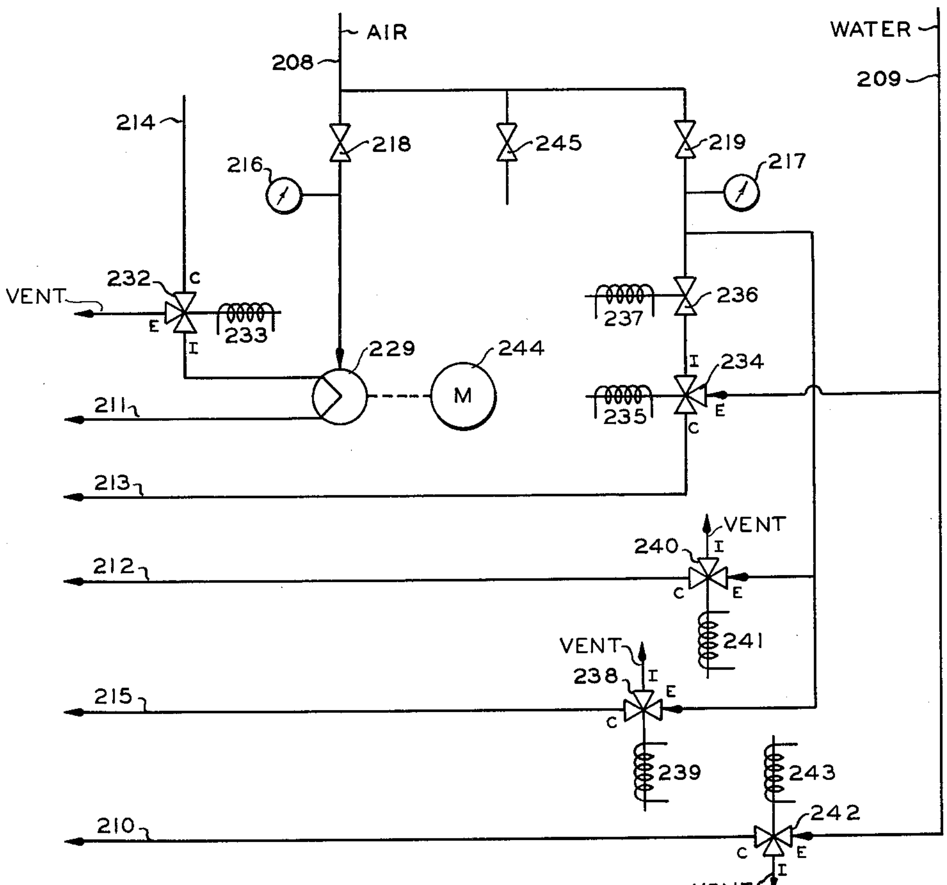

FIG. 11.

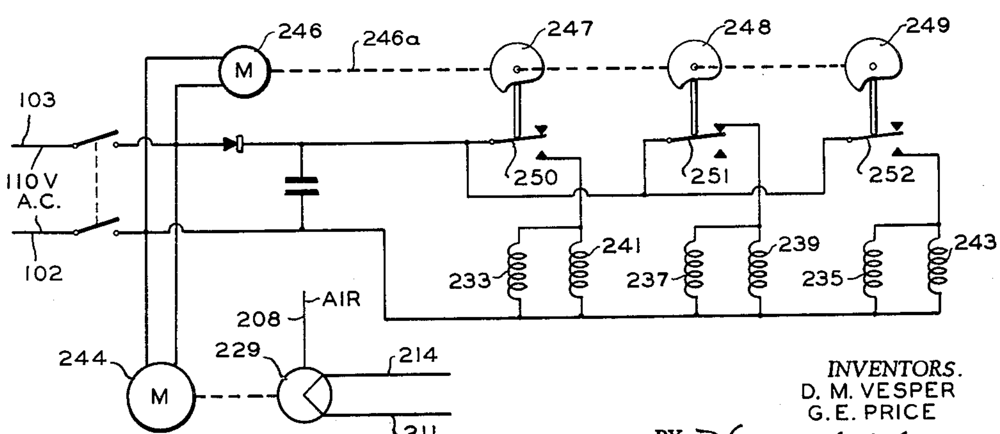

FIG. 12.

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PNEUMATICALLY ACTUATED PUMP AND SAMPLING SYSTEM

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Filed Sept. 13, 1957, Ser. No. 683,877
15 Claims. (Cl. 73—421)

This invention relates to a pneumatically operated pump. In one aspect it relates to systems employed in the sampling of liquids in which our pneumatically operated pump is employed.

The pump of this invention has special application in the pumping of small volumes of liquid which normally corrode metals of which pumps are usually made. The pump is also adapted to pump liquids containing solid materials, and is particularly adapted to pump slurries.

Broadly speaking, our pump is made of a rigid tubular member, such as a metal pipe or tube, in which is disposed a tight fitting flexible tube or hose. The tube or hose is slightly longer than the encasing rigid tubular member or pipe so that the tube or hose can be rolled back over the end of the encasing member. Valves are made in the same manner and such a valve is joined to the pump by flanges, clamps, etc., then provides a continuous flexible, corrosion resistant lining. Corrosive materials pumped do not contact metal parts. These valves are herein termed flexible tube or flexible hose valves.

One application of our pump is its use in a sampling system for phosphate analysis in which a slurry was withdrawn with our pump from a vessel in which a dilute aqueous phosphoric acid solution, water, finely ground phosphate rock and sulfuric acid were reacted. This sampling system involves withdrawing the sample of slurry from a launder, filtering solid material from the reaction mixture and passing the filtrate to a phosphate (P_2O_5) analyzer. The filter and connecting pipes or tubes are washed, then blown with air so as not to dilute the next quantity of sample. In another instance, sampling of the above-mentioned reaction mixture and for sulfate ion analysis, in addition to filtering the slurry, a predetermined volume of filtrate is passed to a dilution vessel, and an equal or other predetermined volume of water is added to dilute the acid filtrate, and the diluted filtrate is then passed to a sulfate ion analyzer. Only a small portion of the slurry transferred by a single pump stroke is used for analysis, the remainder being rapidly flushed through the filter vessel to clean the filter. The filter vessel and the sample dilution vessel are water washed, then blown with air for removal of water after each sampling cycle so as not to dliute the next successive sample.

One object of our invention is to provide a pump for transferring small volumes of corrosive liquids.

Another object of our invention is to provide a pump for transferring liquids containing solid matter, such as slurries.

Still another object of our invention is to provide such a pump which is not abraded or otherwise eroded by pumping liquids containing solids.

Yet another object of our invention is to provide such a pump which is inexpensive to manufacture and to maintain.

Still another object of our invention is to provide a pump which finds utility in commercial manufacturing operations for sampling corrosive and erosive slurries.

Still other objects and advantages of our invention will be realized upon reading the following disclosure and drawing, which, respectively, describes and illustrates preferred embodiments of our invention.

In the drawing:

FIGURE 1 is an elevational view, partly in section, of one embodiment of our invention.

FIGURE 2 is a portion of FIGURE 1 on an enlarged scale.

FIGURE 3 is another portion of FIGURE 1 on an enlarged scale.

FIGURE 4 is an elevational view, partly in section of another embodiment of our invention.

FIGURE 5 is an elevational view, partly in section, of still another embodiment of our invention.

FIGURE 5A is a diagrammatic illustration of a portion of our invention.

FIGURES 6, 7, 8 and 9 are diagrammatic representations, in detail of portions of FIGURE 5A.

FIGURE 10 is an elevational view, partly in section, of another embodiment of our invention.

FIGURE 11 is an illustration, in detail, of a portion of FIGURE 10.

FIGURE 12 is an illustration, in detail, of another portion of FIGURE 10.

Our invention specifically comprises a fluid operated pump comprising, in combination, an elongated rigid tubular member, a flexible tubular member disposed within and throughout the length of said rigid member, said flexible member tightly fitting said rigid member, corresponding ends of the rigid tubular member and the flexible tubular member being joined to each other fluid-tight, an opening in the wall of said rigid member near one end thereof for inlet and outlet of pump operating fluid, and a vent in the wall of said rigid member near its other end for outlet of said operating fluid.

Our invention further comprises a fluid operated pump assembly comprising, in combination, an elongated first rigid tubular member, a second rigid tubular member, one end portion of said second rigid tubular member being disposed fluid-tight to one end portion of said first rigid tubular member, said first and second rigid tubular members being disposed along a common axis, a flexible tubular member of uniform inner and outer diameters being disposed within and throughout the combined lengths of said rigid members, said flexible tubular member tightly fitting said first rigid tubular member, the inner diameter of said second rigid tubular member being greater than the outer diameter of said flexible tubular member thereby providing an annular space therebetween, the ends of said flexible tubular member being disposed fluid tight to the ends of said rigid tubular members adjacent the ends of said flexible tubular member, an opening in the wall of said second tubular member for passage of pump operating fluid, and a vent in the wall of said first rigid tubular member near the end thereof remote from said second rigid tubular member.

While we have herein disclosed our pump as being pneumatically operated, as by air pressure, it is within the scope of our invention to employ a liquid, such as water, in place of air or other gas, for operating the pump and valves.

Referring now to the drawing and specifically to FIGURE 1, reference numeral 11 identifies a pump while reference numerals 12 and 13 identify a lower or inlet valve and an upper or check valve, respectively. Pump 11 comprises a rigid tubular member 16 in which is disposed a flexible tube 19. In one instance flexible tube 19 was a rubber tube which fitted snugly or tightly inside tubular member 16. The ends of the rigid tube or tubular member 16 are preferably so formed that the ends of the flexible tube or flexible tubular member can be inverted or rolled back over the preformed ends of tubular member 16. However, if desired, the ends of the rigid tubular member 16 can be special flanges bolted or otherwise attached to the ends of the tubular member. In any event is is preferable that the effective ends of the tubular member 16 be rounded as illustrated in the FIGURE 1 so that the ends of the flexible tube can be rolled back as illustrated. These rolled back tube ends are held tightly in place by clamps 30 or by other suitable means, as desired. The lower or inlet valve 12 is constructed substantially the same as pump 11 excepting it is much shorter. The valve comprises a rigid tubular member 15 having an upper end generally similar in form to the lower end of the tubular member 16 and contains a flexible tubular member 18 with end rolled back over the ends of the encasing tube 15. The lower end of tubular member 15 is, in general, similar to its other end. Check or discharge valve 13 is more or less similar to valve 12 and comprises a rigid tubular member 17 in which is disposed a flexible tube 20 with ends rolled back similar to those mentioned relative to pump 11. The valves 12 and 13 are provided with openings 12*a* and 13*a* to which are attached, respectively, conduits 21 and 23 for inlet and outlet of actuating fluid. Tubular member 16 is also provided with a connection 16*a* near its lower end as illustrated. The particular positioning of connections 12*a* and 13*a* is more or less immaterial since the corresponding valves are relatively short. However, connection 16*a* to tubular member 16 is positioned at a point near its bottom or inlet end so that actuating fluid from a conduit 22 is introduced into tubular member 16 at a point near the pump inlet. Clamps 30 are employed to attach the ends of the flexible tubes to the rigid tubes of the valves as well as to attach the ends of tube 15 to the rigid tube 16 of the pump. The lower end of valve 12 is protected from entry of large-size, solid matter by a flexible strainer or perforate membrane 28. In one instance this perforate membrane was made of rubber or a synthetic elastomer perforated with openings of about ⅛ inch diameter. These perforations are identified by reference numeral 29 (FIG. 2). This strainer 28 is held in place against the bottom end of valve 12 by a strainer clamp 32 attached to flange 31 at the lower portion of the tubular member 15. This strainer clamp 32 is constructed, preferably, of a plastic or other corrosion resistant and nonabradable material.

FIGURE 2 illustrates the arrangement of strainer clamp 32 with respect to flange 31 on an enlarged scale. Reference numeral 33 identifies an opening in the strainer clamp or flange 32 for inlet of liquid to valve 12.

FIGURE 3 illustrates on an enlarged scale one method of attaching one end of a valve to one end of the pump and this particular illustration shows the connection of the upper end of pump 11 with the lower end of valve 13 with clamps 30 holding the rolled back ends of flexible tubes 19 and 20 to the ends of the respective rigid tubular members 16 and 17. Flanges 36 are bolted with bolts 37, as shown.

Near the upper end of pump 11 there are provided one or more vents or openings 38 in the walls of the tubular member 16. An air sequence valve 14, which is a motor driven valve, is illustrated in communication with conduits 21, 22 and 23. The sequence valve 14 is provided with a conduit 25 for inlet of pump actuation air, from a source not shown, and with a vent 24 for exhaust of

air as required. We have illustrated the pump assembly of FIGURE 1 with its lower end immersed in a body of liquid 27 containing suspended solids 27*a* disposed in a vessel 26. Reference numeral 35 identifies the discharge end of the pump assembly.

Air sequence valves such as valve 14 are obtainable from instrument supply houses and the actual construction of such a valve will, therefore, not be given in detail. In operation of this peristaltic type pump this sequence valve 14 admits air under pressure to conduit 21. This pressured air collapses the flexible tube 18 in such a manner as to provide a seal against flow of fluid in any direction through valve 12. Thus valve 12 is closed. With valve 12 remaining closed the air sequence valve admits air under pressure through conduit 22 to the lower portion of pump 11 and the corresponding lower portion of the flexible tube 19 is collapsed first. Upon further admission of air under pressure through conduit 22, flexible tube 19 is progressively collapsed in an upward direction until such time as the entire tube is collapsed. At about the time the upper portion of tube 19 becomes collapsed the air sequence valve 14 admits air under pressure through conduit 23 to the upper valve 13 until this valve is closed. The operation of this valve is exactly like that explained relative to valve 12. About the time valve 13 is fully closed the air between flexible tube 19 and the inner walls of tubular member 16 reaches vents 38, and the air is vented therethrough. The air sequence valve also operates to release air from pump 11 and from valve 12 through conduits 22 and 21, respectively, this air being vented from the air sequence valve through vent 24. Upon venting of air from the space between flexible tube 18 and the inner walls of tubular member 15, valve 12 is opened and the venting of air through conduit 22 and vents 38 of pump 11 permits flexible tube 19 to become fully opened. With valve 13 closed, as previously described, and upon opening of valve 12 and pump 11, liquid 27 from vessel 26 is sucked up through valve 12 into pump 11. After passage of sufficient time, which is obviously very short, such as a matter of seconds, the air sequence valve admits air by way of conduit 21 to close valve 12. After valve 12 is closed air is vented from valve 13 for opening it and air is admitted through conduit 22 to the pump and pump 11 begins to discharge liquid upward. As the flexible tube 19 is progressively collapsed from bottom to top liquid contained therein is discharged from its upper end through open valve 13. At about the time the upper portion of flexible tube 19 becomes collapsed air is vented through vents 38 and the air sequence valve 14 operates to close valve 13 so that as flexible tube 19 expands to its normal position liquid will not be drawn back into the pump through valve 13. Thus upon closing of valve 13 one complete pumping stroke has occurred. If desired the suction end of the pump is immersed several feet into the liquid to be pumped to avoid vapor lock, in case the liquid is hot, or normally volatile.

In FIGURE 4 is illustrated another embodiment of our pump which, by means of its particular construction, is operated without the need for a separate lower valve such as valve 12 of FIGURE 1. A rigid tubular member 52 of FIGURE 4 corresponds to the rigid tubular member 16 of FIGURE 1 while a flexible tubular member or tube 62 replaces flexible tubes 19 and 18 of FIGURE 1. The lower portion of the pump of FIGURE 4 which corresponds to valve 12 of FIGURE 1 is provided with a rigd tubular member 54 which has substantially the same outside diameter as tubular member 52 but has a greater inside diameter than that of tubular member 52. The flexible tube 62 has the same inside diameter and the same outside diameter throughout its length. An annular space 50 is thus provided between the outer wall of flexible tube 62 and the inner wall of the tubular member 54. A collar or coupling 53 is illustrated as providing a connection between tubular members 52 and 54.

A connection **55** is provided for inlet and outlet of pump actuating fluid from such an air sequence valve as valve **14** of FIGURE 1. The lower end of the tubular member **54** is constructed, in general, in the same manner as the lower end of tubular member **15** and has the end of the flexible tube **62** rolled back as illustrated. A flange **57** is illustrated as being bolted to a flange near the lower end of tubular member **54** for holding the flexible tube **62** fluid-tight to tube **54**. Flange **57** is preferably constructed of corrosion resistant material, such as a plastic material, in case this lower and suction end of the pump is to be submerged in a corrosive and erosive liquid. A perforate strainer **58** which, if desired, is made of a rubber or synthetic elastomer and containing perforations **58***a*, is attached to the lower end portion of flange **57** by a clamp **61**, as shown.

In the operation of the pump illustrated in FIGURE 4 the lower portion of this pump assembly replaces the valve **12** of FIGURE 1 in that air admitted from a sequence valve through connection **55** to the annular space **50** first collapses the tube **62** adjacent the annular space first and then subsequently collapses tube **62** progressively upward upon continued introduction of air through connection **55**. This embodiment of our pump requires use of an upper valve similar to valve **13** of FIGURE 1.

The pump of our invention is useful in pumping small volumes of corrosive liquids with or without suspended solids, for sampling and for analytical purposes. In one instance our pump is used for pumping small volumes of liquid from a reaction vessel in which sulfuric acid, dilute phosphoric acid, water and pulverized phosphate rock are reacted in the production of phosphoric acid. In the production of fertilizer phosphoric acid by reacting the above-mentioned materials large quantities of these materials are reacted in large vessels. Obviously such contents are highly corrosive. The particular construction of our pump exposes substantially nothing but rubber or acid resistant synthetic elastomer to the liquid being transferred so as to reduce corrosion to a minimum.

Another problem encountered in the production of phosphoric acid by reaction of sulfuric acid and phosphate rock is the production of hydrated calcium sulfate or gypsum as a by-product. Since agitators are ordinarily employed in the reaction vessels in order to keep the reactant materials in constant agitation the hydrated calcium sulfate produced is also agitated and this material appears to be very effective in eroding any or substantially any solid surfaces with which it comes in contact. By lining our valves with rubber or synthetic elastomer erosion and corrosion of the valves and pump are obviously reduced to a minimum. In order to protect the outer surface of the valve and the portion of the pump immersed in the reaction liquid we attach a rubber tube **56** to the lower end of flange **57** by the same clamp which attaches perforate strainer **58**. After clamp **61** is tightened to hold tube **56** and strainer **58** tightly in place, tube **56** is pulled upward and over such portion of the pump as required to be protected and the upper end of the tube **56** is attached tightly to tubular member **52** by a clamp **52***a*, as illustrated in FIGURE 5. In this manner the entire submerged portion of our pump assembly is protected from erosion and corrosion.

In such a chemical reaction as that herein mentioned the calcium sulfate hydrate as it is formed is very active in precipitating or depositing out upon solid surfaces. Since the valves and pump of our assembly are lined with a flexible material and since perforate strainer **58** is flexible, and also since sleeve or tube **56** is flexible, the deposition of the calcium sulfate upon these flexible materials is, of course, reduced to a minimum. If any calcium sulfate does deposit on these surfaces, upon movement or flexing of these surfaces the deposited calcium sulfate is broken off and is thus not permitted to remain deposited thereon.

The peristaltic pump of our invention is made having any reasonable or desired length. In one instance a pump was made with the flexible tubular member being a rubber hose of ½ inch inside diameter. The capacity of a given pump will depend on such variables as inside diameter of the flexible tubular member, its length, and the number of pump strokes per minute. Pumps of this nature are built as rather long pumps, for example, 15 to 25 feet or more. The pumps are also made in sections, for example, a second 10 foot long section is placed at the discharge end of a first 10 foot section. As many sections are used as necessary to give a desired length of pump.

In FIGURE 5 is illustrated the positioning of our pump in a vessel **59** in which is a reaction mixture of sulfuric acid, dilute phosphoric acid, water and pulverized phosphate rock for the production of phosphoric acid for fertilizer purposes. According to this illustration our pump is used for taking samples of the reaction mixture, filtering solid material from at least a portion of the sample and preparing the filtrate for passage to a chemical analyzer for the determination of sulfate ion concentration in an attempt to follow the reaction as regards consumption of sulfuric acid. Broadly speaking, this sampling device illustrated in FIGURE 5 includes the pump embodiment of FIGURE 4 disposed in vessel **59**. The outer end of the pump assembly discharges pumped liquid into a filter **65** from which filtered liquid or filtrate flows through a tube **69** through a flexible tube valve **74** into a dilution chamber **76**. From this last mentioned chamber filtered and diluted liquid is passed through a tube **92** and a flexible tube valve **81** and thence to a sulfate ion analyzer, not shown. Individual apparatus parts identified by various reference numerals of FIGURE 5 will be mentioned in the following explanation of the operation of this sampling system. FIGURE 5A illustrates, in diagrammatic form, a portion of the electrical control apparatus used for operation of the various valves and other parts of the apparatus of FIGURE 5. FIGURES 6, 7, 8 and 9 illustrate in some detail apparatus parts represented by boxes in FIGURE 5A.

Electrical current, from a source not shown, enters our system through wires **102** and **103**. This current is preferably 110 volt A.C. which, if desired may be obtained from any public utility. This current operates a cam drive motor **151** the speed of which is reduced by a train of gears in a gear reducer **152** so that the mechanical linkage **161** will rotate cams **101**, **111**, **121**, **131**, **156**, **157**, **158**, **159** and **160** at a speed of approximately 1 r.p.m. (revolutions per minute). Gear reducer **152** is in some instances a separate piece of apparatus, or it is, in other instances built into the motor **151**, as desired. It takes approximately 2 minutes to complete one operational cycle, which time, however, includes the sampling time, water washing and air purging times. Cam **156**, positioned nearest the gear reducer **152**, opens and closes an electric current through a sequence valve motor **153**. In addition, cam **156** closes contacts **255** thereby energizing the cam drive motor **151** after the circuit was originally closed by conductivity probes D and A, as illustrated by a circuit shown in FIGURE 5A. After one complete cycle of the cam drive motor, cam **156** will de-energize the cam drive motor **151**.

The sequence valve motor **153** and cam **156** with the corresponding electrical circuit and sequence valve are included in sequence valve **87** of FIGURE 5. Pump and valve actuating air, from a source not shown, enters our system by way of a conduit **83**. This air under pressure passes through a tube **86** into a surge tank **85** from which the air passes to the sequence valve **87**. In some instances, and if desired, a pressure regulator is installed in pipe **86** to replace surge tank **85**. Since the cam drive motor and gear reducer **152** turns linkage **161** at one r.p.m. then each of the cams rotate by linkage 161 requires one minute for a complete revolution after motor 151 is energized by completion of the circuit between probes D and A. Thus the length of time required for the sampling portion of the cycle of this sampling apparatus, for exemplary purposes, i.e., pumping and filtering of the sample, is about one minute. The first step of the sequence valve 87 is to admit air under pressure to a flexible tube valve 75 by way of a tube 71 and to the lower end of the pump assembly 51, via tube 88, the lower end of the pump assembly being disposed in vessel 59. Air to the pump assembly is transmitted from tube 88 and thence through connection 55 into annular space 50 contained within tubular member 54 (FIGURE 4). Upon admission of air into space 50 the adjacent section of the flexible tube 62 collapses and seals a volume of liquid thereabove. In case the operation is just starting the liquid first enters the lower end of pump assembly 51 and may rise to about the level of the liquid in vessel 59. Upon continued addition of air through conduit 88, the flexible tube (62) by peristaltic action moves a volume of liquid from the pump inlet toward the pump outlet. As mentioned above, at the same time air pressure is admitted to the bottom of the pump assembly air is also admitted through tube 71 to check valve 75, which valve is a rubber hose valve like valves 12 and 13 of FIGURE 1, to close valve 75. With valve 75 closed, upon transfer of liquid from the pump into filter 65, liquid is forced through the filter element into tube 69, through open valve 74 and thence into the dilution chamber 76. This filter 65 is provided with a conduit throughout its length with the discharge end of pump 51 being attached fluid tight to the upper end of the filter, the lower end of the filter being attached to valve 75. A small annular space is provided outside the outer surface of the sleeve filter 67 so that liquid filtered therethrough passes through this annular space for outlet in tube 69. With valve 75 closed liquid entering filter 65 is under pressure and this pressure assists in filtration of a small portion of the liquid pumped by each pump stroke. Only a portion of the liquid transferred by any one pumping stroke need be passed into the dilution chamber 76 since the sequence valve motor 153 will continue to turn the sequence valve until liquid reaches the level of probe A in the diluting chamber 76 to close the circuit between probes A and D. Thus sequence valve 87 (FIG. 5) operates to release or to vent pressure air from valve 75 through a vent 87*a* so that the remainder of the liquid being transferred flows downward through valve 75 and through a drain tube 72 into the tank from which the liquid was pumped. Upon opening valve 75 liquid tends to flow rapidly downwardly therethrough and by so doing solid material retained on sleeve filter 67 tends to be washed therefrom and returned to vessel 59. However, during any given pumping cycle, usually not all of the solid material retained by the filter is removed in this washing operation.

From actual runs a pump of the type illustrated in FIGURES 4 and 5, using a ½ inch I.D. rubber hose as a flexible pumping tube, will, by using a 25 r.p.m. sequence valve motor (153 in FIG. 5A) under some conditions, pump as much as 1 gallon of liquid per minute. This 25 r.p.m. motor actuates the pump at 25 pump strokes per minute.

The rigid pump tube, or tubular member 52 is in some cases merely a straight tube, or it is in other cases bent or curved, as shown in FIGURE 5. It can, when desired, be bent or curved to conform to adjacent apparatus since the tube inside is flexible.

The sleeve filter 67 is, in some cases, a porous cylindrical Kel-F unit which is in this instance made of porous fluorocarbon polymer. It might be mentioned that this filter sleeve can be made of other suitable material. By suitable material we mean a material which is resistant chemically and thermally to materials which contact the filter. It should also have sufficient strength to withstand pressures to which it may be exposed. It is obvious that the pores of the filter should be sufficiently small to retain the material to be filtered. The system as illustrated in FIGURE 5 comprises nine solenoid valves and these valves are identified by reference characters V–1, V–2, V–3, V–4, V–5, V–6, V–7, V–8, and V–9. Valves V–2, V–3, V–5, V–6, V–7, and V–8 are solenoid-operated three-way valves so arranged that when the solenoid in question is energized, ports "C" and "I" on the drawing are connected and port "E" is closed, and when the solenoid is de-energized, ports "C" and "E" are connected while port "I" is closed. Valves V–1 and V–4 are on-off solenoid valves so arranged that when a coil is energized, the corresponding valve is open and vice versa. V–9 is an on-off valve connected in the opposite manner. Relay contacts are designated "NO" or "NC" as "normally open" or "normally closed," referring to their condition when the corresponding coil is de-energized. As the operation begins solenoid valves V–1 to V–6, inclusive, are de-energized. Solenoid valves 7 and 8 are energized, the latter allowing pressure air from sequence valve 87 to enter check valve 75 and to exhaust subsequently therefrom through vent 87*a* of the sequence valve. The above conditions will continue until the filtered solution from filter 65 flowing through tube 69 and valve 74 into dilution chamber 76 reaches a level defined by the operative end of a conductivity probe (electrode) A. A common probe electrode D is disposed in the lower portion of dilution chamber 76 to serve as a second electrode for conductivity probes A, B and C. Upon closing of the circuit between probes A and D relay 254 (FIG. 5A) will close, which operation energizes the cam drive motor 151. A short time later cam 156 actuates paralleling contacts 255 to the cam drive motor circuit thus enabling the cam drive motor to continue rotation independently of the closed circuit between probes A and D. Cam 156 also actuates contacts 256 to shut off the sequence valve motor 153 thus stopping the action of the pump during the 1 minute cycle of operation of the cam drive motor 151 and the cams rotated thereby.

Solenoid valve 8 will be de-energized by cam 160, allowing check valve 75 to be exhausted to atmosphere through the vent 98. This venting of air through vent 98 allows check valve 75 to open regardless of the position in which the sequencing valve has stopped. Solenoid valve V–2 also energizes because of cam 158 allowing water from conduit 84 to back wash the filter element in filter 65. This wash water is then allowed to flow through open check valve 75 into tank 59. As soon as the filtered solution reaches conductivity probe A, which conditions may be followed in FIGURE 6 with conductivity probes A and D being in closed circuit with the liquid electrolyte, solenoid valve V–3 de-energizes allowing air to pressure and to close valve 74 thereby shutting off passage of filtrate to the dilution chamber. Solenoid valve V–5 also de-energizes thereby allowing water from tube 91 to enter the dilution chamber 76 by way of tube 92 and pass through a stainless steel filter disk 78. This water dilutes the acid and also cools it. Upon cooling, more calcium sulfate hydrate tends to precipitate out of the solution.

As previously mentioned, when the sulfate ion containing solution from filter 65 enters dilution chamber 76 and reaches conductivity probe A current flows between conductivity probes A and D, illustrated in FIGURE 6, which operation actuates relay 104 to open switch 105, which is a normally closed switch, thus de-energizing relay 106 which operation permits switch 107 to open thus de-energizing coil C–3. The de-energizing of coil C–3 allows valve V–3 to connect air from tubes 83 and 94 under pressure to tube 94*a* to close valve 74 which shuts off the flow of solution to the dilution chamber. With the flow of sulfate ion solution through valve 74 closed off water flows through valve V–5 into the dilution chamber, until the level of the liquid in the dilution chamber reaches the conductivity probe C at which time the following operations take place. Current will flow between electrodes D and C of FIGURE 7 thus energizing relay 116 which permits normally closed switch 117 to open. Relay 114 thus becomes de-energized thus allowing switch 115 to close. The closing of switch 115 permits coil C–5 to become energized thus connecting tube 89*a* with tube 92 thus shutting off the flow of water from conduit 91 through tube 92 to dilution chamber 76 and allowing air under pressure from tube 89*a* to enter dilution chamber 76 by way of conduit 92. At the time tube 89*a* is opened by way of valve V–5 to tube 92, coil C–4 is energized and opens valve V–4 to admit air from tube 89 to the above-mentioned tube 89*a*. From tube 89*a* the air enters the dilution chamber through the filter disc 78 thus causing mixing of the sulfate ion containing solution and the added water. Air is further admitted until the air pressure in the dilution chamber is substantially equivalent to the air supply pressure. This air also purges the water from valve V–5 and tube 92 so as to mix thoroughly the water and sample in the dilution chamber 76.

These above conditions will continue until a predetermined time delay has expired after which the following conditions will occur. The coil C–4 becomes de-energized, valve V–4 closes thus shutting off the air supply from the tube 89*a*. At the same time coil C–6 of the solenoid valve V–6 becomes energized thereby venting air pressure from the rubber hose valve 81 to open this valve thus permitting fluid under pressure in dilution chamber 76 to pass through the stainless steel filter 78 and out of this chamber through tube 92, valve 81 and through tube 100 to the hereinbefore mentioned sulfate ion analyzer. This stainless steel filter disc has a mean pore opening of 5 microns and on forcing the diluted liquid through this filter disc calcium sulfate hydrate, which was formed by dilution of the strong solution with water and by cooling of the solution, is removed from the solution prior to its passage to the sulfate ion analyzer. In one instance, a suitable sulfate ion analyzer utilized a colorimetric system therefore a clear solution, free or substantially free of solids, was required for analysis.

The positions of probes A and C in the dilution vessel are such that two volumes of water are added to one volume of acid solution. By regulating the vertical positions of probes A and C other dilution ratios, as desired, can be obtained.

When the level of the liquid in the dilution chamber drops below the level of the conductivity probe B, the following operations take place. The circuit is opened between electrodes D and B, shown in FIGURE 8, thus de-energizing relay 126. Normally open switch 127 is thus opened which operation de-energizes relay 124 thus allowing normally open switch 125 to open which operation de-energizes coil C–6 of solenoid valve V–6. This operation thus switches solenoid valve V–6 to permit flow of operating air from tube 93 to tube 93*a* thus closing valve 81 against passage of liquid from dilution chamber to the analyzer. Also, when the liquid in the dilution chamber drops below the probe B, the flow of current is interrupted between electrodes B and D, as illustrated in FIGURE 9, thus de-energizing relay 134 which permits normally closed switch 135 to close. Relay 135 is energized thus opening normally closed switch 137 to de-energize coil C–7 of solenoid valve V–7. When coil C–7 is de-energized, valve V–7 switches to permit venting of air from a flexible tube valve 80 through tube 83*a* and vent 97 which operation opens valve 80 to permit outflow of the remainder of the liquid from the dilution chamber. Solenoid valve V–3 energizes to exhaust air from the valve 74 by way of tube 94*a* and vent 99 to open valve 74. The opening of valve 74 allows water, which is entering filter 65, to run into the dilution chamber 76. This water flow will purge the dilution chamber of all remaining acid solution. Solenoid valve V–5 de-energizes to permit flow of water from tube 91 to flush out tube 92 back to the filter disc 78 of the dilution chamber thus cleaning the filter disc and dilution chamber prior to entry of the next sample.

At the end of a time delay of 15 seconds, as occasioned by construction of the cam 158, the following steps will occur. The coil C–2 of the valve V–2 de-energizes this valve to close off the flow of water from tube 84, through valve V–2 and tube 68 into filter 65. Coil C–1 is energized by operation of cam 157 to open valve V–1 thereby allowing air to flow from tube 90 through valve V–1, valve V–2 and thence through tube 68 into filter 65, tube 69, valve 74 and dilution chamber 76 thereby blowing out or purging water from these apparatus parts through open valve 80. Cam 111 then operates to actuate coil C–5 of valve V–5 thereby shutting off the flow of water from tube 89*a* through valve V–5 and tube 92 to the dilution chamber 76. It is noted at this stage of operation that tube 92 remains full of water until needed to dilute the solution in dilution chamber 76 during the next sampling cycle. After a further delay of 15 seconds as occasioned by construction of cam 157, another sampling cycle starts by closing of valve V–1 to shut off the air flowing through valve V–2 and tube 68 into the filter 65. As valve V–1 closes, cam 131 operates to energize coil C–7 of valve V–7 to open this valve to the flow of air from tube 83 through tube 83*a* to close valve 80. At this time cam 160 operates to energize coil C–8 of valve V–8 to open this valve for admission of air from sequence valve 87 to close check valve 75. Cam 156 is also actuated at this time to start the sequence valve motor 153 and to stop the cam drive motor 151 through the action of contacts 256 and 255, respectively. The sequence valve also at the same time admits air through tube 88 to the lower valve portion of pump assembly 51 for starting of a new pump cycle. Prior to this sequence valve opening to tubes 71 and 88, cam 156 operates to start sequence valve motor 153 for admission of air under pressure to the two tubes just mentioned.

The hereinabove explanation is believed to describe clearly the operations which take place during one complete cycle of the pump assembly 51.

One particular advantage of our pump system is in the operation of the lower valve portion of the pump of FIGURE 5, and of the lower valve 12 of FIGURE 1. For example, in the lower valve 12 of FIGURE 1 the center portion of the flexible tube 18 first closes upon admission of air under pressure through connection 12*a* into the space between flexible tube 18 and the rigid tubular member 15. With this central portion of flexible tube 18 closed, upon further admission of air under pressure the portion of the flexible tube above the center and the portion of the flexible tube below the center also close. The portion of the flexible tube below the center upon closing forces liquid downward through perforations 29 thereby tending to backwash strainer 28. This backwashing tends to maintain perforations 29 clear and free from obstruction. This same backwashing occurs in the region of the lower valve portion of the pump assembly 51 of FIGURE 5. Thus upon closing of the center portion (vertically) of the valve portion of the flexible tube 62, the perforate strainer 58 is backwashed by passage of a sudden surge of liquid from above the perforate strainer through the perforations 58*a* thus tending to maintain these perforations clear and free from obstruction. This sudden surge of liquid also flexes the flexible strainer 28 thus breaking off any gypsum tending to deposit on the strainer.

In FIGURE 5 is illustrated a support tube 63 attached by welds 64 and to this support tube is attached by welds, not shown, support flanges 73 and 73*a* for support of the pump assembly in the position illustrated. The filter disc 78 is supported in its operating position on the bottom end of a tube 79 by suitable means. Tube 79 is imperforate and is supported by the upper end wall of the dilution chamber vessel **76**. In this manner any air or water entering the dilution chamber by way of tube **92** must flow through the filter disc. Air operative valves **74**, **75**, **80** and **81** are flexible tube valves similar to valves **12** and **13** of FIGURE 1.

When the above-mentioned mixture of phosphate rock, sulfuric acid, dilute aqueous phosphoric acid and water are reacted for the production of phosphoric acid, the solution is also analyzed for its phosphoric acid content as well as for its sulfate ion content. FIGURES 10, 11 and 12 illustrate a sampling apparatus for use in taking samples of the reaction mixture for passing to a phosphate (P_2O_5) analyzer.

In FIGURE 10 is illustrated diagrammatically one embodiment of apparatus for taking samples of the reaction mixture for phosphate analysis. The reaction mixture is filtered on a rotary filter, the aqueous solution passing through the filter and the calcium sulfate hydrate remaining thereon. The calcium sulfate hydrate is removed from this filter by means of a scraper assisted by spraying water. The removed calcium sulfate hydrate and water form a slurry and this slurry is passed downward through a launder to a subsequent operation. The launder of this apparatus is identified in FIGURE 10 by reference numeral **201**. A peristaltic type pump assembly **202** is used in this sampling operation. The suction end of this pump is inserted into launder **201** and is sealed thereinto by a flange and gasket assembly **201*a*** so that liquid will not leak from the launder. The suction end of this pump assembly is formed in the shape of a funnel **204** so disposed in the launder as to catch and direct into the pump at least a portion of the slurry **231** passing down the launder. The pump employed in this embodiment of our invention is more or less similar to the pump described hereinbefore in relation to FIGURES 4 and 5. A collar **205** corresponds to collar **53** of FIGURES 4 and 5 while the outer pump tube or housing tube **206** corresponds to the rigid tube **52** of FIGURES 4 and 5. At substantially the discharge end of the pump are disposed one or more vents **206*a*** for venting of operating fluid from the space between the flexible tube member and the inner wall of housing **206**. The pump discharges into a filter assembly **203** which is more or less similar to the filter assembly of FIGURES 4 and 5. Within the case of the filter assembly is disposed a tubular hollow cylindrical filter element which, in some cases, is a Kel-F filter, hereinbefore defined. The filter assembly is provided with two discharge means, one being a tube **223** for passage of sample through a valve **224** and thence through a tube **225** to the phosphate analyzer, not shown. The other discharge means comprises a check valve **221** which, in turn, discharges material into a drain tube **222** for such disposal as desired, for example, material flowing through pipe **222** is, if desired, passed into the original reaction zone of the process. At a point in tube **223** and near valve **224** is disposed a side tube **226** for withdrawal of material flowing through tube **223** which is desired not passed to the analyzer. Tube **226** passes material to a drain valve **227** and thence through a drain tube **228** for such disposal as desired. Material from tube **228**, is, if desired, also returned to the original reaction zone. A control box **207** is provided as a housing for the control apparatus employed in this sampling system. A tube **208** conducts air under, for example, 90 pounds per square inch gauge, and tube **209** conducts water, from a source not shown, to the control box. A tube **210** is for passage of water from the control box to the inlet or funnel **204** of the pump while tube **211** is for passage of air to the inlet end of the pump housing **206**. A tube **212** is for passage of air to the sample shutoff valve **224**, tube **213** is for passage of water and air to the filter assembly **203**, tube **214** is for passage of air from a sequence valve within housing **207** to the check valve **221**, and tube **215** is for passage of air to the drain valve **227**. Pressure gauges **216** and **217** are for indication of air pressure in tube **211** to the pump and to the several valves, respectively. Knobs **218** and **219** are for regulation of these air pressures so that pressures exposed to the flexible members of the pump and the valves will not become so high as to injure these flexible pump and valve members. Reference numeral **230** identifies the control assembly disposed within case **207**. Within this control assembly (illustrated in FIGURES 11 and 12) is a sequence valve **229** which is driven by a motor **244**. Included within control assembly **230** are solenoid valves **232**, **234**, **236**, **238**, **240** and **242** while reference numerals **233**, **235**, **237**, **239**, **241** and **243** identify the coils of the respective solenoid valves. These solenoid valves and coils are illustrated in FIGURE 11. A valve **245** is provided, as illustrated, for inlet of air as a positive and continuous purge in the case **207** to eliminate the possibility of entrance of any corrosive atmosphere.

Also disposed within control assembly **230** is the apparatus illustrated in FIGURE 12 and this apparatus includes a motor **246** for driving a system including cams **247**, **248** and **249**. Cam **247** actuates normally open switch **250**, cam **248** actuates a normally closed switch **251**, while cam **249** actuates a normally open switch **252**. Solenoid valves **232**, **234**, **238**, **240** and **242** are 3-way valves while solenoid valve **236** is a 2-way valve.

Broadly speaking, in the operation of this embodiment of our invention sample entering the inlet funnel **204** of the pump is transferred by the pump to the filter assembly **203**. During the first portion of each pumping stroke check valve **221** and drain valve **227** are closed thereby forcing liquid through filter **220**, tube **223**, valve **224** (open) and through tube **225** to the phosphate analyzer. When a small portion of sample liquid has thus been filtered from each pump stroke, valve **224** is closed and valve **221** is opened thereby allowing the remaining portion of sample from each pump stroke to flow directly through the check valve **221** and tube **222** to such disposal as desired. This free flow of sample tends to wash out the precipitated calcium sulfate hydrate retained on the inner wall of the cylindrical filter **220**. At the end of the pumping portion of the cycle valve **224** closes, drain valve **227** remains closed and check valve **221** opens and water is admitted to the filter assembly through tube **213** and water is passed through tube **210** to the inlet funnel **204** so as to wash away any precipitated material. This water washing operation is continued for example for 45 seconds and solid material is removed from funnel **204**, pump **202** and from the interior of the cylindrical filter **220**. The check valve is then closed and valve **27** is opened and air is then admitted to the filter assembly through tube **213** to remove residual water from the annulus surrounding the outer surface of the cylindrical filter **220**. This water passes through tube **223** thereby removing sample liquid remaining therein and is followed by air to remove wash water from the annulus just mentioned and from tube **223** so as not to dilute the next successive filtrate. This air purge continues for about 15 seconds. After this air purging is complete the assembly is then in condition for another pumping cycle. However, in the embodiment of FIGURES 10, 11 and 12, the sequence valve motor **244** operates the sequence valve **229** all the time, i.e., even during the water washing and air purging portions of the cycle. In other words, the pump operates all the time, and during the filtration portion of the cycle the pump pumps only material from the launder **201**, during the water washing portion the pump pumps material from launder **201** and wash water (valves **224** and **227** being closed), and during the air purging portion of the cycle the pump pumps only material from the launder **201**, but valve **224** is closed, valve **227** is open and valve **221** is closed.

By the term stroke or pump stroke as used throughout this specification and claims is meant one complete operation of the actual pump including one intake and one discharge of the pump. The term cycle is intended to mean one complete revolution of mechanical linkage **161** and the attached cams of FIGURE *5a* and one complete revolution of the mechanical linkage **265a** to which cams **247**, **248** and **249** are attached. In FIGURE *5a* the cycle is disclosed as being 2 minutes while in FIGURE 12 the cycle is 5 minutes, there being in each of these cases pump strokes at the rate of 25 per minute during the respective pumping portions of the cycles.

In greater detail the sampling operation is as follows, and on reference to FIGURE 11 with the system in a "no power" condition, at the end of a 4-minute pumping and filtration period the following operations occur: solenoid valve **240** is de-energized which allows pressure air to flow from E to C through valve **240** and thence to sample shutoff valve **224** and this latter valve is thus closed. Solenoid valve **234** is de-energized thus opening C to E through valve **234** and water flows through tube **213** to the filter chamber to backwash the cylindrical filter **220**. The valve sequence motor in this case continues to run and to operate the pump but since check valve **221** opens, liquid will not be forced through filter **220** as sample for passage to the analyzer. Check valve **221** is opened by de-energizing solenoid valve **232** thus connecting C and E of valve **232** and venting air pressure from valve **221**. This valve opens so that water passing through the filter **220** passes through valve **221** and drain **222**. Solenoid valve **242** is de-energized thus opening E to C in valve **242** and allowing water to flow through tube **210** to the inlet **204** of the pump. This water aids in washing away any calcium sulfate hydrate solids which may have come to rest on the pump inlet. This water also aids in flushing the pump and filter because during the washing step the pump is operating.

These four operations just mentioned continue for about 45 seconds, after which time the following operations take place: solenoid valve **234** is energized thus closing C from E in valve **234** and opening I to C in this valve. Solenoid valve **236** is energized thus allowing air passing valve **219** to flow through valves **236** and **234**, through tube **213** to filter chamber **203** thereby purging it of water by way of tubes **223** and **226** and drain valve **227**, which is opened upon simultaneous energizing of solenoid valve **238** which connects C with I of valve **238** to allow exhaust of pressure air from drain valve **227** thereby allowing this latter valve to open. With drain valve **227** open and purge air entering filter **203** via tube **213**, any solution or water remaining in the annulus surrounding filter **220**, in tubes **223** and **226** and valve **227**, are thus blown out. Solenoid valve **242** is also energized which disconnects C from E of valve **242** and connects C with I of this valve for venting of water from tube **210**. Water stops flowing to the inlet **204** of the pump.

These just-mentioned operations continue for about 15 seconds after which time solenoid valve **232** becomes energized which permits check valve **221** to be connected with the operating pressure air from the sequence valve and to close. Solenoid valve **234** also becomes energized which causes water to be closed off from tube **213**. Solenoid valve **240** becomes energized which allows pressure air to be vented from the sample valve **224** thereby allowing this valve to open. Solenoid valve **242** remains energized so that water cannot flow to the pump inlet **204** via tube **210**. Solenoid valve **236** is de-energized thus closing off air to the filter chamber. Solenoid valve **238** is also de-energized which condition opens C and E of valve **238** to allow pressure from tube **215** to close the drain valve **227**. These six valve positions just mentioned are maintained for about a 4-minute period of pump operation. During this 4-minute period a portion of liquid from each pump stroke is filtered and passes through tube **223**, valve **224** and through tube **225** to a phosphate analyzer, not shown. The sequence pump motor also rotates the sequence valve **229** of this embodiment of our invention at about 25 r.p.m. thus giving that number of pump strokes per minute. The pump continues pumping at this rate, i.e., at 25 strokes per minute, for about 4 minutes, after which the washing and air purging portions of the cycle take place for 45 seconds and 15 seconds, respectively, as described above. These time intervals give an over-all time cycle of about 5 minutes.

While 2-minute and 5-minute over-all cycles were described above relative to the sulfate and phosphate sampling systems, respectively, other time cycles suitable for the purpose at hand can be used merely by substituting suitable cams and suitable sequence valves for those herein disclosed. Under some conditions it is desirable to design the sequence valves for a more rapid or a less rapid pumping rate than the herein disclosed pumping rate of 25 strokes per minute.

The sampling systems herein disclosed for use in sampling for sulfate ion and for phosphate analyses obviously are useful in sampling other liquids for other analyses, with or without modification as necessitated by the application at hand.

While certain embodiments of the invention have been described for illustrative purposes, the invention obviously is not limited thereto.

We claim:

1. A fluid operated pump comprising, in combination, an elongated rigid tubular member, a flexible tubular member disposed within and throughout the length of said rigid member, said flexible member tightly fitting the inner surface of the wall of said rigid member throughout its length, corresponding ends of the rigid tubular member and the flexible tubular member being joined to each other fluid-tight, an opening in the wall of said rigid member near one end thereof for inlet and outlet of pump operating fluid, and an open vent in the wall of said rigid member near its other end for outlet of said operating fluid.

2. A fluid operated pump assembly comprising, in combination, a pump having an elongated first rigid tubular member, a first flexible tubular member disposed within and throughout the length of said rigid member, said flexible member tightly fitting said rigid member, corresponding ends of said rigid member and said flexible member being joined to each other fluid-tight, an opening in the wall of said rigid member near one end thereof for passage of pump operating fluid, a vent in the wall of said rigid member near its other end for venting of said operating fluid, said one end of said rigid member being the inlet end and the other end being the discharge end of the pump of said assembly, a fluid inlet control valve and a fluid discharge control valve adjacent the inlet end and the outlet end, respectively, of said pump, each of these valves comprising a separate second rigid tubular member, the first rigid tubular member and each second rigid tubular member being disposed along a common axis, a separate second flexible tubular member disposed within and throughout the length of each second rigid tubular member, corresponding ends of the second rigid and second flexible tubular members being joined fluid-tight, an opening in each second rigid tubular member for passage of operating fluid, said inlet control valve and said discharge control valve being fixed fluid-tight to the inlet end and to the outlet end, respectively, of said pump, the flexible tubular members being turned out and over the ends of the rigid tubular members to which they are joined, the inlet valve, pump and discharge valve being joined in such a manner as to provide a continuous passageway therethrough defined by inner walls of the flexible members, a time sequence valve, separate conduits communicating said time sequence valve with the opening in said first rigid tubular member and with the openings in the fluid inlet and fluid discharge control valves, said time sequence valve being adapted to regulate actuating fluid to said pump and to said inlet and discharge valves.

3. A fluid operated pump assembly comprising, in com-

bination, an elongated first rigid tubular member, a second rigid tubular member, one end portion of said second rigid tubular member being disposed fluid-tight to one end portion of said first rigid tubular member, a flexible tubular member of uniform inner and outer diameters being disposed within and throughout the combined lengths of said rigid members, said flexible tubular member tightly fitting said first rigid tubular member, the inner diameter of said second rigid tubular member being greater than the outer diameter of said flexible tubular member thereby providing an annular space therebetween, said flexible tubular member being adapted to be collapsed thereby providing a free space between the outer wall of said flexible tubular member and the inner wall of said first rigid tubular member and said free space being in communication with said annular space, the ends of said flexible tubular member being disposed fluid-tight to the ends of said rigid tubular members adjacent the ends of said flexible tubular member, an opening in the wall of said second tubular member for passage of pump operating fluid, and an unobstructed vent in the wall of said first rigid tubular member near the end thereof remote from said second rigid tubular member.

4. A fluid operated pump assembly comprising, in combination, an elongated first rigid tubular member, a second rigid tubular member, one end of said second rigid tubular member being disposed fluid-tight with one end of said first rigid tubular member, said first and second rigid tubular members being disposed along a common axis and being of equal outer diameters, a flexible tubular member of uniform inner and outer diameters disposed within and throughout the combined lengths of said first and second rigid tubular members, said flexible tubular member tightly fitting said first rigid tubular member, the inner diameter of said second rigid tubular member being greater than the outer diameter of the flexible tubular member thereby providing an annular space therebetween, said flexible tubular member being adapted to be collapsed thereby providing a free space between the outer wall of said flexible tubular member and the inner wall of said first rigid tubular member and said free space being in communication with said annular space, the ends of said flexible tubular member being disposed fluid-tight to the ends of said rigid tubular members adjacent the ends of said flexible tubular member, an opening in the wall of said second rigid tubular member for passage of pump operating fluid, and an unobstructed vent in the wall of said first rigid tubular member near the end thereof opposite said second rigid tubular member.

5. A fluid operated pump assembly comprising, in combination, a pump having an elongated first rigid tubular member, a second rigid tubular member, said first and second rigid tubular members being disposed along a common axis, adjacent end portions of said members being joined fluid-tight, a flexible tubular member of uniform inner and outer diameters being disposed within and throughout the combined lengths of said rigid members, said flexible tubular member tightly fitting said first rigid tubular member, the inner diameter of said second rigid tubular member being greater than the outer diameter of said flexible tubular member thereby providing an annular space therebetween, the ends of said flexible tubular member being disposed fluid-tight to the ends of said first and second rigid members adjacent the ends of said flexible member, a first opening in the wall of said second tubular member for passage of pump operating fluid, a vent in the wall of said first rigid tubular member near the end thereof remote from said second rigid tubular member, a discharge valve comprising a third rigid tubular member disposed along said common axis and adjacent the vent end of said first rigid tubular member, a second flexible tubular member disposed throughout the length of said third rigid tubular member, the ends of said second flexible member being fixed fluid-tight to corresponding ends of said third rigid tubular member, a second opening in the wall of said third rigid tubular member for passage of said pump operating fluid, the flexible tubular members being turned out and over the ends of the rigid members to which they are attached, said pump and said discharge valve being joined in such a manner as to provide a continuous passageway through said pump assembly defined by the inner walls of the flexible members, a time sequence valve mechanism, separate conduits communicating said first and second openings with said time sequence valve mechanism, said time sequence valve mechanism being adapted to admit and to exhaust said pump operating fluid alternately through said separate conduits.

6. A system for sampling a liquid containing solid material in suspension, comprising, in combination, a vessel for containing said liquid, a peristaltic type pump having an inlet end and an outlet end, said inlet end being disposed in a space in said vessel normally occupied by said liquid to be sampled, a filter, said filter comprising a cylindrical filter element, said filter having an inlet for said liquid containing solid material and an outlet therefor, the outlet end of said pump communicating with the inlet of said filter, a first conduit disposed axially through said filter element providing unrestricted passage therethrough for said liquid containing solid material, a first valve communicating with the outlet of said filter, a second conduit for removal of filtrate from said filter, a second valve in said second conduit for regulation of flow of filtrate, a third conduit communicating with said second conduit, a third valve in said third conduit for regulation of flow of liquid therein, first means for admitting pump operating fluid to said pump whereby liquid containing solid material is transferred from the pump inlet to said filter, and second means for actuating said valves in timed sequence with said first means whereby at least a portion of the liquid pumped is passed through said filter element, said second conduit and said second valve, and the remainder of the liquid and the solid material is passed through said first valve.

7. The system of claim 6 wherein the first, second and third valves are fluid operable flexible tube valves and each valve comprises a rigid tubular member, a flexible tubular member fitting the inner wall of said rigid tubular member, corresponding ends of said rigid member and said flexible member being joined to each other fluid-tight, and an opening in the wall of said rigid tubular member for inlet and outlet of operating fluid.

8. In the system of claim 7, third means for passing washing liquid to the inlet of said pump and for passing washing liquid and subsequently purging air to said filter in timed sequence with the pumping cycle of said system.

9. A system for sampling a liquid containing solid material in suspension, comprising, in combination, a vessel for containing said liquid, a peristaltic type pump having an inlet end and an outlet end, said inlet end being disposed in a space in said vessel normally occupied by said liquid to be sampled, a filter, said filter comprising a cylindrical filter element, said filter having an inlet for liquid containing solid material and an outlet therefor, the outlet end of said peristaltic pump communicating with the inlet of said filter, a first conduit disposed axially through said filter element providing unrestricted passage therethrough for said liquid containing solid material, a first valve communicating with the outlet of said filter, a second conduit for removal of filtrate from said filter, a second valve in said second conduit, a dilution chamber in communication with said second conduit, a third conduit communicating with said dilution chamber for passage of liquid therefrom, said first and second valves being fluid operable valves, first means for passage of operating fluid under pressure to and from said pump whereby liquid containing solid material is transferred from said vessel to said filter, second means for passage of operating fluid under pressure to and from said first valve in timed sequence with said first means whereby said first valve is

closed during a portion of the pumping cycle and liquid passes through said filter to said dilution chamber, liquid level responsive third means for closing said second valve, for admitting water to said dilution cell, for passing air under pressure into said dilution cell and for exhausting liquid from said dilution cell.

10. The system of claim 9 wherein said first and second fluid operable valves are flexible tube valves. and each valve comprises a rigid tubular member, a flexible tubular member fitting the inner wall of said rigid tubular member, corresponding ends of said rigid member and said flexible member being joined to each other fluid-tight, and an opening in the wall of said rigid tubular member for inlet and outlet of operating fluid.

11. In the system of claim 9, fourth means for passing washing liquid and subsequently purge air through said filter and through said dilution chamber.

12. A fluid operated pump assembly comprising, in combination, a pump having an elongated first rigid tubular member, a first flexible tubular member disposed within and throughout the length of said rigid member, said flexible member tightly fitting said rigid member, corresponding ends of said rigid member and said flexible member being joined to each other fluid-tight, an opening in the wall of said rigid member near one end thereof for passage of pump operating fluid, a vent in the wall of said rigid member near its other end for venting said operating fluid, said one end of said rigid member being the inlet end and the other end being the discharge end of the pump of said assembly, a fluid inlet control valve adjacent the inlet end of said pump, said valve comprising a second rigid tubular member, the first and second rigid tubular members being disposed along a common axis, a separate second flexible tubular member disposed within and throughout the length of said second rigid tubular member, corresponding ends of the second rigid and second flexible members being joined fluid-tight, an opening in said second rigid tubular member for passage of operating fluid, said inlet control valve being fixed fluid-tight to the inlet end of said pump, the flexible tubular members being turned out and over the ends of the rigid tubular members to which they are joined, the inlet valve and pump being joined in such a manner as to provide a continuous passageway therethrough defined by the inner walls of the flexible members.

13. A fluid operated pump assembly comprising, in combination, a pump having an elongated first rigid tubular member, a first flexible tubular member disposed within and throughout the length of said rigid member, said flexible member tightly fitting said rigid member, corresponding ends of said rigid member and said flexible member being joined to each other fluid-tight, an opening in the wall of said rigid member near one end thereof for passage of pump operating fluid, a vent in the wall of said rigid member near its other end for venting said operating fluid, said one end of said rigid member being the inlet end and the other end being the discharge end of the pump of said assembly, a fluid inlet control valve and a fluid discharge control valve adjacent the inlet end and the outlet end, respectively, of said pump, each of these valves comprising a separate second rigid tubular member, the first rigid tubular member and each second rigid tubular member being disposed along a common axis, a separate second flexible tubular member disposed within and throughout the length of each second rigid tubular member, corresponding ends of the second rigid and second flexible tubular members being joined fluid-tight, an opening in each second rigid tubular member for passage of operating fluid, said inlet control valve and said discharge control valve being fixed fluid-tight to the inlet end and to the outlet end, respectively, of said pump, the flexible tubular members being turned out and over the end of the rigid tubular members to which they are joined, the inlet valve, the pump and the discharge valve being joined in such a manner as to provide a continuous passageway therethrough defined by the inner walls of the flexible members.

14. A fluid operated pump assembly comprising, in combination, a pump having an elongated first rigid tubular member, a second rigid tubular member, said first and second rigid tubular members being disposed along a common axis, adjacent end portions of said members being joined fluid-tight, a flexible tubular member of uniform inner and outer diameters being disposed within and throughout the combined lengths of said rigid members, said flexible tubular member tightly fitting the first rigid tubular member, the inner diameter of said second rigid tubular member being greater than the outer diameter of said flexible tubular member thereby providing an annular space therebetween, the ends of said flexible tubular member being disposed fluid-tight to the ends of said first and second rigid members adjacent the ends of said flexible member, a first opening in the wall of said second tubular member for passage of pump operating fluid, a vent in the wall of said first rigid tubular member near the end thereof remote from said second rigid tubular member, a discharge valve comprising a third rigid tubular member disposed along said common axis and adjacent the vent end of said first rigid tubular member, a second flexible tubular member disposed throughout the length of said third rigid tubular member, the ends of said second flexible member being fixed fluid-tight to corresponding ends of said third rigid tubular member, a second opening in the wall of said third rigid tubular member for passage of said pump operating fluid, the flexible tubular members being turned out and over the ends of the rigid members to which they are attached and said pump and said discharge valve being joined in such a manner as to provide a continuous passageway through said pump assembly defined by the inner walls of the flexible members.

15. A system for sampling a liquid containing a solid material in suspension, comprising, in combination, a vessel for containing said liquid, a first rigid tubular member, one end portion of which extends into said vessel, a second rigid tubular member, one end portion of said second tubular member being fixed fluid-tight to said end portion of the first rigid tubular member, said first and second rigid tubular members being disposed along a common axis, a flexible tubular member being disposed within and throughout the combined lengths of said rigid members, said flexible member fitting said first rigid member, the inner diameter of said second rigid member being greater than the outer diameter of said flexible member thereby providing an annular space therebetween, the ends of said flexible member being disposed fluid-tight to the corresponding ends of said rigid members, a third rigid tubular member joining the other end of said first rigid member, a second flexible tubular member disposed within and throughout the length of said rigid member, corresponding ends of said third rigid member and said second flexible member being joined fluid-tight, a time sequence valve, first and second conduits operatively connecting said valve with said second and third rigid members, respectively, in such a manner as to transmit operating fluid from said valve to the interior of said rigid members, a vent in the wall of said first rigid member adjacent said third rigid member, a cylindrical filter having an axial opening therethrough, a third conduit communicating the end of said third rigid member with one end of said opening of said filter, a fourth conduit communicating the other end of said opening of said filter with the interior of said vessel, a first diaphragm valve in said fourth conduit, a shell surrounding said filter and providing a second annulus therebetween, a fifth conduit leading from said second annulus, second and third diaphragm valves in said fifth conduit at a spaced distance from one another, sixth, seventh and eighth conduits

communicating said second, third and first valves with said time sequence valve for transmission of actuating fluid, said time sequence valve being adapted to admit actuating pressure fluid to said first, seventh and eighth conduits while venting pressure fluid from said second and sixth conduits, subsequently admitting pressure fluid to said sixth conduit and venting pressure fluid from said seventh and eighth conduits and thereafter admitting pressure fluid to said second, eighth and seventh conduits and venting pressure fluid from said first and sixth conduits.

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