Dec. 16, 1958 P. A. ROBINSON 2,864,317

PUMPING DEVICE

Filed Oct. 5, 1953

2 Sheets-Sheet 1

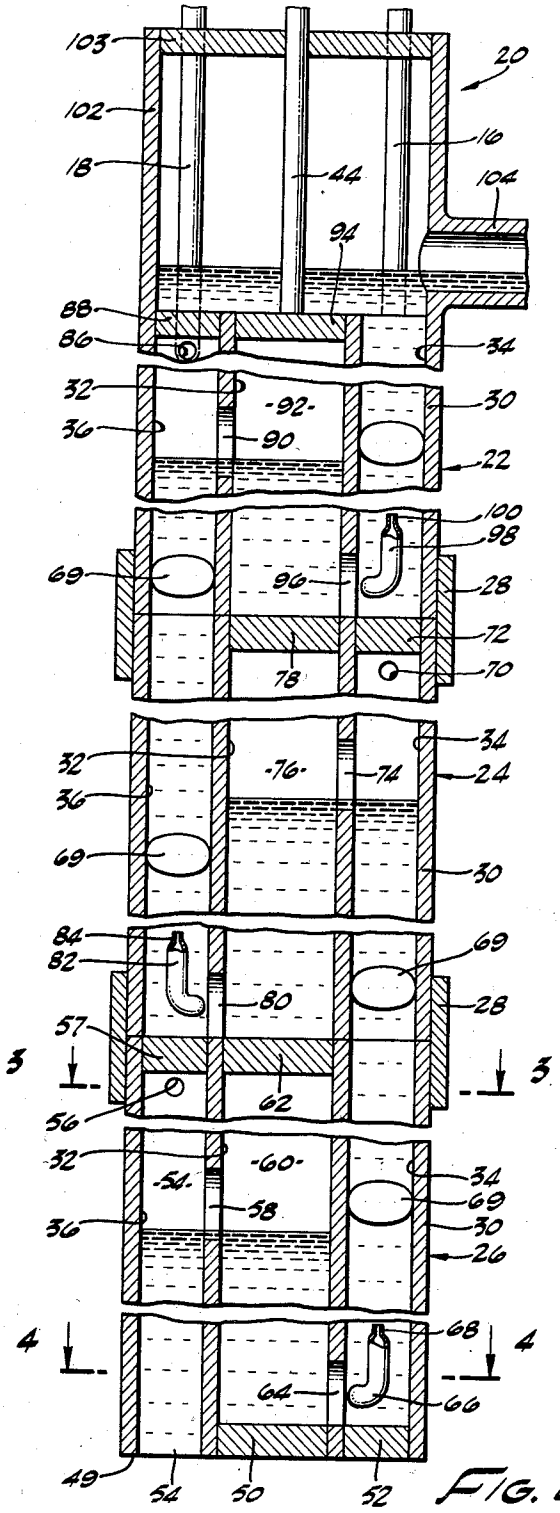


FIG. 2.

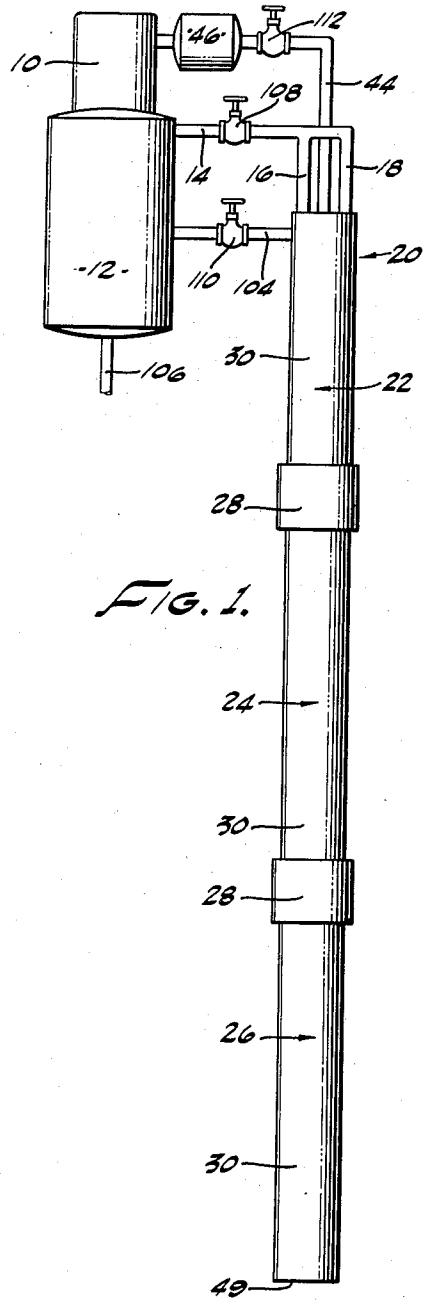


FIG. 1.

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FIG. 3.

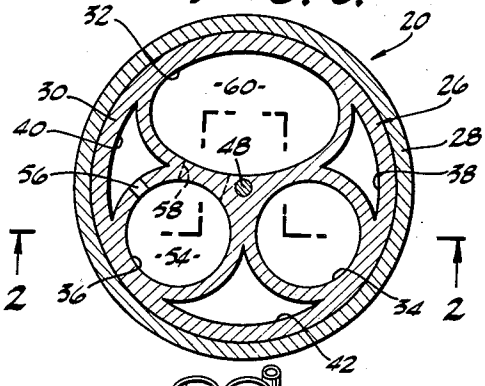


FIG. 4.

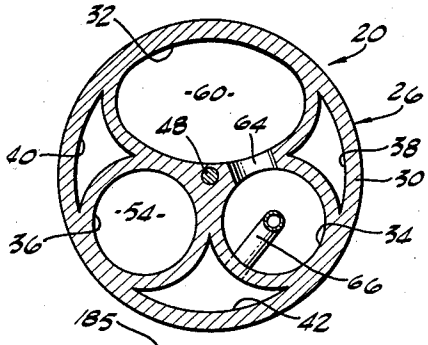


FIG. 6.

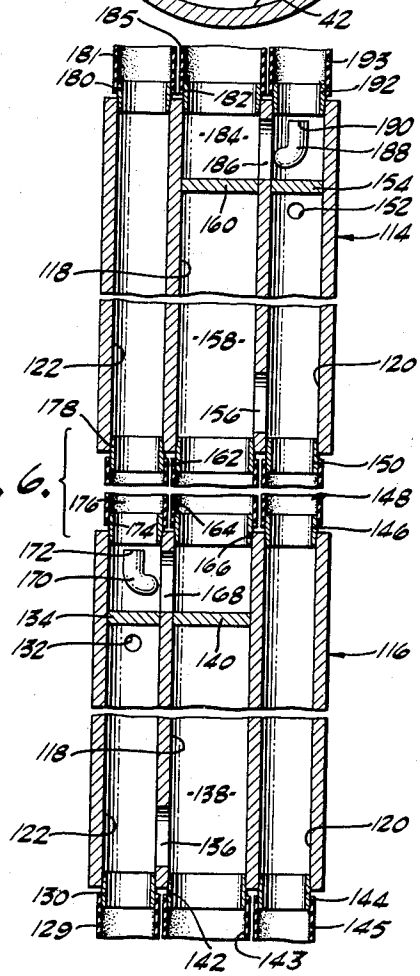
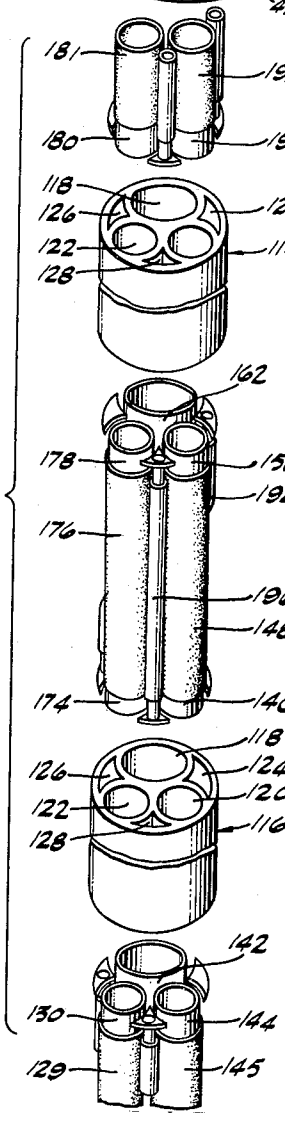


FIG. 5.



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2,864,317

PUMPING DEVICE

Purnell A. Robinson, Los Angeles, Calif.

Application October 5, 1953, Serial No. 384,236
14 Claims. (Cl. 103—235)

My present invention relates to pumps for pumping water, oil or other liquids from one level up to a higher level, such as for pumping liquids out of deep wells, and it relates particularly to pressure differential pumping devices for pumping liquids from one level to a higher level.

It is well known in the art to pump liquids, such as water and oil, from one level to another level, by applying a partial vacuum to a tubular pumping device. However, all of the prior art vacuum pumps with which the applicant is familiar are only capable of pumping fluid to a height which will cause the column of fluid to exert a pressure that is less than the pressure exerted by the atmosphere. In prior art vacuum pumping devices, if the column of liquid to be pumped has a height which is equal to or greater than that which would exert a pressure equal to atmospheric pressure, then moving parts are required down within the well.

Therefore, the principal object of my present invention is to provide a vacuum pumping device which is capable of pumping a liquid to any height by the mere application of a partial vacuum to the top of the pump string without the requirement of any moving parts in the pumping string.

Another object of my present invention is to provide a vacuum-type pumping device in which the pump string can be inserted to any depth within a well to permit the removal of fluid from the well by the mere application of a partial vacuum at the top of the pump string.

Another object of my invention is to provide a vacuum type pumping device which is capable of pumping a column of fluid that is much greater in height than a column of the fluid which would exert a pressure that is substantially equal to the pressure exerted by the atmosphere, without any apparent diminishing of the rate of flow of the fluid at the top of the pumping device as the length of the pump string is increased.

Another object of my invention is to provide a vacuum type pumping device of the character described in which the pump string is relatively narrow in diameter, occupying a minimum of space in any well in which the pumping device is operated.

A further object of my invention is to provide a pumping device of the character described which consists of a plurality of joining sections that are relatively short in length and that are connected together by means of a plurality of hose sections in order to provide a relatively inexpensive pumping device which is convenient to market and to store.

Another object of my present invention is to provide a pumping device in which the pump string may be conveniently and economically made of plastic.

Another object of my present invention is to provide a pressure differential pumping device in which a relatively low pressure differential may be employed to pump fluid regardless of the height to which the fluid is pumped.

Other objects of my present invention will be apparent

from the following description and claims, the novelty of my invention consisting in the features of construction, the combinations of parts, the novel relations of the members and the relative proportioning, disposition and operation thereof, all as is more completely described herein and as more particularly pointed out in the appended claims.

In the accompanying drawings, forming a part of my present specification,

Figure 1 is an elevational view of my preferred embodiment,

Figure 2 is a vertical section of my preferred embodiment with portions broken away to illustrate several stages of my pump string,

Figure 3 is a horizontal section of my preferred embodiment taken along the line 3—3 in Figure 2,

Figure 4 is a horizontal section of my preferred embodiment taken along the line 4—4 in Figure 2,

Figure 5 is an exploded perspective view of an alternative embodiment of my invention, and

Figure 6 is a vertical section illustrating two of my joining sections for my alternative embodiment illustrated in Figure 5.

Referring to my drawings, I provide a vacuum pump 10 which is operatively connected to a reservoir 12 so that gases may be evacuated from reservoir 12. A primary vacuum line 14 is connected to the upper portion of reservoir 12, and divides into two secondary vacuum lines 16 and 18, which are operatively connected to the top of my pump string 20 in the manner hereinafter more fully described in connection with Figure 2 of the drawings.

Although my pump string 20 may include any number of pump sections, I have illustrated a pump string 20 which includes three sections 22, 24 and 26 in Figures 1 and 2 of the drawings. Although pump sections 22, 24 and 26 may be operatively connected to form the entire pump string 20 in any desired manner, a preferred means of attaching the pump sections 22, 24 and 26 together is by the use of coupling sleeves 28.

Referring particularly to Figures 2, 3 and 4, my pump string 20 generally consists of a cylindrical outer shell member 30 within which are disposed a plurality of smaller tubes. In my preferred embodiment, a relatively large reservoir tube 32 and a pair of smaller pumping tubes 34 and 36 are provided. Although these three tubes may have any desired cross-sectional shapes, I prefer to provide pumping tubes 34 and 36 which have circular cross-sections, and a reservoir tube 32 which has a generally parabolic cross-section, so that these three tubes, 32, 34 and 36, may most efficiently fit within the preferably circular cross-section of the outer shell member 30. Although other relative sizes between reservoir tube 32 on the one hand and pumping tubes 34 and 36 on the other hand may be used, I have found that a preferred relationship of the areas of these tubes is a .67 square unit cross-sectional area for each of the smaller tubes 34 and 36, to a .93 square unit cross-sectional area for reservoir tube 32.

In my preferred embodiment I provide a pair of vacuum or low pressure tubes 38 and 40, which need not have smooth internal contours, the tops of which are operatively connected to the secondary vacuum lines 16 and 18, respectively. Although it is most convenient to use two vacuum tubes, such as tubes 38 and 40, in my preferred embodiment, other embodiments of my invention may require only a single such vacuum tube, such as my alternative embodiment illustrated in Figures 5 and 6 of the drawings.

The remaining tube which is included within cylindrical outer shell member 30 is the vacuum relief or high

pressure tube 42, which is operatively connected to a vacuum relief line 44 at the top of pump string 20. Vacuum relief line 44 is operatively connected to the gas output port of vacuum pump 10, and preferably contains a vacuum relief reservoir 46.

If my pump string 20 is made of plastic, I prefer to include a central reinforcing rod or cable which extends the entire length of the pump string 20. This central reinforcing rod or cable 48 is preferably made of stainless steel.

During the operation of my invention, the pump string 20 is lowered into the well or is otherwise immersed in the liquid to be pumped so that the liquid covers the bottom end 49 of pump string 20. Bottom plugs 50 and 52 seal off the bottom ends of reservoir tube 32 and pumping tube 34, respectively. The liquid enters the bottom end 49 of pump string 20 through the open lower end 54 of pumping tube 36, the liquid being lifted by the application of a partial vacuum to the inside of pumping tube 36 through vacuum port 56 which is connected to vacuum tube 40. A plug 57 is disposed just above vacuum port 56 within pumping tube 36.

The liquid is thus raised within pumping tube 36 until it reaches a relatively large flow passage 58 which permits the liquid to flow into chamber 60 within reservoir tube 32, chamber 60 being defined between bottom plug 50 and a plug 62 in reservoir tube 32 adjacent to plug 57 in pumping tube 36. A preferred height for chamber 60 is approximately 8 feet, although chamber 60 may be of greater or lesser height depending on the amount of vacuum applied to the system. I prefer to place passage 58 about three-fourths of the way up from the bottom of chamber 60.

Chamber 60 then becomes about three-quarters filled with water, and a column of water of about the same height fills pumping tube 34 above plug 52, this liquid flowing into pumping tube 34 through a relatively large flow passage 64 just above plugs 50 and 52 at the bottom of the pump string 20.

Vacuum relief tube 42 opens into pumping tube 34 just above bottom plug 52 through a tube 66 at vacuum relief port 68. Although I prefer to place vacuum relief port 68 at the end of a tube 66, vacuum relief port 68 may actually consist of an opening near the lower end of pumping tube 34.

Nozzle 68 is preferably disposed above flow passage 64 in order to prevent backing up of the fluid being pumped due to oscillation set up by the bubble action hereinafter described.

I prefer to provide a tube 66 having a substantially greater diameter than nozzle 68 in order to provide a sufficient quantity of air adjacent to nozzle 68 to permit the rapid release of bubbles from nozzle 68.

A gas bubble 69 forms at regular intervals in pumping tube 34 just above plug 52 by the passage of gas from vacuum relief tube 66 out through port 68. Bubble 69 quickly hoists the liquid above it upwardly pumping tube 34 until the liquid flows laterally through flow passage 74 into the next higher chamber 76 in reservoir tube 32 which is defined between plugs 62 and 78 which are preferably spaced about 8 feet apart.

Adjacent to plug 78 in reservoir tube 32, a plug 72 is disposed in pumping tube 34. Just below plug 72 is a vacuum port 70 which is operatively connected to vacuum tube 38. In addition to the action of bubbles 69 in moving the liquid up from flow passage 64 to flow passage 74, suction applied to pumping tube 34 through vacuum port 70 will hoist the liquid upwardly through pumping tube 34. All of the spaced gas bubbles 69 will, of course, be removed from pumping tube 34 through vacuum port 70 into vacuum tube 38, and thereby none of the bubbles 69 will be permanently mixed with the liquid so as to areate the liquid or cause a foam or otherwise interfere with the pumping operation.

After the fluid has flowed into chamber 76 through flow passage 74, which is preferably about three-quarters of the way up from the bottom of chamber 76, this fluid then flows through a flow passage 80 at the bottom of chamber 76 into pumping tube 36. This fluid is then hoisted upwardly through pumping tube 36 in the same manner that the fluid was hoisted from passage 64 to passage 74 through pumping tube 34. Thus, gas bubbles are periodically released into pumping tube 36 just above plug 57 through vacuum relief port 84 at the end of a tube 82 which is connected to vacuum tube 40. Also, suction is applied in pumping tube 36 through vacuum port 86 which connects pumping tube 36 to vacuum tube 40 just below a plug 88 in pumping tube 36.

The fluid thus lifted through pumping tube 36 then flows through passage 90 into another chamber 92 in reservoir tube 32. Chamber 92 is again preferably about eight feet in length, and has its upper end defined by a plug 94 disposed adjacent to the plug 88 in pumping tube 36. Passage 90 is preferably about two-thirds of the distance between plugs 78 and 94.

The fluid then flows laterally through passage 96 just above plugs 78 and 72 into pumping tube 34, and the fluid is raised in pumping tube 34 by means of bubbles which are released from vacuum relief port 100 at the end of a tube 98 which is connected to vacuum relief tube 42.

I provide a header 102 defined by outer shell member 30, plugs 88 and 94, and a top plug 103. Header 102 is operatively connected to the central portion of reservoir 12 by means of a fluid conduit 104. The partial vacuum applied within header 102 through conduit 104 from reservoir 12 assists in raising the liquid into header 102 and transferring the liquid from header 102 into reservoir 12.

If it is desired, header 102 may be eliminated, and fluid conduit 104 may be connected directly to the top of pumping tube 34.

The fluid thus pumped into reservoir 12 may then be removed for use through a fluid outlet pipe 106 from the bottom of reservoir 12.

Although Figure 2 illustrates my invention with several pumping stages, my pump string may consist of only a single stage in which the fluid enters the string in the usual manner at the open lower end 54 of pumping string 36 with the assistance of the partial vacuum applied through vacuum port 56, the fluid then passing through passage 58 into chamber 60 and then through passage 64 into pumping tube 34. Instead of the additional chambers 76 and 92 and their associated flow passages, pumping tube 34 is connected directly to header 102 or to fluid conduit 104. Fluid may be pumped considerably higher by this single stage of my invention than it could be with an ordinary vacuum pump using a comparable vacuum.

My preferred pumping device includes a closed gas system, instead of merely utilizing air which would enter the system through vacuum relief tube 42 and be pumped out of the system by vacuum pump 10. This is for the reason that the use of air in some pumping operations would cause an explosion hazard, so that the use of an inert gas, such as nitrogen, helium or the like, is preferable. This closed system is effected by a connection between vacuum relief tube 42 and the exhaust port of vacuum pump 10, this connection including vacuum relief line 44 and vacuum relief reservoir 46. Since the only gas which enters the pump string 20 enters through vacuum relief line 44, and all of this gas which thus enters pump string 20 is removed through vacuum tubes 38 and 40, and the corresponding secondary vacuum lines 16 and 18 which connect together into primary vacuum line 14, no air will be permitted to enter the system, and none of the inert gas used will be permitted to escape.

If the particular use of my pumping device does not require an inert gas, such as when my pumping device is used for pumping water out of a well, the above-de-

scribed closed gas circuit is not essential, and the operative connection shown in Figure 1 between vacuum relief tube 42 and the output port of vacuum pump 10 may be eliminated, so that air will be permitted to enter vacuum relief tube 42 from the atmosphere.

I will now describe my preferred method of operating my preferred embodiment shown in Figures 1, 2, 3, and 4 of the drawings. The first step is to lower the pump string 20 to the desired depth into the well. Any number of the pump sections 22, 24 and 26 may be used, according to the depth of the well, and without regard to whether or not the length of the column of liquid pumped is greater than the height of a column of the same liquid which will be required to balance atmospheric pressure. If it is desired, the sections 22, 24 and 26 may be provided separately and may be joined together either just before the pump string 20 is lowered into the well or as it is being lowered into the well. This may be accomplished by externally threading the ends of the various pump sections 22, 24 and 26, and internally threading coupling sleeves 28, with suitable sealing washers being provided at the open ends of the various tubes within the individual pump sections 22, 24 and 26.

After the pump string 20 has thus been lowered into the well, and vacuum pump 10 and reservoir 12 coupled thereto in the manner illustrated in Figure 1 of the drawings, vacuum pump 10 is then turned on to commence the pumping operation.

The amount of suction applied in vacuum tubes 38 and 40 may be adjusted either by adjustment of vacuum pump 10, or by adjustment of a valve 108 disposed in vacuum line 14. The setting of vacuum pump 10 or of valve 108 in line 14 will be determined by the rate of fluid flow desired, and by the height of the individual pump sections 22, 24 and 26, longer individual sections 22, 24 and 26 requiring a higher vacuum in order to properly pump the liquid. The rate of flow of the liquid into reservoir 12 may be independently regulated, regardless of the amount of vacuum applied to vacuum tubes 38 and 40, by adjustment of a valve 110 disposed in fluid conduit 104.

A valve 112 disposed in vacuum relief line 44 permits the regulation of the gas pressure within vacuum relief tube 42 to provide the optimum rate of bubble production through vacum relief ports 68, 84 and 100. Normally, the gas pressure within vacuum relief tube 42 will be below atmospheric pressure, although this is not necessarily the case.

If the closed gas system illustrated in Figure 1 of the drawings is not used, then a valve 112 is preferably still embodied in vacuum relief line 44 which would then connect vacuum relief tube 42 to the atmosphere, in order to adjust the gas pressure within vacuum relief tube 42 to provide the optimum rate of bubble production. If vacuum relief line 44 is not provided with a valve 112, then the orifice sizes of vacuum relief ports 68, 84 and 100 are such that the optimum rate of bubble production will be caused.

The liquid is then raised through the pump string 20 by first being raised into the lower portion of pumping tube 36 by suction from vacuum port 56 and then flowing through lateral passage 58 into reservoir chamber 60. Then the fluid flows out of reservoir chamber 60 through passage 64 at the bottom thereof into pumping tube 34, through which the liquid is raised by means of bubbles 69 released from vacuum relief port 68 and by suction applied through vacuum port 70, the liquid then flowing laterally through passage 74 into a second reservoir chamber 76. Next, the fluid flows through passage 80 at the bottom of the second reservoir chamber 76 into pumping tube 36, through which the liquid is raised by bubbles from vacuum relief port 84 and by suction from vacuum port 86, this fluid flowing laterally through a passage 90 into the third reservoir chamber 92, from which it passes through a passage 96 into pumping tube 34, to be raised again by bubbles from vacuum relief port 100 and by suction applied at the top of pumping tube 34.

This pumping process, although herein illustrated only in connection with three pump sections, 22, 24, and 26, may be carried on in the same manner for any number of pump sections.

The purpose of reservoir chambers 60, 76 and 92 is two-fold. First, these chambers at all times contain sufficient liquid so that the passages 64, 80 and 96 at the respective bottoms thereof are at all times submerged in the liquid, regardless of the pulsating effect caused by the intermittent introduction of bubbles through vacuum relief ports 68, 84 and 100. This prevents any interference with the efficient operation of the bubbles.

The second function of reservoir chambers 60, 76 and 92 is the provision of a cushioning effect against the pulsating in the system caused by the bubbles, the cushion being provided by the gas space at the top of each of the reservoir chambers 60, 76 and 92.

If pump string 20 is built up by individual sections such as 22, 24 and 26 to such a height that a large amount of friction loss appears in vacuum tubes 38 and 40, an additional vacuum tube (not shown) may be embodied in the pump string to accomplish the functions of tubes 38 and 40 for the upper portion of pump string 20.

Although I have shown and described a preferred embodiment of my invention in which the various tubes are all contained within a cylindrical outer shell member 30, it is to be understood that separate, generally rigid tubes may be operatively connected together in above-described manner without the use of an outer shell. In such an embodiment of my invention it would generally be preferable to use a single vacuum tube rather than the two vacuum tubes 38 and 40 shown in Figures 3 and 4 of the drawings.

In Figures 5 and 6 of the drawings I have illustrated an alternative embodiment of my present invention which briefly consists of a plurality of joining sections, such as joining sections 114 and 116, which are joined together by means of a plurality of hose sections, such as hose sections 148, 164, 176, 194 and 196.

This alternative embodiment of my invention operates in exactly the same manner as my preferred embodiment of Figures 1 to 4, and is connected at its upper end to vacuum pump 10 and reservoir 12 in the same manner as my preferred embodiment. Thus, I have only illustrated a single complete section in Figures 5 and 6, with portions of the upper and lower adjoining sections also being shown in order to clearly disclose the manner in which the various parts are operatively inter-connected.

Each of the joining sections 114 and 116 may be made of plastic, metal or other suitable material, and preferably has a cross-sectional shape that is identical with the cross-sectional shape of the preferred embodiment of my invention as is best illustrated in Figure 3 of the drawings. Thus, each of the joining sections 114 and 116 preferably has relatively large reservoir tube 118, a pair of preferably circularly cross-sectioned pumping tubes 120 and 122, a pair of vacuum or low pressure tubes 124 and 126, and a vacuum relief or high pressure tube 128. Joining sections 114 and 116 are preferably each about two feet in length, although this length is not critical.

Fluid will be lifted upwardly through hose section 129 and nozzle 130 into pumping tube 122 by means of suction applied in pumping tube 122 of joining section 116 through vacuum port 132 disposed just below a plug 134. If the next joining section below joining section 116 is the bottom section, then the liquid will have been lifted up into joining section 116 solely by suction applied through vacuum port 132. However, if the next joining section below joining section 116 is merely an intermediate joining section, then the liquid will have been lifted up into joining section 116 through nozzle 130 both by

suction applied through vacuum port **132** and by means of a bubble released in the lower joining section.

The liquid thus hoisted into joining section **116** then passes laterally through a passage **136** into reservoir chamber **138** having its upper end defined by a plug **140**. Passage **136** corresponds to passage **58** in the preferred embodiment of my invention as illustrated in Figure 2, and chamber **138** corresponds to chamber **60** of my preferred embodiment. The lower portion of chamber **138** is operatively connected to the upper portion of chamber **138** within joining section **116** by means of nozzle **142**, the lower portion of chamber **138** consisting of hose section **143**, together with a reservoir tube portion of the next lower joining section (not shown), this lower reservoir tube portion of chamber **138** being identical in construction to chamber **184** in joining section **114**.

The liquid which is thus pumped into reservoir chamber **138** then passes through a lateral passage in the joining section below section **116** which is identical to passage **186** in section **114**, and is raised upward through hose section **145** and through nozzle **144** into pumping tube **120** in section **116**. The liquid then passes upwardly out of nozzle **146**, through hose section **148** and through nozzle **150** in joining section **114** into pumping tube **120** of joining section **114**. The liquid is thus raised through the pumping tube **120** of joining sections **116** and **114**, and through hose section **148**, by means of a bubble released in the joining section below joining section **116**, and also by means of suction applied to pumping tube **120** in joining section **114** through vacuum port **152**, which has a plug **154** disposed directly above it.

The liquid then flows laterally through passage **156** into chamber **158**, the upper portion of which is disposed within joining section **114**. The upper end of chamber **158** is defined by a plug **160**, and the lower portion of chamber **158** consists of a nozzle **162** at the bottom of joining section **114**, a hose section **164** which connects nozzle **162** to a nozzle **166** at the top of joining section **116**, and a portion of chamber **158** in joining section **116** which has its bottom defined in reservoir tube **118** by plug **140**.

The liquid then flows laterally out of chamber **158** to the left through passage **168** in joining section **116** into pumping tube **122** of joining section **116**, the liquid then being lifted upward by a bubble released from vacuum relief port **172** in tube **170** which is operatively connected to vacuum tube **126** in joining section **116**. The liquid flows upward through nozzle **174**, hose section **176**, nozzle **178**, and pumping tube **122** in joining section **114**, the liquid passing upward out of joining section **114** through a nozzle **180** and hose section **181**.

The next joining section above joining section **114** is identical to joining section **116**, with a vacuum port similar to vacuum port **132** to assist in raising the liquid. The bottom portion of the next reservoir chamber **184** is connected to the joining section above joining section **114** by hose section **185** and nozzle **182**, and the liquid from reservoir chamber **184** passes laterally to the right, through passage **186** in joining section **114** into pumping tube **120**, the liquid then being raised in part by bubbles released at vacuum relief port **190** which is operatively connected to vacuum tube **124** in joining section **114** through a tube **188**. This liquid then flows upward out of joining section **114** through nozzle **192** and hose section **193** into the next joining section above section **114**.

Although it will be noted that the preferred embodiment of my invention illustrated in Figures 1 to 4 utilizes six tubes, two of which are vacuum tubes **38** and **40**, in the preferred form of my alternative embodiment of Figures 5 and 6 I utilize only five hose sections between successive joining sections, such as the five hose sections **148**, **164**, **176**, **194** and **196** between joining sections **114** and **116**. The use of only five sections to join the adjacent joining sections in my alternative embodiment of Figures 5 and 6 is accomplished by utilizing only a single vacuum tube in each of the joining sections, and using opposite vacuum tubes in adjacent joining sections. Thus, vacuum tube **126** is used in joining section **116**, and vacuum tube **124** is used in joining section **114**, with hose section **194** operatively connecting vacuum tube **126** of joining section **116** with vacuum tube **124** of joining section **114**. Vacuum tube **124** of joining section **116** is idle, and also vacuum tube **126** of joining section **114** is idle.

If it is desired, an extra hose section may be used to connect adjacent joining sections, and a separate hose section may be used to connect tubes **124** of adjacent joining sections, while a separate hose section is used to connect tubes **126** of adjacent joining sections. This additional, sixth hose section is desirable if the liquid is to be pumped to relatively great heights, as friction is diminished in the vacuum tubes by this means.

The successive joining sections, such as sections **114** and **116**, of my alternative embodiment are preferably approximately 8 feet apart, although they may be spaced at wider intervals.

Ordinary hose can be used to connect adjacent joining sections in my alternative embodiment, so that the structure necessary to produce my pump may be sold as a plurality of joining sections **114** and **116** which are appropriately marked to permit the purchaser to operatively connect the successive joining sections with hose to produce his own pump string of any desired length. Plastic tubing may be used in place of the hose, with rubber adapters being used to connect this tubing to the respective joining sections if it is desired.

This use of successive joining sections coupled together by hose sections has the additional advantages of cheapness to manufacture and of compactness in storage, the integrated pump string being sufficiently flexible to be rolled onto a drum for storage and the entire pump string being readily disassembled to its component parts.

It is to be understood that the form of my invention herein shown and described is my preferred embodiment and that various changes in the shape, size and arrangement of parts may be resorted to without departing from the spirit of my invention, or the scope of my appended claims.

I claim:

1. A vacuum pump string including a reservoir having an elongated chamber therein, said chamber having an upper and a lower flow passage, a tube operatively connected to said reservoir and extending downwardly from said upper flow passage, means communicating with said downwardly extending tube near its upper end for creating a partial vacuum in the upper end of said downwardly extending tube, a tube operatively connected to said reservoir and extending upwardly from said lower flow passage, and means communicating with said upwardly extending tube near its upper end for releasing bubbles in said upwardly extending tube near the lower end thereof.

2. A vacuum pump string including a reservoir having an elongated chamber therein, said chamber having an upper and a lower flow passage, a tube operatively connected to said reservoir and extending downwardly from said upper flow passage, a tube operatively connected to said reservoir and extending upwardly from said lower flow passage, means communicating with said upwardly extending tube near its lower end for releasing bubbles in said upwardly extending tube near the lower end thereof, and means communicating with both of said tubes near their upper ends for creating a partial vacuum in the upper ends of both of said tubes.

3. A vacuum pump string including a reservoir having an elongated chamber therein, said chamber having an upper and a lower flow passage, a tube operatively connected to said reservoir and extending downwardly from said upper flow passage, a vacuum tube, an operative connection between said vacuum tube and the upper end

of said downwardly extending tube, a tube operatively connected to said reservoir and extending upwardly from said lower flow passage, a bubble release port in said upwardly extending tube near the lower end thereof, a vacuum relief tube, and an operative connection between said vacuum relief tube and said bubble release port.

4. A vacuum pump string including a reservoir having an elongated chamber therein, said chamber having an upper and a lower flow passage, a tube operatively connected to said reservoir and extending downwardly from said upper flow passage, a tube operatively connected to said reservoir and extending upwardly from said lower flow passage, a bubble release port in said upwardly extending tube near the lower end thereof, a vacuum pump having gas input and output ports, an operative connection between said gas input port and the upper ends of both of said tubes, and an operative connection between said output port and said bubble release port.

5. A vacuum pump string including a reservoir having an elongated chamber therein, said chamber having an upper and a lower flow passage, a tube operatively connected to said reservoir and extending downwardly from said upper flow passage, means communicating with said downwardly extending tube near its upper end for creating relatively low pressure in the upper end of said downwardly extending tube, a tube operatively connected to said reservoir and extending upwardly from said lower flow passage, said means communicating with said upwardly extending tube near its lower end for releasing bubbles in said upwardly extending tube near the lower end thereof, said reservoir and said tubes consisting in part of a hose section and a portion of a hose joining section.

6. A vacuum pump string including a plurality of reservoirs disposed one above the other, each of said reservoirs having an elongated chamber therein, a lower and an upper flow passage in each of said chambers, a tube connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, said tube being operatively connected to the respective said reservoir, means communicating with each of said tubes near its upper end for creating relatively low pressure in the upper end of each of said tubes, and means communicating with each of said tubes near its lower end for releasing bubbles in each of said tubes near the lower end of that tube.

7. A vacuum pump string including a plurality of reservoirs disposed one above the other, each of said reservoirs having an elongated chamber therein, a lower and an upper flow passage in each of said chambers, a connecting tube connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, said connecting tube being operatively connected to the respective said reservoirs, a vacuum tube, means for maintaining a partial vacuum in said vacuum tube, an operative connection between said low pressure tube and the upper end of each of said connecting tubes, and means operatively connected to each of said tubes near its lower end for releasing bubbles in each of said tubes near the lower end of that tube.

8. A vacuum pump string including a plurality of reservoirs disposed one above the other, each of said reservoirs having an elongated chamber therein, a lower and an upper flow passage in each of said chambers, a connecting tube connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, said connecting tube being operatively connected to the respective said reservoirs, a vacuum tube, means for maintaining a partial vacuum in said vacuum tube, an operative connection between said vacuum tube and the upper end of each of said connecting tubes, a bubble release port in each of said connecting tubes near the lower end of that connecting tube, a vacuum relief tube, and an operative connection between said vacuum relief tube and each of said bubble release ports.

9. A vacuum pump string including a reservoir tube containing a plurality of spaced plugs to provide a plurality of elongated chambers disposed one above the other, a lower and an upper flow passage in each of said chambers, a plurality of pumping tubes each containing a plurality of spaced plugs to provide a plurality of connecting tubes, one of said connecting tubes connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, means communicating with each of said connecting tubes near its upper end for creating relatively low pressure in the upper end of each of said connecting tubes, and means communicating with each of said connecting tubes near its lower end for releasing bubbles in each of said connecting tubes near the lower end of that connecting tube.

10. A vacuum pump string including a reservoir tube containing a plurality of spaced plugs to provide a plurality of elongated chambers disposed one above the other, a lower and an upper flow passage in each of said chambers, a plurality of pumping tubes each containing a plurality of spaced plugs to provide a plurality of connecting tubes, one of said connecting tubes connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, a vacuum tube, means operatively connected to said low pressure tube for maintaining a sub-atmospheric pressure in said vacuum tube, an operative connection between said vacuum tube and the upper end of each of said connecting tubes, a bubble release port in each of said connecting tubes near the lower end of that connecting tube, a vacuum relief tube, and an operative connection between said vacuum relief tube and each of said bubble release ports.

11. A vacuum pump including a reservoir tube containing a plurality of spaced plugs to provide a plurality of elongated chambers disposed one above the other, a lower and an upper flow passage in each of said chambers, a plurality of pumping tubes each containing a plurality of spaced plugs to provide a plurality of connecting tubes, one of said connecting tubes connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, a vacuum tube, an operative connection between said vacuum tube and the upper end of each of said connecting tubes, a vacuum relief port in each of said connecting tubes near the lower end of that connecting tube, a vacuum relief tube, an operative connection between said vacuum relief tube and each of said vacuum relief ports, a vacuum pump having gas input and output ports, and operative connections between said input and output ports and the upper ends of said vacuum and pressure relief tubes, respectively, to provide a closed gas system for said pump.

12. A vacuum pump string including a plurality of reservoirs disposed one above the other, each of said reservoirs having an elongated chamber therein, a lower and an upper flow passage in each of said chambers, a tube connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, means communicating with each of said tubes near its upper end for creating a partial vacuum in the upper end of each of said tubes, and means communicating with each of said tubes near its lower end for releasing bubbles in each of said tubes near the lower end of that tube, each of said reservoirs and tubes consisting in part of a hose section and a portion of a hose joining section.

13. A vacuum pump string including a plurality of reservoirs disposed one above the other, each of said reservoirs having an elongated chamber therein, a lower and an upper flow passage in each of said chambers, a tube connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher

chamber, a vacuum tube, means for maintaining a partial vacuum in said vacuum tube, an operative connection between said low pressure tube and the upper end of each of said connecting tubes, a vacuum relief port in each of said connecting tubes near the lower end of that connecting tube, a vacuum relief tube, and an operative connection between said vacuum relief tube and each of said vacuum relief ports, each of said reservoirs and tubes consisting in part of a hose section and a portion of a hose joining section.

14. A vacuum pump string including a plurality of reservoirs disposed one above the other, each of said reservoirs having an elongated chamber therein, a lower and an upper flow passage in each of said chambers, a tube connecting the lower flow passage of each of said chambers with the upper flow passage of the next higher chamber, means communicating with each of said tubes near its upper end for creating relatively low pressure in the upper end of each of said tubes and means communicating with each of said tubes near its lower end for releasing bubbles in each of said tubes near the lower end of that tube, each of said reservoirs and tubes consisting in part of a hose section and a portion of a hose joining section, each of said hose joining sections containing one of said upper flow passages and one of said lower flow passages.

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