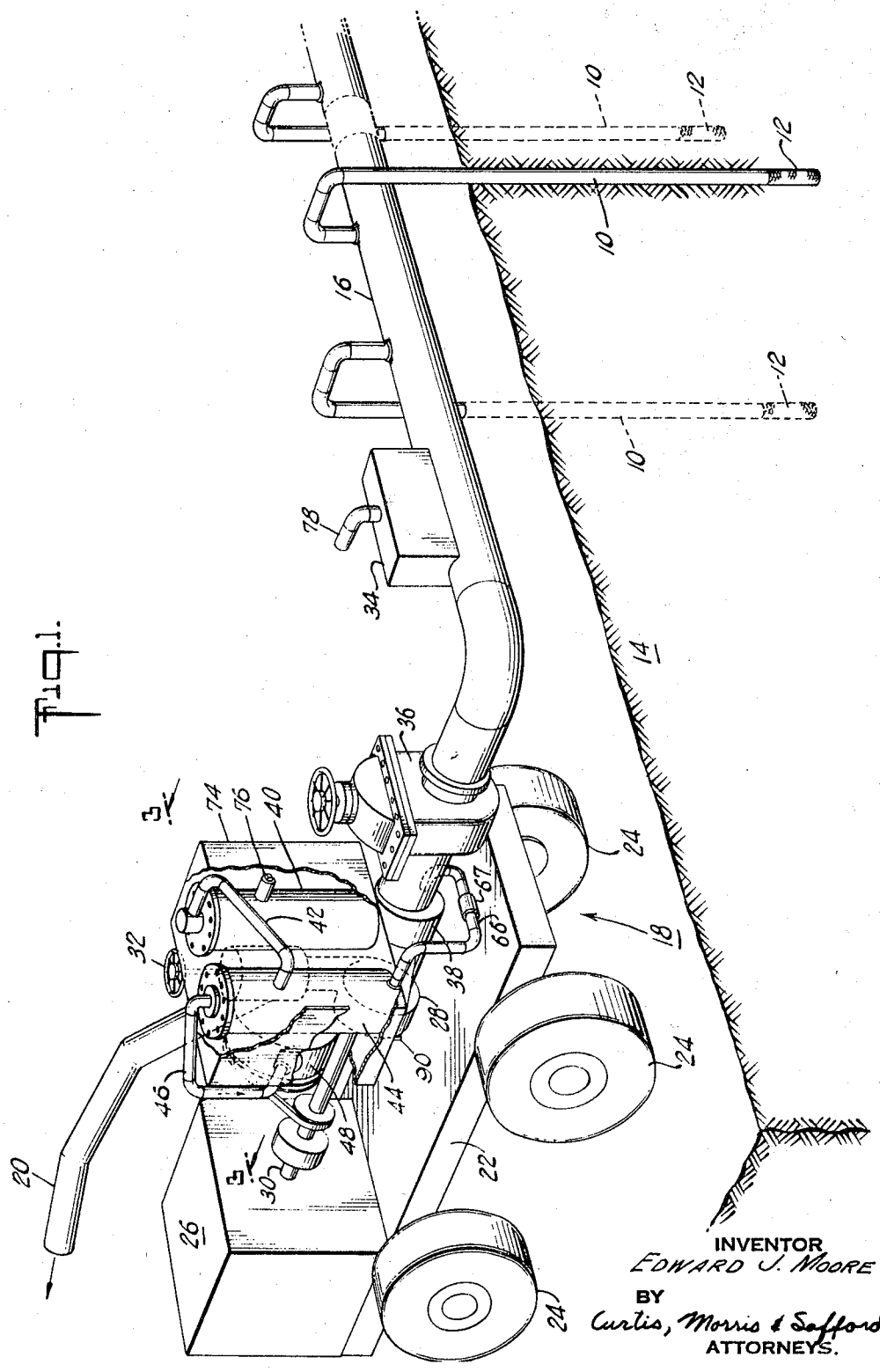
March 11, 1969 E. J. MOORE 3,431,708

VACUUM LINE CLOSURE METHOD AND DEVICE FOR SEPARATION CHAMBERS IN GROUND-WATER PUMPING SYSTEMS

Filed April 25, 1967 Sheet 1 of 3

Fig. 1.



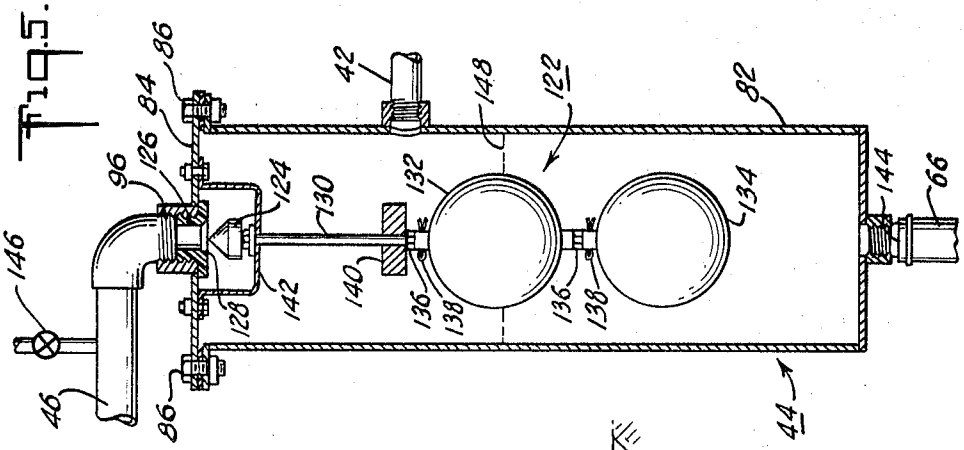
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VACUUM LINE CLOSURE METHOD AND DEVICE FOR SEPARATION CHAMBERS IN GROUND-WATER PUMPING SYSTEMS

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Fig. 5.



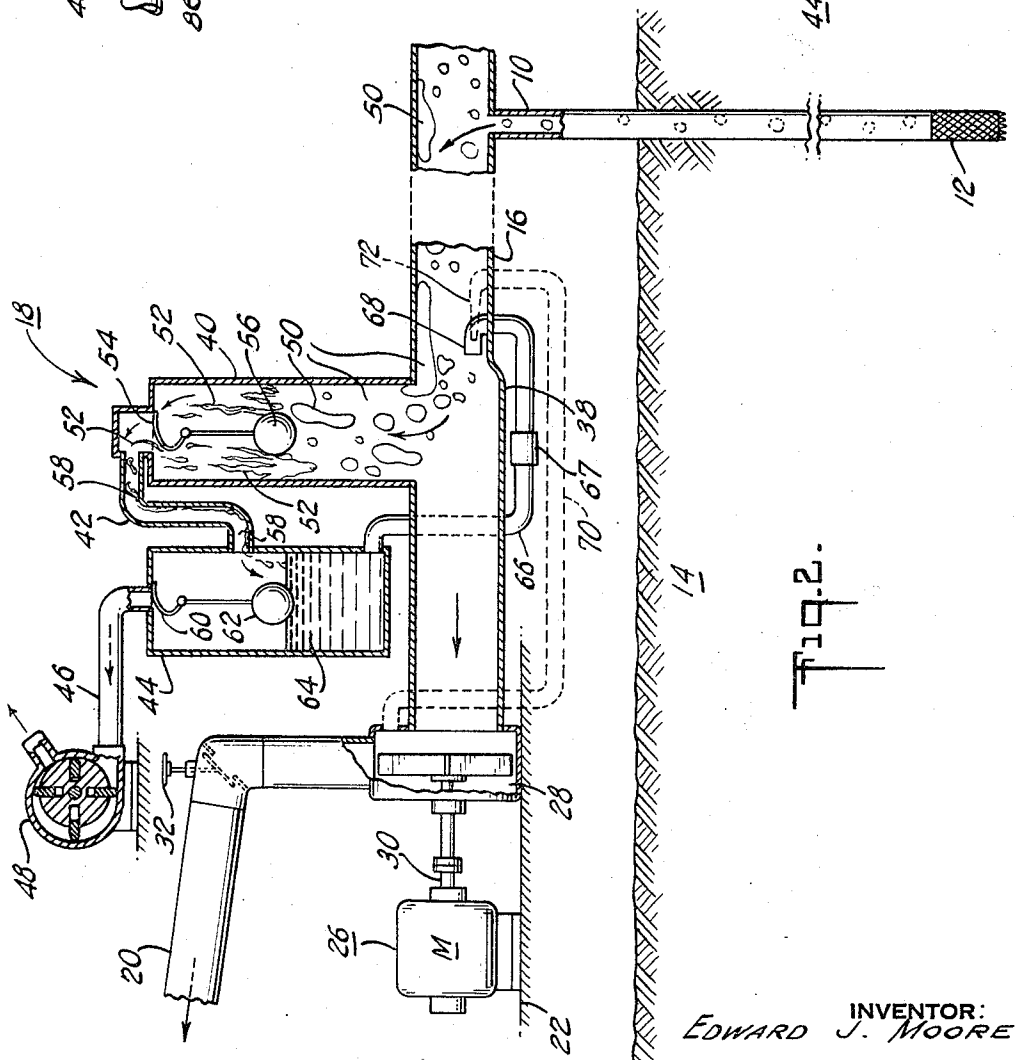


Fig. 2.

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Fig. 3.

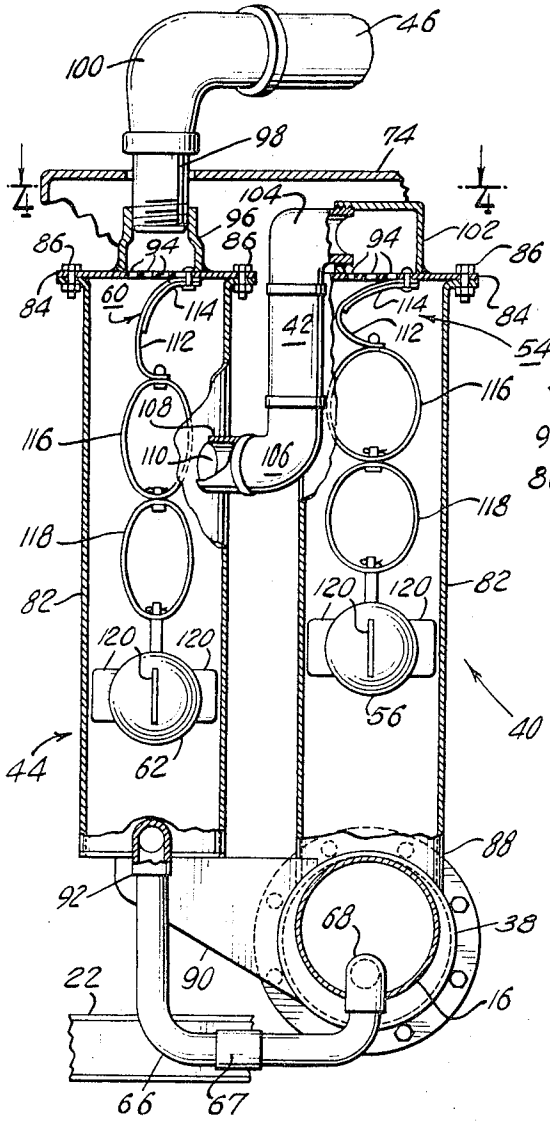
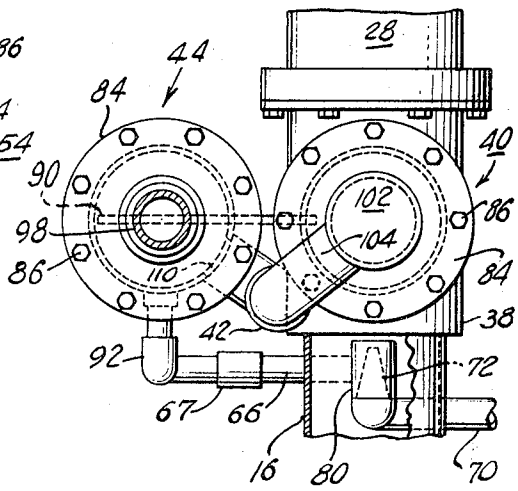


Fig. 4.



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3,431,708

VACUUM LINE CLOSURE METHOD AND DEVICE FOR SEPARATION CHAMBERS IN GROUND-WATER PUMPING SYSTEMS

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Continuation-in-part of application Ser. No. 586,862, Oct. 14, 1966. This application Apr. 25, 1967, Ser. No. 633,612
U.S. Cl. 55—55 9 Claims
Int. Cl. B01d *19/00*

ABSTRACT OF THE DISCLOSURE

A gas vacuum pump is connected to the second of two series connected gas-liquid separation chambers. The connection to the vacuum pump is closed by a float valve whose dimensions and weight are set so that the valve closes when the water level in the chamber rises above a predetermined danger level, and opens when the gas pressure in the chamber increases at a relatively low rate and the water level recedes to a safe level. However, when the gas pressure level in the chamber increases at a relatively high rate, thus indicating a major malfunction in the pumping system, the valve will not re-open until it is manually actuated, even if the water drops to a safe level.

This application is a continuation-in-part of my co-pending U.S. Patent Application Ser. No. 586,862, filed Oct. 14, 1966.

This invention relates to apparatus for removing dispersed liquids from the ground; more particularly, this invention relates to a system for removing water from the ground over a substantial area by means of a series of pipes or "well-points" sunk into the ground at spaced intervals, and including a pumping unit for drawing the water out of the ground through the well-points. Still more particularly, this invention relates to valve arrangements for use in the gas separation apparatus forming a part of the pumping unit.

A major problem found in the use of prior well-point equipment is caused by the fact that the water pumped by the system usually contains rather substantial quantities of air or other gases, and often contains substantial quantities of sand and other foreign particles. The liquid pump in the pumping unit of a well-point system usually is a centrifugal pump. Such pumps suffer a great loss of efficiency when there is any substantial quantity of gas in the liquid being pumped. Hence, in most well-point installations, it is necessary to remove the gas from the liquid in order for the pump to operate at a relatively high efficiency or, in some cases, in order for the pump to operate at all.

One device used to remove gases from the liquid is a separation chamber and vacuum pump. The usual separation chamber is a vertical tank whose bottom opens directly into the top of the pipe-line leading into the centrifugal pump. A vacuum pump is connected to the top of the chamber to evacuate gas separated from the liquid.

A very long-standing problem with such a separation system is caused by the fact that the liquid in the separation chamber bubbles violently and splashes upwardly with great turbulence as the gas is separated from it, and tends to get into the vacuum pump. Although reciprocating vacuum pumps are not seriously affected by the liquid it is desired to use rotary vacuum pumps because of their considerably better performance at a lower cost. However, rotary vacuum pumps can be damaged or ruined if liquid from the well-points is allowed to get into them, especially if the liquid is ground water which carries particles of sand or other foreign matter.

Various systems have been proposed for preventing water carry-over into vacuum pumps. However, such systems, generally have been unsatisfactory. Accordingly, it is an object of the present invention to provide apparatus for continuously removing dispersed liquids from the ground in which gases are removed from the liquid by means of a separation chamber and a vacuum pump without the liquid being carried into the vacuum pump. It is a further object to provide a valve arrangement for use in the gas separation chamber of such apparatus to further insure against carry-over of liquid into the vacuum pump. It is another object of the present invention to provide apparatus having the foregoing beneficial features, and which is simple in operation, requires an absolute minimum of maintenance, is relatively free from malfunction, and is compact and relatively lightweight so as to be easily portable from one construction site to another.

The invention now will be described with reference to the drawings, in which:

FIGURE 1 is a perspective view of a well-point system constructed in accordance with the present invention;

FIGURE 2 is a schematic diagram of the system shown in FIGURE 1;

FIGURE 3 is a partially broken-away and partially cross-sectional view taken along line 3—3 of FIGURE 1;

FIGURE 4 is a cross-sectional view taken along line 4—4 of FIGURE 3 and

FIGURE 5 is a cross-sectional view of a component of an alternative embodiment of the present invention.

FIGURE 1 shows a well-point water removal system constructed in accordance with the present invention. The system includes several well-points, each comprising a pipe **10** and an inlet screen **12** sunk into the ground **14** at spaced intervals. Each well-point is connected to the main pipe **16** on the surace of the ground. The main pipe **16** is connected to a mobile pumping unit **18** which pumps the liquid through the pipe **16** from the well-points and discharges the liquid from an outlet pipe **20**. As is well known, such a well-point system can be used to dry the ground to a certain depth so as to make it easier to dig excavations in it, or to draw water from the ground for industrial or domestic use, or for other well known uses.

The mobile pumping unit **18** includes a frame **22** mounted on wheels **24** or on skids (not shown). A motor or engine **26** drives a rotary pump **28** through a drive shaft **30**. The pump **28** pumps liquid through a discharge check valve **32** and the outlet pipe **20**. The pump **28** draws water through the main pipe **16** past an optional flow-smoothing manifold **34** and an optional inlet valve **36** into an inlet conduit **38** which has a slightly larger diameter than the pipe **16** connected to it.

Rotary pump **28**, which preferably is of the centrifugal type, will not operate at peak efficiency if the liquid being pumped has substantial quantities of gas in it. Therefore, as is shown most clearly in FIGURE 2, a vertical separating chamber **40** is connected to the top of conduit **38** with the conduit **38** having a hole in its top communicating with the open bottom of chamber **40** so that gases will tend to rise from the liquid in the horizontal conduit **38** into the chamber **40**.

In accordance with the present invention, an isolation chamber **44** is provided and connected to the top of chamber **40** by means of a gas conduit **42** of relatively large diameter. A rotary vane type of vacuum pump **48** is connected to the top of isolation chamber **44** by means of another gas conduit **46**, also of relatively large diameter.

Rotary vacuum pump **48** will not operate properly if either foreign matter or water is introduced into its gas flow passages. Even the smallest particles of foreign material are likely to mar the internal components of the

pump and ruin it, causing much lost time and expense in repair or replacement of the pump.

As is shown in FIGURE 2, the gas bubbles **50** rising in the separation chamber **40** often cause turbulent agitation and upward splashes **52** of the water in the tank **40**. A conventional "flap" or "peel" valve **54** is provided at the opening to the outlet pipe **42** at the top of the chamber **40**. Valve **54** is operated by a float **56** in order to block the exit opening of chamber **40** when the water level in the chamber rises too high. The valve opens and closes very rapidly so as to react quickly to the rapid fluctuations of the liquid level in the separation chamber, and to pass as much gas and as little liquid as possible. However, the valve **54** does not prevent all of the water from splashing into the outlet pipe **42**. As a result, drops of water **58**, usually numerous enough to form small streams, flow almost continuously through the pipe **42** into the isolation chamber **44** where no turbulence occurs and separation is complete. Under certain conditions, the water in tank **40** will rise up to the top of the tank and great amounts of water will flow through the pipe **42** into the isolation chamber **44**. Neither the small streams nor the complete overflow of water can be tolerated by the vacuum pump **48**.

In accordance with the present invention, the isolation chamber prevents water from splashing into the vacuum pump. Because there is no upward movement of air through the liquid in chamber **44**, there is no turbulence or splashing of the liquid in chamber **44**. As a result, the vacuum pump **48** receives virtually no water or solids and therefore can operate for very long periods of time at or near maximum efficiency. There are no baffles in the gas flow passages to reduce the efficiency of the pump **48**. In fact, the diameters of the conduits **42** and **46** can be made practically as large as necessary to permit the full flow of gas to the vacuum pump at its rated capacity, and can be made at least as large as the inlet opening to the vacuum pump **48**.

A flap valve **60** and float **62** are provided as a safety feature to prevent water carry-over into the vacuum pump if the water level reaches the top of the isolation chamber **44** due to major malfunction of the system.

The removal of the accumulated liquid **64** from the isolation chamber **44** creates special problems. The chamber **44** cannot simply be opened at its bottom to let the water run out because the water is under a vacuum and will not run out. Removal of the accumulated liquid is accomplished in accordance with the present invention automatically and without the need for another pump by providing an open return conduit **66** connected at one end to the bottom of chamber **44**, and at its other end **68** into the bottom of the inlet conduit **38** at which point the liquid from chamber **44** flows into the liquid in the conduit **38** from which a substantial portion of the gas has escaped. Under normal conditions, the pressure at the return conduit outlet **68** usually is somewhat greater than that in the upper part of the isolation chamber **44**. For example, the vacuum (negative pressure) at the end **68** of the return conduit might be from 9 to 29 inches of mercury, and typically is around 25 inches of mercury. Typically, the vacuum at the top of chamber **44** is around 26 inches of mercury. The isolation chamber **44** is made tall enough so that the static pressure of the accumulated liquid **64** in the chamber will overcome any excess pressure at point **68** and cause the liquid **64** to discharge automatically from chamber **44** prior to the point where the level of the liquid **64** rises to the entrance of the vacuum pump feed line **46** at the top of the chamber. Thus, the accumulated liquid is removed from chamber **44** automatically and without a separate pump.

In an alternative embodiment of the invention, additional suction can be applied to the return line **66** to aid in removal of accumulated liquid from the isolation tank **44**. Accordingly, another conduit **70** (shown in dashed lines in FIGURE 2) is connected at one end to the high-pressure outlet of the centrifugal water pump **28**, and at the other end forms a jet nozzle **72** which extends into the return tube outlet **68** as is shown in FIGURE 2. By means of conduit **70**, a high-velocity jet of liquid is forced through the tubular end **68** of the return tube **66** so as to provide continuous pumping action to aid in removing liquid **64** from the chamber **44**.

Regardless of which of the above-described emptying arrangements is used, the provision of the isolating chamber **44** solves the very long-standing problem of liquid carry-over into the vacuum pump in a well-point system without occluding the gas flow passages. Since the liquid in the isolation chamber **44** is calm, water is not splashed into the vacuum feed line **46**. The emptying of accumulated liquid from chamber **44** is automatic and is accomplished without the use of a separate pump. Furthermore, the automatic emptying arrangement is simple and relatively fool-proof. The exit end **68** of return line **66** is located at or near the bottom of conduit **38** so as to prevent air which accumulates near the top portion of the conduit **38** from entering the return line and causing any turbulence in the liquid **64** in isolation chamber **44**. The vacuum pump **48** operates near peak efficiency because of the prevention of liquid carry-over into the pump. As a result, the centrifugal liquid pump **28** operates near peak efficiency because the gases are continuously removed from the liquid with high efficiency. This is true despite the constant violent turbulence in the separation tank **40**, and even sudden inrush of great quantities of gas into the system which frequently occurs when one of the well-point pipes **10** is broken. Also, since none of the liquid gets into the vacuum pump, very dirty water can be pumped without fear of damaging the vacuum pump.

As is shown in FIGURE 1, the separation chamber **40** and isolation chamber **44** are enclosed in an insulated housing **74** which is shown broken-away in FIGURE 1 to exposed the chambers **40** and **44** to view. Also, an outlet pipe **76** is connected to the separation chamber **40**. This pipe usually is plugged and is not used. However, it can be connected by means of a hose to a pipe **78** on the top of the smoothing manifold **34**, if desired. Manifold **34** is substantially similar in operation to the separation chamber **40**. It may be used, if desired, to initially remove some of the gas from the liquid and smooth the flow of the liquid before reaching the separation chamber **40**.

Superficially similar ideas have been proposed for use in different types of pumping arrangements, as is shown, for example in U.S. Patents 2,275,500; 2,275,501 and 2,275,502 to Broadhurst. However, such prior art arrangements are inoperative and impractical for use in well-point systems.

Now referring to FIGURES 3 and 4, the construction of the separation chamber **40** is virtually identical to that of the isolation chamber **44**. Each chamber includes a vertical cylinder **82**, and a top plate **84**. The cylinder **82** is secured to the top plate by means of a plurality of bolts **86**.

The bottom of cylinder **82** for the separating chamber **40** is welded onto an upstanding neck-portion **88** of conduit **38** which connects the bottom of chamber **40** into the conduit **38**. The diameter of the chamber **40** is only slightly less than that of conduit **38**, thus providing a large area for the escape of gas into the chamber **40** from the liquid. As is shown in FIGURES 2 and 4, the conduit portion **38** is of larger diameter than the pipe **16**, and its centerline is located below that of pipe **16**. The larger diameter of conduit **38** slows down the liquid flow, decreases its turbulence, and improves separation.

The bottom of chamber **44** is welded onto a bracket **90** which is welded onto the outside of conduit **38** so as to support the isolation chamber **44**. The return conduit **66**, which is either a metal pipe or a hose, is connected between a hole in the bottom of chamber **44** and the pipe **66** by means of a conventional elbow fitting **92**. Fitting

68 also is a conventional elbow fitting which is positioned at the bottom of conduit 16 so as to prevent air from flowing up into the return line 66. A check-valve 67 is positioned in the return line 66 in order to prevent air from flowing into the chamber 44 through line 66 if massive turbulence causes air bubbles to be located temporarily at the bottom of the conduit 16. The outlet of fitting 68 opens towards the centrifugal pump 28 and thus tends to gain the benefit of slight suction at its opening produced by the liquid flow past it.

FIGURE 4 shows the optional ejector emptying arrangement which also is shown in FIGURE 2. A T-shaped pipe fitting 80 is fastened to the end of return conduit 66. The jetting tip 72 is fitted into one end of the T-fitting. The conduit 70 passes through the bottom of the pipe 16 and is connected to the high-pressure outlet of the pump 28.

Referring again to FIGURE 3, the top plate 84 of each chamber 40 and 44 has a grid formed by a number of holes 94 in its center. These holes serve as the gas outlet openings for each chamber and are made as large as possible while still providing a seat for the flaps of the valves 54 and 60. Conventional pipe fittings 96, 98 and 100 are provided to connect the holes 94 of chamber 44 to the vacuum pump inlet conduit 46. Furthermore, conventional fittings 102, 104, 106 and 108 are used to connect the conduit 42 between the holes 94 in separation chamber 40 and the inlet opening 110 in chamber 44. The latter opening is located about one-third of the way down from the top of chamber 44.

The valves 54 and 60 and floats 56 and 62 are identical in both chambers. The construction of each is well-known. Each valve includes a flexible flap portion 112 and a relatively stiff resilient member 114 which tends to press the flap 112 upwardly to close the holes 94. The floats 56 and 62 are joined to the flaps 112 by means of a pair of rubber rings 116 and 118. As is well known, as each ball 56 or 62 rises, the flap 112 moves upwardly to close the openings 94. When the ball drops, the flap 112 is "peeled" away from its valve seat, the valve thus being relatively easy to open. The "peel" valves provide protection only against the flow of relatively large amounts of liquid out of the respective gas outlets of the chambers 40 and 44. However, they do not excessively constrict the flow of air from the chambers because they have openings large enough to easily pass the full flow of gases to the vacuum pump, and because they open so quickly.

FIGURE 5 shows an alternative valve arrangement for the isolation chamber 44. The valve arrangement generally indicated 122 in FIGURE 5 is not a flap valve as in the above-described embodiment of the invention, but instead has a solid, conically-shaped metal valve member 124 which moves upwardly to seat itself in a frustro-conical valve seat 128 in a valve seat body 126. The valve member 124 is secured to the uppermost end of a rod 130. Secured to the lower end of the rod 130 are two hollow metal float spheres 132 and 134. The spheres 132 and 134 are secured together and to the rod 130 by means of lock nuts 136 and cotter pins 138. The rod 130 passes through a central hole in a weight 140. The rod 130 also passes through a centrally-located hole in a U-shaped guide bracket 142 which is bolted to the upper plate 84 of the isolation chamber 44.

The isolation chamber arrangement shown in FIGURE 5 is the same as that shown in the previous figures of the drawings except that its drain opening is centrally located in the bottom of the chamber and the drain conduit 66 is a flexible hose secured to a pipe fitting 144 which is screwed into a fitting at the bottom of the isolation chamber. Also, an air vent valve 146 is provided in the gas conduit 46. The valve 146 can be opened to allow air to enter the conduit 46 from the atmosphere.

The valve arrangement 122 operates as follows: When the water in chamber 44 reaches a certain pre-determined level such as that indicated by the dashed line 148, for example, there is a considerably increased danger of splashing liquid into the vacuum line, and it is desired to securely close the opening to the vacuum line 46 in order to insure that no liquid enters the vacuum line. The valve 122 closes tightly by means of a solid valve member and a solid valve seat, an arrangement which virtually eliminates leakage. The valve seat body 126 is made of a TFE fluorocarbon material such as "Teflon," sold by Du Pont, in order to provide an acid-resistant, long-wearing tight-sealing valve seat. The downward forces on the valve member due to the weight of the valve components 124, 130, 132, 134 and 140 are balanced against the upward buoyancy forces provided by the hollow spheres 132 and 134 so that the valve 122 closes when the water level reaches the pre-determined danger level 148.

It will be recalled that the vacuum pump 48 is connected to the end of vacuum line 46 as is shown in FIGURE 2. Thus, as soon as the valve 122 closes, the pressure in the vacuum line almost immediately drops to the lowest pressure that the pump 48 is capable of providing. For example, substantially immediately after the closing of the valve 122, the "vacuum" in the line 146 typically will increase from around 26 inches of mercury to around 30 inches of mercury. Simultaneously, the gas pressure in the chamber 44 starts to rise; that is, the "vacuum" decreases. The reason for this is that gas continues to separate out from the liquid being pumped. This gas collects in the chambers 40 and 44. Since gas is not being removed from the chambers due to the fact that the vacuum line 46 is closed, the pressure in chamber 44 increases. Thus, there is created a corresponding upward force on the valve member 124 due to the pressure difference between its upper and lower surfaces. What is more, this pressure difference almost always is substantial, e.g., 3 to 5 inches of mercury almost immediately after closing of the valve. In accordance with the present invention, this pressure differential is used to hold the valve tightly shut for a substantial length of time after the water level in chamber 44 has receded below the danger level 148. The water drains from chamber 44 at a relatively slow rate. For example, it normally takes about 7 seconds to drain all of the water from the danger level 148. When the system is operating normally, after the water level has dropped almost to the bottom of the lowest globe 134, the weight of the valve components exceeds the total upward forces created by the pressure differential and the buoyancy of the floats, and the valve member 124 falls away from the valve seat 128 and comes to rest against the bracket 142. This opens the vacuum line so that normal removal of gases from the chambers 40 and 44 is resumed.

If the pumping system is operating normally, the rate of pressure rise in the chamber is gradual, e.g., about one inch of mercury per second. However, if there is a major malfunction in the system, such as where one of the well-points 10 accidentally has been broken off and great quantities of air are being drawn into the liquid, the pressure in chamber 44 will rise at a much faster rate due to the much greater quantities of air being introduced into the separation and isolation chambers. This fact is used to advantage in the present invention by setting the weight of the valve components at a value substantially less than the maximum amount of force which will be applied to the valve member 124 to hold the valve shut due to the maximum pressure differential which can exist between the vacuum line and the interior of the chamber 44. This maximum pressure differential, which can approach 30 inches of mercury, will not exist until after the water level has receded to a position below the lower globe 134 unless there is a major malfunction of the system. In the latter instance, the pressure in the chamber 44 rises very rapidly e.g., in one or two seconds to a level such that the pressure difference between the line 46 and the chamber interior 44 will alone maintain the valve closed with-

out any assistance from the buoyancy of the globe **132** or **134**.

The latter feature of the invention has the advantage that when there is a major malfunction of the system, the valve will remain closed even after the water level has dropped below the lowest globe **134** and the chamber **44** has completely drained. This has the beneficial result that absolutely no water can pass into the vacuum line during major malfunction of the wellpoint system. The valve **122** cannot be re-opened until either the vacuum pump **48** is turned off or the air valve **146** is opened to allow air to enter the vacuum line **46** from the atmosphere, thus breaking the vacuum hold on the valve **122**. Since an operator must perform either of these functions, he will have discovered the existence of the major malfunction and will have either made the necessary repairs or shut down the equipment before resuming operation of the system.

As it can be seen from the foregoing, the valve **122** can be said to be sensitive to the rate of pressure change in the chamber **44** to determine its operating cycle. That is, if, after the closing of the valve the gas pressure in the chamber increases at a rate greater than a certain pre-determined "safe" rate, the valve remains shut until the condition is corrected. However, if the gas pressure increases at a rate lower than the pre-determined "safe" rate, the valve opens automatically when the water level has receded to a satisfactorily low level in the chamber **44**.

It should be evident that other forms of float mechanism can be used without departing from the teachings of this invention. For example, a single float can be used instead of the two separate globes **132** and **134**. Similarly, a separate weight need not be used if the weight of the other components is set at a level satisfactory for performance of the functions described above.

The vacuum pump **48** preferably is lubricated by recirculating oil. The oil is circulated through a heat exchanger which uses clean water, preferably water which is being pumped in the pumping unit **18**, to cool the oil as it flows through the heat exchanger. By this means, the temperature of the vacuum pump is maintained at a safe level, for example, from around 150° to around 180° F.

The above description of the invention is intended to be illustrative and not limiting. Various changes or modifications in the embodiments described may occur to those skilled in the art and these can be made without departing from the spirit or scope of the invention as set forth in the claims.

I claim:

1. A control method for a system for pumping dispersed liquids from the ground, said system including a separation chamber connected with evacuation means for withdrawing gases from said chamber and from a liquid being pumped by said system, valve means selectively operable for closing the connection between said chamber and said evacuation means in response to the rise of said liquid in said chamber to a predetermined level, and drain means for draining said liquid from said chamber, said method comprising closing said valve means in response to the rise of said liquid in said chamber to said predetermined level, maintaining said valve means in a closed condition when, after the closing of said valve means, the gas pressure in said chamber is above a predetermined value, and opening said valve means when, after the closing of said valve, said gas pressure is below said predetermined value and the level of liquid in said chamber is substantially below said predetermined level.

2. A method as in claim **1** in which said valve means is a float valve having a float member, and in which the closing of said valve means includes the step of applying to said valve means a closing force having a buoyancy component developed by the buoyancy of said float in said liquid, and a pressure component developed by the pressure differential between said chamber and said evacuation means.

3. A method as in claim **2** in which the opening of said valve means includes the step of applying an opening force to said valve means, and in which said opening force is a gravitational force provided by the weight of said valve means.

4. A method as in claim **3** including the step of maintaining the weight of said valve means at a valve substantially less than the maximum possible value of said pressure component of said closing force.

5. A method as in claim **2** including the steps of causing said buoyancy component to decrease at a rate substantially greater than the rate at which said pressure component increases during normal operation of said pumping device after the closing of said valve means, and causing said buoyancy component to decrease at a rate substantially lower than the rate at which said pressure component increases during periods after the valve closes when abnormally large amounts of air are entering the separation chamber.

6. In or for a system for removing dispersed water from the ground by means of a plurality of pipes extending into the ground at separate locations, each of said pipes having at least one liquid inlet opening adjacent its lower end, a liquid pump for producing sub-atmospheric liquid pumping pressures for lifting water out of the ground, main conduit means for connecting said pipes to said liquid pump, and a separation chamber connected to said main conduit means for receiving gas separated from said liquid before it reaches said liquid pump, the improvement comprising; a second chamber connected to said separation chamber to receive gas therefrom, a gas vacuum pump connected to said second chamber to remove gas therefrom, gas conduit means for conducting gas from said separation chamber into said second chamber and from said second chamber to said vacuum pump, return conduit means for automatically returning separated liquid from said second chamber to said main conduit means, a float valve in said second chamber for closing the connection to said vacuum pump when the liquid level in said second chamber rises above a predetermined level, means for movably mounting said float valve so that at least a component of its weight tends to pull the valve open, said weight component of said valve being substantially less than the closing force on said valve which is exerted by a pressure difference of approximately 30 inches of mercury between said vacuum pump and said second chamber.

7. Apparatus as in claim **6** including a vacuum conduit connecting said vacuum pump to said second chamber, and manually operable vent means between said valve means and said vacuum pump for venting said vacuum conduit to the atmosphere.

8. Apparatus as in claim **7** in which said return conduit means comprises a pipe connecting said second chamber directly to said main conduit means.

9. In a wellpoint system including a plurality of wellpoints, a liquid pump, a first liquid conduit connecting said wellpoints to said liquid pump, a first chamber atop of and communicating with said first liquid conduit, a second chamber adjacent said first chamber, a first gas conduit interconnecting said first and second chambers from a point adjacent the top of said first chamber to a point spaced upwardly from the bottom of said second chamber, a second liquid conduit connecting said second chamber to said first liquid conduit at points adjacent the bottom of each of the latter, a second gas conduit connected at one end to said second chamber adjacent its top, a gas evacuation pump connected to the other end of said second gas conduit, valve means in said second chamber, said valve means comprising at least one float member, a relatively rigid conical valve member, a rigid rod connecting said valve member to said float member, a frustro-conical valve seat at the entrance of

said second gas conduit at the top of said second chamber, means for guiding the movement of said valve member upwardly toward and downwardly away from said valve seat to close and open said valve in response to the rise and fall of said float in said chamber, the total weight of said float member, said valve member and said rod being equal to the total upward force applied to said valve member due to a predetermined difference in gas pressure between said second chamber and said second gas conduit when said valve is closed, said second liquid conduit having dimensions such that liquid drains from said second chamber at a rate such that said valve remains closed after closing when said pressure difference reaches or exceeds said predetermined level before the liquid level drops below said float member.

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U.S. Cl. X.R.

55—168