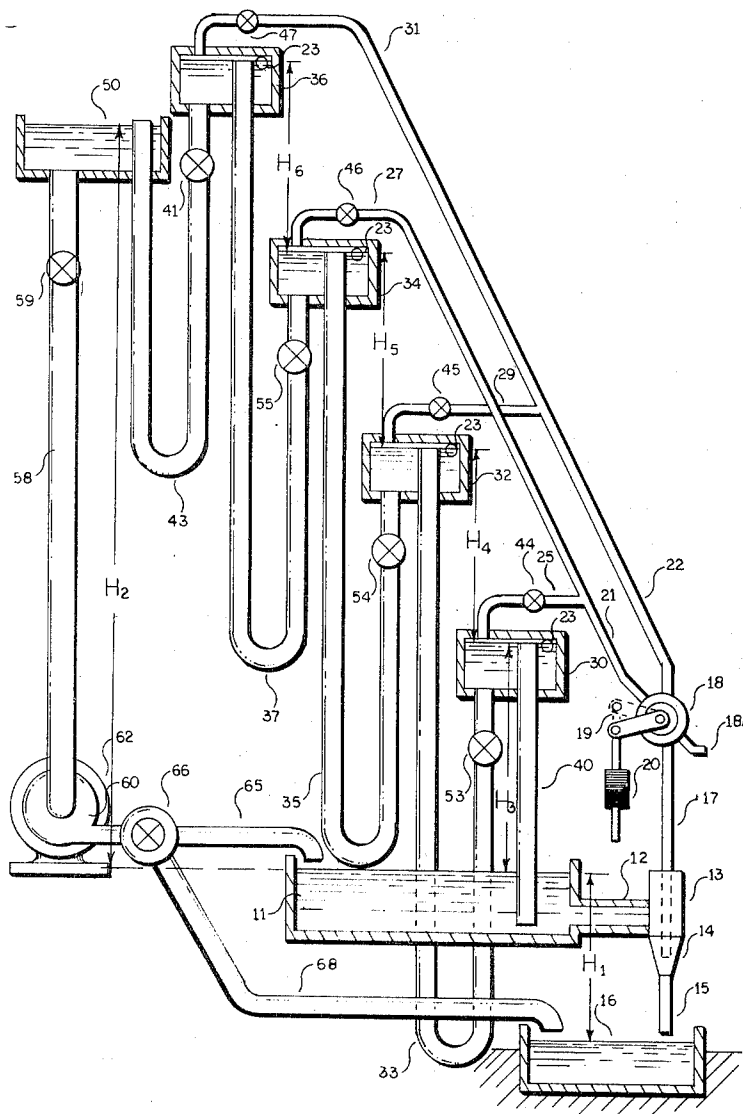
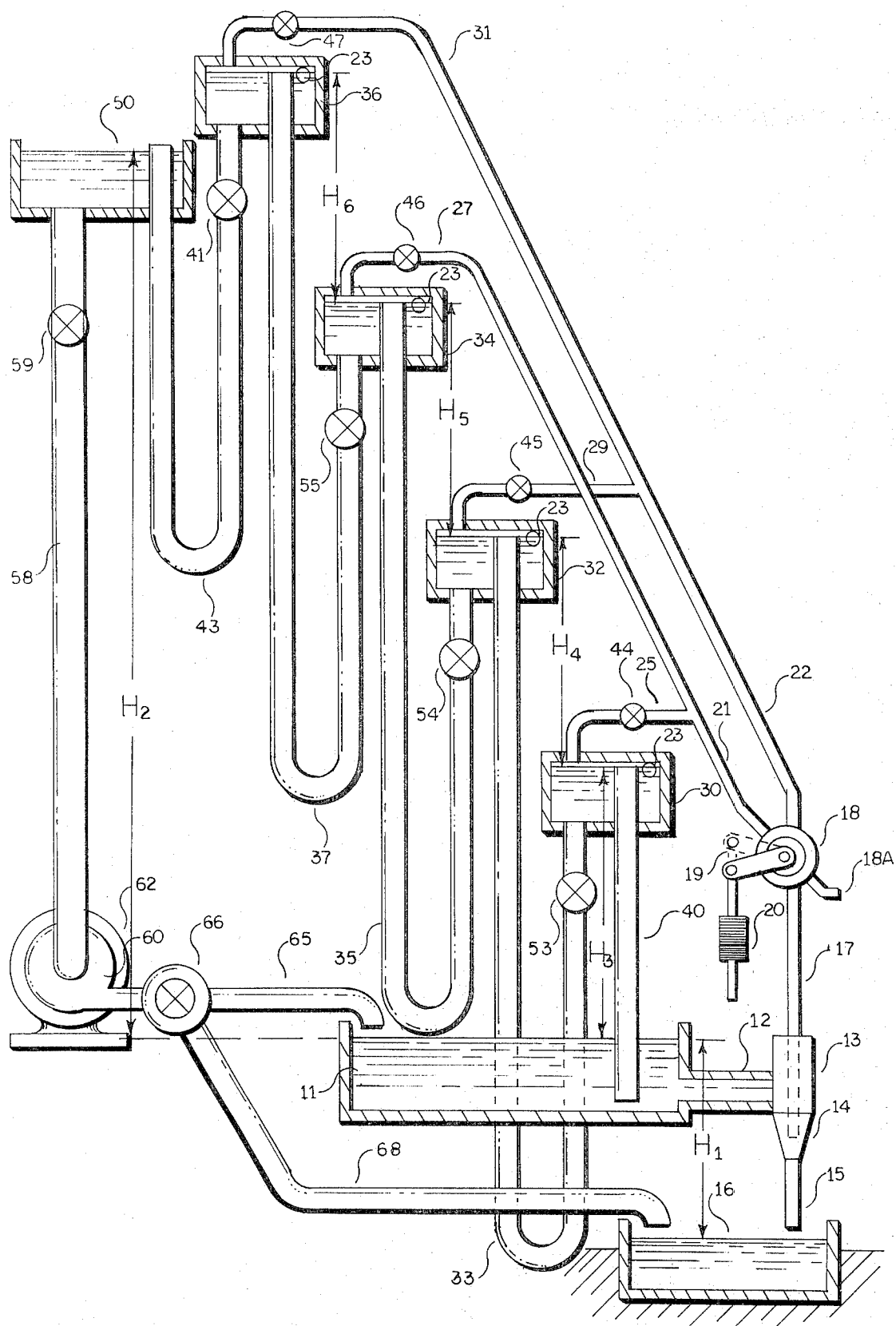






SYSTEM FOR RAISING AND USING WATER

The hydraulic ram has been used for many years for raising a relatively small amount of water to a high elevation, employing the force of a larger flowing stream to build up momentum and inertia. By allowing a relative large mass of water to flow and then suddenly cutting off the flow, a relatively small part of the water is driven up to a higher elevation. These devices are not very efficient but they are simple and effective as long as they are operating properly. Because of intermittent shocks due to the sudden closing of a main valve by the inertia of the flowing stream, hydraulic rams tend to hammer themselves to pieces after passage of time. The purpose of the present invention is to replace hydraulic rams with apparatus which is entirely free of hammering and pounding. Compared to the hydraulic ram the device or system of the present invention may be more efficient in many installations and more practicable for lifting substantial quantities of water to relatively high elevations.

The trompe, which was used centuries ago for producing a blast of air by the driving force of water, using the air-entrapping effect of a falling stream of water, has not been used, so far as the present inventor is aware, for lifting water from a lower source to a relatively higher elevation, in stages or otherwise. In a U.S. application, Ser. No. 803,384 filed Feb. 28, 1969, by the present inventor and others, now abandoned, a system is disclosed which employs the trompe principle in using the energy of ocean waves to produce power. The system therein disclosed, however, is not designed for lifting water in stages by aspiration of air. It is not suitable for purposes of the present invention wherein water is to be raised to substantial height or elevation. Preferably, according to this present invention, water is lifted to considerable heights in a series of stages. Each stage or lifting step is accomplished by direct application of the vacuum or lifting power derived from falling water and withdrawing air from water-tight reservoirs by aspiration.

The principle by which air or other gas is aspirated into a flowing stream of water or other liquid is well known and is based on Bernoulli's principle. Stated mathematically, this principle may be set forth as follows:

The sum $mpg/d + mgh + \frac{1}{2}mv^2$ remains a constant for a small mass of liquid flowing without rotation in a conduit, where m = the mass, d = its density, h = the pressure head, and v = the velocity at any given point in the conduit. Using the foot-pound-second notation, p = pressure in pounds per square foot and g represents the gravitational constant, having a value of about 32.2.

At different points a and b in a given conduit, the total expression thus remains constant. The first term mpg/d varies inversely with the last term, $\frac{1}{2}mv^2$. Assuming that the head of hydrostatic pressure does not change significantly along a conduit then, the middle term mgh remains constant. Further, assuming that the density d for water = 62.4 lb. per cubic foot, then

$$(mp_{ag}/d) + \frac{1}{2}mv_a^2 = (mp_{bg}/d) + \frac{1}{2}mv_b^2.$$

The term m for mass is common to all the elements of the equation and may be cancelled. This leaves

$$(p_{ag}/d) + \frac{1}{2}v_a^2 = (p_{bg}/d) + \frac{1}{2}v_b^2.$$

If the pressure, for example, is 20 psi at point a and the velocity at the same point is 20 feet per second,

whilst at point b , (in the vena contract for example) the velocity is 55 feet per second, simple calculations show that p_b equals approximately 2.25 psia which represents a lifting force or a vacuum of about 12.5 psi at sea level.

The atmospheric pressure at sea level will balance a column of water about 34 feet high. A vacuum of 12.5 psi will lift water to a height in excess of 28 feet, disregarding friction.

The present invention is based on the discovery that by suitable equipment design a plurality of lifting stages may be employed sequentially to raise water, according to the principles just discussed, to any height desired without facing the disadvantages or mechanical difficulties encountered in use of conventional hydraulic rams. This invention, in effect, produces a shock-free hydraulic lift of good efficiency. Efficiency is somewhat less than 100 percent, of course, due to friction in the pipes and in the aspirator equipment, but can be considerably higher than with the average or conventional hydraulic ram. By connecting the air inlet side of an aspirator to a series of stages alternately stepped, and by shifting the connections periodically, water may be lifted to a first, third, fifth, and further odd consecutive stages simultaneously on one cycle and to second, fourth, etc., on another. The lifted water is stored in these stages temporarily when the suction or aspirator is connected to the alternative stages. The stored water in the first stage is later lifted to the second, that in the third is lifted to the fourth, that in the fifth is lifted to the sixth, etc. Then the cycles are repeated, lifting water to the odd stages and then to the even, next to odd, and next to the even, etc.

According to an alternative modification, using two separate aspirators, water may be lifted to first, third, fifth, and subsequent odd stages simultaneously by one aspirator, while being lifted from these stages respectively simultaneously to a second, fourth, sixth, etc., by a second aspirator.

BRIEF DESCRIPTION OF DRAWINGS

The FIGURE is a schematic view in elevation of a system, according to the present invention, which employs a single aspirator and has four lifting stages, arranged in pairs, certain parts being shown in section.

DESCRIPTION OF PREFERRED EMBODIMENT

The FIGURE shows a water-lifting system, according to the present invention, wherein a source of water supply is assumed to have sufficient head that, in falling, it will generate a substantial vacuum and consequent lifting force by aspiration of air from a series of closed vessels. To be operative, the main source should have a fall of at least a few feet; for good efficiency it should be 20 feet or more, and preferably 50 feet or more, although water sources with lesser heads can be used.

The source, such as a river, lake, or canal, is shown diagrammatically at 11. It has a head above the tail race 16 or discharge level, of H_1 , which is assumed to be sufficient to give a satisfactory pressure and velocity of flow through an aspirator to produce an effective lifting force. Water is permitted to flow through outlet line 12 to an aspirator 13 which has a vena contracta or equivalent constriction at 14. From this constriction the passage widens out below at 15 which must be at least five times as long as its diameter, and discharges into a race or channel 16, or into a vessel which may store the aerated water and make use of the pressurized air con-

tained therein. For further details of the latter, see the application mentioned above.

Centered within the aspirator is a downcomer pipe 17 which is connected at its upper end to a four-way valve 18. The latter has an opening 18A to the atmosphere, and connections above to two pipes 21 and 22. It has a control level 19 which can be operated manually, if desired, or by a fluidic device of known type, or preferably, as shown, it is operated by a solenoid 20 to shift the valve intake alternately between air inlet lines 21 and 22. That is, the aspirator will draw air from either line 21 or line 22, depending on the setting of valve 18. At the same time, it will permit air from opening 18A to flow upwardly into the other of these two lines. The valve operating mechanism, such as solenoid 20, is activated by a sensor 23 which detects the water level when reservoir 30 is full. The details of this detector are not shown, being conventional, but each reservoir described preferably has a detector.

Line 21 has two branches 25 and 27, whereas line 22 has two branches 29 and 31. Each line may have more. These branches connect respectively to separate temporary storage tanks or water-lifting reservoirs to be described in more detail below. The first reservoir 30, to which line 25 is connected, is mounted with its upper or high water level at a height H_3 not greater and preferably a little less than the height to which water may be lifted by the aspirator 13. In the theoretical discussion above, it was suggested that under specified conditions stated, the lift might be as much as 28 feet or more. In this case, H_3 would not be in excess of 28 feet and desirably a little less, e.g., 25 feet. That is, a single stage lift by vacuum, produced by aspirator 13, can lift water up to about 28 feet above its normal level in the source 11 and thus store it in the temporary storage reservoir. Maximum theoretical lift is about 34 feet. As air is evacuated from the tank 30 through lines 25, 21, valve 18, line 17 and aspirator 13, water will flow up from the bottom of supply source 11 into the reservoir 30 through a line 40. It is to be understood that the tank 30, and other similar tanks to be described, must be air tight.

Tank 30 is thus filled from supply 11. When this is accomplished, valve 18 is operated, preferably automatically on signal from detector 23, to apply the suction of aspirator 13 to line 22 and to permit air to flow into tank 30 from opening 18A. Branch 29 of line 22 is connected to a second air-tight tank or reservoir 32 and will now draw the air out of tank 32 and cause water to flow through a U-shaped line 33 and to be lifted through the height H_4 from tank 30 into tank 32, thus emptying or nearly emptying tank 30. Here again, the maximum head must not be greater than the lift capacity of the aspirator, allowing of course for fluctuation of the level in tank 30, and for friction encountered in the pipes. When tank 32 is full, the valve 18 is again shifted under control of sensor 23 in tank 32 to reconnect line 21, applying vacuum to branch line 27 as well as to branch 25. Line 27 connects to a third lift stage tank or reservoir 34, which again is air-tight. As vacuum is applied, and air is allowed to flow into tank 32 from valve opening 18A, water flows through another U-shaped line 35 from tank 32 into tank 34, thus filling or substantially filling the latter.

Now, once again the valve 18 is shifted under control of a sensor such as 23 to apply suction to line 22 and to its branch line 31, as well as line 29. Line 31 con-

nects to the top of a fourth air-tight tank 36, drawing water through a U-shaped line 37 from tank 34 to the top of tank 36. When tank 36 is filled the series of steps is repeated. The U-shaped tubes 33, 35 and 37 serve as stand pipes to prevent drawing air into any reservoir being filled. However, any or all of them may be replaced or supplemented by check valves, if desired, as will be obvious. Otherwise, that part of each U-tube which extends below the lower tank, to which it is connected, should be longer, i.e., have a greater head, than distance H_4 or H_5 , etc.

Assuming adequate size and power of the aspirator, lines 25 and 27 will be operated simultaneously to fill both tanks 30 and 34 at the same time after start up. Similarly, the tanks 32 and 36 will be filled simultaneously after start up, when the valve 18 is turned to connect line 22 to the aspirator.

In order to get the system started or primed, it may be necessary to fill the U-tubes 33, 35, 37, 43, by some means, or to close certain of these lines so that full suction by the aspirator will be applied to the desired tank. For example, if tank 30 and the tanks above also are empty, air could be drawn from the outside through tanks 36, 34, and 32 to break the vacuum imposed by the aspirator. For this reason, at least one valve 41 is preferably installed in the outlet line 43 from tank 36. After start up, these valves are not necessary. This outlet line 43 will be opened at appropriate times to allow water stored in tank 36 to flow by gravity into a larger or more permanent reservoir 50 from which water may be used continuously for power generation, for domestic use, or for other purposes. Obviously, tank 50 is larger than tank 36, or the other lift tanks, to maintain continuous flow. For convenience a valve 44 also is shown installed in line 25, valve 45 in line 29, valve 46 in line 27, and valve 47 in line 31. In many cases these valves may be omitted, as long as at least one valve can be closed or a stand pipe of water is maintained between the aspirator and the outside atmosphere.

After the system is in operation, tanks 30 and 34 are filled simultaneously, water flowing from tank 32 into 34 as aspiration is applied to line 21 through valve 18. When these two tanks are full, valve 18 is operated preferably automatically by solenoid 20, to shift to line 22. The sensing means 23 which activates the valve control 20, may be a float which closes a circuit to the solenoid 20 when tank 30, for example, is full. Since no air can get into tank 32, line 35 being closed by a valve or a head of water (valve 41 at the upper reservoir also may be closed), the full vacuum effect is applied to both tanks 30 and 34 which are thus filled. A check valve, as suggested above, may be installed in each line, or valve 44 in line 25, for example, may be closed manually or automatically, at the appropriate time. Likewise, in tank 32 overflow back into the vacuum line 29, etc., may be prevented by a sensor 23, or by a sensor controlled valve which is closed automatically when the tank becomes full. Obviously, any of the valves mentioned may be operated manually, if desired, but automatic operation by solenoids or other obvious and conventional means normally will be preferred. Valves 53, 54 and 55 are shown in lines 33, 35, 37, respectively for convenience but these may be omitted if desired.

The total height H_2 to which the water is lifted will depend on the number of stages and the vacuum pull or lifting force available for each stage. As shown, the

maximum height H_2 , or total height from the source 11 to reservoir 50 equals the cumulative height or heads of the four stages shown, represented at H_3 , H_4 , H_5 , and H_6 .

Water from the storage reservoir 50 may be released through a line 58, under control of a valve 59 in this line, to drive a turbine or other water motor 60. The latter is shown connected to an electric generator 62. The effluent water from the turbine may be returned through a line 65 to the primary water source 11 to replenish it to that extent, or it may go directly to the mill race or lower level 16. A valve 66 at the turbine outlet is shown which can be set to direct the spent water through line 65 into original source 11 or through the downwardly sloping line 68 into the mill race. In the latter case, the extra head H_1 will help to pull the turbine and improve efficiency. This is preferred if there is no need to recycle the water to the original source. In any case, the major part of the water in source 11 is lost through the aspirator. The part that is lifted will depend on the height of the lift, as compared to the operating head H_1 and, to a lesser extent, on efficiency of the system.

Obviously, although only four stages are shown in the FIGURE and are described above, the number of stages can be increased to any reasonable number desired, as long as each stage is located and designed within the aspirating capacity of the equipment 13, etc. Thus, water may be raised 250 feet in 10, 25-foot stages, where the primary source has capacity to set up a vacuum pull that will lift water 25 feet in a single stage. Alternatively, 25, 10-foot stages can be used, if the primary source can lift only in 10-foot stages, and so on.

In summary, it will be seen that the invention involves a system for raising water in steps from a source which has sufficient energy, in flowing through an aspirator, to lift any part of its own water to a significantly higher level by application of the Bernoulli principle, as described above. The energy may be kinetic or potential or a mixture of both, as long as the capability is presented of passing a stream of water through an aspirator device which has air inlet means and wherein the velocity of water passing through will generate a significant lifting force or vacuum. The invention thus contemplates that a stream will be driven, at reasonably high velocity, through a path where its velocity will be varied or controlled by apparatus designed to effect a substantial negative pressure (as compared to the ambient or atmospheric pressure). This negative pressure, or vacuum or lifting force is applied to plural air-tight compartments or lifting reservoirs in alternative fashion, in the case of the embodiment described. In any case, a first reservoir of the series, which has a water connection with the primary supply, will be evacuated at least partly by suction at the aspirator to the extent necessary to fill with water. Thereafter, or simultaneously, depending on the system followed, the tank above, or the second water-raising reservoir is partially evacuated and water flows into it from the first reservoir. Obviously, the inlet 40 may be connected to a different source of water than 11, so that flowing sewage, impure water or salt water, or any other liquid, can be used to lift fresh water or any other liquid; sewage can be used, e.g., to lift petroleum products.

Preferably, more than two stages will be used, in most instances. In such case, a third reservoir is filled from

the second, using preferably and simultaneously the same source of suction of lifting pressure that is operating on the first reservoir. Similarly, the fourth reservoir is filled by the same source that is filling the second, and so on. Operating thus preferably in pairs, although odd numbers of total stages may be used, if desired, or alternating from one line to the other, water or other liquid may be raised to fill a fifth reservoir from the fourth, a sixth from the fifth, and so on indefinitely. In each case, of course, the elevational difference between any two consecutive water-raising reservoirs must be within the limits stated above.

The storage reservoir such as 50 may be large and is provided to receive and hold for future use the water raised to the highest storage or accumulator of the series. In some cases, however, such a reservoir may not be necessary; the water may be used at the upper level or released immediately to flow to a lower level, either for power generation or for any other purpose. The various apparatus elements, such as the control valves for the aspirator and for all the other lines may be modified and/or automated, as will be self-evident to those skilled in the art. Other modifications and adaptations will suggest themselves to those skilled in the art. It is intended by the claims which follow to cover all such, as far as the state of the prior art properly permits. In the claims, it will be understood that "first liquid" and "second liquid" may refer either to the same or to different liquids.

What is claimed is:

1. A system for raising a desired liquid from a source of supply thereof, using a flowing stream of liquid which has sufficient fall to drive an aspirator with a substantial lifting force, said system comprising, in combination, an aspirator having a passageway for said flowing stream, an aspirating air inlet terminating within said flowing stream passageway, a single selectively operable control valve connected to said air inlet and having an outlet to the atmosphere, a first air-tight reservoir connected by a single air-tight line to said valve and located at an elevation higher than said source but within the height to which said aspirator can lift said desired liquid from said source a conduit for said desired liquid connected from said source to said first reservoir, a second air-tight reservoir also connected by a second single air-tight line to said valve and located at an elevation above said first reservoir but within the height to which the aspirator can lift said desired liquid from said first reservoir, a further conduit connected from the bottom of said first reservoir to the second reservoir for emptying the desired liquid from the first reservoir, sensor means in each of said reservoirs for producing a signal when its reservoir is full of the desired liquid, and valve operating means initiatable in response to a signal from the sensor in a full reservoir to operate the valve, thereby to apply aspirator force to the other reservoir through its air-tight line and to connect the air-tight line of the full reservoir through the valve and its air outlet to the atmosphere, thereby to permit emptying of the full reservoir while the other reservoir is being filled.

2. A system according to claim 1 where the conduit connected between the bottom of said first reservoir and the second reservoir is a U-tube.

3. A system according to claim 1 in which at least four reservoirs are serially connected to each other by U-tubes.

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4. A system according to claim 1 in which the highest air-tight reservoir has its outlet connected to an open elevated storage reservoir located at a level which makes it capable of generating useful power.

5. A system according to claim 1, in which a high storage reservoir is located to receive water from the highest located water-raising reservoir.

6. A system according to claim 1, which includes at least four water-raising reservoirs, at least two of which connect to a single aspirator air inlet means for simultaneously filling at least said two reservoirs, and a further storage reservoir means for receiving and storing more water from the highest elevation of said water-raising reservoirs than said highest reservoir can hold.

7. A system according to claim 1, which includes a plurality of alternate water-raising reservoirs and means for alternately connecting a first said plurality and a second separate plurality of said reservoirs to a single aspirator.

8. A system according to claim 1, in which the valve has an atmospheric air inlet and including sensor means in at least one of the water-raising reservoirs connected to each air-tight line.

9. A system according to claim 1, in which the flowing liquid and the source of supply of desired liquid are obtained from the same liquid source.

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