AIR-LIFT PUMP WITH SCALLOPED AIR-LIBERATION RINGS, AT TWO LEVELS

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ABSTRACT

Efficiency for a large diameter air-lift pump is achieved with a scalloped air liberation ring, inwardly projecting portions having orifices to liberate air with good distribution through the liquid flow area. The under sides of the projections slope steeply toward the tips and are gently rounded to avoid catching elongated strands. Liberation of air at near the lowest level possible, for efficiency, is achieved by first liberating air at a higher level until flow causes dropped liquid head pressure, permitting the same air pressure to be used for the deeper liberation.

2 Claims, 4 Drawing Figures
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AIR-LIFT PUMP WITH SCALLOPED AIR-LIBERATION RINGS, AT TWO LEVELS

The invention, of which this disclosure is submitted for public dissemination in the event that adequate patent protection is available, relates to air-lift pumps. For many years air-lift pumps have been widely used in connection with sewage treatment. There have been recognized problems, especially in regard to air-lift pumps of larger diameters. Unless the air is well distributed at the level of introduction into the eductor tube for producing the pumping action, it may be less than fully effective, particularly in its initial foot or two of rising action. In eductor tubes of small diameter, a perforated girdle will adequately distribute the air. Air has also been distributed, satisfactorily in tubes not too large, by a centrally disposed sparger liberating air radially more or less in all directions. To avoid having transversely extended air pipes on which strands in the sewage could catch, air has been supplied to such central sparger by a pipe extending down along the axis of the eductor tube from above the flow of water. With larger eductor tube diameters, this ceases to be desirable because a plurality of spargers would be needed, and providing a separate downwardly extending air supply pipe for each becomes somewhat expensive when there is no other advantage.

According to the present invention, this problem is solved by providing a new type of air induction girdle or ring which has projections extending inwardly to release air approximately at the centroids of the cross section of the eductor tube. The bottom surfaces of these projections slope inwardly and upwardly so that elongate strands carried by the upwardly flowing liquid will veer off of them instead of catching on them.

In addition, there has been a problem as to liberation of air at the lowest point practicable for the air pressure available. The exact nature of the problem in sewage treatment plants may not have been recognized, although the desirability of deep introduction of air has long been recognized as being doubly desirable. To liberate air at a higher level than the lowest level possible for the air pressure simply wastes energy consumed in pumping. Furthermore, it has long been recognized that efficiency of air-lift pumps depends on the "submergence ratio." This is the ratio of the distance through which the buoyancy of the air is effective to the total distance which the air and water mixture rises. The greater the lift through which the water is to be pumped, the greater must be the depth of effective introduction of air to achieve efficiency of pumping.

The static liquid level in an air-lift pump is determined by the level in the tank from which the pump would draw when pumping. Heretofore the depth of air introduction has seemed to be limited to the greatest distance below this level at which the air pressure available exceeded the static head, for otherwise the air would not issue from the orifices. The present invention lowers the normal depth of liberation by recognizing and utilizing the fact that during pumping, friction losses of liquid approaching the pump have an effect equivalent to reducing the head.

The special rings of this invention lend themselves very readily to the concept of using two full-distribution rings at different levels with a valve for admitting air initially to the upper ring. When a sufficient rate of pumping has been reached so that the head loss due to flow resistance on approaching the air liberation point result in a reduced head pressure such that the air, at the same pressure, may be introduced at the lower level, the valve for the upper level is closed.

Additional objects and advantages of the invention will be apparent from the following description and from the drawings.

DESIGNATION OF FIGURES

FIG. 1 is a somewhat diagrammatic view of a typical installation embodying an air-lift pump according to the present invention.

FIG. 2 is a view on a larger scale of key portions shown in FIG. 1, partly in vertical section and partly in elevation.

FIG. 3 is a horizontal sectional view taken approximately along the line 3--3 of FIG. 2, and showing especially a top view of one of the scalloped rings of this invention.

FIG. 4 is a vertical sectional view taken approximately along the line 4--4 of FIG. 3, and showing connected portions.

BACKGROUND DESCRIPTION

FIG. 1, except for novel features to be described, represents a typical installation of an air-lift pump for pumping sludge from a hopper 11 of a settling tank or clarifier 12 to a basin 13 at a moderately higher elevation. From basin 13 the sludge may flow through a conduit 14, which may be a pipe or a channel, to another point in the process. If settling tank 12 is a final clarifier of an activated sludge treatment process, most of the sludge in conduit 14 will flow to an activated sludge aeration tank, where it is mixed with raw sewage and aids in accomplishing the treatment thereof. The treated mixed liquor from that tank will flow through a conduit such as 16 to the clarifier 12. Although the illustration of clarifier 12 is more typical of a rectangular tank, a circular clarifier is commonly used.

The air-lift pump typically comprises an eductor tube 18, with means 19 for liberating air into the contents of the tube near its bottom. The air is supplied by a compressor, not shown, through a supply pipe 21.

When the air is not being supplied through pipe 21, the liquid of tank 12 will seek its own level in eductor tube 18, this level being indicated by the broken line 22. When air is introduced in the eductor tube 18 by the predecessor of the air introduction means 19, the air would rise through the water in the eductor tube, reducing its average density so that the head pressure derived from the liquid in tank 12 could push this less dense water upwardly to overflow the eductor tube into basin 13.

For efficient operation of such an air-lift pump, the lift representing the height between the liquid level 22 and the liquid level 23 must not be too great as compared to the pressure at the air introduction point 19 available from the tank 12. It has been well known that air-lift pumps should have a submergence ratio of at least 70 percent. Ignoring considerations to be mentioned below, this would mean that the distance from static water level 22 to air introduction level 24 should be at least 70 percent of the distance from air introduction level 24 to the outflow level 23. Greater efficiency
is achieved with still greater submergence ratios. From this standpoint the air introduction point 19 should be as deep as possible.

However, it is desirable to use air pressure such as is available for other purposes, and hence for practical reasons it has been the practice not to locate the air introduction level 24 any further below the static water level 22 than the depth at which the available air pressure would function. This in turn tended to limit the height to which the water could be raised, with the result that the entire system had to be designed so that the outflow level 23 would be slightly lower than would be the design if there were no such limitation. As an alternative, inefficiency in the air pump, as by using a submergence ratio a little less than 70 percent would sometimes be tolerated.

The foregoing difficulties have increased as air-lift pumps have become of larger diameter to pump larger volumes of sludge. This is partly because it is difficult, with larger diameters of eductor tube 18, to obtain adequate distribution of air at the level of introduction 24 to make the air fully effective at or near that level.

**INTENT CLAUSE**

Although the following disclosure offered for public dissemination is detailed to ensure adequacy and air understanding, this is not intended to prejudice that purpose of a patent which is to cover each new inventive concept therein no matter how others may later disguise it by variations in form or additions or further improvements. The claims at the end hereof are intended as the chief aid toward this purpose, as it is that these meet the requirement of pointing out the parts, improvements, or combinations in which the inventive concepts are found.

**SCALLOPED RING DIFFUSERS**

According to one aspect of the present invention, a great improvement is made in the distribution of air throughout the eductor tube at or near its level of introduction by making the air introduction means 19 in the form of a scalloped ring, as seen best in FIGS. 3 and 4. The air supply pipe 21, or an extension 26 from it, supplies air to an annular manifold or ring 27. As seen in FIG. 3, the inner wall 28 of this ring is of a scalloped shape, with apertures at or near the tips of the inwardly projecting nodes 29. The bays 30 between the nodes 29 not only increase the cross-sectional area available for flow upwardly through the ring 19, but also provide a portion of the flow outwardly beyond the air orifices in the vicinity of the nodes 29, so that the released air has a much better effect of being distributed with fair uniformity throughout the cross-section of the liquid than if the air were introduced from a simple circular ring or girdle as in the past.

As seen in FIG. 4, there is preferably at least one orifice 31 leading radially from near the tip of each node 29. Other orifices are preferably provided at points chosen for giving the best distribution of air through the cross-section of flow. FIG. 4 illustrates two orifices 32 adjacent each orifice 31, one at each side thereof. In FIG. 3, these orifices are indicated by center lines to which the numbers are applied. At the lower left-hand side of FIG. 3 is illustrated a different arrangement of three nonradial orifices 32 and 33. Within the limita-

tions of convenient drilling, these orifices may be located as a particular engineer specifies. Although there could be both arrangements, as illustrated in FIG. 3, a particular engineer will probably choose one arrangement to be used on all of the nodes 29. For different diameters, differing arrangements may give the best results.

Each node 29 has a steeply sloping undersurface 36, as seen in FIG. 4. This steep slope, together with the gently rounded shape of the node, is believed to avoid any danger that elongate strands will hang up on the projecting portions of the rings.

**UPPER STARTING LEVEL OF AIR-INTRODUCTION**

According to another aspect of the present invention, greater efficiency of operation is achieved by locating the air introduction means 19, preferably the scalloped ring already described, a little too far below the static level 22 for the air pressure available to be able to overcome the static head. The air pressure available usually depends upon such factors as the depth of air liberation in the main aeration tanks, inasmuch as a small amount of the air from the compressors for that purpose is usually used for air-lift pumps.

The location of the ring 19 at the too-great depth indicated is made possible by providing a slightly higher starting ring 38. Ring 38 is connected to the supply pipe 21 through a normally closed valve 39, opened by a solenoid 41 during starting. The starting ring 38 may be identical to the ring 19, and is in any event preferably an air liberation means which achieves good distribution of the air at or slightly above the level of liberation.

In starting up the air-lift pump, solenoid 41 is energized by a switch which may be controlled manually or automatically. For example, if pumping on a timed cycle is desired, the timer for starting the pumping may close a switch to energize solenoid 41. A short-period timer will de-energize solenoid 21; and another solenoid valve, not shown, may cut off all flow in air supply pipe 21 when pumping is to stop. Ring 38 is not deep enough for the maximum efficiency achieved by ring 19, but it is deep enough to start the pumping action of the eductor tube 18. As water starts flowing, a head loss is produced. This is at least in part due to the slight resistance to flow which is offered by the inflow pipe 43. As a result of this head loss, the liquid, within the flow area through the ring 19 is no longer at the pressure represented by its static head but is below this pressure by the amount of the head loss due to flow through pipe 43. The first effect of this reduced head pressure is to permit increased air flow through the starting ring 38, and that in turn increases the flow of the liquid so that there is still greater head loss due to flow through inflow pipe 43. As soon as the head loss is sufficient so that the liquid pressure at the level 24 flowing through ring 19 is less than the air pressure, the air will begin to flow through ring 19. When the pumping rate is nearly normal, solenoid 41 will be de-energized to close the valve 39 so that all of the air introduced into eductor tube 18 will be introduced through the lower ring 19 for maximum pumping efficiency. A regulating valve 44 may be adjusted to avoid excessive air flow during normal operation or to control the pumping rate through eductor tube 18. This may be desirable where
there is to be continuous pumping of sludge, to regulate the drawoff rate so that only relatively dense well-settled sludge will be drawn from hopper 11.

Those skilled in the art will recognize that if tank 12 is a rectangular tank there would usually be a cross-collector in hopper 11 and a main collector along the floor of settling tank 12 to keep all of the sludge which settles in that tank moving to the draw-off point at the entrance to inflow pipe 43. Such persons would also recognize that there might be a plurality of such tanks 12 with hoppers 11 which could be connected either simultaneously or in sequence to a single eductor tube 18.

The transition from ring 38 to ring 19 may present a problem. Unless air flows through the orifices of ring 19 before it stops flowing in ring 38, there will be an interval in which water unmixed with air will flow up through ring 38. This will rapidly increase the head at ring 19, and unless the interval is extremely short air might fail to flow at ring 19. One way to overcome this is to provide a valve 46 for by-passing regulator valve 44 during start up, so that there will be enough air available to flow out through ring 19 while flow continues through ring 38. With valve 46 open, and if supply pipes 21 are large enough, air will begin to flow through the orifices of lower ring 19 as soon as the head within it is less than the available air pressure. Valve 46 may be opened by solenoid 47. Solenoid 47 and 41 may be jointly energized. Even without by-passing regulator valve 44 it may be possible to achieve the transition. For example, if the orifices of upper ring 38 are smaller than those of ring 19, they may cause enough back pressure to force air out of ring 19, or down close enough to pipe 26 so that on closing valve 39 air will very quickly reach the orifices of ring 19.

Each of rings 19 and 38 is preferably provided with a drain opening 48 so that sludge will drain out either entirely or to a low enough level not to impede the air flow.

The air passages leading to the respective orifices should, as shown, be substantially free of water-seal dips or loops, so that the air can start flowing (or blowing out the liquor, initially) at just above the pressure to which the orifices are exposed on their discharge side. A desire to have an air flow rate which develops a small back-pressure at the orifice makes minute dips tolerable.

Although the static level 22 has been illustrated as at the level of liquid in tank 12, there are some possible conditions in which it might be slightly below that level. For example, the inflow conduit 43 could draw from a hopper or chamber to which there is normally flow from tank 12 but which flow can be shut off in periods of non-pumping. Here, as in the illustrated situation, if the resulting static level in eductor tube 18 is high enough to prevent starting the pumping action by liberating air through ring 19, the higher starting ring can be used to solve the problem.

ACHIEVEMENT

By utilizing both aspects of the present invention, a pumping efficiency approximately equal to the maximum efficiency possible with the air pressure available can be achieved. Thus the air is introduced at nearly the lowest possible level, a level too low for starting, and with prompt good distribution of the air through the cross-section of the water in the eductor tube, so that it is fully effective, at or quite close to its exceptionally low level of introduction, for activating the air-lift pumping action.

The two-level aspect of this invention is especially useful in any system having a high decrease of head as pumping begins. For example, if tank 12 is a circular clarifier with multipoint suction collection, this may incorporate a large head loss of perhaps 2 feet, even aside from flow loss from it to the air-lift pump. This initial 2 feet gives great need for the deep introduction of air because it subtracts from the submergence ratio. It also adds to the possible distance of separation of rings 38 and 19.

In some of the claims below, the inner wall of ring 19 may be considered the defined "ring," the manifold portion 27 of the ring being part of the defined conduit.

I claim:

1. The combination of a gas-lift pump including an eductor tube, an inflow conduit, a container connected to the bottom of the said eductor tube by the inflow conduit, and having a liquid level which determines the static level to which the liquid will rise within the eductor tube when the gas-lift pump is not operating, means for supplying gas at a given pressure for operating the gas-lift pump, orifice means comprising a scalloped ring with orifices near its innermost points for dispersing gas in said eductor tube at a depth too far below said static level for said given pressure to be effective to introduce air and initiate pumping under static conditions, and orifice means at a higher level at which the given pressure will be effective for initiating pumping under static conditions; and a valve for temporally connecting the air supply means to said higher orifices for starting the pumping action; said inflow conduit being adapted for copious flow commensurate with the size of the eductor tube, but having significant flow resistance whereby the flow therethrough resulting from the pumping action causes a head loss sufficient to make the given gas pressure adequate to discharge gas through the first named orifices when said valve is closed for maintaining the pumping action.

2. A gas-lift pump including an eductor tube providing an upflow path and having means for liberating gas within said tube at a low position therein comprising a scalloped ring surrounding the up-flow path for liquid through said eductor tube and which has inwardly projecting nodes having orifices near their innermost tips, the nodes extending less than half way from the periphery of the flow space to its center to expose the tips near the area centroids of their respective sectors of the tube, and conduit means for supplying gas under pressure to said orifices; substantially the entire inwardly extending surfaces of said nodes where impinged by the upflowing water sloping steeply upwardly and being gently rounded to shed any elongate material flowing through the ring, the orifices in the nodes being close to the top thereof so that liquid flowing through the eductor tube is expanded by air only as it is about to pass from the partially constricted area of said nodes, and a large proportion of the orifices being concentrated near the inner tips of the node, with some thereof being directed generally toward the center of the tube.

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