

Spotte (1970) promoted the use of airlift pumps over mechanical pumps for a number of reasons which include: lower initial cost, lower maintenance, easy installation, ability to resist clogging, small space requirements, simplistic design and construction, ease of flow rate regulation, and versatility in many applications. The airlift pump concept was discovered by a German engineer in the mining industry by the name of Carl E. Loescher in 1797 where he found it useful for pumping wells (Castro et al, 1975). Much of the early use of the airlift pump was seen in the coal mining industry because of its ability to extract minerals from deep mine shafts. The first practical application of this technology in the United States was not seen until 1846 where it was used in Pennsylvania in the oil field industry (Castro et al, 1975). Airlift pumps have been used for sample collection of seawater (Tokar et al., 1981) as well as water circulation and aeration in aquaculture ponds (Parker and Suttle, 1987; Wurts et al, 1994). Airlift pumps have also seen a great deal of use in recirculating aquaculture systems (RAS) because of their ability to aerate, circulate, and degasify CO₂ from the water column (Loyless, 1995; Gudipati, 2005; Castro, 1975; Reinemann et al., 2001). Reinemann et al. (1987) reported that approximately one third of the energy for a properly designed airlift pumped RAS was needed for overall system operation as apposed to that necessary for a traditional RAS supported by a centrifugal pump and aerator configuration. Similar findings can be seen in studies conducted by Castro and Zielinski, 1980; Castro et al, 1975; and Reinemann et al, 2001)

Airlift Pump Operation

Awari et al. (2004) described an airlift pump as a device for raising liquids or mixtures of liquids (mostly water) and solids through a vertical pipe partially submerged in the liquid, by means of compressed air introduced into the pipe near the lower end by means of an opening or nozzle. A rising main covered this

assembly which was fixed in the well of water. A mixture of air and water would be formed within the rising main. Since the density of the air-water mixture is much less than that of pure water, a very long column of air-water mixture will be required to balance even a very short column of pure water. As such, the air-water mixture will begin to flow upwards though the rising main and it will be issued continuously at the top of the rising main so long as the supply of air is maintained. Most of the literature agrees that for a given configuration, water discharge increases as air input increases until an optimum air

be noted that discharge from an airlift will not occur until a minimum air input volume is reached for a given airlift configuration i.e. riser pipe diameter, submergence depth, and lift height (Awari et al., 2004, Todoroki et al, 1973).

The airlift phenomena occurs because of a pressure differential created when air which has a much lower density than water is injected into a contained water column (i.e. a submerged pipe) and a lower combined density of the air/water mixture reduces to something less than that of the pure water surrounding. Nicklin (1963) suggested that the major factors contributing to the performance of airlift pumps are: submergence depth, lift height, gas

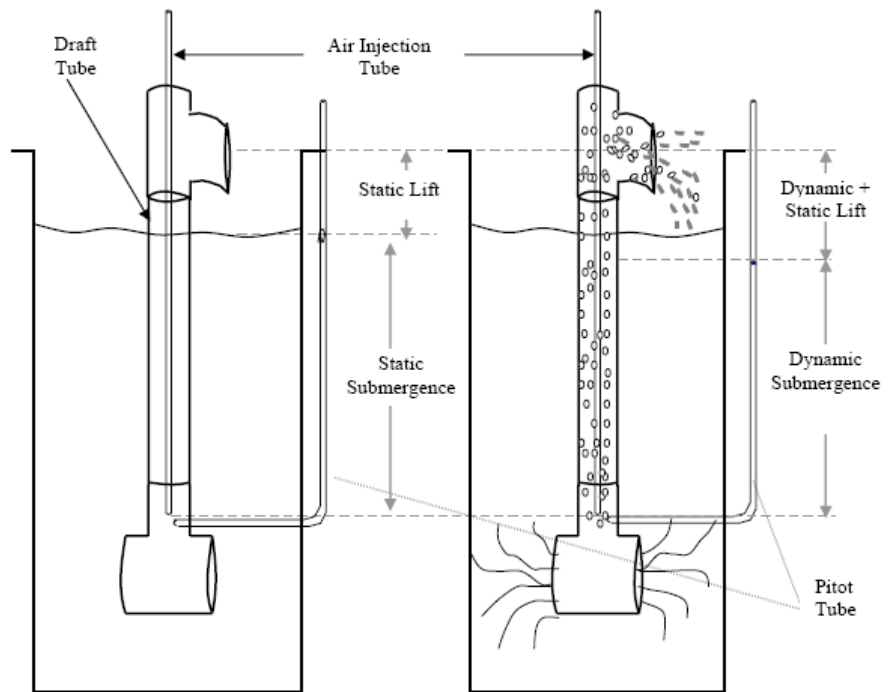


Figure 2-2 Sketch of common airlift pump showing the difference between static lift, dynamic lift, and submergence (Gudipati, 2005)

flow rate is reached after which discharge is reduced (Awari et al., 2004, Castro et al, 1975; Castro and Zielinski, 1990; Grandjean et al Part 1, 1987; Khalil et al, 1999; Morrison et al, 1987; Stenning and Martin, 1968; Todoroki et al, 1973). It should also

flow, and area of riser pipe.

Submergence Depth to Lift Height Ratio, S:L

The total lift height (L) was defined as the combination of the static water height and the dynamic head loss that the airlift must overcome. The static water height was measured as the dis-

tance at which water was being pumped above the surface of the surrounding water column (figure 2-2). The dynamic head loss was defined as the pressure loss incurred in the water loop preceding the point of discharge in the airlift pump which was commonly referred to as frictional head loss. In his application, L was usually defined in units of inches of water.

The second major factor controlling airlift pump operation was the submergence depth (S). Usually defined as the vertical distance between the tank water elevation and the depth of air injection (static submergence), S, in this application is best envisioned as the vertical distance between the water level in a pitot tube located just prior to the point of air injection and the water level in the tank only when water is flowing through the pump (dynamic submergence). The difference between static and dynamic submergence reflected the significant headloss that can be incurred as water flows from the tank through the filter and subsequent pipes before reaching the airlift. S dictates the required energy or pressure needed to drive the airlift operation.

These two terms were usually described together in the form of an S:L ratio or percent submergence. The lift to submergence ratio (S:L) was described using the following equation: $\text{HeightLiftTotalDepthSubmergenceL:S} = \text{Equation 2-1}$

For an airlift pump having a dynamic lift of 12 inches and a submergence of 48 inches, the S:L ratio would be 4:1 or just 4 and the percent submergence would be 80% with a 20% lift. Gudipati (2001) looked at the pumping capacity of 2" and 3" diameter airlifts with percent submergence of 67%, 75%, and 80% of which correlated to a 2:1, 3:1, and 4:1 S:L ratio respectively. Using a 3" draft tube, she found that an air inflow rate of 3 cfm for an 80%

submergence, 4 cfm for a 75% submergence and 7 cfm for a 66% submergence was needed in order to pump 15 gallons per minute.

Gas to Liquid Ratio, $Q_g:Q_w$

The third factor controlling airlift pump operation was the air input (Q_g) or flow of air injected. The gas to liquid ratio ($Q_g:Q_w$) referred to the amount of gas that was required to generate a given liquid or water flow (Q_w) in an airlift pump. The $Q_g:Q_w$ ratio also known as the G:L, helped to identify the level of efficiency that a pump was operating under. In the aquaculture industry, Malone and Gudipati (2005) strived to achieve a $Q_g:Q_w$ ratio between 1:1 and 2:1. For example, a $Q_g:Q_w$ ratio of 1.6 for a given airlift pump would imply that 1.6 gallons per minute of air was needed to pump 1.0 gallon per minute of water. Loyless (1995) found that lift could have a big impact on $Q_g:Q_w$. Using a 2" airlift, he supplied 9 scfm of Q_g at 92% submergence (33" submergence, 3" lift) and 59% submergence (21" submergence, 15" lift) and was able to pump 27 and 12 gallons per minute respectively. This correlated to a $Q_g:Q_w$ ratio of 2.5 and 6.7 for the two configurations. He was able to show that for a given injection depth, a small increase in either static or dynamic lift can have a significant impact on airlift performance. Wurts (1994) conducted several tests using 6" airlift pumps at 100% submergence (pumped water returned to the surface of the pond) for applications related to pond destratification. He found that at injection depths of 127", 165", and 203" optimal $Q_g:Q_w$ ratios equated to 0.39, 0.65, and 0.93 for water discharge performance of 27, 56, and 56 gallons per minute respectively.

Riser Pipe Diameter and Air Injection Method

Airlift pumps have also effectively performed the role of aeration. The riser pipe diameter referred to the

diameter or cross-sectional area available in the airlift pump for air bubble and water interaction/movement. A pipe diameter of 6 inches was the focus for this study. The physical geometric configuration of an airlift pump and method of air injection (i.e. air diffusers or open end pipe) could also influence airlift pump operation. Discharge performance for smaller diameter pumps has also been enhanced through the use of various distributed air injection methods i.e. air stones, injector plates, injector jackets (Khalil et al, 1999; Morrison et al, 1987). Loyless (1995) was able to show that an increase in the overall surface area of gas bubbles within the draft tube of an airlift (or number of bubbles per volume of air injected) through the use of an air stone could significantly enhance performance. This phenomenon was particularly true for oxygen transfer into the water column due to the increased amount of air/water interface which resulted from the increased surface area. However, these techniques have only really been effective in the bubble flow regime. Therefore, these configuration modifications were beyond the scope of this study.

Airlifts by the very nature of their design induce oxygen transfer into the water that is being pumped. Loyless (1995) studied the oxygen transfer properties of 2" riser airlift pumps for recirculating aquaculture system (RAS) with lift height and percent submergence as high as 12" and 75% respectively. He found that the multiple roles supported by the airlift pump could adequately support the circulation and oxygen demands exerted by properly sized RAS. Bellelo (2006) successfully utilized the airlift pump to provide for recirculation and aeration within a SLDM filter used for tertiary treatment of domestic wastewater generated by a road-side rest stop. Reinemann and

Timmons (1989) found that the maximum pumping efficiencies for a 1.5" airlift pump occurred in the bubble flow regime but was limited to the physical constraint that for 1 unit of lift, over 6 units of submergence were required (S:L of 6:1). They also proclaimed that the maximum airlift oxygen transfer efficiencies in the bubble flow regime are equal to or above those reported by Colt and Tcho-banoglous (1981) for fine bubble diffused aeration systems and approach those for U-tube aerators.

Airlift Pump Flow Regimes

Airlifts have also been described to transform into different two-phase flow regimes as air input increases. At low air input rates, if small bubbles are injected into the draft tube through a diffuser, the bubbles will remain distributed over the cross section of the tube with little interaction and sustain a flow regime known as **bubble flow** (figure 2-3). As the input rate increases, the smaller bubbles begin to coalesce into larger bubbles or gas slugs which in essence separate the water column into the **slug flow** regime. The transition between these two flow regimes is characterized as the **bubbly-slug flow** regime where small bubbles are found suspended within the liquid slugs between the larger gas slugs (Reinemann and Timmons, 1989).

Much of the research performed to date correlates these latter two flow regimes with the familiar pulsating nature of airlift pump operation (Castro and Zielinski, 1980; Cachard and Delhay, 1998; Richardson et al, 1962). Castro and Zielinski (1980) advocated a simple method for "tuning" an airlift for maximum liquid flow rate by adjusting the air flow until the period of flow oscillations fell between 0.5 and 2.0 seconds for each cycle. This maximum liquid flow rate would imply that for a given airlift pump configuration, the $Q_g:Q_w$ ratio reached its lowest level.

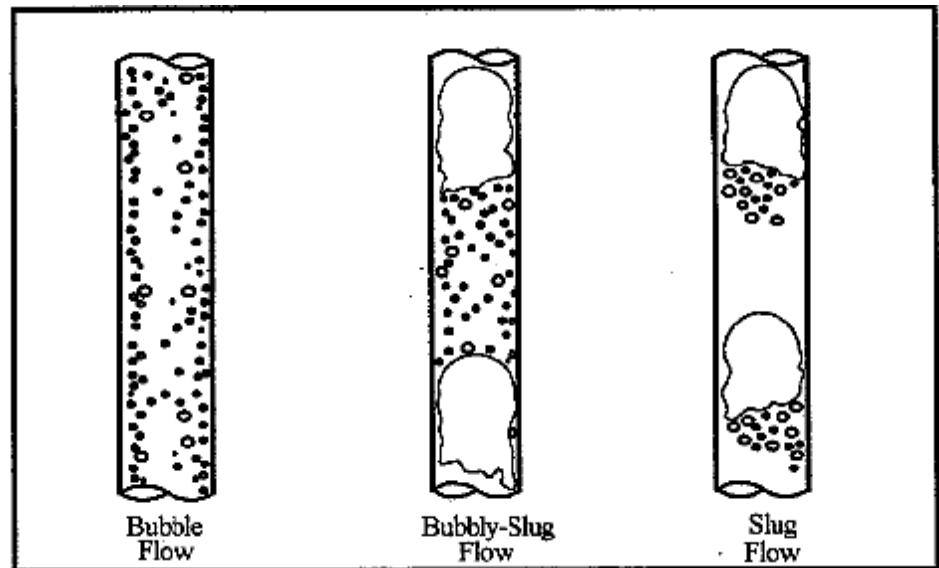


Figure 2-3 Two-Phase flow regimes in airlift pumps as air input increases (Reinemann and Timmons, 1988)

NOTE: This only covers a small portion of this thesis. Copy the link above for the full text.

The following pages are other articles that I have found.

Air-lift pumps are used entirely in well pumping. Unlike the pumps studied earlier, the air-lift pump needs no moving or rotating mechanism to produce liquid movement. Instead, the pump uses compressed air to move or lift the liquid.

The air-lift pump operates on the principle that water mixed with air has less weight, or is more buoyant, than water without air. When compressed air is introduced, a mixture of water and air is formed in one leg of the U-shaped pipe, as shown in figure 6-25. The solid column of water in the other leg now has greater weight or is exerting a greater static pressure than the column containing air. Thus the air-water column is

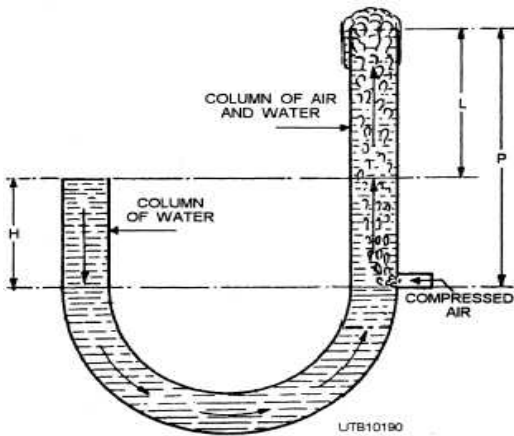


Figure 6-25.

forced upward until it discharges over the top of the U-shaped pipe. In practice, of course, wells are not dug in a U-shape.

Figure 6-26 shows a CENTRAL AIR-LIFT PUMP. Compressed air is led down an air pipe to a nozzle or foot piece submerged well below the water level. Notice that the foot piece is suspended within a discharge pipe which, in turn, is contained within the well casing. Notice that the discharge pipe is open at the bottom, directly beneath the foot piece. When compressed air is discharged through the foot piece, a column or mixture of air is formed above the foot piece in the discharge pipe. The solid column of water in the well casing, resting high above the foot piece and discharge pipe inlet, now has greater weight or static pressure. This effect forces the air-water mixture upward in the discharge pipe where it is vented to the atmosphere through an open discharge outlet. In effect, the flow of water has a U-shape down the well casing,

around the foot piece, and up the discharge pipe. The air-water discharge then strikes a separator or deflector that relieves the water of air bubbles and entrained air vapor. The discharge then settles in a collector tank. The airlift pump can deliver considerable quantities of water in the manner just described. The discharge pressure, at which it

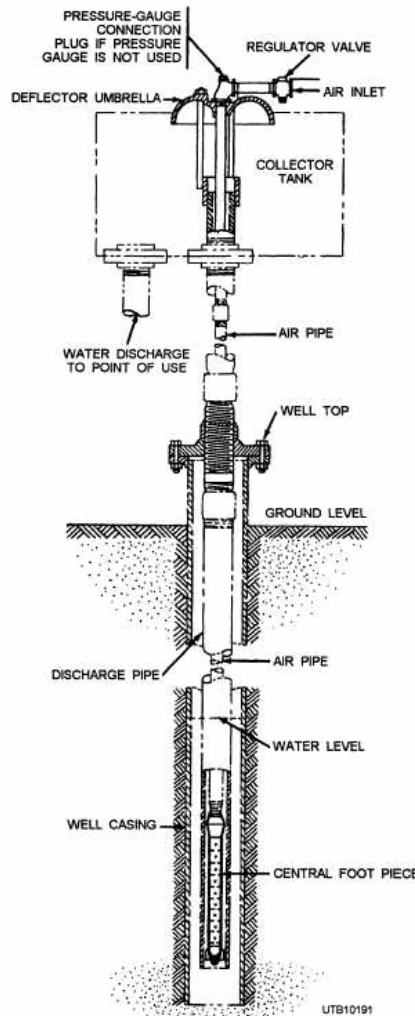


Figure 6-26.

is delivered, however, is relatively low. For this reason air-lift pumps cannot be used to discharge directly into a water distribution system. They do not develop sufficient pressure to distribute water horizontally above the ground for any appreciable distance, and the discharge can only be collected at the well for ground storage. The capacity of the air-lift pump depends largely on the percentage of submergence of the foot piece; that is, the greater the

submergence of the foot piece below the water level in the discharge pipe the greater the volume (column) of water the pump can deliver per unit of time. However, the deeper the foot piece is submerged, the greater the compressed air pressure must be to lift the column of water. In other words, a higher column of water (in the discharge pipe) above the foot piece exerts a greater weight or pressure at the foot piece. The greater the static water pressure at the foot piece, the greater the air pressure must be to infuse air with the water. Starting air pressure is always greater than working air pressure. When the pump is started, the static (at rest) level of water is drawn down somewhat to a pumping or working level. In effect, the column of water above the foot piece is decreased or lowered, and this, in turn, decreases the air pressure required to infuse the water with air. In wells where the drawdown is rather large, the pump is sometimes equipped with an auxiliary air compressor, connected in series with the main compressor, for starting. Once the pump has been started and the pumping level reached, the auxiliary compressor is no longer required, and is secured. Air-lift pumps have a low discharge pressure and require more depth so the foot piece can submerge deep enough. Additionally, the entrained oxygen in air-lifted water tends to make it more corrosive. In spite of these drawbacks, air-lift pumps have several advantages especially their simplicity of construction and lack of maintenance problems. Particularly useful in emergencies for deep well pumping, air-lift pumps can be used to pump crooked wells and wells with sand and other impurities. They can also pump hot-water wells with ease. In air-lift pump operation, compressed air has to be regulated correctly. The amount of compressed air should be the minimum needed to produce a continuous flow of water. Too little air results in water being discharged in spurts, or not at all. Too much air causes an increase in the volume of discharge but at lower discharge pressure. If air is increased still further, discharge volume begins to decrease.

Airlifts are simple but efficient devices for moving water. The concept of airlifts has been around for centuries. This article will show you how you can use an airlift pump to operate your Koi pond, including waterfalls. Under some circumstances, using an airlift can help you to realize significant savings on your power bill by using a low power air pump instead of a much higher power water pump. Much has been written about the use of airlift pumps for aquaculture where airlifts are used for aeration and circulation. Koi ponds differ from aquacultural ponds in that they are smaller (500 to 50,000 gallons vs. 100's of thousand of gallons) and they usually include ornamental features such as streams and waterfalls. Operating these features requires lifting the water instead of just moving it.

Before delving into the design of airlifts, it is important to understand their limits. Airlifts are extremely good for aerating and circulating water. Airlifts can be good for lifting water if the amount of lift is small. Airlifts will not lift water to great heights. Airlifts are not appropriate for operating tall waterfalls or filters requiring a lot of pressure (such as a pool style sand filter).

General Airlift Principles

Airlift pumps are simple devices. An airlift is simply a vertical pipe. Water enters at the bottom of the pipe and air is injected into the pipe, usually near the bottom. The rising air bubbles create an upward water current. The top of the airlift pipe can be from even with the top to several inches above the pond level. You are probably already familiar with airlifts and don't even know it. Did you ever notice the aquarium filters that have air bubbles going up a vertical pipe to draw water through the filter - that's an airlift. The critical factors in airlift design and the range of values that are typical for a Koi pond are:

- air volume up to 10 cfm
- air pressure (air injection depth) 4 to 12 feet
- water volume 1 to 100 gpm
- lift height (water pressure) 0 to 36 inches
- lift pipe diameter 0.5 to 3 inches

Some generalizations can be made about the relationship of these parameters and the design of an airlift.

- Increasing air injection depth increases water flow.
- Increasing lift height decreases water flow.
- Smaller diameter pipes are capable of higher lift.
- Small air bubbles produce more lift than large bubbles.

The key to producing an efficient airlift is to find the best air flow. Very low air flow will just produce bubbles in the pipe and no water will make it to the top. As the air volume is increased, water will start to flow to the top. Shortly beyond this point, increasing the volume of air will result in the most efficient flow of water (efficiency measured in water flow per air flow). Continuing to increase the air volume will produce increases in water flow, but at reduced efficiency. To efficiently increase the flow of water, you should add more lift pipes operating in parallel instead of putting more air into a single lift pipe. (or use a larger diameter pipe.)(bdt)

Design Details

There are many ways to construct an airlift. The diagram shows the design I prefer which is also the design I used on my previous pond. The best method of injecting air is to use air stones. Air stones provide the smallest bubbles which result in the best lift and aeration. When using air stones, you should increase the diameter of the pipe at the injection area to allow water to flow better since part of the pipe area is blocked by the air stones. When using multiple airlifts that are driven by a common air pump, the air stones provide enough resistance that the air will distribute evenly without having to use any other valves to control air flow.

I have found that gluing air stones

inside threaded pipe/hose barb adapters is a convenient way of connecting the air stone. The threaded end of the adapter makes it easy to remove the air stone for cleaning or replacement. For small diameter lift pipes, I use a tee to connect a single air stone. For large diameter lift pipes, I drill and tap several holes in the pipe and then screw the adapters into the threaded holes. To provide more pipe thickness for threading, you can put a pipe coupling in the place where you want the air stones and drill and tap through the coupling and pipe. I like to put some clear pipe just above the air stones so that I can keep an eye on things. If your airlift does not exit directly into your pond or filter, be sure to provide some means to allow the air to escape before piping the water back to the pond. You may be able to incorporate a foam fractionator into the system at this point.

There are many combinations of design parameters that will work. The diagram shows details of the design I used. On my pond I used L-70 linear air pumps from AES. These pumps are efficient, quiet, and capable of producing pressures of over 4PSI. On my old pond, I was using an air injection depth of 8', six airlift pipes in parallel, four air stones per lift pipe, and my pond required around 36" of lift. Recent improvements in normal pump performance combined with the cost of repair kits for the air pumps would cause me to either use a normal pump or design the pond with shorter water falls if I were to use airlifts again.

For a typical pond, I would suggest the following: Lift Pipe - 1.5", Air Injection Depth - 6', Lift Height - 0 to 24". Use the charts to determine an appropriate air flow. Use enough lifts in parallel to achieve the desired water flow rate. To keep wear on your air pump reasonable, I would not use the maximum air injection depth that the air pump is capable of supporting. Running the pump at lower pressure will lengthen the life of the valves which are expensive to replace.

Airlift Performance Data

The results of my tests are shown in the charts. The charts show performance of airlifts in a range that is typical of those that would be used in a Koi pond. The chart titled Performance shows the amount of water that flows for given air flows and lift heights. The chart titled Efficiency shows how well the airlift works. You will probably want to design your system to work in the most efficient range possible.

Designing Your Airlift

I will assume that you will be using a diaphragm type of air pump (other common types include piston compressor, rotary lobe blower and regenerative blowers). Diaphragm air pumps operate at air pressures of 1 to 5 psi (26 to 130 inches of water). Better results will be had operating the pump at the higher pressure end of its operating range. The reason for this is that the pump's air output volume changes relatively little with changes in the operating pressure over its rated pressure range, but the airlift's performance changes significantly, producing more water volume with greater air injection depths. The water flow rate and lift required will be dictated by the nature of the pond. The lift required is the total of: the drop of all streams and waterfalls, the drag of all plumbing, and the drop across the filter system. The air injection depth will probably be determined by the landscape subject to the limits of the air pump. Many pond keepers will not be willing or able to use the full pressure available from the air pump since doing so would require hav-

ing the bottom of the airlift at a significant depth below the level of the pond. The air pressure required is the air injection depth plus the resistance of air lines and air stones. Air stones produce a pressure drop of a few inches.

The remaining design parameters to be set are: air pump selection, lift pipe diameter, number of lift pipes in parallel. Setting these parameters is largely a matter of compromise. Some factors to consider are:

Air Pump: Performance (air flow and pressure); purchase cost; operating cost; availability; indoor/outdoor use; operating noise; maintenance. Consider the fail-safe redundancy of multiple pumps vs. efficiency of single larger pump.

Airlift: There are no good formulas to find the best design. The best way to develop your design is to use the performance charts to calculate the air requirements for some possible configurations.

Design Example

Lets consider using an airlift for a pond with the following specs.

- Total pond volume 5,000 gal
- Waterfall height 8 inches
- Filter drag 4 inches

- Plumbing drag 3 inches (each way)
- Total lift required 18 inches
- Flow required 2500 gph - 42 gpm

Looking at the performance chart, you can see that an airlift with 1.5" lift pipe, air injection depth of 6', and lift of 18" will produce the following water flows vs. air flows:

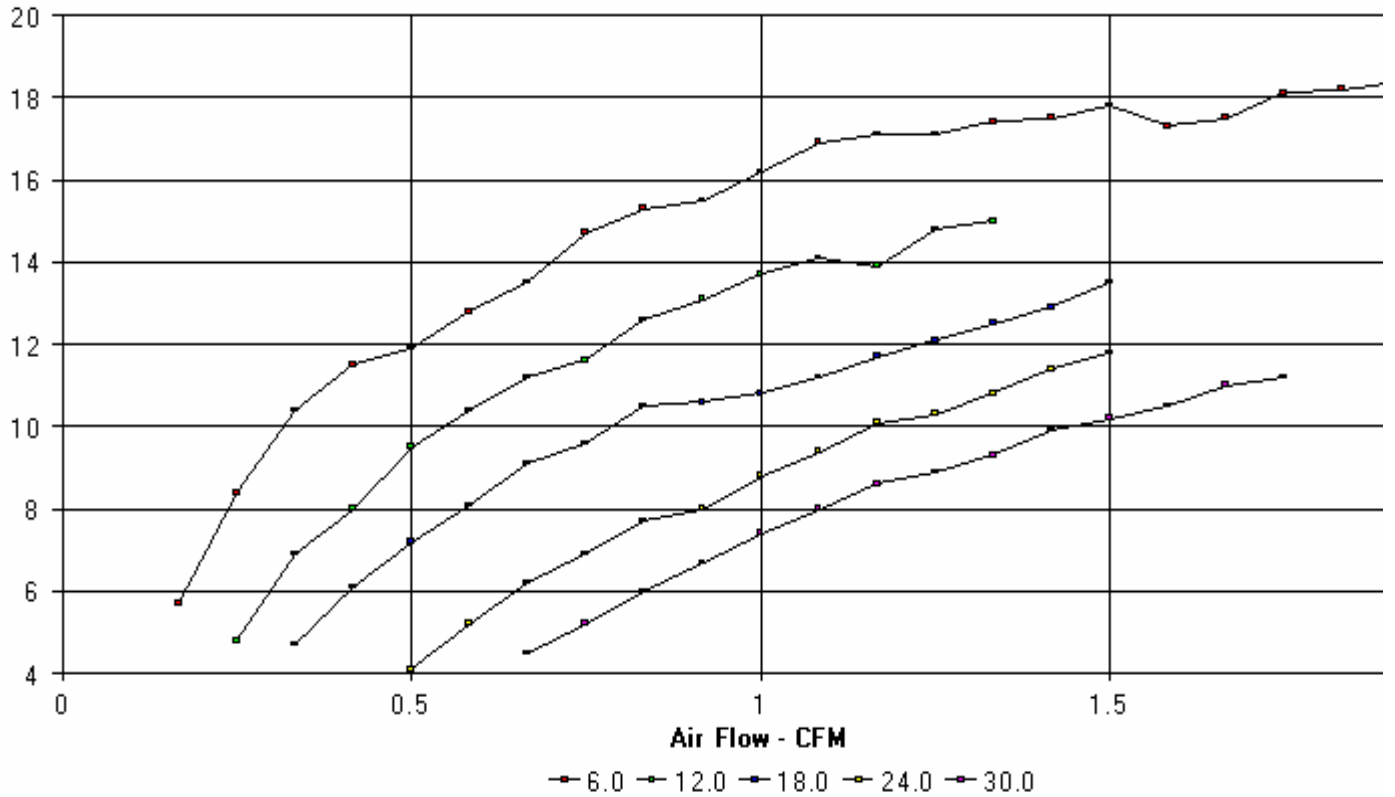
- 7 GPM water with 0.5 CFM air, 11 GPM water with 1.0 CFM air, and 13 GPM water with 1.5 CFM air.

To achieve the desired flow of 42 GPM, you would need one of the following configurations:

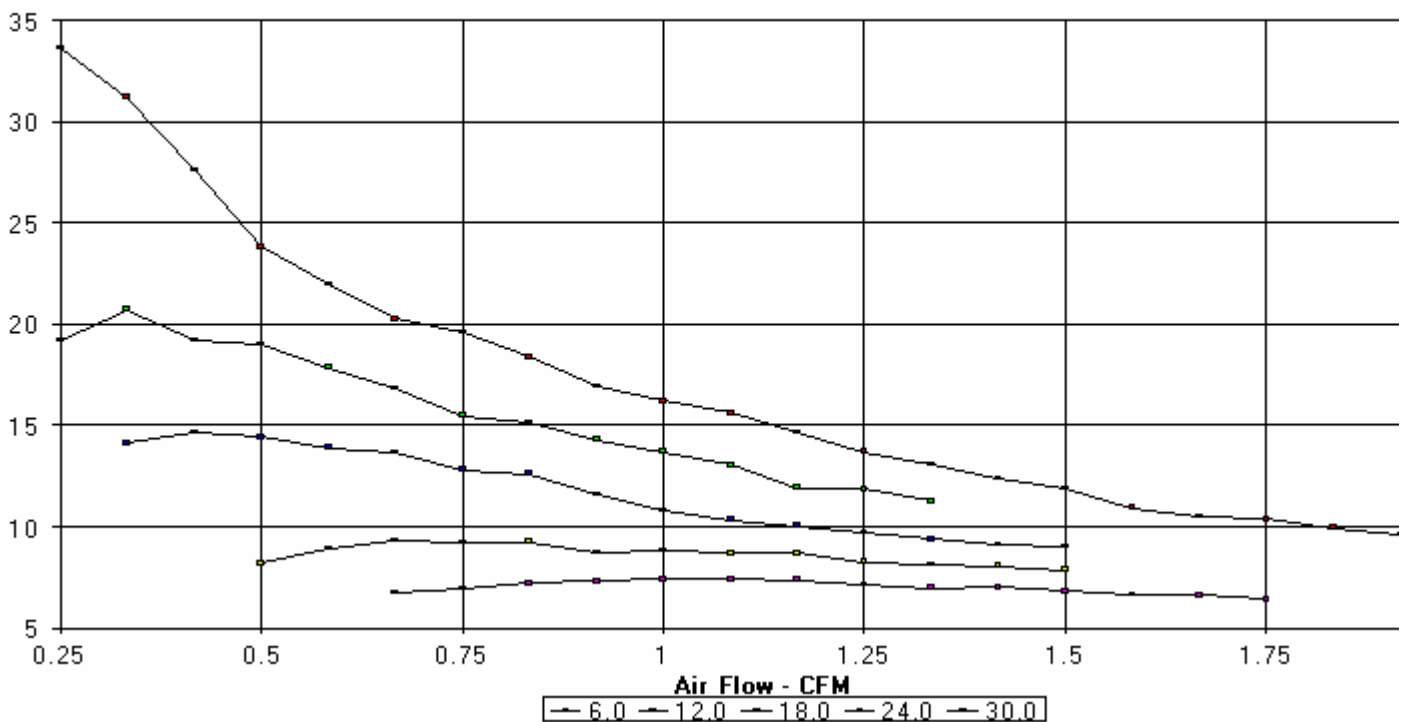
- 6 lifts at 0.5 CFM each (total air - 3.0 CFM)
- 4 lifts at 1.0 CFM (total air - 4.0 CFM)
- 3 lifts at 1.5 CFM (total air - 4.5 CFM)

Building a set of airlifts using 6 pipes will allow you to use a smaller air pump. If space is more of a concern, you can use fewer lifts, but they will require a larger air pump.

Performance - 1.5" Pipe, 72" Air Injection Depth, 6" to 30" Lift

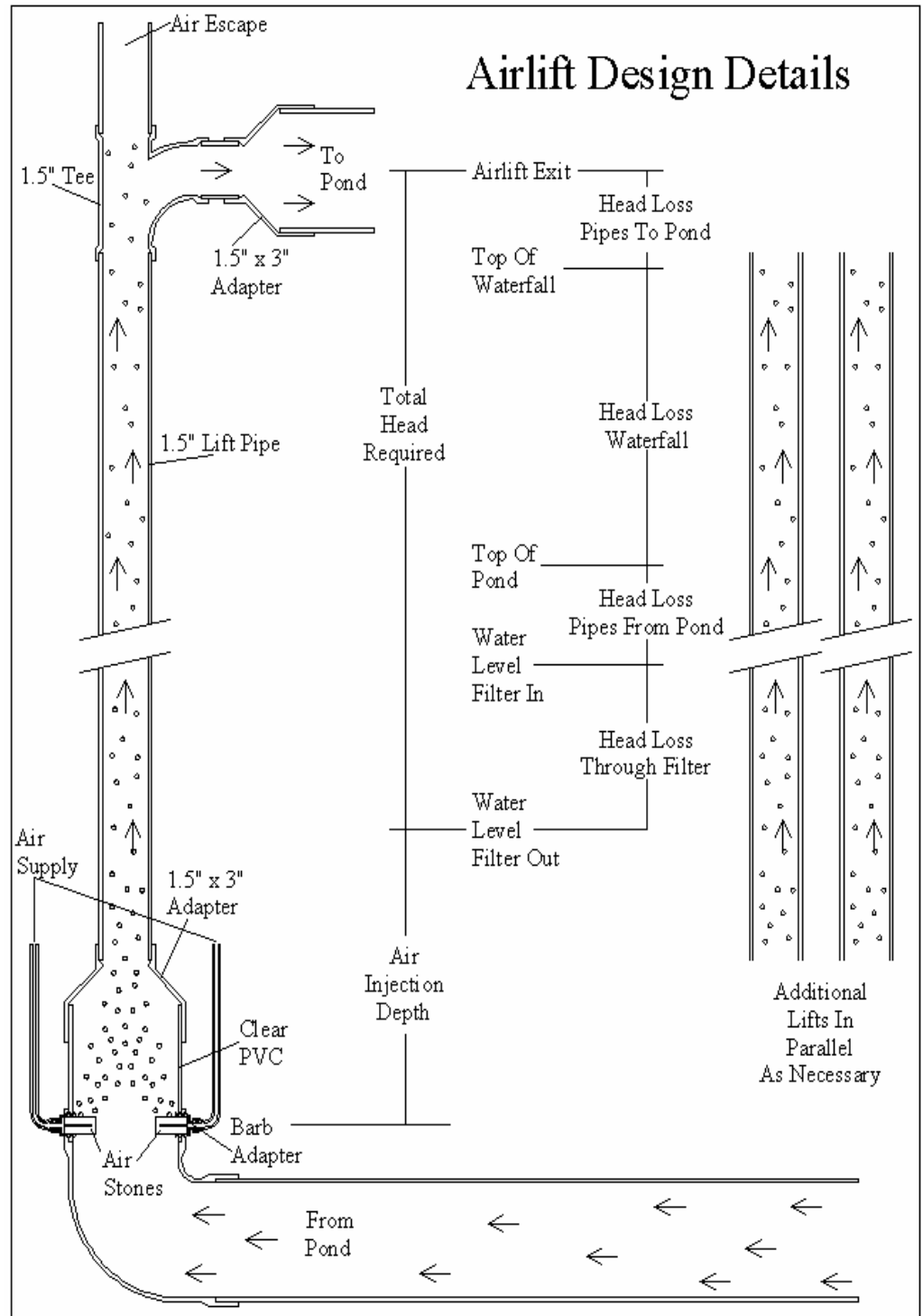


Efficiency - 1.5" Pipe, 72" Air Injection Depth, 6" to 30" Lift



Misc.

Pond product suppliers should be able to provide you with data on the performance of their products. They should be able to provide information on electrical power consumption and on pressure vs. volume for any air pump that is large enough to be practical for a pond airlift. Most small aquarium air pumps do not have much data available about their performance, but these pumps are too small for this type of application. I've done a lot of testing of various airlift configurations. I will be posting more performance data as time permits.



Air lift is far more energy efficient than water pumps in moving water between the pond and the water purification system. Other advantages include: the benefits of aeration and air stripping, no need for ground fault circuiting, no electrical contact with the pond, they can be modified as heating units, fish and eggs can pass through the entire filtration system without being harmed, multiple systems can be operated on one power source they are quiet, they don't leak oil into the pond, an impeller can not get stuck and they are simple to operate.

Disadvantages of air lift powered Koi ponds include a loss of efficiency when used to lift water a significant height, which limits their use with some waterfalls. They are large volume, low pressure systems, and can not be used when the filter has significant resistance. Large piping is needed with broad, sweeping bends, and open flow media with low resistance is also required. They can be adapted to some, but not all, ponds currently powered by water pumps.

Air lift is the main system used for commercial fish farming and for small aquariums. The largest and smallest systems are powered by this method. Why did we overlook it in the mid-sized systems'? One reason is it's hard to find an inexpensive mid-size air source.

The principle of air lift is simple. Air is introduced into a vertical pipe containing water. As the air rises, it imparts energy to the water and forces the water to move vertically up the pipe. In a small plastic aquarium filter, periodic bubbles are released with a column of water in between each bubble. In a large system, the bubble and column of water approach is not used: it is, in-

stead, powered by the force of the rising air. Air lift systems by divers to gently lift lobsters from the ocean floor up to the boat without being harmed in the process. The simplest air lift system is a vertical pipe with an air stone dropped down into the pipe. The air stone however, creates resistance to the escaping air and also creates resistance to the flow of water in the lumen of the pipe. Some of you may recall a system using air stones which I was using about 10 years ago.

[A more efficient system employs the injection of air into a series of holes in the circumference of the pipe. This eliminates the resistance to both air and water which is created by the air stone.](#)

I'll describe an example of a system I have used. I powered an Everflow 500 filter with a Sweetwater 2 cu. ft/minute air pump at 57 watts. This unit filtered my 9,000 gallon pond from October to March. The water was crystal clean (32 fish). In the colder months, I placed the air pump in a Styrofoam box and wrapped extra lengths of the air hose in the box to heat the air from the heat of the pump. A 3' vertical 2" Pvc pipe was used, and it moved about 50 gallons per minute through the filter.

To construct this system on the 2" pipe. I drew a circle and drilled 8 holes 1/8" in diameter on this circle. Around this pipe, I placed a 4" PVC pipe about 8" long. I modified 2-4" to 2" re-

ducing bells to fit the 4" pipe around the 2" pipe. Rubber bushings can also be used to connect the 4" pipe around the 2" pipe. A 1/2" hole was drilled into the 4" pipe at the center and a 1/2" PVC pipe was glued in place. This 1/2" pipe was connected to the air line.

Multiple air lifts can be used from the same power source. High efficiency air pumps and air blowers are preferred. The depth of injection is a critical issue to maximize the efficiency of the air pump. Other critical considerations are the size of the pipe, volume of water to be moved, volume of air, and the size and number of the injection holes. If the injection holes are too small, they can clog in hard water conditions. The water can exit from the pipe below the water level. If an elbow is used at the exit, it would preferably be positioned so half the exit flow is below water level and one half is above the water level. Let's save money and make greater use of air lift systems. With the greater use of open flow, low pressure filters, it's a good method of powering our systems.

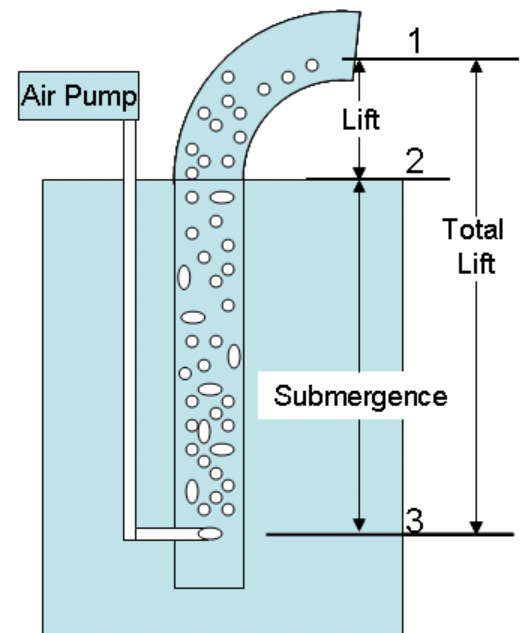
Recirculation aquaculture is energy intensive because water must move continuously through the system to remove wastes and replace oxygen. The standard method of moving water is the use of a centrifugal pump. An alternative pumping system is the airlift pump, which uses the buoyancy produced by entrained air bubbles to lift water. Studies by Reinemann (1987), Turk et al (1991), and others indicate that use of the airlift pump is substantially more energy efficient for moving water under low-head conditions than centrifugal pumps. The economic benefits of the airlift pump are further increased when the electrical requirements for aeration, carbon dioxide removal, and foam fractionation are considered. The airlift pump does all of these simultaneously, whereas separate component systems are required when standard pumps are used. Energy usage for a combination pumping and aeration are approximately one-third the cost of a conventional pumping system (Reinemann et al., 1987).

The airlift pump has other important benefits to the aqua culturist. Capital costs are significantly less than that for standard electrical (i.e., centrifugal) pumps. The simplicity in its design—there are no moving parts—means that maintenance costs are also low.

Despite the fact that the existing body of research indicates that the airlift pump is under most instances the preferred system for recirculation aquaculture, the aquaculture industry is generally biased against investment in culture systems employing the airlift pump. The reasons for this are lack of awareness of its inherent advantages, lack of available systems that employ the airlift pump, and performance deficiencies in instances where they are used. The simplicity in its design—made mostly from PVC pipe—makes it less profitable to market relative to standard electrical pumps. Most of the major supply

catalogs for the aquaculture industry do not market airlift pumps. Furthermore, companies that sell package aquaculture systems typically use electrical pumps. The majority of recirculation aquaculture systems are not designed to take advantage of the efficiencies of the airlift pump. Changes in hydraulic grade line through the system are typically too great. This is done as a cost saving measure (when using centrifugal pumps) to avoid the use of multiple pumps. Conversely, multiple airlift pumps are not a significant cost consideration; they are actually necessary to maintain the hydraulic grade line within the optimal range of the airlift pump. Furthermore, where airlifts are employed, the design of the airlift typically employed does not maximize its performance capabilities. For instance, the flow rate is typically less than optimum because the lift is either too high or the pipe diameter-to-rise is too large. Hydraulic efficiency is also reduced when obstructions such as air stones are placed in the airlift tubes. It is anticipated that the growth of recirculation aquaculture will provide a new market to the utility industry for electrical power. For example, based upon an energy requirement of 8 Mcal per kilogram of fish (Reinemann, 1987) and a business producing 150,000 pounds of fish per year, the expected annual energy requirement is approximately 475,000 kWh. The most efficient use of this electrical power will be achieved through use of airlift

pumps. If this technology is to become a standard for recirculation aquaculture, the utility industry needs to become proactive by providing information to its prospective customers. The information will be extremely valuable to the customer when planning the design of the recirculation aquaculture system.



Operating principals of the air-lift pump.

Lift is the distance between the surface of the water and the discharge point or the vertical distance the water must be moved above the surface. (1 to 2)

Total lift is the distance between the air injection point and the water discharge point, or the total vertical distance that the water must be moved. (1 to 3)

Submergence is the distance between the water level and the air injection point (2 to 3).

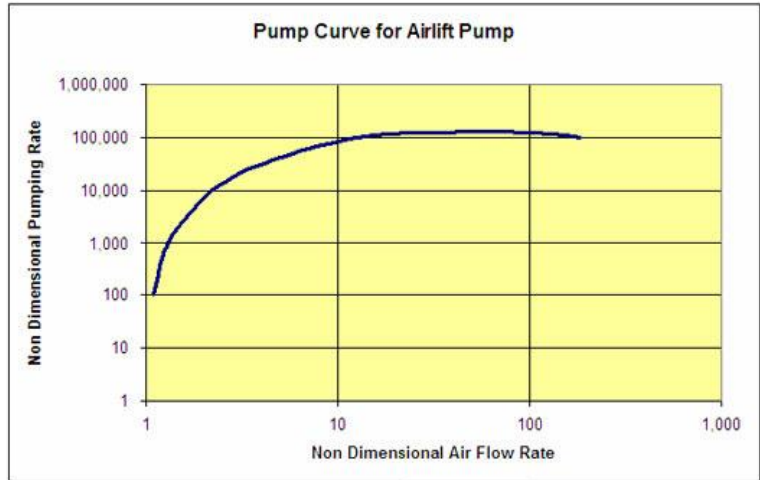
Submergence ratio is the ratio of the distance between the air injection point and the surface of the water (2 to 3) to total lift (1 to 3).

More Accurate Pump Curve with All Parameters

F.A. Zenz with AIMS proposed a way to relate most important parameters in the Journal of "Chemical Engineering Progress" in 1993. The parameters and his graph are summarized below.

A	Pipe cross-sectional area, sq. ft.
D	Pipe inside diameter, in.
L	Lift height, ft.
S	Submergence, ft
V_G	Gas flow at discharged conditions, cu. ft./min
V_L	Dense phase flow, gal/min
P_G	Gas density, lb/cu. ft.
P_L	Liquid density, lb/cu. ft.

$$\frac{V_L}{A} \sqrt{\frac{48L}{D}} \frac{P_L}{62.4} \frac{1}{\log_{10} \left[\frac{34+S}{34} \right]}$$



$$\frac{V_G}{A} \sqrt{\frac{48 P_G}{D L P_L}}$$

Pumping rate [GPM]	Submergence [ft]	Lift [ft]	Submergence Ratio [%]	Required Air Flow [cfm]	Source
200	5	1.25	80	Not possible	Zenz(1993)
200	8	2	80	28	Zenz(1993)
200	10	2.5	80	23	Zenz(1993)
200	15	3.75	80	17	Zenz(1993)
200	?	?	80	23	Company A
200	?	?	80	19	Company B

Comparison of Three Pump Curves

Required air flow is calculated for the condition of 200 GPM, 6" airlift pump, submergence ratio of 80%, Obviously the graphs by Company A and B are erroneous.

Air Lift Pump

This pump uses compressed air, delivered to the bottom of a submerged pipe in a well, to lift an air/water mixture to the surface. The pump principle is that an air/water mixture, with as little as half the density of water, will rise to a height above the water level approximately equal to the immersed depth of the pipe. Depending on the lift required, this submersion depth may require a deep well (refer to “Total Length” in table 2 below). The air line can be placed inside the discharge pipe or, as shown in figure 8 below, outside and parallel to it. A ‘foot piece’ breaks the air into small bubbles that conserve air and improves efficiency. A homemade device can be used consisting of 1/16” holes in a copper tube that extends up into the pipe. (We would likely use an air stone or a diffuser). The main advantage of this pump is its simplicity. The disadvantages are the very low overall efficiency when higher lifts are required. Submergence in Table 2, below, is “minimum” (the least submergence but requires more compressed air per volume of water delivered) or “best” (least amount of compressed air per volume of water delivered but deepest well—total depth—required).

Table 2 Air Lift Pump Requirements for Livestock Watering Conditions ¹					
Pumping Rate		Water Discharge Pipe Size			
		½ inch air line inside water line ¹		½ inch air line outside water line ¹	
litres per min	USgal per min	mm	inch	mm	inch
4 to 15	1 to 4	25	1	13	0.5
15 to 26	4 to 7	32	1.25	19	0.75
26 to 42	7 to 11	38	1.5	25	1

Air Lift Performance for Minimum and Best Submergence ¹													
Depth to Pumping Water (lift L)		Depth of Air Line Below Pumping Water (submergence S)				Total Length (lift L + submergence S)				Volume of Air Required per Volume Water Pumped			
m	feet	m		feet		m		ft		m ³ /min per m ³		ft ³ /min per USgal	
		min	best	min	best	min	best	min	best	min	best	min	best
7.6	25	8.8	16.8	29	55	16.4	24.4	54	80	2.06	1.35	0.28	0.18
15.2	50	15.8	28.4	52	93	31.0	43.6	102	143	3.74	2.24	0.50	0.30
30.5	100	27.1	45.7	89	150	57.6	76.2	189	250	6.58	3.52	0.88	0.47
45.7	150	34.5	55.8	113	183	80.2	101.5	263	333	8.83	4.64	1.18	0.62
60.1	200	42.4	65.9	139	216	102.5	126.0	339	416	10.92	6.21	1.46	0.83

¹ refer to Figure 8, next page

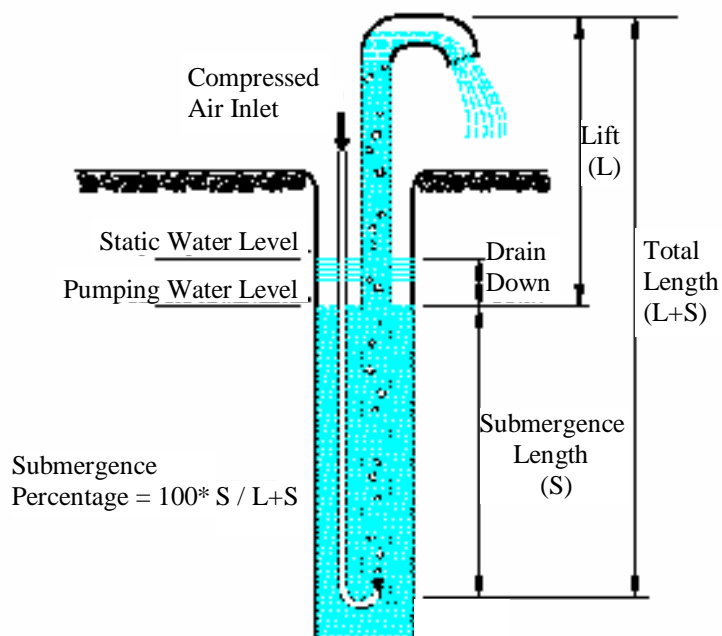


Figure 8 Air Lift Pump

Tested Flow Rates

diffuser	pressure in PSI	air flow in LMP	Water flow in GPM	lift	Pipe dia	submergence
7 micron x 3" dia	5	25	1	20	3"	52"
50-90 micron x 3" dia	2	22	3	20	3"	52"
50-90 micron x 3" dia	2.25	62	4.5	23	3"	52"
90-130 micron x 3" dia	1.8	30	5	23	2"	52"
70 micron 3/4" muffler	2	28	5	23	2"	52"
50-90 micron x 3" dia	2	32	5	23	2"	52"
250 micron 3/4" muffler	2	96	5	23	3"	52"
90-130 micron x 3" dia	2	46	5.5	23	2"	52"
90-130 micron x 3" dia	2.2	94	6	23	3"	52"
70 micron 3/4" muffler	2	45	6.6	23	2"	52"
50-90 micron x 3" dia	2.4	90	6.6	23	3"	52"
250 micron 3/4" muffler	2	48	7.5	23	2"	52"
50-90 micron x 3" dia	2.2	50	7.5	23	2"	52"
250 micron 3/4" muffler	1.9	62	8.5	23	1.5"	52"
90-130 micron x 3" dia	2	62	8.5	23	2"	52"
35 micron 3/4" muffler	2.4	34	8.5	23	2"	52"
250 micron 3/4" muffler	2	62	10	23	2"	52"
70 micron 3/4" muffler	2	62	10	23	2"	52"
35 micron 3/4" muffler	2.5	50	10	23	2"	52"
250 micron 3/4" muffler	2.1	92	11.1	23	1.5	52"
90-130 micron x 3" dia	2.1	78	12	23	2"	52"
70 micron 3/4" muffler	2.2	78	12	23	2"	52"
35 micron 3/4" muffler	2.75	64	12	23	2"	52"
250 micron 3/4" muffler	2	78	13	23	2"	52"
90-130 micron x 3" dia	2.2	92	13	23	2"	52"

Alita AL-80

— Alita's Published Flow
— Actual Flow as Tested

