Research Report

Performance and design characteristics of airlift pumps for field applications

Click here for Rectangular Airlift Design

William A. Wurts,(1) Sam G. McNeill(2) and Douglas G. Overhults(2)

Individual and combined pumping capacities were determined for floating airlift pumps, powered by a centrifugal blower. Individual airlift pumping rates ranged from 66-225 liters of water per minute (L/min) for all variables examined. Airlift pumps, 185 cm long, were made from PVC pipe of 7.6, 10.2 and 15.2 cm inner diameters. Air was injected through a 2.5-cm pipe at 50, 65, and 80 cm below the water discharge outlet. Water flow rates were measured at differing air flow injection rates (71-324 L/min). Individual airlift pumping rates increased as pipe diameter, air flow and air injection depth increased. Using the data from these experiments and a manufacturer's performance curve, it was calculated that a 1.0-horsepower (0.75 kw) centrifugal blower could pump 3107 ñ 75 (SD) L/min water by combining the individual outputs of twenty-eight 7.6-cm diameter airlift pumps. To achieve this total, each airlift would require 71 L/min air flow injected at 80 cm depth (82.6 cm water pressure) to pump 111 L/min water.

Introduction

The theory and principle of airlift pumps were described in detail by Nicklin.(5) From a simple conceptual viewpoint, air bubbles act as pneumatic pistons, pushing or drawing water up a pipe or stack as they rise and expand. A more precise explanation describes the pumping action as the result of an air-water mixture. The air-water mixture is less dense than and therefore is displaced by the surrounding water of higher density.

Airlift pumps are widely used by aquaculturists. Common airlift applications are to pump, circulate and aerate water in closed, recirculating systems as well as in ponds. Several researchers have examined the performance characteristics of airlift pumps used for aquacultural applications. Castro et al.(4) and Castro and Zielinski(3) studied performance for 1.27-8.0 cm diameter airlifts at different levels of submergence (40-100%) in water tanks. Parker and Suttle(6) examined the performance characteristics of 3.75-30 cm diameter airlift pumps at various air flow rates and air injection depths at 100% submergence (level flow) in ponds, and concluded that 7.6-10 cm diameter pumps were the most practical.

Centrifugal blowers are one of the most effective and inexpensive methods to produce or pump air because they produce relatively high volumes of air at low operating pressures. One might conclude from the results of Parker and Suttle (6) that individual, large-diameter pipes are the most effective airlift pumps. However, that does not take into consideration actual, and most efficient, blower operating pressures. The purpose of this study (7) was to test airlift pumping characteristics for a specific design configuration and to determine reasonable expectations of water pumping capacity under practical field conditions.

Methods

Airlift pumps were constructed from commonly used and readily available materials and equipment (PVC and polyethylene pipes, PVC fittings, stainless steel ring-clamps and a centrifugal blower). Pumping capacities were

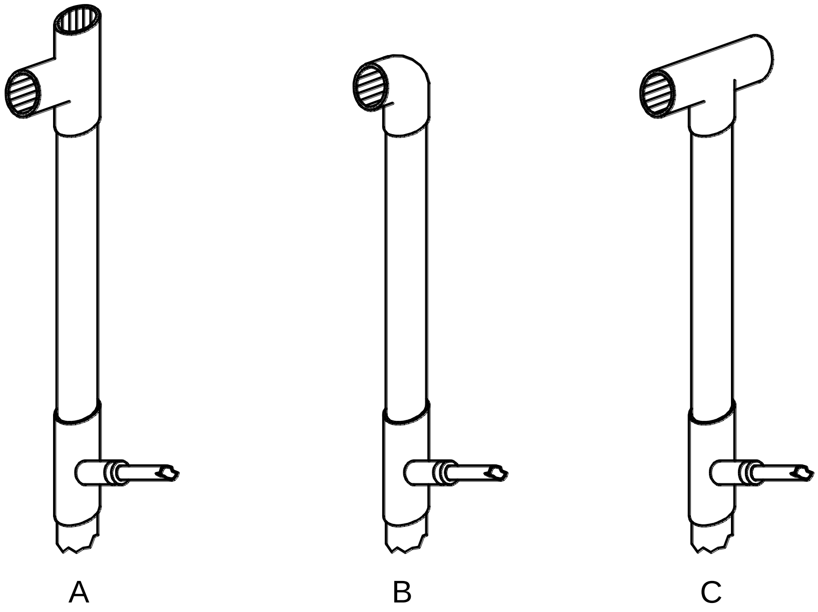

Figure 1. General diagrams of three basic airlift pump designs.

determined for floating airlift pumps (Fig. 1A, basic test configuration) powered by a 2.5-hp (1.9 kw) centrifugal blower. Airlift pumps, 185 cm long, were made from PVC pipes of 7.6, 10.2 and 15.2 cm inner diameters. Air was injected through a 2.5-cm inner diameter pipe (14.2 m long) at 50, 65, and 80 cm below the discharge outlet. The bottom of the discharge outlet ranged from 0-2.5 cm above the water surface and was buoyed with foam flotation. Air flow rates were varied between 71 and 324 liters per minute (L/min) and corresponding water flow rates were measured. Operating pressures were recorded for each airflow rate tested.

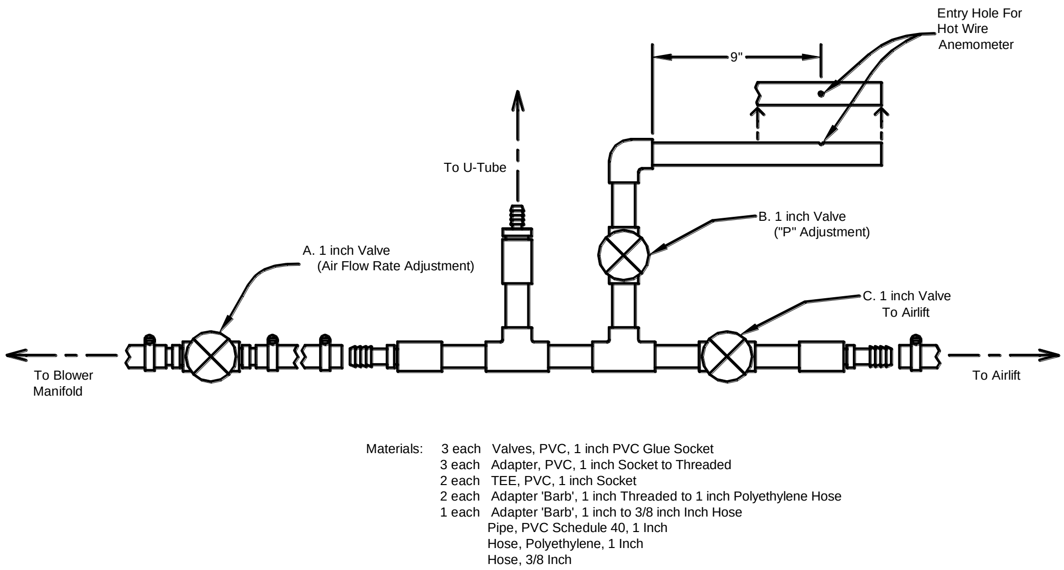

Figure 2. Air pressure flow regulator system for testing and adjusting air flow

Air flow rates and operating (in-line) air pressures were measured with a hot wire anemometer, a U-tube manometer and an air pressure/flow regulator system constructed from 2.5-cm PVC pipe and gate valves (Fig. 2). System operating pressures were determined for each injection depth and approximate air flow rate before adjusting actual air flow rates. Once operating pressure was determined, valve C was closed and valve A was used to adjust air flow while adjusting air pressure with valve B (Fig. 2). After air flow had been adjusted for the appropriate pressure, valve C was opened, valve B was closed and water flow was then measured. Air and water temperatures were between 27 and 32øC. The study was conducted in a 0.13 ha pond (2.44 m deep) at 173.7 m above sea level.

Water flow was calculated by measuring the time required to fill a 127-L, rigid plastic container. Five measurements were collected and timed for each combination of pipe diameter, air flow and air injection depth. Mean and standard deviation were calculated for each of the five water flow rates observed. Flow rates for air and water were plotted and compared with linear, power, exponential and logarithmic regressions.

Results and Discussion

Logarithmic regression (y=b+m*1nx) had the best fit with the data collected (Fig. 3). Values for the coefficient of determination (R2) ranged from 0.82 to 0.998. Overall, individual airlift pumping rates increased

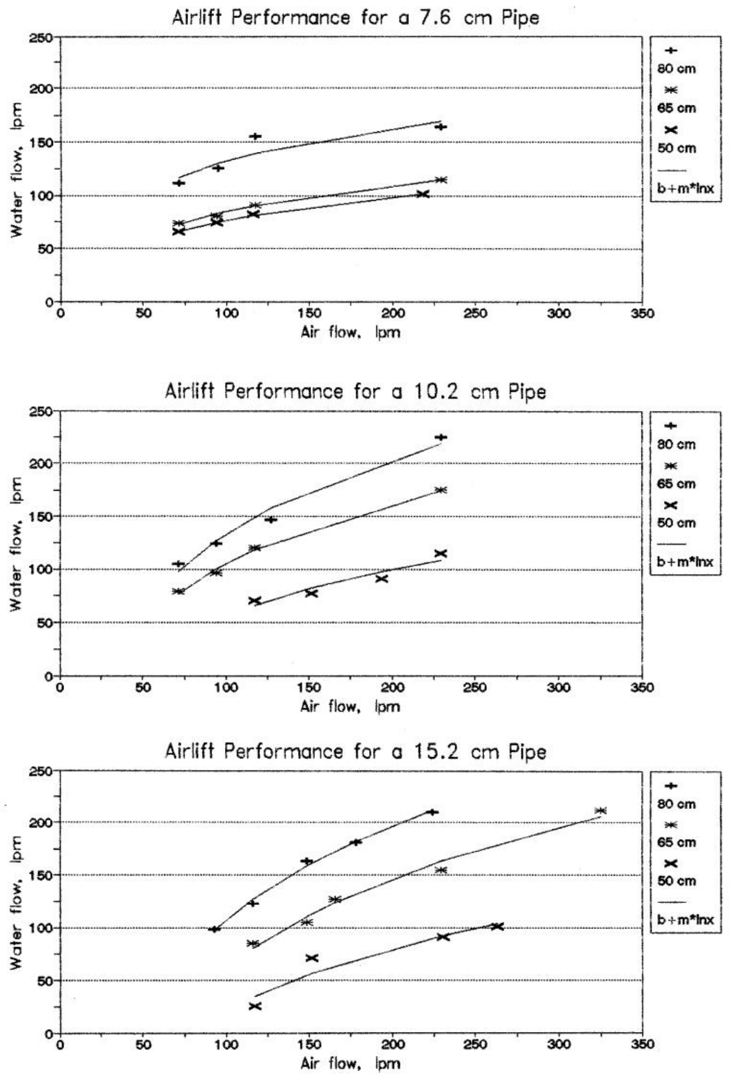

Figure 3. Regression (y=b+m*lnx) and data plots of air flow and mean water flow rates for three injection depths (50, 65 and 80 cm) and airlift pipe diameters (7.6, 10.2 and 15.2 cm).

Table 1. Mean water flow rates and corresponding standard deviations produced at various air injection depths, operating pressures and air flow rates in 7.6 (A), 10.2 (B) and 15.2 cm (C) inner diameter airlift pumps.

Injection depth (cm)	Pressure (cm H_2O)	Air flow (liters/min)	Water flow (liters/min)	Standard Deviation
A. 50	55	71.1	65.5	±2.5
	55	94.3	74.5	±0.9
	55	115.8	82.7	±1.4
	55	217.8	101.6	±1.4
65	65	71.1	73.9	±2.7
	65	94.3	80.4	±2.6
	65	117.5	90.7	±3.3
	65	228.5	115.6	±1.5
80	83	71.1	111.4	±2.7
	83	94.9	125.2	±3.3
	83	117.5	155.2	±2.1
	83	228.5	163.9	±1.9
B. 50	53	117.5	70.3	±5.9
	52	151.5	77.2	±1.4
	53	193.1	91.7	±1.1
	56	228.5	114.9	±1.9
65	65	71.1	78.6	±3.1
	65	94.3	96.2	±3.8
	67	117.5	120.5	±4.8
	70	228.5	175.1	±4.0
80	80	71.1	105.1	±1.9
	80	94.3	124.2	±1.0
	80	126.6	146.9	±3.1
	83	228.5	224.8	±3.1
C. 50	56	117.5	<25.4	----
	56	148.4	70.7	±3.9
	57	230.2	83.2	±1.2
	60	230.2	98.2	±1.9
	60	262.5	100.7	±2.5
65	70	115.8	85.2	±2.2
	71	148.4	105.4	±5.2
	72	165.4	127.3	±4.7
	74	228.5	154.9	±4.0
	86	324.2	212.1	±2.1
80	84	92.6	98.2	±2.8
	85	115.8	123.0	±5.8
	87	148.4	163.6	±3.9
	88	177.5	181.7	±5.8
	88	224.0	210.3	±6.2

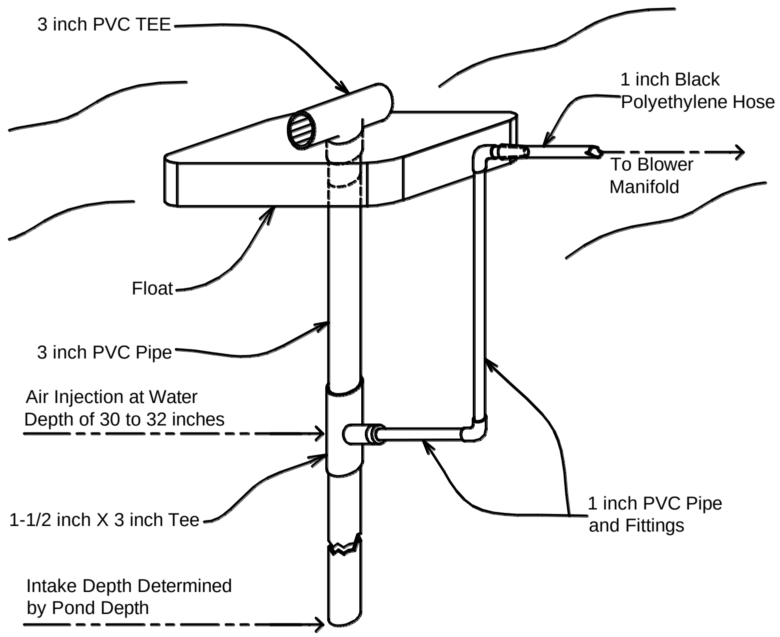

Figure 4. A design of an easily constructed 7.6 cm diameter airlift de-stratifying pump.

as pipe diameter, air flow and air injection depth increased. Individual airlift pumping rates ranged from 66-225 L/min water for all variables examined. Operating pressures were 0-21.6 cm water greater than corresponding injection depths and increased as air flow increased (Table 1).

While the water flow rates measured in this study were good, they were somewhat lower than the findings of Parker and Suttle.(6) It is difficult to determine whether the pumping rates observed by Parker and Suttle(6) were significantly greater than those observed in the present study without an indication of data set variability. The discrepancies observed in this study may relate to placement of the discharge pipe at slightly less than 100% submergence (0 to 2.5 cm above water level), longer pipe lengths (185 vs. 130 cm) and different test equipment (Figure 1A vs. 1B, and Figure 2). Parker and Suttle(6) demonstrated that water flow rates in 5 to 10-cm airlifts increased as much as 12 to 38% when the water discharge pipe was lowered from 1.25 cm above the water surface, to a position level with or slightly below the water surface. Equations used by Castro and Zielinski(3) predicted the maximum water flow rates possible for a given pipe diameter and percent submergence, but do not predict water flows for various air injection depths at virtual 100% (98.6-100%) submergence.

Of practical importance, but not readily apparent from the findings of Parker and Suttle,(6) is that operating or system in-line pressure increases as air flow increases. For any given air flow rate, the in-line pressure increases as length of the air injection pipe increases and as pipe diameter decreases (7.6 vs 2.5 vs 1.25 cm). Air flow rates of 36.8 and 73.1 L/min, or greater, would create turbulent flow and back pressure in 1.25- and 2.5-cm inner diameter air lines, respectively. An air flow rate of 1,138 L/min(6) would generate significant back pressure in a 1.25-cm diameter injection line. Back pressure develops as a result of line resistance (friction), and is the most plausible explanation for the observed operating pressures exceeding corresponding air injection depths in the present study. The most notable example was observed when air was injected, at a flow rate of 324 L/min and 65 cm depth, into the 15.2 cm airlift. Operating pressure increased by 16 cm water over that observed for the lowest air flow rate (115 L/min) tested at the same injection depth and airlift diameter (Table 1).

Conclusions

While high air flow rates injected into large diameter airlift pumps may generate impressive water flow rates, they also produce dramatic increases in air injection line back pressure. As noted by Parker and Suttle,(6) pressure increases of several centimeters water can substantially reduce airlift performance efficiency. As operating pressure increases, total air output can decrease significantly in centrifugal blowers, particularly for blowers rated at 2.5 hp (1.9 kw) or less. Using standard manufacturers' performance curves for commercially available, 1.0-hp (0.75 kw) centrifugal blowers and the data in Table 1, it was calculated that the highest water pumping rates (2775-3107 L/min) could be achieved by combining the individual outputs of 25 to 28, 7.6-cm diameter airlifts. Each airlift would require 71 L/min air flow (at 82.6 cm water pressure) injected at 80 cm depth to pump 111 L/min water.

Airlift pumps appear to have excellent potential for use in cages, floating raceways, closed or recirculating systems, and for pond de-stratification or aeration. Some general design schematics are depicted in Figure 1A, B and C. Each configuration would have a more practical use depending on system design or construction and the intended application. Figure 1A might be better suited for construction of airlift cages (in-frame) while 1C would be more practical for floating airlift de-stratifiers. The basic design presented in Figure 1B could facilitate incorporation of multiple airlift outputs into a common, floating reservoir (e.g. a raceway) or into a closed, recirculating system. Figure 4 is a diagram of an easily constructed, floating airlift de-stratifier which will closely parallel the performance characteristics of the pumps tested in this study.

Acknowledgments

We gratefully acknowledge John Earnest for developing CAD graphics of the original sketches.

Notes and References

1. Cooperative Extension Program, Kentucky State University, P. O. Box 469, Princeton, Kentucky 42445-0469 USA.

2. Cooperative Extension Service, University of Kentucky, P. O. Box 469, Princeton, Kentucky 42445-0469 USA.
3. Castro WE, Zielinski PB. 1980. Proc. World Mariculture Soc. 11:163-174.
4. Castro WE, Zielinski PB, Sandifer PA. 1975. Proc. World Mariculture Soc. 6:451-461.
5. Nicklin, DJ. 1963. Trans. Inst. Chem. Engrs 41:29-39.
6. Parker NC, Suttle MA. 1987. Aquacul. Engineer.6:97-1107.
7. Wurts WA, Overhults DG, McNeill SG. 1990. Ann. Mtg. World Aq. Soc., Halifax, Nova Scotia. Book of Abstracts, p. 36.