FloMov
Testing Performance in Purge Tanks

Technology Evaluation Report

Report: Field Trail for AquaBounty Purge Tanks

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During the spring of 2018, the FloNergia airlift team conducted a series of field trials to test a novel dual-injection airlift pump design for aquaculture applications. One of the experiment locations was a newly designed Atlantic salmon farm, located in eastern Prince Edward Island. The farm is located on land and will use recirculating technology to maintain the system's water quality. This facility was building concrete rectangular tanks at a volume of over 58000 litres, intended for fish at the final stage of production. The salmon going into these tanks would not be fed and instead be simply held till their digestive waste content is removed; hence the naming of these tanks as 'purge' tanks. As a result of no feeding occurring, maintenance of the water quality will simply require a circular loop going through the tank, drawing used water from the back of the tank and releasing it at the front. This water circulation is to be performed using 2 dual-injection airlifts of an 8" inner diameter for each tank. The airlifts are also intended to provide gas mass transfer to the system, in order to replenish dissolved oxygen (DO) and to remove excess carbon dioxide. To assess the functionality of the pumps for these purposes, we visited the site to conduct performance trials to assess the flow, velocity and oxygenation capabilities of the airlifts in this setup.

Figure 1: *Rotameter setup along with head of airlift pumps*

Trip Events:

Day 1: System Assessment

When we first arrived at the site, the tank with the FloNergia pumps was still being filled with water. Seeing as it would take the whole day to completely fill up, it was not possible to conduct any research yet. For this reason, the experimentation would have to be conducted the following day, and the current one was spent determining the dimensions and setup of the system. This primarily consisted of measuring the airline pipe lengths that led to the pumps which were built using 2" PVC pipe, before then being reduced to 1" at the rotameters (Figure 1).

Figure 2: *Pipe setup leading from the air blower to the tank head*

The total length of pipe from the blower to each of the rotameters was 301” and contained 11 90°-turn pipe elbows that could act as potential sources of resistance (Figure 2). The hose length was 71”, from each rotameter to the respective air inlet, while the inner diameter was 1” (Figure 3). This system would be run with a 3-kW air blower, though during our visit the facility was temporarily using a 1.5-kW air blower that provided an average airflow rate of 34 cfm to each airlift.

Figure 3: *Bottom view of the airlift setup*

Day 2: Performance Testing

The first test that was conducted with the airlifts was to assess their oxygen transfer capacity. This was because once the pumps started running and they began to increase the DO, it would be impossible to decrease it again without fish present to deplete it. For this reason, only one oxygenation test could be conducted, namely to see how long it took for the pumps to increase the water DO to saturation. This experiment was performed using the Handy Polaris oxygen probe from OxyGuard® as with the previous field trials (Figure 4). The initial water conditions were at 6.8° C and at a DO of 12.0 mg/L. Provided that the oxygen saturation level at this temperature is at 12.2 mg/L, there was little increase available and which provided only a few data points reaching full saturation.

Figure 4: *Recording data during the trial, including initial DO level (left) and the water velocity (right)*

After the pump stopped increasing the tank's DO level, we began measuring the water velocity using the Sontek Flowtracker (Figure 4). The velocity was measured at three locations in the cross section of the outlet, as this data along with the pipe's inner diameter could then be used to determine the flow performance of these pumps. The tank was still being filled with new water when the airlifts started running, meaning that the submergence was increasing over time. We took advantage of this by measuring the pipe's cross-section velocities at different times to determine the flow performance at various submergences. The initial testing was conducted at a submergence ratio of 0.75, and was repeated at ratios of 0.80 and 0.91.

The final tests were also conducted with the Flowtracker and were solely intended to measure the water velocity in the tank. The velocity was tested at 6 locations within the tank, 3 locations in front of each airlift pumping trajectory at different distances away from the pumps. The distances were: 3' in front of the outlet, the exact midway point between the front and back of the tank, and at 3' away from the back of the tank. Each velocity test had three replicates to test accuracy of results.

Data Analysis:

The DO concentration was measured at regular intervals for an hour after the pump started running, as that was the time it took for the DO to stabilize (Figure 5). Surprisingly, the pumps were able to increase the oxygen content of the tank past the saturation level of the observed temperature, showing good oxygenation capability despite the large volume of water.

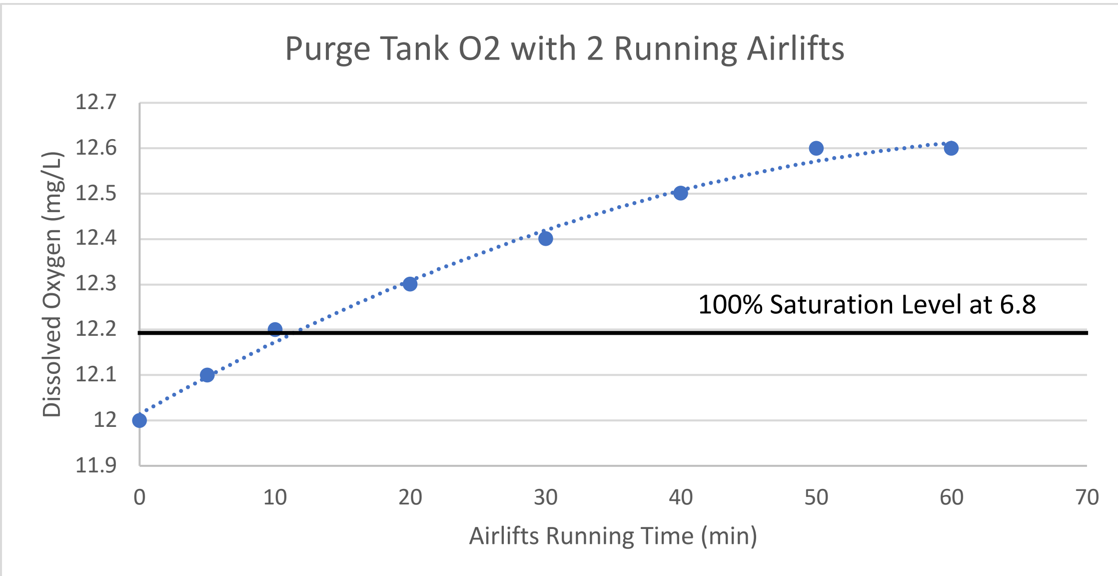

Figure 5: *Change in tank DO as a result of the two dual-injection airlifts.*

The rate of oxygenation from the initial point to the saturation level was at a slightly faster rate than post-saturation, and was used to determine the setup's standard oxygen transfer rate (SOTR) and standard aeration efficiency (SAE) with equations obtained form Loyless and Malone, 1998. This was done by first calculating the mass transfer coefficient ($K_L a_T$), using time (*t*) and the dissolved oxygen concentrations at the initial (C_0), temporal (C_t), and saturation (C_S) stages of the experiment.

$$-\ln\left(\frac{C_S - C_t}{C_S - C_O}\right) = K_L\, a_T \times t$$

The calculated coefficient was then corrected to the standard reference temperature of 20°C ($K_L a_{20}$), by using an Arrhenius type relationship where the θ = 1.024, and taking into account the experimental temperature (*T*).

$$K_L a_T = K_L a_{20} \times 1.024^{(T-20)}$$

The adjusted coefficient was then used to determine the SOTR taking into account the dissolved oxygen concentration at 20°C of 9.07, as well as the volume of the tank (V). The value was also converted from amount of oxygen transferred per minute to amount transferred per hour by multiplying by 60, and converted from milligrams to kilograms by multiplying by 10^{-6}. This was determined to be 6.00 kg O_2/hr.

$$SOTR = K_L a_{20} \times 9.07 \times V \times 60 \times 10^{-6}$$

The SAE was then calculated using the determined SOTR and the blower power that was utilized (kW_{ad}). This was determined to be 4.00 kg O_2/hr*kW.

$$SAE = SOTR \div kW_{ad}$$

A major study analyzing a multitude of oxygenation devices used in pond aquaculture found the highest SAE values from certain paddle wheels, which gave an efficiency of 3.0 kg O_2/hr*kW (Table 1). In the same study, the analyzed commercial diffused air systems (such as airlifts) performed relatively poor, with the highest SAE of 1.2 kg O_2/hr*kW. This shows that the FloNergia pumps in their current setup were able to provide efficiencies comparable to industry values and would thus reasonably be a more economic choice. It should also be noted that the current setup has many elbows in the airline which would provide increased resistance to the airflow, and if eliminated could potentially provide even greater efficiencies.

Table 1: *SOTR an SAE values for commonly used pond aeration devices (Boyd and Ahmad, 1987)*

Type of aerator	Number of aerators	Range of SOTR	SAE	
			Average	Range
Paddle wheel	24	2.5 – 23.2	2.2	1.1 – 3.0
Propeller-aspirator-pump	11	0.1 – 24.4	1.6	1.3 – 1.8
Vertical pump	15	0.3 – 10.9	1.4	0.7 – 1.8
Pump sprayer	3	11.9 – 14.5	1.3	0.9 – 1.9
Diffused-air	5	0.6 – 3.9	0.9	0.7 – 1.2

The flow rates achieved by the 8" airlift pumps for a submergence ratio of 0.9 is shown in figure 6. The water flow rates produced is given by (gpm-US) for the air flow rates provided in (cfm). What is also know is that when the submergence ratio is lower the performance of the airlift pump also decreases, therefore at a submergence ratio of 0.75 and 0.8 will have lower flow rates then what is shown. This performance curve was collected from a previous test conducted at a different location. The flow rate measurements collected at the aquabounty facility were unusable due to an instrumentation error with the Flowtracker device. The data shown below has been confirmed by a theoretical model and is what has been noted by other tests on the 8" airlift pump.

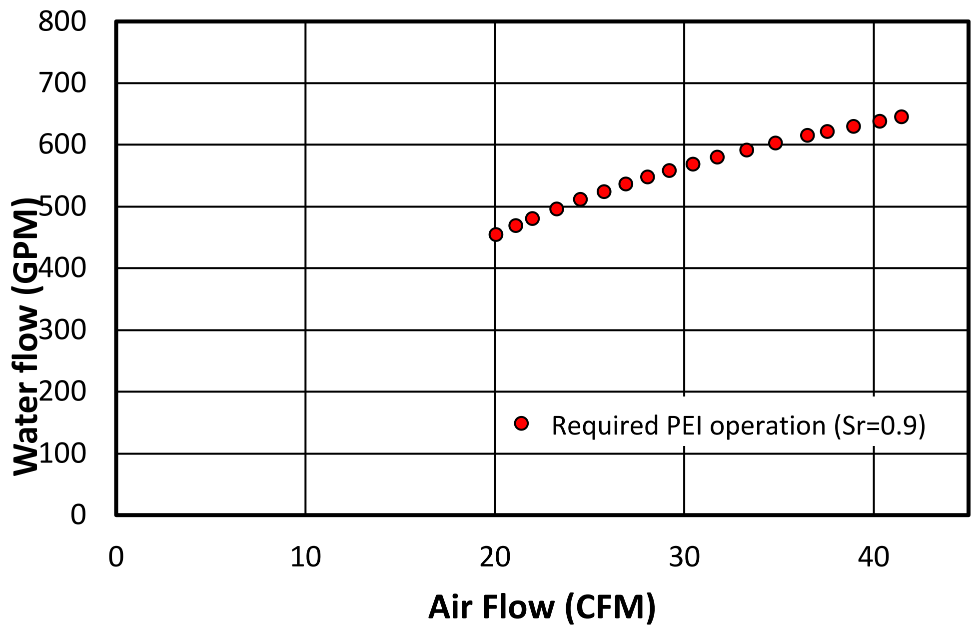

Figure 6: *Operating points for FloNergia Pumps installed onsite.*

Conclusion

The data obtained during the field trials was able to quantify the oxygenation and water flow performance of the airlift pumps. The measurement of oxygen increase over time as a result of the pumps running indicates that using two dual-injection airlifts at a 0.75 submergence provided with 34 cfm of airflow each will transfer 6.0 kg of dissolved oxygen each hour into the tank if the water is at 20°C. However, it should be noted that the observed oxygen transfer during tank operation can be higher. The oxygenation tests were conducted while the tank was still filling, and hence was not at the setup's maximum submergence for the pumps. Meanwhile, the air blower used was only a temporary model; while the one to be used during operation will have double the wattage and should therefore also provide greater airflows. Airlifts under higher submergences and greater airflow rates have both shown to provide greater water flows and thus faster oxygen transfer as well (Reinemann and Timmons, 1981; Loyless and Malone, 1998). It should also be noted that the SOTR value calculates the mass transfer for 20°C water, and seeing as the operation will be handling cold-water fish, the water will be at a lower temperature and can thus hold more oxygen (Boyd, 1998). However, although the operating conditions will thus see a greater oxygen transfer than 6.0 kg per hour, the actual improvement over this number can not be quantified until the purge tank is run under operating conditions.

References

Boyd, C.E. and Ahmad, T. 1987. Evaluation of aerators for channel catfish farming, Bulletin 584, Alabama Agricultural Experiment Station, Auburn University, Alabama, pp. 52

Boyd, C.E. 1998. Pond water aeration systems. Aquacultural Engineering. 18: 9-40.

Loyless, J.C. and Malone, R.F. 1998. Evaluation of air-lift pump capabilities for water delivery, aeration, and degasification for application to recirculating aquaculture systems. Aquacultural Engineering. 18: 117-133.

Reinemann, D.J. and & Timmons, M.B. 1989. Prediction of Oxygen Transfer and Total Dissolved Gas Pressure in Airlift Pumping. Aquacultural Engineering. 8: 29-46.