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EVALUATION

OF THE

OXYGEN TRANSFER CAPABILITIES

OF

CANADIANPOND.CA PRODUCTS LTD.

1” BUBBLE TUBING™ AERATION SYSTEM
¾” BUBBLE TUBING™ AERATION SYSTEM
½” BUBBLE TUBING™ AERATION SYSTEM
OctoAir-10™ AERATION SYSTEM
OctoAir-60™ AERATION SYSTEM

BY

GSEE, INC.
LA VERGNE, TN.

SEPTEMBER, 2017

9/5/17

GSEE
ENVIRONMENTAL CONSULTANTS

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1. INTRODUCTION

During June-August, 2011, CanadianPond.ca Products Ltd. retained GSEE, Inc., to perform unsteady state clean water shop oxygen transfer tests on the CanadianPond.ca Products Ltd. ½" & ¾" Bubble Tubing™ and the OctoAir-10™ aeration systems. Tests were performed on each system at airflow rates of 2.5, 5 and 10 SCFM at water depths of 5, 10 and 15 feet.

As a follow-up and expansion of those tests in 2017, Canadianpond.ca Products ltd retained GSEE, Inc., to perform additional unsteady state clean water oxygen transfer tests in the GSEE 21'Ø test basin as outlined below:

Table 1 - Test Series

CODE	Device to be tested	Previously Tested	Flow previously tested per unit	New Flow rates to be tested	New product Flow Rates	Depth to be tested new depth	Notes:
Octoair10	OctoAir10-tm : 4' wide diffuser with 100' of non-weighted BUB12	yes	2, 5 & 10 cfm	-	-	20'	3 tests at 20' to complement 2011 tests curve
Octoair10	OctoAir10-tm : 4' wide diffuser with 100' of non-weighted BUB12	yes	-	15 cfm	-	5', 10', 15', 20'	plus 4 tests at 4 similar depth with a higher flow of 15 cfm
Octoair60	Octoair60-tm : 8' wide diffuser with 300' of non-weighted BUB34	no	n/a	n/a	30 & 60 cfm	12', 18', 24'	6 tests - new product, this unit is designed for heavier needs in O2
BUB12	Bubble Tubing 1/2'' : 100' line of weighted BUB12	yes	2, 5 & 10 cfm	-	-	20'	3 tests at 20' to complement 2011 tests curve
BUB12	Bubble Tubing 1/2'' : 100' line of weighted BUB12	yes	-	15 cfm	-	5', 10', 15, 20'	plus 4 tests at 4 similar depth with a higher flow of 15 cfm
BUB34	Bubble Tubing 3/4'' : 100' line of weighted BUB34	yes	2, 5 & 10 cfm	-	-	20'	3 tests at 20' to complement 2011 tests
BUB34	Bubble Tubing 3/4'' : 100' line of weighted BUB34	yes	-	20 cfm	-	5', 10', 15, 20'	plus 4 tests at 4 similar depth with a higher flow of 20 cfm
BUB1.0	Bubble Tubing 1.00'' : 100' line of weighted BUB1.0	no	-	-	15 & 25 cfm	5', 10', 15, 20'	8 tests - new bubble tubing with larger ID to achieve longer distance and more O2

Oxygen transfer is determined using the ASCE clean water non-steady state test procedures. The ASCE standard requires a regression analysis on the data from *each* sample location and then averages the obtained results.

Test results are reported at standard conditions of 20°C liquid temperature, one (1) atmosphere barometric pressure, zero (0) dissolved oxygen, and alpha (α) and beta (β) equal to 1.0 (clean tap water). All test results have also been calculated using both the ASCE linear and non-linear regression analysis methods for the determination of the mass transfer coefficient K_La_T, the steady-state D.O. saturation value C^*_∞, and the D.O. concentration at time zero C_0.

2. DESCRIPTION OF THE AERATION TEST BASIN

All testing occurred in the 21' diameter x 31' GSEE, Inc. test basins located in LaVergne, TN. The GSEE 21'Ø test basin is shown in Figure 2-1.

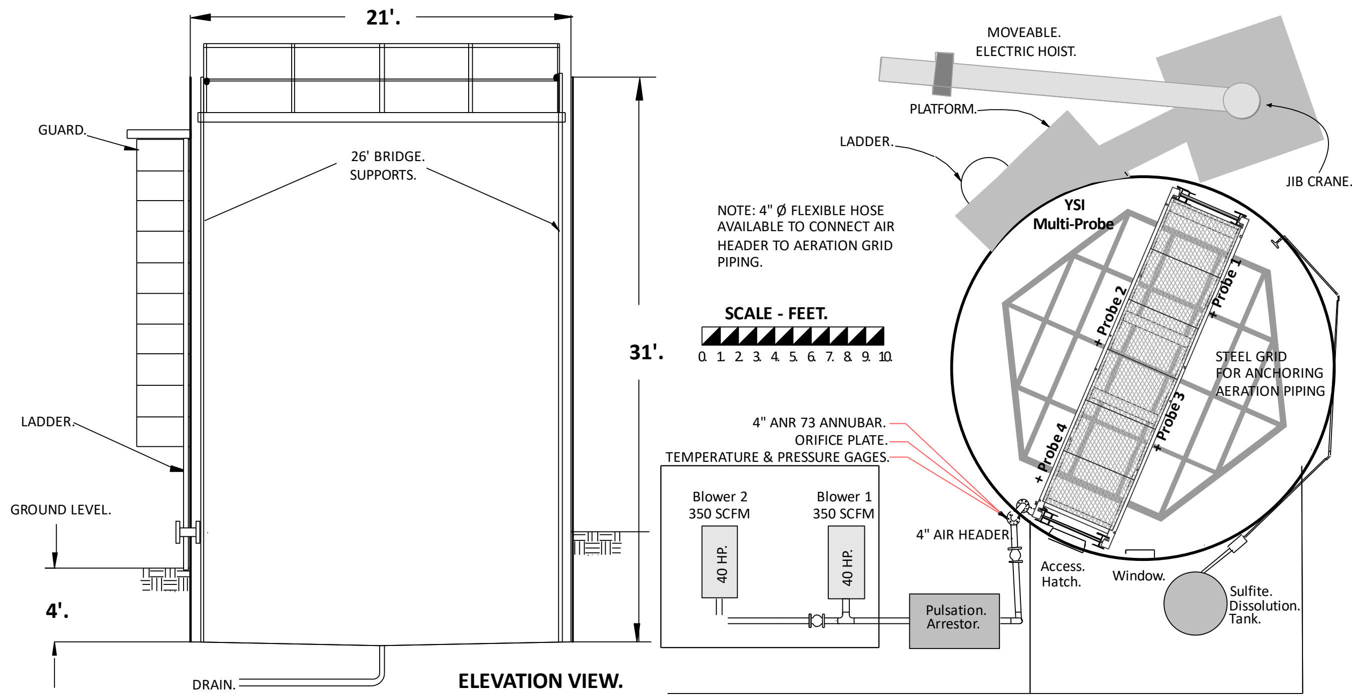


Figure 2-1 - GSEE Test Facility

The air source for the 1” Ø bubble tubing is a positive displacement blower driven by 40HP motors. The blower used for the testing has a maximum operating pressure of 14 PSIG. A bypass valve is used to obtain airflow rates from 0 to 350 SCFM. Exact measurement of the airflow supplied to the test basin is determined using a 1.002” Ø orifice plate installed in the header pipe. Measurement of airflow across the Orifice plate is monitored using a DWYER oil-filled combination vertical/inclined manometer. A mercury manometer is used to monitor the flowing air line pressure. A temperature probe monitors line temperature during each test. A mercury barometer is used to monitor local atmospheric pressure.

The air source for the OctoAir10 aerator and the ½”and ¾” Ø bubble tubing is a pair of 1 HP blowers. A bypass valve is used to obtain airflow rates from 0 to 20 SCFM. Exact measurement of the airflow supplied to the test basin is determined using either a ¾” or 1¼” Annubar installed in the air supply hose. Measurement of airflow across the Annubar is monitored using a DWYER oil-filled combination vertical/inclined manometer. A mercury manometer is used to monitor the flowing air line pressure. A temperature probe monitors line temperature during each test. A mercury barometer is used to monitor local atmospheric pressure.

For the OctoAir60 tests, an Atlas Copco variable speed compressor was used to supply air flow to the test unit. A combination of VFD and a bypass valve is used to obtain airflow rates from 0 to 60 SCFM. Exact measurement of the airflow supplied to the test basin is determined using 1¼” Annubar installed in the air supply hose. Measurement of airflow across the Annubar is monitored using a DWYER oil-filled combination vertical/inclined manometer. A pressure gauge is used to monitor the flowing air line pressure. A temperature probe monitors line temperature during each test. A mercury barometer is used to monitor local atmospheric pressure.

2.1. Air Flow Calculations

Airflow rate is defined as follows:

SCFM = Standard Cubic Feet per Minute (14.7 PSIA, 68°F, 36% RH and a density of 0.075 Lb./Ft³)

ACFM or Actual Cubic Feet per Minute refers to air flowing _at any condition other than standard_. ACFM can be calculated as follows:

$$\text{ACFM} = \left[\frac{BP_S - (Rh_s \times Pv_s)}{BP - (Rh_a \times Pv_a)}\right] \times \frac{BP}{(BP + LP)} \times \frac{(460 + LT)}{528} \times SCFM$$ **Eq. 2-1**

Where:

BP_S	=	Standard Barometric Pressure, 14.7 PSIA
Rh	=	Relative Humidity, % (s = Standard 36%, a = actual operating conditions)
Pva	=	Vapor Pressure of Water, psi (s = standard 0.3391, a = at actual temperature)
BP	=	Site Barometric Pressure, PSIA
LP	=	Flowing Line Pressure, PSIG
LT	=	Flowing Line Temperature, °F
528	=	Standard Temperature (460 + 68°F), °R

The exact airflow rate for each test run is calculated using the following equation[1]:

$$\text{SCFM} = C''\sqrt{\frac{(\text{BP}+\text{LP})}{(460+\text{LT})}\Delta h}$$ **Eq. 2-2**

Where:

C''	=	Annubar/Orifice Coefficient, corrected for site relative humidity
LT	=	Line Temperature, °F
LP	=	Line Pressure, PSIG
BP	=	Site Barometric Pressure, PSIA
Δh	=	Differential across air flow meter, inches of H_2O
SCFM	=	Standard Cubic Feet per Minute (14.7 PSIA, 68°F, 36% RH and a density of 0.075 Lb./Ft^3)

The air flow device coefficient C'' is a C' value that produces the humidity corrected SCFM.

Once C' is determined, the air flow rate in SCFM is calculated by the following:

$$\text{SCFM} = C'\sqrt{\frac{(\text{BP}+\text{LP})}{(460+\text{LT})}\Delta h}$$ **Eq. 2-3**

Where:

C'	=	Annubar Coefficient[2], Orifice Coefficient

This value of SCFM is not corrected for the observed relative humidity. To correct for humidity, SCFM is converted to ACFM by:

$$\text{ACFM} = \frac{14.7}{(BP + LP)} \times \frac{(460 + LT)}{528} \times SCFM$$ **Eq. 2-4**

The airflow rate in ACFM is then corrected for relative humidity using Eq. A-1 from the ASCE Standard:

[1] Spink, L.K.
"Principles and Practice of FLOW METER ENGINEERING" Ninth Edition, 1975
The FOXBORO COMPANY, Foxboro, Mass.

[2] "**ANNUBAR FLOW HANDBOOK**", DS-7300, 1980
Dieterich Standard Corporation, Boulder, Co.

$$Q_S = 36.2 \times \left[\frac{(BP + LP) \times \left(1 - \frac{Rh \times Pva}{BP}\right)}{460 + LT} \right] \times ACFM$$ **Eq. 2-5**

Where:
Rh = Relative Humidity, %
Pva = Vapor Pressure of Water at ambient temperature
Q_S = Humidity corrected air flow rate, SCFM

Once Q_s has been determined, the value of C'' is calculated as follows:

$$C'' = \frac{Q_S}{\sqrt{\frac{(BP + LP)}{(460 + LT)} \Delta h}}$$ **Eq. 2-6**

Where:
C'' = Humidity corrected C'

The observed airflow rate may be converted to SI units as follows:

$$\frac{Nm^3}{hr} = \frac{SCFM}{0.6366}$$ **Eq. 2-7**

Where:
Nm^3/h = Normal Cubic Meters per Hour (1013 hPa, 0°C, 0% Rh)

2.2. Horsepower

The blower HP_{motor} can be determined as follows:

$$HP_{motor} = GHP + MHP$$ **Eq. 2-8**

Where:
GHP = Gas Horsepower (From adiabatic compression, shown below)
MHP = Mechanical Horsepower (Loss in gear reducers, etc.)

The basic equation for determining the gas horsepower is:

$$GHP = \frac{W_a \times H_a}{33{,}000 \times \eta_o}$$ **Eq. 2-9**

Where:
W_a = Weight flow of gas, Lbs./Min
H_a = Adiabatic Head, $Ft\text{-}Lb_f/Lb_m$
η_o = Blower Overall Efficiency, %
33,000 = Units Conversion Factor, $Ft\text{-}Lb_f/Min/HP$

The Weight Flow of gas (W_a) can be determined as follows:

$$W_a = ACFM \times \rho$$ **Eq. 2-10**

Where:
ACFM = Actual flow of gas at discharge conditions

ρ = Density of flowing gas at discharge conditions

$$= \frac{MW_m \times (BP + LP)}{10.72 \times (LT + 460)}$$

Where:

MW_m = Molecular Weight of Moist flowing gas

$$= MW_d \times G$$

Where:

MW_d = Molecular Weight of dry gas

G = Specific Gravity of moist gas

$$= 1 - \frac{0.378 \times Rh \times Pv_a}{BP}$$

The Adiabatic Head (H_a) is calculated as follows:

$$H_a = \frac{R \times Ta \times \left[\left(\frac{BP + LP}{BP} \right)^{\frac{k-1}{k}} - 1 \right]}{\frac{k-1}{k}} \qquad \textbf{Eq. 2-11}$$

Where:

R = Gas Constant, Ft-Lb_f/Lb_m °R

$$= \frac{1{,}545}{MW_m}$$

k = Ratio of specific heats, C_p/C_v

Four (4) Yellow Springs Instruments (YSI) D.O. probes are installed in the test basin to monitor the dissolved oxygen concentrations during each test. A YSI Model 556 MPS multi parameter meter and probe are used to monitor water quality (Temp, TDS, D.O., and Barometric Pressure) during each test.

The following sketch and photos show the arrangement used for the ½", ¾" and 1.0" Bubble Tubing™ in the GSEE, Inc. test basin. For both sizes of Bubble Tubing™ 100-feet of tubing was installed in the GSEE test basin. The OctoAir-10™ and OctoAir-60™ was installed centered in the GSEE test basin. The OctoAir-10™ consists of 100-feet of ½" tubing installed in a compact spiral configuration on an easily retrievable stainless steel frame. The OctoAir-60™ consists of 300-feet of ½" tubing installed in a compact spiral configuration on an easily retrievable stainless steel frame.

Figure 2-2 - Photo of typical Bubble Tubing™ Arrangement

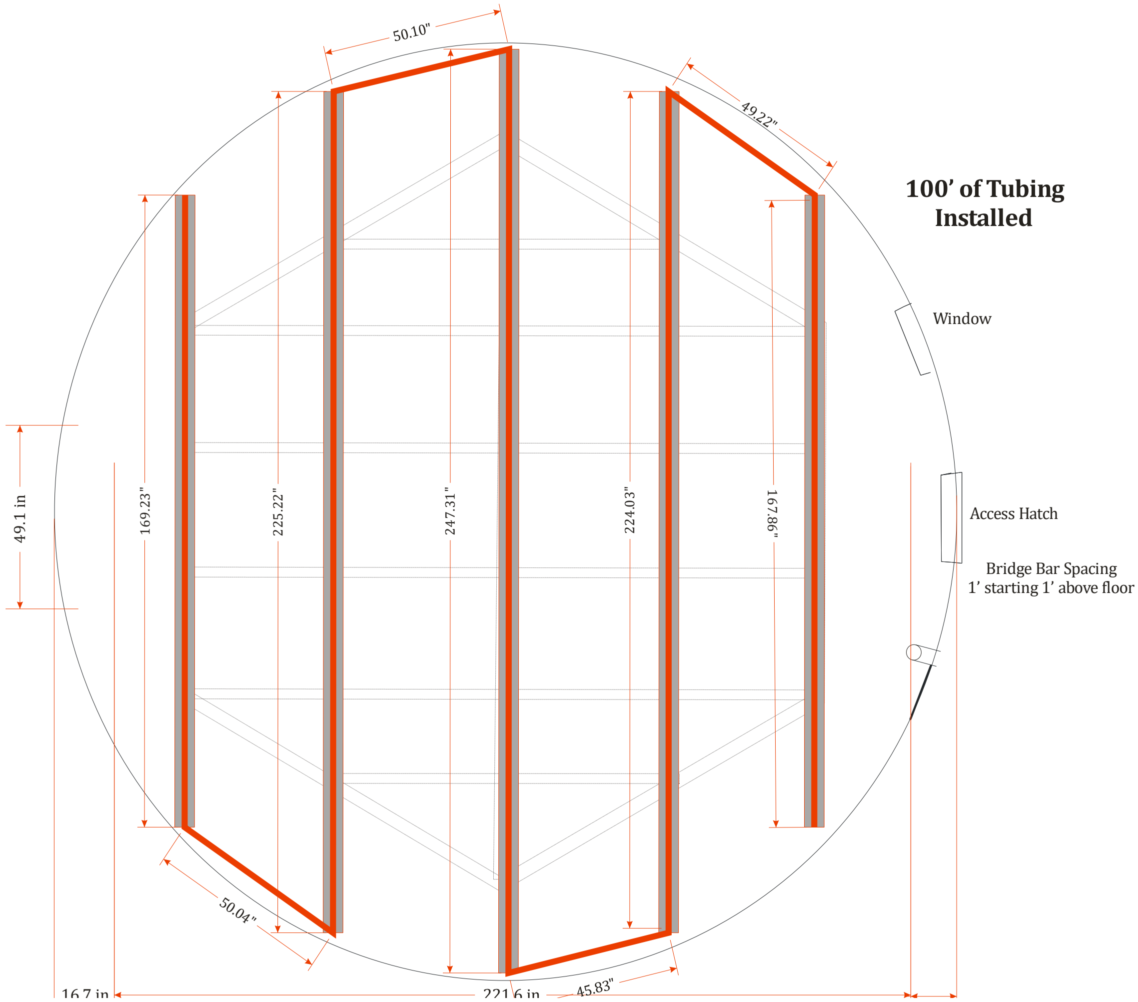


Figure 2-3 - Bubble Tubing™ Arrangement

Figure 2-4 - Photos of the OctoAir-60™

3. TEST PROCEDURES

Before testing, the aeration basin was thoroughly cleaned and filled with potable water.

Four (4) YSI dissolved oxygen meters and probes were placed in the test basin and later used to monitor the dissolved oxygen concentration during each test. The probes were located as follows:

Probe	Probe Depth (Ft)
1	2' Below Surface
2	3' Above Floor
3	Mid Depth
4	5' Below Surface
YSI MPS 556	Mid Depth

Overall test procedures include:

After filling the test basin with tap water, add enough cobalt catalyst to obtain a concentration of cobaltous ion less than 0.2 mg/l. Dissolve the catalyst into the basin contents by running the aeration system a minimum of thirty minutes before testing.

Add enough (200-500% of stoichiometric) sodium sulfite to deoxygenate the tap water in the basin to start each test. Monitor the dissolved oxygen concentration as it depletes then starts to rise, using the *in-situ* dissolved oxygen probes. Measure the water temperature using the D.O. Probe thermistors.

With the aeration system operating at the specified liquid depth, start monitoring as the oxygen concentration increases. Collect data to cover a range of dissolved oxygen concentrations from 1.0 mg/l to 98% of saturation, obtaining a minimum of 100 data points for each probe.

I. The **general test procedures** are:

1. Thoroughly clean the aeration basin before testing and fill with tap water to the desired liquid depth.
2. Operate the aeration system in potable water at the test airflow rate and operating liquid depth for <u>30</u> minutes before testing to obtain temperature and mixing equilibrium. Record the liquid temperature a minimum of two times during each test run. Maintain the required airflow rate during testing by monitoring manometers connected across the airflow devices. Monitor operating air pressure and headloss via a mercury manometer. Measure the operating line temperature.
3. Install <u>4</u> dissolved oxygen probes with integral stirrers at locations in the test tank as required.
4. Use Cobalt Chloride ($CoCl_2 * 6H_2O$) as a catalyst at a concentration of 0.2 mg/l.
5. Use anhydrous sodium sulfite <u>technical grade</u> (Na_2SO_3) to deoxygenate the test liquid. Add sulfite solution before each test run to decrease the oxygen concentration to zero (1.00 mg/l or less D.O.) and maintained zero for 1 to 3 minutes.
6. Use the azide modification of the Winkler method to calibrate the D.O. probes. Collect a minimum of one-hundred (100) D.O. observations for each D.O. probe between 10 and 98% of saturation.

II. Detailed test procedures:

A. Initial setup

1. Inspect aeration basin for adequate cleanliness, level of diffusers and correct water depth.
   Check installation of airflow monitoring devices.
2. Check D.O. probe thermistors for liquid temperature monitoring.
3. Prepare YSI (Yellow Springs Instruments) Dissolved Oxygen (D.O.) probes for installation.
   a) Replace electrolyte solution and membranes on each D.O. probe

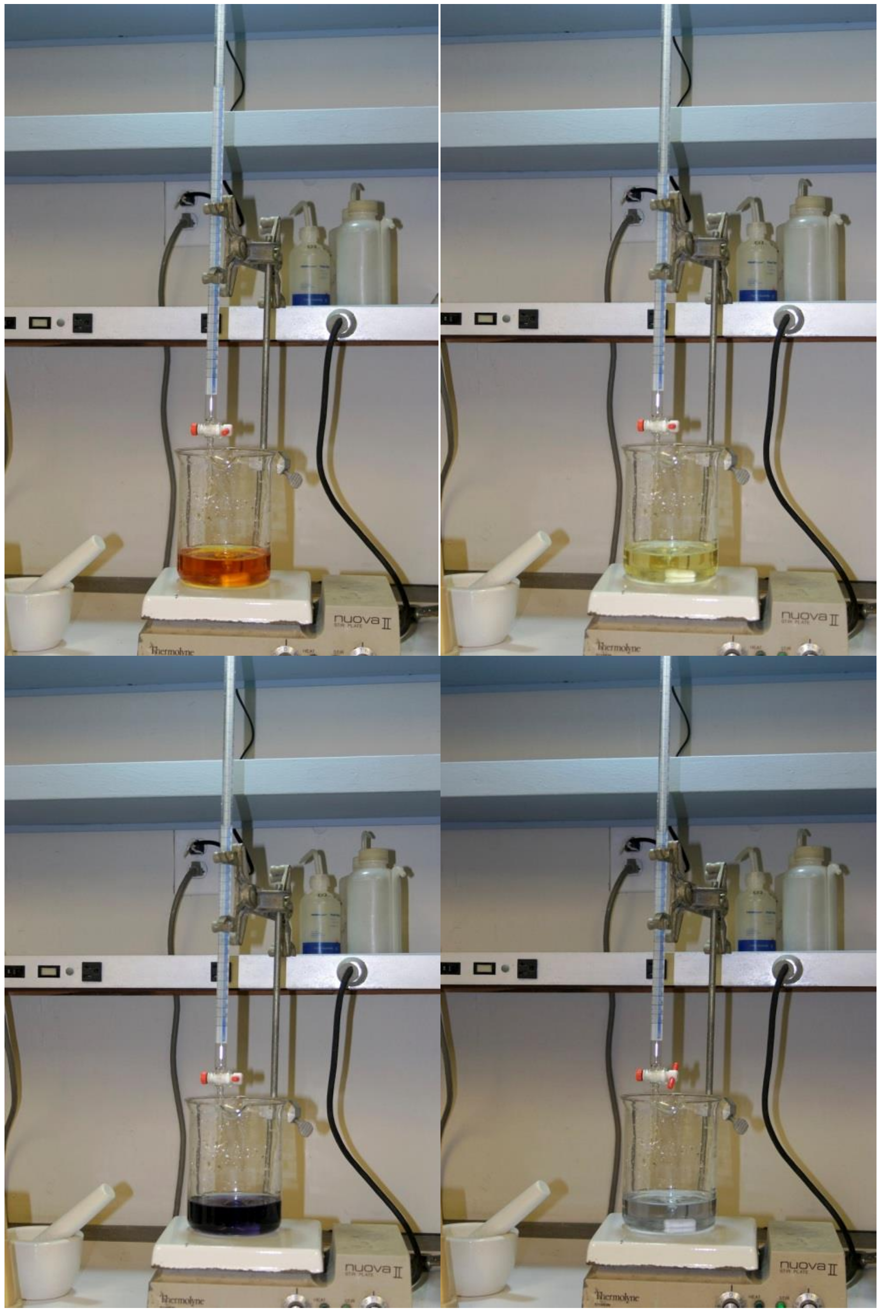
b) Connect probes to YSI D.O. meters
c) Check each probe for functioning stirrer mechanism
d) Connect all D.O. meters to computer for data logging

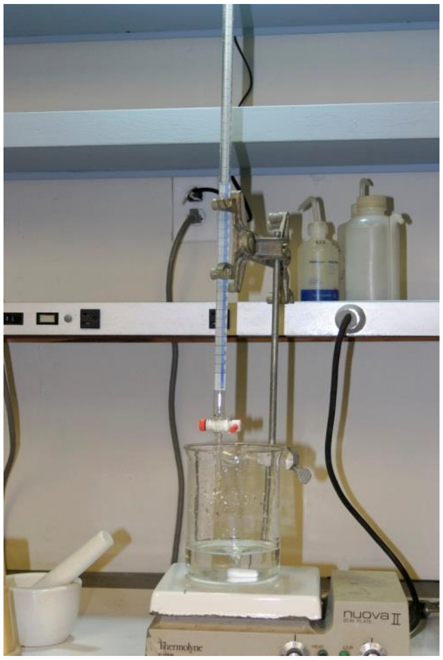
4. Check the placement of each D.O. probe in the test basin.
5. Start the blowers and begin aerating the test tank.
6. Check all air flow meters, gages, valves, and fittings on the air supply system for air leakage.
7. Collect at least two samples from the oxygen saturated aeration basin for analysis using the Winkler titration method to determine the D.O. concentration.


Starch Indicator Solution
nuova II
288
WHEATON


Starch Indicator Solution
288
WHEATON


Starch Indicator Solution
nuova II
154
WHEATON


nuova II
Thermolyne



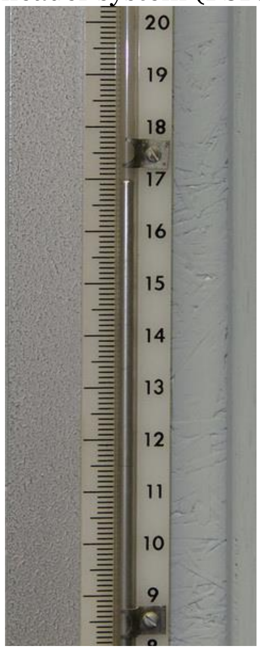
8. Calibrate all D.O. probes and meters to the saturation value determined by the Winkler method.
9. Check installation of the temperature gage in the aeration header piping system for the accurate determination of flowing air temperature.
10. Dissolve Cobalt Chloride into a container of water.

11. Pour Cobalt solution into the aeration basin.
12. Allow a minimum of thirty minutes mixing of the cobalt into the aeration basin before the start of testing.

B. Procedure for clean water aeration testing.

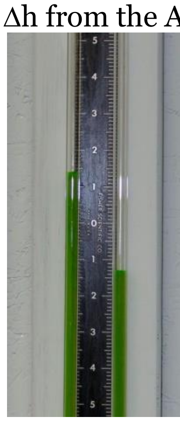
1. Adjust the airflow rate to the test basin to the required test airflow.
2. Read and record the following data:
   a) Site barometric pressure (PSIA)

b) Operating line pressure from the mercury manometer connected to the header system (PSIG)



c) Operating line temperature (°F)

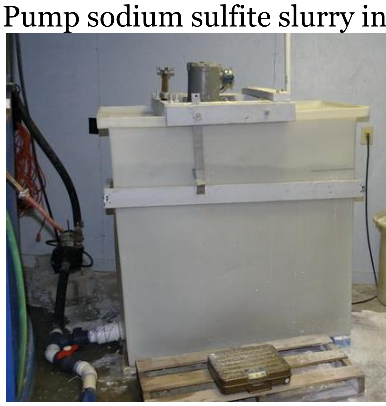
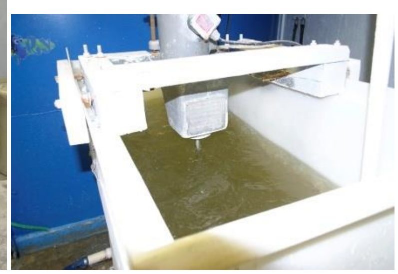
d) Δh from the Annubar and Orifice, (Inches of H_2O)



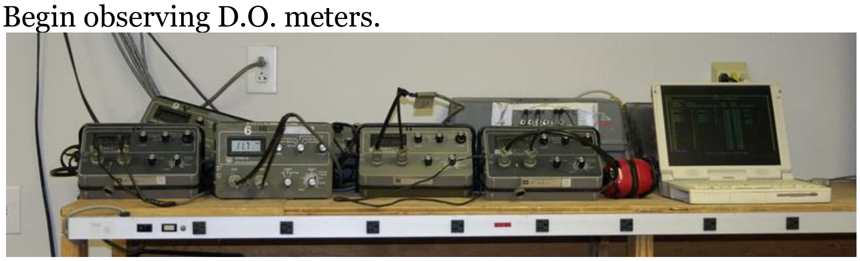

e) Liquid Temperature (°C)

f) Aeration basin oxygen saturation value C_{so} (mg/l) [Winkler Analysis]
g) Ambient temperature
h) Relative Humidity, %
i) Diffuser headloss differential pressure from two pressure taps.

3. Pump sodium sulfite slurry into the aeration test basin.


4. Begin observing D.O. meters.



5. Monitor D.O. on each of the YSI meters as it drops to 1.0 mg/l.
6. Continue recording D.O. values versus time for each of the D.O. probes, obtaining a minimum of 300 D.O. values for each probe.
7. Stop all recording of D.O. values when the aeration basin has reached $6/K_La$.
8. Record Total Dissolved Solids (TDS – mg/L)
9. Perform non-linear regression analysis on the collected data.
   a) Determine K_La_{20} values for each probe
   b) Calculate SOTR and SOTE.
10. Repeat steps 1-9 for each test run.
11. Collect a final water sample on each tank of water for determination of TDS.

4. DATA ANALYSIS METHODS

4.1. Standard ASCE Data Analysis Method

The basic mass-transfer model used to determine oxygen transfer is as follows:

$$\frac{dC}{dT} = K_L a\left(C_\infty^* - C\right) \qquad \textbf{Eq. 4-1}$$

Which, upon integration, with initial condition C = C_o at t =0, becomes:

(logarithmic form)

$$\ln\left[\frac{C_\infty^* - C}{C_\infty^* - C_o}\right] = -K_L a\ t \qquad \textbf{Eq. 4-2}$$

or

(exponential form)

$$C = C_\infty^* - \left(C_\infty^* - C_O\right) e^{-k_L a\ t} \qquad \textbf{Eq. 4-3}$$

Where:

C	=	D.O. Concentration, mg/L
C^*_∞	=	Equilibrium D.O. concentration, the concentration obtained as time approaches infinity, mg/L
C_o	=	D.O. concentration at time zero, mg/L
K_La	=	Apparent volumetric mass transfer coefficient, t^{-1}

The overall mass transfer coefficient (K_La_T) is obtained experimentally by aerating deoxygenated water and observing the rate of change of dissolved oxygen (D.O.) concentration about time.

A non-linear regression of D.O. about time is used to determine K_La_T, C^*_∞, and C_o.

The logarithmic form of the mass transfer model can be rearranged to determine K_La_T using a log-deficit linear regression as follows:

$$K_L a_T = \frac{60}{t_2 - t_1}\ln\left[\frac{C_\infty^* - C_1}{C_\infty^* - C_2}\right] \qquad \textbf{Eq. 4-4}$$

Where:

K_La_T	=	Apparent volumetric mass transfer coefficient at test liquid temperature T, hr^{-1}
C^*_∞	=	The observed saturation concentration of oxygen in the test basin at test temperature and barometric pressure at equilibrium, mg/L after an aeration period equal to $6/K_La_T$
C_1 and C_2	=	Dissolved oxygen concentration at time t_1 and t_2 respectively, mg/L

For purposes of comparison, K_La_T must be corrected to standard temperature, 20°C. The appropriate correction has been found empirically to be:

$$K_L a_{20} = K_L a_T \Theta^{(20-T)} \qquad \textbf{Eq. 4-5}$$

Where:

T	=	test liquid temperature (°C)
Θ	=	1.024 for all T

With the value of K_La_{20} known, it is possible to calculate the pounds of oxygen transferred to the test liquid at standard conditions of 20°C, maximum oxygen deficit (dissolved oxygen equal to zero), one atmosphere barometric pressure, and alpha and beta equal to 1.0 (clean tap water) for each sample point.

$$\mathrm{SOTR_i} = K_L a_{20i}\, C^*_{\infty 20i}\, V \qquad \textbf{Eq. 4-6}$$

Where:

$SOTR_i$ = pounds of oxygen transferred to the test liquid, lb. O_2 /hr., for Probe i
V = Liquid volume of water in the test tank with aerators turned off
$C^*_{\infty 20i}$ = $C^*_\infty \left(\frac{1}{\tau \Omega} \right)$
☐ = Temperature correction factor, C^*_{st}/C^*_{s20}
C^*_{s20} = 9.092 mg/L, standard D.O. concentration at 20°C and one atmosphere
C^*_{st} = oxygen saturation concentration from **Standard Methods**, mg/L, at test liquid temperature *T*
☐ = Pressure correction factor, P_b/P_s
P_b = Site barometric pressure, PSIA
P_s = Standard barometric pressure, 14.73 PSIA

The overall average value of SOTR is then calculated as the average of the individual $SOTR_i$ values determined for each sample point.

Calculate the standard percent oxygen transfer (SOTE - %) once the oxygen transfer rate is known using the following equation:

$$\mathrm{SOTE} = \frac{SOTR \times 100}{SCFM \times 0.075 \times 60 \times 0.232} \qquad \textbf{Eq. 4-7}$$

The blower wire HP is determined using the adiabatic compression formula as described in Section 2 of this report.

Calculate the standard aerator efficiency (SAE) using the following equation:

$$\mathrm{SAE} = N_O = \frac{SOTR}{HP} \qquad \textbf{Eq. 4-8}$$

Where:

No = aerator efficiency, lb. O_2/hr-Hp
SOTR = Qo, standard oxygen transfer rate, lb. O_2/hr.
HP_{wire} = Blower HP determined by the adiabatic compression formula

Finally, the reported values are corrected to a standard TDS concentration of 1,000 mg/L using the following:

$$K_L a_{T\ TDS\,Corrected} = K_L a_{T\ observed} \times e^{(0.0000965 \times [1000 - TDS])} \qquad \textbf{Eq. 4-9}$$

Where:

TDS = Observed Total Dissolved Solids concentration for each run, mg/L

All values are then recalculated based on the corrected K_La_T.

5. DISCUSSION OF RESULTS

5.1. Bubble Tubing™

Tables 2 - 4 summarize the results of the GSEE, Inc. analysis of the data obtained during the oxygen transfer testing on the CanadianPond.ca Products Ltd. ½", ¾", and 1" Bubble Tubing™. Individual computer printouts of the data analysis including time versus D.O. plots for each test run are contained in the Appendix.

Table 2 - Summary of Test Results (½" Bubble Tubing™)

PROJECT:	Bubble Tubing ½"	Bubble Tubing ½"	Bubble Tubing ½"	Bubble Tubing ½"	Bubble Tubing ½"	Bubble Tubing ½"	Bubble Tubing ½"
DATE:	23-May-17	23-May-17	22-May-17	25-May-17	25-May-17	25-May-17	27-May-17
RUN:	3.00	2.00	1.00	4.00	5.00	6.00	7.00
Barometric Pres. (PSIA)	14.13	14.15	14.31	14.24	14.30	14.32	14.34
Ambient Temperature (°F)	70.90	74.67	73.60	71.67	69.67	73.87	74.57
Relative Humidity (%)	0.53	0.50	0.43	0.48	0.50	0.49	0.47
Line Pressure (PSIG)	13.25	13.00	10.40	10.35	16.08	13.40	11.53
Line Temperature (°F)	108.00	109.00	106.33	91.67	102.00	112.67	114.00
Water Temp. (°C)	20.00	20.37	20.12	19.93	19.83	20.05	20.51
Feet of Aeration Tubing	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Side Water Depth (ft)	15.00	10.00	5.42	20.00	20.00	20.00	20.00
Air Release Depth (ft)	15.00	10.00	5.00	20.00	20.00	20.00	20.00
Temp. Correction Factor (τ)	1.00	0.99	1.00	1.00	1.00	1.00	0.99
Pressure Correction Factor (Ω)	0.96	0.96	0.97	0.97	0.97	0.97	0.98
Average Air Flow (SCFM)	15	15	15	2	16	10	5
Average Air Flow (Nm^3/h)	22.97	23.48	23.12	3.92	24.48	15.57	8.11
Average Air Flow (SCFM/ft)	0.15	0.15	0.15	0.02	0.16	0.10	0.05
Average Air Flow ($Nm^3/h/m$)	0.23	0.23	0.23	0.04	0.24	0.16	0.08
C* (mg/l)	10.29	9.66	9.30	10.71	10.93	10.81	10.81
C_{smT} (Standard Methods, mg/l)	8.71	8.66	8.81	8.79	8.84	8.81	8.74
C^*_{20} Standard Conditions	10.71	10.12	9.58	11.04	11.20	11.11	11.20
Tank Volume (Ft^3)	5,195	3,464	1,876	6,927	6,927	6,927	6,927
(Gallons)	38,864	25,910	14,034	51,819	51,819	51,819	51,819
(m^3)	147.12	98.08	53.13	196.16	196.16	196.16	196.16
Effective Saturation Depth (d_e)	7.34	5.11	2.76	8.28	8.76	8.41	8.74
TDS (mg/L)	453	397	356	500	611	732	860
AVG KLA-NLR	1.20	1.38	1.64	0.24	1.15	0.81	0.47
KLa20 NLR	1.20	1.37	1.64	0.24	1.15	0.81	0.47
KLa20 (TDS Corrected)	1.27	1.45	1.74	0.25	1.20	0.83	0.48
SOTR (TDS Corrected) (Lb O2/Hr)	4.4	3.2	1.9	1.2	5.8	4.0	2.3
SOTR (TDS Corrected) (Lb O2/Ft)	0.04	0.03	0.02	0.01	0.06	0.04	0.02
SOTE (TDS Corrected)	28.9%	20.3%	12.7%	45.5%	35.6%	38.5%	42.7%
SOTE/Ft (TDS Corrected)	1.92%	2.03%	2.54%	2.28%	1.78%	1.93%	2.13%
SAE (TDS Corrected)	3.52	2.52	1.93	6.92	3.73	4.71	5.94

Table 3 - Summary of Test Results (¾" Bubble Tubing™)

PROJECT:	Bubble Tubing ¾"	Bubble Tubing ¾"	Bubble Tubing ¾"	Bubble Tubing ¾"	Bubble Tubing ¾"	Bubble Tubing ¾"	Bubble Tubing ¾"
DATE:	23-May-17	29-May-17	28-May-17	29-May-17	30-May-17	30-May-17	30-May-17
RUN:	3.00	2.00	1.00	4.00	5.00	6.00	7.00
Barometric Pres. (PSIA)	14.13	14.37	14.27	14.34	14.40	14.42	14.43
Ambient Temperature (°F)	71.67	74.43	76.00	75.67	73.67	77.87	78.57
Relative Humidity (%)	0.55	0.50	0.44	0.63	0.65	0.64	0.62
Line Pressure (PSIG)	13.25	12.83	10.20	10.05	15.78	13.10	11.23
Line Temperature (°F)	108.00	108.00	106.33	95.67	106.00	116.67	118.00
Water Temp. (°C)	21.33	21.34	21.45	20.93	20.83	21.05	21.51
Feet of Aeration Tubing	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Side Water Depth (ft)	15.00	10.00	5.42	20.00	20.00	20.00	20.00
Air Release Depth (ft)	15.00	10.00	5.00	20.00	20.00	20.00	20.00
Temp. Correction Factor (τ)	0.97	0.97	0.97	0.98	0.98	0.98	0.97
Pressure Correction Factor (Ω)	0.96	0.98	0.97	0.98	0.98	0.98	0.98
Average Air Flow (SCFM)	15	15	15	3	16	10	5
Average Air Flow (Nm^3/h)	23.92	23.85	23.56	4.03	24.73	15.34	7.93
Average Air Flow (SCFM/ft)	0.15	0.15	0.15	0.03	0.16	0.10	0.05
Average Air Flow ($Nm^3/h/m$)	0.24	0.24	0.24	0.04	0.25	0.15	0.08
C* (mg/l)	9.98	9.65	9.09	10.56	10.61	10.57	10.47
$C_{sm}T$ (Standard Methods, mg/l)	8.49	8.63	8.56	8.68	8.73	8.70	8.62
C^*_{20} Standard Conditions	10.67	10.14	9.63	11.03	11.01	11.00	10.99
Tank Volume (Ft^3)	5,195	3,464	1,876	6,927	6,927	6,927	6,927
(Gallons)	38,864	25,910	14,034	51,819	51,819	51,819	51,819
(m^3)	147.12	98.08	53.13	196.16	196.16	196.16	196.16
Effective Saturation Depth (d_e)	7.18	4.69	3.02	8.01	7.84	7.77	7.72
TDS (mg/L)	453	473	363	510	620	620	875
AVG KLA-NLR	1.39	1.55	1.80	0.31	1.33	0.87	0.58
KLa20 NLR	1.35	1.50	1.74	0.30	1.30	0.85	0.56
KLa20 (TDS Corrected)	1.42	1.58	1.85	0.32	1.35	0.88	0.54
SOTR (TDS Corrected) (Lb O2/Hr)	4.9	3.5	2.1	1.5	6.4	4.2	2.6
SOTR (TDS Corrected) (Lb O2/Ft)	0.05	0.03	0.02	0.02	0.06	0.04	0.03
SOTE (TDS Corrected)	31.0%	21.8%	13.3%	56.6%	39.0%	41.0%	48.7%
SOTE/Ft (TDS Corrected)	2.06%	2.18%	2.66%	2.83%	1.95%	2.05%	2.44%
SAE (TDS Corrected)	3.77	2.78	2.05	11.13	5.30	6.49	8.78

Table 4 - Summary of Test Results (1” Bubble Tubing™)

PROJECT:	Bubble Tubing 1"	Bubble Tubing 1"	Bubble Tubing 1"	Bubble Tubing 1"	Bubble Tubing 1"	Bubble Tubing 1"	Bubble Tubing 1"	Bubble Tubing 1"
DATE:	14-Apr-17	14-Apr-17	18-Apr-17	18-Apr-17	19-Apr-17	19-Apr-17	14-Apr-17	14-Apr-17
RUN:	1.00	2.00	3.00	4.00	5.00	6.00	1.00	2.00
Barometric Pres. (PSIA)	14.38	14.41	14.41	14.42	14.45	14.50	14.40	14.39
Ambient Temperature (°F)	64.67	72.67	67.00	71.00	69.67	77.00	78.00	77.67
Relative Humidity (%)	1.00	0.81	0.92	0.82	0.83	0.61	0.35	0.35
Line Pressure (PSIG)	11.54	11.40	10.39	8.36	8.17	6.81	12.67	11.03
Line Temperature (°F)	144.00	133.00	131.00	131.00	131.33	128.33	148.00	136.00
Water Temp. (°C)	18.54	18.69	18.78	18.90	18.91	19.17	16.88	17.13
Feet of Aeration Tubing	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Side Water Depth (ft)	15.00	15.00	10.00	10.00	5.13	5.13	20.00	20.00
Air Release Depth (ft)	15.00	15.00	10.00	10.00	5.13	5.13	20.00	20.00
Temp. Correction Factor (τ)	1.03	1.03	1.03	1.02	1.02	1.02	1.07	1.06
Pressure Correction Factor (Ω)	0.98	0.98	0.98	0.98	0.98	0.99	0.98	0.98
Average Air Flow (SCFM)	25	15	25	15	25	16	25	15
Average Air Flow (Nm^3/h)	39.26	23.54	39.53	23.23	39.10	24.43	39.23	23.52
Average Air Flow (SCFM/ft)	0.25	0.15	0.25	0.15	0.25	0.16	0.25	0.15
Average Air Flow ($Nm^3/h/m$)	0.39	0.24	0.40	0.23	0.39	0.24	0.39	0.24
C* (mg/l)	10.69	10.67	10.16	10.32	9.67	9.65	11.54	11.60
CsmT (Standard Methods, mg/l)	9.13	9.12	9.10	9.08	9.09	9.07	9.53	9.46
C^*_{20} Standard Conditions	10.61	10.61	10.11	10.28	9.62	9.62	10.99	11.12
Tank Volume (Ft^3)	5,195	5,195	3,464	3,464	1,775	1,775	6,927	6,927
(Gallons)	38,864	38,864	25,910	25,910	13,279	13,279	51,819	51,819
(m^3)	147.12	147.12	98.08	98.08	50.27	50.27	196.16	196.16
Effective Saturation Depth (d_e)	6.42	6.34	4.54	5.18	2.69	2.58	7.71	8.25
TDS (mg/L)	515	585	692	786	897	1,019	298	408
AVG KLA-NLR	1.95	1.28	2.12	1.44	2.50	1.78	1.74	1.12
KLa20 NLR	2.02	1.32	2.18	1.48	2.56	1.81	1.87	1.19
KLa20 (TDS Corrected)	2.12	1.37	2.25	1.51	2.59	1.81	2.00	1.27
SOTR (TDS Corrected) (Lb O2/Hr)	7.3	4.7	4.9	3.4	2.8	1.9	9.5	6.1
SOTR (TDS Corrected) (Lb O2/Ft)	0.07	0.05	0.05	0.03	0.03	0.02	0.09	0.06
SOTE (TDS Corrected)	27.9%	30.1%	18.7%	21.7%	10.6%	11.9%	36.4%	38.9%
SOTE/Ft (TDS Corrected)	1.86%	2.01%	1.87%	2.17%	2.07%	2.32%	1.82%	1.94%
SAE (TDS Corrected)	4.85	5.32	3.57	5.01	2.50	3.31	5.96	7.13

The following figures present plots of the results obtained during the Bubble Tubing™ testing. Note that results from the 2011 tests are included for completeness.

Figure 5-1 is a plot of the total system air flow rate (SCFM) versus the observed Mass Transfer Coefficient (K_La_{20} – Hr^{-1}).

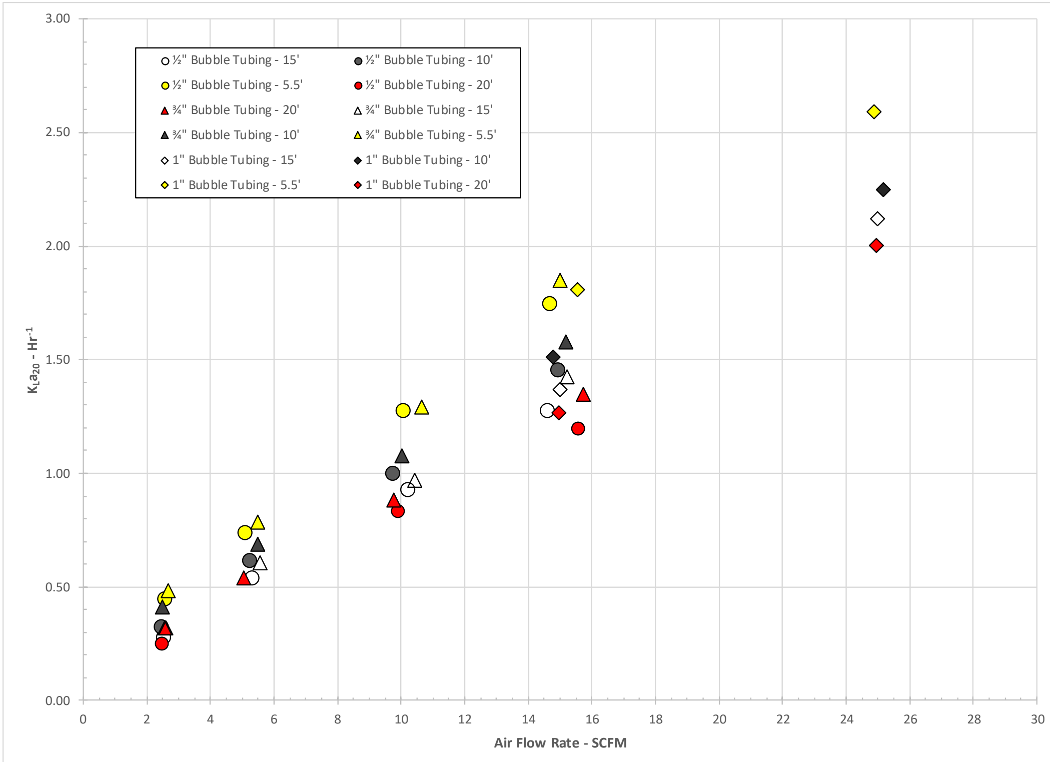


Figure 5-1 - Total Airflow v KLa20

Figure 5-2 is a plot of the air flow rate per diffuser (SCFM/100') versus the Standard Oxygen Transfer Rate per diffuser (SOTR – lb. O2/Hr./100').

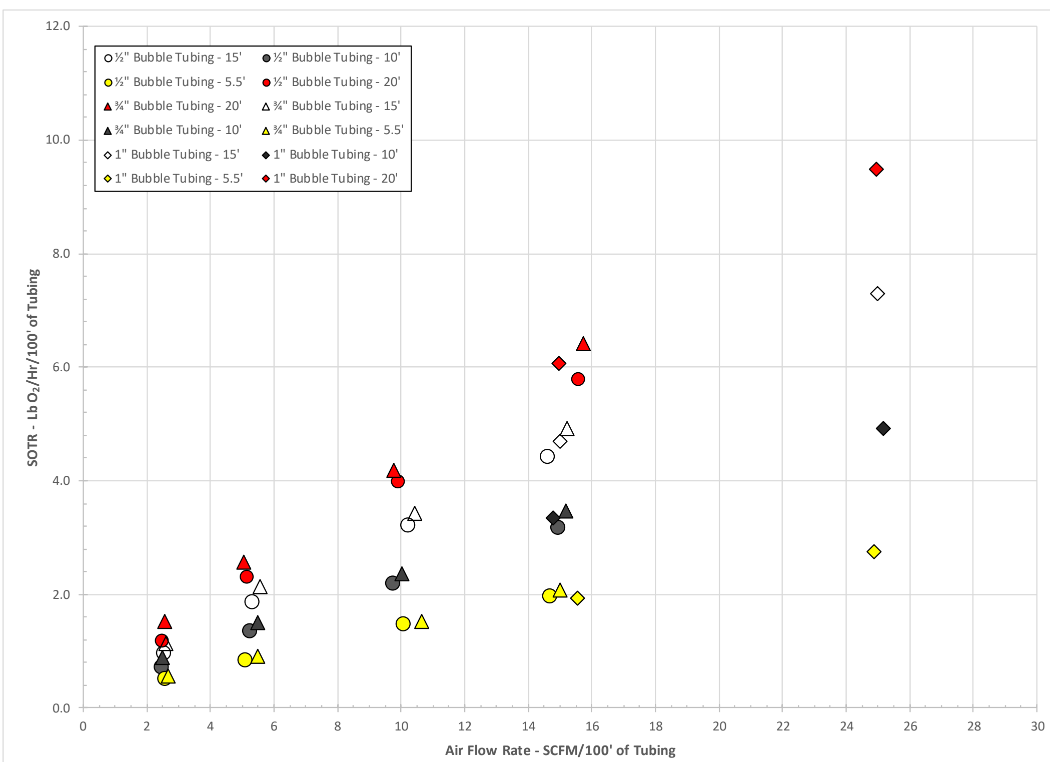


Figure 5-2 – SCFM/100' v SOTR/100'

Figure 5-3 is a plot of the air flow rate (SCFM/100') versus the Standard Oxygen Transfer Efficiency (SOTE – %).

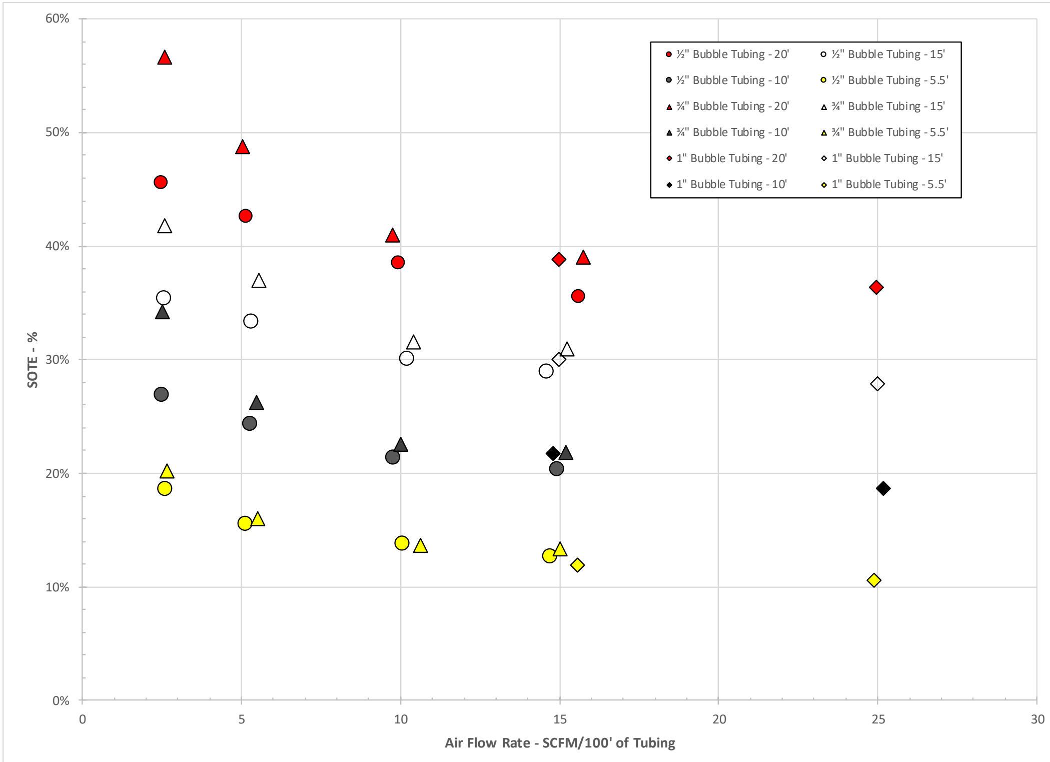


Figure 5-3 – SCFM/100' v SOTE

Figure 5-4 is a plot of air flow rate per 100' of tubing (SCFM/100') versus the Standard Oxygen Transfer Efficiency (SOTE – %/Ft submergence).

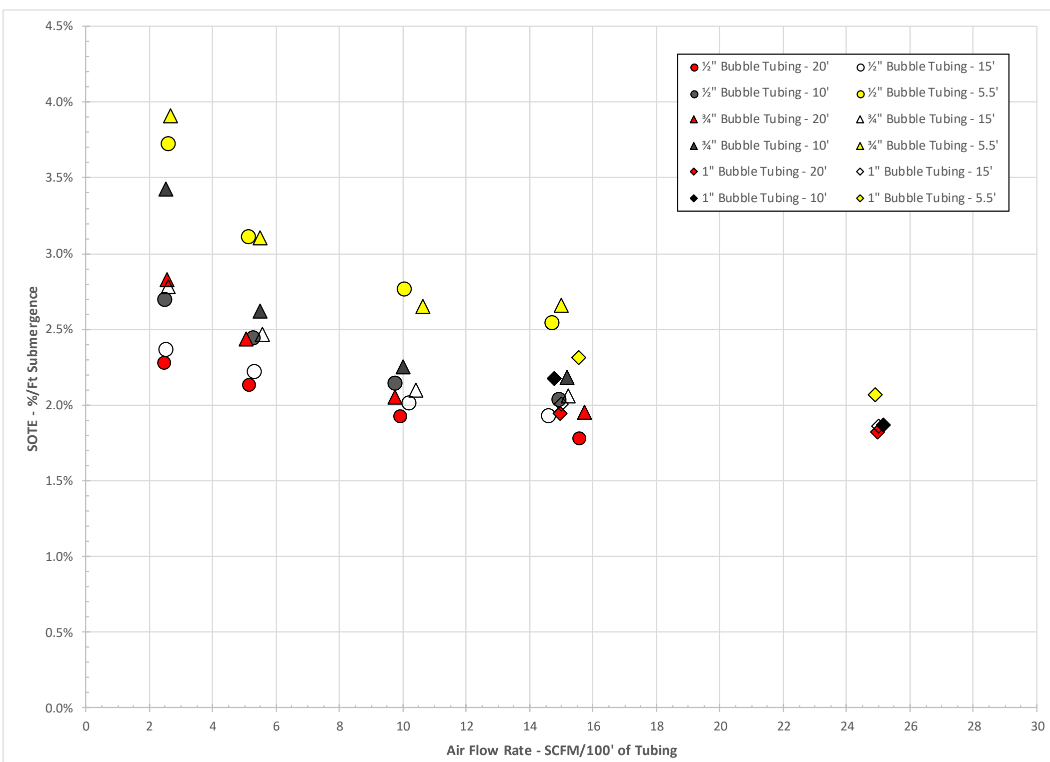


Figure 5-4 – SCFM/100' v SOTE/FT Submergence

Figure 5-5 is a plot of liquid depth (Ft.) versus the Standard Oxygen Transfer Rate per 100' of Tubing (SOTR – lb. O2/Hr./100').

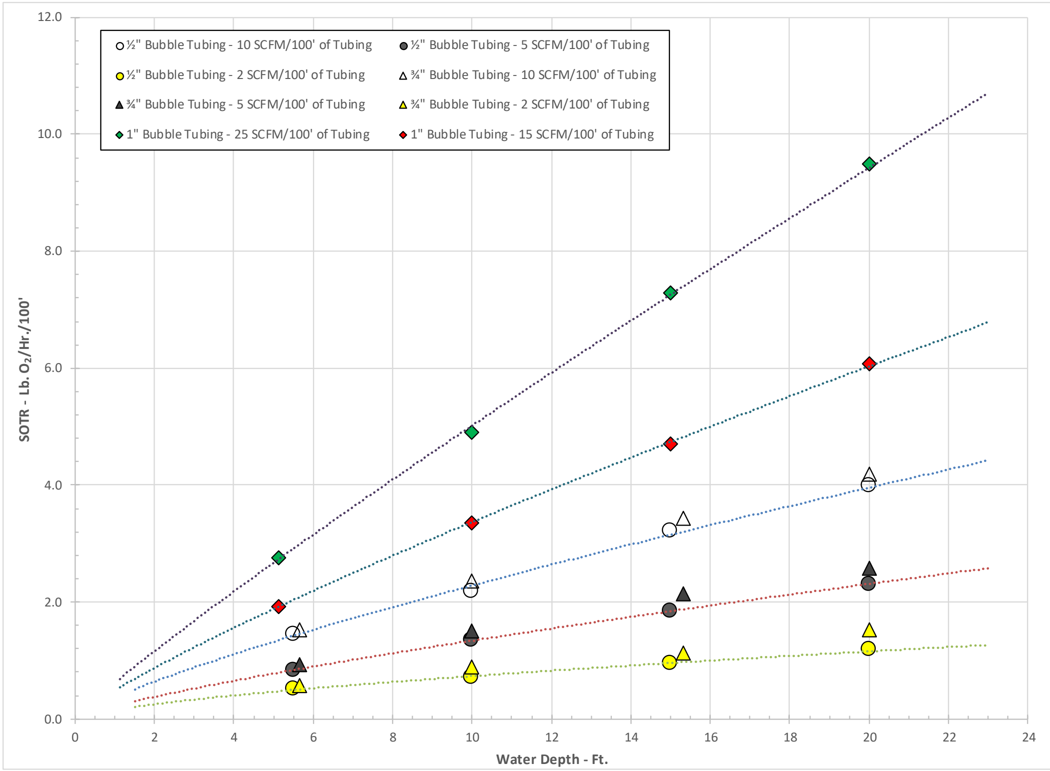


Figure 5-5 – Water Depth v SOTR/100'

Figure 5-6 is a plot of water depth (Ft.) versus the Standard Oxygen Transfer Efficiency (SOTE – %).

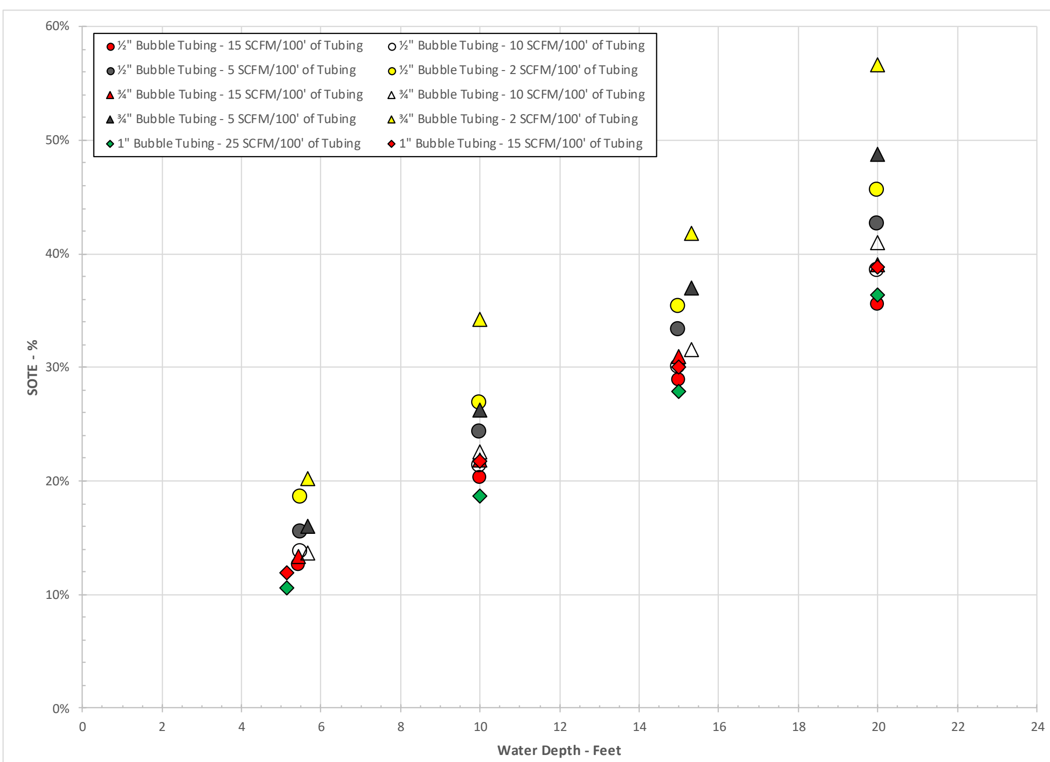


Figure 5-6 - Water Depth v SOTE

Figure 5-7 is a plot of water depth (Ft.) versus the Standard Oxygen Transfer Efficiency (SOTE – %/Ft submergence).

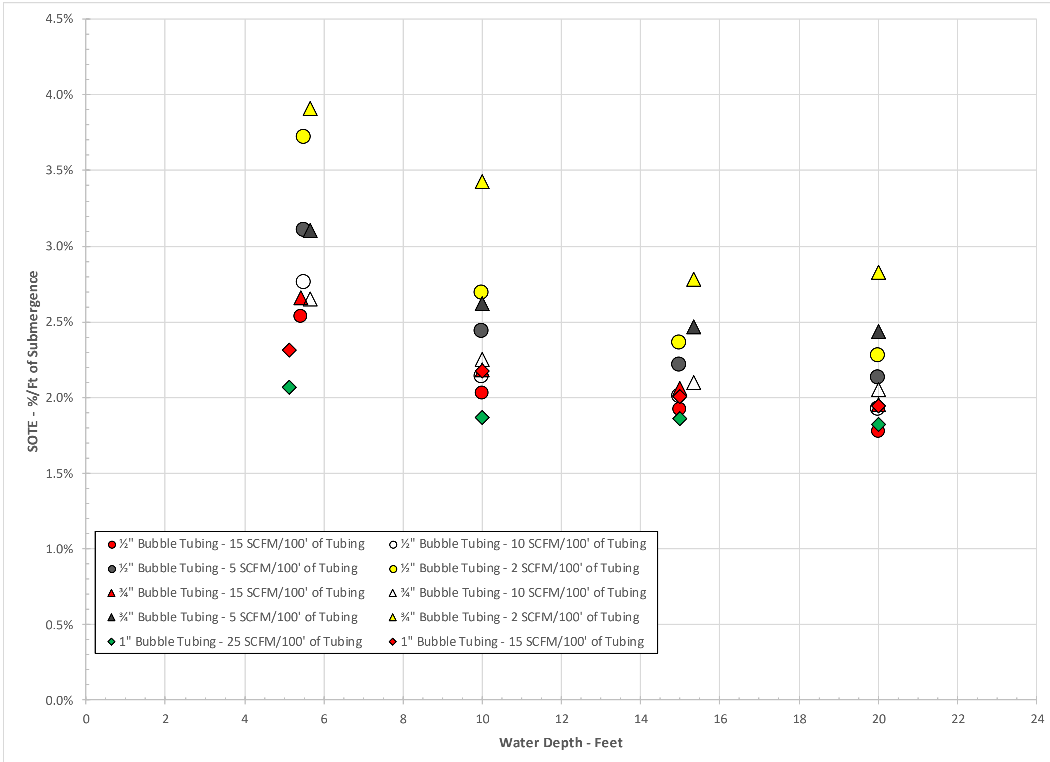


Figure 5-7 – Water Depth v SOTE/FT Submergence

5.1. OctoAir™

Tables 5 and 6 summarize the results of the GSEE, Inc. analysis of the data obtained during the oxygen transfer testing on the CanadianPond.ca Products Ltd. OctoAir10™ and OctoAir60™ aeration systems. Individual computer printouts of the data analysis including time versus D.O. plots for each test run are contained in the Appendix.

Table 5 - Summary of Test Results (OctoAir10™)

PROJECT:	OctoAir10	OctoAir10	OctoAir10	OctoAir10	OctoAir10	OctoAir10	OctoAir10
DATE:	12-May-17	10-May-17	10-May-17	4-May-17	8-May-17	8-May-17	8-May-17
RUN:	7.00	5.00	6.00	1.00	2.00	3.00	4.00
Barometric Pres. (PSIA)	14.25	14.35	14.28	14.15	14.36	14.35	14.35
Ambient Temperature (°F)	75.33	75.33	75.67	68.33	69.00	73.33	74.33
Relative Humidity (%)	0.66	0.45	0.51	0.60	0.46	0.45	0.45
Line Pressure (PSIG)	13.50	16.28	14.00	14.62	12.20	17.57	14.37
Line Temperature (°F)	78.00	113.00	113.00	95.00	88.00	113.33	115.00
Water Temp. (°C)	20.15	19.40	20.06	18.43	17.29	17.86	18.45
Feet Of Aeration Tubing	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Side Water Depth (ft)	5.00	15.00	10.00	20.00	20.00	20.00	20.00
Air Release Depth (ft)	4.33	14.33	9.33	19.33	19.33	19.33	19.33
Temp. Correction Factor (τ)	1.00	1.01	1.00	1.03	1.06	1.04	1.03
Pressure Correction Factor (Ω)	0.97	0.98	0.97	0.96	0.98	0.98	0.98
Average Air Flow (SCFM)	16	15	15	15	2.5	11	5.5
Average Air Flow (Nm^3/h)	25.10	23.85	22.88	23.12	4.00	16.91	8.66
Average Air Flow (SCFM/100')	15.98	15.19	14.56	14.72	2.55	10.76	5.51
Average Air Flow ($Nm^3/h/m$)	0.25	0.24	0.23	0.23	0.04	0.17	0.09
C* (mg/l)	9.22	10.43	9.74	11.04	11.44	11.33	11.19
CsmT (Standard Methods, mg/l)	8.74	8.94	8.78	9.01	9.36	9.24	9.12
C^*_{20} Standard Conditions	9.54	10.56	10.04	11.12	11.08	11.12	11.11
Tank Volume (Ft^3)	1,732	5,195	3,464	6,927	6,927	6,927	6,927
(Gallons)	12,955	38,864	25,910	51,819	51,819	51,819	51,819
(m^3)	49.04	147.12	98.08	196.16	196.16	196.16	196.16
Effective Saturation Depth (d_e)	2.87	6.34	4.63	8.75	8.19	8.35	8.33
TDS (mg/L)	977	734	844	324	424	520	632
KLaT	1.39	0.79	0.93	0.63	0.16	0.53	0.33
KLa20	1.38	0.80	0.93	0.66	0.18	0.55	0.34
KLa20 (TDS Corrected)	1.39	0.82	0.94	0.70	0.19	0.58	0.36
SOTR (TDS Corrected) (Lb O2/Hr)	1.4	2.8	2.0	3.4	0.9	2.8	1.7
SOTR (TDS Corrected) (Lb O2/100')	1.43	2.82	2.04	3.36	0.89	2.78	1.71
SOTE (TDS Corrected)	8.6%	17.8%	13.4%	21.9%	33.3%	24.7%	29.6%
SOTE/Ft (TDS Corrected)	1.98%	1.24%	1.44%	1.13%	1.72%	1.28%	1.53%
SAE (TDS Corrected)	1.03	1.86	1.58	2.46	4.43	2.43	3.43

Table 6 - Summary of Test Results (OctoAir60™)

PROJECT:	OctoAir60	OctoAir60	OctoAir60	OctoAir60	OctoAir60	OctoAir60
DATE:	14-Apr-17	14-Apr-17	28-Apr-17	28-Apr-17	29-Apr-17	29-Apr-17
RUN:	1.00	2.00	3.00	4.00	5.00	6.00
Barometric Pres. (PSIA)	14.22	14.27	14.29	14.30	14.34	14.35
Ambient Temperature (°F)	64.67	64.67	69.67	74.33	75.00	80.67
Relative Humidity (%)	0.80	0.72	0.72	0.71	0.79	0.63
Line Pressure (PSIG)	16.29	8.50	19.73	11.71	18.84	10.97
Line Temperature (°F)	165.00	166.00	166.00	166.00	166.67	174.33
Water Temp. (°C)	17.93	18.05	17.90	18.11	18.94	19.21
Feet Of Aeration Tubing	300.00	300.00	300.00	300.00	300.00	300.00
Side Water Depth (ft)	12.00	12.00	24.00	24.00	18.00	18.00
Air Release Depth (ft)	10.25	10.25	22.25	22.25	16.25	16.25
Temp. Correction Factor (τ)	1.04	1.04	1.04	1.04	1.02	1.02
Pressure Correction Factor (Ω)	0.97	0.97	0.97	0.97	0.98	0.98
Average Air Flow (SCFM)	61	31	60	30	60	30
Average Air Flow (Nm^3/h)	96.05	48.02	94.45	46.70	94.02	47.67
Average Air Flow (SCFM/100')	20.38	10.19	20.04	9.91	19.95	10.12
Average Air Flow ($Nm^3/h/m$)	0.32	0.16	0.31	0.16	0.31	0.16
C* (mg/l)	10.27	10.27	11.60	11.51	10.73	10.70
CsmT (Standard Methods, mg/l)	9.16	9.16	9.20	9.16	9.03	8.98
C^*_{20} Standard Conditions	10.18	10.17	11.43	11.39	10.76	10.79
Tank Volume (Ft^3)	4,156	4,156	8,313	8,313	6,234	6,234
(Gallons)	31,091	31,091	62,183	62,183	46,637	46,637
(m^3)	117.69	117.69	235.39	235.39	176.54	176.54
Effective Saturation Depth (d_e)	5.17	5.04	9.63	9.48	7.10	7.18
TDS (mg/L)	311	408	450	560	690	800
KLaT	2.59	1.47	2.23	0.96	2.66	1.36
KLa20	2.72	1.54	2.34	1.01	2.73	1.39
KLa20 (TDS Corrected)	2.91	1.63	2.47	1.05	2.81	1.42
SOTR (TDS Corrected) (Lb O2/Hr)	7.7	4.3	14.6	6.2	11.8	5.9
SOTR (TDS Corrected) (Lb O2/100')	2.56	1.44	4.88	2.07	3.92	1.98
SOTE (TDS Corrected)	12.0%	13.5%	23.3%	20.0%	18.8%	18.7%
SOTE/Ft (TDS Corrected)	1.17%	1.32%	1.05%	0.90%	1.16%	1.15%
SAE (TDS Corrected)	1.57	3.05	2.63	3.44	2.21	3.42

The following figures present plots of the results obtained during the OctoAir™ testing. Note that results from the 2011 OctoAir10™ tests are included for completeness.

Figure 5-8is a plot of the total system air flow rate (SCFM) versus the observed Mass Transfer Coefficient (K_La_{20} – Hr^{-1}).

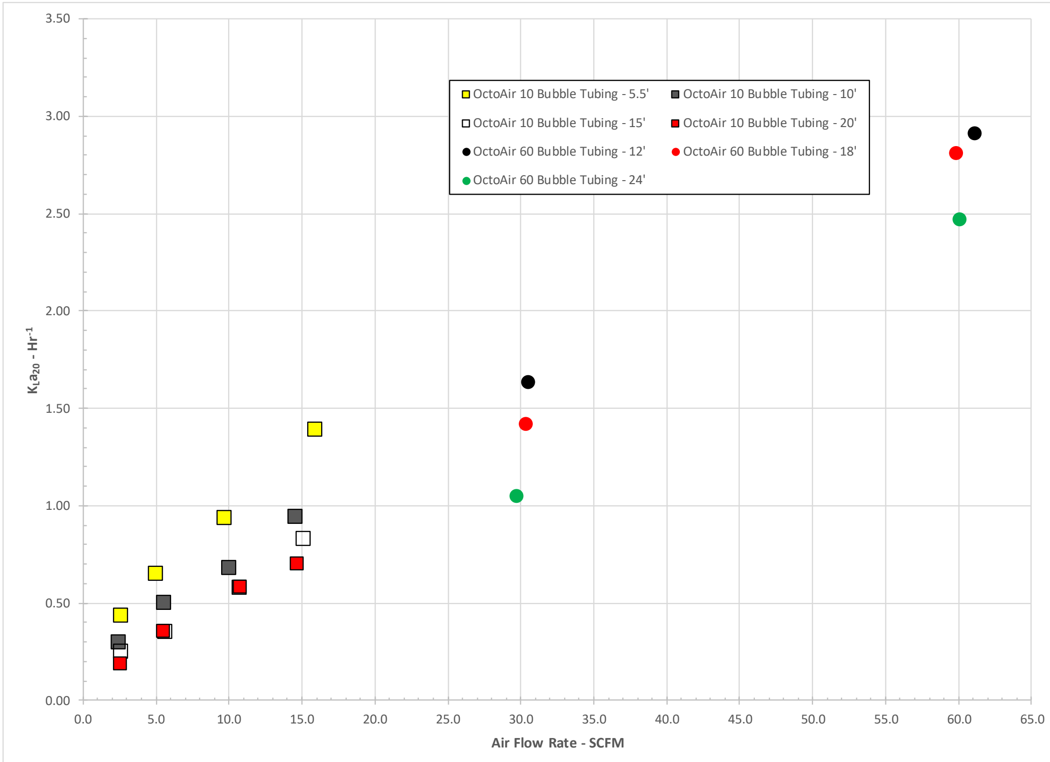


Figure 5-8 - Total Airflow v KLa20

Figure 5-9 is a plot of the total air flow rate per diffuser (SCFM) versus the Standard Oxygen Transfer Rate per diffuser (SOTR – lb. O2/Hr.).

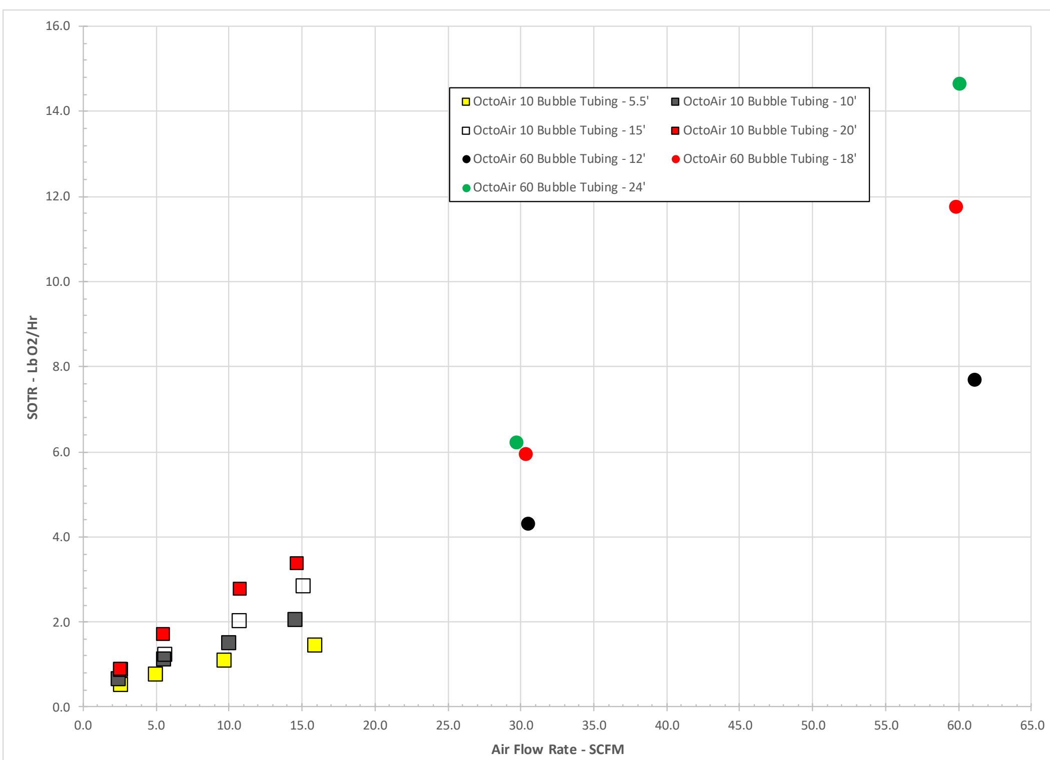


Figure 5-9 – SCFM v SOTR

Figure 5-10 is a plot of the air flow rate (SCFM) versus the Standard Oxygen Transfer Efficiency (SOTE – %).

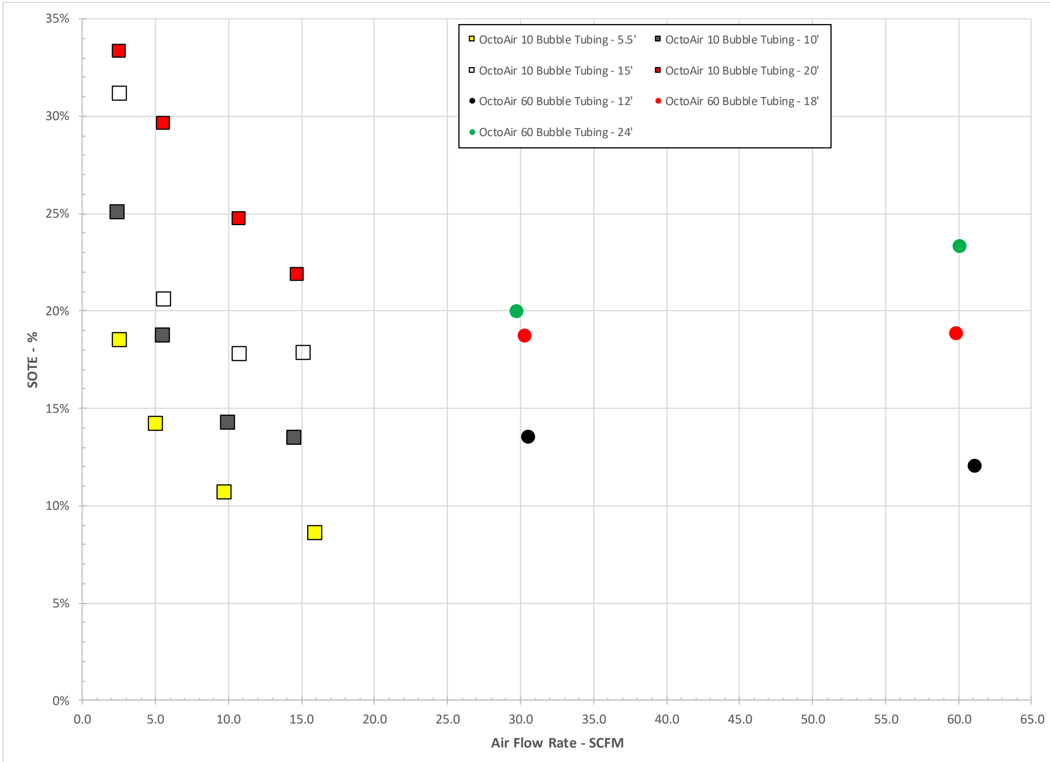


Figure 5-10 – SCFM v SOTE

Figure 5-11 is a plot of air flow rate (SCFM) versus the Standard Oxygen Transfer Efficiency (SOTE – %/Ft submergence).

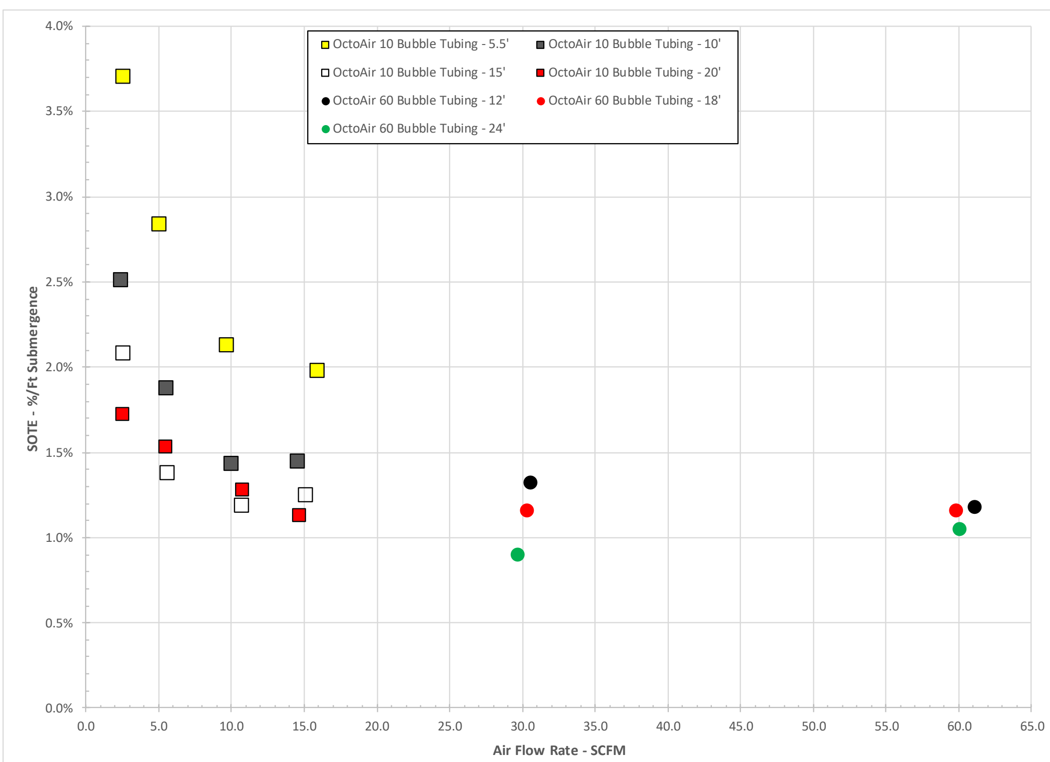


Figure 5-11 – SCFM v SOTE/FT Submergence

Figure 5-12 is a plot of liquid depth (Ft.) versus the Standard Oxygen Transfer Rate (SOTR – lb. O2/Hr.).

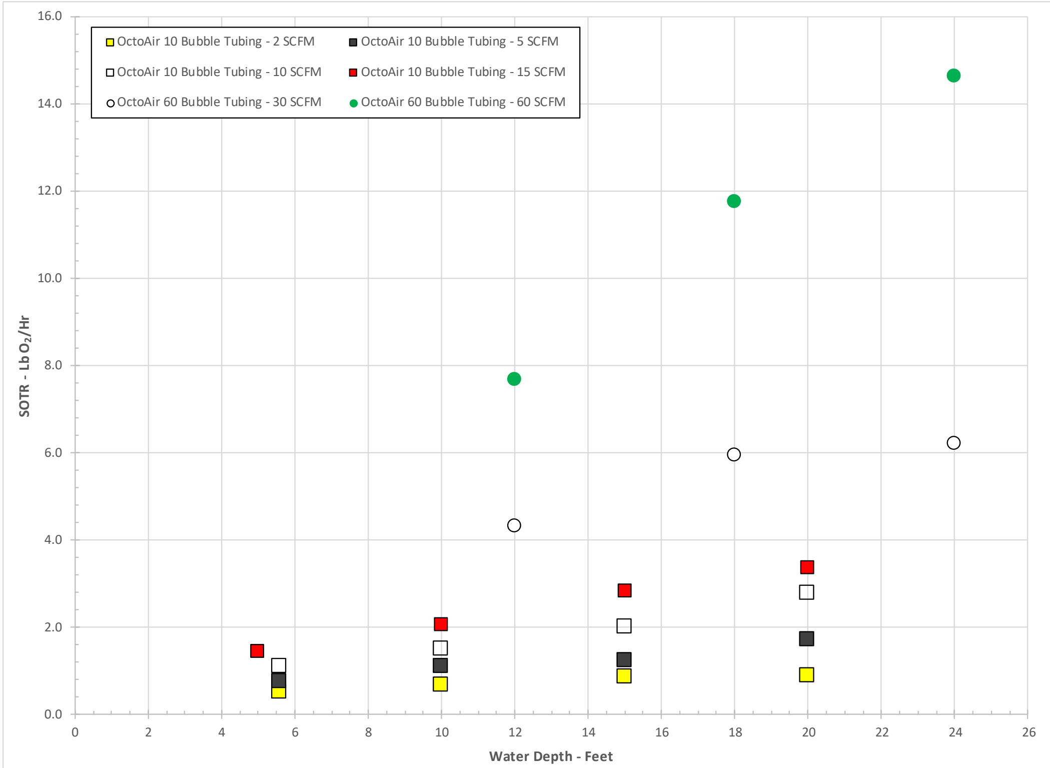


Figure 5-12 – Water Depth v SOTR

Figure 5-13 is a plot of water depth (Ft.) versus the Standard Oxygen Transfer Efficiency (SOTE – %).

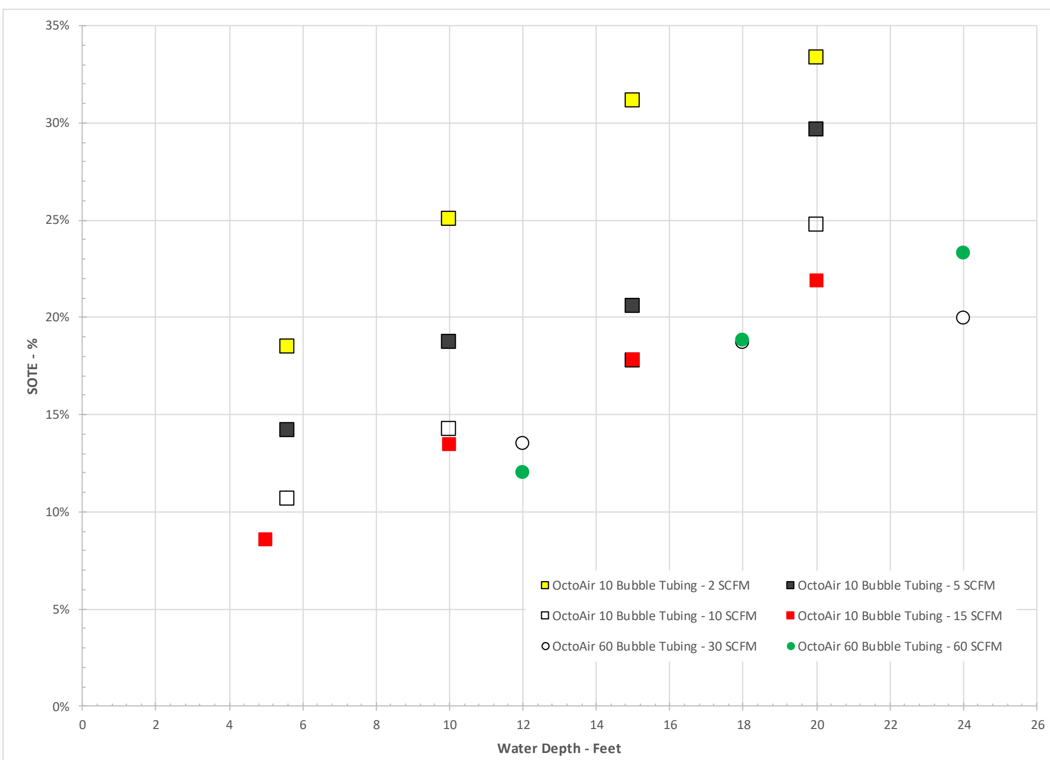


Figure 5-13 - Water Depth v SOTE

Figure 5-14 is a plot of water depth (Ft.) versus the Standard Oxygen Transfer Efficiency (SOTE – %/Ft submergence).

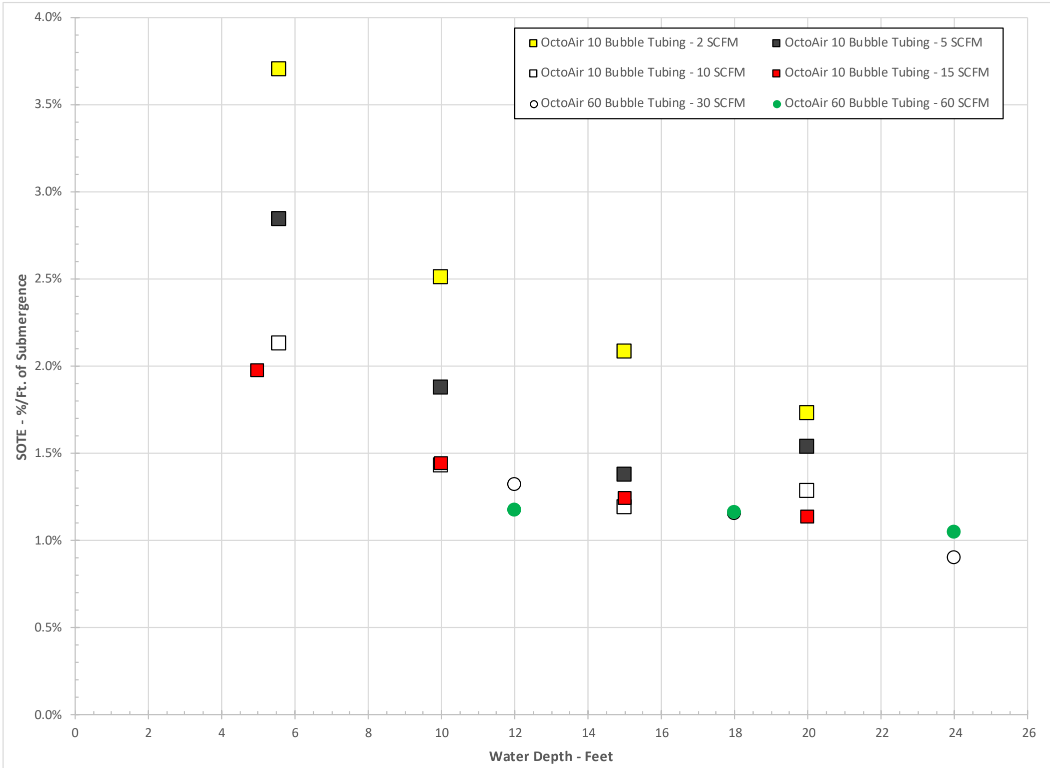


Figure 5-14 – Water Depth v SOTE/FT Submergence

6. CONCLUSIONS

Based on the results obtained testing the CanadianPond.ca Products Ltd. aeration systems, the following conclusions are offered:

1. SOTR increases with increasing airflow rate and increasing air release depth.
2. SOTE decreases with increasing airflow rate.
3. SOTE increases with increasing air release depth.
4. The ¾" and 1.0" Bubble Tubing™ have similar performance.
5. The ¾" and 1.0" Bubble Tubing™ results indicate a performance advantage over the ½" Bubble Tubing™.
6. The OctoAir™ units produced lower results than the Bubble Tubing™. Note that this is expected due to the concentration of the aeration system in a small area of the tank as opposed to the Bubble Tubing which has more complete floor coverage of the basin.

Overall, the results obtained for the CanadianPond.ca Products Ltd. aeration systems were uniformly excellent and produced some of the highest SOTE values GSEE, Inc. has observed.

7. CERTIFICATION

GSEE, Inc., certifies that the results presented in this report are accurate and were obtained using the test procedures described above.

Gerald L. Shell, PE