Characterization and Optimization of An Airlift Photobioreactor

Christopher Neighbor, Jeremy Campbell, Greg Rorrer

Oregon State University
College of Engineering

Department of Chemical Engineering, Oregon State University

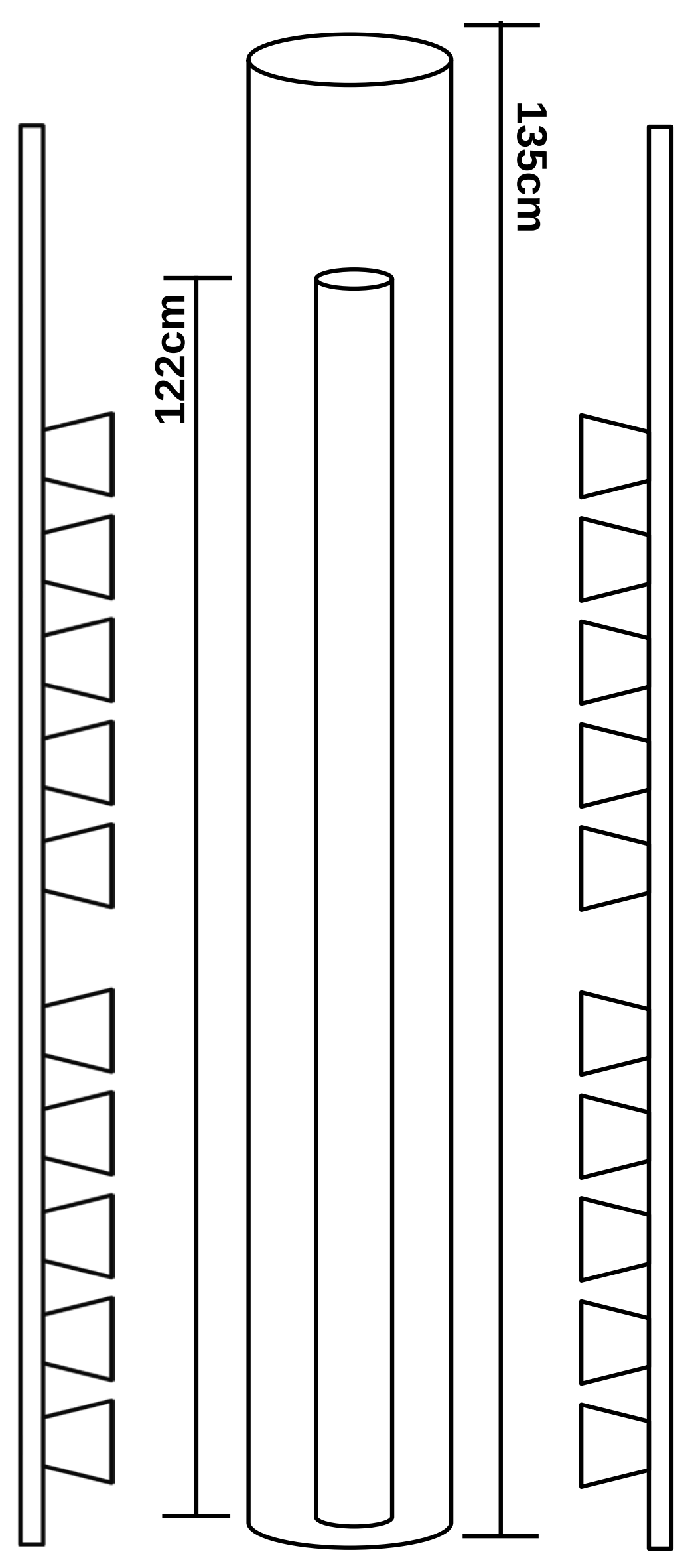
Abstract

An airlift photobioreactor's light distribution was measured and modeled as well as having a draught tube fitted. The reactor was designed for the culturing of marine diatoms. Time was spent performing a light mapping and modeling in order to determine the total and mean light flux across the surface of the bioreactor. A draught tube was fitted in the bioreactor to enhance airlift and to prevent settling on the bottom of the reactor. k_La calculations were performed to determine the relative saturation which would occur within the draught tube for size optimization.

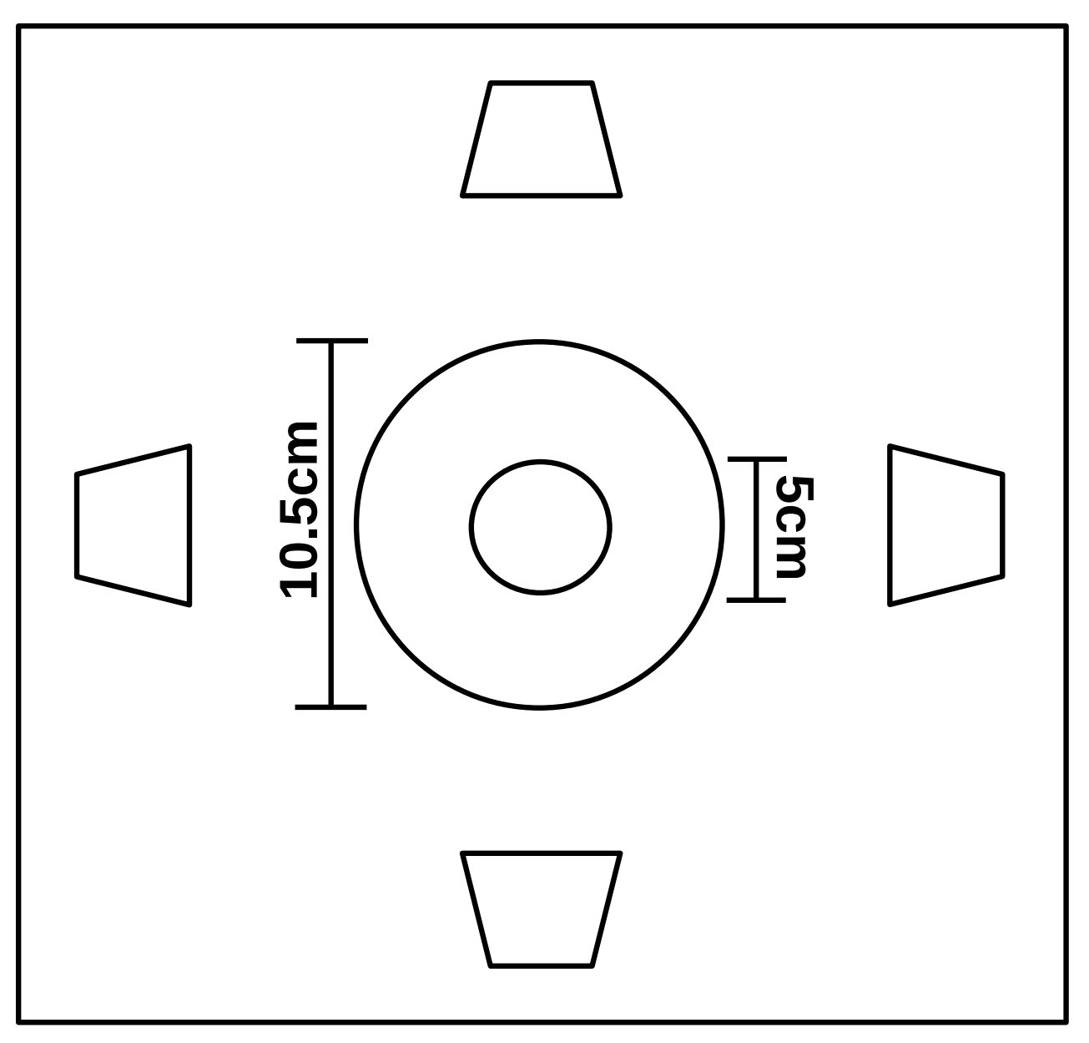
Photobioreactors

Photobioreactors are typically a closed system designed for the growth of a photosynthetic organism. Photobioreactors allow for the control of the system's parameters such as gas flow, temperature, and light. This reactor was designed with diatoms as the planned culture. Diatoms have many unique and useful uses such as in biofuels, solar cells, biosensors, and CO_2 absorption.

Side view



Top View



Operational Parameters

- Air flow rate (Q_r) = 0.5 L/min
- Light Intensity = 227 μmol/m²-s
- Temperature = 295 K
- Reactor Volume = 12 L

Light Characterization

Light measurements were taken at 1cm intervals on the inside of the bioreactor. A 2D Gaussian function was used to model the incident light distribution within the reactor by minimizing the sum of the squares error. Total and mean light intensity were then determined using the model function.

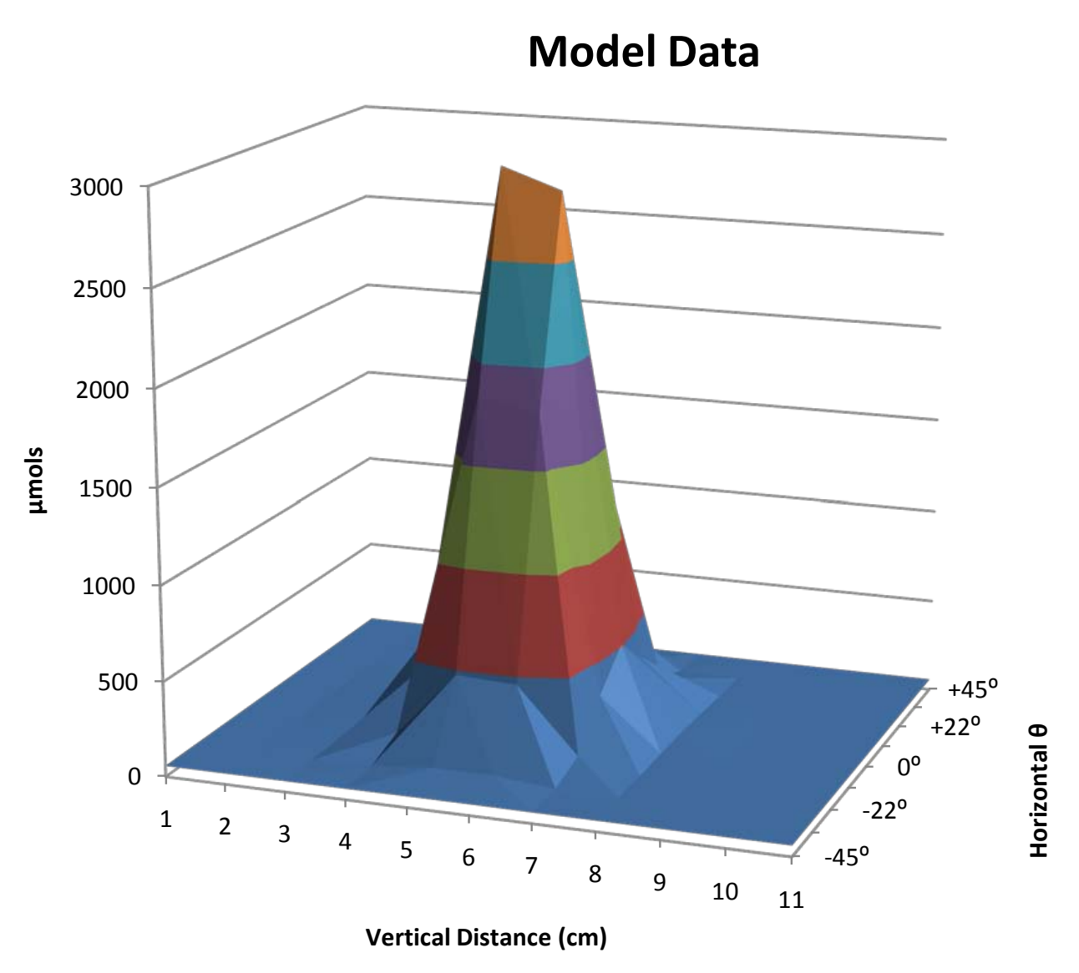
Measurements were taken over one light panel, which consisted of five individual lights. The Gaussian parameters were averaged from all five lights to provide an overall reactor light model.

2D Gaussian Model Equations

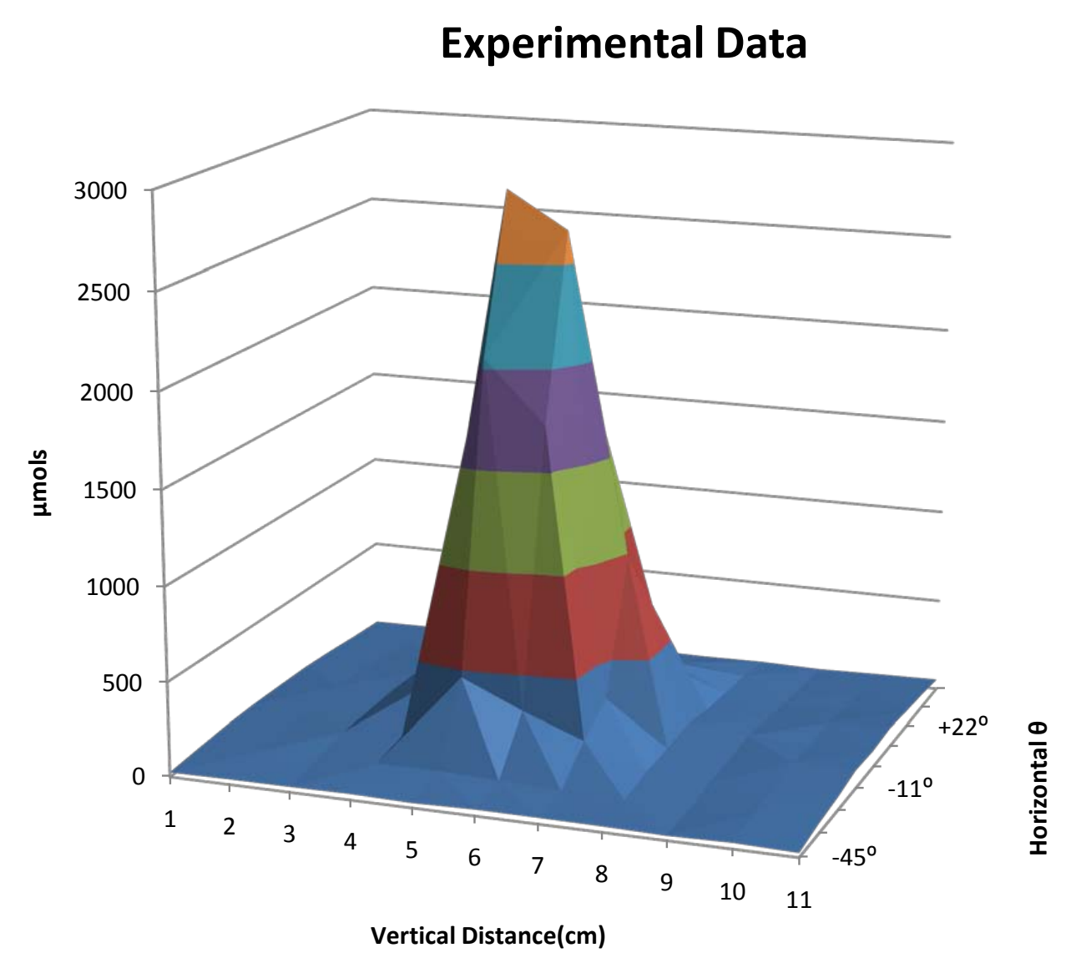
$$f\left(x,y\right)=Ae^{-\left(\frac{(x-x_o)^2}{2\sigma_x{}^2}+\frac{(y-y_o)^2}{2\sigma_y{}^2}\right)}+b_0$$

$$\int f(x,y)=A\left(\sigma_x\right)\left(\sigma_y\right)\left(2\pi\right)+A_s b_0$$

Description	Parameter	Model Value
Peak light intensity	A (μmol/s)	3799
Horizontal width of curve	σ_x(cm)	0.97
Vertical width of curve	σ_y(cm)	0.81
Background light intensity	b_0 (μmol/s)	49



Total Light = 2.168 μmol/s

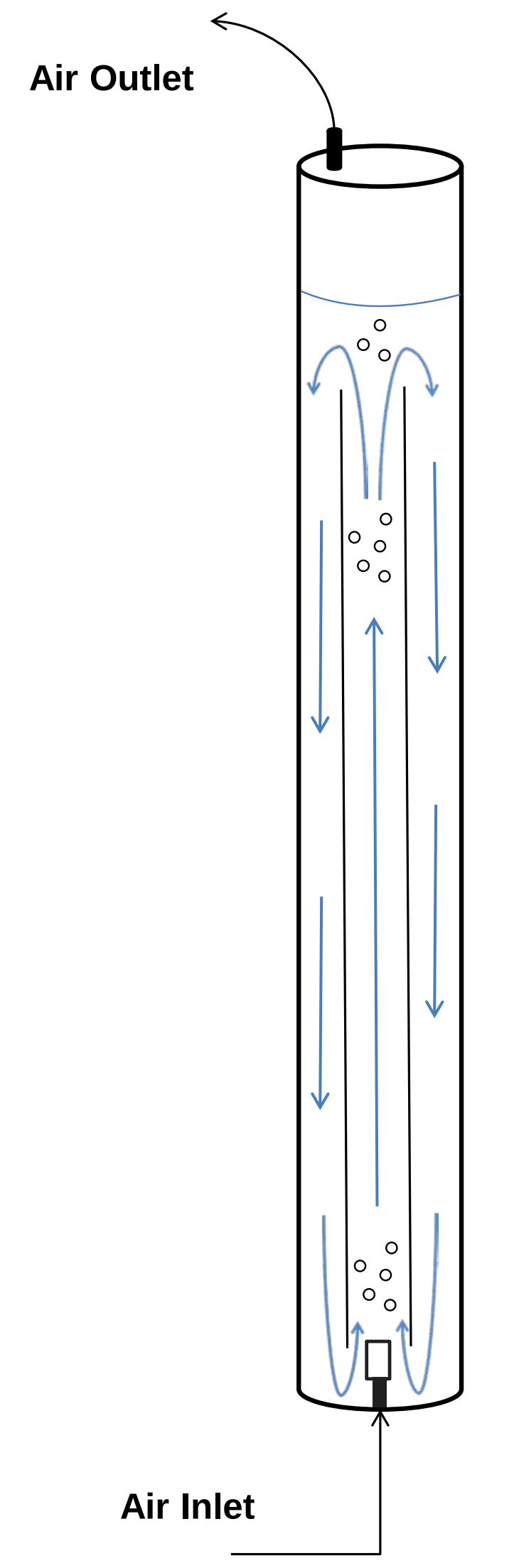


Total Light = 2.190 μmol/s

Model error using trapezoidal approximation was found to be 0.92%

Using the overall model values
The total light flux was calculated as 91.5 μmol/s and
the mean light intensity was determined to be 227 μmol/m²-s.

Draught Tube



During initial testing of the reactor a significant amount of particle settling was visually observed on the bottom. This cell settling prevented a reliable cell density measurement from being taken. A draught tube was proposed as a solution to this settling problem.

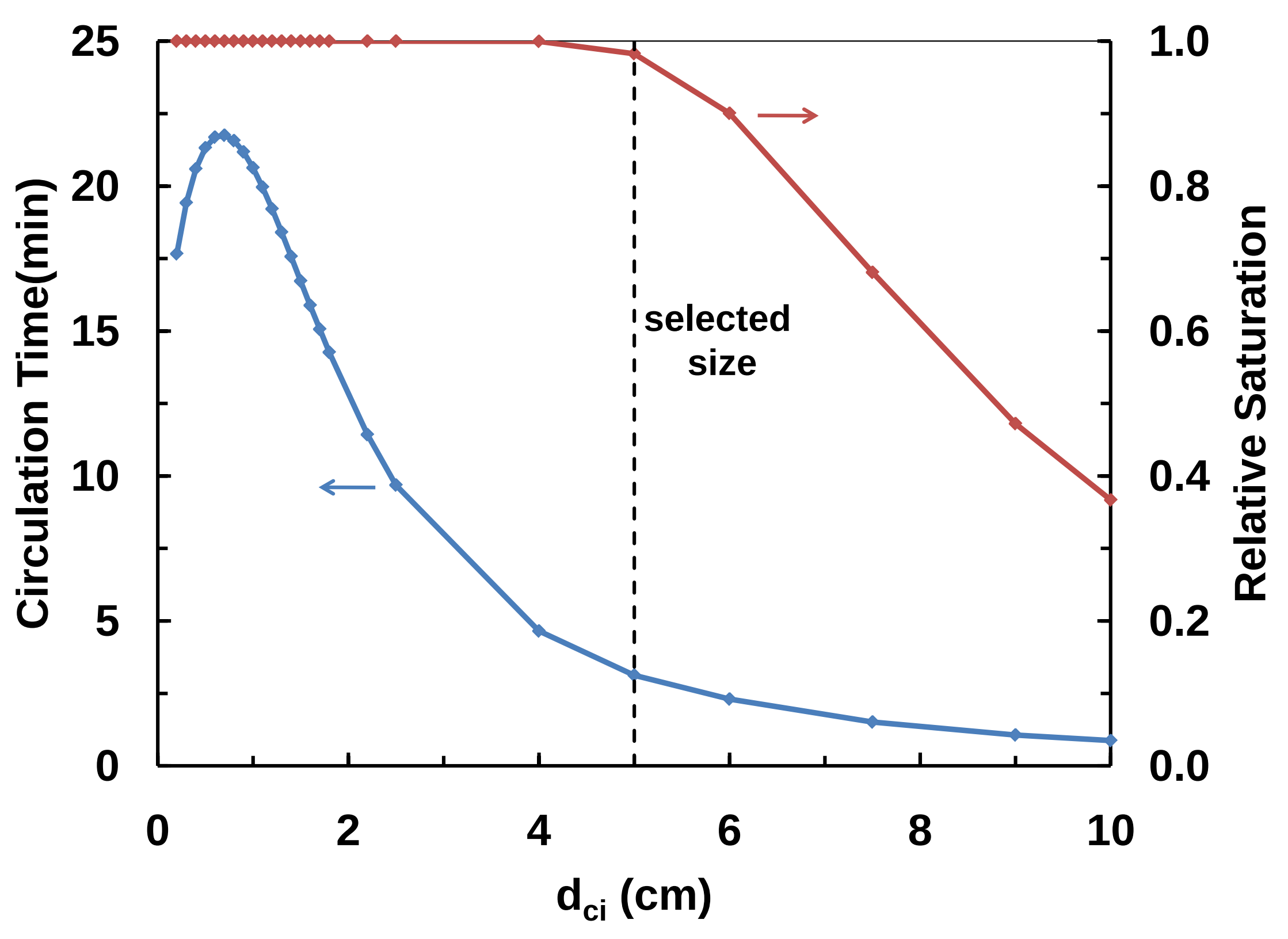
To ensure adequate airlift in the reactor and to prevent settling on the bottom of the reactor, a draught tube was suspended concentrically inside the reactor tube.

The optimum draught tube size was determined to be the diameter which provided the fastest circulation time while still reaching full saturation within the draught tube.

Draught Tube Equations

$$\frac{k_L a_L d_c^2}{D_L}=0.477\left(\frac{\mu_L}{\rho_L D_L}\right)^{0.5}\left(\frac{g d_c^2\rho_L}{\sigma}\right)^{0.837}\left(\frac{g d_c^3\rho_L{}^2}{\mu_L^2}\right)^{0.257}\left(\frac{d_{ci}}{d_c}\right)^{-0.542}\varepsilon_G^{1.36}$$

Relative Saturation = $1-e^{\left(-k_L a\left(U_{Lr}\right)\right)}$



Total circulation time is composed primarily of the time spent in the annulus. Increasing the diameter of the inner tube decreases the annulus transit time, therefore the largest inner tube diameter that still achieves nearly complete saturation was selected. A 5.0cm draft tube was selected.