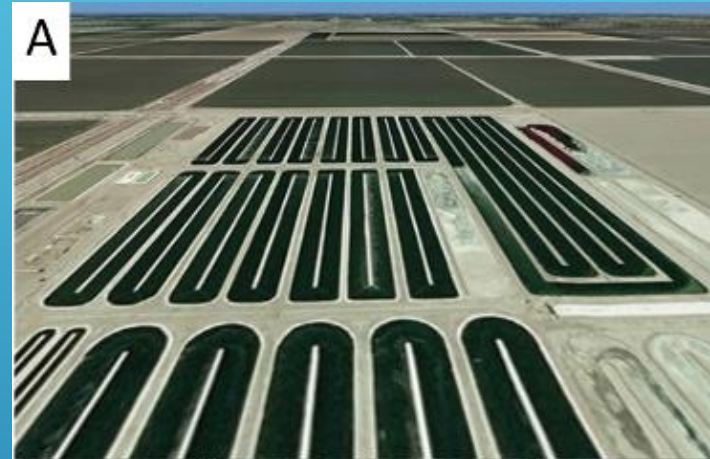
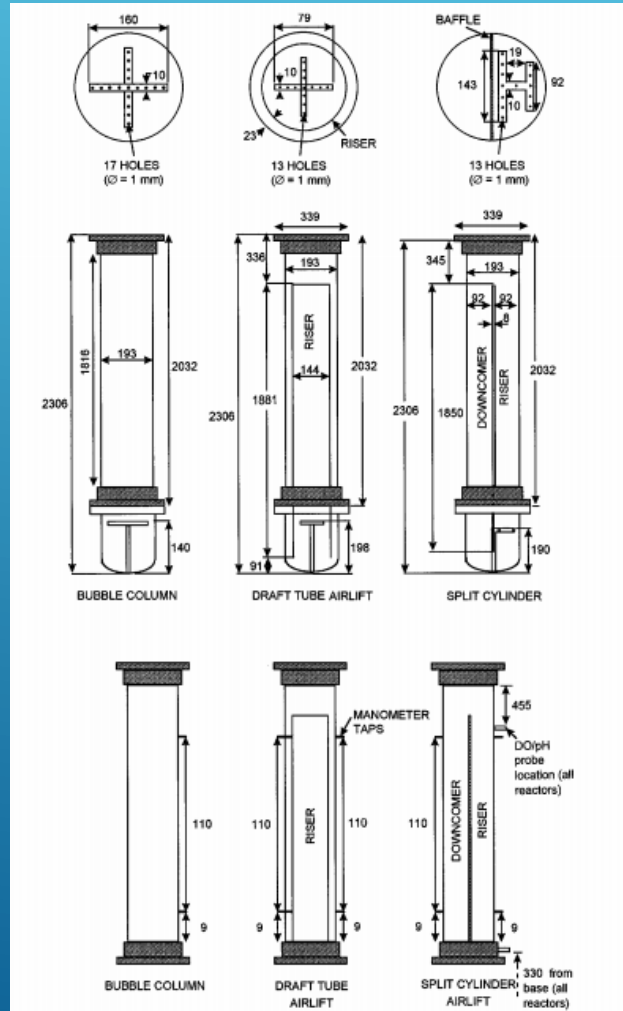


Airlift Photo Bioreactor

Autophyte Activators

Lucas Becia, Samuel Funk, Matthew Jungert,
Sage Pratt, Nate Wiedenmeyer

What is An Airlift Photo Bioreactor?



©Fraunhofer

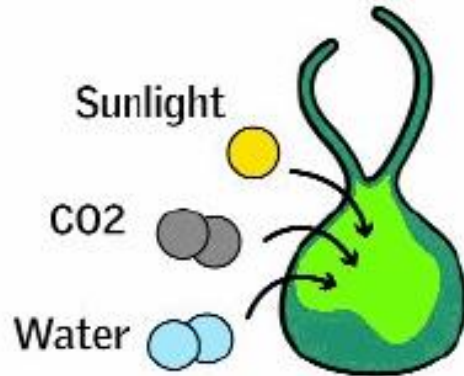
Biodiesel

Biodiesel from algae

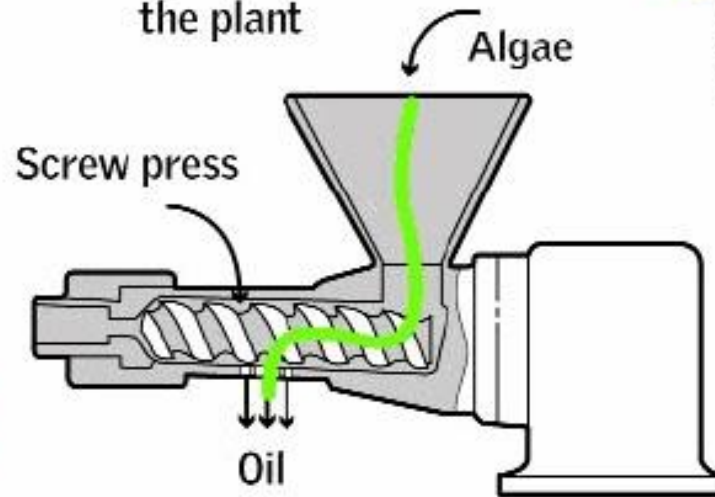
High oil prices and advances in biotech over the past decade have refueled the algae biofuel race.

The process

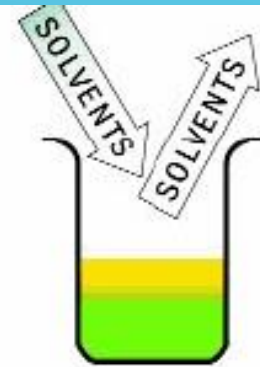
- 1** After initial growth, algae is deprived of nutrients to produce a greater oil yield



- 2** Extraction of oil
A press produces 70-75% of the oils from the plant



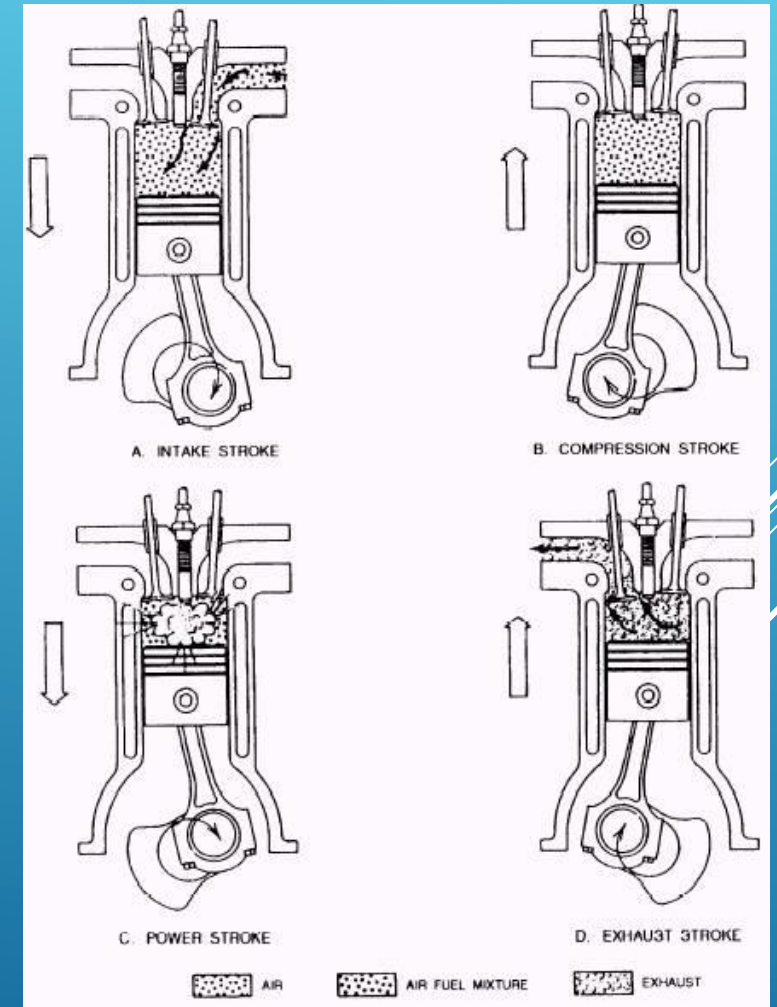
- 3** Solvents used to separate sugar from oil; solvents then evaporate



- 4** Oil is ready
Can be used as oil directly in diesel engines or refined further into fuel



Compression Ignition (Diesel) Engines



Overview

► Specifications

1. Flow Analysis
2. Construction
3. Lighting
4. CO2 Introduction

► Cost Estimations

► Current Status

Metric No.	Needs No.	Our Metrics	Importance	Units
1		Minimized energy input		kW-hr
2		Capable of microalgal cultivation		List
3		Observable/ display capable		List
4		Uniform Nutrient Distribution		ppm
5		Minimal dead volume		liters
6		Maximum efficiency of light utilization		kW-hr/lumen
7		Controllable light intensity		Lumens
8		Artificial Light source		Lumens
9		Uniform light distribution		Lumens
10		Light source must comply with relevant standards/codes		List
11		Carbon Dioxide introduction system		List
12		Controllable Carbon dioxide flow		m ³ /s
13		CO2 flow promotes medium circulation		m ³ /s
14		Control Sensors (PH,CO,Nitrate etc)		
15		Visual Appeal		
16		Scalability		

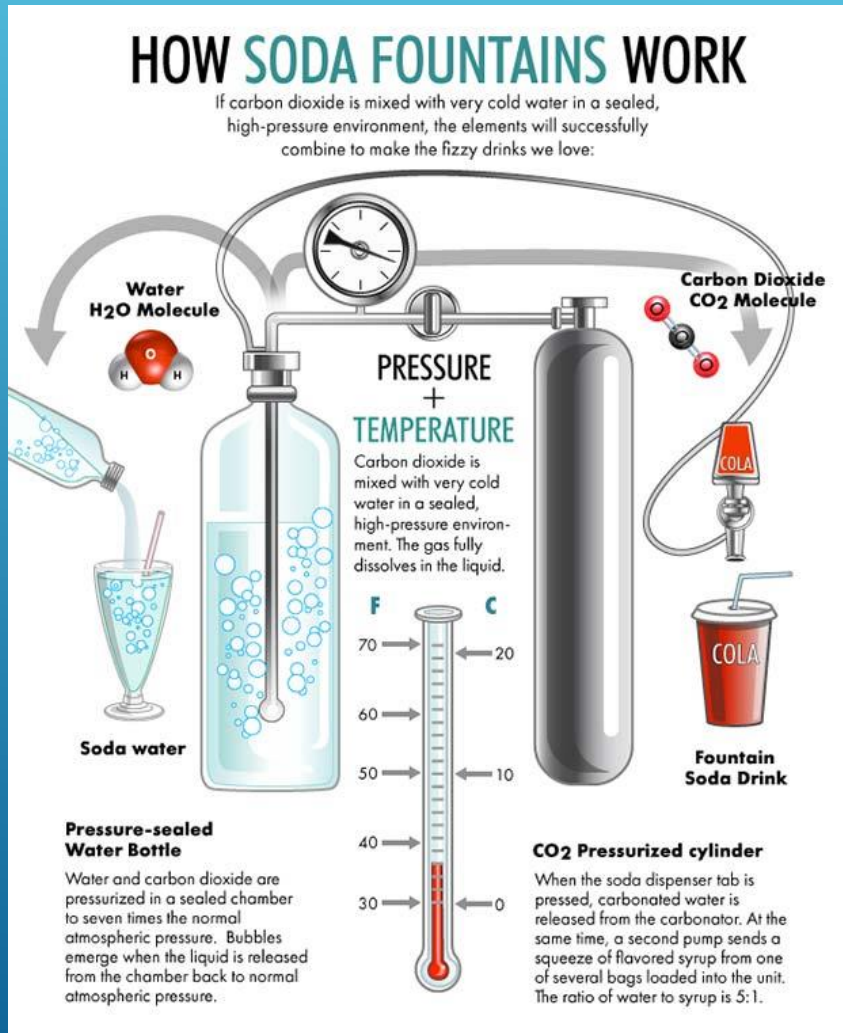
CO₂ Saturation

► In order to saturate a fluid with CO₂ efficiently, two criteria must be met:


► The chamber must be well sealed

► The fluid must be as cold as possible

► Most types of algae thrive with large concentrations of CO₂ in their environment



Design Logic

- ▶ In order to minimize CO₂ waste, the system must be sealed with as little air gap as possible at the top to promote the saturation of gas into the tank water
 - ▶ The circulation system must use as little gas as possible while still maintaining a functional circulation velocity
 - ▶ The continuous nature of the system allows it to be filled as it is also drained, which should help limit gas pressure build up.
- 
- A series of white diagonal lines of varying lengths and thicknesses are positioned on the right side of the slide, extending from the middle towards the bottom right corner.

Flow Analysis

AIRLIFT BIOREACTORS

M.Y. Chisti

Elsevier Applied Science

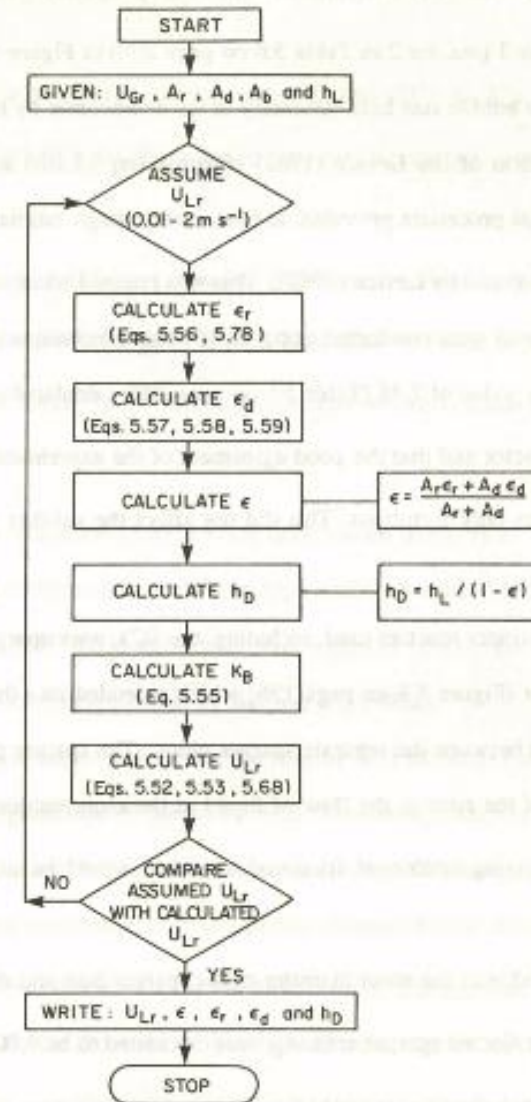


Figure 5.40:

The liquid circulation velocity calculation procedure. Algorithm for the simultaneous calculation of various gas holdups and the riser superficial liquid velocity for a given reactor geometry and gas flow.

Computations



Figure 5.40 Flowchart

Rules Sheet

Rules

Figure 5.40 Flow Chart Calculations

1: U_{Gr} , A_r , A_d , A_b , and h_L

2: Assume U_{Lr} (0.01 to 2 m s⁻¹)

3: Calculate ϵ_r (Eqn. 5.58, 5.78)

$$\epsilon_r = \left[\frac{U_{Gr}}{0.24 + 1.35 \cdot (U_{Gr} + U_{Lr})^{0.85}} \right]; \quad (5.58)$$

$$\epsilon_r = \left[\frac{U_{Gr}}{U_{Gr} + U_{Lr} + 0.5 \cdot \left[1 + 20 \cdot w \cdot \sqrt{\rho_L} \right]} \right]; \quad (5.78)$$

4: Calculate ϵ_d (Eqn. 5.57) [draught internal tube], 5.59 [external loop], 5.59 [external loop]

$$\epsilon_d = 0.89 - \epsilon_r; \quad (5.57)$$

$$\epsilon_d = 0.74 - \epsilon_r - 0.057; \quad (5.58)$$

$$\epsilon_d = 0.460 - \epsilon_r - 0.024; \quad (5.59)$$

5: Calculate ϵ

$$\epsilon = \frac{A_r \cdot \epsilon_r + A_d \cdot \epsilon_d}{A_r + A_d}$$

6: Calculate h_D

$$h_D = \left[\frac{h_L}{1 - \epsilon} \right]$$

7: Calculate K_B (Eqn. 5.55)

$$K_B = 11.40 \cdot \left[\frac{A_d}{A_b} \right]^{0.79}; \quad (5.55)$$

8: Calculate U_{LrCalc} (Eqn. 5.52, 5.53, 5.68)

$$U_{Lr} = \left[\frac{2 \cdot g \cdot h_D \cdot (\epsilon_r + \epsilon_d)}{K_B \cdot \left[\frac{A_r}{A_d} \right]^2 \cdot \left[\frac{1}{(1 - \epsilon_d)^2} \right]} \right]^{0.5}; \quad (5.52)$$

$$U_{Lr} = \left[\frac{2 \cdot g \cdot h_D \cdot (\epsilon_r + \epsilon_d)}{K_B \cdot \left[\frac{1}{(1 - \epsilon_r)^2} + \left[\frac{A_r}{A_d} \right]^2 \cdot \left[\frac{1}{(1 - \epsilon_d)^2} \right] \right]} \right]^{0.5}; \quad (5.53)$$

Rules

8.1: Calculate Re_r and Re_d (Eqn. 5.75, 5.76)

8.2: Calculate x_{dot} (Eqn. 5.77)

8.3: Calculate t_{Ld} and t_{Lr} (Laminar Eqn. 5.71, Turbulent Eqn. 5.73)

8.4: Calculate S_r (Eqn. 5.76)

8.5: Calculate t_{Dr} , t_{Dd} (Eqn. 5.72, 5.74)

8.6: Calculate ΔP_{Fr} and ΔP_{Fd} (Eqn. 5.69)

$$\Delta P_{Fr} = 4 \cdot \left[\frac{L}{d} \right] \cdot t_{Dr}; \quad (5.69)$$

$$\Delta P_{Fd} = 4 \cdot \left[\frac{L}{d} \right] \cdot t_{Dd}; \quad (5.69)$$

$$U_{Lr} \cdot A_r \cdot (\Delta P_{Fr} + \Delta P_{Fd}) - \rho_L \cdot g \cdot h_D \cdot U_{Lr} \cdot A_r \cdot (\epsilon_r + \epsilon_d) + \left[\frac{1}{2} \right] \cdot \rho_L \cdot U_{Lr}^3 \cdot A_r \cdot \left[\frac{K_T}{(1 - \epsilon_r)^2} \right] + K_B$$

9: Compare U_{Lr} and U_{LrCalc}

10: Write: U_{Lr} , ϵ , ϵ_r , ϵ_d , and h_D

11: Stop

Variables Sheet

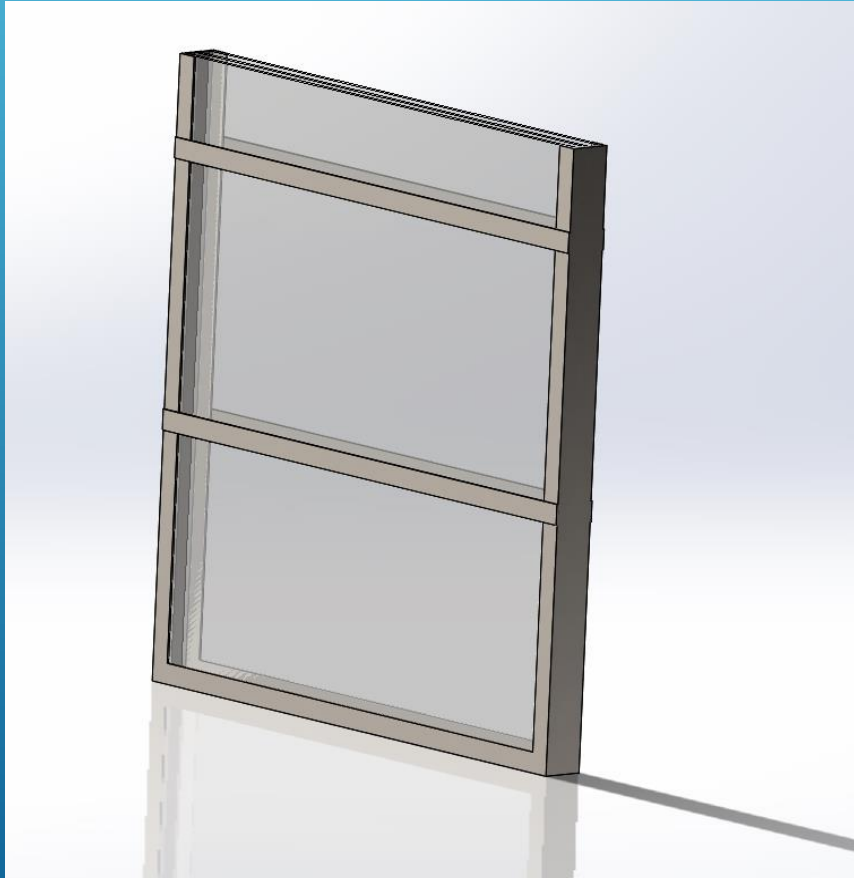
Input	Name	Output	Unit	Comment
	U_{Gr}			Superficial Gas Velocity (relative to riser)
	A_r			Cross-Sectional Area Riser
	A_d			Cross-Sectional Area Downcomer
	A_b			Free area blow baffle/drop tube (concentric tube)
	h_L			Unagitated Liquid Height
	U_{Lr}			Superficial Liquid Velocity Downcomer
	ϵ_r			Gas Holdup Riser
	ϵ_d			Gas Holdup Downcomer
	ϵ			Overall Gas Holdup
	h_D			Dispersion Height
	K_B			Fractional Loss Coefficient Bottom
	U_{LrCalc}			Superficial Liquid Velocity Downcomer (Calculated)
	w			$w = 5.25$ to 19.8 kgm^{-3}
	ρ_L			Density of Liquid
	g			Acceleration due to gravity
	K_T			Fractional Loss Coefficient Top
	ΔP_{Fr}			Fractional Pressure Drop Riser
	ΔP_{Fd}			Fractional Pressure Drop Downcomer
	L			
	d			

CO2 Introduction

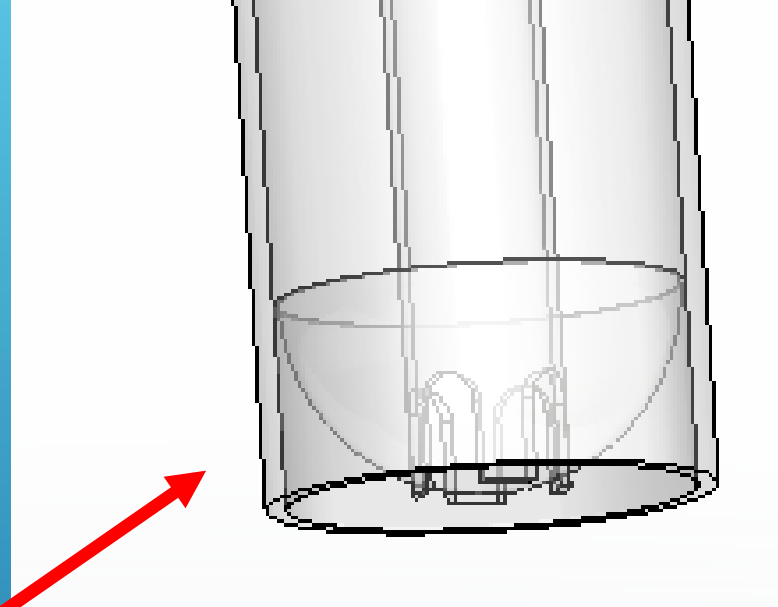
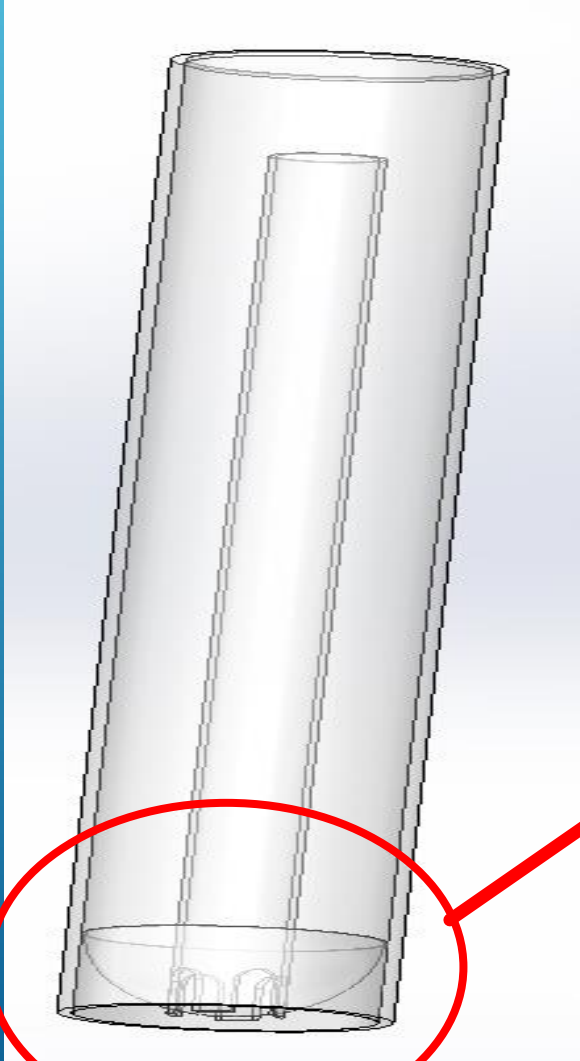
- ▶ Food Grade CO2 Cylinder
- ▶ Regulator
- ▶ Sparger
- ▶ Valves, Pipes, Misc. Fittings



Initial Designs

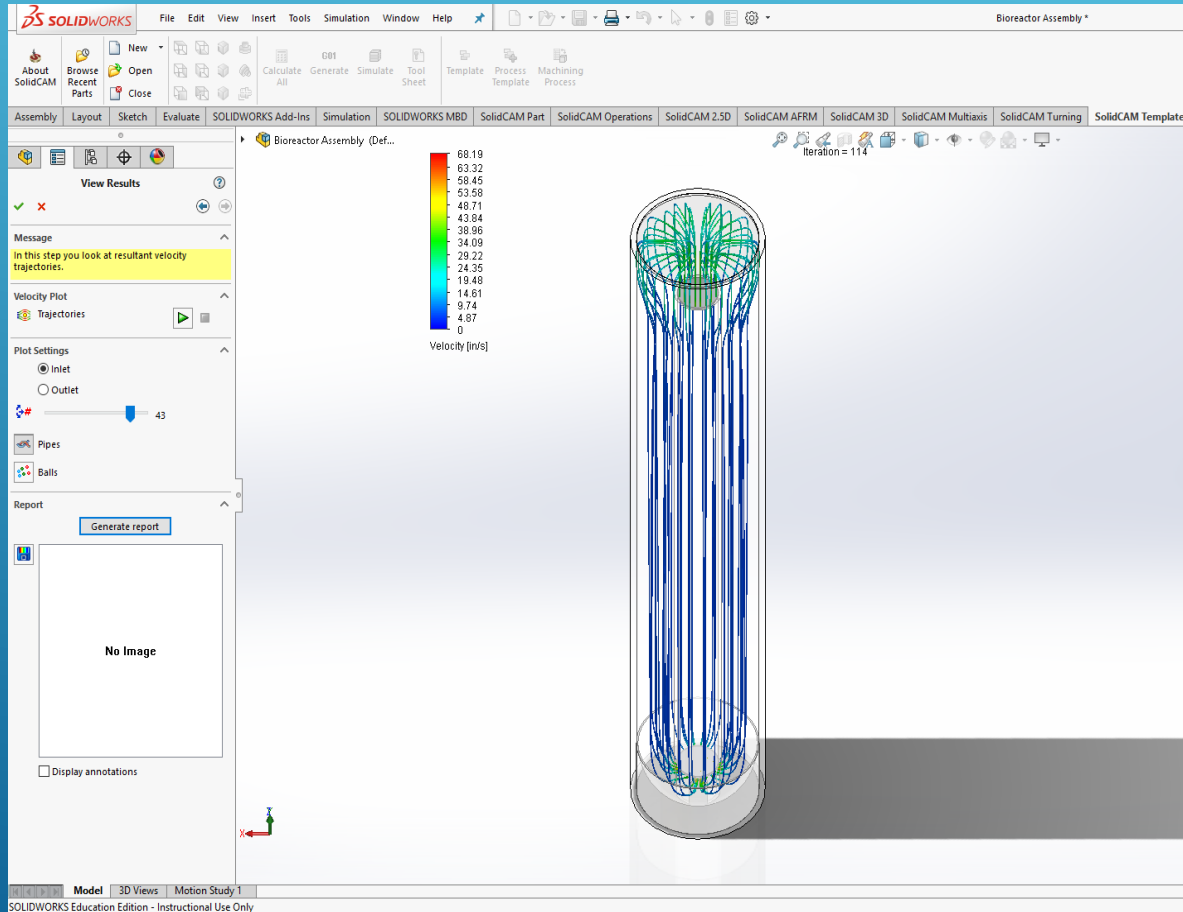


Concentric Design

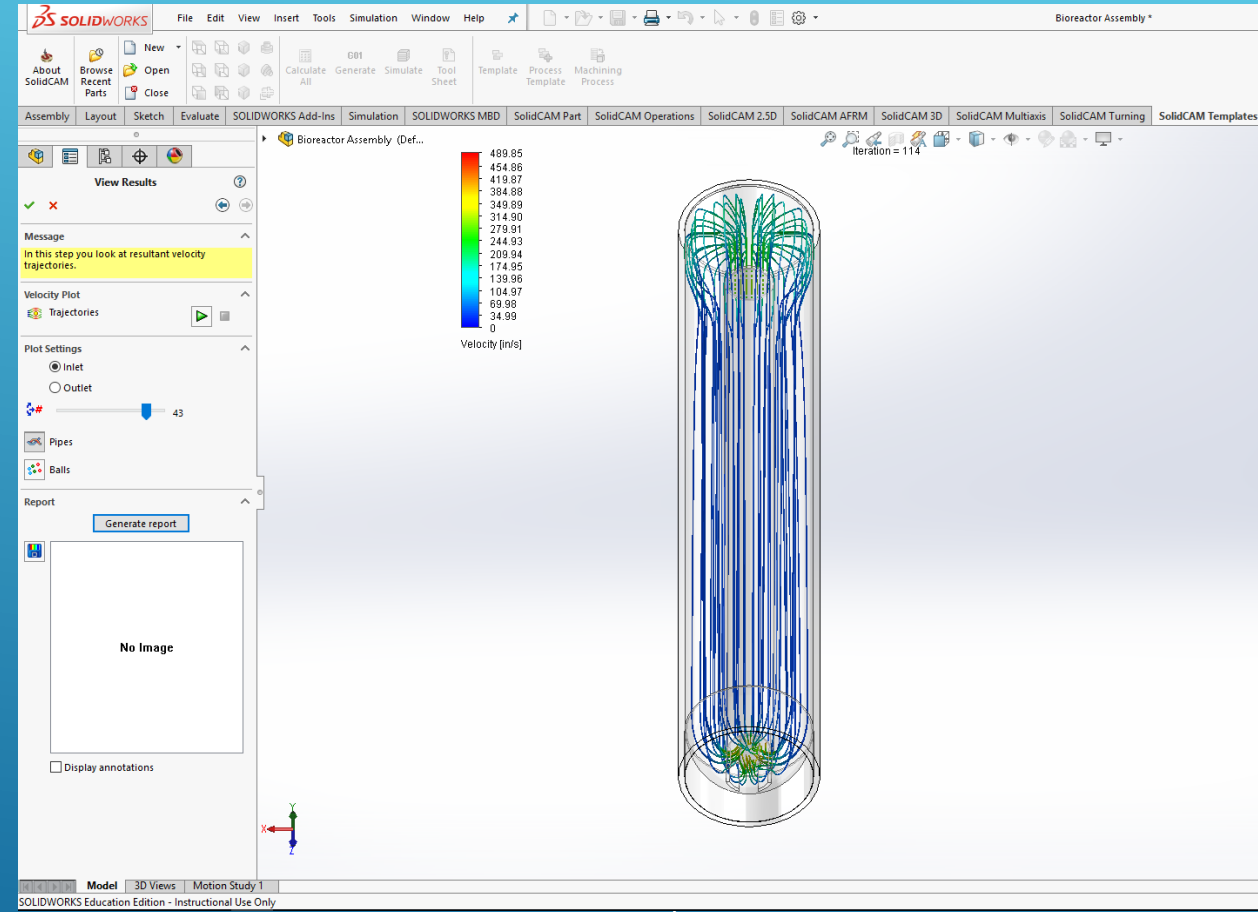


If the sparger is above the inlet, it will generate a dead spot underneath it!

FloXpress Simulations




~1 psi inlet pressure

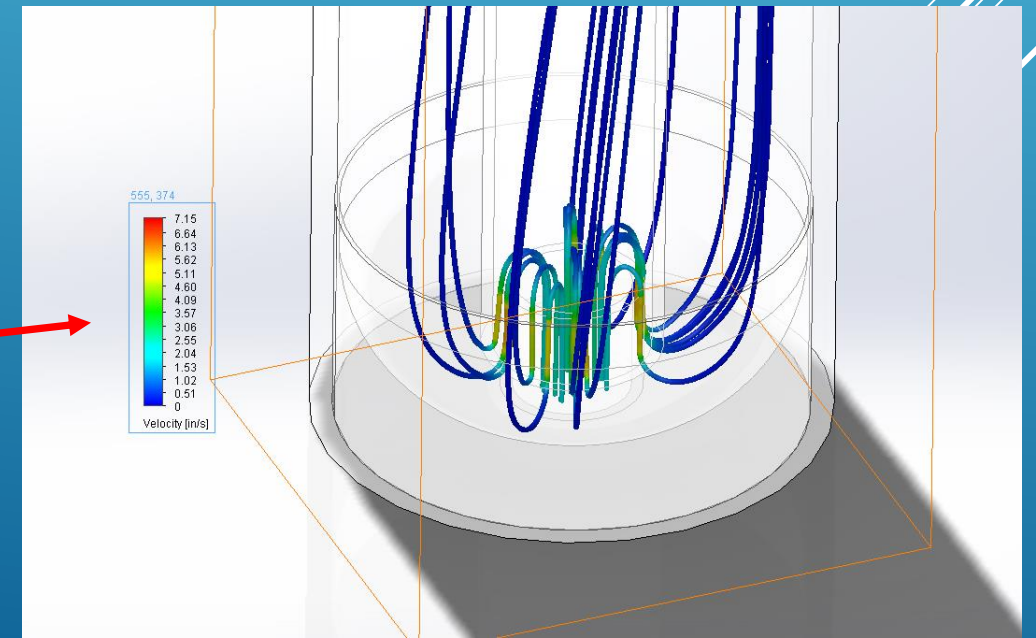
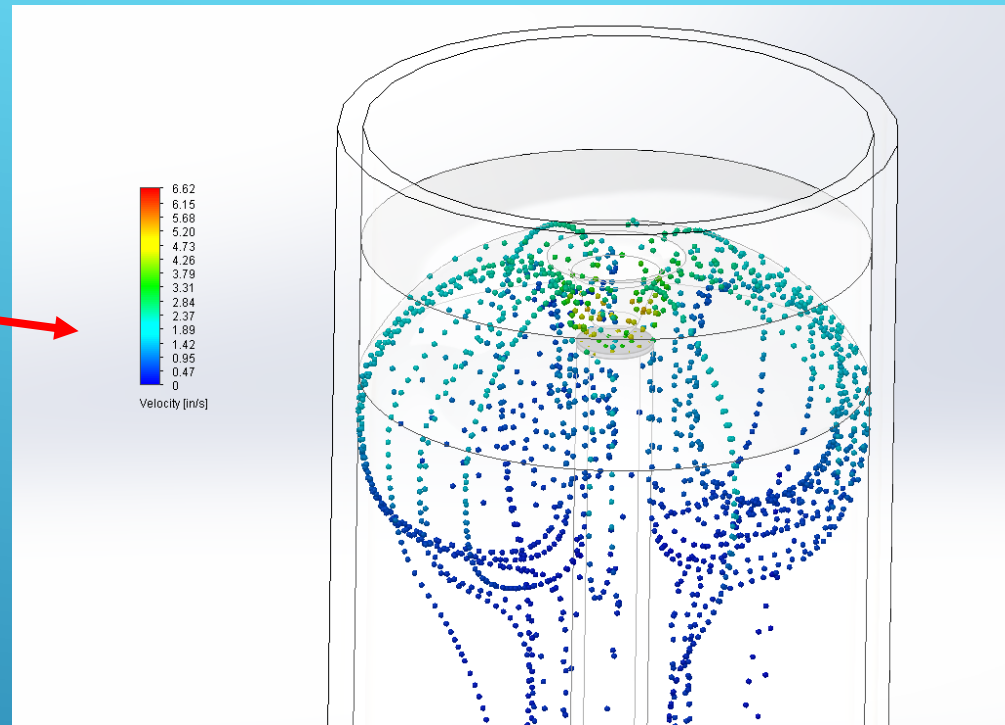
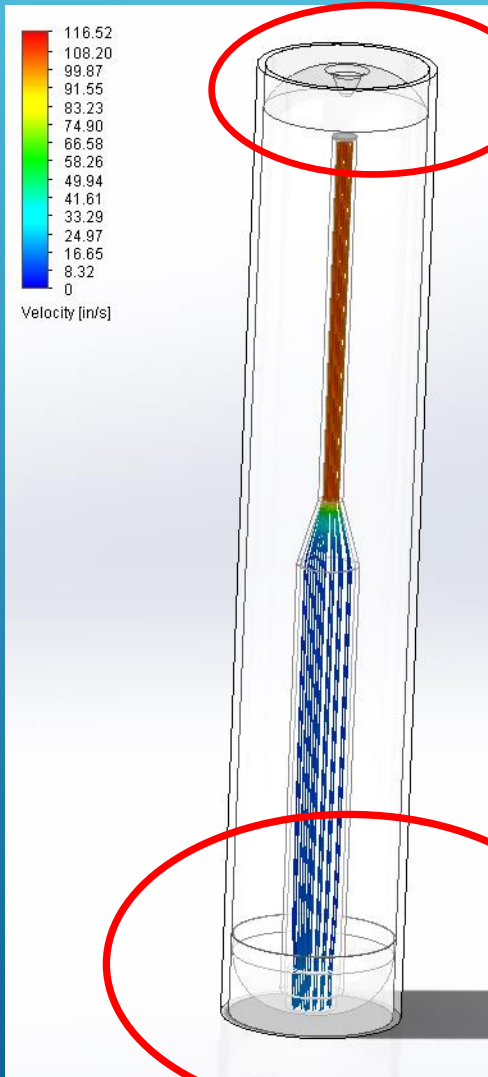


~15 psi inlet pressure

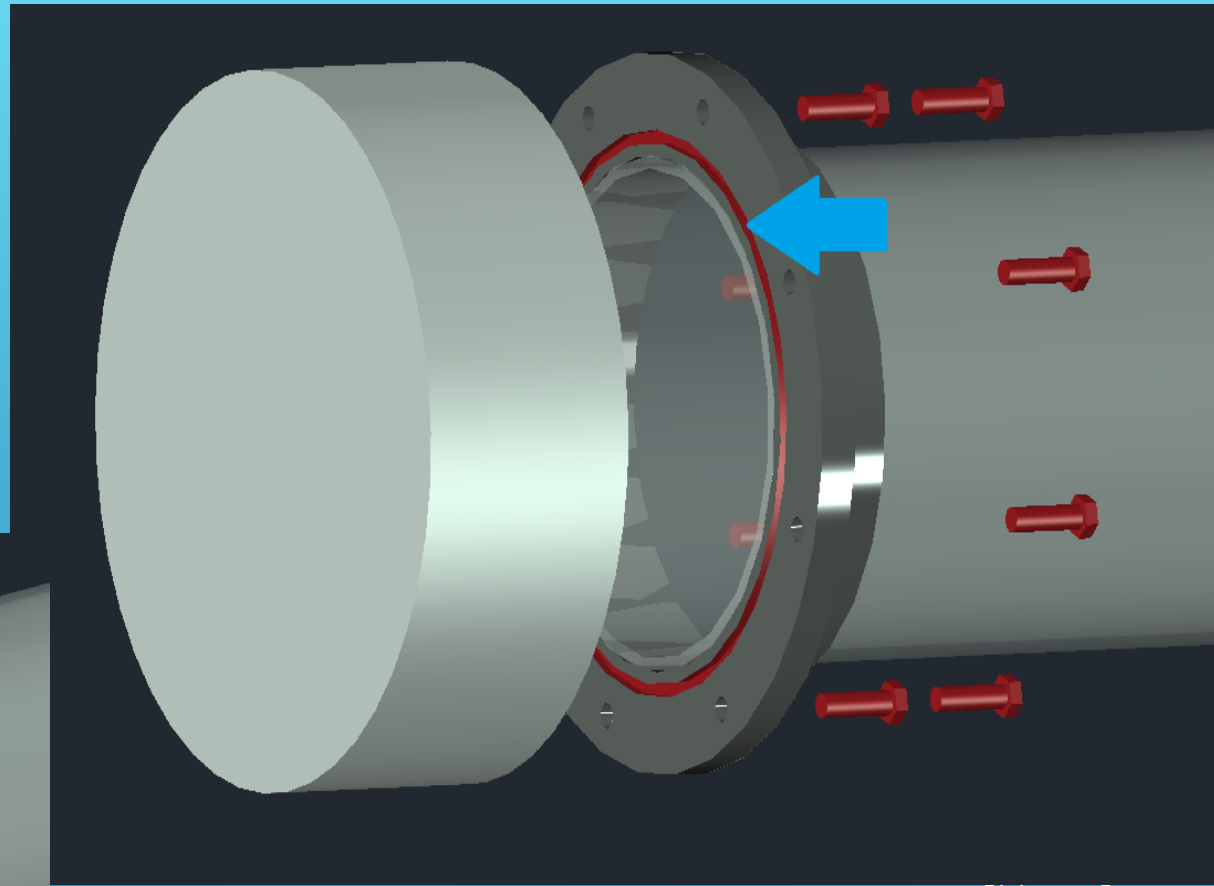
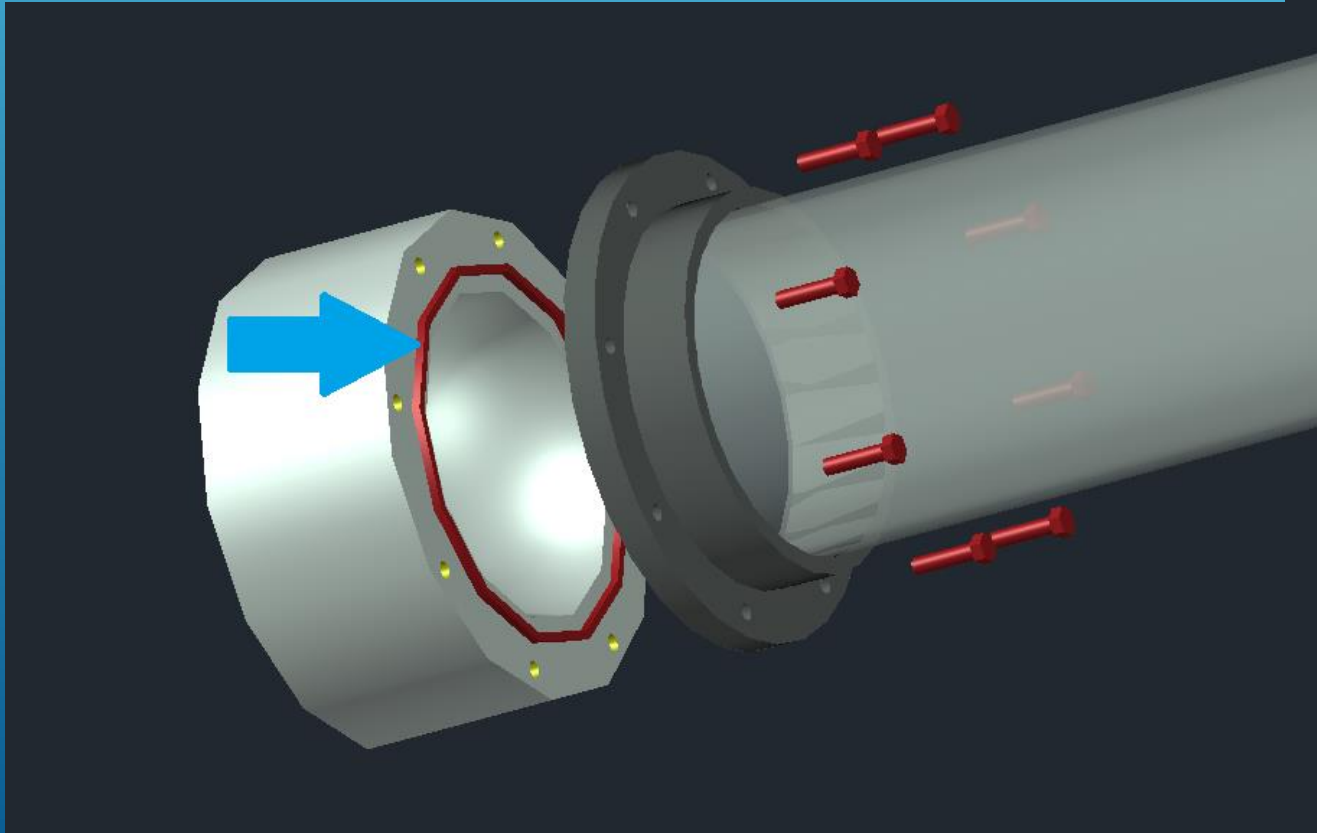
Lessons Learned From Flow Simulation

- ▶ Bottom slots (may) allow gas into the down comer
 - ▶ A flatter bottom with concave corners is more efficient
 - ▶ A guided lid surface may help redirect momentum out of the riser downward and thus promote circulation
- 
- A series of white lines of varying lengths and orientations are positioned in the bottom right corner of the slide, creating a modern, abstract graphic element.

New Design



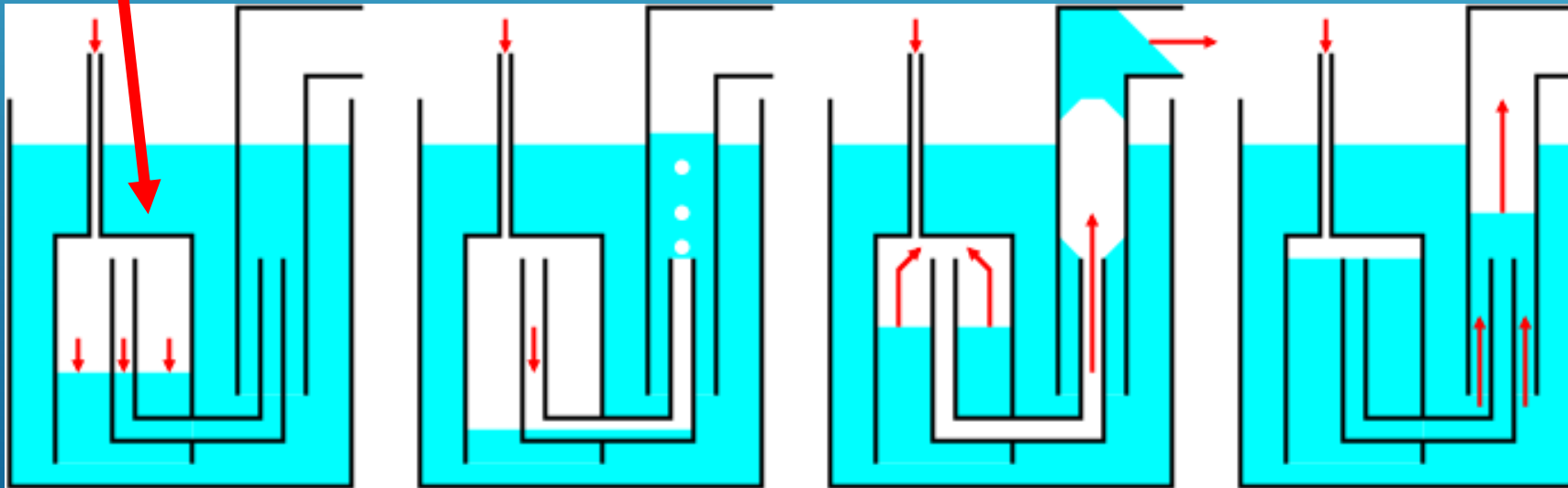
Base Fastening




Another Proposition

Premix tank water with gas and use an auto-siphon mechanism to circulate the fluid

This system (referred to as a geyser pump) would be able to generate a higher circulation force without using a separate pump

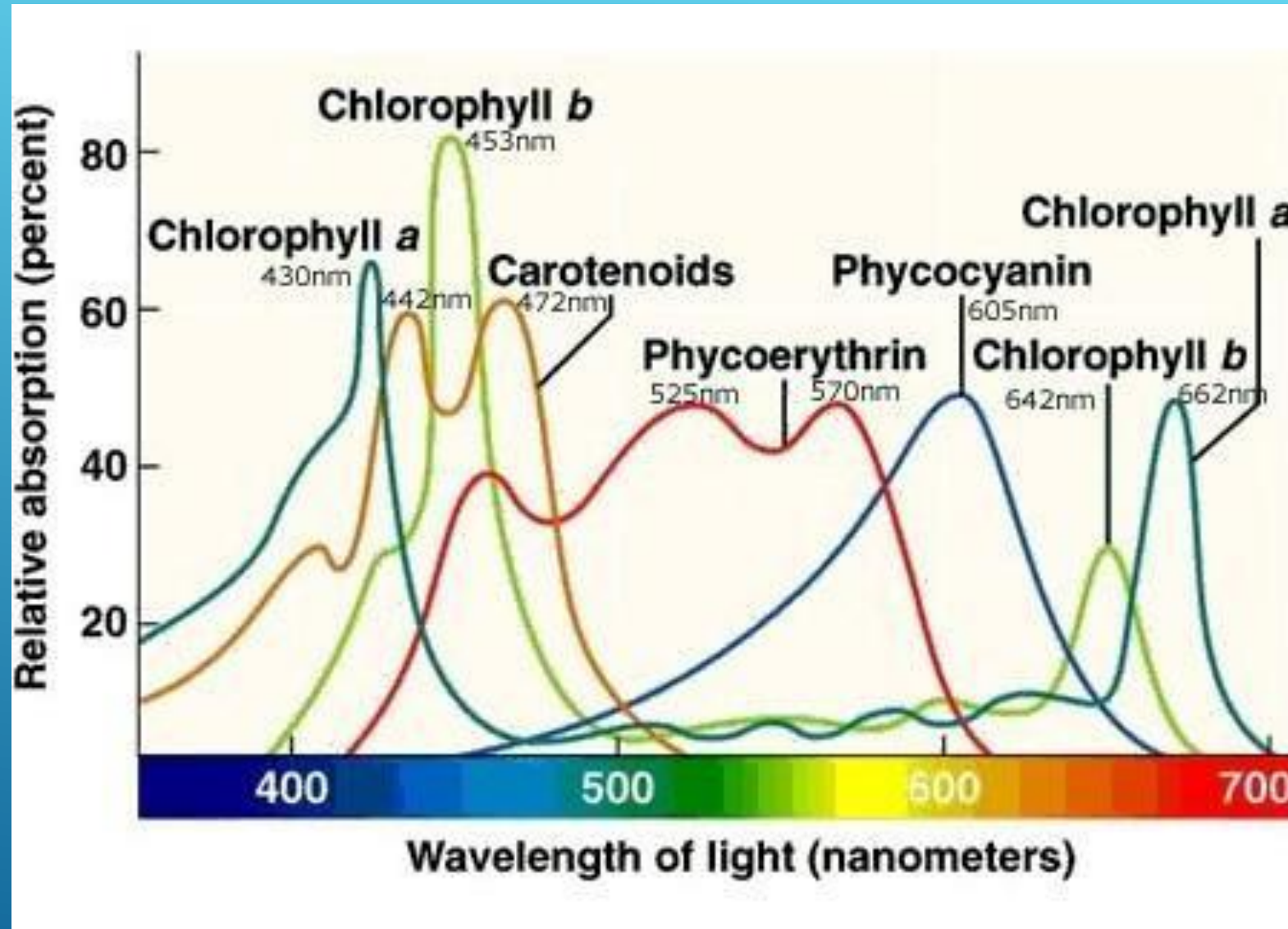


Steps in Choosing Light

- ▶ Determine the major pigments in the algae strain
 - ▶ Choose a light type that emits wavelengths to be absorbed by previous pigments
 - ▶ Choose light array that fits our needs and design
- 
- A decorative graphic consisting of several parallel white lines of varying lengths, slanted diagonally from the bottom right towards the top right, set against a blue gradient background.

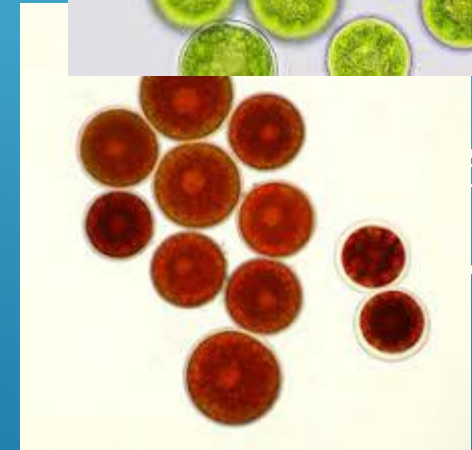
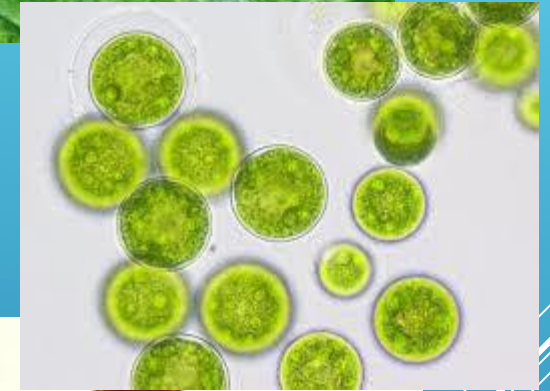
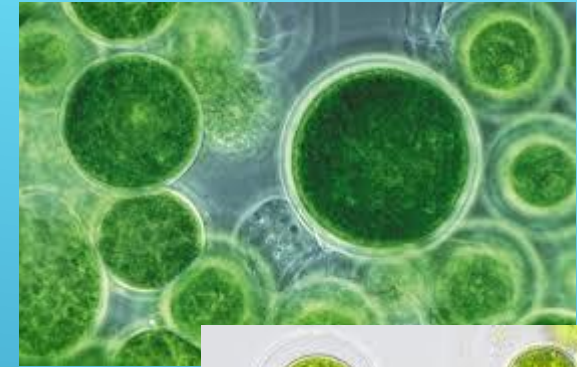
Wavelengths and Pigments

- ▶ Different algae and plants absorb different wavelengths of light based on their types of pigments.
 - ▶ Chlorophyll-a – all plants, algae, and cyanobacteria (bacteria that get energy from light)
 - ▶ Chlorophyll-b – green algae and land plants
 - ▶ Carotenoids – all plants and algae
 - ▶ Phycoerythrin – red algae
 - ▶ Phycocyanin – cyanobacteria



What type Are We Working With?

- ▶ We do not know yet
- ▶ Doesn't really matter
 - ▶ Want the reactor to be very versatile
- ▶ Assume all types



So, What Are We Going to Do?

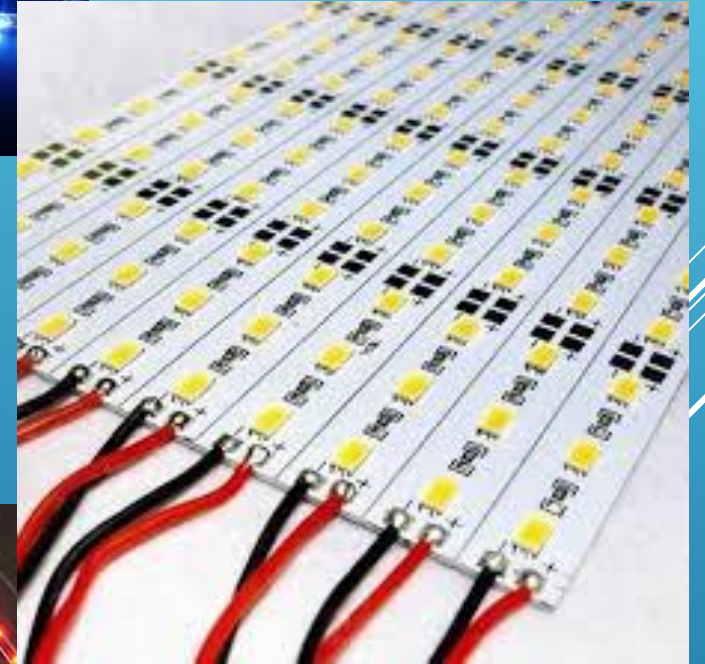
- ▶ RGB LED

- ▶ Customizable to any visible wavelength
- ▶ Use very low power
- ▶ Cheap
- ▶ Program with Arduino



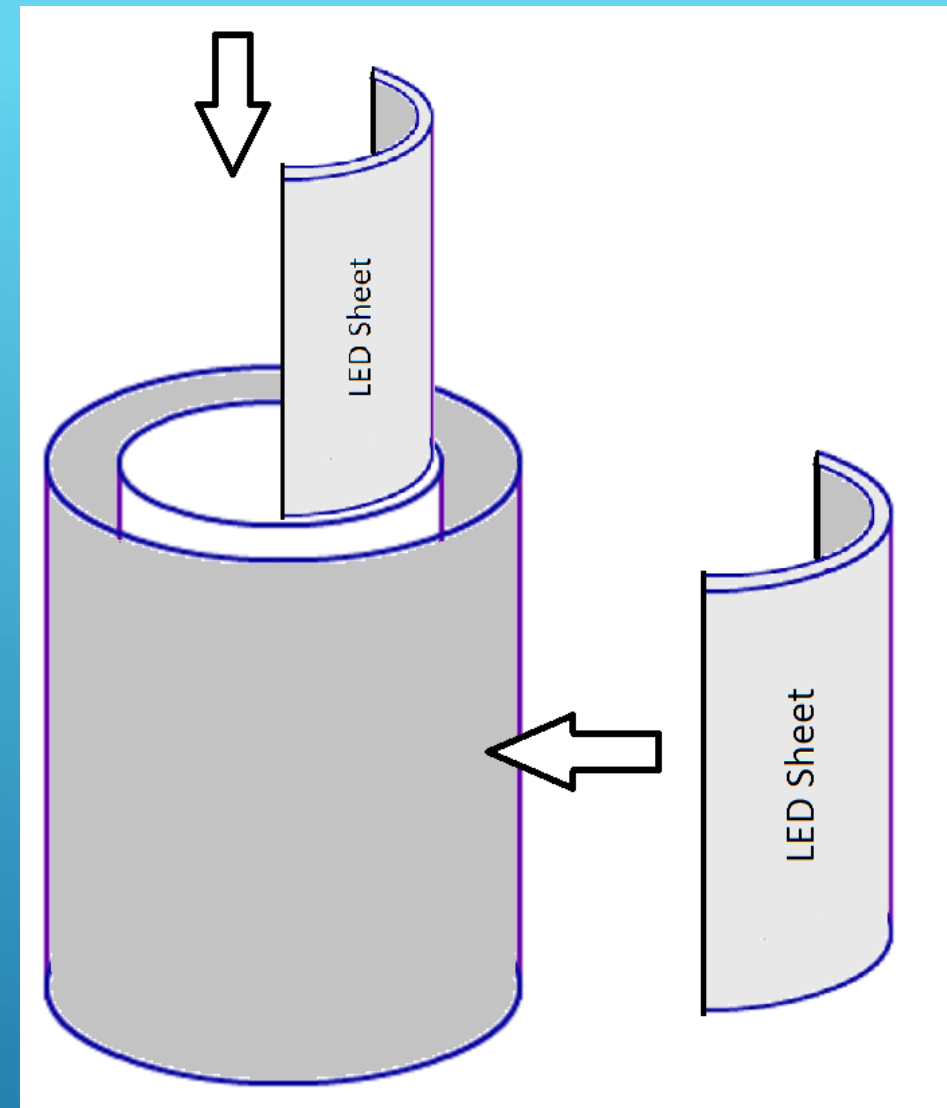
How Are We Going to Build It?

- ▶ Use sheets of LED strips
- ▶ Assemble them so all wavelengths can be represented



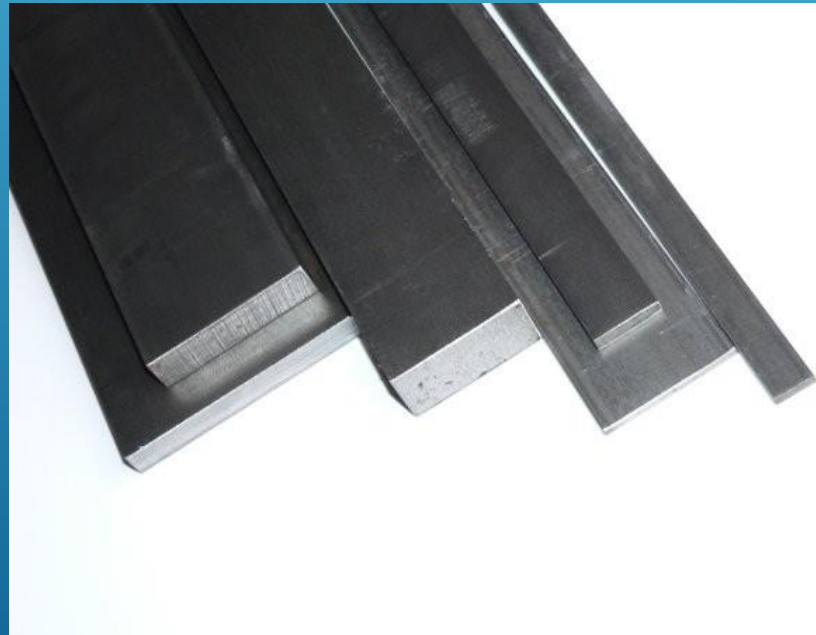
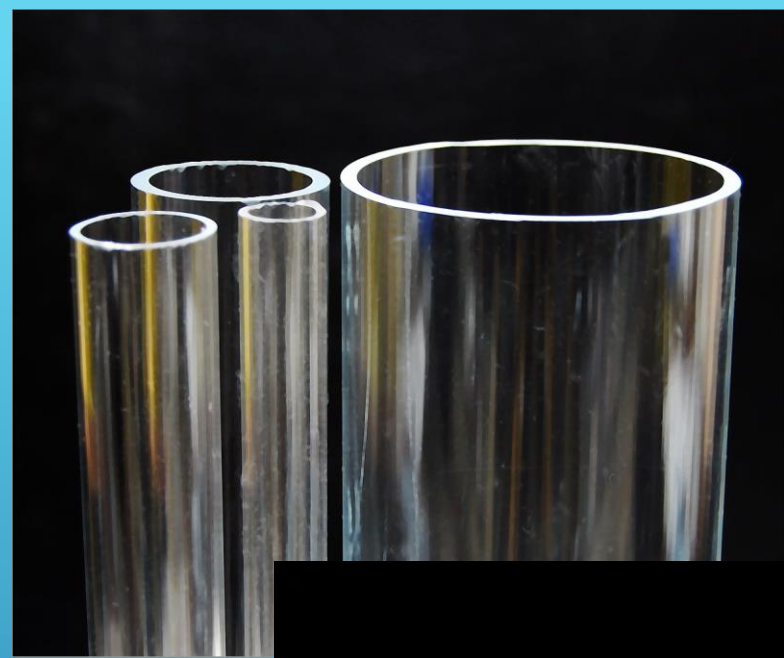
Incorporation to the Design

- ▶ Lay sheets on the downcomer facing in.
- ▶ Lay sheets in the riser facing out.



Construction Materials

- ▶ Clear Plastic Tubing
- ▶ Machinable Plastic for base
- ▶ Steel for Frame



Cost Estimate


11/14/2017

Expense	Category	Budget		Actual	Difference (\$)		Difference (%)	
CO2	Operating	\$	150.00		\$	150.00		100%
Plastic (Base)	Operating	\$	100.00		\$	100.00		100%
Plastic (Cylindrical Column)	Operating	\$	300.00		\$	300.00		100%
Lighting (LED Strip Lights)	Operating	\$	100.00		\$	100.00		100%
Sparger	Operating	\$	40.00		\$	40.00		100%
Regulator & Fittings	Operating	\$	150.00		\$	150.00		100%
Support Apparatus	Operating	\$	50.00		\$	50.00		100%
Sensing Equipment	Operating	\$	200.00		\$	200.00		100%
Control Unit (Arduino)	Operating	\$	80.00		\$	80.00		100%
	Operating				\$	-		
Total Expenses		\$	1,170.00	\$	-	1,170.00		100.00%

Key:

Sensing Equipment: Ammonium,Nitrate, Ph, Temp, Dissolved O2, Algae Density, gas Co2

Current Status

- Flow Analysis
 - Math Model
 - Flow Simulation
 - Construction
 - Valves, Sensors, Fittings
 - Stand
- 
- A series of white lines of varying lengths and orientations are positioned in the bottom right corner of the slide, creating a modern, abstract graphic element.

Questions?

