Team 7: Microalgae Photobioreactor Final Presentation

Stephen Kassing, Diego Soler, Markus Dillman, Matthew Vedrin

Project Advisors:
Dr. Juan Ordonez (Department of Mechanical Engineering, FSU)
Dr. José Vargas (Department of Mechanical Engineering, UFPR)

Stephen Kassing

Presentation Outline

Microalgae for Photobioreactor
Mini Airlift Photobioreactor Design
Algae Growth Equations
Why Semi-Continuous System?
Concentration/Mass Flow Sensor
Addition/Extraction Unit Design
Mechatronic Control Design
Future Plans
Conclusion

Microalgae for Photobioreactor

- Algae use photosynthesis to convert solar energy to chemical energy
  - Store this energy in forms of carbohydrates and proteins

- Chlorella Vulgaris has higher concentration levels and will be used to fill the photobioreactor

Scenedesmus **Chlorella Vulgaris**

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Current Photobioreactor at FSU

- **Current System**: Pump Operated Closed Batch Photobioreactor
  - Requires lots of manual labor and very time consuming!

- **Objective**: Make modifications to this system to make it semi-continuous

- **Plan**: Implement UFPR/FSU Semi-continuous design into the old system

Photobioreactor (Previous Year)

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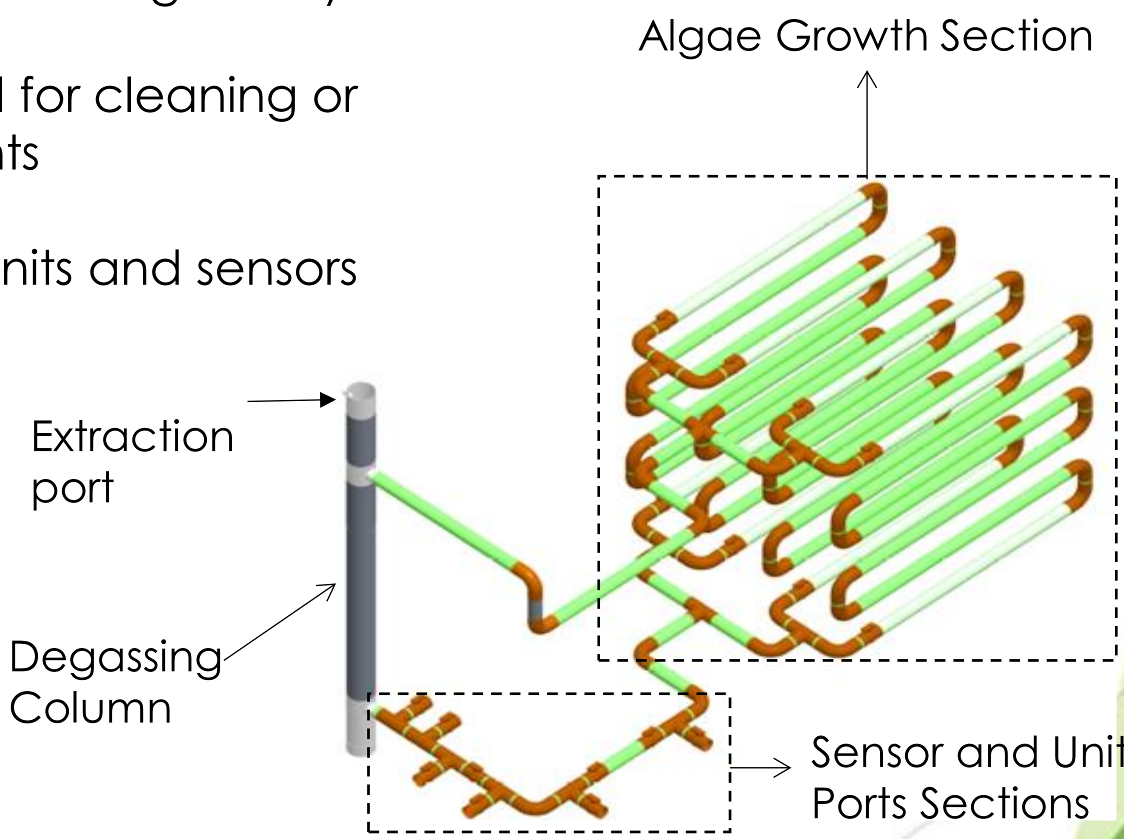
Semi-Continuous Airlift Photobioreactor

- Uniform flow rate throughout system
- Pump is optional for cleaning or other experiments
- Implements all units and sensors



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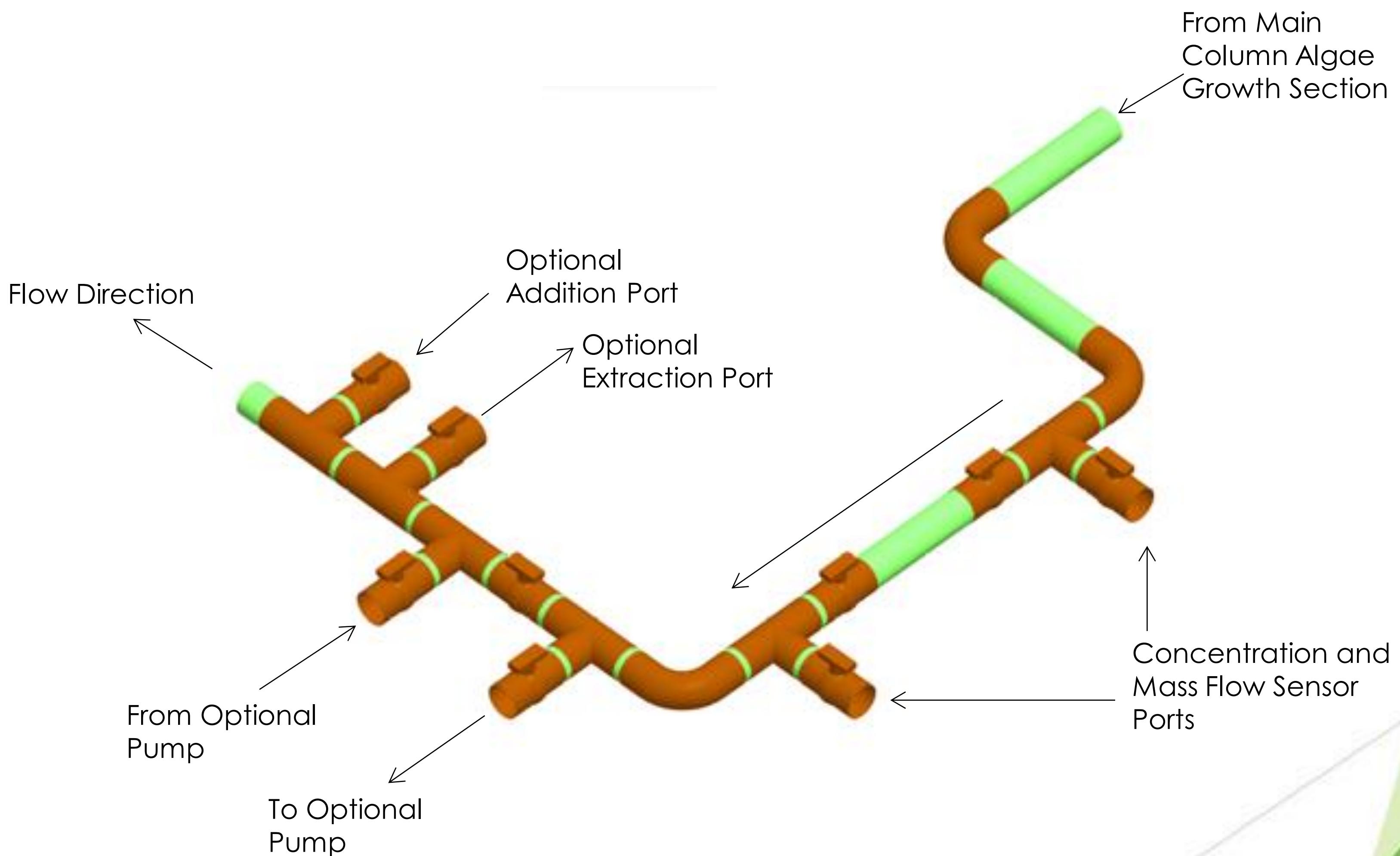
Airlift Sensor and Unit Port Section



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Algae Growth Equations
(Matthew Vedrin)

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Algae Growth Equations

- Batch System Analysis (Exponential Growth)
  - Idealized: No limiting factors (i.e. sufficient light, food, gas exchange, etc.)
  - Real: Clouds, rain, imperfect gas exchange

$$X = X_0 e^{kt} \dashrightarrow X_t = X_0 e^{mt} \dashrightarrow \boxed{m = \ln(X_t / X_0) / t}$$

$$\frac{\ln(X_t / X_0)}{t} = \frac{d}{dt}\ln(X) = \frac{d\ln(X)}{dX} \times \frac{dX}{dt} = \frac{dX/dt}{X} \dashrightarrow \boxed{m = \frac{dX/dt}{X}}$$

- Physical significance of specific growth rate: rate of change in concentration over concentration

X_0 ° *Initial concentration* $= [g/L]$ $\quad$ t ° *Time* $= [h]$ $\quad$ dX ° *Differential change of concentration* $= [g/L]$

X_t ° *Concentration at time,* $t = [g/L]$ $\quad$ m ° *Specific growth rate* $= [h^{-1}]$ $\quad$ dt ° *Differential change of time* $= [h]$

Matthew Vedrin

Algae Growth Equations

- Continuous System Analysis (Mass Balance)

$$Net\ increase\ in\ biomass = Growth - Biomass\ removal$$

$$VdX = V\mu Xdt - FXdt \longrightarrow \frac{dX}{dt} = \mu X - \frac{F}{V}X = (\mu - D)X$$

<u>Steady State</u>

$$\frac{dX}{dt} = 0 \rightarrow \mu = D$$

<u>Transient State</u>

$$\frac{dX}{dt} = (\mu - D)X$$

$$\mu' = \frac{dX/dt}{X} = (\mu - D)$$

$dx \equiv Differential\ change\ of\ concentration = [g/L]$

$dt \equiv Differential\ change\ of\ time = [h]$

$V \equiv Total\ volume = [L]$

$\mu \equiv Specific\ growth\ rate = [h^{-1}]$

$X \equiv Concentration = [g/L]$

$F \equiv Addition\ rate = [L/h]$

$D \equiv Dilution\ rate = [h^{-1}]$

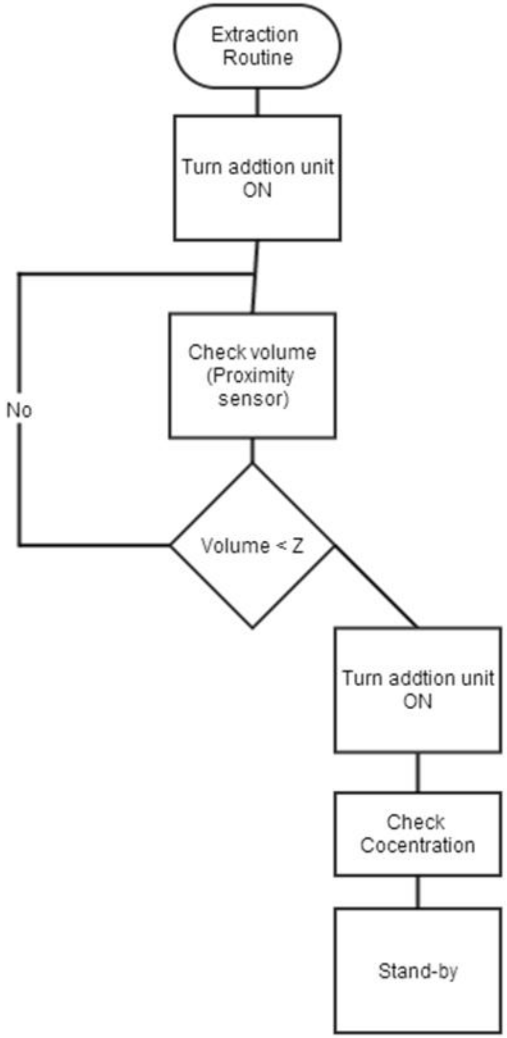
Matthew Vedrin

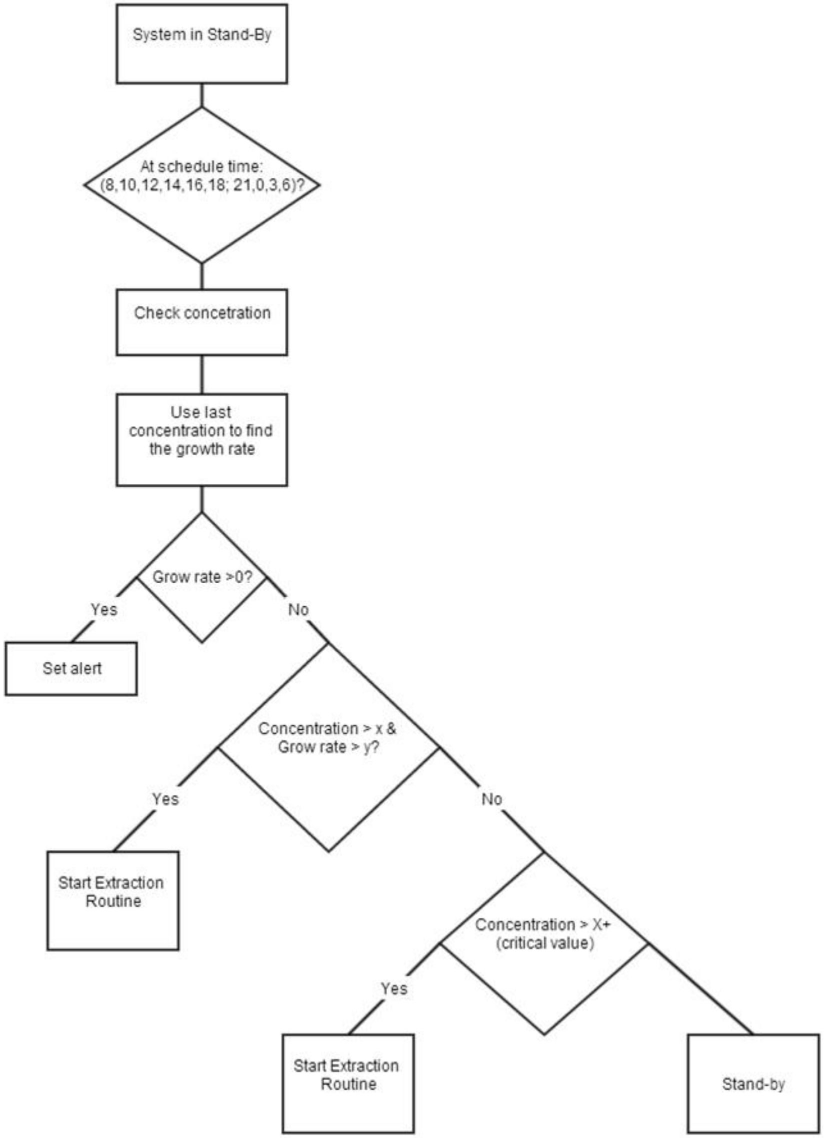
Why Semi-Continuous System Over Continuous?

- **Original Concept**: Fully automated and continuous system to improve growth of algae
- **Semi-Continuous System:** Addition and extraction does not happen continuously but periodically
- **Cons of a Continuous System**
  - Very complex design and research needed
  - Variable speed pump and computer controlled valves are expensive and outside our budget
  - The optimal concentration for operation is still unknown

Markus Dillman

Mechatronic Control





Diego Soler

Addition/Extraction Unit Control

- Target addition/extraction concentration: N_h = 800
- Target post-dilution concentration: N_0 = 500

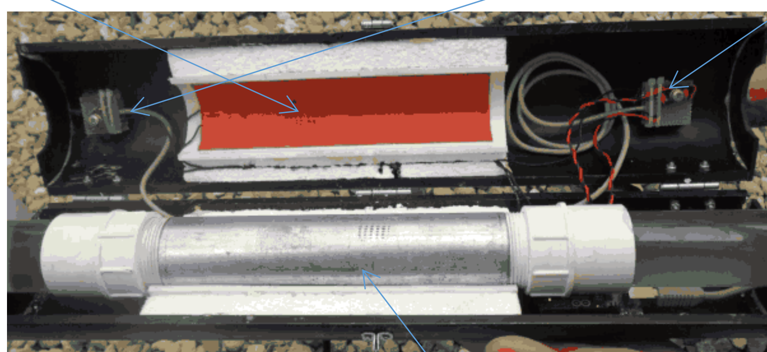
Example Dilution Process for 24 Hours					
Day	Time of Day	Measured Concentration 1 (N_t1)	Dilute?	Measured Concentration 2 (N_t2)	Notes
1	08:00 AM	500	NO	500	System Start
1	10:00 AM	650	NO	650	Low concentration
1	12:00 PM	850	YES	500	Target conc. & sufficient growth rate
1	02:00 PM	600	NO	550	Low concentration
1	04:00 PM	750	YES	500	Close to target conc. & high growth rate
1	06:00 PM	550	NO	550	Cloudy for past 2 hours
1	08:00 PM	615	NO	615	Light intensity is down
1	11:00 PM	675	NO	675	Night growth
1	3:00 AM	715	NO	715	Night growth
1	6:00 AM	765	NO	765	Close to target conc. but insufficient growth rate
2	08:00 AM	800	YES	500	Target conc. & sufficient growth rate

non-linear growth

Mass Flow Sensor

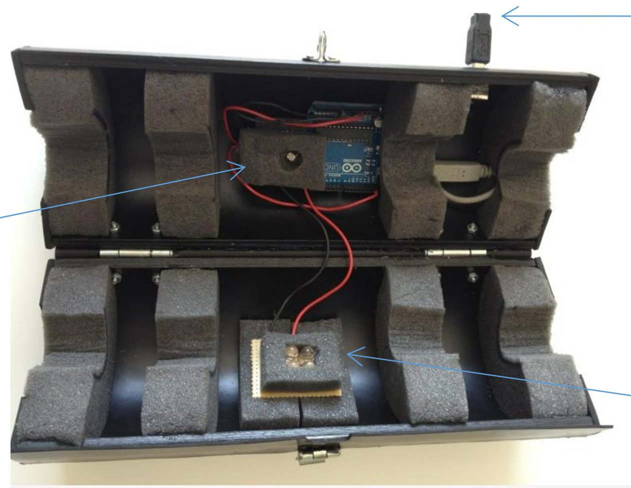
- Mass flow is measured using a basic thermodynamic property which correlates heat input to mass flow rate and the equation is below:

$$\dot{m} = \dot{Q}/(C_p * \Delta T)$$



Concentration Sensor

- LED's emit light through the PVC pipe to a sensor on the other side of the pipe
- This sensor's resistance varies with the amount of light and is converted to voltage
- **Calibration**: comparison tests from counting the algae under a microscope and correlating it to the resistance recorded from light sensor.



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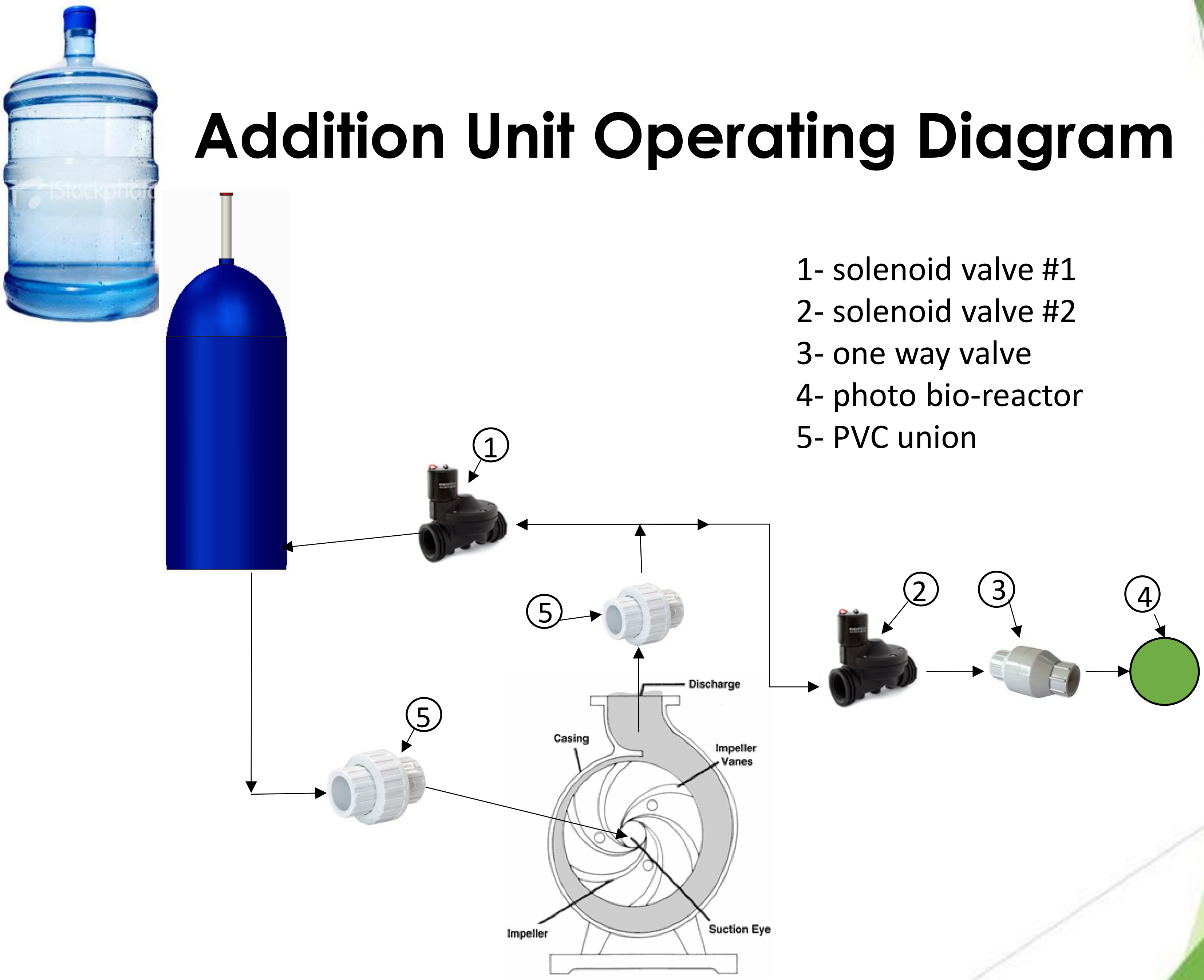
Addition Unit Design Concept

- Media storage container is located above pump to maintain minimum required pressure head to avoid cavitation
- Pipe network from pump to photobioreactor will contain valves with major and minor head loss which create pump resistance
- Pumping pressure must be higher in the pump than in the photobioreactor to obtain flow into the system
- These head losses can be plotted and match up with the pump curve to find the operating point for the addition unit
- The algae food storage tank will have buoy with distance sensor to determine how much volume has entered the photobioreactor
- Distance sensor will also tell us when we reach the minimum volume inside the unit or when the storage tank needs to be refilled

Markus Dillman

Addition Unit Operating Diagram

1- solenoid valve #1
2- solenoid valve #2
3- one way valve
4- photo bio-reactor
5- PVC union



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Materials For Addition/Extraction Unit

Calculations for Addition Unit Design			
		Qty	Cost
General Materials	PVC Cement Glue	1	$3.67
		subtotal	$3.67
Addition Unit	* Size 1 NPT		
Major Components			
Pipe network from pump to PBR	PVC Straight Pipe (10ft, 1 in D)	1	$3.49
	PVC union	1	$4.96
	90 deg connections (5pk)	1	$2.97
	solenoid valve (automatable)	2	$50.00
	check valve	1	$8.95
	end cap (5pk)	1	$2.53
		subtotal	$72.90
Pipe network from food storage to pump	1in adapter	2	$0.66
	PVC union	1	$4.86
	PVC Straight Pipe (10ft, 1 in D)	1	$3.49
	1/2 in adapter	1	$0.46
	distance sensor	1	$12.99
	1 1/2 pvc straight pipe (10ft)	1	$5.16
	5g Water Jug	1	$20.00
		subtotal	$47.62

Extraction Unit				
Overflow System	4x4x1 in T connection		1	$15.79
	PVC Straight Pipe (10ft, 1 in D)		1	$3.49
	5g Water Jug		1	$20.00
			subtotal	$39.28
			TOTAL	$163.47

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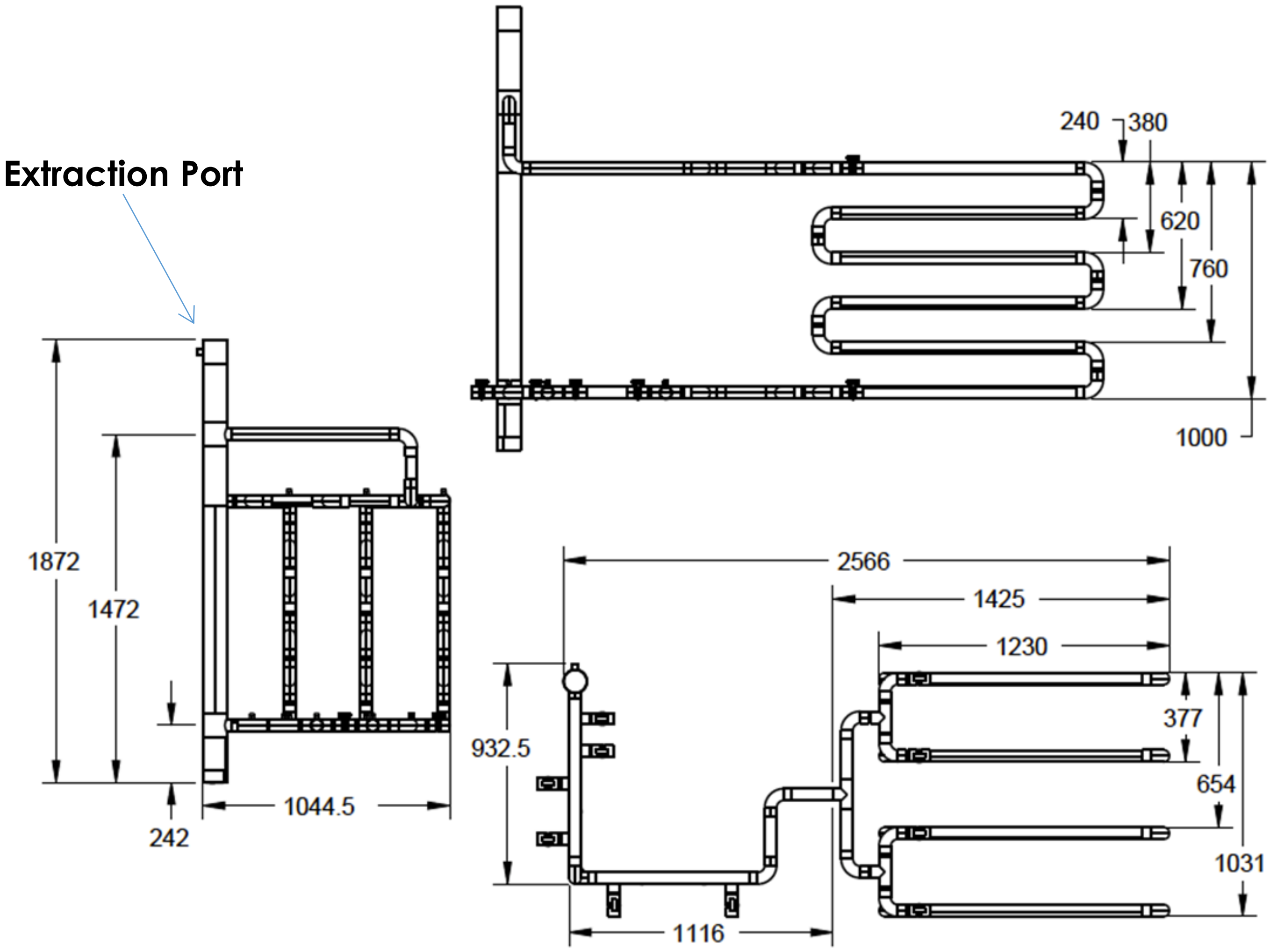
Airlift CAD Drawings



Airlift Photobioreactor Unit (all units in mm)

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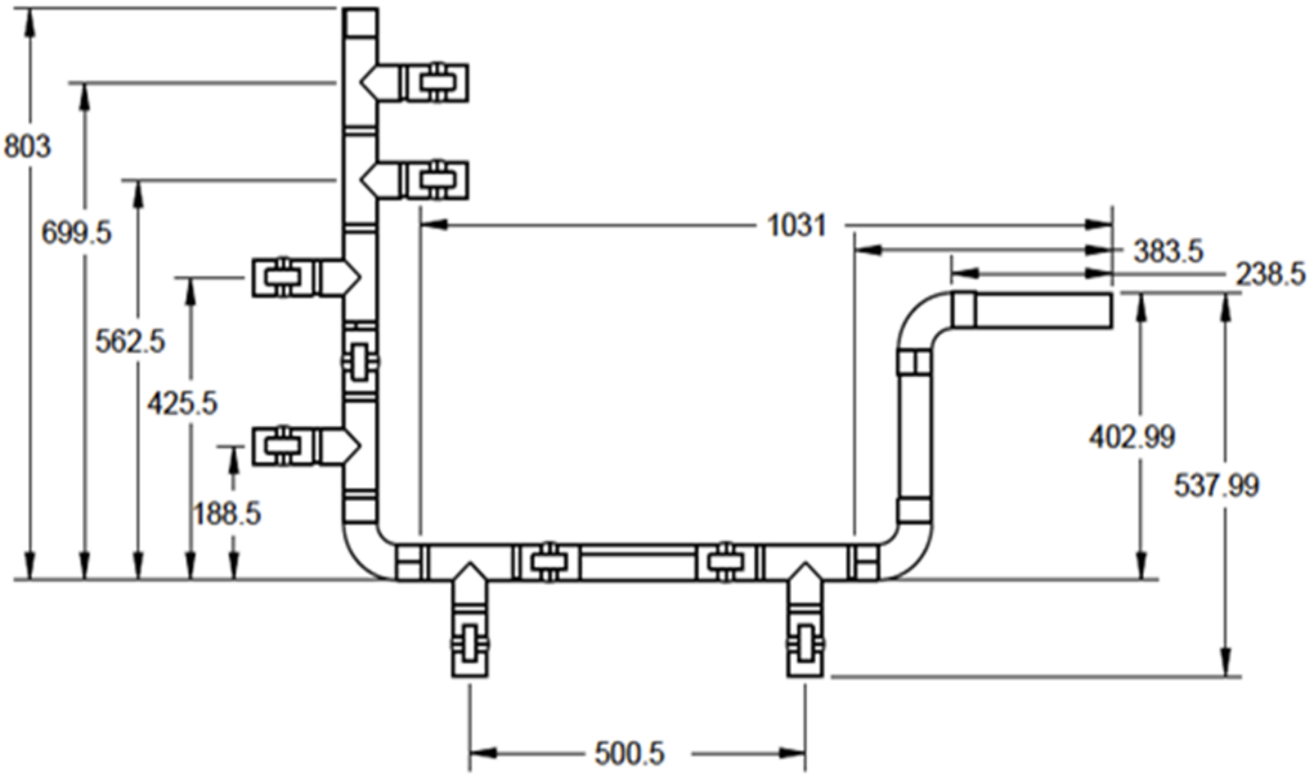
Airlift CAD Drawings



Sensor and Units Port Section (all units in mm)

Future Plans (Spring Semester)

- ✓ **WEEK 4**: Test Unit and Calibration of Concentration Sensor Completed
- ✓ **WEEK 6**: Control/Communication Design Complete
- ✓ **WEEK 6**: All parts for new airlift photobioreactor with unit prototypes (CAD) and purchase orders completed
- ✓ **WEEK 8**: All parts for new units arrive at FSU
- ✓ **WEEK 9**: New airlift photobioreactor built and perform first water test

Future Plans (Spring Semester)

- **WEEK 9**: Control/Communication Purchase forms complete and submitted
- **WEEK 10**: SPRING BREAK
- **WEEK 13**: Algae placed in airlift photobioreactor and testing started
- **WEEK 14-15**: Troubleshoot and evaluate test results

Questions?