Automated Flow Control and Mixing Performance in Fluidized Bottle Upweller Systems

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Motivation

Fluidized bottle upweller systems (BUPSYs) use upward flow to suspend oyster spat, promoting uniform feeding and growth. However, industry-standard criteria for setting flow are not well defined, and little testing has been done to evaluate the effectiveness of different silo geometries. Because growth depends on maintaining a consistent fluidized state over time, this work evaluates flow-setting strategies and silo geometries to quantify their impact on mixing . These insights to inform an automated flow-control system that maintains target operating conditions with reduced labor.

Objective

Flow and Geometry Testing

1. Compare flow setting strategies
2. Testing mixing performance of silo geometries

Automated Flow Control System

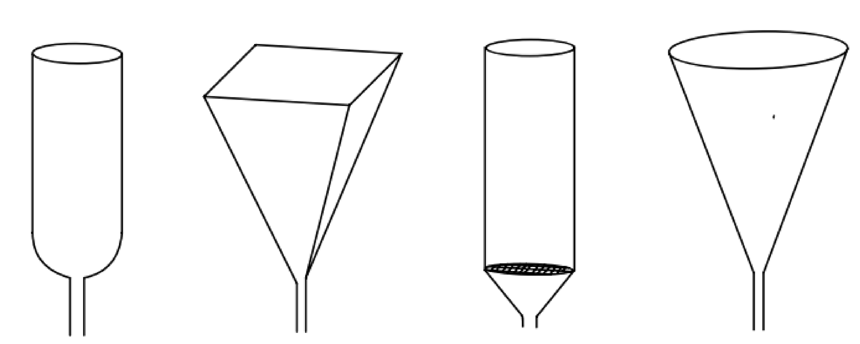
1. Integration of camera and flow sensor to control flow valve

Flow Setting Strategies

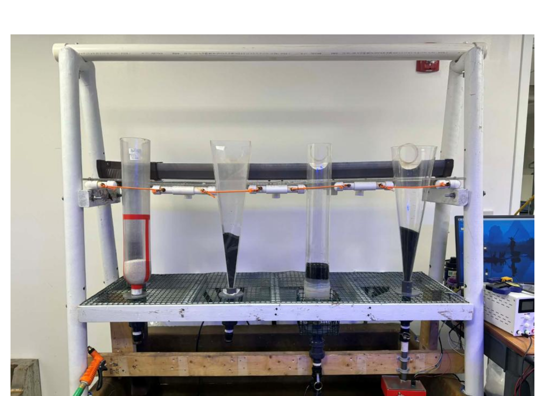
Strategy A: Increase flow until bed expansion of 35% is achieved

Strategy B: Increase flow until bottom layer of spat is moving (indicating the onset of a fully fluidized bed)

Silo Geometries



Hipped Cylinder | Inverted Pyramid | Straight Cylinder | Inverted Cone



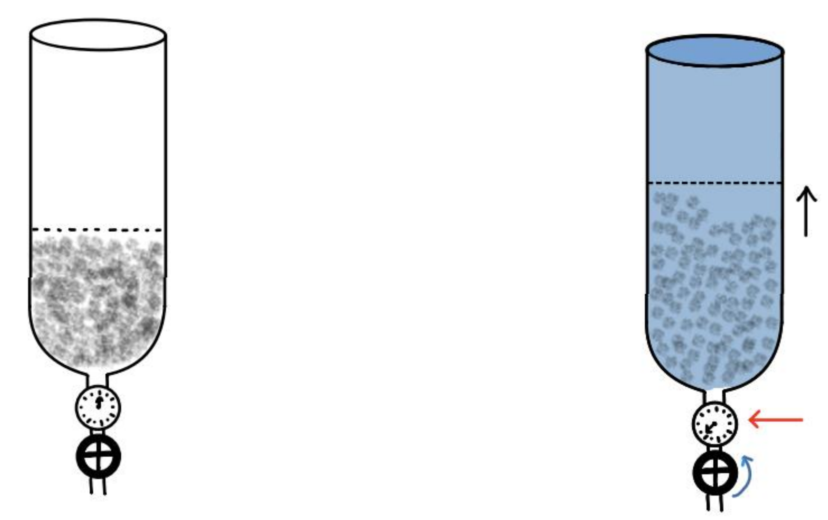
BUPSY setup used for testing flow setting strategies and silo geometries.

Comparing Flow Strategies

Objective

- Measure the input flow (L/min) of the two strategies
- Determine the bed expansion that corresponds to onset of fluidization for each silo geometry

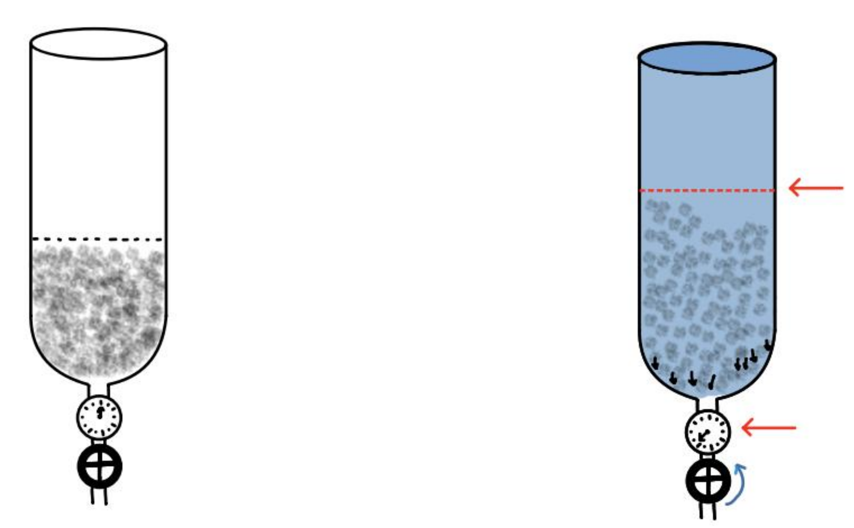
Method A: Bed Expansion



Add 500 ml of sand (size 400 - 700 um) into the silo and mark the packed bed height

Increase flow until fluidized bed height is 135% of the packed bed height and measure flow rate

Method B: Onset of Fluidization



Add 500 ml of sand (size 400 - 700 um) into the silo and mark the packed bed height

Increase flow until bottom layer of sand just begins to move; mark the measured flow rate and the fluidized bed height

Results

Average Flow Valve Corresponding to 35 % Bed Expansion and Onset of Fluidization Different Silo Geometries

Silo Geometry	Bed Expansion Flow	Onset Fluidization Flow
Hipped Cylinder	15 L/min	13 L/min
Inverted Pyramid	11 L/min	10 L/min
Straight Cylinder	14 L/min	13 L/min
Inverted Cone	10 L/min	9 L/min

Bed Expansion corresponding to Onset of Fluidization for Different Silo Geometries

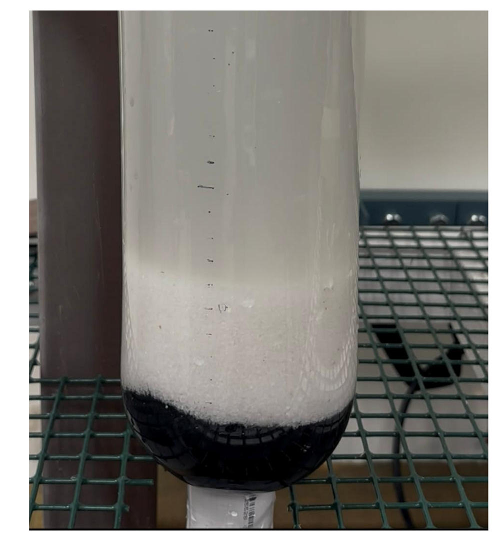
Silo Geometry	Bed Expansion
Hipped Cylinder	27%
Inverted Pyramid	23%
Straight Cylinder	27%
Inverted Cone	24%

Comparing Silo Geometries

Objective

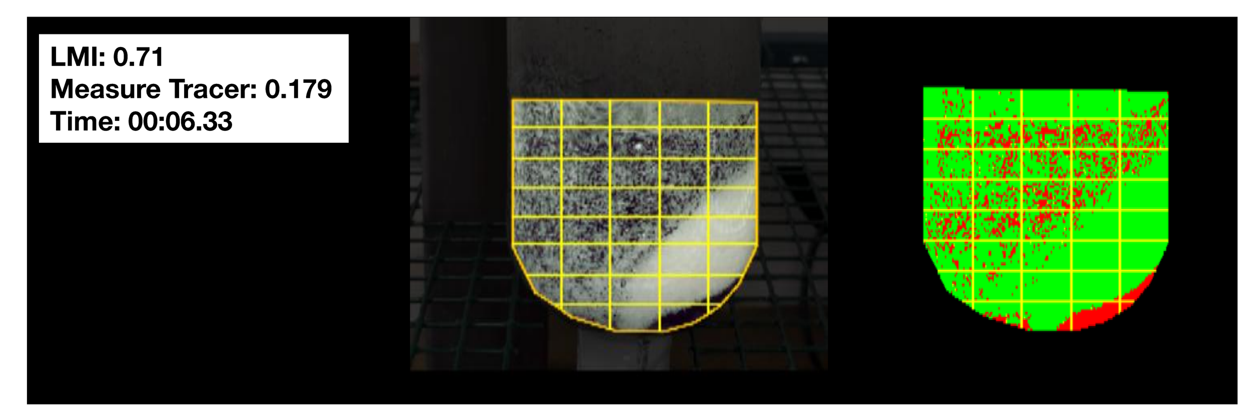
Determine which silo geometry best promotes mixing of spat

Method



Add a layer of 100 mL black sand to the bottom of the silo followed by 400 mL of white sand

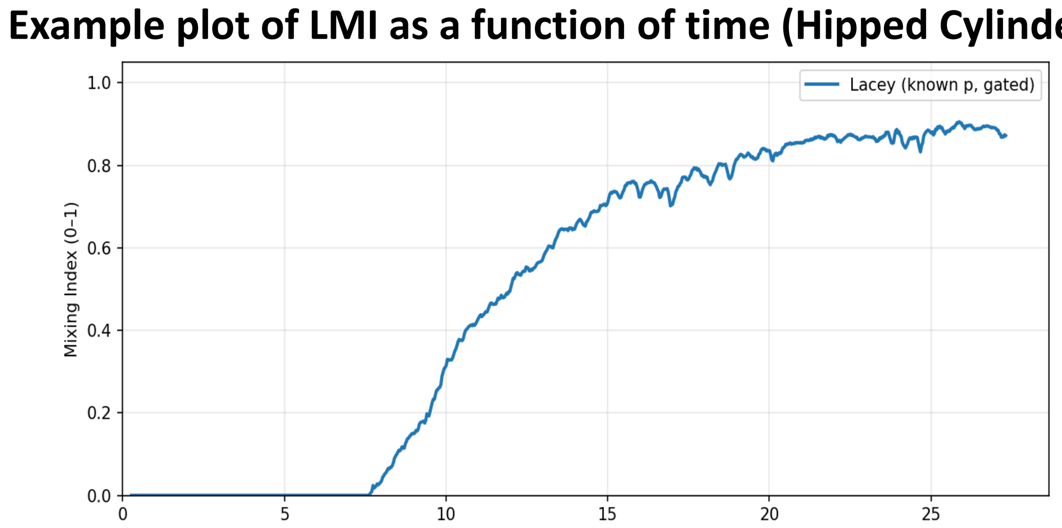
Increase the flow until the fluidized bed reaches 35% expansion



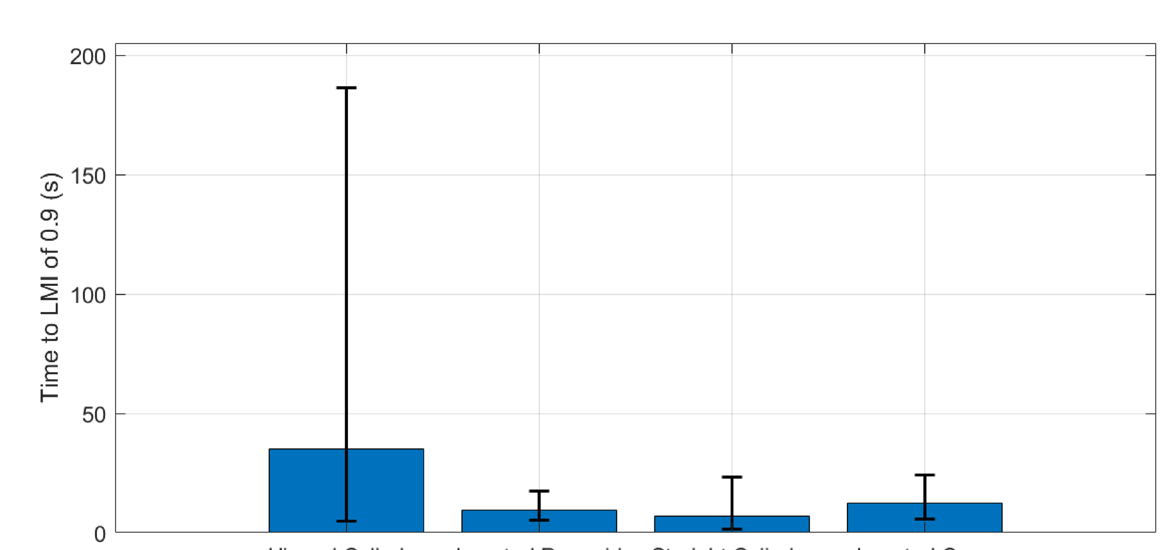
A camera tracks dyed cultch to measure the time to reach a Lacey Mixing Index (LMI) of 0.9, used as a proxy for particle redistribution and mixing effectiveness across silo geometries.

Results

Example plot of LMI as a function of time (Hipped Cylinder)



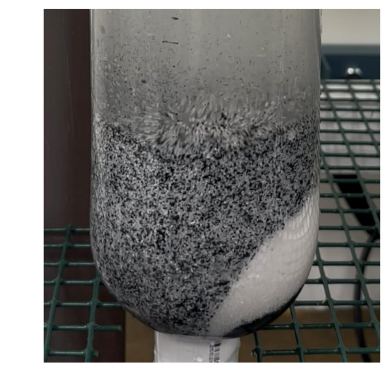
Time for each Silo Geometry to reach a LMI of 0.9 where flow is set for 35% Bed Expansion



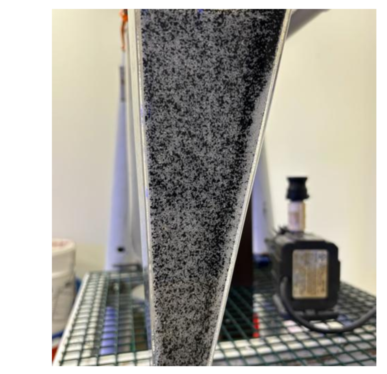
*error bars are calculated for 95% confidence interval in log space and n=3 trials

Comparing Silo Geometries

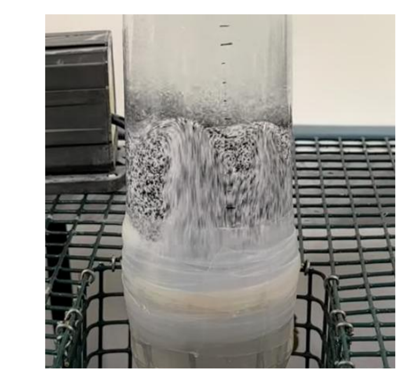
Qualitative Observations of Different Silo Geometries



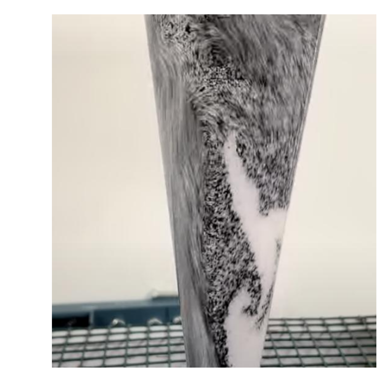
Hipped Cylinder
Limited channelization causes particles move as a single mass rather than mix.



Inverted Pyramid
Geometry-dependent dead zones near the corners resulting in clumps



Straight Cylinder
Channelization results in effective mixing; bottom-layer behavior was slightly obscured by tape



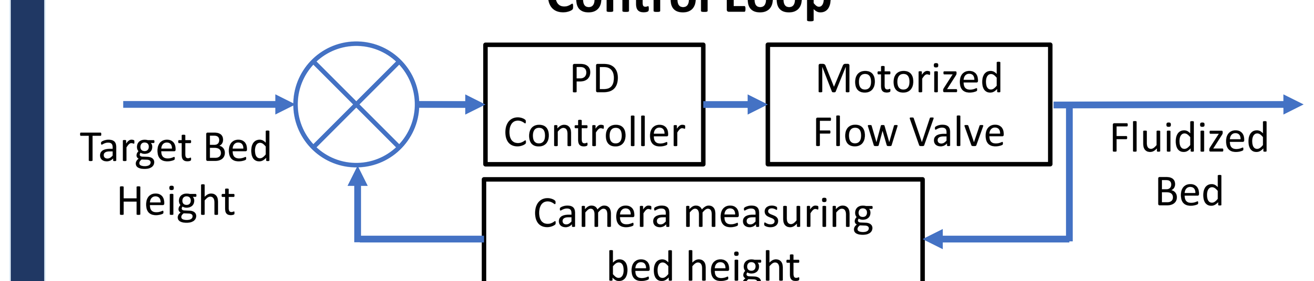
Inverted Cone
Asymmetric spiral channel results in effective mixing despite uneven local velocities.

Automated Flow Control System

System Overview

- Overhead camera measures bed height in real time
- Motorized valve adjusts flow to maintain target expansion
- PD controller compensates for disturbances (e.g., pump drift)

Control Loop



Hardware

Motor housing clamps to existing valve and gear train drives valve position

Conclusion

Key Takeaways

- Silo geometry does not significantly affect mixing time, but greatly influence flow patterns
- Bed expansion is a reliable, observable metric for achieving fluidization, but does not consider oyster growth

Next Steps

- Integrate dense optical flow with bed expansion to dictate flow
- Field validation with live oysters to link flow profiles to growth