Advancing Land-Based Shrimp RAS Engineering & Design

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RAS Engineering & Design

- We’ve come a long way in advancing the state of the art.
- Systems are now designed using a disciplined process that considers mass balances, heat balances, and unit process engineering.
- Fundamental design parameters have been characterized for various species, environments, and unit processes.
- Advanced tools and techniques are routinely employed.

RAS Engineering & Design

Design parameters have been defined for:

- Water quality requirements and metabolite production
- Hydrodynamics for self-cleaning tanks, mixing and fish health
- Kinetics and capacity of biofilters to oxidize TAN
- Efficiency and capacity of oxygenation devices
- Efficiency and capacity of carbon dioxide removal devices
- Filter sizing and settling velocities for clarifiers
- Many others…

RAS Engineering & Design

Shrimp RAS can take advantage of finfish RAS to accelerate development:

- Applied Research Models
  - To identify fundamental design parameters specific to shrimp, including water quality criteria, swimming speed, waste solids characterization, and metabolite production.
- Advanced Modeling Techniques
  - Start the design process from an advanced point using tools and techniques that are now routine, like computational fluid dynamic modeling of rearing vessel hydrodynamics and mixing.

Case Study: CFD Tank Analysis

- Increasing production intensity in shrimp ponds has led to disease outbreaks due to various factors, including the **buildup of waste solids creating optimal conditions for pathogens**

- Solutions to address waste solids buildup include:
  - Biofloc system
  - "Shrimp Toilet"
  - Increased water exchange

Why not use pond and tank hydrodynamics to create self-cleaning ponds and tanks?

Analyze Design Options with CFD

Process/Parameter	Type/Range
Circulation	Water Reuse/Reinjection by: Air Lift Pumping, Pumped Inlets
Effective HRT	Provided by Circulation Pumping: 30, 60, 90 minutes
Aeration	Airlift Pumping, Spray Bar Above Surface, Sidestream Oxygenation
Solids Removal	Central Drain Flow with External Settling: 12, 18, 24 lpm/m^2
Tank Diameter	16 m, 36 m
Tank Depth	2 m
Tank Floor Slope	2%
Tank Central Drain Diameter	10% of Tank Diameter

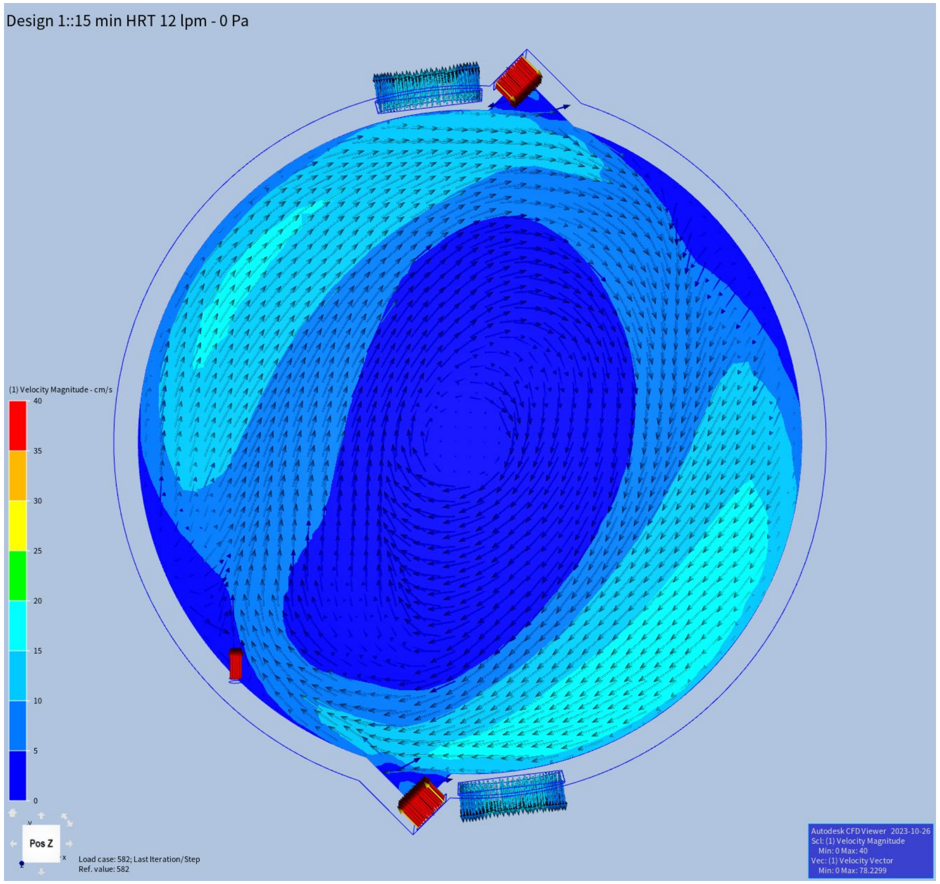
Using Water Velocity as Criteria

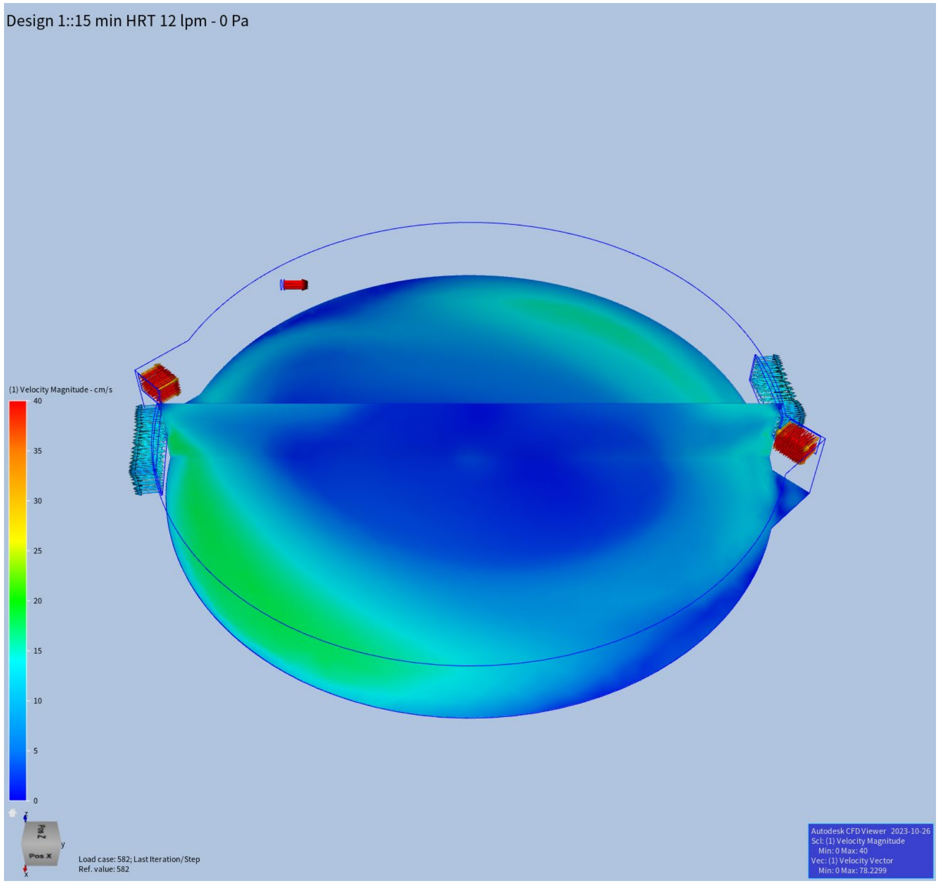
- Velocities greater than 25 cm/sec will be considered too high for shrimp
- Velocities less than 15 cm/sec will be considered too low to move waste solids toward a central drain adequately

Methods

- Computational fluid dynamic modeling was completed using Autodesk® CFD 2024 to solve the three-dimensional, time-dependent continuity, Navier-Stokes, and energy equations. A low Reynolds number turbulence model was utilized throughout.
- Model outputs are leveled velocity contour maps for the bottom of the tank and continuous velocity contour maps for the bottom of the tank with a cross-section at the middle of the tank.

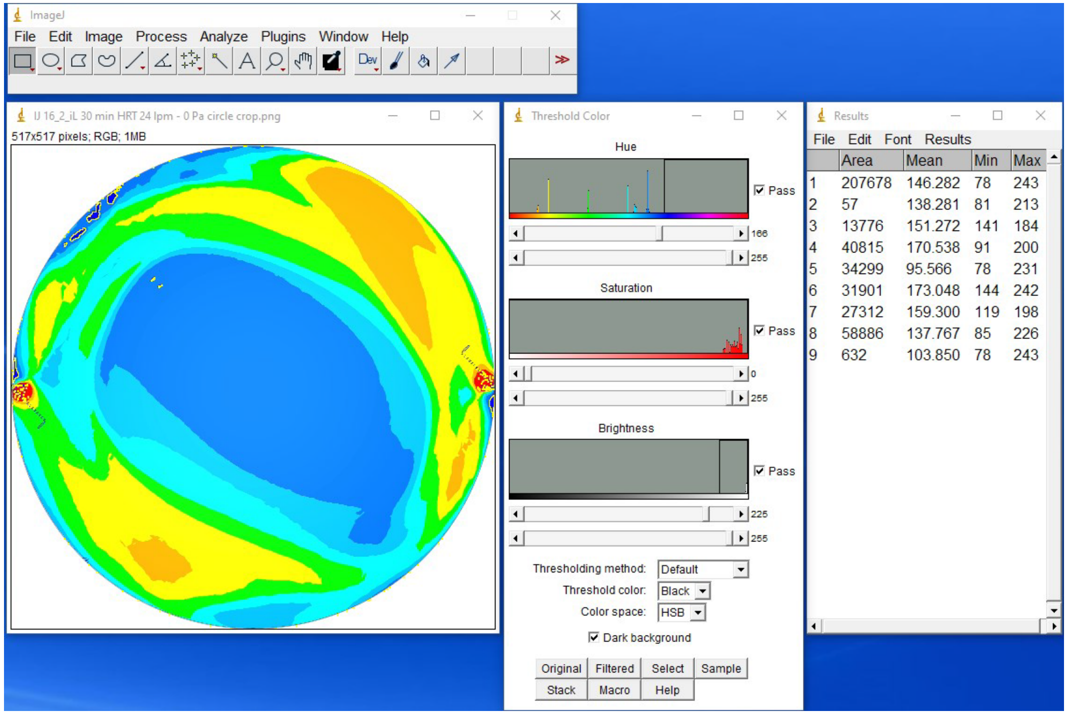
Leveled and Continuous Velocity Maps



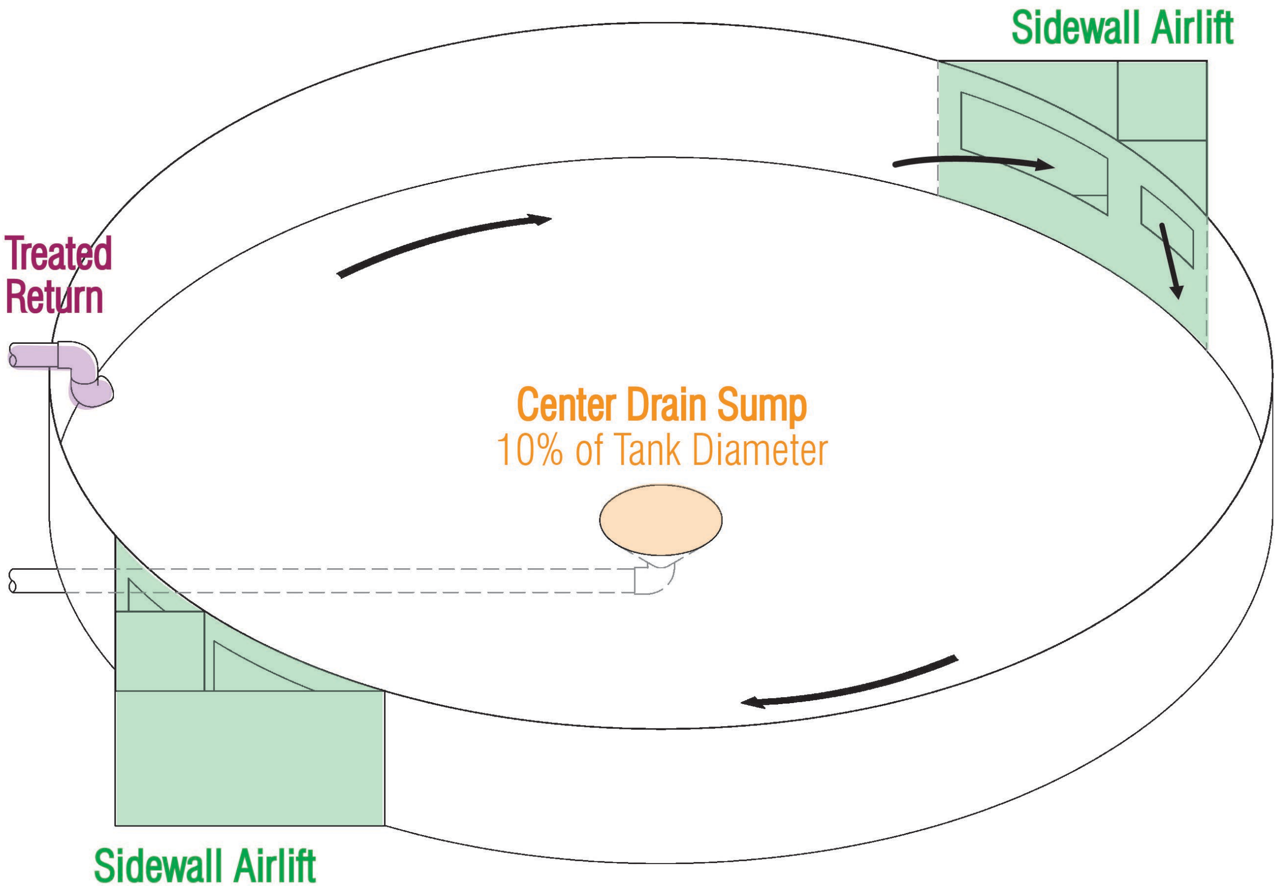


Methods (cont.)

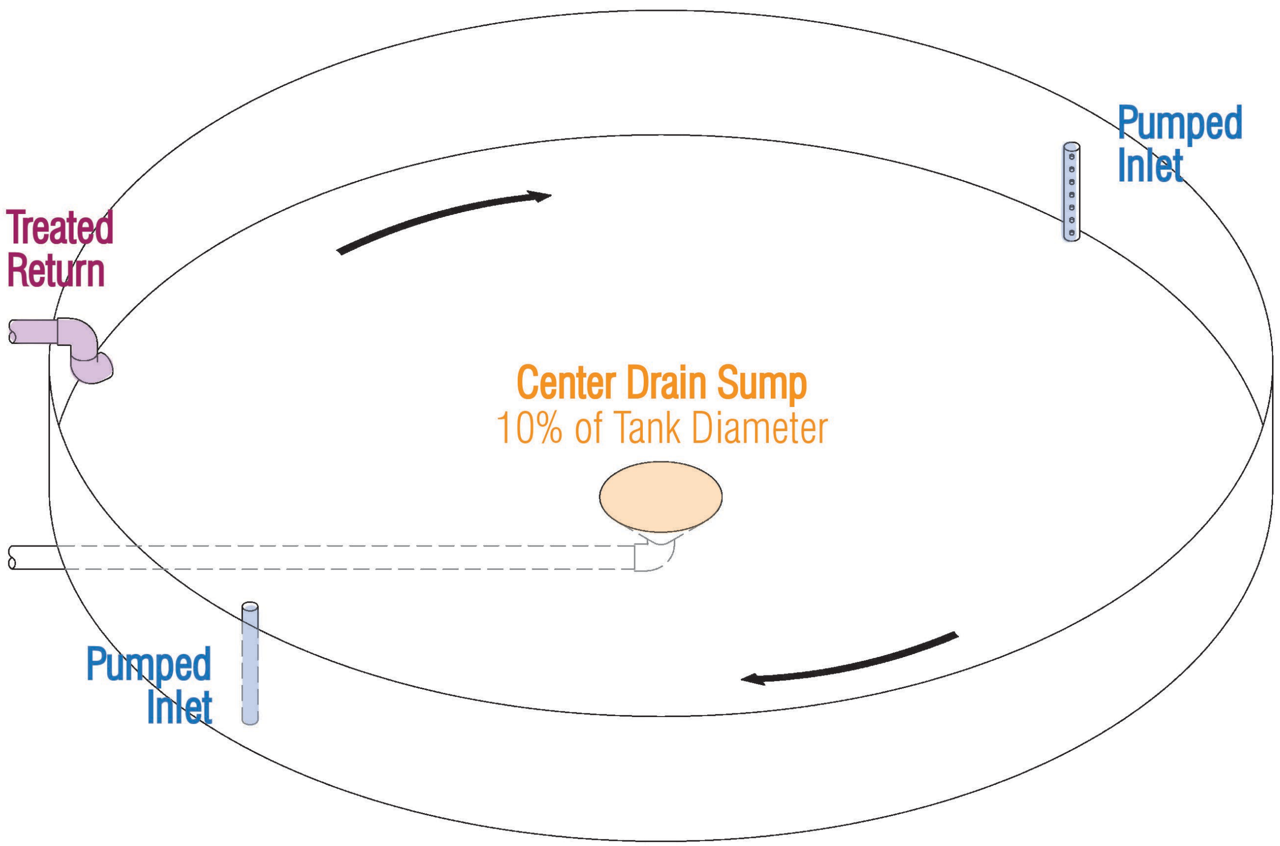
- Image analysis of leveled velocity contour maps to calculate the percent bottom area in 5 cm/sec ranges was completed using ImageJ. The total area in the target range of 15–25 cm/sec was calculated, and scenarios were ranked based on the totals to identify the best-performing ones.



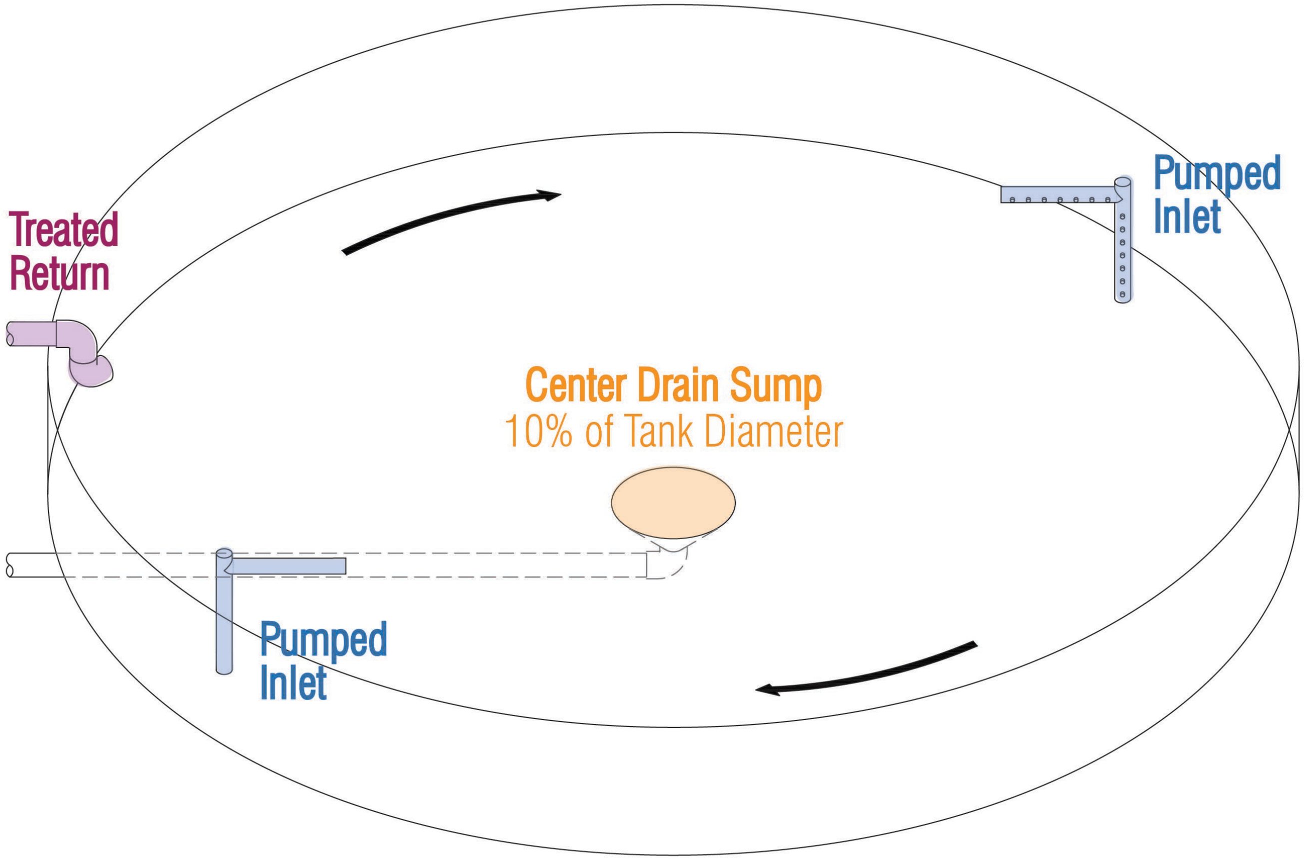
Sidewall Airlift



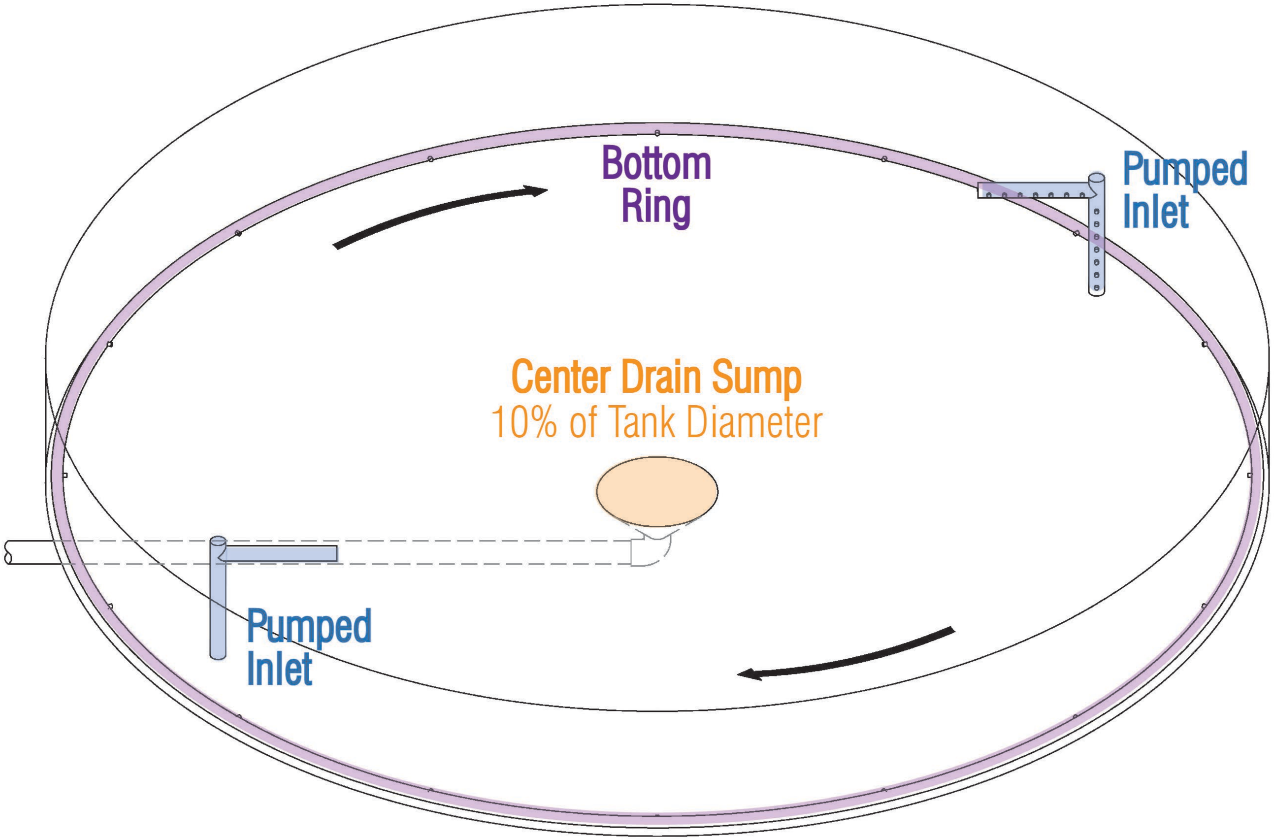
Pumped Inlets (vertical)



Pumped Inlets (vertical & horizontal)



Pumped Inlets w/ bottom ring

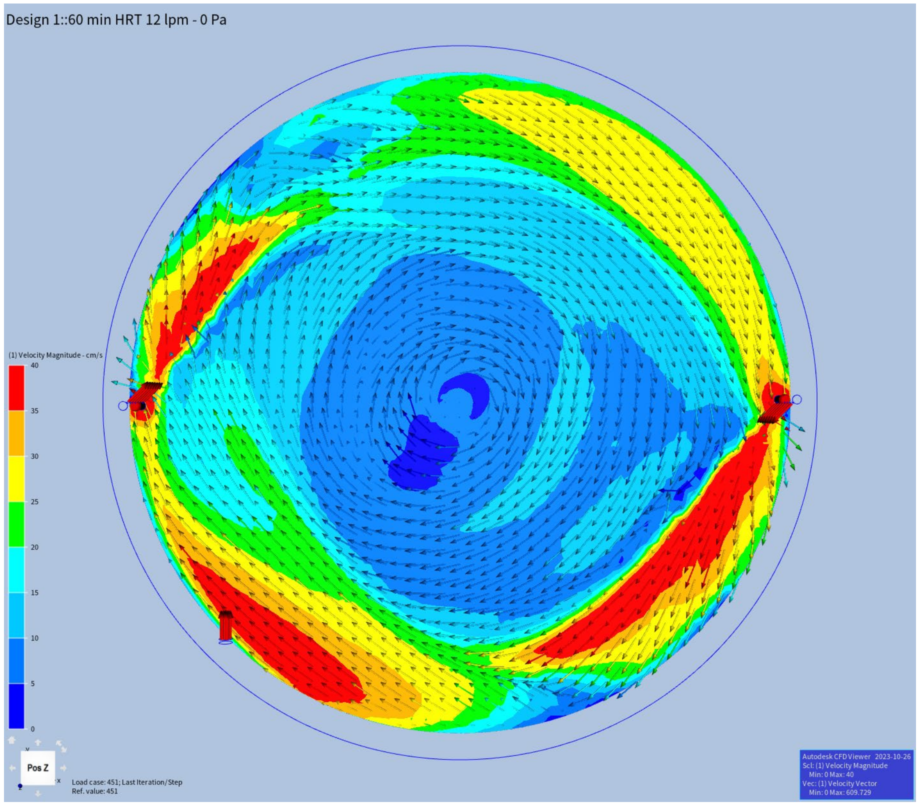


Scenarios Tested

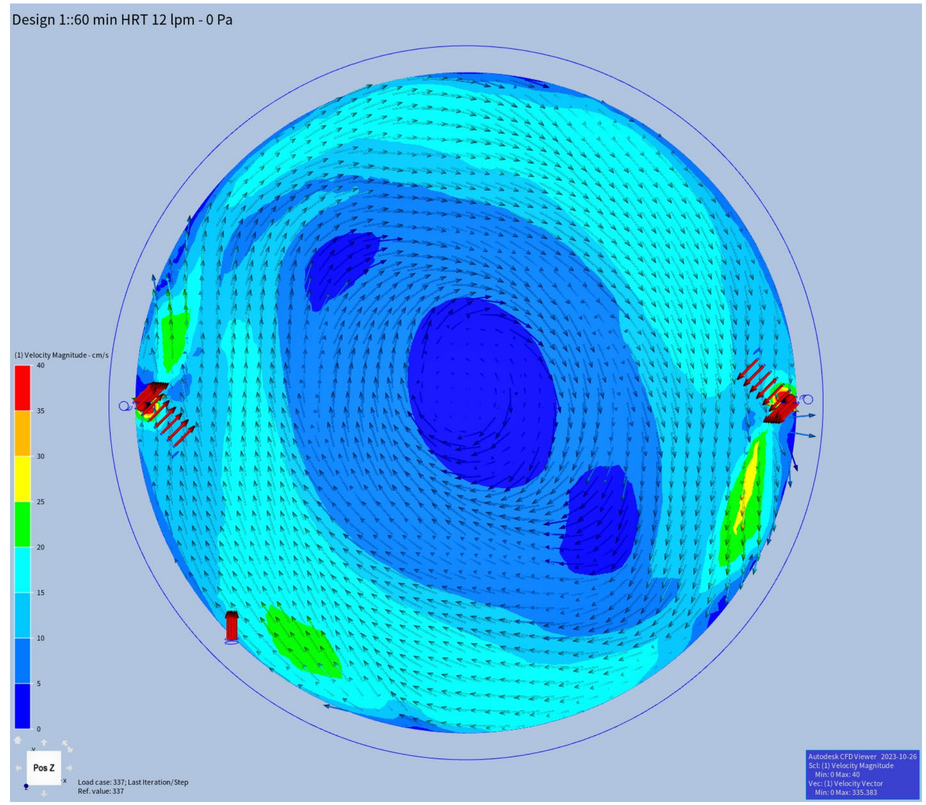
Scenario	Circulation	Inlet Type	Center Drain Flow (Lpm/m^2)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)[1]
1	Sidewall Airlift	Dual Airlift	12	16	7082	15	–
2	Sidewall Airlift	Dual Airlift	12	16	1771	60	–
3	Reuse/Reinjection	Vertical Only	12	16	1771	60	4
4	Reuse/Reinjection	Inverted L	12	16	1771	60	2
5	Reuse/Reinjection	Inverted L	18	16	1771	60	2
6	Reuse/Reinjection	Inverted L	24	16	1771	60	2
7	Reuse/Reinjection	Inverted L	12	16	3541	30	2
8	Reuse/Reinjection	Inverted L	18	16	3541	30	2
9	Reuse/Reinjection	Inverted L	24	16	3541	30	2
10	Reuse/Reinjection	Inverted L mod	12	16	1771	60	2
11	Reuse/Reinjection	Inverted L mod	24	16	1771	60	2
12	Reuse/Reinjection	Inverted L w/ring	12	16	1771	60	2
13	Reuse/Reinjection	Inverted L w/ring	12	16	1180	90	1.3
14	Reuse/Reinjection	Vertical Only	12	36	8964	60	4
15	Reuse/Reinjection	Inverted L	12	36	8964	60	2
16	Reuse/Reinjection	Inverted L w/ring	12	36	8964	60	2
17	Reuse/Reinjection	Inverted L w/ring	24	36	8964	60	2

[1]Nominal; values are 3.935 m/s, 1.968 m/s, and 1.312 m/s

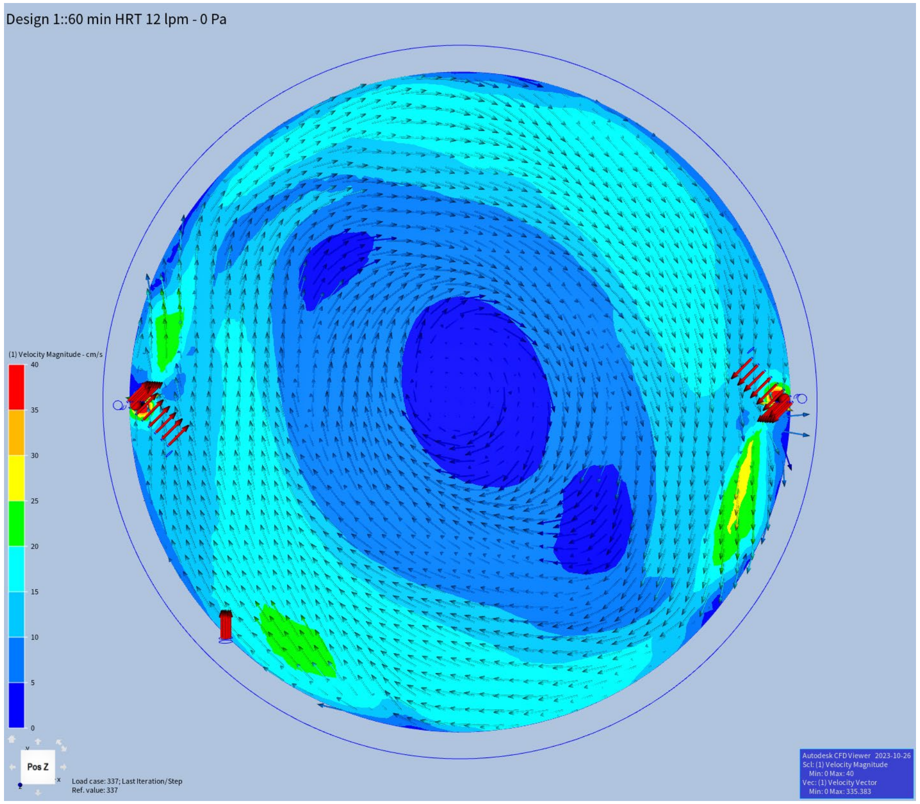
Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
3	12	16	1771	60	4



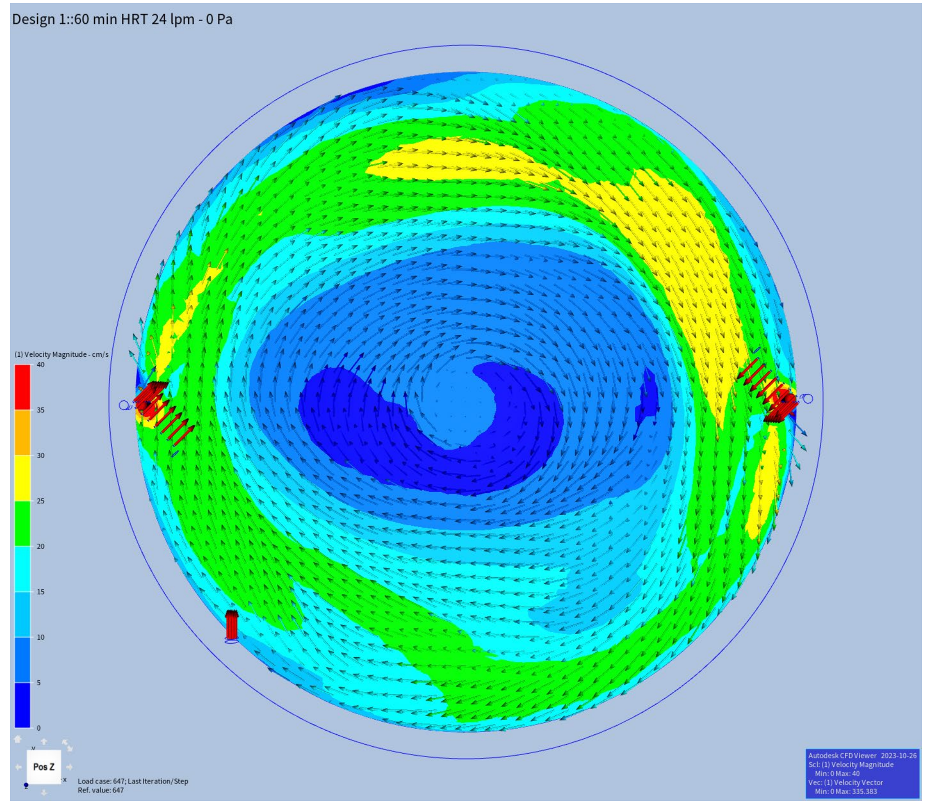
Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
4	12	16	1771	60	2



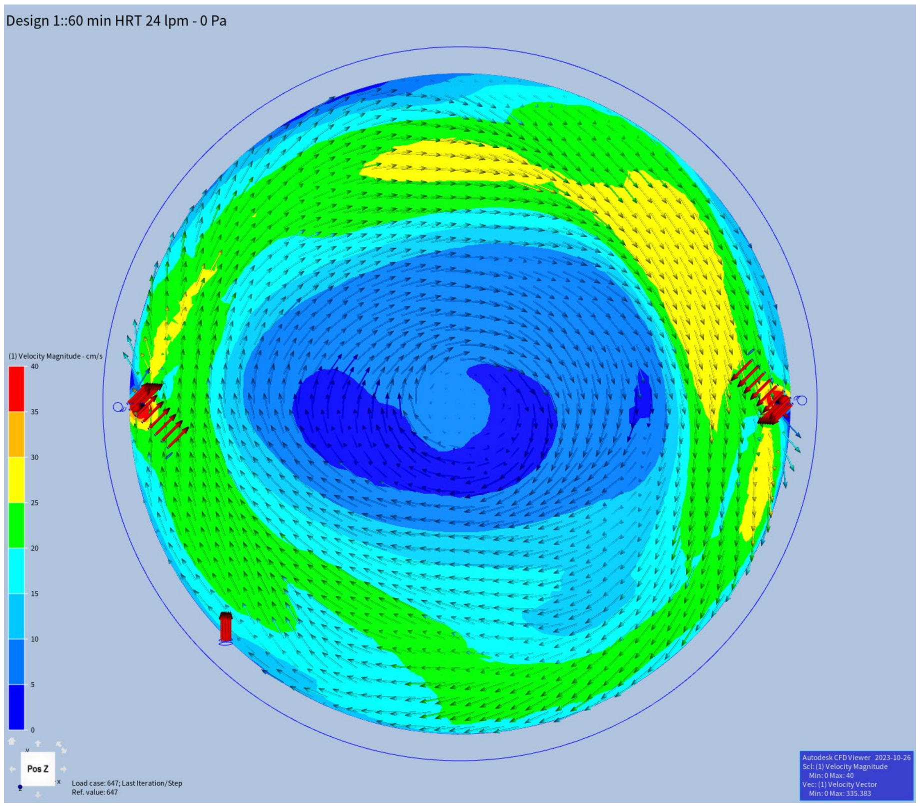
Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
4	12	16	1771	60	2



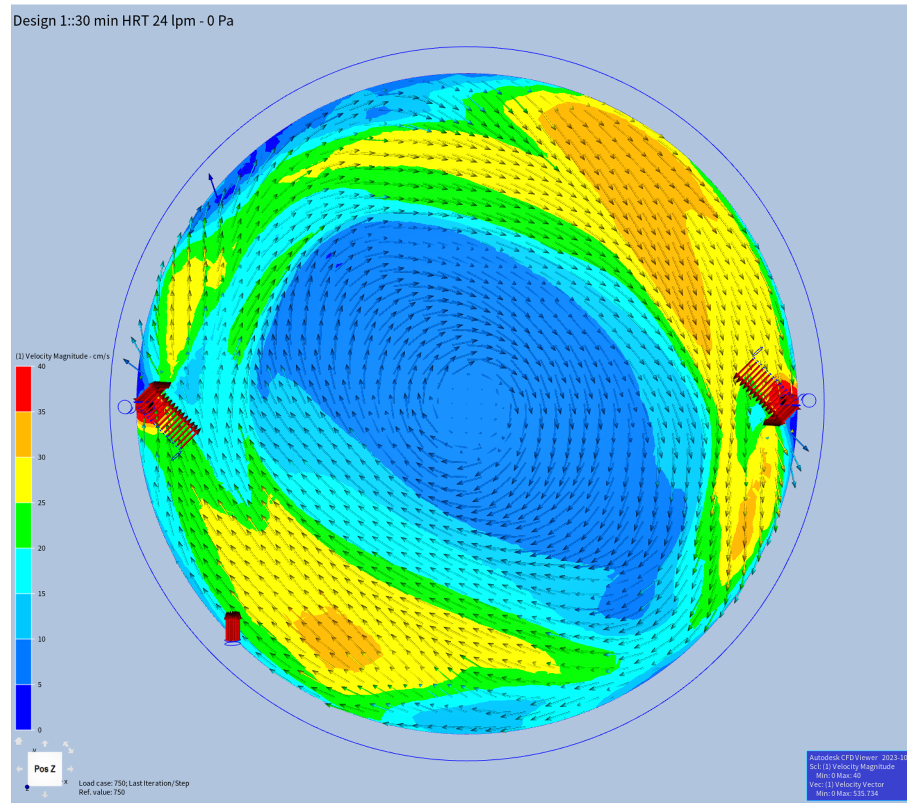
Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
6	24	16	1771	60	2



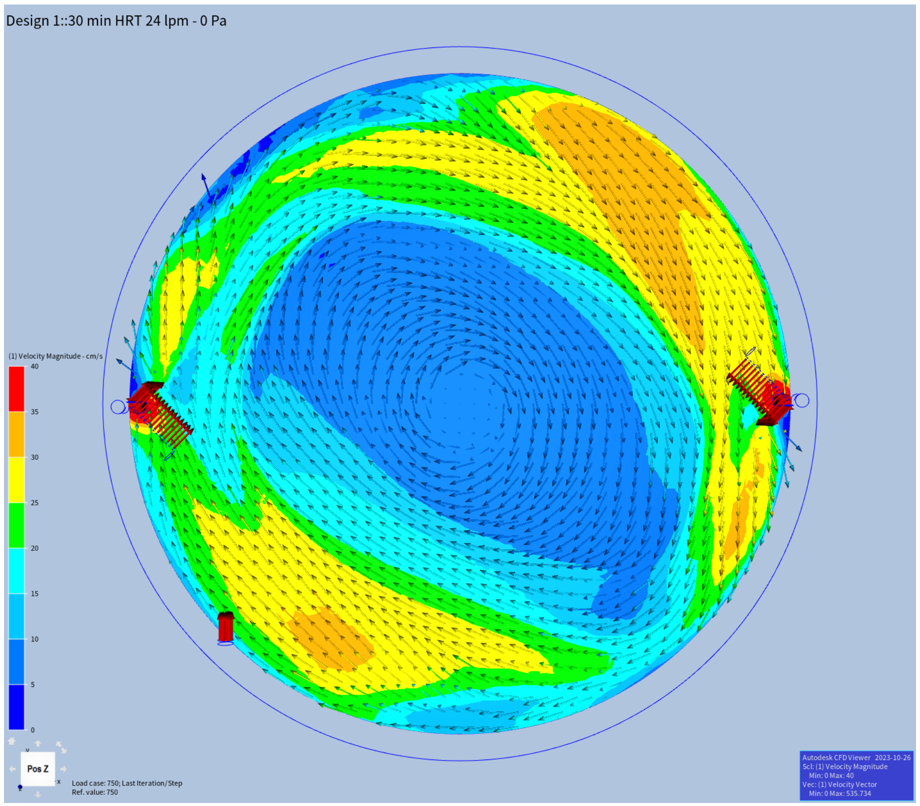
Scenario	Center Drain Flow (Lpm/m^2)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
6	24	16	1771	60	2



Scenario	Center Drain Flow (Lpm/m^2)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
9	24	16	1771	30	2



Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
9	24	16	1771	30	2



Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
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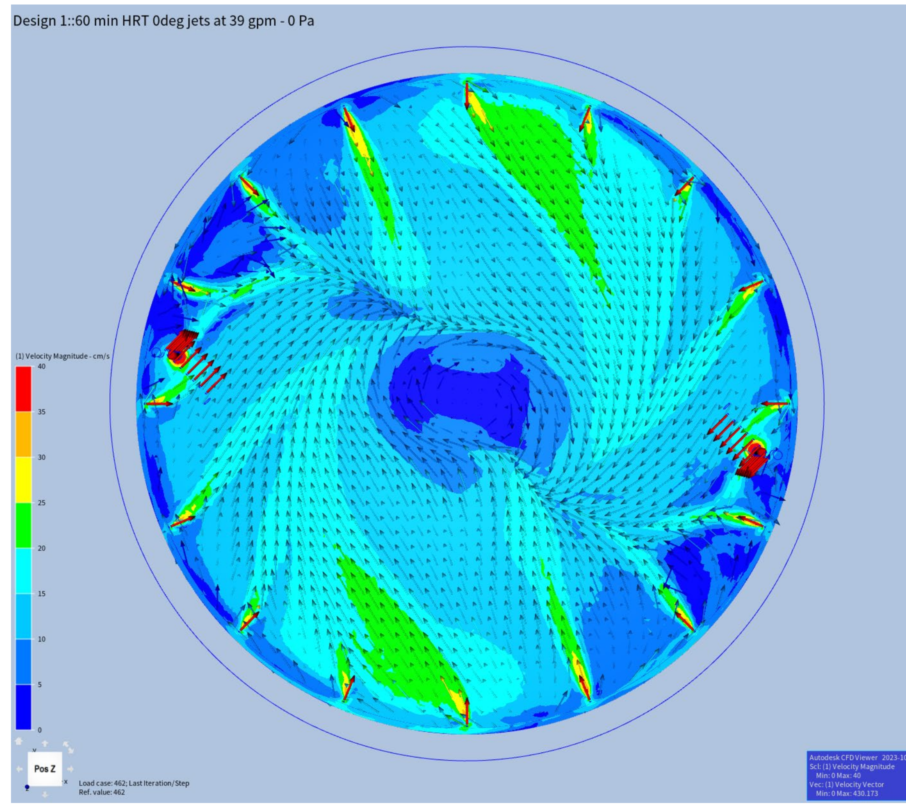

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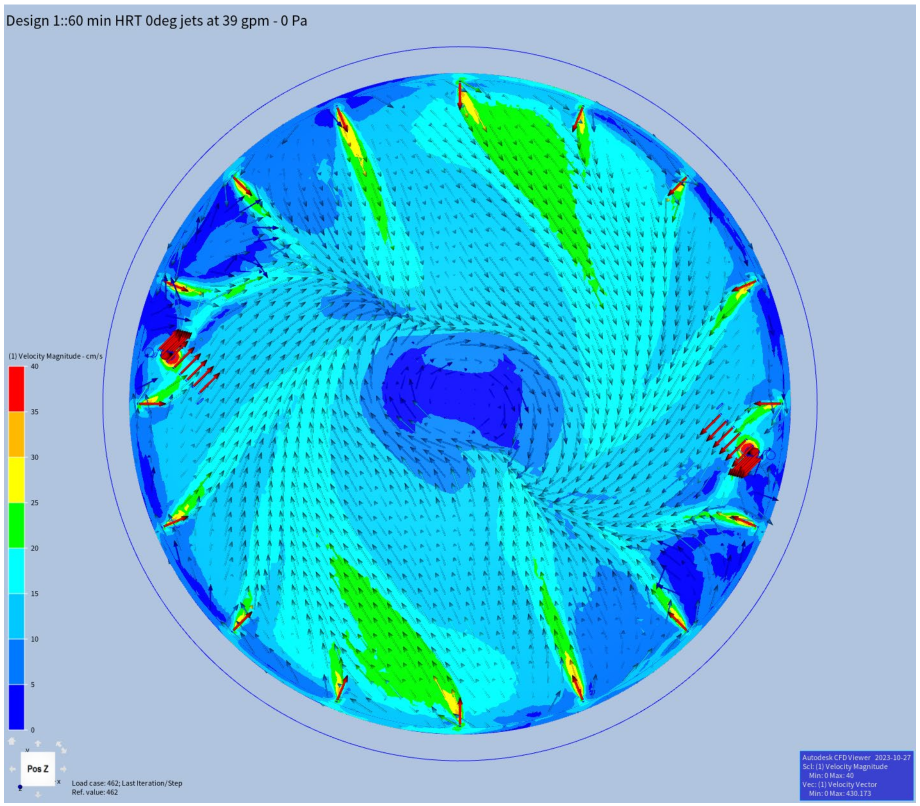
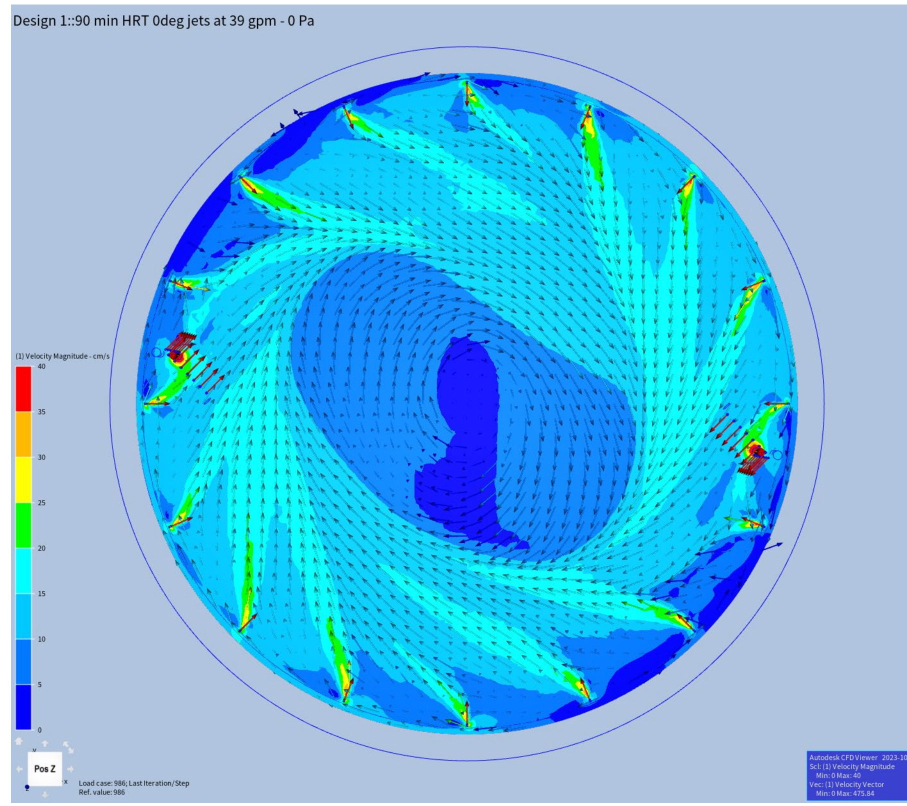
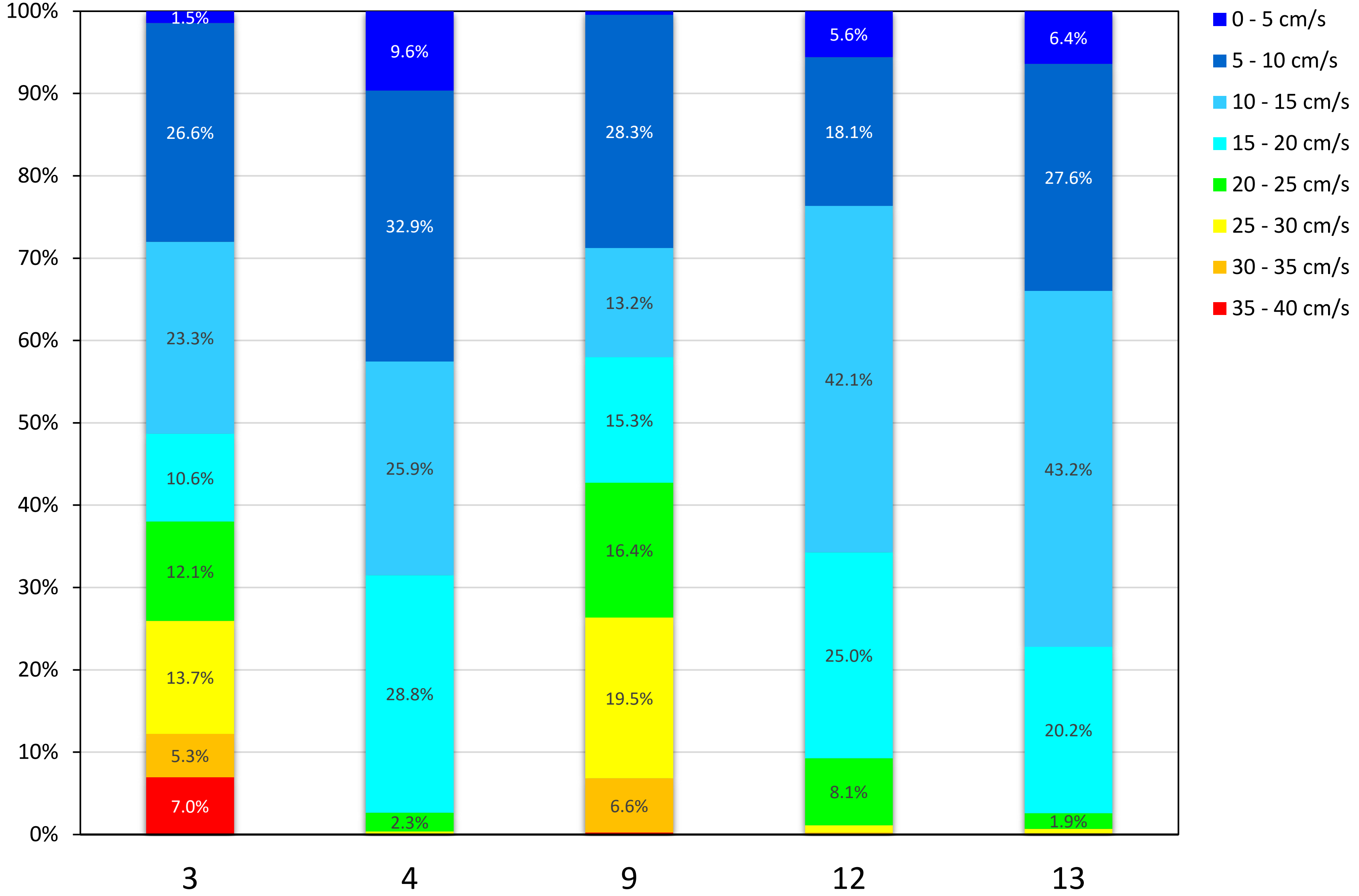
12	12	16	1771	60	2



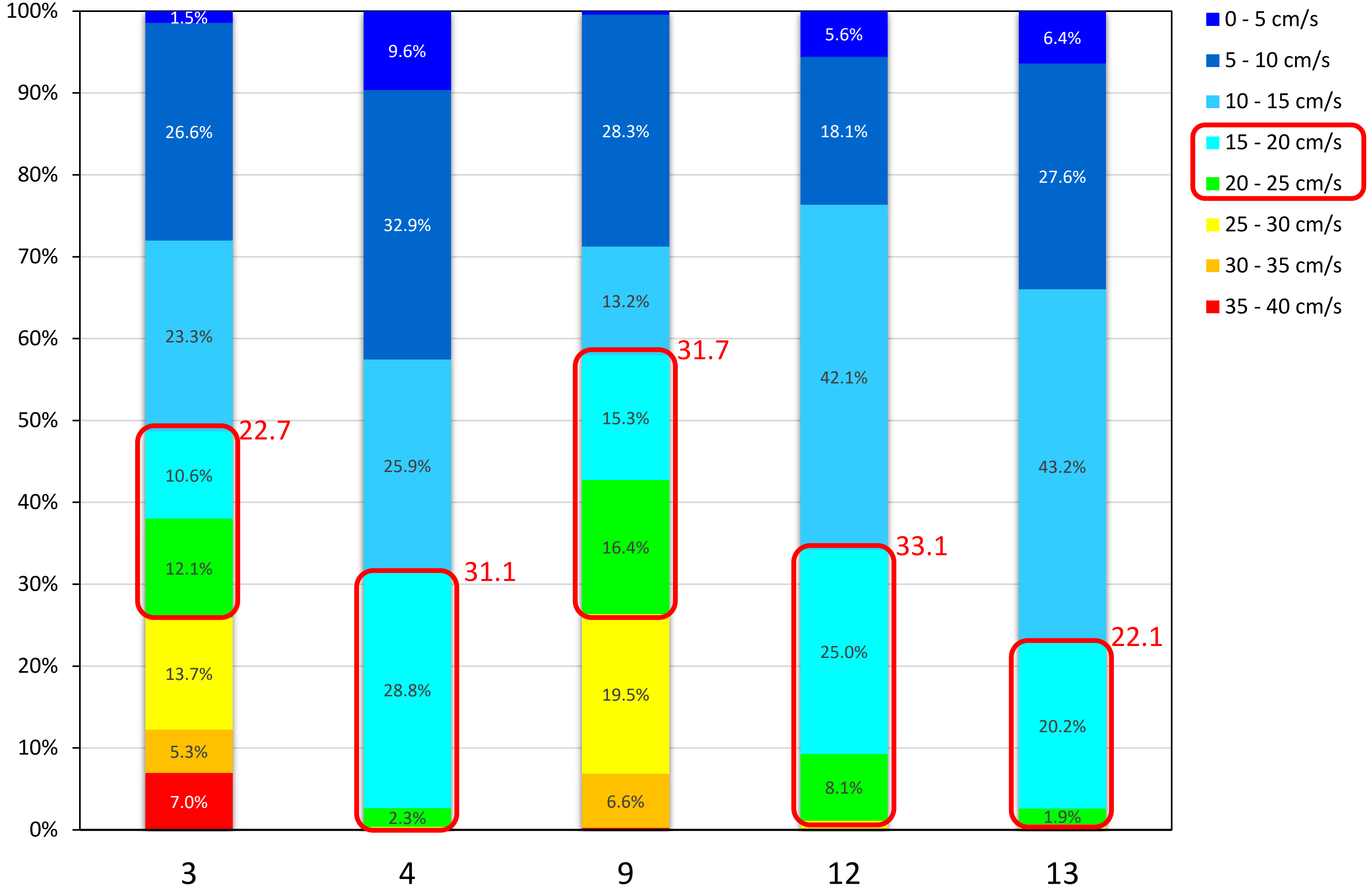
Scenario	Center Drain Flow (Lpm/m²)	Tank Diameter (m)	Pumped Flow (gpm)	Equivalent HRT (min)	Inlet Jet Velocity (m/s)
13	12	16	1180	90	1.3



Velocity Distribution for Select Scenarios



Velocity Distribution for Select Scenarios



Observations

- Inlets designed to have a jet velocity of approximately 4 meters per second (m/s) create large tank areas where the velocities are too high for shrimp, i.e., greater than 30 centimeters per second (cm/s).
- Inlets designed to have a jet velocity of approximately 2 m/s eliminate areas with high velocities and create more area in the target velocity range of 15–25 cm/s.

Observations (cont.)

- The center drain hydraulic loading of 12 liters per minute per square meter of bottom tank area (Lpm/m^2) creates 5–10 cm/s velocities around the tank center drain. This velocity may be too low for the continuous movement of waste solids to the center drain outlet, especially for heavier particles, e.g., shrimp molts.

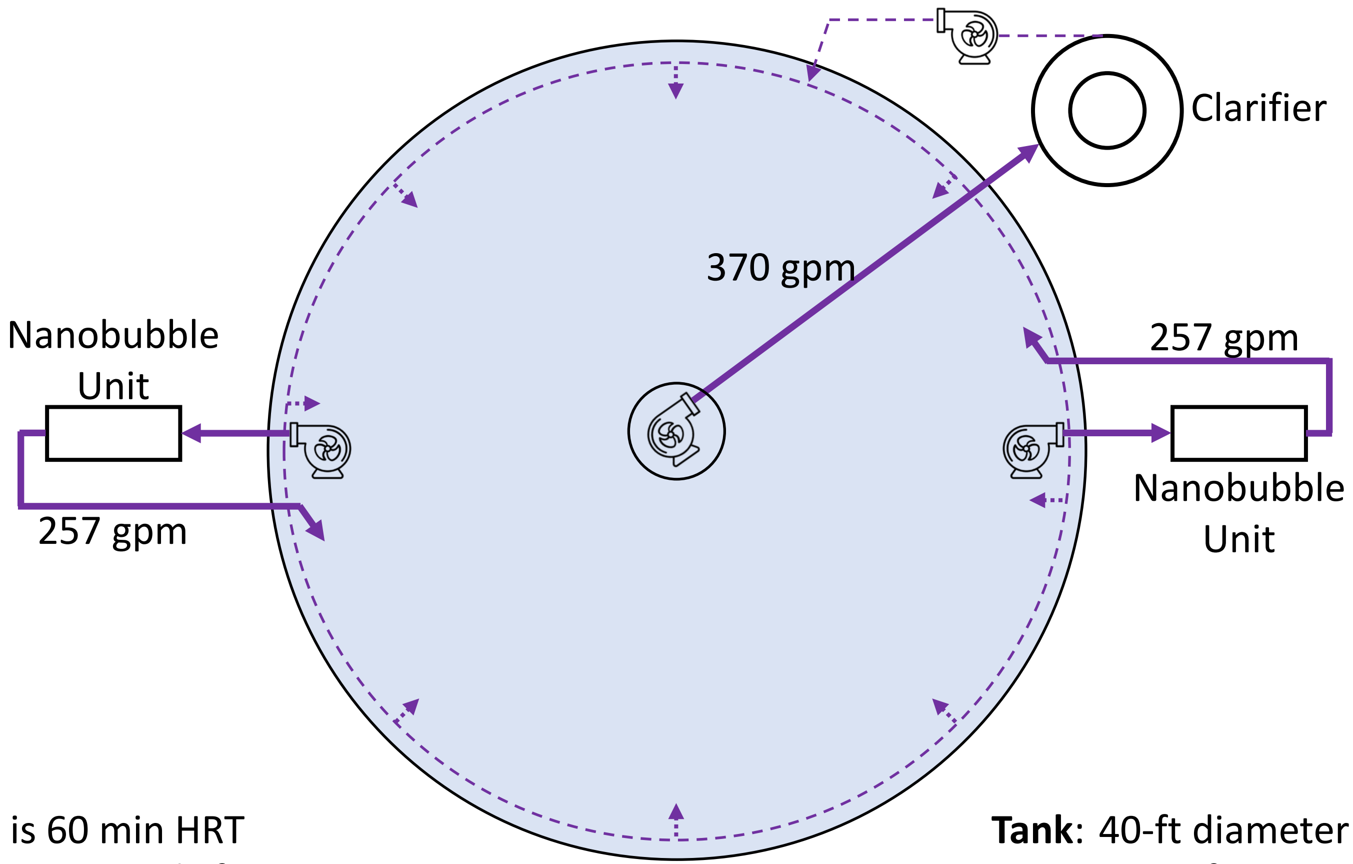
Observations (cont.)

- The criteria required for sizing the airlift box outlet, i.e., a water velocity of less than 30 cm/s, limits the resulting velocity field to velocities that are too low for good waste solids movement.
- Utilizing an independent method to create or enhance the radial current that carries waste solids to the center drain separate from the primary rotating flow results in the smallest areas of low velocities (0–10 cm/s) at the tank center.

Next Steps…Field Research

- Design setup to test design parameters for re-injected flow and center drain flow
- Verify model results for water velocities and self-cleaning of waste solids.
- Incorporate external unit processes to provide solids capture/removal and aeration/oxygenation.
- Test at 5.5 kg/m^2 and 11 kg/m^2

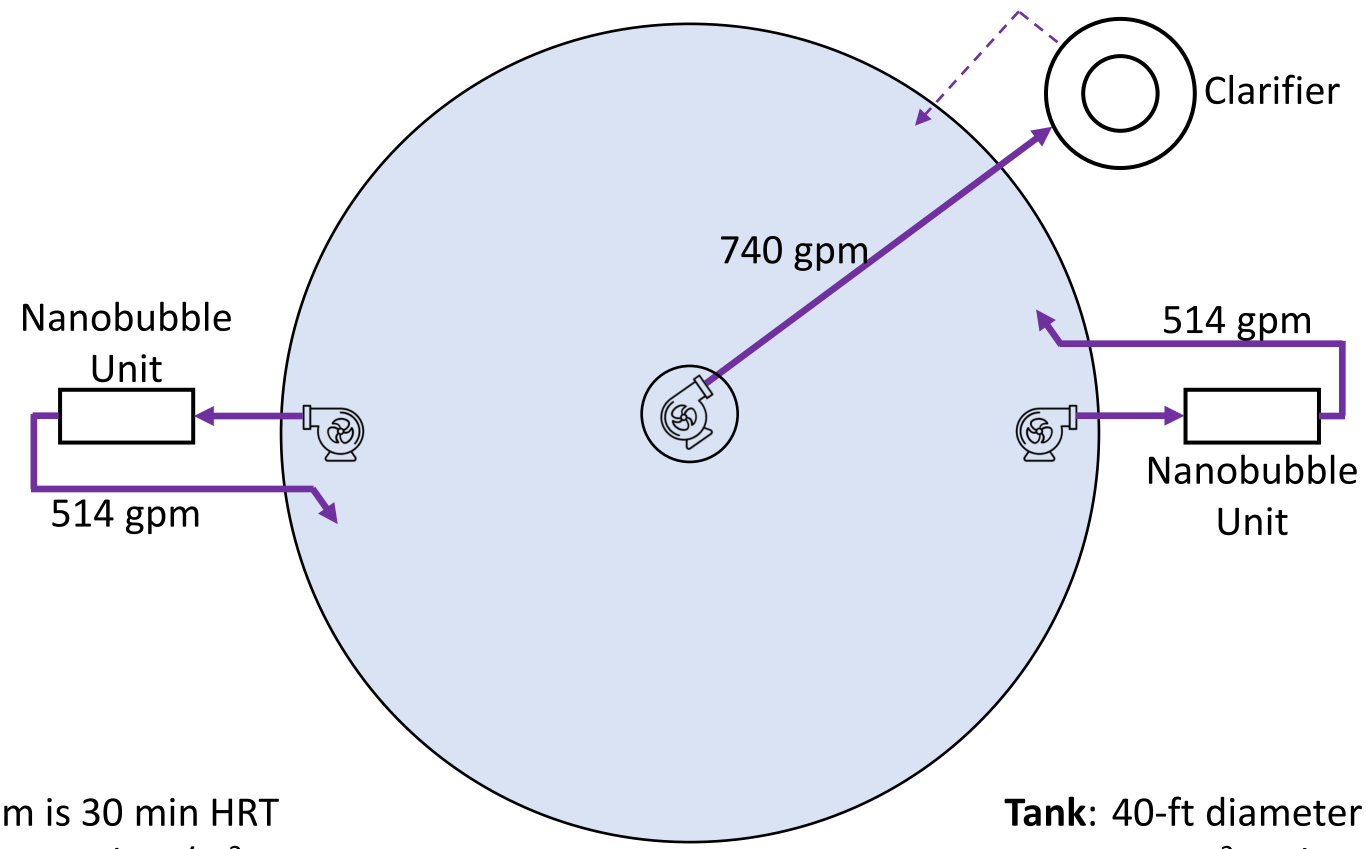
Option #12 Setup



Flow: 514 gpm is 60 min HRT
370 gpm is 12 lpm/m^2
Jet Velocity is 2 m/sec

Tank: 40-ft diameter by 3.3-ft deep
117 m^2 and 117 m^3
642 kg capacity at 5.5 kg/m^2

Option #9 Setup



Flow: 1028 gpm is 30 min HRT
740 gpm is 24 lpm/m^2
Jet Velocity is 2 m/sec

Tank: 40-ft diameter by 3.3-ft deep
117 m^2 and 117 m^3
642 kg capacity at 5.5 kg/m^2

Thank you for your attention

TCRS
The Center for Responsible Seafood

The Conservation Fund
Freshwater Institute

The Nature Conservancy