Aqua Nor 2023

Linde’s latest learnings in scaling up land based fish tanks

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Linde Technology

Making our world more productive

Linde

- The leading industrial gases and engineering company
- Formed in 2018 with the merger of Linde AG and Praxair, Inc – two world-class companies with nearly 140 years of shared history and successful achievements

One Linde

Uniting with a shared Vision, Mission and Strategic Direction, and demonstrating our Values and Behaviors in everything we do

100+
countries
Enabling strong, complementary positions in all key geographies and end markets

USD 31 billion
2021 Sales

2 million+
customers
Establishing a more diverse and balanced portfolio

~72,000
employees
Achieving our full potential, individually and collectively

6,500+
active patent assets worldwide
Leading with innovative products, solutions and technologies

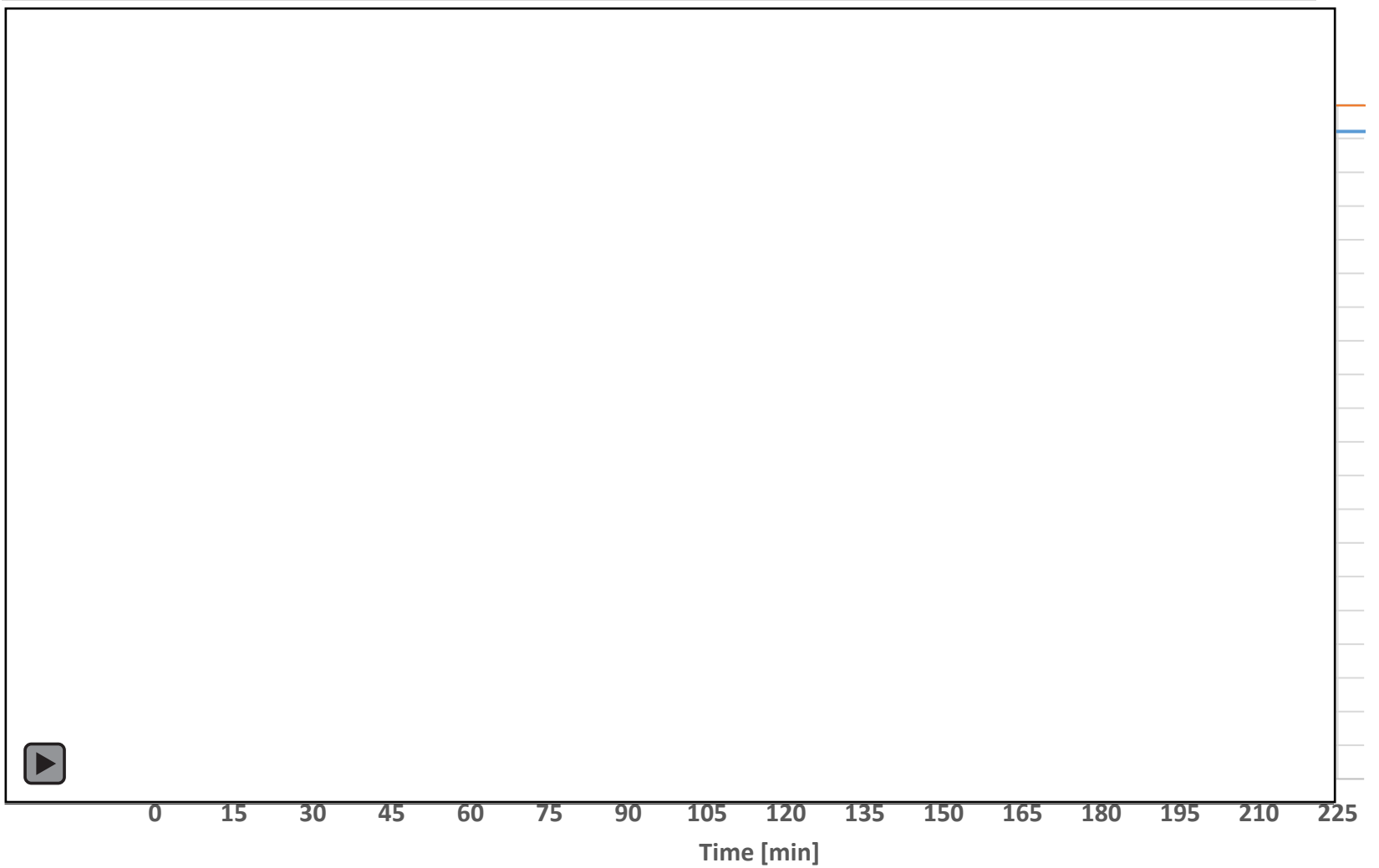
Global Aquaculture Innovation Centre

Ålesund, Norway

Challenges in scaling up fish tank volumes

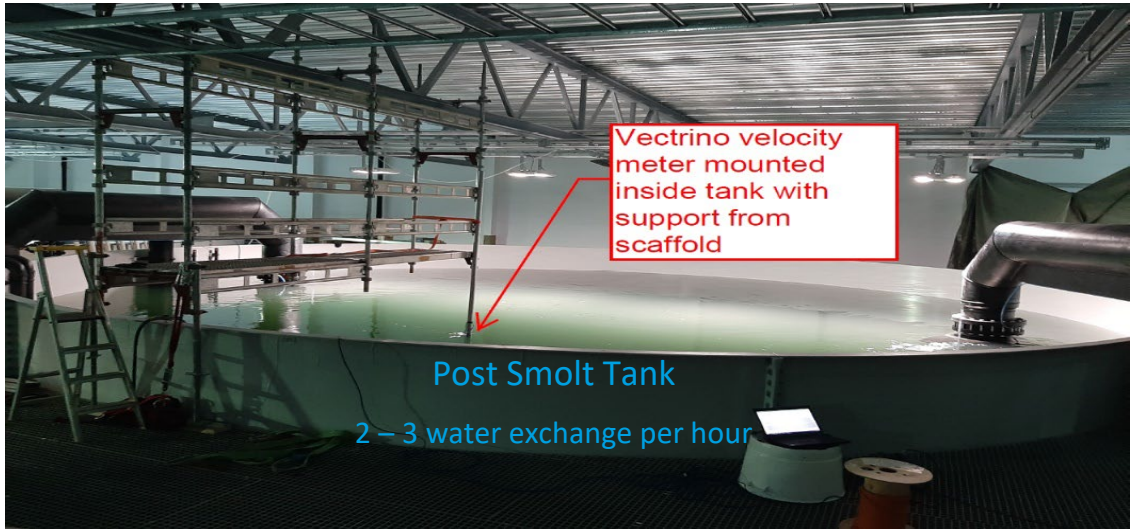
Challenges

- ✓ Vortexes, especially close to tank outlet
- ✓ Waves forming in the tank
- ✓ Water shortcuts, poor flow pattern
- ✓ Large span in velocity distribution
- ✓ Poor water exchange



General Design Validation

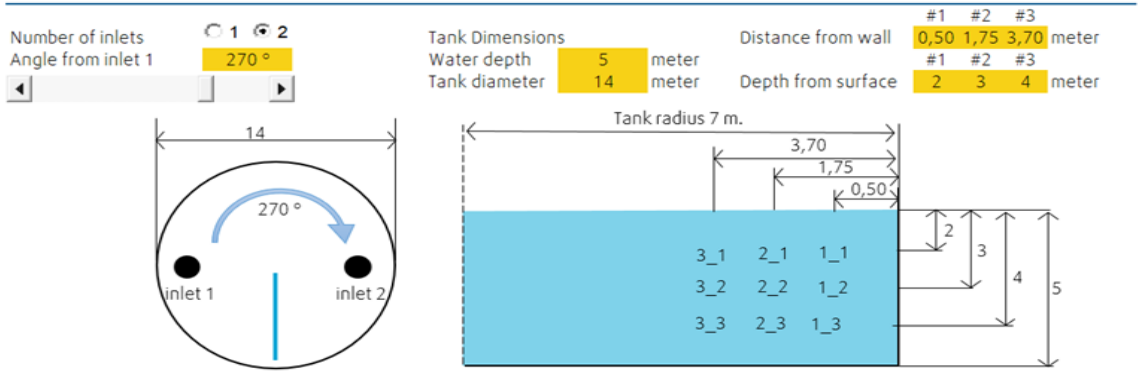
Measurement of Tanks Hydraulics

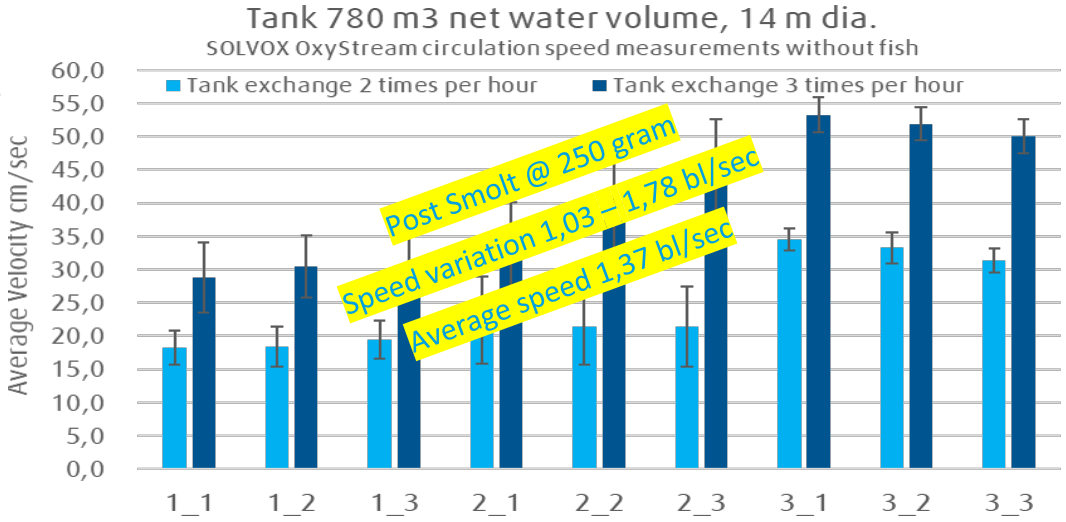


Measured tank speed at 3 x exchange per hour			
Measuring point #	X- axis Average Circulation Speed cm/sec	X- axis Average Circulation Speed cm/sec	Turbulence Intensity
1_1	28,8	30,0	16,0 %
1_2	30,4		13,8 %
1_3			15,2 %
2_1	1,9	37,4	17,7 %
2_	37,4		18,8 %
	42,9		24,2 %
3_1	53,2	51,7	6,5 %
3_2	51,9		14,3 %
3_3	50,0		7,0 %
Average tank speed cm/sec		39,7	

Linde target design - average dominant speed 39 cm/sec

Tank hydraulics. Visualisation.

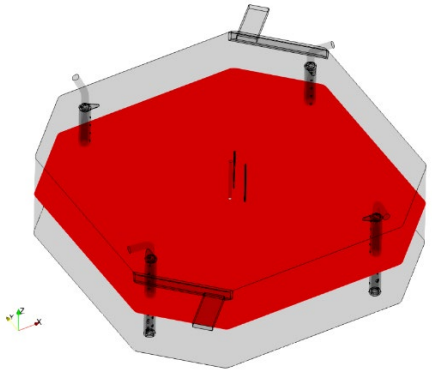




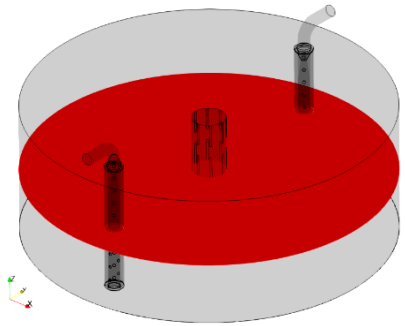
Velocity distribution & water exchange

Tank configuration with same footprint, volume & water flow.

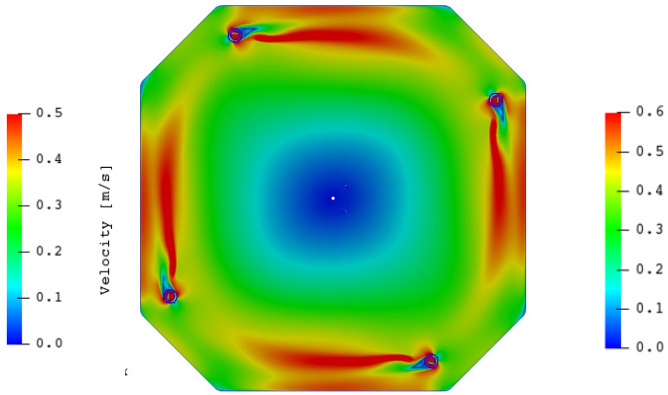
81% of tank volume at velocity $0.30 - 0.45 \frac{m}{s}$ ➔ 0,9 – 1,3 bl./sec (450g)

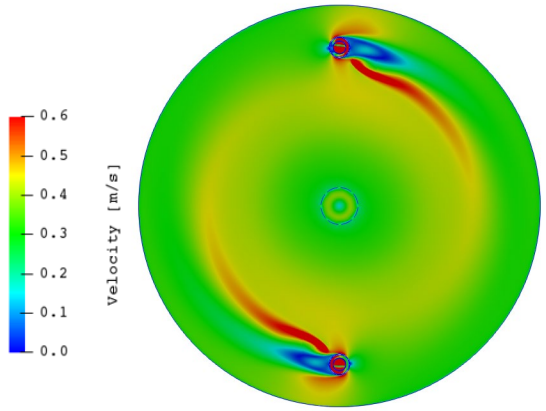


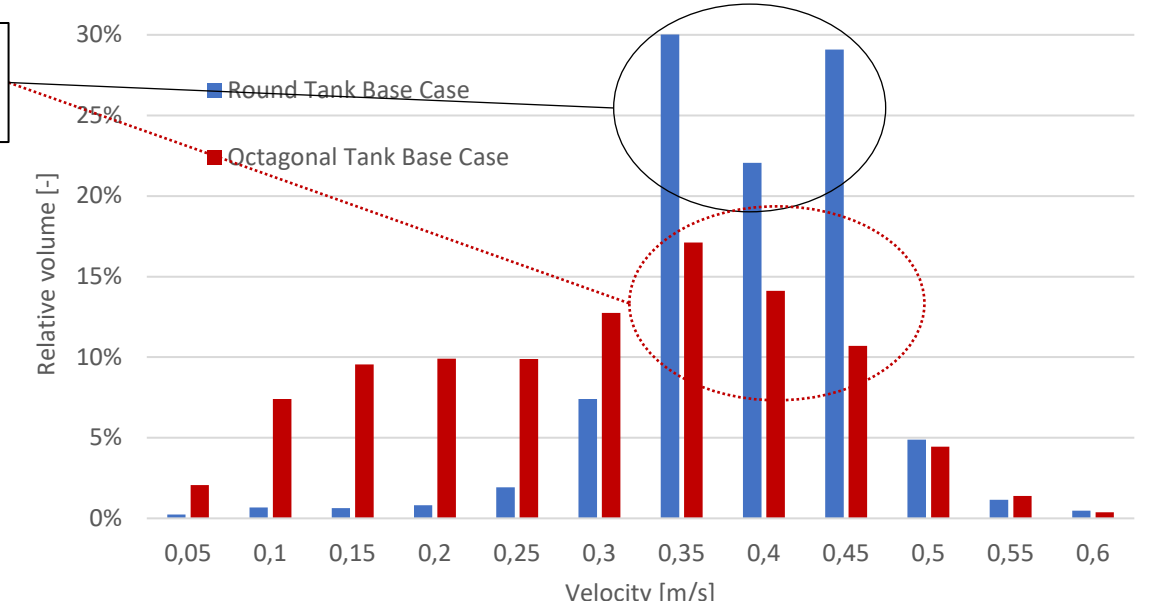
Octagonal tank average speed $0.28 \frac{m}{s}$ ➔ 0,8 bl./sec (450g)

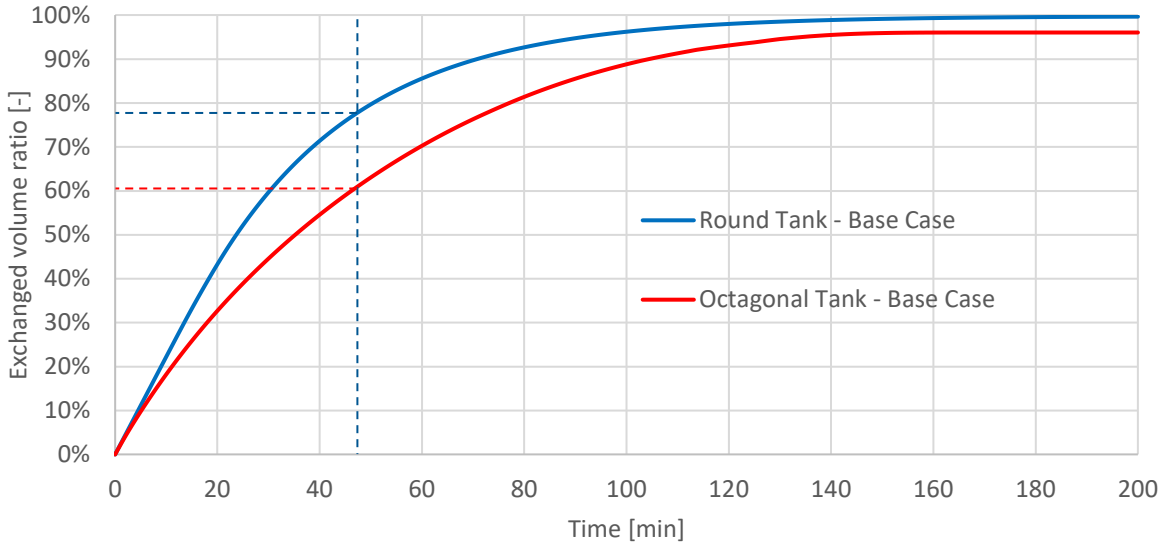


Round tank average velocity: $0.37 \frac{m}{s}$ ➔ 1,1 bl./sec (450g)









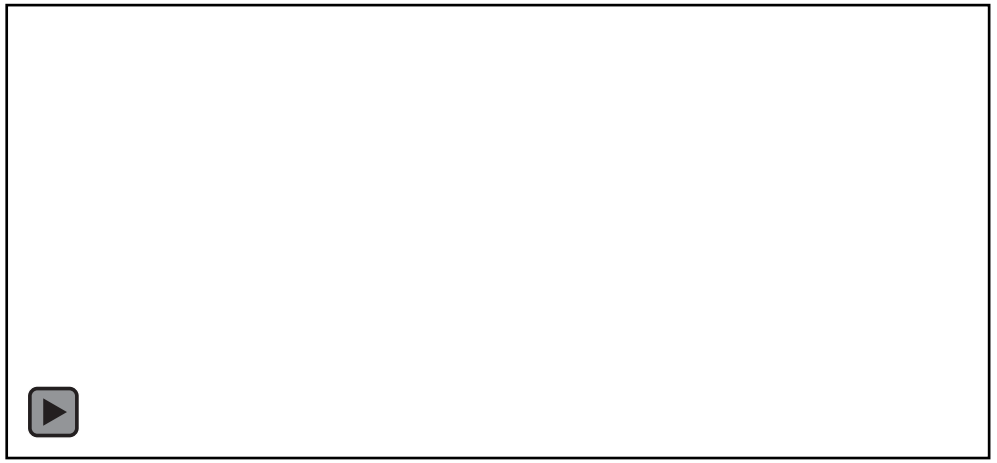
Tank volume 2 070 m3, identical footprint, Round Tank central outlet and two inlets, Octagonal dual drain 80/20 and four inlets

Selected CFD Studies

Latest customer projects

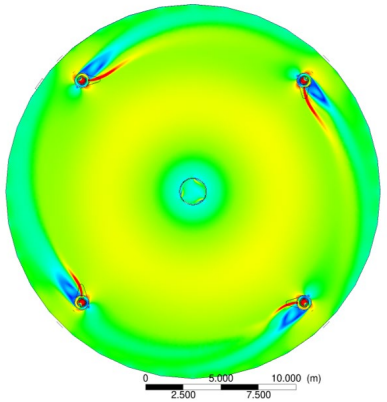
Post Smolt RAS

4 500 m³ tank



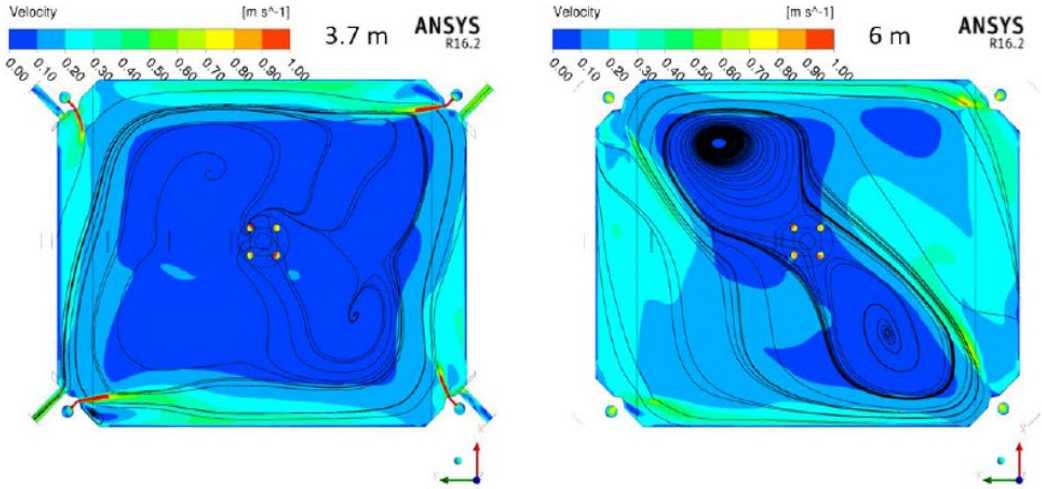
Grow Out RAS

3 500 m³ tank

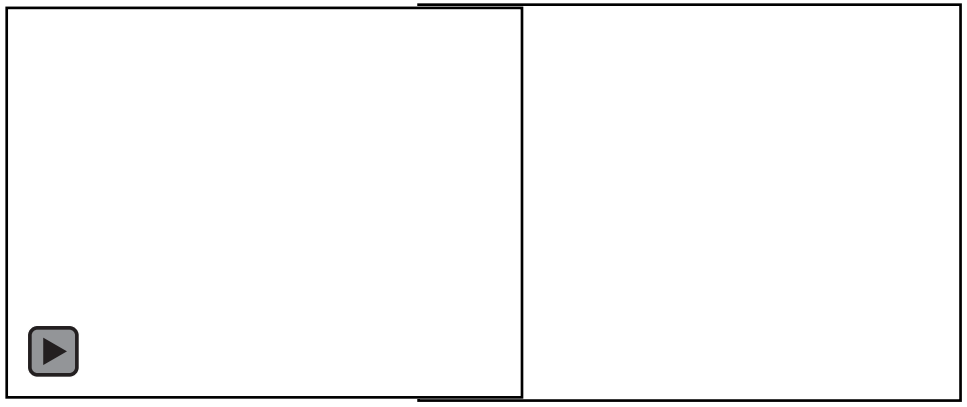


Grow Out Flow Through

10 000 m³ tank

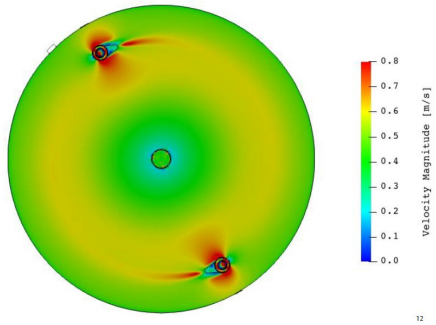


Post Smolt RAS



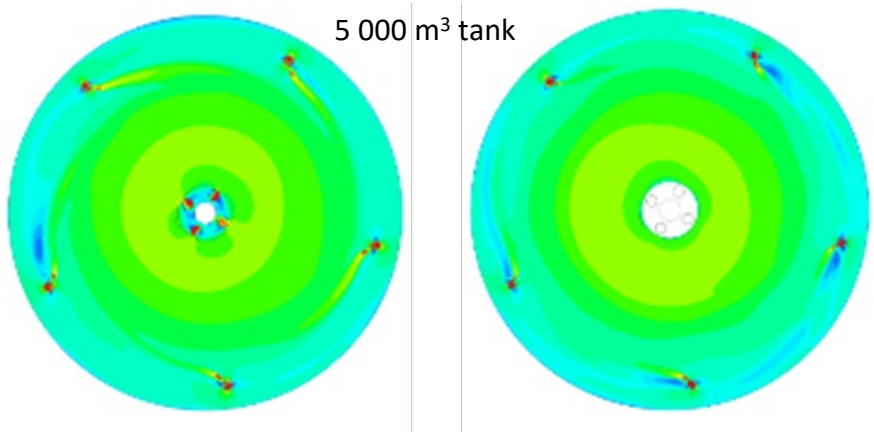
Pre Grow RAS

1 000 m³ tank



Post Smolt Flow Through

5 000 m³ tank



SOLVOX®OxyStream

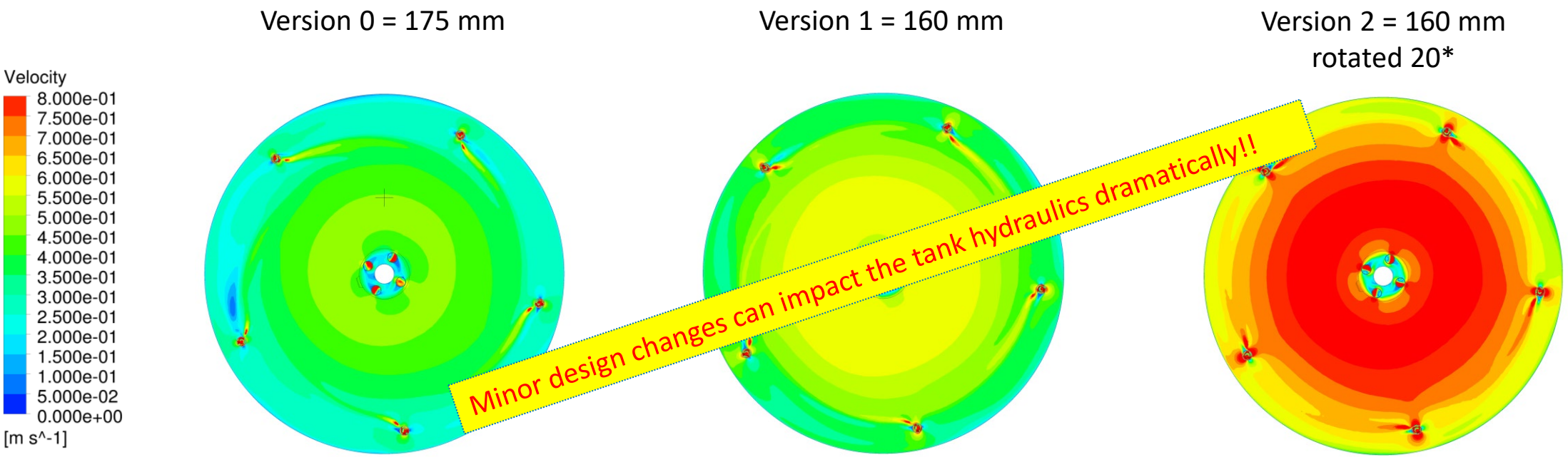
Impact of minor design/operational changes on tank hydraulics

Tank Parameters

- Diameter 33 m.
- Outlet in center of tank
- 5 water inlets
- Net volume 5 400 m^3

Risks to be addressed when designing large tanks on land

- Dead zones/segmentation
- Velocity distribution
- Vortex creation
- Waves



Energy usage in RAS oxygenation

Smolt production in RAS

Example calculation

Energy usage RAS smolt production in Norway*	8,8	kWh/$kg_{prod.}$
Energy price***	1,2	NOK/kWh
Energy cost smolt production total	10,6	NOK/$kg_{prod.}$
Energy usage oxygenation*	13,2	%
Energy usage oxygenation*	1,16	kWh/$kg_{prod.}$
Energy cost oxygenation	1,39	NOK/$kg_{prod.}$
Oxygen consumption**	0,50	kg_{O2}/$kg_{prod.}$
Oxygen price***	3,5	NOK/kg
Oxygen cost	1,75	NOK/$kg_{prod.}$
Total cost of oxygenation (oxygen & energy)	3,14	NOK/$kg_{prod.}$

2,32 kWh/kgO2

*Current and Future Energy Use for Atlantic Salmon Farming in Recirculating Aquaculture Systems in Norway (Andrea Nistad 2020)

** Estimated average of Norwegian smolt production (Linde Gas)

*** Example figures

Smolt production in RAS

Linde customer trials

#of tanks part of trial	2	pcs.
Tank size	≈ 800	m^3
Fish size	≈ 100 - 300	Gram
Peak density	55	kg/m^3
Water exchange	≈2,2	times/hour
FCR (average)		
Oxygen consum…	0,45	kg_{O2}/$kg_{feed.}$
Oxygen …mption	0,38	kg_{O2}/$kg_{prod.}$
…usage oxygenation & tank hydraulics	0,28	kWh/$kg_{prod.}$
…rgy usage oxygenation (excluding tank hydr.)	0,07	kWh/$kg_{prod.}$
Energy cost oxygenation	0,09	NOK/$kg_{prod.}$
Energy cost oxygenation & tank hydraulics	0,33	NOK/$kg_{prod.}$
Oxygen cost	1,34	NOK/$kg_{prod.}$
Total cost of oxygenation	1,43	NOK/$kg_{prod.}$

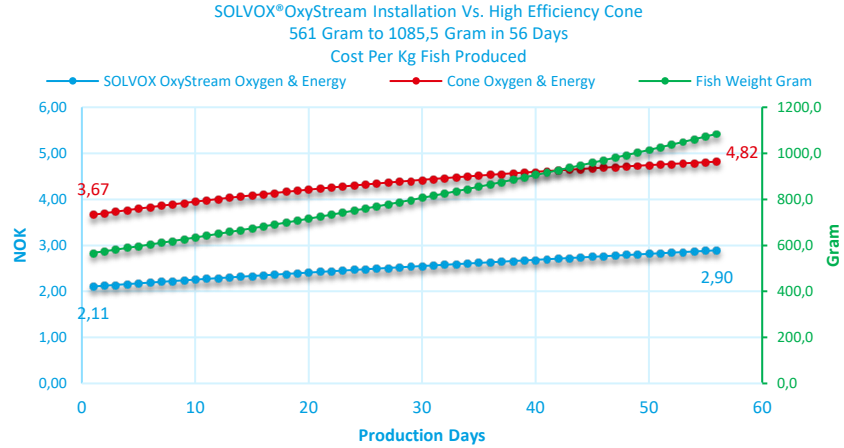
0,62 kWh/kgO2

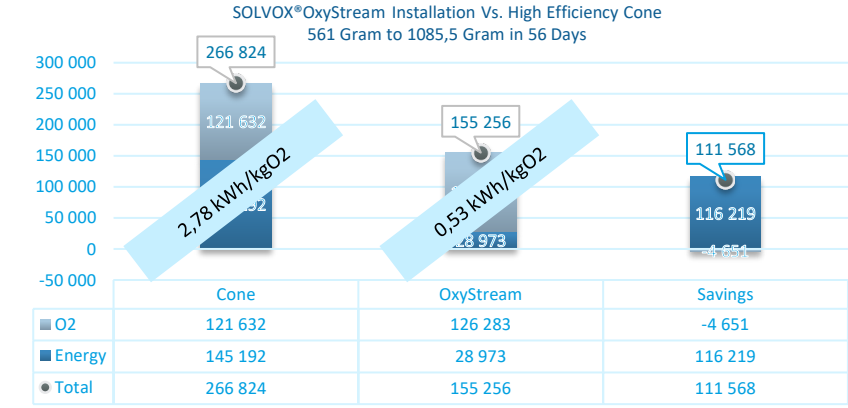
- 93,5%
- 76,3%
- 54,5%

Assuming oxygen cost 3,5 NOK/kg, Energy price 1,2 NOK/kWh

Smolt production in RAS

Linde comparison study





	Cone	OxyStream	Savings
O2	121 632	126 283	-4 651
Energy	145 192	28 973	116 219
Total	266 824	155 256	111 568

"Volume = 1 858 m^3, Retention time= 44,6 - 29,9 min., Biomass produced = 60,5 ton, Density= 35,0-67,5 kg/m^3, Salinity 30 ppt, Oxygen cost 3,5 NOK/kg, Energy cost 1,5 NOK/kWh


Linde
Thank you for your attention!
Kenneth Glomset
Associate Director Aquaculture Solutions
Linde Technology
Meet us at Aqua Nor 2023!
Visit our booth F-580 or check out our digital booth and learn more about our SOLVOX® oxygenation solutions. Please contact us for more information!
Booth F-580
22-24. August

Power Need for Fish Tank Hydraulics

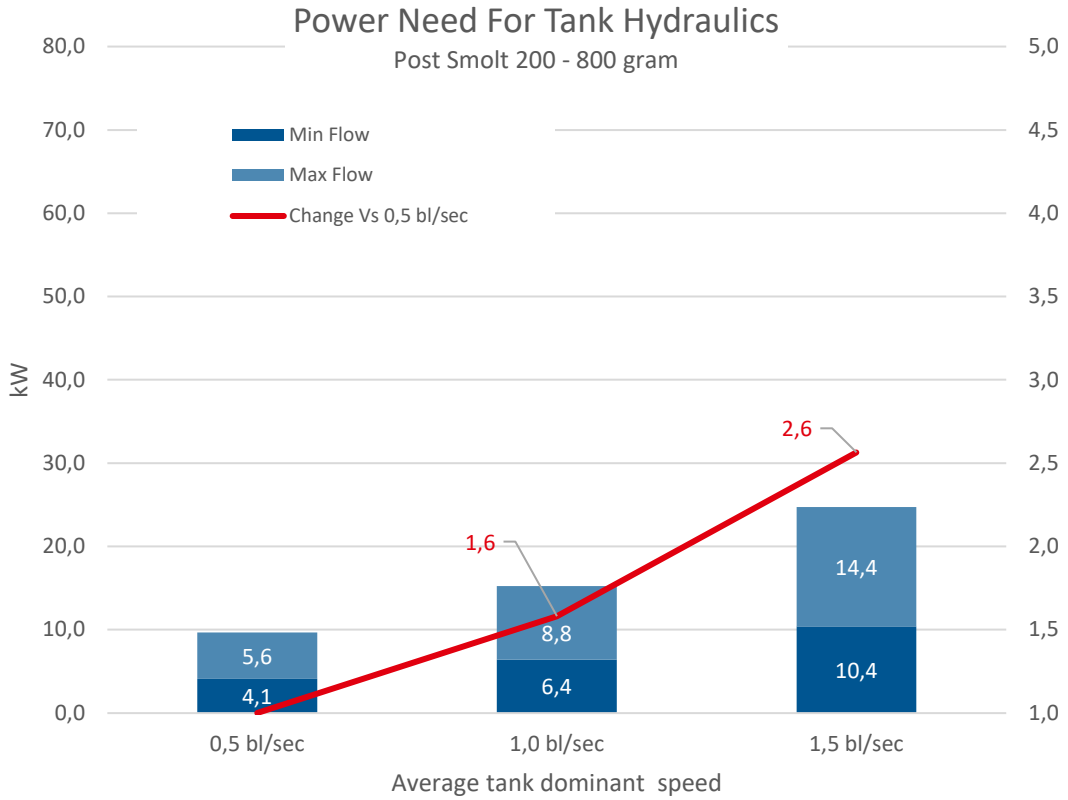
Vertical water inlets

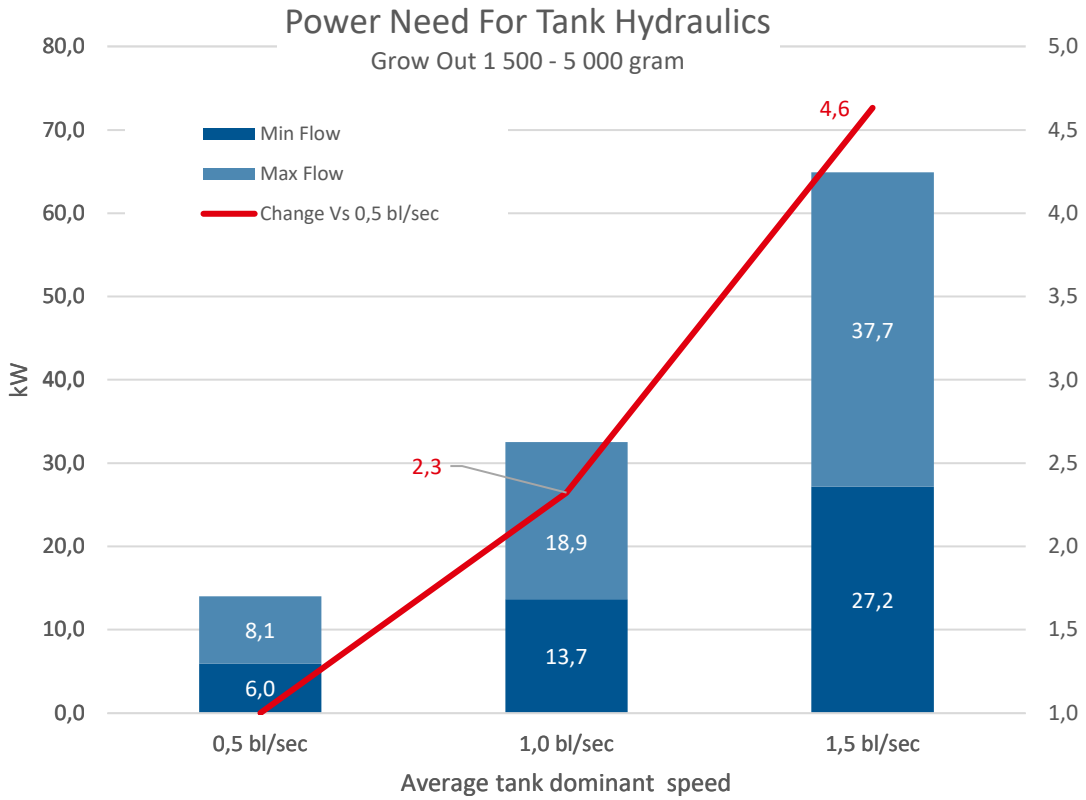
Example calculations

Circular tank with central drain outlet design (dia.20m.)

Tank net water volume 2 000 m^3 with two water inlets

Water exchange 40 – 30 minute (1,5 – 2,0 times/hour)





Average dominant speed of the tank calculated based on Linde experience figures.