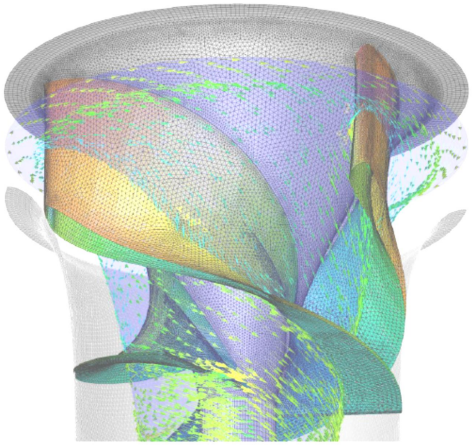
Session D4 - The Science Behind a Fish-Friendly Turbine

National Conference on Engineering and Ecohydrology for Fish Passage,
U.Mass Amherst, June 5-7, 2012

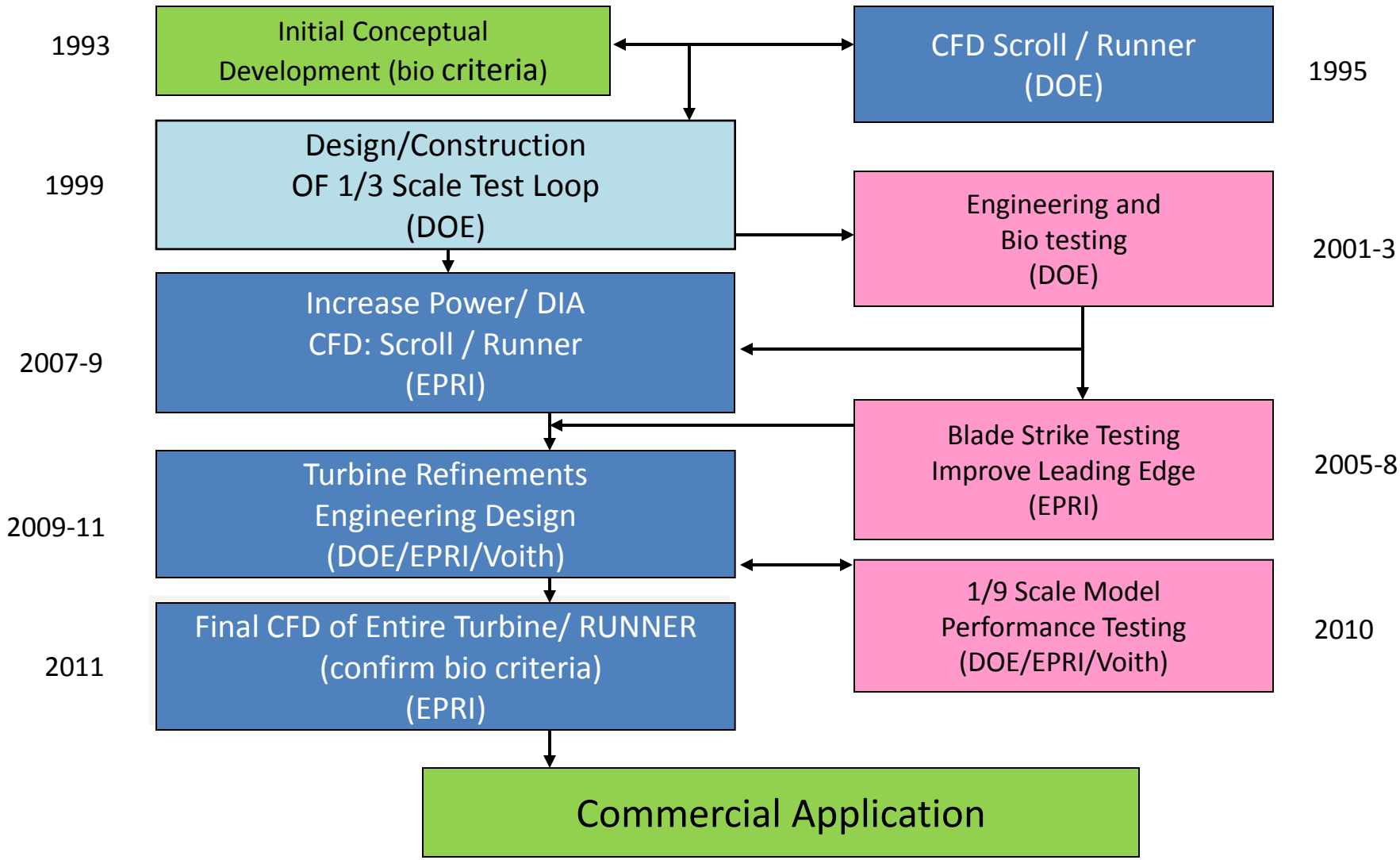
The Science Behind a Fish Friendly Turbine



George E. Hecker, Stephen Amaral, Greg Allen,
Songheng Li, Norman Perkins: Alden
and Doug Dixon: EPRI

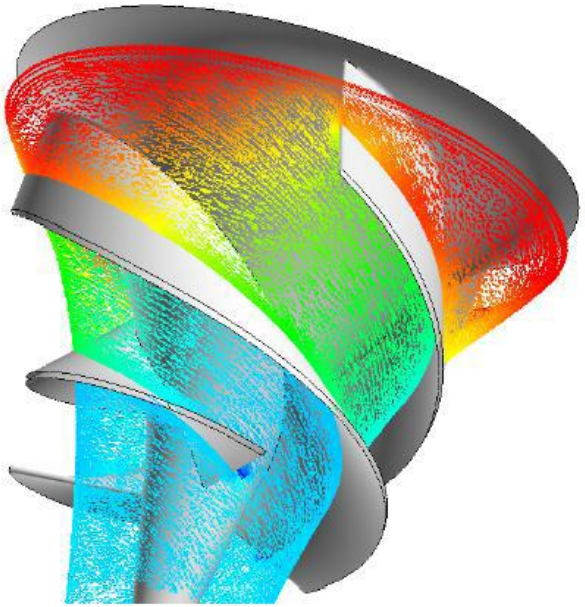
ALDEN

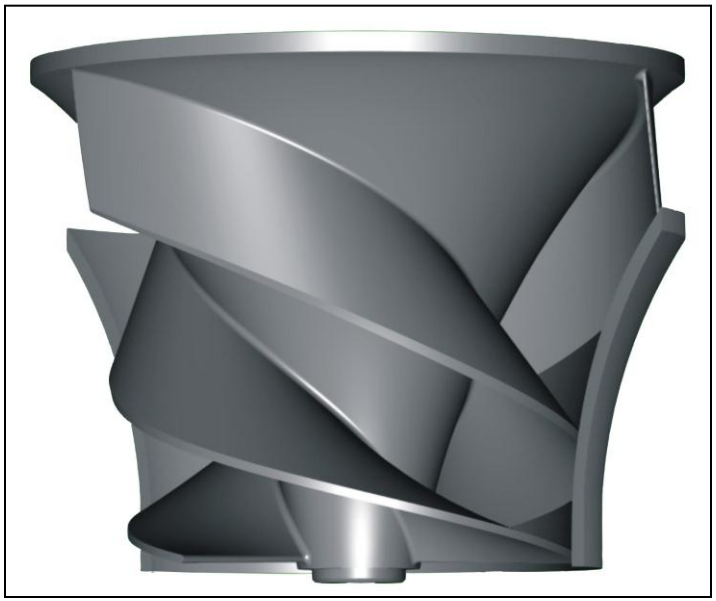
Evolution of the Alden Turbine



Basic Features of the Initial Design

- Few (3) leading edges to minimize strike
- No Gaps (Rotating Shroud)
- Fewer (longer) wicket gates to increase clearance
- Relatively slow runner RPM
- Maximize flow passage per DIA

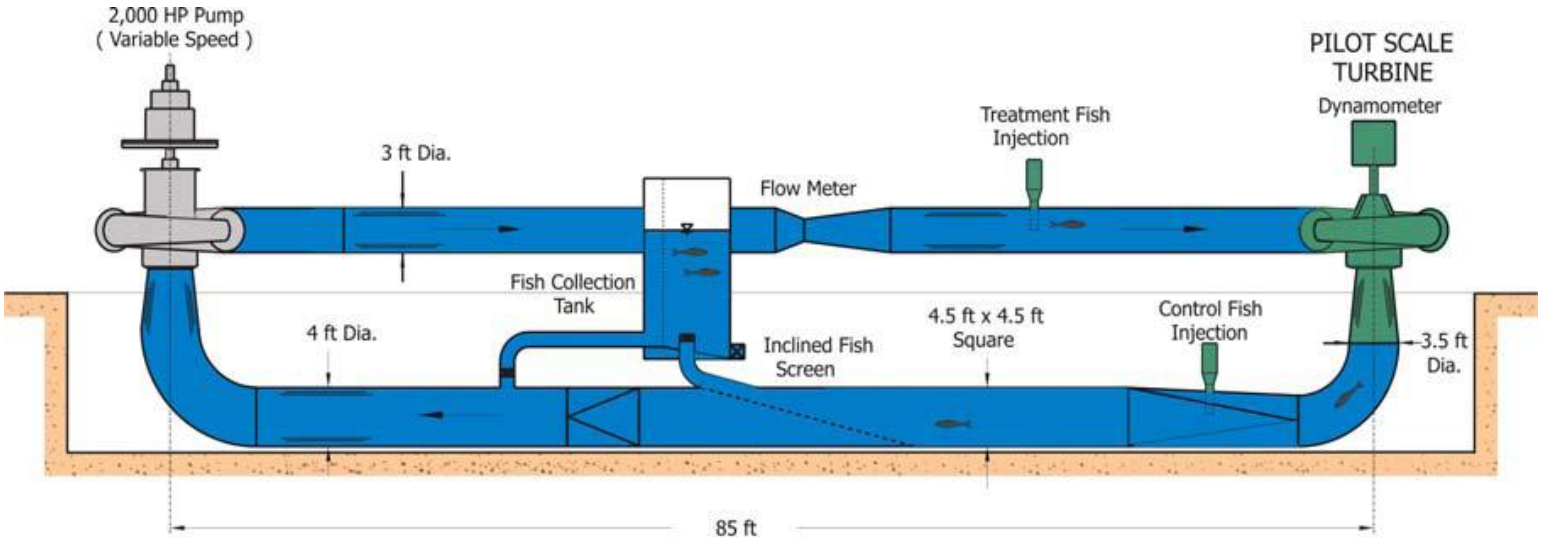


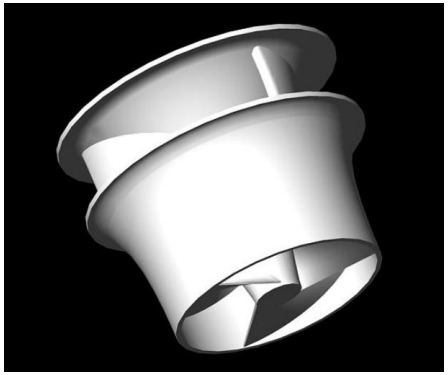


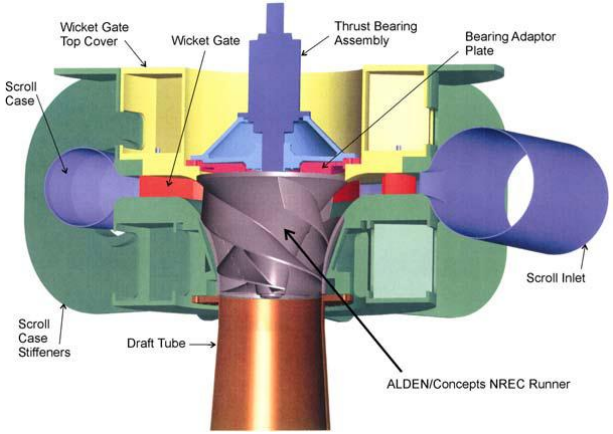
CFD to meet bio criteria for

- Flow Shear
- Pressure change rate
- Min pressure

1/3 Scale Turbine Test Loop







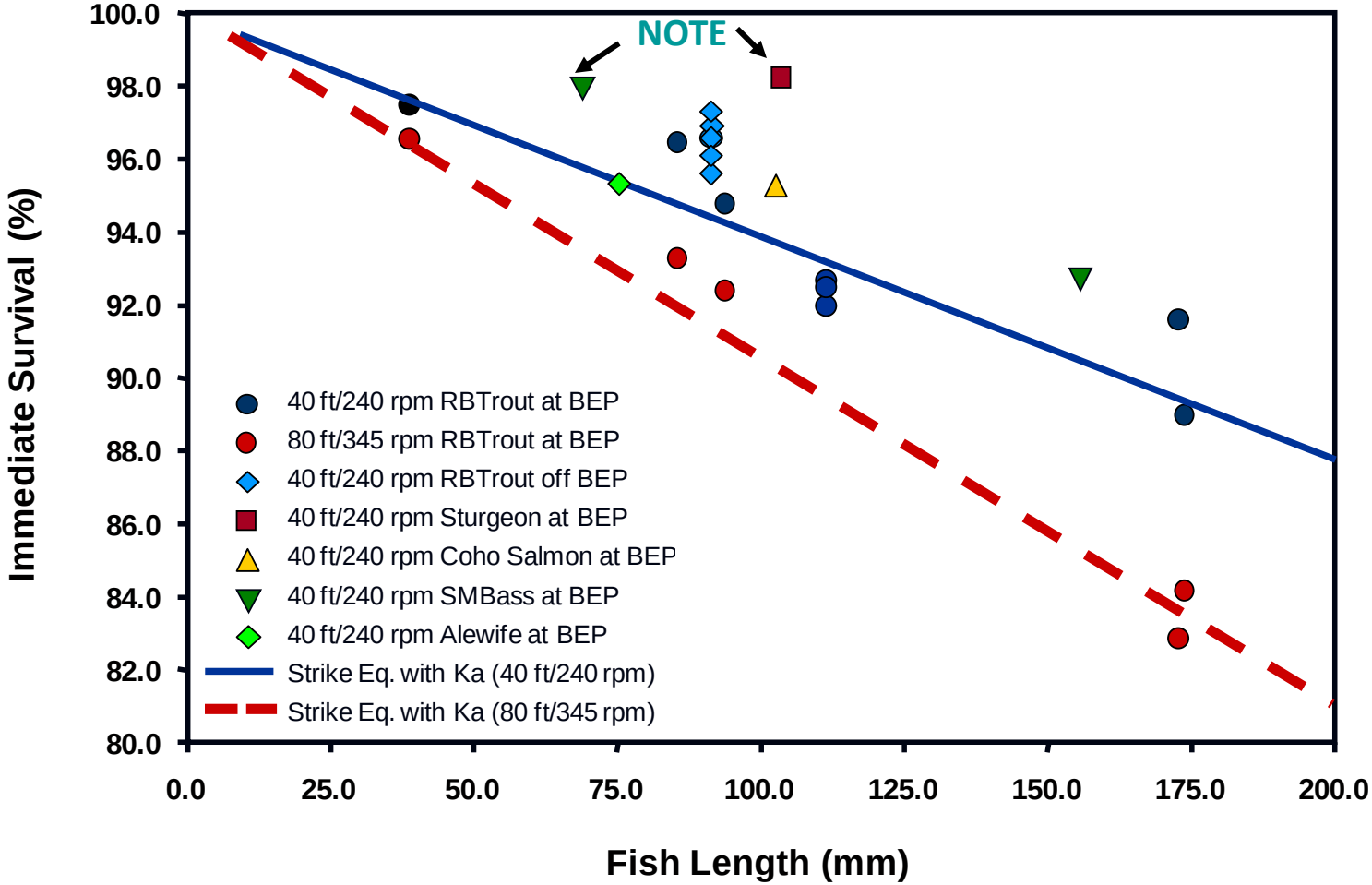
Runner Diameter =4 Ft

Pilot Scale Test Loop

Looking Toward Turbine

Pilot Scale Test Results

Survival of 250 mm and 430 mm EEL About 100%



Probability of Blade Strike and Probability from Strike

$$P_S = n(L\sin\alpha)N/(60V_r)$$

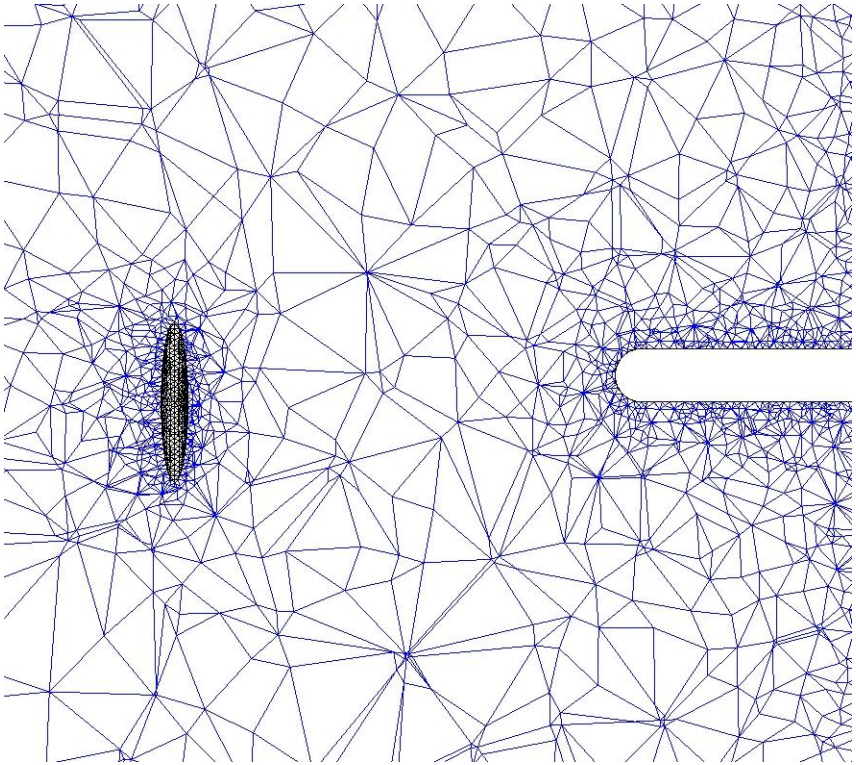
n = rpm; L = Fish Length; α = Inflow Angle;
N = Number of Blades; V_r = Radial Velocity

$$P_{MS} = K\, n(L\sin\alpha)N/(60V_r)$$

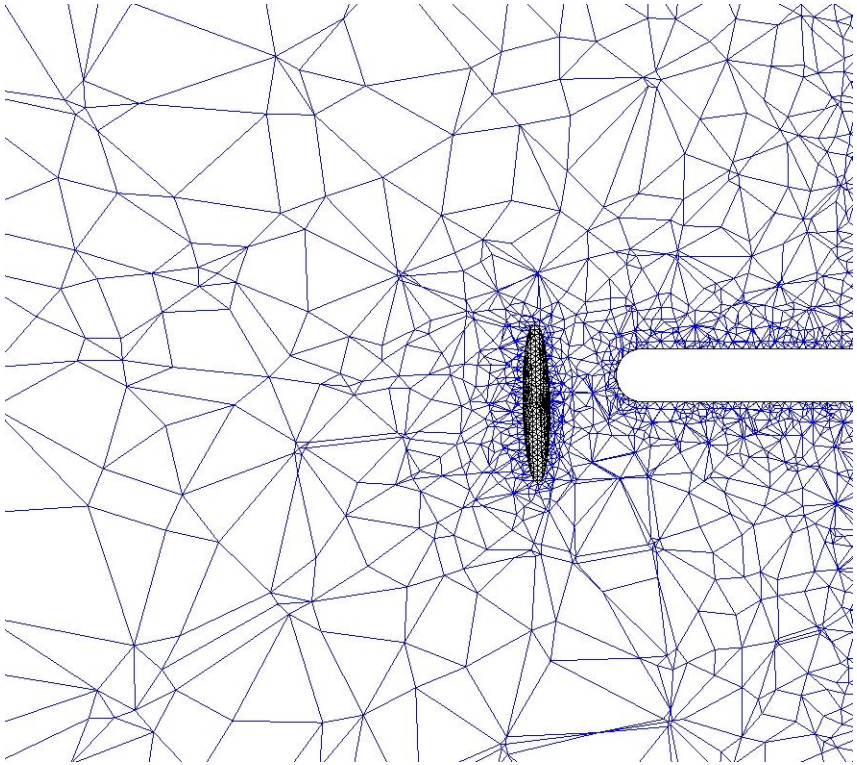
where **K** is % mortality from strike

Blade Strike Study

CFD Simulations of Strike with Ridge Fish



Grid at time step t_1

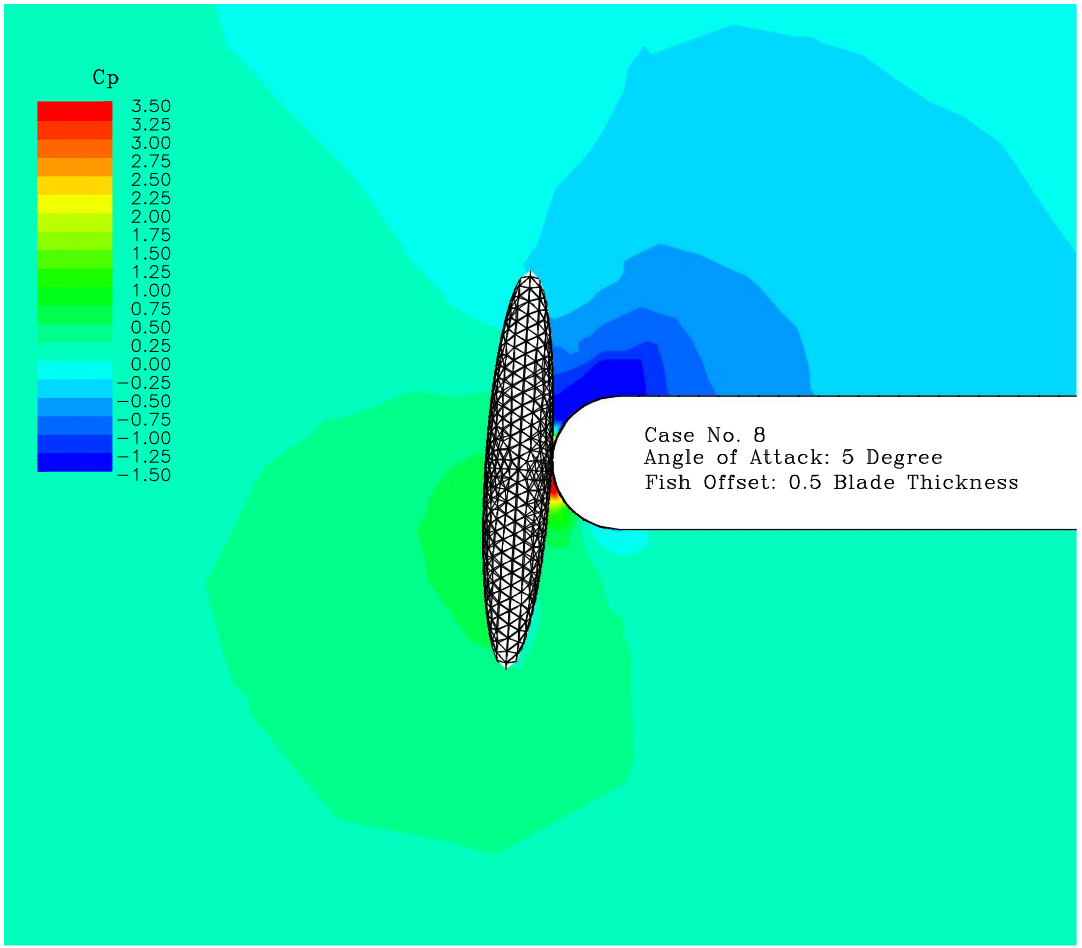


Grid at time step t_{1+x}

Blade Strike Test

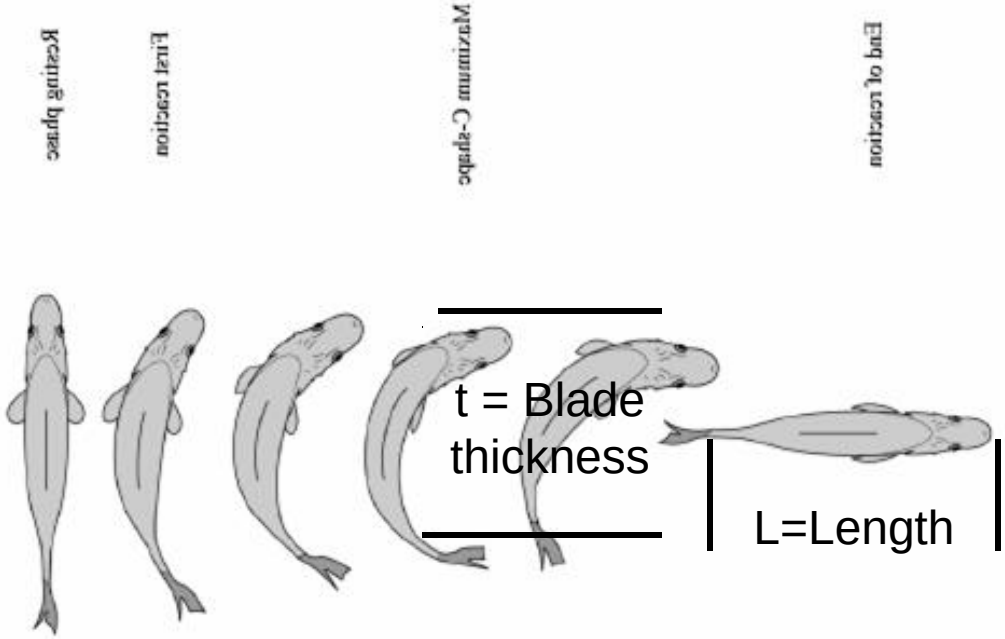
Fish Position and Pressure Coefficient Distribution

Case 8: 5° Approach Flow



Blade Strike Study

Fish Curvature: C-Start Response

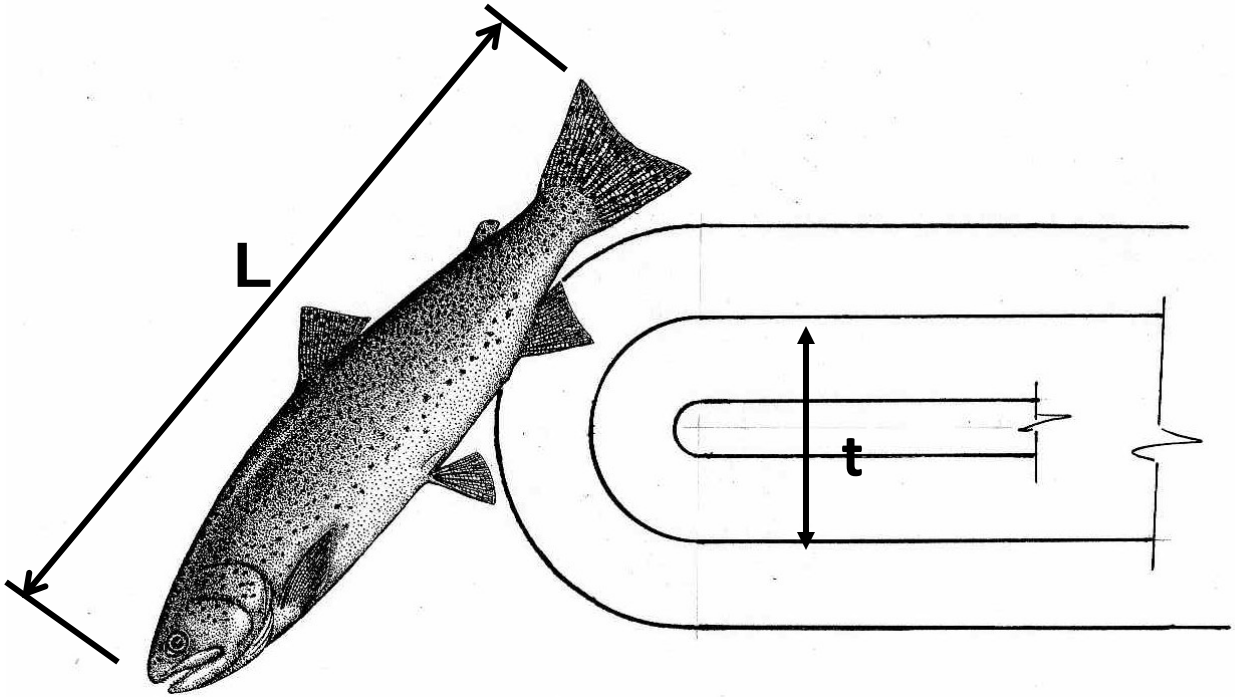


L/t = 1.6

ORNL/TM-2003/288

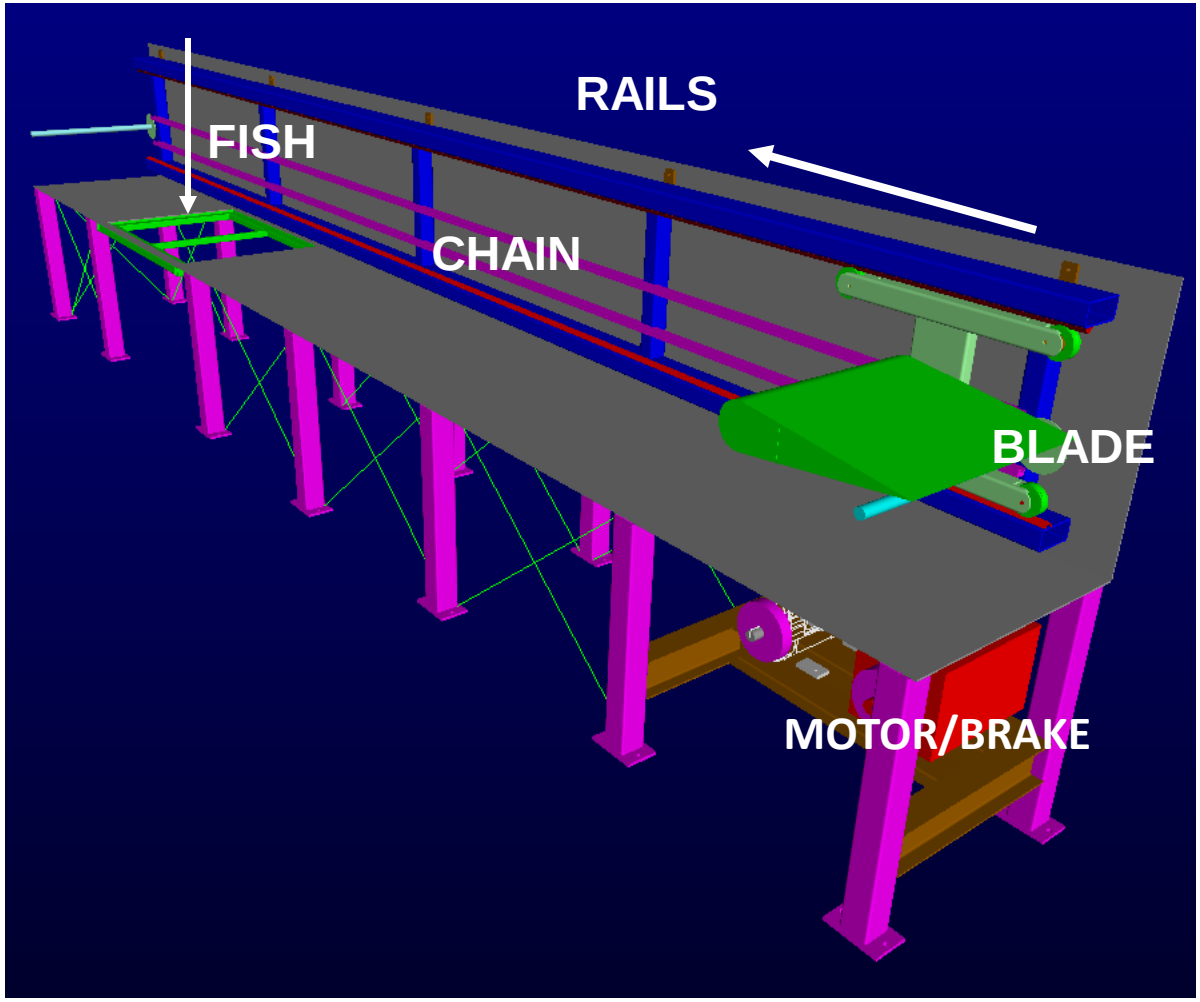
Blade Strike Study

Fish length to blade thickness ratio



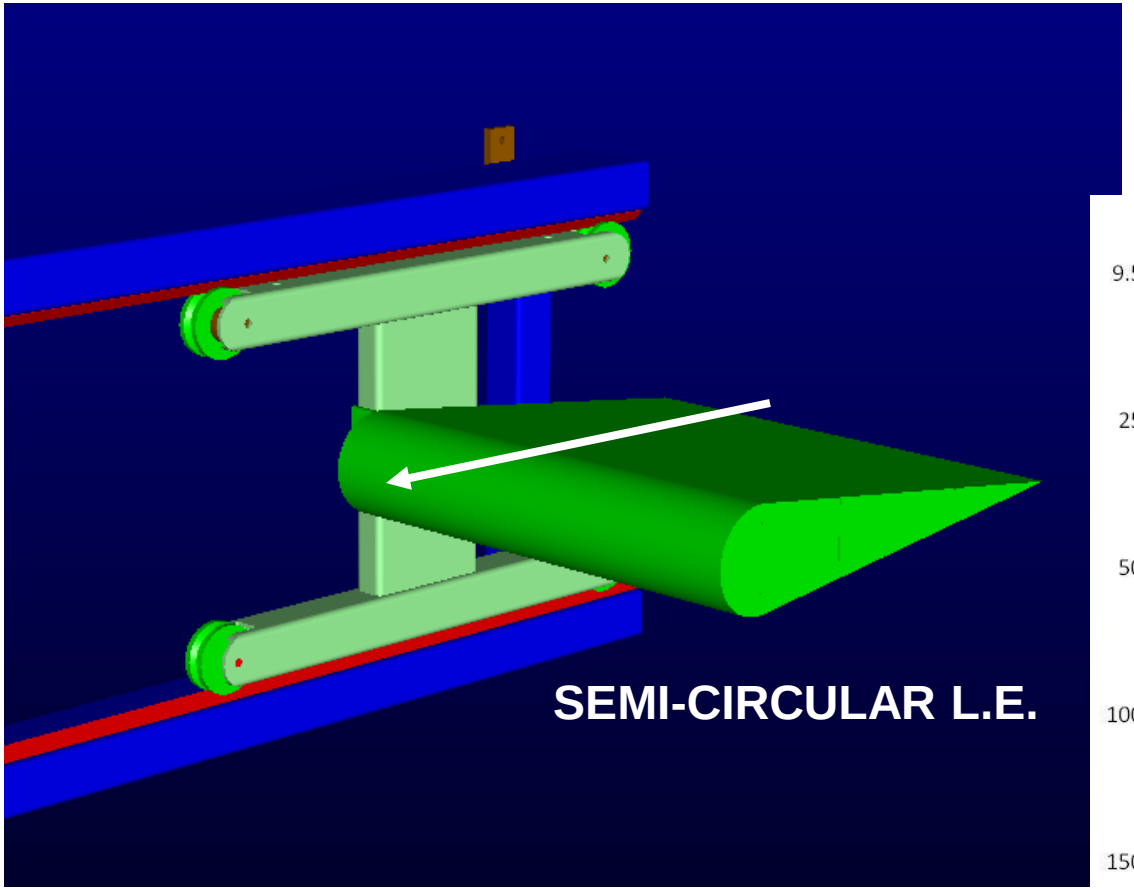
Blade Strike Study

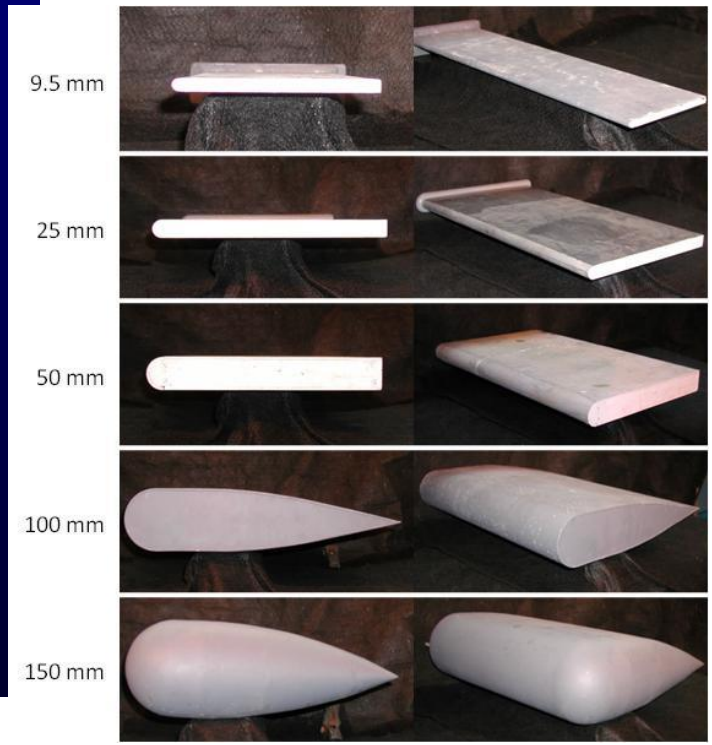
Test Facility – Internal



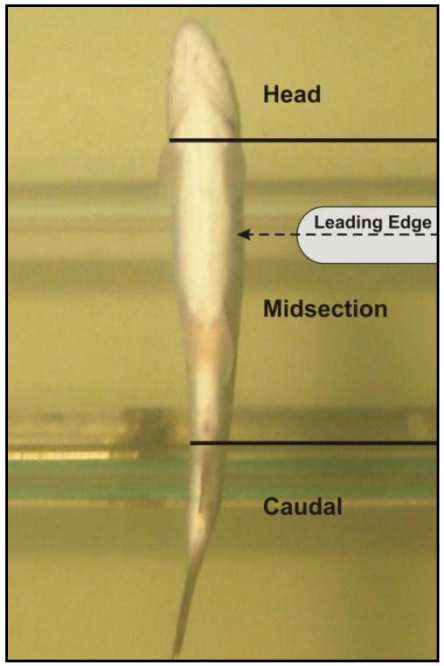
Blade Strike Study

Blade on Moving Cart



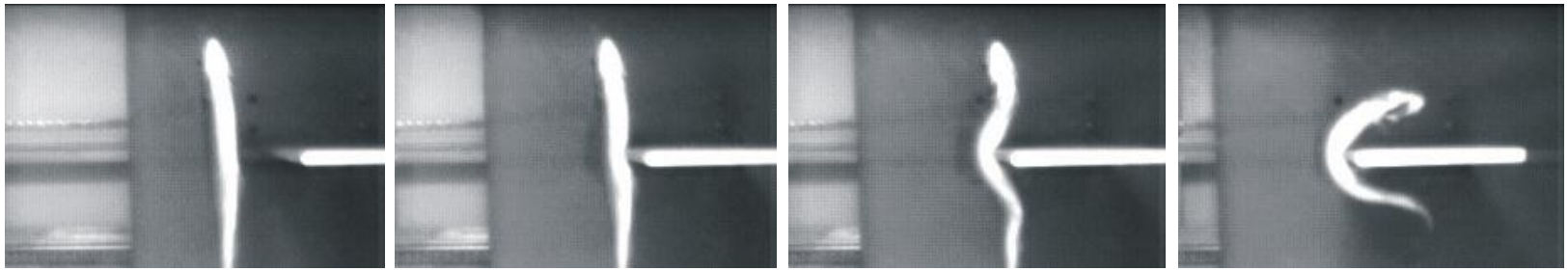


Blade Strike Study

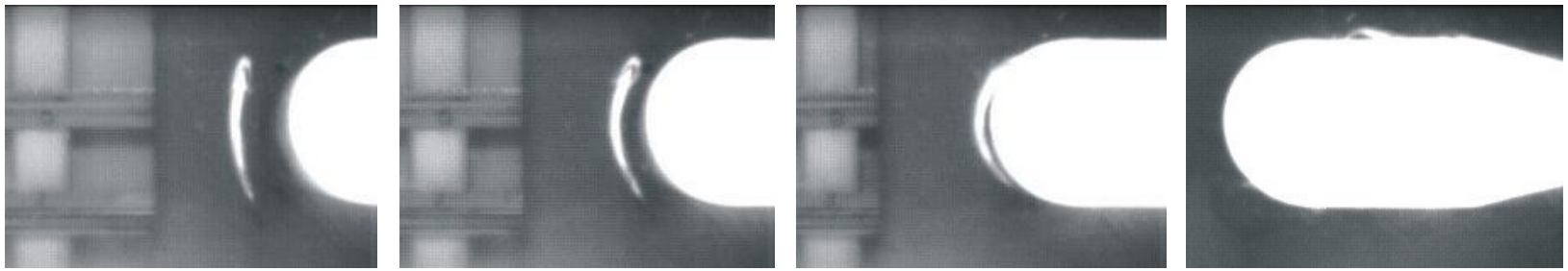


Blade Strike – High Speed Video

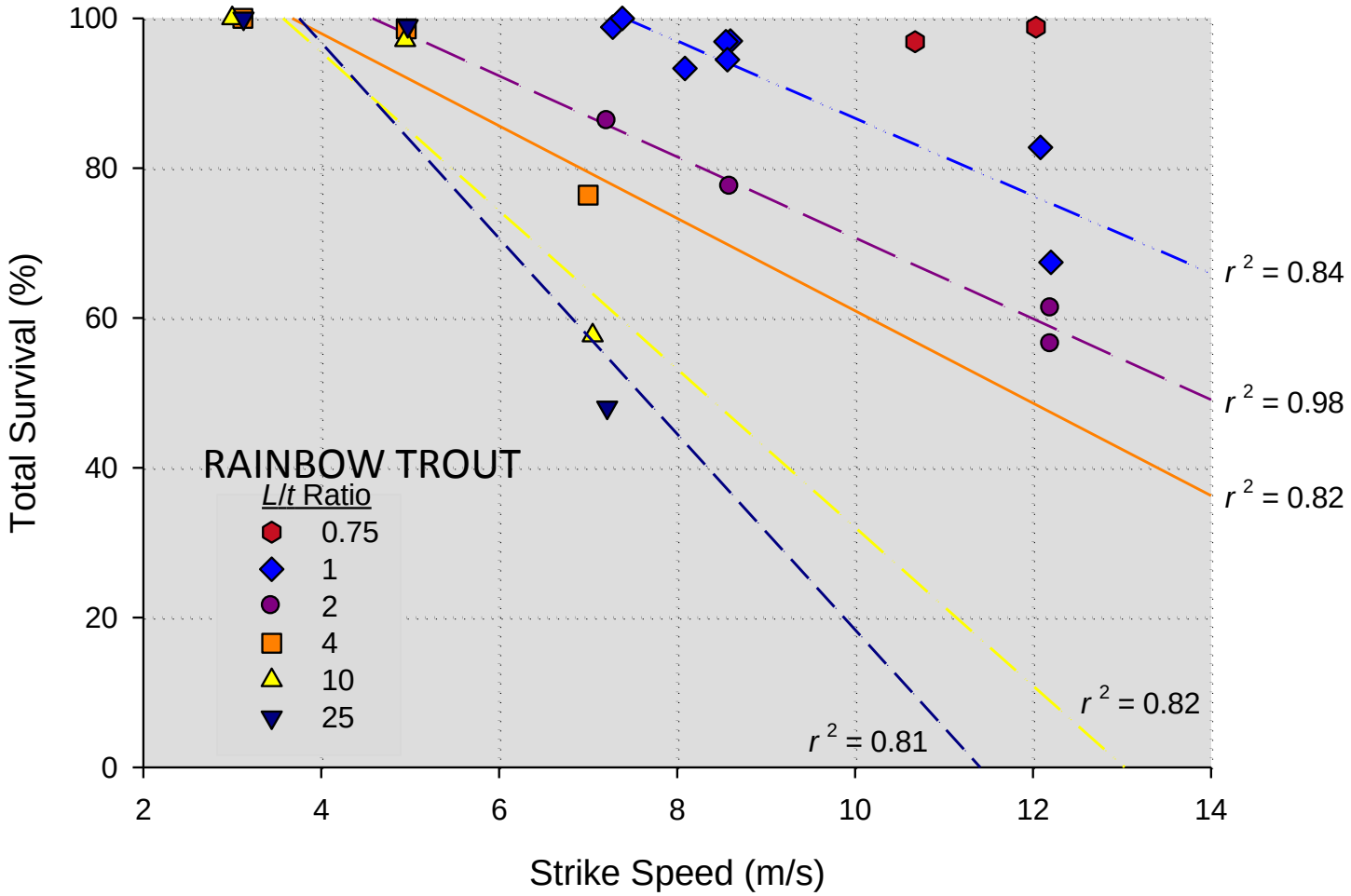
Fish L=250 mm; Blade t=10 mm; V=24 ft/s



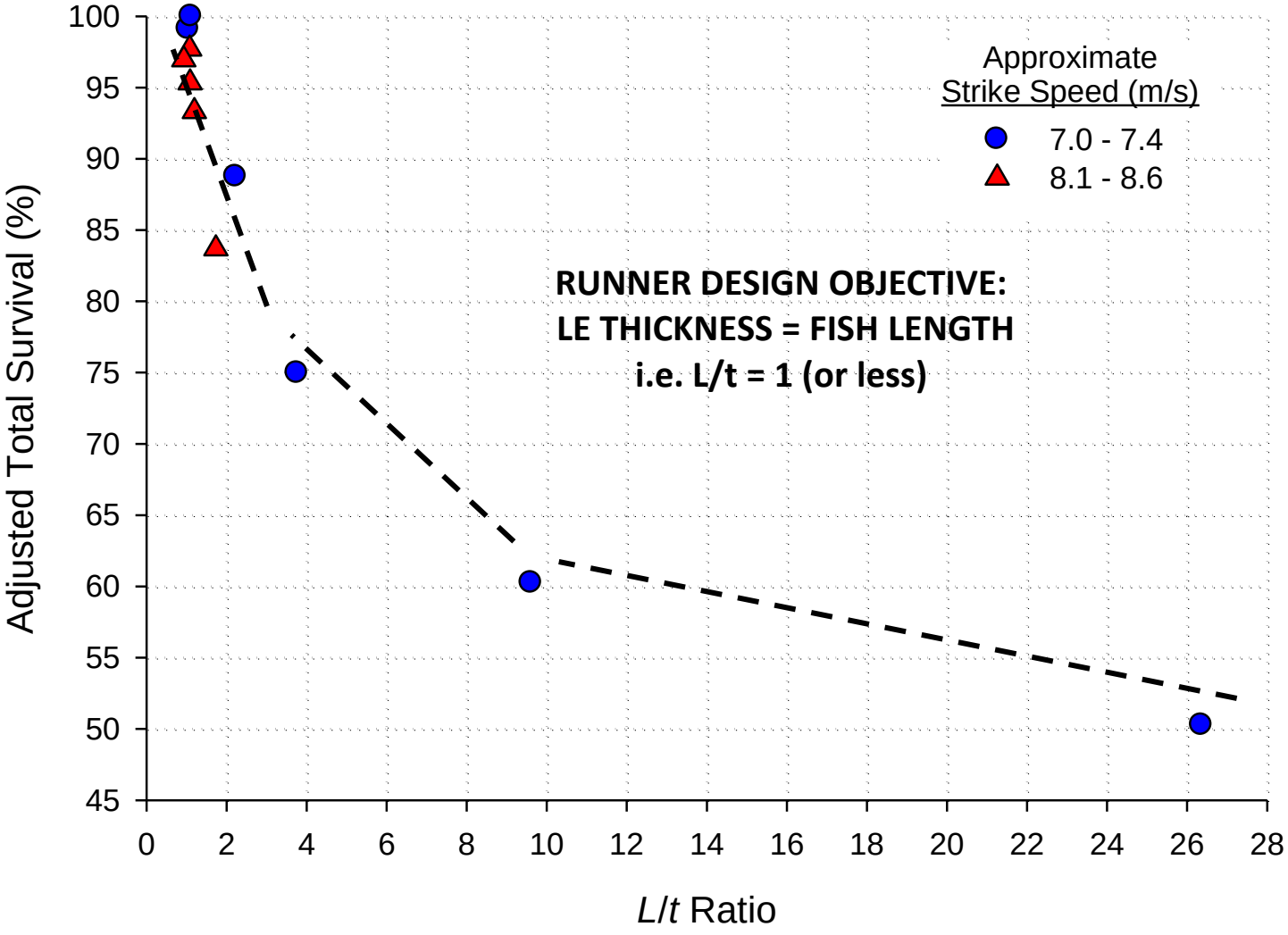
Fish L=150 mm; Blade t=150 mm ; V=24 ft/s



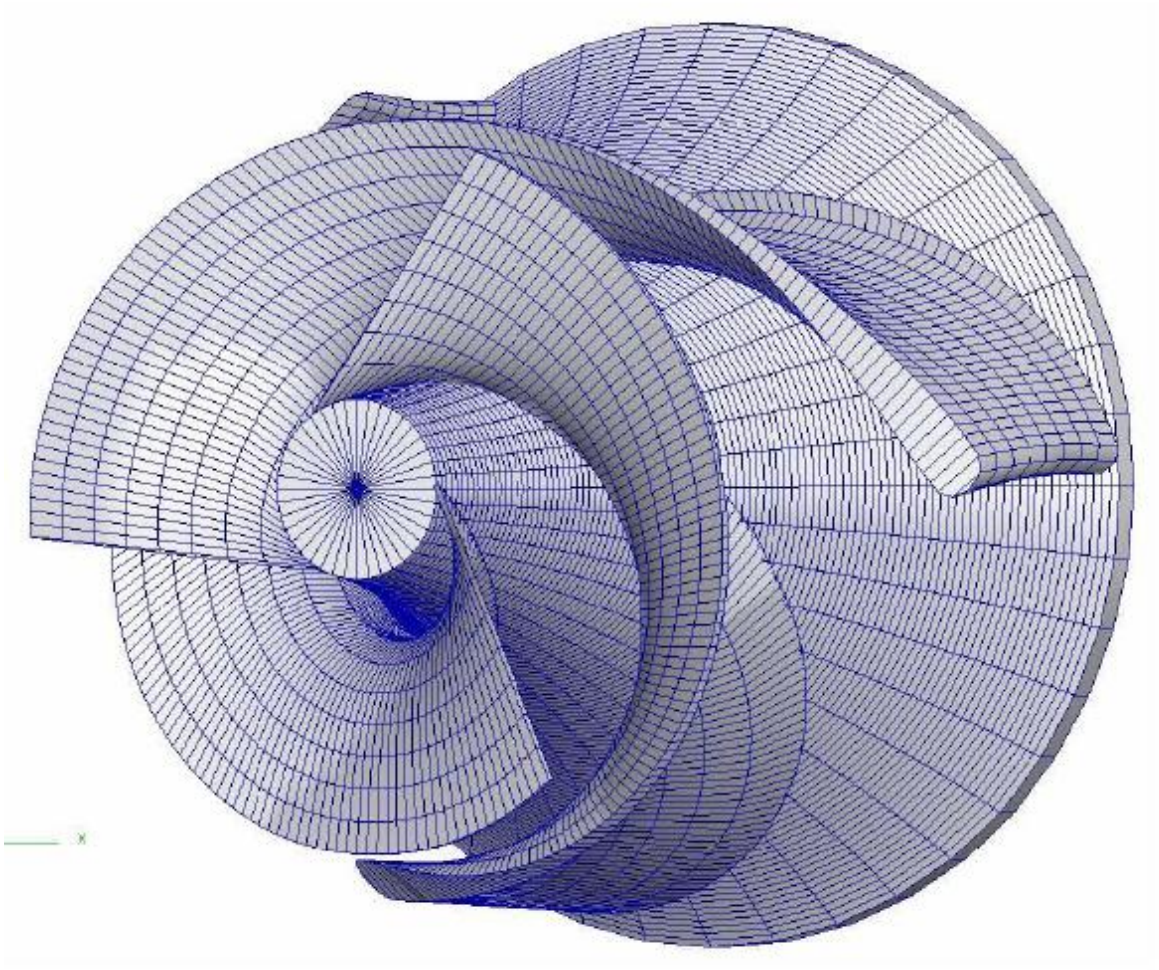
Survival from Blade Strike Versus Impact Velocity



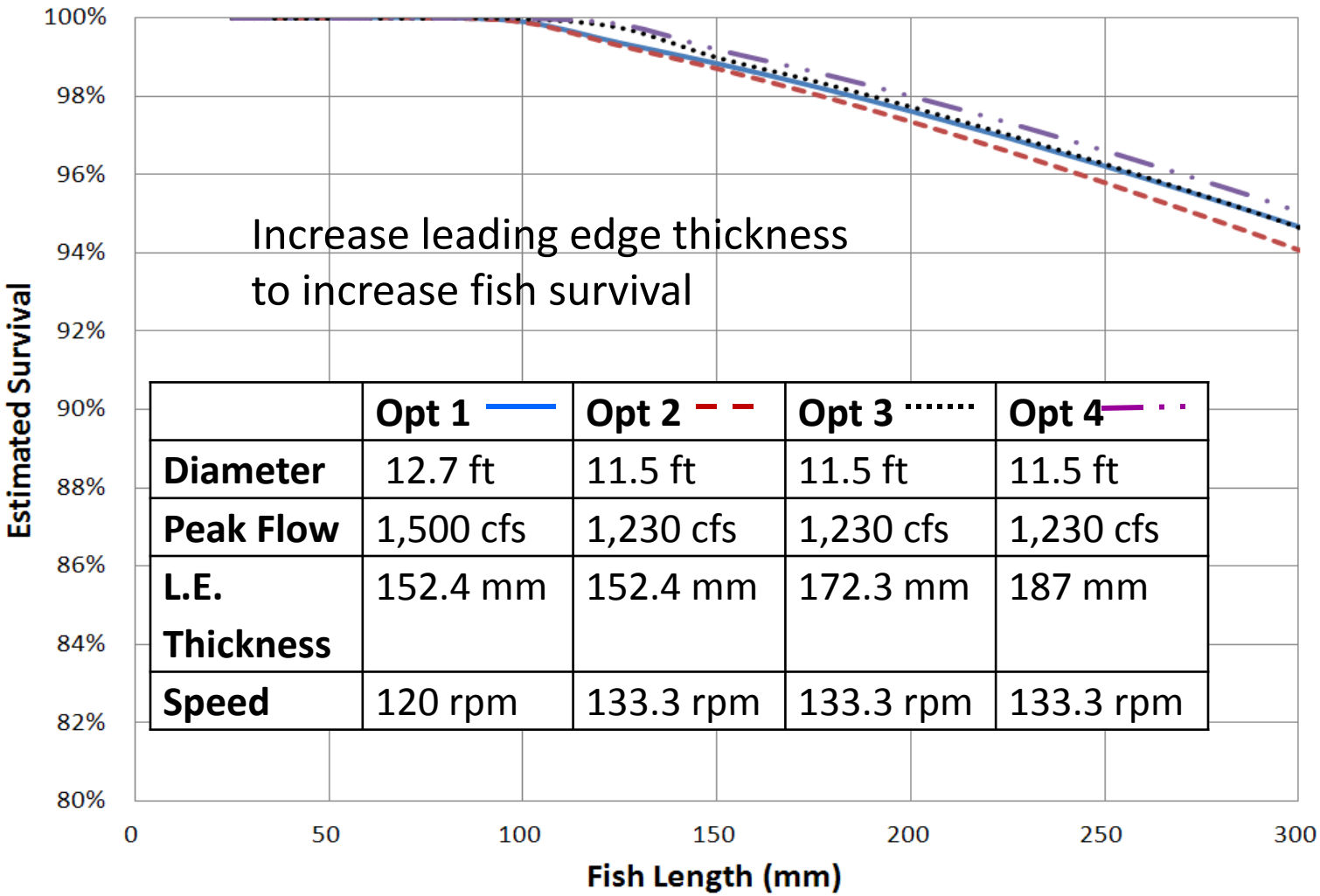
High Survival at Low L/t Ratio



Increased LE Thickness for Runner



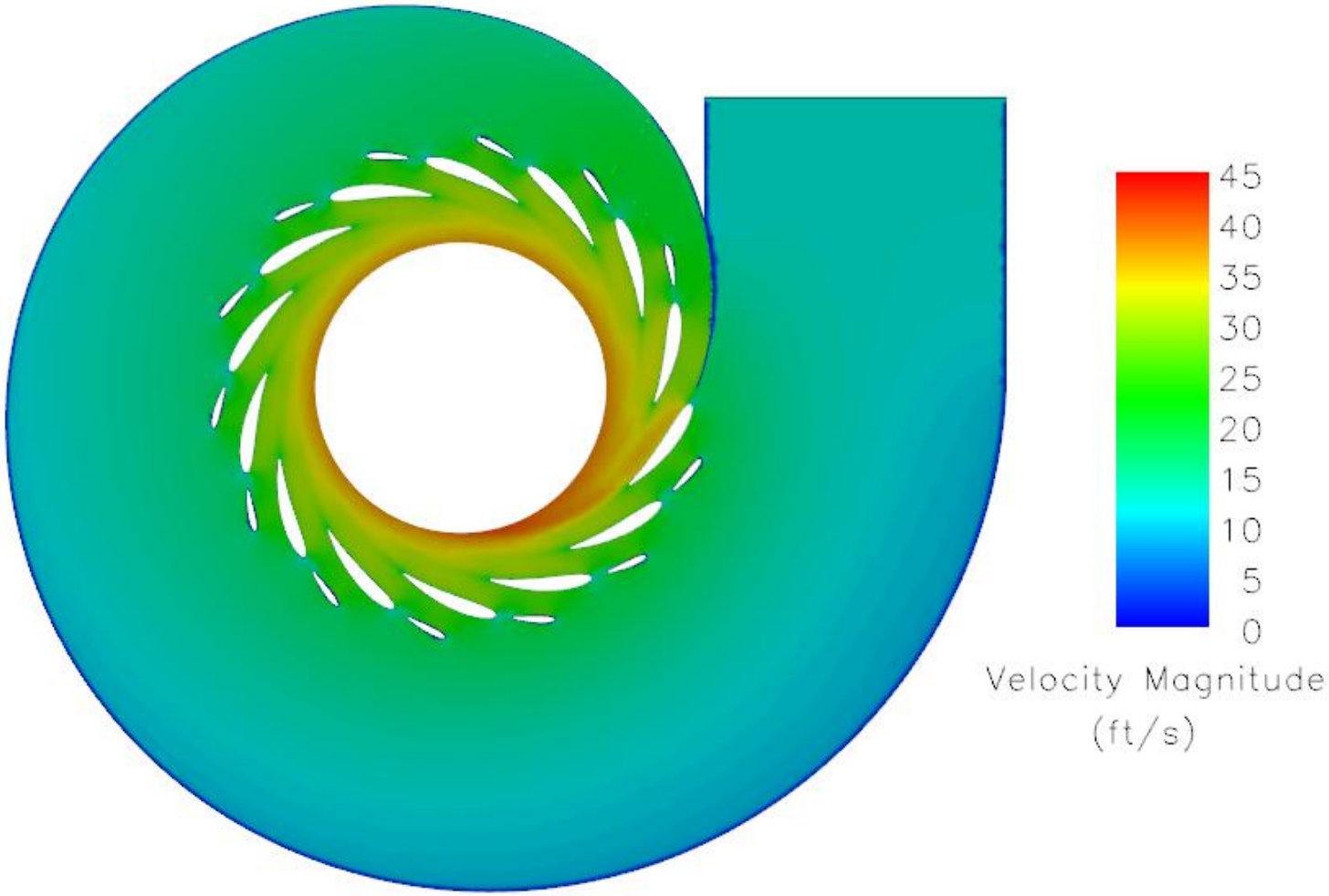
Predicted Fish Survival; H=92 ft



Increase leading edge thickness to increase fish survival

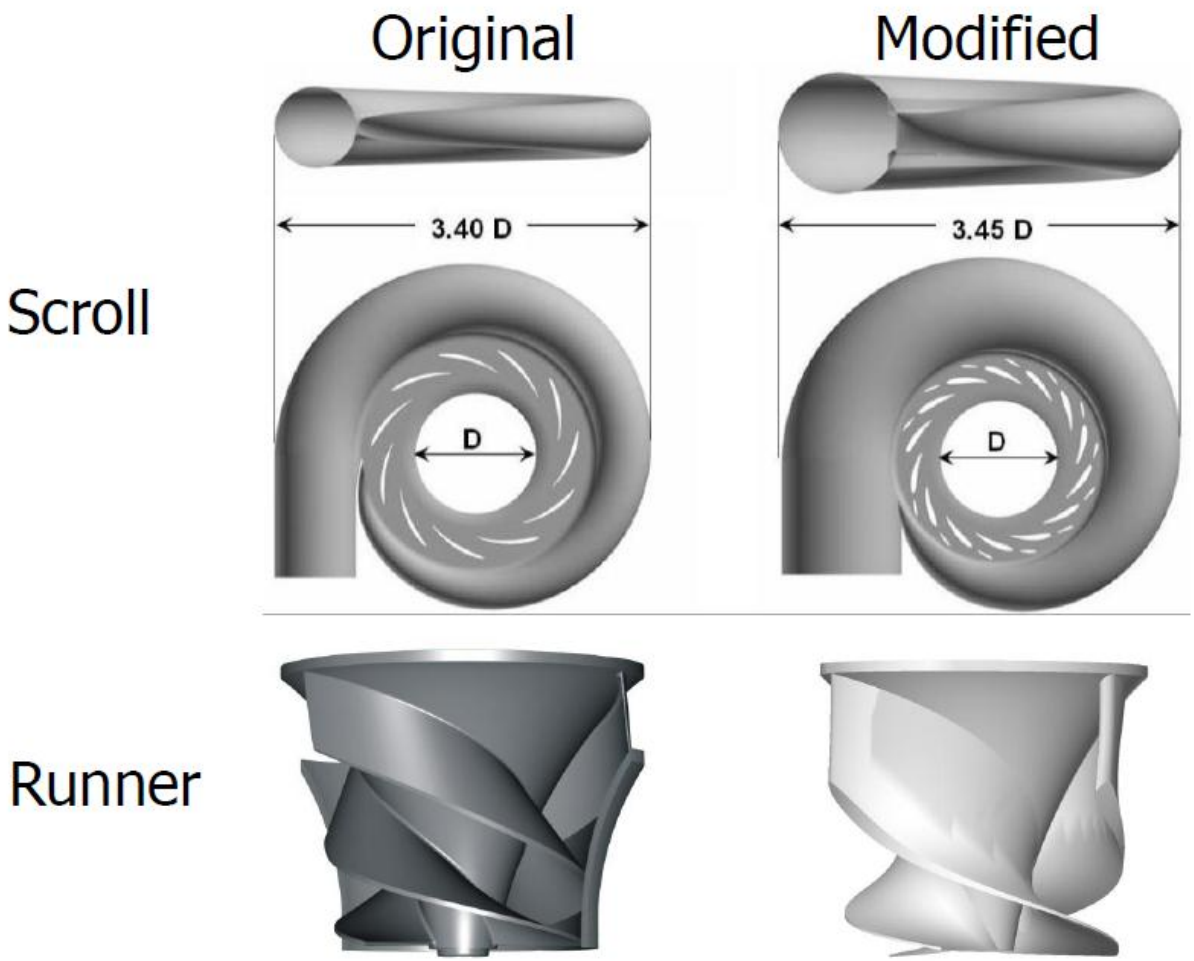
	Opt 1	Opt 2	Opt 3	Opt 4
Diameter	12.7 ft	11.5 ft	11.5 ft	11.5 ft
Peak Flow	1,500 cfs	1,230 cfs	1,230 cfs	1,230 cfs
L.E. Thickness	152.4 mm	152.4 mm	172.3 mm	187 mm
Speed	120 rpm	133.3 rpm	133.3 rpm	133.3 rpm

Redesign of Turbine to Increase Power / DIA

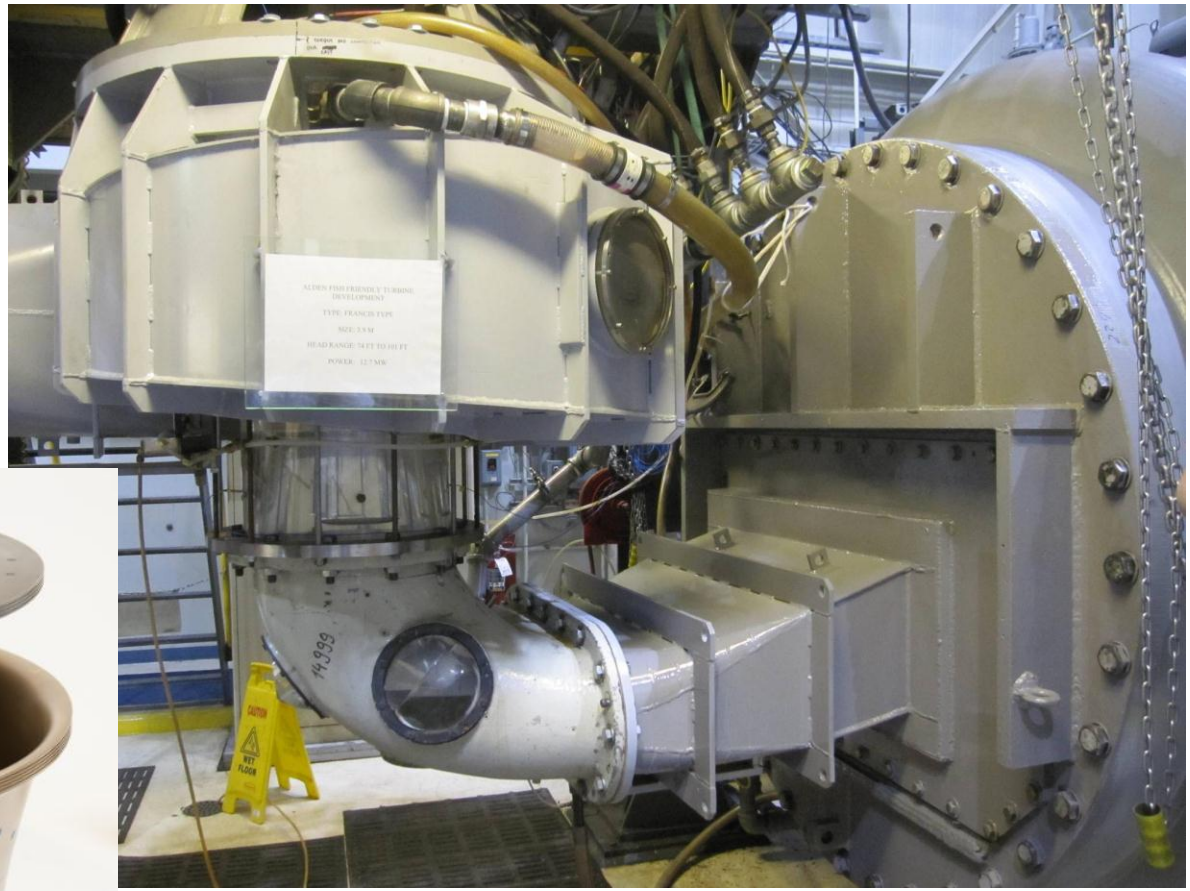


Redesign of Scroll and Runner

Modified for Increased Flow and Power

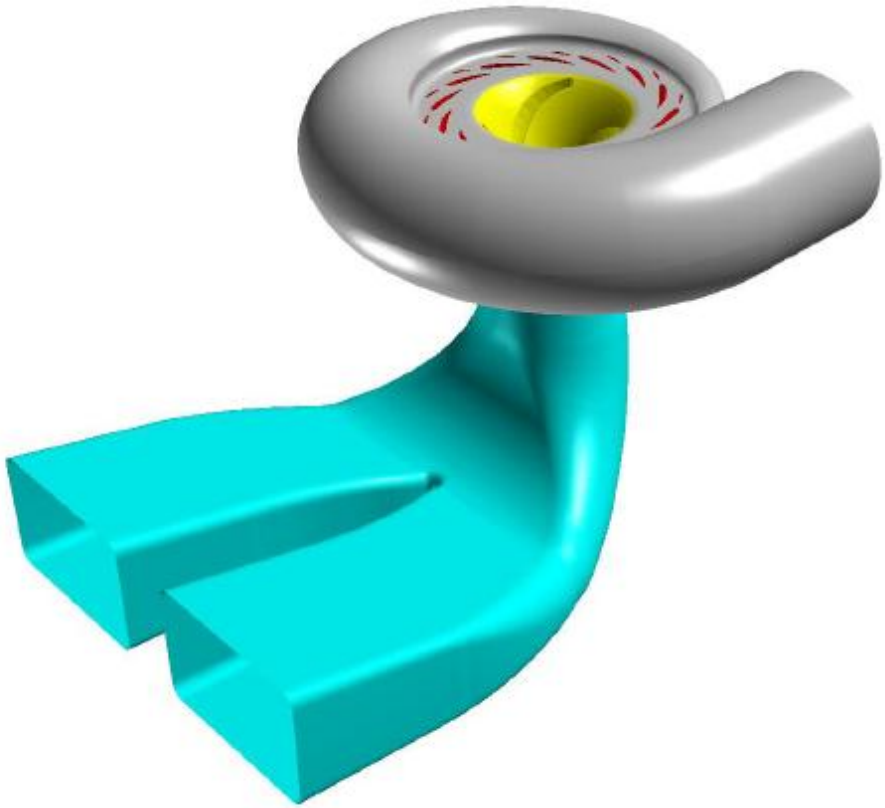


Voith Test Stand



Engineering design and
model tests for power performance

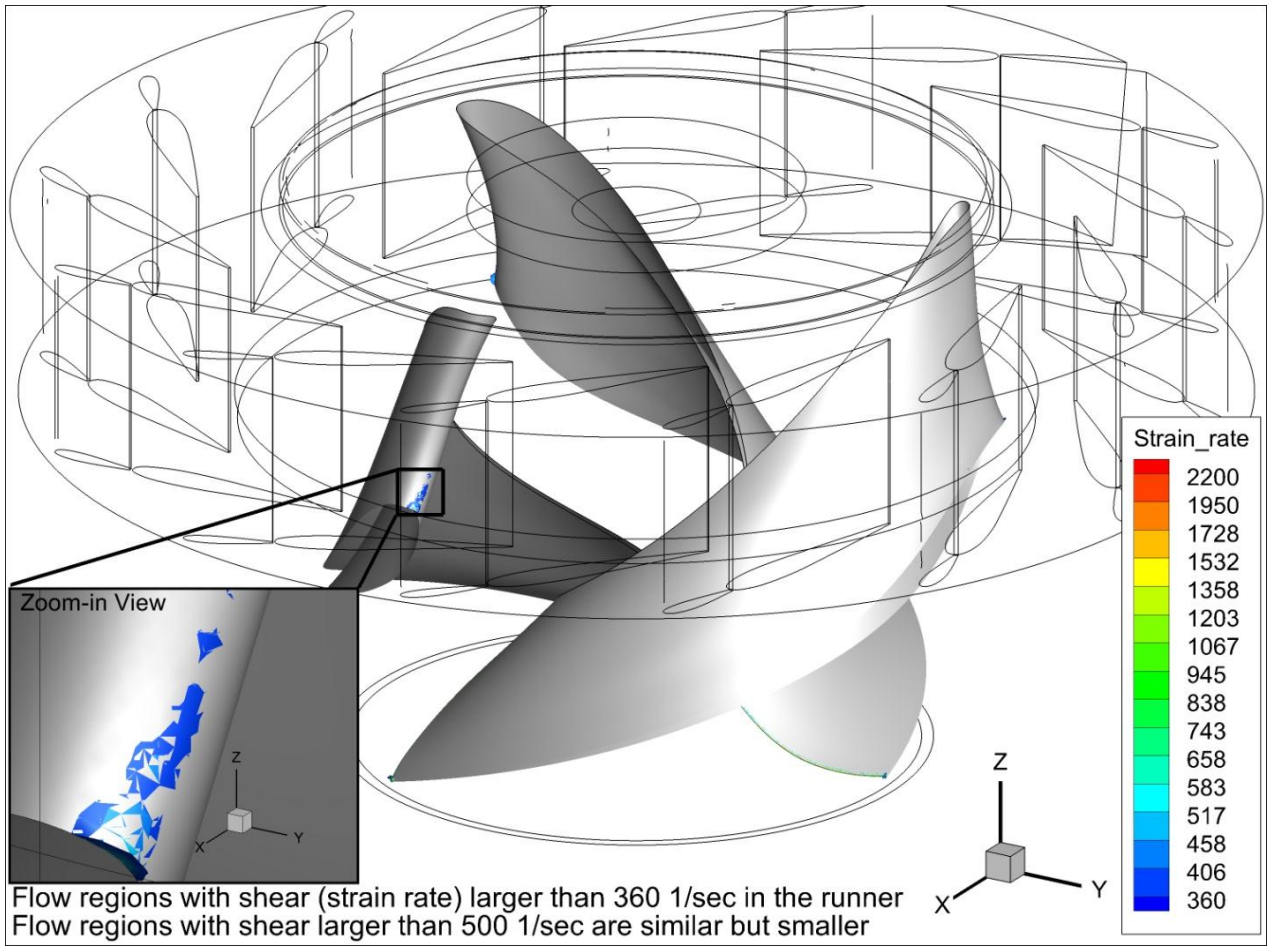
Final CFD of Entire Turbine



CFD Simulations verified by close agreement with experimental Hill Chart
(Flow, head, efficiency and power at various wicket gate openings)

Check on Biological Criteria

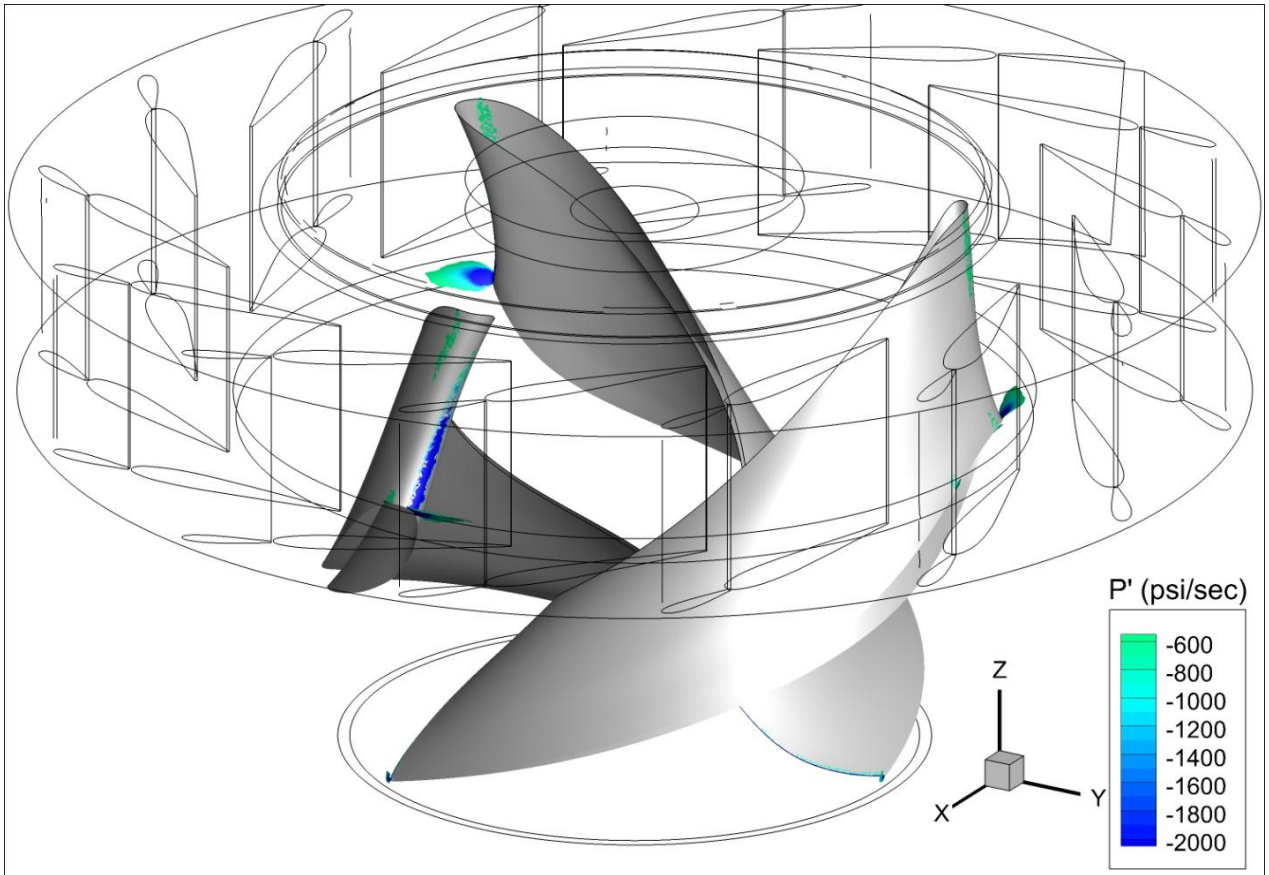
Flow Shear



Flow regions with shear (strain rate) larger than 360 1/sec in the runner
Flow regions with shear larger than 500 1/sec are similar but smaller

Check on Biological Criteria

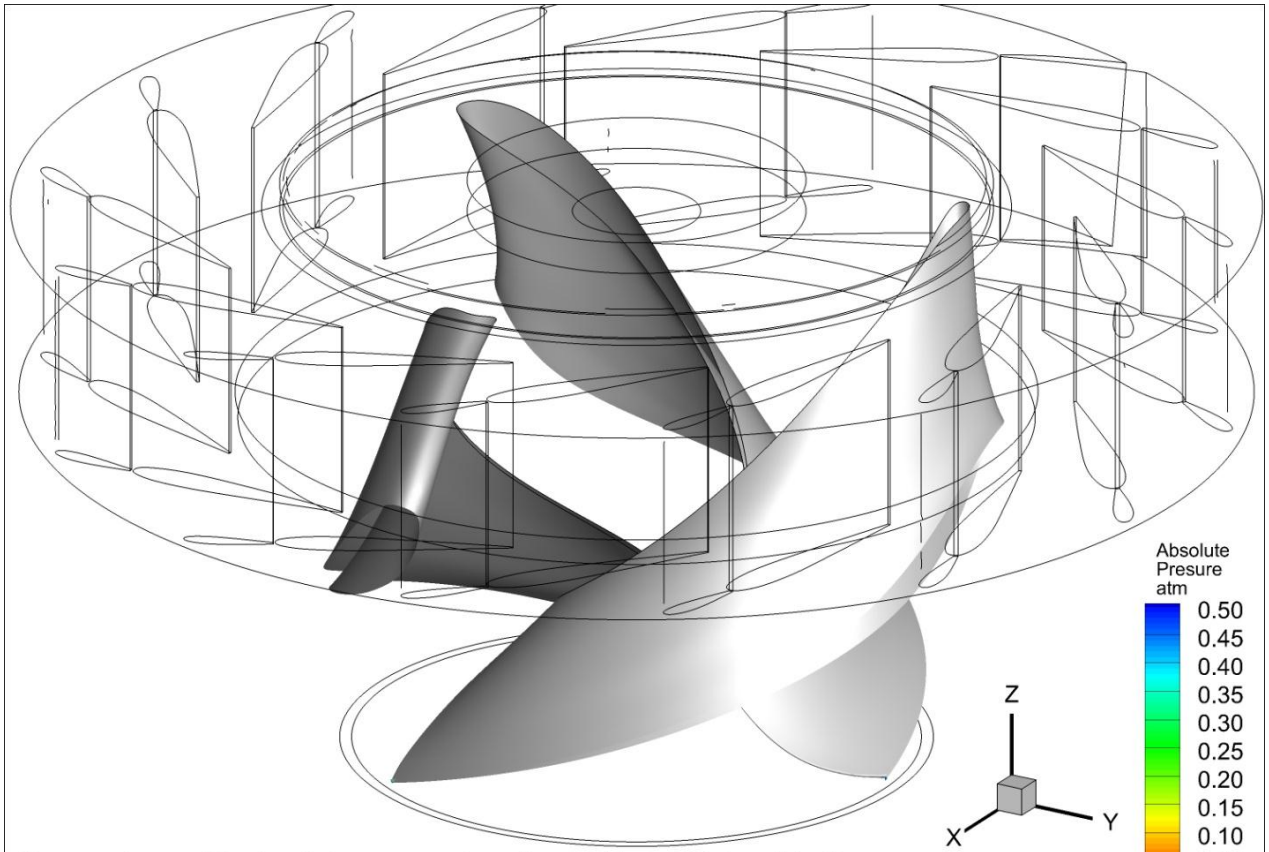
Pressure Drop Rate



Flow regions with absolute presure change rate larger than -500 psi/sec in the runner

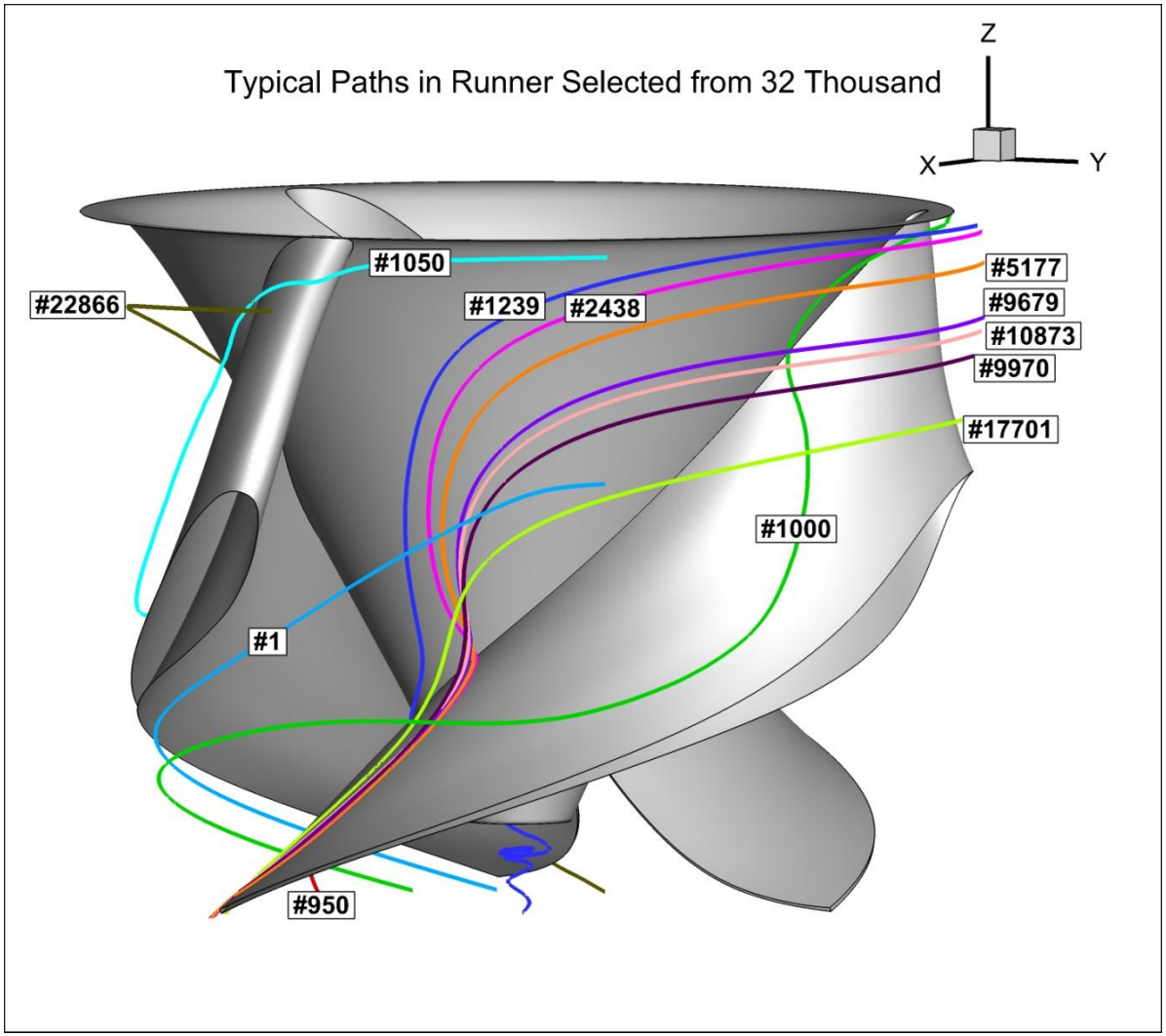
Check on Biological Criteria

Minimum Absolute Pressure

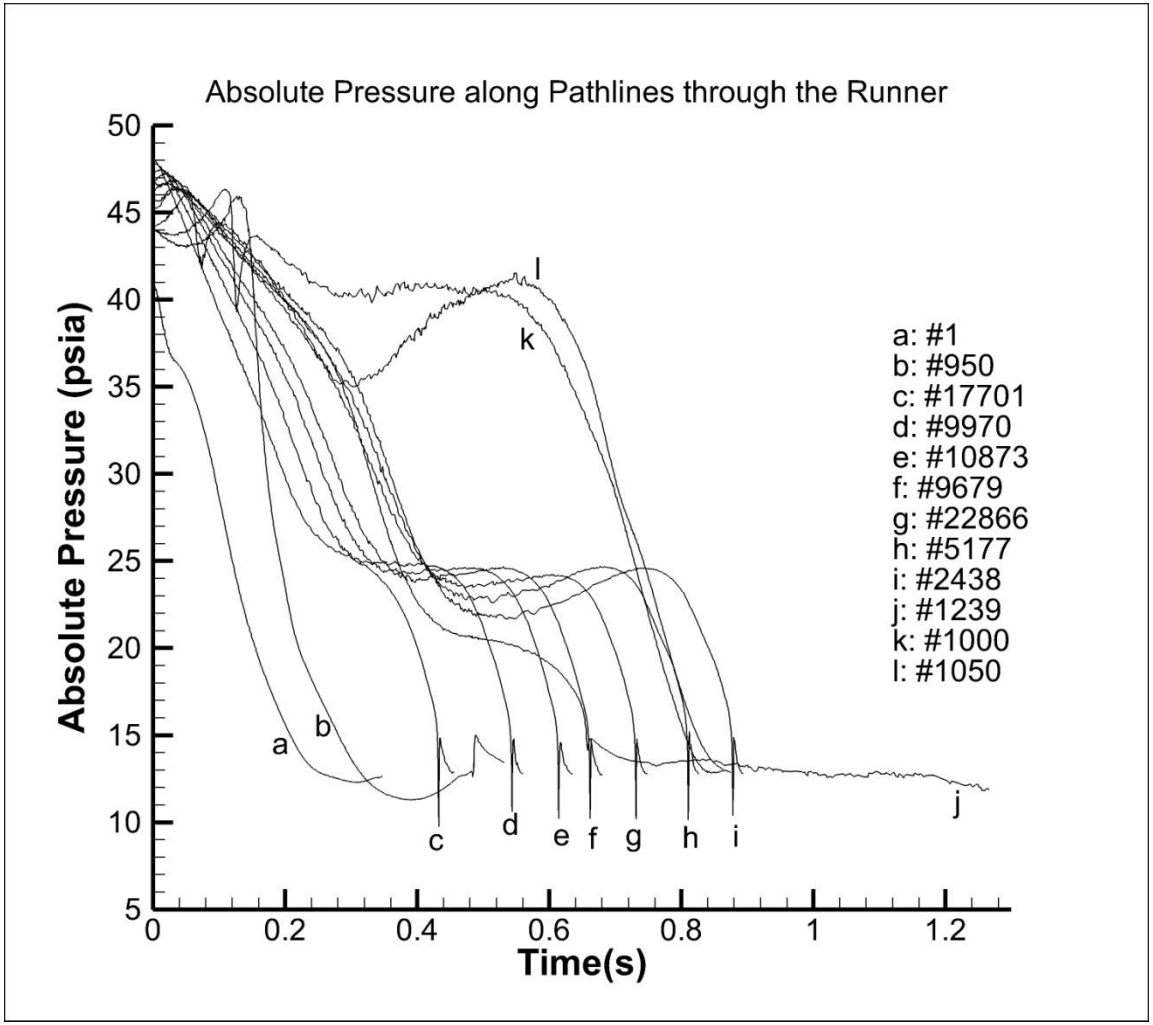


Flow regions with absolute presure less than 0.5 atm (7.4 psi) in the runner.
Flow regions with absolute presure less than 0.6 atm (8.8 psi) in the runner is similar..

Flow Paths Through Runner



Pressure Versus Time Along Flow Paths



Questions?