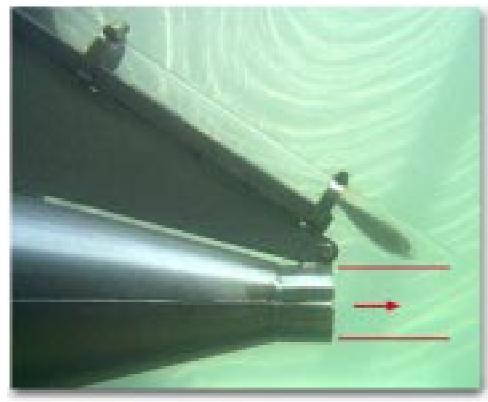
Developing Biological Specifications for Fish Friendly Turbines



Juvenile salmon entering shear zone of laboratory test system.

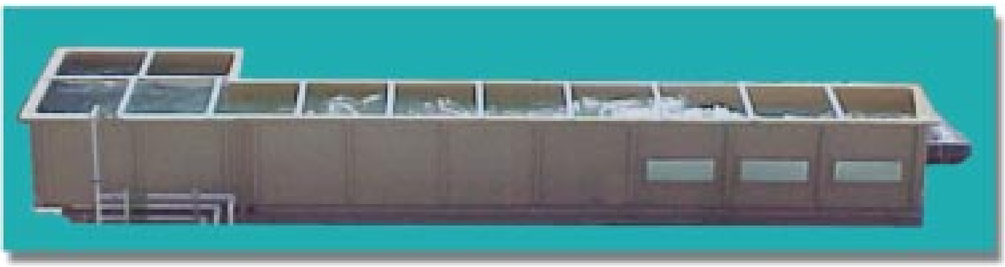
The U.S. Department of Energy's Advanced Hydropower Turbine System (AHTS) Program supports the research and development of "environmentally friendly" turbines, i.e., turbine systems in which environmental attributes, such as entrainment survival for fish, are emphasized. Advanced turbines would be suitable for installation at new hydropower facilities and potentially suitable for replacing aging turbines at existing plants. It is expected that these turbines would permit the efficient generation of electricity while minimizing the damage to fish and their habitats. Development of environmentally friendly hydroelectric turbines requires knowledge of the physical stresses (injury mechanisms) that impact entrained fish and the fish's tolerance to these stresses.

Fish recorded by high-speed video being exposed to shear zone downstream of laboratory jet.

For example, the sensitivity of fish to shear stress or turbulence predicted to occur in a turbine environment are not well understood, and as a result we do not know what effect altering the amount of turbulence in a new turbine design will have on fish survival. To help answer this question, Pacific Northwest National Laboratory scientists designed studies to provide turbine design engineers with biological criteria that define a safety zone for fish within which pressures, shear stresses, turbulence, cavitations, and the chance of mechanical strike are at acceptable levels for survival.

We were able to quantify, in a highly reproducible manner, the biological effects to fish exposed to a shear environment in the laboratory. We used strain rate as the index of intensity to describe the hydraulic force experienced by a fish in a shear environment. We determined that no significant injuries occurred to any fish subjected to strain rates equal to or less than

500 cm/s/cm. This value was based on a measurement scale of 1.8 cm or the average width of the juvenile salmonids used in our studies. The no-effect value of 500 cm/s/cm would not be equivalent to the fluid-strain rate computed at a finer scale resolution. Turbulence intensities at the point of exposure ranged from only 3 to 6%, indicating that strain rate values based on mean velocity are suitable for developing biological criteria.



High-velocity test flume showing flow from right to left. The flume measured 9 m long x 1.2 m wide x 1.2 m deep. An electric pump capable of producing exit velocities in excess of 20 m/s was used to produce a consistent shear environment. Viewing windows at the sides and bottom were inserted to facilitate video recording.

We found that species sensitivity to shear/strain varied. Juvenile American shad were more susceptible to hydraulic forces experienced in a shear environment than were chinook salmon, steelhead, or rainbow trout. Juvenile rainbow trout exposed to the edge of the plume in a headfirst orientation were injured at a higher rate than trout exposed tail first. Similarly, rainbow trout exposed to the edge of the jet plume were injured at a higher rate than those exposed to the shear zone from the center of the jet plume. Factoring in indirect effects of exposure (i.e., increased susceptibility to predation) lowered the minimum strain rate required to protect juvenile rainbow trout exposed to a shear environment.

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(www.inel.gov/national/hydropower/turbine/turbine.htm)

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