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Laboratory Evaluation of Wedgewire Screens for Protecting Early Life Stages of Fish at Cooling Water Intakes

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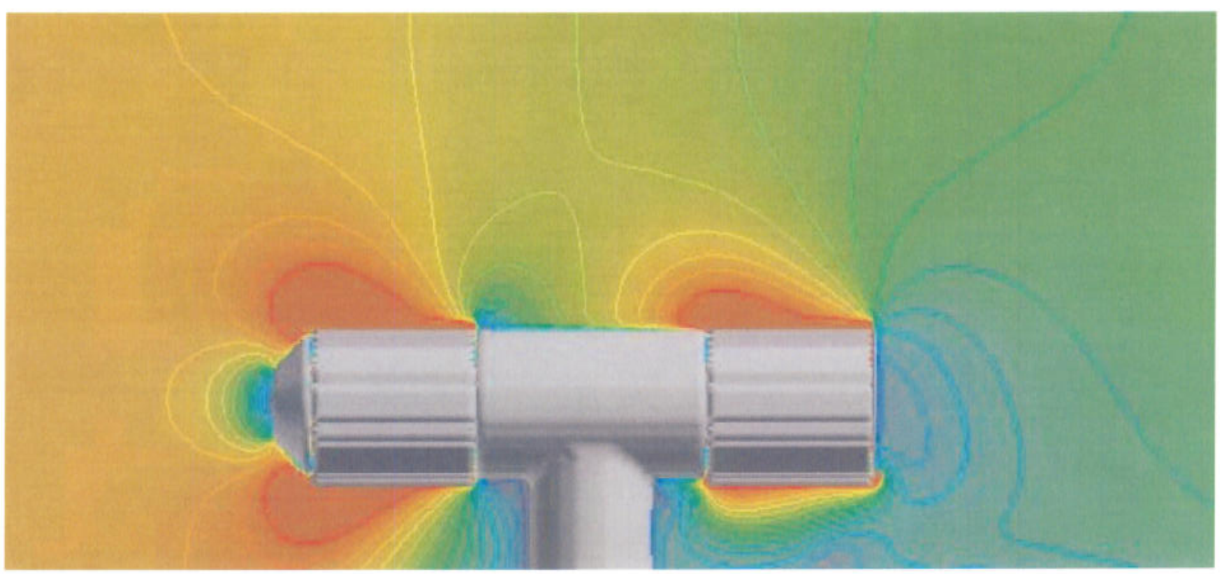
Technical Report



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REPORT SUMMARY

This report presents the results of a laboratory study examining the effectiveness of cylindrical wedgewire screens for protecting the early life stages (eggs and larvae) of fish at water intakes. A three-dimensional computational fluid dynamics (CFD) evaluation was also performed to gather pertinent hydraulic data describing the flow fields associated with operation of these screens. Information in this report increases the performance database for this technology and supports its evaluation for potential application at cooling and other water intakes.

Background

Following passage of the Clean Water Act (CWA) in 1972, wedgewire screens were the subject of research in both laboratory and field studies to evaluate their ability to minimize entrainment and impingement of aquatic organisms at cooling water intake structures (CWIS). These studies examined various biological and engineering aspects of wedgewire screens, including slot sizes, velocities, and orientations with the potential for optimizing passive protection of early life stages of fish. A few quantitative biological evaluations were conducted in the laboratory with live eggs and larvae of selected species of interest. Because this research ended with the slowdown in new power plant construction in the early 1980s, the database on wedgewire screens falls short of allowing scientists and engineers to determine the optimal screen design and operational parameters and to estimate the biological effectiveness of this technology. EPRI—with supporting funds from the U.S. Environmental Protection Agency under the CWA § 104(b)(3) Water Quality Cooperative Agreements Program—sponsored this study.

Objectives

- To determine, under controlled laboratory conditions, the relative importance of various screen design parameters and hydraulic conditions in minimizing entrainment and impingement of selected fish species in early life stages.
- To perform a CFD analysis in order to determine the degree of similarity between flow patterns associated with test conditions (bounded flume flows) and flow patterns associated with field conditions (unbounded flows).
- To examine the similarity between the bounded and unbounded flows in order to extrapolate the results of the laboratory biological tests to similar field operating conditions.

Approach

The project team evaluated entrainment and impingement of eight species of fish in early life stages. Screen design and hydraulic parameters examined in the laboratory flume included screen orientation to approach flow, slot size, through-slot velocity, and approach flow velocity. Known numbers of fish were released upstream of the screens for each set of test conditions evaluated. The team estimated impingement by counting eggs and larvae impinging on a screen at the completion of a test. Similarly, they estimated entrainment by collecting and enumerating organisms that passed through the screens. The CFD evaluation involved the use of three-dimensional computer modeling techniques to examine the effects of approach velocity and screen flow on velocity distributions around the wedgewire screens. The team conducted analyses for the laboratory flume geometry and for a laterally unbounded installation, which was similar to a field application.

Results

In general, entrainment increased with both slot size and slot velocity and decreased with channel velocity and larval length. Impingement also increased with slot and channel velocity, but decreased with slot size. Interrelationships existed among the various test parameters (for example, the effects of slot velocity were not uniform for all slot sizes evaluated, and response of larvae to varying hydraulic conditions was related to fish size and swimming ability). The results of this study demonstrate that cylindrical wedgewire screens are capable of reducing entrainment and impingement rates to low levels for most species and life stages of fish. However, optimum design criteria will differ depending on biological factors and hydraulic conditions. Future studies, whether conducted in the laboratory or field, should focus on a narrower range of screen design and hydraulic parameters in order to better define the relationships between the various parameters and effective protection for fish larvae and eggs. The CFD evaluation demonstrated that the hydraulic environment of the laboratory test flume was similar to that of screens in an unbounded setting such as field installation. Additionally, the flow fields described by the CFD models supported observations of egg and fish approach paths and locations where organisms were most likely to be impinged on the screens.

EPRI Perspective

This report provides CWIS and other water intake operators with information on the ability of cylindrical wedgewire screens to minimize entrainment and impingement of fish in early life stages. Research results will permit water intake designers to configure these screens for optimal effectiveness in different water body types and will allow resource managers to more accurately predict the potential for biological effectiveness at a given site.

Keywords

Fish Protection
Water Intakes
Clean Water Act Section 316(b)
Computational Fluid Dynamics Analysis

ABSTRACT

Section 316(b) of the Clean Water Act (CWA) requires that the location, design, construction, and capacity of a cooling water intake structure (CWIS) reflect the "best technology available" (BTA) for minimizing adverse environmental impacts (AEI). Cylindrical wedgewire screens are considered a technology that has potential for minimizing entrainment and impingement of aquatic organisms at cooling water intakes. A laboratory evaluation of cylindrical screens was conducted to determine hydraulic and design criteria that contribute to greater protection of fish larvae and eggs. Entrainment and impingement rates associated with various slot sizes, slot velocities, and channel velocities were estimated for early lifestages of eight species of fish (striped bass, winter flounder, yellow perch, rainbow smelt, common carp, white sucker, alewife, and bluegill) that are commonly impinged and/or entrained at CWIS. Entrainment and impingement rates varied considerably depending on velocity conditions and slot width, ranging from about 0 to 95%. For most combinations of test conditions that were evaluated, the mean percent of fish lost to entrainment and impingement was less than 50%, with rates as low as 0 to 10% for tests that included the highest approach velocity and the lowest through-slot velocity. In general, entrainment increased with slot size and slot velocity and decreased with channel velocity and larval length. Impingement also increased with slot and channel velocity, but decreased with slot size. Interrelationships existed among the various test parameters (e.g., the effects of slot velocity were not uniform for all slot sizes evaluated and response of larvae to varying hydraulic conditions was related to fish size and swimming ability). The results of this study demonstrate that cylindrical wedgewire screens are capable of reducing entrainment and impingement rates for a wider range of fish species and lifestages than has previously been reported. Reductions in fish losses may be considerable if an optimum ratio of ambient velocity (i.e., flow approaching a screen) to through-slot velocity can be identified and maintained for target species and lifestages. However, optimum design criteria will differ depending on biological factors and local hydraulic conditions. Future studies, whether conducted in the laboratory or field, should focus on a narrower range of screen design and hydraulic parameters in order to better define the relationships between the various parameters and effective protection for fish larvae and eggs.

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