Zu.5

EPRI 2005
AR-206

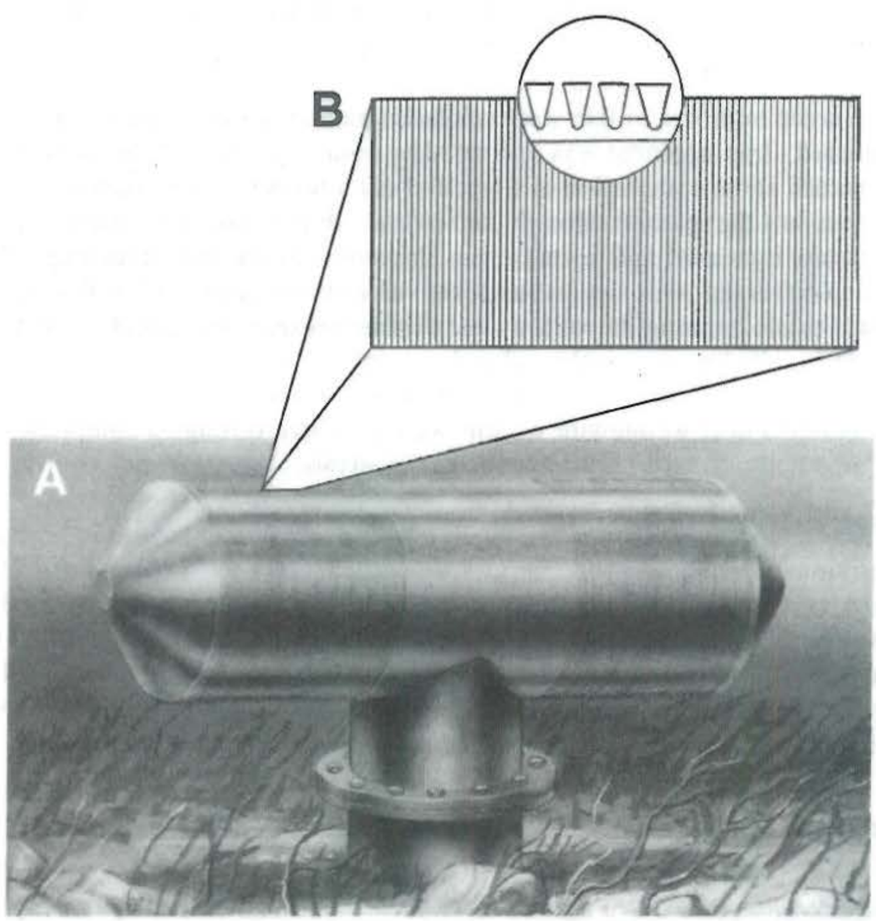

Figure 1-1
Depiction of a Cylindrical Wedgewire Screen Installation (A) and Close-up of Slotted Wedgewire Elements (B) (EPRI 2003, Modified from Hanson 1978 and EPRI 1999).

EPRI Laboratory Evaluation

The purpose of the EPRI laboratory study (EPRI 2003) was to determine, under controlled conditions, the relative importance of various screen design parameters and hydraulic conditions in minimizing entrainment and impingement of selected species and life stages. Entrainment and impingement rates were evaluated for early life stages of eight fish species (striped bass, winter flounder, yellow perch, rainbow smelt, common carp, white sucker, alewife, and bluegill) commonly entrained and/or impinged at CWIS. The following are descriptions of the screen design and hydraulic parameters that were examined in the laboratory flume. Screen orientation is the direction in which the axis of the test screen is oriented (either parallel or perpendicular) relative to the approaching ambient flow. Slot width (or slot size) is the spacing between the wire elements that make up the test screen. Screens with slot widths of 0.5, 1.0, or 2.0 mm were evaluated. Slot velocity (or through-slot velocity) is the velocity of water as it moves through the slots of the screen. Testing was conducted with slot velocities of 0.15 or 0.3 m/s. Ambient velocity (or sweeping velocity) is the velocity of water in the vicinity of test screen. In the case of laboratory testing, ambient velocity was the velocity of water in the flume (or channel velocity) as it approached the test screen. Tests were conducted at ambient velocities of 0.08, 0.15, or 0.3 m/s.

During testing, known numbers of fish were released upstream of the screens for each set of test conditions evaluated. Impingement was estimated by counting eggs and larvae that were impinged on a screen at the completion of a test and entrainment was estimated by collecting and enumerating organisms that passed through the screens. In general, entrainment increased as slot size and slot velocity increased and decreased as ambient velocity and larval length increased. Impingement also increased with slot and ambient 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). In addition to these findings, detailed hydraulic flow patterns near wedgewire screens were provided through a comprehensive, three-dimensional Computational Fluid Dynamics (CFD) analysis.

The results of the laboratory study demonstrated that cylindrical wedgewire screens are capable of reducing entrainment and impingement rates to low levels for most species and life stages of fish. In addition, this study identified a narrower range of screen design and hydraulic parameters that optimize effectiveness in a laboratory setting. The next logical step in developing wedgewire screens to the point where they can be considered for general application at CWIS was to perform field evaluations at locations in different water body types with different species, varied flow regimes, and in the presence of suspended debris.

Previous Field Studies

Several wedgewire screen field evaluations have been conducted over the past 25 years. However, the range of fish species and operational and design parameters that have been evaluated remains limited. Taxa for which the most comprehensive data exist include striped bass (EA Science and Technology 1986; Ehrler and Raifsnider 1999), clupeids (Otto et al. 1981; Zeitoun et al. 1981a,b), and bay anchovy (Browne et al. 1981; Weisberg et al. 1987). The majority of field evaluations tested wedgewire screens with slot widths of 1.0 mm or greater. Screen effectiveness was typically estimated by comparing the densities of ichthyoplankton entrained through a test screen to densities entrained through an open port (a control intake without wedgewire screening) and/or collected from the surrounding water body in tow samples of ambient ichthyoplankton (Browne 1979; Browne et al. 1981; Lifton 1979; Otto et al. 1981; Weisburg et al. 1987; Zeitoun et al. 1981a,b).

Browne et al. (1981) performed tests at an estuarine site in southern New Jersey with 1.0 and 2.0 mm screens operating at a slot velocity of 0.15 m/s and found no significant difference between the two slot widths for nearly all taxa. Compared to an open port, densities in 1 mm and 2 mm screen samples were not always significantly lower. However, ambient sample densities were consistently higher than densities in 1 mm and 2 mm samples.

Otto et al. (1981), conducted tests in the Mississippi River, Illinois with 1-mm slot screens operated at a slot velocity of 0.12 m/s and found that, for a given species, entrainment sample densities were less than densities of ambient samples. In addition, it was suggested that larvae longer than 6 to 8 mm had sufficient swimming abilities to avoid being entrained through the 1-

mm slot screen, despite being small enough to fit through the slots. Otto et al. (1981) also found that larvae over 10 mm in length have exclusion efficiencies approaching 100 percent.

In the intake canal of the Chalk Point Steam Electric Station (Patuxent River, Maryland), Weisberg et al. (1987) evaluated the effectiveness of 1-, 2-, and 3-mm screens by comparing entrainment densities to samples from an open port and ambient samples. In addition, larvae were partitioned into length classes for the two dominant species collected, bay anchovy and naked goby. They determined that the exclusion of both species was generally dependent on larval length. Larvae less than 5 mm in length were not effectively excluded by any of the slot widths. In contrast, more than 47 percent of fish between 5-10 mm and more than 90 percent of fish longer than 10 mm were excluded by a 1-mm screen.

Zeitoun et al. (1981) used prototype 2.0-mm and 9.5-mm wedgewire screens near the southeastern shore of Lake Michigan to predict the effectiveness of a proposed intake for Unit No. 3 of the J. H. Campbell Plant. Effectiveness was estimated by comparing densities of ichthyoplankton pumped through both types of screens to densities pumped through an open port, which represented an experimental control. In addition, surrounding ichthyoplankton densities were estimated by collecting towed (ambient) samples. Concurrent sampling was conducted at two sites, an offshore location (1,067 m from shore) and in the intake canal of Units 1 and 2. The dominant species collected were rainbow smelt, alewife, and yellow perch. At the offshore site, entrainment densities collected through the open port and both screen types were not significantly different. However, samples densities collected through both screen types in the intake canal were significantly less than open port samples. In addition, ambient sample densities at both sites were 11 times greater than sample densities collected through the test screens. There were no significant differences between sample densities collected through the two test screens at either site except during August sampling in the intake canal when sample densities through the 9.5-mm screen were higher than through the 2.0-mm screen. Observed differences in entrainment at the two sites were attributable to localized biological characteristics and water currents.

To varying degrees, the above studies examined different biological and engineering aspects of wedgewire screens and their effects on the successful protection of early fish life stages. However, these studies did not examine a full suite of design parameters for all species of interest at cooling water intakes. Unfortunately, this research ended with the slowdown in new power plant construction in the early 1980s. Thus, the available database on wedgewire screens fell short of allowing current scientists and engineers to determine the optimal design and operational parameters and to estimate the potential biological effectiveness of this technology.

Field Evaluation Objectives

The results of the EPRI laboratory study provided information to support the selection of specific design and operational criteria to improve the biological benefits of field applications. However, the laboratory data reflect the performance of the screens in an environment with uniform flow distributions and without debris or biofouling, which are factors that may affect entrainment rates. Therefore, the next logical step in developing wedgewire screens to the point where they can be considered for general application at CWIS was to perform field evaluations at locations in different water body types. To determine if biological screen performance data collected in the laboratory are applicable to actual intake installations, the present study tested the biological effectiveness of wedgewire screens at two sites that were representative of CWIS located on important water body types with respect to environmental and biological conditions.

Using optimum design and operational conditions identified in the laboratory study, the primary goal of the present field evaluation was to provide detailed information on the relative susceptibility of naturally-occurring fish species and life stages to entrainment when passing in the vicinity of wedgewire screens located at the different field sites. To achieve this goal, the following objectives were set:

1. Estimate entrainment rates for naturally-occurring fish eggs and larvae exposed to 0.5- and 1.0-mm wedgewire screens in a field environment.
2. Conduct testing in two different water body types (estuarine and freshwater) with different species assemblages and environmental conditions.
3. Estimate the exclusion efficiency of cylindrical wedgewire screens for representative species and the different size classes thereof.
4. Determine the relative importance of design and hydraulic parameters by evaluating the effects of different slot widths (0.5 and 1.0 mm), slot velocities (0.5 and 1.0 ft/sec), and ambient velocities.
5. Develop recommendations for optimum design and operational criteria for future wedgewire screen applications and develop expected ranges of entrainment rates for installations in different water body types based on these criteria.

These objectives were addressed by constructing a barge-mounted wedgewire screen test facility from which entrainment sampling was conducted at two field sites. Density-based estimates of entrainment (i.e., number of larvae/eggs per unit flow volume) were calculated for each set of test conditions (slot width/velocity, open pipe). More specific details associated with the design and operation of the test facility are provided in Chapter 2. Details regarding the experimental design, test procedures, and data analysis methods employed to achieve the study goal and objectives are provided in Chapter 3 for the estuarine site and Chapter 4 for the freshwater site. A discussion of the results and how they pertain to future full-scale applications is provided in Chapter 5.