Mitigating the Impact of Cooling-Water Intake

When using raw water, minimizing the impingement of aquatic life helps the process and the environment.

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For large-scale process cooling such as is required in power plants, refineries, petrochemical complexes and thermal desalination processes, it is a common practice to use water extracted from a river, lake or ocean, which then is returned a few degrees warmer. The flows can be large, with at least one Middle East petrochemical complex extracting in excess of 6,850 million gal/day (300 m³/sec). The raw water must be screened to remove both solid materials such as weeds and aquatic life as well as pollutants such as plastics. Screening usually is performed by a combination of coarse raked-bar screens followed by fine screening via either travelling band screens (figure 1) or rotating drum screens (figure 2). These devices typically remove solids larger than 0.079 to 0.197” (2 to 5 mm) in cross-section.

Concern is growing regarding the impact of such cooling-water intakes on the aquatic ecosystem, however. Legislation in the United States (Section 316(b) of the Environmental Protection Agency’s Clean Water Act) and, to a lesser extent, in Europe (for selected species) increasingly requires measures to be undertaken to minimize the entrainment and impingement of fish and other biota by the intake screening system. There also are operational advantages in minimizing the impingement of fish. Disposal costs of the entrained aquatic life can be eliminated. Also, minimizing the impingement of fish reduces the potential for process disruptions due to the loss of cooling water following massive inundations of schooling species.

No single solution can completely eliminate the impingement and entrainment of aquatic life. Therefore, success requires a combination of technologies used together with more conservative hydraulic design parameters.

First Stage: Behavioral Barriers

A number of behavioral barriers exist. Each provides a sensory stimulus to fish that encourages an avoidance reaction and diverts them away from the point of water abstraction. Commonly used stimuli include sound, strobe lights, bubble curtains (sometimes combined with sound), electric fields and louvre screens. Electric barriers are affected by water conductivity and are not suitable for marine or brackish water environments. Their use creates a potential safety issue for the public as well.

Sound has the advantage of penetrating turbid waters. Research has
FIGURE 1. Screening often is performed by a combination of coarse raked-bar screens followed by fine screening via travelling band screens. At this power plant in China, such screening is used for the cooling-water intake.

FIGURE 2. A 14-drum screen installation in the Middle East provides cooling water to a large petrochemical complex.
established that a varying frequency within the range of 10 Hz to 3 kHz is most effective. For larger cooling-water intakes (greater than 5 m³/sec), this is the preferred technology. An acoustic deflection system typically consists of a number of special loudspeakers arranged underwater to form a sound-projector array (SPA). Six to more than 90 speakers are used, depending upon the size of the cooling-water intake. The speakers are coupled to dedicated amplifiers, a signal generator and a diagnostic unit.

The sound-projector arrays normally are located at the point of abstraction, typically just upstream of the coarse bar screen. They are mounted on rails attached to the civil structure, allowing them to be raised for annual maintenance (figure 3). The goal is to produce an underwater sound field that increases in intensity as fish approach the intake, leading to an avoidance reaction.

**Second Stage: Screens Fitted with Fish Recovery and Return Systems**

Combining technologies is necessary because not all fish species are equally sensitive to acoustic or other stimuli. Also, the behavioral barrier is not 100 percent effective even on sensitive species. The fish most sensitive to acoustic deflection stimuli tend to be pelagic fish (midwater swimming silvery fish) — those that also tend to be the most susceptible to damage from contact with equipment.

More robust bottom-feeders (flat-type fish) and sinuous fish (eels, lampreys, etc.) tend to be much less sensitive to the acoustic deflection system. They also are less susceptible to injury through physical contact or handling.

To protect the fish that circumvent the behavioral barrier, mechanical screening equipment should incorporate modifications to provide fish recovery and return (FRR). The FRR system should be designed to collect and return the fish back to the water body with the minimum amount of stress.

**Band Screens.** Band screens have unit capacities up to 365 million gal/day (16 m³/sec) per screen. They are offered in three flow patterns (figure 4):

- Through flow (TF).
- Center flow (CF).
- Dual flow (DF).

A special adaptation such as a stabilized, integrated marine-protection lifting environment can provide a carefully engineered fish-bucket profile. Developed using full-scale models in test flumes, the marine-protection...
lifting devices provide a stable area for the fish to shelter while under the surface. When the bucket exits the intake flow, it provides a pool of water for the trapped fish (figure 5).

The band screen head-section is modified to provide two washing stages. The first stage uses low pressure wash water that sluices the fish and some of the light trash into a flooded launder trough for return to the water body. A second-stage, high pressure backwash removes the more persistent trash, which is either collected in a self-draining debris basket or returned to the water body.

Drum Screens. Drum screens are used mainly outside of the United States as an alternative to band screens. They offer the advantages of a larger unit capacity, which can exceed 913 million gal/day (40 m³/sec), and low maintenance requirements.

Four drum screen flow patterns are used commercially, but the most common is an in-out, double-entry, single-exit flow pattern. Typically, it is called a double-entry (DE) drum screen (figure 6).

Fish recovery and return via double-entry drum screens has a relatively recent history. The first trial unit was installed on one of four drum screens operating on a 2,400 MWe coal power plant in the United Kingdom in 2007. Each drum screen is 55’ (16.5 m) diameter and fitted with 0.315” (8 mm) mesh. It is designed to pass a flow of 514 million gal/day (22.7 m³/sec).

Following a trial period at the U.K. coal plant, a number of improvements were made to the elevators, flushing system and hopper geometry. The improved fish-recovery-and-return system then was implemented on the remaining three drum screens in 2009 together. At the same time, a permanent ~656’ (200 m) long fish-and-debris return trough was engineered to discharge below the lowest tide level.
The approach adopted to recover fish on drum screens is similar in principle to that used on band screens. The screen is fitted with a fish bucket that provides an area for the fish to shelter while underwater. The fish bucket also provides a pool of water that helps ensure survival up to the point of discharge. At deck level, the fish and some trash are removed and returned to the source water via a low pressure sluice system. The higher pressure backwash that follows removes the more persistent trash.

In conclusion, the need for mitigating the impact of large, once-through, cooling-water systems is of paramount importance. It is
expected that other regions will follow the example set by American environmental legislation. One example is the recent European Union Eels Directive, which requires member states to take measures to allow at least 40 percent of adult eels to escape from inland waters to the sea. This will have a major impact on river- and estuary-based cooling-water-intake systems — and all forms of water pumping stations.

The technology and the knowledge to reduce the impact of once-through cooling-water systems is available and improving with increasing experience being gained by suppliers, consultants and plant operators. 

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