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SUPPLEMENT TO BACKGROUND PAPER 3: COOLING WATER INTAKE TECHNOLOGIES

September 30, 1996

Prepared for:

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INTRODUCTION AND METHODOLOGY

This paper presents a continuation of EPA's past efforts to examine cooling water intake technologies currently being used or tested for minimizing the loss of aquatic organisms due to entrainment and impingement effects. The information is intended for use by the U.S. Environmental Protection Agency (EPA) as additional baseline data for evaluating the range of future regulatory options under Section 316(b) of the Clean Water Act (CWA).

Background Paper 3, dated April 4, 1994 and entitled, "Cooling Water Intake Technologies," identified technologies used or being tested at cooling water intakes. Various types of intake screening systems, passive intake systems, and fish avoidance technologies were discussed. As a supplement to Paper 3, this paper focuses specifically on fish handling systems and other technologies used alone or in conjunction with screening systems for the protection of aquatic life.

This paper presents the results of a search of available literature and existing 316(b) Demonstrations for additional specific information on fish protection technologies used at cooling water intakes. A list of the literature reviewed is found in Appendix B. An attempt was made to gather the most current data regarding these technologies, however, it should be noted that the literature reviewed does not represent an exhaustive list of all available information on this topic.

To initiate the study, the Edison Electric Institute (EEI) Power Statistics Database was searched for the number of facilities using specific fish protection technologies. The results of this search are presented below (EEI Power Statistics Database, 1994).

Fish Protection Technology	Number of Facilities Using the Technology
Low Velocity (includes approach velocity)	84
Baffle System and Flow Vanes	None found
Skimmer Wall (curtain wall)	25
Fish Pump	5
Lift Basket	None found
Fish Bypass	15
Bar Rack	None found
Fish Basket	6
Fish Return (collection and return)	64
Fish Trough	None found
Screen Wash (spray wash)	182

It should be noted that the results of the EEI Database search may not reflect the true number of facilities using each technology since many of these technologies are used together as part of a larger system and may not be specified individually in the EEI Database. For example, a fish return system may consist of a baffle system, a fish bypass, fish buckets, fish troughs, a lift basket, and a spray wash system. However, these individual components of the fish return system may not be found in the EEI Database.

Results of the literature search were compiled into fact sheets for each fish protection technology. The fact sheet provides the following information on each technology: description of technology, testing facilities

APPENDIX A

OTHER TECHNOLOGIES	FACT SHEET NO. 1
	APPROACH VELOCITY REDUCTION

DESCRIPTION:

Approach velocity may be defined as the velocity of the current in the area approaching the screen. The approach velocity should be based on the swimming ability of the species in the area. The component of the approach velocity that is perpendicular to the screen face must not exceed the swimming ability of the fish, or the fish will be unable to avoid impingement on, or contact with the screen which may result in injury. Areas of high velocity into the screen can impinge fish, while areas of low velocity can result in fish delay or accumulations of predatory fish. (Committee on Hydropower Intakes, 1995)

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Argonne National Laboratory. (Freeman and Sharma, 1977)
- Major nuclear power plant in the Northeast (unspecified). (USEPA, 1976)

RESEARCH/OPERATION FINDINGS:

- Research indicates that approach velocities lower than 0.8 to 1.1 fps may be required to protect certain species against impingement. (USEPA, 1976)
- Studies conducted with white perch and striped bass indicate a marked increase in impingement at approach velocities greater than 0.8 fps. (USEPA, 1976)
- Studies have shown that fish swimming ability is a function of fish size and ambient water temperature, and oxygen level. (USEPA, 1976)
- Approach velocity criteria for screening salmonids range from 0.0825 fps for fry to 1.0 fps for fingerlings depending on the regulating agency. (Committee on Hydropower Intakes, 1995)
- Approach velocity design criteria typically range from 0.2 to 1.5 ft/s (6-46 cm/s) for shoreline intake structures and offshore intakes with point of withdrawal screening, and 1.5 to 2.0 ft/s (46-61 cm/s) for offshore uniform velocity cap structures. (USEPA, 1976)

DESIGN CONSIDERATIONS:

- A distance of three inches in front of the screen face has been used to determine approach velocity criteria. (Committee on Hydropower Intakes, 1995)
- An intake should have a uniform velocity profile across the entrance for fully screened intakes.
- Fish cruising, sustaining and darting swimming speeds should be considered in determining approach velocities; to avoid entrapment, low approach velocities may be used for systems which rely on the sustained swimming abilities of fish. (USEPA, 1976)

OTHER TECHNOLOGIES	FACT SHEET NO. 2
	FLOW REDUCTION

DESCRIPTION:

This technology involves reducing the amount of water drawn through the intake structure to minimize impacts to fish and other organisms from impingement and entrainment.

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Considered as part of Cook Nuclear Power Plant's 316(b) Demonstration
- Considered as part of San Onofre Nuclear Generating System's 316(b) Demonstration
- Considered as part of San Diego Gas & Electric Company (SDGE) Encina Power Plant's 316(b) Demonstration

RESEARCH/OPERATION FINDINGS:

- Studies conducted as part of Cook Nuclear Power Plant's 316(b) Demonstration show that reducing flow at night may reduce impingement. (Thurber and Jude, 1985)
- Studies conducted as part of San Onofre's Encina Power Plant's 316(b) Demonstration showed that larval entrainment could be reduced by 15% or more by flow reduction alone, 50% by rescheduling high volume water intake to avoid March and April, and 60% or more if these techniques were combined. (SDGE, 1980)

DESIGN CONSIDERATIONS:

- Reducing flows during the months of maximum impingement, e.g., April through July for Cook Nuclear Power Plant, was considered in the Section 316(b) Demonstration. Since refueling and maintenance require lower water volumes anyway, these activities were considered for re-scheduling during the months of maximum impingment.
- Cooling towers should be considered for use in cooling excess heat resulting from the reduced flow. (SDGE, 1980)

ADVANTAGES:

- May reduce impacts to fish and aquatic life.

LIMITATIONS:

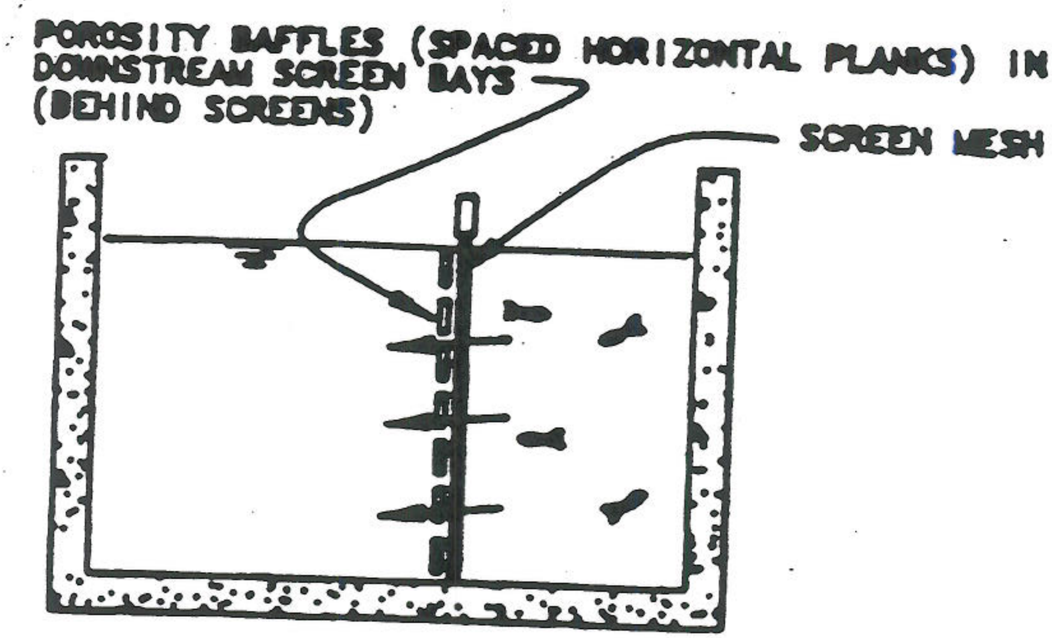
- Reducing flow volume without reducing power input may increase the temperature of the thermal discharge.

OTHER TECHNOLOGIES	FACT SHEET NO. 3
	BAFFLE SYSTEM AND FLOW VANES

DESCRIPTION:

Baffles are horizontal planks placed downstream of the screen that are used to assist in obtaining uniform flow. Baffles produce a desired localized head loss by creating a constriction of the flow, followed by an abrupt expansion of the flow. (Committee on Hydropower Intakes, 1995)

In cases where approach flow problems cannot be corrected using a baffle system, flow vanes may be used upstream of the screen.

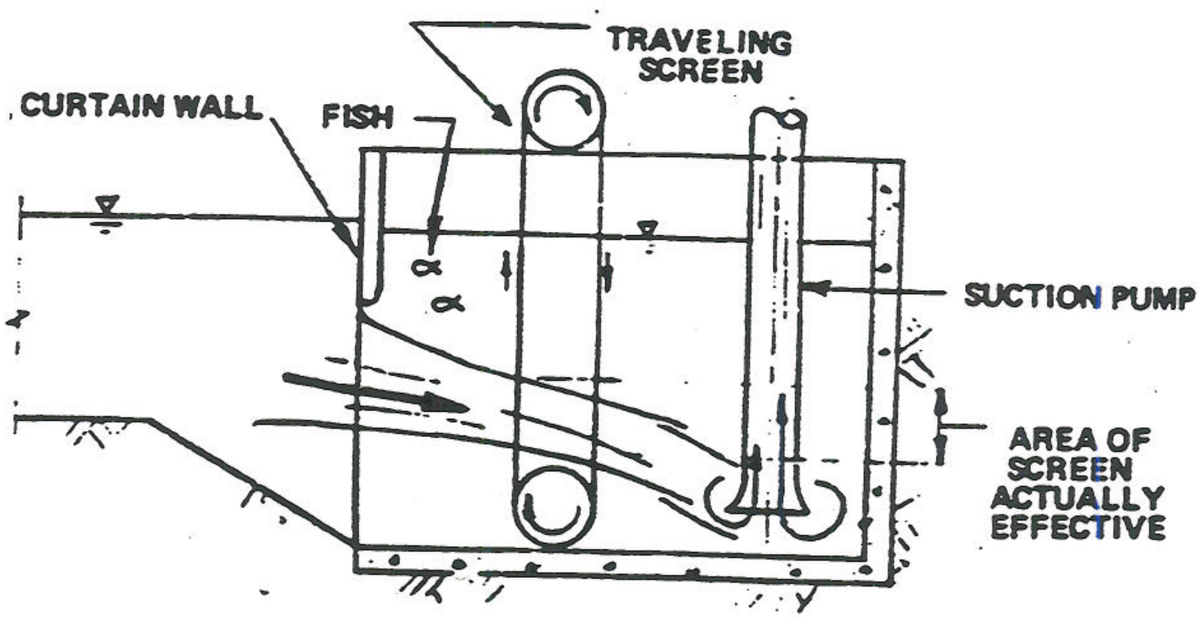


Baffle System (Committee on Hydropower Intakes, 1995)

OTHER TECHNOLOGIES	FACT SHEET NO. 5
	SKIMMER WALLS

DESCRIPTION:

Skimmer walls, also referred to as curtain walls, prevent warmer surface water and floating debris from entering the intake. Intake water passes under the skimmer wall, through trash racks and traveling screens. To prevent fish from being impinged on the screens, an area in front of the screen is open to provide a continuous path for lateral movement of the fish. Fish are guided away from the intake screen toward exit apertures which lead to open waters. (Author unspecified, 1980)

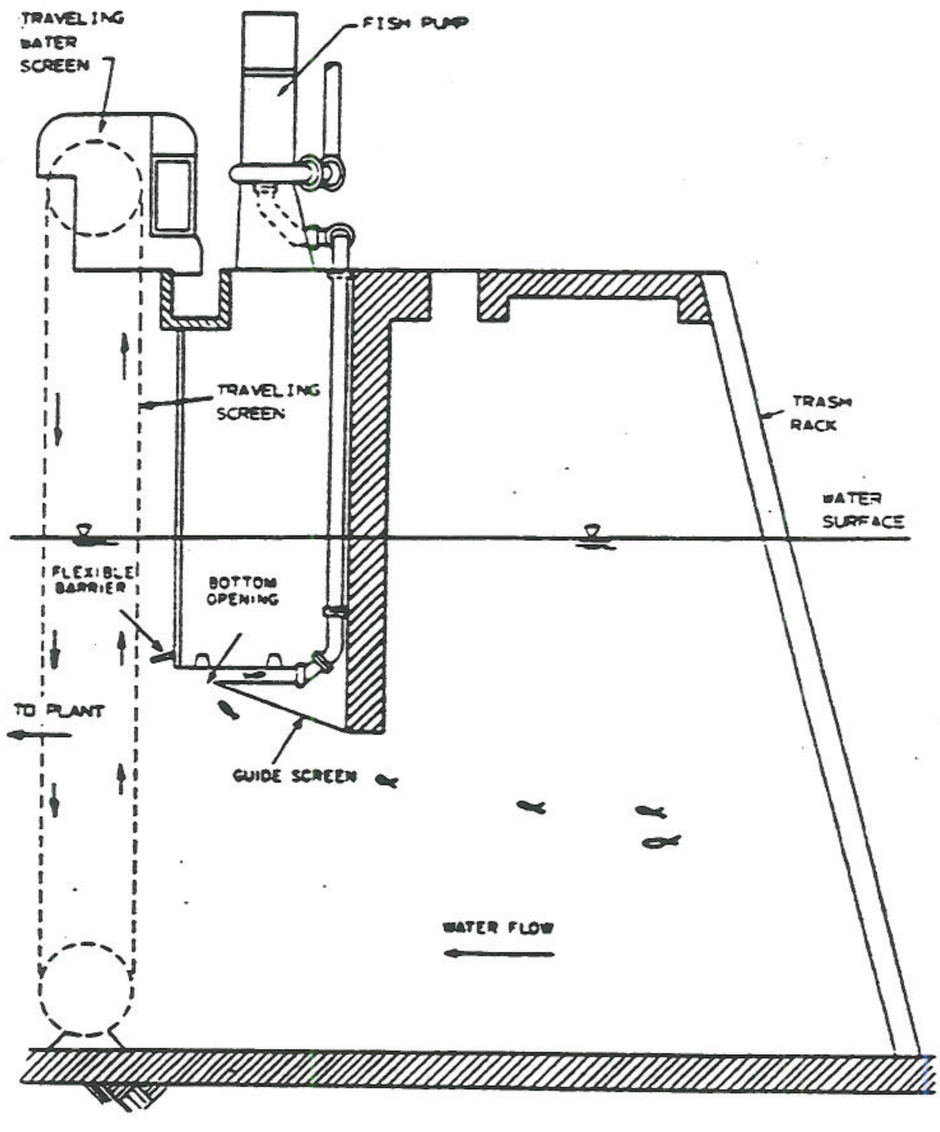


Skimmer wall (USEPA, 1976)

FISH HANDLING SYSTEMS	FACT SHEET NO. 6
	FISH PUMPS

DESCRIPTION:

The fish pump technology uses a pump collector placed in front of the traveling screen, the screenwell, to remove fish that have been concentrated in this area. Fish are pumped out of the screenwell area and returned to open water. (Taft and Mussalli, 1981)

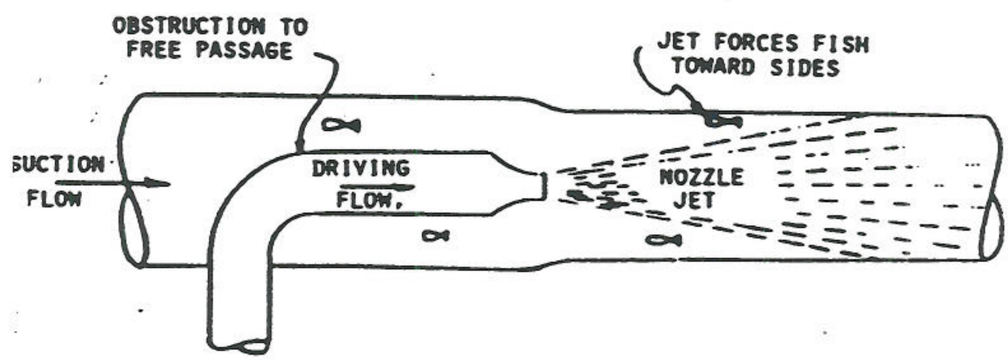


Fish Pump (ASCE, 1982)

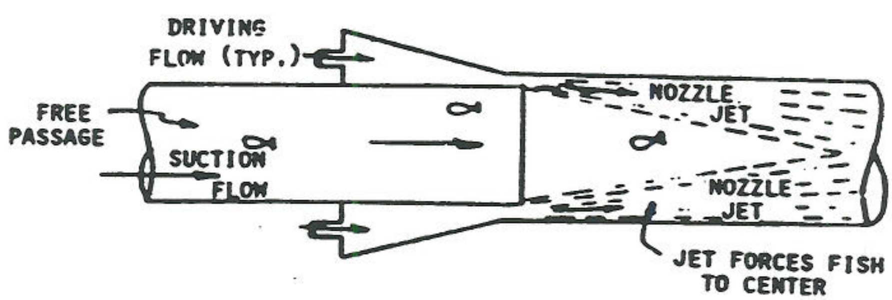
FISH HANDLING SYSTEMS	FACT SHEET NO. 7
	JET PUMPS

DESCRIPTION:

Bypass systems often use jet pumps which induce flow into the bypass system and drive the flow into the pipes used to transport fish. The jet pump creates a pumping action by transferring energy from a high-velocity jet to a low-velocity jet. Two types of jet pumps are available: a core type and a peripheral type. The core type uses a concentric nozzle which is placed centrally on the tube, while the peripheral type has the nozzle placed around the periphery of the tube. (Taft, Hoffman, *et. al*, 1976)



CORE-TYPE JET PUMP



PERIPHERAL-TYPE JET PUMP

Jet Pumps (Taft, Hoffman, *et. al*, 1976)

REFERENCES:

1. E.P. Taft, P. Hoffman, P.J. Eisele, and T. Horst, "An Experimental Approach to the Design of Systems for Alleviating Fish Impingement at Existing and Proposed Power Plant Intake Structures," Third National Workshop on Entrainment and Impingement, February 24, 1976, New York.

2. San Diego Gas & Electric (SDGE). *Encina Power Plant Cooling Water Intake System Demonstration, Volumes I and II.* San Diego, CA, December 1980.

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Tracey Pumping Station (USEPA, 1976)
- San Diego Gas and Electric's (SDGE) Encina Plant (SDGE, 1980)
- Proposed for use at San Onofre Station in 1980.

RESEARCH/OPERATION FINDINGS:

- The bypass, skimmer wall, and collection area proved to be effective in serving to congregate fish over the lift basket. (ASCE, 1982)
- Lift baskets may not be successful with larvae or eggs. (SDGE, 1980)

DESIGN CONSIDERATIONS:

- None found.

ADVANTAGES:

- None found.

LIMITATIONS:

- Lift baskets may not be protective of fish larvae or eggs.

REFERENCES:

1. "Design of Water Intake Structures for Fish Protection," Task Committee on Fish-Handling Capability of Intake Structures of the Committee on Hydraulic Structures of the Hydraulics Division of the American Society of Civil Engineers, 1982.

2. U.S. EPA, Office of Water and Hazardous Materials, *Development Document for Best Technology Available for the Design, Construction, and Capacity of Cooling Water Intake Structures for Minimizing Adverse Environmental Impact*, April 1976.

3. San Diego Gas & Electric (SDGE). *Encina Power Plant Cooling Water Intake System Demonstration, Volumes I and II*. San Diego, CA, December 1980.

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Southern California Edison's San Onofre Nuclear Generating Station.
- Niagara Mohawk Power Corporation's Oswego Steam Station - Unit 6.
- New England Power Company's Brayton Point Generating Station, Unit 4.
- Danskammer Station, Milton, NY and Oswego 7, Oswego, NY.

RESEARCH/OPERATION FINDINGS:

- At Brayton Point, 75% of the fish passing through the intake structure were diverted and bypassed. Survival of fish through the bypass varied by species. (Lawler *et. al*, 1987)
- At Brayton Point, bay anchovy was found to be the most frequently impinged fish. Bay anchovy and Atlantic menhaden exhibited significant mortality rates. Winter flounder over 7.6 cm were found to be the most hardy fish. (Lawler *et. al*, 1987)
- Using alewives and smelt, transport velocities were tested at Niagara Mohawk Power Corporation's Oswego Steam Station to determine appropriate water velocities in bypass pipes. Individual fish were introduced to the pipe, their behavior was observed during passage through the system, and then they were removed to a holding tank for one week. Velocities of up to 9.5 ft/sec were tested. No individuals showed signs of damage or stress. Results showed that velocities up to 8 ft/sec are safe for transporting fish. (Taft, Hoffman, *et. al*, 1976)
- For larvae, the efficiency of returning fish larvae unharmed was 6.4% (4.3% diversion and 2.0% impingement) at Edgar Energy Park. (Edgar Energy Park, 1990)

DESIGN CONSIDERATIONS:

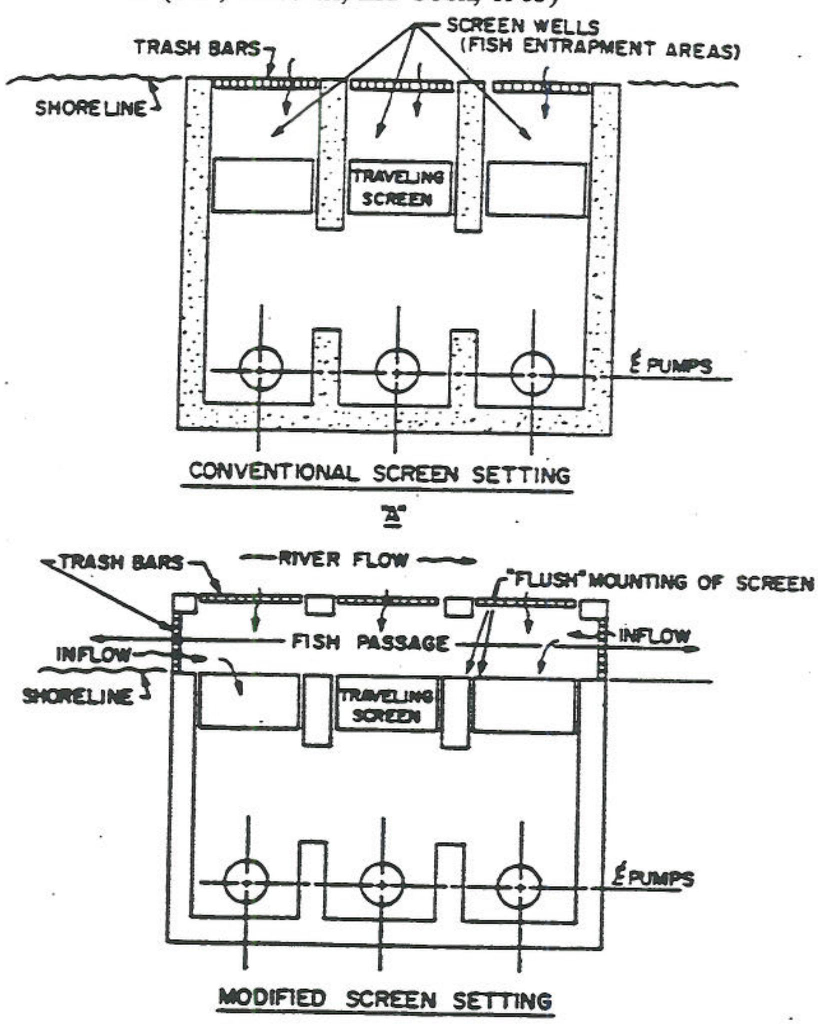
- Maintain uniform velocity distribution at entrance of bypass; avoid situations where flow separation and resultant eddies or backflow can occur. (ASCE, 1982)
- Width of the bypass pipe should be based on the size of the fish; typical widths range from 0.5 ft to 3 ft. (ASCE, 1982)
- Consider use of fused polyethylene pipe with ground smooth joints for the final straight section of the bypass flume. The system was installed at Lower Monumental Dam on the Snake River, but has not yet been biologically evaluated. (Committee on Hydropower Intakes, 1995)
- Appropriate transport velocities must be determined to safely move fish through a pipe with a minimum amount of physical damage and stress.
- The transition area between a channel and a pipe must have a gradual taper and create a uniform velocity distribution across the bypass opening.

INTAKE SCREENING SYSTEM	FACT SHEET NO. 10
	BAR RACK SYSTEM

DESCRIPTION:

The bar rack system consists of a series of closely spaced bars set upstream of the intake and or around the powerhouse. Bars are typically spaced at distances of one inch which acts as a barrier to larger fish (Taft, Mussalli, and Cook, 1983). Bar racks may be used alone or in conjunction with two angled screens to enhance fish protection.

When used with angled screens, bar racks are placed in front of the screens to screen out larger fish. The two screens are oriented such that they form a v-shape and are placed vertically in front of the cooling water intakes. The angled screens are intended to screen the smaller fish. The angled screens allow water to pass through while collecting debris on the screen and guiding fish such that they bypass the screens. The fish bypass is located at the junction of the two screens. Bar racks are located upstream of the screens for large fish removal. (Taft, Mussalli, and Cook, 1983)



Bar Rack System (ASCE, 1982)

4. Design of Water Intake Structures for Fish Protection, Prepared by the Task Committee on Fish-Handling Capability of Intake Structures of the Committee on Hydraulic Structures of the Hydraulics Division of the American Society of Civil Engineers, New York, 1982.

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Salem Nuclear Generating Station.
- The Hope Creek Nuclear Generating Station.
- Boston Energy Company's Edgar Energy Park.
- Virginia Electric and Power Company's (VEPCO) Surry Station.
- New England Power Company - Brayton Point Generating Station, Unit 4.

RESEARCH/OPERATION FINDINGS:

- VEPCO found that survival immediately after removal from screens employing fish buckets was high for a large number of fish species at the Surry Station site. Latent survival was not measured. (Taft and Mussalli, 1981)
- Studies indicate that latent survival depends on the relative hardiness of the fish species collected. A Hudson River power plant in New York found that the 96-hour survival of several species of the herring family approached zero after removal from a traveling screen outfitted with fish buckets, while mean 96-hour survival of yellow perch under the same operating conditions at a power plant on Green Bay in Wisconsin exceeded 85 percent. (Taft and Mussalli, 1981)
- Boston Edison's Mystic Station reported an overall survival rate of impinged fish ranging from 47.8 to 89.9% depending on species.
- The frequency of screen rotation and screen travel speed impact the length of time that an organism is impinged which directly affects organism survival rates. (Taft and Mussalli, 1981)

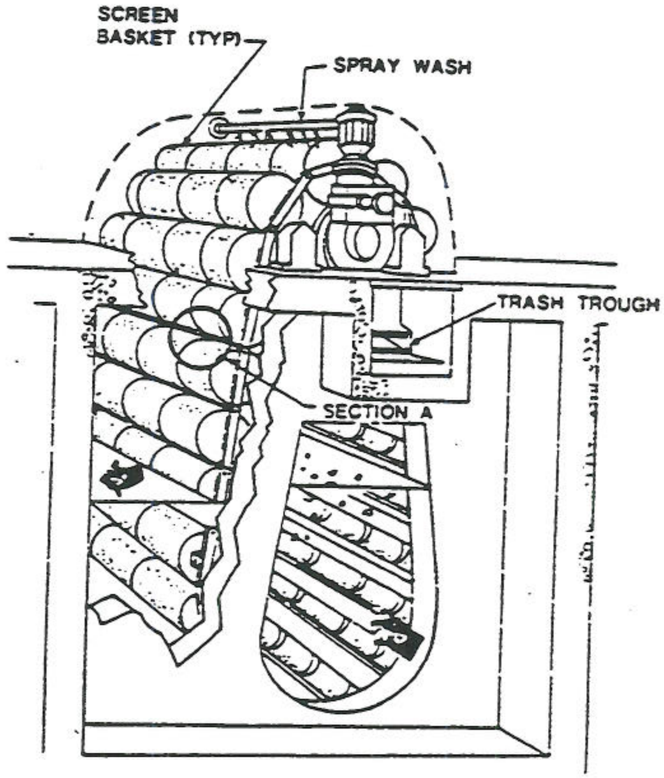
DESIGN CONSIDERATIONS:

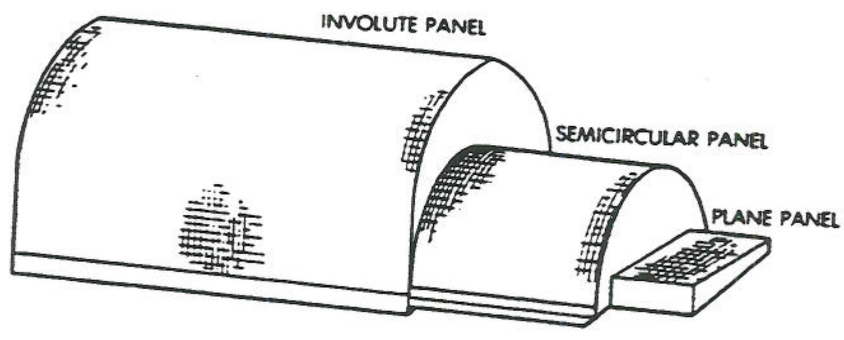
- Screens used for fish recovery must operate frequently or continuously.
- The frequency of screen rotation and screen travel speed should be based on the ability of local species to withstand impingement stresses. (Taft and Mussalli, 1981)
- Since screens must be operated frequently or continuously, increased wear on parts is expected. The use of heavy duty chains, roller bearings at the head shaft, journal bushings at the foot shaft, light weight components, and provisions for proper slack tensioning will aid in minimizing operational problems and maintenance requirements.

FISH HANDLING SYSTEMS	FACT SHEET NO. 12
	FISH BASKET

DESCRIPTION:

Fish baskets are separate framed screen panels attached to vertical traveling screens. The baskets may be flat or semicircular and assist in guiding fish to a bypass. Fish baskets are commonly used with spraywash systems. (Committee on Hydropower Intakes, 1995)





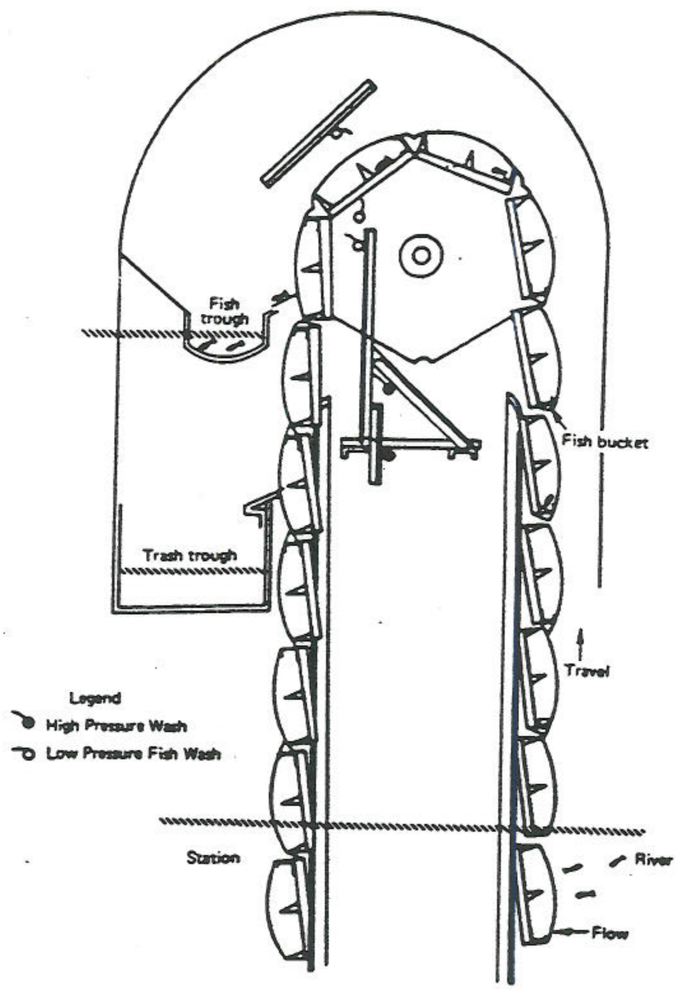
Comparison of Basket Types

Fish Basket (Mussalli, Taft and Hoffman, 1978)

FISH HANDLING SYSTEMS	FACT SHEET NO. 13
	FISH TROUGH

DESCRIPTION:

Fish troughs are collection receptacles for fish that have been sluiced from cooling water intake screens. The fish are then transported to a location downstream of the intake structure for release to open water.

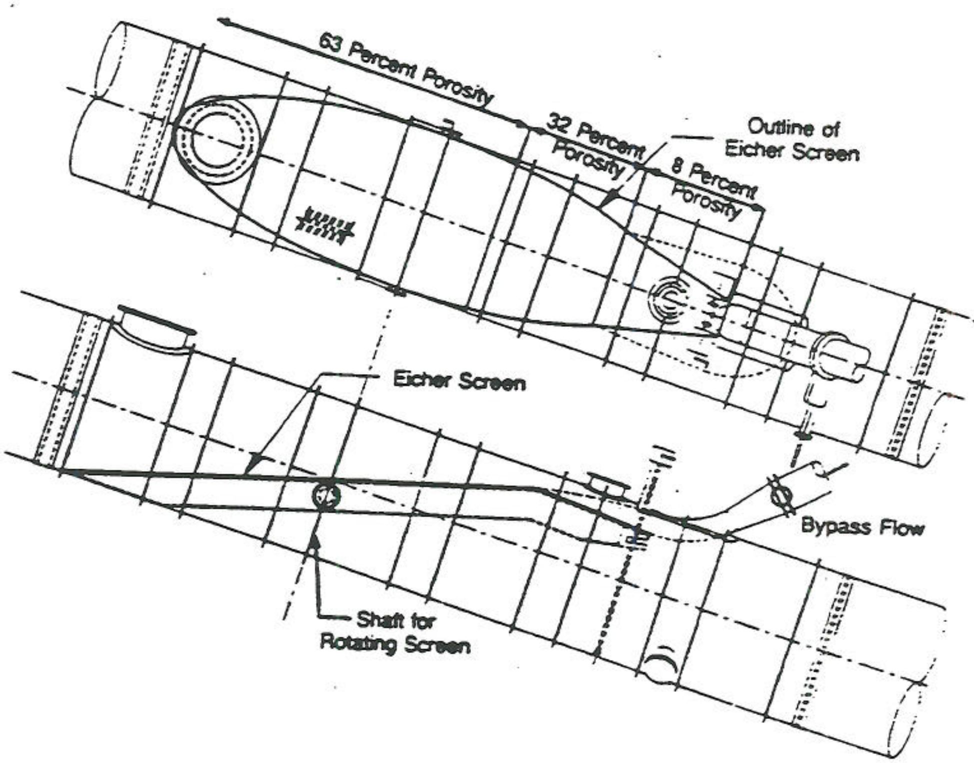


Fish Trough (Masnik and Wilson, 1980)

INTAKE SCREENING SYSTEMS	FACT SHEET NO. 14
	EICHER SCREEN

DESCRIPTION:

The Eicher screen is a wedgewire screen with varying porosity. Its upstream end (20 feet) has a porosity of 63%; the downstream end (7.5 feet) has a porosity of 32%, while the section of screen in the bypass section (7 feet) has a porosity of 8 percent. The screen is mounted on a pivot in order to allow backwashing of the screen. As water flows through the screen, debris is trapped on the screen and fish are diverted over the screen to a bypass pipe. From the bypass pipe, the fish are returned to the water source at a remote location. A trashrack is located upstream of the Eicher screen. (Winchell *et. al*, 1993)



Eicher Screen (Winchell, 1990)

LIMITATIONS:

- Operating velocities are limited to < 7 fps for some species of fish. (Winchell *et. al*, 1993)
- Has limited operational experience and is not fully accepted by many fisheries agencies. (Committee on Hydropower Intakes, 1995)
- Fish have some contact with screen.

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2. Winchell, F. C., E. P. Taft, T. C. Cook, and C. W. Sullivan. 1993. Research Update on the Eicher Screen at Elwha Dam. Waterpower '93.
3. Winchell, C. F. and C. W. Sullivan. 1991. Evaluation of an Eicher Fish Diversion Screen at Elwha Dam. Waterpower '91.
4. "Guidelines for Design of Intakes for Hydroelectric Plants," Committee of Hydropower Intakes of the Energy Division of the American Society of Civil Engineers, 1995.

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Boston Edison's Mystic Station
- Virginia Electric and Power Company's (VEPCO) Surry Station
- New England Power Company's Brayton Point Generating Station, Unit 4.

RESEARCH/OPERATION FINDINGS:

- None found.

DESIGN CONSIDERATIONS:

- For the frontwash screen, all fish must be removed from the screen without the aid of gravity, so the trash lip shape and spray design and location/orientation are of the utmost importance. (Mussalli, Taft and Hoffman, 1978)
- The frontwash screen requires the use of both internal and external spray headers to ensure that the proper removal of fish and debris occurs on the front side of the screen, preventing carryover. (Mussalli, Taft and Hoffman, 1978)
- With the backwash screen, proper sealing of the gap between the fish collection trough and the screen face is necessary to prevent fish from entering the cooling system.
- To protect larval organisms, the entire contents of the wash water should be returned to the source water body.

ADVANTAGES:

- Low pressure spray washes protect the organisms from further damage.

LIMITATIONS:

- With a frontwash system, organisms could be exposed to two sprays which may result in increased damage or mortality.

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2. "Guidelines for Design of Intakes for Hydroelectric Plants," Committee of Hydropower Intakes of the Energy Division of the American Society of Civil Engineers, 1995.

TESTING FACILITIES AND/OR FACILITIES USING THE TECHNOLOGY:

- Boston Energy Company's Edgar Energy Park.

RESEARCH/OPERATION FINDINGS:

- None found.

DESIGN CONSIDERATIONS:

- None found.

ADVANTAGES:

- None found.

LIMITATIONS:

- None found.

REFERENCES:

1. Edgar Energy Park, Clean Water Act, Sections 316(a) and 316(b) Demonstration, January 1990, Vol. #4, Appendix A.

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