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Intake Screens for Small Hydro Plants

Perforated plate screens have been used for many years for diverting fish and debris from the intakes of small, high head hydro projects. Now, an alternative is available that makes use of the "Coanda effect."

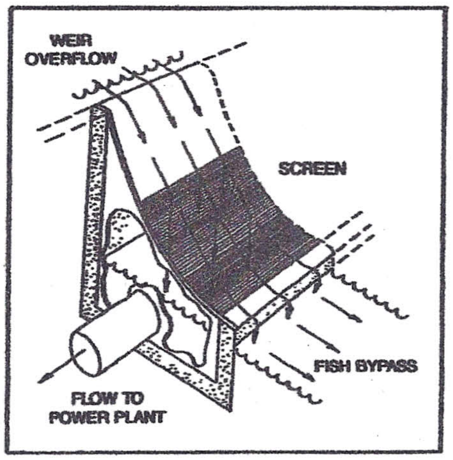
By James J. Strong and Ronald F. Ott

The successful operation of small hydro projects requires an intake system with the ability to separate fish and debris from water that passes through the turbine. Ideally, such a system should be reliable and require minimum maintenance; it should also protect fish; and prevent materials from wearing or clogging turbine components. An intake technique that meets these requirements has been in operation at several California hydro sites. Its design originated in 1955 as a simple apparatus for the wet screening of slurries in the mining industry. The design utilizes the Coanda effect: the phenomenon whereby a fluid tends to follow a solid surface.

Perforated Plate Screens

The system has shown its effectiveness in separating sub-millimeter particles from intake flows, thus allowing fish and other material to be diverted safely past the turbine intake. Pine needles, leaves, and gravel are kept out of the penstock and the turbine. This in turn minimizes the problems of clogging and reduced flow.

Prior to 1983, virtually all of the hydropower screening facilities for fish protection at small, high head projects in California consisted of standardized perforated plate screens. Up to that time, this system was considered state-of-the-art, and was frequently used by California's Department of Fish and Game. The usual design of these screens consists of 14-gauge punched plate with 5/32-inch holes on 7/32-inch centers. A brush driven by a cable and pulley mechanism and powered by a reversible motor continuously cleans the screens. Although costing only about $150 per cfs, this type of screen system has many inherent problems.



Configuration of Coanda-effect intake screen

One problem is that electrical power is required to operate the brush mechanism. Providing this power the mechanism can be expensive since the intake diversion at most remote small hydro sites is far removed from the available power supply. Another problem is that when icing occurs, the moving parts are subject to considerable maintenance, which often requires screen removal.

Pine needles and small rocks also tend to become wedged in the punched holes, clogging the screen. Clogging by filamentous algae can also occur during summer months in some streams. A special coating or repeated hand brushing may be necessary to control some types of algae growth. Finally, provisions are needed to ensure that bypass flow parallel to the screen will remove debris from the screen face, as well as guide fish downstream.

Because of such problems, there was a need for a screening technique for remote, high-head projects that met regulatory criteria, had neither moving parts nor power requirements, was simple and inexpensive to install, was self-cleaning, and required little or no maintenance.

Coanda-Effect Screens

In response to this need, a screen employing the Coanda effect was developed. This effect is the phenomenon exhibited by a fluid, whereby the flow tends to follow the surface of a solid object that is placed in the path of

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the flow. Aspects of the Coanda-effect design in actual installations are described in the following.

Prather Ranch

To demonstrate the effectiveness of the Coanda-effect design, a prototype screen was installed at the 100 kW Prather Ranch Hydroelectric project in Shasta County, Calif. The screen can handle 4 cfs, or 1 cfs per foot through the screen width.

The Prather Ranch screen has been operating more than five years without ice clogging or debris and fish impingement problems. A minor problem of occasional algae buildup on the underside of the screen surface has occurred at certain times of the year. However, scrubbing the underside with soap and water once a year appears to control this problem.

Kitchen experiment demonstrates the Coanda effect: a flowing fluid tends to follow a solid surface. Named for Romanian engineer Henri Coanda, an early 20th century aerodynamics pioneer, the phenomenon can be used to keep solid matter from entering hydro plant intakes.

Bear Creek

Based upon experience gained at the Prather Ranch, the Coanda-effect screen design was applied to a larger site, the 3 MW Bear Creek Hydroelectric Project, also located in Shasta County. These screens are capable of handling 70 cfs (1 cfs per foot of width).

The screens were applied as a side channel weir with the fish bypass over the check dam at the diversion. Flow variation is achieved by use of stop logs at the weir crest. A submerged walkway allows the operator to place stop logs. Installed in 1984, they survived severe flooding in February, 1986. Even though the entire diversion was under 10 feet of water, the turbine operated successfully. There was little damage, even though boulders rolled over the screen.

Montgomery Creek

The largest Coanda-effect screen installation to date is at the 3 MW Montgomery Creek project near Redding, Calif. Installed in November, 1986, the screens have a capacity of 120 cfs; total weir length is 120 feet. These screens have no provision for flow variation; however, no debris has accumulated and little maintenance has been required.

The diversion structure at Montgomery Creek incorporates a side channel weir configuration similar to Bear Creek. There is another fish weir adjacent to the inlet valve chamber which allows flow for fish passage below the screen deck to the main stream flow.

Bluford Creek

Because of the successful performance of the Coanda-effect screen at the Bear Creek plant during severe flooding, the owners of the 850 kW Bluford Creek Hydroelectric Project in Trinity County, Calif. decided to retrofit their intake structure to utilize the screens for protection of turbine equipment.

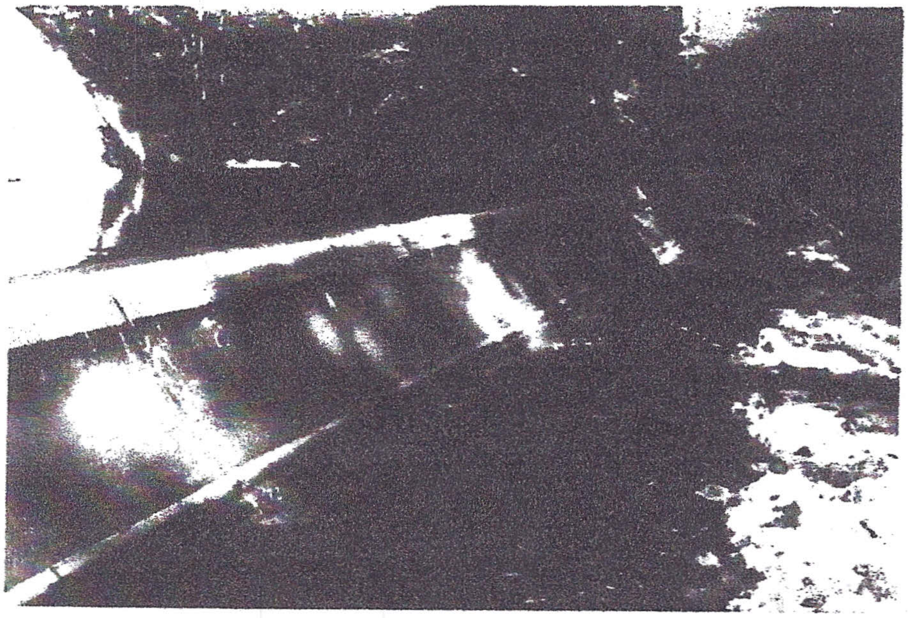
Bluford Creek has extremely high bed load turbidity during the spring runoff. This high turbidity caused considerable turbine blade wear, resulting in high maintenance costs, and requiring considerable operator time keeping the intake structure free of debris.

Prior to the Coanda-effect screen installation, the site had a simplified Y-type diversion that included a version of the kicker exclusion method; that is, a controlled flow area incorporating vortex-type sediment ejectors and a small settling basin with sluicing capability. The settling basin originally included the standard perforated plate-type screen. It was extremely difficult keeping these screens clean in the Fall; so many leaves would be carried down the stream that it was impossible for one man to keep the screens raked clean. During high water run-off, the suspended solids in Bluford Creek would be so thick that regardless of open areas and size, the ejectors would get compacted with rock and debris and cease functioning. On February 15, 1986, during a particularly heavy storm, the 8-inch by 27-inch injector plugged and the 8-foot-long settling tank filled with rock and gravel in less than 15 minutes.

In view of Bluford Creek's heavy load of suspended solids, a side channel weir configuration, similar to that used at Bear Creek, was not considered. Instead, the Coanda-effect screens were installed in a check dam configuration on two stem walls placed directly across the stream. A third stem wall two feet higher than the weir crest of the Coanda-effect screens was placed 28 inches upstream to serve as a rock trap. A sluice was installed between the upstream stem wall and the Coanda screen crest to permit removal of solids from the rock trap.

The structure was completed in the Fall of 1986. The total screen length along the weir crest is 20 feet. There are four screen sections, each five feet wide.

Considerable turbulence was created by the high upstream stem wall which forms the upper portion of the rock trap. This turbulence reduced the capacity of the screens and caused a 13 percent reduction in the peak power of the plant. (This problem was subsequently corrected by cutting



The 3 MW Montgomery Creek project, near Redding, Calif., has a weir length of 120 feet. It is currently the largest installation of Coanda effect screens.

down the height of the stem wall by several inches.)

However, even though the Bluford Creek drainage area received only about 69 percent of its average annual precipitation during 1986-87, the plant produced 71 percent of the expected average annual energy–and no downtime was attributed to the intake system.

The Coanda-effect screens have been self cleaning and maintenance free. Rocks, limbs, logs, silt, and leaves pass over the screens and are carried downstream when excess flows occur. The plant operator has been largely relieved of attending to the intake structure and can now devote full time to plant management. The screens, used in conjunction with one 4-inch tube sediment ejector, allowed only two inches of sediment to accumulate in the settling tank during 76 days of continuous operation.

The Coanda screens at the Bluford Creek site have a total capacity of 30 cfs with a weir crest length of 20 feet. This is the first installation where flow density over the screens was increased from 1 to 1 1/2 cfs per foot of weir length. At Bluford Creek the flow density was raised to 1 1/2 cfs per foot by increasing the arc length of the screens.

Notes and Comments

Coanda-effect screens are installed along the crest of small dams or diversions. They employ one or more concave screen panels arranged in a linear array. As water flows over the screen, a portion passes through the screen to the hydropower turbine inlet. The remainder flows across the screen surface, carrying fish and debris downstream. Components are made from stainless steel, and are designed for maintenance-free operation.

The design features a V-shaped profile wire that is tilted on support rods during the manufacturing process, producing an offset which causes a shearing action along the screen surface. Water flows over the weir plate and onto an acceleration plate, which provides for even distribution of flow across the screen width and an increase in velocity of the fluid across the horizontal slot. The screen is shaped in an ogee spillway configuration as is frequently used in overflow dam spillway design.

Water flow to the collection system of the turbine is through the screen slots, which are normally 1 mm wide. Because the velocity of the water across the slots is increased by the acceleration plate, 90 percent of the suspended solid particles (as small as 0.5 mm) may be removed by the screen, thus providing excellent protection for the turbine equipment.

Aquatic life is also prevented from entering the turbine through the slots. The smooth surface of the stainless steel screen provides for excellent fish passage. Since debris and fish pass over the screen surface, very little cleaning is required. The underside of the screen is reinforced with supports and resists the weight of large debris passing over it. This may include rocks and tree limbs that put a perforated plate screen out of service. The Coanda-effect design has been very effective in passing flow under heavy ice conditions including frazil ice.

When stream flow is low, all the water can enter the upper face of the Coanda-effect screen and leave the bottom portion of the screen dry. Thus, there is a possibility that fish could be stranded on the dry surface.

To correct this potential problem, a V-notch weir arrangement can be placed at the top of the screen. This concentrates the flow so that some water always travels to the end of the screen, carrying fish and debris downstream. Generally, these screens have been sized to handle 1 to 1 1/2 cfs per lineal foot of screen width at the weir plate. The cost of the screening material and supports is about $500 per cfs. Installation is relatively simple.

The Coanda-effect screen offers promise in many applications, enabling fish and debris to be economically diverted from the turbine intake. The Coanda-effect screen requires approximately four feet of head to allow the water over the weir crest and down into the collection system to the penstock. Consequently, this type system is primarily applicable to higher head projects. □

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