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HYDRAULIC TESTING OF STATIC SELF-CLEANING INCLINED SCREENS

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Abstract

Several configurations of static, self-cleaning, inclined screens were tested in the hydraulics laboratory of the Bureau of Reclamation. The screens were tested in an overflow weir configuration with potential for fish exclusion and fine debris removal applications at water intakes and diversion structures. Similar screens are used in the mining industry, primarily in coal-handling applications, and this type of screen has been successfully used for debris and fish exclusion at several prototype sites (Ott et al., 1987). This paper describes the testing program and results, and discusses how the Coanda effect may contribute to the high flow capacity of the screens.

Introduction

There is a growing need on Bureau of Reclamation projects to screen water for very fine debris and small aquatic organisms. Unfortunately, as screen openings are reduced, maintenance effort required to keep screens clean is increased. One screen design that offers potential for screening fine debris with minimum maintenance is the static inclined screen (fig. 1). A concave wedge-wire screen is installed in the downstream face of an overflow weir. Flow accelerates down the face of the weir and across the screen. Clean water drops through the screen while debris is discharged off the downstream end of the screen. A small bypass flow ensures that debris is carried off the screen. The nature of the flow across the screen face makes the screen largely self-cleaning. This screen has been successfully used for debris and fish exclusion at several prototype sites (Ott et al., 1987), but there is little detailed design information available. Installations similar to those tested here have been reported to have screening capacities of 0.09-0.14 m^3/s/m (1.0-1.5 ft^3/s/ft).

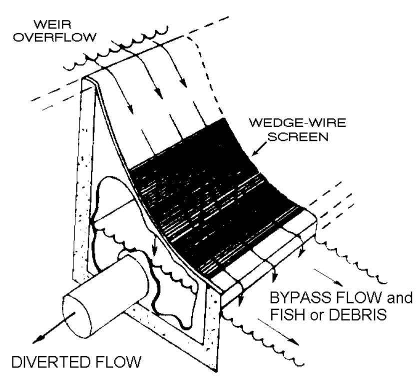

***Figure 1.** - Typical static inclined screen used for water diversion (after Ott et al., 1987).*

To develop design data for possible Reclamation use of static inclined screens, several screen configurations were tested in Reclamation's hydraulics laboratory. Objectives of the testing were to establish the flow capacity of a typical configuration and to qualitatively assess the tendency of the screens to clog with debris.

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The high capacity of the static screens tested by Reclamation is due primarily to a tilted-wire construction in which each wire is tilted so that its upstream edge is offset into the flow. A thin layer of the flow is sheared off the bottom of the water column and directed through the screen. This shearing action may depend somewhat on a phenomenon known as the Coanda effect. Past literature concerning these screens has attributed their high capacity to the Coanda effect, but the mechanism by which the effect improves the capacity has not been fully explained.

The Coanda effect is familiar to most hydraulicians, although perhaps not by name. The effect was first observed in 1910 by Henri-Marie Coanda, in connection with exhaust flow from an experimental jet engine (Stine, 1989). The Coanda effect is the tendency of a fluid jet to remain attached to a solid boundary. When a jet is discharged along a solid boundary, flow entrainment into the jet is inhibited on the surface side. For the jet to separate from the surface there must be flow entrainment into the jet on the surface side beginning at the separation point. However, the close proximity of the surface limits the supply of flow to feed such entrainment. Thus, the jet tends to remain attached to the surface. If the surface deviates sharply away from the jet, separation will occur, but if the surface curves gradually away, the flow may remain attached for long distances. Primary applications of the Coanda effect have been in aeronautics; wings and engines using the effect have achieved increased lift and thrust. Reba (1966) describes experimental work on propulsion systems using the Coanda effect, including hydrofoils, jet engines, and a levitating vehicle. The Coanda effect has also been used in the design of improved nozzles for combustion applications.

Figure 2 shows the flow over a flat-wire screen and over a tilted-wire screen as it would occur with and without the Coanda effect. The flow is shown as it would appear near the top of the screen, where the flow direction has been established by the ogee crest. Without the Coanda effect, the flow separates off the high point of each wire and skips to the next wire, with essentially no flow being sheared off. Gravity, pressure forces and the curvature of the screen panel will force a small amount of flow through the screen, and as the flow continues down the screen the flow field will begin to deviate toward the screen. Once this deviation matches the tilt angle of the wires, the flow will be similar to that shown at the right of figure 2.

The Coanda effect causes the flow to remain attached to the screening surface of

Figure 2. - *Schematic representation of flow over flat-wire and tilted-wire inclined static screens, with and without the Coanda effect.*

each wire, directing the flow into the offset created at the next downstream wire. A thin layer of the flow is sheared off by the next wire, which is offset into the flow due to the tilted-wire construction. The incremental discharge through the screen at any wire is a function of the flow velocity and the thickness of the sheared water layer. The elevation drop from the crest to the screen produces high velocity flow over and through the screen. Since the Coanda effect keeps the flow in contact with the screening surface of each wire, even near the top of the screen, it helps produce high capacity flow over the full length of the screen. The significance of this benefit is uncertain.

Testing Program

Two concave, stainless steel, wedge-wire screen panels were tested in the laboratory facility in three different configurations shown in table 1. Both screens were constructed with a 254-cm (100-inch) radius and covered a 25E arc, producing a total length of 1.11 meters (3.64 ft) in the flow direction. Each screen was installed on the downstream face of an ogee crest spillway in a 30.5-cm (1-ft) wide flume. A 19-mm (0.75-inch) wide support beneath the screen restricted the flow-through width of the screen to 28.6 cm (11.25 inches).

Table 1. *— Test screen configurations.*

Test	Screen Type	Dimensions
A	Tilted wires	C Crest designed for flow of 0.116 m^3/sec/m (1.25 ft^3/s/ft) C 0.366 meter (1.2 ft) drop to start of screen C 60E starting angle at top of screen (from horizontal)
B	Flat wires, parallel to flow	
C	Tilted wires	C Crest designed for flow of 0.372 m^3/sec/m (4 ft^3/s/ft) C 0.249 meter (0.817 ft) drop to start of screen C 50E starting angle at top of screen

The first screen used V-shaped wires oriented perpendicular to the flow direction. The wires were 1.52 mm wide, with a clear spacing between wires of 1 mm. The wires were tilted 5E from the normal orientation (fig. 2). This configuration is capable of screening out debris smaller than the 1-mm clear spacing, depending on screen inclination, flowrate, and debris characteristics. This screen was tested in two different crest configurations, with the upstream edge of the screen set into the downstream face of the crest at 60E and 50E angles from vertical, tangent to the ogee profile.

The second screen was constructed with the same V-shaped wires and wire spacing, but the wires were run parallel to the flow direction and were not tilted. This configuration was tested because of the possibility that it would be a preferable design for use in applications involving fish; this wire orientation would likely cause less descaling of fish and less abrasion of fish eggs passing over the screen. This screen does not take advantage of the Coanda effect.

All quantitative testing was done with clean water. To qualitatively evaluate clogging potential, each configuration was also tested with debris consisting of saturated sawdust and wood chips from model construction activities.

Screen A was installed on the downstream face of an ogee crest spillway designed for a flow of 0.116 m^3/s/m (1.25 ft^3/s/ft). This screen was initially tested with the full length of the screen open to flow, but it was quickly apparent that the screen capacity was

***Table 2.** — Screen capacities with zero bypass flow.*

Screen	Length of Open Screen meters (ft)	Screened Flow with Zero Bypass Flow $m^3/s/m$ ($ft^3/s/ft$)
A	0.457 (1.5)	0.116 (1.25)
	0.787 (2.58)	0.260 (2.80)*
B	1.086 (3.56)	0.048 (0.519)
C	0.457 (1.5)	0.106 (1.14)
	1.086 (3.56)	0.334 (3.59)

** Largest flowrate tested did not reach the end of screen A. Extrapolating data from lower flowrates suggests a zero-bypass screening capacity of about 0.37 $m^3/s/m$ (4 $ft^3/s/ft$) for a 1.086-meter long screen A.*

much greater than the design flow rate of the test facility. To permit testing at a flowrate that would produce bypass flow, covers were constructed so that the open screen length could be limited to the upper 0.457 meters (1.5 ft), or 0.61 meters (2 ft). To permit testing the full-length screen A to full capacity, a new crest was constructed and the screen was retested as configuration C. Screen B was installed in the same crest configuration as screen A. The capacity of screen B was relatively low, permitting all testing to be done with the full screen length open to the flow.

Data recorded for each test flowrate were the inflow to the screen (measured with laboratory venturi meters), and the flowrate through the screen (measured with a suppressed rectangular weir). The bypass flow off the screen was determined from continuity. For flowrates that produced no bypass flow, the flow distance down the screen was recorded.

Results

Table 2 shows the capacity of the full-length screens and the partially covered screen sections at the zero-bypass condition. Screens A and C both had much higher capacities than those previously cited in the literature. Screen A had the highest capacity due to its steeper inclination angle (60E vs. 50E for screen C) and greater head drop that produced higher velocities across the screen face.

Figure 3 shows the re-sults of tests on screen A, with the cover in place to limit the open screen length to 0.457 m. The maximum screened flow shown in table 2 was reached when flow was observed down the full length of the open screen. As the inflow was increased further the bypass flow increased as shown in the figure.

Figure 4 shows the screening capacities of the unmodified screen A and the shortened sections of screen A tested with the cover plate in place. The capacity is expressed in terms of the flow per unit screen area, and is plotted as a function of the specific energy input to the screen at the upstream edge. The specific energy was calculated 2 meters upstream of the crest, referenced to the elevation of the upstream edge of the screen. The figure shows that within the range of conditions tested, the discharge per unit area through screen A is a single function of the input energy for both the fully open screen and the partially covered screens. This indicates that the Coanda effect is influencing the flow through the screen. If the Coanda effect were not a factor, the upstream portion of each screen would be less efficient, and there would be a significant reduction in the screened flow per unit area when the lower portions of the screen were covered.

Testing with debris showed that all screen configurations were resistant to clogging. Screen B in particular showed no debris buildup on the screen face; the orientation of the wires parallel to the flow allowed the flow to easily sweep debris off the screen. Screens A and C did exhibit some clogging and an increased bypass flow when debris was initially introduced, but most debris was quickly dislodged and carried down the screen face. Generating turbulence in the flow near the crest seemed to accelerate the self-cleaning process; a paddle wheel or other device that generates turbulence at the crest might prove beneficial.

Testing of screen C revealed a very loud, high frequency noise emanating from the screen at flow rates above about 0.28 m^3/s/m (3 ft^3/s/ft). This noise was likely due to some form of flow-induced screen vibration, although the exact source could not be determined during the tests. This is a condition that requires further study as it may affect long-term screen durability.

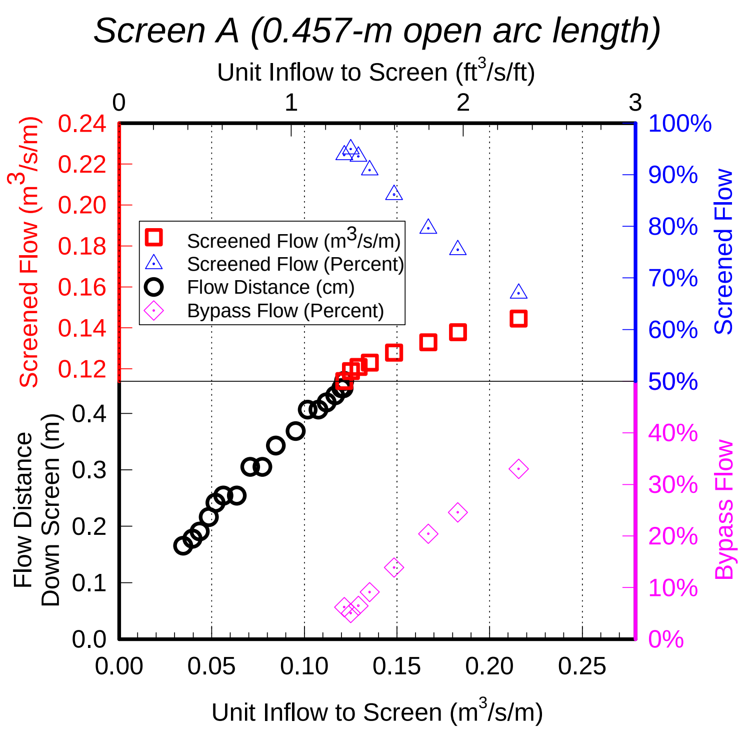

***Figure 3.** - Results of screen A tests with cover limiting open screen length to 0.457 meters.*

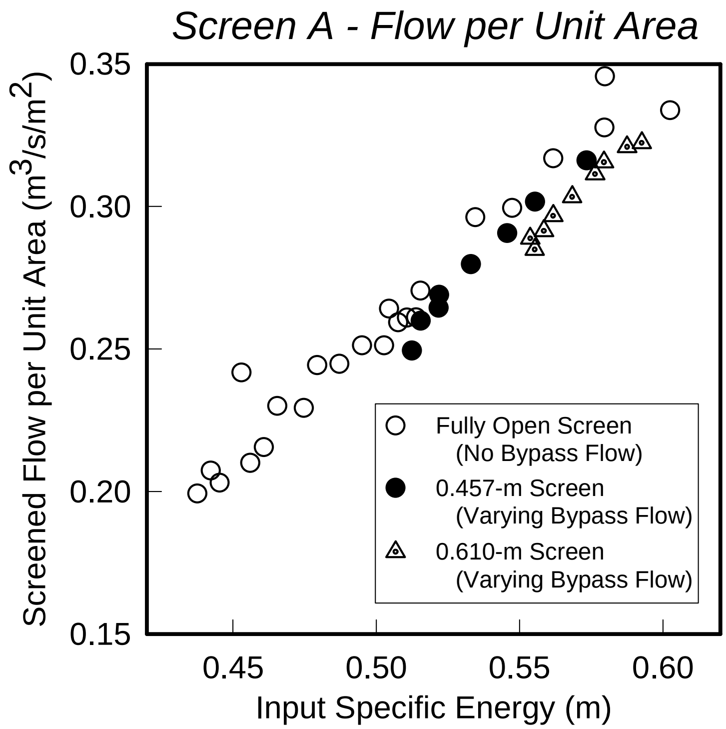

Figure 4. - *Results of screen A tests with and without covers to limit open screen length.*

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Keywords

screens
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