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Labor-Saving Debris and Fish Screens

By Tony L. Wahl[1], Robert K. Weir[2], John K. Cerise[3], Brian Sauer[4], Jack Wergin[5]

Problems caused by debris in irrigation water can be expensive and troublesome issues for irrigators and water districts, especially as many water users convert from traditional set-tube flood irrigation to more modern application methods such as gated pipe and sprinklers. Debris can plug gated pipe orifices and sprinkler nozzles, or clog valves and flow metering equipment. These problems usually lead districts to attempt to screen debris from irrigation water before it can cause such problems, but even on projects where debris screens have been installed, the maintenance and cleaning of screens themselves often becomes a full-time job.

Many different trash screen and trashrack designs have been developed through the years to address the need for low-maintenance screening. Traveling screen systems, vibratory screens (e.g., the Yak screen), and turbulent fountains have all had some success, but the goal of truly maintenance-free screening has not yet been reached. Now, a new application of an old technology first developed in the mining industry is bringing us closer to this goal. Although not absolutely maintenance free at every site, Coanda-effect screens are substantially self-cleaning with no moving parts, and require less maintenance than most other screening systems. They are able to remove debris as small as a fraction of a millimeter when necessary. There have been many applications of these screens throughout the world and in the U.S. during the past 25 years, mostly on small hydropower installations where the screens remove both debris and fish. In the past few years several small screens have been installed in irrigation applications in the western U.S. Several of those installations are described in this article.

For those seeking additional information, brief case histories of many small hydropower screen installations are given in the appendix of a new design guide for Coanda-effect screens (Wahl 2003). Additional technical details and a mathematical model for evaluating the hydraulic performance of these screens are given in Wahl (2001). Finally, a computer program available via the Internet from the Bureau of Reclamation can be used to analyze screen hydraulic performance, and was used to develop the new design guide. That program and other references are available at http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/.

[1] Hydraulic Engineer, U.S. Department of the Interior, Bureau of Reclamation, Water Resources Research Laboratory, Denver, CO <twahl@do.usbr.gov>

[2] Hydroscreen Co. LLC, Denver, Colorado, <rkweir@aol.com>

[3] ClearWater Solutions, Carbondale, Colorado. <jkcerise@rof.net>

[4] Water Conservation Specialist, Bureau of Reclamation, Boise, Idaho. <bsauer@pn.usbr.gov>

[5] Water Conservation Specialist, Bureau of Reclamation, Grand Island, Nebraska. <jwergin@gp.usbr.gov>

How Coanda-Effect Screens Work

The primary features of a Coanda-effect screen are illustrated in Figure 1. The screen is installed on the downstream face of an overflow weir. Flow passes over an acceleration plate, and then across a wedge-wire screen panel. The wires in the panel are horizontal, perpendicular to the flow across the screen. The screen panel may be either flat or concave. Flow passing through the screen (screened flow) is collected in a conveyance channel beneath the screen, while overflow, fish, and debris pass off the downstream end of the screen. Flow velocities across the screen are typically 6.5 to 10 ft/s, increasing toward the toe of the screen. In past hydropower applications, commercially available designs typically had the screen inclined 60° from horizontal at the upstream edge, with a total head drop across the structure of about 4 to 5 ft. However, many of the applications described in this paper use much flatter screen angles and operate with much smaller head loss.

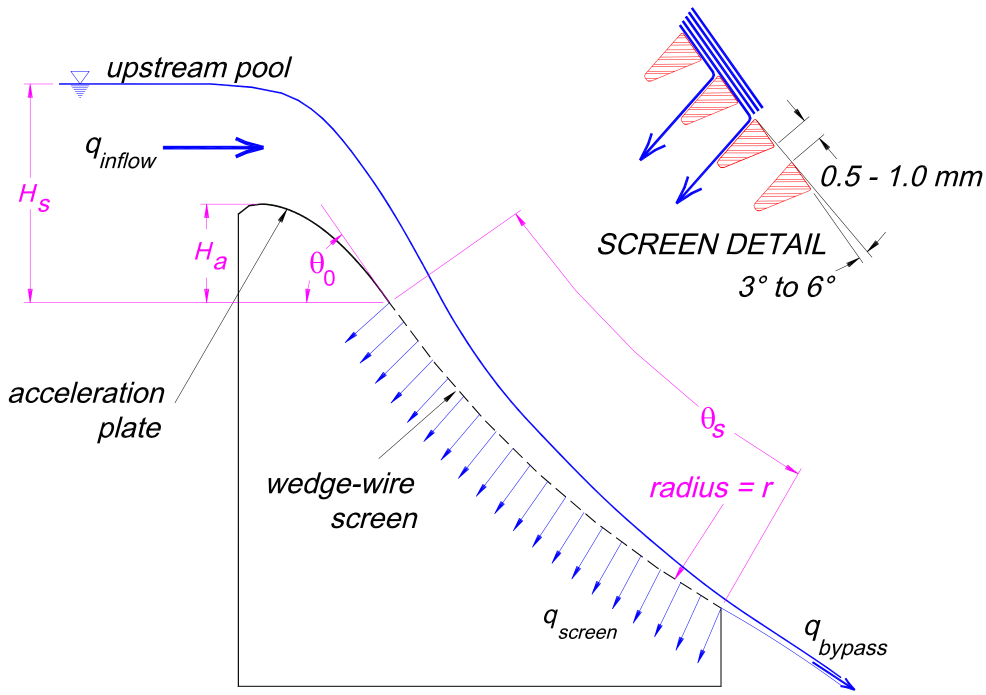

Figure 1. — Features, typical arrangement, and design parameters for Coanda-effect screens.

Coanda-effect screens utilize a unique tilted-wire screen panel. The individual wires are tilted a few degrees downstream (see detail, Fig. 1) to produce shearing offsets into the flow above the screen. The typical tilt angle is 5°, but angles of 3° to 6° are available from most screen manufacturers. Slot widths between the wires are typically 1 mm (0.04 in.) or less. The shearing action is enhanced by the fact that flow remains attached to the top surface of each wire, and is thus directed into the offset created at the next downstream wire. This attachment of the flow to the top surface of each wire is an example of the Coanda effect, the tendency of a fluid jet to remain attached to a solid flow boundary. A detailed discussion of the Coanda effect and its application to tilted-wire screens is provided by Wahl (1995).

The benefits of improved screening are numerous. With less debris, water can be applied faster and with better uniformity. On one gated pipe system, it was reported that fields that formerly took 5 days to poorly irrigate could now be irrigated in two days with more uniform flow for each row. Irrigation ditches are also a common source of weed seeds that move into the fields with the water. A commonly used wire spacing of 0.5 mm (0.019 inches) will screen out about 90% of the debris larger than 0.25 mm (.009 inches). This will effectively remove most weed seeds. This will reduce labor and costs incurred in the control of noxious weeds.

Boise Project, Idaho

The screen shown in Figure 2 was installed on the Boise Project to provide removal of fine debris at a drop structure and flow metering box serving both flood and sprinkler-irrigated farms. The Coanda-effect screen was installed during the spring of 2003. The new stainless steel screen is 3 ft long and 8 ft wide, with 0.5 mm slots. This screen is cleaned a couple of times per week. The project made two minor modifications after the screen was installed. First, they added small flow deflectors near the top edge of the accelerator plate because debris was collecting where the screen met the sidewall of the concrete box. The deflectors successfully keep the edges of the screen clean. Second, the project added a staff gate upstream from the weir to allow them to make a rough estimate of the flow being delivered to the screen. This measurement only approximates the flow actually delivered to farmers on this lateral, since a small amount of overflow passes off of the screen into a bypass pipe that leads back to the canal. Downstream from the screen, piped farm deliveries are measured with paddle-wheel-type insertion flow meters, and since the screen was installed, the project has had little problem with the meters. This screen was installed as a demonstration project through a 50% cost share between the irrigation district and Reclamation's Science & Technology program.

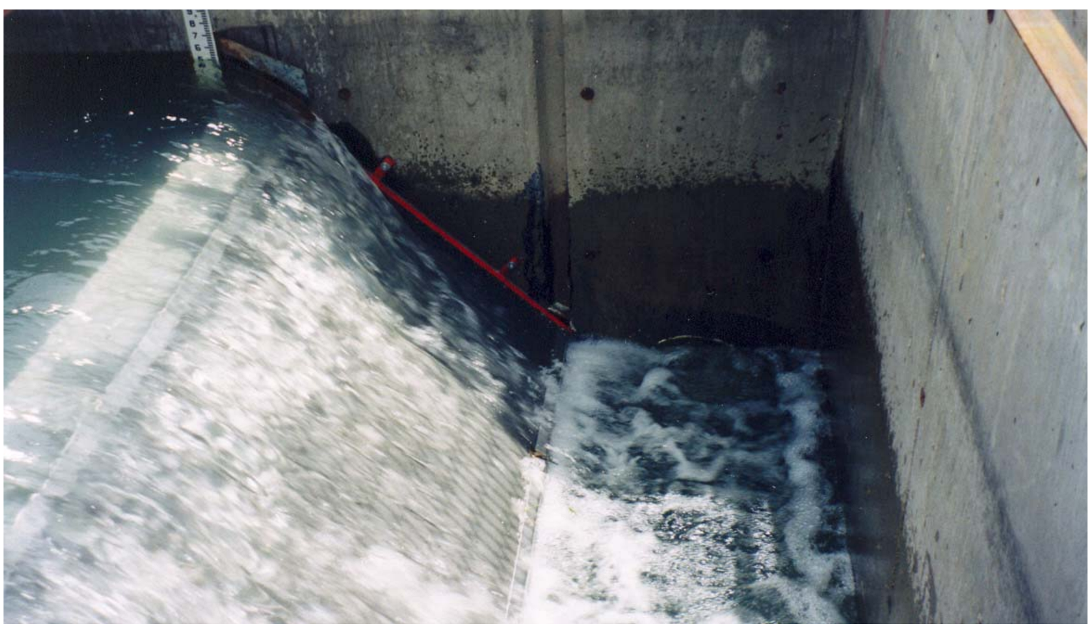

Figure 2. — Coanda-effect screen installed on the Boise Project. Clean water drops through the screen section into a conveyance channel beneath the screen. A staff gage and sheet-metal flow deflector are visible at the upstream corner of the screen.

Pioneer Irrigation District, Colorado-Nebraska

As part of recent modernization efforts, the Pioneer Irrigation District has been converting from flood to sprinkler irrigation systems. To facilitate this conversion, the district has added several Coanda-effect screen devices. Those shown in Figures 3-5 are incorporated into low-pressure piped delivery systems. In each case, the pipe is interrupted by a well that contains a Coanda-effect screen. Flow enters the well and builds up to flow over a weir and across the screen. The screened flow is collected beneath the screen and exits the well into a discharge pipe. The debris passes over the screen and is discharged out of the side of the structure. These devices consume a few feet of head, which has not been a problem for this district, but might be an issue on other projects.

Figure 3. — Coanda-effect screen structure built with corrugated metal pipe. Raw water enters from the right. Clean water is discharged through the center and left-hand pipes, while debris exits onto the ground through the slot in the left side of the structure.

Figure 4. — Coanda-effect screen structure feeding two irrigation pipelines. Raw water enters the back of the structure through the white, PVC pipe. Screened water exits to the right and left. Overflow and debris are discharged onto the ground at the front of the screen.

Figure 5. — Coanda-effect screen structure similar to that shown in Fig. 4, operating at a relatively high flow rate. All flow still passes through the screen before reaching the toe.

Lake John

For many years the Colorado Division of Wildlife has tried to limit the entry of carp and sucker eggs and larvae into Lake John in an effort to preserve and maintain a sport fishery there. In the 1990's they constructed a sand filter device (Fig. 6) like those often used in water treatment applications, but maintenance of the filter was a serious problem, with backwashing and reconditioning of the filter required on a frequent basis. Cleaning involved lowering a burning cherry bomb held in the jaws of a wrench into the structure, where its detonation disturbed the accumulated fine sediments.

Figure 6. — Sand filter at Lake John. This structure presented some exciting maintenance challenges.

In July of 2001 the Division replaced the sand filter structure with 4 panels of tilted-wire Coanda screens on the irrigation ditch diversion to Lake John. Each panel measured 5 ft wide by 47 inches long. The wire slot opening was 0.5 mm (0.019”), small enough to exclude the undesirable fish and larvae. The design discharge was approximately 30 ft^3/s. To date the screens have easily accepted the full design flow, but the outlet channel capacity beneath the screens has been somewhat less, preventing screen operations at the full design flow. Despite this problem, the screens themselves have worked well and have significantly reduced the maintenance problems associated with this site. Plans are currently under way to install similar screens on the supply to adjacent lakes.

Figure 7. — Coanda-effect screen structure at Lake John, constructed in 2001. This structure replaced that shown in Fig. 6.

Rocky Mountain Arsenal Wildlife Refuge

The Rocky Mountain Arsenal is a former Dept. of Defense facility near Denver, Colorado that is being converted to a wildlife refuge. A Coanda-effect screen was installed in the spring of 2000 for the U.S. Fish & Wildlife Service to exclude undesirable fish, fish eggs, and larvae from water being supplied from the Farmer’s Highline Canal to several wetland ponds and lakes on the refuge. The screen replaced previous wire mesh screen panels that had required cleaning several times per day. The new screen has required cleaning only intermittently, when personnel visit the site for other reasons. The structure is 20 ft long with a design flow of 20 ft^3/s. The screen would be capable of accepting much greater flows, but the receiving channel beneath the screen proved to be slightly undersized and cannot quite accept the full 20 ft^3/s. A small amount of flow bypasses the screen due to obstructions beneath the screen surface created by the support structure for the screen. The screen has performed well since its installation.

Figure 8. — Rocky Mountain Arsenal screen.

Small Hydro Installations

Small hydropower sites have been a common application for Coanda-effect screens, due to the need for low-maintenance screening in remote environments. Two notable installations with relatively long operating histories are Montgomery Creek (since 1985) and Forks of Butte (since 1991), both in northern California.

The Montgomery Creek site is about 40 miles northeast of Redding, California, just below the confluence of two creeks. The design flow is about 120 ft^3/s. The screen structure utilizes 24 Aqua Shear panels manufactured by Aquadyne, for a total crest width of about 36 m (120 ft).

The project operators have been pleased with the performance of the structure, although they have modified the original design to make it more durable. These modifications included increasing the thickness of the accelerator plate and strengthening its attachment to the weir. Bolts used to attach the screens to the frame were modified and screens were welded to the accelerator plate. The width of the screen section is more than double the theoretically required width, but several factors reduce the theoretical capacity of the screens, including:

- One third of the screens are original and 15 to 16 years old. Wear has occurred on the screens, especially due to an increase in bed-load sediment passing over the screen following a large forest fire in the area several years ago.
- The water at this site is relatively warm and algae grows easily on the wedge wires. During the summer months the operator cleans the screens once per day.
- The accelerator plate curvature is too tight, causing the flow to arc over the top section of the screen during high flows.
- The transition between the accelerator plate and the screens is not smooth enough, causing water to skip over approximately 10% of the screen area.
- Some of the screens that were changed out due to wear have been replaced with planar panels rather than the original concave panels, which reduces their capacity somewhat.

The operators report that some sediment gets clogged between the wires, requiring an annual cleaning with a vibratory cleaner.

Figure 9. — Montgomery Creek intake.

The Forks of Butte diversion and powerhouse is located at Paradise, about 85 miles southeast of Redding, California. At this site a dam diverts water into a side channel and the screen structure is parallel to the river. The structure is about 47 m (150 ft) long, with a design capacity of about 210 ft^3/s. Sediment has filled most of the pool upstream from the structure, causing an increase in approach velocity as the flow reaches the structure.

The operating experience here has been similar to that at Montgomery Creek. To strengthen the structure against vibration, the screen was welded completely to the support structure. Knee braces were also added beneath each panel. When screen panels were replaced due to wear, the wire thickness was increased from the original 1/16 in. to 3/32 in. Unlike Montgomery Creek, there is no algae growth, due to the fact that the intake is in a deep canyon where little direct sunlight reaches the screens. The screens do not clog and no cleaning maintenance is necessary.

Figure 10. — Forks of Butte intake.

Small Agricultural Diversions in Western Colorado

Several small Coanda-effect screen structures have been installed in the past 2 to 3 years in western Colorado, primarily on projects converting from flood irrigation to sprinkler systems. The screens provide low-maintenance removal of fine debris that would potentially plug sprinkler nozzles. The screens are installed in modular turnout boxes that are installed into existing irrigation ditches (Figs. 11 and 12). Because head is limited, screens are often installed on slopes of about 10º to 15º. Typical sizes are about 2 to 3 ft wide and 3 ft long, with design diversion capacities less than 10 ft^3/s. Screens typically have a 0.5 mm slot width. Most of these screens have worked very well and new installations continue to be made. The few problems have occurred at sites where there was very little head drop available, so tailwater submerged most of the screen and reduced the velocity across the screen surface, which allowed some clogging to occur.

Figure 11. — A small Coanda-effect screen provides water to a sprinkler irrigation system near Carbondale, Colorado.

Figure 12. — Modular Coanda-effect screen structure. Flow is toward the reader. Screened flow exits to the right through the flanged pipe connection.

Modular Screen Structures for Diversions at Canal Checks

At canal check structures, a unique screen structure has been developed that is easily incorporated into an existing check. Fig. 13 shows the structure, which contains a wedge-wire screen and an underlying stainless steel chute attached to a PVC pipe. The flow passes through the screen and down the chute into the PVC pipe. The deep vault beneath the screen shown in Fig. 12 has been eliminated. Note the flap at the bottom of the screen in Fig. 13. When one wishes to stop the diversion, check boards are removed to eliminate flow over the screen and the flap is raised to prevent flow entering the screen from the downstream channel. Figs. 14 and 15 show plan and elevation views of a typical installation.

Figure 13. — Coanda-effect screen structure in the shop, configured to discharge directly into a PVC pipe.

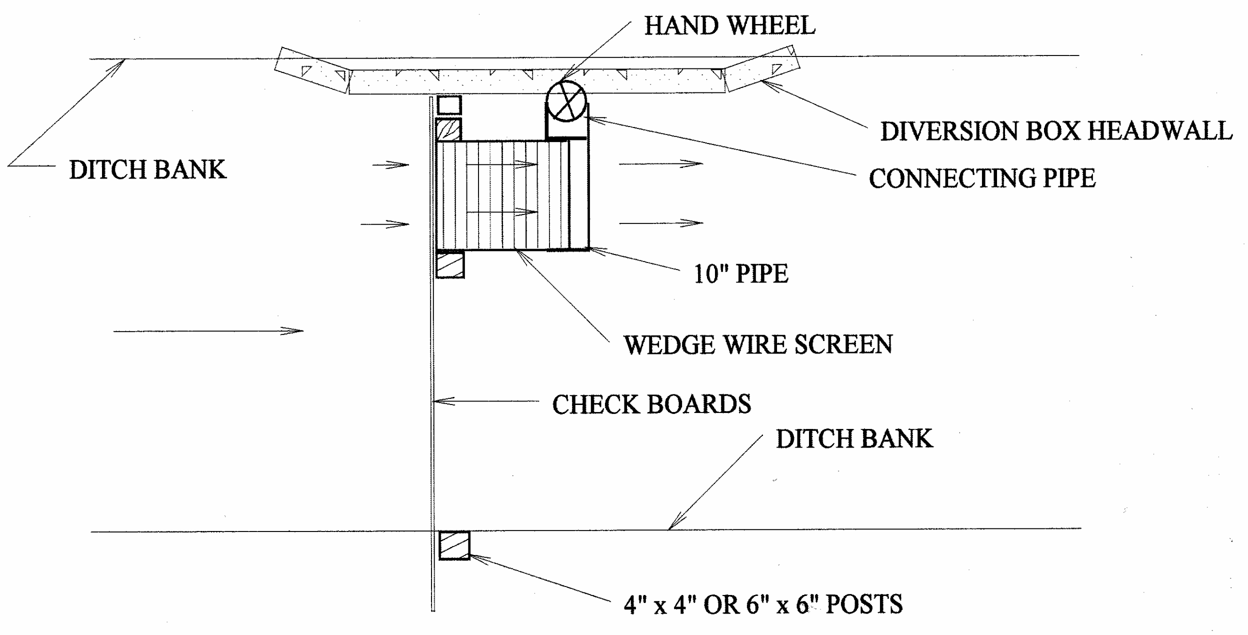

Figure 14. — Plan view of a Coanda-effect screen incorporated into a stoplog check.

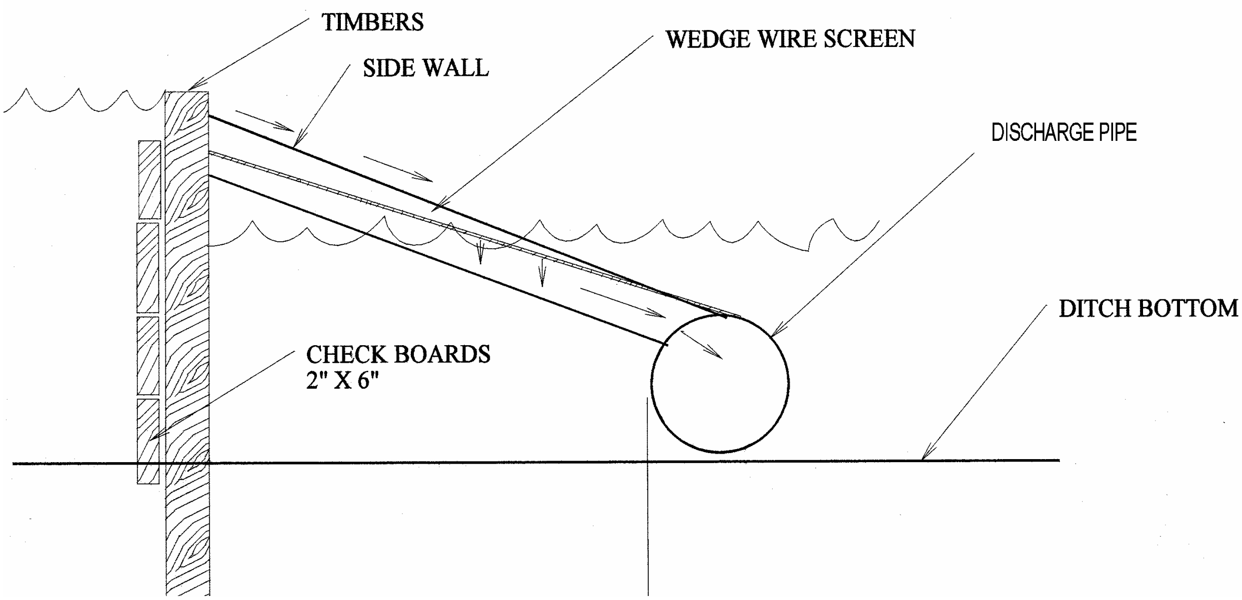

Figure 15. — Elevation view of Coanda-effect screen installation at a stoplog check.

Conclusions

Coanda-effect screens can be adapted to solve a wide variety of water screening problems. If adequate sweeping flow is maintained across the screen face, minimal cleaning maintenance will be required. Screens are available from several manufacturers, and design assistance is available from the Technical Service Center of the Bureau of Reclamation.

WEB RESOURCES

Coanda-Effect Screen Software – http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/

AquaScreen Enterprises – http://www.aquascreen.jbmj.com/

Hydroscreen Co., LLC – http://www.hydroscreen.com/

Norris Screens – http://www.norrisscreen.com/products/hydroelectric.htm

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Wahl, Tony L., 1995, "Hydraulic Testing of Static Self-Cleaning Inclined Screens," *Water Resources Engineering*, Proceedings of the First International Conference on Water Resources Engineering, American Society of Civil Engineers, San Antonio, Texas, August 14-18, 1995.

Note: Electronic copies of these references are available at **http://www.usbr.gov/pmts/hydraulics_lab/twahl/coanda/**