RECLAMATION
Managing Water in the West

PAP-1016

ISI Cylindrical Screen Performance

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Background

Fish screens are required on water diversion intakes in many locations to prevent entrainment of fish and other aquatic species. Maintaining the screen surface in a clean condition is imperative for water diversion and aquatic species protection. Screens are generally designed with cleaning devices that remove impinged aquatic debris off the screen surface. Quagga mussels, an invasive species, have recently been found in a number of locations in the western United States. Quagga mussels are filter feeders that attach in large numbers to almost any surface, and would likely find fish screens ideal. Reclamation's Research Office is funding a study to investigate the impact that Quagga mussels could have on operation of common styles of fish screens. The study presented herein provides baseline data on the performance of the ISI (Intake Screens Inc.) cylindrical fish screen. The ISI screen is one of several screens that have been selected to be evaluated in a field study of screen performance where Quagga mussels are present in large numbers.

Resource agencies have adopted standards that require that screens meet a maximum approach velocity criteria ranging from 0.2 ft/s to 0.40 ft/s depending on the fish species residing in a given area (i.e. velocity measured perpendicular to the screen surface). These screens must meet the criteria despite having to shed heavy debris loads.

It is also important for screen manufacturers to produce screen designs that provide uniform approach velocities in order to meet screen criteria guidelines while minimizing screen surface area or size required at a diversion. In order to accomplish this objective an improved understanding of fish screen hydraulics is needed. As a result, the Hydraulics Investigations and Laboratory Services Group at the U.S. Bureau of Reclamation (Reclamation) in Denver has conducted testing to study the performance of cylindrical fish screens for providing an effective positive barrier for fish exclusion. In this study two 30-inch diameter cylindrical screens were loaned to Reclamation by ISI for testing and performance evaluation (figure 1). These screens have a unique cleaning system (patented) that uses an internal and external brush system. The screens were loaned to Reclamation to determine headloss through the screen and to determine the level of uniformity of approach velocities.

Model Set-Up

Both 30 inch diameter cylindrical screens tested were comprised of #69 wedgewire (0.068 inch width at top) with slot openings of 0.068 inches (1.75 mm). The wedgewire cylinder (23.6 ft surface area with 50 percent open area) rotated against both external and internal brushes for cleaning (figure 2). One screen used a hydraulically activated (HA) system to drive the rotation of the screen, while the second one used an internal propeller (IP) to drive the rotation against the brush system for cleaning. The adjustable external brush was bolted to a fixed support arm above the cylinder. The internal brush was mounted to the suction manifold inside the screen. At an approach velocity of 0.33 ft/s (slot velocity of 0.66 ft/s) both screens were rated at 7.8 ft^3/s. In addition, the outer wedge-wire cylinder rotated around a fixed cylinder suction pipe with holes patterned to promote even velocity distribution of water through the screen.

Screen approach and sweeping velocities were measured with a Sontek acoustic Doppler velocimeter (ADV probe) at 2-in. intervals at the left and right center lines along the length of each screen. Measurements were performed starting 1/2 inch from the leading edge (upstream end), to determine the overall flow distribution for the maximum flow provided by the test configuration. Screen performance was evaluated by measuring velocities at a 3-in distance from the screen surface, as required to meet resource agency screen velocity criteria.

Figure 1. ISI hydraulically operated cylindrical screen inside test flume.

In each test case, approach velocity is defined as the component perpendicular to the screen surface, and sweeping velocity is defined as the component parallel to the screen surface. In addition, positive approach velocities indicate flow is going into the screen, while positive sweeping velocities indicate flow is in the downstream direction toward the suction end of the screen. It is worth noting that because it is impossible to measure velocities over the entire screen control surface, the velocities measured at positions along the two centerlines (3.0 in. from the screen face) cannot necessarily be extrapolated to represent total through-screen flow to satisfy continuity. In addition, there may be some flow recirculation that occurs between the outside cylinder and the inside suction tube.

Figure 2. ISI brush cleaning system.

Hydraulically Activated Screen Tests

The HA screen was the first screen to be tested. The cylinder rotation was driven by a submersible hydraulic motor located within the screen that allowed for rotation either clockwise or counter clockwise in direction. The system was controlled from a control panel that could be programmed for a rotation schedule based on site conditions, depending on type and amount of debris load and cleaning requirements.

The HA screen was installed near the downstream end of a 90 ft long by 4 ft wide by 8 ft deep flume and was supported 18 inches above the flume floor on two mounting stands designed to minimize flow disturbance around the screen. The screen was attached to a pipe leading to the suction side of a recirculating pump and located beside a clear plexiglass window to allow clear viewing during screen operation. The initial test set-up was designed so that once the flume was filled to a depth of 5.0 ft, all flow drawn through the screen was recirculated back into the flume by re-injecting the flow about 50 ft upstream from the leading edge of the screen. Flow through the screen was controlled by adjusting control valves on the recirculating system. Flow was set and measured using a Controlotron transit-time acoustic flow meter.

In order to simulate an approximate reservoir withdrawal condition, flow entering back into the flume was directed away from the screen. In addition, a baffling plate was installed across the upstream channel, extending the full depth of the flume, to create reasonable quiescent flow conditions. However, since all flow was recirculated back into the flume upstream from the screen, a small sweeping component (approximately 0.34 ft/s for a test flow of 5.0ft^3/s) was introduced into the flume. The average approach and sweeping velocities measured for this test case are shown in figures 3 and 4.

In addition, because the test set-up produced a maximum flow below the screen's design flow, an 8 inch long portion of the surface area at the leading edge of the screen was blocked off, simulating a screen sized for the maximum flow of the test facility (28 inch screen). The average approach and sweeping velocities measured for this test configuration are shown in figures 5 and 6.

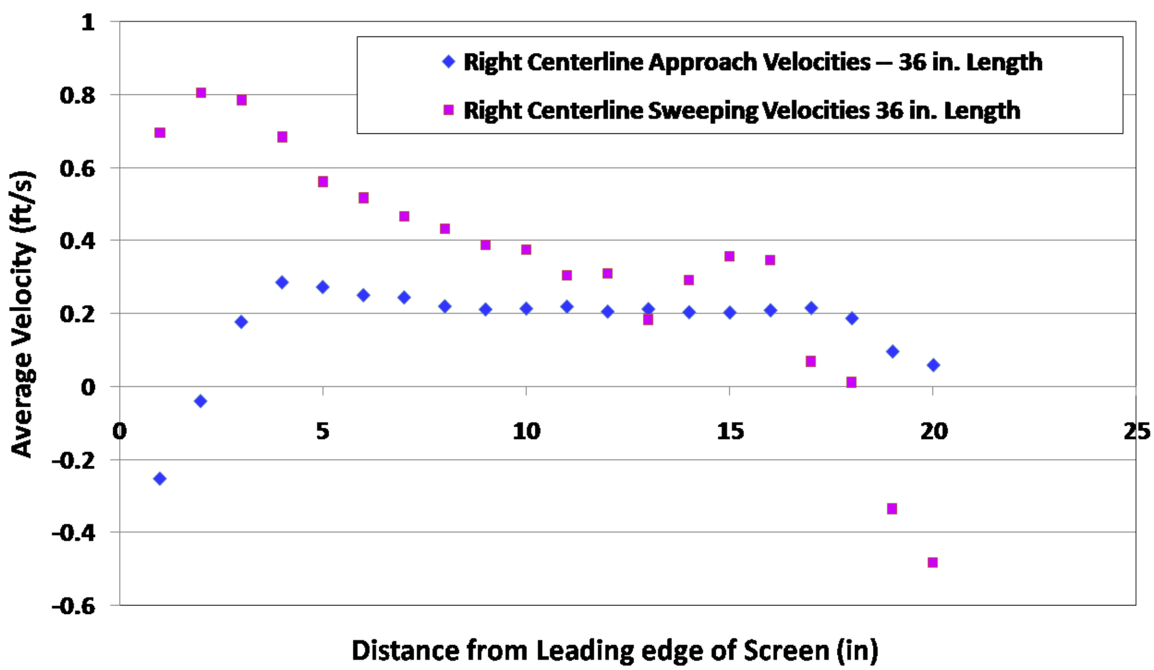

Figure 3. HA screen approach and sweeping velocities along right centerline.

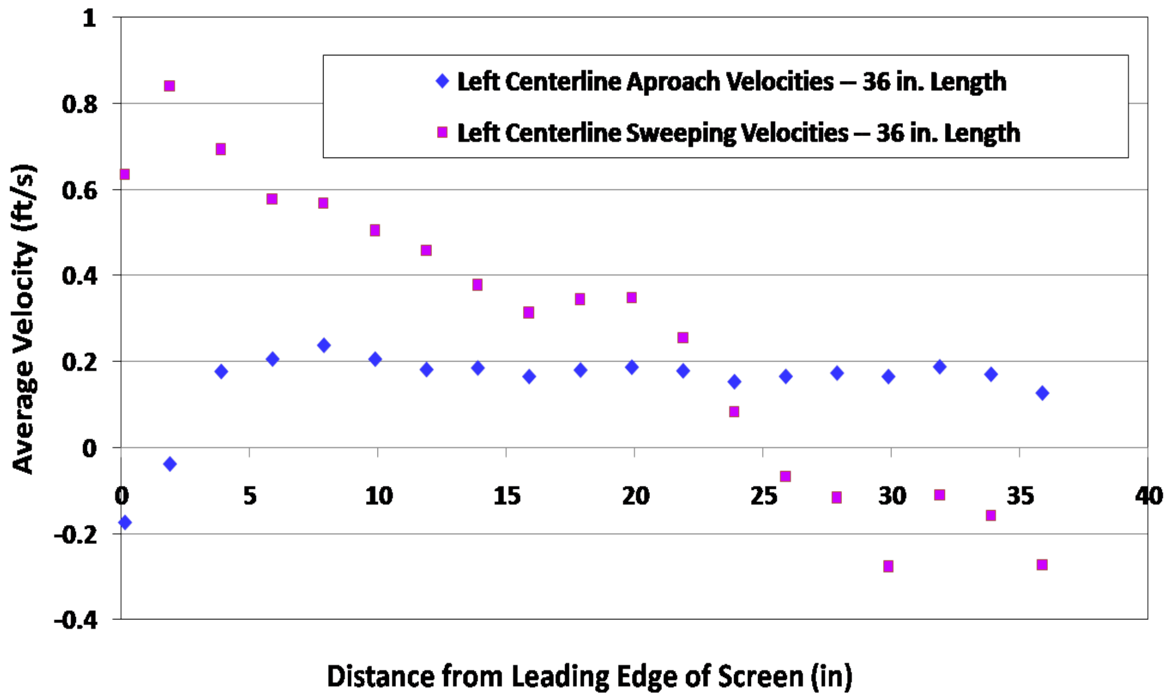

Figure 4. HA screen approach and sweeping velocities along left centerline.

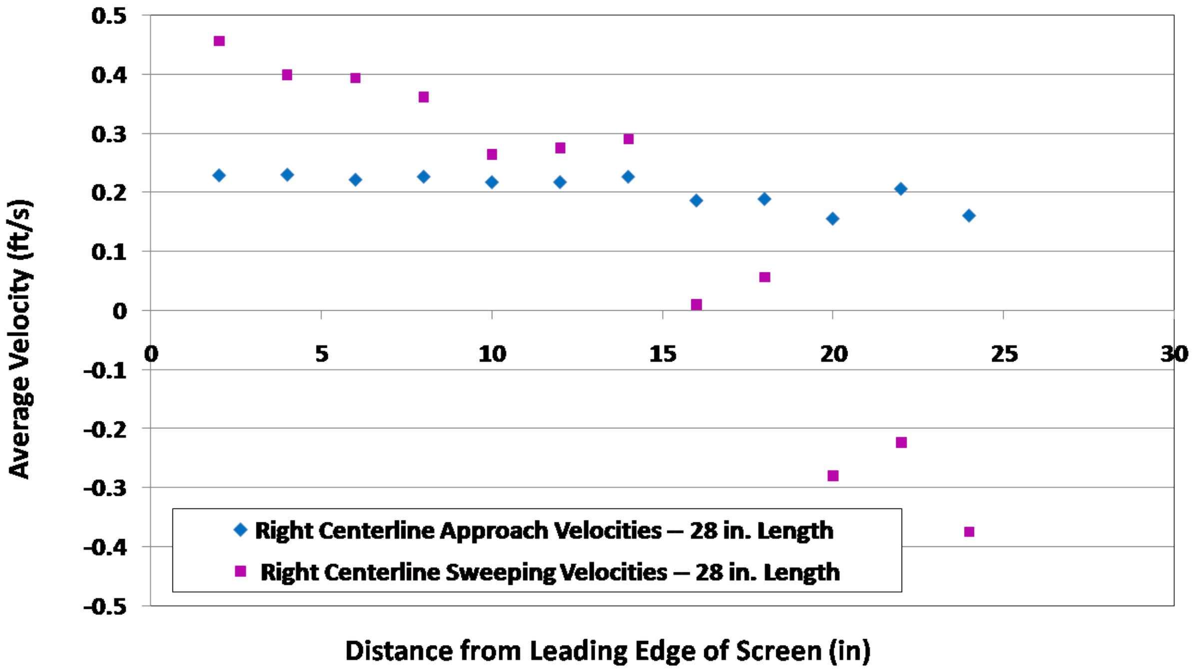

Figure 5. HA screen -- reduced surface area -- approach and sweeping velocities along right centerline.

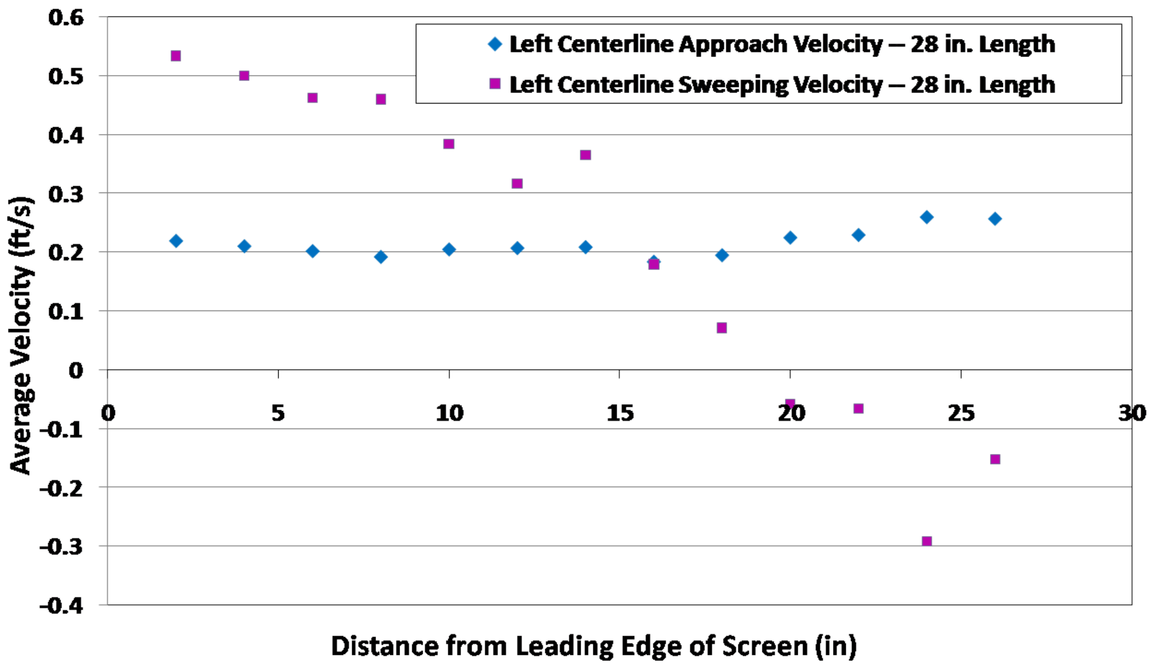

Figure 6. HA screen -- reduced surface area -- approach and sweeping velocities along left centerline.

Internal Propeller Screen Tests

The IP screen (figure 7) was tested separately and was installed, centered along the length of the 90 ft long by 8 ft deep by 4 ft wide flume. The test set-up had changed slightly from the previous set-up due to other testing being conducted in the flume. This time, flow entering the flume was split in half, with half deposited at each end of the flume behind baffling plates, to still the flow before entering into the main channel. This set-up produced an average flume velocity of 0.20 ft/s approaching from each end of the screen for a 5.0 ft^3/s flow condition. The maximum flow that could be achieved with this test configuration was 6.93 ft^3/s.

Figure 7. ISI propeller driven cylindrical screen.

The IP screen rotates at a speed proportional to the volume flow rate passing through it and can only rotate in one direction (counter clockwise). Screen rotation was timed and it was determined that it took about 8 minutes for the screen to complete one full revolution while at the maximum test flow of 6.93 ft^3/s. Approach and sweeping velocities were measured for this configuration the same as before, along the left and right centerlines of the screen, and are shown in figures 8 and 9.

Discussion of Velocity Data

The approach velocities measured for the full length (36 inch) HA screen show reasonable uniformity (figures 3 and 4). The larger percentage open area in the inside suction cylinder, near the leading edge of the screen, helps to compensate for higher energy losses and the small separation zone that occurs at that location. However velocities measured for the first 3 to 4 inches at leading edge of the screen were still significantly lower than those measured along the remaining length.

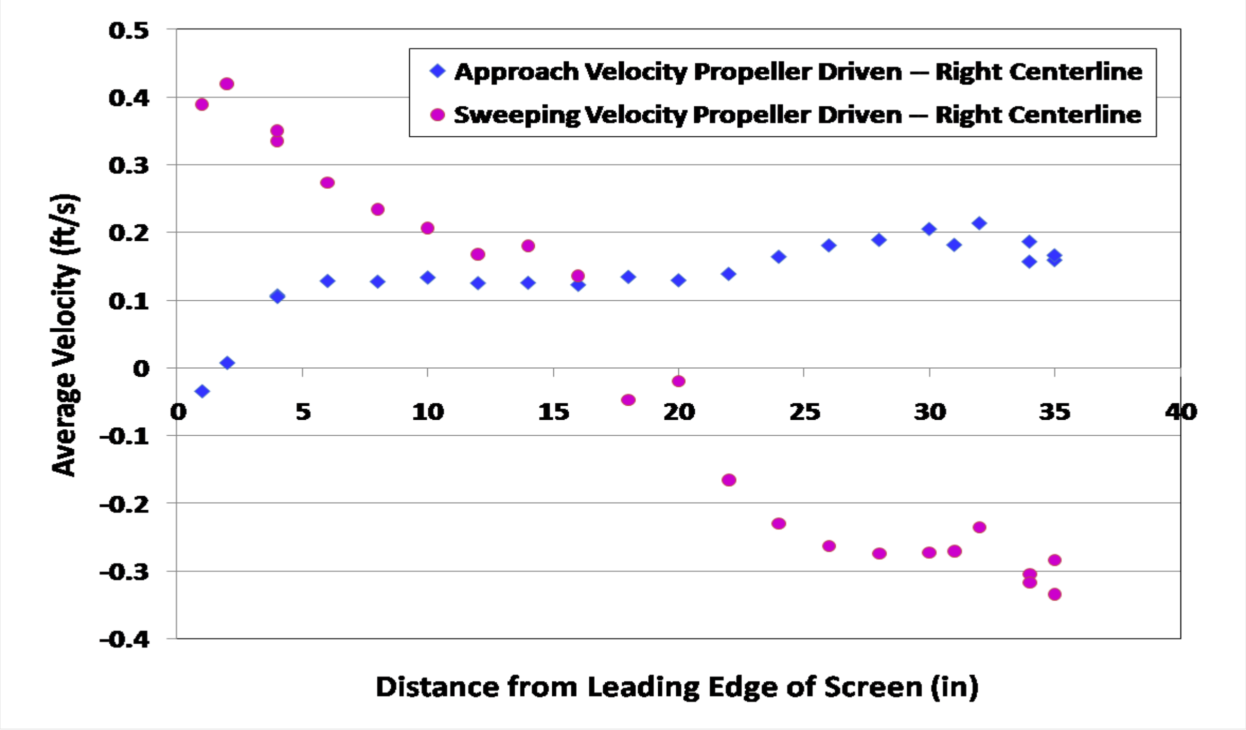

Figure 8. IP screen approach and sweeping velocities along right centerline.

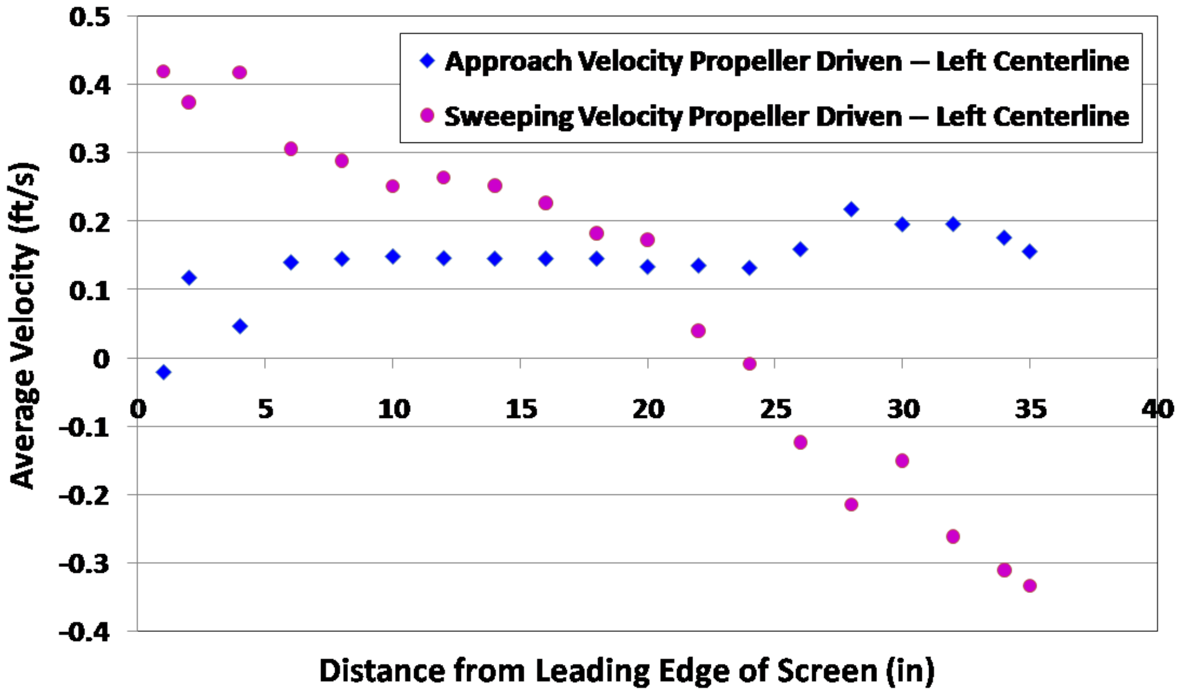

Figure 9. IP screen approach and sweeping velocities along left centerline.

When the first 8 inches of the screen were blocked off (28 inch screen) the uniformity of approach velocities along the length of the screen improved (figures 5 and 6). This is because the separation zone occurred over the blocked off area, therefore flow separation had little effect on the velocities measured along the length of the remaining open screen area.

The approach velocities measured along the length of the propeller driven screen again showed reasonable uniformity for this type of screen, with decreased magnitude near the leading edge of the screen due to higher energy losses and a small separation zone (figures 8 and 9). In addition there was a small increase in magnitude of approach velocities near the suction end of the IP screen. This may be due to differences in baffling with the propeller drive.

Headloss

To determine headloss through each screen, piezometer taps were installed at four equally spaced positions around the pipe circumference at a location about 1.5 ft downstream from the suction end of the cylindrical screen. One tube from a manometer board was extended to a manifold ring constructed out of plastic tubing and attached to each of the 4 taps. A second tube from the manometer board was attached to the flume to measure reservoir depth so that headloss could be calculated from the two measurements as follows:

$HL = (P1-P2) - V_h$

Where:

HL = total headloss (ft)

$P1$ = Manometer reading (ft) - flume reservoir

$P2$ = Manometer reading (ft) - pipe piezometer

V_h = velocity head (ft) at piezometer location, calculated ($V^2/2g$)

Head loss was determined by increasing the flow incrementally from zero to the maximum flow provided by the pump for each configuration. Manometer readings were taken at each incremental flow setting so that headloss could be calculated for various flow rates over the full operating range for each screen tested.

Figure 10 shows headloss as a function of flow rate for each screen and demonstrates that there is no significant difference in head loss between the two designs. When the curves were extrapolated, the calculated headloss at design flow (7.8 ft^3/s) is 0.75 ft and 0.73 ft for the HA and IP screens respectively

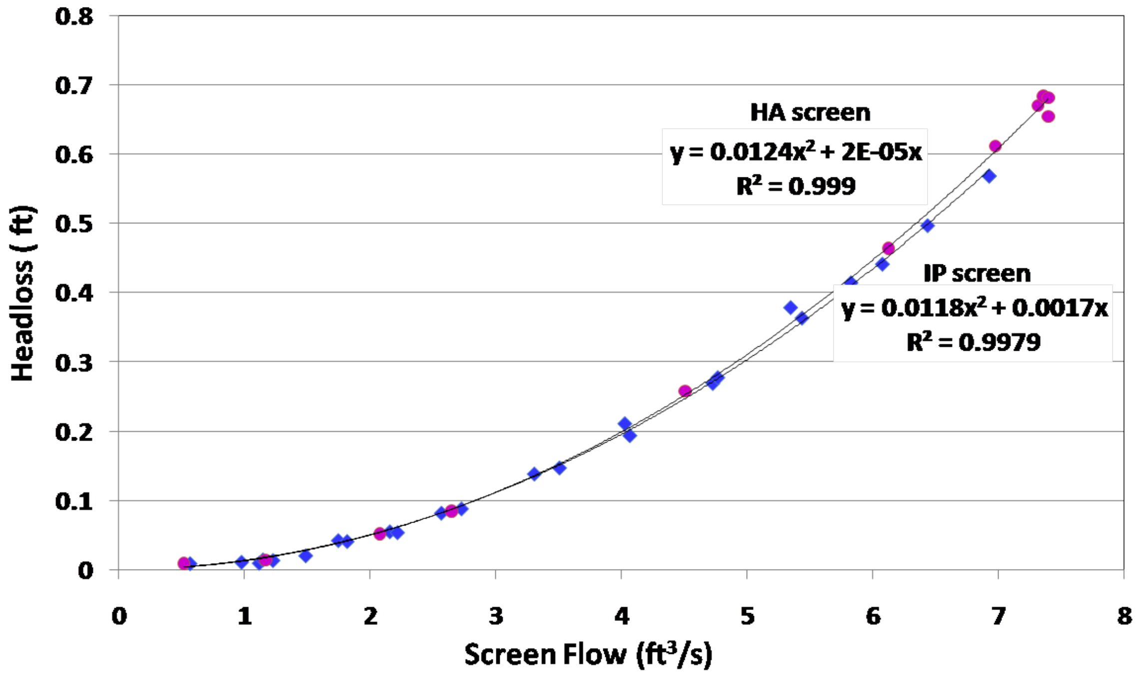

Figure 10. Headloss as a function of flow rate for the HA and IP screens.

IP Screen Torque Measurements

The torque associated with the rotation of the IP screen was of interest. A test apparatus was designed to determine the force required to resist screen rotation for various flow rates up to the maximum of 6.93 ft^3/s. To accomplish this, a 15.5 inch steel arm was attached horizontally to the bolts holding the screen's cylindrical suction pipe. Then a vertical arm extending above the flume was welded to the horizontal piece (figure 11). A flat horizontal plate was attached at the top of the vertical arm and was used to push against a scale mounted above the flume. The scale mounting prevented the screen from rotating while at the same time measured the load required to resist movement. A load reading was taken at each incremental increase in flow rate up to the maximum flow. Torque as a function of flow rate is shown in figure 12. Although the best fit line and equation reflects all the data, the figure clearly demonstrates that a flow of about 1.5 ft^3/s is needed to initiate movement of the screen and develop torque. The figure also shows that at maximum flow, the torque required to resist screen rotation is about 160 ft-lb.

Figure 11. Test apparatus for torque measurement.

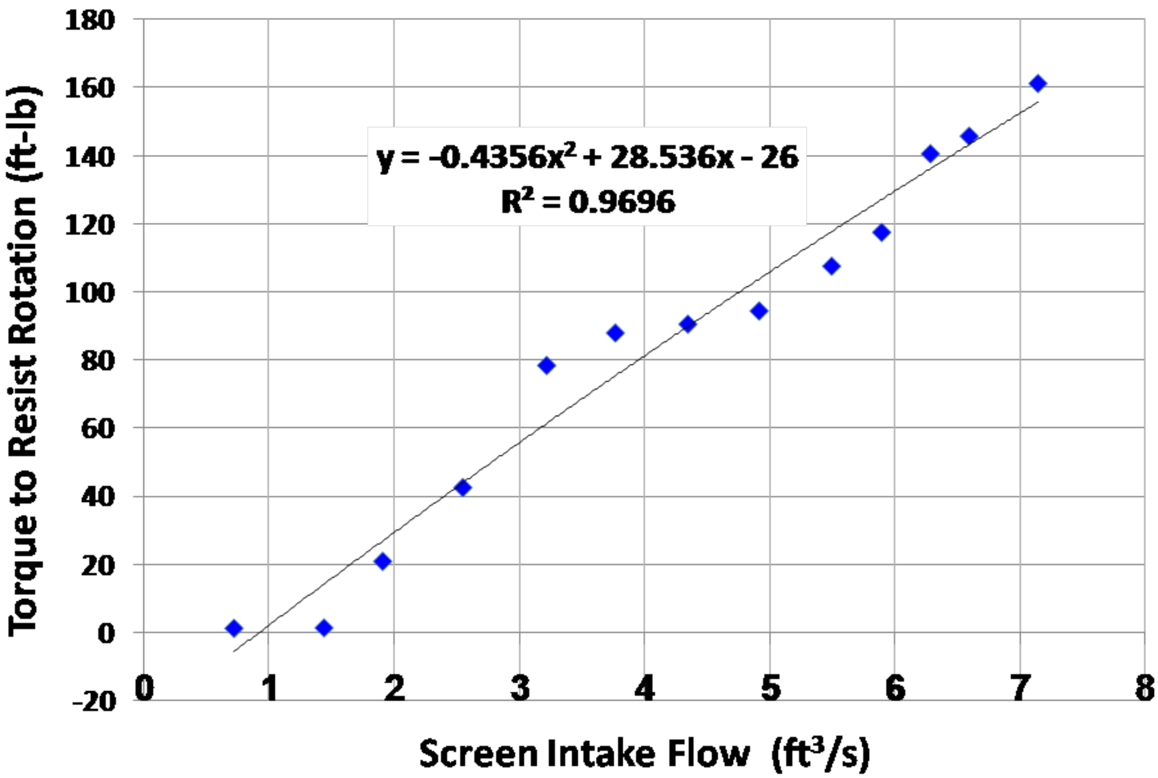

Figure 12. Torque as a function of flow rate for the IP screen.

Conclusions

The following conclusions were determined from the study:

- The velocity data indicates reasonably uniform approach velocities occur along the length of the HA and IP screens. The inner core baffle design did a good job of compensating for higher energy losses and flow separation, however approach velocities near the leading edge of the screen were still lower compared with the remaining length of the screen.

- Approach velocities measured near the suction end of the propeller driven screen were somewhat higher when compared with similar measurements on the HA screen.

- Comparing headloss data for the two screens shows that the difference in headloss for the two designs was insignificant.

The data provided here shows distribution of approach velocities and headloss for each screen tested. This data can be used to determine screen sizing and performance for a given flow rate as required to meet fish screening criteria mandated by resource agencies.