RECLAMATION

Managing Water in the West

Hydraulic Laboratory Technical Memorandum PAP-1056

Coanda-Effect Screen Tests for Kwoiek Creek Project

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Bureau of Reclamation
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Introduction

The Bureau of Reclamation performed research in 2000 (Wahl 2001) to develop methods for computing the hydraulic capacity of Coanda-effect screens used for removal of fine debris on agricultural diversions and small hydropower intakes like that shown in Figure 1. Coanda-effect screens remove debris from a supercritical flow that passes over a wedge wire screen panel constructed with wires oriented horizontally, perpendicular to the flow direction. The individual wires are tilted along their axes so that the leading edge of each wire projects into the flow, causing the screen to shear a thin layer of the flow from the bottom of the water column at each slot opening. The screens have been marketed for many years under the name Coanda-effect screen because the Coanda effect causes flow to remain attached to the top surface of each wire, thus enhancing the shearing action.

The Kwoiek Creek hydroelectric project in British Columbia will utilize a run-of-the-river intake equipped with a Coanda-effect screen for debris exclusion. For increased durability, the screen will be constructed with a heavier V-shaped wire than has typically been used on past Coanda-effect screen installations. On the back of the screen, the wire has a relief angle λ=10° (Figure 2), which is smaller than the typical 13° angle. Coanda Water Intakes Ltd. of Kamloops BC requested Reclamation to perform hydraulic testing of screens representative of those being considered for the Kwoiek Creek project, and comparison testing of screens with more typical wire geometry in order to determine whether screen capacity is affected by the smaller relief angle. This report describes the test facility that was constructed and gives results of the testing that was performed. Improved methods for predicting screen capacity are described.

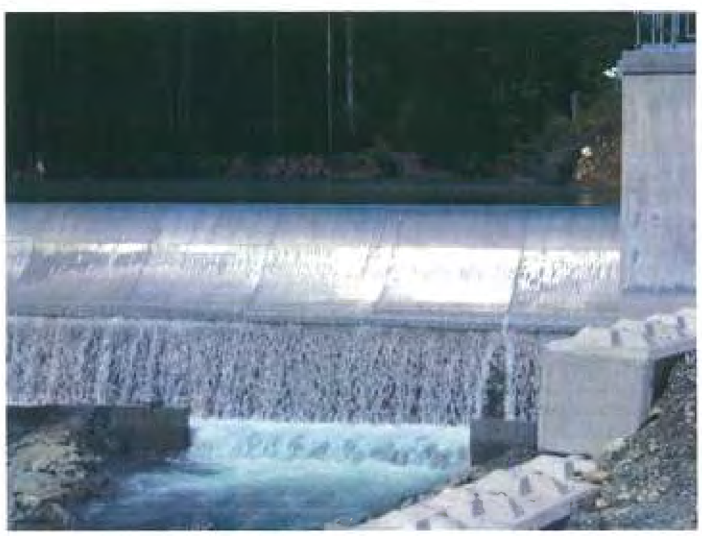

Figure 1. — Typical Coanda-effect screen intake for a small hydropower development.

Experimental Setup

A small-scale facility was constructed in the hydraulics laboratory to determine screen throughput under a range of hydraulic conditions. The facility does not produce velocities or depths comparable to the Kwoiek Creek project, but does create flows with similar Froude numbers. The Froude number is the most crucial parameter for simulating open channel flows and was a key parameter influencing Coanda-effect screen capacity in previous work (Wahl 2001). Figure 3 shows the test facility, which consists of a head tank, a 6-inch (0.15-m) wide adjustable-slope flume with three available screen test locations (top, middle, bottom), two V-notch weirs for measurement of screened flows, and a tailwater tank. Flow rates up to 0.26 ft^3/s (442 L/min) can be provided. All tests were carried out with the flume at a 15° slope, with the exception of one series of validation tests performed at a 30° slope. At the 15° slope, velocities at the screen test positions varied from 5.25 to 8.2 ft/s (1.6 to 2.5 m/s), and depths ranged up to about 0.94 in. (2.4 cm). Froude numbers at the top of the screens ranged from about 3.8 to 10. Froude numbers in this study were computed from $\mathsf{Fr} = V / \sqrt{gD\cos\theta}$ where Fr is the Froude number, V is the flow velocity, g is the acceleration due to gravity, D is the hydraulic depth, and θ is the slope of the screen panel.

Figure 4 and Figure 5 show close-up views of the screen test locations and the special flow collector box used to capture the flow that passes through the screen. The collector box is divided into upstream and downstream compartments so that the flow through the first half of the screen can be collected and measured separately from the flow through the second half of the screen. This allows proper development of the flow profile above the screen face before the flow reaches the test section (the downstream half of the screen). Because flow approaching the first half of the screen has not had an opportunity to align with the face of the tilted wires (it is initially aligned with the flume slope), the flow rate through the first few wire slots is lower than the flow through the downstream slots. This configuration allows the test section to accurately represent the performance of a slot located in the midst of an operating screen structure. An adjustable knife-edge divider attached to the bottom of the screen mounting plate (Figure 6) can be positioned exactly at a desired wire position so that the number of waste slots and test slots is known.

Tested Screens

Ten screens were supplied for potential testing by Coanda Water Intakes Ltd. The geometric properties of each screen were measured and are summarized in Table 2. Wire tilt angles were measured used the optical light reflection technique described in Wahl (2001). After initial measurements, screens were selected for testing with input from Coanda Water Intakes Ltd. For those screens selected for

Figure 5. — Flow divider box in operation.

Figure 6. — Test screen B-1 in mounting block and a view of the underside of the screen with divider plate installed. Flow is left to right in both photos.

The two A-series screens are representative of the screens being considered for the Kwoiek Creek project, with a 10° relief angle. These screens were manufactured with wire having an estimated (specified) edge radius of 0.005 in. For comparison testing, the B-series screens utilize a 13 degree relief angle. These screens were manufactured with sharp-edged wires (no specified edge radius).

Table 2. — Screen properties. Shaded columns indicate screens selected for hydraulic testing.

Screen	scratched surface A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	sharp wires B-1	sharp wires B-2
Type	3/16-10	3/16-10	3/16-10	3/16-10	3/16-10	3/16-10	3/16-10	3/16-10	3/16-13	3/16-13
Relief angle, λ (designated, not measured)	10	10	10	10	10	10	10	10	13	13
Width, inches	3.875	3	3	3	3	3	3	3	3.5	3.5
Length, inches	3.875	3.125	3.125	3.125	3.125	3.125	3.125	3.125	3.5	3.5
Support bar spacing, inches	3.3125	2.125	2.125	2.125	2.125	2.125	2.125	2.125	2	2.0625
Support bars	3/8" round	3/8" round	3/8" round	3/8" round	3/8" round	3/8" round	3/8" round	3/8" round	1/4" rectangle	1/4" rectangle
TILT ANGLE, degrees	3.25	6.5	6.5	6.25	5.6	7.5	6.25	6.9	4.3	6.5
Avg. slot width, s (mm)	1.99	2.01	2.01	2.01	1.99	1.93	2.01	1.96	2.05	2.05
Avg. wire thickness, w (mm)	4.76	4.71	4.71	4.71	4.72	4.71	4.75	4.74	4.60	4.62

respectively, the ratios of the inertial and gravitational forces, viscous and inertial forces, and surface tension and inertial forces.

Since design of the Kwoiek Creek screen structure was being performed with the Coanda screen software (Wahl 2003) that uses this equation, the data from these tests were used to compute values of C_{cv} for each test and compare them to values predicted by the equation based on Fr, Re, and We. This normalizes the test results, accounting for differences in screen geometry such as different slot widths and different wire tilt angles, and also demonstrates how accurately the relation by Wahl (2001) predicts performance of these screens. Figure 7 shows the results graphically.

Careful examination of Figure 7 reveals that in general the B-series screens accept more flow than the A-series screens (higher observed values of C_{cv}). This could be due to the different wire relief angles, but is more likely a result of the sharpness of the B-series wires. An interesting aspect of the results is the fact that performance of any one screen at the three different test positions shows wide variability, with higher values of C_{cv} occurring at the lower test positions. For the A-series screens there is good agreement at the middle and bottom positions, but observed values of C_{cv} at the top test position are much lower than those predicted by the equation from Wahl (2001). For the B-series screens the observed values of C_{cv} at the lower test positions are higher than expected. The discharge prediction model developed in Wahl (2001) should fully account for variations of depth, velocity and Froude number at the different test positions, but the model is clearly failing to account for a systematic change in the screen performance as a function of a flow parameter associated with the test location.

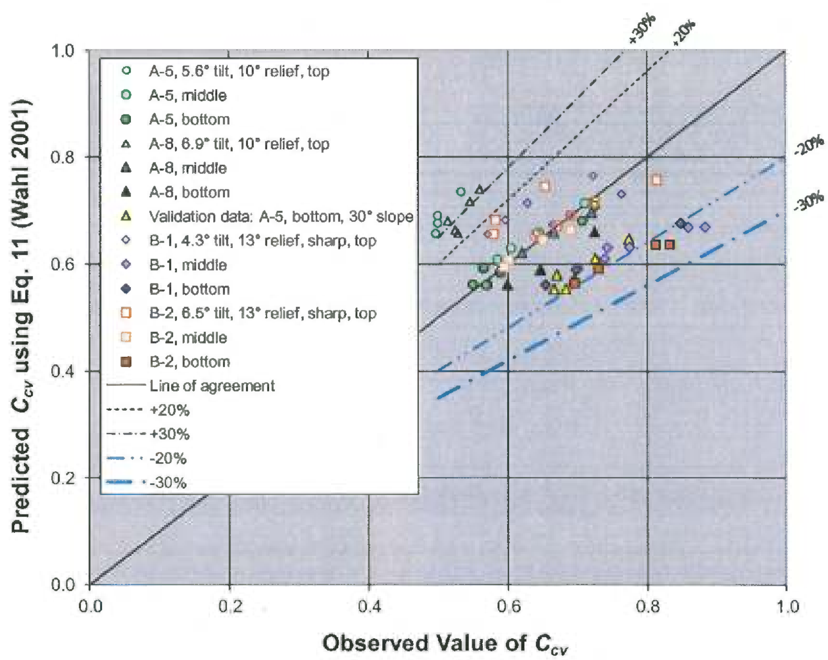

Figure 7. — Screen test results showing observed and predicted C_{cv} values for the A- and B-series screens tested at the three different flume locations.

are approximately ±8% for the A-series screens, ±10% for the B-series screens, and ±12% for the equation developed using the entire data set. Note that the validation data collected at a 30° slope fits well to the A-series line developed using only the data from the tests at 15° slope. Table 3 includes equation parameters for the A-series screens developed using only the data for 15° slope, and including the validation data collected at 30° slope. Inclusion of the 30° data causes only a small change in the curve fit parameters.

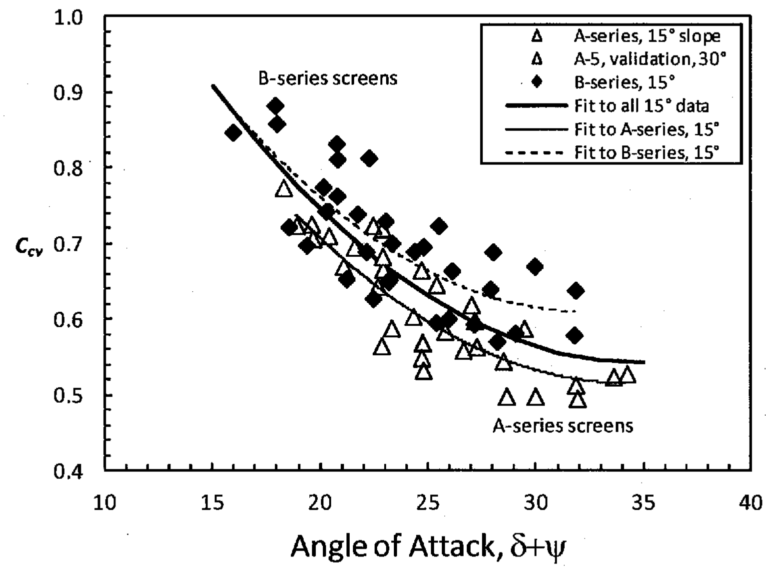

Figure 9. — Relation between C_{cv} and flow attack angle for A- and B-series screens. Best-fit polynomial lines for the A-series, B-series, and full data sets are shown. Curve fit parameters are given in Table 3. Curve fits shown here were developed without use of the validation data set.

Table 3. — Parameters of best-fit lines for predicting C_{cv}. Shaded rows are the parameters for the curves shown in Figure 9. The lowest Froude numbers were obtained from tests at the maximum flow capacity of the test facility. The highest Froude numbers were obtained at low flow rates that barely maintained a wetted condition on the last slot of the test screens.

Parameters of $C_{cv}=m_2(\delta+\psi)^2+m_1(\delta+\psi)+b$				Range of supporting data		
Screens	m_2	m_1	b	δ+ψ	Fr	V, m/s
A-5 and A-8	0.000933	-0.06410	1.615	19° – 34°	12.8 – 4.0	1.6-2.54
B-1 and B-2	0.000990	-0.06413	1.648	16° – 32°	12.3 – 4.1	1.56-2.55
A-5, A-8, B-1 and B-2	0.000945	-0.06553	1.678	16° – 34°	12.8 – 4.0	1.56-2.55
Validation data set, A-5 on 30° slope, bottom position				18° – 23°	14.2 – 7.8	2.34-2.69
A-5 and A-8, including validation data	0.000965	-0.06645	1.657	18° – 34°	14.2 – 4.0	1.6-2.69
All data from A- and B-series screens (including validation data)	0.000906	-0.06314	1.642	16° – 34°	14.2 – 4.0	1.56-2.69

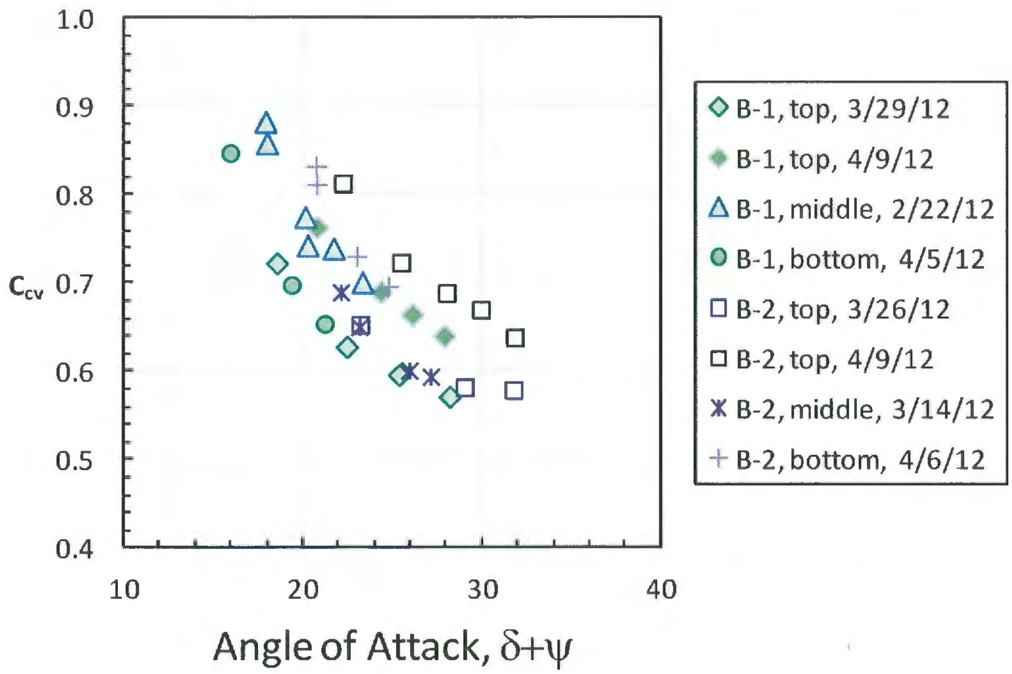

Figure 11. — Test results for screens B-1 and B-2 for different test locations. Legend indicates date on which each test was performed.

Discussion

The C_{cv} values determined from the hydraulic tests were compared to those predicted by the relation developed in Wahl (2001) and the new relations shown in Table 3 (Figure 12). The relations used from Table 3 were those in the second and fifth rows, which were specific to the A-series and B-series screens, utilizing all collected data (including the A-5 validation data at 30° slope).

Figure 12 shows that the new relations more effectively predict the values obtained from the testing. The previous equation (Wahl 2001) was

$$C_{cv} = 0.21 + 0.0109(\mathrm{Re}/\,\mathrm{We}) + 0.00803(\mathrm{Fr})$$

in which C_{cv} was a function of the Froude number, Fr, Reynolds number, Re (ratio of viscous and inertial forces), and Weber number, We (ratio of surface tension and inertial forces). This equation is significantly in error for some flow conditions. The standard deviations of the relative errors for the two methods are 16.5% for Wahl (2001) and 7.0% for the new relations. A careful analysis of the old and new equations shows that the source of the errors is the dependence on the Reynolds and Weber numbers. The testing by Wahl (2001) covered a different and smaller range of these parameters than the current tests (Re=950 to

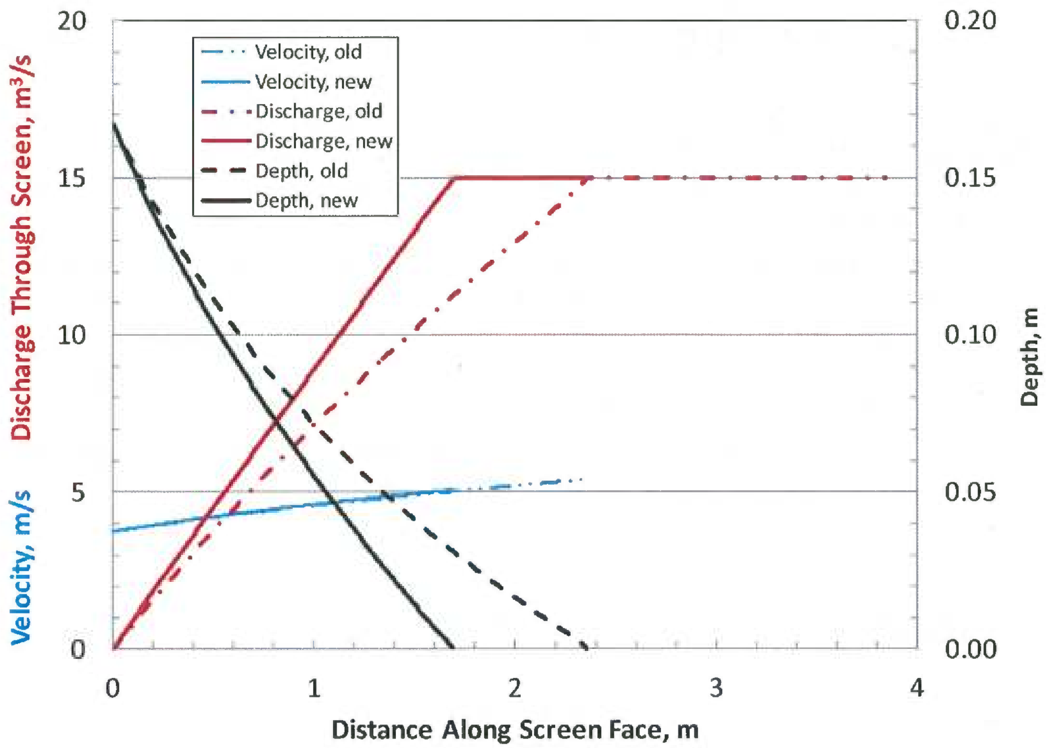

Figure 13. — Comparison of flow profiles for the proposed Kwoiek Creek screen structure at 15 m^3/s inflow, using the Coanda screen software with old (Wahl 2001) and new equations for computing C_{cv}.

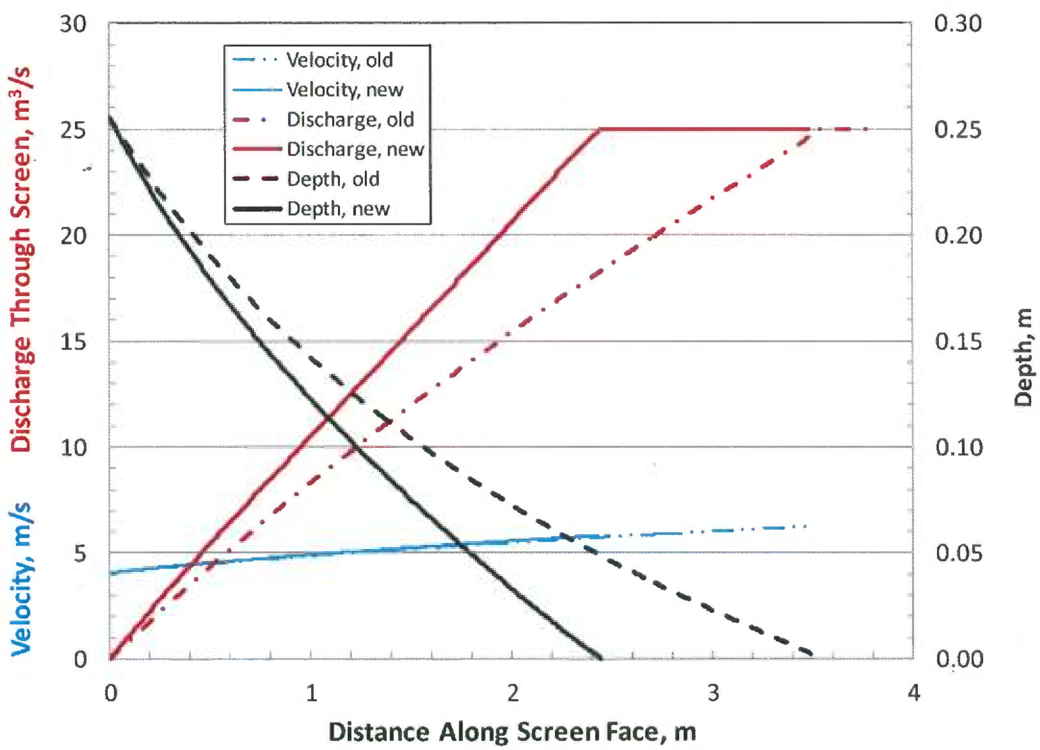

Figure 14. — Comparison of flow profiles for the proposed Kwoiek Creek screen structure at 25 m^3/s inflow.