PAP 881

Idaho Fish and Game Cylindrical Screen Test

by

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Background

In the last decade, increasing concern for fisheries has created interest in excluding fish from water diversions with minimal impact to fish. In order to accomplish this objective, an improved understanding of fish screen hydraulics and fishery response to various conditions is needed. Resource agencies have adopted standards that require that screens meet a maximum approach velocity criteria in the range of 0.2 ft/s to 0.4 ft/s depending on the specific site under consideration. As a result, the Water Resources Research Laboratory (WRRL) at the U.S. Bureau of Reclamation (Reclamation) in Denver is currently involved in studying the performance of cylindrical fish screens for shedding debris and to provide an effective positive barrier for fish exclusion. In conjunction with this program, WRRL was contracted by Idaho Fish and Game to test a cylindrical screen with three different diffuser configurations, as described herein.

The Model

The three screens were tested in the WRRL facility designed to test fish screens. The facility consists of a 5.5-ft-wide by 5-ft-deep recirculating flume (figure 1). The screen was installed on a 2-in. diameter pipe leading to the suction side of a recirculating pump, and located beside a clear plexiglass window to allow viewing and underwater videotaping of screen operation. Flow velocity in the flume was generated by a separate recirculating pump. The three screen configurations were tested to determine how well each design would perform in providing a uniform flow distribution through all areas of the screen for two different flume flow conditions. Each screen was installed within its provided frame (figure 2) and with the cylindrical axis oriented parallel to the flume flow. A foot valve connected the screen with the intake pipe to prevent reverse flow through the screen. Flows in the flume and through the screen were controlled by adjusting separate control valves.

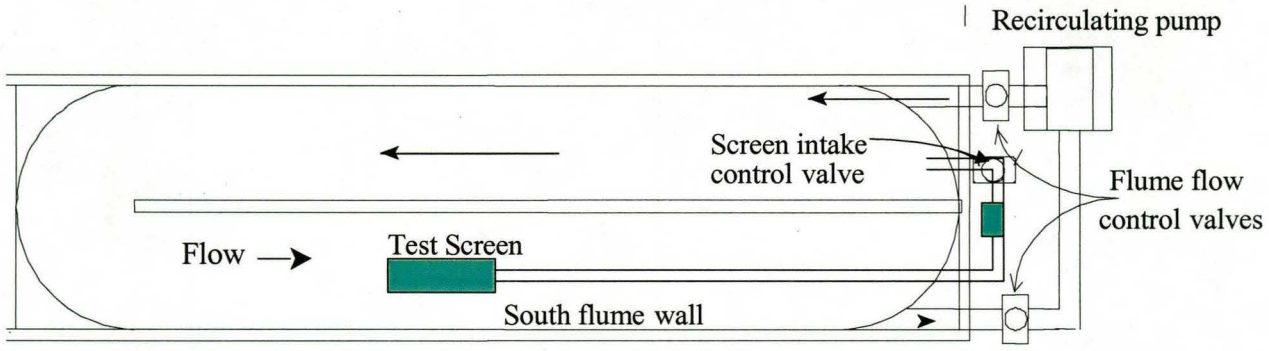


Figure 1. Test flume and screen set-up.

Test Set-up and Investigations

Each screen consisted of a 6-5/8 inch diameter outer cylinder made of stainless steel perforated plate with 3/32-in. diameter openings and 40% open area. The three screens tested were identical with the exception of the core diffuser design. The three screen configurations tested were:

a) Screen with no diffuser.
b) Screen with uniform hole diffuser - This screen contained a 2-in. diameter internal diffuser with 5/16-in. diameter holes.
c) Screen with variable hole diffuser - This screen contained a 2-in. diameter internal diffuser with holes ranging from 3/16-in. to 7/16-in. in diameter.

Each screen was tested with three different screen intake flow rates:

a) 30 G.P.M.
b) 60 G.P.M.
c) 85 G.P.M.

For each intake flow condition the screens were tested with a high and low sweeping velocity condition of 2.0 ft/s and 0.5 ft/s. Screen approach velocities were measured with an acoustic Doppler velocimeter at 2-inch increments (positions 1 through 7; figure 3) along the length of the screen at the top and at the centerline elevation of the screen on the north and south sides. Velocities were measured at a 3-in. distance from the face of the screen for each operating condition, since this is standard for meeting resource agency velocity criteria for fish. In addition, velocities were measured 0.5 inch from the screen face to give a more accurate representation of the near screen flow field and to determine the flow field effect for each diffuser configuration.

A piezometer ring was installed on the 2-in. intake pipe approximately 2 ft downstream from where the foot valve was located. The piezometer ring was attached to a mercury manometer that was used to measure head loss through the screen for each test condition.

In addition, tests with debris were conducted at the maximum operating condition to evaluate debris control.

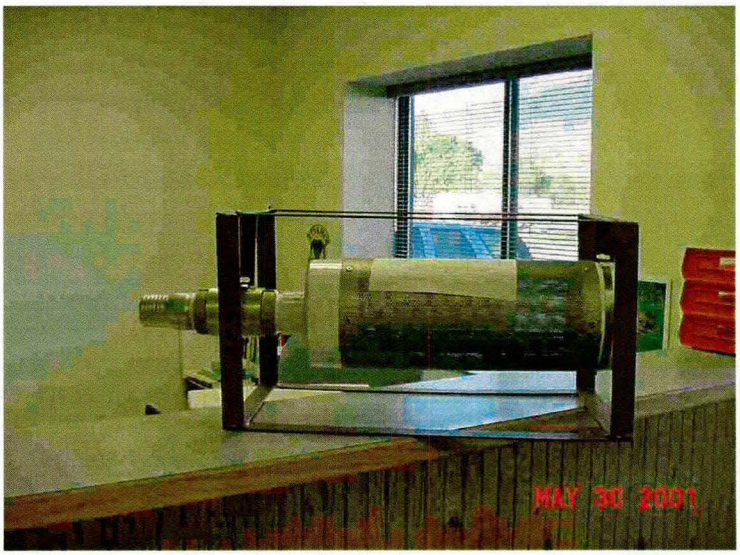


Figure 2. Screen and frame mount.

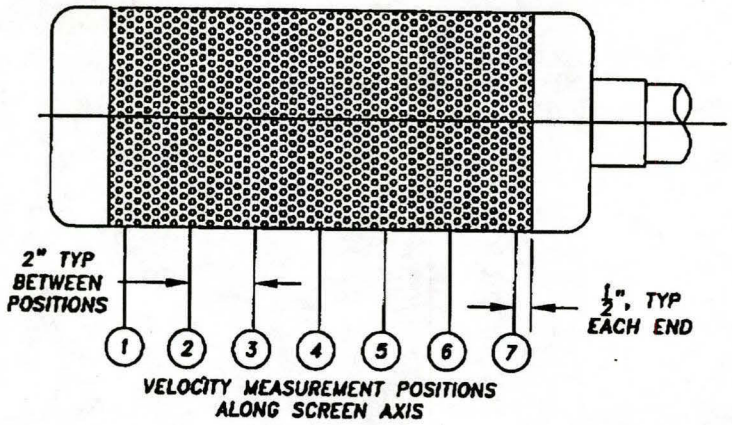


Figure 3. Velocity measurement positions 1 through 7 for each screen.

Results and Conclusions

Velocity Measurements

Screen approach velocities were measured and plotted with sweeping flows of 2.0 ft/s and 0.5 ft/s for the three screen configurations (figures 4 - 7, no diffuser; figures 8-11, uniform hole diffuser, and figures 12-15, variable hole diffuser). For all test cases, positive approach velocities indicate flow is going into the screen, while positive sweeping velocities indicate flow is in the downstream direction. Dye tests were also used to visually verify the results from these tests.

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 three centerlines (0.5 in. and 3.0 in. from the screen face) can not neccesarily be extrapolated to represent total through-screen flow and to satisfy continuity. In addition, there may be some flow recirculation that occurs within the outside tube and outward through the screen surface. However, although assessing the total through-screen flow is important information for the manufacturer and designer of the screen, it does not affect the screens ability to meet required screen criteria. Current National Marine Fisheries Service criteria is based on approach velocities measured at a 3-in. distance from the screen face.

The following conclusions were made from the study:

- All three screen configurations meet NMFS 0.2 ft/s approach velocity criteria for positive barrier screens for fish exclusion.

- The figures demonstrate, in general, that approach velocities measured in screen positions 1 and 2 are lower, due to separation that occurs near the leading edge of the screen. The separation zone occurs because flow approaching the screen is being forced radially outward by the bluff screen face and the resulting eddy moves flow from inside the screen outward. The leading edge separation zone causes the effective screen area to be reduced, resulting in increased approach velocities downstream from this zone.

- Higher flume sweeping velocities create a larger separation zone; therefore more uniform approach velocities occur for all three configurations when the sweeping velocity is low.

- Comparison of velocities for the different diffuser designs, shows baffling provided by the diffussers yields some improvement in approach velocity uniformity for the higher sweeping flows, especially with the VH diffuser design. However, this improvement is not as significant on the top centerline and may be because eddies formed on the sides of the screen are more suppressed due to their close proximity to the walls of the flume. In addition, a vertical piece of the framing structure is positioned in line and immediately upstream from the top centerline of the screen and may have some effect on the velocities measured near the leading edge of the screen.

- Although approach velocities continue to be low in positions 1 and 2 for the UH and VH diffuser screens, there is a noticeable shift in increasing magnitude of approach velocities measured near the screen's leading edge. This indicates that the effective length of screen has increased due to the diffusers. However, it may be impossible to provide a diffuser design that can completely overcome the effects of the large separation zone created by high sweeping flows.

- Because the screen is oversized for this application, approach velocities are very small and therefore the effects of adding a diffuser are less significant. In addition, since the screen surface area is large with respect to the design flow, the screen meets NMFS most stringent criteria even without a diffuser.

Debris Tests

Although the scope of these tests did not include a detailed study of this parameter, investigations were conducted to test screen performance for shedding debris. Observations and videotape were used to assess screen performance while operating at maximum capacity (83.5 g.p.m.) and with flume sweeping velocities set to 0.5 ft/s and 2 ft/s. Various debris including aquatic weeds and grasses were deposited into the flume.

The following are general observations that were made during the debris tests:

Screen with no diffuser

0.5 ft/s flume velocity - Small amounts of debris attached to the downstream half of the screen where approach velocities were highest.

2 ft/s flume velocity - Most debris swept past the screen, although a small amount of debris did collect on the screen surface.

Screen with uniform hole diffuser

0.5 ft/s flume velocity - Some small debris collected along the downstream 2/3rds of the screen.

2 ft/s flume velocity - Most debris swept past the screen. Very little debris collected on the screen

surface.

Screen with variable hole diffuser
0.5 ft/s flume velocity - Some small debris collected along the full length of the screen, indicating a more uniform velocity distribution along the length of the screen.

2 ft/s flume velocity - Most debris was swept past the screen. Very little debris collected on the screen surface.

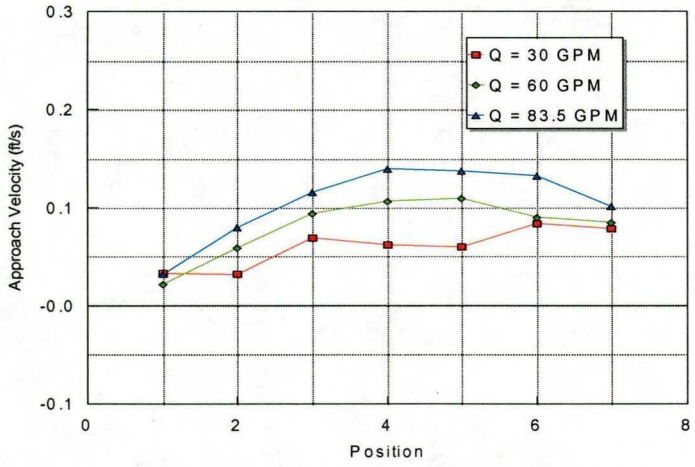
Head loss

A piezometer ring was installed on the screen discharge pipe approximately 2 ft downstream from the foot valve, to determine head loss for each configuration. (Table 1). In addition, head loss was measured without the screen attached to determine headloss through the foot valve only. Head loss as a function of discharge is also plotted in figure 16.

The table indicates that the majority of the head loss measured through each screen for each test condition is due to the presence of the foot valve attached to the screen.

Table 1. Screen/Valve head loss as a function of screen discharge.

Screen Discharge (gal/min)	Headloss (ft)			
	No Diffuser	Uniform Hole Diffuser	Variable Hole Diffuser	Valve Only
30	2.0	2.2	2.2	1.8
60	4.6	5.5	5.5	4.4
83.5	8.2	9.6	9.7	8.0



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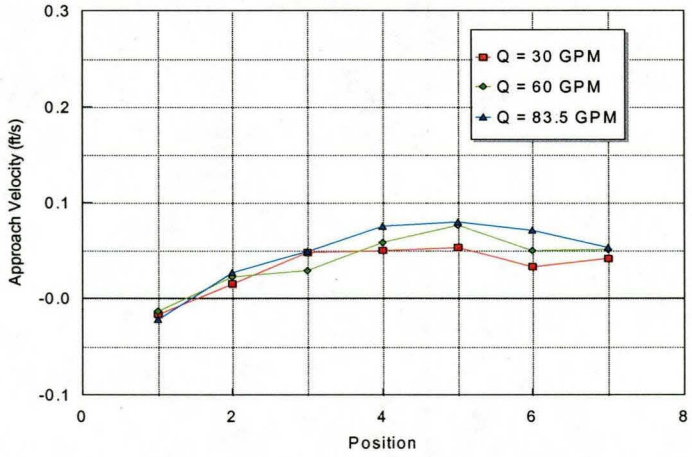

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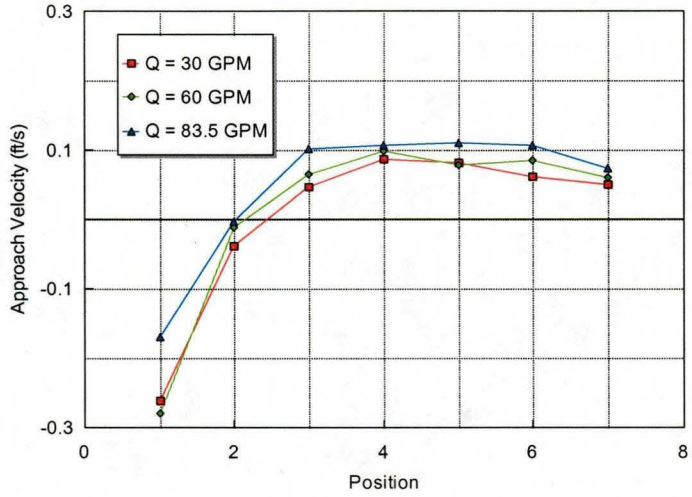
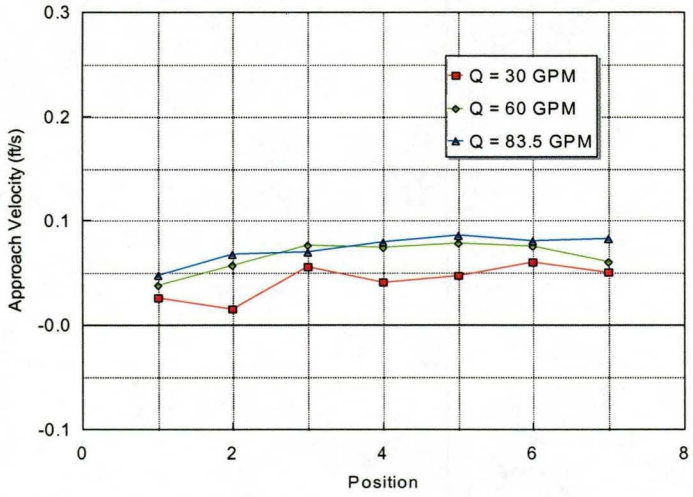


c)

Figure 4. **Screen with no diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 3-in. from the screen surface with a sweeping velocity of 2 ft/s .**



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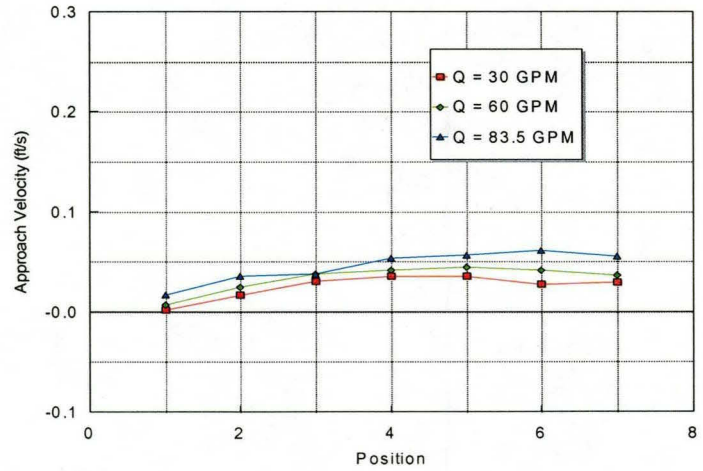

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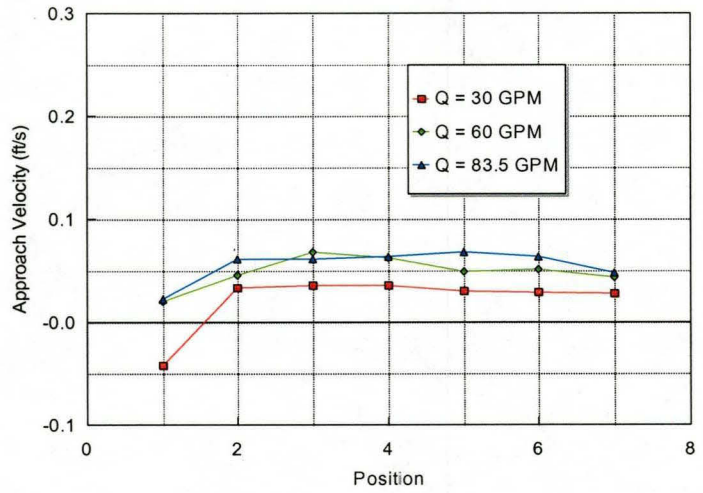
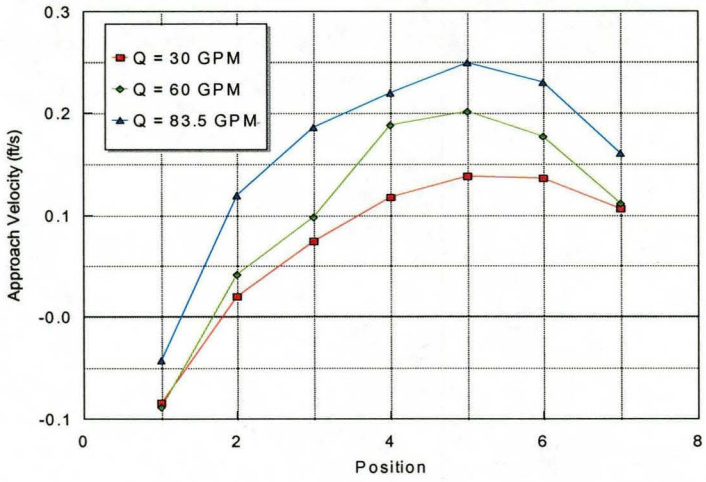


c)

Figure 5. **Screen with no diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 3-in. from the screen surface with a sweeping velocity of 0.5 ft/s.**



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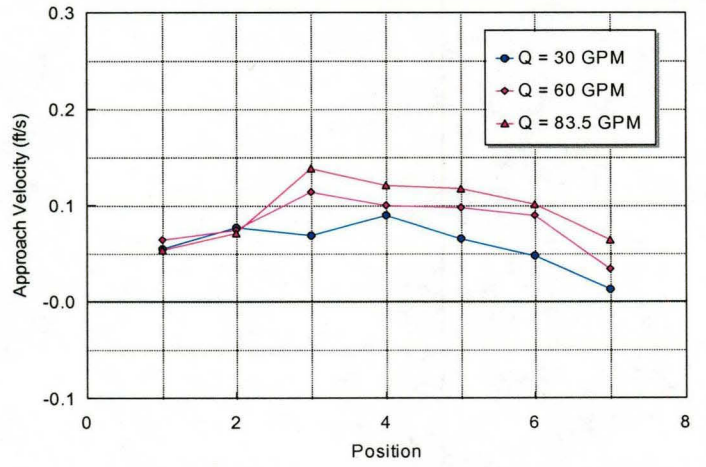

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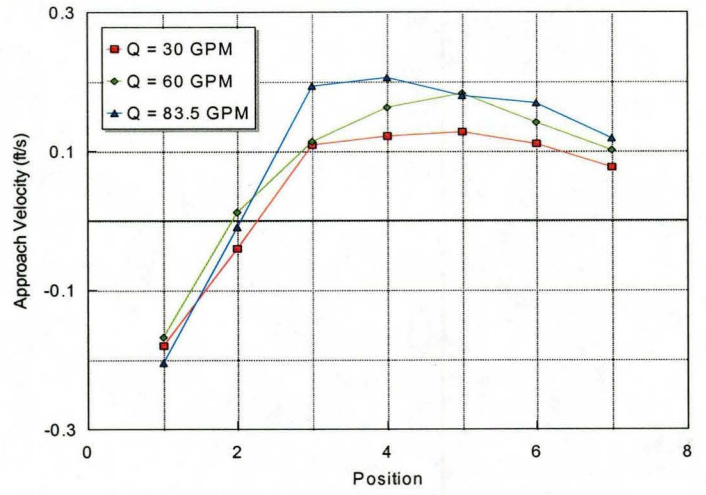
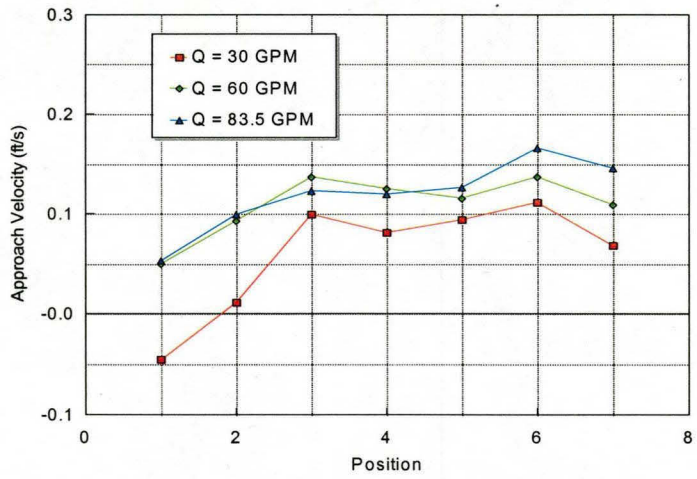


c)

Figure 6. Screen with no diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 0.5 in. from the screen surface with a sweeping velocity of 2.0 ft/s.



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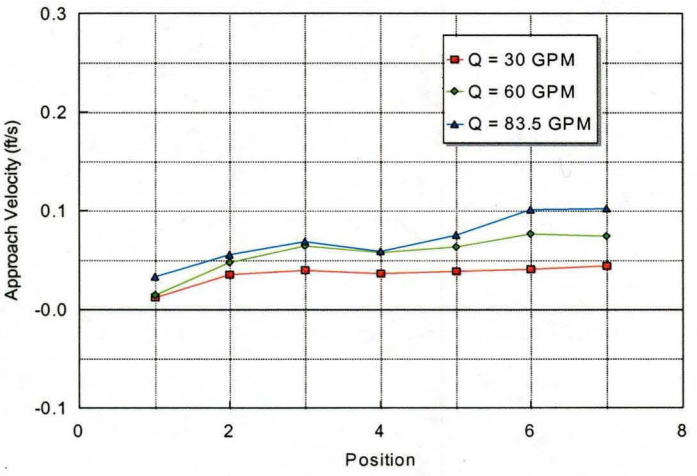

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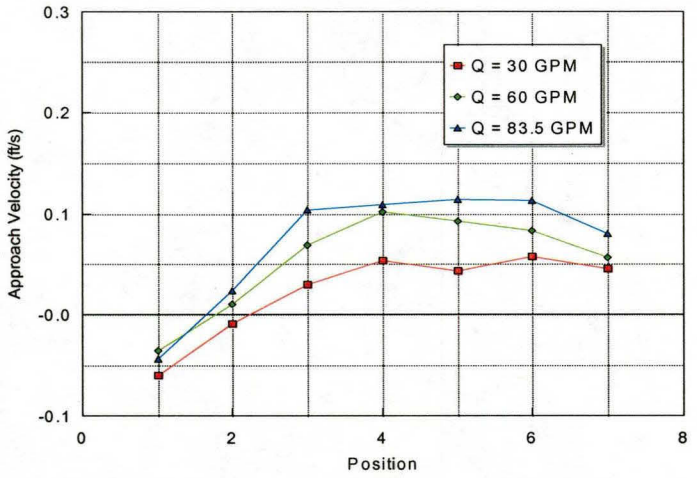
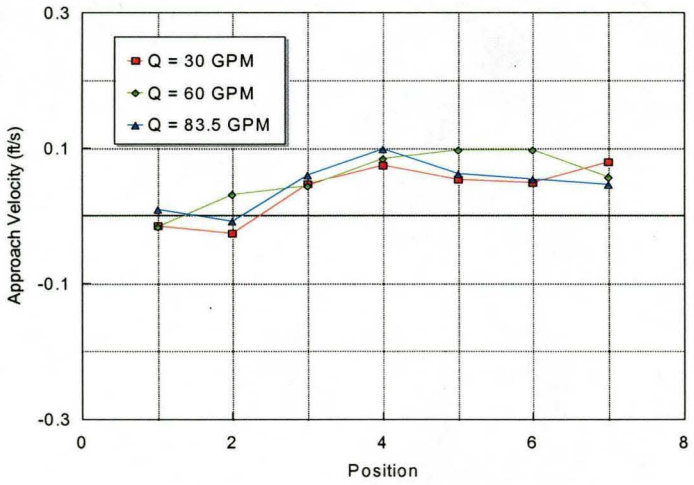


c)

Figure 7. Screen with no diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 0.5-in. from the screen surface with a sweeping velocity of 0.5 ft/s.



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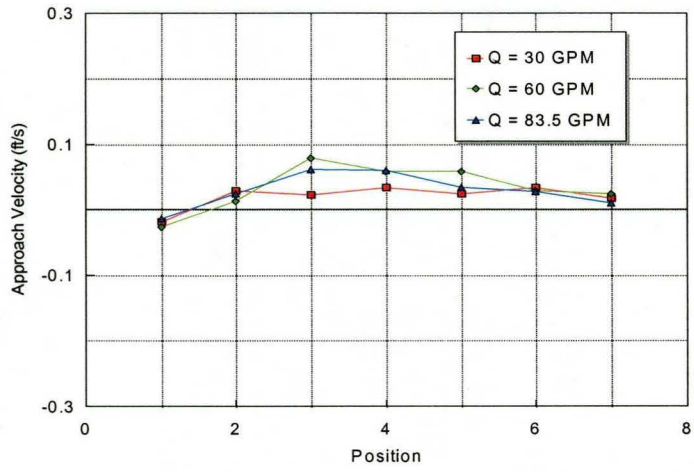

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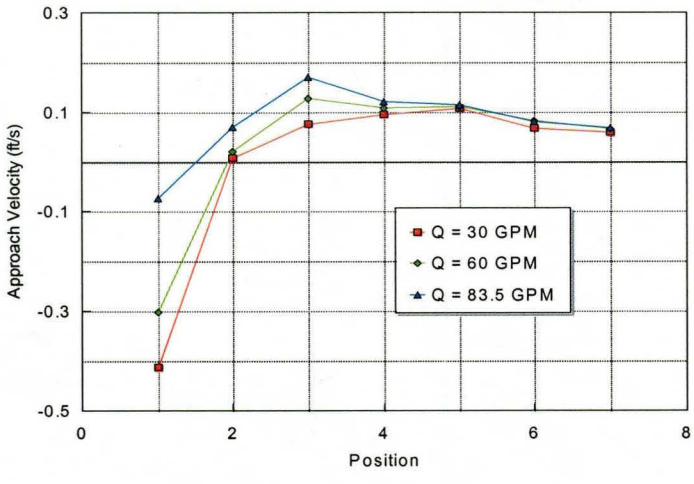
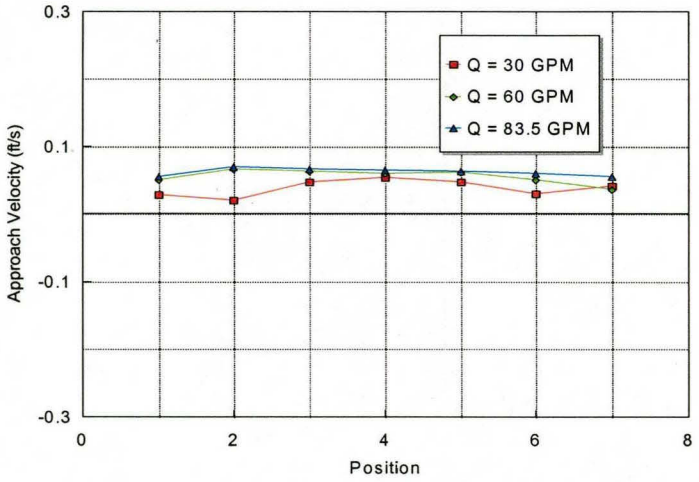
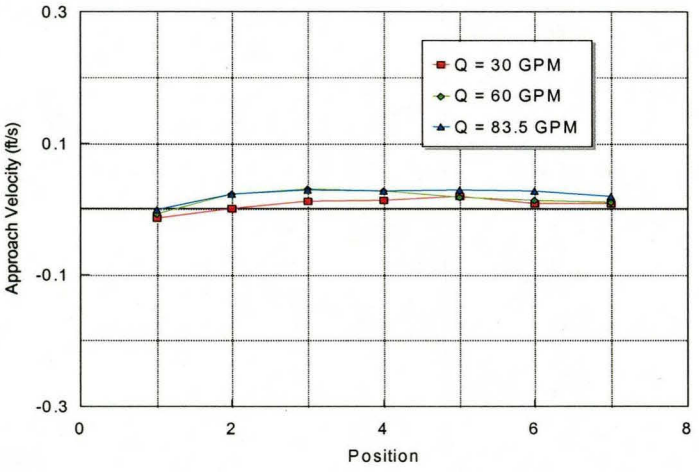


c)

Figure 8. **Screen with uniform hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 3-in. from the screen surface with a sweeping velocity of 2 ft/s.**



a)



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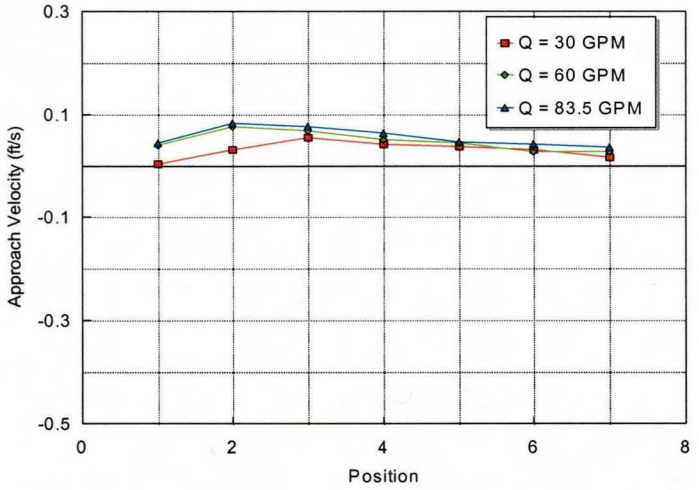
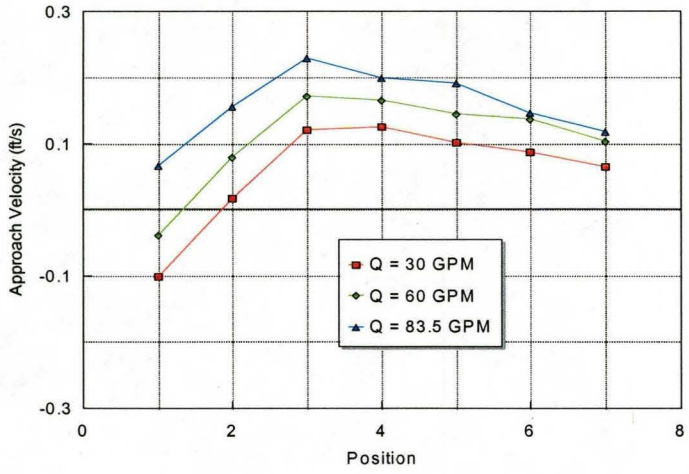


c)

Figure 9. Screen with uniform hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 3-in. from the screen surface with a sweeping velocity of 0.5 ft/s sweeping velocity



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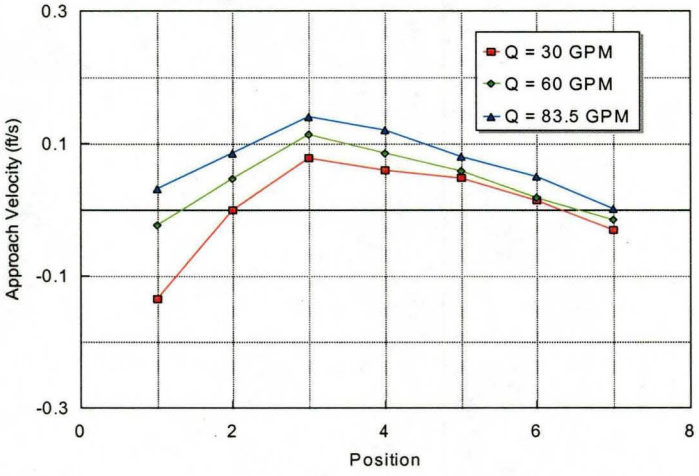

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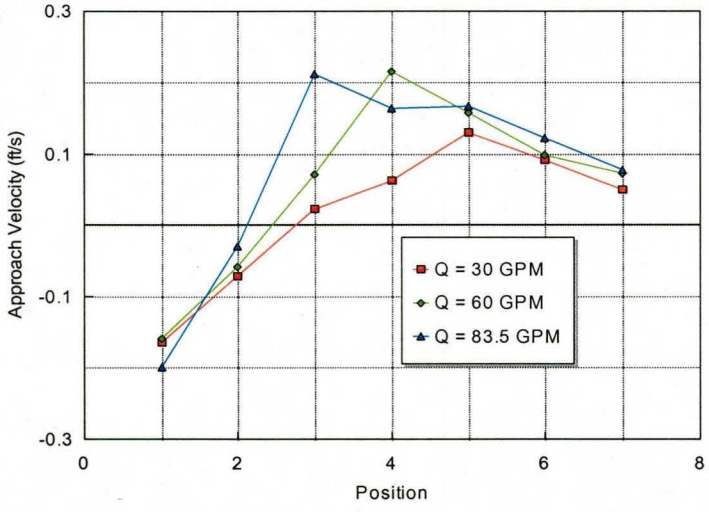
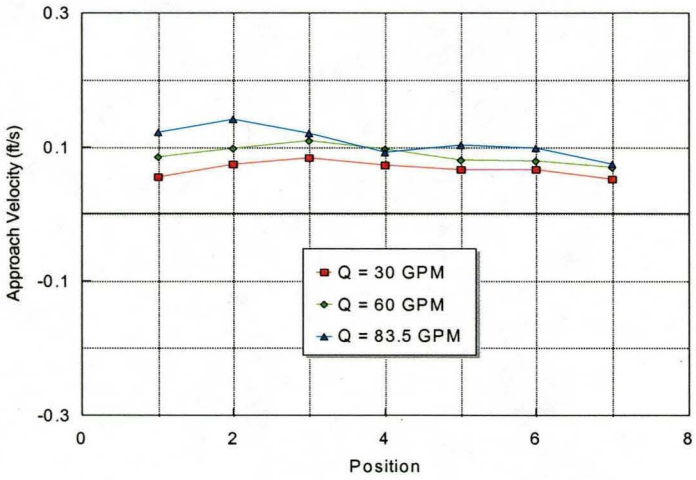


c)

Figure 10. **Screen with uniform hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 0.5 in. from the screen surface with a sweeping velocity of 2.0 ft/s.**



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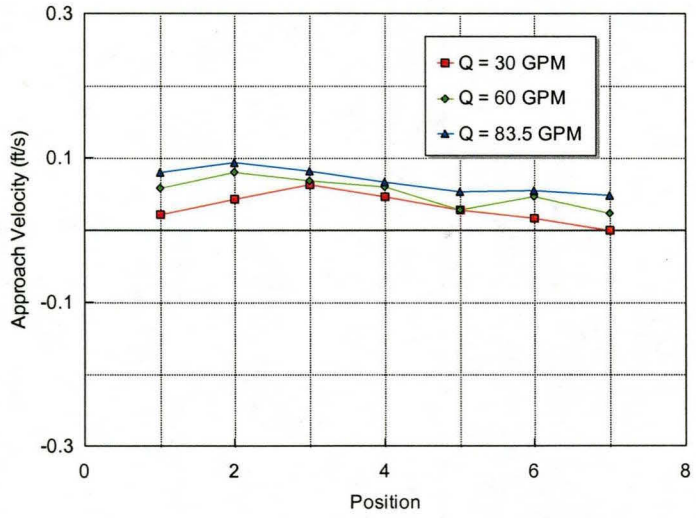

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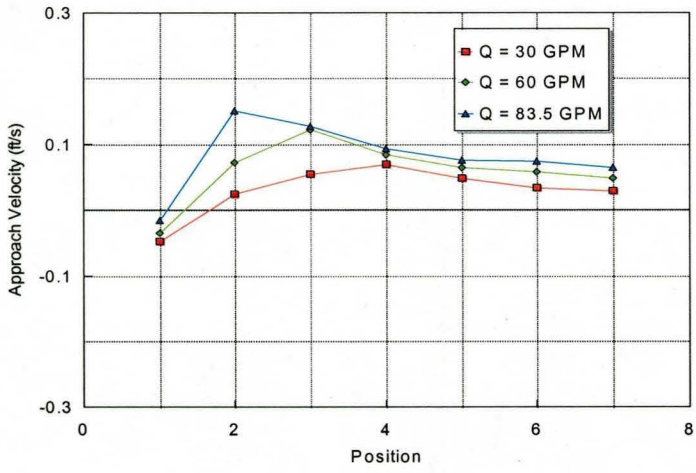
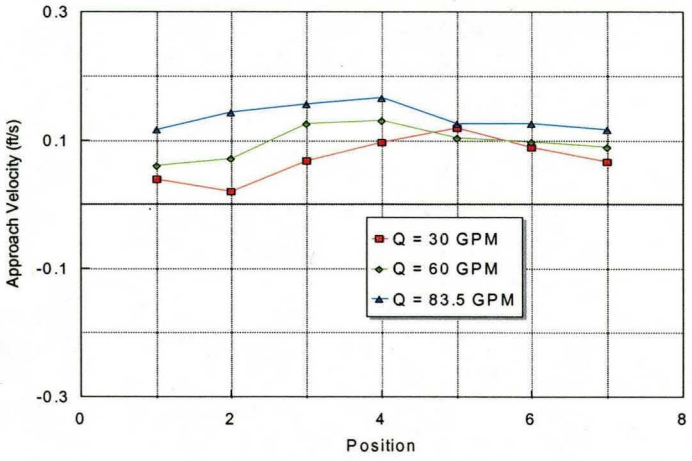


c)

Figure 11. Screen with uniform hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 0.5 in. from the screen surface with a sweeping velocity of 0.5 ft/s.



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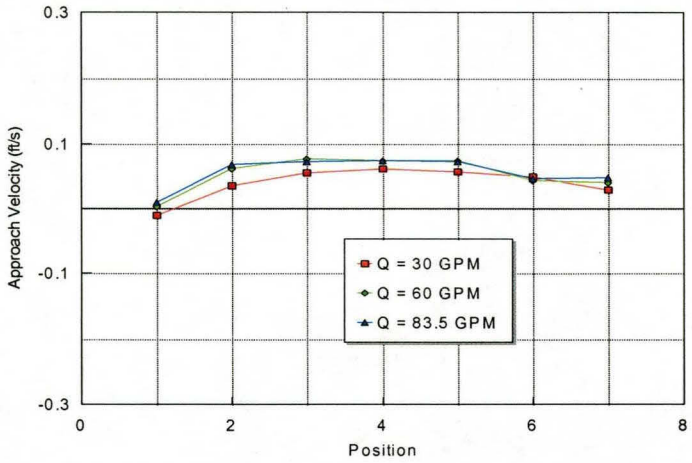

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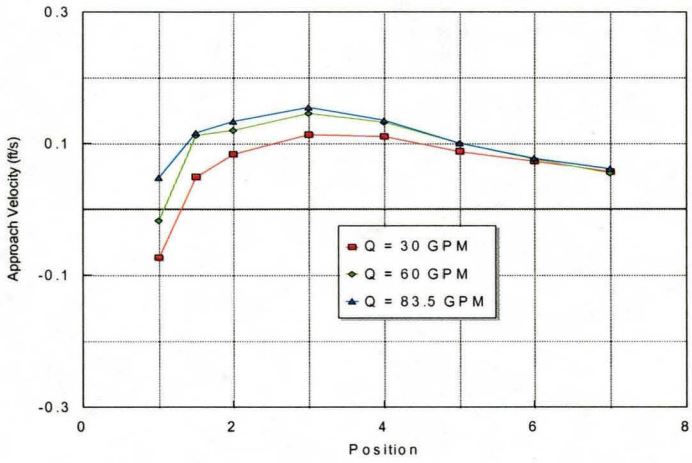
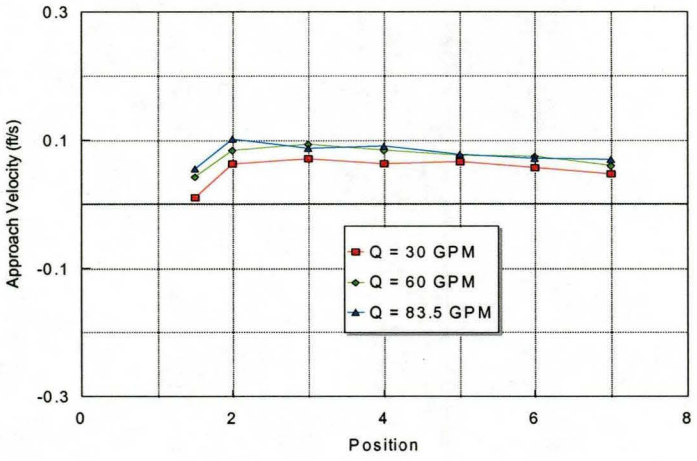
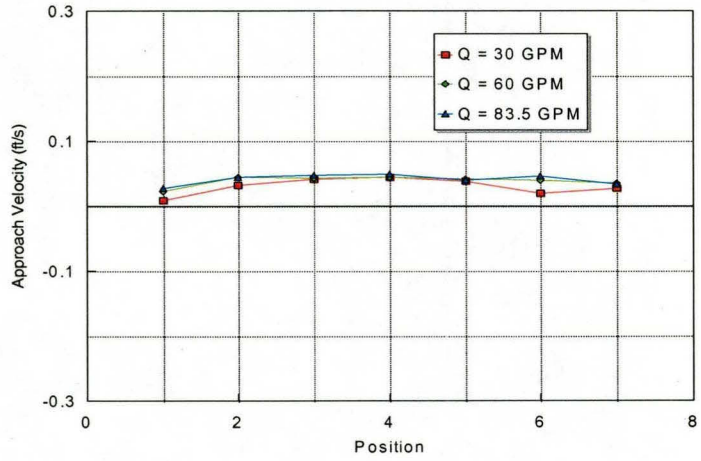


c)

Figure 12. **Screen with variable hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 3 in. from the screen surface with a sweeping velocity of 2 ft/s.**



a)



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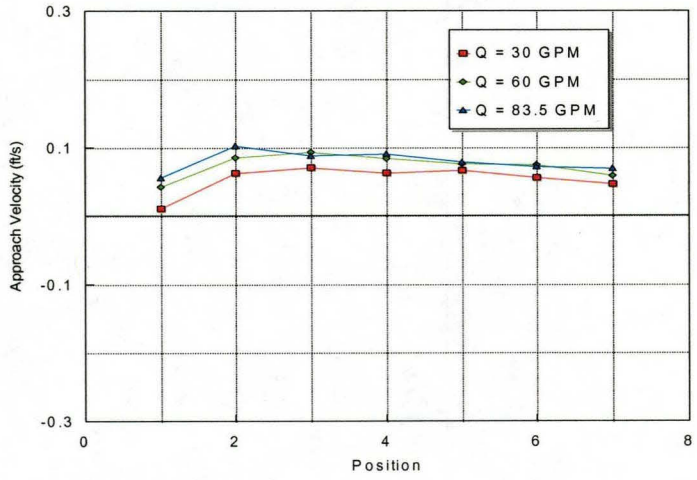
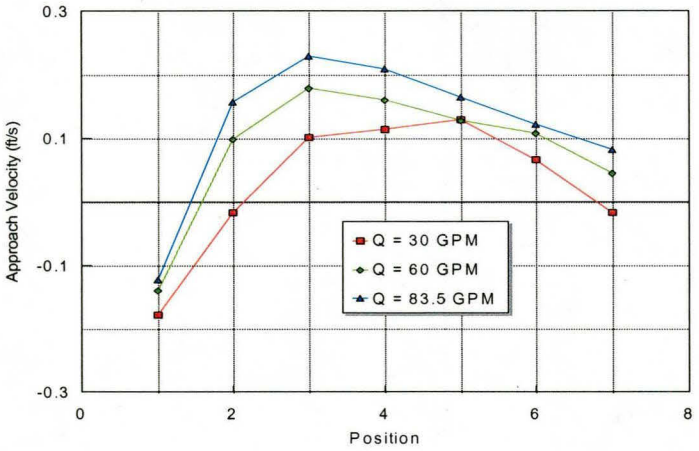
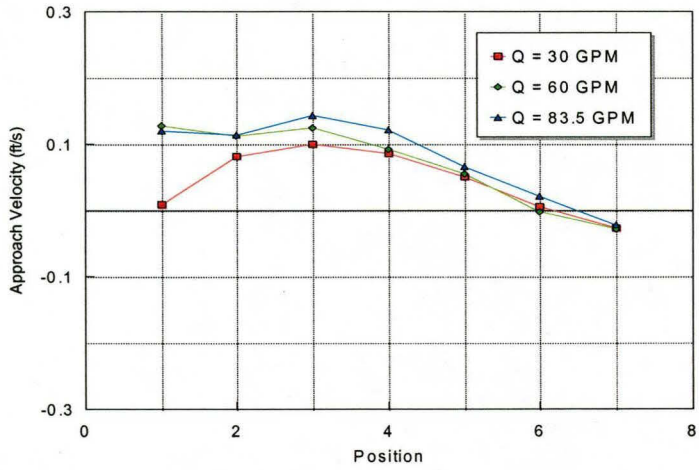


c)

Figure 13. Screen with variable hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 3-in. from the screen surface with a sweeping velocity of 0.5 ft/s sweeping velocity



a)



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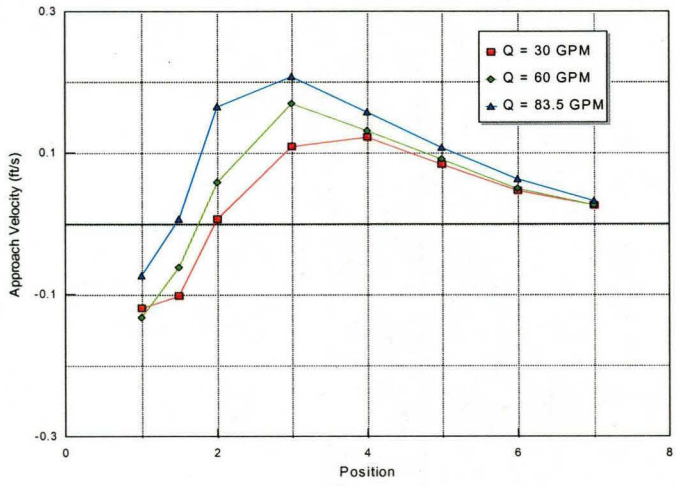
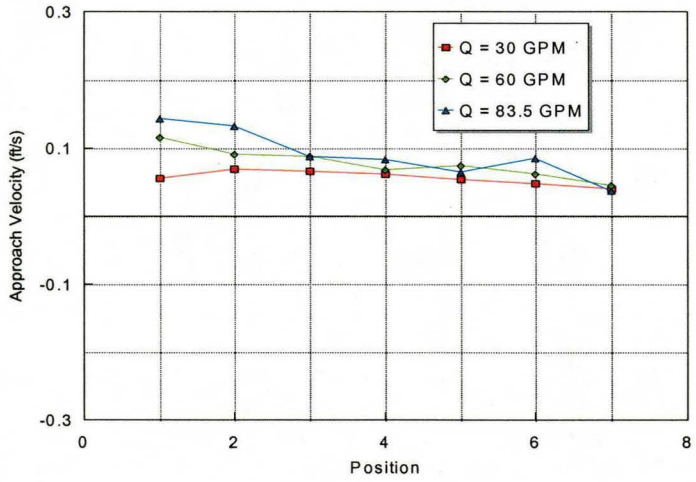


c)

Figure 14. Screen with variable hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 0.5 in. from the screen surface with a sweeping velocity of 2.0 ft/s sweeping velocity



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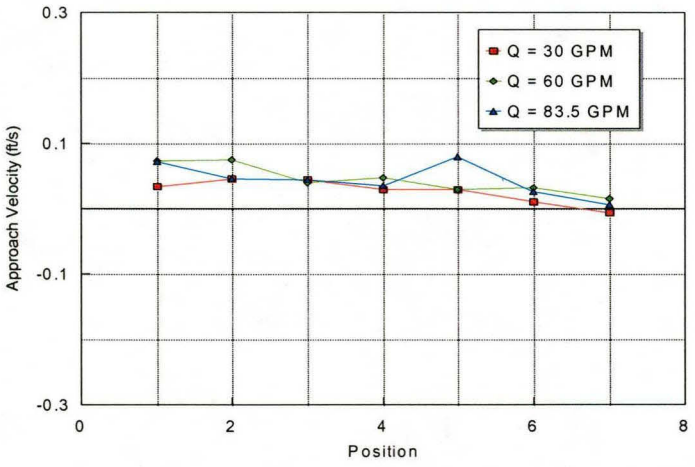

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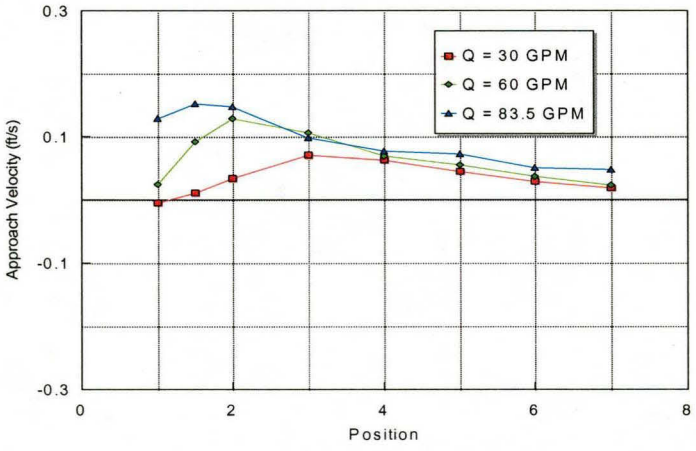

c)

Figure 15. Screen with variable hole diffuser - approach velocities measured along the a) north centerline, b) south centerline and c) top centerline, 0.5 in. from the screen surface with a sweeping velocity of 0.5 ft/s sweeping velocity

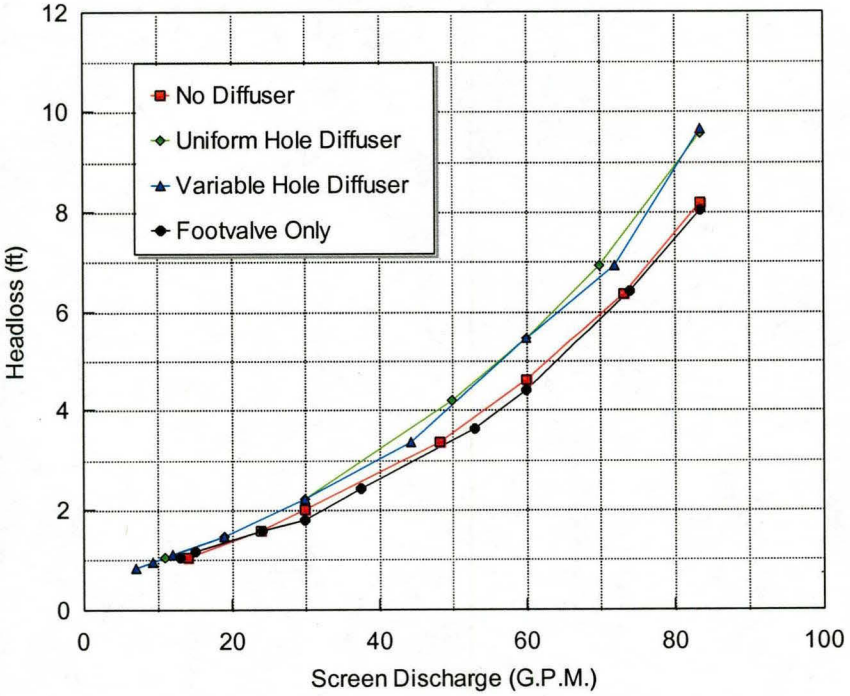

Figure 16. Head loss as a function of screen discharge