Pacific-Ag Systems Screen Tests

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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. Resource agencies have adopted standards that require screens meet a maximum approach velocity criteria of 0.2 ft/s in some areas. As a result, the Water Resources Research Laboratory (WRRL) at the U.S. Bureau of Reclamation in Denver is currently conducting research to study the performance of fish screens for both fish and debris control. Two screens were loaned to Reclamation by Pacific-Ag Systems , Inc. to determine if their present screen designs will meet this criteria.

The Model

Two low velocity suction 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). Pacific-Ag Systems' T1000 and T500 screens (figure 2) were each installed for testing on a pipe teed to the suction side of a recirculating pump and located beside a clear plexiglass window to allow viewing and underwater video taping of screen operation. The length of screen on each side of the tee is 5 ft and 10 ft respectively for the T500 and T1000 screens. Each screen consists of an outside tube about 11 inches in diameter with large uniform slotted openings covered with a lightweight mesh; and an inside tube about 6 inches in diameter with long narrow (about 1/8-in) slotted openings. The inside tube for each screen is designed with slots of variable length to provide a uniform flow distribution throughout the length of the screen. Flow velocity in the flume and through the screen were controlled by adjusting control valves on pipes extending from the recirculating pump.

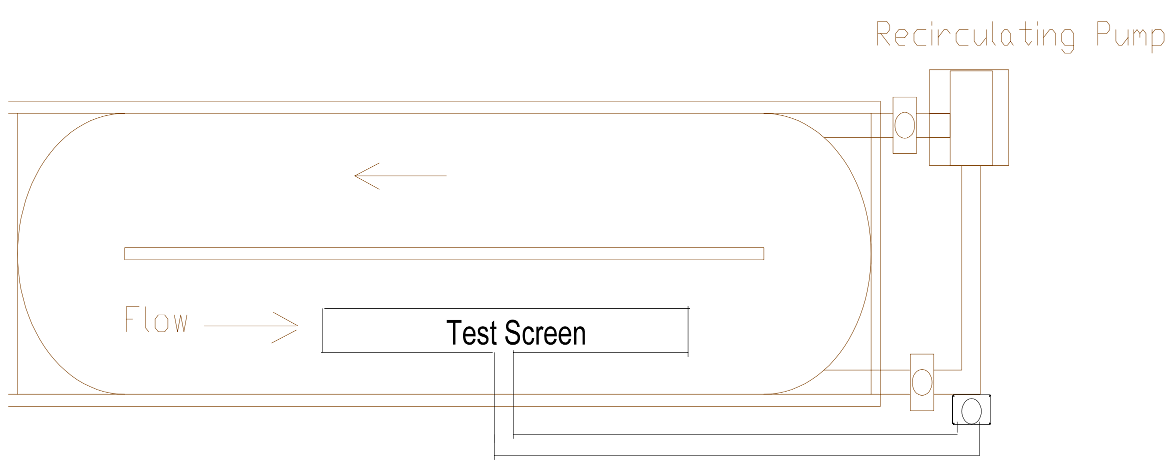

Figure 1. Layout of fish screen trash rake test facility.

Study Objectives

Model tests were conducted to determine:

1) The approach velocity distribution (normal component) along the length of the screen with a) sweeping velocities greater than or equal to twice the average approach velocity (as required by the resource agencies) and b) with a reduced sweeping velocity component (to simulate certain field conditions).

2) The maximum flow through the screen that can be achieved without a) exceeding the 0.2 ft/s velocity criteria and b) without exceeding a minimum screen discharge pressure of -7.5 inches mercury (in Hg) measured on the discharge line 3.5 ft downstream from the tee.

3) Headloss through the screen

4) The potential for vortex formation during low depth screen operation.

Each screen was tested with two flow rates:

a) the specified rated capacity for each screen.
b) the flow corresponding to objective number 3.

Using the test facility, screen performance was evaluated by measuring approach and sweeping velocities at a 3 inch distance from the outer screen surface (as required to meet velocity criteria). Velocities were measured with a Sontek acoustic doppler velocimeter (ADV probe) at 1.0 ft or 0.5 ft increments at the top, right, and left center lines along the length of the screen to determine the overall flow distribution. Velocities were also measured at a distance of 0.5 inch from the screen surface for some flow conditions to give an indication of the near screen velocity field.

In addition, a pressure tap was installed at the centerline of the screen discharge pipe approximately 3.5 ft downstream from the centerline of the screen to determine discharge pressures as well as headloss through the screen.

Test Results

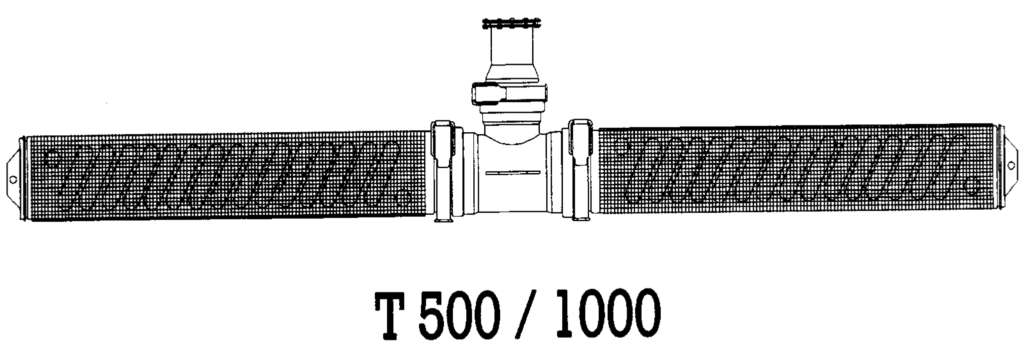

Figure 2. Screen layout for the T500 and T1000 low velocity suction screens

Each screen was tested under the flow specified by the manufacturer as the screen's maximum capacity. The screen capacity for the T500 and T1000 screens are specified as 500 gal/min and 1000 gal/min respectively. In addition, the second test condition was determined by gradually increasing the flow until the screen's average approach velocity reached 0.2 ft/s or the discharge line pressure reached a minimum value of -7.5 in Hg. In each case, minimum discharge pressure was reached before approach velocity exceeded criteria. Figures 3 and 4 show the discharge line pressure versus discharge for each screen. The flow rates corresponding to a pressure of -7.5 inches Hg were 2152 gal/min and 2287 gal/min respectively for the T500 and T1000 screens.

The six test conditions for each screen are listed in table 1.

Table 1. Flow conditions tested for each screen.

T500 Screen				T1000 Screen			
Test Case	Discharge (gal/min)	Sweeping Velocity Category	Distance from screen Surface (in)	Test case	Discharge (gal/min)	Sweeping Velocity Category	Distance from screen Surface (in)
A	500	$2 x approach velocity	3	G	1000	$2 x approach velocity	3
B	500	low	3	H	1000	low	3
C	2152	$2 x approach velocity	3	I	2287	$2 x approach velocity	3
D	2152	low	3	J	2287	low	3
E	500	$2 x approach velocity	0.5	K	1000	low	0.5
F	2152	$2 x approach velocity	0.5	L	2287	low	0.5

In order to simulate an approximate reservoir withdrawal condition (low sweeping velocity), the flume discharge valve was completely closed so that flow was discharging through the test screen only. In addition, a perforated plate was installed upstream of the screen to help reduce incoming velocities discharging into the flume. However, because the test flume must always have an incoming flow to supply discharge through the screen, a true reservoir condition could not be simulated in the flume. Tests with low sweeping velocity were conducted for cases B, D, F , H, I and L.

Conclusions

Figures 7 Through 18 show the flow distribution along the length of the screen for each case tested. Negative approach velocities indicate flow is going into the screen. Positive sweeping velocities indicate flow is downstream.

The following conclusions were determined from the study:

- The T500 and T1000 screens both meet the 0.2 ft/s approach velocity criteria (measured at the required 3 inch distance) for all flow conditions tested.

- In general the approach through-screen velocities are stronger at the top centerline than at the left or right center lines. This conclusion was also verified with dye tests.

- Through-screen approach velocities measured at the top of the screen were stronger when measured at a distance of 0.5 in from the screen surface than at a distance of 3 inches. In case F, velocities measured 0.5 in from the screen exceeded 0.2 ft/s at some locations along the top centerline.

- For all flow conditions tested, flow depth was reduced to less than 3 inches above the top surface of the screen without any vortex formation observed.

- Very little debris was drawn into the T500 screen during tests with maximum discharge through the screen. The smaller debris that clung to the screen was eventually swept downstream, even with minimal sweeping flow.

Investigations

Discharge Pressure and Headloss

For each screen, discharge pressure was measured over a range of discharges. Figures 3 and 4 show discharge pressure as a function of discharge for the T500 and T1000 screens. Discharges of 2152 and 2287 gal/min correspond to the minimum acceptable discharge pressure of -7.5 inch mercury for the T500 and T1000 screens respectively. At each of these flows the average measured approach velocity remained below 0.2 ft/s therefore these discharge values set the second flow condition for each screen.

In addition, this information was used to determine headloss through each screen as a function of discharge (figures 5 and 6). The similarity between the headloss curves for the T500 and T1000 screens indicates that the pipe tee section used for both configurations may be responsible for a large portion of the headloss in the system. The maximum headloss for each screen over the range of flows tested was approximately 7 ft.

Velocity Measurements

The results show that the screen is over-sized for meeting velocity criteria for the flow conditions tested. As a result, in the presence of a strong sweeping flow, excess flow will enter and exit the screen along its length. This is apparent along the left screen centerline where velocities are positive in magnitude, which indicates a flow pattern away from the screen. This may also occur as a result of the test setup geometry, which causes more flow to approach the screen from the right side.

It is also worth noting that the screen's inside tube provides control through the screen. Since the outside tube or screen surface has a diameter 5 inches greater than that of the control section, the measured velocities are an additional 2.5 in from the control section. As a result of measuring velocities through a control volume so far from of the screen, measurements may not be an exact representation of the flow going into the screen. Flow recirculating against the screen or conditions resulting from headloss through the screen may affect velocity measurements. In addition, there may be flow that is unaccounted for, sweeping inside and parallel to the control volume. In either case, applying the measured velocities to the assumed control volume may not represent the through-screen flow. However, although this is important information for the manufacturer and designer of the screen it does not affect the screen's ability to meet required screen criteria.

Dye Test and Vortex Observations

Dye was injected next to the screen so that flow patterns along the length of the screen could be observed. When dye was injected above the top centerline of the T500 screen, the majority of flow was observed to be pulled directly into the screen with little flow sweeping in the downstream direction. This was especially true for the higher discharge. A similar observation was made for the T1000 screen, although the flow traveled slightly farther downstream before fully disappearing into the top of the screen. However, when dye was injected along the left or right sides of the T500 or T1000 screen, the flow had a much stronger sweeping component and less flow was drawn directly into the screen. These observations were consistent throughout the range of flows tested.

In addition the water surface in the flume was slowly lowered to determine the potential for vortex formation at low depth operations. At a water surface depth of 3 inches above the top surface of the screen there was still no indication of any vortex formation throughout the range of flows tested for either screen.

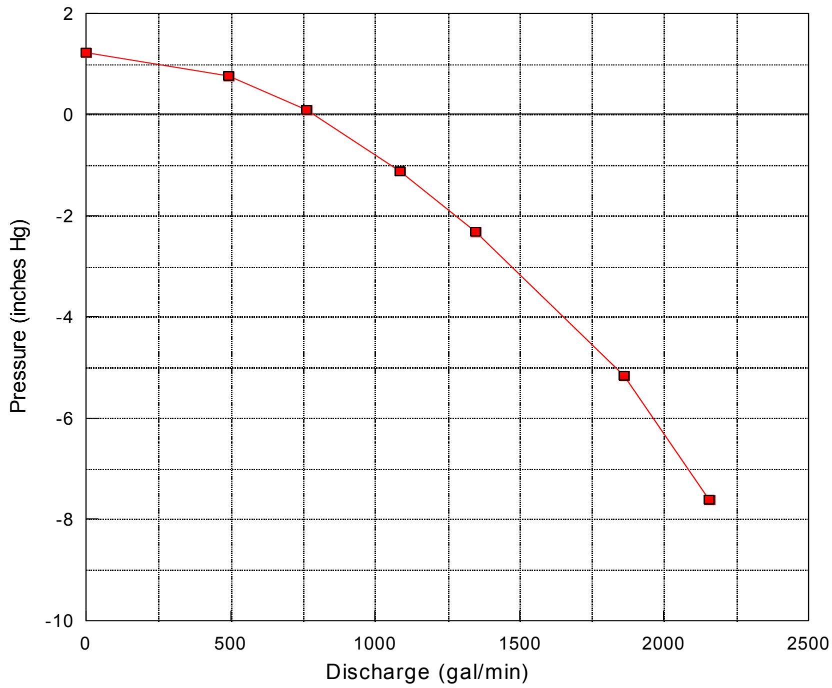

Figure 3. Discharge pressure versus discharge for the T500 screen

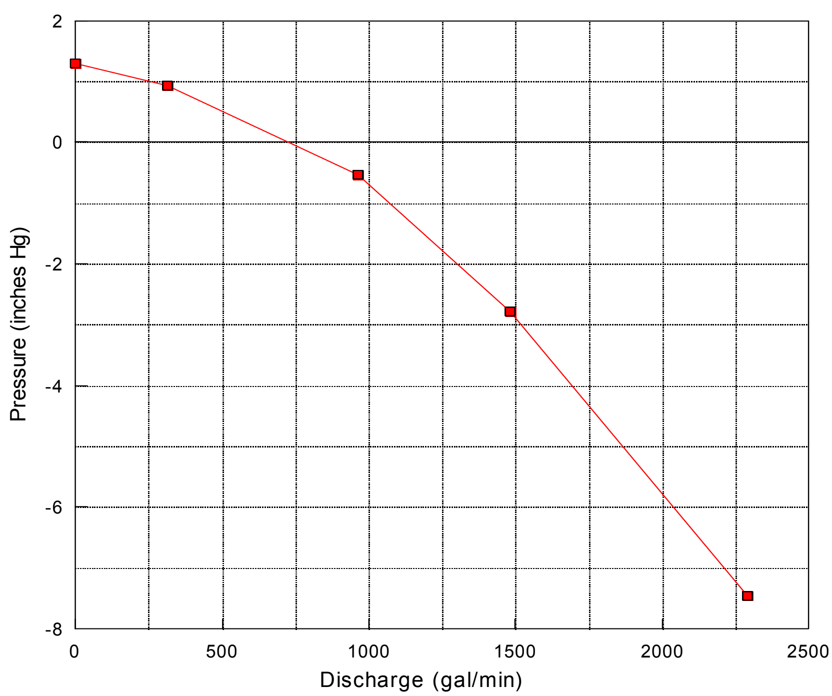

Figure 4. Discharge pressure versus discharge for the T1000 screen.

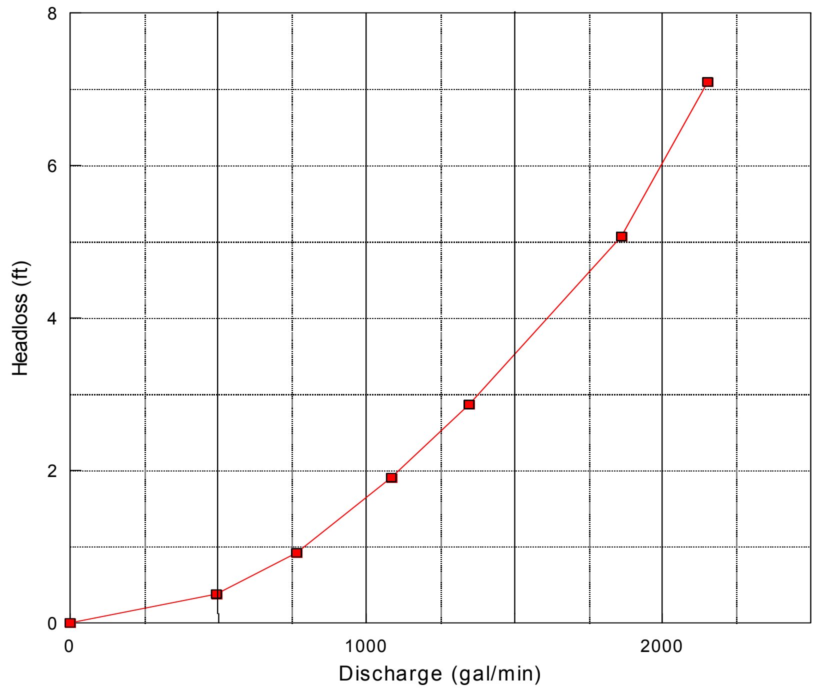

Figure 5. Headloss versus discharge for the T500 screen

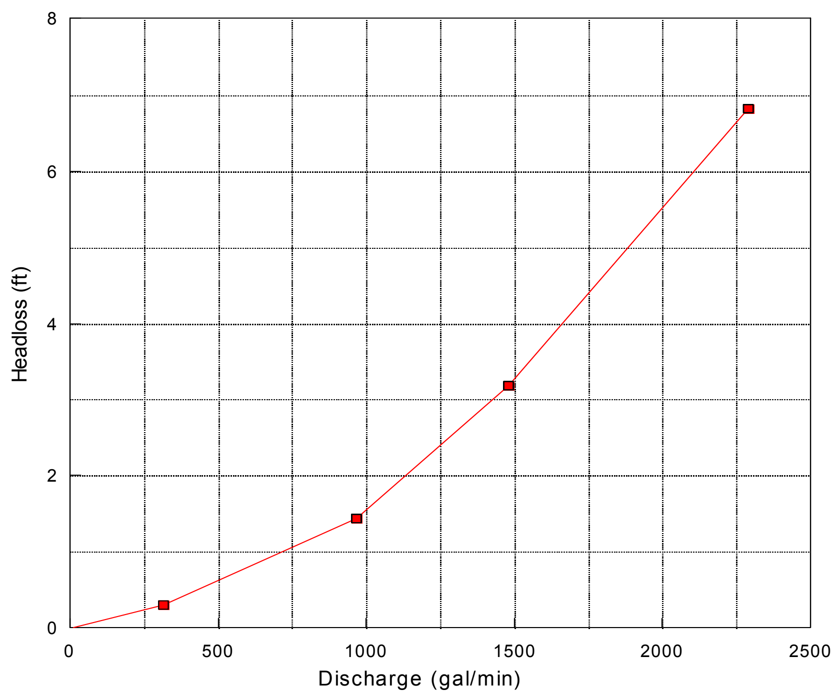

Figure 6. Headloss versus discharge for the T1000 screen.

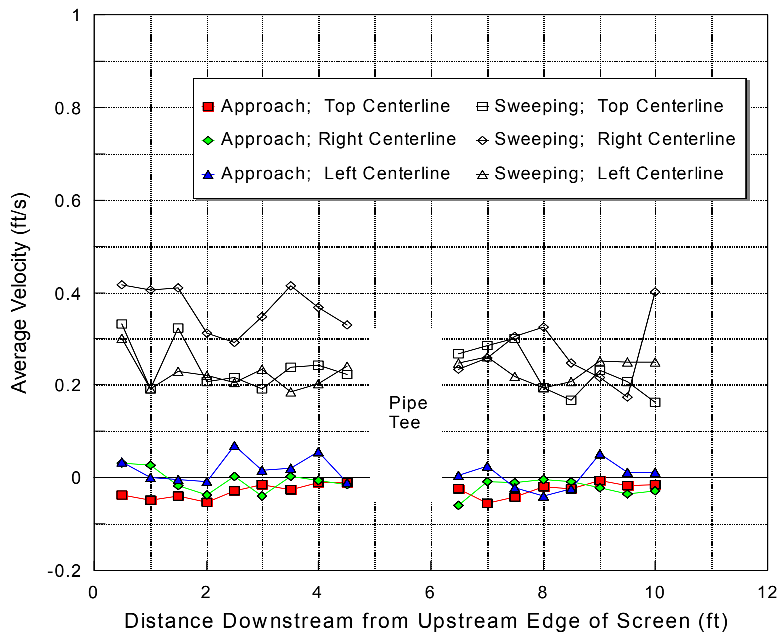

Figure 7. T500 screen, Case A - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 500 gal/min and with sweeping velocities $ 2x average approach velocity

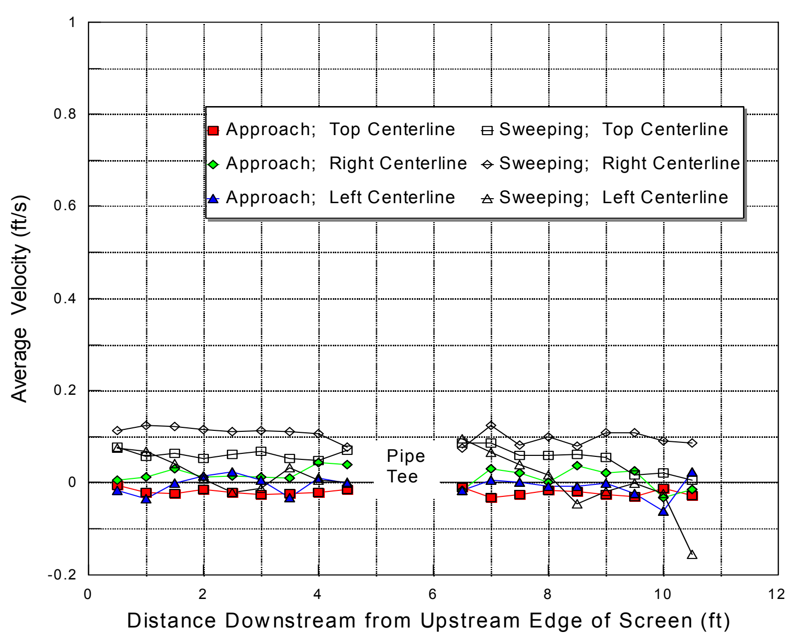

Figure 8. T500 screen, Case B - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 500 gal/min and with reduced sweeping velocities.

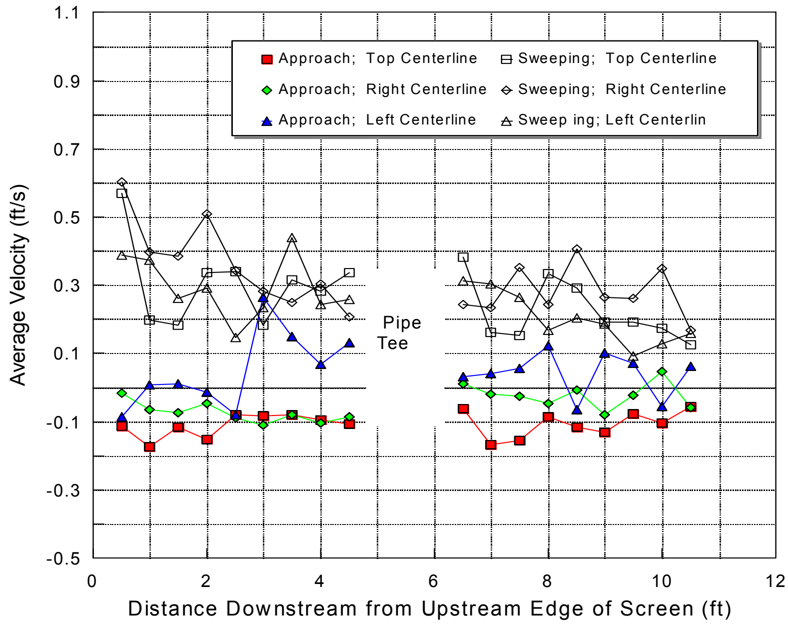

Figure 9. T500 screen, Case C - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 2152 gal/min and with sweeping velocities $ 2x average approach velocity

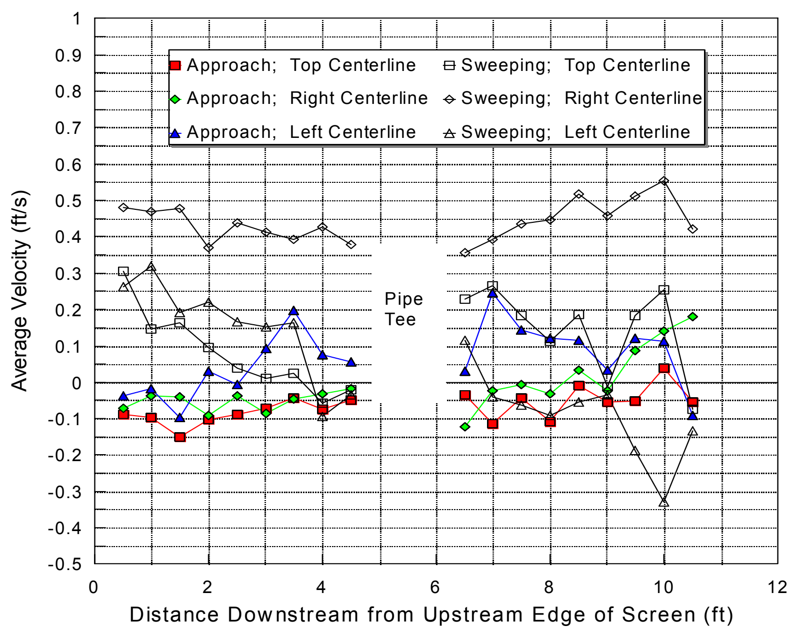

Figure 10. T500 screen, Case D - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 2152 gal/min and with reduced sweeping velocities.

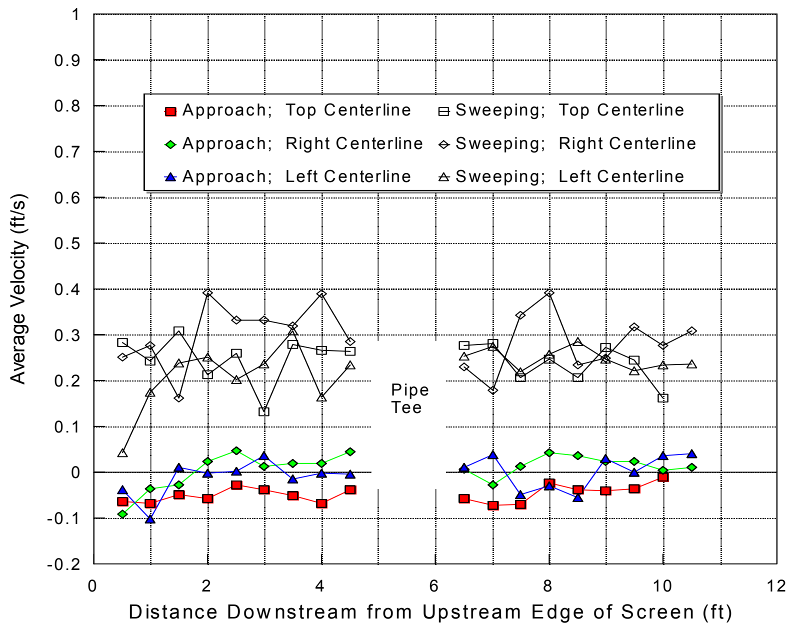

Figure 11. T500 screen, Case E - Approach and sweeping velocities measured 0.5 inches from the screen surface at a screen discharge of 500 gal/min and with sweeping velocities $ 2x average approach velocity

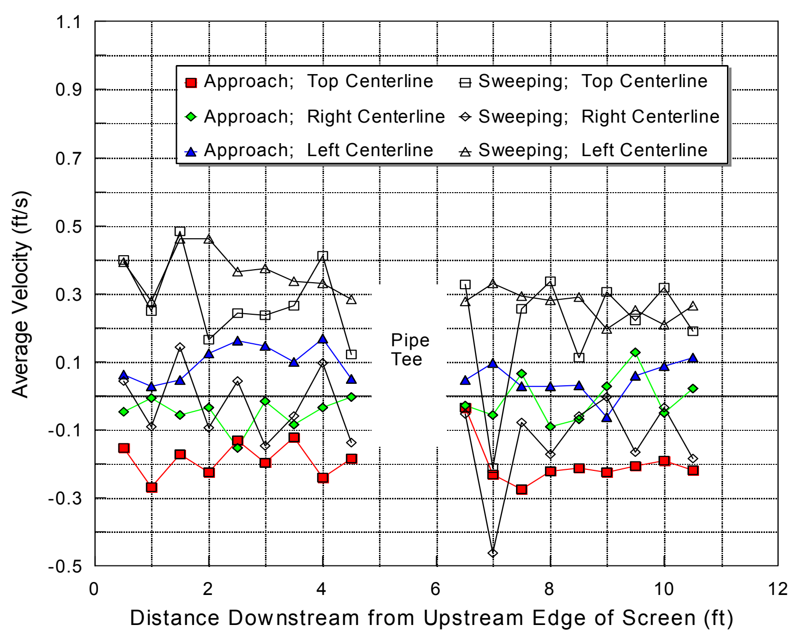

Figure 12. T500 screen, Case F - Approach and sweeping velocities measured 0.5 inches from the screen surface at a screen discharge of 2152 gal/min and with sweeping velocities $ 2x average approach velocity

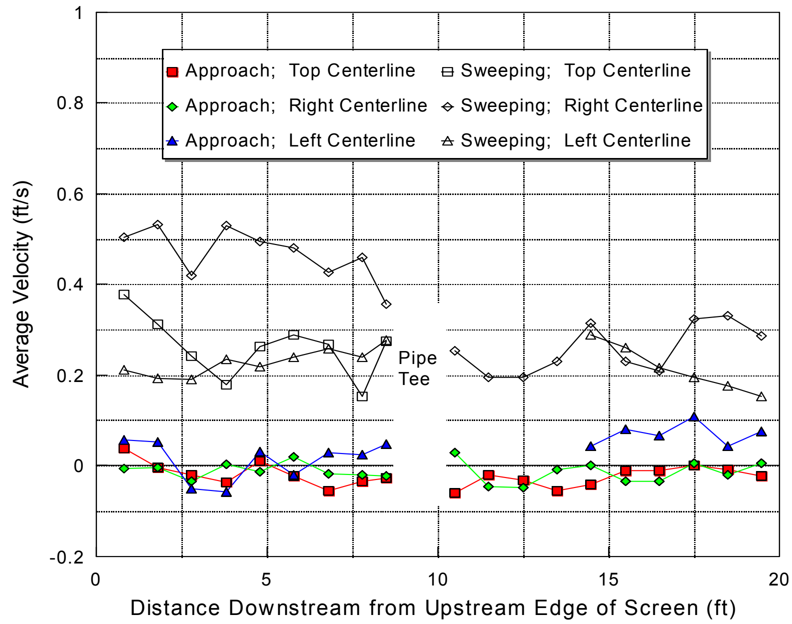

Figure 13. T1000 screen, Case G - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 1000 gal/min and with sweeping velocities $ 2x average approach velocity

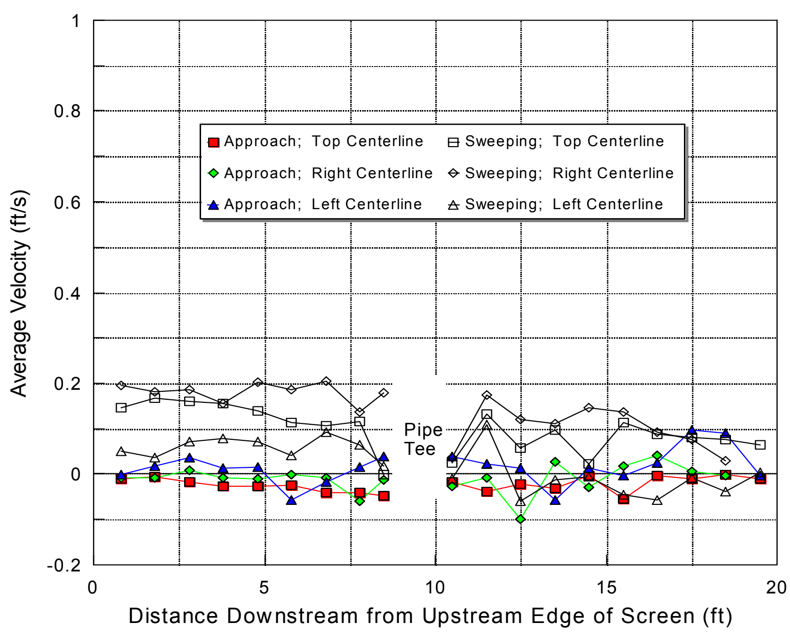

Figure 14. T1000 screen, Case H - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 1000 gal/min and with reduced sweeping velocities.

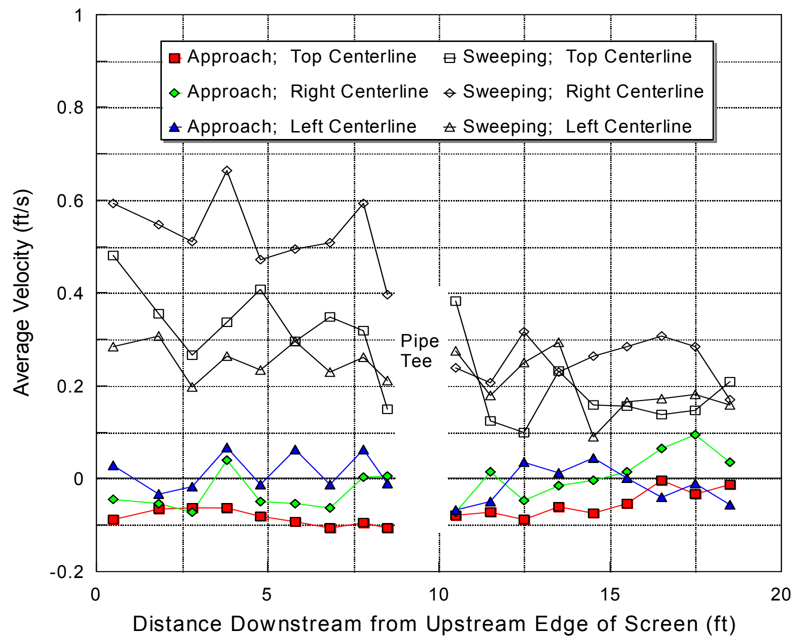

Figure 15. T1000 screen, Case I - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 2287 gal/min and with sweeping velocities $ 2x average approach velocity

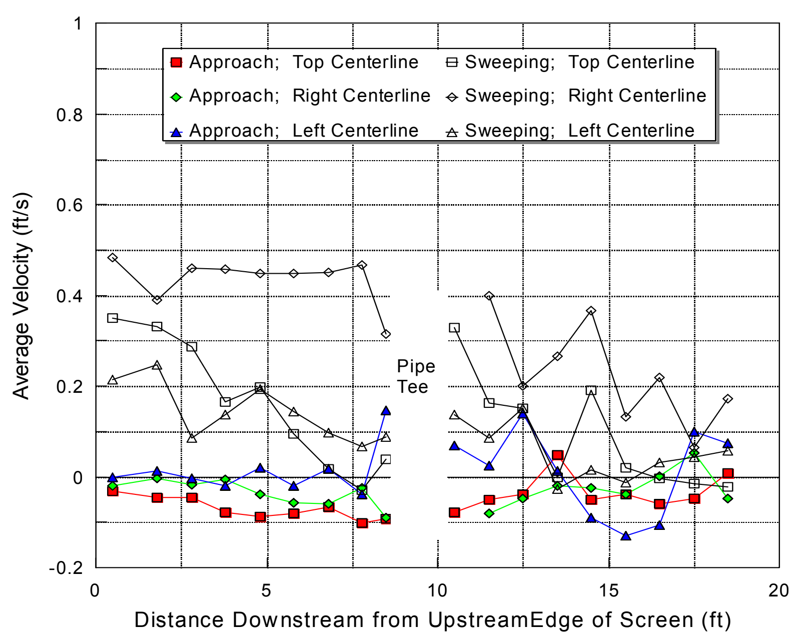

Figure 16. T1000 screen, Case J - Approach and sweeping velocities measured 3 inches from the screen surface at a screen discharge of 2287 gal/min and with reduced sweeping velocities

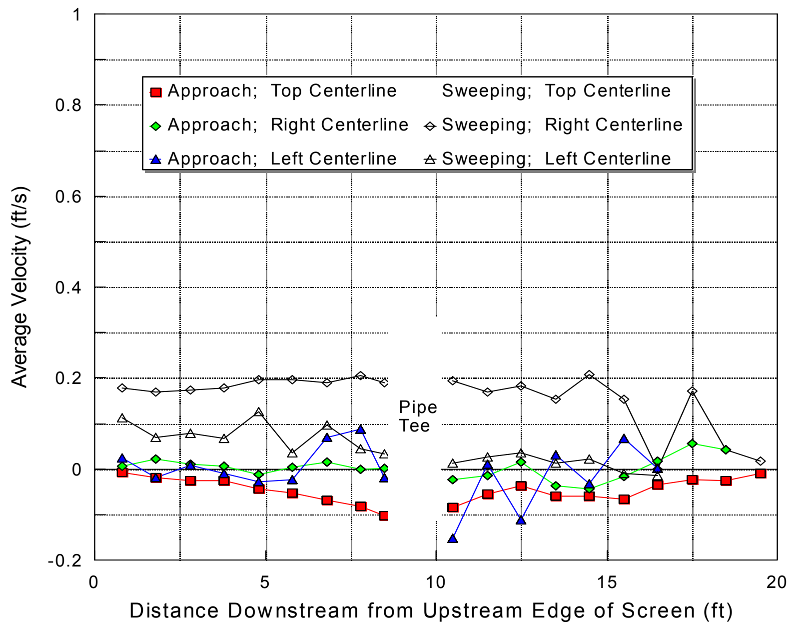

Figure 17. T1000 screen, Case K - Approach and sweeping velocities measured 0.5 inches from the screen surface at a screen discharge of 1000 gal/min and with reduced sweeping velocities

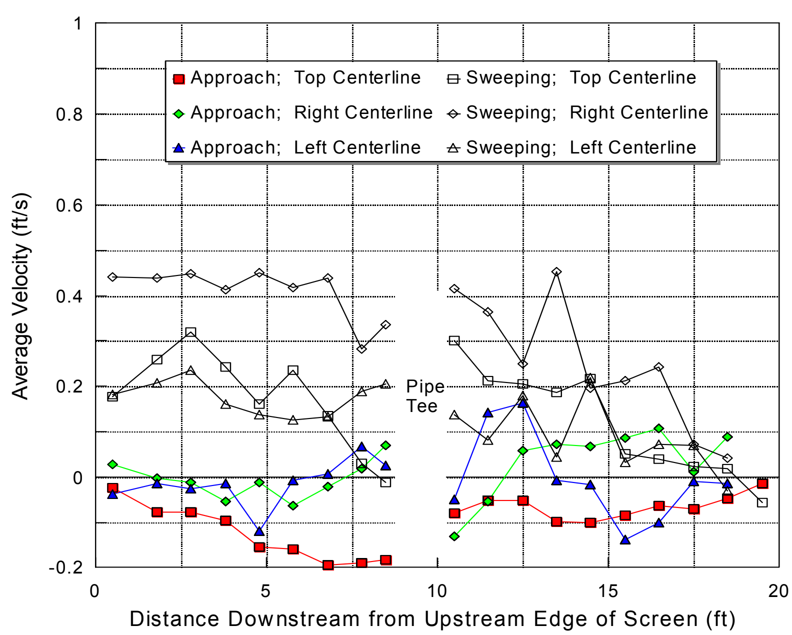

Figure 18. T1000 screen, Case L - Approach and sweeping velocities measured 0.5 inches from the screen surface at a screen discharge of 2287 gal/min and with reduced sweeping velocities