MODEL TESTS OF AIR BURST AND HYDRAULIC BACK-FLUSH CLEANING EFFICIENCY FOR A COOK CYLINDRICAL SCREEN

Model Test Summary Report
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by

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Model Description -

A 2-ft-diameter by 2-ft-long cylindrical fish screen was loaned to Reclamation by Cook Screens for cleaning efficiency tests. The screen was constructed of wedgewire with 1.75 mm openings between the wires. The screen was installed in a recirculating flume located at Reclamation's Water Resources Research Laboratory in Denver, Colorado. The flume, figure 1, is 5.5 ft wide by 5 ft deep. The screen was mounted 1.0 ft off the flume floor, pointing upstream (flow parallel to the screen axis). A clear Plexiglas viewing window on the flume wall adjacent to the screen allowed viewing and video taping of screen operation and cleaning tests. Flow through the screen was measured using an acoustic transit time flow meter located on the discharge pipe. The screen was mounted on pipe teed to the suction side of the recirculating pump. Flow velocity in the flume was controlled by adjusting the recirculating pump and control valves.

Tests-
The following test sequence was conducted on the screen:

- Clean screen velocity profile,
- Clogged screen velocity profile,
- Air burst cleaning tests,
- Hydraulic back-flushing cleaning and,
- Clean screen velocity profile with 45 degree upstream cone.

Clean screen velocity profile -
Velocity profiles were measured along the screen to identify screen performance prior to and following substantial debris clogging. Three dimensional velocities along the screen were

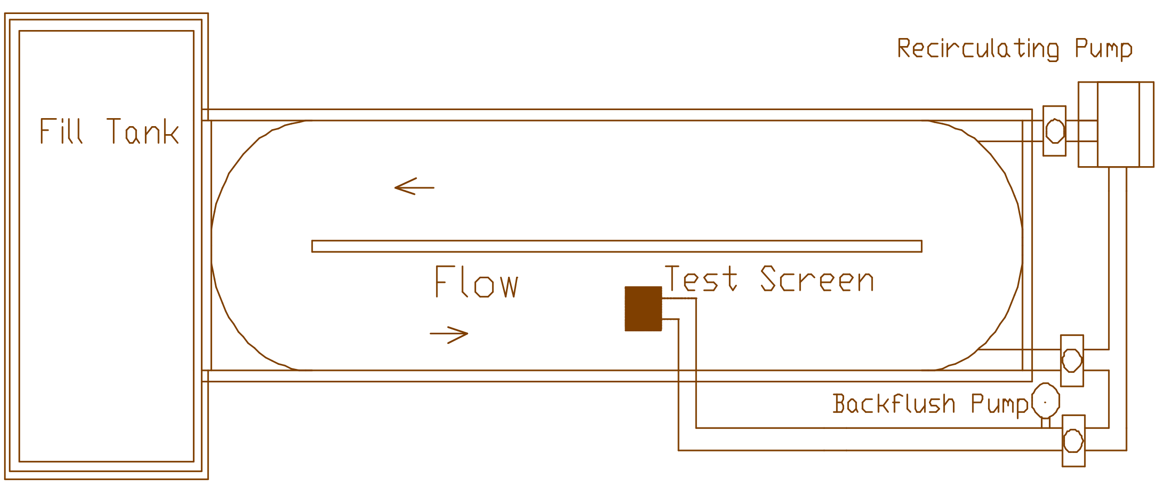

Figure 1 - Layout of Fish Screen Test Facility

measured using an acoustic doppler velocimeter. Velocities were measured at a distance of 0.75

inches above the screen surface to give a good indication of the near screen velocity field. Figure 2 shows screen approach velocities (normal component) measured along the screen crown and along each side. Negative velocity represents flow into the screen. The flow conditions represent an average approach flow velocity to the screen of 0.37 ft/s, assuming a screen area of 12.56 ft^2 and a discharge of 4.7 ft^3 /s. The velocity profile shows a separation zone (indicated by positive velocities) starting at the upstream edge and extending downstream about 0.25 ft. The separation zone is caused by flow approaching the screen being forced radially outward by the bluff upstream screen face. Within this zone, an eddy exists that moves flow from inside the screen outward. Flow patterns along the screen were also observed by injecting dye above the screen. In an unsteady mode, dye injected just upstream of the screens mid-point moved upstream inside the screen and flowed out of the screen in the upstream separation zone. The screen area effected by the leading edge separation zone reduces the effective screen area resulting in increased through screen velocity downstream of this zone. This is seen by the rise of through screen velocity above 0.37 ft/s at about 0.6 ft downstream of the screen's leading edge followed by a leveling off at about the predicted average velocity. According to the manufacturer the screen is designed to provide the best uniformity of through-screen velocity under reservoir conditions. There is no baffling inside the screen, however the manufacturer uses a re-entrant pipe extended into the screen a distance of one third the screen length to adjust the through-screen flow uniformity. The size of the separation zone at the leading edge of the screen varies as a function of several factors. The zone will increase with stream velocity, decrease with increasing discharge through the screen, and decrease if a nose cone is placed on the screen.

Clogged screen velocity profile - Eurasian Watermilfoil (milfoil) was placed in the flume and

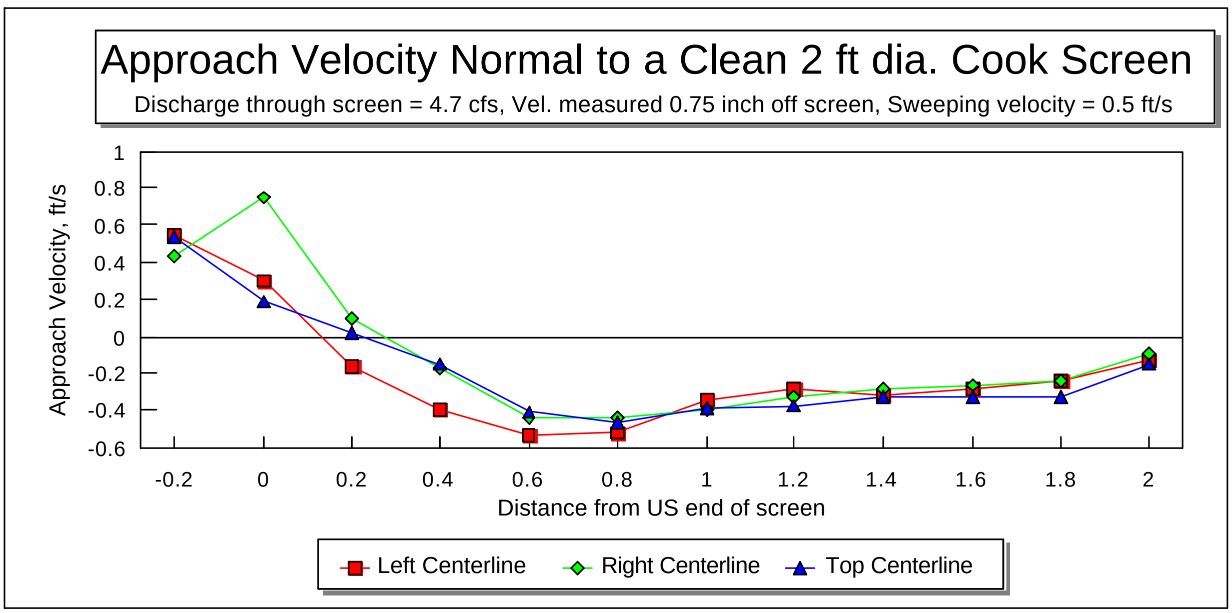

Figure 2 - Velocity profile normal to a clean screen.

allowed to circulate, providing a nearly constant source of debris passing the fish screen. Milfoil was obtained for the screen cleaning tests from a U.S. Corp of Engineers fish hatchery in Lewisville, Texas. The milfoil placed in the flume ranged from fine filamentous material to strands of about 3 ft in length. Following a four hour test, much of the milfoil fractured into strands of 1 ft in length or less. The debris initially accumulated on the clean screen fairly evenly over the downstream three quarters of the screen. The upstream one quarter of the screen's length remained clean until the density of debris covering the downstream length of screen created sufficient head loss to suppress the separation zone, figure 3. As debris continued to collect on the screen, the length of the separation zone progressively decreased until the entire screen was covered with milfoil, figure 4. The fine leaf structure of the milfoil resulted in a fairly uniform porous mat of material covering the screen surface. After four hours of operation, the screen surface appeared to be totally covered with about a one-half inch thickness of weed mat. The visually dense mat resulted in an added head loss through the screen of less than 0.05 ft. As debris collected on the screen the uniformity of the normal velocity along the screen improved due mainly to a reduction in the eddy zone near the screen's leading edge, figures 5 and 6. Debris collected on the screen spatially as a rough function of through screen velocity. The highest velocity areas impinged the highest quantity of debris, thus acting as a porous filter and a self-regulating form of screen baffling. Once fully covered, additional impingement of debris on the screen showed no change in the uniformity of through-screen velocity, only increased head loss across the screen. Any debris composed largely of fine scale material that is distributed through the water column will likely yield a similar baffling effect on the screen hydraulics. However, less porous larger scale debris such as tree leaves may not produce the same baffling effect. The debris would

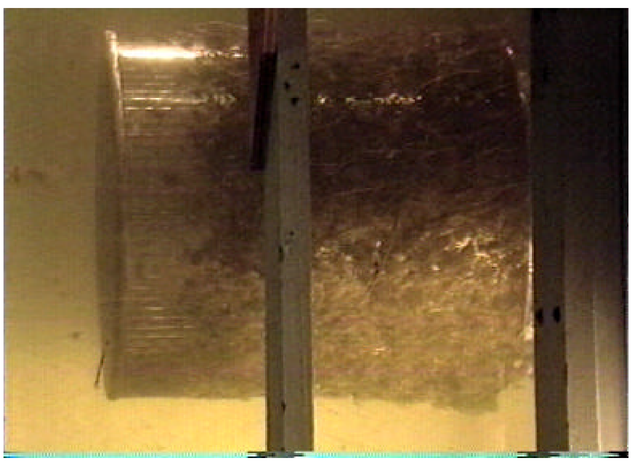

Figure 3 - Debris loading on the screen after about 2 hours operation. The partially plugged screen shows little debris loading on the upstream end of the screen.

Figure 4 - Debris loading on the screen after about 4 hours operation.

likely totally plug part of the screen area rather than acting as a porous filter.

Air burst cleaning tests -

Air burst cleaning tests were evaluated largely by visual observation of before and after debris accumulation on the screen. Initially, a correlation between debris accumulation and head loss was tried to quantify debris cleaning efficiency. This proved unworkable due to a small head loss and a large fluctuation in the pressure readings measured. Air was supplied to the screen through a two inch pipe from the laboratory air supply. The two inch line connected with a six inch header line about 100 ft from the screen. A quick opening ball valve was used to control the release of air to the screen. Prior to each cleaning test, the screen was operated for four hours to collect debris on the screen. The test parameters and ranges covered in the cleaning tests were:

Average flow velocity normal to the screen, 0.2 ft/s, 0.3 ft/s, and 0.4 ft/s
Mean stream velocity measured upstream of the screen, 0 to 2 ft/s
Length of air burst, 2 to 15 sec
Amount of debris impinged on the screen, (visual assessment)

An air regulator of sufficient size was not available for these tests. Therefore, air burst pressure could not be widely varied. Air was supplied to the screen at shutoff pressure of 100 psig. The pressure dropped to about 50 psig during a 3 to 5 sec valve opening. Assuming an average supply pressure of 75 psig and head losses associated with the supply piping, the air flow to the screen was about 870 scfm (neglecting compressibility effects). The manufacturer recommended an air supply of 859 scfm.

The duration of screen operation prior to cleaning was adjusted (longer operation for lower discharges) for different screen discharges to attain similar levels of debris impingement on the screen for all tests. Prior to activating an air burst, milfoil was allowed to cover the entire screen to a mat thickness of about one half inch. For most tests, pumping was continued during an air burst representing worst case conditions for screen cleaning. This operation resulted in some loss of air to the pump suction line. The cleaning tests showed no apparent difference between cleaning efficiency as a function of screen normal velocity or length of air burst for the range tested. The best cleaning was achieved by using two short air bursts with a time delay of 15 seconds or more between bursts. For a screen heavily matted with debris, we found the initial air burst typically cleaned 90 percent or more of the screen, figure 7. Debris remaining on the screen was typically located along the on the screen invert and sides near the screen centerline. A second

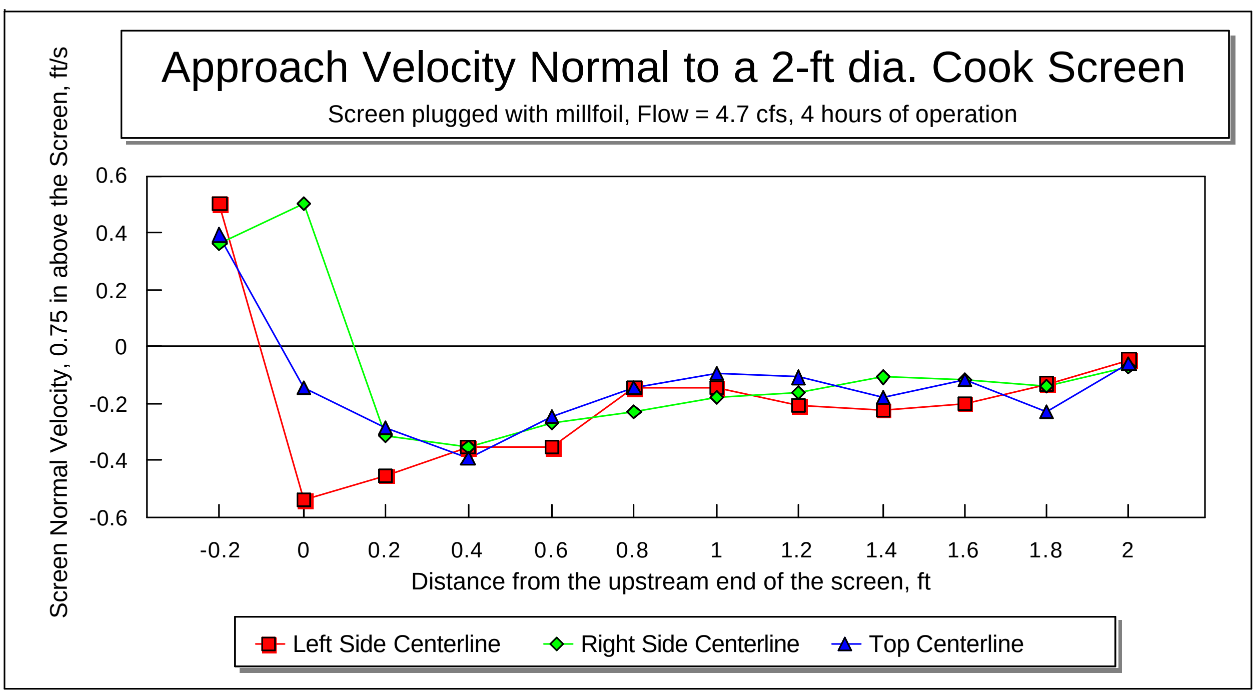

Figure 5 - Velocity profile normal to the screen under plugged conditions.

air burst removed most of the remaining material except in a small zone along the screen invert, figure 8. The poorest cleaning occurred along the invert from about mid-screen to the downstream edge, covering a width of 6 inches or less. In this area repeated bursts failed to fully remove debris. Visually it appeared that air jets from the internal air manifold penetrated the debris mat as concentrated jets. These jets dislodged debris they contacted, but generally passed through the debris matt. The air then penetrated below the screen, reversed direction due to buoyancy and passed upward back through the screen holding much of the initial debris against the screen invert. Air bursts conducted with continuous pump operation provided better cleaning with high sweeping velocity along the screen. The higher the sweeping velocity the quicker debris dislodged from the screen by the air burst was carried downstream, thus reducing the amount of re-impingement of material on the screen.

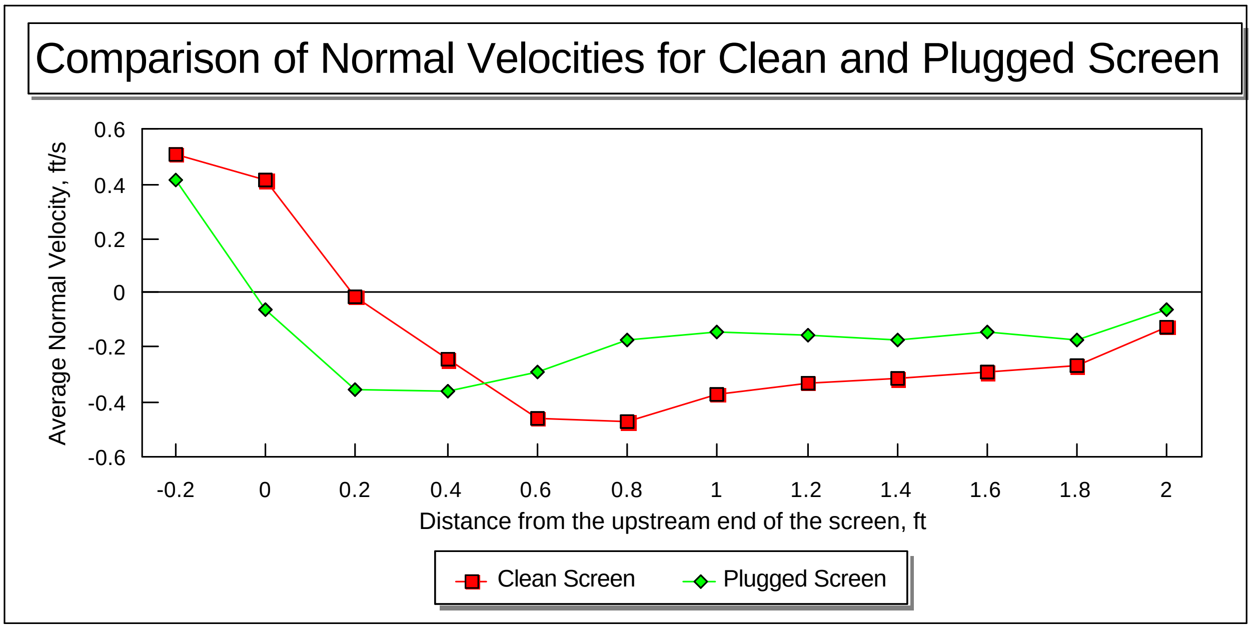

Figure 6 - Comparison of approach velocities normal to the screen for clean and plugged conditions.

Hydraulic backflushing tests - Cleaning the screen by hydraulicly backflushing was also evaluated. To clean the screen the discharge pump was stopped and water was pumped backward through the suction pipe and fish screen. This procedure was not a standard cleaning method used by the screen manufacturer.   The procedure was found to be ineffective for cleaning an as-built screen.   A typical velocity profile of reverse flow through the screen is shown in figure 9. Hydraulic backflushing forces reverse flow out the end of the reentrant pipe internal to the screen. The jet impinges on the screen's circular end and then moves radially outward, remaining concentrated. As shown in figure 9, flow out the screen near the end plate is followed by flow into the screen due to an eddy formed by the exiting jet. Little flow passes out the screen from about the screen midpoint to its discharge end. This is partially due to the reentrant pipe inside the screen.   To use hydraulic backflushing to clean the screen would require substantial modifications to the screen design.

Screen with 45 degree cone -

A cone was added to the upstream end plate to evaluate the change in the velocity profile normal to the screen compared to the screen with a flat end plate, figure 10. A comparison of average velocity normal to the screen for the two cases is given in figure 11. The 45E cone does not significantly reduce the length of the separation zone that forms downstream of the leading edge of the screen. Some improvement in the uniformity of normal velocity along the screen is indicated by the data. However, difference between the data for the two conditions is not statistically significant for the limited amount of data obtained.

Conclusions -

- Flow moving around the upstream end of a cylindrical screen produces an eddy zone on the upstream portion of the screen that effectively reduces the inward through-flow screen area. The length of screen affected is a function of many factors; the average velocity of the flow upstream of the screen, discharge, debris plugging, and the bluntness of the upstream end of the screen. The scope of these tests did not include detailed study of these parameters. However, within the expected operating range of the screen, the data shows that the upstream most 10 to 15 percent of the total screen area is effected by the eddy that forms downstream of the leading edge of the screen. The non-uniformity of flow normal to the screen documented in the study should be considered in the sizing of the screen to ensure fish screen approach flow criteria is met.
- Adding a 45 degree cone to the end plate does not significantly reduce the eddy zone.
- Uniformity of approach velocity measured normal to the screen showed little change with milfoil accumulation on the screen.
- Two or more air bursts were required to effectively clean the screen. The air burst system failed to totally clean the screen along the screen invert near the downstream end. In this area, material appeared to move off the screen for a short time during the start of a burst and then reattach. The air manifold design and location relative to the screen invert could possibly be changed to improve cleaning of the screen invert.
- Hydraulic back-flushing is not an effective method for cleaning the as-built manufactured screen. To achieve good cleaning by back-flushing would require modifications internal to the screen.

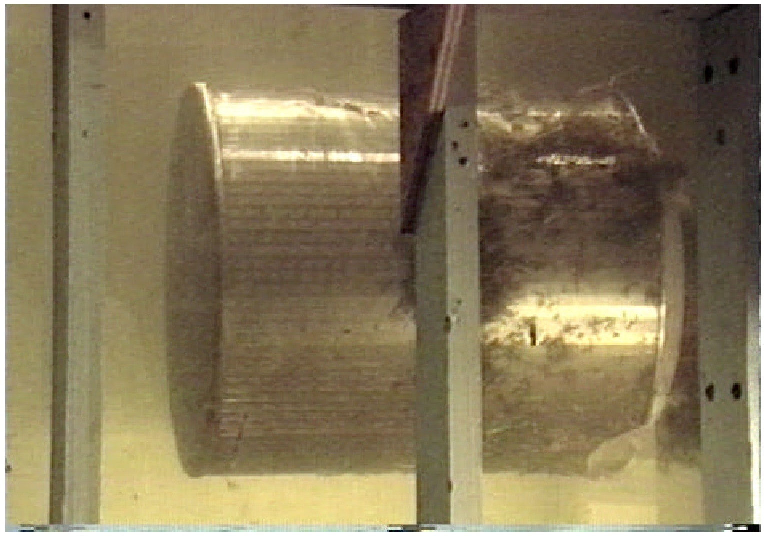

Figure 7 - Screen following a three second air burst. Debris loading prior to air burst is shown in figure 6.

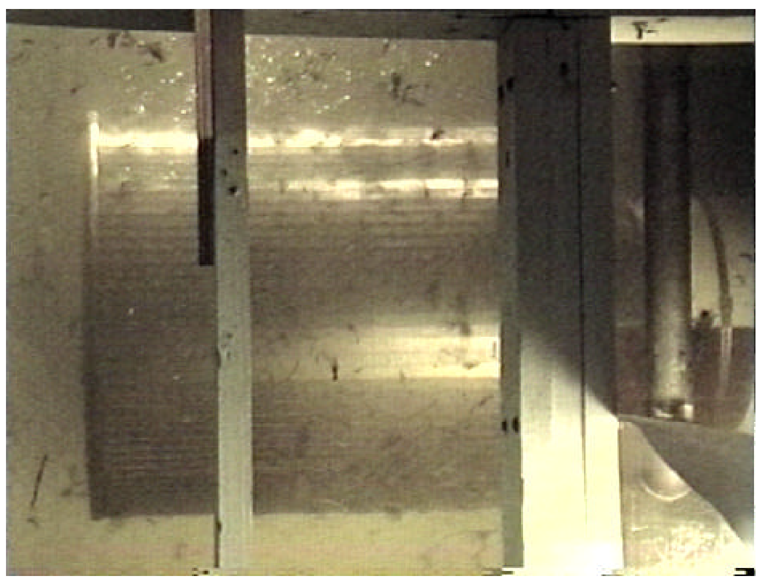

Figure 8 - Screen following second air burst showing removal of additional debris compared to figure 7.

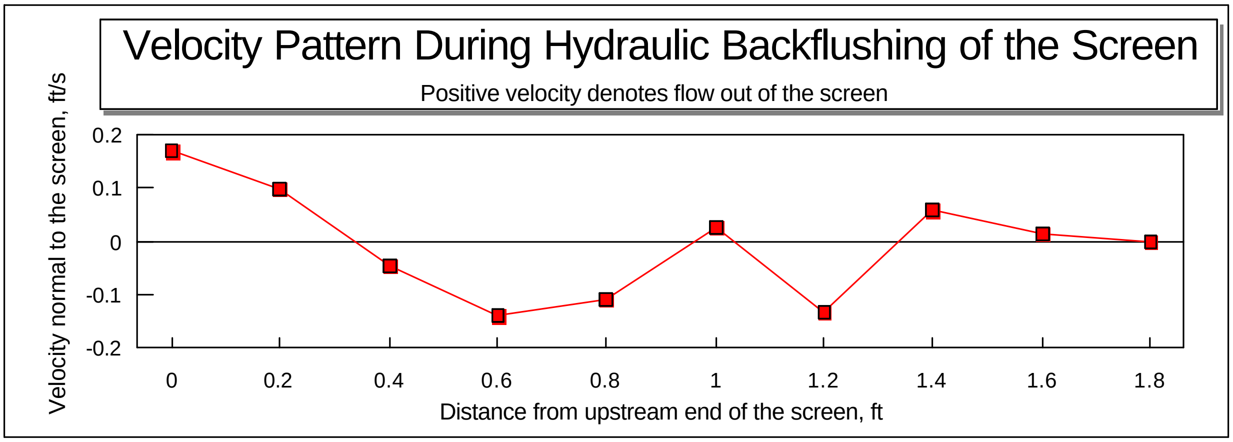

Figure 9 - Velocity measured normal to the screen during hydraulic backflushing.

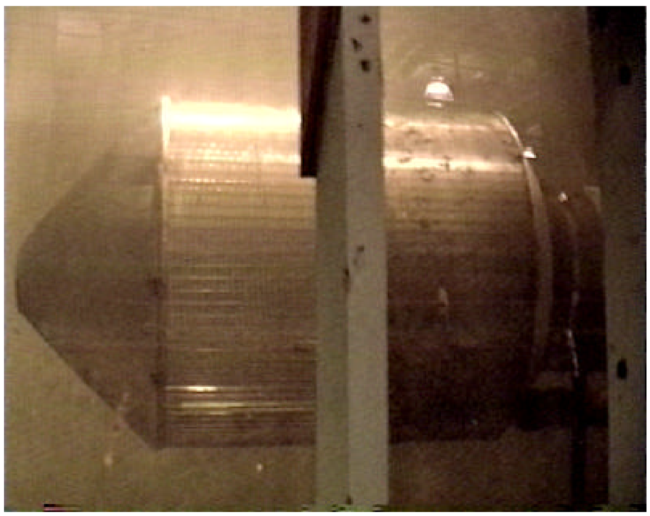
Figure 10 - Screen with 45E nose cone.

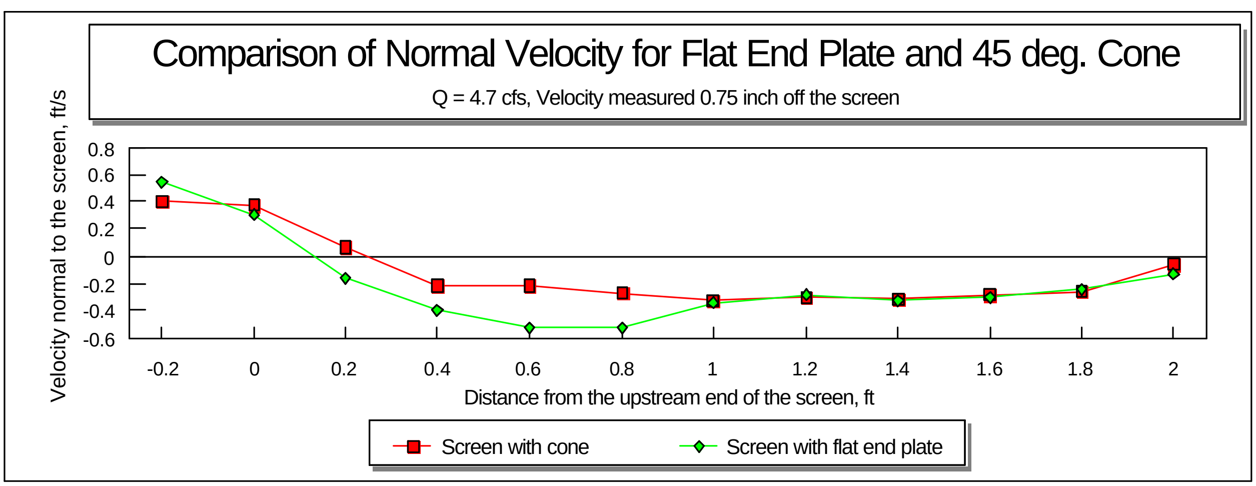

Figure 11 - Comparison of approach velocity normal to the screen for a flat end plat and a 45 degree end cone.