LABORATORY STUDIES OF A NONTRAVELING BAR SCREEN FOR GUIDING JUVENILE SALMONIDS OUT OF TURBINE INTAKES

by
Thomas E. Ruehle
Clifford W. Long
Michael H. Gessel

July 1978

CZES

LABORATORY STUDIES OF A NONTRAVELING BAR SCREEN FOR GUIDING JUVENILE SALMONIDS OUT OF TURBINE INTAKES

by

Thomas E. Ruehle

Clifford W. Long

and

Michael H. Gessel

Final Report of Research

Financed by
U.S. Army Corps of Engineers
(Contract No. DACW57-77-F-0071

and

NOAA
National Marine Fisheries Service
Northwest and Alaska Fisheries Center
Division of Coastal Zone and Estuarine Studies
2725 Montlake Boulevard East
Seattle, Washington 98112

July 1978

CONTENTS

INTRODUCTION

Since 1975 the National Marine Fisheries Service, (NMFS) under contract to the U.S. Army Corps of Engineers, has been conducting a research program to develop an improved fingerling protection system for use at Bonneville, McNary, and other Corps of Engineers' Dams on the main stem of the Columbia and Snake Rivers. A portion of this study called for developing a nontraveling screen (bar screen) that could be substituted for the expensive submersible traveling screen presently used to guide fish out of turbine intakes and into gatewells.

The research approach was to conduct preliminary studies of bar screens under controlled laboratory conditions to aid in designing a prototype fish-guiding bar screen for field evaluation. In these initial studies, we were first concerned with whether fish could be guided without incurring significant descaling or mortality. Second, we needed to know if debris would accumulate on the screen and present a significant problem.

A special oval flume was constructed at the Pasco Biological Field Station for these tests. Test apparatus installed in the flume provided measures of the effect of varying screen configurations on fish and debris. This report describes the results of these studies.

METHODS AND PROCEDURES

CONCEPT OF PROTOTYPE BAR SCREENS

Figure 1 shows our concept for employing nontraveling screens in a turbine intake that should enable us to divert 70 to 80% of the fingerlings entering an intake up into the gatewell. The bar screen attached to the trash racks would intercept fish traveling at lower elevations and divert them up into flows at higher elevations. These fish, along with the fish already contained in the upper flows, would be intercepted by the second bar screen and diverted up into the gatewell.

The use of nontraveling screens for guiding fish has been of concern in the past because of the likelihood of fish incurring damage by impinging on or contacting with the screen and the gradual occlusion of such a screen due to accumulations of debris. We believed that such problems might be sufficiently mitigated by: 1) constructing the screen to eliminate cross members at the screen face; 2) employing very shallow guiding angles (the angle between the direction of flow and the face of the screen); 3) maintaining free egress for debris at the terminal end of the screen by providing a gap between the screen and the vertical barrier wall; and/or 4) backflushing the screen as needed to remove debris.

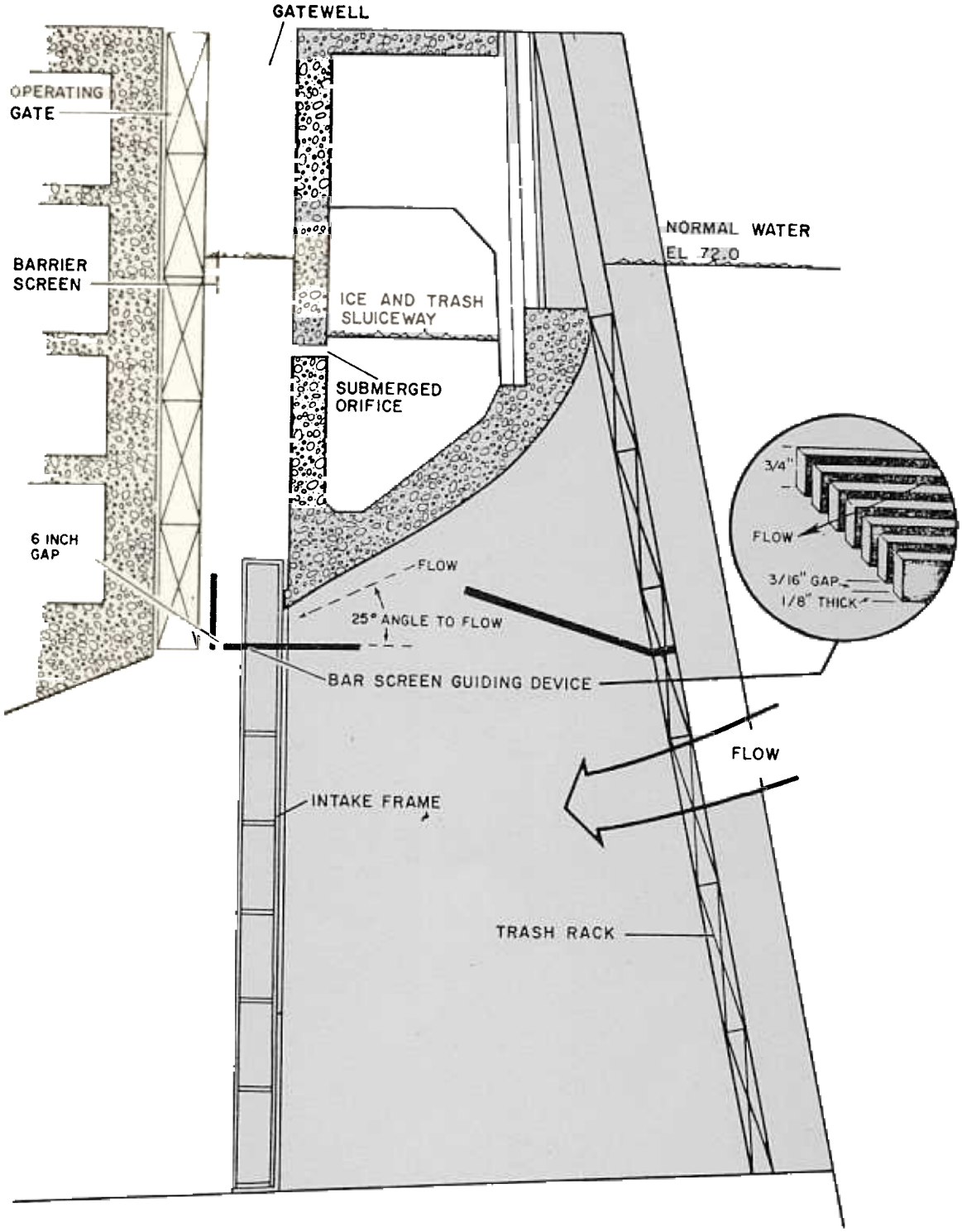


Figure 1.--Conceptual deployment of bar screens in turbine intakes to divest fish into gatewells.

TEST APPARATUS

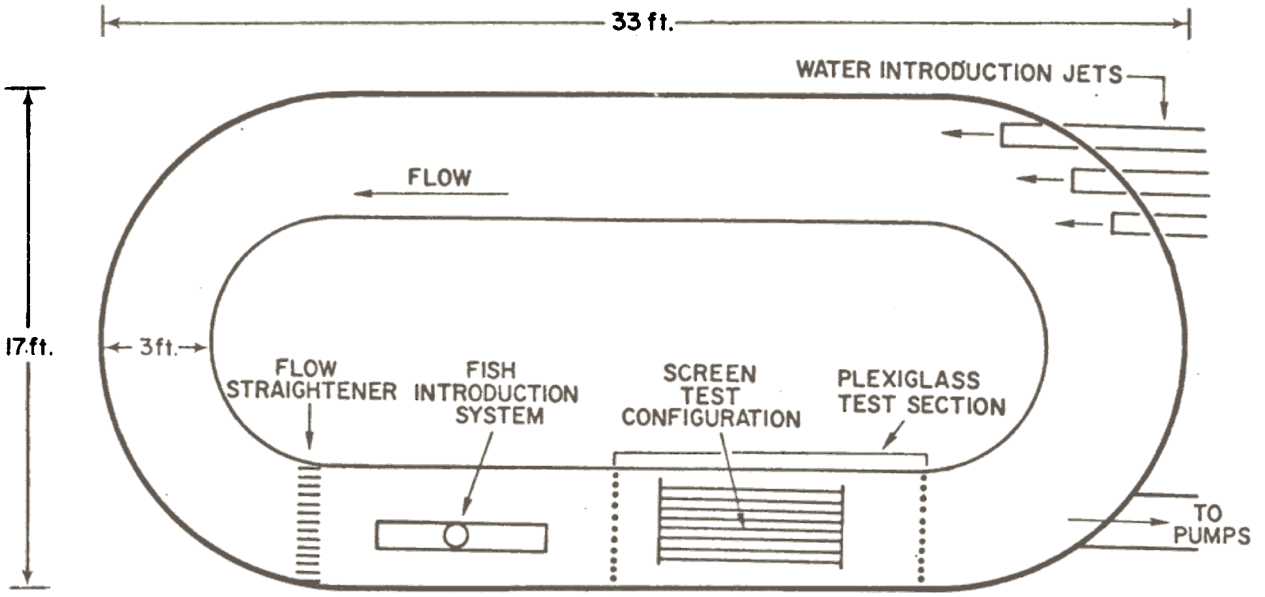
The oval flume in which these studies were conducted was 3 feet wide and 7 feet deep. It was constructed with two straight sections, each 16 feet long, connected with two semicircular sections (Figure 2). A 6-foot length of the downstream end of one straight section was constructed entirely of clear Plexiglass[1/] and served as the test area. Three pumps provided the capability of recirculating water in the flume at velocities up to 8 feet per second (fps).

Two basic test configurations were employed in the test area. For measures of fish descaling, impingement, and rate of escapement, we installed a bar screen leading to a simulated gatewell entrance (Figure 3-A). For debris studies, the simulated gatewell entrance was removed (Figure 3-B).

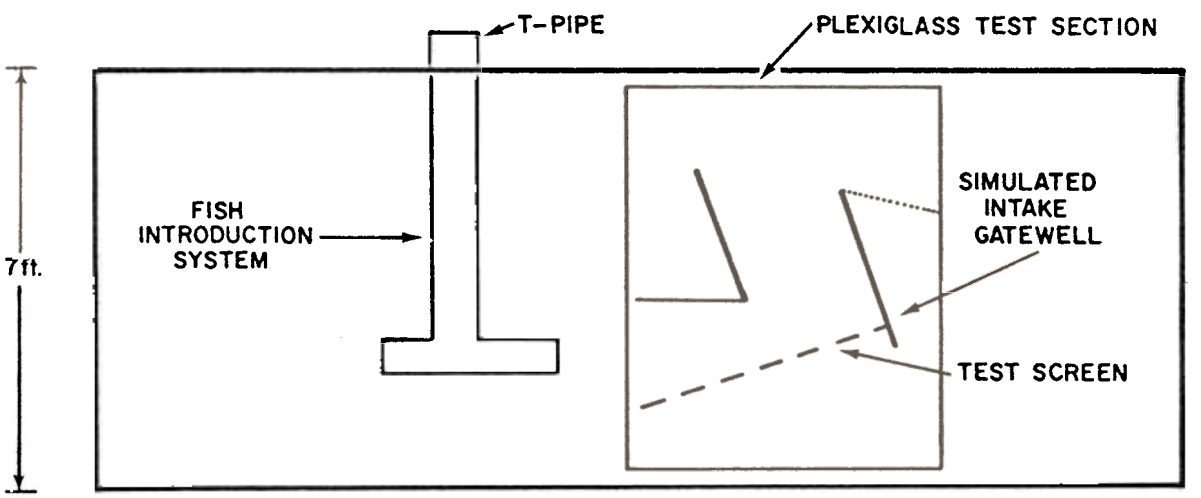
For both test configurations, fish or debris was introduced upstream from the test area by means of 6-inch diameter tubing (Figure 2). The downstream end of the tube terminated within 6 to 12 inches of the floor of the flume to ensure that the fish or debris was confronted with most of the length of the test screen.

When the structure simulating the gatewell was employed, the top of the vertical barrier wall was adjusted to allow 23 to 32% of the water to flow up into the gatewell and over the top of the vertical barrier wall. This simulated the condition at Bonneville Dam where 70 to 90 cfs was flowing up and through the gatewell.

1/ Reference to trade names does not imply endorsement by National Marine Fisheries Service, NOAA



PLAN VIEW



ELEVATION

Figure 2.--Oval flume showing relative location of fish introduction system and test screen position.

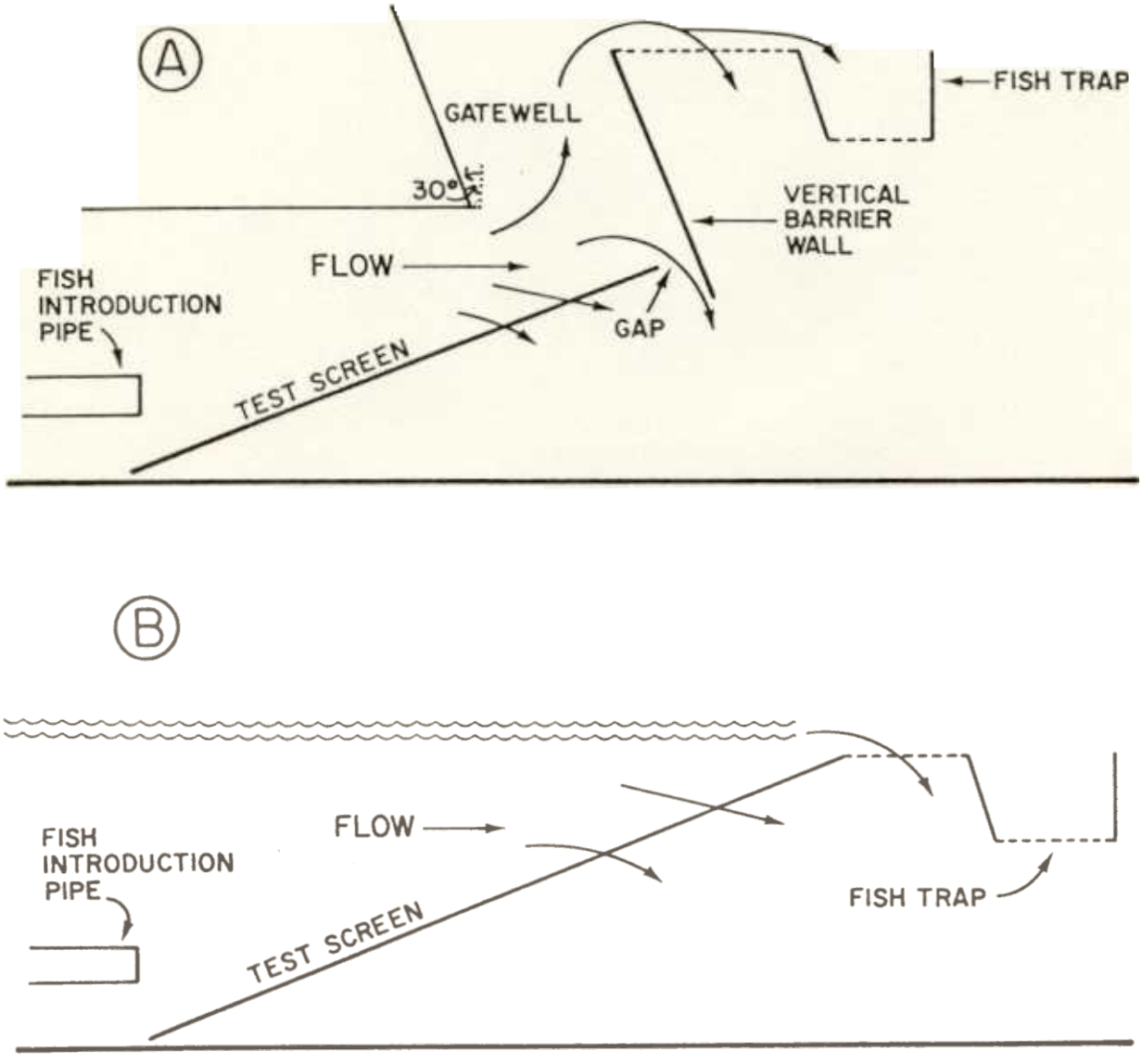


Figure 3.--(A) Configuration of test screen and simulated gatewell in oval flume used to measure fish descaling, impingement, and escapement through gap. (B) Configuration of test screen in oval flume used to measure debris accumulation.

Screens tested included a flat bar screen designed by NMFS; a commercially manufactured bar screen (hereafter termed Johnson screen); and a standard screen of crosswoven mesh (similar to that used on existing traveling screens).

The flat bar screen tested was constructed of flat steel bars inch thick and 3/4 inch wide, placed on the narrow edge with set interspaces and fastened to 5/16 inch diameter round rods set 8 inches apart. interspaces between the bars were varied to produce overall open areas of 33, 50, and 60%. Theoretically, the face of such a screen should cause less damage to fish and pass debris more readily than standard screens of crosswoven mesh.

The Johnson screen differed from the flat bar screen in that the bars were triangular in cross section. Each bar was 0.15 inch wide (at the screen face) and was spaced 0.06 inch apart for an estimated open area of 40%. Round 1/2 inch diameter rods spaced 3 inches apart provided support.

EXPERIMENTAL PROCEDURE

Rates of descaling and impingement were measured on fish subjected to a flat bar screen abutted against the vertical barrier wall. Variables tested included: screen lengths of 6 feet and 10 feet; open areas of 33, 50, and 60%; screen angles of 20, 22, or 25 degrees to the direction of flow; and water velocities of 2.1 or 3.5 fps.

Groups of 18 to 46 undescaled fish were selected for each test After testing, fish were examined and classified as being descaled or not descaled. Descaling was determined by assessing the loss of scales in each of 10 equal surface areas (5 areas per side) on the fish. Any fish which had lost 15% of their scales as determined by averaging the percent scale loss across the 10 scale areas was classified as descaled.

In a second series of tests, we adjusted the test bar screen so that it did not abut against the vertical barrier wall. The resulting gap would, hypothetically, allow debris to wash off the screen and through the gap. The danger, of course, was that significant numbers of fish would escape—as was the case with the initial gap opening tested (Figure 3-A). Efforts to reduce this escapement resulted in the development and testing of the four additional gap configurations shown in Figure 4. We also created both light and dark conditions in the test area to determine if either condition was beneficial in reducing fish escapement.

For measuring debris accumulation on screens, the structure used to simulate the gatewell was removed from the oval flume. Tests were conducted to determine the percent of debris that would accumulate in accordance with screen design and angle of screen to flow. The flat bar screen with 50% open area and the Johnson screen with 40% open area were compared with the standard crosswoven screen having a 60% open area Angles of screen to flow ranged between 15 and 27°

Primarily we used sphagnum moss, but in some tests we employed dead Russian thistle broken into pieces 2 to 4 inches in length. Prior to testing, all debris was soaked until waterlogged (negatively buoyant). Excess water was removed by vigorous shaking and the amount of debris to be used in a test was weighed. After completion of a test, the debris remaining on screen was recovered, the excess water was removed by vigorous shaking and debris was weighed. The data were expressed as the percent of the original debris (by weight) retained by the bar screen at the end of a test.

We also examined one method of intermittently removing accumulated debris by mechanical manipulation of the screen. This method requires that the entire screen be rotated so that the water flow is used to backflush the screen. For these tests, we merely raised the leading edge of the test screen while the terminal edge rotated but remained at the same elevation.

RESULTS

IMPINGEMENT AND DESCALING

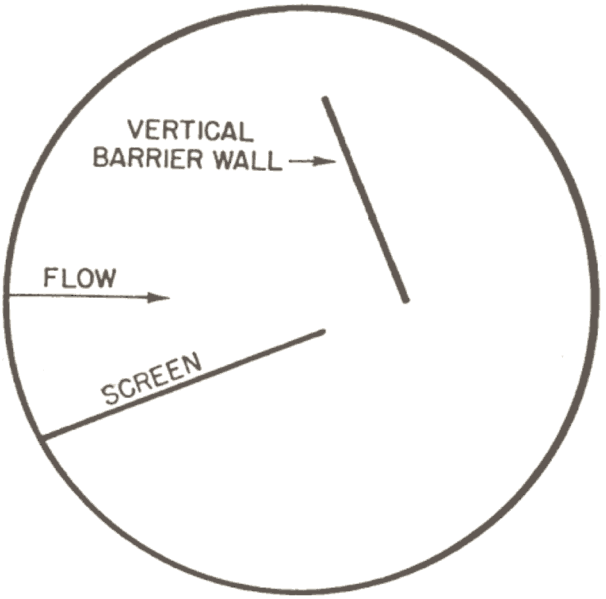
Results from most tests showed that impingement and descaling were low for velocities of approach from 2.0 to 3.5 fps, screen angles from 20 to 25° to flow, and screens with open areas of 33 to 60%. Impinged fish were found in only 2 of 33 tests; and in these two tests, only 2 and 4% of the fish were impinged. Descaling ranged from 0 to 19%, with an overall average of 4.3% (Table 1).

ESCAPEMENT

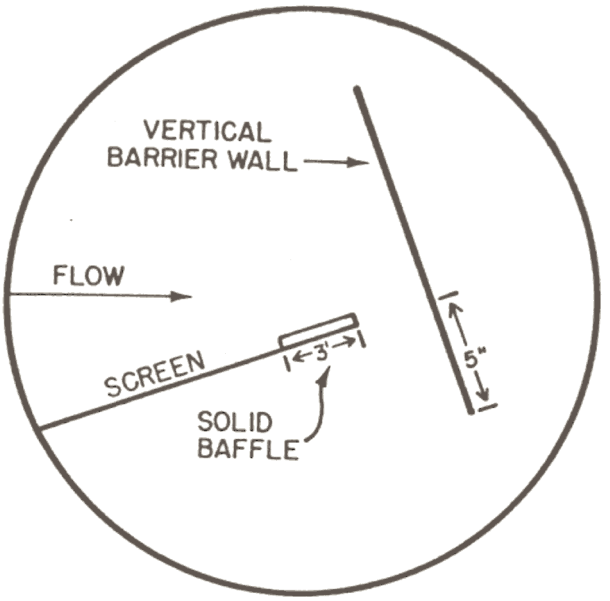
The initial test configuration with a gap between the terminal end of the bar screen and the vertical barrier wall (Figure 3A) resulted in an escapement of 23 to 78% of the fish. Escapement with the four other designs tested ranged from 0 to 90% (Figure 4). Elimination of escapement

Table 1.--Numbers of juvenile salmonids descaled on 33, 50, and 60% open area flat bar screens.

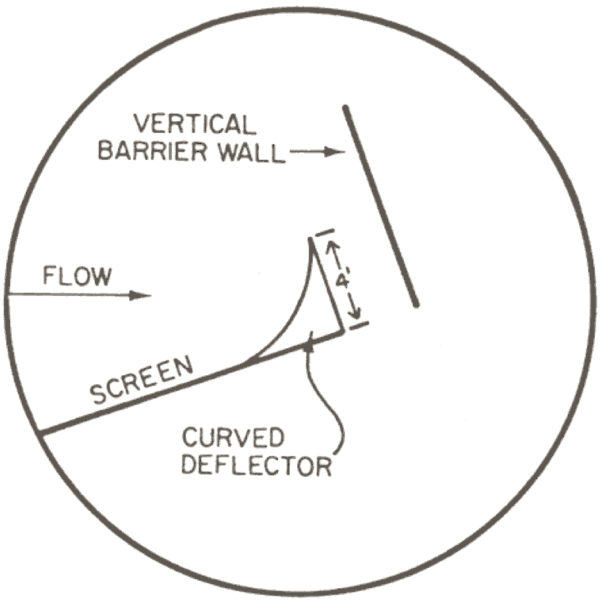
Open Area of Scoop (%)	Scoop Length (ft.	Water Velocity (fps)	Angle of Scoop to Flow (o)	Fish Examined (No.	Fish Descaled (%)
33	6	3.5	22	45	0.0
	"		"	46	
"	"	"		44	
"	"	"	"	46	
"	"		"	20	
"	"		"	46	2.2
				AVERAGE	
60	6	3.5	25	31	
	"		"	42	
		"		25	
			"	28	0.0
				AVERAGE	
50	10	2.1	20	20	
	"	"		18	
		3.5	"	20	15.8
				AVERAGE	
				Overall increase	



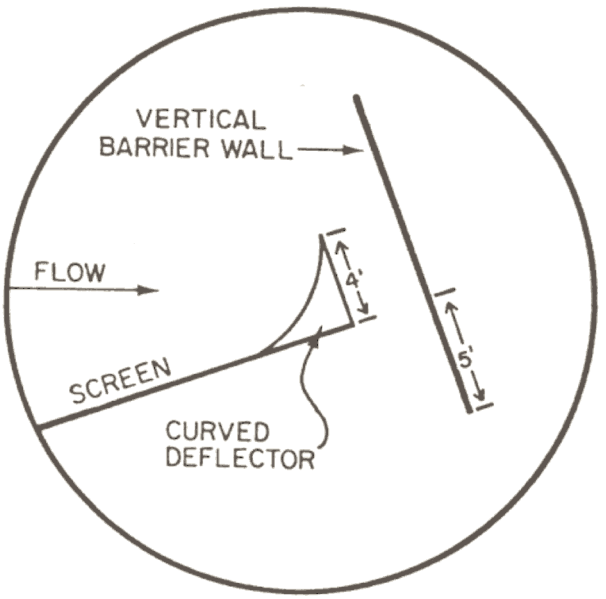
A. Escapement = 67.3 to 90%



B. Escapement = 58.0 to 68.9%



C. Escapement = 51.4 to 64.0%



D. Escapement = 0.0%

Figure 4.--Variations in the junction of the bar screen and vertical barrier wall tested to reduce escapement of fish through the gap. Elimination of escapement was achieved with configuration D.

was achieved with a 4-inch curved deflector in conjunction with the trailing edge of the bar screen raised above the downstream edge of the vertical barrier wall (Figure 4D). Escapement was eliminated whether the tests were conducted in light or darkness.

ACCUMULATION OF DEBRIS

Tests with the 50% open area flat bar screen showed there was a gradual increase in the amount of sphagnum moss collected as the screen's angle to flow was increased (Figure 5). Results with Russian thistle as the debris were similar. Regardless of angle, the flat bar screen collected less debris than either the 40% open area Johnson screen or the 60% open area woven-wire screen (Figure 6).

For those conditions which resulted in a significant collection of debris upon the face of the bar screen, the backflushing technique was tested. Reversal of water flow through the screen for 10 seconds was sufficient to remove virtually all of the debris

CONCLUSIONS

Information obtained from tests with fish and debris in the oval flume justifies additional studies to measure guiding potential of a prototype nontraveling screen in a turbine intake gatewell. The optimum configuration that minimizes descaling of fish and accumulation of debris appears to be a flat bar screen of 50% or greater open area with a curved deflector at the terminal end. Screen angle to direction of flow should not exceed 20° and the screen should be positioned so that the terminal end is raised above the downstream edge of the vertical barrier wall. Whether this configuration would also successfully guide fish out of intakes into gatewells, could not be determined from tests in the oval flume, but must be tested in the prototype.

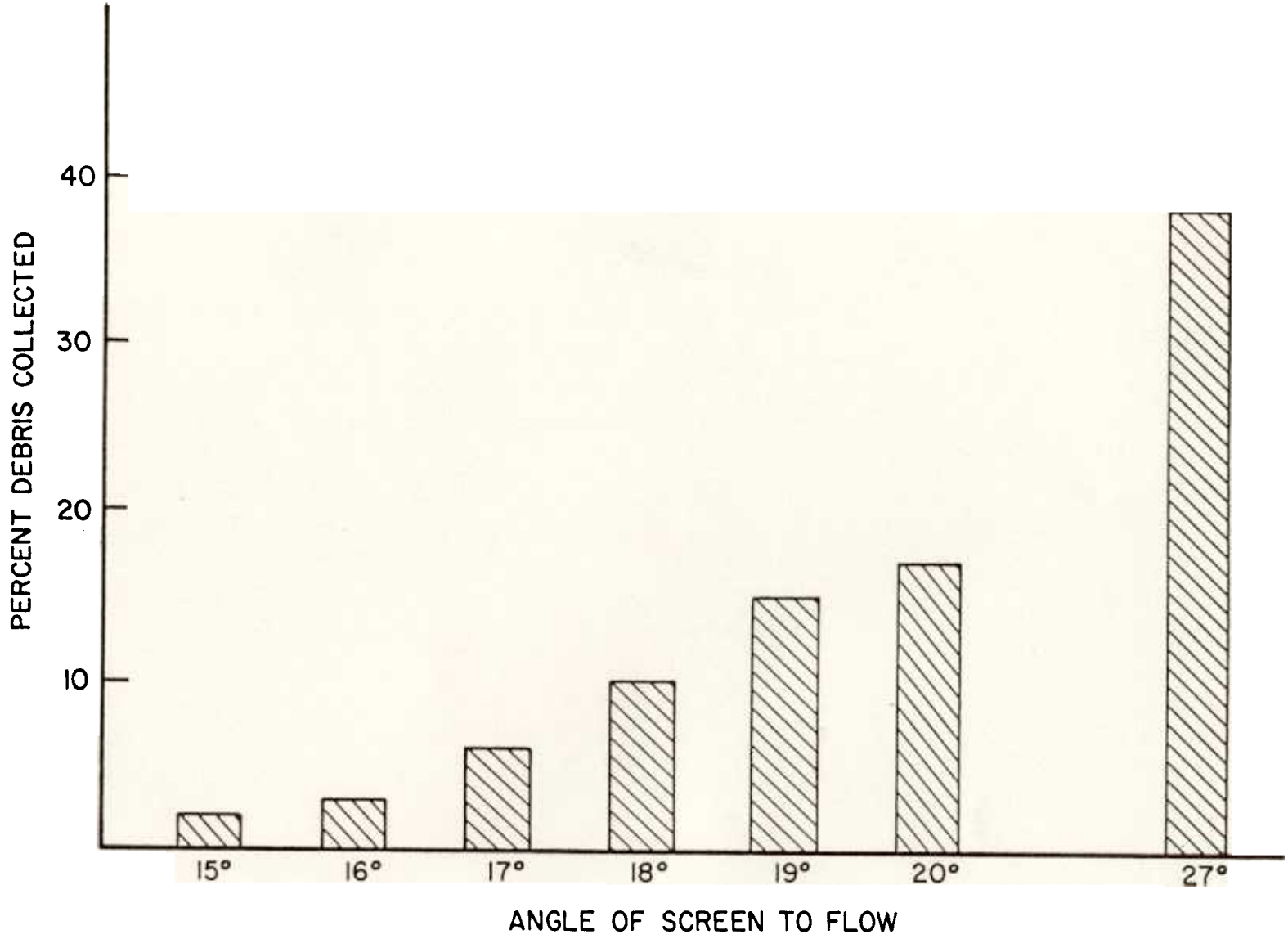


Figure 5.--Collection of sphagnum moss on the standard flat-bar screen having an open area of 50%.

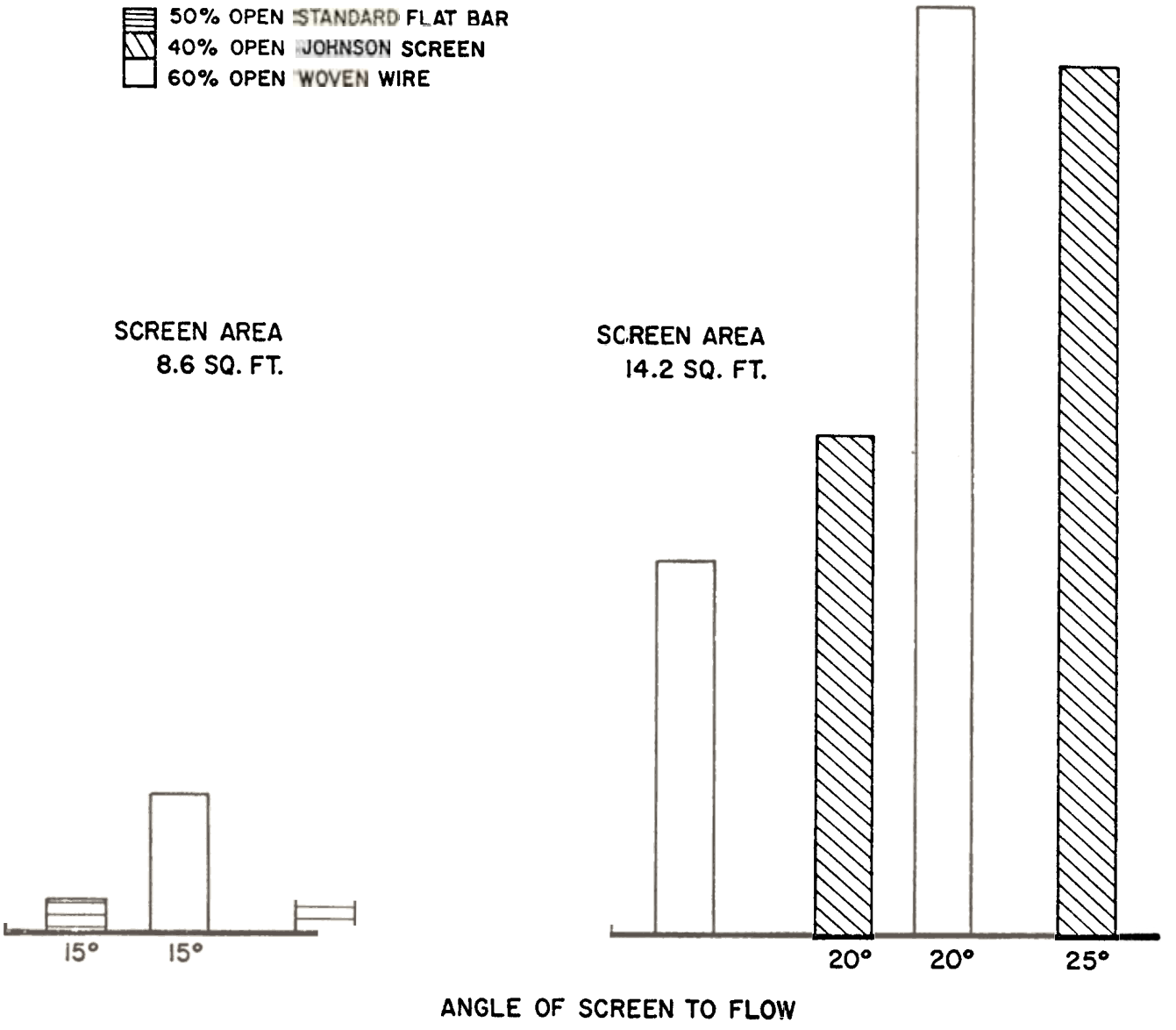


Figure 6.--Collection of sphagnum moss or Russian thistle on three types of screens.