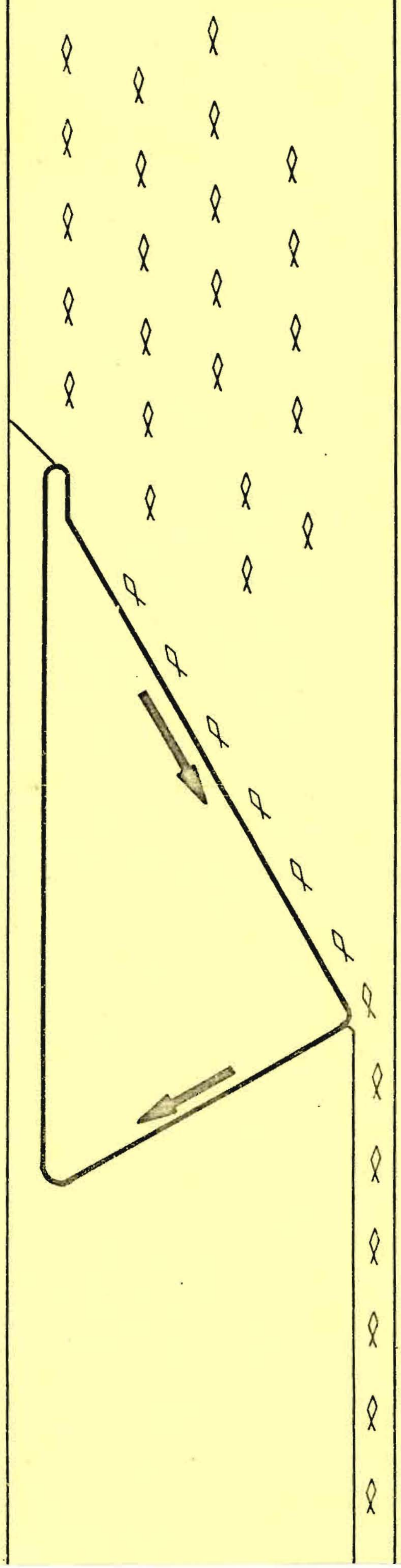

SUMMARY REPORT

MECHANICAL OPERATION OF HORIZONTAL TRAVELING SCREEN MODEL VII

By

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INTRODUCTION

The design of Horizontal Traveling Screen (HTS) Model VII was based on information from work done by the National Marine Fisheries Service (NMFS) on six previous traveling screens (Bates, 1970; Bates, Murphy, and Prentice, 1970; Bates and Vanderwalker, 1970) while attempting to devise a system to safely divert young salmon, Oncorhynchus spp., and steelhead trout, Salmo gairdneri, away from hazardous areas in channels and rivers of the Pacific Northwest. Horizontal screening was proposed for use in water of higher approach velocities than is normally possible with other types of screening installations. At the conclusion of the earlier developmental work, a functional structure for field evaluation (Model VII) was designed by a consulting engineer and fabricated by Rex Chainbelt Co.[1] of Milwaukee, Wisconsin, under contract to the NMFS.

Considerations for possible adaptation of the Model VII design in a prototype situation required that a full examination be made of the mechanical operation to assess performance and limitations. These studies were made in the spring of 1972 concurrently with biological tests to determine guiding efficiency and physical effects on fish. During observations, the screen was in operation for 1,050 hours and traveled about 1,000 miles at speeds of 1.34 to 4 fps.

This report describes the mechanical and hydraulic aspects of HTS VII; the biological observations are covered in a separate report.

GENERAL DESCRIPTION OF THE SCREEN AND ASSOCIATED STRUCTURES

Figure 1 depicts the envisioned method of installing a horizontal traveling screen with the triangular configuration. Figure 2 is an overall view of HTS VII as installed in a large hydraulic test flume located on the Grande Ronde River near Troy, Oregon. The traveling screen consisted of a series of curvilinear panels set in frames connected together in a vertical position (Figure 3) and attached at the top to carriage wheels that traveled on an "I" beam track (Figure 4). The carriage wheels were attached to an endless chain driven by an electric gear drive that provided power to move the panels horizontally around the triangular configuration. The screen panels were 1 ft 7 inches x 6 ft 3-1/2 inches and were set in a metal frame. Forty-eight screen panels and frames were linked together to make the endless screen structure. The upstream leg was 32 feet long, the downstream leg 15 feet, and the return leg 36 feet (excluding length in turns).

The support system consisted of a main beam of square tubing to which the "I" beam was attached to provide a support for the carriage wheels. The carriage wheel track was covered with a vinyl material to reduce the noise generated by the carriage wheels.

The screen panels (Figure 5) were set in a frame and were hinged on the trailing edge in a manner that allowed the panels to open when the water pressure was sufficient to overcome tension on the springs. The tension springs (Figures 4 and 6) were attached at the top of each screen

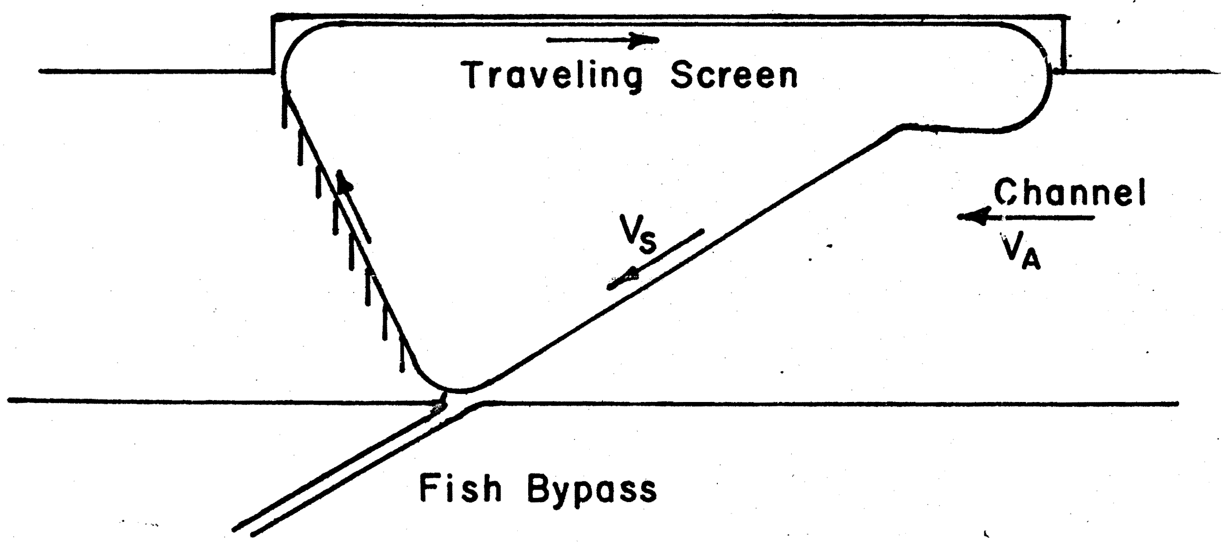

Figure 1.--Proposed horizontal traveling screen installation.

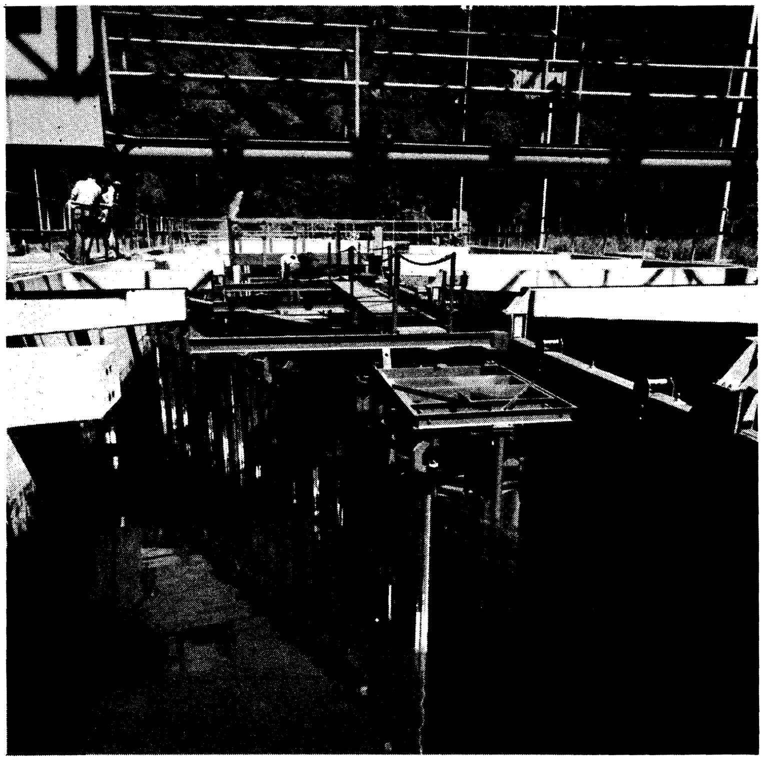

Figure 2. --General view of traveling screen as installed near Troy, Oregon. (Bureau of Reclamation)

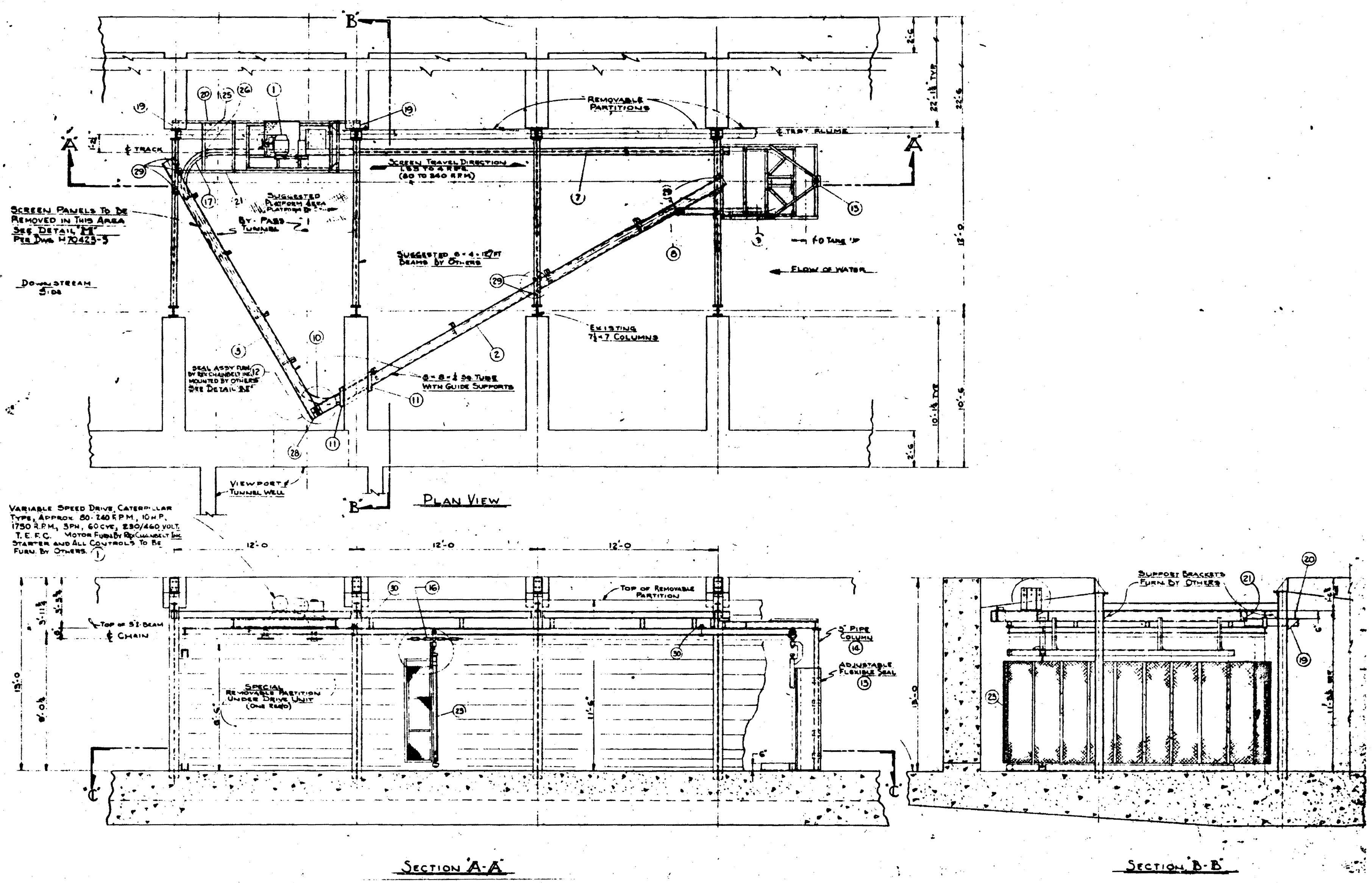

Figure 3.--Plan and elevations of traveling screen installed near Troy, Oregon.

Figure 4. --Front view of screen assembly (Bureau of Reclamation)

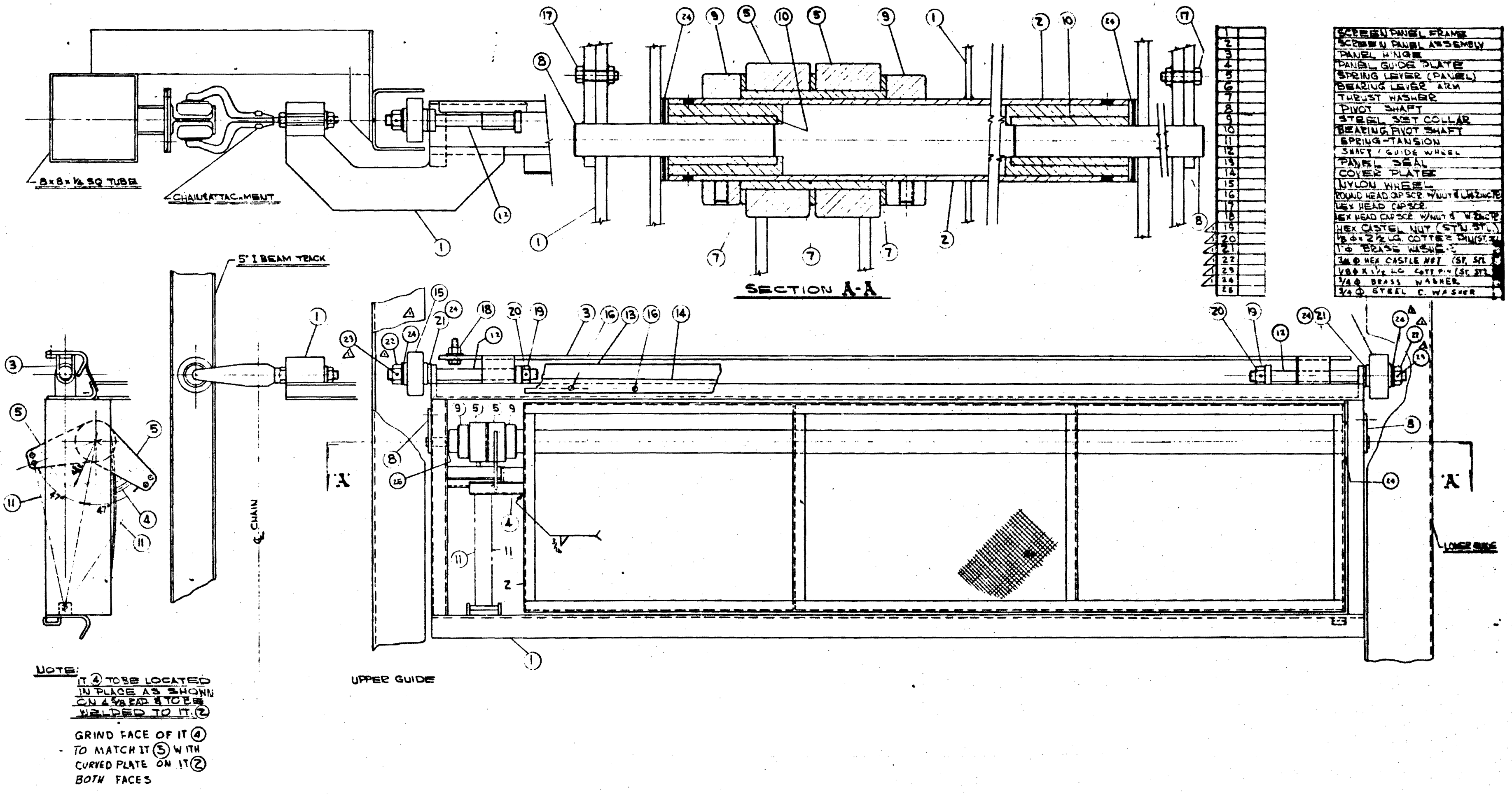

Figure 5. -- Details of screen panel and frame.

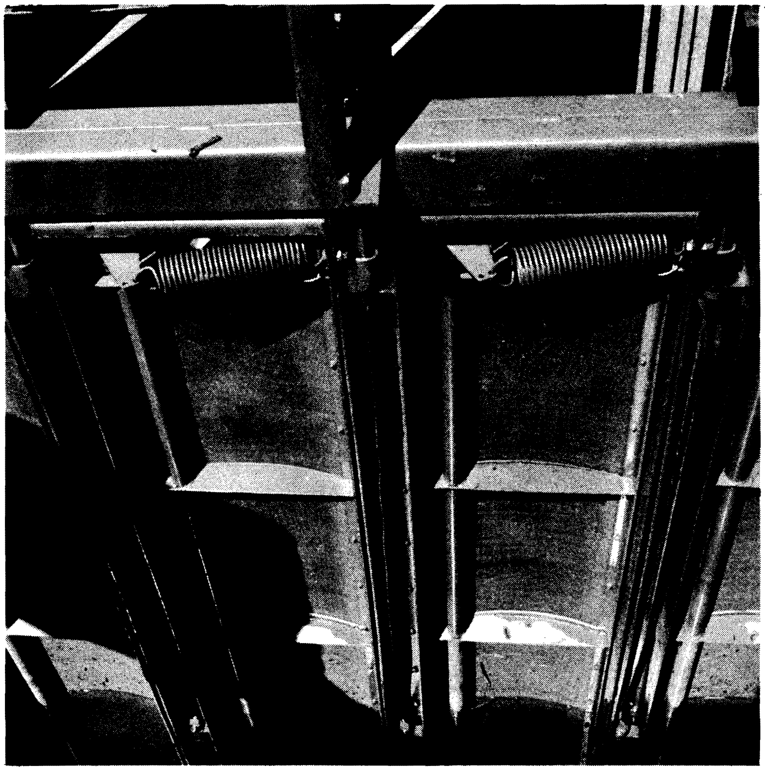

Figure 6. -- Back view of screen assembly (Bureau of Reclamation)

panel to return the screen panel to its operating position when the water pressure was relieved.

The screen on the panels was 8- x 8-inch mesh and made of 0.028-inch diameter galvanized wire which provided 0.097-inch clear opening per mesh and 60.2% net open area for the screen. Figure 7 shows the net open area for water passage on the upstream leg of the facility at different depths of water. Nylon wheels (Figure 8), attached to the top and bottom of the panel frame and traveling in "U"-shaped guides, carried the horizontal load on the structure. The upper guide was supported by the main beam and the bottom guide was anchored to the concrete floor of the flume. The screen panels were supported by two steel carriage wheels (one on each side of "I" beam track) for each of 48 frames; each wheel had a zerk fitting for lubrication.

A 10-hp (1,750-rpm, single-phase, 60 cycle), 220-volt electric motor supplied power to a variable speed (80-240 fpm), caterpillar-type drive situated on the downstream end of the return leg (Figure 9).

Power was transmitted to the screen panels through a standard drive chain that was connected to each frame. A special hanger was used to connect the frame to the drive chain.

Proper tension of the drive chain was accomplished by means of a special adjustment section located on the upstream end of the facility (Figure 8).

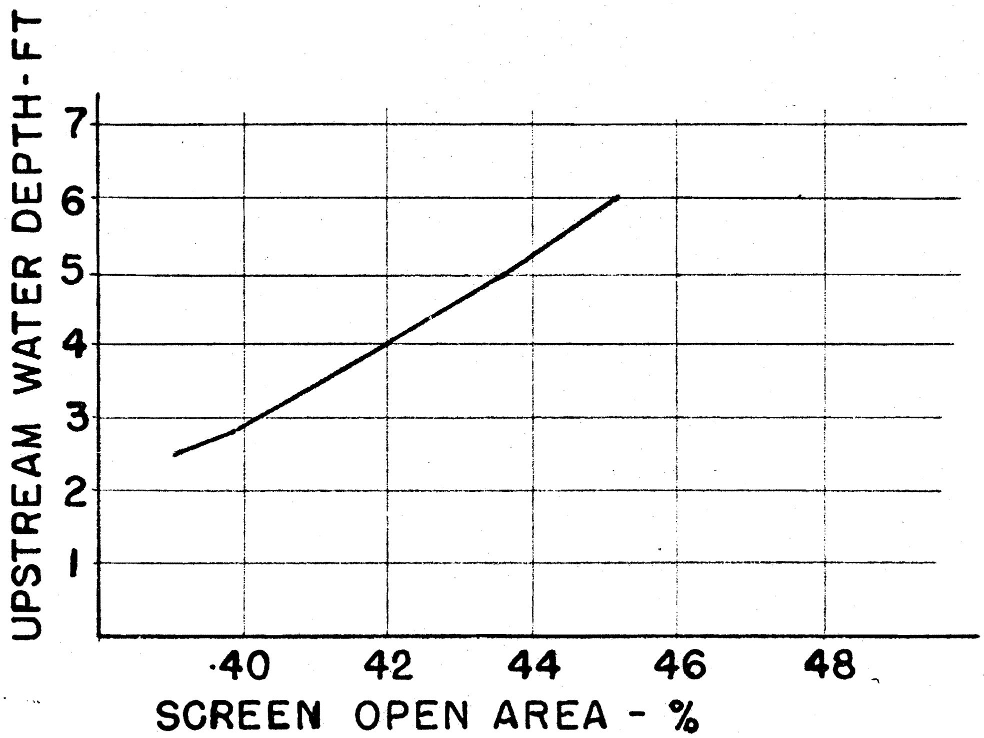

Figure 7.--Percentage of open area on the upstream leg of traveling screen in relation to water depth at screen.

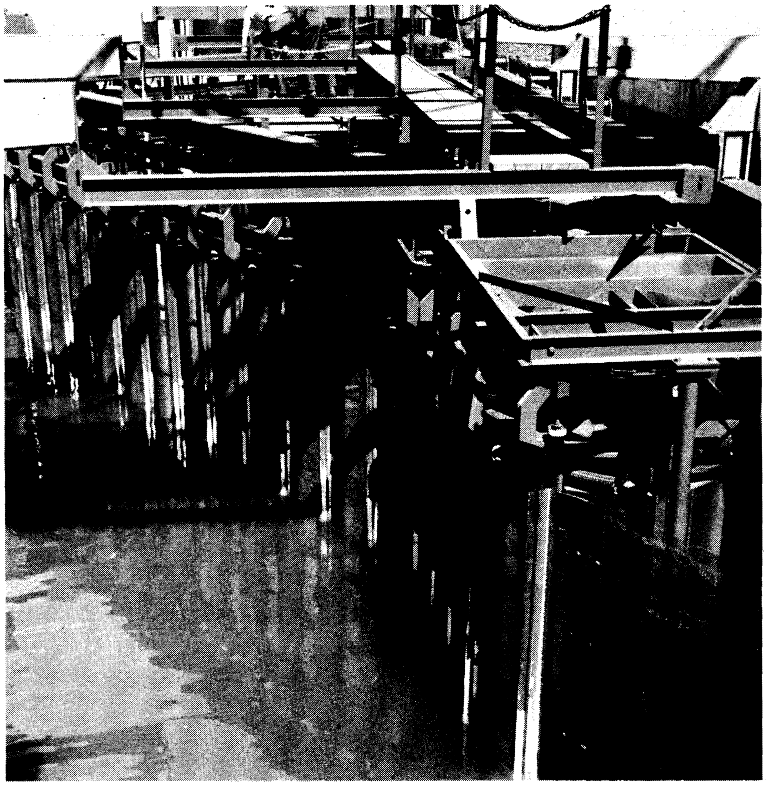

Figure 8. --Upstream view of traveling screen assembly. Black arrow indicates chain adjustment section, white arrow--upper nylon wheel.

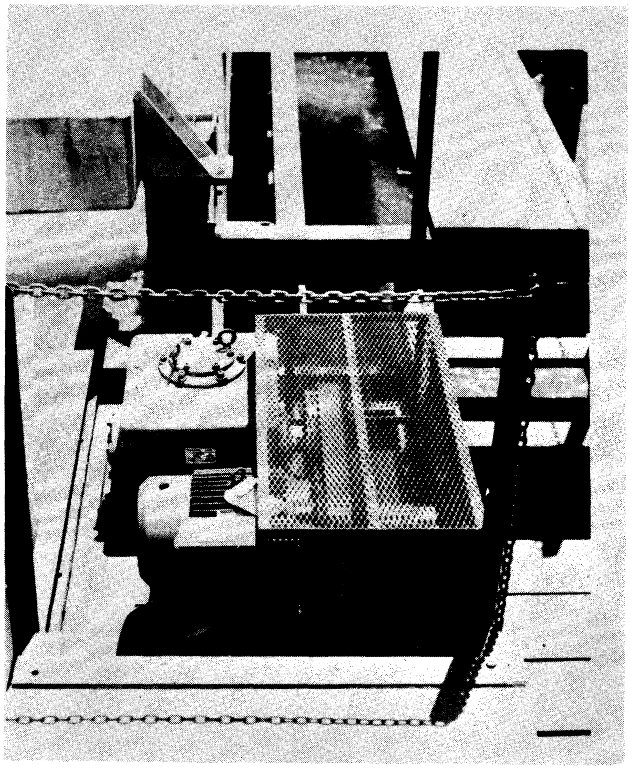

Figure 9.--Screen drive unit.

MECHANICAL AND HYDRAULIC OBSERVATIONS

Measurements and observations on the mechanical and hydraulic features provided information on head loss, stress loadings, wear, horsepower requirements, gravel movement, bypass conditions, and the overall operation.

Head Loss

Head loss or gain is the difference in water surface elevation from a point upstream to a point downstream in the flume. Head differences were determined from point gages placed as six locations in the vicinity of HTS VII. Table 1 lists the gage readings for water approach velocities up to 2 fps, and Figure 10 shows the location of the point gages.

Because the screen panels were hinged on the trailing edge rather than the leading edge, the head created on the downstream leg by water velocities above 2 fps opened the screen panels excessively and, as a consequence, the panels jammed in the downstream corner as the array turned to begin its upstream traverse. To relieve this condition, the panels were bolted together when tests were made with water approach (channel) velocities higher than 2 fps.

Total head loss (between points 2 and 5) was not significant (less than 0.15 feet) up to about 1.5 fps approach velocity. Above 1.5 fps the total head loss increased rapidly (Figure 11). An example of head loss across the downstream leg appears in Figure 12. Total head loss across the structure was considerable at the higher approach velocities (i.e., 0.55 ft at 2 fps). The majority of this loss occurred across the downstream leg of the facility.

Table 1.--Velocity and point gage readings at traveling screen installation. See accompanying schematic for location of point gages.

Test	Average water velocity (fps)1/			Point gage readings (ft)2/					
	Vs	Va	Vbp	1	2	3	4	5	6
1	2.06	0.824	--	1.04	1.025	1.005	1.043	0.988	1.023
2	1.80	1.830	--	0.936	0.903	0.702	0.950	0.456	1.029
3	1.85	1.234	1.017	--	--	--	--	--	--
4	1.85	1.526	0.993	1.488	1.486	1.518	1.562	1.444	1.726
5	1.85	1.330	0.896	1.470	1.426	1.444	1.489	1.359	1.557
6	1.80	1.258	0.848	1.285	1.246	1.232	1.330	1.173	1.396
7	1.50	1.258	0.824	1.278	1.233	1.263	1.269	1.194	1.255
8	1.97	1.089	0.896	1.518	1.493	1.496	1.525	1.445	1.523
9	1.97	1.161	0.800	1.460	1.337	1.291	1.342	1.182	1.300
10	1.80	1.968	1.499	1.191	1.179	1.006	1.182	0.640	--
11	1.50	1.354	1.282	1.186	1.162	1.147	1.165	0.993	1.179
12	0	1.209	1.041	1.489	1.476	1.184	1.457	0.855	1.424
13	1.50	2.078	1.554	0.941	0.886	0.738	0.902	0.158	0.922
14	0	2.078	1.609	1.058	0.982	0.796	0.933	0.078	0.937
15	1.50	2.271	1.475	1.200	1.086	1.004	1.128	0.314	1.215

1/ Explanation:
Va = Water approach velocity
Vs = Screen travel speed
Vbp = Bypass water velocity

2/ A reading of 1.500 on a gage indicates 6-foot water depth in the flume; 0.000 indicates a 4.5-foot water depth. Location of each gage is shown in Figure 10.

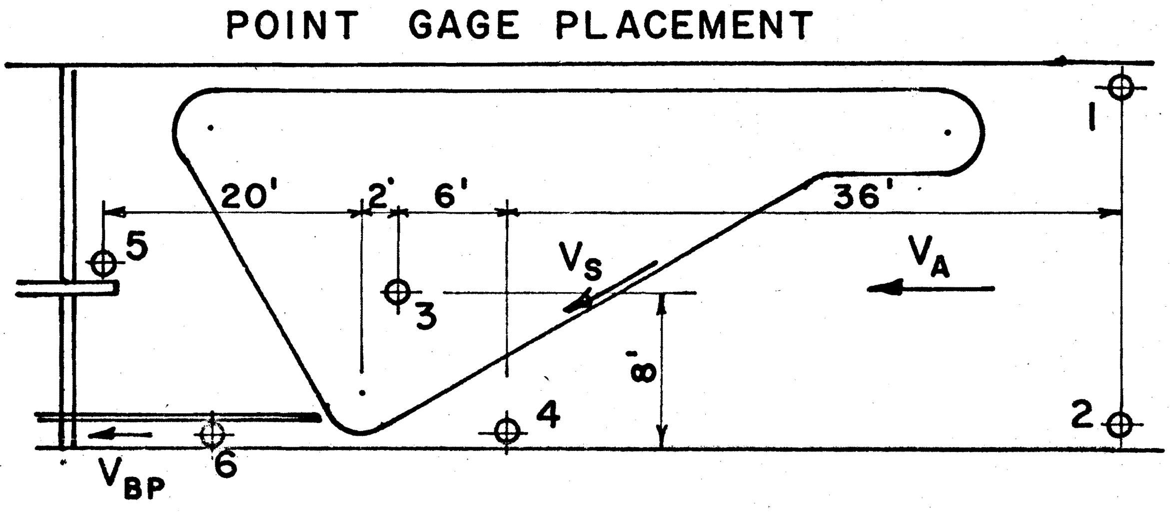

Figure 10.--Location of the six point gages used to measure head loss or gain.

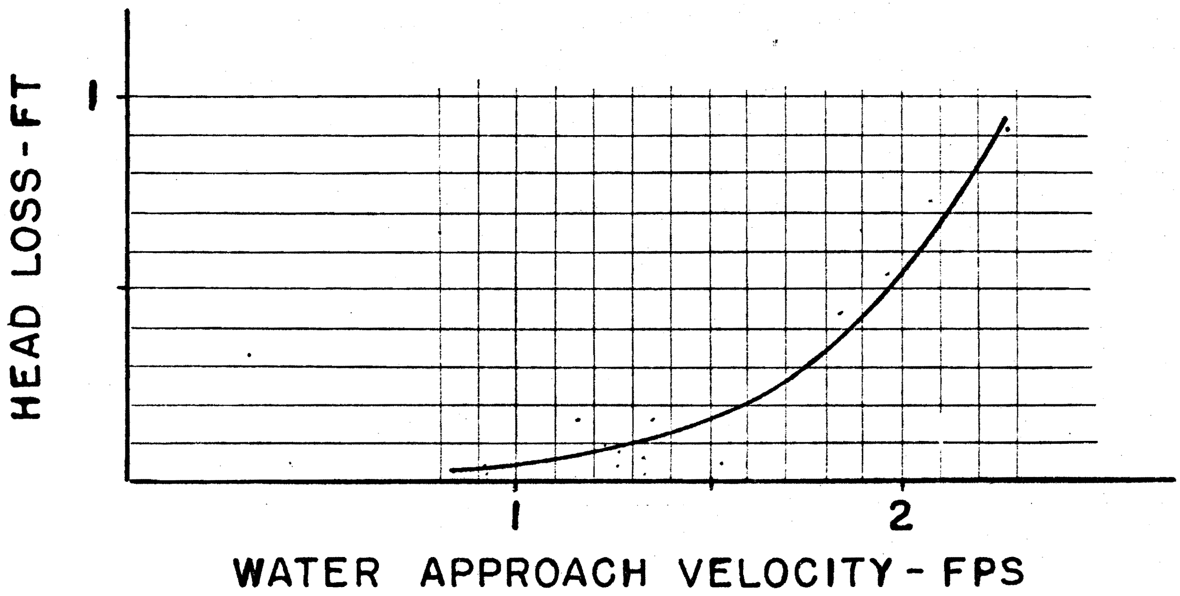

Figure 11.--Relation between approach velocity and total head loss.

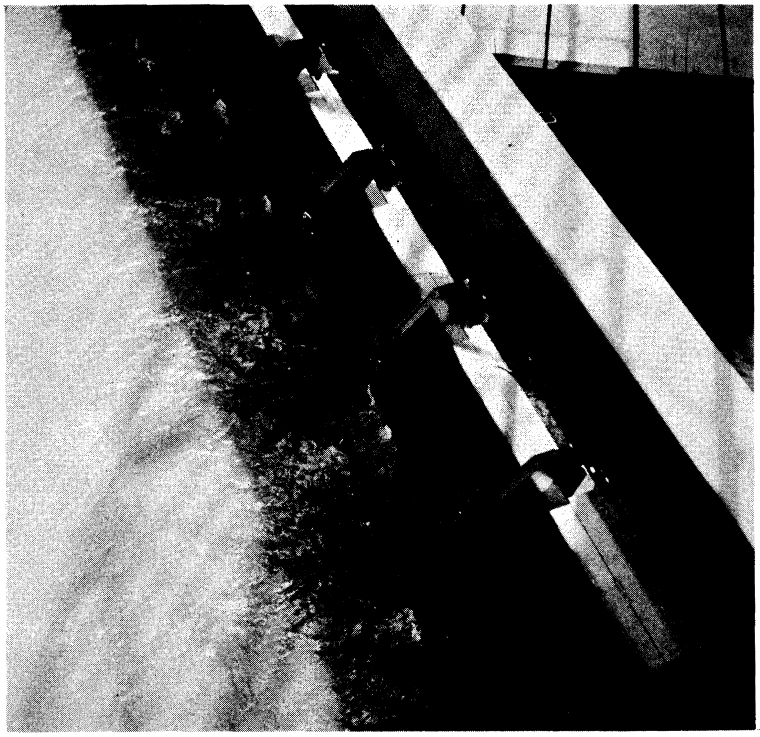

Figure 12.--Head loss at downstream leg of facility. Screen panels closed. (Bureau of Reclamation)

The following description of water flow in the flume and through the upstream and downstream legs of the screening facility will suffice to explain the origin of excessive head loss. Assume the depth of the water in the channel is 5 feet and refer to Figure 13 for dimension orientation.

(a) The cross-sectional area of the water approaching the facility is 14.5 x 5 ft = 72.5 sq ft

(b) Applying the percentage open area in the screen structure (Figure 7), the net opening for water passage in the upstream leg would be 32 ft x 5 ft x 0.437 = 69.9 sq ft

(c) Applying the same percentage for the downstream leg, the net opening would be 15 ft x 5 ft x 0.437 = 32.8 sq ft

From the foregoing, it is evident that the area available for water passage through the downstream leg of the facility will have to be greatly increased in order to reduce total head loss.

Stress Loadings

Strain gages placed on a screen panel provided data on the area of maximum loading. Maximum loading occurred at the downstream corner where the panels turned and began to move upstream. Water typically piled up in that corner and developed the largest head differential and consequently the greatest stress.

Wear

The major point of wear on the structure was in the connection between the screen panel frames. When the screens were first installed, a direct metal to metal sliding contact was used between parts of the screen frames.

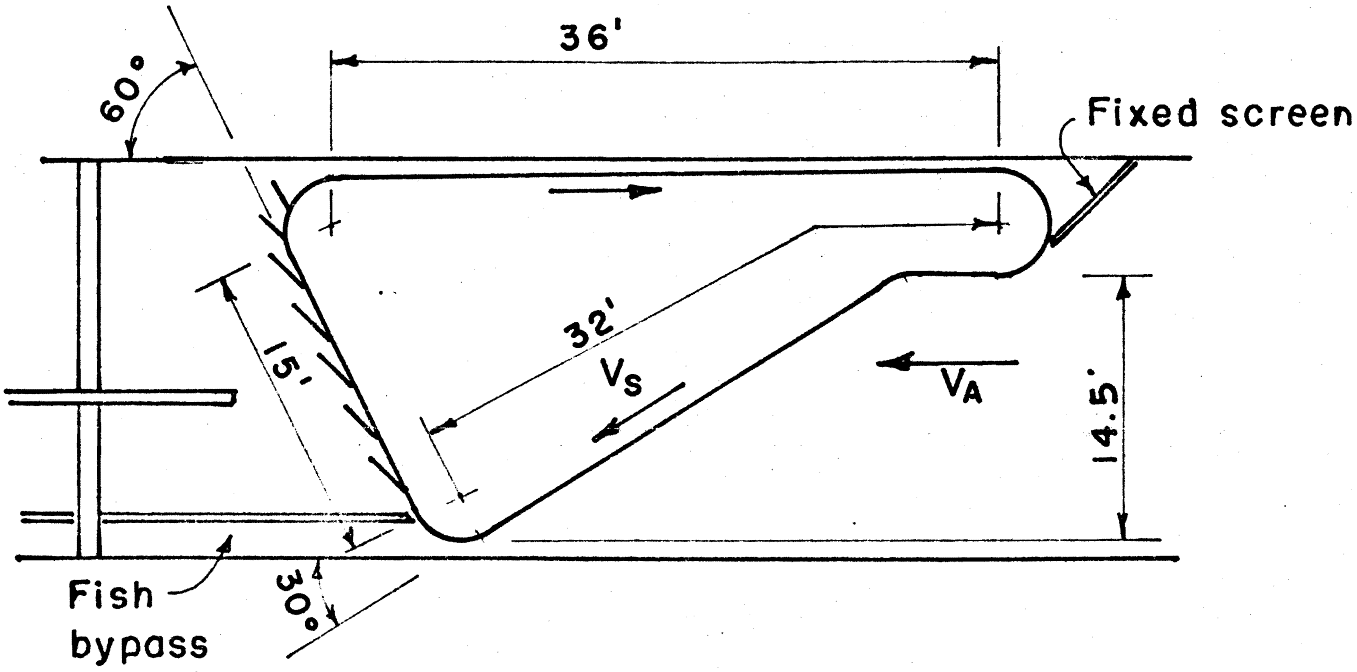

Figure 13.--Plan view of traveling screen installation on Grande Ronde River near Troy, Oregon.

These metal parts were mild carbon steel and, consequently, the rate of wear was rapid. Washers were subsequently installed between the areas of contact and this reduced the wear.

Wear also was evident on all tracks at the turns and was most apparent on the extreme downstream turn. Major wear on the downstream turn occurred because the "U" guides were not extended around the turn.

Horsepower Requirements

Power requirements were calculated using the theoretical voltage and the measured amperage. Table 2 gives the horsepower required to drive the screen under varying conditions. Design loads were evidently less than the measured loads since the power required was more than the power available for operation at the higher screen speeds with water in the channel. Undoubtedly friction was greater than anticipated, which could account for a good part of the discrepancies between design and measured loads. After washers were installed on the screen panel connections, a significant reduction in power requirements was noted (Table 2 and Figure 14).

Debris

Sand, small gravel, straw, hay, sticks, and ice moved past the facility without undue difficulty. In addition to the debris in the water entering the flume, special releases of various types of debris were made. Movement of the wheels in the bottom "U" guides apparently kept the sand and gravel out, but small sticks occasionally would lodge between the bottom of the screen panel frames and the bottom guides. This was not a serious problem, however, and could be eliminated in future designs.

Table 2.--Power requirements for traveling screen in relation to screen travel speed (Vs), water approach velocity (Va), and water depth (D) in flume upstream from facility.

Date (1972)	Vs (fps)	Va (fps)	"D" (ft)	AMP	KW	Apparent horsepower
6/24	1.35	0	0	22.0	4.84	6.49
6/24	1.50	0	0	22.5	4.95	6.63
6/24	2.00	0	0	23.0	5.06	6.78
6/24	2.50	0	0	26.0	5.72	7.67
6/24	3.00	0	0	30.0	6.60	8.85
6/24	3.50	0	0	33.0	7.26	9.74
6/24	4.00	0	0	37.0	8.14	10.92
6/24	4.50	0	0	43.0	9.46	12.68
7/07	1.50	0	0	20.5	4.51	6.05 1/
7/07	2.00	0	0	21.0	4.62	6.20
7/07	2.50	0	0	22.5	4.95	6.64
7/07	3.00	0	0	23.5	5.17	6.93
7/07	3.50	0	0	25.0	5.50	7.38
7/07	4.00	0	0	33.0	7.26	9.34
7/07	4.50	0	0	34.0	7.48	10.03
7/04	1.34	2.52	4.0	20.5	4.51	6.05
7/05	1.54	3.15	4.0	20.5	4.51	6.05
7/08	1.50	3.05	3.6	21.0	4.62	6.20
7/11	1.53	3.00	3.0	23.0	5.17	6.93
7/14	1.34	1.08	0	21.0	4.62	6.20
7/15	1.34	0.91	3.2	20.5	4.51	6.05
7/15	1.34	1.01	0	1.0	4.62	6.20
7/18	1.34	1.11	4.3	20.5	4.51	6.05
7/19	1.50	3.33	0	21.5	4.73	6.34
7/19	1.34	1.08	4.1	22.0	4.84	6.49

1/ Washers installed in sliding screen panel connections on July 7 and applicable to all subsequent calculations of apparent horsepower.

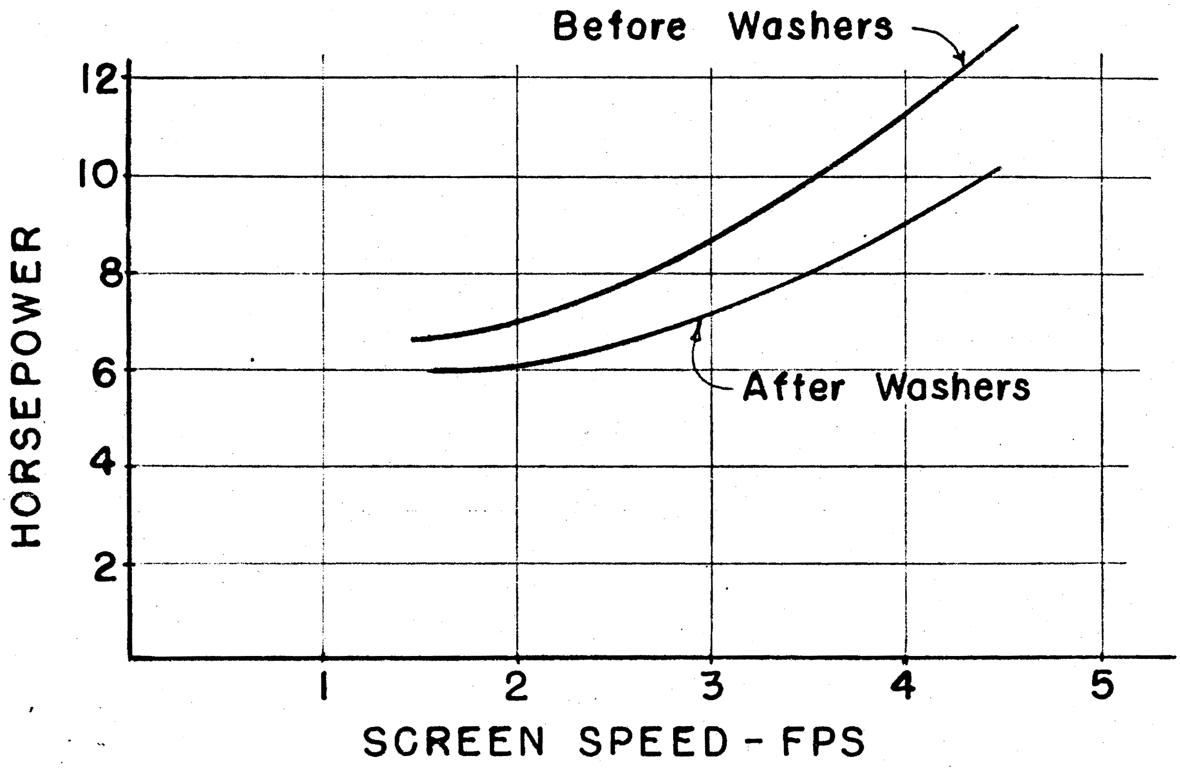

Figure 14.--Power required to drive the screen before and after installation of washers at the panel connections.

General Observations

The following observations apply to the traveling screen as installed in the test flume. Recommendations for improving the mechanical and hydraulic features appear thereafter.

The hydraulic test flume at Troy was adequate for testing the screen structure but lacked flexibility for independent control of bypass water velocities. As a consequence, the ability to regulate flows into the bypass was limited, and the desired condition (increasing velocity at the throat of the bypass) was not always possible.

With the screen panels hinged on the trailing edge (Figures 13 and 15), panels opening in the downstream leg pushed water while the screen was moving. Although tension springs were designed to close the screen panels before the panels negotiated the downstream turn, water approach velocities in excess of 2 fps prevented rapid closure of the panels and they subsequently jammed against the adjoining wall.

Supports for the screen panel frames were designed on 24-inch centers. This is a fixed dimension and wheels that support the screen panel followed a curve around the turns. The difference between the curve length (on the turns) and the straight chord segments--and the necessity of providing a means of tightening the drive chain--required a sliding connection between the screen panel frames. These sliding connections were subject to considerable wear.

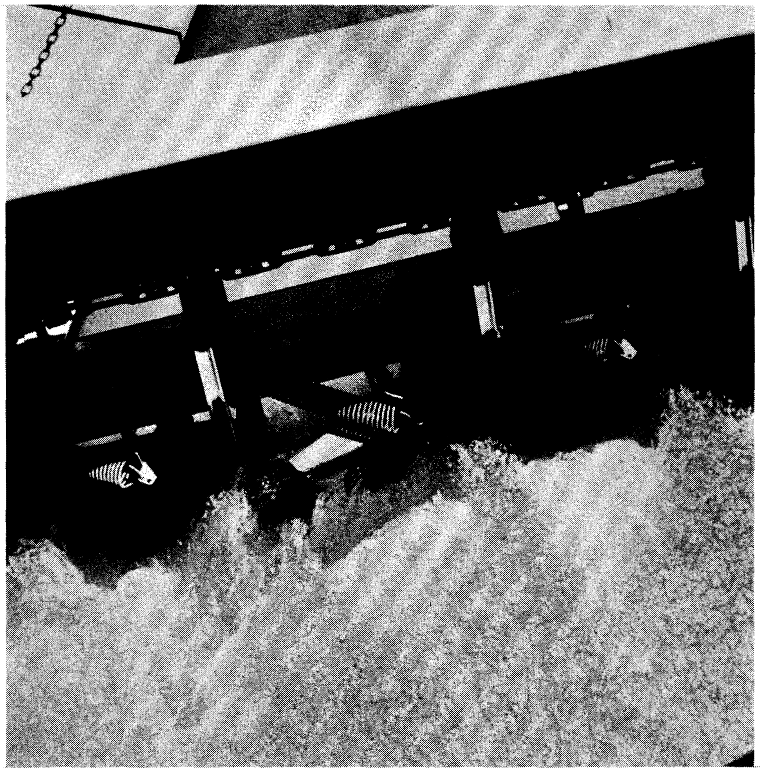

Figure 15.--Panels open on downstream leg (Bureau of Reclamation).

The drive chain and drive assembly appeared to work satisfactorily with one exception: Because the drive assembly was located at the downstream end of the return leg, the chain would tend to go slack as it left the drive sprocket. This slack chain would sometimes drag on the sprocket teeth.

The carriage wheels were standard steel wheels with zerk fittings. Since there were two wheels per screen panel (48 panels), 96 zerk fittings required lubrication. Lubrication of these fittings was obviously impractical while the screen was moving.

Standard bolts and nuts were used for assembling HTS VII. Vibrations and movement during operation of the screen caused the nuts to work loose and fall off. It was necessary to correct this problem before the tests could proceed.

Clearance between the screen panels and the screen frames varied from ¼ to 3/8 inch. This opening was larger than the mesh opening of the screen and allowed small fish to escape.

RECOMMENDATIONS

Based on observations of HTS VII, the following recommendations are made to improve the operation of a horizontal traveling screen of this type.

1. To provide a traveling screen facility that will create the minimum of head loss, the porosity of the structure will have to be increased. The open area for water passage through the structure should be greater than the cross sectional area of the water in the channel immediately upstream of the facility. Head loss on the upstream leg can be reduced by placing the structure on an angle less than 30° to flow.

Head loss on the downstream leg can be reduced by hinging the panels on the leading edge and additionally by enlarging the channel on the downstream right bank as shown in Figure 16.

2. Remove the tension springs on the screen panels for free outward movement on downstream leg. Hinging the panels on the leading edge would eliminate much of the water buildup on the screens as they move across the flume to the downstream turn. Hence, the opening for water passage would be much greater and the head loss across the downstream leg would be appreciably reduced.

3. If it is desired (for safety of the structure) to have the screen panels open inward on the upstream leg, shear pins could be installed. Since the necessity for opening the panels on the upstream leg would be in emergency situations only, tension springs would not be needed.

4. Eliminate the sliding connection between the panel frames or provide some type of long wearing slide plate. Perhaps the panel connections could be designed solidly and the drive changed to utilize a large special sprocket similiar to the conveyor drive system used in some clothes cleaning establishments.

5. Establish the drive system near or at the upstream turn. Racking of the screen panels may occur with a single drive attachment on larger structures; in this event it may be necessary to place a drive at the bottom as well as at the top.

6. Use carriage wheels made of an ultra high molecular weight plastic. This would eliminate the need of having to lubricate the many zerk fittings on standard carriage wheels and the need for coating the . .

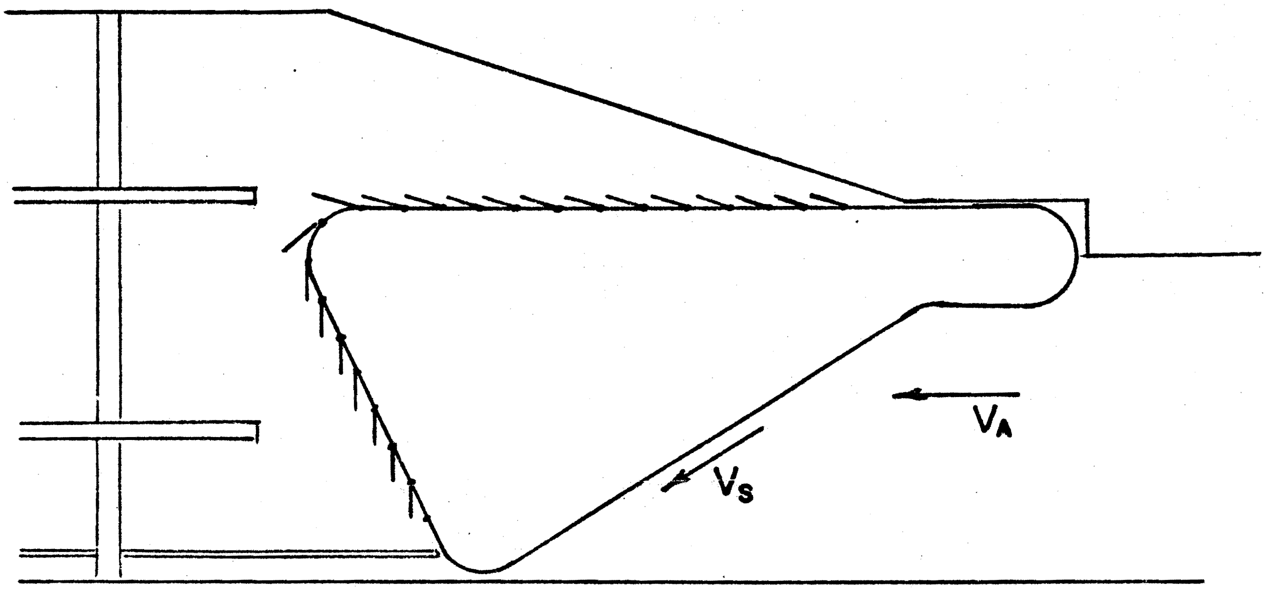

Figure 16.--Suggested installation of traveling screen to increase the water passage area and reduce the head loss.

carriage wheel track with a noise dampening compound.

7. Extend top and bottom "U" guides around the downstream corner to a point at least 3 feet beyond the turn into the return leg to provide support for the screen frames through the area of maximum load.

8. Cotter key all bolted connections to keep the nuts from working loose.

9. Reduce clearances between screen panels, frames, etc., to equal that of the clear opening of the mesh used.

10. Although very little problem was caused by the movement of sand, gravel, and small sticks past the facility, movement of these materials to the bypass could be enhanced by attaching a small angle or square tubing to the screen frame and extending it down alongside the bottom "U" guide. As the screen travels, this extension would sweep the material in the area adjacent to the bottom "U" guide.

11. Provide separate water controls for the bypass so that proper velocities can be maintained at the entrance to the bypass.

12. Provide a trash rack upstream from the traveling screen to divert large debris that could damage the traveling screen or jam the fish bypass. A rock trap should also be provided upstream from the facility.

CONCLUSION

Despite problems encountered in operation of the small prototype of the horizontal traveling screen, the concept is good. Mechanical and hydraulic problems can be solved. Additional work should be done to determine the proper bypass velocity to expedite passage of fish and debris at the entrance to the bypass.

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TABLES

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FIGURE 14.--Power required to drive the screen before and after installation of washers at the panel connections.

FIGURE 15.--Panels open on downstream leg (Bureau of Reclamation).

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