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M. J. Whalls
D. S. Shetter

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A Simplified Rotary Fish Screen and an Automatic Water Gate

By

Marvin J. Whalls, David S. Shetter, and James E. Vondett

Michigan Department of Conservation

Lewiston, Michigan

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[1] Contribution from the Institute for Fisheries Research.

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Abstract

A simplified, rotary fish screen and an automatic water gate have been developed for use in streams or hatchery raceways.

The rotary screen is designed to replace stationary, vertical screens which become plugged with leaves, sticks, and other water-borne debris and require periodic cleaning in order to prevent considerable water level fluctuations. The rotary screen is self-cleaning; therefore, it eliminates raceway water fluctuations and greatly reduces the labor involved in cleaning vertical screens. Its construction is simple, it operates for long periods, and is readily portable. It is not designed to replace large-capacity, gear-driven rotary screens.

The gate is used in conjunction with a gear-driven rotary screen, and is designed to open automatically during floods and pass water through the screen and to close automatically and seal off the screen when the water recedes to a normal level.

Introduction

Rotary fish screens have been used to carry excess water past fish traps at the Michigan Department of Conservation Hunt Creek Fisheries Experiment Station since 1949. These gear-driven screens designed by J. D. Alexander are similar to the Saunders inner-drive rotary fish screen described by Leitritz (1952a). Fish screens used in California were described by Wales (1948), Wales, Murphey, and Handley (1950), and Leitritz (1952a and b). Rounsefell and Everhart (1953, pp. 197-210) gave general descriptions of the types and uses of fish screens; Carbine and Shetter (1953) described the use of a rotating screen with a weir in Michigan; John (1954) proposed a spaced-disc type of fish screen; and Whalls, Proshek, and Shetter (1955) touched on some limitations of the Michigan gear-driven screen.

The gear-driven screens used at Hunt Creek are well suited for passing water in the Station's main stream (Fig. 1) where they are permanently installed, but operate only during periods of high water. They are not suited for use in raceways because constant operation results in frequent breakdowns and high maintenance costs. Also, special lifting devices are required to handle these heavy pieces of equipment. The simplified rotary screen (Figs. 2, 3, and 4) is not intended to replace the gear-driven one, but is designed to replace the vertical screens in the Station's raceways where the volume of water flow can be regulated with a by-pass, and where a portable, lightweight, easily maintained screen is desirable. Vertical screens are rapidly clogged with debris, which disrupts the normal flow and results in unnatural stream conditions in the raceways.

The automatic water gate (Figs. 5A, 5B, 6, 7, and 8) was developed to be used with the gear-driven rotary screens. The gear-driven screens are used only during high water; they are not used during periods when water

Figure 1.

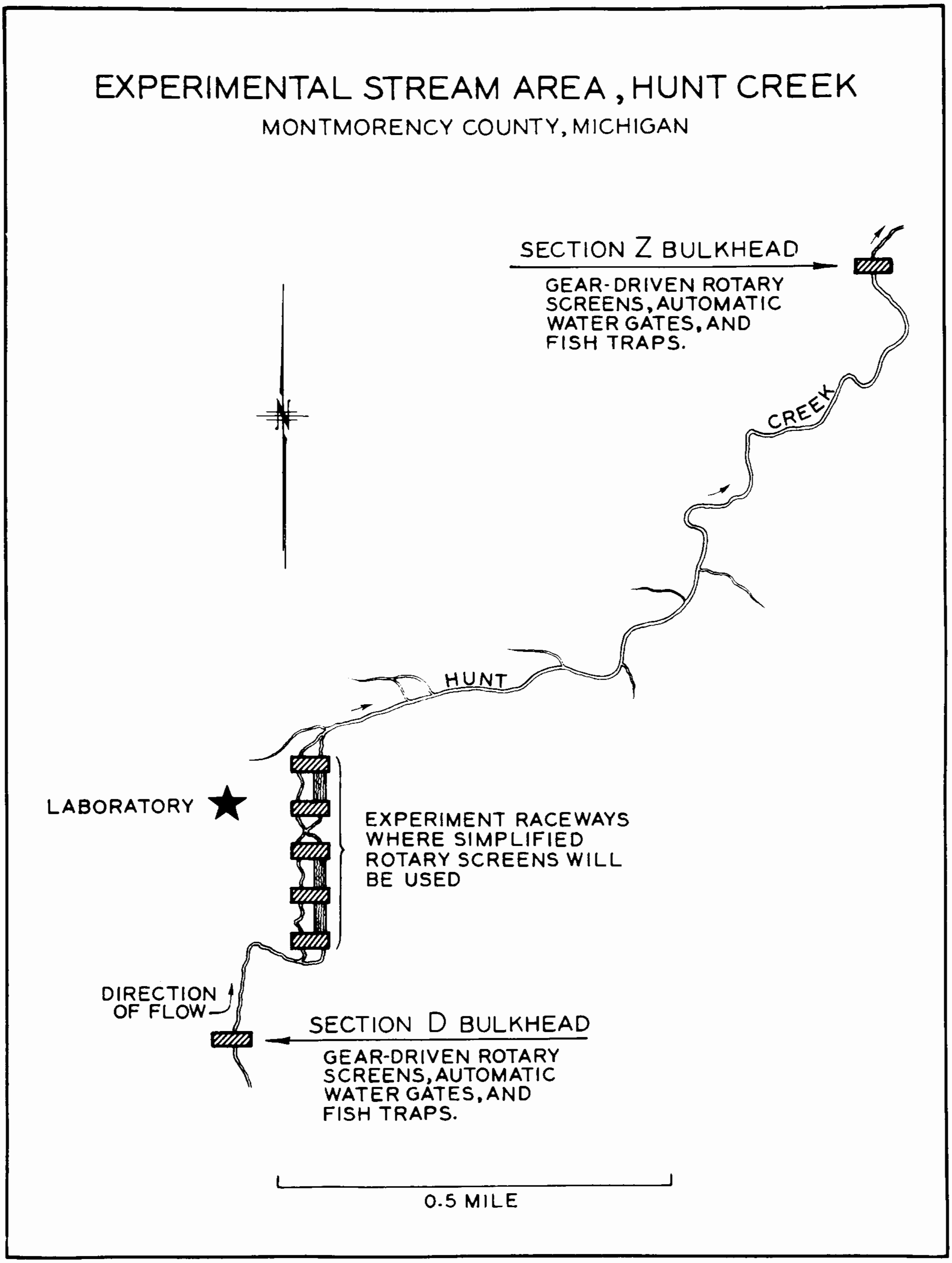
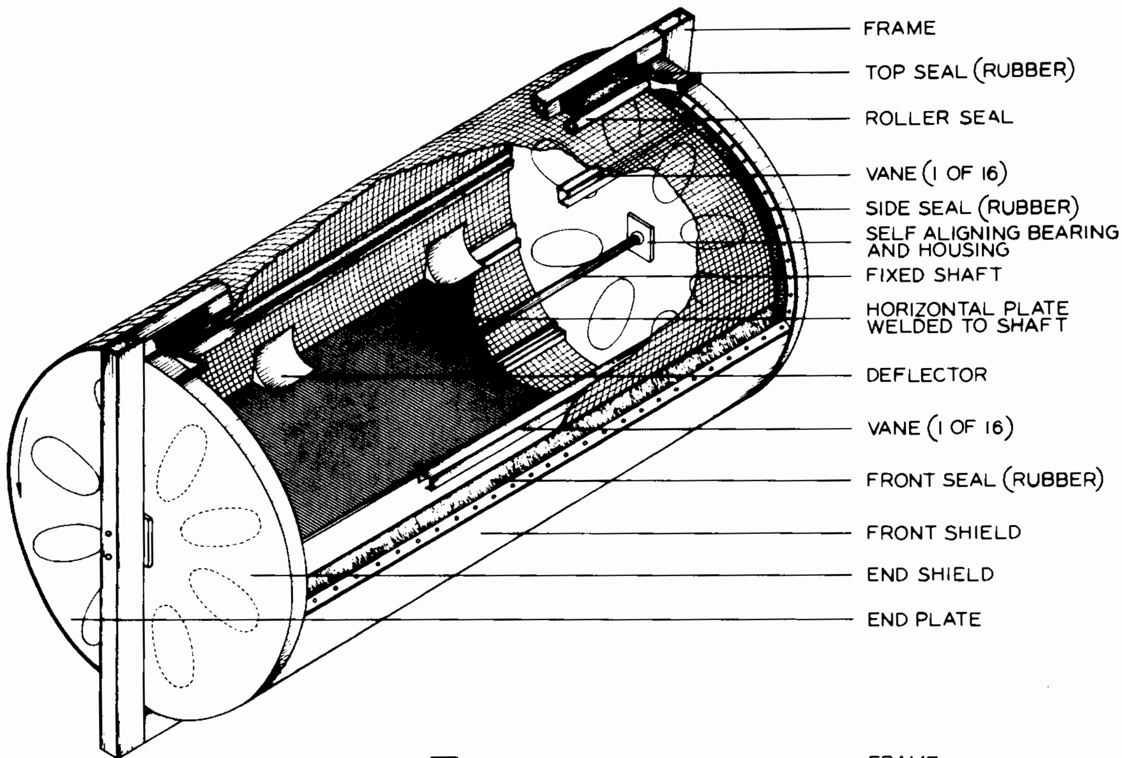
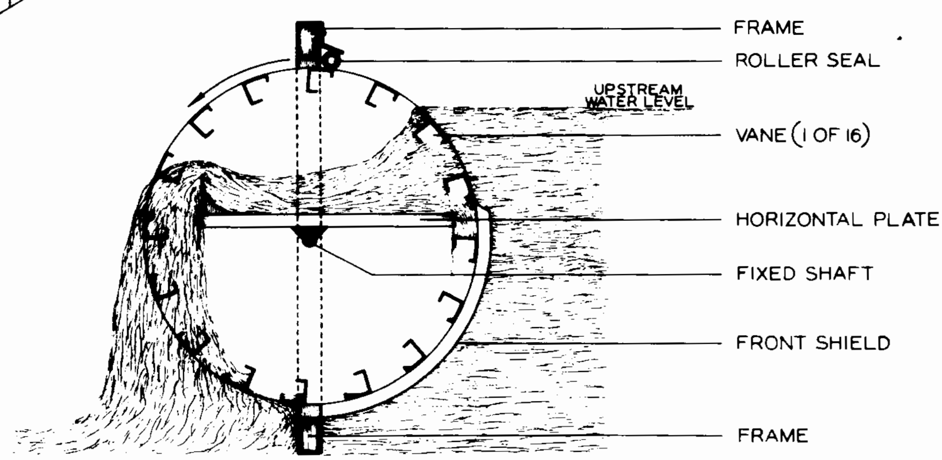

EXPERIMENTAL STREAM AREA, HUNT CREEK
MONTMORENCY COUNTY, MICHIGAN
SECTION Z BULKHEAD
GEAR-DRIVEN ROTARY SCREENS, AUTOMATIC WATER GATES, AND FISH TRAPS.
CREEK
HUNT
LABORATORY
EXPERIMENT RACEWAYS WHERE SIMPLIFIED ROTARY SCREENS WILL BE USED
DIRECTION OF FLOW
SECTION D BULKHEAD
GEAR-DRIVEN ROTARY SCREENS, AUTOMATIC WATER GATES, AND FISH TRAPS.
0.5 MILE

Figure 2.

GEARLESS, VANE-TYPE ROTARY FISH SCREEN





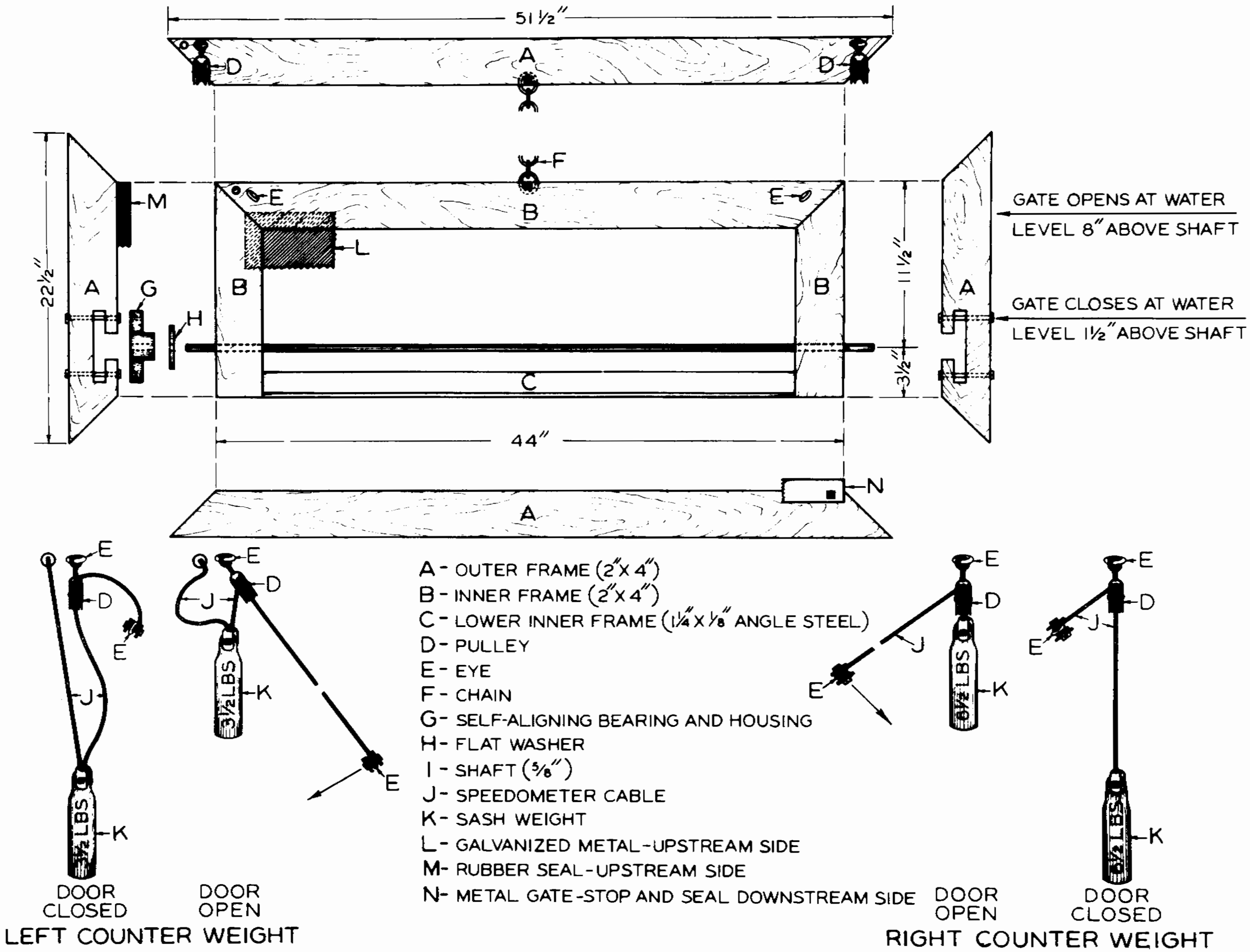
CROSS SECTION

Figure 3.—The 12-vane model of the simplified rotary screen operating in a Station raceway in January, 1956. Roller seal not attached, front shield shown.

Figure 4.—Upstream view of the 12-vane model of the simplified rotary screen, showing the position of a vane filling with water and the fall (16 inches) required to operate the 24-inch diameter revolving drum.

Figure 5A.

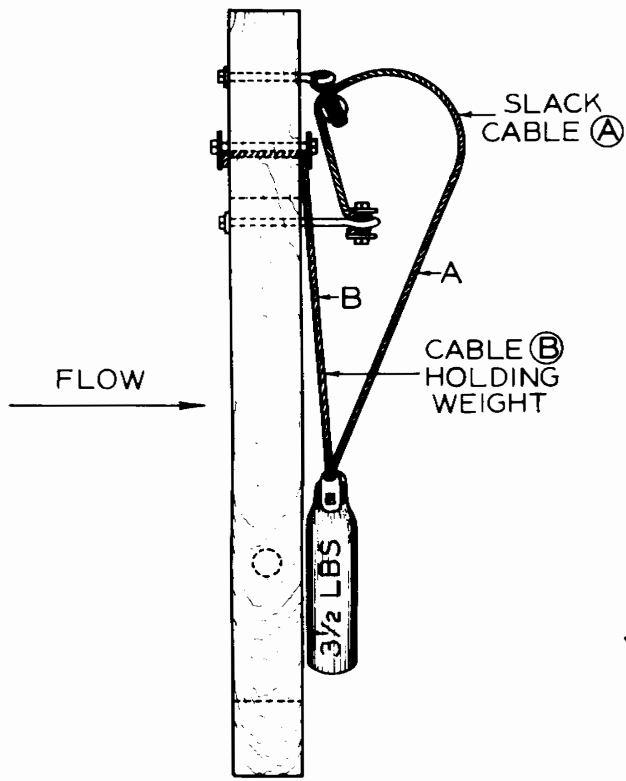
AUTOMATIC WATER GATE



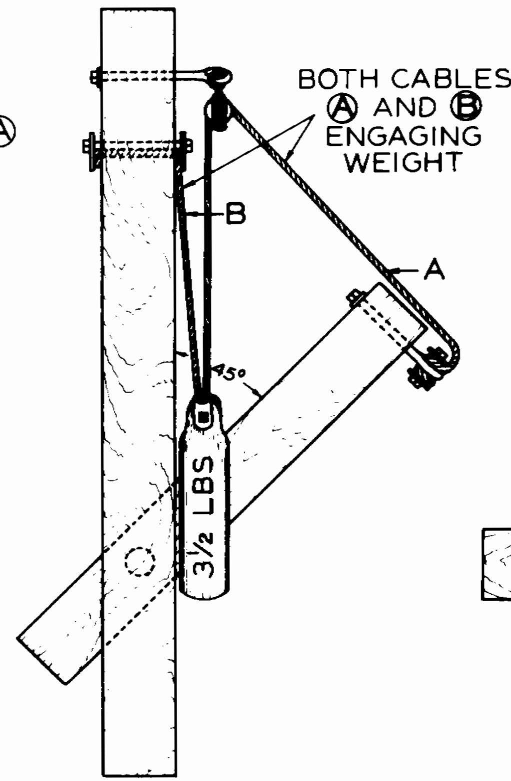
A - OUTER FRAME (2" X 4")
B - INNER FRAME (2" X 4")
C - LOWER INNER FRAME (1 1/4" X 1/8" ANGLE STEEL)
D - PULLEY
E - EYE
F - CHAIN
G - SELF-ALIGNING BEARING AND HOUSING
H - FLAT WASHER
I - SHAFT (5/8")
J - SPEEDOMETER CABLE
K - SASH WEIGHT
L - GALVANIZED METAL-UPSTREAM SIDE
M - RUBBER SEAL-UPSTREAM SIDE
N - METAL GATE-STOP AND SEAL DOWNSTREAM SIDE

Figure 5B.

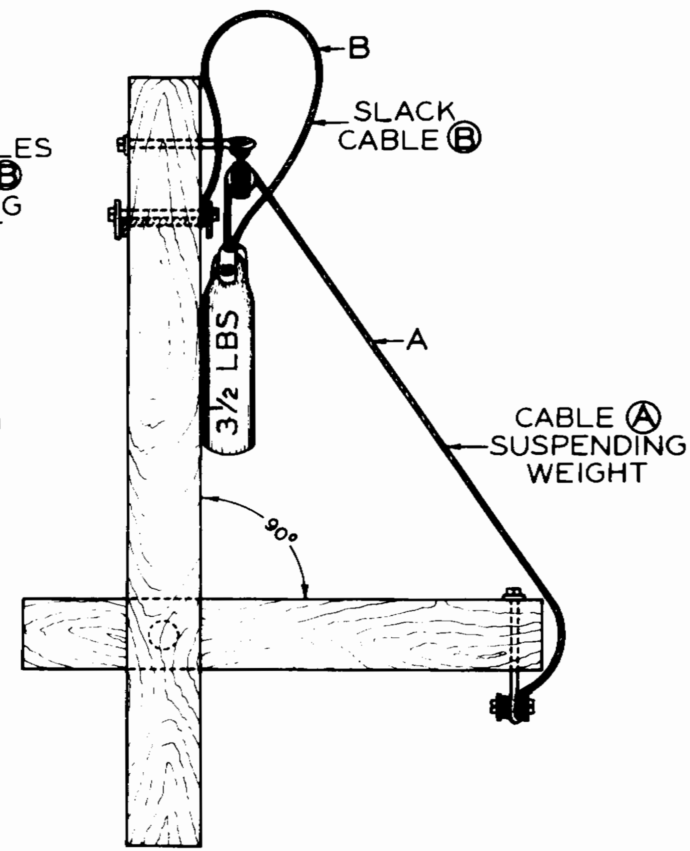
DETAIL OF LEFT COUNTERWEIGHT



GATE CLOSED WITH
CABLE B HOLDING
COUNTERWEIGHT
FREE FROM GATE



GATE OPENING AND
COUNTERWEIGHT AT
END OF SECOND
CABLE B BEING EN-
GAGED BY CABLE A



GATE OPEN AND COUNTER-
WEIGHT ENGAGED ON
CABLE A WHICH WILL CLOSE
GATE WHEN WATER RECEDES

Figure 6.—Section D bulkhead, showing from the left a down-trap; a gear-driven rotary screen behind an automatic water gate; an up-trap; and in the slot on the far right, a solid water gate ahead of another gear-driven rotary.

Figure 7.—Upstream view of an automatic water gate (propped partly open with a stick) showing the right weight fully engaged and the left weight disengaged from the gate by a second cable.

Figure 8.—An automatic water gate in the full-open position, showing the chain supporting the open gate, and both weights engaged to close the gate when the water level recedes to normal—this gate is almost at the closing point as will be noted from the slack chain.

levels in the main stream are normal (normal discharge is 23.2 c.f.s. at the Section Z bulkhead). Prior to the development of the automatic water gate the screens were sealed off by solid, framed, sheet-steel gates (Fig. 6) placed in slots in the bulkhead upstream from the rotary screens. When there was a possibility that the fish traps would be flooded because of melting snow, heavy rains, beaver dam breakage, or other causes, a man was dispatched to remove the solid gates to allow excess water to pass through the rotary screens. To avoid flooding of the fish traps and loss of fish (Fig. 9), gates had to be removed when high water came, night or day, fair weather or foul. The water gate is designed to open automatically when the water rises to a determined point above normal, and close automatically when the water level recedes to a normal level. The rotary screen operates only when the gate is open.

Simplified Rotary Screen

General description.—The simplified rotary screen is activated by water that passes through its upper one-half on the upstream side, over the horizontal plate, and into the fixed vanes. The water retained in the vanes on the downstream side causes a torque that revolves the screen. Deflectors are placed on the horizontal plate to cause the vanes to fill with water before they reach the shaft level, thus adding to the revolving force. The vanes also serve as driving paddles at high water levels. A full-scale model (Figs. 3 and 4) was in operation for 814 hours in the Station's raceways, and for 215 hours in a raceway at the Wolverine Trout Rearing Ponds, Wolverine, Michigan. Performance was satisfactory at both locations. With the upstream water level about five inches above the shaft, the screen turns at 11 revolutions and passes 720 gallons of water per minute. Ice, leaves, grass, and

Figure 9.—Fish traps in Section Z bulkhead flooded by excess water in the main stream.

small debris do not jam the screen; however, large debris will cause jamming when it wedges between the screen and the roller seal, but the simplified rotary screen will pass any object that will pass over the Michigan gear-driven screen.

The simplified rotary screen can be built for one-half the cost of the gear-driven screen, according to estimates made by engineers at the Michigan Department of Conservation Forest Fire Experiment Station, Roscommon, Michigan. If aluminum is substituted for steel in many of the parts, weight will be considerably reduced. The steel model is easily handled by two men.

Detailed description.—The design of the vanes is important to the proper functioning of the screen. Calculations must be made to insure that the torque exerted by the weight of the water in the vanes on the downstream side is greater than the torque exerted by the water pressure against the vanes and screen on the upstream side, otherwise the screen will revolve in the upstream direction or not at all. Also, allowance for friction from bearings and seals must be made. If few, large vanes are used, an undesirable pulsating action results and the screen is subject to jamming caused by reduced torque and slow rate of revolution at the ebb point of the pulse. Reduced torque and slower revolution result when the large, widely spaced paddles reach a position where one (or more) paddle is obstructing the flow of water on the upstream side of the screen, thereby reducing the water flow over the horizontal plate and into the vanes on the downstream side. It is the reduced volume and weight of water in the vanes at the ebb point that reduces the torque and rate of revolution. Twelve vanes were tried first (Figs. 3 and 4), but because of the pulsating motion these were replaced with 16 smaller vanes designed to allow the same volume of water to pass through the screen. The vanes must be shaped to hold a maximum amount of water on the downward swing, yet empty rapidly as they begin their upward movement. The vane design shown in Figure 2 is satisfactory.

The shaft is non-rotating, and is secured to the frame by set-screws; the horizontal plate is welded on top of it. The end-plates revolve on the shaft on self-aligning bearings. A fall of 16 inches is required for end-plates having 12-inch radii.

The front and side shields serve to bring the upstream water level up to the shaft level; and, with the horizontal plate, serve to direct the water into the vanes on the downstream side of the screen. The shields are welded directly to the frame and must be constructed so as to clear the bulkhead when the screen is in place in the keyways. The side shields also serve as a barrier to the passage of fish, so, if the frame fits securely in the keyways, the side shields may be separated from the bulkhead without loss of fish. The water exerts considerable force against the shields so they must be braced to prevent them from being pressed against the screen and the end plates.

The purpose of the seals is to prevent the loss of fish. The front, side, and top seals are made from heavy-duty inner-tubes. The roller seal is made of metal tubing covered with heavy-duty, reinforced rubber hose. In operation, the roller seal lifts on end hinges to pass debris between it and the revolving screen. The roller seal and the top seal are designed to prevent the loss of fish should the water level rise above the upper frame. Where possible, a framed, vertical screen should be placed in the keyways above the rotary screen.

The rotary screen used at Hunt Creek is contained in a concrete bulkhead 4 feet by 4 feet by 8 feet. Each keyway is 2 inches deep. The rotary screen outer frame is 51.5 inches long and 31 inches high. The revolving cylinder is 48 inches long and its diameter is 24 inches. The dimensions of the vanes (Figure 2, cross section) are: narrow lip, 0.5-inch; screen side, 2 inches; vertical side, 2 inches; wide lip, 1.25 inches; length, 47.5 inches. The horizontal plate is made of sheet steel framed with 0.25-inch angle steel. The shaft is 0.620-inch solid, steel rod.

Automatic Water Gate

General description.—The automatic water gate is a barrier, placed vertically in a bulkhead, and at right angles to the stream. It does not swing on hinges but turns on a horizontal shaft, and when open is in a position roughly parallel to the stream surface, permitting water to flow past it. The gate is designed to take advantage of the fact that water pressure on an immersed vertical surface varies widely, and increases with depth (Randall, Williams, and Colby, 1929, pp. 107-126). The gate is designed to stay closed at normal water levels, when the force, resulting from water pressure, against the portion of the gate below the shaft is greater than it is against the portion of the gate above the shaft. The shaft must be placed below the center of the gate, because the position of the shaft (fulcrum) determines what force (water level) will be required to keep the gate closed, or to open it when the water level rises. The gate opens when the increased force, resulting from higher water levels, against the gate above the shaft exceeds the force against the gate below the shaft. If the shaft were centered, forces below it would always exceed those above it and the gate would remain closed at all water levels.

Counterweights are used to close the gate when water level returns to normal after a flood. As the water recedes, and only a small amount is passing over the gate (weight of water on gate is reduced), the weights cause the gate to shut. Water pressure against the lower portion of the closing gate assists in the closure.

Detailed description.—Proper dimensions of the gate are dependent upon the width of the bulkhead, water discharge, and permissible fluctuations in water level. The height of the gate and position of the shaft are determined from calculations. A shallow gate works best where tolerable water fluctuations are small, and a deep gate works best where greater fluctuations in water level are permissible and large amounts of water must be passed. The gate here described is 15 inches high by 44 inches wide. The shaft is centered 3.5 inches above the gate bottom. It is designed to operate with the normal water level 5.0 inches above the shaft. It opens when water level reaches a point 8 inches above the shaft, and closes when flood waters recede to a point 1.5 inches above the shaft. Force required to open the gate is determined by using data such as are included in Table 1, plus calculating added force needed to overcome closing torque due to friction and the suspended counterweights. At normal water levels the gate is kept closed because the force of 106 poundals against the 154 square inches (3.5 by 44 inches) of area below the shaft is greater than the force of 70 poundals against the 242 square inches (5.5 by 44 inches) of area above the shaft.

To eliminate as much friction as possible the shaft rotates on self-aligning bearings—this is especially important to the proper closing of the gate where counterweights should be kept to a minimum. The shaft is centered laterally in the inner frame to keep the forces caused by the weight of the closed gate perpendicular to the center of the shaft.

The counterweights used to close the gate must be heavy enough to overcome the weight of the gate above the shaft (acting to hold the gate open) and friction. Action of the counterweights is supplemented by the weight of the gate below the shaft (acting to close the gate).

Table 1.—Computations used to estimate the water level at which a 15- by 44-inch gate will open with the shaft (fulcrum) centered 3.5 inches above the gate bottom.

Points on gate below surface of water (feet)	Force on gate resulting from weight of water[1] (poundals)	Water level above shaft (feet)	Forces acting to close gate (poundals)	Forces acting to open gate (poundals)
0.08	4	0.00	37	0
0.17	8	0.13	51	8
0.25	12	0.21	65	18
0.33	15	0.29	78	31
0.42	20	0.38	92	49
0.50	23	0.46	106	70[2]
0.58	27	0.54	119	96
0.67	31	0.63	133	125
0.75	35	0.71	147	158[3]
0.83	39	0.79	160	195
0.92	43	0.88	174	236
1.00	47	...	...	...
1.08	51	...	...	...
1.17	55	...	...	...
1.25	59	...	...	...

[1] 0.08 ft. x 0.08 ft. x 3.67 ft. x 62.4 lbs./ft.^{3} x 32 ft./sec.^{2} x height.

[2] The gate is adjusted in the bulkhead so normal water level is about 0.42 feet above the shaft.

[3] The gate opens when the water level rises about 0.67 foot above the shaft.

If both counterweights are suspended directly to the gate as the right counterweight in Figure 5A, a greater force (necessitating a higher water level) is required to open the gate. To overcome this undesirable feature the left counterweight is connected to a second cable which is attached to the outer frame. The left counterweight is disengaged when the gate is closed. Operation of the left counterweight is illustrated in Figure 5B. With a closed gate and a rising water level, only the right counterweight is resisting the force that acts to open the gate; when the water level rises to the opening point on the gate, the gate swings to the one-half open (45 degrees) position, and cable A engages the left counterweight and the gate continues to open to the full-open position. Both counterweights act to close the gate when the water recedes. When the gate reaches the one-half closed (45 degrees) position, the left counterweight is disengaged from cable A and is engaged by cable B, and the gate continues to close to the full-closed position. No counterweights are necessary if the gate is closed manually. At Hunt Creek, only the left counterweight has cable B attached, but, if necessary, both counterweights could be attached to a second cable to permit the gate to open at a lower water level, and thus decrease the over-all water level fluctuation.

If the gate is made of wood, heavier counterweights must be used to overcome the buoyancy of the bottom board before the gate will close properly. This buoyancy may be greatly reduced either by constructing the bottom cross piece of the gate of angle steel (Fig. 5A) or by constructing the entire gate frame of welded angle steel. The latter method not only reduces buoyancy to a minimum, but also reduces the total weight of the gate, and thus reduces the size of the counterweights required. The gate framed at top and sides with wood and with angle steel at the bottom is simple to construct and low in cost. Wood and steel should be used in pilot models until all specifications are determined, and then a more permanent steel gate built.

A length of chain holds the open gate perpendicular to the outer frame to allow the greatest area for water passage.

Acknowledgments

The authors wish to express their appreciation to Messrs. Steve Such and Gil Stewart, engineers, who offered valuable criticism of the simplified rotary screen, to Max Bradley who prepared blueprints and preliminary drawings, and to William L. Cristanelli who prepared the final drawings of the screen and the water gate.

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INSTITUTE FOR FISHERIES RESEARCH

Marvin J. Whalls, David S. Shetter, and James E. Vondett

Approved by: Walter R. Crowe

Typed by: Anne E. Kruse