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CLAMSHELL GATE

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T. J. Isbester

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Memorandum

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Denver, Colorado

TO : Chief, Hydraulics Branch

DATE: November 20, 1981

FROM : T. J. Isbester

SUBJECT: Clamshell Gate

INTRODUCTION

The clamshell gate was conceived to eliminate some major problems associated with controlling high velocity flow. The prevention of cavitation erosion was of primary concern and was accomplished by eliminating the need for gate slots and complicated internal curvatures often attacked by cavitation. Additional advantages of the design are the high discharge coefficient which reduces the size of the gate needed to pass a given release and reduces construction costs which result from the elimination of complicated curvature and shaping within the gate body. Also, the clamshell gate is well suited for passing debris without sustaining damage. Other presently used valves may be heavily damaged if debris is passed.

The clamshell gate is covered under U.S. Patent No. 3,998,426 issued to Thomas John Isbester on December 21, 1976, with license to the Government dated April 21, 1977.

The gate is suited for both free and submerged releases, but is not suited for in-line service unless an expansion chamber is used downstream from the gate.

Reasonable applications for the gate would include river outlet works and other larger conduits where it is required to control high pressure flows. The gate is well suited for controlling flows at partial openings without any adverse effects.

GATE CONSTRUCTION

The body of the gate is a cylindrical steel section with a single radius (in the direction of the flow) machined from the centerline to the top and bottom of the cylindrical section on the downstream end, figure 1. The operating members are two radial segments which meet along the transverse centerline of the body.

The gate is opened by moving the two radial segments away from each other so that the opening is symmetrical about the transverse centerline. The radial segments are attached to the cylindrical body by trunnion pins which are fixed to the outer body centerline and extend laterally to the left and right. The seal used on the clamshell gate is a wedge-shaped, continuous rubber peripheral seal attached to the end of the cylindrical body and is actuated by internal pressure forcing the wedge into the space between the end of the body and the downstream radial gate segments. Small brass bars were attached to the mating surfaces of the radial members to seal the gate and provide a stable control point. The continuous peripheral portion of the seal could easily be replaced in the field. Although the seal is not droptight, only very slight leakage occurred while operating at a head of 115 feet of water.

The operating mechanism presently used consists of a slider mechanism operating a pinned link which was attached to a second set of sliders operating the upper and lower gate segments. An unlimited number of modifications could be made to the gate opening mechanism to reduce construction costs and simplify the assembly.

A number of construction options could be used to reduce the cost of the gate. Rolled sections, requiring suitable stiffeners welded to the downstream side to prevent buckling of the skin plate, could be used to replace the machined sections of the radial segments. Also, trunnion bearing caps would allow for permanent attachment of the trunnion shafts to the body and allow for field replacement of bearings with a minimum of effort. The use of heavy walled pipe for the gate body would prevent the need for costly fabrication.

Presently no size or head limitations have been considered for the clamshell gate; however, there should be no difficulty in producing a gate which would meet the capacity requirements of present hollow-jet valves or jet flow gates. Table 1 provides a comparison of size requirements, in inches, for the clamshell gate and other presently used control devices. The reduced size of the clamshell gate is the result of the high coefficient of discharge as compared to that of other devices.

The coefficient of discharge is based on the following equation:

$$C_d = \frac{Q}{\frac{\pi D^2}{4}\sqrt{2gH_T}}$$

where: Q = discharge in ft^3/s
D = internal diameter of the gate flow passage - ft
g = gravitational acceleration in ft/s^2
H_T = total head on the gate - ft

Table 1. - Comparison of valve diameters (inches)

Clamshell gate	Jet flow gate	Hollow-jet valve	Fixed cone valve	Needle valve
		Coefficient of discharge		
0.964	0.80 to 0.84	0.70	0.85	0.45 to 0.60
		Diameter (inches)		
100	109.8 to 107.1	117.4	105.5	146.4 to 126.8
50	54.9 to 53.6	58.7	53.2	73.2 to 63.4
25	27.4 to 26.8	29.3	26.6	36.6 to 31.7

TESTING OF CLAMSHELL GATE

An 8-inch version of the clamshell gate was fabricated in the laboratory shops. This gate was tested for free and submerged releases in the laboratory.

Free Releases

The gate was placed in an 8-inch line and supplied through our laboratory pumping system. Discharges were measured through calibrated laboratory Venturi meters. The general appearance of the jet issuing from the gate varied considerably from small to intermediate to large openings (figures 2 and 3). However, the main body of the jet was well guided in the downstream direction and only thin fins associated with the intersection of the sides of the gate body and the radial segments were responsible for the change in appearance. These fins contain very little energy and may be confined easily with deflector walls.

The discharge coefficient was obtained for 10 percent increments of opening, based on the inside diameter of the body of the gate. The 100 percent coefficient approaches that of a wide open, nonrestricted pipe and is reduced only by the slight peripheral seal protrusion into the flow passage. Figure 4 provides discharge coefficients for the gate openings from 0 to 100 percent. The seal protrusion is shown in figure 5.

Submerged Releases

The submerged tests on the gate were limited to small partial openings at high heads and only low heads at large openings because the tailbox used on the downstream end could not handle the energy associated with large openings at high heads. For small openings, extended tests were performed at heads of about 100 feet of water to search for cavitation erosion on the gate segments. No cavitation erosion was found on the gate segments; however, cavitation was visible in the shear zone downstream from the gate. This type of cavitation occurs any time a high velocity jet enters a stilling pool, and it can produce a considerable amount of noise in the region where the cavities collapse.

Photographic coverage of the submerged releases was not satisfactory because of the distance between the plastic wall of the tailbox and the jet issuing from the clamshell gate. Light would not adequately penetrate the pool to light the jet. Dye was used to define the pattern of the submerged jet for a 20 percent opening (figure 6). A light cloud of cavitation forming at the boundary between the jet and the tailwater pool could be seen with the eye, but did not show up in photographs.

Discharge coefficients were obtained for the range of openings from 0 to 100 percent with the submerged gate, and found to be the same as the free release coefficients.

Another advantage of the clamshell gate is the shape of the jet for various openings. For high head conditions upstream of the gate when the upstream energy is at maximum (i.e., low upstream head losses), small gate openings are required to pass a given discharge. The small openings provide a thin jet which extends the full width of the gate body. The thin high velocity jet is acted upon by shear on the upper and lower surfaces until the shear zone reaches the centerline of the jet and begins to retard the centerline velocity. The distance required for the velocity retardation to occur is much shorter for a thin jet than for a thicker one. For low head conditions upstream from the gate (high upstream head losses and reduced centerline velocities), larger openings are required. For this condition, jet velocity is low to begin with so that distance for total energy dissipation is relatively short.

Future Tests

In order to establish the operator requirements for the radial segments, additional tests will have to be performed to measure torque required to open and close the two radial members. On the test gate very little force is required and the gate segments appear to be very stable, with no tendency to vibrate. These observations will be verified with electronic measurements in future tests.

T. J. Isbester

Attachments
Figures 1 through 6

Copy to: D-220, D-252, D-430, D-1530, D-1530A, D-1531, D-1532, D-1533, D-1533 (Isbester)

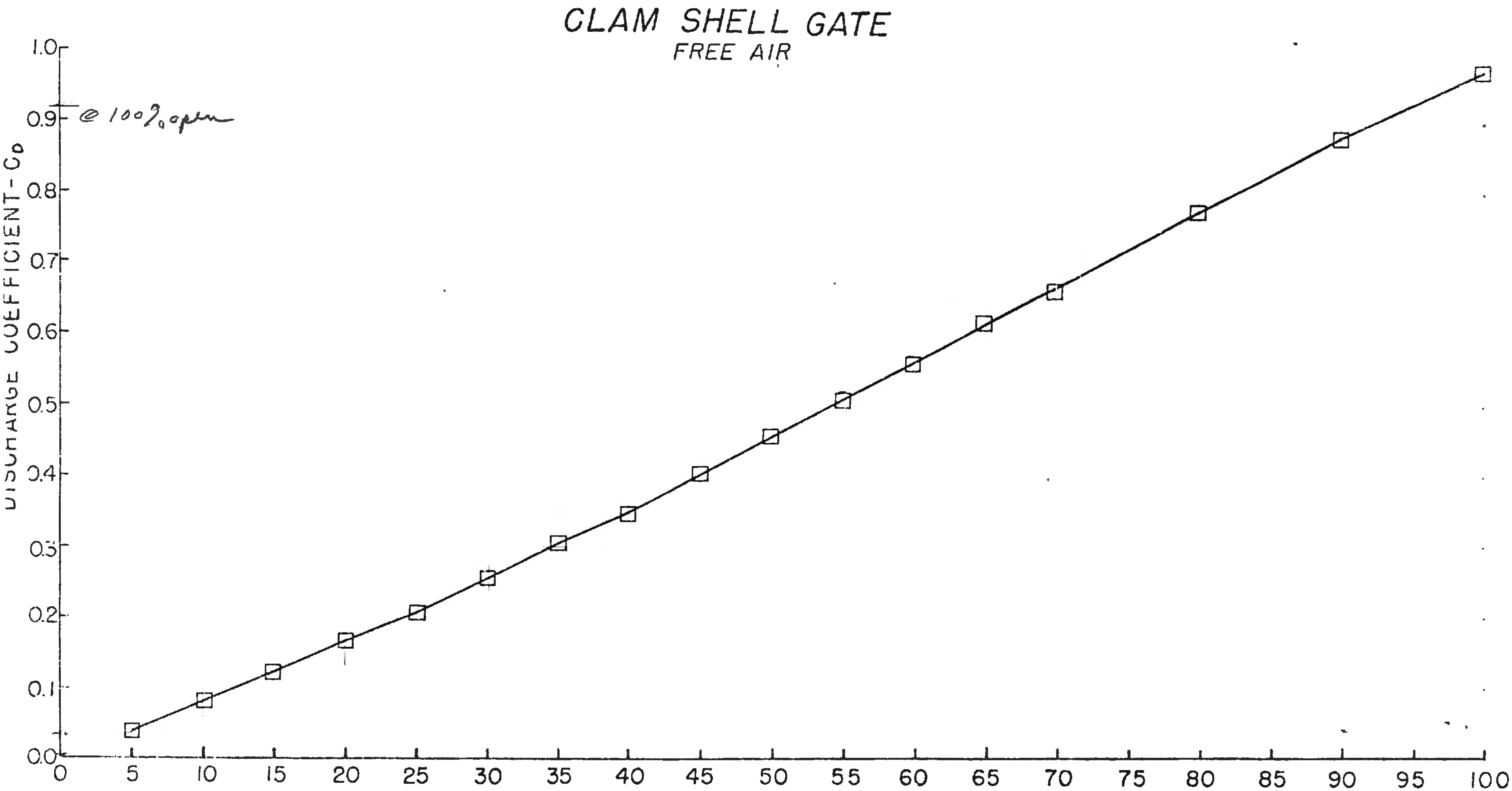


Figure 4. - % GATE OPENING

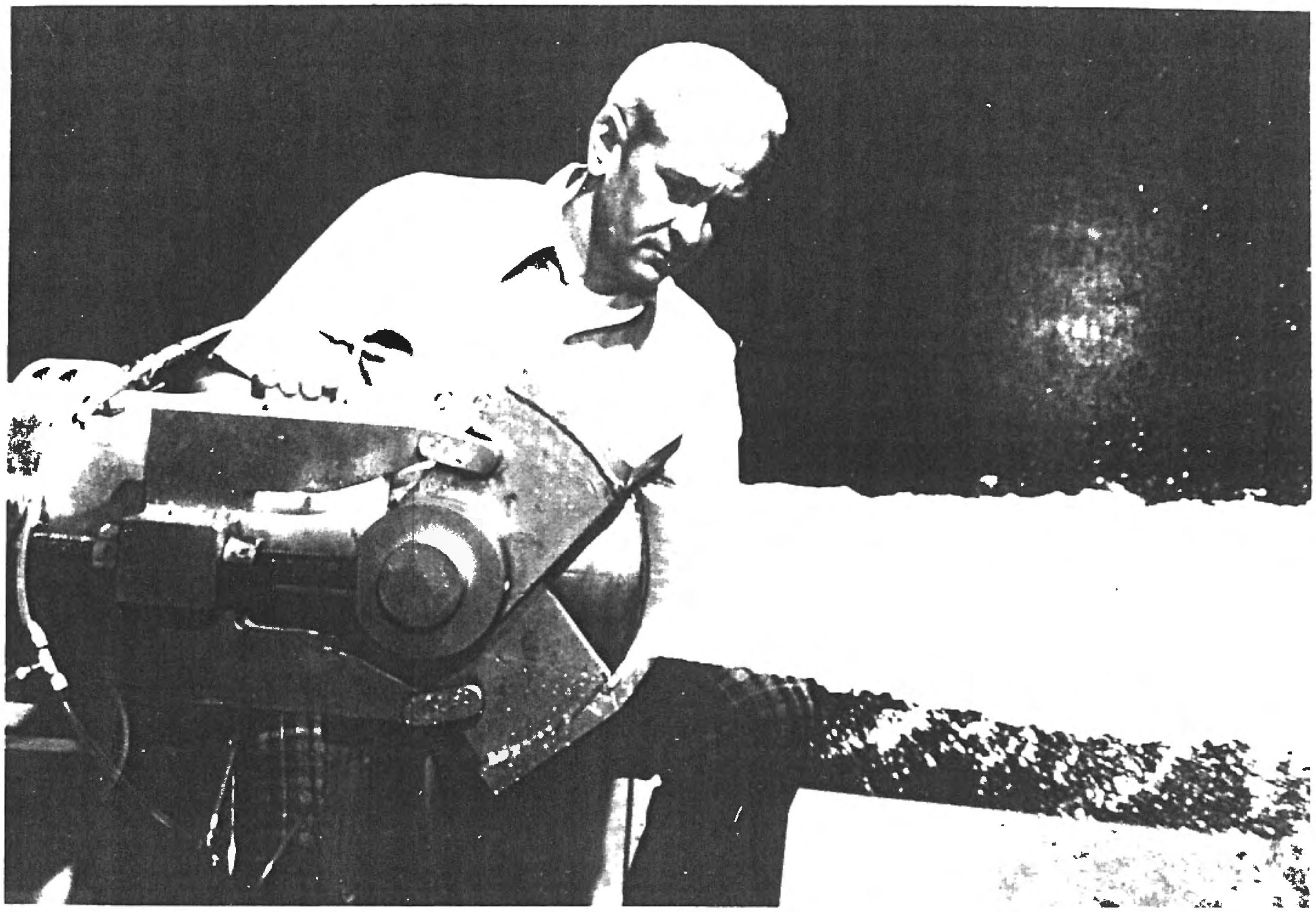


Figure 1. - Clamshell gate with upper and lower radial members and simple radius machined on downstream end of pipe.

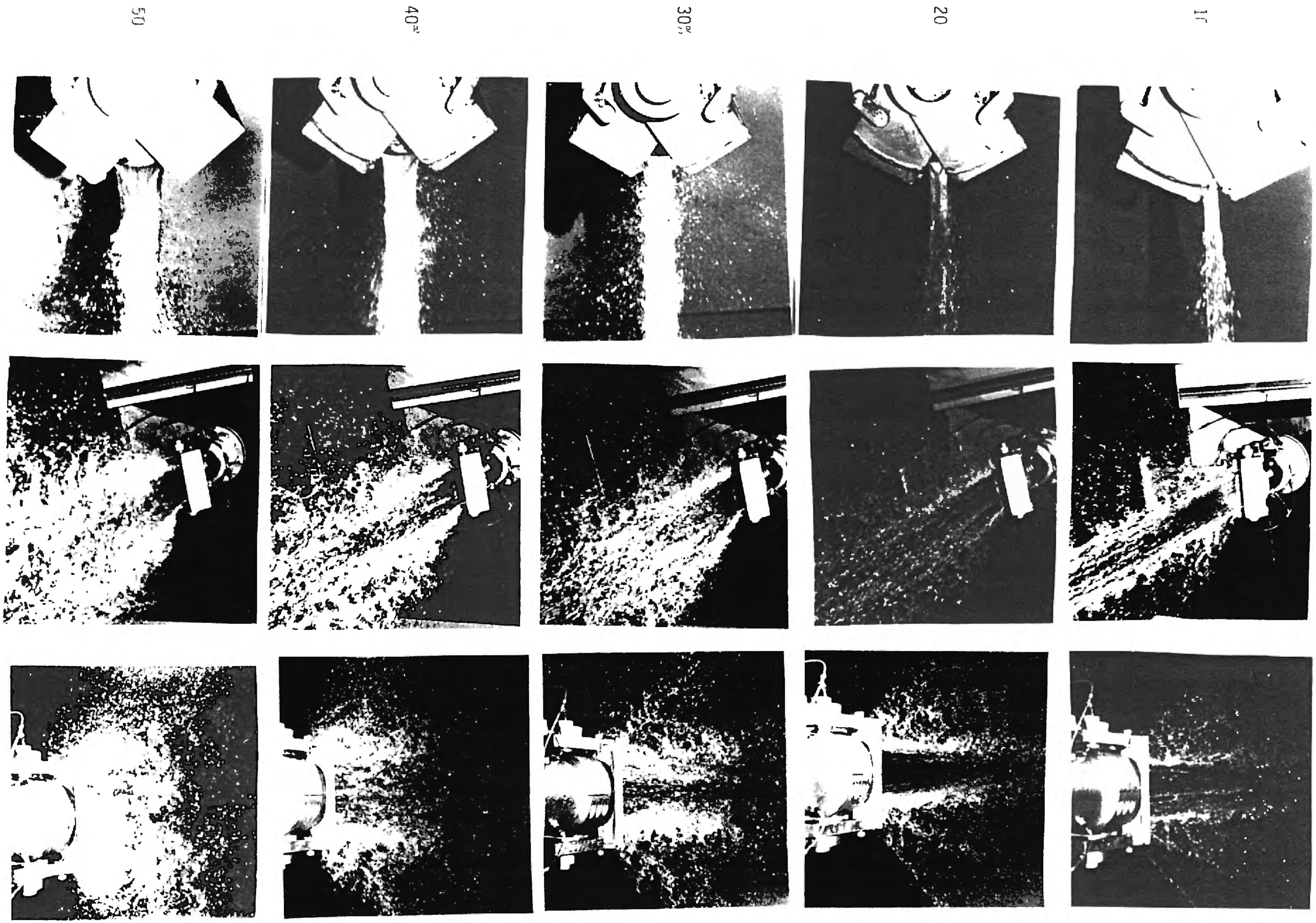


Figure 2. - Gate openings - 10 to 50 percent.

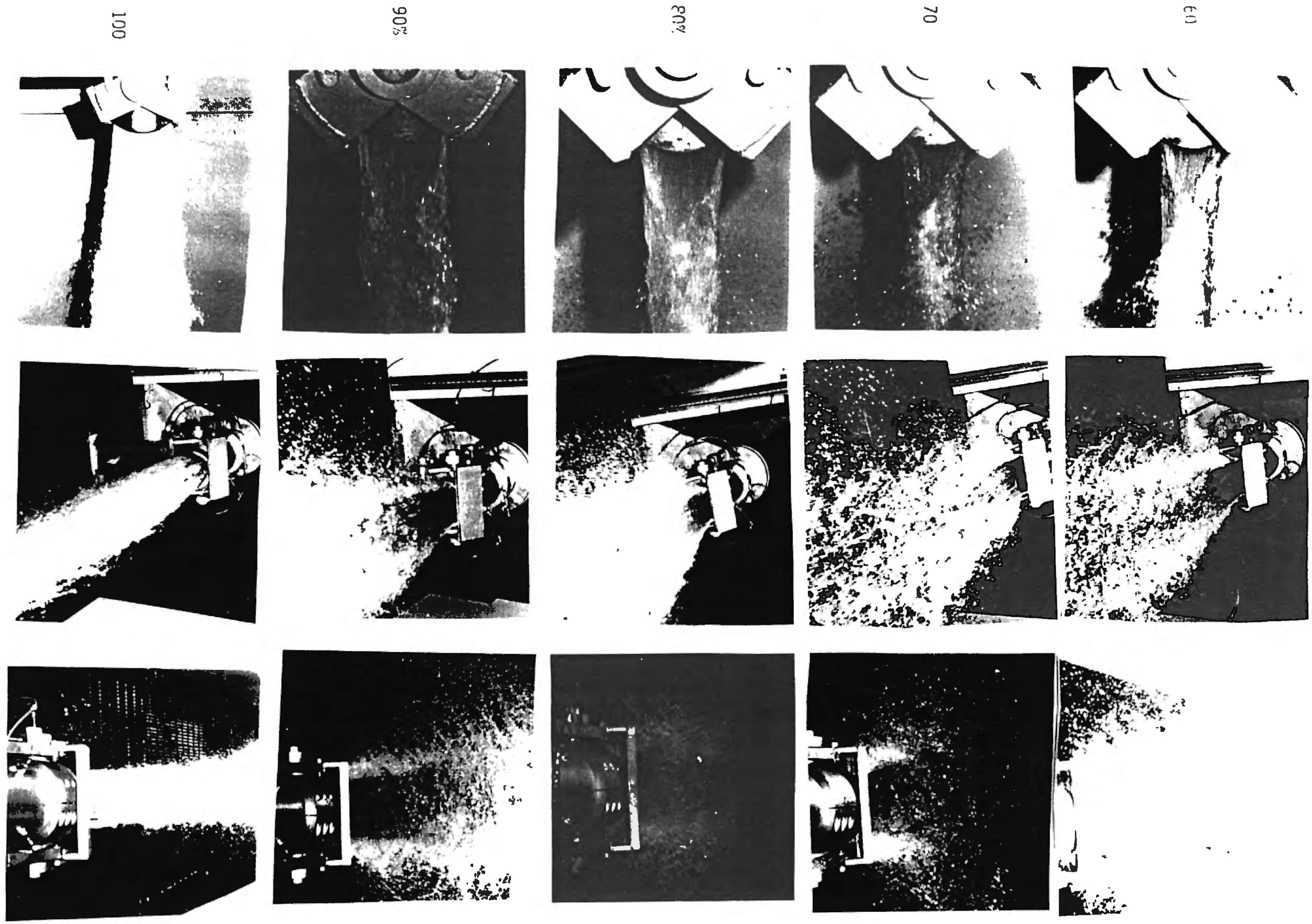
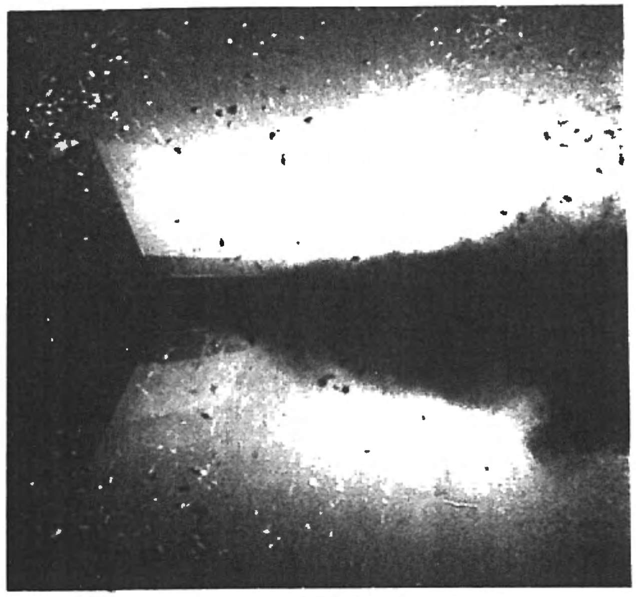
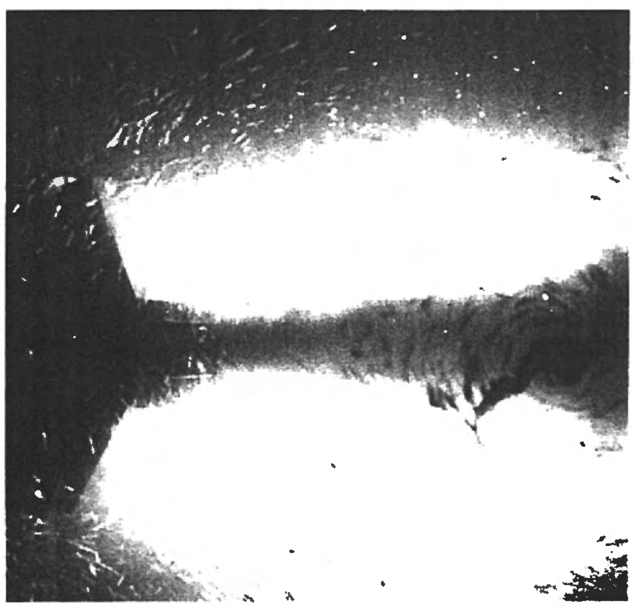


Figure 3. - Gate openings - 60 to 100 percent.



a. Dye pattern downstream from the clamshell gate operating at a 20 percent gate under submerged conditions.



b. Clamshell gate operating at a 20 percent gate opening. Note near horizontal vortex caused by high intensity shear.

Figure 6. - Submerged jet - 20 percent gate opening.

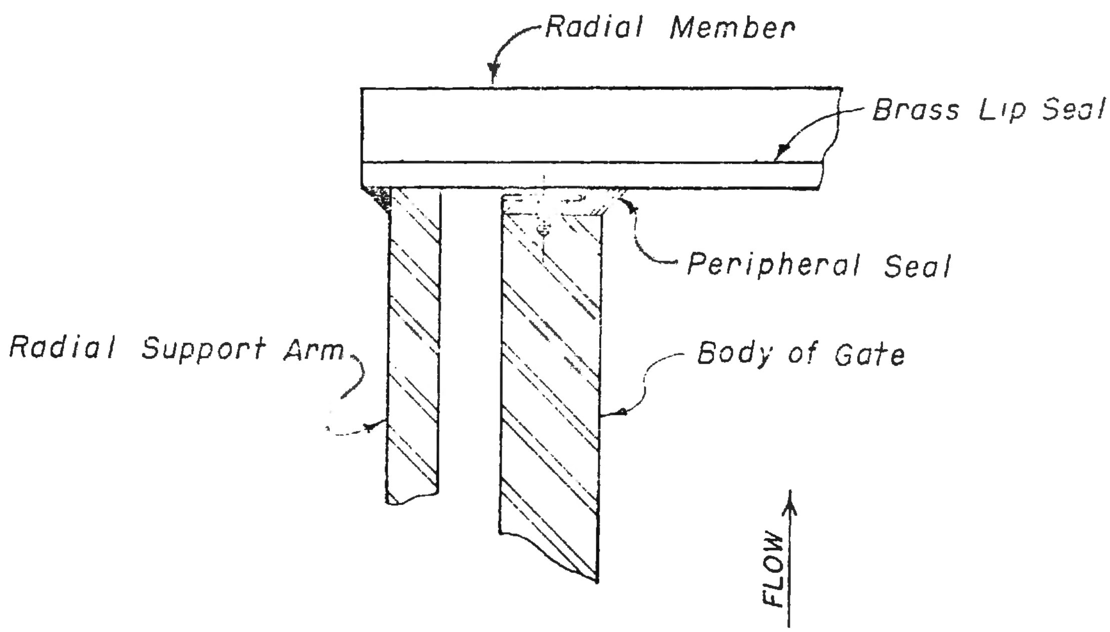


Figure 5. - SECTIONAL VIEW
OF SEAL
TRANSVERSE CENTERLINE