PAP-788

Japanese Visit Concerning Clamshell Gate Technology

August 17, 1998

by

Tracy Vermeyen
K. Warren Frizell

AIR 788

PAP # _____

JAPANESE VISIT CONCERNING CLAMSHELL GATE TECHNOLOGY

AUGUST 17, 1998

A contingent of Japanese engineers visited with WRRL (T. Vermeyen and W. Frizell) and Mechanical Equipment group (B. Todd, W. Delzer, R. Arrington, and B. Sund) personnel to discuss Reclamations experience with the Clamshell Gates. The Japanese have developed a similar type gate for use in replacing top-seal radial gates. Attached are some drawings and handouts covering the Japanese gate concept and some hydraulic model study results. The 4-hour meeting was informational for both sides.

A Japanese contact is:
Dr. Seizo TAKEBAYASHI, Director
Public Works Research Center
Nishizawa 2-2, TSUKUBA-SHI
IBARAKI-KEN, 300-2624 JAPAN

KEYWORDS: Clamshell gates, hydraulic model study, tension radial gates, Japan, Public Works Research Institute, discharge coefficient

United States Department of the Interior

BUREAU OF RECLAMATION
Commissioner's Office
PO Box 25007
Denver Federal Center
Denver, Colorado 80225-0007

IN REPLY REFER TO:
D-1520

International Visitor Program
Prepared August 11, 1998
for
9 Member Gate Technology Committee
Fuudo (Climate) Technology
(Names Attached)
JAPAN

Cost Authority: G60-0980-9827-140-IA-D-V(9)
WOID: IA97V

Sponsor: Mr. Kazuaki Kamei, Research Engineer, Institute of Fuudo Technology, Public Works Research Center, Nishizawa 2-2, Tsukuba, Ibaraki, Japan, telephone 81-298-77-1383, fax 81-298-77-1404

Interests: Interested in discussions and visits to clamshell gates at Glassy Lake Dam, Salt River Siphon, and failed radial gate at Folsom Dam.

International Affairs Team Coordinator: Ms. Barbara Fullwood, International Affairs Specialist, (303) 445-2129, fax (303) 445-6322

Monday, August 17, 1998

9:45 a.m. Arrive at the entry gate to the Denver Federal Center, where each member of the delegation will be required to show a picture I.D. to enter the Denver Federal Center. Delegation will proceed to the main entrance of Building 56, the research building located just east of Building 67 (the 13-story high-rise). Each member of the delegation will be required to show a picture I.D. to receive a visitor badge to enter the building. The delegation will be met by **Ms. Barbara Fullwood** of the International Affairs Team who will escort them to **Conference Room 2770.**

10:00 a.m. Delegation will meet with **Mr. Tracy Vermeyen** of the Water Resources Research Laboratory, for discussions on clamshell gates.

11:30 a.m. Lunch, which can be purchased in the cafeteria located on the first floor in Building 67. After lunch, delegation will return to **Conference Room 2770,** located in Building 56.

12:30 p.m. Delegation will meet with **Mr. Ron Arrington** of the Hydraulic Equipment Group, for discussions on the design and use of clamshell gates and view a video on the clamshell gate at the Salt River Siphon.

2:00 p.m. Depart the Denver Federal Center.

Wednesday, August 19, 1998

8:00 a.m. Delegation will depart the Best Western Lodge at Jackson Hole, Wyoming, and travel to the Flagg Ranch, which is approximately 55 miles north of Jackson and 1/2-mile south of the South Entrance to Yellowstone National Park.

9:00 a.m. Delegation will meet **Mr. Dick Bauman** in front of the Flagg Ranch Lodge (a large log building). Mr. Bauman will be driving a white Jeep Cherokee and will lead the delegation to Grassy Lake Dam.

10:00 to 12:00 p.m. Delegation will participate in discussions and view the clamshell gates at Grassy Lake Dam. **Mr. Mike Marriott** will assist in accommodating the delegation needs at the dam. It is important to note that a Comprehensive Facility Review of Grassy Lake Dam is being conducted that day by the Technical Service Center, the Regional Office, the Area Office, the State of Wyoming, and the Fremont Madison Irrigation District. The delegation will depart Grassy Lake Dam and travel to Idaho Falls.

Thursday, August 20, 1998

9:45 a.m. Delegation will arrive at the Bureau of Reclamation Central California Area Office, 7794 Folsom Dam Road, Folsom, California, which is located approximately 2 miles north of Folsom, California.

10:00 a.m. As arranged by **Mr. W. Louis Moore**, the delegation will receive a briefing and short tour of Folsom Dam and discuss the failed radial gate.

12:00 Delegation will depart Folsom Dam.

Friday, August 21, 1998

9:45 a.m. Delegation will be met in the lobby of the Scottsdale Princess Hotel by **Mr. Fred Stanek** of the Bureau of Reclamation Phoenix Area Office. Mr. Stanek will escort the delegation to the Salt River Siphon, which is approximately 45 minutes from the hotel, to view the clamshell gate. After viewing the gate, Mr. Stanek will escort the delegation back to the Phoenix area.

END OF BUREAU OF RECLAMATION ARRANGEMENTS

bc: Director, Policy and External Affairs, Attention: W-1520
Regional Director, Boise, Idaho, Attention: PN-1010 (Konrath)
Regional Director, Sacramento, California, Attention: MP-450 (Billingsley)
Regional Director, Boulder City, Nevada, Attention: LC-1140 (Walsh)
Deputy Area Manager, Snake River Area Office - East, Burley, Idaho, Attention: SRA-6300
Area Manager, Central California Area Office, Folsom, CA, Attention: CC-200 (Moore)
Area Manager, Phoenix Area Office, Phoenix, Arizona, Attention: PxAO-1000, and PxAO-4300 (Stanek)
D-8420 (Arrington)
D-8560 (Vermeyen)
D-1520 (Staff)
D-1520 (Book)

H:\HOME\BFULLWOO\DOC\VISITOR\CLAMSHEL.PRO

List of Participants
9 Member Delegation
Fuudo (Climate) Technology
August 17-21, 1998
JAPAN

Prof. Dr. Eng. Hiroji Nakagawa
Faculty of Science and Engineering
Department of Environment Systems
Ritsumeikan University

Dr. Eng. Seizo Takabayashi
Director, Institute of Fuudo Technology
Public Works Research Center

Mr. Yasuto Hada
Senior Manager of Hydro-Mechanical Equipment Engineering Department
Steel Structure Division, Kawasaki Heavy Industries, Ltd.

Mr. Haruhisa Kojima
Section Manager, Design Department, Steel Structure Division
Ishikawajima-Harima Heavy Industries, Ltd.

Mr. Hiroaki Takubo
Chief, Steel Structure Design Department
Hitachi Zosen Corporation

Mr. Shin Takahaski
Assistant General Manager, Dam Development and Construction Division
Nishida Tekko Corporation

Mr. Tasunobu Seto, Manager
No. 1 Steel Structure Design Section
Steel Structure Design Department, Sato Tekko Co., Ltd.

Mr. Masataka Amano
President, Resistered Consulting Office, Unitec's Corporation

Mr. Tomihiro Shimeda
Assistant Manager, Hitachi Zosen Tourist Co., Ltd.

Summary of the hydraulic experiment of

The Tension Radial Gate.

We investigated the hydraulic characteristics of Tension radial gate by the experiments with an acrylic model. The end of conduit pipe of the model was throttled. The experiments carried out in Public Works Research Institute Ministry of Construction, Government of Japan. (see fig-1)

We got the release ability curve from the experiment result. (see fig-2)
The model experiments indicated that the coefficient of discharge of The Tension Radial Gate was higher than that of the other type gate or valve. (see fig-3)

The water jet issuing from the partial opening of the gate fan out.
The jet coming from the intersection of the gate lip and the pipe end spread out. (In the technical report of a model test of the CLAMSHELL-GATE, this jet was called "thin fins".)
In addition, the water jet emerging from the space between the gate leaf and end of the pipe splash widely. (see fig-4)
In the case that there was no space between the gate leaf and the end of the pipe, this jet didn't occur. (see fig-5)

We considered that there was no problem in hydraulic characteristics of the Tension Radial Gate from the model experiments.

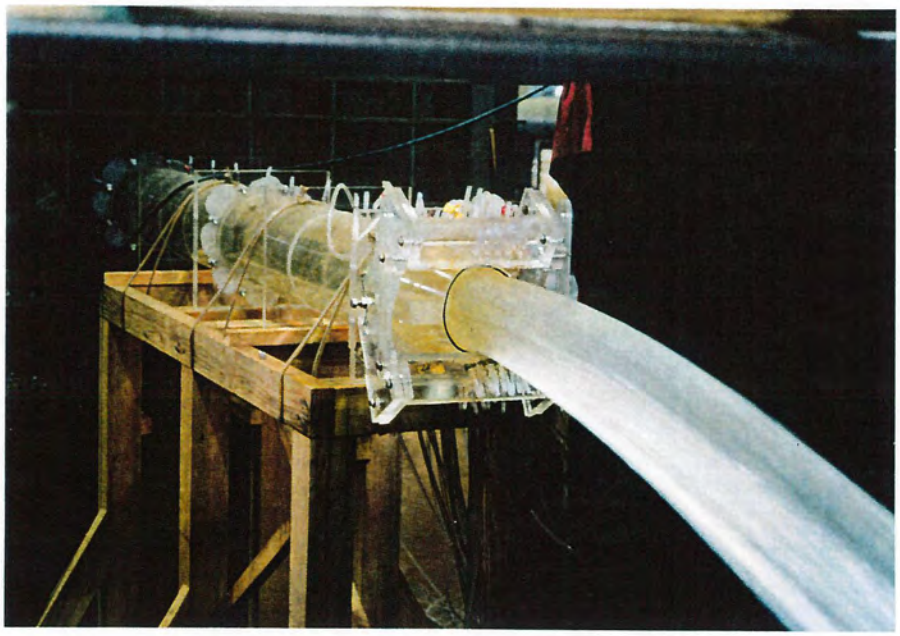
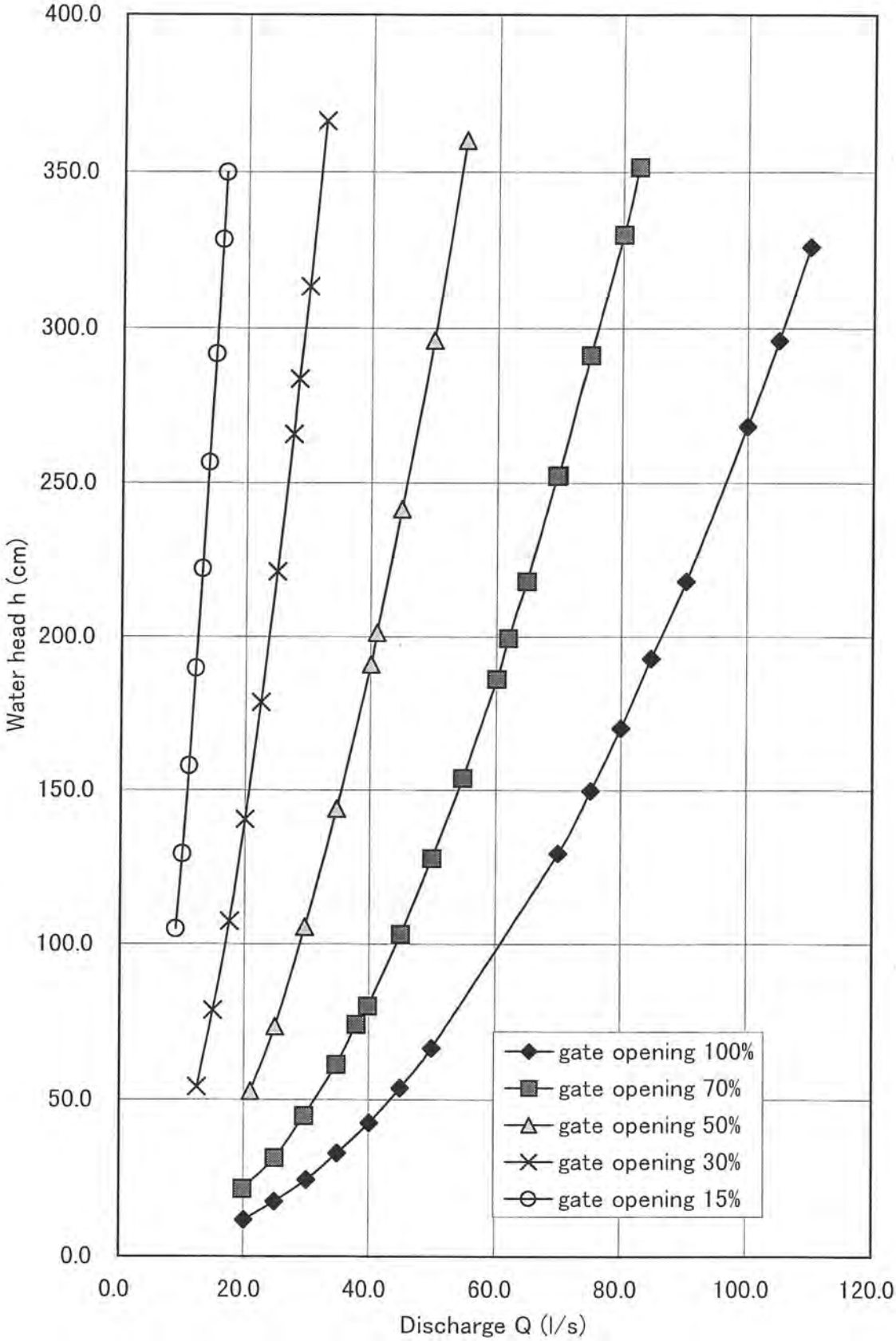
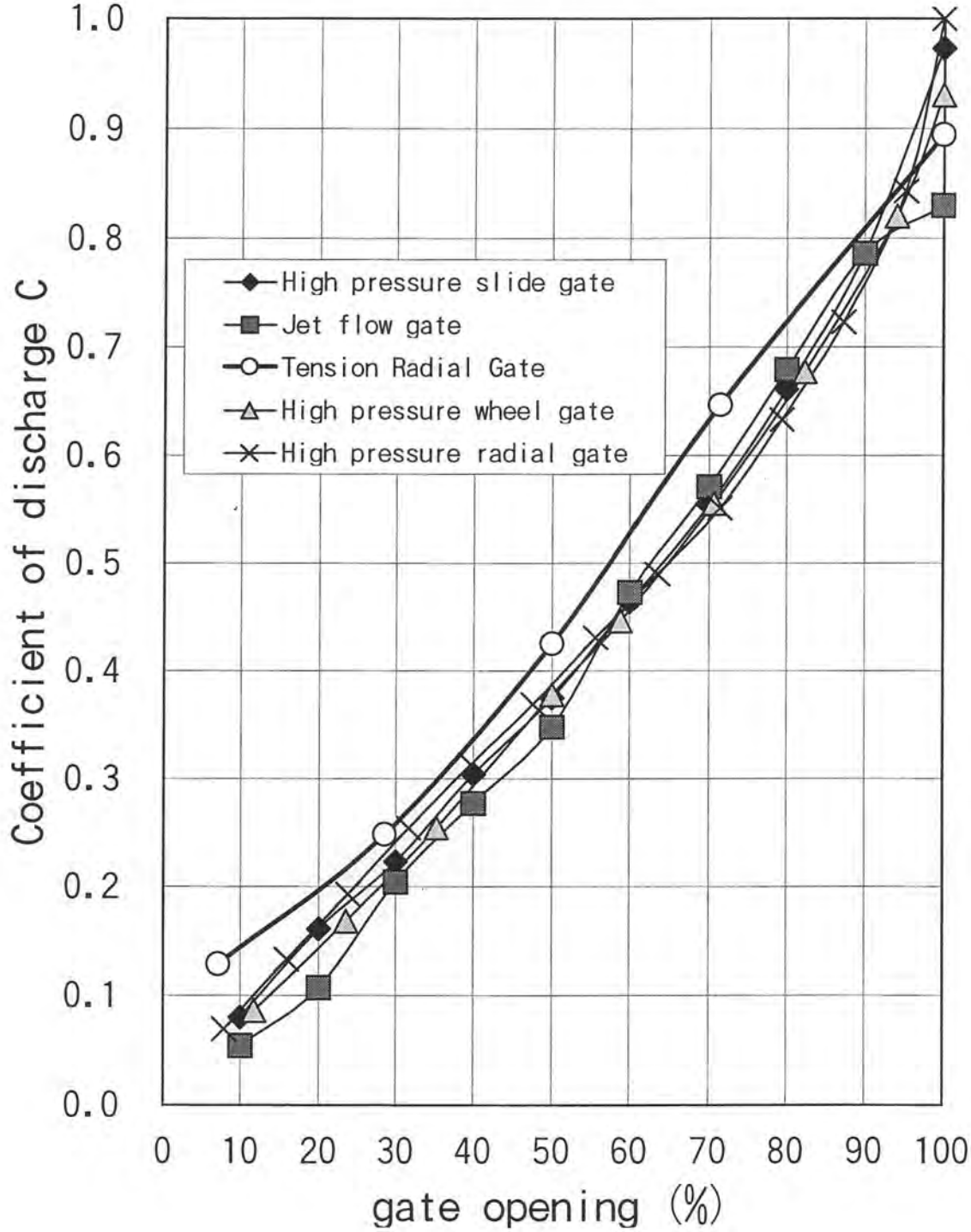


Figure-1 The acrylic model of The Tension Radial gate


400.0
350.0
300.0
250.0
200.0
150.0
100.0
50.0
0.0
Water head h (cm)
0.0
20.0
40.0
60.0
80.0
100.0
120.0
Discharge Q (l/s)
gate opening 100%
gate opening 70%
gate opening 50%
gate opening 30%
gate opening 15%


1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Coefficient of discharge C
High pressure slide gate
Jet flow gate
Tension Radial Gate
High pressure wheel gate
High pressure radial gate
0
10
20
30
40
50
60
70
80
90
100
gate opening (%)

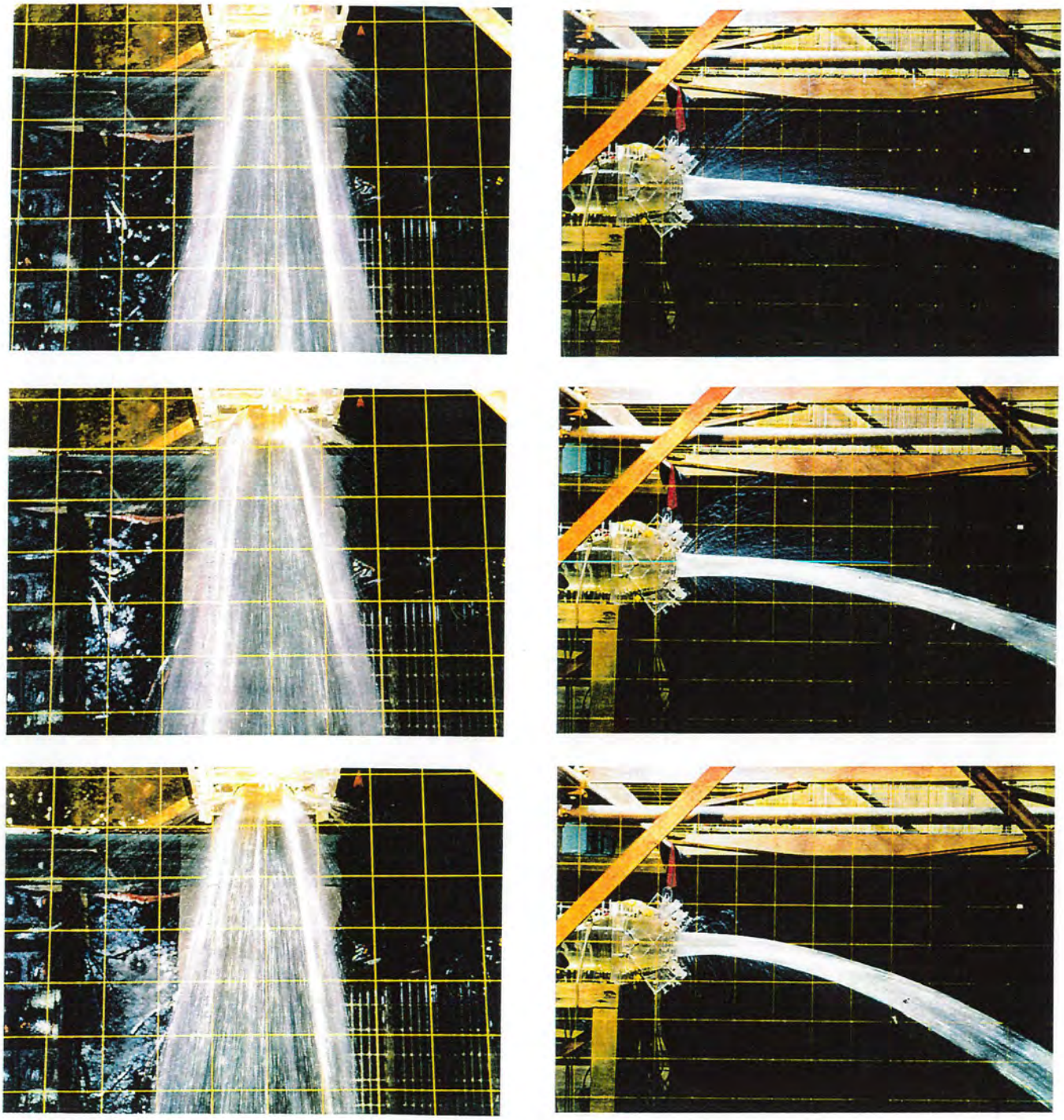
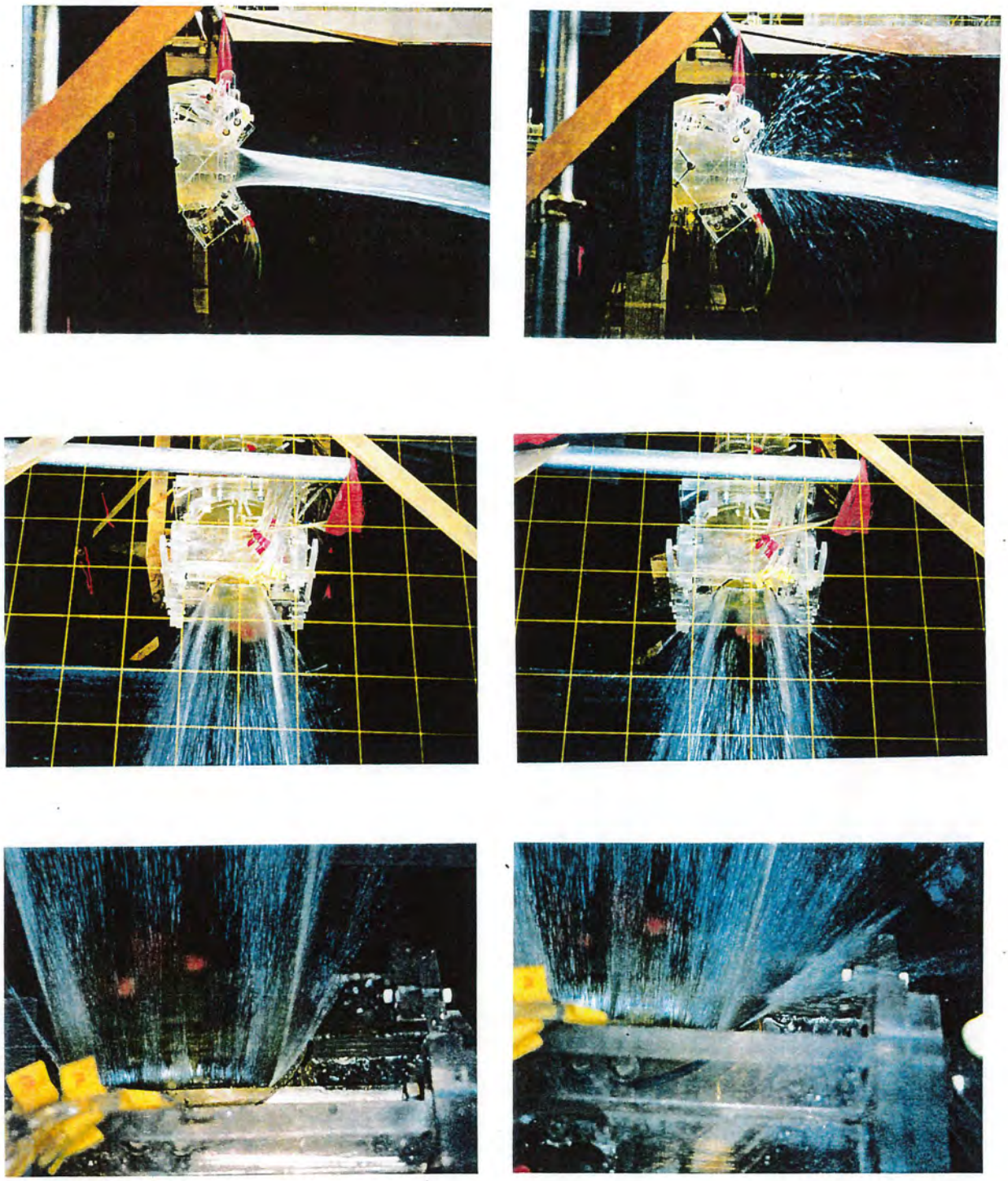


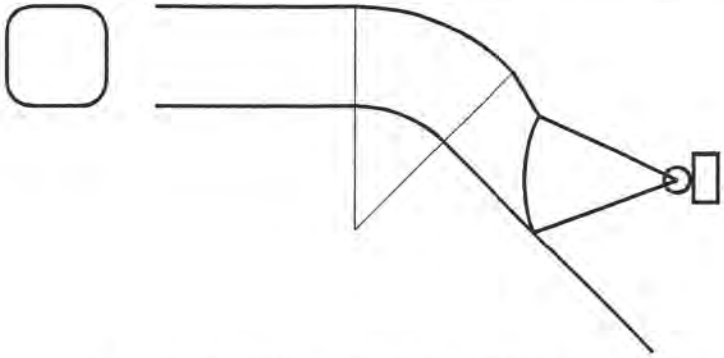
Figure-4 The water jet issuing from the partial opening of the gate
(h= 300 , 200 , 100 cm)



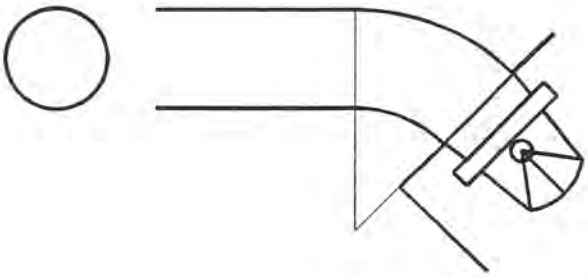
Clearance 0mm　　Clearance 1mm

Figure-5 Comparison of the water jet(clearance 1mm and 0mm)

Our Basic Concepts of TENSION-RADIAL GATE



CONVENTIONAL HIGH PRESSURE RADIAL GATE



TENSION-RADIAL GATE

POINTS OF ADVANTAGE

1. RECTANGULAR CONDUIT → CIRCULAR CONDUIT
   To Relieve the Stress Concentration of Dam Concrete

2. ONE LARGE GATE LEAF →TWO COMPACT GATE LEAVES
   To Decrease the Weight of Equipment

3. SEPARATE ANCHOR SUTRUCTURE → CONDUIT ITSELF IS LARGE ANCHORAGE
   Easy to Keep the Accuracy of Installation Tolerance

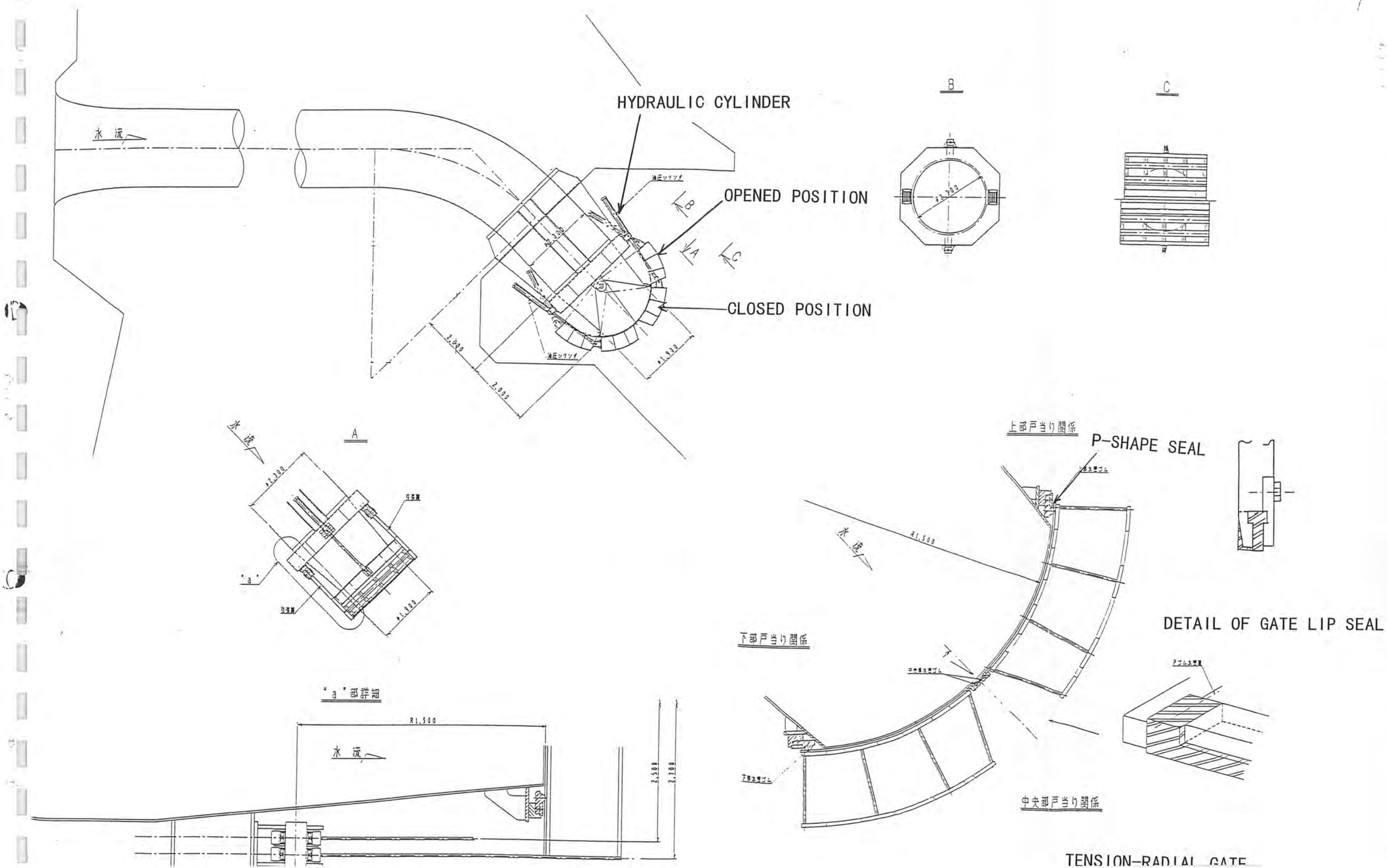
4. COMPRESSIVE RADIAL ARM → TENSILE FAN-SHAPED PLATE
   No Buckling (Structurally Stable)

Finite Element Analysis of Structures

1. Conditions of Analysis
   - Static Analysis
   - Pressure Head = about 50 m
   - Diameter of Orifice = 1900 mm
   - Radius of Gate Leaf = 1500 mm
   - Members of Structure are Made of Thin Plates.

2. General Arrangement of TENSION-RADIAL GATE
   See next page

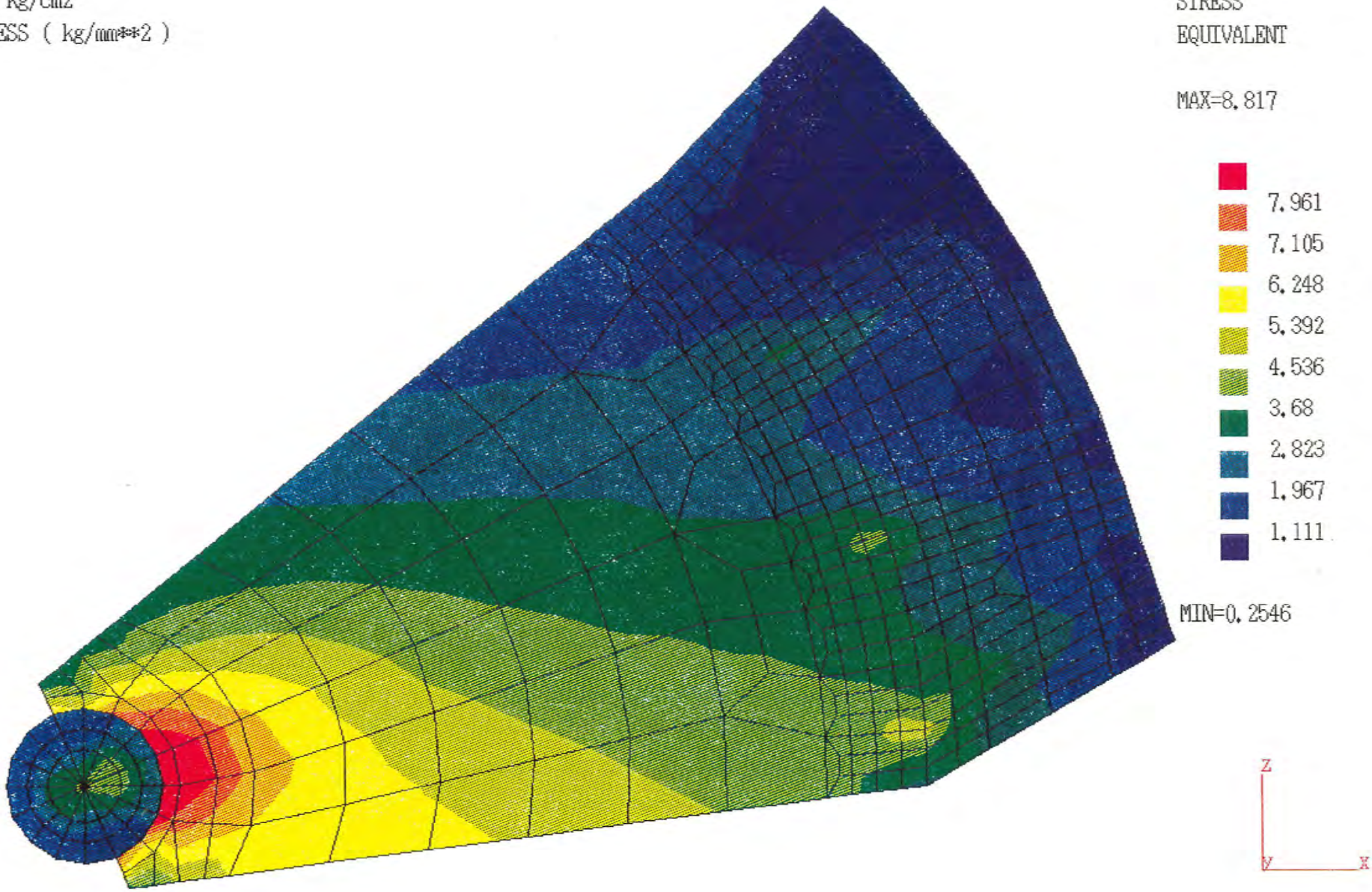
3. Results of Analysis
   - Relatively High Stress Area of Fan-Shaped Plate and Conduit Pipe is Only Near the Trunnion.
   - Deformation of Structure is Adequately Small so that can Keep Water Tightness by Rubber Seals.


HYDRAULIC CYLINDER
OPENED POSITION
CLOSED POSITION
水流
B
C
A
"a"部詳細
上部戸当り関係
P-SHAPE SEAL
DETAIL OF GATE LIP SEAL
下部戸当り関係
中央部戸当り関係
TENSION-RADIAL GATE

20 RADIALGATE 侧板

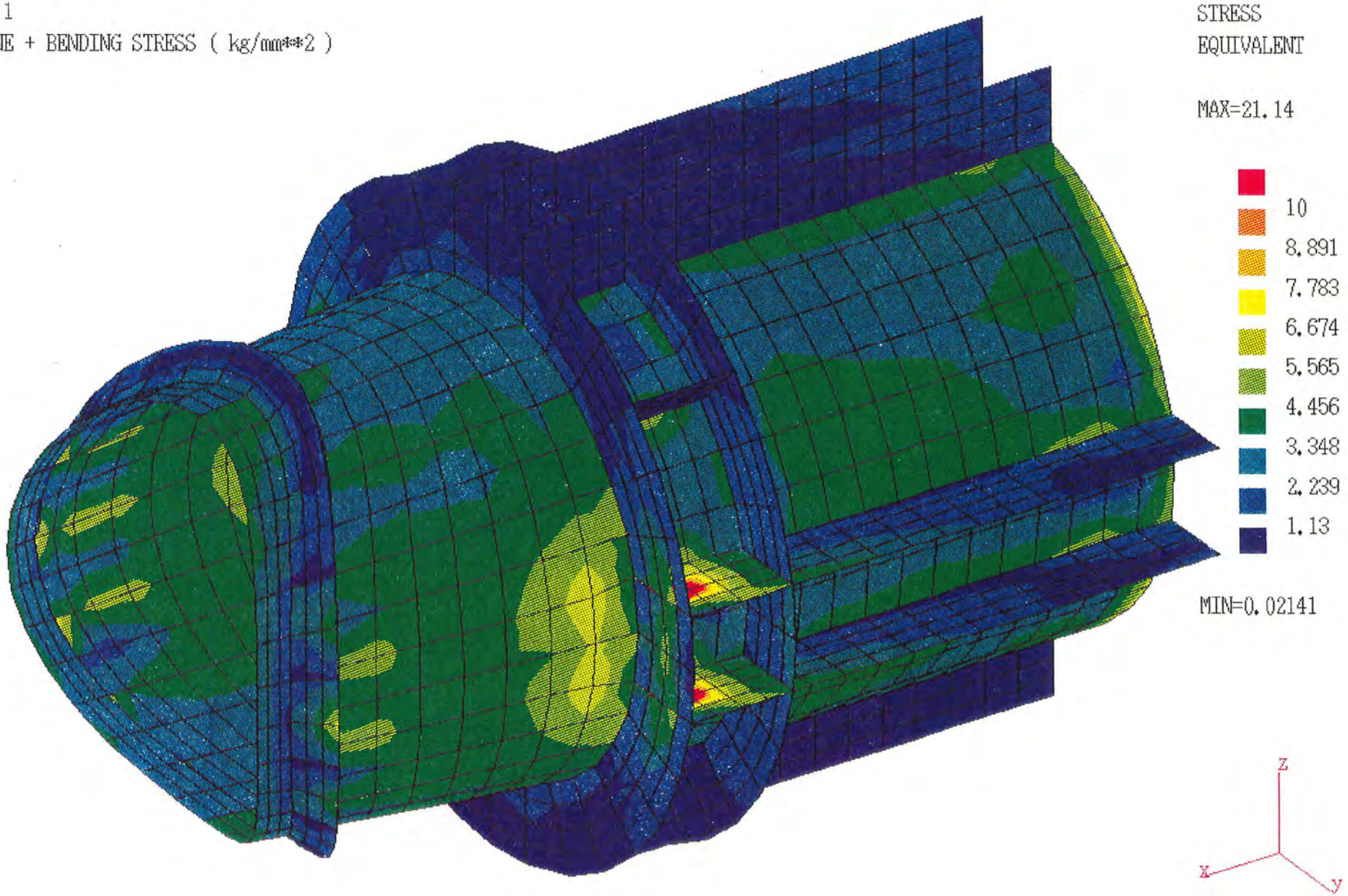
ING 1 5.4 kg/cm2

BRANE STRESS (kg/mm**2)



4

. 32 RAGIAL GATE PIPE
ING 1
BRANE + BENDING STRESS (kg/mm**2)



5

Questionnaire About CLAMSHELL-GATES

Seal System:

In the technical report of a model test of the CLAMSHELL-GATE ,the rubber seal system was adopted .And the cross-sectional shape of the seal rubber was similar to the seal-ring of a JET-FLOW GATE .

For the design of prototype of CLAMSHELL-GATE ,rubber seal system like the tested model was adopted ?

The rubber seems to be always exposed to the flow ,isn't there any trouble on the seal rubber ?

Restraint of small opening discharge:

To avoid occurring the problem of cavitation ,is there any restriction on the small openings of the gate leaves ?

Influence of emergency closure by a guard gate (or valve):

When there happens some trouble or accident in CLAMSHELL-GATE during the discharge , a guard gate (or valve) , which installed at just upstream of the regulating clamshell-gate , shall be closed in emergency .In case that the CLAMSHELL-GATE is in partial open condition ,does the emergency closure by a guard gate causes the vibration of CLAMSHELL-GATE or the unstable flow between both gates ?

Is air inlet necessary ?

Operating mechanism:

What is the most suitable operating mechanism for the CLAMSHELL-GATE ?

PAP-423

CLAMSHELL GATE

November 1981

T. J. Isbester

OPTIONAL FORM NO. 10
JULY 1973 EDITION
GSA FPMR (41 CFR) 101-11.6

UNITED STATES GOVERNMENT

Memorandum

Memorandum

TO : Chief, Hydraulics Branch

Denver, Colorado
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)

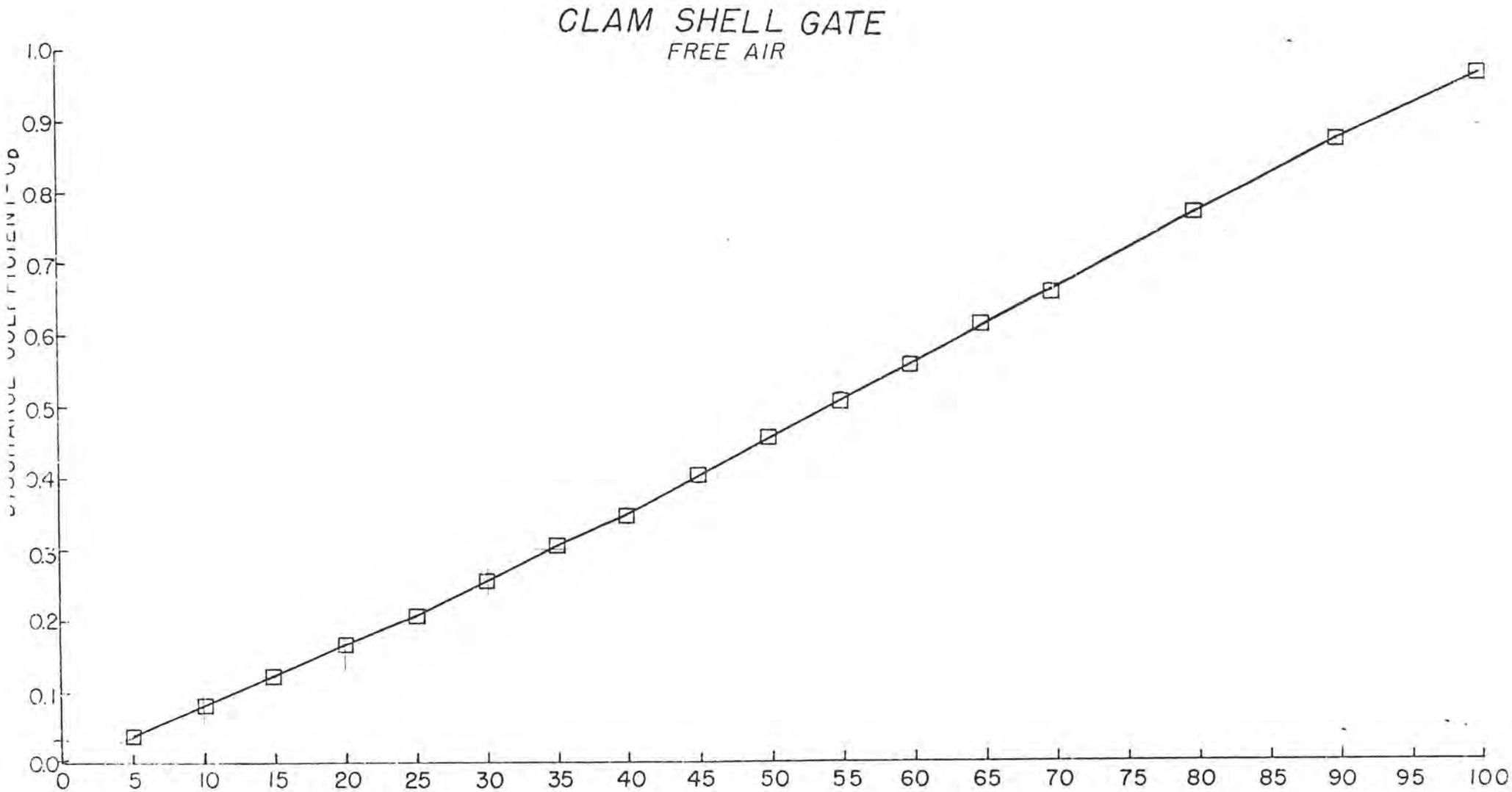


Figure 4. - % GATE OPENING

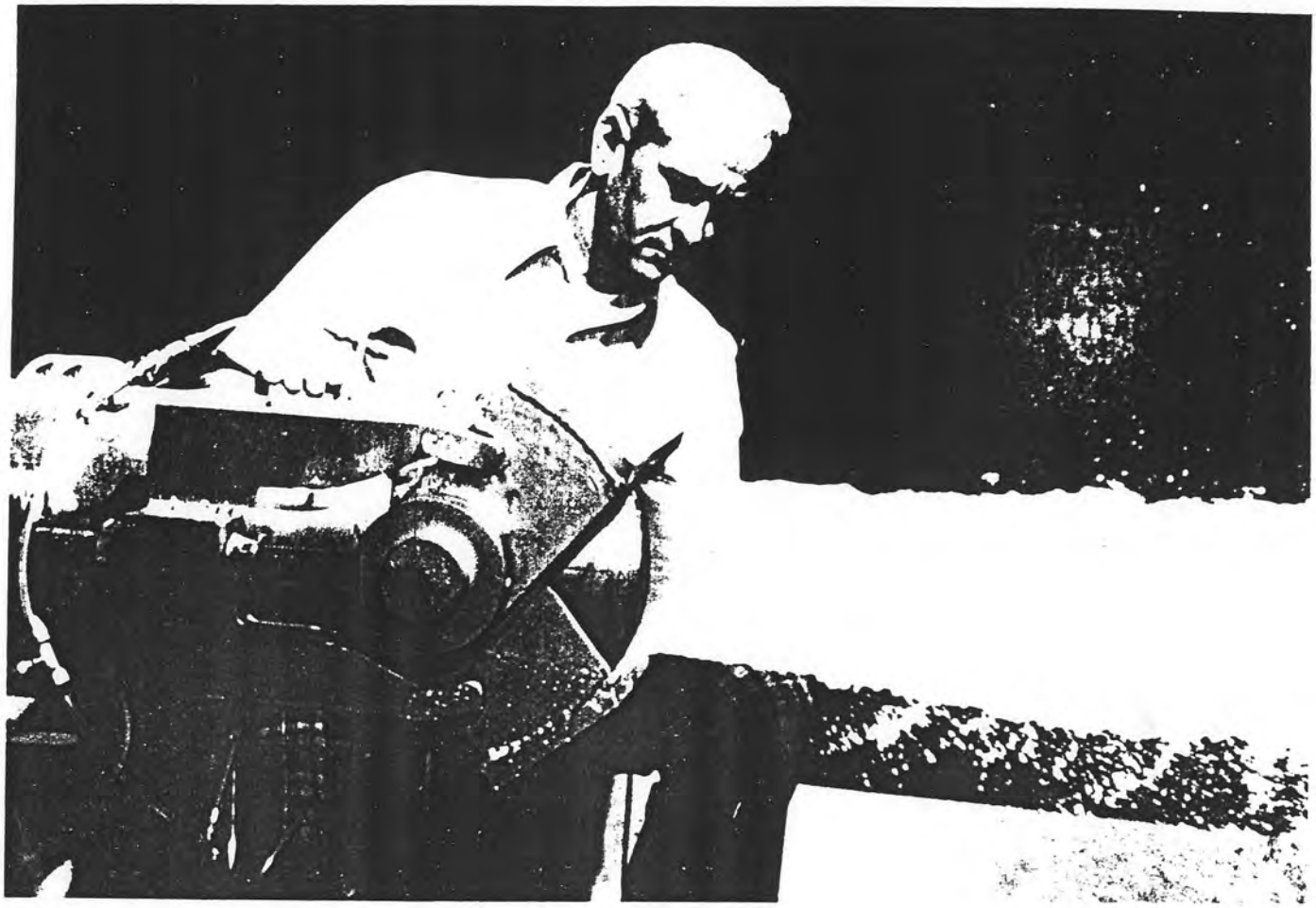


Figure 1. - Clamshell gate with upper and lower radial members and simple radius machined on downstream end of pipe.

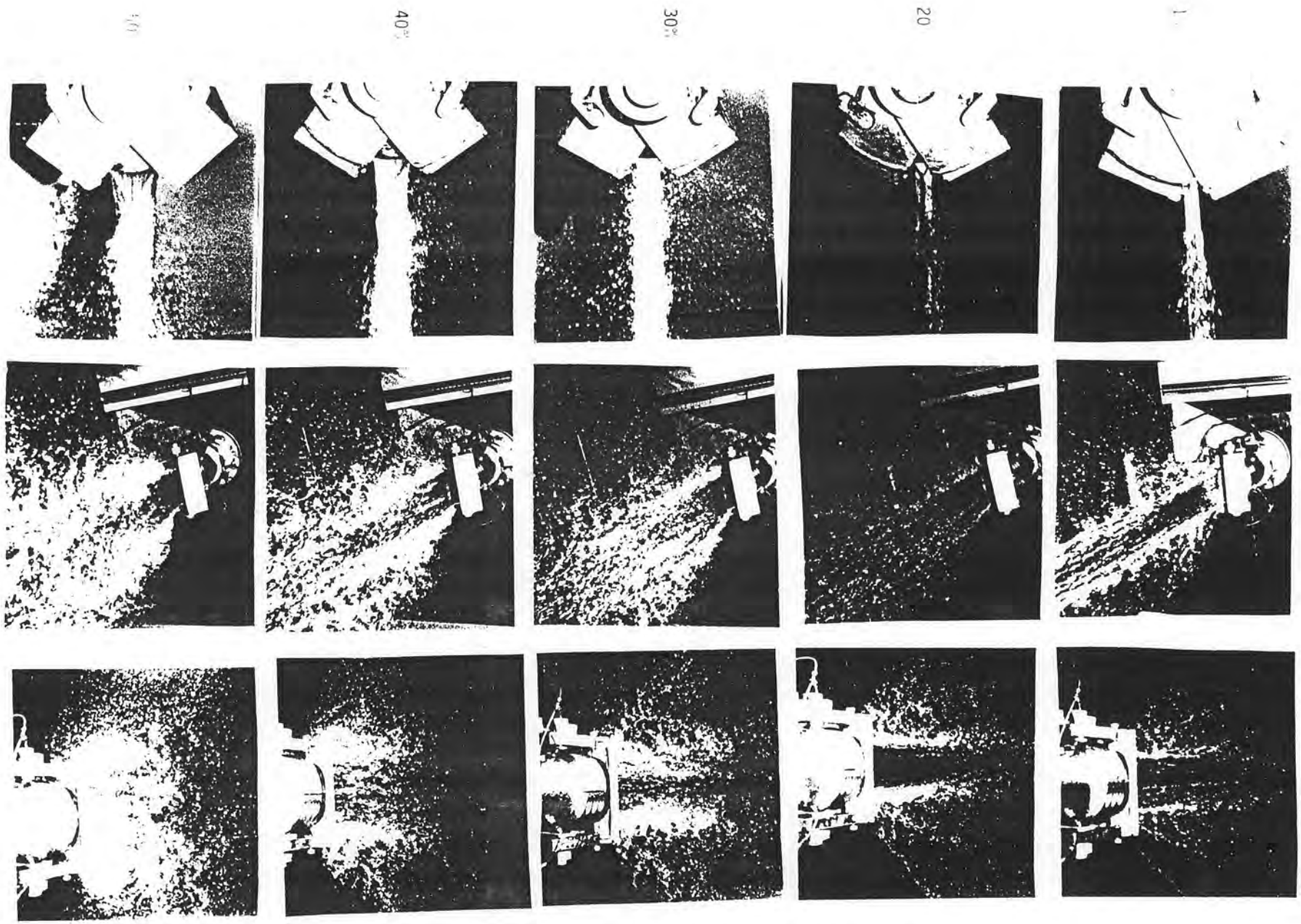


Figure 2. - Gate openings - 10 to 50 percent.

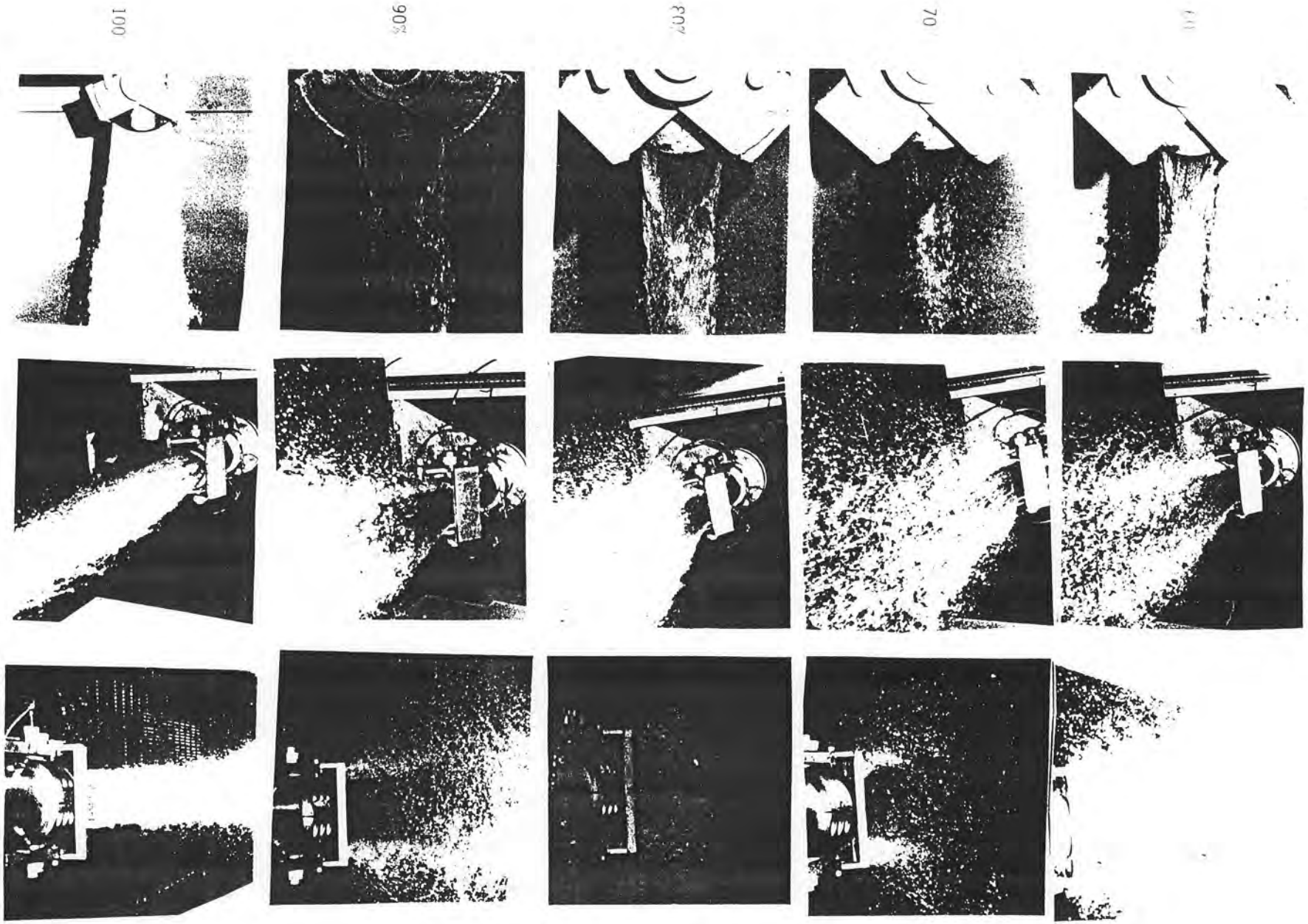
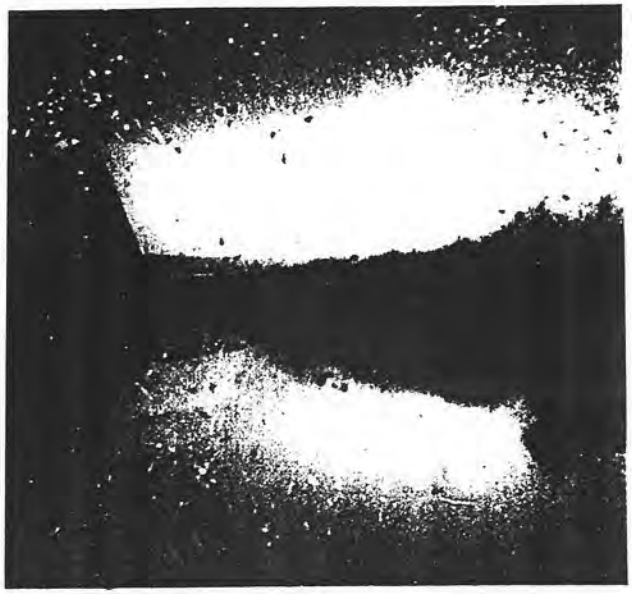
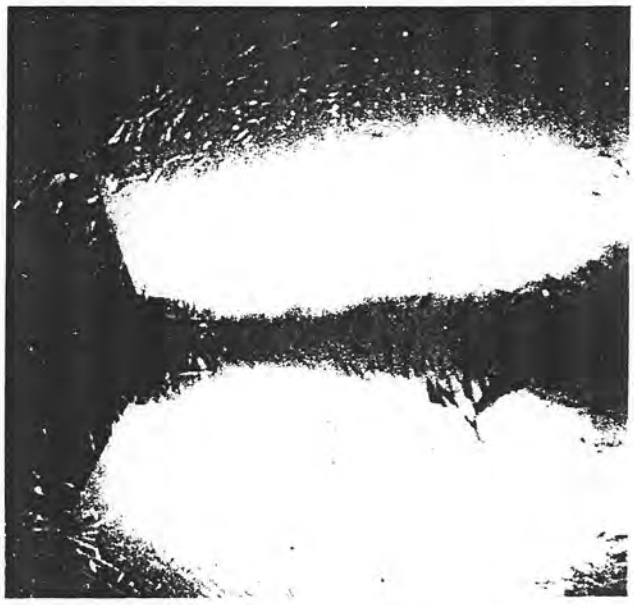


Figure 3. - Gate openings - 60 to 100 percent.



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.

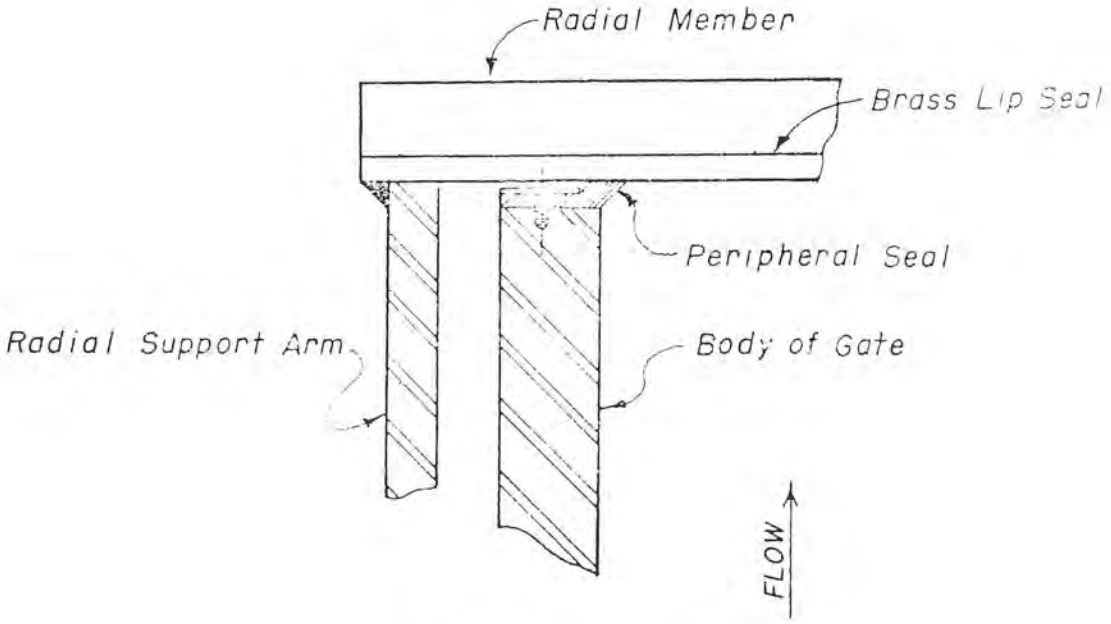


Figure 5. - SECTIONAL VIEW OF SEAL TRANSVERSE CENTERLINE