UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 171

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MODEL TEST FOR THE PROPOSED HIGH-HEAD RADIAL GATES FOR DAVIS DAM OUTLETS
DAVIS DAM PROJECT

By

R. C. BESEL, JUNIOR ENGINEER

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Denver, Colorado
May 3, 1945

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SUBJECT: MODEL TEST FOR THE PROPOSED HIGH-HEAD

RADIAL GATES FOR DAVIS DAM

DAVIS DAM PROJECT

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By R. C. BESEL, JUNIOR ENGINEER

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Under Direction of

J. E. WARNOCK, SENIOR ENGINEER

and

R. F. BLANKS, SENIOR ENGINEER

- - -

Denver, Colorado,
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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
February 28, 1945

Laboratory Report No. 171
Hydraulic Laboratory

Compiled by: R. C. Besel
Reviewed by: J. E. Warnock

Subject: Model test for the proposed high-head radial gates for Davis Dam, Davis Dam project.

1. General. The Davis Dam is located on the Colorado River approximately 67 miles downstream from Boulder Dam, and about 29 miles west of Kingman, Arizona. The dam powerhouse will contain four or five generators to augment the Boulder Dam output. The discharge regulation will be provided by two outlets and by an overflow spillway constructed near the powerhouse. It is proposed that the outlets will have a rectangular bellmouth entrance with 22- by 19-foot radial gatesinstalled in them. These gates will regulate sluice water which will discharge onto an ogee apron having a 75-foot radius bucket.

In the past, radial-type gates have been used for surface-water regulation only; in this installation they are to operate under 113 feet of head. This caused considerable uncertainty and apprehension as to the behavior of this type of gate under a high head, especially at partial openings. It was therefore desired to determine the characteristics of the gate from an hydraulic model.

2. Description of the model. To obtain the best possible results, the model was constructed to as large a scale as possible. The limiting facilities in the laboratory permitted a 1:30 scale ratio.

The model of the gate was constructed entirely of sheet metal and as near a facsimile of the prototype as possible. The structural members, diaphragms, and skin plates were made to scale, this resulting in a mechanical model of the prototype with the mass ratio closely related to the prototype. Most of the rubber seals were eliminated in the model because the frictional forces due to the seals would have been disproportionate in the model. In the testing for vibrations of the gate, all the seals were removed and a clearance of one-sixteenth of an inch along the sides of the skin plate was made to free the gate completely from restraint by the outlet structure.

The outlet structure was construoted of sheet metal (figure 1), one side of which was faced with pyralin so that the action of the water passing the gate could be observed. The path of movement of the gate and the details of the prototype installation are shown in figure 2.

3. Scope of the tests. The studies of the model of the radial gate were made to determine the behavior of the gate under high heads with partial gate openings, the presence of any vibration in the gate during operation, and the coefficient of discharge of the gate.

4. Test procedure. The radial-gate model was tested under high heads, variable discharges through the structure, and at partial gate openings. The model indicated satisfactory operation of the gate at all openings and heads. The flow upon leaving the lower lip of the gate cleared the remainder of the gate and followed the parabolic

floor through to the downstream portal as shown in figure 3. The shape of the vena-contracta was characteristic of the flow under gates of similar design where the gate has been used for regulation of surface flow.

The next step in the test procedure was to investigate the possibilities of vibrations of the gate during operation. The control rod used to raise and lower the gate was replaced by a very fine wire which allowed the gate to move in any direction. Two Ames dials were attached at the sides of the top lip of the gate and mounted such that vibrations other than those from the gate would not be recorded. The dials did not show any vibration. It was noticed that after each change in head, the corresponding change in discharge caused a downward movement of the gate. This motion was due to the increase in the downward force of friction between the water and the skin plate of the gate. The motion stopped when the flow became steady.

To study the possibility of the existence of vibrations more thoroughly, the gate and outlet structure were moved to a different location so that a higher head and a more solid mounting for the gate structure could be obtained. The gate rod was attached to an induction-type pressure cell adapted to the measuring of vibrations. This cell records movements as small as one-millionth of an inch on an oscillograph. The oscillograph records of the vibrations of the gate are shown in figure 4.

The first record, figure 4A, shows the vibrations due to a light tapping on the gate with no water flowing and indicates the natural frequency of the apparatus in the vertical plane. The other records, figures 4B, C, and D, show the vibration record with flow under the gate and do not indicate any movement in the vertical direction. The small wave in figures 4C and D is due to a lateral movement of the gate of the same frequency as the natural lateral frequency shown in figure 4E. This movement was about 0.000004 to 0.000005 inch and probably was due to the gate being free to move laterally when the entire structure vibrated. Figure 4B shows the gate movement in a vertical direction with the gate out of the line of flow.

The lateral movement of the gate was obtained in a similar manner. The vibration record is shown on figures 4F, G, and A. The records show a periodic lateral movement of the gate. Further investigation revealed that this movement was transmitted to the gate from the gate structure and was due to the model flow rather than from any hydraulic forces acting on the gate. This was evident from the oscillograms, which show the lateral movement of the gate increasing in amplitude with an increase in gate opening and flow, until the maximum amplitude of lateral movement was obtained with the gate out of line of the flow and no hydraulic forces acting on it, figure 4F.

Tests were made to determine the coefficient of discharge of the gate. The curve, figure 5, shows that at large gate openings the coefficient approaches 1, and at the low openings drops to about 0.665.

5. Conclusions. From the tests performed on the model of the radial-type gate under the high-head conditions the following conclusions were made:

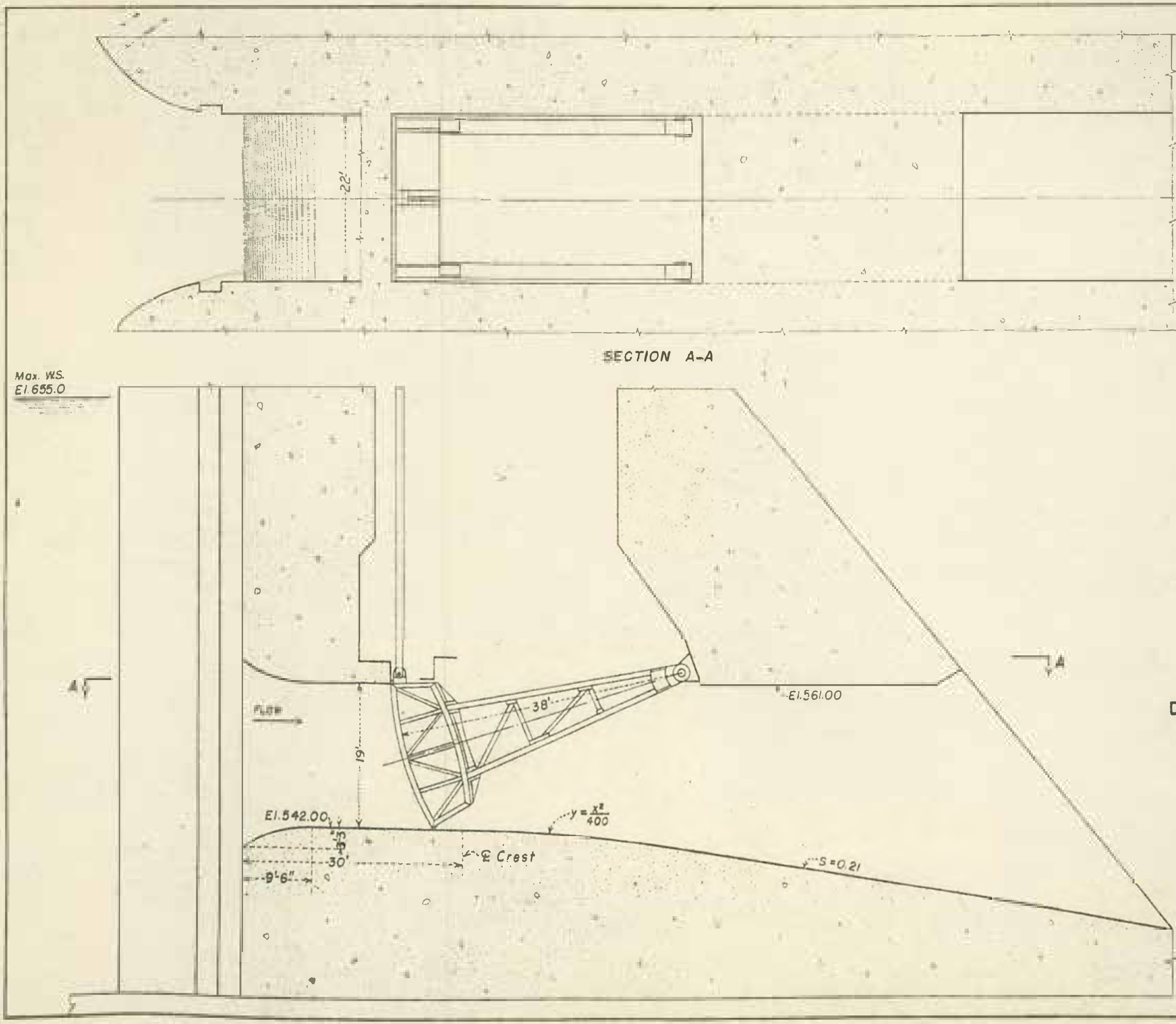
During operations of the radial-type gate under high heads the water springs free at the lower lip and clears the remaining part of the gate as shown in figure 3.

The gate will close by forces of gravity alone, thereby permitting the use of a cable for hoisting if desired.

No critical vibrations were present in either the horizontal or vertical planes on the model, figure 4.

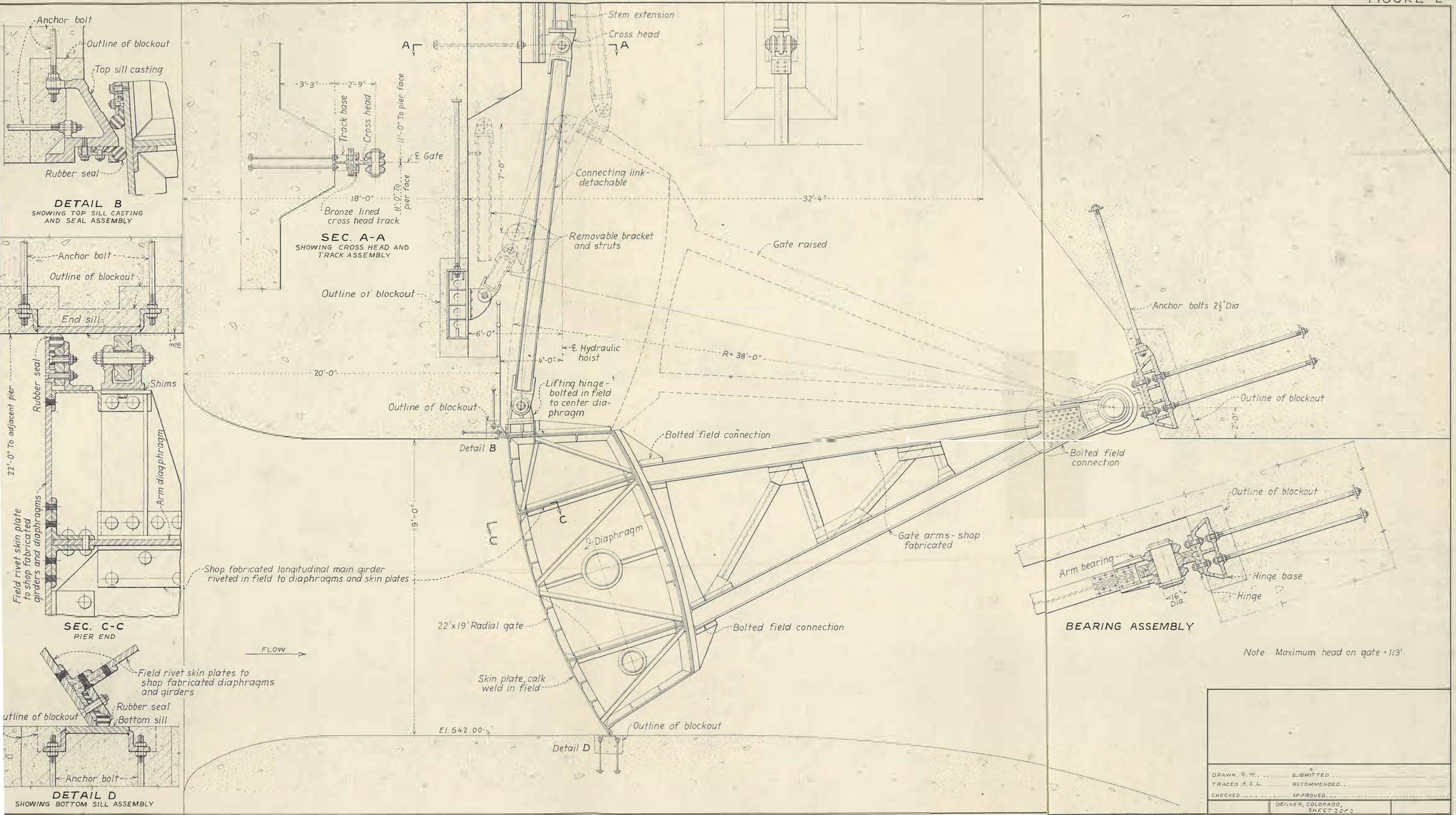
- - -

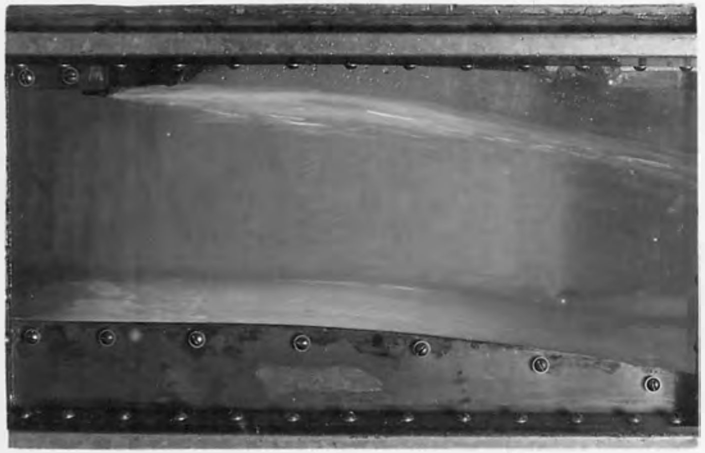
FIGURE 1.



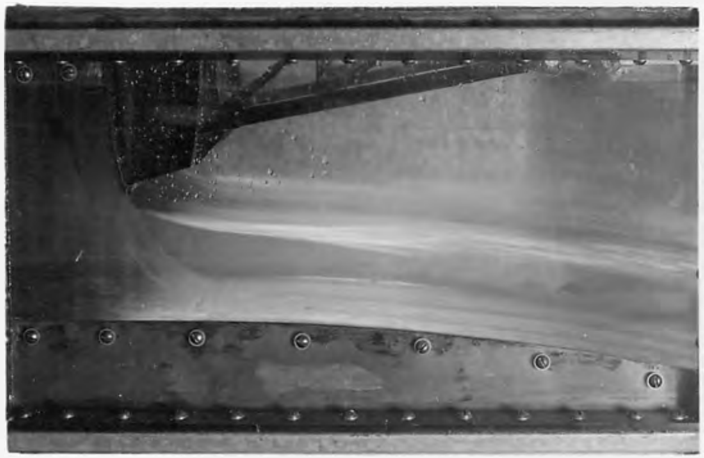
DAVIS DAM OUTLET
RADIAL GATE

FIGURE 2

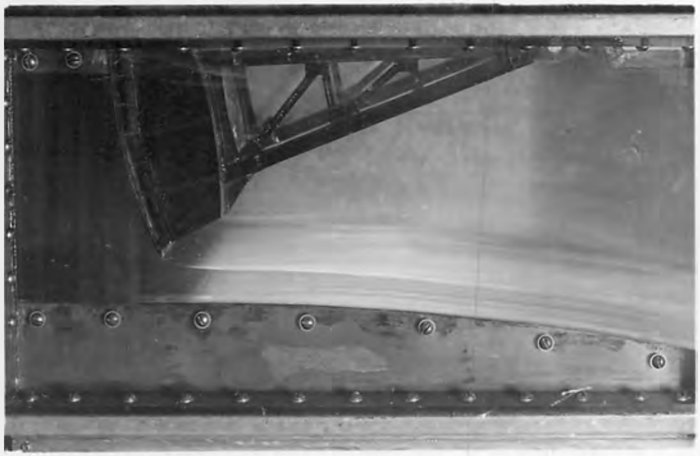

Anchor bolt
Outline of blockout
Top sill casting
Rubber seal
DETAIL B
SHOWING TOP SILL CASTING AND SEAL ASSEMBLY
Anchor bolt
Outline of blockout
End sill
Rubber seal
Shims
22'-0" To adjacent pier
Arm diaphragm
Field rivet skin plate to shop fabricated girders and diaphragms
SEC. C-C
PIER END
Field rivet skin plates to shop fabricated diaphragms and girders
Rubber seal
Bottom sill
Outline of blockout
Anchor bolt
DETAIL D
SHOWING BOTTOM SILL ASSEMBLY
3'-3"
2'-9"
Track base
Cross head
11'-0" To pier face
℄ Gate
18'-0"
11'-0" To pier face
Bronze lined cross head track
SEC. A-A
SHOWING CROSS HEAD AND TRACK ASSEMBLY
Stem extension
Cross head
A
A
7'-0"
Connecting link-detachable
Removable bracket and struts
Outline of blockout
6'-0"
4'-0"
℄ Hydraulic hoist
20'-0"
Lifting hinge-bolted in field to center diaphragm
Outline of blockout
Detail B
32'-4"
Gate raised
R= 38'-0"
Bolted field connection
Bolted field connection
C
C
℄ Diaphragm
9'-0"
Shop fabricated longitudinal main girder riveted in field to diaphragms and skin plates
Gate arms-shop fabricated
22'x19' Radial gate
Bolted field connection
FLOW
Skin plate, calk weld in field
El. 542.00
Outline of blockout
Detail D
Anchor bolts 2½" Dia
Outline of blockout
2'-0"
Outline of blockout
Arm bearing
Hinge base
Hinge
16" Dia
BEARING ASSEMBLY
Note Maximum head on gate = 113'
DRAWN G.W.
SUBMITTED
TRACED A.E.L.
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO, SHEET 2 OF 3



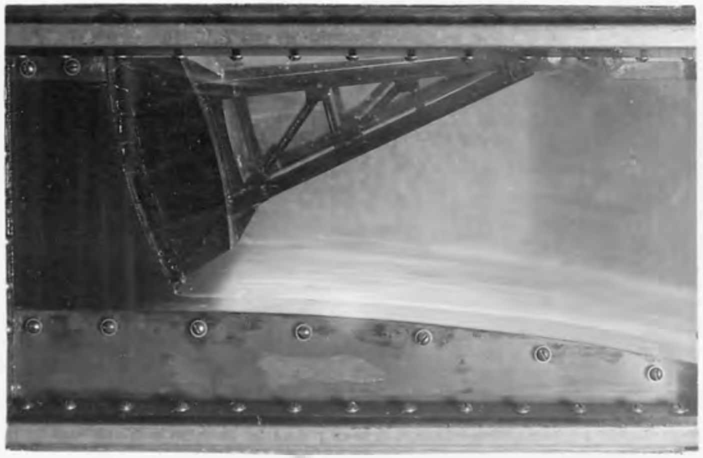
A. 100% OPENING



B. 50% OPENING



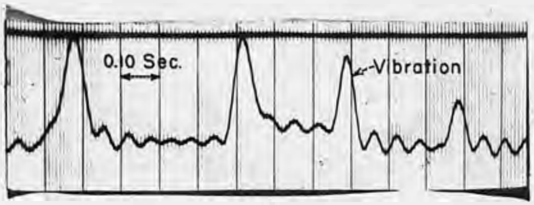
C. 19% OPENING



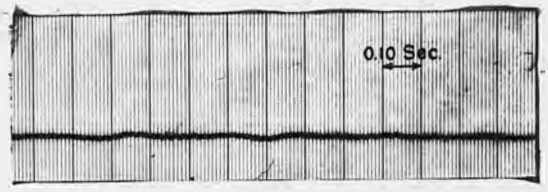
D. 7% OPENING

RADIAL GATE WITH VARIABLE HEADS AND OPENINGS

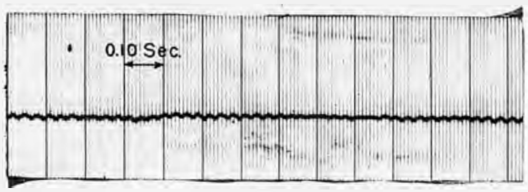
FIGURE 3



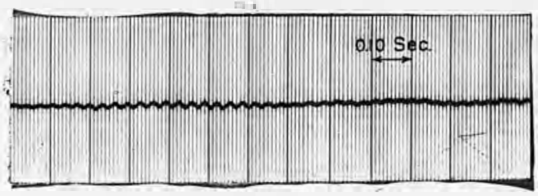
A. VIBRATION DUE TO TAPPING ON GATE



B. 100% OPENING
NO WATER IN CONTACT WITH GATE

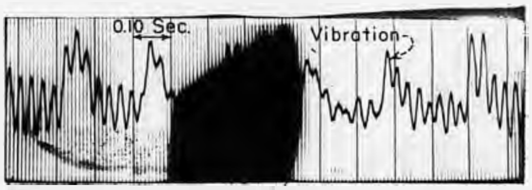


C. 85.52 % OPENING

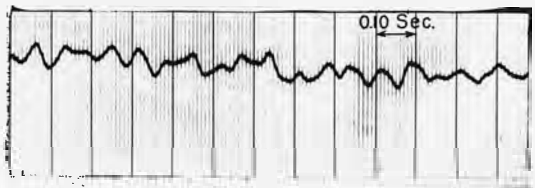


D. 32.89 % OPENING

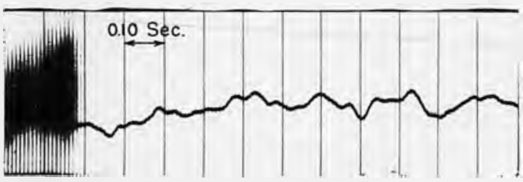
VIBRATION IN VERTICAL PLANE



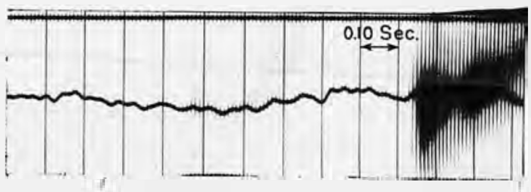
E. VIBRATION DUE TO TAPPING ON GATE



F. 100% OPENING
NO WATER IN CONTACT WITH GATE



G. 75.65 % OPENING



H. 37.81 % OPENING

VIBRATION IN HORIZONTAL PLANE

VIBRATION STUDIES OF DAVIS DAM RADIAL GATES

NOTE

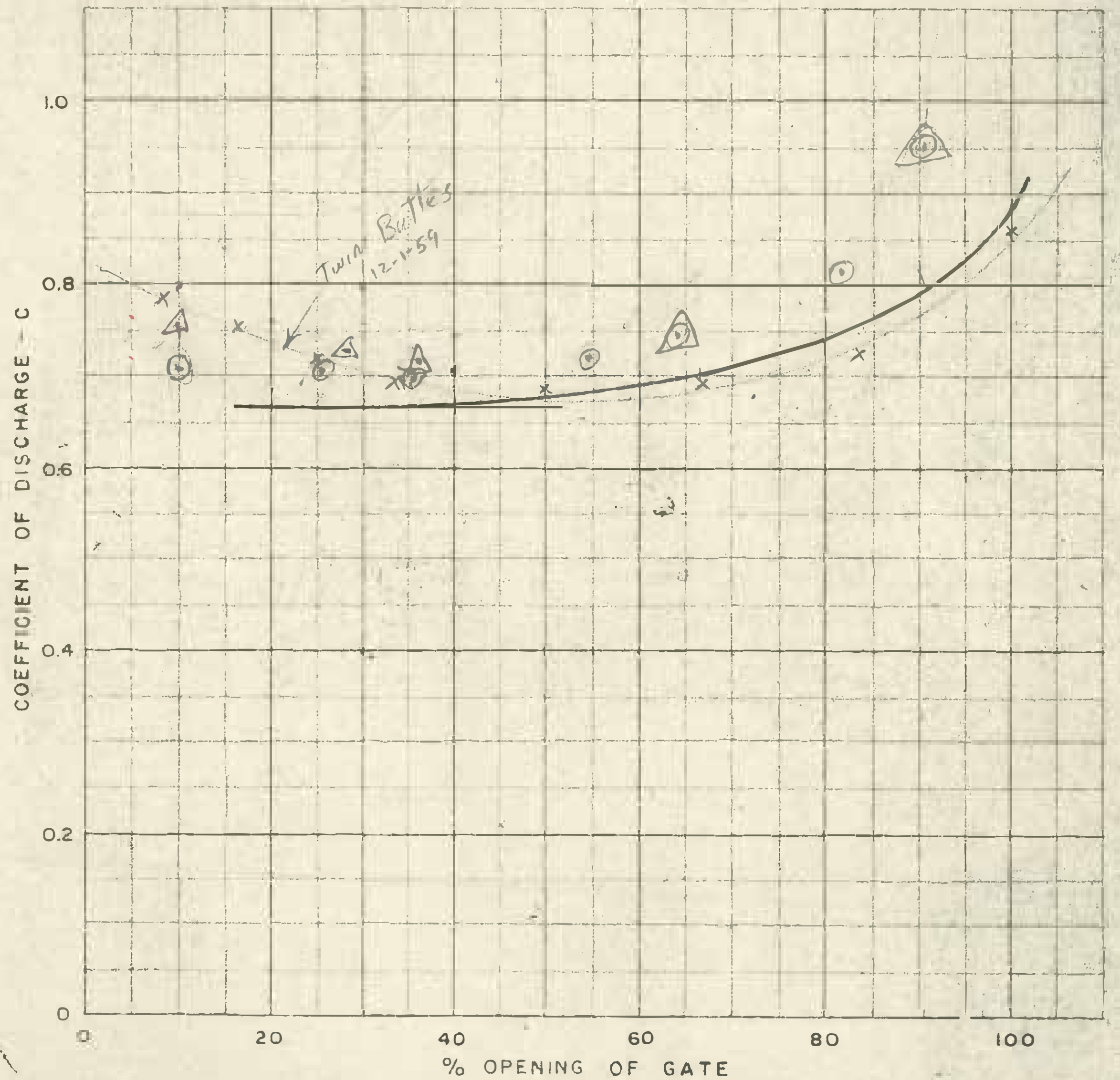
$$C = \frac{Q}{A\sqrt{2gh}}$$

h = Total head

A = Area of gate opening

○ Preliminary Fontenelle

△ Final Fontenelle



DAVIS DAM RADIAL GATE STUDY

COEFFICIENT OF DISCHARGE CURVE