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C O P Y RJD

Memorandum
Denver, Colorado
April 2, 1956

To: Chief, Mechanical Branch
Attention: W. G. Weber

From: Chief, Division of Engineering Laboratories (D. Colgate)

Subject: Model tests to determine the hydraulic downpull forces on the fixed-wheel gate at Glendo Dam--Missouri River Basin Project

The 16.5- by 21-foot fixed wheel gate at Glendo Dam will be partially opened (3 to 6 inches) to backfill approximately 1,865 feet of 21-foot-diameter tunnel and 5 pipe branches leading to the outlets and turbines. A model study was made primarily to determine the magnitude of the hydraulic downpull forces to which the gate would be subjected during the period of backfilling. The tests were extended to include the complete range of gate openings.

If, at any instant, the pressures on the gate bottom are less than the pressure in the tunnel immediately downstream from the gate, a downward hydraulic force will result. If the magnitudes of the pressures are known the actual force on the gate can be computed. Since pressures alone are involved in the solution of the problem, a model using air as the flowing medium was considered adequate for the study. One binding restriction of an air model is that the system always represents submerged flow. In the case of the Glendo gate with an upstream seal this condition is acceptable because when the gate is not submerged the bottom surface is subjected to atmospheric pressure and there can be no hydraulic downpull force on the gate.

A model gate 2.82 inches thick was installed in a rectangular air duct 9.1 inches wide and 16.8 inches high. The ratio of the gate thickness to tunnel height in the model was the same as that in the prototype. Ten piezometer openings on the gate bottom and on or near the gate center line (Figure 3-A) were used to determine the pressures on the gate during a test run. One piezometer opening in the tunnel roof upstream from the gate, and one downstream, were used to measure the head drop across the gate. The position of the gate could be viewed and measured through the plastic windows forming the gate slots. Figure 3-B shows the model during a typical test run.

The head drop across the gate was determined by computation. The assumption was made that the 21-foot-diameter tunnel was blown off at the power bifurcation with the reservoir at maximum water surface, elevation 4669.0. The head loss through the intake structure with trashracks, and through the tunnel, would permit the passage of 21,500 cfs with the gate opened 100 percent. As the gate closed to stop the flow the tunnel losses would become smaller and smaller and the head drop across the gate larger and larger until, at very small gate openings, the total head of 178 feet would be expended across the gate. A plot was made, Figure 1, showing head drop across the gate versus gate opening.

The air model was tested for various gate openings. The pressure head was measured both upstream and downstream from the gate, and at 10 points on or near the bottom of the gate. From the chart, Figure 1, the prototype head drop for the tested gate opening was determined. This value was divided by the head drop in the model to obtain a pressure factor by which the model values could be transferred to prototype pressures.

A plot was made of the downpull caused by the reduction in pressure (1) under the seal, (2) under the lower web of the gate, and (3) under the downstream lip (see Figure 2). A smooth curve was drawn to average the plotted points and these average downpull curves, together with the total downpull curve, are shown on Figure 2.

Sample computation

3-inch (prototype) gate opening

Model measurements, inches of water

| Upstream | Downstream | Seal | Gate | DS lip |
| --- | --- | --- | --- | --- |
| +8.07 | -0.09 | -1.25 | -0.51 | -0.52 |

Prototype head drop (from Figure 2) = 178 feet

$$\text{Pressure factor} \equiv \frac{178}{8.07 + 0.09} = 21.80$$

Downstream head = -(0.09)(21.80) = -1.96

Under the seal = -(1.25)(21.80) = -27.21

Under the gate = -(0.51)(21.80) = -11.12

Under the DS lip = -(0.52)(21.80) = -11.34

Downpull

$$\text{Seal} = (27.21 - 1.96)(62.4)(16.5)(0.3802) = 9{,}900 \text{ pounds}$$

$$\text{Gate} = (11.12 - 1.96)(62.4)(16.5)(2.9282) = 27{,}610$$

$$\text{DS lip} = (11.34 - 1.96)(62.4)(16.5)(0.2240) = \underline{2{,}160}$$

Total 39,670 pounds

The Glendo downpull information may be converted to apply to any geometrically similar installation by the following method:

A. Find the downpull on the Glendo gate for the desired percent gate opening and the desired head drop:

$$DP_2 = DP_1 \times \frac{Hn}{Hg}$$

where

$DP_1$ = Glendo downpull, Figure 2
$DP_2$ = Glendo downpull with Hn
Hg = Head drop across the Glendo gate, Figure 1
Hn = Desired head drop

B. Find the desired hydraulic downpull by the ratios of the areas under the two gates:

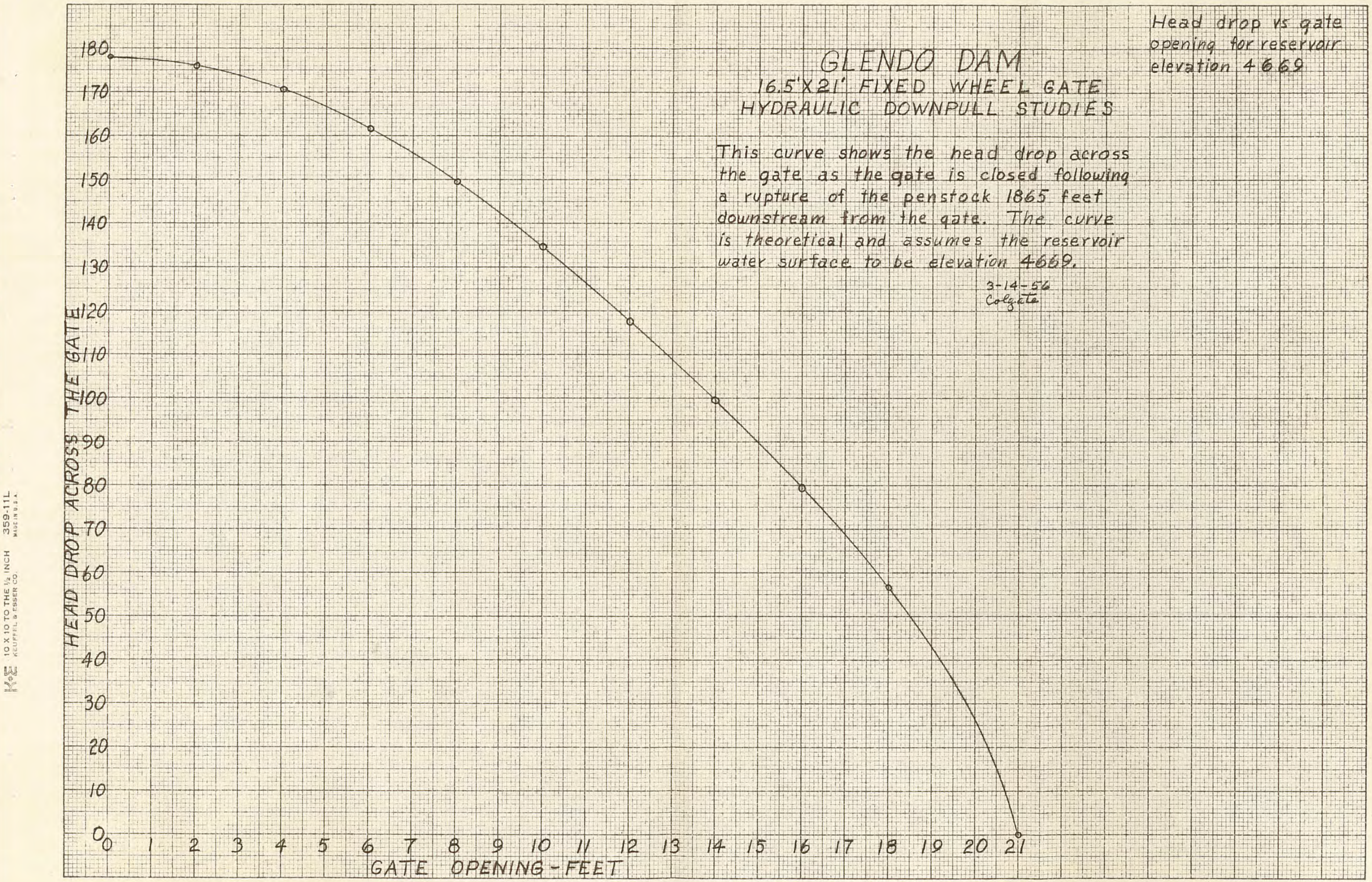
$$DP_3 = DP_2 \times \frac{An}{Ag}$$

where

$DP_3$ = Downpull under the new gate with Hn
An = Area under the new gate
Ag = Area under the Glendo gate

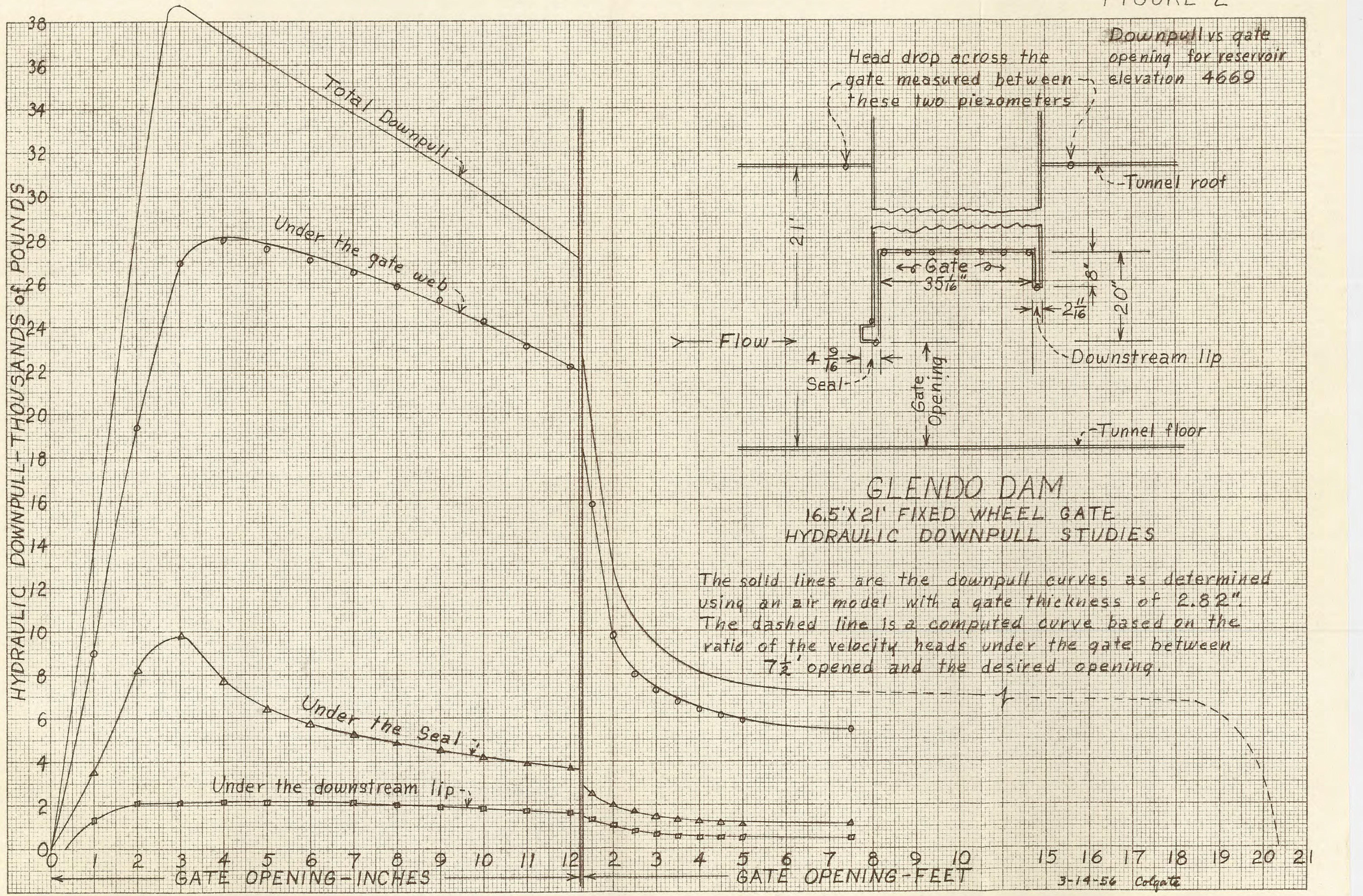
Cavitation pressures are apt to exist under the seal when the gate opening is small and the differential head across the gate is large. If these conditions prevail, the downpull under the seal may be computed by applying cavitation pressures to the area under the seal of the gate being studied. The above method of conversion may be used for the downpull under the gate web and downstream lip.

FIGURE I



Head drop vs gate opening for reservoir elevation 4669
GLENDO DAM
16.5'X21' FIXED WHEEL GATE
HYDRAULIC DOWNPULL STUDIES
This curve shows the head drop across the gate as the gate is closed following a rupture of the penstock 1865 feet downstream from the gate. The curve is theoretical and assumes the reservoir water surface to be elevation 4669.
3-14-56
Colgate
HEAD DROP ACROSS THE GATE
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
GATE OPENING - FEET
10 X 10 TO THE 1/2 INCH 359-11L
KEUFFEL & ESSER CO.

FIGURE 2



Downpull vs gate opening for reservoir elevation 4669
Head drop across the gate measured between these two piezometers
Tunnel roof
21'
Gate 35 1/16"
8"
20"
2 11/16"
Flow
4 9/16
Seal
Gate Opening
Downstream lip
Tunnel floor
GLENDO DAM
16.5'X21' FIXED WHEEL GATE
HYDRAULIC DOWNPULL STUDIES
The solid lines are the downpull curves as determined using an air model with a gate thickness of 2.82". The dashed line is a computed curve based on the ratio of the velocity heads under the gate between 7½' opened and the desired opening.
Total Downpull
Under the gate web
Under the Seal
Under the downstream lip
HYDRAULIC DOWNPULL-THOUSANDS of POUNDS
GATE OPENING-INCHES
GATE OPENING-FEET
3-14-56 Colgate

A. View of the gate bottom.
A few of the 12 piezometer openings used may be seen on the gate bottom center line.


B. Test in progress.
The blower seen at the left draws air in through an orifice (center) and forces it past the gate causing a flow disturbance similar to that caused by water flowing past the prototype gate.

GLENDO DAM
16.5- X 21-foot Fixed Wheel Gate
Hydraulic Downpull Tests
(Air model)