HYDRAULIC DOWNPULL FORCES ON HIGH HEAD GATES

Discussion by W. P. Simmons, Jr.*, M. ASCE

The author clearly points out a number of difficulties encountered with the direct weighing method of determining downpull in tests of high head gates that are fully submerged. The usual use of a pressure tank for these high heads in place of a high and cumbersome head box introduces friction at the point where the gate lifting stem emerges from the tank. In this respect, the high head tests differ from the simpler ones often conducted for spillway gates, etc.1/ In the latter case, downpull measurements by direct reading of scales or similar equipment are possible without any such frictional interference on the stem itself.

Strain gages similar to the ones mentioned in the Shasta prototype studies may be placed on the lifting stems of models within the pressure tank. They thus offer a partial solution to the problem in that they measure the load inside the tank and eliminate any stem friction from the load measurements. They do not take care of another major problem posed by the sliding or rolling friction between the leaf itself and its supporting tracks or guides.

Several excellent methods of reducing or eliminating this leaf to frame friction have been developed throughout the world.1/2/ However, all these methods seem to have the effect of releasing the seals from the seating surface, thereby permitting leakage. Leakage past the top seal can

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1/ "Vertical Hydraulic Forces on Water Controlling Gates," by J. B. Bryce and D. M. Foulds. Proceedings Eighth Congress, IAHR, August 1959.
2/ "Investigations of the Total Pulsating Hydrodynamic Load Acting on Bottom Outlet Sliding Gates and Its Scale Modelling," by A. S. Abelen, Proceedings Eighth Congress, IAHR, August 1959.

appreciably alter the measurement of heads acting on the top of the leaf in high head gates because it will change the depth of water within the bonnet or shaft and hence over the leaf top. Leakage past either the top or the side seals of the gate can influence the flow pattern in filled tunnels downstream from the leaf and at the leaf bottom. Unfortunately, the effects of leakage are relatively indeterminant factors, but they are, nevertheless, real and must be considered.

Downpull determinations by the pressure-area method also have limitations. Adequate coverage of representative areas of the leaf bottom by many piezometers is mandatory but not always easily obtained. Frequently a sizable percentage of the gate leaf is situated within the gate slots. This is particularly true of fixed-wheel and roller-train gates that are built up from standard structural rolled beams and plates and require very wide slots. The pressures acting on the portions of the leaf within the slots are markedly different from those in the main flow passage. Furthermore, the pressure gradient from a point just inside the slot to a point deeply inside may be steep and of unpredictable pattern. Only extensive piezometric coverage will suffice to produce reasonably accurate downpull results. To further complicate the situation, appurtenances like box enclosures around the roller trains or flow cutoff plates below the fixed wheels must be considered and included. In the direct measurement method, the effects of these variables do not require special treatment, other than being sure the gate is truly represented in the model, because their effects are automatically included in the load measurement.

Difficulty may also be encountered in deciding what the pressure acting downward on the top of the gate should be and where it will act. The problem is

simple in the case of a fully enclosed, downstream seal leaf because the pressures in the bonnet can be measured and referred to the elevation of the gate top. But in the case where the leaf is built up from structural members and has an open upstream face it may be impossible to say where the downward force may be considered to act and hence what the effective force will be. In addition there may be appreciable downward drag force due to the action of high velocity water on the exposed horizontal beams. Thus the net value found by subtracting the upward acting leaf bottom pressures from the downward acting leaf "top" loads and drag forces may not be readily obtained. In the direct measurement method these problems need not be considered because their effects are included in the stem load measurement.

It thus appears that there is no single best method for determining, through model studies, the hydraulic downpull forces acting on all high head control gates. Each determination will require careful evaluation of the principal factors contributing to downpull and of the test arrangements most suitable for that structure. In some cases, it may be desirable to use both testing methods.

Other examples of downpull studies based on the pressure-area method described by the author are found in the January 1959 ASCE Hydraulics Division Journal, Paper 1903.3/ These studies were made using air as the flowing fluid instead of water. This is a practice which can result in considerable economies in time, money, and testing equipment. One of the studies concerned a high-pressure, downstream seal, slide gate. The leaf bottom had a 45° sloping

3/ "Air Model Studies of Hydraulic Downpull on Large Gates," by W. P. Simmons, Jr. Paper 1903, Journal of the Hydraulics Division, ASCE° January 1959.

surface that was followed by a short, horizontal section that seated on the floor (Figure 1). The gate was of the type used by the Bureau of Reclamation at Palisades Dam, Idaho for free-discharge regulation under heads up to 237 feet.

The data obtained in the air tests were necessarily for the condition of submerged discharge because the airflow was discharging into a limitless reservoir of like fluid, the atmosphere. However, it was stated that the pressure distribution upon the sloped portion of the leaf bottom would be the same for either free discharge or submerged operation because the flow pattern in this area would remain the same. The pressures themselves would be affected by any submergence on the structure, but the difference in pressure from one station to another on this portion of the leaf would remain unchanged for either type of operation at a given rate of flow.

In the interim between the publication of Reference 3 and the publication of Mr. Colgate's paper, the writer has conducted additional studies with components of the air model. In these later tests, water was used as the flowing fluid so that both free-discharge and submerged conditions could be represented. Considerable strengthening and waterproofing were required on the model to enable it to withstand the greater loads imposed by the water and to avoid excessive warpage. To further limit distortion in the model, the tests were conducted in as short a time as possible.

~~The test results were plotted in two different forms.~~ A new leaf was used for the water tests in place of the original one, which had become damaged and unserviceable.

¶ The test results were plotted in two different forms. ~~were unserviceable.~~ In the first, the measured pressures acting on the leaf bottom, divided by the velocity head at the vena contracta of the flowing water, were plotted against gate opening (Figure 2). It is readily apparent that the free discharge and submerged discharge values differ greatly, and that the submerged values for these tests are lower than the free discharge ones. The previous air model data are also plotted and show good agreement with the submerged tests using water.

A parameter that better describes the pressure distribution within a flow system is lower case $\frac{P_o - P_x}{h_v}$; where p_o is a reference pressure ahead of the gate; p_x is the pressure at any point in the system; for instance, on the leaf bottom slope, and h_v is the velocity head of the flow passing beneath the gate leaf. The test data, when expressed in this form, take into account the effect of tailwater because the upstream reference head, which is also directly affected by the tailwater, is used as the datum. The free discharge and submerged discharge data obtained with water tests plot together (Figure 3). The submerged discharge data obtained with air tests show a similar pattern, but with slightly lower values. Thus, the pressure distributions on the sloped portion of the leaf are shown to be the same for free discharge and submerged operation, and the reasonable agreement of the air and water models is evidence that air models can be used effectively for certain downpull studies.

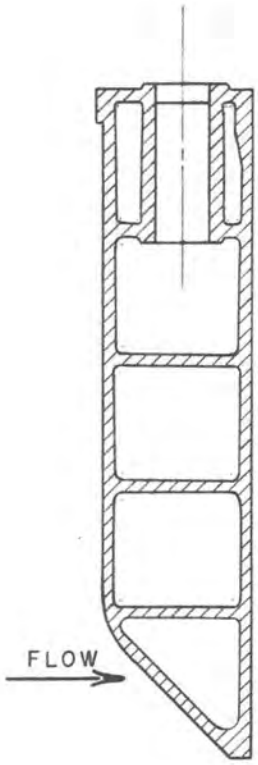

FIGURE 1 – GATE LEAF

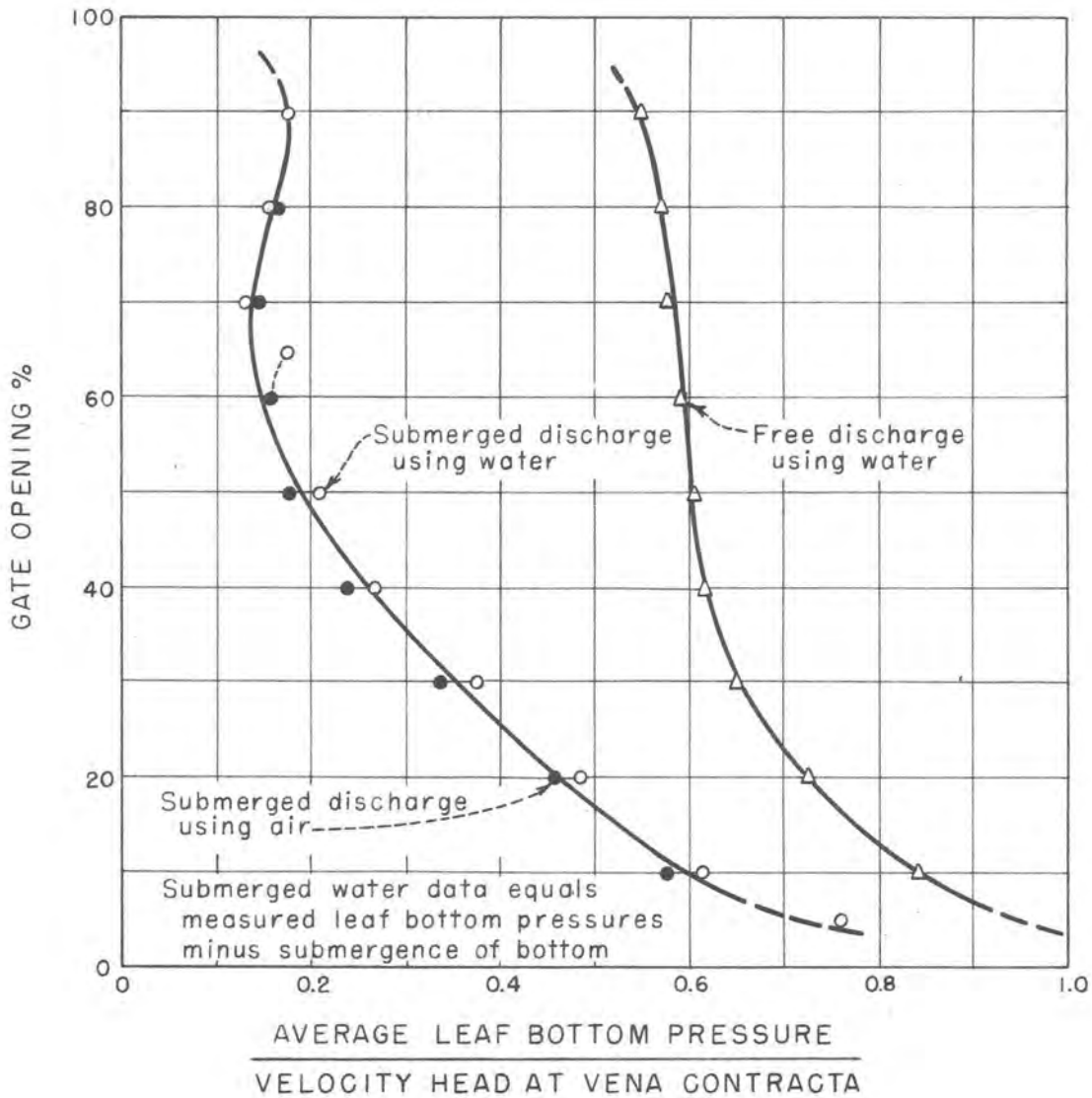
100
80
60
40
20
0
GATE OPENING %
0
0.2
0.4
0.6
0.8
1.0
Submerged discharge using water
Free discharge using water
Submerged discharge using air
Submerged water data equals measured leaf bottom pressures minus submergence of bottom
AVERAGE LEAF BOTTOM PRESSURE
VELOCITY HEAD AT VENA CONTRACTA

FIGURE 2

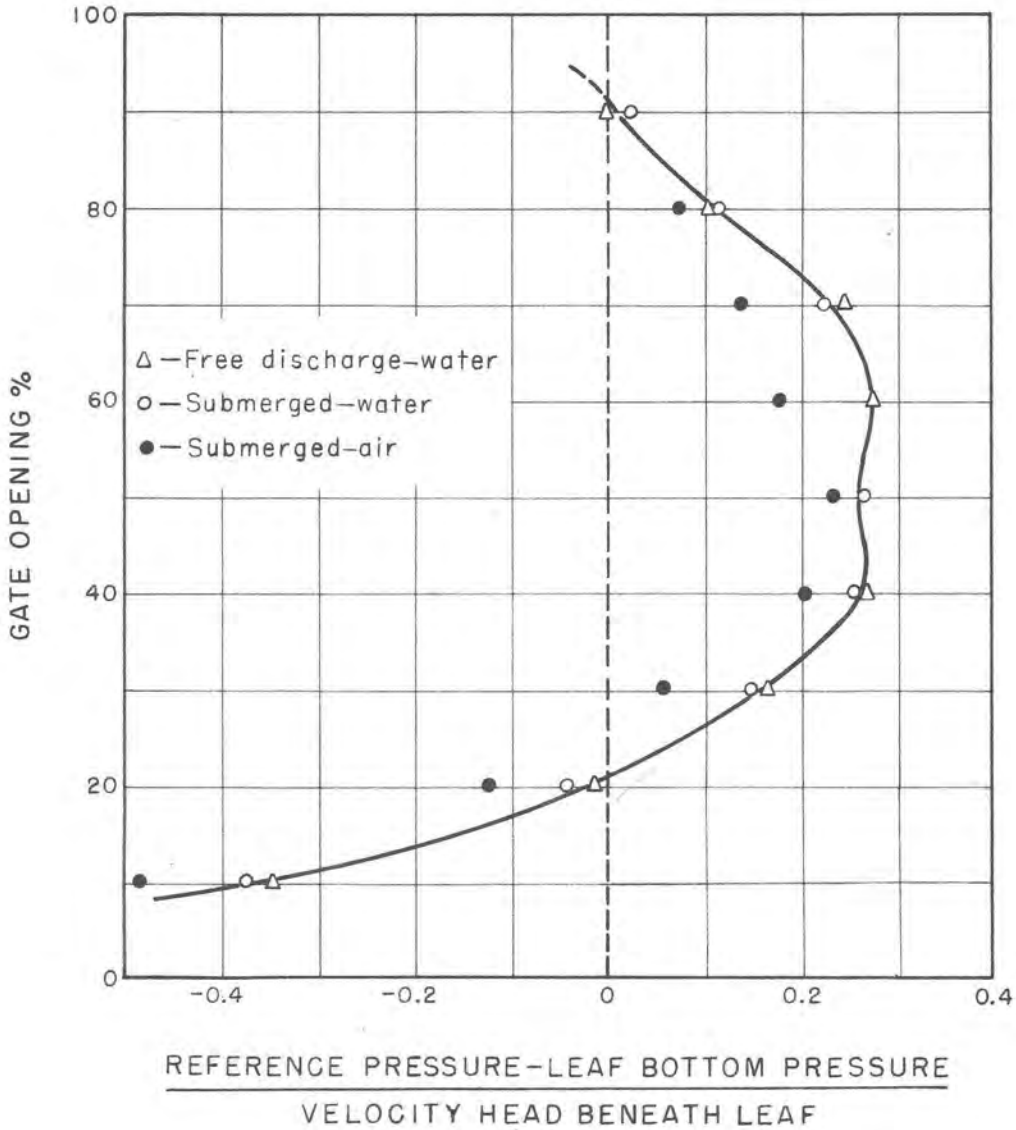
100
80
60
40
20
0
GATE OPENING %
Δ — Free discharge-water
o — Submerged-water
● — Submerged-air
-0.4
-0.2
0
0.2
0.4
REFERENCE PRESSURE-LEAF BOTTOM PRESSURE
VELOCITY HEAD BENEATH LEAF

FIGURE 3