

53:071 Principles of Hydraulics  
Laboratory Experiment #2

**WEIR CALIBRATION**

**Principle**

The discharge over a weir is a function of the weir geometry and of the head on the weir.

**Introduction**

A weir is an obstruction in an open channel over which liquid flows. The purpose of this experiment is to determine the head-discharge relationship of three different shapes of weirs, and to compare the experimental results with their corresponding analytical expressions.

Consider a weir with an irregular cross-section, as shown in Figure 1.

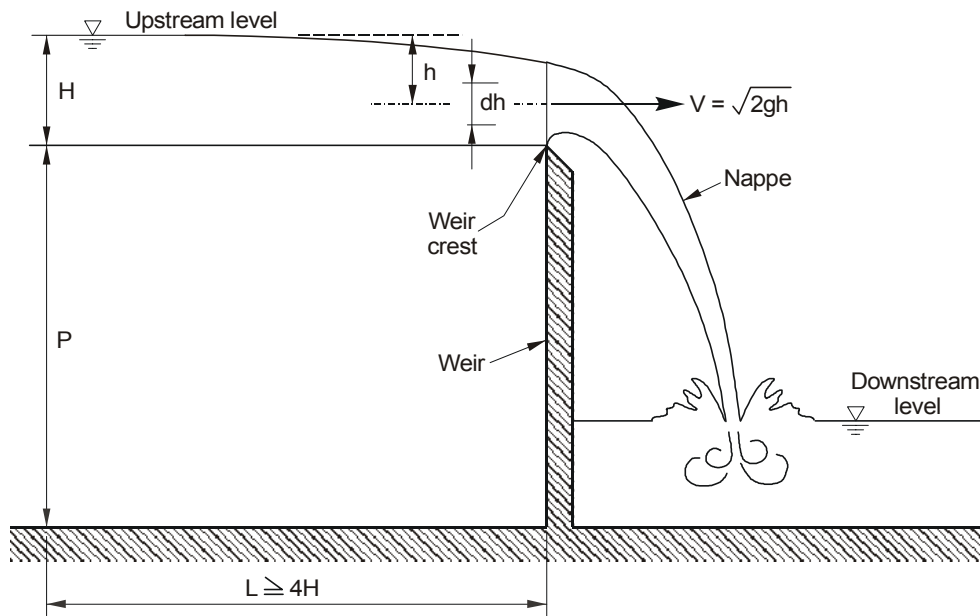


Figure 1. Definition sketch for a weir

Applying Bernoulli's equation along a streamline between a point upstream of the weir (where the velocity head is neglected) and a point in the plane of the weir, the velocity,  $V$ , at the weir is

$$V(h) = \sqrt{2gh} \quad (1)$$

where  $g$  is the gravitational acceleration and  $h$  is the elevation of the streamline below the free surface. Assuming that the velocity is constant throughout the cross-section of the weir, the expression for the discharge,  $Q$ , over the weir becomes

$$Q = \int_A dQ = \int_A V(h)dA = \int_0^H \sqrt{2gh}b(h)dh = \sqrt{2g} \int_0^H b(h)\sqrt{h}dh \quad (2)$$

where  $A$  is the cross-section of the weir and  $b(h)$  is the width of the weir at elevation  $h$ .

Thus, the general expression for the weir head-discharge relationship is

$$Q = kh^n \quad (4)$$

where  $k$  is a flow coefficient and  $n$  is an exponent. Both  $k$  and  $n$  are dependent on the shape of the weir (e.g., rectangular, triangular, trapezoidal or parabolic) and flow conditions (velocity distribution in the approach section, fluid viscosity, surface-tension effects, contraction coefficient).

### Apparatus

The experiment is conducted in 2-foot open channel flume facility located in Model Annex, Iowa Institute of Hydraulic Research (IIHR). The weir shapes subjected to measurements in this experiment are rectangular and triangular. The geometry of these weirs is sketched in the Figure 2. The weir shapes are cut from brass/tin sheets and can be considered as being sharp-edged.

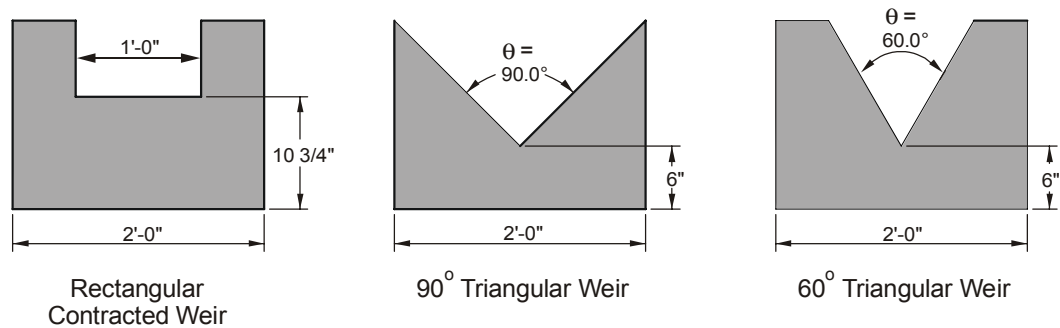


Figure 2. Geometry for typical weirs

The water in the flume is recirculated using a pump. The flume entrance is conditioned with baffles and screens to ensure smooth entry of water in the flume. Slots in the sidewalls are located in the middle section of the flume, between which the weir plates can be inserted. The slope of the flume is such that no submergence of the weir occurs. Water is returned to the headbox through a 8” pipe.

A side-contraction meter is used to measure the discharge in the facility. The pressure taps connected to the side contraction meter lead to a differential water manometer. The head drop on the side-contraction meters can be measured by sliding the markers of the manometer to the meniscus of each column and reading the scale. The finest graduation of the manometer scale is 0.001 ft. The flow discharge in the channel is determined using the calibration equation obtained in the Institute’s calibration facility

$$Q = 2.04\sqrt{\Delta h} \quad (5)$$

where  $Q$  is the discharge in  $\text{ft}^3/\text{s}$ ; and  $\Delta h$  is the pressure head differential across the contraction as measured using a precision two-tube manometer in ft.

A point gauge attached to the flume is provided to enable measurement of the head on the weir. The weir reference point is measured when the flume is empty and the weir plate is in place. The tip of the point gauge has to be lowered so that it is at the same level with the weir reference point. Subsequently, when the desired steady discharge is established in the flume, the point gauge is set so that it slightly touches the water surface, upstream of the weir. Subtracting the reference point elevation from that of the water-surface upstream the weir, the head on the weir (in feet of water) is obtained.

### **Procedures**

The experiment requires to set a series of discharges (say, five for each weir shape). Set the discharges approximately by setting the head drops at the desired values. Using the head measured on the weir and the corresponding discharge measured on the side-contraction meter (equation 5), a head-discharge relationship is determined and subsequently compared with the derived analytical expression. The coefficient of discharge for each weir is determined by comparing the theoretical and measured results. Proceed with the following sequence:

1. Insert the weir of the desired shape in the slots.
2. Read the reference point of the weir.
3. Set the appropriate discharge in the flume. First, determine the desired head difference,  $\Delta h$ , across the side-contraction meter using equation (5). Then, adjust the valve on the 8" return pipe or, alternatively, change the setting on the pump-motor controller until this head difference is obtained on the differential water manometer.

Note: The tubing from the pressure taps to the differential manometer must be bled to ensure that air is removed from the system.

4. Read the point gauge set on the water surface upstream of the weir.
5. Repeat steps 2 - 4 four each of the three weir shapes.

### **Measurements**

Determine using the calibration equation (5) the desired head difference (diligently calculated prior to the measurements) in the side-contraction meter:

$$\Delta h_1 = \underline{\hspace{2cm}} \quad \Delta h_2 = \underline{\hspace{2cm}} \quad \Delta h_3 = \underline{\hspace{2cm}} \quad \Delta h_4 = \underline{\hspace{2cm}} \quad \Delta h_5 = \underline{\hspace{2cm}}$$

According to the procedures described above, measure the quantities specified in the following table:

Discharge		Rectangular			Discharge		Triangular 90°		
$\Delta h$	$Q$ (cfs)	Ref. point (ft)	W.S. elev. (ft)	Weir head (ft)	$\Delta h$	$Q$ (cfs)	Ref. point (ft)	W.S. elev. (ft)	Weir head (ft)

Discharge		Triangular 60°		
$\Delta h$	$Q$ (cfs)	Ref. point (ft)	W.S. elev. (ft)	Weir head (ft)

**Data Analysis**

1. Plot  $\log Q$  vs.  $\log H$ . From the best-fit line to the experimental points determine the  $n_{exp}$  (i.e., the slope of the best-fit line) and  $k_{exp}$  (i.e., the intercept of the best-fit line with the ordinate).
2. Compare the experimental ( $n_{exp}$ ) and analytical ( $n_t$ ) values of the exponent  $n$ .
3. Compare  $k_{exp}$  with values indicated in the literature.

**Further Considerations**

1. Derive, analytically, the head-discharge relationship for each of the weir shapes given in Figure 2. The analytical head-discharge relationship for the rectangular and the triangular weirs are given in standard textbooks.
2. If data seem to imply,  $n_{exp} \neq n_t$ , why this difference?

**References**

Gupta, R. S. (1989). *Hydrology and Hydraulic Systems*, Waveland Press, NY  
Hwang, N.H. and Houghtalen, R.J. (1996). *Fundamentals of Hydraulic Engineering Systems*, 3<sup>rd</sup> edition, Prentice Hall, NJ  
Rouse, H. (1967). *Engineering Hydraulics*, 6<sup>th</sup> Edition, John Wiley and Sons, NY