راهنمای نرم افزار اندازه گیری ضرائب سرریز

Flow over weirs

Object

The object of this experiment is to demonstrate how a weir can be used as a meter to measure fluid discharge in an open channel and to find the coefficient of discharge (Cd) of the device. Three weirs from F1-13 apparatus will be considered; a rectangular and a VEE shaped notch weir.

This page shows a diagrammatic representation of the equipment needed to undertake the investigation. You will require the following items:

- Hydraulics Bench F1-10
- Basic Weirs F1-13
- Stop Watch

You will find it useful to obtain a printout of these diagrams by accessing the above PRINT rectangle. After you have studied these diagrams and noted the abbreviations for the dimensions, you may scroll this window to move onto the Theory Page.

T H E O R Y

Nomenclature: (also see diagram)

g = acceleration due to gravity (9.81 m/s^2)

Z = height from horizontal datum

H = distance between crest and still water surface

i = upstream suffix

j = downstream suffix

V = fluid velocity

P = fluid pressure

p = density

Qa = actual flow rate

Qt = theoretical flow rate

Qincpt = apparent flow rate from graph when H=0

dA = small element of area of thickness dh

Cd = coefficient of discharge

K = meter constant

theta = angle of wier edge from vertical

w = width of rectangular weir

Refer to the diagrammatic representation on the Equipment Page for other symbols.

Cd is an experimental correction factor, which must be applied to the theoretical discharge value to obtain the actual discharge, hence:

$$Cd = \frac{\text{actual measured discharge}}{\text{theoretical discharge}}$$

Bernoulli's equation :

$$Z_i + \frac{V_i^2}{2g} + \frac{P_i}{pg} = Z_j + \frac{V_j^2}{2g} + \frac{P_j}{pg}$$

Consider the motion of a particle of fluid flowing from i to j (see diagram). The upstream velocity is be assumed to be zero (still water) and the downstream pressure (in the nappe) is assumed to be atmospheric, so working in gauge pressure:

$$\frac{P_i}{pg} + Z_i = \frac{V_j^2}{2g} + Z_j \qquad \text{..................} \ 1$$

From the diagram $H = Z_i + x$

The upstream pressure is obviously x metres head of water, so:-

$$H = Z_i + \frac{P_i}{pg}$$

Also from the diagram $H = Z_j + h$, equating and rearranging:-

$$\frac{P_i}{pg} = Z_j - Z_i + h$$

pg

substituting in 1, rearranging and cancelling:-

Vj = SQRT(2gh)

From CONTINUITY (dQ = dAi Vi = dAj Vj) considering the flow through the elemental thickness dh (see diagram) :

F O R R E C T A N G U L A R W E I R

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dQt = SQRT(2gh) w dh

The total flow is found by integrating between zero and H (neglecting the lowering of the surface of the water)

Qt = 2/3 SQRT(2g) w H^1.5

This equation may be written as :- Qt = K H^1.5 where K may be called the Weir Constant and equals:- K=2/3 SQRT(2g) w Introducing the Coefficient of Discharge (Cd) takes account ofچ

the following assumptions:

a) Upstream of weir, the water is still.

b) Effect of drop down is neglected.

c) Pressure throughout the sheet of liquid (or nappe) is atmospheric.

d) Effects of viscosity (friction) and surface tension are negligible.

e) The contraction of the nappe due to curvature of streamlines.

ACTUAL FLOW RATE (Qa) = Cd K H^1.5

F O R V E E N O T C H W E I R

For the VEE Notch Weir it can be shown by using elementary trigonometry that the width of an element is 2(H-h) tan(Theta) so:

dQt = SQRT(2gh) 2(H-h) tan(theta) dh

Integrating between zero and H gives:

Qt = 8/15 SQRT(2g) tan(theta) H^2.5

so for the Vee Shaped Weir:- K = 8/15 SQRT(2g) tan(theta)

ACTUAL FLOW RATE (Qa) = Cd K H^2.5

If Cd as well as K is constant, a graph of Qa against H^1.5 for a rectangular weir or H^2.5 for a VEE Notch Weir will be a straight line having a slope equal to Cd K.

Qa and H are found by experiment, K can be calculated. Hence the best value of the Coefficient of Discharge may be found.

FURTHER ASSUMPTIONS

If the Cd graph appears to be a straight line, for practical purposes it is reasonable to assume that the relationship is linear and hence Cd is constant. However it can be seen that this assumption results in an apparent discharge Qincpt when H=0

Once Cd has been determined experimentally the meter may be used to measure any flow rate by observing H and using the formula:

Q = Cd K (H^1.5) (rectangular)

However to be really accurate Qincpt should be taken into account

Q = Cd K (H^1.5) + Qincpt (rectangular)

CAUTION:- The above theory relates to practical turbulent flow and should not be used for laminar and small flows, and may account for "apparent" error resulting from the graph not passing through the origin.

Use the Armfield Basic Weirs Equipment F1-13 and carry out the following procedure:

Install the appropriate weir plate with the sharp edge of the weir facing downstream. Admit water to the channel until the water discharges over the weir plate. Close the flow control valve and allow the water level to stabilise. Set the Vernier Height Gauge to a datum reading using the top of the hook. The datum is the apex of the Vee notch or the sill of the rectangular weir. In practice it is easier to fill the channel with water and use the minimum water level as the datum - although not strictly accurate this method will prevent damage to the weir plate. Position the gauge about half way between the notch plate and stilling baffle.

Admit water to the channel, adjust flow control valve to obtain heads, H, increasing in steps of about 10 mm. For each flow rate stabilise conditions, measure and record H. Take readings of volume and time using the volumetric tank to determine the flow rate.

The computer will then be able to calculate:- Q, Cd, H^1.5 for the Rectangular Weir and H^2.5 for the Vee Notch Weir for each set of readings.

A graph of Q against H^1.5 (rect) or H^2.5 (vee) is then drawn to find the accurate Cd for the meter.

For each weir you should ensure that you calculate a single set of results from the first set of readings to verify the computed results. These should be included in your report.

his is the Readings Page. As the readings are entered the appropriate graph is drawn.The graph scales have been preset, however you may alter the graph axes to suit your readings. Note that the units used on the graph are more appropriate to the calculations, whereas the units used for entering the readings are more appropriate for the equipment.

Move the cursor to appropriate rectangles and enter the sets of experimental readings in the following order:

1. H (mm) The height of the water surface above the crest of the weir.

2. Vol (l) The volume of water collected in litres.

3. t (s) The time taken to collect that volume of water.

After each set of readings have been entered the following will be calculated and displayed:

1. H^1.5 (m^1.5) For the Rectangular Weir

or H^2.5 (m^2.5) For the VEE Notch Weir

2. Q (m^3/s x 10^-3) or (l/s) The flow rate.

3. Cd The apparent coefficient of discharge calculated for that unique set of readings only.

QUESTION 1

The weirs used in this experiment are known as sharp edge notches. Why do you think they are made with sharp edges ?

a) to prevent the water springing clear

b) to reduce the amount of viscous friction

c) easier to manufacture

d) to increase the amount of viscous friction

(b) is correct, but in practice the edge is not a knife edge, but manufactured with a small flat. See the next question for an explanation.

QUESTION 2

Why are the notches not made with sharp knife edges

a) because they would be dangerous to handle

b) because the water would erode the edge

c) because they would be expensive to manufacture

d) because the water would spring clear

The correct answer is (b). The main reason is that erosion would have an adverse effect on weir performance.

QUESTION 3

In the experiment the approach velocity is assumed to be zero. When would the approach velocity be of importance ?

a) in a wide channel

b) when measuring high flow rates

c) when the channel is deep

d) when the channel is narrow

The correct answer is (d). As the cross sectional area decreases, the velocity increases, making the assumption less justifiable

QUESTION 4

The upstream depth measurement should be taken:

a) as close as possible to the weir

b) as far upstream as practical

c) just clear of the drop-down curve

d) as far downstream as possible

(c) is the correct answer. To move further upstream would introduce errors due to the slope of the water surface. To go too near the weir would give an incorrect value because of the drop_down curve.

QUESTION 5

If the Cd of the rectangular weir is 0.6, and the weir constant is 0.09 (all in consistent units). Indicate which of the following values gives a good estimate of the discharge if the depth of water is 0.077 metres:

a) 6.6 l/s

b) 5.6 l/s

c) 3.4 l/s

d) 1.2 l/s

e) 0.05 l/s

The correct answer is (d). You should have used the following formula:- Q = Cd K H^1.5

QUESTION 6

The triangular Vee Notch Weir is more accurate than the Rectangualar Notch Weir for flow mesurement because:

a) it can cater for larger flow rates

b) the head rises quicker as the discharge increases

c) as the flow rate increases the water surface rises proportionally

d) because the water must be deeper

The correct answer is (c). Because of the shape of a Rectangular Weir, a small change in a low flow rate is difficult to measure.

QUESTION 7

In the formulae used, H is always the:

a) measured head + velocity head based on the depth to the weir crest

b) measured head + velocity head based on the depth to the channel base

c) height of the upstream water above the weir crest

d) height of the upstream water above the channel base

The correct answer is (a). The datum for H is always the lowest point of the weir, i.e. the crest of the weir.