EXPERIMENT G

The Hydraulic Jump

OBJECTIVE

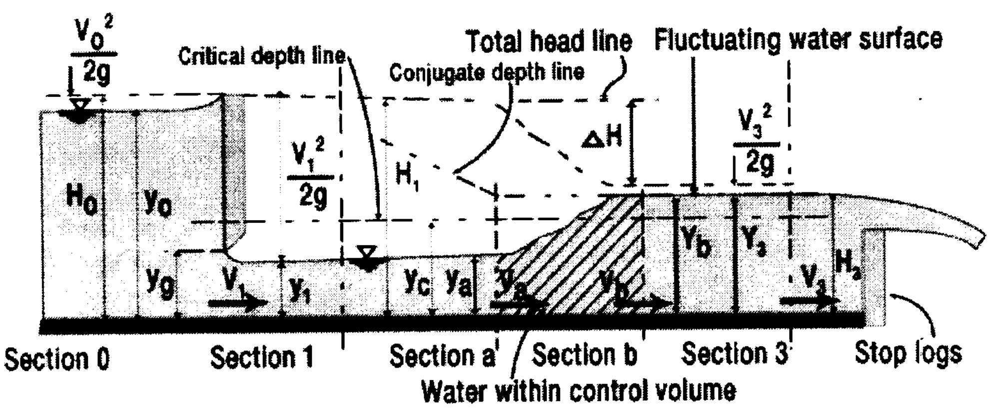
To investigate the characteristics of a standing wave (the hydraulic jump) produced when water flows beneath an undershot weir and to observe the flow patterns obtained.

EQUIPMENT SET-UP

Multi-Purpose Teaching Flume, C4

Adjustable undershot weir
Hook and point gauge, 300mm scale – 2 required
Stopwatch if measuring flowrate using the volumetric tank (not supplied)

Note: If available, the Pitot tube and manometer, C4-61 (optional accessory) can be used to measure velocity of the water directly.



SUMMARY OF THEORY/BACKGROUND

When water flowing rapidly changes to slower tranquil flow a hydraulic jump or standing wave is produced. This phenomenon can be seen where water shooting under a sluice gate mixes with deeper water downstream. It occurs when a depth less than critical changes to a depth which is greater than critical and must be accompanied by a loss of energy.

An undular jump occurs when the change in depth is small. The surface of the water undulates in a series of oscillations which gradually decay to a region of smooth tranquil flow

A direct jump occurs when the change in depth is great. The large amount of energy loss results in a zone of extremely turbulent water before it settles to smooth tranquil flow.

By considering the forces acting within the fluid on either side of a hydraulic jump of unit width it can be shown that:

$$\Delta H = y_a + \frac{V_a^2}{2g} - \left(y_b + \frac{V_b^2}{2g} \right)$$

where:

ΔH	= Total head loss across jump (energy dissipated)	(m)
V_a	= Mean velocity before hydraulic jump	(m s^{-1})
y_a	= Depth of flow before hydraulic jump	(m)
V_b	= Mean velocity after hydraulic jump	(m s^{-1})
y_b	= Depth of flow after hydraulic jump	(m)

Because the working section is short $y_a \approx y_1$ and $y_b \approx y_3$

Therefore simplifying the above equation:

$$\Delta H = \frac{(y_3 - y_1)^3}{4 y_1 y_3}$$

PROCEDURE

Ensure the flume is level, with no stop logs installed at the discharge end of the channel. Measure and record the actual breadth b (m) of the undershot weir.

Clamp the undershot weir assembly securely to the sides of the channel close to the upstream end of the flume with the sharp edge on the bottom of the gate facing upstream. For accurate results the gaps between the weir and the channel should be sealed on the upstream side using Plasticine.

Position two hook and point level gauges on the channel sides, downstream of the weir, each with the point fitted.

The datum for all measurements will be the bed of the flume. Carefully adjust the level gauges to coincide with the bed of the flume and record the datum readings.

Adjust the knob on top of the weir to position the sharp edge of the weir 0.020m above the bed of the flume. Place one stop log at the discharge end of the flume.

Gradually open the flow control valve and adjust the flow until an undular jump is created with small ripples decaying towards the discharge end of the flume. Observe and sketch the flow pattern.

Increase the height of water upstream of the weir by increasing the flowrate and increase the height of the stop logs to create a hydraulic jump in the centre of the working section. Observe and sketch the flow pattern.

Move one level gauge to the region of rapid flow just upstream of the jump (section a). Move the second level gauge to the region of tranquil flow just after the jump (section b). Measure and record the values of y_1, y_3, y_g and Q. Repeat this for other flowrates Q (upstream head) and heights of the gate y_g.

RESULTS AND CALCULATIONS

Tabulate your readings and calculations as follows:

Breadth of gate, b =...........(m)

y_g	y_1	y_3	Q	H_b	ΔH

Calculate V_1 and plot $\frac{V_1^2}{gy_1}$ against $\frac{y_3}{y_1}$

Calculate $\frac{\Delta H}{y_1}$ and plot $\frac{\Delta H}{y_1}$ against $\frac{y_3}{y_1}$

Calculate y_c and verify $y_1 < y_c < y_3$.

CONCLUSIONS

Verify the force of the stream on either side of the jump is the same and that the specific energy curve predicts a loss equal to $\frac{\Delta H}{y_c}$.

Suggest an application where the loss of energy in hydraulic jump would be desirable. How is the energy dissipated?