## 28.2 Classification of Jumps

As mentioned earlier, the supercritical flow Froude number influences the characteristics of the hydraulic jump. Bradley and Peterka , after extensive experimental investigations, have classified the hydraulic jump into five categories as shown in Figure 28.4.

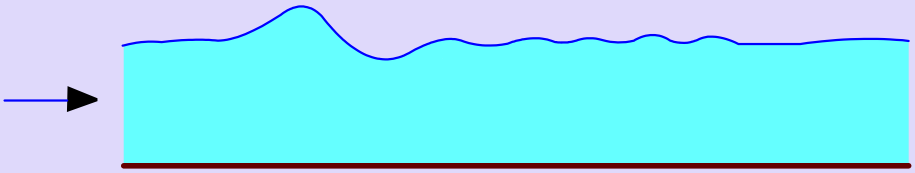
The hydraulic jump is the phenomenon that occurs where there is an abrupt transition from supercritical (inertia dominated) flow to sub critical (gravity dominated) flow. The most important factor that affects the hydraulic jump is the initial Froude number $F_1$.

$$F_1 = \frac{\overline{V}_1}{\sqrt{gD}}$$

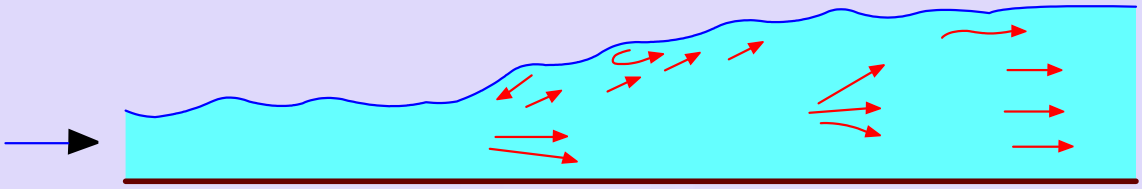
in which $\overline{V}_1$ is the longitudinal average velocity at the initial section, g is the acceleration due to gravity and D is the hydraulic mean depth (ratio of area of flow at free surface width).

As mentioned above, it occurs in a straight prismatic horizontal channel of rectangular shape in which boundary friction is negligible (NHJ).

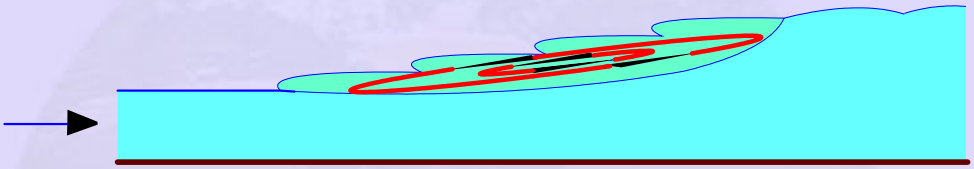
The hydraulic jump can be classified based on initial Froude number as Undular $(F_1 = 1-1.7)$, weak $(F_1 = 1.7-2.5)$, oscillating jet $(F_1 = 2.5-4.5)$, steady $(F_1 = 4.5-9.0)$ and strong $(F_1 > 9.0)$.



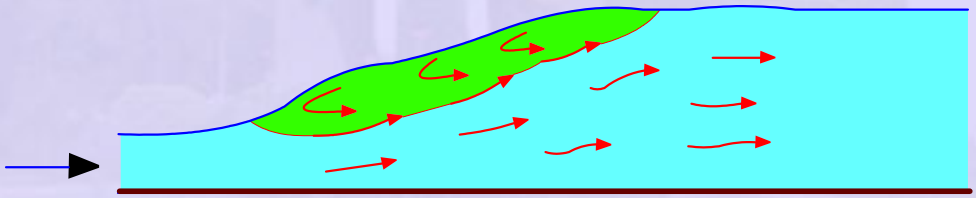
Undular jump $1.0 < F_1 < 1.7$



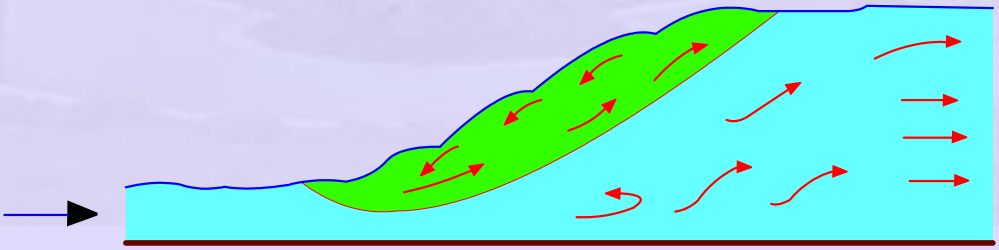
Oscillating jump $2.8 < F_1 < 4.8$



Weak jump $1.7 < F_1 < 2.5$



Steady jump $4.5 < F_1 < 9.0$



Strong jump $F_1 > 9.0$

Fig. 28.4 - Classification of the Jump

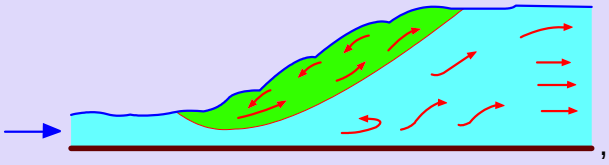
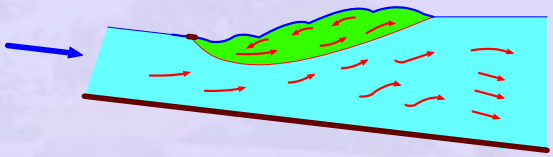
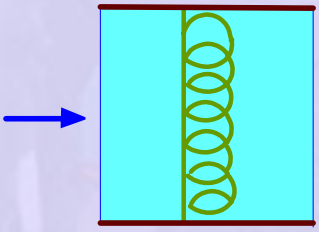
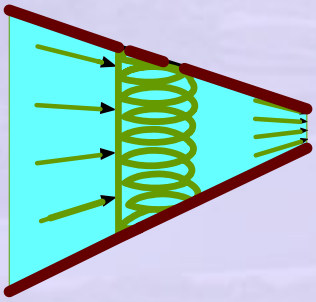
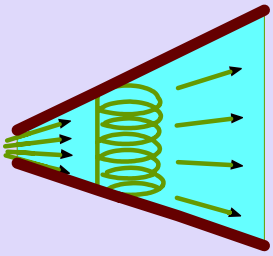
| Type of Jump | Froude Number | Remarks |
|---|---|---|
| Critical flow | $F_1 = 1$ | Wavy surface , celerity $c = \sqrt{gy}$ |
| Undular jump | $1 < F_1 < 1.7$ | Undulations on the surface |
| Weak jump | $1.7 < F_1 < 2.5$ | Small rollers, No baffles. |
| Oscillating Jump | $2.5 < F_1 < 4.5$ | No periodicity. Rip rap may get damaged<br><br>Canal drops, difficult to handle.<br><br>Baffle blocks or appurtenances are of little value. Wave suppressors may be designed. |
| Steady jump | $4.5 < F_1 < 9.0$ | Position, is sensitive to variation of Tail Water,<br><br>Efficiency is 45 to 70 %. |
| Strong Jump | $F_1 > 9.0$ | Efficiency is 85 % |

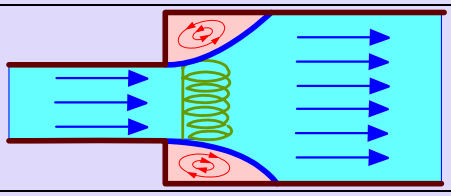
The jumps can also occur on horizontal bed or sloping bed. The jump can take place in radially diverging, radially converging, rectangular, sudden convergence or expansions in plan. The jump can occur in different shape of the cross section of the channel such as rectangular, trapezoidal, parabolic, circular channels. The jump can occur in the conduit either at the free surface or fully flowing downstream condition. The annular jump is yet another type. The jump can be either free (unsubmerged) or submerged condition such as in the downstream of sluice gates. The jump can be a forced one with the appurtenances (such as baffles, sills, chute blocks) or free (i.e. either without any appurtenances). Jump could be either stationary or moving (hydraulic bore).

The jump can be in stratified flows such as warm and cold water (flowing over each other), air and water (classical jump) or in case of gas to gas (internal jump).

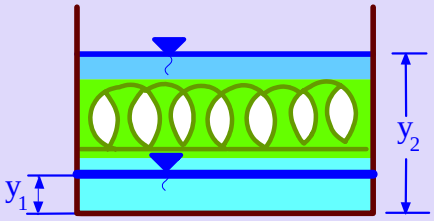
The Important macroscopic parameters are initial depth $y_1$, sequent depth $y_2$, Initial mean velocity $\overline{V_1}$, mean velocity at the end of the jump (exit velocity) $\overline{V_2}$, length of jump $\left(L_j\right)$ and the roller $\left(L_{rj}\right)$.

## Classifications of Jumps

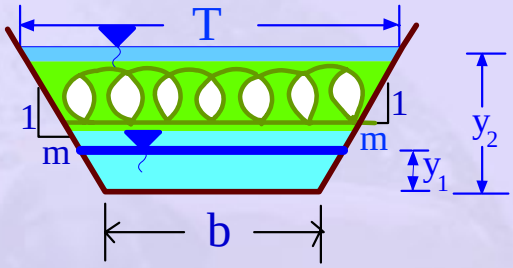
| | |
|---|---|
| I. Based on Froude Number | Undular, weak, oscillating, steady and strong (See the figure - 2 above) |
| II. Based on Bed Slope | Horizontal  , Sloping  |
| III. plan shape of boundary | Rectangular  Radial Diverging Channel  Radial Converging Channel  Sudden Expansion |



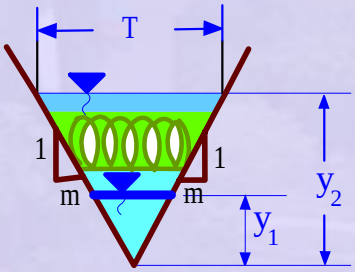
IV. Shape



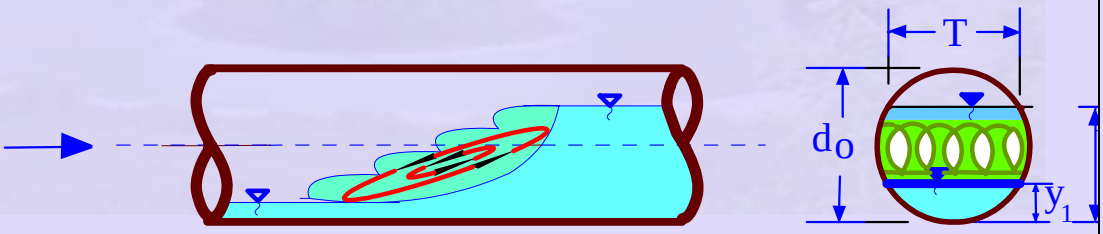

Rectangular



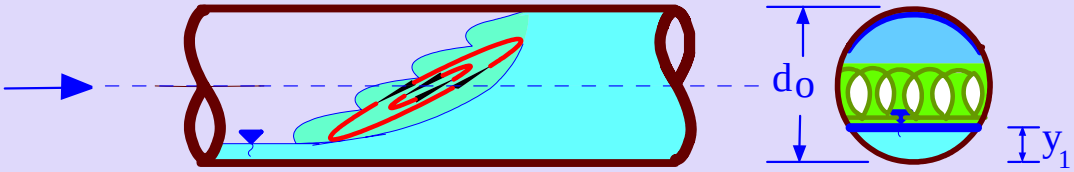

Trapezoidal



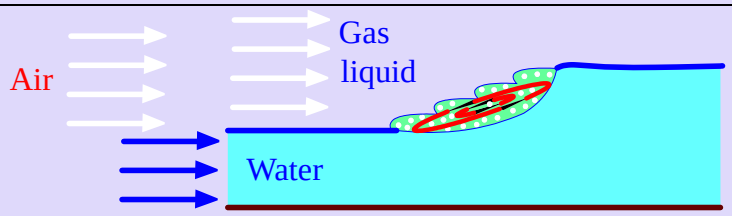
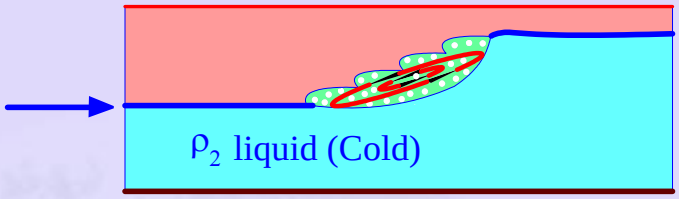
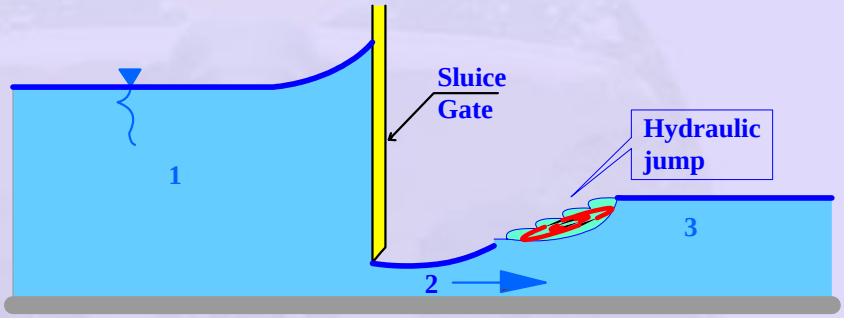
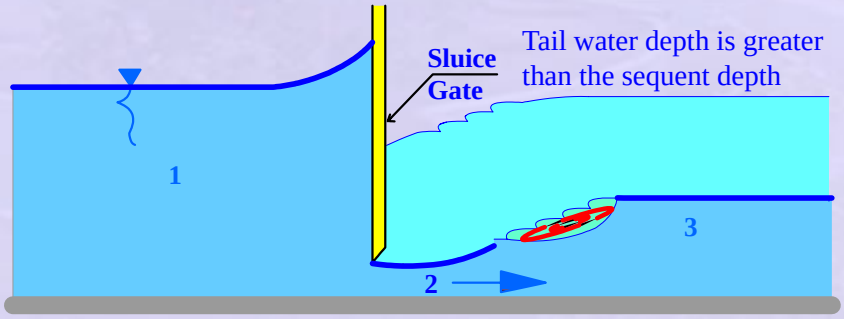
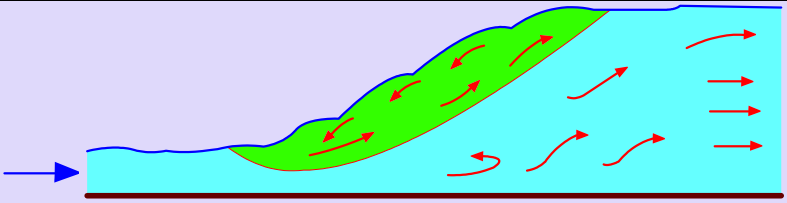

Triangular

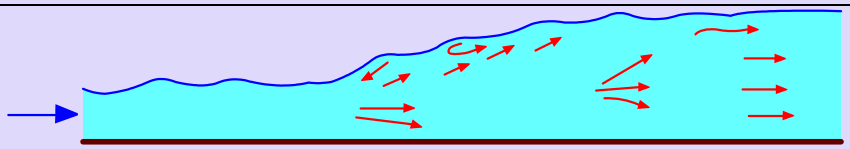



Circular free surface flow



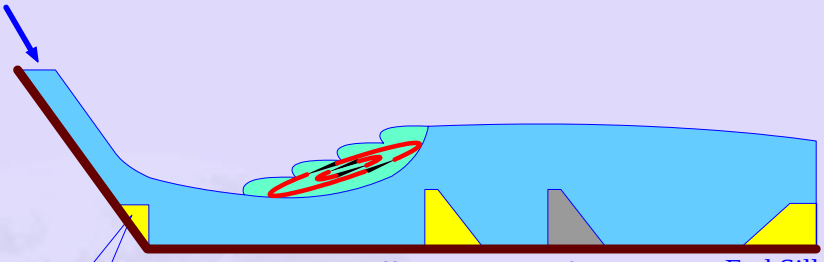

Circular free surface to Pressure flow

| | |
|---|---|
| V. Fluid Status |  <br>Classical Hydraulic jump<br><br>  <br>Liquid to Liquid ( $\rho_2 > \rho_1$ )<br>Gas to Gas Internal jump |
| VI. Submergence |  <br>Rapidly varied flow with Hydraulic jump (1 and 3 subcritical flows, 2 Super critical flow)<br>Free Jump (Not Submerged)<br><br>  <br>Rapidly varied flow with Hydraulic jump (1 and 3 subcritical flows, 2 Super critical flow)<br>Submerged Jump |
| VII. Motion |  <br>Stationary Jump | Moving Jump<br><br>Example: Hydraulic Bore |
| VIII. Appurtenances | unforced or Free | |



Free Jump (Unforced)
(without Appurtenances)

Forced




Forced Jump (with Appurtenances)

Jump in gradual expansion - looking upstream

Jump in gradual expanison - looking downstream

Super critical approach flow - Shocks can be seen