34.1 Siphon Spillway

Siphon Spillway is a closed duct. Following points are to be kept in mind.

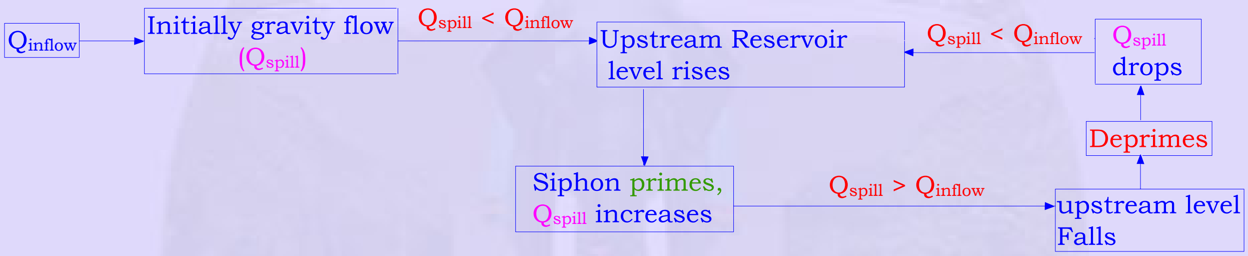
1. Hood level is higher than Reservoir level. Hence, when flowing full the water level in pipe is higher than the reservoir level.

2. Siphon must be self priming.

Problems with Spillway

(i) The aerated condition is unstable.

$$\text{If} \left.\begin{array}{l} Q_{inflow} > Q_{spillway} \\ Q_{inflow} < Q_{blackwater} \end{array}\right\} \qquad Q_{spill} < Q_{inflow} < Q_{blackflow}$$



Typical Cycle of functioning of Siphon Spillway

This cyclic behaviour of spillway results in Radial surges and Transients, Vibration.

Head discharge characteristics of an air regulated siphon are shown in figure 34.1.

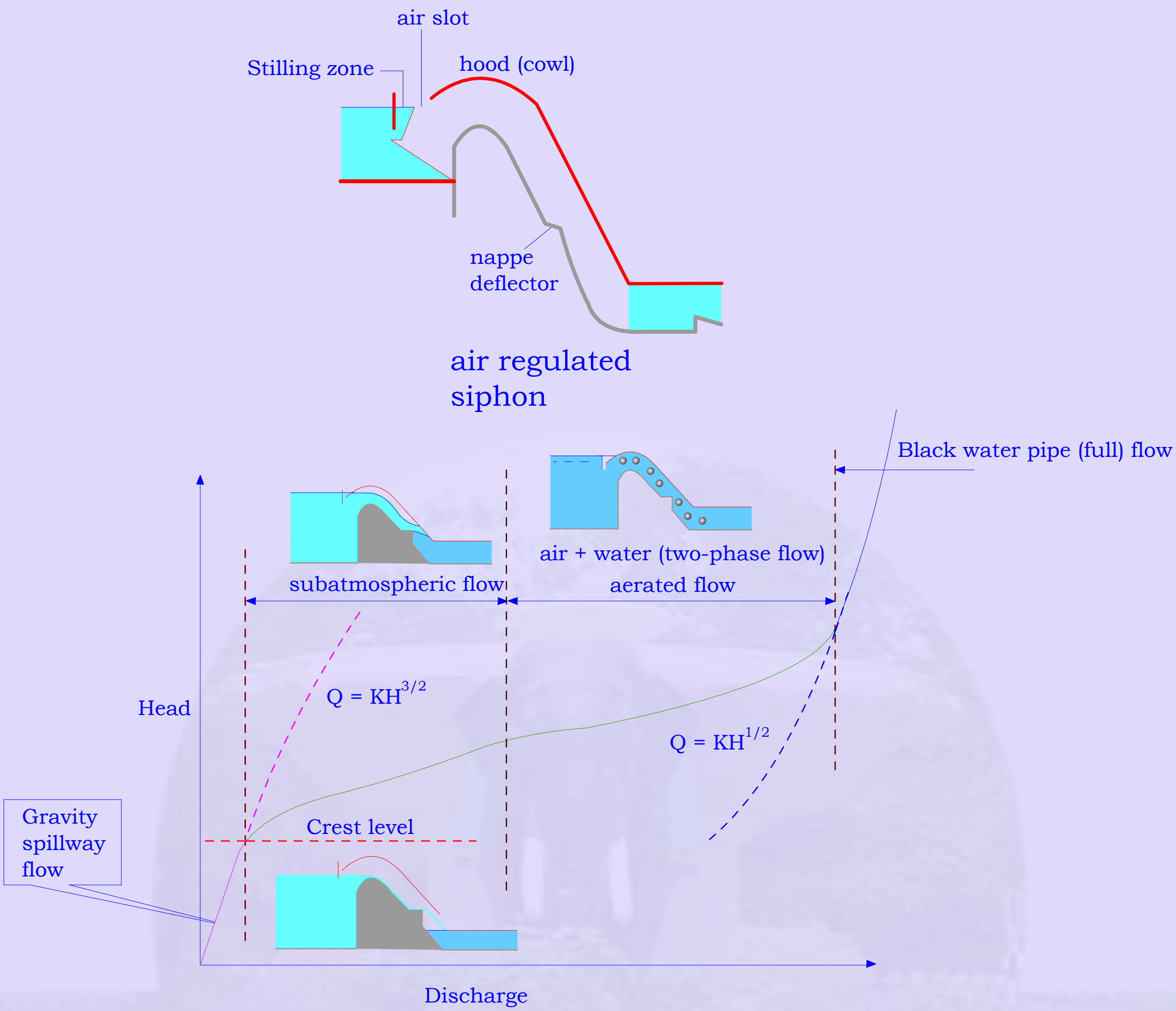


Figure 34.1 - Head Discharge characteristics of air regulated siphon

The flow takes place as channel flow, vortex flow, pipe flow depending on the head.

The following problems may occur in the field.

1) Blockage of debris - Trash Rack could be introduced.

2) Freezing of water in the lower leg.

3) Waves may uncover the entry alternatively.

Discharge Equation

Referring to Figure – 34.2, Energy equation can be written as

$$H_1 - H_2 = \left(K_1 + K_2 + K_3 + K_4 + f\frac{L}{D} \right) \frac{V^2}{2g}$$

- K_1: Entry
- K_2: First bend
- K_3: Second bend
- K_4: exit
- $f\frac{L}{D}$: Frictional losses

$$vR = constant; \quad v = \sqrt{2gh_c}\,\frac{R_c}{R}$$

In which h_c is the head over spillway crest and R_c is the radius of the spillway crest

$$Q = \sqrt{2gh_c}\; R_c \; b \; \ln\left(\frac{R_0}{R_c}\right)$$

$\left(H - \frac{P}{\gamma}\right) = h_c$ should not be more than 7 m water below the atmospheric pressure.

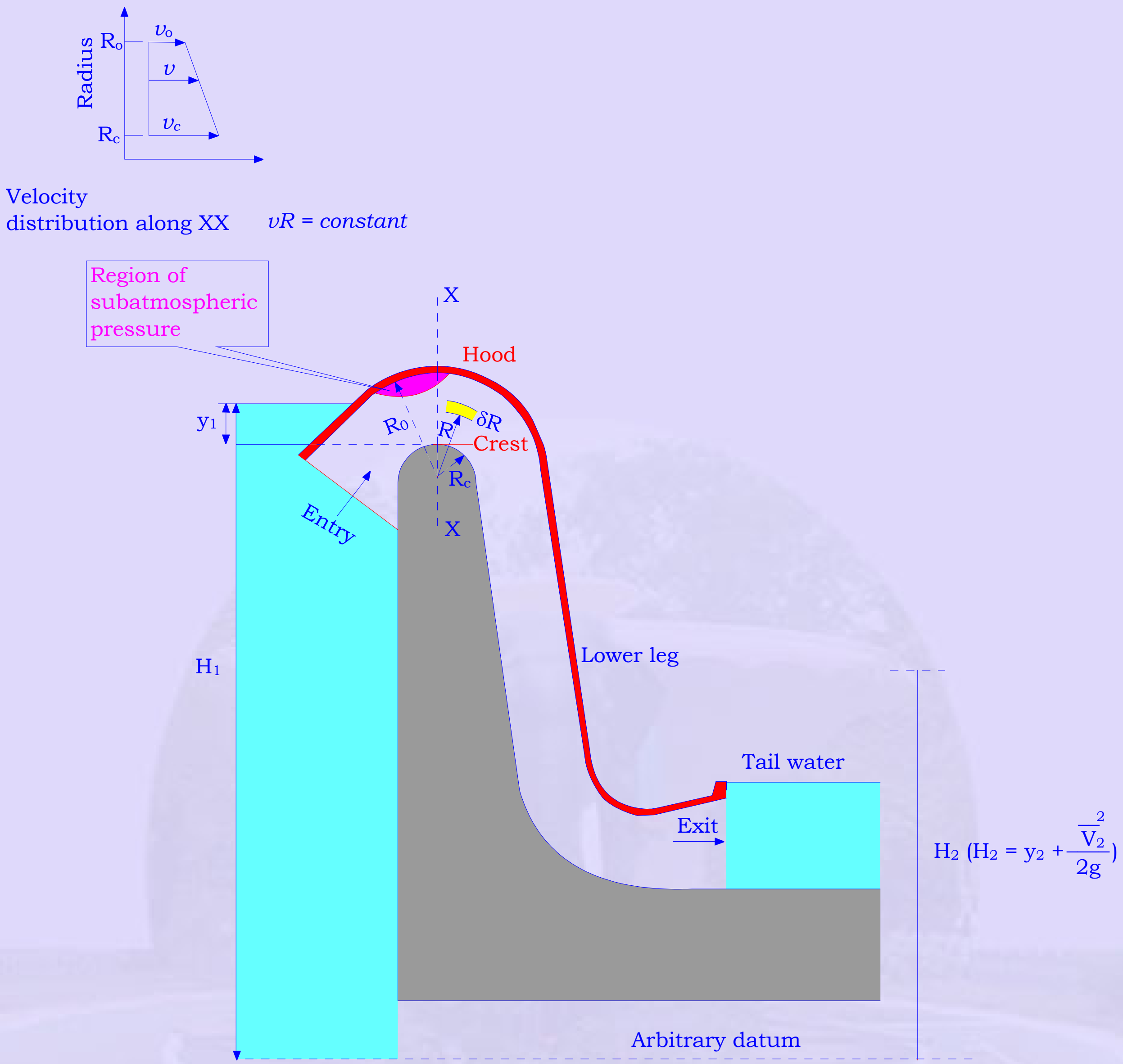


Figure 34.2 - Discharge in a Siphon Spillway

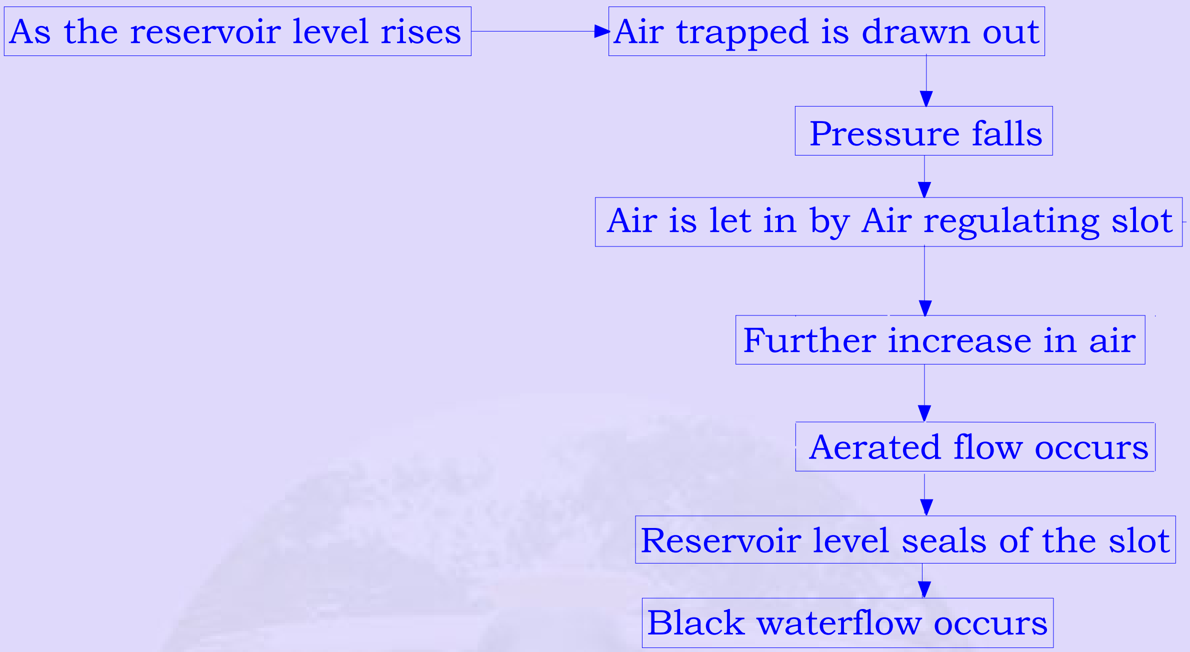
Uncontrolled surging occurs: Two approaches to solve.

(1) Multiple siphons with different crest heights.

(2) Air regulation - Modification of intake is required.

(1) Gravity flow at low heads

(2)



There are three possible operating conditions depending on upstream depth.

1. Gravity spillway flow

2. Aerated flow.

3. Pipe (black water flow).

The aerated condition is unstable and is maintained only for a short time while the siphons begins to prime, since air cannot enter once the entry is covered. Therefore in a simple siphon a small change in head reduces a sharp increase or decrease in the discharge through the spillway. This can lead problems if the discharge entering the reservoir is greater than the spillway flow but less than the black water flow. Since the following cycle of events is set in motion.

1. If the spillway is operating initially with gravity flow then the upstream water level should rise.

2. When the upstream level has sufficiently increase the siphon primes and the discharge through the spillway increases substantially.

3.Upstream level falls till the siphon deprimes and the discharge reduces.

As the head increases the annular nappe thickness must increase and eventually the nappe occupies the section at the entry to the drop shaft. The behaviour is similar to flow through orifice and hence is known as orifice control. The outlet tunnel will not be running full as the design discharge is higher. Further increase in the head will induce black water fall flow throughout the drop and outlet shafts. When the downstream is submerged the weir flow changes to pipe flow. If the design is improper it is likely that the water will overtop the dam. The design head is usually less than the head required for black water flow. This is adopted from the point of flood lift during higher floods. It is also to be noted that the flow enters the transition in the form of a spiral vortex and the vortex must be minimised by providing anti vortex baffles or piers.

If large capacity is not required as available space is restricted then siphon spillway can be adopted. A battery of siphon spillways is used at different elevation. Very close limits of operation of water surface elevation.

A stable discharge could be achieved through if the air slot is well designed.

$$\frac{Q_{air}}{Q} = K\ F_r^2$$

K is a function f^n of angle between deflected nappe and the hood and

F_r is the Froude number at the toe of the deflector.

K is generally taken as 0.002.

Siphons are used for automatic disposal of floods from reservoirs. In India, saddle siphons were first used to spill the surplus water at Maramcilli (Madhya Pradesh) designed by Davis in 1921. The Ganesh Iyer Volute Siphon is named after the investigator. Many siphons of this design have been constructed in earstwhile Mysore State, presently known as Karnataka the largest 5.5 m diameter being at Hirebhasgar in 1948.

34.2 Saddle Siphons (Figure 34.3)

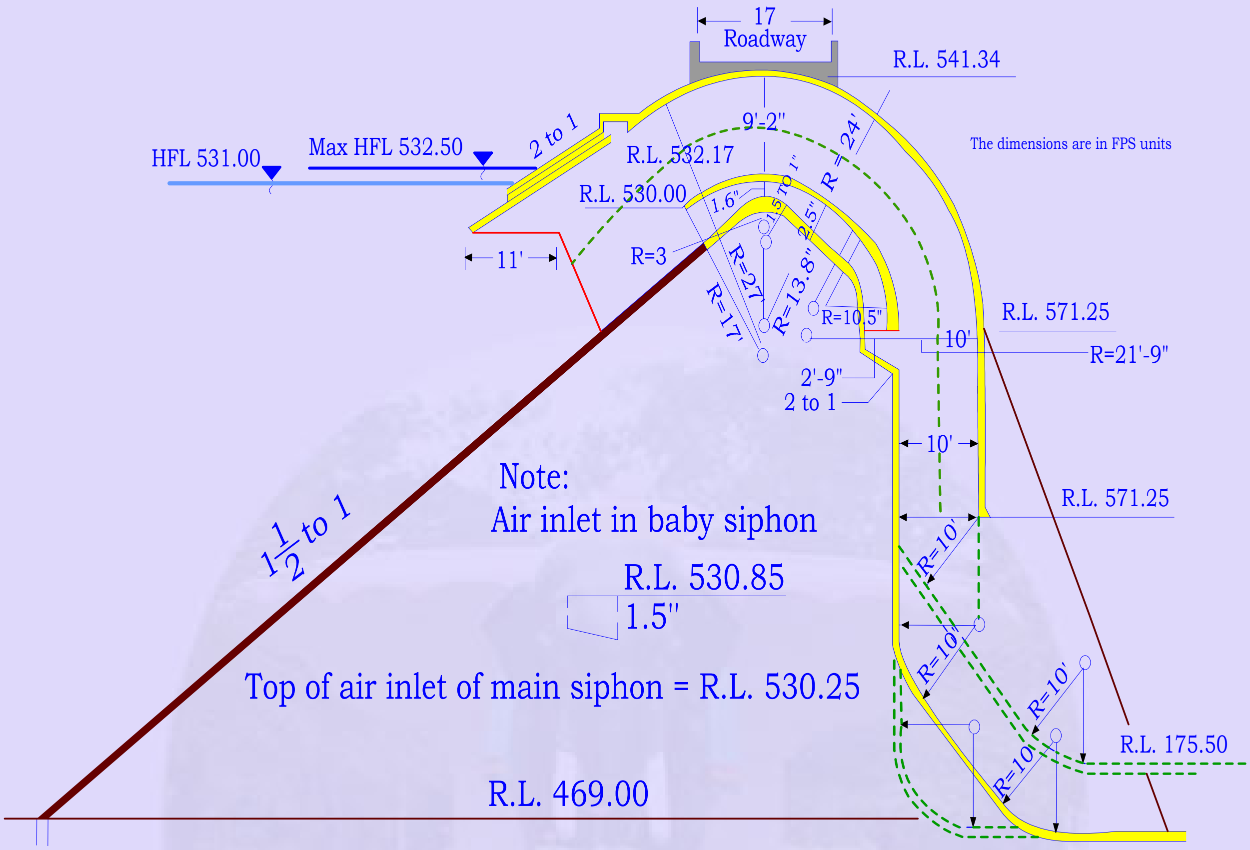


Figure 34.3 - Typical Saddle siphon with a baby siphon

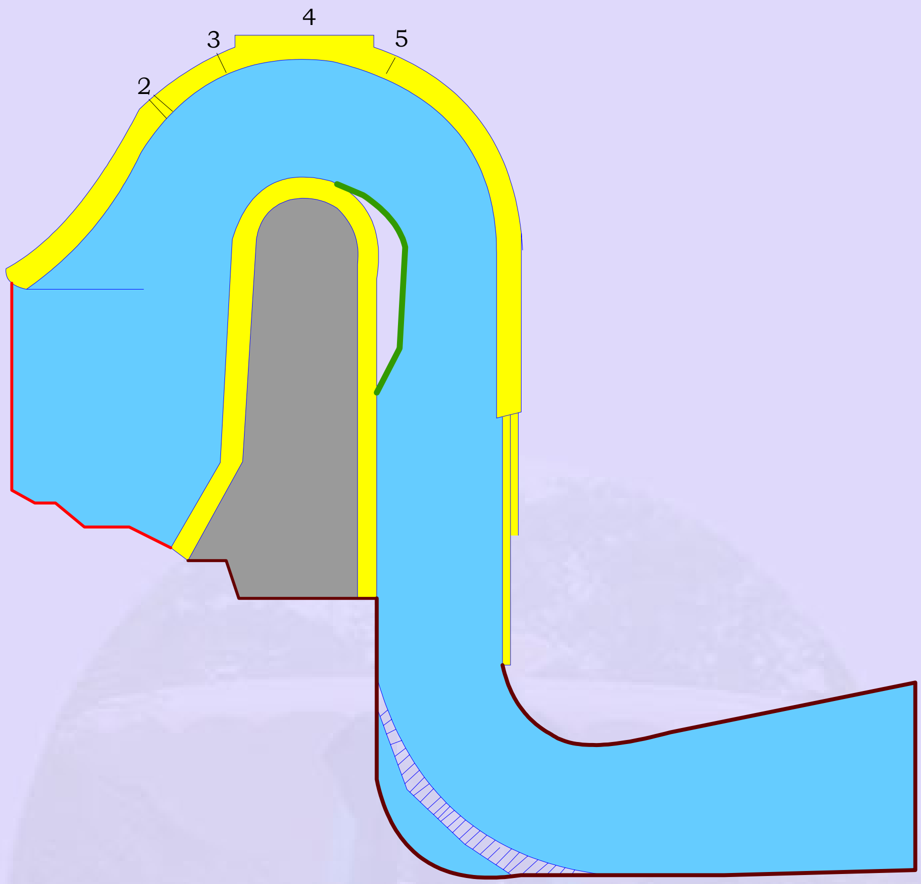
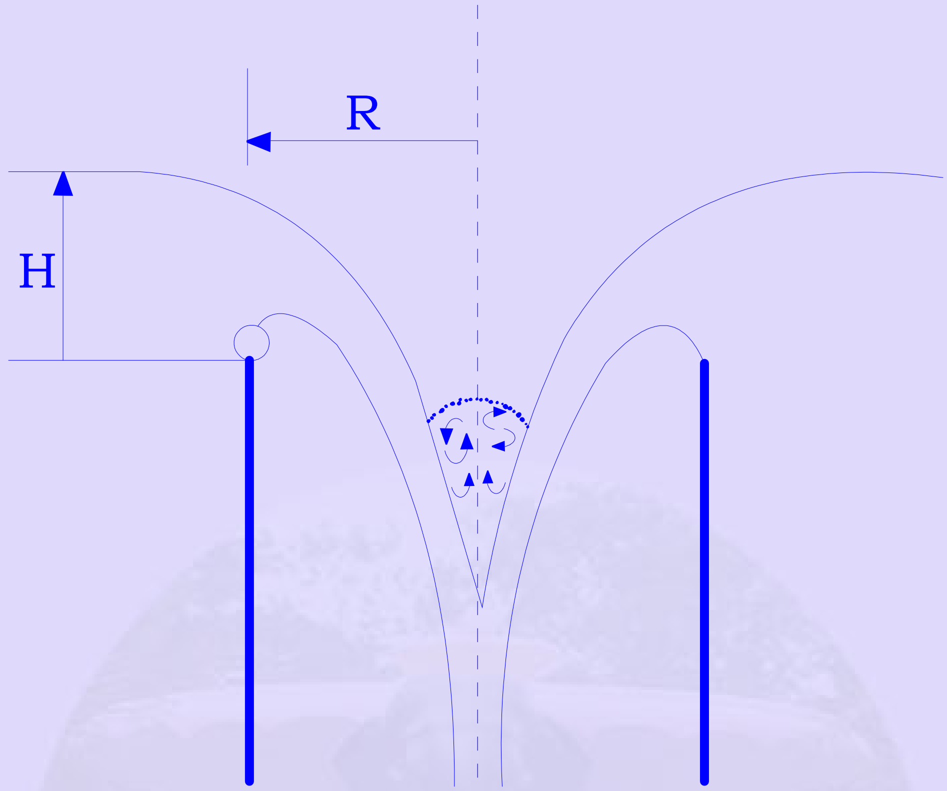


Figure 34.4 - Sketch of a Typical Siphon - with flared extension

In the Maramcilli siphon, designed by Davis (Figure 34.3), a baby siphon has been incorporated in the main siphon for causing early priming. The baby siphon first comes into action and evacuates the air from the main siphon, causing it to prime early. But the coefficient of discharge is adversely affected in this design also, as the flow shooting through the baby siphon interferes with the flow of the main siphon.

34.3 Ganesh Iyer's Volute Siphons (Figure 34.5).



Volute siphon

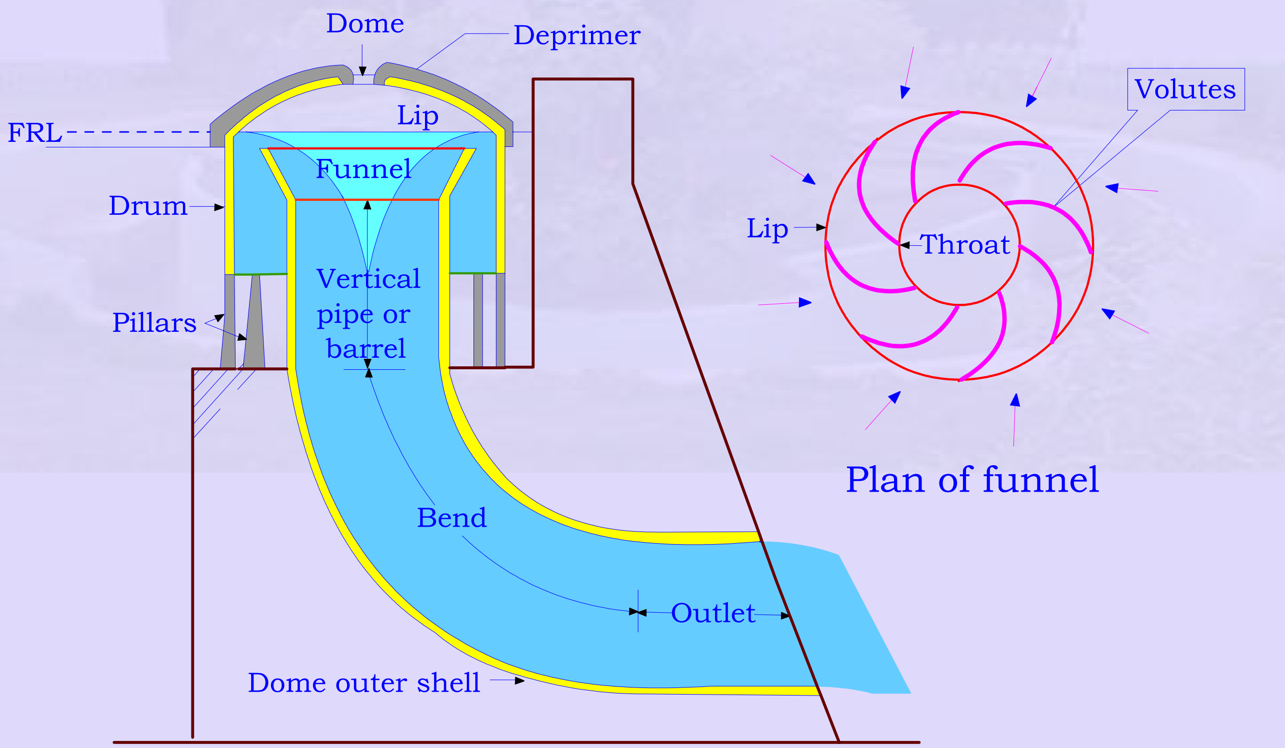


Figure 34.5 - Parts of a volute siphon

The Ganesh Iyer Volute Siphon (Figure 34.5) consists essentially of a dome with a funnel placed underneath leaving an annular space alround, with a vertical pipe taken down the funnel, to pass the discharge through the dam.

The lip of the funnel is kept at the F.S.L for the reservoir and a number of volutes (as in centrifugal pumps) are fixed on the funnel to induce a spiral motion to the flow. When the water in the reservoir rises over the the F.S.L., it spills over the circumference of the lip of the funnel and flows along the volutes in a spiral motion forming a forced vortex near the top of the vertical pipe. The vortex so formed induces a strong suction creating a powerful vaccum; this step the siphon in action. To stop the siphonic action, air is automatically let in through small pipes connected to the crown of the dome with their inlets kept at the F.S.L. of the reservoir.

The volute siphons are very efficient, giving a discharge coefficient of 0.75 to 0.80. Early priming has been obtained in the prototype, as for example in the Hirebhasgar siphons, the siphon primed at a depth of 0.5 m only. These siphons, eleven in number, built in 1947, have diameter of 5.5 m and operate under a head of 17.7 m. Some of the factors which assumed special significance with the increased size and operating heads, as evidenced in the working of the siphons at Hirebhasgar the largest Ganesh Iyer Volute

Siphons in size and surplussing capacity constructed- were:

(i) flow conditions and pressure distribution, and limit,

(ii) vibrations, and

(iii) effect of air drawn through powerful vortex.

In particular, the permissible head under which these siphons would work safely without reaching cavitation conditions has been subjected to a close study. The working of siphon No.7 at Hirebhasgar, which had a uniform 4.9 m diameter barrel had caused cavitation damage.

Table 1. gives the critical head at which cavitation starts and the corresponding maximum discharge for various diameters of volute siphons.

Diameter (m)	0.15	0.30	1.80	4.50	6.00
Critical head (m)	27	17.1	14.1	14.0	13.8
Maximum discharge m^3/s	0.23	0.92	34.0	219	391

In the case of the Hirebhasgar Siphons, the range of the observed discharging capacity of a siphon under the limit of partial and full running of the outlet has been between 270 m^3/s and 300 m^3/s.

Vibrations

One of the consequences of high head siphons is generating of vibrations, the magnitude of which depends upon the entrainment of air and changes of pressure in the flow, and the position of adjoining siphons and vortices.

Group working of siphon Numbers 1, 4 and 6 was tested during 1954. All the three siphons worked partially full with Numbers 4 and 6 occasionally trying to close the gap at the outlet. In siphon No. 6 there was damage comprising a hole 45.7 cm wide in the barrel at R.L. 535.503 just above the R.C. joint, a crack right round the barrel ring joint and damaged plaster (Figure 6).

The volute siphons during their working produce appreciable vibratory forces and it is necessary to know about their magnitude for design purposes under different conditions.

The period of transition from pre primed to primed stage has been found to be 40 seconds. This has direct influence on the stress distribution. The vibration was at 8 Hz and localised higher vibration was at 30 Hz. The general level of the vibrational force varied from 0.059 to 0.15 g, but some transients have been found to be as high as 0.2 g accompanied by high frequency oscillations.

References

GANESH IYER, V "Volute Siphons". Journal of Central Board of Irrigation and Power, 1950.

Govinda Rao N.S. "Ganesh Iyer's, Volute Siphons - A note on the design and working" , Central Board of Irrigation and Power, New Delhi, Publication No. 80, 1966.

34.4 Morning Glory Spillway

Introduction

Most of the shaft spillways in the world were constructed in United States, Portugal and Italy in earlier days. As the inlet funnel resembles the morning glory flower, the spillway is termed as morning glory spillway in English - speaking countries.

The first of this kind was built in 1896 and was designed by James Mansergh for the Blackton reservoir in England. The second and third spillways were constructed in the years 1908 and 1911 for Front Reservoir in England and Taf Fechan reservoir in South Wales respectively. Shaft spillways are also constructed around this time in Krauserbauden and Koenigreicherwalde reservoirs and Czechoslovakia. Italy also took to the construction of these spillways in the year 1917 for the Bassono power canal and for San Dal mazzo di Tenda reservoir.

The first morning glory spillway in the United States was constructed in the year 1926 at the Davis Bridge dam. With the construction of this spillway, a new phase started. This was the first spillway where the hydraulic performance was checked by model studies.

In general, a morning glory shaft spillway consists of an inlet funnel, conical transition shaft, bend, outlet tunnel and a stilling basin.

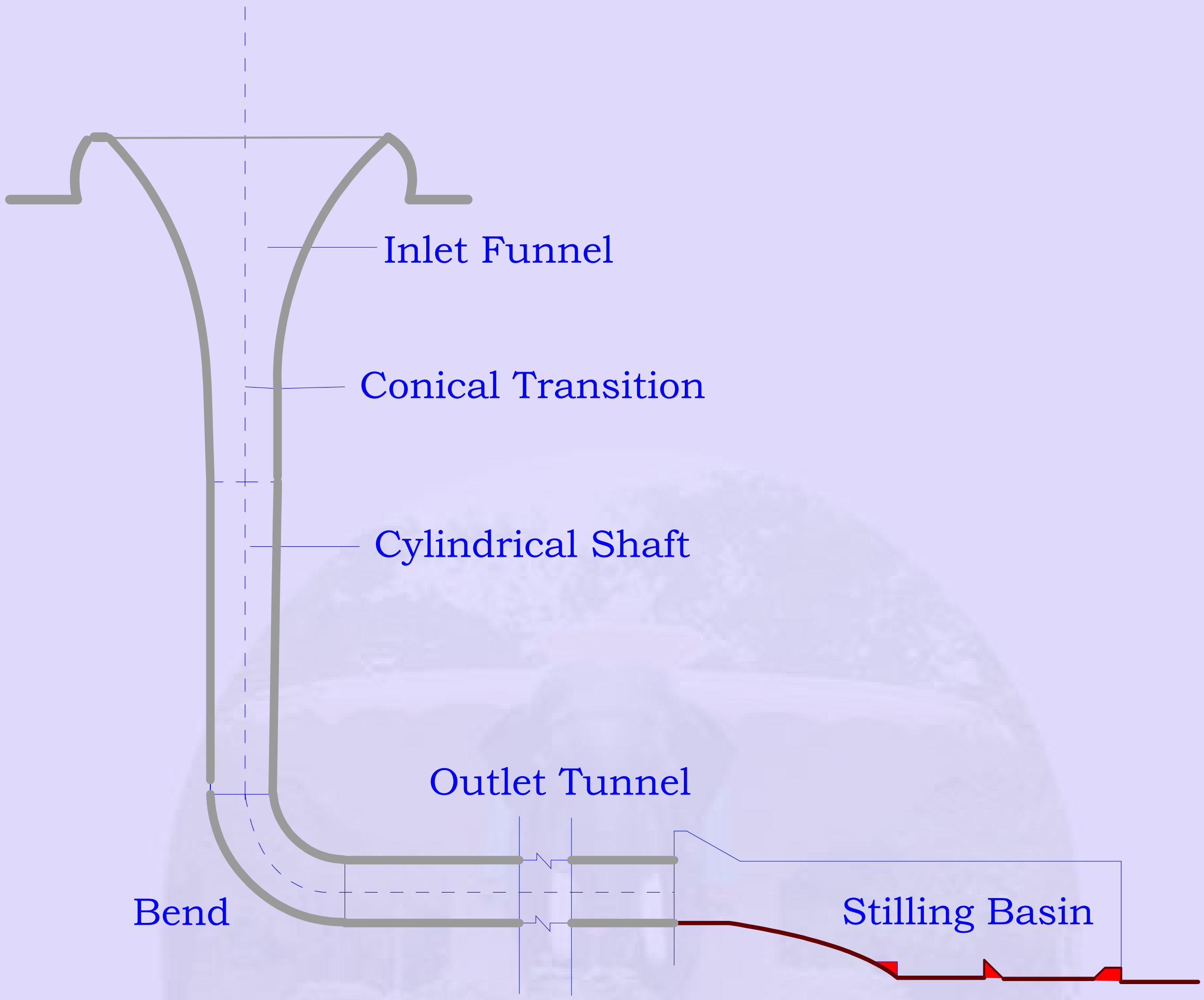


Figure 34.6 - Definition Sketch of Morning Glory Shaft Spillway

The crest of the inlet funnel is generally circular in plan. There are also spillways in Portugal with a polygonal and square crest. The crest of the shaft spillway at Oued Sarno dam in Algeria is made to resemble marguerite flower, so as to increase the spilling length considerably.

The inlet funnel has different forms. The classical forms are (a) the standard - crested type, the flat crested type. However, there are many other forms, which are also in vogue. For example, Taf Fechan, Fountain Ketchil, Silent Valley and Burnhope shaft spillways have their inlet funnels made up of circular segments. Steps are provided in the inlet funnel of Lady Bower Shaft Spillway. Mae and Jubilee shaft spillways have trumpet-shaped funnels.

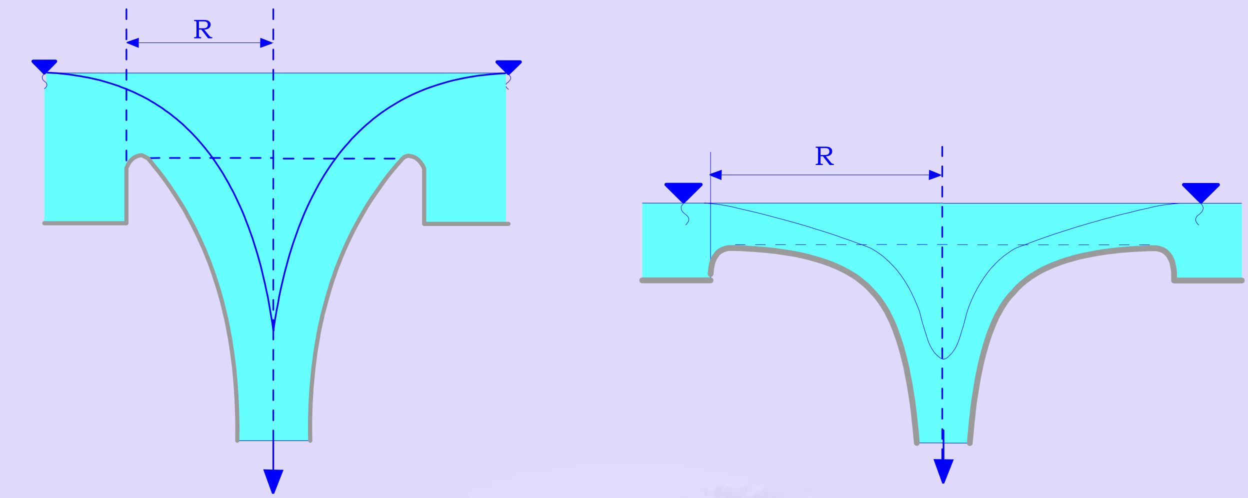


Figure 34.7 - Types of Inlet Funnels

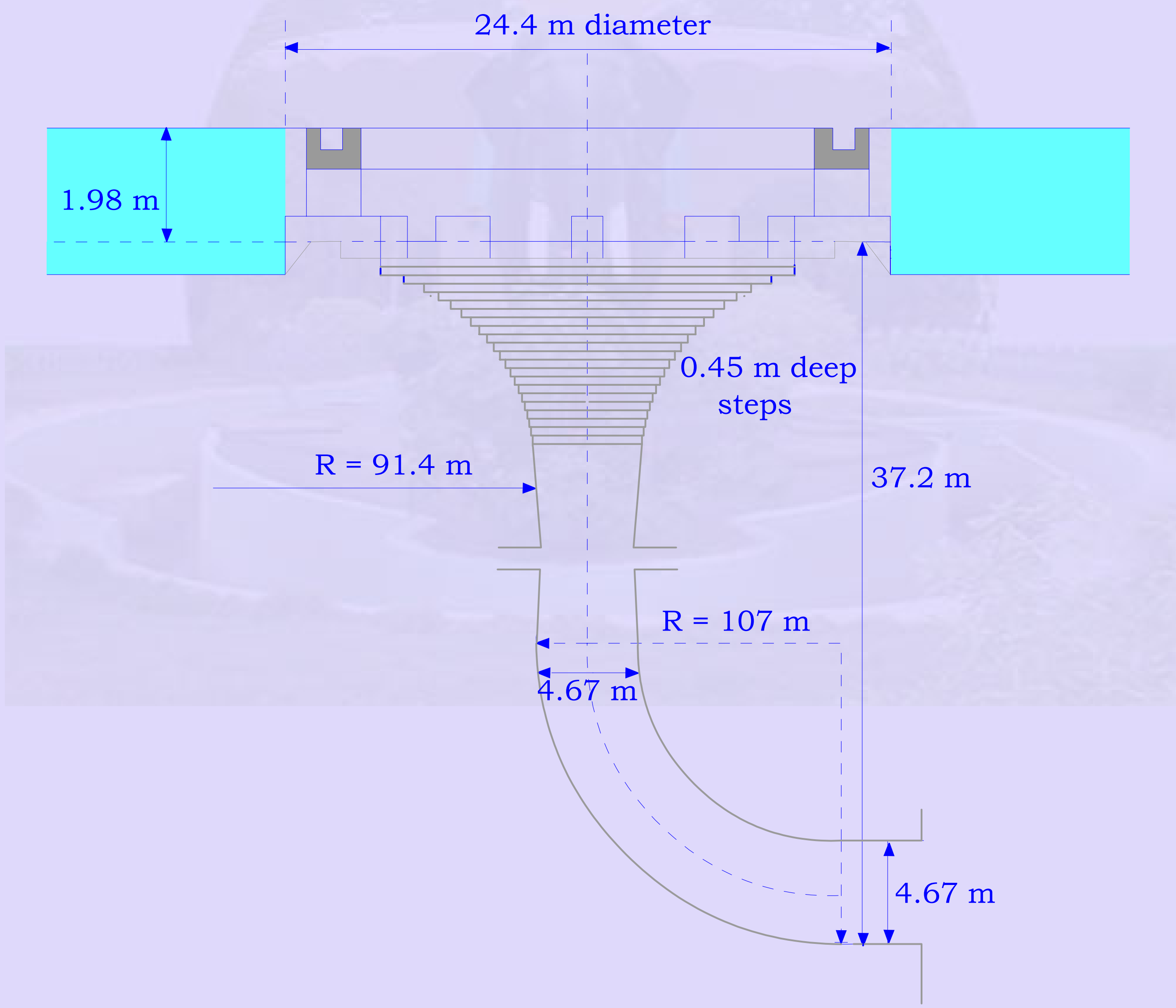


Figure 34.8 - Schematic of Lady Bower Dam Spillway

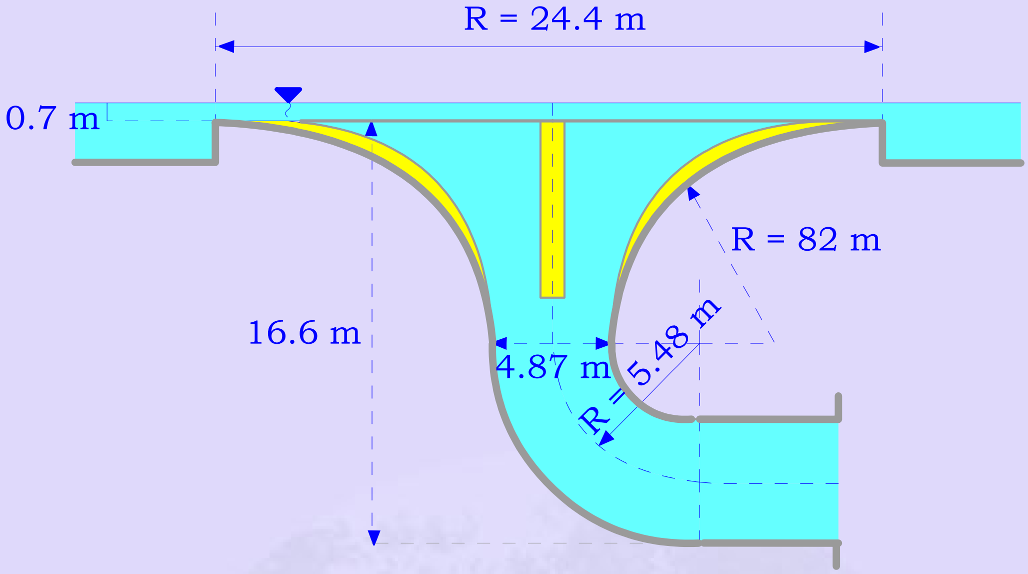


Figure 34.9 - Silent Valley Dam Shaft Spillway with 4 Fins of .23 m width

Reveris shaft spillway and also Front shaft spillway are provided with stilling chambers directly beneath the shaft, and the water flows from there with a free surface in the outlet tunnel. Following guidelines are provided in eliminating damage due to caviatation.

1. The concrete structure must be made very smooth, and if required, cleanly ground. The concrete surface in the inlet funnel and the bend of the shaft spillway at the Hungry Horse dam is made extremely smooth by grinding many times.

2. Construction joints must be eliminated in the vicinity of the bend and the inlet funnel.

3. Misalignment must be avoided. Shaft spillways are lined with cast iron, in order to avoid erosion.

4. For heads more than 60 cm which generally is the case, the entrained air is forced through the outlet end of the spillway.

5. Because of the assymetric conditions the non-uniform flow occurs and hence the formation of a major vortex.

6. The vortex formation reduces the discharging capacity, considerably which results in a rise in reservoir level, and it causes also objectionable noise. The reduction to be about 44%, about 74% for bell-mouthed inlets and about 90% for cylindrical inlets.

7. There are many artifices to prevent the formation of vortex.

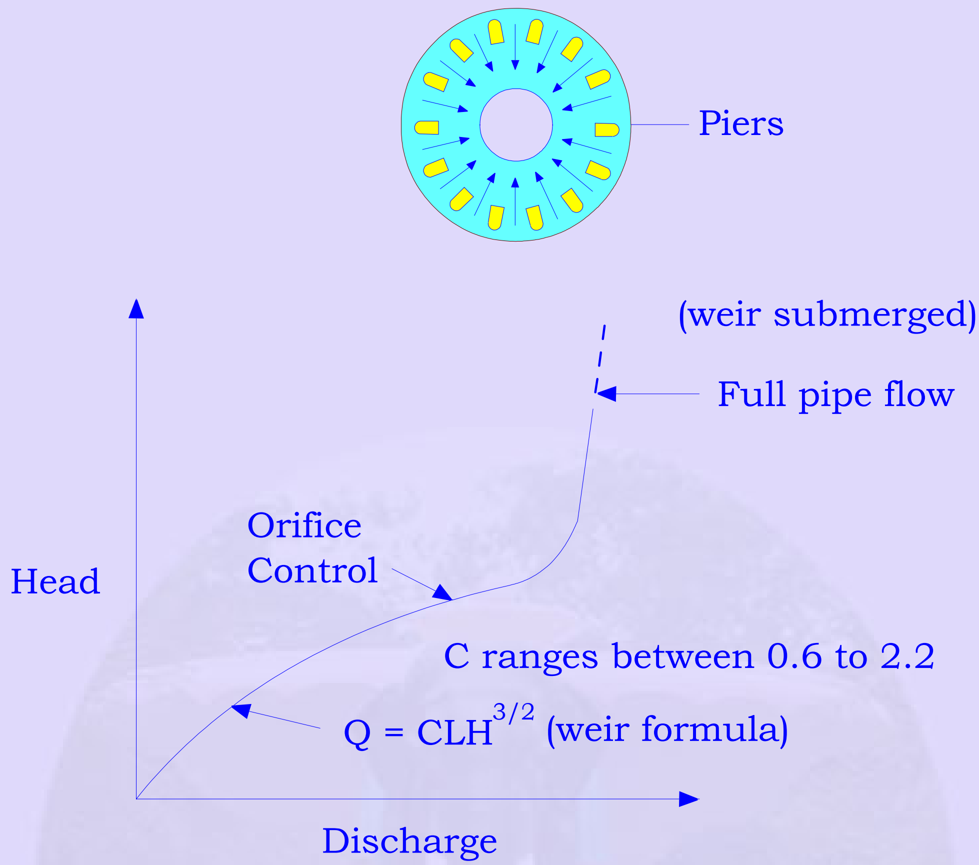


Figure 34.10 - Head-discharge characteristic for a Shaft Spillway

Reference

Sastry P.G., "Morning Glory Shaft Spillways - A detailed survey" , Vishwakarma, page 340 to 348.