Mechanical Engineering Courses

impulse turbines - Pelton wheels

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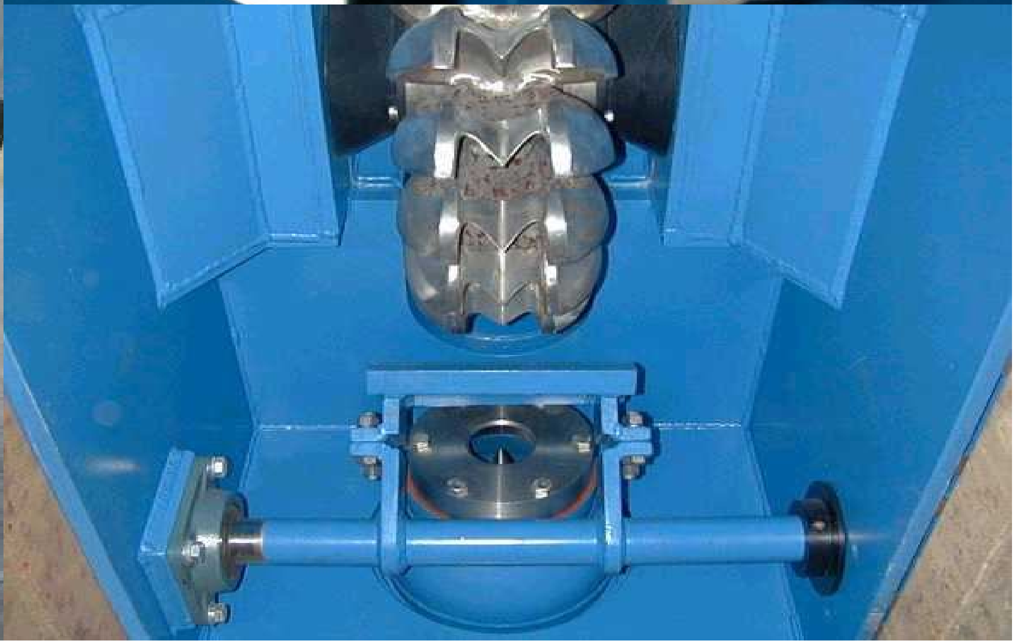
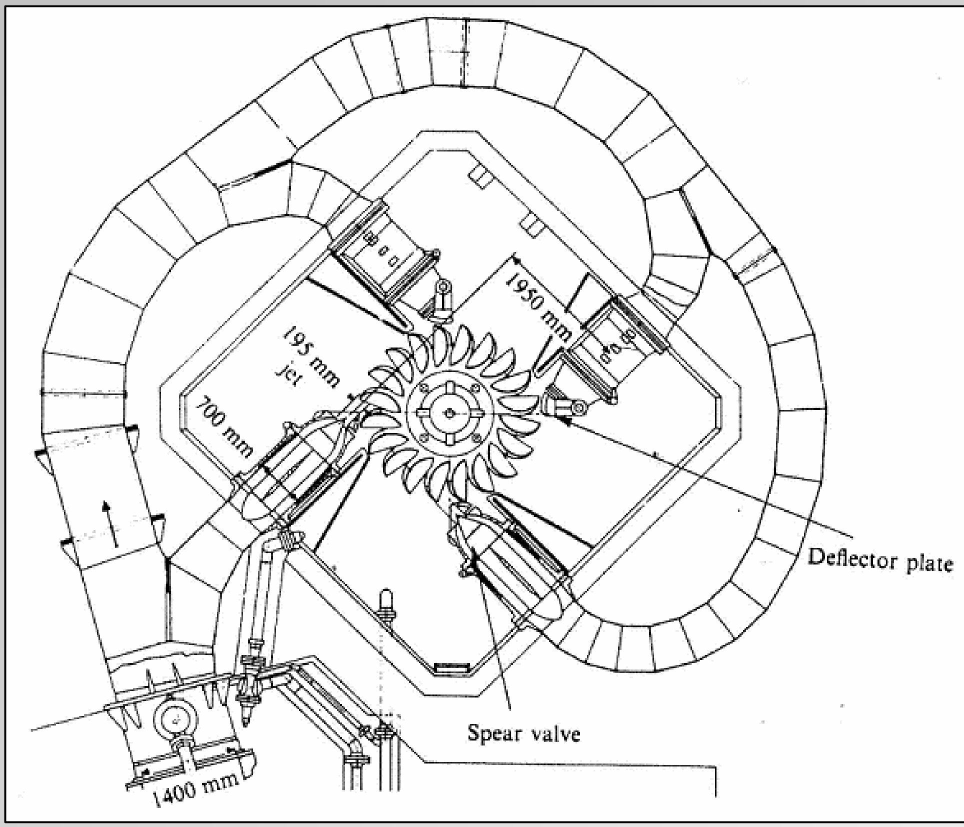
Construction and Component



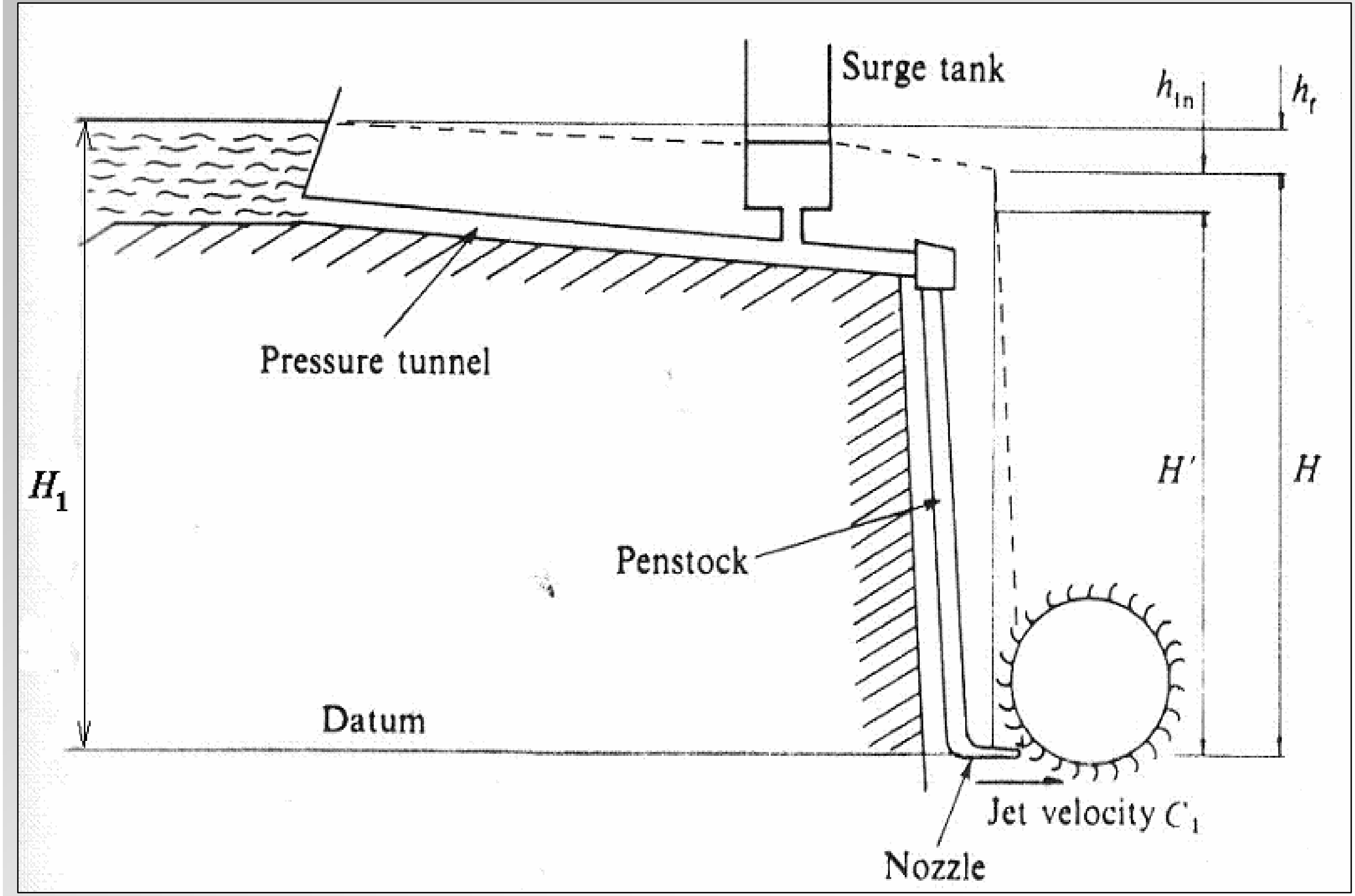
Construction



Multi Jet

Single Jet

Installation



Velocity Triangle

Euler Equation:

$$W/m = U_1 C_{x1} - U_2 C_{x2}$$

$$W/m = U\{(U + W_1) + [W_2 \cos(180° - \alpha) - U]\}$$

Assume no loss of relative velocity, *$W_1 = W_2$*

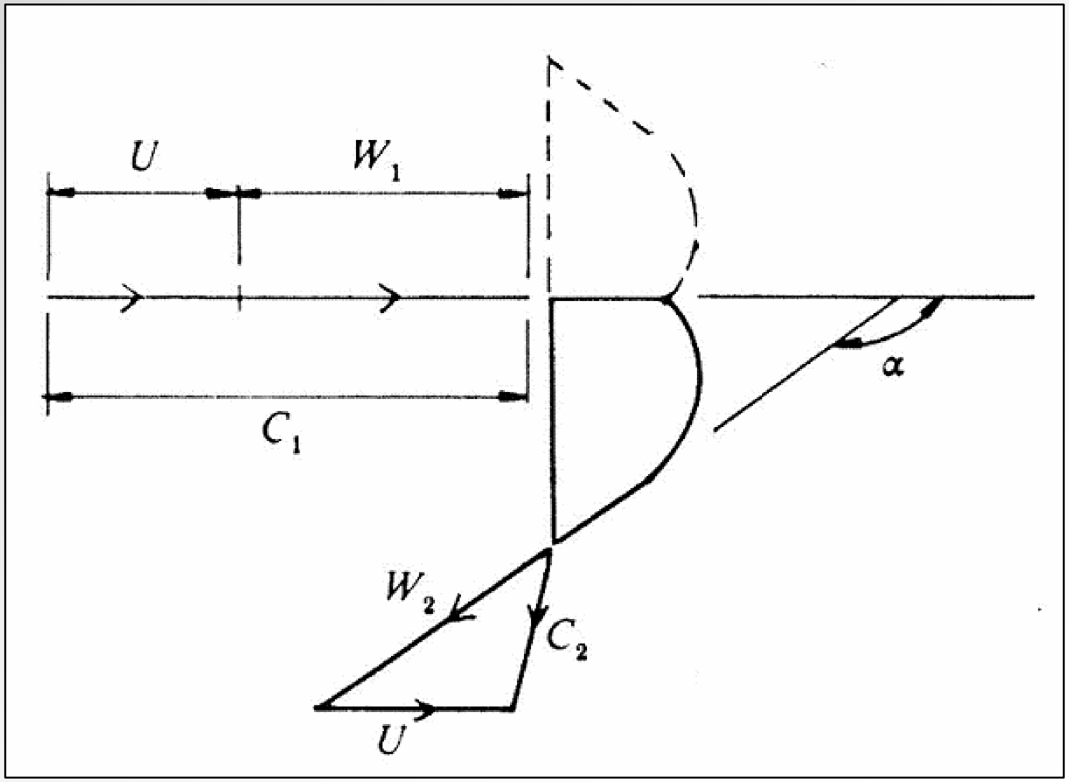
$$W/m = U(W_1 - W_1 \cos\alpha)$$

$$E = U(C_1 - U)(1 - \cos\alpha)/g$$

For maximum *E* → d*E*/d*U* = *0*

$$C_1 = 2U \qquad U = C_1/2$$

$$E_{max} = C_1^2(1 - \cos\alpha)/4g$$



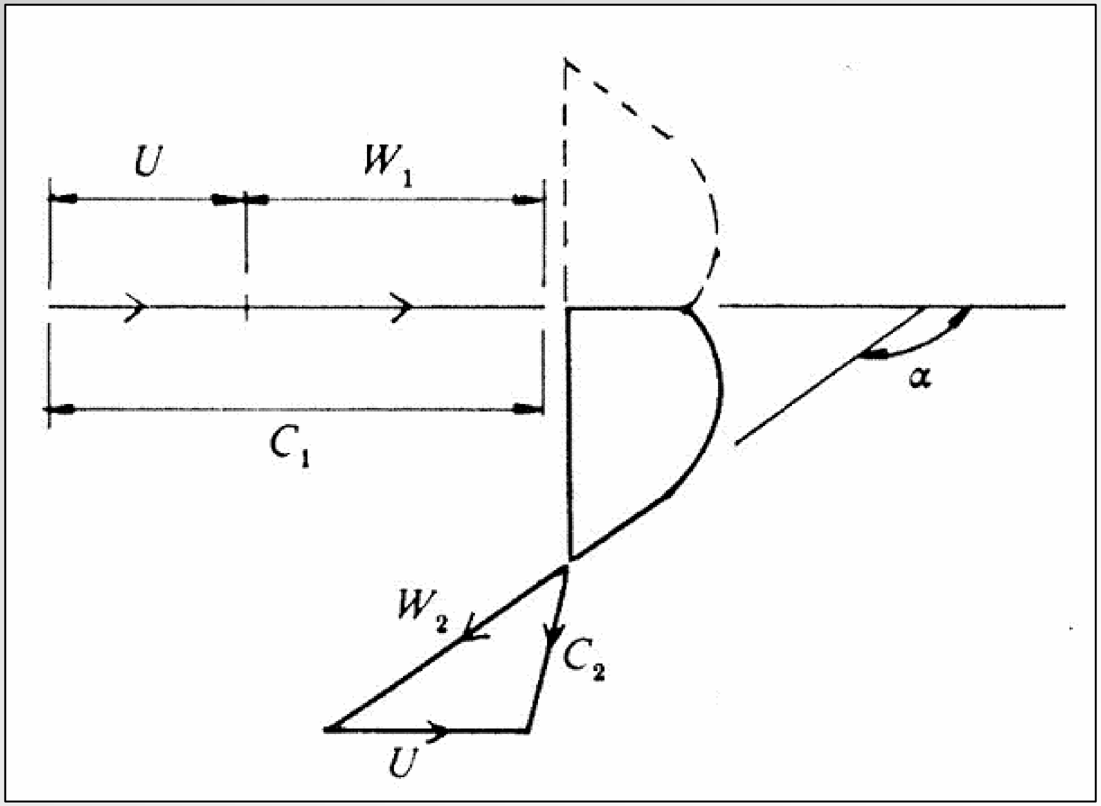
Velocity Triangle

In practice :

Surface friction of the bucket → $W_2 \neq W_1$

$$E = U(C_1 - U)(1 - k\cos\alpha)/g$$

k is the relative velocity ratio W_2/W_1.



Losses and Efficiency

Pipeline transmission efficiency → pipeline losses, *h*$_f$

$$\eta_{trans} = \frac{\text{energy at end of pipeline}}{\text{energy available at reservoir}} = \frac{\left(H_1 - h_f\right)}{H_1} = \frac{H}{H_1}$$

Nozzle efficiency → nozzle losses, *h*$_{in}$

$$\eta_N = \frac{\text{energy at nozzle outlet}}{\text{energy at nozzle inlet}} = \frac{\left(H_1 - h_f - h_{in}\right)}{\left(H_1 - h_f\right)} = \frac{\left(H - h_{in}\right)}{H} = \frac{H'}{H}$$

Energy available in jet at nozzle outlet : $H' = C_1^2 / 2g$

Nozzle velocity coefficient

$$C_v = \frac{\text{actual jet velocity at nozzle outlet}}{\text{theoretical jet velocity at nozzle inlet}} = \frac{C_1}{\sqrt{2gH}}$$

$$\Rightarrow \quad \eta_N = C_v^2$$

Hydraulic efficiency

$$\eta_H = \frac{\text{energy transferred}}{\text{energy available in jet at nozzle outlet}} = \frac{E}{H'} = \frac{E}{\left(C_1^2 / 2g\right)}$$

Losses and Efficiency

Overall Efficiency

$$\eta_o = \frac{\text{Power developed by the turbine}}{\text{Power available at nozzle inlet}} = \frac{P}{\rho g Q H}$$

Turbine discharge, *Q*

$$Q = (\text{nozzle area})(\text{actual jet velocity at nozzle outlet})$$
$$= AC_1 = \left(\pi d^2/4\right)C_1$$

***d* = nozzle diameter**

Example

A Pelton turbine develops 2000 kW under a head of 100 m and with an overall efficiency of 85%. The coefficient of velocity for the nozzle is 0.98. Determine:

(a) The theoretical velocity of the jet ?

(b) The actual velocity of the jet ?

(c) The flow rate ?

(d) The diameter of the nozzle

Solution:

Given: *P* = 2000 kW; *H* = 100 m; η_o = 0.85 ; C_v = 0.98

Let : *d* = diameter of the nozzle ; *Q* = discharge flow rate of the turbine

(a) The theoretical velocity of the jet

$$C_{theo} = \sqrt{2gH} = \sqrt{2(9.81)(100)} = 44.3\,\mathrm{m/s}$$

(b) The actual velocity of the jet

$$C_v = \frac{C_1}{\sqrt{2gH}}$$

$$\Rightarrow C_1 = C_v\sqrt{2gH} = C_v C_{theo} = (0.98)(44.3) = 43.4 \;\; m/s$$

Example

(c) The flow rate

$$\eta_o = \frac{P}{\rho g Q H}$$

$$\Rightarrow Q = \frac{P}{\rho g H \eta_o} = \frac{2000.10^3}{(10^3)(9.81)(100)(0.85)} = 2.4 \;\; m^3/s$$

(d) The diameter of the nozzle

$$Q = AC_1 = \left(\pi d^2/4\right)C_1$$

$$\Rightarrow d = \sqrt{\frac{4Q}{\pi C_1}} = \sqrt{\frac{4(2.4)}{\pi(43.4)}} = 0.265 \;\; m$$

Design of Pelton Wheels

Pelton wheel is designed with the following input:

1. **Head of water**
2. **Power to be developed**
3. **Speed of the runner**

Pelton wheel is designed to find out the following data:

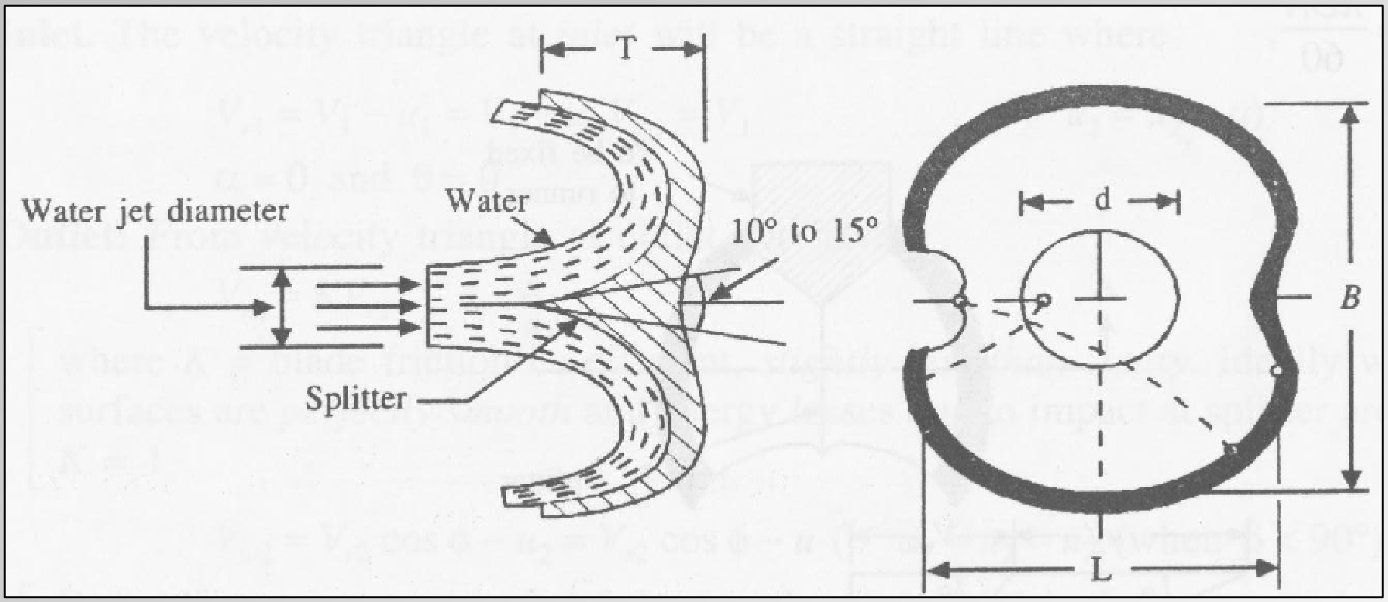
1. **Diameter of the wheel (*D*)**
2. **Diameter of the jet (*d*)**
3. **Size (i.e. width and depth) of the buckets**
4. **Number of buckets (*z*)**

Pelton wheel is usually designed with the following assumption:

1. **Overall efficiency, η_o between 80% and 87%**
2. **Coefficient of velocity, C_v as 0.98 to 0.99**
3. **Ratio of peripheral velocity to the jet velocity, U/C_1 as *0.43* to *0.48***

Design of Pelton Wheels

Size of the buckets



$$\frac{L}{d} = 2 \text{ to } 3$$

$$\frac{B}{d} = 3 \text{ to } 4$$

$$\frac{T}{d} = 0.8 \text{ to } 1.2$$

$$\frac{D}{d} = 11 \text{ to } 16$$

Number of the buckets (z)

Theoretical :

$$\boxed{z = 360^o / \alpha}$$

where:

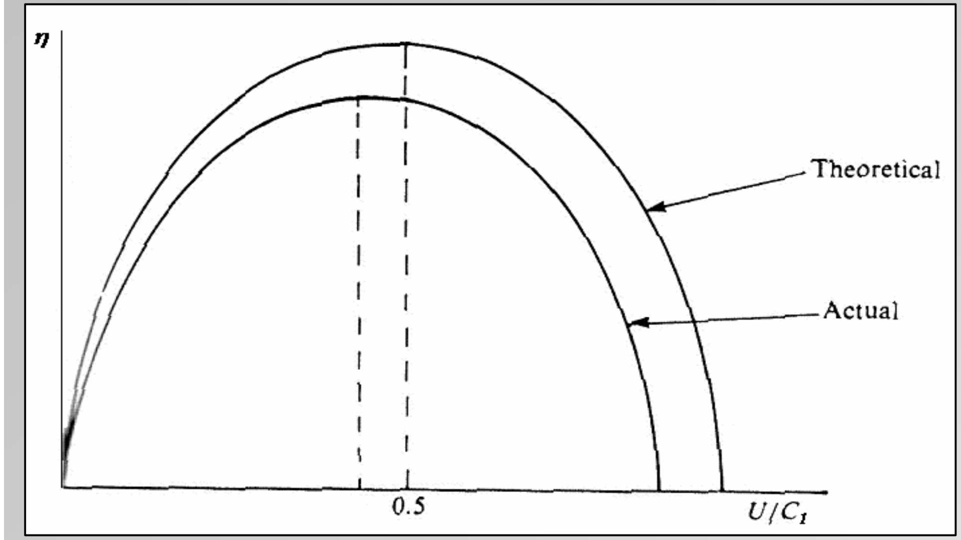
$$\cos\alpha = \frac{R + 0.5d}{R + 0.6d}$$

$$R = D/2$$

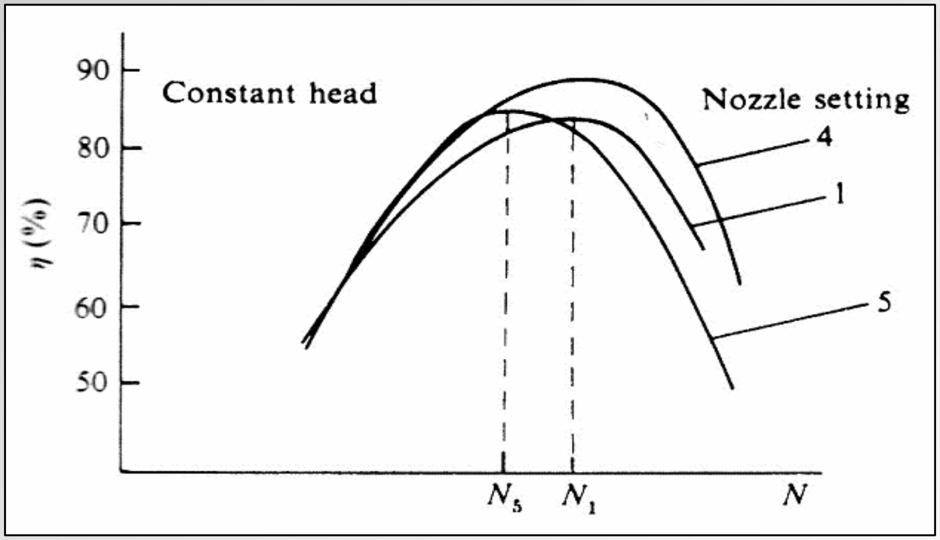
Empirical :

$$\boxed{z = 15 + \frac{D}{2d}}$$

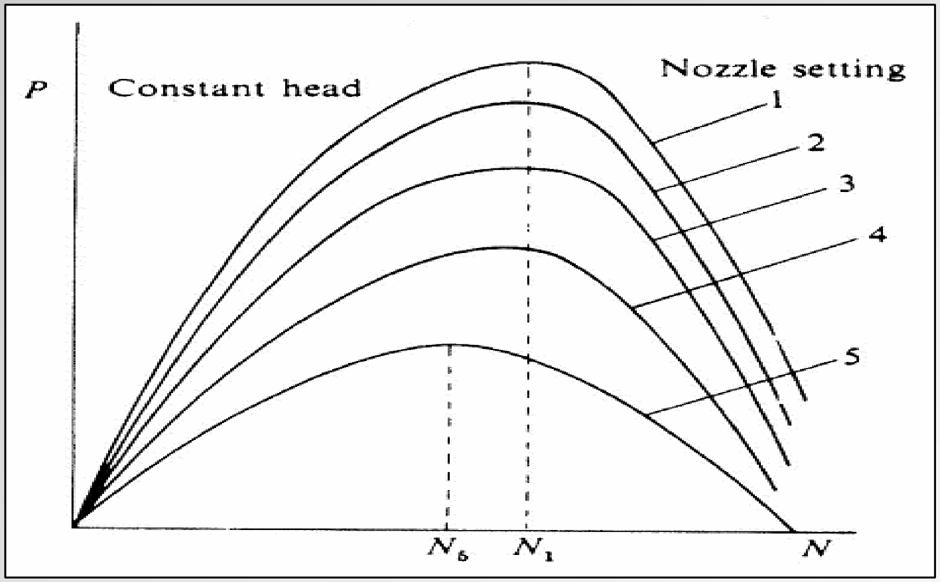
Characteristics Curves



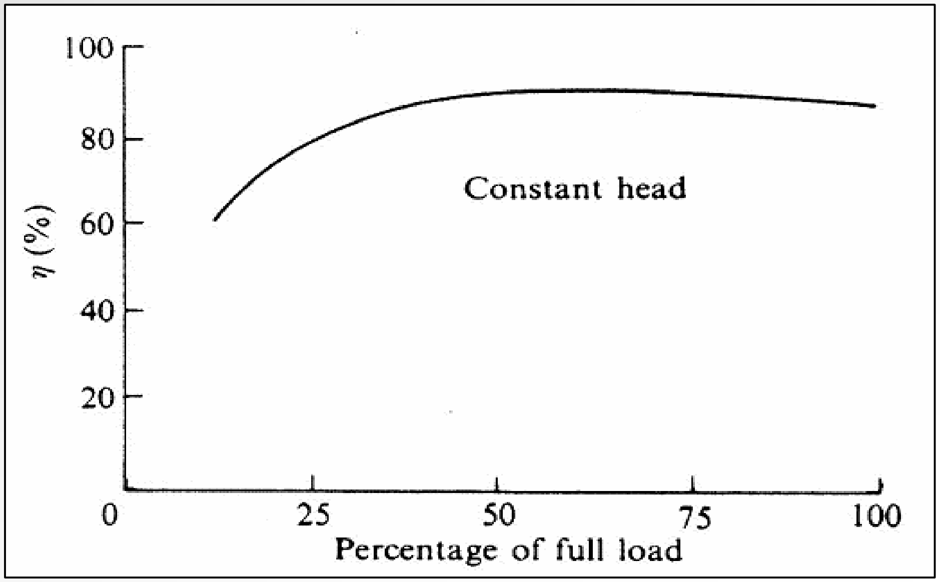
Efficiency and jet speed ratio



Efficiency vs speed at various nozzle setting



Power vs speed at various nozzle setting

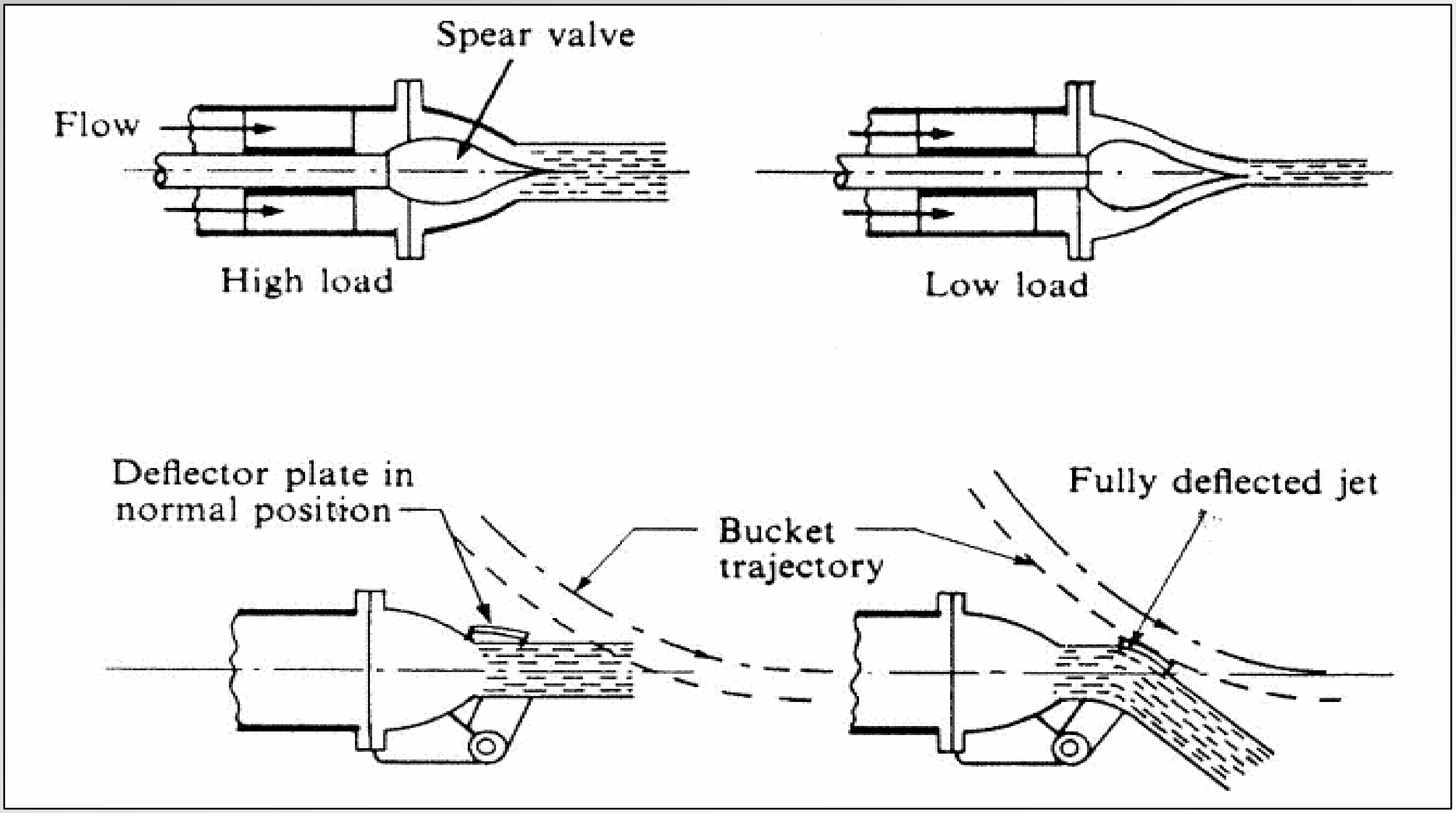


Variation of efficiency with load

Load Changes

In practice :

U* must remain constant when the load changes → to maintain maximum efficiency *U*/C_1 must stay the same → change the input of water power → change in *Q* → change in nozzle area *A



Load Control : spear valve and deflector plate

Load Changes