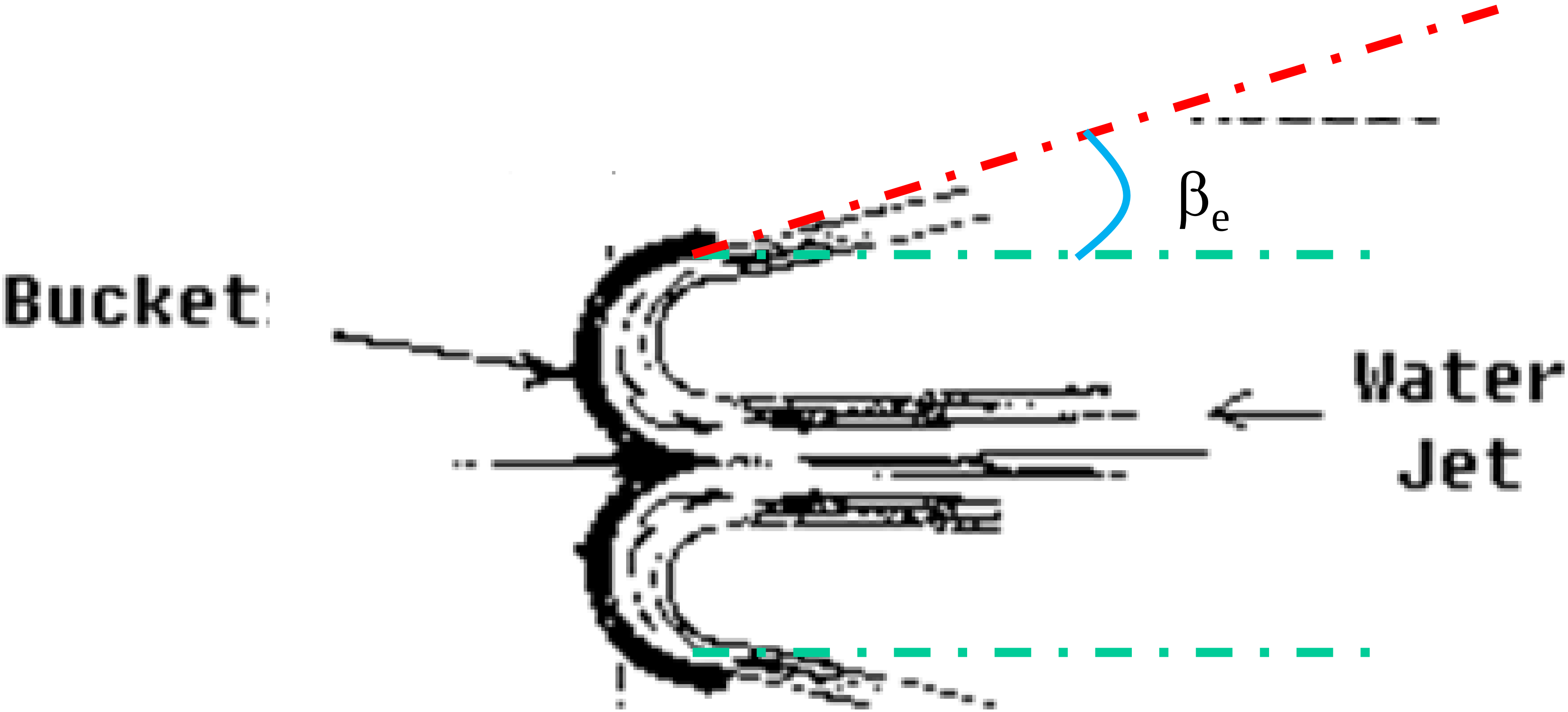
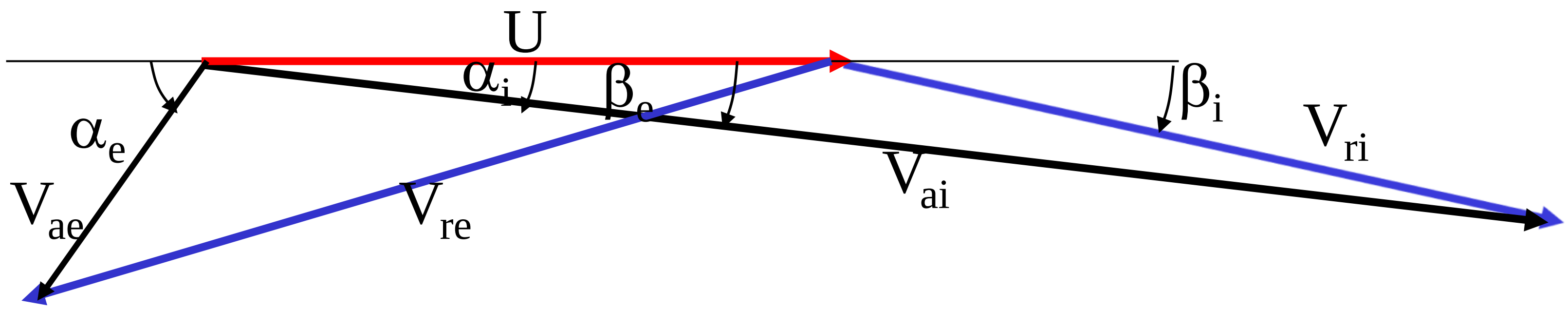
Pelton Wheel

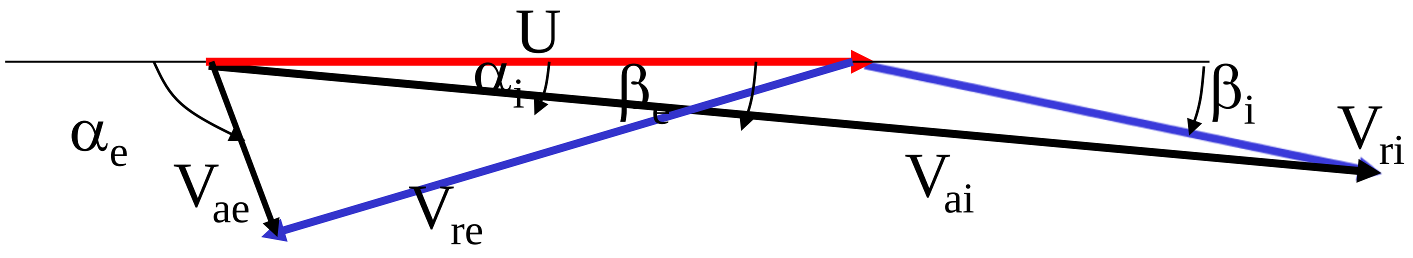
- The first scientifically developed concept and also patented product.
- The only one option for high heads (> 600 m)
- Best suited for low flow rates with moderate heads (240m -- 600m).
- A better choice for moderate heads with medium flow rates.
- Easy to construct and develop, as it works at constant (atmospheric) pressure.
- Low rpm at moderate or marginal heads is a major disadvantage.



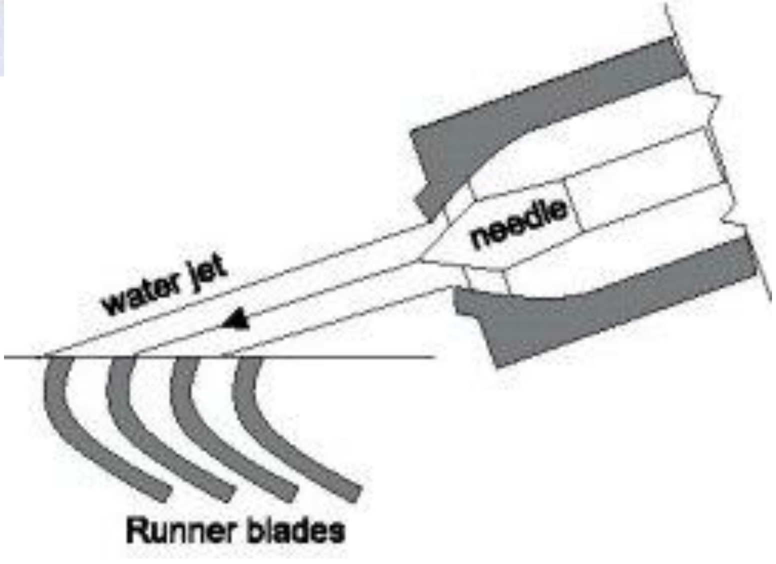
Is it possible to use Pure Momentum for Low Head Jets?

Options for Options for Low Heads & Low Flow Rate

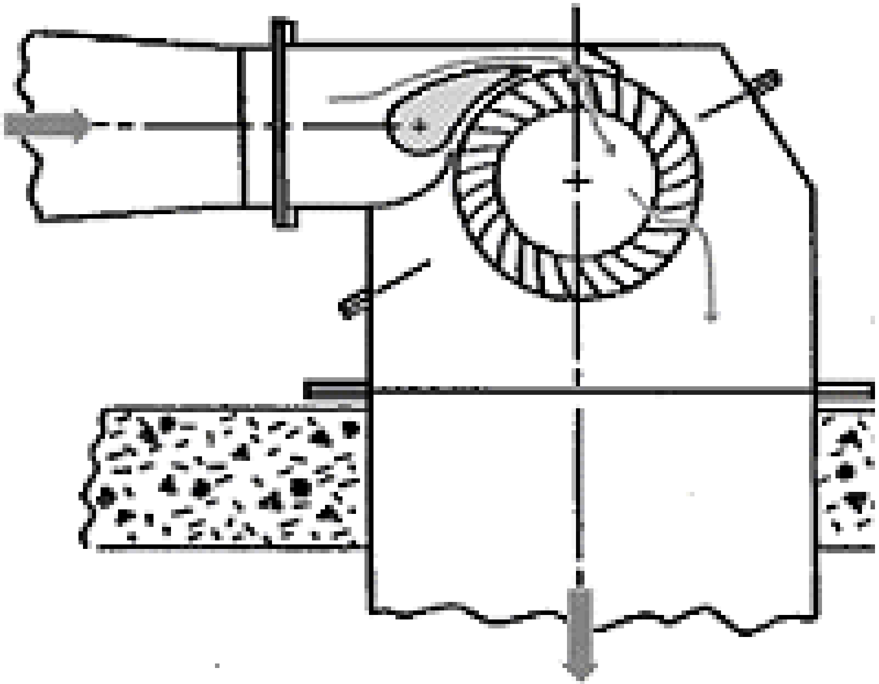


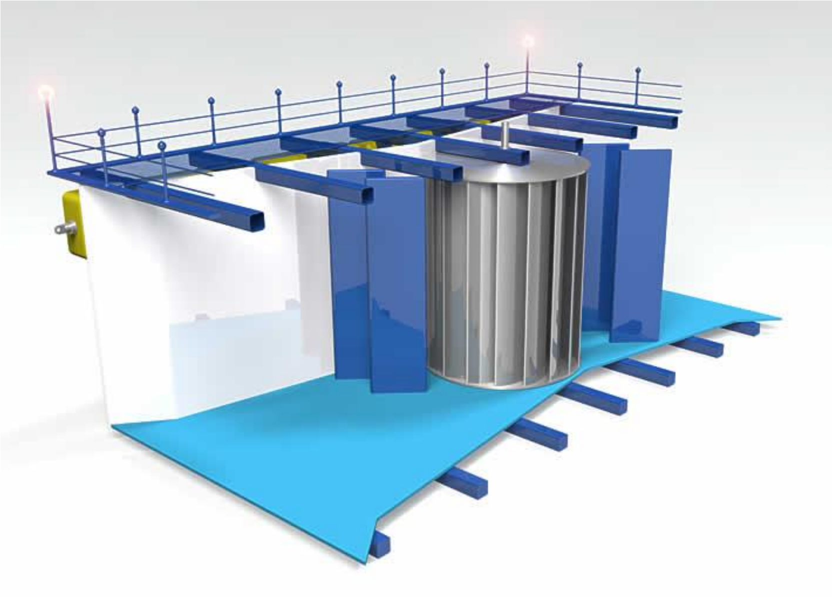


Turgo Turbine

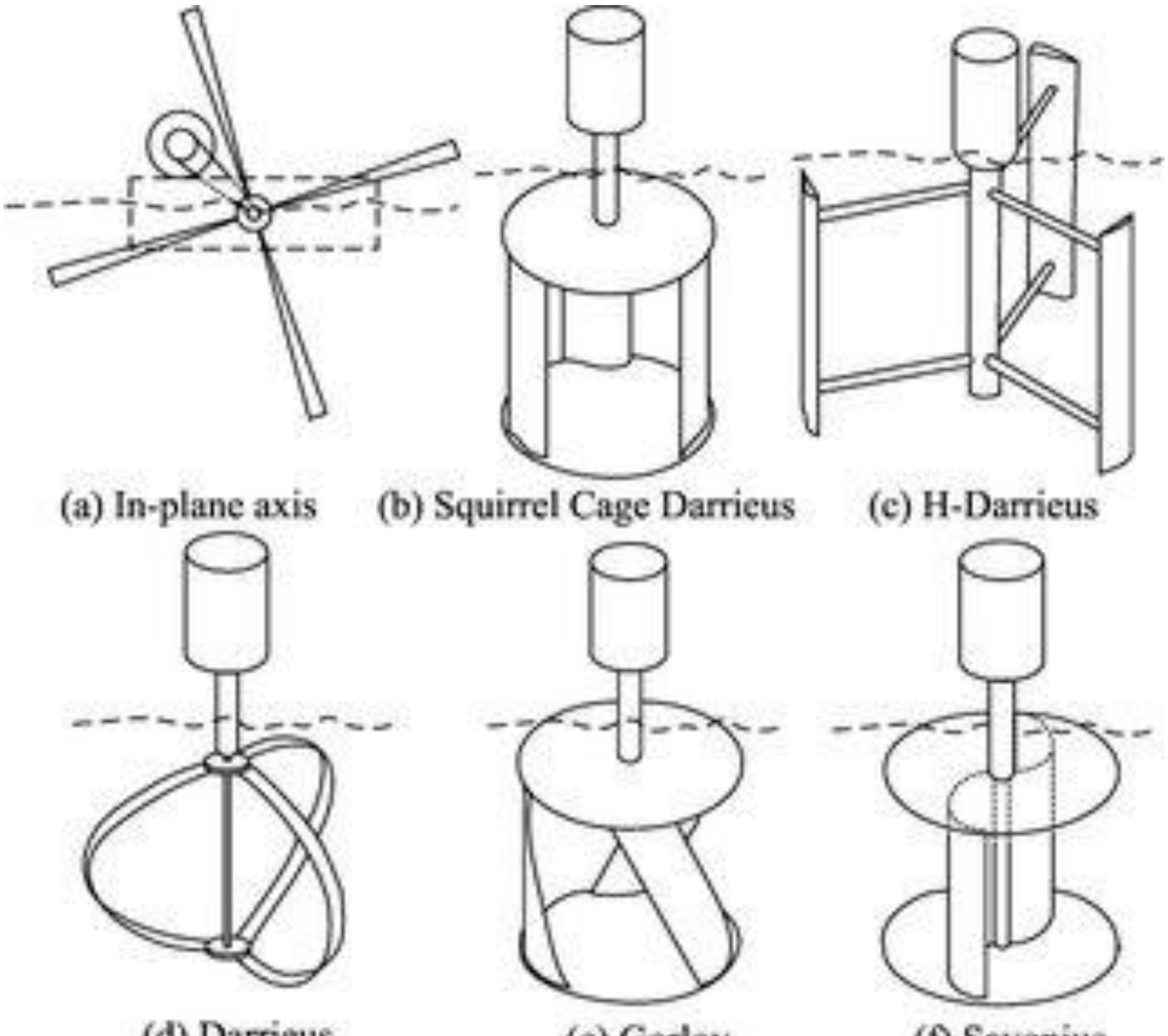


Cross-flow Turbine



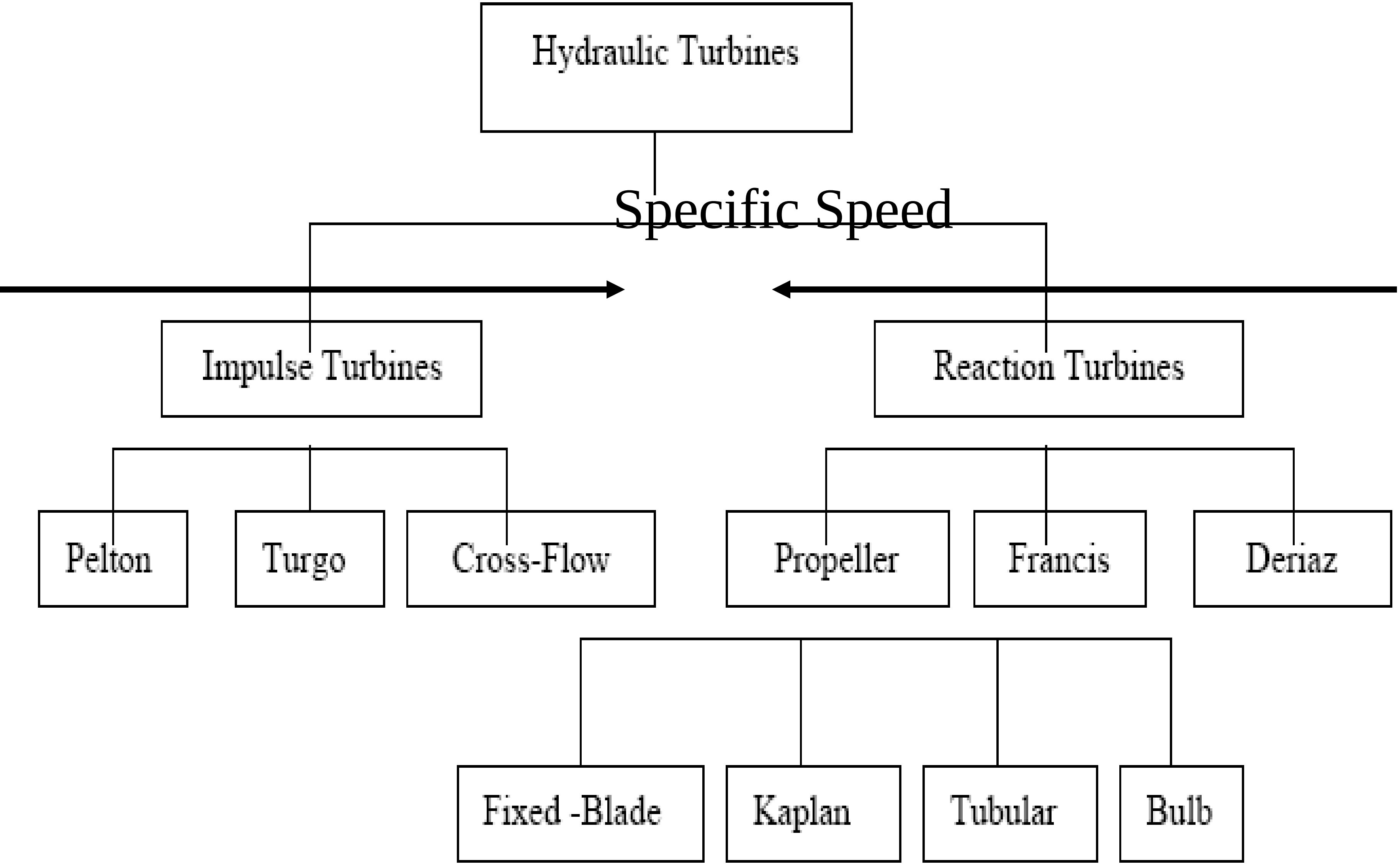


Variations of Cross-Flow Turbines

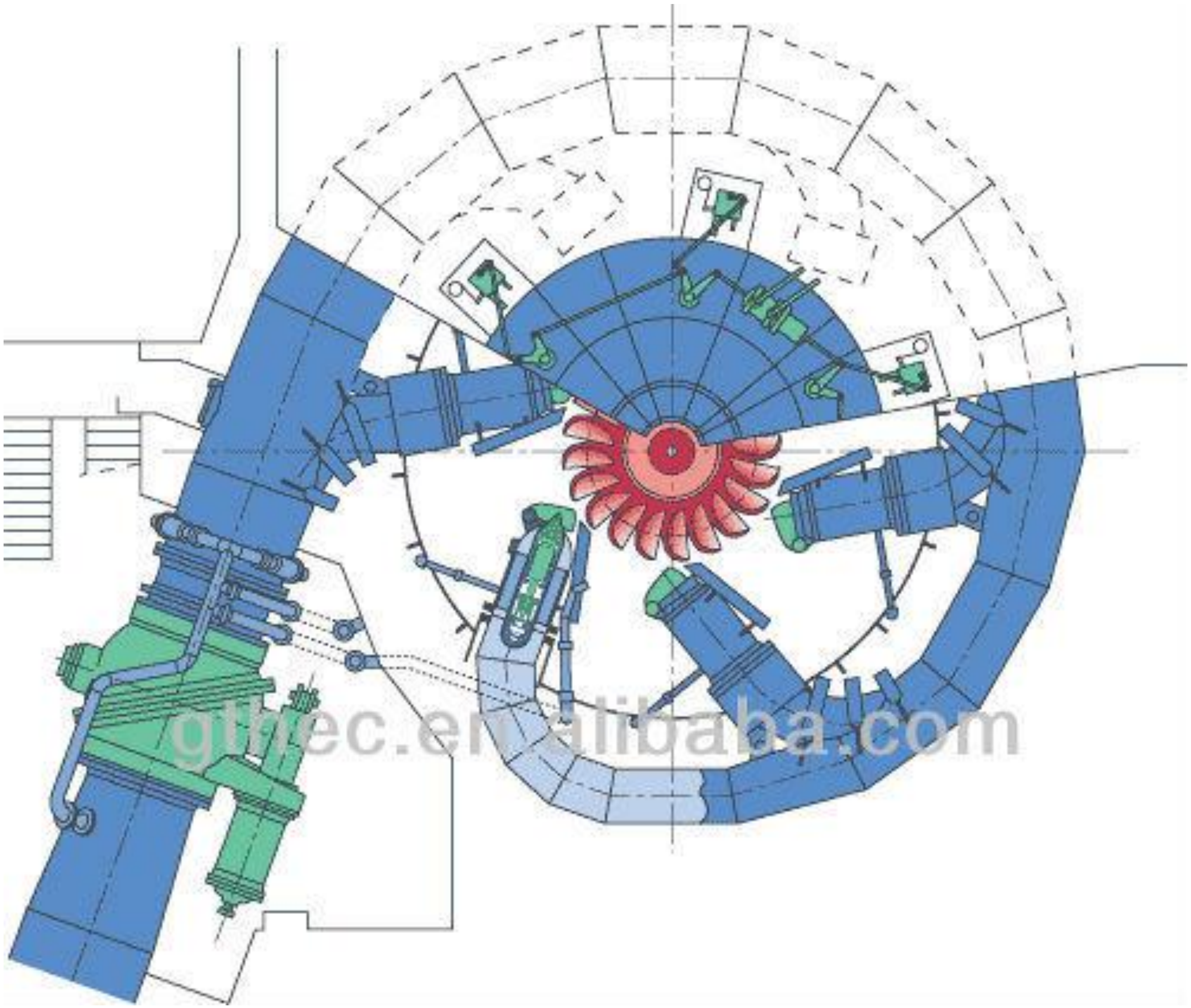


(a) In-plane axis (b) Squirrel Cage Darrieus (c) H-Darrieus

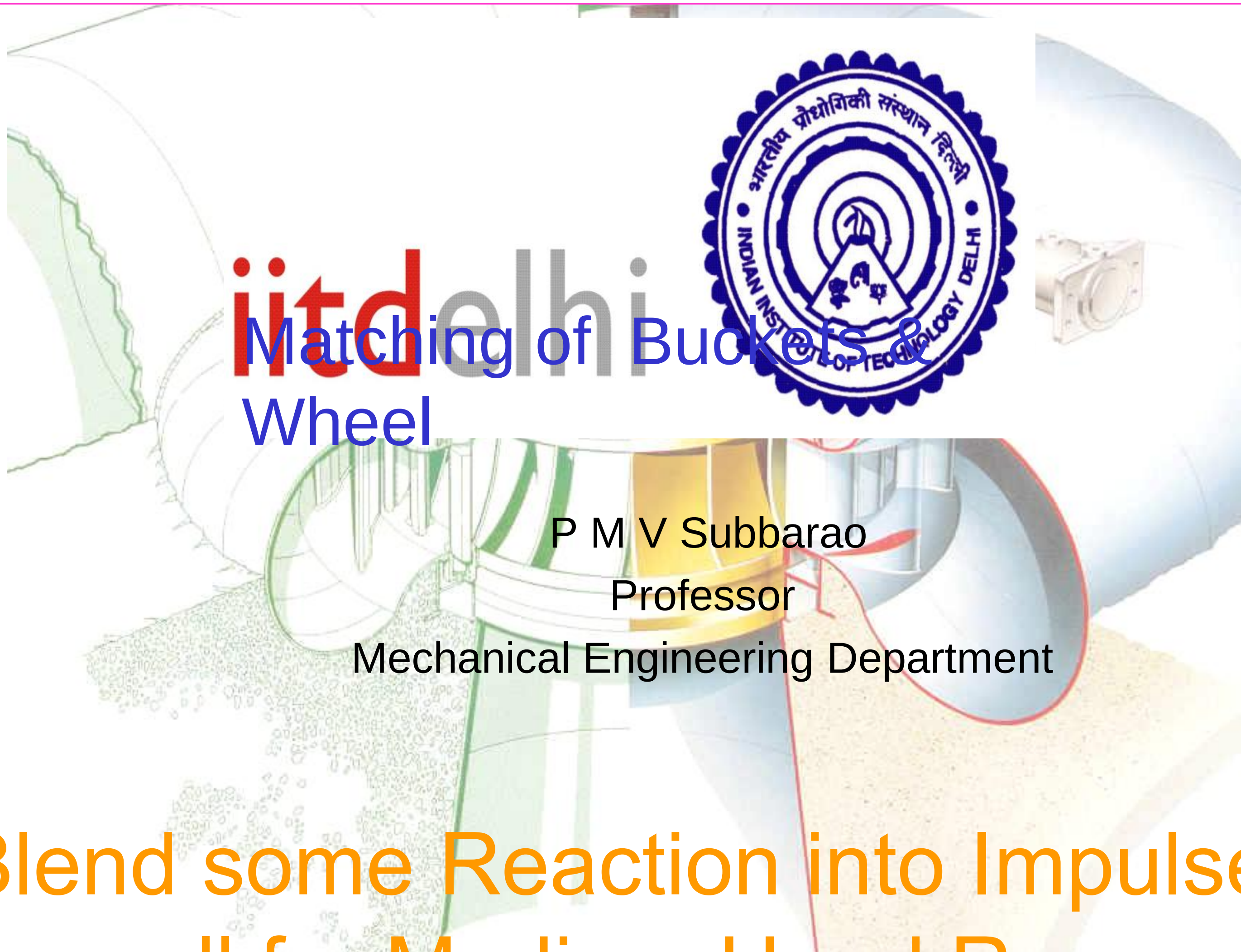
(d) Darrieus (e) Gorlov (f) Savonius


Hydraulic Turbines
Specific Speed
Impulse Turbines
Reaction Turbines
Pelton
Turgo
Cross-Flow
Propeller
Francis
Deriaz
Fixed -Blade
Kaplan
Tubular
Bulb

Only for Relative low Flow Rates



Francis Turbine



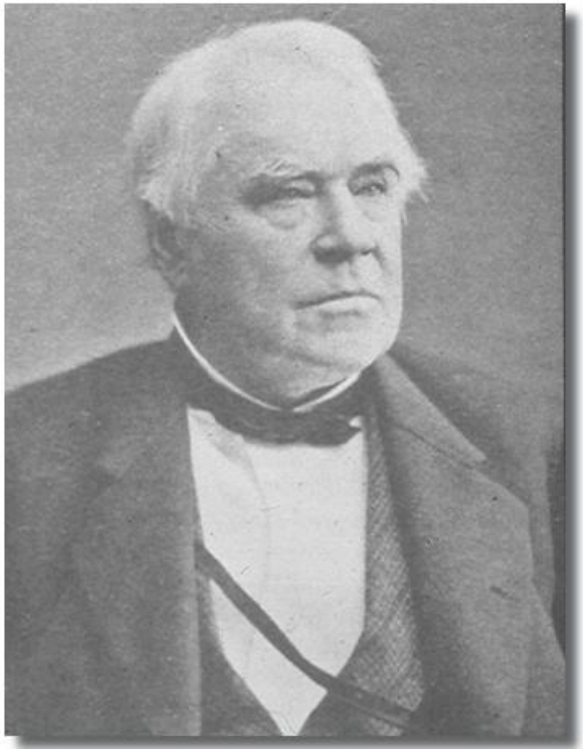
Matching of Buckets & Wheel

P M V Subbarao
Professor
Mechanical Engineering Department

Blend some Reaction into Impulse…
Works well for Medium Head Resources…..

Sir James B. France

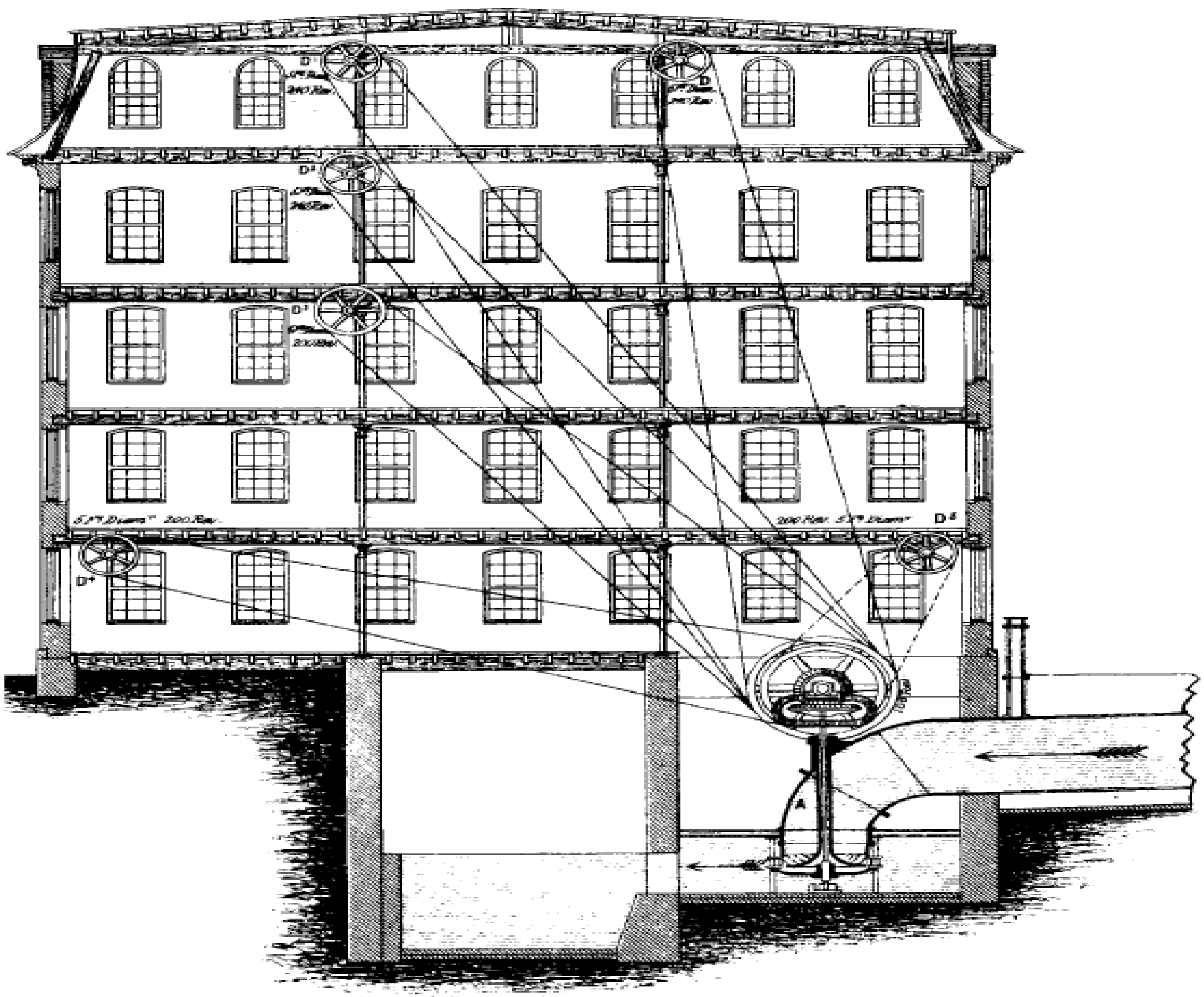
- When the city of Lowell became the first successful planned industrial city in America, it not only revolutionized manufacturing but also created a new way of life:
- A life ruled by time, a life powered by new opportunities.
- Perhaps one of the most enduring legacies left to the city of Lowell was that of James Bicheno Francis.
- Throughout Francis's life his bold and innovative ideas made him one of the driving minds behind America's Industrial Revolution.



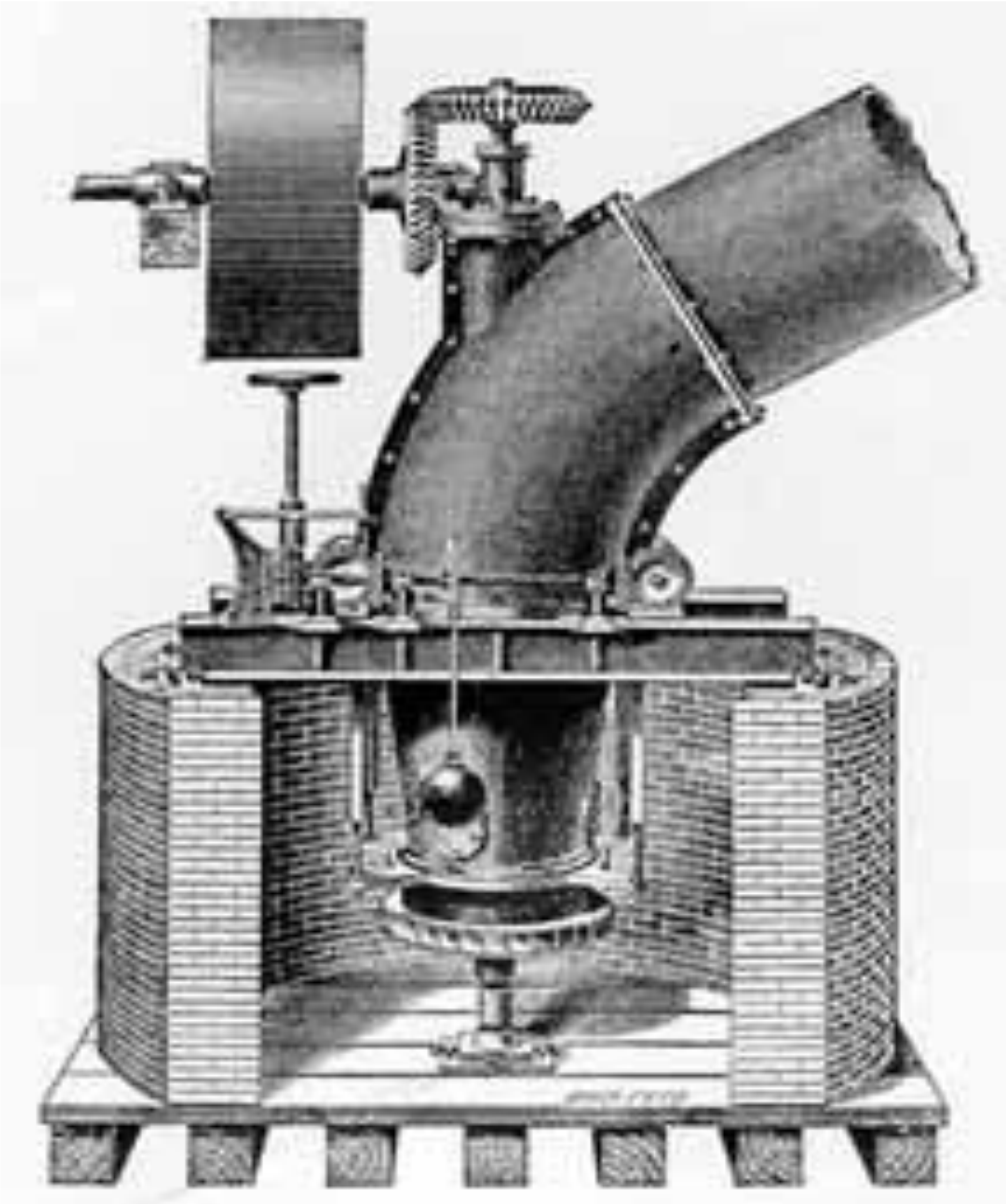
The Chief of Police of water ….

The Textile Industry : Reason for the Birth of Large Hydro-Turbines

SECTION OF MILL SHOWING TURBINES AND BELTING.



The Boyden Turbine



Improper Fluid Mechanics to Proper Fluid Mechanics

- Originally the textile mills had used waterwheels or breast-wheels that rotated when filled with water.
- These types of wheels could achieve a 65 percent efficiency.
- One such problem with these wheels was backwater which prevented the wheel from turning.

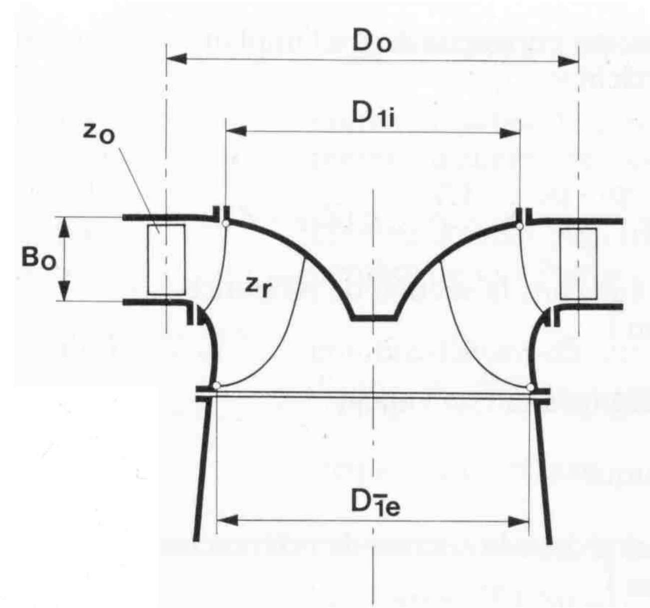
The Invention

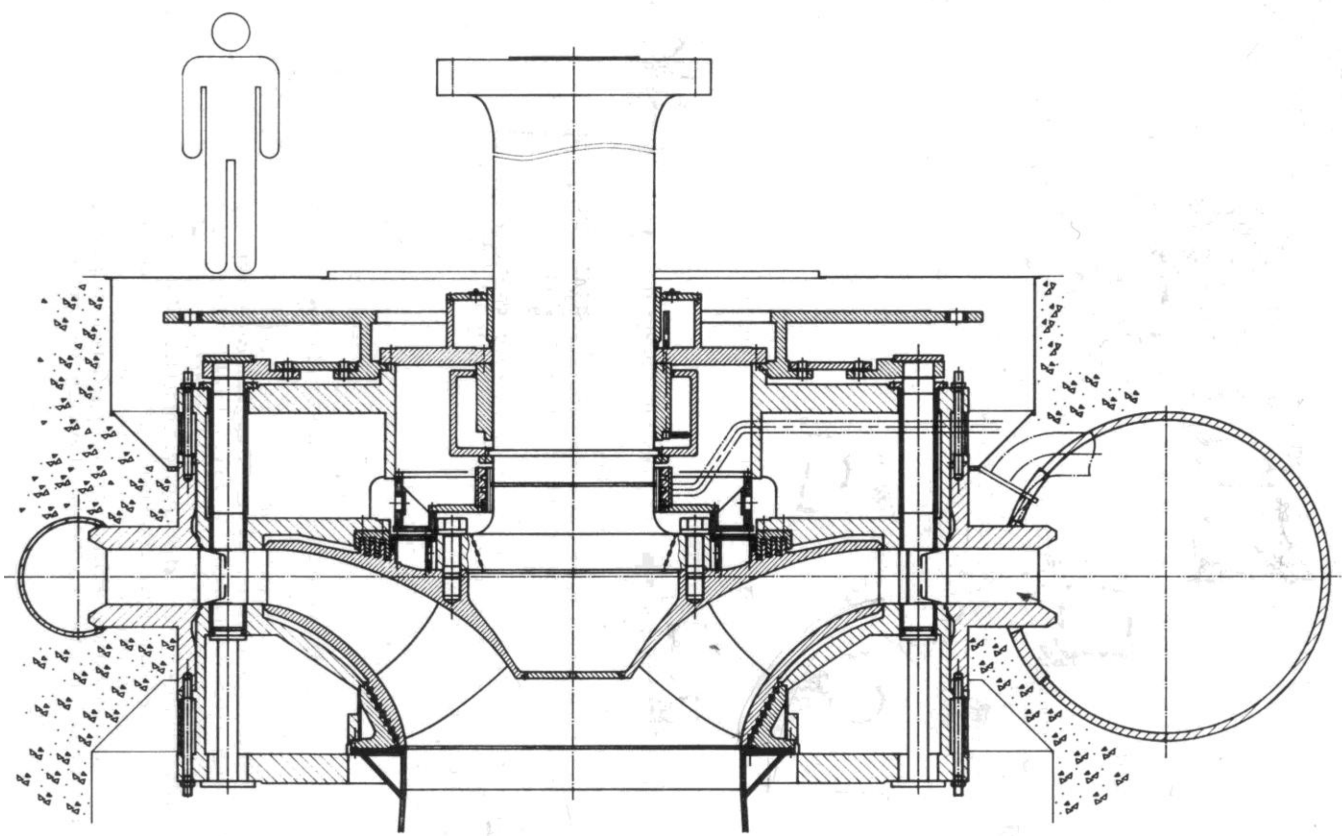
- Studying the Boyden turbine Francis was able to redesign it to increase efficiency.
- Constructing turbines as “sideways water wheels,” Francis was able to achieve an astounding 88 percent efficiency rate.
- After further experimenting, Francis developed the mixed flow reaction turbine which later became an American standard.
- Twenty-two of the “Francis turbines” reside in Hoover Dam to this day.
- His work on these turbines was later published as *The Lowell Hydraulic Experiments* in 1855.

Francis turbines

- It is a reaction turbine developed by an English born American Engineer, Sir J.B. Francis.
- The water enters the turbine through the outer periphery of the runner in the radial direction and leaves the runner in the axial direction, and hence it is called ‘mixed flow turbine’.
- It is a reaction turbine and therefore only a part of the available head is converted into the velocity head before water enters the runner.
- The pressure head goes on decreasing as the water flows over the runner blades.
- The static pressure at the runner exit may be less than the atmospheric pressure and as such, water fills all the passages of the runner blades.
- The change in pressure while water is gliding over the blades is called ‘reaction pressure’ and is partly responsible for the rotation of the runner.
- A Francis turbine is suitable for medium heads (45 to 400 m) and requires a relatively large quantity of water.

Variations of Francis : SVARTISEN





$P = 350$ MW

$H = 543$ m

$Q^* = 71{,}5\ m^3/s$

$D_0 = 4{,}86$ m

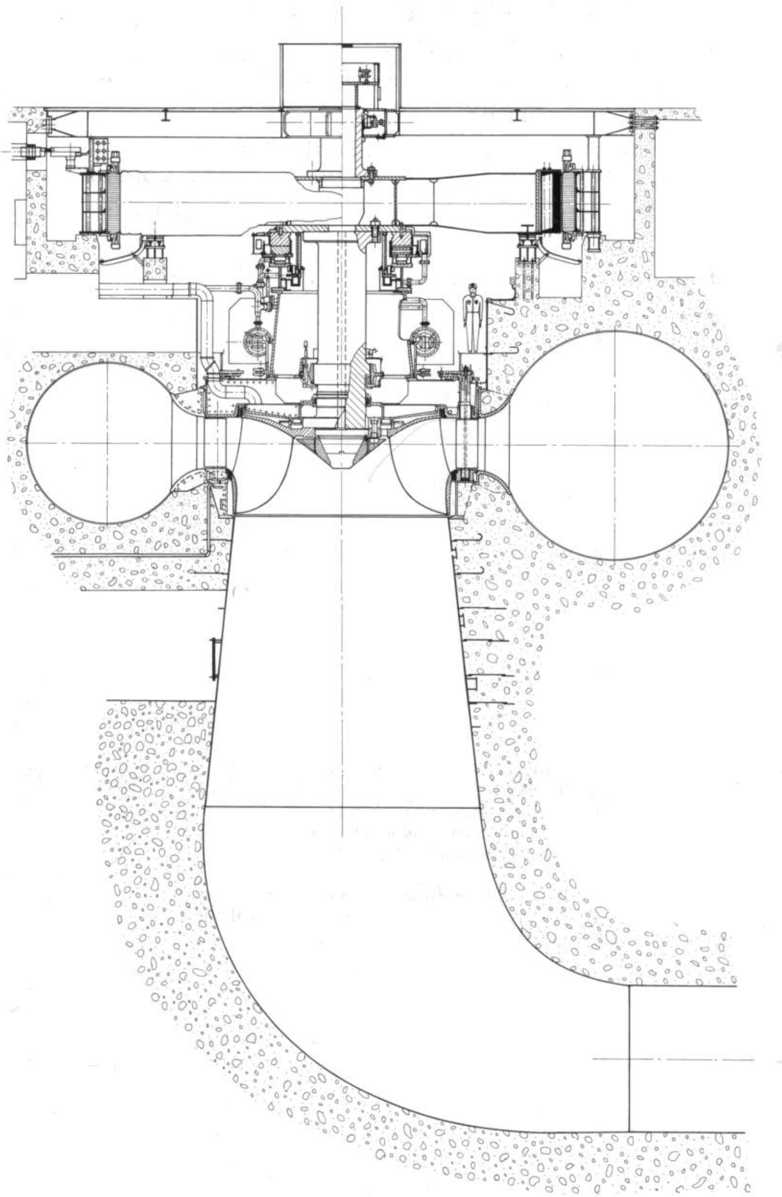
$D_1 = 4{,}31$m

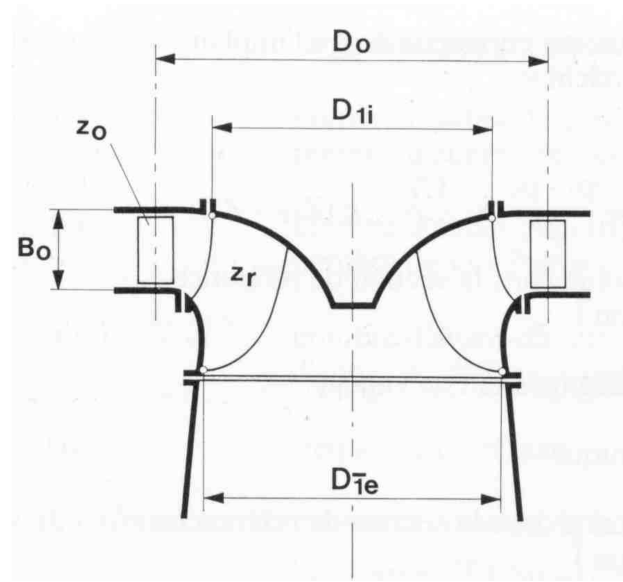
$D_2 = 2{,}35$ m

$B_0 = 0{,}28$ m

$n = 333$ rpm

Variations of Francis : La Grande, Canada





$P = 169$ MW

$H = 72$ m

$Q = 265\ m^3/s$

$D_0 = 6{,}68$ m

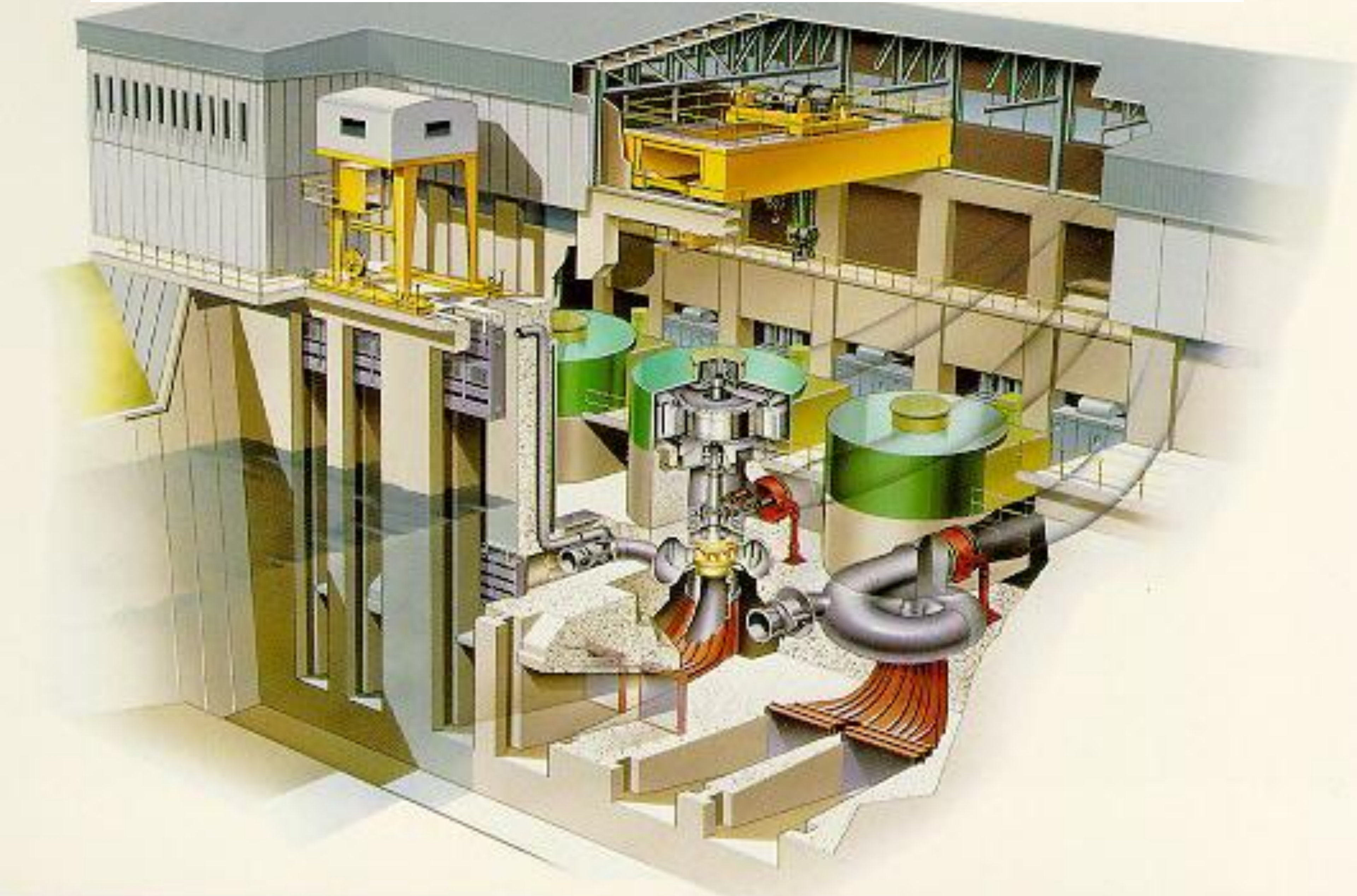
$D_{1e} = 5{,}71$m

$D_{1i} = 2{,}35$ m

$B_0 = 1{,}4$ m

$n\ \ = 112{,}5$ rpm

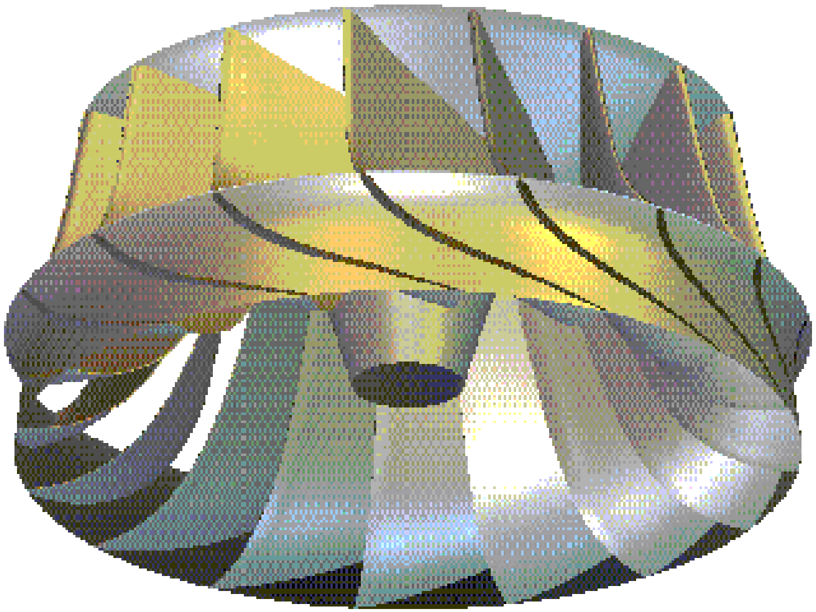
The Francis Installation



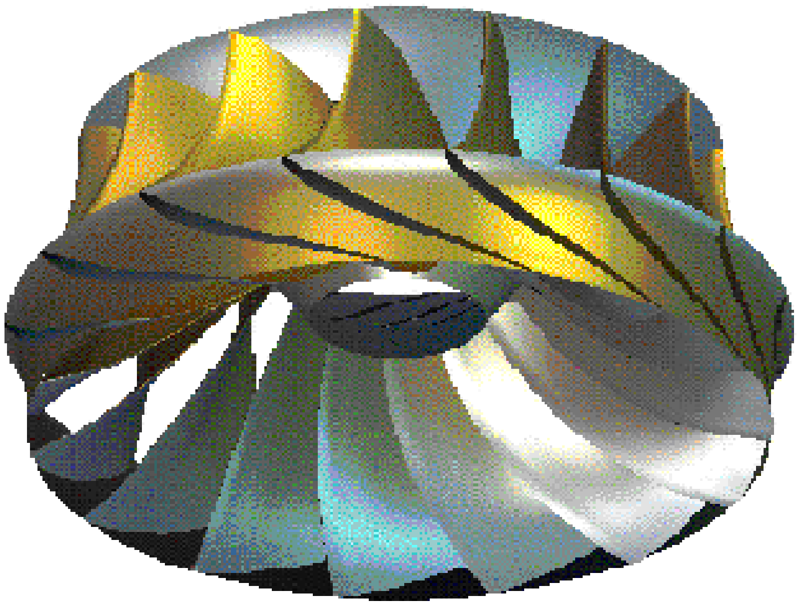
The Francis Turbine

The Francis Runner

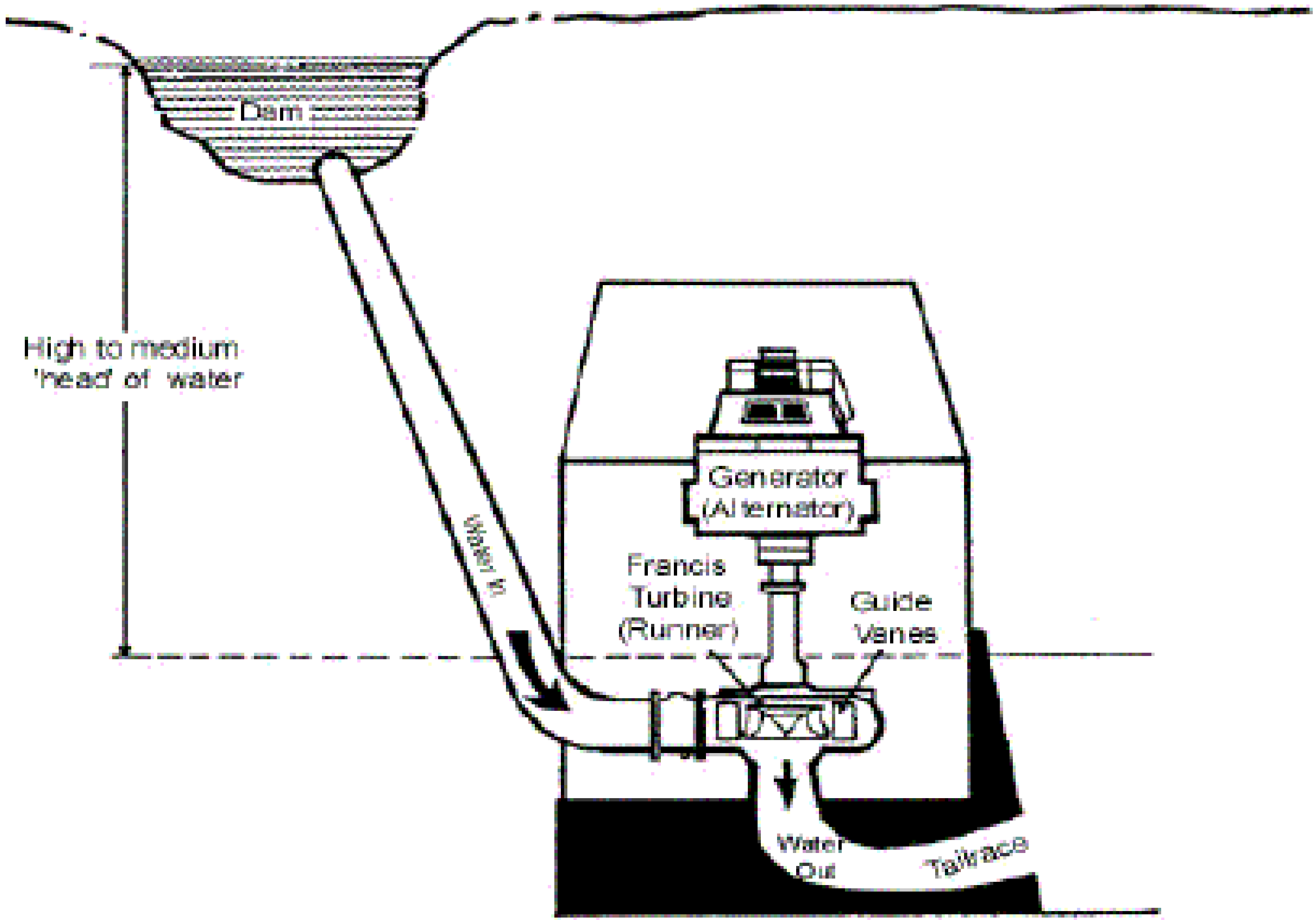
Traditional runner



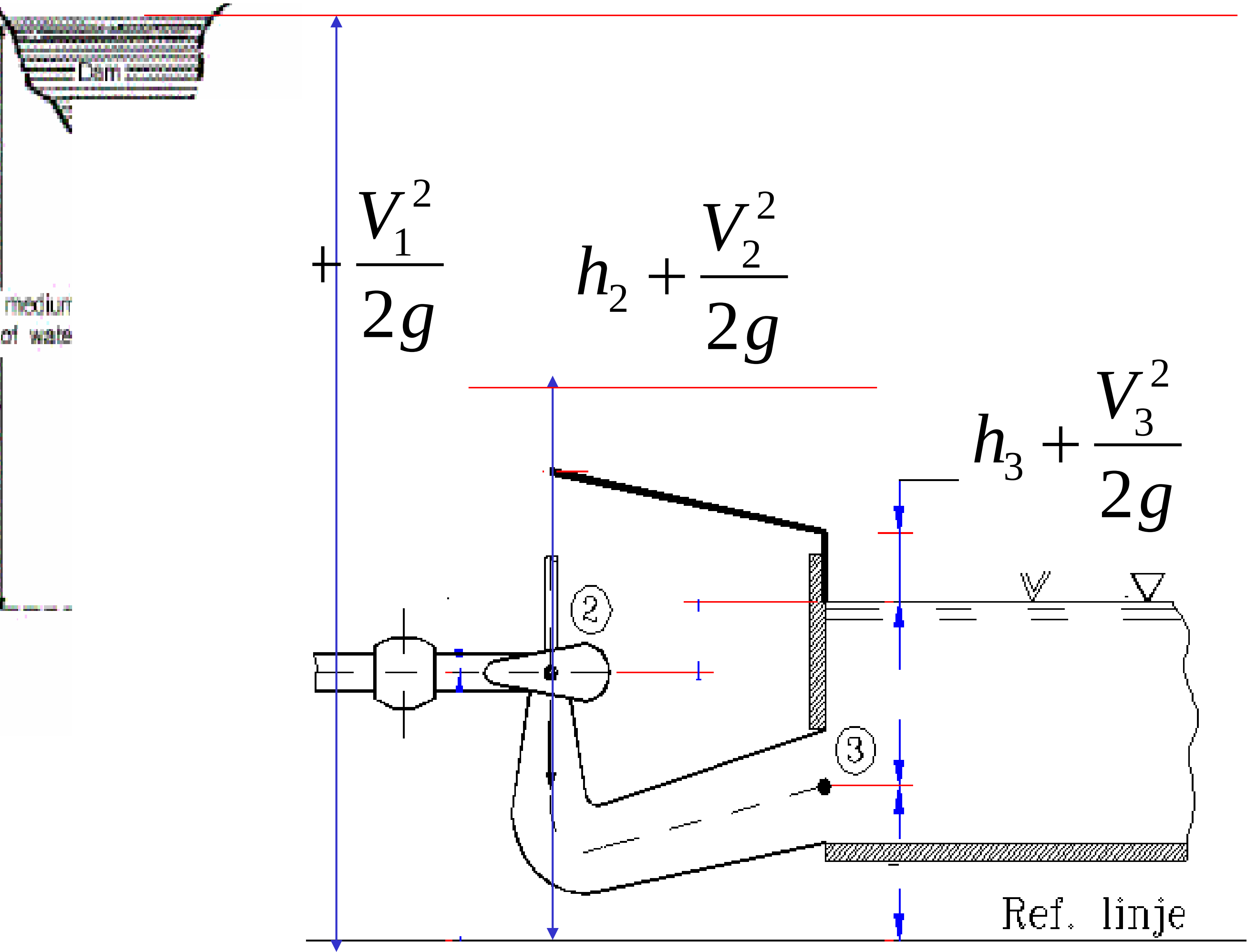
X blade runner



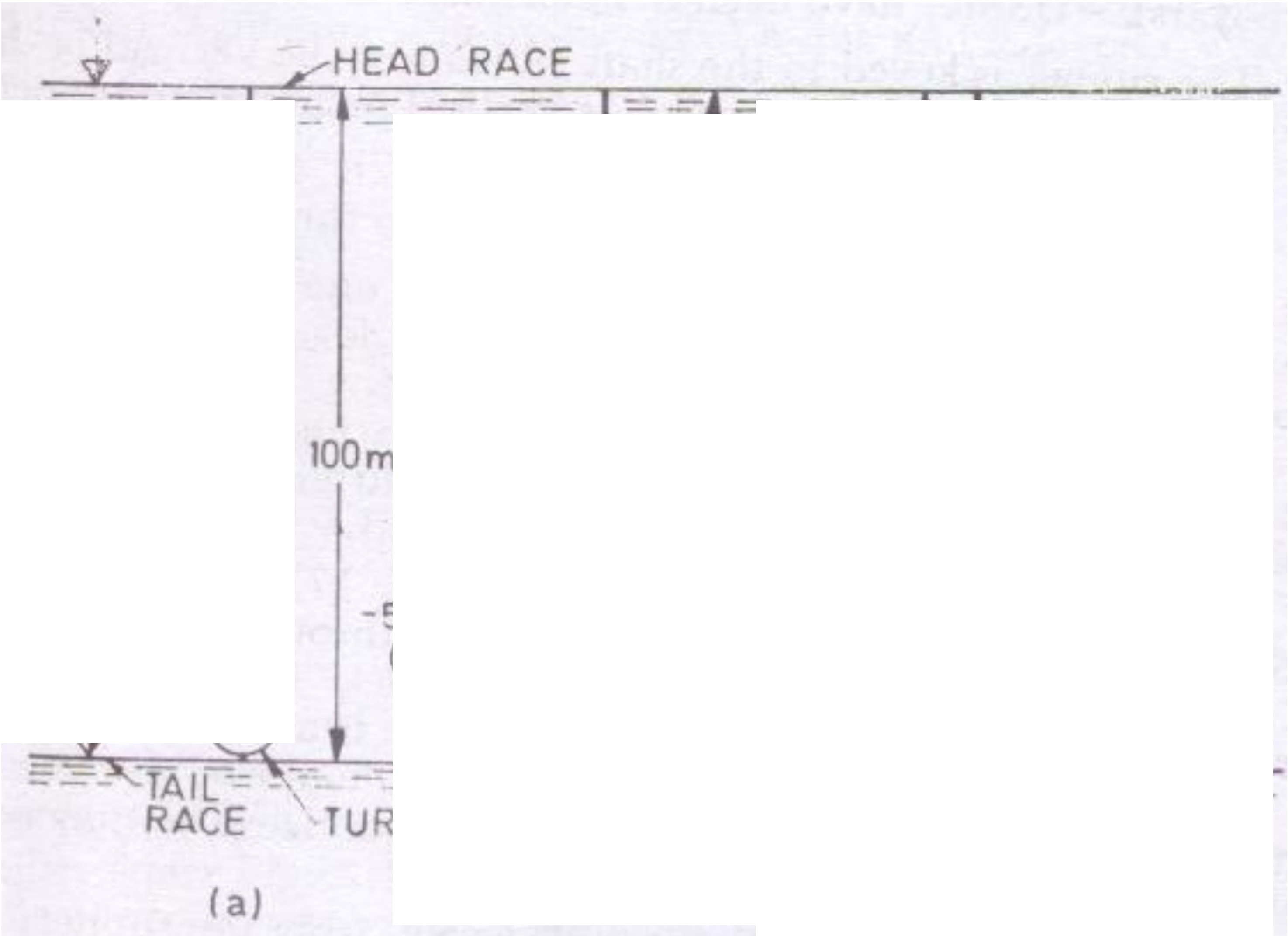
Francis Turbine Power Plant : A Continuous Hydraulic System

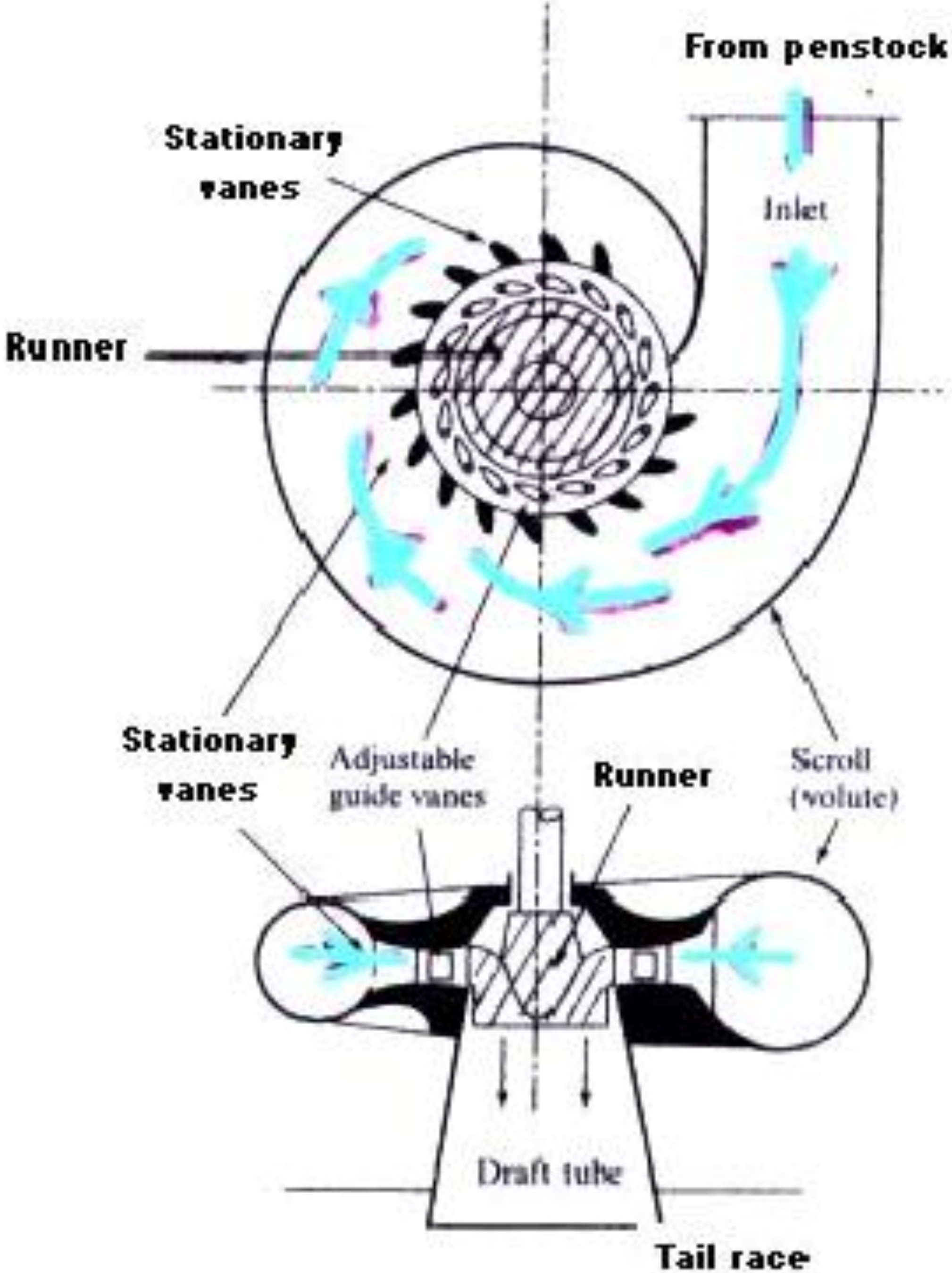


An Active Pascal Law : A Hydraulic Model for Francis Units

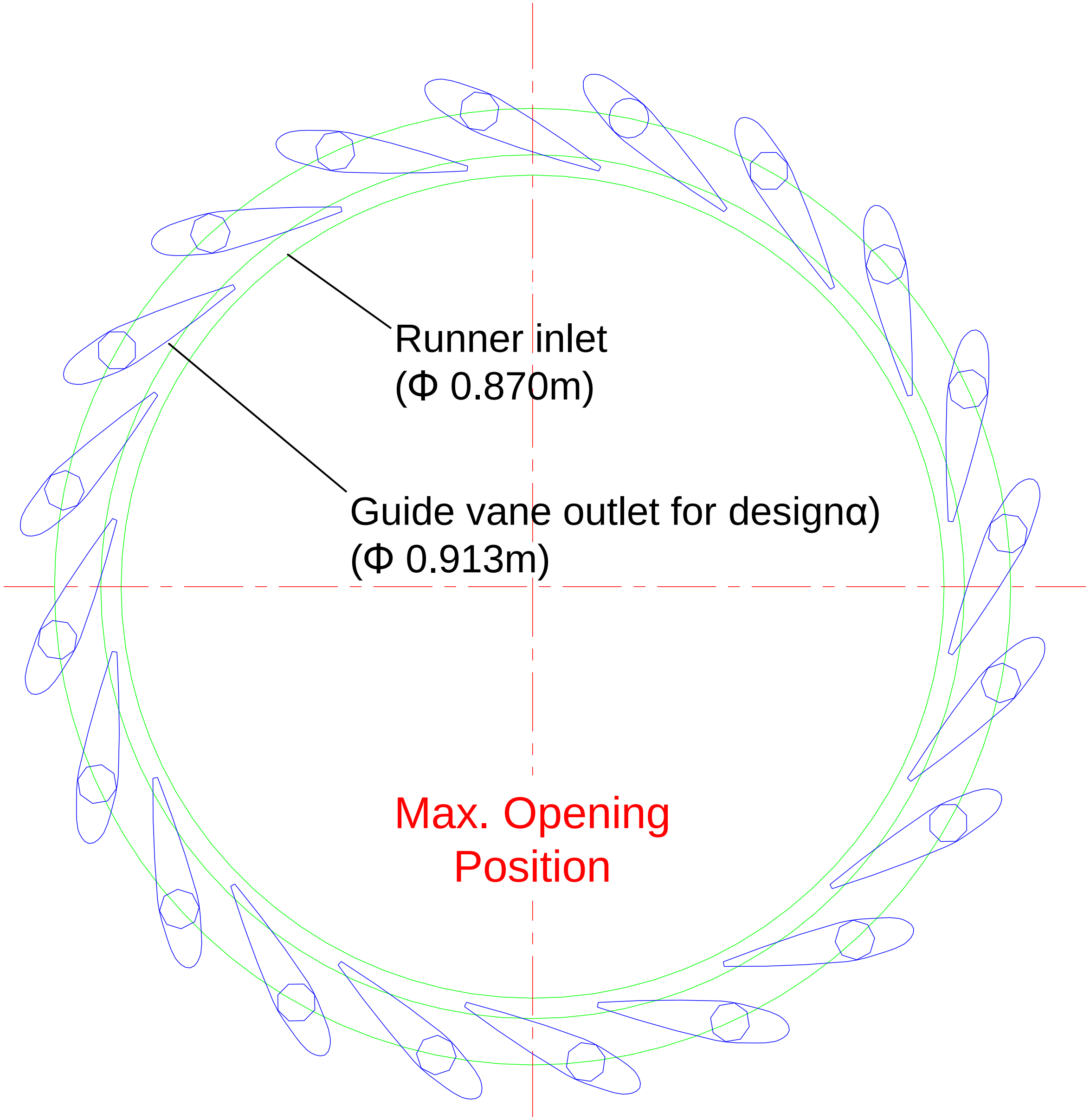


Location of Francis Turbine



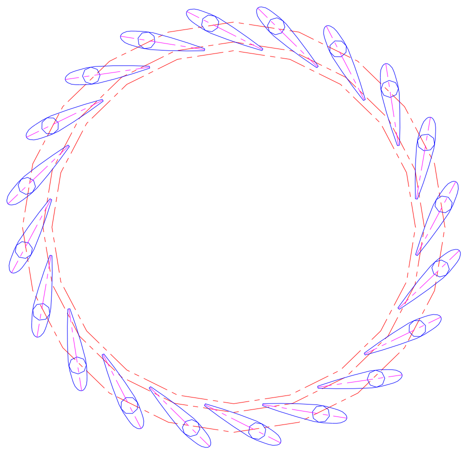


Parts of A Francis Turbine

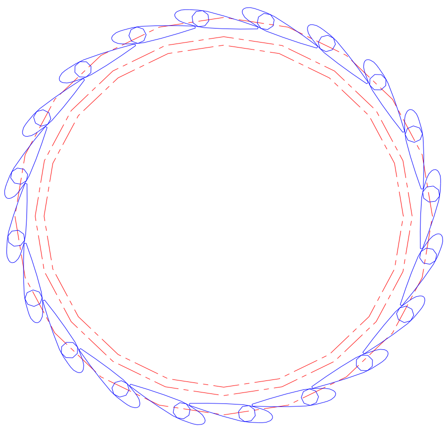

Runner inlet
(Φ 0.870m)
Guide vane outlet for designα)
(Φ 0.913m)
Max. Opening
Position

Guide vanes

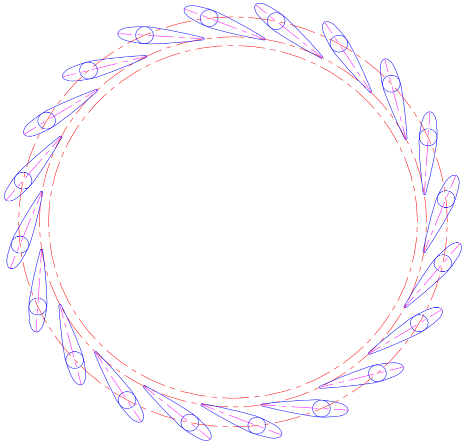
Operation of Guide Vanes



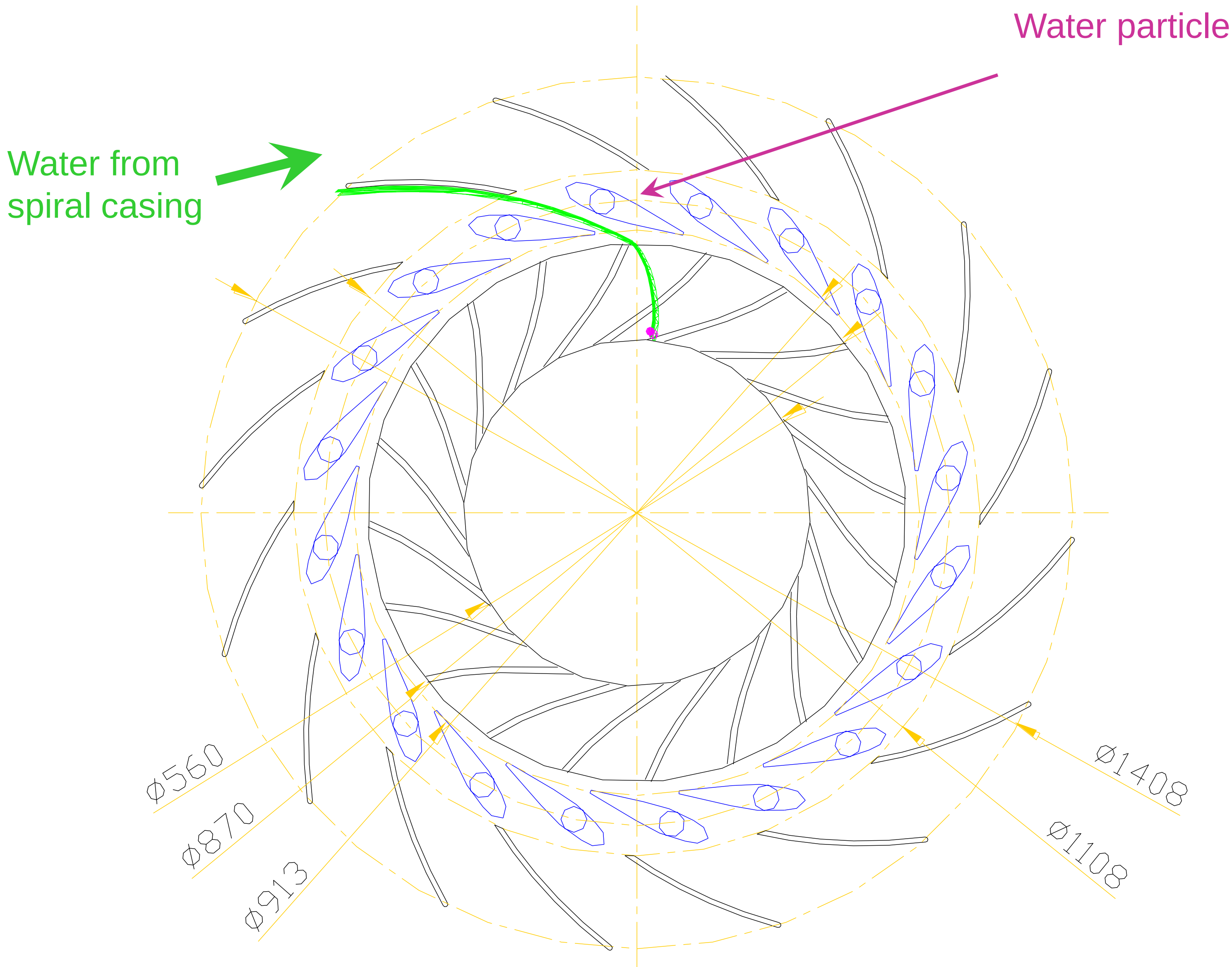
Guide vane at Design
Position α= 12.21°



Guide vane at closed position

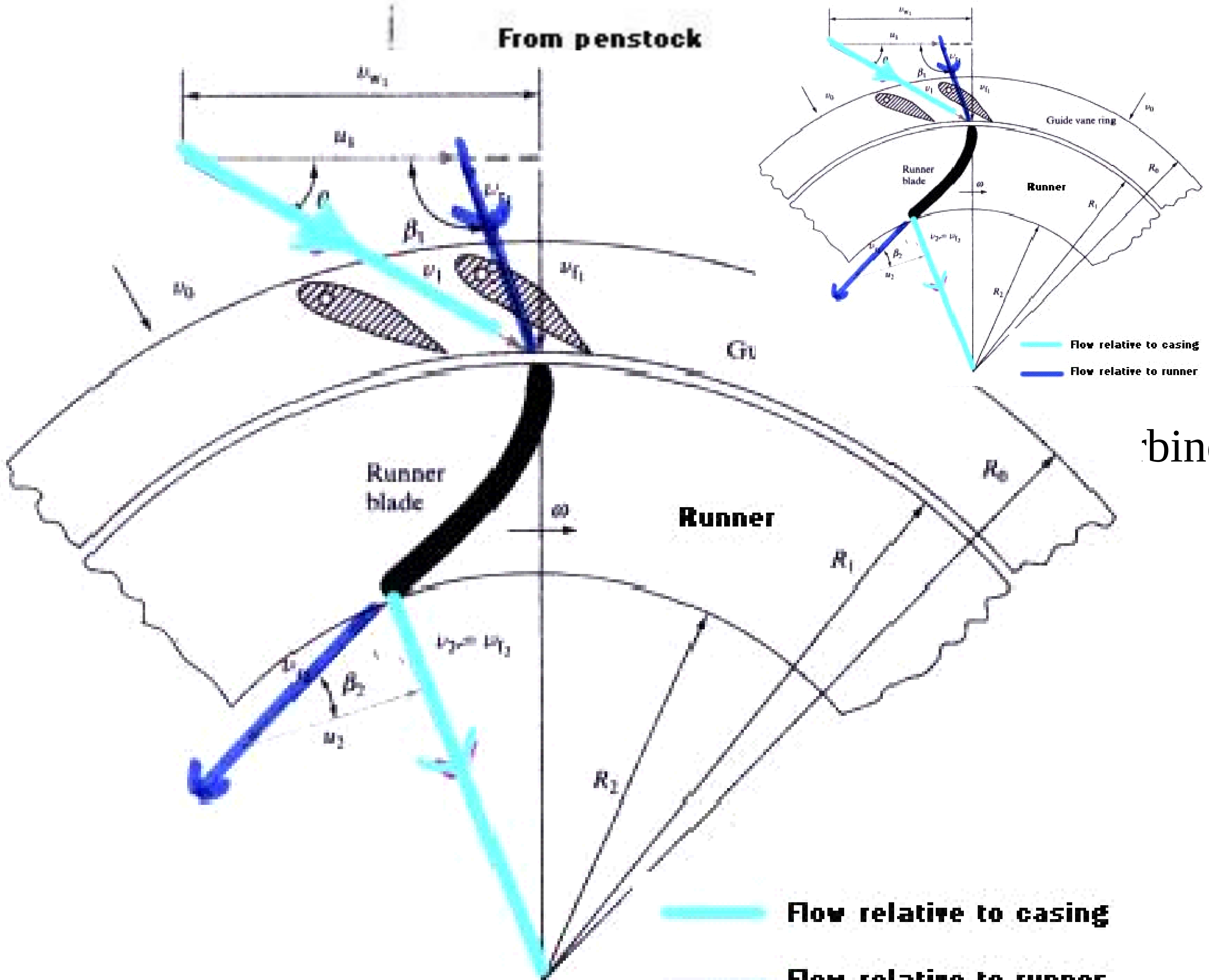


Guide vane at Max. open
Position α= 18°



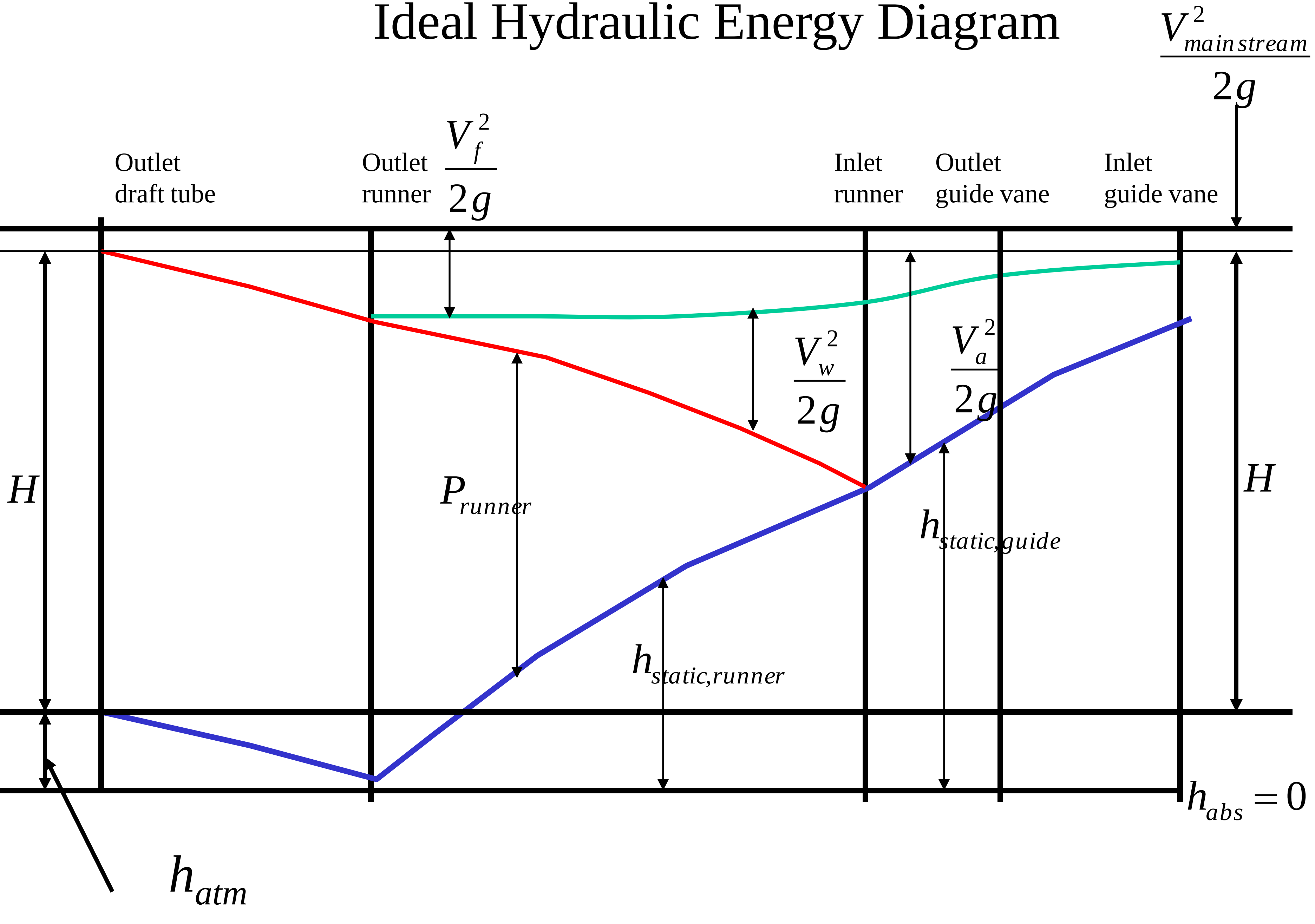
R a d i a l v i e w
runner guide vanes and stay vanes

Rt


From penstock
Runner blade
Runner
Flow relative to casing
Flow relative to runner
Guide vane ring

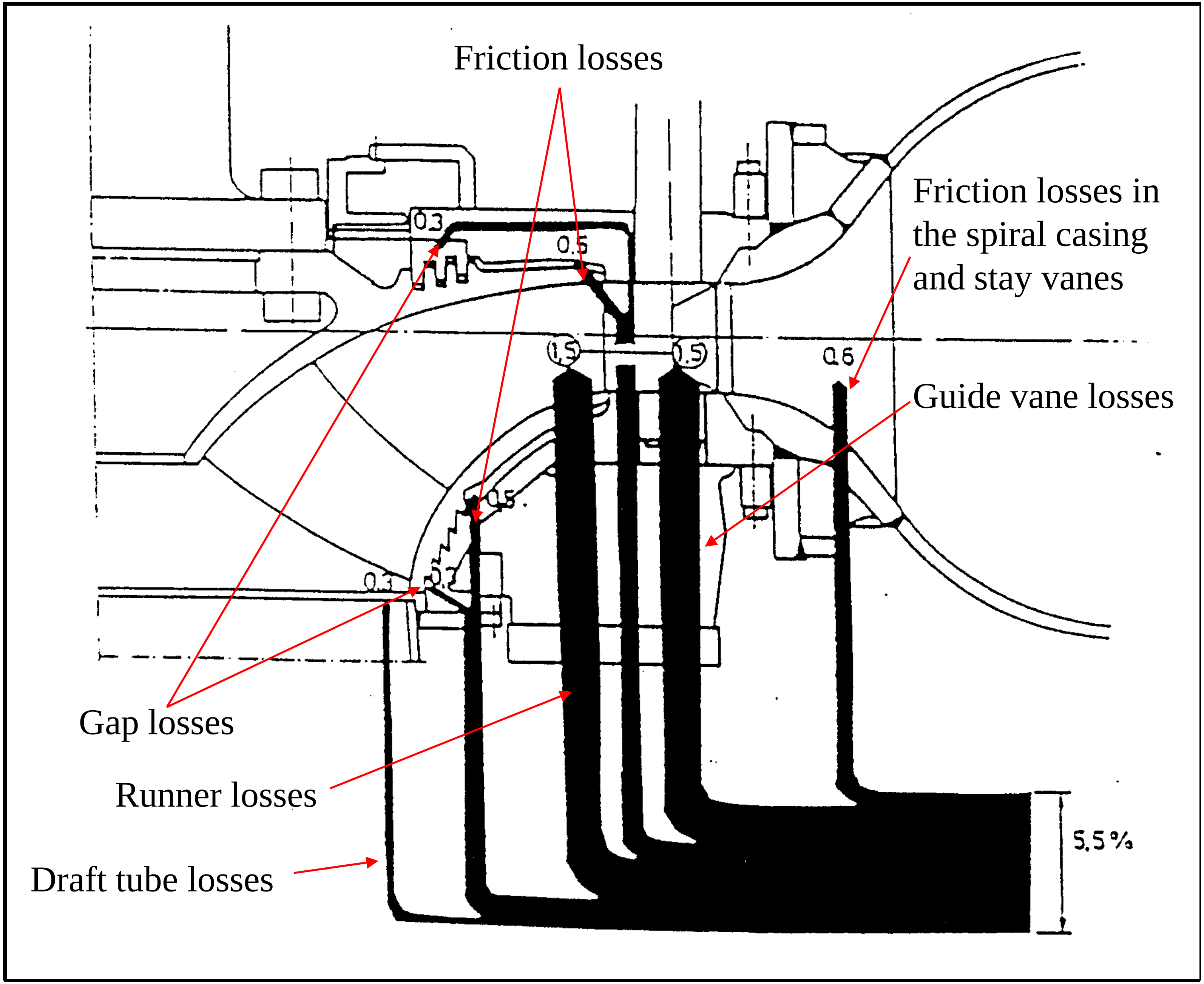
bine

Ideal Hydraulic Energy Diagram



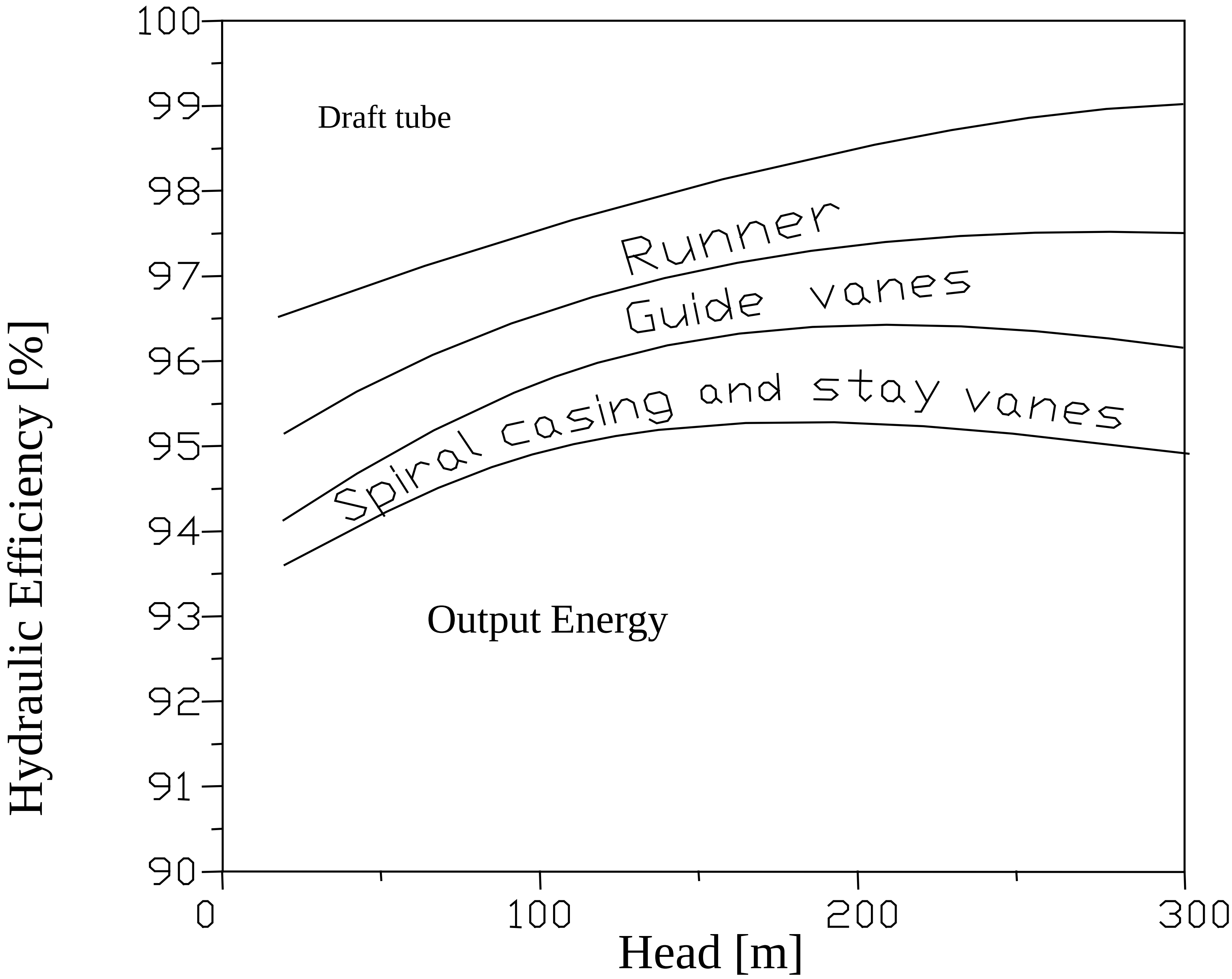
Hydraulic efficiency of Francis Hydraulic System

$$\eta_{hydraulic} = \frac{h_1 + \frac{V_1^2}{2g} - \left(h_3 + \frac{V_3^2}{2g} \right) - hydraulic\ Losses}{h_1 + \frac{V_1^2}{2g} - \left(h_3 + \frac{V_3^2}{2g} \right)}$$

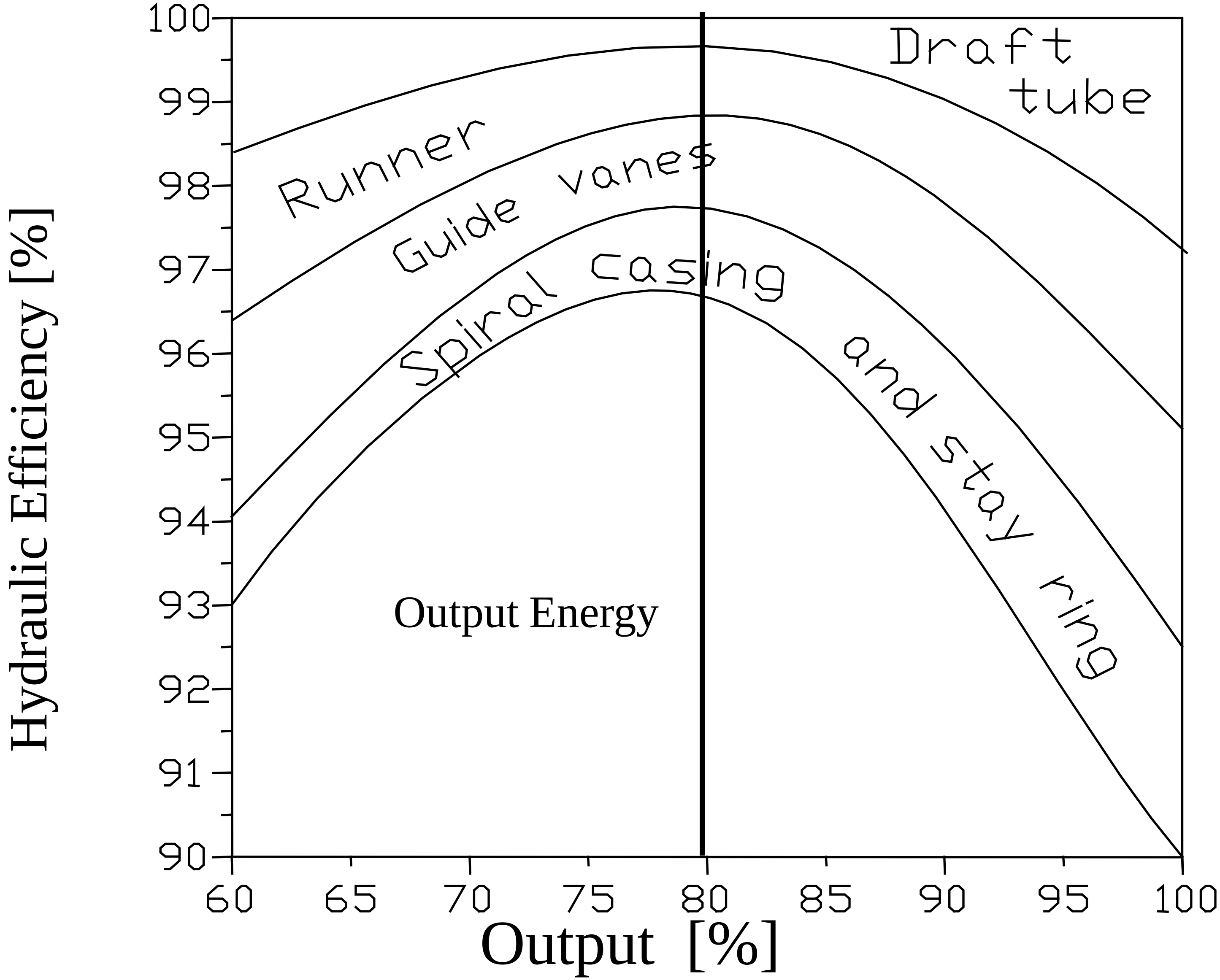


Friction losses
Friction losses in the spiral casing and stay vanes
Guide vane losses
Gap losses
Runner losses
Draft tube losses
0.3
0.5
1.5
1.5
0.6
0.5
0.3
0.3
5.5 %

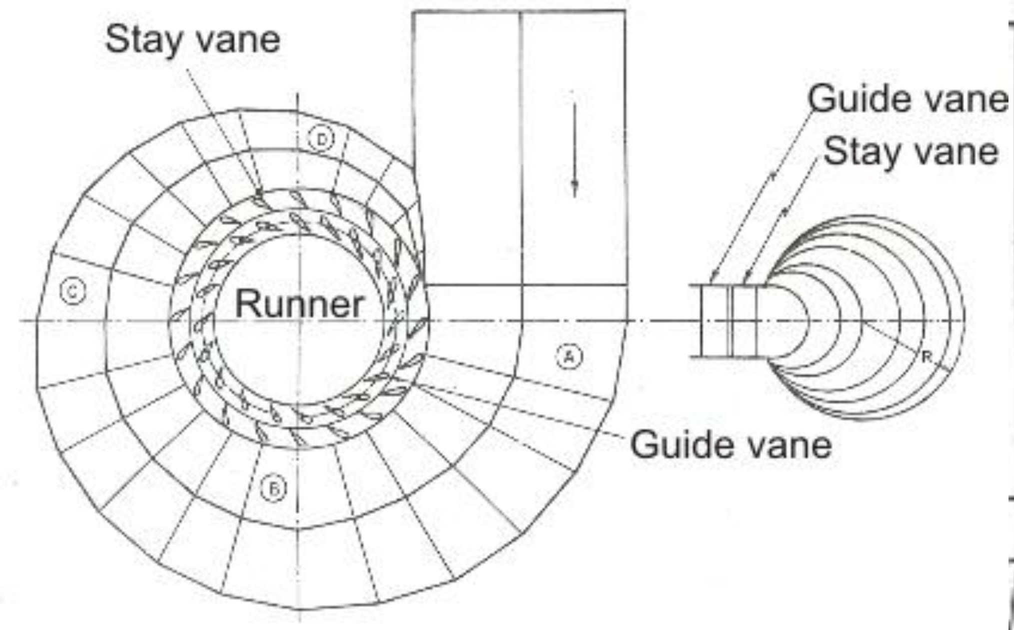
Losses in Francis Turbines



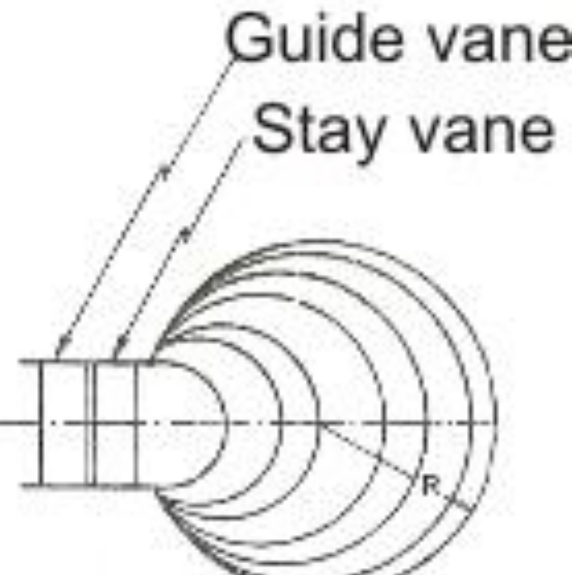
Losses in Francis Turbines



Spiral Casing



(a) Plan view (b) Elevation



- **Spiral Casing :** The fluid enters from the penstock to a spiral casing which completely surrounds the runner.
- This casing is known as scroll casing or volute.
- The cross-sectional area of this casing decreases uniformly along the circumference to keep the fluid velocity constant in magnitude along its path towards the stay vane/guide vane.