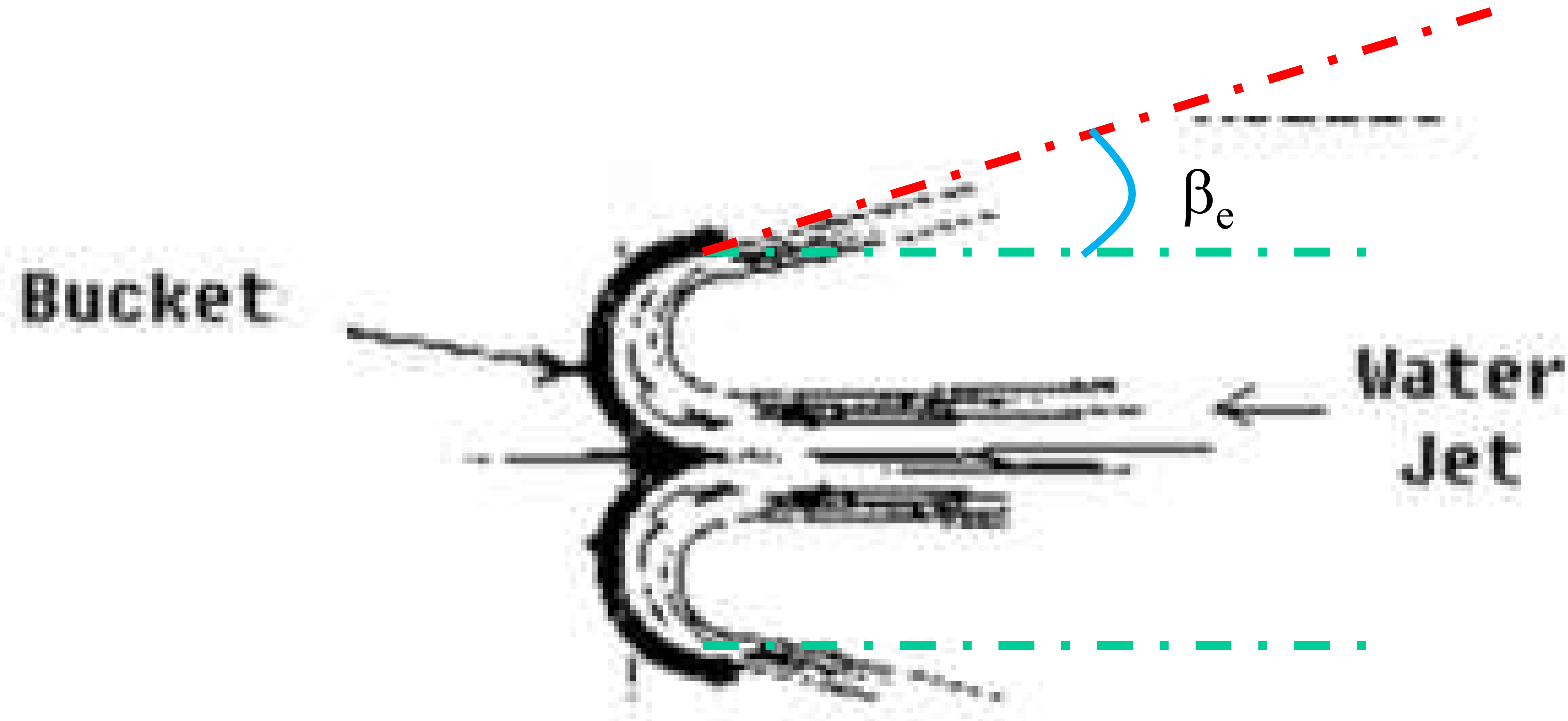
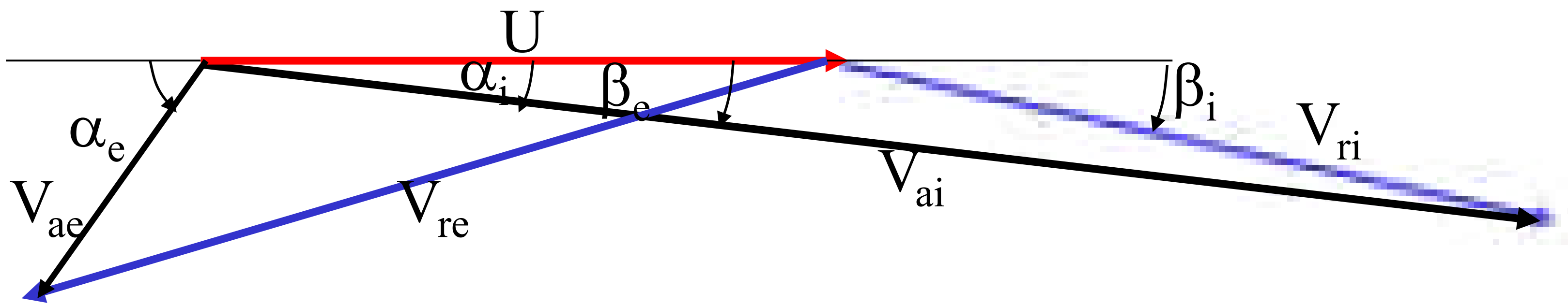
Closing Remarks on Pelton Wheel

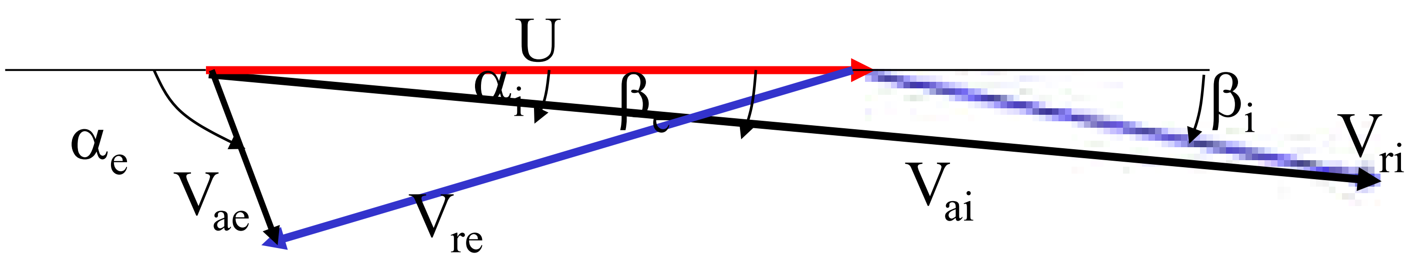
- The first scientifically developed concept and also patented product.
- The only one option for high heads (> 600 m)
- Best suited for low flow rates with moderate heads (240m -- 600m).
- A better choice for moderate heads with medium flow rates.
- Easy to construct and develop, as it works at constant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



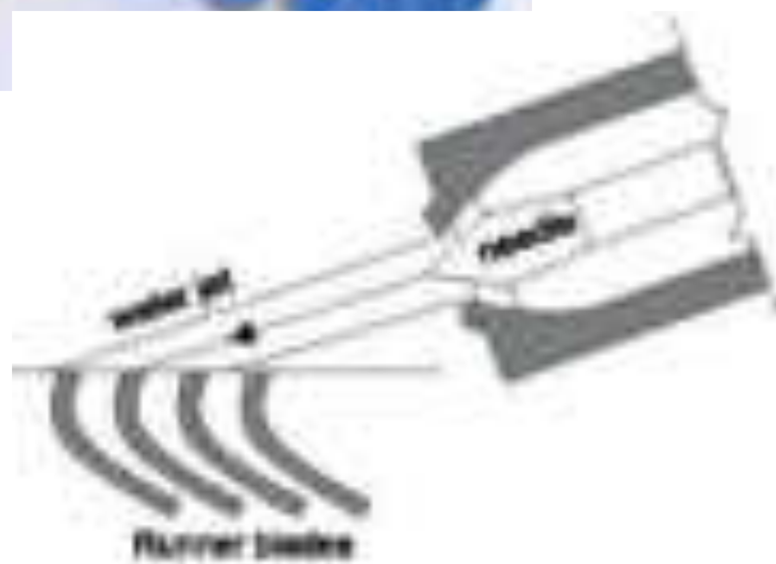
Is it possible to use Pure Momentum for Low Head Jets?

Options for Options for Low Heads & Low Flow Rate

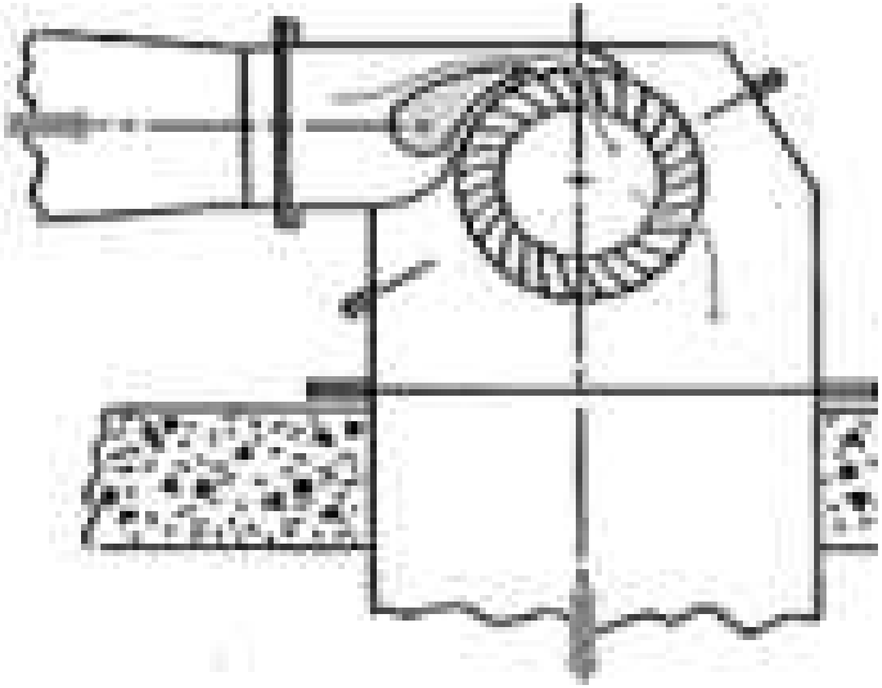




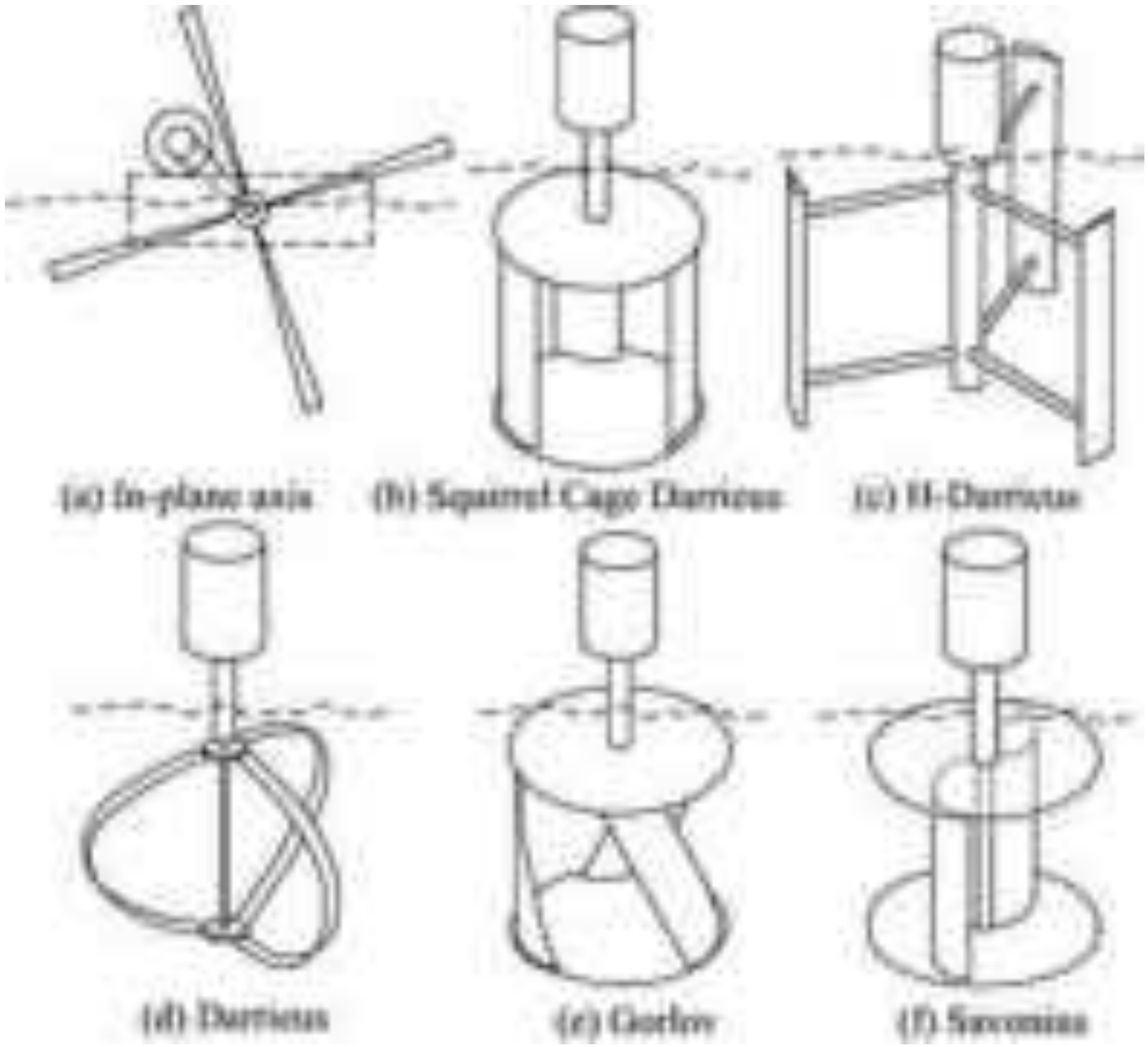
Turgo Turbine

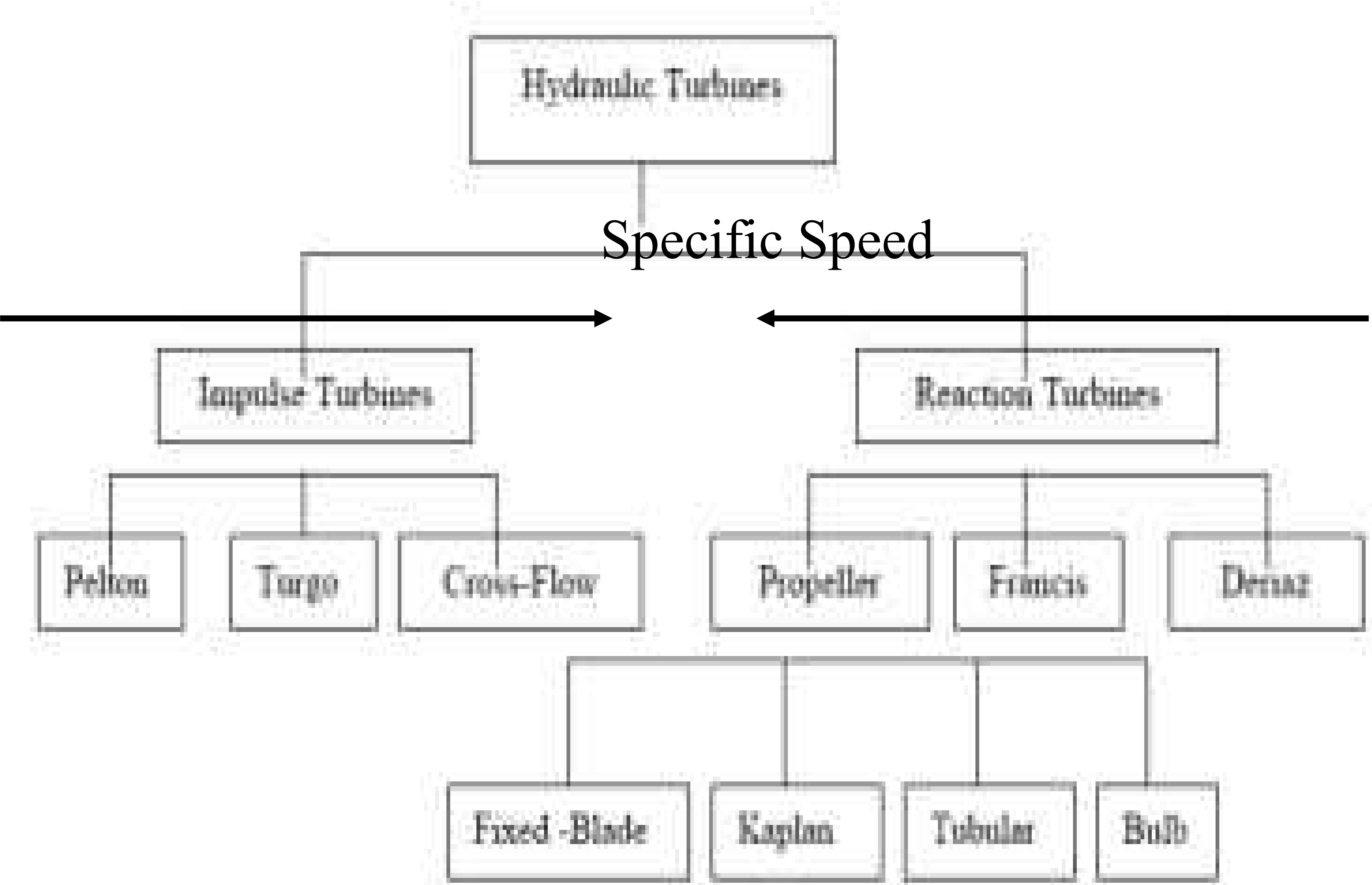


Cross-flow Turbine

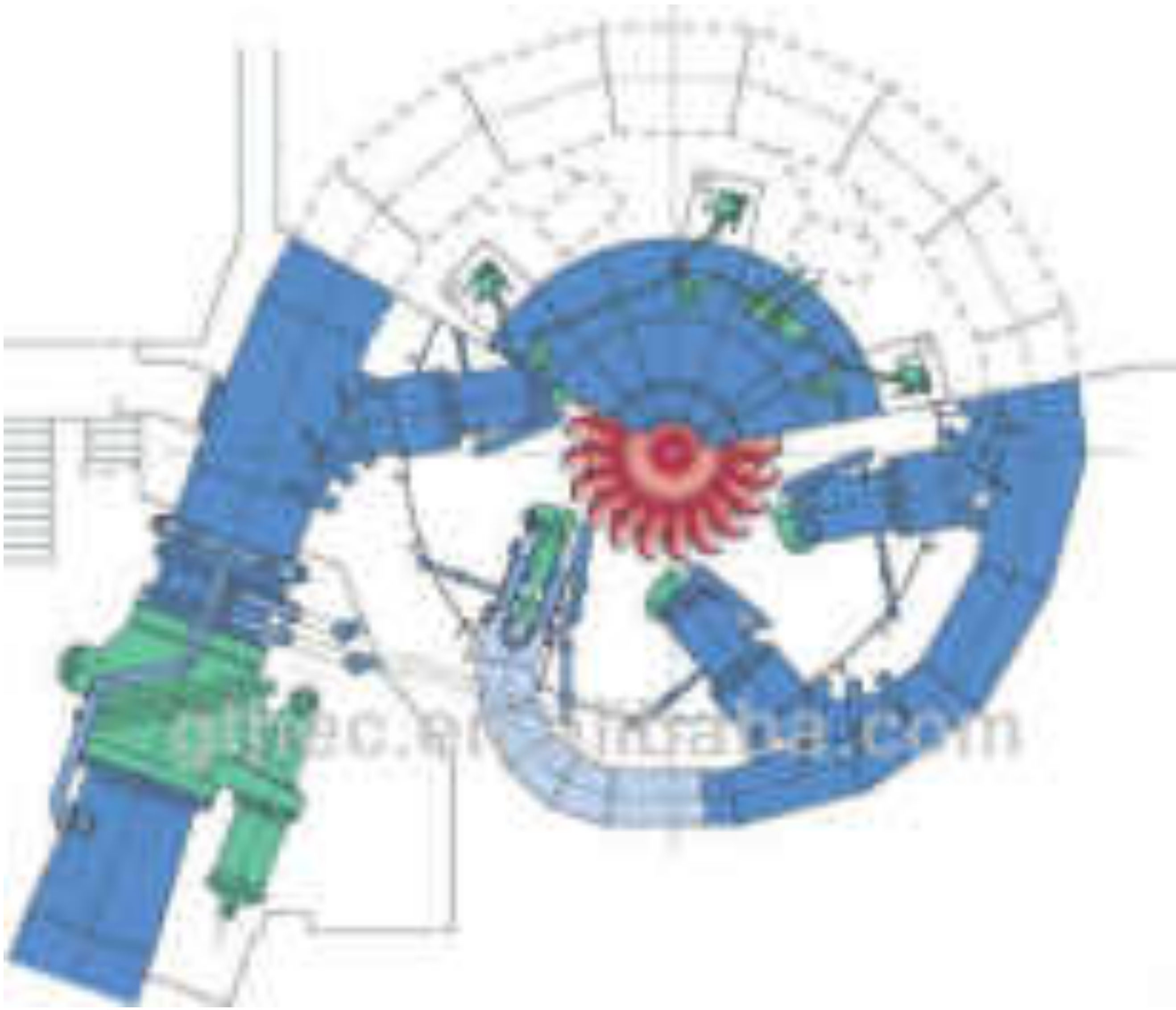


Variations of Cross-Flow Turbines




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…

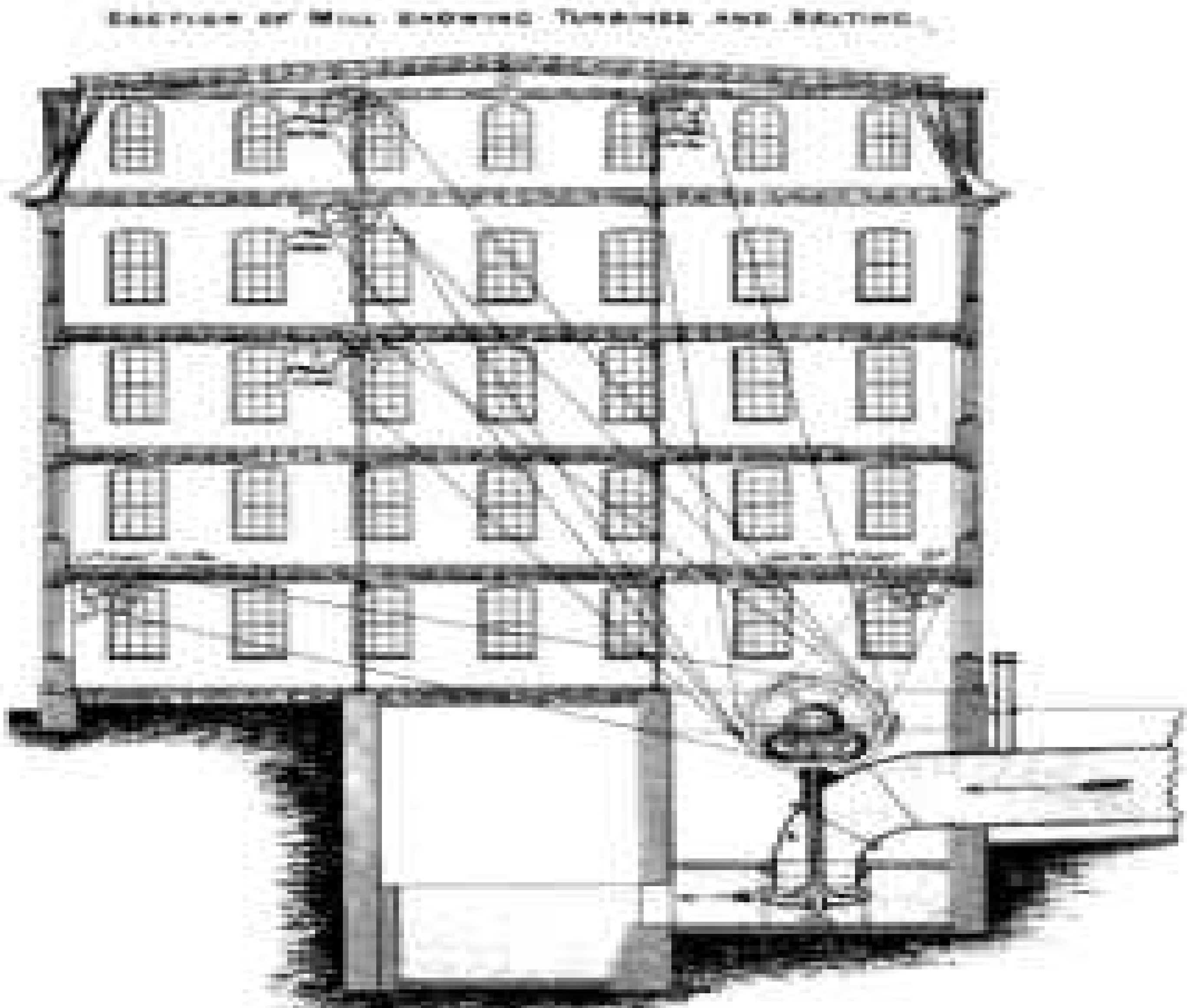
Works well for Medium Head Resources…..

Sir James B. France

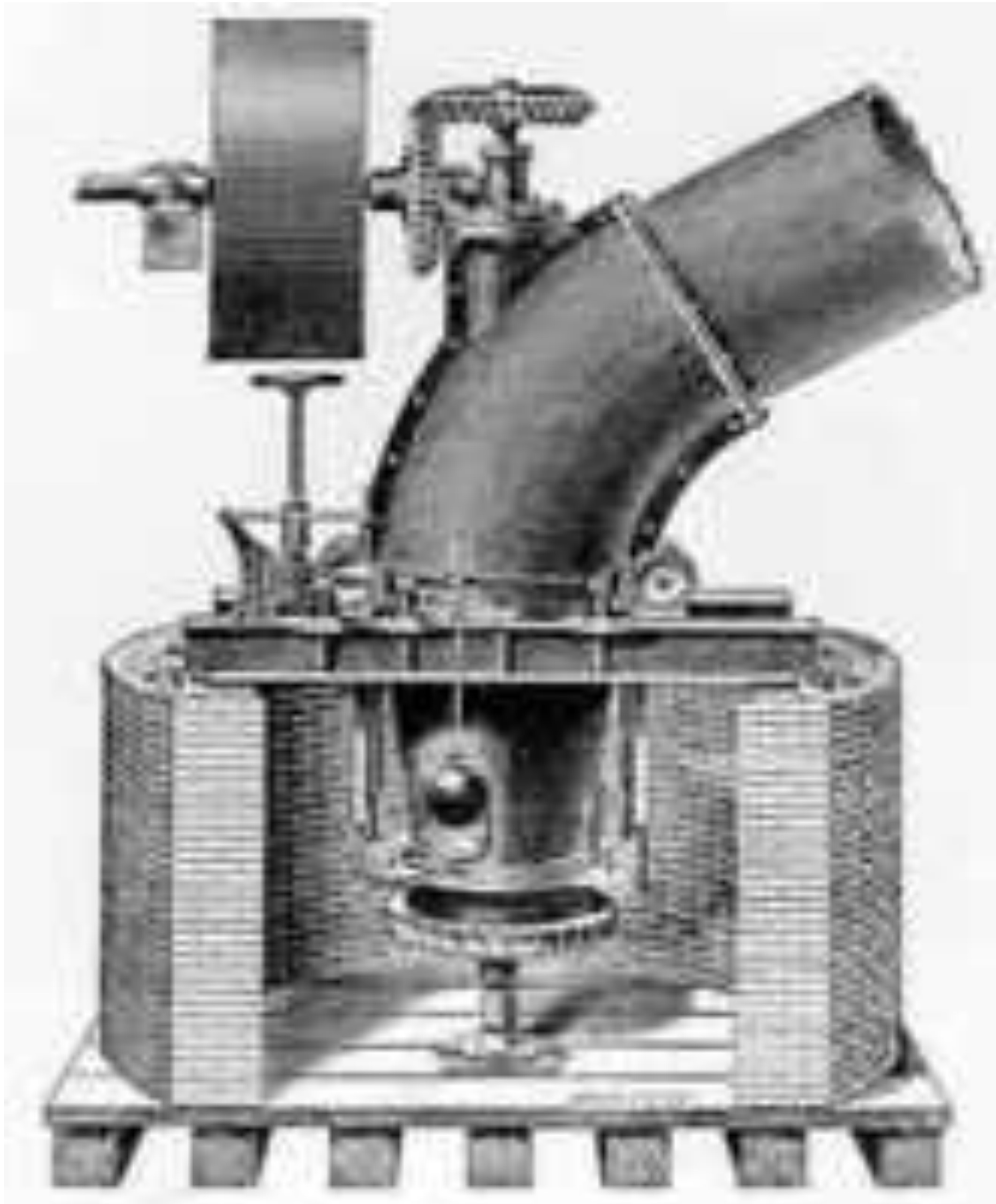
- When the city of Lowell became the first successful planned industrial city in America, it not only revolutionized manufacturing but also created a new way of life:
- A life ruled by time, a life powered by new opportunities.
- Perhaps one of the most enduring legacies left to the city of Lowell was 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



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.

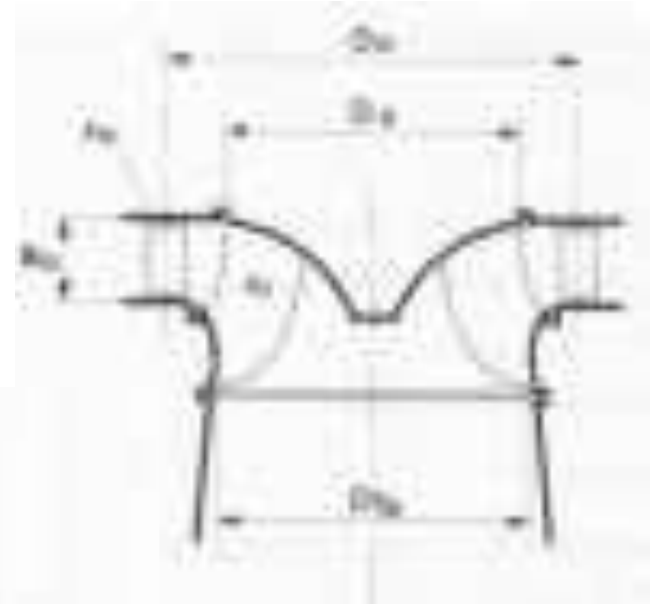
The Invention

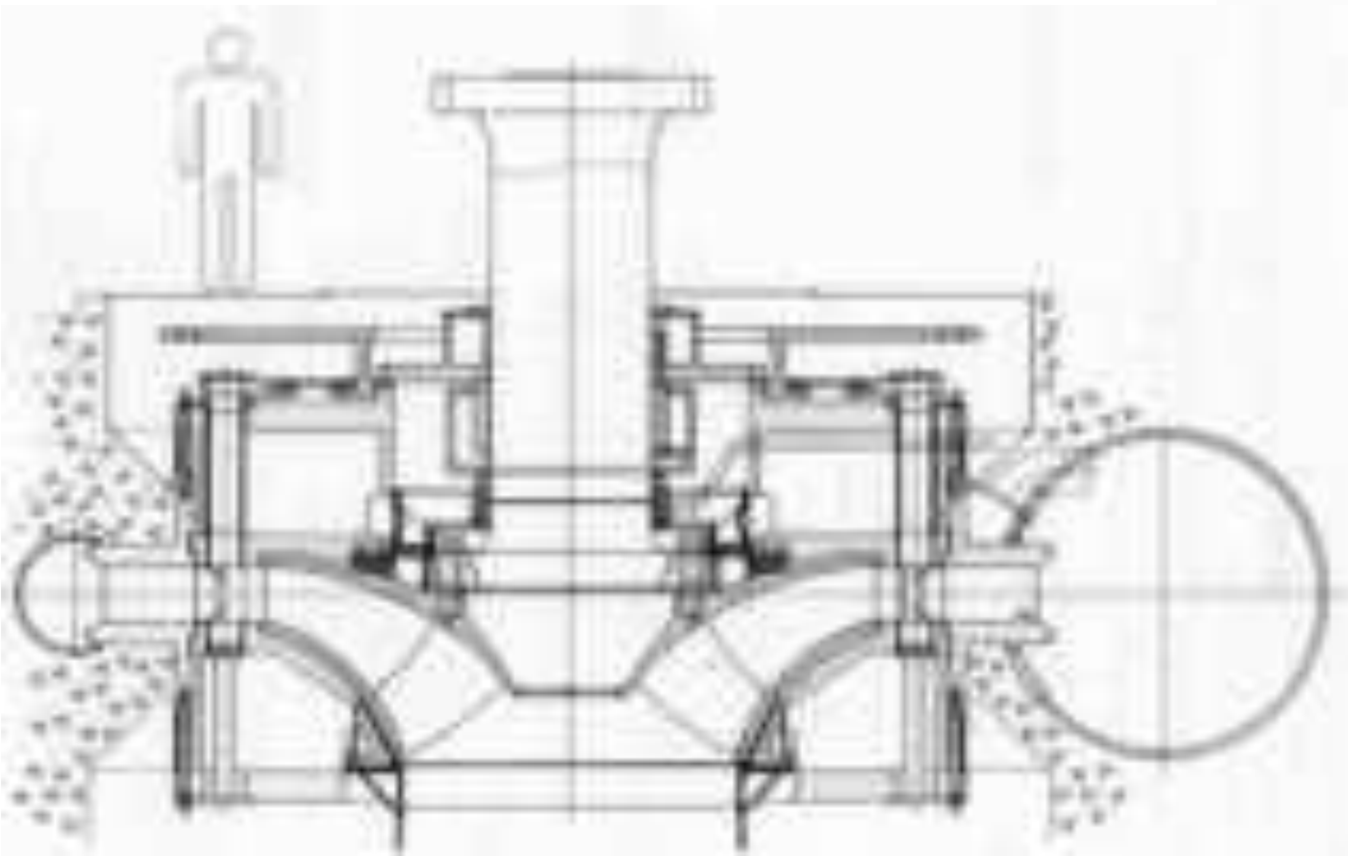
- Studying the Boyden turbine Francis was able to redesign it to increase efficiency.
- Constructing turbines as “sideways water wheels,” Francis was able to achieve an astounding 88 percent efficiency rate.
- After further experimenting, Francis developed the mixed flow reaction turbine which later 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

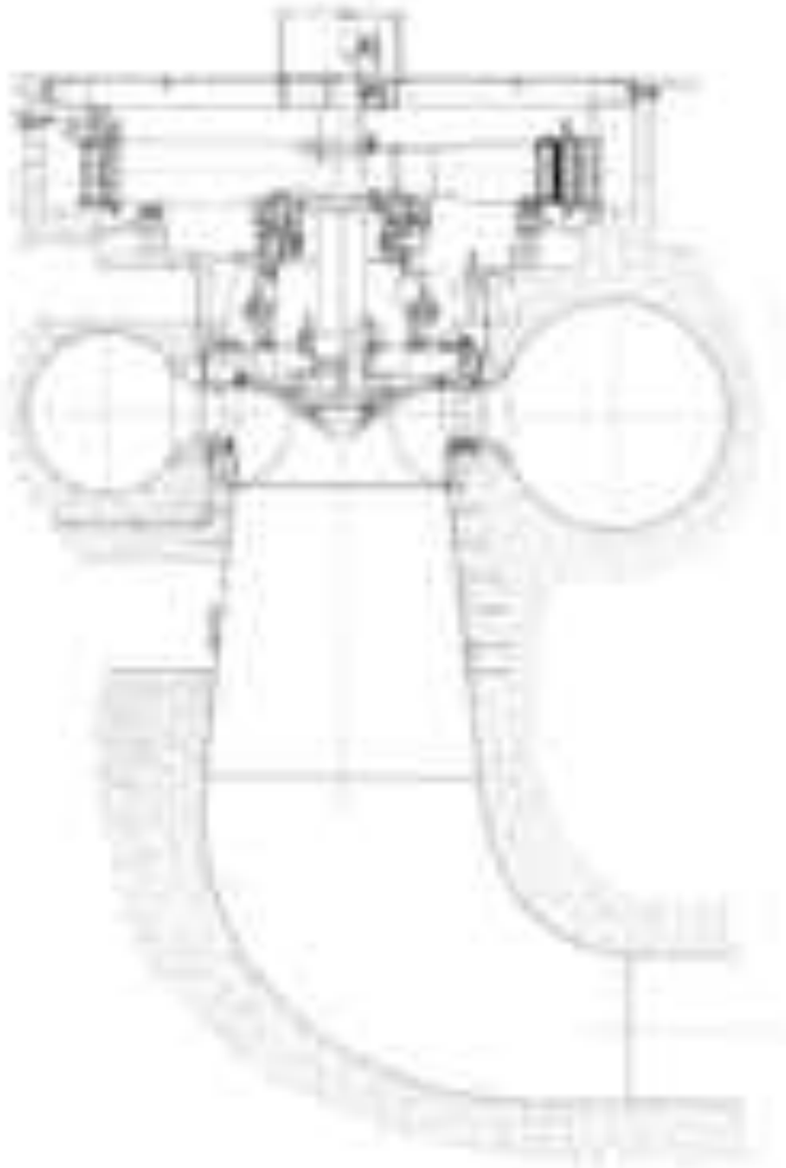
$D_1 = 4{,}31$m

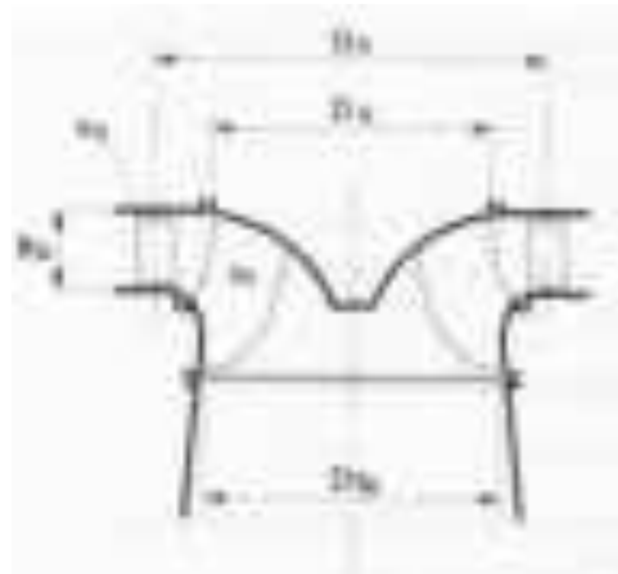
$D_2 = 2{,}35$ m

$B_0 = 0{,}28$ 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

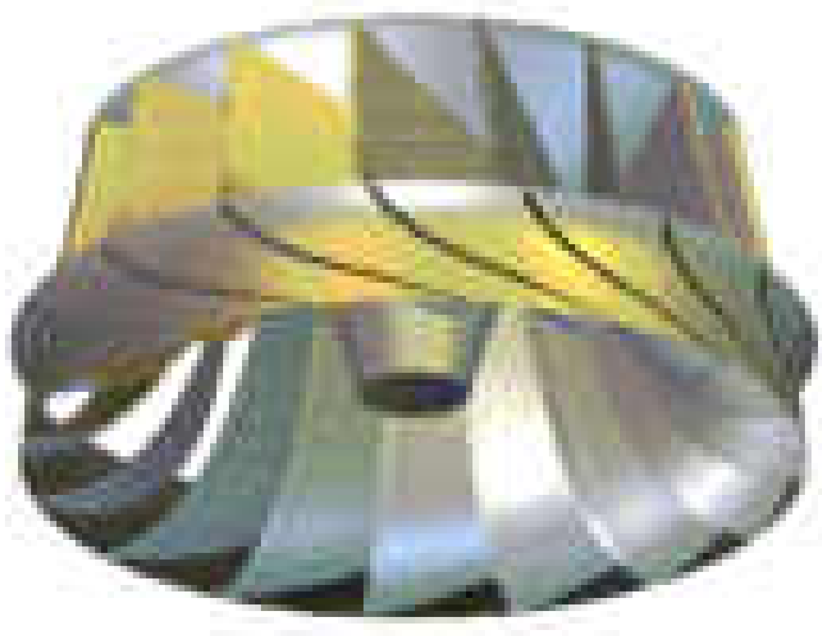
$n = 112{,}5$ rpm

The Francis Installation

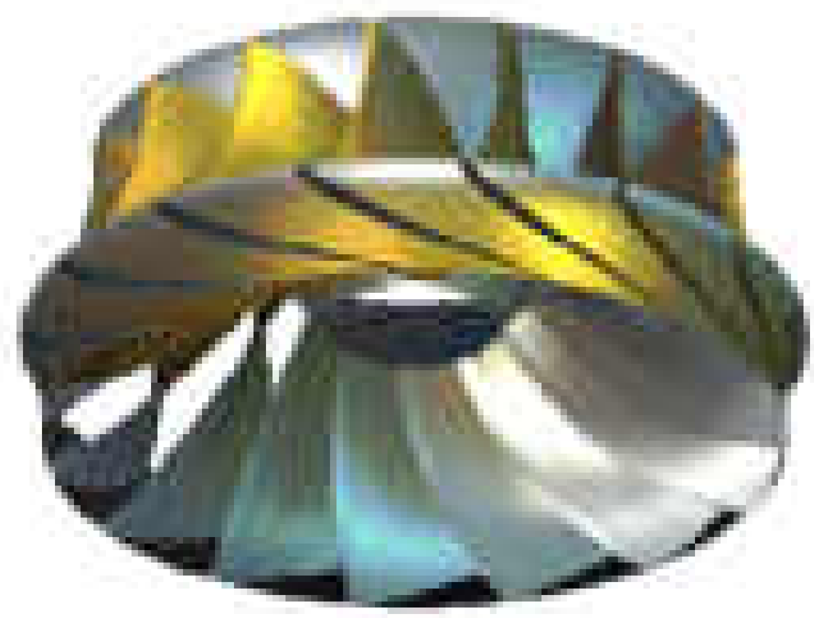
The Francis Turbine

The Francis Runner

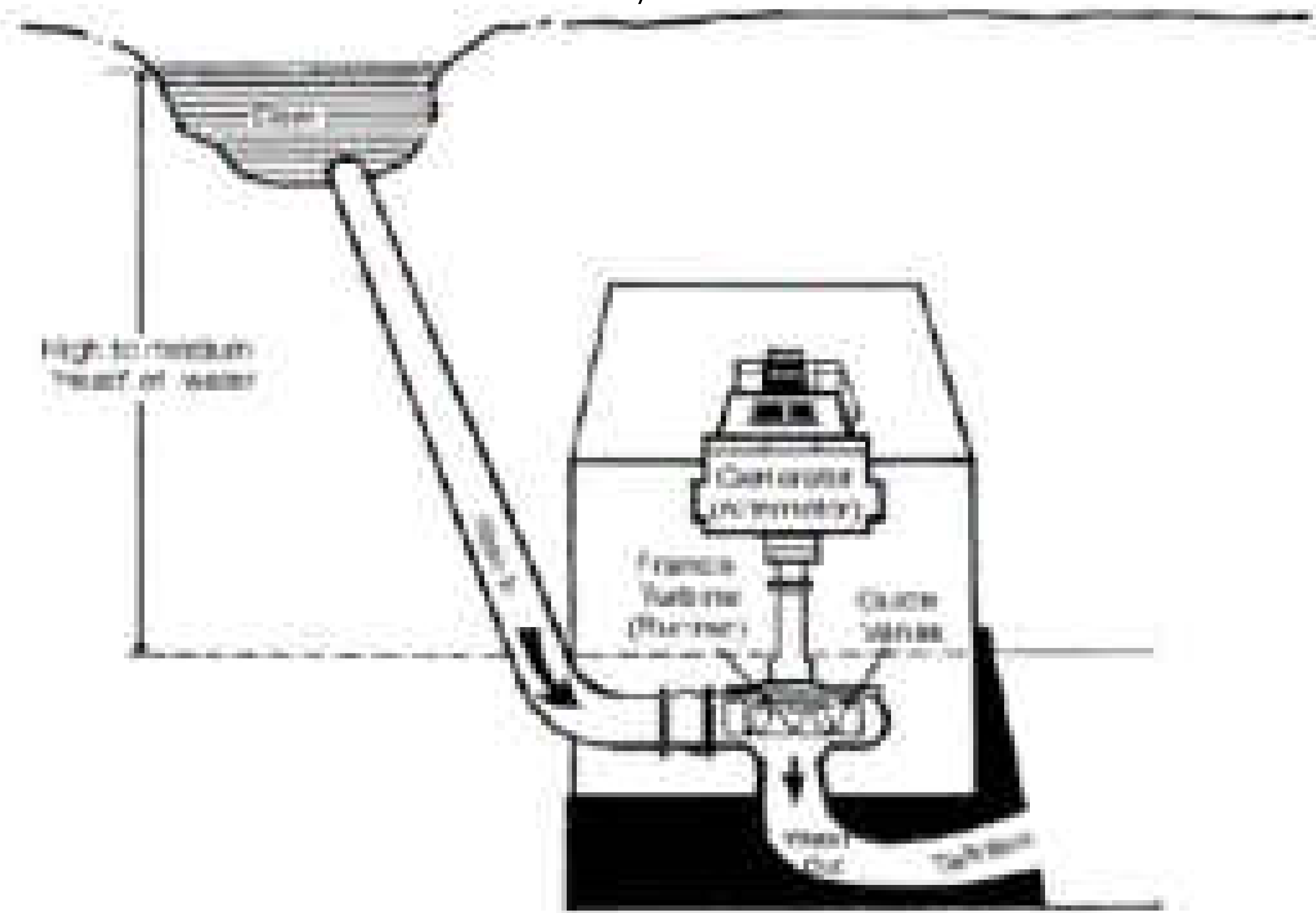
Traditional runner



X blade runner



Francis Turbine Power Plant : A Continuous Hydraulic System

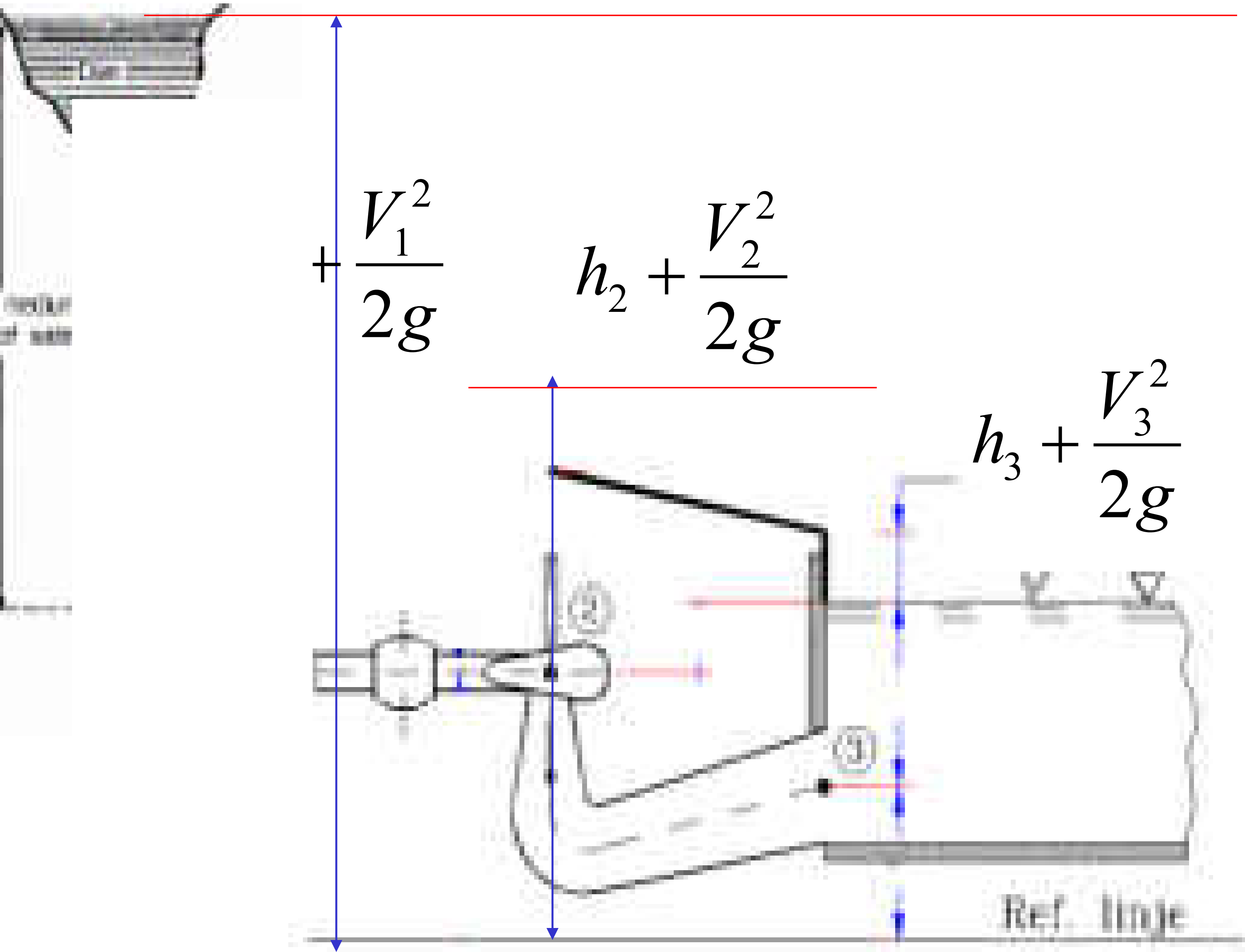


An Active Pascal Law : A Hydraulic Model for Francis Units

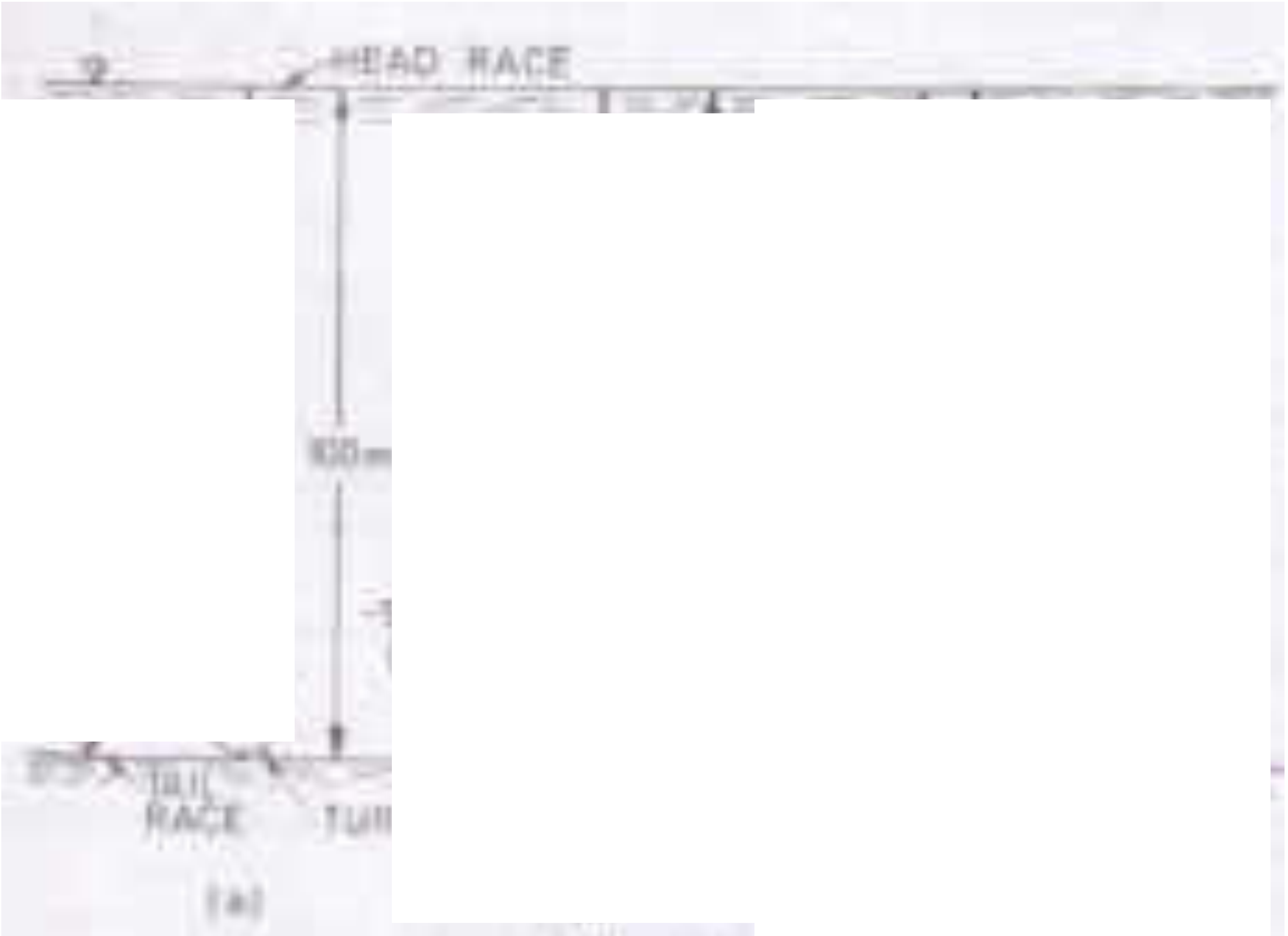
$$+\frac{V_1^2}{2g}$$

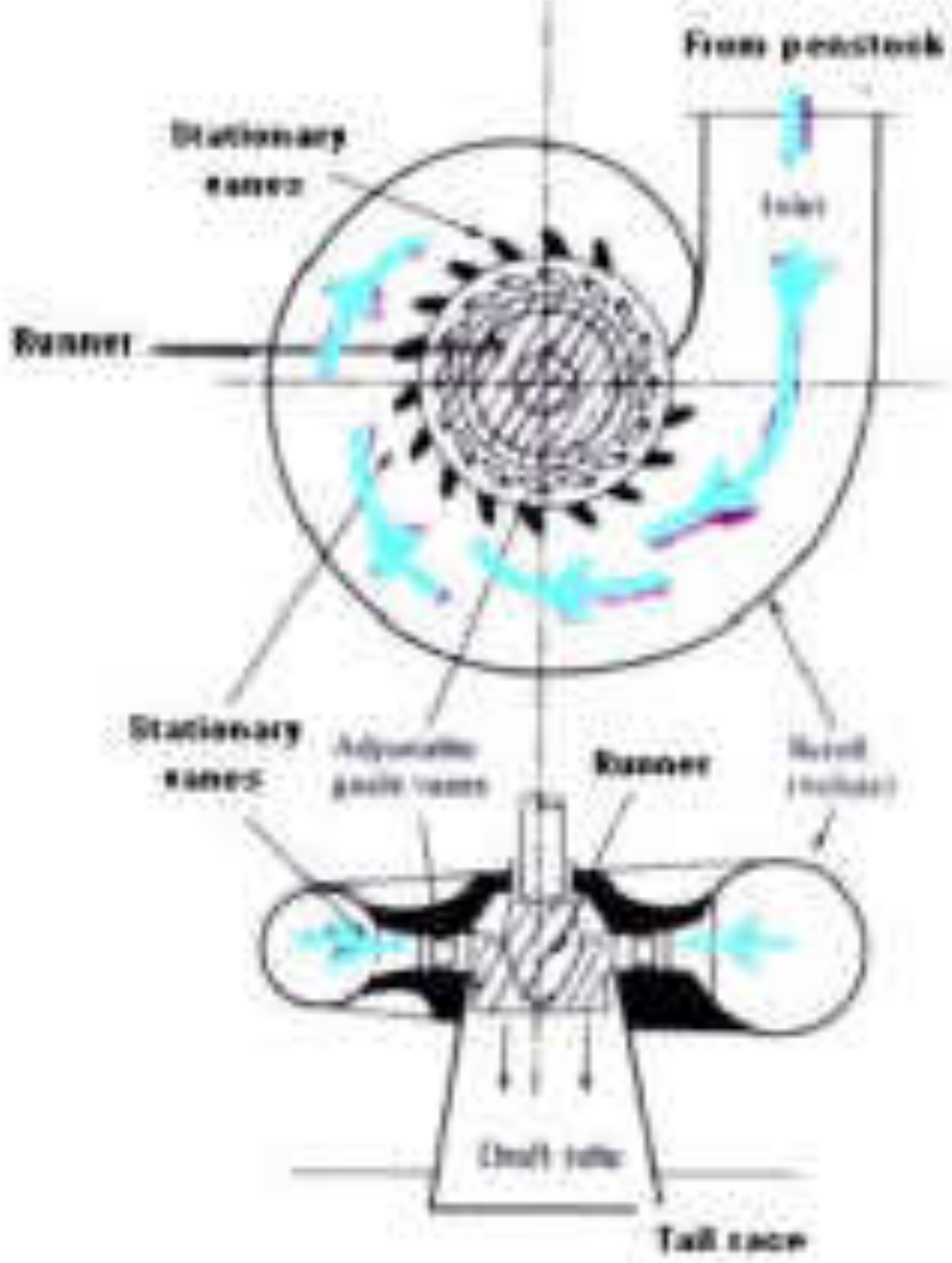
$$h_2+\frac{V_2^2}{2g}$$

$$h_3+\frac{V_3^2}{2g}$$

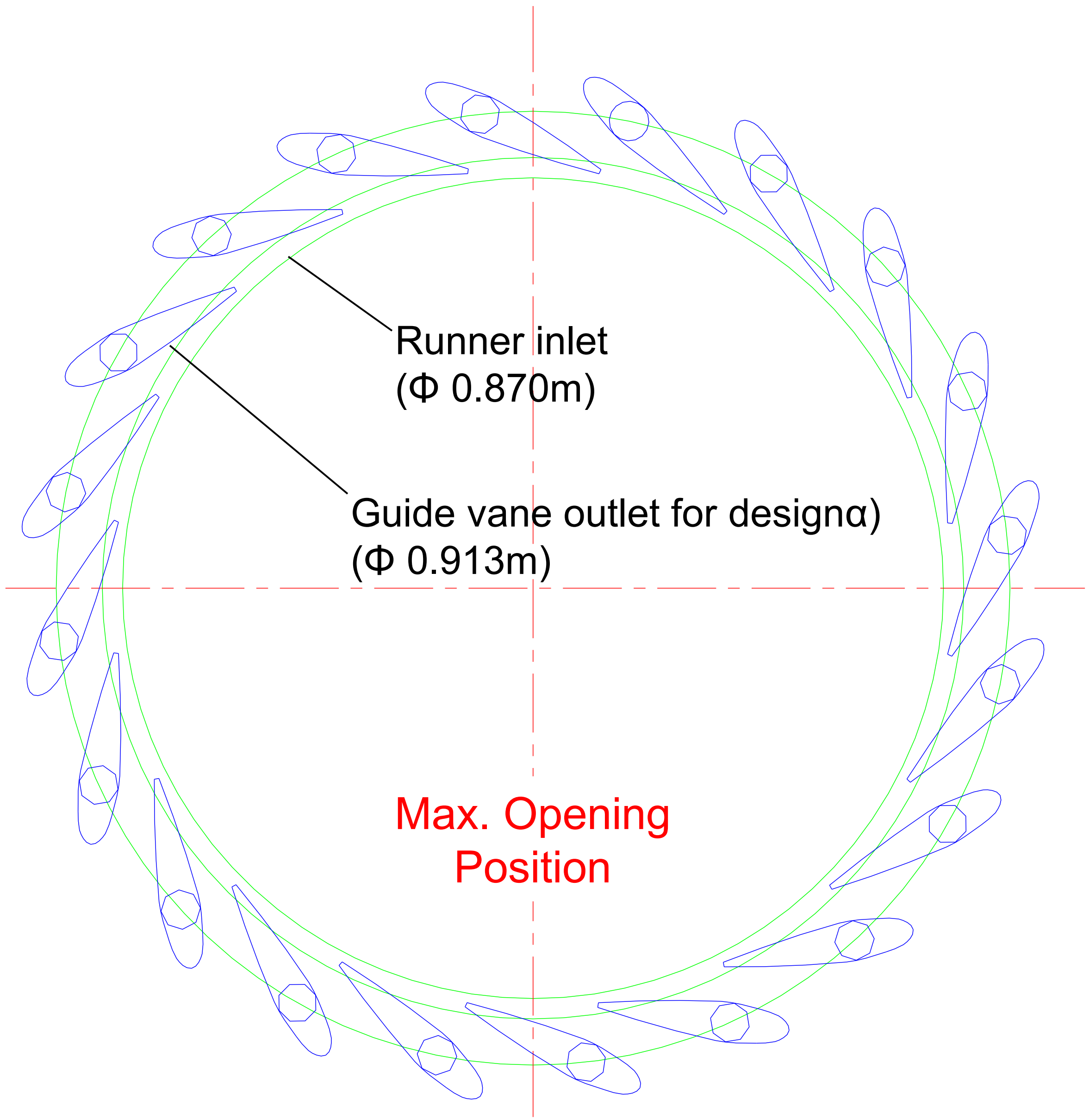


Location of Francis Turbine



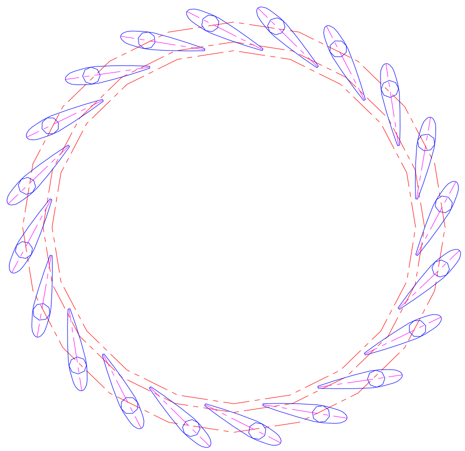


Parts of A Francis Turbine

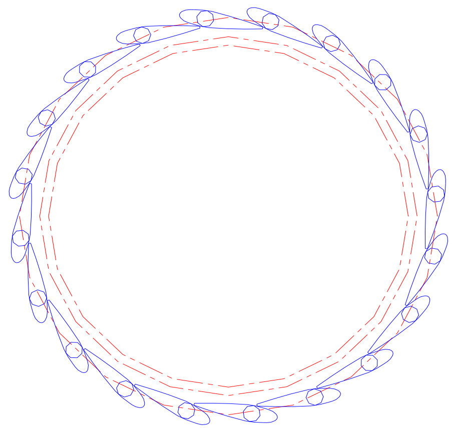

Runner inlet
(Φ 0.870m)
Guide vane outlet for designα)
(Φ 0.913m)
Max. Opening
Position

Guide vanes

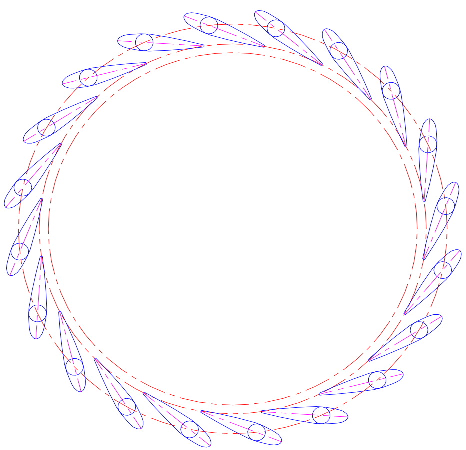
Operation of Guide Vanes



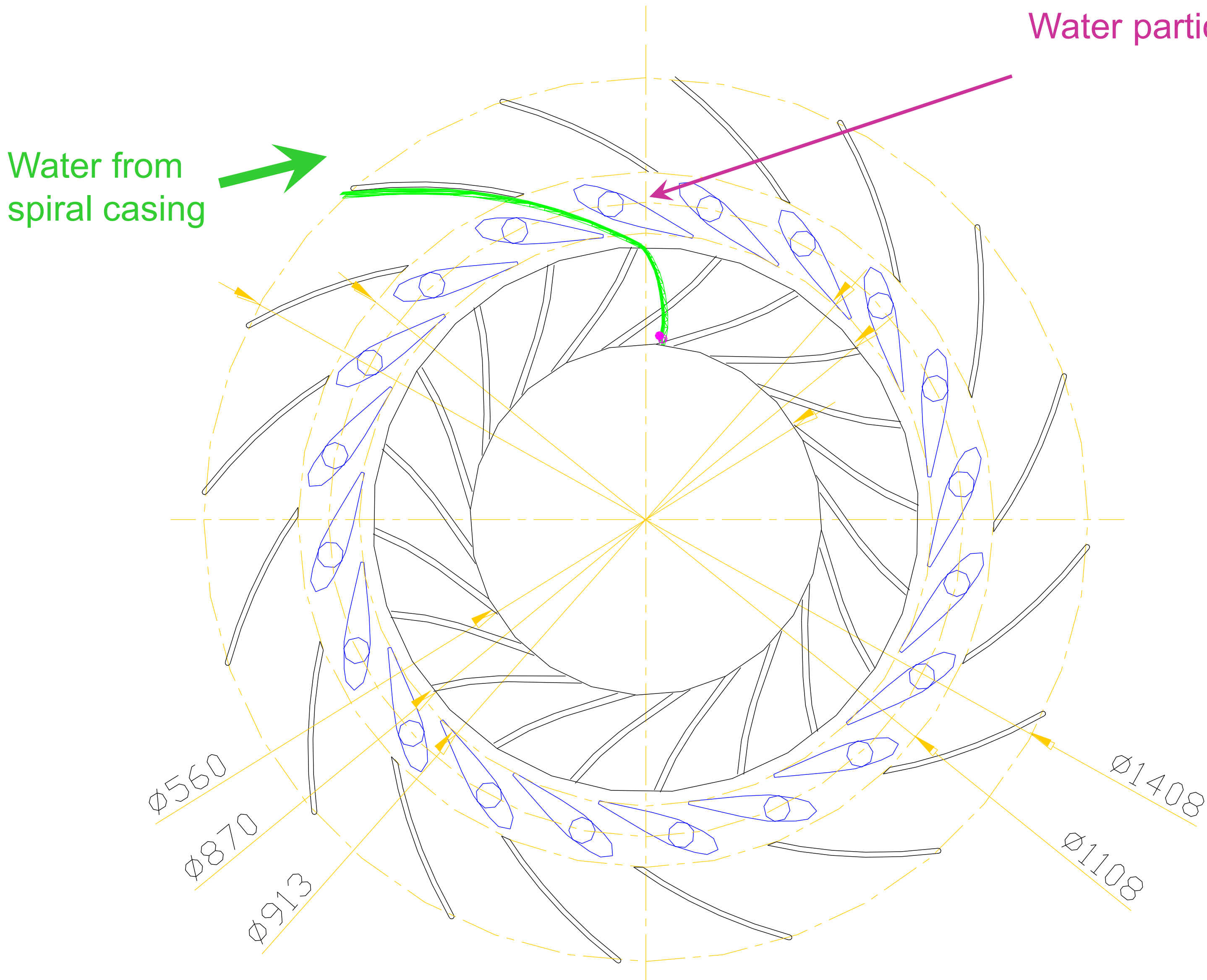
Guide vane at Design
Position α= 12.21°



Guide vane at closed position

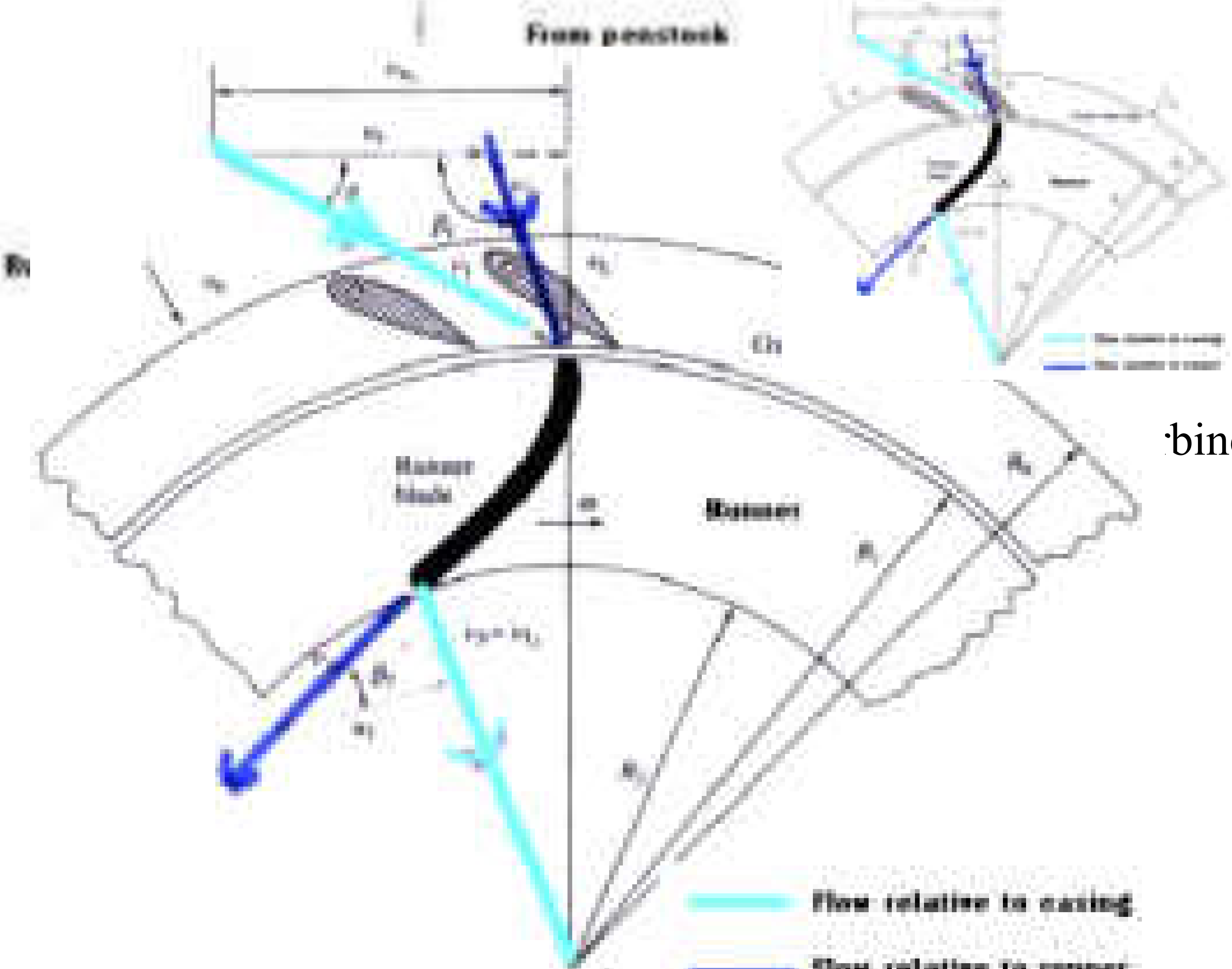


Guide vane at Max. open
Position α= 18°



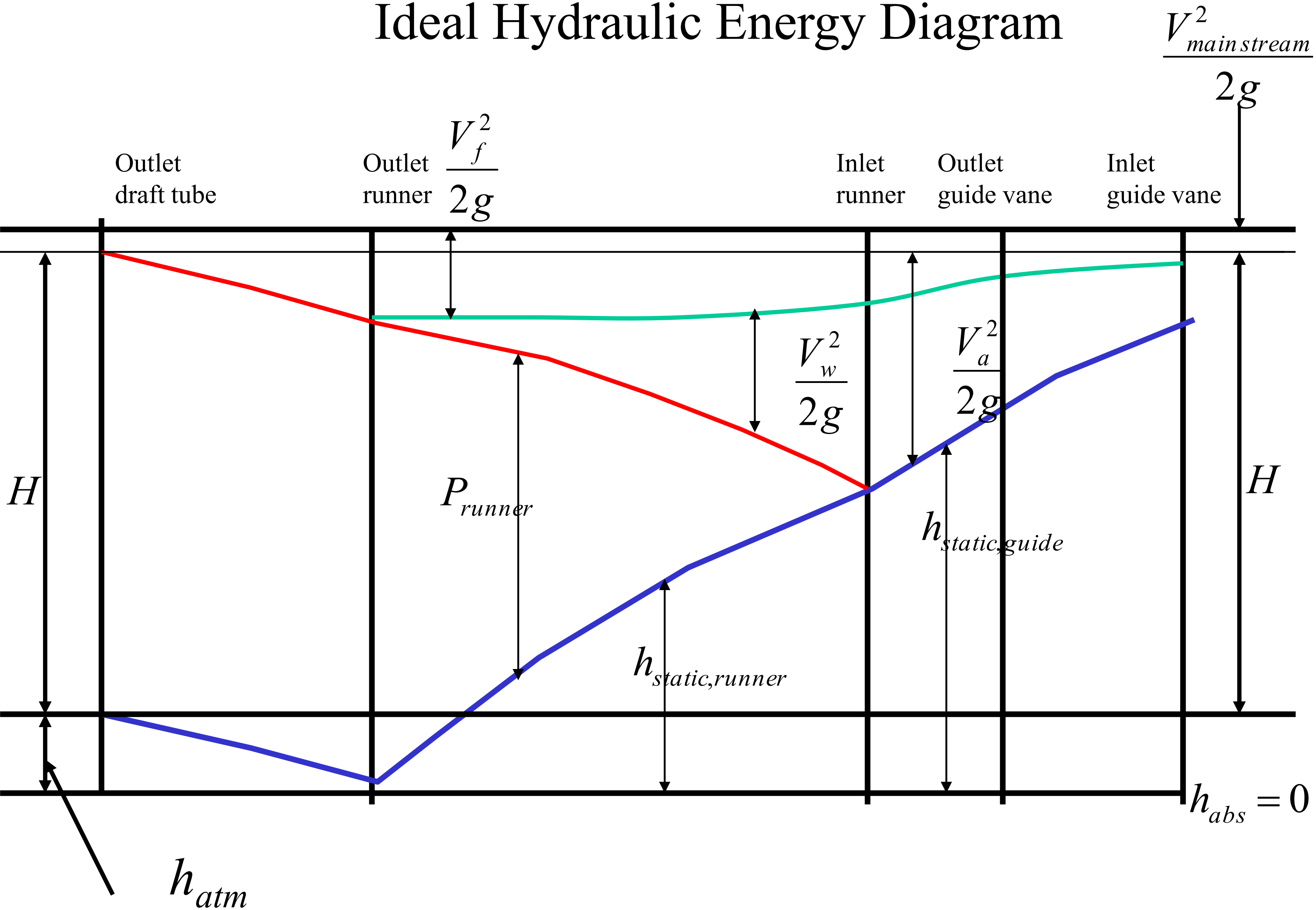
R a d i a l v i e w
runner guide vanes and stay vanes

R


From penstock
Runner blade
Runner
Flow relative to casing
Flow relative to runner

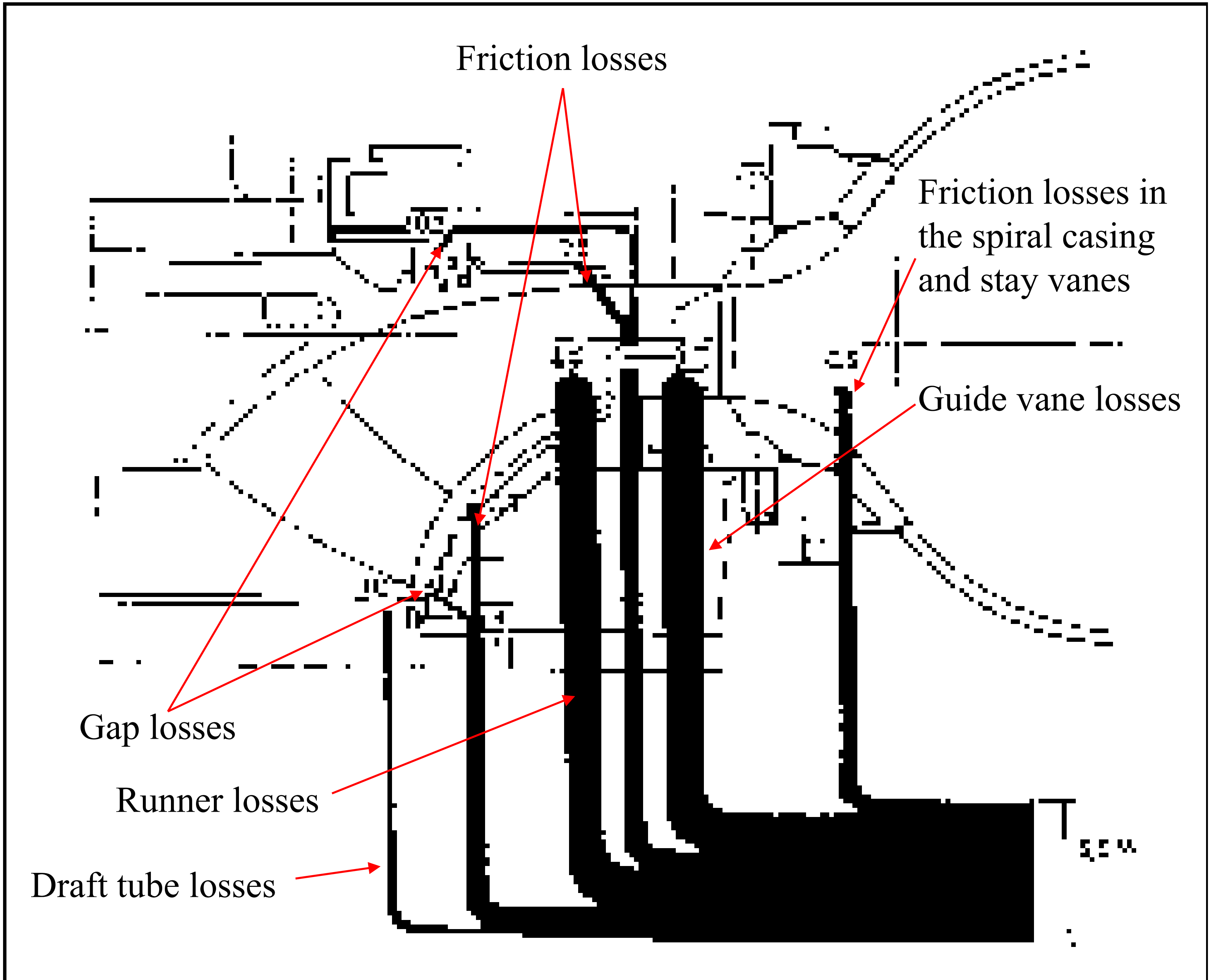
bine

Ideal Hydraulic Energy Diagram



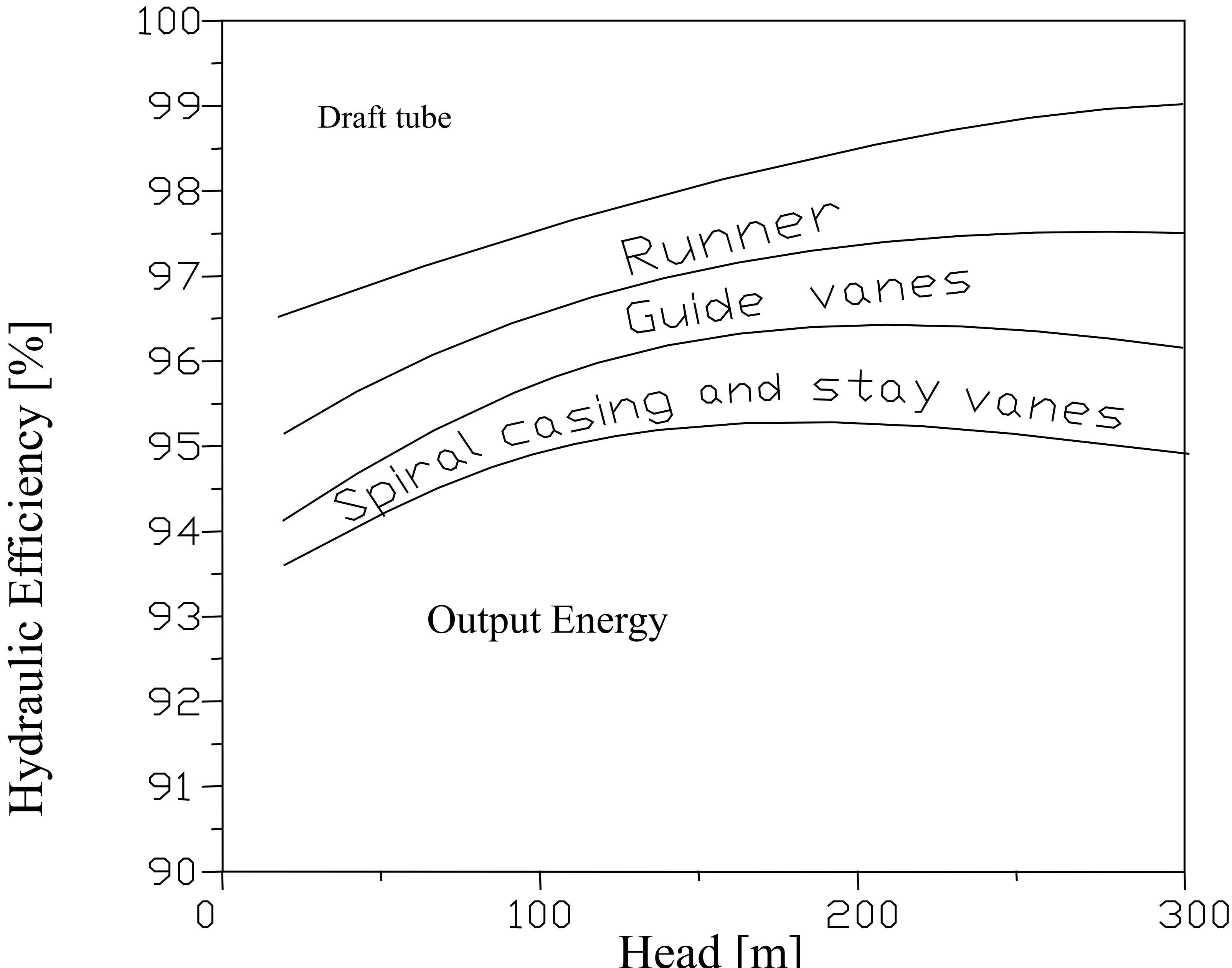
Hydraulic efficiency of Francis Hydraulic System

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

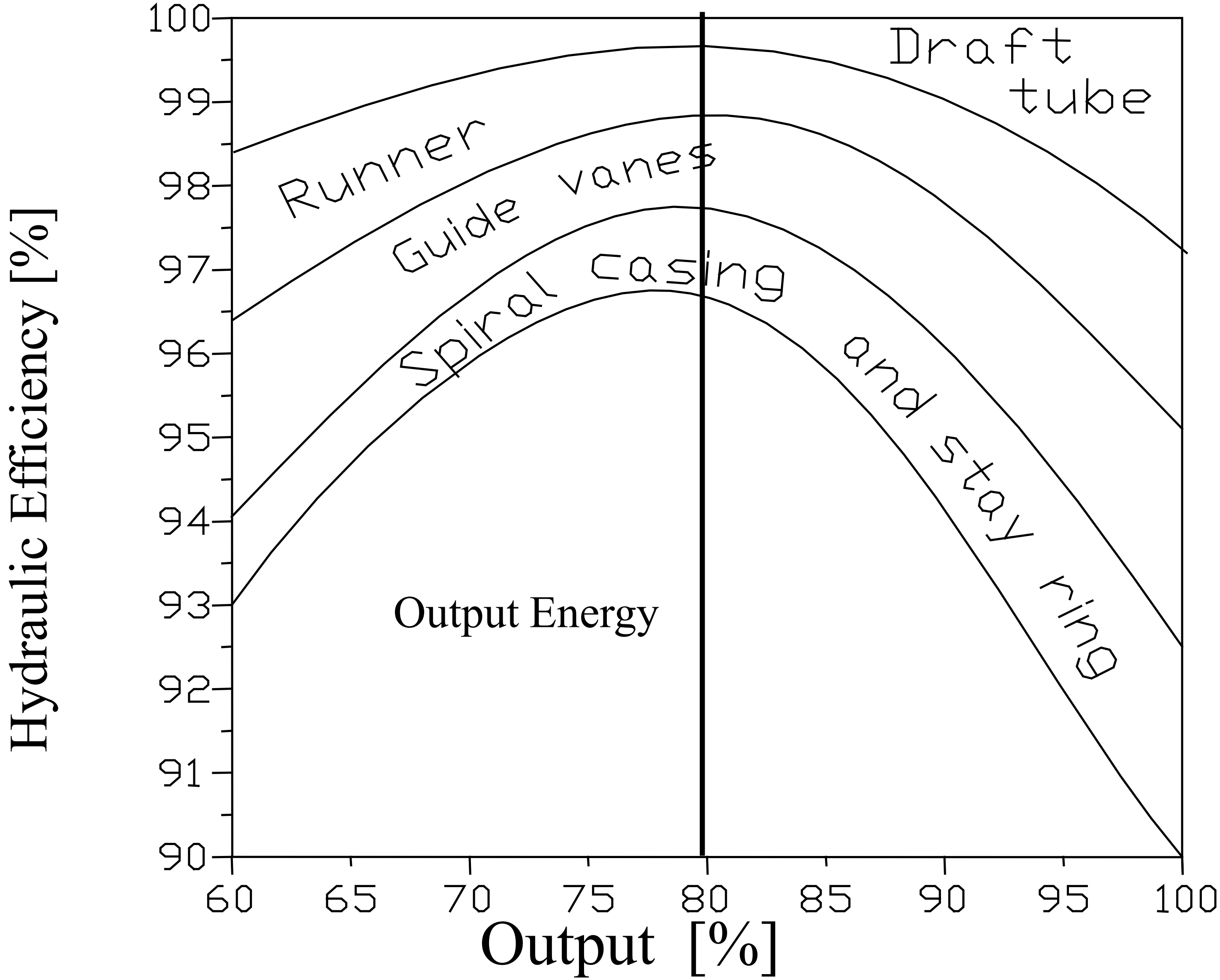


Friction losses
Friction losses in the spiral casing and stay vanes
Guide vane losses
Gap losses
Runner losses
Draft tube losses

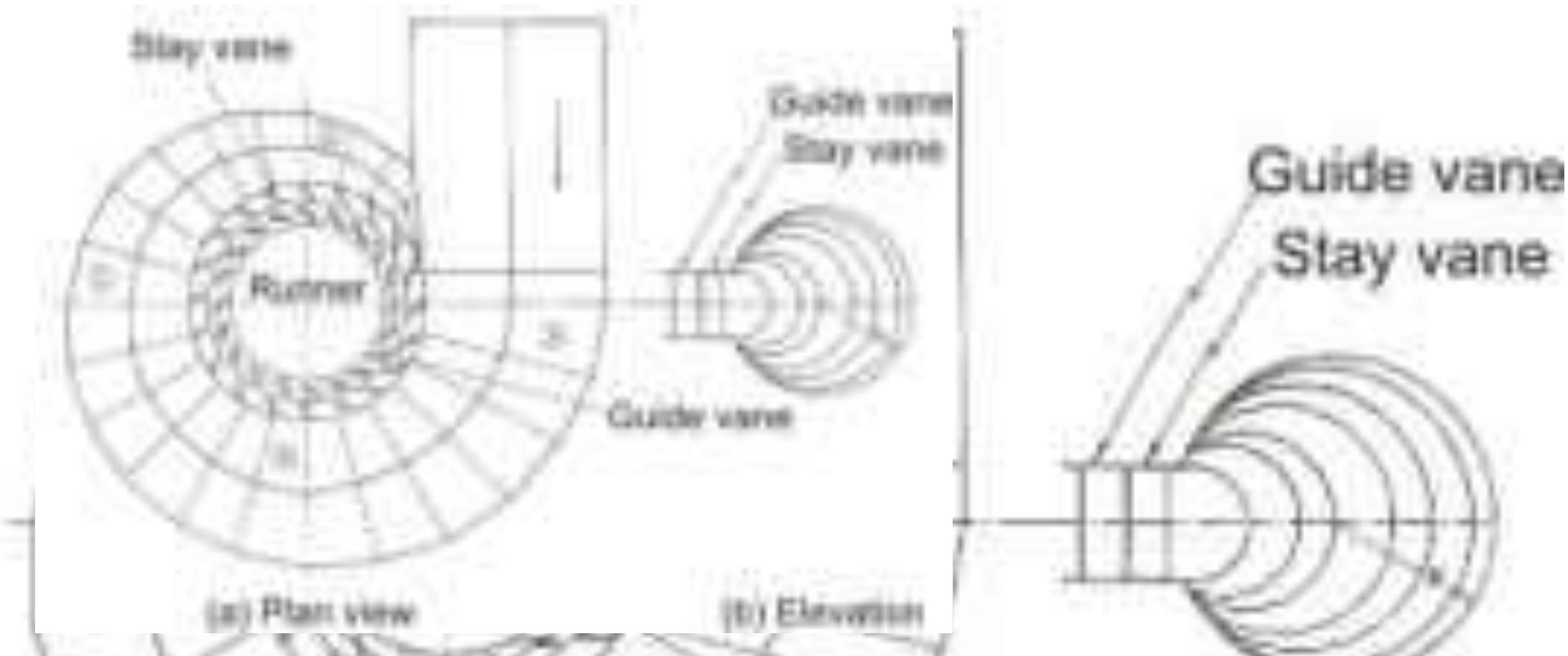
Losses in Francis Turbines



Losses in Francis Turbines

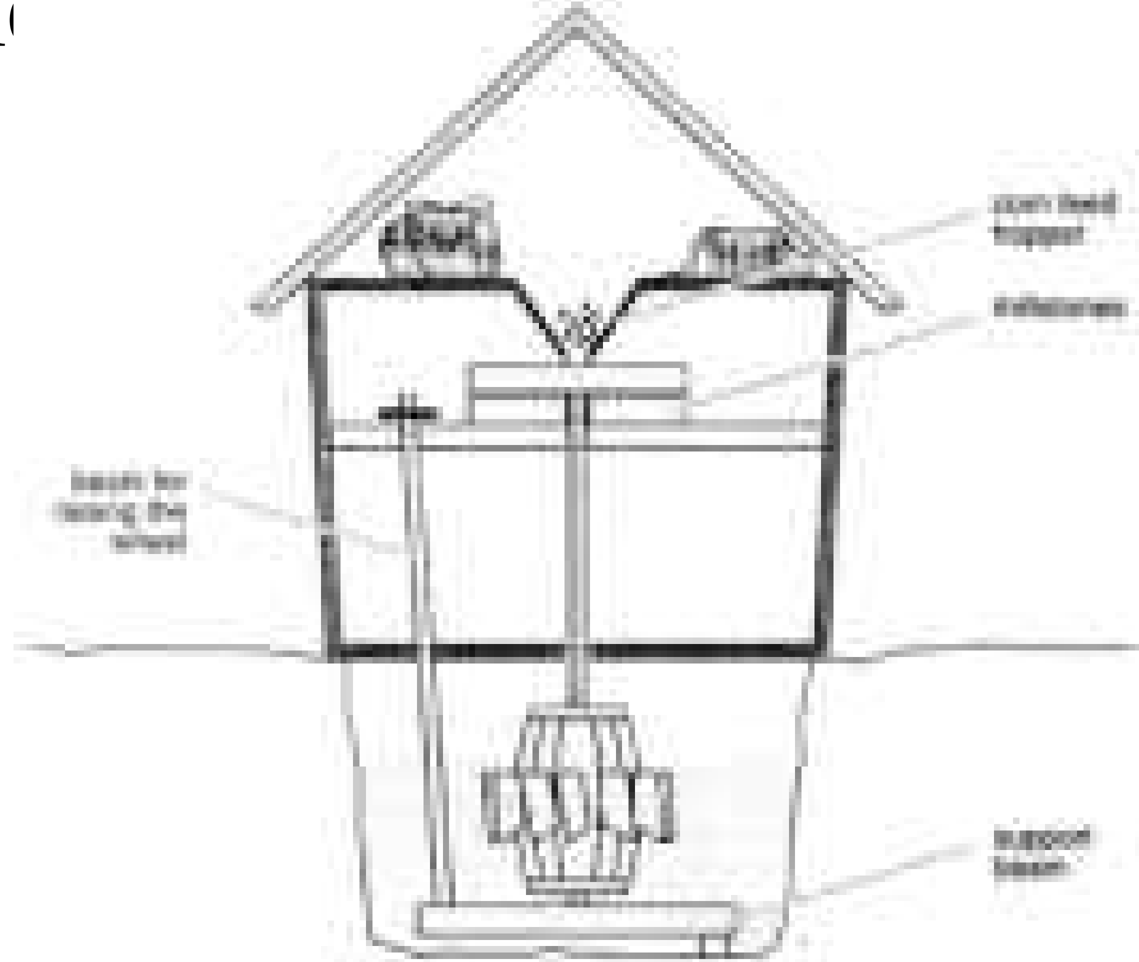


Spiral Casing

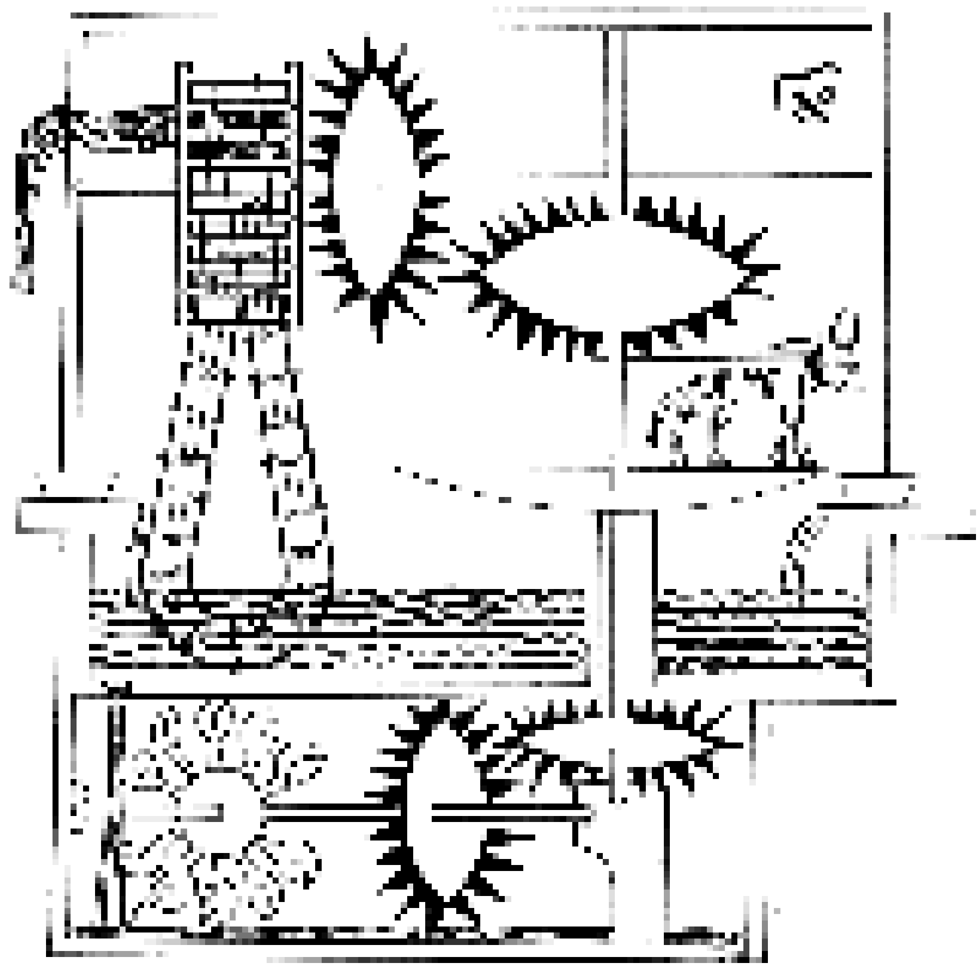


- **Spiral Casing :** The fluid enters from the penstock to a spiral casing which completely surrounds the runner.
- This casing is known as scroll casing or volute.
- The cross-sectional area of this casing decreases uniformly along the circumference to keep the fluid velocity constant in magnitude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

B2.2.4 Hydropower system design
Turbines: Greek mill (c. 100BC)

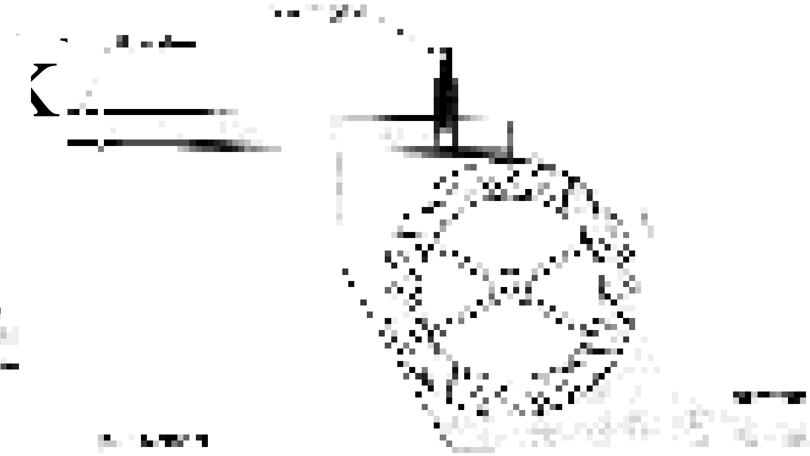


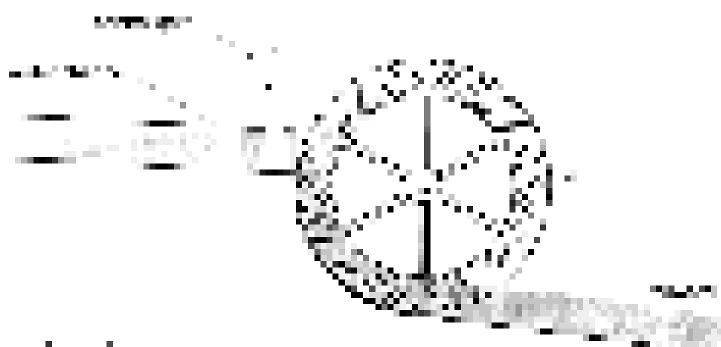
B2.2.4 Hydropower system design Turbines:Mesopotamian Saquia (c. 1200 AD)



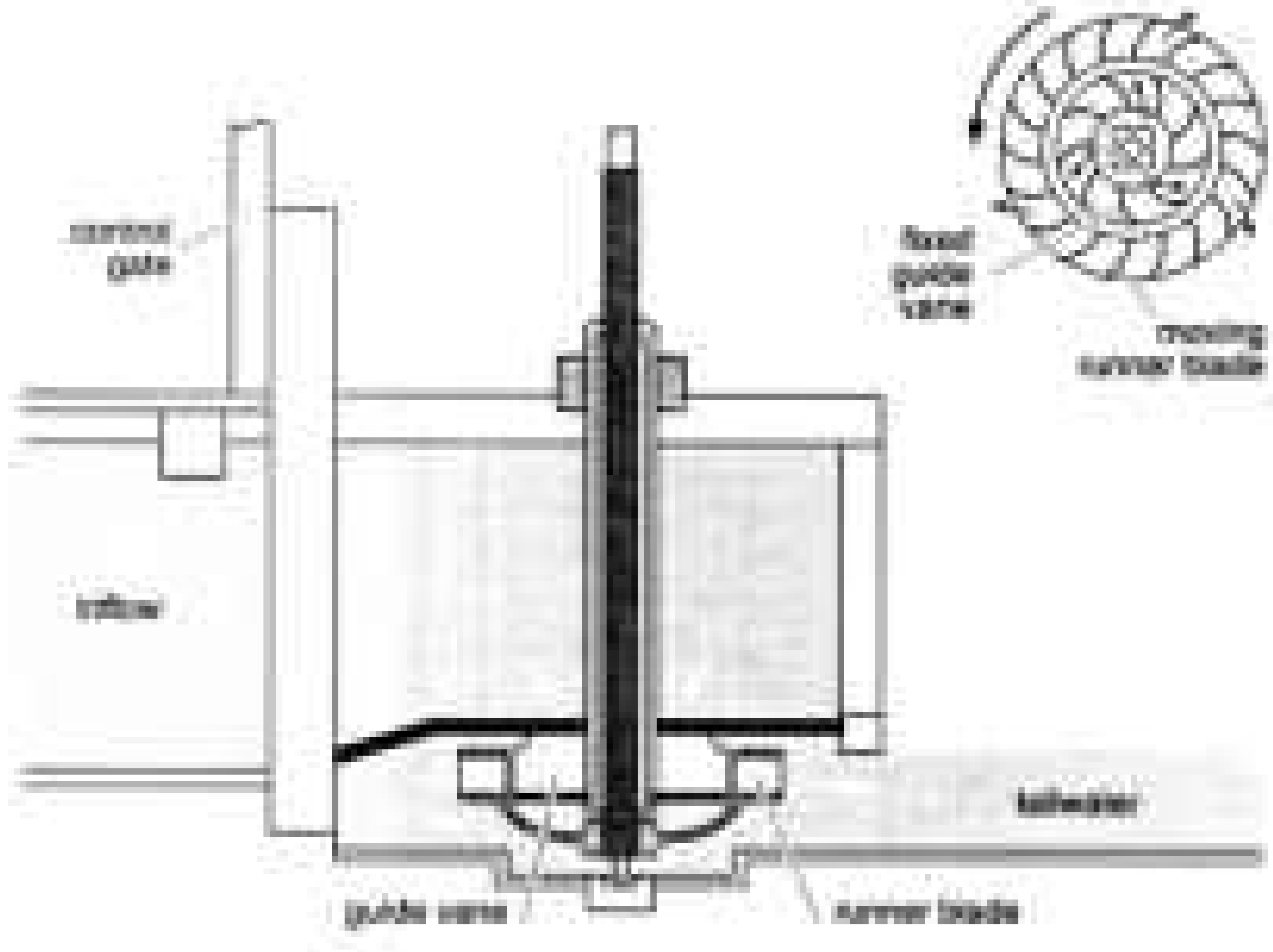
the Book of Knowledge of Ingenious Mechanical Devices of al-Jahazi

B2.2.4 Hydropower system design
Turbines: Water wheels (c. 1800)





B2.2.4 Hydropower system design
Turbines: Fournevron’s turbine



B2. Hydropower Seminars A206a

Read summary of case studies

- Nepal
- Peru

Discussion

- What were the good and bad projects
- What makes a “good project”
- What were the social benefits of the projects? Were these valued?
- Who benefits and who loses

B2. Reservoirs
Seminar groups

Group 1 (14:00)		Group 2 (14:30)	
Gunjan Dhingra	Dafydd Caffery	Rob Morford	Roger Palmer
Mike Farrow	Samuel Carter	Chris Swinburn	Anthony Pearson
Hannah Jones	Nedim Dzananovic	Kate Taylor	Gareth Pilmoor
Matt Knight	Philip Hallgarth	Celia Way	Ann Ruthven
Paul Knowles	Neil Harding	Marie Wells	Matthew Scott
Peter Adams	Martin Hill	Matt Whitley	Ben Sheterline
Elizabeth Aldridge	Karen Hockey	Eral Kahveci	Melanie Sim
Jonathan Bailey	Ching Hong	Imra Karimn	Nicholas Thompson
Khesraw Bashir	Adam Ithier	Martin Kendrick	Daniel Tkotsch
Christopher Baxter	Peter Jordan	Shua Lii	Christopher Tompkins
Richard Buckland	Jan Jozefowski	Beth Mcdowall	Ian Yeung
		Adil Munir	

B2.2.4 Hydropower system design
Turbines: Power conversion

$$P = Q\rho g h \quad \Rightarrow \quad P = T\omega$$

B2.2.4 Hydropower system design
Turbines: Power conversion

$$T = Fr$$

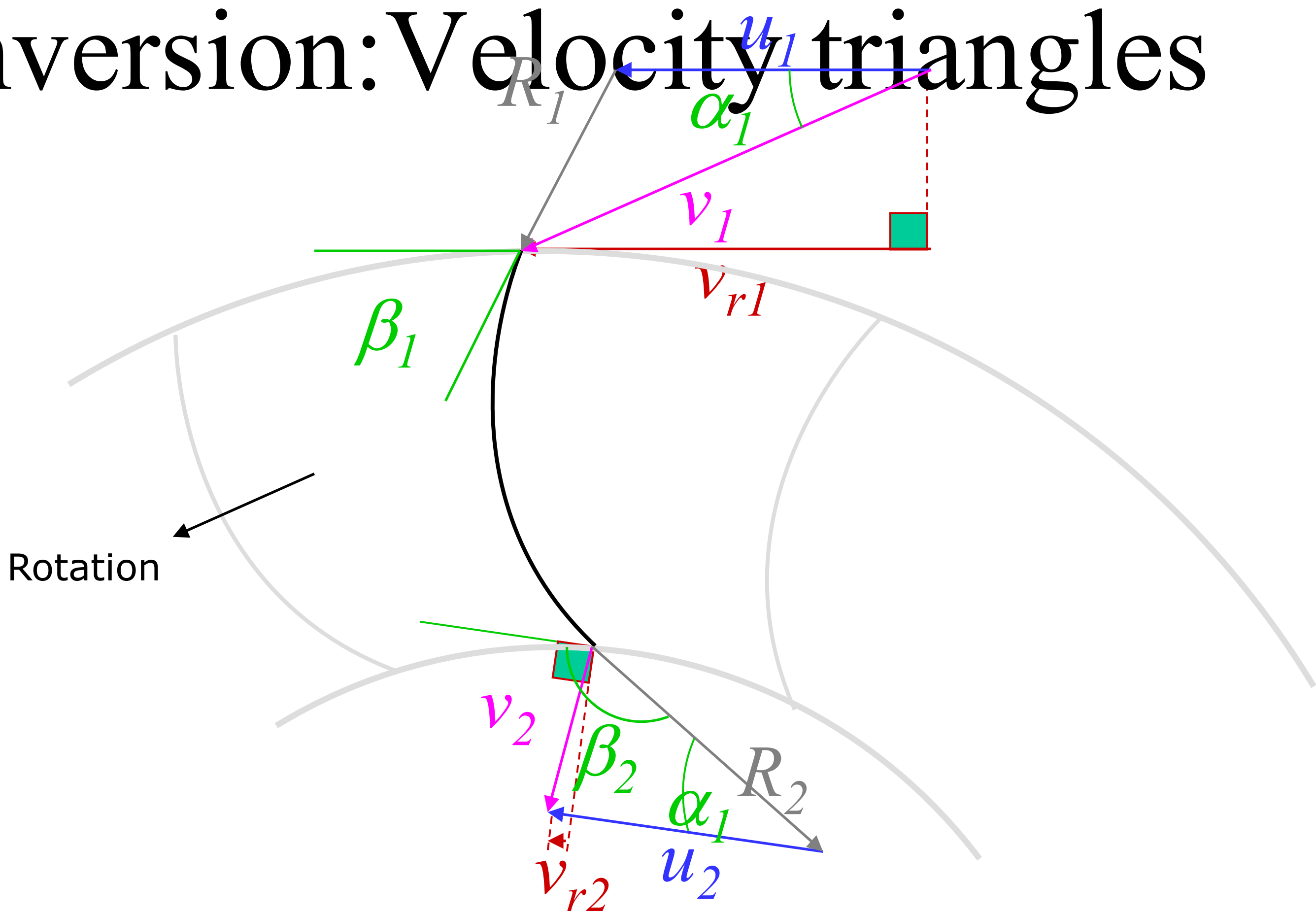
↑

$$F = \Delta M$$

$$= \dot{m}\Delta v$$

$$= \rho Q \Delta v$$

B2.2.4 Hydropower system design
Turbines: Power conversion:Velocity triangles

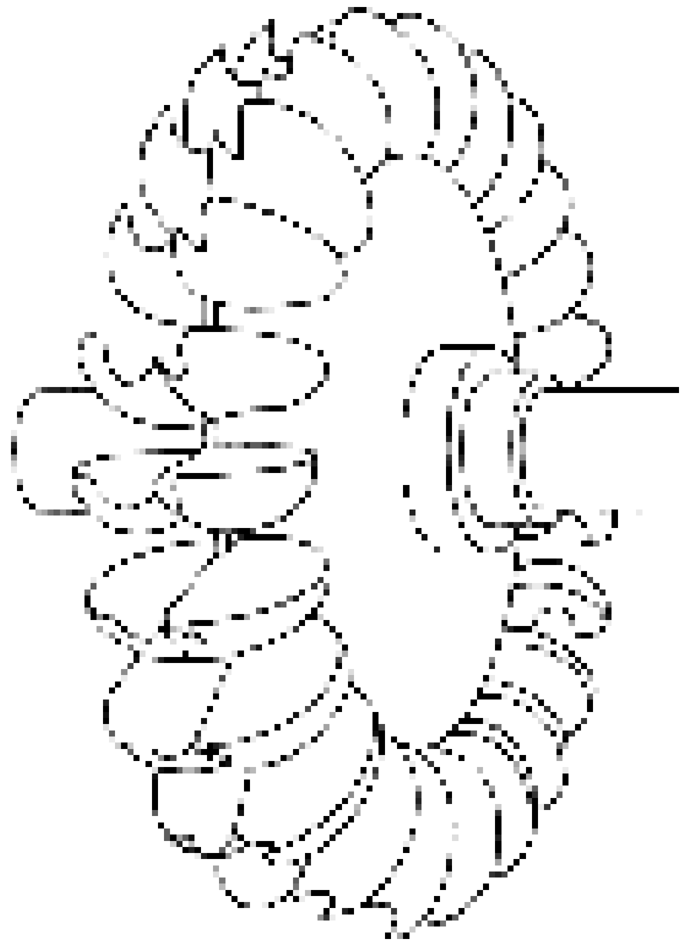


B2.2.4 Hydropower system design
Turbines:

- Impulse
  - Pelton wheel
  - Turgo
  - Crossflow
- Reaction
  - Radial (e.g. Francis)
  - Axial (e.g. propeller, bulb, Kaplan)

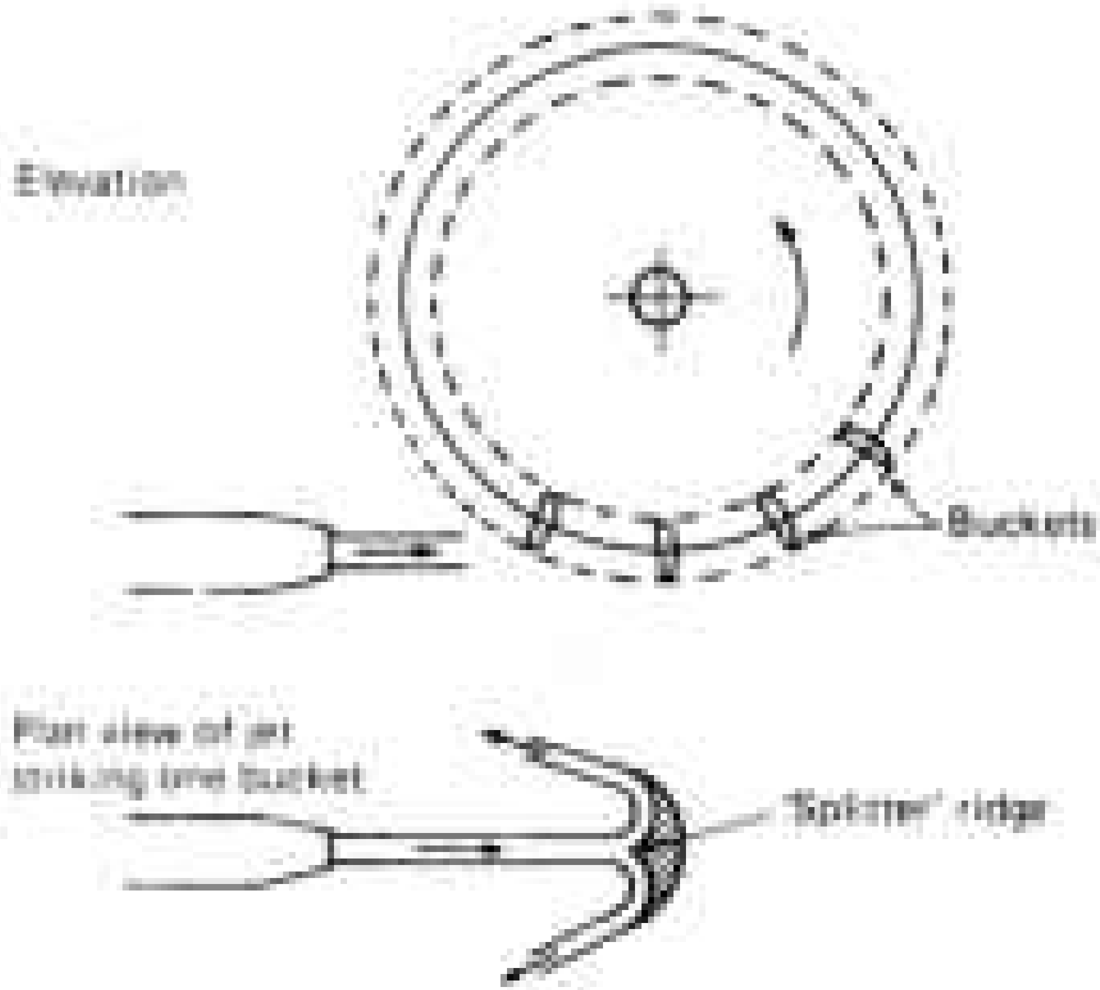
B2.2.4 Hydropower system design

Turbines: Pelton wheel (1889)



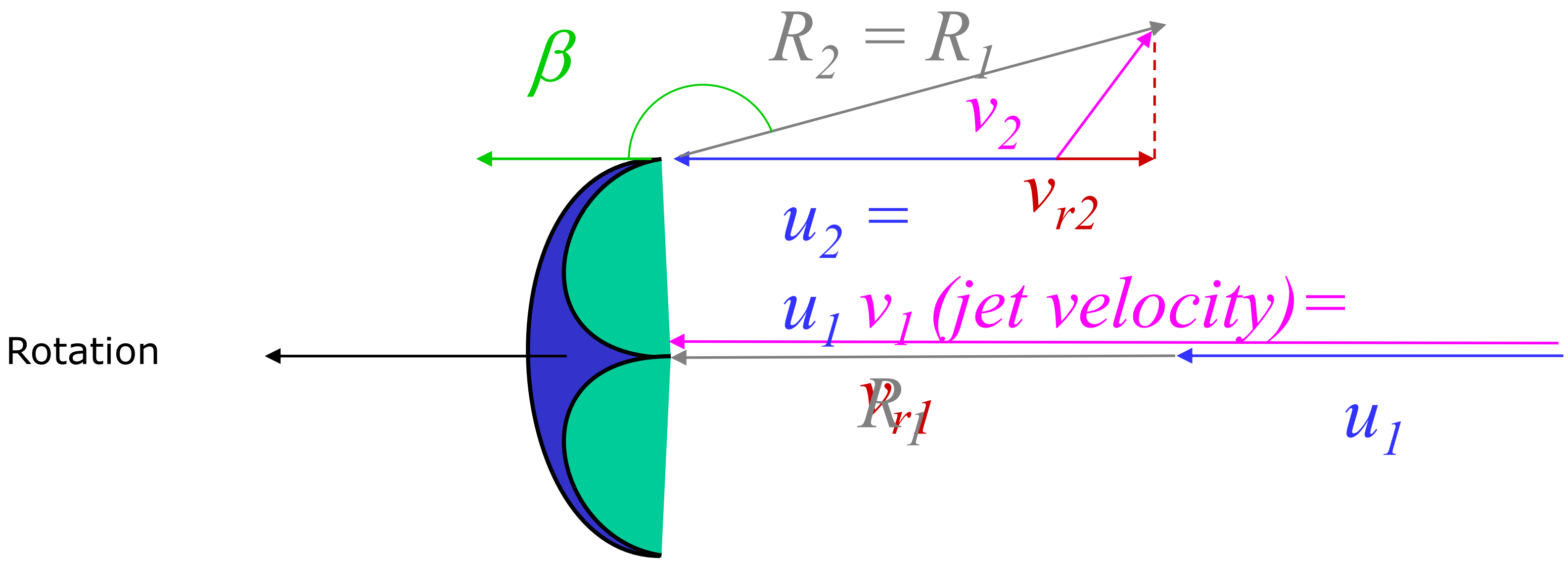
B2.2.4 Hydropower system design
Turbines: Pelton wheel

B2.2.4 Hydropower system design

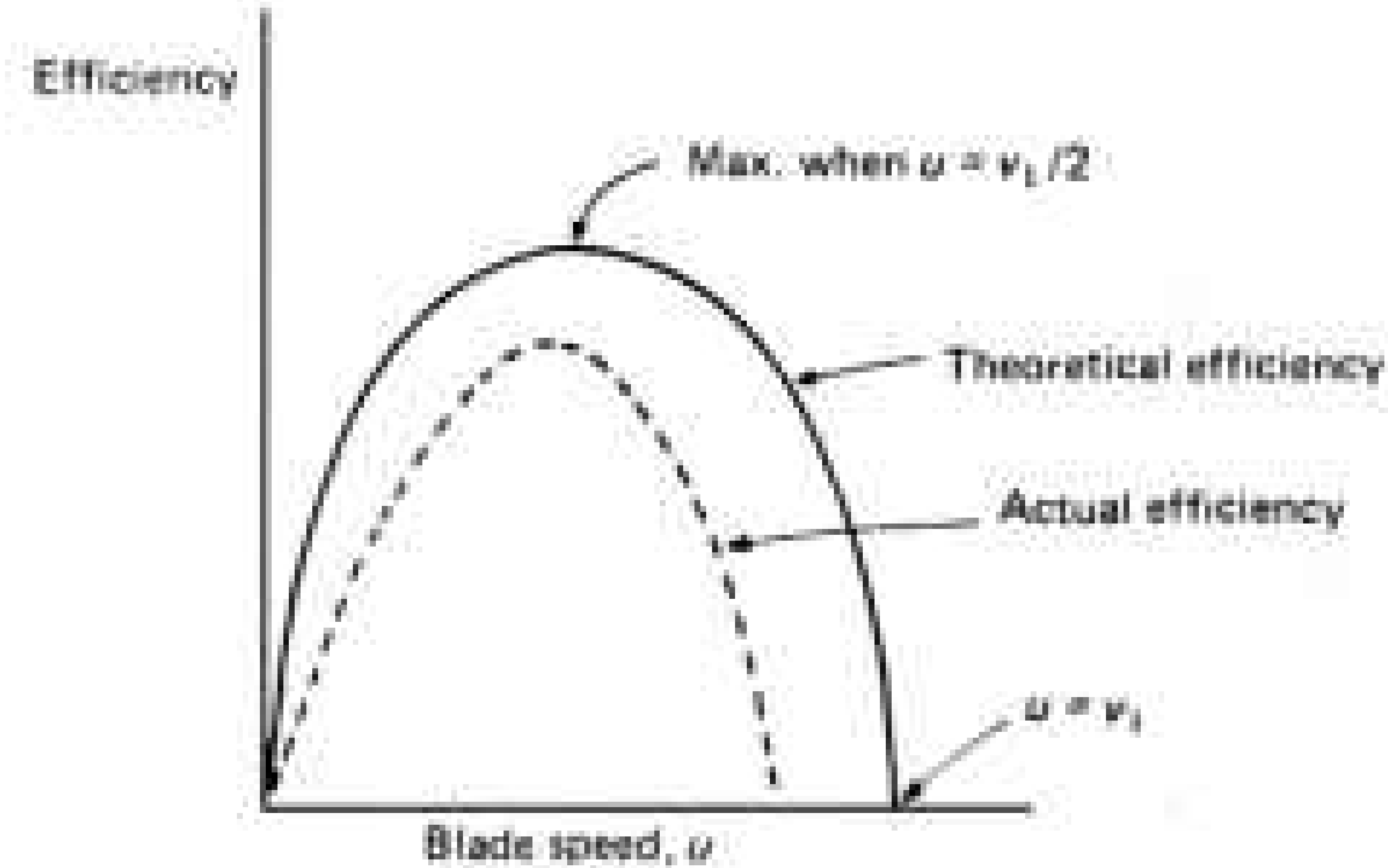


B2.2.4 Hydropower system design
Turbines: Pelton wheel

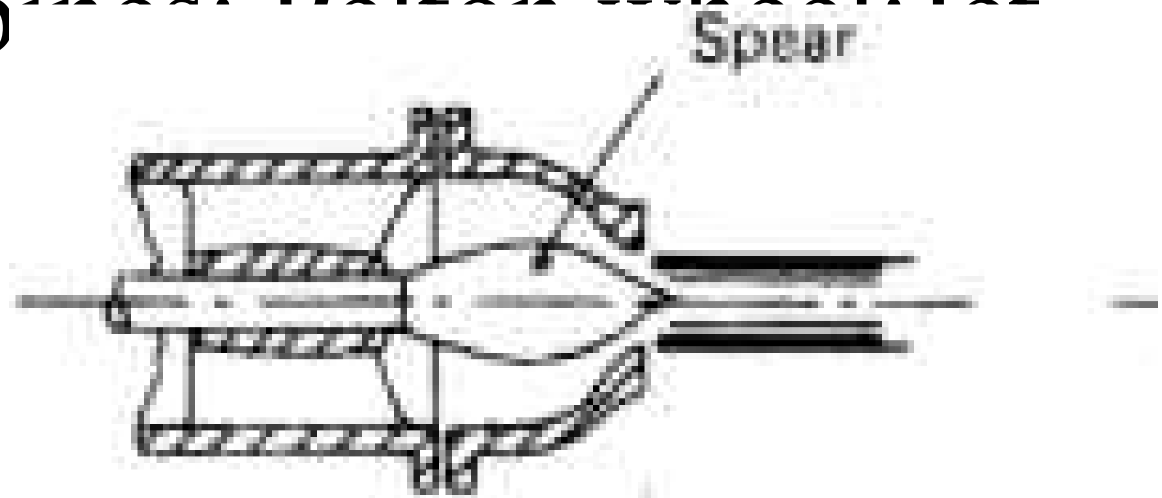
B2.2.4 Hydropower system design
Turbines: Pelton wheel



B2.2.4 Hydropower system design
Turbines: Pelton wheel



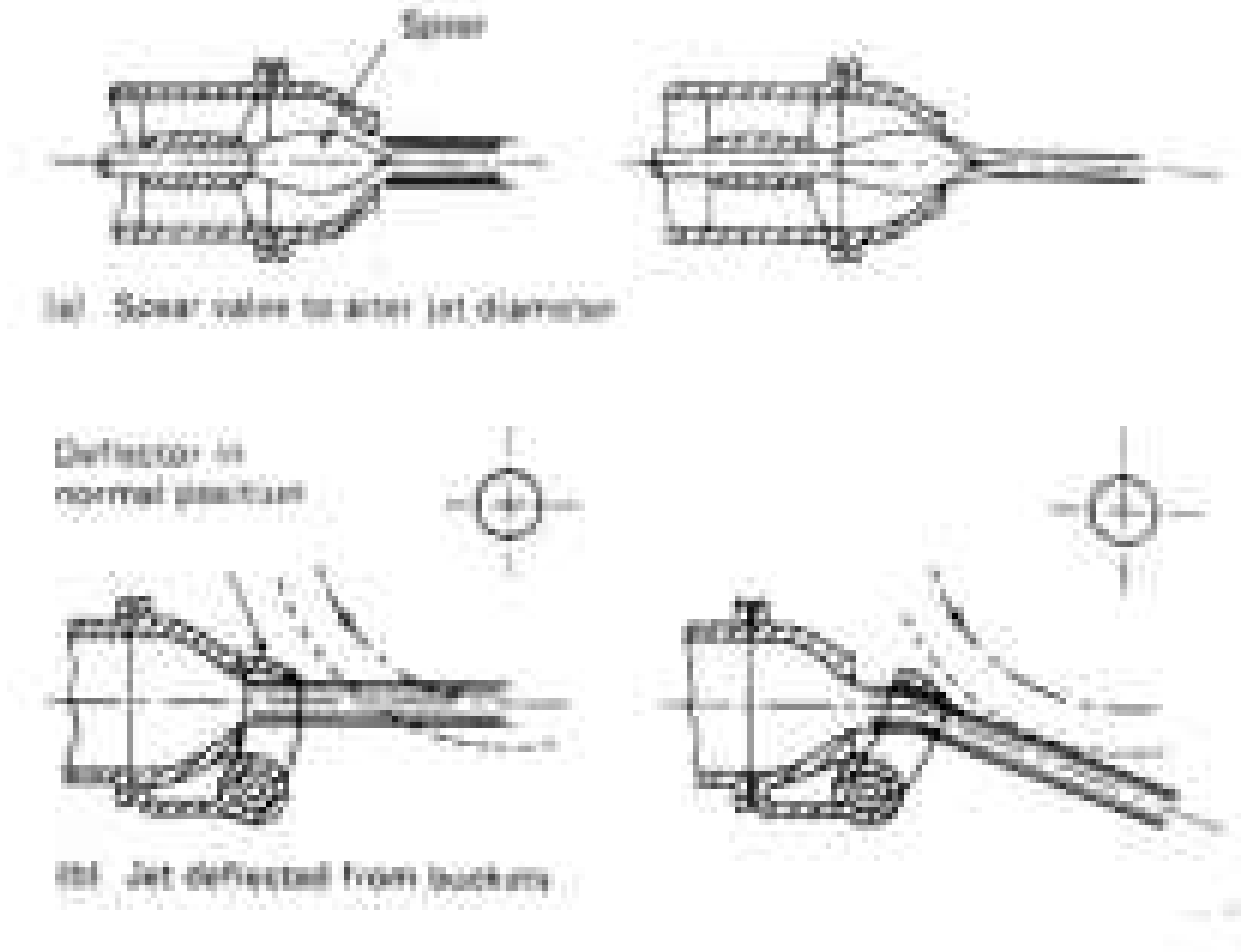
B2.2.4 Hydropower system design
Turbines: Pelton wheel: Jet



$$v_{jet} = C_j \sqrt{2gh} + v_{penstock}$$

0.94-0.98

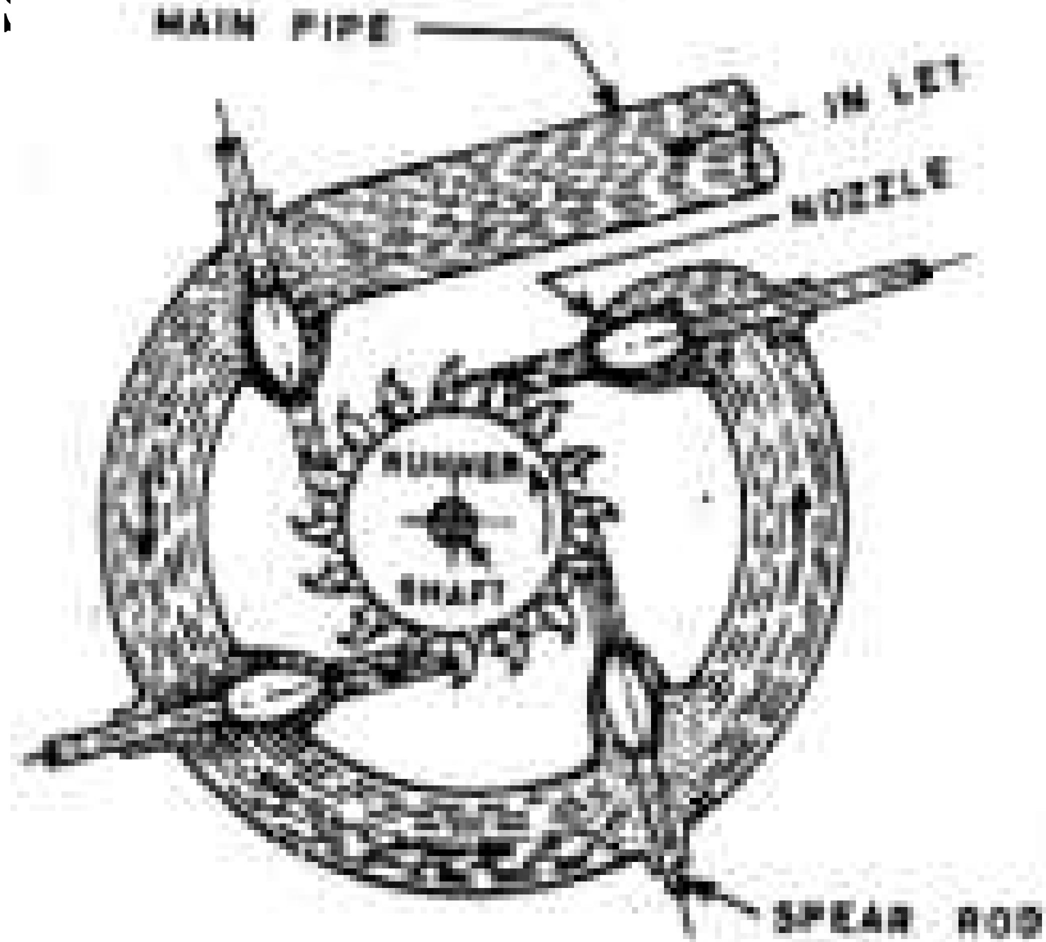
B2.2.4 Hydropower system design
Turbines: Pelton wheel



(a) Spear valve to alter jet diameter

(b) Jet deflected from buckets

B2.2.4 Hydropower system design
Turbines: Pelton wheel: Multi jet



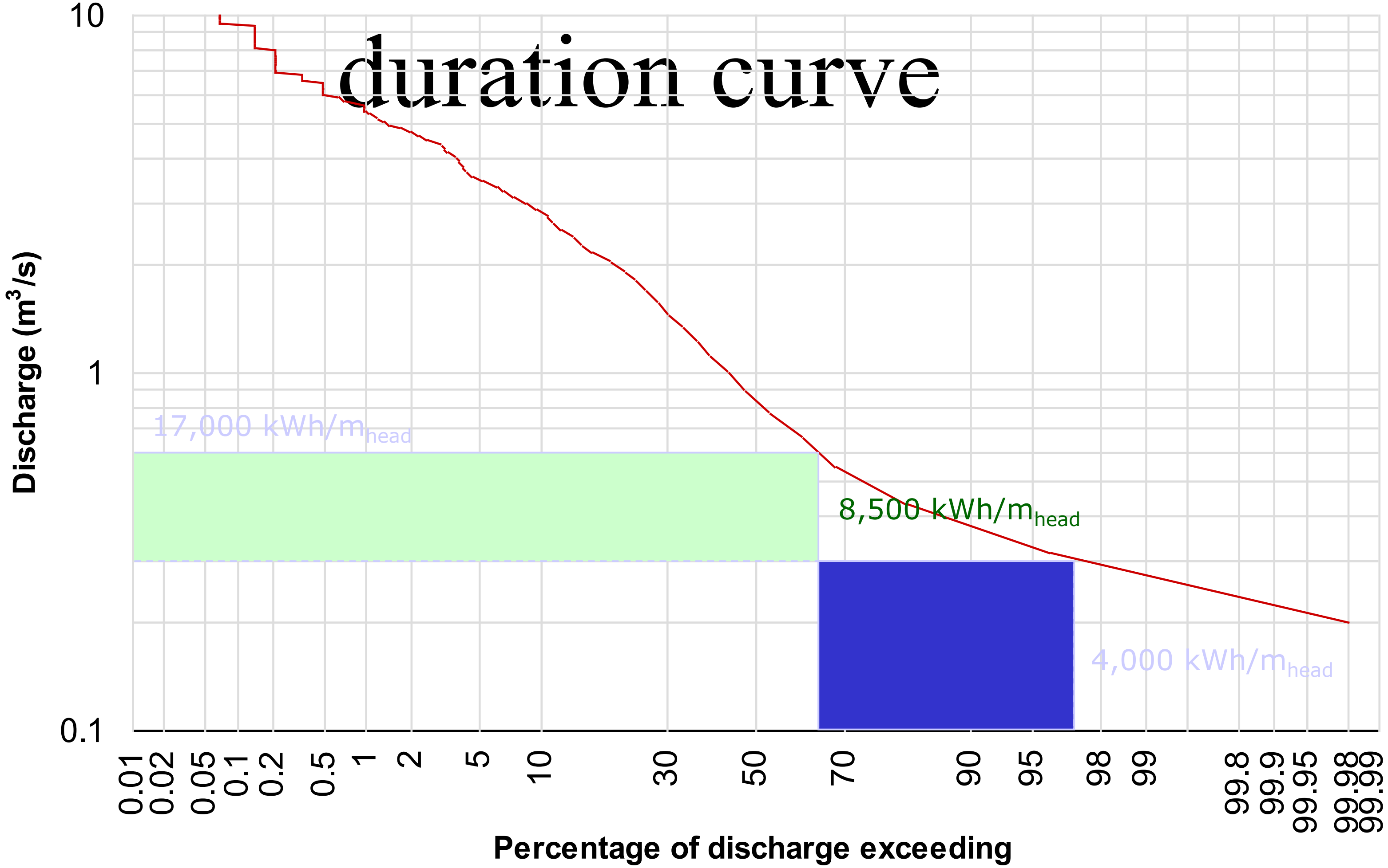
B2.2.4 Hydropower system design
Turbines: Pelton wheel: Multi jet

- Higher rotational speed
- Smaller runner
- Simple flow control possible
- Redundancy
- Can cope with a large range of flows

But

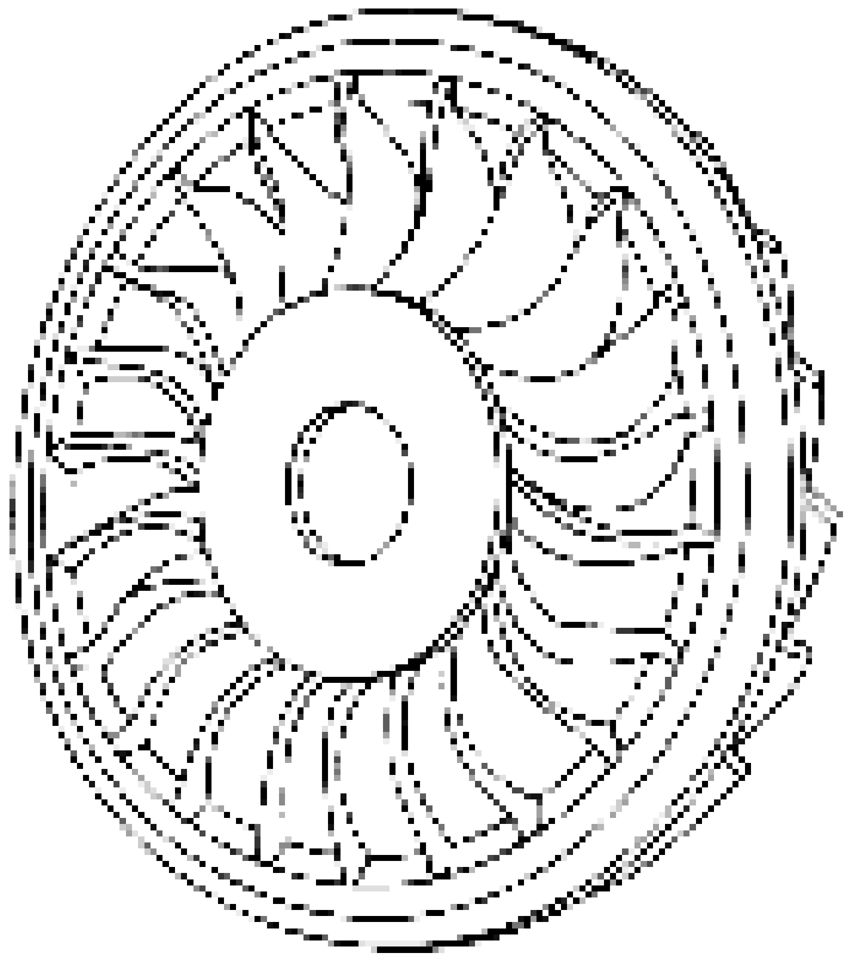
- Needs complex manifold
- May make control/governing complex

B2.1.4 Fundamentals of Hydro power
Yields and economics: Flow-duration curve

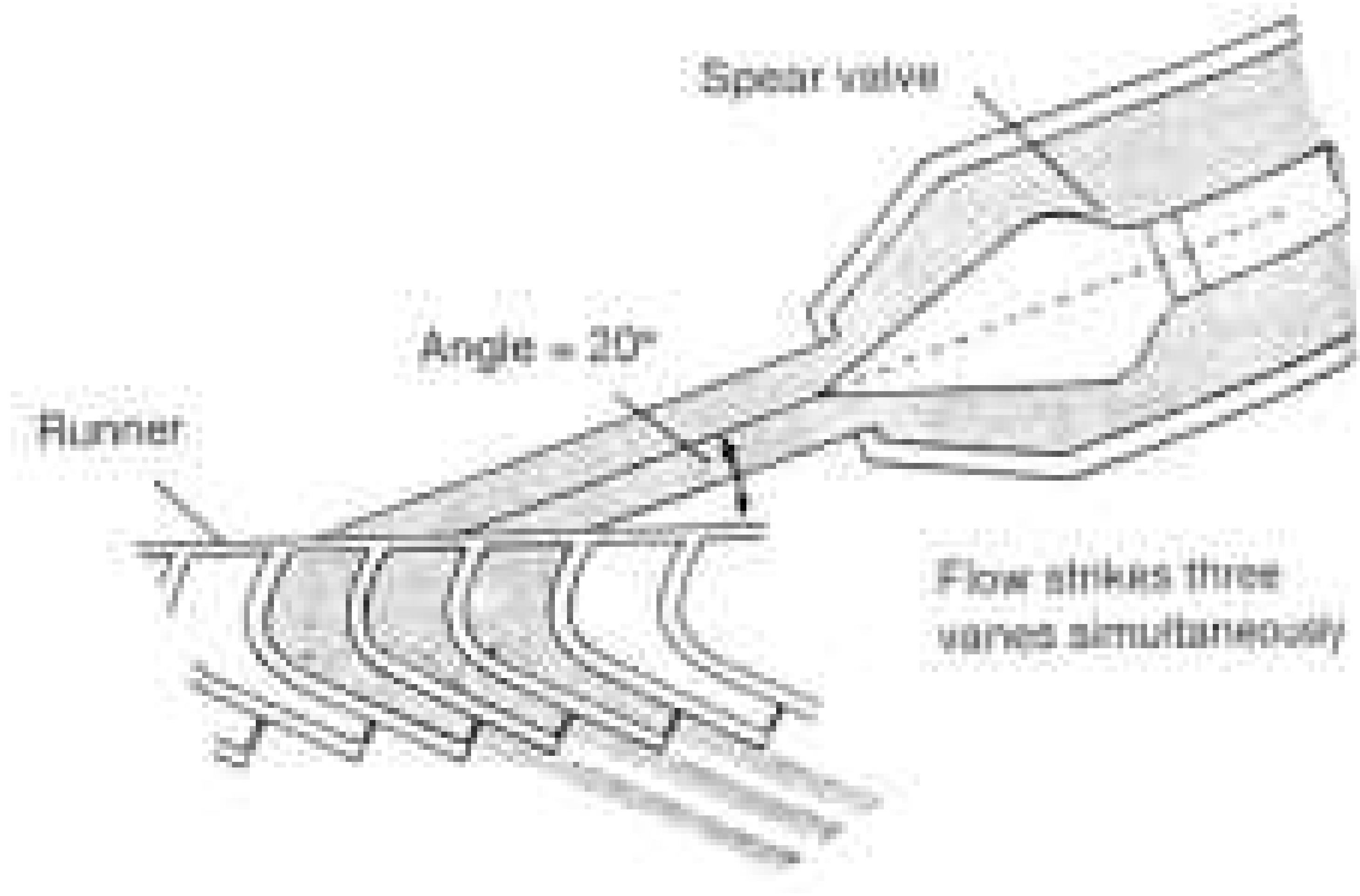


B2.2.4 Hydropower system design Turbines: Pelton wheel: Sri Lankan

B2.2.4 Hydropower system design
Turbines: Turgo (1904)



B2.2.4 Hydropower system design

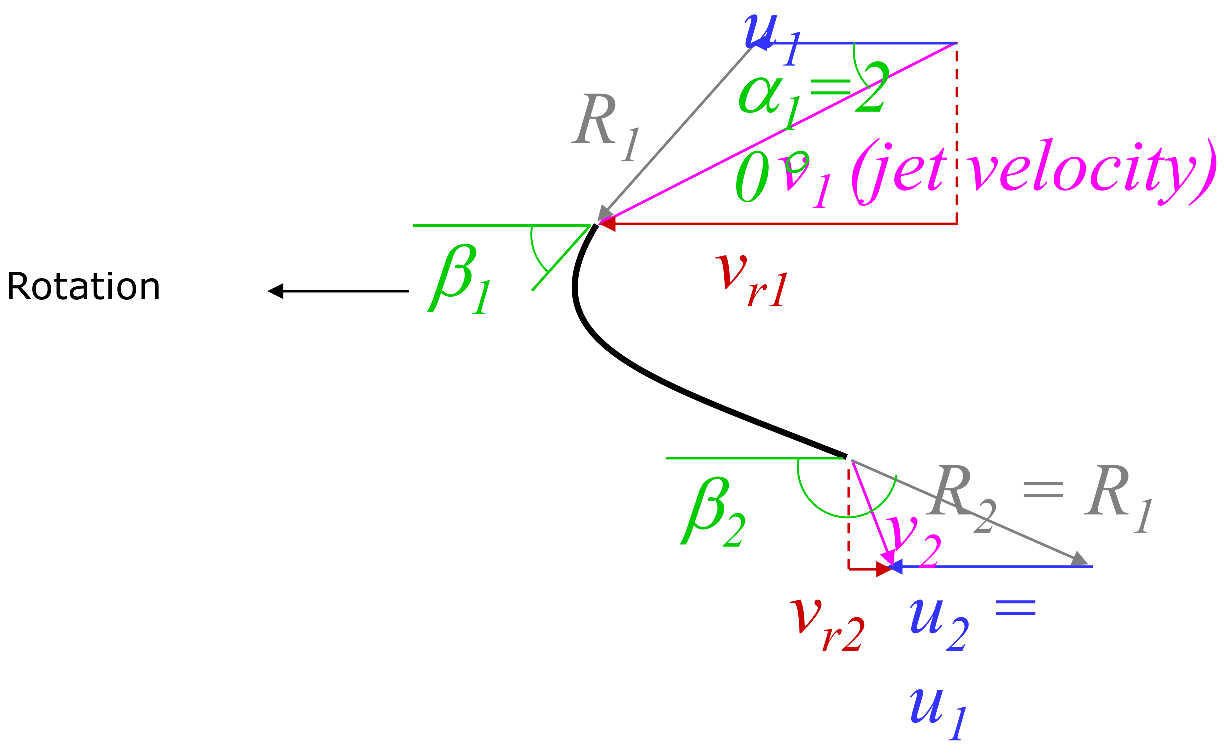


B2.2.4 Hydropower system design

Turbines: Turgo

B2.2.4 Hydropower system design
Turbines: Turgo

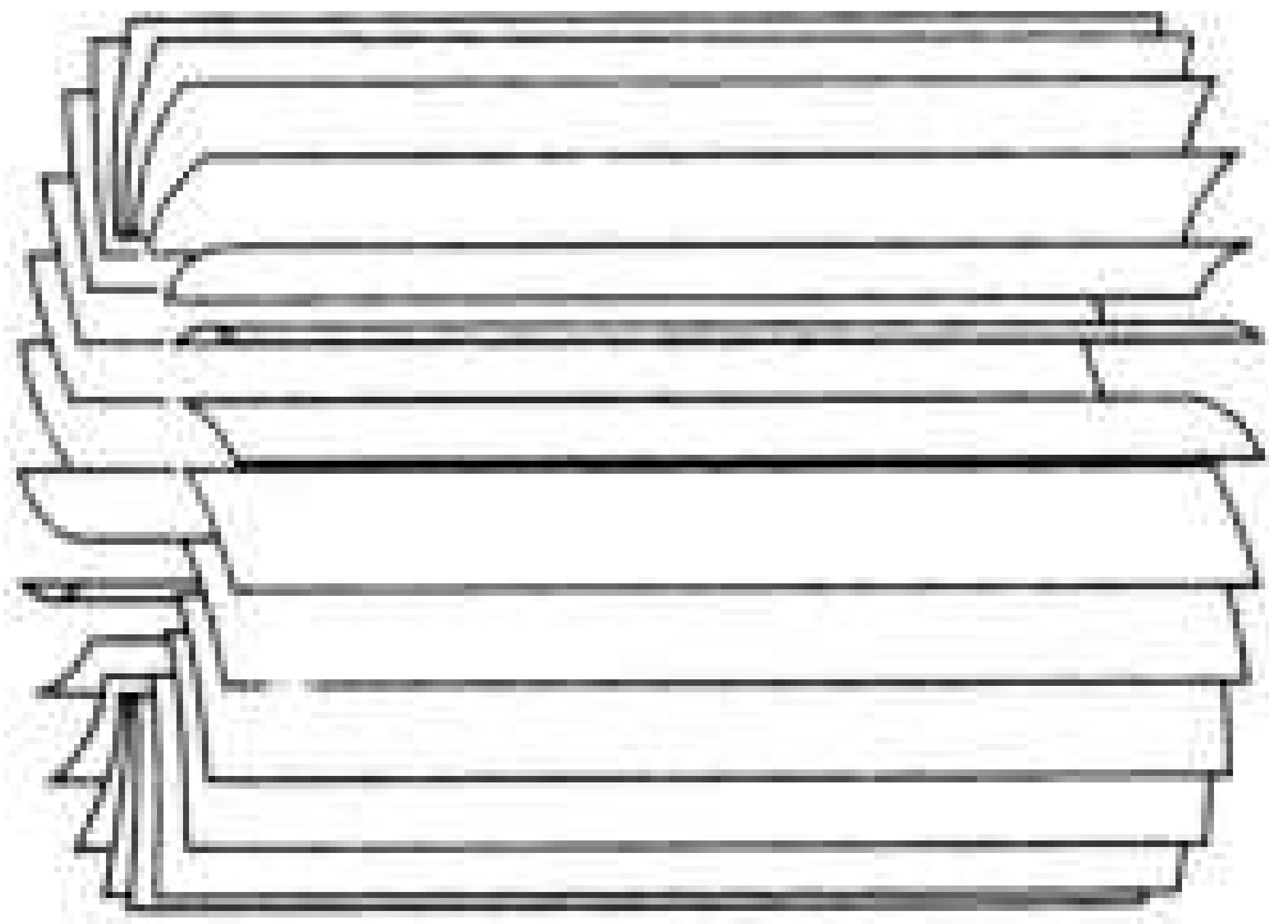
B2.2.4 Hydropower system design
Turbines: Turgo



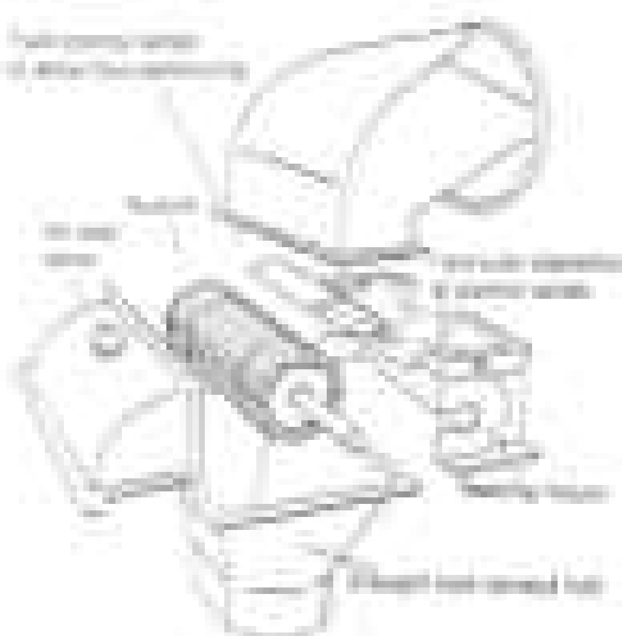
B2.2.4 Hydropower system design
Turbines: Turgo: MPPU – based

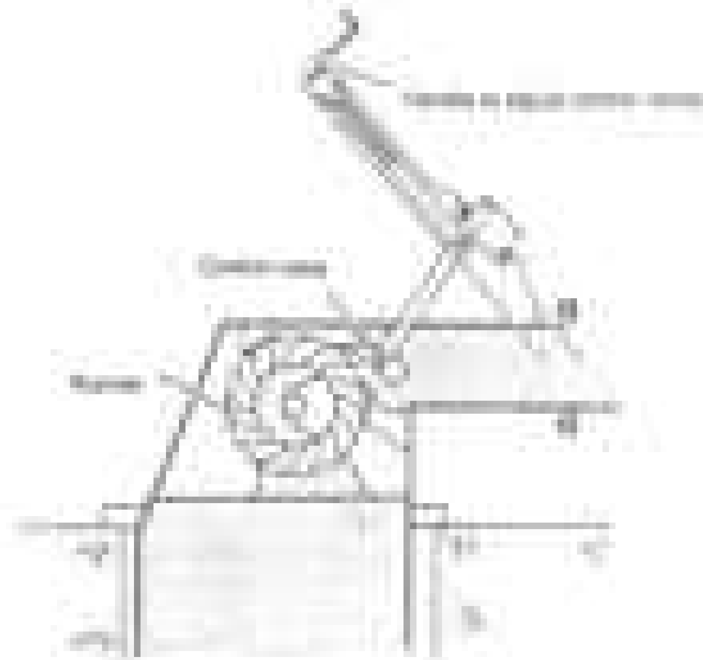
B2.2.4 Hydropower system design

T



B2.2.4 Hydropower system design
Turbines: Crossflow



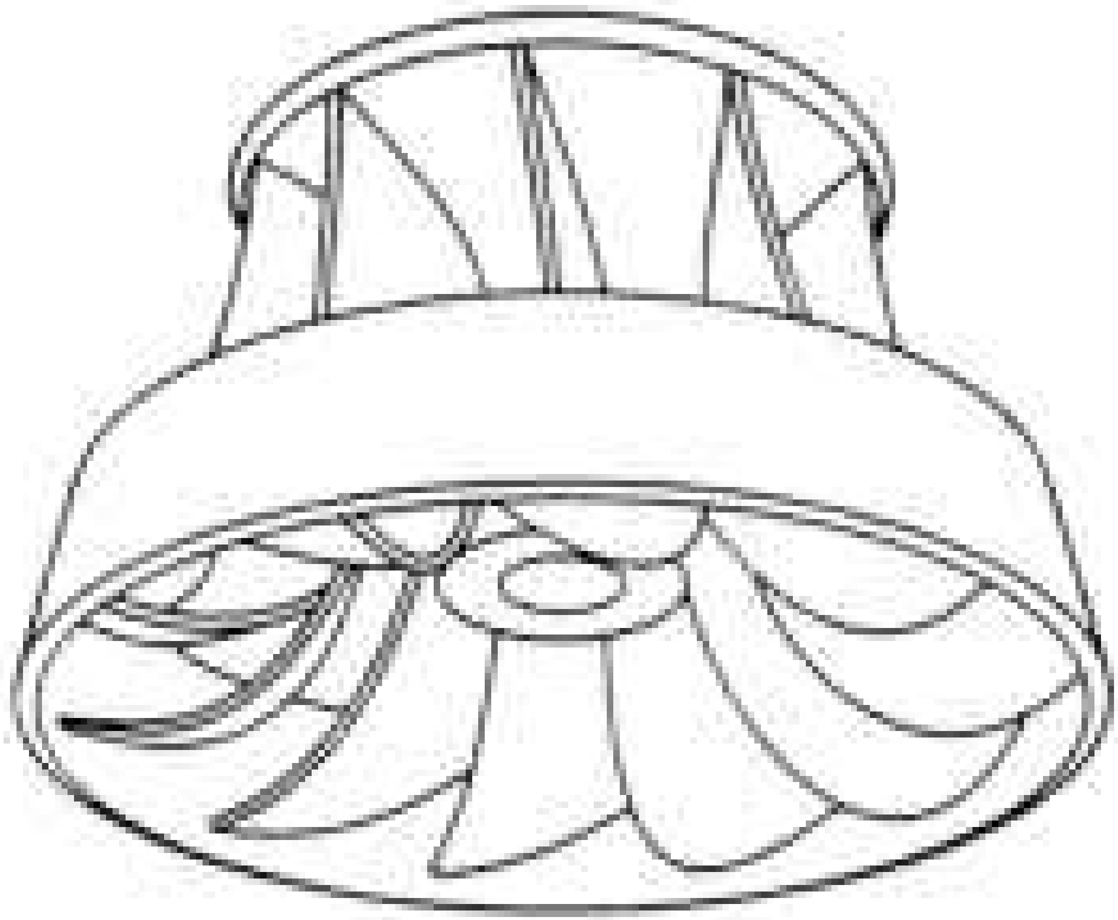


B2.2.4 Hydropower system design
Turbines: Crossflow: Panama

B2.2.4 Hydropower system design

Turbines: Crossflow

B2.2.4 Hydropower system design
Turbines: Francis (1849)



B2.2.4 Hydropower system design

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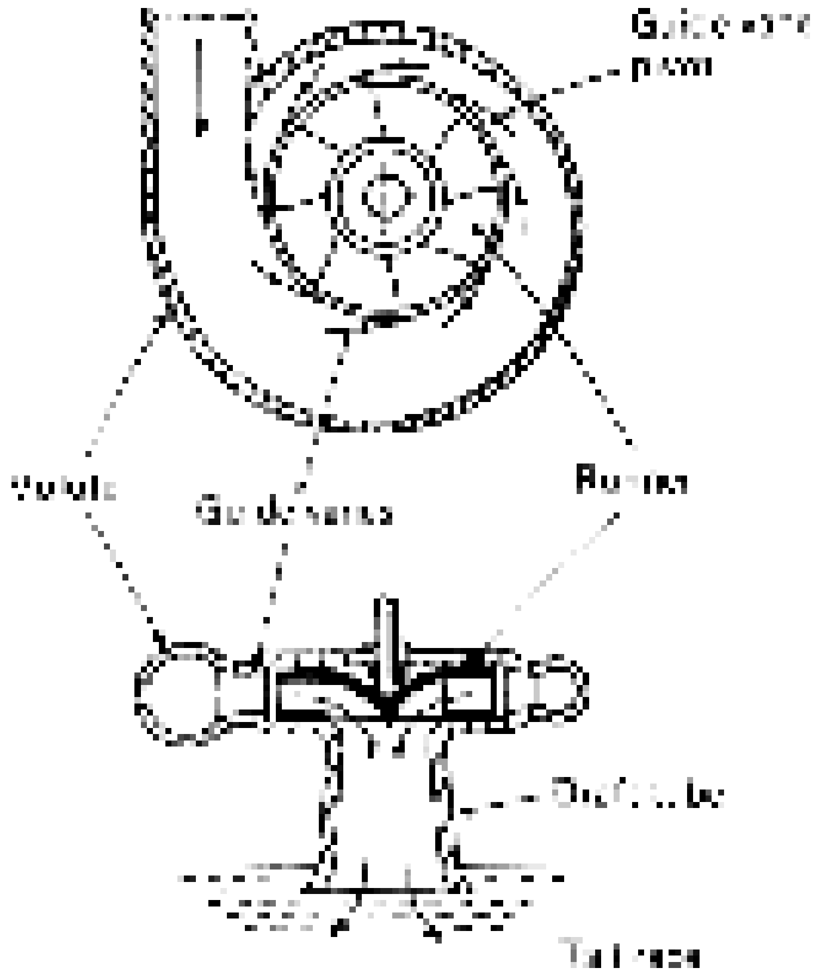


B2.2.4 Hydropower system design

Turbines: Francis

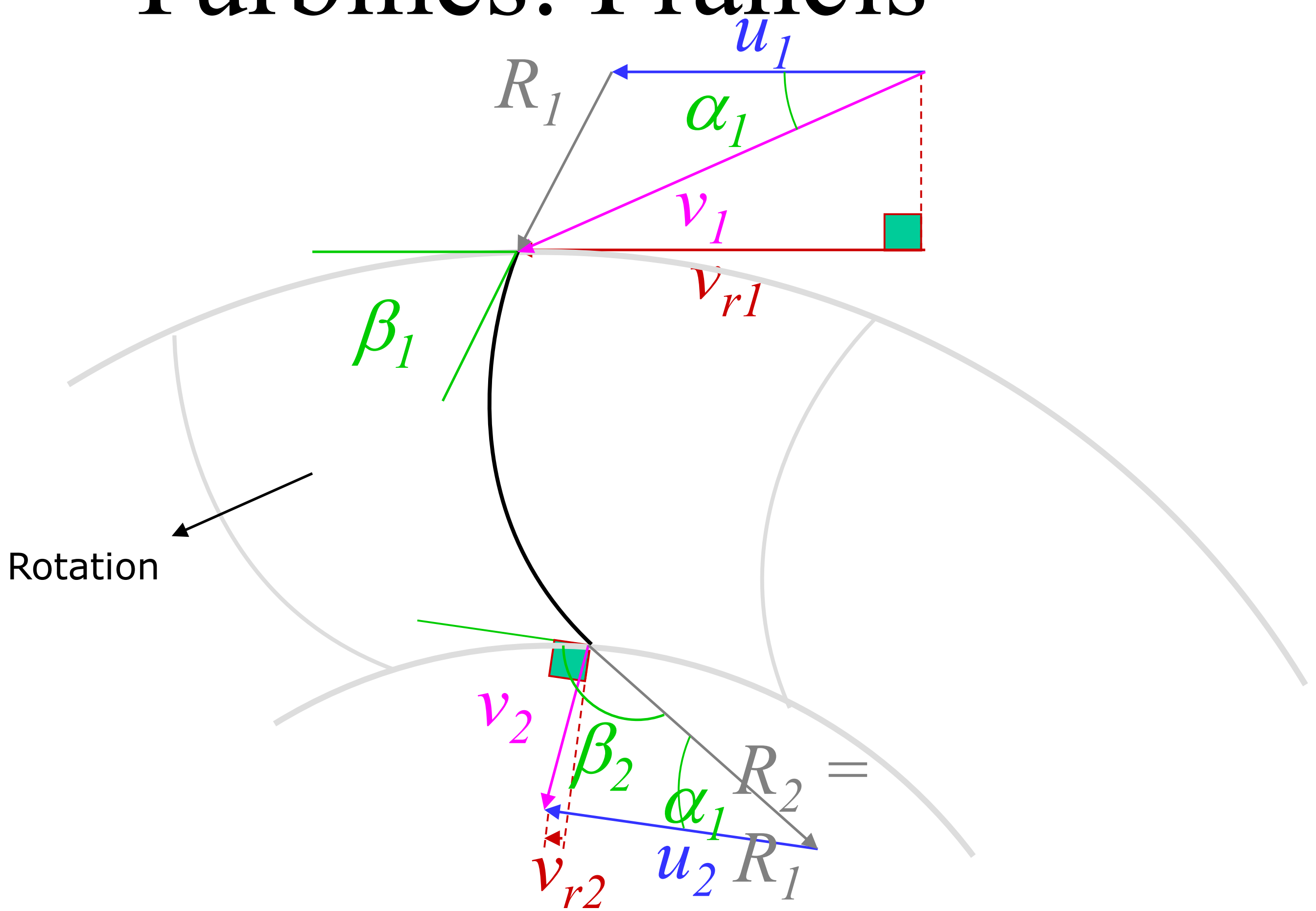
B2.2.4 Hydropower system design

Turbines: Francis

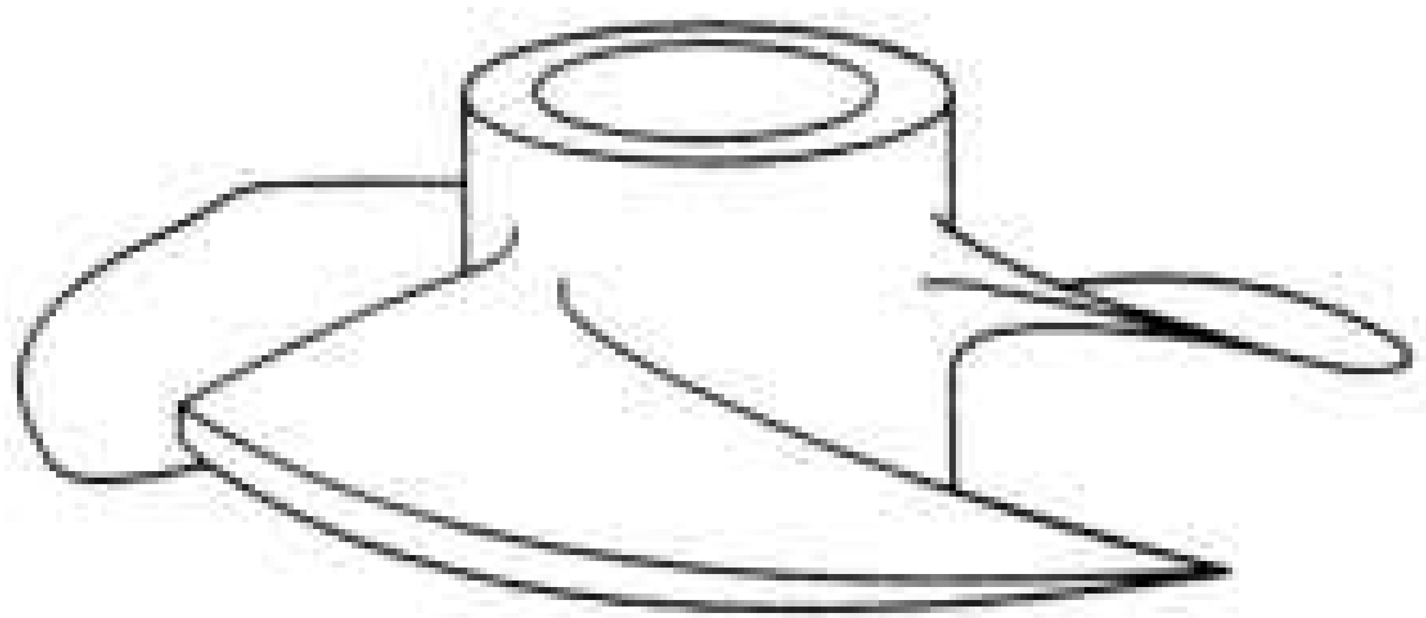
B2.2.4 Hydropower system design

Turbines: Francis

B2.2.4 Hydropower system design
Turbines: Francis



B2.2.4 Hydropower system design
Turbines: Propeller



B2.2.4 Hydropower system design

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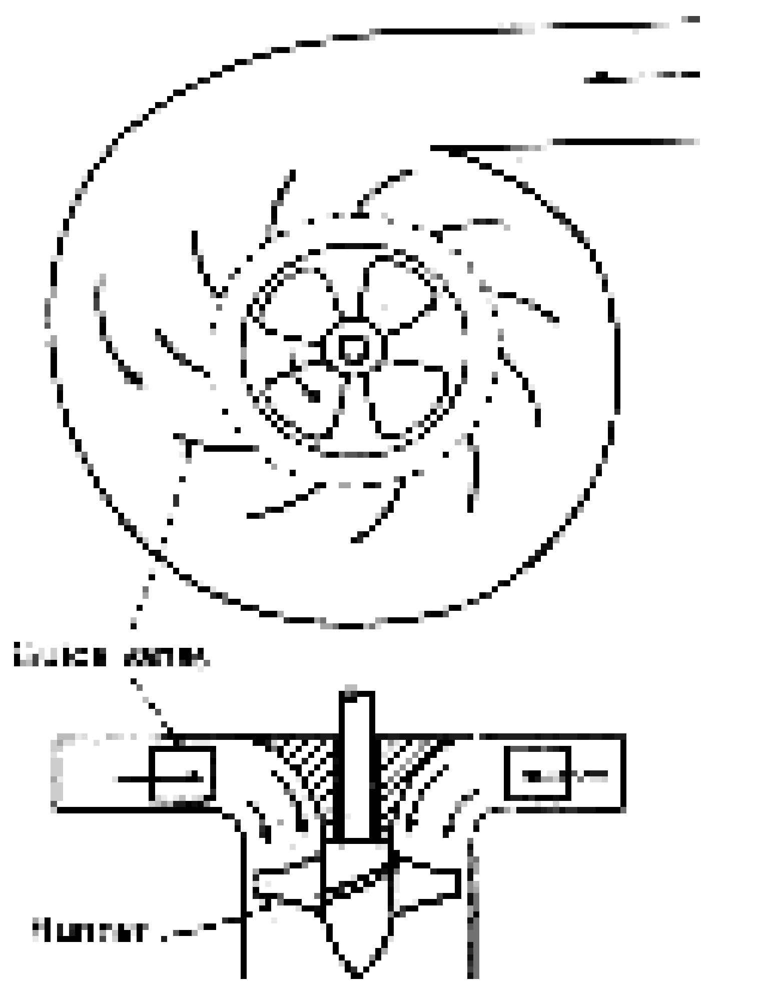
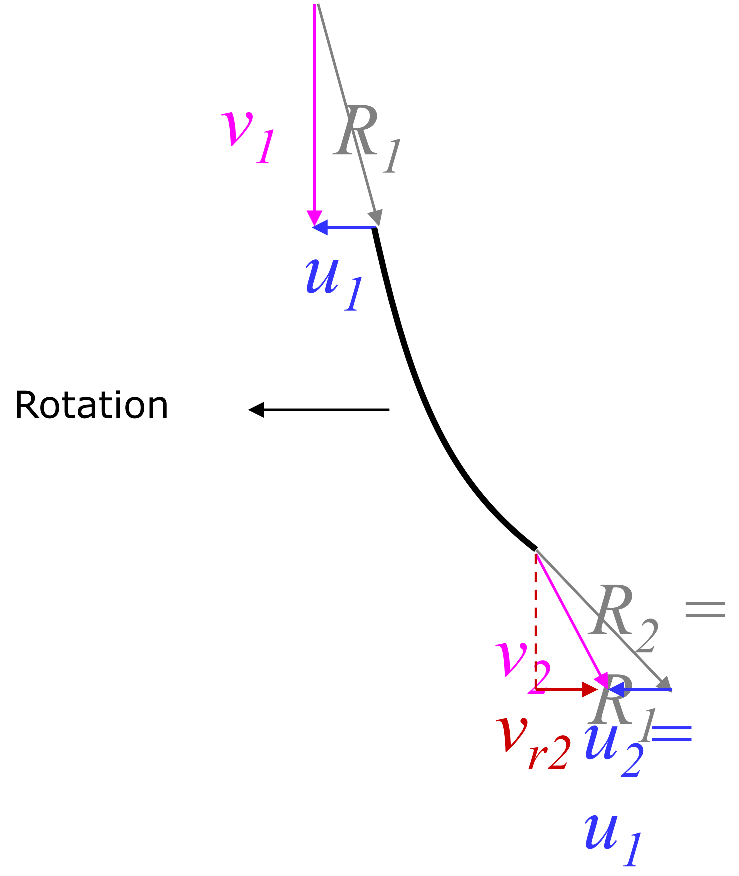
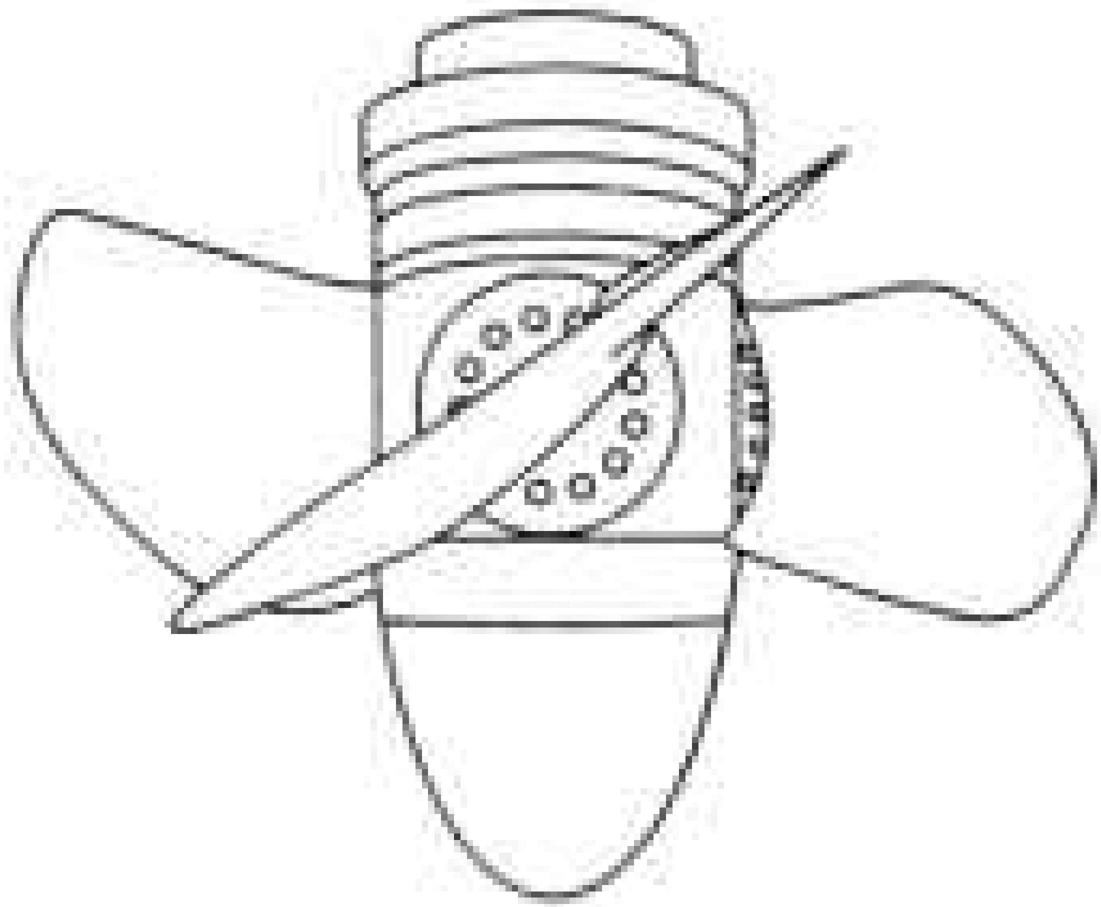


B2.2.4 Hydropower system design
Turbines: Propeller



B2.2.4 Hydropower system design

Turbines: Kaplan (1913)



B2.2.4 Hydropower system design

Turbines: Kaplan

B2.2.4 Hydropower system design

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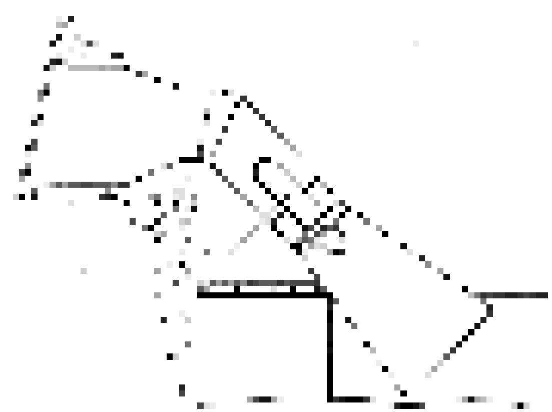
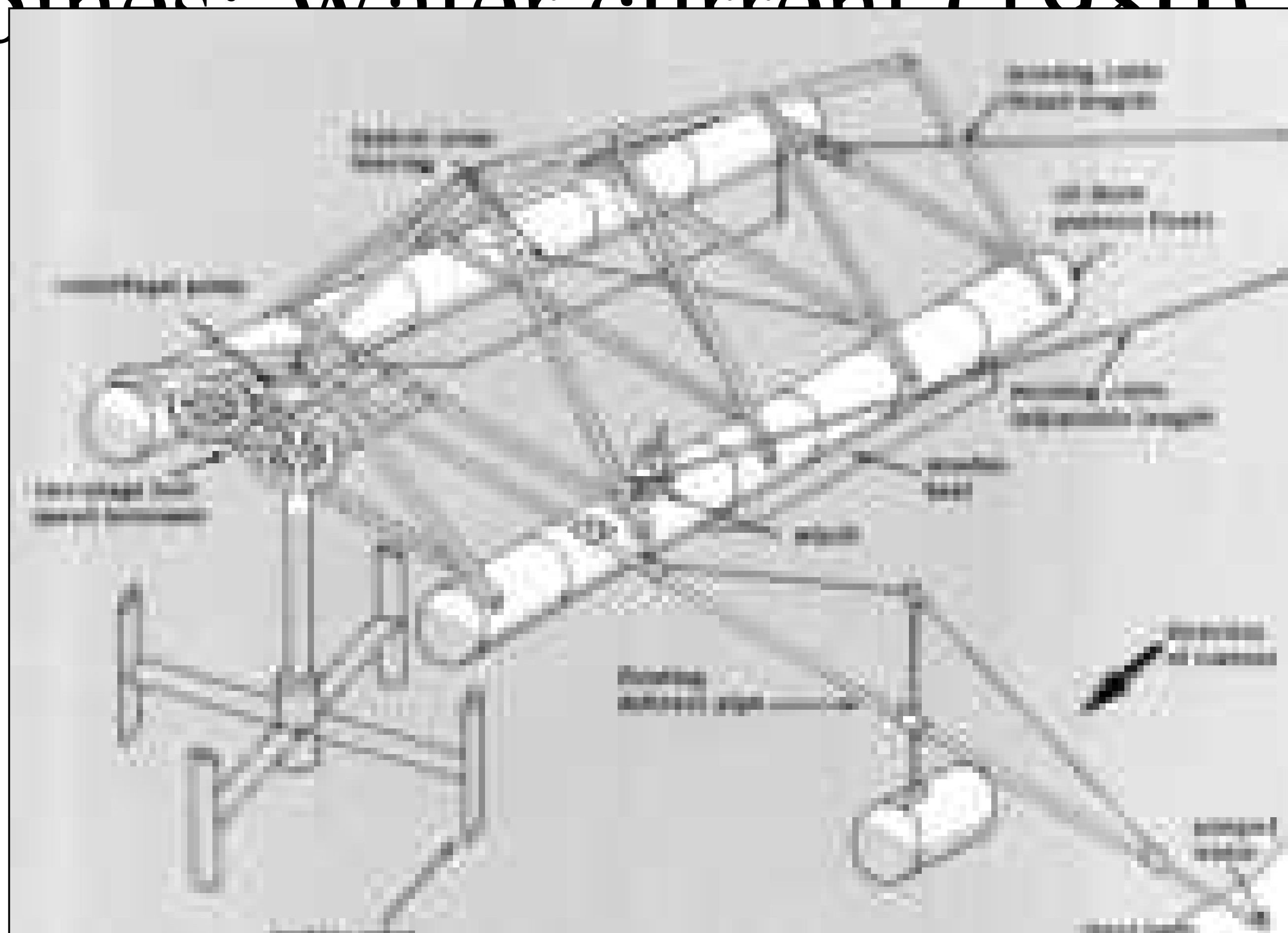


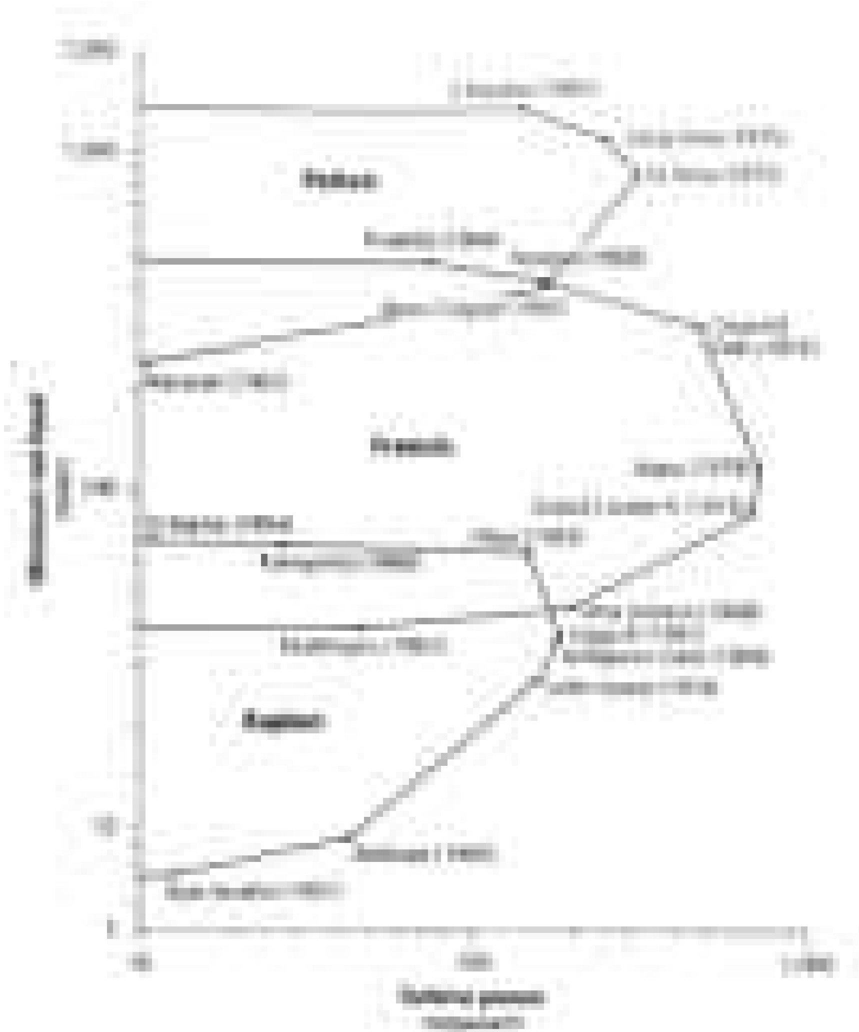
B2.2.4 Hydropower system design
Turbines: Water current (1980)



B2.2.4 Hydropower system design
Turbines: Water current

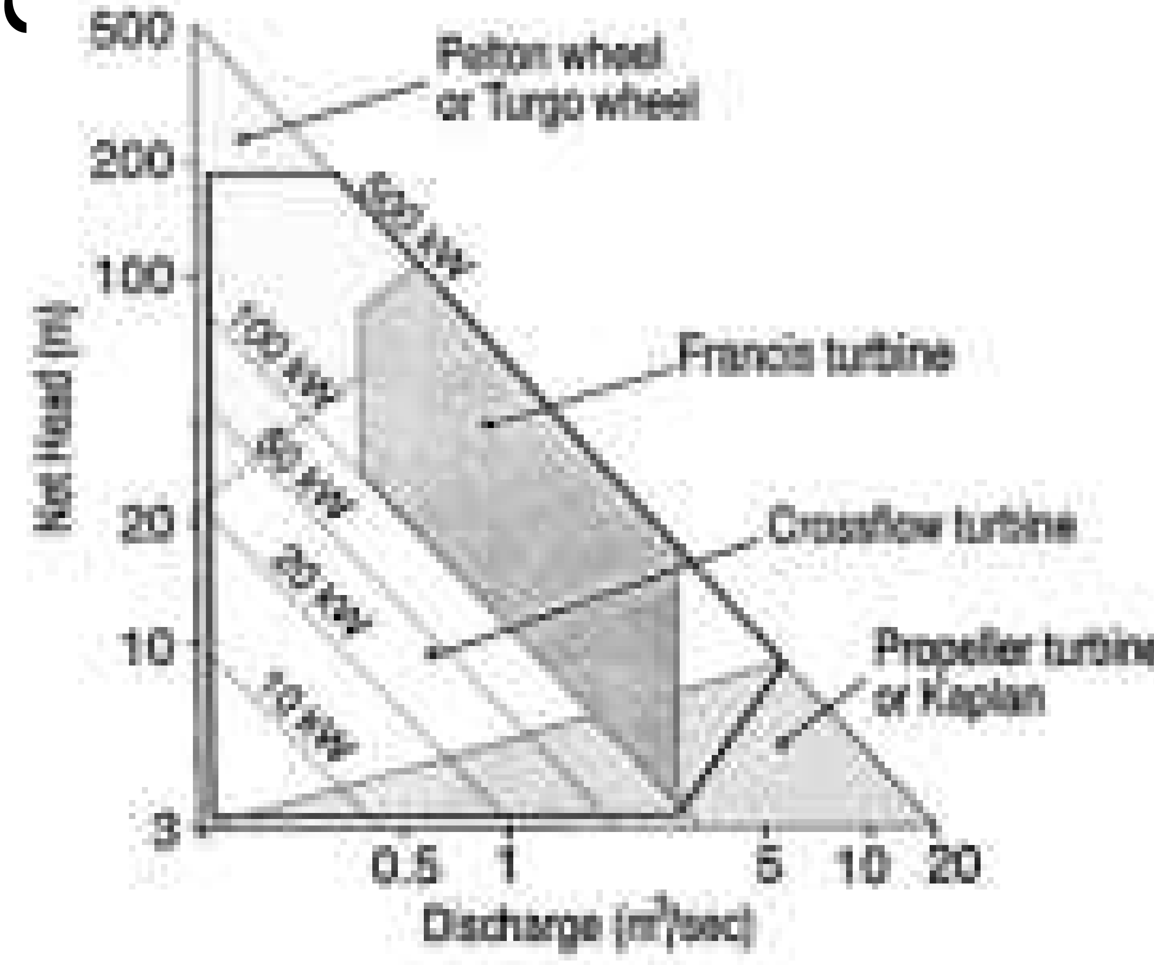
B2.2.4 Hydropower system design

Turbines: bines



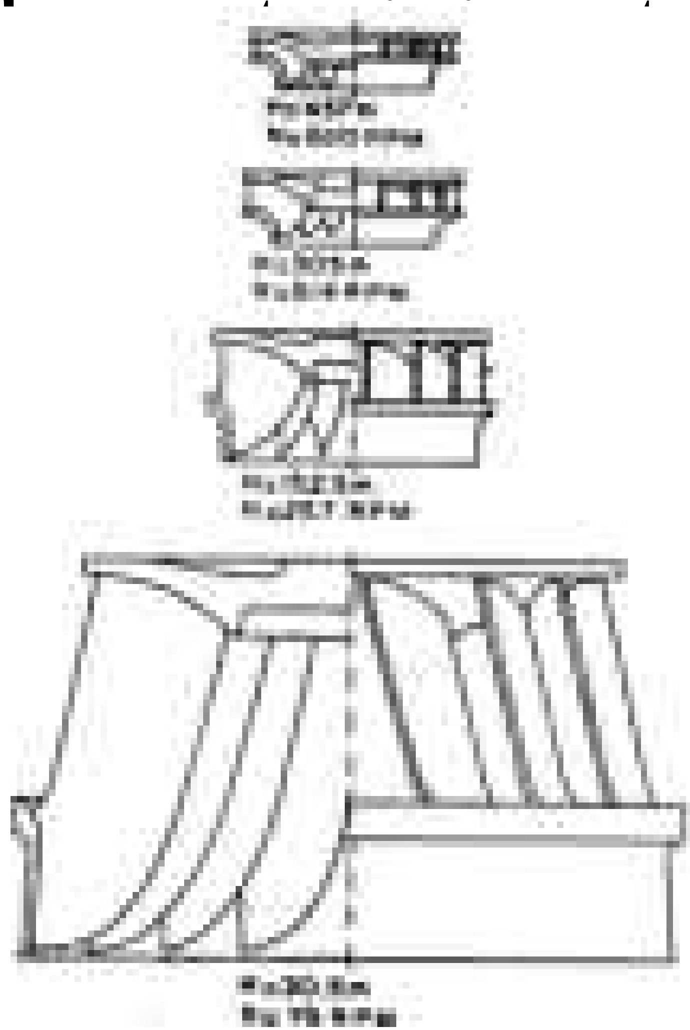
B2.2.4 Hydropower system design

Turbine es



B2.2.4 Hydropower system design

Turbines: C ... rbines



B2.2.4 Hydropower system design
Turbines: Characterising turbines: Dimensionless groups

$$C_Q = \frac{Q}{ND^3} \propto \frac{\text{Fluid velocity}}{\text{Blade velocity}}$$

$$C_H = \frac{gH}{N^2 D^2}$$

$$C_P = \frac{P}{\rho N^3 D^5}$$

C_Q = flow coefficient

C_H = head coefficient

C_P = power coefficient

Q = discharge

N = rotational speed

B2.2.4 Hydropower system design
Turbines: Characterising turbines: Dimensionless groups: Specific speed

$$N_{sp} = \frac{C_P^{1/2}}{C_H^{5/4}}$$

$$= \frac{NP^{1/2}}{\rho^{1/2}\left(gH\right)^{5/4}}$$

$$N_{sp} = \frac{NP^{1/2}}{H^{5/4}}$$

N_{sp} = Specific speed

C_H = head coefficient

C_P = power coefficient

N = rotational speed

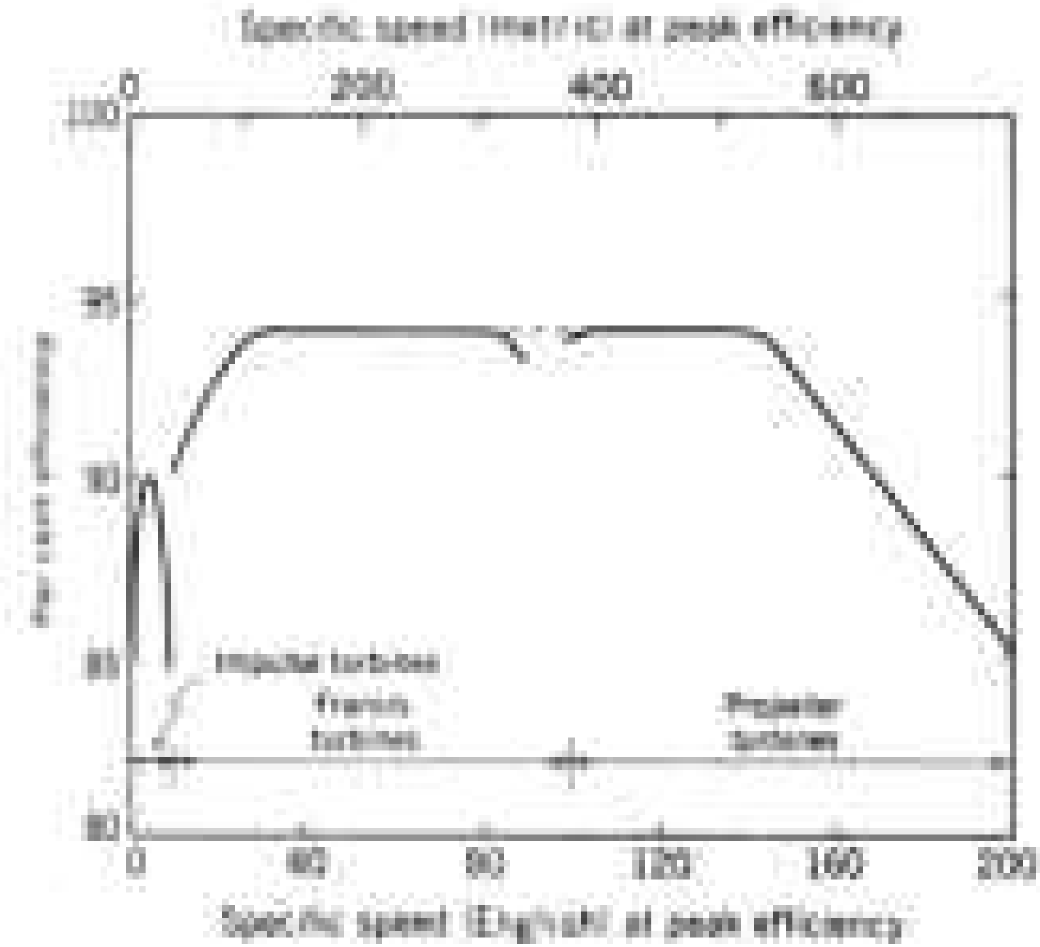
P = power

ρ = density

B2.2.4 Hydropower system design
Turbines: Characterising turbines: Specific speed: Dimensional

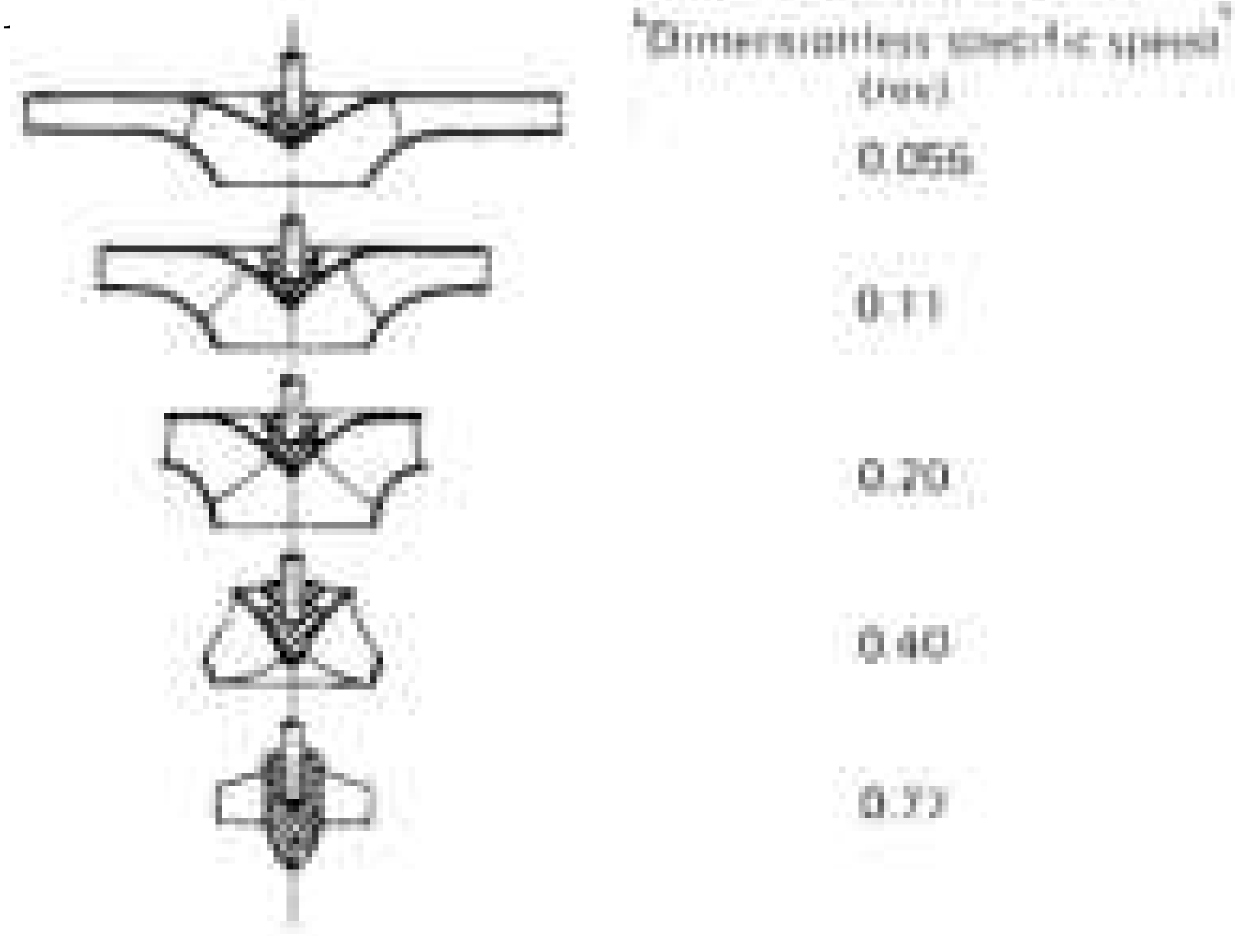
Type	Typical head	Rad	Rev	Metric	British
Pelton	>300	<0.2	<0.03	<30	<10
Francis	500-30	0.25-1.3	0.04-0.2	50-250	10-60
Kaplan	50-4	2-6	0.3-1	360-1200	100-300

B2.2.4 Hydropower system design
Turbines: Characterising turbines

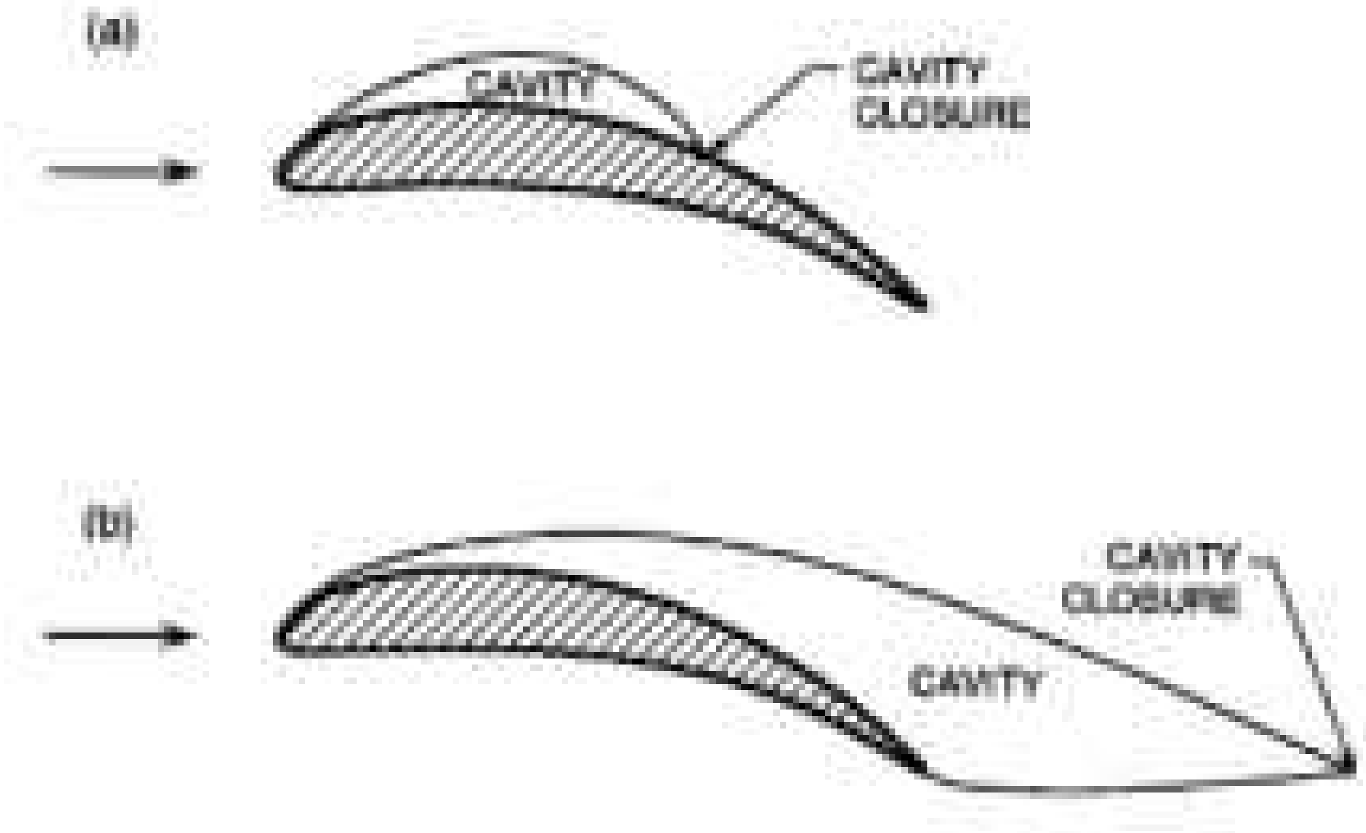


B2.2.4 Hydropower system design

Turbines: Characterising turbines



B2.2.4 Hydropower system design
Turbines: Cavitation



B2.2.4 Hydropower system design
Turbines: Cavitation

B2.2.4 Hydropower system design
Turbines: Cavitation

B2.2.4 Hydropower system design

Turbines: L-1 propeller turbine desi

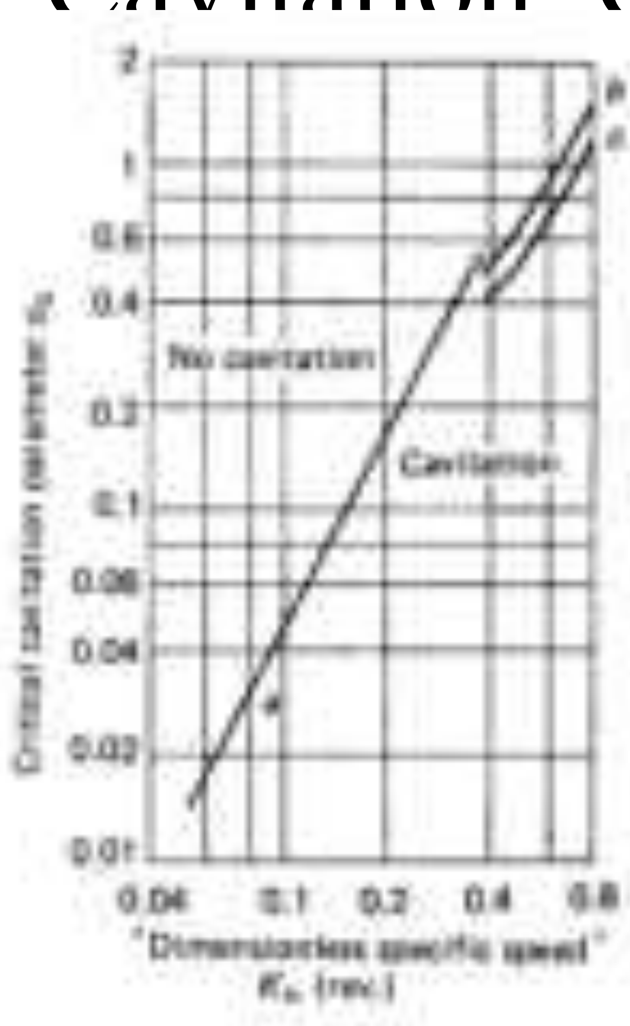
B2.2.4 Hydropower system design
Turbines: L-1 propeller turbine designed for minimal cavitation

B2.2.4 Hydropower system design
Turbines: Cavitation: Thoma number

$$\sigma = \frac{\dfrac{p_A}{\rho g} - \dfrac{p_v}{\rho g} - h_s}{H}$$

- σ = Thoma number
- p_a = atmospheric pressure
- p_v = vapour pressure
- h_s = elevation above tailwater
- H = total head

B2.2.4 Hydropower system design
Turbines: Cavitation: Critical



CO: Describe the concept of Impact of jet on plate in various condition

CHAPTER-04

IMPACT OF JET

Force exerted by the jet on a stationary plate

Impact of Jets

The jet is a stream of liquid comes out from nozzle with a high velocity under constant pressure. When the jet impinges on plates or vanes, its momentum is changed and a hydrodynamic force is exerted. Vane is a flat or curved plate fixed to the rim of the wheel

1. **Force exerted by the jet on a stationary plate**
   a) Plate is vertical to the jet
   b) Plate is inclined to the jet
   c) Plate is curved
2. **Force exerted by the jet on a moving plate**

Impulse-Momentum Principle

From Newton's 2nd Law:

$$F = m\,a = m\,(V_1 - V_2)\,/\,t$$

Impulse of a force is given by the change in momentum caused by the force on the body.

$$Ft = mV_1 - mV_2 = \text{Initial Momentum} - \text{Final Momentum}$$

Force exerted by jet on the plate in the direction of

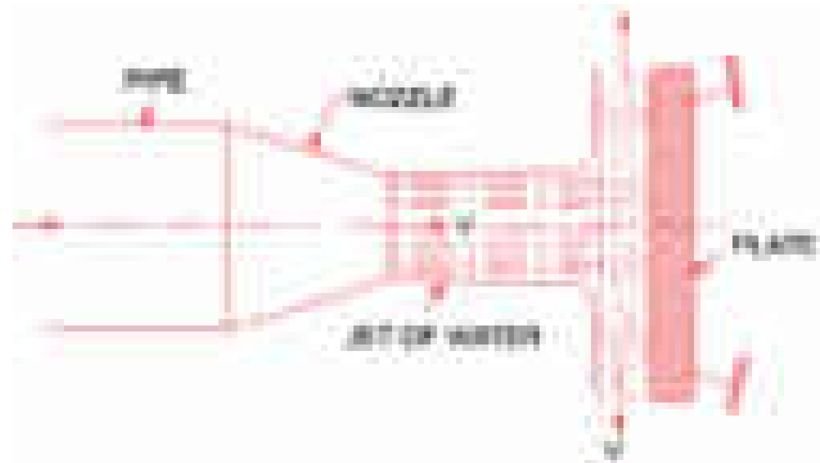
Force exerted by the jet on a stationary plate

Plate is vertical to the jet

$$F = \rho a V^2$$

If Plate is moving at a velocity of ‘U’ m/s,

$$F = \rho a (V-U)^2$$



Problems:

1. A jet of water 50 mm diameter strikes a flat plate held normal to the direction of jet. Estimate the force exerted and work done by the jet if

a. The plate is stationary

b. The plate is moving with a velocity of 1 m/s away from the jet along the line of jet.

The discharge through the nozzle is 76 lps.

2. A jet of water 50 mm diameter exerts a force of 3 kN on a flat vane held perpendicular to the direction of jet. Find the mass flow rate.

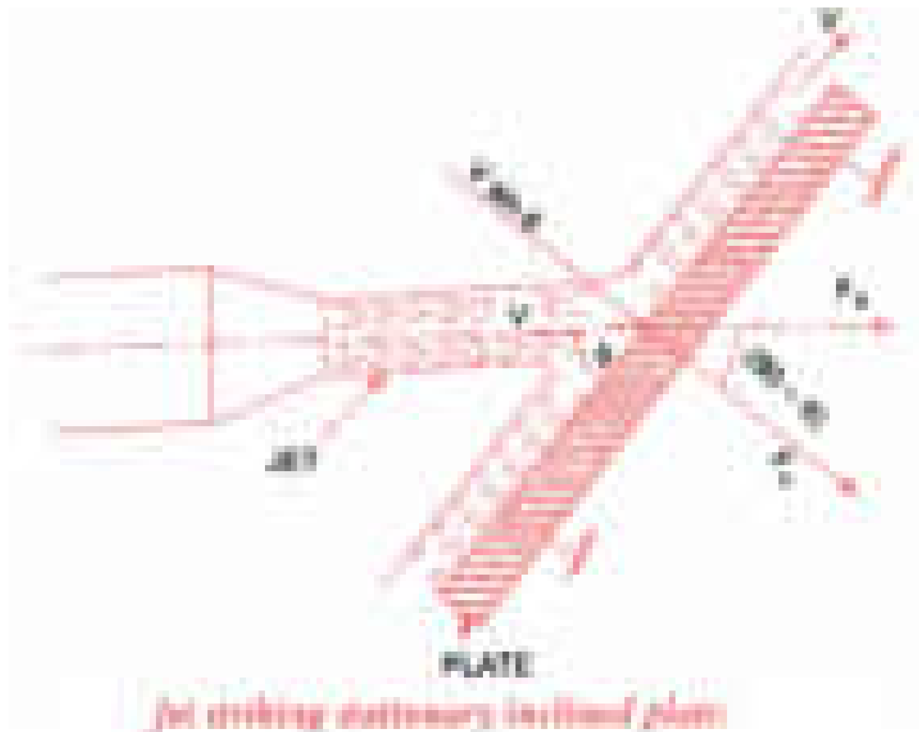
Force exerted by the jet on a stationary plate

Plate is inclined to the jet

$$F_N = \rho a V^2 \sin\theta$$

$$F_x = F_N \sin\theta$$

$$F_x = F_N \cos\theta$$



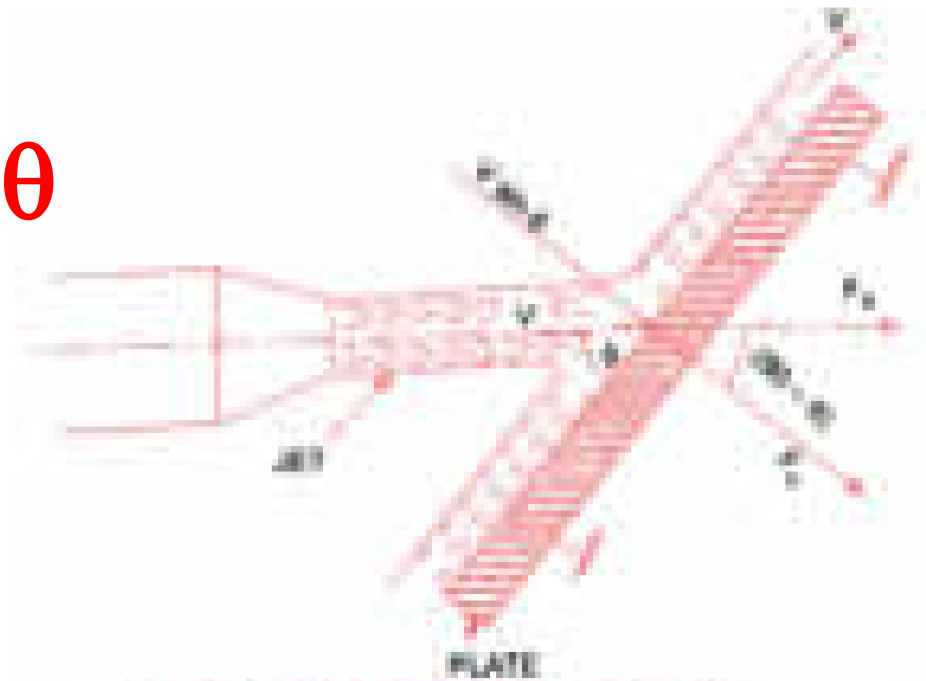
Force exerted by the jet on a moving plate

Plate is inclined to the jet

$$F_N = \rho a(V-U)^2 \sin\theta$$

$$F_x = F_N \sin\theta$$

$$F_x = F_N \cos\theta$$



Problems:

1. A jet of data 75 mm diameter has a velocity of 30 m/s. It strikes a flat plate inclined at 45^0 to the axis of jet. Find the force on the plate when.

a. The plate is stationary

b. The plate is moving with a velocity of 15 m/s along and away from the jet.

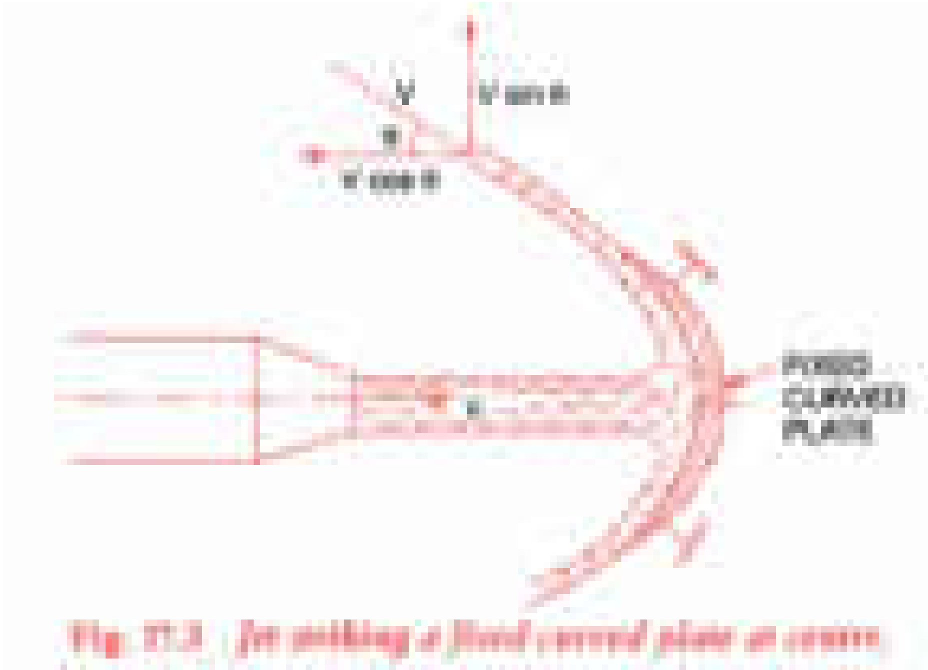
Also find power and efficiency in case (b)

2. A 75 mm diameter jet having a velocity of 12 m/s impinges a smooth flat plate, the normal of which is inclined at 60^0 to the axis of jet. Find the impact of jet on the plate at right angles to the plate when the plate

Force exerted by the jet on a stationary plate

Plate is Curved and Jet strikes at Centre

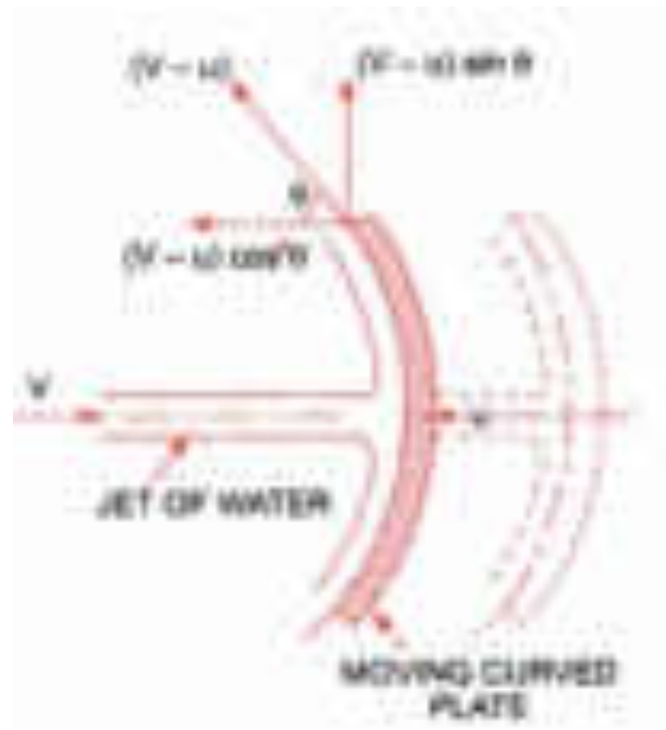
$$F = \rho a V^2 (1 + \cos\theta)$$



Force exerted by the jet on a moving plate

Plate is Curved and Jet strikes at Centre

$$F = \rho a(V-U)^2 (1 + \cos \theta)$$



Problems:

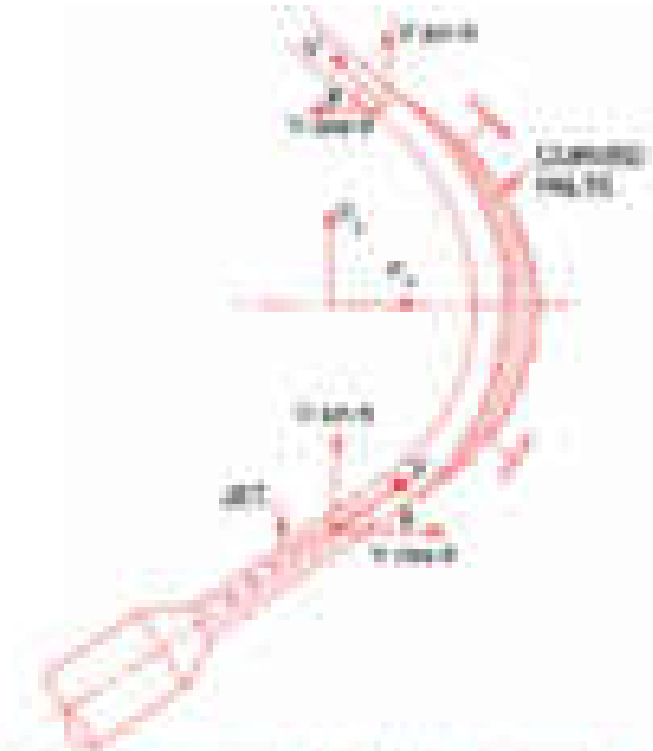
1. A jet of water of diameter 50 mm strikes a stationary, symmetrical curved plate with a velocity of 40 m/s. Find the force extended by the jet at the centre of plate along its axis if the jet is deflected through 120^0 at the outlet of the curved plate

2. A jet of water from a nozzle is deflected through 60^0 from its direction by a curved plate to which water enters tangentially without shock with a velocity of 30m/s and leaver with a velocity of 25 m/s. If the discharge from the nozzle is 0.8 kg/s, calculate the magnitude and direction of resultant force on the

Force exerted by the jet on a stationary plate (Symmetrical Plate)

Plate is Curved and Jet strikes at tip

$$F_x = 2\rho a V^2 \cos\theta$$



Force exerted by the jet on a stationary plate (Unsymmetrical Plate)

Plate is Curved and Jet strikes at tip

$$F_x = \rho a V^2 (\cos\theta + \cos\phi)$$

Problems:

1. A jet of water strikes a stationery curved plate tangentially at one end at an angle of 30^0 . The jet of 75 mm diameter has a velocity of 30 m/s. The jet leaves at the other end at angle of 20^0 to the horizontal. Determine the magnitude of force exerted along ‘x’ and ‘y’ directions.

Force exerted by the jet on a moving plate

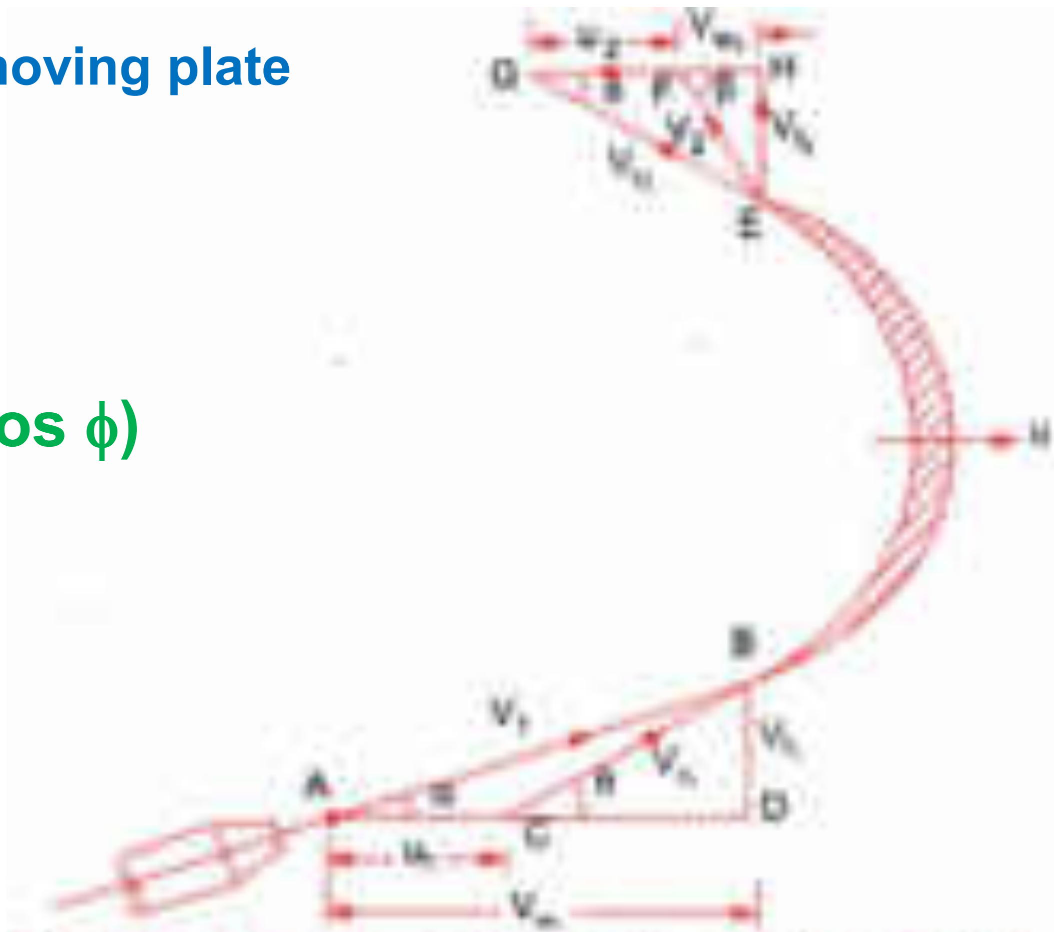
Considering Relative Velocity,

If $\beta < 90^0$

$$F_x = \rho a V_{r1} (V_{r1} \cos \theta + V_{r2} \cos \phi)$$

OR

$$F_x = \rho a V_{r1} (V_{W1} + V_{W2})$$



Jet striking a moving curved vane at one of the tips.

Force exerted by the jet on a moving plate

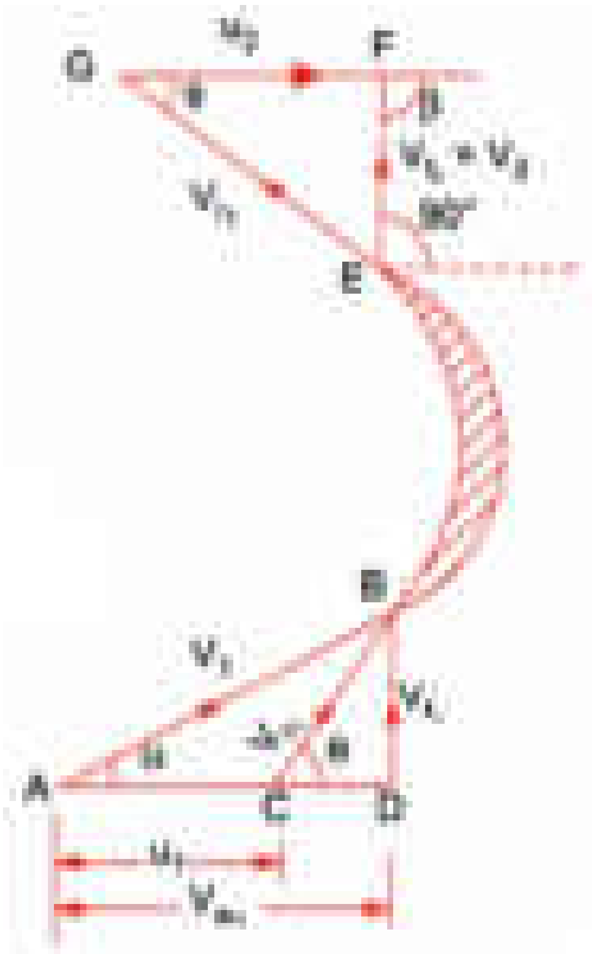
Considering Relative Velocity,

If $\beta = 90^0$

$$F_x = \rho a V_{r1} (V_{r1} \cos \theta - V_{r2} \cos \phi)$$

OR

$$F_x = \rho a V_{r1} (V_{W1})$$



Force exerted by the jet on a moving plate

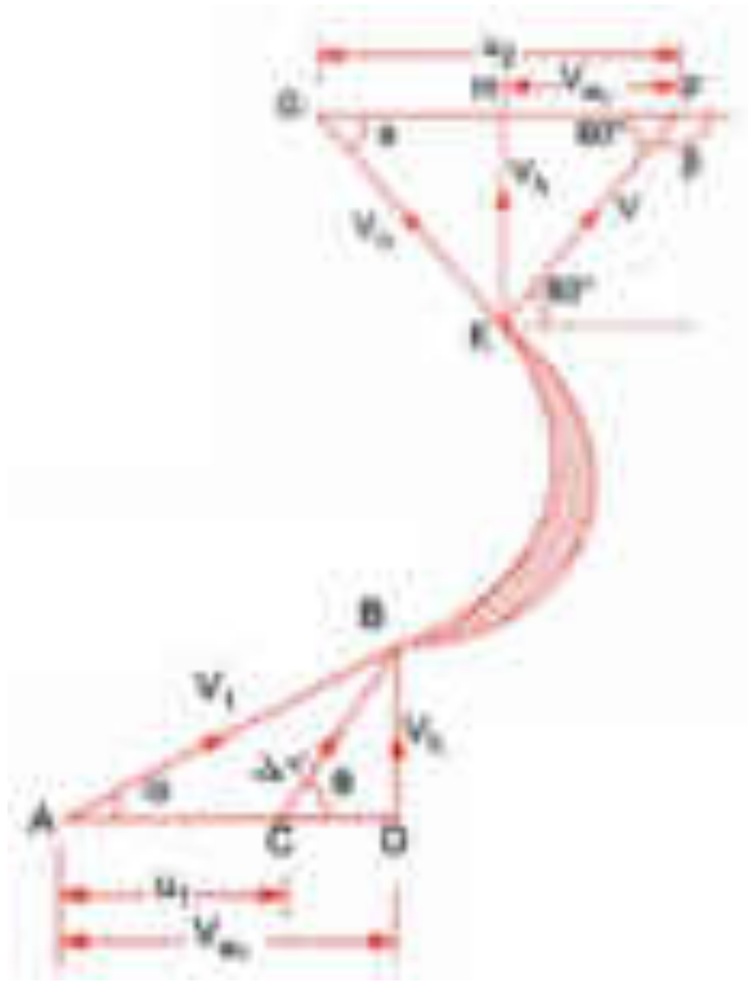
Considering Relative Velocity,

If $\beta = 90^0$

$$F_x = \rho a V_{r1} (V_{r1} \cos \theta - V_{r2} \cos \phi)$$

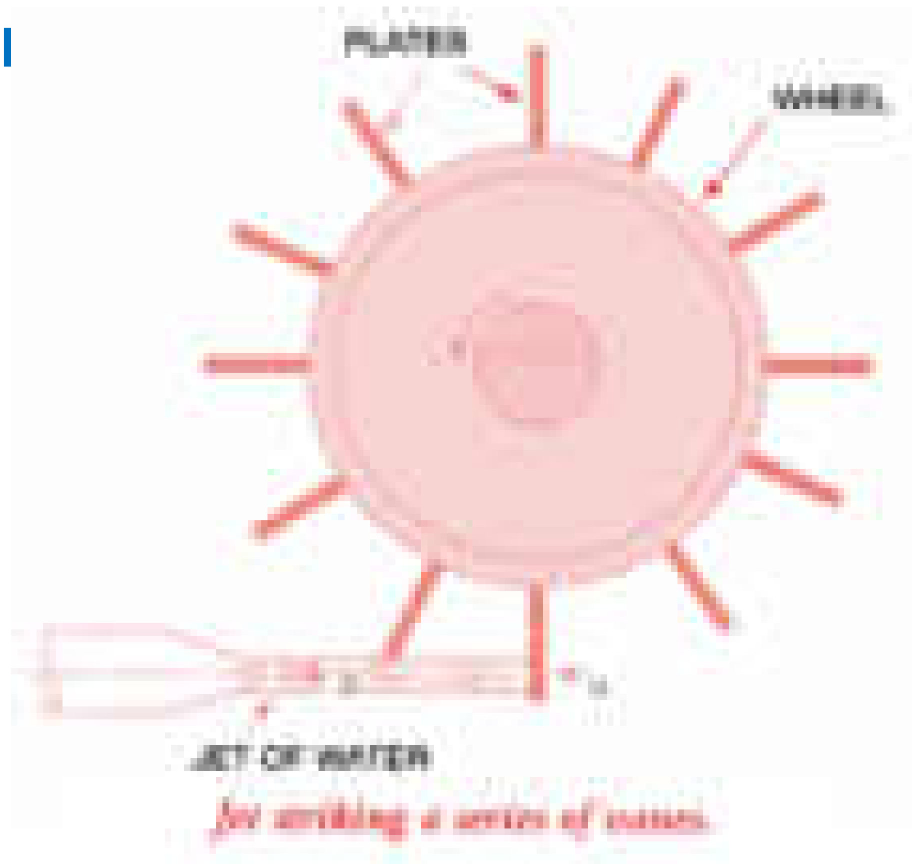
OR

$$F_x = \rho a V_{r1} (V_{W1} - V_{W2})$$



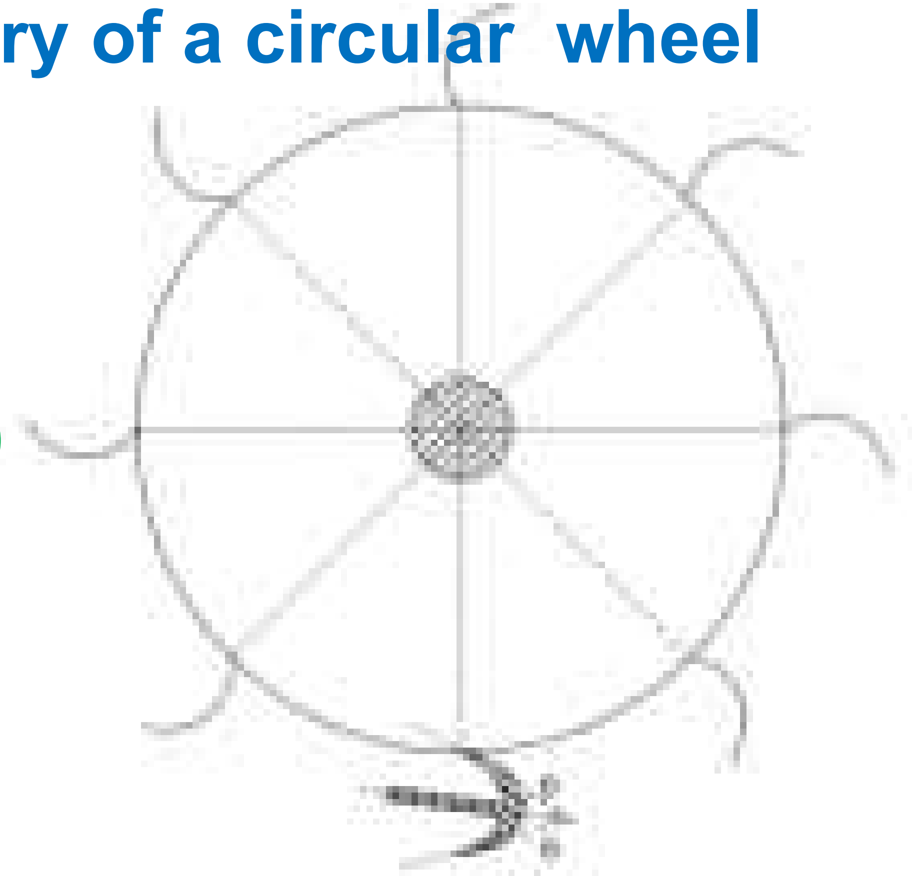
Impact of jet on a series of flat vanes mounted radially on the periphe

$$F = \rho a V (V-U)$$



Jet striking a series of vanes.

Impact of jet on a series of flat vanes mounted radially on the periphery of a circular wheel



$$F = \rho a V (V-U)(1+\cos\theta)$$

Problems:

1. A jet of water of diameter 75 mm strikes a curved plate at its centre with a velocity of 25 m/s. The curved plate is moving with a velocity of 10 m/s along the direction of jet. If the jet gets deflected through 165^0 in the smooth vane, compute.

a) Force exerted by the jet.
b) Power of jet.
c) Efficiency of jet.

2. A jet of water impinges a curved plate with a velocity of 20 m/s making an angle of 20^0 with the direction of motion of vane at inlet and leaves at 130^0

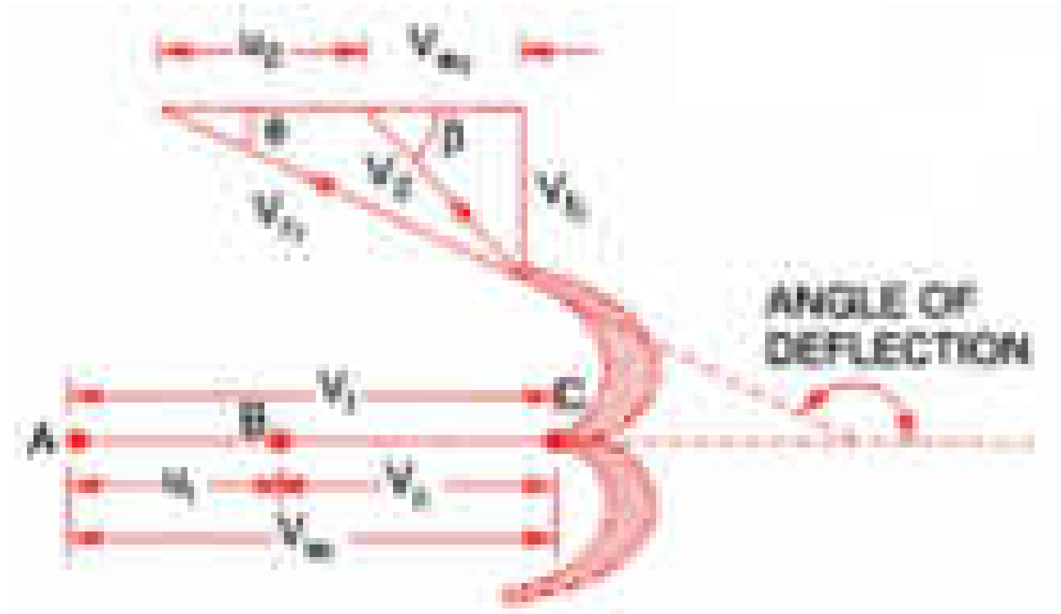
Force exerted by the jet on a moving plate (PELTON WHEEL)

Considering Relative Velocity,

$$F_x = \rho a V_{r1} (V_{r1} - V_{r2} \cos \phi)$$

OR

$$F_x = \rho a V_{r1} (V_{W1} - V_{W2})$$



Work done / sec = F.U

Power = F. U

$$\text{Efficiency} = \frac{F.U}{\frac{1}{2} m V^2}$$

Problems:

1. A jet of water having a velocity of 35 m/s strikes a series of radial curved vanes mounted on a wheel. The wheel has 200 rpm. The jet makes 20^0 with the tangent to wheel at inlet and leaves the wheel with a velocity of 5 m/s at 130^0 to tangent to the wheel at outlet. The diameters of wheel are 1 m and 0.5 m. Find

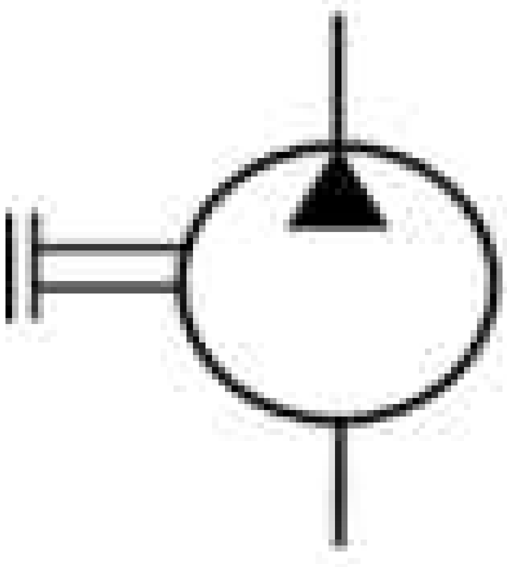
i) Vane angles at inlet and outlet for radially outward flow turbine.

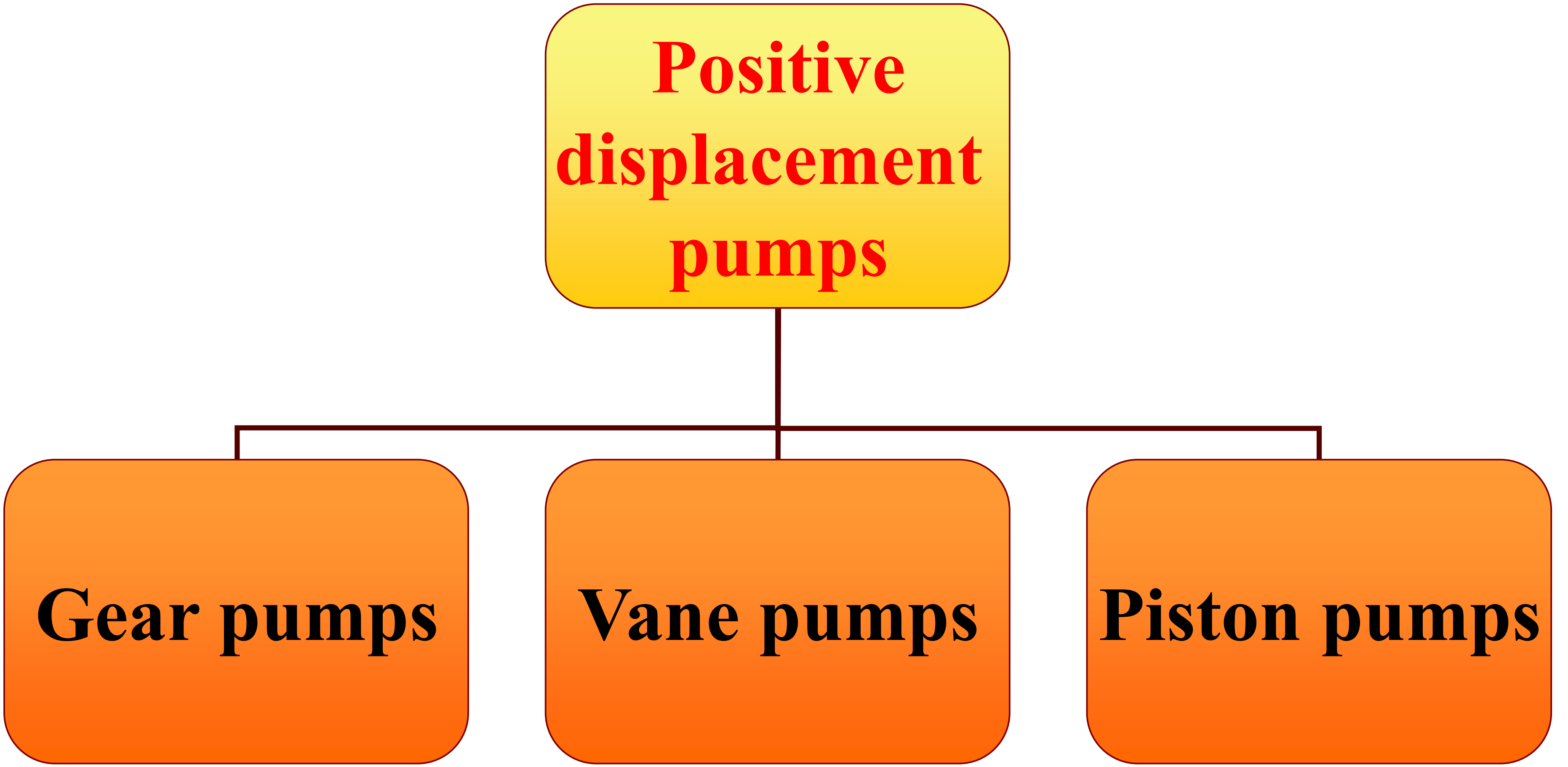
ii) Work done

iii) Efficiency of the system

Chapter (2)

Hydraulic Power (pumps)





Positive displacement pumps
Gear pumps
Vane pumps
Piston pumps

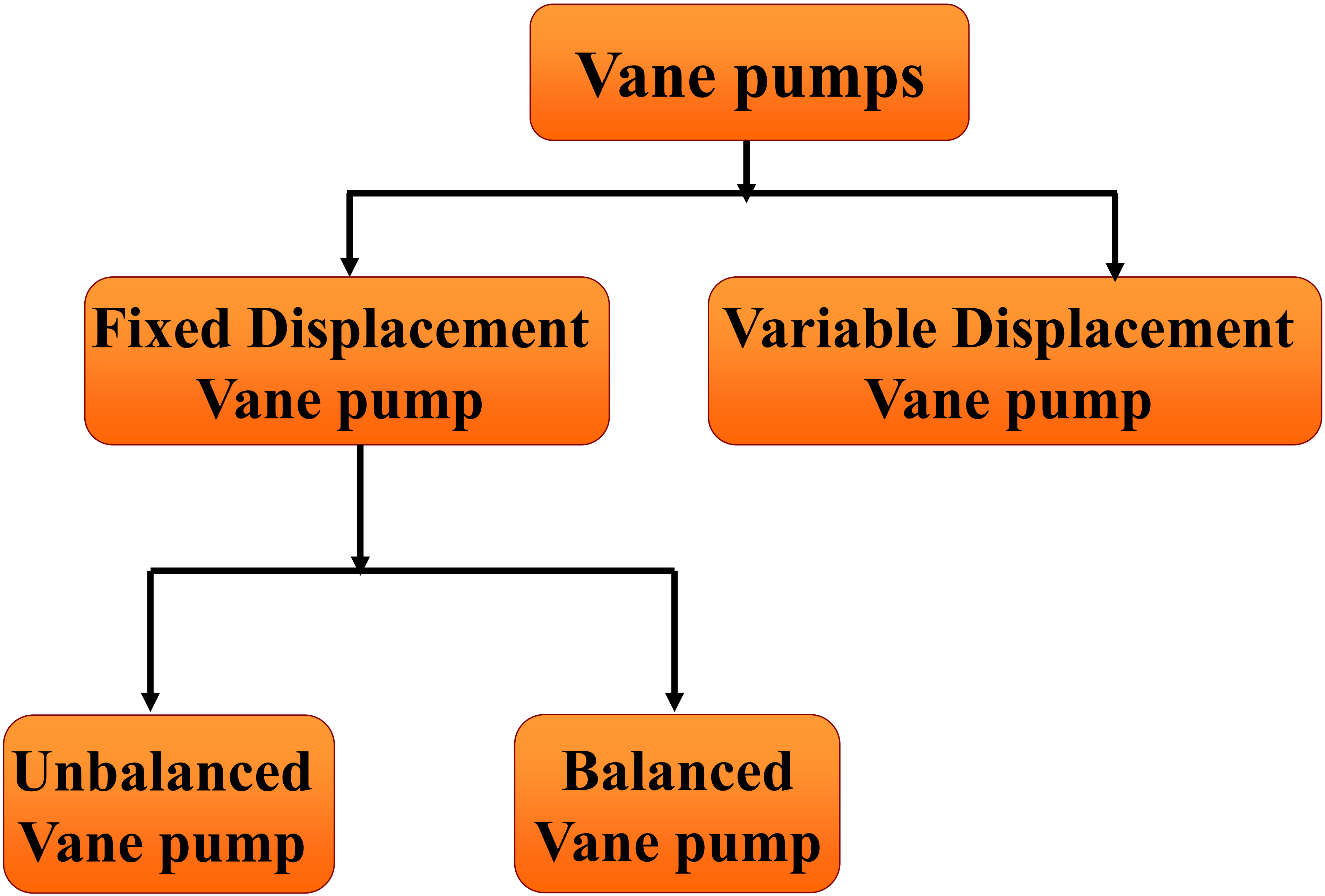
B-Vane pumps

The operation of the vane pump is based on , the rotor which contain radial slots rotate by a shaft and rotate in cam ring (housing), each slot contain a vane design as to comes out from the slot as the rotor turns. During one half of the rotation the oil inters between the vane and the housing then this area starts to decrease in the second half which permit the pressure to be produced , then the oil comes out pressurizes to the output port.

Types of vane pump

1- Fixed Displacement vane pump

2- Variable Displacement vane pump


Vane pumps
Fixed Displacement Vane pump
Variable Displacement Vane pump
Unbalanced Vane pump
Balanced Vane pump

1- Fixed Displacement vane pump

In this type of pump the eccentricity between pump cam-ring and rotor is fixed and pump discharge always remain same at a particular pressure.

There are two types of fixed displacement Vane Pump:-

1- Unbalanced Vane Pump

2- Balanced Vane Pump

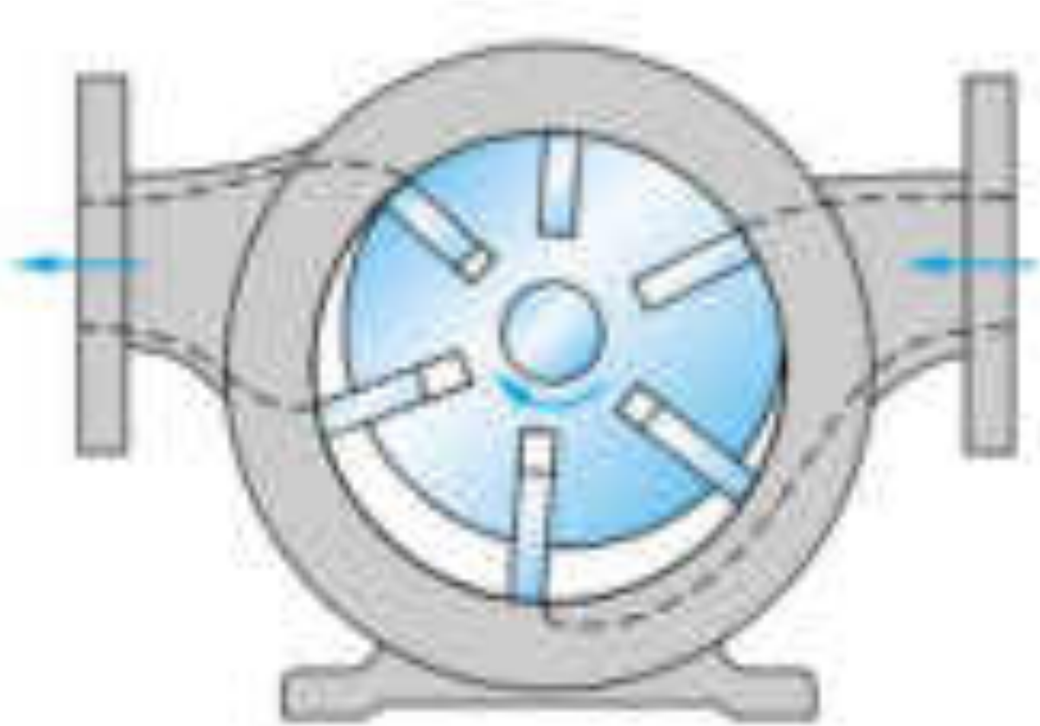
1- Unbalanced vane pump

1. A slotted rotor is eccentrically supported in a cycloidal cam.

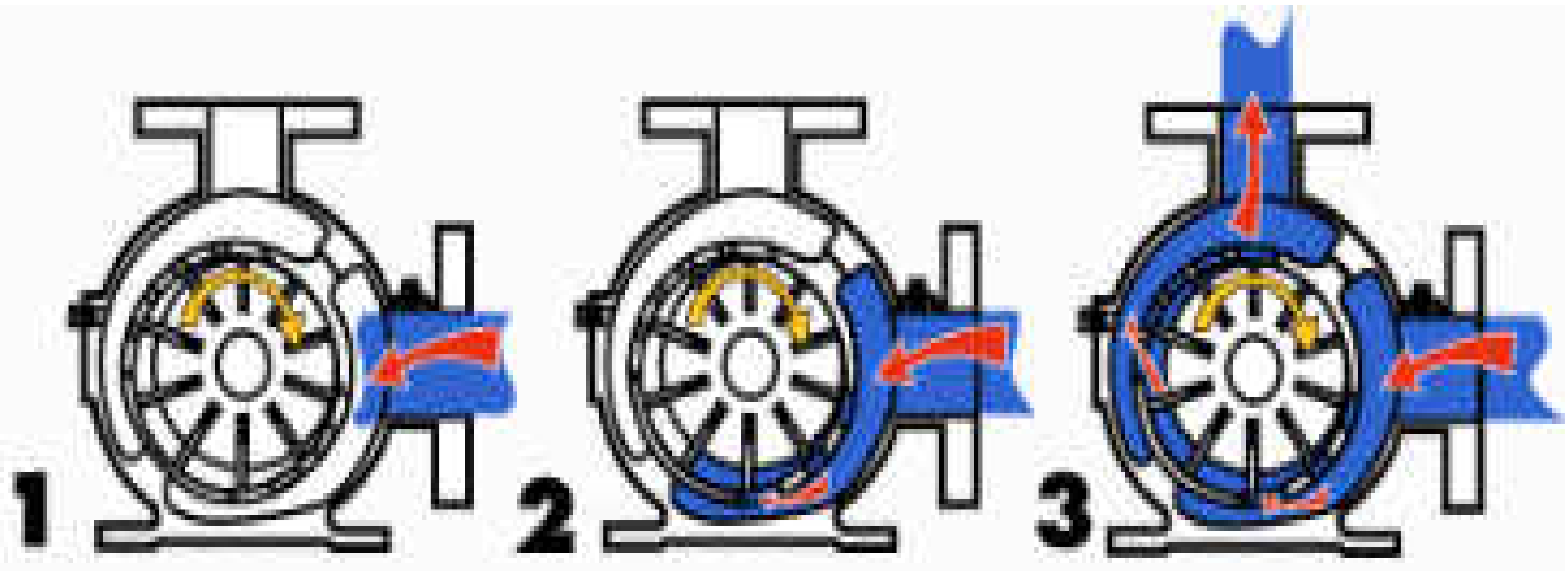
The rotor is located close to the wall of the cam so a crescent-shaped cavity is formed.

The rotor is sealed into the cam by two sideplates.

Vanes or blades fit within the slots of the impeller. .



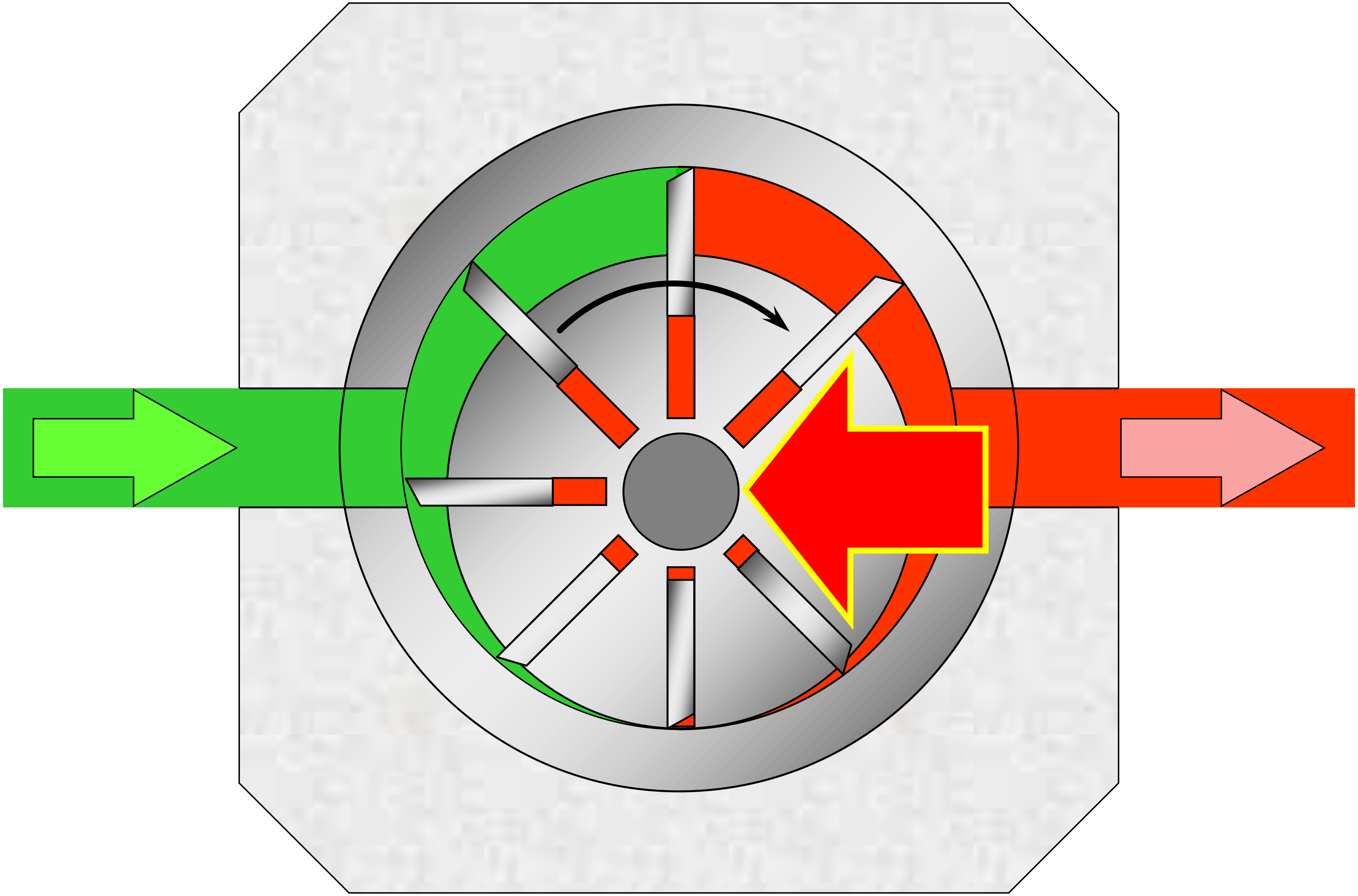
1- As the rotor rotates (*yellow arrow*) and fluid enters the pump, centrifugal force, hydraulic pressure, and/or pushrods push the vanes to the walls of the housing. The tight seal among the vanes, rotor, cam, and side plate is the key to the good suction characteristics common to the vane pumping principle.



2. The housing and cam force fluid into the pumping chamber through holes in the cam (*small red arrow on the bottom of the pump*). Fluid enters the pockets created by the vanes, rotor, cam, and side plate.

3. As the rotor continues around, the vanes sweep the fluid to the opposite side of the crescent where it is squeezed through discharge holes of the cam as the vane approaches the point of the crescent (*small red arrow on the side of the pump*). Fluid then exits the discharge port.

Unbalanced Vane Pump



Advantages

1- Handles thin liquids at relatively higher pressures

2- Compensates for wear through vane extension

3- Can run dry for short periods

4- Can have one seal or stuffing box

5- Develops good vacuum

Disadvantages

1- Complex housing and many parts

2- Not suitable for high pressures

3- Not suitable for high viscosity

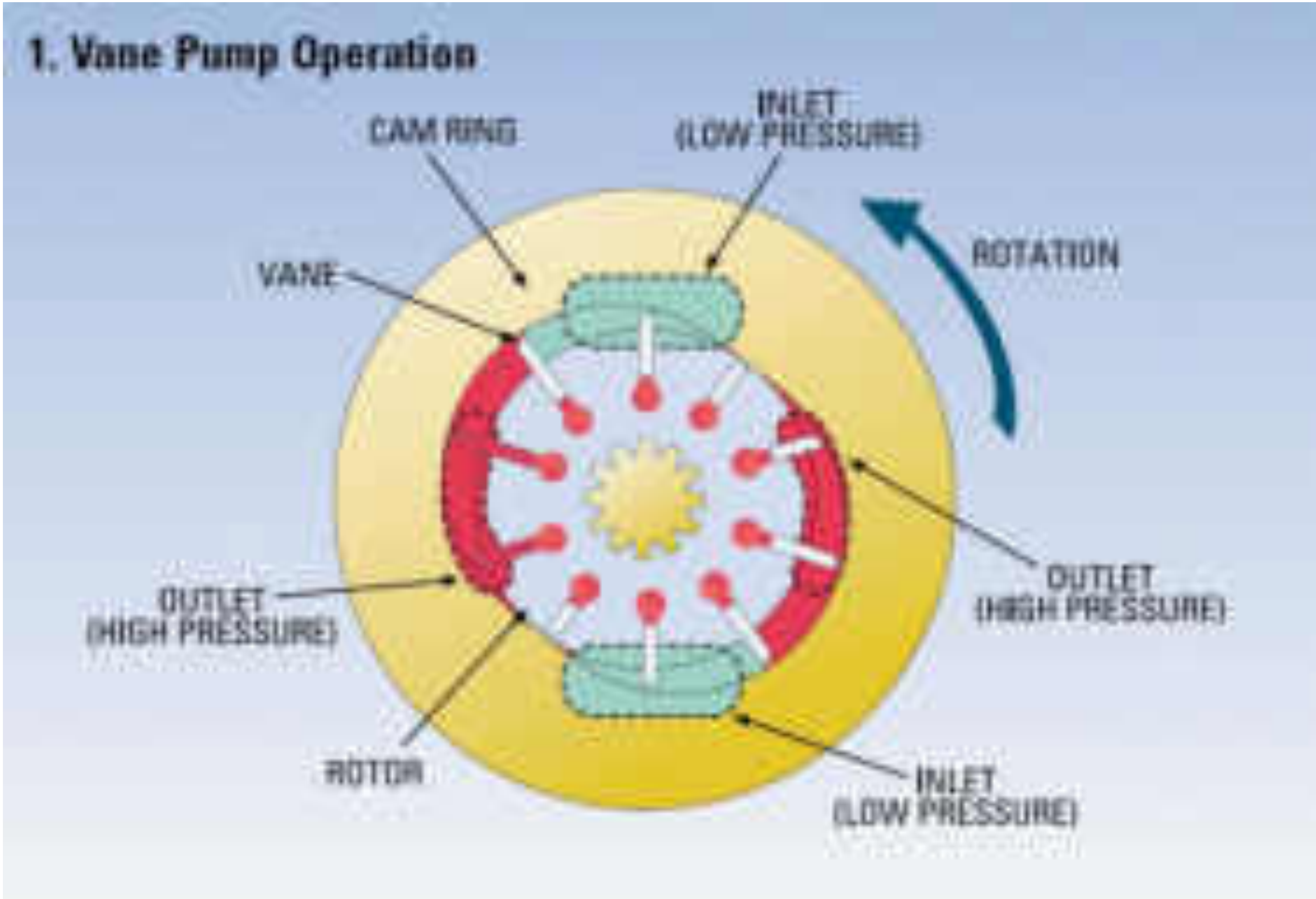
2- Balanced vane pump

a balanced vane pump is one that has two intake and two outlet ports diametrically opposite each other.

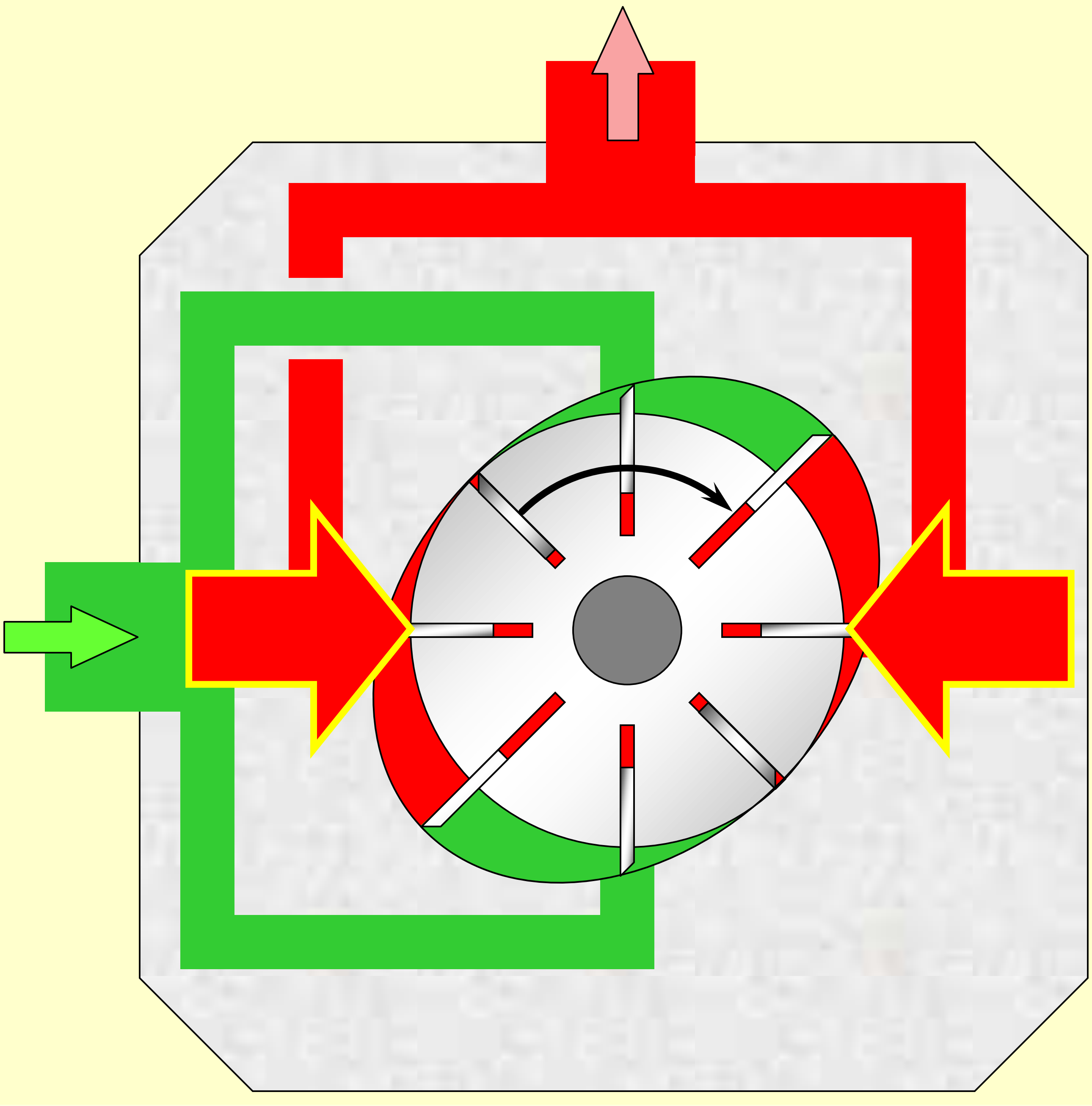
Pressure ports are opposite each other and a complete hydraulic balance is achieved.

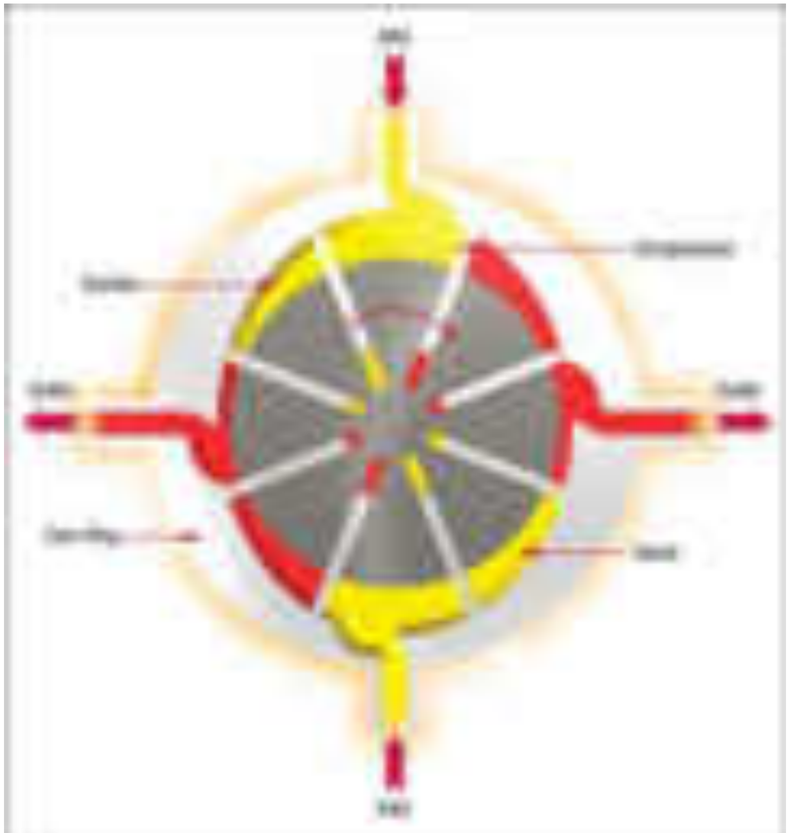
One disadvantage of the balanced vane pump is that it can not be designed as a variable displacement unit.

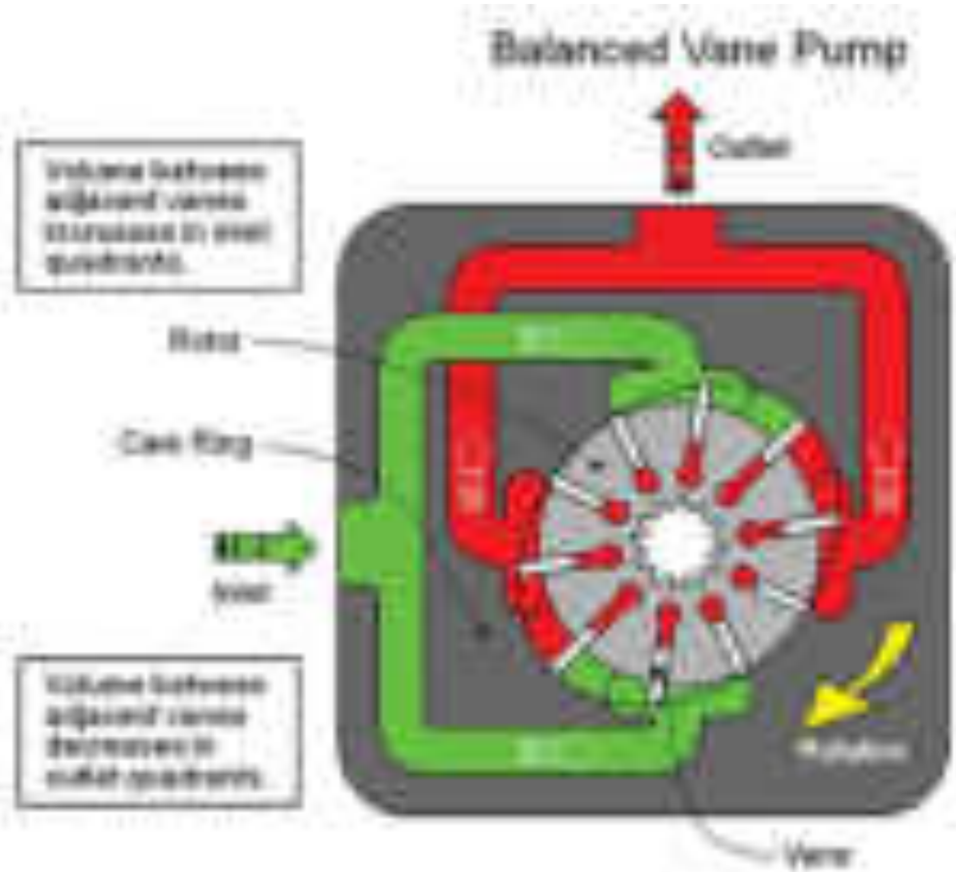
It have elliptical housing which formed two separate pumping chambers on opposite side of the rotor. This kind give higher operating pressure.



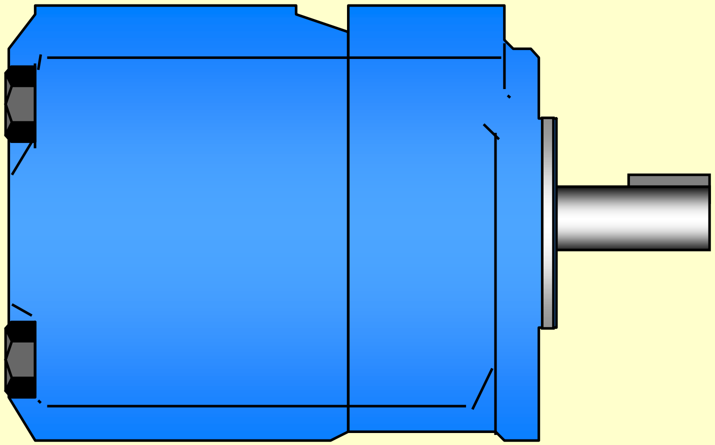
1. Vane Pump Operation

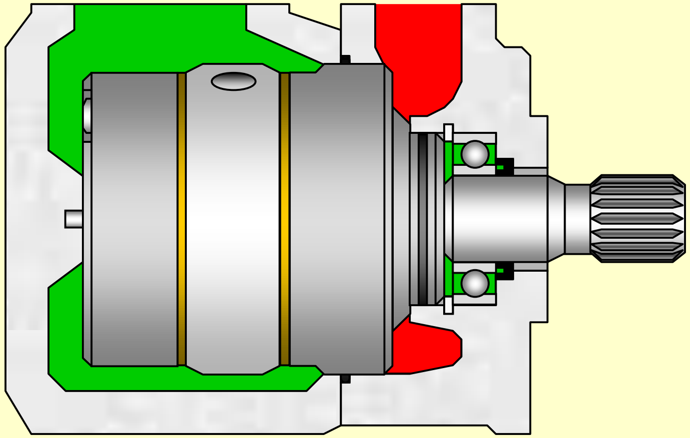





Balanced Vane Pump
Outlet
Rotor
Cam Ring
Inlet
Vane

FIXED VANE PUMP CHARACTERISTICS





- Typical displacements to 200 cm^3/r
- Typical pressures to 280 bar
- Fixed displacement only
- Provides prime mover soft-start
- Simple double assemblies
- Low noise
- Good serviceability.

Advantage of balanced pump over unbalanced vane pump

1- it has bigger flow

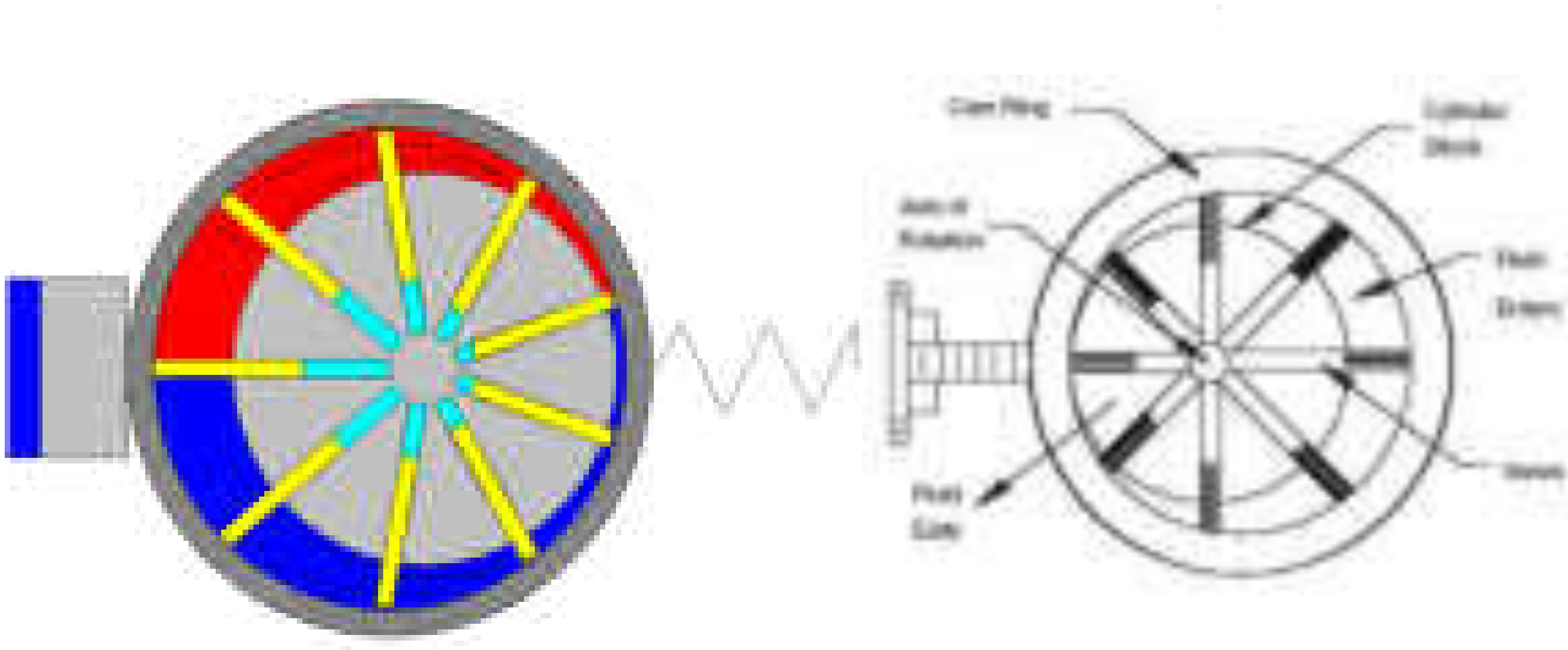
2- it has bigger pressure

3- its life is bigger

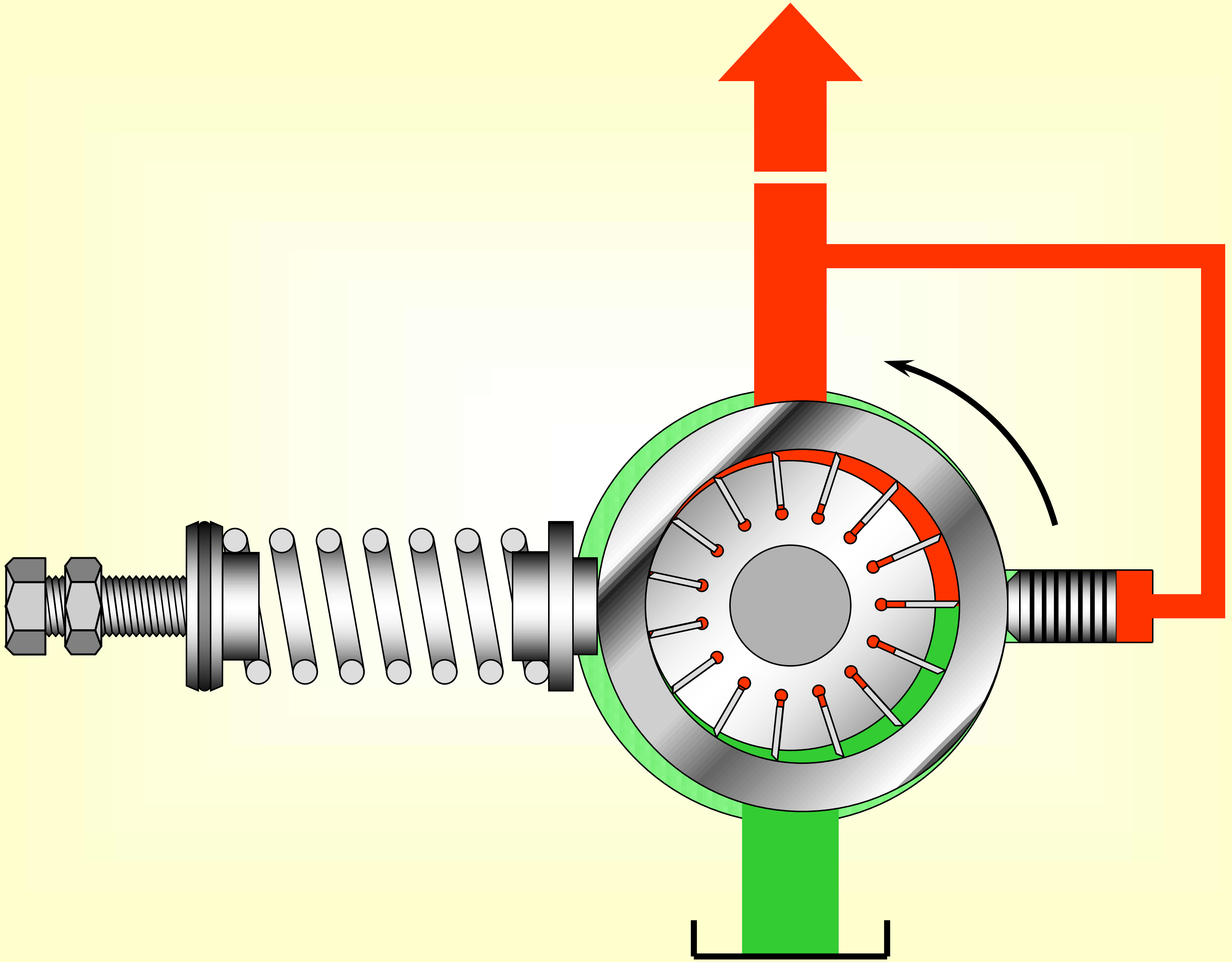
4- constant volume displacement

2-Variable Displacement Vane Pump

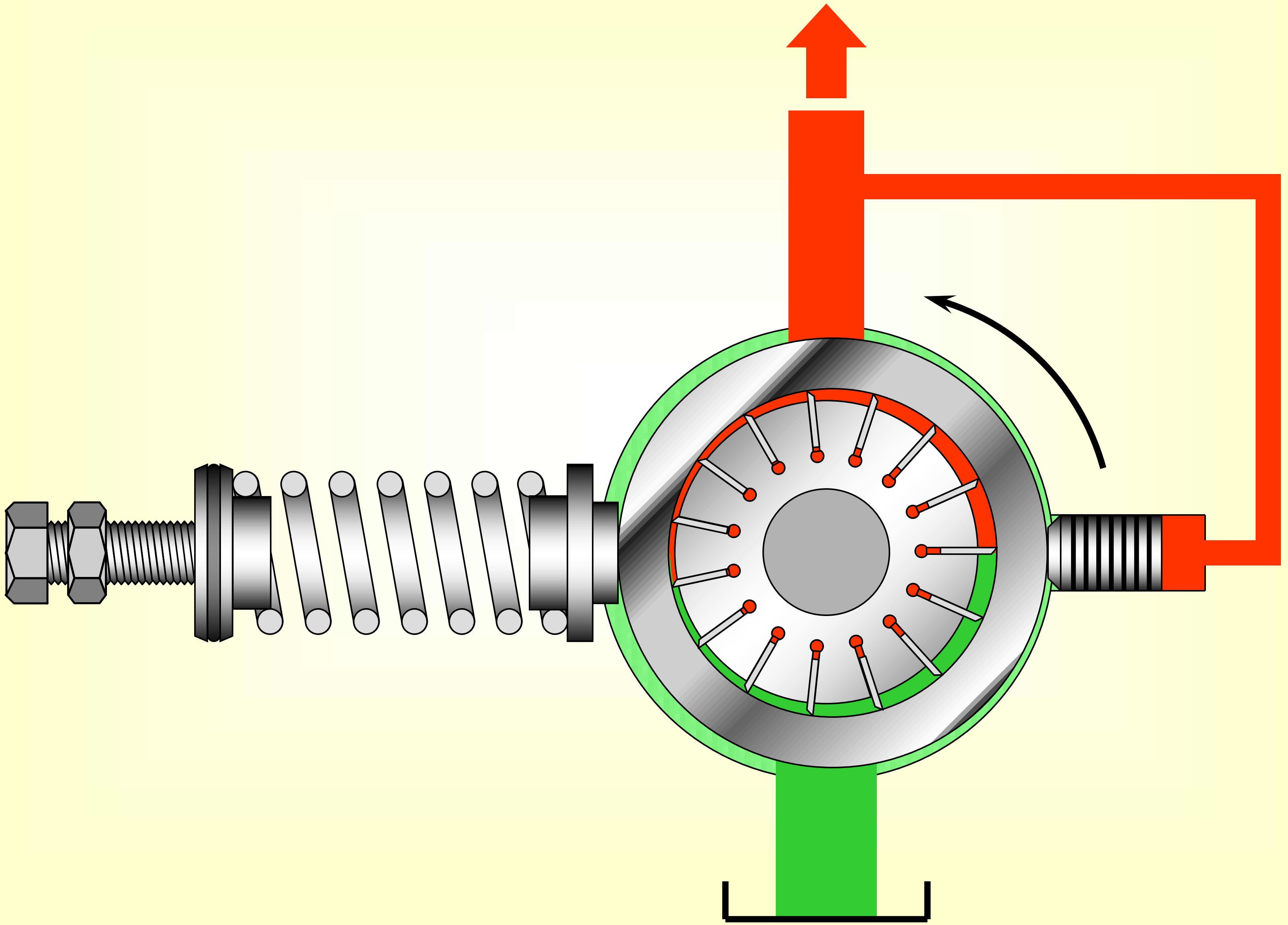
In variable displacement the discharge of pump can be changed by varying the eccentricity between rotor and pump cam-ring.
As eccentricity increases pump discharge increases.
With decrease in eccentricity discharge decreases and oil flow completely stop when rotor becomes concentric to pump cam ring.



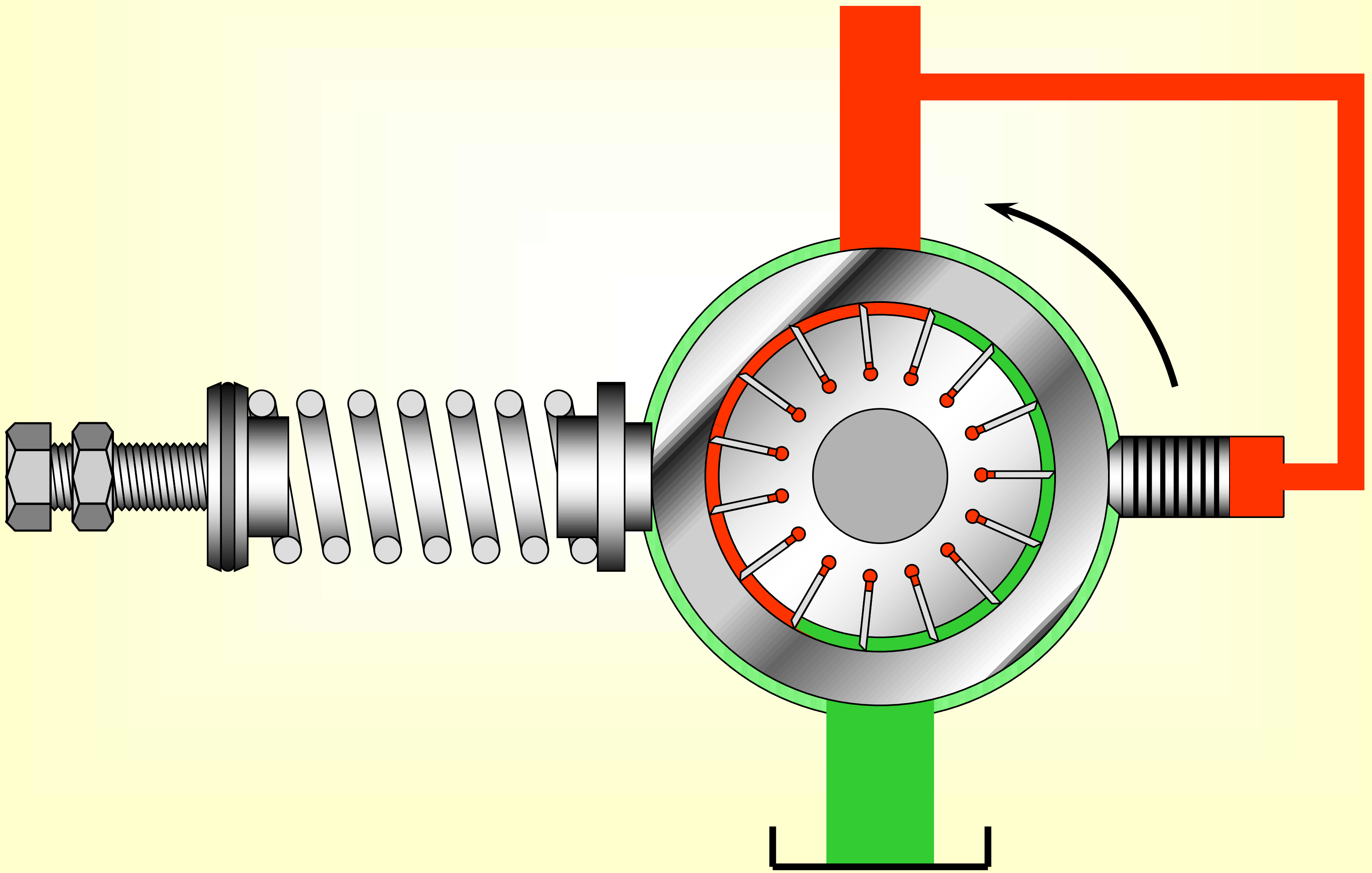
VARIABLE VANE PUMP PRINCIPLE



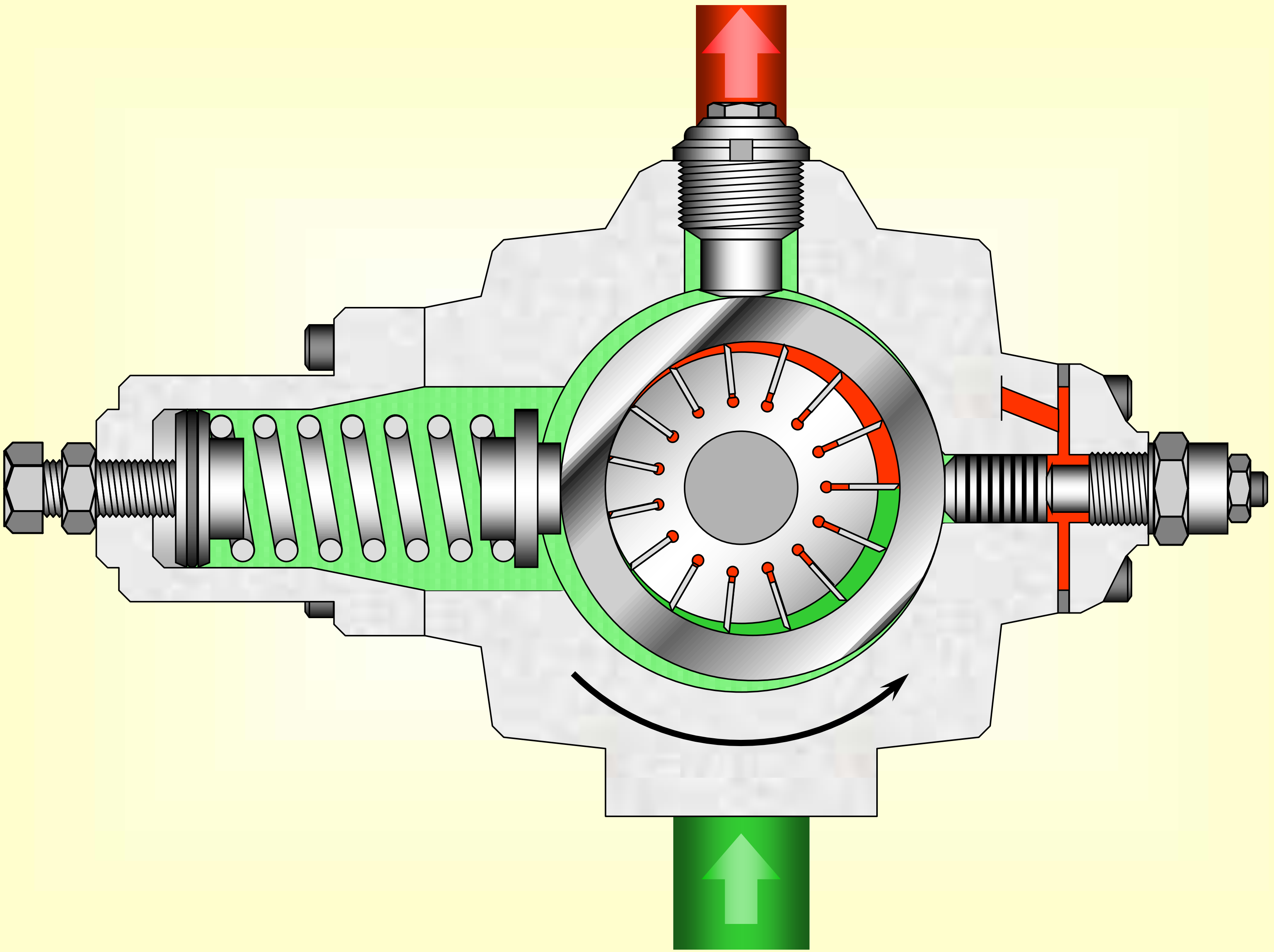
VARIABLE VANE PUMP PRINCIPLE

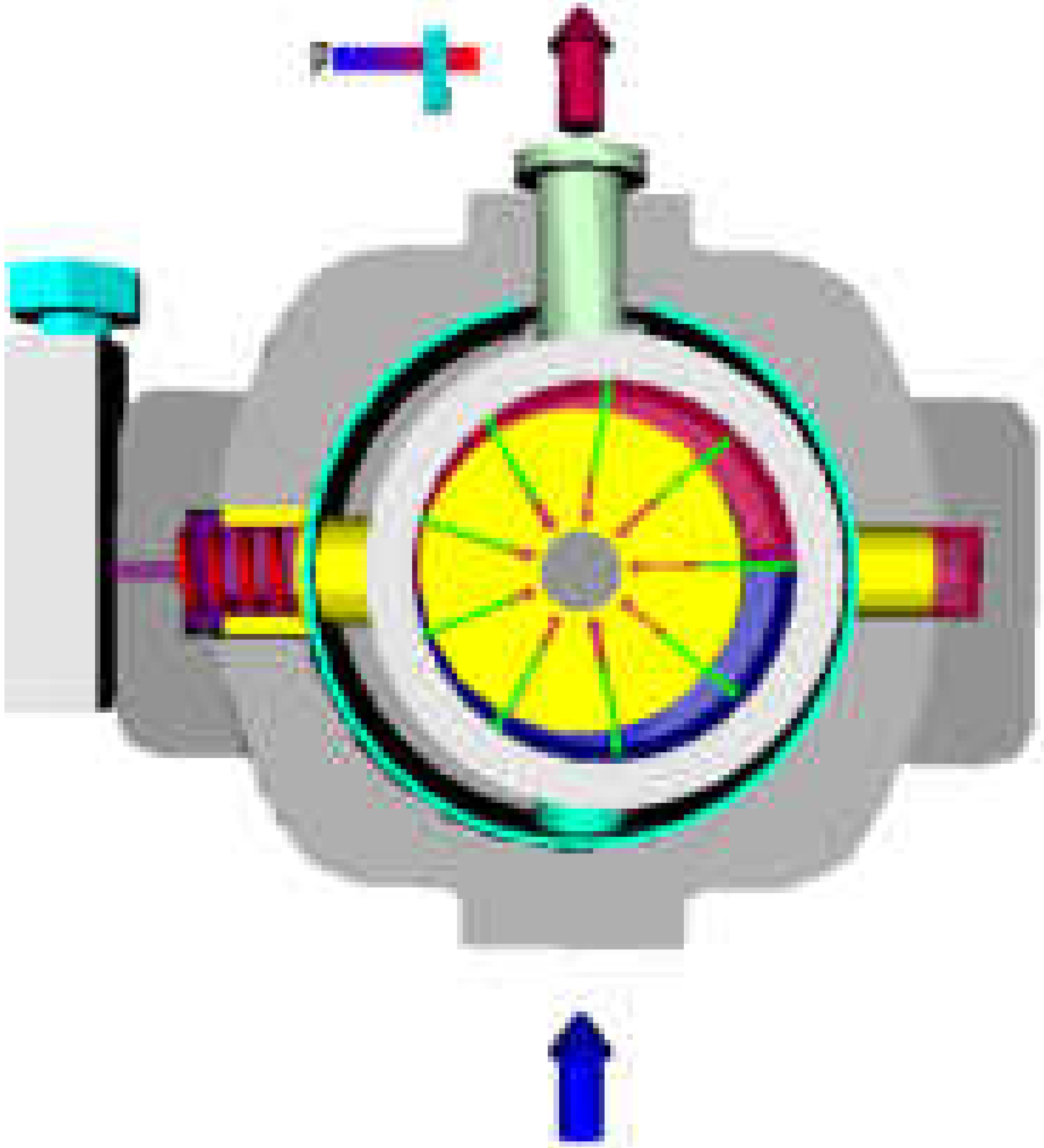


VARIABLE VANE PUMP PRINCIPLE

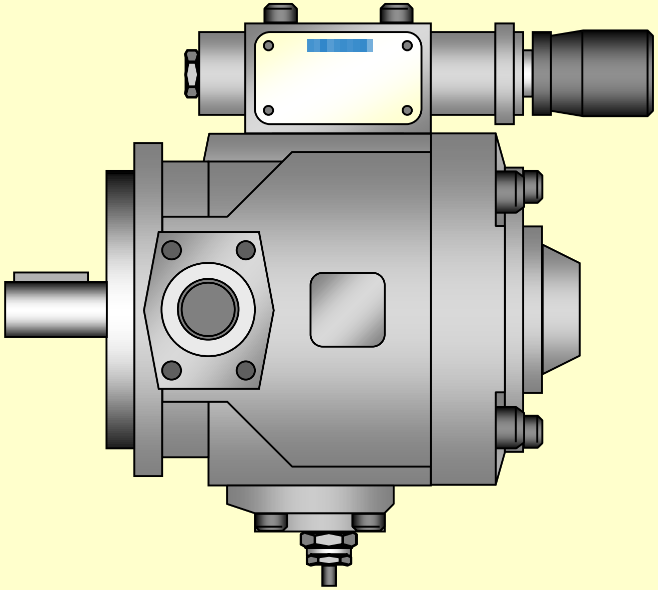


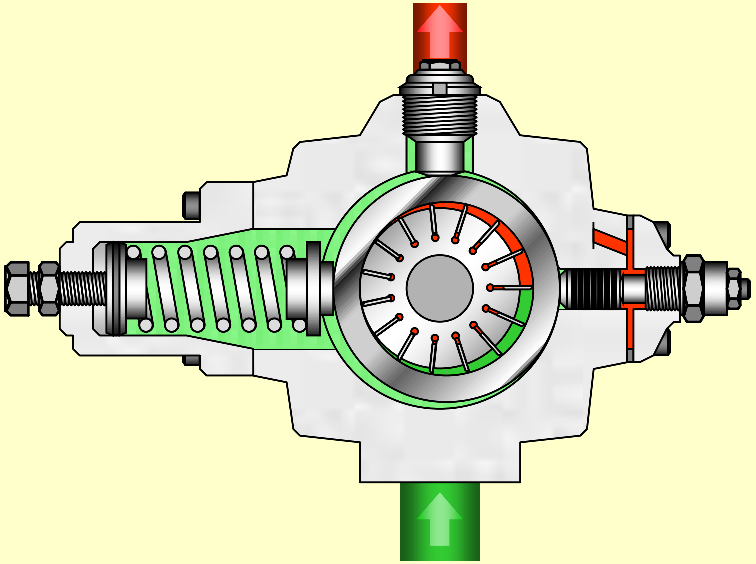
VARIABLE VANE PUMP





VARIABLE VANE PUMP CHARACTERISTICS





- Typical displacements to 100 cm^3/r
- Typical pressures to 160 bar
- Simple multiple assemblies
- Range of pump controls
- Low noise
- Low cost.

Advantage of vane pump

1- low noise but higher than screw pump.

2- range of work from 500 – 1800 r.p.m

3- semi continuous flow

4- pressure of work between 50 – 80 bar

5-the vane motor must have spring backward to the vane to face the flow.

C- Piston pumps

A piston pump works on the principle that a reciprocating piston can draw in fluid when it retracts in a cylinder bore and discharge it when it extends.

They are mainly used in systems which need pressure of 140 bar and above.

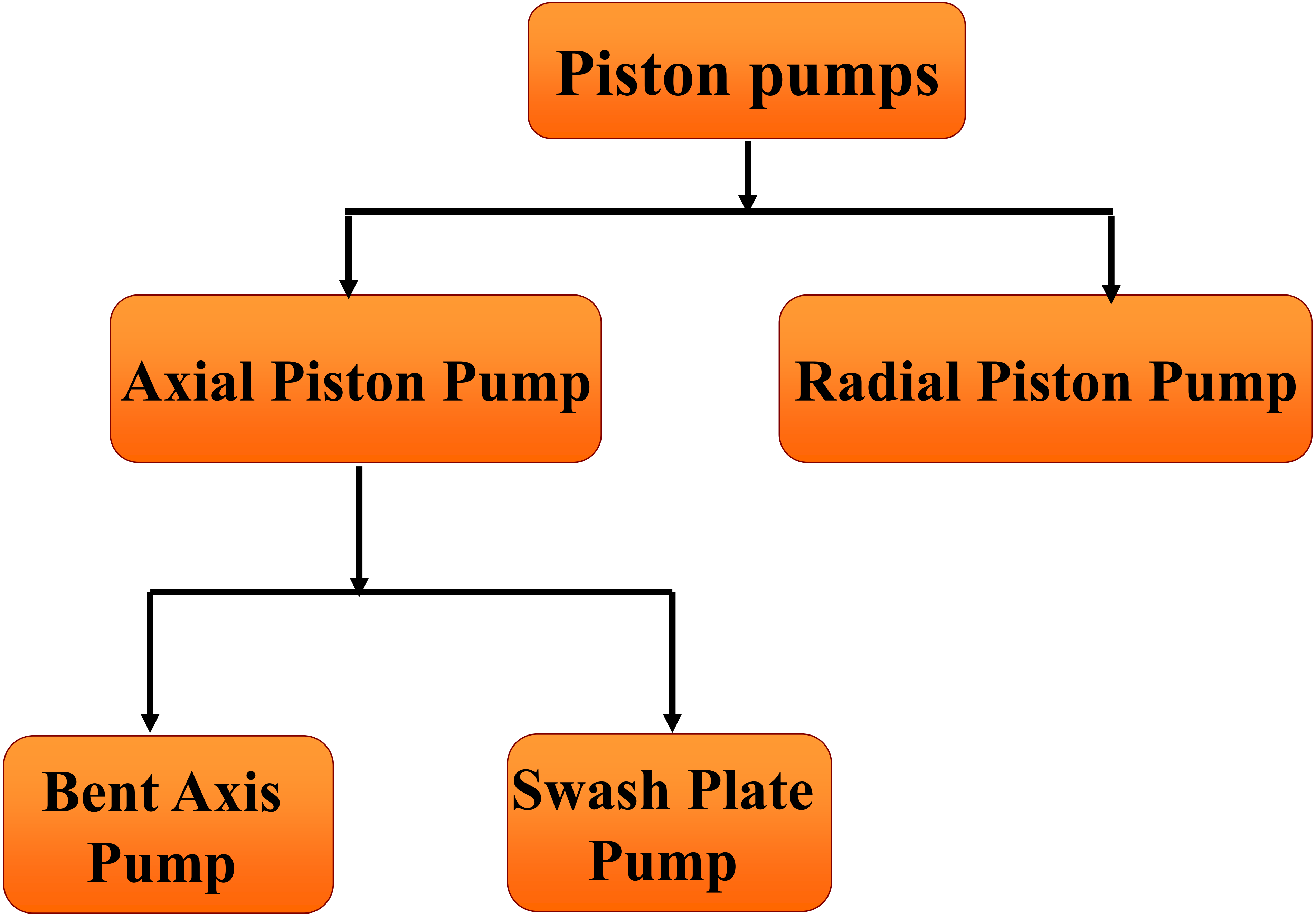
It used in high efficiency at high pressure which is important when a constant flow is required independent of pressure variations.

Piston pump mainly divided into two main types, axial design which having pistons that are parallel to the axis of the cylinder block. Axial design have three kinds,

1- bent axis pump.

2- swash plate pump.

The second type is the radial design, which has pistons arranged radially in a cylinder block.


Piston pumps
Axial Piston Pump
Radial Piston Pump
Bent Axis Pump
Swash Plate Pump

A- Axial piston pump

these consists of a number of pistons which are caused to reciprocate by the relative rotation of an inclined plate or by angling the piston block.

1- Bent axis design

1- Bent axis piston Pumps have a rotating cylinder containing parallel pistons arranged radially around the cylinder centre line.

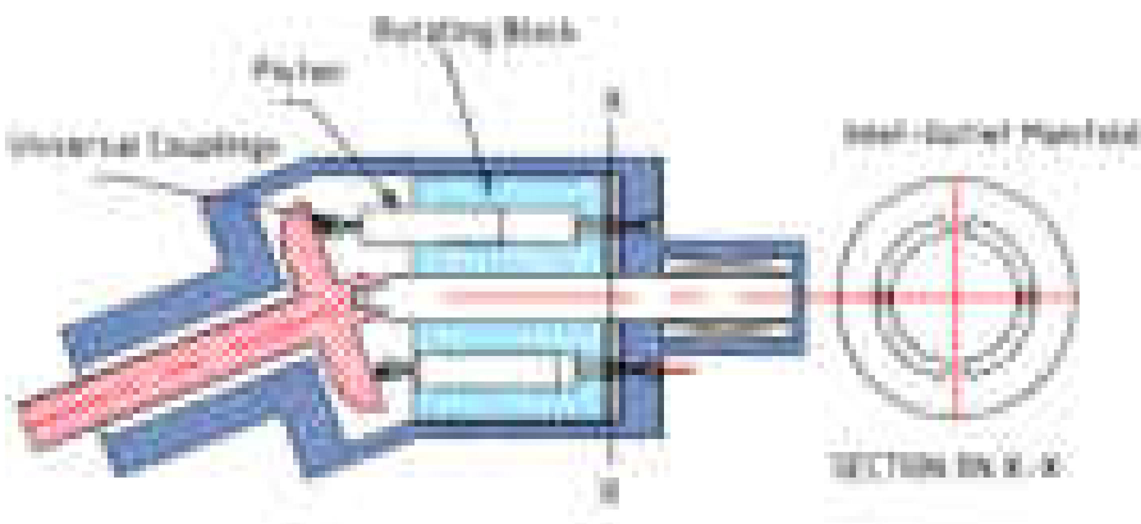
2- The pressure in the fluid causes the pistons to reciprocate over a stroke based on the relative angle of the shaft and cylinder.

3- The motion of the pistons results in the rotation of the shaft.

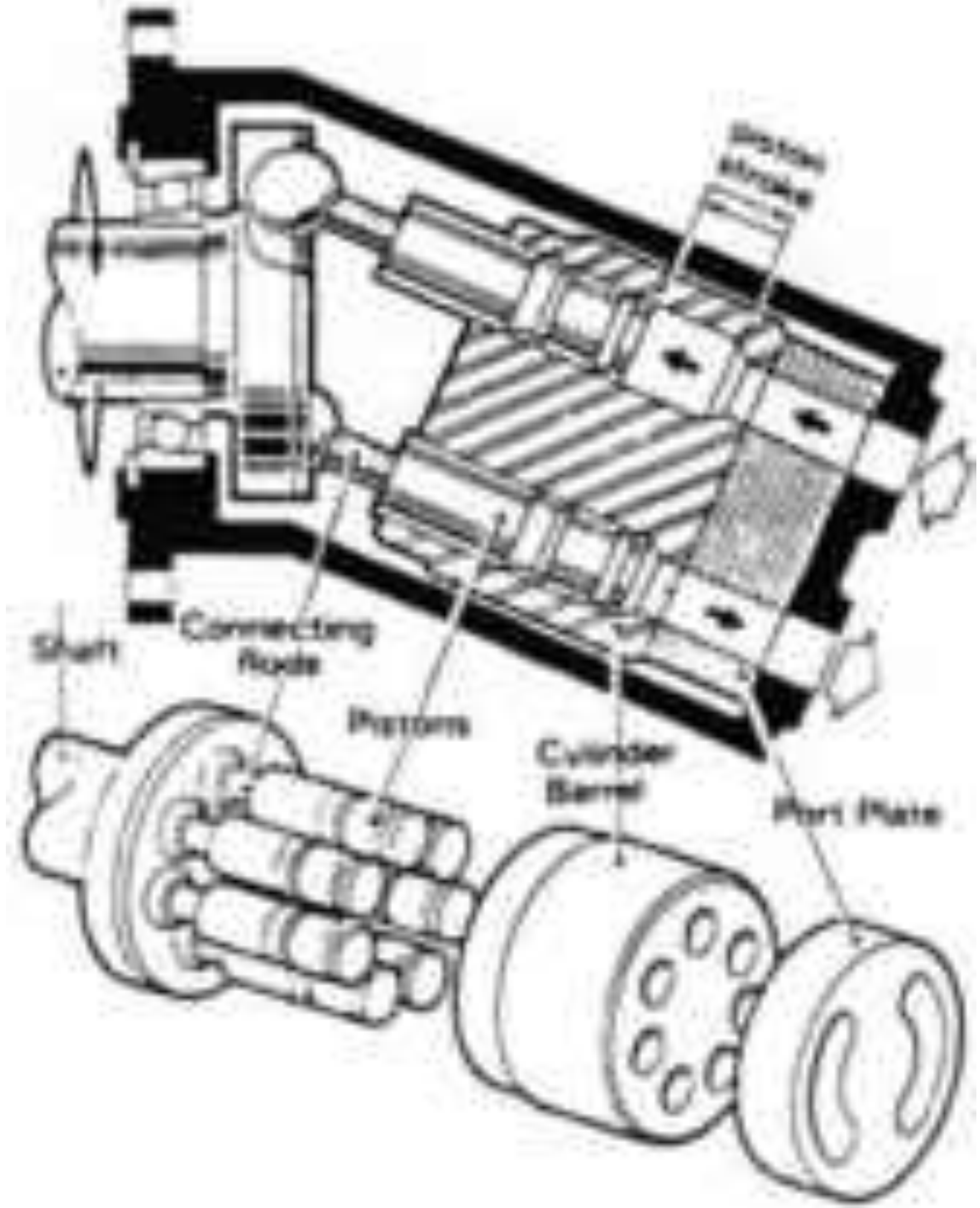
4- The cylinder is driven by an shaft which is arranged at an angle to the cylinder axis.

5- The shaft includes a flange with a mechanical connection to each piston.

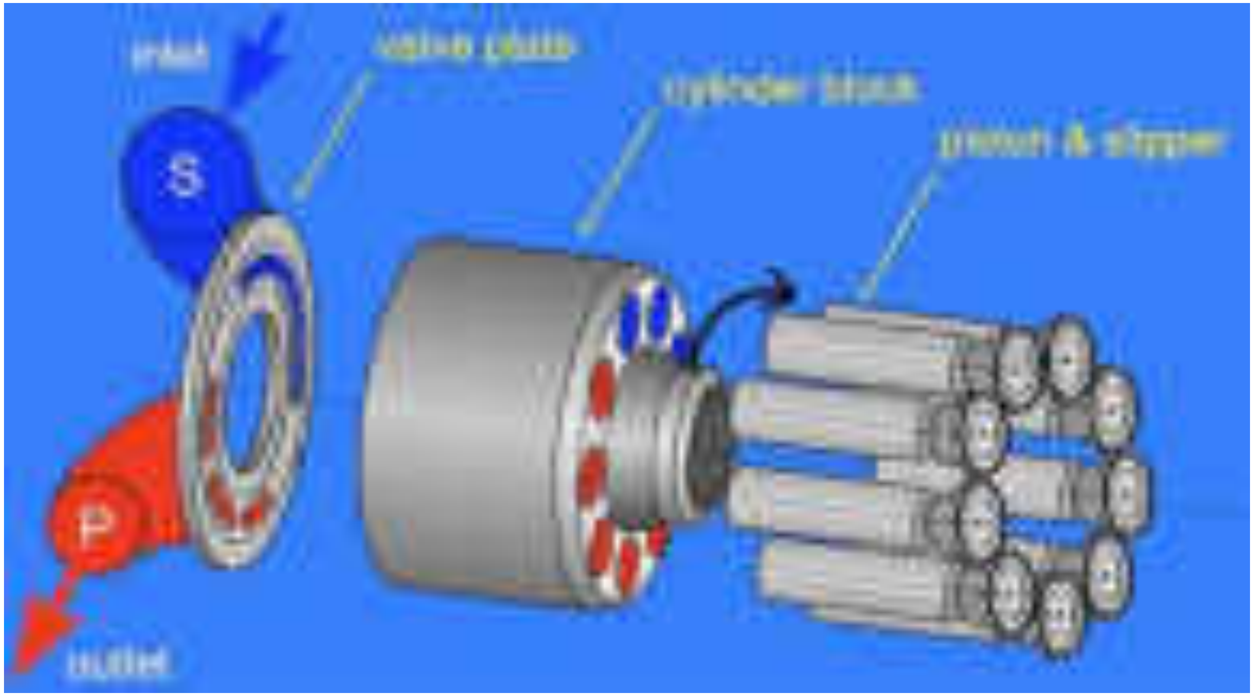
6- The greater the angle of the cylinders to the shaft axes the longer the pistons stroke and the less the rotation speed per unit fluid flow rate.

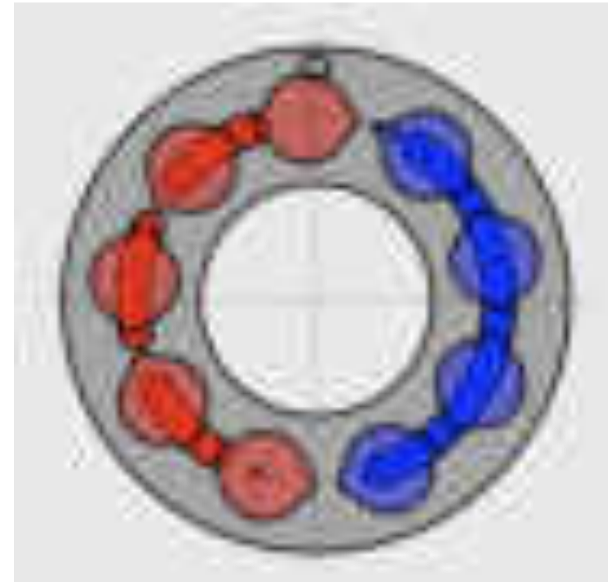


Bent Axis Pump

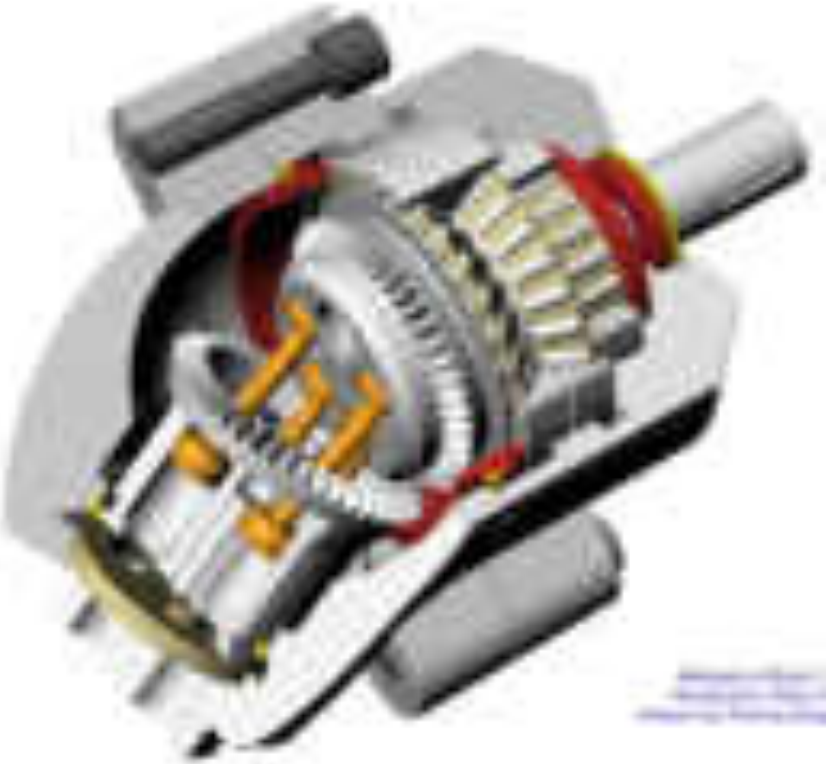


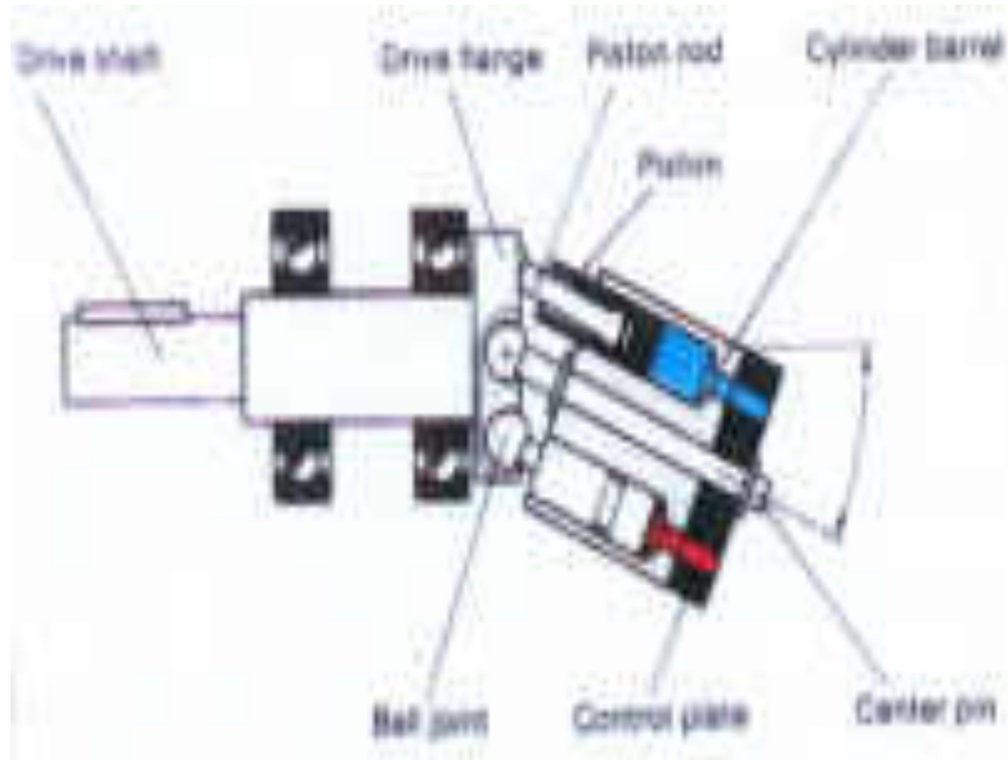
Piston stroke
Shaft
Connecting Rods
Pistons
Cylinder Barrel
Port Plate

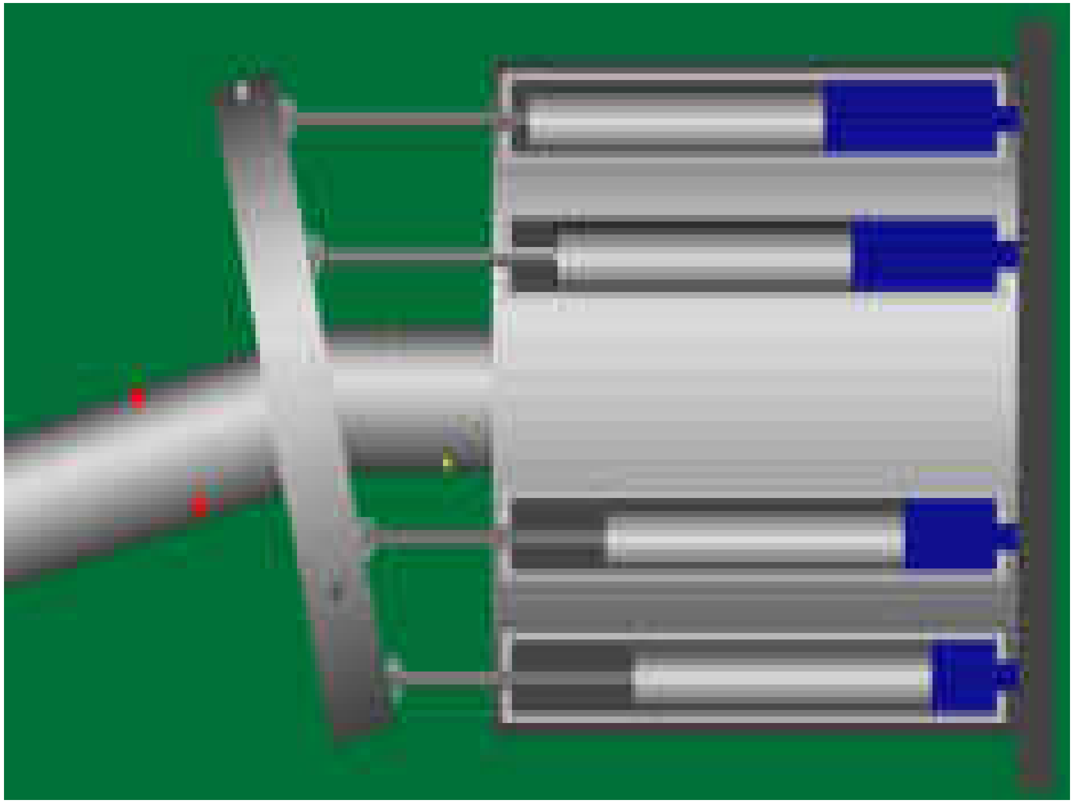




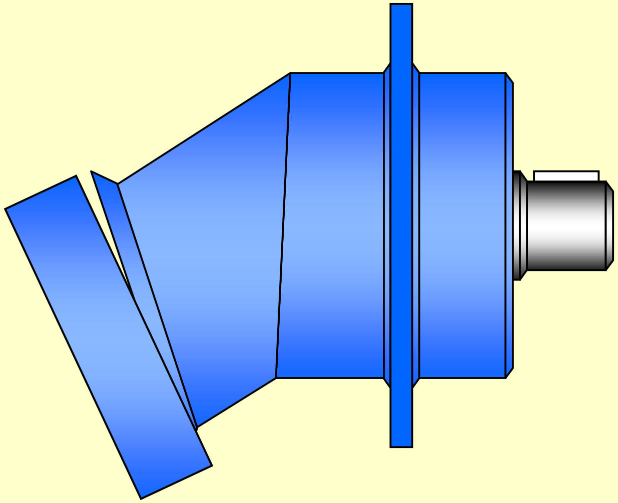
Bent Axis Piston Pump




Drive shaft
Drive flange
Piston rod
Cylinder barrel
Piston
Ball joint
Control plate
Center pin

BENT AXIS PISTON PUMP



- Typical displacements to 500 cm^3/hr
- Typical pressures to 350 bar
- No through shaft option (multiple assemblies not possible)
- High overall efficiency
- Compact package.

2- Swash plate Pump

1- Swash plate pumps have a rotating cylinder containing pistons.

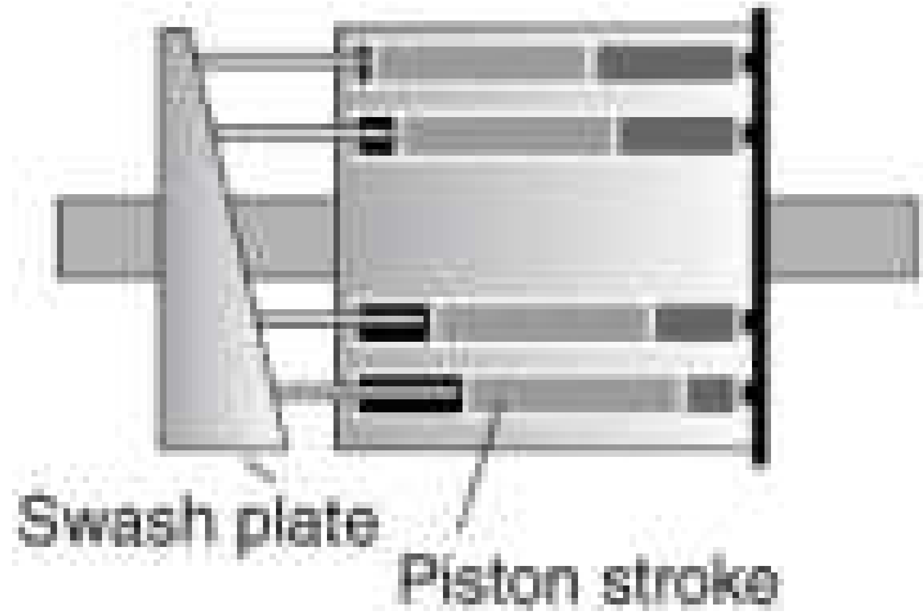
2- A spring pushes the pistons against a stationary swash plate, which sits at an angle to the cylinder.

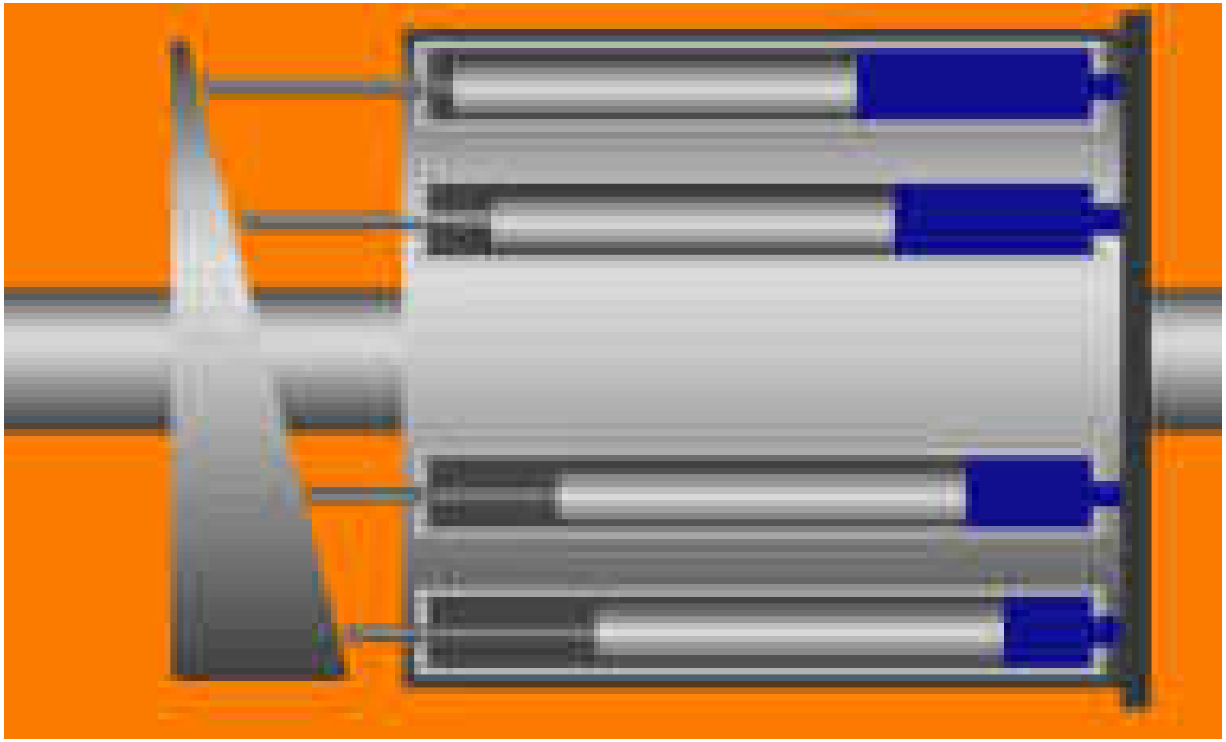
3- The pistons suck in fluid during half a revolution and push fluid out during the other half.

4- It contains two semi-circular ports.

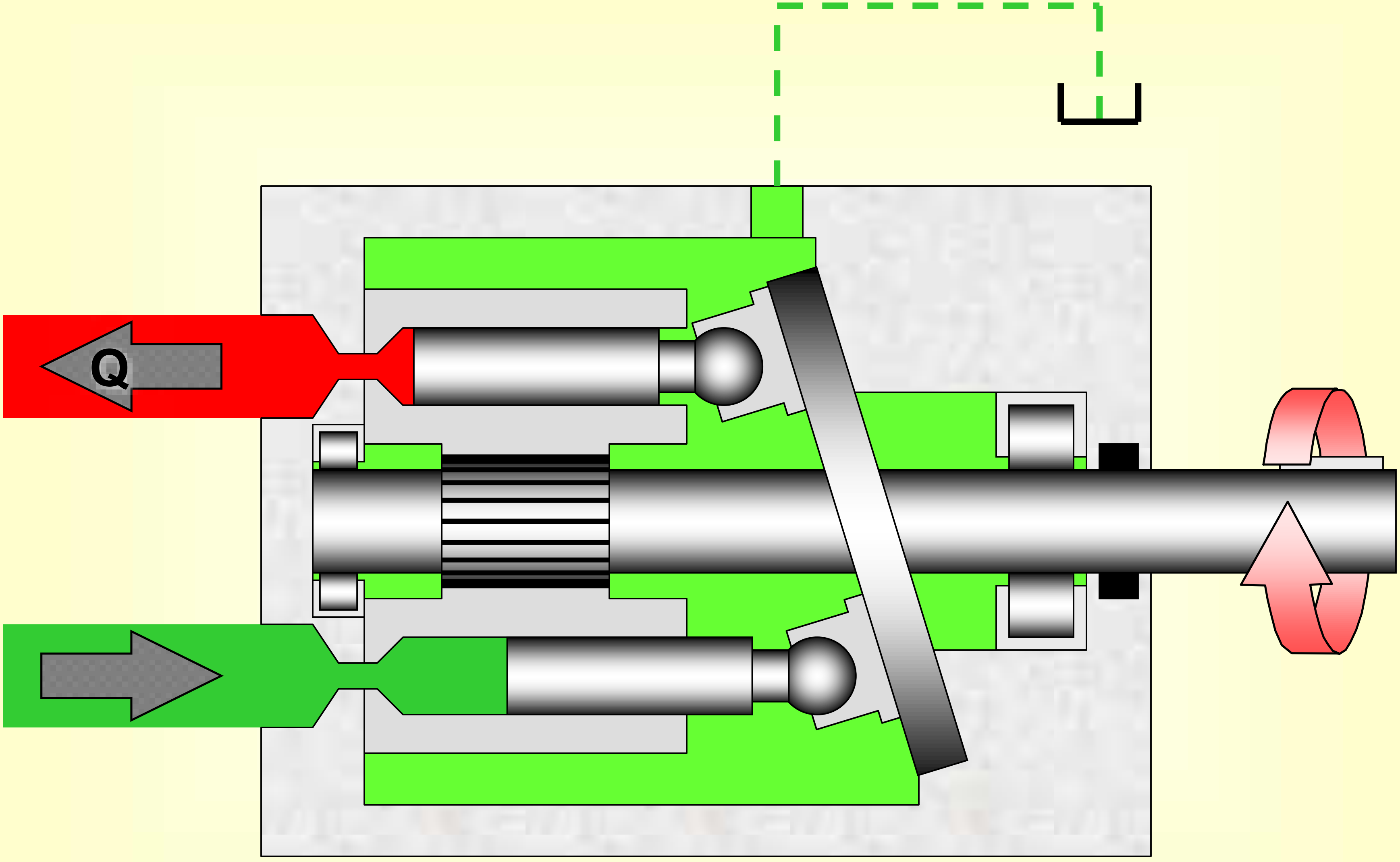
5- These ports allow the pistons to draw in fluid as they move toward the swash plate (on the backside and not shown here) and discharge it as they move away.

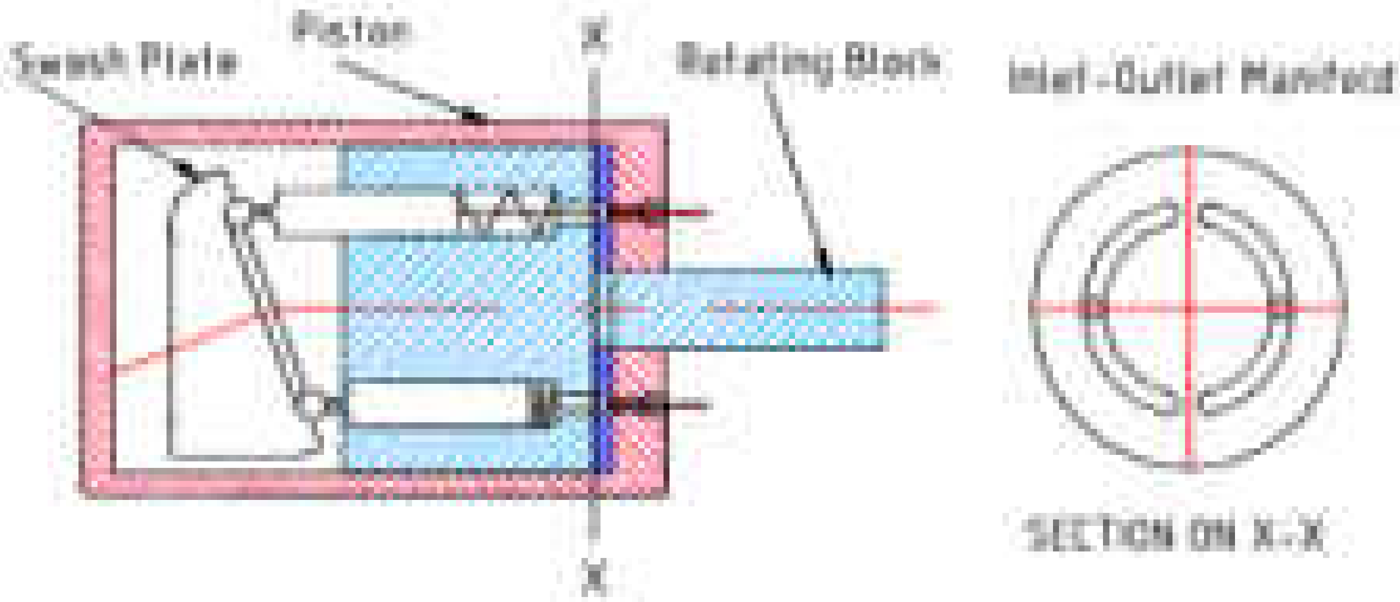
6- For a given speed swash plate pumps can be of fixed displacement like this one, or variable by having a variable swash plate angle.



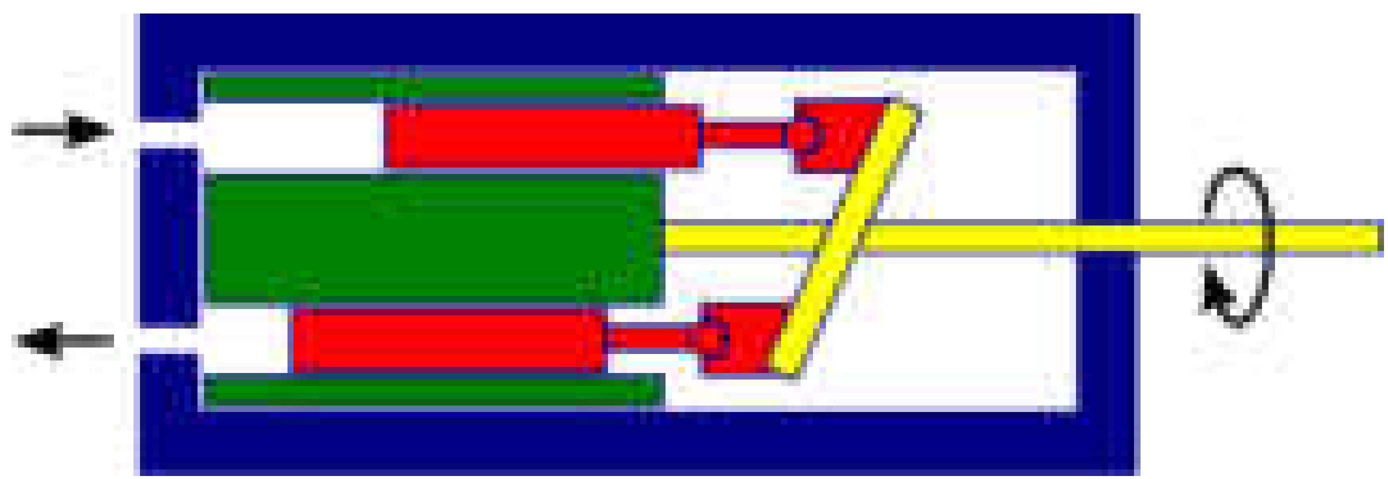


Swash plate Piston Pump

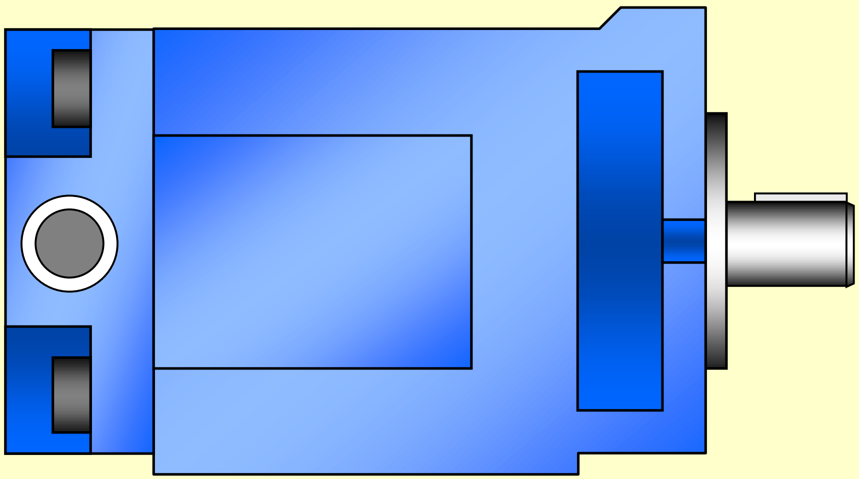


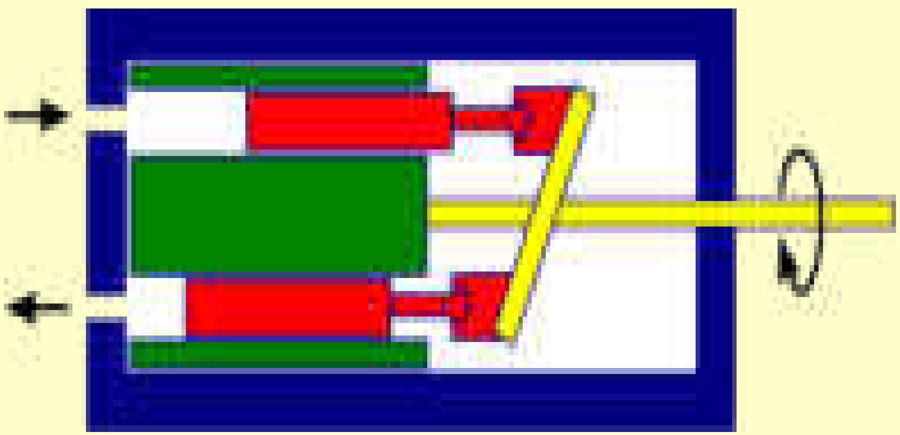


Swashplate Pump



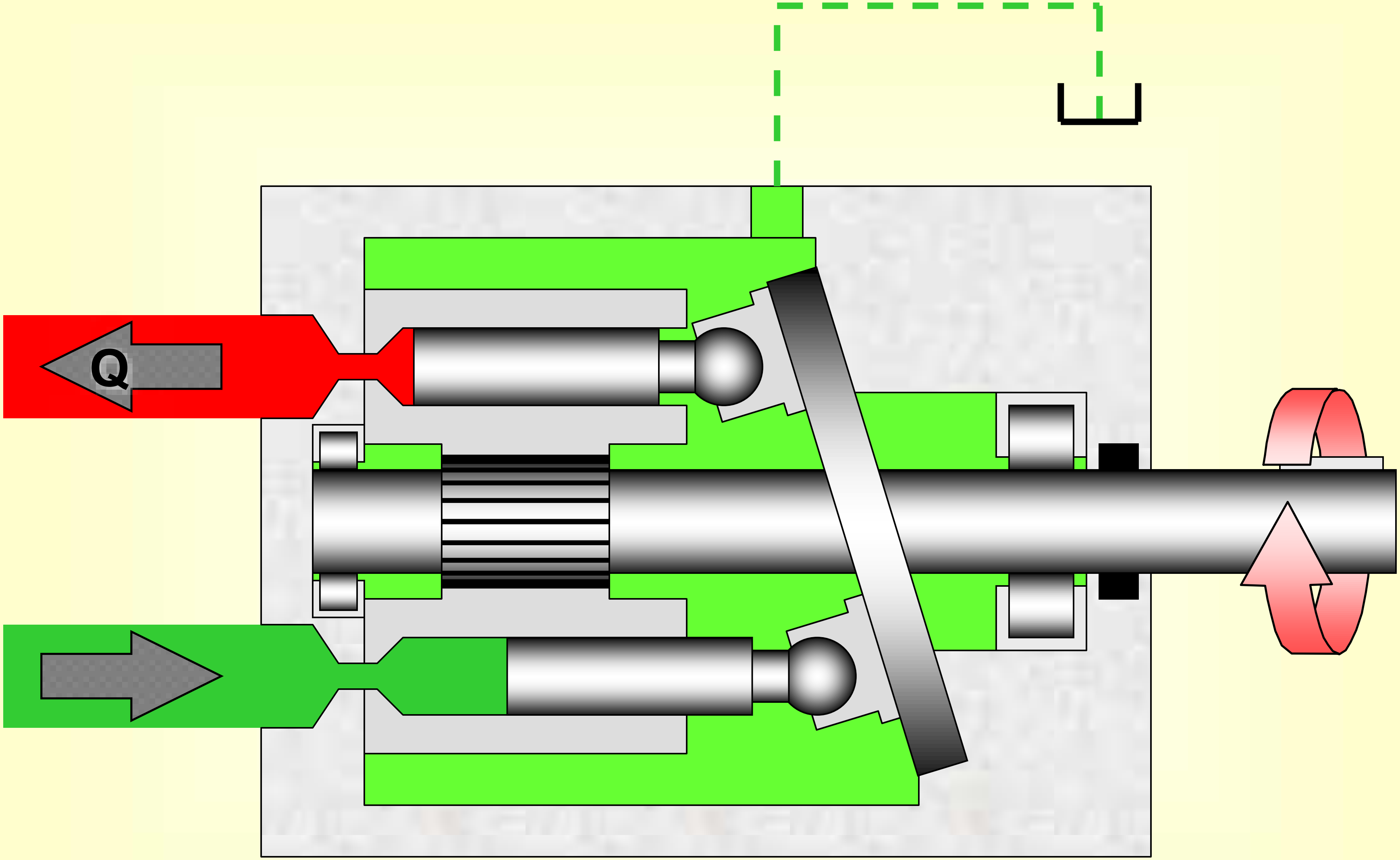
FIXED AXIAL PISTON PUMP CHARACTERISTICS





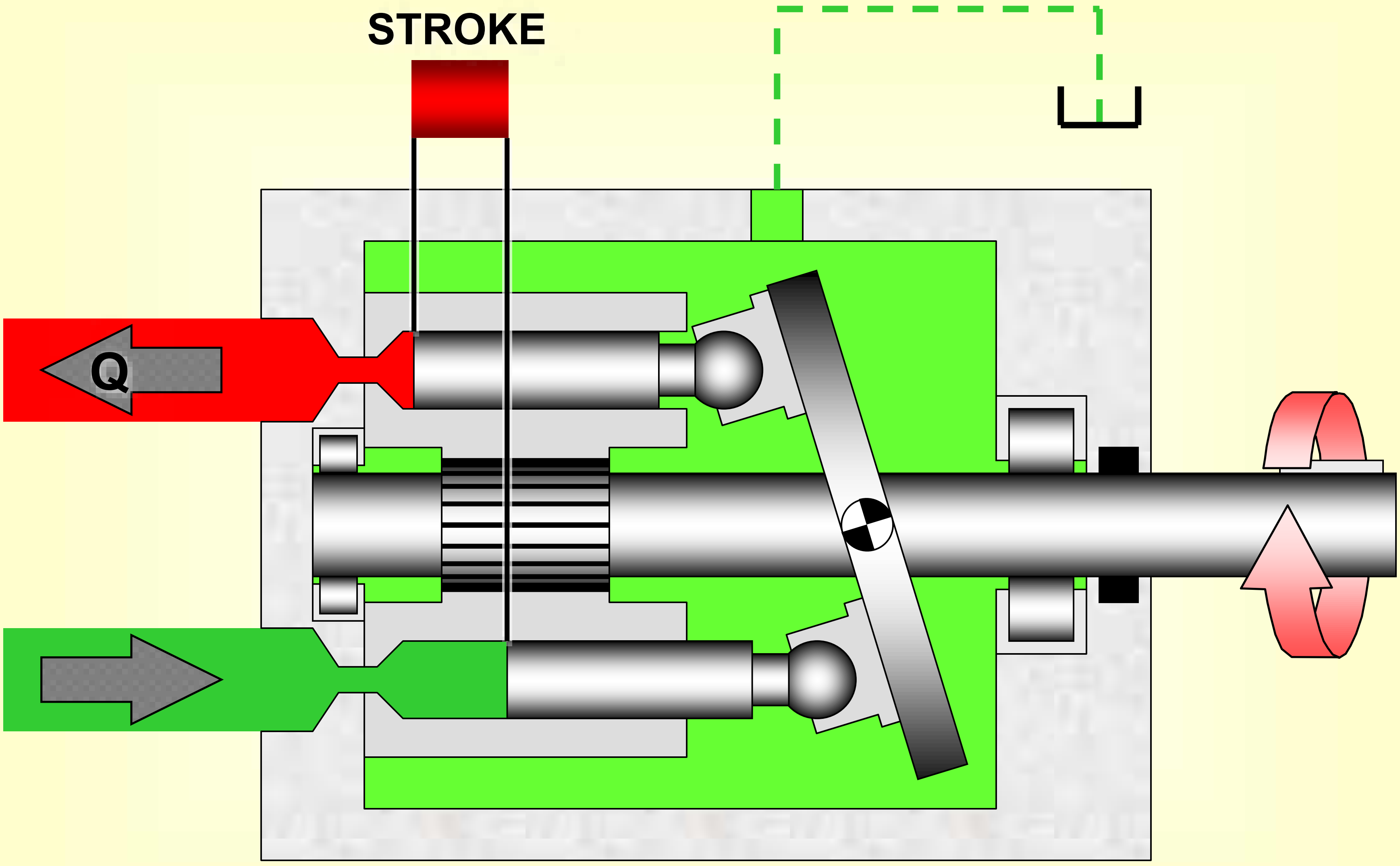
- Typical displacements to 500 cm^3/r
- Typical pressures to 350 bar
- Multiple assemblies possible
- High overall efficiency
- Compact package.

VARIABLE DISPLACEMENT PUMP - MAX FLOW



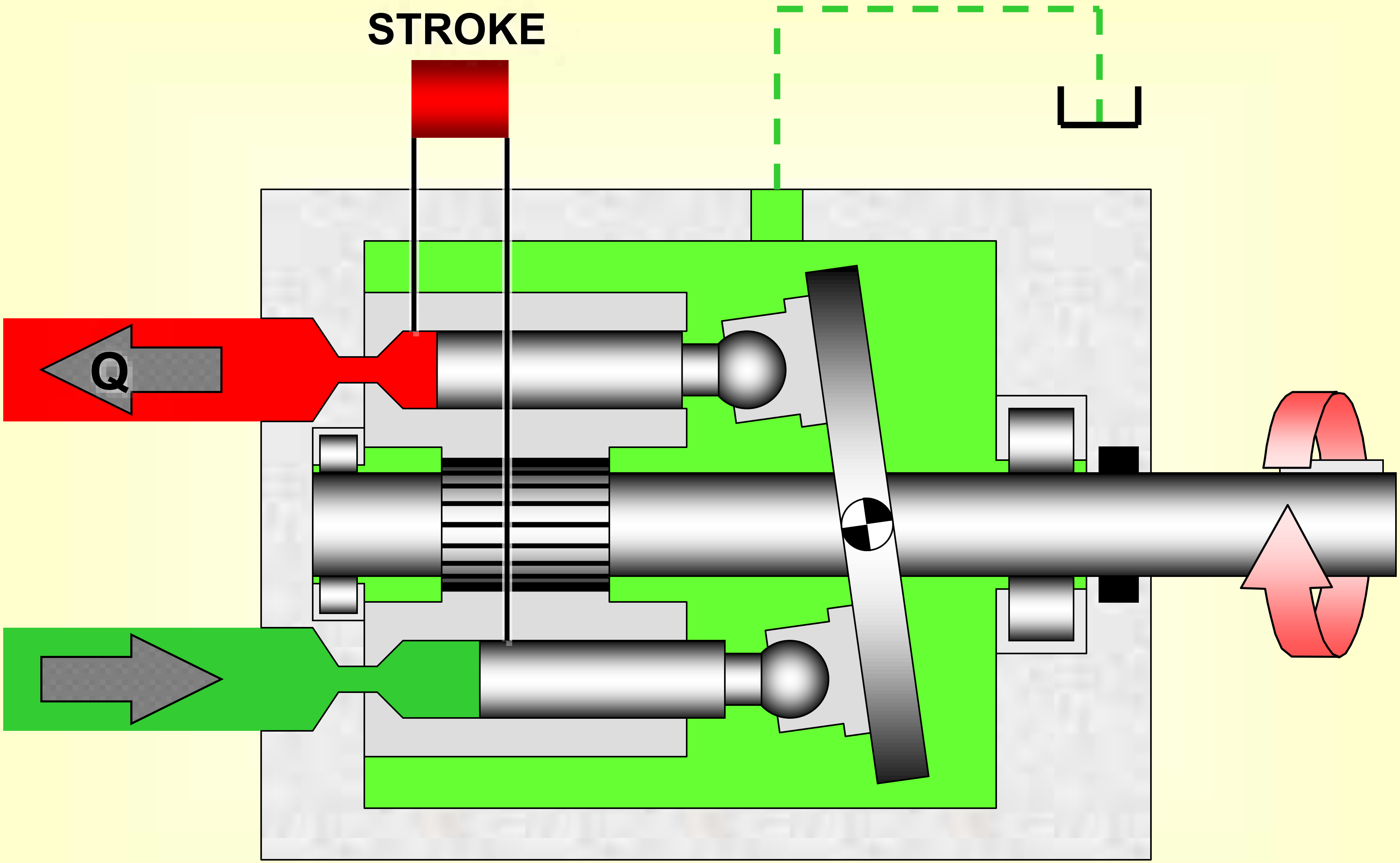
Q = (No. of Pistons) x (Piston Size) x (Piston Stroke) x (Drive Speed)

VARIABLE DISPLACEMENT PUMP - MAX FLOW



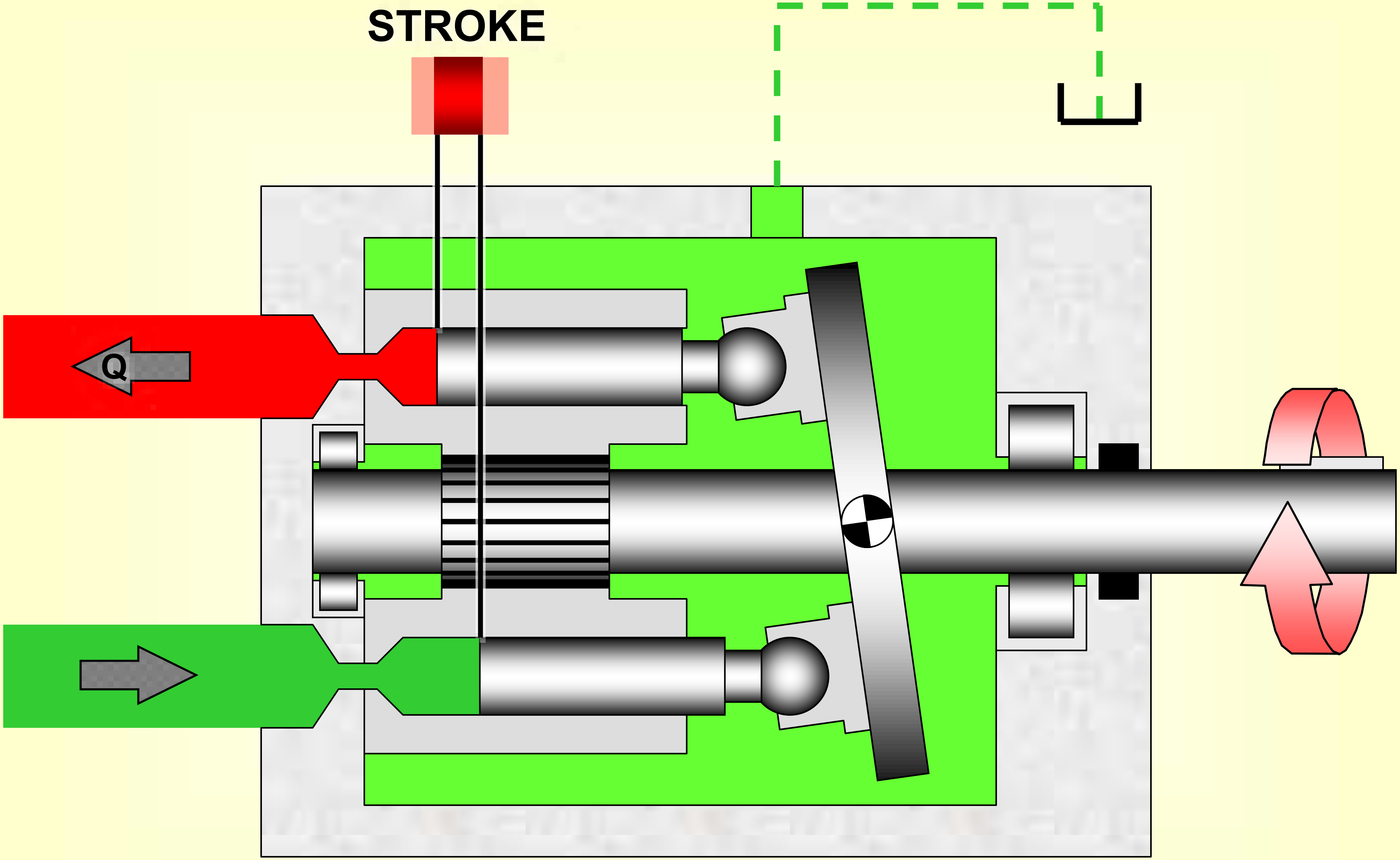
Q = (No. of Pistons) x (Piston Size) x (Piston Stroke) x (Drive Speed)

VARIABLE DISPLACEMENT PUMP - REDUCED FLOW



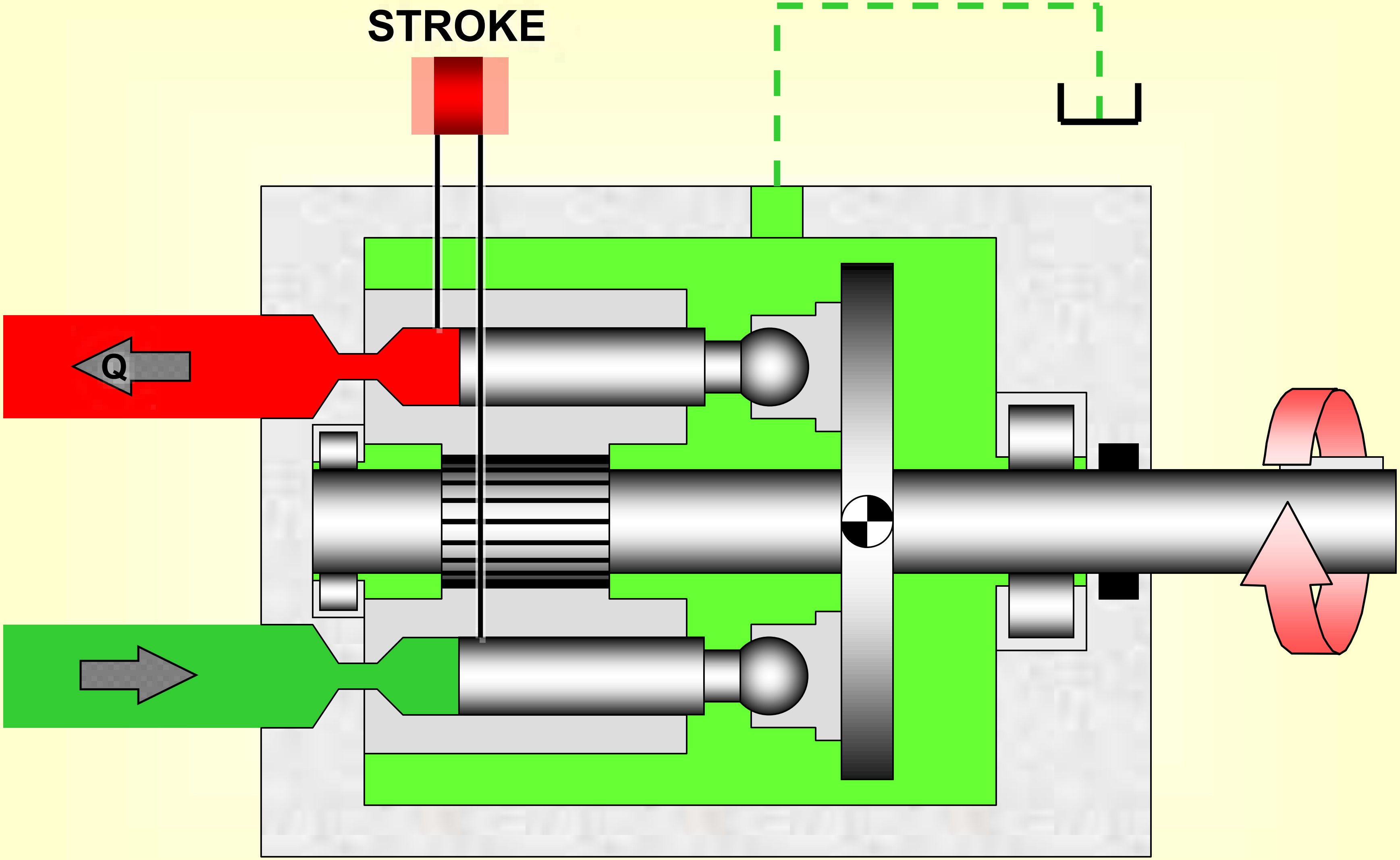
Q = (No. of Pistons) x (Piston Size) x (Piston Stroke) x (Drive Speed)

VARIABLE DISPLACEMENT PUMP - REDUCED FLOW



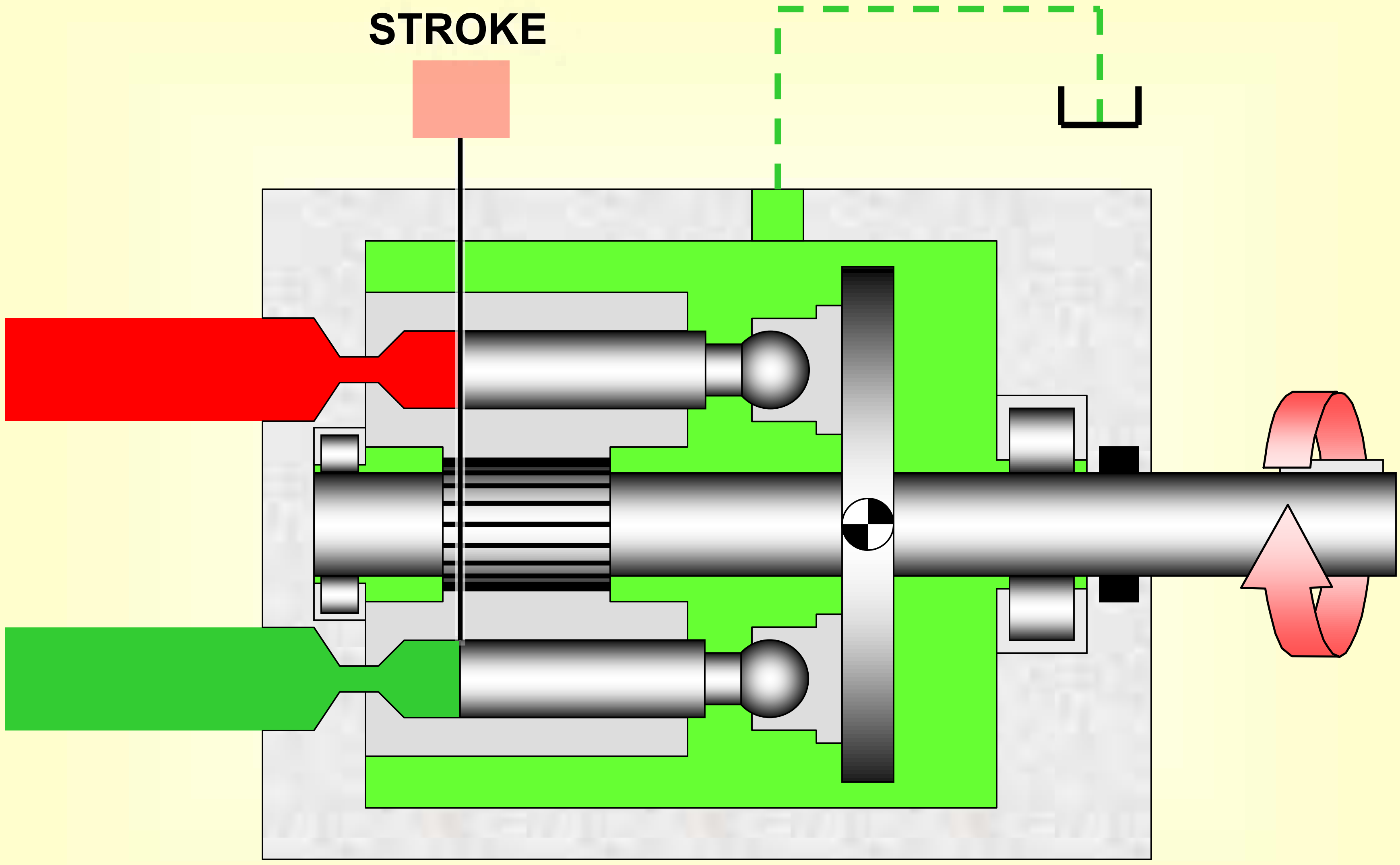
Q = (No. of Pistons) x (Piston Size) x (Piston Stroke) x (Drive Speed)

VARIABLE DISPLACEMENT PUMP - ZERO FLOW



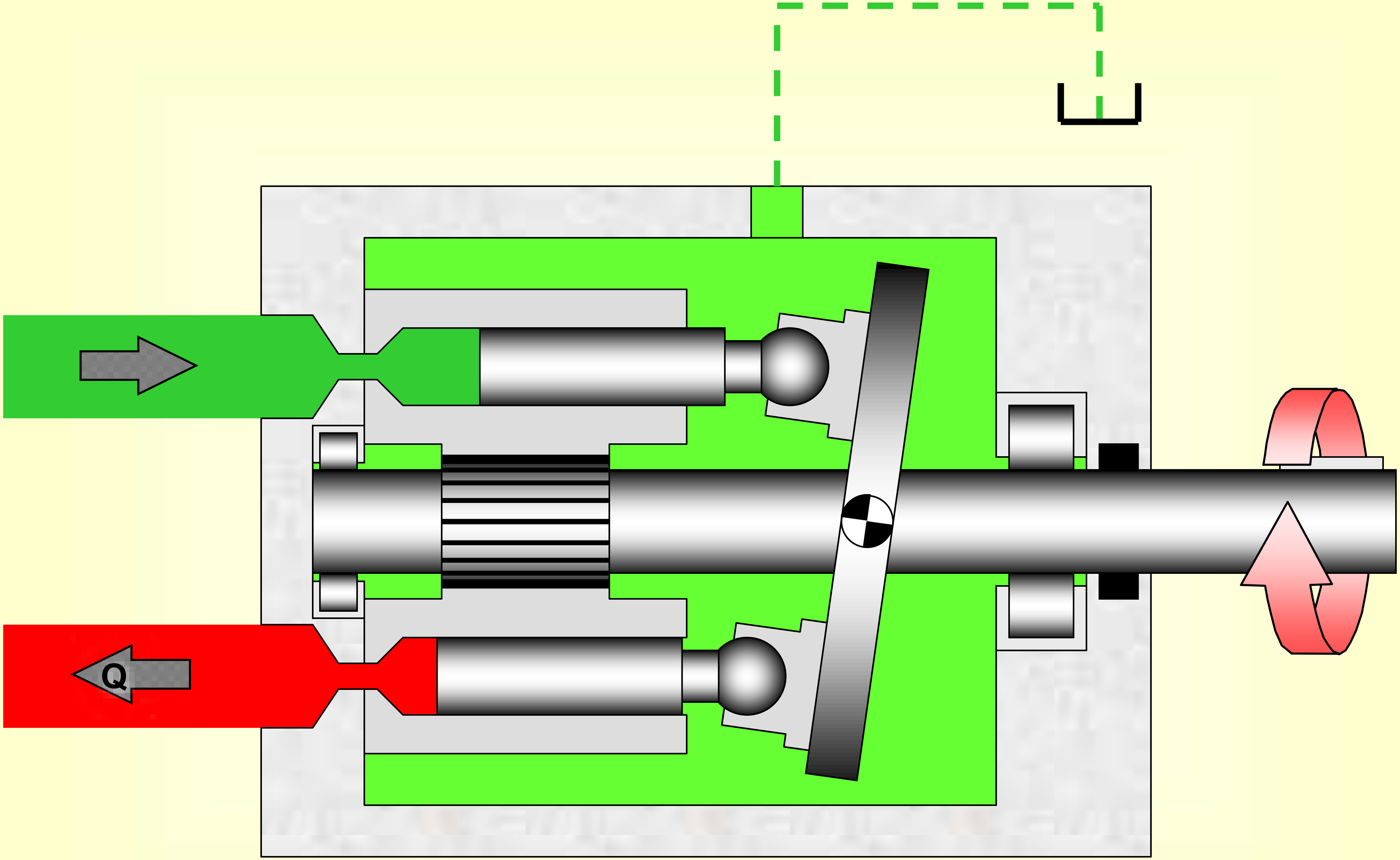
Q = (No. of Pistons) x (Piston Size) x (Piston Stroke) x (Drive Speed)

VARIABLE DISPLACEMENT PUMP - ZERO FLOW



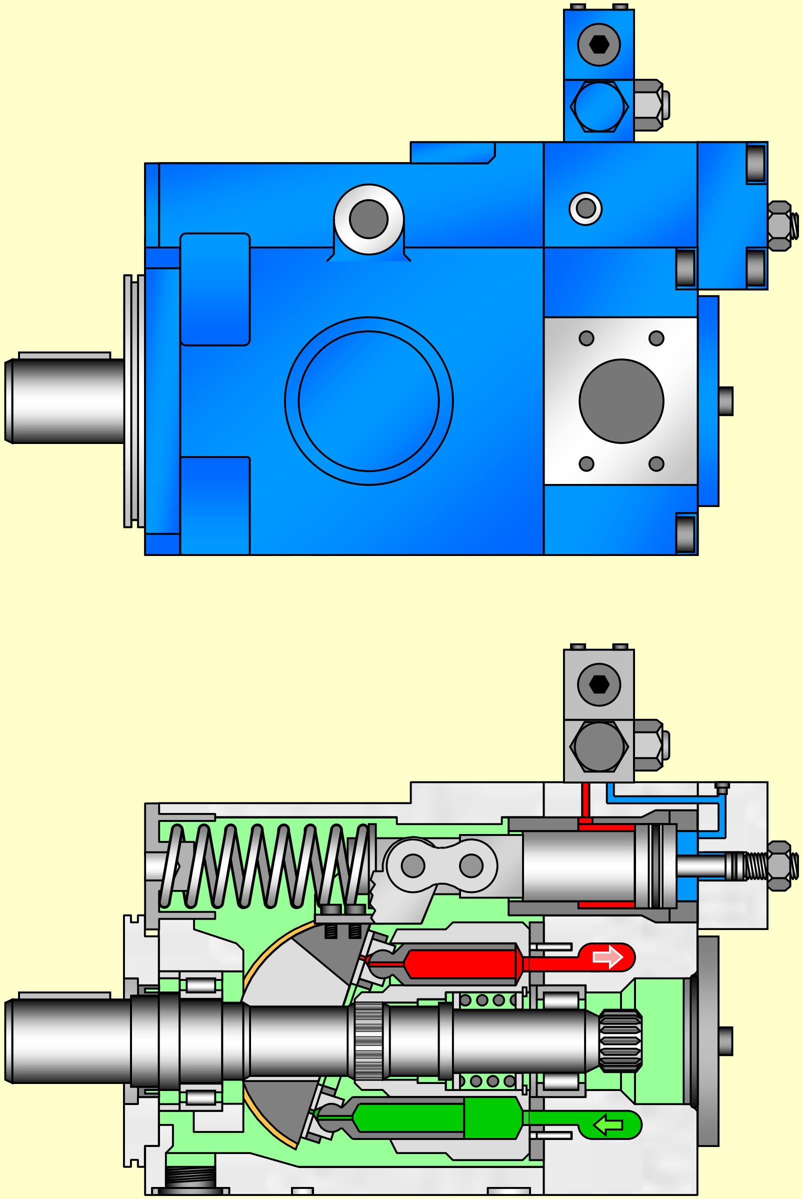
Q = (No. of Pistons) x (Piston Size) x (Piston Stroke) x (Drive Speed)

VARIABLE DISPLACEMENT PUMP - REVERSED FLOW



Variable Displacement Piston Pump

Variable AXIAL PISTON PUMP CHARACTERISTICS



- Displacements to 750+ cm^3/r
- Pressure capabilities to 350/400 bar
- High noise level
- Sensitive to poor inlet conditions & contamination
- High overall efficiency
- Good life expectancy
- Large, bulky units
- Good fluid compatibility
- High cost.

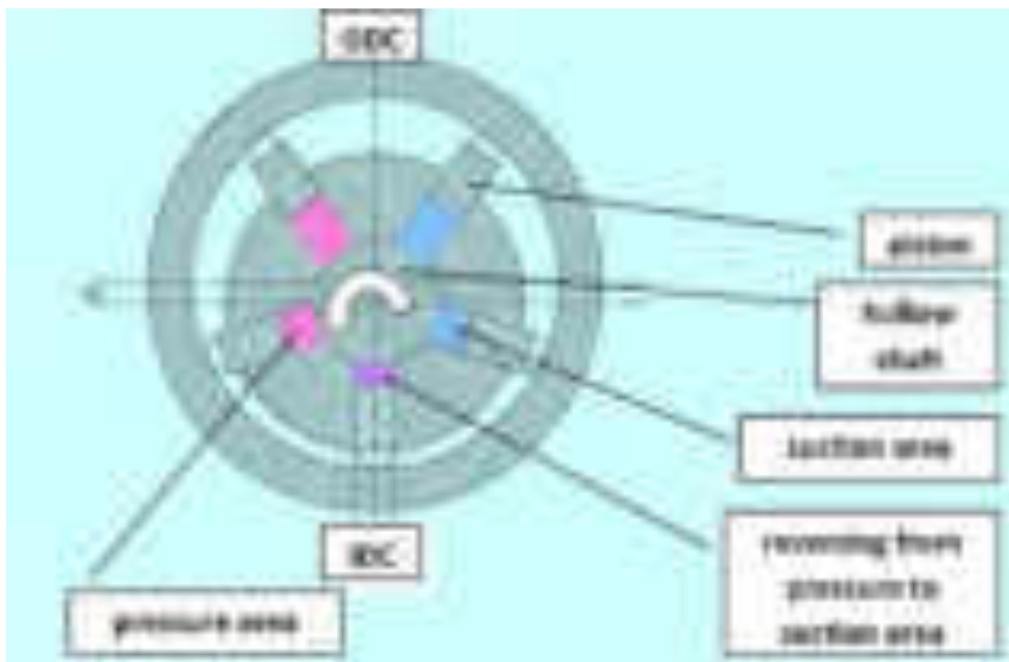
B- Radial piston pump

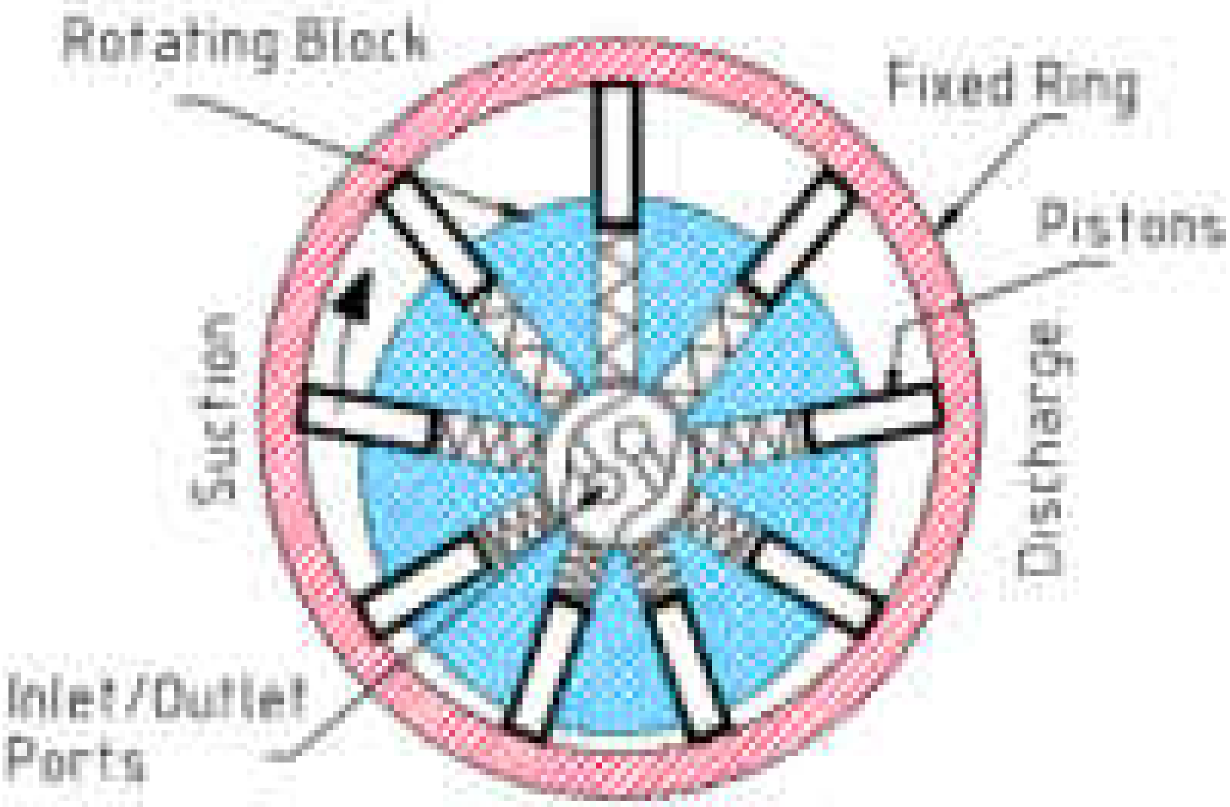
This kind of pump consists of piston mounted radically in a housing and spring loaded which permit the piston to goes out to be filled with oil.

Another type the pistons remains in contact with the reaction ring due to the centrifugal force, as the piston rotate the piston comes out to make a suction and by returning around the ring it goes back to the cylinder to make the pressure. Certain models are operate at 1000 bar and flow rate 1000 liter/min

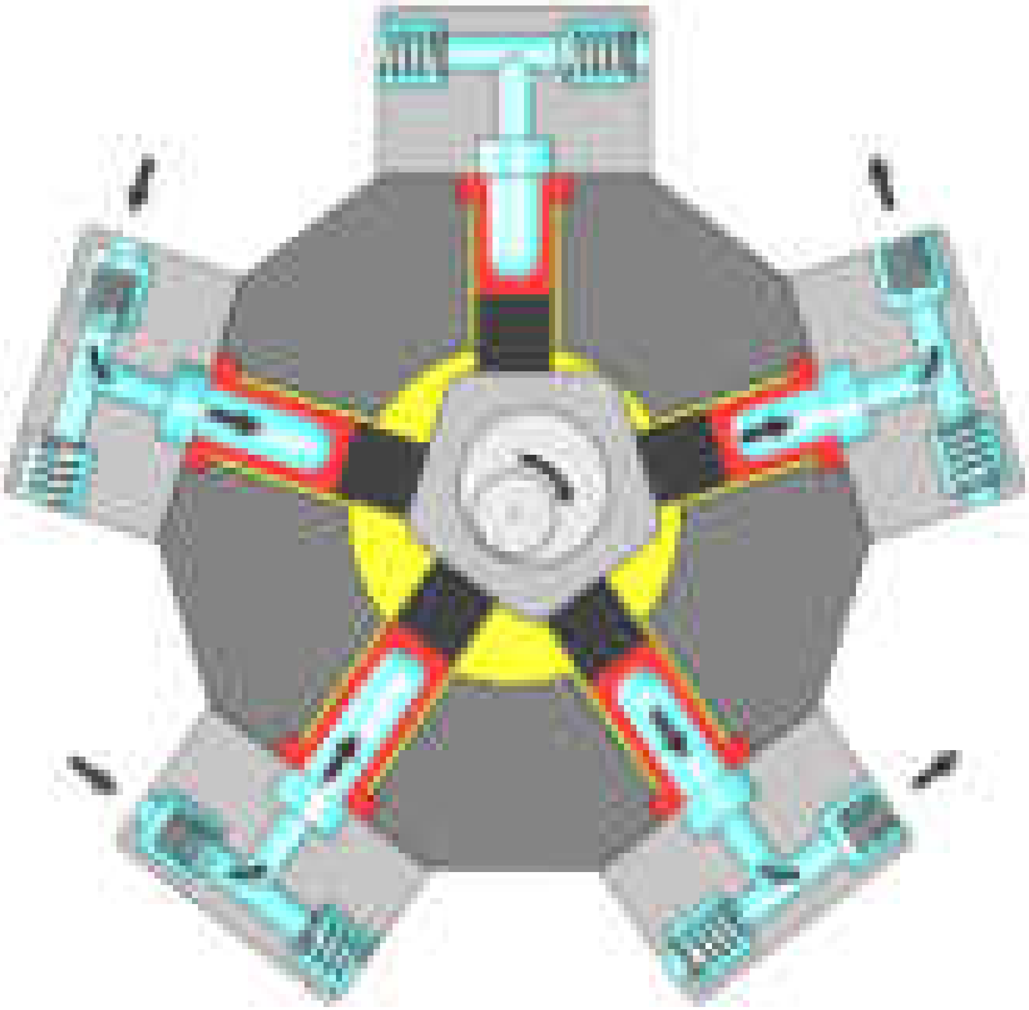
The outer ring for bracing of the pumping pistons is in eccentric position to the hollow shaft in the center. This eccentricity determines the stroke of the pumping piston.

The piston starts in the inner dead center (IDC) with suction process. After a rotation angle of 180° it is finished and the workspace of the piston is filled with the to moved medium. The piston is now in the outer dead center (ODC). From this point on the piston displaces the previously sucked medium in the pressure channel of the pump.

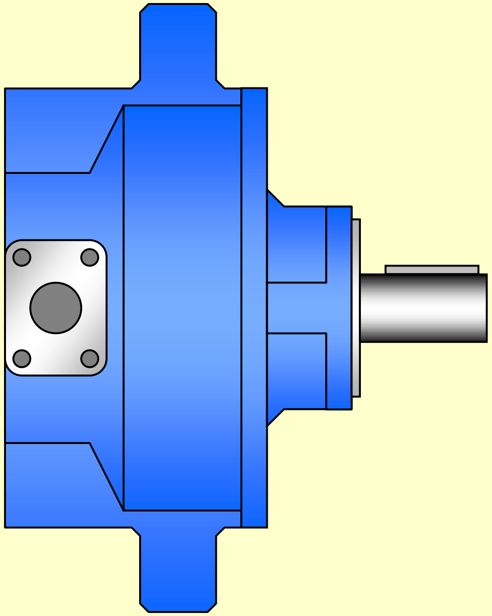


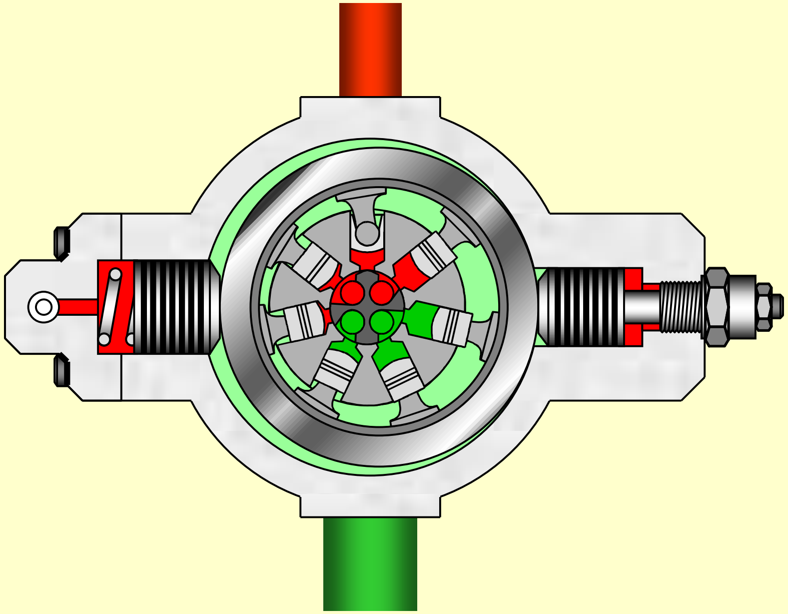


Radial Piston Pump



RADIAL PISTON PUMP CHARACTERISTICS





- Displacements to 250 cm³/r
- Pressure capabilities to 350 bar
- Suitable for open & closed loop
- High overall efficiency
- Good life expectancy
- Short, wide shape
- Simple multiple pump assemblies
- High cost.

Different Types of Pumps

Type of Pump	Pressure Rating (bar)	Speed Rating (rpm)	Overall Efficiency (%)	HP per Ib Ratio	Flow in Ipm
External gear pump	130-200	1200-2500	80-90	2	5-550
Internal gear pump	35-135	1200-2500	70-85	2	5-750
Vane pump	70-135	1200-1800	80-95	2	5-300
Axial piston pump	135-800	1200-1800	90-98	4	5-750
Radial piston pump	200-800	1200-3000	85-95	3	5-750

Factors Affecting Pump Performance

1- Presence of foreign particles

2- Foams and bubbles

3- Overheating of oil

4- Wrong selection of oil.

Major aspects in the selection of pumps

1- Flow rate requirement

2- Operating speed

3- Pressure rating

4- Performance

5- Reliability

6- Maintenance

7- Cost and Noise

8- Fluid Type