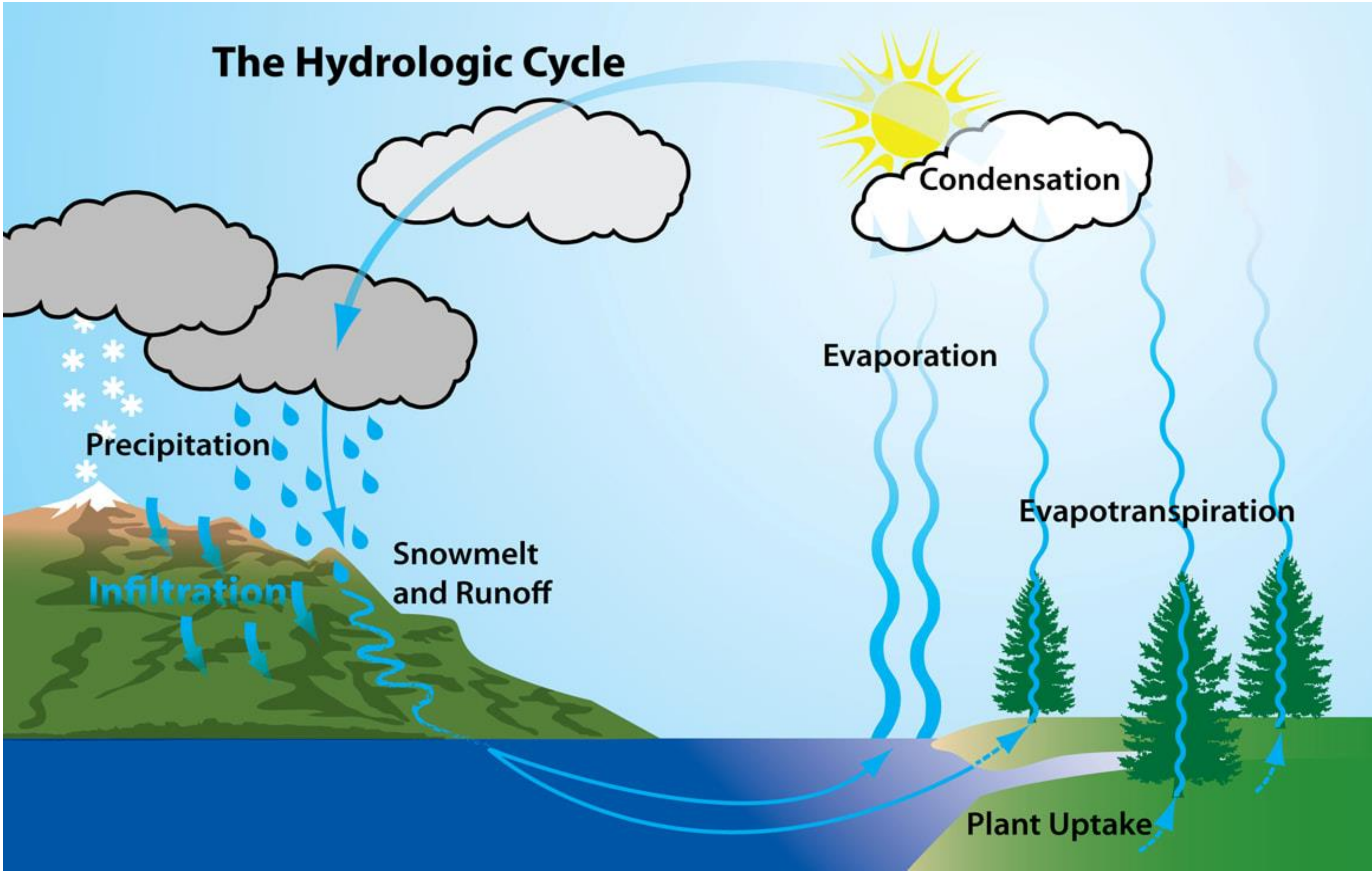
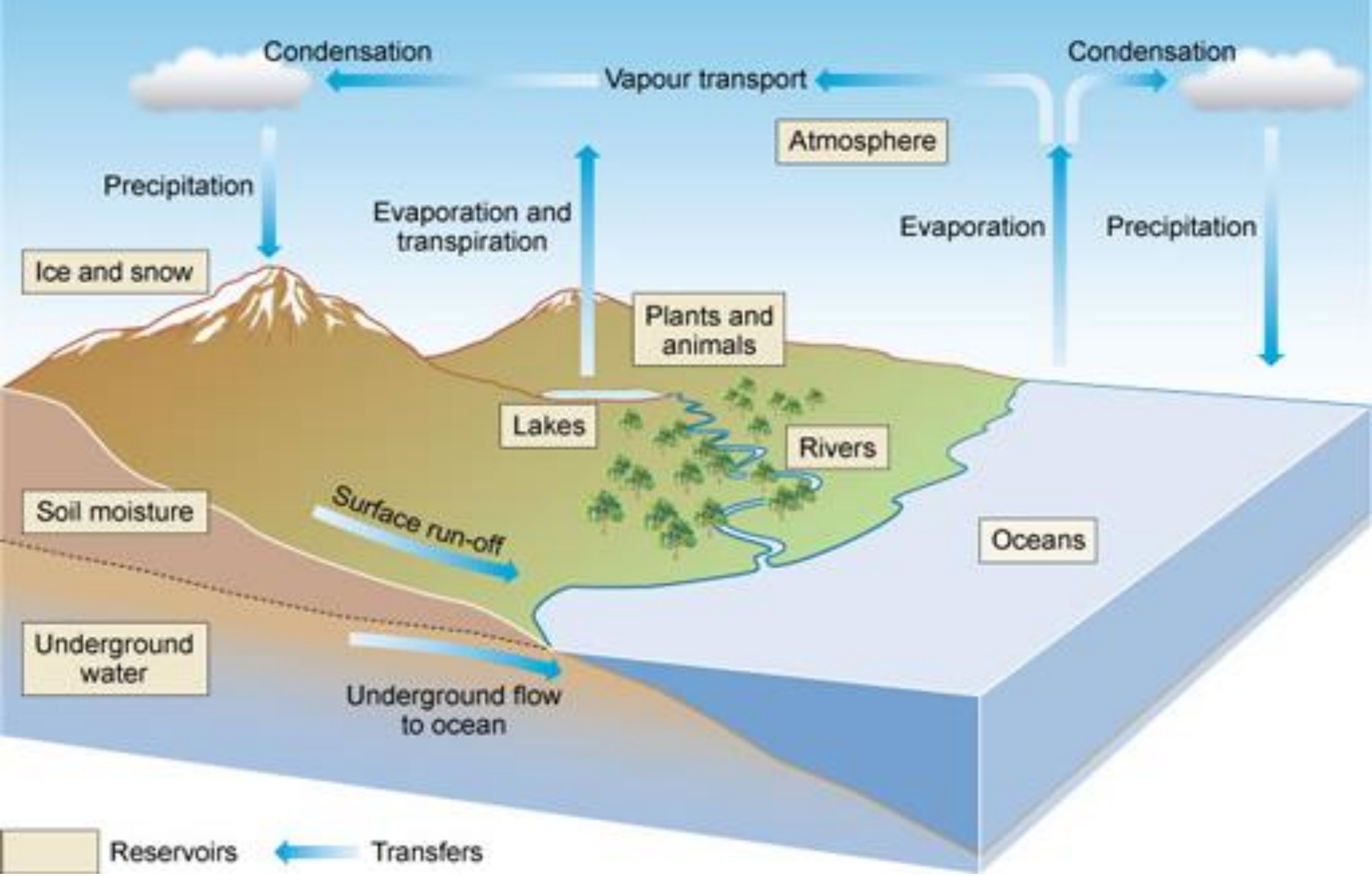
Energy Environment and Society (EES)
(EX 701)(BCT IV/I)

Lecture 2

Hydropower

Water Sources and The Hydrologic Cycle





Water sources

Power from Water

Hydropower Equation

- Hydro Power uses mechanical energy of water in streams.
- The energy of water in the stream manifests in form of kinetic and potential energy.
- Kinetic energy of water is due to its velocity of movement through the river course and potential energy is due to its position above the sea level.

Power from Water…

- Everyone is aware of the energy that flowing-water possesses. But one may not be aware of the energy of water calmly stored in lakes or ponds above the sea level.

Power from Water…

- The energy stored in water elevated from the sea level may be expressed mathematically as:

$$\boldsymbol{E = m} \times \boldsymbol{g} \times \boldsymbol{h} \qquad [1]$$

Where,

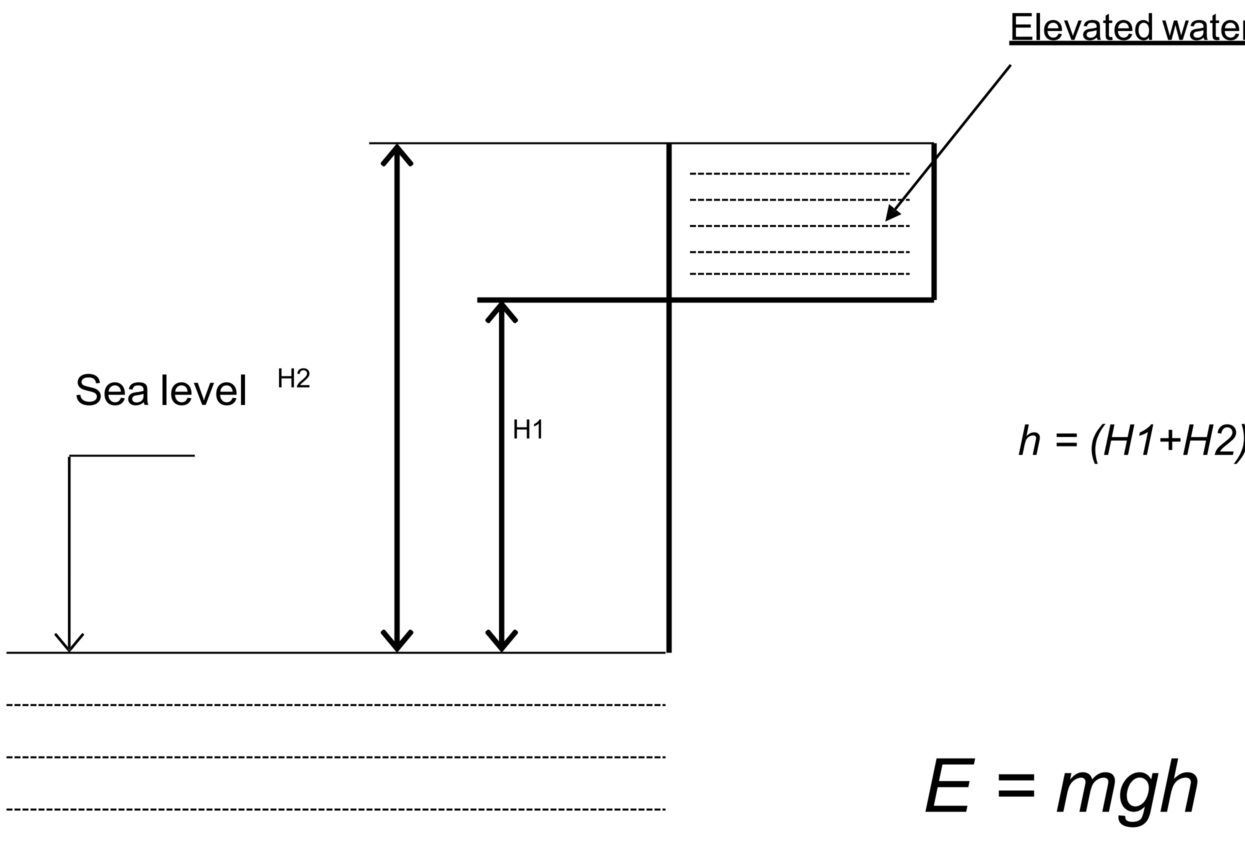
E - energy of water in Joules;

m - mass of water in *kg;*

g - acceleration due to gravity in *m/s2;* and

h – elevation of water with respect to the sea level in *m*.

Power from Water…



$h = (H1+H2)/2$

$$E = mgh$$

Illustration of energy of elevated water

Power from Water…

- Equation [1] may be rewritten as

$$
\begin{aligned}
E &= \rho \times V \times g \times h \; [(kg/m3) \times (m3) \times (m/s2) \times m] \\
&= 1000 \times V \times g \times h \; [kg \times (m/s2) \times m] \\
&= 1000 \times V \times g \times h \; [N \times m] \\
&= 1000 \times V \times g \times h \; [J]
\end{aligned}
$$

Power from Water…

- *The corresponding power may be calculated as*

$$P = E/t\ [J/s] = E/t\ [W]$$
$$= 1000 \times V \times g \times h/t\ [W]$$
$$= 1000 \times (V/t) \times g \times h\ [W]$$
$$= Q \times g \times h\ [kW]$$
$$P = 9.81\ Qh\ [kW] \qquad [2]$$

Power from Water…

- *Equation [2] represents the theoretical power that may be generated from elevated water. In reality some losses are involved in power generation. Let η be the efficiency of the process of power generation. Then equation [2] may be rewritten as*

$$P = 9.8 \times \eta \times Q \times h \qquad [3]$$

- *This equation is known as hydropower equation. The η represents in equation [3] expressed for losses in civil works and electromechanical components. For micro-hydropower plants the value η varies from 0.5 to 0.6.*

Power from Water…

- *If overall efficiency η taken as 50% and value of acceleration due to gravity "g" taken as 10 then for rough estimation of MHP potential then the equation [3] may be rewritten as:*

$$P = 5\,Q\,h \qquad [4]$$

Where, Q *is expressed in m3/s.*

h *is expressed in m.*

P *is expressed in kW.*

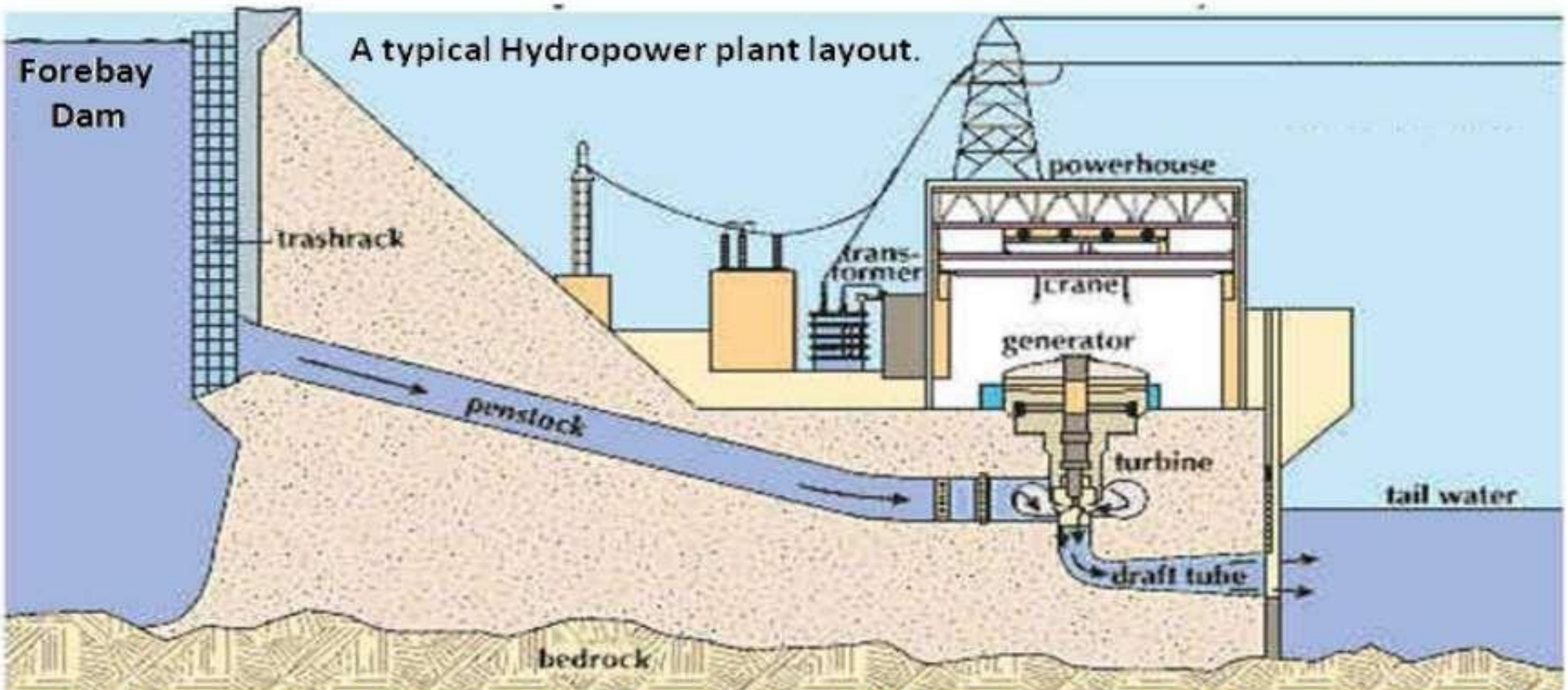
Hydroelectric Power

- What is it?
  - Conversion from kinetic energy of water to mechanical energy to electrical energy.
- Hydropower plants dam a flowing body of water
- The water is then stored reservoir.
- When the water is released from the reservoir, it flows through a turbine, causing it to spin and activating a generator to produce electricity.

Hydropower: *Basic Concept*

- Hydropower: *Power produce from water*

Hydropower plants capture the energy of falling water to generate electricity.

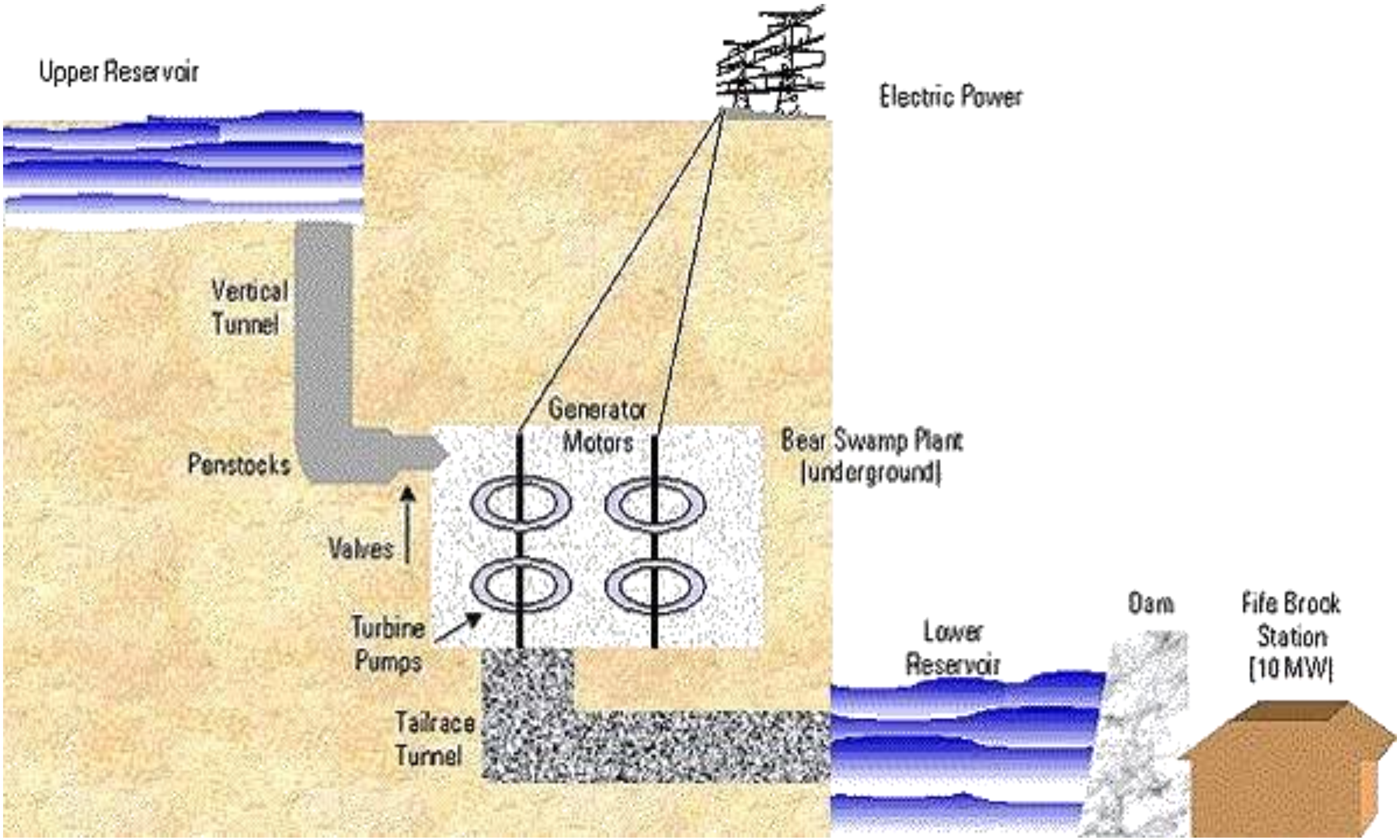


A turbine converts the kinetic energy of falling water into mechanical energy. Then a generator converts the mechanical energy from the turbine into electrical energy

How it works

- A dam blocks the water, holds it in a reservoir.
- Pipes called the penstock bring water from the reservoir to the powerhouse.
- The drop in elevation in the penstock is call the “head.” The force created is the force need to create electricity.
- Higher volume of water and a higher force of the head create a greater amount of energy.
- The powerhouse contain the turbines. The turbines move from the force of the head as it flows down the penstock.
- The rotating turbines turn a shaft that drives generators that produce electricity.
- Water not used for producing energy is released over the spillway of the dam.”

Hydo power conversion process



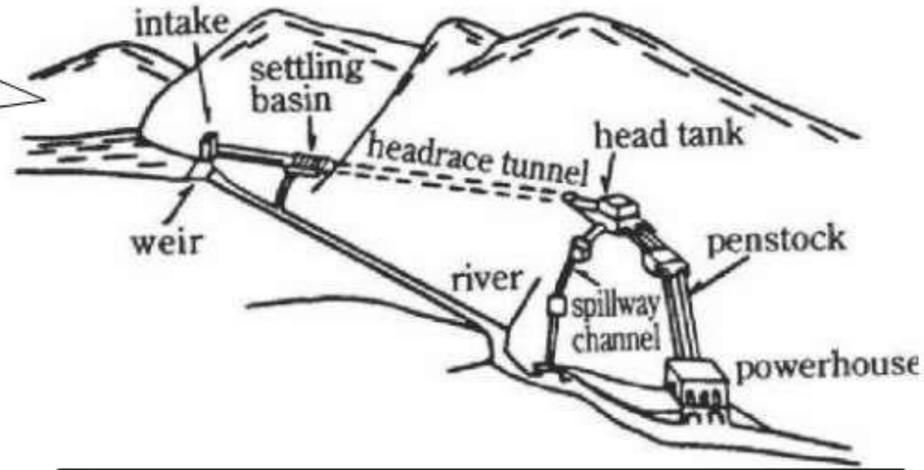
Dams aren't always necessary

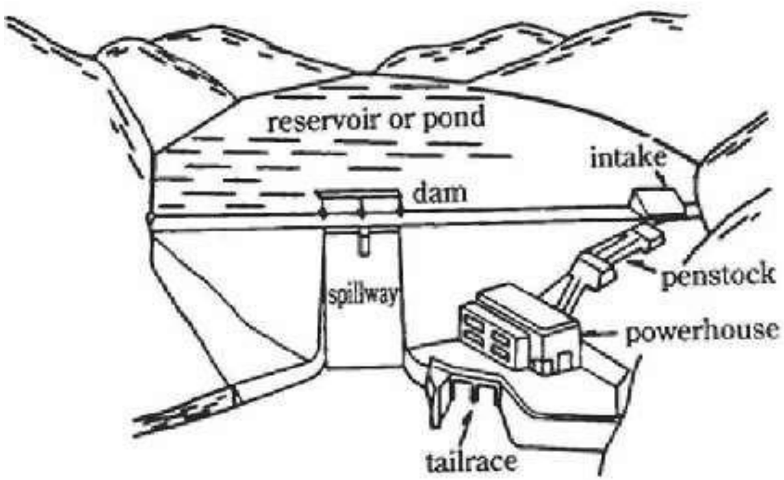
- Some hydro power comes from channeling a portion of the river into a canal.
- The water would then be pumped into a holding area.
- When it is released, the generator housed in the canal would generate electricity.

Types of hydropower plants

Run-off-River type

- Uses water within the range of the natural river flow.
- Seasonal Variation of Flow
- No Storage of Water Energy



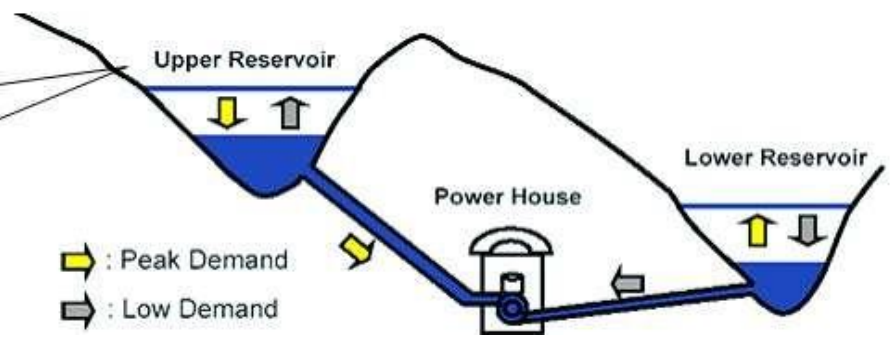


Reservoir / Pondage type

- Has a reservoir that enables regulating the river flow
- Supplies power in response to the demand.
- Head may alter as per reservoir water Level

Pump storage type

- Has an upper reservoir and a lower reservoir.
- Generates power during peak demand.
- Pumps up water during low demand.
- Improves Load Factor



Present categorization of HP schemes:

- Less than 5 kW	:	Pico-hydro
- Less than 100 kW	:	Micro-hydro
- less than 1000 kW	:	Mini-micro-
- from 1000 kW to 10 MW	:	Small hydro
- from 10 MW to 300MW	:	Medium hydro
- plants above 300 MW	:	Big hydro

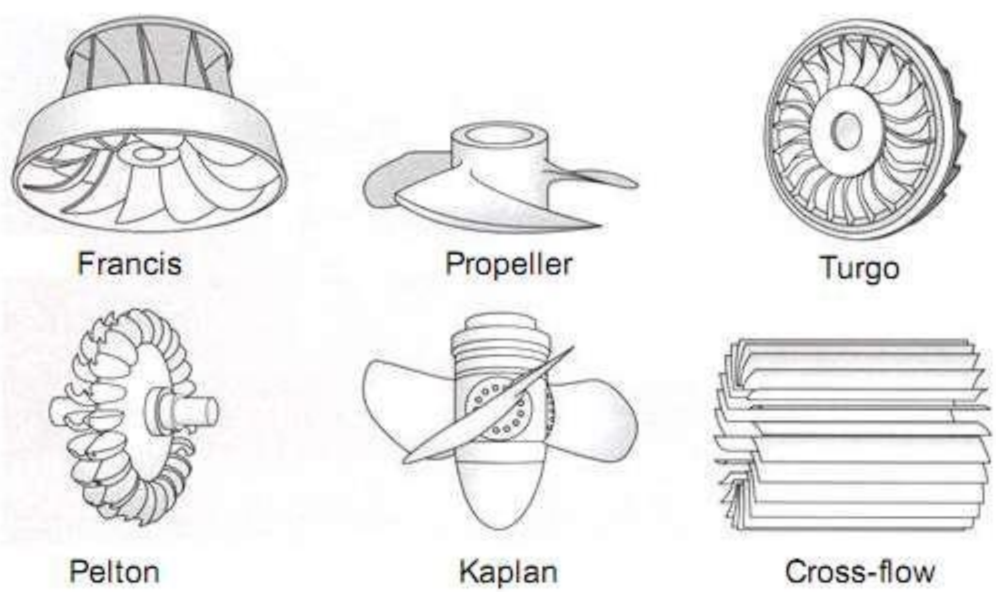
Fundamentals of Hydraulic Machinery

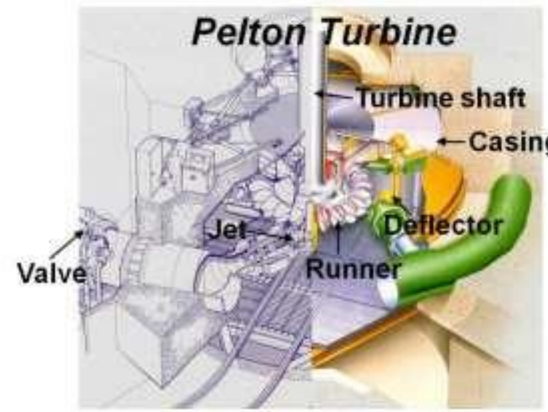
A hydraulic Turbine is a Roto-dynamic fluid machine, which converts hydraulic energy into mechanical energy.

Basic Construction

- The Runner (Rotor) having identical blades or bucket mounted on it.
- The flow guide mechanism or nozzle to direct the flow at the required angle.
- The outer casing (housing)

Runner for different type of Turbines:





Turbines

- Converts energy in the form of falling water into rotating shaft power

CLASSIFICATION OF TURBINES

- **According to basic working principle**
  - Impulse and reaction turbine
- **According to head**
  - High head (Pelton)
  - Medium head (Cross flow, Francis)
  - Low head (Kaplan)
- **According to specific speed**
  - Low Specific Speed (Pelton)
  - Medium Specific Speed (Cross flow, Francis)
  - High Specific Speed (Kaplan)
- **According to flow directions**
  - **Axial Flow**
  - **Radial Flow**
  - **Tangential flow**
  - **Mixed Flow**

According to basic working principle

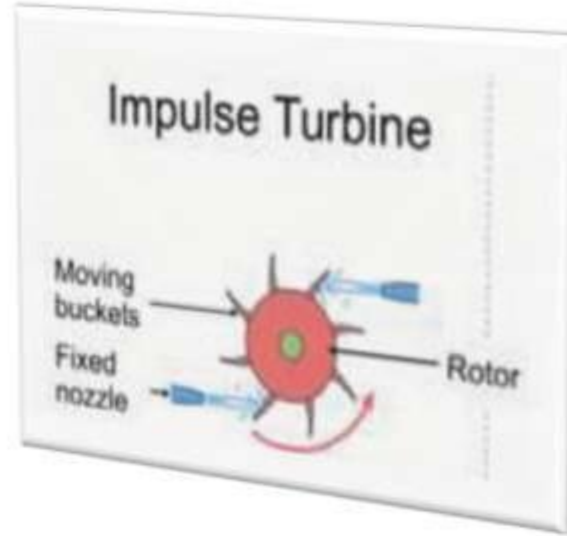
1. Impulse turbines: major portion of potential energy (Hydro energy) is converted to kinectic energy of water. For eg. Pelton, Crossflow, Turgo

2. In reaction turbines, major portion of potential energy of water is converted to pressure energy which rotates the turbine. For eg. Francis Turbine, Propeller Turbine, Kaplan Turbine

Energy Conversion

Impulse Turbine (Part Flow Turbine)

The hydraulic Energy of Impulse Turbines are completely converted into kinetic energy before transformation in the turbine runner. The impulsive force imparted by high velocity jet of water on runner bucket produce a mechanical power on the turbine shaft

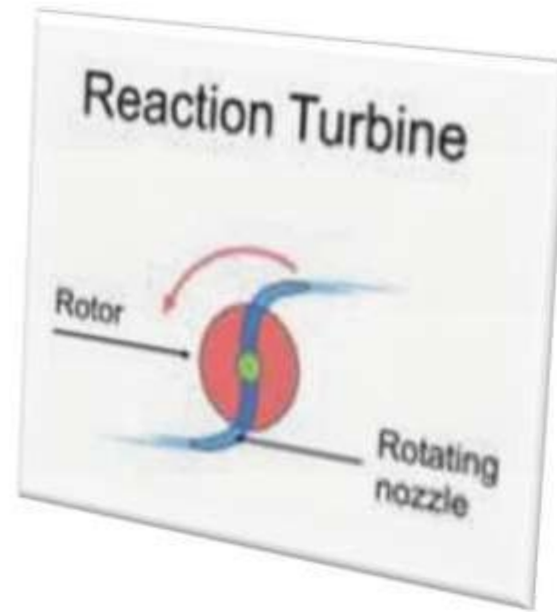


Reaction Turbine (Full Flow Turbine)

In the reaction type turbines two effects cause the energy transfer from the flow to mechanical energy on turbine shaft

First it drop the pressure energy as it flow from inlet to the out let of the turbine runner. This is denoted by reaction part of the energy conversion.

Secondly change in direction of the velocity vectors of the flow through passage between the runner blades transfer the impulsive force. This is denoted by the impulsive part of the energy conversion.



Turbine: is a mechanical device that capture the power of falling water and produce useful mechanical power

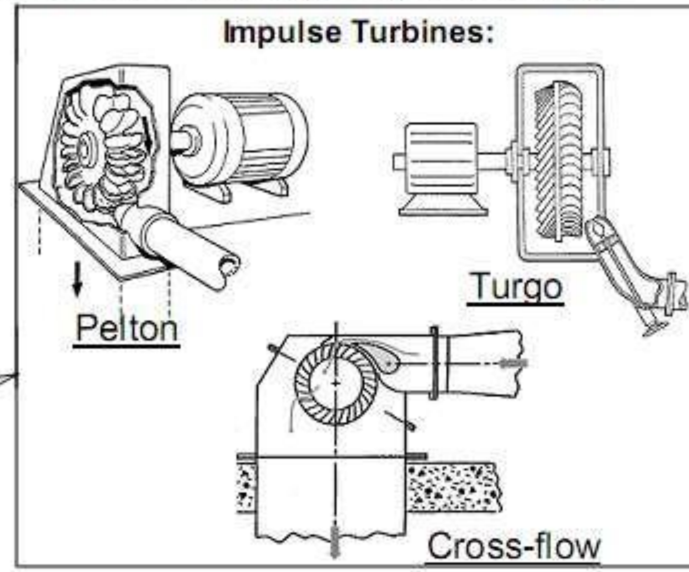
- *Water under pressure contains energy.*
- *Turbines convert the energy in water into rotating mechanical energy.*

Turbine Types / Principle of operation

Based on the working Principle, Turbines are grouped in two main groups namely **Impulse** and the **Reaction**.

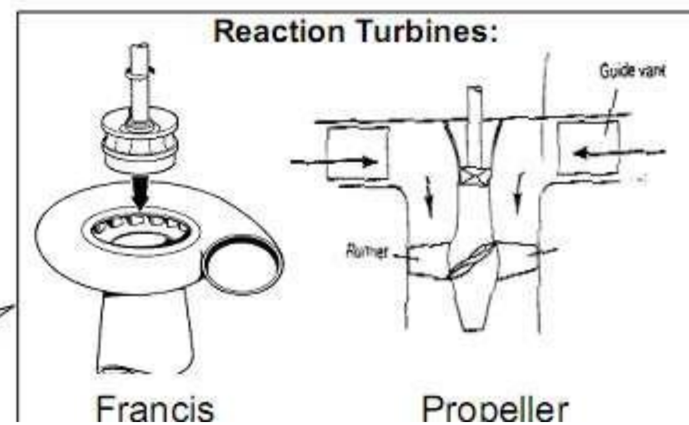
In Impulse Turbine, pressure energy of water is completely converted into Kinetic energy before hitting to the Turbine Runner. There is no pressure different between Inlet and outlet of Turbine Runner..

Impulse turbines convert the kinetic energy of a Jet of water to mechanical energy



In Reaction type turbine, there is Pressure different between Inlet and Outlet of Turbine Runner. The energy transformed due to decrease in Pressure energy or pressure different is known as Reaction effect.

Reaction turbines convert pressure energy of water to mechanical energy.



General features and use of Impulse and Reaction Turbines

Impulse Turbines

- Tolerate sand.
- Easy to fabricate.
- Suitable for medium to high head.
- Efficient at wide a range of head & flow.
- Jet of water strike the runner bucket.
- No cavitations problem
- A nozzle converts pressurized water into a high-speed jet of water.
- Low specific speed

Commonly used Impulse Turbines are:

- Pelton
  - Low Flow
  - Medium to High Head
- Turgo
  - Medium Flow
  - Medium to High Head
- Crossflow
  - High Flow
  - Low to Medium Head

Reaction Turbines

- Water to be clean
- Difficult and Expensive to fabricate
- Suitable for low to medium head.
- Poor part-flow efficiency.
- Runner to be completely filled with water.
- Uses pressure drop across turbine runner.
- Cavitations must be avoided.
- High specific speed.

Commonly used Reaction Turbines are:

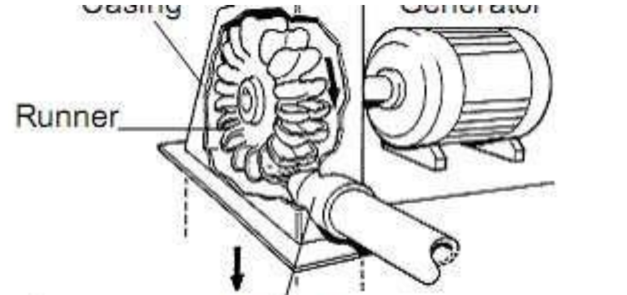
- Francis
  - Medium Flow
  - Medium Head
- Propeller and Kaplan
  - High Flow
  - Low Head

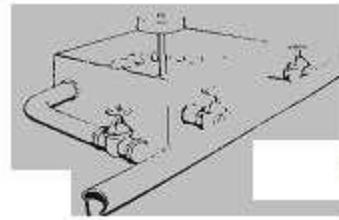
CAVITATION

Pelton Turbine

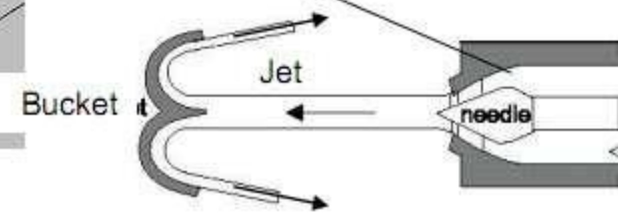
- is a impulse type turbine
- normally use for medium to high head site
- At least one jet of water strike the buckets at atmospheric pressure
- Maximum jet diameter about 1/3 of bucket width.
- Multi-Jet Pelton increase flow and are used at medium head.
- can be mounted horizontally or vertically

Twin runner



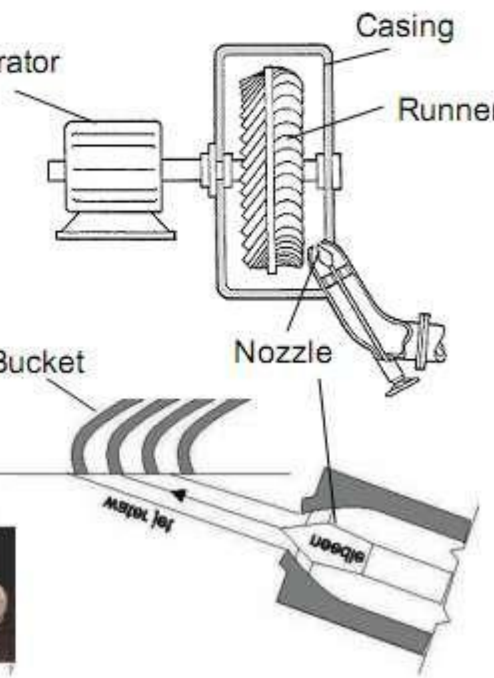


Multi-Jet Pelton



Turgo Turbine

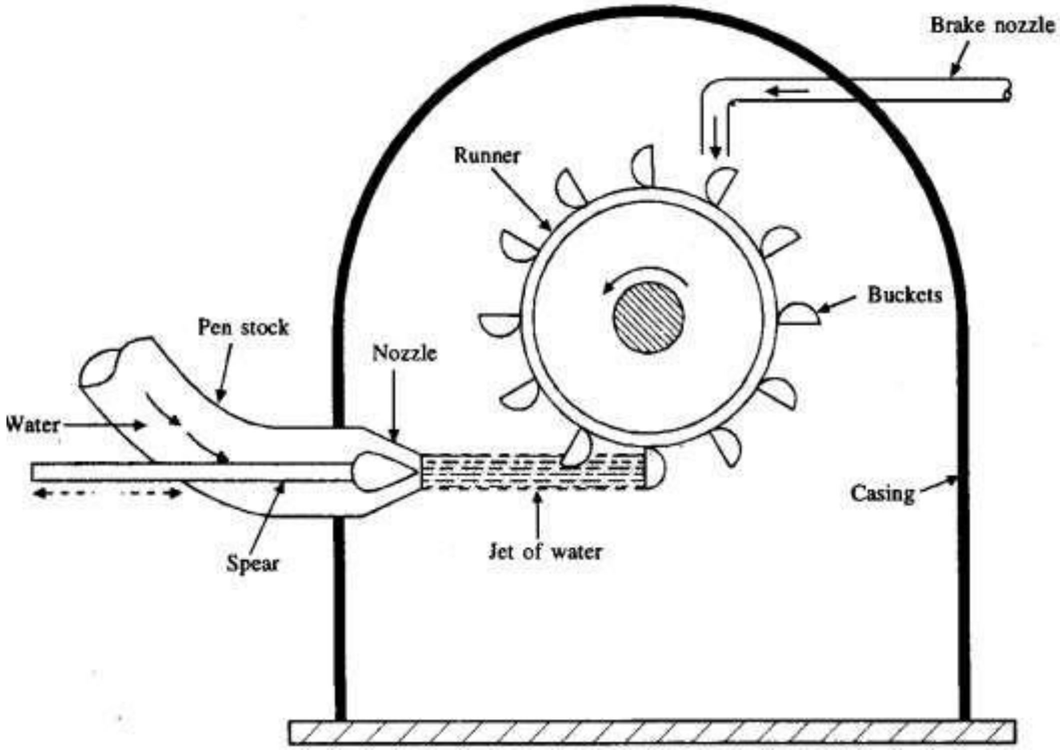
- is a impulse type turbine similar to Pelton but more complex blade design.
- normally use for medium head site
- The water jet strike from one side and leave from other side of the bucket.
- It experienced axial load.

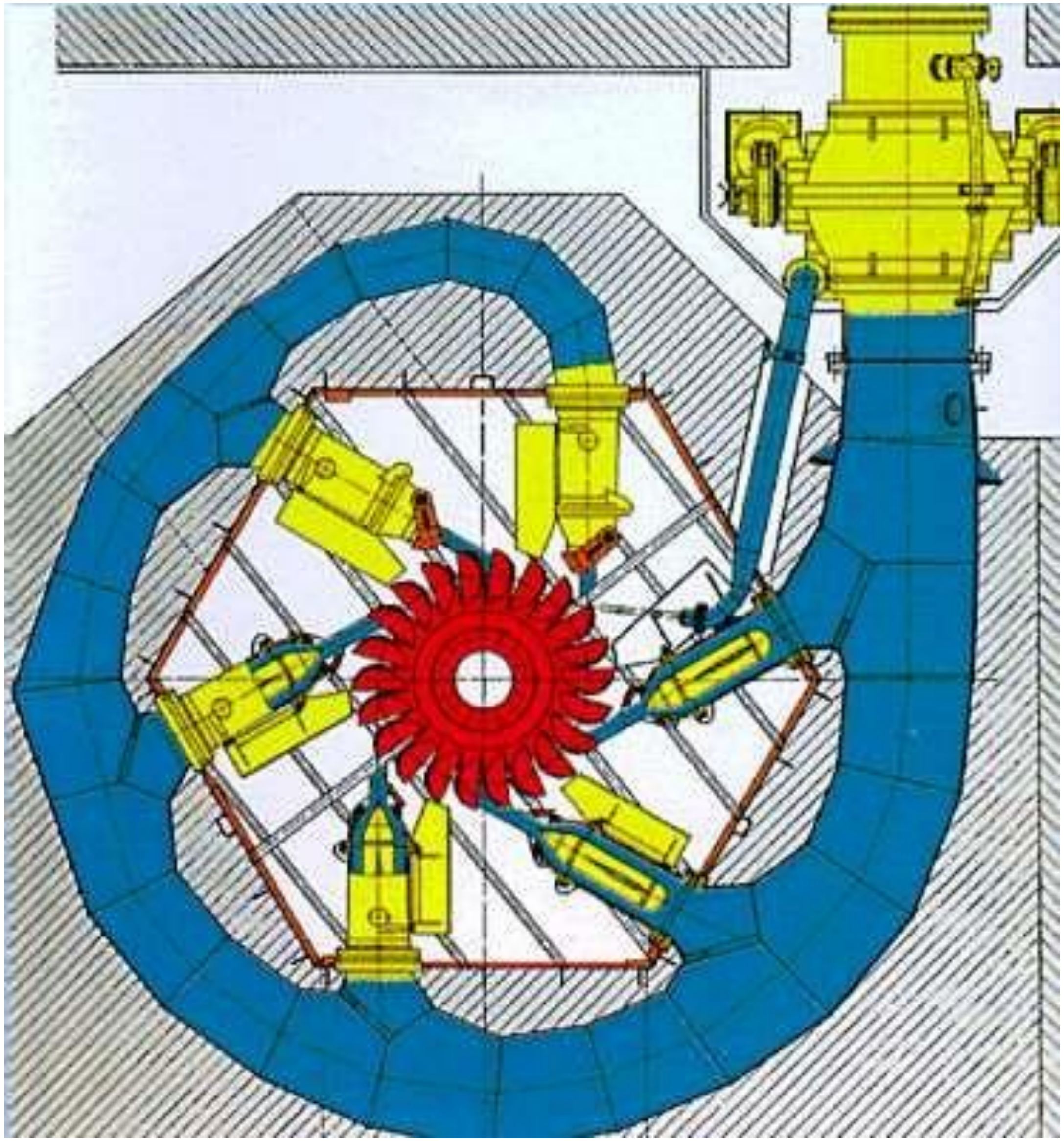


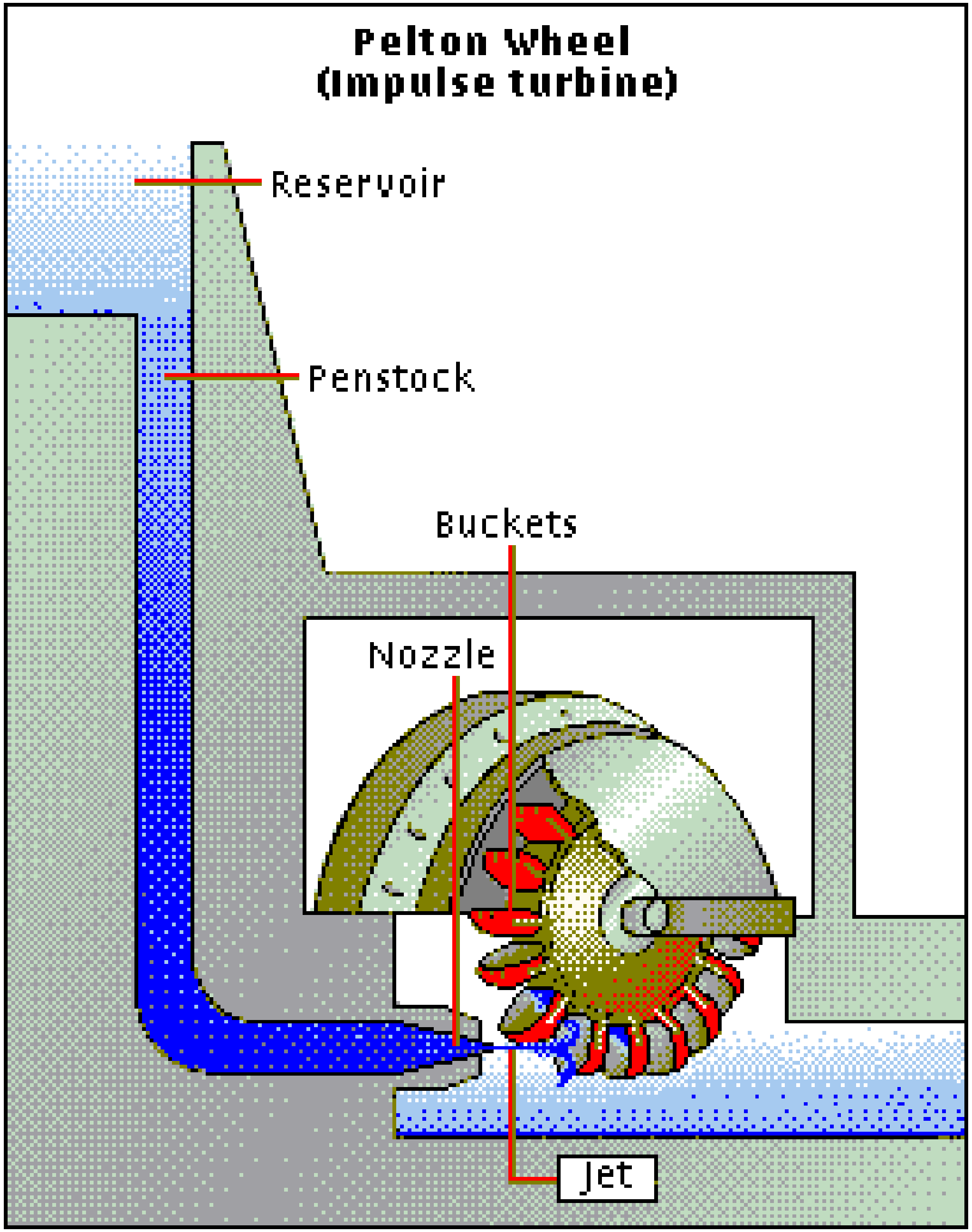
PELTON TURBINE

2.Construction (different Parts):

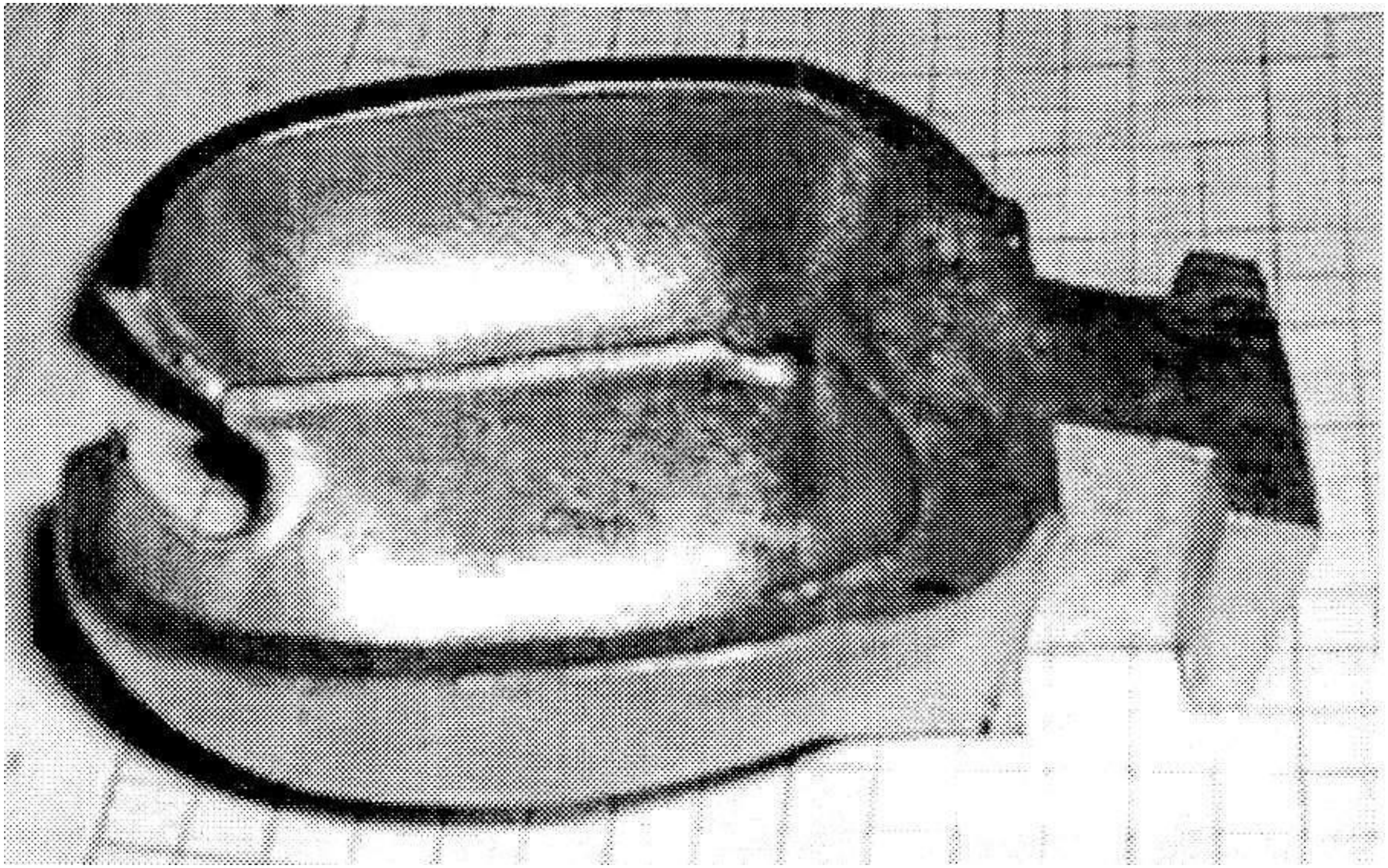
- Max. 6 nozzles

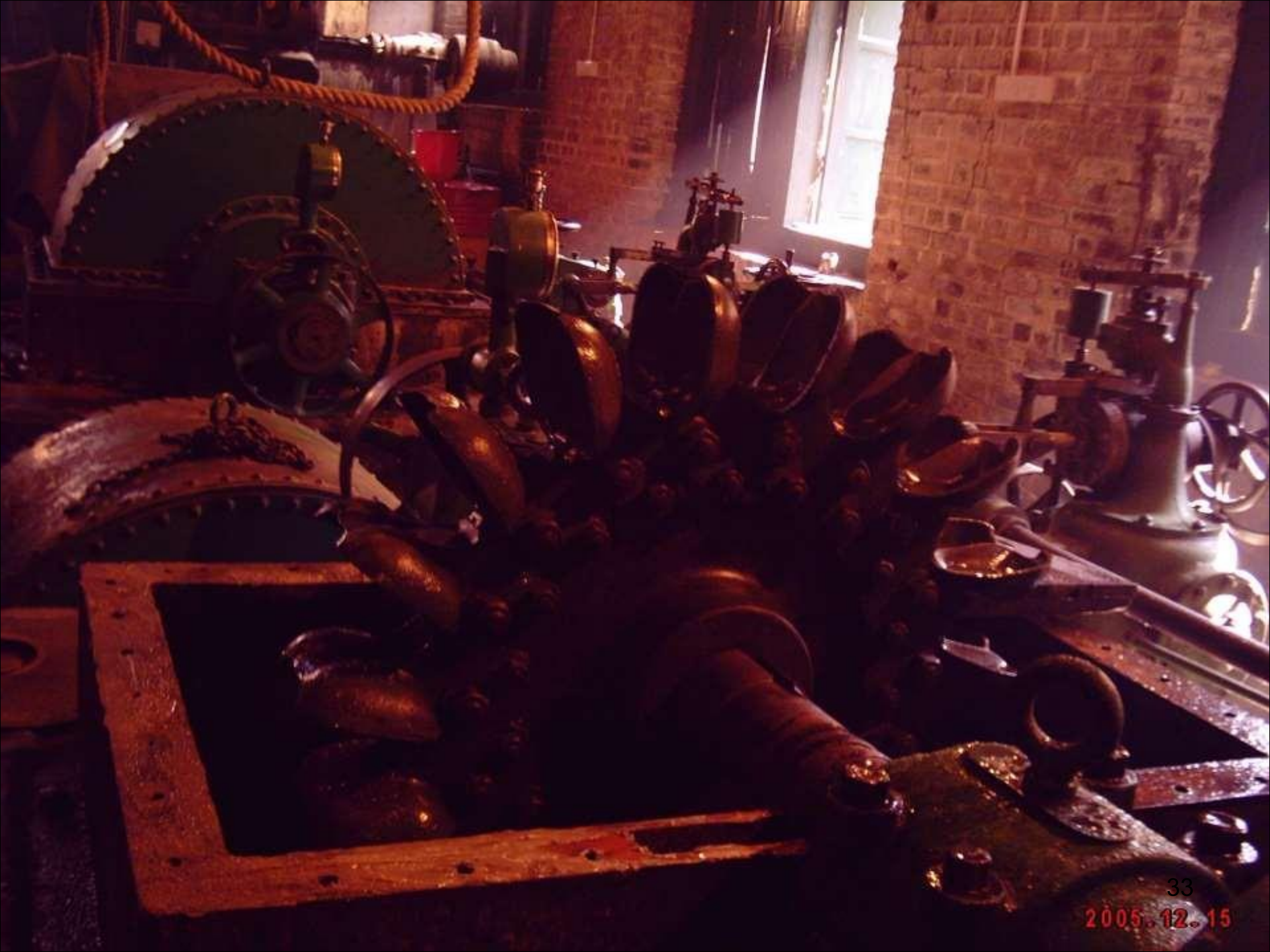





Pelton Wheel
(Impulse turbine)
Reservoir
Penstock
Buckets
Nozzle
Jet

Bucket:




2005. 12. 15

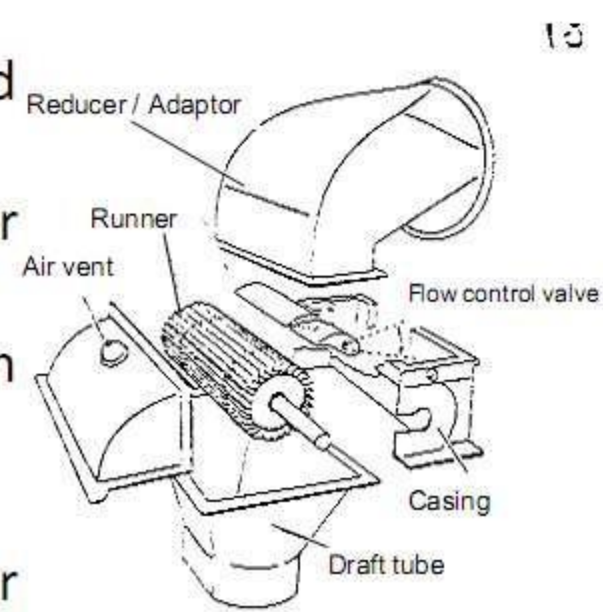
7.Pelton turbine in Nepal

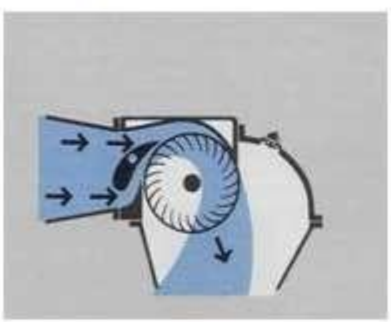
- **The major power plant having pelton turbine are**

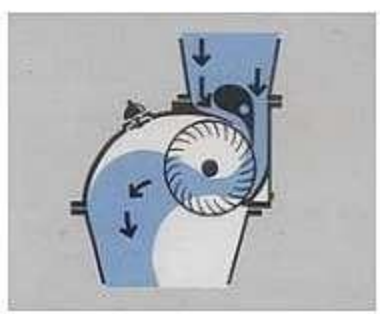
1. **Kulekhani first (30x2)MW**
2. **Puwa khola (3x2) MW**
3. **Sundarijal (300x2)KW**
4. **Pharping (250x2)KW**
5. **Khimti (12x5)MW**
6. **Chilime (11X2)MW**
7. **Adhikhola (1.7x3)MW**
8. **Piluwa-turgo (1.5x2)MW**

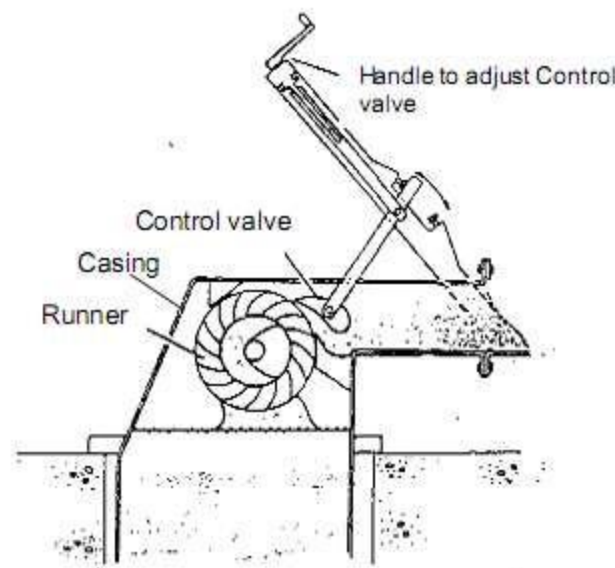
Crossflow Turbine

- is a impulse type turbine having drum shaped runner.
- also known as Banki, Mitchell and ossberger turbine
- rectangular nozzle forms the jet, strike full length of the runner.
- Water strike the blade twice
- Flow can be increased with increase in runner length
- part flow achieve with partition valve.
- can only be mounted horizontally
- a draught can increase the effective head









CROSSFLOW TURBINE

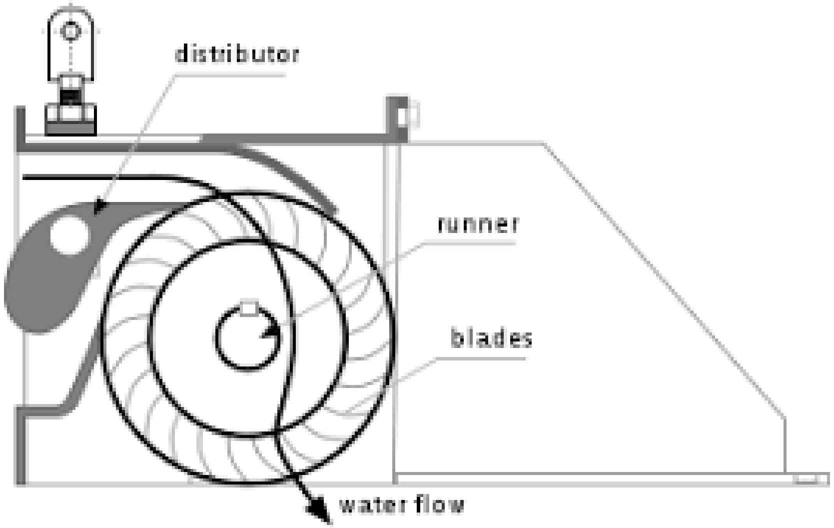
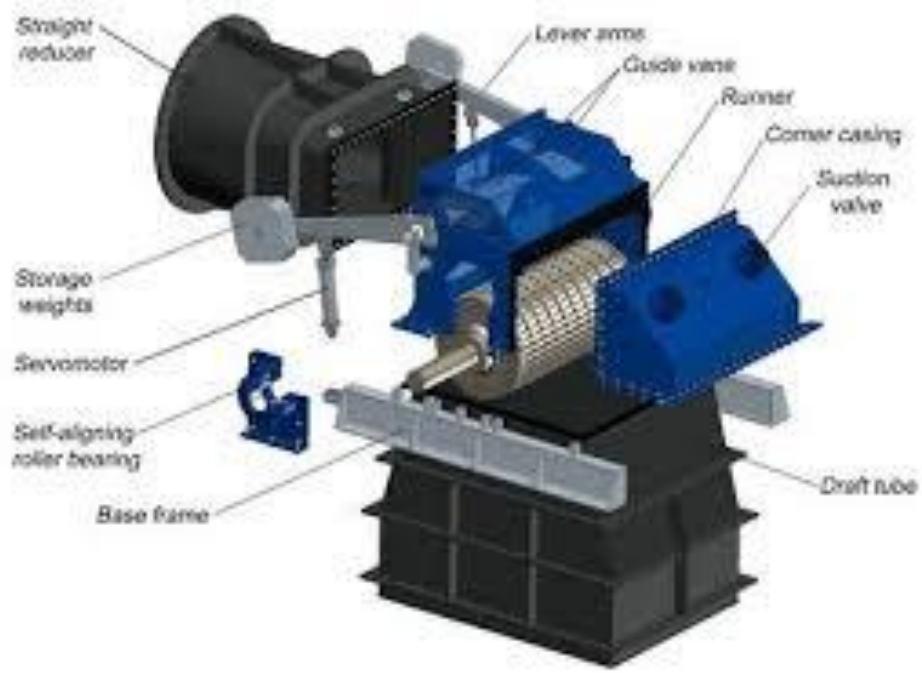

distributor
runner
blades
water flow

figure 6.7


Straight reducer
Lever arms
Guide vane
Runner
Corner casing
Suction valve
Storage weights
Servomotor
Self-aligning roller bearing
Base frame
Draft tube

Characteristics of Reaction turbines

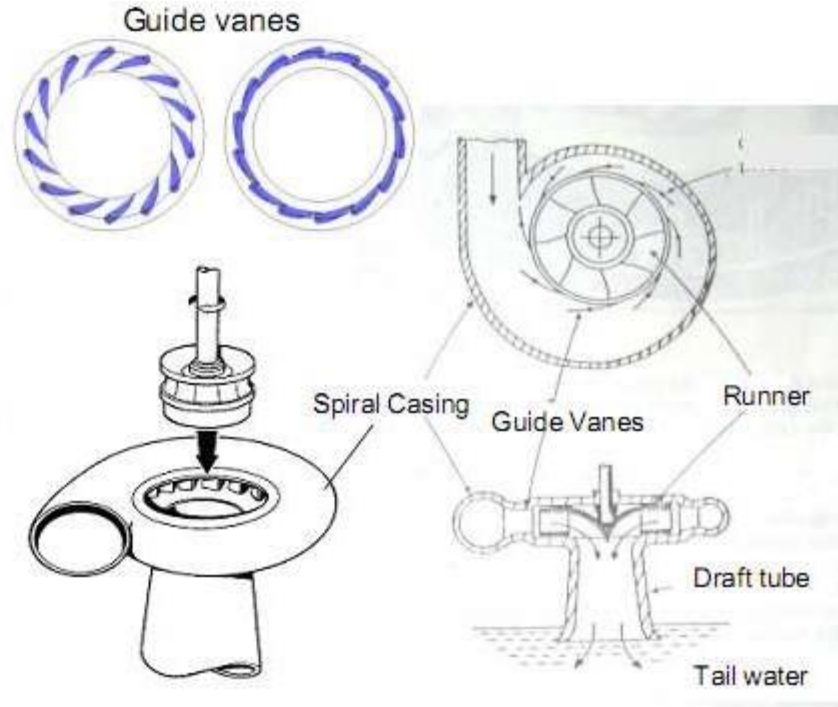
- Turbines rotate faster than impulse for the given head and flow conditions.
- High running speeds at low heads.
- Can be directly coupled to an alternator.
- Significant cost saving in eliminating speed-increasing drive system.
- Suitable for low to medium heads.
- More sophisticated fabrication than impulse.
- Less attractive for use in micro-hydro in developing countries.
- Danger of cavitations and poor part load efficiencies

Reaction turbine:

- **It runs by the reaction force of the exiting fluid.**
- **PE and KE of the fluid come to guide vanes of T and partly changes PE into KE.**
- **Moving part (runner) utilize both PE and KE.**
- **It works above atmospheric pressure.**
- **It will be fully immersed in water.**
- **It has draft tube.**
- **Eg.: Francis turbine.**

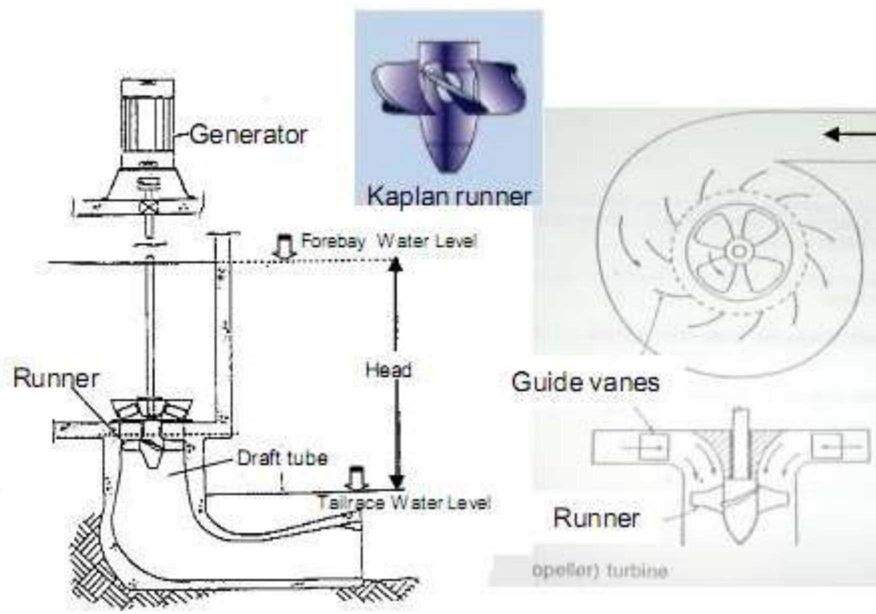
Francis Turbine

- is a reaction type turbine
- runner to be completely filled with water
- efficiency decreases as flow decreases
- water flow radially from outer tip to inner tip of the runner.
- flow gradually changes from radial to axial.
- guide vane are used to regulate the flow
- always fitted with draft tube.
- can be mounted vertically or horizontally

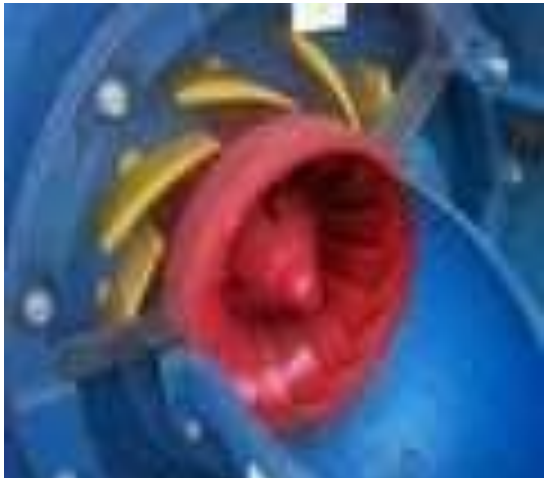


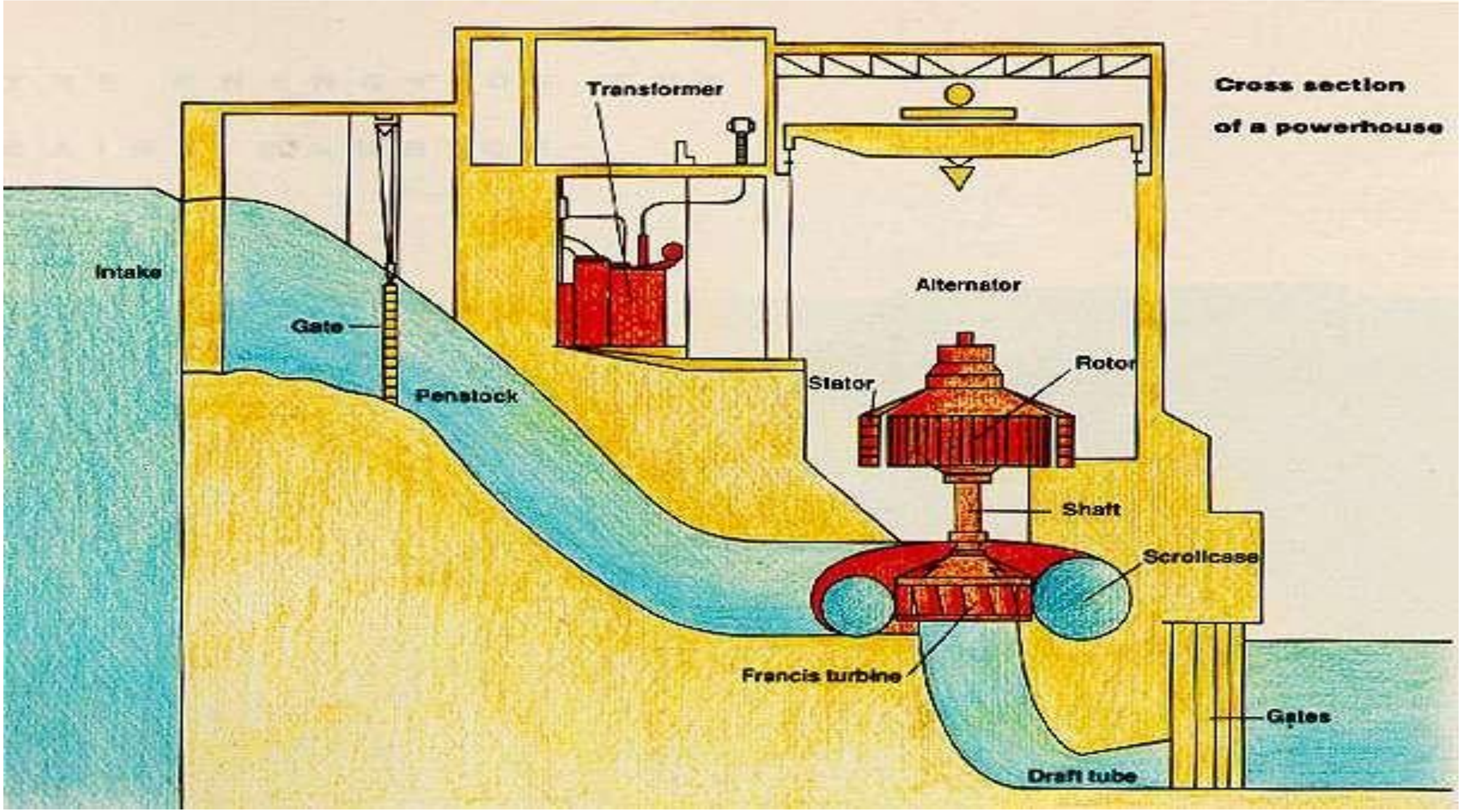
Propeller and Kaplan Turbine

- is a reaction type turbine
- turbine runner is called propeller
- runner to be completely filled with water
- efficiency decreases as flow decreases
- water flow axially in the propeller
- always fitted with draft tube.
- in Kaplan turbine blade angle can be adjusted
- can be mounted vertically or horizontally



FRANCIS TURBINE



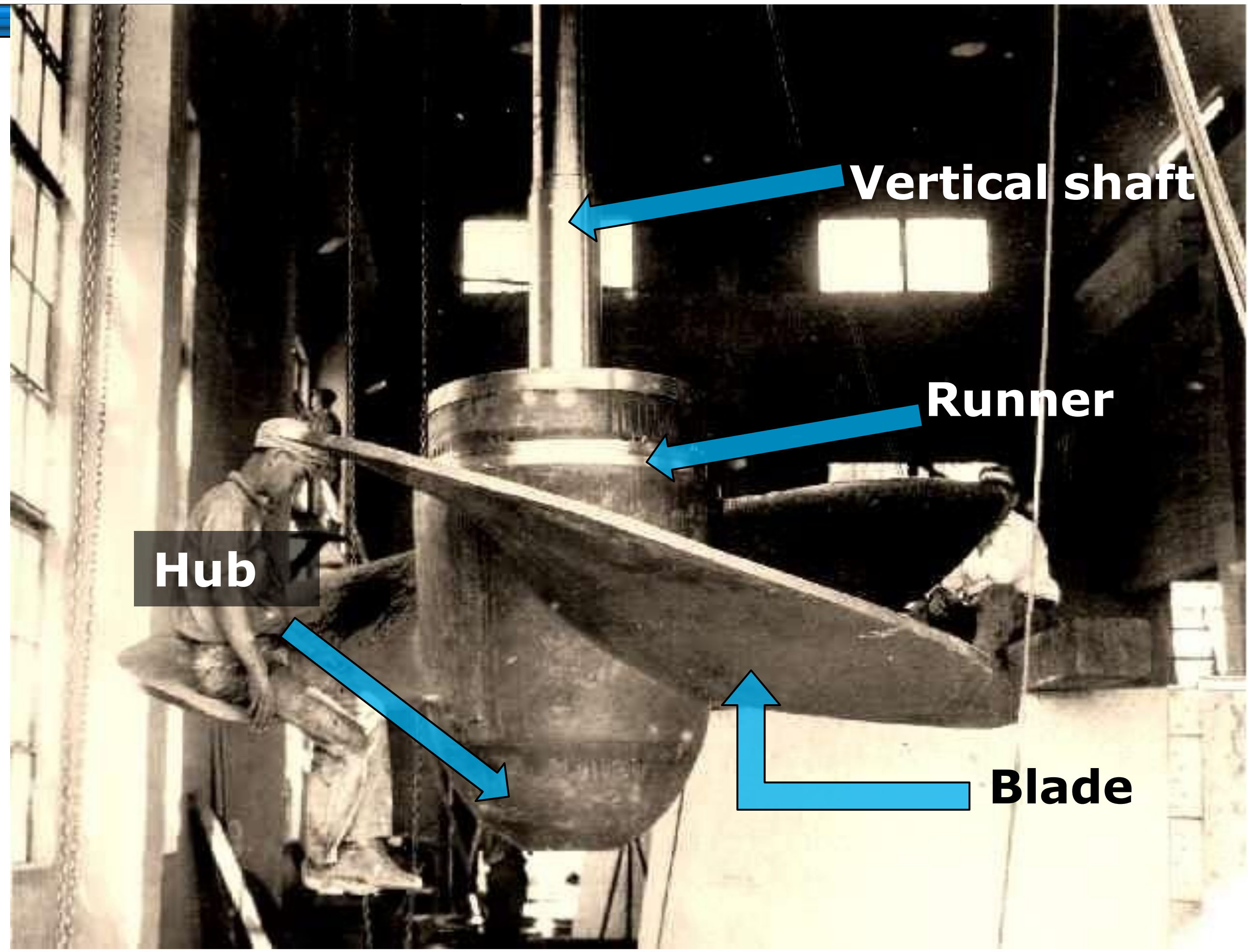

Cross section
of a powerhouse
Transformer
Intake
Gate
Penstock
Alternator
Stator
Rotor
Shaft
Scrollcase
Francis turbine
Gates
Draft tube

KAPLAN TURBINE

Propellor Turbine

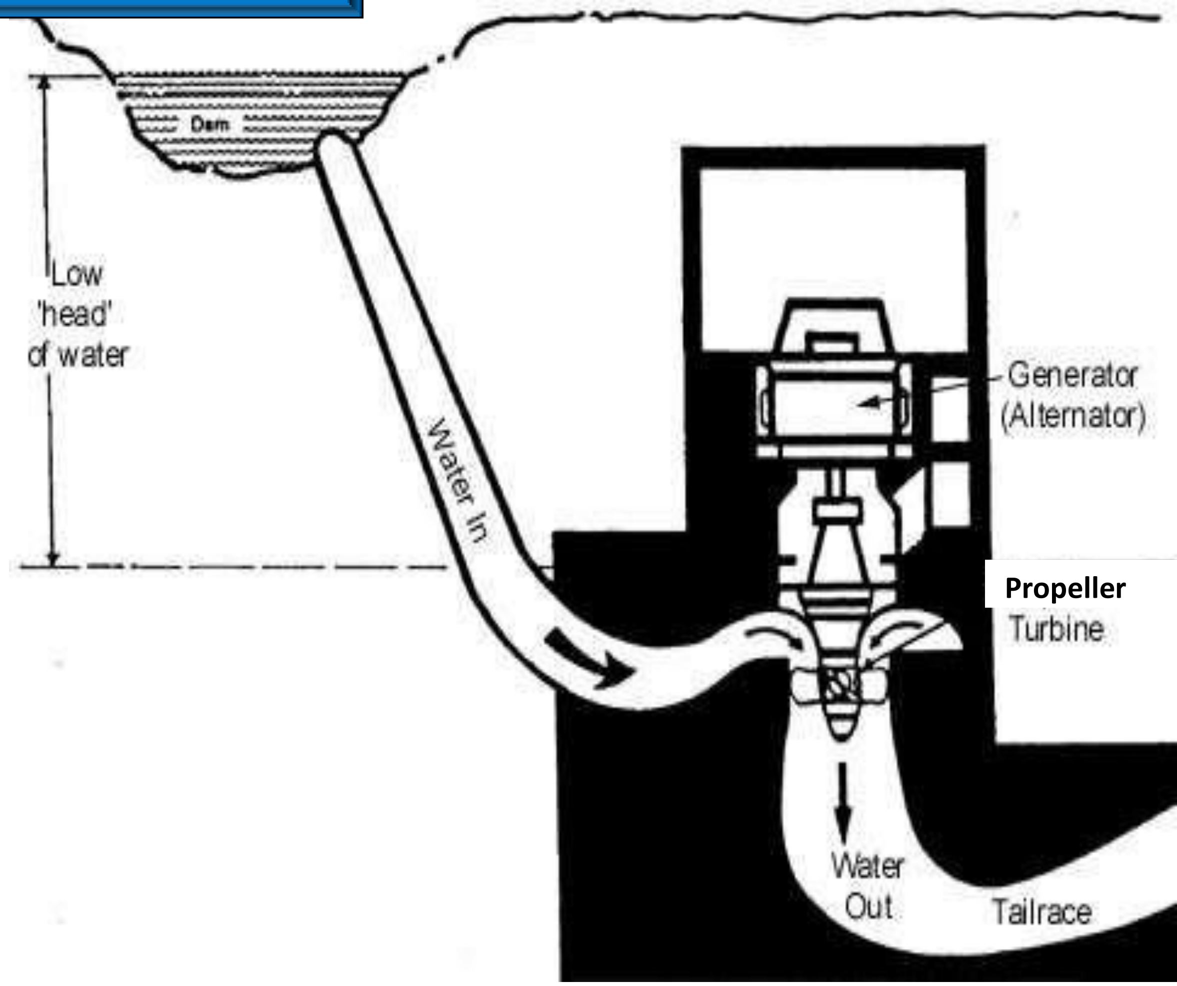
Consists of

- Shaft
- Axial flow runner
  - Hub
  - Air-foil shape blades
- Spiral casing
- Draft tube



WORKING

- Water enters the runner in the axial direction and leaves axially.
- The pressure at the inlet of the blade is larger than at the exit of the blades.
- Energy transfer is due to the reaction effect of pressure differences.



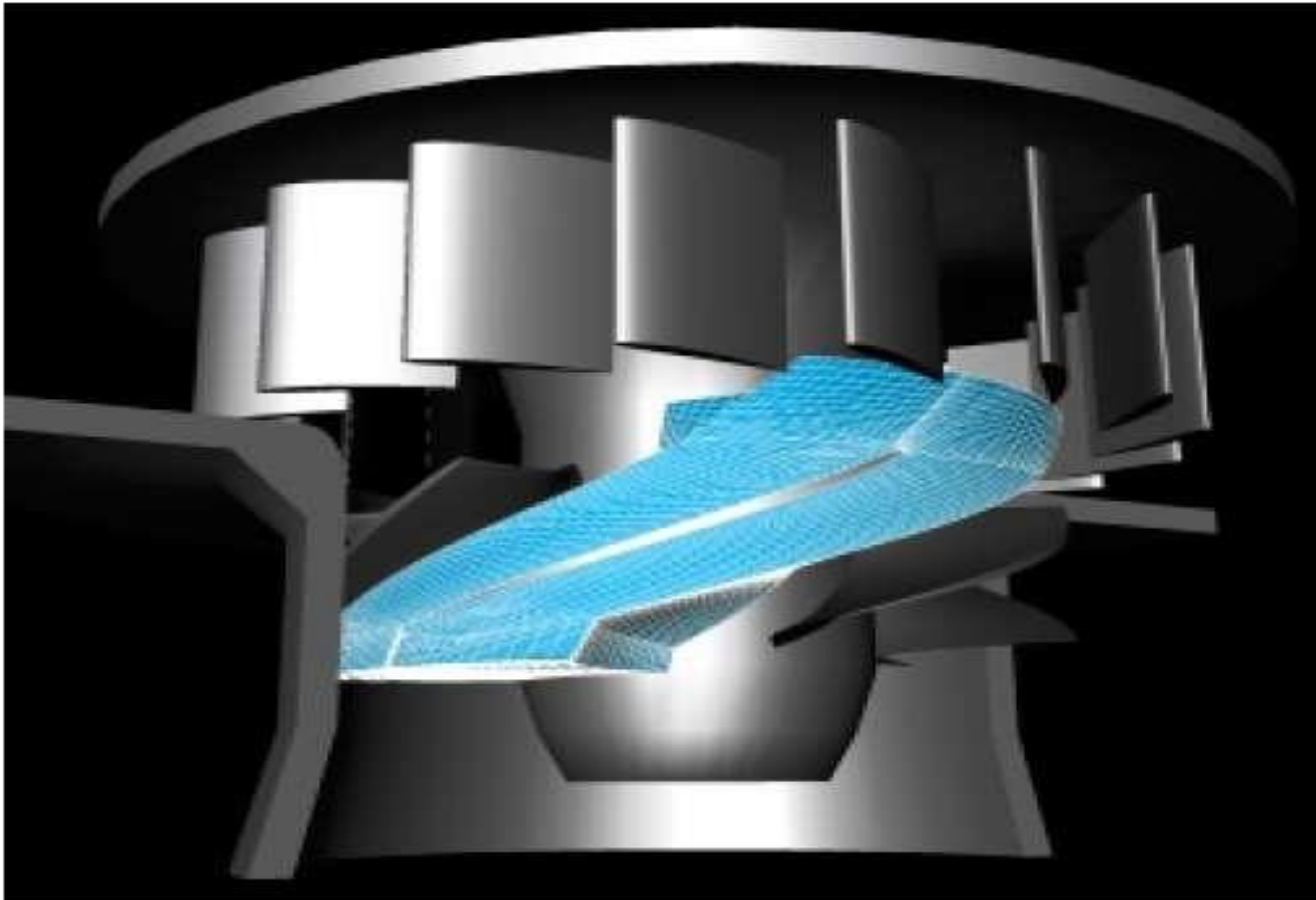


Fig: Direction of the flow

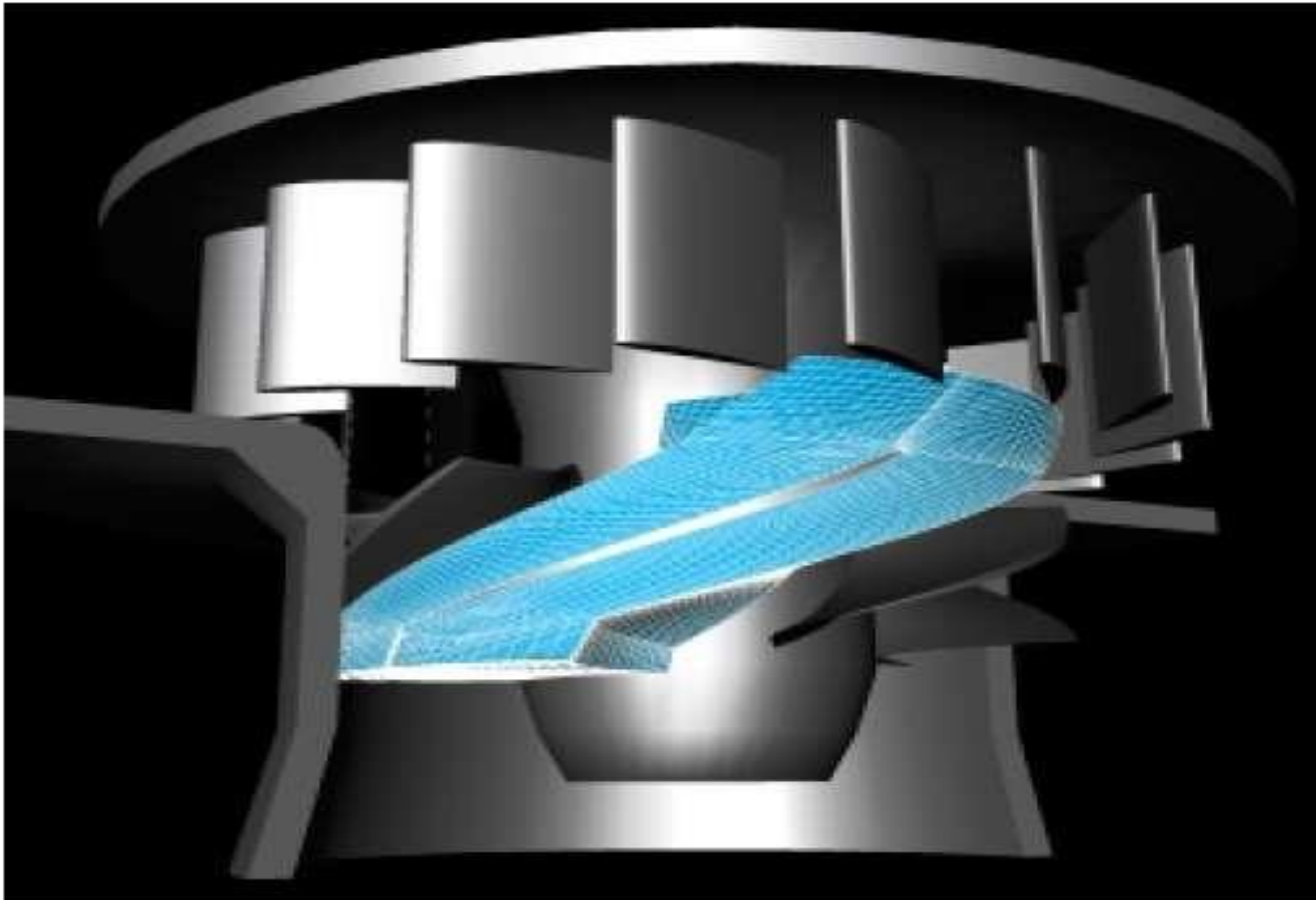
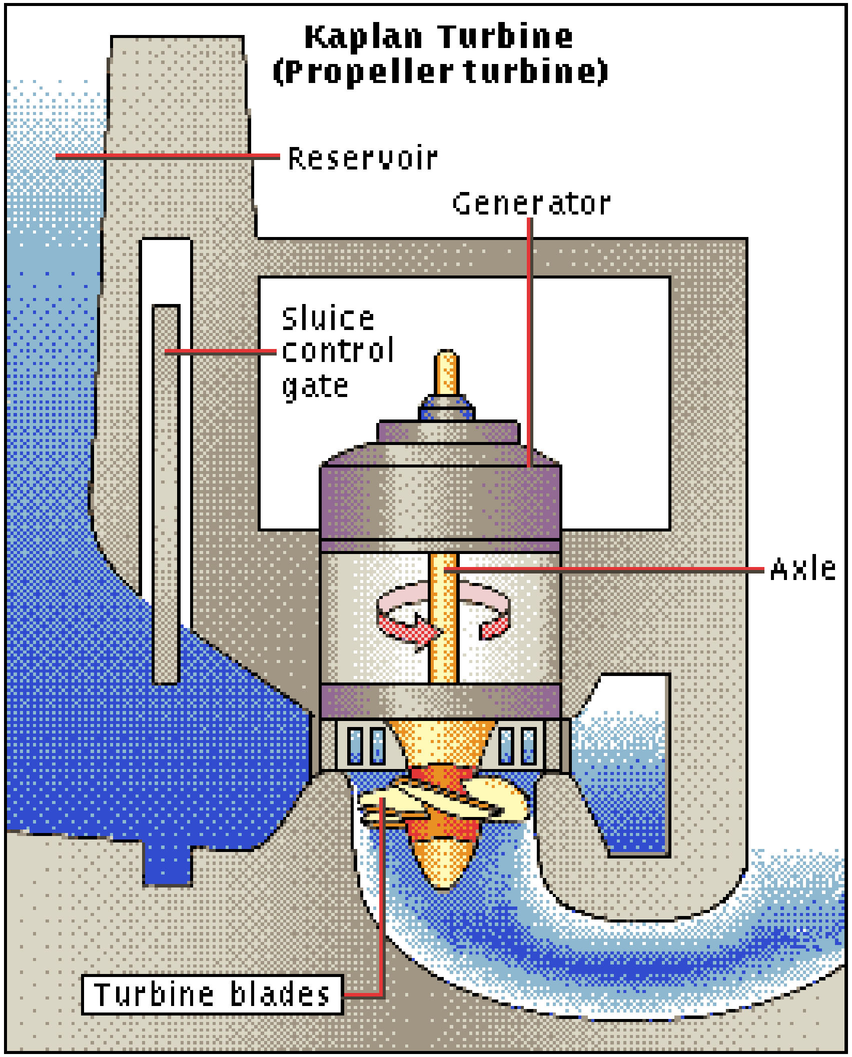
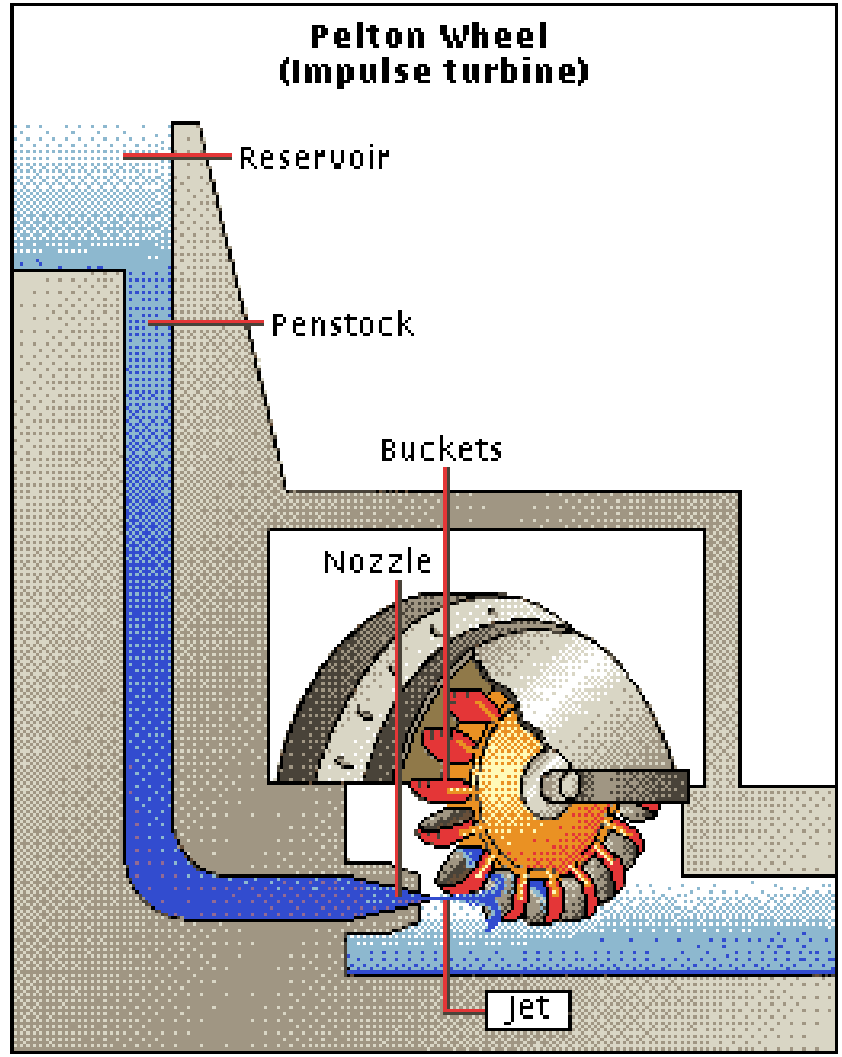
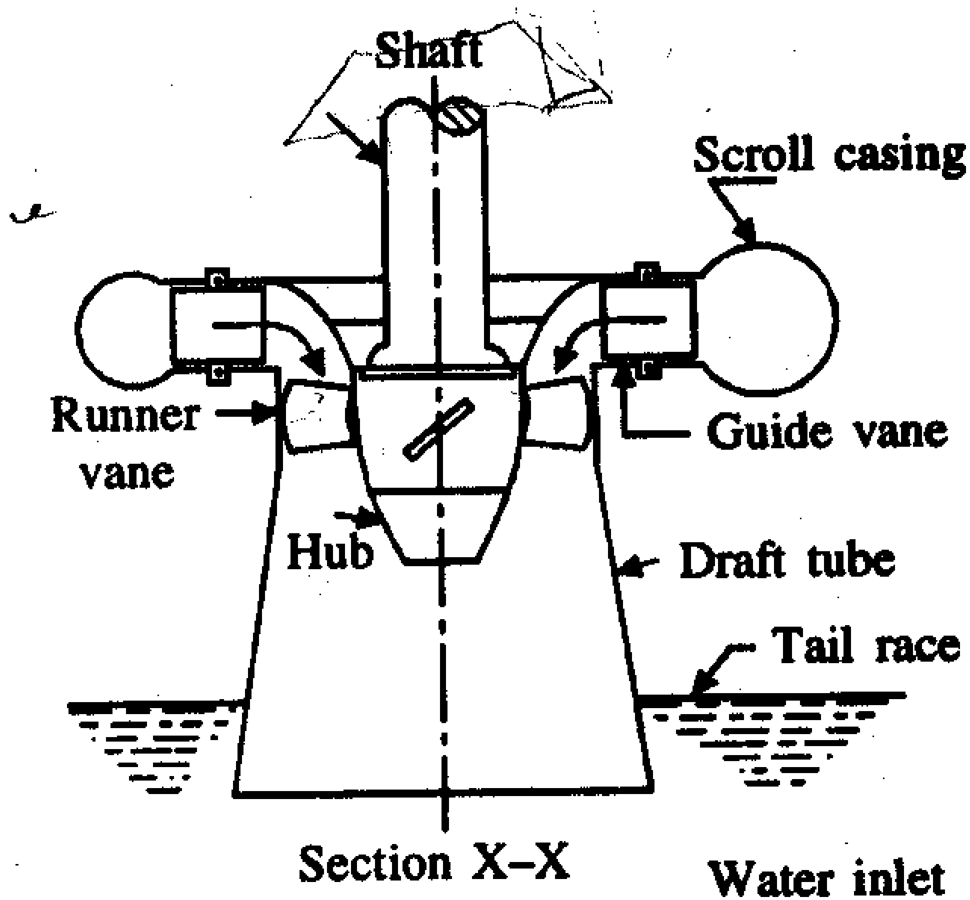
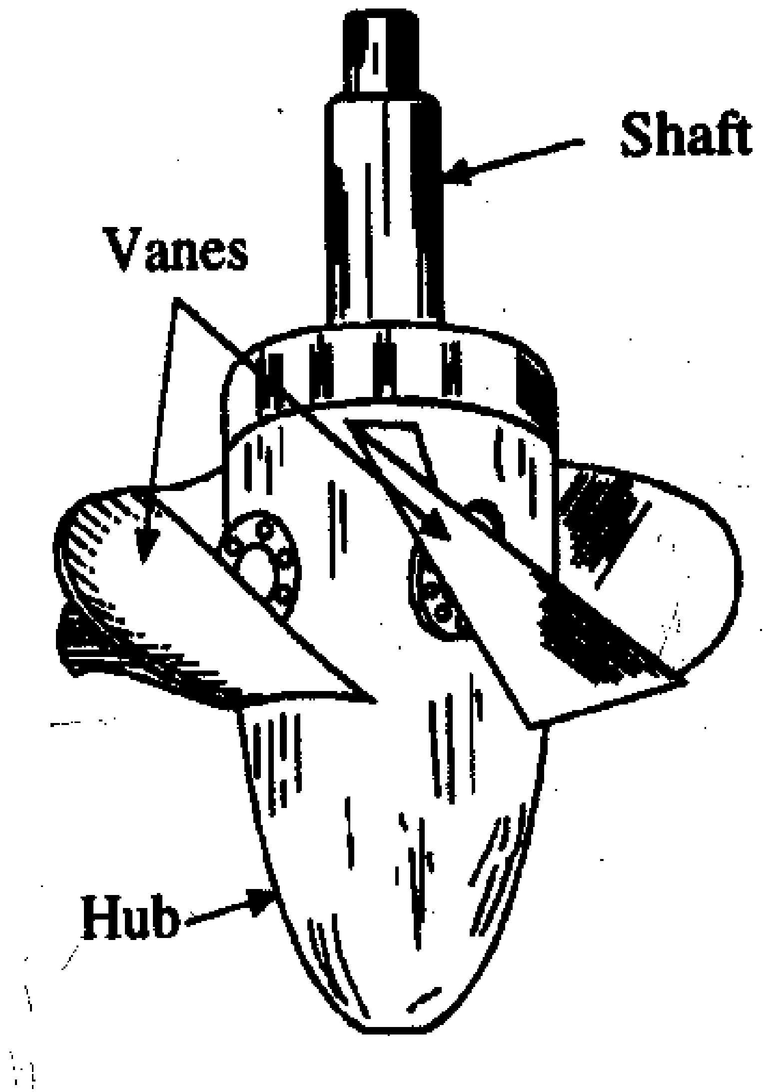


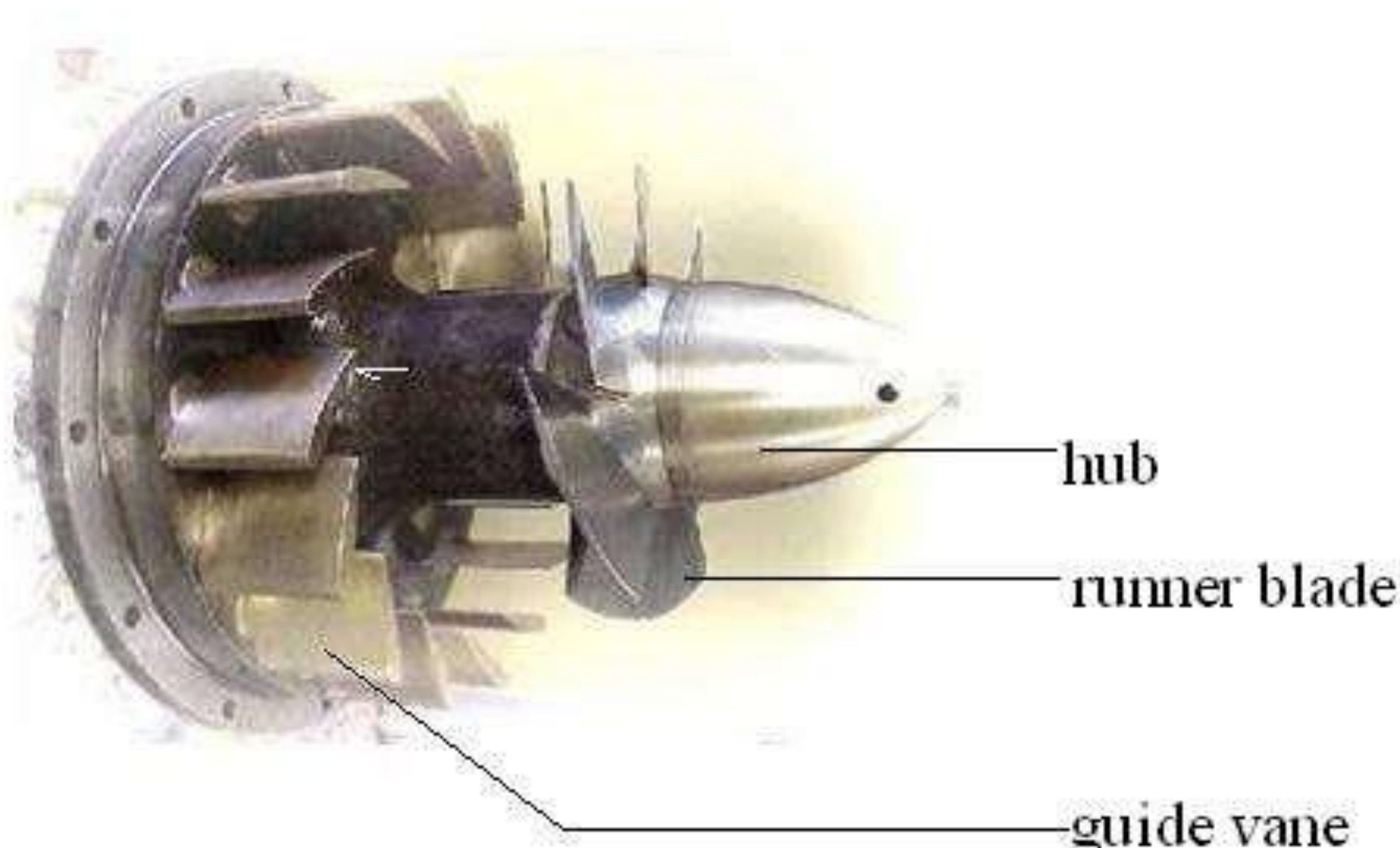
Fig: Direction of the flow

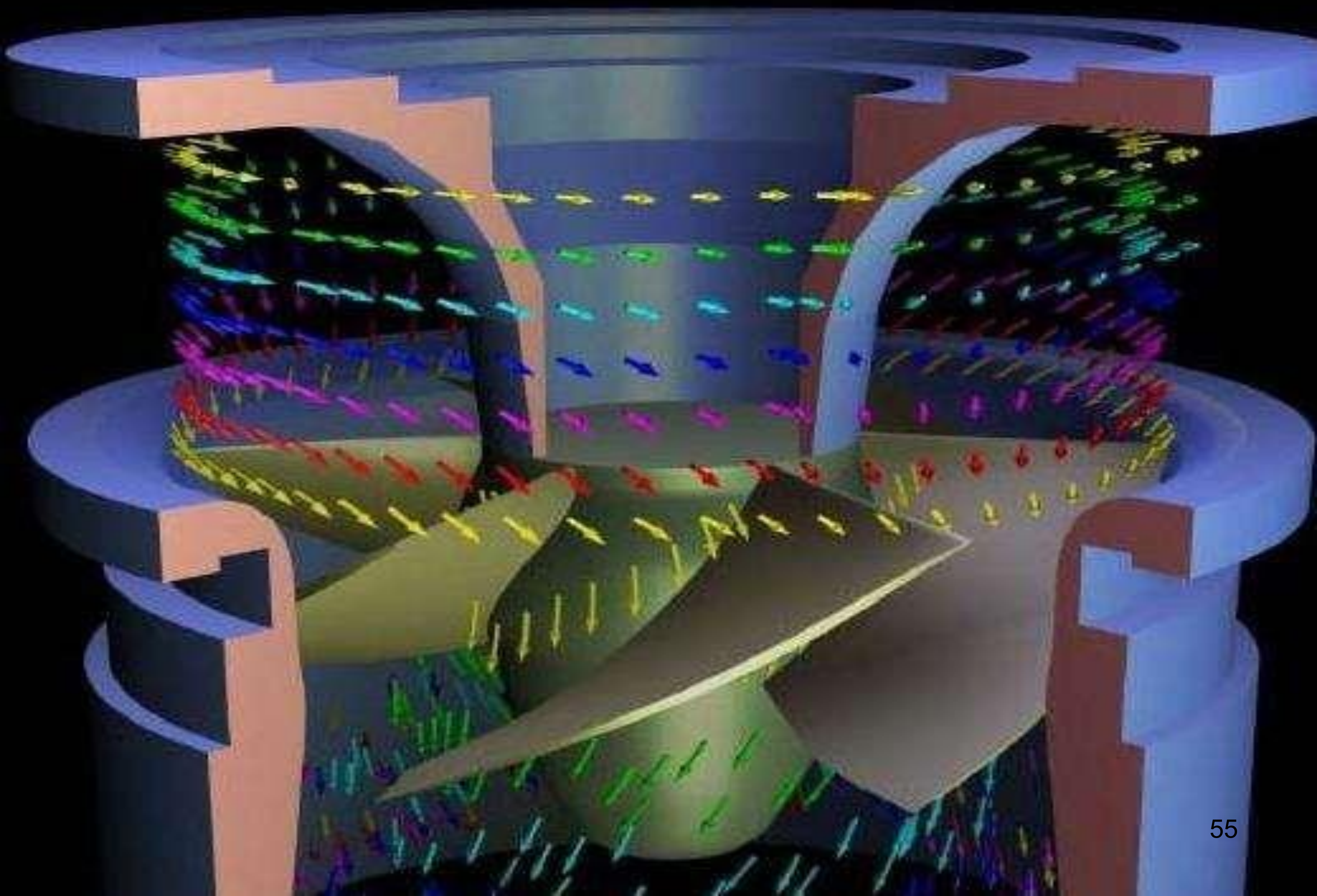

Kaplan Turbine
(Propeller turbine)
Reservoir
Generator
Sluice
control
gate
Axle
Turbine blades


Pelton Wheel
(Impulse turbine)
Reservoir
Penstock
Buckets
Nozzle
Jet


Shaft
Scroll casing
Runner
vane
Guide vane
Hub
Draft tube
Tail race
Section X–X
Water inlet


Shaft
Vanes
Hub


hub
runner blade
guide vane



Specific Speed N_s

The Specific Speed N_s of a turbine is the speed in rotations per minute (r.p.m.) at which a similar model of the turbine would run under a head of 1meter when of such size as to develop 1kW power.

$$\therefore \quad N_s = \frac{N\sqrt{P}}{H^{\frac{5}{4}}}$$

Where N is speed of the generator

Turbine/Speed	Slow	Medium	Fast
Pelton	4 -10	10-25	25-60
Francis	60-150	150-250	250-400
Propeller or Kaplan	400-450	450-700	700-1200
(Source: https://www.slideshare.net/talhaali14224/selection-of-turbine-with-respect-to-head-vs-specific-speed/17)			

Table: 2 Specific Speed and head range for different turbines

S.N.	Turbine type	Range of specific Speed	Range of head
1	Kaplan	300 – 1000	4 m to 40 m
2	Francis	50 – 450	30 m to 450 m
3	Pelton	10 – 70	100 m to 2000 m
4	Cross-flow	20 – 70	5 m to 200 m
5	Turgo	20 – 80	30 m to 300 m

The general efficiency trends for different types of turbines and their best efficiency for calculation purpose is presented in Table 3

Turbine type	General efficiency trend	Best efficiency
Kaplan	Good efficiency range for full and part load condition and can be operated up to 20% load.	0.91
Francis	Full load efficiency is good and part load efficiency is poor and not recommends operating below 50% load.	0.92 to 0.94
Pelton	Good efficiency range for full and part load condition and can be operated up to 30% load.	0.90
Cross flow	Good efficiency range for full and part load condition and can be operated up to 30% load.	0.80
Turgo	Good efficiency range for full and part load condition and can be operated up to 25% load.	0.85

Turbine Selection: Based on Head

Turbine Type	Head Classification		
	High (>50m)	Medium (10-50m)	Low (<10m)
Impulse	Pelton Turgo Multi-Jet Pelton	Crossflow Turgo Multi-Jet Pelton	Crossflow
Reaction		Francis	Propeller Kaplan

According to direction of flow

- Radial Flow Turbine
  - crossflow
- Axial Flow Turbine
  - Kaplan, propellor
- Tangential Flow Turbine
  - Pelton turbine
- Mixed Flow Turbine
  - Francis turbine

IMPORTANCE OF MHP - NEPAL'S CONTEXT

- Make use of locally available water resources
- Per kW cost is low (in compare to bigger plant/ other Renewable Energy sources)
- Suitable for Nepal
  - *hilly and isolated settlement*
  - *Abundance water resources*
  - *Nation Grid connection - Limited in urban area*
- Power source for operating cottage industries
- Income generation - for rural people
- Health improvement, Social and Educational Benefit
- Eco-friendly - less environmental adverse impact

LIMITATIONS

- Site specific *(Availability of Head / Flow)*
- Long distance transmission - not suitable
- Power Limitation *(Demand based / Availability)*

Components of scheme:

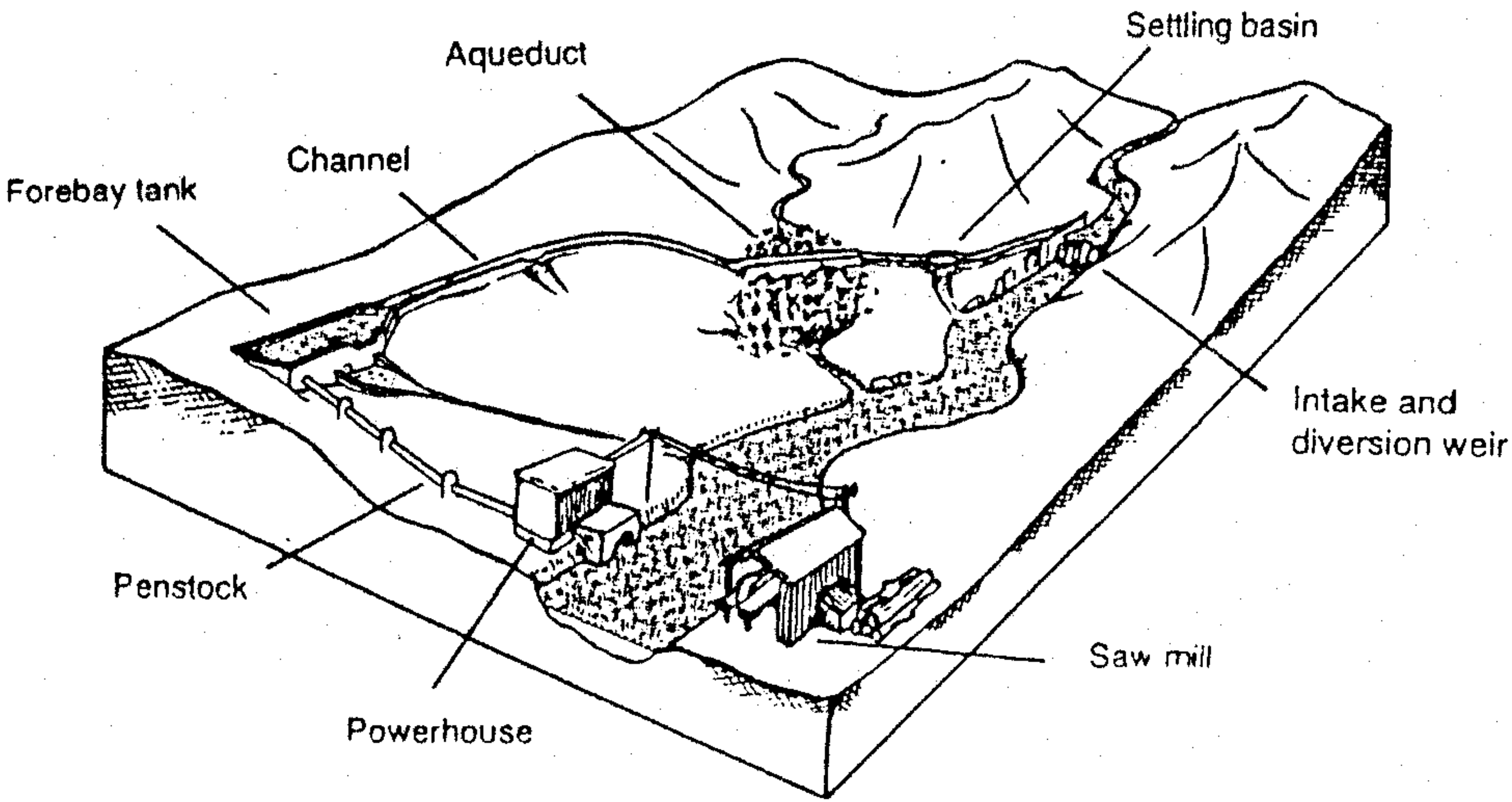
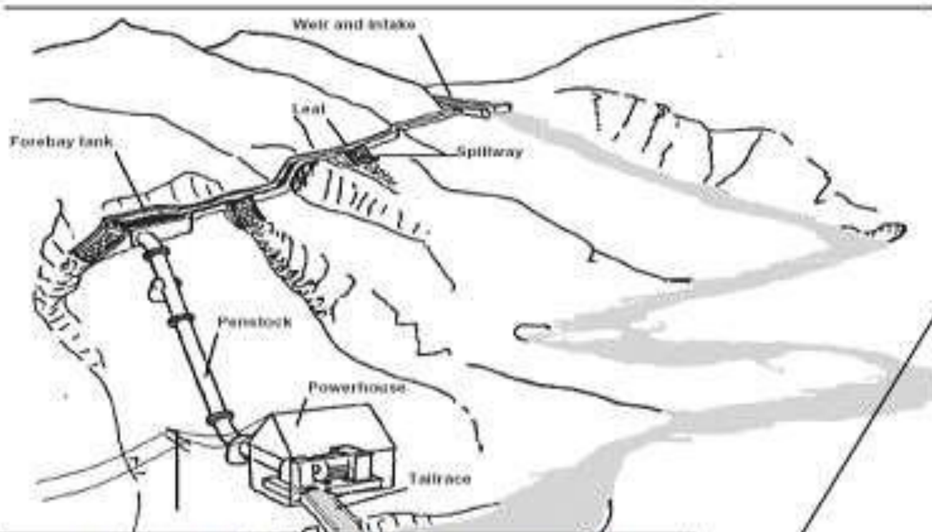


Fig 1.2.1 Major components of a micro-hydro scheme

Hydro-scheme components



MAJOR MHP COMPONENTS

CIVIL

MECHANICAL

ELECTRICAL

TRANSMISSION/ DISTRIBUTION

PROTECTION / CONTROL

CIVIL COMPONENTS

- Intake structure
- weir
- headrace Canal
- Gravel trap
- Spill way
- Settling/ Desanding Basin
- Forebay Tank
- Anchor Block and support pier
- Power House
- Tailrace Canal

MECHANICAL COMPONENTS

- Turbine (Pelton/ Crossflow ...)
- Penstock (Steel / PVC / HDPE ...)
- Drive System (Belt / Coupling / Gear)
- Expansion Joint
- Valves (Gate / Sphere / Butterfly)
- Trash rack (Coarse / Fine)
- Flushing system (Cone / Sluice gate)
- Governor (Mechanical / Hydraulic)

ELECTRICAL COMPONENTS

- Generator
- Electronic Load Controller
- Transformer (Step-up / Step-down)
- Control Panel
- Power cable (Armored / Unarmored)

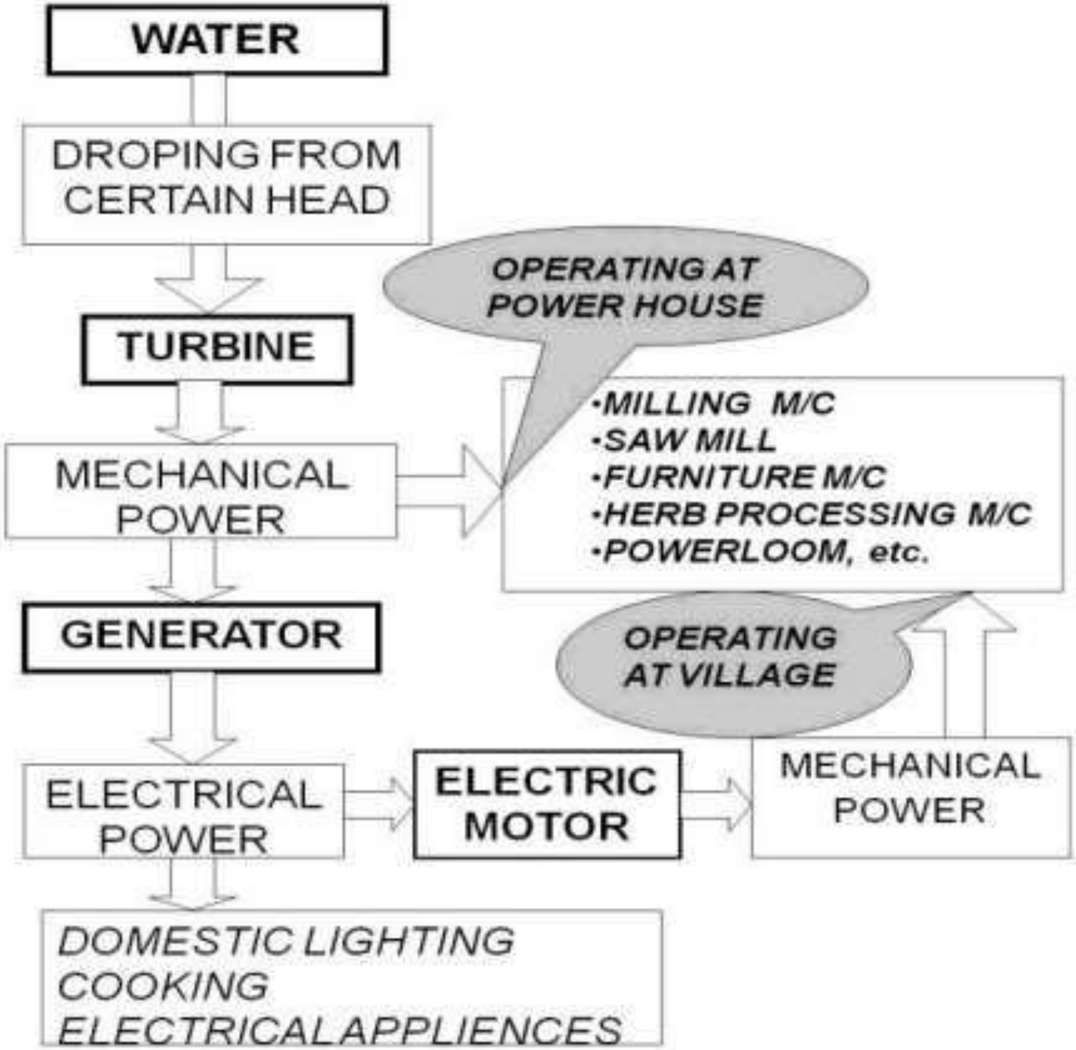
TRANSMISSION & DISTRIBUTION SYSTEM

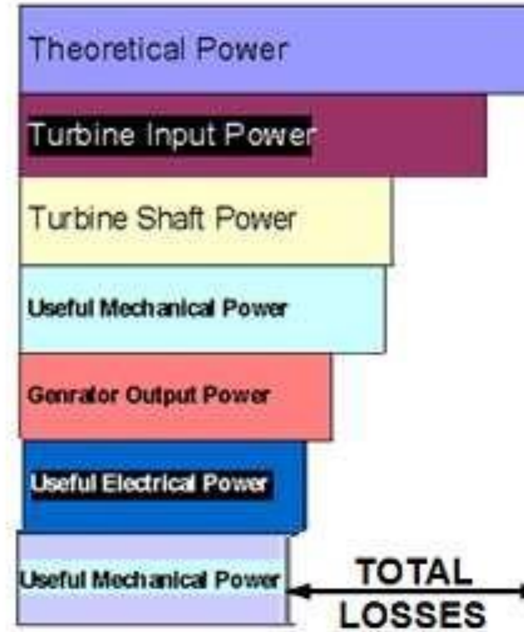
- Conductor (Aluminum / Copper)
- Insulator
- Staywires
- Poles (Wooden / Concrete / Steel)

PROTECTION & CONTROLLING SYSTEM

- Lighting arrestor
- Earthing
- Fuse / MCB, etc.

MHP: Applications





Mini Hydro in Nepal

- Mini hydro is the hydro-power system that generates electric power from 100 kW to 1MW capacity and serves nearby households through a mini-grid.
- AEPC has mandate to support mini hydro projects (100kW to 1MW).
- Latest Subsidy Policy for Renewable Energy 2069 BS has a provision to provide subsidy to community/ cooperative owned mini hydro off-grid projects from 100kW to 1MW and mini hydro projects connected to grid.
- Mini-hydro is the promising solutions for providing electricity in the rural areas. However, there are only few successful Mini-Hydro schemes running in the country. Therefore, time has come to analyze the issues and challenges in the development of Mini-Hydro schemes in large numbers.
- Now, AEPC is coordinating with different stakeholders to allow, facilitate, and create conducive environment for rapid development of mini-hydro.

Micro Hydro in Nepal

- Micro hydro shall be understood as hydroelectric generating units with capacities ranging above 10 to 100 kW.
- Micro-hydro has the potential to be a major source of energy for rural areas as water is plentiful in the rugged hills of Nepal and micro-hydro provides a more practical and cost-effective alternative to the national grid.
- Micro hydro consists of following activities:
  - Develop and promote the use of micro-hydro technology.
  - Carry out surveys and feasibility studies for micro-hydro projects.
  - Provide services to support the sustainable development of micro-hydro projects in Nepal.
  - Conduct training for micro-hydro users and service providers.
  - Work to establish local support structures for mini-grid electrification.
  - Provide quality control services for micro-hydro equipment.

Peltric Set or Pico Hydro Technology

- Pico hydro shall be understood as hydroelectric generating units with capacities up to 10 kW.
- It is simple and cheap technology that can be developed in local level.
- It includes Peltric Sets and also technologies which uses Pelton Turbine (low discharge and high head), Cross flow Turbine and other technologies (high discharge and low head) depending on available discharge and head.
- In Nepal, local manufacturer have developed Peltric Sets up to 5 kW capacities.
- Peltric Set is a single combined unit of induction generator, Pelton turbine and simple control mechanism.
- Peltric Sets can be installed at hilly regions using high density polythene (HDPE) pipe of water supply projects.

Peltric Set or Pico Hydro Technology

Pico Hydro Technology has following advantages:

- It can be implemented and managed by local knowledge.
- It is cheap as Peltric Sets and other Pico Hydro Technology with low discharge and high head uses HDPE pipe which saves cost of transportation, canal construction and installation
- Its total project cost is low, and necessary resources can be generated at local level (VDC, DDC, other agencies).
- It can be installed in short period of time and community can get immediate benefit.
- It serves small community and therefore well manageable.
- Medium level trained technician can easily install the technology
- It can be installed at Break Pressure Tank (BPT) of water supply projects which is easy and cost effective.
- Community people can get easy access of technical and management support of DDC: DEEU/S

Improved Water Mill (IWM)

- IWM is an intermediate technology that increases the efficiency of Traditional Water Mills (TWMs) resulting in increased energy output thus helping both the millers and its users.
- Replacement of wooden parts (rotor and shaft) with metallic parts is the main improvement made in this technology.
- Two types of IWMs are in practice: short shaft solely for grinding, and long shaft for grinding and other end uses such as paddy hulling and husking, rice polishing, saw-milling, oil expelling, lokta beating, chiura (flattened rice) making, and a number of others as per the need.
- IWM provides energy services to households at a cheap investment and maintenance cost within a short period required for the construction work.
- The technology can also generate electricity up to 3-5 kW, sufficient for lighting and operating small electric and electronic devices such as televisions, radios, computers, battery charging stations, and other small electric home appliances- suitable for remote small clustered hamlets.

S No	Project	Capacity (MW)	River	Promoter	VDC/District
1	Kali Gandaki A	144	Kali Gandaki	Nepal Electricity Authority	Shreekrishna Gandaki (Syangja)
2	Madhya Marsyangdi	70	Marsyangdi	Nepal Electricity Authority	(Lamjung)
3	Marsyangdi	69	Marsyangdi	Nepal Electricity Authority	(Tanahu)
4	Upper Trishuli 3A	60	Trishuli	Nepal Electricity Authority	Dandagoun, Laharepouwa, Thulogoun, Ramche (Rasuwa)
5	Kulekhani-I	60	Kulekhani	Nepal Electricity Authority	(Makawanpur)
6	Khimti -I	60	Khimti Khola	Himal Power Limited	Sahure, Hawa (Dolakha) Betali (Ramechhap)
7	Upper Marsyangdi A	50	Marsyangdi	Sinohydro-Sagarmatha Power Company Pvt Ltd	Bhulbhule, Bahundada, Khudi (Lamjung)
8	Upper Bhotekoshi	45	Bhote Koshi	Bhotekoshi Power Company	(Sindhupalchok)
9	Kulekhani-II	32	Kulekhani	Nepal Electricity Authority	(Makawanpur)
10	Chameliya Khola	30	Chameliya Khola	Nepal Electricity Authority	Latinath, Seri, Sikhar (Darchula)
11	Kabeli B - 1	25	Kabeli Khola	Arun Kabeli Power Limited.	Nagi, Tharpu (Panchthar)
12	Upper Madi	25	Madi Khola	Madi Power Pvt Ltd.,	Namarjung, Thumakodada, Sildujure (Kaski)
13	Trishuli	24	Trishuli	Nepal Electricity Authority	(Nuwakot)
14	Solu Hydropower Project	23.5	Solu Khola	Upper Solu Hydroelectric Company Pvt Ltd	Gora Khami, Garma, Salleri (Solukhumbu)
15	Bagmati Nadi	22	Bagmati	Mandu Hydropower Pvt. Ltd.	Kogate, Ipa Panchakanya, Sisneri Mahadevsthan (Makawanpur)
16	Mai	22	Mai Khola	Sanima Mai Hydropower Limited	(Ilam)
17	Chilime	22	Chilime	Chilime Hydropower Company Limited	Chilime (Rasuwa)
18	Lower Hewa	21.6	Hewa Khola	Mountain Hydro Nepal (P.) Ltd	Bharapa, Nangeen, Phidim (Panchthar)
19	Gandak	15	Narayani	Nepal Electricity Authority	(Nawalparasi)
20	Hewa Khola A	14.9	Hewa Khola	Panchthar Power Company Pvt. Ltd.	Bharapa, Nangeen, Yanganam (Panchthar)
21	Modi Khola	14.8	Modi Khola	Nepal Electricity Authority	(Parbat)
22	Devighat	14.1	Trishuli	Nepal Electricity Authority	(Nuwakot)
23	Madkyu Khola	13	Madkyu	Silkes Hydropower Pvt.Ltd	(Kaski)
24	Jhimruk Khola	12.5	Jhimruk	Butwal Power Company	(Pyuthan)
25	Namarjun Madi	12	Madi Khola	Himalayan Hydropower Pvt.Ltd	Namarjung, Sildujure (Kaski)
26	Upper Mai Hydropower Project (Panchakanya Mai Hydropwer limi	12	Mai Khola	Mai Valley Hydropower P Ltd.	Mabu, Maimajhuwa (Ilam)
27	Thapa Khola	11.2	Thapa Khola	Mount Kailash Energy Co. Ltd	(Mustang)
28	Sun Koshi	10.05	Sun Koshi	Nepal Electricity Authority	(Sindhupalchok)
29	Lower Modi -1	10	Modi Khola	United Modi Hydropower Pvt. Ltd., 1st Floor Heritage Plaza 2; Kamaladi, Kathmandu Metropolitan - 31	(Parbat)
30	Sipring Khola	10	Sipring	Synergy Power Development P Ltd	Khare, Gauri Sankar (Dolakha)