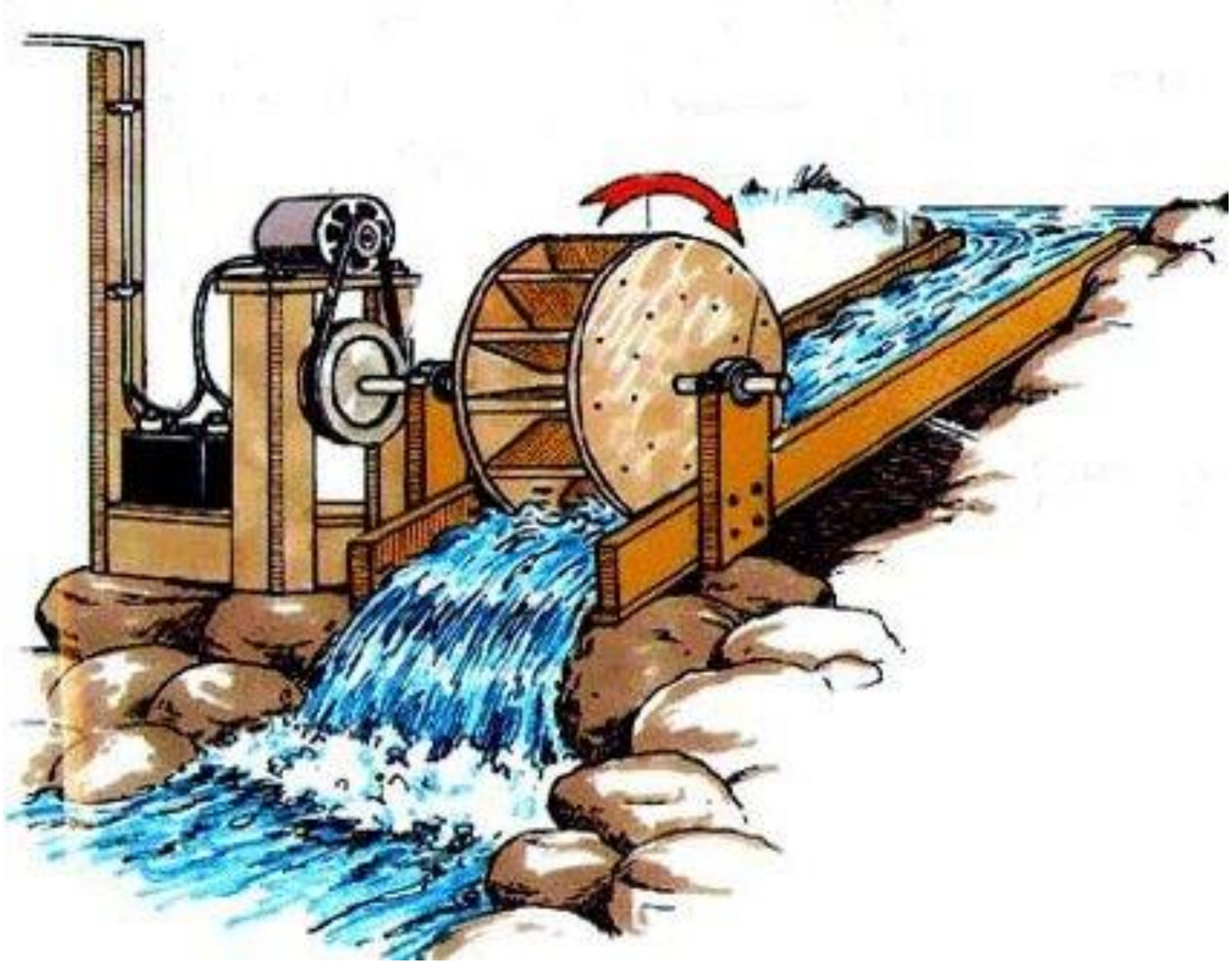
TURBINES



Turbine

- Turbine is a device that extracts energy from a fluid (converts the energy held by the fluid to mechanical energy)

- Pumps are devices that add energy to the fluid (e.g. pumps, fans, blowers and compressors).

- Hydro electric power is the most remarkable development pertaining to the exploitation of water resources throughout the world
- Hydroelectric power is developed by hydraulic turbines which are hydraulic machines.
- Turbines convert hydraulic energy or hydro-potential into mechanical energy.
- Mechanical energy developed by turbines is used to run electric generators coupled to the shaft of turbines
- Hydro electric power is the most cheapest source of power generation.

TURBINES: Machines to **<u>extract fluid power from flowing fluids</u>**

Steam Turbine

Water Turbines

Wind Turbines

Gas Turbines

Aircraft Engines
Power Generation

- High Pressure, High Temperature gas
- Generated inside the engine
- Expands through a specially designed TURBINE

Types of Turbines

1. Water (Hydraulic) Turbine

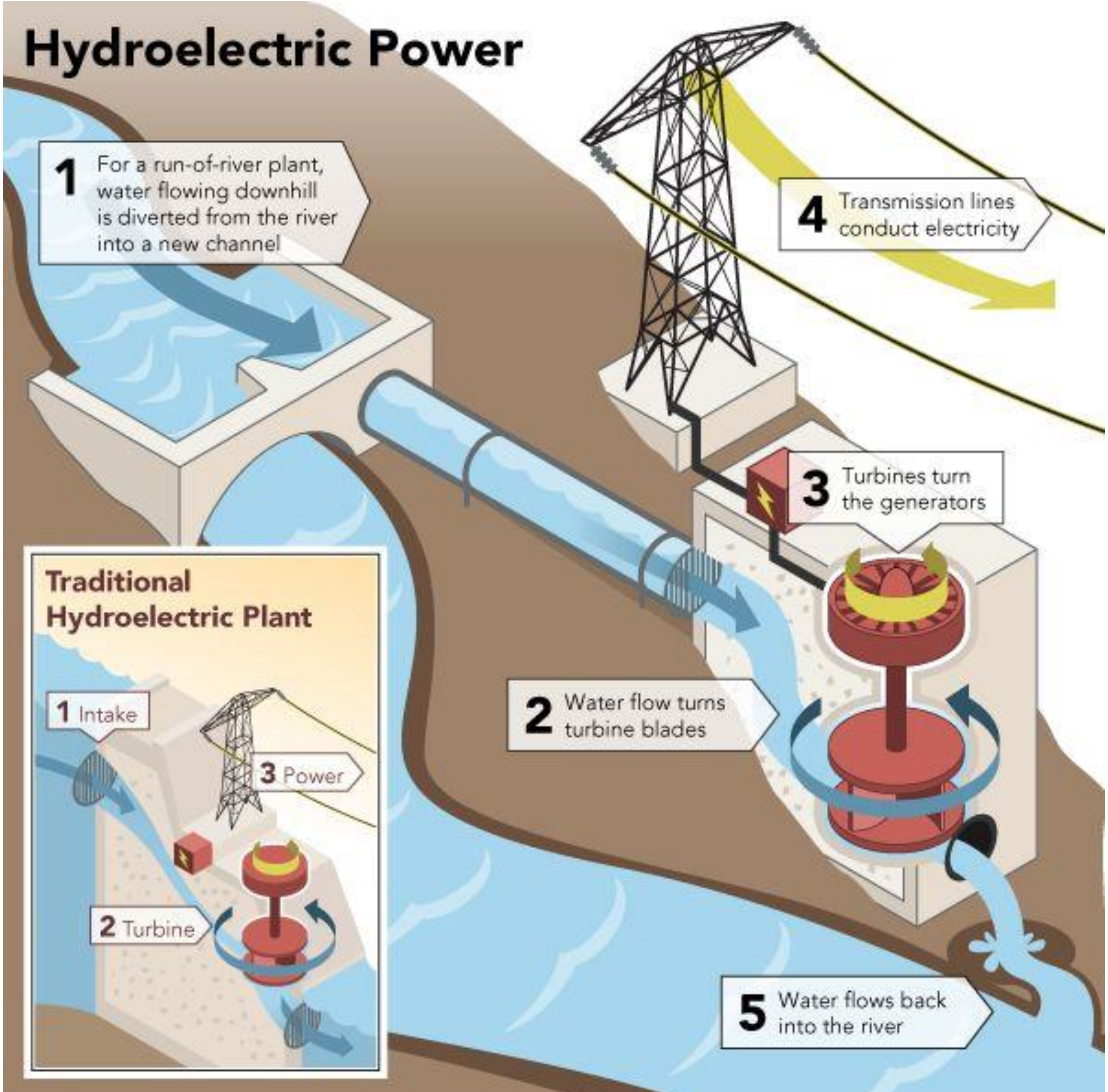
2. Steam Turbine

3. Gas Turbine

HYDRAULIC TURBINES

- J.V. Poncelet first introduced the idea of the development of mechanical energy through hydraulic energy
- Modern hydraulic turbines have been developed by L.A. Pelton (impulse), G. Coriolis and J.B. Francis (reaction) and V Kaplan (propeller)

Turbines


Hydroelectric Power
1 For a run-of-river plant, water flowing downhill is diverted from the river into a new channel
4 Transmission lines conduct electricity
3 Turbines turn the generators
2 Water flow turns turbine blades
5 Water flows back into the river
Traditional Hydroelectric Plant
1 Intake
3 Power
2 Turbine

Types of turbines

Turbines can be classified on the basis of:

- Head and quantity of water available
- Hydraulic action of water
- Direction of flow of water in the runner
- Specific speed of turbines
- Disposition of the shaft of the runner

Classification of turbines

- Based on head and quantity of water

  According to head and quantity of water available, the turbines can be classified into

  a) High head turbines

  b) Medium head turbines

  c) Low head turbines

  a) **High head turbines**

  High head turbines are the turbines which work under heads more than 250m. The quantity of water needed in case of high head turbines is usually small. The Pelton turbines are the usual choice for high heads.

Classification of turbines

- Based on head and quantity of water

  b) **Medium head turbines**

  The turbines that work under a head of 45m to 250m are called medium head turbines. It requires medium flow of water. Francis turbines are used for medium heads.

  c) **Low head turbines**

  Turbines which work under a head of less than 45m are called low head turbines. Owing to low head, large quantity of water is required. Kaplan turbines are used for low heads.

Classification of turbines

- Based on hydraulic action of water

According to hydraulic action of water, turbines can be classified into

a) Impulse turbines

b) Reaction turbines

a) **Impulse turbines**

If the runner of a turbine rotates by the impact or impulse action of water, it is an impulse turbine.

b) **Reaction turbines**

These turbines work due to reaction of the pressure difference between the inlet and the outlet of the runner.

Classification of turbines

- Based on direction of flow of water in the runner

Depending upon the direction of flow through the runner, following types of turbines are there

a) Tangential flow turbines

b) Radial flow turbines

c) Axial flow turbines

d) Mixed flow turbines

a) **Tangential flow turbines**

When the flow is tangential to the wheel circle, it is a tangential flow turbine. A Pelton turbine is a Tangential flow turbine.

Classification of turbines

- Based on direction of flow of water in the runner

  b) **Radial flow turbines**

  In a radial flow, the path of the flow of water remains in the radial direction and in a plane normal to the runner shaft. No pure radial flow turbine is in use these days.

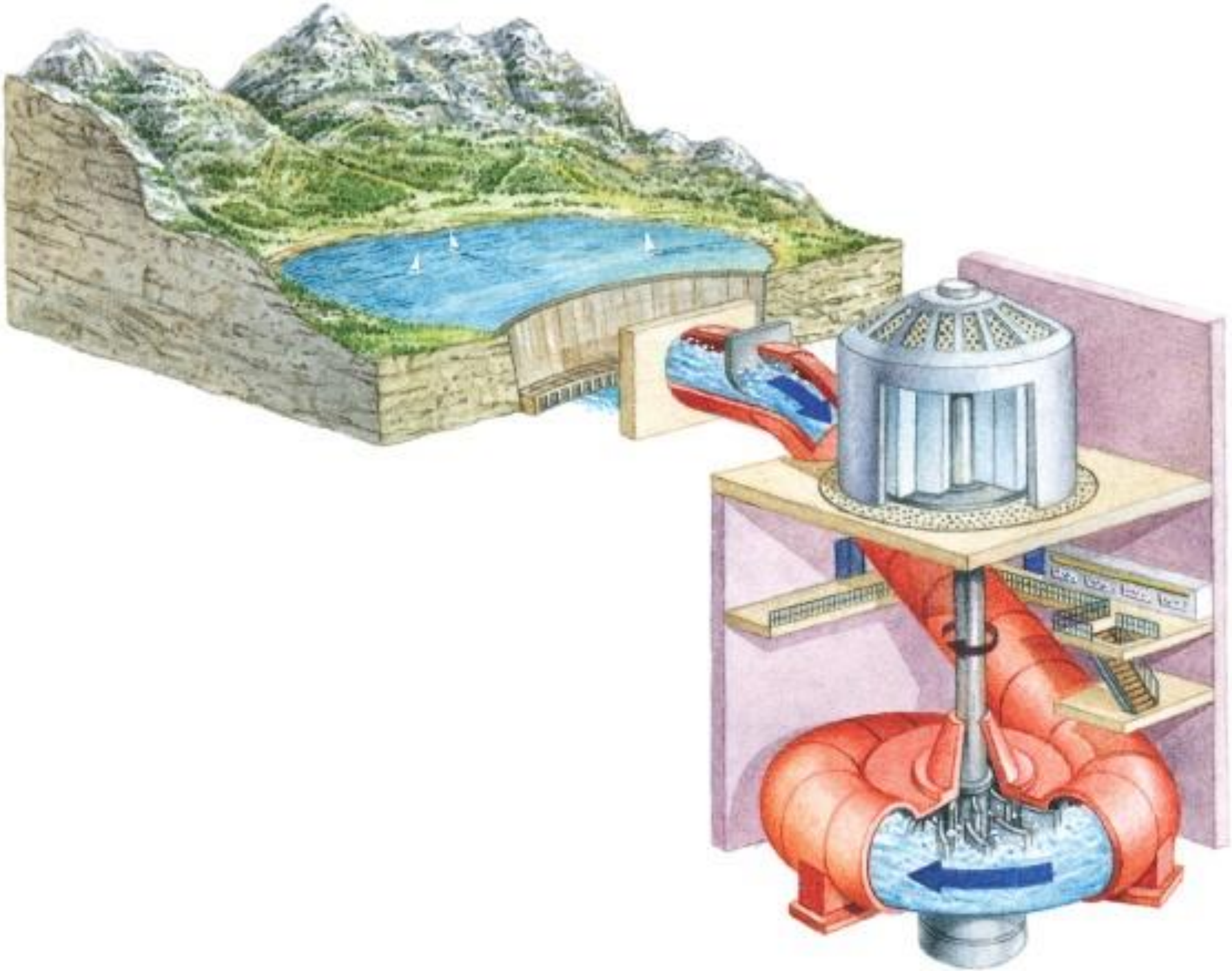
  c) **Axial flow turbines**

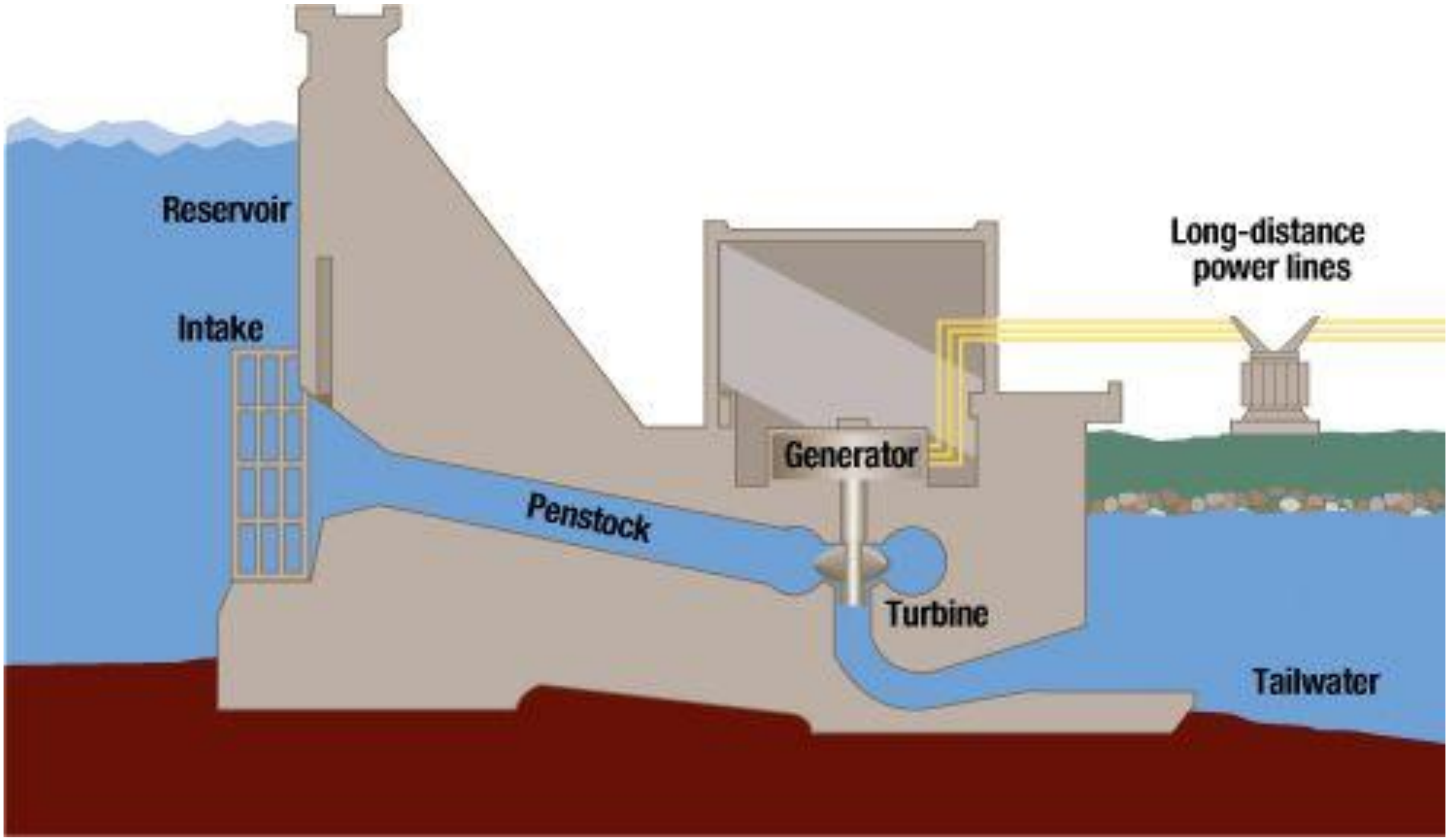
  When the path of flow water remains parallel to the axis of the shaft, it is an axial flow turbine. The Kaplan turbine is axial flow turbine

  d) **Mixed flow turbines**

  When there is gradual change of flow from radial to axial in the runner, the flow is called mixed flow. The Francis turbine is a mixed flow turbine.

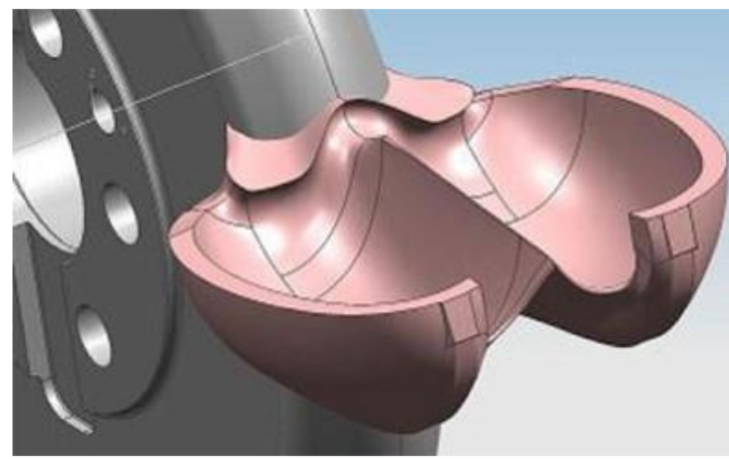
Examples of Hydro-electric plant



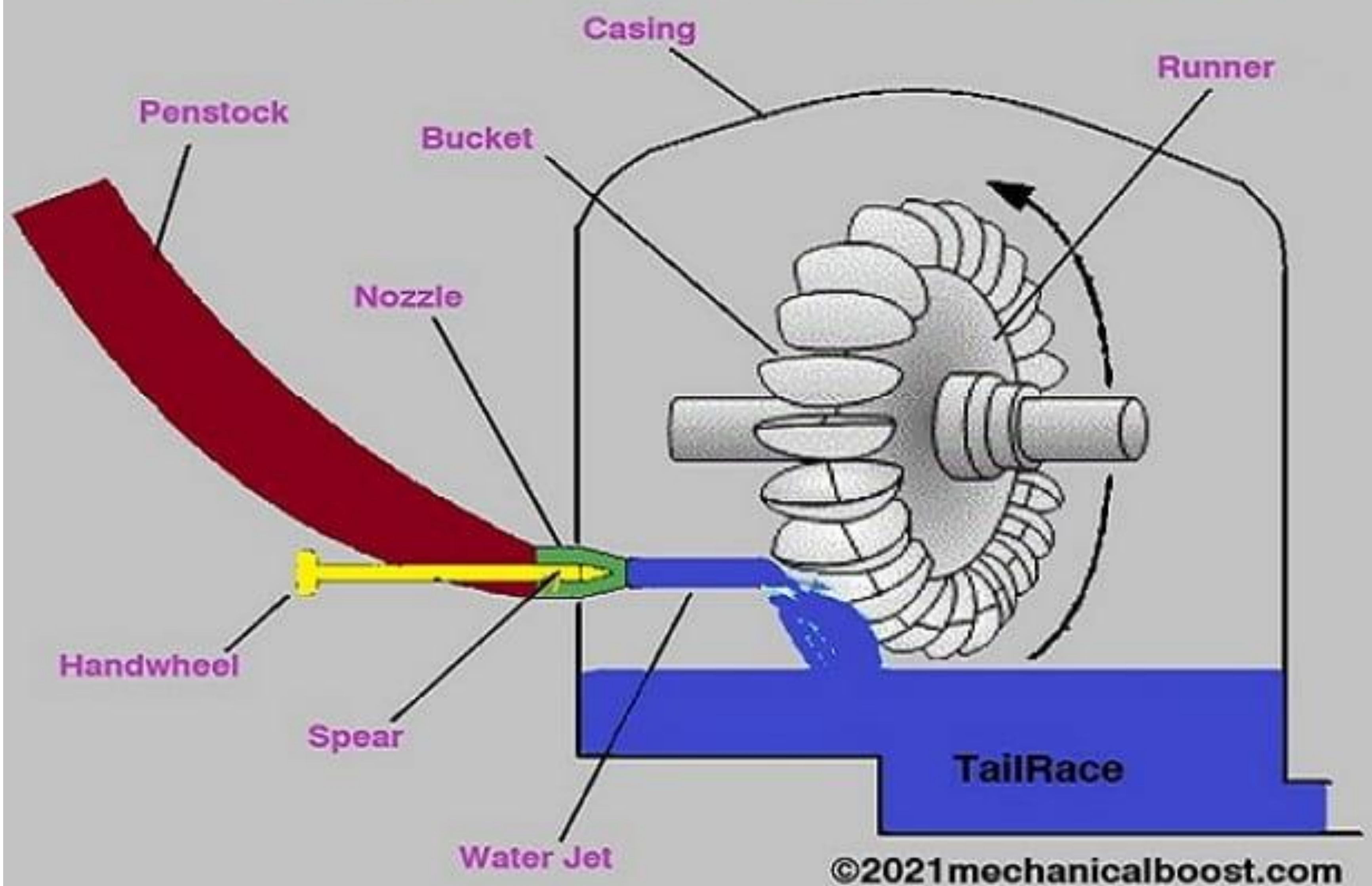

Reservoir
Intake
Penstock
Generator
Turbine
Long-distance power lines
Tailwater

Impulse Turbine

PELTON WHEEL

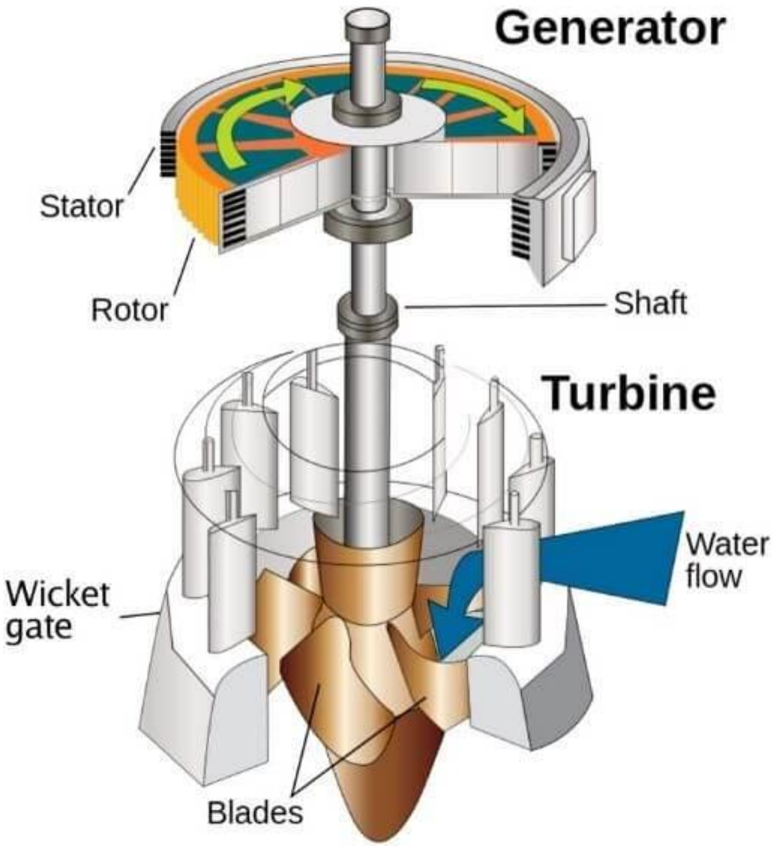


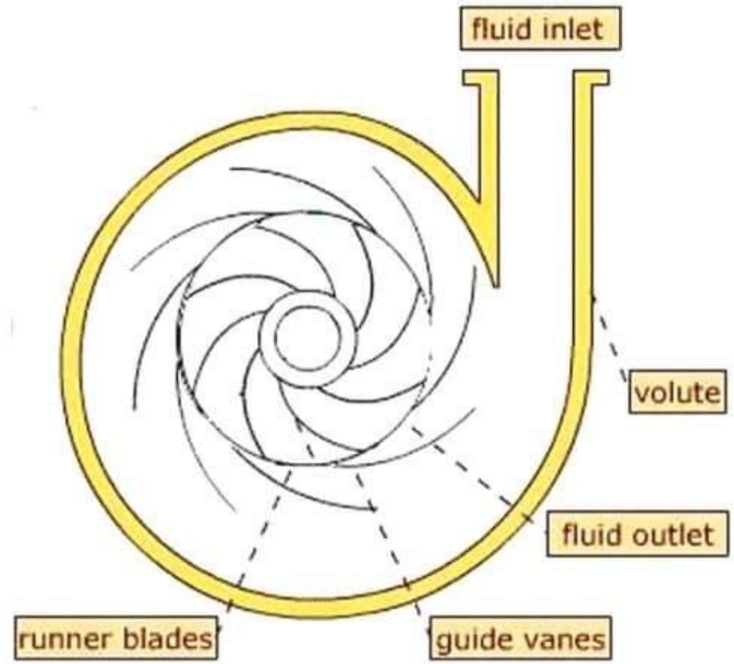
Components of Pelton Wheel Turbine



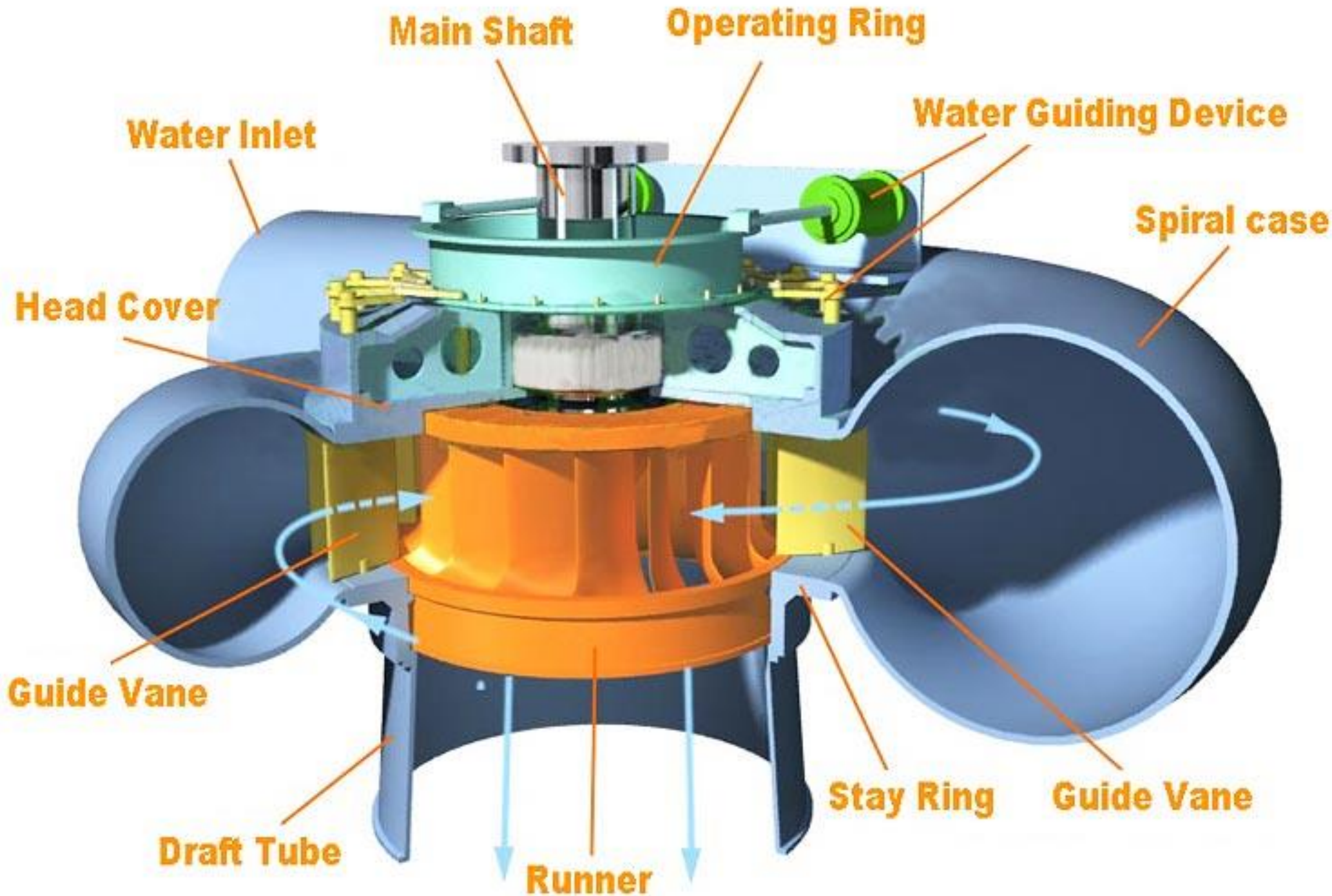
Reaction Turbine

Reaction Turbines

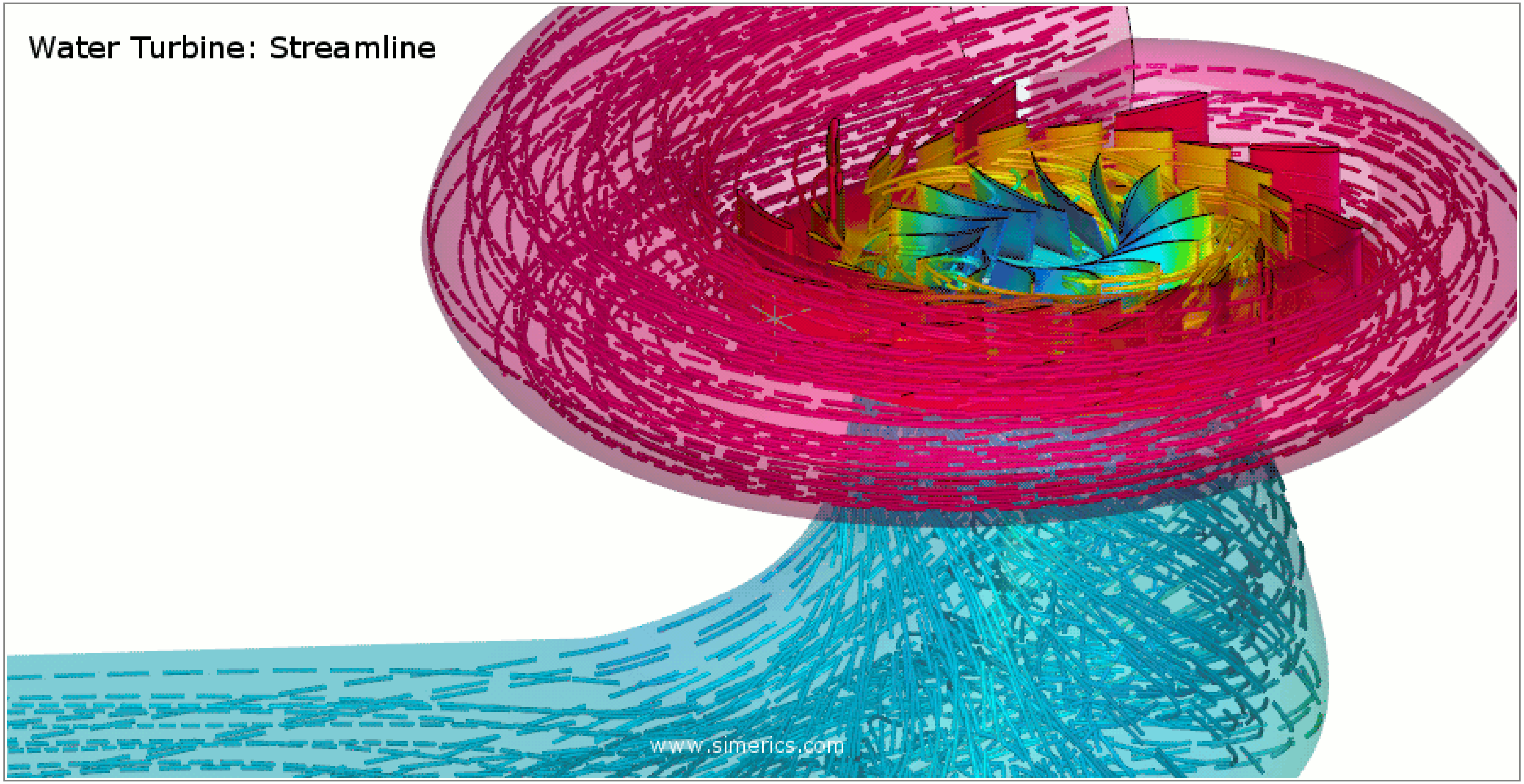




Engineeringchoice.com



Francis Turbine


Water Turbine: Streamline
www.simerics.com

Heads, Losses and Efficiencies of Hydraulic Turbines

- Heads

These are defined as below:

(a) Gross Head: Gross or total head is the difference between the headrace level and the tail race level when there is no flow.

(b) Net Head: Net head or the effective head is the head available at the turbine inlet. This is less than the gross head, by an amount, equal to the friction losses occurring in the flow passage, from the reservoir to the turbine inlet.

Heads, Losses and Efficiencies of Hydraulic Turbines

- Losses

Various types of losses that occur in a power plant are given below:

(a) Head loss in the penstock: This is the friction loss in the pipe of a penstock.

(b) Head loss in the nozzle: In case of impulse turbines, there is head loss due to nozzle friction.

(c) Hydraulic losses: In case of impulse turbines, these losses occur due to blade friction, eddy formation and kinetic energy of the leaving water. In a reaction turbine, apart from above losses, losses due to friction in the draft tube and disc friction also occur.

Heads, Losses and Efficiencies of Hydraulic Turbines

(d) Leakage losses: In case of impulse turbines, whole of the water may not be striking the buckets and therefore some of the water power may go waste. In a reaction turbine, some of the water may be passing through the clearance between the casing and the runner without striking the blades and thus not doing any work. These losses are called leakage losses.

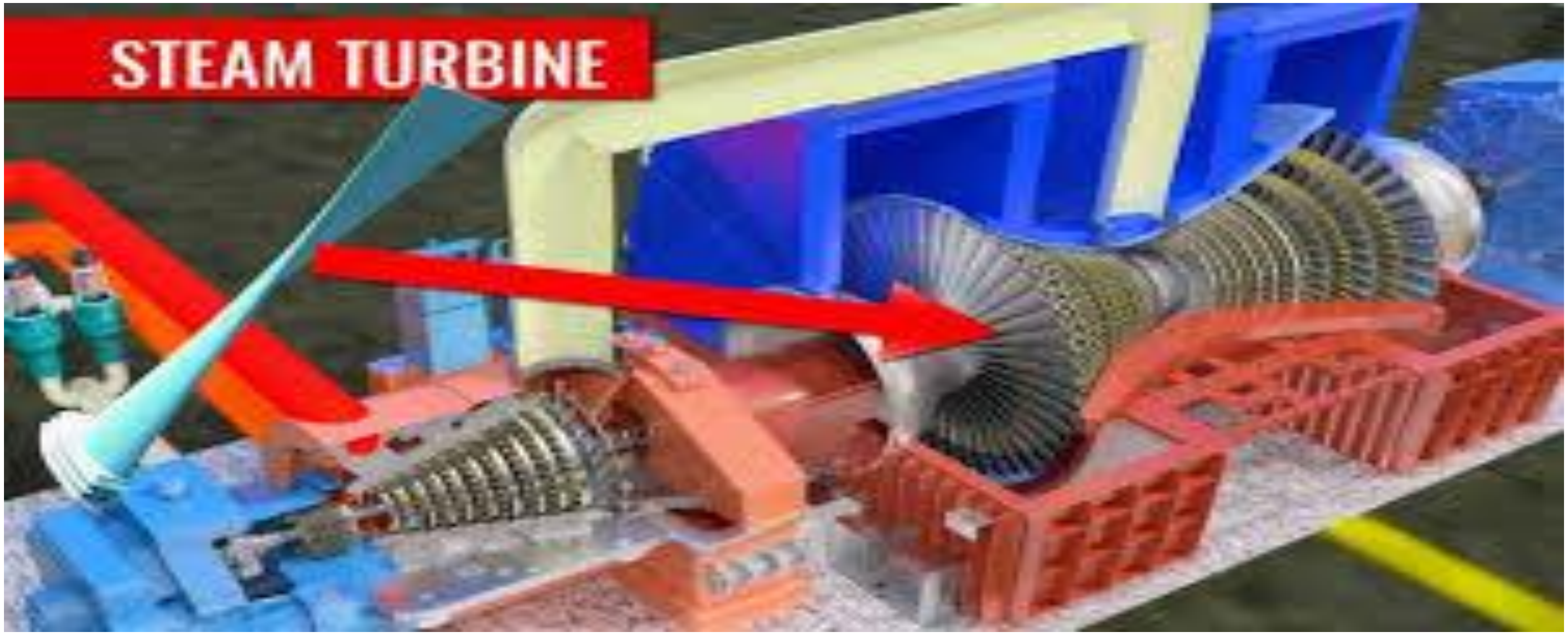
(e) Mechanical losses: The power produced by the runner is not available as useful work of the shaft because some power may be lost in bearing friction as mechanical losses.

f) Generator losses: Due to generator loss, power produced by the generator is still lesser than the power obtained at the shaft output.

Steam Turbines

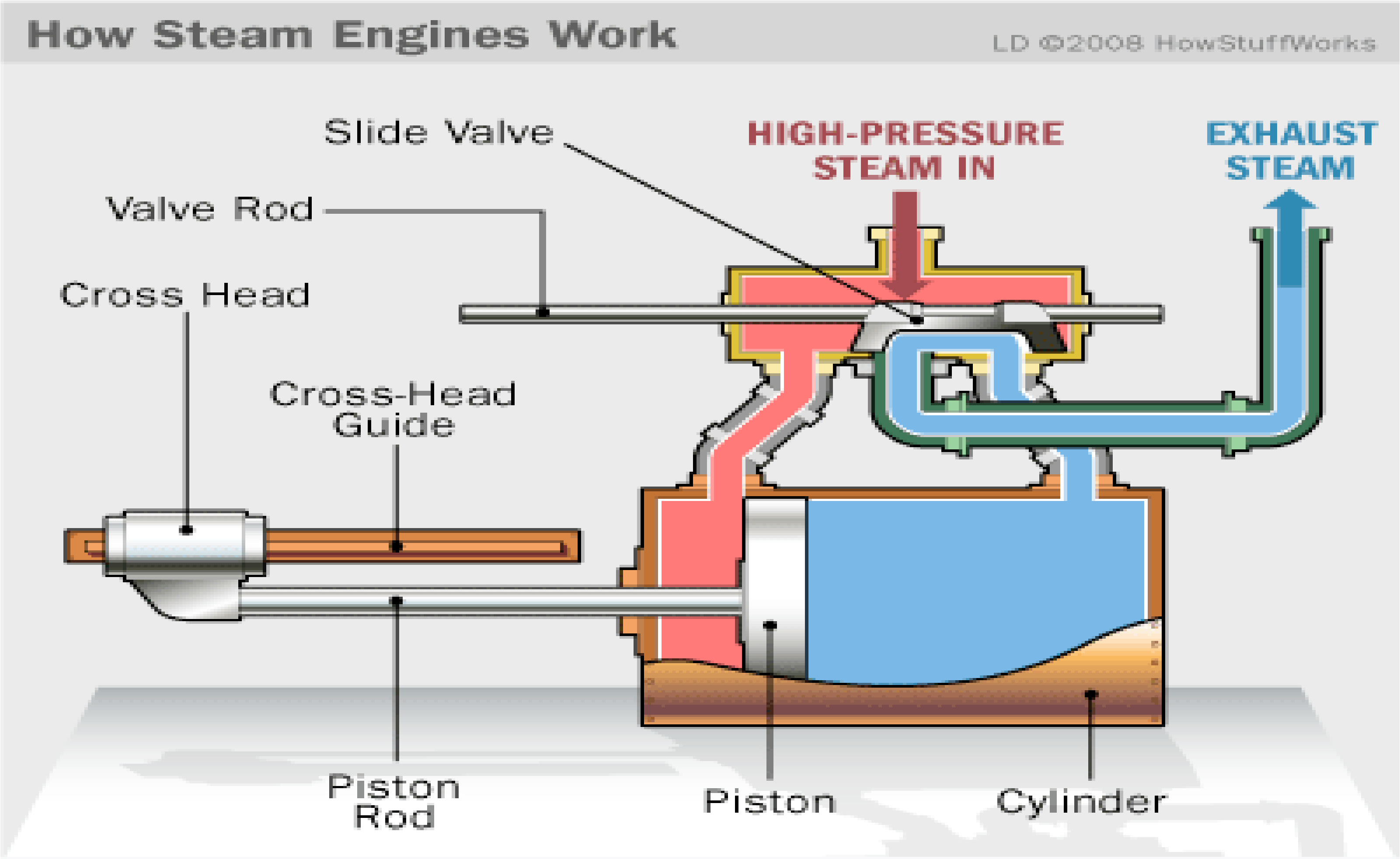
Steam turbine

- A Steam Turbine is a mechanical device that extracts thermal energy from pressurized steam and transforms it into mechanical work and with the help of an alternator finally convert it in electrical energy.



Working

Steam Engine



Steam Turbine

The various **advantages of using the steam turbine over steam engine** are as follows:

- It requires less shaft workspace compared to the steam engine.
- The absence of various links such as a piston, piston rod, crosshead, etc. make the mechanism simple.
- The steam turbine is quiet and smooth in operation.
- In steam turbine power is generated at a uniform rate. Therefore, the flywheel is not needed.

Steam Turbine

- The internal lubrication is not required in a steam turbine. This reduces the cost of lubrication.
- Steam turbine overload capacity is large.
- Steam turbine can be designed for much greater capacities of power as compared to the steam engine.
- Steam turbines can be built in for generating power ranging from a few horsepower to over 200,000 horsepower in single units.

Steam Turbine

- It can be designed for greater range of speed of operation.
- Thermodynamic efficiency of the steam turbine is higher compared to the steam engine.
- In a steam turbine, the steam consumption does not increase with an increase in years of service.

Classification of Steam Turbine :

Steam turbines are classified according to :

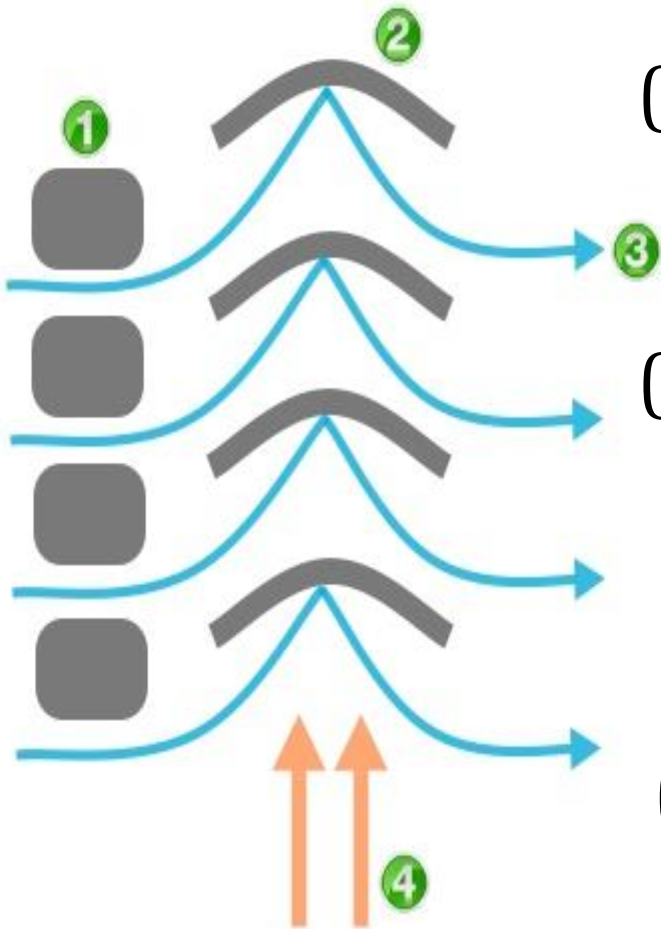
- **Principle of action of steam**
  - a. Impulse turbine
  - b. Reaction turbine
- **Direction of steam flow**
  - a. Axial
  - b. Radial
  - c. Tangential
- **Number of pressure stages**
  - a. Single stage
  - b. Multi stage

Impulse turbine

- **Impulse turbine** is a type of steam turbine where the rotor derives its rotational force from the impact force, or the direct push of steam on the blades.
- The impulse turbine was first built in 1883 by the Swedish engineer De Laval.
- The impulse turbine consists of a rotor mounted on a shaft that is free to rotate.

Impulse turbine

- Attached to the rotor are a set of curved blades. Nozzles then direct the high pressure and high temperature steam towards the blades of the turbines
- The blades catch the impact force of the rapidly moving steam and rotate from this force.

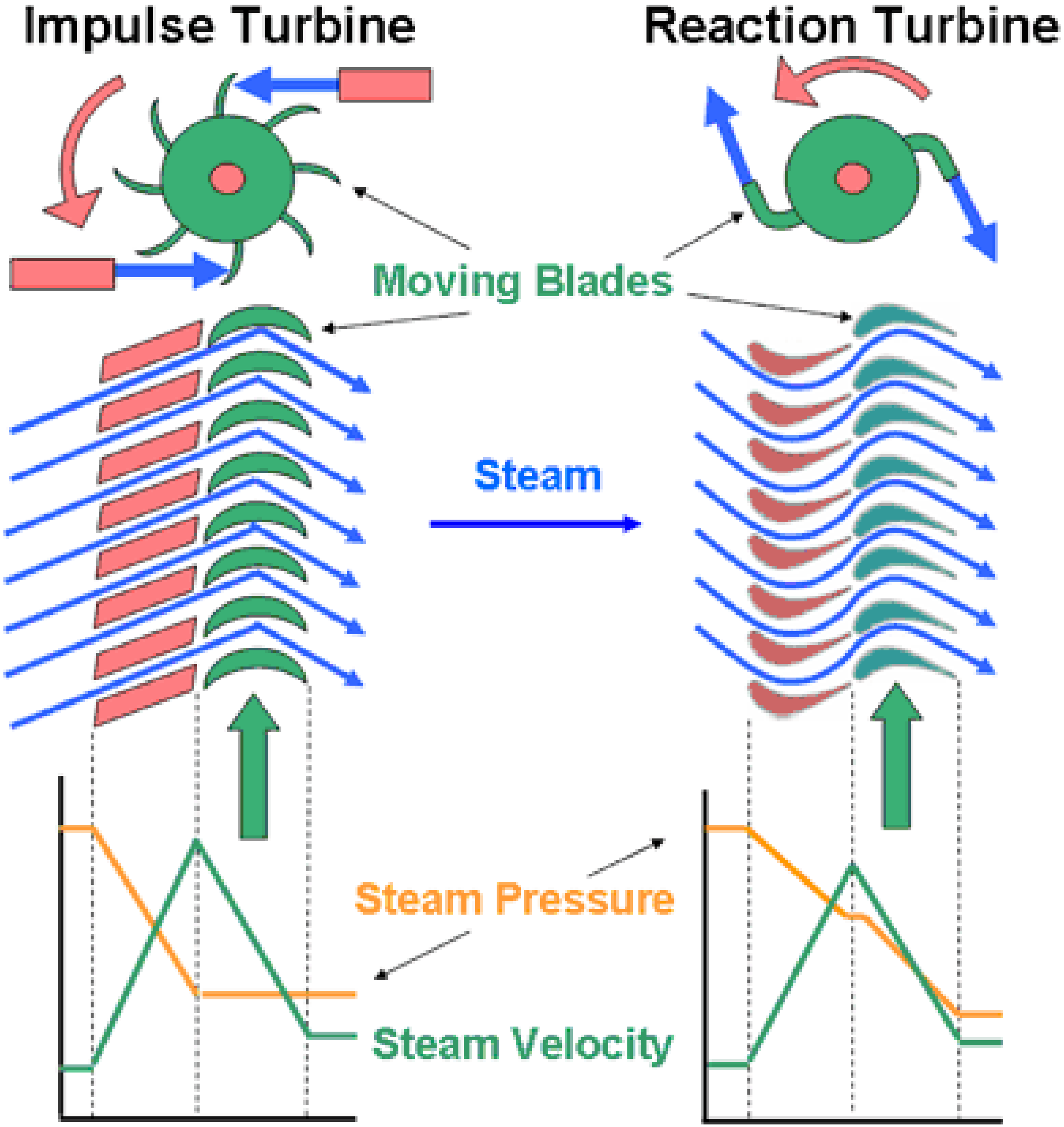


(1) The steam first enters the impulse turbine through a fixed Nozzle.

(2) The steam strikes the blades that are free to rotate with a strong enough force to move the blades.

(3) The steam exits the blade towards the condensing system of the steam turbine generator system.

(4) The direction of the blades due to the force of steam.



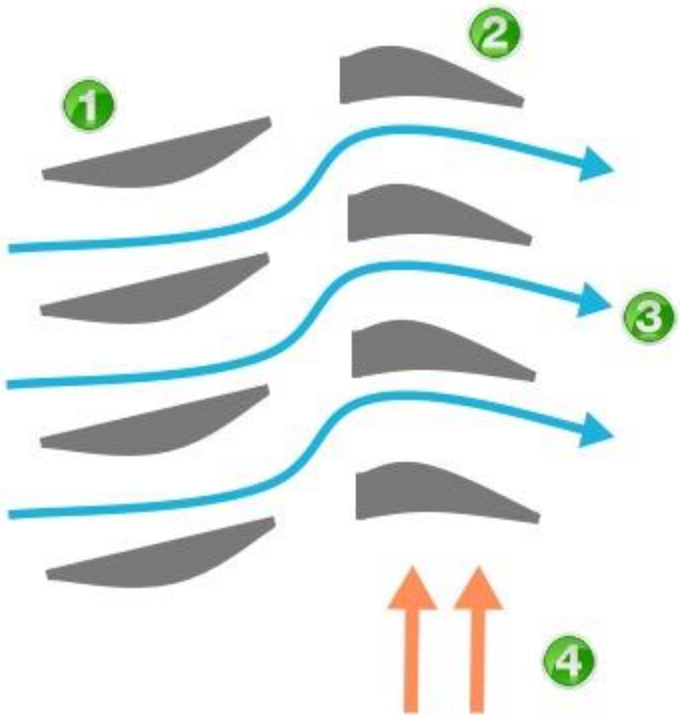
Impulse Turbine
Reaction Turbine
Moving Blades
Steam
Steam Pressure
Steam Velocity

Reaction turbine

- A **reaction turbine** is a type of steam turbine that works on the principle that the rotor spins, as the name suggests, from a reaction force rather than an impact or impulse force.
- In a reaction turbine there are no nozzles to direct the steam like in the impulse turbine.
- Instead, the blades that project radially from the outer edge of the rotor are shaped and mounted so that the shape between the blades, created by the cross-section, create the shape of a nozzle. These blades are mounted on the revolving part of the rotor and are called the moving blades.

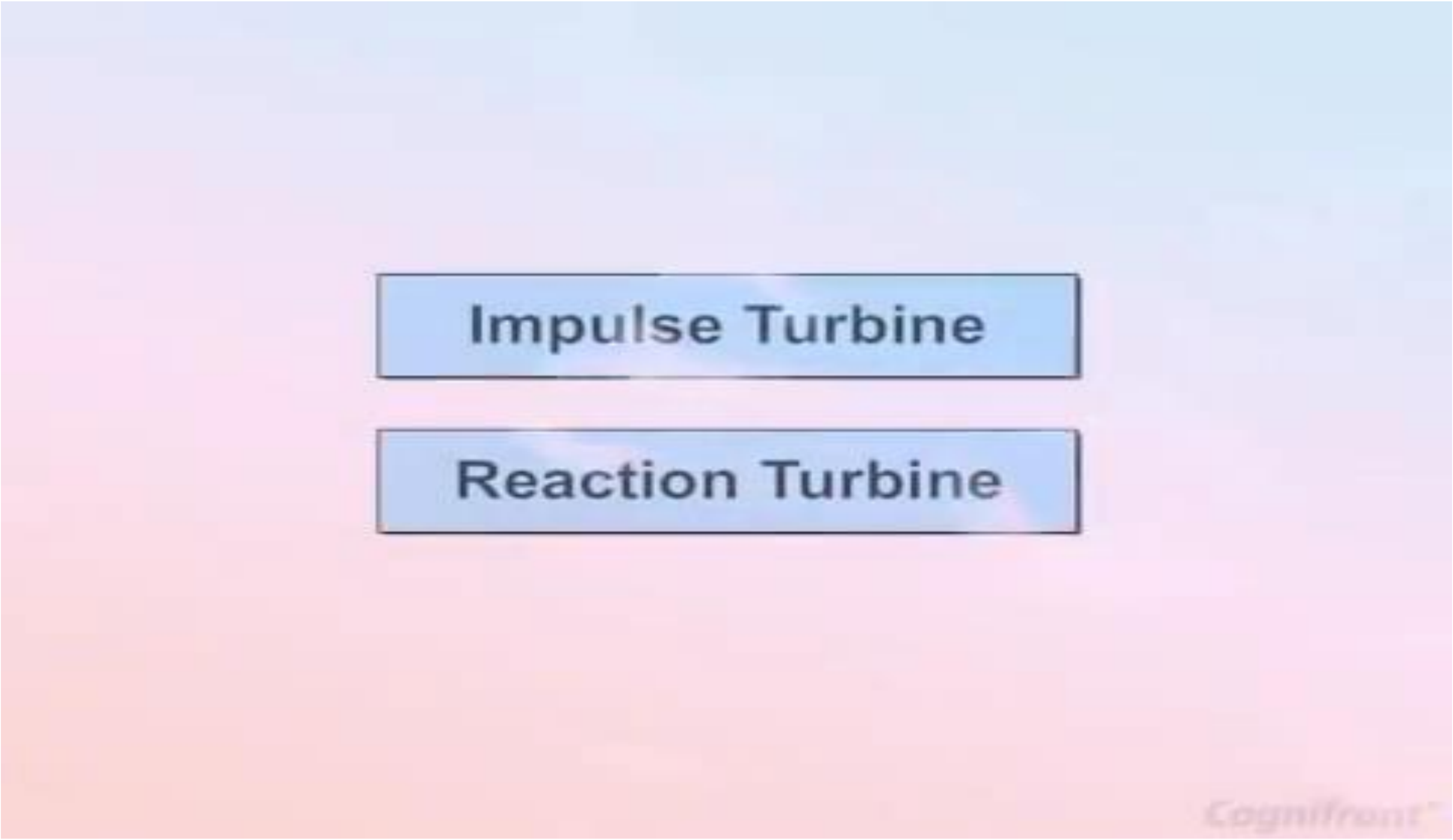
Reaction turbine

- The fixed blades, which are the same shape as the moving blades, are mounted to the outer casing where the rotor revolves and are set to guide the steam into the moving blades.



- (1) The steam enters through a section of curved blades in a fixed position.
- (2) The steam then enters the set of moving blades and creates enough reactive force to rotate them,
- (3) The steam exits the section of rotating blades.
- (4) The direction of rotation.

Impulse and Reaction Turbine Working



Reaction turbine

- There are three main forces that act to move a reaction turbine.
- First, from the reactive force that is created on the moving blades as it expands and increases in velocity as it moves through the nozzle shaped spaces between the blades.
- Second, from the reactive force produced on the moving blades as the steam passes through and changes directions.
- Third, and to a lesser extent, from the impact force of the steam on the blades helps rotate the reaction turbine.

Difference between Impulse and Reaction Turbine

1. In impulse turbine, there are nozzle and moving blades are in series while there are fixed blades and moving blades are present in Reaction turbine (No nozzle is present in reaction turbine).
2. In impulse turbine pressure falls in nozzle while in reaction turbine in fixed blade boiler pressure falls.
3. In impulse turbine velocity (or kinetic energy) of steam increases in nozzle while this work is to be done by fixed blades in the reaction turbine.
4. In impulse turbine pressure drop per stage is more than reaction turbine.

Difference between Impulse and Reaction Turbine

6) Not much power can be developed in impulse turbine than reaction turbine.

7)Efficiency of impulse turbine is lower than reaction turbine.

8)Impulse turbine requires less space than reaction turbine.

9)Blade manufacturing of impulse turbine is not difficult as in reaction turbine it is difficult.

Losses in turbine

1) Friction loss

It is important loss in impulse turbine , which occurs when the steam flows through the nozzle.

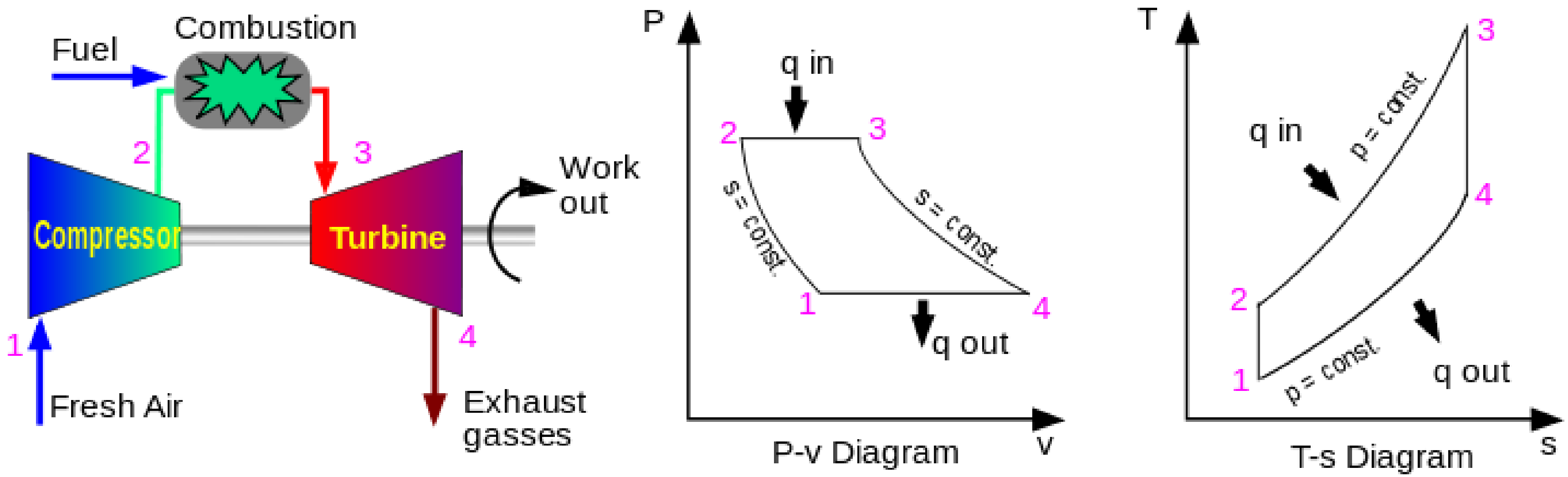
This loss takes place due to friction in the nozzle.

2) Leakage loss

It is important loss in reaction turbine , which occurs when the steam flows through the rotors/blades.

Gas Turbine

Brayton Cycle



Ideal Brayton Cycle

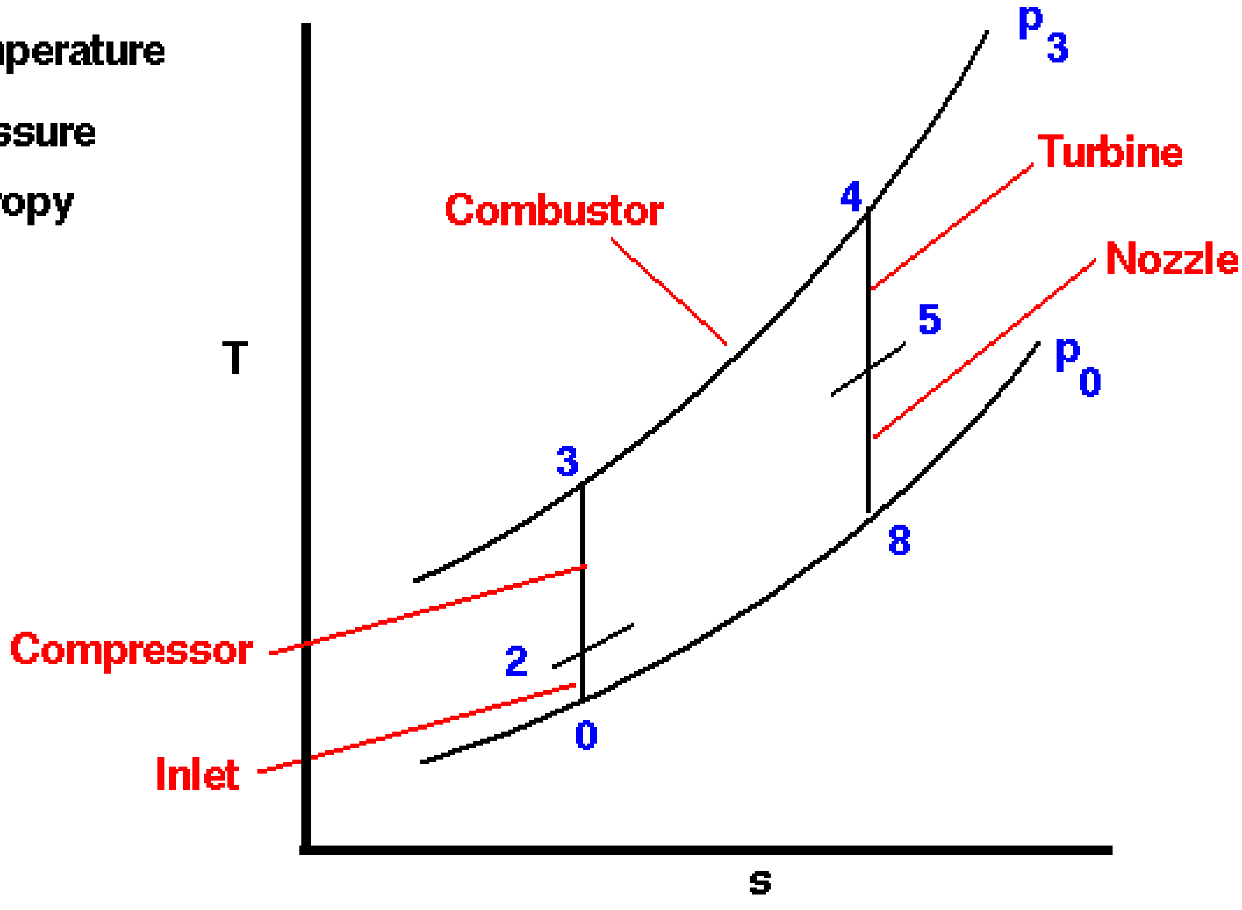
T–s diagram

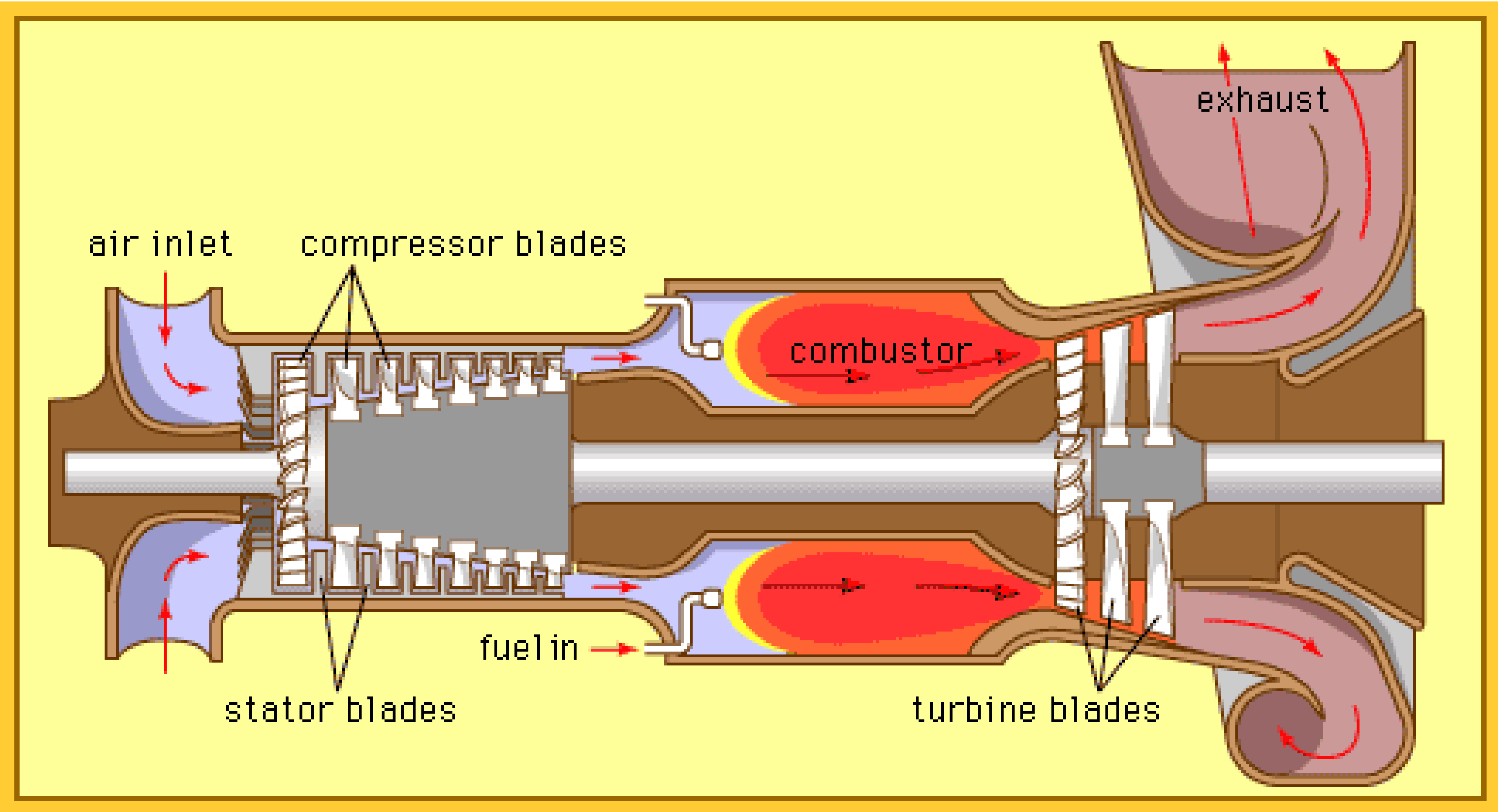
Glenn
Research
Center

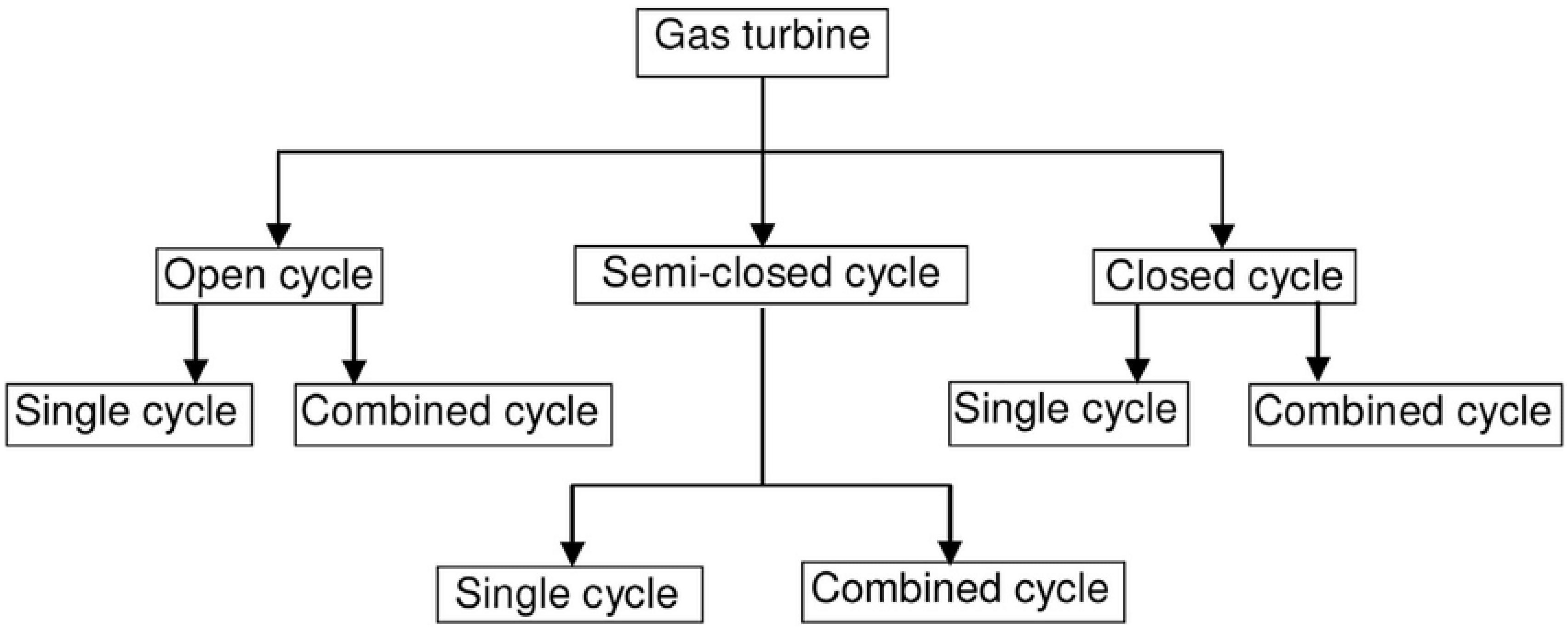
T = Temperature

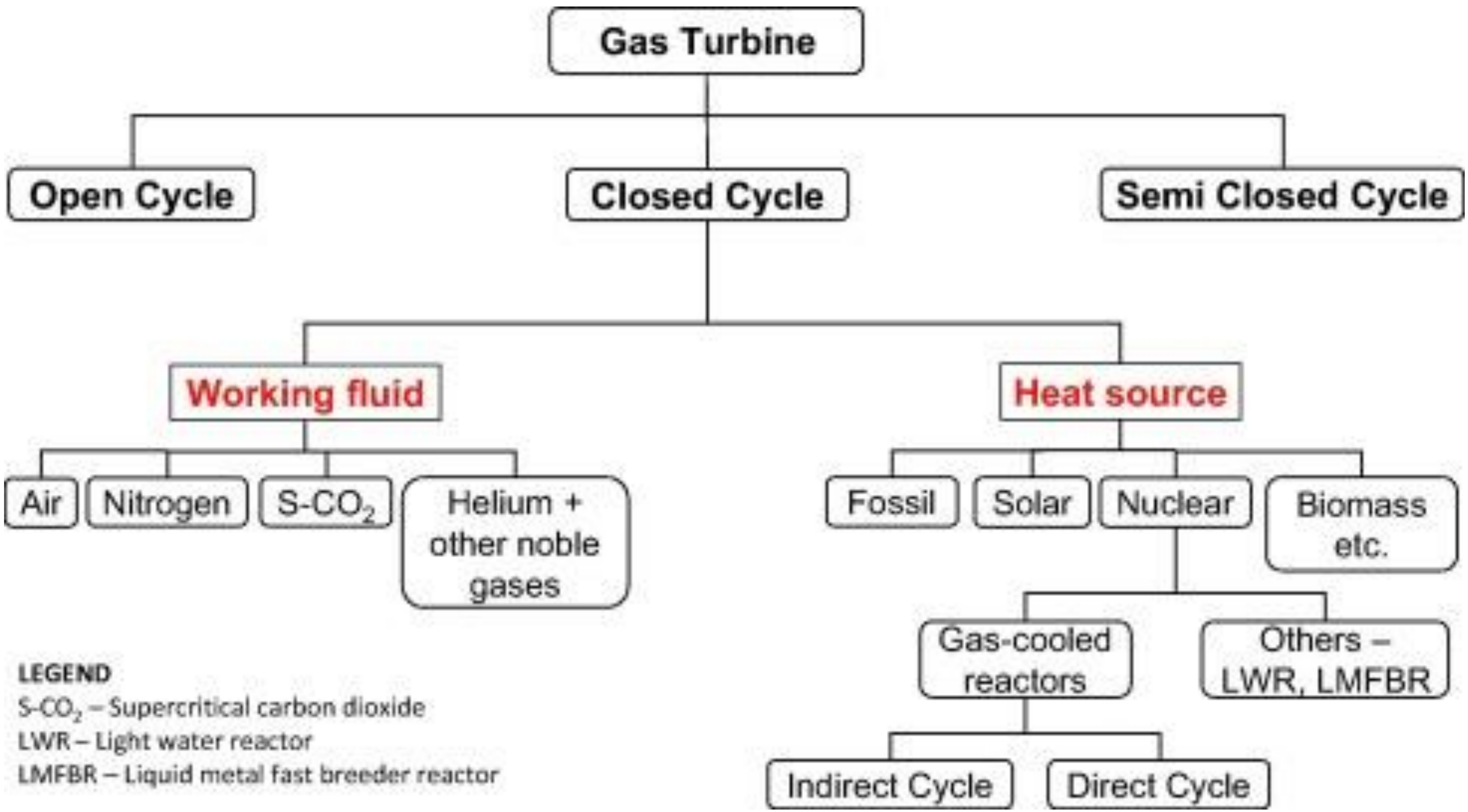
p = pressure

s = entropy

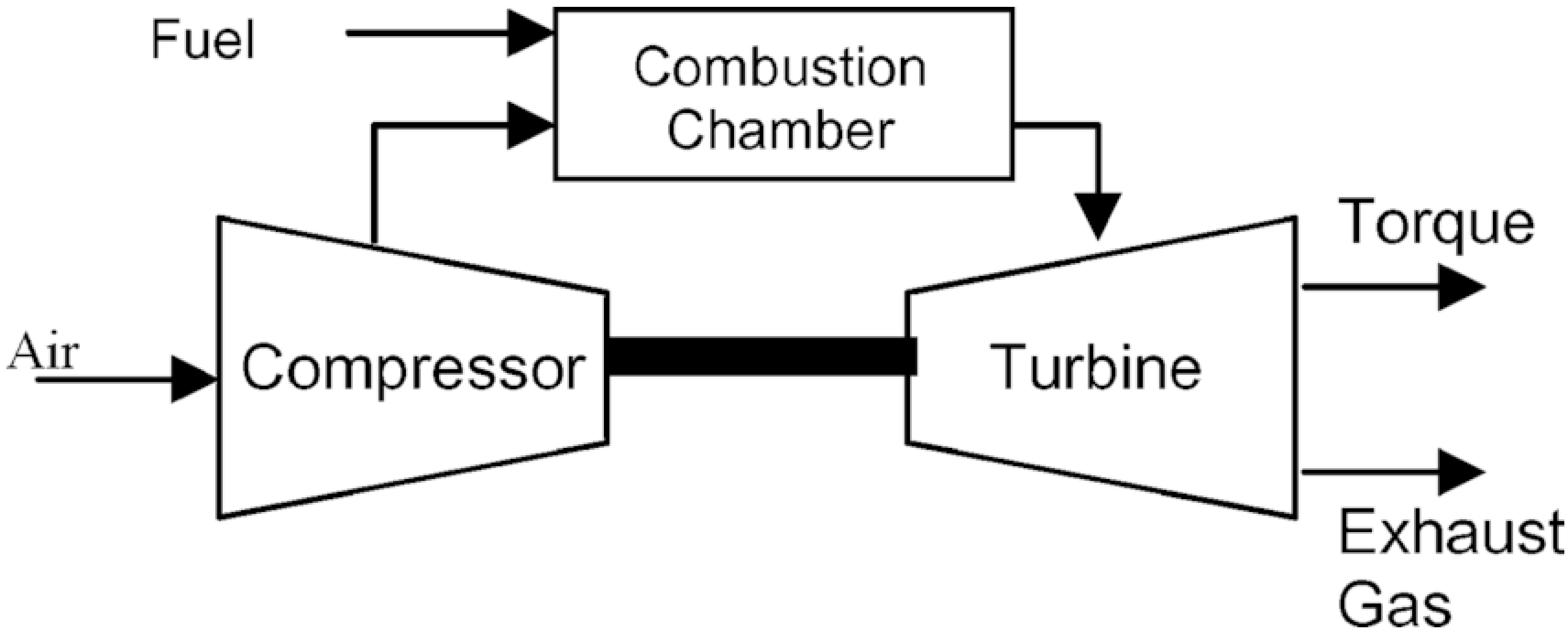


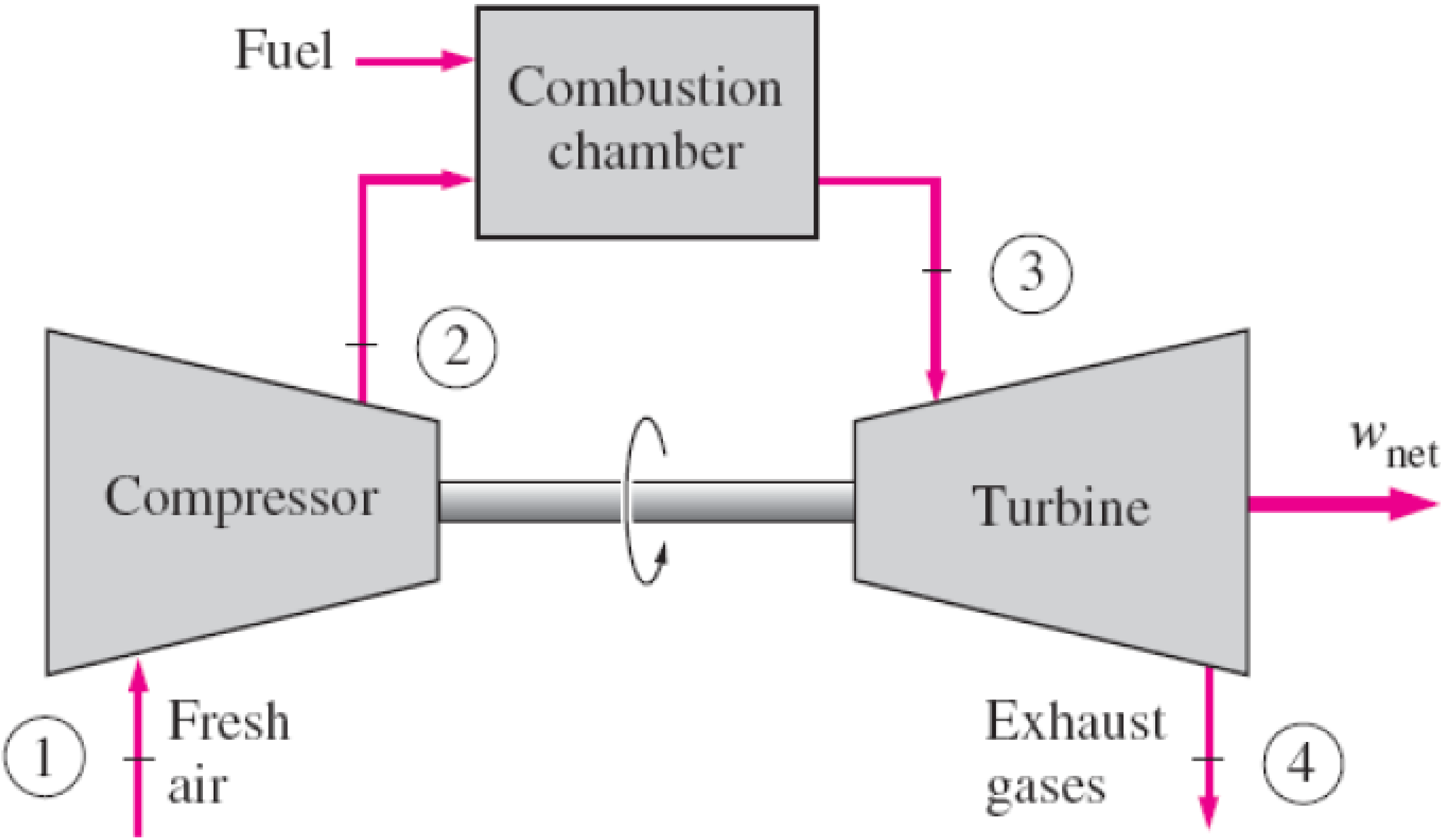

air inlet
compressor blades
exhaust
combustor
fuel in
stator blades
turbine blades

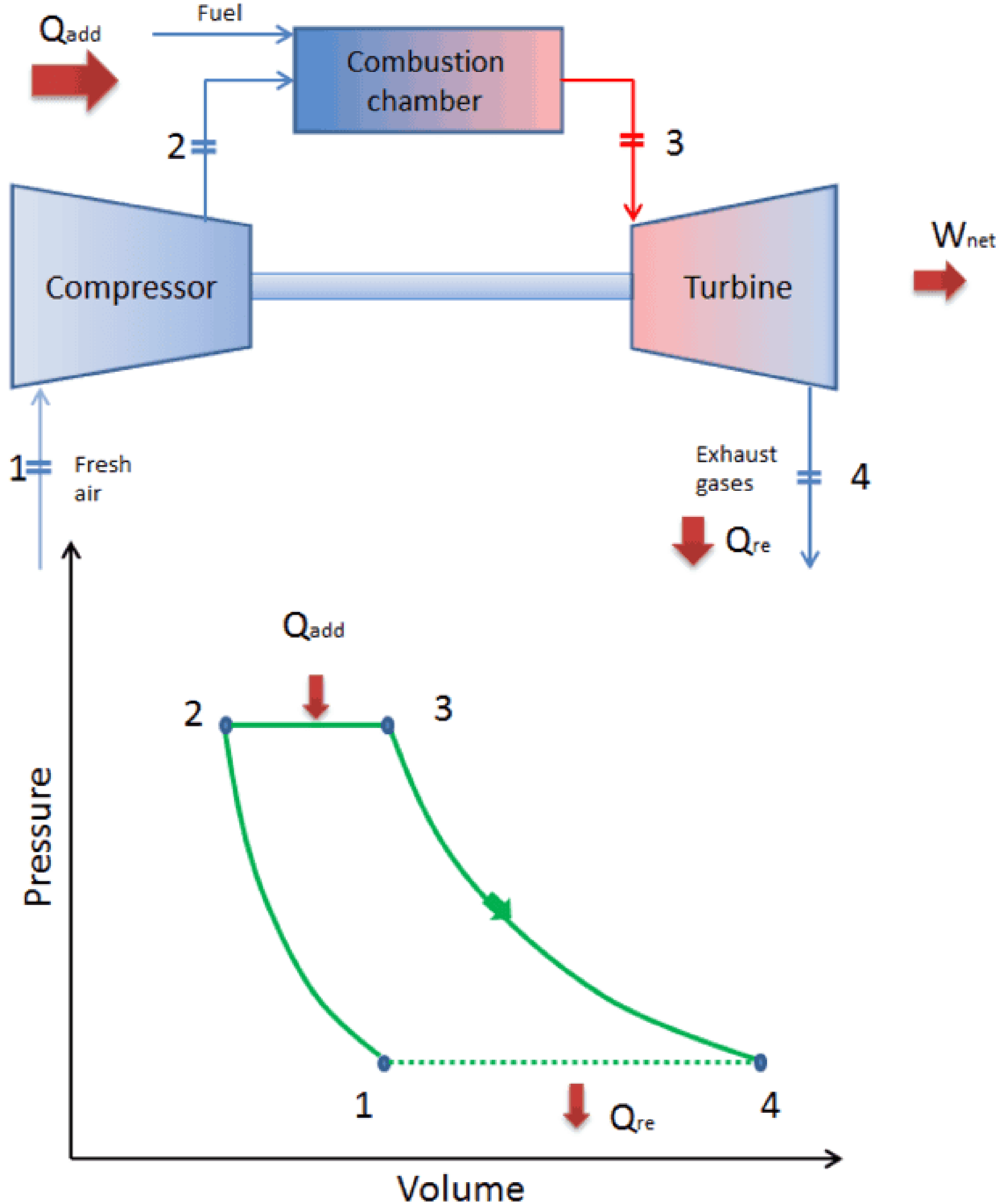

Gas turbine
Open cycle
Semi-closed cycle
Closed cycle
Single cycle
Combined cycle
Single cycle
Combined cycle
Single cycle
Combined cycle


Gas Turbine
Open Cycle
Closed Cycle
Semi Closed Cycle
Working fluid
Heat source
Air
Nitrogen
S-CO_2
Helium + other noble gases
Fossil
Solar
Nuclear
Biomass etc.
Gas-cooled reactors
Others – LWR, LMFBR
Indirect Cycle
Direct Cycle
LEGEND
S-CO_2 – Supercritical carbon dioxide
LWR – Light water reactor
LMFBR – Liquid metal fast breeder reactor

OPEN CYCLE GAS TURBINE POWER PLANT




Fuel
Combustion chamber
3
2
Compressor
Turbine
w_{net}
1
Fresh air
Exhaust gases
4



Qadd
Fuel
Combustion chamber
2
3
Compressor
Turbine
Wnet
1
Fresh air
Exhaust gases
4
Qre
Qadd
2
3
Pressure
1
Qre
4
Volume

Open cycle gas turbine power plant

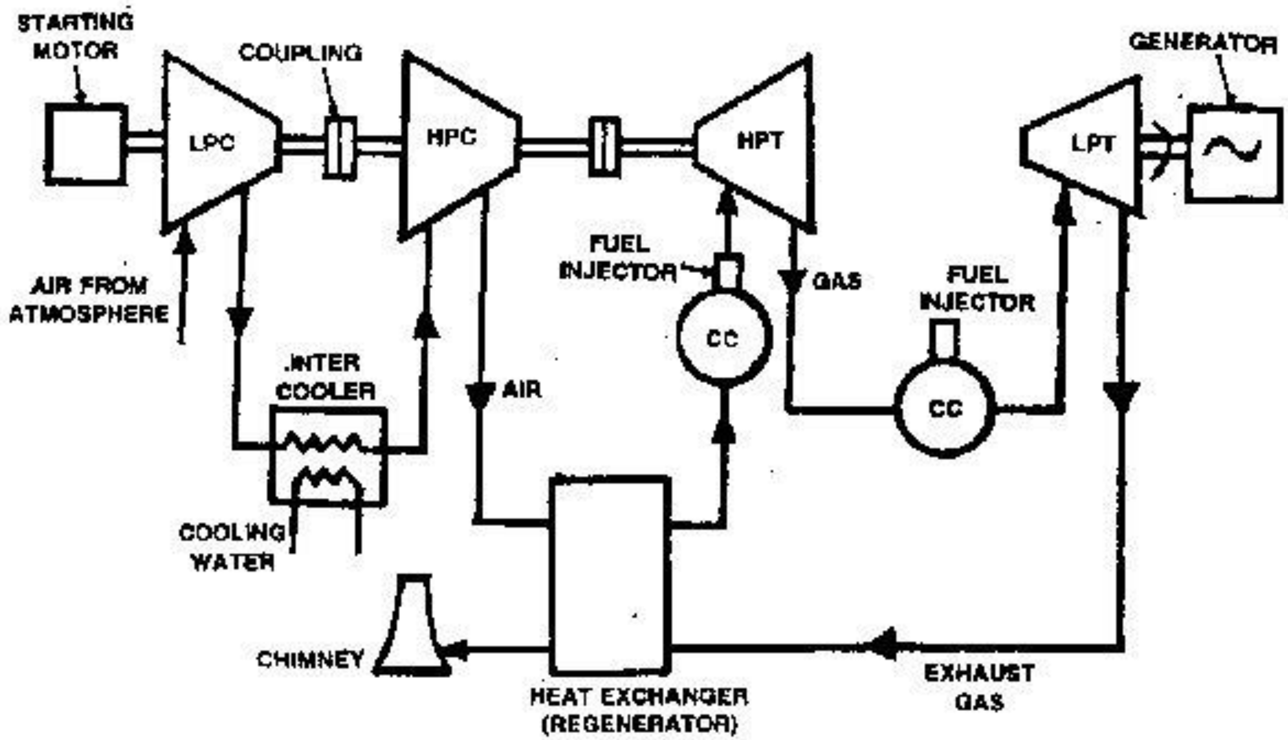
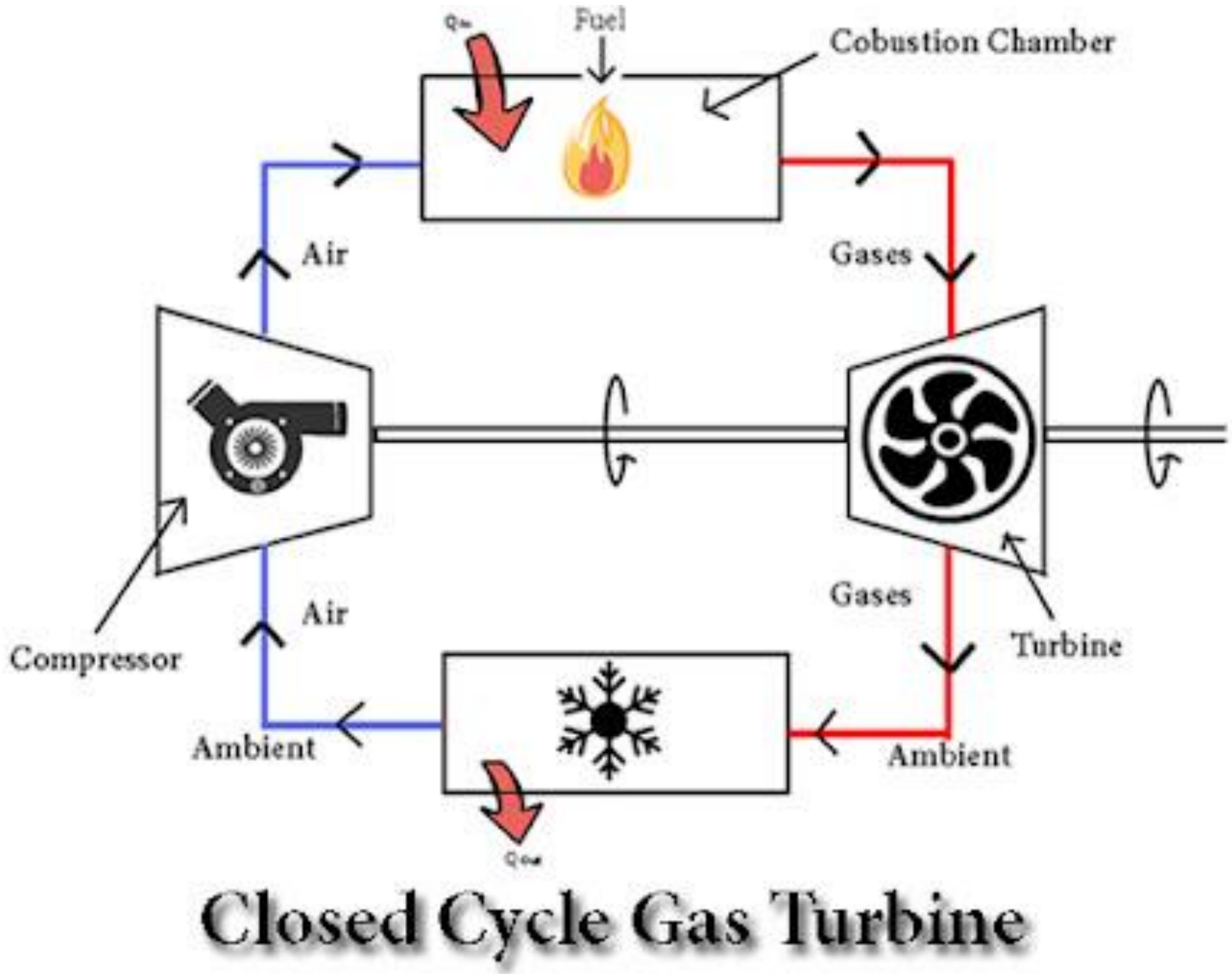
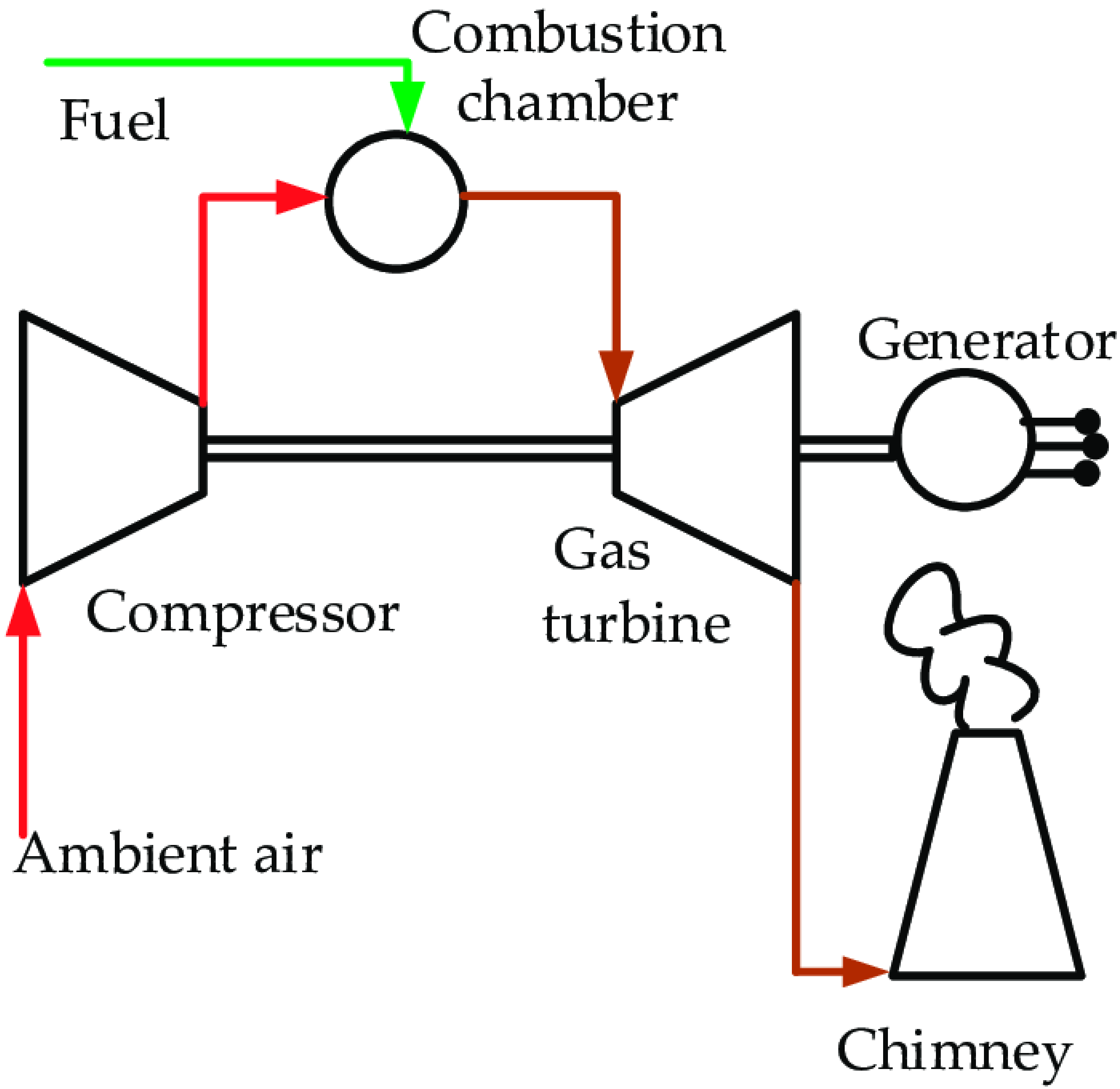


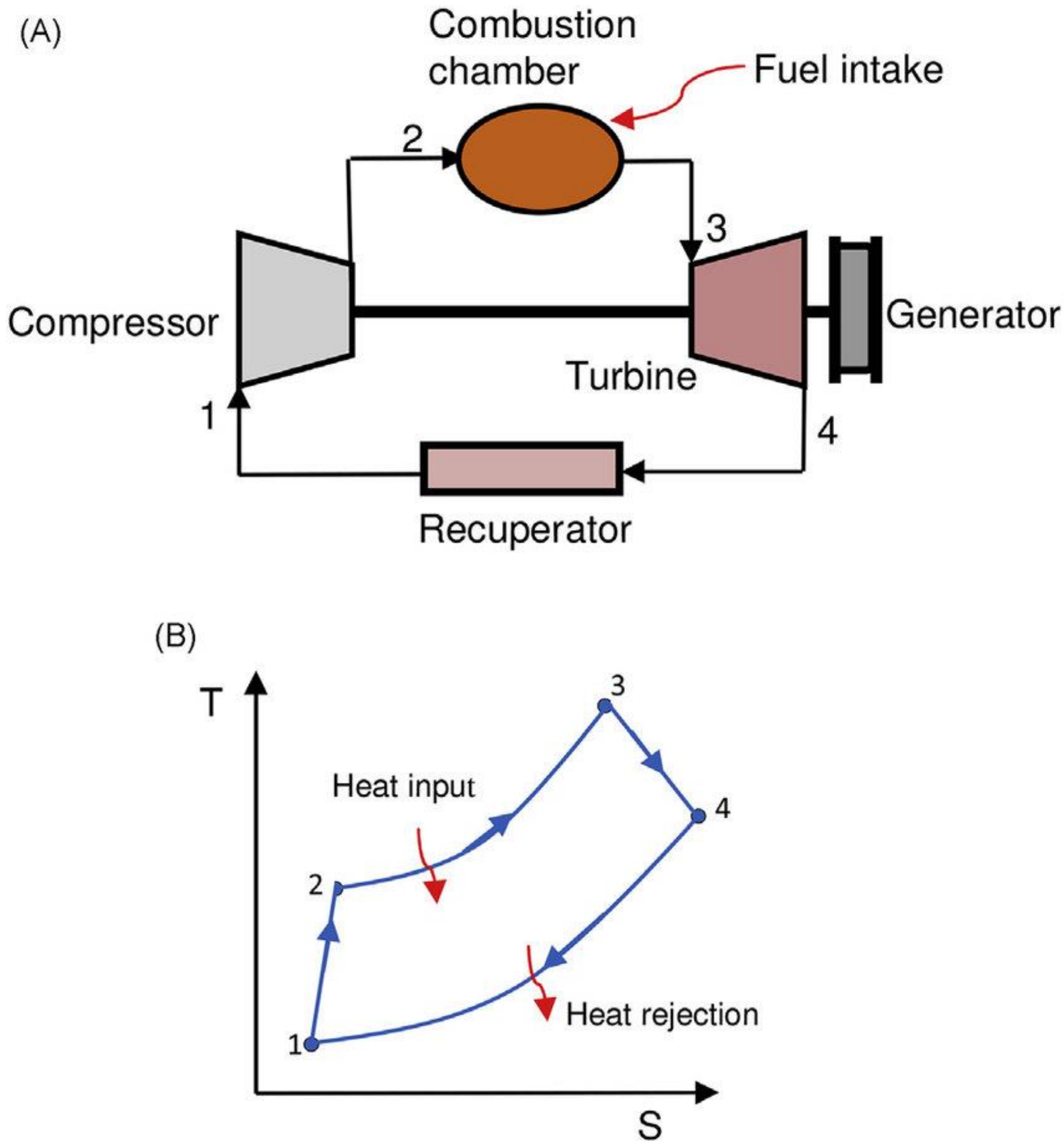
Fig. 3.12: OPEN CYCLE GAS TURBINE POWER PLANT

CLOSED CYCLE GAS TURBINE POWER PLANT



Closed Cycle Gas Turbine


Combustion chamber
Fuel
Generator
Gas turbine
Compressor
Ambient air
Chimney


(A)
Combustion chamber
Fuel intake
2
3
Compressor
Generator
Turbine
1
4
Recuperator
(B)
T
3
Heat input
4
2
Heat rejection
1
S