Energy conversion

Power Plant : General layout of thermal power plant and heat to work/power conversion, efficiency of conversion. Requirements of coal, air and water just to produce unit of electricity

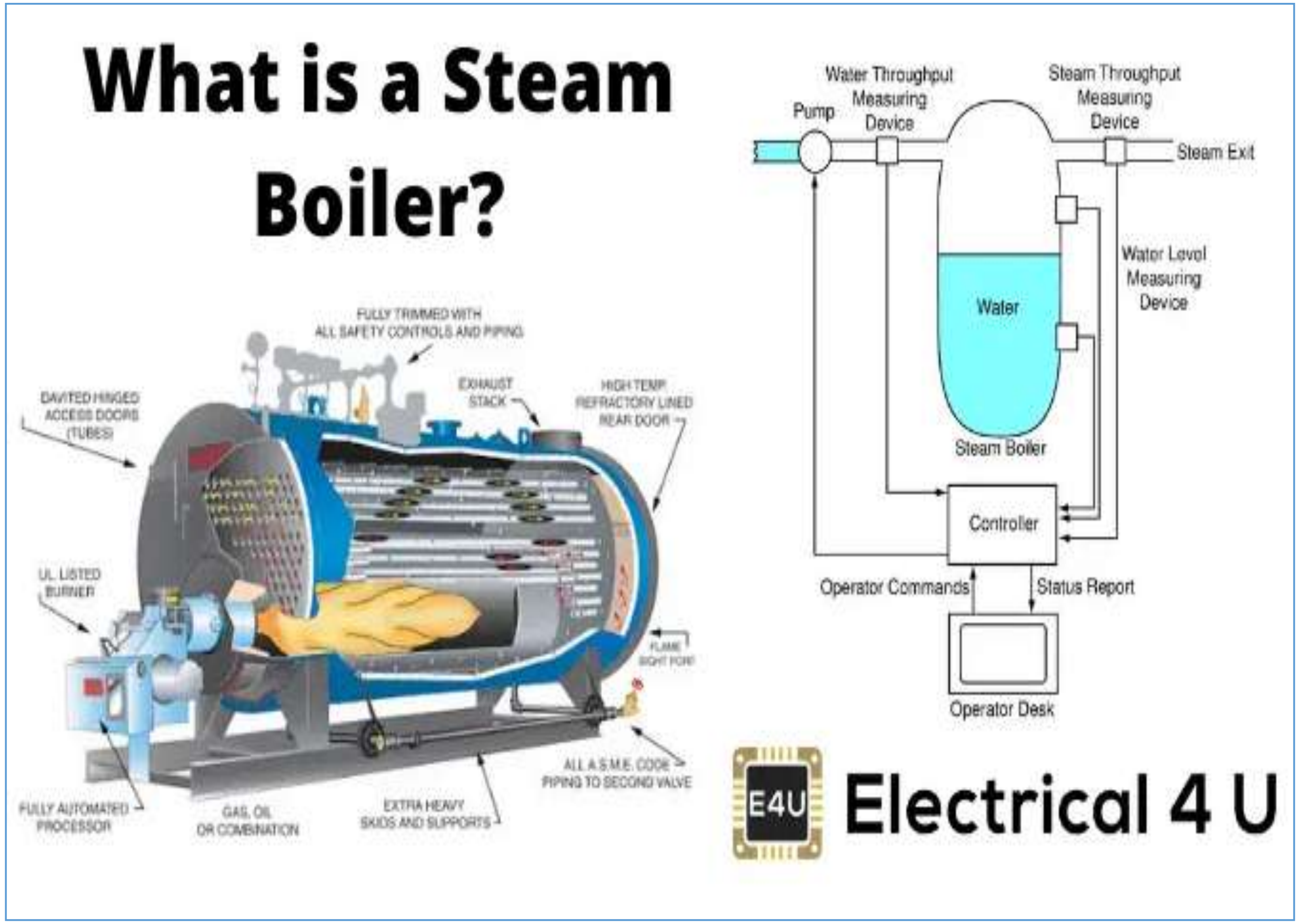
Surat: Steam power plant, Nani Naroli Village (225 MW)

In India, the total number of **269** Thermal Power Plants. Out of these, **138** Thermal Power Plants are in the public sector and the remaining **131** Thermal Power Plants are in the private sector. Ans.

The installed capacity of all Thermal Power Plants in India is about **393,389.46** MW.

Major Parts of Steam Power Plant

1. Boilers
2. Superheater
3. Turbine
4. Condenser
5. Economizer
6. Air preheater
7. Chimney
8. Coal Handling Plant
9. Ash Handling Plant
10. Cooling Tower
11. Alternator

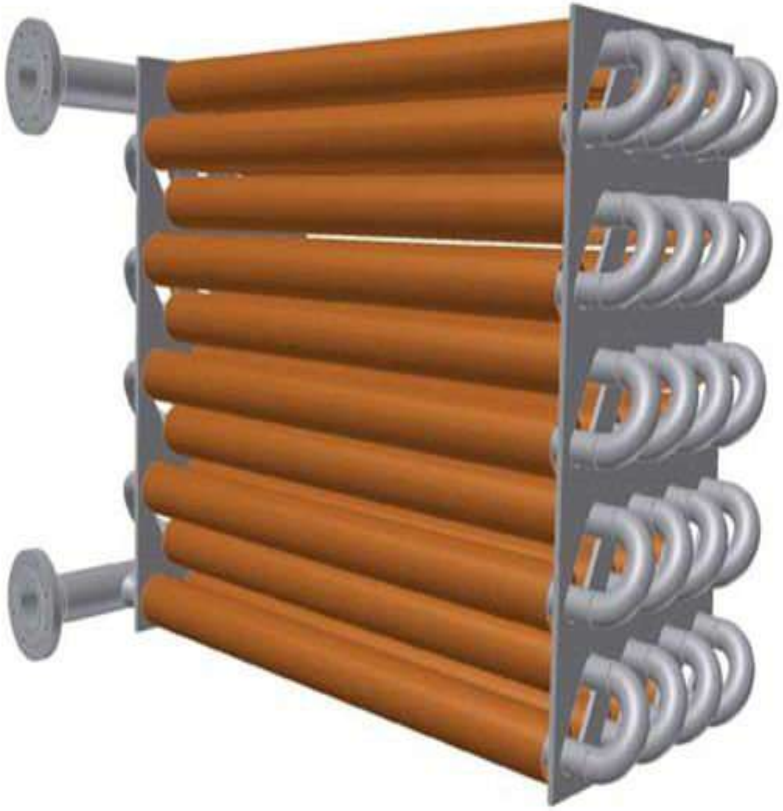


A **steam boiler** is a closed vessel that uses heat from a fuel source to convert water into steam.
It serves various industrial and commercial purposes, including heating and power generation.

Steam Turbine

steam turbine is a type of rotary heat engine that converts **thermal energy** from pressurized steam into either **mechanical energy** (used for driving machinery) or **electrical energy** (used for generating electricity)

Economizer of SPP



An **economizer** is a heat-exchanging device designed to save energy by preheating a process fluid. In the context of power plants, it plays a crucial role in enhancing efficiency and reducing fuel consumption

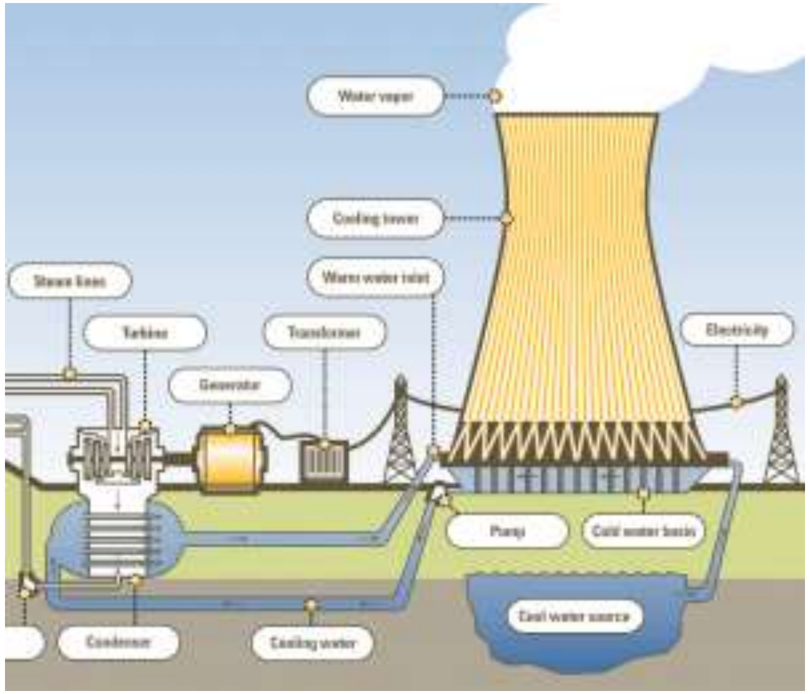
Chimney of SPP

Chimney ensures efficient venting and contributes to the overall performance of a steam power plant

Ash Handling Unit

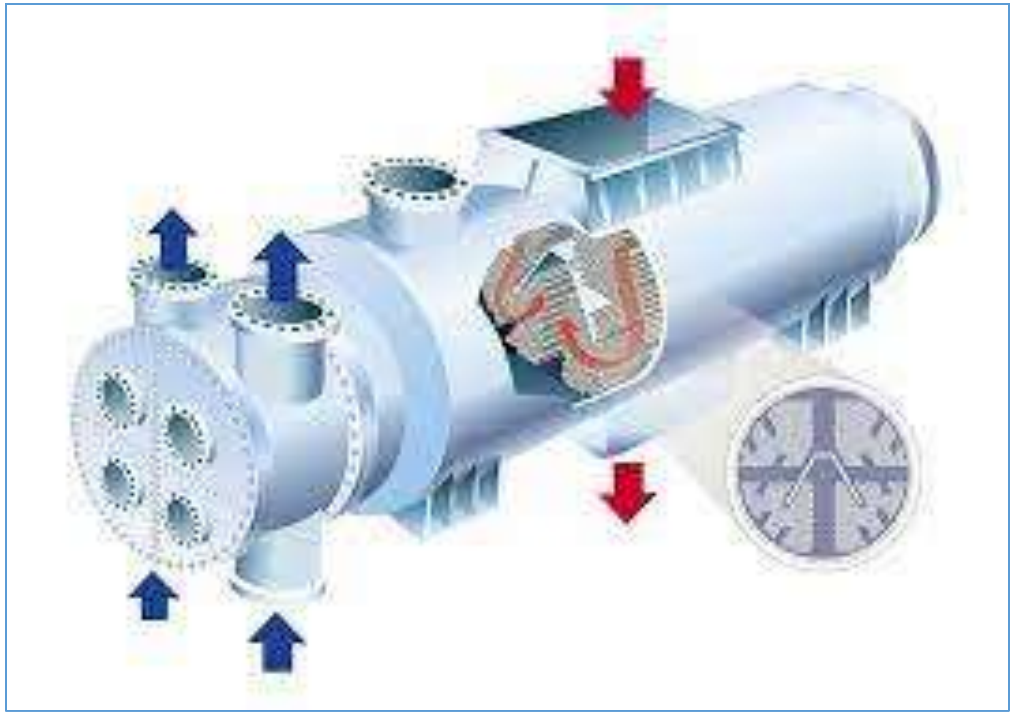
Ash handling unit ensures proper disposal and
management of ash generated during power generation

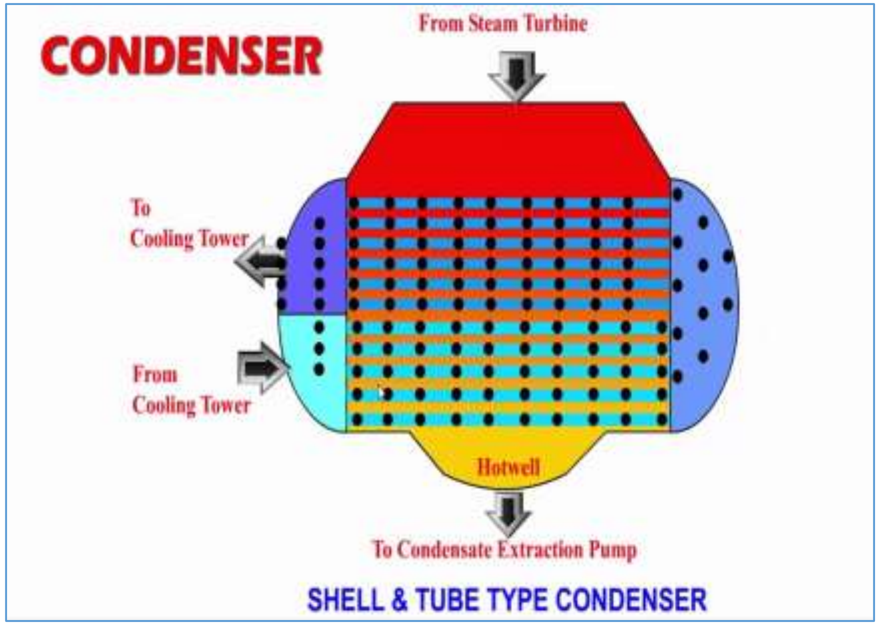
Condenser of Steam power plant



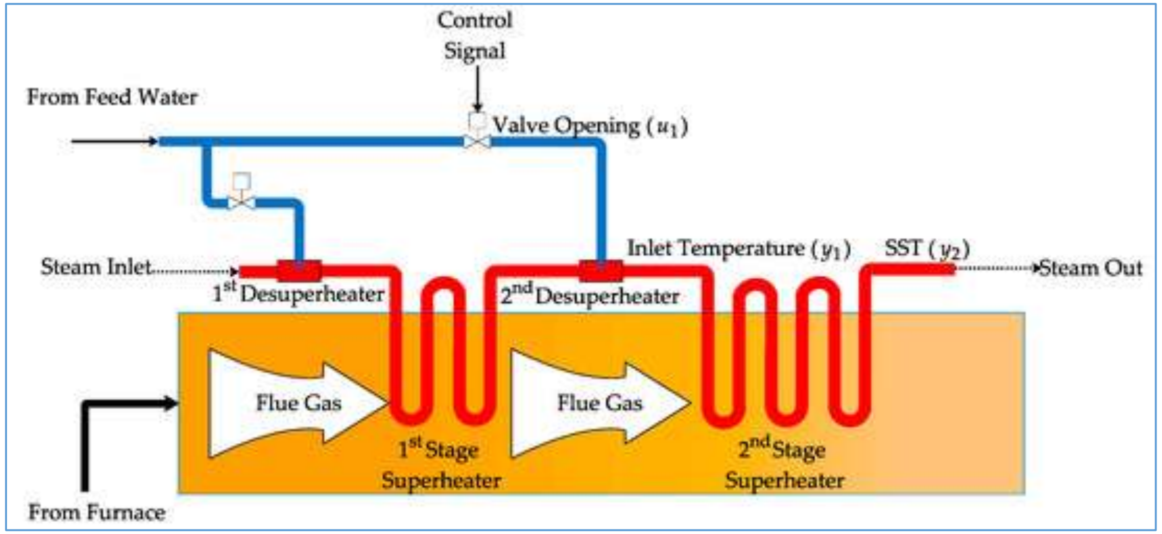
A **steam condenser** is a closed vessel designed to **condense low-pressure steam** into water. It serves as a heat exchanger, transferring heat from the steam to a cooling medium (usually water) while maintaining pressure below atmospheric levels.
The primary purpose of a steam condenser is to **increase the overall efficiency** of a steam power plant.

Condensers in steam power plant





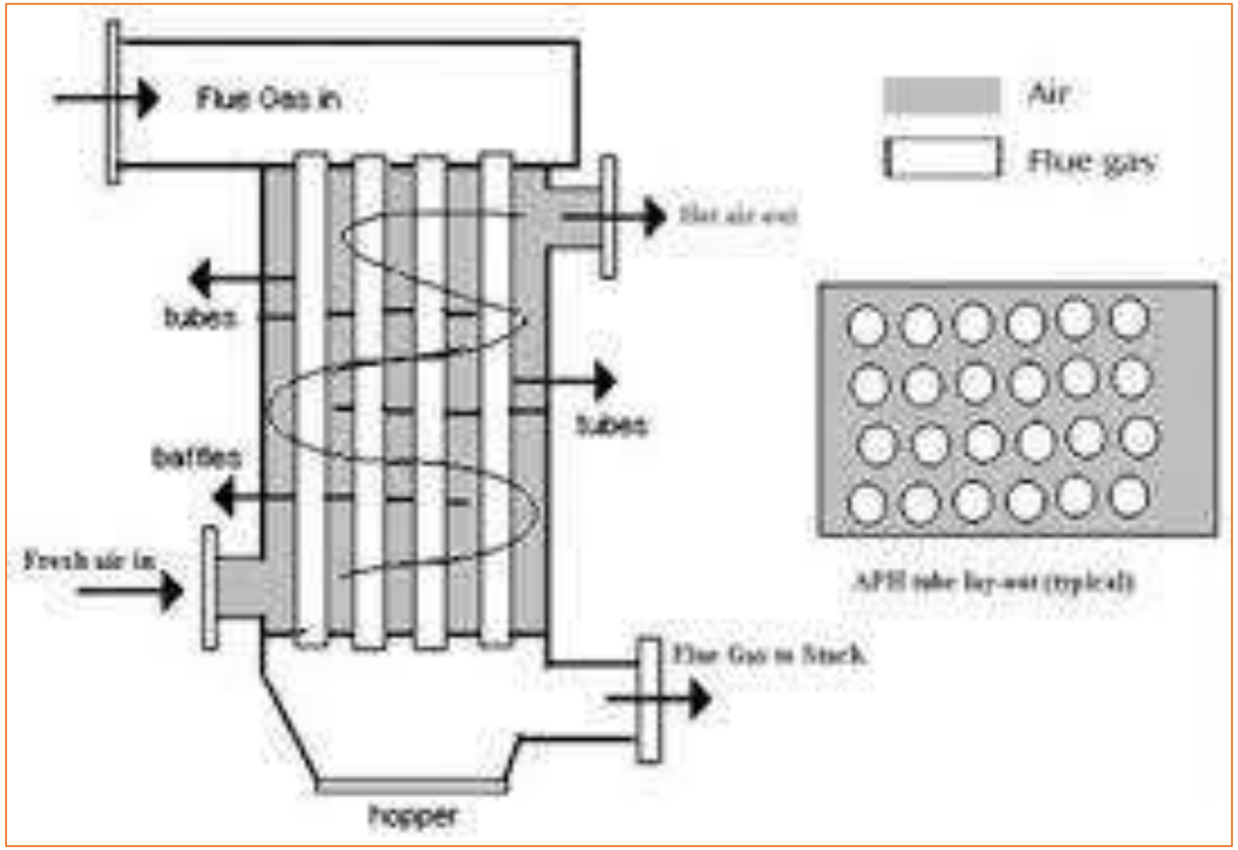
Superheater of steam power plant



A **superheater** is a device used to **convert saturated steam or wet steam into superheated steam or dry steam**.

Superheated steam has higher energy content and is essential for various applications, including electricity generation in steam turbines and industrial processes.

Air preheater in steam power plant



An **air preheater** is a heat exchanger designed to **increase the thermal efficiency** of a steam power plant.
It achieves this by recovering heat from the **boiler flue gas** (exhaust gases) and using it to preheat the combustion air before it enters the boiler

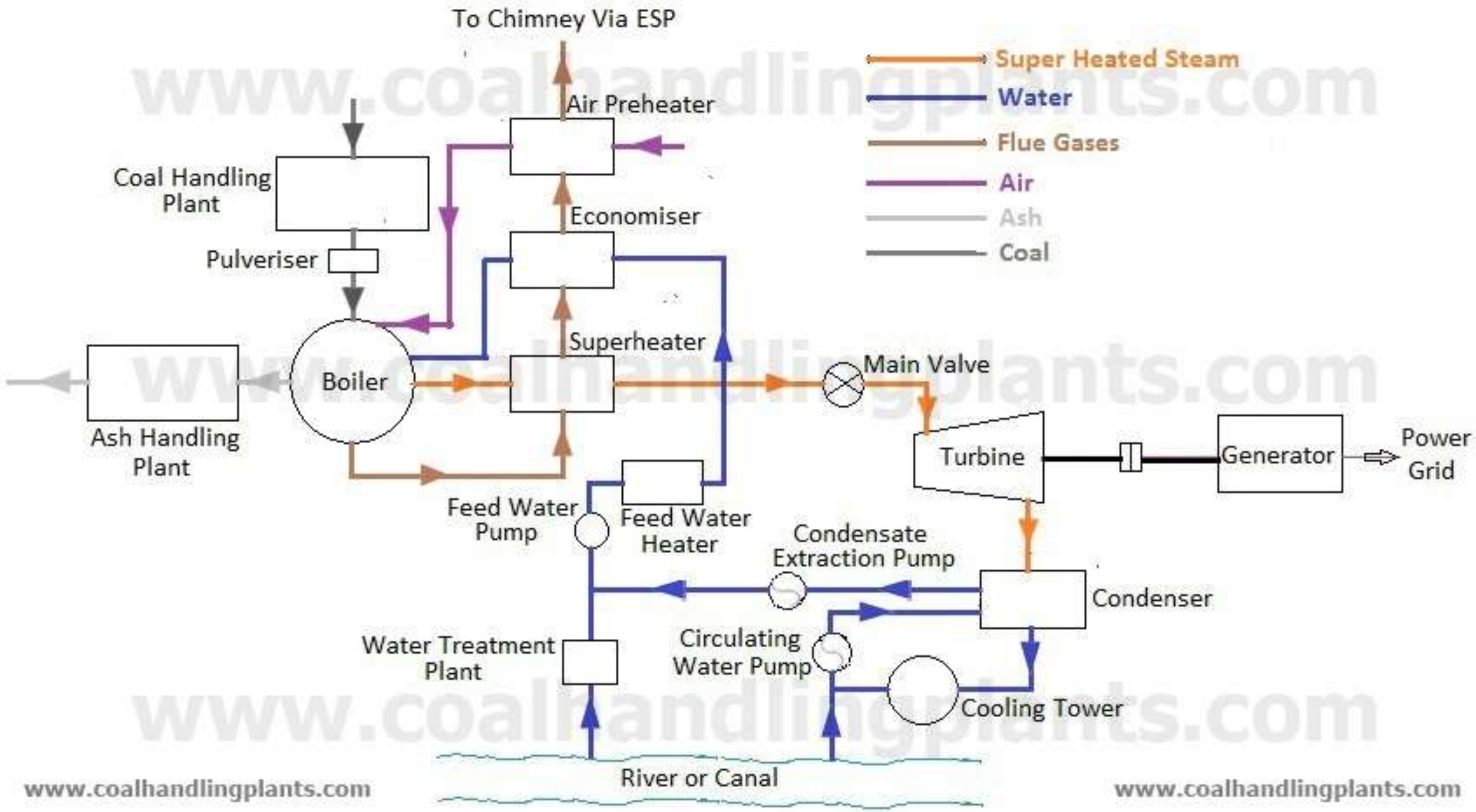
Coal Handling unit

Its primary function is to **receive, process, store, and feed coal** consistently over the entire life of the power plant.
Efficient coal handling ensures uninterrupted fuel supply to the boilers, which is essential for electricity generation.

Steam turbine with Alternator in Steam power plant

The combination of a steam turbine and an alternator is a fundamental component in power generation, ensuring efficient and reliable electricity production

Block diagram of steam power plant



Thermal Power plant

Thermal power plants are vital for meeting our energy demands, employing the combustion of fossil fuels like coal, natural gas, or oil to generate electricity efficiently. However, their operations have significant implications for both energy production and
the environment.

TPP Animation

https://www.youtube.com/watch?v=IdPTuwKEfmA

Thermal Or Steam Power Plant

Advantages:

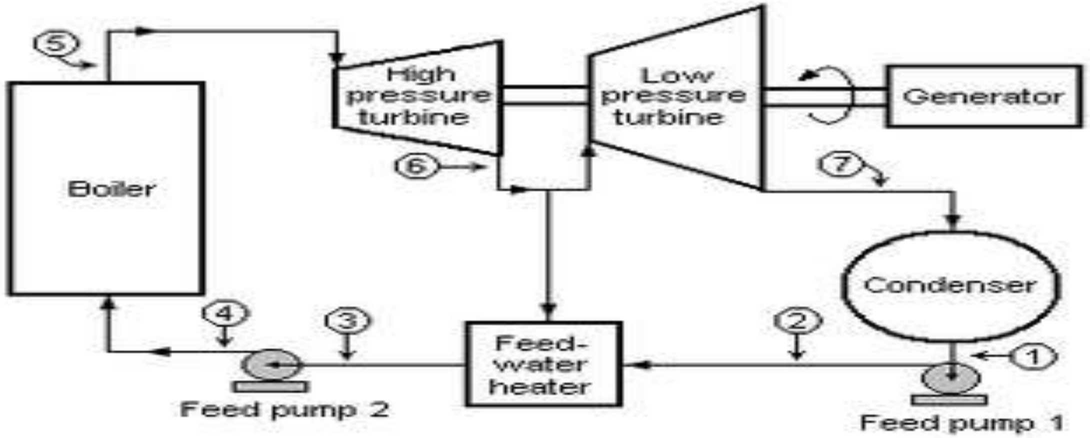
- Initial cost is low as compared to other generating station.
- Fuel used mainly coal is quite cheap.
- Required less space compared to hydro-electric plants.
- Generating cost per unit is less as compared to diesel power plants.
- Rapidly changing load without any difficulty.
- It can run more than 25% of over load capacity.

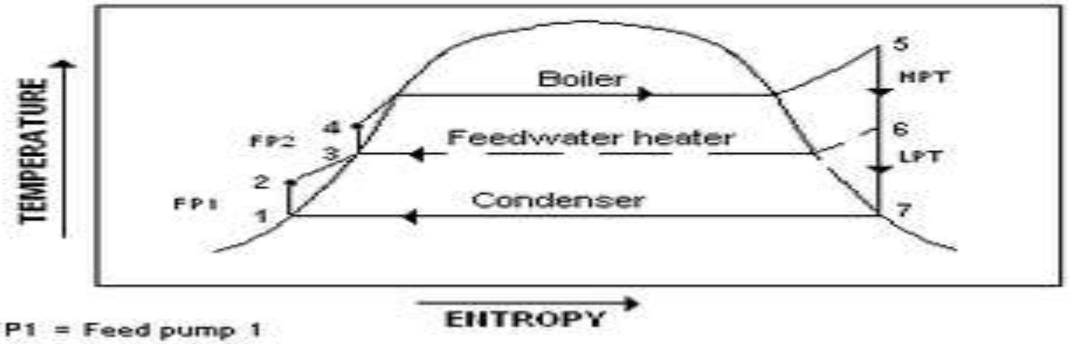
Disadvantages:

- Pollution is the main disadvantages of this type of plants.
- Running cost is more than hydro-electric power plant.
- Huge water is required.
- Operating cost is high as compared to nuclear and hydro-electric power plants.

TPP

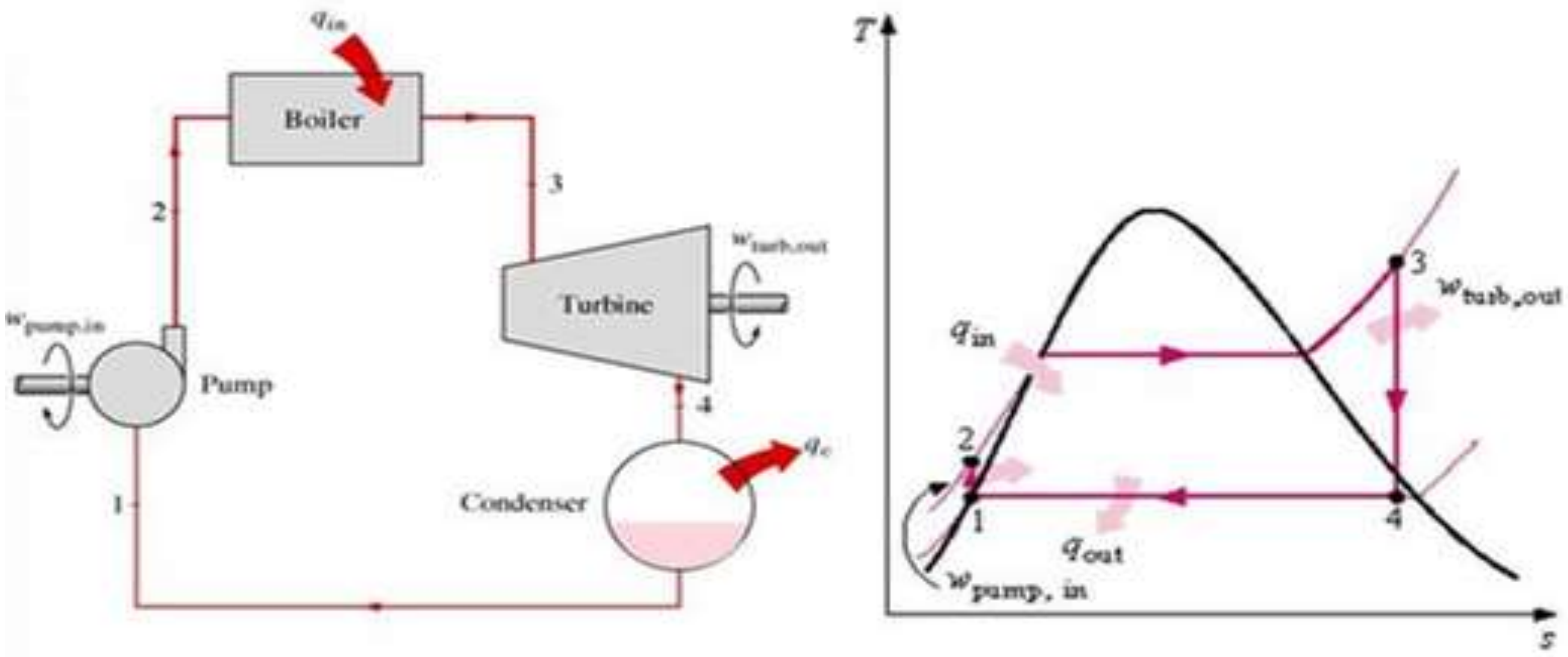
- A thermal power station is a power station in which heat energy is converted to **electricity**. Typically, fuel is used to boil water in a large pressure vessel to produce high-pressure steam, which drives a steam turbine connected to an electrical generator.





FP1 = Feed pump 1
FP2 = Feed pump 2
HPT = High pressure turbine
LPT = Low pressure turbine

The Simple Ideal Rankine Cycle



Energy conservation opportunities in thermal power plant

- Reduction of boiler steam pressure
- Waste heat recovery
- Control excess air in combustion chamber which leads to huge dry flue gas
- Control flue gas temperature. It is said that for every 22 degree rise in boiler temp leads to decrease in boiler efficiency by 1%.
- Optimize fuel moisture
- Maintain feed water temperature through economizer (15 deg rise in temp increases efficiency by 3%)
- Fix all boiler steam, flue gas and water leakages
- …

Efficiency of Thermal Power Station

- **Thermal Efficiency :** Thermal efficiency of modern thermal power stations is about 30%.

$$\text{Overall Efficiency} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat produced by coal combustion}}$$

- **Overall Efficiency :** The overall efficiency of a thermal plant is about 29% (slightly less than the thermal efficiency).

$$\text{Thermal Efficiency} = \frac{\text{Heat equivalent of mech. energy transmitted to the turbine shaft}}{\text{Heat produced by coal combustion}}$$

Overall Efficiency of steam Power plant ($\eta_{Power\ plant}$)

Lec-121

$$\eta_{overall} = \eta_{Power\ plant} = \eta_{boiler} \times \eta_{cycle} \times \eta_{turbine} \times \eta_{generator}$$

1. Boiler Efficiency, $\eta = \boxed{\dfrac{\text{Heat output}}{\text{Heat Input}} \times 100}$

$$= \boxed{\dfrac{\text{Heat in steam output (kCals)}}{\text{Heat in Fuel Input (kCals)}} \times 100}$$

2. Evaporation Ratio $= \boxed{\dfrac{\text{Quantity of Steam Generation}}{\text{Quantity of fuel Consumption}}}$

Performance of Ideal Rankine Cycle

Thermal Efficiency

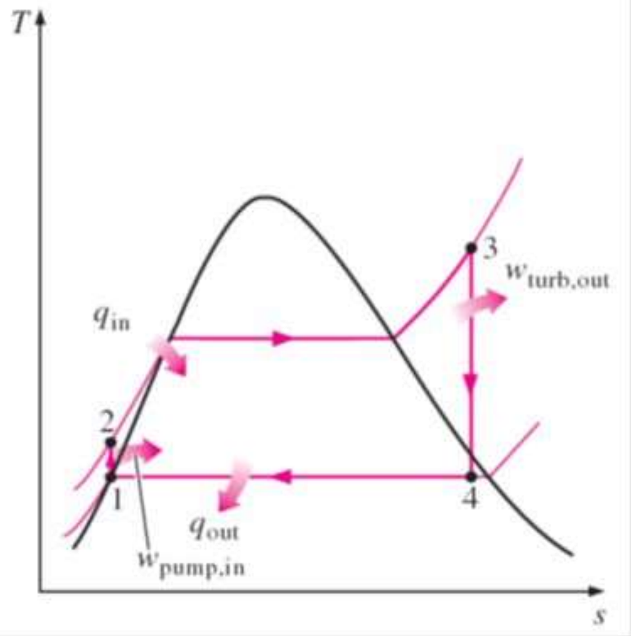
The thermal efficiency of the Rankine cycle is determined from,

$$\eta_{th} = \frac{w_{net}}{q_{in}} = 1 - \frac{q_{out}}{q_{in}}$$

where the **net work** output,

$$w_{net} = q_{in} - q_{out} = w_{turb,out} - w_{pump,in}$$

Note: +ve quantities only!



Thermal efficiency of Rankine cycle can also be interpreted as the ratio of the area enclosed by the cycle on a *T*-*s* diagram to the area under the heat-addition process.

Isentropic Turbine Efficiency:

$$\eta_T = \frac{Real\ Turbine\ Work}{Isentropic\ Turbine\ Work} = \frac{W_{real}}{W_s}$$

Isentropic Pump Efficiency:

$$\eta_C = \frac{Isentropic\ Pump\ Work}{Real\ Pump\ Work} = \frac{W_s}{W_{real}} =$$

$$\% \eta_g = \frac{\text{generator output}}{\text{generator output} + \text{generator losses}} \times 100$$

$$= \frac{\text{generator input} - \text{generator losses}}{\text{generator input}} \times 100$$

A thermal power plant of 100 MW capacity uses coal of 25 MJ/kg calorific value. If the thermal efficiency of the power plant is 40% and generator efficiency is 90%. What will be the approximate coal consumption per hr when the plant run at full load?

Consumption in a Thermal Plant:

- Overall efficiency = product of all given efficiencies.
- The heat produced / hour, H = (Units Generated per hour / overall efficiency)
- Coal Consumption / hour = (H / Calorific value)

$$\eta_{overall} = \eta_{thermal} \times \eta_{electrical}$$

Given:

Calorific Value = 25 MJ/kg

Capacity of plant or heat generated = 100 MW

Thermal efficiency = 40%

Electrical efficiency = 90%

$\eta_{overall} = 0.40 \times 0.90 = 0.36$

Units Generated / Hour = 100 × 3600 MWh

Therefore, $H = \frac{100 \times 3600}{0.36}$

Coal consumption / Hour = (H / Calorific Value)

Coal consumption / Hour = $\frac{100 \times 3600}{0.36 \times 25} = 40000\ Kg/hr$

coal consumption per hr when the plant run at full load = 40 tons/hr