ENGINEERING PLANT TECHNOLOGY

STEAM POWER PLANT (CHAPTER 1)

Leanna binti Mohd Yunos
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STEAM POWER PLANT

CHAPTER 1

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ENGINEERING PLANT TECHNOLOGY

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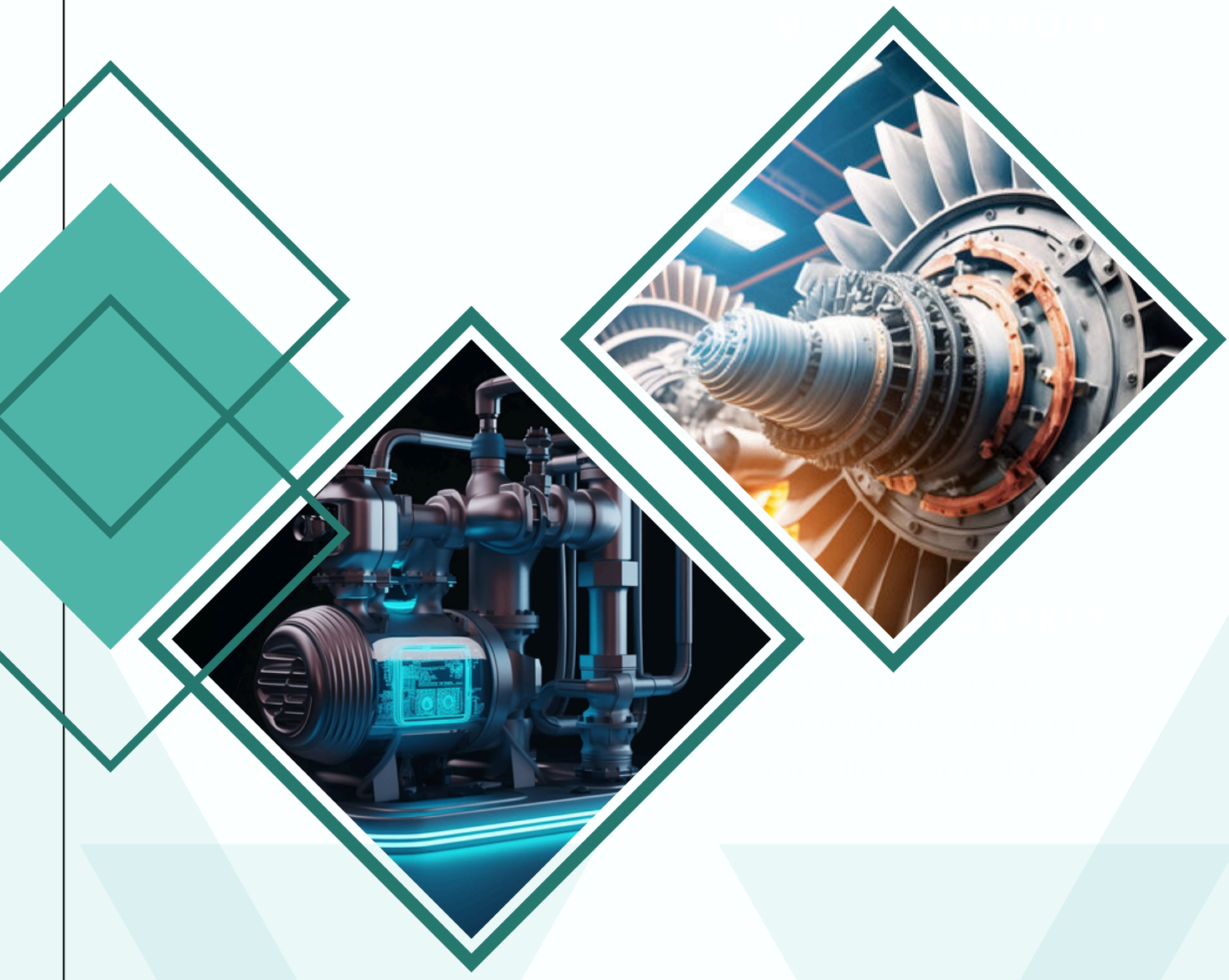
SYNOPSIS

ENGINEERING PLANT TECHNOLOGY introduces power plant technology industry such as steam power plant, gas turbine power plant, diesel power plant, compressed air plant and water pump.

- Editor



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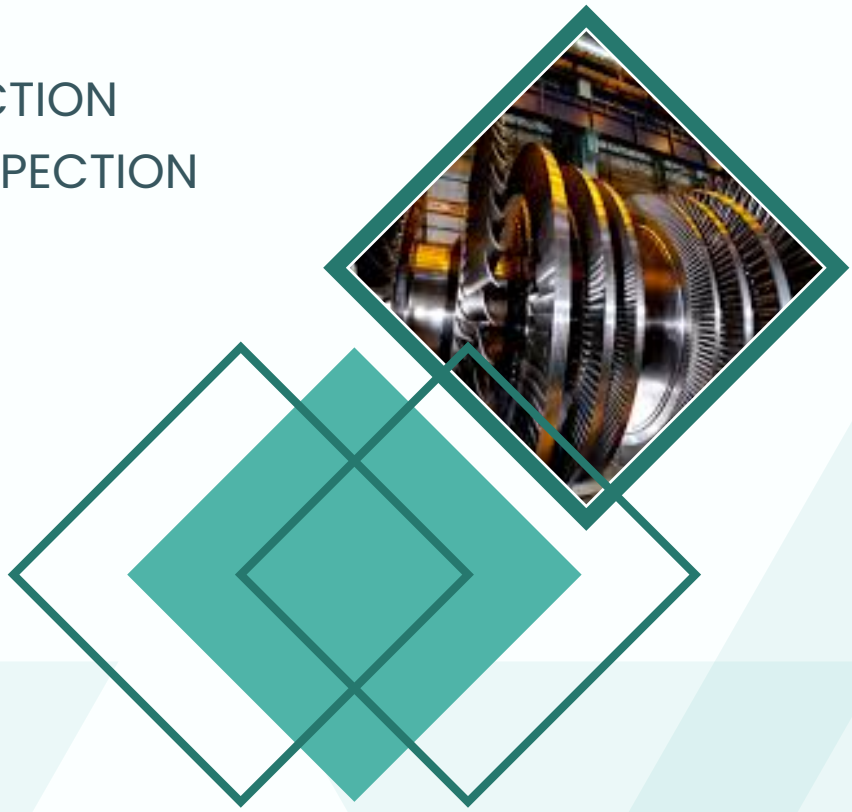
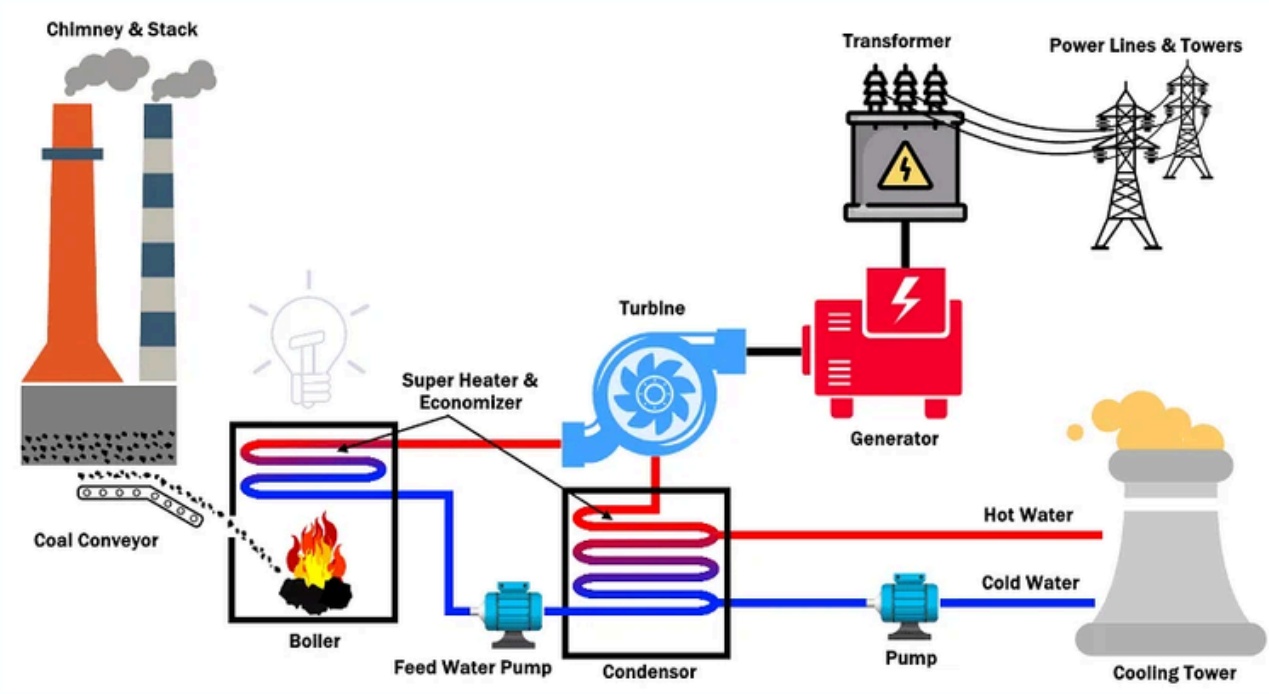


INTRODUCTION

A steam power plant is a facility that generates electricity by using steam to drive turbines. Water is heated to produce steam, which then rotates turbines connected to generators, producing electricity. These plants are commonly used for large-scale power generation due to their efficiency and reliability.



THE PURPOSE OF STEAM GENERATED

Power

- Steam engines, steam turbine, steam pumps

Drying

- Bleaching, palm kernel, ironing, curing concrete

Sterilizing

- Operation theatre equipment, palm oil

Heating

- Buildings, bulk storage

Cooking

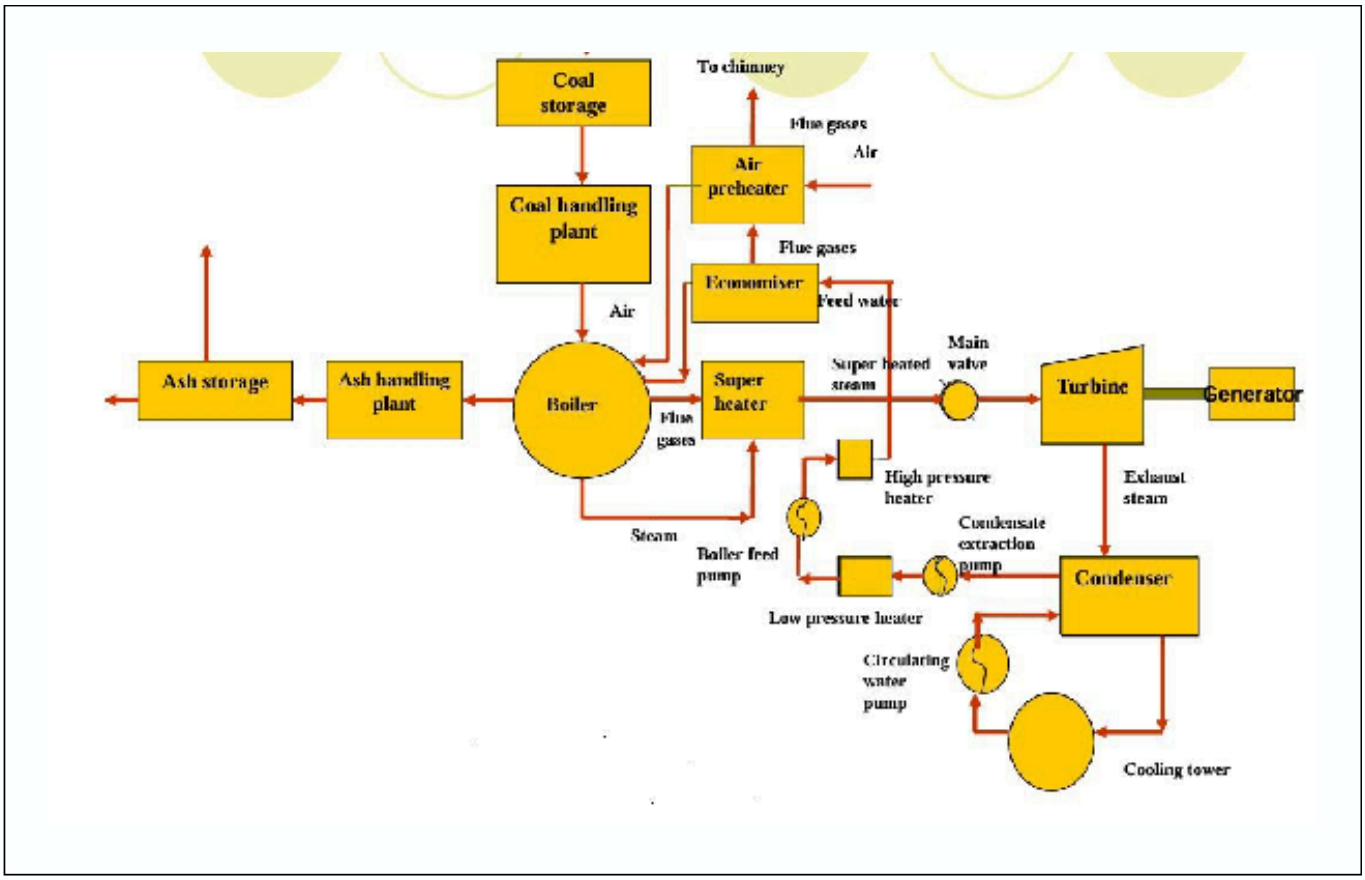
- Pressure cooking, steam jackets

PURPOSES OF STEAM POWER PLANT

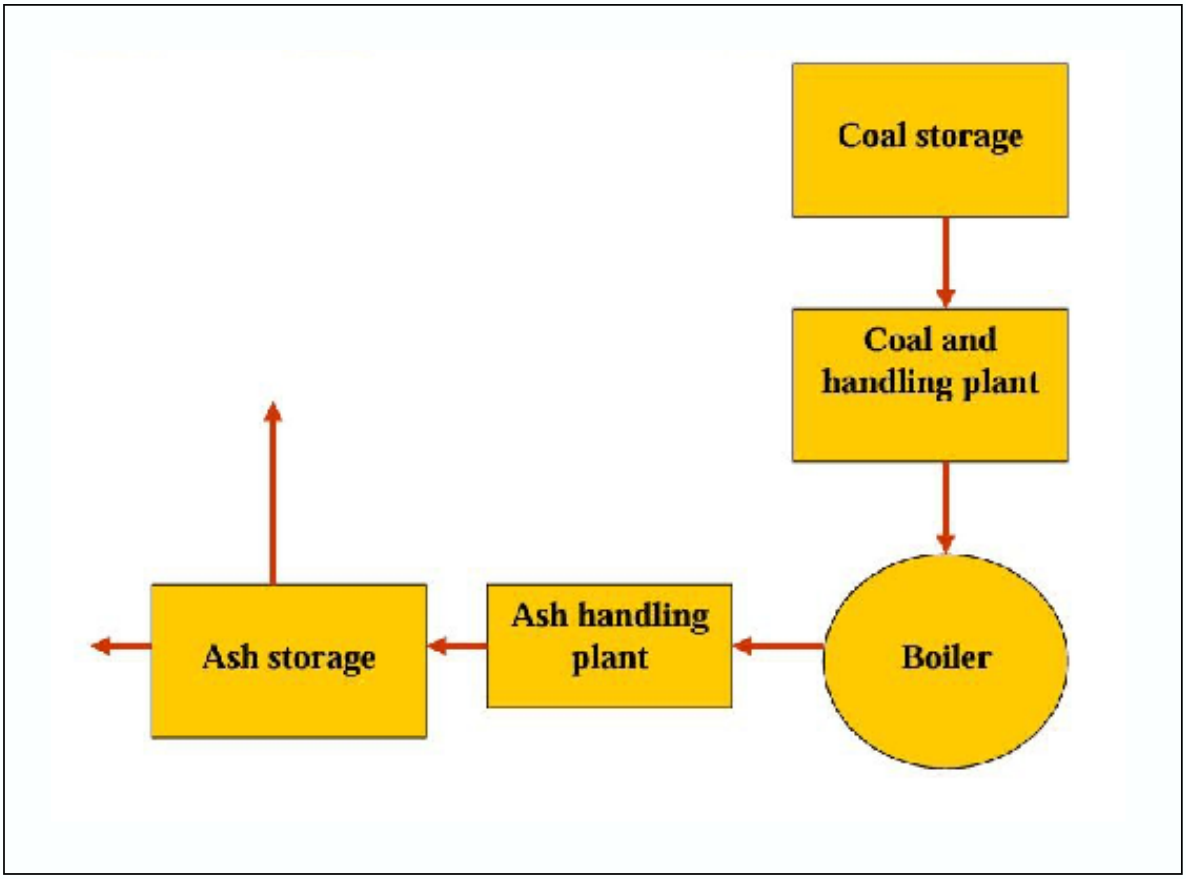
TO PRODUCE ELECTRIC POWER

TO PRODUCE STEAM FOR INDUSTRIAL PURPOSES (TEXTILES, PAPER MILLS, SUGAR MILLS, ETC.)

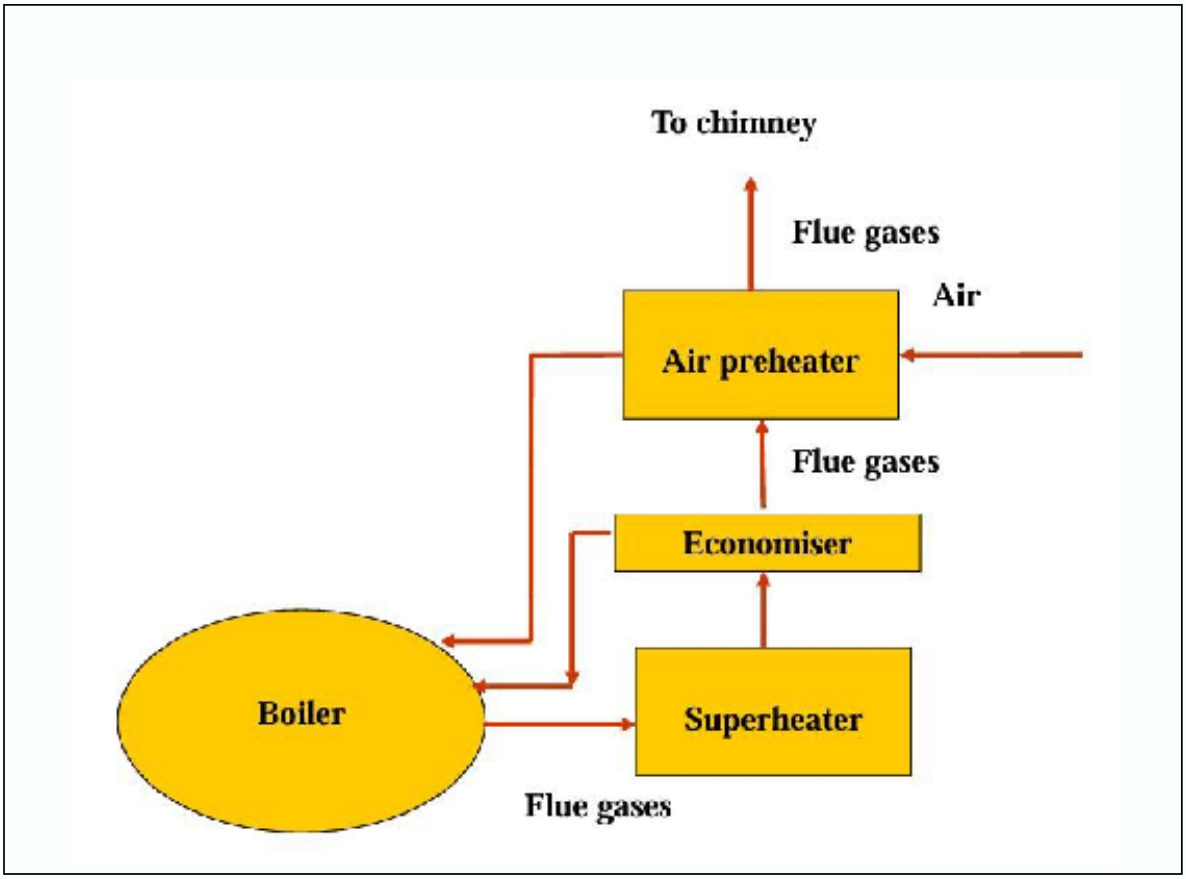
LAYOUT OF STEAM POWER PLANT

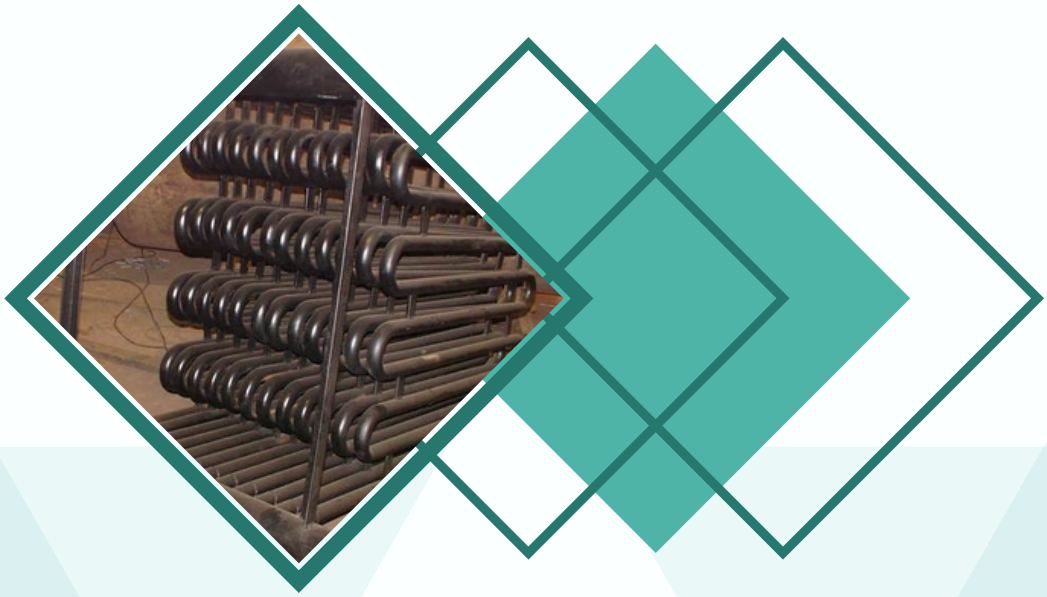


COAL AND ASH CIRCUIT

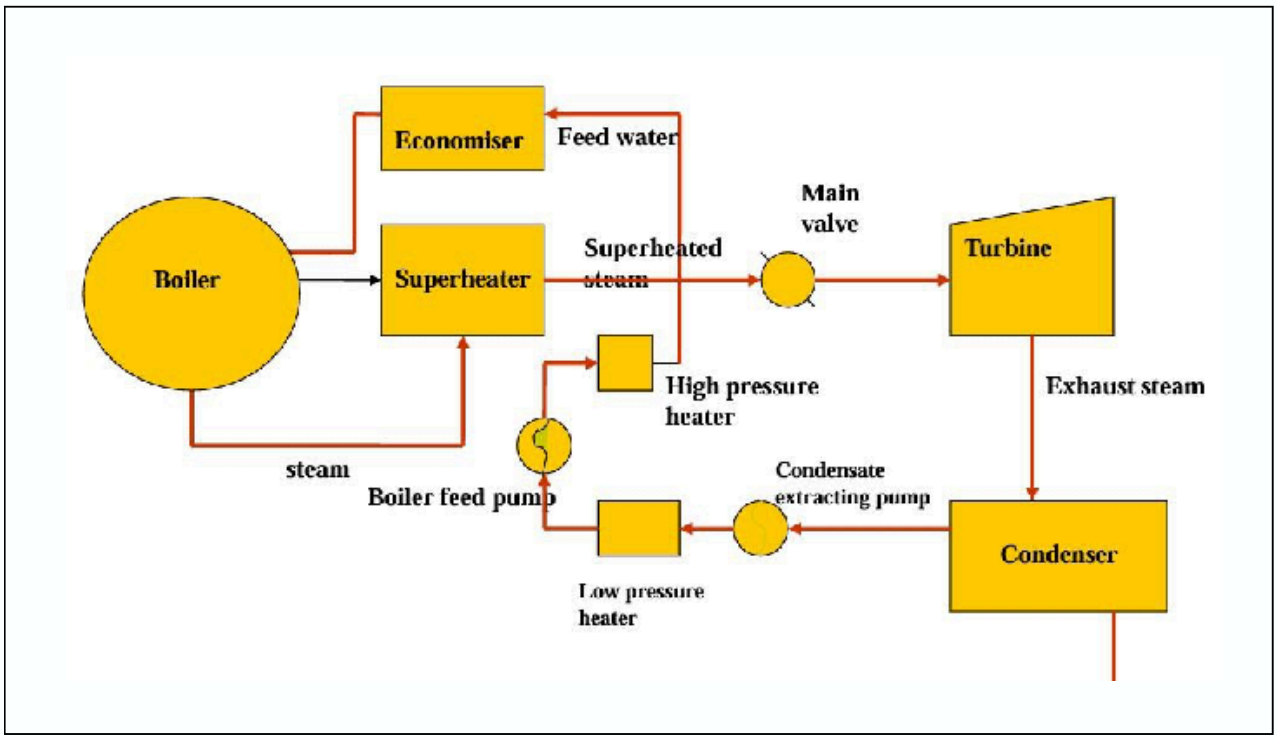


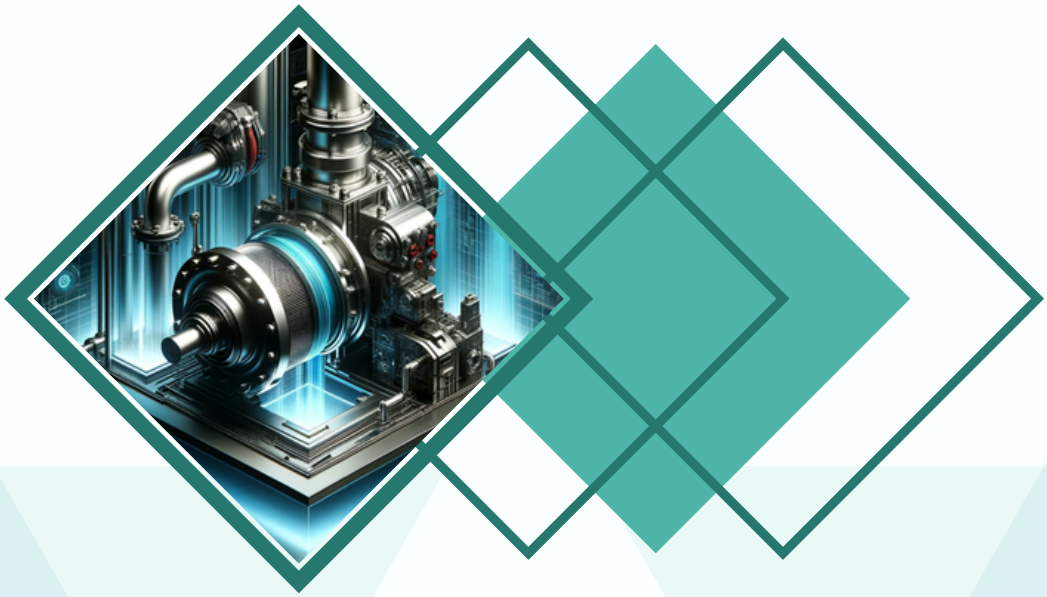
ASH AND GAS CIRCUIT



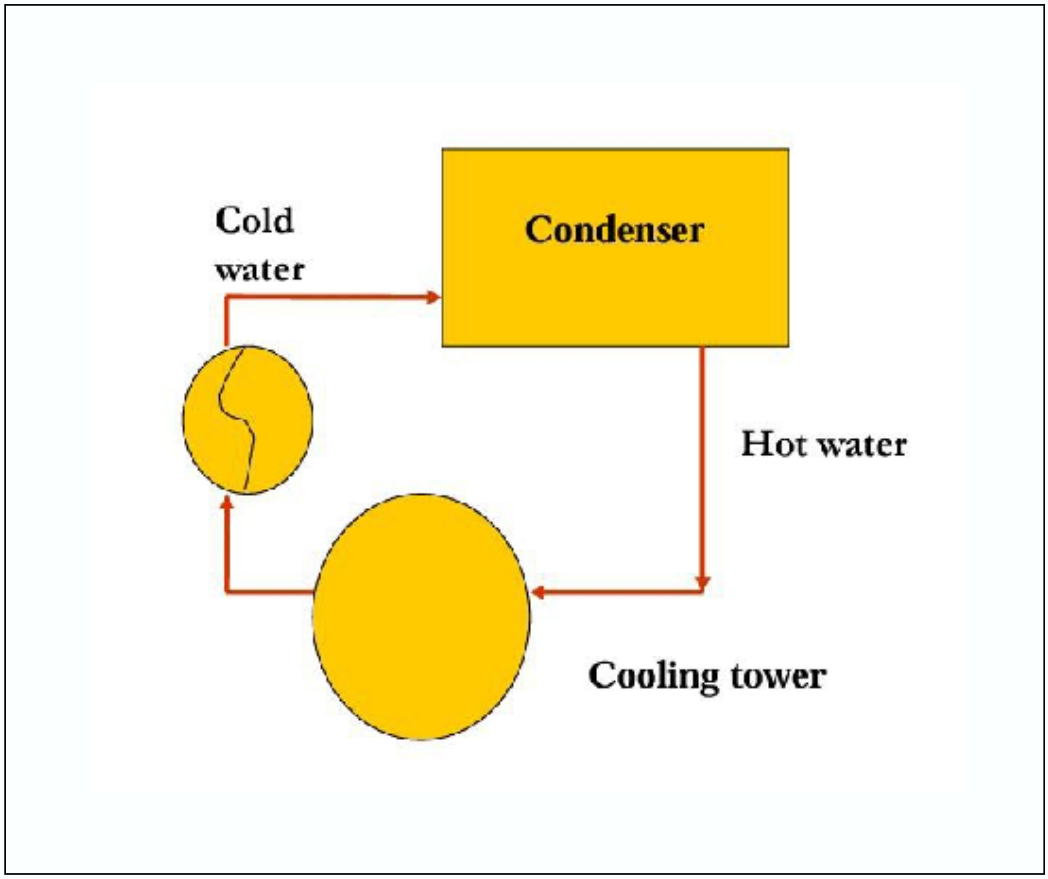


FEED WATER AND STEAM FLOW CIRCUIT



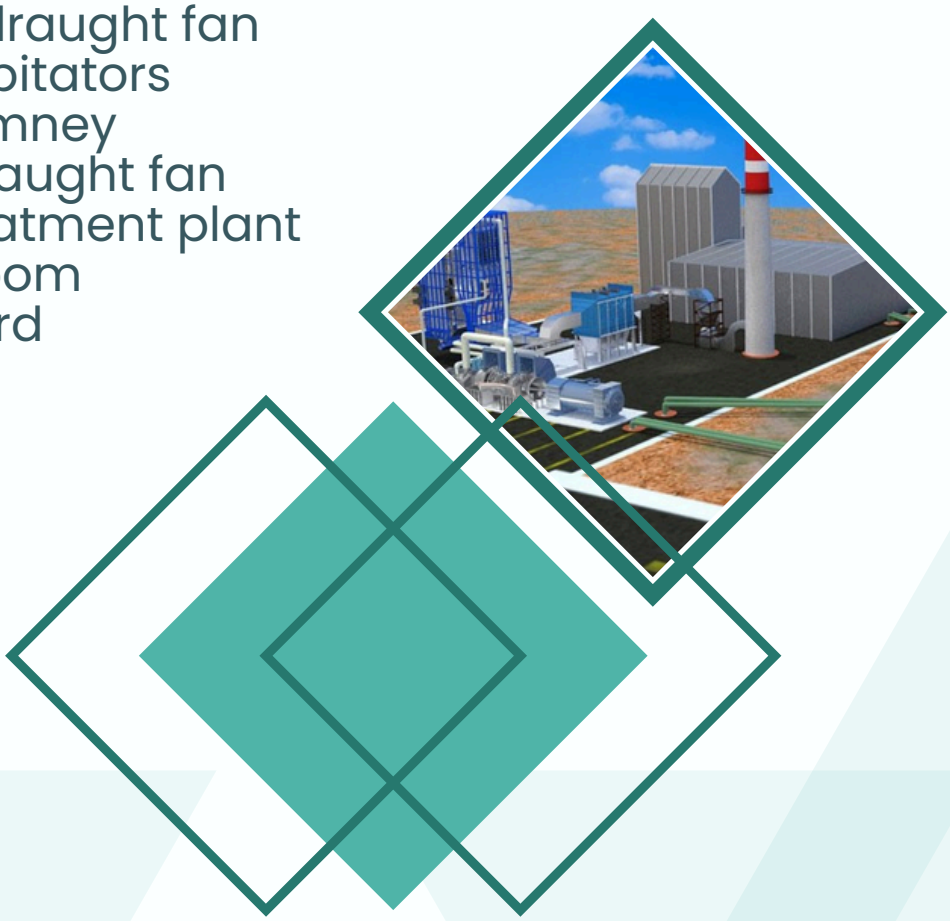


COOLING WATER CIRCUIT

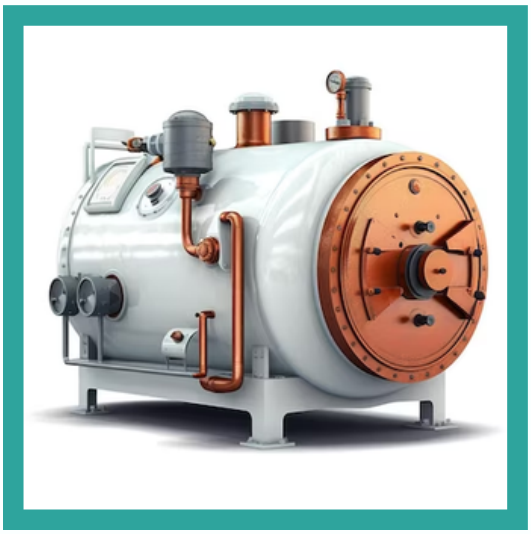


COMPONENTS OF STEAM POWER PLANT

- Boiler
- Steam turbine
- Generator
- Condenser
- Cooling tower
- Circulating water pump
- Boiler feed water pump
- Wagon tippler
- Crusher house
- Coal mill
- Induced draught fan
- Ash precipitators
- Boiler chimney
- Forced draught fan
- Water treatment plant
- Control room
- Switch yard



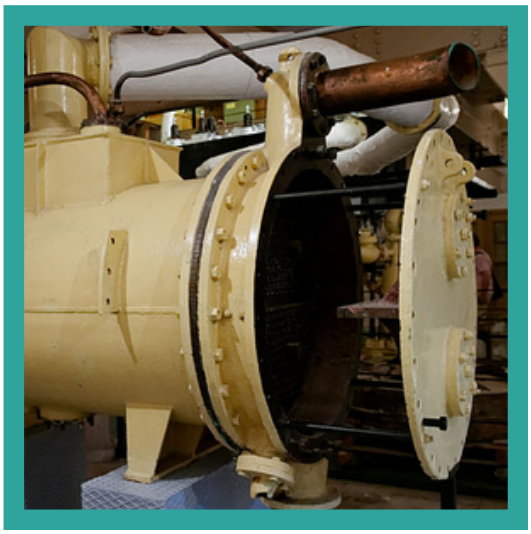
Boiler



Steam turbine

Boiler chimney

Generator



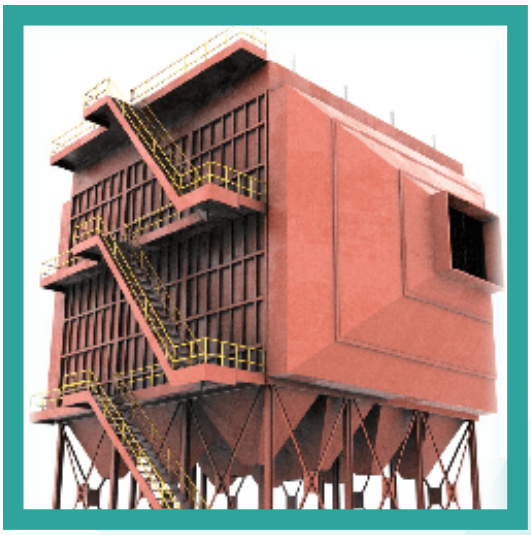
Condensor

Cooling tower

Water pump

Coal mill

Ash precipitators



Crusher house

Water treatment plant

Control room

Wagon tippler

Induced draught fan

Switch yard

STEAM TURBINE

A steam turbine is like a giant wheel that spins when steam blows on it. Steam is created by boiling water, and when it's directed onto the turbine's blades, it pushes them, causing the whole turbine to rotate. This spinning motion is used to generate electricity in power plants or to drive machinery in factories. Steam turbines are important because they efficiently convert heat energy from steam into mechanical energy, which can then be used for various purposes.

Impulse Turbine

Definition :

A pure impulse turbine is a type of steam turbine that operates based on the principle of impulse reaction. In an impulse turbine, the steam's kinetic energy is converted into mechanical energy as it impacts turbine blades

Function of the Steam Impluse Turbine :

To efficiently harness the kinetic energy of the steam jet to produce mechanical work, whether it's generating electricity or powering machinery. These turbines are commonly used in applications where high-pressure steam is available, offering a reliable and efficient means of converting thermal energy into useful work.

CHARACTERISTICS

Nozzle Arrangement :

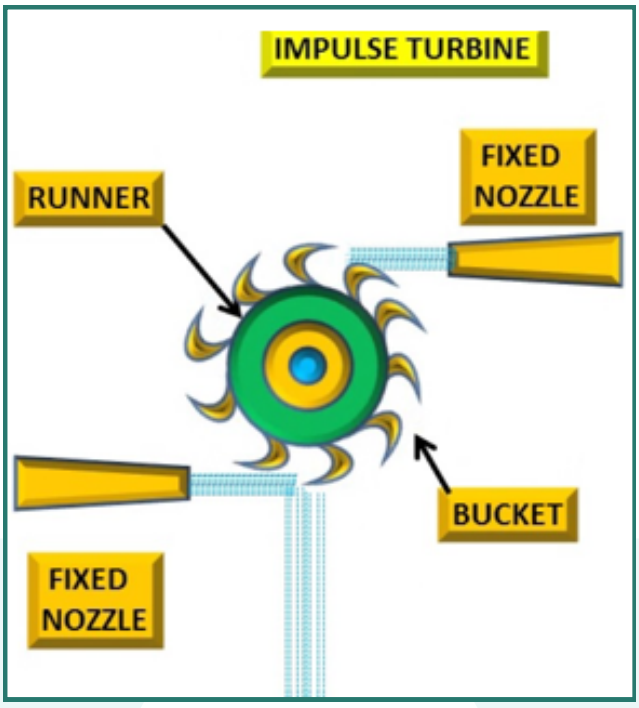
- Steam enters the turbine through a set of nozzles which direct high-pressure steam jets onto the turbine blades. These nozzles are arranged in a manner to efficiently direct the steam onto the blades.

Blade Design :

- The turbine blades in an impulse turbine are designed to efficiently capture the kinetic energy of the steam jet. They typically have a symmetrical airfoil shape to ensure that the steam flow does not separate from the blade surface, maximizing energy transfer.

Simple Construction :

- Compared to reaction turbines, impulse turbines often have simpler construction because they don't involve complex blade profiles or multiple stages.



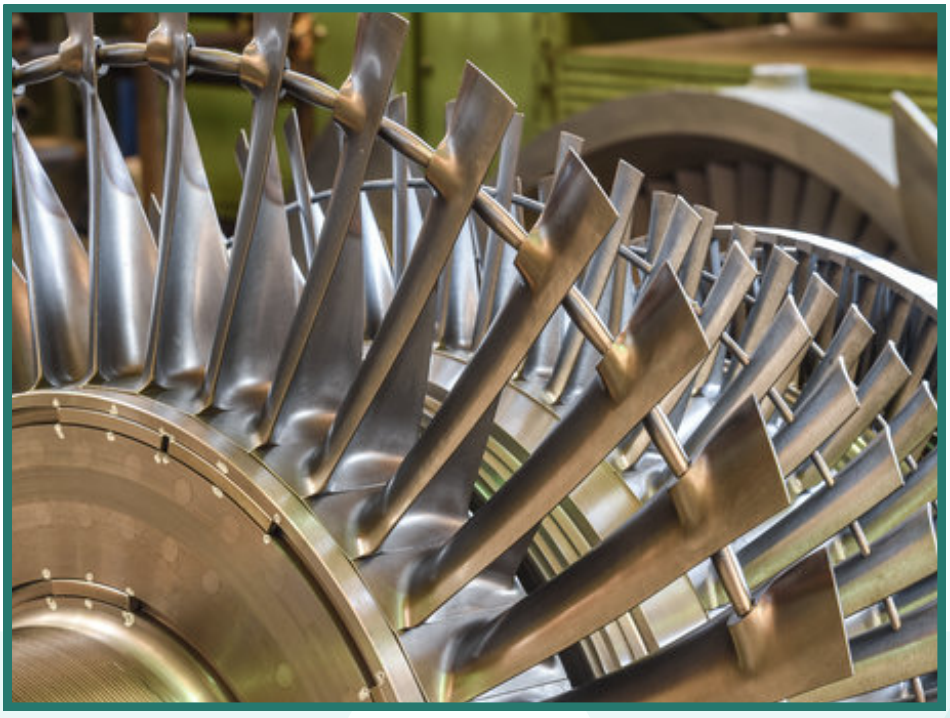
Reaction Turbine

Definition :

A reaction turbine is a type of steam turbine that operates on the principle of both impulse and reaction. Unlike pure impulse turbines, which rely solely on the impact of high-velocity steam jets on turbine blades, reaction turbines utilize a combination of steam expansion and reaction with the turbine blades to generate mechanical energy.

Function of the Steam Reaction Turbine :

To convert the kinetic energy of a fluid (such as steam, water, or gas) into mechanical energy, typically to generate electricity or to perform mechanical work



CHARACTERISTICS

Steam Inlet :

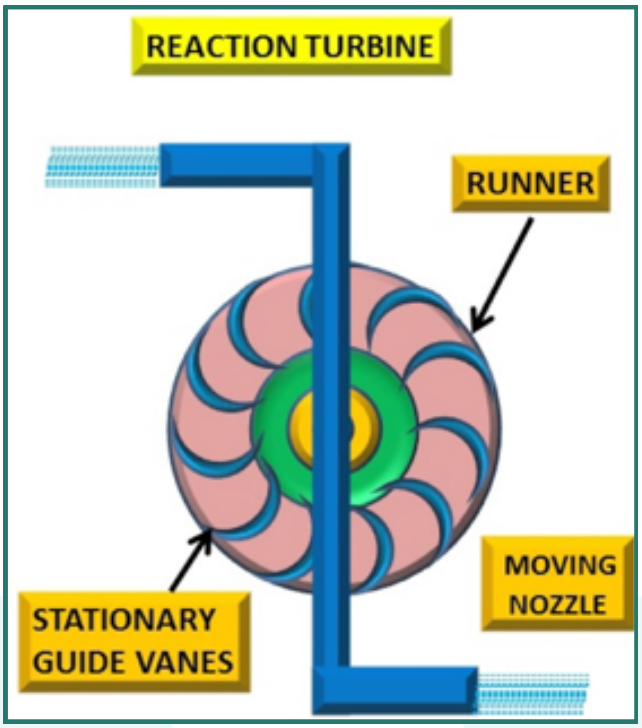
- High-pressure steam enters the turbine casing and flows through a series of fixed blades called stator blades or nozzles.

Blade Design :

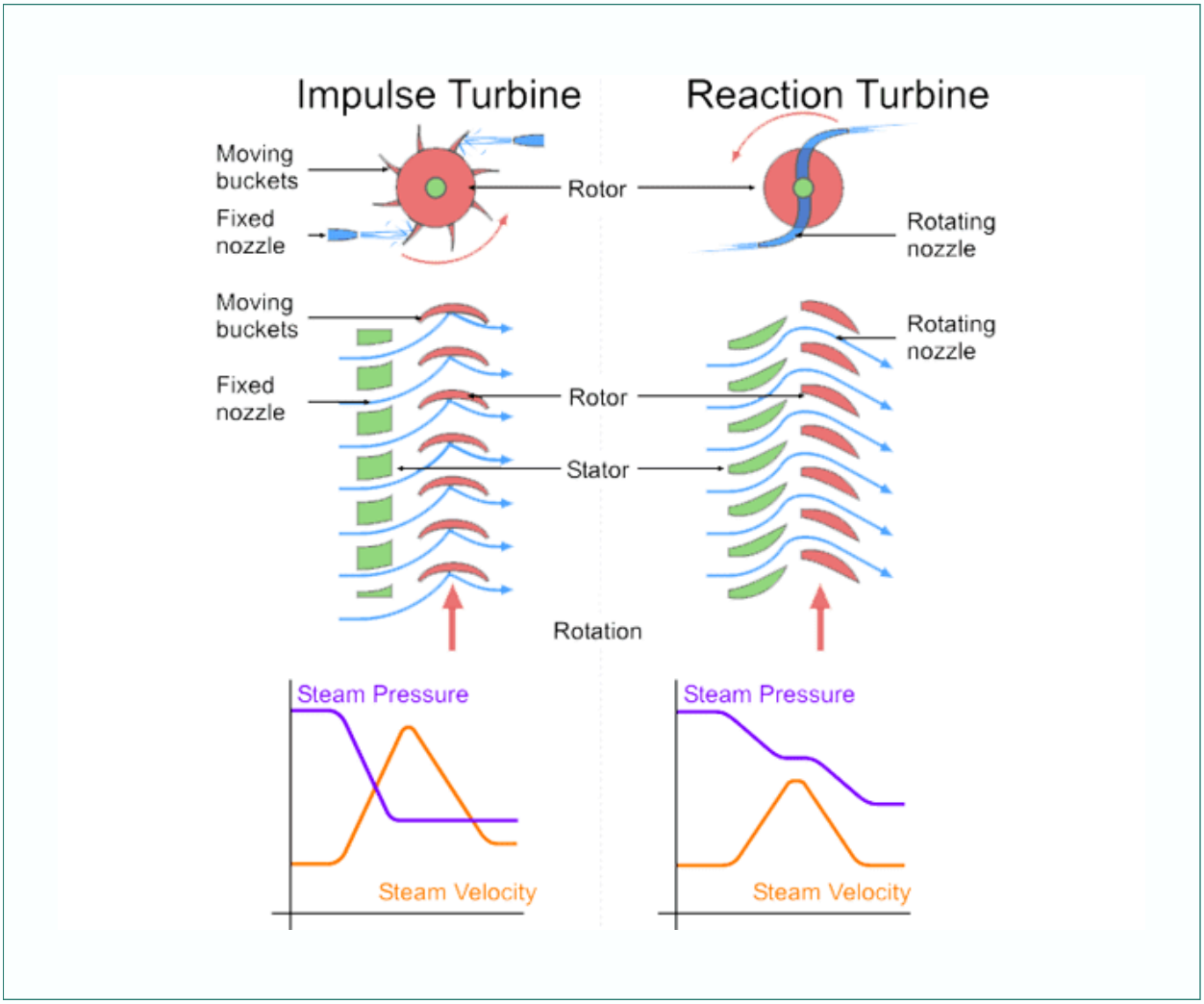
- The turbine rotor, also known as the runner, contains a series of curved blades. These blades are designed to efficiently capture the energy from the high-velocity steam flow

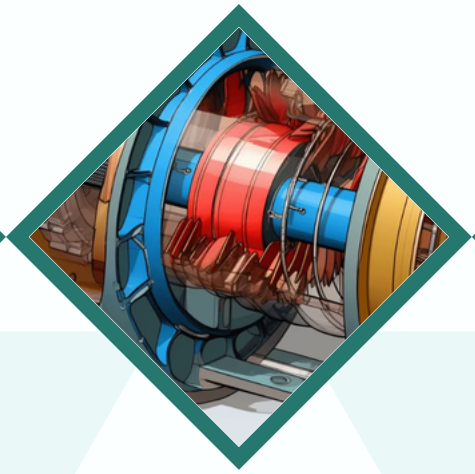
Continuous Energy Conversion :

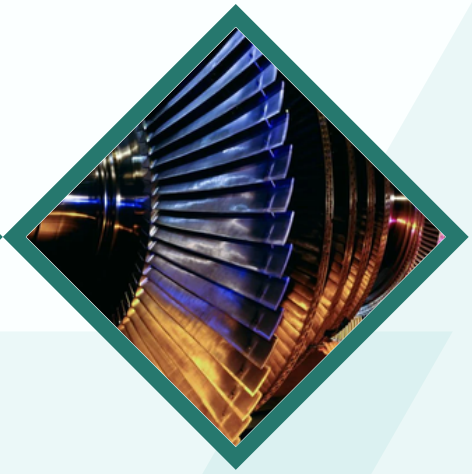
- Unlike impulse turbines, where energy conversion occurs primarily due to the impact of high-velocity jets, reaction turbines rely on both steam expansion and reaction with the blades for energy conversion.



IMPLUSE VS REACTION



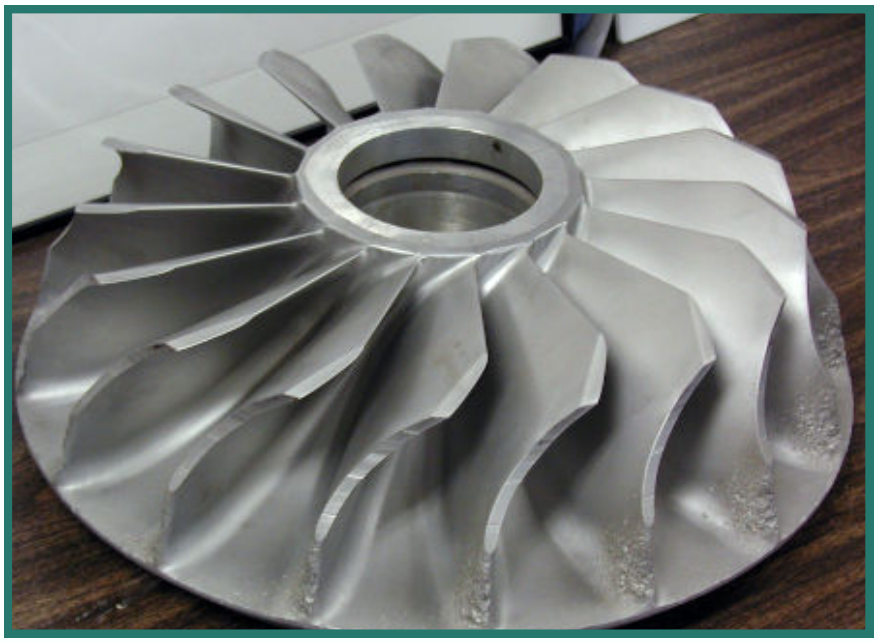




Combination of Impulse – Reaction Turbine

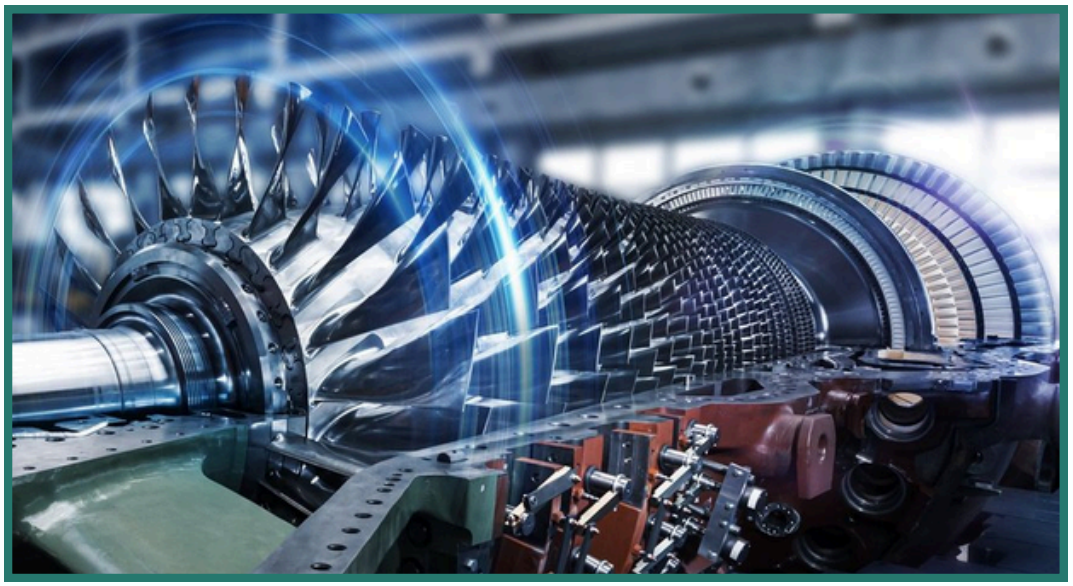
Definition :

The combination of impulse-reaction turbine, also known as a compound turbine, integrates features of both impulse and reaction designs within a single turbine unit. This combination is achieved by arranging the turbine stages in a manner that optimizes energy extraction from the steam flow.



IMPULSE STAGE

In the impulse stage, high-pressure fluid (such as steam or water) is directed through a nozzle, which converts the pressure energy into kinetic energy. The high-velocity jet of fluid then impacts the blades of the turbine, causing it to rotate. Impulse turbines typically have buckets or blades on a rotor, and the kinetic energy of the fluid jet causes the rotor to turn.



REACTION STAGE

The remaining pressure energy of the fluid is converted into additional kinetic energy by the shape and arrangement of the turbine blades. The fluid's pressure decreases as it moves through the reaction stage, and the rotor continues to extract energy from it. Reaction turbines typically have curved blades that accelerate the fluid as it flows over them, producing both lift and rotation.

Application of Steam Turbine

Powering Machinery and Equipment :

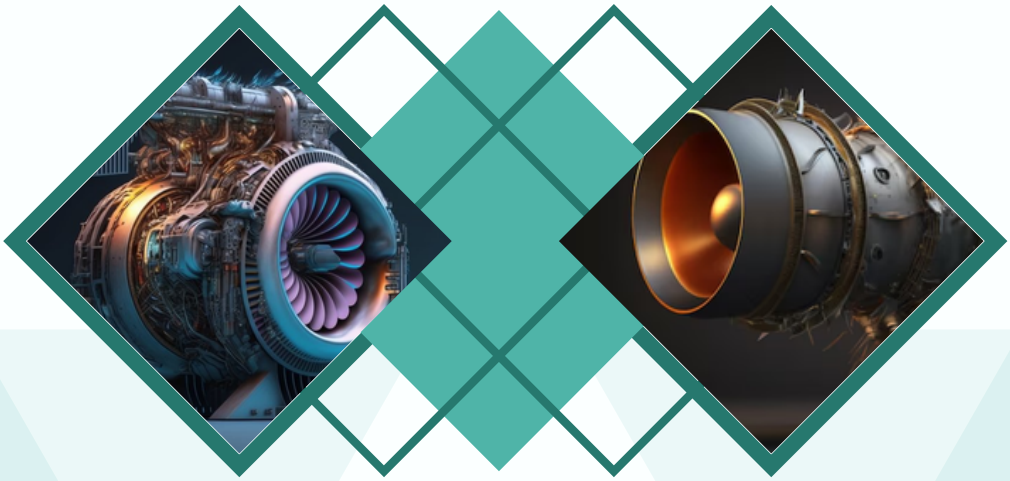
Steam turbines are used to provide mechanical power to drive machinery and equipment. For example, steam turbines can power pumps, compressors, fans, and generators in manufacturing plants.

Process Heating and Drying :

Steam turbines are employed to generate steam at high pressure and temperature, which is then used directly for process heating or to drive steam-powered equipment such as heat exchangers, dryers, and sterilizers.

Power Generation :

Steam turbines are widely used in industrial power plants to generate electricity. The steam drives the turbine blades, which are connected to a generator, converting the rotational motion into electrical energy.



BOILER

Definition :

Closed vessel in which steam is produced from water by combustion of fuel.

Function of the Steam Boiler :

- Generate steam.
- Supply steam at required pressure and quality.

Classification of Boiler

Axis :

- Horizontal boiler can be inspected easily, but it occupies more space.
- The vertical boiler occupies less area.

Relative position of water and hot gases :

- ***Fire tube*** - hot gases inside the tubes, water surrounds the tubes.
- ***Water tube*** - the water inside the tubes and gases surround them.

Method of furnace :

- Externally fired
  - the furnace placed outside the boiler shell.
  - example: water tube boiler
- Internally fired
  - the furnace located inside the boiler shell.
  - example: fire tube boiler

Method of water circulation :

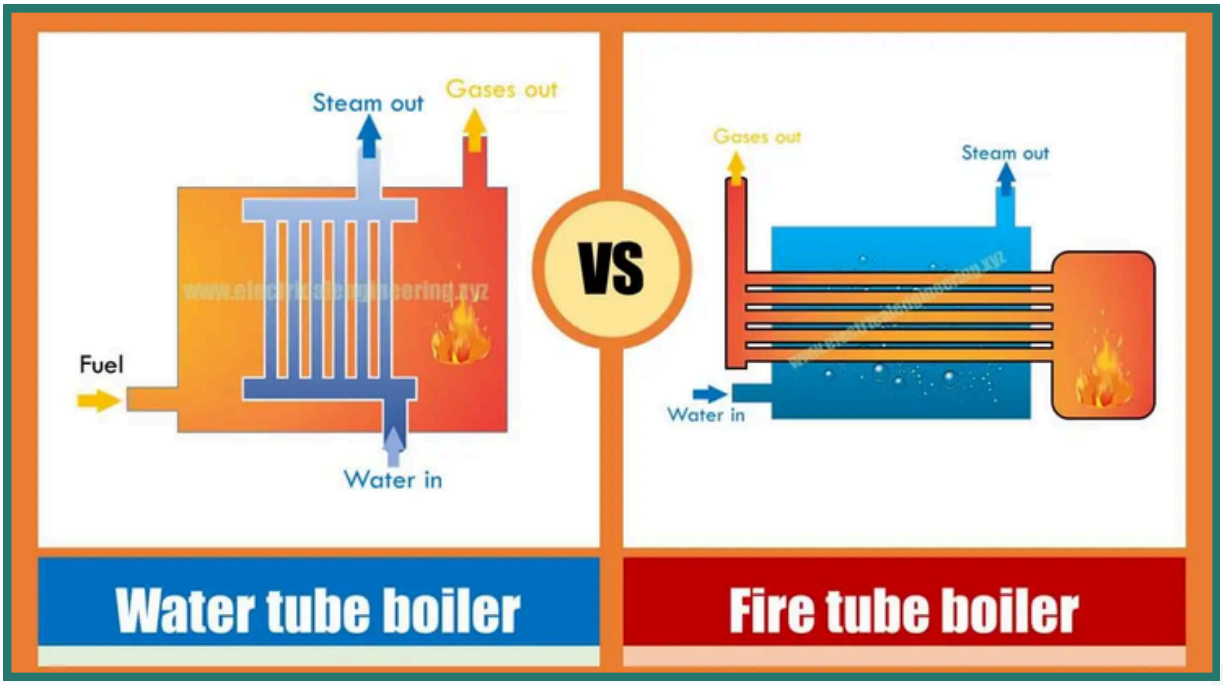
- Forced circulation
  - the circulation water is done by a forced pump.
  - suitable for high pressure and high capacity boiler.
- Natural circulation
  - the circulation of water is due to natural convection current.
  - for low capacity boiler

Pressure :

- High pressure
  - produced steam at 80bar or above.
- Low pressure
  - produced steam below 80bar.

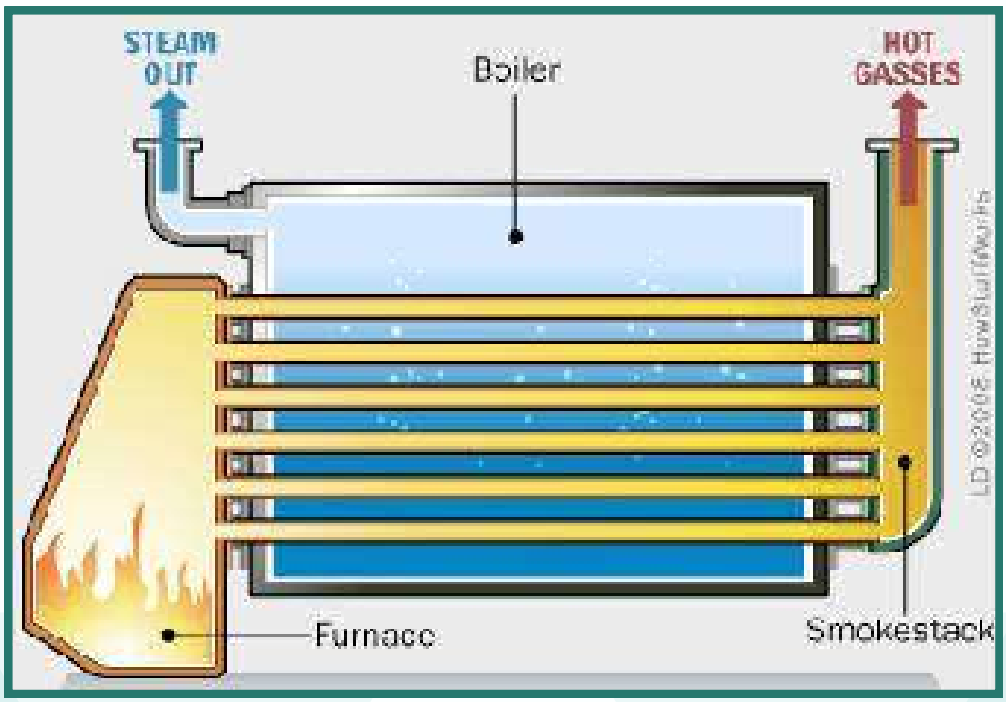
Purpose :

- Stationary boiler (land)
  - used for power plant steam, for central station utility or for plant process steam.
- Mobile boiler (portable)
  - small units boiler for temporary use.



Advantages of Fire Tube Boiler

- Fire tube boilers are easy to install and maintain due to their simple design and fewer components, facilitating straightforward troubleshooting and repairs.
- Fire tube boilers are compact, occupying less space, ideal for limited installations.
- Fire tube boilers produce steam quickly due to their small water content and efficient heat transfer from combustion gases.

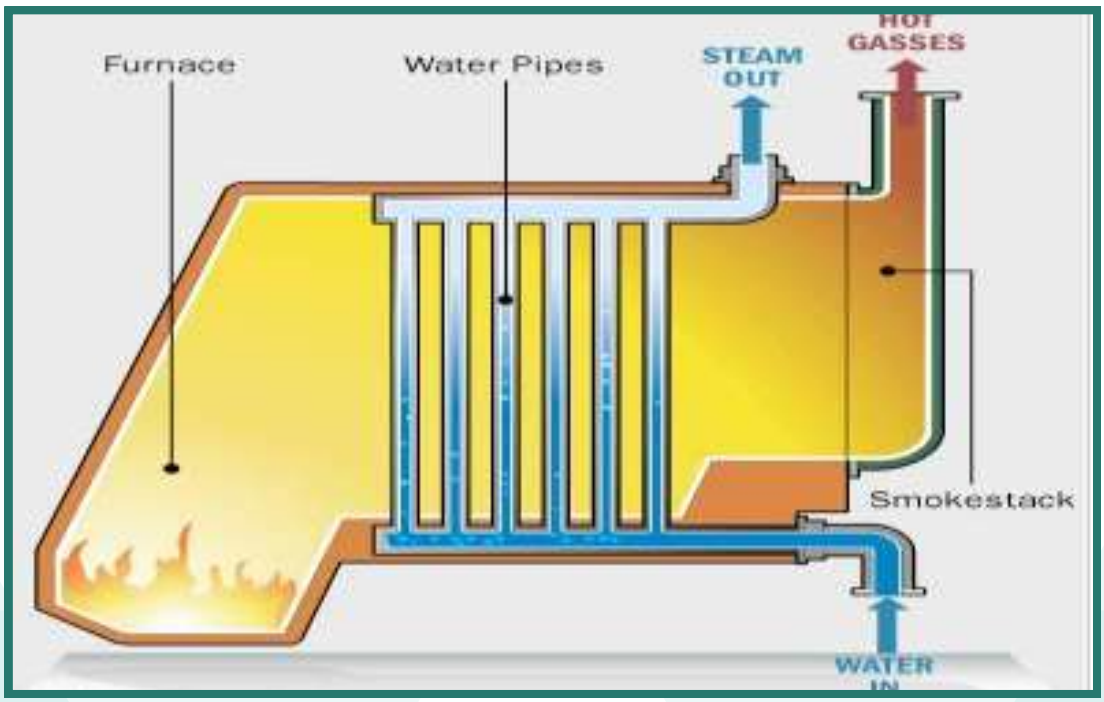


Disadvantages of Fire Tube Boiler

- Fire tube boilers have limited pressure capacity due to their cylindrical shell's structural integrity, which can handle only moderate pressure levels.
- Fire tube boilers can be less efficient than water tube boilers, especially under high pressure and temperature conditions, due to limited heat transfer surface area and lower steam temperature capability.
- Fire tube boilers are prone to thermal shock, which can stress the structure, potentially causing premature failure or reduced lifespan.

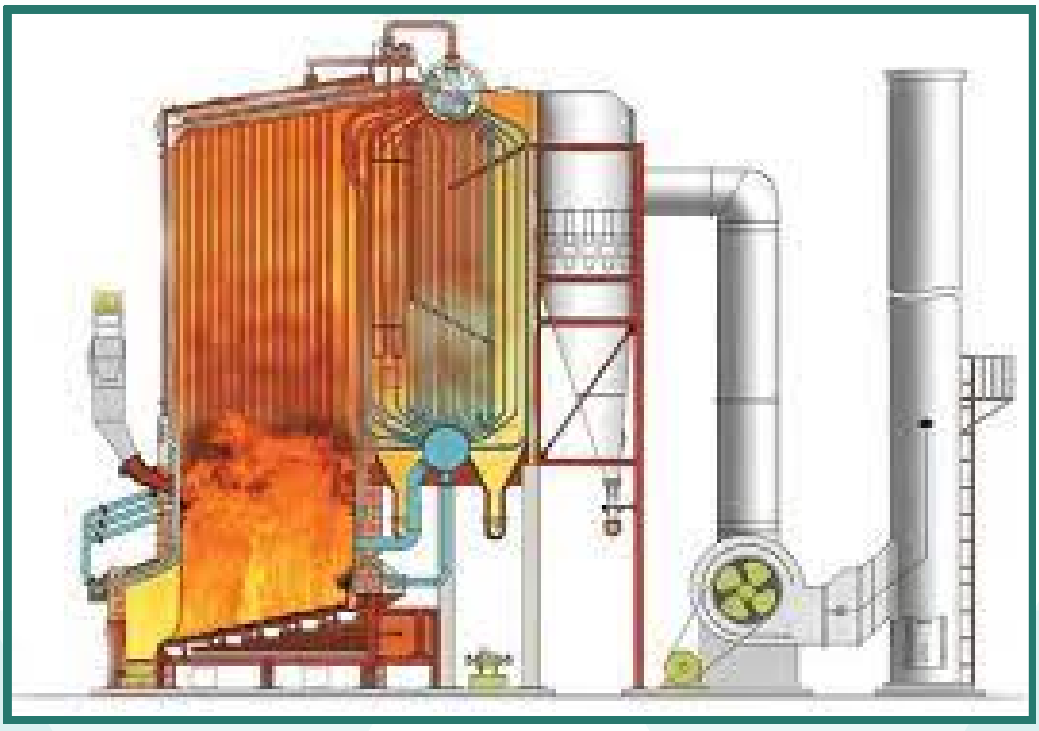
Advantages of Water Tube Boiler

- Water tube boilers are more efficient due to their larger heating surface area, enhancing heat transfer from hot gases to water.
- Water tube boilers withstand higher pressures, ideal for high-pressure steam applications like power generation.
- Water tube boilers produce high-quality, dry steam due to separate steam and water compartments in the tubes, crucial for precise industrial processes.



Disadvantages of Water Tube Boiler

- Water tube boilers have complex construction with interconnected tubes, headers, and drums, leading to higher initial costs.
- Water tube boilers need more maintenance due to their complex design, requiring regular cleaning and inspection to prevent performance issues.
- Water tube boilers require proper water treatment to prevent scale, corrosion, and fouling, ensuring optimal efficiency and longevity.



Choice of Fuel

01
- Gas: Natural gas, LPG

02
- Liquid: Diesel, Kerosene, etc

03
- Solid: Coal, Wood, Fibre and Shell

04
- Waste heat: from gas turbine, diesel engine exhaust

05
- Electricity

06
- Hot oil

Boiler Horsepower

- Steam engine – boiler horsepower is used rating a boiler's capacity to deliver steam to a steam engine
- Power plant – the amount of energy needed to produce 34.5 pounds (15.65kg) of steam at temperature 212 F (100C) in one hour.
- One boiler horsepower is about 33,479 Btu per hour (about 9,810 watts, 8430 Kcal/Hr).
- Boiler horsepower can be determined from the heat transfer area

$$P_{BoHP} = A / 17 \quad (1)$$

where

P_{BoHP} = boiler horsepower

A = heat transfer area (ft^2)

Selection of Boiler

While selecting a boiler the following factors should be considered :

- The working pressure and quality of steam required
- Steam generation rate
- Floor area available
- Accessibility for repair and inspection
- Comparative initial cost
- Erection facilities
- The probable load factor
- The fuel and water available
- Operating and maintenance costs

Essential of a good Steam Boiler

01 • Produce the maximum weight of steam

02 • Reliable

03 • Occupy minimum space

04 • Light in weight

05 • Quick starting

06 • Simple installation

07

- Easy for repairs and inspection

08

- The boiler components should be transportable without difficulty

09

- The tubes of the boiler should not accumulate soot or water deposits and should be sufficiently strong to allow for wear and corrosion

Drum

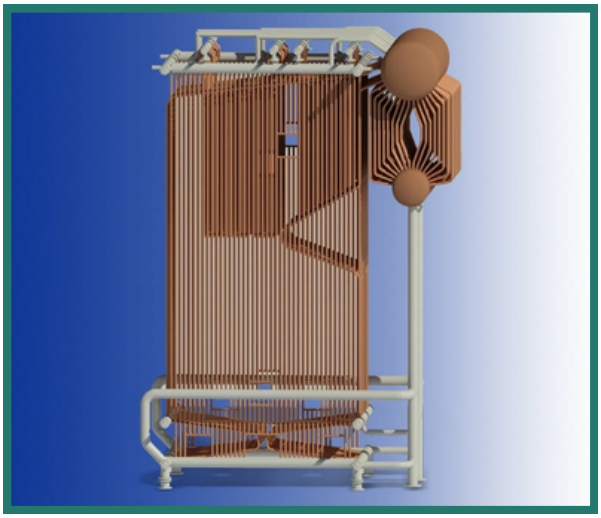
A steam boiler drum is a crucial component in a boiler system. It serves as a storage unit for water and system, allowing for separation of water and steam phases. The drum's primary function is to ensure a steady supply of high-quality steam by regulating water levels, providing a buffer against fluctuations in steam demand, and facilitating the removal of impurities from the steam-water mixture.

Function :

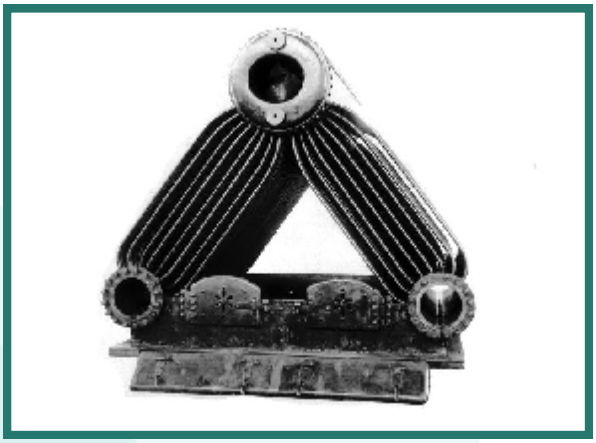
- A pressure vessel it is used to separate steam and water mixture.
- Mixing feed water with water separated from steam-water mixture and re-circulate through the evaporating tubes.
- Reduce dissolved solid contents of the steam (blow down)
- Storage of water.

Types of Boiler Drum

Single drum boilers



Bi - drum boilers



Tri - drum boilers

HYDROSTATIC TEST

- Spading the boiler attachments eg; safety valves and water gauge, except for the feed water inlet and blowdown valves
- Use appropriate pressure gauge
- Leave one vent open at the top to ensure water pumped in completely fills the boiler
- Raise pressure to design pressure. Check.
- Raise pressure to 1.5x design pressure, maintain for at least 20 mins. Check for leaks.
- Slight weeping is acceptable
- Fill in the hydrostatic test FORM JKJ 127

STEAM TEST

- Warm up the boiler
- Fire the boiler – adequate slow firing. Check.
- Raise the pressure to the operating pressure. Check. Increase the pressure.
- Bypass the fire cut-off if necessary, to test the pressure relied valves. The highest pressure setting should not exceed the design pressure. Note the seating pressure.
- If provided with superheater, test the superheater relief valve first; it should have the lowest setting
- Test the high water and low water alarms
- Ensure safe blowdown; check blowdown pit or tank.

ANNUAL INSPECTION

- The boiler must be shut down and allowed to cool
- Water is drained and all the fittings including caps in headers and mud drums are dismantled
- The boiler is effectively disconnected from any other steam boiler or source of steam.
- The fireside is thoroughly cleaned.
- The internals are cleaned as necessary by hydro jet and wire-brushed clear of scales and deposits
- Fittings such as cocks and valves, floats, and gauge glasses are cleaned and serviced
- Temporary scaffolds or ladders must be provided if permanent ones are not available for inspection of remote areas
- The boiler is empty, cool and dry

STATUTORY INSPECTION

What the inspectors usually look for :

- Signs of shell wall thinning
- Cracks at welds and connections
- Damage to the shell by impact
- Leaking gaskets and seals
- Soundness of foundation
- Protective coatings
- Safety relief valve functions
- Alarm functions
- Pressure gauge calibration
- Hazards such as sumps and blowdowns

REFERENCE

- https://www.thermodyneboilers.com/steam-power-station/
- https://en.wikipedia.org/wiki/Steam-electric_power_stationDamage to the shell by impact
- https://www.britannica.com/technology/boilerSoundness of foundation
- https://en.wikipedia.org/wiki/Steam_turbineSafety relief valve functions
- https://www.araner.com/blog/what-is-a-steam-turbine-and-how-does-it-workPressure gauge calibration
- https://www.power-eng.com/coal/steam-turbine-maintenance-repair-management/#gref
- https://www.flyability.com/power-plant-maintenance

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