An Internship Report on

STUDY OF TURBINE & ITS AUXILIARIES AND EFFICIENCY CALCULATION
AT
KAKATIYA POWER PLANT (1X500MW)

By
ARAVIND MACHARLA
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DISCIPLINE OF MECHANICAL ENGINERRING
INDIAN INSTITUTE OF TECHNOLOGY INDORE

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STUDY OF TURBINE & ITS AUXILIARIES AND EFFICIENCY CALCULATION

A report

Submitted in partial fulfillment of the requirements for the award of the degree

of

BACHELORS

by

ARAVIND

Certificate

Pursuing bachelors degree and studying second year in **MECHANICAL ENGINEERING** at the Indian Institute of Technology (IIT) Indore, has successfully completed an internship at KAKATIYA POWER PLANT PROJECT, Telangana State Power Generation Corporation Limited (TSGENCO) is a bonafide report of work carried out by them at TURBINE MAINTENANCE DIVISION/KTPP STAGE-1 from 01/06/2024 to 30/06/2024 in the academic year of 2023-2024 under the guidance and super vision of **MR.M.NAGAPHANI ,**ADE/MD/KTPP-1 and **Mr.L.THIRUPATHI** DE/MD/KTPP-1.

During the internship, ARAVIND demonstrated exceptional dedication, technical knowledge, and a keen interest in the field of power generation. The internship involved hands-on experience in various aspects of power plant operations, maintenance, and management, including Technical Exposure, Project Work, Research and Analysis, Team Collaboration.

Dr. S. Dhinakaran
HOD/Dept. of Mechanical

DR. SUHAS S.JOSHI
Director

TELANGANA STATE POWER GENERATION CORPORATION LIMITED

Certificate of Internship

This is to certify that the internship report entitled

STUDY OF TURBINE & ITS AUXILIARIES AND EFFICIENCY CALCULATION

At

KAKATIYA THERMAL POWER PLANT (1X500MW)

SUBMMITED BY

ARAVIND MACHARLA

(22003050_IITI)

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(M.NAGAPHANI)	(L.THIRUPATHI)
ADE/TMD/KTPP-1	DE/TMD/KTPP-1

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INDIAN INSTITUTE OF TECHNOLOGY INDORE

CANDIDATE'S DECLARATION

I declare that the internship report entitled

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AND EFFICIENCY CALCULATIONS

AT

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does not form part of any other thesis on which a degree has been awarded. further declare that this report is based on my work carried out at INDIAN INSTITUTE OF TECHNOLOGY INDORE and KAKATIYA THERMAL POWER PROJECT in the second year of B-Tech course in the academic year 2023-2024.

I also declare that this report has not been submitted to any other university or institute for any awards of Degree or Diploma.

ARAVIND
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Introduction to Power Generation

Power generation is the process of producing electricity from various sources of energy. Electricity is a vital utility that powers homes, industries, and businesses, and is fundamental to modern society's functioning. Power generation can be broadly categorized based on the primary energy sources used, such as fossil fuels, nuclear energy, and renewable resources.

1. **Early Developments**:
    - **Mechanical Power**: Before the advent of electricity, mechanical power was generated using water wheels and windmills.
    - **Steam Engine**: In the late 18th century, the steam engine revolutionized power generation, leading to the Industrial Revolution.
2. **Electricity Generation**:
    - **Michael Faraday**: In the early 19th century, Faraday's experiments with electromagnetic induction laid the foundation for electric generators.
    - **Thomas Edison and Nikola Tesla**: In the late 19th century, Edison developed the direct current (DC) power system, while Tesla pioneered alternating current (AC) power systems, which became the standard for electricity distribution.

Basic Principles of Power Generation

1. **Electromagnetic Induction**:
    - **Faraday's Law**: When a conductor moves through a magnetic field, an electromotive force (EMF) is induced in the conductor, generating electricity.
    - **Generators**: Devices that convert mechanical energy into electrical energy using electromagnetic induction. Common types include steam turbines, gas turbines, and hydro turbines.
2. **Energy Conversion**:
    - **Primary Energy Sources**: Includes fossil fuels (coal, oil, natural gas), nuclear energy, and renewable sources (solar, wind, hydro, geothermal, biomass).
    - **Conversion Processes**: Involves converting primary energy into mechanical energy (e.g., steam production in a boiler) and then into electrical energy using generators.

Types of Power Generation

1. **Thermal Power Generation**:
    - **Fossil Fuel Power Plants**: Use coal, natural gas, or oil to heat water in boilers, producing steam that drives turbines connected to generators.

- **Nuclear Power Plants**: Use nuclear reactions (fission) to generate heat, which produces steam to drive turbines.

2. **Renewable Power Generation**:
   - **Hydroelectric Power**: Utilizes the potential energy of stored water in dams to drive turbines.
   - **Wind Power**: Uses wind turbines to convert kinetic energy from wind into electrical energy.
   - **Solar Power**:
     - **Photovoltaic (PV) Cells**: Convert sunlight directly into electricity.
     - **Concentrated Solar Power (CSP)**: Uses mirrors or lenses to focus sunlight to heat a fluid, producing steam to drive turbines.
   - **Geothermal Power**: Uses heat from the Earth's interior to generate steam and drive turbines.
   - **Biomass Power**: Burns organic materials to produce steam for driving turbines.
3. **Combined Cycle Power Plants**:
   - Combine gas turbines and steam turbines to improve efficiency. The waste heat from the gas turbine is used to produce steam for a steam turbine, enhancing overall power output.

Components of Power Generation Systems

1. **Boilers and Heat Exchangers**:
   - **Boilers**: Convert water into steam using heat from burning fuels or nuclear reactions.
   - **Heat Exchangers**: Transfer heat from one medium to another, such as in condensers and evaporators.
2. **Turbines**:
   - **Steam Turbines**: Driven by high-pressure steam to rotate the generator.
   - **Gas Turbines**: Use high-pressure gases from combustion to drive the turbine blades.
   - **Hydro Turbines**: Driven by the flow of water.
3. **Generators**:
   - Convert mechanical energy from turbines into electrical energy through electromagnetic induction.
4. **Transformers**:
   - Step up (increase) or step down (decrease) the voltage of electricity for efficient transmission and distribution.
5. **Control Systems**:
   - Monitor and regulate the operation of the power plant to ensure efficiency and safety.

Environmental Impact and Sustainability

1. **Emissions and Pollution**:
   - Fossil fuel power plants emit greenhouse gases (GHGs), such as CO_2, and pollutants like sulfur dioxide (SO_2) and nitrogen oxides (NOx), contributing to climate change and air pollution.
2. **Nuclear Waste**:
   - Nuclear power generates radioactive waste that requires long-term management and storage.
3. **Renewable Energy**:
   - Renewable sources like wind, solar, and hydro have minimal emissions and are sustainable, but may have other environmental impacts, such as habitat disruption.
4. **Efficiency Improvements**:
   - Advances in technology, such as combined cycle plants and carbon capture and storage (CCS), aim to improve efficiency and reduce emissions.

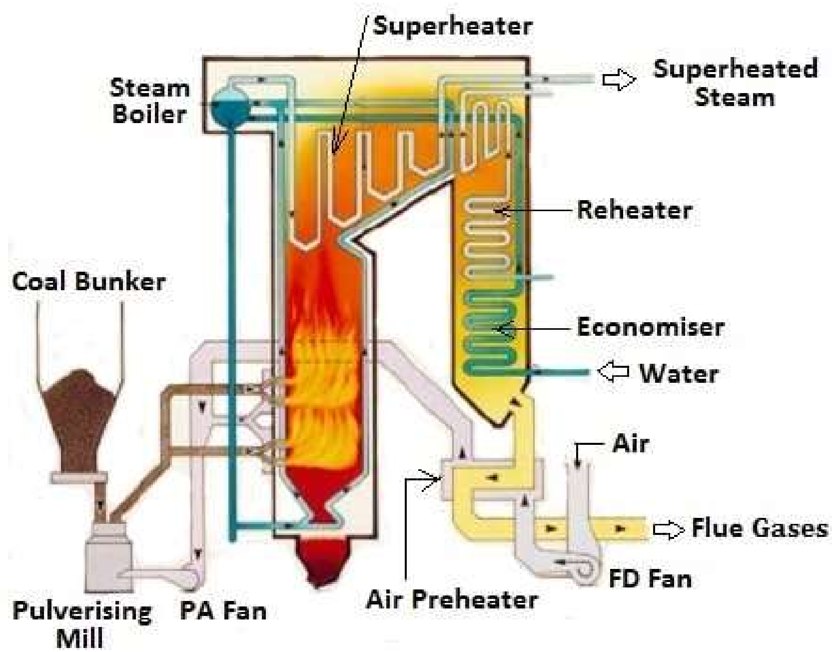
RANKINE CYCLE: THE IDEAL CYCLE

FOR VAPOR POWER CYCLES

The **Rankine cycle** is a practical and widely used thermodynamic cycle that improves upon the Carnot cycle by incorporating real-world considerations.

1. Boiler (Heating)

- Water is heated in the boiler at constant pressure, converting it into high-pressure steam.
- Superheating occurs, which means the steam is heated beyond its boiling point to increase the cycle's efficiency.
  Heat Added : Qin=h3−h2Qin=h3−h2

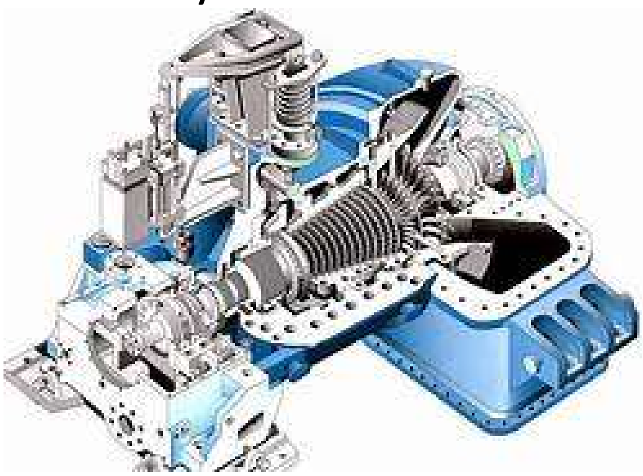


Pulverized Coal-Fired Boiler

2. Turbine (Expansion)

- The superheated steam expands in a turbine, doing work (e.g., generating electricity).

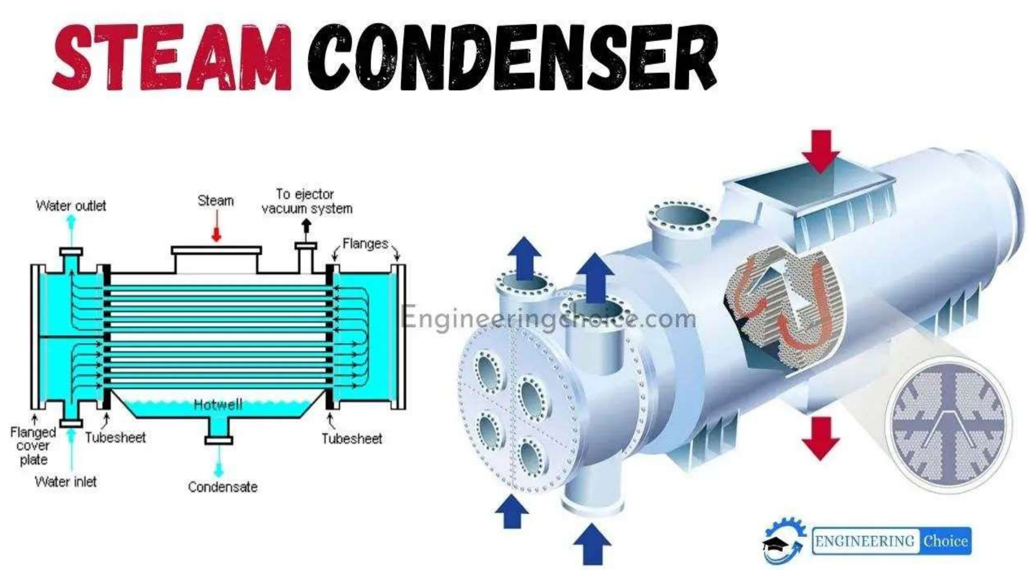
- As the steam expands, its temperature and pressure decrease.
  Work Done by the Turbine : Wt=h3−h4Wt=h3−h4



3. Condenser (Cooling)

- The steam is then cooled in the condenser, where it releases heat and condenses back into a liquid at constant pressure.

This complete condensation is crucial for the cycle’s efficiency and practicality. **Heat Rejected** Qout=h4−h1Qout=h4−h1



Condensers are classified as jet condensers and surface condensers. In jet condensers the steam to be condensed mixes with the cooling water and the condensate can't be recovered for use as feed water to the boiler. In this plant surface condensers are using. In surfacecondensers there is no direct contact between the steam to be condensed and the circulating cooling water. There is a wall interposed between them through heat must be connectively transferred. The temperature condensate may be higher than the temperature of the cooling water at outlet and the condensate is recovered as feed water to the boiler. Both the cooling water and the condensate are separately with drawn. Separated condensate can be reused as feed water. This condensate maintains approx.45.6^{0}C,-0.9Kg/cm^2 temperature and pressure respectively.

- The purpose of condenser to condense steam to obtain maximum efficiency and also to get the condensed steam in the form of pure water, otherwise known as condensate, sent back to boiler as boiler feed water.

  However, in this thermal power plant the LP Turbine steam extraction can be given to the condenser shell side to exchange the heat with cooling water (flow in tubes) from cooling tower to use as feed water again. After condensation, still some non-condensable gases / leakage air may be there in condenser. These gases and air will create back pressure in the condenser. These are to be removed.

CONDENSOR TUBE CLEANING SYSTEM:

Tube cleaning system of the Condensers by using Sponge Rubber Balls has been in use all over the world for more than four decades now. This system is found to be an effective solution for maintaining the cleanliness factor at the optimum level.

Sponge rubber balls with a special composition and size 1 to 3mm greater than the inner diameter of the Condenser Tubes are injected into the Cooling Water stream at the inlet. These balls which have specific gravity close to that of the cooling water are carried into the Condenser by the velocity of the inlet water. Cleaning balls are then pushed through the tubes by the differential pressure against the walls of the tube removing all deposits on the inner surface of the tubes. A specially designed screen arrangement called the Ball Separator separates the balls from the main Cooling Water system and the balls collected in the Ball Vessel. The balls are injected into the Cooling Water through the Ball Recirculating Pump. The Ball Separator is specially designed to facilitate the smooth passage of the Cleaning Balls to the extraction point. The unique design of the Ball Separator ensures that the Cleaning Balls will have to move through only a small angle, since lager angles may result in the balls sticking to the screen in case of adverse conditions.

The main advantages of a Tube Cleaning System are:

* Increase in the Heat Transfer Rate
* Optimum Turbine Back Pressure
* Increased Generation Efficiency
* Avoidance of corrosion in Tubes
* Avoidance of Shutdown for Manual Cleaning
* Reduction of Chemical costs for Water Treatment
* Reduction in fuel costs.

4. Pump (Compression)

- The condensed water is pumped back to the boiler, increasing its pressure to restart the cycle.
- Pumping liquid water requires significantly less work than compressing
- **Work Done on the Pump :** Wp=h2−h1Wp=h2−h1

T-s Diagram of the Rankine Cycle

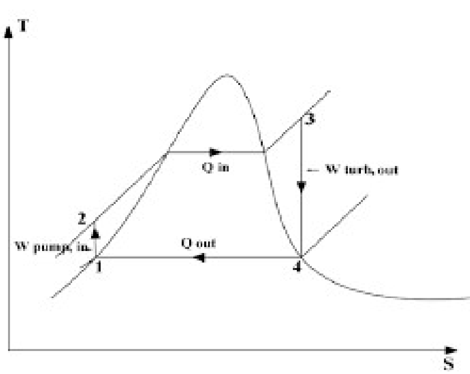
A Temperature-Entropy (T-s) diagram for the Rankine cycle illustrates the process:

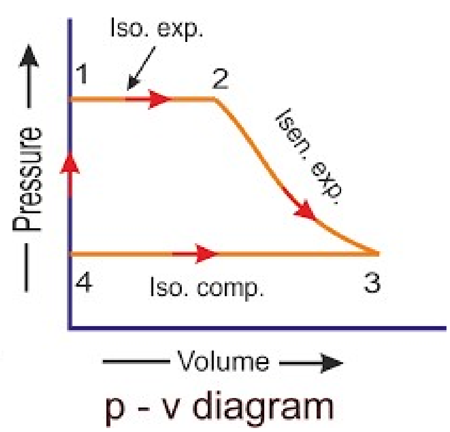
1. **1-2:** Isentropic compression in the pump (liquid water).
2. **2-3:** Heat addition in the boiler (water to superheated steam).
3. **3-4:** Isentropic expansion in the turbine (superheated steam to wet steam).
4. **4-1:** Heat rejection in the condenser (steam to liquid water).

Key Advantages over the Carnot Cycle

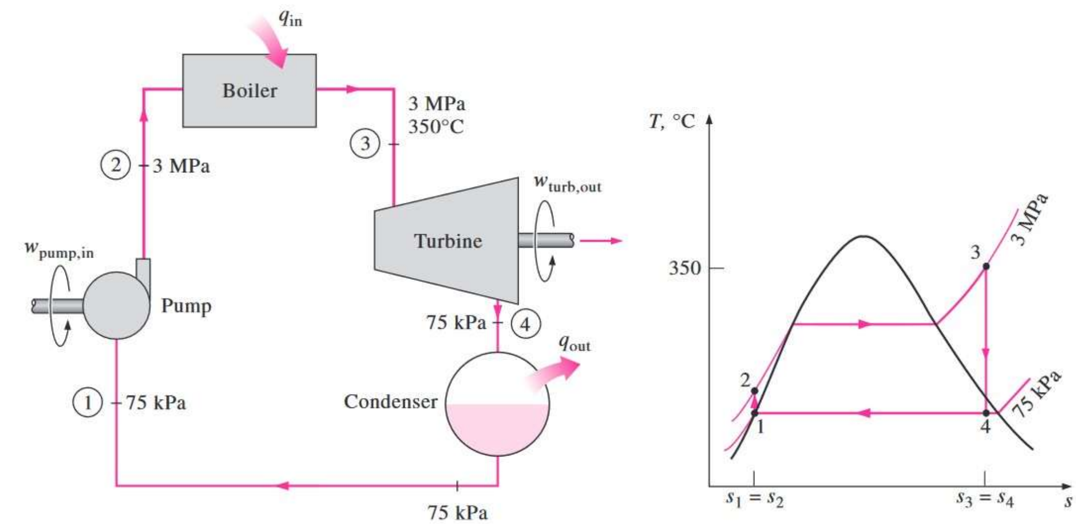
- **Superheating:** Increases efficiency by increasing the average temperature at which heat is added.
- **Complete Condensation:** Ensures the working fluid returns to the liquid phase, making the pumping process much more efficient.

t-s diagram:



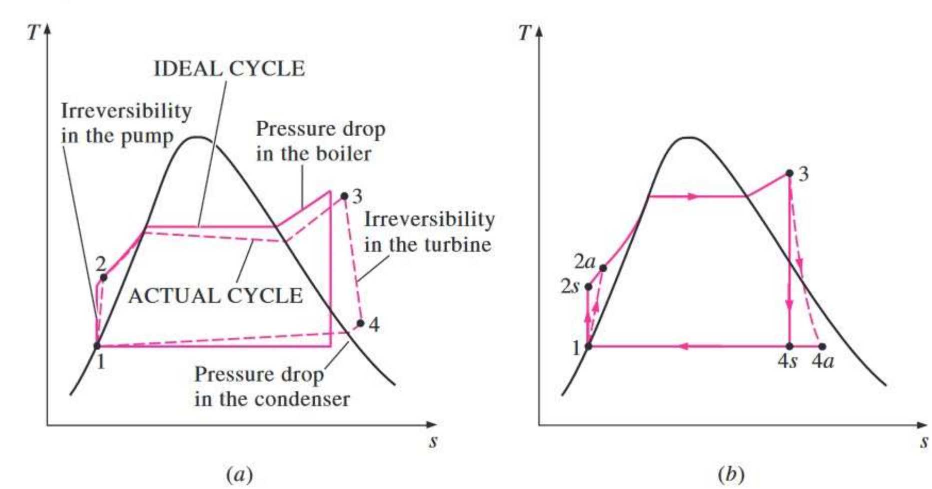


Practicality: Uses components (boiler, turbin e, condenser, and pump) that are feasible to implement and operate in real-world power plants.
small example:



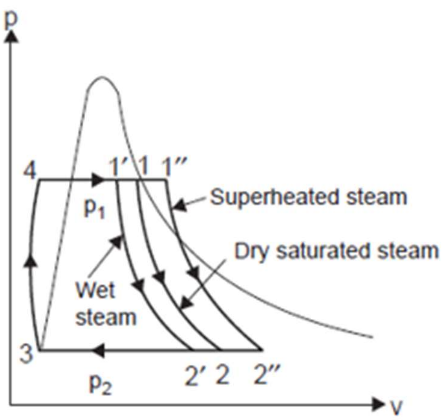
DEVIATION OF ACTUAL VAPOR POWER CYCLES FROM IDEALIZED ONES:

The actual vapor power cycle differs from the ideal Rankine cycle, as a result of irreversibilites in various components. Fluid friction and heat loss to the surroundings are the two common sources of irreversibilites. Fluid friction causes pressure drops in the boiler, the condenser, and the piping between various components. As a result, steam leaves the boiler at a somewhat lower pressure. Also, the pressure at the turbine inlet is somewhat lower than that at the boiler exit due to the pressure drop in the connecting pipes. The pressure drop in the condenser is usually very small. To compensate for these pressure drops, the water must be pumped to a sufficiently higher pressure than the ideal cycle calls for. This requires a larger pump and larger work input to the pump. The other major source of irreversibility is the heat loss from the steam to the surroundings as the steam flows through various components. To maintain the same level of net-work output, more heat needs to be transferred to the steam in the boiler to compensate for these undesired heat losses. As a result, cycle efficiency decreases.

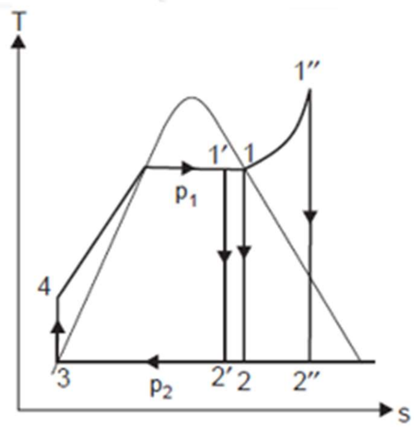


(a) Deviation of actual vapor power cycle from the ideal Rankine cycle. (b) The effect of pump and turbine irreversibilities on the ideal Rankine cycle.

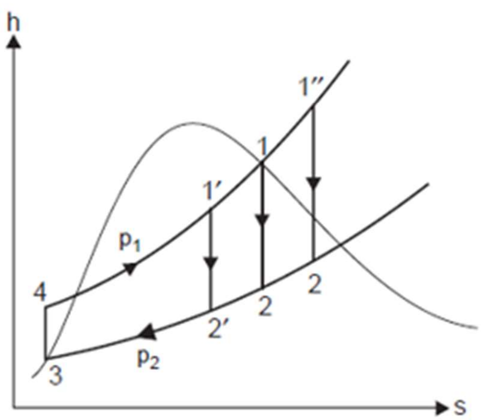
P-V, T-S, H-S diagram with isentropic lines



p-v diagram of Rankine cycle



T-s diagram of Rankine cycle



h-s diagram of Rankine cycle

THE IDEAL REHEAT RANKINE CYCLE:

We noted in the last section that increasing the boiler pressure increases the thermal efficiency of the Rankine cycle, but it also increases the moisture content of the steam to unacceptable levels. Then it is natural to ask the following question:

How can we take advantage of the increased efficiencies at higher boiler pressures without facing the problem of excessive moisture at the final stages of the turbine?

Two possibilities come to mind:

1. **Superheating Steam to High Temperatures:**
   - **What:** Heat the steam to very high temperatures before it enters the turbine.
   - **Why:** This would make the cycle more efficient because heat would be added at a higher average temperature.
   - **Problem:** This isn't practical because it would make the steam too hot for the materials used in the turbine, potentially causing damage.
2. **Two-Stage Expansion with Reheating:**
   - **What:** Expand the steam in the turbine in two steps and reheat it between these steps.
   - **Why:** This helps to manage the problem of too much moisture in the steam, which can damage the turbine.

Key Processes in the Reheat Rankine Cycle:

1. **Isentropic Compression in the Pump**
   - **Process 1-2:** Water is pumped from low pressure (condenser) to high pressure (boiler). This process is isentropic (entropy remains constant).
2. **Isobaric Heat Addition in the Boiler**
   - **Process 2-3:** The high-pressure liquid water is heated at constant pressure in the boiler, converting it to superheated steam.
3. **Isentropic Expansion in the High-Pressure Turbine (HPT)**
   - **Process 3-4:** The superheated steam expands isentropically in the high-pressure turbine, doing work. The steam's pressure and temperature decrease.
4. **Isobaric Reheating in the Reheater**
   - **Process 4-5:** The partially expanded steam from the HPT is reheated at constant pressure in the reheater. This increases the steam’s temperature.
5. **Isentropic Expansion in the Low-Pressure Turbine (LPT)**
   - **Process 5-6:** The reheated steam expands isentropically in the low-pressure turbine, doing additional work. The steam’s pressure and temperature decrease further.
6. **Isobaric Heat Rejection in the Condenser**
   - **Process 6-1:** The low-pressure steam is condensed at constant pressure in the condenser, converting it back into liquid water.

Energy Analysis of the Reheat Rankine Cycle:

1. **Pump Work (1-2):**

$W_{pump} = h_2 - h_1$

2. **Heat Added in the Boiler (2-3):**

   $Q_{in}^{1} = h_3 - h_2$

3. **Work Done by the High-Pressure Turbine (HPT) (3-4):**

   $W_{HPT} = h_3 - h_4$

4. **Heat Added in the Reheater (4-5):**

   $Qin2 = h_5 - h_4$

5. **Work Done by the Low-Pressure Turbine (LPT) (5-6):**

   $WLPT = h_5 - h_6$

6. **Heat Rejected in the Condenser (6-1):**

   $Qout = h_6 - h_1$

Net Work Output and Efficiency:

- **Net Work Output (WnetWnet):**

  $W_{net} = (W_{HPT} + W_{LPT}) - W_{pump}$
  $W_{net} = [(h_3 - h_4) + (h_5 - h_6)] - (h_2 - h_1)$

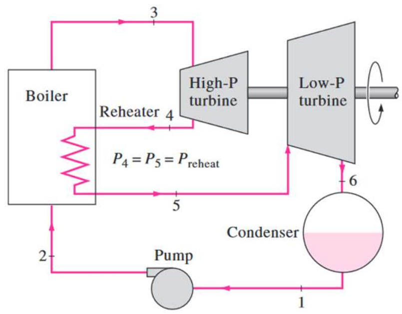
- **Total Heat Added (QinQin):**

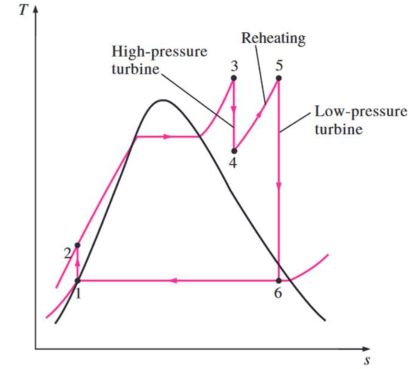
  $Q_{in} = Q_{in}^{1} + Q_{in}^{2}$
  $Q_{in} = (h_3 - h_2) + (h_5 - h_4)$

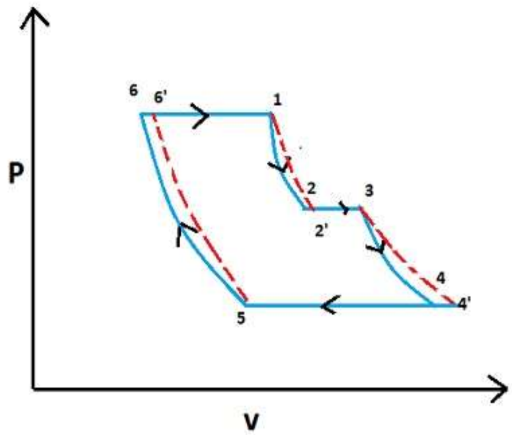
- **Thermal Efficiency (ηη):**

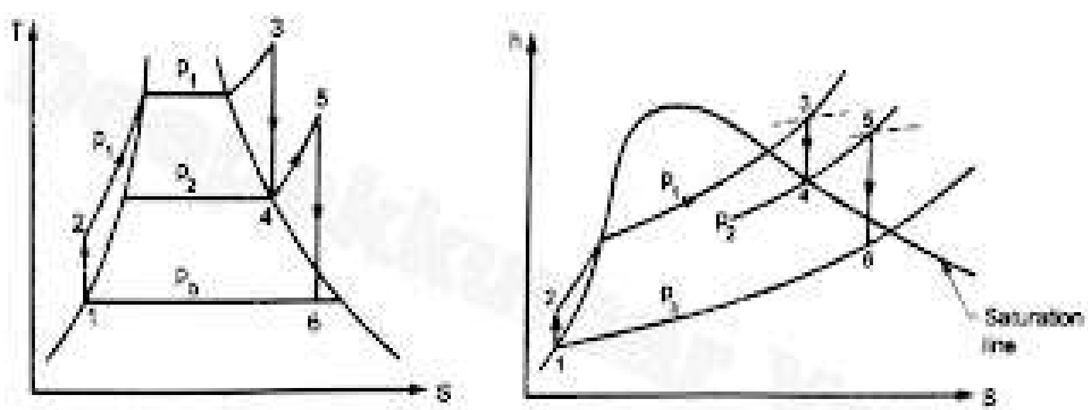
  $\eta = W_{net} / Q_{in}$

  $\eta = [(h_3 - h_4) + (h_5 - h_6)] - (h_2 - h_1) / (h_3 - h_2) + (h_5 - h_4)$









(b) (T-S) diagram (c) (h-S) diagram

Ranking Cycle with Reheat

Example Calculation (Hypothetical Values)

Suppose the following enthalpy values (in kJ/kg):

- h1=200
- h2=210
- h3=3500
- h4=2500
- h5=3500
- h6=2400

1. **Pump Work:**

   W_{pump}=h2−h1=210−200=10 kJ/kg

2. **Heat Added in the Boiler:**

   Qin1=h3−h2=3500−210=3290 kJ/kg

3. **Work Done by the HPT:**

   W_{HPT}=h3−h4=3500−2500=1000 kJ/kg

4. **Heat Added in the Reheater:**

   Qin2=h5−h4=3500−2500=1000 kJ/kg

5. **Work Done by the LPT:**

   W_{LPT}=h5−h6=3500−2400=1100 kJ/kg

6. **Heat Rejected in the Condenser:**

   Q_{out}=h6−h1=2400−200=2200 kJ/kg

7. **Net Work Output:**

   $W_{net}=(W_{HPT}+W_{LPT})-W_{pump}$ =(1000+1100)−10=2090 kJ/kg

8. **Total Heat Added:**

   $Q_{in}=Q_{in}^{1}+Q_{in}^{2}$=3290+1000=4290 kJ/kg

   Thermal Efficiency:

$\eta = W_{net}/Q_{in} = 20904290 \approx 0.487$ or 48.7%

THE IDEAL REGENERATIVE RANKINE CYCLE:

The ideal regenerative Rankine cycle improves efficiency by using feedwater heaters to preheat the water before it enters the boiler. This reduces the amount of fuel needed to heat the water to steam and improves overall cycle efficiency.

Key Processes in the Regenerative Rankine Cycle:

1. **Isentropic Compression in Pump 1:**
    - **Process 1-2:** Water is pumped from the condenser (low pressure) to an intermediate pressure where it enters the feedwater heater (FWH).
2. **Isobaric Heating in the Feedwater Heater (Open Type):**
    - **Process 2-3:** Water is heated by extracting steam from the turbine. This steam mixes with the feedwater in the open feedwater heater, raising its temperature.
3. **Isentropic Compression in Pump 2:**
    - **Process 3-4:** The water, now at a higher temperature, is pumped to the boiler pressure.
4. **Isobaric Heat Addition in the Boiler:**
    - **Process 4-5:** Water is heated in the boiler at constant pressure, converting it to superheated steam.
5. **Isentropic Expansion in the Turbine:**
    - **Process 5-6:** The superheated steam expands in the turbine, producing work. During this process, some steam is extracted at an intermediate pressure to be used in the feedwater heater.
6. **Isentropic Expansion in the Remaining Turbine Stages:**
    - **Process 6-7:** The remaining steam continues to expand in the turbine stages until it reaches the condenser pressure.
7. **Isobaric Heat Rejection in the Condenser:**
    - **Process 7-1:** The low-pressure steam is condensed at constant pressure, rejecting heat and converting the steam back into liquid water.

Energy Analysis of the Regenerative Rankine Cycle:

State Points and Calculations:

1. **Pump Work (1-2):**
    - $W_{pump}^{1} = h_2 - h_1$
2. **Heat Added in Feedwater Heater (2-3):**
    - Mixing occurs, and the enthalpy at state 3 is determined based on mass and energy balance.

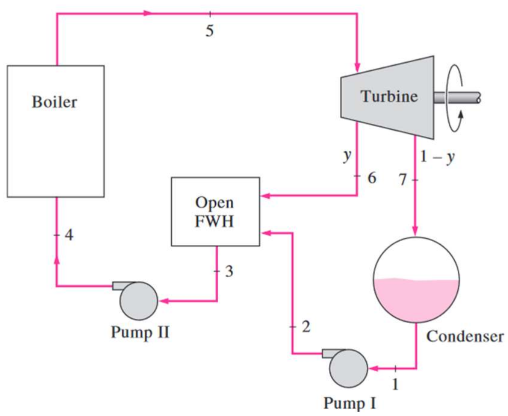
3. **Pump Work (3-4):**
    - $W_{pump}^{2} = h_4 - h_3$

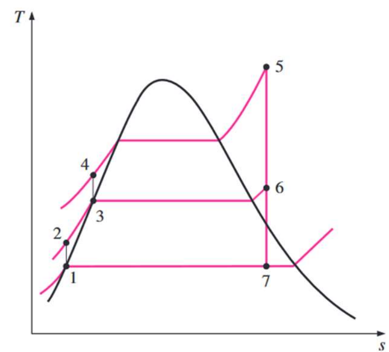
4. **Heat Added in Boiler (4-5):**
    - $Q_{in} = h_5 - h_4$
5. **Turbine Work (5-6 and 6-7):**
    - $W_{turbine} = (h_5 - h_6) + (h_6 - h_7)$
6. **Heat Rejected in Condenser (7-1):**
    - $Q_{out} = h_7 - h_1$

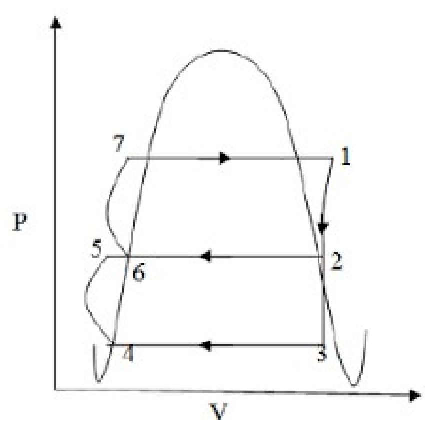
Efficiency Calculation:

The thermal efficiency of the regenerative Rankine cycle can be calculated as:
$\eta = W_{net}/Q_{in} = (W_{turbine} - W_{pump1} - W_{pump2})$
Where:

$W_{net} = (h_5 - h_6 + h_6 - h_7) - (h_2 - h_1 + h_4 - h_3)$







Types of Turbines:

Turbines are rotary mechanical devices that extract energy from a fluid flow and convert it into useful work. The types of turbines can be broadly categorized based on the working fluid and the application. The major types include steam turbines, gas turbines, water (hydraulic) turbines, and wind turbines. Each type has subcategories and specific applications based on their design.

1. Steam Turbines:

Steam turbines are crucial devices in power generation, mechanical drive, and various industrial applications. They convert thermal energy from steam into mechanical energy. Here is a detailed overview of the different types of steam turbines based on their operating principles, steam flow direction, stages of expansion, and specific applications.

STEAM TURBINE CAPACITY AND CAPABILITY:

CAPACITY:

The capacities of small turbines and coupled generators vary from 500 to 7500 kW whereas large turbo alternators have capacity varying from 10 to 90 MW. Very large size units have capacities up to 500 MW.

Generating units of 200 MW capacity are becoming quite common. The steam consumption by steam turbines depends upon steam pressure, and temperature at the inlet, exhaust pressure number of bleeding stages etc. The steam consumption of large steam turbines is about 3.5 to 5 kg per kWh.

$$\text{Turbine kW} = \text{Generator kW} / \text{Generator Efficiency}$$

Generators of larger size should be used because of the following reasons:

(i) Higher efficiency.
(ii) Lower cost per unit capacity.
(iii) Lower space requirement per unit capacity.

CAPABILITY:

The capability of steam turbine is the maximum continuous output for a clean turbine operating under specified throttle and exhaust conditions with full extraction at any openings if provided.

The difference between capability and rating is overload capacity. A common practice is to design a turbine for capability of 125% nominal rating and to provide a generator that will absorb rated power at 0.8 power factor. By raising power factor to unity, the generator will absorb the full turbine capability.

STEAM TURBINE GOVERNING:

Governing of steam turbine means to regulate the supply of steam to the turbine to maintain speed of rotation sensibly constant under varying load conditions. Some of the methods employed are as follows:

(i) Bypass governing.

(ii) Nozzle control governing.

(iii) Throttle governing.

(i) Bypass governing: In this system the steam enters the turbine chest (C) through a valve (V) controlled by governor.

In case of loads greater than economic load a bypass valve (Vi) opens and allows steam to pass from the first stage nozzle box into the steam belt (S).

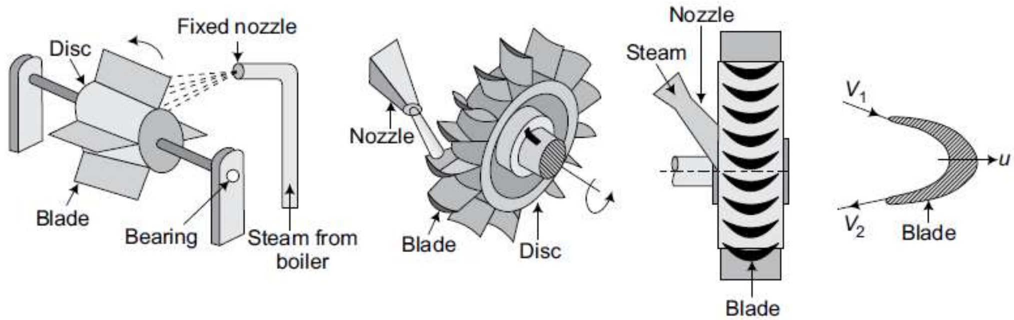
(ii) Nozzle control governing: In this method of governing the supply of steam of various nozzle groups N_1, N_2, and N_3 is regulated by means of valves V_1, $V_2$and V_3 respectively.

(iii) Throttle governing: In this method of governing the double beat valve is used to regulate the flow of steam into the turbine. When the load on the turbine decreases, its speed will try to increase. This will cause the fly bar to move outward which will in return operate the lever arm and thus the double beat valve will get moved to control the supply of steam to turbine. In this case the valve will get so adjusted that less amount of steam flows to turbine.

Based on Operating Principle

1. Impulse Turbines

- **Description**: In impulse turbines, the entire pressure drop of the steam occurs in the nozzles, converting pressure energy into kinetic energy before the steam impacts the turbine blades. The blades change the direction of the steam flow, causing a change in momentum and generating mechanical work.



- PRINCIPLE OF IMPULSE TURBINE

- **Types**:
  - **Simple Impulse Turbine**: A single set of nozzles and blades.
  - **Velocity Compounded Impulse Turbine**: Multiple sets of moving and fixed blades to reduce the steam's velocity in stages. Example: Curtis stage.
  - **Pressure Compounded Impulse Turbine**: Multiple sets of nozzles and blades to handle high-pressure drops in stages. Example: Rateau stage.

Uses: Suitable for high-pressure, low-flow applications. Often used in smaller-scale applications or as the first stage in multi-stage turbines.

Example: HP TURBINE:

The outer casing of the HP turbine is of barrel type construction. This avoids mass accumulation due to absence of flanges. As a result of the almost Complete rotation symmetry the wall thickness is kept moderate and of nearly equal strength at all section .The inner casing carries the guide blades and is axially split and Cinematically supported. The space between the inner and outer shells is sealed from the neighbouring spaces by sealing rings .As the inner casing is not subjected to large pressure drops the joint flange and bolts are designed for less stringent conditions. The inner casing is fixed in the horizontal and vertical planes in the outer casing so that it can freely expand radially in all direction and axially from a fixed point when heating up while maintaining eccentrically.

High pressure turbine

The barrel construction permits rapid start up and higher rates of load changes due to absence of high thermal stresses. Barrel type casing are also easy to cast which means the castings can be of exceptionally good quality. The connections of the main steam piping with the HP turbine are by means of sleeve joint having buttress threads. These threads are located in the outer casing and connection with the piping is made through breech nuts. This arrangement provides ease of opening the joint during maintenance.

High pressure turbine

Efficiency Formula: $\eta=(V_2^2-V_3^2)/(V_1^2-V_3^2)\times\eta_{nozzle}$
where:

- η = efficiency
- V_1= absolute velocity of steam entering the nozzle
- V_2 = absolute velocity of steam leaving the nozzle and entering the moving blades
- V_3= absolute velocity of steam leaving the moving blades
- η_{nozzle} = nozzle efficiency

2. Reaction Turbines

- **Description**: In reaction turbines, the pressure drop occurs in both the stationary and moving blades, creating a continuous change in pressure and velocity. The steam expands in both stationary and moving blades, generating reaction forces in addition to impulse forces.
- **Types**:
  - **Single-Stage Reaction Turbine**: One stage of stationary and moving blades.

- **Multi-Stage Reaction Turbine**: Multiple stages of stationary and moving blades for gradual pressure reduction. Example: Parsons turbine.

Uses: Ideal for low-pressure, high-flow applications. Commonly used in large power plants due to their efficiency in handling large volumes of steam.

Example:

LP TURBINE:

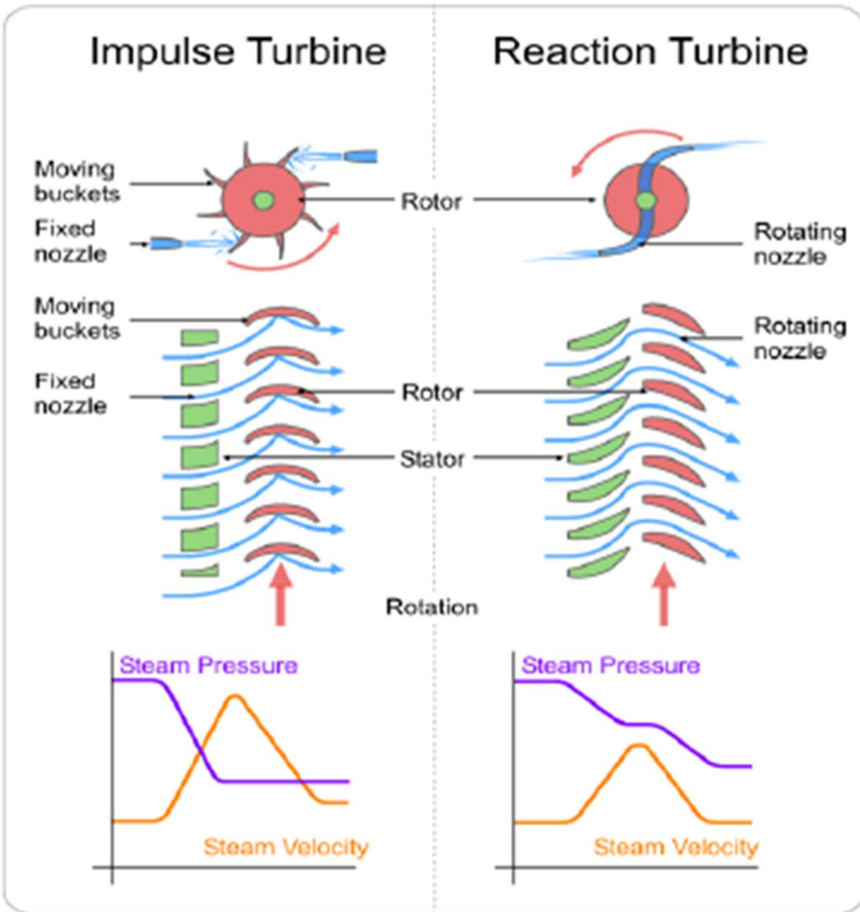
The LP casing is of triple shell fabricated construction. The outer casing consists of the front & rear end walls; two side members called longitudinal girders and top cover.

Fig. 4.2.3 LP TURBINE

The shell inner casing is supported kinematically at each end by two support arms resting on the side members of the outer casing. The inner shell of the inner casing carriers the guide blade carrier of the first idle blade carriers, which constitute the remaining stages of the turbine, are bolted to the middle inner outer casing.

Efficiency Formula: $\eta=2(V_1 \cdot U - U^2/2)/ V_1{}^2 \times \eta_{blade}$
where:

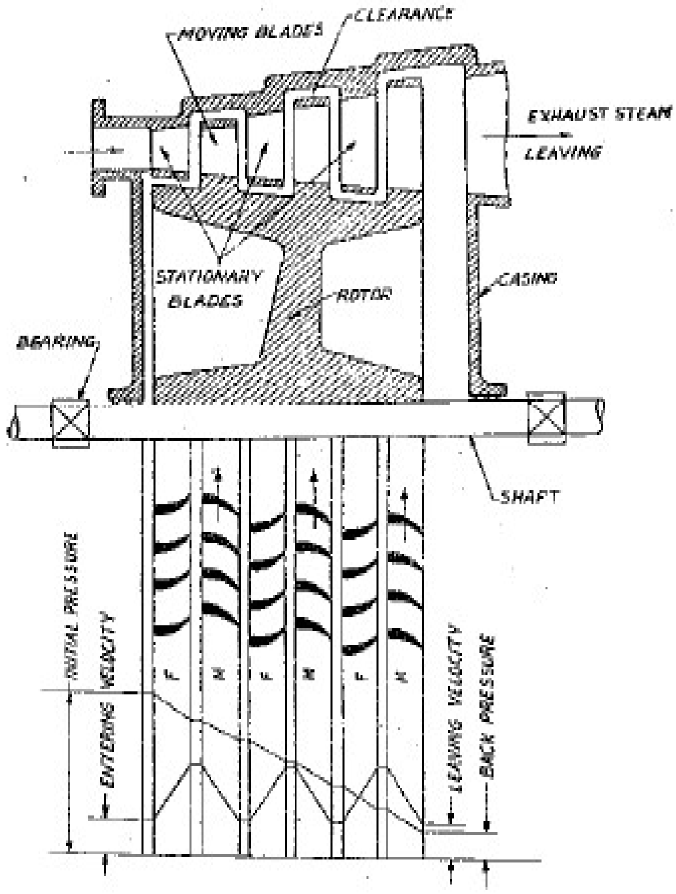
- η= efficiency
- V_1 = absolute velocity of steam entering the turbine
- U= blade speed
- η_{blade} = blade efficiency.



3.Impulse-Reaction Turbine:

In this turbine, the drop-in pressure of steam takes place in fixed (nozzles) as well as moving blades. The pressure drops suffered by steam while passing through the moving blades cause a further generation of kinetic energy within the moving blades, giving rise to reaction and adds to the propelling force which is applied through the rotor to the turbine shaft. Since this turbine works on the principle of impulse and reaction both, so it is called impulse-reaction turbine.

- This is achieved by making the blade passage of varying cross-sectional area (converging type).In general, it may be stated that energy transformation occurs in both fixed and moving blades.
- The rotor blades cause both energy transfer and transformation. Since there is an acceleration of flow in moving blade passage hence chances of separation of flow is less which results in higher stage efficiency.



IMPULSE – REACTION TURBINE

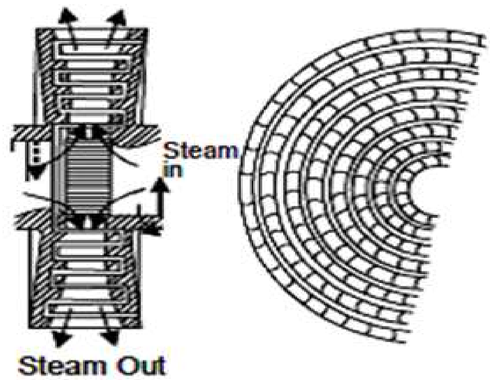
Based on Direction of Steam Flow

1. **Axial Flow Turbines**

- **Description**: Steam flows parallel to the axis of the turbine shaft. These turbines are highly efficient and commonly used in power generation due to their straightforward design and high efficiency.
- **Uses**: Power plants, industrial applications requiring reliable and efficient power generation.

2. Radial Flow Turbines

- **Description**: Steam flows radially, either inwards or outwards, relative to the axis of the turbine shaft. Radial flow turbines are less common than axial flow turbines but are used in specific applications where design constraints require radial flow.
- **Uses**: Specialized industrial applications where space or design limitations favor radial over axial flow.



Based on Stages of Expansion

1. Single-Stage Turbines

- **Description**: The entire pressure drop occurs in a single set of nozzles and blades. They are simpler in design and construction.
- **Uses**: Small-scale applications where high efficiency is not critical. Suitable for low-pressure steam applications.

2. Multi-Stage Turbines

- **Description**: The pressure drop is divided across multiple sets of nozzles and blades, improving efficiency for high-pressure steam applications. Each stage extracts energy from the steam.
- **Uses**: Large power plants and industrial processes requiring high efficiency. Suitable for high-pressure and high-temperature steam applications.

Based on Steam Conditions

1. Condensing Turbines

- **Description**: Operate with exhaust steam at sub-atmospheric pressures (below ambient). They maximize energy extraction by condensing the steam to water at the turbine's exit, often using a condenser.
- **Uses**: Large power generation plants where maximizing efficiency is critical.

2. Non-Condensing (Back Pressure) Turbines

- **Description**: Exhaust steam remains at or above atmospheric pressure and is utilized for heating or other processes. They provide steam for industrial processes while generating power.

- **Uses**: Industrial processes where steam is needed for both power generation and process heating (cogeneration).

3. Reheat Turbines

- **Description**: Steam is expanded in stages with reheating between stages to improve efficiency and reduce moisture content. Reheating reduces the risk of blade erosion caused by wet steam.
- **Uses**: Large power plants to enhance efficiency and extend the life of turbine components.

4. Extraction Turbines

- **Description**: Allow steam to be extracted at intermediate stages for process heating or other applications, while the remaining steam continues to expand and generate power. This dual-purpose design improves overall plant efficiency.
- **Uses**: Combined heat and power (CHP) systems, industrial processes requiring both mechanical power and steam for heating.

Specialized Types

1. Geothermal Turbines

- **Description**: Designed to operate with geothermal steam, which may contain impurities and have different thermodynamic properties than conventional steam.
- **Uses**: Geothermal power plants, typically located in regions with geothermal activity.

2. Nuclear Turbines

- **Description**: Specifically designed to handle steam produced in nuclear reactors, which can have different pressure and temperature characteristics.

***Uses**: Nuclear power plants, where safety, efficiency, and reliability are paramount.*

Thermodynamic Efficiency (Isentropic Efficiency)

$\eta(\text{isentropic})=h_2-h_2'/h_1-h_2$
where:

- h_1= enthalpy of steam entering the turbine
- h_2'= enthalpy of steam at the exit if the process were isentropic

- h_2 = actual enthalpy of steam at the exit

Mechanical Efficiency

$\eta_{(mechanical)} = W_{output}/W_{input}$

- W_{output} = mechanical work output
- W_{input} = energy input to the turbine.

Overall Efficiency

$\eta_{overall} = \eta_{isentropic} \times \eta_{mechanical}$

Practical Considerations

- **Impulse Turbines**: Typically more efficient at high-pressure, low-flow conditions. Simpler design with easier maintenance.
- **Reaction Turbines**: More efficient at low-pressure, high-flow conditions. Better suited for large power plants with multiple stages.
- **Mixed Type Turbines**: Provide a balance between high efficiency and operational flexibility. Used in large-scale power generation with varying load demands.

Understanding these types and their respective characteristics helps in selecting the most appropriate steam turbine for a given application, optimizing performance and ensuring efficient energy conversion.

Deciding Factors:
- Steam pressure and temperature.
- Load requirements and efficiency.
- Operational speed and maintenance considerations.

2. Gas Turbines
- Gas turbines operate on the Brayton cycle, using compressed air mixed with fuel, combusted to generate high-speed exhaust gases that drive the turbine blades.
Types:
Jet Engines: Used primarily for aircraft propulsion.
-Industrial Gas Turbines: Used for power generation and mechanical drives.
Uses:
- Aircraft propulsion (jet engines).
- Power generation in peaking power plants.
- Mechanical drive in industrial applications like natural gas compressors.
Deciding Factors:
- Fuel type and availability.
- Efficiency and specific power output.
- Environmental considerations (emissions, noise).

3. Water (Hydraulic) Turbines:
- Water turbines convert the energy of flowing or falling water into mechanical energy.
Types:
-Impulse Turbine: Uses the velocity of water to move the blades, water pressure remains constant. Example: Pelton wheel.
-Reaction Turbine: Uses both pressure and velocity of water. Example: Francis and Kaplan turbines.
Uses:
- Hydroelectric power generation.
- Water pumping and irrigation systems.
Deciding Factors:
- Water flow rate and head.
- Efficiency and suitability for varying water levels.
- Environmental impact on aquatic ecosystems.

4. Wind Turbines:
- Wind turbines convert kinetic energy from wind into mechanical energy, which is then typically converted into electrical energy.
Types:
Horizontal Axis Wind Turbine (HAWT): The main rotor shaft and electrical generator are at the top of a tower and must be pointed into the wind.
- Vertical Axis Wind Turbine (VAWT): The main rotor shaft is set vertically, and the main components are located at the base.
Uses:
- Wind power generation.
- Small-scale applications like water pumping and battery charging.

Deciding Factors:
- Wind speed and consistency.
- Site location and land use.
- Environmental impact and noise levels.

Deciding Factors for Differentiating Turbines
1. Working Fluid:
- Steam, gas, water, or air.
2. Energy Source:
- Thermal energy (steam turbines).
- Chemical energy (gas turbines).
- Potential and kinetic energy of water (water turbines).
- Kinetic energy of wind (wind turbines).
3. Design and Operational Principles:
- Impulse vs. reaction turbines.
- Axial vs. radial flow.

4. Application:
- Power generation.
- Mechanical drive.
- Propulsion.

5.Efficiency and Performance:
- Specific to the type of turbine and its application
- Operational efficiency and maintenance requirements.

6. Environmental Impact:
- Emissions (for steam and gas turbines).
- Ecosystem disruption (for water turbines).
- Noise and visual impact (for wind turbines).

7.Cost and Economic Factors**:**
- Initial investment and installation costs
- Operational and maintenance costs.
- Return on investment and lifecycle cost analysis.

Understanding these factors is crucial for selecting the appropriate turbine type for a specific application, ensuring optimal performance, and meeting environmental and economic objectives.

Based on Means of Heat Rejection:

(i) Pass-out or extraction turbine,

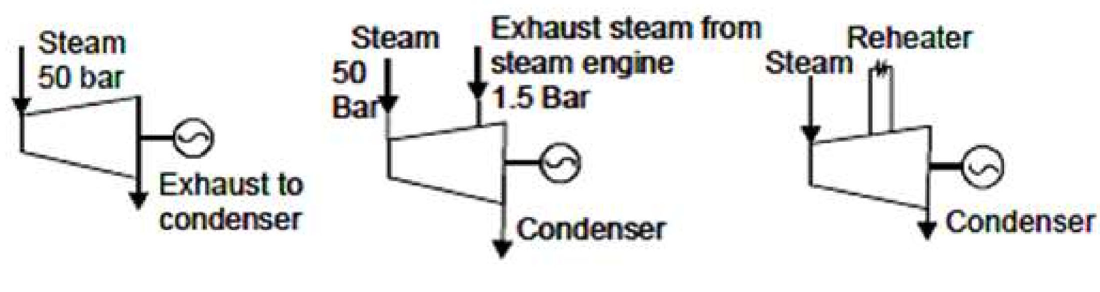
(ii) Regenerative turbine,

(iii) Condensing turbine,

(iv) Non-condensing turbine,

(v) Back pressure or topping turbine.

(i) Pass-Out Turbine: In this turbine, (Fig. 3.12), a considerable proportion of the steam is extracted from some suitable point in the turbine where the pressure is sufficient for use in process heating; the remainder continuing through the turbine. The latter is controlled by separate valve-gear to meet the difference between the pass-out steam and electrical load requirements. This type of turbine is suitable where there is dual demand of steam-one for power and the other for industrial



heating, for example sugar industries. Double pass-out turbines are sometimes used.

Fig 3.12. Pass-Out Turbine

(ii) Regenerative Turbine: This turbine incorporates many extraction branches; through which small proportions of the steam are continuously extracted for heating the boiler feed water in a feed heater in order to increase the thermal efficiency of the plant. Now a day, all steam power plants are equipped with reheating and regenerative arrangement.

(iii) Condensing Turbine: In this turbine, the exhaust steam is condensed in a condenser and the condensate is used as feed water in the boiler. By this way the condensing turbine allows the steam to expand to the lowest possible pressure before being condensed. All steam power plants use this type of turbine.

(iv) Non-Condensing Turbine: When the exhaust steam coming out from the turbine is not condensed but exhausted in the atmosphere is called non-condensing turbine. The exhaust steam is not recovered for feed water in the boiler.

(v) Back Pressure or Topping Turbine: This type of turbine rejects the steam after expansion to the lowest suitable possible pressure at which it is used for heating purpose. Thus, back pressure turbine supplies power as well as heat energy. The back-pressure turbine generally used in sugar industries provides low pressure steam for heating apparatus, where as a topping turbine exhausts into a turbine designed for lower steam conditions.

Based on Number of Cylinders:

(i) Single cylinder and

(ii) Multi-cylinder.

(i) Single Cylinder: When all stages of turbine are housed in one casing, then it is called single cylinder. Such a single cylinder turbine uses one shaft.

(ii) Multi-Cylinder: In large output turbine, the number of the stages needed becomes so high that additional bearings are required to support the shaft. Under these circumstances, multi-cylinders are used.

Based on Arrangement of Cylinder and Based on General Flow of Steam:

(i) Single flow,

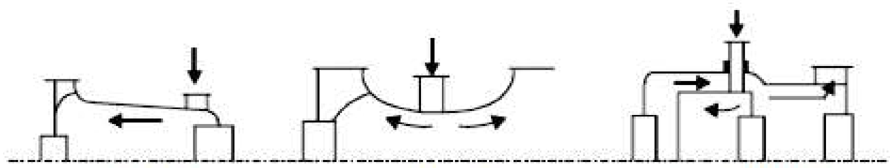
(ii) Double flow, and

(iii) Reversed flow

(i) Single Flow: in a single flow turbine, the steam enters at one end, flows once through the bladings in a direction approximately parallel to this axis, emerges at the other end. High pressure cylinder uses single flow. This is also common in small turbines.

(ii) Double Flow: In this type of turbines, the steam enters at the center and divides, the two portions passing axially away from other through separate sets of blading on the same rotor Fig. 3.13(b). The low-pressure cylinder normally uses double flow). This type of unit is completely balanced against the end thrust and gives large area of flow through two sets of bladings. This also helps in reducing the blade height as mass flow rate becomes half as compared to single flow for the same conditions.

(iii) Reversed Flow: Reversed flow arrangement is sometimes used in h.p, cylinder where higher temperature steam is used on the larger sets in order to minimize differential expansion i.e. unequal expansion of rotor and casing. The



use of single, double and reversed flow is shown in the layout Fig. 3.13(c).

Based on Number of Shafts:

(i) Tandem compound,

(ii) Cross compound

(i)Tandem Compound: Most multi-cylinder turbines drive a single shaft and single generator. Such turbines are termed as tandem compound turbines.

(ii) Cross Compound: In this type, two shafts are used driving separate generator. The may be one of turbine house arrangement, limited generator size, or a desire to run shafting at half speed. The latter choice is sometimes preferred so that for the same centrifugal stress, longer blades may be used, giving a larger leaving area, a smaller velocity and hence a small leaving loss.

Based on Rotational Speed:

(i) Constant speed turbines

(ii) Variable speed turbines

(i) Constant Speed Turbines: Requirements of rotational speed are extremely rigid in turbines which are directly connected to electric generators as these must be a-c unit except in the smallest sizes and must therefore run at speeds corresponding to the standard number of cycles per second and governed by the following equation:

$$N = 120 \times \text{Number of cycles per second} = 120\ f/p$$

Number of poles:

The minimum number of poles, in a generator is two and correspondingly the maximum possible speed for 60 cycles is 3,600 rpm; for 50 c/s of frequency, the speeds would be 3,000, 1500 and 750 rpm for 2, 4 and 8 poles machines respectively.

(ii)Variable Speed Turbines: These turbines have geared units and may have practically any speed ratio between the turbine and the driven machine so that the turbine may be designed for its own most efficient speed. Such turbines are used to drive ships, compressors, blowers and variable frequency generators etc.

Types of Pumps

Pumps are mechanical devices used to move fluids (liquids or gases) by mechanical action. They are essential in various industries and applications, each type tailored to specific needs based on the fluid characteristics and operational requirements. The major types of pumps can be categorized into dynamic pumps and positive displacement pumps.

1. Dynamic Pumps:

Dynamic pumps impart velocity to the fluid, converting kinetic energy into pressure energy.

Types:

Centrifugal Pumps

Description:

- Utilize a rotating impeller to increase the velocity of the fluid, which is then converted to pressure in a volute casing.

Subtypes:

- **Single-stage**: One impeller, used for low head applications.
- **Multi-stage**: Multiple impellers in series, used for high head applications.

Uses:

- Water supply systems.
- Industrial applications.
- HVAC systems.
- Irrigation.

Deciding Factors:

- Flow rate and head requirements.
- Fluid properties (viscosity, temperature).

- Efficiency and maintenance considerations.

b. Axial Flow Pumps

Description:

- Fluid moves parallel to the pump shaft, using axial impellers to generate lift.

Uses:

- High flow, low head applications.
- Flood control.
- Circulating water in power plants.

Deciding Factors:

- High flow rate requirement.
- Low head and large volume applications.
- Efficiency at low pressure.

c. Mixed Flow Pumps

Description:

- Combine features of centrifugal and axial flow pumps, with fluid flowing in both radial and axial directions.

Uses:

- Moderate head and flow applications.
- Irrigation and drainage systems.

Deciding Factors:

- Moderate head and flow requirements.
- Efficiency over a range of conditions.

2. Positive Displacement Pumps

Positive displacement pumps move a fixed amount of fluid per cycle, providing consistent flow regardless of pressure variations.

Types:

a. Reciprocating Pumps

Description:

- Use a piston or diaphragm to displace fluid in a cylinder, creating a pulsating flow.

Subtypes:

- **Piston Pumps**: Use a piston and cylinder.
- **Diaphragm Pumps**: Use a flexible diaphragm.

Uses:

- High-pressure applications.
- Chemical injection.
- Water supply in remote areas.

Deciding Factors:

- High pressure and precise flow control.
- Fluid characteristics (corrosive, viscous).
- Pulsating flow acceptable.

b. Rotary Pumps

Description:

- Use rotating elements (gears, screws, vanes) to move fluid.

Subtypes:

- **Gear Pumps**: Use meshing gears to pump fluid.
- **Screw Pumps**: Use one or more screws to move fluid.
- **Vane Pumps**: Use vanes mounted on a rotor.

Uses:

- Lubrication systems.
- Fuel transfer.
- Hydraulic systems.

Deciding Factors:

- Viscous fluids handling.
- Continuous, smooth flow.
- Compact design and reliability.

Deciding Factors for Differentiating Pumps

1. **Fluid Properties**:
   - Viscosity, temperature, corrosiveness, and particulates.
2. **Flow Rate and Pressure**:
   - Required flow rate and head (pressure) for the application.
3. **Efficiency and Performance**:
   - Overall efficiency and specific energy consumption.
   - Performance characteristics (flow vs. head curve).
4. **Application and Environment**:
   - Industrial, agricultural, commercial, or domestic use.
   - Environmental conditions (e.g., outdoor vs. indoor, hazardous locations).
5. **Maintenance and Reliability**:
   - Maintenance frequency and ease.
   - Reliability and lifespan.
6. **Cost and Economic Factors**:
   - Initial cost and installation.
   - Operating and maintenance costs.
   - Return on investment and total cost of ownership.

Uses and Applications

- **Centrifugal Pumps**: Widely used in water supply, HVAC, industrial processes, and irrigation due to their simplicity and efficiency.
- **Axial Flow Pumps**: Suitable for high flow, low head applications like flood control and circulating water in power plants.
- **Mixed Flow Pumps**: Versatile for moderate head and flow applications in irrigation and drainage systems.
- **Reciprocating Pumps**: Ideal for high-pressure, low-flow applications such as chemical injection and remote water supply.
- **Rotary Pumps**: Best for handling viscous fluids in lubrication systems, fuel transfer, and hydraulic systems.

By understanding the specific requirements of an application and the characteristics of the various pump types, one can select the most appropriate pump to ensure efficient and reliable operation.

PUMPS AND TURBINES ARE CONNECTED THROUGH DIFFERENT TYPES OF **COUPLING**. Direct shaft connection may not be efficient because of torque generation

<u>COUPLING :</u>

Functions of Coupling

1. **Power Transmission**: Couplings transmit torque and rotary motion from one shaft to another.
2. **Misalignment Accommodation**: They allow for slight misalignments between connected shafts.
3. **Vibration Dampening**: Couplings can absorb and dampen vibrations and shocks between connected components.
4. **Overload Protection**: Some couplings provide protection by disconnecting the shafts during overload conditions, preventing damage.
5. **Ease of Maintenance**: Couplings facilitate easier assembly and disassembly of machinery for maintenance purposes.

Types of Coupling

1. **Rigid Couplings**:
    - **Flange Coupling**: Consists of two flanges, one on each shaft, bolted together. Suitable for precisely aligned shafts.
    - **Sleeve or Muff Coupling**: A simple cylindrical sleeve that fits over the ends of both shafts. It is used where minor misalignment is acceptable.
    - **Clamp or Split Muff Coupling**: Similar to sleeve coupling but split into two halves for easier assembly.

2. **Flexible Couplings**:
    - **Jaw Coupling**: Consists of two metal hubs and an elastomer insert, providing flexibility and shock absorption.
    - **Oldham Coupling**: Uses a central disk that slides between two hubs with grooves, allowing for parallel misalignment.
    - **Universal Joint**: Allows for large angular misalignments between shafts, commonly used in automotive drive shafts.
    - **Disc Coupling**: Uses a series of thin metal discs to transmit torque while accommodating misalignment.

3. **Fluid Couplings**:
    - **Hydrodynamic Coupling**: Uses a fluid medium to transmit torque between the driving and driven shafts. Provides smooth torque transmission and overload protection.
    - **Torque Converter**: A type of fluid coupling with a stator, used in automatic transmissions to multiply torque.

4. **Special Purpose Couplings**:

    - **Magnetic Coupling**: Uses magnetic fields to transmit torque without direct contact between shafts. Suitable for sealed or sterile environments.
    - **Gear Coupling**: Uses toothed gears to connect shafts, allowing for high torque transmission and some misalignment.

Selection Criteria for Couplings

1. **Torque Requirements**: The coupling must be able to handle the torque generated by the machinery.
2. **Misalignment Tolerance**: The degree of angular, parallel, and axial misalignment the coupling can accommodate.
3. **Operating Conditions**: Consideration of temperature, environment, and presence of chemicals or abrasives.
4. **Speed**: The rotational speed of the shafts, as high-speed applications may require special balancing.
5. **Maintenance and Reliability**: Ease of installation, maintenance requirements, and reliability under operating conditions.
6. **Cost**: Balancing performance requirements with budget constraints.

Coupling Alignment

Proper alignment of coupled shafts is crucial for the longevity and performance of the coupling and connected machinery. Misalignment can lead to excessive wear, vibration, and premature failure.

1. **Angular Misalignment**: Occurs when the axes of the two shafts are at an angle to each other.
2. **Parallel Misalignment**: Occurs when the axes of the shafts are parallel but offset.
3. **Axial Misalignment**: Occurs when the shafts move closer together or farther apart along their.

1. **Maintenance**:

    - Regular inspection for signs of wear, misalignment, or damage.
    - Lubrication of flexible elements, if applicable.
    - Periodic alignment checks and adjustments.
    - Replacement of worn or damaged components to prevent failure.

Understanding the functions, types, selection criteria, alignment, and maintenance of couplings is essential for the efficient and reliable operation of mechanical systems. Properly selected and maintained couplings can significantly enhance the performance and lifespan of machinery.

Hydraulic Coupling:

A hydraulic coupling, also known as a fluid coupling, is a hydrodynamic device used to transmit rotating mechanical power. It provides smooth torque transmission by using fluid dynamics rather than direct mechanical contact. This type of coupling is widely used in various applications, including automotive, industrial, and marine equipment.

Key Features of Hydraulic Coupling:

Smooth Power Transmission: Uses fluid to transmit torque, ensuring smooth acceleration and deceleration.

Shock Absorption: Dampens shocks and vibrations, protecting the mechanical system from sudden loads.

Overload Protection: Limits the maximum torque transmitted to prevent damage during overload conditions.

No Mechanical Wear: Absence of direct mechanical contact between the driving and driven components reduces wear and maintenance.

Components of Hydraulic Coupling:

Pump (Impeller): The driving component connected to the input shaft. It accelerates the fluid, converting mechanical energy into kinetic energy.

Turbine (Runner): The driven component connected to the output shaft. It receives the kinetic energy from the fluid and converts it back into mechanical energy.

Housing: Encloses the pump and turbine and contains the working fluid (usually oil or another hydraulic fluid).

Working Fluid: The medium through which energy is transferred. Its properties, such as viscosity, significantly influence the coupling's performance.

Working Principle:

Fluid Dynamics: When the input shaft rotates, the pump impeller spins, causing the fluid to flow outward due to centrifugal force.

Energy Transfer: The moving fluid carries kinetic energy, which is transferred to the turbine runner, causing it to rotate.

Output Shaft Rotation: The turbine's rotation drives the output shaft, transmitting torque and power from the input to the output.

Speed and Torque Regulation: The fluid coupling automatically adjusts the speed and torque transmitted based on the load and input speed, ensuring smooth operation.

Advantages of Hydraulic Coupling:

Smooth Operation: Provides gradual acceleration and deceleration, reducing mechanical stress.

Protection Against Overloads: Automatically slips under excessive load, preventing damage to the system.

Dampening of Vibrations: Absorbs shocks and vibrations, improving system stability and longevity.

Low Maintenance: Fewer mechanical parts subject to wear, reducing maintenance requirements.

Applications:

Automotive: Used in automatic transmissions and torque converters to provide smooth gear changes and efficient power transfer.

Industrial Machinery: Applied in conveyor systems, crushers, and mills to handle varying loads and ensure consistent operation.

Marine Propulsion: Utilized in ship drives to transmit power from the engine to the propeller smoothly.

Power Generation: Employed in auxiliary drives and coupling generators to prime movers.

Types of Hydraulic Couplings:

Constant-Fill Fluid Couplings: Always filled with a specific amount of fluid. Suitable for applications requiring constant speed.

Variable-Fill Fluid Couplings: Fluid level can be adjusted during operation to control the amount of torque transmitted, allowing for more flexibility in controlling output speed and torque.

Key Considerations:

Fluid Characteristics: The type and properties of the working fluid (e.g., viscosity, temperature stability) significantly affect the coupling’s performance.

Operating Environment: Consideration of temperature, pressure, and potential contaminants that may affect the fluid and coupling components.

Torque and Speed Requirements: Selection based on the specific torque and speed requirements of the application to ensure optimal performance.

Hydraulic couplings play a crucial role in applications requiring smooth and controlled power transmission, offering significant advantages in terms of shock absorption, overload protection, and low maintenance.

Cavitation:

Cavitation is a phenomenon that occurs in a fluid flow system when the local pressure drops to the vapor pressure of the fluid, leading to the formation of vapor bubbles. These bubbles can collapse violently when they move to higher pressure regions, causing noise, vibrations, and potentially severe damage to the equipment, such as pumps, turbines, and propellers.

Key Concepts of Cavitation

1. Vapor Pressure: The pressure at which a liquid turns into vapor at a given temperature. Cavitation occurs when the local fluid pressure drops below the vapor pressure.
2. Nucleation: The initial stage where vapor bubbles form in the liquid. Nucleation can be homogeneous (within the liquid) or heterogeneous (at solid boundaries or impurities).
3. Growth and Collapse: Once formed, vapor bubbles grow in low-pressure regions. When they move to high-pressure areas, they collapse, releasing energy and causing potential damage.

4**. Effects of Cavitation:**

- Noise and Vibration: Cavitation can produce loud noise and vibrations.

- Damage: The collapse of bubbles near solid boundaries can cause pitting and erosion.

- Performance Loss: Cavitation reduces the efficiency of hydraulic machinery by disrupting the smooth flow of fluid.

Factors Affecting Cavitation:

1. Fluid Properties: Vapor pressure, temperature, and viscosity.

2. Flow Velocity: Higher velocities can lead to pressure drops that cause cavitation.

3. System Design: Sharp turns, obstructions, and rapid expansions or contractions in flow paths can create conditions conducive to cavitation.

4. Pressure Conditions: Lowering the inlet pressure or increasing the outlet pressure can contribute to cavitation.

Net Positive Suction Head (NPSH)

NPSH is a critical concept in understanding and preventing cavitation in pumps.

1. NPSH Available (NPSHA):

- The actual pressure energy available at the pump suction to prevent cavitation.
- Calculated using the formula:

$NPSHA = P_{atm}/\rho g + V_s^2/2g - P/\rho g - H_f$

Where:

- P_{atm} = Atmospheric pressure.
- ρ = Density of the fluid.
- g = Gravitational acceleration.
- V_s = Suction velocity.
- P_V = Vapor pressure of the fluid.
- H_f = Head losses in the suction line.

2. NPSH Required (NPSHR):

- The minimum pressure energy required at the pump suction to avoid cavitation, as specified by the pump manufacturer.
- This is a characteristic of the pump and depends on the pump design and operating conditions.

Relation between NPSHR and NPSHA for Cavitation

To prevent cavitation in a pump system, the following condition must be satisfied:

NPSHA > NPSHR

- NPSHA > NPSHR: If the available NPSH is greater than the required NPSH, the pressure at the pump suction is sufficient to prevent cavitation. This ensures the fluid does not reach its vapor pressure and vapor bubbles do not form.

- NPSHA < NPSHR: If the available NPSH is less than the required NPSH, cavitation is likely to occur. This means the suction pressure is not high enough to keep the fluid in the liquid state, leading to the formation of vapor bubbles and the associated problems.

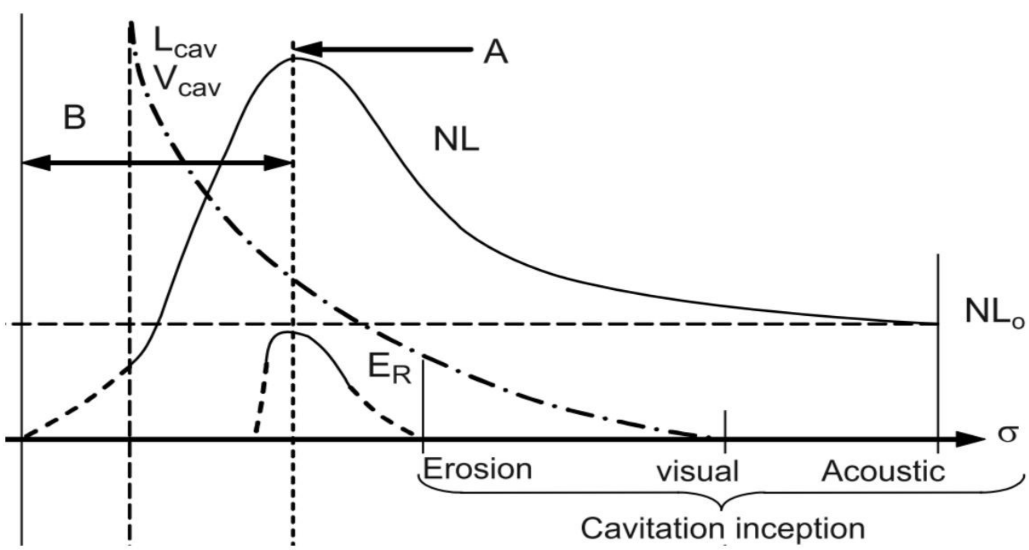
Preventing Cavitation

1. **Increase NPSHA:**
   - Increase the fluid level in the supply tank.
   - Reduce suction line losses by using larger diameter pipes or shorter lengths.
   - Minimize flow obstructions and sharp bends.

2. **Decrease NPSHR:**
   - Use a pump with a lower NPSHR for the given operating conditions.
   - Operate the pump within its recommended flow range.

3. **Control Fluid Properties:**
   - Lower the temperature of the fluid to reduce its vapor pressure.
   - Ensure the fluid is free of impurities and gases that might facilitate nucleation.

Understanding and managing NPSH is crucial for the reliable and efficient operation of pumps and preventing the detrimental effects of cavitation in fluid systems.



Coupling refers to a mechanical device used to connect two shafts together at their ends for the purpose of transmitting power. Couplings are essential in rotating machinery and play a critical role in the efficient transfer of energy between different components of a mechanical system.

COOLERS:

Coolers are devices used to remove heat from systems and components. They are essential in various industries to maintain optimal operating temperatures. Here are some common types of coolers:

1. **Air-Cooled Heat Exchangers**:
   - **Mechanism**: Uses air to dissipate heat from the system.
   - **Applications**: Automotive radiators, air conditioning systems.
   - **Advantages**: Simple design, no need for water supply.
   - **Disadvantages**: Less efficient in hot environments, requires airflow.

   COOLING TOWER:

2. **Water-Cooled Heat Exchangers**:
   - **Mechanism**: Uses water to absorb and carry away heat.
   - **Applications**: Power plants, marine engines, industrial machinery.
   - **Advantages**: More efficient cooling, suitable for high heat loads.

  - **Disadvantages**: Requires a continuous water supply, potential for corrosion and fouling.
3. **Evaporative Coolers**:
  - **Mechanism**: Uses the evaporation of water to cool the air.
  - **Applications**: Residential and commercial cooling, data centers.
  - **Advantages**: Energy-efficient, environmentally friendly.
  - **Disadvantages**: Dependent on humidity levels, requires water supply.
4. **Shell and Tube Heat Exchangers**:
  - **Mechanism**: Uses a series of tubes within a shell to transfer heat between two fluids.
  - **Applications**: Oil refineries, chemical plants, HVAC systems.
  - **Advantages**: High heat transfer efficiency, handles high pressures.
  - **Disadvantages**: Larger footprint, potential for fouling.
5. **Plate Heat Exchangers**:
  - **Mechanism**: Uses thin plates to transfer heat between fluids.
  - **Applications**: Food processing, pharmaceuticals, HVAC systems.
  - **Advantages**: Compact design, high heat transfer efficiency.
  - **Disadvantages**: Limited to lower pressure applications, prone to fouling.
6. **Radiators**:
  - **Mechanism**: Uses fins to increase the surface area for heat dissipation.
  - **Applications**: Automotive engines, power transformers.
  - **Advantages**: Effective cooling, simple design.
  - **Disadvantages**: Requires airflow, can be bulky.
7. **Cooling Towers**:
  - **Mechanism**: Uses evaporation to cool water by exposing it to air.
  - **Applications**: Industrial cooling, power plants, HVAC systems.
  - **Advantages**: Efficient for large-scale cooling, reduces water temperature effectively.
  - **Disadvantages**: Requires large space, potential for water loss and drift.
8. **Thermoelectric Coolers**:
  - **Mechanism**: Uses the Peltier effect to create a temperature difference.
  - **Applications**: Electronic cooling, portable coolers, medical devices.
  - **Advantages**: Compact, precise temperature control.
  - **Disadvantages**: Limited cooling capacity, less efficient than traditional methods.

Each type of cooler has its own specific applications, advantages, and disadvantages, making them suitable for different environments and requirements.

Heat Exchangers:

A heat exchanger is a device designed to efficiently transfer heat from one medium to another. The media involved can be gases, liquids, or a combination of both, and they may be separated by a solid wall to prevent mixing or they may be in direct contact. Heat exchangers are widely used in various industries and applications where thermal energy needs to be transferred between fluids.

Types of Heat Exchangers

1. **Shell and Tube Heat Exchanger**:
   - **Design**: Consists of a series of tubes, one set carrying the hot fluid and the other the cold fluid. The tube bundle is enclosed within a cylindrical shell.
   - **Applications**: Oil refineries, chemical processing, power plants.
   - **Advantages**: High efficiency, can handle high pressure and temperature differences, easy to clean and maintain.

2. **Plate Heat Exchanger**:
   - **Design**: Made up of multiple thin, corrugated plates stacked together, forming channels for the fluids to flow through.
   - **Applications**: HVAC systems, refrigeration, food and beverage processing.
   - **Advantages**: Compact size, high heat transfer efficiency, easy to expand capacity by adding more plates.

3. **Air Cooled Heat Exchanger**:
   - **Design**: Uses ambient air to cool the fluid, typically consisting of finned tubes and a fan to enhance air flow.
   - **Applications**: Power plants, petrochemical plants, air conditioning systems.
   - **Advantages**: Eliminates the need for water cooling, suitable for remote and arid areas, lower operational costs.

4. **Double Pipe Heat Exchanger**:
   - **Design**: Comprises two concentric pipes, with one fluid flowing through the inner pipe and the other through the annulus between the pipes.
   - **Applications**: Small-scale industrial processes, laboratory applications.
   - **Advantages**: Simple design, easy to construct and maintain, suitable for small heat transfer areas.

5. **Plate-Fin Heat Exchanger**:
   - **Design**: Uses fins to increase the surface area for heat transfer, and plates to separate the fluids.

- **Applications**: Aerospace, automotive, cryogenics.
- **Advantages**: High heat transfer efficiency, lightweight, suitable for high-pressure applications.

6. **Regenerative Heat Exchanger**:
    - **Design**: Uses a thermal storage medium (such as a matrix of material) that alternately absorbs and releases heat from the fluids.
    - **Applications**: Waste heat recovery systems, gas turbines.
    - **Advantages**: Efficient for cyclic processes, can achieve high effectiveness.

7. **Condensers and Evaporators**:
    - **Design**: Specialized heat exchangers where phase change occurs, commonly used in refrigeration and air conditioning systems.
    - **Applications**: HVAC systems, refrigeration units, power plants.
    - **Advantages**: Effective in phase change heat transfer, compact and efficient.

Key Factors in Heat Exchanger Design

1. **Heat Transfer Coefficient**: A measure of the heat transfer capability of the exchanger. Higher coefficients indicate better performance.

2. **Temperature Difference**: The driving force for heat transfer. Larger temperature differences enhance heat transfer rates.
3. **Flow Arrangement**:
    - **Counterflow**: Fluids flow in opposite directions, maximizing the temperature difference and heat transfer efficiency.
    - **Parallel Flow**: Fluids flow in the same direction, resulting in lower heat transfer efficiency.
    - **Crossflow**: Fluids flow perpendicular to each other, commonly used in air-cooled exchangers.

4. **Pressure Drop**: The resistance to fluid flow through the exchanger. Lower pressure drops are desirable for energy efficiency.

5. **Material Selection**: Materials must withstand operating temperatures, pressures, and potential corrosive environments. Common materials include stainless steel, copper, and aluminum.

Applications of Heat Exchangers

1. **Power Generation**:

- **Steam Turbines**: Heat exchangers are used to condense steam and preheat feedwater.
- **Nuclear Reactors**: Transfer heat from the reactor core to the steam generator.

2. **HVAC Systems**:

   - **Air Conditioners and Heaters**: Use evaporators and condensers to transfer heat between indoor and outdoor environments.
   - **Ventilation Systems**: Heat exchangers recover heat from exhaust air to preheat incoming fresh air.

3. **Chemical and Petrochemical Industry**:

   - **Distillation Columns**: Heat exchangers are used for condensing vapors and reboiling liquids.
   - **Reactors**: Maintain optimal reaction temperatures by removing or supplying heat.

4. **Food and Beverage Industry**:

   - **Pasteurization**: Heat exchangers quickly heat and cool products to kill pathogens.
   - **Fermentation**: Control temperatures in fermentation tanks to optimize yeast activity.

5. **Automotive Industry**:

   - **Engine Cooling**: Radiators dissipate heat from the engine coolant to the atmosphere.
   - **Air Conditioning**: Use evaporators and condensers to control cabin temperature.

6. **Marine Applications**:

Ship Propulsion: Heat exchangers cool engine and generator systems.

IMPORTANT NOTABLE EQUPMENTS IN THERMAL POWER PLANT.

CONDENSATE EXTRACTION PUMPS:

The function of these pumps is to pump the condensate to the deaerator through gland steam condenser, drain cooler and LP heaters. In KTPP, 1x500MW unit, 3pumps are installed, having a pumping capacity of 50%each. Two pumps are for normal operation and one is standby. Since the suction is at a negative pressure, the special arrangements have been made for providing sealing to glands.

5.5.1 SPECIFICATIONS

	CONDENSATE EXTRACTION PUMPS		
1	Number of pumps per STG unit	No.	3X50%(2 working, 1 stdby)
2	Type of pump		Vertical, canister type
3	Design capacity per pump	m^3/h	775
4	Run-out flower per pump	m^3/h	830
5	Minimum flow per pump	m^3/h	200
6	Total head at design capacity	mlc	265
7	Pump efficiency at design point	%	81
8	Drive motor rating	KW	900

DESCRIPTION

The condensate extraction pumps are of the vertical centrifugal canister type with the driving motor supported on a fabricated motor stool. The motor is supported on a fabricated head piece which is secured to a fabricated canister. The canister is secured to a foundation ring which is held to the floor with nuts on foundation bolts.

The pump stage casings from an interconnected assembly which is attached to the underside of the head piece and is suspended within the canister. The head piece is provided with a stuffing box which contains a mechanical seal to prevent pump leakage. Small bore pipe work, for sealing purpose, is connected to the stuffing box. The head piece also supports the water cooled oil lubricated thrust and journal bearing.

The pump discharge branch and vent pipe are integral with the head piece and the pump suction branch is integral with the canister. The motor stool, secured to the top of the head piece, supports the driving motor. Cooling water pipe work along with the oil filling/vent pipe and gauge glass extension pipe are attached to the motor stool.

Apertures formed on the motor stood and head piece provide access to the coupling thrust bearing and mechanical seal.

The motor shaft is connected to a top shaft via a flexible spacer coupling and the top shaft connects to connect to the intermediate shaft via a solid muff coupling. The intermediate shaft in turn is connected to a bottom shaft through muff coupling. The top shaft passes through the combined thrust and journal bearing and stuffing box, and also carries the fourth to sixth stage rotating assemblies. The intermediate shaft carries second and third stage rotating assemblies. The bottom shaft carries the first stage rotating assembly. The shafts are supported by two cut less rubber bearings at the first stage and by a single cut less rubber bearing at the second to sixth stages. The thrust bearing absorbs the downward axial thrust from the pump rotating assembly, and the white metal lined journal bearing with in the thrust bearing assembly supports the shafts along with the cut less rubber journal bearing within each intermediate stage assembly and element assembly.

A snubber secured into the bottom of the canister engages the suction bell mouth fitted to the first stage casing. This arrangement provides support to the bottom end of the pump.

VACUUM PUMP

The vacuum pump is a two-stage liquid ring type pump. Rotor revolves without metal contact in a circular body that contains a liquid compressant. The rotor is eccentrically fitted into the circular body. So during each revolution liquid compressant will be compressed (discharge of air) to atmosphere and expanded (suction of air from the system). Evacuated air discharge by the first stage of vacuum pump finds way to second stage manifold.

Fig. 5.3 VACUUM PUMP

During normal vacuum operation, a check valve in the 2nd stage discharge manifold allows the incoming air & compressant from 1st stage directly to outside separator bypassing the second stage. During low vacuum operation, a check valve closes allowing the 1st stage discharge into 2nd stage suction, the air and compressant from 2nd stage is discharged to the separator. Circulating water pump sucks seal water from the separator tank. The tank level is maintained automatically by an external DM water source through a float operated make-up valve. The discharge of the pump passes through a strainer and water to water cooler and is fed to vacuum pump for liquid ring formation and stuffing box sealing and lubrication.

GLAND STEAM CONDENSER (GSC)

Gland steam condenser is a shell & tube type heat exchanger having water boxes on both side and stainless tubes for heat exchanger surface**.** Gland steam leak from the turbines is provided to the GSC shell side to exchange the heat with condensate (water) flowing through the tubes of GSC for the criteria of efficiency of the boiler. Here condensate gains the temperature of 47.6^0C.

NON -RETURN VALVE:

A non-return valve (NRV), also known as a check valve, allows fluid to flow in one direction only, preventing backflow. Here are some common types of non-return valves:

1. **Swing Check Valve**:
   - **Mechanism**: Uses a hinged disc that swings open when fluid flows in the correct direction and closes when flow reverses.
   - **Advantages**: Simple design, suitable for low-pressure applications.
   - **Disadvantages**: Slower response to backflow.
2. **Lift Check Valve**:
   - **Mechanism**: Uses a disc that lifts off its seat to allow forward flow and falls back onto the seat to prevent reverse flow.
   - **Advantages**: Reliable sealing, suitable for high-pressure applications.
   - **Disadvantages**: Requires a higher pressure differential to open.
3. **Ball Check Valve**:
   - **Mechanism**: Uses a ball that moves to open or close the valve based on the direction of flow.
   - **Advantages**: Simple and compact, good for viscous fluids.
   - **Disadvantages**: Limited to smaller applications and lower flow rates.
4. **Diaphragm Check Valve**:
   - **Mechanism**: Uses a flexible diaphragm that opens when the fluid flows forward and closes when flow reverses.
   - **Advantages**: Can handle contaminants, good for sanitary applications.
   - **Disadvantages**: Limited to low-pressure applications.
5. **Wafer Check Valve**:
   - **Mechanism**: Thin, compact design that fits between flanges; can use swing or dual plate mechanisms.
   - **Advantages**: Lightweight, minimal space requirement.
   - **Disadvantages**: Requires careful alignment during installation.
6. **Duckbill Check Valve**:
   - **Mechanism**: A rubber valve that opens to allow flow and closes to prevent backflow, resembling a duck's beak.

- **Advantages**: Simple design, resistant to clogging, suitable for slurries and wastewater.
- **Disadvantages**: Limited to low-pressure applications.

Each type of non-return valve has its own advantages and disadvantages, making them suitable for different applications based on factors like pressure, flow rate, and the nature of the fluid.

LUBE OIL PUMP:

Lube oil pumps are essential components in machinery and engines, ensuring the proper circulation of lubricating oil to reduce friction and wear. Here are some short notes on various types of lube oil pumps:

1. **Gear Pump**:
    - **Mechanism**: Uses meshing gears to pump oil.
    - **Advantages**: Simple design, reliable, suitable for high-pressure applications.
    - **Disadvantages**: Can be noisy, may wear out over time.
2. **Vane Pump**:
    - **Mechanism**: Uses vanes mounted on a rotor to create suction and discharge.
    - **Advantages**: Smooth and quiet operation, good for moderate pressures.
    - **Disadvantages**: Sensitive to contamination, requires clean oil.
3. **Gerotor Pump**:
    - **Mechanism**: Uses an inner and outer rotor with a different number of teeth to move oil.
    - **Advantages**: Compact, efficient, and provides a steady flow.
    - **Disadvantages**: Limited to low to moderate pressures, complex design.
4. **Plunger Pump**:
    - **Mechanism**: Uses a plunger or piston to displace oil.
    - **Advantages**: High pressure capabilities, precise flow control.
    - **Disadvantages**: More complex and expensive, can be noisy.
5. **Centrifugal Pump**:
    - **Mechanism**: Uses an impeller to create centrifugal force, moving oil radially outward.
    - **Advantages**: High flow rates, simple and durable.
    - **Disadvantages**: Not suitable for high-pressure applications, efficiency drops with viscous oils.

Lube oil pumps are critical for maintaining the lubrication and cooling of moving parts in engines and machinery, ensuring efficient operation and prolonging the lifespan of equipment.

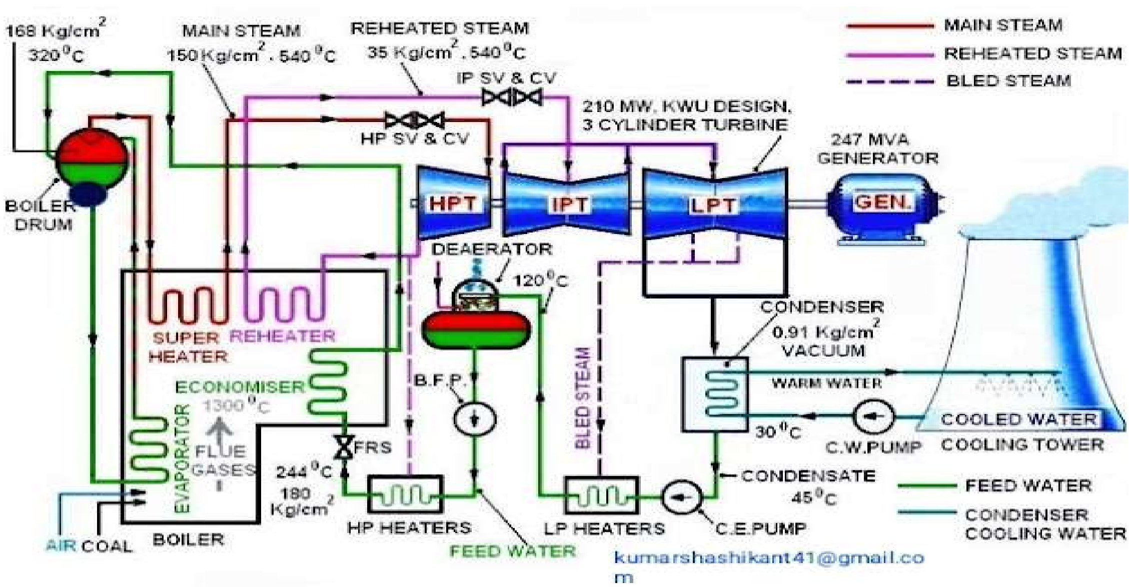
JACKING OIL PUMP:

Jacking oil pumps are specialized pumps used to lift or jack up heavy machinery, such as turbine shafts, to reduce friction during startup and shutdown. Here are some short notes on jacking oil pumps:

1. **Purpose**:
   - **Function**: Provides high-pressure oil to lift heavy rotating equipment slightly off their bearings, reducing metal-to-metal contact.
   - **Applications**: Commonly used in large turbines, generators, and heavy industrial machinery.
2. **Operation**:
   - **Mechanism**: Delivers high-pressure oil (often in the range of 150-400 bar) to bearing surfaces.
   - **Process**: Typically used during the startup and shutdown phases when rotational speeds are low and lubrication is critical.
3. **Types**:
   - **Piston Pump**: Utilizes pistons to generate high pressure.
   - **Plunger Pump**: Similar to piston pumps but uses plungers for higher pressure capabilities.
   - **Hydraulic Pump**: Uses hydraulic mechanisms to generate the required pressure.
4. **Advantages**:
   - **Reduced Wear**: Minimizes friction and wear on bearings during critical phases of operation.
   - **Improved Efficiency**: Ensures smoother startup and shutdown processes.
   - **Enhanced Reliability**: Prevents damage to expensive machinery components.
5. **Disadvantages**:
   - **Complexity**: Additional system complexity and maintenance requirements.
   - **Cost**: Higher initial costs due to specialized equipment and installation.

Jacking oil pumps are vital for protecting and extending the lifespan of heavy machinery by providing necessary lubrication and reducing friction during the most vulnerable operational phases.

KTPP 500MW POWER GENERATION OVERVIEW



Technical Data:

Rated load	500MW
Rated speed	50.0 c/s
Single flow HP Turbine	with 17 reaction stages
Double flow IP Turbine	with 12 reaction stages per flow
Double flow LP Turbine	with 6 reaction stages per flow
HP casing	2 Main Stop and Control valves mounted

STEAM-PRESSURE :

Initial Steam	166.7 bar
Before 1 HP drum stage	154.4 bar
HP cylinder exhaust	44.03 bar
IP cylinder stop valve inlet	39.63 bar
Extraction6	44.03 bar
Extraction 5	17.02 bar
Extraction 4	6.9 bar
Extraction 3	2.75 bar
Extraction 2	1.47 bar
Extraction 1	0.339 bar
LP cylinder exhaust	0.0953 bar

***All pressures are absolute pressures**

STEAM TEMPERATURE:

HP turbine inlet	535 °C
HP turbine exhaust	338.9 °C
Extraction 6	338.9 °C
Extraction 5	414.8 °C
Extraction 4	290.9 °C
Extraction 3	191.4 °C
Extraction 2	133.4 °C
Extraction 1	70.9 °C
LP turbine exhaust	44.9 °C

PERFORMING ANALYSIS AND EFFICIENCY CALCULATIONS OF STEAM TURBINE

POWER PRODUCED BY HPT, IPT AND LPT

500 MW 0%MU 33°C COOLING WATER TEMP

		PRESSURE (Abs. Gauge)	TEMP.	QUA-LITY	MASS FLOW RATE	ENTHALPY		ISENTRO--PIC ENTHALPY	ACTUAL ENTHALPY DROP	ISENTROPIC ENTHALPY DROP	POWER OUTPUT	NET POWER OUTPUT	% POWER SHARING	INTERNAL EFFICIENCY
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	-	% η
UNITS		Kg/cm²	°C	-	T/hr	kCal/kg	kJ/Kg	kJ/Kg	kJ/Kg	kJ/Kg	MW	MW	%	-
HPT	**INLET**	170	537	-	1496.8	811.1	3393.6		338.485	380.942		**140.738**	**27.7**	**88.85**
	OUTLET	45.02	339.9	-	1333.9	730.2	3055.1	3012.70			140.738			
	Ext-6	45.02	339.9	-	157.45	730.2	3055.1							
IPT	**INLET**	40.52	537	-	1333.9	843.3	3528.3		489.109	522.427		**175.47**	**34.53**	**93.62**
	Ext-5	17.51	415	--	85.148	784.7	3283.1				90.85			
	OUTLET	7.18	291.3	-	1115.2	726.4	3039.2	3005.94			84.62			
	Ext-4	7.18	291.3	-	136.49	726.4	3039.2							
LPT	**INLET**	7.18	291.3	-	1115.2	726.4	3039.2		667.348	735.746		**191.82**	**37.75**	**90.70**
	Ext-3	2.843	191.7	-	41.244	680.7	2848.0				59.23			
	Ext-2	1.527	133.9	-	75.784	654.5	2738.4				32.70			
	Ext-1	0.355	-	0.953	42.078	602.4	2520.4				60.44			
	OUTLET	0.1033	-	0.911	956.80	566.9	2371.9	2303.511			39.44			
		TOTAL										*508.034*	*100*	

500MW 0%MU 33^0C COOLING WATER TEMP.

Calculations:

POWER CALCULATIONS:

h_{IN}= Enthalpy at inlet

h_{OUT} = Enthalpy at outlet

h_s = Isentropic Enthalpy at outlet

HIGH PRESSURE TURBINE:

Mass Flow Rate (m) = 1496.8 T/hr
Enthalpy at Inlet (h_{IN}) = 3393.6 kJ/kg
Enthalpy at Outlet (h_{OUT}) = 3055.1KJ/kg

Power Output of HPT = 140.738 MW

INTERMEDIATE PRESSURE TURBINE:

From IPT Inlet to Extraction-5:

Mass Flow Rate (m) = 1333.9 T/hr
Enthalpy at Inlet (h_{IN}) = 3528.3 KJ/kg
Enthalpy at Outlet (h_{OUT}) = 3283.1 KJ/kg
Power Output = 90.85 MW

From Extraction-5 to IPT Outlet:

Mass Flow Rate (m) = 1248.752T/hr
Enthalpy at Inlet (h_{IN}) = 3283.1KJ/kg
Enthalpy at Outlet (h_{OUT}) = 3039.2KJ/kg
Power Output = 84.62MW

Total Power Output of IPT =175.47

LOW PRESSURE TURBINE:

From LPT Inlet to Extraction-3:

Mass Flow Rate (m) = 1115.2T/hr
Enthalpy at Inlet (h_{IN}) = 3039.2kJ/Kg
Enthalpy at Outlet (h_{OUT}) = 2484 kJ/Kg
Power Output = 59.23MW

From Extraction-3 to Extraction-2:

Mass Flow Rate (m) =1073T/hr
Enthalpy at Inlet (h_{IN}) = 2848 Kj/kg

Enthalpy at Outlet (h_{OUT}) =2738.4 KJ/kg

Power Output = 32.70MW

From Extraction-2 to Extraction-1:

Mass Flow Rate (m) = 997.216T/hr
Enthalpy at Inlet (h_{IN}) = 2738.4 kJ/Kg

Enthalpy at Outlet (h_{OUT}) = 2520.4 kJ/Kg

Power Output = 39.44 MW

From Extraction-1 to LPT Outlet:

Mass Flow Rate (m) = 955.13T/hr
Enthalpy at Inlet (h_{IN}) = 2520.4kJ/Kg

Enthalpy at Outlet (h_{OUT}) = 2371.9kJ/Kg

Power Output = 39.44MW

Total Power Output of LPT = 191.82MW

Total Power Output of all turbines = Total Power Output of (HPT+LPT+IPT)

=508.034

% POWER SHARING CALCULATIONS:

% Power sharing by HPT=27.7

%Power sharing by IPT = 34.53

%Power sharing by LPT = 37.75

INTERNAL EFFICIENCY CALCULATIONS:

To calculate Internal efficiency, the isentropic enthalpy at outlet must be calculated from inlet and outlet conditions (irrespective of outlet temperature).

FOR HIGH PRESSURE TURBINE:

INLET CONDITIONS:

Pressure = 170 Kg/cm²

Temperature = 537°C

Enthalpy at Inlet (h_{IN}) = 3393.6kJ/Kg

OUTLET CONDITIONS:

Pressure = 45.02Kg/cm²

Temperature = 339.9°C

Enthalpy at Outlet (h_{OUT}) = 3055.1kJ/Kg

From Mollier chart/Steam tables, at inlet conditions,

Entropy = 6.41272kJ/Kg°C

From Mollier chart/Steam tables, at outlet pressure and entropy = 6.41272 kJ/Kg, Isentropic Enthalpy at Outlet (h_s) = 3012.7kJ/Kg

Efficiency= (Actual enthalpy drop / Isentropic enthalpy drop) x 100

= [(h_{IN} - h_{OUT}) / (h_{IN} - h_s)]x 100
=88.89%

For Intermediate Pressure Turbine:

INLET CONDITIONS :

Pressure= 40.52Kg/cm²

Temperature= 537°C

Enthalpy at Inlet (h_{IN}) =3528.03 kJ/Kg

OUTLET CONDITIONS :

Pressure= 7.18Kg/cm²

Temperature = 291.3°C

Enthalpy at Outlet (h_{OUT}) = 3039.257kJ/Kg

From Mollier chart/Steam tables, at inlet conditions,

Entropy= 7.2 kJ/Kg°C

From Mollier chart/Steam tables, at outlet pressure and entropy =7.2 KJ/kg°C

Isentropic Enthalpy at Outlet (h_s)= 2669.11kJ/kg

Efficiency = (Actual enthalpy drop / Isentropic enthalpy drop)x100

= [(h_{IN} - h_{OUT}) / (h_{IN} - h_s)] x100
=93.6%

For Low Pressure Turbine:

INLET CONDITIONS :

Pressure = 7.198 kg/cm^2

Temperature = 291.8°C

Enthalpy at Inlet (h_{IN}) =3039.26 kJ/Kg

OUTLET CONDITIONS :

Pressure = 0.1033 Kg/cm²

Dryness Fraction =0.911

Enthalpy at Outlet (h_{OUT}) = 2371.9kJ/Kg

From Mollier chart/Steam tables, at inlet conditions,

Entropy = 7.264 kJ/Kg °C

From Mollier chart/Steam tables, at outlet pressure and entropy =7.264 kJ/Kg°C,

Isentropic Enthalpy at Outlet (h_s) = 2303.5114kJ/Kg

Efficiency= (Actual enthalpy drop / Isentropic enthalpy drop) x 100

= [(h_{IN} - h_{OUT}) / (h_{IN} - h_s)] x 100

= 90.70%

POWER PRODUCED BY HPT, IPT AND LPT

400 MW 0%MU 33℃ COOLING WATER TEMP

		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	*-*	*% η*
UNITS		*Kg/cm²*	*°C*	*-*	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	*-*
HPT	**INLET**	170	537	-	1185.6	811	3393.64		335.1	431.66		**110**	**27**	**77.631**
	OUTLET	36.28	332.5	-	109.62	731	3058.5	2961.94			110			
	Ext-6	36.28	332.5	-	1071.6	731	3058.5							
IPT	**INLET**	32.66	537	--	1071.6	845.1	3535.8		487.5	521.73		**141.254**	**34.77**	**93.84**
	Ext-5	14.23	416.3	-	63.753	786.6	3291.1				72.611			
	OUTLET	5.85	293.2	-	905.18	728.2	3048.4	3014.07			68.643			
	Ext-4	5.85	293.2	-	104.98	728.2	3048.4							
LPT	**INLET**	5.85	293.2	-	905.18	728.3	3048.4		662.3	379.29		**154.955**	**38.14**	**91.16**
	Ext-3	2.324	193.7	-	31.785	682.3	2854.7				48.288			
	Ext-2	1.243	135.2	-	58.316	655.7	2743.4				27			
	Ext-1	0.293	-	0.959	31.805	603.9	2526.7				49.079			
	OUTLET	0.09119	-	0.919	783.98	570.3	2386.1	2669.11			30.587			
		TOTAL										***406.209***	***100***	

400MW 0%MU 33^{0}C COOLING WATER TEMP.

Calculations:

POWER CALCULATIONS:

h_{IN}= Enthalpy at inlet

h_{OUT} = Enthalpy at outlet

h_s = Isentropic Enthalpy at outlet

HIGH PRESSURE TURBINE:

Mass Flow Rate (m) = 1185.6 T/hr
Enthalpy at Inlet (h_{IN}) = 339.6kJ/kg

Enthalpy at Outlet (h_{OUT}) = 3058.5KJ/kg

Power Output of HPT = 110 MW

INTERMEDIATE PRESSURE TURBINE:

From IPT Inlet to Extraction-5:

Mass Flow Rate (m) = 1071.6T/hr
Enthalpy at Inlet (h_{IN}) = 3535.8KJ/kg

Enthalpy at Outlet (h_{OUT}) = 3291KJ/kg

Power Output = 72.611MW

From Extraction-5 to IPT Outlet:

Mass Flow Rate (m) = 1007.847T/hr
Enthalpy at Inlet (h_{IN}) = 3291KJ/kg

Enthalpy at Outlet (h_{OUT}) = 3048.4KJ/kg

Power Output = 68.643MW

Total Power Output of IPT =1241.254MW

LOW PRESSURE TURBINE:

From LPT Inlet to Extraction-3:

Mass Flow Rate (m) = 905.18T/hr
Enthalpy at Inlet (h_{IN}) = 3048.4kJ/Kg

Enthalpy at Outlet (h_{OUT}) = 2854.7kJ/Kg

Power Output = 48.288MW

From Extraction-3 to Extraction-2:

Mass Flow Rate (m) =873.395T/hr
Enthalpy at Inlet (h_{IN}) = 2854.7 KJ/kg

Enthalpy at Outlet (h_{OUT}) =2743.54KJ/kg

Power Output = 27MW

From Extraction-2 to Extraction-1:

Mass Flow Rate (m) = 815.079T/hr
Enthalpy at Inlet (h_{IN}) = 2743.8kJ/Kg

Enthalpy at Outlet (h_{OUT}) = 2526.7kJ/Kg

Power Output = 49.079MW

From Extraction-1 to LPT Outlet:

Mass Flow Rate (m) = 783.98T/hr
Enthalpy at Inlet (h_{IN}) = 2526.7kJ/Kg

Enthalpy at Outlet (h_{OUT}) =2386.1kJ/Kg

Power Output =30.587MW

Total Power Output of LPT = 141.254MW

Total Power Output of all turbines = Total Power Output of (HPT+LPT+IPT)

=MW

% POWER SHARING CALCULATIONS:

% Power sharing by HPT=27

%Power sharing by IPT = 34.77

%Power sharing by LPT = 38.14

INTERNAL EFFICIENCY CALCULATIONS:

To calculate Internal efficiency, the isentropic enthalpy at outlet must be calculated from inlet and outlet conditions (irrespective of outlet temperature).

FOR HIGH PRESSURE TURBINE:

INLET CONDITIONS:

Pressure = 170 Kg/cm²

Temperature = 537°C

Enthalpy at Inlet (h_{IN}) = 3393.6kJ/Kg

OUTLET CONDITIONS:

Pressure = 36.28Kg/cm²

Temperature = 332.5°C

Enthalpy at Outlet (h_{OUT}) = 3058.5kJ/Kg

From Mollier chart/Steam tables, at inlet conditions,

Entropy = 6.41272kJ/Kg°C

From Mollier chart/Steam tables, at outlet pressure and entropy = 6.41272kJ/Kg,

Isentropic Enthalpy at Outlet (h_s) = 2961.94kJ/Kg

Efficiency= (Actual enthalpy drop / Isentropic enthalpy drop) x 100

= [(h_{IN} - h_{OUT}) / (h_{IN} - h_s)]x100
=77.631%

For Intermediate Pressure Turbine:

INLET CONDITIONS :

Pressure= 32.66Kg/cm²

Temperature= 537°C

Enthalpy at Inlet (h_{IN}) = 3535.8kJ/Kg

OUTLET CONDITIONS :

Pressure= 5.85Kg/cm²

Temperature = 293.2°C

Enthalpy at Outlet (h_{OUT}) = 3048.4kJ/Kg

From Mollier chart/Steam tables, at inlet conditions,

Entropy= 7.309kJ/Kg°C

From Mollier chart/Steam tables, at outlet pressure and entropy = 7.309KJ/kg°C

Isentropic Enthalpy at Outlet (h_s)= 3014.7KJ/kg

Efficiency = (Actual enthalpy drop / Isentropic enthalpy drop)/100

= [(h_{IN} - h_{OUT}) / (h_{IN} - h_s)] x100
=93.84%

For Low Pressure Turbine:

INLET CONDITIONS :

Pressure = 5.85 kg/cm^2

Temperature = 293.2°C

Enthalpy at Inlet (h_{IN}) = 3048.4kJ/Kg

OUTLET CONDITIONS :

Pressure = 20.0911Kg/cm²

Dryness Fraction =0.919

Enthalpy at Outlet (h_{OUT}) = 2386.1kJ/Kg

From Mollier chart/Steam tables, at inlet conditions,

Entropy = 7.370kJ/Kg °C

From Mollier chart/Steam tables, at outlet pressure and entropy =7.370 kJ/Kg°C,

Isentropic Enthalpy at Outlet (h_s) = kJ/Kg

Efficiency= (Actual enthalpy drop / Isentropic enthalpy drop) * 100

= [(h_{IN} - h_{OUT}) / (h_{IN} - h_s)]x100

= 91.16%

POWER PRODUCED BY HPT, IPT AND LPT

500 MW 0%MU 33°C COOLING WATER TEMP

		PRESSURE (Abs. Gauge)	TEMP.	QUA-LITY	MASS FLOW RATE	ENTHALPY		ISENTRO--PIC ENTHALPY	ACTUAL ENTHALPY DROP	ISENTROPIC ENTHALPY DROP	POWER OUTPUT	NET POWER OUTPUT	% POWER SHARING	INTERNAL EFFICIENCY
SYMBOL		p	T	X	M	h		hs	$h_{IN} - h_{OUT}$	h_{IN} - hs	P	P	-	% η
UNITS		Kg/cm²	°C	-	T/hr	kCal/kg	kJ/Kg	kJ/Kg	kJ/Kg	kJ/Kg	MW	MW	%	-
HPT	INLET	170	537	-	1496.8	811.1	3393.6							
	OUTLET	45.02	339.9	-	1333.9	730.2	3055.1	3012.70	338.485	380.942	140.738	**140.738**	**27.7**	**88.85**
	Ext-6	45.02	339.9	-	157.45	730.2	3055.1							
IPT	INLET	40.52	537	-	1333.9	843.3	3528.3							
	Ext-5	17.51	415	--	85.148	784.7	3283.1				90.85	**175.47**	**34.53**	**93.62**
	OUTLET	7.18	291.3	-	1115.2	726.4	3039.2	3005.94	489.109	522.427	84.62			
	Ext-4	7.18	291.3	-	136.49	726.4	3039.2							
LPT	INLET	7.18	291.3	-	1115.2	726.4	3039.2							
	Ext-3	2.843	191.7	-	41.244	680.7	2848.0				59.23			
	Ext-2	1.527	133.9	-	75.784	654.5	2738.4		667.348	735.746	32.70	**191.82**	**37.75**	**90.70**
	Ext-1	0.355	-	0.953	42.078	602.4	2520.4				60.44			
	OUTLET	0.1033	-	0.911	956.80	566.9	2371.9	2303.511			39.44			
		TOTAL										***508.034***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

400 MW 0%MU 33°C COOLING WATER TEMP

		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	*-*	*% η*
UNITS		*Kg/cm²*	*°C*	*-*	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	*-*
	INLET	170	537	-	1185.6	811	3393.64		335.1	431.66				
HPT	**OUTLET**	36.28	332.5	-	109.62	731	3058.5	2961.94			110	**110**	**27**	**77.631**
	Ext-6	36.28	332.5	-	1071.6	731	3058.5							
	INLET	32.66	537	--	1071.6	845.1	3535.8							
	Ext-5	14.23	416.3	-	63.753	786.6	3291.1			521.73	72.611			
IPT	**OUTLET**	5.85	293.2	-	905.18	728.2	3048.4	3014.07	487.5		68.643	**141.254**	**34.77**	**93.84**
	Ext-4	5.85	293.2	-	104.98	728.2	3048.4							
	INLET	5.85	293.2	-	905.18	728.3	3048.4							
	Ext-3	2.324	193.7	-	31.785	682.3	2854.7				48.288			
	Ext-2	1.243	135.2	-	58.316	655.7	2743.4		662.3	379.29	27	**154.955**	**38.14**	**91.16**
LPT	Ext-1	0.293	-	0.959	31.805	603.9	2526.7				49.079			
	OUTLET	0.09119	-	0.919	783.98	570.3	2386.1	2669.11			30.587			
		TOTAL										***406.209***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

400 MW 0%MU 33°C COOLING WATER TEMP, SLIDING PRESSURE OPERTATION

		PRESSURE (Abs. Gauge)	*TEMP.*	QUALITY	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	*-*	*% η*
UNITS		*Kg/cm²*	*°C*	*-*	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	127.02	537	-	1165.90	822.4	3440.9							
	OUTLET	35.78	345.4	-	1055.18	738.9	3091.5	3063.76	349.4	377.14	113.145	**113.14**	**27.62**	**92.629**
	Ext-6	35.78	345.4	-	345.4	738.9	3091.5							
IPT	**INLET**	32.185	537	-	1055.18	845.2	3536.3							
	Ext-5	14.05	416.6	-	62.735	786.8	3291.9		486.2	523.54	72.860	**141.268**	**34.48**	**92.861**
	OUTLET	5.85	295	-	903.03	729	3050.1	3012.76			68.408			
	Ext-4	5.85	295	-	91.594	729	3050.1							
LPT	**INLET**	5.85	295	-	903.03	729	3050.1							
	Ext-3	2.325	195.2	-	31.284	683	2857.6				48.286			
	Ext-2	1.243	136.6	-	57.419	656.3	2745.9		671.8	680.47	27.056	**155.222**	**37.89**	**96.5071**
	Ext-1	0.293	-	0.96	31.565	604.5	2529.2				49.034			
	OUTLET	0.0911	-	0.92	783.47	570.6	2387.3	2369.93			30.846			
		TOTAL										***409.633***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

300 MW 0%MU 33℃ COOLING WATER TEMP

		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	$h_{IN} - h_{OUT}$	h_{IN} - hs	*P*	*P*	-	*% η*
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	886.49	811.1	3393.5							
	OUTLET	27.61	324.8	-	70.192	731.7	3061.4	2899.48	332.1	494.02	81.803	**81.803**	**26.754**	**67.66**
	Ext-6	27.61	324.8	-	812.9	731.7	3061.4							
IPT	**INLET**	24.86	537	-	812.98	846.9	3543.4							
	Ext-5	10.92	417.6	-	44.278	788.4	3298.6				55.274			
	OUTLET	4.48	294.7	-	691.14	729.7	3053.0	3020.4	490.4	523	52.442	**107.716**	**35.229**	**93.754**
	Ext-4	4.48	294.7	-	79.294	729.7	3053.0							
LPT	**INLET**	4.48	294.7	-	691.14	729.7	3053.0							
	Ext-3	1.787	195.3	-	22.908	683.7	2860.6				36.95			
	Ext-2	0.952	136.2	-	41.749	656.8	2748.0		644.7	704.68	20.969	**116.235**	**38.015**	**91.487**
	Ext-1	0.228	-	0.966	21.265	605.3	2532.5				37.425			
	OUTLET	0.0814	-	0.930	605.93	575.6	2408.3	2348.32			20.891			
		TOTAL										***305.754.***	***100***	

		POWER PRODUCED BY HPT, IPT AND LPT												
		300 MW 0%MU 33°C COOLING WATER TEMP, SLIDING PRESSURE OPERATION												
		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	$h_{IN} - h_{OUT}$	h_{IN} - hs	*P*	*P*	-	*% η*
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	95.01	537	-	861.66	830.3	3473.97		356.06	389.31		**85.243**	**20.12**	**91.457**
	OUTLET	26.93	348.3	-	790.94	745.2	3117.91	3084.66			85.243			
	Ext-6	26.93	348.3	-	67.783	745.2	3117.91							
IPT	**INLET**	24.21	537	-	790.94	847	3543.8		483.63	516.32		**103.252**	**24.37**	**93.667**
	Ext-5	10.67	418	-	43.812	788.7	3299.9				53.544			
	OUTLET	4.48	298	-	689.45	731.4	3060.17	3027.48			49.708			
	Ext-4	4.48	298	-	59.283	685.1	2866.45							
LPT	**INLET**	4.48	298	-	689.45	731.4	3060.17		65019	709.73		**117.11**	**38.39**	**91.61**
	Ext-3	1.792	198.3	-	22.655	685.1	2866.45				37.1			
	Ext-2	0.939	137.7	-	40.706	657.5	2750.98				21.389			
	Ext-1	0.229	-	0.968	21.001	606.3	2536.75				37.293			
	OUTLET	0.0804	-	0.931	606.41	576	2409.98	2350.44			21.329			
		TOTAL										***305.606***	***100***	

		POWER PRODUCED BY HPT, IPT AND LPT												
		200 MW 0%MU 33°C COOLING WATER TEMP												
		PRESSURE (Abs. Gauge)	*TEMP.*	QUALITY	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	$h_{IN} - h_{OUT}$	h_{IN} - hs	*P*	*P*	-	*% η*
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	619.26	811.1	3393.5		355.08	591.2		**61.106**	**29.784**	**60.07**
	OUTLET	17.41	303.5	-	508.72	726.2	3038.42	2802.3			61.106			
	Ext-6	17.41	303.5	-	108.46	726.2	3038.42							
IPT	**INLET**	15.72	537	-	508.72	849	3552.21		463.17	493.39		**64.083**	**31.235**	**93.87**
	Ext-5	7.16	422.1	-	21.957	791.9	3313.3				35.067			
	OUTLET	3.22	310.6	-	487.76	738.3	3089.04	3058.82			30.323			
	Ext-4	3.22	310.6	--	0	738.3	3089.04							
LPT	**INLET**	3.22	310.6	-	487.76	738.3	3089.04		622.58	685.99		**79.974**	**38.98**	**90.7**
	Ext-3	1.288	209.05	-	15.263	691	2891.14				26.813			
	Ext-2	0.676	147.7	-	27.258	662.7	2772.73				15.540			
	Ext-1	0.162	-	0.980	10.889	609.8	2551.40				27.374			
	OUTLET	0.0743	-	0.956	435.06	589.5	2466.46	2403.05			10.247			
		TOTAL										***205.163***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

200 MW 0%MU 33°C COOLING WATER TEMP,SLIDING OPERATION

		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	*-*	*% η*
UNITS		*Kg/cm²*	*°C*	*-*	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	*-*
HPT	**INLET**	65.26	537	-	589.31	837.5	3504.1							
	OUTLET	17.33	342	-	82.062	746.7	3124.19	3094.18	379.91	409.92	62.190	**62.190**	**30.80**	**92.67**
	Ext-6	17.33	342	-	505.24	746.7	3124.19							
IPT	**INLET**	15.60	537	-	505.24	849	3552.2							
	Ext-5	7.07	421.6	-	23.608	791.8	3312.89		463.6	494.57	33.588	**63.592**	**30.99**	**93.73**
	OUTLET	3.18	310.4	-	482.59	738.2	3088.6	3057.63			30.004			
	Ext-4	3.18	310.4	-	0	738.2	3088.6							
LPT	**INLET**	3.18	310.4	-	482.59	738.2	3088.6							
	Ext-3	1.277	209.4	-	14.349	691	2891.14				26.473			
	Ext-2	0.673	148	-	25.688	662.8	2773.15		622.97	685.63	15.346	**79.359**	**38.69**	**90.8611**
	Ext-1	0.162	-	0.980	10.437	610.0	2552.24				27.146			
	OUTLET	0.07333	-	0.956	432.63	589.3	2465.63	2402.97			10.393			
		TOTAL										***205.141***	***100***	

		POWER PRODUCED BY HPT, IPT AND LPT												
		500 MW 3%MU 33°C COOLING WATER TEMP												
		PRESSURE (Abs. Gauge)	*TEMP.*	QUALITY	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	-	% η
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	1511.8	811.1	3393.5		340.86	380.1		**143.206**	**28.199**	**89.67**
	OUTLET	44.90	338.7	-	175.0	729.6	3052.64	3013.4			143.206			
	Ext-6	44.90	338.7	-	1331.4	729.6	3052.64							
IPT	**INLET**	40.41	537	-	1331.4	843.3	3528.36		490.78	523.54		**175.491**	**34.556**	**93.741**
	Ext-5	17.36	414.5	-	88.492	784.5	3282.34				90.986			
	OUTLET	7.11	290.4	-	1104.6	726	3037.58	3004.82			84.505			
	Ext-4	7.11	290.4	-	141.16	726	3037.58							
LPT	**INLET**	7.11	290.4	-	1104.6	726	3037.58		666.09	732.48		**189.139**	**37.244**	**90.9**
	Ext-3	2.807	190.8	-	42.618	680.3	2846.37				58.669			
	Ext-2	1.501	132.9	-	77.696	654	2736.33				32.461			
	Ext-1	0.349	-	0.958	42.629	602	2518.76				59.486			
	OUTLET	0.1099	-	0.911	942.37	566.8	2371.49	2305.1			38.523			
		TOTAL										***507.836***	***100***	

		POWER PRODUCED BY HPT, IPT AND LPT												
		500 MW 3%MU 35°C COOLING WATER TEMP												
		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	$h_{IN} - h_{OUT}$	$h_{IN} - hs$	*P*	*P*	-	*% η*
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	1519.8	811.1	3393.5							
	OUTLET	45.12	338.99	-	1338.1	729.5	3052.2	3014.61	341.3	378.89	144.142	**144.142**	**28.37**	**90.0**
	Ext-6	45.12	338.99	-	176.33	729.5	3052.2							
IPT	**INLET**	40.61	537	-	1338.1	843.3	3528.36							
	Ext-5	17.44	414.5	-	89.073	784.5	3282.34				91.446			
	OUTLET	7.13	290.2	-	1108.5	725.8	3036.74	3004.18	491.62	389.32	85.412	**176.660**	**34.773**	**93.787**
	Ext-4	7.13	290.2	-	143.39	725.8	3036.74							
LPT	**INLET**	7.13	290.2	-	1108.5	725.8	3036.74							
	Ext-3	2.817	190.6	--	42.59	680.2	2845.95				58.75			
	Ext-2	1.51	132.9	-	77.119	654.0	2736.3		655.64	720.75	32.46	**187.233**	**36.85**	**90.96**
	Ext-1	0.355	-	0.953	40.366	602.2	2519.6				59.534			
	OUTLET	0.114	-	0.914	949.19	569.1	2381.1	2315.99			36.489			
		TOTAL										***508.035***	***100***	

		POWER PRODUCED BY HPT, IPT AND LPT											
		VWQ 3%MU 33°C COOLING WATER TEMP											
		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	$h_{IN} - h_{OUT}$	h_{IN} - hs	*P*	*P*	-	% η
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	1587.4	811.1	3393.5		341.3	368.58		**166.713**	**30.455**	**92.59**
	OUTLET	47.03	340.6	-	1395.3	729.5	3052.2	3024.92			166.713			
	Ext-6	47.03	340.6	-	186.49	729.5	3052.2							
IPT	**INLET**	42.32	537	-	1395.3	842.9	3526.6		491.11	523.83		**184.023**	**33.617**	**94.05**
	Ext-5	18.16	414.8	-	93.428	784.1	3280.67	3002.77			95.355			
	OUTLET	7.42	289.9	-	1155	725.5	3035.49				88.668			
	Ext-4	7.42	289.9	-	149.89	725.5	3035.49							
LPT	**INLET**	7.42	289.9	-	1155.0	725.5	3035.49		666.51	737.76		**196.66**	**35.926**	**90.34**
	Ext-3	2.930	190.3	-	45.096	679.9	2844.70				61.212			
	Ext-2	1.568	132.5	-	82.187	653.7	2735.08				33.797			
	Ext-1	0.364	-	0.951	45.149	601.7	2517.5				62.111			
	OUTLET	0.105	-	0.910	983.45	566.2	2368.98	2297.73			40.540			
		TOTAL										***547.396***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

VWQ 0%MU 33°C COOLING WATER TEMP

		PRESSURE (Abs. Gauge)	*TEMP.*	QUALITY	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - hs	*P*	*P*	-	*% η*
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	1587.4	811.1	3393.5							
	OUTLET	47.51	341.9	-	1408.9	730	3054.32	3027.46	339.18	366.04	149.628	**149.628**	**27.874**	**92.66**
	Ext-6	47.51	341.9	-	172.8	730	3054.32							
IPT	**INLET**	42.76	537	-	1408.9	842.8	3526.27							
	Ext-5	18.43	14.6	-	91.62	784.2	3281.09				95.959			
	OUTLET	7.55	290.7	-	1173.9	725.8	3036.74	3004.26	489.53	522.01	89.413	**185.372**	**34.532**	**93.77**
	Ext-4	7.55	290.7	-	146.38	725.8	3036.74							
LPT	**INLET**	7.55	290.7	-	1173.9	725.8	3036.78							
	Ext-3	2.987	191.1	-	44.01	680.2	2845.12				62.217			
	Ext-2	1.605	133.5	-	80.84	654.1	2736.33		667.8	738.35	34.276	**201.8**	**37.593**	**90.44**
	Ext-1	0.372	-	0.951	44.953	602	2518.76				63.526			
	OUTLET	0.107	-	0.910	1004.8	566.2	2368.98	2298.43			41.781			
		TOTAL										***536.8***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

500 MW 3%MU 33°C COOLING WATER TEMP,BOTH HP HEATERS OUT OF SERVICE

		PRESSURE (Abs. Gauge)	*TEMP.*	QUALITY	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		***p***	***T***	***X***	***M***	***h***		***hs***	***h_{IN} - h_{OUT}***	***h_{IN} - hs***	***P***	***P***	**-**	***% η***
UNITS		***Kg/cm²***	***°C***	**-**	***T/hr***	***kCal/kg***	***kJ/Kg***	***kJ/Kg***	***kJ/Kg***	***kJ/Kg***	***MW***	***MW***	***%***	-
HPT	**INLET**	170	537	-	1366.7	811.1	3393.5		312.41	372.75		**118.650**	**23.36**	**83.81**
	OUTLET	46.25	651	-	1351.2	736.4	3081.09	3020.75			118.659			
	Ext-6	46.25	351	-	10	736.4	3081.09							
IPT	**INLET**	41.72	537	-	1351.2	843	3527.11		475.61	507		**178.405**	**35.12**	**93.8**
	Ext-5	19.56	422.9	-	0	788.1	3297.41				86.218			
	OUTLET	7.84	298.1	-	1211.0	729.4	3051.80	3020.41			92.186			
	Ext-4	7.84	298.1	--	142.95	729.4	3051.80							
LPT	**INLET**	7.84	298.1	-	1211.0	729.4	3051.80		677.88	748.32			**41.513**	**90.455**
	Ext-3	3.10	197.3	-	47.106	683.1	2858.09				65.617			
	Ext-2	1.648	138.3	-	85.122	656.4	2746.37				36.118			
	Ext-1	0.382	-	0.954	47.487	603.8	2526.29				65.951			
	OUTLET	0.108	-	0.912	1032.0	567.4	2374.00	2303.48			43.614			
		TOTAL										***507.905***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

500 MW 0%MU 33°C COOLING WATER TEMP,BOTH HP HEATERS OUT OF SERVICE

		PRESSURE (Abs. Gauge)	*TEMP.*	*QUALITY*	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	h_{IN} - h_{OUT}	h_{IN} - *hs*	*P*	*P*	-	*% η*
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	1358.1	811.1	3393.5							
	OUTLET	46.30	351.7	-	1352.6	736.8	3082.77	3021.02	310.73	372.48	128.689	**128.689**	**25.37**	**83.42**
	Ext-6	46.30	351.7	-	351.7	736.8	3082.77							
IPT	**INLET**	41.77	537	--	1352.6	843	3527.11							
	Ext-5	19.5*	423	-	0	788.2	3297.82				86.152			
	OUTLET	7.88	298.6	-	1216.4	729.6	3052.64	3021.33	474.47	505.78	79.267	**165.419**	**32.61**	**93.8**
	Ext-4	7.88	298.6	-	138.97	729.6	3052.64							
LPT	**INLET**	7.88	298.6	-	1216.4	729.6	3052.64							
	Ext-3	3.12	197.8	-	45.66	683.4	2859.34				65.316			
	Ext-2	1.66	138.9	-	83.07	656.7	2747.63		678.64	749.12	36.330	**212.419**	**41.887**	**90.53**
	Ext-1	0.387	-	0.954	46.77	604.1	2527.55				66.494			
	OUTLET	0.109	-	0.912	1041.6	567.5	2374.00	2303.52			44.278			
		TOTAL										***506.5***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

500 MW 3%MU 33°C COOLING WATER TEMP,1 STRING HP HEATERS OUT OF SERVICE

		PRESSURE (Abs. Gauge)	*TEMP.*	QUALITY	*MASS FLOW RATE*	*ENTHALPY*		*ISENTROPIC ENTHALPY*	*ACTUAL ENTHALPY DROP*	*ISENTROPIC ENTHALPY DROP*	*POWER OUTPUT*	*NET POWER OUTPUT*	*% POWER SHARING*	*INTERNAL EFFICIENCY*
SYMBOL		*p*	*T*	*X*	*M*	*h*		*hs*	$h_{IN} - h_{OUT}$	h_{IN} - hs	*P*	*P*	-	% η
UNITS		*Kg/cm²*	*°C*	-	*T/hr*	*kCal/kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*kJ/Kg*	*MW*	*MW*	*%*	-
HPT	**INLET**	170	537	-	1441.4	811.1	3393.5							
	OUTLET	45.71	345	-	1347.5	733	3066.87	3017.83	326.63	375.67	130.837	**130.837**	**25.756**	**86.9**
	Ext-6	45.70	345	-	88.87	733	3066.87							
IPT	**INLET**	41.18	537	---	1374.0	843.2	3527.94							
	Ext-5	18.49	418.2	-	52.23	786	3288.62				89.553			
	OUTLET	7.46	293.8	-	1156.1	727.5	3043.86	3011.58	484.08	516.36	88.044	**177.597**	**34.96**	**93.52**
	Ext-4	7.46	293.8	-	141.49	727.5	3043.86							
LPT	**INLET**	7.46	293.8	-	1156.1	727.5	3043.86							
	Ext-3	2.947	193.6	-	44.729	681.5	2851.39				61.812			
	Ext-2	1.572	135.3	-	81.242	655	2740.52		671.54	742.47	34.231	**199.536**	**39.28**	**90.44**
	Ext-1	0.365	-	0.953	44.974	602.8	2522.11				62.500			
	OUTLET	0.105	-	0.911	985.94	567	2372.32	2301.39			40.993			
		TOTAL										***507.97***	***100***	

POWER PRODUCED BY HPT, IPT AND LPT

500 MW 0%MU 33°C COOLING WATER TEMP,1 STRING HP HEATERS OUT OF SERVICE

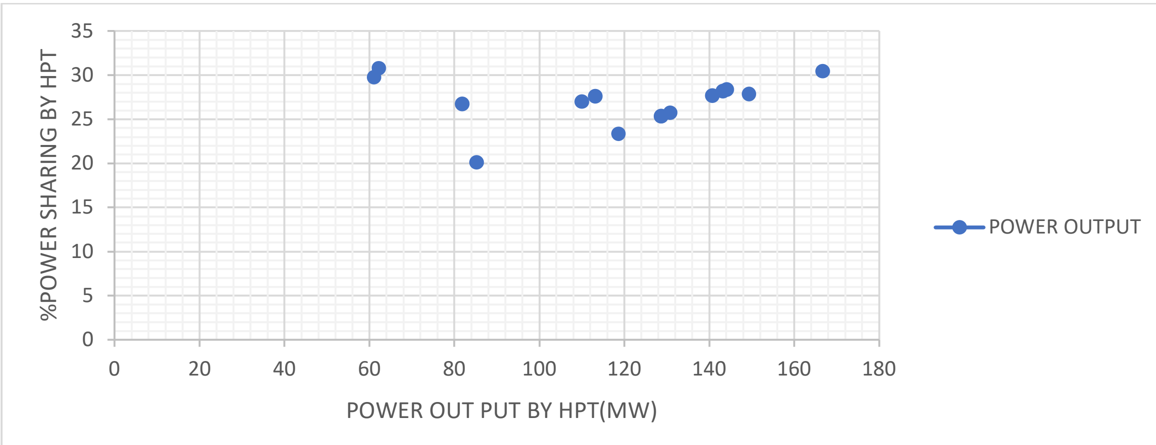
		PRESSURE (Abs. Gauge)	TEMP.	QUALITY	MASS FLOW RATE	ENTHALPY		ISENTROPIC ENTHALPY	ACTUAL ENTHALPY DROP	ISENTROPIC ENTHALPY DROP	POWER OUTPUT	NET POWER OUTPUT	% POWER SHARING	INTERNAL EFFICIENCY
SYMBOL		p	T	X	M	h		hs	h_{IN} - h_{OUT}	h_{IN} - hs	P	P	-	% η
UNITS		Kg/cm²	°C	-	T/hr	kCal/kg	kJ/Kg	kJ/Kg	kJ/Kg	kJ/Kg	MW	MW	%	-
	INLET	170	537	-	1428.7	811.1	3393.5							
HPT	OUTLET	45.8	346	-	1348.7	733.6	3069.38	3018.32	324.12	375.18	128.69	**128.69**	**25.34**	**86.39**
	Ext-6	45.84	346	-	74.48	733.6	3069.38							
	INLET	41.26	537	-	1348.7	843.1	3527.53							
	Ext-5	18.59	418.5	-	49.504	786.2	3289.45		483.67	514.53	89.196	**177.384**	**34.92**	**93.75**
IPT	OUTLET	7.52	294.5	-	1164.8	727.5	3043.86	3013			88.188			
	Ext-4	7.52	294.5	-	137.26	727.8	3043.86							
	INLET	7.52	294.5	-	1164.8	727.8	3043.86							
	Ext-3	2.978	194.4	-	43.348	681.9	2853.06				62.139			
	Ext-2	1.595	136.2	-	79.297	655.4	2742.19		671.12	740.42	34.540	**201.771**	**39.73**	**90.655**
LPT	Ext-1	0.371	-	0.954	44.34	603.2	2523.78				63.227			
	OUTLET	0.106	-	0.911	998.55	567.1	2372.74	2303.44			41.865			
		TOTAL										***507.845***	***100***	

S.NO	CASE	POWER OUTPUT (MW)			NET POWER OUTPUT (MW)	%POWER SHARING			EFFICIENCY (%η)		
		HPT	IPT	LPT		HPT	IPT	LPT	HPT	IPT	LPT
1.	500 MW 0%MU 33^{0}C COOLING WATER TEMP.	140.738	175.47	197.82	508.034	27.7	34.53	37.75	88.85	93.62	90.70
2.	400 MW 0%MU 33^{0}C COOLING WATER TEMP.	110	141.254	154.955	406.209	27	34.77	38.14	77.63	93.84	91.16
3.	400 MW 3%MU 33^{0}C COOLING WATER TEMP.	113.14	141.268	155.222	409.633	27.62	34.48	37.89	92.62	92.82	96.50
4.	300 MW 0%MU 33^{0}C COOLING WATER TEMP.	81.803	107.716	116.235	305.754	26.754	35.229	38.015	67.66	93.75	91.48
5.	300 MW 0%MU 33^{0}C COOLING WATER TEMP, SLINDING PRESSURE OPERATION	85.243	103.252	117.11	305.606	20.12	24.37	38.39	91.45	93.66	91.61
6.	200 MW 0%MU 33^{0}C COOLING WATER TEMP.	61.106	64.083	79.974	205.163	29.784	31.235	38.98	60.07	93.87	90.7
7.	200 MW 3%MU 33^{0}C COOLING WATER TEMP.	62.190	63.592	79.359	205.141	30.80	30.99	38.69	92.67	93.73	90.86

S.NO	CASE	POWER OUTPUT (MW)			NET POWER OUTPUT (MW)	%POWER SHARING			EFFICIENCY (%η)		
		HPT	IPT	LPT		HPT	IPT	LPT	HPT	IPT	LPT
8.	500MW 3%MU 33^0C COOLING WATER TEMP.	143.206	175.491	189.139	507.836	28.199	34.556	37.244	89.67	93.74	90.9
9.	500MW 3%MU 35^0C COOLING WATER TEMP.	144.14	176.66	187.23	508.035	28.37	34.77	36.85	90	93.78	90.96
10.	VWQ 3%MU 33^0C COOLING WATER TEMP.	166.71	184.02	196.66	547.39	30.455	33.617	35.926	92.59	94.05	90.34
11.	VWQ 0%MU 33^0C COOLING WATER TEMP	149362	185.37	201.8	536.8	27.87	34.53	37.59	92.66	93.77	90.44
12.	500 MW 0%MU 33^0C COOLING WATER TEMP, BOTH HP HEATERS OUT OF SERVICE.	118.65	178.40	210.85	507.90	23.36	35.12	41.51	83.81	93.8	90.45
13.	500 MW 3%MU 33^0C COOLING WATER TEMP, BOTH HP HEATERS OUT OF SERVICE.	128.68	165.41	212.41	506.5	25.37	32.61	41.887	83.42	93.8	90.53
14.	500 MW 3%MU 33^0C COOLING WATER TEMP, ONE STRING OF HP HEATERS OUT OF SERVICE.	130.83	177359	199.53	507.97	25.76	34.96	39.28	86.9	93.52	90.44
15.	500 MW 3%MU 33^0C COOLING WATER TEMP,ONE STRING OF HP HEATERS OUT OF SERVICE.	128.69	177.384	201.771	507.84	25.34	34.92	39.73	86.39	93.75	90.65

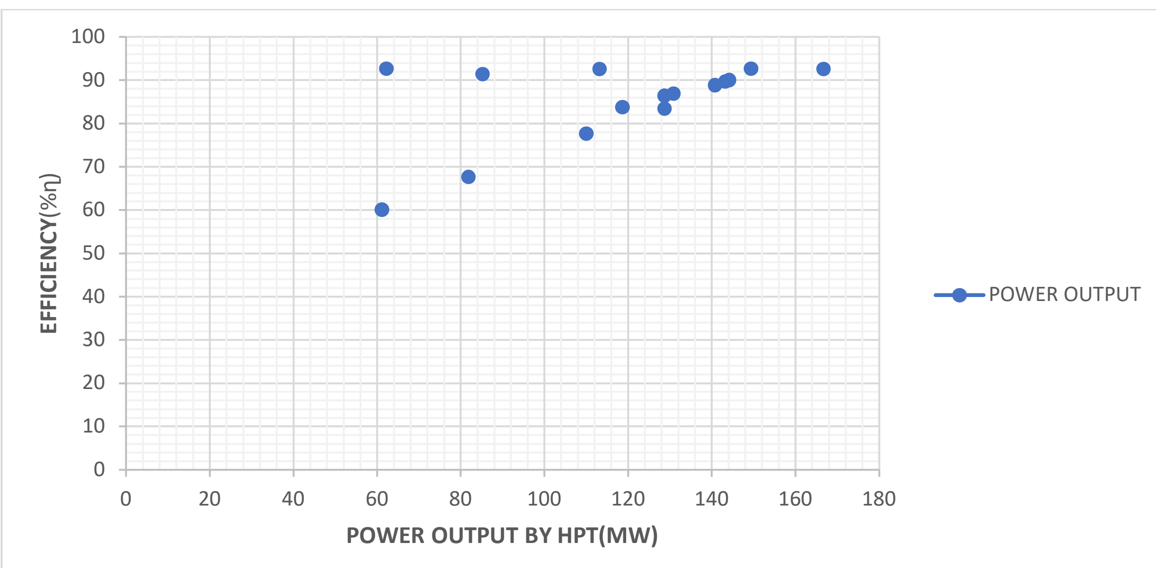
HPT - POWER OUTPUT(MW) TO %POWER SHARING BY HPT

GRAPH



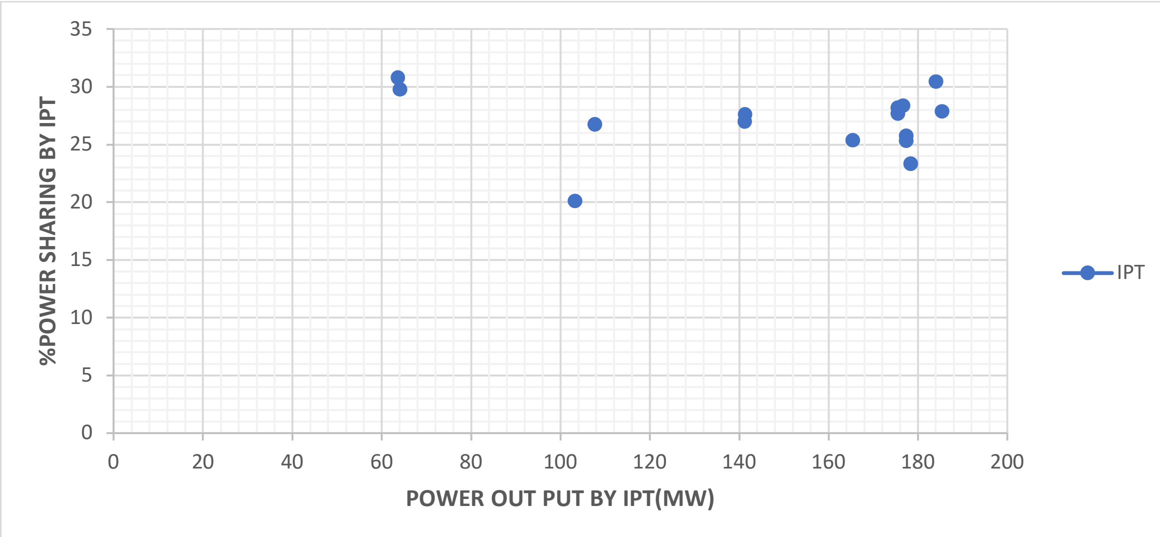
HPT - POWER OUTPUT(MW) TO EFFICIENCY(%η)

GRAPH



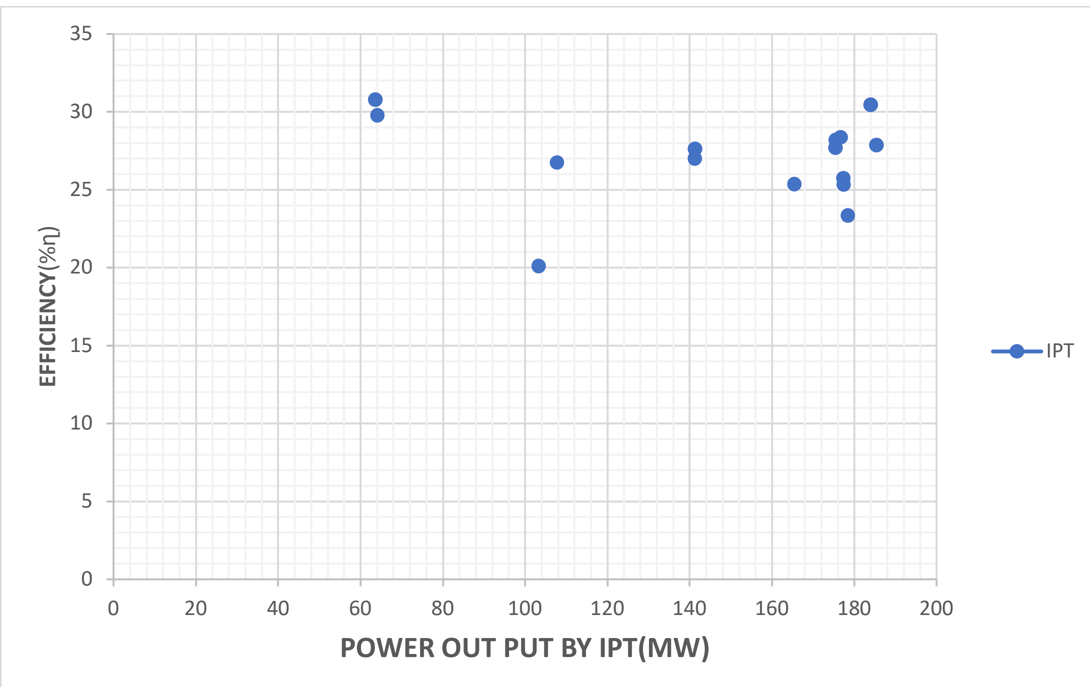
IPT - POWER OUTPUT(MW) TO %POWER SHARING BY HPT

GRAPH



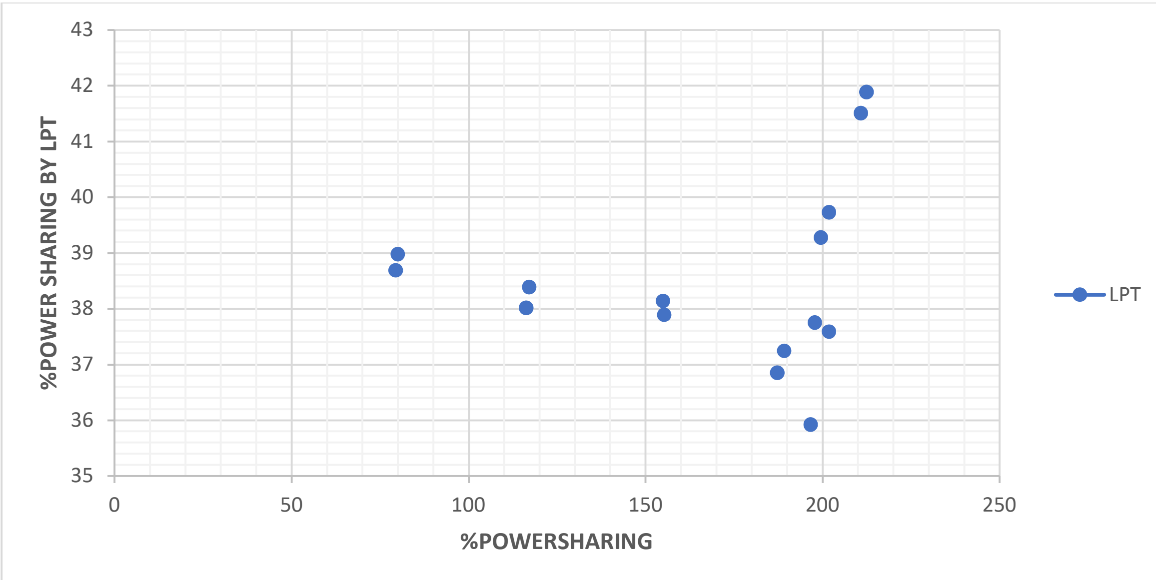
IPT - POWER OUTPUT(MW) TO EFFICIENCY(%η)

GRAPH



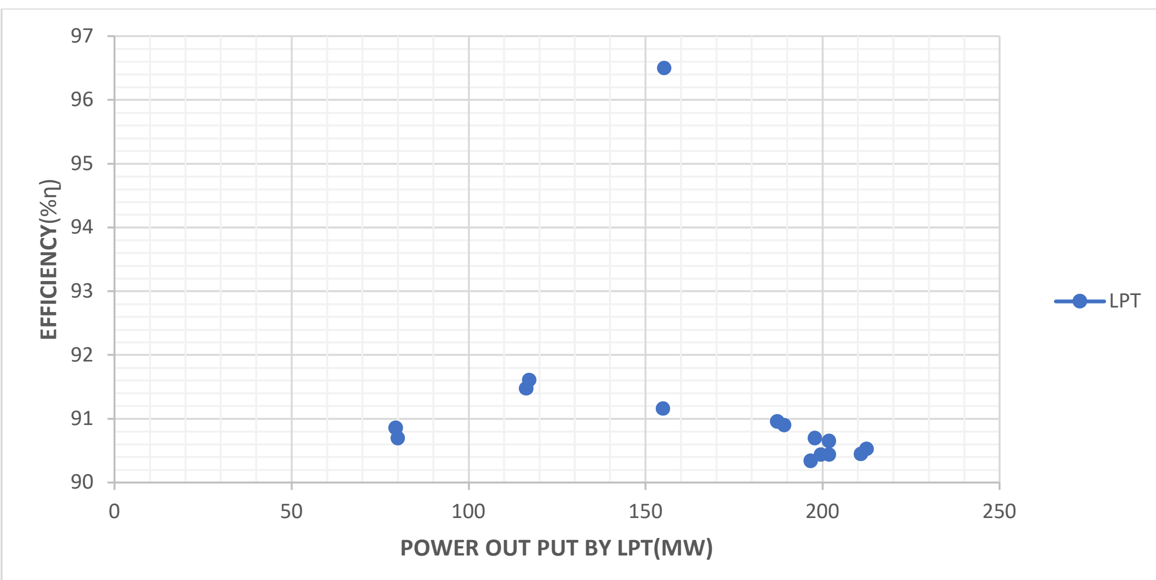
LPT - POWER OUTPUT(MW) TO %POWER SHARING BY HPT

GRAPH



LPT - POWER OUTPUT(MW) TO EFFICIENCY(%η)

GRAPH



Conclusion and Comparison of Power Produced by HPT, IPT, and LPT

This report analyzes the performance of High-Pressure Turbines (HPT), Intermediate-Pressure Turbines (IPT), and Low-Pressure Turbines (LPT) under different power output scenarios. The analysis focuses on key metrics including power output, enthalpy drop, mass flow rate, and efficiency. This detailed comparison will cover each turbine's performance at various power levels, providing a comprehensive understanding of their roles and efficiency in power generation.

High-Pressure Turbine (HPT)

1. **Power Output and Efficiency:**
    - The HPT demonstrates a high power output and efficiency across all power levels. At 500 MW, the HPT contributes significantly with an efficiency of 88.85%. As the power output decreases, the efficiency also drops, reaching 60.07% at 200 MW. This decline is due to lower steam pressure and temperature conditions.
2. **Enthalpy Drop:**
    - The enthalpy drop in the HPT is substantial, indicating its role in the initial stages of energy extraction from steam. For example, at 500 MW, the enthalpy drop is 338.485 kJ/kg. The enthalpy drop reduces slightly as the power output decreases, but remains critical for overall efficiency.
3. **Mass Flow Rate:**
    - The mass flow rate for the HPT remains high, demonstrating its capacity to handle large volumes of steam. At higher power outputs, the mass flow rate is significantly higher compared to lower outputs, aligning with the turbine's design for high-pressure conditions.

Intermediate-Pressure Turbine (IPT)

1. **Power Output and Efficiency:**
    - The IPT maintains a moderate to high power output and efficiency. At 500 MW, the IPT operates with an efficiency of 93.62%, contributing significantly to the total power output. Even at lower power outputs like 200 MW, the efficiency remains high at 93.87%, indicating the IPT's consistent performance across different loads.
2. **Enthalpy Drop:**
    - The enthalpy drop in the IPT is significant, though less than the HPT, reflecting its mid-stage role in the power cycle. At 500 MW, the enthalpy drop is 489.109 kJ/kg. This value indicates effective energy

extraction and conversion, crucial for maintaining overall system efficiency.

3. **Mass Flow Rate:**
    - The mass flow rate for the IPT is lower than the HPT but remains substantial. This is due to the IPT's operation at intermediate pressure levels, handling the steam that has already undergone partial expansion in the HPT.

Low-Pressure Turbine (LPT)

1. **Power Output and Efficiency:**
    - The LPT shows lower power output compared to the HPT and IPT but still plays a vital role, especially at lower power outputs. At 500 MW, the LPT's efficiency is around 90.70%. As the power output decreases to 200 MW, the efficiency improves slightly to 91.487%, demonstrating its effective operation under varying conditions.
2. **Enthalpy Drop:**
    - The enthalpy drop in the LPT is the lowest among the three turbines, reflecting its role in the final stage of energy extraction. At 500 MW, the enthalpy drop is 667.348 kJ/kg, indicating the energy conversion from steam to mechanical work in the later stages of the power cycle.
3. **Mass Flow Rate:**
    - The mass flow rate for the LPT is the lowest, as it handles the steam after significant energy has been extracted by the HPT and IPT. This is typical for LPTs, which operate at lower pressures and temperatures.

Detailed Comparison of Different Power Levels

500 MW Operation

- **HPT:** At this high power level, the HPT shows a substantial enthalpy drop (338.485 kJ/kg) and efficiency (88.85%), highlighting its role in the initial energy extraction phase.
- **IPT:** The IPT performs efficiently with a significant enthalpy drop (489.109 kJ/kg) and high efficiency (93.62%), crucial for the mid-stage energy conversion.
- **LPT:** The LPT's efficiency (90.70%) and enthalpy drop (667.348 kJ/kg) underscore its importance in the final energy extraction stage.

400 MW Operation

- **HPT:** Efficiency decreases to 77.631% with an enthalpy drop of 335.1 kJ/kg, indicating reduced performance at lower steam conditions.

- **IPT:** Maintains high efficiency (93.84%) and an enthalpy drop of 487.5 kJ/kg, showing consistent mid-stage performance.
- **LPT:** Slight improvement in efficiency (91.16%) and an enthalpy drop of 662.3 kJ/kg, highlighting its adaptability to varying loads.

300 MW Operation

- **HPT:** Efficiency further decreases to 67.66% with a reduced enthalpy drop (332.1 kJ/kg), reflecting lower steam energy availability.
- **IPT:** High efficiency (93.754%) and an enthalpy drop of 490.4 kJ/kg, maintaining effective energy conversion.
- **LPT:** Efficiency remains high (91.487%) with a lower enthalpy drop (644.7 kJ/kg), indicating stable performance at reduced power levels.

200 MW Operation

- **HPT:** Efficiency drops significantly to 60.07% with an enthalpy drop of 355.08 kJ/kg, showing the impact of low power operation.
- **IPT:** Maintains high efficiency (93.87%) with an enthalpy drop of 463.17 kJ/kg, underscoring its robust mid-stage performance.
- **LPT:** Efficiency stabilizes (90.7%) with the lowest enthalpy drop (622.58 kJ/kg), effectively managing the final energy extraction stage.

Conclusion

The HPT, IPT, and LPT collectively ensure efficient power generation by handling different stages of steam energy conversion. The HPT excels in the initial high-energy extraction, the IPT maintains high efficiency in the mid-stage, and the LPT effectively manages the final energy conversion. The overall system efficiency is sustained through the complementary roles of these turbines, adapting well to varying power outputs. This synergy is crucial for optimizing power plant performance and ensuring reliable and efficient energy production across different operational conditions.

Conclusion

1. **Understanding Turbine and Auxiliary Systems:** The detailed study of turbines and their auxiliary systems provided an in-depth look at how these critical components work together to convert thermal energy into mechanical and then electrical energy. Key aspects such as the design, operation, and maintenance of high-pressure, intermediate-pressure, and low-pressure turbines were explored extensively. The role of auxiliary systems, including condensers, feedwater heaters, and cooling towers, was also examined, highlighting their importance in ensuring efficient and reliable plant operation.

2. **Efficiency Calculations:** Learning to calculate the efficiency of turbines was a significant part of this internship. The process involved understanding enthalpy changes at various stages of the turbine cycle and using Mollier charts and steam tables for accurate data interpretation. Calculations for isentropic and actual enthalpy drops provided insights into the performance of the turbines and areas for potential improvement. This knowledge is crucial for optimizing plant operations and reducing energy losses.
3. **Operational Insights:** Observing the real-time operations of the Kakatiya Thermal Power Plant was invaluable. The experience underscored the complexities of managing a large-scale power plant, including the challenges of maintaining optimal performance, handling unexpected issues, and ensuring safety protocols are followed rigorously. The interaction with plant engineers and technicians provided practical knowledge and strategies for effective power plant management.
4. **Technological Advancements:** Exposure to the latest technological advancements in power generation was another highlight. Understanding how modern control systems and advanced materials are used to enhance the efficiency and longevity of power plant components has broadened my perspective on the future of energy production. These advancements not only improve efficiency but also contribute to reducing the environmental impact of power generation.
5. **Environmental and Regulatory Considerations:** The internship also emphasized the importance of environmental and regulatory considerations in power plant operations. Learning about emissions control, waste management, and regulatory compliance reinforced the need for sustainable practices in the energy sector. The integration of environmental standards into the operational framework is essential for minimizing the ecological footprint of power plants.