Comprehensive Review on Heat Exchangers in Thermal Power Plants

Mrs. Nausheen Pathan[1], Prof. Avinash Mankar[2]

[1] Student, Heat Power Engineering, Guru Nanak Institute of Technology, Maharashtra, India.
[2] Assistant Professor, Heat Power Engineering, Guru Nanak Institute of Technology, Maharashtra, India

ABSTRACT

This project aims to enhance the heat rate of thermal power plants, crucial for efficiency and financial feasibility. It focuses on turbine components, including high/low-pressure heaters, deaerator, turbine-driven pumps, and condensers, to identify key parameters affecting the heat rate.

After a comprehensive analysis, the research identifies the outlet temperature of heater 8 in unit 8 as a critical parameter significantly impacting the heat rate. A minor 10-degree Celsius difference in this parameter leads to a 2% reduction in heat rate, causing substantial financial losses.

The project recommends strategies to optimize the outlet temperature of heater 8, aiming to elevate the heat rate, improve efficiency, and enhance financial performance. These findings provide valuable insights for thermal power plant operations, offering practical recommendations to minimize energy consumption and promote sustainable practices, benefiting operators and stakeholders.

Keyword : *heat rate, heater, deaerator, turbine components, condenser*

---

1. System description of Coal fired thermal power plant

The Rankine cycle, fundamental to steam power plants, relies on isentropic expansion of high-pressure gas, commonly steam, to generate work. Water is preferred in this cycle due to its incompressible nature, requiring minimal energy for compression and offering efficient control within the vapor dome on a phase diagram.

Advancements in coal-fired power plant technology, specifically supercritical power plants, aim to increase power output and efficiency to reduce CO2 emissions. Enhancing the Rankine steam cycle by raising temperature and pressure in the turbine is a strategy to achieve this, mitigating fossil fuel consumption and emissions. However, coal-fired plants still contribute significantly to CO2 emissions.

The power plant operates on the Rankine cycle, involving four processes: adiabatic compression, constant pressure heat addition, adiabatic expansion in a steam turbine, and constant pressure heat rejection in the condenser.

The original Rankine cycle lacked optimal efficiency, prompting improvements such as increased steam temperature and pressure. Steam reheat during turbine expansion further improved thermal efficiency by 1.5 to 2%. The regenerative feedwater heating cycle extracts steam for feedwater heating, enhancing thermal efficiency with benefits like improved turbine efficiency and reduced equipment sizes.

Regenerative feedwater heating in modern steam power plants, utilizing a modified Rankine Cycle, achieves higher thermal cycle efficiency (45-50%). Power plants like Koradi Thermal Power Station employ modified Rankine cycles for enhanced efficiency and emission reduction.

2. Detailed Description of the Components of Power Plant

The turbine cycle is a critical element in power generation systems, serving as a key component for converting thermal energy into mechanical energy. This cycle consists of interconnected components that work together to efficiently capture and utilize thermal energy for power generation. A comprehensive understanding of how these components operate within the power plant is crucial for acquiring in-depth knowledge and ensuring the effective functioning of the entire system.

Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work.

2.1 High Pressure Closed Feedwater Heaters

High-pressure feedwater heaters are integral components in power generation systems, designed as three-zone, horizontal, U-tube type shell & tube heat exchangers with a removable shell. These heaters play a crucial role in the efficient utilization of thermal energy for power generation. Here are key details about their construction and functionality:

1. Design Characteristics:
   - Three-zone, horizontal, U-tube type shell & tube heat exchangers.
   - Removable shell for ease of maintenance.
   - Circumferentially welded shell to the integral skirt with a tube sheet.
   - Identification rings and a 6-inch diameter rod for maintenance personnel guidance during shell cutting.
   - Stainless steel flame protection band to prevent tube damage during disassembly and re-welding operations.

2. Shell and Tube Configuration:
   - Feedwater passes through the tube side in two passes.
   - Heated by extraction steam from the turbine exit on the shell side.

3. Construction Details:
   - Shell is equipped with a self-sealing elliptical manway cover.
   - Tube bundle divided into three zones on the shell side: Desuperheating zone, Condensing zone, and Drains cooling zone.

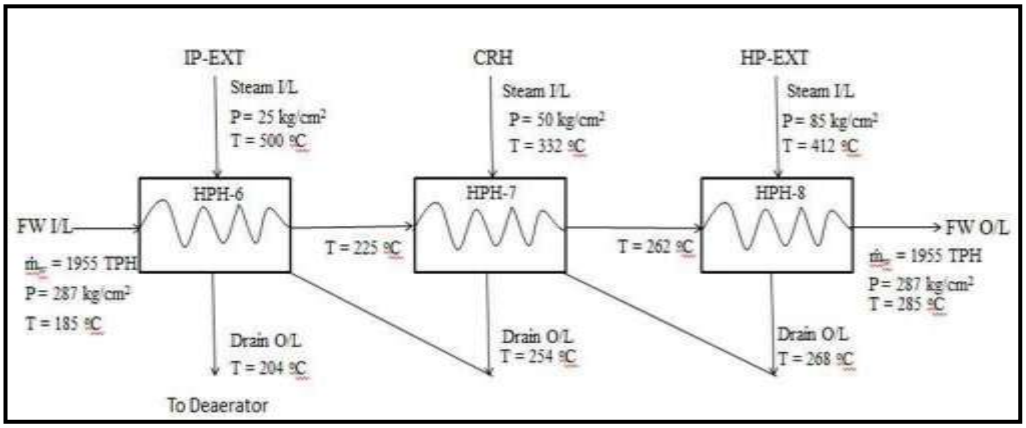
4. Desuperheating Zone:
   - Raises outlet temperature of feedwater close to saturation temperature of extraction steam.
   - Prevents reduction in heat transfer rate from highly superheated steam entering the condensing zone.
   - Achieves sensible cooling of dry superheated steam under dry wall conditions.
   - Envelops the outlet tube pass's entire tube bundle in a shroud for a specific length.
   - Steam enters the shell side through cutouts on the shroud, flowing countercurrent to feedwater.

5. Condensing Zone:
   - Tubes supported by carbon steel support plates to prevent sagging and protect against flow-induced vibrations.
   - Sliding strips welded to support plates for easy shell removal.

6. Drains Cooling Zone:
   - Enclosed by curved plates welded to a flat plate.
   - Achieves sufficient subcooling of drains leaving the condensing zone.
   - Inlet nozzle at the start of the Drains cooling zone allows saturated condensate to enter and further subcool.

7. Erosion Prevention and Maintenance:

   - Stainless steel impingement plate under the steam inlet nozzle to prevent tube erosion.
   - Vent and drain connections for start-up, shutdown, and trouble-free operation.



8. Control and Efficiency Measures:
- Water level in the shell maintained within prescribed levels using level gauges and indicators.
- Continuous venting (approximately 0.5% of steam entering the heater) to clean non-condensable on the shell side, ensuring maximum thermal efficiency (ηT).

2.2 Low Pressure Heaters

Low-pressure feedwater heaters, specifically LPH3, LPH-4, and the Duplex Heater, play a crucial role in power generation systems. Here are key details about their design, construction, and operational parameters:

1. Design Characteristics:
- Two-zone, horizontal, U-tube type shell & tube heat exchangers with removable shells.
- Condensate passes on the tube side with two passes, heated by extraction steam on the shell side.
- Circumferentially welded shell to the integral skirt with a tubesheet.
- Hoop rings (6 diameter CS rod) guide maintenance personnel during shell cutting.
- Stainless steel flame protection band prevents tube damage during disassembly, cutting, and re-welding.

2. Duplex LP Heater:
- Combines LP1 & LP2 in the shell side, with a Divider plate separating the steam side of LP1 & LP2.
- Two nozzles on the channel side for condensate inlet (LP1 bottom half) and outlet (LP2 top half).
- Mounted inside the condenser neck.

3. Tube Bundle Zones:
- Divided into two distinct zones on the shell side: Condensing zone and Drains cooling zone.

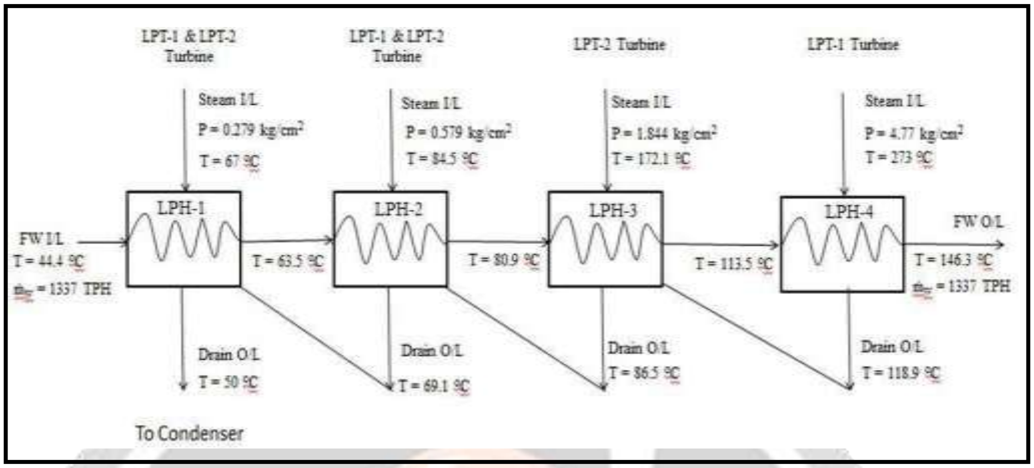
4. Construction Details:
- All-welded closure with a flanged-type access opening.
- Stainless steel impingement plate (10 THK) under the steam inlet nozzle to prevent tube erosion.
- Carbon steel support plates prevent sagging in the condensing zone.
- Sliding strips (16 THK) facilitate easy shell removal for LP3 & LP4.
- Drains cooling zone (DC zone) of full pass type envelops the shell and extends for part of the tube length.

5. Drains Cooling Zone (DC Zone):
- Achieves sufficient subcooling of drains by flooding tubes with condensate.
- High mass velocities for efficient heat transfer aided by closely spaced baffles.
- Inlet nozzle at the start of the DC zone allows saturated condensate to enter for further subcooling.
- Water level controlled to prevent steam entry into the drains cooling zone.

6. Operational Parameters:
- Terminal Temperature Difference (TTD) guaranteed value of 2.8°C for all LP heaters.
- Drains Cooler Approach (DCA) value guaranteed at 5.6°C for all LP heaters.

- Tube side pressure drop guaranteed at ≤ 0.55 kg/cm2 for LP3, ≤ 0.65 kg/cm2 for LP4 & ≤ 0.6 kg/cm2 for each LP lA/lB or LP 2A/2B.

7. Venting and Maintenance:



- Equipped with suitable vent and drain connections for startup, shutdown, and trouble-free operation.
- Provisions for continuous venting (approximately 0.5% of steam entering the heater) to clean non-condensable on the shell side, ensuring maximum thermal efficiency (ηT).

2.3 Deaerator

Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work Introduction related your research work The Stork feedwater deaerator is a vital component in power generation systems, serving the essential function of removing oxygen from feedwater using steam. This process is crucial in water-based systems, where even small amounts of oxygen can cause significant corrosion. The deaerator employs a process of physical deaeration, consisting of two main steps:

1. Pre-deaeration:
   - Water, whether condensate or makeup water, is introduced into the deaerator through a sprayer.
   - Simultaneously, steam is injected below the water level.
   - This phase involves spraying water into a portion of the steam space.

2. Final Deaeration:
   - This step takes place in the water tank, where steam comes into close contact with the water.
   - The design of the sprayer and internal components is tailored for efficient deaeration of incoming water.

The Stork feedwater deaerator is specifically engineered to achieve optimal deaeration while serving additional functions:

- Mixer/Pre-heater: The deaerator acts as a mixer and pre-heater, contributing to the overall efficiency of the system.
- Storage Tank: It serves as a storage tank for the deaerated water.

In summary, the Stork feedwater deaerator plays a critical role in maintaining water quality by eliminating oxygen, thereby preventing corrosive issues in the system. It ensures that the incoming water is effectively deaerated through a well-designed process, safeguarding the integrity and longevity of the power generation system.

2.4 Steam Turbine

The provided text describes a three-cylinder tandem compound four flows exhaust, condensing reheat turbine. Here are the key details:

1. Turbine Type and Construction:
   - Three-cylinder tandem compound four flows exhaust, condensing reheat turbine.
   - Designed for high operating efficiencies and maximum reliability.
   - Illustrated in the Turbine Sectional Assembly (Figure 1.8), showing a longitudinal section through the vertical centerline.

2. High-Pressure Intermediate Pressure Turbine:
   - Combination impulse (Rateau stage) and reaction type.
   - Steam enters through two main stop valve-steam chest assemblies on each side.
   - Inlet sleeves connect steam chest outlets to the HP-IP casing through slip joints.
   - Features impulse stage, high-pressure blading, and reheater.
   - Steam exits through exhaust openings in the outer casing base.

3. Intermediate Pressure Element and Low-Pressure Turbines:
   - Intermediate pressure element with reaction blading.
   - Connected to the low-pressure turbines through a crossover pipe with expansion joints.
   - Low-pressure turbines designed as reaction, four-flow type elements.
   - Steam extraction for feedwater heating from openings in the lower casing.

4. Admission Valves:
   - Two steam chests along each side of the HP-IP turbine casing.
   - Each steam chest contains four plug-type governing valves controlled by a governor.
   - Main stop valve located horizontally at each steam chest.

5. Casing Design:
   - Casings and supporting structures designed for symmetrical movements to minimize distortion.
   - Outer casing of HP-IP turbine made from alloy steel casting, split horizontally.
   - Inner casing split in the center plane, supported in the outer casing to allow for free expansion.
   - Nozzle chamber and dummy ring supported and guided similarly for correct positioning.

6. LP Turbines Casing:
   - Outer and inner casings for LP turbines consist of fabricated bases and covers.
   - Continuous foot or skirt integral with the outer casing base supports each LP turbine.
   - LP turbines in a double-flow arrangement, with steam entering at the center and descending into the condenser.

7. Assembly and Tightening:
   - Joint faces finished for a tight joint under standard hydrostatic and steam tests.
   - Large stud bolts used to bolt the base and cover of the high-pressure intermediate-pressure outer casing.

8. Figure 1.8 - Steam Turbine Assembly:
   - Illustrates the arrangement of the steam turbine assembly, including HP turbine, IP turbine, and two LP turbines.

The overall turbine design emphasizes efficiency, reliability, and careful construction to accommodate thermal changes and ensure optimal performance within the power generation system.

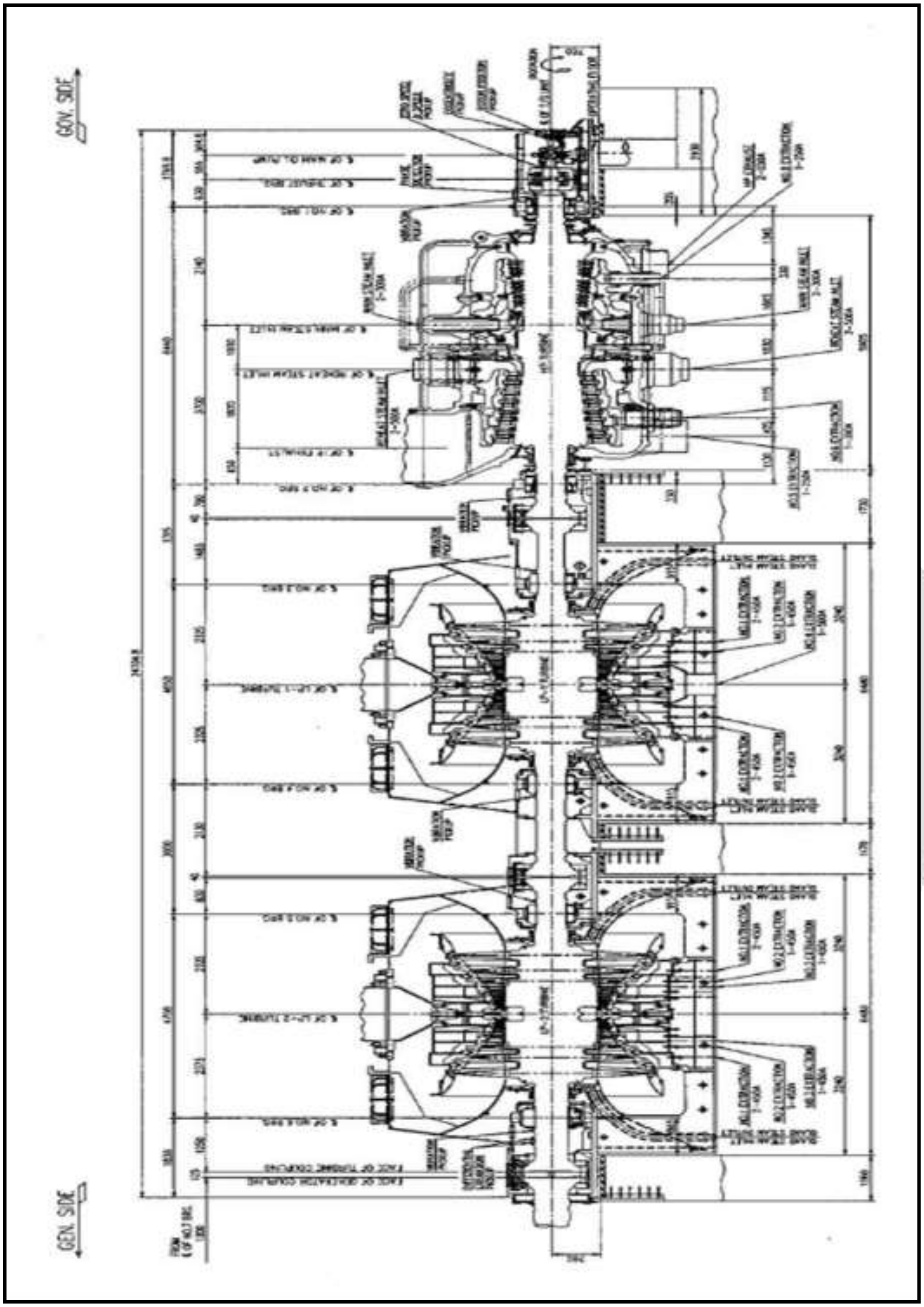


Fig -2 Name of the figure

2.5 Condenser

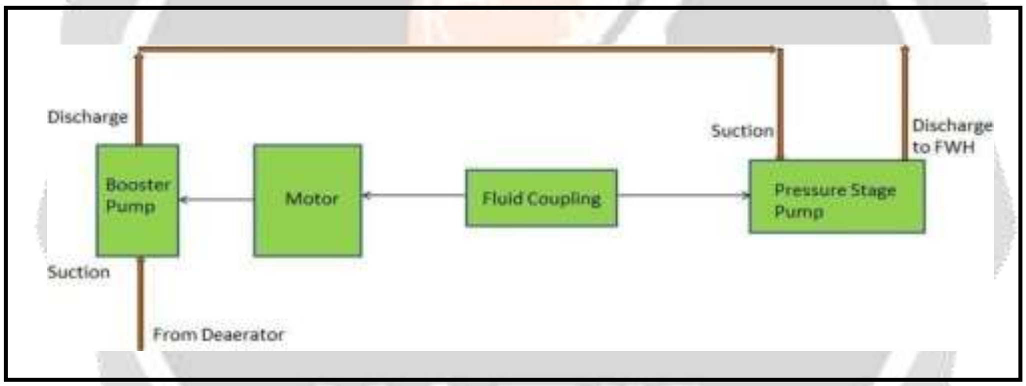
The dual-shell, dual-pressure surface condenser, located at the steam turbine exhaust's bottom, serves a pivotal role in the power generation system. With an effective heat transfer area of 20345.4 m² / 19857.3 m², evenly divided into two tube bundles, its primary function is to efficiently condense steam from the turbine exhaust and act as a condensate storage chamber. Beyond condensation, the condenser also internally deaerates and reheats the condensate, ensuring optimal steam quality. Moreover, it handles the deaeration, reheating, or cooling of all vents, drips, and drains. This multifunctional condenser significantly contributes to the overall efficiency and effectiveness of the steam turbine system.

2.6 Boiler feed pump

Boiler Feed Pumps in Thermal Power Plants: A Comparative Overview

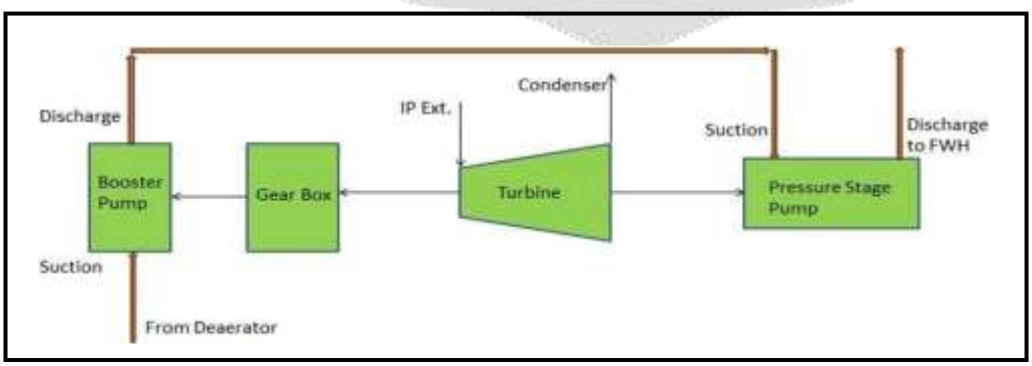
Boiler Feed Pumps (BFPs) are crucial auxiliary components in coal-fired power plants, ensuring the efficient delivery of liquid medium to steam generators. Two driving modes, Motor Driven Boiler Feed Pump (MDBFP) and Turbine Driven Boiler Feed Pump (TDBFP), play key roles in plant operation.

Motor Driven Boiler Feed Pump (MDBFP):
Powered by an 8 MW motor, consuming 30% of total generation capacity, MDBFP layout features a booster pump, motor, fluid coupling, and main pressure stage pump. Figure illustrates this schematic layout.



`![MDBFP Schematic](Figure1.6_MDBFP_Schematic.png)`

Turbine Driven Boiler Feed Pump (TDBFP):
Utilizing steam from the intermediate pressure turbine exhaust, TDBFP offers advantages like reduced net heat consumption, enhanced operating stability, and regulatory compliance. Figure 1.7 details the TDBFP system.



`![TDBFP Schematic](Figure1.7_TDBFP_Schematic.png)`

Advantages of TDBFP over MDBFP:
1. Reduced net heat consumption for increased overall unit output.
2. Improved operating stability and regulating performance.
3. Aligns with regulatory norms, reducing auxiliary power consumption.

In conclusion, the choice between MDBFP and TDBFP in thermal power plants significantly impacts efficiency, stability, and regulatory compliance. This comprehensive overview provides insights for informed decision-making in power plant design and operation.

4. CONCLUSIONS

In conclusion, the described three-cylinder tandem compound turbine, with its combination of impulse and reaction stages, demonstrates a sophisticated design for high efficiency and reliability in power generation. The meticulous construction of the casings, precise support structures, and incorporation of features like admission valves and reheaters highlight the turbine's comprehensive functionality. The tandem arrangement of high-pressure, intermediate-pressure, and low-pressure elements, as illustrated, underscores a well-engineered layout. This turbine not only efficiently converts thermal energy into mechanical power but also addresses challenges such as oxygen removal in feedwater, showcasing a holistic approach to power plant performance and longevity.

6. REFERENCES

[1] Feed Water Heater manuals, Koradi expansion project (3*660 MW) Project, L&T, 2012.
[2] Steam Turbine Assembly, Koradi expansion project (3*660 MW) Project, L&T, 2012.
[3] Deaerator manuals, Koradi expansion project (3*660 MW), L&T, 2012.
[4] Condenser manuals, Koradi expansion project (3*660 MW), L&T, 2012.
[5] Heat Balance Diagram, Koradi expansion project (3*660 MW), L&T, 2012.
[6] Technical Diary, Unit: 8,9 and 10, Koradi expansion project (3*660 MW)