Performance analysis and efficiency enhancement of cooling tower in 210 MW thermal unit

G Ravikumar Solomon¹, R Balaji¹ *, K Ilayaperumal², B Chellappa¹

¹Department of Mechanical Engineering, Hindustan Institute of Technology & Science, Chennai-603103, Tamil Nadu, India
²Department of Mechanical Engineering, Rajalakshmi Institute of Technology, Chennai-600124, Tamil Nadu, India.

*E-mail: sridharabalaa@gmail.com

Abstract

Heat exchangers, condensers plays a vital role in any kind of power cycle like modified Rankin cycle, these components involves transfer of both sensible and latent heat and have great influence over the power plant performance. The condenser employed in MTPS involves transfer of latent heat into steam. Yet it as to induce a phase change in thereby forming water. Increase in the effectiveness of condenser resulted in the increase of vacuum in the condenser. Thereby work done by steam is increased and coal saving (per ton of steam production) is achieved. This condensation process results in the formation of sludge’s (temporary) and (permanent). Along the inner periphery of the condenser tubes. These permanent scales have decreased thermal conductivity and inhibit the heat transfer rate. The more the thickness of the scale the less the heat is removed from the steam. This scale formation limits the life of the condenser tubes with maximum performance. In this project the thickness of the scale formed in the condenser tubes is calculated theoretically and the performance is analysed before and after scale formation in the condenser. Different materials which involve less scale formation, different ways of reducing scales and various scale removing methods are suggested.

Keywords: Cooling Tower, 210 MW Thermal Unit, Scale formation, Condenser, MTPS

1. Introduction:

In recent years, With the consistently expanding growth of an industry the power demand that cause serious effect in the near future energy should be developed at the optimum level to cope up with the demand the power plants are set up to achieve a definitive objective of energy [1]. As on continuous working any equipment tends to deviate from the standard value which is nothing but the losses[2]. By minimizing the losses the efficiency of the cooling tower is increased. Cooling tower assumes an imperative part in a large portion of the power plants and furthermore goes about as the significant consideration for the power plant effectiveness [3]. The main objective of the research is to determine the energy conversion to increase the efficiency of the cooling tower by implementing number of cell compare to the pervious cooling tower. The objectives also include identification of technically and economically viable energy saving proposals with coat benefit analysis [4,5].
efficiency of the cooling tower is regained by conducting several tests periodically that ensures the extended life span of the cooling tower. This can lead to sustain the actual power generation [6]. In this research an attempt has been made to analyse the performance and to improve the efficiency of Condenser in 210MW thermal unit [7]. Practical problems encountered and the losses are studied and discussed. Energy saved is twice energy generated [8]. Hence the present need of the power scenario is to optimize the performance of the Power plant by economic operation [9]. This can be achieved only by reducing the losses. The Thermal Power station has 4 units of 210 MW, is limited to one unit to 210 MW since all are similar in construction [10]. The main objective of the research is to study and evaluate the performance of steam turbine of 210 MW units in Mettur Thermal power Station and to carry out Condenser conditioning assessment. The performance evaluation and monitoring of condenser was carried out. The research also deals with monitoring the condition of condenser, studying the condenser back pressure

Condenser Back Pressure is due to the deviations in:
1. Cooling water inlet temperature
2. Cool water Flow
3. Heat transfer across the tubes of the condenser.

The performance evaluated is compared with the design values and the remedies to improve the heat rate and efficiency are suggested [11]. Power Station performance and generating cost are significantly affected by the operating efficiencies of turbine and condenser. The capital cost of installing a new power station is capital intensive in the range of Rs.4 to 5 crores per MW. Hence any improvement in efficiency of existing operating stations will be cost effective. Performance evaluation and condenser condition assessment will help to improve the efficiency and cost economies. Cost implications of heat rate degradation based on the above performance studies are also discussed.

The Surface Condenser is the standard term used in the exhaust vapor of a steam turbine for a water-cooled heat shell and tube exchanger mounted on a thermal power station. The condensers are

![Figure 1. General layout of MTPS-I](image-url)
heat exchangers that transform steam at pressure below atmospheric pressure, from its gaseous state to its liquid state. Where there is a lack of cooling water, an air cooled condenser is also used. However, an air-cooled condenser is much more costly and cannot reach the low pressure of the steam-turbine exhaust like the cooled surface condenser [12]. In diverse applications of industries, surface condensers are often used in industries other than steam turbine exhaust condensation in power plants. The condenser's key function is to condense the exhaust vapor for reuse in the cycle and optimize the turbine performance by proper vacuum preservation. The lowering of the condenser's pressure (increasing the vacuum) would further raise the enthalpy decrease of the expanding vapor. The amount of work available from the turbine would then be increased (electrical output). Reducing the working pressure of the condenser, the following will occur:

- Increased turbine output
- Increased plant efficiency
- Reduced steam flow (for a given plant output)

The purpose of the condenser is to produce the vacuum by condensing steam, eliminating the dissolved non-condensable gas from the condensate that re-uses the condensate as the supply of feed water to the steam generator, providing a leakage-tight barrier between condensation of the high-grade condensate contained within the shell and the untreated cooling water. Providing a leak-tight buffer that prevents excess back pressure on the turbine. A drain receptor, receiving vapor and condensate from many other exchangers of plants, steam dumps and bleeding turbines supply a convenient receptacle for adding feed water.

2. Experimental Methodology:

The Mettur Thermal power station (MTPS) stage —1 & 2 comprises of 4units 10 MW capacity. The evaporator has membrane type water wall tubes, three type of super heater, two stages of repeater and three banks of non-streaming type Economizer are arrange in first horizontal and seconds passes of boiler. Two axial flow draught fans supply the air required for combustion.

The coal being the main fuel which is received from coal mine of north India through rail route by railway wagon. Railways track is the laid the coal for receiving the loaded wagons are unloads one by one with the help of the wagons triples. The coal from the wagon fell in to the apron feeder through unloading Hooper and fed in to the conveyer belt.

2.1 Hot Water Pipe and Basin

The foreign material in the coal are supplied by installing IMS(Inline Magnetic Separators) suitable points in the line of coal flow to avoid is scrunched of min size, which is further crushed to a size of 20mm in the secondary crusher extend to mill through bunker at stock yard for stocking. There
are 6 numbers bunkers for each unit, each of 30m height and have 620T capacity, a bunker gate is provided at the bottom of the bunker. There are number feeders per unit with capacity of 30T/hr. Each feeder received the raw coal of size 20 mm from it concerned bunked and delivers 1t through discharge pipe which connects the mill at its top and extends central portion of mill. The coal is forced to the bull ring portion due to centrifugal action of rotating bowl. Three rollers are kept over the bull ring segment 120 degrees with a gap of 3mm to 6mm, when coal comes in between this full ring segment and roller. The coal in contact with roller make the roller to rotate the pulverization of coal takes place. The hard particles if any will tend to go faster towards the extend end from there it chops down through holes to the under bowl position

2.2 Coal to Electricity Process

Steam coal, also known as thermal coal, is used in power stations to generate electricity. Coal is first mined to fine powered, which increases the surfaces area and allows it to burn more quickly. In the Pulverized Coal Combustion (PCC), the powered coal combustion of a boiler where it burns at higher temperature. The hot gases and heat energy produced converts water-in tube lining the boiler into steam. The high pressure stream is passed into a turbine shaft to rotate at high speed. A generator is mounted at one end of the turbine shaft and consists of wounded wire coils. Electrically is generated these are rapidly rotated in a strong magnetic field. After passing through the turbine, the considered and returned to the boiler to the heated once again.

2.3 Cooling Tower

A cooling tower is equipment used to reduce the temperature of water extracting heat from water and emitting to the atmosphere. Cooling tower make use evaporation whereby some of the water is evaporated into moving air steam and subsequently discharged into the atmosphere. As a result, the remainder of the water is cooled down significantly cooling tower are able to lower the water temperature more than devices that use only air to reject heat, like the radiator in a car and are therefore more cost-effective and energy efficient as shown in figure 3 and 4.

Figure 3. Cooling tower fill bar
2.4 Analysis of Most Effective Biocide In Cooling Tower

Chlorine dioxide (ClO$_2$) is viable as both a disinfectant and an oxidant in water treatment. Chlorine dioxide is an expansive range microbiocide powerful over a wide pH range. In contrast to chlorine, chlorine dioxide doesn't respond with natural materials to shape TriHaloMethanes (THMs). Chlorine dioxide is likewise non-receptive with alkali nitrogen and with most treatment synthetic compounds (erosion and scale inhibitors) present in cooling water frameworks as shown in fig.5. Chlorine dioxide is viable in the control of microbiological developments in modern cooling waters under conditions negative to chlorine. It is especially viable in frameworks having a high pH, alkali nitrogen pollution, constant sludge issues, or the microbial tainting is exasperated by defilement with vegetable or mineral oils, phenols, or other high chlorine-demand in producing compounds.

2.5 Mechanical Draught Cooling Tower

Mechanical draft towers have large fans to force or draw air through circulated water. The water falls downwards over till surfaces. Which help increase the contact time between the water and the air fills the system resistance. This helps to maximize heat transfer between the two cooling tower drafts of mechanical tower depends upon various parameters such as fan diameter and speed of the orientation as shown in figures 6 and fig 7.
Mechanical draft towers are available in large range of capabilities. Tower can be either factory built or field erected — for example concrete towers are only filled erected. Many towers are connected so that they can be grouped together to achieve the desired capacity.

3. RESULTS AND DISCUSSION

3.1 Condenser Condition Assessment Calculation

Table 1. Parameters Observed

| PARAMETERS                                      | DESIGN(D) | ACTUAL(A) |
|------------------------------------------------|-----------|-----------|
| Cooling Water I/L Temp, (°C)                   | 34        | 30.89     |
| Cooling Water O/L Temp, (°C)                   | 42.6      | 37.81     |
| Cooling Water Temp Rise (AT), (°C)             | 81        | 6.92      |
| Saturation Temperature, (°C)                   | 46.09     | 43.62     |
| Terminal Temp Difference (TTD), (°C)            | 3.49      | 5.81      |
| Back Pressure, (ksc)                           | 0.1033    | 0.0910    |
| Condenser Vacuum, (mm Hg)                       | 684       | 693       |

3.2 Scale Formation Readings

Table 2. Scale Formation Readings

| Parameter                                | Before scale formation | After scale formation |
|------------------------------------------|------------------------|-----------------------|
| Inlet temperature of water (°C)           | 27.8                   | 30.93                 |
| Outlet temperature of water (°C)          | 39.93                  | 40.03                 |
| Rise in Temperature of Water (°C)         | 12.13                  | 9.1                   |
| Vacuum in condenser (Bar)                 | 0.08                   | 0.11                  |
| Temperature corresponding to vacuum in condenser (°C) | 41.53 | 47.71 |
3.3 Efficiency Calculation

Table 3. Efficiency

|                      | Before scale formation | After scale formation |
|----------------------|------------------------|-----------------------|
| $\eta = \frac{12.13}{41.53 - 27.8}$ | $= 88\%$               | $\eta = \frac{9.1}{47.71 - 30.93}$ | $= 54\%$ |

Figure 8. Before & After Scale Formation Characteristic chart

Figure 9. Before & After Scale Formation Efficiency, $\eta \%$

It is observed that the performance of 210 MW Turbine and Condenser system needs further attention to achieve better performance in regard to Efficiency and Condenser heat transfer aspects. Periodical review of performance of various components of a power plant and unit as a whole, have a key role in efficient performance and economic production of power as shown in table 1, 2 and 3. The availability of much-sophisticated instrumentations for measuring accurate readings is essential for carrying out regular performance monitoring and carry out remedial measures, if any required. Condenser performance has a profound effect on heat rate degradation and hence all efforts are to be made to ensure that the condenser performance is kept close to optimum at all times. The condenser condition must be continuously monitored to improve the efficiency of Turbine and plant to achieve better cost economics in the highly competitive world to stay in the power generation. The performance parameter of the condenser employed in MTPS is analysed before and after scale formation with an eye to increase the overall efficiency of power plant. Also the thickness of the scale formed in the condenser tubes are calculated theoretically with the help of heat transfer equations. As
the scale formation and its increased thickness value limits the tube life at its maximum performance, and different ways of reducing scales and also different scale removing techniques are suggested.

4. DESIGN SPECIFICATION OF COOLING TOWER

4.1 Design and Technical Specification of Cooling Tower

| S.NO | DESCRIPTION | UNITS | STAGE1(COOLING TOWER ) |
|------|-------------|-------|------------------------|
| 1    | Tower make  |       | Paharpur                |
| 2    | Tower model |       | 1514-11                |
| 3    | Type of tower |     | Induced draft – cross flow |
| 4    | Total design capacity | m³/hr | 32000 |
| 5    | Flow per cell | m³/hr | 2909.3 |
| 6    | Hot water inlet temperature | °C | 40 |
| 7    | Recooled water inlet temperature | °C | 32 |
| 8    | Design inlet wet bulb temperature | °C | 25.5 |
| 9    | Design approach | °C | 4.5 |
| 10   | Total no. of cells/tower | Continuous | |
| 11   | Wind velocity for performance | Km/hr | 9 |
| 12   | Tower operation | Continuous | |
| 13   | Dry air flow per tower | m³/hr | 1423222/23470 |
| 14   | Temperature of air leaving the stack | °C | 35.4/36.36 |
| 15   | Inlet air enthalpy above 0°C per kg of dry air | Kcal/Kg | 19.2696 |
| 16   | Exit air enthalpy above 0°C per kg of dry air | Kcal/Kg | 33.73/33.41 |
| 17   | Total heat exchange per kg of dry inlet | Kcal/Kg | 14.2034/14.1404 |
| 18   | Drift loss (per tower) | Kg/hr | 16000 |
| 19   | Evaporating loss (per tower) | Kg/hr | 493162/494350 |
| 20   | Total wet volume of air per fan | m³/hr | 2016868/2037527 |
| 21   | Fan pressure (total static) | mm | 4.60/3.06 |
| 22   | Fan static efficiency | % | 55.95/57.3 |
| 23   | Power input to fan | KW | 45.93/49.74 |
| 24   | Water velocity through riser | m/sec | 2.21 |
| 25   | Type of air inlet | Dual | |
| 26   | Fill arrangement | Splash type | |
| 27   | Drift eliminator arrangement | Full wave ACB | |
| 28   | Water distribution nozzles | Polypropylene | |
| 29   | Types of recovery stock | RCC | |
| 30   | Fan | No’s | 8 |
|      | No.of blades/fan | | |
|      | Fan speed | Rpm | 116 |
|      | Blade diameter at tip | mm | 10000 |
|      | Hub diameter | mm | 2390 |
|      | Fan blade material | | |
|      | Casing | | |
|      | Fan | | |
|      | No.of stage | Bevel/worm | |
|      | Type of gear reducer | Cum single | |
|      | Reduction gear | | |
| 31   | Fill | PVC/RCC | |
| 32   | Reduction gear | Bevel/worm | |
| 33   | Driver (motor) | | |
|      | Motor speed | Rpm | 1500 |
|      | Motor rating | Kw | 67.11 |
| 34   | Basin inside area (l*b) | m² | 153.75x18.97 |
|  | Volume of water in the basin | m³ | 8750 |
4.2 Cooling Tower Water Basin before Cleaning Algae

Table 5. Reading taken before cleaning Algae

| CELL NO | Water Temperature °C | Water Velocity at Nozzle m/s | Air Temperature °C |
|---------|------------------|------------------|------------------|
|         | HOT WATER BASIN | COLD WATER BASIN | INLET | OUTLET | INLET | OUTLET |
| 1       | 39.0             | 30.0             | 3.2     | 11.0   | 32.5   | 33.9   |
| 2       | 39.0             | 30.0             | 2.6     | 9.7    | 32.7   | 33.0   |
| 3       | 38.0             | 31.0             | 2.5     | 9.9    | 33.2   | 34.1   |
| 4       | 39.0             | 30.0             | 3.0     | 11.7   | 33.3   | 34.2   |
| 5       | 38.0             | 31.0             | 2.5     | 7.4    | 33.8   | 34.4   |
| 6       | 40.0             | 30.0             | 2.1     | 9.6    | 33.6   | 34.0   |
| 7       | 38.0             | 30.0             | 3.1     | 11.1   | 34.3   | 34.4   |
| 8       | 40.0             | 31.0             | 2.4     | 10.1   | 33.8   | 35.0   |
| 9       | 38.0             | 30.0             | 2.3     | 10.2   | 34.0   | 36.0   |
| 10      | 40.0             | 30.0             | 2.2     | 11.0   | 32.0   | 35.5   |

The readings for the cooling tower are given here.

- Hot water temperature = 39°C
- Cold water temperature = 30°C
- Inlet Air temperature = 32.5°C
- Outlet air temperature = 33.9°C
- Cold water basin temperature = 30°C
- Wet bulb temperature = 26°C
- Dry bulb temperature = 32.5°C

Figure 10. Nozzle outlet velocity, Cooling tower efficiency and Cold water basin temperature comparison

5. Growth of Algae Cooling Tower

5.1 Biological Growth and the Cooling Water System

Uncontrollable biological growth results in failure, lack of power for heat exchange, equipment failure and waste of energy. Therefore, we need to consider and monitor the various forms of microbiological growth as shown in fig. 11 in cooling water. The cooling water, algae, bacteria and fungi demonstrate three usually biological growths. Among the three kinds, the different algae varieties make their own food. This is achieved using a green chlorophyll pigment found in algae.
Chlorophyll enables algae to produce their own food in the same way as plants generate their own food supply by photosynthesis.

Figure 11. Biological Growth in Cooling Tower

5.2 Biocide

A biocide is the chemical solution intended to regulate microbiological development effectively. Oxidization of biocides: chlorine, hydrogen peroxide, by carbonate, bromine, chlorine oxidant and oxone. There are two basic biocidal types; oxidising and non-oxidizing. Chlorine is found most commonly, but only in a pH range lower than 7.4, it is extremely corrosive.

Chlorine dioxide is safer than chlorine, though it is considerably less corrosive and efficient at 4.5 to 10.0 pH amounts. It is environmentally cleaner than chlorine, but typically more costly. Bromohydantoins, percarbonates and the oxone compounds are used because they are extremely economical and low environmentally friendly. A wide range of preparations are available for anti-oxidising biocides, among them: compounds of amine, ammonium quaternary blends, thiocyanates, glutaraldehyde and carbamates. Such biocidal forms react with the organism in order to stop the organism's growth. This is performed by various approaches, depending on the type of biocide and on the type of organism present and to be regulated as shown in table 6.

5.3 Calculation for Cooling Tower After Cleaning Algae

Readings Taken After Cleaning Algae

| Table 6. Readings taken after cleaning algae |
|---------------------------------------------|
| Water temperature °C | Water velocity at nozzle m/s | Air temperature °C |
| Hot water basin | Cold water basin | Inlet | Outlet | Inlet | Outlet |
| 39 | 28.5 | 3.2 | 38.82 | 32.5 | 33.9 |

Cold water temperature =30°C
Inlet Air temperature =32.5°C
Outlet air temperature =33.9°C
Cold water basin temperature = 28.5°C
Wet bulb temperature = 24.5°C
Dry bulb temperature = 34°C
5.4 Comparison Result for Cooling Tower

Table 7. Comparison result for cooling tower

| PERFORMANCE                      | UNIT     | BEFORE CLEANING | AFTER CLEANING |
|----------------------------------|----------|-----------------|----------------|
| Cooling tower range              | °C       | 9               | 9              |
| Cooling tower approach           | °C       | 4               | 4              |
| Effectiveness                    | %        | 69.23           | 72.49          |
| L/G ratio                        |          | 2.7164          | 2.7164         |
| Fan air flow actual/ cell        | Nm³/hr   | 25.824*10⁶      | 25.824*10⁶     |
| Air mass flow / cell             | Kg/hr    | 3386.07         | 3386.07        |
| Evaporation                      | m³/hr    | 277.28          | 223.93         |
| Makeup water consumption         |          | 616.17          | 497.62         |
| Enthalpy of inlet air            | KJ/kg    | 78              | 78.5           |
| Enthalpy of exit air             | KJ/kg    | 102.44          | 107.018        |
| NTU                              |          | 0.12324         | 0.1659         |
| Cooling load (Q1)                | KJ/hr    | 82620.84        | 96564.79       |
| Convective heat transfer ratio (Q)| KJ/hr    | 679102.92       | 9141777.019    |
| Humidity (Y)                     |          | 9.66            | 8.564          |
| Motor power of cooling tower fan | Kw       | 46.578          | 46.578         |
| Efficiency                       | %        | 69.23           | 72.4           |
| Heat load                        | KJ/hr    | 162193.2        | 162193.2       |
| Density ratio                    |          | 15.52           | 15.52          |
| Fraction of water                |          | 0.0115          | 0.0115         |
| Drift loss                       | m³/hr    | 41.588          | 41.588         |
| Total loss                       | m³/hr    | 945.038         | 763.138        |

Figure 12. Efficiency Comparison

6. Conclusion

In this research, the efficiency of the cooling tower have been determine by taking the valve temperature of the hot water and cold water, the velocity of the louver at inlet and outlet of the nozzle and air temperature of inlet and outlet and cleaning the presence of the algae in the nozzle. In this research, analyzed the flow path of nozzle, before and after the presence of the algae in the hot water basin. From that analysis it is observed that the Velocity of the hot water at the nozzle in the
presence of the algae is 11 m/s, without the presence of the algae is 38.8 m/s. The increases of the velocity of the hot water at the nozzle tend to increases the efficiency of the cooling tower-l from 69.23% to 72.4%. Because of frequent and periodic maintenance of fans, gearbox, drive shaft, hot water basin, hot water flow control valves, hot water pipelines and nozzles. It will attain stable efficiency. Due to scheduled maintenance, there is no algae formation in the hot water basin and so the cooling tower is still in better condition.

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