STUDY ON THE EFFECT OF COOLING WATER TEMPERATURE RISE ON LOSS FACTOR AND EFFICIENCY OF A CONDENSER FOR A 210 MW THERMAL POWER UNIT

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ABSTRACT

In this paper an attempt has been taken to perform a thermodynamic study and its analysis on the effect of cooling water temperature rise on Loss Factor and Efficiency of a condenser used in 210 MW thermal power unit. A new concept of Loss Factor has been introduced in this work and it is defined as the ratio of the heat released by the steam entering the condenser to the heat gained by its cooling water. The study has been carried out for the load of 210 MW, for fixed values of condenser pressure, mass flow rate of steam entering the condenser, mass flow rate of cooling water, total surface area of the tube and materials property respectively. The rise in cooling water temperature has been varied from 5^0C to 19^0C. The outcome of the study is that the efficiency increases and the Loss Factor decreases with increase in temperature rise in cooling water.

Keywords: Loss Factor (LF), Temperature Rise in Cooling Water, Condenser Pressure, Efficiency of the Condenser.

1. INTRODUCTION

A condenser, where the exhaust steam from the turbine is condensed, operates at a pressure lower than the atmosphere. There are mainly two objectives of using a condenser in a steam power plant, first is to reduce the turbine exhaust pressure so as to increase the specific work output of the turbine and second is to recover high quality feed water in the form of condensate and feed it back to the steam generator without any further treatment. Surface condensers are mostly used in thermal power plants. In a conventional condenser of a thermal power plant, steam from the low pressure turbine exhaust enters into the shell and tube type surface condenser and flow over the condenser tubes. Cooling water passes through the tubes of the condenser. Finally steam gets condensed and condensate is collected in reservoir, called hot well. A simplified schematic diagram of conventional condenser used in a thermal power plant is shown in Fig.1. The concept of Loss Factor has been incorporated to understand the losses inside the condenser. The temperature rise of the cooling water is having impact on Loss Factor and efficiency of a condenser which finally affect condenser's performance.
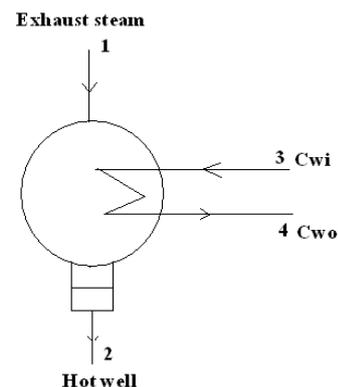

Fig. 1: Schematic diagram of a shell and tube type surface condenser

A number of studies have been carried out in the field of shell and tube type surface condenser. From the survey, it is observed that several activities have been carried out mostly in the area of shell and tube heat exchanger design, optimization of heat exchanger, enhancement of heat transfer using different type of fins etc. But till now, probably, no work has been done on

the effect of cooling water temperature rise on the performance of a condenser viewed from Loss Factor. Among these, J. Arman and A. K. Ghoshal [1] have suggested an optimum design problem for the different constraints involved in the designing of a shell and tube heat exchanger consisting of longitudinally finned tubes. They have found out that the optimum fin height increases linearly with the increase in tube outer diameter. Min-Soo kim et al. [2] have presented numerical evaluation of the flow distribution and thermal performance of a multi pass, multi channel heat exchanger as functions of the number of passes of inlet diameter. To determine the optimal number of passes for a fixed size of heat exchanger, they have investigated the JF factor by varying the number of passes and the inlet diameter of the tubes. S. Chakrabarti [3] has studied on the various availability losses in the condenser for five different loads of a 210MW thermal power unit by using second law of thermodynamics. The effects of flow of water in cooling tower on the thermal efficiencies of turbines and condensers of a paper mill power plant have been studied by Jinson Tao et al. [4]. Based on the model of turbines, condensers and cooling tower the optimization was made. A. Dutta et al. [5] have studied the performance of a condenser used in thermal power plant. With respect to our review of literature, in this paper, an endeavour has been made to study the effect of cooling water temperature rise on loss factor and efficiency of a condenser for a 210 MW thermal power unit of Kolaghat thermal power station.

2. MATHEMATICAL FORMULATION

Fig. 2 shows the energy balance diagram of the condenser.
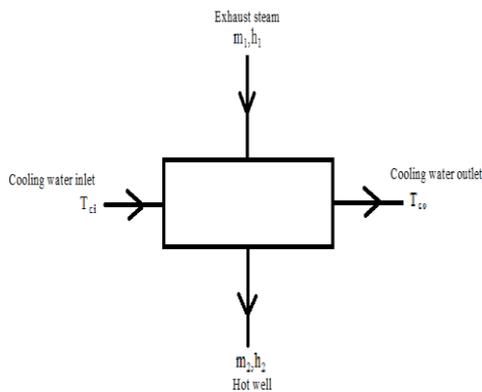

Fig. 2: Energy balance of a condenser

From the Figure 2, heat rejected by the exhaust steam inside the condenser can be written as,

$$Q_{steam} = m \times h_{fg} \qquad (1)$$

where, $m =$ Mass flow rate of exhaust steam (kg/sec.).

$h_{fg} =$ Latent heat of evaporation (KJ/kg).

and heat gained by the cooling water can be written as,

$$Q_{water} = m_{cw} c_p \Delta T \qquad (2)$$

Where,

$m_{cw} =$ Mass flow rate of cooling water (kg/sec.).

$c_p =$ Specific heat of water (KJ/kg).

$\Delta T =$ Temperature difference in cooling water (^{0}C).

The LF is defined as,

$$LF = \frac{Q_{steam}}{Q_{water}} \qquad (3)$$

The temperature distributions of the condensed steam and cooling water along the length of the condenser are shown in Fig. 3.
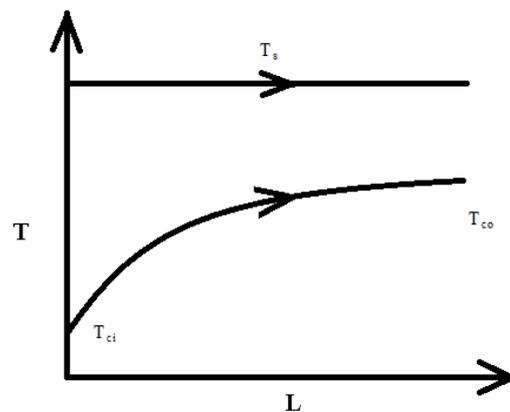

Fig. 3 T-L diagram of the condenser

The efficiency of the condenser is computed by,

$$\eta = \frac{T_{co} - T_{ci}}{T_s - T_{ci}} \qquad (4)$$

where,

$T_{co} =$ Temperature of the cooling water outlet (^{0}C).

$T_{ci} =$ Temperature of the cooling water inlet (^{0}C).

$T_s =$ Saturation temperature of the steam (^{0}C).

3. RESULTS AND DISCUSSIONS

In this study, the effect of cooling water temperature rise on Loss Factor and efficiency of a condenser has been carried out. All the calculations during analysis have been performed on the basis of available plant data [6]. The intention of this research is to observe the effect of cooling water temperature rise on Loss Factor and efficiency of a condenser. The analysis has been carried out on the basis of First law of thermodynamics. The load considered during analysis is 210 MW. The rise in cooling water temperature has been varied from 5^0C to 19^0C.

3.1 Effect of Temperature Difference in Cooling Water on Condenser Efficiency

Effect of temperature rise in cooling water on the condenser efficiency has been stated in Fig. 4.

At a particular load and condenser pressure, the heat rejection by the exhaust steam is fixed. The range of the cooling water temperature rise has been taken from 5^0C to 19^0C. If the rise in cooling water temperature is higher and reaches nearly to the saturation temperature (Fig. 3) of the steam, then it gives higher efficiency. Similarly, when the temperatures rise in cooling water is less, it gives less efficiency. These happen because the terminal temperature difference is inversely related to the condenser efficiency.
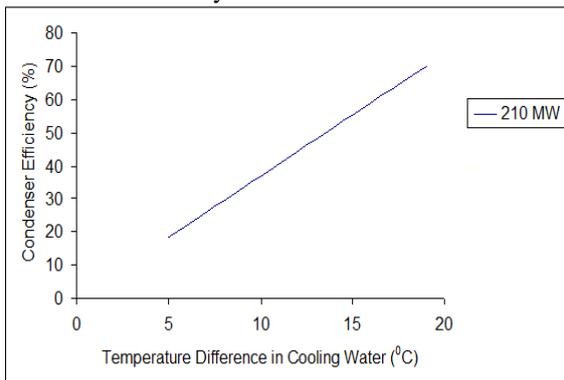

Fig. 4: Condenser efficiency with the temperature difference in cooling water

In Fig. 4, the constants and variables have been stated in Table 1.

Table 1: List of constants and variables

Constants	Variables
Tube diameter (inner and outer). Tube thickness. Tube length. Tube material. Condenser pressure (absolute) at a particular load. Mass flow rate of cooling water. Mass flow rate of steam entering the condenser. Number of tubes. Load (MW).	Temperature rise in cooling water

From the observation it may be concluded that the higher temperature rise in cooling water offers higher efficiency and the lower temperature rise in cooling water offers lower efficiency.

It may be recommended to allow the higher temperature rise in cooling water, during operation of the plant, to obtain higher efficiency of the condenser.

3.2 Effect of Temperature Difference in Cooling Water on the Loss Factor

The effect of temperature difference in cooling water at a fixed load (i.e. 210MW) on the Loss Factor has been shown in Fig. 5.

Loss Factor is the ratio of heat rejection by the exhaust steam to the heat gained by the cooling water. Actually at a particular condenser pressure, when the exhaust steam releases the heat, the cooling water becomes unable to gain the whole amount of heat and that's why the Loss Factor concept has been introduced in this study. In accordance with our thought, the Loss Factor includes all the relevant possible losses of the condenser. If it is assumed that the whole amount of heat is transferring from steam to the cooling water (though it is practically impossible), the rise in cooling water temperature is maximum, e.g. at load 210MW the maximum theoretically possible temperature rise is 19^0C respectively. The value of cooling water temperature rise in no loss condition (when Loss Factor is equal to 1) is 19^0C. In this study, intentionally the temperature difference in cooling water has been varied from 5^0C to 19^0C because, in practice, the temperature rise of the cooling water has been noted to be more or less of around 11^0C when the plant operates at 210MW load.

From Fig. 5 it is noted that at a particular load, LF increases with decrease in temperature rise in cooling water or LF decreases with increase in temperature rise in cooling water.
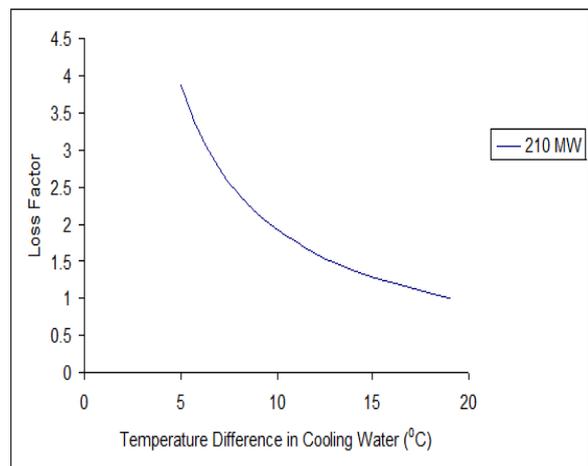

Fig. 5: Loss Factor vs. temperature difference in cooling water

In Fig. 5, the constants and variables have been stated in Table 1.

From the observations, it may be concluded that the condenser is always recommended to operate under high temperature rise in cooling water, to achieve lower Loss Factor.

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3.3 Effect of Efficiency of the condenser on the Loss Factor

The effect of efficiency of the condenser on its Loss Factor has been illustrated in Fig.6.

At a particular load and condenser pressure, Loss Factor decreases with increase in efficiency. It has been also noted that the efficiency is maximum when the Loss Factor equals to one.
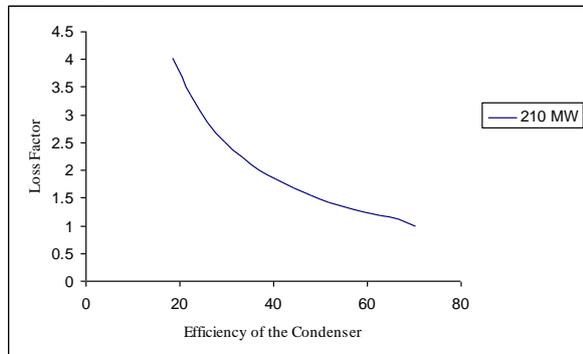

Fig.6. Loss Factor with the efficiency of the condenser.

In Fig.6, the constants and variables have been stated in Table 2.

Table 2: List of constants and variables

Constants	Variables
Tube diameter (inner and outer). Tube thickness. Tube length. Tube material. Condenser pressure (absolute) at a particular load. Mass flow rate of cooling water. Mass flow rate of steam entering the condenser. Number of tubes. Load (MW).	Temperature rise in cooling water Loss Factor.

The observation motivates us to conclude to operate the condenser at higher efficiency to obtain lower Loss Factor.

4. CONCLUSIONS

The study in this paper presents the effect of cooling water temperature rise on Loss Factor and efficiency of a condenser used in 210MW thermal power plant on the basis of first law of thermodynamics. The effects of variation in cooling water temperature rise on the Loss Factor and condenser efficiency have been assessed. A new term Loss Factor has been defined. The relation between the Loss Factor and efficiency of the condenser has been established. The results of these analyses provide the following conclusions.

At a particular load and condenser pressure, with the decrease in temperature rise in cooling water the condenser efficiency decreases. Similarly, at higher temperature rise in cooling water the condenser offers higher efficiency.

At a particular load and condenser pressure, Loss Factor (LF) increases with decrease in temperature rise in cooling water.

At a particular load and condenser pressure, Loss Factor decreases with increase in efficiency. It has been also noted that the efficiency is maximum when the Loss Factor equals to one.

5. ACKNOWLEDGEMENT

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NOMENCLATURE

Symbol

C_p	Specific heat of water	KJ/kg
h	Enthalpy	KJ/kg
LF	Loss Factor	
m	Mass flow rate	Kg/sec
T	Temperature	^{0}C
η	Efficiency	

Subscripts

ci	Cooling water inlet
co	Cooling water outlet
cw	Cooling water

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s   Steam

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