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COOLING TOWER IN STEAM POWER PLANT: ITS PERFORMANCE REGARDING THE FLOW RATE CONTROL AND WATER MAKE UP CONTROL

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"I Hereby declare that this thesis is my own work except the ideas and summaries which I have clarified their sources"

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Specially dedicated to my family, supervisor, friends and companion

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A debt of gratitude to my parents that always has encouraged me to come to this level. To my supervisor Mr. Safarudin Ghazali Herawan who has guide me to run this project until I achieved the objectives. Without them I will not overcome the obstacle and pressure to finish the project. And not forget my friends who always care for each other towards the success of their project. The memories that we had whether it is good or bad experience I keep it to be my guidance towards the future.

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ABSTRACT

A study on the performance of cooling tower in steam power plant by using the Cussons technology steam plant to conduct an experiment and analyze the effect of flow rate control and water make-up control to the cooling tower. This study investigate the flow rate of water from cooling tower effect the condensate time, the condensate flow rate, and the efficiency of steam turbine by using 3 different flow rate of cooling tower for 12,000 L/hr, 10,000 L/hr and 8,000 L/hr. Then the experiment is separated for 2 types, one is for the 2 nozzles fully open and the other is 3 nozzles fully open. Comparison between 2 nozzles and 3 nozzles was also performing in this analysis. An attempt was made for analyzing the effect of water make-up control to the performance of cooling tower but due to technical problems there are no data taken regarding the amount of make-up water. The calculation for efficiency of cooling tower has been calculated and the best efficiency is at the flow rate of 12,000 L/hr followed by 10,000 L/hr and 8,000 L/hr. Not much significance difference was observed between 2 nozzles and 3 nozzles with the efficiency is range between 0.5 - 0.65. The result also show the time of condensate which is taken and recorded for each 15 L of condensate water fill in the condensate tank. Condensate flow rate is faster as the cooled water flow rate is faster due to the less time of condensate occurred. The 3 nozzles were found to be the best effect in the cooling tower performance than the 2 nozzles. For more cooled water flow rate is set, we can have a better performance effect to the power plant.

ABSTRAK

Kajian tentang prestasi menara penyejuk di dalam system jana kuasa dengan menggunakan jana kuasa Cussons Technology untuk membuat experiment dan analisa kesan kawalan halaju air dan kawalan air tambahan terhadap menara penyejuk. Pengajian ini melibatkan pengajian mengenai kawalan halaju air daripada menara penyejuk mempengaruhi masa kondensasi, halaju air kondensasi dan kecekapan turbin stim dengan menggunakan 3 halaju air dari menara penyejuk yang berbeza iaitu 12,000 L/hr, 10,000 L/hr dan 8,000 L/hr. Di samping itu eksperimen ini juga diasingkan kepada dua jenis, satu adalah dengan 2 nozzel yang terbuka dan 3 nozzel yang terbuka. Perbandingan antara 2 nozzel dan 3 nozzle juga telah dijalankan di dalam analisis ini. Usaha untuk mendapatkan kandungan air tambahan yang akan ditambah ke menara penyejuk telah di jalankan tetapi terdapat maslah teknikal yang tidak dapat dielakkan telah merosakkan kajian untuk menganalisa kesannya terhadap kecekapan menara penyejuk. Untuk kecekapan menara penyejuk telah berjaya di kira dan secara keseluruhan kecekapan terbaik adalah pada halaju air 12,000 L/hr, dan mengikut turutan menurun diikuti dengan halaju 10,000 L/hr dan 8,000 L/hr. Tiada perbezaan yang ketara antara kecekapan 2 nozzel dan 3 nozzel kerana jarak nilainya adalah antara 0.5 – 0.65. Daripada keputusan yang direkod masa untuk pemeluwap adalah direkod bagi setiap sukatan 15 L air di dalam tangki air hasil pemeluwapan. Halaju air hasil pemeluwapan adalah laju apabila halaju dari menara penyejuk semakin laju yang disebabkan oleh masa yang diambil untuk hasil pemeluwapan adalah pantas. Untuk kesan yang ketara terhadap menara penyejuk adalah 3 nozzel berbanding 2 nozzle. Dengan halaju air dari menra penyejuk yang lebih laju akan menghasilkan kesan besar tehadap prestasi jana kuasa.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOL

SYMBOL	DEFINITION
K	convective mass-transfer coefficient
a	the surface area of the water interface per unit volume
V	the active volume of the cooling tower per unit of plan area
L	water flow rate
T1	bulk water temperature at the inlet
T2	bulk water temperature at the exit
i_i	specific enthalpy of saturated air
i_g	specific enthalpy of the bulk of air locally
ε	cooling tower efficiency
$T_{w,in}$	inlet water temperature
$T_{w,out}$	outlet water temperature
T_{wb}	wet bulb temperature of inlet/supply air
V	volume flow rate of condensate
h	enthalpy
η	Rankine cycle efficiency
W_T	work of turbine
q_{2-3}	work of steam generator
$W_{in, P}$	work of pump

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION TO COOLING TOWER

1.1 Overview

A cooling tower is a heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a lower temperature. The type of heat rejection in a cooling tower is termed "evaporative" in that it allows a small portion of the water being cooled to evaporate into a moving air stream to provide significant cooling to the rest of that water stream. The heat from the water stream transferred to the air stream raises the air's temperature and its relative humidity to 100%, and this air is discharged to the atmosphere. Evaporative heat rejection devices such as cooling towers are commonly used to provide significantly lower water temperatures than achievable with "air cooled" or "dry" heat rejection devices, like the radiator in a car, thereby achieving more cost-effective and energy efficient operation of systems in need of cooling. Think of the times you've seen something hot be rapidly cooled by putting water on it, which evaporates, cooling rapidly, such as an overheated car radiator. The cooling potential of a wet surface is much better than a dry one.

1.2 Objectives

i. Study and determine the performance of cooling tower in steam power plant regarding the flow rate control and water make up control.
ii. Monitor and learned the cooling tower performance with variable of flow rate and water make up control.
iii. Involve in the experiment setup to get an experienced for operating the cooling tower unit.

1.3 Scope

The scope of this thesis is as below:

1) Study of cooling tower in steam power plant.
2) Selection of importance equations that involve in the performance of cooling tower.
3) Conduct the experiment using steam power plant.
4) Gathered the data and result of performance.
5) Analysis the effect of flow rate control and water make up control.

1.4 Problem statement

As mentioned before, the objectives for this thesis is to study the performance of the cooling tower regarding its flow rate and make up water control. The type of cooling tower that will be experimented is the P7615 cooling tower that is built with the steam power plant. The understand of application concept of cooling tower, fans and motors characteristics, flow rate and make up water quantity are the various parameter that have to be considered during this thesis.

1.5 Problem analysis

Some of the approach that has to be considered overcoming the problems mentioned above:

1) Identified all the problem statement and try to solve it.
2) Design and developed an experiment based on the problem.
3) Study on the cooling tower performance and characteristics.
4) Familiarized with all the equations, theory and concept related to the problem.
5) Collecting the data from the experiment and analyze the data.

CHAPTER 2

LITERATURE REVIEW

This chapter has the research from other people regarding the performance of cooling tower. The explanation on types, parts and the theory involving cooling tower are described thoroughly as the cooling tower used in the industry. Without cooling tower, a big facility or building temperature might not stable at it will increased the heat to the people in the building. There are also some explanation about the system and the theory on heat transfer between air and water in the cooling tower.

2.1 Research in cooling tower

1. Rafat Al-Waked and Masud Behnia made research about computational fluid dynamics (CFD) simulation of wet cooling tower. Heat and mass transfer inside a natural draft wet cooling tower (NDWCT) have been investigated numerically under different operating and crosswind conditions. The three-dimensional CFD model has utilized the standard k–ε turbulence model as the turbulence closure. The current simulation has adopted both the Eulerian approach for the air phase and the Lagrangian approach for the water phase. The film nature of the water flow in the fill zone has been approximated by droplets flow with a given velocity. The required heat and mass transfer have been achieved by controlling the droplet velocity. At that specific droplet velocity, effects of the following operating parameters on the thermal

performance of the NDWCT have been investigated: droplet diameter, inlet water temperature, number of nozzles, water flow rate and number of tracks per nozzle. As a result, the effect of crosswind velocity on the thermal performance has been found to be significant. Crosswinds with velocity magnitude higher than 7.5 m/s have enhanced the thermal performance of the NDWCT.

2. S.V. Bedekar, P. Nithiarasu and K.N. Seetheramu have studied the performance of fluidized-bed cooling towers; ignoring the higher pressure drop compared to other film- and flash-type towers, their performance was excellent. Sisupalan and Seetharamu examined the performance variation of a fluidized-bed cooling tower for different static bed heights. Recently, Dreyer and Evens studied the modeling of a cooling tower splash pack. The performance of a falling film-type cooling tower has been studied by Ibrahim. There are many studies available on mathematical modeling of cooling tower heat- and mass-transport, including a number of recent publications. The available literature shows a lack of experimental data on film-type, packed-bed cooling towers. In this study, they give results for an induced draft packed-bed cooling tower.

3. To relief hot climate in summer season, direct evaporative cooling system (Shower Cooling Tower System) was examined. Satoshi Yajima has studied the performance of the shower cooling tower in Japan. This system was developed by B. Givoni. In general, evaporative cooling system is recognized that it is suit for hot and dry climate. But this system can supply cooled water and generate cooled air flow. This characteristic means the ability of utilize this system also in humid climate. They tested this system with objective to plan and apply this system in Japan, and examined its cooling effectiveness and air flow generation.

4. J.C. Kloppers and D.G. Kroger has made a critical investigation into the heat and mass transfer analysis of counterflow wet-cooling towers. This study gives a detailed derivation of the heat and mass transfer equations of

evaporative cooling in wet-cooling towers. The governing equations of the rigorous Poppe method of analysis are derived from first principles. The method of Poppe is well suited for the analysis of hybrid cooling towers as the state of the outlet air is accurately predicted. The governing equations of the Merkel method of analysis are subsequently derived after some simplifying assumptions are made. The equations of the effectiveness-NTU method applied to wet-cooling towers are also presented. The governing equations of the Poppe method are extended to give a more detailed representation of the Merkel number. The differences in the heat and mass transfer analyses and solution techniques of the Merkel and Poppe methods are described with the aid of enthalpy diagrams and psychrometric charts. The psychrometric chart is extended to accommodate air in the supersaturated state.

5. J. Smrekar, J. Oman and B. Sirok have made a research to improve the efficiency of natural draft cooling towers. This study shows how the efficiency of a natural draft cooling tower can be improved by optimizing the heat transfer along the cooling tower (CT) packing using a suitable water distribution across the plane area of the cooling tower. On the basis of cooling air measurements, it is possible to distribute the water in such a way that it approaches the optimal local water/air mass flow ratio and ensures the homogeneity of the heat transfer and a reduction of entropy generation, thus minimizing the amount of energy lost. The velocity and temperature fields of the airflow were measured with the aid of a remote control mobile robot unit that was developed to enable measurements at an arbitrary point above the spray zone over the entire plane area of the cooling tower. The topological structures of the moist air velocity profiles and the temperature profiles above the spray zone were used as input data for calculation of the local entropy generation in the tower. On the basis of the measured boundary conditions, a numerical analysis of the influence of the water distribution across the cooling tower's plane area on entropy generation and energy destruction in the cooling tower was conducted.

6. J.C. Kloppers and D.G. Kroger has studied the influence of temperature inversions on wet-cooling tower performance. Nocturnal temperature inversions have a detrimental effect on the performance of natural draft wet cooling towers. The effects of the temperature inversion profile, the height of the inversion and the height from which air is drawn into the cooling tower, on the performance of cooling towers are investigated. Relatively simple and accurate equations are employed in the analysis to determine the temperature inversion profiles and inversion heights, which only have ground based measurements as input. The detrimental effect in tower performance, during nocturnal temperature inversions, is due to the reduced potential in draft and the increase of the effective air inlet temperature.

7. Jameel-Ur-Rehman Khan and M. Yaqub, Syed M. Zubair studied the performance characteristics of counter flow wet cooling towers. Cooling towers are one of the biggest heat and mass transfer devices that are in widespread use. In this paper, we use a detailed model of counter flow wet cooling towers in investigating the performance characteristics. The validity of the model is checked by experimental data reported in the literature. The thermal performance of the cooling towers is clearly explained in terms of varying air and water temperatures, as well as the driving potential for convection and evaporation heat transfer, along the height of the tower. The relative contribution of each mode of heat transfer rate to the total heat transfer rate in the cooling tower is established. It is demonstrated with an example problem that the predominant mode of heat transfer is evaporation. For example, evaporation contributes about 62.5% of the total rate of heat transfer at the bottom of the tower and almost 90% at the top of the tower. The variation of air and water temperatures along the height of the tower (process line) is explained on psychometric charts.

8. Paisarn Naphon studied on the heat transfer characteristics of an evaporative cooling tower. In the present study, both experimental and theoretical results of the heat transfer characteristics of the cooling tower are investigated. A column packing unit is fabricated from the laminated plastic plates consists of

eight layers. Air and water are used as working fluids and the test runs are done at the air and water mass flow rates ranging between 0.01 and 0.07 kg/s, and between 0.04 and 0.08 kg/s, respectively. The inlet air and inlet water temperatures are 23 °C, and between 30 and 40 °C, respectively. A mathematical model based on the conservation equations of mass and energy is developed and solved by an iterative method to determine the heat transfer characteristics of the cooling tower. There is reasonable agreement from the comparison between the measured data and predicted results.

2.2 Types of cooling tower

Common applications for cooling towers are providing cooled water for air-conditioning, manufacturing and electric power generation. The smallest cooling towers are designed to handle water streams of only a few gallons of water per minute supplied in small pipes like those might see in a residence, while the largest cool hundreds of thousands of gallons per minute supplied in pipes as much as 15 feet (about 5 meters) in diameter on a large power plant.

The generic term "cooling tower" is used to describe both direct (open circuit) and indirect (closed circuit) heat rejection equipment. While most think of a "cooling tower" as an open direct contact heat rejection device, the indirect cooling tower, sometimes referred to as a "closed circuit cooling tower" is nonetheless also a cooling tower.

A direct or open circuit cooling tower is an enclosed structure with internal means to distribute the warm water fed to it over a labyrinth-like packing or "fill" **(Figure 2.1)**. The fill provides a vastly expanded air-water interface for heating of the air and evaporation to take place. The water is cooled as it descends through the fill by gravity while in direct contact with air that passes over it. The cooled water is then collected in a cold water basin below the fill from which it is pumped back through the process to absorb more heat. The heated and moisture laden air leaving the fill is discharged to the atmosphere at a point remote enough from the air inlets to prevent its being drawn back into the cooling tower.

Figure 2.1 Cooling tower in HVAC systems

The fill may consist of multiple, mainly vertical, wetted surfaces upon which a thin film of water spreads (film fill), or several levels of horizontal splash elements which create a cascade of many small droplets that have a large combined surface area (splash fill).

An indirect or closed circuit cooling tower involves no direct contact of the air and the fluid, usually water or a glycol mixture, being cooled **(Figure 2.2)**. Unlike the open cooling tower, the indirect cooling tower has two separate fluid circuits. One is an external circuit in which water is recirculated on the outside of the second circuit, which is tube bundles (closed coils) which are connected to the process for the hot fluid being cooled and returned in a closed circuit. Air is drawn through the recirculating water cascading over the outside of the hot tubes, providing evaporative cooling similar to an open cooling tower. In operation the heat flows from the internal fluid circuit, through the tube walls of the coils, to the external circuit and then by heating of the air and evaporation of some of the water, to the atmosphere.

Operation of the indirect cooling towers is therefore very similar to the open cooling tower with one exception. The process fluid being cooled is contained in a "closed" circuit and is not directly exposed to the atmosphere or the recirculated external water.

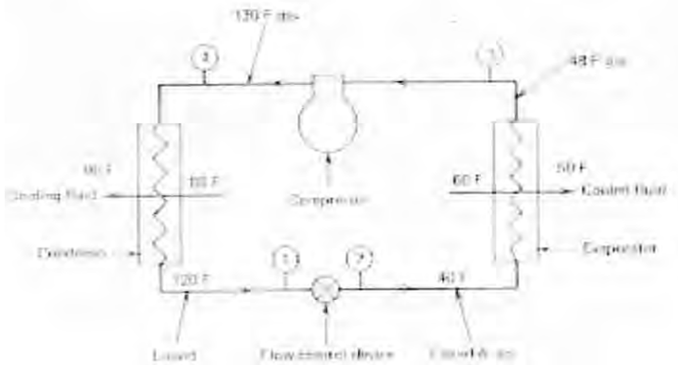

Figure 2.2 The basic components and concept of cooling tower.

In a counter-flow cooling tower air travels upward through the fill or tube bundles, opposite to the downward motion of the water. In cross-flow cooling tower air moves horizontally through the fill as the water moves downward.

Cooling towers are also characterized by the means by which air is moved. Mechanical-draft cooling towers rely on power-driven fans to draw or force the air through the tower. Natural-draft cooling towers use the buoyancy of the exhaust air rising in a tall chimney to provide the draft as in **Figure 2.3**. A fan-assisted natural-draft cooling tower employs mechanical draft to augment the buoyancy effect. Many early cooling towers relied only on prevailing wind to generate the draft of air.