"I declare that I had read this thesis and according to my opinion, this thesis is enough to fulfill the purpose for award of the Bachelor 's Degree in Mechanical Engineering from the aspect of scope and quality."

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Date: May 2008

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Date: May 2008

STUDY OF COOLING WATER SYSTEM (CLOSED LOOP) AT HYDROELECTRIC POWER PLANT

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“I confess this report is my effort on written except for summarization and quotation which explained in the resources”

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ABSTRAK

Stesen janaelektrik Sultan Mahmud, Kenyir menjana 400 MW hampir setiap hari untuk memenuhi keperluan negara. Malangnya, stesen yang dibina dengan teknologi dua puluh tahun terkebelakang ini terpaksa menanggung kerugian tenaga akibat daripada masalah penukar atau penyejuk haba. Penyejuk- penyejuk tersebut mengalami masalah pemindahan haba yang serius sekiranya ia tersumbat dengan kotoran ‘ferrite’ yang berpunca dari air tasik. Lantaran itu, sistem penyejukan litar terbuka unit generator ini dicadangkan oleh pihak pengurusan untuk ditukar kepada sistem litar tertutup. Beberapa rekabentuk telah dikenal pasti, dan sistem rekebentuk yang mengandungi penukar haba jenis cengkerang dan tiub telah dipilih sebagai sistem yang paling baik kerana kosnya yang berpatutan dan pemulangan modal untuk pembinaan projek ini tidaklah mengambil masa yang begitu penjang. Berdasarkan spesifikasi yang diberi, kajian ini memfokus kepada perincian parameter yang perlu diketahui, iaitu bilangan tiub (N), NTU dan keberkesanannya. Kemudian, berdasarkan ciri – ciri penting yang perlu dikekalkan, ciri – ciri lain dicadangkan diubah untuk menambahkan keberkesanan penukar haba. Ciri yang dikekalkan ialah kuasa penukar haba dan tekanan semasa operasi. Ini dicapai dengan mengubah kuantiti air dan suhu yang terlibat dengan setiap penukar haba. Selain dari itu, pengubahsuaian ini menjadikan LMTD dapat ditentukan kerana sebelum ini ia tidak dapat dikenalpasti kerana suhu keluar pada tiub dan cengkerang adalah sama. Walaubagaimanapun, skop kerja kajian ini terhad kepada pengiraan dan teori Termodinamik dan teori Pemindahan Haba sahaja. Hasil kajian ini pasti berbeza dengan penggunaan perisian khas yang digunakan untuk merekabentuk penukar haba.

ABSTRACT

Sultan Mahmud Hydro Electric Power Station generates 400MW almost everyday to occupy the country needs. Unfortunately, this more than two decades old power station has quite a lot of loss, due to the inefficient cooler system. These coolers that used to cool the turbine parts face a serious heat transfer problem when their piping system are clogged with ferrite formed sludge. This sludge is sourced out from the tailrace. Due to the above reasons, the management has decided to change out open loop cooling water system to closed loop system. Several designs of closed loop system had been recognized, and the system that contains tube and shell heat exchanger was suggested to be the replacement for the existing one. This is because the cost incurred is acceptable and the cost recovery period is not too long. According to the specification, this study focuses to the important parameters, which are; the number of tubes (N), number of transfer unit (NTU) and its effectiveness. Then, another design was suggested, but still maintaining the duty and operating pressure parameters. This suggested idea is to enhance its performance. The varied values of parameters are the mass of fluids and the temperatures. Besides, the modification of the original idea enables the LMTD to be determined. The original LMTD could not be determined since the temperatures of both outlets of the exchangers are same. The scope of work was limited to the theories and calculation of Thermodynamics and Heat Transfer. The overall results of using the theoretical calculation will differ from the using the heat exchanger specialized software.

TABLE OF CONTENT

NOMENCLATURE

A heat transfer area

C thermal capacity, flow stream rate, $\dot{m}c$, W/K

ºC degrees Celcius

C_{min} minimum thermal capacity, W/K

C_{max} maximum thermal capacity, W/K

E total energy, kJ

E_{in} total energy enter

E_{out} total energy exit

F log mean temperature difference correction factor, dimensionless

Hz hertz

kW kilowatts

kv kilovolts

Δlm log mean temperature difference

LMTD log mean temperature difference

NTU Number of Transfer Unit, dimensionless

$\dot{m}$ mass flow rate, kg/s

MW Mega Watt

ρ density, kg/m^3

$\dot{Q}$ heat transfer rate in exchanger, or duty, W or kW

U overall heat transfer coefficient, W/m^2

λ thermal conductivity,

R heat capacity ratio, dimensionless

ε effectiveness, dimensionless

r_1 radius of internal tube

r_2 outer tube radius

T_{si} inlet temperature of shell side

T_{so} outlet temperature of shell side

T_{ti} inlet temperature of tube side

T_{to}	outlet temperature of tube side
T_{hmax}	maximum temperature from hot fluid
T_{cmin}	minimum temperature from cold fluid
$\dot{v}$	volume flow rate, m^3/s

LIST OF ABBREVIATION

CW	Cooling Water
GAC	Generator Air Cooler
JBA	Jabatan Bekalan Air
LMTD	log mean temperature difference
NTU	Number of Transfer Unit
UGB	Upper Guide Bearing
TNB	Tenaga Nasional Berhad

LIST OF FIGURE

LIST OF TABLE

LIST OF APPENDIX

CHAPTER 1

INTRO DUCTION

This chapter will describe about the background, problem definition, the objectives, scopes and methodology of the research briefly.

1.1 Background: Kenyir Power Station

Kenyir power station possesses 4 units of generator, each of them generates up to 100 MW power. The turbine is Francis type, vertically operated. Normally, the units undergo 3 conditions; Generate, Synchronous Condition/ Spinning Reserve and Standby. The turbine will work in 2 types of conditions, Generate and Spinning Reserve. Standby is the condition where the generators do not operate or put to the rest.

The important work that must be ensured when the Units begin to work is, the Turbine ancillary equipments and the Cooling Water (CW) system must also start to operate. In other words, the operation of generator and CW system must be started and operated synchronously.

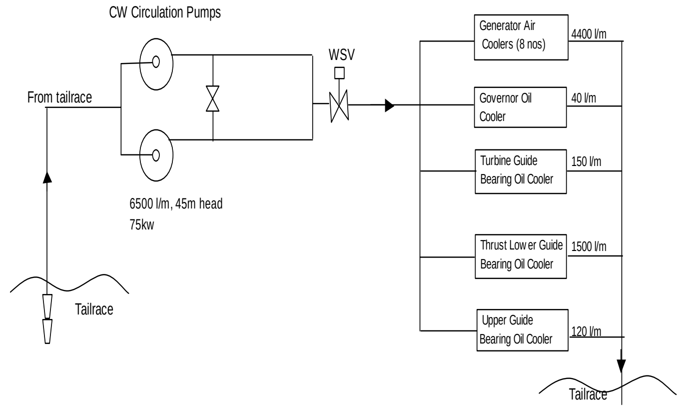

FIGURE 1.0: The open loop CW system of Kenyir Power Station

(TNB Kenyir)

1.1.1 Kenyir Open Loop CW System

The power station's CW system is an open loop type. It uses the water from the tailrace via the embedded pipe to enter the turbine ancillary equipment. The CW system is used to cool and removed the heat from air of generator and from the lubricant turbine parts such as turbine bearing, thrust bearings and guide bearings. (Refer to Figure 1.0)

The power station experiences problem of clogging due to accumulation of scales inside the heat exchanger cooler tubes inside. The clogs, sludge or fouling contains ion ferrite is believed originates from the tailrace. This results to plant shutdown about once in a month. Extra manpower deployment needed due to the frequent maintenance since the heat exchangers or Generator Air Cooler (GAC) tubes need to be cleaned regularly. Moreover, the clogs causing the Turbine Generator output declined and finally the generator has to be shut down. The long term effect is to the Generator Winding Insulation, which short circuit and Generator damage eventually happen.

According to research from TNB, this table shows the loss;

TABLE 1.0: Losses of Kenyir Power Station Due to Generator Maintenance

	MWh loss per year for 4 Turbine Generators	Annual financial loss per year @ 6.7 sen / KWh
1. Forced outage	11040 Mwh	RM 739,700
2. Load reduction	30000 Mwh	RM 2,010,000
3. Generator winding loss	9000 Mwh	RM 603,000
4. Consumables / parts replacements for all coolers	Inclusive of chemical cleaning works	RM 100,000
Total losses per year		**RM 3,452,700**

(TNB Research)

Besides GAC, the other coolers such as Thrust Lower Guide Bearing oil cooler and Upper Guide Bearing oil cooer also needs to be cleaned when their alarms on. But, fortunately, this will not result to the plant shutdown, as the cooler comes with 2 sets, one normal and another for standby. But, it still require additional manpower usage and the tubes itself unable to stand in longer operation period.

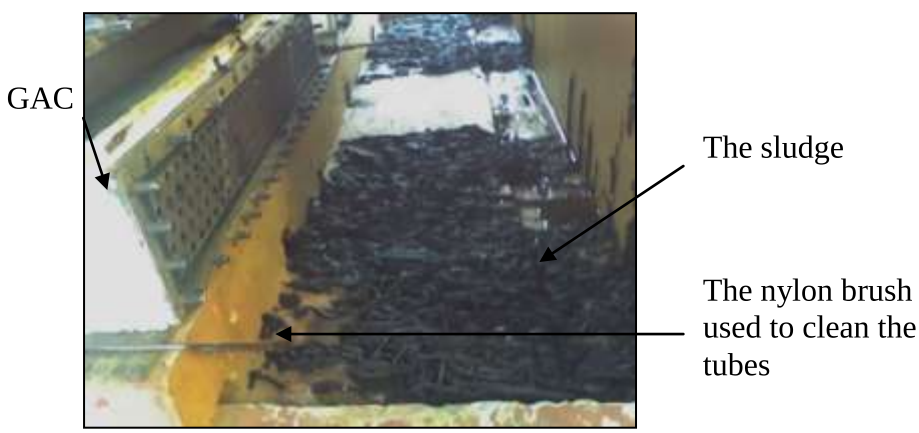

Figure 1.1 : The sludge, after being removed from GAC tubes

(Source: TNB Kenyir)

1.2 Problem Statement

a) The open loop system of Kenyir Power Station causes fouling effect to the generator and other coolers tubes. This fouling drags to the very big loss to this power plant from the electricity energy, human source and profitability aspects. The fouling was found occurred from any source of the tailrace, which contains ferrite that always clogs in the heat exchangers tubes.

b) Hence, this system needs modification. A study from TNB has proved that, the open loop CW system should be changed into closed loop system due to its performance.

1.3 Objectives

The objectives of this study are to;

a) Understand the overall problem of cooling water system faced by Kenyir Power Station
b) Study all the recommended designs of closed loop CW system proposed.
c) Describe what is the best design and why it is proposed.
d) Analyze the best design.
e) Suggest other design solution for the design proposed.

1.4 Scopes

The scopes of this study are to do thermal analysis by calculation and to apply Thermodynamics law. This study doesn’t include any simulation of fluid. The designs and component involved in this study only the designs are restricted to the designs which recommended by TNB (Tenaga Nasional Berhad) Research Group.

1.5 Methodology

The methods that will be used to conduct the study are;

a) Comparative data by using Morphological Chart
b) Thermodynamic First Law
c) Heat Transfer

1.6 Expected Results

This study will enable a reliable design which could be easily constructed and understood by technical persons and the workers in the power station. This can be easily benefited in not only economic and energy savings, but also in maintenance aspect.

CHAPTER 2

LITERATURE REVIEW

This chapter describes about the energy sources in Malaysia briefly. Then, the topic focuses on the Kenyir hydroelectric power station and its relevance. Also, the description about main components in the power plants, including the Cooling Water (CW) system, cooling tower, fan and radiator be discussed.

2.1 Power Plants in Malaysia

Malaysia has many hydro, gas and thermal plants. The renewable energy, RE also will be the most popular energy source to this country.

At present, Malaysia use many source from gas. According to Ministry of Water, Energy and Communication;

"Gas is still a major primary energy input for the electricity sector constituting 68%, with 63.8% of the installed generating plants firing on gas. Coal is fast gaining significance in the generation fuel mix from 11.1% in 2002 to the present 31.1%. Coal as a primary fuel will gain more significance with the commissioning of the Tg. Bin and Jimah power plants by the IPP within this 9th Malaysia Plan period. Hydro contributed 13.8% for 2006 and oil acting as just standby and back-up fuel."

FIGURE 2.0: The power plants (thermal, gas and hydro) in Peninsular Malaysia

(Source: TNB Kenyir)

Referring to the Figure 2.0, the main source of hydroelectric energy can be gain from Pergau Power Station (600 MW) and Kenyir Power Station (400 MW). The Pergau use Francis type Turbine, while Cameron Highland use Pelton type, while Sungai Perak use Francis, Pelton and Kaplan turbines, depend on its branches (Temenggor, Sg, Piah, Bersia and Chenderoh)

2.1.1 Kenyir Hydro Power Station

Kenyir Hydro Power Station or formerly known as ***Stesen Janaelektrik Sultan Mahmud Al Muktafibillah Shah*** is officially opened at July 1987. The power station is conventional indoor type superstructure and is provided with two electric overhead travelling cranes.

The power station has four generating units consisting of vertical shaft Francis reaction water turbines directly coupled to synchronous type air-cooled, three-phase generators. The turbines are rated at 102 MW each at the rated head of 120 m while generators are rated 112 MVA, 0.9 p.f. (power factor), 13.8 kV, and 50 Hz.

Each generator is connected to a three phase transformers rated at 112 MVA where the voltage can be increased from 13.8 kV to 275 kV for transmission.

(TNB Kenyir)

2.2 Hydro Power Plant Characteristics

The general components of hydro electric power plants;

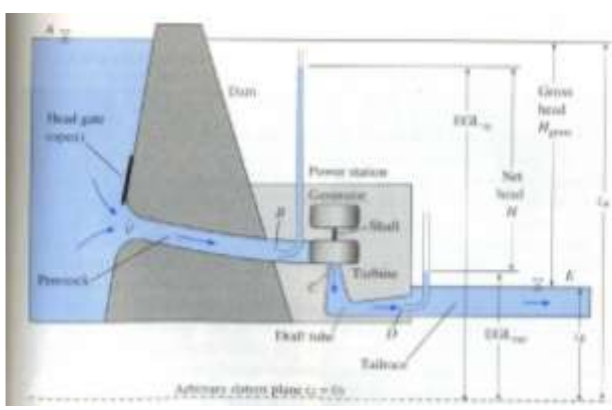

Figure 2.1 : The hydroelectric power plant characteristics

(Cengel, Y & Cimbala, J, (2006))

Basically, a hydroelectric power station that use Francis turbine must have a reservoir, dam, spillway, power station, water turbines, generators and tailrace. (Refer to **Figure 2.1**) Reservoir is where the source of water is placed in dam to rotate the turbine. The generator, turbines and turbine ancillary equipments needs cooling system to operate properly and continuously.

2.3 The Cooling Water System

The cooling water system (CW) can be divided into a few types. There are evaporative and non evaporative types, which consider if the water loss are substantial are under evaporative category. The CW system also can be divided into into open loop and closed loop types.

Open Loop

The water in this system is used to cool the processes or equipments and finally it discharged into waste. This system is applied at the place readily has a large volume at low cost. The large volume refers to lakes, river and well, which means this cost of this system is low, which only consider the pumping cost. This system is said it doesn't give chance to increasing of dissolved or suspended solid, since there is no evaporation process happened. However, other problem such as scale, waterborne fouling and biological fouling can occur in the open loop system.

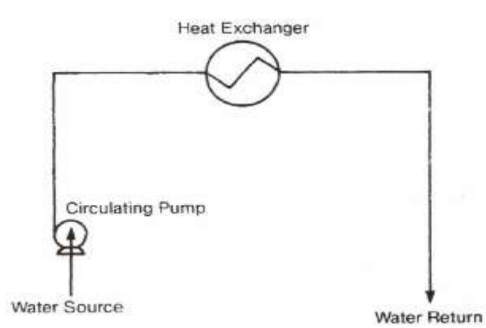

FIGURE 2.2 : Open Loop or Once-Through Cooling System

(Rosaler, Robert C.,(1995))