Analysis of Condenser N-16000-2 Unit I PLTU I Central Kalimantan (2x60) MW

Abdul Ghofur(✉), Faisal Arifin, Rachmat Subagyo, Aqli Mursadin, Ahmad Syarief, and Apip Amrullah

Mechanical Engineering Study Program, Faculty of Engineering, Lambung Mangkurat University, Jln. Ahmad Yani Km. 36, Banjarbaru, South Kalimantan, Indonesia
ghofur70@ulm.ac.id

Abstract. This paper compares the performance of a condenser during the period between August and December 2018 to that during the commissioning period. It belongs to the Steam Power Plant (PLTU) I in Central Kalimantan. The comparisons are carried out in terms of the load, LMTD, temperature efficiency, capacity ratio, and effective heat transfer coefficient. The overall results suggest that time evidently takes its toll on the performance as the Ueff decreased from 1980 W/m^{2}K during the commissioning to 1319,4 W/m^{2}K in December 2018. Fouling is the main reason for this.

Keywords: Condenser · Ueff · Fouling

1 Introduction

Along with the increasing need for electrical energy, Indonesia implements an accelerated program of power generation by establishing several power plants, the biggest potential of power plants in Indonesia is Steam Power Plants (PLTU) because it is supported by abundant coal supplies. PLTU is prioritized to meet electricity needs because PLTU has high efficiency, where coal fuel in Indonesia is abundant and relatively cheap compared to other types of plants. The Steam Power Plant built one of them in Kalimantan is PLTU I Central Kalimantan (2x60 MW) where, PLTU I Central Kalimantan with installed power 2 units x 60 MW is a new plant built to meet the electricity needs of South and Central Kalimantan. The distribution of electrical power from PLTU I Central Kalimantan 2x60 MW will use a 150 kV / SUTT Double Phi Connection transmission line that cuts the Kapuas Substation Transmission Line to Palangkaraya. With such great power, PLTU I Kalimantan is expected to always be in a reliable condition. In its operation there are several main equipment that greatly affects the operating conditions of PLTU I Kalimantan such as one of them is the condenser.

Condenser is a heat exchanger in a power plant unit that serves to condense exhaust steam from the turbine into a liquid phase through heat transfer from steam to cooling water so that high-quality feed water is produced for reuse in cycles.

Decreased efficiency of generation is something that must be avoided because it will interfere with electricity production. The role of the condenser is very vital, if the

S. Sugiman et al. (Eds.): MIMSE-M-E 2022, AER 216, pp. 207–217, 2023.
https://doi.org/10.2991/978-94-6463-078-7_22

performance of the condenser is impaired / decreased resulting in reduced turbine and generator power. Condenser installed on PLTU I Central Kalimantan, namely shell and tube model.

The decrease in the mass of the condenser's performance is generally caused by a decrease in the effectiveness of heat transfer caused by the fouling of the pipe surface in the condenser. Surface fouling in the pipe occurs due to fouling by the content of salt compounds contained in cooling water obtained from river water to find out the masseur's work can be done by calculating the Effective Condenser Heat Transfer Coefficient (Ueff) (Cengel, Jonah A., 2004).

In a previous study in 2011 entitled "Analysis of Condenser Performance in Oil Refinery PLTU Installations Related to Tube Leaks" by Endang Prihastuty et al. explained that the analysis of the causes of condenser performance declines. Referring to the research and considering the importance of the condenser function in PLTU I Kalimantan central unit I, a study of the performance of the condenser at the same load is 60 MW where the calculation compares the performance of the condenser at the time of commissioning and during August-December 2018 where the type of condenser in PLTU I Central Kalimantan is a type of shell and tube.

2 Condenser Show Formula

To calculate the massing of the condenser's work can be in the following way:

1. Find the heat of cooling water with the formula:

$$Q_{cooling\ water} = m_1 cp(T_2 - T_1) \tag{1}$$

2. Calculate the average temperature difference in Condenser or LMTD (*Log Mean Temperature Differential*) with the following formula:

$$LMTD = \frac{(T_3 - T_2)(T_4 - T_1)}{in\left\{\frac{(T_3 - T_2)}{(T_4 - T_1)}\right\}} \tag{2}$$

3. Determine correction factors in LMTD (F) by:

   a. Determining Temperature Efficiency

$$P = \frac{(T_2 - T_1)}{(T_3 - T_1)} \tag{3}$$

   b. Determining *capacity ratio* (R):

$$P = \frac{(T_3 - T_4)}{(T_2 - T_1)} \tag{4}$$

   Once P and R are known, see the LMTD Correction Factor chart for STHE's single pass shell & cross flow as in Fig. 1.

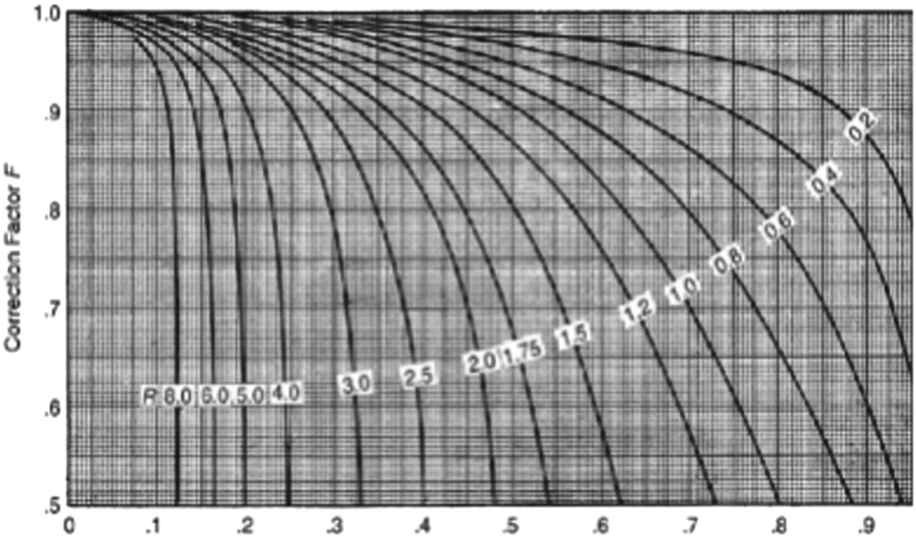

Fig. 1. LMTD Correction Factor Chart

4. Calculate corrected LMTD with the formula:

$$corrected\ LMTD = F\ x\ LMTD \tag{5}$$

5. Calculating Effective Condenser Heat Transfer Coefficient (Ueff)

$$U_{eff} = \frac{Qcoolingwater}{A\ x\ (F\ x\ LMTD)} \tag{6}$$

Where:

m_1: cooling water *mass flow* (kg/s)
cp: specific heat (kj/kg ^{o}C)
*Q cooling water: (*Kj/s)
F LMTD correction factor
LMTD: Log Mean Temperature differentia (^{o}C)
A: Heat transfer area (m^2)
T1: Incoming water Temperature (^{o}C)
T2: Water temperature out (^{o}C)
T3: Incoming vapor temperature (^{o}C)
T_4: Temperature steam out (^{o}C)

3 Research Methods

This research data collection was conducted at PT. PLN (Persero) PLTU I Central Kalimantan (2x60) MW Unit 1. Literature study is carried out at PLTU! Central Kalimantan, related manual books, data in the Engineering and Central Control Room (CCR) section, as well as syllabuses related to condensers.

Table 1. Table of specifications of Type N condensers - 16000 – 2

Items	Unit	Specification
Model		N-16000-2
Condensor Type		Surface Type
Performance parameters		
Design Pressure of The Water Room	MPa	0.3
Cooling Water Temperature	^oC	30
Outlet Cooling Water Temperature	^oC	37
Total heat exchanging area	m^2	16000
Cooling Water amount	T/h	58169
Back Pressure of The Condenser	MPa	0.0085
Tube Bundle		
Total Number of The Cooling Water Pipes	Piece	14924
Material of Cooling Water Pipes		Ti
Specification of Cooling Water Pipe	mm	F 25 × 0.7/0.5
Boundary Dimension of The Equipment	mm	17750 × 7980 × 11110 (length × width × height)
Net Weight of The Condenser	T	339.6

Table 2. Condenser data at 60 MW load when commissioning

No.	Data	Symbol	Commissioning	Unit
1.	Burden	W	60	MW
2.	Incoming Steam Temperature	T_3	48.54	^oC
3.	Incoming Steam Pressure	P_3	0.00692	MPa
4.	Steam Enthalpy In	h_3	2590.04	kJ/kg
5.	Steam Temperature Out	T_4	43.14	^oC
6.	Outgoing Steam Pressure	P_4	0.00692	MPa
7.	Steam Enthalpy Out	h_4	2579.71	kJ/kg
8.	Incoming Water Temperature	T_1	29.5	^oC
9.	Incoming Water Enthalpy	h_1	123.644	kJ/kg
10.	Water Temperature Out	T_2	38.2	^oC
11.	Outgoing Water Enthalpy	h_2	160.009	kJ/kg

(*continued*)

Table 2. (*continued*)

No.	Data	Symbol	Commissioning	Unit
12.	Cooling Water Flow	m_1	9440.4	kg/s
13.	Heat Cooling Water	Q	344130.9	kJ/s

Table 3. 60 MW load condenser data for August – December 2018.

No	Data	Symbol	Unit	Month				
				August	September	October	November	December
1.	Burden	W	MW	60	60	60	60	60
2.	Incoming Steam Temperature	T_3	^oC	48.56	48.74	48.2	47.94	48.56
3.	Incoming Steam Pressure	P_3	MPa	0.00789	0.00799	0.00743	0.00704	0.00789
4.	Steam Enthalpy In	h_3	kJ/kg	2589.8	2592.1	2589.24	2588.86	2589.8
5.	Steam Temperature Out	T_4	^oC	45.88	46.14	44.3	43.52	45.88
6.	Outgoing Steam Pressure	P_4	MPa	0.00789	0.00799	0.00743	0.00704	0.00789
7.	Steam Enthalpy Out	h_4	kJ/kg	2583.99	2584.45	2581.77	2580.4	2584.66
8.	Incoming Water Temperature	T_1	^oC	28.61	30.87	29.85	29.23	30.61
9.	Incoming Water Enthalpy	h_1	kJ/kg	128.284	129.371	125.107	122.515	128.284
10.	Water Temperature Out	T_2	^oC	37.12	38.5	36.97	36.24	37.52
11.	Outgoing Water Enthalpy	h_2	kJ/kg	157.164	161.263	154.868	151.817	157.164
12.	Cooling Water Flow	m_1	kg/s	9413.39	9409.331	9410.573	9408.026	9413.39
13.	Heat of Cooling Water	Q	kJ/s	335652.306	300813.5	280743.742	276331.6	272544.9393

The data used as research material is a parameter used to calculate the performance of the condenser. The data is used to analyze the causes of the decline in condenser performance. Data - data needed in the calculation of condenser performance will be recorded with the help of Microsoft excel software in the table format that has been provided as in Table 1.

The data retrieval of initial parameters is to use data when initial commissioning i. e. when first year's inspection includes data as in Table 2 (Table 3).

After the data processing is completed, the results of processing the data will be arranged in the form of tables and graphs so that analysis is easy. Presentation in the form of a table aims to show the results of the analysis of all data taken. Through the analysis of the graph, it will be able to draw conclusions about the performance of the condenser unit 1 of PLTU I Central Kalimantan.

4 Results and Discussions

Based on the results of the calculation of the work of the condenser unit 1 can be known the value of Ueff at the time of commissioning in July, compared to the results of calculations in August-December 2018. Results are displayed in Table 4 and Fig. 2.

Table 4. Calculation results

No.	Data	Symbol	Unit	Month				
				August	September	October	November	December
1	Burden	MW	60	60	60	60	60	60
2.	Heat of Cooling Water	kj/s	344130.9	272544.9	300813.49	280744	276331.6	272544.9
3.	LMTD	^oC	11.314	13.0408	12.58795	12.772	12.9518	13.0408
4.	Temperature Efficiency	-	0.482	0.3849	0.4269726	0.388	0.374	0.3849
5.	Capacity Ratio	-	0.516	0.3878	0.3407602	0.547	0.63	0.3878
6.	Corrected LMTD	^oC	10.862	12.91	12.336191	12.516	12.6928	12.91
7.	Heating Transfer Area	m^2	16000	16000	16000	16000	16000	16000
8.	Effective Condenser Heat Transfer Coefficient	$W/m^2\ ^oC$	1980	1624.963	1524.0396	1401.8	1360.6	1319.4
9.	Heat of Cooling Water	kJ/s	344130.9	272544.9	300813.49	280744	276331.6	272544.9

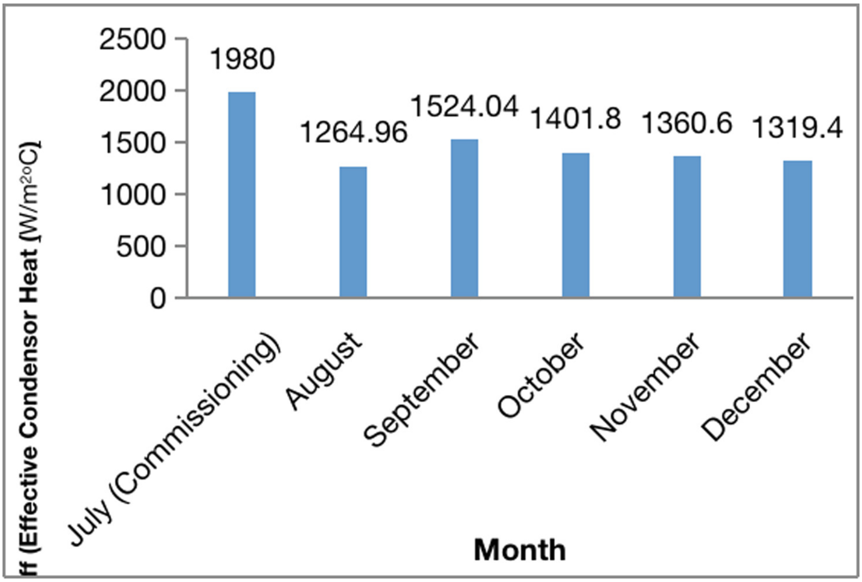

Fig. 2. Time Relationship Diagram to Ueff

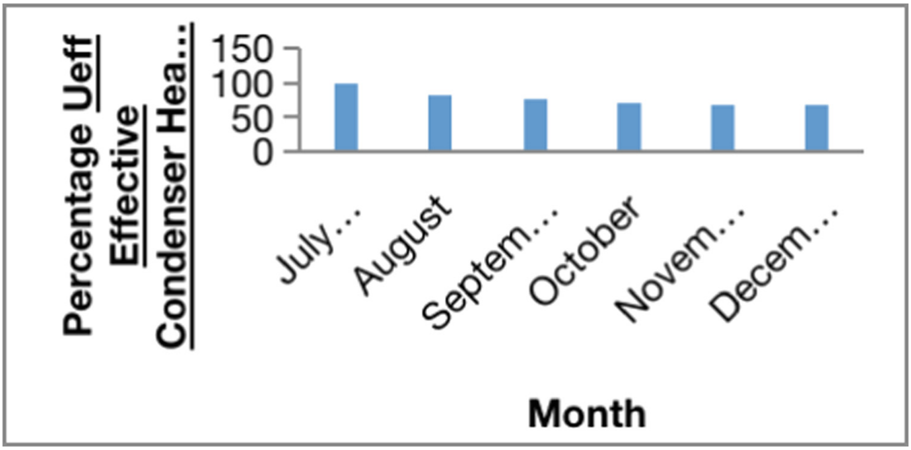

Fig. 3. Time Relationship Bar Chart Against Value Percentage Ueff Decline

From Fig. 3 it is known that the Ueff value of the unit 1 condenser when commissioning (July) is 1980 W/m^2 ^{o}C while at the time of August it is worth 1624.96 W/m^2 ^{o}C so that the difference is 355,037 W/m^2 ^{o}C. The difference indicates a considerable decrease in performance even though the new unit is operating for about 1 month. Then the commissioning conditions compared to March. In September Ueff condenser was worth 1524.04 W/m^2 ^{o}C, meaning a decrease in employment by a margin of 455. W/m^2 ^{o}C. Then the commissioning conditions were compared to October. In October Ueff condenser was worth 1401.80 W/m^2 ^{o}C, meaning a decrease in employment by a margin of 578.2 W/m^2 ^{o}C. Then the commissioning conditions were compared to November. In November Ueff condenser was worth 1360.60 W/m^2 ^{o}C, meaning a decrease in the performance by a margin of 619.4 W/m^2 ^{o}C. Then the commissioning conditions were compared to December. In December Ueff condenser is worth 1319.40 W/m^2 ^{o}C, meaning a decrease in performance by a difference of 660.6 W/m^2 ^{o}C. In each month there is always a decrease and the difference is greater when compared to Ueff when commissioning conditions.

With the data obtained in Table 4, it was also obtained the value of the presentation of Ueff's decline in commissioning results compared to August-December. Results are displayed in Fig. 3.

It can be seen in Fig. 4 where in August the value of Heat water cooler condenser unit I PLTU 1 Kalimantan decreased the heat value of cooling water by 17.93% compared to the time of commissioning. In September, the heat value of cooling water decreased by 5.1% compared to August. In October there was a decrease in the heat value of cooling water by 6.17% compared to September. In November there was a decrease in the heat value of cooling water by 2.08% compared to October. In December there was a decrease in the heat value of cooling water by 2.08% compared to November. In the chart above it can also be analyzed that the possibility in January 2019 is in a bad condition. Where it can also be made SOP preventive maintenance condenser. The SOP for Preventative Maintenance is in the form of ball cleaning or taproge ball cleaning.

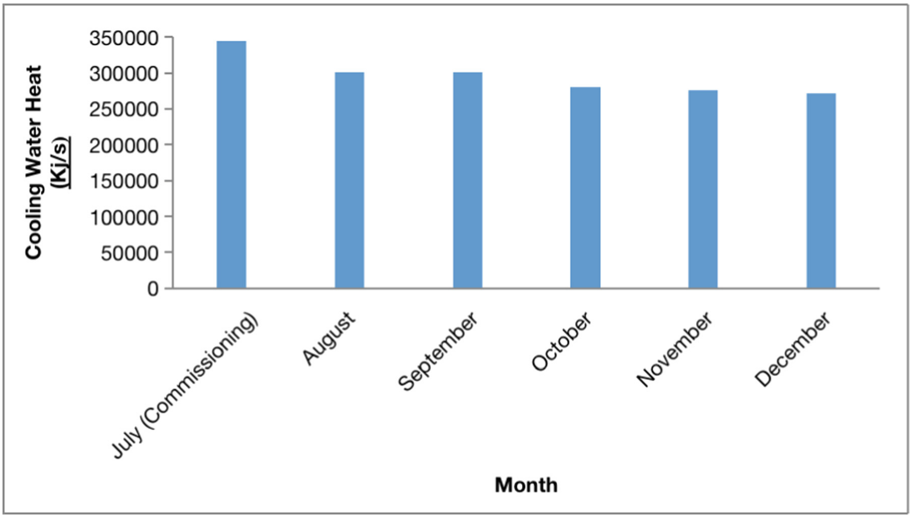

Fig. 4. Time Relationship Diagram to Heat Cooling Water

This ball cleaning is sprayed by the pump. The balls used are sponge rubber balls whose diameter is 10% larger than the diameter in the pipe. Cleaning is carried out at a time when it is not burdened.

The main cause of the decline in Ueff value is the smaller the heat value of cooling water. From commissioning conditions to actual data collection in August - December 2018 continues to decline. The main cause of the decrease in cooling water heat is

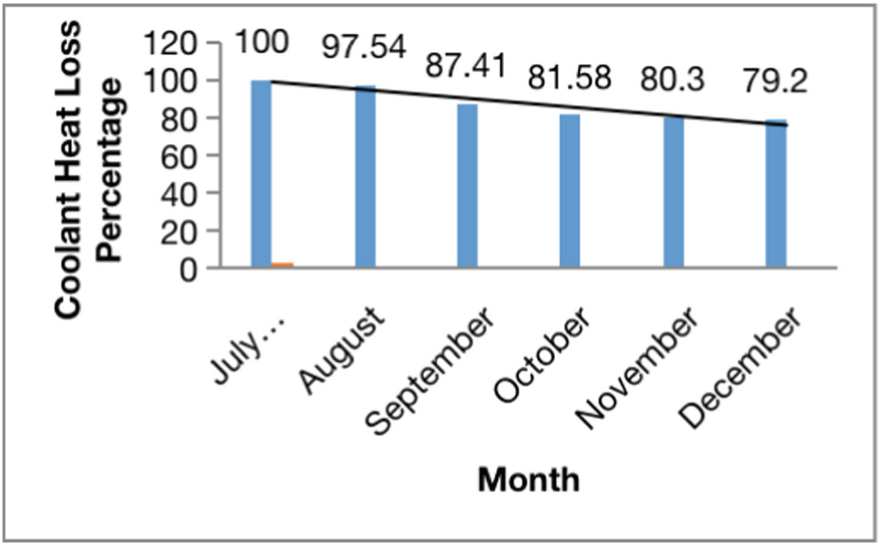

Fig. 5. Time Relationship Diagram to Decrease Percentage Heat Cooling Water

the continued decrease in the enthalpy differential between the outgoing cooling water enthalpy and the cooling water enthalpy in. The decrease in the heat value of the cooler can be seen in Fig. 4.

With the data obtained in Table 4, the value of the decrease in the presentation of cooling heat from commissioning results compared to August-December was obtained. Results are displayed in Fig. 5.

It can be seen in Fig. 6 where in August the value of Heat water cooler condenser unit I PLTU 1 Kalimantan decreased the heat value of cooling water by 2.46% compared to the time of commissioning. In September, the heat value of cooling water decreased by 10.13% compared to August. In October there was a decrease in the heat value of cooling water by 5.83% compared to September. In November, the heat value of cooling water decreased by 1.28% compared to October. In December there was a decrease in the heat value of cooling water by 1.1% compared to November. In the graph above if the trendline formula is entered where y becomes 50% then obtained x = 11.6 where in June 2019. The condenser of unit I PLTU I Kalimantan requires a complete overhaul.

The decrease in the condenser of unit I PLTU I Central Kalimantan has actually been maintained.

Fig. 6. Photo *fouling* During Commissioning (*Overhaul*) Earlier

Table 5. Ueff standard table and cooling heat

Ueff Standard (from commissioning)	Cooling Heat Standard (commissioning standard)	Treatment
Bad (<50%)	Bad (<50%)	*Overhaul* as a whole
Medium (50–75%)	Medium (50–75%)	*Corrective Maintenance*
Good (>75%)	Good (>75%)	*Preventive Done Maintenance* (Ball *cleaning*, Check water quality, *back wash* condenser, check *flange* condition)

1. PM (*Preventive Maintenance*), namely by checking the control side or mechanical side.
2. Check the condition of all *flanges* related to the *vacuum* and the *water* side
3. Check the water quality on the *hot wall*.
4. *Corrective* is done when there is a leaking tube. This is done by turning off one of the tubes on the condenser.
5. Backwash the condenser, which is by reversing the direction of the flow of cooling water to remove dirt that enters the water box inlet.
6 *Ball Cleaning,* this cleaning process is done by inserting a ball known as *Ball Taproge* on the condenser inlet and then the ball follows the direction of fluid flow in the condenser and exits at the water box outlet.

The decrease in performance and the heat value of cooling water is caused by several things, namely caused by fouling:

Fouling or deposits are very likely to occur, because the cooling water in the condenser comes from river water and the water contains deposits or dirt that goes into the condenser. The deposits directly affect the value of heat transfer in the condenser and can cause a decrease in the performance of the condenser.

To avoid a decrease in the performance of the condenser unit I PLTU I Central Kalimantan which is too high, it is necessary to make an IK (Work Instruction) based on the value of the condenser's own performance value. The data is displayed in Table 5.

5 Conclusion

From the research that has been done can be concluded, namely:

1. Comparison of the demonstration of condenser unit 1 PLTU 1 Central Kalimantan during the first year inspection and during August-December 2018 (5 months) can be known by calculating the Effective Condenser Heat transfer Coefficient. Where the value at the time of first year inspection is 1980 W/m^{2}K, in August it was 1624.953 W/m^{2}K, in September it was 1524.0396 W/m^{2}K, in October it was 1401.8 W/m^{2}K, in November it was 1360.6 W/m^{2}K, in December it was 1319.4 W/m^{2}K.
2. The decrease in performance and the heat value of cooling water is caused by several things, namely due to fouling.

Bibliography

1. Bergmen, Ted, and lavine, Adrienne: Fundamental of Heat and Mass Transfer. Wiley Press, New Jersey (2007).
2. Cengel, Yunus A.: Heat Transfer. Mc.Graw-Hill (2004).
3. Cengel Yunus A & Boles, Michael A.: Thermodynamics an Engineering Approach. McGraw-Hill (2007).
4. China National Electric Engineering Co. Ltd: Turbin Operation Manual. Beijing (2014).

5. Endang Prihastuty: Analisis Kinerja Kondensor pada Instalasi PLTU Kilang Minyak Kaitannya dengan Kebocoran Tube. Jurnal Ilmiah Teknobiz Vol 1 No. 1 Juli (2011).
6. Fujian Longking Co., Ltd: Turbine Maintenance PLTU I Kalimantan Tengah. Pulang Pisau. PLN Persero (2010).
7. Fujian Longking Co., Ltd: Turbine Operation PLTU I Kalimantan Tengah. Pulang Pisau. PLN Persero (2010).
8. Kakac, Sadic & Hongtan Liu: Heat Exchanger, Selection, Rating and Thermal Design. CRC PRESS, Boca Raton (2002).
9. Kreith, Frank & Wiliam Z. Black: Basic Heat Transfer. Harper and Row, Publishers, New York (1980).
10. Orianto, dan Pratikto, W.A.: Mekanika Fluida I. Teknologi Kelautan Institut Teknologi Sepuluh Nopember, Surabaya (1984).