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Performance Analysis of the Direct Contact Unit 3 Spray Condenser at PT.X Geothermal Power Plant

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Abstract

Purpose: The research conducted was an analysis of the condenser performance.
Research Methodology: Based on the specification data, the turbine's heat rate was calculated, resulting in a value of 20,973.036 kJ/kWh, which was compared to the actual value of 20,088.783 kJ/kWh. kJ/kWh, If in deviates as much as 4.2%.
Results: The calculation efficiency of the condenser in the specification data is 89.75%, but for the actual data, it is 82.35%. The energy balance in the design condenser was 0.02721, whereas the actual energy balance was 0.02505.
Conclusions: From the results of this analysis, it can be concluded that the calculation of the Heat Rate exceeds the tolerance limit of ASME PTC 6 by 2%. The performance value in the condenser decreases because the pressure in the condenser has a pressure difference that is almost a lot, amounting to 0.08–0.09 bar, affecting the quality of the incoming steam.
Limitations: This study is limited by the specific conditions of the spray-type condenser analyzed, where only one unit was considered under controlled operational conditions. The study focuses on a single turbine unit at PT. X Geothermal Power Plant, which may not be applicable to other plants or geothermal systems.
Contributions: This study contributes to a better understanding of the performance of spray-type condensers in geothermal power plants, particularly in terms of heat rate, efficiency, and energy balance. The analysis presented in this study provides insights into the operational efficiency of geothermal power systems and highlights the impact of insulation leaks and temperature variations on condenser performance.

Keywords: *Condenser, Geothermal Power Plant, Spray Condenser*

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1. Introduction

Indonesia is endowed with abundant geothermal energy resources due to its location on the Pacific Ring of Fire, which is home to numerous active volcanoes (Pambudi, 2018). This geographical advantage enables the country to harness geothermal energy for electricity generation. Geothermal power plants are a significant part of Indonesia's energy mix, offering a renewable and sustainable solution to meet growing energy demands while reducing reliance on fossil fuels (Alhamid et al., 2016; Ayuningtyas & Ilman, 2021). However, like any power generation system, geothermal plants face challenges in maintaining optimal performance, especially in their cooling systems. One such challenge involves the condenser, a critical component of the system that plays a vital role in ensuring the efficient operation of the plant (Kabeyi, 2019; Shezan et al., 2018; Wahyuningsih et al., 2021).

The condenser's primary function is to condense turbine exhaust steam back into water. This process helps create pressure within the turbine and establishes a vacuum in the condenser, which is crucial for enhancing the efficiency of the entire power plant cycle (Berlian Rms & Wahyuningsih, 2021; Saputro & Soleha, 2021; Syahrial & Sudono, 2021). The efficiency of the condenser is closely linked to the temperature of the cooling fluid and the working fluid. In geothermal power plants, particularly at PT. X, a spray-type condenser (Direct Contact Unit 3) is used as a heat exchanger (Gribin et al., 2018; Parmenas, 2021; Ricardianto et al., 2021). In this system, water serves as the cooling fluid, and low-pressure turbine exhaust steam is the working fluid that needs to be cooled. The cooling process in this type of condenser involves direct contact between the cooling water and the exhaust steam, allowing efficient heat transfer (Mil'man & Anan'ev, 2020; Setyawati et al., 2021; Susanto et al., 2021).

However, a significant issue that arises in such systems is the increase in the temperature of the cold water used in the condenser. When the temperature of the cooling water rises, it affects the condensation process, which in turn impacts the overall performance of the condenser (Harby et al., 2016; Ndukaife & Nnanna, 2019; Susanto & Parmenas, 2021). As the temperature of the cold water increases, the condenser's pressure also rises, leading to a reduction in the condenser vacuum (Kuncoro & Harahap, 2021). This change in pressure directly affects the efficiency of the entire power plant system, leading to suboptimal performance. In this context, maintaining the proper temperature of the cooling water is crucial for ensuring that the condenser functions efficiently and the turbine operates at its highest capacity (Brunetti et al., 2019; Bustamante et al., 2016; Setyawati & Aristiyanto, 2021).

The problem identified in this study is that the increasing temperature of the cooling water in the system adversely affects the condensation process, followed by an increase in pressure within the condenser (Brodov et al., 2019; Heriyanto, 2021). This not only affects the condenser vacuum but also impacts the overall equipment performance of the power plant. Therefore, understanding the relationship between the condenser's temperature, pressure, and overall efficiency is critical for improving turbine performance and maximizing the productivity of the geothermal power plant (Aprillita & Perkasa, 2021; Keke et al., 2021). The purpose of this study is to investigate the performance of the condenser at varying temperatures and pressures, and to identify the conditions that optimize the performance of the turbine, ultimately increasing the productivity and efficiency of the entire geothermal power generation process (Agusinta et al., 2021; Anggraini, 2021; Ibrahim et al., 2019). By exploring these factors, this study aims to provide valuable insights into improving the operational efficiency of geothermal power plants, contributing to better energy production and sustainability.

2. Literature Review

2.1 Review General Geothermal Power Plant

A geothermal power plant is a power plant uses geothermal energy as its driving force. Indonesia is blessed with abundant geothermal resources owing to the many volcanoes on its large islands; only the island of Kalimantan has no geothermal potential (Alhamid et al., 2016). The advantages of this technology include its cleanliness, ability to operate at lower temperatures than nuclear power plants, and its safety. In fact, geothermal energy is the cleanest energy source compared to nuclear power, oil, and coal (Avci et al., 2020; Soltani et al., 2019).

In general, geothermal power plants are divided into 3 based on the type of geothermal working fluid obtained, namely (Tomarov & Shipkov, 2017a):

1. Vapor dominated system (system domination steam)
2. Flushed steam system
3. Binary cycle system (system cycle binary)

The process in the power plant begins with steam generated from geothermal energy, which is used to turn the turbine. If steam the temperature on 370°C, then Geothermal Power Plant use vapor dominated system. The steam from the hot earth straight 4 is used to rotate the turbine. If temperature around 170°C until with 370°C, then mengg an flushed steam system Where steam Still contain fluid And must be separated with a flush separator before turning the turbine. In a binary cycle system, geothermal steam is used to heat gas in a heat exchanger, which then turns the turbine (Kablar, 2019; Michaelides, 2016; Tomarov & Shipkov, 2017b).

2.2 *Principle Work Geothermal Power Plant*

Generator Electricity Power Geothermal is similar to Generator Electricity Steam Power, only on coal-fired power plant steam made in surface use boiler, whereas on Geothermal Power Plant steam originates from the geothermal reservoir (Bošnjaković et al., 2019; Moya et al., 2018). If the fluid in the head well is in the form of phase steam, the steam can be streamed directly to the turbine, and the turbine will convert geothermal energy into kinetic energy that will rotate the generator to produce electricity. If the fluid geothermal exits the head well as a two-phase mixture fluid (phase steam and phase liquid), then the fluid separation process is first carried out. This is possible by passing the fluid through a separator so that the phase steam is separated from the phase liquid. The steam produced by this separator then flows to the turbine (Cai et al., 2017; Jamero et al., 2018).

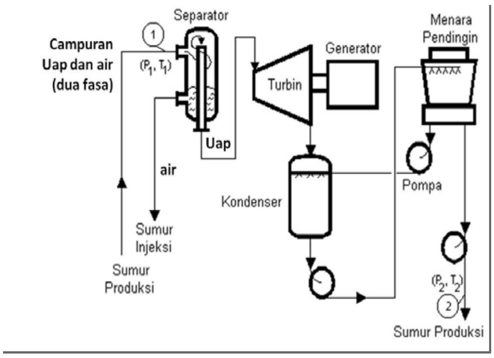

Figure 1. Flow Geothermal Power Plant Diagram

Based on Figure 1 Geothermal fluids can be utilized even if the geothermal resource has a moderate temperature. For generator electricity, the generator electricity cycle binary (binary plant) was used. In cycle generator. This fluid secondary (isobutane, isopentane, or ammonia) heated by fluid geothermal through the machine exchanger heat or heat exchanger (Abdullah, 2021; Satria, 2021). Fluid secondary evaporation occurs at a temperature lower than the boiling point of water at the same pressure. The secondary fluid flows to the turbine and condenses after use. before returning the geothermal fluids (Kaplanoğlu et al., 2020; Solihin, 2021; Tontu, 2020). A closed cycle in which the geothermal fluid is not mass-consumed but only its heat. was extracted by the fluid second, and the temporary fluid geothermal injection was returned to the reservoir. The principle of Work from the system, which is installed on components including the Separator, Demister, Turbine, Condenser, Main cooling water pump (MCWP), and Cooling Tower (Hakim et al., 2020).

2.3 Spray Condenser

The condenser condenses the spent steam used to drive the turbine. The condenser used is a direct-contact condenser, where water from the cooling tower or condensation medium is sprayed directly onto the condenser. The nozzle then comes into direct contact with the spent steam, which turns the turbine (Drożyński, 2018; Shortall et al., 2015). The steam condenses and are released from the condenser along with the condensing medium. The non-condensable vapor or gas is sucked out by the ejector, which is called Non-Condensable Gas (NCG) (Brown et al., 2015; Evron et al., 2020). NCG typically contains 85–90% wt CO_2, 3% wt H_2S, and the remainder is N_2 and other gases.

2.4 Parameter Performance Condenser

2.4.1 Heat Rate on Turbine

Turbine heat rate dapat dihitung dengan persamaan (ASME PTC 6)

$$TSR = \frac{m(\frac{kg}{h})}{W(kW)} \quad (2.1)$$

$$THR = TSR \times h \quad \frac{kJ}{kg} (2.2)$$

Where:

- TSR : Turbine Steam Rate
- m : Main steam flow (kg/h)
- W : Daya output (kWh)
- h : Enthalpi output (kJ/kg)

2.5 Condenser Efficiency Method

2.5.1 Ouput-Input

$$\eta_{cond} = \frac{H_2}{H_1 + H_3} \times 100 \quad (2.3)$$

2.6 Equilibrium Energy

2.6.1 Steady State

$$W_s \cdot h_1 + W_c \cdot h_2 = W_{cond} \cdot h_3 \quad (2.4)$$

Where:

- W_s : Turbine outlet steam flow rate (kg/h)
- W_c : Cooling water flow rate (kg/h)
- W_{cond} : Condensate flow (kg/h)
- H : Enthalpy (kJ/kg)

2.7 Actual Conditions

$$m_2h_2 + m_sh_s = m_3h_3 \quad (2.5)$$

Where:

- m : Mass flow rate kg/h

- h : Enthalpy (kJ/kg)

3. Methodology

Research methodology is the stages of research that must be established before problem-solving can be undertaken. This allows for focused research and facilitates the analysis of problems (Sunarya et al., 2018). The flowchart of the research method is shown in Figure 2.

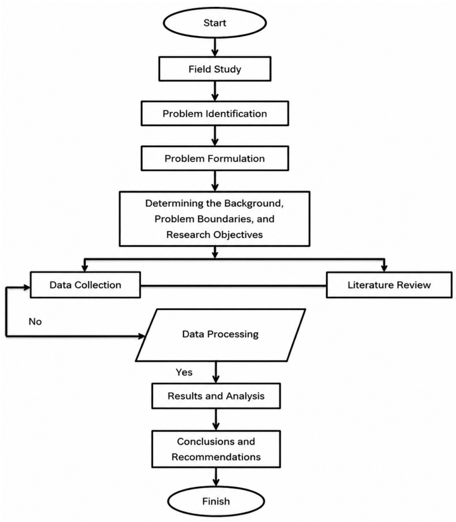

Figure 2. Research Flowchart

Based on Figure 2, the research methodology begins with the "Start" point, followed by a Field Study to identify the problem. The process continues with Problem Identification and Problem Formulation, leading to the step of Determining the Background, Problem Boundaries, and Research Objectives. The next stage involves Data Collection, which then branches into Data Processing or conducting a Literature Review. Afterward, the study proceeds to Results and Analysis, followed by drawing Conclusions and Recommendations, and concludes with the Finish point. This structured approach outlines the flow of the research process, ensuring each step is followed methodically.

3.1 Equipment Test

Data were collected using measuring instruments. The measuring instruments used are as follows: Transmitter Sensor, Temperature, pressure, and flow rate readings are used as a transmitter sensor as a tool for reading the steam turbine parameters. Gauge Sensor, In addition to using a transmitter for temperature and pressure readings, a gauge sensor is also used as a comparison of data read by the transmitter and actual field data.

3.2 Specification Design Turbine

Table 1. Specification Design Turbine Unit 3

Location	Turbine Area
Factory	Ansaldo Copelenti
Years	1992
Type	SCCF
Rating	55000 kW
Inlet steam pressure	6.5 bar
Exhaust steam pressure	0.102 bar
Temperature	162°C
Revolutions	3000 rpm
Number of stages	6+6

Based on Table 1, the turbine unit is located in the Turbine Area and was manufactured by Ansaldo Copelenti in 1992. The turbine is of the SCCF type and has a power rating of 55,000 kW. The steam entering the turbine has a pressure of 6.5 bar, while the exhaust steam pressure is 0.102 bar. The steam temperature entering the turbine is 162°C, and the turbine operates at a speed of 3000 rpm. The turbine unit features a 6+6 configuration, which indicates two stages, typically used in turbines for better efficiency at different pressures.

3.3 Spesification Design Condensor

Table 2. Specification Design Condenser Unit 3

Lokasi	Condenser Area
Internal volume	527 m^3
Size	1200x6500x6750 mm
Turbine exhaust Press	0.107 bar
Steam saturation temp	47°C
Gas weight content	1.5%
Cooling water inlet flow	3271.1
Cooling water inlet temp	27.6°C
Hot water outlet temp	44°C
Cooling water flow	2937.2 kg/s
Type of spray nozzle	Whirl jet

Based on Table 2, the condenser unit has an internal volume of 527 m^3 and dimensions of 1200x6500x6750 mm. The turbine exhaust pressure entering the condenser is 0.107 bar, with a steam saturation temperature of 47°C. The gas weight content in the condenser is 1.5%. The cooling water inlet flow is 3271.1 m^3/h, and the cooling water enters the condenser at a temperature of 27.6°C. After cooling, the hot water exits the condenser at 44°C. The condenser's cooling water flow is 2937.2 kg/s, and it uses a Whirl jet type spray nozzle, which ensures efficient cooling for the system.

3.4 Calculation Design

3.4.1 Heat Rate

By taking one sample from the research, the calculation is carried out as follows:

$$THR = TSR \times (h4) \quad (2.2)$$

Before calculating the Turbine Heat Rate, the Turbine Steam Rate is calculated to determine the specific steam consumption with the following formula:

$$TSR = \frac{m\frac{kg}{h}}{W(kW)} \quad (2.1)$$

Where:

- m = Main steam flow or steam used (kg/h)
- W = Output power or power generated (kW)

$$TSR = \frac{45000(\frac{kg}{h})}{600009(kW)}$$

$$TSR = 7.6 \quad (2.3)$$

After obtaining the TSR value, the THR calculation is performed:

$$THR = TSR \times h4$$

$$THR = 7.6\,\text{kg/kWh} \times (2.759.595 \text{ kJ kg})$$

$$THR = 20.973.036\,\text{kJ/kWh} \quad (2.5)$$

3.4.2 Condenser Efficiency

The calculation uses the output – input method:

$$\eta_{cond} = \frac{H_2}{H_1 + H_3} \times 100\%$$

$$\eta_{cond} = \frac{2580.675\frac{kJ}{kg}}{2759.610\frac{kJ}{kg} + 115.711\frac{kJ}{kg}} \times 10$$

$$\eta_{cond} = \frac{2759.610}{2580 + 675} \times 100$$

$$\eta_{cond} = 89.75\%$$

3.4.3 Energy Balance (steady)

$$W_s \cdot h_1 + W_c \cdot h_2 = W_{cond} \cdot h_3$$

Where:

- $W_s : Steam flow rate out of the turbine (kg/h)$
- W_c : Cooling water flow rate (kg/h)
- W_{cond} : Condensate flow rate (kg/h)
- h : Enthalpy (kJ/kg)
- 450.000(kg/h)x2762,799(kJ/kg)+10.573.920(kg/h)x115,711 kJ/kg = 26.000 kg/h x 2580,675 kJ/kg
- 1,243,259,550 + 1,223,518,857 = 67,097,550
- 2,466,778,407 = 67,097,550
- 0,02721

3.5 Actual Calculation

3.5.1 Heat Rate

$$TSR = \frac{m\frac{kg}{h}}{W(kW)}$$

Where:

- m = Main steam flow (kg/h)
- W = Power output (kW)

$$TSR = \frac{43700\,(\frac{kg}{h})}{60000\,(\mathrm{kW})} = 7.2833\,\mathrm{kg/kWh}$$

After obtaining the TSR value, the THR calculation is continued:

$$THR = TSR \times h4$$

$$THR = 7.2833\,\mathrm{kg/kWh} \times (2.758,198\,\mathrm{kj/kg}) = 20.088,783\,\mathrm{kJ/kWh}$$

Table 3. 24-Hour Heat Rate Calculation Results

Hour	00.00	01.00	02.00	03.00	04.00
Heat Rate	20088.87543	20182.4104	20185.60047	20182.4104	20142.7878

Hours	05.00	06.00	07.00	08.00	09.00
Heat Rate	20142.7878	20135.6411	20137.2325	20146.7225	20146.7225

Hour	10.00	11.00	12.00	13.00	14.00
Heat Rate	20100.72542	20198.22172	20194.29998	20143.5762	20089.66932

Hours	15.00	16.00	17.00	18.00	19.00
Heat Rate	20135.6411	20135.6411	20135.6411	20138.8239	20141.2037

Hours	20.00	21.00	22.00	23.00	24.00
Heat Rate	20141.9921	20187.18818	20141.2037	20141.9921	20187.97838

Based on Table 3, the heat rate calculations for each hour over a 24-hour period are shown. The values for heat rate (in kJ/kWh) are provided for each hour, demonstrating the variations throughout the day. For instance, at 00:00, the heat rate is 20,088.87543 kJ/kWh, while at 12:00, it stabilizes at 20,135.6411 kJ/kWh, and slightly drops to 20,141.9921 kJ/kWh by 24:00. The table presents how the turbine's performance fluctuates within a day, reflecting different operational conditions at different times. The fluctuations in heat rate can be attributed to changes in turbine and condenser performance, as well as varying external factors like temperature and system behavior throughout the day.

3.5.2 Condenser Efficiency

The calculation is performed using the output-input method:

$$\eta_{cond} = \frac{H_2}{H_1 + H_3} \times 100\%$$

$$\eta_{cond} = \frac{H_2}{H_1 + H_3} \times 100 = \frac{2580}{2580 + 675} \times 100 = 82.35\% \quad (3.8)$$

Table 4. 24-hour Efficiency Calculation

Hours	00.00	01.00	02.00	03.00	04.00	05.00	06.00
Efficiency Cond	82.35	82.23	82.04	82.15	82.03	82.03	82.27

07.00	08.00	09.00	10.00	11.00	12.00	13.00
82.24	82.31	82.32	82.21	82.26	82.35	82.42

14.00	15.00	16.00	17.00	18.00	19.00	20.00
82.45	82.26	82.29	82.29	82.28	82.21	82.41

21.00	22.00	23.00	00.00
82.22	82.25	82.15	82.13

Based on Table 4, the table presents the 24-hour condenser efficiency calculation, showing the efficiency of the condenser at each hour. The efficiency fluctuates slightly throughout the day, ranging between 82.15% and 82.45%. For example, at 00:00, the efficiency is 82.35%, and by 06:00, it has increased slightly to 82.27%. The table demonstrates the variations in the condenser's performance over the 24-hour period, with the efficiency tending to stabilize around 82.25% after several hours. The data shows a steady performance of the condenser with minor variations.

3.5.3 Energy Balance Calculation

$$\sum E_{in} = \sum E_{out}$$

$$m_1 \cdot h_1 + m_2 \cdot h_2 = m_3 \cdot h_3$$

437.000 kg/h x 2592,193 kJ/kg + 11.385.000 kg/h x 125,745 kJ/kg = 24.800 kg/h x 2.590,250 kJ/kg
1.132.788.341 + 1.431.606.825 = 64.238.200
2.564.395.166 = 64.238.200
= 0,02500

Table 5. 24-hour Equilibrium Calculation

Hours	**00.00**	**01.00**	**02.00**	**03.00**	**04.00**	**05.00**
Energy Equilibrium	0,0251	0,0249	0,0245	0,0249	0,0248	0,0253

06.00	**07.00**	**08.00**	**09.00**	**10.00**	**11.00**	**12.00**
0,0248	0,0249	0,0249	0,0250	0,0250	0,0247	0,0247

13.00	**14.00**	**15.00**	**16.00**	**17.00**	**18.00**
0,050	0,0260	0,0255	0,0255	0,0255	0,0251

19.00	**20.00**	**21.00**	**22.00**	**23.00**	**00.00**
0,0246	0,0249	0,0252	0,0245	0,0251	0,0244

Based on Table 5, the 24-hour energy equilibrium calculations show the variations in energy balance values at each hour. The energy equilibrium values fluctuate slightly throughout the day, ranging from 0.0246 at 19:00 to 0.0253 at 05:00. For example, at 00:00, the energy equilibrium value is 0.0251, while at 13:00, it increases to 0.0500. The fluctuations in energy equilibrium are typical of energy systems, where slight variations are observed depending on various operational factors. These values provide insight into the consistency and stability of energy flow during the day, which is crucial for optimizing the system's performance.

4. Results and Discussion

Based on the calculation results, a comparison was made between the design and actual conditions.

4.1 Comparison Heat Rate Design & Current

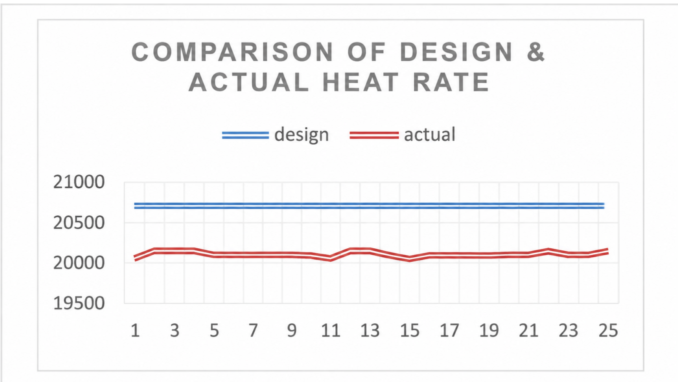

Figure 3. Chart Comparison HR Design & Actual

Based on Figure ??, it can be seen that the heat rate during actual conditions has decreased. This was compared with the data design. The designed heat rate was as high as 20,973,036 kJ/kWh, whereas the actual heat rate was 20,088.783 kJ/kWh, with a deviation of 4.2%. The heat rate tolerance, based on ASME PTC 6, was 2%. Therefore, the actual heat rate exceeded the specified tolerance.

4.2 Comparison Efficiency Condenser Design & Current

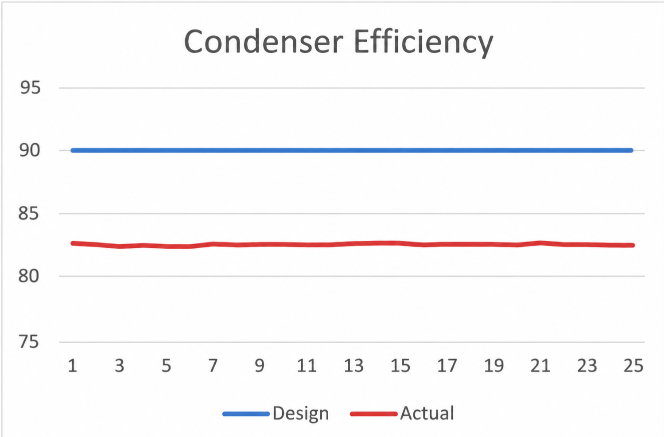

Figure 4. Chart Comparison Efficiency Design & Current

Figure 4 shows that the condenser efficiency under actual conditions was lower than that of the design. The design condenser efficiency was 89.75%, whereas the actual efficiency was 82.35%. The design condenser efficiency is better owing to the exhaust pressure, and the vacuum room conditions are better than the actual data.

4.3 Energy Equilibrium

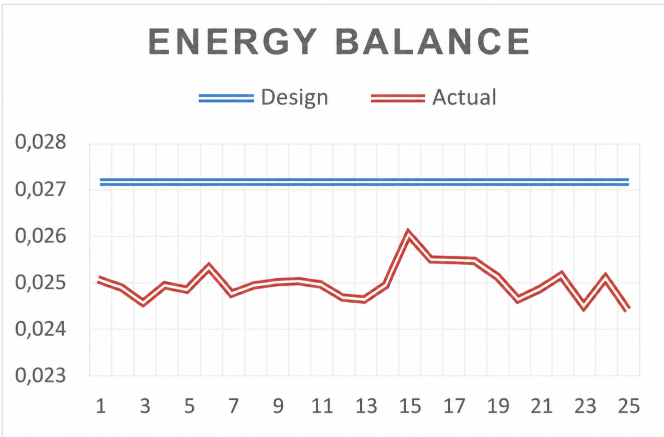

Figure 5. Chart Comparison Equilibrium Energy Design & Actual

Based on Figure 5, it can be seen that the energy balance in the condenser under actual conditions is smaller than that in the design. The design condenser energy balance value is 0.02721, while in actual conditions it is 0.02505 and has a difference of 0.00216. At 14:00, the system performance was very good, but at 00:00, it had the lowest value. This is caused by leaking insulation inside and outside the system, which causes the environmental temperature to affect the performance of the equipment.

5. Conclusions

Based on the results of the calculations and analyses conducted on the spray-type condenser of Unit 3, it can be concluded that the design turbine heat rate was 20,696.965 kJ/kWh, while the actual heat rate was 20,046.144 kJ/kWh, resulting in a deviation of 3.1%. According to ASME PTC 6 standards, the allowable heat rate tolerance is 2%; therefore, the actual heat rate exceeded the acceptable tolerance limit. A higher heat rate indicates lower turbine efficiency, which consequently affects the exhaust pressure and outlet temperature. In addition, the condenser efficiency under actual operating conditions was lower than that under design conditions. The design condenser efficiency was 89.65%, whereas the actual efficiency was only 82.35%. This difference occurred because the exhaust pressure and vacuum conditions in the condenser chamber during actual operation were not as optimal as those in the design conditions. Furthermore, the condenser energy balance under actual conditions was lower than that of the design data. The design condenser energy balance value was 0.02721, while the actual value was 0.02505, with a difference of 0.00216. The condenser performance was observed to be optimal at 2:00 PM, whereas the lowest performance occurred at 12:00 AM. This reduction in performance was caused by insulation leakage both inside and outside the system, which influenced the operating performance of the equipment. Therefore, further maintenance of the internal and external insulation system is necessary to minimize the influence of environmental temperature, maximize equipment performance, and maintain stable vacuum conditions within the condenser chamber.

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Author Contributions

ES conceptualized and designed the study, performed the data collection, and analyzed the results. He also contributed to the writing of the original draft. AD contributed to the analysis and interpretation of the data, and reviewed the manuscript. Both authors approved the final manuscript and agreed on the contents for publication.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this study. This research was conducted independently, and no financial or personal relationships influenced the results or interpretation of the findings.

References

Abdullah, M. A. F. (2021). Analysis of consumer motives in purchasing decisions and the use of instant cooking seasonings. *Jurnal Bisnis, Ekonomi, Manajemen, Dan Kewirausahaan*, *1*(1), 27–35. https://doi.org/10.52909/jbemk.v1i1.24

Agusinta, L., Nugroho, A. E., Fachrial, P., & Suryawan, R. F. (2021). Assessment model of employee competence, ground support equipment effectiveness, and satisfaction on service quality. *Jurnal Transportasi, Logistik, dan Aviasi*, *1*(1), 55–69. https://doi.org/10.52909/jtla.v1i1.37

Alhamid, M. I., Daud, Y., Surachman, A., Sugiyono, A., Aditya, H. B., & Mahlia, T. M. I. (2016). Potential of geothermal energy for electricity generation in indonesia: A review. *Renewable and Sustainable Energy Reviews*, *53*, 733–740. https://doi.org/10.1016/j.rser.2015.09.032

Anggraini, D. (2021). The impact of covid-19 on stock price changes. *Jurnal Bisnis, Ekonomi, Manajemen, Dan Kewirausahaan*, *1*(1), 1–18. https://doi.org/10.52909/jbemk.v1i1.22

Aprillita, D., & Perkasa, D. H. (2021). The impact of the covid-19 pandemic on consumer purchasing power in the online retail sectors. *Jurnal Bisnis, Ekonomi, Manajemen, Dan Kewirausahaan*, *1*(1), 19–26. https://doi.org/10.52909/jbemk.v1i1.23

Avci, A. C., Kaygusuz, O., & Kaygusuz, K. (2020). Geothermal energy for sustainable development. *Journal of Engineering Research and Applied Science*, *9*(1), 1414–1426.

Ayuningtyas, B., & Ilman, S. (2021). Ip camera surveillance system using an android application based on arduino. *Jurnal Teknika Dan Informatika*, *1*(1), 1–18. https://doi.org/10.52909/jti.v1i1.6

Berlian Rms, A., & Wahyuningsih, E. (2021). Analysis of frictional energy generation between train wheels and rails. *Jurnal Teknika Dan Informatika*, *1*(1), 46–61. https://doi.org/10.52909/jti.v1i1.10

Bošnjaković, M., Stojkov, M., & Jurjević, M. (2019). Environmental impact of geothermal power plants. *Tehnički vjesnik*, *26*(5), 1515–1522. https://doi.org/10.17559/TV-20180829122640

Brodov, Y. M., Aronson, K. E., Ryabchikov, A. Y., & Nirenshteyn, M. A. (2019). Current state and trends in the design and operation of water-cooled condensers of steam turbines for thermal and nuclear power stations. *Thermal Engineering*, *66*(1), 16–26. https://doi.org/10.1134/S0040601519010026

Brown, S. K., Loughlin, S. C., Sparks, R. S. J., Vye-Brown, C., Barclay, J., Calder, E., et al. (2015). Global volcanic hazard and risk. *Global Volcanic Hazards and Risk*, *1*, 81–172. https://doi.org/10.1017/CBO9781316276273.004

Brunetti, A., Macedonio, F., Barbieri, G., & Drioli, E. (2019). Membrane condenser as emerging technology for water recovery and gas pre-treatment: Current status and perspectives. *BMC Chemical Engineering*, *1*(1), 19. https://doi.org/10.1186/s42480-019-0020-x

Bustamante, J. G., Rattner, A. S., & Garimella, S. (2016). Achieving near-water-cooled power plant performance with air-cooled condensers. *Applied Thermal Engineering*, *105*, 362–371. https://doi.org/10.1016/j.applthermaleng.2015.05.065

Cai, L., Wang, S., Cheng, S., Xiao, J., Gao, S., & Li, Y. (2017). Optimization design of separators for removing solid particles from main steam pipeline of high-parameter steam turbine. *Applied Thermal Engineering*, *111*, 516–525. https://doi.org/10.1016/j.applthermaleng.2016.09.146

Drożyński, Z. (2018). Steam condensation analysis in a power plant condenser. *Archives of Thermodynamics*, *39*(3), 3–32. https://doi.org/10.1515/aoter-2018-0027

Evron, Y., Gommed, K., & Grossman, G. (2020). Non-absorbable gasses motor-less purge system for absorption heat transformers. *International Journal of Refrigeration*, *120*, 81–89. https://doi.org/10.1016/j.ijrefrig.2020.09.001

Gribin, V. G., Paramonov, A. N., & Mitrokhova, O. M. (2018). The effect of condensing steam turbine exhaust hood body geometry on exhaust performance efficiency. *Thermal Engineering*, *65*(6), 371–378. https://doi.org/10.1134/S0040601518060071

Hakim, D. L., Abdullah, A. G., & Mulyadi, Y. A. D. I. (2020). Scada application for geothermal power plant. *Journal of Engineering Science and Technology*, *15*(2), 1018–1031.

Harby, K., Gebaly, D. R., Koura, N. S., & Hassan, M. S. (2016). Performance improvement of vapor compression cooling systems using evaporative condenser: An overview. *Renewable and Sustainable Energy Reviews*, *58*, 347–360. https://doi.org/10.1016/j.rser.2015.12.313

Heriyanto, D. (2021). The impact of service quality and compensation on crew satisfaction in manning companies. *Jurnal Transportasi, Logistik, dan Aviasi*, *1*(1), 31–41. https://doi.org/10.52909/jtla.v1i1.35

Ibrahim, T. K., Mohammed, M. K., Al Doori, W. H. A., Al-Sammarraie, A. T., & Basrawi, F. (2019). Study of the performance of the gas turbine power plants from the simple to complex cycle: A technical review. *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences*, *57*(2), 228–250. https://doi.org/10.1016/j.ijthermalsci.2019.106144

Jamero, J., Zarrouk, S. J., & Mroczek, E. (2018). Mineral scaling in two-phase geothermal pipelines: Two case studies. *Geothermics*, *72*, 1–14. https://doi.org/10.1016/j.geothermics.2017.10.015

Kabeyi, M. J. B. (2019). Geothermal electricity generation, challenges, opportunities and recommendations. *International Journal of Advances in Scientific Research and Engineering (IJASRE)*, *5*(8), 53–95. https://doi.org/10.31695/IJASRE.2019.33408

Kablar, N. A. (2019). Renewable energy: Wind turbines, solar cells, small hydroelectric plants, biomass, and geothermal sources of energy. *Journal of Energy and Power Engineering*, *13*, 162–172. https://doi.org/10.17265/1934-8975/2019.04.004

Kaplanoğlu, M. A., Baba, A., & Gokcen Akkurt, G. (2020). Use of abandoned oil wells in geothermal systems in turkey. *Geomechanics and Geophysics for Geo-Energy and Geo-Resources*, *6*(1), 2. https://doi.org/10.1007/s40948-019-00125-0

Keke, Y., Tobing, N. G. L., & Tanjung, I. (2021). The effect of occupational safety and health on employee performance at pt. angkasa kargo. *Jurnal Transportasi, Logistik, dan Aviasi*, *1*(1), 42–54. https://doi.org/10.52909/jtla.v1i1.36

Kuncoro, H., & Harahap, V. (2021). Effect of electronic flight bag usage and safety culture on flight safety performance at pt. garuda indonesia. *Jurnal Transportasi, Logistik, dan Aviasi*, *1*(1), 18–30. https://doi.org/10.52909/jtla.v1i1.34

Michaelides, E. E. S. (2016). Future directions and cycles for electricity production from geothermal resources. *Energy Conversion and Management*, *107*, 3–9. https://doi.org/10.1016/j.enconman.2015.07.057

Mil'man, O. O., & Anan'ev, P. A. (2020). Air-cooled condensing units in thermal engineering. *Thermal Engineering*, *67*(12), 872–891. https://doi.org/10.1134/S0040601520120058

Moya, D., Aldás, C., & Kaparaju, P. (2018). Geothermal energy: Power plant technology and direct heat applications. *Renewable and Sustainable Energy Reviews*, *94*, 889–901. https://doi.org/10.1016/j.rser.2018.06.047

Ndukaife, T. A., & Nnanna, A. A. (2019). Enhancement of performance and energy efficiency of air conditioning system using evaporatively cooled condensers. *Heat Transfer Engineering*, *40*(3–4), 375–387. https://doi.org/10.1080/01457632.2018.1429063

Pambudi, N. A. (2018). Geothermal power generation in indonesia, a country within the ring of fire: Current status, future development and policy. *Renewable and Sustainable Energy Reviews*, *81*, 2893–2901. https://doi.org/10.1016/j.rser.2017.06.096

Parmenas, N. H. (2021). Strategies for maintaining employee well-being during the covid-19 pandemic. *Journal of Economics, Management, Entrepreneurship, & Business*, *1*(1), 15–31. https://doi.org/10.52909/jemeb.v1i1.3

Ricardianto, P., Sakti, R. F. J., Sembiring, H. F. A., & Abidin, Z. (2021). Safety performance analysis of state and commercial ships in accordance with solas 1974. *Journal of Economics, Management, Entrepreneurship, & Business*, *1*(1), 1–14. https://doi.org/10.52909/jemeb.v1i1.2

Saputro, A., & Soleha, I. (2021). Analysis of the performance of extraction-condensing turbine unit 1 at bablean power plant. *Jurnal Teknika Dan Informatika*, *1*(1), 62–79. https://doi.org/10.52909/jti.v1i1.11

Satria, B. (2021). The effect of transformational leadership and work motivation on employee performance at pt. xyz. *Jurnal Bisnis, Ekonomi, Manajemen, Dan Kewirausahaan*, *1*(1), 36–47. https://doi.org/10.52909/jbemk.v1i1.25

Setyawati, A., & Aristiyanto, F. K. (2021). Improving discipline through apron movement control (amc) at pt angkasa pura i adi soemarmo airport. *Jurnal Transportasi, Logistik, dan Aviasi*, *1*(1), 1–17. https://doi.org/10.52909/jtla.v1i1.33

Setyawati, A., Huda, M. N., Suripno, S., & Tannady, H. (2021). Analysis of integrated bus terminal services and their impact on customer satisfaction at pulo gebang. *Journal of Economics, Management, Entrepreneurship, & Business*, *1*(1), 44–55. https://doi.org/10.52909/jemeb.v1i1.5

Shezan, S. K. A., Al-Mamoon, A., & Ping, H. W. (2018). Performance investigation of an advanced hybrid renewable energy system in indonesia. *Environmental Progress & Sustainable Energy*, *37*(4), 1424–1432. https://doi.org/10.1002/ep.12790

Shortall, R., Davidsdottir, B., & Axelsson, G. (2015). Geothermal energy for sustainable development: A review of sustainability impacts and assessment frameworks. *Renewable and Sustainable Energy Reviews*, *44*, 391–406. https://doi.org/10.1016/j.rser.2014.12.020

Solihin, A. (2021). The effect of workload, compensation, and career development on employee loyalty at pt. abc. *Jurnal Bisnis, Ekonomi, Manajemen, Dan Kewirausahaan*, *1*(1), 48–58. https://doi.org/10.52909/jbemk.v1i1.26

Soltani, M., Moradi Kashkooli, F., Dehghani-Sanij, A. R., Nokhosteen, A., Ahmadi-Joughi, A., Gharali, K., et al. (2019). A comprehensive review of geothermal energy evolution and development. *International Journal of Green Energy*, *16*(13), 971–1009. https://doi.org/10.1080/15435075.2019.1650047

Sunarya, P. A., Budiarto, E., & Lestari, F. H. N. (2018). Improved management understanding of research through concepts and preliminary studies for empirical problem solving. *Aptisi Transactions on Management*, *2*(2), 89–96.

Susanto, P. C., & Parmenas, N. H. (2021). Development of a succession planning model for insurance subsidiaries. *Journal of Economics, Management, Entrepreneurship, & Business*, *1*(1), 56–75. https://doi.org/10.52909/jemeb.v1i1.16

Susanto, P. C., Suryawan, R. F., Hartono, H., & Purwoko, B. A. (2021). Analysis of accident-prone areas along the ciawi–puncak road, bogor. *Journal of Economics, Management, Entrepreneurship, & Business*, *1*(1), 32–43. https://doi.org/10.52909/jemeb.v1i1.4

Syahrial, E., & Sudono, R. H. (2021). Cooling load analysis of a new building at pmi bogor hospital using the cltd method. *Jurnal Teknika Dan Informatika*, *1*(1), 34–45. https://doi.org/10.52909/jti.v1i1.9

Tomarov, G. V., & Shipkov, A. A. (2017a). Modern geothermal power: Binary cycle geothermal power plants. *Thermal Engineering*, *64*(4), 243–250. https://doi.org/10.1134/S0040601517040097

Tomarov, G. V., & Shipkov, A. A. (2017b). Modern geothermal power: Geopp with geothermal steam turbines. *Thermal Engineering*, *64*(3), 190–200. https://doi.org/10.1134/S0040601517030089

Tontu, M. (2020). Performance analysis of a large-scale steam condenser used in a steam power plant. *European Mechanical Science*, *4*(2), 72–77. https://doi.org/10.26701/ems.644733

Wahyuningsih, E., Widodo, S., & Rahmanto, R. (2021). Prototype manufacture of the arjuno autobost covid-19 robot. *Jurnal Teknika Dan Informatika*, *1*(1), 19–33. https://doi.org/10.52909/jti.v1i1.8