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Performance Evaluation of a Chiller Plant in a Bottling Company

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Abstract: This study is focused on the performance evaluation of a water-cooled chiller. Exergy analysis of a water-cooled chiller was carried out in order to identify the contributions of individual components to the total exergy destruction. The second law efficiency of each component as well as the exergetic efficiency of the chiller were assessed. Data were taken at two-hour intervals (six readings daily) for thirty days. Data obtained from the chiller inventory records include suction and discharge pressure and temperature of the refrigerant in the compressor, as well as temperature and mass flow rates of cooling water and chilled water. Other properties of the refrigerant were obtained from ammonia property table. From the results obtained, the compressor was identified as the largest contributor to exergy destruction (about 59% of the total exergy destruction in the chiller), the evaporator contributed about 16%, the condenser contributed 20% while the throttle valve contributed the least to exergy destruction (5%). It was ascertained that the evaporator has the highest second law efficiency of 70.29%, while the efficiencies of the compressor and condenser were 60.01% and 36.09%, respectively. The average exergetic efficiency of the chiller was found to be 35.10%. The overall results reveal that the potential capacity of the chiller remained unutilized. Measures to improve the performance indices and overall efficiency of the chiller have been suggested in this study.
Keywords: Chiller, Irreversibility, Exergetic efficiency, Coefficient of performance, Refrigeration effect.

I. INTRODUCTION

The demand for refrigeration is increasing day by day due to global warming. Industrial chemical processes use cold utilities for different purposes such as separation of gases, temperature control in chemical reactors, dehumidification of air, recovery of solvents, and cooling streams in heat exchangers; these cold utilities are provided by large scale refrigeration systems which consume high amounts of energy (Dangelo *et al.*, 2016). Refrigeration is based on continuous cyclic extraction of heat from a low temperature reservoir and the release of heat to a high temperature reservoir, at the expense of work input (Memet, 2014). Arya and Chavda (2014) described a chiller system as an overall package which includes refrigeration plant, chilled water cycle and air or water-cooled condenser with the compressor, condensers, internal piping and controls combined into a single unit.

Conventional methods of refrigeration require hydro-floro-carbons (HFC) as refrigerants, but the emissions of these refrigerants play a significant role in ozone layer depletion, hence enhancing global warming. In 2014, Nigeria's total greenhouse gas emissions (GHG) were 492.44 million metric tons of carbon dioxide equivalent ($MtCO_2e$), totaling 1.01 percent of global GHG emissions *(*Climate links, 2019). Consequently, strong basis for the need to embrace the use of environmentally friendly natural refrigerants as replacement for the halocarbon refrigerants has been established (Bolaji & Huan, 2013). Natural refrigerants like R717 (ammonia) and R718 (water) have zero global warming potential and zero ozone depletion potential (Santos *et al.*, 2020).

Chillers running inefficiently may result to a decrease in equipment reliability, reduced maintenance intervals and shortened lifespan. The slightest decrease in chiller performance can have a major impact on the productivity required. A slight performance improvement in the components of a vapour compression cycle, such as the compressor and the heat exchangers, can play a significant role in reducing energy consumption. Energy consumption ranges from 3 to 8% of the production costs of brewed products, making energy efficiency a potential way to reduce and control production costs (Galitsky *et al*., 2003). One of the largest sectors that consume a large amount of energy in Nigeria is cooling. Cooling demands in a building could rack up a percentage of 30% of the total energy needs (Adewale *et al*., 2018).

There is a need for the development of refrigeration components to align with global best practices and regulations. In this study, an assessment is made on a water-cooled chiller plant in Nigeria Bottling Company Limited located in Port Harcourt which uses ammonia (R717) as the refrigerant. The investigation encompasses assessment of a vapor compression cycle and each component's behaviour toward the effectiveness of the system.

Studies carried out in the past have contributed in broadening knowledge relating to chiller plants. For instance, Parera *et al.* (2018) carried out an exergy analysis on a water-cooled chiller in order to determine its exergetic efficiency and identify the contribution of each component to the total exergy destruction occurring in the chiller. They observed that the largest contributor to exergy destruction was the compressor, the condenser and evaporator showed an equal exergy destruction rate, while the expansion valve contributed the least exergy destruction. They also varied the temperature of the chilled water between 7^{o}C and 17^{o}C and observed that exergy destruction increased by a rate of 1.2% per degree rise in chilled water temperature while the exergetic efficiency decreased at a rate of 1.4%. They suggested that the chiller components such as the compressor should be improved on to reduce irreversibility occurring in the chiller.

Zhang *et al.* (018) carried out an exergy analysis to investigate the effects of chilled water temperature and mass concentration of zeotropic mixture on a double evaporating temperature (DET) chiller. Experiments with different concentration ratios of R32 to R236fa were carried out on a 4.0-kW DET chiller. The results show that the DET chiller achieves the lowest exergy loss and highest exergy efficiency when the mass concentration ratio of R32 to R236fa is 4: 6. Furthermore, to improve the energy utilization of the chiller, they recommended a design inlet temperature of 16^{o}C for the chilled water.

Kadam *et al*. (2021) carried out energy, exergy, environmental and economic (4E) analysis of vapour compression refrigeration (VCR) chillers, used in a heavy-duty district cooling (DC) plant. The chillers used R134a. R134a was then replaced with and compared with refrigerant R717. It was observed that the COP and the exergy efficiency of the VCR chillers with R717 are around 3 % higher compared to the VCR chillers with R134a; this was attributed to the significantly higher latent heat of evaporation, which ultimately requires a lower mass flow rate of R717. It was also observed that the total global warming impact (TEWI) and the combined cost of R717 are lower by 1.6 % compared to the R134a. With respect to the 4E analysis, R717 was suggested as a better option to R134a refrigerant.

Paula *et al*. (2020) carried out a comparative assessment of a VCR chiller and two different integrated VCR-and-VAR (vapour compression refrigeration and vapour absorption refrigeration) chillers. One of the VCR-and-VAR chillers use NH_3/H_2O refrigerant-absorbent mixture while the other uses the novel acetaldehyde/N, N-dimethylformamide (Acet/DMF). The integrated chillers consist of parallel and cascade configurations. Coefficient of performance, total equivalent warming impact and cost rate were used as performance indicators. It was observed that the connection of the evaporator of the VAR with the condenser of the VCR in the cascade configuration increases the COP of the VCR unit by 292% compared to the stand alone VCR system. Overall, the thermodynamic, environmental and cost benefits of the novel Acet/DMF with the cascade arrangement of the VCR and the VAR system are superior to those of NH_3/H_2O.

Kasera and Bhadurib (2017) carried out an investigation into a likely alternative chilling system that is very economical, ecologically friendly and can last a service life of 20 years. Using “Muthgasse II” (a chiller in Boku building, Vienna, installed in 1995 which uses cross flow heat exchangers and two semi-hermatic piston compressors) and replacing the R22 refrigerant with R407C, they discovered that the use of R22 resulted in a higher cooling capacity and lower energy consumption whereas the R407C led to a decrease in the cooling efficiency from 13.5% to 7.9%. Yet R407C was still considered as a viable option because of the environmental impact factor. Rapport (2019) carried out performance analysis on R32 and R134a to seek for an alternative to R407C. R407C chiller has energy efficiency ratio (EER) of 2.3 when the water to be chilled enters the chiller at 12^{o}C and leaves at 7^{o}C. The new alternatives (R32 and R134a) have EER of 2.61 and 2.89 respectively. Total equivalent warming impact (TEWI) of R32 is 6.2% greater than that of R134a due to low EER. The economical comparison which is based on investment and electricity cost favoured R134a.

Al-Hassani and Al-Badri (2020) carried out an experimental investigation on the effect of compressor speed and electronic expansion valve (EEV) opening on the performance of a water chiller system using R410a refrigerant. The system comprised of variable speed rotary compressor, water cooled condenser and electronic expansion valve. The result showed that refrigerant superheats increased with closing the EEV at constant compressor speed. Moreover, the degree of superheat was inversely proportional to the compressor speed at constant EEV opening. The coefficient of performance was improved by about 2.2 to 4.0% by controlling the EEV at constant compressor speed. Increasing compressor speed from 1200 to 3600 rpm resulted in decreasing system COP from 5.2 to 2.35 due to the increase of the power consumed by the compressor. They concluded that regulating compressor speed and EEV opening can minimize power consumption by chillers.

Li *et al.* (2001) undertook an analysis of energy efficiency of chillers operating at night. The chillers used piston compressors and R22 refrigerant. Wet bulb readings of air were taken at 2-hour interval for 31 days (day and night). They found that the cooling capacity of the chiller under consideration increased by 9% at night, whereas the power consumption was observed to decrease by

17.2% and the overall coefficient of performance was raised by 31.5%. They concluded that chillers operating at night consume less electrical energy.

To minimize energy consumption and to reduce emission that can affect the environment, calls have been made to carry out performance analysis on chillers that use zero ozone layer depletion refrigerants. The present study used a case of Nigeria Bottling Company Limited in Port Harcourt to evaluate the performance of a chiller using ammonia refrigerant based on the current data. This would enhance full utilization of the chiller potential.

II. METHODOLOGY

The materials used in this study include temperature sensors, pressure gauges, ammonia property table, catalogue of the chiller including recorded operational data for temperature and pressure, and Excel software. The procedure for obtaining data in the course of the investigation was as follows:

1) Temperature sensors were attached at the liquid line, evaporator outlet, expansion valve and at the refrigerant tank
2) Pressure gauges were connected to the suction and discharge lines.
3) Temperature and pressure readings were taken for 2-hour intervals (6 times daily) for 30days.
4) The mass flow rate of chilled water was recorded during the course of the work.

The methods implemented in this study are enumerated and discussed in the following sections.

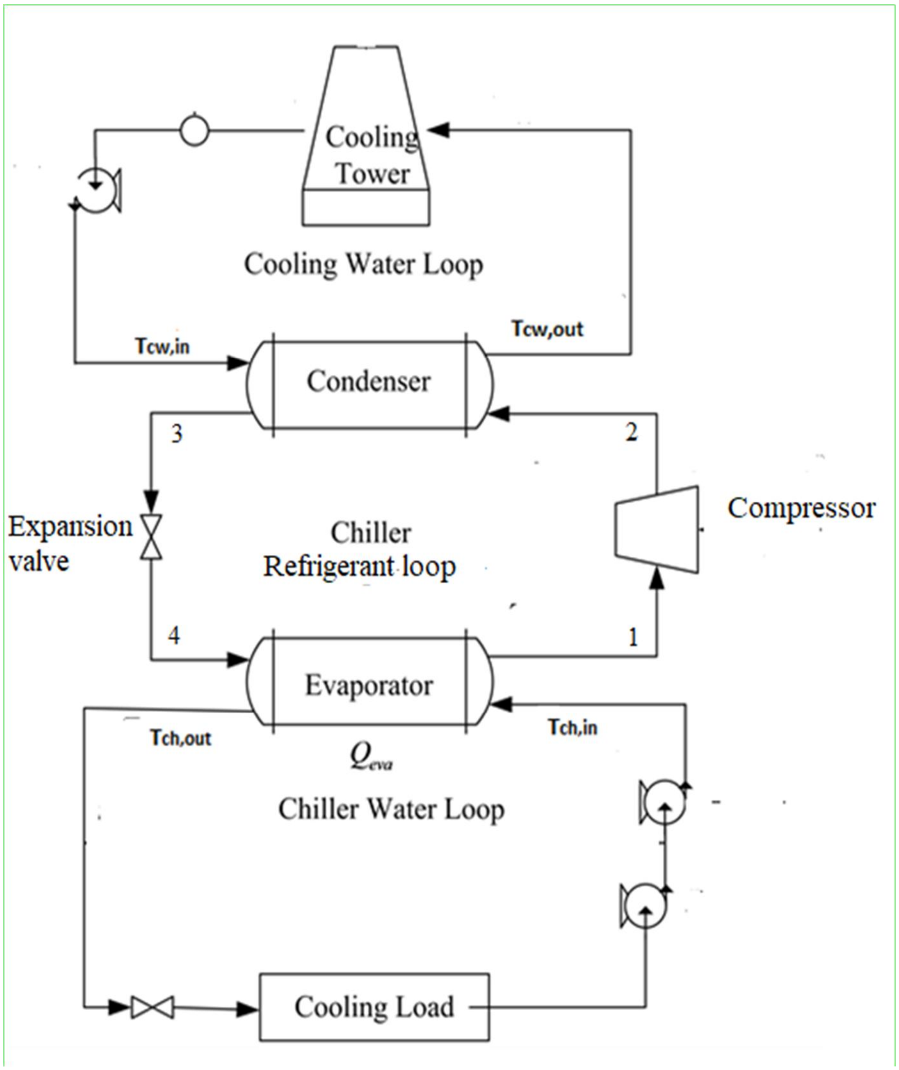

Figure 1: Schematic of a Water-cooled Chiller

Figure 1 shows the flow circuit of the cooling water, refrigerant and chilled water of the chiller.

A. Vapor Compression Cycle

Figure 2 shows the pressure-enthalpy diagram of a vapour compression cycle

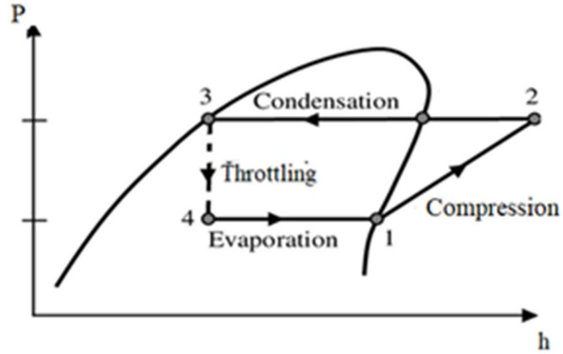

Figure 2: P-h Diagram of a Vapor Compression Cycle

The chiller operates on the principle of vapour compression cycle. Circulating refrigerant enters the compressor as a saturated vapour or slightly superheated vapour, it is then compressed to a higher pressure, resulting in a high temperature superheated vapour. The high temperature superheated vapour is routed through a condenser where it is cooled and condensed as a liquid. The condensed liquid refrigerant is either in a saturated state or subcooled state. The saturated or subcooled liquid then flows through a throttle valve (mitering device) where it undergoes an abrupt reduction in pressure and temperature. The low temperature refrigerant then enters the evaporator where it is heated, causing it to undergo a phase change to vapor. The pressure-enthalpy (p-h) diagram of the cycle is shown in Figure 2. It consists of process 1-2 – isentropic compression in the compressor; process 2-3 –isobaric heat rejection in the condenser; process 3-4 – throttling of saturated liquid in the expansion valve and process 4-1 – isobaric heat extraction in the evaporator.

B. State Properties of Refrigerant

Enthalpy and entropy are functions of pressure and temperature (h=f(P,T)); therefore, the values of h(enthalpy) and s(entropy) are obtained from ammonia property table when pressure and temperature of the refrigerant at any state are known.

C. Refrigeration Capacity

The refrigeration capacity (cooling effect) is the heat transfer rate in the evaporator (process 4-1) and is given as

$$Q_{Evap} = m_{ref}(h_1 - h_4) = m_{ch}c_p(T_{ch,in} - T_{ch,out}) \quad (1)$$

where m_{ref} is the mass flow rate of the refrigerant, h is the specific enthalpy at various states, m_{ch} is the mass flow rate of the chilled water, c_p is the specific heat capacity of water at constant pressure, $T_{ch,in}$ and $T_{ch,out}$ are the temperatures of chilled water entering and leaving the evaporator, respectively.

D. Condenser Heat Rejected

The refrigerant rejects heat to the water flowing down from the cooling tower; this occurs at a constant pressure. The heat rejected by the refrigerant in the condenser (process 2-3) is given as

$$Q_{Cond} = m_{ref}(h_2 - h_3) = m_{cw}c_p(T_{cw,out} - T_{cw,in}) \quad (2)$$

where m_{cw} is the mass flow rate of the cooling water, $T_{cw,out}$ and $T_{cw,in}$ are the temperatures of cooling water leaving and entering the condenser, respectively.

E. Work done by the Compressor

The actual work done by the compressor is the amount of useful mechanical energy obtained from electrical energy input to the compressor. The actual work done by the compressor (process 1-2) is given as

$$W = m_{ref}(h_2 - h_1) \quad (3)$$

Since the throttle process by the expansion valve is isenthalpic, it follows that (4) is true for the relationship between the enthalpies.

$$h_4 = h_3 \quad (4)$$

F. Coefficient of Performance

Coefficient of performance is the measure of the performance of the vapor compression system based on energy analysis. It denotes the amount of cooling obtained in the evaporator as compared to the quantity of electric power input to the chiller's compressor. The coefficient of performance (COP) is given as

$$COP = \frac{Q_{Evap}}{P_{comp}} \tag{5}$$

where P_{comp} is the electrical power input to the compressor.

G. Exergy Destruction

Exergy destruction is a measure of the destruction of useful energy (availability) by a system or component.

Specific exergy change of flowing water is given as

$$e_{in} - e_{out} = (h_{in} - h_{out}) - T_0(s_{in} - s_{out}) \tag{6}$$

where e_{in} and e_{out} are the specific exergies of water at inlet and outlet, respectively.
$(h_{in} - h_{out})$ is the enthalpy change of flowing water, T_0 is the ambient temperature, and
$(s_{in} - s_{out})$ is the entropy change of flowing water

$$(h_{in} - h_{out}) = c_p(T_{in} - T_{out}) \tag{7}$$

$$(s_{in} - s_{out}) = c_p in(\frac{T_{out}}{T_{in}}) \tag{8}$$

Exergy destroyed in the condenser is given by

$$E_{D(cond)} = m_{ref}((h_2 - h_3) - T_O(s_2 - s_3)) - m_{cw}(e_{cw,in} - e_{cw,out}) \tag{9}$$

where s is the entropy at various states is, E_D is the exergy loss (destroyed) and T_0 is the ambient temperature.

Exergy destroyed in the compressor is given by

$$E_{Dcomp} = P_{comp} + m_{ref}((h_1 - h_2) - T_O(s_2 - s_1)) \tag{10}$$

Exergy destroyed in throttle valve is given by

$$E_{Dthrottle} = m_{ref}(T_O(s_4 - s_3)) \tag{11}$$

Exergy destroyed in the evaporator is given by

$$E_{Devap} = m_{ref}((h_4 - h_1) - T_O(s_4 - s_1)) - m_{ch}(e_{ch,in} - e_{ch,out}) \tag{12}$$

Total exergy destroyed in the chiller is given by

$$E_{Dtotal} = E_{Dcond} + E_{Dcomp} + E_{Dthrottle} + E_{Devap} \tag{13}$$

H. Exergetic Efficiency of the Components

Exergetic efficiency is a measurement of the perfection of each of the operating components. It is a measure of how nearly the performance of a system or component approaches ideality.
Exergetic efficiency of the condenser is given as

$$\eta_{cond} = \frac{m_{cw}(e_{cw,in} - e_{cw,out})}{m_{ref}((h_2 - h_3) - T_O(s_2 - s_3))} \tag{14}$$

Exergetic efficiency of the compressor is given as

$$\eta_{comp} = \frac{m_{ref}((h_1 - h_2) - T_O(s_2 - s_1))}{P_{comp}} \tag{15}$$

Exergetic efficiency of the evaporator is given as

$$\eta_{evap} = \frac{m_{ch}(e_{ch,in} - e_{ch,out})}{m_{ref}((h_4 - h_1) - T_O(s_4 - s_1))} \tag{16}$$

I. Exergetic Efficiency (Exergetic COP) of the Chiller

This efficiency is the ratio of the first law efficiency (COP) and the reversible process efficiency (Lior & Zhang, 2007).
Exergetic efficiency of the chiller is given as

$$\eta_{ex} = COP(\frac{T_0}{T_{evap}} - 1) \tag{17}$$

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J. Design Specification

The design specifications of some of the chiller plant parameters are shown in Table 1.

Table 1: Design Specifications of the Chiller

Description	Value
Cooling tower tank	515 litre
Refrigerant surge tank	150 litre
Compressor rating	270kW
Diameter of expansion valve pipe	38.1mm
Diameter of connecting pipes for refrigerant flow	76.2mm
Refrigeration capacity	2160kW

Source: Nigeria Bottling Company Limited (2021)

III. RESULTS AND DISCUSSION

The performance indices that were used in evaluating the chiller are discussed as follows:

A. Performance Parameters based on Energy Analysis

Table 2 shows the daily average of some parameters such as compressor work done, condenser heat rejected, refrigeration capacity, and the COP.

Table 2: Average daily compressor work done, condenser heat rejected, refrigeration capacity, and coefficient of performance of the chiller

Day	Compressor work done (kW)	Condenser heat rejected (kW)	Refrigeration capacity (kW)	Coefficient of performance
1	181.6346	1714.38	1532.745	6.296467
2	172.083	1628.907	1456.824	5.986176
3	175.3266	1682.333	1507.006	6.199892
4	176.045	1635.716	1459.671	5.977986
5	162.1487	1596.925	1434.776	5.86836
6	161.4578	1529.305	1367.847	5.586482
7	152.0925	1506.696	1354.603	5.631693
8	163.8959	1559.226	1395.33	5.835258
9	159.7372	1462.956	1303.219	5.430883
10	177.988	1631.403	1453.415	6.030293
11	193.4571	1780.134	1586.677	6.486128
12	193.3082	1655.491	1462.183	5.985773
13	189.3877	1795.099	1605.711	6.627821
14	143.7888	1438.036	1294.247	5.329182
15	178.558	1774.344	1595.786	6.576098
16	155.3402	1532.83	1377.49	5.770395
17	174.2971	1608.421	1434.124	5.978817
18	185.3954	1659.616	1474.22	6.151542
19	159.1614	1473.897	1314.735	5.465925
20	173.7455	1661.802	1488.056	6.161351
21	202.313	1730.494	1528.181	6.233632
22	162.8198	1632.519	1469.699	6.003984
23	158.527	1585.129	1426.602	5.875343
24	160.0446	1574.76	1414.715	5.813155
25	164.0001	1554.206	1390.205	5.701771
26	167.0437	1528.897	1361.853	5.692291
27	170.8738	1564.809	1393.935	5.808596
28	164.0636	1512.296	1348.232	5.585046
29	176.2898	1619.676	1443.387	5.889274
30	169.4494	1610.846	1441.397	5.902468
Average	170.8167	1608.040	1437.205	5.929405

The average power input to the compressor for the month is 243kW. The average work done by the compressor for the month is 170.8167kW with a minimum value of 143.7888kW in day 14 and a maximum value of 202.313kW in day 21. The actual work done by the compressor is the amount of useful mechanical energy obtained from electrical energy input to the compressor. This shows that 29.5% of the power input to the compressor is dissipated as mechanical and electrical losses.

The average cooling effect for the month is 1437.2058kW with a minimum value of 1294.247kW in day 14 and a maximum value of 1605.741kW in day 13. This shows that the chiller is not being utilized to obtain its optimal cooling effect of 2160kW as stated by the manufacturer.

The average coefficient of performance (COP) of the chiller for the month is 5.9294 with a minimum value of 5.3291 in day14 and a maximum value of 6.6278 in day13; this is less than the chiller's expected COP of 8.0. The coefficient of performance is the measure of the performance of the vapor compression system based on energy analysis; this shows that the chiller is not efficient in energy utilization.

B. Components and Total Irreversibility

It would be useful to ascertain how the components rank with respect to the total irreversibility (exergy destruction) within the system. Figure 3 shows the irreversibility of the compressor, condenser, throttle valve and evaporator during the period under consideration.

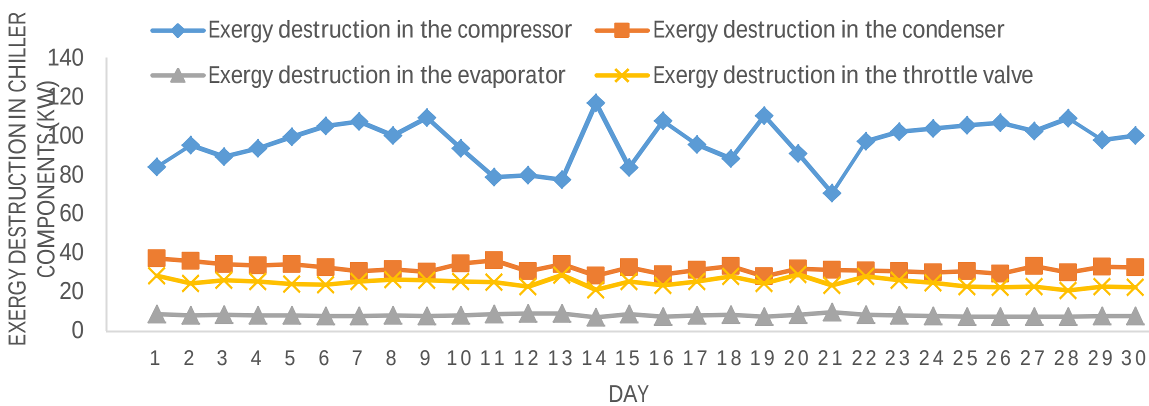


Figure 3: Component Daily Irreversibilities

For the reviewed month, the average irreversibility occurring in the compressor is 93.2804kW, that in the condenser is 32.1734kW, that in the throttle valve is 8.1614kW, while that in the evaporator is 24.9493kW.

A sectorial representation of the average exergy destruction by each component is shown in Figure 4.

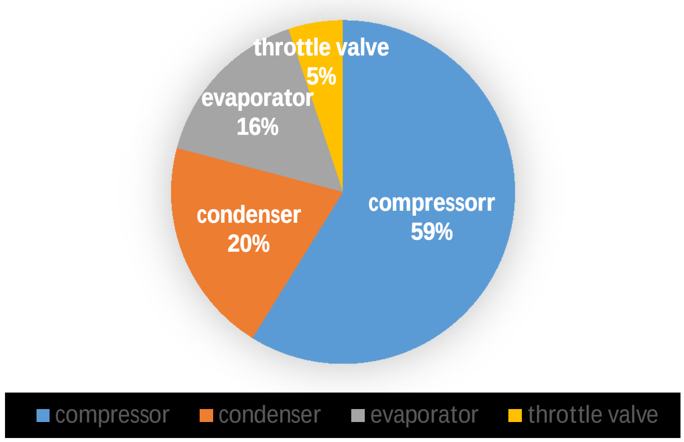


Figure 4: Sectorial Representation of Average Exergy Destruction by each Component

The average irreversibility occurring in the chiller is 158.5645kW, with the compressor contributing 59%, the condenser 20%, the evaporator 16% and the throttle valve contributing 5%. This reveals that the highest exergy destruction taking place in the chiller is contributed by the compressor, followed by the condenser, the evaporator, and then the expansion valve (being the least contributor to exergy destruction).

C. Compressor Exergetic Efficiency

Figure 5 shows the exergetic efficiency of the compressor during the period under consideration.

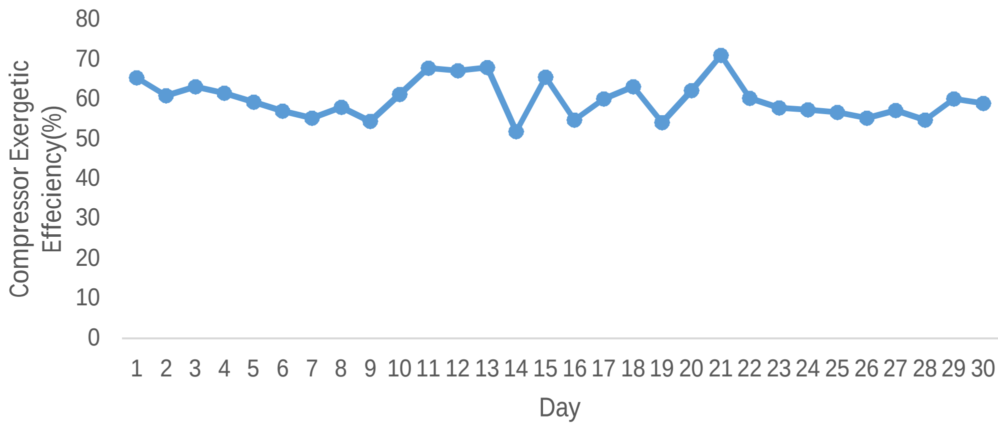


Figure 5: Compressor Daily Exergetic Efficiencies

The average exergetic efficiency of the compressor for the reviewed month is 60.01% with a minimum value of 51.87% in day 14 and a maximum value of 71.08% in day 21. The compressor exergetic efficiency determines how effective the compressor is converting input exergy to useful output. . High exergetic efficiency is required for a viable economic operation of the chiller. The average compressor exergetic efficiency of 60.01% for the period under review shows that the exergy utilization from electrical to mechanical by the compressor is low; this reveals that the capacity of the compressor remains under-utilized. If scheduled routine maintenance of the compressor and its electric motor is significantly improved, the frequency of failure and unavailability will reduce and high exergetic efficiency will be achieved.

D. Condenser Exergetic Efficiency

[Figure 6 shows the exergetic efficiency of the condenser during the period under consideration.

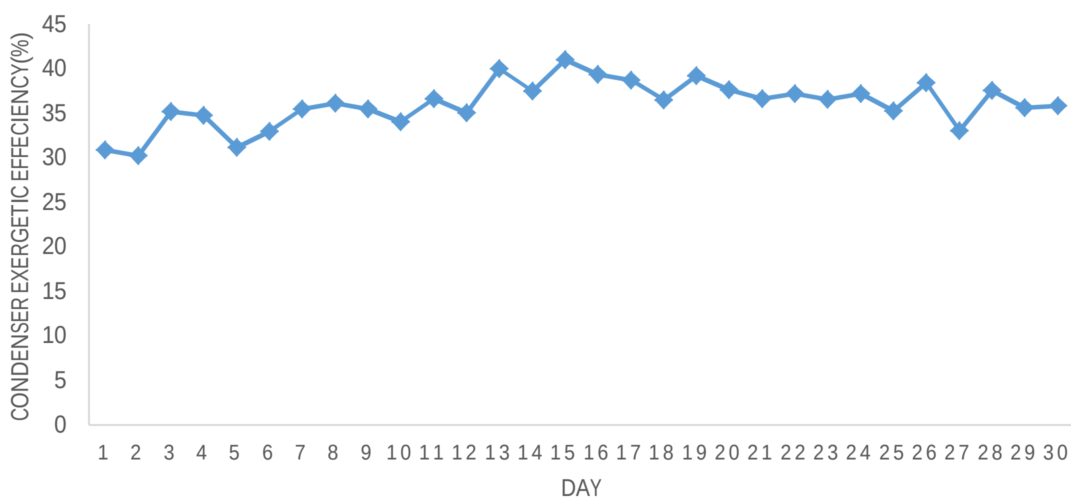


Figure 6: Condenser Daily Exergetic Efficiencies

The average exegetic efficiency of the condenser for the month is 36.09% with a minimum value of 30.26% in day 2 and a maximum value of 41.06% in day15. The exergetic efficiency of the condenser is very low; this shows that the condenser and cooling tower unit are not well managed to achieve maximum exergy utilization. This is due to inadequate routine maintenance, water management and equipment fault development. To increase the exergetic efficiency of the condenser, planned and routine predictive maintenance should be upheld, the tower should be washed regularly to remove debris and reduce fouling of the condenser tube.

E. Evaporator Exergetic Efficiency

Figure 7 shows the exergetic efficiency of the evaporator during the period under consideration.

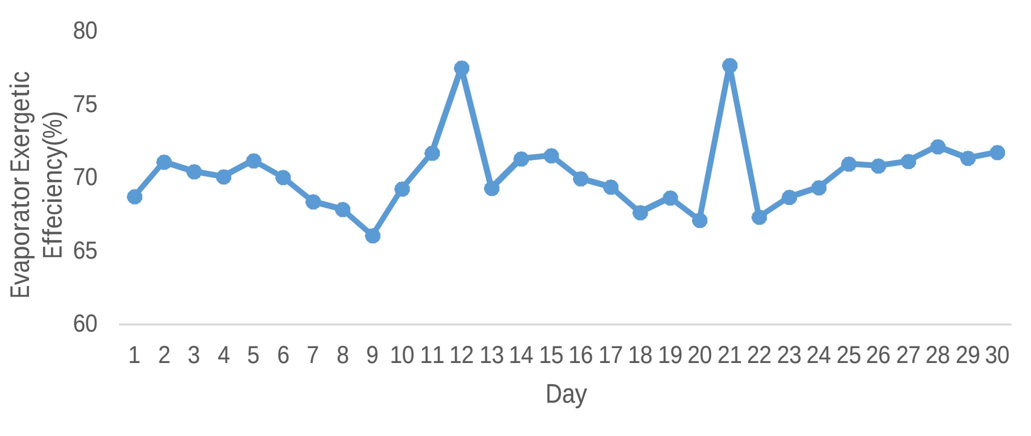


Figure 7: Evaporator Daily Exergetic Efficiencies

The average exergetic efficiency of the evaporator for the month is 70.29% with a minimum value of 66.09% in day 9 and a maximum value of 77.68% in day 21. The exergetic efficiency of an evaporator is an indication of the utilization of refrigerant exergy by the water to be cooled, and is expected to be high so that the exergy input to the chiller may be exploited at maximum, so as to enhance lower cost of electricity consumption.

F. Overall Chiller Efficiency

Figure 8 shows the overall efficiency of the chiller during the period under consideration.

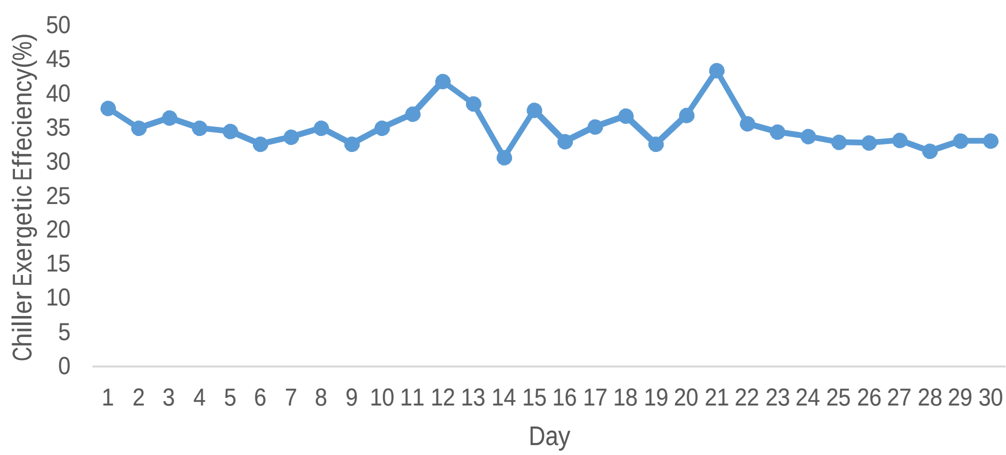


Figure 8: Daily Overall Efficiency

The average overall efficiency of the chiller for the month is 35.10%, with a minimum value of 30.69% in day 14 and a maximum value of 43.50% in day 21. The overall efficiency of the chiller is an indication of how effective the exergy input to the compressor is utilized to attain the required cooling (thermal exergy) by the evaporator. An average overall chiller efficiency of 35.10% is low for international best practice.

IV. CONCLUSION

This study has developed an effective approach of evaluating the performance of a water-cooled chiller plant on daily basis with emphasis on irreversibility and operational parameters such as compressor efficiency, efficiency of the heat exchangers and the overall efficiency of the chiller. Computation of the exergy destruction taking place in the compressor, condenser, throttle valve, and evaporator showed average irreversibility values of 93.280kW, 32.173kW, 8.161kW and 24.949kW respectively. This shows that irreversibility occurring in the chiller is highest in the compressor and lowest in the throttle valve. In analyzing the technical performance of the compressor and the heat exchangers, the average exergetic efficiencies of the compressor, condenser and evaporator are 60.01%, 36.092%, and 70.293% respectively. Based on the exergetic efficiencies obtained, it can be deduced that the chiller's component with the highest performance is the evaporator while the condenser is the component with the lowest performance. Assessment of the overall performance of the chiller shows that the average coefficient of performance is 5.9294 as against the intended COP of 8.0. The average overall exergetic efficiency of the chiller is 35.10%. Based on the averages of the performance indices evaluated, it can be concluded that the plant is utilized below the rated capacity in the period under review.

It is suggested that breweries and other similar industries adopt this study as a framework for performance evaluation of their chillers. This will greatly reduce the wastage in the use of electrical energy in cooling.

REFERENCES

[1] Adewale, A. A., Adekitan, A. I., Idoko, O. J., Agbetuyi, F. A. & Samuel, I. A. (2018). Energy Audit and Optimal Power Supply for Commercial Buildings in Nigeria. Cogent Engineering, 5(1), 1-12.

[2] Al-Hassani, A. H. & Al-Badri, A. R. (2020). Effects of Compressor Speed and Electronic Expansion Valve Opening on the Performance of R410a Water Chiller System. WASIT Journal of Engineering Sciences, 8(1), 12–20.

[3] Arya, J. S. & Chavda, N. K. (2014). Design and Performance Analysis of Water Chiller. International Journal of Engineering Research and Applications, 6(4), 19-25.

[4] Bolaji, B. O. & Huan, Z. (2013). Ozone Depletion and Global Warming: Case for the Use of Natural Refrigerant-a Review. Renewable and Sustainable Energy Reviews, 18(1). 49-54

[5] Climate links (2019). Greenhouse Gas Emissions Factsheet: Nigeria. Retrieved November 16, 2020 from https://www.climatelinks.org /resources/greenhouse-gas-emissions-factsheet-Nigeria.

[6] Dangelo, J. V. H., Araujo, H. V., Ling, J., Aute, V. & Radermacher, R. (2016). Performance Analysis of a Vapor Injection Cycle with Flash Tank Using a Low-GWP Inorganic Blend Refrigerant. International Refrigeration and Air Conditioning Conference. Paper 1599. June 2016, Purdue University.

[7] Galitsky, C., Martin, N., Worrell, E. & Lehman, B. (2003). Energy Efficiency Improvement and Cost Saving Opportunities for Breweries: An Energy Star(r) Guide for Energy and Plant Managers. Lawrence Berkeley National Laboratory, United States. Retrieved August 11, 2021 from https://escholarship.org/uc/item/17r6j759.

[8] Kadam, S.T., Khan, M.S., Hassan, I., Rahman, M.A., Papadopoulos, A.I. & Seferlis, P. (2021). Energy, Exergy, Environmental and Economic Analysis of Heavy-Duty Vapor Compression Chiller with Alternative Fluids in District Cooling. Chemical Engineering Transactions. 88(1), 511-516.

[9] Kasera, S. & Bhadurib, C. (2017). Performance of R407C as an Alternate to R22: A Review. Energy Procedia, 109 (1), 4–10.

[10] Li, Y. A., Yu, M. Z. & Xu, G. L. (2001). Analysis of Energy Efficiency of Chillers Operation at Night. International Journal on Architectural Science, 2 (1), 18-22.

[11] Memet, F. (2014). A Performance Analysis on a Vapor Compression Refrigeration System Generated by the Replacement of R134a. Journal of Maritime Research, 11(3), 83–87.

[12] Nigeria Bottling Company Limited (2021). Refrigerators Operational Data. Engineering Section. Nigeria.

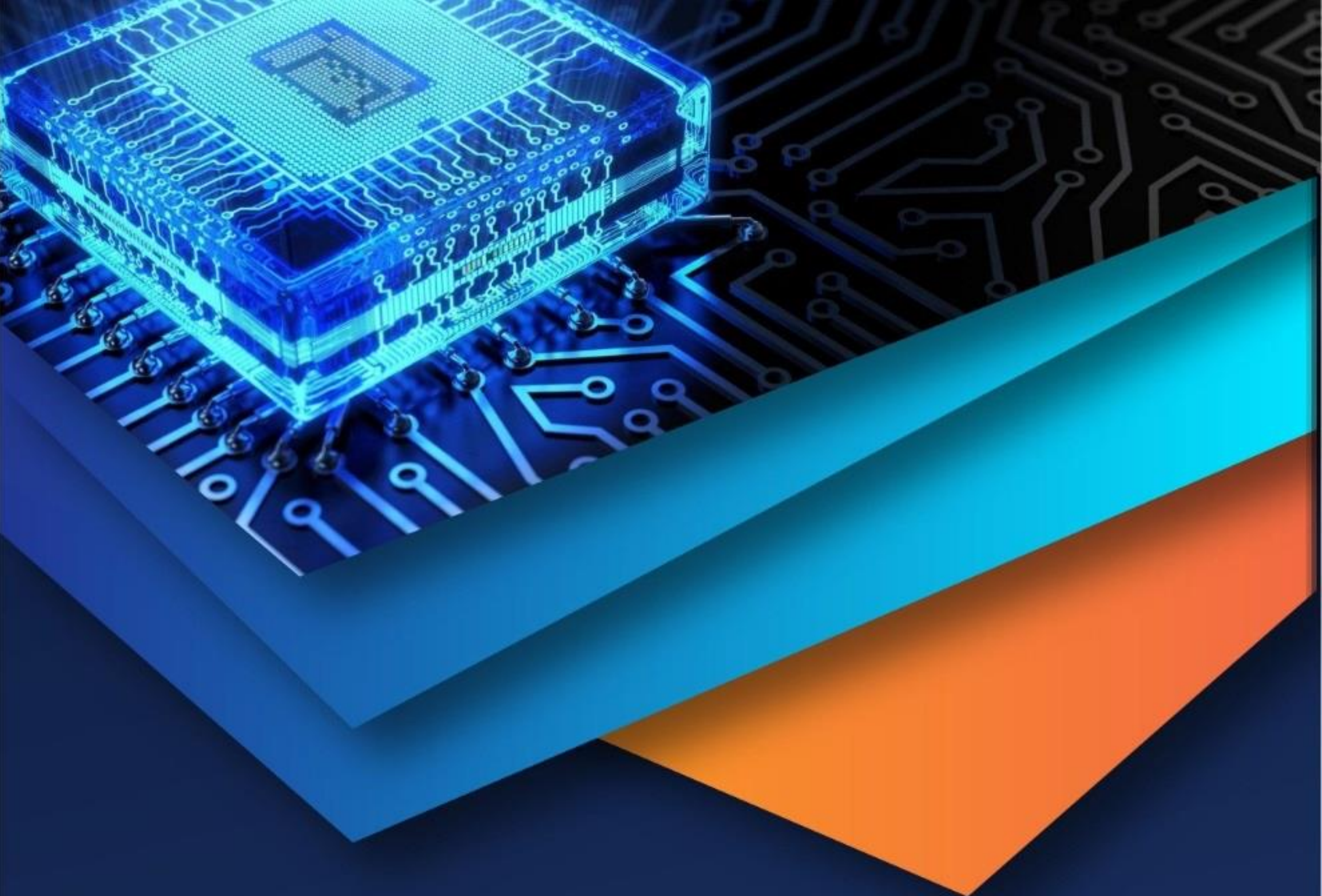
[13] Paula, C.H., Duarte, W.M., Rocha, T.T.M., Oliveira, R.N. & Maia, A.A.T. (2020). Thermodynamic, Environmental and Cost Evaluation of Compression-Absorption Parallel and Cascade Refrigeration Chiller. International Journal of Refrigeration, 113(1), 10–20.

[14] Perera, U., Saha, B., Miyazaki, T., Koyama, S. & Thu, K. (2018). Exergy Analysis of a Vapor Compression Chiller at Elevated Chilled Water Outlet Conditions. Engineering Sciences Reports, 39(2), 7-13

[15] Rapport, M. (2019). Energy Analysis of the Chillers in the BOKU Location Muthgasse II. (Master Thesis, Institute for Chemical and Energy Engineering, Vienna), 57-89. Retrieved April 14, 2020 from https://permalink.obvsg.at/bok/AC15500554

[16] Santos, E. C., Azevedo, C., Macêdo, C., Azevedo, C., Araújo, R., Gomes, S. S., Baia, L. & Alexandrino, Y. (2020). An Experimental Study of Synthetics and Natural Refrigerants Gases. In T. Morosuk & M. Sultan (Eds.), Low-temperature Technologies. Intech Open.

[17] Zhang, K., Zhu, Y., Liu, J., Niu, X. &Yuan, X. (2018). Exergy and Energy Analysis of a Double Evaporating Temperature Chiller. Energy and Buildings, 165(1), 464-471.



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