

Performance Evaluation of Counter-Current Shell and Tube Heat Exchangers in Central Processing Facility

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Abstract

This study evaluates the performance of counter-current heat exchangers at a Local Central Processing Facility (LCPF) in Sudan, where hot treated crude oil is cooled to 75°C before being stored. Despite compliance with initial design specifications, the heat exchangers fail to achieve operational requirements, leading to storage temperature consistently exceeding 85°C, which is undesirable. The performance analysis utilizes the logarithmic mean temperature difference (LMTD) method with supplementary calculations performed using MS Excel. The real operating data and crude oil samples from the heat exchanger streams were gathered, calculated and analyzed. The results reveal a low overall heat transfer coefficient (U) of 16.99%, and a heat duty of only 25.39% compared to the design parameters value. These findings highlight a significant performance deficit in the heat exchangers. Furthermore, the pressure drop on the tube side is measured at 233.1 kpag, significantly exceeding the design value of 100 kpag, suggesting the presence of fouling, which further exacerbates the inefficiency. The study concludes that the low heat transfer coefficient (U) is the primary causes poor heat exchanger performance. The study recommends a comprehensive design review and further investigations of the factors affecting heat exchanger performance, to optimize efficiency and ensure the treated crude oil achieves the desired storage temperature in the LCPF.

Key words-Heat exchanger performance, Local Central Processing Facility (LCPF), Logarithmic Mean Temperature Difference (LMTD), Overall heat transfer coefficient, heat duty, pressure drop, fouling, efficiency optimization, design review.

I. INTRODUCTION

In the crude oil central processing facilities (CPF) plants, heat exchangers are the important equipment used to facilitate the transfer of energy and heat as in petroleum refineries, petrochemical industries, and power plants. Heat exchangers are necessary used to optimize the energy in these plants. Hence, it's unfeasible to have those plants without heat transfer systems et al[1]. The local Crude Oil Central Processing Facility (LCPF) plant where the heat exchangers are under evaluation in this study can be describe that, it is design with capacity of 300,000 barrels per day. The plant consists of crude oil receiving system, crude oil processing system, storage and export system as well as various utilities system. The processing system comprises of Surge Vessels crude/crude heat exchangers, crude oil heaters and electrostatic dehydrators (EDH). Crude/Crude Exchanger are installed downstream the surge vessels to increases the temperature of cold raw crude oil from 45 to 70 °C after exchanging heat with hot treated crude oil from Dehydrator. Then the temperature of raw crude from the crude/crude exchanger is further increased from 70 to 105°C in the crude oil heater exchanger using thermal oil T55. The Electrostatic Dehydrator receives hot the crude from the crude oil heaters with temperature of 105 °C where remained emulsify water is knockout using electrode grids to produces treated crude oil with maximum BS&W of 0.5%. The produced treated crude oil is routed back to the crude/crude exchangers to pre-heat the raw cold crude oil and cool itself to the required storage temperature of 75 °C. Demulsifier and Pour Point Depressant (PPD) chemicals are injected at

upstream of Surge Vessels to break oil/water emulsion in crude for better separation of oil and water, and to lower the pour point of crude respectively. The gases from the processing vessels and hydrocarbon vapors are releases to the atmosphere through vent stack and gas boot vents respectively. Produced water from the processing vessels flows to the produced water treatment system before flowing to the evaporation pond. Crude oil from sales oil storage tanks is pumped through metering system then to the export pipeline using booster Pumps. The specifications of exported crude oil are 0.5% BS&W, 75 °C, and RVP of 11 psig. Figure(1) is showing the simple scheme of the LCPF.

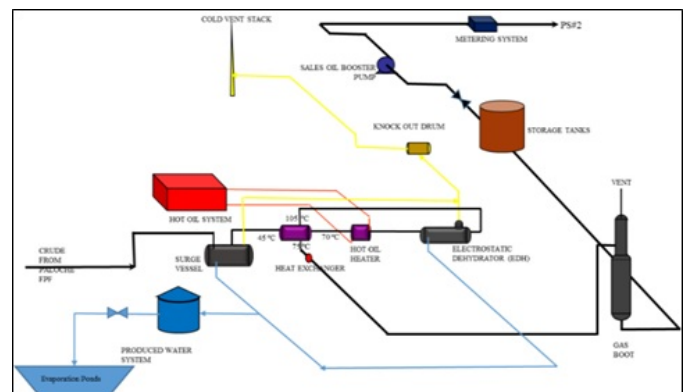


Fig. 1: Local Central Processing Facility Simple Scheme

A. Problem Statement

In the Local Central Processing Facility (LCPF), heat exchangers are crucial for enhancing the temperature of crude oil during the processing stages. Specifically, the system is designed to exchange heat between hot treated crude oil and cold raw crude oil, ensuring that the treated crude oil reaches a desired temperature of 75 °C before being sent to the storage system. However, it has been observed that the crude oil is consistently being delivered at temperatures exceeding 85 °C, which is higher than the desired operating temperature. This indicates that the heat exchangers are not functioning at optimal efficiency and are failing to meet the recommended operational requirements for temperature regulation. This issue is critical because the improper temperature of the treated crude oil could lead to operational inefficiencies, energy wastage, and possible long-term equipment damage. The present study aims to investigate the performance issues of heat exchangers in the LCPF and propose solutions to improve their performance and ensure the optimal operation of the system.

B. Objective of the Study

It is required to carry out a performance analysis for the heat exchanger to evaluate the efficiency and to find out the factors affecting the performance of the crude/crude heat exchanger. The study aims to contribute to improving the overall performance of heat exchangers in the LCPF, leading to more efficient crude oil processing and better operational stability.

There are relatively few historical studies in the area of crude oil blend characteristic which confirmed that this type of crude oil blend is waxy and viscous heavy crude oil with an API of 23.5 – 25. et al[2]. To prevent operational issues, dehydration and desalting plants are commonly installed in crude oil production units to remove water-soluble salts from the oil stream et al[3]. Temperature plays a crucial role in oil-water separation, influencing properties such as density, viscosity, and conductivity, all of which contribute to the efficient separation of oil and water, as well as salt removal. To minimize additional heating costs, the study suggests preheating the oil before it enters the dehydration unit. This approach allows for cost-effective operation without the need for extra investment in equipment[4]. This type of analysis is applicable to all crude oil types. Increasing the temperature reduces viscosity, while decreasing the temperature increases it[4]. In the LCPF, crude oil is processed at a high temperature of 105°C before being cooled prior to storage in tanks. In the upstream dehydration train, a demulsifier is injected to enhance the emulsion breaking rate, thereby improving the dehydration efficiency. Despite these efforts, the temperature of the outlet stream from the heat exchanger to the storage tank remains high, even when increasing the inlet flow rate of the cold stream or lowering the process temperature set point however, This temperature condition hinders effective crude oil/water separation. Storing crude oil at high temperatures is unnecessary due to the significant impact of the temperature

on the Reid Vapor Pressure (RVP)[5]. Notably, no significant change in the temperature difference in the crude/crude exchanger was observed, even after cleaning activities were performed on the shell and tube side of the exchanger, which prompted the need for this study. Heating crude oil in the plant can enhance oil-water separation by removing produced water, which is corrosive, and thereby reduce downstream processing costs. However, excessively high temperatures can lead to the formation of coke and the release of light components from the crude oil. The importance of this study lies in its potential to improve heat transfer efficiency in the LCPF plant, stabilize stored crude oil, and ensure that crude oil is delivered to Pump Station 2 at the appropriate temperature for the pump seal components.

II. LITERATURE REVIEW

The performance assessment of counter-current shell and tube heat exchangers in crude oil operation and processing has been an area of significant research and case studies and it is widely explored topic among researchers, who uses various analysis methods to evaluate and optimized the efficiency of these systems. A systematic comprehensive review compared heat transfer enhancement techniques for shell and tube heat exchangers, with a focus on counter current applications. Its findings serve as a crucial resource, providing valuable insights for industries, researchers, and engineers in optimizing heat exchanger performance[6]. According to a previous survey, approximately 45% of heat exchangers in use are of the shell and tube type, largely due to their capability to handle high-pressure applications. This makes them ideal for crude oil processing's heat recovery optimization applications[7]. Methods like Log Mean Temperature Difference (LMTD) and Effectiveness-Number of Transfer Units ($\epsilon - NTU$) were applied and both of which provide reliable outcomes in the analysis of heat exchanger efficiency by utilizing Computational Fluid Dynamics (CFD) to model and evaluate heat transfer on surfaces[8]. The study indicates that both the heat transfer coefficient and pressure drop rise as the mass flow rate increases[8]. The study also concluded that reduction of the fouling to enhance the heat transfer coefficient could be achieved using helical baffle instead of segmental shape because it creates turbulence which reduces fouling and pressure drop and enhances the heat transfer coefficient[8]. Similar study examines how pitch layout and baffle spacing impact heat exchanger performance. It utilizes standard analytical calculations and includes simulations performed using SolidWorks 2016 for both laboratory and industrial heat exchangers to find overall heat transfer coefficient. It finds that using a square pitch layout reduces the overall heat transfer coefficient, whereas decreasing baffle spacing improves heat transfer efficiency[1]. There were additional study focuses on configurations and modifications of baffles spacing and tubes pitch layout and length. It discussed key heat transfer characteristics such as LMTD and pressure drop. It suggests that using helical baffles will enhance heat transfer while reducing pressure drop[9][10]. The study results confirmed that 100% increase in fouling resistance leads to an average reduction

of 0.37% in heat transfer efficiency. Additionally, higher values of the logarithmic mean temperature difference (LMTD) and larger ratios of the external to internal diameter of the exchanger tubes amplify the impact of fouling on the thermal performance of these exchangers in term of pressure drop[11]. Moreover, increase in shell diameter leads to an equivalent rise in both heat transfer coefficient and pressure drop. Conversely, increasing baffle spacing and cutting space resulted in a reduction in the heat transfer coefficient so that the performance reduced. Similarly, the fouling has significant impact on heat transfer at shell side compared to that on the tube side. This deeper understanding not only improves performance analysis techniques but also provides a robust foundation for design and performance optimization[10]. The findings indicate that as the mass flow rate increases, the heat transfer rate also improves. However, beyond a certain threshold, further increases in flow rate lead to a decline in heat transfer efficiency[12]. The study evaluates the performance of two heat exchanger units operating under steady-state conditions. Data were collected through direct measurements and analyzed to determine heat transfer coefficient, heat duty, and effectiveness. Results show that the heat duty and heat transfer coefficient are below the design value. The improvement was attributed to injecting the exchanger tubes with water treatment fluid[13][14]. In a review of the comparative performance of shell-and-tube heat exchangers with various design configurations using the LMTD method, the heat transfer coefficient is thoroughly analyzed. These studies also examine the effect of heat exchanger design on the heat transfer rate and temperature distribution. Thermal equations for calculating the overall heat transfer coefficient were applied in these analyses, and the results are valuable for assessing the performance of heat exchangers[14]. A large volume of published studies and review papers focuses on the design and performance analysis of shell and tube heat exchangers, particularly using the log mean temperature difference (LMTD) method[15]. The Logarithmic Mean Temperature Difference (LMTD) method is commonly used for effectiveness analysis in heat exchangers. This method is based on several assumptions, including that there is no energy loss to the environment, the heat exchanger operates at steady state, there are no phase changes in the fluids, the heat capacities of the fluids are independent of temperature, and the overall heat transfer coefficient remains constant across temperature and position within the heat exchanger[11]. Additional study examines the impact of mass flow rate and inlet temperature on overall heat transfer coefficient. The overall heat transfer coefficient for various flow rates is calculated using both the LMTD and NTU methods, with results compared for accuracy it found that the results of NTU are much better but for parallel flow without baffles[16]. Further study presents a computational methodology to determine temperature effectiveness (S) and the LMTD correction factor (F) in shell and tube heat exchangers. The methodology is validated against existing literature, showing strong agreement. Additionally, the study introduces new mathematical relations for P and approximate F correlations, aiding in preliminary computerized design and optimization of thermal performance evaluation of counter-current flow heat exchanger[17]. Moreover, the performance of

the heat exchanger is influenced by the flow rate. Studies have shown that as the fluid flow rate increases, the heat transfer rate and efficiency improve mathematically[18]. Recent studies have increasingly focused on the performance analysis of shell and tube heat exchangers in crude oil processing plants and refineries, with an emphasis on assessing the efficiency of these systems. Research efforts aim to enhance the performance efficiency of heat exchanger networks in refineries, often using Microsoft Excel as a calculation tool for data analysis[19]. Case studies have been conducted, to calculating the overall heat transfer coefficient and comparing it with the design specifications. Historically, the LMTD method has been widely used for heat exchanger analysis, especially to determine the overall heat transfer coefficient when the inlet and outlet temperatures of both hot and cold fluids are known or can be determined through energy balance calculations[20][21]. The concept of using the LMTD method for performance analysis was proposed, and it is considered especially useful when both the inlet and outlet temperatures of the fluids are available, as well as other key parameters like flow rates[22]. Based on the previous analysis of the thermal performance of the heat exchanger, it is essential to justify that the effectiveness of the heat exchanger depends on the overall heat transfer coefficient, heat duty, pressure drop and the temperature of the fluid. it is observed from literatures review that the researchers were focusing of the overall heat transfer coefficient, pressure drop as fouling phenomena occurs on the heat exchanger and heat exchangers, parts configuration and modification are the most key parameters for performance analysis and evaluation of the heat exchangers. As such, the LMTD method is highly recommended for performance analysis of shell and tube heat exchangers, as demonstrated in this study. In addition, the collected data strongly support the use of the LMTD method equations to calculate the heat transfer coefficient and compare it with design data.

III. MATERIALS AND METHOD

A. Materials

The materials used in this study include the following:

- 1) Operational Data of the Shell and Tube Heat Exchangers:
 - Flow rate readings for both the inlet and outlet of the tube side.
 - Flow rate readings for both the inlet and outlet of the shell side.
 - Temperature and pressure readings for both the inlet and outlet of the tube side.
 - Temperature and pressure readings for both the inlet and outlet of the shell side.
 - Samples of raw and treated crude oil for density testing at different temperatures.
- 2) Design Parameters of the shell and tube heat exchangers in the LCPF.
- 3) Main LCPF Process Description Scheme - A simple flow diagram of the process.
- 4) Anton Paar DMA 4500 M - Density Meter (DMA4500M) - Used for density measurements

- 5) MS Office Excel 2021 - For creating data sheets and performing calculations.

ρ = density of treated crude oil
f=flow rate of treated crude oil
Heat gained by cold raw crude oil stream:

B. Methodology

- 1) The Logarithmic Mean Temperature Difference (LMTD) method is used to perform the performance analysis of the shell and tube heat exchanger.
- 2) The overall heat transfer coefficient (U) is the key parameter targeted for performance evaluation, which is then compared to the design value set by the system.
- 3) Flow rates, stream pressures, and crude oil samples (both raw and treated) are recorded and collected from the inlet and outlet streams of the shell and tube heat exchanger.
- 4) The standard method of the American Society for Testing and Materials (ASTM D5002) is used to determine the density of the crude oil.

The analysis could be carried out as in the following steps:

1) *Performance Analysis for the Heat Exchangers Using LMTD Method:* The calculation of the thermal parameters of the heat exchanger's heat transfer involves the following assumptions[21][22].

- 1) Steady-state condition is assumed.
- 2) The crude/crude heat exchanger is fully insulated. Thus, heat losses are negligible.
- 3) The thermal resistance is equally distributed along the exchanger.
- 4) Overall heat transfer coefficient is constant along exchanger, and specific heat of raw and treated crude oil is constant too.
- 5) The heat transfer surface area (A) is distributed constantly on each fluid side.
- 6) No electrical heating trace or chemical reaction in the fluid.
- 7) It's assumed no phase change or creation of the vapor in the shell and tube side for the crude oil.
- 8) Velocity, flow rate and temperature at the entrances are uniform over the flow cross section.
- 9) No flow leakages or mixes occur in shell or tube streams.

2) *Heat Duty Calculations:* Heat Duty by hot treated Crude oil:

$$q = m C_p \Delta T \quad (1)$$

Heat lost by hot treated crude oil stream:

$$Q = m_h * C_{ph} * (T_{hi} - T_{ho}) \quad (2)$$

Where:

m_h :hot stream flow rate kg/hr
 C_{ph} : Specific heat of hot stream kJ/kg. °C
 T_{hi} :Inlet temperature of hot stream, °C
 T_{ho} : Outlet temperature of hot stream, °C
Temperature range for hot treated crude oil:

$$\Delta T_h = T_{hi} - T_{ho} \quad (3)$$

$$m_h = \rho * f = \quad (4)$$

$$Q = m_c * C_{pc} * (T_{CO} - T_{Ci}) \quad (5)$$

Where:

m_c :Cold stream flow rate kg/hr
 C_{pc} : Specific heat of hot and cold stream kJ/kg. °C
 T_{Ci} :Inlet temperature of hot stream, °C
 T_{Co} : Outlet temperature of hot stream, °C
Temperature range for cold raw crude oil:

$$\Delta T_C = T_{co} - T_{ci} \quad (6)$$

$$m_c = \rho * f = \quad (7)$$

ρ = density of treated crude oil
f=flow rate of treated crude oil

3) *Log Mean Temperature Difference (LMTD) Calculations:* The log-mean temperature difference (LMTD) could be calculated by the following equation[13][22][23].

$$\Delta T_{LMTD} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln \left\{ \frac{(T_{hi} - T_{co})}{(T_{ho} - T_{ci})} \right\}} \quad (8)$$

Where:

ΔT_{LMTD} : Log Mean Temperature Difference
 T_{hi} :Inlet temperature of hot stream, °C
 T_{ho} : Outlet temperature of hot stream, °C
 T_{ci} : Inlet temperature of cold stream, °C
 T_{co} : Outlet temperature of cold stream, °C

4) *The Corrected Log Mean Temperature Difference (LMTD):*

$$\Delta T_m = F * LMTD \quad (9)$$

Where F is correction factor and it have been expressed by the following equation which is derived by Kern[20][21].

$$F = \frac{(R + 1)^{0.5} * \ln \left(\frac{1 - SR}{1 - S} \right)}{(1 - R) * \ln \left(\frac{2 - S(R + 1 - (R + 1)^{0.5})}{2 - S(R + 1 + (R + 1)^{0.5})} \right)} \quad (10)$$

Capacity ratio, R

$$R = \frac{m_h C_{ph}}{m_c C_{pc}} = \frac{(T_{hi} - T_{ho})}{(T_{co} - T_{ci})} \quad (11)$$

C_{ph} , and C_{pc} : Specific heat of hot and cold stream Thermal Effectiveness, S

$$S = \frac{(T_{co} - T_{ci})}{(T_{hi} - T_{ci})} \quad (12)$$

5) *Overall Heat Transfer Coefficient U*: Following basic equation was applied to calculate overall heat transfer coefficient U, so that to analyze and evaluate the heat exchanger performance. The equation is defined by:

$$U = \frac{Q}{A * \Delta T_m} \quad (13)$$

Where:

Q: heat transfer duty, w,

U: the overall heat transfer coefficient, w/m² °C,

A: heat-transfer area, m²,

ΔT_m : the mean temperature difference, the temperature driving force, °C.

6) *Streams pressures drop calculation*: Hot stream (treated crude oil) - shell side Pressure Drop, kPag

$$\Delta P_h = P_{hi} - P_{ho} \quad (14)$$

Where:

P_{hi} : Inlet pressure of hot stream

P_{ho} : Outlet pressure of hot stream

Cold stream (raw crude oil) - tube side pressure drops, kPag

$$\Delta P_c = P_{ci} - P_{co} \quad (15)$$

Where:

P_{ci} : Inlet pressure of cold stream

P_{co} : Outlet pressure of cold stream

IV. RESULTS AND DISCUSSION

In this study, the performance evaluation of the counter-current shell and tube heat exchanger was carried out with focus on the overall heat transfer coefficient (U), heat duty, pressure drop and temperature difference. Operation parameters were systematically collected from the plant and measured under controlled conditions to ensure accuracy and reliability. The results analyze the efficiency of the heat exchanger under varying operational conditions, identifying key trends and deviations from design specifications. The table(I) shows the data of the flow rate of the shell and tube streams, and table(II) is showing pressure readings.

TABLE I: Shell and Tube Side Flow Rates of the Crude Oil

Flow rates f (m ³ /hr) in the Shell and Tube Side				
No	Tube Side		Shell Side	
	In	Out	In	Out
1	58.54	58.54	57.32	57.32
2	53.74	53.74	51.83	51.83
3	57.45	57.45	55.77	55.77
4	56.07	56.07	56.95	56.95
5	59.10	59.10	58.04	58.04
6	57.25	57.25	56.34	56.34
7	57.41	57.41	56.16	56.16
8	57.17	57.17	56.03	56.03
9	54.90	54.90	52.49	52.49
10	56.35	56.35	53.79	53.79
Average	56.80	56.80	55.47	55.47

TABLE II: Pressure readings of shell and tube sides

No	Tube Side (kpag)			Shell Side (kpag)		
	Inlet	Outlet	ΔP_c	Inlet	outlet	ΔP_h
1	580	349	231	289	188	101
2	582	351	231	288	188	100
3	582	351	231	288	188	100
4	583	351	232	289	189	100
5	586	352	234	288	187	101
6	586	351	235	289	186	103
7	585	350	235	288	189	99
8	586	351	235	289	189	100
9	583	350	233	288	189	99
10	585	351	234	288	189	99
Average	583.8	350.7	233.1	288.4	188.2	100.2

The average results of the pressure drop (ΔP_h) in the shell side of the heat exchanger are in the table(II) along with the results of shell and tube sides inlet and outlet pressure readings. It was found that the pressure drop (ΔP_h) is 100.2 kpag. The found result is still within the allowable range of pressure drop as per design.

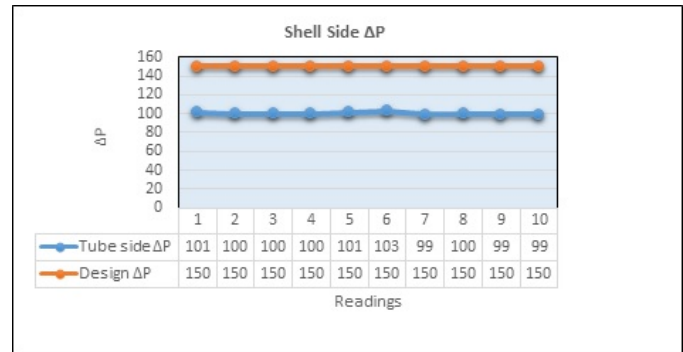


Fig. 2: Shell side pressure drop compared to design pressure drop.

Similarly, the average results of the pressure drop (ΔP_c) in the tube side are in the table(II) along with the results of shell and tube sides inlet and outlet pressure readings. It was found that the pressure drop (ΔP_c) is 233.1 kpag higher compare to 100 kpag the design value. Figure(3) shows the comparison of the pressure drop (ΔP_c) result and the design value. The high pressure drop (ΔP_c) result clarified the flow resistance, which may result from factors such as fouling, high flow velocity, tube blockage, or tube geometry and arrangement factor.

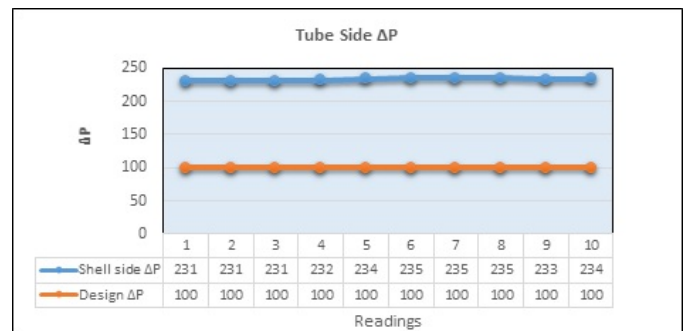


Fig. 3: Tube side pressure drop compared to design pressure drop.

The table(III) shows the results of the temperature data and the average temperature range (ΔT) of the inlet and outlet streams of crude oil in the tube and shell sides. The results of the average temperature range (ΔT) found in the tube and shell side are 14 °C and 23 °C respectively as shown in table(III).

TABLE III: Temperature reading of the shell and tube heat exchanger

No	Tube Side		Shell side	
	Inlet	Outlet	Inlet	outlet
1	43	59	105	83
2	42	58	104	82
3	41	59	105	83
4	43	58	105	82
5	43	54	105	82
6	43	57	104	82
7	43	54	105	82
8	42	56	105	82
9	43	56	105	82
10	42	56	105	83
Average	43	57	105	82
$\Delta T(^{\circ}C)$	14		23	

The temperature difference (ΔT) results found in both shell and tube side are less compared to the temperature difference of design value. Figure(4) and figure(5) below is illustrating the comparison of the results and the design value.

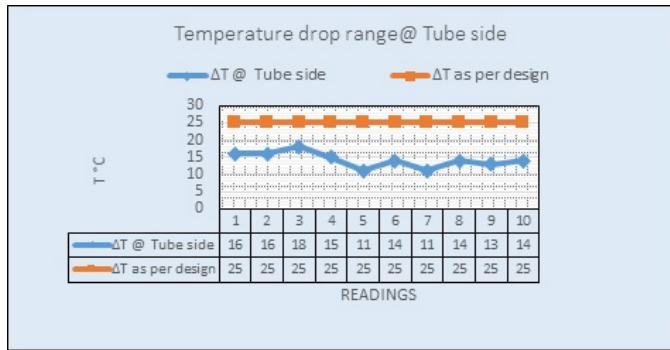


Fig. 4: Tube side inlet temperature difference compared to the design temperature difference.

The table(IV) is showing the test results of the crude oil density at different temperature, the tests were completed at the CPF's Laboratory using the standard ASTM D5002 method. The results were used to calculate the mass flow rate used to calculate heat duty.

The Table(V) shows the entire obtained averages results of the heat exchanger parameters which were used to calculate thermal parameters to evaluate the performance of the shell and tube heat exchanger in term of overall heat transfer coefficient, heat duty and effectiveness (S).

Based on these assumptions in this study, the LMTD method equations were set in the MS office by using the data in Table(V), the analysis of the shell and tube heat exchanger was carried out to evaluation the performance. In the figure(6),

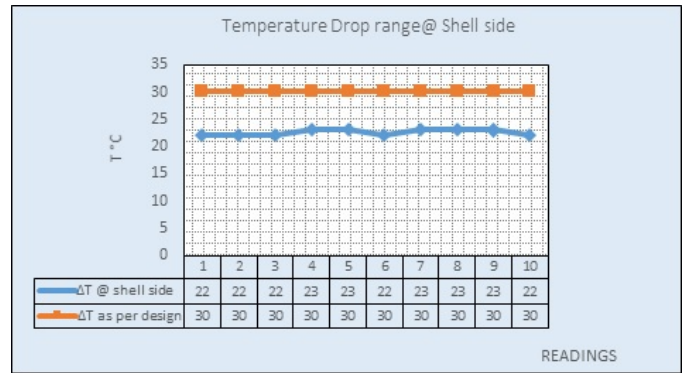


Fig. 5: Shell side temperature difference compared to the design temperature difference.

TABLE IV: Density (g/cm³) of the raw and treated crude oil at different Temperature.

Sample No	Results			
	@ 42 °C	@ 57 °C	@ 105 °C	@ 82 °C
Sample#1	0.9109	0.9086	0.9051	0.9078
Sample#2	0.9108	0.9085	0.9051	0.9078
Sample#3	0.9108	0.9085	0.9051	0.9077
Sample#4	0.9105	0.9085	0.9050	0.9077
Sample#5	0.9107	0.9086	0.9052	0.9078
Sample#6	0.9106	0.9085	0.9050	0.9076
Sample#7	0.9107	0.9086	0.9051	0.9077
Sample#8	0.9108	0.9086	0.9051	0.9078
Sample#9	0.9107	0.9086	0.9051	0.9078
Sample#10	0.9107	0.9085	0.9050	0.9076
Average	0.9107	0.9086	0.9051	0.9077

TABLE V: Average results of the Heat Exchanger data and measured parameters.

Parameters	Inlet	Outlet
Treated crude oil flow, m (m ³ /hr)	55.47	55.47
Raw crude oil flow, m (m ³ /hr)	56.8	56.8
Treated Crude oil Temp, T (°C)	105	82
Raw Crude oil Temperature, t (°C)	43	57
Shell Side Pressure, P (kPag)	288.4	188.2
Tube Side Pressure, p (kPag)	583.8	350.7
Treated Crude Oil density, ρ_h (kg/m ³)	905.1	907.7
Raw Crude Oil density, ρ_c (kg/m ³)	910.7	908.6
Treated crude Oil specific heat Capacity, C_{ph} (kJ/kg.°C)	1.921	1.801
Raw Crude Oil specific heat Capacity, C_{pc} (kJ/kg.°C)	1.948	2.044

the average heat duty obtained is 500,000 kW, significantly lower than the design heat duty of 2,353,999.4 kW. This discrepancy is attributed to a lower mass flow rate compared to that in the design, which reduces turbulence in the flow and, consequently, the heat duty.

The average overall heat transfer coefficient achieved is 10.49 W/m².°C, which is only 16.99% of the design value of 61.74 W/m².°C, as shown in Figure(7) and the summary in the table 6. The due to insufficient mass flow rate leading to laminar flow instead of turbulent flow, reducing the heat transfer efficiency. In addition to that the small value of the temperature difference (ΔT) between the hot at shell side and cold fluids in the tube side reduces the driving force for heat transfer, leading to a lower the overall heat transfer coefficient (U). also, fouling occurrence lowering the overall heat transfer coefficient (U).

TABLE VI: The summary of Comparison of Calculated Parameters with Design.

Parameters	Calculated Parameters	Design Parameters (Value)	Remarks
Heat Duty, Q (W)	597791.57	2353999.40	25.39 % only compare to the design value
Shell side pressure drop, ΔP_h (Kpag)	100.2	150	Less than design value
Tube side pressure drop, ΔP_c (Kpag)	233.1	100	Higher than design value
Temperature difference at shell side, ΔT ($^{\circ}C$)	23	30	23.33% less than design value
Temperature difference at tube side, ΔT ($^{\circ}C$)	14	25	44 % less than design
Capacity ratio, R	1.64	1.20	36.67 % higher the design value
Effectiveness, S	0.23	0.42	45% less than design value
Corrected LMTD ($^{\circ}C$)	43.34	32.44	33.60 % higher than design value
Overall Heat Transfer Coefficient, U . W/(m ² . K)	10.49	61.74	Only 16. 99% compared to the design value

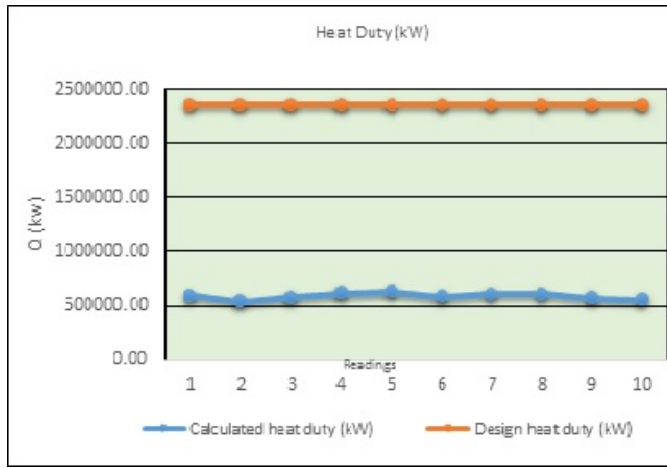


Fig. 6: Calculated Heat duty Results

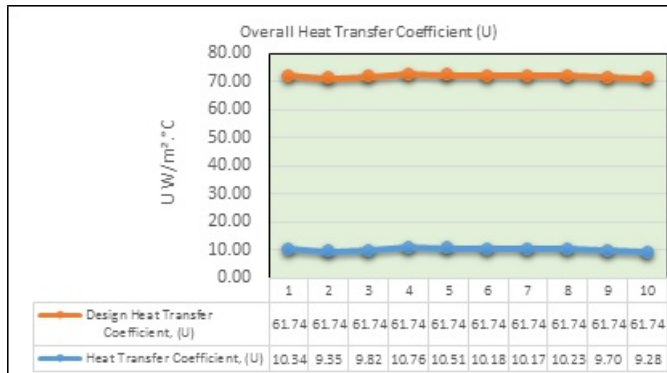


Fig. 7: Calculated Overall Heat Transfer Coefficient (U) Results

The table(VI) was formed as summary to compare the finding results for the performance evaluation of the counter-current shall and tube heat exchanger in this study. The results of temperature range (ΔT) in the shell and tube side are found as 23.33% and 44% respectively less than the design. The calculated heat duty (w) is only 25.39% comparing to the design. The pressure drop on the shell side is 133.1% higher than and the pressure drop on the tube side is 33.2% less than in the design.

The capacity ratio (R) is 36.67% higher than in the design while, the thermal effectiveness (S) is less by 45% than the

design; and the corrected LMTD is found 33.60% higher see Table(VI). The

temperature difference (ΔT) at the shell and tube sides were found 23.33% and 44% respectively less than the design value.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusion

This study analysis was completed for counter-current shell and tube heat exchangers in the local central processing facility (LCPF) to evaluate their efficiency and to provide a comprehensive understanding of the heat exchanger's performance, identify the causes of inefficiency, and offer practical solutions and recommendation to optimize the system for improved temperature control, energy efficiency, and overall operational reliability. The method that used was focus on analyzing overall heat transfer coefficient (U) and heat duty comparing to the designed values in addition to the pressure drop. The method provided satisfactory results for the analysis and based on these results; it is evident that the efficiency of the LCPF heat exchangers is very low.

B. Recommendations

For optimization and increasing heat exchangers' efficiency in the LCPF, based on the findings, suggest potential optimization techniques to improve heat exchanger performance. This might include advanced investigative studies to identify the factors affecting their performance. Additionally, it is recommended to conduct a design review of the heat exchangers in the LCPF to explore potential improvements in increasing the heat transfer surface area or modifying the flow arrangement and baffle spacing and cutting and tube pitch pattern. Moreover, conducting studies of increasing the flow velocity and reducing fouling through better maintenance or chemical cleaning to enhance heat transfer accordingly.

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