Performance Analysis of Heat Exchangers in Central Processing Facilities of Crude Oil:

A Case Study of Aljabalayn Processing Facilities, White Nile State, Sudan

Ibrahim Adam Ghordon Kakni

B.Sc. (Honors) in Chemical Engineering
University of Gezira (2003)

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Faculty of Engineering and Technology

November, 2018
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<td></td>
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<tr>
<td>Dr. Imad Eldeen Abdelmoniem Mahajoub</td>
<td>Co-Supervisor</td>
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Date of Examination: 10/11/2018
Dedication

I dedicate this work to my father’s soul, and to my mother, whom gave me life and hope, affection, great love, and a passion for knowledge.

It’s also dedicated to my wives and kids for their endless support. And then to everyone who taught and guided me in learning journeys.
Acknowledgment

I would like to convey my sincere gratitude to my supervisor Prof. Ahmed Alzain Alhassan for his invaluable suggestions, motivation and guidance for carrying out this dissertation by current contents. His encouragement towards the current topic helped me a lot in this dissertation.

I owe my thankfulness to Dr. Imad Eldeen Abdelmoniem Mahajoub, Head of the Department of Chemical Engineering and Chemical Technology, University of Gezira for providing necessary facilities in the department.

I am greatly indebted to my colleague Engineers in the work place for their guidance and knowledge sharing.

I thank my family for their always great and endless support throughout my entire life.
Ibrahim Adam Ghordon Kakni

Abstract

Heat exchanger is device that facilitates the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other, Shell and tube heat exchanger are the most common type of heat exchangers used in oil fields, refineries, and other chemical process industries. The objective of this study is to carry out performance analysis of the nine heat exchangers of Aljabalayn field, and to find out the problems that may affect their performance. Steady state monitoring and direct collection of data from these heat exchangers were done and the samples of crude oil from inlet and outlet of the hot and cold streams were collected and analyzed to measure the density and specific heat. An MS excel program has been developed for the ease of calculation; the equations of shell and tube heat exchangers performance analysis have been applied. Logarithmic Mean Temperature Difference (LMTD) method has been used for the analysis. The heat duty, pressure drop, temperature difference (ΔT), thermal effectiveness and overall heat transfer coefficient for the nine heat exchangers have been determined. The results show that the calculated heat duties ranged between (147430.9 – 338479.5W), these results are much less when compared with the (2353999.4W) as the recommended design data. The results of pressure drop in the shell and tube sides were found in the range (1.48 – 2.04 bar) and (0.98 – 1.08 bar), it’s slightly higher when compared with (1.5 bar) and (1.0 bar) respectively. The temperature differences were found less than the limits of the design, the results for shell and tube sides were in the range (7 - 10ºC) and (6 – 14 ºC) respectively comparing with (30 and 25 ºC) the recommended (ΔT) as design data. The results of thermal effectiveness were found also less than the limits of the design, it’s in the range (0.12 - 0.17) Compared to (0.42) the value of (ε) as design data. The overall heat transfer coefficient (U) (W/m²·K) of the nine heat exchangers was found as (5.20), (3.29), (4.76), (5.31), (2.33), (2.30), (4.20), (4.61) and (2.14) compared to (61.74) the value of overall heat transfer coefficient (U) (W/m²·K) as design data. The study has concluded that the performance of the nine heat exchangers have deteriorated, so an urgent mechanical or chemical cleaning was recommended as troubleshooting process for these heat exchangers due to the fouling occurred. Also the study recommends that to study design review for these heat exchangers considering current Dar-Blend crude oil specifications.
تحليل أداء المبادلات الحرارية في منشآت المعالجة المركزية للنفط الخام:
دراسة حالة منشأة المعالجة المركزية، الجليلين، ولاية النيل الأبيض، السودان
إبراهيم ادم غردون كاکتي

ملخص الدراسة
المبادل الحراري عبراء عن مادة هندسية تنتقل فيه الطاقة الحرارية من طبقة ساخنة إلى طبقة بارد دون اختلاط المائعين
بعضهما البعض. تعتبر المبادلات الحرارية ذات الغلاف والأنتاب من المعدات الهامة في الصناعات الهندسية التي
تطلق فيها عمليات الانتقال الحراري، وهي الأكثر شيوعًا وانتشارًا في حقول النفط وعوامل التكير وغيرها من
الصناعات، والعملات الكيميائية كما أنها مناسبة لتطبيقها على الضغوط العالية. توجد عدد تسع مبادلات
حرارية ذو الغلاف والأنتاب من النوع ذات السريان المتاخم في سلسلة متوازية بمحطات المعالجة المركزية للنفط
بالجيلين، ولاية النيل الأبيض، السودان. الهدف من هذا البحث هو تحليل أداء هذه المبادلات الحرارية، وأيضاً المشاكل
التي تؤثر على أدائها بواسطة حساب معدل انتقال الحرارة الكلي. وان ثم كتبية التوصيات اللازمة لحل هذه المشاكل
بغير تعديل أداء هذه المبادلات الحرارية. وإمام هذه الدراسة تم جمع البيانات المتعلقة بالدراسات من المبادلات
الحرارية المعنية في محطات المعالجة المركزية للنفط بالنيل، وتلك السلسلة ذات السريان المتاخم في، وتحمل
الدراسة عند نقطة دخول وخروج النطاق الخام في المبادل الحراري وكذلك الضغط من جانب الغلاف والأنتاب ومعدل
طرق الساخن والبارد، وان ثم جمع عبارة من نقطة الدخول والخروج لكل مبادل حراري من جانب
الماء والبارد كل على حدة ومن ثم تحويلها إلى كمية الحرارة الحرارية، وإجراء التحليل تم استخدام طريقة
السطوح المغربي في فرق درجات الحرارة لحساب كمية الحرارة المتبادلة ومعامل انتقال الحرارة الكلي للمبادلات
الحرارية التسعة كل على حدي، بالإضافة إلى حساب فرق الضغط، وفرق درجة الحرارة من الجانب الأدنوي و
الغلاف للفرق الساخن والبارد، وحساب الفعالية الحرارية. وقد أجرى الدراسات في ورقة برنامج مايكروسوفت
إكسل باستخدام المعادلات المطلوبة تحليل أداء المبادلات الحرارية هذه. وقد أظهرت النتائج الدراسة أن كمية الحرارة
المتبادلة هي (38479.5 - 338479.5) مقارنة بـ (235399.4) مقارنة بـ (VII)
بجانب الفرق الساخن والبارد (7.10)°م و (6.14)°م على التوالي مقارنة بـ (30 و 25)°م حسب بيانات التصميم
الموصى بها. أما نتائج فرق الضغط في جانب الغلاف والأنتاب فسجلت قيم أعلى مقارنة بفرق الضغط المحسب ببيانات
التصميم (1.48 - 2.04 بار) و (0.98 - 1.08 بار) مقارنة بـ (1.5 بار) و (1 بار) على التوالي. ووجد أن قيم
معاملات إنتقال الحرارة الكلية للمبادلات الحرارية التسعة كل على حدي هي (5.20)°م (2.9)°م (3.7)°م (4.76)°م (3.20)°م (5.31)°م (3.33)
(2.30)°م (4.61)°م (6.17)°م (2.14)°م (4.20)°م (2.40)°م (2.20)°م (2.60)°م مقارنة بـ (VII).
فيما يتعلق بالتصميم، وادي وجد أن قيمة الفعالية الحرارية لهذه المبادلات الحرارية تقلل من قيمة الفعالية
الحرارية عند التصميم حيث تراوحت بين (0.12 - 0.17) مقارنة بـ (0.42) قيمة الفعالية الحرارية عند التصميم. وقد
خلصت الدراسة إلى أن المبادلات الحرارية تتعادل عدد قد كلها ونسبة من احترها بروابض المكونة على الاحترب
الداخلية والخارجية لأنتابها. وأوصت الدراسة بالظروف الميكانيكية أو الكيميائية لهذه المبادلات الحرارية من الظروف
المتاركة على الأنابيب، كما توصى بدراسة ومرافعة تصميم هذه المبادلات الحرارية وإجراء المزيد من التحليل
والدراسات المتقدمة من أجل حل المشاكل الحالية وزيادة كفاءة هذه المبادلات الحرارية.
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<td>DCS</td>
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List of Nomenclatures

\( T_h \): Temperature of Hot Stream, °C
\( T_c \): Temperature of Cold Stream, °C
\( \rho_h \): Density of Treated Crude Oil, (kg/m³)
\( \rho_c \): Density of Raw Crude Oil, (kg/m³)
\( Q \): Heat Duty, W
\( m_h \): Hot Stream Flow Rate, (kg/hr)
\( m_c \): Cold Stream Flow Rate, (kg/hr)
\( C_{ph} \): Specific Heat of Hot and Cold Stream kJ/kg.°C
\( T_{hi} \): 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
\( P_h \): Shell Side Pressure, kPa
\( P_c \): Tube Side Pressure, kPa
\( CP \): Centipoise
\( U \): Overall Heat Transfer Coefficient, w/m² °C,
\( A \): Heat Transfer Area, m²,
\( \Delta T_m \): The Mean Temperature Difference, °C.
\( F \): Correction Factor
\( R \): Capacity Ratio
\( S \): Thermal Effectiveness
\( \Delta P_h \) and \( \Delta P_c \): Hot and Cold Stream Pressure Drop, (kPa )
\( P_{hi}/P_{ho} \): Inlet/Outlet Pressure of Hot Streams, (kPa )
\( P_{ci}/P_{co} \): Inlet/Outlet Pressure of Cold Streams, (kPa )
Chapter One
1. Introduction

1.1 Heat Exchangers
Heat exchangers are equipments and devices that facilitate the exchange of heat between two fluids that are at different temperatures while keeping them from mixing with each other. Heat exchangers are commonly used in practice in a wide range of applications, such as power production, chemical processing and food industries, electronics, environmental engineering, waste heat recovery, manufacturing industry, air-conditioning, oil and gas fields and refrigeration as well as refineries (Yunus A. Cengel, 2003).

1.2 Heat Exchangers can be Classified According to the Following Main Criteria:
- Geometric Construction: There are many types of heat exchangers applied in the process industries under this classification. These types include: Tubular heat exchanger which are Double pipe exchangers, Shell and tube exchangers, Coiled Tube Heat Exchanger, Spiral tube heat exchangers, Air coolers and condensers, Direct contact (quenching towers), Fired heaters, Plate exchangers, Plate-fin exchangers and Extended Surface Heat Exchangers (Ramesh K. Shah et al, 2003).
- Transfer processes: The type of heat exchangers under this classification includes Director and Indirect transfer processes heat exchangers
- Degrees of surface compactness: Such as Compact and non-compact heat exchangers
- Flow arrangements: It includes Parallel flow, Cross flow and counter current flow.
- Pass arrangements: passage arrangement exchangers are Single-Pass or multi-pass
- Phase of the process fluids: Gas-Liquid, Liquid-Liquid and Gas-Gas heat exchangers
- Heat-transfer mechanisms: Single phase convection forced or free, Two phase convection (condensation or evaporation) and Combined(convection and radiation) (Mukherjee R. et al, 2004)
1.3 Shell and Tube Heat Exchangers

Shell and tube heat exchanger are the most common type of heat exchangers in oil fields, refineries, and other large chemical process industries, and is suited for higher-pressure applications. Prabhu Kishore. N. (2016).

Shell and tube heat exchanger consists of a tube bundle enclosed in a cylindrical casing called a shell. One fluid passes through the tubes, and another fluid flows over the tubes (through the shell) to transfer heat between the two fluids. Heat is transferred from one fluid to the other through the tube walls, either from tube side to shell side or vice versa.

The fluids can be liquid/liquid, gas/liquid or gas/gas on either the shell or the tube side. Usually, the ends of each tube are connected to plenums through holes in tube sheets. The tubes may be straight or twisted in the U shape.

Heat exchangers may have one shell pass and one tube pass, or one shell pass with two tube passes or two shell passes and four tube passes. (See the figures (1-1) and (1-2) below)

![Figure (1-1): One Shell Pass and One Tube Pass. (Gajanan P Nagre , 2013)](image-url)
1.4 Types of shell-and-tube exchangers

The types of shell and tube heat exchangers are clarify and shown below (Harry Silla et al, 2003)

1.4.1 Fixed tube sheet heat exchanger

Heat exchanger of this type has straight tubes. Both tube sheets are fastened or welded to the shell and the tube bundle is not removable.

Figure (1-3): Fixed Tube Sheet Heat Exchanger
(http://engineering.wikia.com/wiki/shell_and_tube_heat_exchanger)
1.4.2 Floating Head Heat Exchanger
Shell-and-tube unit has one restrained tube sheet, called the stationary tube sheet, located at the channel end. Differential expansion problems are avoided by use of a freely riding floating tube sheet at the other end. The tube bundle is removable from the channel end, for maintenance and mechanical cleaning or inspection.

Figure (1-4): Floating Head Heat Exchanger (website: www.coade.com)

1.4.3 U-Tube Heat Exchangers
As the name implies, the tubes of a U-tube heat exchanger are bent in the shape of a U and there is only one tube sheet in a U-tube heat exchanger.

Figure (1-5): U-Tube Heat Exchanger
(http://engineering.wikia.com/wiki/shell_and_tube_heat_exchanger)
1.5 Components of Shell and Tube Definitions

Following are the mechanical features of shell and tube heat exchangers (Mukherjee R. 2004);

1.5.1 Baffles

Baffles are used in the shell to direct the fluid stream across the tubes to avoid short cut flow, to increase the fluid velocity and so improve the rate of heat transfer. As well as baffles are used to support tubes, and to prevent failure of tubes due to flow-induced vibration.

1.5.2 Tube-sheets

Tube sheets are the barrier between the shell and tube fluids to prevent any possibility of intermixing due to leakage at the tube sheet joint. They are usually made from a round flat piece of metal with holes drilled for the tube ends in an exact location and pattern relative to one another. Tubes are fixed to the tube sheet by pneumatic or hydraulic pressure or by roller expansion. Tube holes are drilled and reamed and can be machined with one or more grooves. This greatly increases the strength of the tube joint.

1.5.3 Heat Exchanger’s Shell

Shell of heat exchanger is cylindrical casing where tube bundle enclosed in. shell of heat exchangers has seven types according to the standards of the Tubular Exchanger Manufacturers Association (TEMA).

1.5.4 Heat Exchanger Bundles

Tube bundles are also known as tube stacks are designed for applications according to customer requirements, including direct replacements for existing units.

Typical configurations of shell and tube type heat exchangers as per TEMA-AES are exemplified below, but the basic design permits many modifications and special features, some of which are described below.

1) Stationary Head-Channel.
2) Stationary Head Flange-Channel or Bonnet
3) Channel Cover.
4) Stationary Head Nozzle.
5) Stationary Tube sheet.
6) Tubes.
7) Shell.
8) Shell Cover.
9) Shell Flange-Stationary Head End.
10) Shell Flange-Rear Head End.
11) Shell Nozzle.
12) Shell Cover Flange.
13) Floating Tube sheet.
14) Floating Head Cover.
15) Floating Head Cover Flange.
16) Floating Head Backing Device.
17) Tie rods and Spacers.
18) Transverse Baffles or Support Plates.
19) Impingement Plates.
20) Pass Partition.
21) Vent Connection.
22) Drain Connection.
23) Instrument Connection.
24) Support Saddle.
25) Lifting Lug

Figure (1-6) : (Modified from TEMA, Standards 7th edition, Tubular Exchanger Manufacturers Association, Tarrytown, NY, 1988) (by Santhosh et al, 2014)
1.6 Fluid Allocation

Fluid allocation in the shell or tube side is applied under the following conditions (Harry Silla et al, 2003).

1.6.1 Fluids to be Passed Through Shell Side:
- Fluids of which pressure drop should be low.
- Highly viscous fluids
- Fluids which exhibit a low heat transfer rate
- Fluids which undergo the phase change

1.6.2 Fluids to be Passed Through Tube Side:
- Fluids at higher pressure.
- More Corrosive.
- More Fouling (Fouling is scale formation is referred to as fouling and may be caused by the following mechanisms (Harry Silla, 2003)
  (a) Precipitation of a salt from solution - frequently calcium carbonate in water
  (b) Chemical reaction - such as polymerization of a monomer or corrosion, which are accelerated by a warm surface
  (c) Growth of a microorganism
  (d) Depositing of suspended matter
- Fluids at higher flow rate
- Fluids with less viscosity
- Hotter

Also if the fluid requires a low pressure drop, generally, the more "obnoxious" fluid is placed on the tube side because (Harry Silla et al, 2003):
- The tube side is relatively easy to clean
- Tubes are easier to replace or plugged if damaged
- High heat-transfer coefficients can be obtained at a low pressure drop
- A high-pressure fluid is more economically contained in tubes because of their smaller diameter compared to the shell
1.7 Heat Exchangers Performance Analysis Techniques

1.7.1 The Log Mean Temperature Difference (LMTD) Method
The rate of heat transfer between the two fluids at a location in a heat exchanger depends on the magnitude of the temperature difference at that location, which varies along the heat exchanger.

In the analysis of heat exchangers, it is usually convenient to work with the Logarithmic Mean Temperature Difference (LMTD), which is an equivalent mean temperature difference between the two fluids for the entire heat exchanger (Holman. J.P. et al, 2010).

1.7.2 Overall Heat Transfer Coefficient, (U)
Heat transfer in a heat exchanger usually involves convection in each fluid and conduction through the wall separating the two fluids, any radiation effects are usually included in the convection heat transfer coefficients. In the analysis of heat exchangers, it is convenient to work with an overall heat transfer coefficient (U) as expression of combination of the all thermal resistance in the path of heat flow from the hot fluid to the cold one (Yunus A. Cengel et al, 2003).

1.8 The Factors Affect Heat Transfer in Heat Exchanger
- Shell and tube sides flow rate, its temperature and specific heat
- The inlet and outlet temperature of the hot and cold streams
- Surface area allowing heat transfer
- Thermal conductivity of maternal from which the tubes are made
- Scales formed inside the tubes
- Convection heat transfer coefficient from the inside and outside surfaces, this may added in the overall heat transfer coefficient. (Gurashi A. Gasmelseed, 2010)

1.9 Aljabalyan Central Processing Facilities (CPF) Description
The information in this study is intended as an aid to understand and be familiar with Central Processing Facilities (CPF) plant.

The objective is to provide guidance and assistance in the form of definitions and facilities descriptions, simplified plant schemes, illustrated pictures, as well as principle of operation emphasis on heat exchangers in the CPF so as to have well knowledge about Central Processing Facilities (CPF) plant.
Central Processing Facilities (CPF) receives partially-treated crude oil with maximum 10% water cut at feed. This crude oil receives in surge vessels. From the surge vessel outlet headers crude oil will be is fed to the tube side of the heat exchangers and will get heated up by the hot treated crude oil from Electrostatic Dehydrators (EDH). The hot raw crude oil will then flows to the tube side of the Crude Oil heaters Synthetic oil is used in heaters to heat raw crude oil where the hot oil flowing through the shell side will heat up the crude oil to 105°C before feeding to the Electrostatic Dehydrators (EDH) for final water separation and removal.

Electrostatic Dehydrators (EDH) are designed to achieve a maximum water cut of 0.5% v/v at the outlet. De-watered treated crude oil from Electrostatic Dehydrators (EDH) will then flows to the shell side of the heat exchanger to heat up the raw crude oil inlet stream.

The final desired outlet temperature of the treated crude oil to the storage tanks will be 75°C as per the design requirements of the storing and downstream export pump station.

Treated crude oil outlet from the shell side of the heat exchangers will be then routed to the Gas Boot to separate and release any remaining gas and hydrocarbon vapors in the crude oil.

Gas boot is operated at atmospheric pressure and the crude oil is finally directed to the Sales Oil Storage tanks by gravity.

Crude is then pumped from the storage tanks to the export pipeline using Sales Oil Booster pumps followed by metering using Custody Transfer Metering (CTM) downstream of the pumps and sent to the port export terminal via an export pipeline with specification of Basic Sediments and Water (BS&W) 0.5% by volume and Reid Vapor Pressure (RVP) of 11 psig. Produced water from Electrostatic Dehydrators (EDH) and Surge vessels is routed to the produced water handling system and burrow pits to reduce oil content to 10 parts per million (ppm) before sending to bioremediation.

Part of the final produced water is recycled by using recycling pumps to the crude processing system inlet to maintain a minimum water cut of ≥3.5% v/v in the raw crude oil for better performance of the Electrostatic Dehydrators (EDH).

Skimmed crude oil from produced water system is recycled back to the raw crude oil manifold to mix with the raw crude oil for re-processing.
Slop oil (interface content) from the Electrostatic Dehydrators (EDH) is routed to the slop oil system and then recycled back to the raw crude oil manifold to mix with the raw crude oil for re-processing.

Separated gases from surge vessels and Electrostatic Dehydrators (EDH) equipments is routed to the cold vent knock out drum and then to the cold vent stack for disposal to the atmosphere (CPF Operation Manual, 2006).

1.10 Central Processing Facilities (CPF) Plant Heat Exchangers Design Data

Heat exchangers in the Central Processing Facilities (CPF) are identical countercurrent shell & tube heat exchangers, TEMA type AES horizontal with one shell pass side and two passes of tube side connected in parallel series, its design code is ASME sec VIII dev. VI-TEMA with the following design and operating information and parameters:

1.11 Problem of Central Processing Facilities (CPF) Heat Exchangers Statement and Background

Central Processing Facilities was constructed to process and treat raw crude oil that coming from south Sudan oil fields. But after short time of operation the heat exchangers performance has deteriorated quickly and the heat transfer in these exchangers reduced which directly affects the performance of Electrostatic Dehydrators (EDH) that utilized to separate oil/water phase by using electric field, heating and chemical demulsifiers.

The current problems of heat exchangers in (CPF) originally are as following:

- The performance is very low, that due to the temperature difference between raw crude oil (cold stream) in the tube side and the treated crude oil (hot stream) is very low. That led to store and export crude oil with high temperature, more than 75°C the recommended operating temperature.

- Processing temperature to enhance oil/water separation is limited with such operation.

- In addition to the heat consumption heating in the crude oil heaters is high due to the low temperature of the raw crude.

Below two figures (1-7) and (1-8) were sketched to simplify the understanding and do simple comparison between required operating temperature approach and current operating temperature approach:
The required operating temperature approach referred to the as built recommended design data for Central Processing Facilities (CPF) heat exchangers. (CPF operation manual, 2006)

Current operating temperature approach is referred to the current operating temperature condition of Central Processing Facilities (CPF) heat exchangers. The temperature is average operating temperature (CPF operation manual, 2006).
1.12 Purpose and Objectives of the Case Study

The main purpose and objective of this case study is to carry out performance analysis of the shell and tube heat exchangers in the Central Processing Facilities (CPF) - Al-Jabalayn, in order to find and sort out the possible potential problem that affecting the performance of them, then to recommend necessary corrective action and advice on certain proven techniques of monitoring and improving the performance of crude/crude heat exchangers based on observed results of the analysis for the current operating data.

Following are the state objectives of this case study regarding to the reduction of the transferred heat between the raw crude oil (cold stream) in tube side and the treated crude oil (hot stream) at shell side.

A. To calculate the thermal parameters of heat exchanger and compare them with the design data, then to evaluate any significant deviations.

B. To analyze and find out the possible potential problems that caused the deterioration of crude/crude heat exchangers performance in CPF plant

C. To find appropriate solutions to increase efficiency of heat exchangers to achieve 75 ºC, the temperature required to store sales crude oil in the tank.
Chapter Two

2. Literature Review

The efficiency of the heat exchangers are depends on the how much heat transfer is done during the service. As the service life passes the heat transfer rate decreases and the efficiency as well. The dirt and the deposits in the process fluid tend to adhere to inner and outer surface of the shell and tube type heat exchanger tubes. This phenomenon is known as fouling of the heat exchanger.

In the performance analysis of heat exchangers, it is usually convenient to work with the logarithmic mean temperature difference (LMTD), which is an equivalent mean temperature difference between the two fluids for the entire heat exchanger. Overall heat transfer coefficient (U) that accounts for the contribution of all these effects on heat transfer. The rate of heat transfer between the two fluids at a location in a heat exchanger depends on the magnitude of the temperature difference at that location, which varies along the heat exchanger (Yunus A. Cengel, 2003).

This chapter provides an overview of the literature on the works carried out in the performance analysis of shell and tube heat exchangers for the thermal parameters and efficiency which are relevant for this study regarding different factors affecting the thermal efficiency of the shell and tube heat exchanger, On the basis of that a brief summaries were reviewed as follow:

Barinaadaa Thaddeus Lebele-Alawa et al, 2013 were studied Performance Evaluation of three Heat Exchangers units (2-E-2301, 3-E-901 and 3-E-401) in a Polyethylene Plant, Steady state monitoring and direct collection of data from the equipment in the plant were performed and the data were analyzed by using energy equations to determine the overall heat transfer coefficient, heat duty, temperature and pressure range of hot and cold fluids, capacity ratio and effectiveness so to evaluate performance of the heat exchangers, The results show that for 2-E-2301, the overall heat transfer coefficient is over 50 percent less than the design figure and the heat duty is over 75 percent than the design figure. For the 3-E-901 the heat duty and the overall heat transfer are over 75 percent less than the design figure which was traceable to fouling. This affected the effectiveness, capacity ratio and temperature range of the hot and cold fluid. For the 3-E-401, the heat duty was found to be
within the limit of design figure. The temperature difference in the hot fluid side and the
capacity ratio were within the limits of the design figure. Thus, the results show qualitative
performance evaluation of the heat exchangers. Arun Kumar Patel et al, 2018 their study
was investigated the thermal performance in a shell and tube heat exchanges first analyzed
the heat exchanger experimentally and find out parameters on which the performance of
heat exchanger is mainly depends. After analyzing experimentally it is found that the heat
transfer rate is mainly depend upon the mass flow rate of fluid and flow pattern of heat
exchanger. From the study it was concluded that the performance of heat exchanger is
depending on different parameter. It depends on the use, area availability, space required,
and rate of heat transfer and depends on the working fluid. In order to increase the
performance of heat exchanger different input parameters and boundary conditions were
enhance or optimize. In order to increase the heat transfer rate different flow pattern were
used.
Santhosh G.V.N et al, (2014) they have concerned with the study of shell and tube heat
exchanger with counter flow arrangement. Also the factors affecting the performance of
shell and tube heat exchanger is studied and its details discussion is given. Thermal analysis
is carried out considering various parameters such as baffle spacing, baffle inclination, flow
rates of hot and cold fluids, tube diameter etc. by using CFD. Similar studies were also
examined by MadhuriKumaria et al, 2017, studied Performance Analysis of Shell and Tube
Heat Exchanger using CFD package ANSYS16.0 then, and the boundary conditions are set
in fluent in order to get high efficiency. The objective is the design of shell and tube heat
exchanger and study the flow and temperature distribution inside the shell and tube using
ANSYS 16.0 software tool. The heat transfer capacity of heat exchanger is calculated using
mathematical modeling equations. It found that varying of flow rate and flow pattern result
in a significant increase in heat transfer coefficient per unit pressure drop in the heat
exchanger the effect of baffle spacing on pressure drop, heat transfer coefficient and overall
heat transfer coefficient is considered in a Shell and Tube Heat Exchanger with single
segmental baffles and staggered tube layout. The effects of baffle spacing are considered.
Shell and tube heat exchanger with single segmental baffles was designed with same input
parameters using Kern’s theoretical method and Bell-Delaware method.
Investigated performance of shell and tube heat exchanger to study shell and tube side
pressure drop and heat transfer coefficient by varying geometry, he found that the baffle
Spacing has an effect on pressure drop and overall heat transfer coefficient in a shell and tube heat exchanger with single segmental baffles and staggered tube layout. A study was carried out by Abubeker Negesa Gemeda, 2018. Durgesh Bhatt et al., 2012 studied Shell and Tube Heat Exchanger Performance Analysis involving the condition where different constructional parameters are changed for getting the performance review under different conditions. They developed an excel program for the ease of calculation. The results were obtained and it found that the baffle spacing and tube metallurgy are the parameters that effect on the heat transfer and heat transfer coefficient.

Ebieto C.E et al., 2012, presented performance analysis of shell and tube heat exchangers, a case study, the data of five different industrial heat exchangers from Port Harcourt Refinery was collected. He used an analytical method to develop correlation in MATLAB program to check for the thermal and hydraulic suitability of the heat exchangers and to test the reliability of MATLAB program for performance analysis of shell and tube heat exchangers. The study concluded the reliability and applicability of the program due to the obtained result were matching field data.

Arun Kumar Patel et al., 2018 studied Performance analysis of shell and tube type heat exchanger to enhance the heat transfer rate. He stated that the performance of heat exchanger is depending on different parameters. The design of heat exchanger depends on the use, area availability, space required, and rate of heat transfer and depends on the working fluid. In order to increase the performance of heat exchanger different input parameters and boundary conditions were enhance or optimize. In order to increase the heat transfer rate different flow patterns were used. In his analysis, it has first analyzed the heat exchanger experimentally and find out parameters on which the performance of heat exchanger is mainly depends. After analyzing experimentally it is found that the heat transfer rate is mainly depend upon the mass flow rate of fluid and flow pattern of heat exchanger. Experimental analysis is a time consuming process and also not a cost effective method. So to reduce the analysis cost, here it has developed the numerical model of heat exchanger and applies the computational fluid dynamic analysis to optimize different parameters. In the analysis, he was analyzed the cross flow pattern of heat exchanger and find the effect of different mass flow rate on cross flow pattern. After analysis it was found that as the mass flow rate increases the heat transfer rate increase, hence performance of heat exchangers increases.
Chapter Three

3. Materials and Methods

3.1 Materials

The materials used in this study are as following:

- Heat exchangers units.
- Local gauges.
- Transmitters.
- Digital Density Analyzer
- Raw and Treated Crude Oil.
- PC with installed MS office excel program
- CPF Shell and Tube Heat Exchangers Design and Operation Data Sheet, See Table (3-1) and Table (3-2)


| Aljabalyan Central Processing Facilities CPF Shell & Tube Heat Exchangers Data Sheet: |
| Design & Construction Code: ASME VIII, Dev. VI 2001+2003, TEMA 8th ED. | |
| Manufacturer PT. Indonesia | |
| TEMA Type: AES 1400 X 8000, Straight | |
| Surface Area: 1356 m² | |
| Number of Tubes = 2832 Tubes, tube diameter 16-20 mm, Pattern: Triangular | |
| Fluid Allocation | Shell Side | Tube Side |
| Fluid Name | IN | OUT | IN | OUT |
| Treated Crude Oil | 138333 | 154222 | |
| Raw Crude Oil | 105 | 75 | 45 | 70 |
| Design Temperature (°C) | 867.9 | 890.3 | 921 | 901.9 |
| Density (kg/m³) | 18 | 60 | 667 | 107 |
| Viscosity (CP) | 411.5 | 486.6 | |
| Design Pressure (kPa) | 28.3 | 150 | |
| Pressure kPa | 1 | 2 |
| No. of passes (shell-Tubes) | 3.0 | 3.0 |
| Corrosion Allowance (Shell/Tube) (mm) | | |
Table (3-2): Shell and Tube Heat Exchangers Operating Data

<table>
<thead>
<tr>
<th>Operating Parameters</th>
<th>Shell side</th>
<th>Tube side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid</td>
<td>Hot Treated</td>
<td>Crude Raw Crude</td>
</tr>
<tr>
<td>Operating Temperature (in/out)</td>
<td>105 - 75 °C</td>
<td>40 – 70°C</td>
</tr>
<tr>
<td>Operating Pressure (min/max)</td>
<td>175 – 725 kPa</td>
<td>525 – 725 kPa</td>
</tr>
</tbody>
</table>

3.2 Methods

Monitored data and reading of steady state parameters of the individual heat exchangers under evaluation were collected from Distribution Control System (DCS) in Central Processing Facilities (CPF) Central Control Room’s (CCR) console, local gauges and transmitters.

The collected and measured data included:

1. Inlet flow rates of shell and tube side of each heat exchanger.
2. Temperature of hot and cold streams of each heat exchanger.
3. Streams pressure of each heat exchanger.

The readings of flow rate, streams temperature and streams pressure of raw and treated crude oil were shown in table (3-3).

Samples of raw and treated crude oil were collected from inlet and outlet of each of heat exchanger used to determine the density and specific heat of raw and treated crude. The density has been measure in all required temperature degrees by using digital density meter analyzer apparatus by method ASTM D5002. Specific heat collected from plant hand book. Table (3 - 4) is showing density and specific heat of raw and treated crude oil

So in to achieve the overall objective and purpose of the case study the Logarithmic Mean Temperature Difference (LMTD) has been used, all required applicable equations and essential assumptions in this method for heat exchangers analysis have been used and tracked step by step to do performance analysis for the nine heat exchangers, the required data and calculation method has been developed in ms excel program sheet with necessary and all required equation.
### Table (3 - 3): Readings of Flow Rate, Streams Temperature and Streams Pressure of Raw and Treated Crude Oil

<table>
<thead>
<tr>
<th>Heat Exchangers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Treated crude oil flow, ( m_h )</strong></td>
<td>m³/hr</td>
<td>55</td>
<td>55</td>
<td>51</td>
<td>51</td>
<td>58</td>
<td>58</td>
<td>56</td>
<td>56</td>
</tr>
<tr>
<td><strong>Raw crude oil flow, ( m_c )</strong></td>
<td>m³/hr</td>
<td>58</td>
<td>58</td>
<td>49</td>
<td>49</td>
<td>67</td>
<td>67</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td><strong>Treated crude oil Temperature, ( T_h )</strong></td>
<td>°C</td>
<td>104</td>
<td>90</td>
<td>104</td>
<td>90</td>
<td>105</td>
<td>92</td>
<td>105</td>
<td>92</td>
</tr>
<tr>
<td><strong>Raw crude oil Temperature, ( T_c )</strong></td>
<td>°C</td>
<td>45</td>
<td>52</td>
<td>45</td>
<td>52</td>
<td>45</td>
<td>52</td>
<td>45</td>
<td>54</td>
</tr>
<tr>
<td><strong>Shell side Pressure, ( P_h )</strong></td>
<td>kPa</td>
<td>343</td>
<td>185</td>
<td>287</td>
<td>185</td>
<td>286</td>
<td>185</td>
<td>285</td>
<td>183</td>
</tr>
<tr>
<td><strong>Tube side Pressure, ( P_c )</strong></td>
<td>kPa</td>
<td>440</td>
<td>368</td>
<td>500</td>
<td>352</td>
<td>523</td>
<td>360</td>
<td>521</td>
<td>337</td>
</tr>
</tbody>
</table>
### Table (3 - 4): Density and Specific Heat of Raw and Treated Crude Oil

<table>
<thead>
<tr>
<th>Heat Exchangers</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit</strong></td>
<td>In</td>
<td>Out</td>
<td>In</td>
<td>Out</td>
<td>In</td>
<td>Out</td>
<td>In</td>
<td>Out</td>
<td>In</td>
</tr>
<tr>
<td><strong>Treated Crude Oil Density, $\rho_h$</strong></td>
<td>846.5</td>
<td>852.75</td>
<td>846.5</td>
<td>855.2</td>
<td>845.5</td>
<td>855.2</td>
<td>847.5</td>
<td>851.9</td>
<td>846.5</td>
</tr>
<tr>
<td><strong>Raw Crude Oil Density, $\rho_c$</strong></td>
<td>891.8</td>
<td>890.8</td>
<td>891.8</td>
<td>890.8</td>
<td>891.8</td>
<td>890.8</td>
<td>891.8</td>
<td>890.2</td>
<td>891.8</td>
</tr>
<tr>
<td><strong>Treated Crude Oil Specific Heat, $C_{ph}$</strong></td>
<td>1.921</td>
<td>1.801</td>
<td>1.921</td>
<td>1.801</td>
<td>1.921</td>
<td>1.801</td>
<td>1.921</td>
<td>1.801</td>
<td>1.921</td>
</tr>
<tr>
<td><strong>Raw Crude Oil Specific Heat, $C_{pc}$</strong></td>
<td>1.948</td>
<td>2.044</td>
<td>1.948</td>
<td>2.044</td>
<td>1.948</td>
<td>2.044</td>
<td>1.948</td>
<td>2.044</td>
<td>1.948</td>
</tr>
</tbody>
</table>
3.3 Determination of the Thermal Parameters for Shell and Tube Heat Exchanger

To carry out calculation of the thermal parameters for exchanger heat transfer, a set of assumptions were introduced below so that applied formulas and equation would be simple enough for the analysis so that to evaluate the overall heat transfer coefficient $U$ the assumptions were (Ramesh K. Shah et al, 2003):

a) The energy balances, rate equations, boundary conditions, and subsequent analysis
b) The heat exchanger operates under steady-state conditions.
c) Heat losses to or from the surroundings are negligible (i.e. the heat exchangers outside walls are fully insulated (adiabatic)).
d) There are no thermal energy sources or sinks in the exchangers walls or fluids, such as electric heating, or chemical reaction.
e) Wall thermal resistance is distributed equally in the entire exchangers.
f) Either there are no phase changes (condensation or vaporization) in the Crude oil streams flowing through the shell and tube.
g) Longitudinal heat conduction in the fluids and in the wall is negligible.
h) The individual and overall heat transfer coefficients are constant throughout the exchangers, including the case of phase-changing fluids in assumption (e).
i) The specific heat of raw and treated crude oil in the two streams is constant throughout the exchanger, so that the heat capacity rate on each side is treated as constant.
j) The heat transfer surface area $A$ is distributed constantly on each fluid side.
k) The velocity and temperature at the entrance of the crude/crude heat exchangers on each fluid side are uniform over the flow cross section. There is no gross flow misdistribution at the inlets.
l) The raw and treated crude oil flow rates are uniformly distributed through the exchangers on each side in each pass i.e., no passage-to-passage or viscosity-induced misdistribution occurs in the exchangers center. Also, no flow stratification, flow bypassing, or flow leakages occur in any stream. The flow condition is characterized by the bulk (or mean) velocity at any cross section.
3.3.1 Determination of Heat Duty:

\[ Q = mC_p\Delta T \]  

(1)

3.3.1.1 Heat Duty Of Hot Stream (Treated Crude Oil):

\[ Q = m_h * C_{ph} * (T_{hi} - T_{ho}) \]  

(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

3.3.1.2 Temperature Range of Hot Stream (Treated Crude Oil):

\[ \Delta T_h = T_{hi} - T_{ho} \]  

(3)

3.3.1.3 Heat Duty of cold stream (Raw Crude oil):

\[ Q = m_c * C_{pc} * (T_{CO} - T_{Ci}) \]  

(4)

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

3.3.1.4 Temperature Range for Cold Stream (Raw Crude Oil)

\[ \Delta T_C = T_{CO} - T_{Ci} \]  

(5)
3.3.2 Log Mean Temperature Difference (LMTD)

3.3.2.1 The Log-Mean Temperature Difference (LMTD) defines as:

\[
\Delta T_{LMTD} = \frac{(T_{hi} - T_{co}) - (T_{ho} - T_{ci})}{\ln \left( \frac{(T_{hi} - T_{co})}{(T_{ho} - T_{ci})} \right)} \tag{6}
\]

Where:

\(\Delta T_{LMTD}\): 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

3.3.2.2 The Corrected Log Mean Temperature Difference (LMTD)

\[
\Delta T_m = F \times LMTD \tag{7}
\]

Where \(F\) is correction factor and it have been expressed by the following equation which is derived by Kern, [3]:

\[
F = \frac{(R + 1)^{0.5} \times \ln \left( \frac{1 - SR}{1 - S} \right)}{(1 - R) \times \ln \left( \frac{2 - S(R + 1 - (R + 1)^{0.5})}{2 - S(R + 1 + (R + 1)^{0.5})} \right)} \tag{8}
\]

Where:

\(R\): Capacity Ratio
\(S\): Thermal Effectiveness

Also correction factor \(F\) could be found from figure (3-1) shown in the appendices

3.3.2.3 Capacity Ratio, \(R\)

\[
R = \frac{(T_{hi} - T_{ho})}{(T_{co} - T_{ci})} \tag{9}
\]

Where:

\(T_{hi}\): Inlet Temperature of Hot Stream, °C
\(T_{ho}\): Outlet Temperature of Hot Stream, °C
\(T_{co}\): Outlet Temperature of Cold Stream, °C
\(T_{ci}\): Inlet Temperature of Cold Stream, °C
3.3.2.4 Thermal Effectiveness, S

\[ S = \frac{(T_{co} - T_{ci})}{(T_{hi} - T_{ci})} \]  

(10)

\( T_{co} \): Outlet Temperature of Cold Stream, °C
\( T_{ci} \): Inlet Temperature of Cold Stream, °C
\( T_{hi} \): Inlet Temperature of Hot Stream, °C

3.3.3 Overall Heat Transfer Coefficient (U) Calculation

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:

\[ U = \frac{Q}{A \cdot \Delta T_m} \]  

(11)

Where:
\( Q \): Heat Transfer Duty, W,
\( U \): Overall Heat Transfer Coefficient, W/m² °C,
\( A \): Heat Transfer Area, m²,
\( \Delta T_m \): Mean Temperature Difference, °C.

3.3.4 Streams Pressures Drop Calculation:

Inlet and outlet pressures of raw crude oil stream (cold) which is flowing in tube side, and inlet & outlet pressures treated crude oil stream (hot) which is flowing through shell side of the heat exchanger was recorded in the below table and it has been used to calculate the pressure drop in each stream as following:

3.3.4.1 Hot Stream (Treated Crude Oil)-Shell Side Pressure Drop, kPa

\[ \Delta P_h = P_{hi} - P_{ho} \]  

(12)

Where:
\( P_{hi} \): Inlet pressure of hot stream
\( P_{ho} \): Outlet pressure of hot stream

3.3.4.2 Cold Stream (Raw Crude Oil)-Tube Side Pressure Drop, kPa

\[ \Delta P_c = P_{ci} - P_{co} \]  

(13)

Where:
\( P_{ci} \) and \( P_{co} \): Inlet and Outlet pressure of cold stream
Chapter Four

4. Results and Discussion

4.1 Results

Performance analysis of the shell and tube heat exchangers in the Central Processing Facilities (CPF) was carried out by using LMTD method to determine thermal parameters and overall heat transfer coefficient. The equations and formulas used in the methodology were developed in MS excel sheet. Following tabulated results were obtained for each of individual heat exchanger from (1 to 9) then it’s were compared with the design data.
<table>
<thead>
<tr>
<th>Thermal Parameters</th>
<th>Heat Exchangers Calculated Results</th>
<th>Design Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heat Duty (W)</td>
<td>338190.9 224174.5 320477.1 338479.5 160689.0 156811.4 279739.6 302873.2 147430.9 2353999.4</td>
<td></td>
</tr>
<tr>
<td>Shell Side Pressure Drop $\Delta P_h$ (kPa)</td>
<td>101 108 105 102 98 101 101 102 108 100</td>
<td></td>
</tr>
<tr>
<td>Tube Side $\Delta P_c$ (kPa)</td>
<td>172 148 188 184 204 187 156 161 196 150</td>
<td></td>
</tr>
<tr>
<td>Shell Side $\Delta T_h$ (°C)</td>
<td>14 10 13 14 6 7 12 13 7 30</td>
<td></td>
</tr>
<tr>
<td>Tube Side $\Delta T_c$ (°C)</td>
<td>7 7 7 9 8 8 7 10 9 25</td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>2 1.43 1.86 1.56 0.75 0.88 1.71 0.00 0.78 1.20</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>0.12 0.12 0.12 0.15 0.14 0.14 0.12 0.17 0.15 0.42</td>
<td></td>
</tr>
<tr>
<td>$U$ (W/m².K)</td>
<td>5.20 3.29 4.76 5.31 2.33 2.30 4.20 4.61 2.14 61.74</td>
<td></td>
</tr>
</tbody>
</table>
Comparison of the Calculated Results with the Design Date for the Nine CPF Heat Exchangers

Heat Duty of Heat Exchangers

![Heat Duty of Heat Exchangers](image)

Figure (4-1): Heat Duty of Heat Exchangers

Shell Side Pressure Drop

![Shell Side Pressure Drop](image)

Figure (4-2): Shell Side Calculated Pressure Drop Vs Allowable Pressure Drop
Heat Exchangers

Figure (4-3): Tube Side Calculated Pressure Drop Vs Allowable Pressure Drop

Figure (4-4): $\Delta T$ of Shell Side vs $\Delta T$ as per Design Recommended Data
**ΔT of Tube Side vs ΔT as per Design Recommended Data**

- **Temperature (°C)**
- **Heat Exchangers**
- *Figure (4-5): ΔT of Tube Side vs ΔT as per Design Recommended Data*

**Calculated Capacity Ratio (R) vs Capacity Ratio (R) as per Design Recommended Data**

- **Capacity Ratio (R)**
- **Heat Exchangers**
- *Figure (4-6): Calculated Capacity Ratio (R) vs Capacity Ratio (R) as per Design Recommended Data*
Figure (4-7): Calculated Thermal Effectiveness (S) vs Thermal Effectiveness (S) as per Design Recommended Data

Figure (4-8): Calculated Overall Heat Transfer Coefficient (U) vs Overall Heat Transfer Coefficient as per Design Recommended Data
4.2 Discussions

The performance analysis for heat exchanger was done by LMTD method via all applicable equation and formulas as they stated in the methodology of calculation. Thermal parameters calculations of the heat exchangers were done by developing MS excel calculation sheet, the outcome results were shown in the tables and presented in the charts as well. Followings were the discussions on the obtained results:

1. Referring to the results in table (4-1), the calculated heat duties (w) were found as (338190.9), (224174.5), (320477.1), (338479.5), (160689.0), (156811.4), (279739.6), (302873.2), and (147430.9) for heat exchangers from 1 to 9 respectively which are individually very low when compared with (2353999.4) value of the heat duty as per the recommended design data. See figure (4-1). The deviation range of the calculated heat duties from the heat duty of the recommended design data could be due the temperature difference ($\Delta T$) of inlet and outlet of hot stream. Also, there could be due to the current differences of inlet and outlet mass flow rate of hot and cold streams.

2. In reference to the table (4-1), the value of pressure drop for both tube and shell sides of all heat exchangers from 1 to 9 are slight increased. See figure (4-2) and figure (4-3) for comparison. Increased of pressure drop is indication of dirt and blockage occurrence inside the tubes.

3. There was considerable deviation in the temperature differences ($\Delta T$) ranges, values for both shell and tube side inlet and outlet temperatures. See figure (4-4) and (4-5). This considerable deviation is an indication of lack of proper heat transfer, which could be due to the scale deposits and accumulation inside the tubes of these heat exchangers which led to the fouling occurrences.

4. Referring to table (4 - 1) the calculated values of thermal effectiveness (S) for these heat exchangers are ranged from (0.12 - 0.17). Comparing with (0.42) the value of thermal effectiveness as per design recommended data. The calculated values were very less than the design value. See figure (4-7).

5. Referring to the capacity ratio R. the obtained results values were (2), (1.43), (1.86), (1.56), (0.75), (0.88), (1.71), (0.00), and (0.78) comparing with (1.20).

6. The calculated values of overall heat transfer coefficient (U) (W/m².K) of the heat exchangers from 1to 9 are: (5.20), (3.29), (4.76), (5.31), (2.33),(2.30), (4.20), (4.61) and
these values were considered very low comparing with (61.74) the value of overall heat transfer coefficient (U) (W/m².K) as per designed recommended data; the values were decreased due to increased fouling that has resulted in minimized active area of heat transfer. See figure (4-8). Decreased value of overall heat transfer coefficient U is an indication of decreased of heat exchangers performance.
Chapter Five

5. Conclusions and Recommendations

5.1 Conclusion

This dissertation has considered the overall heat transfer coefficient, heat duty, capacity ratio, and effectiveness as applicable parameters for the evaluation of the heat exchanger performance analysis with steady state monitoring and direct collection of data from these heat exchangers in the CPF. The obtained results were compared with the heat exchangers design data and this provided performance analysis of these heat exchangers.

On the basis of the above analysis for the shell & tube heat exchangers in the CPF it is clear that a lot of factors affect the performance of these heat exchangers that through the calculated value of the overall heat transfer coefficient $U$. First it observed that, from the analysis results as it shown in table (4-1), mass flow rates in shell and tube sides has great affects on the value of heat duty of these exchangers. The temperature ranges of inlet and outlet streams is from 6 to 14 °C in shell side and 7 to 10 in tube side which are very less compared with 25 and 30°C respectively the recommended design temperature this drop in temperature ranges is due to the lack of proper heat transfer as result of fouling occurrence which led to lower the performance of heat exchangers. As well as slight increasing value of pressure drop, mainly in tube side (> 1.0 bar) is as a consequence of dirt and blockage is expected inside the tubes of these exchangers. All mentioned factor has negative effects on the performance of these heat exchangers that led to store and export crude oil with high temperature, more than 75°C the recommended operating temperature as per design in addition to the rest of the problems in this dissertation.

5.2 Recommendations

Heat exchangers are very important part of the process in the Aljabalyan CPF in which they are installed in terms of heat transfer within the plant. As such, in order to maintain them at high efficient level following were the recommendations set according the study results:

1. To perform an urgent mechanical or chemical cleaning as troubleshooting process for all under analysis study heat exchangers due to they are classified fouled exchangers.

2. Routine cleaning and inspection must be carried out frequently to avoid any blocking or diameter reduction that may occur due to the scale deposits and dirt accumulation.
inside the tubes causing fouling.

3. To record temperature, flow rates and pressure on daily basis for all individual heat exchangers, so that precise factor associated with low performance can be identified easily while doing performance analysis of these heat exchangers.

4. To determine overall heat transfer coefficient (U) for these heat exchangers quarterly from the daily recorded data, then to develop a plots of overall heat transfer coefficient U versus time/date so that to permit plan of cleaning program.

5. To keep all overall heat transfer coefficient U records as a history of observation. This would be a fairly rigorous method of monitoring the heat exchanger performance.

6. It is necessary to assess periodically the heat exchanger performance in order to maintain them at a high performance level.

7. It recommended installing air cooler, water cooler or chilled water cooler downstream heat exchangers so as to control the temperature of stored crude oil at 75 ºC.

8. The test and evaluation of the performance of the heat exchangers is carried out by measurement of operating parameters upstream and downstream of the each heat exchanger. Due care needs to be taken to ensure the accuracy and correctness of the measured parameter. The instruments used for measurements required calibration and verification periodically to keep them in high accuracy level.

5.2.1 Further Recommendations

1. It is highly recommended to study and review the design of these heat exchangers in central processing facilities (CPF) with the use of the Kern’s technique, by the use of Commercial Computational Fluid Dynamics (CFD) software, or for the simulation by using Aspen HYSYS software.

2. To review that design by considering the current Dar-Blend crude oil specification.
REFERENCES


Appendix-1: Central Processing Facilities (CPF) Simplified Scheme
Appendix-2: Heat Exchangers in the Central Processing Facilities (CPF)

Appendix-3: Heat Exchangers in the Central Processing Facilities (CPF)
Appendix-4: Heat Exchangers in the Central Processing Facilities (CPF)
Appendix-5: LMTD Correction Factor for 1-2 Heat Exchangers

Appendix-5: LMTD Correction Factor for 1-2 heat exchangers, (Holman J. P. et al, 2010)