MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

A comprehensive hazard and operability study in a crude oil refining factory: A case study in Afghanistan

AHMAD FAWAD MIAZADA

MASTER THESIS

Department of Chemical Engineering

Thesis Supervisor
Doc. Dr. Gökçen ÇİFTÇİOĞLU

ISTANBUL, 2020

MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES

A comprehensive hazard and operability study in a crude oil refining factory: A case study in Afghanistan

AHMAD FAWAD MIAZADA

(524517911)

MASTER THESIS

Department of Chemical Engineering

Thesis Supervisor

Doc. Dr. Gökçen ÇİFTÇİOĞLU

ISTANBUL, 2020

PREFACE

In this study, the current working condition of a crude oil refining factory was investigated. Operational Hazards are identified using HAZOP methodology. To define the importance of HAZOP, all greenhouse gas emissions during a normal work of the production are calculated and compared with an abnormal situation or while an accident happens.

ACKNOWLEDGMENT

I would like to thanks my thesis supervisor Doç. Dr. Gökçen Alev ÇİFTÇİOĞLU for her support and faith in me during this thesis.

TABLE OF CONTENTS

ABSTRACT

A comprehensive hazard and operability study in a crude oil refining factory: A case study in Afghanistan

This study assessed all existing hazards in a crude oil refining factory located in Afghanistan. Cause, deviations, required actions are identified. In addition, greenhouse gas emissions (GHG) of the oil production in its normal working condition is calculated and compared with the GHG release during the accidents to show the importance of HAZOP to have a safe work and safe environment. Since, HAZOP, identifies the importance of an effective management system to help planners, managers, specialists, and operators to achieve a high standard in preventing risks and having a safe environment. Also, accidents that happened due to weak risk management of the factory, are investigated. Generated greenhouse gas emissions during production and consequences are calculated and compared which showed that, the environmental impacts of accidents are 10 times more than the daily impacts of crude oil production.

ÖZET

HAM PETROL RAFİNERİSİNDE TELİKE VE İŞLETEBİLİRLİK ÇALIŞMASI: Afganistan da vaka incelemesi

Bu çalışma Afganistan'da bulunan bir ham petrol arıtma tesisinde mevcut tüm tehlikelerini değerlendirmaktadir. Nedenler, sapmalar, gerekli eylemler tanımlanmış.Ayrıca, HAZOP'un güvenli bir çalışma ve güvenli bir ortama sahip olmasının önemini göstermek için, Petrol üretiminin normal çalışma koşullarında Sera gazı emisyonları (GHG) hesaplayıp ve kazalar sırasında sera gazı salınımı ile karşılaştırırılmakta. HAZOP, planlamacılara, yöneticilere, uzmanlara ve operatörlere riskleri önlemede ve güvenli bir çevreye sahip olmalarında, yüksek bir standart elde etmelerinde yardımcı olup, etkili bir yönetim sisteminin önemini belirlemekte. Ayrıca fabrikanın zayıf risk yönetimi nedeniyle meydana gelen bazı kazalar da araştırılmış olup üretim sırasında ortaya çıkan sera gazı emisyonları, ve kazalar sonucunda sera gazı emisyon miktarlarını karşılaştırdığında, ortaya çıkan sonuç kazaların çevresel etkilerini 10 kat daha fazla olduğunun göstermesi, HAZOP'ün önemini yansıtmıştır.

SYMBOLS

% Percentage

K_1 Distillation column

K_2 Distillation column

K_3 Distillation column

F_1 Furnace

F_3 Furnace

C_1 Separator

C_2 Separator

T_1 Heat exchanger (diesel and crude oil)

T_2 Heat exchanger (diesel and crude oil)

T_3 Heat exchanger (Mazut and crude oil)

T_4 Heat exchanger (Mazut and crude oil)

KX_1 Heat exchanger (gasoline and water)

KX_{1A} Heat exchanger (gasoline and water)

KX_2 Heat exchanger (gasoline and water)

KX_{2A} Heat exchanger (gasoline and water)

X_3 Heat exchanger (Diesel and water)

X_4 Heat exchanger (Diesel and water)

X_7 Heat exchanger (Mazut and water)

X_{7A} Heat exchanger (Mazut and water)

ABBREVIATIONS

AFPM : American Fuel and Petrochemical Manufacturers

AIChE : American Institute of Chemical Engineers

API : American Petroleum Institute

ATEX : Atmospheres Explosives

BP : British Petroleum

CAT : Category

CCPS : Center for Chemical Process Safety

CCTV : Closed Circuit Television

CIA : Association of Chemical Industries

CMA : Chemical Manufacturers Association

ER : Emergency Response

ERTAO: Response Team is available onsite

ESD : Emergency Shutdown

ESDV : Emergency Shutdown Valve

FCV : Flow Control Valve

FMEA : Failure mode and effects analysis

FR-PPE: Flame Retardant Personal Protected Equipment

FTA : Fault tree analysis

LCA : Life Cycle Assessment

HAZOP: Hazard and operability study

HSE : Health Safety and Environment

HV : Hand Valve

HVAC : Heating, Ventilation and Air Conditioning

ISOM : Isomerization1

ICSS : Integrated Control and Safety System

IECEx : International Electro technical Commission System for Certification to Standards Relating to Equipment for Use in Explosive Atmospheres

ILO : International Labor Organization

FCC : Fluid catalytic cracking

ISO : International Organization for Standardization

GHG : Greenhouse gas

MAOP : Maximum Allowable Operating Pressure

WMO : World Meteorological Organization

MOL : Main Oil Line

TOE : Ton of Oil Equivalent

OHS : Occupational Health and Safety

ORC : Operational Resource Consultants

OSHA : Occupational Safety and Health Administration

PCV : Pressure Control Valve

PIG : Pipeline Inspection Gauge

PPE : Personnel Protective Equipment (PPE)

PSM : Process Safety Management

PSV : Pressure Safety Valve

CSB : Chemical safety and hazard investigation board (CSB)

P&ID : Piping and Instrumentation Diagram

RBPS : Risk Based Process Safety

RR : Risk Ranking

S : Severity

MOC : Management of change

SIL : Safety Integrated Level

SIS : Safety Instrumented System

UK : United Kingdom

ESP : Electrostatic Precipitator

LCIA : Life cycle impact assessment

LCI : Life cycle inventory

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Sustainability is an essential concept to protect the earth, protect the resources and future generation needs. In the twenty-one century, sustainable management of technology is very important, because it offers a situation where humans can live with properly using natural benefits of the environment [1].

World Meteorological Organization (WMO) reported so far that greenhouse gas concentration in the atmosphere has reached 407.8 PPM in 2018, whereas on 2017 was 405.5 PPM, which means that upcoming generations will be the witness of more and more dangerous impacts of the greenhouse gas, including increasing temperatures, more dangerous weather, water stress, sea-level rise and disruption to marine and land ecosystems. There are multiple indications that the increase in the atmospheric levels of CO_2 are related to fossil fuel combustion. The harm and dangers of global warming warn to reduce GHG emissions more and more, and efficient actions should be taken by stakeholders to work on reducing GHG emissions [2].

Global warming is one of the most important anxiety of the environment in our lifetime. With the growing attention on global warming, understanding the main drivers of GHG emissions are important [3]. The newly issued data on GHG emissions shows that the petroleum sector emit significantly more GHG pollution than before [4-5]. If it is a need to reduce greenhouse gas emissions and combat climate change, we need more control over the pollution of petroleum production. Recognizing this need, the LCA study of crude oil production can guide the emission reduction actions and helps to have sustainable production. LCA skills and methods help to make decisions about the manufacturing, usage, and disposal of a product. It offers essential data about the life cycle of the product to easily bring changes in economic or environmental perceptions [6].

Since crude oil can’t be used directly, it is being refined to useful products, which are used in several technologies for human needs; engines, electricity generators, etc. crude oil is being used because of its efficiency, ready-made and well-established technology which it has been used and processed for more than a century. We can’t ignore that it is one of the most important causes of global warming with a risky production, and however, it is none renewable. Thus, switching to another energy source would mean completely changing the way we impact the environment by changing the way we live and the way we understand energy [7].

In crude oil refineries, crude oil separates into light fuels using the distillation process, which works with distillation towers, pumps, furnaces, and heat exchangers. Thus, with all these equipment and existing of temperature and pressure with flammable liquid and gases, it is a hazardous process, like equipment falling, fire, explosion, human error, noise, and toxicity are the possible hazards that can happen due to deferent causes. To prevent these threats or reduce the risk possibilities, a comprehensive risk assessment needs to be conducted. In loading crude oil from storage into tankers and unloading from tankers to storage and in all processes, it needs pumps, pipes, and valves and one side automatic valves [6]. And it is more important, that how to install the pumps and where must to install how must be its quality and also pips and valves quality and usability in crude oil because crude oil is very toxic and harmful to the environment [7]. And all pumps have to be carefully handled and analyzed to avoid the potential incidents that can affect staff, assets, and the environment. Therefore, industrial processes and plants increasingly experience concern to reduce those potential incidents. The main objective in a risk assessment is to avoid these potential accidents inside and outside the plants, such as fires, explosions, equipment damages, protection of production and property and, more than that, avoiding life risk or personal health damages, and catastrophic impacts to the community by producing corrective and preventive actions [3].

One of the most worldwide used method to define the risk and hazard is, hazard and operability (HAZOP), which is the technique for identifying present hazards in a plant or process and the techniques for assessing those hazards for deciding how far we ought to go in removing the hazards or protecting people from them. It developed in 1960 and it started being used as a hazard identifying technique in 1977 which was encouraged and developed by chemical industries association (CIA) to make the processes and operations safe [8].

HAZOP analysis done by a HAZOP team that forms with all professional workers of the factory in several meetings. It operates the mind of team members to imagine intentions, deviations, causes, and hazards in which a terminal can fail, mal-operate and accident happens. Each part of the plant is subjected as a node and for each node, the number of questions with guide words are given which are resulting from the HAZOP methodology. This usually produces possible deviations in a node and all causes for each deviation and the probability of the consequence which will happen [9].

The basic concept of HAZOP is to have a complete review of the plant layout and P& ID. It highlights the hidden operability problems which are likely to result from the expected intention of seemingly safe components or methods of operation. Also, it motivates the imagination and procedure for creating new and efficient ideas. Considering the control, strategy, material properties, options of design, operation and maintenance options, and the potential duty of HAZOP is, identifying and evaluate many risks, to determine poor system reliability and to provide qualitative recommendations [10].

In this thesis, all existing potential hazards in a crude oil refining factory are analyzed comprehensively to identify the probability of all consequences. Therefore it aims to find the undesired events and hazards to reduce incidents with pointing ways and reactions. Moreover, to describe the importance of HAZOP, the life cycle of oil production is realized to find daily CO_2 release to the atmosphere during the normal process to compare it with CO_2 release during an accident. The methodology is applied using cradle to gate approach where it takes into account the steps starting from extraction, transportation, and process. Required data for each step analysis after LCA calculations GHG emissions were acquired. The outputs were then interpreted to find out overall GHG emissions as well as every individual step's burden on the environment. Thus, the highest impact on the environment can be also pointed out. It was found that the process step had the highest GHG emissions and the transportation step had the lowest GHG emissions. And total daily CO_2 release was found 10 times less than CO_2 released during an accident.

To show the importance of the HAZOP study in having a safe production, we can point to Tosco Corporation's Avon oil refinery accident which happened in 1999, in the refinery while replacing a pipe attached to the fractionator tower during operation by workers. The flame surrounded 5 employees positioned on different floors on the tower. 1 of them injured and 4 others were killed. Within an investigation, the U.S chemical safety and hazard investigation board (CSB) found that flammable and toxic gases hazards will be found during oil refinery maintenance. To prevent their harm to staff and the environment, it should be operated carefully. The reasons that were found in Avon; occupations weren't planned, hazard identification and assessment weren't done, unit shutdown decision making, management oversight, permitting and line breaking, corrosion controller and mechanical reliability, and management of change (MOC) [11].

1.1. Purpose of The Thesis

The continuously increasing of the world population and technological needs, energy consumption dramatically increases in the world. The most used energy source, even though new investments are made to renewable energy sources, is still the petroleum crude oil. Because of the continuous increase in demand, crude oil refining factories are the priority and the factory's priority is its staff and property's safety. As the world population and technology needs to grow, energy consumption in the world increases significantly. Even if new investments are made for renewable energy sources, the largest energy source is still crude oil. Due to the constantly increasing demand, crude oil production is one of the most important industries [4].

Since crude oil is a significant worth to economic and general use, it is one of the most dangerous industries that must be operated safely with great attention. The most primary refining is atmospheric refining and it has many risks; greenhouse gases, leak oil to the environment, explosion due to overpressure in distillation columns, explosion due to over temperature in furnaces, toxic gas effects on staff due to working on-site, Fire, etc. [5].

HAZOP is one of the most used international techniques when HAZOP is applied to a crude oil process. It classifies the actions in the plant according to the risk. It uses primary and secondary keywords that are chosen according to the process. Once the risk scenarios are generated using HAZOP the most important action is to provide quantified risk values.

Thus, we aim to analyze one crude oil refining factory according to the HAZOP process. And show the importance of HAZOP by studying GHG released during the life cycle of oil production and investigate some accidents.

1.2. Method of Thesis

The studies in the literature related to a crude oil refinery were examined, and the HAZOP study selected as the method of determining the risks of process accidents. The application was carried out in two stages in the crude oil refinery, which is located in Afghanistan. In the first stage, GHG release during the normal process and abnormal process identified using LCA, then possible Hazards were identified using HAZOP methodology which will be explained further down.

1.3. General information

1.3.1 Hazard

Probability of a consequence called hazard, which can cause harm to the environment, people and property. And risk is the probability of a damage or hazard within the time. Hazards can be defined as mechanical, natural, chemical, and environmental hazards. Also, a hazard can be measured as a group of process conditions, which together with other conditions in the environment, will cause an accident [12].

For example, a flammable gas leak from a capsule to the atmosphere will create an explosive mixture in the atmosphere and it will ignite in contact with an ignition source. Thus, all ignition sources should be removed from there and especially smoking is prohibited in such a place [13].

1.3.2. Safety

It is a safe side where, the hazard percentage is near zero, or the place in which the hazards are identified and the protection forms are all covered [12].

1.3.3. Crude oil production

Before the appearance of gasoline in the late nineteenth century, petroleum products were being used for the basic needs as; lighting, cooling, and heating. After first well with a depth of 69 m with Colonel Edwin in Pennsylvania, his investors were excited. By offering a similar crude oil product, they had the chance to compete with whale oil in the lighting market. Before kerosene was recovered, gasoline and naphtha were generally considered waste, and were often "vented". Sometimes refineries burn only light materials in pits or throw them into streams to get rid of it. It didn't take long for refiners to realize that heavy crude oil could be used as fuel to upgrade steam and heat buildings. Bulk separation of these various products from crude oil was continued for 30 years after the discovery of crude oil. And it worked boringly each time of the crude oil tank. The batch processing operation essentially consisted of a tank in which the oil was heated and evaporated, and a condenser to convert the vapor into liquid. Since about 1900, refineries have been secretly rotating these tanks, which are called a continuous intensive process and still use an energy-intensive separation method. Fractional distillation, which uses distillation columns with trays used worldwide [14].

1.3.4. Refinery

Crude oil is a multipart mixture of hydrocarbons continuing from methane to bitumen, with varying amounts of paraffin's, naphthenic, and aromatics. The objective of crude distillation is to refine crude oil into light-end hydrocarbons to make it able to be marketed directly [15].

A Petroleum Refinery is a group of facilities that produce gasoline, kerosene, diesel, residual fuel oil, and asphalt (bitumen) by the distillation of petroleum or the re-distillation, cracking or reforming of incomplete petroleum products. Petroleum refining processes emit GHG from venting, flares, and leaks from equipment. In addition to emissions from petroleum refining processes, this sector includes combustion emissions from combustion units like furnaces. Most petroleum refineries also report as suppliers of petroleum products and also report as the emitters of CO_2 [16].

1.3.5. Refinery hazards

Possible hazards in crude oil refineries are:

- Explosion or fire
- Noise
- Human error (operating error)
- Mechanical moving parts
- Toxicity
- Software failure

1.3.6. Greenhouse gas

GHG is a gas that emits radiant energy inside the thermal infrared range. The primary GHG is water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3). Climatologists believe that increasing atmospheric concentration of carbon dioxide, methane, and nitrous oxide released by human activities, such as burning fossil fuels and deforestation, are warming the earth. The mechanism is commonly known as the "Greenhouse effect" is what makes the earth habitable. But the human activities have altered the chemical composition of the atmosphere through the buildup of greenhouse gases-primarily carbon dioxide, methane, and nitrous oxide [17].

- Water vapor (H_20)
- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_20)
- Ozone (O_3)
- Chlorofluorocarbons (CFCs)

1.3.7. Big accidents happened in crude oil refineries

Some of the big accidents that happened in refineries which were investigated by CSB are given as examples to show the importance of HAZOP for having a safe production.

1.3.7.1. Chevron Richmond refinery

A high-temperature gas oil released due to a pipe rupture and ignited in Richmond, California in 2012, vapor surrounded 19 workers, and fortunately, all of them were able to escape. Six of them suffered little injuries. The black smoke released by the fire surrounded the area and effected 15000 people by causing breathing problems, chest pain, and shortness of breath, sore throat, and headaches [18].

The most important hazard in a full aged pipe is the "rupture" which can cause at the end of the pipes life. In such a case before trying to cover the rupture we need to assess that what are the possible hazards in this situation, because in such a situation urgently we need to know all the reasons and possible consequences to prevent an accident. In such a less time only it can be found in HAZOP sheets which is done already for the factory. Thus, the importance of the HAZOP and risk assessment can be seen clearly in the Richmond accident.

1.3.7.2. BP Texas City refinery

Flammable liquid release, due to an overfill in an isomerization (ISOM) unit caused an explosion and fire in 2005 in BP Texas City Refinery, 15 workers killed and 180 other injured the financial losses of the accident exceed 1.5 billion dollars [19].

In HAZOP, while studying deviations, "level" is one of the most important parameters which will be analyzed carefully with all possible deviations. While a level measurement error in a process the ways to keep the property secure are;

- Repair the level measurement instrument in a less time.
- Shutting down the process.
- Change the level measurement.

None of the above actions were taken in the BP refinery.

1.3.7.3. ExxonMobil Torrance refinery

ExxonMobil Torrance experienced an explosion in Fluid Catalytic Cracking (FCC) unit due to the backflow of hydrocarbons to the Electrostatic Preceptor (ESP) in 2015.

Key factors that caused this incident includes:

- All the hazards in the factory needed to be assessed after the maintenance and development but, the kept the same assessment after the development in 2012 and it wasn’t sufficient to cover hazards in the newly developed system.
- The equipment failure which caused the flow back shows that its safe operating life was ended already.
- The system required a flammable mixture’s detector to analyze the explosive limit inside the ESP and other parts.
- A catalyst beerier cannot be used as a valve in such a hazardous system.
- ESP unit shouldn’t stay energized during Safe Park [20].

.

1.3.7.4. Sonat Exploration Company

Petroleum separation unit located near Pitkin, Louisiana got fired due to vessel failure in 1998, it caused significant financial damages and 4 workers were killed. The fire occurred while a vessel ruptured due to high pressure and released flammables ignited [21].

2. METHODS

In this section, information on the facility and chosen methods are introduced.

2.1. LCA Methodology

The methodology to analyze the environmental impacts of the products developed in 1960 for having a better view of the production to recognize environmentally dangerous phases during the production of a product [22]. It has been used worldwide in numerous studies of production, energy, including heating, ventilation, air conditioning systems [23, 24].

An LCA study done by defining the aim, functional unit, boundaries and objectives. Inventory analysis (LCIA) is one of the most important steps in LCA which have to be considered. Because the production and environmental impacts of a product can be different in different countries due to their inventory [23].

Essential steps of a complete LCA study:

• **Planning**: Goals, targets, objectives, and boundaries of the framework should be defined and explained while starting the study, in the planning step.

• **Inventory analysis**: The input and output amount that matters during the process will be accounted for in the inventory analysis part.

• **Impact assessment**: It is all environmental loads of the production step by step, using both qualitative and quantitative methods to investigate the material use, energy demand, air pollution, waste, and effluent output streams.

• **Improvement analysis**: It is the improvement of the system to reduce environmental loads which can result in changes in product shape, process changes or developments in the waste materials route [24-25].

2.1.1. Cradle to gate LCA study of crude oil production

The GHG calculation is done for a refining factory located in Hairatan Afghanistan. This factory has a capacity of refining 300 tons of crude oil per day. From this several products are produced as gasoline, diesel, and residential oil. The detailed inventory will be further discovered in this study.

To start the assessment first, one needs to identify the boundaries and functional unit. Second, choosing the assessment methodology. In this section, the planning, inventories, selected methodology are presented. Thus, it is important because the inventories are going to be acquired accordingly. But it should be kept in mind that inventories are also affected by the methodology.

2.1.2. Goal and scope

Increasing Greenhouse Gases are having profound effects on the environment. Thus this study is to calculate the environmental impacts of the refining factory located in Afghanistan to enlighten the society that the impacts come from not only extraction and production steps but mostly is generated upon consumer usage(as fuel) step.

2.1.3. Functional unit

The functional unit in this study is chosen to be the total amount of greenhouse gases being emitted daily. By refining 1-ton crude oil (CO_2e/toe).

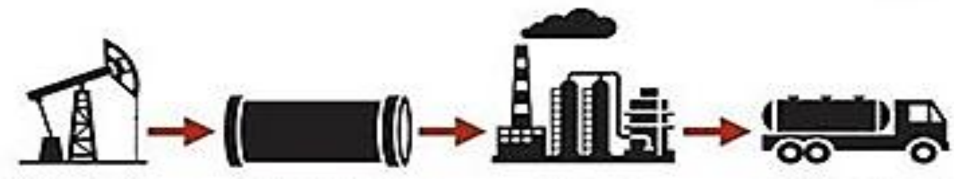
(Toe) is representing energy released by burning one-ton of crude oil, which is 41.87 gigajoules [24].

2.1.4. Audience

The potential audience is energy members especially practitioners of crude oil refineries. Also, the society that is interested in GHG emissions.

2.1.5. Boundaries

As it is a cradle-to-gate analysis, in it we assess environmental impacts associated with some of the stages of a product's life from raw material extraction through materials processing, manufacture, and distribution. Excluded (Use, repair and maintenance, and disposal or recycling).



Extraction Transportation Refining Transportation Of products

Figure 2.1. LCA system boundaries

2.1.6. Impact assessment

In Impact assessment, all environmental loads of the production can be assessed using both qualitative and quantitative approaches. The purposes of the impact assessment implementation may change, as the proposed end-user information [1-3].

In this thesis environmental impacts of crude oil production are identified using GHG as the category indicator in a normal process day.

2.2. Hazard and Operability (HAZOP)

HAZOP is an organized and methodical investigation of a new based or current process or operation to identify hazards that may turn into risks to staff or equipment and suggest the required actions to prevent the possible consequences. It is investigated during a discussion by a multi-disciplinary team (HAZOP team) in HAZOP meetings. This technique aims to build the imagination of the practitioners to find potential hazards and operability problems. The relevant international standard calls for team members to display 'intuition and good judgment' and for the meetings to be held in 'a climate of positive thinking and frank discussion'.

HAZOP team is formed from professional practitioners which does systematically studies of the process operations stage by stage and it objects to be open for ideas and creativity. It is done through using guidewords, parameters, and possible deviation in the process. Deviations are unwanted changes in the process that are physically possible. For example, a high level in the distillation column, no flow in, high temperature or high pressure, etc. Deviations such as no pressure or no temperature are not practical and physically doesn't exist, thus they are not considered. The team focusses on the deviations which could cause a potential hazard to the environment, health, and safety [26].

Hazard and risk are the different concepts as:

Hazard is a situation that has the potential to harm human health, property, and the environment.

Risk is the probability of an unwanted event that happens in a specific time under specific conditions.

HAZOP offers opportunities for people to let their imaginations go free and think of all possible ways in which hazards or operating problems might arise, but to reduce the chance that something is missed it is done systematically, and each pipeline and each sort of hazard is considered in turn [27].

2.2.1 Severity

Severity is the load and effect of an incident that how dangerous can it be. Severity can be less harmful (cut, minor cut, etc.), harmful (injuries, serious pains, minor break), and extremely harmful (major break, amputation) [13].

There are some other ways to categorize also:

• Minor: without any injury

• Major: Low-level contact to workers, activates public alarm

• Critical: Minor injury to staffs, fire or chemical release to the environment

• Catastrophic: heavy injury, death, huge leakage [13].

2.2.2. Likelihood

The likelihood is used to define the probability of a consequence. Likelihood is an informal way of discussing the likeliness that something will happen, without specific reference to numerical probability measured [13].

2.2.3. Intention

The intention describes how the unit is projected to be operated. This can take numerous procedures and can be both imaginative and graphic. In several cases, it will be a piping and instrumentation diagram (P & ID).

2.2.4. Deviation

These are unwanted differences in parameters from the projected process, which are discovered by systematically applying the guide words.

2.2.5. Causes

These are the reasons which will lead to unwanted differences in parameters and will let deviation to occur. Once a deviation has been shown to have a believable or accurate cause, it can be treated as meaningful.

2.2.6. Consequences

These are the consequences, which can cause damage, injury or loss.

2.2.7. Nodes

The points that the HAZOP team focuses on, to analyze and find hazards, are called “Nodes”. Which all parameters, deviations, and causes are examined and explored using guide words. Nodes are used to distribute a process system into controllable parts for analysis. There are many ways to select nodes and there isn’t an incorrect way of doing it. The important consideration is the size of the node. A node that is too small may lead to the study being longer as each deviation would have to be recorded many times. Nodes that are too large can be complex to analyze, leading to hazards being overlooked. Nodes may be selected by using one of the following principles for the transition between adjacent nodes:

- Change in design intent
- Change in the fluid state (liquid and gas sections of a vessel)
- Change in equipment specification (piping class)
- Major pieces of equipment

Selecting nodes based on the main pieces of equipment is the most communal method used. When used, the HAZOP team must then consider the effects of changes in fluid state and specifications when analyzing a node. Transitions between nodes should occur at easily recognizable points, such as separation valves or equipment inlets/outlets [28].

The node description shall include:

- The boundaries of the node
- The design conditions for the equipment within the node
- The normal operating conditions for the equipment within the node
- The design intent of the node
- The P&IDs for the node

3. APPLICATION OF LCA AND HAZOP IN CRUDE OIL REFINING FACTORY

3.1. Process introduction

In this factory crude oil is preheated in T_1, T_2, T_3, and T_4 exchangers and then it gets into the K_3 distillation column with around 200 ^{0}C. A pump continuously circulates it from K_3 to F_3 fired furnace to heat it up to 300 ^{0}C. In column K_3 a part of gasoline and gases separates from crude oil, it exchanges their temperature with cold water inside KX_1 and KX_{1a} heat exchangers and stores into C_1 separator. The remained crude oil in column K_3 discharges and gets pumped to furnace F_1 and heated to 380 ^{0}C and gets into K_1 distillation column. In the K_1 distillation column crude oil vapors will raise along to the top side direction and it condenses due to temperature and hydrocarbons, liquid diesel exits from 14th tray which has 260 ^{0}C temperature then it flows to K_2 and from there diesel will be pumped to T_1 and T_2 to heat crude oil and then it became cold with water inside X_3 and X_4 heat exchanger to store safely. gasoline exits as vapors from the top side with 100 ^{0}C it condenses in KX_2 and KX_{2a} conduction heat exchangers with water and stores in C_2 separator, gases and water will be separated from gasoline in $C_{1\text{-}2}$, then part of gasoline will be pumped as reflux to columns and rest to storage tanks. Mazut locates at the bottom side of the K_1 column with 360 ^{0}C temperature. H_1 pump pushes it to T_3 and T_4 to heat crude oil then cool it in X_5 and X_6 to store it safely in storage tanks.

3.2. LCA Application

3.2.1. Inventory

In the life cycle inventory (LCI) analysis, data are collected to interpret the results using GHG methodology for this all the inputs are acquired for extraction, transportation and production steps. In Table 3.1. Daily crude oil along with the required energy demand to conduct the production to produce the products can be seen. All process in the refinery takes place in a furnace which burns 25 kg fuel per ton of crude oil and cooler system with pumps which consumes 20 kW electricity per ton of crude oil. Thus the daily energy demands of the process section given in Table 3.1. Emissions, energy demands and material flows are estimated for each process. These data will then be modified to the functional unit, which is defined in the goal and scope so that the entire life cycle of the product can be taken into account [6]. The energy carriers, raw materials, and emissions to the atmosphere are quantified and calculated as below:

Table 3.1. Daily Process flow chart for LCA inventory

Description	Amounts
Evaporation (methane)	0.000316%
Electricity	6000 kW
Furnaces	7500 kg
Gasoline	25.6 ton
Diesel	141 ton
Residential Oil	130.7 ton

As mentioned before, end-user consumption, in other words, the impact which will be generated from consuming the products of this oil refining factory is not taken into account. However, in the inventory, the amount of produced products in the factory is given in Table 3.1.

3.2.2. Extraction

Oil and gas extraction is an energy-intensive activity. Most of the GHG emissions in extraction comes from the use of electricity for pumping crude oil.

Electricity supply technology is natural gas (combined cycle).

The world average is around **130 kg CO_2 e** per ton of oil equivalent (toe) [29].

3.2.3. Transportation

Petroleum transportation can be via rail cars, trucks, tanker vessels, and pipelines. The method which is used to transport crude oil depends on the amount of crude oil, area's topography, and its destination.

In this study, Kashkari region is selected. Thus, mostly trucks are used for transportation. Because there is no railway and the distance is about 200 miles. Thus, the low amount of crude oil and long-distance between refinery and extraction-site do not allow us to use the pipeline for transportation. Here we calculated using equation (1) and total emission showed in Table 3.2. Transportation of refined products which have a 50 miles distance with the factory is also added in this calculation.

GHG of transportation= distance (mile)*weight (ton)*emission factor (gr) [30]. (1)

=250*32*161.8 gr CO_2=1294.4 kg CO_2/32 ton

=40.45kg CO_2/1ton

*The average freight truck in the U.S. emits 161.8 grams of CO_2 per ton-mile [30].

Table 3.2. Emission resources and total emissions of transportation

Description	Amount
Truck capacity	40 m^3
Diesel consumption of truck	260 L
Density of diesel	860 gr/L
Diesel consumption per ton of crude oil	7.44kg
CO_2 emission of diesel combustion	3.15 kg CO_2/kg of diesel
Diesel combustion's carbon footprint	24.45 kg CO_2/toe
Truck uses foot print	16kg CO_2e/toe
Total CO_2 emissions of transportation	40.45 kg CO_2/toe

3.2.4. Process

As already known, a crude oil refinery is an industrial process plant where crude oil is transformed and refined into more useful products such as petroleum naphtha, gasoline, diesel fuel, asphalt base, heating oil, kerosene, liquefied petroleum gas, jet fuel, and fuel oil. Products produced in this factory and the daily capacities are given in Table 3.1.

As given in the inventory (Table 3.1) for the refining process there are three major inputs. The detailed emission factors for these major inputs are further given in the sections below.

3.2.5. Fuel for heating crude oil in furnaces

In this factory, there are three furnaces to heat crude oil to 400℃ and these furnaces use mixed (diesel 30% and fuel No 6 70%) as fuel. CO_2 Emissions of furnaces shown in Table 3.3.

Table 3.3. Emission factors and total emissions of furnace

Description	**Amount**
Fuel consumption per day	7500 kg
Fuel content	30% diesel 70% fuel NO.6
Fuel consumption per ton of crude oil	24.9 kg
Diesel percentage	30% , 7.5 kg
Residential oil percentage	70% , 17.4 kg
CO_2 Emission of diesel combustion	3.15 kg CO_2/kg
CO_2 emission of residential oil combustion	3.11 kg CO_2/kg
Total CO_2 emissions of furnaces per toe	78 kg CO_2/toe

3.2.6. Electricity consumers and emissions

Pumps, lighting, boiler, control system, maintenance, and labor accommodation consumption [31].

The electricity which is used by this oil refinery is generated by natural gas power plants. Thus, the total consumption of electricity per 1 ton of crude oil and carbon footprint for producing 1 kW electricity is given in Table 3.4.

Table 3.4. CO_2 Equivalent of electricity production

Description	**Amount**
Electricity to refine 1 Ton crude oil	20kW
Total consumed electricity in 24 hours	6000 kW
Consumed energy per ton oil in kWh	480 kWh
Carbon footprint of 1-kWh electricity consumption	500 gr CO_2e/kWh
Carbon footprint of 480-kWh electricity consumption	240 kg CO_2 e/toe

3.2.7. Evaporation:

Crude oil has 3.617 gr methane per ton and it evaporates while transportation, storage, and process [16]. Methane is 25 times more dangerous than CO_2 as greenhouse gases so total emissions in CO_2 equivalent given in Table 3.5.

Table 3.5. CO_2 Equivalent of methane

Description	**Amount**
Methane amount in crude oil	0.000316 %
Methane per ton of crude oil	3.617 gr
CO_2e per TOE	0.09kg CO_2e/toe

3.2. HAZOP Preparation

In this part all equipment in the factory is explained with details, nodes are selected, and given some information about hazards during start-up and shutdown of the process.

3.3.1. Equipment

Refinery is a group of equipment which are connected to make done the process.

3.3.2. Heat exchangers

Heat exchanger is a device for transferring heat from one liquid or vapor stream to another. A typical heat exchanger will have a cylindrical vessel through which, one stream can flow and a set of pipes or tubes in series in the cylinder through which the other can flow. Heat transfers through the tubes by conduction. There are 14 heat exchangers in this factory 10 of them used to cool the products with water and in the other 4 heat exchangers products give their temperature to raw materials by conduction method. Refined products have a high temperature during discharging from the column and they need to be cold to prevent from its vaporization. Thus first they flow to the first heat exchangers to heat crude oil then in the second exchangers they become cool and stored into their tanks.

3.3.3. Distillation columns

The distillation column is a cylinder-shaped tower containing trays or padding that provide a contact point for the vapor and liquid. The contact between the vapor and liquid in the column results in a separation of components in the mixture based on differences in boiling temperatures. There are 3 columns (K_1, K_2, and K_3) in this factory.

3.3.4. Furnaces

there are tree high-temperature cabin furnaces (F_1, F_2, F_3) to heat large volumes of raw materials.it is a very popular direct fired heater used in the chemical processing industry for large commercial operations. They are located above the ground to making it possible to drain the tubes and provide easy access to the burners, which can be located on the bottom, sides, or ends. Radiant tubes may be configured in a helical or serpentine layout. The radiant section in a cabin furnace is designed to contain the flames while avoiding direct contact with the tubes.

3.3.5. Separators

It is a drum to separate gases and water from gasoline. There are 3 separators (C_1, C_2, and C_3) in this refinery.

3.3.6. Pumps

Devices used to move liquids from one place to another; classified as positive displacement or dynamic. There are more than 50 pumps in this factory.

3.3.7. Water cooler system

There is one Air cooling system compound by four ventilators and four pumps to cool hot water which is used to cool the products.

3.3.8. Gasoline storage tanks

There are 2 tanks with 1400 m^3 capacity for gasoline in this factory.

3.3.9. Diesel storage tanks

Kashkari crude oil contents 40 percent diesel so there are 3 tanks with 4000 ^{m3} capacity to store refined diesel.

3.3.10. Mazut storage tanks

About 50 percent of Kashkari crude oil is free of light hydrocarbons like gasoline and diesel fractions so it called Mazut and there are 5 tanks for Mazut with about 15000 m^3 capacity.

3.3.11 Oil storage tanks

There are 4 storage tanks for crude oil with a total of 6600 m^3 capacity.

3.3.12. Firewater tanks

There are 5 water tanks equipped by 2 pumps for fire extinguish.

3.3.13. Oily Water Tank

There is an underground tank with 10 m^3 capacity to store the emulsions of water and crude oil which exits the distillation column with gasoline vapors.

3.3.14. Hazards during startup and shut down the process

Process unit start-up and shutdown operations are significantly more dangerous than normal oil refinery or chemical plant operations. Initialization is a chain of stages planned to put a process from inactive to normal operation. Shutdown is the opposite instruction. Process safety events are five times more common during startup than normal operations. According to the 2010 incident investigation in the refineries, half of process safety incidents occur during start-up, shutdown, and other rare events. This is because it involves many non-routine procedures during startup and shutdown times, and these times can cause unexpected and unusual situations. To prevent such events from occurring, facilities should communicate effectively, provide appropriate training to employees, and have solid and updated policies and procedures for hazardous operations such as start-up and closing [32].

3.3.15. Selected Nodes

In this part, the system is divided into controllable parts to be analyzed easily. Main process equipment, changes in the fluid state, and specifications are considered during analyzing and selecting the nodes. All hazards are identified in each node and written in HAZOP sheets in Appendix B. The selected nodes are numbered below:

1. Gasoline coolers KX_1 and KX_{1A}
2. Diesel coolers X_4, X_5, X_6
3. Mazut coolers X_7, and X_{7A}
4. Heat exchangers T_1 T_2 and T_3
5. Heat exchanger T_4 HAZOP
6. Distillation column K_3
7. Furnace F_3
8. Furnace F_1
9. Distillation column K_1
10. Separator C_1
11. Separator C_2

4. RESULTS AND DISCUSSION

All the results are given in this section for the crude oil processing.

4.1. LCA Results

In this thesis, LCA analysis was carried out to calculate GHG emissions using cradle to gate approach. Thus, the environmental burden starting from extraction, which is the cradle point, to transportation to consumers where production step is also included is taken into account in this study, not only the impact of each step is calculated but also the total GHG emission for the whole system is reported.

The calculated GHG emission for extraction is 130 kg CO_2 e/toe, for the process is 318.09 kg CO_2 e/toe and for transportation is 40.45 kg CO_2 e/toe which are added to find the total GHG emissions. Thus, Total GHG Emissions of all sections found to be 488.54 kg CO_2/toe. This means that carbon footprint is 488.54 kg CO_2 e in each 41.87 GJ and for 1-ton Gasoline which has 44 GJ/ton it is 513.3 Kg CO_2 e and for one-liter gasoline, it is 390 gr CO_2 e. Total emissions of diesel and residential oil are given in Table 4.1.

According to the calculation, total GHG emissions of producing a liter of gasoline is 390 gr CO_2e/l, for diesel, it is 450.5 gr CO_2e/l and for residential oil, it is 400 gr CO_2e/l. That 26.6% of these emissions come from extraction, 8.4% from transportation and 65% of the emission comes from process step.

Here it can be seen that the extraction step has a big role in the impacts. Because 26.6% of GHG is being produced. On the other hand, the highest-burden comes from the refining step (furnace, cooling, lighting, and pumping). The lowest impact was generated from transportation steps which is 8.4% (6.72% while transporting from extraction site to refinery and 1.68% while transporting refined products to end-user) of the total burden.

Also, the highest GHG emission is generated by the diesel production step. As can be seen, the burdens of residential oil and gasoline are closer to each other and their burdens are lower than the burden of diesel.

Table 4.1. Total greenhouse gases emissions of refined products per liter

Products	Gasoline		Diesel		Residential oil	
GHG emissions per ton	513.3	kg CO_2 e	542.5	kg CO_2 e	455	kg CO_2 e
GHG emissions per liter	390	gr CO_2e	450.5	gr CO_2e	400	gr CO_2e

According to the estimation, during the normal process, the total greenhouse gas emissions per day in this factory is around 40 ton CO_2.

4.2. HAZOP Results

In this thesis, the crude oil refining factory is divided into several nodes and all hazards are identified in each node using HAZOP methodology to decrease the happening probability of the consequences. 11-nodes were found and different parameters and deviations studied as the details of the nodes are given in Table 4.2.

Table 4.2. Nodes

	Nodes	Parameters	Deviations	Causes	Actions
1	Gasoline coolers KX_1 and KX_{1A}	4	6	12	11
2	Gasoline coolers KX_2 and KX_{2A}	4	6	13	12
3	Diesel coolers X_4, X_5, X_6	4	6	13	13
4	Mazut coolers X_7, X_{7A}	4	5	12	12
5	heating crude oil in (T_1, T_2) heat exchangers by diesel	3	5	15	16
6	heating crude oil in (T_4, T_3) heat exchangers by Mazut	5	6	19	18
7	Distillation column K_3	4	11	35	38
8	furnace F_3	4	8	17	16
9	furnace F_1	4	8	22	23
10	distillation column K_1	4	11	41	45
11	gasoline separator C_1	4	5	8	9
12	gasoline separator C_2	4	5	8	9

In this factory, there is no flare system to burn the gases (C_{1-5}) and release CO_2 to the atmosphere. Gas stream passes through a water cooler and store in G_4 gas tank, from the gas tank the lighter hydrocarbons which exist with a low percentage in crude oil will exit from the top of the tank to the atmosphere and as its amount is under explosive limit thus, the likelihood of explosion is less but in case of high temperature and more gas flow, the gas amount can raise to explosive limit and create danger.

For each Gasoline heat exchanger (KX_2 a, KX_{2A}, KX_1, and KX_{1A}) six deviations and 12-causes were found. According to the HAZOP sheet high temperature of gasoline vapors can create explosive limit around the gas tank, as there is no flare system, thus, the risk of explosion is enough high as much the likelihood looks low but the severity of the explosion is much more, which can cause about 50 % equipment damage in the factory, And all flammables around the tank will burn.
All the deviations, causes and required actions can be found in the Gasoline HAZOP sheet in Appendix B.

4 parameters analyzed in diesel cooler (X_4, X_5, and X_6), 6 deviations were founded due to 13 causes. The most considerable consequence is diesel vaporization which can happen, while there is no or less water flow into the exchanger because the vaporization will cause economic loss. The more consequences and required actions are explained in the HAZOP sheet in Appendix B.

Mazut is the heaviest fraction with a high temperature and low auto-ignition temperature, therefore it should be cooled well and carefully because any air leakage can cause an explosion or fire. The X_7 and X_{7A} are being used to cool Mazut in this factory, after a HAZOP study, 5 deviations were found due to 12 causes and it is enlightening that the most significant hazard is while Mazut stream is not cooled well in the heat exchanger and if it is more than 250 ^{0}C it will ignite automatically while getting in touch with air. Also, crude oil leakage inside the cylinder will create a high pressure due to light hydrocarbon existence which should be considered as it is mentioned in the Mazut cooler HAZOP sheet in Appendix B.

T_1 and T_2 are the heat exchangers that, heat crude oil to 80 ^{0}C and decrease the diesel temperature to 120 ^{0}C. The most common hazard in these heat exchangers is the changing composition of the diesel due to leakage in crude oil pipes inside the exchanger, it will destroy the diesel quality. Thus, controlling the color and quality of diesel before sending it to the tank was suggested. Causes and required actions for more consequences are identified in the HAZOP sheet of T_1 and T_2 in Appendix B.

In the K_1 distillation column's HAZOP sheet charted in Appendix B. a high interval level measurement instrument is suggested to be able to measure a higher level to know the exact level inside the column to prevent over full.

4.3. Discussion

Life cycle assessment will support considerably to the quality of integrated decision making, mainly against the perspectives of a government's commitments to sustainable improvement. As an extra tool in the environmental organization toolbox, it will help in raising awareness on integrated environmental management and sustainability issues and will encourage a greater degree of inter-disciplinary connections [6].

LCA results showed that within the selected boundary the huge part of GHG emission generated during electricity consumption in extraction and process step. The environmental impact of electricity consumption as given in Table 3.4 was calculated to be 488.54 kg CO_2 e/toe due to using electricity generated using natural gas. Whereas it can be minimized by up to 90 % by using electricity generated using renewable sources like wind, solar panel, and hydropower. Thus more effort should be given to these steps. Thus the importance of using renewable energies as resources of electricity supply can be clearly seen [17].

Energy use for transportation systems is delivered through a compound system like manufacturing vehicle, operation, maintenance and insurance which all consumes energy and causes emissions when performing their jobs. For this specific studied plant in Kashkari, the only method used to transport the crude oil from extraction site to the factory and products to users are via ground transportation, where trucks with thirty tow tons capacity are used because the only available method of transportation is tanker trucks in here as the details are given in Table 3.2. Therefore it is recommended to the crude oil transportation Company to use new vehicles with more efficiency and consider the routing and vehicle technology of a new fixed guideway system. Also for liquid and natural gas fuels, an agency can look at fuel production cycle emissions and consider biofuels with low energy production requirements [33].

When most people think of petroleum they think of gasoline and diesel fuel. They may even conjure up images of jet fuel. However, there are many uses for crude oil that affects our life, which means that reducing our dependence on oil may not be as easy as buying a hybrid car. Because crude oil contains a vast number of different hydrocarbons, various refined products have found their way into everything from plastics to pharmaceuticals. It means that if crude oil is not being used as a fuel and there is no combustion then there are less Greenhouse gas emissions.

As it is explained above, the huge CO_2 source is a petroleum product's combustion, thus, an explosion can cause a million tons of CO_2 released to the atmosphere, and therefore the importance of HAZOP, to have safe work and safe environment can be understood easily. For example, some happened accidents in the refining factory are investigated below:

T_3 and T_4 Mazut heat exchangers are the most hazardous heat exchanger in the factory which contain hot Mazut with 300 ^{0}C temperature which will ignite automatically in contact with air. T_4 experienced steel torn due to high pressure while shutting down the process that the temperature was around 200 ^{0}C. As it is explained in Appendix B, the possible causes of high pressure were identified as bellow:

- The temperature difference between the Mixed liquid (Mazut & crude oil) and Heat exchanger's body.
- Leakage in crude oil pipes, which contain light hydrocarbons.
- Existed rupture.
- Rotten steel.
- Metal quality and shape.

During process shutdown, the mixed liquid temperature is around 200 ^{0}C and it is under auto-ignition temperature, in case of any torn or leakage the consequence will be just oil spill and a flammable atmosphere that needs a spark. But if this torn or leakage happened during the normal process in which the Mazut has 300 ^{0}C, it will automatically ignite in the atmosphere and its high-temperature flame will melt all equipment around it which can cause several explosions. In this situation HAZOP suggested that the maximum possible pressure inside a heat exchanger can be around 10 atmospheres, thus, all exchangers should be checked in the same pressure with the same temperature because the ability of the metal is deference in different temperatures.

In case of its explosion during the process the following steps should be done urgently:

Operators:

- Fire alarm.
- Turn off Mazut pump and close the valves.

- Turn off feed in the pump and valves.
- Evacuate heat exchangers and gasoline tanks around.

Safety personal:

- Start fire extinguishing.
- Cool all equipment around with water.
- First aid to injured workers.

Keep automation:

- Turn off furnaces.

The listed actions on the top are the actions that should be done at the same time to cover the fire.

In 2016 while unloading crude oil from truck tankers to underground storage tanks, pump station exploded, storage tank got fire and 3 workers injured.

Causes:

- Pump station was established in a deep-set near the storage tank.
- The high percentage of light gases (C_1-C_5) in Crude oil.
- Unloading directly to an underground tank caused more vaporization and it flowed inside the deep-set pump station.
- Electric equipment was placed inside the deep-set pump station.
- Absence of ventilation system.
- The electric man was working on the electric box inside the deep-set pump station which probably caused a spark by equipment.

Suggestions:

- Distance between the truck tanker and storage tank should be enough that they should be safe from each other’s hazards.

- Pump station should have a ventilation system, which takes out the flammable mixtures out of the pump station.
- The electric equipment should be installed outside and far from the pump station.
- All ignition sources should be removed from around. And electrostatic charges should be grounded.

4.4. Conclusion

The atmospheric percentage of GHG is at its high level again since pre-industrial time. Even if it became managed and stopped today and this is far from the case they would continue to remain in the atmosphere for years to come and so continue to affect the balance of our living planet and our climate. Now more than ever before, we need to understand the complex and unexpected interactions between greenhouses gases in the atmosphere, Earth's biosphere and oceans [34].

Reducing the flow of the greenhouse gases that spur global warming could prevent up to 3 million premature deaths annually by the end of the twenty-one century. Due to this importance, Governments are required to report their national greenhouse gas inventories, comprising estimates of greenhouse gas emissions and removals to the United Nations Framework Convention on Climate Change (UNFCCC) including under processes such as the Kyoto Protocol and Paris Agreement [35].

According to the big accidents in page 8-10, which have been investigated by CSB, the explosions and fires in refineries are not just an accident which is finished with some injury and some economic loss but, the environmental impacts can be much more dangerous. For example, in Richmond refinery, a ruptured pipe released flammable, high-temperature light gas oil and the released process fluid ignited. As a result, six chevron workers suffered little injuries. The black smoke released by the fire surrounded the area and effected 15000 people by causing breathing problems, chest pain, and shortness of breath, sore throat, and headaches. And million tons of CO_2 released to the atmosphere due to the oil combustion.
In this thesis, it can be seen that the environmental impacts will be reduced while having a safe process because the hugest volume of CO_2 release was recorded during explosions and fires. Thus, it is very important to assess, plan, design the boundaries and acquire the data. To reduce GHG emissions, all steps should be analyzed and all risk issues should be identified. Blaming crude oil production as the main concern of greenhouse gas is not the

solution. Because LCA results showed that the majority of GHG emissions (>80%) occurs during the industrial incident like fire or explosion and while combustion by end-user. For example, the carbon footprint of 1-liter diesel from extraction until use is 450.5 gr CO_2e/l whereas the combustion (use) carbon footprint is 3150 gr CO_2/l and it shows that there are less GHG emissions in crude oil production than its combustion or consumption field. And in case of an accident, it can be million tons of CO_2. So refineries are not the main cause of climate change or global warming. Thus, all hazards should be identified and reduced via safeguards. Also, manufacturers should consider LCA where fossil fuels are used for burning which are the main causes of environmental burdens.

REFERENCES

1. Gülşah YILAN, Mehmet Arif NEŞET KADIRGAN, Gökçen Alev ÇİFTÇİOĞLU. Analysis of Electricity Generation Options for Sustainable Energy Decision Making: the Case of Turkey. Renewable Energy. Cilt 146. Sf 519-529, 2020.
2. World meteorological organization, press release. (November **2019**) https://public.wmo.int/en/media/press-release/greenhouse-gas-concentrations-atmosphere-reach-yet-another-high
3. Andreoni and Galmarini, 2016 V. Andreoni, S. GalmariniDrivers in CO_2 emissions variation: a decomposition analysis for 33 world countries Energy, 103 (2016), pp. 27-37
4. Sevencan Suat,ÇİFTÇİOĞLU Gökçen ALEV. Life cycle assessment of power generation alternatives for a standalone mobile house. International Journal of Hydrogen Energy. Cilt 38. Sf 14369-14379, 2013.
5. ÇİFTÇİOĞLU Gökçen ALEV, Gokulu Onur, KADIRGAN Mehmet Arif Neşet, kadirgan Figen. Life cycle assessment LCA of a solar selective surface produced by continuous process and solar flat collectors. Solar Energy. Cilt 135. sf 284-290, 2016.
6. DEAT (2004) Life Cycle Assessment, Integrated Environmental Management, Information Series 9, Department of Environmental Affairs and Tourism (DEAT), Pretoria.
7. yıldız geyhan eren,YILAN Gülşah ,ÇİFTÇİOĞLU Gökçen ALEV,KADIRGAN Mehmet Arif Neşet. Environmental and social life cycle sustainability assessment of different packaging waste collection systems. Resources, Conservation and Recycling. Cilt 143. sf 119-132, 2019.
8. Iraj MOHAMMADFAM[1*] , Amene SAJEDI[2], Shahram MAHMOUDI[3], and Farhad MOHAMMADFAM[4], (2012) International journal of occupational hygiene, Tehran Iran.
9. Wiley, (2016) , Introduction to process safety for undergraduates, and Engineers. Center for chemical process safety of the American institute of chemical engineers New York.

10. Hazard and operability study, Vaibhu safety consultants, Kutch Chemical Industries Limited
11. MARTINEZ, Tosco Avon refinery investigation report No. 99-014-I-CA (MARCH 2001), California
12. John Gardenier & Roger B Keey and Proceedings of a Workshop held 21 - 22 August 1991, Risk assessment of industrial and natural hazards Molesworth House, Wellington
13. Swapan Basu, (2016) Plant Hazard Analysis and Safety Instrumentation Systems, Academic Press is an imprint of Elsevier, 125 London Wall, London EC2Y 5AS, United Kingdom
14. William L. Leffler (2008) PETROLEUM REFINING IN NONTECHNICAL LANGUAGE Fourth Edition,. PennWell Corporation, 1421 South Sheridan Road Tulsa, Oklahoma 74112-6600 USA
15. Surinder Parkash, (2003) REFINING PROCESSES HANDBOOK, Gulf Professional Publishing is an imprint of Elsevier.
16. Greenhouse Gas Reporting Program and the U.S. Inventory of Greenhouse Gas Emissions and Sinks (2014), https://www.epa.gov/ghgreporting/greenhouse-gas-reporting-program-and-us-inventory-greenhouse-gas-emissions-and-sinks
17. Better Meets Reality journal, Humans, Animals, the Environment, the Economy & Space
18. Final investigation report NO. 2012-03-I-CA Chevron Richmond refinery pip rupture and fire, U.S. Chemical safety and hazard investigation board, Richmond, California
19. U.S. Chemical safety and hazard investigation board, investigation report NO. 2005-04-I-TX, refinery explosion and fire BP Texas city , Texas.
20. U.S. Chemical Safety and Hazard Investigation Board (CSB), (2015) ExxonMobil Torrance Refinery Electrostatic Precipitator Explosion, Torrance, California
21. U.S. Chemical Safety and Hazard Investigation Board (CSB), (1998) investigation report , Catastrophic vessel over pressurization, Pitkin, Louisiana
22. Heikkilä, K. (2004). Environmental impact assessment using a weighting method for alternative airconditioning systems. Building and Environment, 39(10), 1133-1140.
23. Khalid, A. (2009). Hybrid desiccant cooling system for hot regions. LAP Lambert Academic Publishing, Germany, s. 110-143.
24. Legarth, B. J., S. Åkesson, S., Ashkin, A., ve Imrell, A. M. (**2000**). A screening-level life cycle assessment of the ABB EU 2000 air handling unit. Int. J LCA, 51, 47–58.
25. David Bodansky, "Appendix: Energy Units," in The Energy Source Book, Ruth Howes and Anthony Fainberg, editors (New York: American Institute of Physics, **1991**)

26. Dennis P. Nolan, Safety and Security, Review for the Process Industries Application of HAZOP, PHA and What-If Reviews 2nd Edition, William Andrew Inc. 13 Eaton Avenue Norwich
27. Trevor kletz, (2001) HAZOP and HAZAN, identifying and assessing process industry hazards. Fourth edition, institution of chemical engineers, Warwickshire, UK
28. Genesis, (2015) Hazard and Operability (HAZOP) Study Work Instruction GNH-RIM-WI-031-1, North America
29. Simon Mui, Luke Tonachel, Bobby McEnaney, and Elizabeth Shope, GHG Emission Factors for High Carbon Intensity Crude Oils Ver. 2 Natural Resources Defense Council. Table 4. (September **2010**)
30. Green Freight Handbook page 13.
31. A crude oil refining factory in Afghanistan.
32. Safety Digest: CSB Investigations of Incidents during Startups and Shutdowns, https://www.**csb**.gov/assets/1/6/**csb_digest_-_startup_shutdown**.pdf
33. Mikhail Chester1, Juan Matute2, Paul Bunje2, William Eisenstein3, Stephanie Pincetl*2, Zoe Elizabeth2, and Connery Cepeda (2014). Life Cycle Assessment for Transportation Decision-making, institute of the environment and sustainability.
34. World Meteorological Organization, press release. https://public.wmo.int/en/media/news/ipcc-updates-methodology-greenhouse-gas-inventories (May **2019**).
35. World Meteorological Organization, press release. https://public.wmo.int/en/media/press-release/no-934-greenhouse-gas-concentrations-continue-climbing (November **2011**).

APPENDICES

Appendix A: HAZOP Parameters, Deviations and Possible Causes

PARAMETERS	DEVIATION,	POSSIBLE CAUSES
Flow	High	● Increased pumping capacity ● Increased suction pressure ● Reduced delivery head ● Greater fluid density ● Exchanger tube leaks ● Restriction orifice plates not installed ● Cross-connection of systems ● Control faults ● Control valve trim changed ● Running multiple pumps
	Less	● Restriction ● Wrong routing ● Filter blockage ● Defective pump(s) ● Fouling of vessel(s), valves, orifice plates ● Density or viscosity changes ● Cavitation ● Drain leaking ● Valve not fully open
	None	● Wrong routing ● Blockage ● Incorrect slip plate ● One-way (check) valve in backward ● Pipe or vessel rupture ● Large leak ● Equipment failure ● Isolation in error

		• Incorrect pressure differential • Gas locking
	Reverse	• Defective one-way (check) valve • Siphon effect • Incorrect pressure differential • Two-way flow • Emergency venting • Incorrect operation • Inline spare equipment • Pump failure • Pump reversed
Level	High	• Outlet isolated or blocked • Inflow greater than outflow control failure • Faulty level measurement • Gravity liquid balancing • Flooding • Pressure surges • Corrosion • Sludge
	Low	• Inlet flow stops • Leak • Outflow greater than the inflow • Control failure • Faulty level measurement • Draining of vessel • Flooding • Pressure surges • Corrosion • Sludge
Pressure	High	• Surge problems • Connection to high pressure • Gas (surge) breakthrough • The inadequate volume of vents

		● Incorrect vent set pressure for vents ● Relief valves isolated ● Thermal overpressure ● Positive displacement pumps ● Failed open PCV ● Boiling ● Freezing ● Chemical breakdown ● Scaling ● Foaming ● Condensation ● Sedimentation ● Gas release ● Priming ● Exploding ● Imploding ● External fire ● Weather conditions ● Hammer ● Changes in viscosity/density
	Low	● Generation of vacuum conditions ● Condensation ● Gas dissolving in liquid ● Restricted pump/compressor line ● Undetected leakage ● Vessel drainage ● Blockage of blanket gas regulating valve ● Boiling ● Cavitation ● Freezing ● Chemical breakdown ● Flashing ● Sedimentation

		● Scaling ● Foaming ● Gas release ● Priming ● Exploding ● Imploding ● Fire conditions ● Weather conditions ● Changes in viscosity/density
Temperature	High	● Ambient conditions ● Fouled or failed exchanger tubes ● Fire situation ● Cooling water failure ● Defective control valve ● Heater control failure ● Internal fires ● Reaction control failures ● Heating medium leak into the process ● Faulty instrumentation and control
	Low	● Ambient conditions ● Reducing pressure ● Fouled or failed exchanger tubes ● Loss of heating ● Depressurization of liquefied gas—Joule Thompson effect ● Faulty instrumentation and control
Part of	Concentration wrong	● Leaking isolation valves ● Leaking exchanger tubes ● Phase change ● Incorrect feedstock specification ● Process control upset ● Reaction by-products ● Ingress of water, steam, fuel, lubricants, corrosion

		products from the high pressure system ● Gas entrainment
As well as	Contaminants	● Leaking exchanger tubes ● Leaking isolation valves ● Incorrect operation of the system ● Interconnected systems ● Wrong additives ● Ingress of air: shutdown and start-up conditions ● Elevation changes and fluid velocities ● Ingress of water, steam, fuel, lubricants, corrosion ● Products from the high-pressure system ● Gas entrainment ● Feed stream impurities (e.g., mercury, H 2S, CO 2)
Other than	Wrong material	● Incorrect or off-specification feedstock ● Incorrect operation ● Wrong material delivered
Relief system		● Relief philosophy (process and fire) ● Type of relief device and reliability ● Relief valve discharge location ● Pollution implications ● Two-phase flow ● Low capacity (inlet and outlet)
Corrosion/erosion		● Cathodic protection arrangements (internal and external) ● Coating applications ● Corrosion monitoring methods and frequencies ● Materials specification ● Zinc embrittlement ● Stress corrosion cracking ● Fluid velocities ● Sour service (e.g., H 2S, mercury)

Abnormal operation		● Purging ● Flushing ● Start-up ● Normal shutdown ● Emergency shutdown ● Emergency operations ● Inspection of operating machines ● Guarding of machinery
Maintenance/procedures		Isolation philosophy ● Drainage ● Purging ● Cleaning ● Drying ● Access ● Rescue plan ● Training ● Pressure testing ● Work permit system ● Condition monitoring ● Lift and manual handling
Sampling/procedures		● Sampling procedure ● Time for analysis results ● Calibration of automatic samplers ● Reliability and accuracy of the representative sample ● Diagnosis of results
Action		Overkill ● Underestimated ● None ● Reverse ● Incomplete ● Knock-on ● Wrong action

Sequence		● Operation too early ● Operation too late ● Operation left out ● Operation performed backward ● Operation not completed ● Supplemental action is taken ● Wrong action in operation
Safety systems		● Fire and gas detection and alarms ● Emergency shutdown (ESD) arrangements ● Firefighting response ● Emergency training ● TLVs of process materials and method of detection ● First aid/medical resources ● Vapor and effluent disposal ● Testing of safety equipment ● Compliance with local and national regulations
Global		● Layout and arrangement ● Weather (temperature, humidity, flooding, winds, sandstorm, blizzards, and so on) ● Geological or seismic ● Human factors (labeling, identification, access, instructions, training, qualifications, and so on) ● Fire and explosion ● Adjacent facility exposures

Study Title: Gasoline vapor cooling						**Sheet :1 of 13**		
Part considered			**Heat exchangers KX_1 KX_{1A}**			**Date:9/1/2020**		
Design Intent			**Material: water , Gasoline vapors**			**Activity: cooling**		
			Source: Distillation Column K_3			**Destination: separator C_1**		
No	Guide word	element	Deviation	Possible causes	consequences	Safeguards	Comments	Action required
1	High flow	Gasoline	More Gasoline vapor	More gasoline concentration in crude oil, T>120 ^{0}C in top side of K_1	cooling gain will decrease and most of gasoline will vaporize and it will create an explosive atmosphere around the gas tank			Increase water flow in to heat exchanger, open ventilators to cool water well, or add one exchanger more
2	Low flow	Gasoline	Less Gasoline vapor	Less gasoline percentage in crude oil, T<100 ^{0}C in top side of K_1	Law temperature in top side of K_1 will destroy the process			Decrease reflux, increase feed in temperature
3	High pressure	Gasoline	High pressure in exchanger inlet	Failure of inlet or outlet gasoline vapors valve to open, blockage in gasoline vapor pipes	Increasing pressure in K_1 top side, cause vapor leakage, gain of process will come down and process fails			Check inlet and out let valves of exchangers, clean the gasoline blocked pipes
4	High temperature	Gasoline	High temperature of Gasoline in exchanger outlet	More flow in, less cooling water flow in, cooling water temperature is not enough	Part of gasoline will vaporize and it will create an explosive atmosphere around the gas tank			Balance the temperature and amount of cooling water
5	Changing composition	Gasoline	Water in Gasoline, change in gasoline color	High percentage of water in crude oil, high temperature in K_1 top side, leakage inside heat exchangers	Decrease gasoline quality and destroy it			Check the color and water amount in both exchangers and maintain the problem

Study Title: diesel cooler								**Sheet :4 of 13**
Part considered			**Heat exchange X_4,X_5,X_6**					**Date:9/01/2020**
Design Intent			**Material: Water , Diesel**			**Activity: Cooling diesel**		
			Source: column $K2_{1,2,3}$			**Destination: storage tanks**		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High flow	Diesel	More Diesel flow in	More diesel percentage in crude oil, T>240 ^{0}C and more heavy vapors raised to diesel plate or if T<180 ^{0}C and more gasoline vapors condensed	Storing hot stream diesel will cause diesel to vaporize (economical loss)			Raise exchanger's water flow I, add exchangers, check and balance the temperature of diesel plate
2	Low flow	Diesel	Less Diesel flow in	Less diesel percentage in crude oil, T<200 ^{0}C in diesel plate in K_1, U shaped diesel discharge pipe in K_1 is blocked	Unbalance the process, destroy the process			Check the U shaped pipe which connects K_1 and K_2, and check the temperature in diesel discharge plate
3	High pressure	Diesel	High pressure in exchanger inlet	Failure of inlet or outlet diesel valve to open, blockage in diesel pipes	Decrease process gain			Check the valves and pipes, check all parameters in process
4	High temperature	Diesel	High temperature of Diesel in exchanger outlet	More diesel flow in, no water flow in to exchanger, water temperature Is not enough cool	Storing hot stream diesel will cause diesel to vaporize (economical loss)			Check water flow in, temperature and valves, add an exchanger more
5	Changing composition	Diesel	Water in Diesel, dark hydrocarbons	leakage inside the heat exchanger, changing in the temperature of diesel plate in K_1	Destroy process, Diesel waste (economical loss)			Check the color of diesel and analyze it, check process all parameters, shut down and maintain the exchanger

Study Title: Gasoline vapor cooling							Sheet :2 of 13	
Part considered			Heat exchanger KX_2 KX_{2A}				Date:9/01/2020	
Design Intent			Material: Water , Gasoline			Activity: Cooling Gasoline		
			Source: Distillation Column K_1			Destination: separator C_2		
No	Guide word	element	Deviation	Possible causes	consequences	Safeguards	Comments	Action required
1	High flow	Gasoline	More Gasoline vapor	More gasoline concentration in crude oil, T>120 ^{0}C in top side of K_3	cooling gain will decrease and most of gasoline will vaporize and it will create an explosive atmosphere around the gas tank			Increase water flow in to heat exchanger, open ventilators to cool water well, or add one exchanger more
2	Low flow	Gasoline	Less Gasoline vapor	Less gasoline percentage in crude oil, T<100 ^{0}C in top side of K_3	If the reason is T then it mean that the process is going to fail			Increase the temperature on top side of K_3
3	High pressure	Gasoline	High pressure in exchanger inlet	Failure of inlet or outlet gasoline vapors valve to open, blockage in gasoline vapor pipes	Increasing pressure in K_3 top side, cause vapor leakage, gain of process will come down and process fails			Check inlet and out let valves of exchangers, clean the gasoline blocked pipes
4	High temperature	Gasoline	High temperature of Gasoline in exchanger outlet	More flow in, less cooling water flow in, cooling water temperature is not enough	Part of gasoline will vaporize and it will create an explosive atmosphere around the gas tank			Balance the temperature and amount of cooling water
5	Changing composition	Gasoline	Water in Gasoline	High percentage of water in crude oil, high temperature in K_3 top side, leakage inside heat exchangers	Decrease gasoline quality and destroy it			Check the color and water amount in both exchangers and maintain the problem

Study Title: Distillation							**Sheet :6 of 13**	
Part considered			**Distillation Column K3**				**Date:9/01/2020**	
Design Intent			**Material: Crude oil , Benzene**			**Activity: distilling**		
			Source: heat exchanger			**Destination: furnace 1**		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High level	Distillate	High liquid level in K_3	level control valve is not working, More flow in, feed in control valve is not working, instrument failure	Error in level shower instrument			Check level shower instrument, check control valves, check the color of gasoline in C_1, check the pump and all parameters
2	Low level	Distillate	Liquid level is down in K_3	level control valve is not working, no flow in	Temperature will raise in furnace F_1 and create coke collection inside the pipes, less gain, destroy the process			Check the level control valve, check flow in, check level instrument, shutdown furnaces and system
3	Empty	Distillate	No liquid level in K_3	Level control valve failure, no flow in, leakage in column, level instrument failure	Temperature will raise in furnaces (F_1-F_2) and create coke collection inside the pipes, less gain, destroy the process			Check the level control valve, check flow in, check level instrument, shutdown furnaces and system
4	High pressure on top side	Distillate	P>0.5atm	High gasoline percentage in crude oil, high temperature in top side of K_3, instrument failure	Prevents gasoline vapors to reach the top, it cause more emulsion in C_1, if it is due to high temp. it cause color change in gasoline			Check flow in and temperature of reflux, make sure that the pressure instrument is working, make sure that the gas exit valve is open

5	High pressure in down side	Distillate	P>0.5 atm	High liquid level, blockage in plates	gain Decreases			Check the level, check all gasoline coolers valves, plate maintenance control
6	Low pressure on top side	Distillate	P<0.3	Less gasoline vapor, low temperature, pressure instrument failure, gas discharge valve is open	Process gain decrease			Check the pressure instrument, balance the temperature, check gas discharge valve
7	Low pressure in down side	Distillate	P<0.3	Low liquid level, empty, vacuum due to temperature deference, instrument failure	Decrease in process gain and speed		cool the system well while shutting it down	Check level control valves, raise the level, make sure that the gas discharge valves close
8	High temperature on top side	Distillate	T>120 ^{0}C	High gasoline percentage in crude oil, C_1 gas discharge valve is open, instrument failure, more heating in furnaces, less reflux shower	Change in Gasoline's color, quality and density, unbalance process			Decrease heating in furnace, check the pressure and balance it on top side, check the instruments, check reflux amount on top side
9	High temperature in down side	Distillate	T>250 ^{0}C	More heating in furnaces, more heavy fractions percentage in crude oil	Raising top side temperature, Change in gasoline color, quality and density, more reflux consumption			check gasoline color, check the instruments, decrease heating in furnace, balance the process
10	Low temperature top side	Distillate	T<120 ^{0}C	Distillate Is not heated enough, gasoline percentage is low, more reflux is given, instrument failure	Low gasoline discharge with low density, less gain			Check temperature in furnaces, check the control valve of reflux, check thermocouples

11	Low temperature down side	Distillate	T<250 ^{0}C	Distillate Is not heated enough, less heavy fractions in crude oil, instrument failure	Low temperature on top side, less gasoline discharge with low density, less gain			Raise temperature in furnaces, check the instruments, decrease reflux flow in, check thermocouples

Study Title: Distillation							Sheet :5 of 13	
Part considered			Distillation Column K_1				Date:9/01/2020	
Design Intent			Material: Crude oil , Benzene , Diesel , Mazut			Activity: distilling		
			Source: Furnace F_1			Destination:		
No	Guide word	element	Deviation	Possible causes	consequences	Safeguards	Comments	Action required
1	High level	Distillate	Liquid level is raised in K_1	More flow in, feed in control valve is not working, level control valve is not working	Error in level shower instrument, raise up to diesel plate and mix with diesel or gasoline and destroy them			Check level shower instrument, check both control valves, check the color of products, check the mazut pump and all parameters
2	Low level	Distillate	Liquid level is down in K_1	Less flow in, more flow out, level control valves are not working, bypass is open, any leakage, feed in stopped	Process destroy, if there is any leakage between furnace and column then distillate vapors can burn within any spark			Check flow In and flow out pumps, valves, level shower and controllers. Supervise the site
3	Empty	Distillate	No liquid level in K_1	Level shower is not working, Less flow in, more flow out, level control valves are not working, control valve's bypass is open	Process will destroy, crude oil preheating won't done, less temperature of crude oil will make noises even explosions in furnaces, process gain will decrease		Add a level shower instrument with more level height interval	Check control valves, bypasses, level shower instrument
4	High pressure on top side	Gasoline vapors	P>0.5atm	High gasoline percentage in crude oil, high temperature in top side of K_1, instrument failure	Prevents gasoline vapors to reach the top, it wıll cause more emulsion in C_2, if it is due to high temp. it cause color change in gasoline			Check flow in and temperature of reflux, make sure the pressure instrument is working, make sure that the gas exit valve is open
5	High pressure in down side	Mazut	P>0.5	High liquid level, blockage in plates	gain Decreases			Check the level, check all valves, plate maintenance control

6	Low pressure on top side	Gasoline	P<0.3	Less vapor, low temperature, pressure instrument failure	Process gain decrease			Check the pressure instrument, balance the temperature
7	Low pressure in down side	Mazut	P<0.3	Low liquid level, empty, vacuum due to temperature deference	Decrease in process gain and speed			Check level control valves, while shutting down the system make sure that it is cooled
8	High temperatur e on top side	Gasoline vapors	T>110 ^{0}C	High gasoline percentage in crude oil, high pressure in top side of K_1, instrument failure, more heating in furnaces, less reflux shower	Change in Gasoline's color, quality and density, unbalance process			Decrease heating in furnace, check the pressure and balance it on top side, check the instruments, check reflux amount on top side
9	High temperatur e in down side	Mazut	T>360 ^{0}C	More heating in furnaces, more heavy fractions percentage in crude oil	Temperature raising in diesel and gasoline discharge plates, Change in products color, quality and density more reflux consumption, more mazut density cause pressure while pumping			Check Mazut density, check other products color, check the instruments, decrease heating in furnace, balance the process
10	Low temperatur e top side	Gasoline	T<100 ^{0}C	Distillate Is not heated enough, gasoline percentage is low, more reflux is given, instrument failure	Low gasoline discharge, low density of products, less gain			Check temperature in furnaces, check the control valve of reflux, check thermocouples
11	Low temperatur e down side	Mazut	T<350 ^{0}C	Distillate Is not heated enough, less heavy fractions in crude oil, instrument failure	Low temperature on top side, less gasoline discharge, low density of products, less gain			Raise temperature in furnaces, check the instruments, decrease reflux flow in

Study Title: Crude oil Heating							Sheet :7 of 13	
Part considered			Furnace F_1				Date:9/01/2020	
Design Intent			Material: Crude oil Source: Distillation Column K_3			Activity: Heating Destination: Distillation Column K_1		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High flow in	Crude oil	More crude oil flow to furnace	Crude oil feed in raised, feed In control valve is not working, K_3 level control valve failure	Less gain			Check K_3 liquid level, balance feed in
2	Low flow in	Crude oil	Less crude oil flow to furnace	Crude oil feed in decreased, feed in control valve failure, K_3 level control valve failure	Less gain, more heating and collect cokes in pipes			Check feed in and K_3 level control valve
3	High temperature outlet	Crude oil	T>370 ^{0}C	Less flow in, more flame temperature	Raise temperature in K_1 and unbalance the process, create cokes inside the pipes			Check flow in and flame temperature
4	Low temperature outlet	Crude oil	T<350 ^{0}C	More flow in, low flame temperature	Decrease temperature in K_1, unbalance the process			Check flow in and level control valves in K_3, check the flame temperature
5	High pressure inlet	Crude oil	More pressure in furnace inlet than outlet	Valves failure, cokes inside the pipes	Raise temperature , decrease gain, consume more fuel			Check the valves and maintain the furnace

6	No flow out	Crude oil	No crude oil in outlet	Related valves failure, cokes blocked the pipes, no flow in	Temperature increase, create cokes			Check the valves , shutdown the system and maintain the furnace
7	No flow in	Crude oil	Zero pressure in furnace inlet	Pressure measurement instrument failure, K_3 level control valve blocked, pump breakdown	Temperature increase, create cokes			Check feed in pump and valves, check K_3 level control valve, check the pressure measurement instrument
8	Breakdown	Crude oil	Furnace turned off	Fuel tank empty, filter blockage, change in fuel density and temperature	Temperature decrease and process destroy			Check the fuel and turned on, decrease feed in, in long time furnace failure cool and shutdown the system

Study Title: Crude oil heating							**Sheet :8 of 13**	
Part considered			**Furnace F_3**				**Date:9/01/2020**	
Design Intent			**Material: Crude oil**			**Activity: Heating**		
			Source: Distillation Column K_3			**Destination: Distillation Column K_3**		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
2	Low flow in	Crude oil	Less crude oil flow to furnace	Low level in K3, circulation pump failure	Less gain, more heating and collect cokes in pipes			Check circulation pump, add some crude oil from appendix valve to decrease the temperature in furnace
3	High temperature outlet	Crude oil	T>280 ^{0}C	Less flow in, more flame temperature	Raise temperature in K_3 and unbalance the process, create cokes inside the pipes			Check circulation pump and flame temperature
4	Low temperature outlet	Crude oil	T<250 ^{0}C	More flow in, low flame temperature	Decrease temperature in K_3, unbalance the process			Check flow in and level control valves in K_3, check the flame temperature
5	High pressure inlet	Crude oil	More pressure in furnace inlet than outlet	Valves failure, cokes inside the pipes	Raise temperature , decrease gain, consume more fuel			Check the valves and maintain the furnace
6	No flow out	Crude oil	No crude oil in outlet	Related valves failure, cokes blocked the pipes, no flow in	Temperature increase, create cokes			Check the valves , shutdown the system and maintain the furnace

7	No flow in	Crude oil	Zero pressure in furnace inlet	Pressure measurement instrument failure, circulation pump breakdown	Temperature increase, create cokes			Check circulation pump, check the pressure measurement instrument
8	Breakdown	Crude oil	Furnace turned off	Fuel tank empty, filter blockage, change in fuel density and temperature	Temperature decrease and process destroy			Check the fuel and turned on, decrease feed in, in long time furnace failure cool and shutdown the system

Study Title: Heat exchanger							Sheet :9 of 13	
Part considered			Heat exchanger T(1,2)				Date:9/01/2020	
Design Intent			Material: Diesel , Crude oil			Activity: heat exchanging between diesel and crude oil		
			Source: Diesel from K2 and crude oil from stock			Destination: diesel to water cooler and crude oil to process		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High flow	Diesel	More Diesel flow in	More diesel percentage in crude oil, T>240 ^{0}C and more heavy vapors raised to diesel plate or if T<180 ^{0}C and more gasoline vapors condensed, liquid level in K_1 raised	More energy consumption while cooling it, changing its color and quality			Raise exchanger's water flow In, add exchangers, check and balance the temperature of diesel plate, check the liquid level in K_1, check the color of diesel
2	Low flow	Diesel	Less Diesel flow in	Less diesel percentage in crude oil, T<200 ^{0}C in diesel plate in K_1, U shaped diesel discharge pipe in K_1 is blocked	destroy the process			Check the U shaped pipe which connects K_1 and K_2, and check the temperature in diesel discharge plate
3	High pressure	Diesel	High pressure in exchanger inlet	Failure of inlet or outlet diesel valve to open, blockage in diesel pipes, exchanger cylinder blockage	Decrease process gain, leakage in exchanger			Check the valves and pipes, check all parameters in process, maintain the exchanger
4	High temperature	Diesel	High temperature of Diesel in exchanger outlet	More diesel flow in, no crude oil flow in to heat exchanger, crude oil temperature high	Storing hot stream diesel will cause diesel to vaporize(economical loss), more energy consumption for cooling it			Check crude oil flow in, temperature and valves, make sure that the water cooler is enough to make it cool

5	Changing composition	Diesel	Crude oil leakage in Diesel, dark hydrocarbons	leakage inside the heat exchanger, changing in the temperature of diesel plate in K_1, liquid level in K_1 raised	Destroy process, Diesel waste (economical loss)			Check the color of diesel and analyze it, check process all parameters, shut down and maintain the exchanger

Study Title: Heat exchanger							Sheet :10 of 13	
Part considered			**Heat exchanger T_{3-4}**				**Date:9/01/2020**	
Design Intent			**Material: Mazut , Crude Oil**			**Activity: cooling Mazut and heating crude oil**		
			Source: Mazut from K1 and crude Oil from stock			**Destination: Mazut to water cooler and crude oil to process**		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High flow	Mazut	More Mazut flow in	K_1 level control valve is not working, process feeding capacity is increased, K_1 level is raised	It will consume more water while cooling maybe it will be stored with high temperature if it is >200 ^{0}C then it can burn easily			K_1 level should be balanced, control valve should be checked, increase water flow to exchanger, balance crude oil flow in to T_{4-3}
2	Low flow	Mazut	Less Mazut flow in	K_1 level is down, K_1 level control valve is not working, process feeding is decreased	Process gain comes down, discharged Mazut from exchanger will be cold and pumping will consume more energy			Decrease water flow, control the Mazut temperature and keep it under 80 ^{0}C in KX_{7-7A},check the level control valve and level shower instruments, raise crude oil feed in capacity
3	High pressure	Mazut	High pressure in inlet	Heat exchanger clogged, control valve is blocked, cokes collected inside cylinder, valve failure	Process gain will decrease, High pressure on pumps during pumping cold Mazut with high density, leakage and explosion can happen, level will raise in K_1			Balance both exchangers Mazut inlets, use one exchanger and maintain the damaged one, check the level in K_1, supervise exchangers
4	High temperature	Mazut	High temperature at outlet	Crude oil temperature is high, Mazut flow in is increased, K_1 down side temperature is high	hot mazut will make noises in KX_{7-7A}, if it discharged with high temperature, it will melt washers in joints, and it became high flammable			Make sure that its temperature will decrease in KX_{7-7A} , raise crude oil flow in, check K_1 down side temperature and parameters of process

5	Changing composition	Crude oil	Mazut density changed suddenly	Hole in crude oil pipes inside the heat exchangers, leakage inside pipes and valves, process is not normal	Mazut will mix to crude oil and enter process, and crude oil will mix with mazut			Find the damaged exchanger maintain it, check all parameters of process analyze Mazut composition, or shut down the system
6	leakage	Mazut	Leakage of hot mazut to the atmosphere	Temperature deference, high pressure, physical pressures	Fire , explosion			Check temperature deference and pressure

Study Title: Mazut cooler						Sheet :4 of 13		
Part considered			Heat exchange X7 X7A			Date:9/01/2020		
Design Intent			Material: Water , Mazut			Activity: Cooling Mazut		
			Source: column K1			Destination: storage tanks		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High flow	Mazut	More Mazut flow in	K_1 level control valve is not working, process feeding capacity is increased, K_1 level is raised	Mazut will be stored with high temperature if it is >200 ^{0}C then it can burn easily			K_1 level should be balanced, control valve should be checked, increase water flow to exchanger
2	Low flow	Mazut	Less Mazut flow in	K_1 level is down, K_1 level control valve is not working, process feeding is decreased	Process gain comes down, discharged Mazut from exchanger will be cold and pumping will consume more energy			Decrease water flow, control the Mazut temperature and keep it under 80 ^{0}C
3	High pressure	Mazut	High pressure in exchanger inlet	Heat exchanger clogged, control valve is blocked	Process gain will decrease, High pressure on pumps during pumping cold Mazut with high density, level raise in K_1			Balance both exchangers Mazut inlets, use one exchanger and maintain the damaged one
4	High temperature	Mazut	High temperature of Mazut in exchanger's outlet	Water temp. is not enough to cool Mazut well, Mazut flow in is increased	If T>200 ^{0}C it will be near to its auto ignition temp. and it became more flammable , it will melt washers in joints			Increase water flow in, decrease cooling water temp (adding new water to chiller and turning on ventilators
5	Changing composition	Mazut	Water in Mazut	Hole in water pipes inside the heat exchangers	Mazut will mix to water and enter cooling system, water will mix with Mazut			Decrease crude oil feed in, use one of the exchangers and maintain the damaged one

Study Title: separator						Sheet :11 of 13		
Part considered			C1 Tank			Date:9/01/2020		
Design Intent			Material: Benzene , gas Source: Distillation Column K_3			Activity: separating Destination: Stock		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High pressure	Gasoline	>0.5 atm	Temperature is >120 ^{0}C on K_3 top side, more gases concentration in crude oil	Pressure will go up on top side of K_3 and it prevents gasoline vapors to reach the top, it cause more emulsion in C_1	Automatic safety valve and manual safety valves are exist	Needs to be controlled	Adjust it by the manual valve located on top of C_1 tank
2	High temperature	Gasoline	>50 ^{0}C	K_3 top side temperature is >120 ^{0}C , light gases concertation is high, coolers are not enough to cool the gasoline vapors	C_{1-5} escape from the tank and can create an explosive atmosphere around the tank			turn on Ventilator in water chiller, add more water to cooling system,
3	Changing composition	Gasoline , heavy fractions, water	Color change, emulsion	K_3 top side temperature is >120 ^{0}C, more water percentage in crude oil	The quality of gasoline will decrease	Water discharge valve		Check temperature K_3 top side, control the color, discharge water, balance the process
4	Instruments	Gasoline, gases, water	Important instruments	To know the situation inside the separator	Gasoline color can change, water level can rise and make more emulsion, heavy gases will exit and create an explosive atmosphere around the tank	Level and pressure instruments are exist		Gas concentration should be checked, water level should be installed

Study Title: separator							Sheet :12 of 13	
Part considered			Separator Tank C2				Date:9/01/2020	
Design Intent			Material: Gasoline , Gas Source: Distillation Column K_1			Activity: separating gas from Gasoline Destination: stock		
No	**Guide word**	**element**	**Deviation**	**Possible causes**	**consequences**	**Safeguards**	**Comments**	**Action required**
1	High pressure	Gasoline	>0.5 atm	Temperature is >120 ^{0}C on K_1 top side, more gases concentration in crude oil	Pressure will go up on top side of K_1 and it prevents gasoline vapors to reach the top, it cause more emulsion in C_2	Automatic safety valve and manual safety valves are exist	Needs to be controlled	Adjust it by the manual valve located on top of C_2 tank
2	High temperature	Gasoline	>50 ^{0}C	K_1 top side temperature is >120 ^{0}C , light gases concertation is high, coolers are not enough to cool the gasoline vapors	C_{1-5} escape from the tank and can create an explosive atmosphere around the tank			turn on Ventilator in water chiller, add more water to cooling system,
3	Changing composition	Gasoline, heavy fractions, water	Color change, emulsion	K_1 top side temperature is >120 ^{0}C, more water percentage in crude oil	The quality of gasoline will decrease	Water discharge valve		Check temperature K_1 top side, control the color, discharge water, balance the process
4	Instruments	Gasoline, gases, water	Important instruments	To know the situation inside the separator	Gasoline color can change, water level can rise and make more emulsion, heavy gases will exit and create an explosive atmosphere around the tank	Level and pressure instruments are exist		Gas concentration should be checked, water level should be installed

Curriculum Vitae

Ahmad Fawad MIAZADA

Place & Date of Birth : Afghanistan 05/11/1993
Marital Status : single
Adress : cumhuriyet mahallesi cumhuriyet caddesi 1985. Sk. Tezyuve sitesi A2 D 25 esenyurt istanbul

I have 2 years of experience in a crude oil refining factory in Afghanistan. Between June 2014 and September 2016, I worked as operator and safety committee member during this two years.

Education

BS Balkh university Chemical engineering

Work Experience

Kam International Oil crude oil refining factory 2014-2016

Languages:

Persian, Turkish, English