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A THESIS REPORT ENTITLED:

FRACTIONAL DISTILLATION OF SPILLED CRUDE OIL CONTAINING ADDITIONAL OLEOPHOBIC AND OLEOPHILIC IMPURITIES

BY

BEN ASANTE

SUBMITTED IN FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN MINERALS ENGINEERING

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DECLARATON

I declare that this thesis is my own work. It is being submitted for the degree of Doctor of Philosophy in Minerals Engineering in the University of Mines and Technology (UMaT), Tarkwa. It has not been submitted for any degree or examination in any other University

………………………………………..
(Signature of Candidate)

10th day of August 2023

ABSTRACT

Crude oil spillages on the oceans cause huge financial losses to businesses and harm to the environment and the species that depend on the oceans for survival. In order to cut down the losses caused by spillages, decision was made to distill the crude oils for consumption. Before distilling the crude, salt and sulphur had to be removed from it in order to avoid the destruction of the distillation column during fractionation and the emission of sulphur compounds into the atmosphere when the oil is used. Chemical desalting and oxidative extractive desulphurisation methods were used for those processes. The distillation column used in the research was designed and built by the researcher. The crude oil used for the work was obtained from Tema Oil Refinery (TOR) and the seawater fetched from the New Amanfrom Beach. The crude oil was medium dark sour compound having a density of 900.8 kg/m^3. The American Petroleum Institute (API) index of the crude was 25.47^o. Before desalting and desulphurisation, testing the unspilled crude oil for salt and sulphur contents gave 13.2 g/m^3 of salt and 3000 ppm of sulphur in the unspilled crude oil. The test of the spilled crude oil also showed 89 g/m^3 of salt and 3530 ppm of sulphur contents. After two successive desulphurisation processes, the sulphur in the spilled and the unspilled crude reduced by about 92 % and 88.82 % correspondingly. Similarly, after five desalting processes, the salt in the spilled and the unspilled crude reduced by about 63.13 % and 27.27 % respectively. The samples obtained from the distillation were analysed using Fourier Transform Infrared (FTIR) Spectrometry and Gas Chromatographic /Mass Spectrometry (GC-MS). The major fractions identified included gasoline, naphtha, kerosene, diesel, fuel oil, and bitumen. The value of the API, the size of the distillation column, the relative volatility of the crude components, and the surface area for the vapour and liquid available in column influenced the fractions obtained. The total energy consumed to fractionate the 2 liters of the crude was 1.813 x 10^3 kJ. The specific energy consumed by the crude fractions are presented in an increasing order as follows: Gasoline, 388 J/g < naphtha, 502.8116 J/g < kerosene, 543.15 J/g < diesel, 611.4441 J/g < fuel oil, 763.7259 < bitumen, 863.2596 J/g. The analysis of the specific energy consumed by the crude oil fractions showed that more energy was needed to fractionate the less volatile crude oil fractions than to fractionate the more volatile crude oil fractions.

DEDICATION

I dedicate this thesis to the Almighty God for the strength and guidance he gave me.

To my children:

Hillary Agyapomaa Nsroma Asante

Ben-Bill Okatakyie Asante and

Lady-Alexia Owusuaa Asante

To my wife: Gifty Adu-Poku Asante

To my supervisors:

Assoc Prof J. R. Dankwah and

Dr Solomon Adjei Marfo

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CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Oil spilled into the sea need to be cleaned and converted to a useful product by fractional distillation. Crude oil spillage causes big financial loss but the loss could be reduced if it is cleaned, distilled, and consumed. In doing so, the relationship between the energy consumed during the conversion processes and the quantity of oil distilled need to be established so that predictions and economic decisions could be made from that relationship by companies who decide to refine the spilled oil. Furthermore, the spilled crude oil needs to be desalted and desulphurised before embarking on the fractional distillation of the crude oil to avoid the destruction of the distillation epuipments, fouling of catalysts, and the destruction of plants in the environment. An economically acceptable novel method of desulphurisation and desalting is needed, especially for the current economic situation in Ghana where transportation fuel prices keep soaring frequently.

At the moment, the sea is the predominant medium for transporting crude oil from one country to the other.The problem that occurs during the transporting of the crude oil from one place to the other is the spillage of the crude oil into the sea. More often than not, the spillages have been a bane to the environment since the invention, the drilling, the transporting, and the uses of this commodity (Mwai, 2020; Marsh, 2022; Ahmed, 2022; Webb, 2018, Helm *et al*., 2014; Hatchwell, 2008). West (2018) reported that the causes of oil spills are damaged tankers, damaged pipelines, damaged offshore oilrigs. He added that the occurrence of oil spills has a devastating impact on birds, beaches, marshlands, fragile aquatic ecosystems, marine mammals, fish, wildlife habitat, and breeding grounds. Furthermore, oil spill can have a disastrous impacts on coastal ocean ecosystem, human health, and the economy as seen in the Gulf of Mexico Deepwater Horizon spill in 2010 (Frost, 2014, Wiese and Robertson, 2010).

Undoubtedly, as reported by the vast majority of researchers, crude oil spillages into the ocean cause a great deal of harm to the environment, to the species in the oceans, to other species that depend on the ocean for survival, and to a host of other living organisms (Roser and Ritchie, 2022; Okafor, 2022; Meade, 2022; Wright, 2022; Libenson, 2017; Edmond, 2021; Sadogurskaya, 2022; Eklund *et al*., 2019, Fiorello, 2021). Not only do crude oil spills occur during transporting it from one place to the other but also they occur through explosions, leakages of oil pipelines, and sinking of rigs (Kramer, 2018; Sivas and Driscoll, 2021; Harvey, 2011, Bhushan, 2019). An example of such an accident is the explosion and sinking of the Deepwater Horizon oil rig which occured in the Gulf of Guinea in April 2010. The British Petroleum (BP) spent about US$15 billion to clean the Deepwater Horizon spill of about 3 million barrels of crude oil. Including the cleanup cost and other legal obligations, the company spent more than US$60 billion on the spillage (Uhlmann, 2020; Pallardy, 2010). Besides other expenditure involved with cleaning crude spillage, the retrieval of information from spillage site also cost money. The drifters alone deployed by the Consortium for Advanced Research on Transport of Hydrocarbon in the Environment (CARTHE) workers in the Gulf of Guinea cost about US$300,000 (Card, 2014). The purpose of the drifters was to send information about the situation of the locations back to the scientists through GPS satellite.

During the Gulf war in January 1991, the leader of Iraq, the late Saddam Hussein, intentionally spilled a great amount of oil into the sea, causing huge financial losses and damages to the environment (Barber, 2018). The oil spilled was cleaned using enormous amount of money and resources. Nevertheless, that spilled oil could have been cleaned, distilled, and used as fuel. In 2020 and 2021 alone, the amount of crude oil spilled in Nigeria was 28,003 barrels as reported by Nigeria Oil Spill Detection and Response Agency (Saint, 2022). This quantity of crude oil on average was about US$1577128.96. This huge sum of money could have been channeled into doing some developmental project for Nigeria, but it was wasted through spillage. In January 2022, the United Nation Office for the Coordinaton of Humanitarian Affairs (OCHA) reported crude oil spill of 6000 barrels of crude oil off the coast of Lima. This quantity of crude oil calculated was about US$545340. Again, recently more than 10,000 barrels of crude oil spilled into the Pacific Ocean by a tanker in Peru (Collyns, 2022). This spilled crude oil was priced at about US$908900. In summary, spillages waste a great amount of money (Prendergast and Gschwend, 2014; Cohen, 2010; Aguilar, 2022; Cagle, 2022; Quartz, 2015; Trang, 2006:

Hanna *et al.*, 2022; Takahashi, 2022,). Most of these costs emanating from crude oil spillages could be offset if the crude oil is cleaned, refined, and sold for consumption.The sea contains a great amount of impurities (Aslam *et al.*, 2020; Vance *et al.*, 2021; Bhattacharya *et al.*, 1999; Buffo *et al.*, 2020; Legrand and Delmas, 2017; Anissimov, 2022; Balasubramanian, 2017; Balasubramanian, 2013, Sapozhnikov, 2022; Manasrah *et al.*, 2019; Jeong, *et al.*, 2017). And when crude oil is spilled into the sea, it encounters those impurities because of the emulsification between the seawater and the crude oil. Substances such as salt, sodium, chloride, calcium, magnesium, potassium, sand, mud, iron sulphide, iron oxide, soluble emulsified water, and finely dispersed water already exist in the crude when it is drilled from the ground (McDaniels and Olowu, 2016; Babalola and Susu, 2019; Traine, 2017; Solomon *et al.*, 2018; Barrett *et al.*, 2017; Martiensen, 2020; Kondyli and Schrader, 2021). These impurities are classified the oleophobic impurities of crude oil. Spilled crude oils pick some of the impurities from the sea. Among the impurities picked up by the spilled crude oil is salt.

The presence of extra salt increases the extent of corrosion of the materials used in the distillation process (Chis *et al.*, 2022; Puna *et al.*, 2011; Sani *et al.*, 2021; Joshi *et al.*, 2015). Rust is subsumed under corrosion. Rust is the destructive chemical process in which metals undergo spontaneous oxidation (Chang and Shih, 2003; Suppe, 2019; Sabhadiya, 2022). In addition, the most significant problem involved with rust is the rendering of the metals involved in the distillation process to loose their strengths. Corrosion is the destruction of materials including iron and its alloys. It occurs when part of the material forms an anode and the other part forms a cathode. Dissolved salt serves as the electrolyte to speed up propagation of electrons from one end to the other of the electrochemical cells which in turn speeds up corrosion (Thirumalal *et al.*, 2020: Gillespie, 2018). Additionally, acid is detrimental to the safety of the distillation equipment and higher acidic environment increases corrosion of materials (Bahadori, 2014). If sulphur and water are allowed to stay in the crude oil, they react to produce sulfuric acid. Thus, it is important to eliminate these impurities from the crude oil before it is distilled. The oleophilic impurities of crude include sulphur compounds, organometallic compounds, Iron, nickel, vanadium, arsenic, nitrogen compounds, and naphthenic compounds. These are considered soluble. The presence of the oleophilic impurities such as sulphur compounds is greatly undesirable in transportation fuels because of regulatory issues and the environmental destruction problems. Furthermore, energy is an essential ingredient in distillation process. Knowing the amount of energy and the cost involved in distilling crude oil assists tremendously in making economic decisions during plant operations.

Therefore, it is important to find out the quantity of energy needed to distill the spilled crude oil. The factors that are likely to affect the quantity of energy required for the distillation include the quantity of the crude oil present, the volatility of the constituents of the crude oil, the affinity of the constituents of the crude oil, etc. Researchers have separated crude oils into their constituents using various methods (Eser, 2020; Hanifa and Elzagheid, 2019; Mir *et al*., 2022; Aljamali and Salih, 2021; Oschmann *et al*., 2007). Separation process changes or converts the species into their constituents. Crude oil separation is accomplished taking into consideration both physical and chemical properties such as the relative volatilities, the mass, the size, the density, the chemical affinity, etc., of the species involved. The methods of crude oil separation include fractional distillation, liquid-solid chromatography, liquid-liquid chromatography, gas-liquid chromatography, fractionation with molecular sieve adsorbent, thermal diffusion, separation of aromatic types through the complexes which they form with certain aromatic nitro compounds, and crystallization.

Albeit environmentalists and researchers have identified the effects of oil spills on the environment, they have not come up with the effect of the seawater on the separation of the components of spilled crude oil. Guipeng *et al*. (2006) conducted research about the photochemical reaction of crude oil in seawater by using high-pressure mercury light or sunshine but generally did not delve into the general aspects of the effects of seawater on the separation of petroleum. Salt constitute a greater amount of the impurities of seawater. Mostly, the sea is the major environment of crude oil because this mineral is drilled predominantly from and transported primarily through the seas. Spilled crude oil should not be allowed to go wasted. It needs to be collected and distilled into its various components for utilization. Undoubtedly, the main source of transportation fuel used today is derived from crude oil. With increasing global energy demand, crude oil remains the primary supply of energy around the world contributing to approximately 50% of the World's total supply of energy (Betiha *et al*., 2018).

It is undeniable that recently the world is finding ways to use renewable forms of energy such as solar energy, wind energy, geothermal energy, and what have you, so that it can do away with the uses of the energy derived from crude oil because of its somewhat negative impact it may cause to the environment. Nevertheless, it is without doubt the uses of energy derived from crude oil still dominates the uses of all other forms of energy. The uses of crude oil products spans from powering automobiles, producing medicines, manufacturing cosmetics, and so forth, to the preparation of medicines. According to the Organisation of Petroleum Exporting Countries (OPEC), the world oil demand was projected to increase by 1.54 million barrels per day (mb/d) in 2018. Again, as stated by the OPEC, the total global oil consumption for the year 2018 was expected to increase to the average of 98.79 mb/d. It is obvious that the figures above indicate that as much as the world is trying to move away from using crude oil, imperatively, the demand of it is still soaring.

Again, the report OPEC submitted to the world shows that the world oil demand was anticipated to grow by 1.36 mb/d to the average of 100.15 mb/d. According to the report, most of the oil demand growth is anticipated to originate from Asia, led by India, followed by China, then the Organisation for Economic Cooperation and Development (OECD) Americas. The OECD countries are forecasted to see a rise in oil demand growth by 0.25 mb/d while non-OECD countries will drive oil demand growth by adding an estimated 1.11 mb/d (Al-Qahtani, 2018).

1.2 Statement of the Problem

Crude oil spillage causes huge financial loss to corporations and other businesses involved with drilling, storing, transporting, etc, of this commodity (Barber 2018; Uhlmann, 2020; Pallardy, 2010). Besides the financial losses incurred by businesses that encounter this problem, species in the spillage area, human beings, and the environment suffer greatly when there is spillage. But how could the economic impact of this calamity be reduced? To reduce this huge impact, there was the need to conduct thorough research about how useful the spilled crude oil could be to humanity. Variuos researchers have suggested diverse ways to reduce the economic impacts of crude spillages but by not reducing the impacts through distilling the spilled crude oil for consumption (Radka, 2021; Laruelle, 2020; Ojimba, 2011; Ipingbemi, 2009; Ribeiro et al., 2020; Cohen, 2010; Dyer, 2010). Before distilling the spilled crude oil, it was essential to remove the major unwanted impurities from it in order to avoid further problems (Fajobi *et al*., 2019; Pereira et al., 2015).

Emulsification takes place between seawater and crude oil when there is spillage. Because of this reason, the crude oil carries with it some seawater containing salt, sulphur, etc, when the spillage is cleaned from the ocean for distillation. Hydrodesulphurisation (HDS), which is the the most popular method used by most refineries is not without problems. The cost of using this technology is so high as a result of the high temperature and pressure operating parameters (Sadare *et al*., 2017). Although there has been a research study on the effects of sulphur on human beings, and the desulphurisation of the sulphur containing compounds found in the distillates of a refined crude, there has not been any research on desulphurisation of spilled crude oils (Sadare *et al*., 2017; Hameed and Tahseen, 2019; Demirbas *et al*., 2014: Ismagilov *et al*., 2011; Shafiq, 2021; Samokhvlov, 2012; Keynejad *et al*., 2017). Furthermore, because of the high cost of hydrodesulphurisation of crude oils that transforms partly to the rising cost of transportation fuels, Ghana has waived to some degree the amount of sulphur content allowable in the locally refined transportation fuels (Reed, 2022). Because of that, a cheaper method of desulphurisation will be extremely helpful to the crude refining companies in Ghana.

Similarly, electrostatic demulsification, the most popular method of demulsifying crude oil/brine mixture also has efficiency uncertainty problem (Sprenkel, 2020; Bai and Wang, 2008). For an unknown reason, this technology is sometimes effective and sometime ineffective. Other researchers desalted fuel oil using diverse ways but have not conducted desalting of spilled crude oil using akpeteshie as demulsifier (Majumdar *et al.*, 2002; Pareira *et al*., 2015). A review has also been done on desalting process techniques and economic analysis of the salts from retentates but not on desalting of spilled crude oil (Kim, 2011). McDaniels and Olowu (2016) conducted a research on the limitation on desalting effectiveness, and the increasing of fouling and corrosion risks in downstream units by natural and introduced contaminants, but they did not take into consideration desalting of spilled crude oil. Because of the above mentioned gaps in previous researches and ways used to desalt and desulphurise crude oils, it was important to adopt a novel method that could remove the salt and sulphur (the most undesirable impurities) from the spilled crude oil in a cost effective manner and a higher degree of efficiency certainty. Undoubtedly, energy plays an indispensable role in crude oil refining processes. In the refining business, the mainstay of fianancial and economic assessment of the operating cost is the energy needed to refine the crude. The crude refining companies spend about 50 % of their operating cost on energy (Worrell and Galitsky, 2005). Because of that, it will be important to research about the energy needed to distill the spilled crude oil which will be beneficial to business entities seeking to venture into the spilled crude oil refining business. Although it is obvious that refinery companies have information about how much energy is needed to refine some amount of normal crude oil at the public domain, there are scanty information available to the public about the cost of energy needed to refine spilled crude oil (Haynes, 1979; Kalinenko and CavKov, 2021; Jobson *et al*., 2005; Rikhtegar and Sadigi, 2015).

Although, Damanabi and Bahadori (2016) conducted research of distillation on spilled crude oil, the spillage occured on fresh water but not on seawater. Furthermore, the energy they reported about in their research was just incremental enegy consumed during the distillation process. Because there is no known company that is in the business of distilling spilled crude oil, it was crucial to design and construct the distillation column exclusively that could fractionate the spilled crude. The success of this innovation could be scaled up by corporations to distill spilled crude oil so that the financial losses and the environmental impacts on society beset by spillages could be reduced. Although, businesses are making good strides in the cleaning of spillages, that seems a dead end to the public about this quandary. Therefore, it was important to find a method to desalt and desulphurise the spilled crude oil, to design and construct a distillation column, and to distill the spilled crude oil for consumption.

1.3 Objectives of the Research

The main objective of the research was to assess the specific energy consumed to fractionate spilled crude oil. In doing so, the following specific objectives were taking into consideration:

i) To determine the quantity of salt and sulphur in a spilled and unspilled crude oils;

ii) To establish the effectiveness of using locally manufactured reagents in desalting the crude oils (spilled and unspilled);

iii) To desulphurise the crude oils (spilled and unspilled) using locally manufactured reagents and ascertain the effectiveness of the local reagents used;

iv) To design and construct the distillation column;

v) To distill the desalted and desulphurised spilled crude oils in order to ascertain the crude oil fractions;

vi) To determine the energy consumed to distill the crude oil.

1.4 Significance of the Study

This research will help to determine the contents of salt and sulphur in a spilled crude oil. It will also give refining companies, especially the Ghanaian crude oil refining companies the option to use akpeteshie to desalt and desulphurise crude oils. Furthermore, this research will draw attention of crude oil refining companies across the world to consider going into the refining of spilled crude oil. This research will give information to refining companies about the amount of energy needed to fractionate some specified quantity of spilled and unspilled crude fractions. The researcher used local materials from Ghana to design and construct the distillation column used in fractionating the spilled and unspilled crude oils. The column could be scaled up to distill crude oil commercially and conduct other researches relating to distillation. Furthermore, the distillation column could be used to give practical education to students in crude oil refining.

1.5 Methods Used

Research methodology is the process followed during the entire research process. This research used experiments under quantitative method. The experimental research strategy and design used in this research exercised control over all the necessary factors to affect the results of the experiment. Desalting and desulfurisation of the spilled crude oil were embarked on. Data were collected from the distillation of the spilled crude oil. Below is the summary of the method followed:

1.5.1 Summary of the Method Used

- Sample preparation (Seawater plus spilled crude oil)
- Electrometric analysis for salt in crude determination
- Dispersive x-ray florescence spectrometry for sulphur in crude determination
- Chemical desalting
- Oxidative extractive desulphurisation
- Distillation column design and construction
- Fractional distillation.
- Gas Chromatograpy/Mass Spectrometry (GC/MS) and Fourier Transform Infrared (FTIR) Spectrometry analysis.
- Computations and drawing of charts Using Microsoft office programs.

1.6 Scope of Work

The scope of the research involved fractionating spilled crude oil in seawater conditions. Desalting and desulphurisation of the crude sample of both the raw and the spilled crude oils using locally manufactured demulsifier and extractant were amongst the areas the research covered. The crude oil sample used in the research was obtained from Tema Oil Refinery. The research included the design and construction of the distillation column. The separation of the crude oil into its constituents using the distillation column is another area the research covered. Furthermore, the research covered the identification of the crude fractions using Gas Chromatography/Mass Spectrometry and Fourier Transform Spectrometry analysis. The assessment of the energies consumed to distill the specified amounts of the crude fractions was considered in this study.

1.7 Facilities Used

The facilities used in conducting the research are provided below:

- The University of Mines and Technology Library.
- The InterTech laboratory, Takoradi.
- The Mineral Engineering Laboratory of the University of Mines and Technology
- The Central Laboratory of the Kwame Nkrumah University of Science and Technology.

1.8 Report Organisation

Chapter 1 presents the summary of various sections of the entire research. The chapter provides the introduction consisting of the background of the study, the scope, the significance of the study, the summary of the methods and the facilities used in the research, the statement of the problem, and the objectives of the study. Chapter 2 presents the relevant literature reviews about the research. It presents empirical literatures and the theoretical literatures in relation to the research. It shows different methods of cleaning crude oil spills from the sea. It shows different methods of desalting and desulphurising crude oils. Furthermore, chapter 2 shows different methods of distillations. Chapter 3 presents the methods used, the facilities used, the research design. It shows the design of the distillation system; the method used in desalting both the raw and the spilled crude oils; the method used in desulphurising both the raw and the spilled crude oils. Additionally, chapter 3 shows the procedure used in determining the quantity of salt and sulphur in both the spilled and the raw crude oils; and the process of distilling the crude oil into the various fractions. Chapter 4 presents the discussions of the results obtained from the desalting and desulphurisation of the raw and the spilled crude oils. It presents discussions of the results obtained from the analysis of the fractions obtained from the distillation. Chapter 5 presents the conlusion, the recommendations, and the future work relating to the research.

CHAPTER 2

LITERATUR REVIEW

2.1 Introduction

This chapter provides the empirical reviews and the theoretical reviews relating to the research. Empirical review focusses on the works researchers have conducted similar to this research. On the other hand, the theoretical review focusses on the theories that relate to the research. Furthermore, the review touches on the methods, the issues and debates, and the key sources of the topic.

2.1.1 Emperical Review of the Reasearch

This section presents the reviews of the works conducted by other researchers and the identification of the daunting problems that confronted their works. In the subsequent sections of this chapter, the following methods were reviewed: the cleaning of the oil spills, the methods of desalting, the methods of desulphurisation, the energy needed to distill the crude oils. In doing so, these problems were identified. Currently, most crude oil refining industries use the conventional hydrodesulphurisation (HDS) method to remove sulphur from the crude oils (Javadli and Klerk, 2012; Robinson and Dolbear, 2006). Although HDS could remove sulphur from crude oils, using this technology is very expensive. The high cost of this technology comes from the use of high temperature and high pressure in the HDS process. The energy efficiency of this technology is also poor because the gas used in the process could not be reused (Behrouzifar, 2019; Ishii and Mochizuki, 1995; Dembaremba *et al*., 2022). As a result of these shortcomings with HDS, a better energy efficient and a lesser cost of desulphurisation was needed. Anothr desulphurisation method known as the oxidative desulphurisation (ODS) is also confronted with challenges. In using this technique, gum is formed and high level of hydrocarhons are wasted. It was proven that about 20 % of the hydrocarbons are wasted during the extraction step in the oxidative desulphurisation process (Mortezaee et al., 2022). Because of the problem facing the use of ODS, it was prudent to find a better method of desulphurising the crude oils.

Another alternate technique that could have been used to solve the problem of desulphurisation without using HDS or ODS is the use of Ionic Liquids. However the Ionic Liquids also poses environmental threat (Rajasuriyan, et al., 2021). Again, biodesulphurisation that could have been used to solve the preceeding problems mentioned earlier on also has major drawbacks (Hirschler, et al., 2021; Olson and Kelly, 1991). The problems associated with biodesulphurisation includes unavailabity of methods to measure the organic sulphur content in the crude and lack of understanding of different types of organic sulphur bacteria. As a result of these problems associated with biodesulphurisation, a novel method was formulated to desulphurise crude oil. Because of all the drawbacks associated with the aforementioned desulphurisation techniques, this research resorted to desulphurise the crude oils by using oxidative extractive technique that employs hydrogen peroxide, acetic acid, and Akpeteshie as reagent.

For the desalting process, Chimin *et al.* (2016) also wrote an article about methodology development that studies chlorides released during the crude oil distillation mimicking the process that occurs in refineries, enabling predictions and minimising equipment damage. The article presented by the researchers included the salinity mass balance as well as their respective chloride release percentage to each oil. However, the paper mentioned nothing about spilled crude oil and the amount of energy needed to conduct the crude separation.

Furthermore, desalting of crude oil involves emulsification and demulsification. The popular demulsification technique employed by most refineries involves using electrostatic field. But the use of the electrostatic field have uncertainties. Currently, it is unknown why the effectiveness of demulsification sometimes enhances or decreases using electrostatic field (Sprenkel, 2020). So to avoid this uncertainties a novel method was needed to demulsify the crude oil. Furthermore, the heating cost expended to reduce the viscosity when using electric desalter could be avoided by using a reagent that could take care of demulsifying the crude oil/brine mixture (Philling, 2021). This research is focused on addressing these desalting problems by applying a novel reagent in the demulsification step.

Although much work have been done on the cleaning of spilled crude oil, few works have been done on the distillation energy of the spilled crude oil. The work on spilled crude oil conducted by a researcher was about the establishment of the relationship between the oil evaporation and temperature change. The work talks nothing about the distillation of spilled crude (Fingas, 1996). Another attempt to conduct research about crude oil spill did not tackle the distillation of this crude. The study developed only the mathematical description of persistence of crude oil spills based on a statistical analysis of historical spill data was made by a group of researchers (Buist *et al*., 2003). Again, the study mentioned nothing about fractional distillation of spilled crude oil and its associated energy. But the energy usage is a major problem confronting refining industries as stated by Kiss and Smith (2020). In this sense this research was focused on building energy efficient distillation column. The column used palm kernel shells which is cheaper than steam which is mostly used by refinery industries.

2.1.2 Review of Methods and Equipments

This section reviews various methods of cleaning oil spills, the methods of measuring salts and sulphur in the crude oils, the techniques of desalting and desulphurising crude oils, and the types of equipment that could be used this research.

2.2.3 Oil Spills

Releasing crude oil into the oceans is considered an oil spill. This occurs because of the factors such as transporting, drilling, etc. Crude oil spill is thought of as another form of environmental pollution. Crude oil spill sometimes occur on land but it mostly occur on the oceans. "Oil spills may be due to the release of crude oil from tankers, offshore platforms, drilling rigs and wells, as well as spills of refined petroleum products (such as gasoline, diesel) and their by-products, heavier fuels used by large ships such as bunker fuel, or the spill of any oily refuse or waste oil," Behnood et al., (2016). Again, the researchers reported that "Oil constitutes one of the major sources of contamination in seas and navigable waters, and spilled oil has an undesirable taste and odor that affects tourism and economy. Therefore, spilled oil causes enormous environmental problems unless it is removed as quickly as possible." Conserve Energy Group also reported that, "The estimated annual quantity of oil spills from tankers transporting oil by sea exceeds one million metric tons," (Anon, 2018). The group added that, "Together with spills from crankcase lubricants and gasoline solvents by industries and individuals, spillage of oil into the world's waterways is approximated to be at the rate of 3.5 million to 6 million metric tons annually," (Anon, 2018). The group highlighted on the oil spills and its impact on the environment but did not make any reference to the usages of the spillage.

The period taken for an ecosystem recovery from oil spill depends on the magnitude of the spill. Even as smaller spills could be eradicated in approximately 15 years, the effect of bigger spill takes more years to be eliminated (Markleen, 2020). Oil spills on the sea have devastating consequences on the various lifeforms that depend on the sea. The Scientists of Science World reported that "Oil spills in the ocean have a severely negative effect on marine life, such as seabirds and filter-feeders. And seabirds, such as seagulls and ducks, spend most of their life on water and go to land only during their nesting period, and the feathers of many seabirds are wettable and must be carefully preened (or dried) for flight. If feathers come into contact with oil, the seabird ingests the oil while trying to preen" (Anon., 2022).

An example of aquatic animal that feeds itself by filtering water to obtain microscopic food is clam. If the water that contains the microscopic food has crude oil in it, then the animal will automatically ingest some of the oil. Because of the devastating effects of oil spills on the ecosystem, it is extremely important to clean the spill as soon as possible after it occurs. If oil spill is not cleaned up as soon as the spillage occurs, there are a number of processes that the oil undergoes. The processes include oil evaporation, oxidation, emulsification, sedimentation, biodegradation, and dispersion. Figure 2.1 illustrates the processed the oil undergoes at the initial stage if the spill is not cleaned up as soon as it happens.

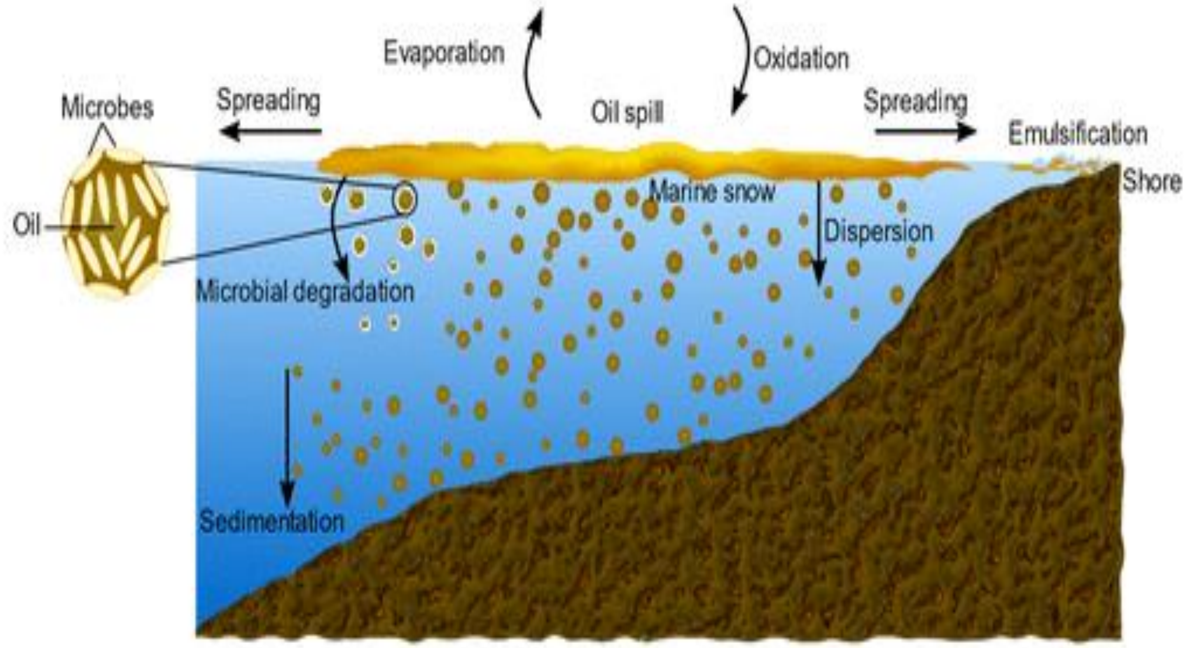


Figure 2.1 Spreading, Evaporation, and Photo-Oxidation of Oil Spill

Source: (Amber *et al*., 2021)

2.2 Methods of Cleaning Oil Spills from the Sea

As stated earlier on, oil spill causes tremendous amount of damage to the aqua life forms, the environment, and the lives of human being since humans depend greatly on the sea for things such as food, medicines, etc. Furthermore, the spilt oil causes damages to the shorelines and to the land at some distance away from the shores. The severity of the spill damages, the extent of the spill, the spread and the behavior of spilt oil depend on factors such as the location of the spill, the weather, the type of oil, the chemical process, the physical process, and the biological process of the oil. "It is estimated that about three million metric tons of oil spill contaminates the seas annually," (Agarwal, 2022). Therefore, it is indispensable to clean the oil from the sea irrespective of the spillage, whether the spillage was deliberate or accidental.

There are different methods of cleaning the crude oil spill. Nevertheless, the cleaning method chosen depends on factors such as the type of oil, the weather conditions of the place of the spill, and the location of the spill. The method of cleaning the oil spills usually depends on the organisation that is given the mandate to perform that task. Among the companies that are tasked to perform the oil clean up duty is a subsidiary of Markleen, a subsidiary of Egersund Group. Markleen (2020) suggested to organisations some phases including the adaptation of skimmers for recovering the oil spill. There are different techniques established to clean up an oil spill in different environments such as in the industry, at the sea, or in any other places. Although this research focusses mainly on the oil spillage that occurs in the sea, there are some instances where the review may include the oil clean-up method when the technique can be applied in other spillage area apart from the sea.

2.2.1 Cleaning of Oil Spill Using Booms

Booms are the devices used in the methods of containing spilled oil for eventual cleaning. It is used to create a fence about the spilt crude oil for containment to prevent it from spreading. By doing so, it facilitates the increment of the thickness of the oil so that it can be cleaned from the surface of the water easily. Furthermore, booms are used to move the spilled oil to a location where it can be collected easily or to a location where the spilled oil may cause less harm to the wild life or the environment. Booms come in several different forms. The forms come in sizes, the weights, the type of materials used in the construction of the boom.

In addition, they range from expensive ones to inexpensive ones. Different types or booms are used taking into consideration the location, the crude oil type, the environment where the spillage occurred, etc. The small inexpensive lightweight booms can be deployed manually in harbors, and such other places and the expensive and robust ones can be used at the offshores. The designers of booms have categorised it into curtain booms and fence booms. “Curtain boom provides a continuous sub-surface skirt or flexible screen supported by an air or foam filled flotation chamber usually of circular cross-section; the fence booms generally comes with a flat cross-section held vertically in the water by integral or external buoyancy, ballast and bracing struts,” (Anon, 2022). Figures 2.2, 2.3, 2.4, 2.5, 2.6, 2.7 show the various types of booms discussed above.

Figure 2.2 Boom used to Contain Spilled Crude Oil

Source: (Anon, 2022)

Figure 2.3 Inflatable Boom

Source: (Anon, 2022)

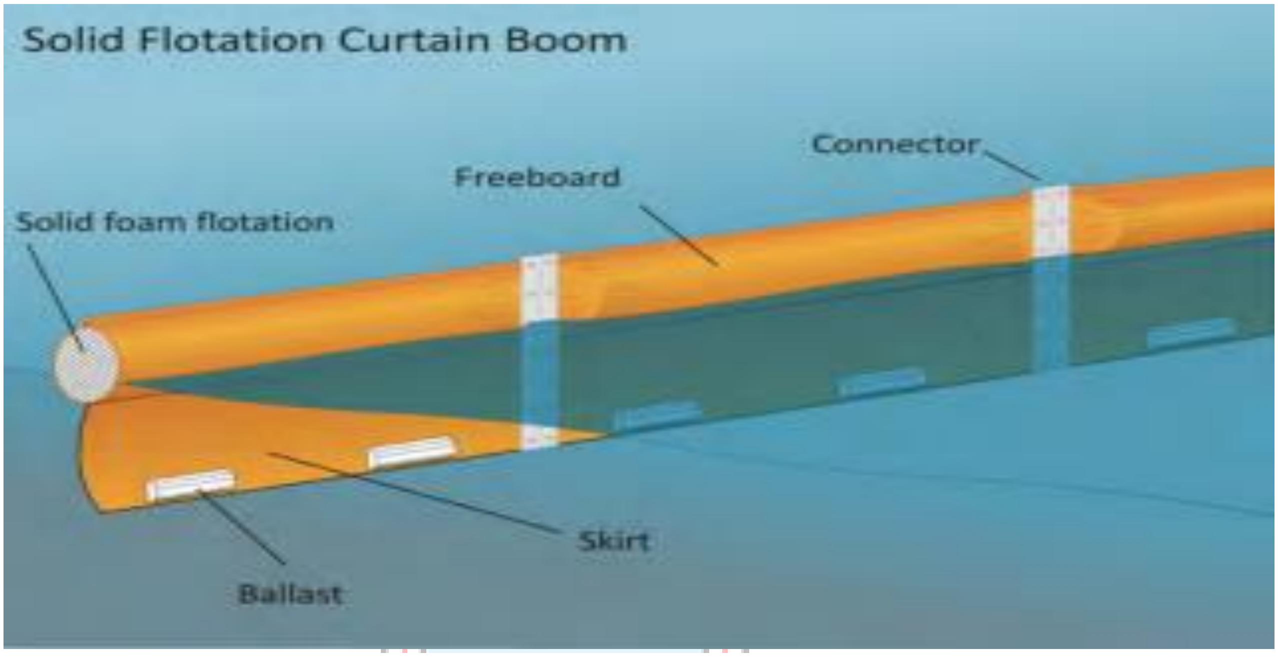


Figure. 2.4 Solid flotation curtain boom with external ballast

Source: (Anon, 2022)

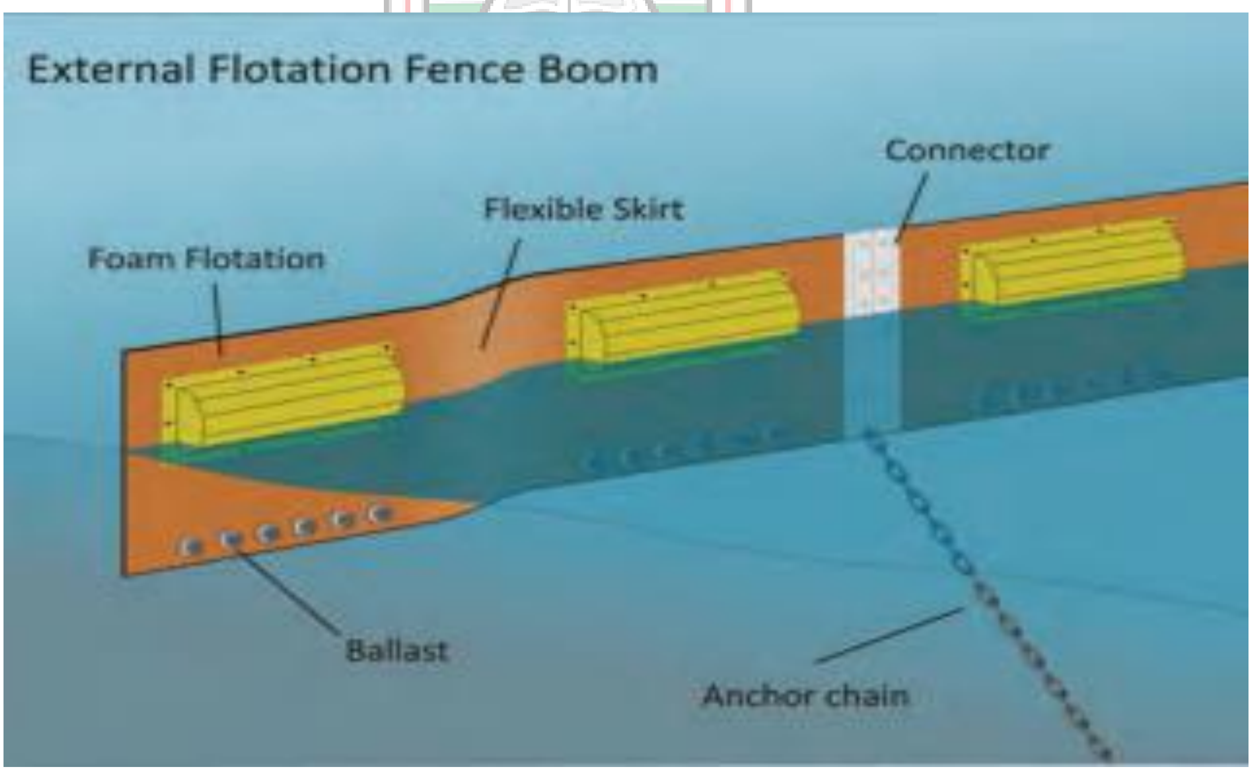


Figure 2.5 External Flotation Fence Boom with External Flotation and Ballast.

Source: (Anon, 2022)

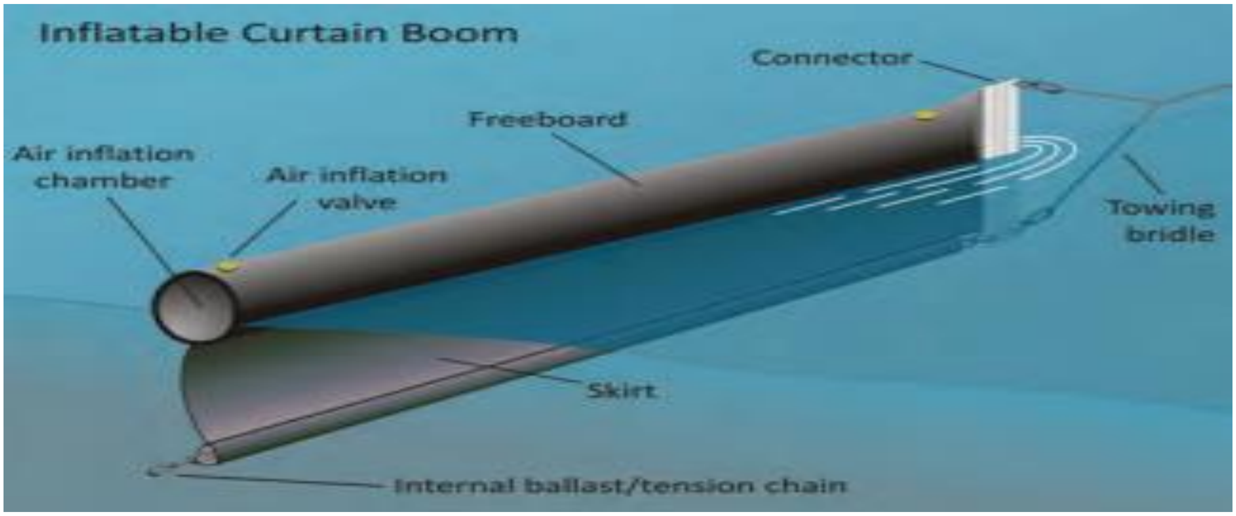


Figure 2.6 Inflatable Curtain Boom

Source: (Anon, 2022)

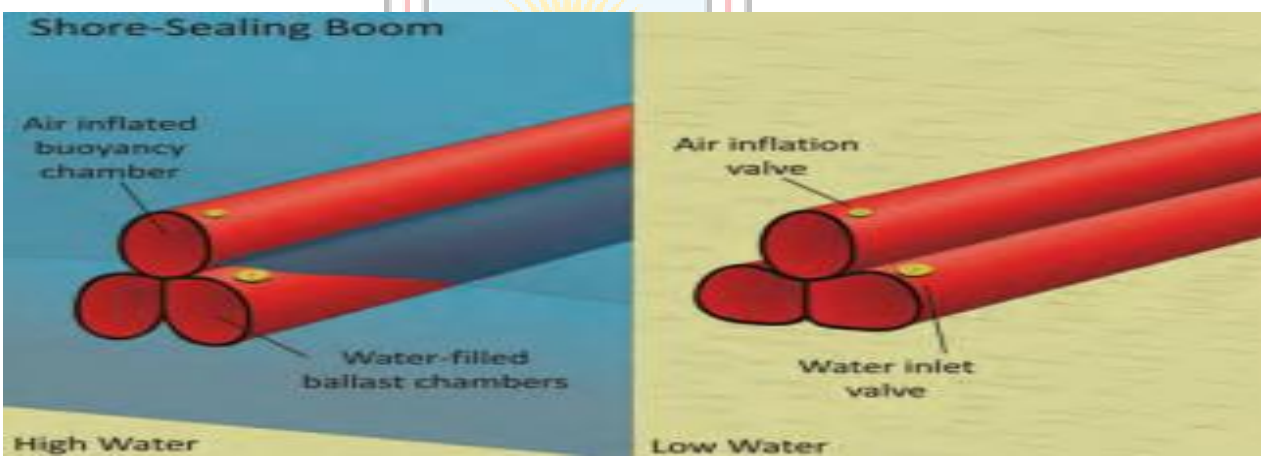


Figure 2.7 Intertidal Shore-Sealing Boom.

Source: (Anon, 2022)

Upper Air of the intertidal shore-sealing boom is an inflated pocket that allows the boom to float. The lower water filled-pockets offer ballast when floating. It seals well with the substrate at low tide. Markleen (2020) has developed a special type of booms called MOS Sweeper dynamic recovery system. The system consists of a multiple boom herringbone design, deployed from a single vessel. This can simultaneously contain and recover the spilled oil.

2.2.2 Cleaning of Oil Spill Using Skimmers

Skimmers are devices developed to recover spilled oil from the surface of water. They are designed to float across the spill and sweep or scoop the oil into tanks situated either on the coastline or at sea. The Skimmers may be operated from the shore, or may be self-propelled, or may be operated from a vessel. These floating devices are best used on calm waters, and not when there are high winds or stormy seas because in moderately rough water, skimmers are unable to recover more oil but rather they recover more water. The types of skimmers include Weir, Suction, Self Launch, and Drum.

2.2.3 Cleaning of Oil Spill Using Sorbents

The oil spill cleaning using sorbents is a type of technique that employs materials and chemicals. Sorbents are insoluble materials employed to liquids by absorption or adsorption or both. The sorbent is required to be both oleophilic and hydrophobic for it to be effective in its tasks. The absorbent soaks up the oil spill by distributing it throughout its molecular structure. It is required that the absorbent swells for about 50 percent or more. The Environmental Protection Agency (EPA) of the USA (2015) states, "The absorbents must be at least 70 percent insoluble in excess fluid." The agency added that, " adsorbents on the other hand, are insoluble materials that are coated by a liquid on its surface, including pores and capillaries without the solid swelling more than 50 percent in excess liquid. and makes it possible to dispose of the material safely and to protect the environment."

There are many varieties of absorbents, but the type used is at the discretion of the user in terms of the location of the spill, the environment of the spill, and the type of the oil spill. SpillPro below presents the commonly used types of absorbent materials.

Natural organic sorbent – This type of sorbents such as cotton, feathers, hay, are capable of absorbing oil 3 to 15 times their own weight. Natural organic sorbents like saw dust are loose and difficult to collect after spreading it over the surface of the water. The EPA came up with a solution to this problem. According to the agency, to overcome the problem of collection, a floatation device such as empty drums can be attached to sorbent bales of hay to overcome the sinking issue, and wrap loose particles in mesh to help in collecting the mixture of dust and oil. This type of sorbent is not used on the surface of the water.

Natural inorganic sorbent- this type of sorbent such as clay, glass wool, vermiculite, volcanic ash, perlite, glass wool, sand is capable of absorbing oil 4 to 20 times their own weight. This type of sorbent is not used on the surface of the water. Synthetic sorbent - this type of sorbent which is man-made material such as polypropylene, polyurethane, polyethylene has the capability to absorb oil up to 70 times their own weight. In addition, there are synthetic sorbents such as cross-linked polymers and rubbers, which absorb liquids into their solid structures. This causes the swelling of the sorbent material.

It must be noted that sorbents can be used to clean final traces of oil, or to recover oil from hard to reach areas where other oil spill mechanisms cannot be employed. To assist in choosing a type of sorbent for a particular oil clean up, the Enviromental Protection Agency of the United States of America listed the rate of absorption, the rate of adsorption, oil retention, the ease of application as the characteristics of both the oil types and the sorbent that must be taken into consideration in making the choice.

To determine which sorbent has better potential in terms of cleaning oil spilt into the sea, Bayat *et al*., (2005) evaluated three sorbents namely, polypropylene nonwoven web, rice hull, and bagasse with two different particle sizes in terms of oil sorption capacities and oil recovery efficiencies. The researchers concluded, "Polypropylene could sorb almost 7 to 9 times its weight from oils. Bagasse 18 to 45 mesh size was the next sorbent to perform better in oil cleanup. Bagasse with 14 to 18-mesh size and rice hull had comparable oil sorption capacities lower than the former sorbents. In addition, the researchers reported that viscosity plays an important part in oil sorption by sorbents." Figure 2.8 illustrates sorbent used to clean up oil spilt into the sea, leaving the sea free of oil and the sorbent-oil mixture collected.

Figure 2.8 Oil Spill Cleaning Using Sorbent

Source: (*Ge et al*., 2016)

2.2.4 Cleaning of Oil Spill by Burning In-Situ

The next method of oil spill cleanup from the ocean is in-situ burning. This method burns the oil spill controllably from the surface of the water where the spillage occurred. Cleaning of oil spill from the ocean in some cases can be challenging especially where boom and skimmers cannot reach. For this reason, in situ burning can be a good alternative to remove the oil spill from the surface of the water. According to Walton and Jason (1998), "In-situ burning is the only viable alternative in many remote locations, where mechanical, dispersant and the no cleanup options are more damaging to the environment." Although containment is required for this method of oil spill cleanup, however, in-situ burning needs fewer equipment and personnel than other methods of spilled oil cleanup such as mechanical methods. Figure 2.9 shows a rigorous burning of oil spill by in situ method of cleaning oil crude oil spill.

Figure 2.9 Cleaning of oil spill by in situ burning

The cleaning of the crude oil using the burning in situ method depends on how much oil is enclosed to provide a layer of oil thick enough to make burning sustainable. The minimum of 2 mm to 3 mm of oil thickness is acceptable to sustain the burning, and the best time to conduct this burning operation is during the day with mild or offshore winds and flat seas (Fingas, 2011). During burning, it is also extremely important to monitor the process to ensure that it does not have negative impacts on the environment and the living organisms. The products of burning crude oil are carbon dioxide, water, and some smoke particulate, and unburned oil in the form of residue. If these products are not monitored carefully, they may have a big impact on lifeform and the environment. Figure 2.10 shows a crew monitoring a Deep Water Horizon cleanup.

Figure 2.10 Deepwater Horizon cleanup surveillance crew
Source: (Fingas, 2011)

In-situ burning offers advantages such as the reduction of cost and the rapid removal of the crude oil. Some of the disadvantages offered by in-situ burning include the risk posed to the personnel conducting the cleaning. The personnel may sustain injuries if adequate training is not provided to them. The smoke that comes out as a result of in-situ burning poses risks to the health of humans.

2.2.5 Cleaning of Oil spill Using Dispersants

This method of oil spill cleanup uses chemical dispersants. The dispersants used in this way is not applied to all types of oils because the chemical may cause problems to some marine lives and coral reefs. The method works effectively if the spillage occurs in a tropical region, and if it is employed shortly after the spillage occurs. The dispersants break down the oil to enable it mix with the water to form droplets thereby increasing the surface area of the particles. This enables the particles to evaporate faster than normally it would have been.

2.2.6 Cleaning of Oil Spill Using Hot Water and High Pressure Washing

The removal of crude oil using hot water is employed when the spillage is situated at a location where the crude oil cannot be removed using mechanical means. The water used to remove the crude oil is heated to about 170 ^{o}C before spraying on the oil. Then the oil is removed using skimmers or sorbents. Figure 2.11 shows washing of spilled crude using high pressure water.

Figure 2.11 Physical Washing Using High Pressure Water

Source: (Birdseye, 2014)

2.2.7 Cleaning of Oil Spill Using Manual Labor

This method of cleaning oil spill mostly uses human labor. In this cases, the workers use handheld tools to conduct the cleaning of the oil spill. Mostly, the personnel conducting the cleaning use hand held tools. This method of cleaning is employed to remove crude oil spilled on the shoreline .

2.2.8 Cleaning of Crude Oil Spill Using Bioremediation and Biodegradation

Unlike the dispersion method of cleaning that is employed when the spillage site is far from the coastline, cleaning by bioremediation is mostly employed when the spill reaches the coastline posing harmful threats to the wildlife. Biodegradation is the breakdown of organic matter by microorganisms, such as bacteria and fungi. Composting, on the other hand, is a human-driven process whereby biodegradation is used in a controlled environment. As defined, this method uses biological agents to conduct the cleaning. It is imperative to emphasize that the success of bioremediation method is dependent on the type of coastline treated, the type of microorganism employed, the type of crude oil being treated, and the kind of fertilizer used. It should be noted that specific bacteria is needed to bioremediate a specific contaminant.

In these method bacteria is introduced to the spill to initiate the process of biodegradation. In addition, fertilizing agents such as phosphorous and nitrogen are spread on the spill to augment the growth of the bacteria. The bacteria breaks down the oil into compounds and if the cleaning is along the coastline, then the compounds seep into the ground afterwards. One of the biggest of oil spillage in the history of United Stated of America occurred sometime ago on March 24, 1989 by the oil tanker Exxon Valdez that ran aground on the Bligh Reef in Prince William Sound spilling estimated 11 million gallons of crude oil. Figure 2.12 shows the cleanup of Exxon Valdez oil spill cleanup. In this method, fertilizers were added to the bacteria employed earlier to accelerate the cleaning process

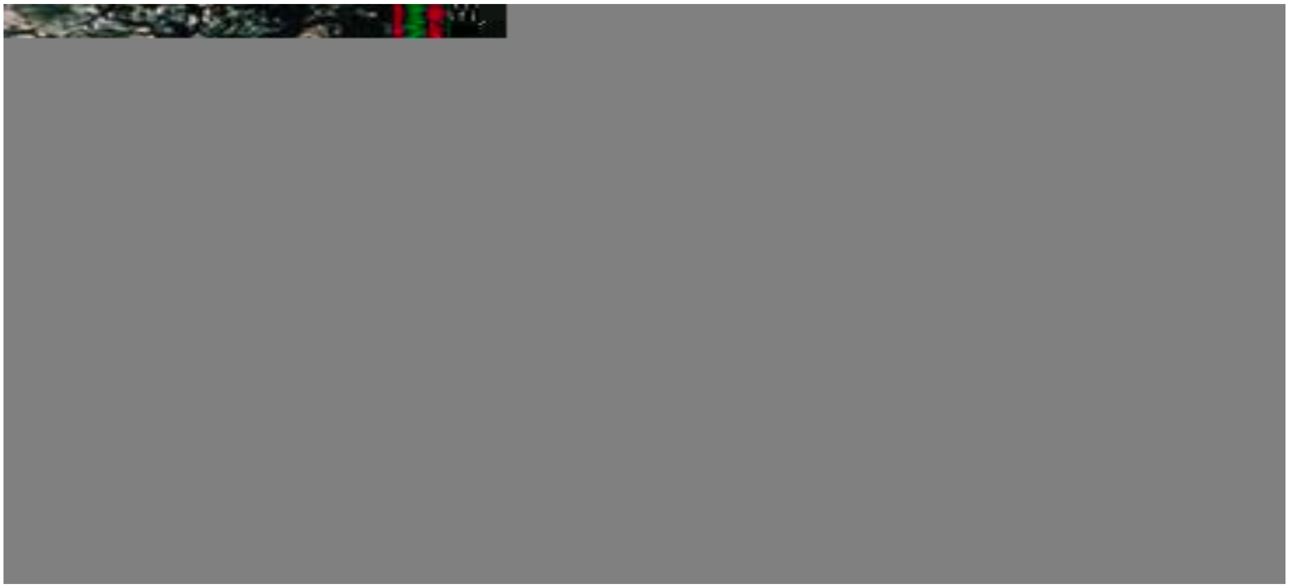


Figure 2.12 Application of fertilizers for bioremediation

Source: (Atlas and Hazen, 2011)

According to Atlas and Hazen (2011), to clean the Exxon Valdez oil spill, two fertilizers were selected for full scale bioremediation: the oleophilic fertilizer Inipol EAP22, manufactured by Elf Aquitaine of France; and the slow release fertilizer Customblen 28–8–0, manufactured by Sierra Chemicals of California. The above-mentioned fertilizers assisted in cleaning the spilled crude oil successfully. Although bioremediation was used to cleanup crude oil spill more than 33 years ago, now it is still used as an effective method to cleanup oil spill that traverse to the shoreline.

2.2.9 Cleaning of Oil Spill Using Natural Recovery Method

This method of cleaning oil spill does not involve expenditure. It is reckoned the best method of clean up if the spillage occurs far away from the shores, and does not pose a threat to the wildlife. In this method, the spilt oil is left alone in the sea. Because of the actions of the sun, weather, and the sea waves, the oil left alone breaks down naturally after some time. This broken down oil mixes with the seawater and impurities such as sand to form tar balls. This compound spreads away and does not pose threat to the aqua life. The density of oil is mostly less than the density of seawater and this makes the oil floats on the surface of the sea.

2.2.10 Combination of Methods Employed to Clean up Oil Spill

Oil spillage is a daunting problem confronting the organizations dealing with crude oil. In the event of the crude oil spill, more than one method is sometimes employed to clean the spillage. Figure 2.13 below shows an example of combinations of methods used to clean oil spill that occurred during a drilling process on 20 April 2010 at the BP's Deepwater Horizon exploratory well in Mississippi Canyon Block 252 located 77 km offshore. The oil released on the ocean during the Deepwater Horizon oil spill accident was estimated 4.9 million barrels (205.8 million gallons (780 million liters) (Atlas and Hazen, 2011). Taking into consideration the 4.9 million oil release during the Deepwater Horizon well accident, the Flow Rate Technical Group upon using Oil Budget calculator estimated the oil spill cleanup as follows: 3% was skimmed, 5% was burned, 8% was chemically dispersed, 16% was naturally dispersed, 17 % was captured, 25 % was evaporated or dissolved, and 26% remained (Atlas and Hazen, 2011).

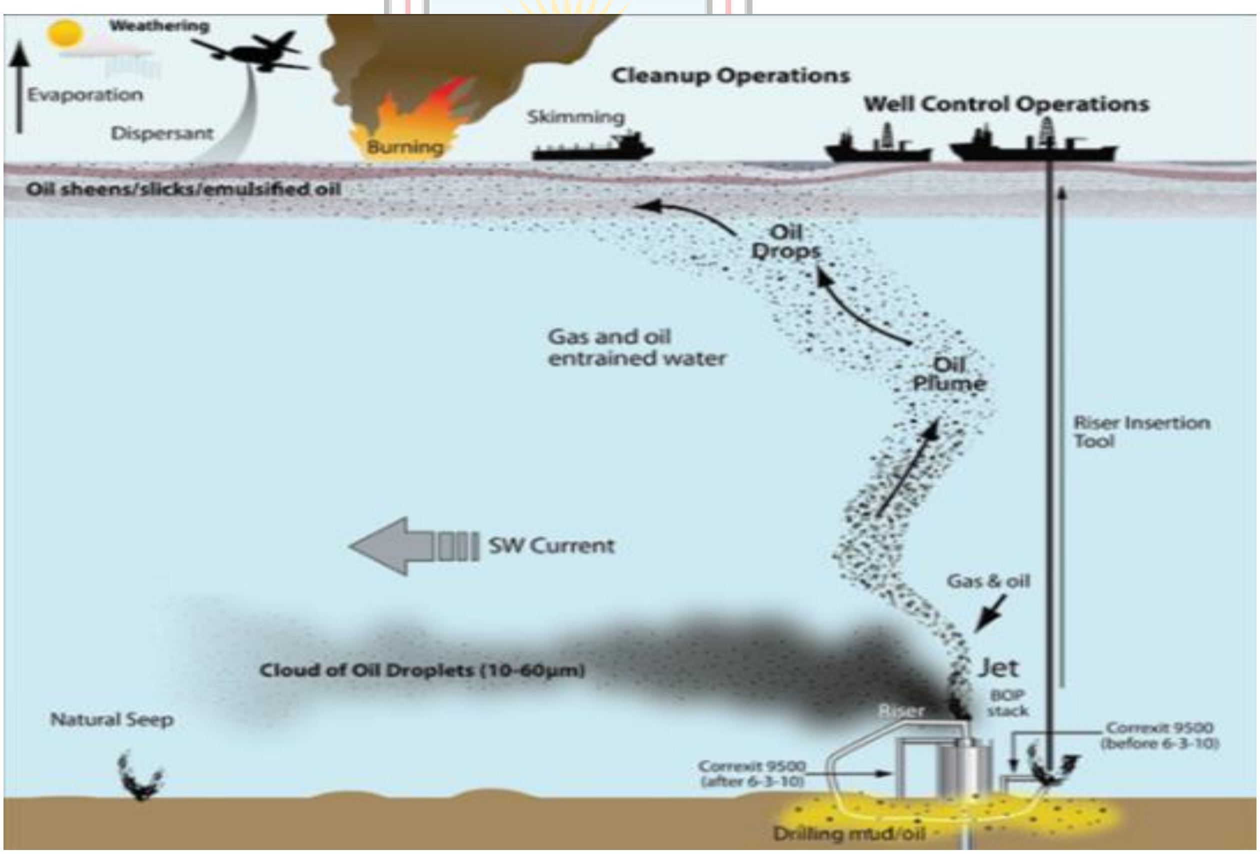


Figure 2.13 Deepwater Horizon Spill and Cleanup

Source: (Atlas and Hazen, 2011)

2.3 Petroleum Refining Product Energy Requirement

According to the Industrial Technologies Program within the U.S. Department of Energy of the Office of Energy Efficiency and Renewable Energy (EERE), "The energy used by petroleum refining processes can be evaluated by considering the distribution of energy to produce various product streams" (Anon, 2005). The stream that contains most energy should be the primary area to commence the energy evaluation.

2.3.1 Theoretical Minimum Energy

The boiling points of the various constituents of crude oil is used to fractionate it. The Department of Energy of the USA used the following method to calculate the heat balance the crude oil distillation (Anon, 2004):

$$\text{Theoretical Minimum Energy (TME)} = \text{Heat In} - \text{Heat Out} \quad (2.1)$$

In calculating the theoretical minimum energy, the Energy Department assumed that the Crude oil behaved as an "ideal solution" indicating that the properties of the component in the solution are equal to the properties of the pure component. The energy required to raise the temperature of each fraction to its boiling point (bp) is calculated as follows:

$$\text{Heat Input}_{\text{crude fraction}} = \text{mass}_{\text{crude fraction}} \times C_p \times \Delta T \quad (2.2)$$

$$\text{Heat Input}_{\text{crude fractib}} = \text{mass}_{\text{crude fraction}} \times C_p \times (T_{bp} - 77\ °F) \quad (2.3)$$

The quantity of the crude oil used for the distillation process can be balanced in terms of volume. The department of Energy of the USA conducted such a calculation using Barrel per stream day assuming 335 days per year (Anon, 1998).

2.4 Fractional Distillation

Fractional distillation is the method of separation in which product is taken to a specific boiling point where, one part is vaporised out by leaving the other," (Earnhart, 2017). Sometimes more than two liquid components are distilled at the same time. Such is the case of distilling crude oil. The crude oil contains more than two components. He says that distilling the product repeatedly becomes necessary because mostly after the distillation, the product that comes out

The process of fractional distillation needs to be controlled in order to yield the desired products. Below is a schematic diagram of a controlled system of a fractionating column.

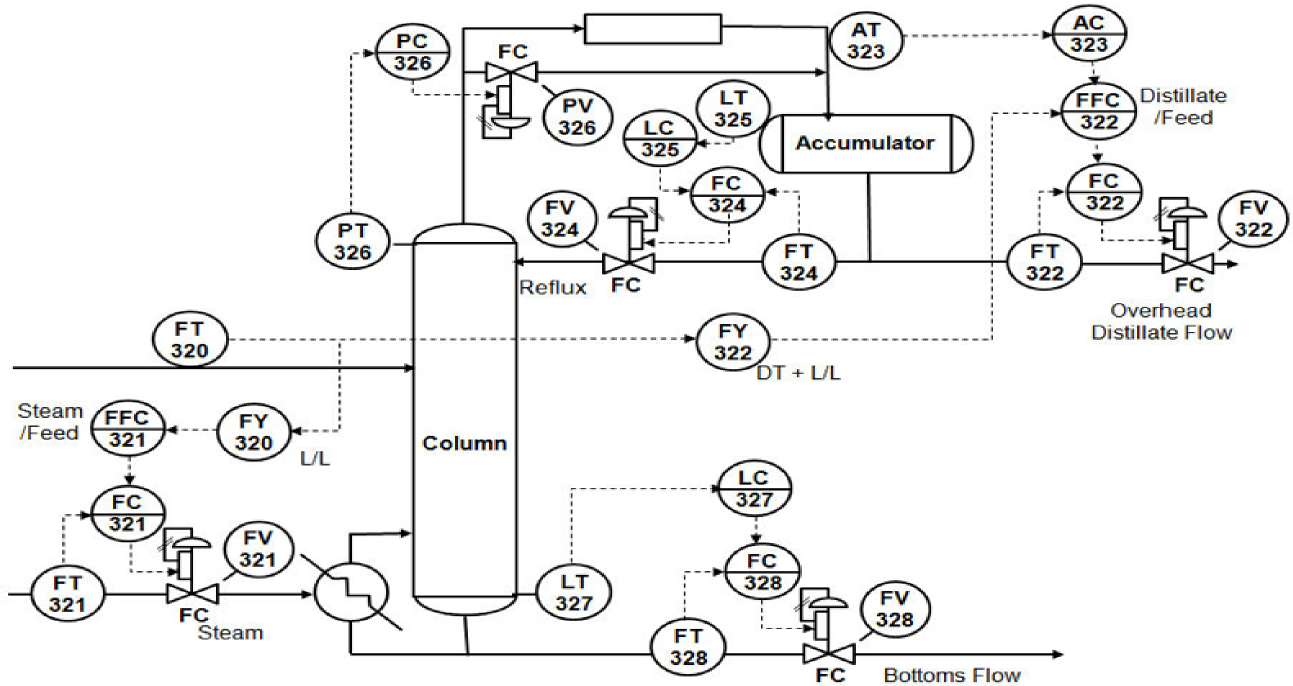


Figure 2.15 Fractional Column Control Schematic Diagram

2.5 Effect of Salt on Crude Oil and on Refining Equipment

Salt is one of the major contaminants of crude oil when received from offshore. When the crude oil is spilled on the sea, it picks up additional contaminants. "The contents of salt in the crude oil received at petroleum refineries range from PTB of 10 to 300 (34 to 1,020 ppm by weight), based on spot samples of many different crude oils as delivered to refineries," (Abdel-Aal et al., 2003). (Anon., 2010), a company specialized in desalting reported that, "Salt in the crude oil can lead to great undesirable operational problems." Using corrosion control can assist to avoid corrosion. The presence of salt in the crude during distillation can cause problems such as decreasing the throughput and increasing plugging, scaling, coking of heat exchanger and furnace tubes. Furthermore, if the salt in the crude oil is not desalted before sending it into the fractionating column, it may cause more corrosion in the exchangers, fractionators, pipelines, etc. Desalting can reduce erosion by solids in the control valves, exchanger, furnace, pumps, and save oil from slops of wasted oil (Anon., 2022).

2.5.1 Corrosion Formation Supported by Salt

The corrosion on equipment, pipes, and vessels is a major challenge in the refinery industry. If salts are not eradicated from the crude this major, challenge will continue to be a bane to the fractional distillation process of crude oils. Corrosion changes metals into other chemicals. Examples of the chemicals are oxides, hydroxides, carbonates or sulphides. Moreover, if salt find itself in the transportation fuels, the engines of the vessels such as automobiles, boats, etc. will suffer tremendous corrosion. For example, salt solution speeds up rusting process mainly because it acts as an electrolyte that permits the metal to lose its electrons more easily. Furthermore, the salt solution accelerates the rusting process because electrons move more easily in saline solutions than they move in pure water.

Depending on the materials used to construct the refinery equipment, corrosion or rusting can occur if salts and water are not removed from the crude oil during the distillation process. Hence, it is important to review the mechanisms and the distinguishing properties between corrosion and rusting. Corrosion is the process by which certain materials, metals and non-metals, deteriorate because of oxidation. Corrosion affects a wide range of objects such as ceramics and polymers; and it requires surface exposure to air or chemicals. When the surface of a metal is open to the atmosphere, the moisture in the air makes it becomes prone to oxidation. A reduction reaction occurs on low energy area of the metal surfaces." When oxidation takes place at the anode and the reduction takes place at the cathode simultaneously then corrosion can take place," (Anon., 2022). Corrosion could be seen as blue and green substances on materials. On the other hand, rust affects iron and its alloys, such as steel. Hence, rust can be classified as one of the forms of corrosion. Although it specifically refers to oxidation of metals containing iron in the presence of air and moisture. Furthermore rusting requires the surface of the iron and its alloys in question get exposed to both air and moisture. Iron oxide, a reddish-brown compound, is normally referred to as rust. In addition, rust can form when iron and oxygen react in water or in moisture in the air. Rust can also form when there is a reaction of iron and chloride underwater. The color of rust is usually seen as an orange brown.

The formation of rust occurs as follows:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3 \quad (2.4)$$

Rodriguez (2018) reported, **"S**altwater and metal do not mix, as it causes metal to corrode." He emphasized that the "Combination of moisture, oxygen and salt, especially sodium chloride, damages metal worse than rust does." The excrement of bacteria in the oceans can also cause rust. Figure 2.16 show corrosion of metal by seawater.

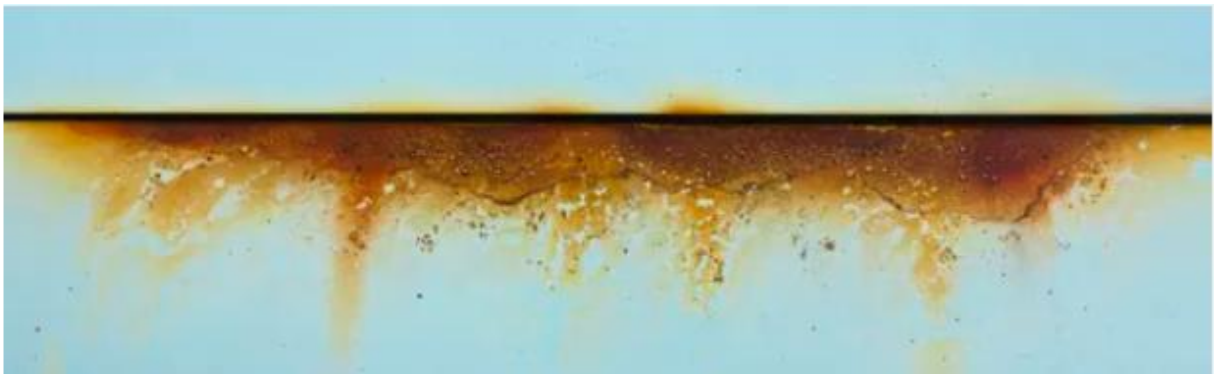


Figure 2.16 Corrosion of Metal by Seawater

Various researchers have investigated damages inflicted on refinery equipment by the oleophobic impurities of crude oil. Nasipouri et al., (2014**)** conducted research about the extent of damage that occurred in a steel tube material grade CK45 (AISI 1045) after a short period of service in an output desalination unit of an oil refinery industry. According to the researchers when visual examinations on the units were conducted, it was revealed that the material of the failed tube had reduced to an appreciable level, and the reduction occurred at a particular region. In short, their findings confirmed that the presence of the above-mentions elements could cause corrosion on the materials used in constructing refinery vessels.

2.6 Methods of salt Determination

It is important to determine the salts in crude oil before desalting process is commenced. The level of salt in crude oil gives information to the refiner to decide whether it is profitable to desalt the crude oil before embarking on the refinery process. Also, this moment of desalting gives information about how much salt was removed after desalting process, Again, it helps the researcher to determine the efficiency of the method adopted for desalting the crude oil. Mohammed (2016) used more complicated method by collecting some samples such as kerosene, crude oil, gasoline, diesel, and determined the salts contents in them using extraction process. Kotona *et al*., (2021) compared the analytical methods of measuring the chloride content in crude oil. They used different methods to measure the chloride concentrations of the crude oils. The methods used included ASTM D3230, D4929 as standard methods, XRF as alternative technique, and Neutron Activation Analysis as a reference method. They did not use Seta Salt in Crude analyser which is simple, effective, no standard mixing, and user friendly.

Figure 2.17 shows the green and high throughput protocol salt determination.

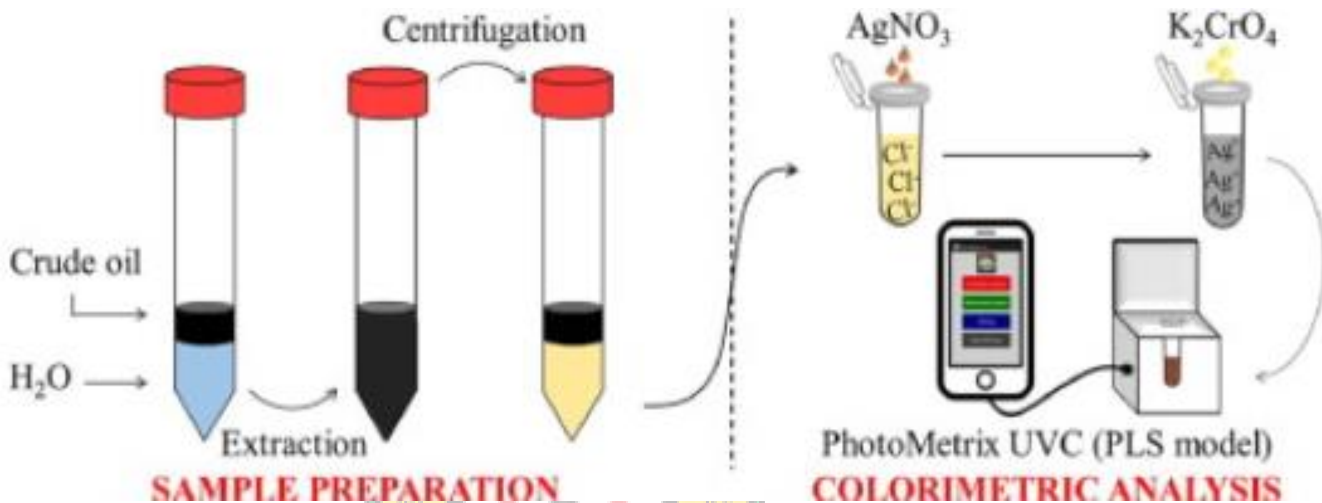


Figure 2.17 Green and High Throughput Protocol Salt Determination
Source: (Holkem *et al*., 2021)

Kamari *et al*., (2015) used the Least Square Support Vector Machine method to determine the salt content in a crude oil. A sample of about sixty- three were gathered from a literature by the researchers to conduct this research. They used a previously published correlation and a multilayer perception artificial neural network (MLP-ANN) to compare and validate the results obtained from the LSSVM model. To detect the outlier or suspected data points or both available in the dataset, they used a reliable approach (Leverage strategy). Although the researchers concluded that there was an agreement between the actual and the values of salt content predicted by the LSSVM model in comparison with the studies methods, they did not use the method to test the salt in spilled crude oil.

2.6.1 Electrometric Salt Determination

In this research the electrometric method the Stanhope-Seta Salt in Crude Analyser-99700-6 with the American Society of Testing and Material (ASTM) standard D3230 was used for determining the salt content in the crude oils. The instrument uses samples that has concentration in the range of 0 mg/kg to 500 mg/kg or 0 lb/1000 bbl to 150 lb/1000 bbl as chloride concentration/volume of crude oil. This test method measures conductivity in the crude oil due to the presence of common chlorides, such as sodium, calcium, and magnesium. Other conductive materials might also be present in the crude oil. The units acceptable for reporting salt concentrations are g/m^3 or PTB (lb/1000 bbl). Figure 2.18 shows the assembly salt in crude analyser. Figures 2.19 and 2.20 show the schematic diagrams of the transformer and the test cell respectively of the analyser.

Figure 2.18 Stanhope-Seta Salt in Crude Analyser

Source: (Anon, 2014)

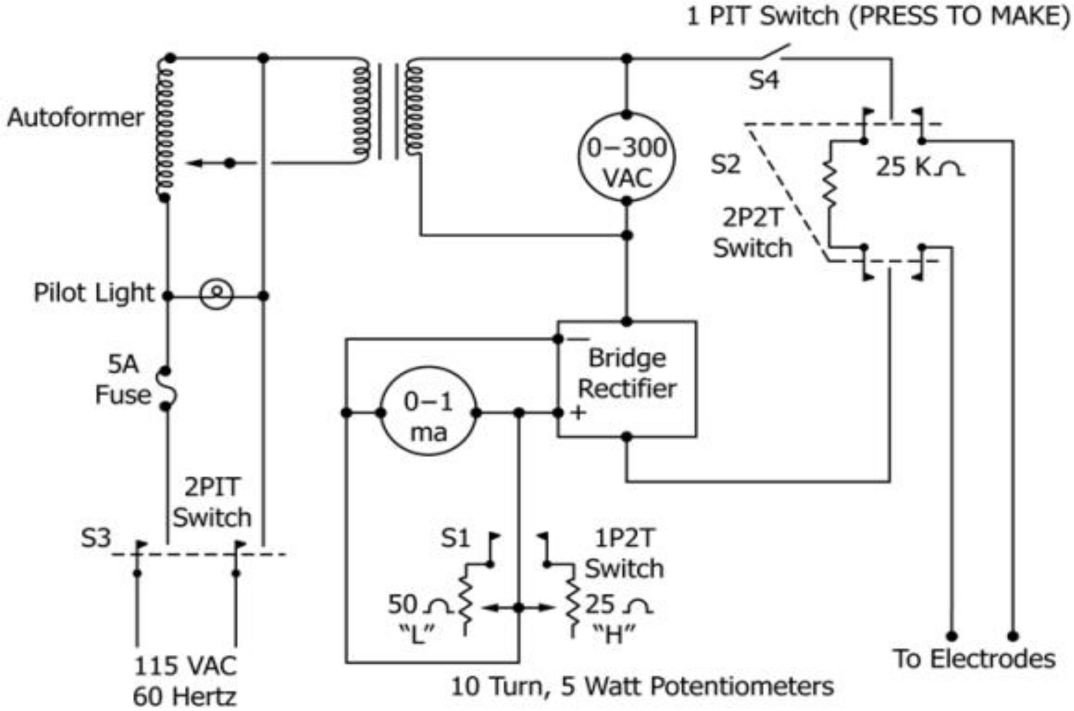


Figure 2.19 Salt Analyser Transformer Schematic Diagram

Source: (Quartey, 2020)

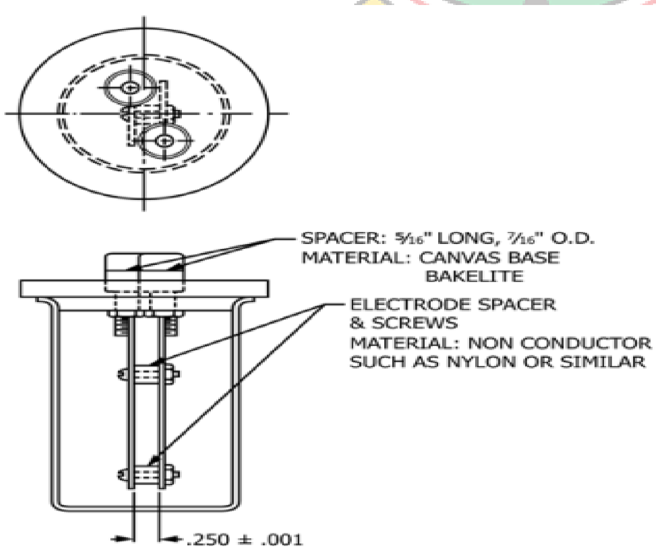


Figure 2.20 Test Cell Seta Salt Analyser

Source: (Quartey, 2022)

Figures 2.21 and 2.22 present the schematic diagrams of the electrode assembly of the seta salt in crude analyser

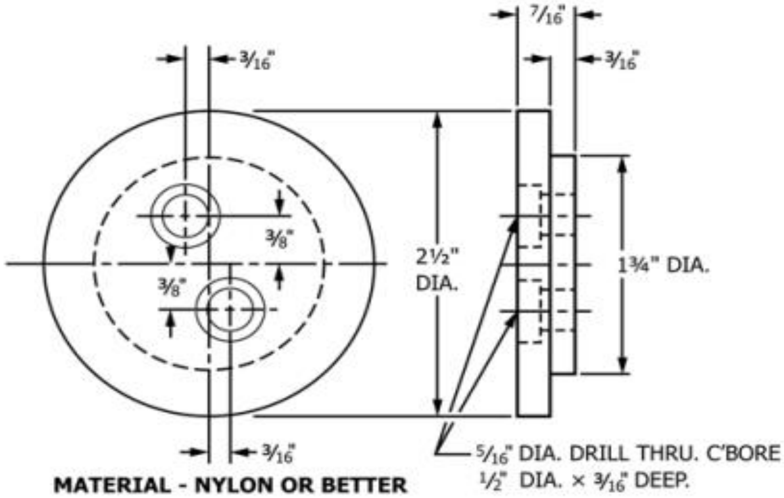


Figure 2.21 Top of Electrode Assembly

Source: (Quartey, 2020)

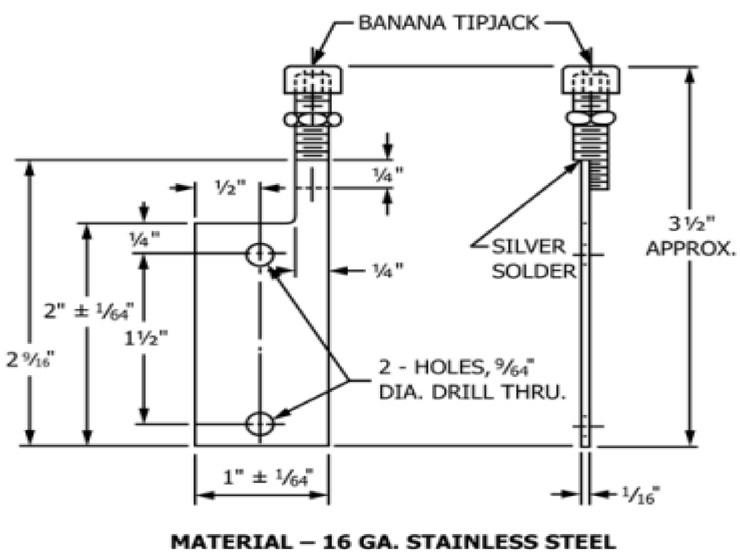


Figure 2.22 Lateral View of Electrode Assembly

Source: (Quartery, 2020)

2.7 Crude Oil Desalting

Desalting is the process embarked on to remove from the crude oil salts, water, drilling mud, polymer, corrosion by-products, and other solid particles. The main purposes of desalting are twofold. Firstly, it is done to reduce operating and maintenance costs. Secondly, it is done to enable the products to meet specifications. Salt is among the most undesirable impurity that needs tremendous attention. During refining process, if the presence of salt in the crude oil is overlooked, this may cause a great deal of problems such as corrosion, poisoning of catalysts, plugging and fouling of equipment, etc. The most common salts in the crude are chlorides, calcium, sodium, and magnesium. The salts in the crude oil may be approximately 75 % by weight sodium chloride, 15 % by weight magnesium chloride, and 10 % by weight calcium chloride (Wauquier, 2000). Salt crystals presents themselves as a component of crude oil emulsion.

2.7.1 Methods of Crude Oil Desalting

In chemical desalting method, water and chemical surfactant are added to the crude oil. Then the mixture is heated for salts and other impurities to dissolve into the water or attach to the water. Then the mixture is allowed to sit for some period for the impurities are left to settle out. Another method of chemical desalting is the application of heat. In this method the crude oil is heated to about 100 ^{o}C. Then chemical agents and wash water are added to the preheated crude oil. Some of the commonly used chemical agents are long chain alcohols, fatty acids, and sulfonate. After adding chemical and wash water follows settling time. The mixture of the crude oil, salt and water is allowed to sit for some period. The settling time may take a few minutes to about two hours. After the settling time, the wash water is pumped out leaving the crude oil. In the electrical desalting, high voltage electrostatic charges are used to draw together the water particles and the salt particles in the crude oil. Then the water particles and the salt particles are drawn to the bottom of the tank. These two aforementioned methods for crude oil desalting employ hot water for extraction. Figure 2.23 presents an example of an electrostatic desalting flow chart.

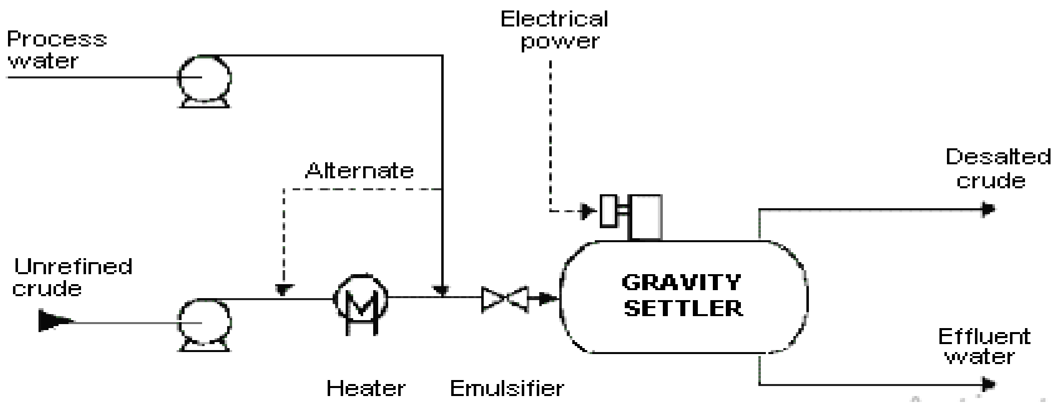


Figure 2.23 Electrostatic Desalting Flow Chart

Source: (Salvo, 2022)

2.7.2 Typical Process of Crude Oil Desalting

Figure 2.24 presents a process flow diagram of crude oil desalting. In this process, water is injected into the tank containing the crude oil. Then the water is mixed with the crude oil to dilute the salt concentration. After the emulsion is distributed in the electrostatic field, the salt and the water compound settle off. Wauquier (2000) reported, "After performing the desalting of the crude oil as required, the water content of the desalted crude oil would be less than 0.2 volume percent of the crude oil."

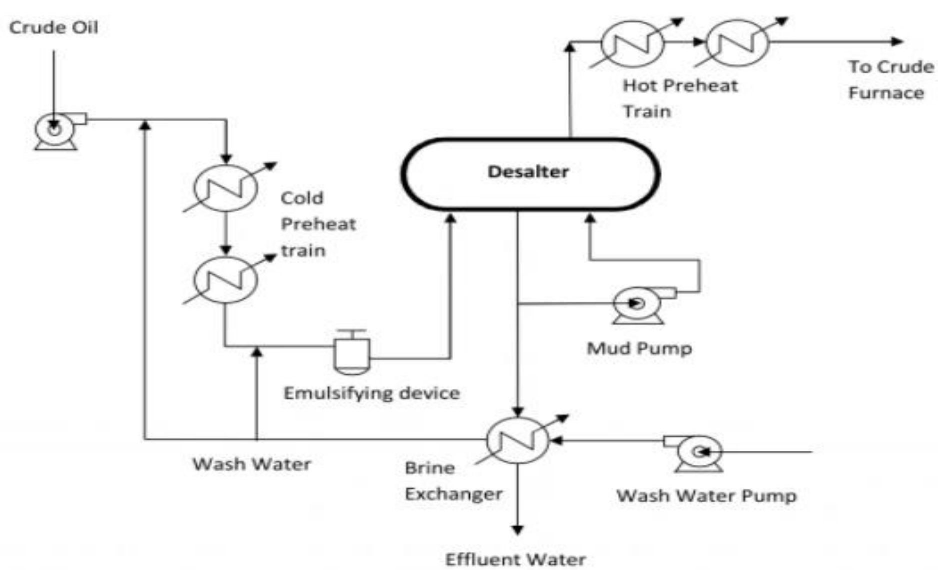


Figure 2.24 Crude Desalting Process Diagram

2.7.3 Batch Desalting Process

The batch process of desalting is a bit different from the continuous process of desalting. Nevertheless, the ultimate aim of both remains the same: the removal of salts and other solid particles from the crude oil. Mostly, the first task involved with crude oil refining is the desalting process. In the batch process, the crude oil is heated to about 100-150 °C. To dissolve the salt in the water, the crude oil is mixed with 4-10% fresh water. This enables the salt water in the crude to be more dilute. The mixture of salt and water is allowed settle at the bottom of the tank and drawn. "An electrostatic field is applied by electrodes in the settling tank, inducing polarisation of the water droplets floating in the larger volume of oil. This results in the water droplets clumping together and settling to the bottom of the tank (Anon., 2017)."

2.8 Sulphur in Crude Oil Determination

The impurities in the spilled crude oil needs to be analysed. Various companies have designed various equipment to analyse the contents found in the crude. Among the companies is Rigaku's NEX XT. The machines measures Sulfur (S) from 200 ppm to 6 wt. %" (Anon., 2013)

2.8.1 X-ray Transmission (XRT) Method

The X-ray Transmission (XRT) gauging machine uses x-ray technique to measure the sulphur content in the hydrocarbons. The designers of the machine emphasized that " whether the machine is used for pipeline switching, crude oil blending or to assay or blend marine and bunker fuels, the Rigaku NEX XT XRT process analyser is well suited to rigorous process environments, with pressures up to 1480 psig and temperature up to 200°C," (Anon, 2013). Figure 2.25 shows sulphur analysing instrument using x-ray detection. Rigaku manufactures this instrument. Although the designers of the instrument are confident in their assertions, the instrument is not user friendly.

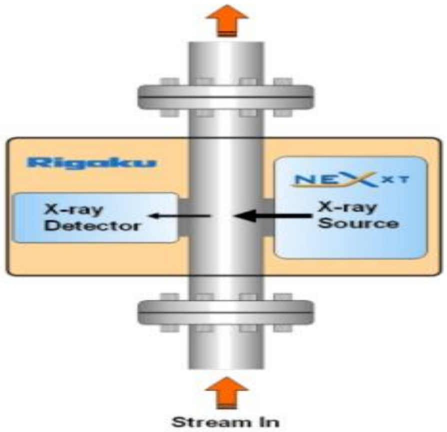


Figure 2.25 Sulphur Analyser (X-Ray Method)

Source: (Anon, 2013)

Another instrument designed to measure not only sulphur content in the sample but also to measure carbon, Nickel, vanadium, calcium, and iron content in the crude sample is the Epsilon 4 Oils and Fuels. According to the manufacturer, "The Epsilon 4 can be used in the refinery operations including the elemental analysis of crude oil to optimise and adapt refinery processes; the determination of low levels of chlorine for optimal desalting and corrosion control; the determination of low levels of S, Ni, V, Ca and Fe to prolong your catalysts' life and improve their performance; and the analysis of the sulfur content during fuel production and blending," (Anon,. 2022). According Scaccabarozzi (2019), "the instrument works well, the major drawbacks facing the instrument is the user interface." Scaccabarozzi emphasizes that "the software is is outdated, the calibration part is not intuitive and does not connect to outside applications like excel. Furthermore, the assay chamber is not separate from the sample carousel so the instrument cannot be loaded and unloaded during operation."

2.8.2 X-ray Fluorescence Sulphur-in-Oil Analyser

In this research, the X-ray dispersive fluorescence spectrometer using ASTM standard D4294 was used to determine the sulphur in the oils. Figure 2.26 shows the Sulphur in Crude Analyser. The instrument measures crude oil, diesel fuel, jet fuel, kerosene, naphtha, residual oil, lubricating base oil, hydraulic oil, unleaded gasoline-ethanol blends, biodiesel, and other similar petroleum products (Quartey, 2020). The design features of the instrument include tube with excitation energy above 2.5 keV, removable sample cup, filters, signal conditioning, data handling electronics, display, analytical balance, x-ray detector with high sensitivity and a resolution value not exceeding 800 eV at keV. The instrument also has an analyser sensitive enough to measure the concentration of sulphur at the 0.05 % level.

Figure 2.26 Sulphur in Crude Oil Analyser

Source: (Anon, 2021)

2.9 The Origin of Sulphur and its Effect on Crude Oil

"Crude oil is a complex liquid mixture made up of a vast number of hydrocarbon compounds that consist mainly of carbon and hydrogen in differing proportions. In addition, small amounts of organic compounds containing sulphur, oxygen, nitrogen, and metals such as vanadium, nickel, iron, and copper are also present. Hydrogen to carbon ratios affects the physical properties of crude oil" (Mohammed *et al*., 2010). In its natural state, crude oils contain some amount of sulphur. A group of researchers conducted studies on Organic Sulphur Compounds (OSC) to find out the origin of these compounds in crude oil. The findings of their research strongly suggested that, "sulphur-containing high molecular weight substances are formed by the same sulphur incorporation reactions as OSC, but in an intermolecular fashion, thus, sulphur incorporation reactions on an intramolecular basis with suitable functionalized precursors at the early stages of diagenesis are probably the major origin for these OSC," (Sinninghe *et al*., 1988).

Seaspray Group studied the origin of sulphur content in coal in relation to their proximity to sediments. According to the group, an increase on sulfur content takes place as the sediments targeted by the Seaspray Group are approached and the maximum values occur where the coal is adjacent to these sediments or overlain by them (Brockway *et al*., 1991).

"The content of sulphur in crude oils ranges from less than 0.05 to more than 10 weight percentage, but generally falls in the range 1–4 weight percent. When the content of sulphur in the crude oil is less than 1 weight percentage, it is called low sulphur crude or sweet crude. Conversely, when the sulphur content in the crude is more than 1 weight percent sulphur, it is referred to as high sulphur crude or sour crude oil," (Mohamed *et al*., 2010). The cost of crude oil having a higher sulphur content is relatively lower than the ones having lower sulphur content. As regards to that, desulphurizing the crude oil is economically beneficial to refiners. "In sulfides and disulphides, the sulphur atom replaces one or two carbon atoms in the chain (R–S–R or R-S-S-R). These compounds are often present in light fractions," (Mohamed *et al*., 2010). Figures 2.27 and 2.28 show Sulphur containing compounds.

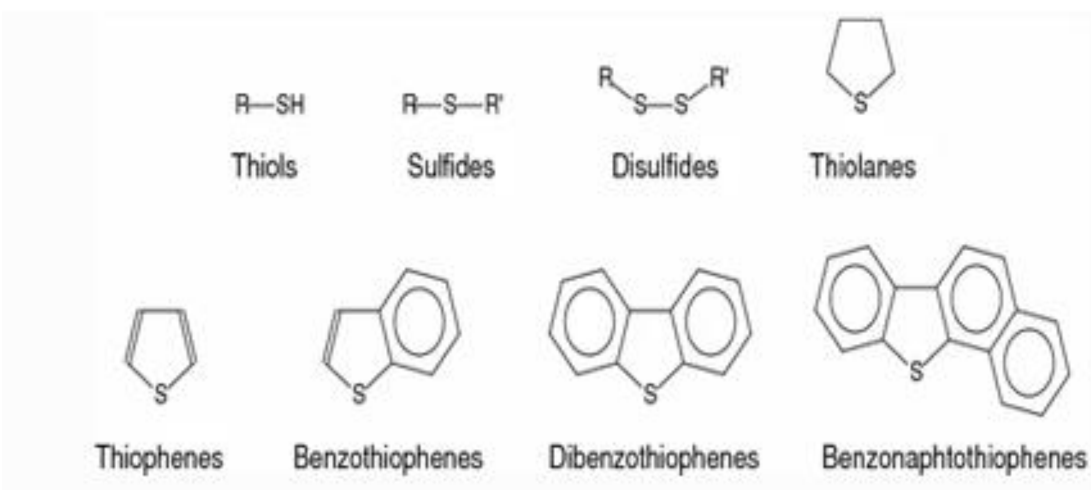


Figure 2.27 Sulphur Containing Compounds in Crude Oils

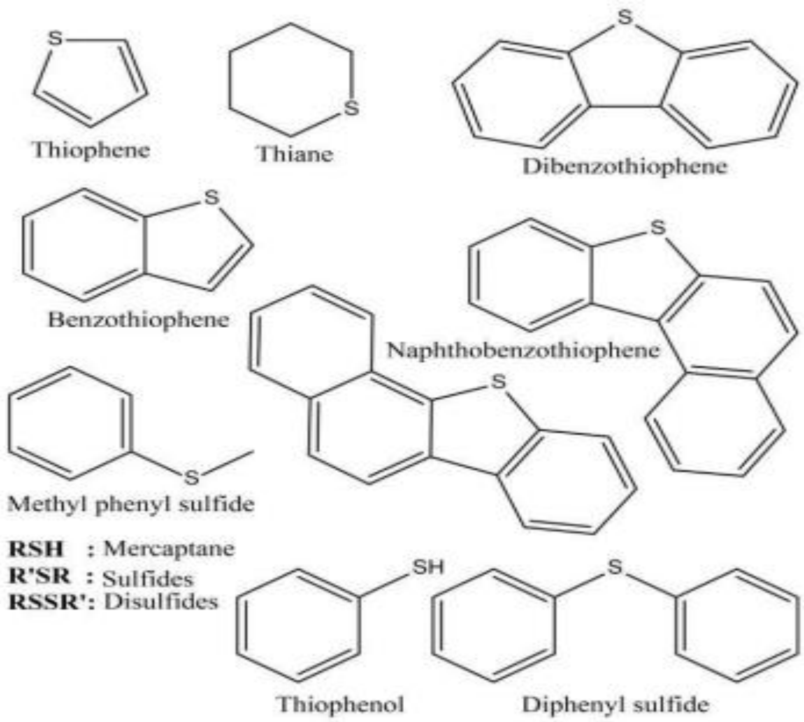


Figure 2.28 Chemical structure of sulphur containing compounds

2.10 Effect of Sulphur in Crude Oil

Besides the direct monetary benefit that can be accrued from the sale of crude oil containing low sulphur, additionally, it is beneficial to refine crude oil having low sulphur content. "Petroleum includes crude oil, natural gas, and heavy oil. Downstream processes such as catalytic cracking and refining will be adversely affected by high sulphur contents. If high-sulphur asphalt is oxidised, there is the potential for production of high levels of sulphur dioxide, which can lead to acid deposition (acid rain)," (Speight, 2005; Speight and Arjoon, 2012). Speight emphasised that, "sulphur is considered an undesirable contaminant because, when burned, it generates sulphur oxides (Speight, 2016). Sulphur oxide is detrimental to the health of human beings.

2.11 Effect of Sulphur on Humans

If sulphur is not removed from the oil used by machines and the automobiles, and subsequently when combustion of the sulphur takes place, the sulfur and the nitrogen are oxidised forming sulphur dioxide and nitrogen dioxide respectively. When these gases are released into the atmosphere, they combine with the moisture in the atmosphere to form acid, which in the end fall as acid rain. Acid rain is very harmful to agriculture, plants, and animals. Acid rain washes away all nutrients that are needed by plants to grow. When plants and animals are affected, humans' are also greatly affected because it is undoubtedly that humans' lives depend on plants and animals. "Acid rain is the water from a rainfall that has a pH less than 5.6, the value typically observed, due to the presence of dissolved carbon dioxide," (Halpern *et al*., 2019). Regardless of the source, the SO_2 dissolves in rainwater to give sulfurous acid that is eventually oxidized by oxygen to sulfuric acid. Undeniably, sulphuric acid and nitric acid are the two main strong acids found in acid rain. These strong acids come about because of the reaction of nitrogen oxide and sulfur dioxide that react with water in the atmosphere and oxygen in the air. Figure 2.29 shows the sources of sulphur dioxide and nitrogen oxides that react with water molecules in the atmosphere to form sulphuric acid and nitric acid (the major chemical constituents) of acid rain.

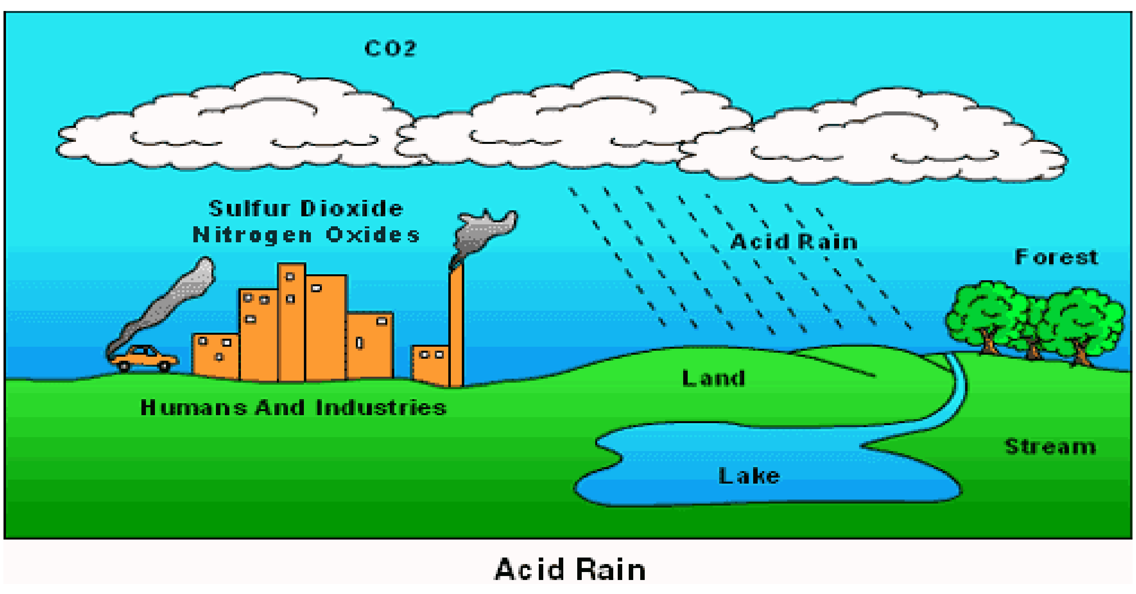


Figure 2.29 Acid Rain

Source: (Kate, 2015)

The chemical equations below show the formation of sulphuric acid and nitric acid

$$SO_2 + \frac{1}{2}O_2 + H_2O \rightarrow H_2SO_4 \quad (2.5)$$

$$H_2SO_2 \rightarrow 2H^+ + SO_4^{2-} \quad (2.6)$$

Similarly

$$HNO_2 + \frac{1}{2}O_2 + H_2O \rightarrow 2HNO_3 \quad (2.7)$$

$$HNO_3 \rightarrow H^+ + NO_3^- \quad (2.8)$$

The following explanations provided by Stefan (2018) give the guide to chemical equations of the formation of the acids that constitute largest part of the chemicals that come together to form acid rain.

2.12 Sulphur Dioxide Formation

Sulphur dioxide (SO_2) is produced from the combustion of sulphur-containing fossil fuels such as crude oil and smelting of sulphide ores (aluminum, copper, zinc, lead, and iron)

$$S_3 + O_{2(g)} \rightarrow SO_{2(g)} \quad (2.9)$$

Sulphur dioxide (SO_2) is then oxidised by sunlight to form trioxide (SO_3)

$$2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)} \quad (2.10)$$

The oxides react with water to form acids

$$SO_{2(g)} + HO_{2(l)} \rightarrow H_2SO_{3(g)} \quad (2.11)$$

$$SO_{3(g)} + HO_{2(l)} \rightarrow H_2SO_{4(g)} \quad (2.12)$$

2.13 Nitrogen Oxides Formation

$$N_2 + O_2 \rightarrow 2NO_{(g)} \quad (2.13)$$

Nitrogen monoxide (NO) oxidises to form nitrogen dioxide

$$2NO_2 + O_{2(g)} \rightarrow 2NO_{2(g)} \quad (2.14)$$

Nitrogen dioxide reacts with water to form nitric acid (HNO_3) and nitrous acid (HNO_2)

$$2NO_{2(g)} + H_2O_{(l)} \rightarrow HNO_{3(aq)} + HNO_{2(aq)} \quad (2.15)$$

Or it reacts with oxygen and water and becomes nitric acid

$$4NO_{2(g)} + O_{2(g)} + H_2O_{(l)} \rightarrow 4HNO_{3(aq)} \quad (2.16)$$

2.12 Desulphurisation of the Crude Oils

As stated earlier on, removal of sulphur from the crude oil is extremely important. "Nowadays, desulphurisation of liquid fuels is inevitable because of strict environmental and industrial regulations on liquid fuels specifications," (Ahmadian *et al*., 2021). There are different ways that sulphur can be removed from crude oil. A group of researchers discussed a number of desulphurisation methods including, "hydrodesulphurisation, extractive desulphurisation, oxidative desulphurisation, biodesulphurisation, and desulphurisation through alkylation, chlorinolysis, desulphurisation using supercritical water," (Agrawal *et al*., 2018). Sulphur can also be removed directly by processing a hydrocarbon stream through hydrotreating, where the sulphur in the hydrocarbon is replaced with a hydrogen atom, and the released sulphur is combined with two free hydrogens to form H_2S gas. In this method, H_2S gas is typically collected from the various conversion and hydrotreating units and converted into elemental sulfur in a sulphur plant" (Speight 2016). The separated sulphur is sold or used to produce sulphuric acid. Another method of desulphurisation of crude oil is performed using supercritical water. Supercritical water desulphurisation is another method adopted to remove high molecular weight organic compounds in crude oils.

An experiment to remove sulphur from crude oil using supercritical water done conducted and it was reported that, "sixty percent of the sulphur was removed through the catalytic desulphurisation of residual oil carried out through partial oxidation in supercritical water," (Demirbas, 2016). Therefore, water can be used as a substitute for organic solvent because supercritical fluids used in the industries include water. "Supercritical fluid treatment depends on various parameters such as pressure, temperature, extraction time, solvent type, and chemical composition of the extracted material. And the supercritical water upgrading of crude oils reduces sulphur content and decreases average molecular weight," (Demirbas, 2016). The chemical nature of sulphur has an influence on how easy it can be removal from crude oil. "Desulphurisation of compounds that contain aliphatic sulfur, i.e. thiols and sulfides, is easier than desulphurisation of compounds that contain aromatic sulfur, i.e. thiophenics. The concentration and nature of the sulphur-containing compounds change over the boiling range. The amount of sulphur in a distillation fraction increases with an increase in boiling range," (Javadli and de Klerk, 2012). To classify and compare crude oil, two properties are especially useful. They are API gravity (a measure of density) and sulphur content. Table 2.1 shows the distillation range of crude oil with respect to various sulphur compounds.

"High viscosities and high API gravities crude oil contains high amount of sulphur content and complex sulphur compounds. A thermal treatment process commonly known as hydrodesulphurisation (HDS) can remove cyclic aliphatic sulphides such as thioethers and cyclic thiolane easily. On the other hand, "aromatic rings sulphur such as thiophene and derived and its benzologs can be removed easily by HDS," (Saddiqui and Ahmed, 2016).

Table 2.1 Sulphur Compounds Distribution Range

Distillation range ^{o}C	**Sulphur content (%)**	**Sulphur compound distribution (%)**			
		Thiols	**Sulphides**	**Thiophenes**	**Other***
70 – 180 (naphtha)	0.02	50	50	Trace	-
160 – 240 (kerosene)	0.2	25	25	35	15

Table 2.1 Sulphur Compounds Distribution Range (Continued)

Distillation range °C	**Sulphur content (%)**	Sulphur compound distribution (%)			
		Thiols	Sulphur	Thiophenes	Other*
230 – 350 (distillate)	0.9	15	15	35	35
350 – 550 (vacuum gas oil)	1.8	5	5	30	60
>550 (vacuum residue)	2.9	Trace	Trace	10	90

*Benzothiophenes, dibenzothiophenes, and heavy sulphides

Table 2.2 shows the physical properties of some sulfur-containing compounds. For example, Thiophenol, an aromatic sulphur-containing compound has a normal boiling point of 168.7 °C, and 1-Ethanethiol, which is an aliphatic sulfur-containing compound, has a normal boiling point of 35 °C. Comparatively, it can be said that aliphatic sulfur-containing compounds need less energy and therefore easier to desulfurize than the aromatic sulphur-containing compounds as stated earlier on.

Table 2.2 Physical Properties of Selected Suphur-Containing Compounds

Compound	**Normal boiling point (°C)**	**Melting point (°C)**	**Density at 20 °C (kg/m^3)**
1-Ethanethiol (ethyl mercaptan)	35	-144.4	839.1
Dimethyl Sulphide	37.3	-98.3	843.3
1-Propanethiol (propyl mercaptan)	67	-113.3	841.1
Thiophene	84.2	-38.2	1064.9
Diethyl sulphide	92.1	-103.8	836.2
1-Butanethiol (butyl mercaptan)	98.4	-115.7	833.7

Table 2.2 Physical Properties of Selected Suphur-Containing Compounds (Contineud)

Compound	Normal boiling point (ºC)	Melting point (ºC	Density at 20 ºC (kg/m³)
Dimethyl disulphide	109.7	-84.7	1062.5
Tetrahydrothiophene (thiolane)	121.1	-96.2	998.7
Dipropyl sulphide	142.4	-102.5	837.7
Thiophenol	168.7	-14.8	1076.6
Dibutyl sulphide	185	-79.7	838.6
Benzothiophene (thianaphthalene)	221	32	1148.4
Dibutyl disulphide	226	*	938.3
Dibenzothophene	332	332	*

2.14 Factors Affecting Desulphurisation

Fatemeh *et al*., (2021) provided the factors that affect oxidative desulphurisation process. The factors include oxidant used, the extractants employed, liquid fuels used, catalysts, and the operating conditions. Figure 2.30 summarises the factors.

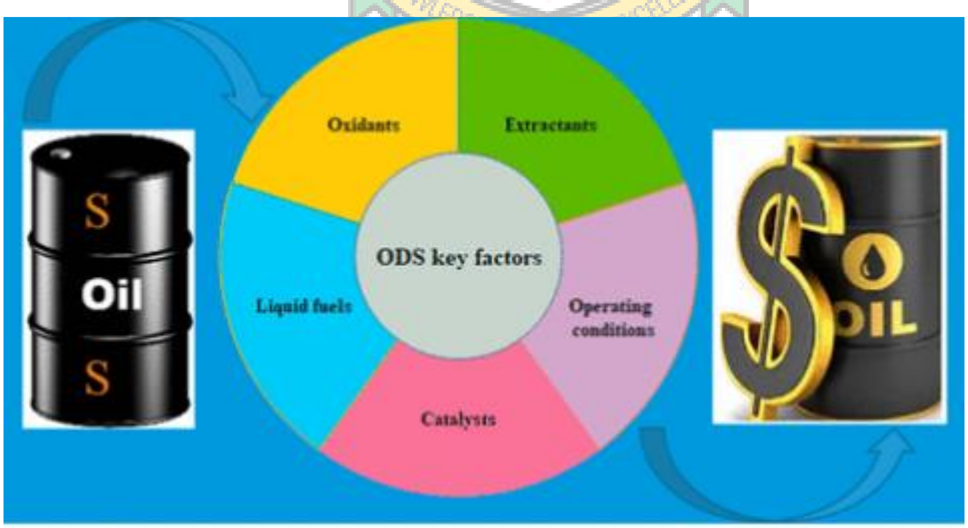


Figure 2.30 Factors Affecting ODS

Source: (Fatemeh *et al*., 2021)

2.15 Hydrodesulphurisation

In hydrodesulphurisation (HDS) method, hydrogen (H_2) gas is used to remove sulphur-containing compounds from oils. This method of desulphurisation reduces the sulphur content in crude oils. “Most suphfur-containing compounds are easily desulphurised by HDS, in which it is used to remove the S-compounds by forming hydrocarbons and H_2S,” (Rafiie *et al*., 2016). “Hydrodesulphurisation or Hydrotreating is a catalytic chemical process by which sulphur (S) is removed from natural gas and from refined petroleum products like petrol, jet fuel, kerosene, diesel fuel and fuel oils in the form of hydrogen sulfide or sulphur dioxide. The hydrogen sulphide gas obtained from HDS are converted to sulphuric acid or elemental sulphur by some industries. Figure 2.33 shows the simplified diagram of a hydrodesulphurisation cycle for thiophene, a constituent of petroleum. The diagram presents the responsibilities of the catalyst in the hydrodesulphurisation process.

The principal hydrodesulphurisation catalysts are molybdenum disulphide (MoS_2) together with smaller amounts of other metals (Siddique and Ahmed, 2016). Figure 2.33 shows the hydrodesulphurisation cycle of thiophene. Hydrodesulphurisation is a conventional process used by most refineries but the process is very expensive.

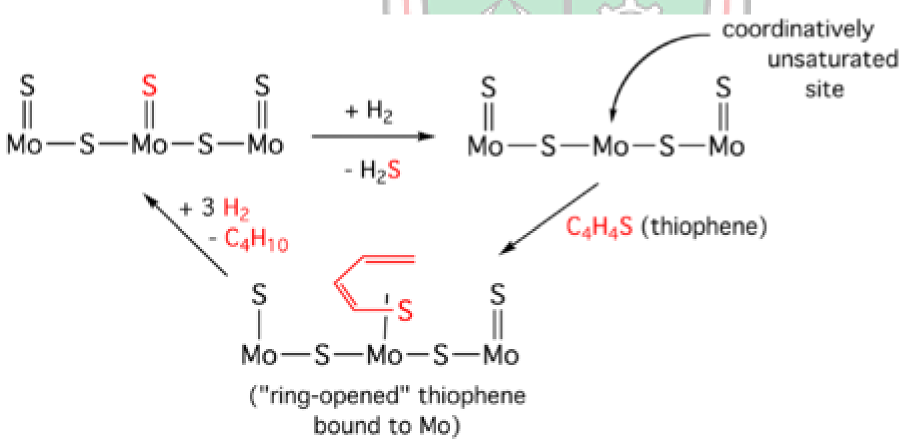


Figure 2.31 Diagram of a hydrodesulphurisation cycle for thiophene

2.15.1 Process Description of Hydrodesulphurisation

A paper presented by Beychok (2013) describes the processes involving the hydrodesulphurisation. The process flow diagram for the hydrodesulphurisation has been presented in Figure 2.32. The process flow diagram is a typical example of hydrodesulphurisation unit of a petroleum refinery. Careful study of the process shows that, "the hydrodesulphurisation reaction occurred using fixed-bed reactor at 300 ^{o}C to 400 °C and at 30 to 130 atmospheres of absolute pressure, typically in the presence of a catalyst consisting of a base Impregnated with cobalt and molybdenum," (Beychok, 2013).

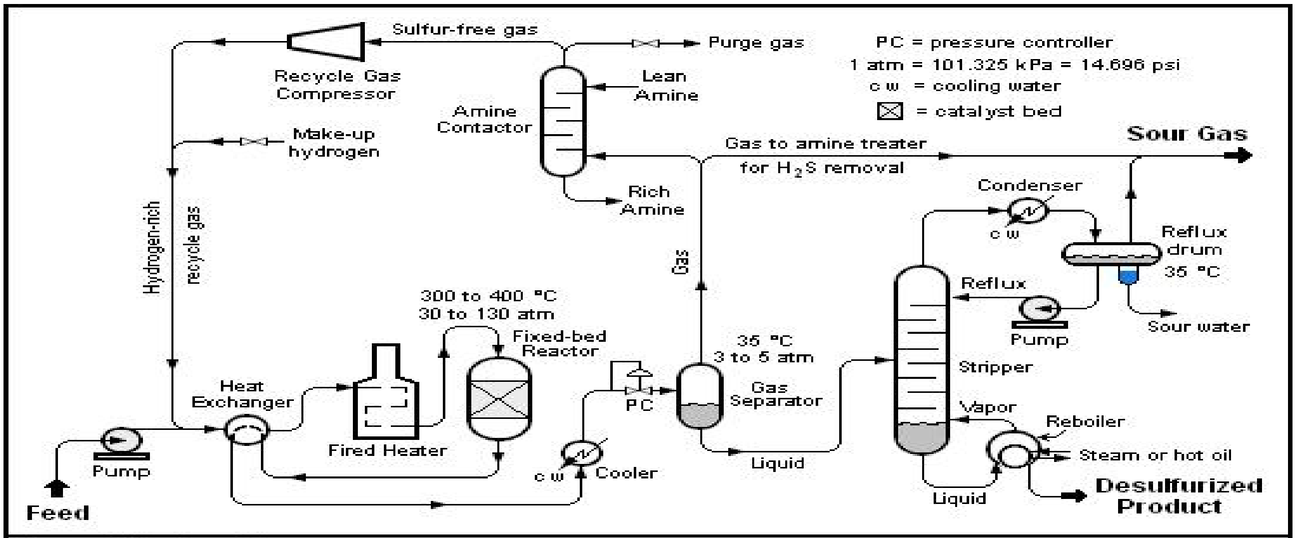


Figure 2.32 Petroleum Refinery Hydrodesulphurisation Unit

Source: (Beychok, 2013)

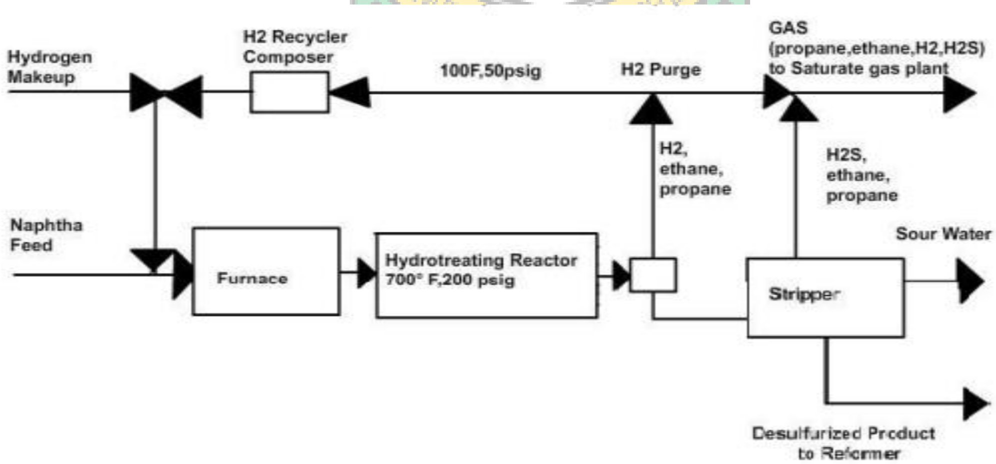


Figure 2.33 Concise HDS Treatment Flow Diagram

Source: (Siddiqui and Ahmed, 2016)

Dehydration chemicals, or demulsifiers, are chemical compounds that are widely used to destabilise, and assist in coalescence of crude-oil emulsions.

2.15.2 Extractive Desulphurisation

"Extractive desulphurisation (EDS) is the method of removing sulphur-containing compounds based on the preferable solvation in a solvent over that in hydrocarbons. Large volumes of volatile organic solvents (such as acetonitrile) are typically used in the EDS process, but that chemical poses both health and environmental concerns," (Anon., 2019). "As a rule, complete removal of sulphur-containing compounds from oil samples by extraction requires a multistep extraction process," (Katasonova *et al*., 2021). Oxidative desulphurisation is employed to augment the ability of the extractive desulphurisation to achieve the desired level of separation. The oxidative desulphurisation increases the polarities of the sulphur containing compounds and the non-sulphur containing compounds in the crude oil. Usually, dimethylformamide (DMF), acetonitrile (AcN), pyrrolidones, and dimethyl sulphoxide (DMSO) are used as reagents in an extractive desulphurisation process. Catalysts or hydrogen is not needed in EDS process. The quality of fuel is maintained by using EDS method to remove sulphur from oils.

The type of extractant used in the extractive desulphurisation is very essential because the polarities of aromatic sulphur compounds and the non-sulfur aromatic compounds in the oils that are similar.

Traditionally, the extractant used for the extractive desulphurisation is ionic liquid. Ionic liquids are compounds completely composed of ions with melting point below 100 °C. "The dominant force in extraction is dispersion-driven binding between the ions and S-compounds," (Player *et al*., 2019). "Two types of ionic liquids, 1-alkyl-3-methylimidazolium [AMIM] tetrafluoroborate and hexafluorophosphate and trimethylamine hydrochloride ($AlCl_3$−TMAC) were used to remove sulphur from transportation fuels. EMIMBF4 (E = ethyl), BMIMPF6 (B = butyl), BMIMBF4, and heavier AMIMPF6 showed high selectivity, particularly toward aromatic sulphur and nitrogen compounds, for extractive desulphurisation and denitrogenation. In conclusion it was found that, "AlCl3−TMAC ionic liquids had remarkably high absorption capacities for aromatics," (Zhang *et al*., 2003).

In order to innovate desulphurisation of oils used in the automobiles, Radriguez-Cabo *et al*., (2013) targeted the use of ionic liquids by solvent extraction to remove sulphur compounds from hydrocarbons. According to the researchers, "The shortfalls of the previous researches is hinged on the fact that the use of ionic liquids were not based on rigorous thermodynamic data and those researchers did not consider the effect of the ionic liquid on the different fuel constituents." The researchers highlighted the following point about desulphurisation:

(a) The fuel nature influences the strategy for its desulphurisation by ionic liquids,

(b) Extraction with the ionic liquid [C_2mim][OAc] is preferred,

(c) Oxidative desulphurisation works better for fuels with heavy sulphur compounds,

(d) The ionic liquid [C_2mim][NTf_2] is proposed for the oxidative desulphurisation of diesel fuel," (Rodriguez-Cabo *et al*., (2013).

Li et al., (2015) studied the reactions involving the extractive desulphurisation mechanism by $[BMIM]^+[AlCl4]^-$ ionic liquid. According to the researchers, "both cation and anion play important roles in EDS on the basis of the structure analysis, reduced density gradient analysis (RDG), energy decomposition analysis, $[BMIM]^+$ cation π–π interaction while $[AlCl_4]^-$ and hydrogen bonding interaction." Other researchers also used ionic liquid for desulphurisation. "Ionic liquids was used as a solvent for the extractive desulphurisation of refinery streams such as diesel oil and fuel catalytic cracking (FCC) gasoline as a supplemental technology to conventional hydrodesulphurisation" (Eber *et al*., 2004). Meng *et al*., (2020) laid down some shortcomings of hydrodesulphurisation in the paper presented in Scientific Reports journal. The report said, "Hydrodesulphurisation is less effective for sulphides containing aromatic rings and their derivatives than for other compounds. In addition, HDS requires a high investment and harsh operating conditions," (Meng *et al*., 2004).

2.15.3 Oxidative Desulphurisation

Although oxidative desulphurisation was discussed briefly when reviewing extractive desulphurisation, it is deemed important to embark on a detailed review of this method. Oxidative desulphurisation is the removal of sulphur containing compounds by oxidising the sulphur containing compounds in the crude oil and extracting the oxidised compounds using extractants. Steric hindrance adsorption makes it difficult for hydrodesulphurisation to remove sulphur-containing compounds such as thiophene, dibenzothiophene removed from the crude oil.

"Thiophenic sulphur is difficult to remove by catalytic hydrodesulphurisation, but it can readily be oxidised," (Javadli *et al*., 2012). "To produce clean fuel oils with lower S-content (*e.g.*, S < 10 ppm), severe conditions such as high temperature, high pressure, active catalyst and complex process are required in HDS, which, however, results into higher cost, more olefin loss, and lower oil yield," (Bhutto *et al*., 2016). Some researchers commenced the usage of ionic liquids instead of organic solvents to conduct the oxidative desulphurisation. This new method achieved good results. Bhutto *et al*., (2016) reported that, "ionic liquids have some advantages such as non-volatility, wide liquid range, high thermal and chemical stability, regenerability and reusability." Figure 2.34 shows oxidative desulphurisation using ionic liquid.

Although, according to the authors, the afore-mentioned advantages make the ionic liquid avoid the problems such as solvent loss/contamination and difficult separation and regeneration in tradition ODS with organic solvents, other authors have opposing views about the use of ionic liquid as an extractant. Andreani et Rocha (2012) reported that as much as ionic liquids can have some advantages as an extractant, it has some disadvantages such as high cost of its production, the difficulty in recovering, and the impossibility of reutilisation of the catalyst for several cycles. Again, Houda *et al*. (2018) reported that the main disadvantage of using ionic liquid as an extractant is the huge amount of the oxidant/IL ratio needed for the extraction. Furthermore, it is worth noting that selecting one suitable Ionic Liquid among the numerous species of the IL for oxidative desulphurisation is also a problem. Bhutto *et al*. (2016) presents "the review for some results to illustrate the novelty, problem and perspective of this method."

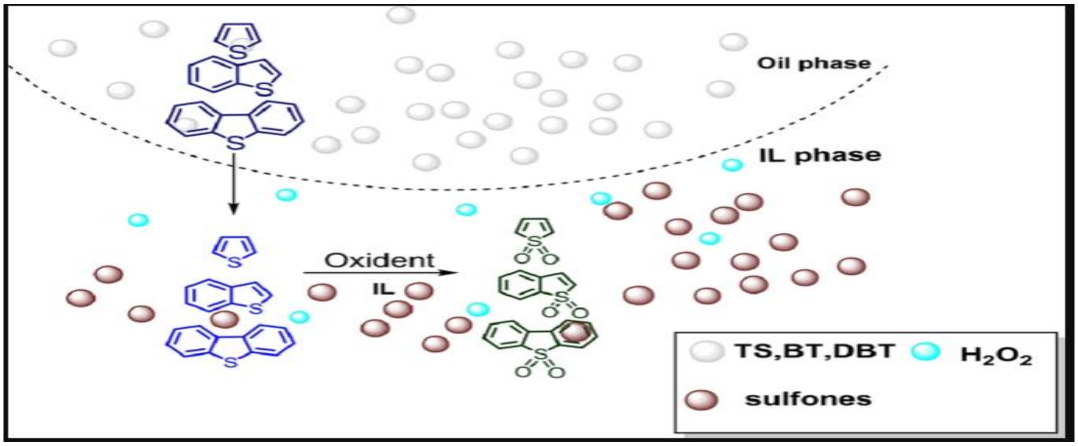


Figure 2.34 Oxidative Desulphurisation Using Ionic Liquid

Source: (Bhutto *et al*., 2016)

The mixtures of petroleum distillates are put into different categories according to their respective boiling temperatures. Additionally, the fractions are obtained during distillation based on their boiling ranges. Generally, as stated by a group of researchers, "the lighter distillates contain mercaptans, sulphides, and disulphides. The heavier distillates contain more of the heterocyclic aromatic sulphur species. The middle distillates contain predominantly benzothiophenes and alkylated derivatives, while the primary contaminants of diesel streams are dibenzothiophene and dibenzothiophene derivatives. The most abundant sulphur compounds found in gasoline are thiophenes (2-methylthiophene, 3-methlythiophene, 2, 4 dimethyl thiophene, benzothiophene and 2-methylbenzothiophene)," (Mohamed *et al*., 2018). The figure below shows the chemical structures of the main organic sulphur compounds (OSCs) found in different petroleum fractions and the reactions they undergo during the oxidative desulphurisation. Figure 2.35 shows thiophenic reaction pathway.

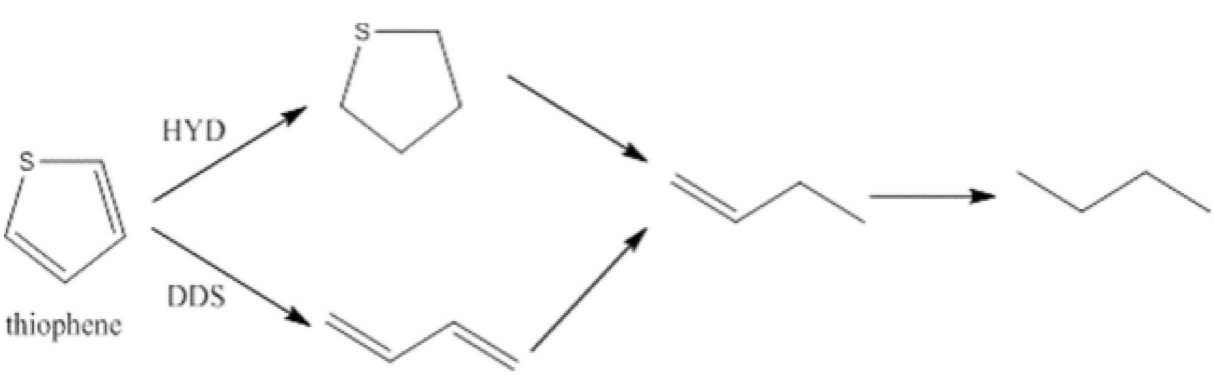


Figure 2.35 Thiophene Reaction Pathway

Source: (Betiha *et al*., 2018)

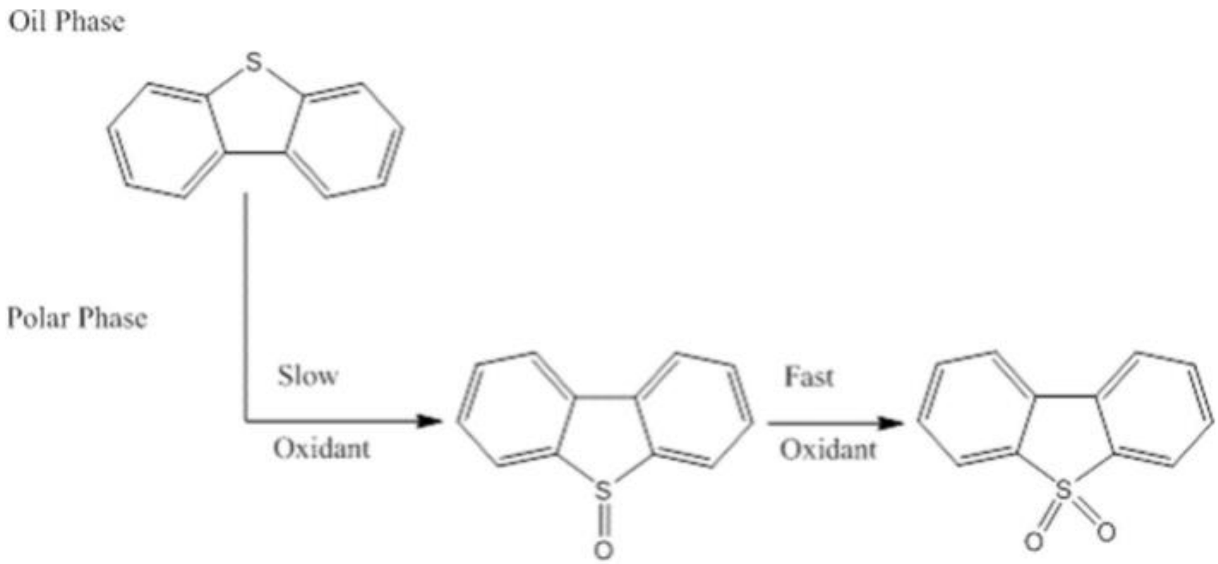


Figure 2.36 Oxidative Desulphurisation (ODS) of Dibenzothiophene (DBT)

Source: (Betiha *et al*., 2018)

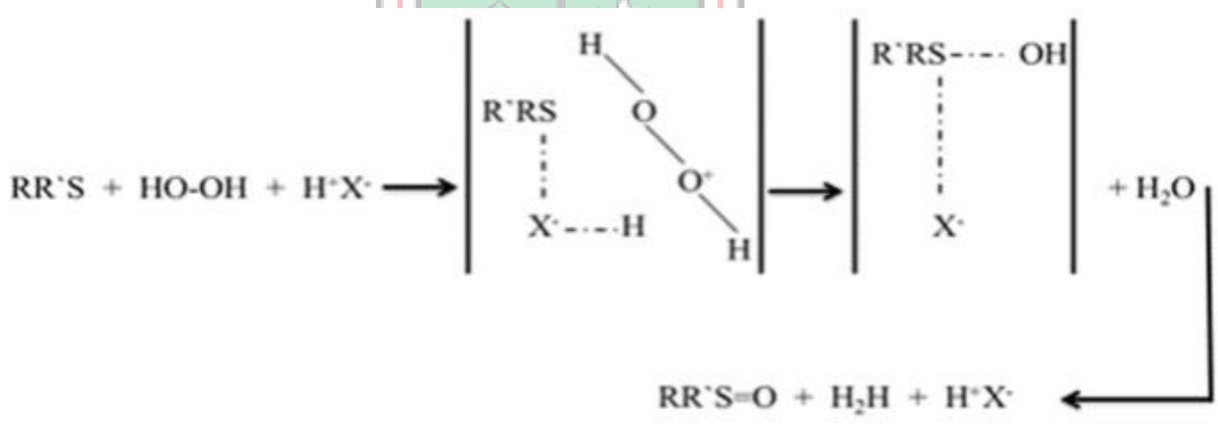


Figure 2.37 Desulphurisation Using Peracid

Source: (Betiha *et al*., 2018)

Furthermore, another group of researchers introduced in details a development made regarding oxidative desulphurisation process using emulsion catalysts. They presented that, "amphiphilic emulsion catalysts can selectively oxidise the sulphur-containing molecules present in diesel to their corresponding sulfones using H_2O_2 as the oxidant under mild conditions," Zongxuan *et* *al*., (2011). Figure 2.38 below shows, how the sulphur-containing compounds in diesel can be oxidized to their corresponding sulfones by the amphiphilic emulsion catalysts under mild conditions, and then the sulfones removed by a polar extractant.

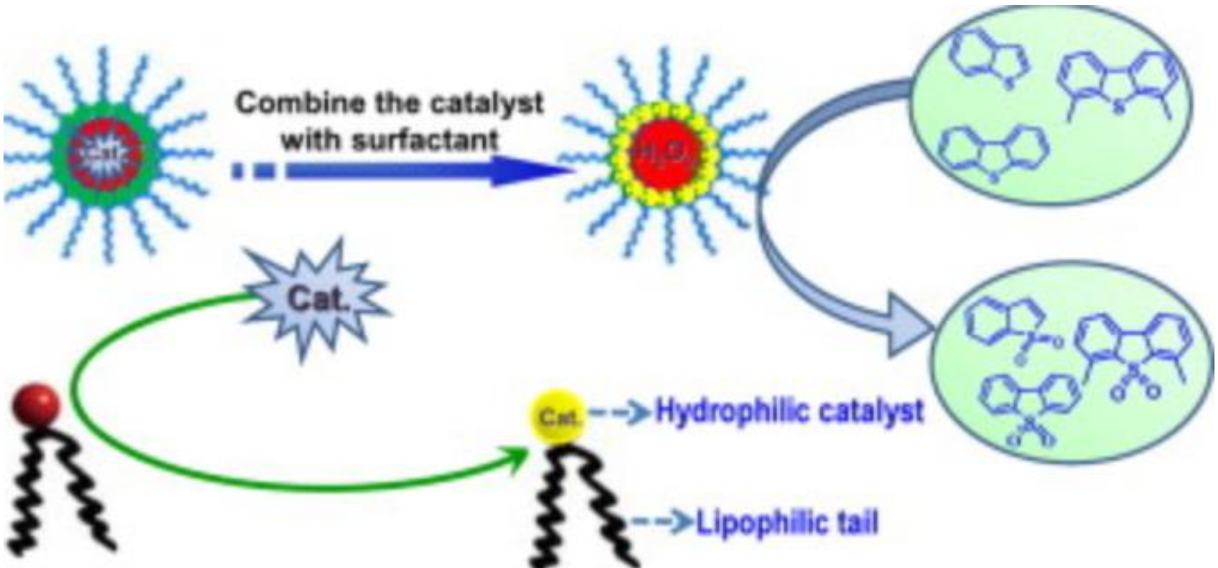


Figure 2.38 Sulphur Containing Compounds Extraction
Source: (Jiang *et al*., 2011)

To conduct more review about oxidative desulphurization of Oils, Otsuki *et al*., (2000) piloteda research on "the oxidation of model sulphur compounds (thiophene derivatives, benzothiophene derivatives, and dibenzothiophene derivatives), straight run-light gas oil (SR-LGO, S: 1.35 wt. %), and vacuum gas oil (VGO, S: 2.17 wt. %) with a mixture of hydrogen peroxide and formic acid." According to the researchers, "the most effective solvent for the removal of sulphur compounds was N, N-dimethylformadide (DMF)," (Otsuki *et al*., 2000). The recovery of oil was, however, lowest with DMF (Seeing the shortcomings of hydrodesulphurisation (HDS) technology used widely to produce fuels with ultralow sulphur content (S ≤ 10 ppm), Ahmadian *et al*., (2021) reported that, "this method is not effective enough for removing refractory sulphur compounds (e.g., benzothiophene, dibenzothiophene, and their derivatives). Consequently, an alternative desulphurisation method as proposed and researched by other researchers was needed to be embarked on by his group." They stated that, "'the oxidative desulphurisation (ODS) process is a promising method with high selectivity, low cost, mild reaction conditions, and high efficiency.' In this regard, they investigated oxidative desulphurisation, among other things, and concluded that 'the removal of S-compounds from fuel oils via the ODS process using homogeneous and heterogeneous polyoxometalate catalysts is advantageous,'" (Ahmadian *et al.*, 2021). Figure 2.39 shows generally the oxidative desulphurisation reaction pathway. The process shows the oxidation of the bivalent sulphur to the corresponding hexavalent sulfones. Oxidant is used in this process. The product shows the addition of two oxygen atoms to the sulphur without any bond breaking. Table 2.3 shows the rate of desulphurization and the properties of extraction solvents.

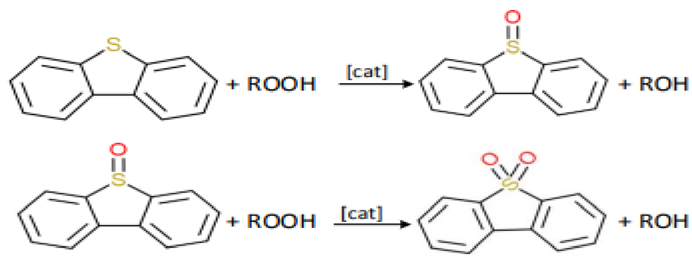


Figure 2.39 Oxidative Desulphurisation Pathway

Source: (Houda *et al.*, 2018)

Table 2.3 Desulphurisation Rates (D.R.) and Extraction Solvents Properties

Extraction Solvent	Dipole Moment (Debye)	Dielectric Constant	Solvent to Oil Ratio S/O	Petroleum Fraction	Sulphur Content (ppm)	D. R. (%)	Extraction Step
N, N-dimethylformamide (DMF)	3.24	36.71	1	VGO + Diesel Fraction	6300	90	3
Acetonitrile	3.53	35.94	1	HFO	27500	59	1
Acetonitril + water (80:20)	-	-	1	Naphtha	20000	83	1
Followed by	-	-	-	LGO	12000	85	1

Source: (Houda *et al.*, 2018)

Table 2.3 Desulphurisation Rates (D.R.) and Extraction Solvents Properties (Continued)

Extraction solvent	Dipole Moment (Debye)	Dielectric Constant	Solvent to Oil Ratio S/O	Petroleum Fraction	Sulphur Content (ppm)	D. R. (%)	Extraction Step
Methanol - water (80:20)	-	-	-	HGO	40000	69	1
	-	-	-	Bitumen	50000	64	1
n-Heptane	-	-	2	Crude oil	14940	85	1
Methanol	2.87	32.66	1	Gas oil	24000	90	1
Acetonitril	3.53	35.94	1	VGO	19800	89	1
DMF	3.24	36.71	1	SR_LGO	13500	92	-
DMF	3.24	36.71	1	VGO	21700	100	10
Acetonitril	3.53	35.94	0.5	Diesel	7744	99	1
Acetonitril	3.53	35.94	1	HFO	38500	35	1
DMF	3.24	36.71	1	Diesel	8286	90	4

Although much has been reported about different types of extractants, few has been discussed about using ethanol as an extractant for sulphur containing compounds. In choosing an extractant after ODS of diesel oil, vacuum oil, and heavy fuel, Houda *et al*., (2018) stated that acetonitrile was taken because of its relatively low boiling point which is 355 K compared with the boiling points of the sulfones that range from 550 K to 950 K. However, it should be noted that the boiling point of ethanol is 351.15 K, which is even lower than that of acetonitrile. Hence, it will be preferable to use ethanol for the extraction of the sulfones instead of acetonitrile.

2.15.4 Alkylation Desulphurisation

Different methods of desulphurisation of crude oil have been reviewed. The next desulphurisation method to be reviewed is alkylation desulphurisation. Alkylation is the transfer of alkyl group from one molecule to the other molecule. The most popular methods of alkylation are C-alkylation and S-alkylation. C-alkylation is a process of forming carbon-

carbon bonds. S-alkylation is the formation of a covalent bond between a sulfur atom in a substrate and an alkyl group. This desulphurisation method removes sulphur compounds called thiophenes. In this method, the thiophenes react with methyl iodate in the presence of silver tetrafluroborate to form sufonium salts of s-methyl. This alkylated sulfonium salts form precipitates in hydrocarbon, which is easily separated without following any distillation process.

2.15.5 Biodesulphurisation

The next method of desulphurisation that needs to be reviewed is biodesulphurisation (DBS). "Biodesulphurisation was developed in the United States by the Enchira Biotechnology Corporation and patented in 1990s," (Speight *et al*., 2018). "Biodesulphurisation is the process of removing sulphur from fuels using living organisms. It is a non-invasive approach that can specifically remove sulphur from refractory hydrocarbons under mild conditions and it can be potentially used in industrial desulphurisation," (Anon., 2019). According to Mohebali *et al*., (2016), "biodesulphurisation is a process that is based around bacterial potential. "The BDS process is applied to desulphurise the more recalcitrant sulphur compounds and offers an attractive alternative to conventional hydrodesulphurisation due to the mild operating conditions and reaction specificity afforded by the biocatalyst," (Anon, 2019). Following the above definitions of biodesulphurisation is its process employed to desulphurise crude oils. In the BDS process, "bacteria remove organosulphur compounds from petroleum fractions without degrading the carbon skeleton of the organosulphur compounds. During the process, alkylated dibenzothiophenes are converted to non-sulphur compounds," (Mohebali *et al*., 2016). "Successful biodesulphurisation hinges on naturally occurring aerobic bacteria to remove organically bound sulphur in heterocyclic compounds devoid of destroying the fuel value of the hydrocarbon matrix," (Anon., 2019). Biodesulphurisation of petroleum occurs in any of these two pathways, namely, oxidative or reductive pathways. In oxidative pathway, the organic sulphur is converted by the use of biological agent to sulphate and then removed using water. The sulphur removed from the crude oil is processed and used. Additionally, the water can also be processed and used again. In the reductive desulphurisation, organic sulfur is converted into hydrogen sulphide, which is catalytically converted into elemental sulphur.

"Biodesulphurisation can be conducted under less energy and hydrogen. It can be operated at ambient temperature and pressure with high selectivity, resulting in decreased energy costs, low emissions and no production of byproducts," (Anon., 2019).A group of researchers developed systematic integrated process for the removal of sulphur from heavy crude oil and Light crude oil. In concluding the research, the researchers reported that, "biodesulphurisation under anaerobic conditions followed by oxy- desulphurisation followed by reactive adsorption integration resulted in maximum removal, i.e., 95.21 % removal of sulphur from HCO and 94.30 % removal of sulphur from LCO," (Agarwal *et al*., 2009). Although the primary aim of this section is the review of biological removal of sulphur from crude oil, it is considered necessary to review the importance of biological removal of particular hydrocarbon from crude oil. Another group of researchers also investigated the possibility of biological removal of hydrocarbons from crude oil with the use of native bacterial strains, isolated from the shorelines of the Caspian Sea. In the report of the findings, the researchers stated that, "the isolate J3 had a better ability to degrade short (C9–C13) and medium length (C13–C25) in comparison with the long length (C32–C35) of n-alkanes in the crude oil residues. The total petroleum hydrocarbon (TPH) reduction by the B. cereus (J3) isolate was about 88.8 mg/g," (Tanzadeh *et al.*, 2020). The next method of removing sulphur from crude oil is supercritical water desulphurisation.

2.15.6 Supercritical Water Desulphurisation (SCWDS)

Supercritical water desulphurisation is a method of removing sulphur compounds from the hydrocarbon using water at the about 400 degree centigrade and 25 MPa. At this temperature and pressure, the bonds between carbon and sulphur disintegrate. This method of desulphurisation is useful for desulphurisation of aliphatic sulphur compounds but not desulphurisation of aromatic sulphur compounds. Conversely, the aliphatic sulphur compounds can be obtained from aromatic sulphur compounds using supercritical water. Ates *et al*. (2014) establishing the role of catalysts in the SCW process demonstrated that, "modest desulphurisation could be achieved in the absence of an external hydrogen source; and provide guidelines for catalyst selection."

According to the researchers, “supercritical water (SCW) alone removes 6–7% of the sulphur present in Arabian Heavy. Addition of MoS_2 to supercritical water improves the sulphur removal by a factor of 2 (to about 12%). For the hexyl sulphide-hexadecane model feed, they found that hexyl sulphide conversion in SCW alone was high (~85 %) and is weakly affected by addition of catalysts, (Ates *et al.*, 2014). Hence, they inferred that catalysts have minimal effect on the decomposition rates of aliphatic sulphide compounds strongest effect (from 3 to 25%). The researchers said, “MoS_2 remained unchanged during the SCW treatment, whereas MoO_3 and ZnO underwent structural and morphological changes primarily related to sulphidation reactions,” (Ates *et al.*, 2014). Figure 2.40 shows supercritical water desulphurisation flow chart.

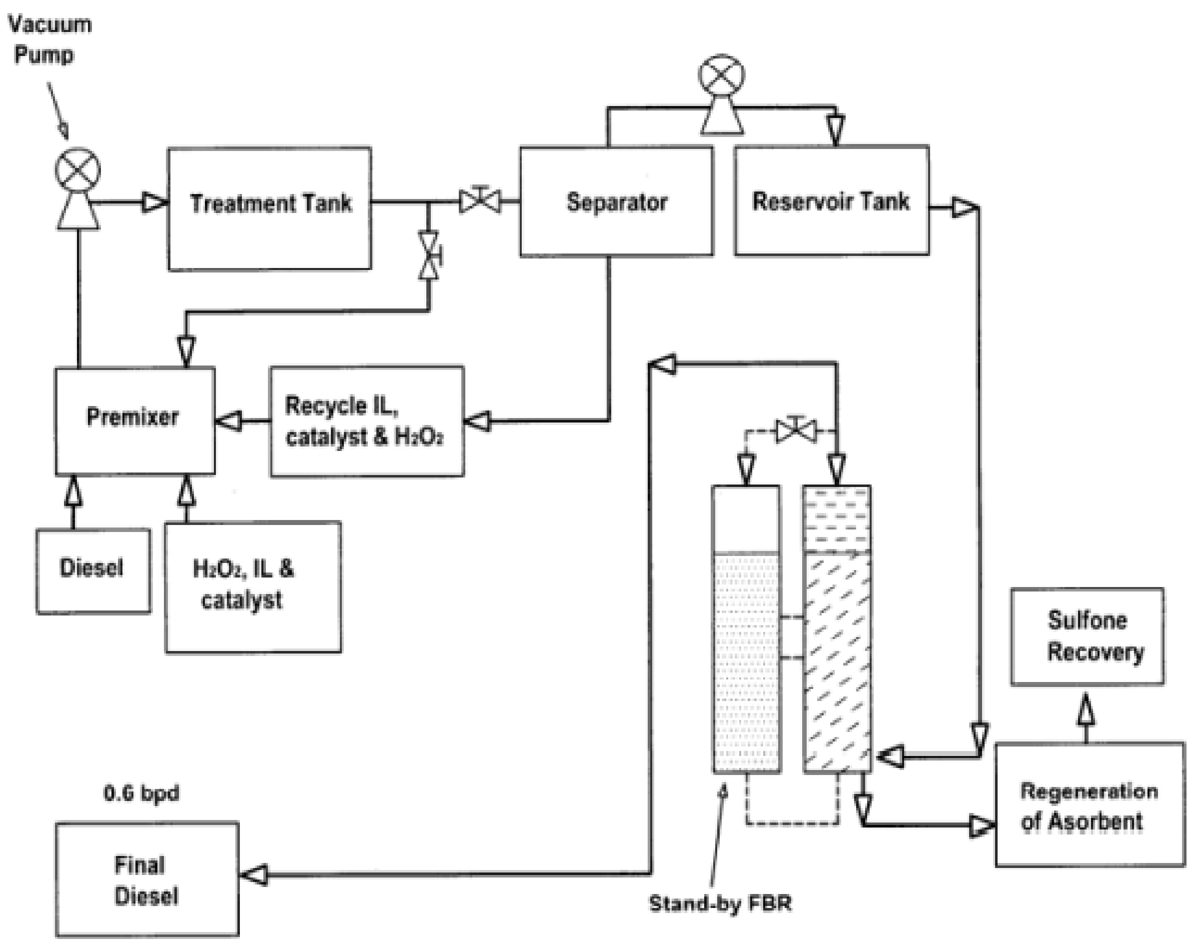


Figure 2.40 Supercritical water desulphurisation flow chart

Source: (Siddiqui *et al.*, 2016)

In addition to the research conducted by the preceding researchers, a group of researchers conducted supercritical water desulphurisation of heavy oil and bitumen. In the work, they measured the kinetics of decomposition of a variety of organic sulphides in the presence of hydrocarbons and critical water in a continuously fed stirred-tank reactor (CSTR). They reported that, "decomposition of several different sulphides is consistent with 3/2 power kinetics, providing evidence that the reaction proceeded via a radical mechanism,'' Padwardhan *et al*., (2014). Desulphurisation of heavy oil using supercritical methanol instead of supercritical water looks promising as proved by Yang *et al*., (2020). The researchers used n-hexyl sulfide, 3-methylthiophene, diphenyl sulphide, and dibenzyl sulphide models to simulate to ascertain the conversion mechanism of the sulphur components in the supercritical methanol. They stated in their conclusion report that, "using supercritical methanol in the simulation proved that the reaction process is accelerated using this solvent, and the desulphurisation reaction is promoted," Yang *et al*., (2020).

2.16 Permissible Sulphur Content in Ghana Transportation Fuels

Reed (2022) presented an article entitled "Ghana Pushes Back Sulphur Limits for Local Fuel" that said that the National Petroleum Authority (NPA) of Ghana has waived the content of sulphur in the transportation fuel in order to keep the local refineries running. According to him, the National Petroleum Authority said that the waiver was effective immediately and would run until the end of 2024. As a result, local refineries can produce diesel and petrol with sulphur levels of not more than 1,500 ppm but the limits of the sulphur content in the transportation fuels imported to Ghana will continue to be 50 ppm (Reed, 2022). The reporter continued that although the ECOWAS has decided to set the target of the sulphur content in the transportation fuels to 50 ppm by 2025, it continues to waive the sulphur content for the local refineries.

Figure 2.41 A Group Inspects Tema Oil Refinery

Source: (Reed, 2022)

2.17 Review of Data Analyis Techniques

This section reviews the method used to analyse the data obtained from the research.

Data analysis can be defined as a process of cleaning, changing, and modelling data with the view of obtaining useful information to make conclusions and to assist in making important decisions

2.17.1 Gas Chromatography/Mass Spectrometry

Gas Chromatography/Mass Spectrometry (GC/MS) and Fourier Transform Infrared Spectrometry are used to analyse hydrocarbons . Generally, with gas chromatography (GC) analysis, the sample is injected into the GC column through a port. Closer to the injector port is a heater that vaporises the sample. The column consists of mobile phase and stationary phase. Inert gas such as helium, nitrogen, hydrogen is used at the mobile phase which serve as the carrier gas to propagate the species through the stationary phase to the end of the column where a detector is placed. The detector is connected to a computer that generates the peaks. The stationary phase is either a polar or a non-polar species placed in a coil. The movement of the components are based on two factors, namely, volatility and polarity. The most volatile component having polarity different from the polarity of the stationary phase reaches the detector before any other component. The response of the electric circuit programmed in the detector is the peak produced by the computer.

In the GC spectrum graph, the retention time is the independent variable on the abscissa. The retention time is the duration it takes for the component to reach the detector from the time the sample is injected into the column. The height of the peak is the dependent variable situated at the ordinate indicating the percentage of the species found in the sample injected into the column. The most predominant component has a corresponding highest percent composition of each run. The species exiting the GC column is transferred to the Mass Spectrometry (MS) column where electron gun bombards it to produce different masses having different polarities. The fragmented particles travels between a pair of magnetics having electromagnetic field. The electromagnetic field deflects the ionic particles. The mass of the particles determines the strength of the deflection. The strength of the deflection determins the particular location landed by the detector based. The electric circuits programmed in the detector detects the landing site of the particle. The electric circuit produces a spectrum with the assistance of the connected computer. The neutral particles go straight through the electromagnetic field onto the detector without producing any peak.

In the MS spectrum, the abscissa is the mass per unit charge and the ordinate is the percent abundance of the species in the sample. The molecular mass spectrometer could provide the molecular weight of the compound. The highest value of the mass per unit charge peak is mostly the molecular ion peak. The most abundant spectrum gives rise to the highest peak. The computer connected to the GC/MS contains a library of different species with their molecular masses. The masses of the particles from the GC/MS are compared with those in the library to find the highest probable match. The strength of the curve has a greatest relationship with the mass of the particle. The following calculation is used to obtain the m/z:

$$F_m = F_c \quad (2.17)$$

$$zvB = \frac{mv^2}{r} \quad (2.18)$$

$$zB = \frac{mv}{r} \quad (2.19)$$

$$r = \frac{mv}{zB} \quad (2.20)$$

Where,

r= radius of curvature

m= mass of the particle

v=velocity of the particle

z= charge of the particle

B= magnitude of magnetic field

So the radius of the curvature of the particle is directly proportional with the mass and inversely proportional to the charge, then we have

$$\frac{m}{z} \quad (2.21)$$

2.17.2 Gas Chromatography /Mass Spectrometry Analysis of Crude Oil Fractions

The Gas Chromatography/Mass Spectrometry is a method of identifying different components found in a compound using the combined gas chromatography technology and mass spectrometry technology. In the mass spectrometry, the m/z is the independent variable on the abscissa and the relative abundance is on the ordinate.

2.17.3 Fourier Transform Infrared Spectroscopy (FTIR)

Fourier transform infrared spectroscopy is a technique used to analyse data by obtaining an infrared spectrum of absorption or transmittance of an organic or inorganic compound in any state of matter. Generally, in the IR spectrometer, a splitter divides the infrared light traveling through the machine. Part of the light travels to the stationery mirror and part also travels to a moving mirror. The lights bounce back to converge at the splitter. The infrared light then goes through the sample placed in the machine. A particular interference is created based on the position of the moving mirror at the time when the light bounced on. As the light goes through the sample, the molecules of the sample absorb some of the photons, and some are transmitted through the sample depending on the nature of that particular sample. Furthermore, as the sample goes through the Interferometer and hit the detector in the instrument, particular wavelength of the light is produced. The computer connected to the spectrometer uses the waves to produce a spectrum by employing Fourier transform technique. In the FTIR spectrum, the wavenumbers are on the abscissa and the percent transmittances are on the ordinate. The FTIR spectrum is demarcated in two major regions, namely, the functional group region and the fingerprint region.

The functional group region extend from 2500 wavenumbers to the wavenumber above the 2500 wavenumber. The fingerprint region starts from 2500 wavenumber and extends below 2500 wavenumber. The FTIR spectrum is further divided into smaller sections. The Single bonds start from 1500 cm-1and extends to the wavenumbers below that. The Double bonds spans from 2000 cm-1 and ends at 1500 cm-1. Triple bonds start from 2500 cm-1 and end at 2000 cm-1. The Csp3– H bonds and Csp2-H bonds start from 3000 cm-1 and ends at 2500 cm-1. Above 3000 cm-1 are the single bonds with hydrogen such as C-H, O-H, etc. It should be noted that the wavenumbers provided above are just base values.

2.18 Desalting and Desulphurisation Reagents

This section reviews the reagents used for the desalting and the desulphurisation of the crude oils. Table 2.4 Show the parameters of the oxidative reagents

Table 2.4 Parameters of the Oxidative Reagents

Physical Parameter	**Acetic Acid**	**Hydrogen Peroxide**
Chemical formula	$C_2H_4O_2$	H_2O_2
Molar weight	60.052 g/mol	34.0147 g/mol
Melting Point	16.6 ^oC	- 0.43 ^oC
Boiling Point	117.9 ^oC	150.2 ^oC
Flash Point	40 ^oC	Non flammable
Specific Gravity	1.049 g/cc	1.4 (90 %), 1.3 (70 %)

2.18.1 Acetic Acid and Hydrogen Peroxide

Acetic acid is also known as ethanoic acid, vinegar acid, methane carboxylic acid, ethanoic acid. It is a byproduct of fermentation. Acetic acid can irritate the skin, the eye and the mucous membrane. It can produce irritation of the nose, eyes, and the throat if one is exposed to its vapor at about 10 parts per million (ppm) for prolonged period. If one is exposed to its vapor at 100 ppm, there is a possibility of the damage to the lungs, eyes, and skin. At the exposure to its vapor at 1000 ppm can cause marked irritation of the eyes nose, and upper respiratory tract and this can cause immediate danger to life or health. Because of the above mentioned effects that could occur if the researcher had been exposed to the vapor of acetic acid, the researcher wore nose mask, a pair of goggles, and hand gloves for protection. Additionally, the researcher avoided exposing himself to the acetic acid vapor for about 8 hours to avoid sustaining health problems. Eight hours is the time-weighted average set by the Occupational Safety and Health Administration for one to avoid exposure to the 10-ppm vapor of acetic acid. The acetic acid oxidizes the sulfur containing compounds in the crude oil such as thiophenes (2-methylthiophene, 3-methlythiophene, 2, 4 dimethyl thiophene, benzothiophene and 2-methylbenzothiophene), thiophene derivatives, dibenzothiophene derivatives. Hydrogen Peroxide was used as an additional oxidizing agent in the desulfurization process. Hydrogen Peroxide is an anticeptic used to prevent infection. Sometimes, it is used as mouthwash to assist in the removal of mucus or to relieve mouth irritations. It releases oxygen at the area it is introduced. Because of its oxidative characteristic it is used as an oxidant in this research.

2.18.2 Akpeteshie

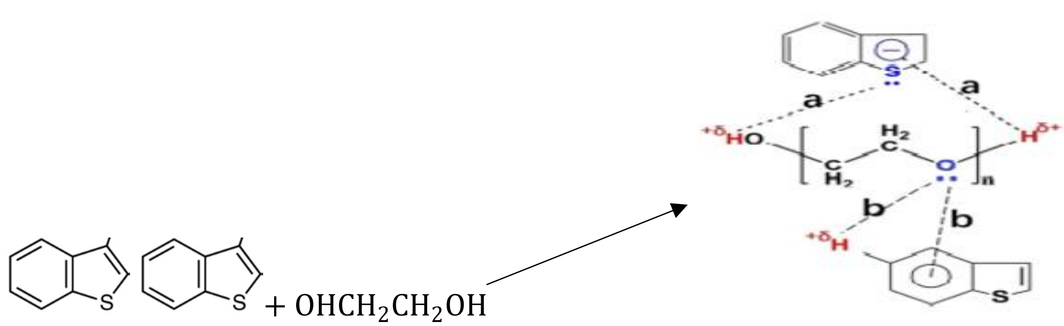
Akpeteshie is an alcoholic beverage mostly consumed in the sub-Saharan Africa. It is manufactured locally within this region. In Ghana, the manufactures of the Akpeteshie use palm wine or in some cases sugar to manufacture this beverage. The akpeteshie that was used for the demulsification step in the desalting process and the extraction step in the desulphurisation step was manufactured using palm wine. The Akpeteshie used in this research has the properties shown in Table 2.5.

Table 2.5 Parameters of the Extractive Reagent

Akpeteshie	
Chemical Formula	CH_3CH_2OH
Alcoholic content	68 %
Total sugar	5.2
Tritrable acidity as acetic acid	0.216
pH	3.1
Specific gravity	0.93

In the extraction step, the Akpetshie containing predominantly ethanol is dehydrated in the presence of the acetic acid to form ethylene (Tagba, et al, 2017; Efeovbokhan et al., 2017, Idoneje et al., 2012; Adakporia, 2021). Then the ethylene is oxidised in the presence of the oxidising agent (hydrogen peroxide) to form the ethylene glycol. Using benzothiophene as an example, the partial positive end of one of the hydroxide groups in the ethylene glycol interacts with the negative molecules in one benzothiophene. The negative end of the hydroxide group in the ethylene glycol bonds with the positive ends of another benzothiophene. The complex then enters into the aqueous phase with velocity in accordance with the Stokes equation. Then the crude oil and the water are separated.

$$CH_3CH_2OH + CH_3COOH \rightarrow C_2H_4 + H_2O_2 \rightarrow OHCH_2CH_2OH$$



CHAPTER 3

METHODS USED

This chapter focuses on the materials and methods used, the equipment, and the facilities used in the distillation of the spilled crude oil containing additional oleophobic and oleophillic impurities. The methods of data acquisition and the tools used for the analysis are also presented in this chapter. The research contains various parts such as desalting, desulphurisation, the design of the distillation column, and the distillation of the crude oil that needed to be tackled differently before they are integrated.

3.1 Research Design

This section presents the design of the research after the formulation of the main and the specific objectives.

3.1.1 Electrometric Method of Salt in Crude Determination

The electrometric method of finding the quantity of salt in the crude oils was adopted. The Stanhope-Seta salt in crude analyser was used. This instrument was used because its advantages over other salt analysing instruments. Some of the advantages include prior calibration by the manufacturer before it is sent to the market, and the display of the measured salt concentration in g/m^3 or $lbs/10^3$ bbl without mixing salt calibration standards (Anon, 2014). Other advantage is the fastness of the testing time which is less than half an hour using this instrument.

3.1.2 Chemical Desalting Method

Some crude oil was heated. Hot water was added to the crude oil. The mixture was stirred and allowed to sit. Then Akpeteshie was added to the mixture to demulsify it. Then the crude oil was separated from the mixture. The desalted crude oil was taken to the Intertek Laboratory for salt analysis.

3.1.3 Crude Oil in Salt Water

Crude oil had to be poured into some unrefined natural salt mixed with water to assess how much salt the crude could pick from it. The salt content had to be compared with how much salt the crude picked from the seawater. The concentration of the salt solution was 41.67 g/L.

3.1.4 Energy Dispersive X-Ray Fluorescence Spectrometry Method

The energy dispersive x-ray fluorescence spectrometry method selected to quantify the concentration of the sulphur in the crude oil used ASTM D4294-standard test. The practical limit of quantification of this technique is 3 mg/kg. In this design method, 2 hrs was chosen as the time for the instrument to condition when turned on before the analysis was started.

- The sample and sample cups had to be prepared using poly-M film for both primary and secondary (safety) windows/cups.
- Each sample needed to be measured twice using two different and freshly prepared sample cups and using new portions of sample.
- The sample cups had to be filled with the samples to be measured to the level mark of the cup capacity (approx. 13mL) immediately prior to measurement so that the potential for cup leakage, sagging of the cup window or sample evaporation could be minimized.
- Air bubbles had to be eradicated from between the cup window and the liquid sample. Leakages and sagging of the cup window needed to be checked just before placing the sample cup on the secondary window on the Twin-X measurement tray.
- The sample to be analyzed needed to be labeled before the appropriate method range selected for the analysis of the sample. The details needed to be confirmed before clicking the accept button.
- The start button had to be pushed to commence the analysis.
- The sample cup had to be removed from the tray and safety window checked immediately after the measurement.
- The result had to be rejected if there were any evidence of sample leakage. If there were, then the measurement would be repeated using a fresh cup and a new safety window.
- After the completion of the analysis, the result had to be recorded as the sulphur concentration of the measured sample.
- The instrument needed calibration using three main calibration methods before the sulphur analysis. The following are the methods neede to be used: For the ultra-low sulphur (sulphur in the range 3 to 150 mg/kg - average reading needed to be taken after running duplicate samples simultaneously.

- For medium sulphur (sulphur in the range 0.015 to 0.5 % m/m) – one reading needed to be taking. And for high sulphur (sulphur in the range 0.5 to 5 % m/m) – only one reading was needed.

3.1.5 Oxidative Extractive Desulphurisation Method

In the design of the desulphurisation method, oxidative extractive method was adopted. This method was chosen because of its ability to oxidise both aliphatic and aromatic sulphur containing compounds. The desulphurisation method used two distinct steps.The steps are oxidative and extractive. In the oxidative step, acetic acid and hydrogen peroxide were selected to be the oxidising agents. In the extractive step, Akpeteshie was used. The mix ratio chosen for the initial mixture was 1000 mL (crude oil): 100 mL (CH_3COOH):100 mL (H_2O_2): 100 mL (Akpeteshie). The initial mix ratio was chosen arbitrarily as the initial trial. Then the mix ratio of the second trial mixture was chosen as 1000 mL (crude oil): 200 mL (CH_3COOH):200 mL (H_2O_2): 200 mL (Akpeteshie).

3.1.6 Design of Distillation Column

The distillation column was designed in Ghana by the researcher. In this design, the following steps were taken into consideration: vapour liquid equilibrium temperatures, column operating objectives, operating pressure, diameter and height of column. Furthermore, The vapourisation temperatures of expected constituents in the crude oil were noted. Table 3.1 shows the constituents and the corresponding standard boiling temperatures of the crude.

The Fenske equation was considered because it simplifies the calculations used to obtain the minimum number of stages needed for the design of the multi-component distillation column

$$N + 1 = \frac{\log\left\{\left(\frac{x_{Lk,D}}{x_{Hk,D}}\right)\left(\frac{x_{Hk,W}}{x_{Lk,W}}\right)\right\}}{\log(\alpha_{Lk,W,Hk})} \tag{3.1}$$

$$\alpha_{Lk,Hk} = \sqrt{\left(\frac{K_{Lk,D}}{K_{Hk,D}}\right)\left(\frac{K_{Lk,w}}{K_{Hk,W}}\right)} \tag{3.2}$$

N_{min} : Minimum number of theoretical stages

X_{LK}: Light Key component molar fraction

X_{Hk}: Heavy key component molar fraction

$\alpha_{Lk,Hk}$: Average relative volatility of light key component to heavy key component

K_{Lk}: Light key component vapour –liquid equilibrium constant

K_{Hk}: Heavy key component vapour –liquid equilibrium constant

Subscript, D: Distillate (D)

Subscript, W: Bottoms (W)

(Fenske, 1932).

The Underwoood equation was chosen for the calculation of the minimum reflux ratio because of its simplicity (Taguchi, 2010). The short-cut method was adopted to design the semi-batch distillation column (Narvaez-Garcia et al., 2013). This method used constant reflux ratio which was typically the characteristic of the distillation column used. Burner containing palm kernel shells was selected to supply heat to the distillation column because the cost of the burner using charcoal was cheaper than the cost of burner using liquefied petroleum gas (LPG). Table 3.2 provides the dimensions used to design the distillation column. The column was constructed in Tarkwa using steel, pump with a horse power of 1 Btu, on/off valves. Steel was used to protect the column against high temperature sulfidation and against attacks by naphthenic acids if available in the fractions to avoid corrosion. Furthermore, steel was used to avoid scaling that can result in plugging the distillation column tubes (Anon., 2020).

$$R_{min} = \sum_i \left(\frac{\alpha_{1i} x_{iD}}{K - \alpha_{1i}}\right) \qquad (3.3)$$

$$\sum \left(\frac{\alpha_{1i} x_{iF}}{K - \alpha_{1i}}\right) = -q \qquad (3.4)$$

$$k = \left(1 + \frac{1}{R}\right) k_{1\infty} \qquad (3.5)$$

R_{min} = minimum reflux ratio

K= Determined from the reflux ratio and the equilibrium xonstant $K_{1\infty}$

X_{iF} = Feed mole fraction of component i

X_{iD} = Distillate mole fraction of component i

α_{1i} = Relative volatility of component 1 (highest volatile component to component i

q = Preheated feed F_{liq}/F_{Total}

3.1.7 Design of Data Acquisition and Analysis

Gas chromatography/mass spectrometry and Fourier Transform Infrared Spectroscopy (FTIR) were selected to analyse the samples. The FTIR is a technique used to analyses data by obtaining an infrared spectrum of absorption or transmittance of an organic or inorganic compound in any state of matter. The selected GC-MS instrument type uses PerkinElmer GC Clarus 580 Gas Chromatograph interfaced to a Mass Spectrometer PerkinElmer (Clarus SQ 8 S) equipped with ZB-5HTMS (5% diphenyl/95% dimethyl poly siloxane) fused a capillary column (30 × 0.25 μm ID × 0.25 μm DF). The instrument identifies different components found in a compound using the combined gas chromatography technology and mass spectrometry technology. Figure 3.1 shows the block diagram of the research design.

3.1.8 Specific Energy Assessment

Equations 3.6 and 3.7 were chosen to assess the energy used to fractionate the crude oil fractions:

Energy (Q) required to raise the temperature of the crude fraction to its respective boiling points, $Q = m \times C_p \times \Delta T$ (3.6)

Where,

m = mass of crude fraction

Cp = heat capacity of the crude fraction at constant pressure

ΔT = Boiling point of the fraction – 25 ^oC

The enthalpy of vapourisation of the crude fraction, $L\left(\frac{Btu}{lb}\right) = \frac{1}{d}(110.9 - 0.09t)$ (3.7)

Where,

d = specific gravity of crude fraction

t = vapourisation temperature in ^{o}F

Therefore, specific energy is $E_{sp} = \frac{Q + L}{m}$ (3.8)

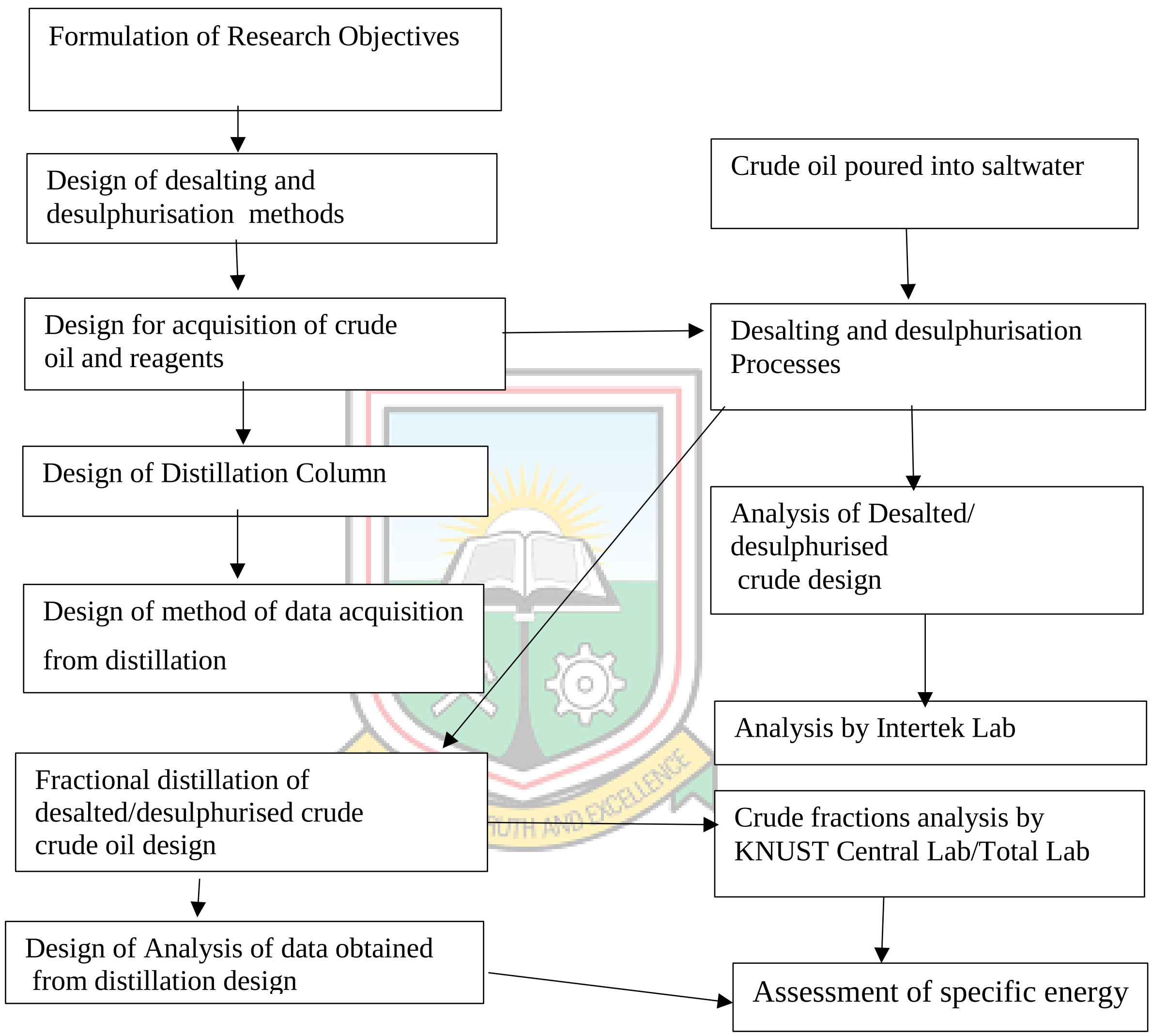


Figure 3.1 Block Diagram of the Research Design

Table 3.1 Crude Oil Constituents and their Standard Boiling Points

Constituent	Gasoline	Naphtha	Kerosene	Diesel oil	Fuel oil	Grease or Wax	Bitumen
Boiling Temperature (°C)	40	110	180	260	310	340	367

3.1.7 Variables used in the Research

The following variables were use in the research:

Independent variables

- The conncentration of the salt in the crude oils before desalting measured in mg/kg or g/m^3
- The concentration of the sulphur in the crude oils before desulphurisation measured in parts per million (ppm) or percentage of weight (w %)
- The specific energy needed to distill the constituents of the 2 L crude oil.
- The density of the crude oils
- The boiling point of the constituents of the crude oil

Manipulated Variables

- The amount of reagents used as demulsifier to desalt the crude oils measured in milliliters
- The temperature of hot water used in desalting the hot water measured in degrees celcius
- The quantity of acetic acid and hydrogen peroxide used in the oxidation step in the desulphurisation of the spilled crude oil measured in milliliters.
- The quantity of Akpeteshie used in the extraction step in the desulphurisation of the crude oil measured in milliliters
- Temperature of the heat applied to the distillation column measured in degree celcius

Response Variables (Dependent)

- The concentration of salt in the crude oil after desalting
- The concentration of sulphur in the crude oil after desulphurisation

- The volumes of the each distillate obtained from the fractionation of the 2 L of crude oil measured in milliliters.
- The percentage of each fraction obtained from the distillation of the 2 L of crude oil
- The energy needed to distill each constituent in the 2 L of the crude oil measured in Joules

3.1.8 Preparation of Laboratory Spilled Crude Oil Sample

Although crude oil accidentally spilled in the ocean was not available during the period of the research, it was necessary to adopt an innovative method to obtain a spilled crude oil.

3.1.9 Materials and Equipment Used

Table 3.2 presents the materials and equipment used in the study.

Table 3.2 Materials and Equipment Used

Seawater	Bottles	Graduated pipet
Crude oil	Test Beaker	Water heater
Basin	Pipet, 10 ml	Water heating bow
Funnel	Cylinders, 100 ml	Thermocouple
Wooden stirrer	Volumetric pipet	Measuring bottle
Sponge	Volumetric flask	500 mL. 750 mL, 1500 mL bottles
Glove	Nose mask	Timer
Stirring rod	Funnel	Sponge
Fresh water	Akpeteshie	Xylene
Type II grade of reagent water		

3.1.10 Spilled Crude Oil Sample Preparation

Seawater was fetched from the beach and conveyed to the Laboratory to prepare spilled crude oil. The picture in Figure 3.1 shows the beach at New Amanfrom, a suburb of Takoradi in the Western Region of Ghana where seawater was fetched and conveyed to the laboratory.

Figure 3.1 Seawater Conveyed from the Sea

The following method was use to prepare the spilled crude oil:

- Some seawater was poured into a basin
- Some crude oil was poured into the seawater in the basin as depicted in Figure 3.2
- The mixture of the seawater and the crude oil was stirred using the wooding stirrer.
- The mixture was allowed to sit for about 48 hours.
- The crude oil was cleaned from the surface of the seawater using the sponge shown in Figure 3.3 after 48 hrs and poured into a bottle.
- The cleaned spilled crude oil was taken to Intertek Laboratory at Takoradi Harbour for analysis of salt and sulphur contents

Figure 3.2 Crude Oil Poured into the Seawater

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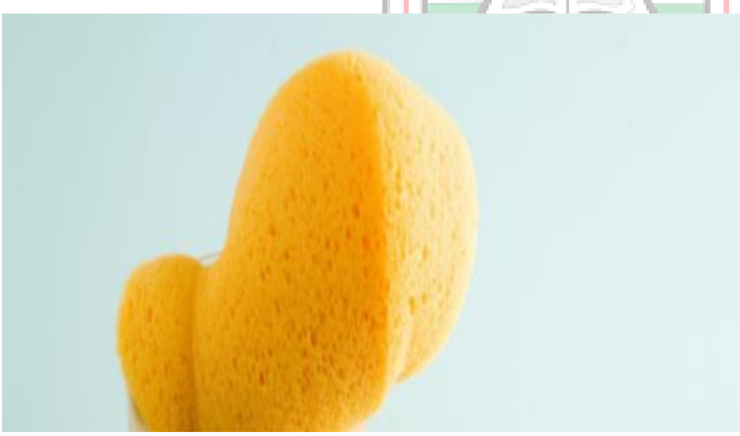


Figure 3.3 Sponge Used in Cleaning the Crude Oil

3.2 Electrometric Method of Salt Concentration Determination

The method used to determine the concentration of salt in this research followed the standard established in accordance with the internationally recognised principles on standardisation established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organisation Technical Barriers to

Trade (TBT) Committee. The test method measured the conductivity due to the presence of the inorganic chlorides, and other conductive material, in the crude oil. The salts measured included sodium chloride, calcium chloride, and magnesium chloride. Desalting of crude oil premiers the processes followed in refining crude oil. But before embarking on this important step, the salt contents in the spilled crude oil and the unspilled crude oil was determined. The analysis of the salt contents was done to ensure the necessity of desalting the crude oils coupled with ascertaining whether the method employed in desalting was effective.

3.2.1 Salt in Crude Determination Procedure

The following procedure was used to analyse the salt contents in both the spilled crude oil and the unspilled crude oil at the Intertek laboratory in Takoradi:

- The analyser was switched on
- Test mode was selected
- The 0 ^{o}C or lbs./1000 bbl was selected for the lower display
- The sensor assembly was cleaned.
- The sample was prepared as follows:

- Fifteen milliliters of xylene was added into the dry 100-mL graduated glass-stoppered mixing cylinder.
- Using a 10-mL pipette (total delivery), 10 mL of crude oil sample was delivered into the 100-mL graduated, glass-stoppered cylinder.
- The 10-mL pipette was rinsed using xylene until it was completely free of oil.
- The mixture in the 100-mL glass-stoppered graduated cylinder was diluted to 50 mL with xylene.
- The 100-mL glass-stoppered cylinder was stoppered and shook vigorously for approximately 60 s.
- The mixture in the glass-stoppered graduated cylinder was diluted again to 100 mL with mixed alcohol solvent,
- Then the mixture was shook for approximately 30 s.
- Then the solution was allowed to stand for approximately 5 min.

- The 100-mL beaker was placed into the beaker holder
- The sample was poured into the beaker until it was leveled the top of the beaker holder.
- The sensor assembly was lifted from the sensor assembly holder and placed into the top of the beaker. It was ensured that the plates of the sensor assembly was covered by the sample.
- Recordings of the salt concentration was made after the upper display was stabilised.

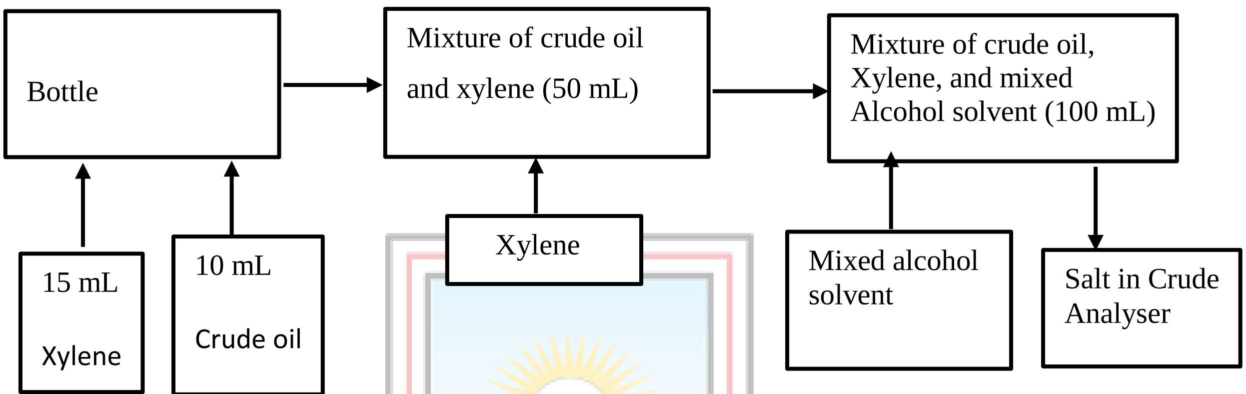


Figure 3.21 Block Diagram of Salt in Crude Analysis

3.3 Chemical Desalting Process

Before the crude oil was placed in the fractionation column for separation, preliminary purifications were performed. Purifications such as desalting and desulfurisation were the major tasks needed to be performed. The first purification process performed was desalting. Desalting is the removal of the salt content from the crude oil. Chemical desalting was chosen among the various methods of desalting because of its feasibility

3.3.3 Procedure Followed in the Desalting

- Two thousand, five hundred and twenty five milliliters of clean water was boiled to 120 ^{o}C as shown in Figue 3.22.
- The boiled water was poured into a basin
- One liter of crude oil boiled to 110 ^{o}C was added to the boiled water in the basin

- The mixture of the crude oil and the boiled water was stirred vigorously for about 3 minutes as shown in Figure 3.23.
- The mixture was allowed to sit for about 15 minutes
- Another two thousand, two hundred and twenty five milliliters of clean water was boiled to 120 ^{o}C
- The boiled water was added to the mixture and stirred for another 3 minutes
- The mixture was allowed to stand for about 2.5 hours
- The crude oil was removed from the surface of the water using the sponge (foam)
- The spilled crude oil was poured into the 1.5 L bottle
- One hundred milliliters of akpeteshie was measured and poured into the 1.5 L bottle containing the removed spilled crude oil.
- The mixture of the crude oil and the akpeteshie in the bottle was shaken vigorously for perfect mixing for 4 minutes
- Another 2.5 L of clean water was boiled to about 110 ^{o}C.
- The boiled water was poured into a clean basin
- The mixture of the crude oil and the apketeshie was poured into the boiled water.
- The mixture of the water-akpeteshie-crude oil was stirred vigorously for 5 minutes.
- The crude oil was cleaned from the surface of the water using sponge.
- The desalted crude oil was tested for the level of salt using the Salt in Crude Analyzer
- The same desalting process was repeated four more times but the demulsifier was increased in each run.
- The steps presented above were repeated for the analysis of both the spilled crude oil and the raw crude oil (unspilled crude oil)

Figure 3.22 Water heated to mix with crude oil

Figure 3.23 The mixture of the hot water and crude oil stirred in a basin

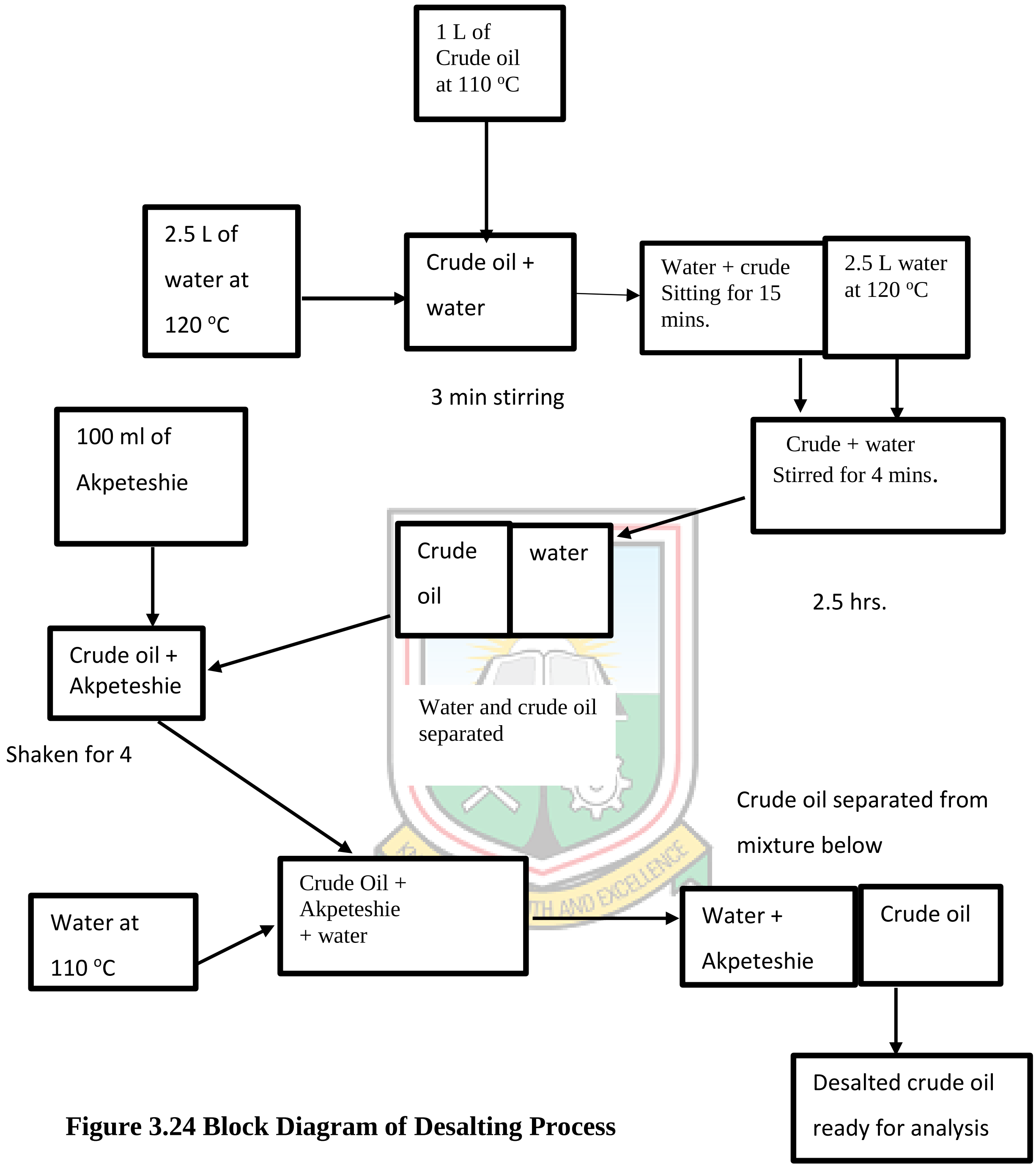


Figure 3.24 Block Diagram of Desalting Process

3.4 Desulphurisation Processes

This section shows the various steps pursued with respect to the desulphurisation process. After desalting the crude oil, the researcher employed oxidative extractive desulphurisation method to remove the sulphur from the crude because of its ability to remove both aromatic and aliphatic sulphur containing compounds. The sulphur contents in the spilled and the unspilled crude oil were determined before desuphurising . This informed the researcher the effectiveness of the method chosen to desulfurise the crude oil.

3.4.1 Determination of Sulphur Content in the Crude Oil

The following procedure was used to determine the sulphur content of the spilled and the usnpilled crude oil:

- The samples and cups were prepared in a clean environment, away from any instrument (to avoid spillage on the instrument) and anyway from any samples or standards containing high concentration of sulfur (>1%) to avoid potential cross contamination. It was ensured that dust was kept on absolute minimum in the working area.
- It was ensured that clean cups and sample film were stored in a clean, dust –free environment when not in use. The box containing the sample cups was kept closed, and the film was stored in a plastic bag. The disposable cups used were stored in a clean, closed package.
- To minimise contamination, films were not fitted on sample cups and safety windows in advance. Cups and safety windows were stored in a clean, dust-free and closed environment.
- When assembling the cups, part of the film that formed the cup windows was not touched. The window was made taut, freed from winkles, and refrained from contacting anything when placing the sample cup onto the sample rack provided. A new piece of film would have been fitted if any contaminant such as spot of oil, dust, hair, etc., were noticed on the film.
- A newly prepared safety window was used for every sample to avoid any potential cross- contamination.
- A disposable pipette was used to transfer the sample to the cup (this avoided spillages and possible contamination of the outer parts of the cup).
- Note: Latex and nitrile gloves contain high levels of sulfur. PVC gloves contain high levels of chlorine. They can potentially contaminate samples and cups. Because of that, gloves were avoided in the preparation of the samples.

- The instrument was switched on from the mains.
- The He gas supply was opened to ensure that the pressure of the cylinder range was between 0 – 5 bar and that of the instrument was 5 psi.
- The instrument was allowed to condition for 2hrs before the analysis was started.
- The sample and sample cups were prepared as detailed above using poly-M film for both primary and secondary (safety) windows/cups.
- The secondary (safety) window was placed in the tray of the equipment.
- Each sample was measured twice using two different and freshly prepared sample cups and using new portions of sample.
- The cup was filled with the sample to be measured to the level mark of the cup capacity (approx. 13mL) immediately prior to measurement. This minimised the potential for cup leakage, sagging of the cup window or sample evaporation.
- It was ensured that no air bubbles were present between the cup window and the liquid sample.
- Leakages and sagging of the cup window were checked just before placing the sample cup on the secondary window on the Twin-X measurement tray
- The sample to be analysed was labeled and the appropriate method and range were selected for the analysis of the sample.
- The details were confirmed and accept button was clicked.
- The start button was clicked to commence the analysis.
- The sample cup was removed from the tray and checks were made on the safety window(s) immediately after the measurement. The result would have been rejected if there were any evidence of sample leakage. If there were, then the measurement would have been repeated using a fresh cup and a new safety window.
- After the completion of the analysis, the result was recorded as the sulphur concentration of the measured sample.
- Poly-M film was used for Sulphur content analysis,

  Note:

➢ The X-Supreme Oxford instrument could be used in analyzing a wide range of product including petroleum and petroleum products among others according to a defined calibration method on the instrument. Because the contents of sulfur in both the spilled crude oil and the unspilled crude oils were not known, it was necessary to employ different calibration methods.

- ➢ The instrument was calibrated using three (3) main calibration methods before the sulphur analysis. The following are the methods used:

- Ultra-low sulphur (sulphur in the range 3 to 150 mg/kg - Average reading was taking after running duplicate samples simultaneously)
- Medium sulphur (sulphur in the range 0.015 to 0.5 % m/m) – one reading was taking
- High sulphur (sulphur in the range 0.5 to 5 % m/m) – one reading was taking

3.4.2 Oxidative Extractive Desulphurisation Process

Oxidative and extractive processes were used in the desulphurisation method. The following are the summary of the processes:

- The desalted crude oil was poured into a 1.5 L bottle
- One hundred ml of acetic acid was added to the crude oil
- The mixture of the acetic acid and the crude oil was shaken vigorously for about 4 minutes
- One milliliters of hydrogen peroxide was added to the mixture of crude oil and the acetic acid
- The bottle containing the acetic acid, the crude oil, and the hydrogen peroxide was shaken for about 4 minutes.
- The mixture was allowed to sit for about 30 minutes before the commencement of the extraction process

Equation 3.1 shows the mechanism of the oxidation step in the desulphurisation process. In the first instance of the mechanism, the acetic acid bonds with the sulphur containing compounds. Then the hydroxide ion produced by the dissociation of the hydrogen peroxide bonds with the compound consisting of the acetic acid and the sulphur containing hydrocarbons. Finally,the hydrogen iron from the hydroxide ion, and the acetic acid are released from the hydrocarbon/hydroxide/acetic acid complex producing hydronium, acetic acid, and oxidised hydrocarbon.

$$RR'S + HO\text{-}OH + CH_3COOH \rightarrow R'RS\ H\text{-}O\text{-}OH \rightarrow R'RS\ldots OH + H_2O \rightarrow RR'S\text{–}O + H_2H + CH_3COOH$$

$$\qquad\qquad CH_3COO\text{-}H \qquad CH_3COOH \qquad\qquad (3.1)$$

Akpeteshie was used as an extractant to remove the oxidised sulphur containing compounds from the crude oil.

- One hundred milliliters of akpeteshie was added to the bottle containing the mixture of oxidized crude oil, acetic acid, and hydronium.
- The mixture was shaken for about 2 minutes
- The mixture was allowed to sit for about 2 hour.
- Then the mixture taken to the Intertek Laboratory for the testing of sulphur content
- After the analyses of the sulphur content in the crude oil, four more desulphurisation proceses were conducted following the same processes but with increased amount of the reagents.

3.5 Determination of Salt in Crude Oil Poured in Saltwater

- Some measured quantity of the unrefined natural salt was poured into a clean water.
- Some measured Crude oil (1 L) was added to the salt water and allowed to stand for 2 days
- The crude oil was cleaned from the surface of the saltwater
- The crude was taken to the laboratory for the analysis of sulphur and salt contents.

3.6 Distillation of the Spilled Crude Oil

Fractional distillation process is based on the principle that different liquid component boils at different temperature. The mixture is heated to a temperature at which one or two components of the mixture will vaporize. Then the separation of the components from a mixture is repeated by distillations and condensations. Crude oil contains different components so it was reasonable to employ fractional distillation to separate the components based on the above-mentioned principle. Fractional distillation is important when conducting the processes of separating liquid mixtures. Vivoni (2017) put it simple that whenever you have to separate one liquid from others, hence comes fractional distillation.

The distillation system used for fractionating the crude oil was designed by the researcher. Various parts of the distillation system were put together locally by the researcher with the assistance of welders in Tarkwa, Western Region of Ghana. The Fractional Crude Oil Distillation System was uniquely designed primarily for distilling relatively smaller amount of crude oil samples of about 1.609 m^3. The units of the distillation system are as follows:

- Reactor- it is used to hold the crude oil for boiling.
- Distillation Tower- inside the tower are plates with holes that allows the flow of down coming liquids and upward flowing vapour. The plates also serve as additional places of contact between the vapour and the liquid
- Pipes - One inches diameter metal pipes are connected from the top of the column to the condenser located down the column.
- Reciever-the vapour that flows through the one half inch pipe into the condenser is condensed in this column.
- Condenser - The condenser holds colder water around the receiver. The condenser has an inlet and outlet openings where water is manually injected into it through the inlet, and the excess water comes out of the condenser through the outlet. Heat is exchanged between the hot vapour that enters the receiver and the water contained in the condenser. This heat exchange allows the vapour to condense producing the desired petroleum fraction.
- Reflux Pipe – This pipe returns some of the liquid back into the distillation column to enable the achievement of the desired purity of the products
- Pump – One horse power pump is attached to the column and pumps the liquid back into the distillation column
- Valves- the valves positioned at various places in the distillation column are turned on and off when there is the need to do so.
- Burner – Burner is positioned under the tank to heat the crude oil.
- Electric Blower – The blower supplies air to the burner. It is turned on when air is needed to increase the temperature of the reactor. Conversely, it is turned off when the temperature of the reactor is exceeding a desired temperature

. Figures 3.41 and 3.42 show the labeling of the distilllation column

Figure 3.41 Ben Asante Distillation Column (BAD Column)

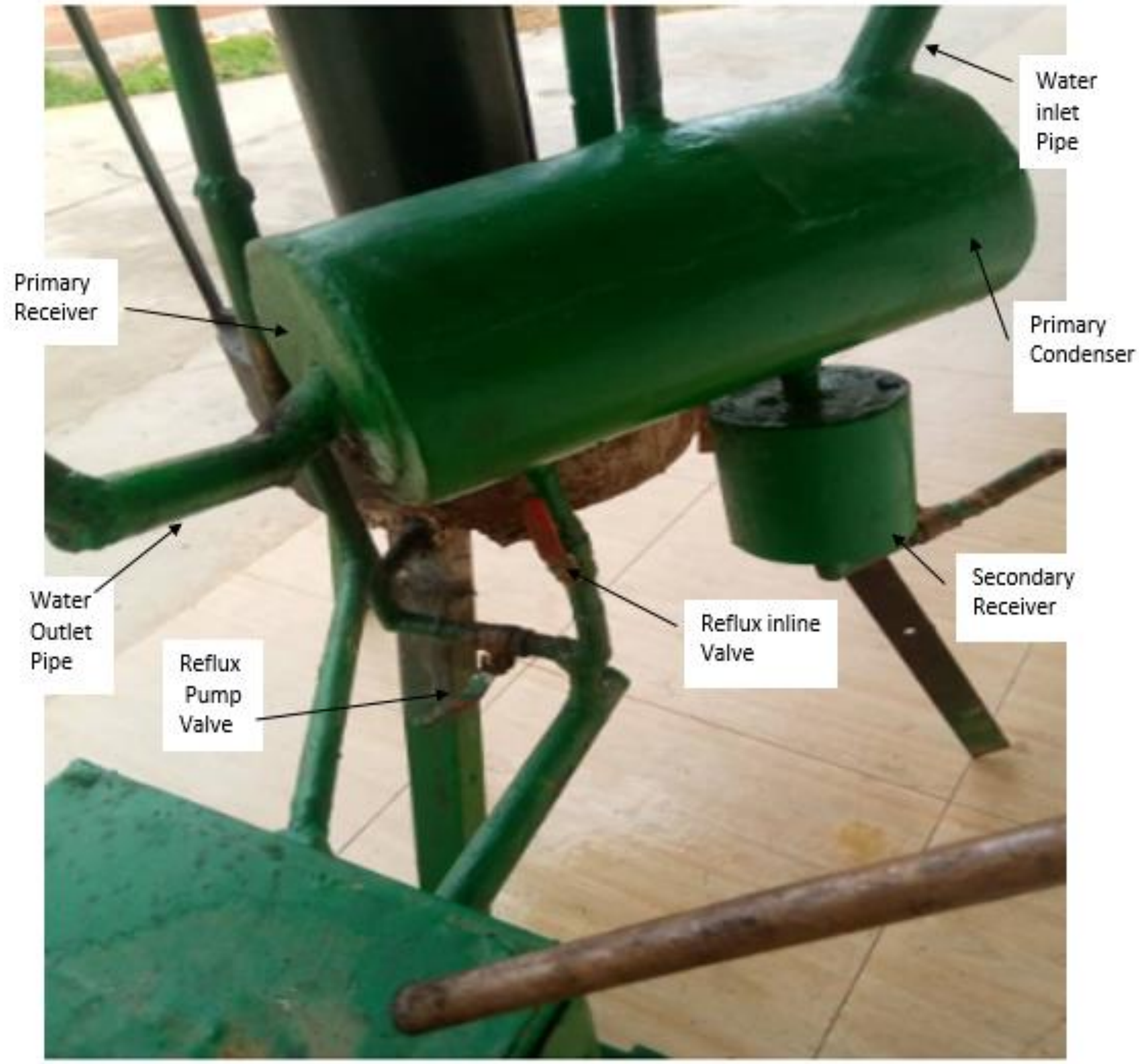


Figure 3.42 Lower segment of BAD Column

3.6.1 Distillation Processes

After desalting and desulfurisation of the laboratory formulated spilled crude oil followed the commencement of the distillation processes. The following steps were adopted to conduct the distillation of crude oil.

- The crude oil was poured into the reactor.
- Water was poured into the primary condenser
- Water was poured into a basin
- The secondary condenser was submerged into the water in the basin.
- Receptacles which were used to collect the crude oil fractions were labeled from one to ten.
- Palm kennels were poured into the burner.
- Blower was inserted into the nozzle of the burner to provide oxygen.
- The palm kennels were set aflamed by pouring some crude oil on them and applying fire.
- The initial temperatures of the burner and the reactor were recorded using the thermocouple. The inline valve in the reflux line was opened.
- The liquid pump in the reflux line was turned on.
- The inline valve in the entrained pipeline was turned off.
- The crude oil was allowed to reflux for about 30 minutes.
- The inline valve of the reflux line and the pump were closed thereon.
- The entrained valve was opened and the crude oil fractions were collected in accordance with the boiling temperatures.

  Figure 3.43 shows the boiling temperatures of the constituents of the crude oil. The boiling temperature served as a benchmark and a guide for the distillation of the spilled crude oil.

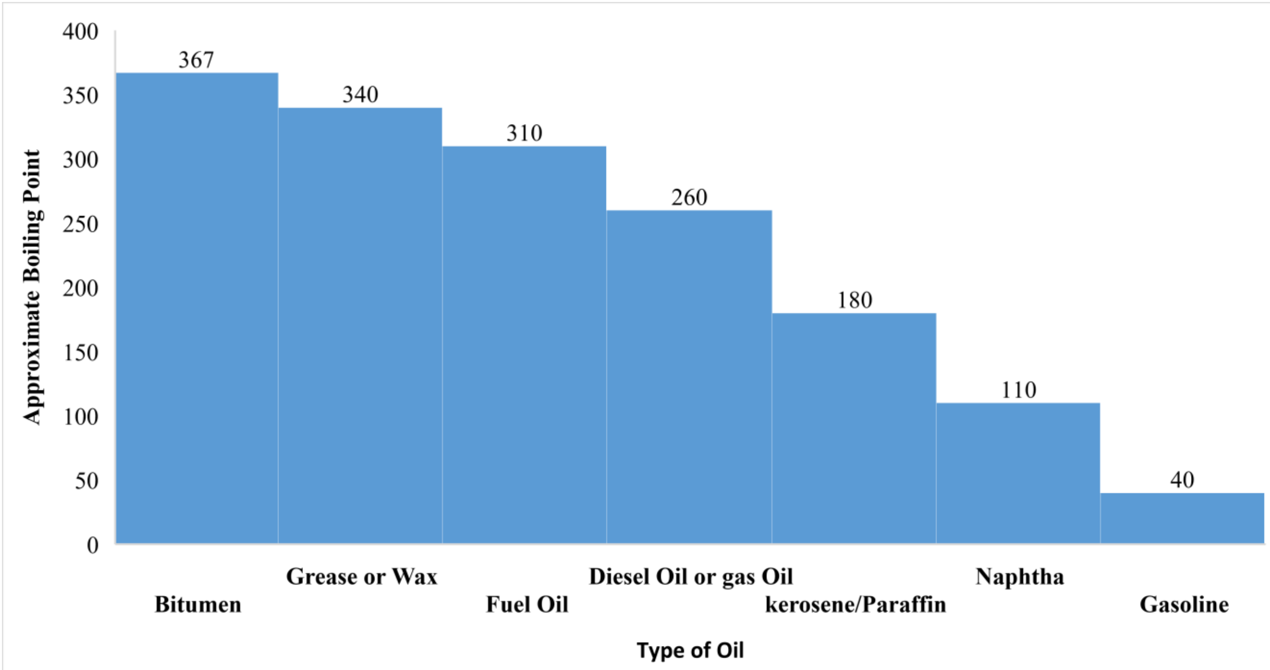


Figure 3.43 Crude Oil Constituents vrs their Approximate Boiling Temperatures

Figure 3.45 Crude Oil Fractions (Sample 0, Gasoline; Sample 1, Naphtha; Sample 2, Kerosene, Sample 3, Diesel, Sample 4, Fuel Oil; Sample 5, Bitumen)

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction to Results and Discussion

The results obtained from the processes of the desalting, desulfurisation, design of the distillation column, distillation of the crude oil poured into the seawater and cleaned from the seawater to mimic a spilled crude oil from the sea are presented and discussed below. Furthermore the results of specific energy consumed to distill the spilled crude oil fractions and the results of desalting crude oil poured into saltwater and cleaned from it are presented and discussed below.

4.2 Crude Oils Desalting

The spilled crude oil and some raw (unspilled) crude oil were taken to Intertek Laboratory, Takoradi for the determination of the salt contents in both the spilled and the unspilled crude oils before the commencement of the desalting processes. Table 4.1 shows the results obtained. According to the tests the salt in the unspilled and the spilled crude oils gave 13.2 g/m^3 and 89 g/m^3 respectively. It was prudent to find the salt contents in the crude oils before desalting so that the quantity of salt removed from the crude could be ascertained by simply computing the difference between the salt contents in the crude before and after desalting. Again, this step provided the details of the effectiveness of the desalting method.

Table 4.1 Salt in the Spilled and the Unspilled Crude Before Desalting

Type of crude oil	Density (g/cm^3)	Salt content (g/m^3)	Salt content (mg/kg)
Spilled	0.9008	89	98.8
Raw crude oil (Unspilled)	0.8719	13.2	15.14

One liter of crude oil was combined with varying amounts of Akpeteshie to assess the effects on the desalting process. The amounts of the Akpeteshie used were 100 mL, 80 mL, 60 mL, 40 mL, and 20 mL . The mix ratios of the crude oils to the Akpeteshies were 1000 mL: 100 mL, 1000 mL: 80 mL, 1000 mL: 60 mL, 1000 mL: 40 mL, and 1000 mL: 20 mL. The result of the crude oils after desalting are detailed in Table 4.2. The information obtained from the table depict that the same volumes of both the spilled and the unspilled crude oils combined with higher volumes of Akpeteshie desalted the crude better. Adding more alcohol to the crude allowed better demulsification. Furthermore, alcohol is hydrophilic so adding more alcohol to the crude oil created more bonding between the water in the crude oil that contains the salt and the alcohol for better desalting (Pereira *et al*., 2015, Igwilo et al., 2017).

Table 4.2 Salt in the Spilled and Unspilled Crude after Desalting

Volume of Akpeteshie (mL)	Spilled crude oil salt content (g/m^3)	Raw (Unspilled) crude oil salt contents (g/m^3**)**	Percent reduction of unspilled crude oil
100	32.8	9.6	27.27
80	35.5	10.1	23.48
60	39.25	10.9	17.42
40	40.2	11.5	12.88
20	51.5	12.3	6.82

Furthermore, Table 4.2 shows in percentage how much the unspilled crude oil was reduced after desalting. The calculations were done using 13.2 g/m^3 the salt found in the unspilled crude before desalting and the quantity of salts found in the unspilled crude after desalting. Different volumes of Akpeteshie were used in every run.

Table 4.3 provides the spreadsheet of the calculation of the standard error obtained as a result of desalting the unpilled crude oil. The 0.42 standard error informs that using the same parameters in the different times to conduct desalting, this is the error that has the greater chance to be encountered (Bhandari, 2022; Kenton, 2022). This small value of standard error is encouraging for the desalting method adopted.

Table 4.3 Standard Error of Unspilled Crude Oil Desalting

Volume of Akpeteshie (mL)	Raw crude oil salt content (g/m^3)	(X-mean)^2
100	9.6	1.6384
80	10.1	0.6084
60	10.9	0.0004
40	11.5	0.3844
20	12.3	2.0164
Sum	54.4	4.648
Mean	10.88	
Standard Deviation	0.9296	
Standard Error	0.42	

Figure 4.1 shows the graph of the relationship between different volumes of Akpeteshie used in the demulsification step and the amount of salt left in the crude oils after desalting. The abscissa is the volumes of the Akpeteshie and the ordinate is the quantity of salt left in the crude oils after desalting. The graph gives a negative slope indicating that with the same amount of crude oil, more quantity of Akpeteshie used as a demulsifier provided better desalting. The desalting was more effective when the demulsifier was increased.

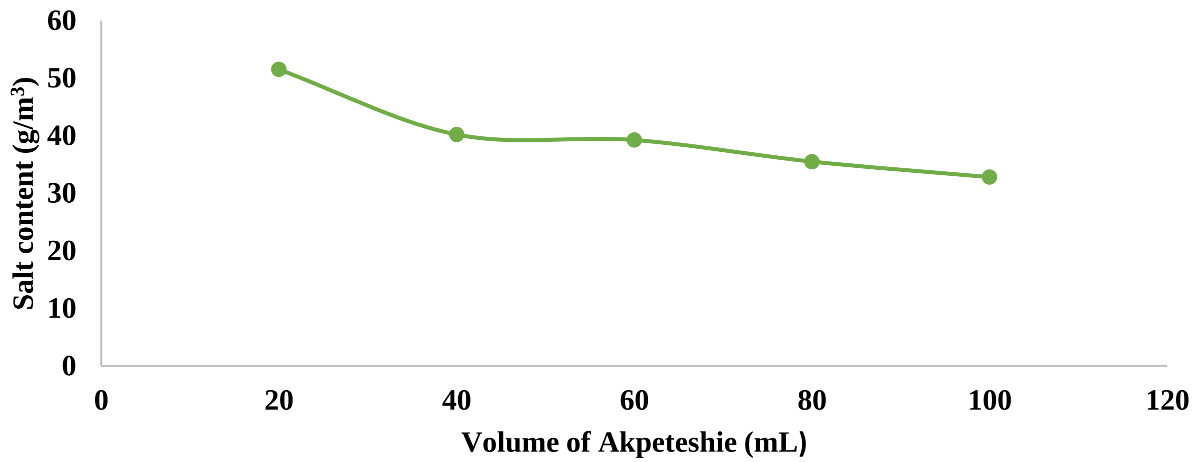


Figure 4.1 Quantity of Akpeteshie vrs Salt in Desalted Spilled Crude Oil

Table 4.4 shows in percentages the differences between the quantity of salt found in the 1000 mL of spilled crude oils before and after desalting. Different volumes of Akpeteshie were added to the same spilled crude oil for each run of the desalting processes.The values show that given the same volume of crude oil, more Akpeteshie was needed to desalt the crude oil for better results.

Table 4.4 Percent Reduction from 89 g/m3 of Salt in Spilled Crude

Volume of Akpeteshie (mL)	Desalted Spilled Crude Oil Salt Content (g/m^3)	Percentage Reduction
100	32.8	63.15
80	35.5	60.11
60	39.25	59.9
40	40.2	54.83
20	51.5	42.13

Table 4.5 gives the standard error obtained from the desalting of the spilled crude oil. The standard error of this desalting process is 18.32.This shows that the data were more spread.

Table 4.5 Standard Error of the Spilled Crude Desalting

Volume of Akpeteshie (mL)	Spilled crude oil salt content (g/m^3)	Spilled Crude (X-mean)^2
100	32.8	49.7025
80	35.5	18.9225
60	39.25	0.36
40	40.2	0.1225
20	51.5	135.7225
Sum	199.25	204.83
Mean	39.85	
Stadard Deviation	40.966	
Standard Error	18.32	

The salt analysis of the crude spilled into saltwater and the crude spilled into seawater was conducted before deasalting and after desalting. Table 4.6 shows the summary of the results. The desalting process was more effective in the crude oil poured into the seawater than it was in the saltwater. Better emulsification occurs with saltwater and crude oil mixture than seawater and crude oil mixture because of the absence of other impurities in the former mixture (Natasha *et al*., 2017). As a result, breaking the emulsion of the saltwater mixed with crude oil was more difficult than breaking the emulsion of the seawater mixed with crude oil. Thus, desalting the seawater mixed with crude oil gave better result than desalting the saltwater mixed with crude oil.

Table 4.6 Comparison of Salt Contents in Crude Oil in Saltwater and in Seawater

State	Salt in seawater (g/m^3)	Salt in plain water (g/m^3)
Before Desalting	89	117.3
After Desalting	32.8	63.6
Difference (%)	63.15	45.78

Among the five desalting experiments, 32.8 g/m^3 was the lowest amount of salt found in the desalted spilled crude oils. Using the 32.8 g/m^3 for computations yielded 63.15 % as the highest reduction of salt in the spilled crude oil. The tests of the unspilled crude oils after desalting showed that the lowest salt content left in the crude using different volumes of Akpeteshie as a demulsifier gave 9.6 g/m^3. Similarly, the calculation of the percentage difference of the salt contents in the unspilled crude oil before and after desalting gave 27.27 % as the highest reduction.

4.3 Sulphur in Crude Oils

The oxidative extractive desulphurisation of the spilled crude oil using hydrogen peroxide (H_2O_2) and acetic acid (CH_3COOH) as oxidants, and Akpeteshie as an extractant gave promising results. Before starting the desulphurisation processes, samples of unspilled and spilled crude oils were tested for sulphur. About 3530 ppm and 3000 ppm of sulphur were found in the spilled crude oil and the unspilled crude oil respectively. Table 4.8 shows the results of the sulphur in the spilled and the unspilled crude oils before desulphurisation.

The sulphur test after the first desulphurisation gave 1680 ppm and 1820 ppm with respect to the spilled and the unspilled crude oils respectively. These translated to about 52.41 % and 39.33 % reduction of sulphur in the spilled and the unspilled crude oils correspondingly. In the first desulphurisation, 100 mL of CH_3COOH and 100 mL of H_2O_2 were added to the 1000 mL of spilled and the unspilled crude oils in the oxidisation steps, then 100 mL of Akpeteshie were added to the spilled crude and the unspilled crude in the extraction steps. In the second desulphrisation, 200 mL of acetic acid, 200 mL of hydrogen peroxide, and 200 mL of

Akpeteshie were employed. The tests after the desulphurisation showed 282.4 ppm of sulphur in the spilled and 335 ppm of sulphur in the unspilled crude oils. Tables 4.7 shows the test results obtained from the first and the second desulphurisations. According to the results, doubling all the reagents of the desulphurisation processes decreased the sulphur in the crude by 1397 ppm. Also, Table 4.8 presents the overall reduction of the sulphur in the crude after conducting two consecutive desulphurisations. The sulphur in the spilled crude was reduced 92 % whereas the sulphur in the unspilled crude was reduced by 88.83 %.

4.4 Fractional distillation Column

The dimensions of the fractional distillation column utilised to distill the crude oils are presented in Appendix 14. In addition, the Engineering drawing of the fractional distillation column is presented in Appendix 14.

4.5 Spilled Crude Oil Distillates

The results obtained after distilling 2000 mL of desalted and desulphurised spilled crude is presented in Table 4.8. The highest and the lowest percentages of the distillates obtained were gasoline and diesel respectively. The following are the distillates obtained in the order of decreasing percent composition: gasoline (35.95 %) > naphtha (31.01 %) >fuel oil (20.13 %) > bitumen (10.59 %) > kerosene (1.26 %) > diesel (1.06). The distillation column designed and constructed by the researcher was used to fractionate the crude oil. Table 4.8 shows the various fractions obtained.

The reports received from Kwame Nkrumah University Central Laboratory distillates were analysed. The functional groups obtained from the Fourier Transform Infrared (FTIR) Spectroscopy analysis, the compounds found in the samples as a result of the Gas Chromatography/mass Spectroscopy (GC-MS) analysis, together with other parameters such as the colours of the fractions were used to characterise the types of various distillates in the next section.

Table 4.7 Overall Sulphur Reduction After Desulphurisations

Type of crude oil	Density (g/cm^3)	Sulphur in crude before desulphurisation (wt %)	Sulphur in crude oils before desulphurisation (ppm)	Sulphur in crude oils after first desulphurisation (wt %)	Sulphur in crude oils after second desulphurisation (wt %)	Sulphur in crude oils after second desulphurisation (ppm)	Reduction of Sulphur after first desulphurisation (%)	Overall Sulphur reduction (%)
Spilled	0.9008	0.353	3530	0.168	0.02824	282.4	52.41	92
Unspilled	0.8719	0.3	3000	0.182	0.9335	335	39.33	88.83

Table 4.8 Weight and Percent Distillates from the Spilled Crude Oil

Type	Weight (Grams)	Distillate (%)
Gasoline	1176.41	35.95
Diesel	34.8	1.06
Kerosene	41.25	1.26
Naphtha	1014.81	31.01
Fuel Oil	658.45	20.13
Bitumen	346.41	10.59

4.5.1 Characterisation of the Crude Oil

The sample of the crude oil obtained from the Tema Oil Refinery was analysed using both FTIR Spectroscopy and GC-MS. The components found in the sample are shown in Table 4.9. Also, Table 4.10 shows the various functional groups found in the sample. Figure 4.2 shows the FTIR spectrum of the crude oil sample.

FTIR Spectrum of Crude Oil

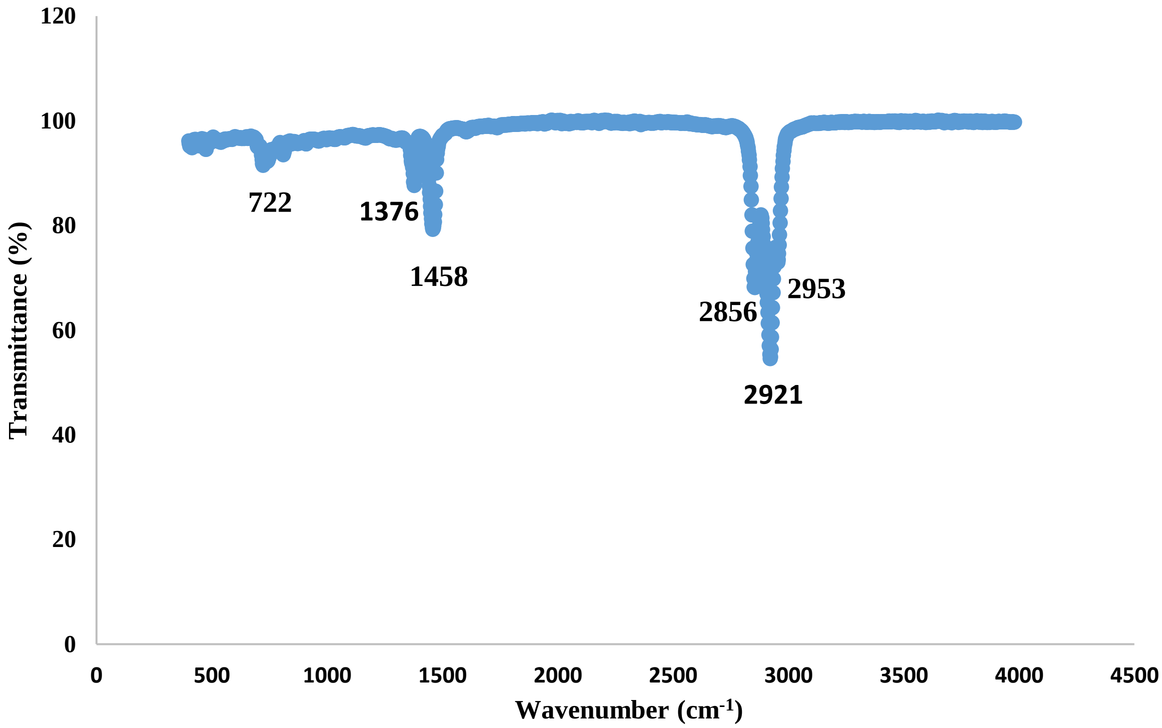


Figure 4.2 FTIR Spectrum of the Crude Oil (Wavenumber vrs Transmission)

Table 4.9 Compounds in Crude Oil (GC-MS)

Pentadecane	1-ethyl-3,5-dimethylbenzene
Tetradecane	Naphthalene
5-methyltetradecane	Decahydro-1,6-dimethylnaphthalene
Octylcyclohexane	Docadecane
Dimethyl phthalate	2,6-dimethylundecane
2,6-dimethylheptadecane	14-chloro-1-tetradecanol
3-methyltetradecane	2-(1-methylethyl)-, trans-1,1-bicyclohexyl
Pentadecane	1,2,3,4-tetrahydro-5-methylnaphthalene
2,6,10-trimethyltetradecane	2,3,7-trimethyloctane
1,6,7-trimethylnaphthalene	1-methylnaphthalene

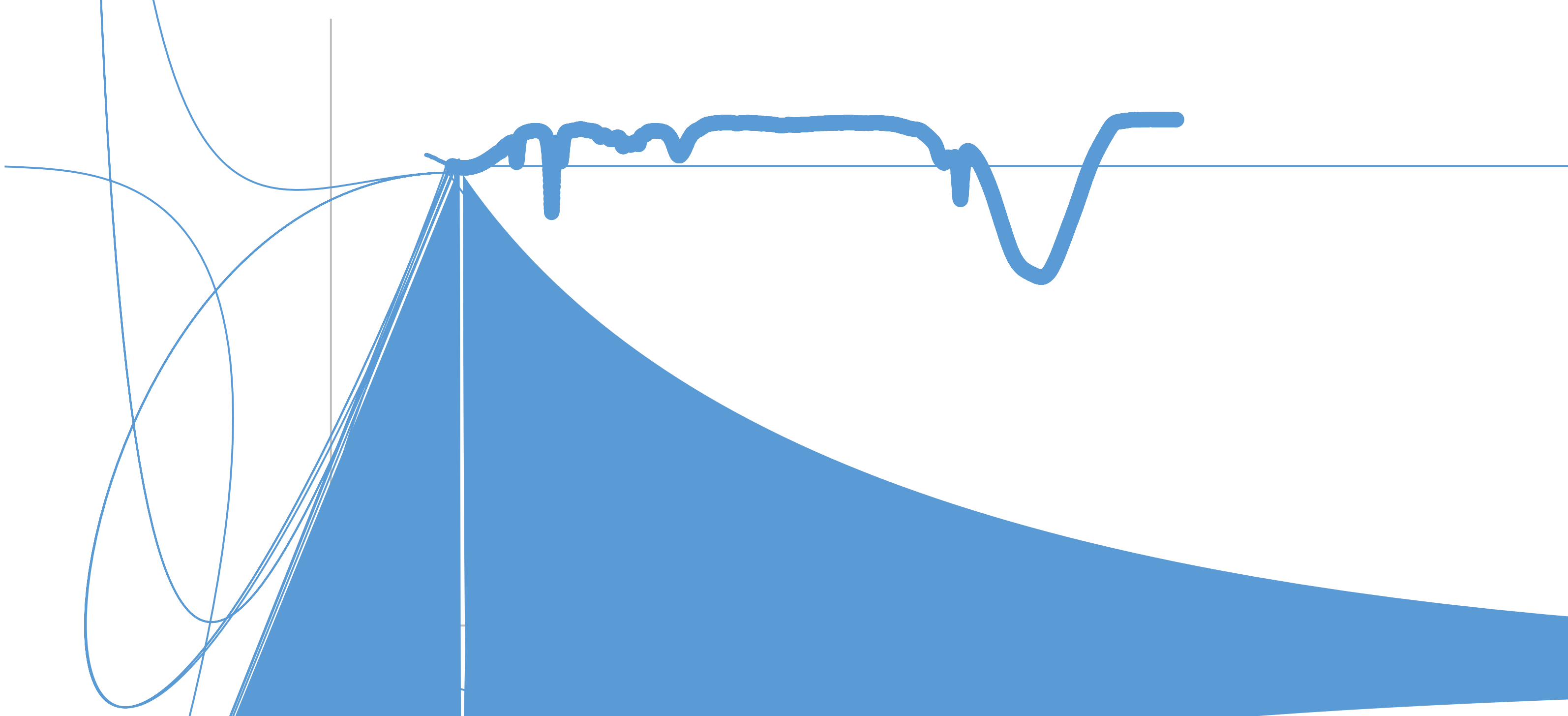
Table 4.9 Compounds in Crude Oil (GC-MS) Continued

2,3,6-trimethylnaphthalene	Tridecane
1-Trifluorosilyltridecane	1-methylnaphthalene
1,7-dimethylnaphthalene	Benzene, (3-ethenyl-5,5-dimethylhexyl)
Nonadecane	2,5-dimethylcyclohexylidenemalononitrile
Eicosane	3-(6,6-Dimethyl-5-oxohept-2-enyl)-cyclohexane
Heneicosane	1H-Indene, 2-butyl-4-hexyloctahydro
Pentacosane	Decahydro-4,4,8,8,10-pentamethylnaphthalene
Hentriacontane	1,2-dimethyl-4-methylene-3-phenylcyclopentene
Heneicosane	3-(2-methyl-propenyl)-1H-indene
Tetratetracontane	Octadecane, 3-ethyl-5-(2-ethylbutyl)-
Tetracosane	1,9-Dioxacycyclohexadeca-4,13-diene-2-10-dione, 7,8,15,16-tetramethyl
Decylcyclohexane	2,6,10,14-trimethylpentadecane
Heptadecane	4a, 10a—Methanophenanthrene-9a-ol, 11-syn-bromo-1,2,3,4,4a,9,10,10a-octahydro
Octadecane	1,4,5,8-tetramethylnaphthalene
Ethanol, 2-(octadecyloxy)-	2,6,10,14-tetramethylhexadecane
Hexadecane	Eicosane, 9-cyclohexyl-
2,6,10,14-tetramethylhexadecane	

Table 4.10 Functional Groups in the Crude Oil

Wavenumber (cm^{-1})	Transmittance (%)	Bond	Functional group
3996.6	99	C–H stretch	Aromatic
3588.09	99	O–H stretch, H–bonded	phenols, alcohols
3088.32	99	=C–H stretch	Alkenes
2953.35	73	C–H stretch	Alkanes
2852.87	68	C–H stretch	Alkanes
2360.66	99	–C≡C– stretch	Alkynes
2295.42	99	–C≡C– stretch	Alkynes
2240.00	99	–C≡C–	Alkynes
2195.34	99	–C≡C– stretch	Alkynes
2082.20	99	overtones	Benzene
1989.81	99	Overtones	Aromatics
1933.19	99	Overtones	Aromatics
1602.71	97	N–H bend	1˚ amines
1458.43	79	C–H bend	Alkanes
1376.82	87	C=C stretch	Alkynes
908.92	95	N–H wag	1˚, 2˚ amines
810.04	93	C–H "oop"	Aromatics
539.22	95	C–Br stretch	alkyl halide
474.18	94	C–H stretch	Alkane

The akpeteshie used in the experiments was taken to the Department of Chemistry Laboratory of the University of Ghana for analyses to ascertain the purity of the alcohol content. The results showed that the density of the akpeteshie was 0.89 g/L and the ethanol content was 71.72 %. The pH of the akpeteshie was 3.78. The FTIR spectrum and the functional groups in the akpeteshie are presented in Figure 4.3 and Table 4.11 respectively. According to the result, the ethanol content in the akpeteshie used for the experiment was high in comparison with the normal akpeteshie sold in the market (Anon., 2022; Zakpaa et al., 2010; Tagba et al., 2018).



F

roups in the Akpeteshie

[illegible] -1)	Transmittance (%)	Bond	Functional Group
	69	O-H stretch	Alcohol, phenol
	84.5	C-H stretch	Alkanes
	96.12	C-O stretch	Alcohols, carboxylic acids, esters, ethers
880	91.76	C–H “oop”	Aromatics

Table 4.12 Compounds in Sample 0 (GC-MS)

1-ethyl-4-methylbenzene	Octane	Propyl cyclohexane
1,2,4-trimethylbenzene	Ethylcyclohexane	2,6-dimethyloctane
1-methyl-3-propylcyclohexane	1,2,3-trimetheylcyclohexane	3-ethyl-2-methylheptane
1,2,3-trimethylbenzene	p-xylene	Dodecyl ethyl ester, carbonic acid
Decane	1-ethyl-4-metyl-,trans-cyclohexane	1-methyl-3-methylbenzene
Butylcyclohexane	Nonane	1-ethyl-3,5-dimethylbenzene
Tridecanal	4-octene-3-one	2-ethyl-1,4-dimethylbenzene
5-methyl-2-(1-methylethyl)-,benzoate,[1R-(1a,2a,5a)]-cyclohaxanol	1-ethyl-3-methylcyclohexane	p-cymene
2-methyltransdecalin	1-heptadecyne	1,2,4,5-tetramethylbenzene
Decahydro-2-methylnaphthalene	2-(1-methylethyl)-cis-1,1-Byclohexyl	Decahydro-4,4,8,9,10-pentamethylnaphthalene
2-methylundecane	1.2.3.4-tetrahydro-6-methylnaphthalene	2,6,10-trimethyldodecane
2-methyltrans-decalin	2,3,7-trimethyloctane	1,7-dimethylnaphthalene
1-ethyl-3,5-dimethylbenzene	Benzocycloheptatriene	Octylcyclohexane
2-methylundecane	1-methylnaphthalene	Decahydro-4.4,8,9,10-pentamethylnaphthalene
[redacted]orododecyl ester, [redacted] acid	Heptylclohexane	Hexadecane
[redacted]cane	2,6-dimethylendecane	3-(2-methyl-propenyl)-1H-indene
[redacted]yl-1-decanol	2,3,6-trimethylnaphthalene	

1-8n /P <</MC06 138.26 Tm 0.

Table 4.14 Compounds in Sample 1 (GC-MS)

Tridecane	1-methylnaphthalene
1-methylnaphthalene	p-Xylene
5,6,7,8,9,10-hexahydrobenzocyclooctene	1,2,4-trimethylbenzene
Heptylcyclohexane	Decane
1,7-dimethylnaphthalene	1,2,3-trimethylbenzene
4-methy-1,1-Biphenyl	Undecane
2,3,6-trimethylnaphthalene	2-methyl-trans-deaclin
Dodecane	1,3-diethylbenzene
1,12-Tridecadiene	Naphthalene
1,2,3,4-tetrahydro-5-methylnaphthalene	

Table 4.15 Functional Groups in Sample 1

Wavenumber (cm^{-1})	Transmittance (%)	Bond	Functional Group
2953.20	71	C–H stretch	Alkanes
2921.59	55	C–H stretch	Alkanes
2853.16	69	C–H stretch	Alkanes
2167.53	99	–C≡C–	Alkynes
2142.53	99	C≡C stretches	terminal alkynes
2066.61	99	R–N=C=S	Isothiocyanates, any
2007.56	99	R–N=C=S	Isothiocyanates, any
1980.76	99	C=C Overtones, weak	Aromatics
1969.25	99	C=C Overtones, weak	Aromatics
1921.52	99	C=C Overtones, weak	Aromatics
1606.52	97	C–C stretch (in–ring)	Aromatics
1457.68	79	C–H bend	Alkanes
1376.84	87	C–H wag (–CH_2X)	Alkanes
809.56	94	C–H Stretches "oop"	Aromatics
767.38	93	=C–H bend	Alkenes
740.91	92	=C–H bend	Alkenes

Table 4.15 Functional Groups in Sample 1 (Continued)

723.61	92	C–H rock	Alkanes
698.74	94	bend –C≡C–H: C–H bend	Alkynes
542.45	95	C–Br stretch	Alkyl halide
472.78	94	C–I stretch	Alkyl halide
430.08	94	C–I stretch	Alkyl halide

4.5.4 Characterisation of Distillates: Sample 2

The compounds found in sample 2 together with the functional groups identified in the FTIR spectrum of Figure 4.6 were used to characterise the sample type. Sample 2 was obtained at about 182 ^{o}C. The compounds in the sample are presented in Table 4.16 and the functional groups are presented in Table 4.17. The compounds in the sample are mainly paraffins, naphthenes, and aromatic hydrocarbons. These compounds are the constituents of kerosene (Donev, 2017; Spasov et al., 1967; Koide *et al*., 2005; Anon. 2018). So comparing these constituents with the information in Tables 4.20 and 4.21 confirmed the sample to be kerosene.

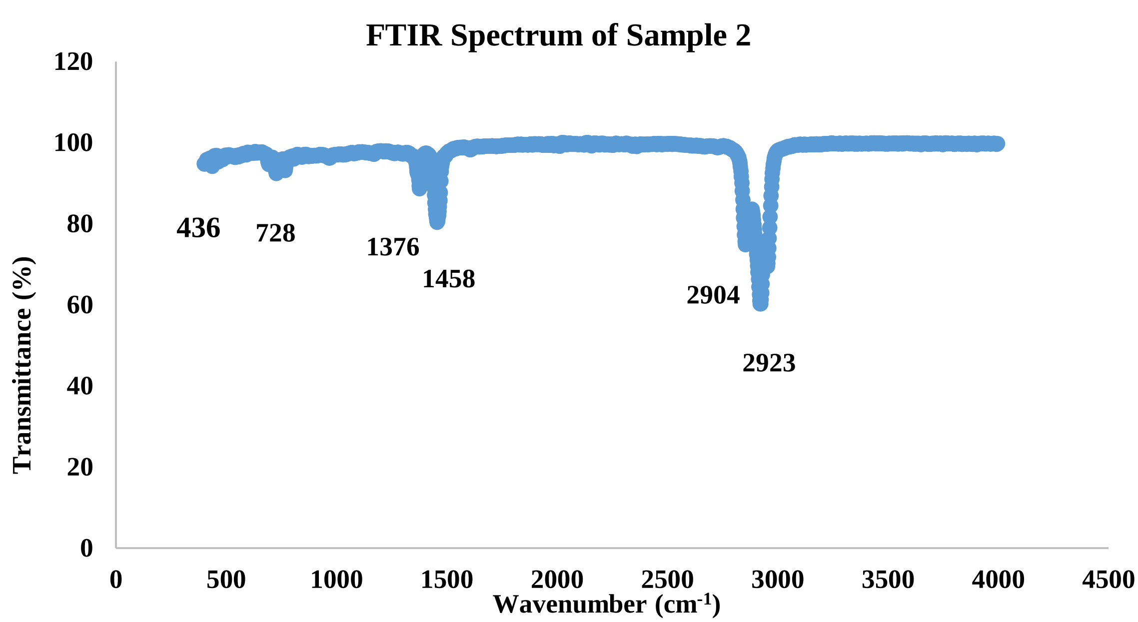


Figure 4.6 Sample 2 Spectrum (Wavenumbers vrs Transmittances)

Table 4.16 Compounds in Sample 2 (GC-MS)

1-ethyl-4-methylcyclohexane	1,1,3-trimethylcyclohexane	Octahydro-cis-1H-Indene
Nonane	2,4-dimethylheptane	1,3-dimethylbenzene
1-ethyl-4-methyl-cis-cyclohexane	1,4-dimethyl-cis-cyclohexane	p-xylene
Octahydro-2-methylpentalene	2,6-dimethyloctane	2-ethyl-1-Decanol
3-ethyl-2-methylheptane	Ethylcyclohexane	Propylcyclohexane
1-ethyl-3-methylbenzene	1,1,4-trimethylcyclohexane	3-methylnonane
1,2,4-trimethylbenzene	Nonene	1,2,2,3-tetramethylcyclohexane
1-ethyl-3-methylbenzene	1,3,5-trimethylcyclohexane	1-methyl-3-(2-methylpropyl)-cyclopentane
1-ethyl-4-methylcyclohexane	1,1,3-trimethylcyclohexane	Octahydro-cis-1H-Indene
Nonane	2,4-dimethylheptane	1,3-dimethylbenzene
1-ethyl-4-methyl-cis-cyclohexane	1,4-dimethyl-cis-cyclohexane	p-xylene
Octahydro-2-methylpentalene	2,6-dimethyloctane	2-ethyl-1-Decanol
3-ethyl-2-methylheptane	Ethylcyclohexane	Propylcyclohexane
1-ethyl-3-methylbenzene	1,1,4-trimethylcyclohexane	3-methylnonane
1,2,4-trimethylbenzene	Nonene	1,2,2,3-tetramethylcyclohexane
1-ethyl-3-methylbenzene	1,3,5-trimethylcyclohexane	1-methyl-3-(2-methylpropyl)-cyclopentane

Table 4.17 Functional Groups in Sample 2

Wavenumber (cm^{-1})	Transmittance (%)	Bond	Functional Group
2953.28	69	C–H stretch	**Alkanes**
2921.92	60	C–H stretch	Alkanes
2854.34	74	C–H stretch	Alkanes
2156.54	99	–C≡C–	Alkynes
2012.37	99	–C≡C–	Alkynes
1606.98	98	N-H bend	Amines
1456.73	80	ring C=C stretch	Aromatic
1377.05	89	CH_3 C-H bend	Alkanes
966.87	96	=C-H bend trans-RCH=CHR′	Alkenes
805.30	95	C-H bend	Aromatic m-disubstituted
767.21	93	C-Cl stretch	Alkyl halide
740.45	93	C–H bend	Aromatic o-disubstituted
727.20	92	C–H "oop"	Alkane
694.57	95	C–H bend	Aromatic m-disubstituted
482.94	95	C-I stretch	Alkyl halide
418.25	94	C-I stretch	Alkyl halide

Note: Out of Plane = oop

4.5.5 Characterisation of Distillate: Sample 3

The functional groups identified from the FTIR spectrum in Figure 4.7 are shown in Table 4.18. The spectrum shows the wavenumbers on the abscissa and their corresponding percentage transmittances on the ordinate. Only the major peaks are presented on the spectrum. The constituents of sample 3 are presented in Table 4.19. Notably, the constituents in diesel are paraffins, aromatic , and naphthenes (Lois, *et al*., 2003; Laraia, 2021; Khobragade *et al*., 2018). Sample 3 obtained at about 265 ^{o}C was identified as diesel using the functional groups, the constituents found in the sample through GC-MS analysis and comparing them with the information about the constituents in diesel obtained from (Lois, *et al*., 2003; Laraia, 2021; Khobragade *et al*., 2018).

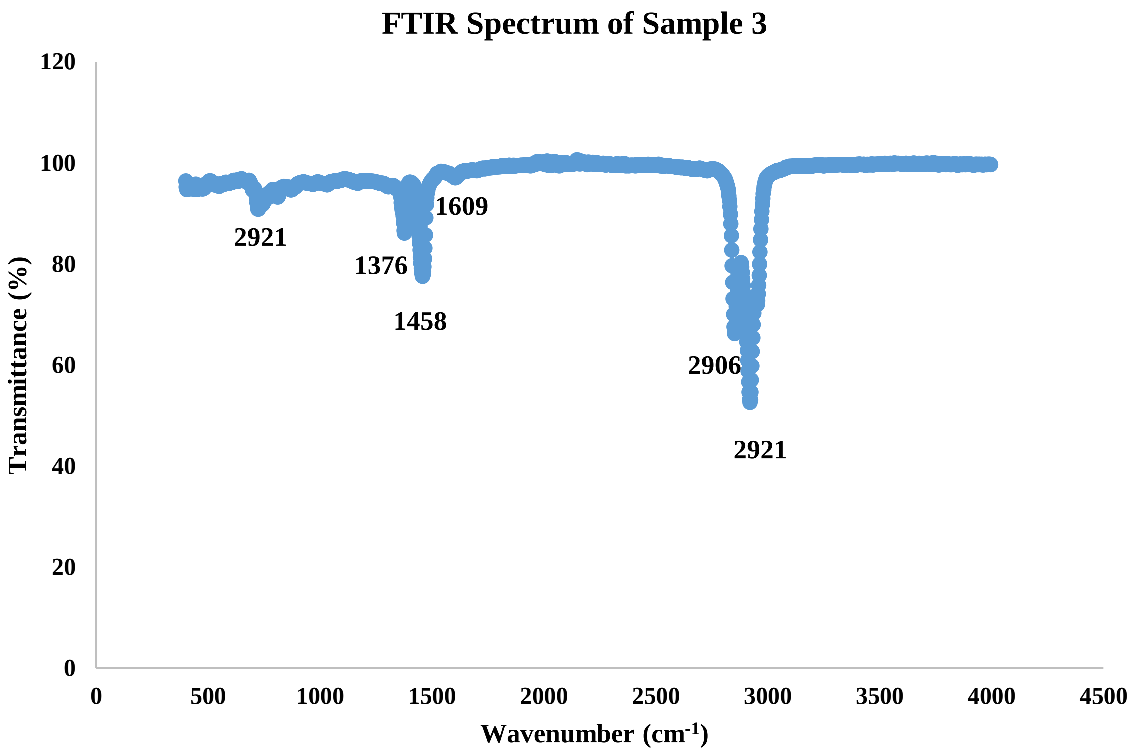


Figure. 4.7 FTIR Spectrum of Sample 3

Table 4.18 Functional Groups in Sample 3

Wavenumber (Cm^{-1})	Transmittance (%)	Bond	Functional Group
2952.35	71	C-H stretch	Alkanes
2921.16	53	Csp3 – H , CH_2, CH_3 stretch	Alkanes
2852	66	CH, CH_2, CH_3 stretch	Alkanes
2318.12	99	–C≡C– stretch	Alkanes

Table 4.18 Functional Groups in Sample 3 (Continued)

Wavenumber (cm^{-1})	Transmittance (%)	Bond	Functional Group
2276.43	99	H–C=O: C–H stretch	Aldehyde
2211.02	99	–C≡N– stretch	Nitriles
2159.61	99	–C≡C– stretch	Alkynes
2067.87	99	–C≡C–	Alkynes
2034.36	99	C≡C	Alkynes
1973.77	100	Overtones	Aromatics
1604.36	97	N-H bend	Amides
1457.78	77	Ring C=C stretch	Aromatic compounds
1376.57	86	CH_3 C-H bend	Alkanes
810.98	93	=C–H bend	Alkenes
741.93	91	C-H bend	Aromatics o-disubstituted
723.16	90	=C–H bend cis-RCH=CHR	Alkenes
699.15	94	=C–H bend cis-RCH=CHR	Alkenes
548.78	95	C-Br stretch	Alkyl halide
474.20	94	C-I stretch	Alkyl halide

Table 4.19 Compounds in Sample 3 (GC-MS)

Naphthalene	Octatriacontyl pentafluoropropionat	1-methylnaphthalene
Dodecane	p-xylene	2,6,10-trimethyldodecane
5-isopropyl-6,6-dimethylhept-3-yne-2,5-diol	Nonane	Tetradecane
Decahydro-2-methylnaphthalene	Mesitylene	2,7-dimethylnaphthalene
2,3,7-trimethyldodecane	1-ethyl-3-methylbenzene	Octylcyclohexane
2,6-dimethylundecane	Decane	1,7-dimethyl-naphthalene
Heptylcyclohexane	1,2,4-trimethylbenzene	Tridecane
2,6,10,14-tetramethylheptadecane	Undecane	2-methylnaphthalene
Tetradecane	2,3,6-trimethylnaphthalene	3-(2-methylpropenyl)-1H-indene
2-methylpentadecane	Hexadecane	2,6,10-trimethylpentadecane
Heptadecane	2,6,10,14-tetramethylpentadecane	5,8-diethyldodecane
Octadecane	2,6,10,14-tetramethylhexadecane	2-(octadecyloxyl)-ethanol
Nonadecane	Eicosane	

4.5.6 Characterisation of Distillates: Sample 4

The components in sample 4 identified from the GC-MS analysis were placed in Table 4.20. As a complex and variable combination of organic compounds, fuel oils cconstitute mostly alkanes, alkenes, cycloalkanes, aromatics, and aromatic hydrocarbons (Baker, 2010; Anyakudo *et al.*, 2017; Hendrik, 1937; Kashio et al., 2010; Miyoshi, 1986). The compound found in the sample as presented in Table 4.21 together with the functional groups identified from the FTIR spectrum and presented in Table 4.21 assisted to characterise sample 4 as fuel oil. The Sample was obtained around 315 ^oC. The FTIR spectrum is shown in Figure 4.8.

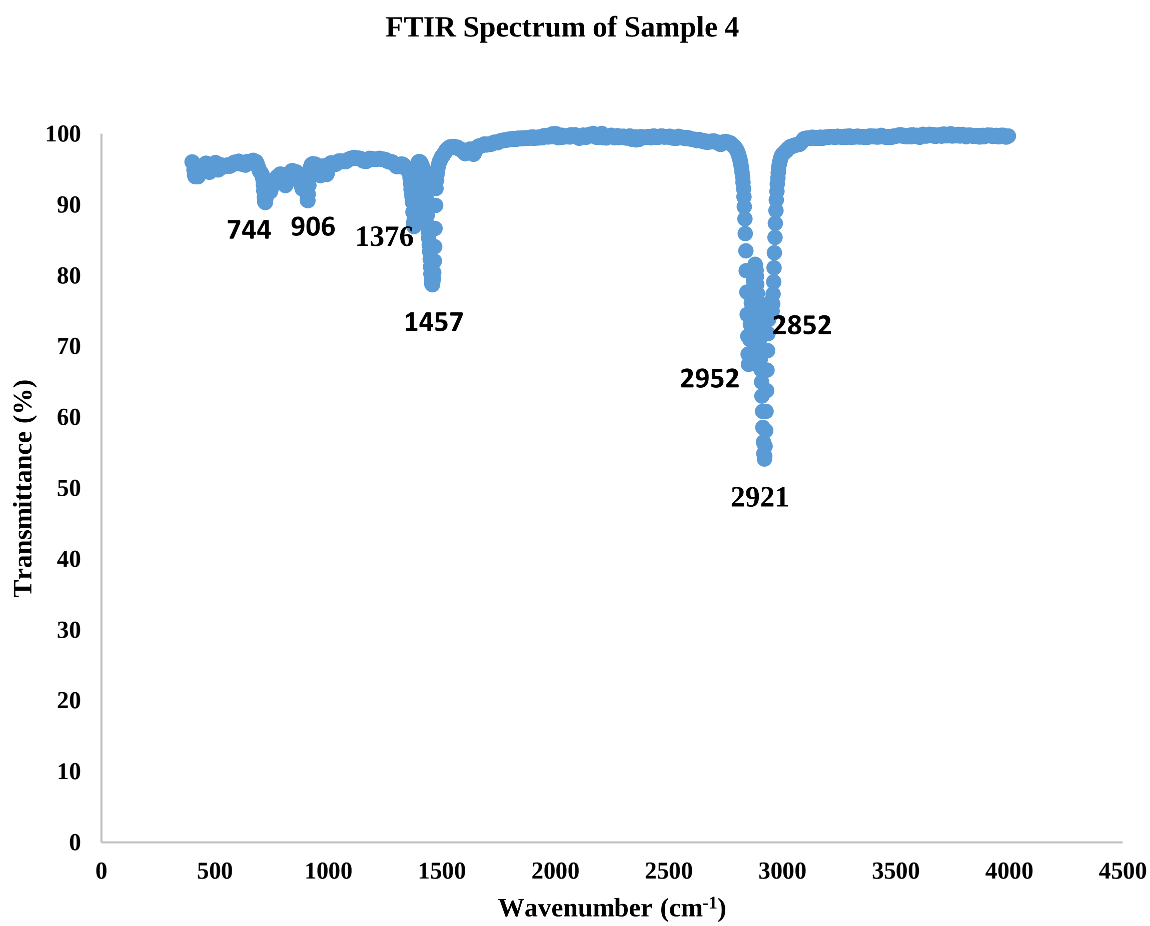


Figure 4.8 FTIR Spectrum of Sample 4 (Wavenumber vrs Transmittance)

Table 4.20 Compounds in Sample 4 (GC-MS)

17 .alfa.,21a-28,30-Bisnorhopane	Cyclohexane, 2-butyl-1,1,3-trimethyl-	Tetratetracontane
Cyclononasiloxane, octadecamethyl-	17-Pentatriacontene	Hexacosane
Heptadecane	2-methylnaphthalene	1-Tetradecane
1-[2-(octadecyloxy)thoxyl]-9-Octadecene	Tetradecane	10,18-Bisnorabieta-5,7,9(10),11,13-pentaene
Heneicosane	1-Decanol, 2-hexyl	1-Nonadecene
17-Pentatriacontene	2,6,10-trimethyldodecane	Octadecane
3-ethyl-5-(2-ethylbutyl)octadecane	1-Pentadecane	1-Nonadecene
Hexacosane	Pentadecane	Octadecane
Octadecane	n-Nonadecanol-1	9-dodecyltetradecahydrophenanthrene
Olean-12-ene-3,15,16,21,22,28-hexol, (3a,15a,16a,21a,22a)-	2(3H)-Naphthalenone, 4,4a,5,6,7,8-hexahydro-4a-phenyl-, (R)-	Tributylboroxin
Pentacosane	Cetene	2-methylanthracene
(E)- Tridecanal	Hexadecane	1-methoxy-13-methyl-Hexadecane
Tetratetracontane	Tripropylboroxin	Eicosane
3-ethyl-5-(2-ethylbutyl)octadecane	2,6,10-trimethylpentadecane	3,3-Diphenyl-5-methyl-3H-pyrazol
Olean-13(18)-ene	1-(ethenyloxy)decane	Eicosane
Cholestane, 2,3-epoxy-, (2a,3a,5a)-	1-Docosene	Octadecane, 3-ethyl-5-(2-ethylbutyl)-
Tridecane	Hentriacontane	

Table 4.21 Functional Groups in Sample 4

Wavenumber (cm^{-1})	Transmittance (%)	Bond	Functional Group
3094.45	98	=C–H stretch	Aromatic
3059.77	97	=C–H stretch	Aromatics
2974.90	90	C–H stretch	Alkanes
2972.05	89	C–H stretch	Alkanes
2970.01	87	C–H stretch	Alkanes
2967.97	85	C–H stretch	Alkanes
2963.89	81	C–H stretch	Alkanes
2952.84	74	C–H stretch	Alkanes
2927.18	57	C–H stretch	Alkanes
2921.22	53	C–H stretch	Alkanes
2372.85	99	–C≡C– stretch	Alkynes
2340.70	99	–C≡C– stretch	Alkyne
2147.25	99	–C≡C– stretch	Alkyne
2092.08	99	–C≡C– stretch	Alkyne
2056.59	99	–C≡C– stretch	Alkyne
1951.82	99	overtones, weak	Aromatics
1604.14	95	N-H bend	Amide
1457.27	97	C–C stretch (in-ring)	Aromatic
1376.45	86	C–F stretch	Alkyl halide
964.93	94	=C–H bend	Alkenes
877.49	91	=C–H bend	Alkenes
721.93	88	C–H rock	Alkane
536.74	84	C–Br stretch	Alkyl halide
471.43	93	C–I stretch	Alkyl halide

4.5.7 Characterisation of Distillates: Sample 5

The compounds and the functional groups of sample 5 are presented in Tables 4.22 and 4.23 respectively. The constituents of bitumen are asphaltenes, maltenes, aromatics, saturates, resins (Natalie, 2019; Holy, 2019; Nair, 1978; Anon, 2016;Whiteoak, 1999; Zhang *et al*., 2019).The information in Tables 4.23 and 4.24 together with the FTIR spectrum in comparison with the information about bitumen presented by the researchers mentioned above aided in the identification of the sample as bitumen. The FTIR spectrum of sample 5 is provided in Figure 4.9 showing the wavenumbers and their corresponding percentage transmittances.

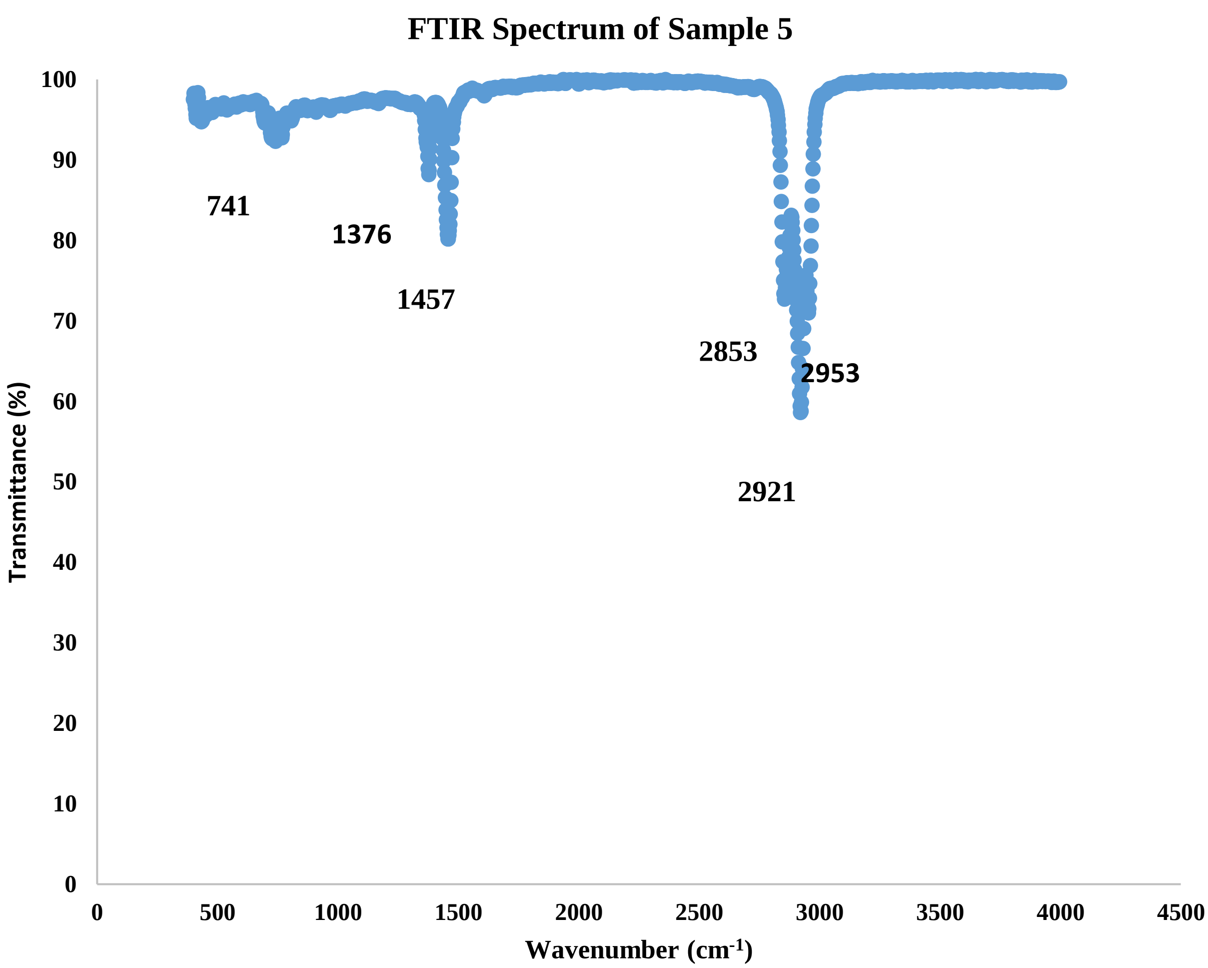


Figure 4.9 FTIR Spectrum of Sample 5

Table 4.22 Compounds in Sample 5 (GC-MS)

p-Xylene	1-ethyl-2-methylbenzene	Tetratetracontane
Nonane	1,2,4-trimethylbenzene	Tetracosane
Decane	1-ethyl-3-methylbenzene	Heptacosane
Undecane	1,2,3-trimethylbenzene	2,6,10-trimethylpentadecane
Naphthalene	5-methyl-2-(1-methylethyl)-, benzoate, [1R-(1a,2a,5a)]cyclohexanol	2,6,10,14-tetramethylhexadecane
1-Decene	1-ethyl-3,5-dimethylbenzene	2,6,10,14-tetramethylpentadecane
Nonylcyclopropane	2,6-dimethylundecane	Octylcyclohexane
Dodecane	1,2,3,4-tetradydro-5-methylhnaphthalene	1-pentadecene
Tetradecane	1-methylnaphthalene	Heptadecane
Octadecane	z-(13,14-Epoxy)tetradec-11-en-1-ol acetate	Decosane
Hexadecane	2,6,10-trimethyldodecane	Cyclohexadecane
Pentadecane	Trichloroacetic acid, hexadecyl ester	7-methyltridecane
Tridecene	3-ethyl-5-(2-ethylbutyl)Octadecane	1H-Indene, 1-ethylidene
Heneicosane	2,6,10,14-tetramethylheptadecane	Eicosane
Hexacosane	3-ethyl-5-(2-ethylbutyl)octadecane	2,7-dimethylnaphthalene
Octadecane	3-(2-methyl-propenyl)-1H-indene	1,7-dimethylnaphthalene
2-Ethyl-1-dodecanol	Trichloroacetic acid, hexadecyl ester	2-cyclohexyleicosane
17-Pentatriacontene		

Table 4.23 Functional Groups in Sample 5

Wavenumber (cm^{-1})	Transmittance (%)	Bond	Functional Group
3996.06	99	C–H stretch	Aromatic
3351.46	99	O–H stretch, H–bonded	Alcohol, phenol
3000.61	97	C–H stretch	Alkanes
2953.20	72	C–H stretch	Alkanes
2921.54	55	C–H stretch	Alkanes
2853.18	69	C–H stretch	Alkanes
2277.76	99	–C≡C– stretch	Alkynes
2178.12	99	–C≡C– stretch	Alkynes
2131.65	99	C≡C stretch	Terminal Alkynes
2080.70	99	–C≡C– stretch	Alkynes
1987.43	99	Overtones	Aromatics
1606.95	97	N–H bend	1° amines
1457.46	79	C–H bend	Alkane
1376.76	87	$-CH(CH_3)_2$ $-(CH_3)_3$ bend	Alkanes and alkyls
909.09	94	=C-H bend	Alkenes
810.00	94	C-Cl stretch	Alkyl halide
741.06	92	C–Cl stretch	Alkyl halide
725.30	91	C–H rock	Alkanes
610.55	96	C≡C –H: C–H bend	Alkynes
593.92	96	C–Br stretch	Alkyl halides
473.28	95	C–H	Alkanes

4.6 Energy Consumed to Distill the Crude Oils

The energy consumed to distill various fractions were calculated. The results are presented in Table 4.25. Sample calculation was done manually and the rest of the energy consumed by the components were calculated using Excel spreadsheet programme. The energy consumed by the constituents are presented in an increasing order as follows: diesel, 21278.25762 J< kerosene, 22305.05726 J < bitumen, 299041.7898 J <gasoline, 456734.2538 J < fuel oil, 502875.3236 <naphtha 510258 J. The total energy consumed to fractionate 2 liters of crude oil was 1812593.01548 J, which is 1.813 x 10^3 kJ.

The volatility of the components in the crude oil are presented in a decreasing order as follows: Gasoline > naphtha > kerosene > diesel > fuel oil > bitumen (Salvo, 2023; Hird, 2022). By using the weights of the distillates provided in Table 4.8, the specific energy consumed by the crude fractions were calculated and presented in Table 4.24. The specific energies are presented in an increasing order as follows: Gasoline, 388 J/g < naphtha, 502.8116 J/g < kerosene, 543.15 J/g < diesel, 611.4441 J/g < fuel oil, 763.7259 < bitumen, 863.2596 J/g.

According to the specific energy consumed by the crude oil fractions, it can be deduced that the more volatile fractional components consumed lesser energy to fractionate than the lesser volatile fractional components consumed (Clark 2021; Ramakrishnan, 2009; Cheremisinoff and Rosenfeld, 2010). For example, the most volatile component (gasoline) consumed 388.24 J/g to fractionate and the least volatile component (bitumen) consumed 863.25 J/g of energy to fractionate.

Table 4.24 Specific Energy Consumed to Distill the Crude Oil Fractions

Fraction	Weight (Grams)	Energy (J)	Specific energy (J/g)
Gasoline	1176.41	456734.2538	388.2441
Diesel	34.8	21278.25762	611.4441
Kerosene	41.25	22405.05726	543.15
Naphtha	1014.81	510258.3334	502.8116
Fuel oil	658.45	502875.3236	763.7259
Bitumen	346.41	299041.7898	863.2596

Table 4.25 Energy Consumed to Distill the Crude Fractions

Fraction	Temp (°K)	Temp (°F)	Mass (g)	Mass (lb)	S. G. (d)	heat capacity (J/gK)	Initial energy (J)	Latent heat (J)	Total energy (J)
Gasoline	326.15	127.4	1176.41	2.59354	0.71	2.22	73517.39013	383216.8637	456734.25
Diesel	548.15	527	34.8	0.07672	0.85	1.75	15234.135	6044.122624	21278.258
Kerosene	473.15	392	41.25	0.0909	0.92	2.01	14522.12438	7882.932883	22405.057
Naphtha	393.15	248	1014.81	2.23727	0.7	2.191	211561.1448	298697.1887	510258.33
Fuel oil	593.15	608	658.45	1.452	0.89	2.09	406173.7716	96701.55206	502875.32
Bitumen	658.15	725	346.41	0.7637	0.97	2.093	261121.7622	37920.02755	299041.79

CHAPTER 5

CONCLUSIONS AND FUTURE RESEARCH

This chapter provides the conclusions arrived at after desalting, desulphurising, designing and constructing the distillation column, distilling the crude oil, identifying the distilled crude oil fractions, and assessing the specific energy consumed to distill the 2 liters of spilled crude oil.

5.1 Concluding Remarks

- The desalting of the spilled and the usnpilled crude oils were successful. Before desalting, the tests of salt in the spilled and the unspilled crude oils gave 98.8 mg/kg and 15.14 mg/kg respectively. The crude oils were desalted using different volumes of Akpeteshie. The salt in the crude kept reducing as more volumes of the Akpeteshie were added. The overall salt content originally found in the spilled and the unspilled crude oils were reduced by about 92 % and about 27.27 % respectively after five consecutive desalting runs.

- The desulphurisation of the spilled and the unspilled crude oils were conducted. The sulphur test of the crude before desulphurisation gave 3530 ppm. After the first desulphurisation, the sulphur in the spilled crude oil reduced to 1680 ppm. This reduction of sulphur was about 52.41 %. The sulphur reduced to about 282.4 ppm after the second desulphurisation. This result translated to about 92 % overall reduction of sulphur in the spilled crude oil. The test of the unspilled crude oil gave 1820 ppm for the first desulphurisation and 332 ppm after the second desulphurisation. The overall suphur reduction in the unspilled crude oil was 88.83 %.

- The distillation column designed and fabricated was able to distill the crude oil successfully. The spilled crude oil fractions obtained from the distillation were analysed. The compounds obtained from the GC-MS analysis, the functional groups obtained from the FTIR spectroscopic analysis, and comparing those information with other information retrieved from various researchers were successfully used in the identification of the crude fractions as gasoline, naphtha, kerosene, diesel, fuel oil, and bitumen

- The assessment of the amount of energy consumed to distill the various crude oil fractions showed that considering the same quantity of crude fraction, the heavier components of the crude oil consumed more energy than the lighter components to fractionate. The following chart shows the energy consumed by the components to fractionate per unit mass of the fractions in an increasing order: Gasoline, 388 J/g < naphtha, 502.8116 J/g < kerosene, 543.15 J/g < diesel, 611.4441 J/g < fuel oil, 763.7259 < bitumen, 863.2596 J/g. The chart confirms the theory that says that less volatile components in a crude oil need more energy than the less volatile components need to fractionate given equal amounts of masses.

5.2 Recommendation for Future Research

It is recommended that the following researches in relation to this current research should be conducted:

- Further research is recommended to be conducted about the automation of the valves inserted in the pipes to control the flow of the crude oil. The researcher had to turn on or turn off the valves manually in order to control the flow of the crude oil. This manual valve control was a problematic. Thick gloves had to be worn by the researcher to avoid being burnt by the hot valve. The presence of valve automation in the distillation system could have made the process easier.
- The temperature automation control system of the distillation process is another research that needs to be embarked. The spilled crude oil fractions were obtained using the standard distillation temperatures of the crude oil components. Careless control of the distillation temperature of a particular component could have allowed mixtures of more than one crude oil fraction to be obtained. The presence of automatic temperature controls in the distillation system will assist to avoid the mixtures of more than one component in the receiver.

- The column designed is a mini type of distillation column. Research can be done to ascertain how the distillation column could be scaled up. The method of scaling up an engineering design has mostly been a daunting problem confronting engineers. Scaling up this distillation column could allow commercial production of crude oil products.
- The Ghanaian locally brewed alcoholic beverage, Akpeteshie, was successfully used as the demulsifier in the desalting process for the original salt content in the spilled crude oil to decrease by about 63.15 %. It is recommended that another research should be conducted to find different method using locally manufactured reagent to desalt spilled crude oil.
- The Ghanaian locally brewed alcoholic beverage, Akpeteshie, was successfully used as the extractant in the desulphurisation of the spilled crude oil. The original sulphur content in the spilled crude oil to decrease by about 92 %. It is recommended that another research should be conducted to find different method using locally manufactured reagent to desulphurise spilled crude oil.

5.3 Research Contribution

The following are the contributions provided by this research:

1. The distillation column used for fractionating the components of the crude oil was designed and constructed by the researcher. The researcher used steel, valves, pumps, and other materials purchased in Ghana to construct the distillation column. According to public records, this is the first time a graduate student has designed and constructed a fractional distillation column to distill crude oil successfully in Ghana.

2. So far, there are no known uses of spilled crude oil. Albeit transportation fuels prices soar almost all the time, the spilled crude oils are not distilled and used for such purposes. In this research, the spilled crude oil was distilled successfully. Hence, the fractions obtained resulting from the distillation could be used as transportation fuels.

3. The desalting of the spilled crude oil was conducted using Ghanaian locally manufactured alcoholic beverage (Akpeteshie). The Akpeteshies was used as a

demulsifier after the emulsification step. This is the first time this Ghanaian locally manufacture alcoholic beverage has been used as a reagent to desalt crude oil.

4. The desulphurisation of the crude oil was performed using two important steps, namely, the oxidation step, and the extracting step. The Akpeteshie was used as an extracting reagent to extract the sulphur containing compounds from the crude oil. This is the first time the Akpeteshie has been used as an extractant in the desulphurisation process.

5. The energy used to distill the crude oil was assessed successfully. Consequently, this information will be made available to the public.

5.4 Research Publications from Thesis Work

1. Asante, B., Ankomah, Y., Cobbinah, I. F., Marfo, S. A., and Dankwah, J. R. (2023), "Demulsification of Crude Oil Using Ghanaian Locally Manufactured Alcoholic Beverage (Akpeteshie) as Demulsifier", *IOSR Journal of Applied Chemistry*, Vol. 16, Issue 1, pp. 19-27.

2. Asante, B., Marfo, S. A., and Dankwah, J. R. (2023), "Oxidative Extractive Desulphurisation of Crude Oil Using Ghanaian Alcoholic Beverage as an Extractant for Petroleum Coke Production" *IOSR Journal of Applied Chemistry*, Vol. 16, Issue 1, pp. 46-55.

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APPENDICES

Appendix A Conversions of Salt Concentrations

$$Salt\left(\frac{mg}{Kg}\right) = \frac{1000x}{d}$$

$$Salt\ \left(\frac{mg}{Kg}\right) = \frac{2853y}{d}$$

$x = Salt\ concentration\ in\ {}^{g}/_{m^3}$

$y = Salt\ concentration\ in\ PTB$

$d = Density\ of\ the\ oil\ at\ 15\ ℃\ in\ {}^{Kg}/_{m^3}$

Appendix B Sample Calculation of API

$$API = \frac{141.5}{SG} - 131.5$$

$Sample\ Calculation$:

$$API_{diesel} = \frac{141.5}{0.885} - 131.5$$

$$= 27.82$$

APPENDIX C CONVERSIONS OF SULPHUR CONCENTRATIONS

$$Concentration(PPM) = \frac{24.45 \times Concentration\ \left({}^{mg}/_{m^3}\right)}{molecular\ weight}$$

$$Concentration\ \left({}^{mg}/_{m^3}\right) = 0.0409 \times concentration\ (PPM) \times molecular\ weight$$

$$Concentration\ (\%) = \frac{PPM}{10000}$$

APPENDIX D1 WAVENUMBER VRS TRANSMITTANCE OF DIESEL (FTIR)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3996.05656	0.99904	3916.5026	0.99901	3834.9088	0.99773
3994.01672	0.99944	3914.46276	0.99894	3832.86895	0.99823
3991.97687	0.99929	3912.42291	0.99893	3830.82911	0.99877
3989.93703	0.99884	3910.38307	0.99876	3828.78926	0.99873
3987.89718	0.99833	3908.34322	0.99842	3826.74942	0.9984
3985.85734	0.99831	3906.30338	0.99806	3824.70957	0.99854
3983.81749	0.99862	3904.26353	0.99798	3822.66973	0.99894
3981.77765	0.99862	3902.22369	0.99829	3820.62988	0.99869
3979.7378	0.99872	3900.18384	0.99878	3818.59004	0.99821
3977.69796	0.99888	3898.144	0.99928	3816.55019	0.99808
3975.65811	0.99845	3896.10415	0.99952	3814.51035	0.99811
3973.61827	0.99799	3894.06431	0.99929	3812.4705	0.9982
3971.57842	0.99822	3892.02446	0.99874	3810.43066	0.99828
3969.53858	0.9985	3889.98462	0.9985	3808.39081	0.99813
3967.49873	0.99813	3887.94477	0.9988	3806.35097	0.99783
3965.45888	0.99762	3885.90493	0.99883	3804.31112	0.99808

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3961.37919	0.9976	3881.82524	0.99776	3800.23143	0.99951
3959.33935	0.99764	3879.78539	0.99747	3798.19159	0.99967
3957.2995	0.99783	3877.74555	0.99774	3796.15174	0.99925
3955.25966	0.99827	3875.7057	0.99813	3794.1119	0.99843
3953.21981	0.99884	3873.66586	0.998	3792.07205	0.998
3951.17997	0.99915	3871.62601	0.99762	3790.03221	0.99822
3949.14012	0.99894	3869.58616	0.99737	3787.99236	0.99857
3947.10028	0.99873	3867.54632	0.9976	3785.95252	0.99823
3945.06043	0.99863	3865.50647	0.9982	3783.91267	0.99766
3943.02059	0.99815	3863.46663	0.99865	3781.87283	0.99786
3940.98074	0.99774	3861.42678	0.99862	3779.83298	0.99826
3938.9409	0.99767	3859.38694	0.99851	3777.79314	0.99858
3936.90105	0.99785	3857.34709	0.99894	3775.75329	0.99903
3934.86121	0.99814	3855.30725	0.99996	3773.71344	0.99912
3932.82136	0.99812	3853.2674	1.00038	3771.6736	0.99854
3930.78152	0.99823	3851.22756	0.99935	3769.63375	0.99789
3928.74167	0.99853	3849.18771	0.99877	3767.59391	0.99792
3926.70183	0.99841	3847.14787	0.99893	3765.55406	0.99821
3924.66198	0.99829	3845.10802	0.99931	3763.51422	0.99866
3922.62214	0.99855	3843.06818	0.99948	3761.47437	0.99909
3920.58229	0.99894	3841.02833	0.99923	3759.43453	0.99888
3753.31499	0.99882	3671.72119	0.9992	3590.12739	0.99913
3751.27515	0.99921	3669.68134	0.99993	3588.08754	0.99895
3749.2353	0.99906	3667.6415	1.00054	3586.0477	0.99856
3747.19546	0.99859	3665.60165	1.0004	3584.00785	0.9982

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
2309.10466	0.99771	2227.51086	0.99808	2145.91705	0.9986
2307.06481	0.9977	2225.47101	0.99785	2143.87721	0.9987
2305.02497	0.99737	2223.43116	0.99869	2141.83736	0.99965
2302.98512	0.99692	2221.39132	1.00086	2139.79752	1.00032
2300.94528	0.99632	2219.35147	1.00161	2137.75767	0.99968
2298.90543	0.99606	2217.31163	0.99976	2135.71783	0.99834
2296.86559	0.99635	2215.27178	0.99762	2133.67798	0.99715
2294.82574	0.99675	2213.23194	0.99786	2131.63814	0.9961
2292.7859	0.9971	2211.19209	0.99965	2129.59829	0.99619
2290.74605	0.99761	2209.15225	0.99981	2127.55844	0.99756
2288.70621	0.99801	2207.1124	0.9993	2125.5186	0.99878
2286.66636	0.99791	2205.07256	1.00007	2123.47875	0.99907
2121.43891	0.99859	2039.84511	1.00043	1958.2513	0.99912
2119.39906	0.99778	2037.80526	1.00195	1956.21146	0.99998
2117.35922	0.9974	2035.76542	1.0016	1954.17161	1.00014
2115.31937	0.99784	2033.72557	1.00041	1952.13177	1.00036
2113.27953	0.99897	2031.68572	0.99978	1950.09192	1.0017
2111.23968	1.00048	2029.64588	0.99945	1948.05208	1.00277
2109.19984	1.00135	2027.60603	0.99817	1946.01223	1.00195
2107.15999	1.00141	2025.56619	0.99767	1943.97239	0.99986
2105.12015	1.00077	2023.52634	0.99955	1941.93254	0.99853
2103.0803	0.99953	2021.4865	1.00214	1939.8927	0.9986
2101.04046	0.99904	2019.44665	1.00329	1937.85285	0.99831
2099.00061	0.99923	2017.40681	1.00313	1935.813	0.99758
2096.96077	0.99919	2015.36696	1.0028	1933.77316	0.99808

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
2084.7217	0.9984	2003.12789	1.00128	1921.53409	0.99801
2082.68185	0.99913	2001.08805	0.99969	1919.49424	0.99679
2080.64201	1.00092	1999.0482	0.99735	1917.4544	0.99713
2078.60216	1.0017	1997.00836	0.99689	1915.41455	0.99767
2076.56232	1.00058	1994.96851	0.99738	1913.37471	0.99751
2074.52247	0.99874	1992.92867	0.99812	1911.33486	0.99752
2072.48263	0.99816	1990.88882	0.99946	1909.29502	0.9978
2070.44278	0.99864	1988.84898	1.00002	1907.25517	0.99763
2068.40294	0.99898	1986.80913	0.99933	1905.21533	0.99719
2066.36309	0.99937	1984.76929	1.00002	1903.17548	0.99684
2064.32325	0.999	1982.72944	1.00319	1901.13564	0.99664
2062.2834	0.99708	1980.6896	1.00552	1899.09579	0.99704
2060.24356	0.99581	1978.64975	1.00414	1897.05595	0.99804
2058.20371	0.99655	1976.60991	1.00021	1895.0161	0.99847
2056.16387	0.99786	1974.57006	0.99827	1892.97626	0.99805
2054.12402	0.99836	1972.53022	1.00037	1890.93641	0.99802
2052.08418	0.99809	1970.49037	1.00292	1888.89657	0.99829
2048.00449	0.99678	1966.41068	1.00257	1884.81688	0.99782
2045.96464	0.9958	1964.37084	1.00201	1882.77703	0.9978
2043.9248	0.99605	1962.33099	1.00055	1880.73719	0.99746
2041.88495	0.9979	1960.29115	0.999	1878.69734	0.99705
1876.6575	0.99695	1795.06369	0.99577	1713.46989	0.99355
1874.61765	0.99701	1793.02385	0.99556	1711.43004	0.99357
1872.57781	0.99741	1790.984	0.99578	1709.3902	0.99352
1870.53796	0.99808	1788.94416	0.99605	1707.35035	0.99345

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

1860.33874	0.99717	1778.74493	0.99584	1697.15113	0.99371
1858.29889	0.99706	1776.70509	0.99593	1695.11128	0.9936
1856.25905	0.99701	1774.66524	0.99608	1693.07144	0.99346
1854.2192	0.99746	1772.6254	0.99598	1691.03159	0.99349
1852.17936	0.99801	1770.58555	0.99539	1688.99175	0.99352
1850.13951	0.99782	1768.54571	0.99507	1686.9519	0.99339
1848.09967	0.99734	1766.50586	0.99518	1684.91206	0.99334
1846.05982	0.99725	1764.46602	0.9954	1682.87221	0.99377
1844.01998	0.9971	1762.42617	0.9956	1680.83237	0.99391
1841.98013	0.9968	1760.38633	0.9957	1678.79252	0.99369
1839.94029	0.99677	1758.34648	0.99554	1676.75268	0.99349
1837.90044	0.99693	1756.30664	0.99518	1674.71283	0.99326
1835.86059	0.99684	1754.26679	0.9947	1672.67299	0.9929
1833.82075	0.99648	1752.22695	0.9943	1670.63314	0.99254
1831.7809	0.99613	1750.1871	0.99416	1668.5933	0.99264
1829.74106	0.99634	1748.14726	0.99391	1666.55345	0.99319
1827.70121	0.99719	1746.10741	0.99367	1664.51361	0.9935
1825.66137	0.99776	1744.06757	0.99375	1662.47376	0.99346
1823.62152	0.9978	1742.02772	0.99365	1660.43392	0.99332
1821.58168	0.99766	1739.98787	0.99348	1658.39407	0.99315
1819.54183	0.99755	1737.94803	0.99359	1656.35423	0.99289
1817.50199	0.99766	1735.90818	0.99353	1654.31438	0.9924
1815.46214	0.99788	1733.86834	0.99335	1652.27454	0.9921
1813.4223	0.9977	1731.82849	0.99366	1650.23469	0.99239
1811.38245	0.99718	1729.78865	0.99405	1648.19485	0.99275
1809.34261	0.99679	1727.7488	0.99419	1646.155	0.99319
1807.30276	0.99673	1725.70896	0.99417	1644.11515	0.99322

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance (%)	Wavenumber (cm^{-1})	Transmittance (%)	Wavenumber (cm^{-1})	Transmittance (%)
1631.87608	0.99218	1550.28228	0.98984	1468.68848	0.85198
1629.83624	0.9923	1548.24243	0.99028	1466.64863	0.83537
1627.79639	0.99209	1546.20259	0.99038	1464.60879	0.82249
1625.75655	0.99146	1544.16274	0.99019	1462.56894	0.81424
1623.7167	0.99062	1542.1229	0.98986	1460.5291	0.80823
1621.67686	0.98966	1540.08305	0.98918	1458.48925	0.80259
1619.63701	0.98869	1538.04321	0.98884	1456.44941	0.80136
1617.59717	0.98719	1536.00336	0.98864	1454.40956	0.80721
1615.55732	0.98545	1533.96352	0.9882	1452.36972	0.81529
1613.51748	0.98472	1531.92367	0.98772	1450.32987	0.82479
1611.47763	0.98404	1529.88383	0.9873	1448.29002	0.837
1609.43779	0.98281	1527.84398	0.98669	1446.25018	0.85288
1607.39794	0.98208	1525.80414	0.98574	1444.21033	0.86975
1605.3581	0.98265	1523.76429	0.98463	1442.17049	0.88666
1603.31825	0.9838	1521.72445	0.98332	1440.13064	0.90166
1601.27841	0.98483	1519.6846	0.98187	1438.0908	0.91486
1599.23856	0.98572	1517.64476	0.98031	1436.05095	0.92921
1597.19872	0.98662	1515.60491	0.97915	1434.01111	0.94019
1595.15887	0.98726	1513.56507	0.97862	1431.97126	0.94714
1593.11903	0.98753	1511.52522	0.97804	1429.93142	0.95335
1591.07918	0.98799	1509.48538	0.97712	1427.89157	0.95834
1589.03934	0.98881	1507.44553	0.9753	1425.85173	0.96158
1586.99949	0.98931	1505.40569	0.97342	1423.81188	0.96425

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1580.87996	0.99091	1499.28615	0.97198	1417.69235	0.97025
1578.84011	0.99121	1497.24631	0.96989	1415.6525	0.97116
1576.80027	0.99133	1495.20646	0.96782	1413.61266	0.97209
1574.76042	0.99168	1493.16662	0.96703	1411.57281	0.9731
1572.72058	0.99188	1491.12677	0.9663	1409.53297	0.97369
1570.68073	0.99155	1489.08693	0.96501	1407.49312	0.97379
1568.64089	0.99092	1487.04708	0.96377	1405.45328	0.97388
1566.60104	0.9906	1485.00724	0.96208	1403.41343	0.97422
1564.5612	0.99057	1482.96739	0.95903	1401.37359	0.9743
1562.52135	0.9906	1480.92755	0.9543	1399.33374	0.97368
1560.48151	0.99023	1478.8877	0.94833	1397.2939	0.97255
1558.44166	0.98943	1476.84786	0.94056	1395.25405	0.97054
1556.40182	0.98947	1474.80801	0.92828	1393.21421	0.96721
1554.36197	0.98947	1472.76817	0.90432	1391.17436	0.96291
1552.32213	0.98948	1470.72832	0.8741	1389.13452	0.95581
1387.09467	0.94295	1305.50087	0.97138	1223.90706	0.97974
1385.05483	0.92812	1303.46102	0.97097	1221.86722	0.97976
1383.01498	0.91509	1301.42118	0.97111	1219.82737	0.97956
1380.97514	0.90114	1299.38133	0.97161	1217.78753	0.97918
1378.93529	0.88763	1297.34149	0.97206	1215.74768	0.97885
1376.89545	0.88199	1295.30164	0.97221	1213.70784	0.97872
1374.8556	0.88947	1293.2618	0.97224	1211.66799	0.97875
1372.81576	0.90496	1291.22195	0.97233	1209.62815	0.97887
1370.77591	0.91651	1289.18211	0.9727	1207.5883	0.97918
1368.73607	0.92135	1287.14226	0.97328	1205.54846	0.9795

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1356.497	0.95972	1274.90319	0.97456	1193.30939	0.98076
1354.45715	0.96167	1272.86335	0.97423	1191.26954	0.98028
1352.4173	0.96291	1270.8235	0.97405	1189.2297	0.98013
1350.37746	0.96391	1268.78366	0.97393	1187.18985	0.98004
1348.33761	0.9648	1266.74381	0.97374	1185.15001	0.97975
1346.29777	0.96528	1264.70397	0.97356	1183.11016	0.9795
1344.25792	0.96532	1262.66412	0.97375	1181.07032	0.97897
1342.21808	0.96527	1260.62428	0.97445	1179.03047	0.97796
1340.17823	0.96567	1258.58443	0.97522	1176.99063	0.97676
1338.13839	0.9668	1256.54458	0.97563	1174.95078	0.97531
1336.09854	0.96813	1254.50474	0.9758	1172.91094	0.97352
1334.0587	0.96953	1252.46489	0.97597	1170.87109	0.97211
1332.01885	0.97081	1250.42505	0.97618	1168.83125	0.97188
1329.97901	0.97163	1248.3852	0.97643	1166.7914	0.97248
1327.93916	0.97223	1246.34536	0.97691	1164.75156	0.97325
1325.89932	0.97282	1244.30551	0.97757	1162.71171	0.97396
1323.85947	0.97316	1242.26567	0.97811	1160.67186	0.97428
1321.81963	0.97334	1240.22582	0.97854	1158.63202	0.97399
1319.77978	0.97368	1238.18598	0.97896	1156.59217	0.97356
1317.73994	0.97381	1236.14613	0.97917	1154.55233	0.97354
1315.70009	0.97334	1234.10629	0.97914	1152.51248	0.9738
1313.66025	0.97266	1232.06644	0.97933	1150.47264	0.97401
1311.6204	0.97226	1230.0266	0.97971	1148.43279	0.97429
1309.58056	0.97219	1227.98675	0.97981	1146.39295	0.97473
1307.54071	0.97197	1225.94691	0.97971	1144.3531	0.97527

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1142.31326	0.97587	1060.71945	0.9739	979.12565	0.96996
1140.27341	0.97628	1058.67961	0.97383	977.08581	0.9693
1138.23357	0.97634	1056.63976	0.97374	975.04596	0.96785
1136.19372	0.97636	1054.59992	0.97374	973.00612	0.96616
1134.15388	0.97678	1052.56007	0.97369	970.96627	0.96508
1132.11403	0.97744	1050.52023	0.97382	968.92643	0.96481
1130.07419	0.97787	1048.48038	0.97399	966.88658	0.96489
1128.03434	0.97788	1046.44054	0.97367	964.84673	0.96543
1125.9945	0.97762	1044.40069	0.97299	962.80689	0.96667
1123.95465	0.97742	1042.36085	0.97244	960.76704	0.96771
1121.91481	0.97767	1040.321	0.97186	958.7272	0.96795
1119.87496	0.9784	1038.28116	0.97126	956.68735	0.968
1117.83512	0.97919	1036.24131	0.97095	954.64751	0.96831
1115.79527	0.97976	1034.20147	0.9707	952.60766	0.96857
1113.75543	0.98002	1032.16162	0.97024	950.56782	0.96856
1111.71558	0.9799	1030.12178	0.96993	948.52797	0.96854
1109.67574	0.97954	1028.08193	0.97006	946.48813	0.96882
1107.63589	0.97908	1026.04209	0.97043	944.44828	0.96959
1105.59605	0.97863	1024.00224	0.97088	942.40844	0.97056
1103.5562	0.97837	1021.9624	0.97114	940.36859	0.97097
1101.51636	0.97809	1019.92255	0.97111	938.32875	0.97087
1099.47651	0.97754	1017.88271	0.97114	936.2889	0.97086
1097.43667	0.97665	1015.84286	0.97135	934.24906	0.97101
1095.39682	0.9759	1013.80302	0.97171	932.20921	0.97127
1093.35698	0.976	1011.76317	0.972	930.16937	0.97145

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1087.23744	0.97628	1005.64364	0.97184	924.04983	0.97174
1085.1976	0.97623	1003.60379	0.97171	922.00999	0.97145
1083.15775	0.97618	1001.56395	0.97153	919.97014	0.97086
1081.11791	0.97585	999.5241	0.97174	917.9303	0.97049
1079.07806	0.97509	997.48426	0.9724	915.89045	0.97047
1077.03822	0.97429	995.44441	0.97283	913.85061	0.97081
1074.99837	0.97414	993.40457	0.9729	911.81076	0.97109
1072.95853	0.97455	991.36472	0.97289	909.77092	0.97096
1070.91868	0.97471	989.32488	0.9725	907.73107	0.9707
1068.87884	0.97455	987.28503	0.97175	905.69123	0.97062
1066.83899	0.9744	985.24519	0.97105	903.65138	0.97056
1064.79915	0.97408	983.20534	0.9705	901.61154	0.97051
1062.7593	0.97385	981.1655	0.97016	899.57169	0.9704
897.53185	0.96979	815.93804	0.96374	734.34424	0.94337
895.492	0.96883	813.8982	0.96066	732.30439	0.94309
893.45216	0.96803	811.85835	0.95762	730.26455	0.93806
891.41231	0.96759	809.81851	0.95531	728.2247	0.9325
889.37247	0.96741	807.77866	0.95311	726.18486	0.93115
887.33262	0.96747	805.73882	0.9515	724.14501	0.93278
885.29278	0.96792	803.69897	0.95309	722.10517	0.93555
883.25293	0.96862	801.65913	0.95834	720.06532	0.94027
881.21309	0.9689	799.61928	0.96365	718.02548	0.94652
879.17324	0.9682	797.57944	0.96522	715.98563	0.95315
877.1334	0.9674	795.53959	0.96381	713.94579	0.95906
875.09355	0.96747	793.49975	0.963	711.90594	0.96296

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
871.01386	0.96812	789.42006	0.96286	707.82625	0.96434
868.97401	0.9692	787.38021	0.96228	705.78641	0.96273
866.93417	0.9703	785.34037	0.95932	703.74656	0.95991
864.89432	0.97108	783.30052	0.95482	701.70672	0.95623
862.85448	0.97199	781.26068	0.953	699.66687	0.95202
860.81463	0.97266	779.22083	0.95433	697.62703	0.94912
858.77479	0.97284	777.18099	0.95556	695.58718	0.94989
856.73494	0.97288	775.14114	0.9545	693.54734	0.95257
854.6951	0.97256	773.10129	0.95046	691.50749	0.95523
852.65525	0.97141	771.06145	0.94319	689.46765	0.96023
850.61541	0.96927	769.0216	0.9349	687.4278	0.96813
848.57556	0.96665	766.98176	0.93163	685.38796	0.97573
846.53572	0.96517	764.94191	0.93675	683.34811	0.98097
844.49587	0.96579	762.90207	0.94616	681.30827	0.98351
842.45603	0.96762	760.86222	0.95356	679.26842	0.98327
840.41618	0.96902	758.82238	0.95673	677.22857	0.98135
838.37634	0.96874	756.78253	0.95711	675.18873	0.98053
836.33649	0.96703	754.74269	0.95558	673.14888	0.98204
834.29665	0.96596	752.70284	0.95354	671.10904	0.98392
832.2568	0.96731	750.663	0.95293	669.06919	0.98489
830.21696	0.96975	748.62315	0.95206	667.02935	0.98509
828.17711	0.97075	746.58331	0.94828	664.9895	0.98499
826.13727	0.97044	744.54346	0.94071	662.94966	0.98474
824.09742	0.96945	742.50362	0.93136	660.90981	0.98458
822.05758	0.9678	740.46377	0.9273	658.86997	0.98547

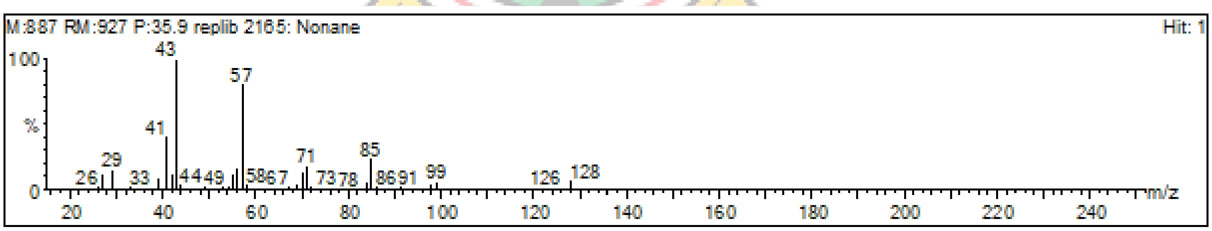
Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

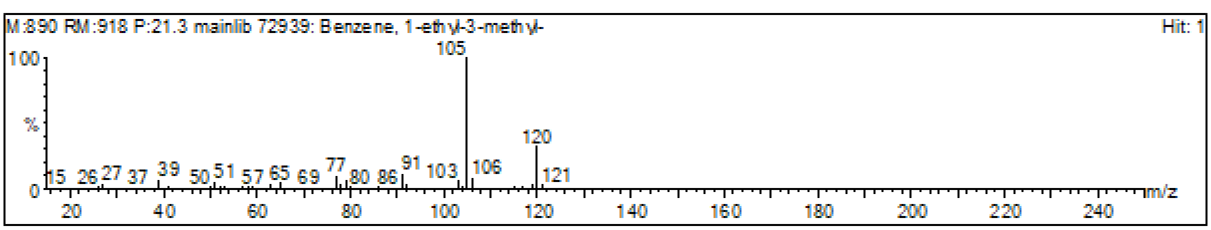
Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
652.75043	0.98764	571.15663	0.98312	489.56283	0.98175
650.71059	0.9882	569.11678	0.98228	487.52298	0.97993
648.67074	0.98842	567.07694	0.98267	485.48314	0.97816
646.6309	0.98814	565.03709	0.98313	483.44329	0.97628
644.59105	0.98789	562.99725	0.98268	481.40344	0.97541
642.55121	0.98774	560.9574	0.98283	479.3636	0.97358
640.51136	0.9874	558.91756	0.98325	477.32375	0.97009
638.47152	0.98741	556.87771	0.98287	475.28391	0.96789
636.43167	0.98739	554.83787	0.98193	473.24406	0.96873
634.39183	0.98614	552.79802	0.98074	471.20422	0.97385
632.35198	0.9855	550.75818	0.97987	469.16437	0.98101
630.31214	0.98692	548.71833	0.97853	467.12453	0.98411
628.27229	0.98799	546.67849	0.97618	465.08468	0.98155
626.23245	0.98731	544.63864	0.97552	463.04484	0.97812
624.1926	0.98565	542.5988	0.97639	461.00499	0.97727
622.15276	0.98403	540.55895	0.97514	458.96515	0.97807
620.11291	0.98414	538.51911	0.97284	456.9253	0.97936
618.07307	0.98644	536.47926	0.97264	454.88546	0.97988
616.03322	0.98833	534.43942	0.9746	452.84561	0.98005
613.99338	0.98799	532.39957	0.97829	450.80577	0.97988
611.95353	0.98731	530.35973	0.98153	448.76592	0.97939
609.91369	0.98734	528.31988	0.98143	446.72608	0.98059
607.87384	0.98669	526.28004	0.98097	444.68623	0.98072
605.834	0.98509	524.24019	0.98258	442.64639	0.97779
603.79415	0.9843	522.20035	0.98299	440.60654	0.97236

Appendix D1 Wavenumbers vrs Transmittance of Diesel (FTIR) (Continued)

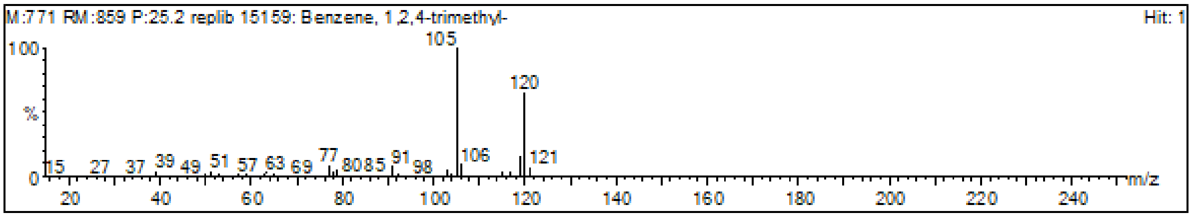
597.67462	0.98727	516.08081	0.98276	434.48701	0.9649
595.63477	0.98901	514.04097	0.98195	432.44716	0.96724
593.59493	0.98813	512.00112	0.98203	430.40732	0.9688
591.55508	0.98591	509.96128	0.98497	428.36747	0.97393
589.51524	0.985	507.92143	0.98708	426.32763	0.97897
587.47539	0.98588	505.88159	0.98513	424.28778	0.9798
585.43555	0.98695	503.84174	0.98265	422.24794	0.98091
583.3957	0.98683	501.8019	0.98277	420.20809	0.98864
581.35586	0.98579	499.76205	0.98336	418.16825	0.99232
579.31601	0.98456	497.72221	0.98223	416.1284	0.98591
577.27616	0.98382	495.68236	0.98139	414.08856	0.98275
575.23632	0.98384	493.64252	0.98272	412.04871	0.98396
573.19647	0.98386	491.60267	0.98347	410.00887	0.98617

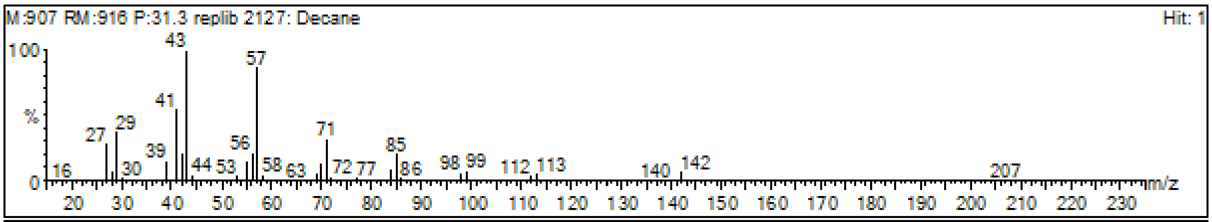
APPENDIX D2 DIESEL CHROMATOGRAM/SPECTRUM PEAK REPORT

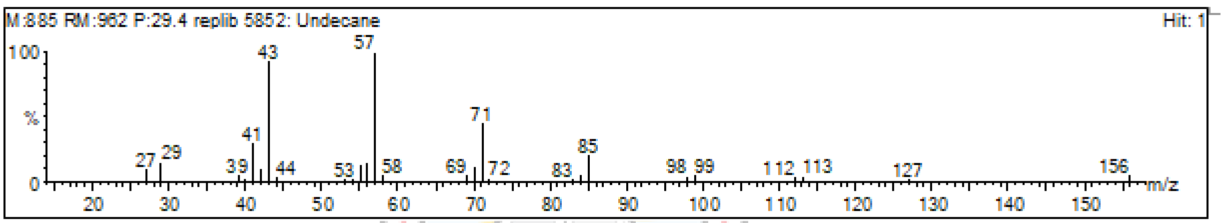


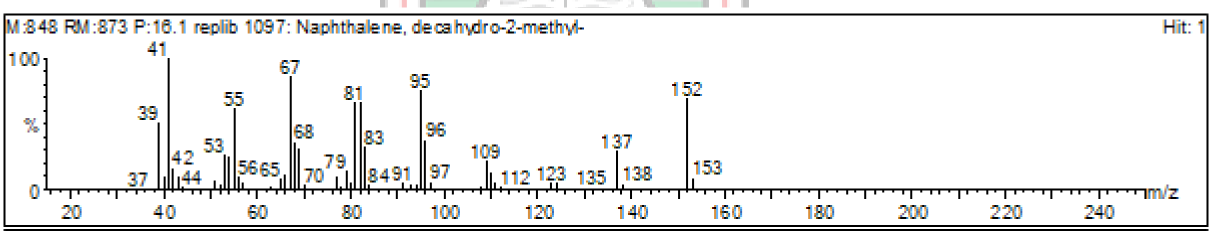


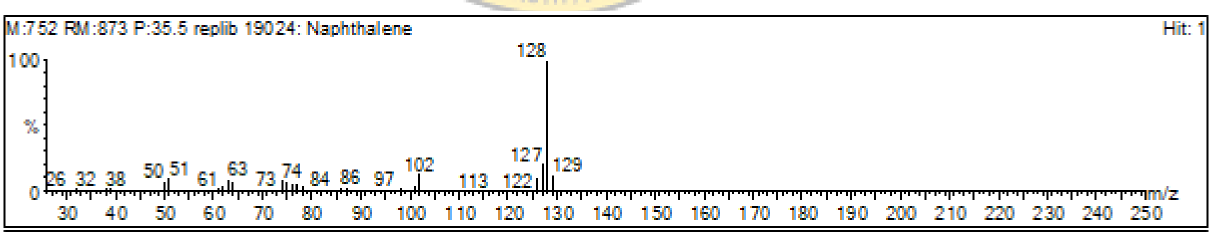
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)

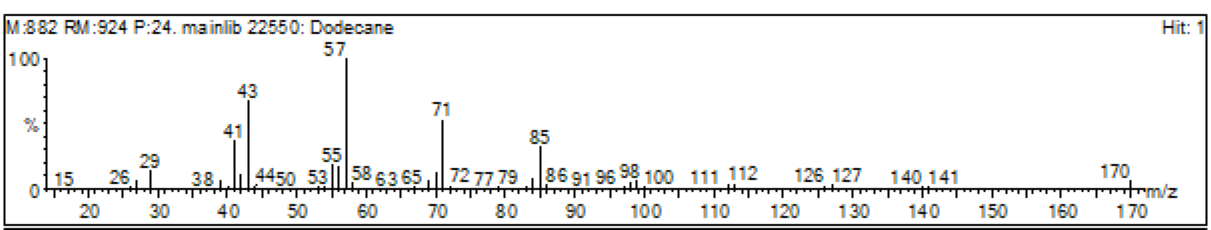




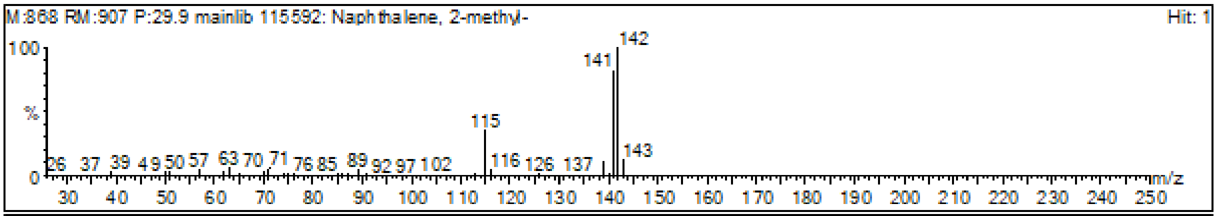


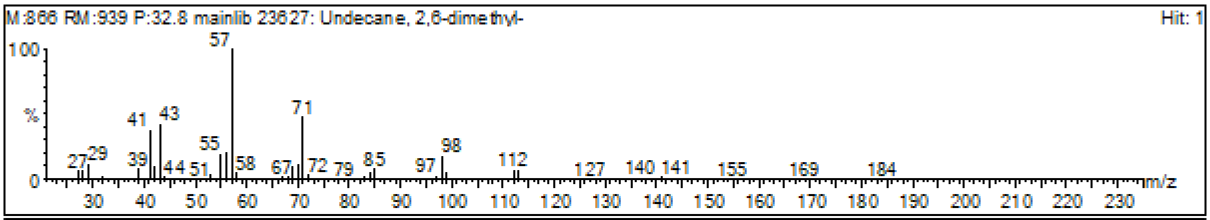


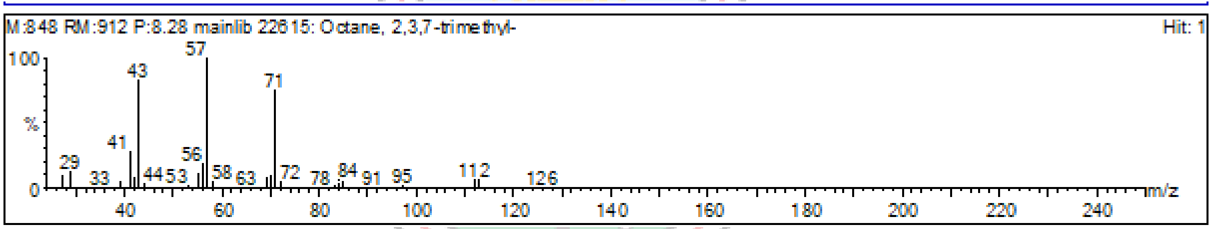


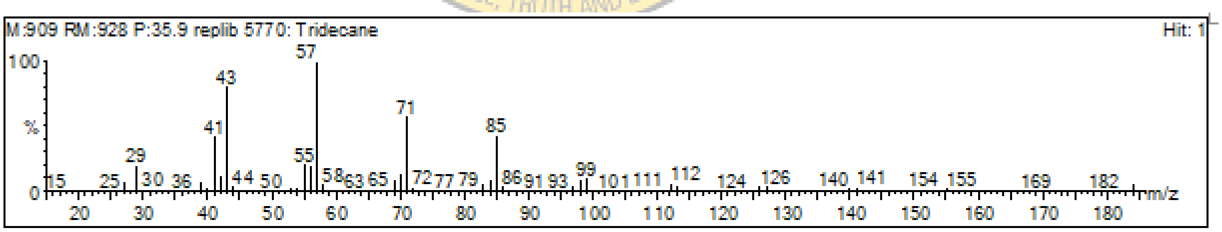


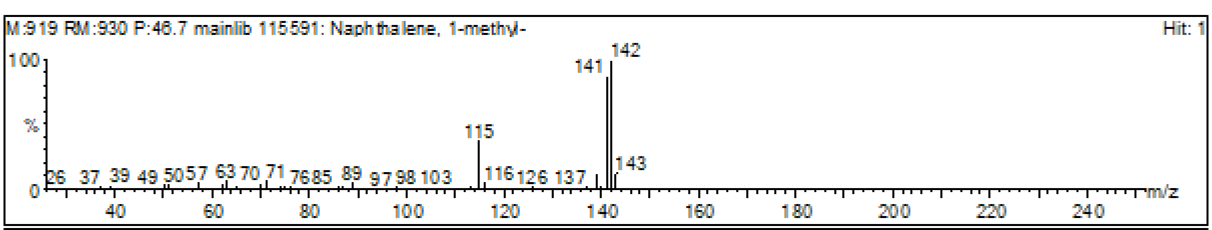
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



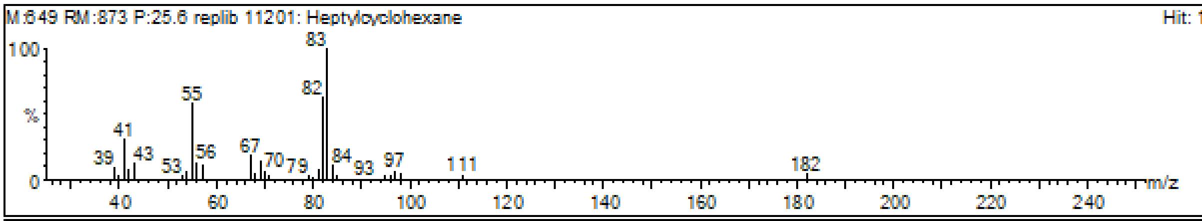


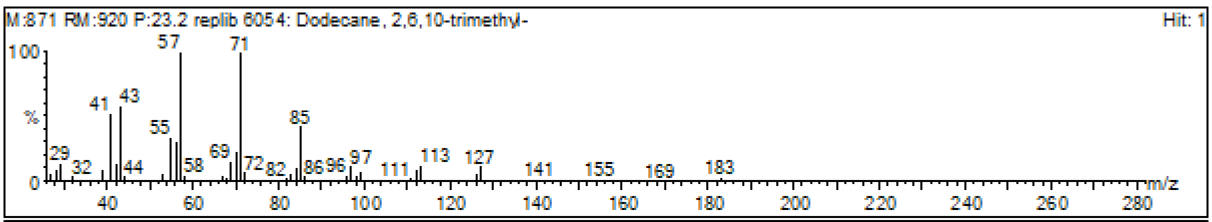


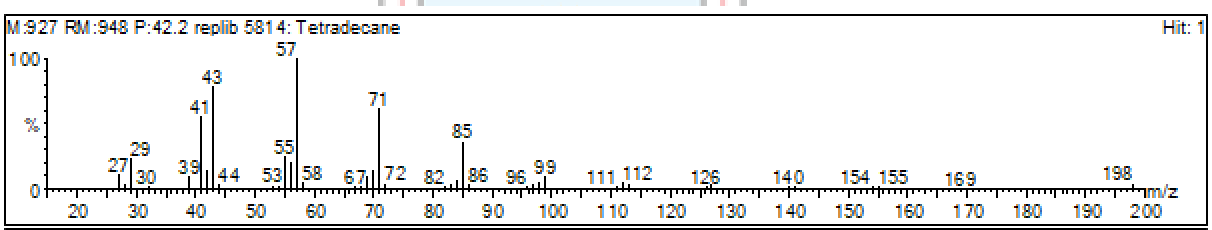


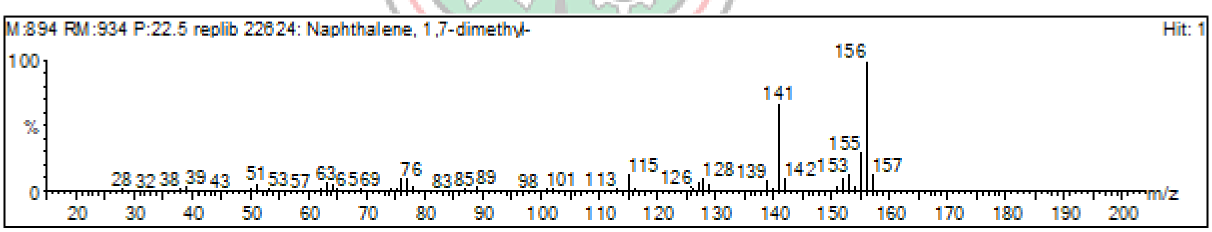


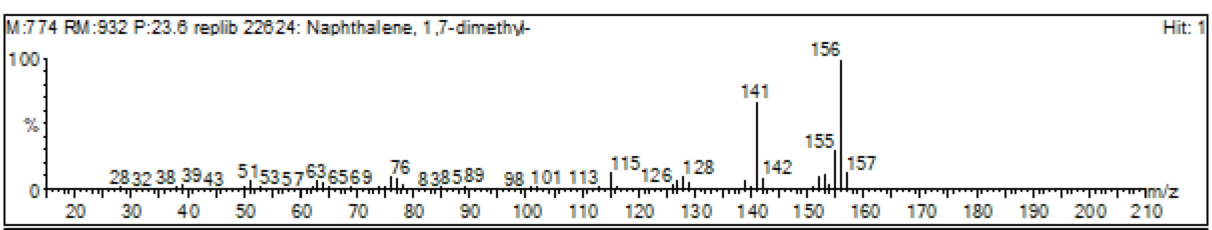
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



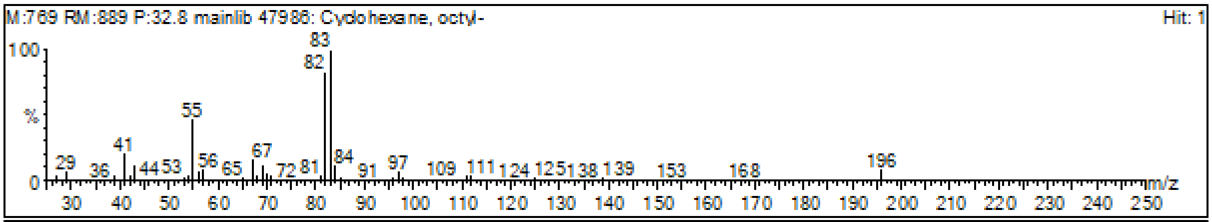


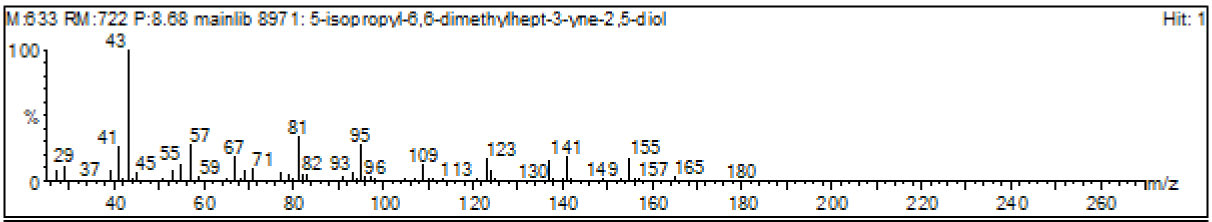


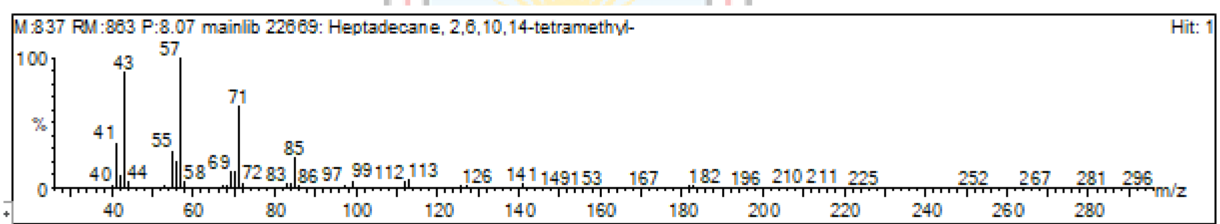


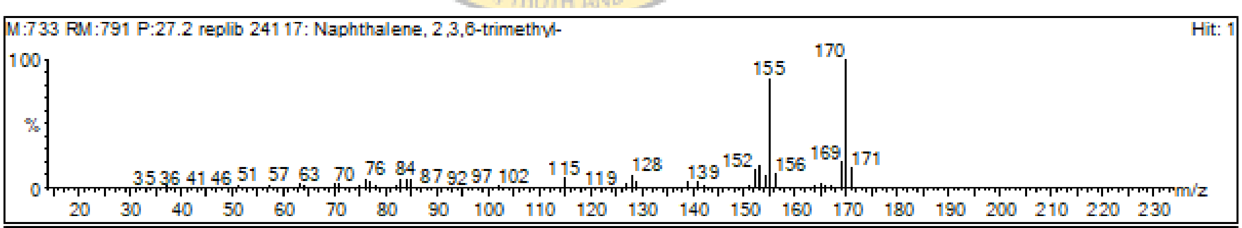


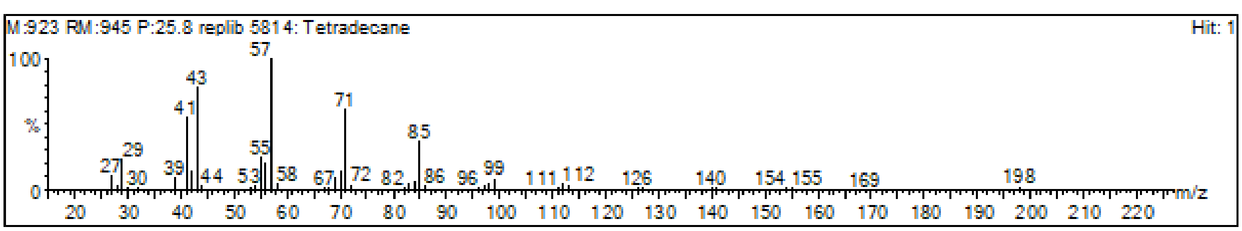
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



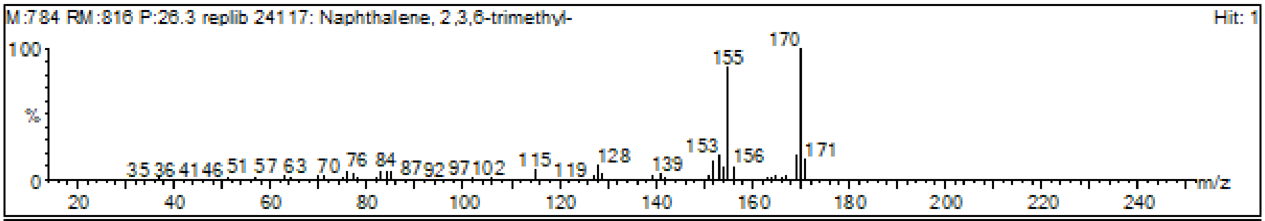


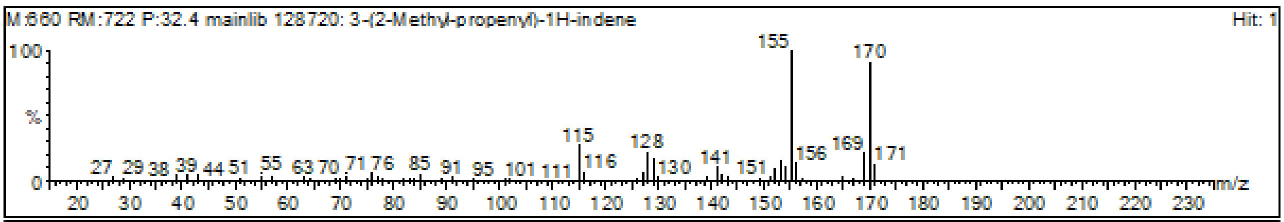


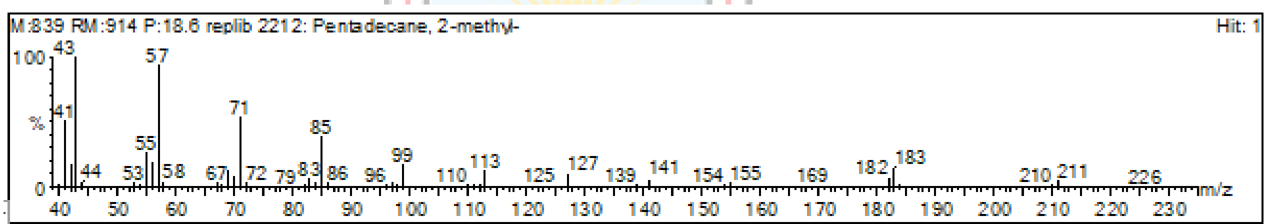


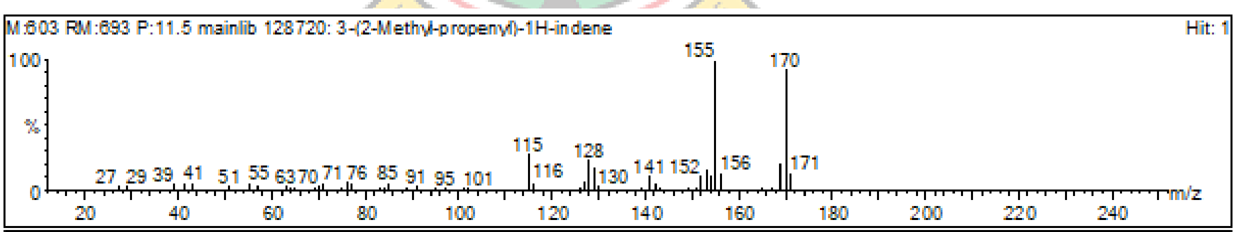


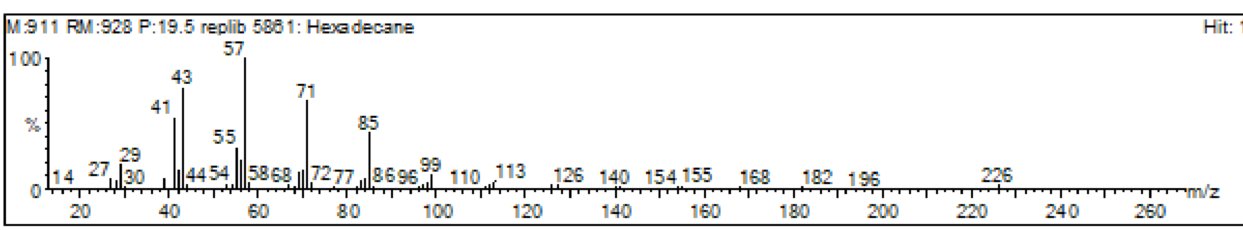
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



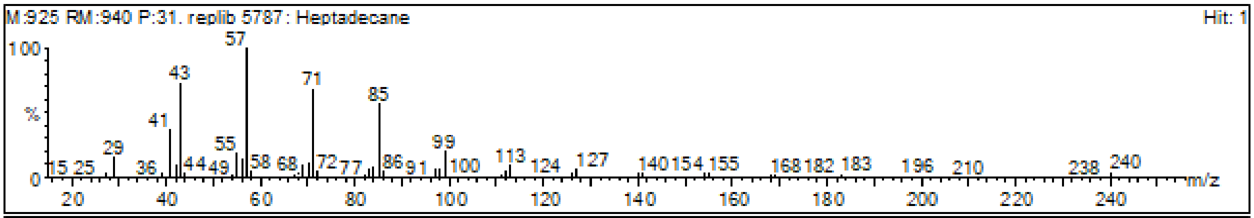


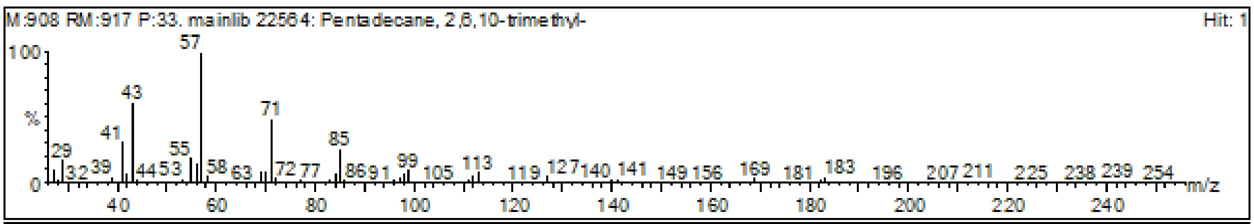


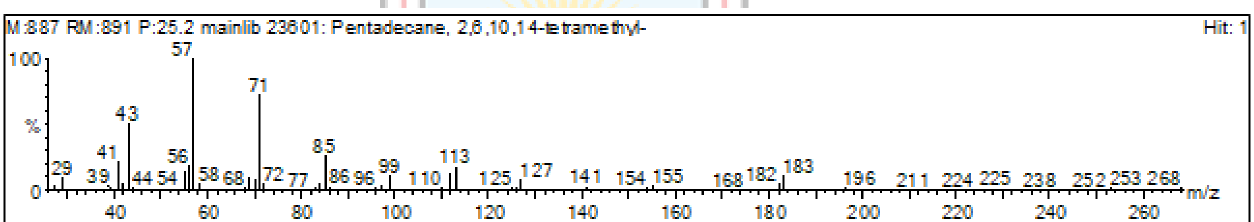


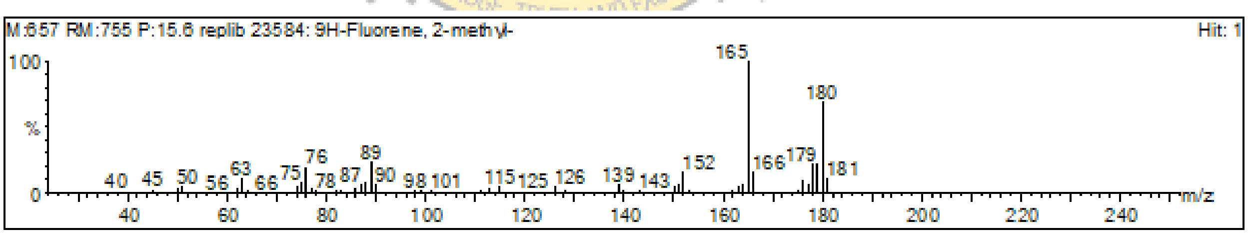


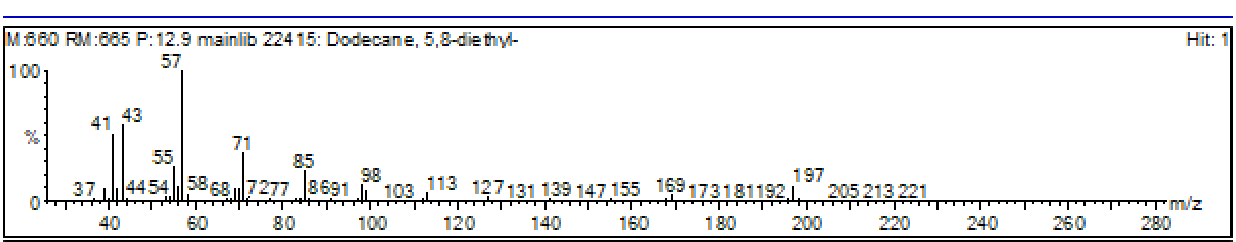
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



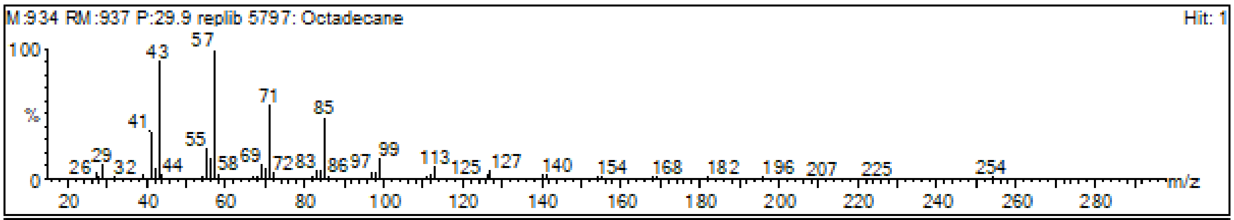


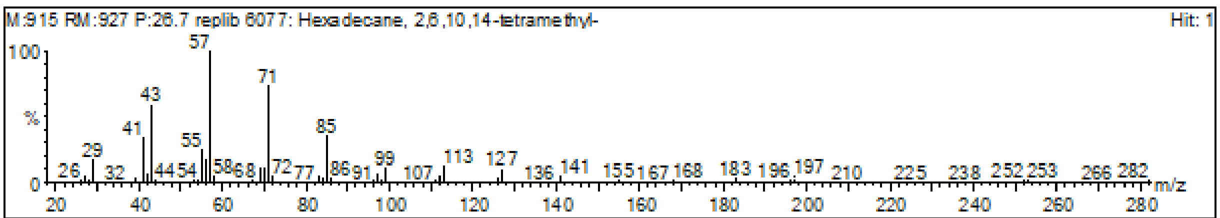


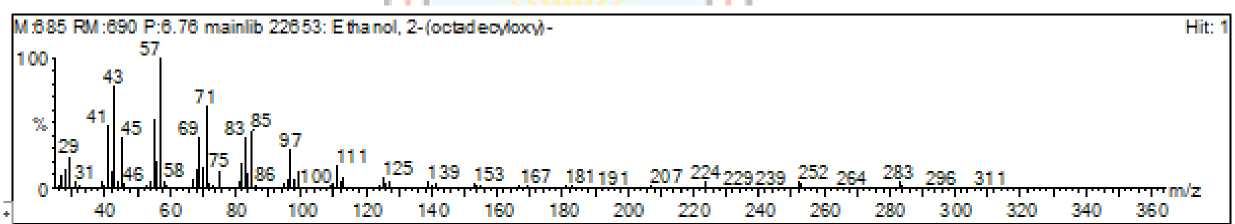


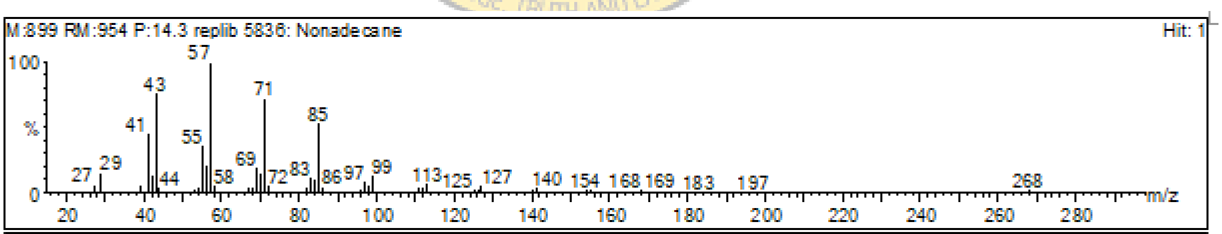


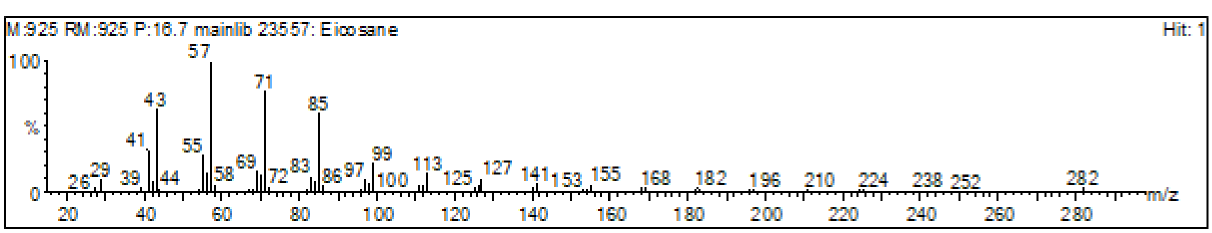
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



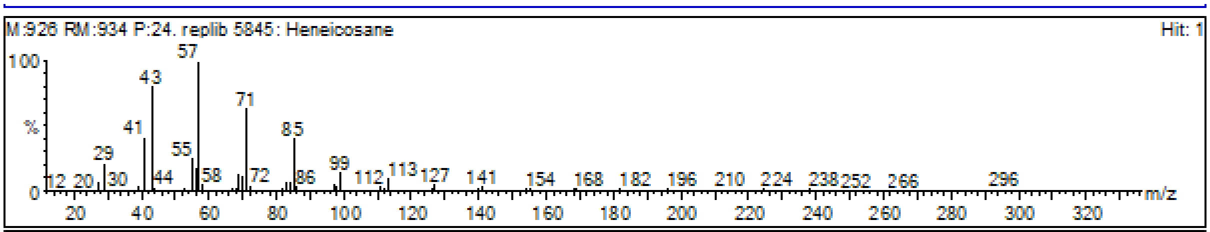


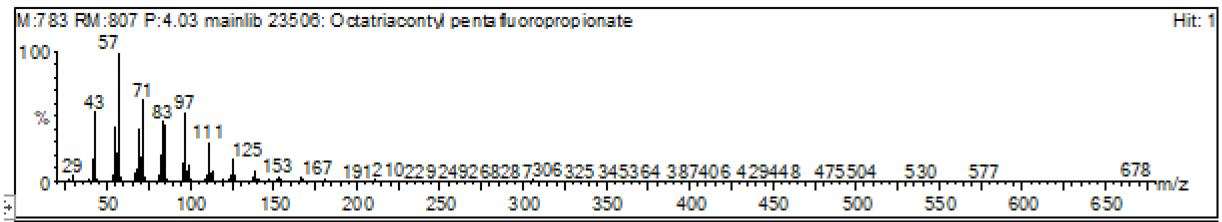


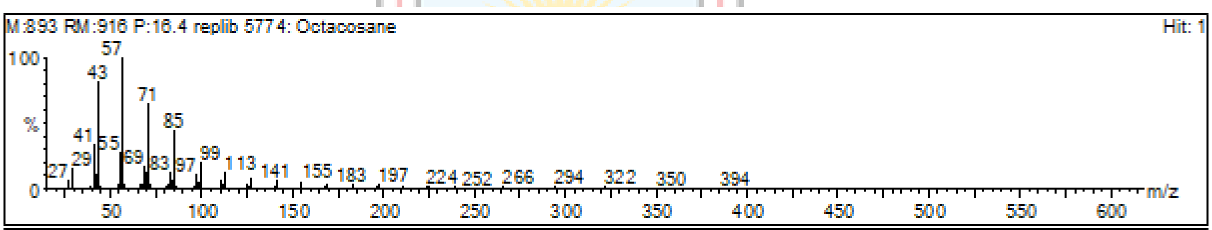


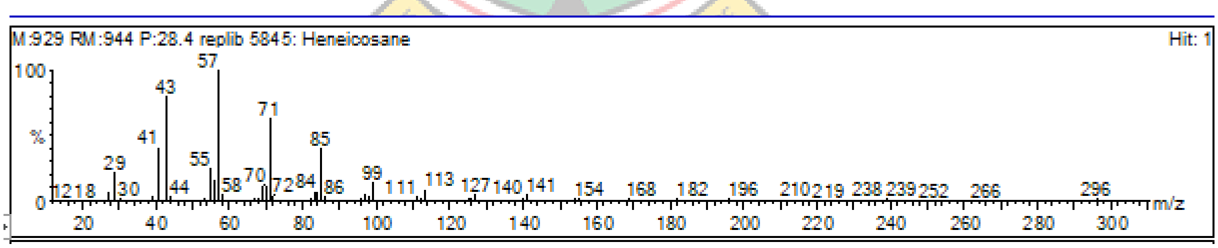


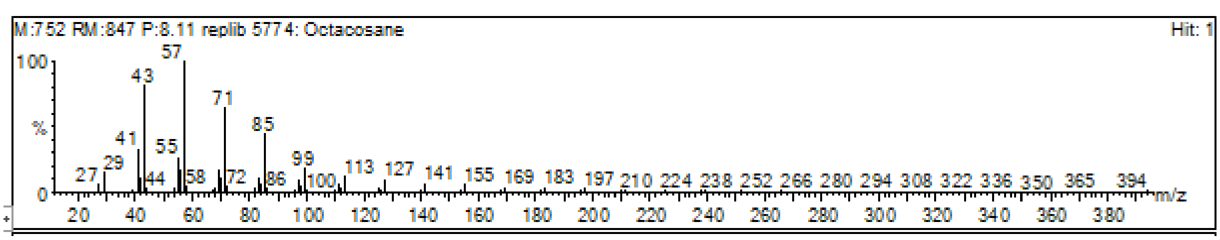
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



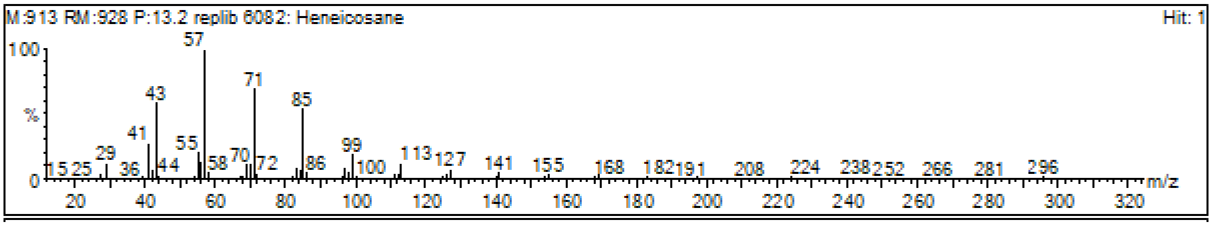


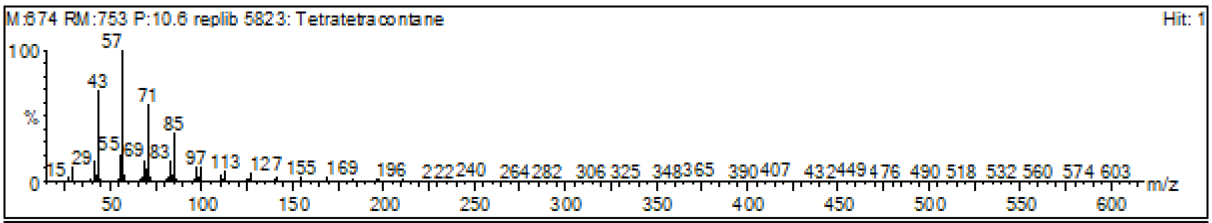


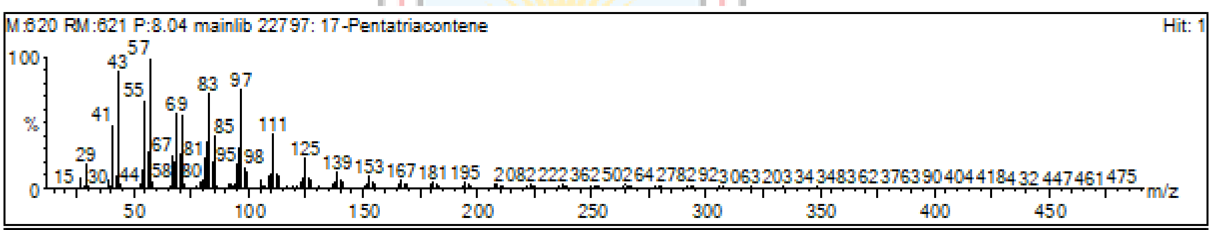


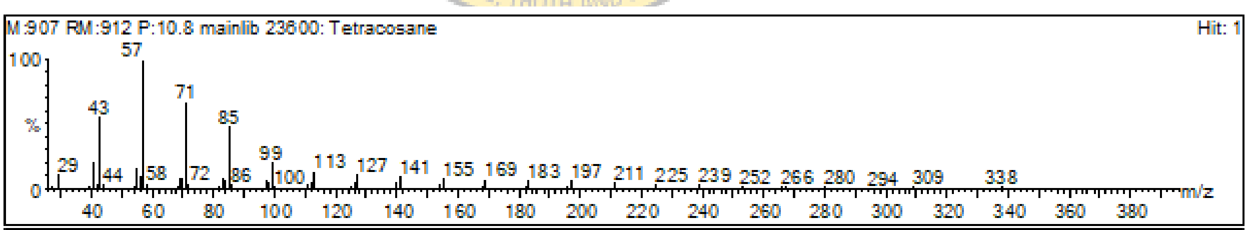


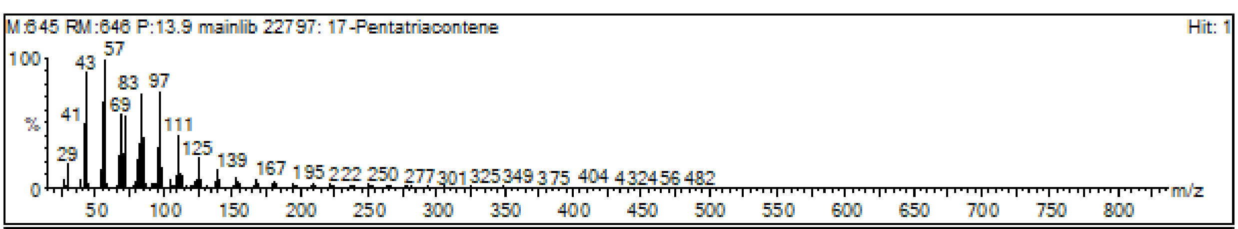
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



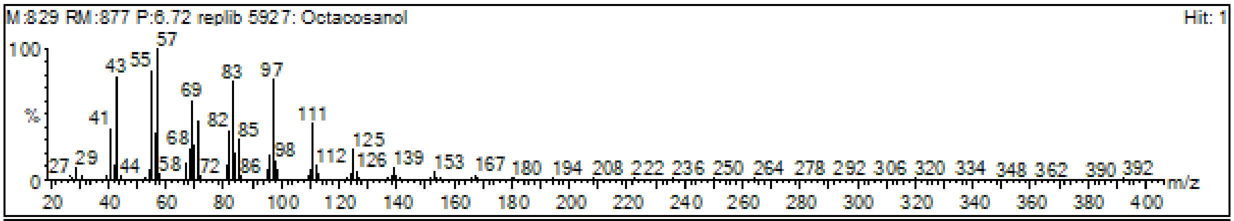


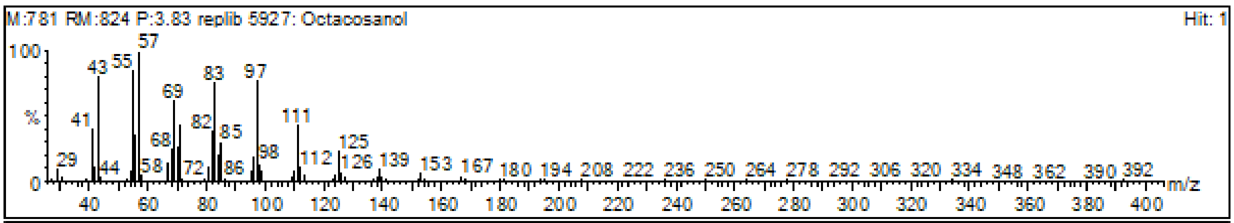


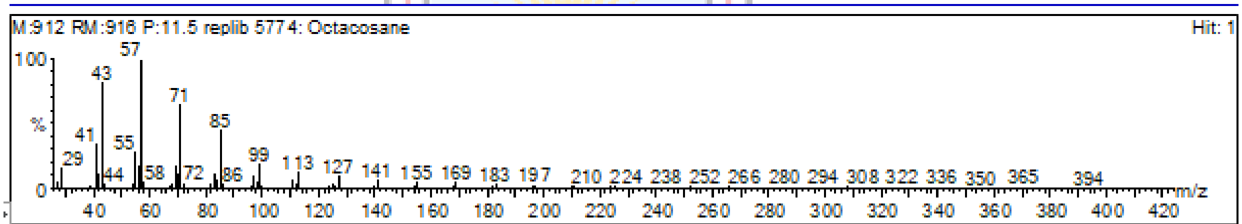


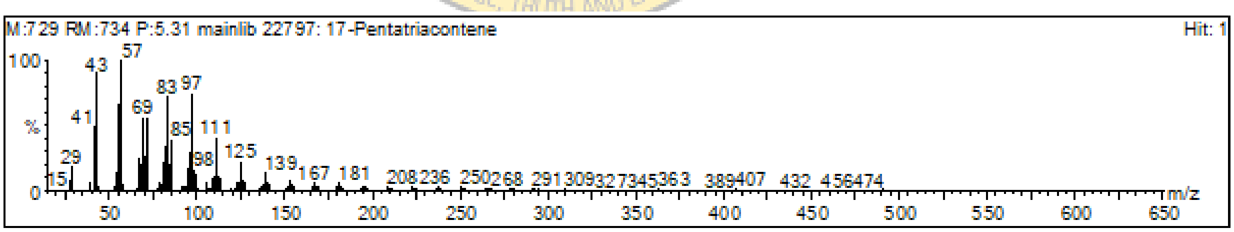


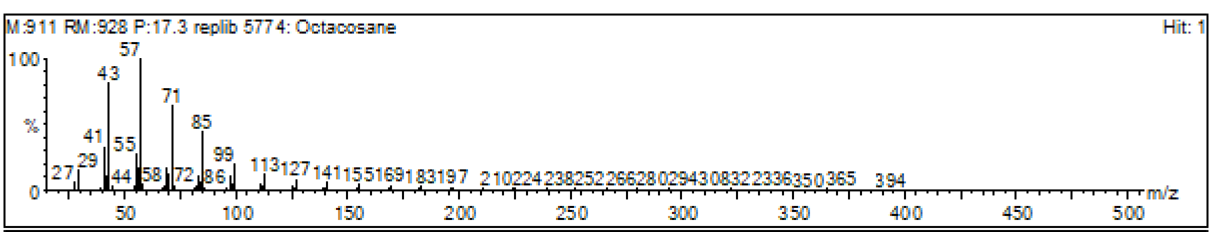
APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)



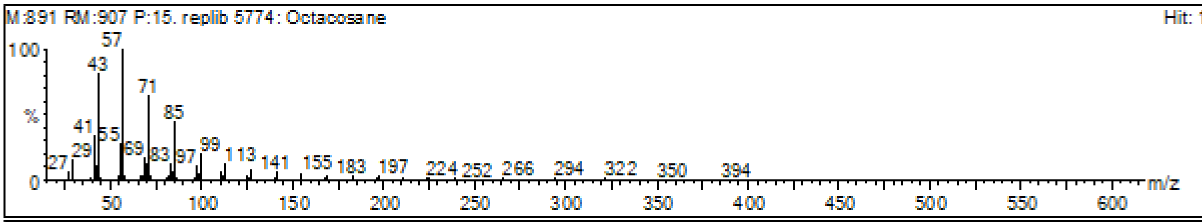


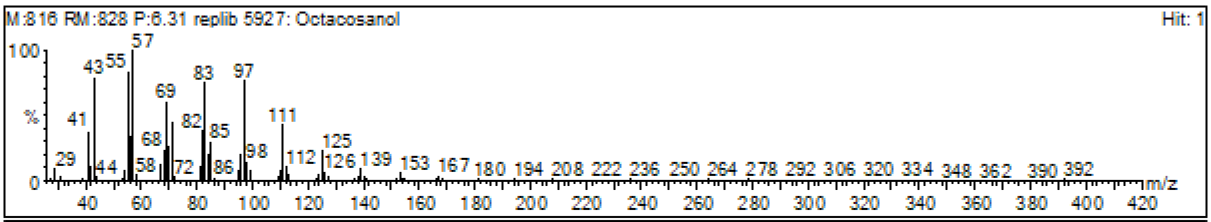


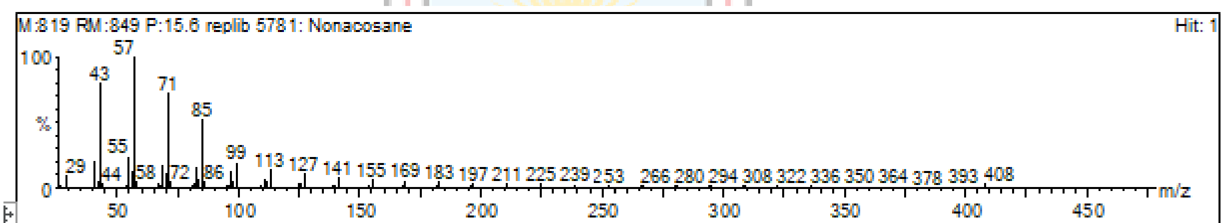




APPENDIX D2 Diesel Chromatogram/Spectrum Peak Report (Continued)







APPENDIX E QUALITATIVE REPORT SHOWING HEXADECANOIC ACID

#	RT	Scan	Height	Area	Area %	Norm %	Name	
1	4.639	164	536,314,208	30,310,706.0	0.803	16.80		
2	5.679	268	308,755,520	18,241,490.0	0.483	10.11		
3	8.189	519	157,951,568	14,958,910.0	0.396	8.29		
4	9.060	606	363,473,504	18,434,318.0	0.488	10.22		
5	9.330	633	359,728,992	19,508,750.0	0.517	10.81		
6	10.060	706	251,626,592	24,543,322.0	0.650	13.60		
7	12.770	977	528,923,840	29,835,580.0	0.790	16.54		
8	13.430	1043	198,175,728	15,497,358.0	0.410	8.59		
9	15.361	1236	161,530,096	15,539,794.0	0.411	8.61	Hexadecanoic acid,	0.000
10	15.901	1290	811,558,272	48,664,536.0	1.289	26.98		
11	16.281	1328	332,653,504	18,284,642.0	0.484	10.14		
12	17.981	1498	415,258,656	34,509,476.0	0.914	19.13		
13	18.621	1562	465,119,648	26,011,120.0	0.689	14.42		
14	18.791	1579	870,138,496	53,108,832.0	1.406	29.44		
15	19.091	1609	382,055,616	23,573,074.0	0.624	13.07		
16	19.862	1686	162,339,200	16,111,305.0	0.427	8.93		
17	20.802	1780	518,605,952	24,462,558.0	0.648	13.56		
18	21.482	1848	1,099,037,056	69,872,784.0	1.850	38.73		
19	21.652	1865	313,491,616	21,369,384.0	0.566	11.85		
20	21.992	1899	599,643,136	42,652,864.0	1.129	23.64		
21	22.082	1908	463,532,512	28,838,408.0	0.764	15.99		
22	22.582	1958	228,827,216	28,949,920.0	0.767	16.05		

Appendix E Qualitative Report Showing Hexadecanoic Acid (Continued)

#	RT	Scan	Height	Area	Area %	Norm %	Name	
23	22.902	1990	310,767,104	19,113,222.0	0.506	10.59		
24	23.002	2000	638,324,672	45,229,844.0	1.198	25.07		
25	23.982	2098	1,241,139,456	92,374,048.0	2.446	51.21		
26	24.142	2114	173,385,936	18,811,824.0	0.498	10.43		
27	25.153	2215	398,826,560	29,045,780.0	0.769	16.10		
28	25.223	2222	344,941,632	19,956,146.0	0.528	11.06		
29	25.443	2244	188,603,120	15,543,507.0	0.412	8.62		
30	25.603	2260	247,905,328	21,289,642.0	0.564	11.80		
31	26.353	2335	1,398,066,176	101,613,072.0	2.691	56.33		
32	27.423	2442	564,815,744	39,562,572.0	1.048	21.93		
33	28.583	2558	1,170,909,440	92,435,304.0	2.448	51.24		
34	28.703	2570	1,253,345,920	84,360,016.0	2.234	46.76		
35	28.813	2581	151,308,816	15,818,302.0	0.419	8.77		
36	29.503	2650	96,836,440	15,766,062.0	0.417	8.74		
37	30.714	2771	1,130,508,032	63,817,508.0	1.690	35.38		
38	30.884	2788	702,483,328	48,238,708.0	1.277	26.74		
39	31.964	2896	171,096,576	17,177,248.0	0.455	9.52		
40	32.744	2974	1,311,478,400	78,232,504.0	2.072	43.37		
41	34.685	3168	1,149,643,520	66,914,772.0	1.772	37.09		
42	35.795	3279	195,000,576	34,265,876.0	0.907	18.99		
43	36.525	3352	1,401,805,696	124,146,376.0	3.287	68.82		
44	37.085	3408	553,284,032	71,779,408.0	1.901	39.79		
45	38.305	3530	1,132,322,048	70,983,880.0	1.880	39.35		
46	38.855	3585	157,383,440	16,480,198.0	0.436	9.14		
47	40.006	3700	1,005,320,704	62,658,908.0	1.659	34.73		
48	40.456	3745	145,344,512	27,625,922.0	0.732	15.31		
49	40.886	3788	114,502,424	17,987,372.0	0.476	9.97		
50	41.636	3863	991,637,120	62,133,012.0	1.645	34.44		
51	41.876	3887	104,815,264	14,689,450.0	0.389	8.14		
52	42.826	3982	350,159,680	49,055,576.0	1.299	27.19		
53	42.996	3999	308,779,680	30,554,000.0	0.809	16.94		
54	43.206	4020	1,729,290,880	180,400,192.0	4.777	100.00		
55	44.036	4103	169,800,208	19,514,386.0	0.517	10.82		
56	44.726	4172	842,245,120	49,757,464.0	1.318	27.58		
57	46.197	4319	874,362,176	62,987,496.0	1.668	34.92		
58	46.307	4330	729,293,440	101,366,640.0	2.684	56.19		
59	46.487	4348	679,032,960	70,318,448.0	1.862	38.98		

APPENDIX F1 WAVENUMBERS VRS TRANSMITTANCES OF GASOLINE

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3996.05656	0.99904	3918.54245	0.99914	3843.06818	0.99948
3994.01672	0.99944	3916.5026	0.99901	3841.02833	0.99923
3991.97687	0.99929	3914.46276	0.99894	3838.98849	0.99849
3989.93703	0.99884	3912.42291	0.99893	3836.94864	0.99779
3987.89718	0.99833	3910.38307	0.99876	3834.9088	0.99773
3985.85734	0.99831	3908.34322	0.99842	3832.86895	0.99823
3983.81749	0.99862	3906.30338	0.99806	3830.82911	0.99877
3981.77765	0.99862	3904.26353	0.99798	3828.78926	0.99873
3979.7378	0.99872	3902.22369	0.99829	3826.74942	0.9984
3977.69796	0.99888	3900.18384	0.99878	3824.70957	0.99854
3975.65811	0.99845	3898.144	0.99928	3822.66973	0.99894
3973.61827	0.99799	3896.10415	0.99952	3820.62988	0.99869
3971.57842	0.99822	3894.06431	0.99929	3818.59004	0.99821
3969.53858	0.9985	3892.02446	0.99874	3816.55019	0.99808
3967.49873	0.99813	3889.98462	0.9985	3814.51035	0.99811
3965.45888	0.99762	3887.94477	0.9988	3812.4705	0.9982
3963.41904	0.99754	3885.90493	0.99883	3810.43066	0.99828
3961.37919	0.9976	3883.86508	0.99826	3808.39081	0.99813
3959.33935	0.99764	3881.82524	0.99776	3806.35097	0.99783
3957.2995	0.99783	3879.78539	0.99747	3804.31112	0.99808
3955.25966	0.99827	3877.74555	0.99774	3802.27128	0.99887
3953.21981	0.99884	3875.7057	0.99813	3800.23143	0.99951
3951.17997	0.99915	3873.66586	0.998	3798.19159	0.99967

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3947.10028	0.99873	3869.58616	0.99737	3794.1119	0.99843
3945.06043	0.99863	3867.54632	0.9976	3792.07205	0.998
3943.02059	0.99815	3865.50647	0.9982	3790.03221	0.99822
3940.98074	0.99774	3863.46663	0.99865	3787.99236	0.99857
3938.9409	0.99767	3861.42678	0.99862	3785.95252	0.99823
3936.90105	0.99785	3859.38694	0.99851	3783.91267	0.99766
3934.86121	0.99814	3857.34709	0.99894	3781.87283	0.99786
3932.82136	0.99812	3855.30725	0.99996	3779.83298	0.99826
3930.78152	0.99823	3853.2674	1.00038	3777.79314	0.99858
3928.74167	0.99853	3851.22756	0.99935	3775.75329	0.99903
3926.70183	0.99841	3849.18771	0.99877	3773.71344	0.99912
3924.66198	0.99829	3847.14787	0.99893	3771.6736	0.99854
3922.62214	0.99855	3845.10802	0.99931	3769.63375	0.99789
3920.58229	0.99894	3765.55406	0.99821	3767.59391	0.99792
3763.51422	0.99866	3690.0798	0.99702	3612.56568	0.99899
3761.47437	0.99909	3688.03995	0.99773	3610.52584	0.99803
3759.43453	0.99888	3686.00011	0.99828	3608.48599	0.99812
3757.39468	0.99833	3683.96026	0.99887	3606.44615	0.99902
3755.35484	0.99832	3681.92042	0.99959	3604.4063	0.99923
3753.31499	0.99882	3679.88057	0.99968	3602.36646	0.9989
3751.27515	0.99921	3677.84072	0.99912	3600.32661	0.99908
3749.2353	0.99906	3675.80088	0.99873	3598.28677	1.00007
3747.19546	0.99859	3673.76103	0.99887	3596.24692	1.00071
3745.15561	0.99797	3671.72119	0.9992	3594.20708	1.00033
3743.11577	0.99782	3669.68134	0.99993	3592.16723	0.99958

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3730.8767	0.99848	3657.44227	0.99884	3579.92816	0.99893
3728.83685	0.99824	3655.40243	0.99891	3577.88831	0.99945
3726.79701	0.99848	3653.36258	0.99898	3575.84847	0.99966
3724.75716	0.99948	3651.32274	0.99958	3573.80862	0.99955
3722.71732	1.00023	3649.28289	1.00023	3571.76878	0.9995
3720.67747	1.00046	3647.24305	0.99892	3569.72893	0.99956
3718.63763	1.00014	3645.2032	0.99759	3567.68909	0.9995
3716.59778	0.99926	3643.16336	0.99774	3565.64924	0.99953
3714.55794	0.99836	3641.12351	0.99881	3563.6094	0.99956
3712.51809	0.9978	3639.08367	0.99962	3561.56955	0.99921
3710.47825	0.99826	3637.04382	0.99942	3559.52971	0.99877
3708.4384	0.99924	3635.00398	0.99885	3557.48986	0.99859
3706.39856	0.9994	3632.96413	0.999	3555.45002	0.99886
3704.35871	0.99898	3630.92429	0.99991	3553.41017	0.99943
3702.31887	0.99856	3628.88444	1.00039	3551.37033	0.99988
3700.27902	0.99887	3626.8446	0.99963	3549.33048	1.00019
3698.23918	0.9997	3624.80475	0.99894	3547.29064	1.00024
3696.19933	0.99973	3622.76491	0.99878	3545.25079	0.9998
3694.15949	0.99872	3620.72506	0.99859	3543.21095	0.99943
3692.11964	0.99745	3618.68522	0.99816	3541.1711	0.9993
3614.60553	0.99928	3616.64537	0.99853	3539.13126	0.99925
3482.01559	0.99917	3406.54133	0.99958	3329.02721	0.99894
3479.97575	0.99951	3404.50148	0.99907	3326.98737	0.99829
3477.9359	0.99941	3402.46164	0.99868	3324.94752	0.998
3475.89606	0.99882	3400.42179	0.99858	3322.90768	0.99786

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3537.09141	0.99925	3461.61714	0.99908	3384.10303	0.99947
3535.05157	0.99915	3459.5773	0.99901	3382.06318	0.99896
3533.01172	0.99889	3457.53745	0.99859	3380.02334	0.99878
3530.97188	0.99877	3455.49761	0.99855	3377.98349	0.99891
3528.93203	0.99865	3453.45776	0.99938	3375.94365	0.99896
3526.89219	0.99844	3451.41792	1.0004	3373.9038	0.99901
3524.85234	0.99864	3449.37807	1.00086	3371.86396	0.99898
3522.8125	0.99918	3447.33823	1.0005	3369.82411	0.99844
3520.77265	0.99936	3445.29838	0.99996	3367.78427	0.99779
3518.73281	0.99906	3443.25854	0.99996	3365.74442	0.99765
3516.69296	0.99899	3441.21869	0.99992	3363.70458	0.99795
3514.65312	0.99943	3439.17885	0.99931	3361.66473	0.9984
3512.61327	0.99993	3437.139	0.99882	3359.62489	0.99883
3510.57343	1.00039	3435.09916	0.99913	3357.58504	0.99892
3508.53358	1.00056	3433.05931	0.9996	3355.5452	0.99858
3506.49374	1.00000	3431.01947	0.99954	3353.50535	0.99825
3504.45389	0.99938	3428.97962	0.99936	3351.46551	0.99824
3502.41405	0.99932	3426.93978	0.99952	3349.42566	0.99879
3500.3742	0.99941	3424.89993	0.99991	3347.38582	0.99944
3498.33436	0.99951	3422.86009	1.00004	3345.34597	0.99925
3496.29451	0.99975	3420.82024	0.9998	3343.30613	0.99858
3494.25467	0.99965	3418.7804	0.99936	3341.26628	0.99832
3492.21482	0.99936	3416.74055	0.9991	3339.22644	0.99835
3490.17498	0.99918	3414.70071	0.99941	3337.18659	0.99815
3488.13513	0.99888	3412.66086	0.9997	3335.14675	0.99797

APPENDIX F1 **Wavenumbers vrs Transmittances of Gasoline (Continued)**

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3386.14287	0.99979	3235.19434	0.9988	3159.72007	0.99653
3308.62876	0.99835	3233.15449	0.99906	3157.68022	0.99668
3306.58892	0.99875	3231.11465	0.99908	3155.64038	0.99682
3304.54907	0.99898	3229.0748	0.99899	3153.60053	0.99679
3302.50923	0.99881	3227.03496	0.9989	3151.56069	0.99673
3300.46938	0.99877	3224.99511	0.99884	3149.52084	0.99662
3298.42954	0.9991	3222.95527	0.99865	3147.481	0.99637
3296.38969	0.99945	3220.91542	0.99813	3145.44115	0.99616
3294.34985	0.9994	3218.87558	0.99755	3143.40131	0.99615
3292.31	0.99884	3216.83573	0.99741	3141.36146	0.99619
3290.27015	0.99835	3214.79589	0.99767	3139.32162	0.99614
3288.23031	0.99839	3212.75604	0.99807	3137.28177	0.99604
3286.19046	0.99833	3210.7162	0.99837	3135.24193	0.99577
3284.15062	0.99796	3208.67635	0.99816	3133.20208	0.99579
3282.11077	0.9979	3206.63651	0.9974	3131.16224	0.99615
3280.07093	0.99855	3204.59666	0.99673	3129.12239	0.99621
3278.03108	0.99945	3202.55682	0.99684	3127.08255	0.99631
3275.99124	0.99972	3200.51697	0.99721	3125.0427	0.99664
3273.95139	0.99947	3198.47713	0.99698	3123.00286	0.99683
3271.91155	0.99931	3196.43728	0.99654	3120.96301	0.99679
3269.8717	0.99907	3194.39744	0.99663	3118.92317	0.99654
3267.83186	0.99871	3192.35759	0.99686	3116.88332	0.99616
3265.79201	0.99848	3190.31774	0.99668	3114.84348	0.99596
3263.75217	0.99828	3188.2779	0.99625	3112.80363	0.99614
3261.71232	0.998	3186.23805	0.99602	3110.76379	0.99632

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3253.55294	0.99816	3178.07867	0.99558	3102.60441	0.99569
3251.5131	0.99865	3176.03883	0.99515	3100.56456	0.99527
3249.47325	0.99893	3173.99898	0.99527	3098.52472	0.99471
3247.43341	0.99851	3171.95914	0.99572	3096.48487	0.99415
3245.39356	0.99811	3169.91929	0.99622	3094.44502	0.99438
3243.35372	0.99813	3167.87945	0.99663	3092.40518	0.99492
3241.31387	0.99796	3165.8396	0.99695	3090.36533	0.99495
3239.27403	0.99786	3163.79976	0.99697	3088.32549	0.99469
3237.23418	0.9983	3161.75991	0.99668	3086.28564	0.9942
3084.2458	0.99359	3006.73169	0.98004	2929.21757	0.64639
3082.20595	0.99348	3004.69184	0.97953	2927.17773	0.62411
3080.16611	0.99377	3002.652	0.97896	2925.13788	0.60649
3078.12626	0.99385	3000.61215	0.97847	2923.09804	0.5965
3076.08642	0.99378	2998.5723	0.97781	2921.05819	0.5957
3074.04657	0.99348	2996.53246	0.9766	2919.01835	0.60374
3072.00673	0.99281	2994.49261	0.97509	2916.9785	0.61848
3069.96688	0.99232	2992.45277	0.9725	2914.93866	0.63685
3067.92704	0.99215	2990.41292	0.97072	2912.89881	0.65597
3065.88719	0.99186	2988.37308	0.9675	2910.85897	0.67386
3063.84735	0.99143	2986.33323	0.9632	2908.81912	0.68973
3061.8075	0.99095	2984.29339	0.95811	2906.77928	0.70392
3059.76766	0.99037	2982.25354	0.95245	2904.73943	0.717
3057.72781	0.98988	2980.2137	0.94529	2902.69958	0.72949
3055.68797	0.98977	2978.17385	0.93537	2900.65974	0.74179
3053.64812	0.98992	2976.13401	0.92245	2898.61989	0.75393
3051.60828	0.98986	2974.09416	0.90706	2896.58005	0.76607
3049.56843	0.98947	2972.05432	0.88916	2894.5402	0.77861

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3041.40905	0.98839	2963.89494	0.79054	2886.38082	0.82466
3039.36921	0.98774	2961.85509	0.76606	2884.34098	0.83087
3037.32936	0.98704	2959.81525	0.74395	2882.30113	0.83302
3035.28952	0.98672	2957.7754	0.72516	2880.26129	0.82976
3033.24967	0.98644	2955.73556	0.71169	2878.22144	0.82013
3031.20983	0.98574	2953.69571	0.70592	2876.1816	0.80555
3029.16998	0.98485	2951.65587	0.70888	2874.14175	0.79028
3027.13014	0.98415	2949.61602	0.71915	2872.10191	0.7789
3025.09029	0.98378	2947.57618	0.73352	2870.06206	0.77374
3023.05045	0.98341	2945.53633	0.74734	2868.02222	0.77335
3021.0106	0.98281	2943.49649	0.75574	2865.98237	0.77387
3018.97076	0.98223	2941.45664	0.7563	2863.94253	0.77188
3016.93091	0.9821	2939.4168	0.74896	2861.90268	0.76599
3012.85122	0.98203	2935.33711	0.71533	2857.82299	0.74648
3010.81138	0.98146	2933.29726	0.69346	2855.78315	0.73778
3008.77153	0.98068	2931.25742	0.67016	2853.7433	0.73521
2851.70346	0.74264	2776.22919	0.98855	2700.75492	0.99152
2849.66361	0.75967	2774.18934	0.98874	2698.71507	0.99183
2847.62377	0.78164	2772.1495	0.98906	2696.67523	0.99202
2845.58392	0.80461	2770.10965	0.98953	2694.63538	0.99194
2843.54408	0.82804	2768.06981	0.99002	2692.59554	0.99165
2841.50423	0.85225	2766.02996	0.99034	2690.55569	0.99136
2839.46439	0.87569	2763.99012	0.9903	2688.51585	0.99132
2837.42454	0.89608	2761.95027	0.99017	2686.476	0.99124
2835.3847	0.91283	2759.91043	0.9901	2684.43616	0.99112

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2823.14563	0.96113	2747.67136	0.99066	2672.19709	0.99002
2821.10578	0.96458	2745.63151	0.99066	2670.15724	0.98982
2819.06594	0.96732	2743.59167	0.99073	2668.1174	0.98981
2817.02609	0.96952	2741.55182	0.9906	2666.07755	0.9897
2814.98625	0.97143	2739.51198	0.99022	2664.03771	0.98956
2812.9464	0.97309	2737.47213	0.98964	2661.99786	0.98973
2810.90656	0.97465	2735.43229	0.98918	2659.95802	0.99022
2808.86671	0.97604	2733.39244	0.989	2657.91817	0.99067
2806.82686	0.97722	2731.3526	0.9886	2655.87833	0.99087
2804.78702	0.97836	2729.31275	0.98799	2653.83848	0.99111
2802.74717	0.97951	2727.27291	0.98784	2651.79864	0.9915
2800.70733	0.98068	2725.23306	0.98801	2649.75879	0.9917
2798.66748	0.98157	2723.19322	0.98813	2647.71895	0.99163
2796.62764	0.98209	2721.15337	0.98836	2645.6791	0.99149
2794.58779	0.9827	2719.11353	0.98877	2643.63926	0.99152
2792.54795	0.98341	2717.07368	0.98926	2641.59941	0.99163
2790.5081	0.98408	2715.03384	0.98966	2639.55957	0.99164
2788.46826	0.98481	2712.99399	0.99006	2637.51972	0.9918
2786.42841	0.98559	2710.95415	0.99049	2635.47988	0.9923
2784.38857	0.98646	2708.9143	0.99072	2633.44003	0.99277
2782.34872	0.98722	2706.87445	0.99099	2631.40019	0.99297
2780.30888	0.98769	2704.83461	0.99137	2629.36034	0.99304
2778.26903	0.98815	2702.79476	0.99146	2627.3205	0.9928
2625.28065	0.99249	2549.80638	0.99699	2474.33211	0.99774
2623.24081	0.99272	2547.76654	0.99659	2472.29227	0.99769

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2611.00173	0.99382	2535.52747	0.99601	2460.0532	0.99711
2608.96189	0.99331	2533.48762	0.99668	2458.01335	0.99686
2606.92204	0.99299	2531.44778	0.9977	2455.97351	0.99671
2604.8822	0.99282	2529.40793	0.9986	2453.93366	0.99654
2602.84235	0.99288	2527.36809	0.99856	2451.89382	0.99729
2600.80251	0.99329	2525.32824	0.99786	2449.85397	0.99826
2598.76266	0.99362	2523.2884	0.99749	2447.81413	0.99832
2596.72282	0.99365	2521.24855	0.99749	2445.77428	0.99805
2594.68297	0.99375	2519.20871	0.99734	2443.73444	0.99797
2592.64313	0.99402	2517.16886	0.99715	2441.69459	0.99796
2590.60328	0.99429	2515.12901	0.99702	2439.65475	0.99775
2588.56344	0.99469	2513.08917	0.99705	2437.6149	0.99715
2586.52359	0.99511	2511.04932	0.99749	2435.57506	0.99697
2584.48375	0.99489	2509.00948	0.99794	2433.53521	0.99776
2580.40406	0.99473	2504.92979	0.9976	2429.45552	0.99861
2578.36421	0.99504	2502.88994	0.99724	2427.41568	0.99788
2576.32437	0.99463	2500.8501	0.99701	2425.37583	0.99713
2574.28452	0.99441	2498.81025	0.997	2423.33599	0.99661
2572.24468	0.99461	2496.77041	0.99706	2421.29614	0.99641
2570.20483	0.99475	2494.73056	0.99682	2419.25629	0.99655
2568.16499	0.99501	2492.69072	0.99663	2417.21645	0.99695
2566.12514	0.99554	2490.65087	0.99709	2415.1766	0.99737
2562.04545	0.99653	2486.57118	0.99775	2411.09691	0.99728
2560.00561	0.99671	2484.53134	0.99746	2409.05707	0.99723
2557.96576	0.99684	2482.49149	0.99764	2407.01722	0.99735

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2398.85784	0.99704	2300.94528	0.99632	2203.03271	1.0006
2396.818	0.99673	2298.90543	0.99606	2200.99287	1.00058
2394.77815	0.99651	2296.86559	0.99635	2198.95302	1.00125
2392.73831	0.99646	2294.82574	0.99675	2196.91318	1.00273
2390.69846	0.99672	2292.7859	0.9971	2194.87333	1.00354
2388.65862	0.99727	2290.74605	0.99761	2192.83349	1.00206
2386.61877	0.99753	2288.70621	0.99801	2190.79364	0.99942
2384.57893	0.99743	2286.66636	0.99791	2188.7538	0.99745
2382.53908	0.99733	2284.62652	0.99751	2186.71395	0.99716
2380.49924	0.99708	2282.58667	0.99745	2184.67411	0.9984
2378.45939	0.99674	2280.54683	0.99781	2182.63426	0.99857
2376.41955	0.99672	2278.50698	0.99821	2180.59442	0.99725
2374.3797	0.99677	2276.46714	0.99842	2178.55457	0.9978
2372.33986	0.997	2274.42729	0.99847	2176.51473	1.00115
2370.30001	0.99805	2272.38745	0.99868	2174.47488	1.00276
2368.26017	0.99907	2270.3476	0.99922	2172.43504	0.99956
2366.22032	0.99833	2268.30776	0.9996	2170.39519	0.99577
2364.18048	0.99602	2266.26791	0.99895	2168.35535	0.99571
2362.14063	0.99471	2264.22807	0.99816	2166.3155	0.99797
2360.10079	0.99495	2262.18822	0.9994	2164.27566	1.00025
2358.06094	0.99506	2260.14838	1.00092	2162.23581	1.00262
2356.0211	0.99562	2258.10853	0.99975	2160.19597	1.00282
2353.98125	0.99595	2256.06869	0.99733	2158.15612	0.9994
2351.94141	0.99528	2254.02884	0.99605	2156.11628	0.99615
2349.90156	0.99519	2251.989	0.99598	2154.07643	0.99576

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2345.82187	0.99784	2247.90931	0.99687	2149.99674	0.99705
2343.78203	0.99929	2245.86946	0.9973	2147.9569	0.99818
2341.74218	0.99922	2243.82962	0.99754	2145.91705	0.9986
2339.70234	0.9978	2241.78977	0.99791	2143.87721	0.9987
2337.66249	0.9964	2239.74993	0.99836	2141.83736	0.99965
2335.62265	0.99651	2237.71008	0.99811	2139.79752	1.00032
2333.5828	0.99699	2235.67024	0.99753	2137.75767	0.99968
2331.54296	0.99643	2233.63039	0.99709	2135.71783	0.99834
2329.50311	0.99567	2231.59055	0.99679	2133.67798	0.99715
2327.46327	0.99518	2229.5507	0.99745	2131.63814	0.9961
2325.42342	0.99458	2227.51086	0.99808	2129.59829	0.99619
2323.38358	0.99482	2225.47101	0.99785	2127.55844	0.99756
2321.34373	0.99641	2223.43116	0.99869	2125.5186	0.99878
2319.30388	0.99753	2221.39132	1.00086	2123.47875	0.99907
2317.26404	0.99741	2219.35147	1.00161	2121.43891	0.99859
2315.22419	0.99685	2217.31163	0.99976	2119.39906	0.99778
2313.18435	0.99663	2215.27178	0.99762	2117.35922	0.9974
2311.1445	0.99714	2213.23194	0.99786	2115.31937	0.99784
2309.10466	0.99771	2211.19209	0.99965	2113.27953	0.99897
2307.06481	0.9977	2209.15225	0.99981	2111.23968	1.00048
2305.02497	0.99737	2207.1124	0.9993	2109.19984	1.00135
2302.98512	0.99692	2205.07256	1.00007	2107.15999	1.00141
2105.12015	1.00077	2050.04433	0.99763	1994.96851	0.99738
2103.0803	0.99953	2048.00449	0.99678	1992.92867	0.99812
2101.04046	0.99904	2045.96464	0.9958	1990.88882	0.99946

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2088.80139	1.00034	2033.72557	1.00041	1978.64975	1.00414
2086.76154	0.99943	2031.68572	0.99978	1976.60991	1.00021
2084.7217	0.9984	2029.64588	0.99945	1974.57006	0.99827
2082.68185	0.99913	2027.60603	0.99817	1972.53022	1.00037
2080.64201	1.00092	2025.56619	0.99767	1970.49037	1.00292
2078.60216	1.0017	2023.52634	0.99955	1968.45053	1.00323
2076.56232	1.00058	2021.4865	1.00214	1966.41068	1.00257
2074.52247	0.99874	2019.44665	1.00329	1964.37084	1.00201
2072.48263	0.99816	2017.40681	1.00313	1962.33099	1.00055
2070.44278	0.99864	2015.36696	1.0028	1960.29115	0.999
2068.40294	0.99898	2013.32712	1.00063	1958.2513	0.99912
2066.36309	0.99937	2011.28727	0.99684	1956.21146	0.99998
2064.32325	0.999	2009.24743	0.9956	1954.17161	1.00014
2062.2834	0.99708	2007.20758	0.99768	1952.13177	1.00036
2060.24356	0.99581	2005.16774	1.00023	1950.09192	1.0017
2058.20371	0.99655	2003.12789	1.00128	1948.05208	1.00277
2056.16387	0.99786	2001.08805	0.99969	1946.01223	1.00195
2054.12402	0.99836	1999.0482	0.99735	1943.97239	0.99986
2052.08418	0.99809	1997.00836	0.99689	1941.93254	0.99853
1939.8927	0.9986	1862.37858	0.99704	1784.86447	0.99612
1937.85285	0.99831	1860.33874	0.99717	1782.82462	0.996
1935.813	0.99758	1858.29889	0.99706	1780.78478	0.99588
1933.77316	0.99808	1856.25905	0.99701	1778.74493	0.99584
1931.73331	0.99926	1854.2192	0.99746	1776.70509	0.99593
1929.69347	0.99936	1852.17936	0.99801	1774.66524	0.99608

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1915.41455	0.99767	1837.90044	0.99693	1760.38633	0.9957
1913.37471	0.99751	1835.86059	0.99684	1758.34648	0.99554
1911.33486	0.99752	1833.82075	0.99648	1756.30664	0.99518
1909.29502	0.9978	1831.7809	0.99613	1754.26679	0.9947
1907.25517	0.99763	1829.74106	0.99634	1752.22695	0.9943
1905.21533	0.99719	1827.70121	0.99719	1750.1871	0.99416
1903.17548	0.99684	1825.66137	0.99776	1748.14726	0.99391
1901.13564	0.99664	1823.62152	0.9978	1746.10741	0.99367
1899.09579	0.99704	1821.58168	0.99766	1744.06757	0.99375
1897.05595	0.99804	1819.54183	0.99755	1742.02772	0.99365
1895.0161	0.99847	1817.50199	0.99766	1739.98787	0.99348
1892.97626	0.99805	1815.46214	0.99788	1737.94803	0.99359
1890.93641	0.99802	1813.4223	0.9977	1735.90818	0.99353
1888.89657	0.99829	1811.38245	0.99718	1733.86834	0.99335
1886.85672	0.99803	1809.34261	0.99679	1731.82849	0.99366
1884.81688	0.99782	1807.30276	0.99673	1729.78865	0.99405
1882.77703	0.9978	1805.26292	0.99699	1727.7488	0.99419
1880.73719	0.99746	1803.22307	0.99729	1725.70896	0.99417
1878.69734	0.99705	1801.18323	0.99718	1723.66911	0.99409
1876.6575	0.99695	1799.14338	0.99675	1721.62927	0.99394
1874.61765	0.99701	1797.10354	0.99627	1719.58942	0.99386
1872.57781	0.99741	1795.06369	0.99577	1717.54958	0.99385
1870.53796	0.99808	1793.02385	0.99556	1715.50973	0.99365
1868.49812	0.99792	1790.984	0.99578	1713.46989	0.99355
1866.45827	0.99715	1788.94416	0.99605	1711.43004	0.99357

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1699.19097	0.99355	1621.67686	0.98966	1544.16274	0.99019
1697.15113	0.99371	1619.63701	0.98869	1542.1229	0.98986
1695.11128	0.9936	1617.59717	0.98719	1540.08305	0.98918
1693.07144	0.99346	1615.55732	0.98545	1538.04321	0.98884
1691.03159	0.99349	1613.51748	0.98472	1536.00336	0.98864
1688.99175	0.99352	1611.47763	0.98404	1533.96352	0.9882
1686.9519	0.99339	1609.43779	0.98281	1531.92367	0.98772
1684.91206	0.99334	1607.39794	0.98208	1529.88383	0.9873
1682.87221	0.99377	1605.3581	0.98265	1527.84398	0.98669
1680.83237	0.99391	1603.31825	0.9838	1525.80414	0.98574
1678.79252	0.99369	1601.27841	0.98483	1523.76429	0.98463
1676.75268	0.99349	1599.23856	0.98572	1521.72445	0.98332
1674.71283	0.99326	1597.19872	0.98662	1519.6846	0.98187
1672.67299	0.9929	1595.15887	0.98726	1517.64476	0.98031
1670.63314	0.99254	1593.11903	0.98753	1515.60491	0.97915
1668.5933	0.99264	1591.07918	0.98799	1513.56507	0.97862
1666.55345	0.99319	1589.03934	0.98881	1511.52522	0.97804
1664.51361	0.9935	1586.99949	0.98931	1509.48538	0.97712
1662.47376	0.99346	1584.95965	0.98956	1507.44553	0.9753
1660.43392	0.99332	1582.9198	0.9902	1505.40569	0.97342
1658.39407	0.99315	1580.87996	0.99091	1503.36584	0.97304
1656.35423	0.99289	1578.84011	0.99121	1501.326	0.97284
1654.31438	0.9924	1576.80027	0.99133	1499.28615	0.97198
1652.27454	0.9921	1574.76042	0.99168	1497.24631	0.96989
1650.23469	0.99239	1572.72058	0.99188	1495.20646	0.96782

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1637.99562	0.99255	1560.48151	0.99023	1482.96739	0.95903
1635.95577	0.99223	1558.44166	0.98943	1480.92755	0.9543
1633.91593	0.99204	1556.40182	0.98947	1478.8877	0.94833
1631.87608	0.99218	1554.36197	0.98947	1476.84786	0.94056
1474.80801	0.92828	1397.2939	0.97255	1319.77978	0.97368
1472.76817	0.90432	1395.25405	0.97054	1317.73994	0.97381
1470.72832	0.8741	1393.21421	0.96721	1315.70009	0.97334
1468.68848	0.85198	1391.17436	0.96291	1313.66025	0.97266
1466.64863	0.83537	1389.13452	0.95581	1311.6204	0.97226
1464.60879	0.82249	1387.09467	0.94295	1309.58056	0.97219
1462.56894	0.81424	1385.05483	0.92812	1307.54071	0.97197
1460.5291	0.80823	1383.01498	0.91509	1305.50087	0.97138
1458.48925	0.80259	1380.97514	0.90114	1303.46102	0.97097
1456.44941	0.80136	1378.93529	0.88763	1301.42118	0.97111
1454.40956	0.80721	1376.89545	0.88199	1299.38133	0.97161
1452.36972	0.81529	1374.8556	0.88947	1297.34149	0.97206
1450.32987	0.82479	1372.81576	0.90496	1295.30164	0.97221
1448.29002	0.837	1370.77591	0.91651	1293.2618	0.97224
1446.25018	0.85288	1368.73607	0.92135	1291.22195	0.97233
1444.21033	0.86975	1366.69622	0.92308	1289.18211	0.9727
1442.17049	0.88666	1364.65638	0.92764	1287.14226	0.97328
1440.13064	0.90166	1362.61653	0.93842	1285.10242	0.9737
1438.0908	0.91486	1360.57669	0.94984	1283.06257	0.97388
1436.05095	0.92921	1358.53684	0.95635	1281.02273	0.9742
1434.01111	0.94019	1356.497	0.95972	1278.98288	0.97471

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1421.77204	0.96653	1344.25792	0.96532	1266.74381	0.97374
1419.73219	0.9686	1342.21808	0.96527	1264.70397	0.97356
1417.69235	0.97025	1340.17823	0.96567	1262.66412	0.97375
1415.6525	0.97116	1338.13839	0.9668	1260.62428	0.97445
1413.61266	0.97209	1336.09854	0.96813	1258.58443	0.97522
1411.57281	0.9731	1334.0587	0.96953	1256.54458	0.97563
1409.53297	0.97369	1332.01885	0.97081	1254.50474	0.9758
1407.49312	0.97379	1329.97901	0.97163	1252.46489	0.97597
1405.45328	0.97388	1327.93916	0.97223	1250.42505	0.97618
1403.41343	0.97422	1325.89932	0.97282	1248.3852	0.97643
1401.37359	0.9743	1323.85947	0.97316	1246.34536	0.97691
1399.33374	0.97368	1321.81963	0.97334	1244.30551	0.97757
1164.75156	0.97325	1087.23744	0.97628	1009.72333	0.97199
1162.71171	0.97396	1085.1976	0.97623	1007.68348	0.97188
1160.67186	0.97428	1083.15775	0.97618	1005.64364	0.97184
1158.63202	0.97399	1081.11791	0.97585	1003.60379	0.97171
1156.59217	0.97356	1079.07806	0.97509	1001.56395	0.97153
1154.55233	0.97354	1077.03822	0.97429	999.5241	0.97174
1152.51248	0.9738	1074.99837	0.97414	997.48426	0.9724
1150.47264	0.97401	1072.95853	0.97455	995.44441	0.97283
1148.43279	0.97429	1070.91868	0.97471	993.40457	0.9729
1146.39295	0.97473	1068.87884	0.97455	991.36472	0.97289
1144.3531	0.97527	1066.83899	0.9744	989.32488	0.9725
1142.31326	0.97587	1064.79915	0.97408	987.28503	0.97175
1140.27341	0.97628	1062.7593	0.97385	985.24519	0.97105

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1128.03434	0.97788	1050.52023	0.97382	973.00612	0.96616
1125.9945	0.97762	1048.48038	0.97399	970.96627	0.96508
1123.95465	0.97742	1046.44054	0.97367	968.92643	0.96481
1121.91481	0.97767	1044.40069	0.97299	966.88658	0.96489
1119.87496	0.9784	1042.36085	0.97244	964.84673	0.96543
1117.83512	0.97919	1040.321	0.97186	962.80689	0.96667
1115.79527	0.97976	1038.28116	0.97126	960.76704	0.96771
1113.75543	0.98002	1036.24131	0.97095	958.7272	0.96795
1111.71558	0.9799	1034.20147	0.9707	956.68735	0.968
1109.67574	0.97954	1032.16162	0.97024	954.64751	0.96831
1107.63589	0.97908	1030.12178	0.96993	952.60766	0.96857
1105.59605	0.97863	1028.08193	0.97006	950.56782	0.96856
1103.5562	0.97837	1026.04209	0.97043	948.52797	0.96854
1101.51636	0.97809	1024.00224	0.97088	946.48813	0.96882
1099.47651	0.97754	1021.9624	0.97114	944.44828	0.96959
1097.43667	0.97665	1019.92255	0.97111	942.40844	0.97056
1095.39682	0.9759	1017.88271	0.97114	940.36859	0.97097
1093.35698	0.976	1015.84286	0.97135	938.32875	0.97087
1091.31713	0.97651	1013.80302	0.97171	936.2889	0.97086
1089.27729	0.97651	1011.76317	0.972	934.24906	0.97101
932.20921	0.97127	854.6951	0.97256	777.18099	0.95556
930.16937	0.97145	852.65525	0.97141	775.14114	0.9545
928.12952	0.97137	850.61541	0.96927	773.10129	0.95046
926.08968	0.97151	848.57556	0.96665	771.06145	0.94319
924.04983	0.97174	846.53572	0.96517	769.0216	0.9349

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
911.81076	0.97109	834.29665	0.96596	756.78253	0.95711
909.77092	0.97096	832.2568	0.96731	754.74269	0.95558
907.73107	0.9707	830.21696	0.96975	752.70284	0.95354
905.69123	0.97062	828.17711	0.97075	750.663	0.95293
903.65138	0.97056	826.13727	0.97044	748.62315	0.95206
901.61154	0.97051	824.09742	0.96945	746.58331	0.94828
899.57169	0.9704	822.05758	0.9678	744.54346	0.94071
897.53185	0.96979	820.01773	0.96654	742.50362	0.93136
895.492	0.96883	817.97789	0.96563	740.46377	0.9273
893.45216	0.96803	815.93804	0.96374	738.42393	0.93182
891.41231	0.96759	813.8982	0.96066	736.38408	0.93903
889.37247	0.96741	811.85835	0.95762	734.34424	0.94337
887.33262	0.96747	809.81851	0.95531	732.30439	0.94309
885.29278	0.96792	807.77866	0.95311	730.26455	0.93806
883.25293	0.96862	805.73882	0.9515	728.2247	0.9325
881.21309	0.9689	803.69897	0.95309	726.18486	0.93115
879.17324	0.9682	801.65913	0.95834	724.14501	0.93278
877.1334	0.9674	799.61928	0.96365	722.10517	0.93555
875.09355	0.96747	797.57944	0.96522	720.06532	0.94027
873.05371	0.96775	795.53959	0.96381	718.02548	0.94652
871.01386	0.96812	793.49975	0.963	715.98563	0.95315
868.97401	0.9692	791.4599	0.96301	713.94579	0.95906
866.93417	0.9703	789.42006	0.96286	711.90594	0.96296
864.89432	0.97108	787.38021	0.96228	709.8661	0.96455
862.85448	0.97199	785.34037	0.95932	707.82625	0.96434

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
699.66687	0.95202	622.15276	0.98403	544.63864	0.97552
697.62703	0.94912	620.11291	0.98414	542.5988	0.97639
695.58718	0.94989	618.07307	0.98644	540.55895	0.97514
693.54734	0.95257	616.03322	0.98833	538.51911	0.97284
691.50749	0.95523	613.99338	0.98799	536.47926	0.97264
689.46765	0.96023	611.95353	0.98731	534.43942	0.9746
687.4278	0.96813	609.91369	0.98734	532.39957	0.97829
685.38796	0.97573	607.87384	0.98669	530.35973	0.98153
683.34811	0.98097	605.834	0.98509	528.31988	0.98143
681.30827	0.98351	603.79415	0.9843	526.28004	0.98097
679.26842	0.98327	601.75431	0.98469	524.24019	0.98258
677.22857	0.98135	599.71446	0.98541	522.20035	0.98299
675.18873	0.98053	597.67462	0.98727	520.1605	0.98228
673.14888	0.98204	595.63477	0.98901	518.12066	0.98247
671.10904	0.98392	593.59493	0.98813	516.08081	0.98276
669.06919	0.98489	591.55508	0.98591	514.04097	0.98195
667.02935	0.98509	589.51524	0.985	512.00112	0.98203
664.9895	0.98499	587.47539	0.98588	509.96128	0.98497
662.94966	0.98474	585.43555	0.98695	507.92143	0.98708
660.90981	0.98458	583.3957	0.98683	505.88159	0.98513
658.86997	0.98547	581.35586	0.98579	503.84174	0.98265
656.83012	0.98693	579.31601	0.98456	501.8019	0.98277
654.79028	0.98743	577.27616	0.98382	499.76205	0.98336
652.75043	0.98764	575.23632	0.98384	497.72221	0.98223
650.71059	0.9882	573.19647	0.98386	495.68236	0.98139

APPENDIX F1 Wavenumbers vrs Transmittances of Gasoline (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
642.55121	0.98774	565.03709	0.98313	487.52298	0.97993
640.51136	0.9874	562.99725	0.98268	485.48314	0.97816
638.47152	0.98741	560.9574	0.98283	483.44329	0.97628
636.43167	0.98739	558.91756	0.98325	481.40344	0.97541
634.39183	0.98614	556.87771	0.98287	479.3636	0.97358
632.35198	0.9855	554.83787	0.98193	477.32375	0.97009
630.31214	0.98692	552.79802	0.98074	475.28391	0.96789
628.27229	0.98799	550.75818	0.97987	473.24406	0.96873
626.23245	0.98731	548.71833	0.97853	471.20422	0.97385
624.1926	0.98565	546.67849	0.97618	469.16437	0.98101
467.12453	0.98411	444.68623	0.98072	420.20809	0.98864
465.08468	0.98155	442.64639	0.97779	418.16825	0.99232
463.04484	0.97812	440.60654	0.97236	416.1284	0.98591
461.00499	0.97727	438.5667	0.96459	414.08856	0.98275
458.96515	0.97807	436.52685	0.96132	412.04871	0.98396
456.9253	0.97936	434.48701	0.9649	410.00887	0.98617
454.88546	0.97988	432.44716	0.96724	407.96902	0.98456
452.84561	0.98005	430.40732	0.9688	405.92918	0.98071
450.80577	0.97988	428.36747	0.97393	403.88933	0.97887
448.76592	0.97939	426.32763	0.97897	401.84949	0.9738
446.72608	0.98059	424.28778	0.9798		
422.24794	0.98091	399.80964	0.96574		

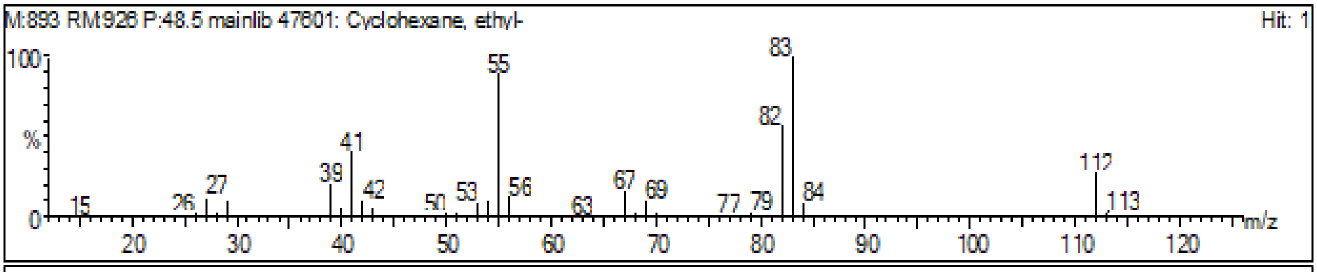
APPENDIX F2 QUALITATIVE REPORT OF COMPONENTS IN GASOLINE

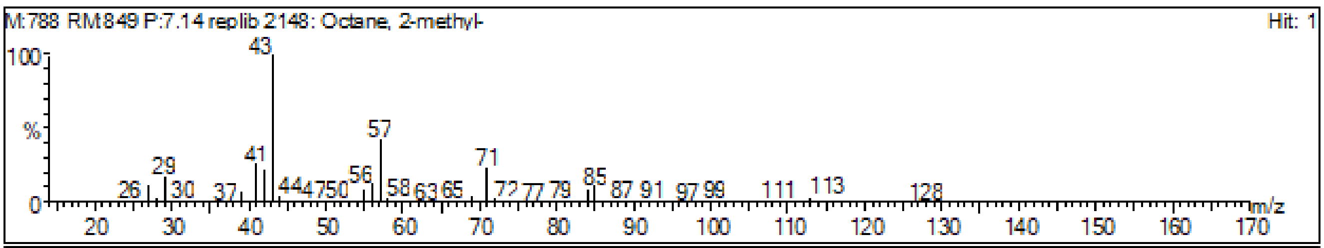
#	RT	Scan	Height	Area	Area %	Norm %	Name	
1	3.739	74	1,830,702,976	126,136,040.0	0.892	23.14		
2	3.829	83	2,741,421,056	200,783,840.0	1.421	36.84		
3	4.589	159	666,624,640	99,037,352.0	0.701	18.17		
4	4.829	183	2,601,655,808	291,173,760.0	2.060	53.42		
5	5.329	233	795,759,680	134,484,432.0	0.951	24.67		
6	5.939	294	1,747,339,136	217,558,176.0	1.539	39.91		
7	6.029	303	1,057,879,936	75,948,248.0	0.537	13.93		
8	6.439	344	1,099,690,752	131,915,280.0	0.933	24.20		
9	6.829	383	864,600,000	145,897,168.0	1.032	26.77		
10	7.089	409	1,085,443,072	116,531,744.0	0.824	21.38		
11	7.319	432	856,226,112	105,332,496.0	0.745	19.32		
12	7.749	475	921,547,008	121,435,368.0	0.859	22.28		
13	8.119	512	1,132,537,984	165,315,232.0	1.170	30.33		
14	8.399	540	1,228,979,968	183,534,064.0	1.298	33.67		
15	8.870	587	1,037,311,808	162,043,744.0	1.146	29.73		
16	9.260	626	1,780,577,664	236,366,976.0	1.672	43.36		
17	9.650	665	2,126,942,464	276,379,232.0	1.955	50.71		
18	10.260	726	1,899,592,832	325,511,936.0	2.303	59.72	Methyl myristoleate	0.000
19	10.540	754	1,012,155,584	86,095,648.0	0.609	15.80	Methyl tetradecanoate	0.000
20	10.700	770	709,749,312	75,708,064.0	0.536	13.89		
21	11.230	823	1,662,591,744	169,842,608.0	1.202	31.16		
22	11.530	853	833,466,496	98,257,552.0	0.695	18.03		

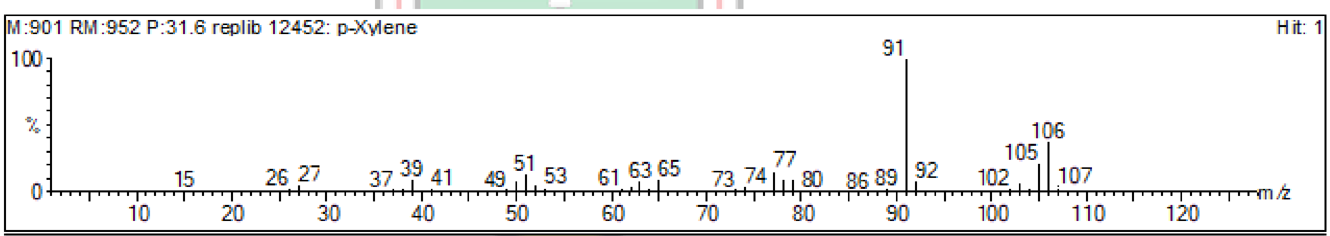
APPENDIX F2 Qualitative Report of Components in Gasoline (continued)

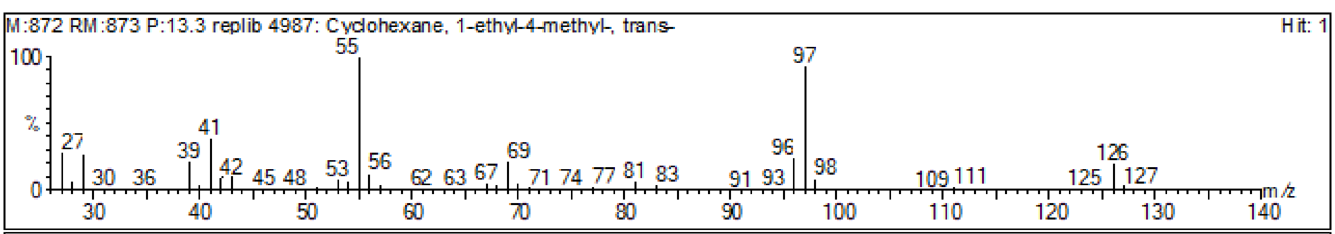
#	RT	Scan	Height	Area	Area %	Norm %	Name	
23	12.380	938	868,937,664	121,230,744.0	0.858	22.24		
24	13.060	1006	2,713,848,832	387,755,456.0	2.743	71.14		
25	13.440	1044	775,276,224	86,413,112.0	0.611	15.85		
26	13.681	1068	1,581,799,040	116,233,792.0	0.822	21.32		
27	14.551	1155	931,464,960	80,302,672.0	0.568	14.73		
28	14.941	1194	958,951,808	75,571,504.0	0.535	13.86		
29	15.571	1257	662,674,560	73,740,456.0	0.522	13.53		
30	16.191	1319	2,900,628,480	469,894,720.0	3.324	86.21		
31	16.521	1352	2,371,418,112	224,580,224.0	1.589	41.20		
32	16.591	1359	727,307,584	84,410,864.0	0.597	15.49		
33	17.661	1466	817,984,832	85,956,688.0	0.608	15.77		
34	17.891	1489	1,260,056,960	115,085,704.0	0.814	21.11	Heptadecanoic acid,	0.000
35	18.201	1520	2,619,970,304	299,548,352.0	2.119	54.96		
36	18.791	1579	2,643,059,968	266,604,544.0	1.886	48.91		
37	19.062	1606	3,303,478,784	503,555,424.0	3.563	92.38		
38	19.282	1628	1,309,634,432	161,614,416.0	1.143	29.65		
39	19.402	1640	1,274,082,176	112,175,264.0	0.794	20.58		
40	20.002	1700	995,495,488	107,916,184.0	0.763	19.80	9-Octadecenoic acid (Z)-,	0.000
41	20.612	1761	1,002,762,880	73,726,216.0	0.522	13.53	Methyl stearate	0.000
42	20.762	1776	958,581,248	81,055,008.0	0.573	14.87		
43	20.982	1798	2,553,401,856	168,558,144.0	1.193	30.92		
44	21.702	1870	3,878,722,816	545,068,736.0	3.856	100.00		
45	21.802	1880	999,453,120	74,006,288.0	0.524	13.58		
46	22.162	1916	2,310,053,376	206,660,576.0	1.462	37.91		
47	22.242	1924	2,318,650,624	128,365,848.0	0.908	23.55		
48	22.702	1970	1,012,727,040	105,633,544.0	0.747	19.38		
49	23.042	2004	1,157,264,512	84,709,856.0	0.599	15.54		
50	23.152	2015	2,671,453,440	244,480,080.0	1.730	44.85		
51	24.143	2114	3,934,791,680	452,520,032.0	3.202	83.02		
52	25.243	2224	1,283,930,368	99,071,072.0	0.701	18.18		
53	25.313	2231	1,212,578,304	81,258,168.0	0.575	14.91		
54	26.473	2347	3,538,976,256	338,212,000.0	2.393	62.05		
55	27.493	2449	1,478,500,352	120,212,456.0	0.850	22.05		
56	28.693	2569	2,441,447,936	234,549,152.0	1.659	43.03		
57	28.783	2578	2,943,631,616	194,307,504.0	1.375	35.65		
58	30.764	2776	1,817,996,544	122,779,944.0	0.869	22.53		
59	30.904	2790	1,234,149,760	85,101,080.0	0.602	15.61		

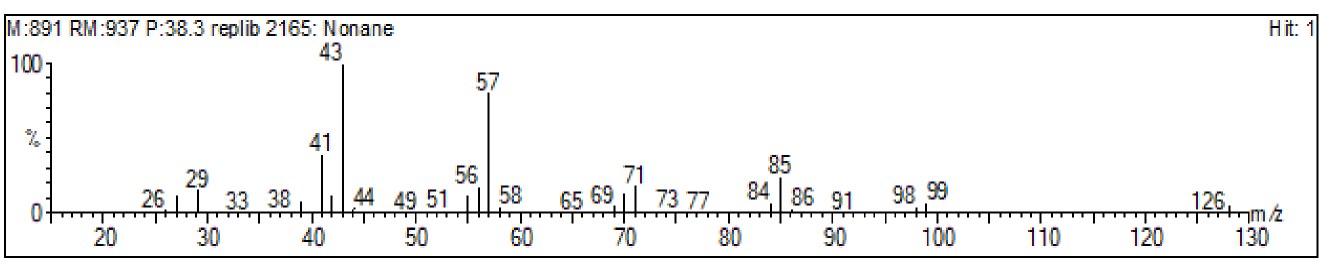
APPENDIX F3 GASOLINE CHROMATOGRAM/SPECTRUM PEAK REPORT



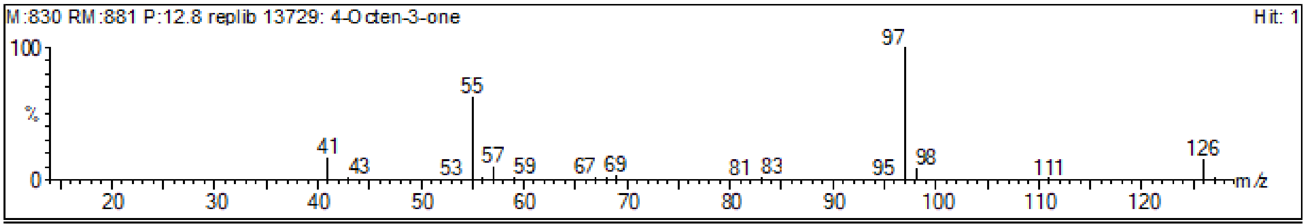


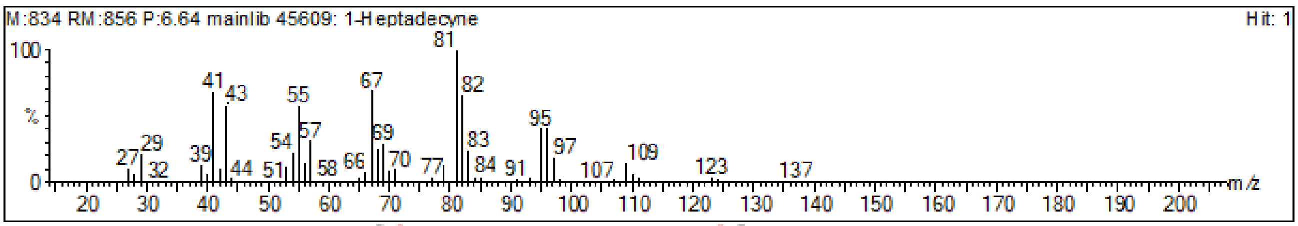


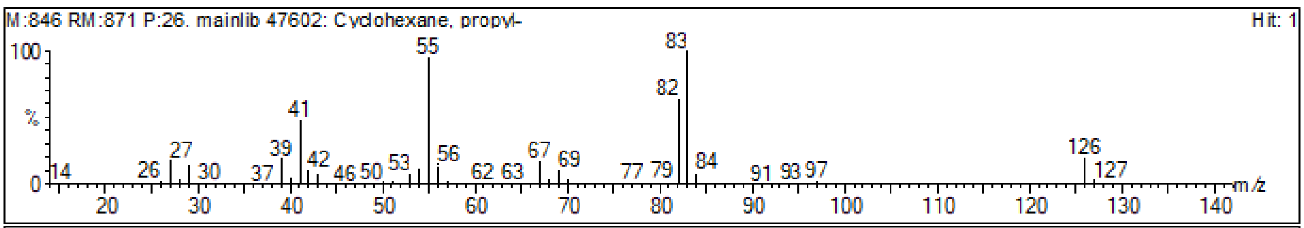


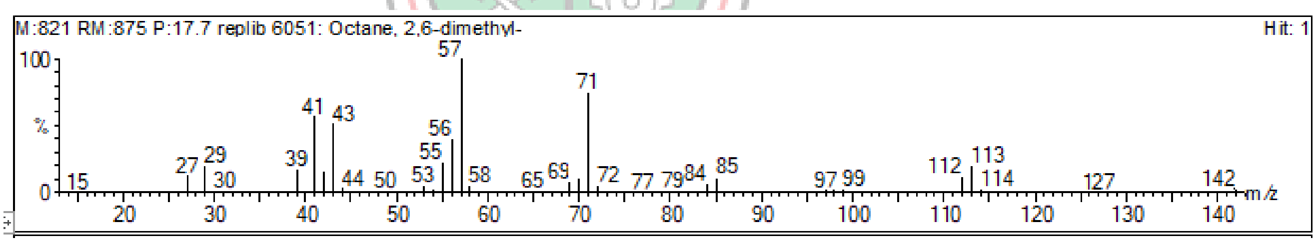


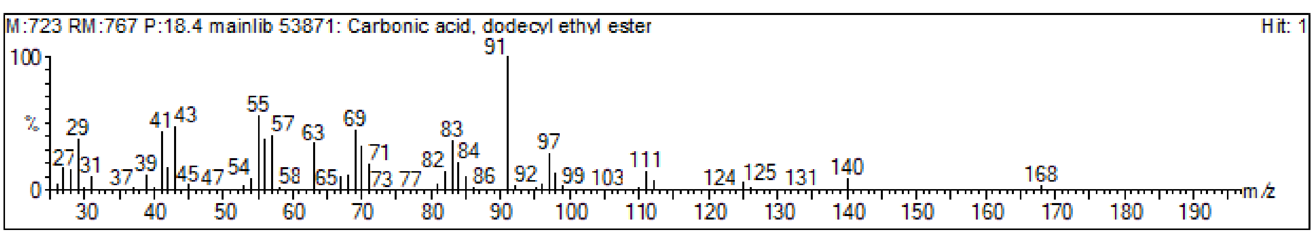
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



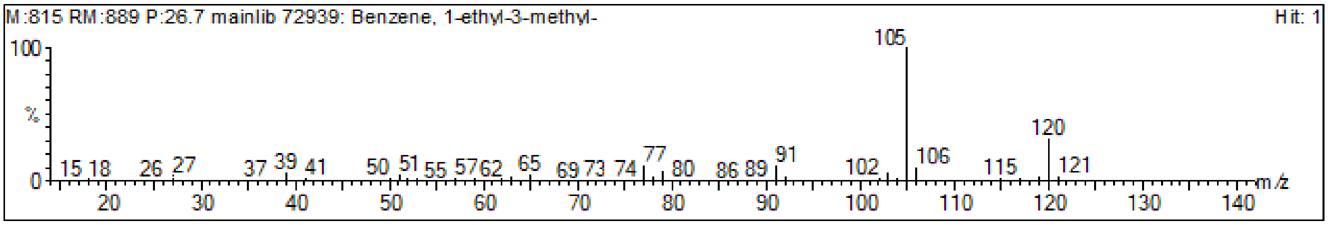


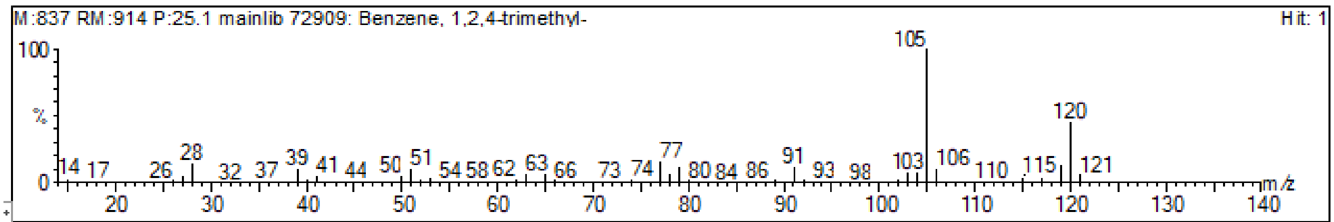


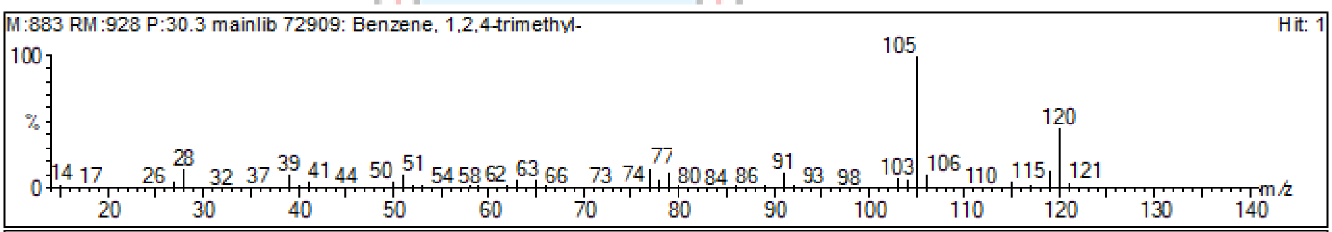


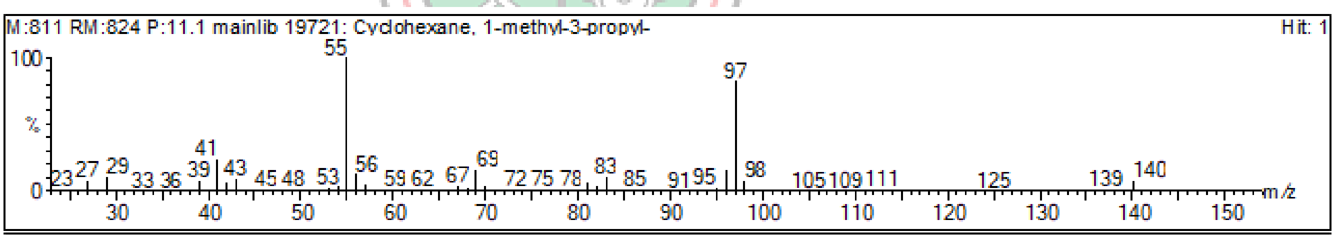


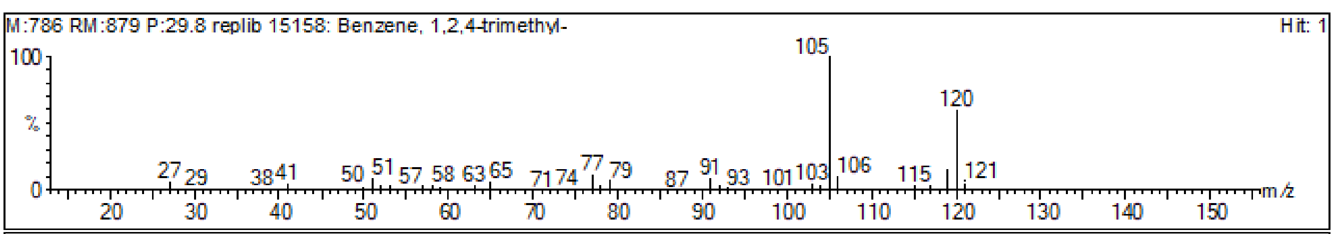
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



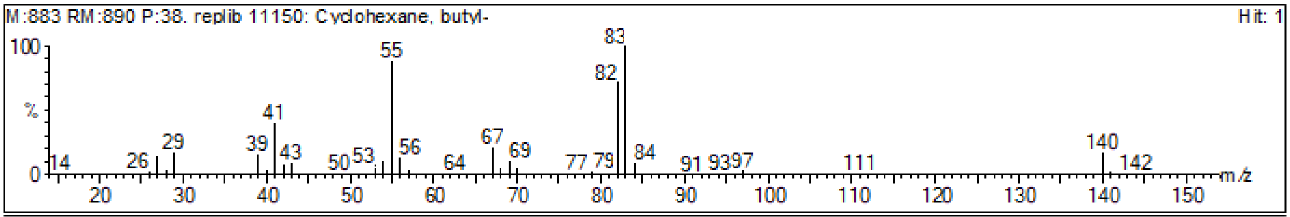


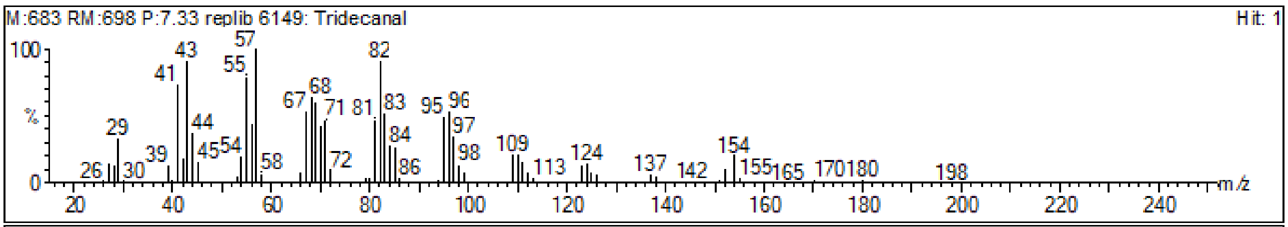


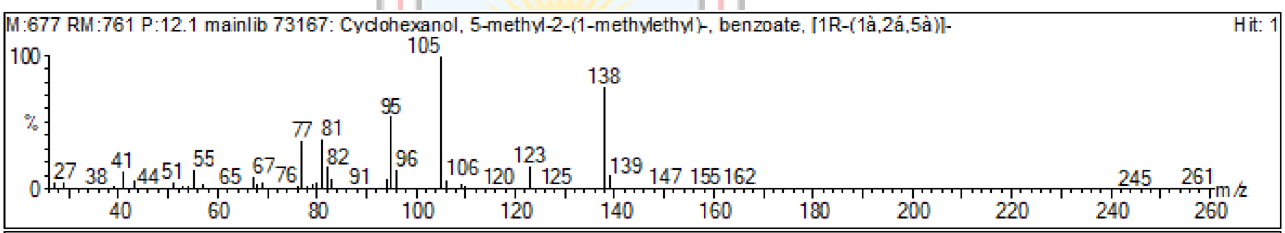


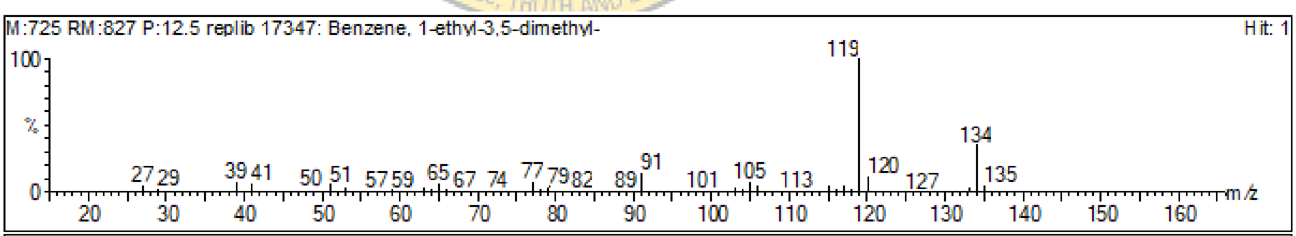


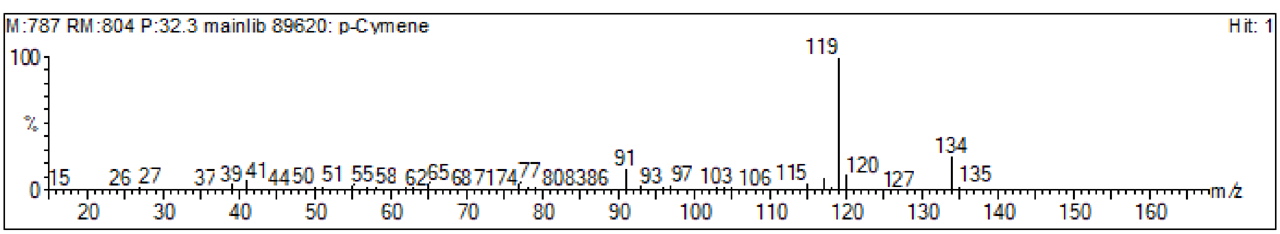
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



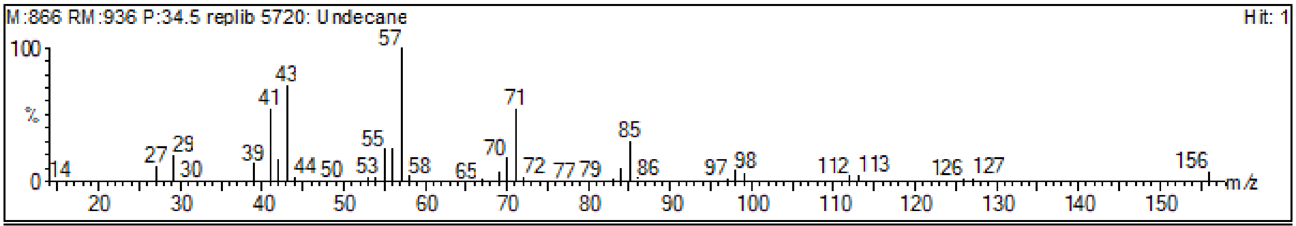


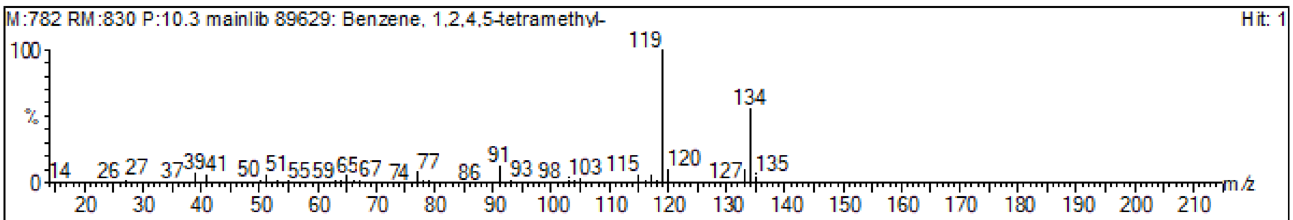


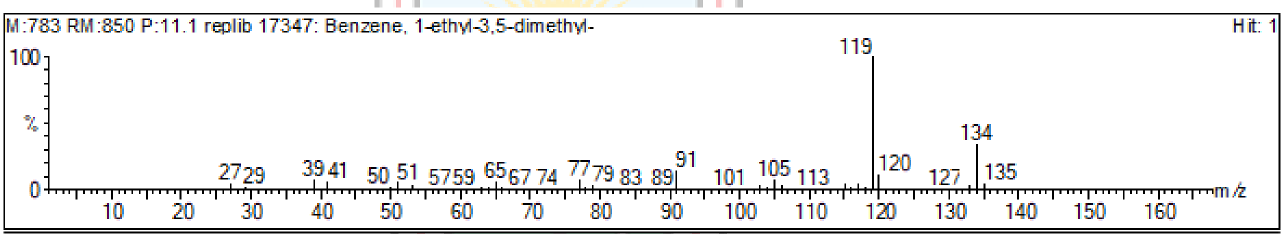


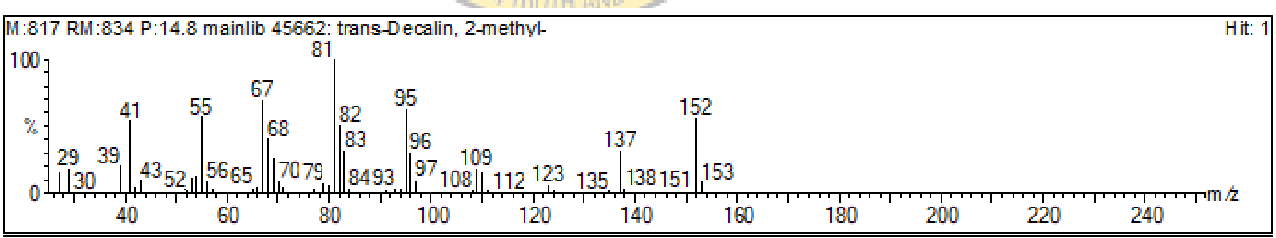


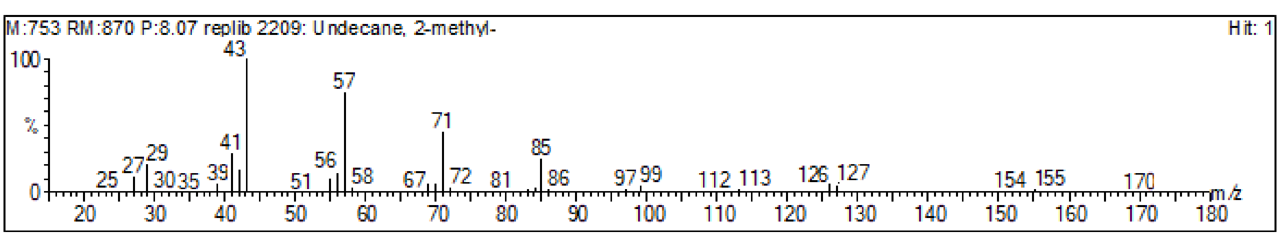
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



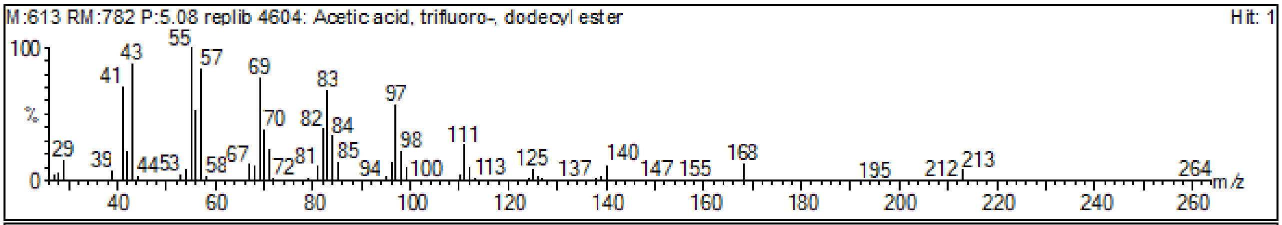


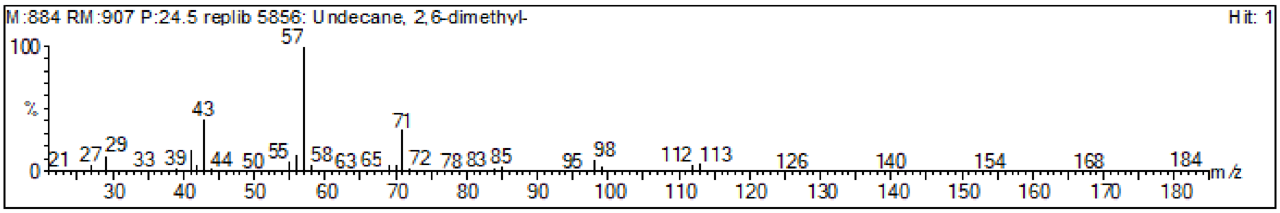


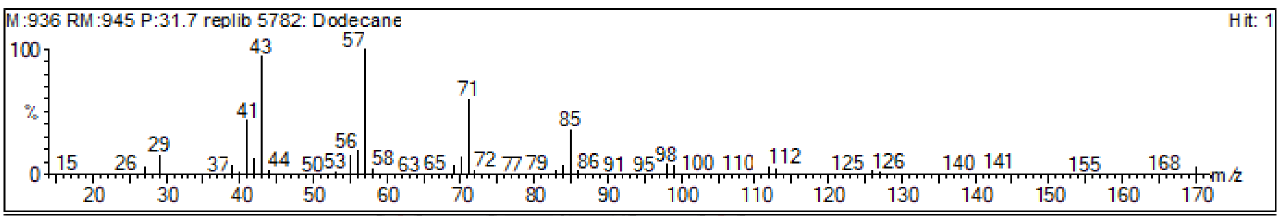


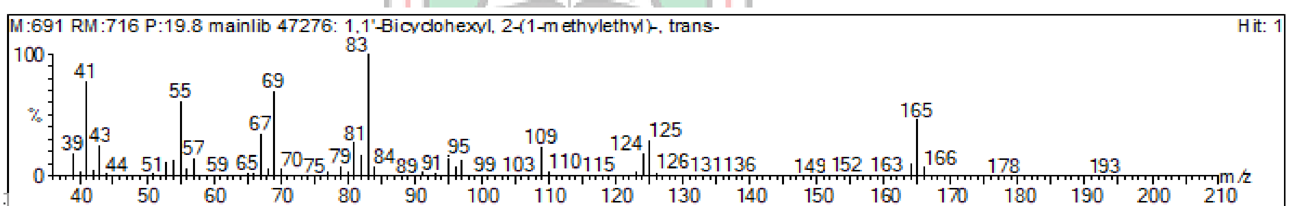


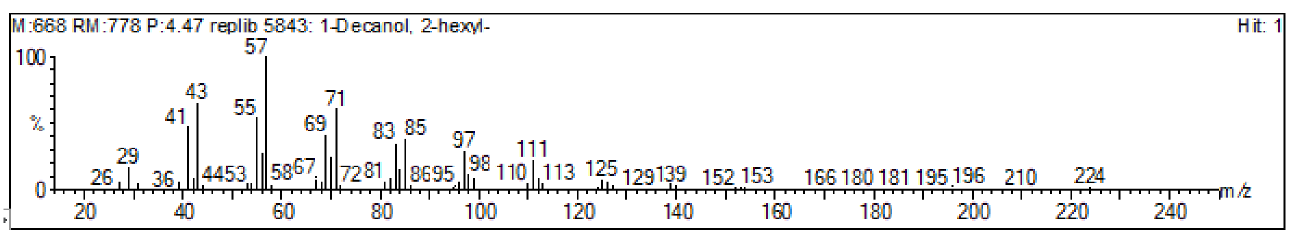
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



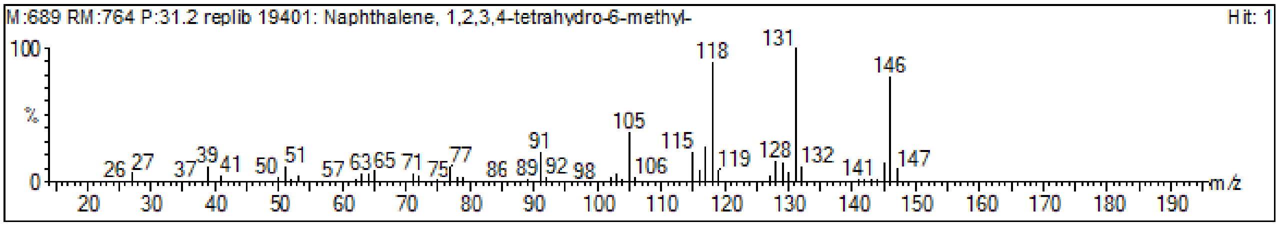


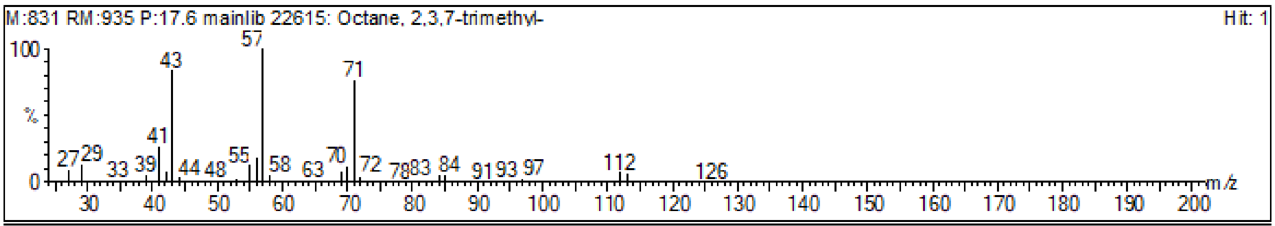


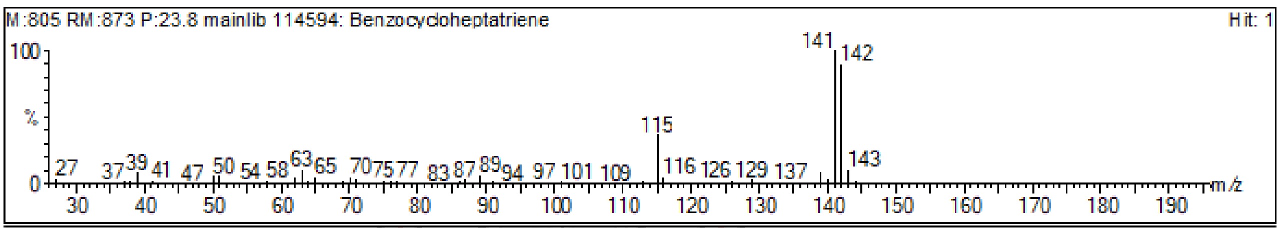


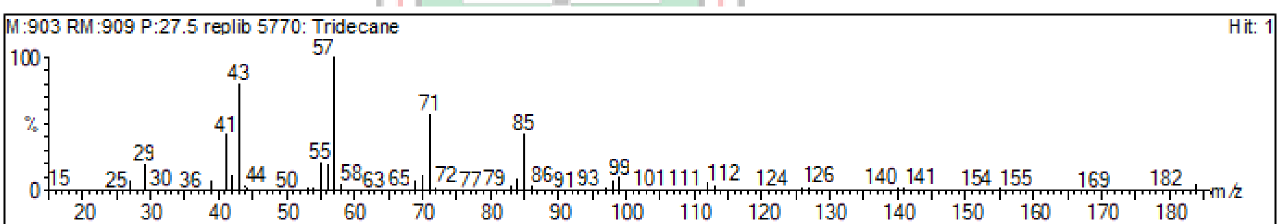


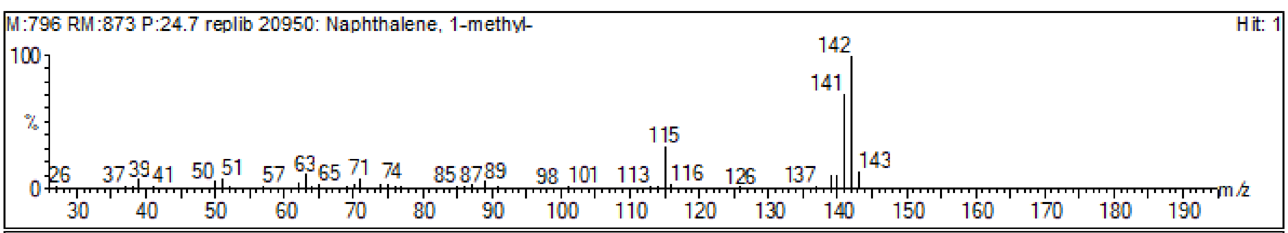
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



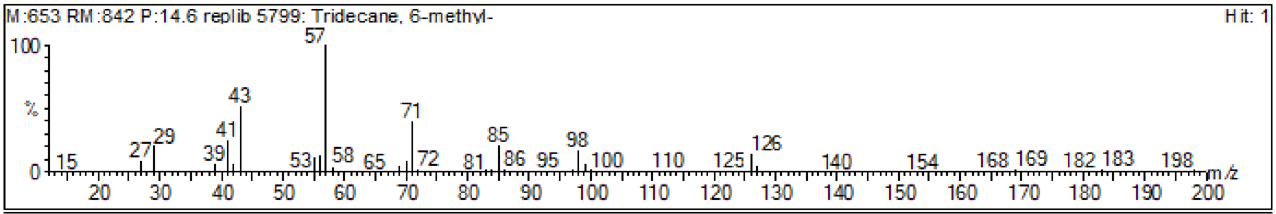


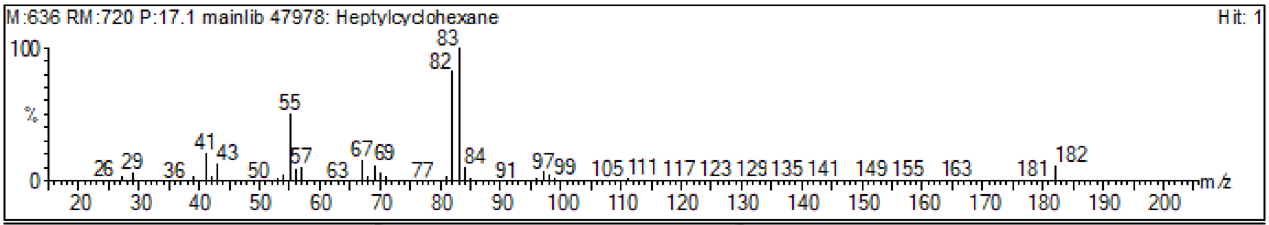


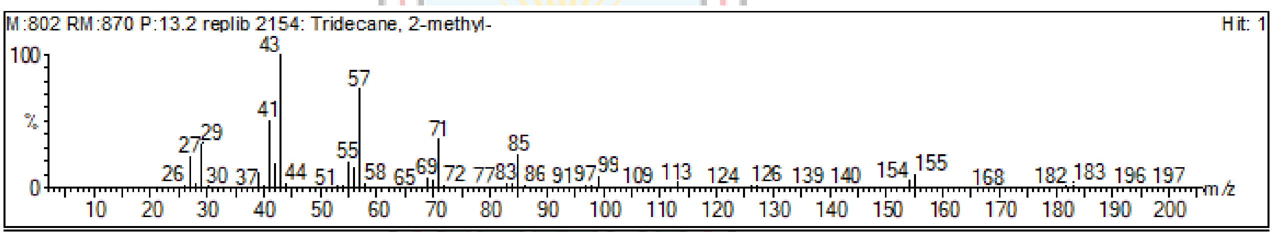


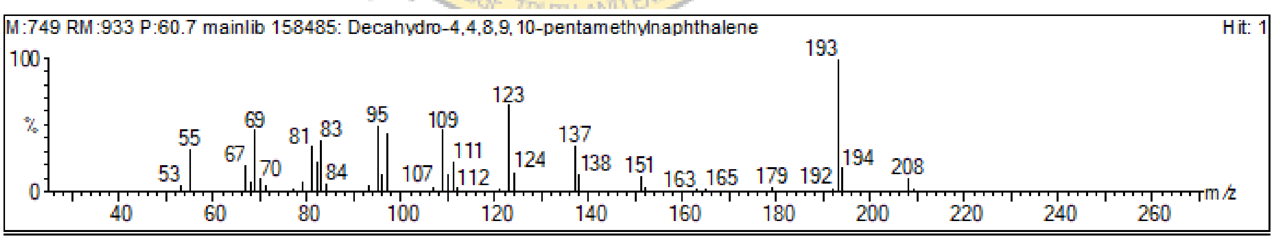


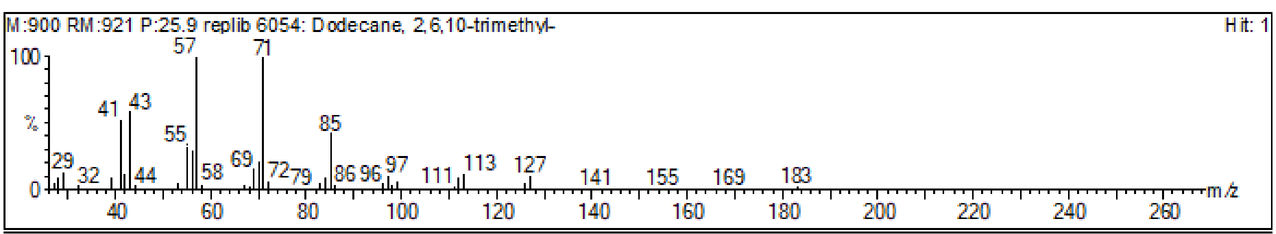
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



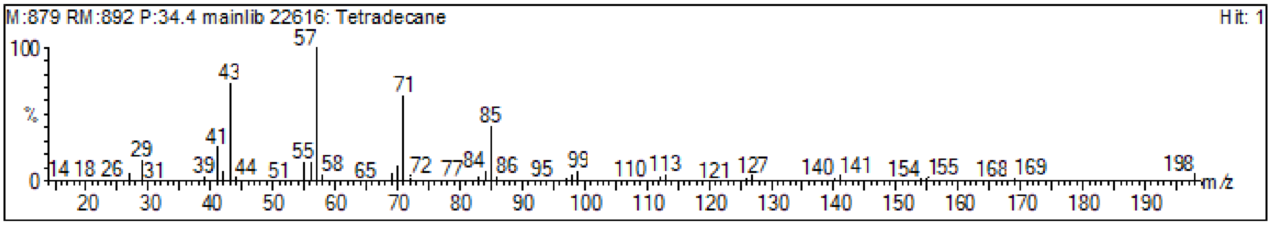


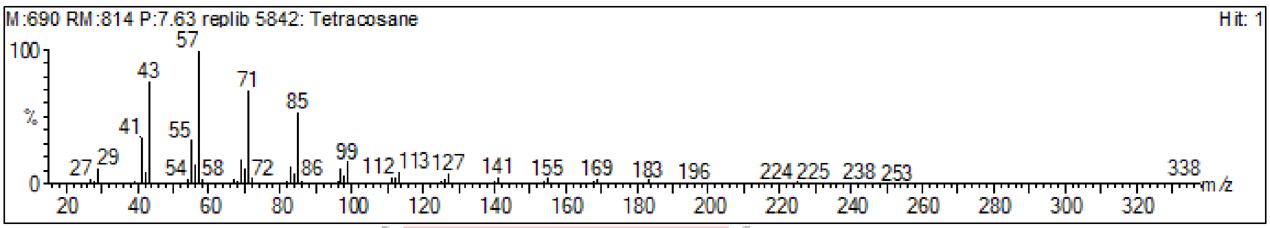


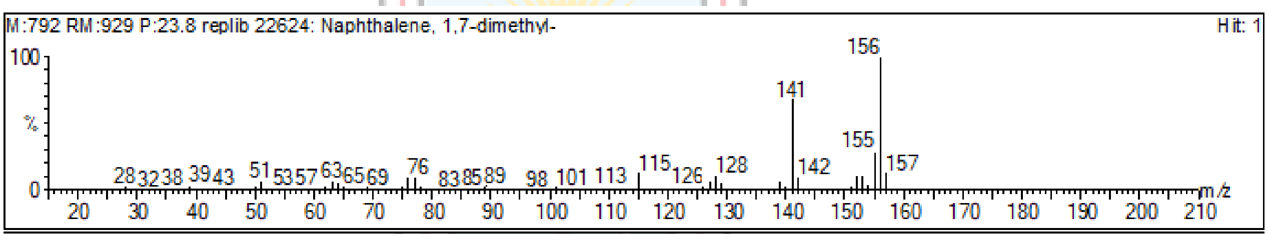


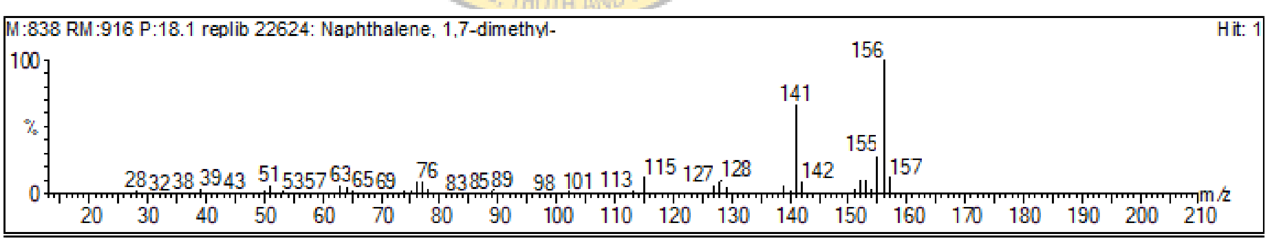


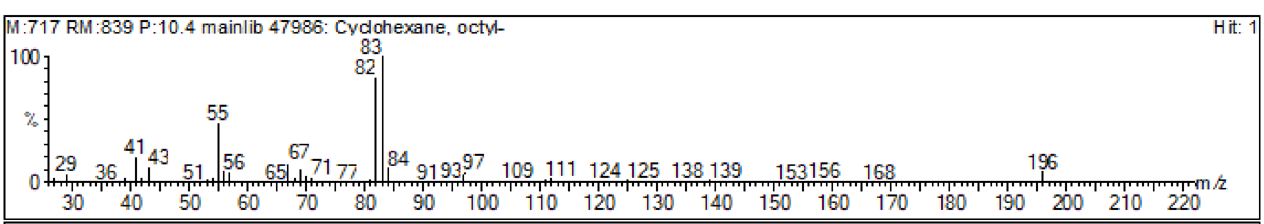
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



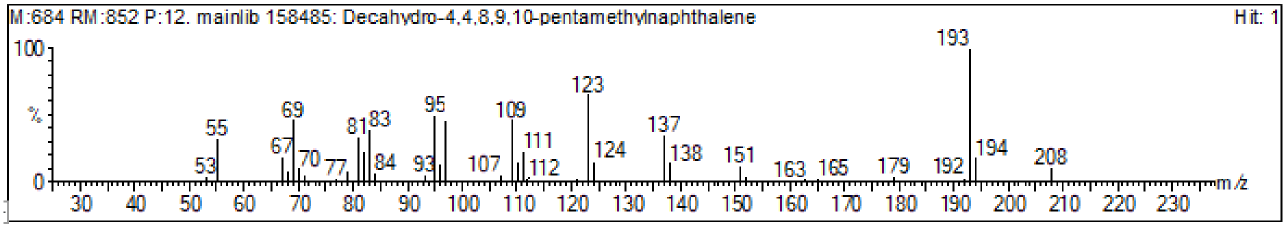


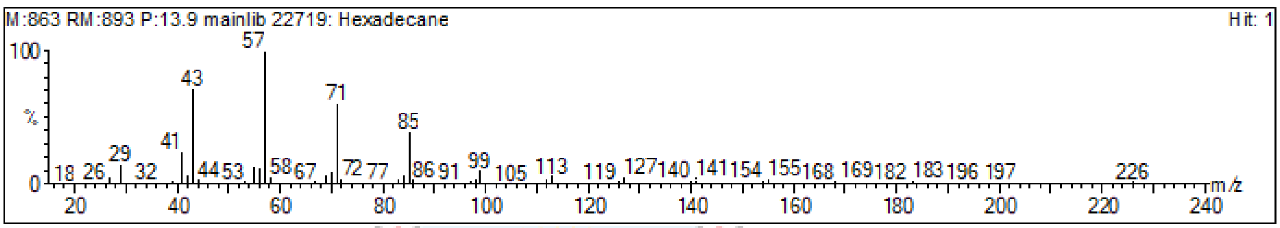


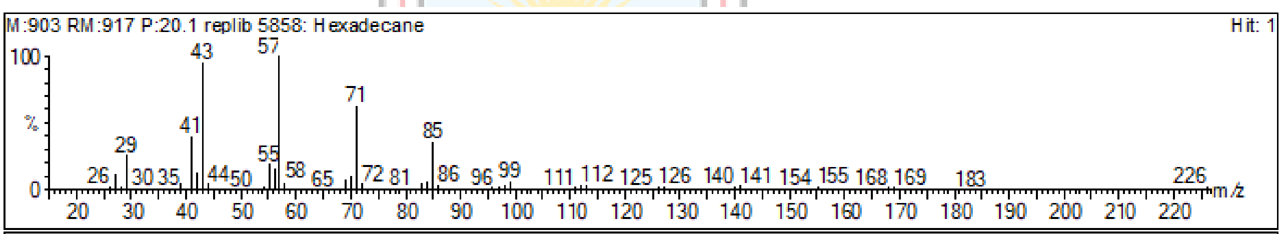


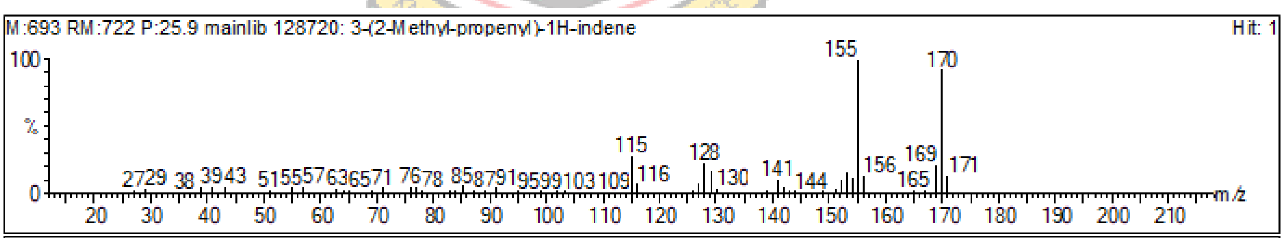


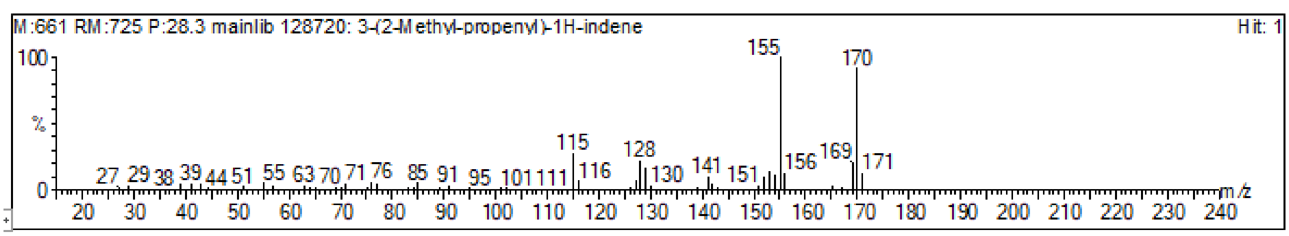
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



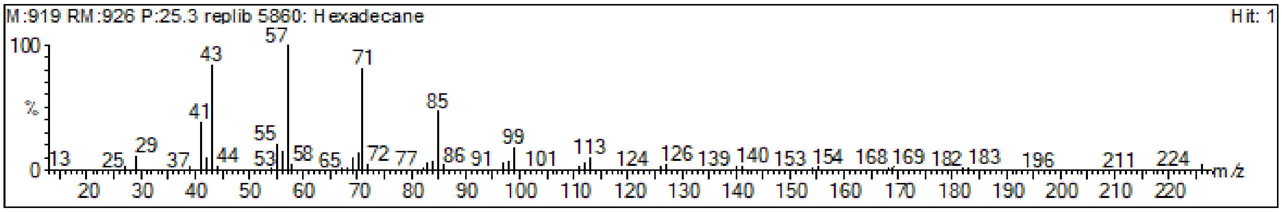


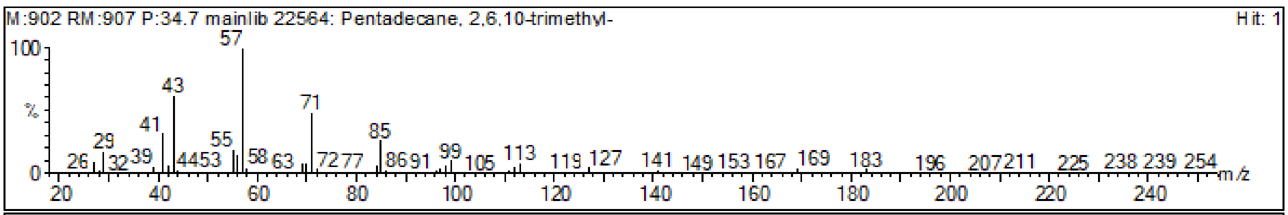


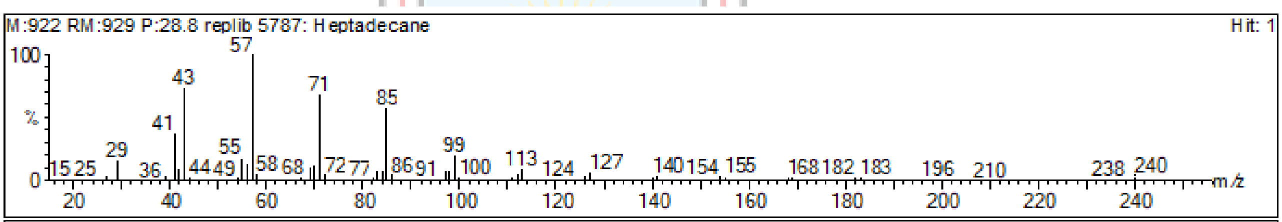


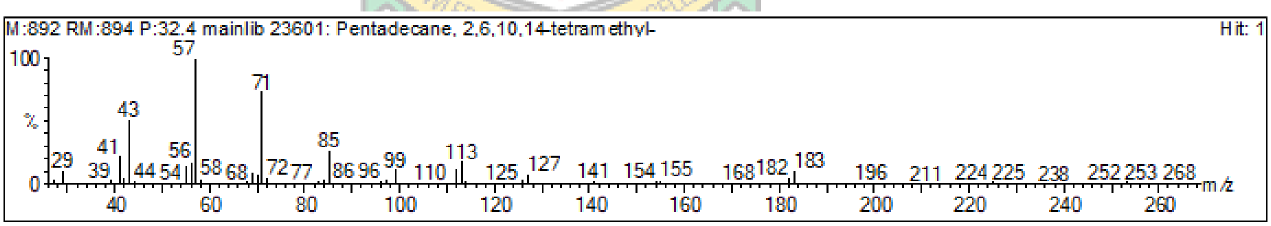


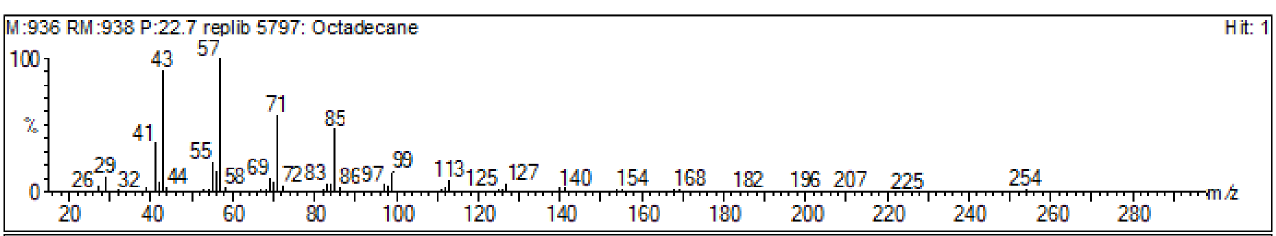
APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)



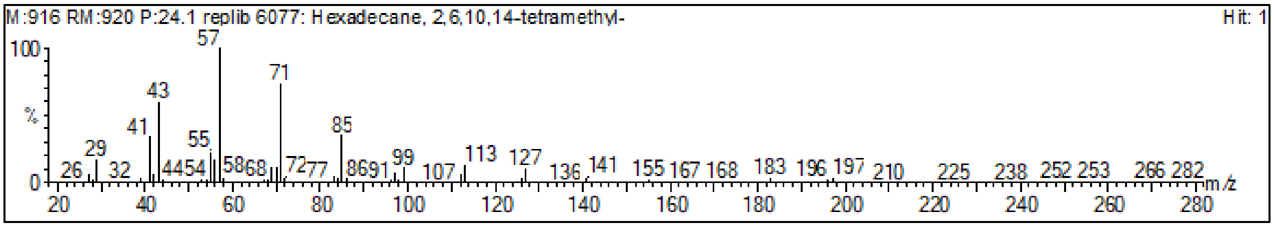


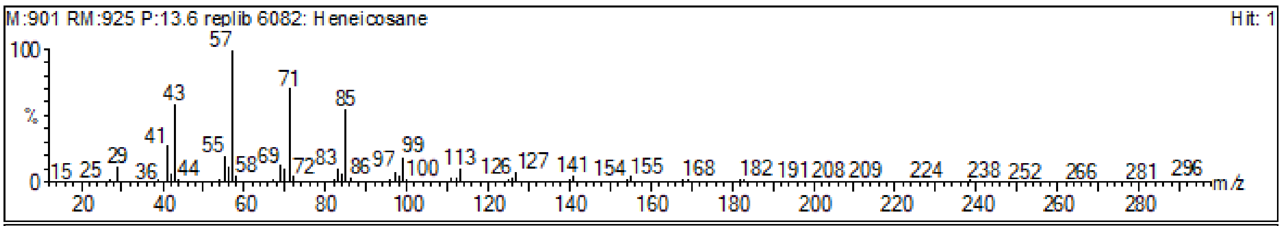


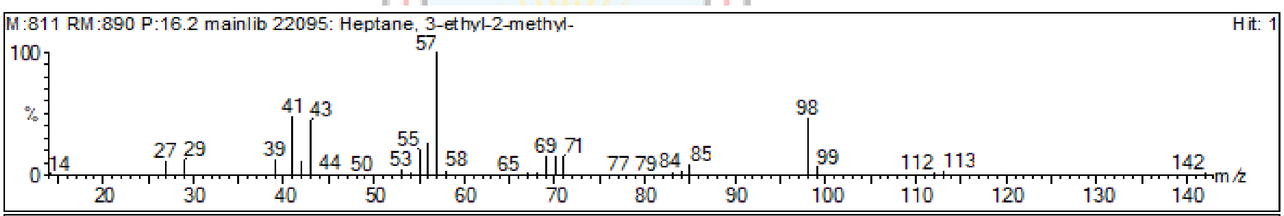


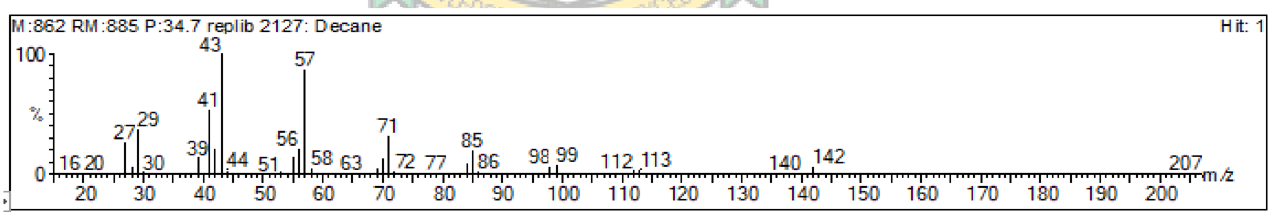


APPENDIX F3 Gasoline Chromatogram/Spectrum Peak Report (Continued)









APPENDIX G1 WAVENUMBERS VRS TRANSMITTANCES OF KEROSENE

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3996.05656	0.99701	3918.54245	0.99707	3841.02833	0.99689
3994.01672	0.99635	3916.5026	0.9969	3838.98849	0.99634
3991.97687	0.99594	3914.46276	0.99719	3836.94864	0.99591
3989.93703	0.99641	3912.42291	0.99742	3834.9088	0.99581
3987.89718	0.99711	3910.38307	0.99732	3832.86895	0.99655
3985.85734	0.99698	3908.34322	0.99665	3830.82911	0.99786
3983.81749	0.99695	3906.30338	0.99581	3828.78926	0.99838
3981.77765	0.99768	3904.26353	0.99523	3826.74942	0.99778
3979.7378	0.99793	3902.22369	0.99501	3824.70957	0.99696
3977.69796	0.99734	3900.18384	0.99546	3822.66973	0.99651
3975.65811	0.99699	3898.144	0.99624	3820.62988	0.99699
3973.61827	0.99736	3896.10415	0.99697	3818.59004	0.9979
3971.57842	0.99757	3894.06431	0.99765	3816.55019	0.99802
3969.53858	0.99717	3892.02446	0.99781	3814.51035	0.99757
3967.49873	0.99679	3889.98462	0.99726	3812.4705	0.99735
3965.45888	0.9967	3887.94477	0.99631	3810.43066	0.99752
3963.41904	0.99676	3885.90493	0.99545	3808.39081	0.99763
3961.37919	0.99689	3883.86508	0.99566	3806.35097	0.99727
3959.33935	0.99714	3881.82524	0.99661	3804.31112	0.99667
3957.2995	0.99747	3879.78539	0.9973	3802.27128	0.99587
3955.25966	0.99779	3877.74555	0.99725	3800.23143	0.99579
3953.21981	0.99793	3875.7057	0.99691	3798.19159	0.99652
3951.17997	0.99758	3873.66586	0.99669	3796.15174	0.99684
3949.14012	0.99717	3871.62601	0.99662	3794.1119	0.99726
3947.10028	0.99718	3869.58616	0.99705	3792.07205	0.99786
3945.06043	0.99698	3867.54632	0.99762	3790.03221	0.9981
3943.02059	0.9968	3865.50647	0.99765	3787.99236	0.99785

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3940.98074	0.99705	3863.46663	0.99737	3785.95252	0.99741
3938.9409	0.99727	3861.42678	0.99687	3783.91267	0.9972
3936.90105	0.99738	3859.38694	0.99623	3781.87283	0.997
3934.86121	0.99772	3857.34709	0.99594	3779.83298	0.99687
3932.82136	0.99829	3855.30725	0.99622	3777.79314	0.99689
3930.78152	0.9983	3853.2674	0.99705	3775.75329	0.99705
3928.74167	0.99748	3851.22756	0.99749	3773.71344	0.99774
3926.70183	0.99689	3849.18771	0.99724	3771.6736	0.99831
3924.66198	0.99719	3847.14787	0.99721	3769.63375	0.99791
3922.62214	0.99782	3845.10802	0.99743	3767.59391	0.99726
3920.58229	0.99772	3843.06818	0.99737	3765.55406	0.99744
3763.51422	0.99806	3686.00011	0.99667	3608.48599	0.99733
3761.47437	0.99851	3683.96026	0.99631	3606.44615	0.99688
3759.43453	0.99853	3681.92042	0.99604	3604.4063	0.99723
3757.39468	0.99784	3679.88057	0.99649	3602.36646	0.99752
3755.35484	0.99715	3677.84072	0.99746	3600.32661	0.99749
3753.31499	0.99665	3675.80088	0.99801	3598.28677	0.99776
3751.27515	0.99565	3673.76103	0.9979	3596.24692	0.99823
3749.2353	0.99503	3671.72119	0.99798	3594.20708	0.99836
3747.19546	0.99577	3669.68134	0.99814	3592.16723	0.99834
3745.15561	0.99678	3667.6415	0.9983	3590.12739	0.99836
3743.11577	0.99754	3665.60165	0.99837	3588.08754	0.99849
3741.07592	0.99777	3663.56181	0.9979	3586.0477	0.99883
3739.03608	0.99789	3661.52196	0.99744	3584.00785	0.99873
3736.99623	0.99814	3659.48212	0.99779	3581.96801	0.99823
3734.95639	0.99773	3657.44227	0.99806	3579.92816	0.99796
3732.91654	0.99709	3655.40243	0.99741	3577.88831	0.99815

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3730.8767	0.99733	3653.36258	0.9967	3575.84847	0.99829
3728.83685	0.99721	3651.32274	0.99577	3573.80862	0.99811
3726.79701	0.99658	3649.28289	0.99464	3571.76878	0.99832
3724.75716	0.9969	3647.24305	0.99585	3569.72893	0.99855
3722.71732	0.99779	3645.2032	0.99702	3567.68909	0.99764
3720.67747	0.99811	3643.16336	0.99673	3565.64924	0.99676
3718.63763	0.99832	3641.12351	0.99663	3563.6094	0.99723
3716.59778	0.99847	3639.08367	0.99725	3561.56955	0.99789
3714.55794	0.99806	3637.04382	0.99773	3559.52971	0.9982
3712.51809	0.99705	3635.00398	0.99758	3557.48986	0.99813
3710.47825	0.99657	3632.96413	0.99691	3555.45002	0.99776
3708.4384	0.99706	3630.92429	0.99615	3553.41017	0.99761
3706.39856	0.99735	3628.88444	0.99629	3551.37033	0.99792
3704.35871	0.99746	3626.8446	0.99757	3549.33048	0.99762
3702.31887	0.99768	3624.80475	0.99789	3547.29064	0.99667
3700.27902	0.99748	3622.76491	0.99737	3545.25079	0.99649
3698.23918	0.99675	3620.72506	0.99679	3543.21095	0.99717
3696.19933	0.9965	3618.68522	0.99635	3541.1711	0.99787
3692.11964	0.99664	3614.60553	0.99738	3537.09141	0.99813
3690.0798	0.9959	3612.56568	0.99794	3535.05157	0.99795
3688.03995	0.99625	3610.52584	0.99794	3533.01172	0.99799
3475.89606	0.99733	3402.46164	0.99823	3329.02721	0.99809
3473.85621	0.99756	3400.42179	0.99826	3326.98737	0.99765
3471.81637	0.99787	3398.38195	0.99763	3324.94752	0.99709
3469.77652	0.99779	3396.3421	0.99721	3322.90768	0.99695
3467.73668	0.99804	3394.30226	0.99713	3320.86783	0.99679
3465.69683	0.99862	3392.26241	0.99706	3318.82799	0.99688

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3310.66861	0.99787	3233.15449	0.99723	3155.64038	0.99502
3308.62876	0.99797	3231.11465	0.99704	3153.60053	0.9957
3306.58892	0.99807	3229.0748	0.9965	3151.56069	0.9958
3304.54907	0.99782	3227.03496	0.99642	3149.52084	0.9955
3302.50923	0.99749	3224.99511	0.99664	3147.481	0.9953
3300.46938	0.99756	3222.95527	0.99659	3145.44115	0.99512
3298.42954	0.99746	3220.91542	0.99664	3143.40131	0.99504
3296.38969	0.99684	3218.87558	0.99688	3141.36146	0.99509
3294.34985	0.99624	3216.83573	0.99675	3139.32162	0.99505
3292.31	0.99621	3214.79589	0.99657	3137.28177	0.99488
3290.27015	0.99651	3212.75604	0.99675	3135.24193	0.99482
3288.23031	0.99674	3210.7162	0.99686	3133.20208	0.9947
3286.19046	0.99712	3208.67635	0.99678	3131.16224	0.99422
3284.15062	0.99769	3206.63651	0.99675	3129.12239	0.99392
3282.11077	0.99804	3204.59666	0.99674	3127.08255	0.99423
3280.07093	0.99781	3202.55682	0.99641	3125.0427	0.9948
3278.03108	0.99712	3200.51697	0.99551	3123.00286	0.99533
3275.99124	0.99667	3198.47713	0.99464	3120.96301	0.99548
3273.95139	0.99683	3196.43728	0.99466	3118.92317	0.99511
3271.91155	0.99722	3194.39744	0.9953	3116.88332	0.99445
3269.8717	0.99735	3192.35759	0.99552	3114.84348	0.99403
3267.83186	0.9973	3190.31774	0.9953	3112.80363	0.99414
3265.79201	0.99741	3188.2779	0.99514	3110.76379	0.9944
3263.75217	0.99757	3186.23805	0.99501	3108.72394	0.99451
3261.71232	0.9975	3184.19821	0.99479	3106.6841	0.99454
3259.67248	0.99716	3182.15836	0.9948	3104.64425	0.99483
3257.63263	0.99704	3180.11852	0.99532	3102.60441	0.9954

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3251.5131	0.99738	3173.99898	0.99615	3096.48487	0.99402
3249.47325	0.99775	3171.95914	0.99581	3094.44502	0.99394
3247.43341	0.99816	3169.91929	0.99542	3092.40518	0.99389
3245.39356	0.99851	3167.87945	0.99515	3090.36533	0.99373
3241.31387	0.99824	3163.79976	0.99535	3086.28564	0.99352
3239.27403	0.99738	3161.75991	0.99574	3084.2458	0.99338
3237.23418	0.99691	3159.72007	0.99536	3082.20595	0.99356
3235.19434	0.99696	3157.68022	0.99476	3080.16611	0.99385
3078.12626	0.99387	3000.61215	0.97953	2923.09804	0.60255
3076.08642	0.99394	2998.5723	0.97842	2921.05819	0.60185
3074.04657	0.99368	2996.53246	0.97716	2919.01835	0.61007
3072.00673	0.99282	2994.49261	0.97576	2916.9785	0.62528
3069.96688	0.99208	2992.45277	0.97382	2914.93866	0.6441
3067.92704	0.99166	2990.41292	0.97114	2912.89881	0.66311
3065.88719	0.99133	2988.37308	0.96793	2910.85897	0.68044
3063.84735	0.99112	2986.33323	0.96394	2908.81912	0.69612
3061.8075	0.9909	2984.29339	0.95906	2906.77928	0.71061
3059.76766	0.99055	2982.25354	0.95321	2904.73943	0.72417
3057.72781	0.99018	2980.2137	0.94593	2902.69958	0.73709
3055.68797	0.98981	2978.17385	0.93671	2900.65974	0.74954
3053.64812	0.9897	2976.13401	0.92469	2898.61989	0.7615
3051.60828	0.99012	2974.09416	0.90938	2896.58005	0.77311
3049.56843	0.99053	2972.05432	0.89083	2894.5402	0.78483
3047.52859	0.99021	2970.01447	0.86895	2892.50036	0.7971
3045.48874	0.98934	2967.97463	0.84395	2890.46051	0.80942
3043.4489	0.98878	2965.93478	0.81698	2888.42067	0.82071
3041.40905	0.98881	2963.89494	0.78981	2886.38082	0.82958

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3035.28952	0.98736	2957.7754	0.71731	2880.26129	0.83137
3033.24967	0.98683	2955.73556	0.70153	2878.22144	0.82058
3031.20983	0.98633	2953.69571	0.69466	2876.1816	0.80519
3029.16998	0.98582	2951.65587	0.69739	2874.14175	0.78954
3027.13014	0.98517	2949.61602	0.70827	2872.10191	0.77831
3025.09029	0.98458	2947.57618	0.72449	2870.06206	0.77347
3023.05045	0.98436	2945.53633	0.74132	2868.02222	0.77368
3021.0106	0.98433	2943.49649	0.75307	2865.98237	0.7755
3018.97076	0.98407	2941.45664	0.75593	2863.94253	0.77511
3016.93091	0.98354	2939.4168	0.74974	2861.90268	0.77103
3014.89107	0.98299	2937.37695	0.73655	2859.86284	0.7645
3012.85122	0.98259	2935.33711	0.71849	2857.82299	0.75686
3010.81138	0.98229	2933.29726	0.69734	2855.78315	0.74998
3008.77153	0.98193	2931.25742	0.67433	2853.7433	0.74835
3006.73169	0.98159	2929.21757	0.65074	2851.70346	0.75612
3004.69184	0.98117	2927.17773	0.62899	2849.66361	0.77264
3002.652	0.98046	2925.13788	0.6121	2847.62377	0.7933
2845.58392	0.81444	2768.06981	0.98997	2690.55569	0.99138
2843.54408	0.83597	2766.02996	0.99004	2688.51585	0.99118
2841.50423	0.85862	2763.99012	0.99024	2686.476	0.99095
2839.46439	0.8809	2761.95027	0.99033	2684.43616	0.99107
2837.42454	0.90037	2759.91043	0.99062	2682.39631	0.99132
2835.3847	0.91633	2757.87058	0.99131	2680.35647	0.99124
2833.34485	0.92947	2755.83074	0.99189	2678.31662	0.99086
2829.26516	0.94818	2751.75105	0.99152	2674.23693	0.99011
2827.22532	0.95426	2749.7112	0.99096	2672.19709	0.98994

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2821.10578	0.96598	2743.59167	0.9909	2666.07755	0.98991
2819.06594	0.96801	2741.55182	0.99026	2664.03771	0.99025
2817.02609	0.96965	2739.51198	0.98955	2661.99786	0.99024
2814.98625	0.97149	2737.47213	0.98901	2659.95802	0.99008
2812.9464	0.97363	2735.43229	0.98872	2657.91817	0.99025
2810.90656	0.97553	2733.39244	0.98852	2655.87833	0.99087
2808.86671	0.97693	2731.3526	0.98812	2653.83848	0.99149
2806.82686	0.97793	2729.31275	0.98766	2651.79864	0.99174
2804.78702	0.97882	2727.27291	0.98749	2649.75879	0.99175
2802.74717	0.97972	2725.23306	0.98761	2647.71895	0.99178
2800.70733	0.98049	2723.19322	0.98803	2645.6791	0.99177
2798.66748	0.98122	2721.15337	0.9887	2643.63926	0.99148
2796.62764	0.98187	2719.11353	0.98931	2641.59941	0.99101
2794.58779	0.98227	2717.07368	0.98974	2639.55957	0.99087
2792.54795	0.98269	2715.03384	0.99006	2637.51972	0.99138
2790.5081	0.98354	2712.99399	0.99035	2635.47988	0.99222
2788.46826	0.98465	2710.95415	0.9906	2633.44003	0.9928
2786.42841	0.98555	2708.9143	0.99077	2631.40019	0.99294
2784.38857	0.98633	2706.87445	0.99078	2629.36034	0.99272
2782.34872	0.98709	2704.83461	0.99069	2627.3205	0.99218
2780.30888	0.98745	2702.79476	0.99081	2625.28065	0.99175
2778.26903	0.98754	2700.75492	0.99119	2623.24081	0.99186
2776.22919	0.98792	2698.71507	0.99142	2621.20096	0.9922
2774.18934	0.98864	2696.67523	0.9913	2619.16112	0.99249
2772.1495	0.98942	2694.63538	0.99119	2617.12127	0.99267
2770.10965	0.9899	2692.59554	0.99131	2615.08143	0.99244
2560.00561	0.99595	2482.49149	0.99612	2404.97738	0.99539

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance)	Wavenumber (cm^{-1})	Transmittance
2613.04158	0.99187	2535.52747	0.99613	2458.01335	0.99695
2611.00173	0.99168	2533.48762	0.99622	2455.97351	0.9967
2608.96189	0.99223	2531.44778	0.99695	2453.93366	0.99599
2606.92204	0.99296	2529.40793	0.99754	2451.89382	0.99527
2604.8822	0.99325	2527.36809	0.99709	2449.85397	0.9953
2602.84235	0.99307	2525.32824	0.99623	2447.81413	0.99565
2600.80251	0.9929	2523.2884	0.99586	2445.77428	0.99577
2598.76266	0.99309	2521.24855	0.99575	2443.73444	0.99617
2596.72282	0.99329	2519.20871	0.99591	2441.69459	0.99695
2594.68297	0.99318	2517.16886	0.9966	2439.65475	0.99722
2592.64313	0.99303	2515.12901	0.99728	2437.6149	0.99662
2590.60328	0.99292	2513.08917	0.9976	2435.57506	0.99608
2588.56344	0.99297	2511.04932	0.99759	2433.53521	0.99585
2586.52359	0.99352	2509.00948	0.99744	2431.49537	0.99545
2584.48375	0.99423	2506.96963	0.99756	2429.45552	0.99533
2582.4439	0.99435	2504.92979	0.99758	2427.41568	0.99593
2580.40406	0.99411	2502.88994	0.99694	2425.37583	0.9964
2578.36421	0.99394	2500.8501	0.99604	2423.33599	0.99598
2576.32437	0.99397	2498.81025	0.99581	2421.29614	0.99555
2574.28452	0.99435	2496.77041	0.99623	2419.25629	0.99565
2572.24468	0.99499	2494.73056	0.99639	2417.21645	0.99546
2570.20483	0.99524	2492.69072	0.99624	2415.1766	0.99493
2568.16499	0.99482	2490.65087	0.99622	2413.13676	0.99491
2566.12514	0.99448	2488.61103	0.99651	2411.09691	0.99538
2564.0853	0.99476	2486.57118	0.9966	2409.05707	0.99565
2562.04545	0.99545	2484.53134	0.9962	2407.01722	0.99552

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2551.84623	0.99533	2474.33211	0.99499	2396.818	0.99513
2549.80638	0.99593	2472.29227	0.99573	2394.77815	0.99495
2547.76654	0.99638	2470.25242	0.9969	2392.73831	0.99505
2545.72669	0.99634	2468.21258	0.99733	2390.69846	0.99507
2543.68685	0.99621	2466.17273	0.99712	2388.65862	0.99534
2541.647	0.99621	2464.13289	0.99719	2386.61877	0.99537
2539.60716	0.99631	2462.09304	0.99733	2384.57893	0.99501
2537.56731	0.99633	2460.0532	0.99717	2382.53908	0.99508
2613.04158	0.99187	2535.52747	0.99613	2458.01335	0.99695
2611.00173	0.99168	2533.48762	0.99622	2455.97351	0.9967
2608.96189	0.99223	2531.44778	0.99695	2453.93366	0.99599
2606.92204	0.99296	2529.40793	0.99754	2451.89382	0.99527
2604.8822	0.99325	2527.36809	0.99709	2449.85397	0.9953
2602.84235	0.99307	2525.32824	0.99623	2447.81413	0.99565
2600.80251	0.9929	2523.2884	0.99586	2445.77428	0.99577
2598.76266	0.99309	2521.24855	0.99575	2443.73444	0.99617
2596.72282	0.99329	2519.20871	0.99591	2441.69459	0.99695
2594.68297	0.99318	2517.16886	0.9966	2439.65475	0.99722
2592.64313	0.99303	2515.12901	0.99728	2437.6149	0.99662
2590.60328	0.99292	2513.08917	0.9976	2435.57506	0.99608
2588.56344	0.99297	2511.04932	0.99759	2433.53521	0.99585
2586.52359	0.99352	2509.00948	0.99744	2431.49537	0.99545
2584.48375	0.99423	2506.96963	0.99756	2429.45552	0.99533
2582.4439	0.99435	2504.92979	0.99758	2427.41568	0.99593
2580.40406	0.99411	2502.88994	0.99694	2425.37583	0.9964
2578.36421	0.99394	2500.8501	0.99604	2423.33599	0.99598
2576.32437	0.99397	2498.81025	0.99581	2421.29614	0.99555

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2570.20483	0.99524	2492.69072	0.99624	2415.1766	0.99493
2568.16499	0.99482	2490.65087	0.99622	2413.13676	0.99491
2566.12514	0.99448	2488.61103	0.99651	2411.09691	0.99538
2564.0853	0.99476	2486.57118	0.9966	2409.05707	0.99565
2562.04545	0.99545	2484.53134	0.9962	2407.01722	0.99552
2560.00561	0.99595	2482.49149	0.99612	2404.97738	0.99539
2557.96576	0.99589	2480.45165	0.99615	2402.93753	0.99546
2555.92592	0.99554	2478.4118	0.99562	2400.89769	0.99567
2553.88607	0.99523	2476.37196	0.99506	2398.85784	0.99563
2551.84623	0.99533	2474.33211	0.99499	2396.818	0.99513
2549.80638	0.99593	2472.29227	0.99573	2394.77815	0.99495
2547.76654	0.99638	2470.25242	0.9969	2392.73831	0.99505
2545.72669	0.99634	2468.21258	0.99733	2390.69846	0.99507
2543.68685	0.99621	2466.17273	0.99712	2388.65862	0.99534
2541.647	0.99621	2464.13289	0.99719	2386.61877	0.99537
2539.60716	0.99631	2462.09304	0.99733	2384.57893	0.99501
2537.56731	0.99633	2460.0532	0.99717	2382.53908	0.99508
2380.49924	0.9957	2307.06481	0.99526	2233.63039	0.99584
2378.45939	0.99622	2305.02497	0.99507	2231.59055	0.9964
2376.41955	0.99574	2302.98512	0.99525	2229.5507	0.99568
2374.3797	0.9942	2300.94528	0.99556	2227.51086	0.99497
2372.33986	0.99332	2298.90543	0.99574	2225.47101	0.99543
2370.30001	0.99411	2296.86559	0.99587	2223.43116	0.99685
2368.26017	0.99462	2294.82574	0.99635	2221.39132	0.99675
2366.22032	0.99326	2292.7859	0.99676	2219.35147	0.99469
2364.18048	0.99222	2290.74605	0.99667	2217.31163	0.99392
2362.14063	0.99145	2288.70621	0.99632	2215.27178	0.99513

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittsnce	Wavenumber (cm^{-1})	Transmittsnce	Wavenumber (cm^{-1})	Transmittsnce
2356.0211	0.99562	2282.58667	0.99555	2209.15225	0.9973
2353.98125	0.99604	2280.54683	0.99512	2207.1124	0.99821
2351.94141	0.995	2278.50698	0.99549	2205.07256	0.99788
2349.90156	0.99404	2276.46714	0.99654	2203.03271	0.99654
2347.86172	0.99348	2274.42729	0.99638	2200.99287	0.99625
2345.82187	0.99287	2272.38745	0.99565	2198.95302	0.99709
2343.78203	0.99156	2270.3476	0.99629	2196.91318	0.99772
2341.74218	0.99128	2268.30776	0.99776	2194.87333	0.9973
2339.70234	0.99328	2266.26791	0.99788	2192.83349	0.99568
2337.66249	0.99515	2264.22807	0.99655	2190.79364	0.99433
2335.62265	0.9955	2262.18822	0.99535	2188.7538	0.99461
2333.5828	0.99525	2260.14838	0.99498	2186.71395	0.99586
2331.54296	0.99466	2258.10853	0.9952	2184.67411	0.9964
2329.50311	0.99428	2256.06869	0.9947	2182.63426	0.9966
2327.46327	0.99488	2254.02884	0.9932	2180.59442	0.99747
2325.42342	0.99539	2251.989	0.993	2178.55457	0.99784
2323.38358	0.99532	2249.94915	0.9945	2176.51473	0.99775
2321.34373	0.99534	2247.90931	0.99562	2174.47488	0.99818
2319.30388	0.99593	2245.86946	0.99586	2172.43504	0.99811
2317.26404	0.99708	2243.82962	0.9958	2170.39519	0.99763
2315.22419	0.99797	2241.78977	0.99557	2168.35535	0.99768
2313.18435	0.99814	2239.74993	0.99486	2166.3155	0.998
2311.1445	0.99756	2237.71008	0.99389	2164.27566	0.99817
2309.10466	0.99627	2235.67024	0.99426	2162.23581	0.99729
2107.15999	0.99636	2029.64588	0.99798	1952.13177	0.99357
2105.12015	0.99624	2027.60603	0.99743	1950.09192	0.99361
2103.0803	0.99618	2025.56619	0.9986	1948.05208	0.99405

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2160.19597	0.99507	2082.68185	0.99682	2005.16774	0.99661
2158.15612	0.99233	2080.64201	0.99599	2003.12789	0.99678
2156.11628	0.99149	2078.60216	0.99578	2001.08805	0.9953
2154.07643	0.99329	2076.56232	0.99652	1999.0482	0.99464
2152.03659	0.99545	2074.52247	0.99721	1997.00836	0.99445
2149.99674	0.99667	2072.48263	0.99673	1994.96851	0.99413
2147.9569	0.9968	2070.44278	0.99573	1992.92867	0.99434
2145.91705	0.99659	2068.40294	0.99559	1990.88882	0.99556
2143.87721	0.9972	2066.36309	0.99625	1988.84898	0.99532
2141.83736	0.99854	2064.32325	0.99642	1986.80913	0.99277
2139.79752	0.99984	2062.2834	0.99623	1984.76929	0.9929
2137.75767	0.99974	2060.24356	0.99689	1982.72944	0.99609
2135.71783	0.99813	2058.20371	0.99832	1980.6896	0.99739
2133.67798	0.998	2056.16387	0.99905	1978.64975	0.99648
2131.63814	0.99944	2054.12402	0.99812	1976.60991	0.99651
2129.59829	0.99901	2052.08418	0.997	1974.57006	0.99743
2127.55844	0.9972	2050.04433	0.99686	1972.53022	0.99701
2125.5186	0.99567	2048.00449	0.99634	1970.49037	0.99535
2123.47875	0.99428	2045.96464	0.99507	1968.45053	0.99354
2121.43891	0.99422	2043.9248	0.99495	1966.41068	0.99299
2119.39906	0.99524	2041.88495	0.99594	1964.37084	0.99449
2117.35922	0.99542	2039.84511	0.99614	1962.33099	0.99599
2115.31937	0.99525	2037.80526	0.9956	1960.29115	0.99658
2113.27953	0.99583	2035.76542	0.99653	1958.2513	0.99691
2111.23968	0.9965	2033.72557	0.99896	1956.21146	0.99602
2109.19984	0.99658	2031.68572	0.9995	1954.17161	0.99432
2099.00061	0.99575	2021.4865	0.99932	1943.97239	0.99513

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2090.84123	0.99581	2013.32712	0.99128	1935.813	0.9935
2088.80139	0.99621	2011.28727	0.99129	1933.77316	0.99383
2086.76154	0.99709	2009.24743	0.99243	1931.73331	0.99433
1927.65362	0.99491	1852.17936	0.99494	1776.70509	0.99327
1925.61378	0.99611	1850.13951	0.99505	1774.66524	0.99351
1923.57393	0.99631	1848.09967	0.99479	1772.6254	0.99343
1921.53409	0.99581	1846.05982	0.99437	1770.58555	0.99296
1919.49424	0.99587	1844.01998	0.99431	1768.54571	0.99303
1917.4544	0.99635	1841.98013	0.99437	1766.50586	0.99324
1915.41455	0.99656	1839.94029	0.99471	1764.46602	0.99313
1913.37471	0.9963	1837.90044	0.99535	1762.42617	0.99286
1911.33486	0.99552	1835.86059	0.99535	1760.38633	0.99252
1909.29502	0.99506	1833.82075	0.99463	1758.34648	0.99224
1907.25517	0.9956	1831.7809	0.99421	1756.30664	0.99209
1905.21533	0.99637	1829.74106	0.99462	1754.26679	0.99208
1903.17548	0.99674	1827.70121	0.99504	1752.22695	0.99204
1901.13564	0.99675	1825.66137	0.99498	1750.1871	0.99186
1899.09579	0.9967	1823.62152	0.99511	1748.14726	0.9917
1897.05595	0.99668	1821.58168	0.99538	1746.10741	0.9915
1895.0161	0.99652	1819.54183	0.99534	1744.06757	0.99121
1892.97626	0.99624	1817.50199	0.99516	1742.02772	0.99092
1890.93641	0.9956	1815.46214	0.99494	1739.98787	0.99072
1888.89657	0.99443	1813.4223	0.99466	1737.94803	0.99072
1886.85672	0.99405	1811.38245	0.99446	1735.90818	0.99083
1884.81688	0.99499	1809.34261	0.99428	1733.86834	0.99106
1882.77703	0.99605	1807.30276	0.99382	1731.82849	0.99115
1880.73719	0.99637	1805.26292	0.99331	1729.78865	0.99088

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1874.61765	0.99514	1799.14338	0.99338	1723.66911	0.99044
1872.57781	0.99496	1797.10354	0.99348	1721.62927	0.99067
1870.53796	0.99448	1795.06369	0.99324	1719.58942	0.99094
1868.49812	0.99371	1793.02385	0.99318	1717.54958	0.99126
1866.45827	0.99371	1790.984	0.99312	1715.50973	0.99113
1864.41843	0.99439	1788.94416	0.99313	1713.46989	0.99068
1862.37858	0.99483	1786.90431	0.99335	1711.43004	0.99066
1860.33874	0.99481	1784.86447	0.99353	1709.3902	0.99108
1858.29889	0.99465	1782.82462	0.99366	1707.35035	0.99147
1856.25905	0.99457	1780.78478	0.99368	1705.31051	0.99142
1854.2192	0.9947	1778.74493	0.9934	1703.27066	0.99118
1701.23082	0.99097	1619.63701	0.98799	1538.04321	0.98477
1699.19097	0.99082	1617.59717	0.98711	1536.00336	0.98494
1697.15113	0.99081	1615.55732	0.98542	1533.96352	0.9849
1695.11128	0.99085	1613.51748	0.9845	1531.92367	0.98498
1693.07144	0.99097	1611.47763	0.9838	1529.88383	0.98485
1691.03159	0.99106	1609.43779	0.98289	1527.84398	0.9842
1688.99175	0.99097	1607.39794	0.98236	1525.80414	0.98302
1686.9519	0.99085	1605.3581	0.98258	1523.76429	0.98182
1684.91206	0.99088	1603.31825	0.98333	1521.72445	0.98098
1682.87221	0.991	1601.27841	0.98438	1519.6846	0.98072
1680.83237	0.99085	1599.23856	0.98548	1517.64476	0.98021
1678.79252	0.99067	1597.19872	0.9862	1515.60491	0.97933
1676.75268	0.99084	1595.15887	0.98638	1513.56507	0.97875
1674.71283	0.99109	1593.11903	0.9864	1511.52522	0.97848
1672.67299	0.99095	1591.07918	0.98659	1509.48538	0.97842
1670.63314	0.99074	1589.03934	0.98682	1507.44553	0.97785

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1664.51361	0.98986	1582.9198	0.98744	1501.326	0.97405
1662.47376	0.98974	1580.87996	0.98796	1499.28615	0.9721
1660.43392	0.98999	1578.84011	0.98834	1497.24631	0.96927
1658.39407	0.99018	1576.80027	0.98827	1495.20646	0.96736
1656.35423	0.99038	1574.76042	0.98788	1493.16662	0.96697
1654.31438	0.99046	1572.72058	0.98756	1491.12677	0.96691
1652.27454	0.98976	1570.68073	0.98738	1489.08693	0.96666
1650.23469	0.98952	1568.64089	0.98746	1487.04708	0.9658
1648.19485	0.98956	1566.60104	0.98763	1485.00724	0.96385
1646.155	0.98945	1564.5612	0.98771	1482.96739	0.96049
1644.11515	0.98979	1562.52135	0.98774	1480.92755	0.95536
1642.07531	0.99024	1560.48151	0.98757	1478.8877	0.9488
1640.03546	0.99048	1558.44166	0.98735	1476.84786	0.94057
1637.99562	0.99055	1556.40182	0.98733	1474.80801	0.9283
1635.95577	0.99029	1554.36197	0.9871	1472.76817	0.90524
1633.91593	0.98999	1552.32213	0.98692	1470.72832	0.87696
1631.87608	0.98999	1550.28228	0.98675	1468.68848	0.85693
1629.83624	0.98981	1548.24243	0.98661	1466.64863	0.84206
1627.79639	0.98929	1546.20259	0.98666	1464.60879	0.82978
1625.75655	0.9889	1544.16274	0.98649	1462.56894	0.82076
1623.7167	0.98858	1542.1229	0.9854	1460.5291	0.81355
1621.67686	0.9882	1540.08305	0.98439	1458.48925	0.8064
1401.37359	0.97302	1327.93916	0.97343	1254.50474	0.9752
1399.33374	0.97206	1325.89932	0.97392	1252.46489	0.97518
1397.2939	0.97084	1323.85947	0.97435	1250.42505	0.97502
1395.25405	0.96934	1321.81963	0.9748	1248.3852	0.9751
1393.21421	0.96694	1319.77978	0.97514	1246.34536	0.9756

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1456.44941	0.80358	1383.01498	0.91707	1309.58056	0.97334
1454.40956	0.80838	1380.97514	0.90376	1307.54071	0.97283
1452.36972	0.81538	1378.93529	0.8911	1305.50087	0.9725
1450.32987	0.82386	1376.89545	0.886	1303.46102	0.97218
1448.29002	0.83551	1374.8556	0.89296	1301.42118	0.972
1446.25018	0.85174	1372.81576	0.90723	1299.38133	0.97212
1444.21033	0.87018	1370.77591	0.91804	1297.34149	0.97237
1442.17049	0.88929	1368.73607	0.92277	1295.30164	0.97273
1440.13064	0.9059	1366.69622	0.92469	1293.2618	0.97313
1438.0908	0.91949	1364.65638	0.92912	1291.22195	0.97342
1436.05095	0.93337	1362.61653	0.93936	1289.18211	0.9737
1434.01111	0.94389	1360.57669	0.95068	1287.14226	0.97401
1431.97126	0.95031	1358.53684	0.95769	1285.10242	0.97429
1429.93142	0.95557	1356.497	0.96154	1283.06257	0.97467
1427.89157	0.95966	1354.45715	0.96362	1281.02273	0.97528
1425.85173	0.96243	1352.4173	0.96475	1278.98288	0.97568
1423.81188	0.96475	1350.37746	0.96548	1276.94304	0.97568
1421.77204	0.96651	1348.33761	0.96596	1274.90319	0.97552
1419.73219	0.968	1346.29777	0.96636	1272.86335	0.97515
1417.69235	0.96966	1344.25792	0.96659	1270.8235	0.97478
1415.6525	0.97063	1342.21808	0.96655	1268.78366	0.9746
1413.61266	0.97117	1340.17823	0.96682	1266.74381	0.97423
1411.57281	0.97193	1338.13839	0.96789	1264.70397	0.97363
1409.53297	0.97275	1336.09854	0.96933	1262.66412	0.97318
1407.49312	0.97324	1334.0587	0.97073	1260.62428	0.97328
1405.45328	0.97344	1332.01885	0.97184	1258.58443	0.97398
1403.41343	0.97341	1329.97901	0.97271	1256.54458	0.97478

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1236.14613	0.97816	1189.2297	0.97852	1187.18985	0.97829
1234.10629	0.97817	1211.66799	0.9781	1185.15001	0.97808
1232.06644	0.97807	1209.62815	0.97851	1183.11016	0.97792
1230.0266	0.97812	1207.5883	0.9787	1181.07032	0.97736
1227.98675	0.97853	1205.54846	0.97874	1179.03047	0.97641
1225.94691	0.97896	1203.50861	0.97884	1176.99063	0.97544
1223.90706	0.97888	1201.46877	0.97883	1174.95078	0.97438
1221.86722	0.97832	1199.42892	0.97876	1172.91094	0.97293
1219.82737	0.97776	1197.38908	0.97881	1170.87109	0.97153
1217.78753	0.97763	1195.34923	0.97892	1168.83125	0.9712
1215.74768	0.97778	1193.30939	0.9789	1166.7914	0.97196
1213.70784	0.97788	1191.26954	0.97872	1164.75156	0.97279
1162.71171	0.9732	1109.67574	0.97617	1056.63976	0.97313
1160.67186	0.97341	1107.63589	0.97591	1054.59992	0.97301
1158.63202	0.97352	1105.59605	0.97607	1052.56007	0.97269
1156.59217	0.97338	1103.5562	0.97647	1050.52023	0.97227
1154.55233	0.97333	1101.51636	0.97656	1048.48038	0.9719
1152.51248	0.97377	1099.47651	0.97609	1046.44054	0.97135
1150.47264	0.97432	1097.43667	0.97552	1044.40069	0.9708
1148.43279	0.97443	1095.39682	0.97506	1042.36085	0.97064
1146.39295	0.97438	1093.35698	0.97456	1040.321	0.97075
1144.3531	0.97461	1091.31713	0.97446	1038.28116	0.97087
1142.31326	0.97502	1089.27729	0.97475	1036.24131	0.97075
1140.27341	0.9753	1087.23744	0.97455	1034.20147	0.97013
1138.23357	0.97542	1085.1976	0.97384	1032.16162	0.96945
1136.19372	0.97547	1083.15775	0.97328	1030.12178	0.96937
1134.15388	0.97545	1081.11791	0.9729	1028.08193	0.96993

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1128.03434	0.97595	1074.99837	0.97336	1021.9624	0.97087
1123.95465	0.97615	1070.91868	0.97494	1017.88271	0.97123
1121.91481	0.9763	1068.87884	0.97497	1015.84286	0.97105
1119.87496	0.97647	1066.83899	0.97473	1013.80302	0.97098
1117.83512	0.97659	1064.79915	0.97418	1011.76317	0.97113
1113.75543	0.9768	1060.71945	0.9733	1007.68348	0.97063
948.52797	0.96738	877.1334	0.9664	805.73882	0.95953
946.48813	0.9681	875.09355	0.96575	803.69897	0.96049
944.44828	0.96861	873.05371	0.96559	801.65913	0.96401
942.40844	0.96911	871.01386	0.96622	799.61928	0.96622
940.36859	0.9697	868.97401	0.96728	797.57944	0.96489
938.32875	0.96987	866.93417	0.96851	795.53959	0.96182
936.2889	0.96968	864.89432	0.9696	793.49975	0.96061
934.24906	0.96955	862.85448	0.97016	791.4599	0.96197
789.42006	0.96364	479.3636	0.96152	707.82625	0.9632
787.38021	0.96425	477.32375	0.96336	705.78641	0.96244
785.34037	0.9632	475.28391	0.96395	703.74656	0.9609
783.30052	0.96042	473.24406	0.9647	701.70672	0.9577
781.26068	0.95818	471.20422	0.96503	699.66687	0.95275
779.22083	0.95834	469.16437	0.96385	697.62703	0.94822
777.18099	0.95932	467.12453	0.95991	695.58718	0.94593
775.14114	0.95849	465.08468	0.95418	693.54734	0.94592
773.10129	0.95448	463.04484	0.95207	691.50749	0.94805
771.06145	0.9461	461.00499	0.95542	689.46765	0.95296
769.0216	0.93553	458.96515	0.96023	687.4278	0.95952
764.94191	0.93769	454.88546	0.96771	683.34811	0.96917

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
711.90594	0.96183	401.84949	0.9469	630.31214	0.97735
709.8661	0.96308	399.80964	0.94739	628.27229	0.97627
626.23245	0.97433	518.12066	0.9672	587.47539	0.97184
624.1926	0.97321	516.08081	0.96782	585.43555	0.97306
622.15276	0.97416	514.04097	0.9686	583.3957	0.97288
620.11291	0.9752	512.00112	0.96928	581.35586	0.97173
618.07307	0.97468	509.96128	0.96859	579.31601	0.97177
616.03322	0.97392	507.92143	0.96624	577.27616	0.9727
613.99338	0.97401	505.88159	0.96466	575.23632	0.97232
611.95353	0.97448	503.84174	0.96514	573.19647	0.97011
609.91369	0.97452	501.8019	0.96645	571.15663	0.96815
607.87384	0.97406	499.76205	0.96819	569.11678	0.96829
605.834	0.97385	497.72221	0.96901	567.07694	0.96834
603.79415	0.97384	495.68236	0.96765	565.03709	0.96751
601.75431	0.97406	493.64252	0.96657	562.99725	0.9686
599.71446	0.97523	491.60267	0.9668	560.9574	0.97003
597.67462	0.97605	489.56283	0.96659	558.91756	0.96876
595.63477	0.97443	487.52298	0.96459	556.87771	0.96636
593.59493	0.97144	485.48314	0.96052	554.83787	0.96512
591.55508	0.96991	483.44329	0.95747	552.79802	0.96502
589.51524	0.97044	481.40344	0.95847	550.75818	0.96599
548.71833	0.96788	538.51911	0.96386	526.28004	0.96719
546.67849	0.96804	536.47926	0.96501	524.24019	0.96758
544.63864	0.96602	534.43942	0.96522	522.20035	0.96795
542.5988	0.9644	532.39957	0.96516	520.1605	0.9675
540.55895	0.96358	530.35973	0.96588	528.31988	0.96672

APPENDIX G1 Wavenumbers vrs Transmittances of Kerosene (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
756.78253	0.95925	446.72608	0.96692	675.18873	0.97014
754.74269	0.95891	444.68623	0.96298	673.14888	0.97208
752.70284	0.95798	442.64639	0.95533	671.10904	0.97333
750.663	0.95755	440.60654	0.94953	669.06919	0.97345
748.62315	0.95618	438.5667	0.94432	667.02935	0.97413
746.58331	0.95233	436.52685	0.94154	664.9895	0.97512
744.54346	0.94523	434.48701	0.94539	662.94966	0.97596
742.50362	0.93631	432.44716	0.94976	660.90981	0.9764
740.46377	0.93208	430.40732	0.94976	658.86997	0.97616
738.42393	0.93578	428.36747	0.95131	656.83012	0.97595
736.38408	0.94158	426.32763	0.9567	654.79028	0.97575
734.34424	0.94403	424.28778	0.96076	652.75043	0.97559
732.30439	0.9414	422.24794	0.95884	650.71059	0.97556
730.26455	0.93273	420.20809	0.95145	648.67074	0.97525
728.2247	0.92365	418.16825	0.9475	646.6309	0.97537
726.18486	0.92358	416.1284	0.95166	644.59105	0.97576
724.14501	0.93078	414.08856	0.95616	642.55121	0.9752
722.10517	0.93787	412.04871	0.95819	640.51136	0.97446
720.06532	0.94419	410.00887	0.95559	638.47152	0.97441
718.02548	0.95043	407.96902	0.95142	636.43167	0.97489
715.98563	0.95553	405.92918	0.94981	634.39183	0.97602
713.94579	0.95934	403.88933	0.94854	632.35198	0.97717
758.82238	0.95789	448.76592	0.96408	677.22857	0.96953

APPENDIX G2 QUALITATIVE REPORT OF COMPONENTS IN KEROSENE

#	RT	Scan	Height	Area	Area %	Norm %	Name
1	3.098	10	1,524,711,424	63,371,556.0	0.720	12.84	
2	3.168	17	2,461,967,104	67,108,240.0	0.762	13.60	
3	3.629	63	1,175,326,336	80,662,120.0	0.916	16.35	
4	3.779	78	2,953,470,720	200,976,800.0	2.283	40.73	
5	3.899	90	3,880,563,456	292,508,192.0	3.323	59.28	
6	4.119	112	983,099,456	51,229,908.0	0.582	10.38	
7	4.219	122	1,656,500,736	86,500,592.0	0.983	17.53	
8	4.359	136	1,156,026,112	69,441,288.0	0.789	14.07	
9	4.509	151	1,019,649,088	57,733,552.0	0.656	11.70	
10	4.679	168	1,319,844,480	133,085,616.0	1.512	26.97	
11	4.879	188	3,624,257,792	493,475,008.0	5.606	100.00	
12	5.129	213	535,000,416	45,239,228.0	0.514	9.17	
13	5.399	240	1,466,260,736	117,897,632.0	1.339	23.89	
14	5.449	245	950,389,632	56,609,528.0	0.643	11.47	
15	5.619	262	1,953,297,024	115,896,024.0	1.317	23.49	
16	5.979	298	1,974,702,592	305,693,728.0	3.473	61.95	
17	6.079	308	1,563,018,752	72,838,464.0	0.827	14.76	
18	6.449	345	1,344,880,896	169,619,360.0	1.927	34.37	
19	6.759	376	474,687,776	58,828,456.0	0.668	11.92	
20	6.879	388	1,208,857,088	105,713,664.0	1.201	21.42	
21	7.129	413	1,478,635,264	132,199,864.0	1.502	26.79	
22	7.349	435	1,108,277,376	138,042,656.0	1.568	27.97	

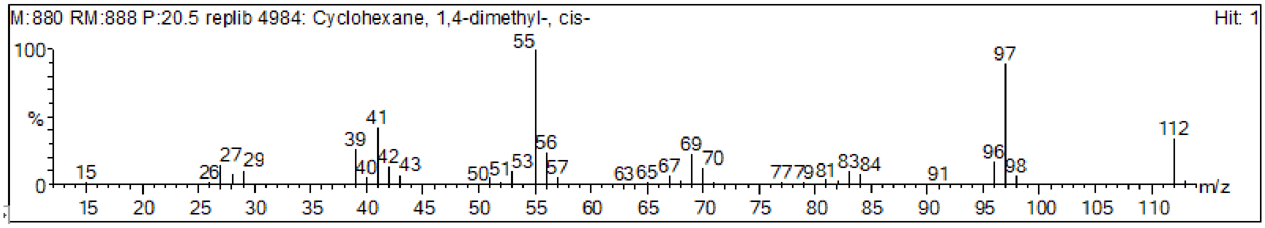
APPENDIX G2 Qualitative Report of Components in Kerosene (continued)

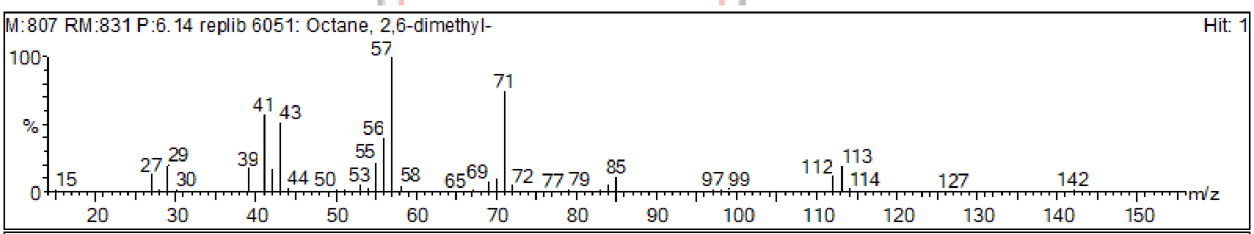
#	RT	Scan	Height	Area	Area %	Norm %	Name
23	7.749	475	1,210,153,088	132,353,640.0	1.504	26.82	
24	8.109	511	1,298,823,424	157,543,248.0	1.790	31.93	
25	8.389	539	1,696,401,152	195,341,664.0	2.219	39.58	
26	8.880	588	1,086,700,288	136,016,512.0	1.545	27.56	
27	9.260	626	1,968,147,712	185,104,960.0	2.103	37.51	
28	9.620	662	1,952,636,544	241,843,344.0	2.747	49.01	
29	10.240	724	1,624,313,728	160,412,912.0	1.822	32.51	Methyl myristoleate
30	10.330	733	1,678,428,928	87,676,344.0	0.996	17.77	
31	10.510	751	943,182,784	64,971,116.0	0.738	13.17	Methyl tetradecanoate
32	10.670	767	560,981,248	46,995,160.0	0.534	9.52	
33	11.200	820	1,526,696,192	121,422,240.0	1.379	24.61	
34	11.500	850	791,562,688	57,263,132.0	0.651	11.60	
35	11.700	870	751,790,080	44,818,744.0	0.509	9.08	
36	11.900	890	750,868,672	49,545,560.0	0.563	10.04	
37	12.340	934	763,015,744	71,577,160.0	0.813	14.50	
38	12.990	999	2,052,465,024	230,797,616.0	2.622	46.77	
39	13.110	1011	445,463,424	46,098,812.0	0.524	9.34	
40	13.380	1038	695,725,056	62,431,480.0	0.709	12.65	
41	13.590	1059	1,097,179,904	65,262,772.0	0.741	13.23	
42	13.881	1088	706,748,992	41,878,964.0	0.476	8.49	
43	14.881	1188	777,213,504	52,844,948.0	0.600	10.71	
44	15.221	1222	467,449,984	44,307,144.0	0.503	8.98	
45	16.071	1307	2,330,899,456	228,234,864.0	2.593	46.25	
46	16.411	1341	1,503,054,592	93,913,400.0	1.067	19.03	
47	17.811	1481	621,512,576	45,284,888.0	0.514	9.18	
48	18.081	1508	1,547,866,240	123,585,064.0	1.404	25.04	
49	18.691	1569	1,087,768,448	66,252,504.0	0.753	13.43	
50	18.891	1589	1,987,357,696	174,204,960.0	1.979	35.30	
51	19.182	1618	808,870,720	52,315,940.0	0.594	10.60	
52	20.862	1786	1,099,617,792	54,014,612.0	0.614	10.95	
53	21.542	1854	1,853,481,344	129,413,024.0	1.470	26.22	
54	22.032	1903	774,164,864	51,849,624.0	0.589	10.51	
55	23.032	2003	842,756,928	59,541,176.0	0.676	12.07	
56	23.992	2099	1,481,615,104	94,761,080.0	1.077	19.20	
57	26.323	2332	833,695,040	49,154,656.0	0.558	9.96	
58	43.196	4019	494,578,816	67,254,592.0	0.764	13.63	
59	43.566	4056	261,574,464	42,900,712.0	0.487	8.69	

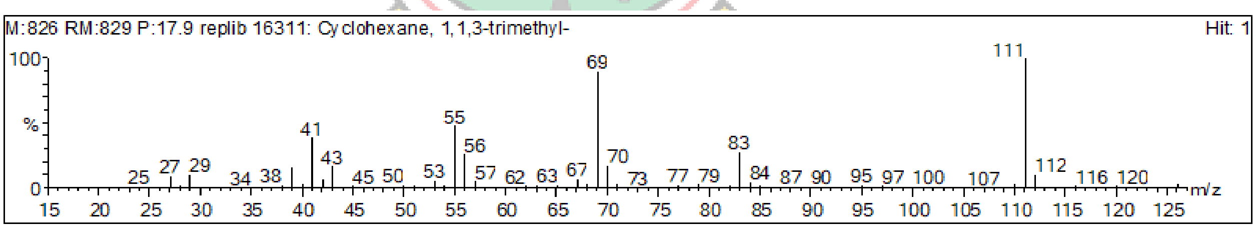
APPENDIX G2 Qualitative Report of Components in Kerosene (continued)

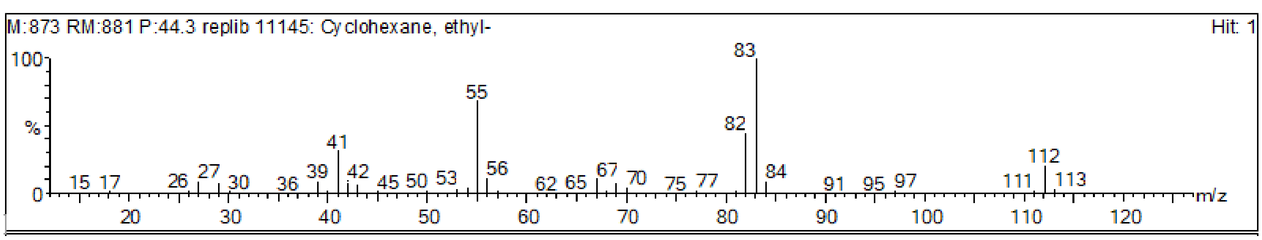
#	RT	Scan	Height	Area	Area %	Norm %	Name
60	43.706	4070	509,826,304	72,167,464.0	0.820	14.62	

APPENDIX G3 KEROSENE CHROMATOGRAM/SPECTRUM

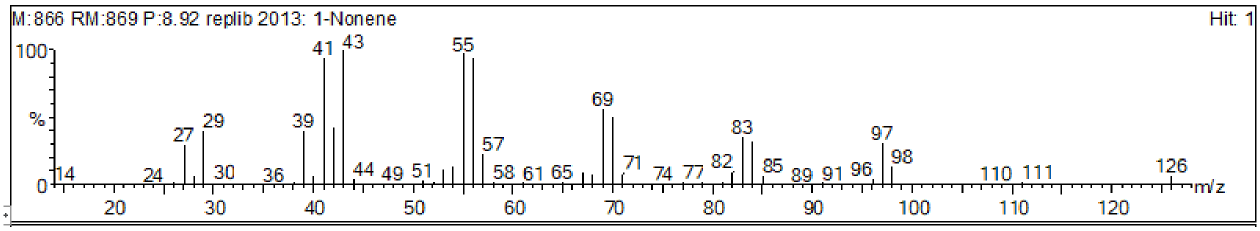


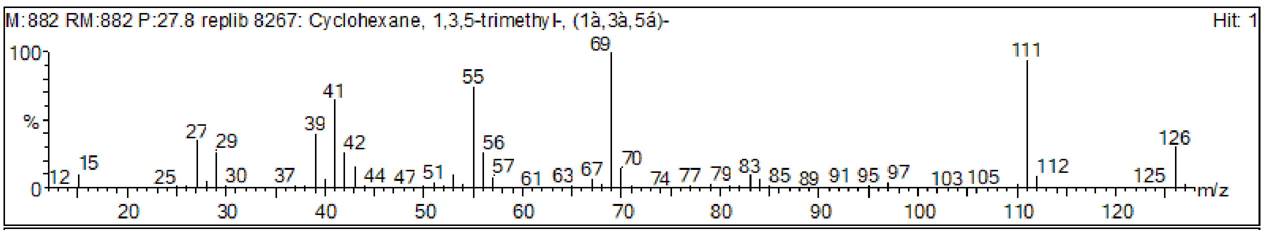


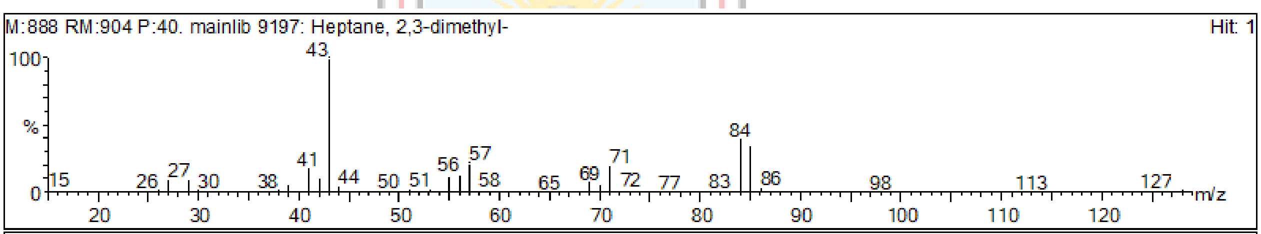


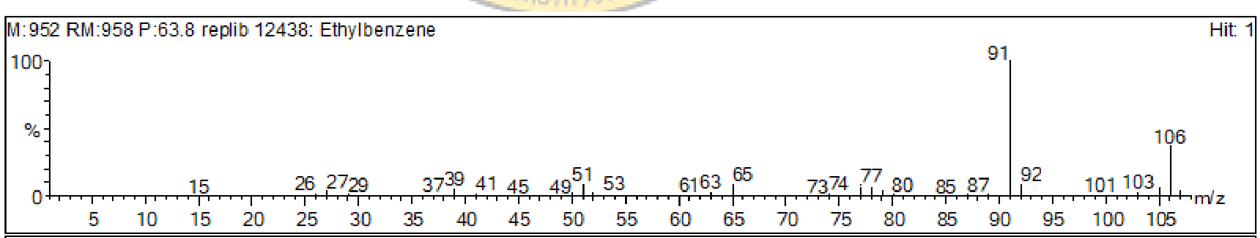


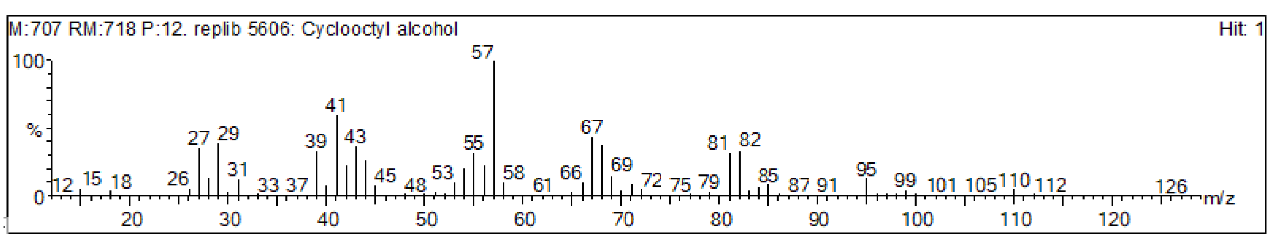
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



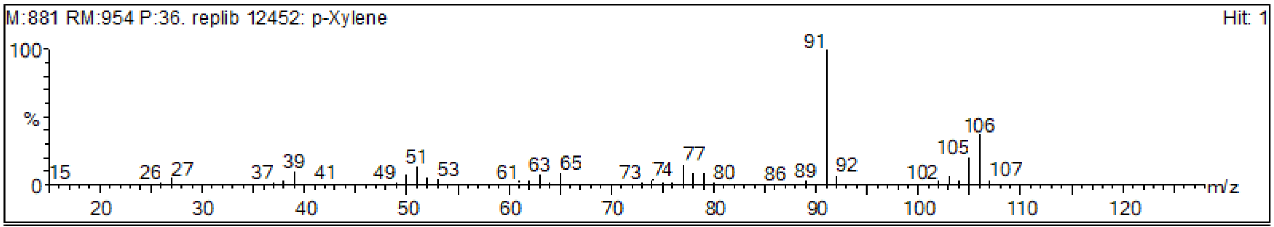


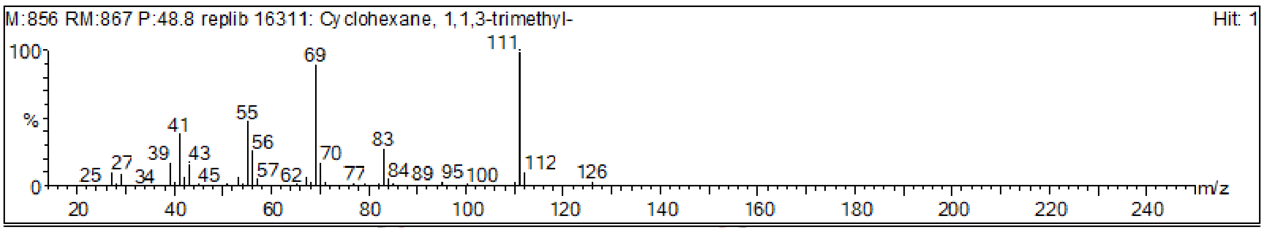


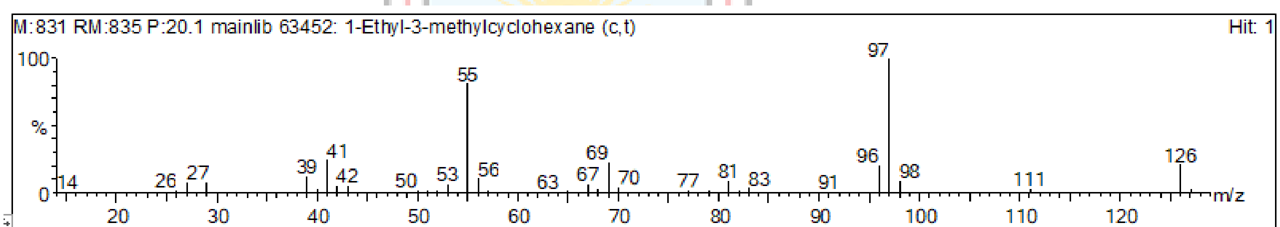


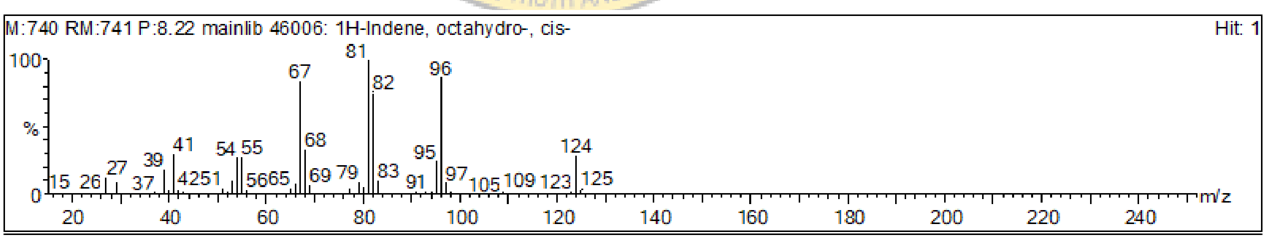


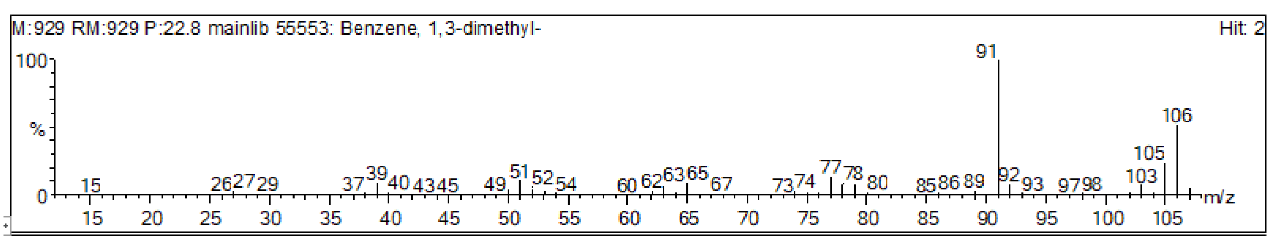
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



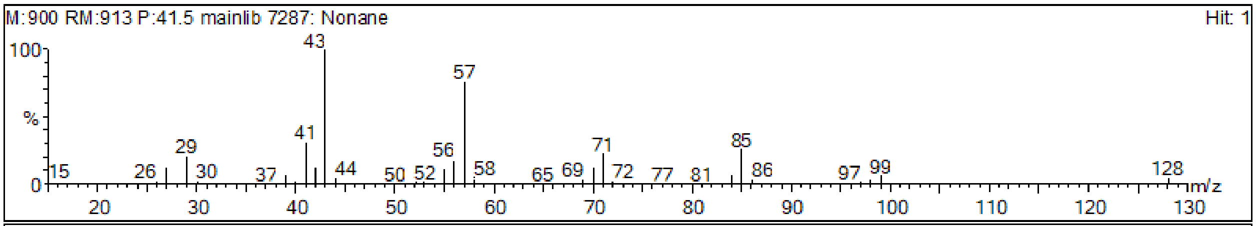


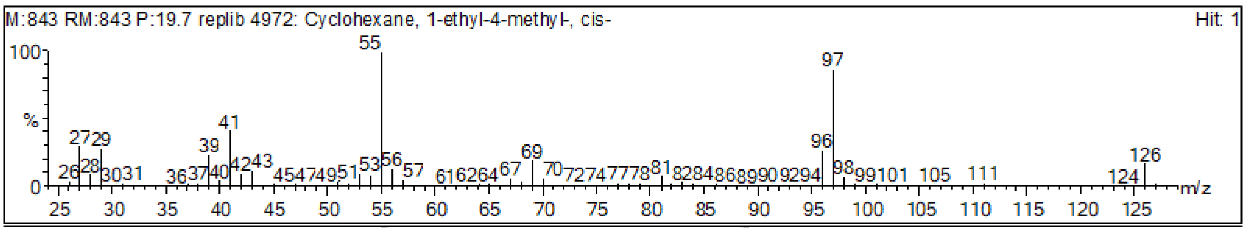


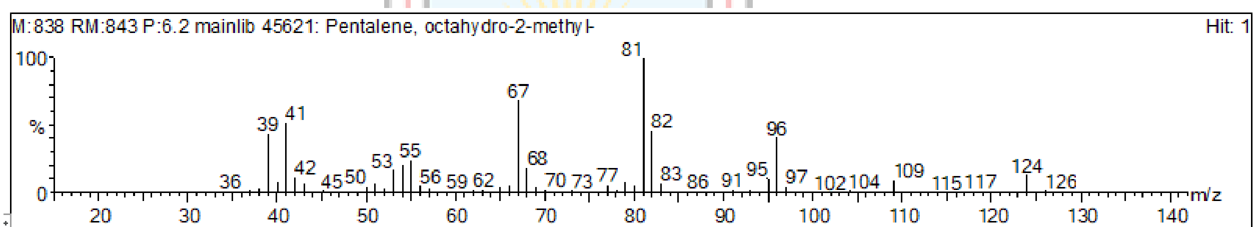


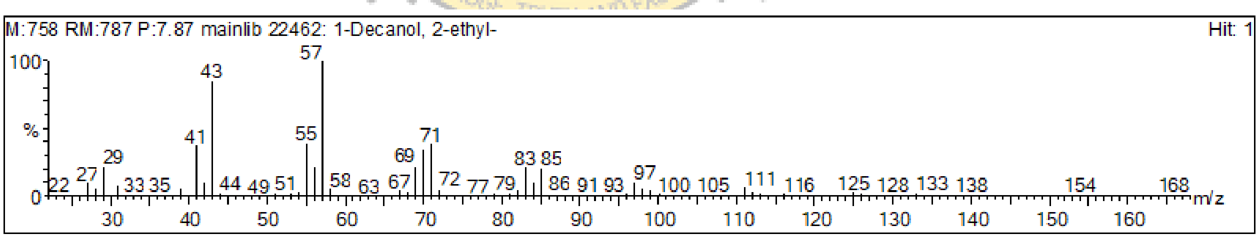


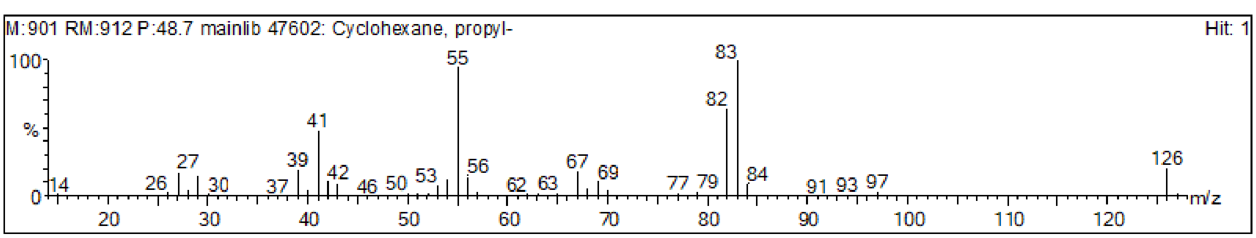
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



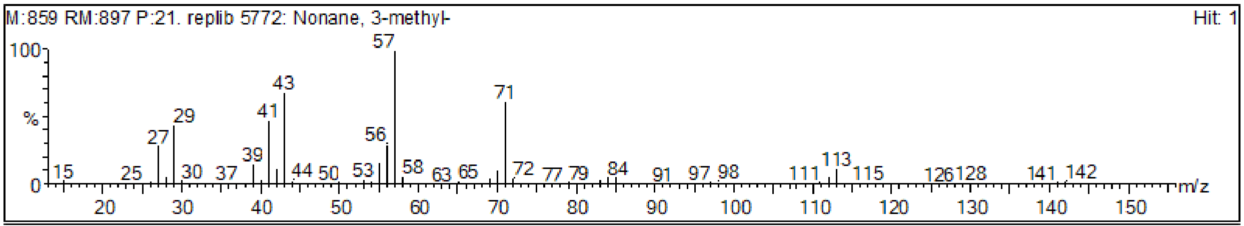


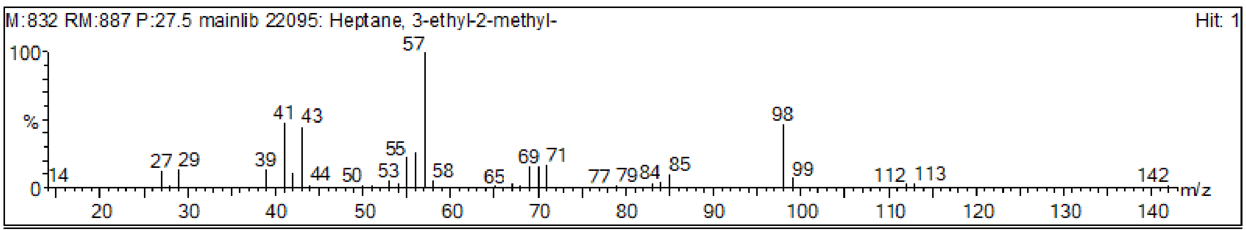


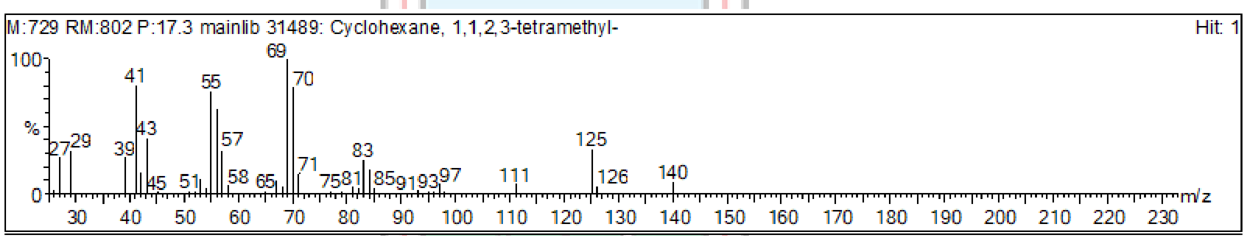


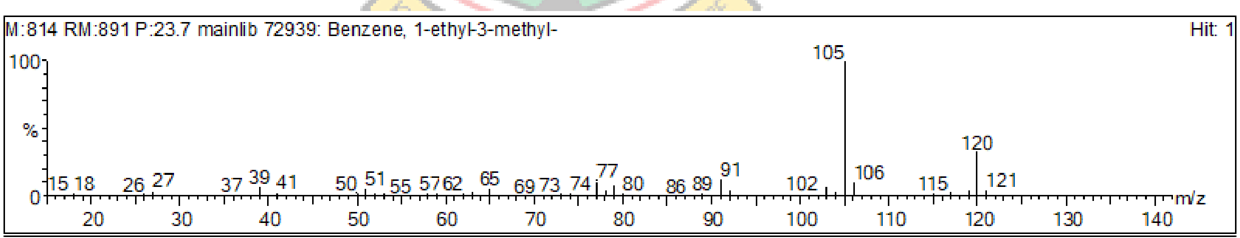


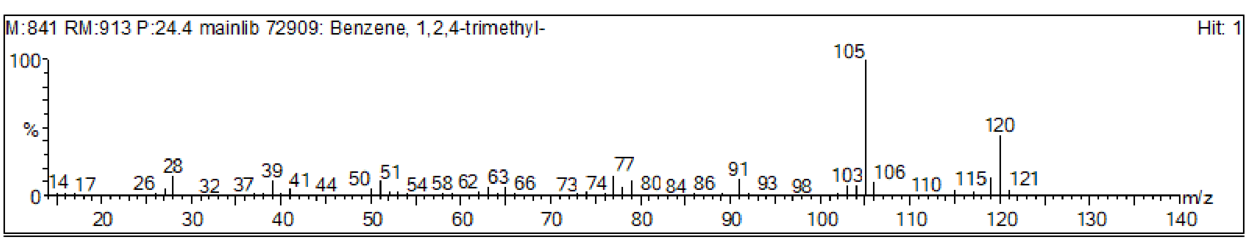
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



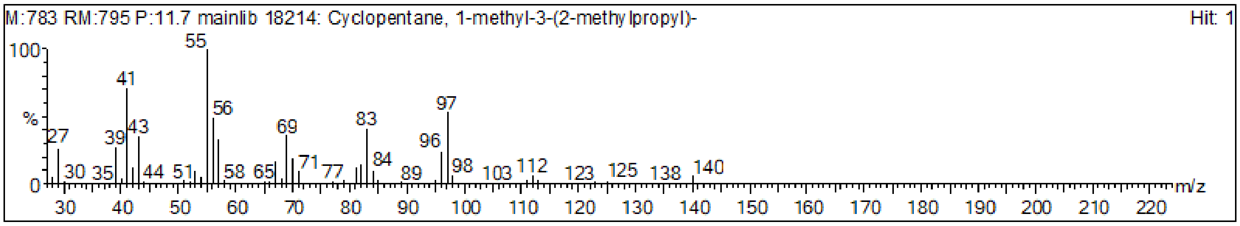


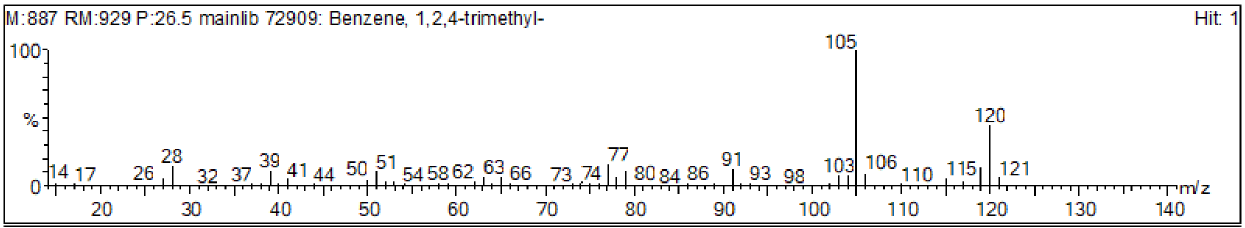


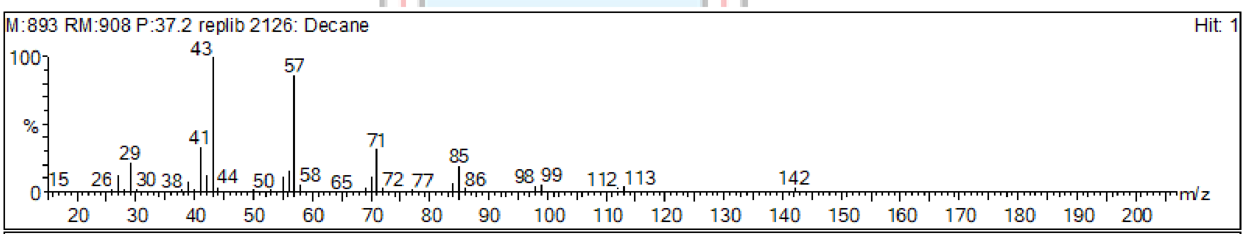


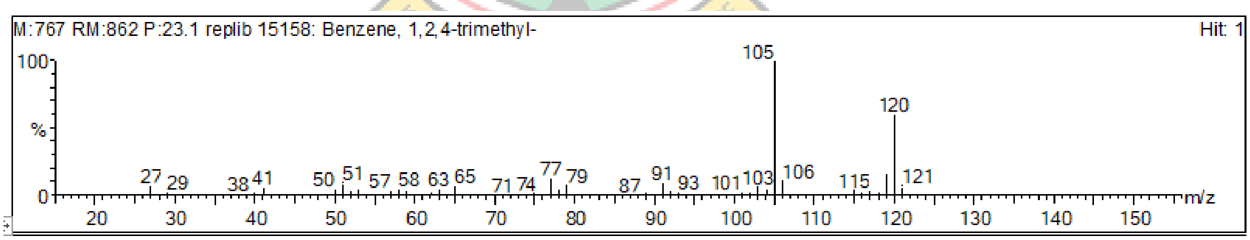


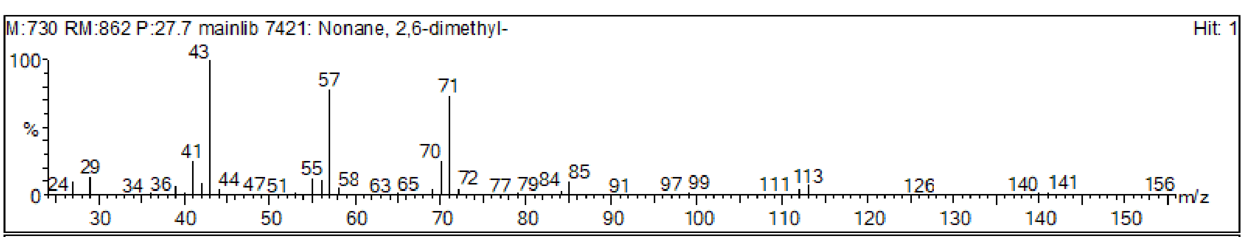
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



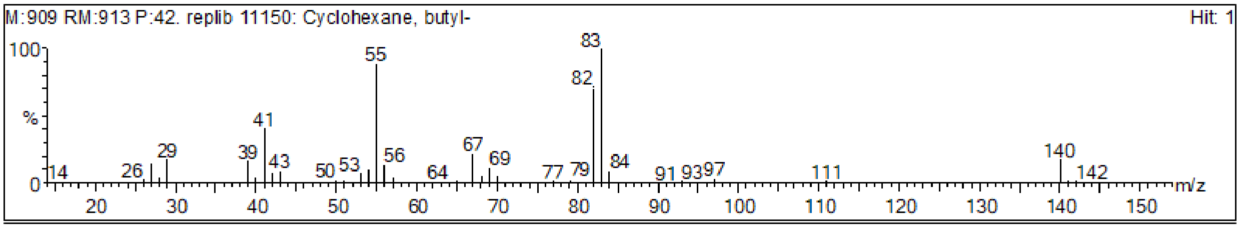


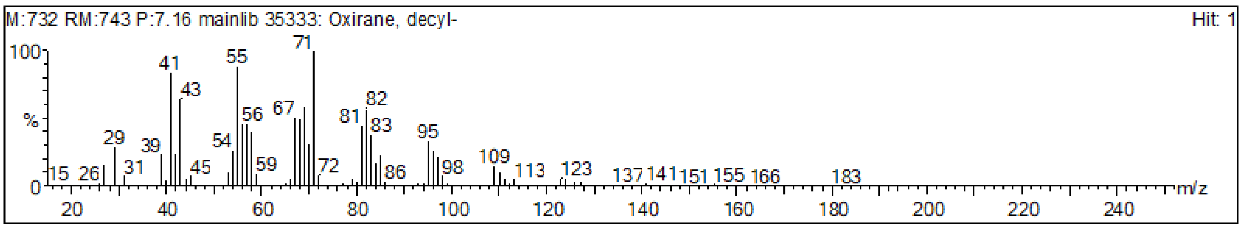


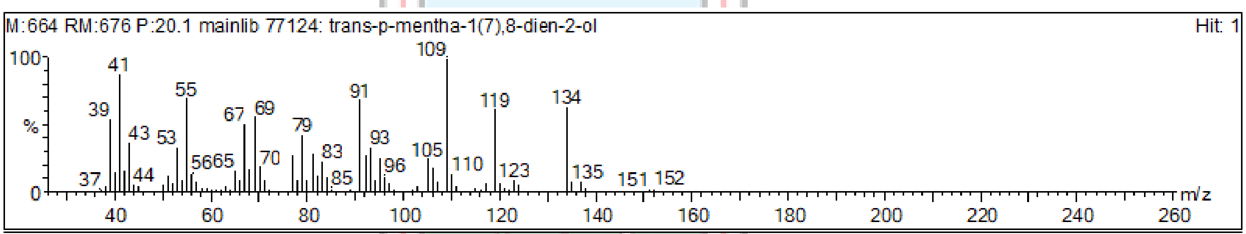


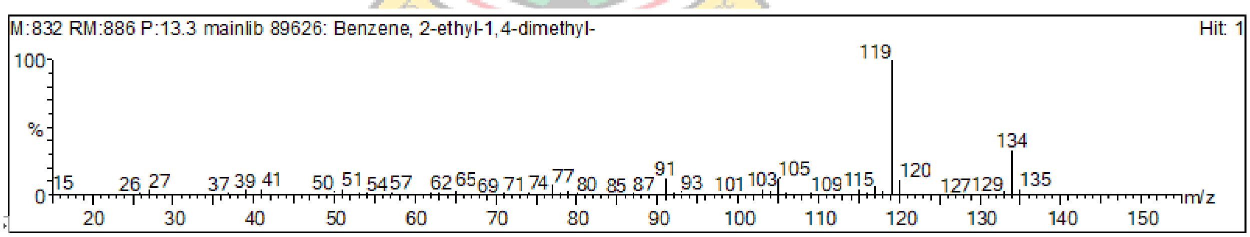


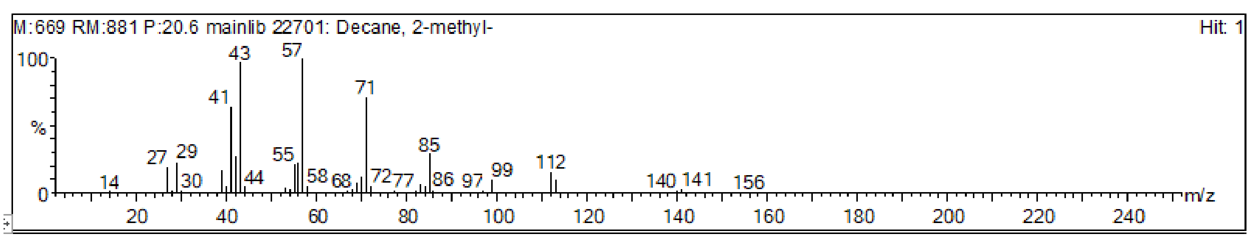
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



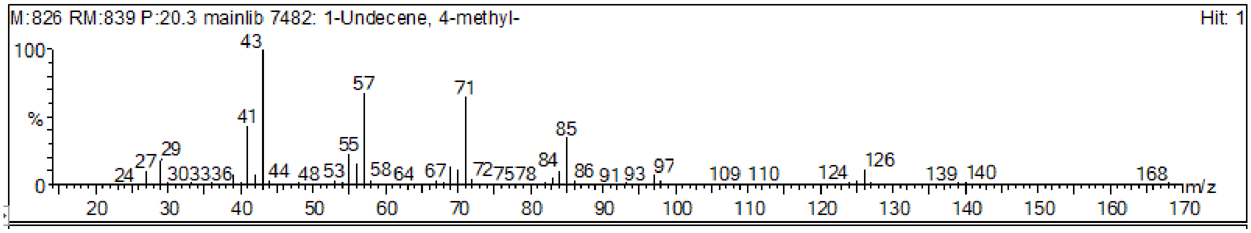


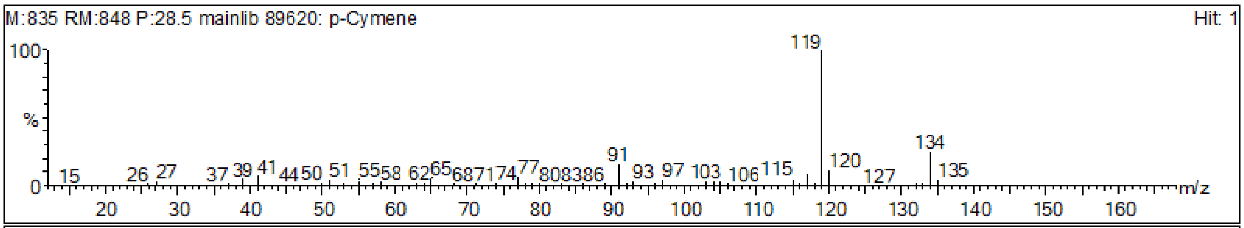


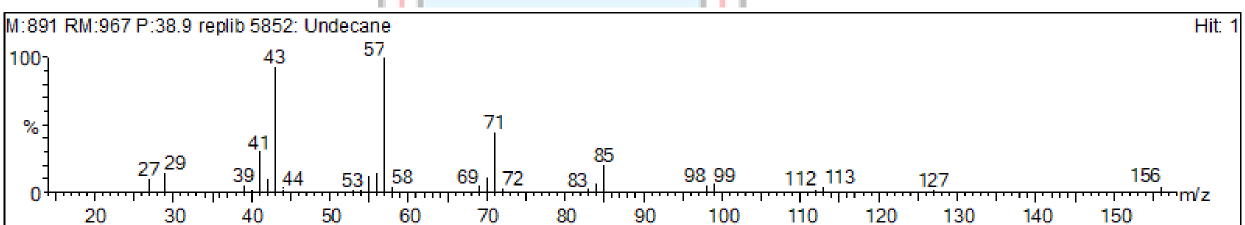


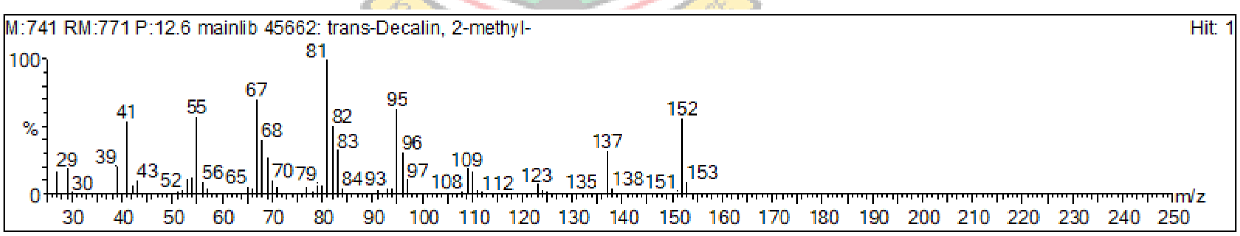


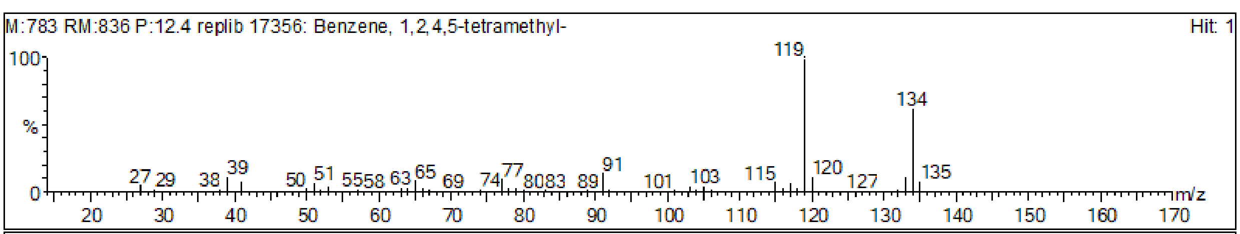
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



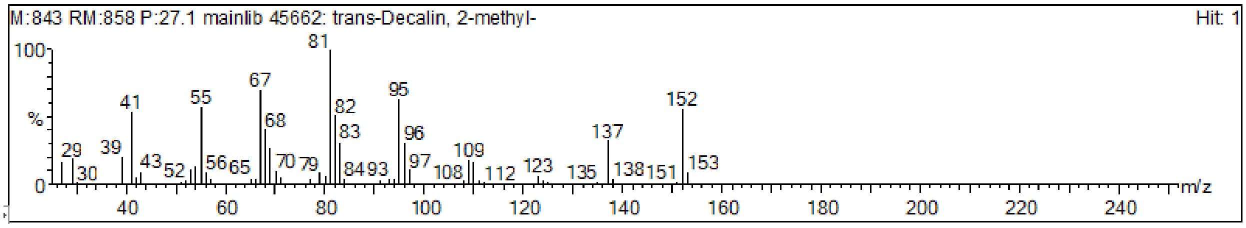


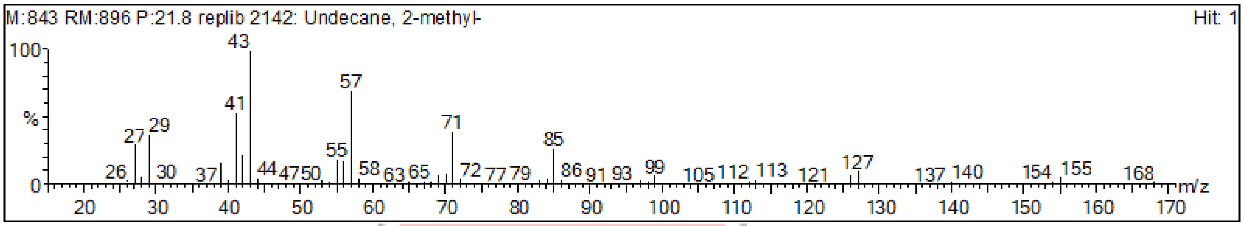


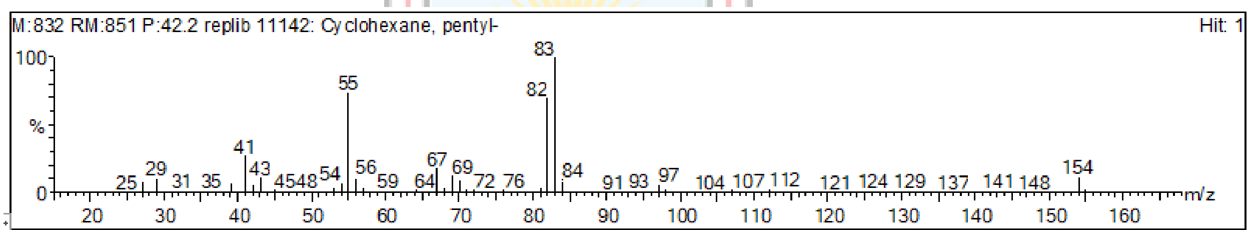


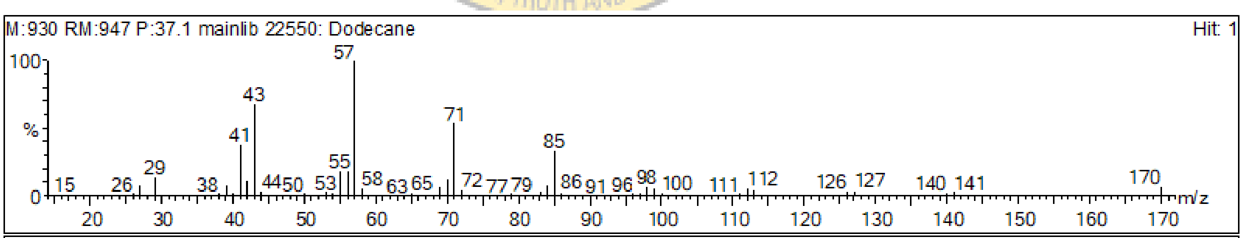


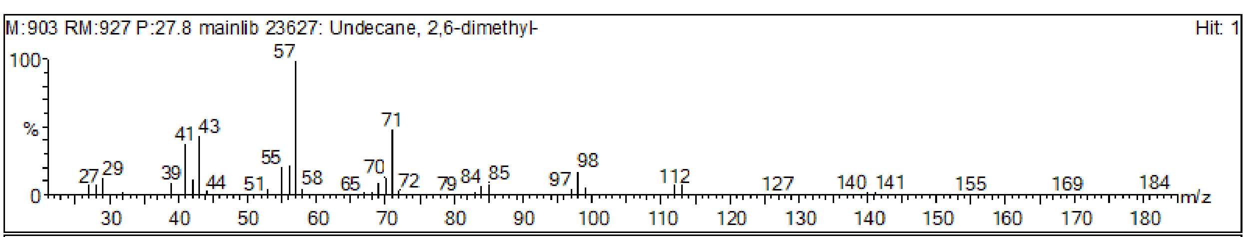
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



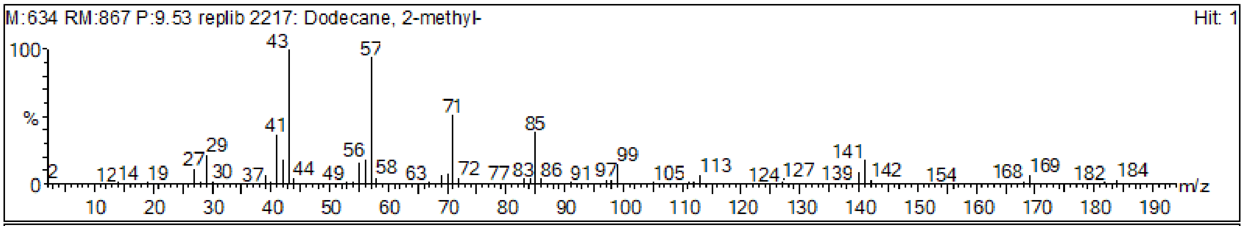


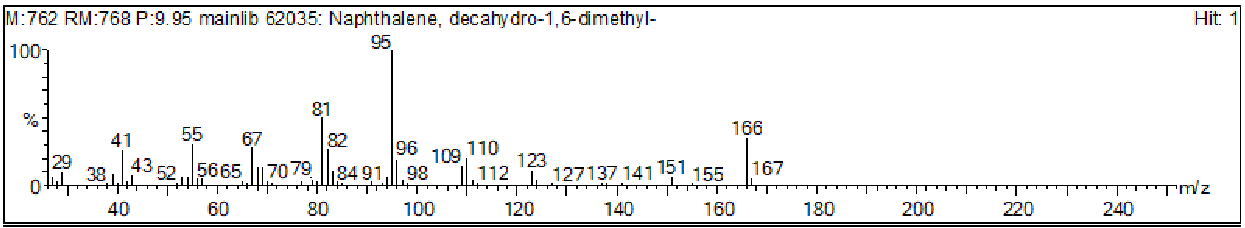


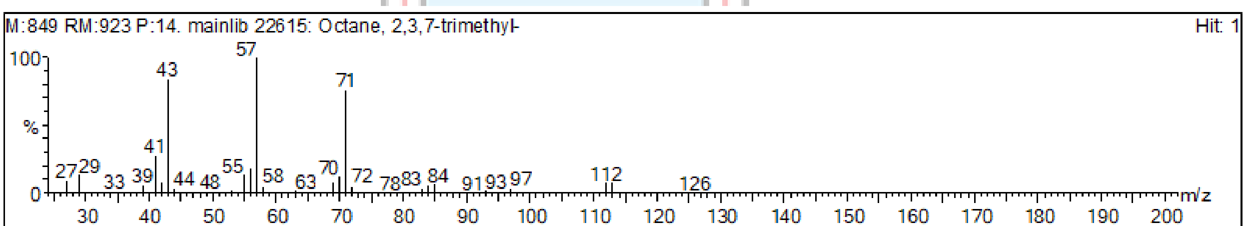


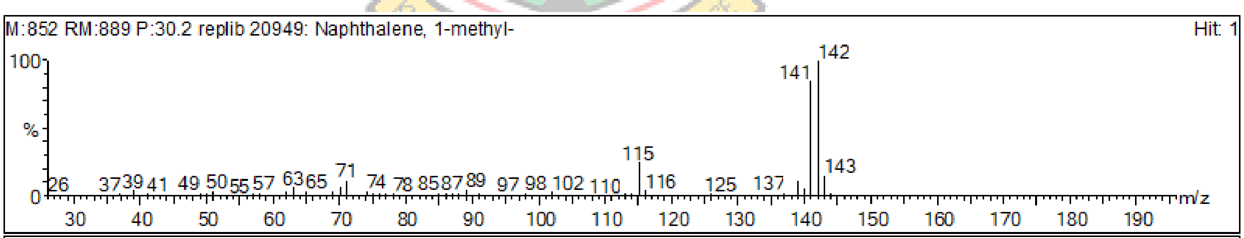


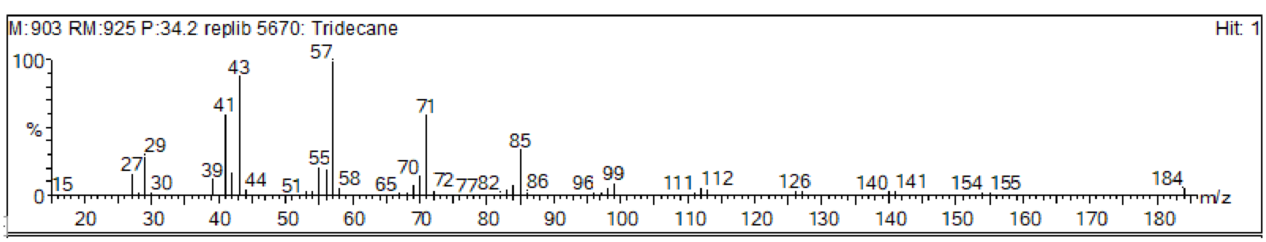
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



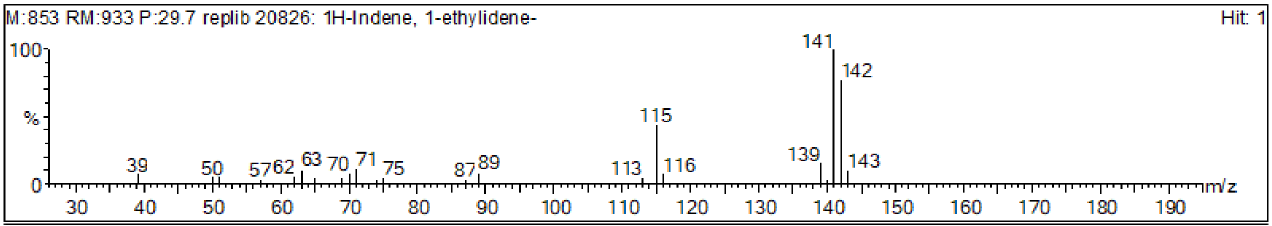


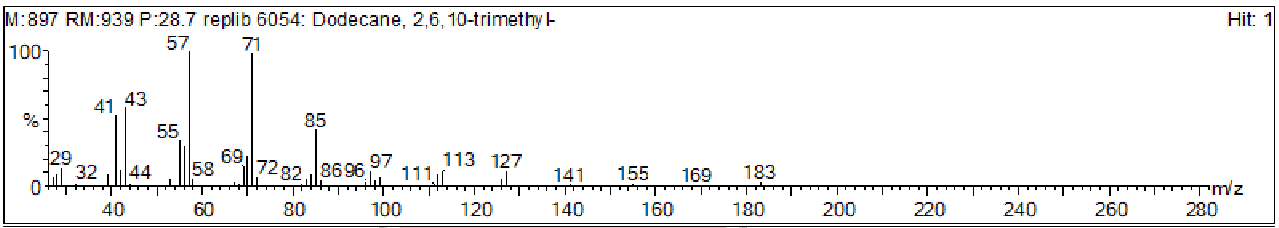


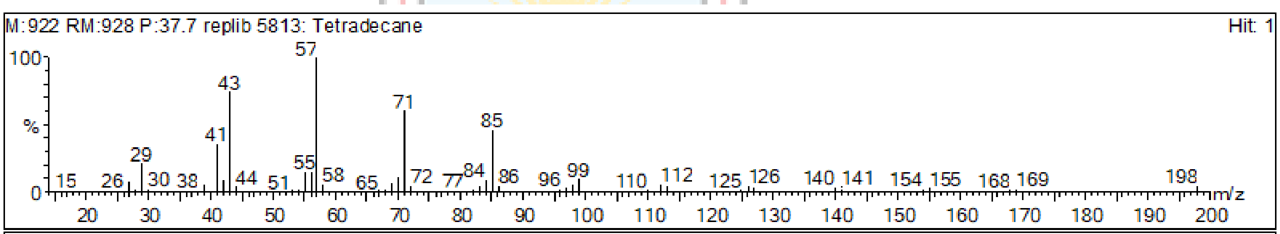


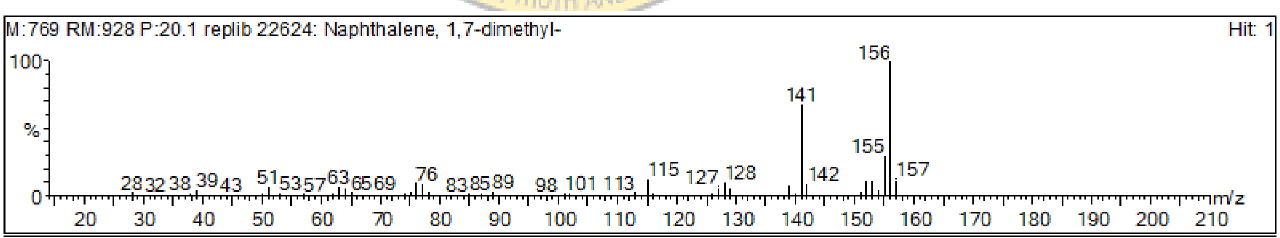


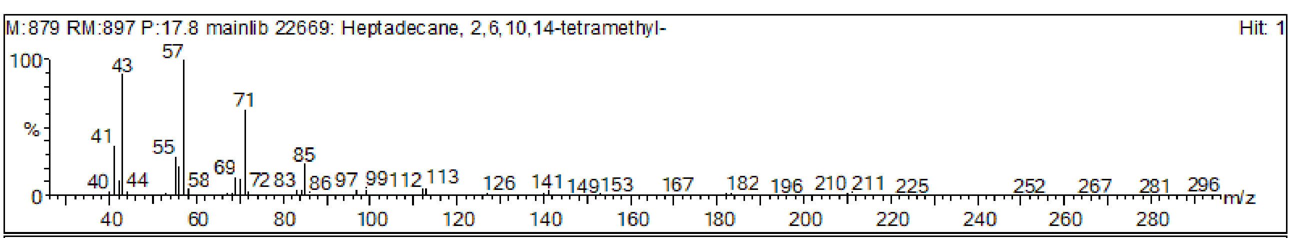
APPENDIX G3 kerosene chromatogram/spectrum (Continued)



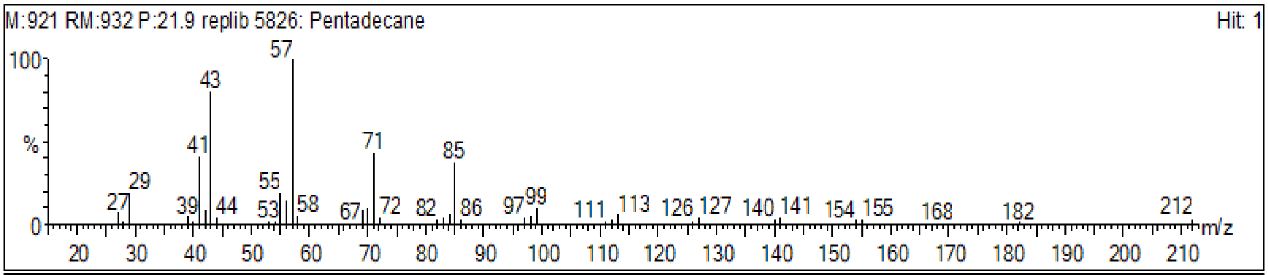


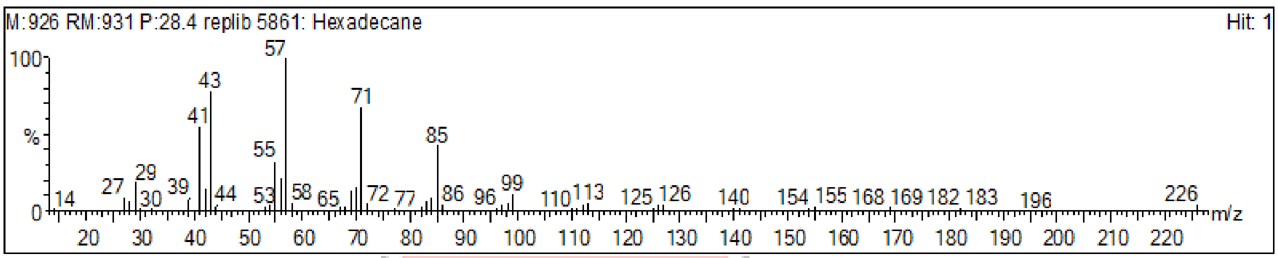


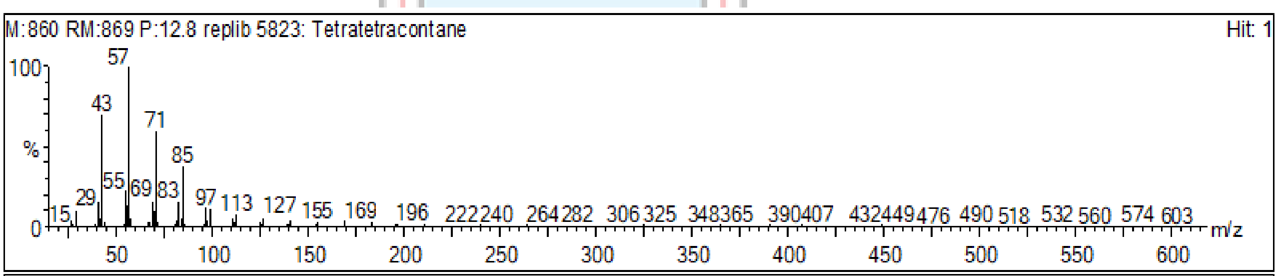


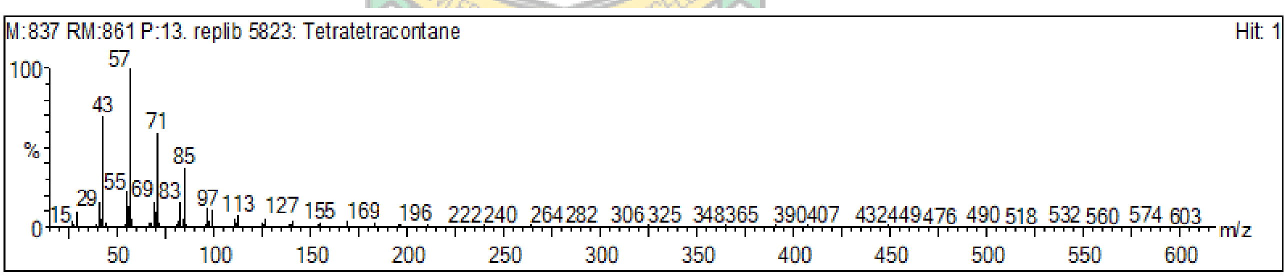


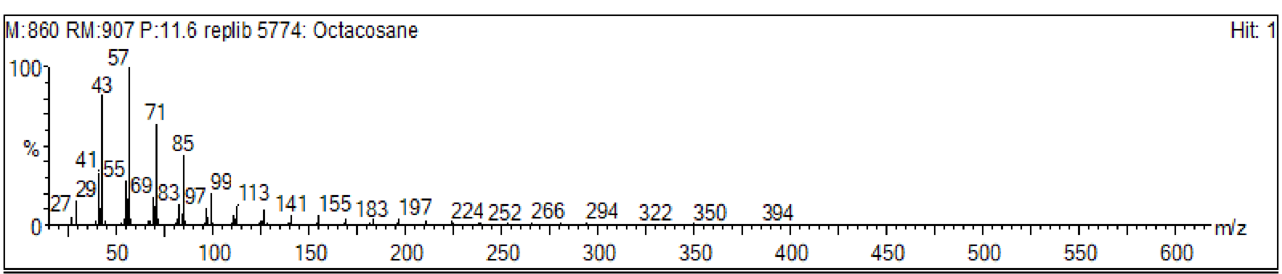
APPENDIX G3 kerosene chromatogram/spectrum (Continued)











APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3996.05656	0.99742	3918.54245	0.99685	3841.02833	0.99599
3994.01672	0.99754	3916.5026	0.9974	3838.98849	0.99594
3991.97687	0.99772	3914.46276	0.99721	3836.94864	0.99649
3989.93703	0.9972	3912.42291	0.99691	3834.9088	0.99705
3987.89718	0.99669	3910.38307	0.99707	3832.86895	0.99711
3985.85734	0.99688	3908.34322	0.99729	3830.82911	0.99725
3983.81749	0.99704	3906.30338	0.99726	3828.78926	0.99769
3981.77765	0.9968	3904.26353	0.99708	3826.74942	0.9981
3979.7378	0.99662	3902.22369	0.99705	3824.70957	0.99829
3977.69796	0.99682	3900.18384	0.99773	3822.66973	0.99861
3975.65811	0.99739	3898.144	0.99842	3820.62988	0.99913
3973.61827	0.99775	3896.10415	0.99779	3818.59004	0.99931
3971.57842	0.99759	3894.06431	0.99639	3816.55019	0.99926
3969.53858	0.99733	3892.02446	0.99561	3814.51035	0.99854
3967.49873	0.99734	3889.98462	0.99573	3812.4705	0.9975
3965.45888	0.99755	3887.94477	0.99593	3810.43066	0.99705
3963.41904	0.99759	3885.90493	0.99616	3808.39081	0.99683
3961.37919	0.99746	3883.86508	0.9968	3806.35097	0.99656
3959.33935	0.99731	3881.82524	0.9975	3804.31112	0.9966
3957.2995	0.99706	3879.78539	0.99753	3802.27128	0.99684
3955.25966	0.99699	3877.74555	0.99705	3800.23143	0.99734
3953.21981	0.99729	3875.7057	0.99672	3798.19159	0.99793
3951.17997	0.9977	3873.66586	0.99669	3796.15174	0.99819
3949.14012	0.99791	3871.62601	0.99695	3794.1119	0.99815
3947.10028	0.99769	3869.58616	0.99735	3792.07205	0.99823
3945.06043	0.9973	3867.54632	0.99751	3790.03221	0.99845
3943.02059	0.99702	3865.50647	0.9973	3787.99236	0.99831

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3763.51422	0.99743	3686.00011	0.99893	3608.48599	0.99888
3761.47437	0.99711	3683.96026	0.99895	3606.44615	0.99931
3759.43453	0.99753	3681.92042	0.99858	3604.4063	0.99866
3757.39468	0.99871	3679.88057	0.99759	3602.36646	0.9981
3755.35484	0.99987	3677.84072	0.99656	3600.32661	0.99773
3753.31499	0.99999	3675.80088	0.99697	3598.28677	0.99685
3751.27515	0.99867	3673.76103	0.99843	3596.24692	0.99631
3749.2353	0.99703	3671.72119	0.99871	3594.20708	0.99733
3747.19546	0.99619	3669.68134	0.99815	3592.16723	0.99859
3745.15561	0.99605	3667.6415	0.99805	3590.12739	0.99887
3743.11577	0.99673	3665.60165	0.9982	3588.08754	0.99886
3741.07592	0.99738	3663.56181	0.99797	3586.0477	0.99867
3739.03608	0.99763	3661.52196	0.99771	3584.00785	0.99775
3736.99623	0.99785	3659.48212	0.99765	3581.96801	0.99701
3734.95639	0.99829	3657.44227	0.99749	3579.92816	0.99735
3732.91654	0.99873	3655.40243	0.99756	3577.88831	0.9984
3730.8767	0.99854	3653.36258	0.99778	3575.84847	0.99887
3728.83685	0.99813	3651.32274	0.99793	3573.80862	0.99825
3726.79701	0.99776	3649.28289	0.9983	3571.76878	0.99752
3724.75716	0.99715	3647.24305	0.99809	3569.72893	0.99745
3722.71732	0.99706	3645.2032	0.99769	3567.68909	0.9977
3720.67747	0.99799	3643.16336	0.99755	3565.64924	0.99791
3718.63763	0.99856	3641.12351	0.99749	3563.6094	0.99836
3716.59778	0.99845	3639.08367	0.99769	3561.56955	0.99896
3714.55794	0.999	3637.04382	0.99801	3559.52971	0.99914
3712.51809	1.00011	3635.00398	0.99801	3557.48986	0.99875
3710.47825	1.00002	3632.96413	0.99782	3555.45002	0.99835

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3704.35871	0.99903	3626.8446	0.9973	3549.33048	0.99869
3702.31887	0.99887	3624.80475	0.9965	3547.29064	0.99899
3700.27902	0.99861	3622.76491	0.9966	3545.25079	0.99849
3698.23918	0.99849	3620.72506	0.99738	3543.21095	0.99832
3696.19933	0.99831	3618.68522	0.99793	3541.1711	0.99845
3694.15949	0.99819	3616.64537	0.99791	3539.13126	0.99819
3692.11964	0.99821	3614.60553	0.9973	3537.09141	0.99773
3690.0798	0.99829	3612.56568	0.99662	3535.05157	0.99753
3688.03995	0.9986	3610.52584	0.99734	3533.01172	0.99754
3940.98074	0.99685	3863.46663	0.99701	3785.95252	0.99768
3938.9409	0.99704	3861.42678	0.99674	3783.91267	0.99713
3936.90105	0.99746	3859.38694	0.99651	3781.87283	0.99712
3934.86121	0.99759	3857.34709	0.99662	3779.83298	0.99752
3932.82136	0.99755	3855.30725	0.99702	3777.79314	0.99798
3930.78152	0.99756	3853.2674	0.99663	3775.75329	0.99812
3928.74167	0.99757	3851.22756	0.99579	3773.71344	0.99802
3926.70183	0.99764	3849.18771	0.99607	3771.6736	0.99771
3924.66198	0.99738	3847.14787	0.99662	3769.63375	0.9972
3922.62214	0.99669	3845.10802	0.99662	3767.59391	0.99721
3920.58229	0.99637	3843.06818	0.99623	3765.55406	0.99764
3475.89606	0.99758	3400.42179	0.99741	3324.94752	0.9964
3473.85621	0.99778	3398.38195	0.99797	3322.90768	0.99638
3471.81637	0.99758	3396.3421	0.99809	3320.86783	0.99667
3469.77652	0.99746	3394.30226	0.99776	3318.82799	0.99718
3467.73668	0.99763	3392.26241	0.99751	3316.78814	0.99742
3465.69683	0.99768	3390.22257	0.99745	3314.7483	0.99715
3463.65699	0.99746	3388.18272	0.99755	3312.70845	0.99695

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3530.97188	0.99763	3455.49761	0.99797	3380.02334	0.99659
3528.93203	0.99772	3453.45776	0.99805	3377.98349	0.9968
3526.89219	0.99745	3451.41792	0.99796	3375.94365	0.99658
3524.85234	0.99709	3449.37807	0.99798	3373.9038	0.9961
3522.8125	0.99734	3447.33823	0.99764	3371.86396	0.99572
3520.77265	0.99797	3445.29838	0.99683	3369.82411	0.99564
3518.73281	0.99831	3443.25854	0.99665	3367.78427	0.99574
3516.69296	0.99764	3441.21869	0.99686	3365.74442	0.996
3514.65312	0.99637	3439.17885	0.99702	3363.70458	0.99663
3512.61327	0.99612	3437.139	0.99745	3361.66473	0.99729
3510.57343	0.99712	3435.09916	0.9978	3359.62489	0.99752
3508.53358	0.99789	3433.05931	0.99765	3357.58504	0.99752
3506.49374	0.99787	3431.01947	0.9973	3355.5452	0.99732
3504.45389	0.99799	3428.97962	0.99701	3353.50535	0.99685
3502.41405	0.99858	3426.93978	0.99691	3351.46551	0.99642
3500.3742	0.99863	3424.89993	0.99722	3349.42566	0.99634
3498.33436	0.99805	3422.86009	0.99761	3347.38582	0.99661
3496.29451	0.99796	3420.82024	0.99755	3345.34597	0.99684
3494.25467	0.99809	3418.7804	0.99723	3343.30613	0.99665
3492.21482	0.99784	3416.74055	0.99712	3341.26628	0.99632
3490.17498	0.99773	3414.70071	0.99755	3339.22644	0.99635
3488.13513	0.99768	3412.66086	0.998	3337.18659	0.99662
3486.09529	0.99767	3410.62102	0.99772	3335.14675	0.9968
3484.05544	0.99801	3408.58117	0.99724	3333.1069	0.99684
3482.01559	0.998	3406.54133	0.99696	3331.06706	0.99665
3479.97575	0.99737	3404.50148	0.99669	3329.02721	0.99649
3477.9359	0.99718	3402.46164	0.99682	3326.98737	0.99648

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3304.54907	0.9974	3227.03496	0.9969	3149.52084	0.99535
3302.50923	0.99669	3224.99511	0.99708	3147.481	0.99581
3300.46938	0.99603	3222.95527	0.99713	3145.44115	0.99587
3298.42954	0.99593	3220.91542	0.99686	3143.40131	0.99543
3296.38969	0.99607	3218.87558	0.99668	3141.36146	0.99526
3294.34985	0.99635	3216.83573	0.9968	3139.32162	0.99547
3292.31	0.99683	3214.79589	0.99647	3137.28177	0.99558
3290.27015	0.9972	3212.75604	0.99579	3135.24193	0.9956
3288.23031	0.99724	3210.7162	0.99564	3133.20208	0.99551
3286.19046	0.99762	3208.67635	0.99567	3131.16224	0.99518
3284.15062	0.99829	3206.63651	0.99559	3129.12239	0.99505
3282.11077	0.99827	3204.59666	0.99571	3127.08255	0.99525
3280.07093	0.99776	3202.55682	0.99598	3125.0427	0.99517
3278.03108	0.99753	3200.51697	0.99635	3123.00286	0.99498
3275.99124	0.99727	3198.47713	0.99633	3120.96301	0.9952
3273.95139	0.99665	3196.43728	0.99554	3118.92317	0.99564
3271.91155	0.99631	3194.39744	0.99508	3116.88332	0.99577
3269.8717	0.99661	3192.35759	0.99564	3114.84348	0.99548
3267.83186	0.99709	3190.31774	0.99632	3112.80363	0.99539
3265.79201	0.99741	3188.2779	0.99642	3110.76379	0.99574
3263.75217	0.99746	3186.23805	0.9965	3108.72394	0.99576
3261.71232	0.99743	3184.19821	0.99673	3106.6841	0.99524
3259.67248	0.99745	3182.15836	0.99619	3104.64425	0.99505
3257.63263	0.9974	3180.11852	0.99523	3102.60441	0.99518
3255.59279	0.9973	3178.07867	0.99494	3100.56456	0.99485
3253.55294	0.99725	3176.03883	0.99514	3098.52472	0.99432
3251.5131	0.99725	3173.99898	0.99514	3096.48487	0.99403

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

3245.39356	0.99657	3167.87945	0.99483	3090.36533	0.99329
3243.35372	0.9967	3165.8396	0.99498	3088.32549	0.99272
3241.31387	0.99672	3163.79976	0.99558	3086.28564	0.99216
3239.27403	0.99666	3161.75991	0.99631	3084.2458	0.99211
3237.23418	0.99672	3159.72007	0.99639	3082.20595	0.99269
3235.19434	0.99671	3157.68022	0.99564	3080.16611	0.99301
3233.15449	0.9966	3155.64038	0.99508	3078.12626	0.99236
3231.11465	0.99666	3153.60053	0.99506	3076.08642	0.99125
3229.0748	0.99679	3151.56069	0.99512	3074.04657	0.99059
3016.93091	0.98107	2939.4168	0.73693	2861.90268	0.74942
3014.89107	0.98053	2937.37695	0.7203	2859.86284	0.7355
3012.85122	0.97993	2935.33711	0.69877	2857.82299	0.71903
3010.81138	0.97954	2933.29726	0.6738	2855.78315	0.70333
3008.77153	0.97923	2931.25742	0.64679	2853.7433	0.69401
3006.73169	0.97869	2929.21757	0.61919	2851.70346	0.69702
3004.69184	0.97798	2927.17773	0.59289	2849.66361	0.7136
3002.652	0.9772	2925.13788	0.57125	2847.62377	0.73929
3000.61215	0.97648	2923.09804	0.55794	2845.58392	0.76842
2998.5723	0.9756	2921.05819	0.55524	2843.54408	0.79794
2996.53246	0.9742	2919.01835	0.56327	2841.50423	0.82703
2780.30888	0.98593	2702.79476	0.98939	2625.28065	0.99117
2778.26903	0.98648	2700.75492	0.98969	2623.24081	0.99148
2776.22919	0.98706	2698.71507	0.98996	2621.20096	0.99142
2774.18934	0.98744	2696.67523	0.98991	2619.16112	0.99113
2772.1495	0.98767	2694.63538	0.98973	2617.12127	0.99099
2770.10965	0.98803	2692.59554	0.9899	2615.08143	0.99102
2768.06981	0.98828	2690.55569	0.99009	2613.04158	0.99108
2766.02996	0.98833	2688.51585	0.99004	2611.00173	0.99097
2763.99012	0.98859	2686.476	0.9898	2608.96189	0.99108

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3072.00673	0.99048	2994.49261	0.97255	2916.9785	0.57922
3069.96688	0.99035	2992.45277	0.97086	2914.93866	0.59922
3067.92704	0.99022	2990.41292	0.96886	2912.89881	0.62045
3065.88719	0.99009	2988.37308	0.96599	2910.85897	0.64073
3063.84735	0.98954	2986.33323	0.96182	2908.81912	0.65875
3061.8075	0.98875	2984.29339	0.95644	2906.77928	0.67467
3059.76766	0.9881	2982.25354	0.9501	2904.73943	0.68934
3057.72781	0.98763	2980.2137	0.94257	2902.69958	0.70331
3055.68797	0.98744	2978.17385	0.93331	2900.65974	0.71661
3053.64812	0.98748	2976.13401	0.92208	2898.61989	0.72937
3051.60828	0.9876	2974.09416	0.90837	2896.58005	0.74209
3049.56843	0.98782	2972.05432	0.89114	2894.5402	0.75517
3047.52859	0.98775	2970.01447	0.87048	2892.50036	0.7686
3045.48874	0.98707	2967.97463	0.84745	2890.46051	0.78197
3043.4489	0.98641	2965.93478	0.8229	2888.42067	0.79483
3041.40905	0.98593	2963.89494	0.79805	2886.38082	0.80641
3039.36921	0.9853	2961.85509	0.77455	2884.34098	0.8152
3037.32936	0.98486	2959.81525	0.75365	2882.30113	0.81985
3035.28952	0.98486	2957.7754	0.73613	2880.26129	0.81935
3033.24967	0.98475	2955.73556	0.72306	2878.22144	0.8127
3031.20983	0.98449	2953.69571	0.71676	2876.1816	0.80043
3029.16998	0.98415	2951.65587	0.71878	2874.14175	0.78589
3027.13014	0.98327	2949.61602	0.72693	2872.10191	0.77368
3025.09029	0.98215	2947.57618	0.73717	2870.06206	0.76685
3023.05045	0.98156	2945.53633	0.74592	2868.02222	0.7646
3021.0106	0.98148	2943.49649	0.74998	2865.98237	0.76313
3018.97076	0.9814	2941.45664	0.74714	2863.94253	0.75872

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance)	Wavenumber (cm^{-1})	Transmittance
2839.46439	0.85455	2761.95027	0.98885	2684.43616	0.98935
2837.42454	0.87864	2759.91043	0.98899	2682.39631	0.98911
2835.3847	0.89874	2757.87058	0.98939	2680.35647	0.98909
2833.34485	0.91506	2755.83074	0.98971	2678.31662	0.98893
2831.30501	0.92755	2753.79089	0.98954	2676.27678	0.98876
2829.26516	0.93681	2751.75105	0.98914	2674.23693	0.98869
2827.22532	0.94423	2749.7112	0.98896	2672.19709	0.98859
2825.18547	0.95056	2747.67136	0.98899	2670.15724	0.9885
2823.14563	0.95552	2745.63151	0.9891	2668.1174	0.98857
2821.10578	0.95921	2743.59167	0.98912	2666.07755	0.98864
2819.06594	0.96216	2741.55182	0.98885	2664.03771	0.98864
2817.02609	0.96489	2739.51198	0.98847	2661.99786	0.98868
2814.98625	0.96769	2737.47213	0.98826	2659.95802	0.98882
2812.9464	0.97004	2735.43229	0.98823	2657.91817	0.98916
2810.90656	0.97152	2733.39244	0.98811	2655.87833	0.98953
2808.86671	0.97274	2731.3526	0.98753	2653.83848	0.98962
2806.82686	0.97428	2729.31275	0.98671	2651.79864	0.98955
2804.78702	0.97575	2727.27291	0.98638	2649.75879	0.98954
2802.74717	0.9769	2725.23306	0.98677	2647.71895	0.98972
2800.70733	0.97795	2723.19322	0.98716	2645.6791	0.99005
2798.66748	0.97879	2721.15337	0.98721	2643.63926	0.99034
2796.62764	0.97955	2719.11353	0.98739	2641.59941	0.99075
2794.58779	0.98032	2717.07368	0.98768	2639.55957	0.99124
2792.54795	0.98096	2715.03384	0.98798	2637.51972	0.99144
2790.5081	0.98173	2712.99399	0.9884	2635.47988	0.99146
2788.46826	0.9828	2710.95415	0.98878	2633.44003	0.9916
2786.42841	0.98378	2708.9143	0.98897	2631.40019	0.99167

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2606.92204	0.9916	2529.40793	0.99429	2451.89382	0.9968
2604.8822	0.99196	2527.36809	0.99412	2449.85397	0.99635
2602.84235	0.99207	2525.32824	0.9944	2447.81413	0.9952
2600.80251	0.99193	2523.2884	0.9948	2445.77428	0.99435
2598.76266	0.99175	2521.24855	0.99491	2443.73444	0.99441
2596.72282	0.99198	2519.20871	0.99471	2441.69459	0.99508
2594.68297	0.99235	2517.16886	0.99478	2439.65475	0.99541
2592.64313	0.99246	2515.12901	0.99526	2437.6149	0.99515
2590.60328	0.9925	2513.08917	0.99572	2435.57506	0.99497
2588.56344	0.99252	2511.04932	0.99589	2433.53521	0.99501
2586.52359	0.9926	2509.00948	0.99577	2431.49537	0.99495
2584.48375	0.99297	2506.96963	0.99549	2429.45552	0.99515
2582.4439	0.99334	2504.92979	0.99539	2427.41568	0.99558
2580.40406	0.9934	2502.88994	0.99569	2425.37583	0.9955
2578.36421	0.9934	2500.8501	0.99596	2423.33599	0.9953
2576.32437	0.99362	2498.81025	0.9957	2421.29614	0.99518
2574.28452	0.99419	2496.77041	0.99531	2419.25629	0.99481
2572.24468	0.99482	2494.73056	0.9952	2417.21645	0.99474
2570.20483	0.99489	2492.69072	0.99513	2415.1766	0.99482
2568.16499	0.99442	2490.65087	0.99531	2413.13676	0.99445
2566.12514	0.99415	2488.61103	0.99584	2411.09691	0.99414
2564.0853	0.99432	2486.57118	0.99598	2409.05707	0.99442
2562.04545	0.99444	2484.53134	0.99586	2407.01722	0.99504
2560.00561	0.99441	2482.49149	0.99593	2404.97738	0.99559
2557.96576	0.99476	2480.45165	0.99568	2402.93753	0.99563
2555.92592	0.99525	2478.4118	0.99538	2400.89769	0.9952
2553.88607	0.99519	2476.37196	0.99586	2398.85784	0.99494

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2547.76654	0.99501	2470.25242	0.99661	2392.73831	0.99527
2543.68685	0.99458	2466.17273	0.99609	2388.65862	0.99422
2541.647	0.99475	2464.13289	0.99567	2386.61877	0.99388
2539.60716	0.9951	2462.09304	0.99538	2384.57893	0.9937
2537.56731	0.99538	2460.0532	0.99507	2382.53908	0.9936
2535.52747	0.99548	2458.01335	0.99464	2380.49924	0.99369
2533.48762	0.99528	2455.97351	0.99495	2378.45939	0.99391
2531.44778	0.99482	2453.93366	0.99606	2376.41955	0.99451
2374.3797	0.99535	2296.86559	0.99517	2219.35147	0.99572
2372.33986	0.99528	2294.82574	0.99471	2217.31163	0.99596
2370.30001	0.9945	2292.7859	0.9945	2215.27178	0.99545
2368.26017	0.99438	2290.74605	0.99506	2213.23194	0.99518
2366.22032	0.99446	2288.70621	0.99577	2211.19209	0.99338
2364.18048	0.9938	2286.66636	0.99596	2209.15225	0.99154
2362.14063	0.99276	2284.62652	0.99561	2207.1124	0.99247
2360.10079	0.99254	2282.58667	0.9954	2205.07256	0.99397
2358.06094	0.99248	2280.54683	0.99595	2203.03271	0.99368
2356.0211	0.99274	2278.50698	0.99684	2200.99287	0.99259
2353.98125	0.9933	2276.46714	0.99735	2198.95302	0.99213
2351.94141	0.9934	2274.42729	0.99747	2196.91318	0.99275
2349.90156	0.9939	2272.38745	0.997	2194.87333	0.99428
2347.86172	0.99447	2270.3476	0.99606	2192.83349	0.9964
2345.82187	0.9948	2268.30776	0.99585	2190.79364	0.99782
2343.78203	0.99491	2266.26791	0.99647	2188.7538	0.99703
2341.74218	0.99491	2264.22807	0.99704	2186.71395	0.99551
2339.70234	0.99491	2262.18822	0.99697	2184.67411	0.99576
2337.66249	0.99423	2260.14838	0.9963	2182.63426	0.99571

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2331.54296	0.99237	2254.02884	0.99482	2176.51473	0.9961
2329.50311	0.99144	2251.989	0.99342	2174.47488	0.9962
2327.46327	0.99231	2249.94915	0.99341	2172.43504	0.99627
2325.42342	0.99347	2247.90931	0.99491	2170.39519	0.99627
2323.38358	0.99343	2245.86946	0.99567	2168.35535	0.99581
2321.34373	0.99249	2243.82962	0.99557	2166.3155	0.9959
2319.30388	0.99243	2241.78977	0.99609	2164.27566	0.9968
2317.26404	0.99403	2239.74993	0.99701	2162.23581	0.99749
2315.22419	0.99531	2237.71008	0.99753	2160.19597	0.99659
2313.18435	0.99505	2235.67024	0.99695	2158.15612	0.99507
2311.1445	0.99454	2233.63039	0.99527	2156.11628	0.99432
2309.10466	0.99451	2231.59055	0.99391	2154.07643	0.99335
2307.06481	0.99432	2229.5507	0.99307	2152.03659	0.99283
2305.02497	0.99412	2227.51086	0.99226	2149.99674	0.99438
2302.98512	0.99413	2225.47101	0.99142	2147.9569	0.99667
2300.94528	0.99436	2223.43116	0.9913	2145.91705	0.99608
2298.90543	0.99493	2221.39132	0.99334	2143.87721	0.99314
2086.76154	0.99451	2009.24743	0.9918	1931.73331	0.99765
2084.7217	0.99481	2007.20758	0.99145	1929.69347	0.99814
2082.68185	0.99596	2005.16774	0.99237	1927.65362	0.99877
2080.64201	0.99643	2003.12789	0.99394	1925.61378	0.9979
2078.60216	0.9959	2001.08805	0.99458	1923.57393	0.99619
2076.56232	0.99549	1999.0482	0.9944	1921.53409	0.99546
2074.52247	0.99587	1997.00836	0.99454	1919.49424	0.99595
2072.48263	0.99666	1994.96851	0.99507	1917.4544	0.99613
2070.44278	0.99641	1992.92867	0.99541	1915.41455	0.99604
2068.40294	0.99465	1990.88882	0.9954	1913.37471	0.99648

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2141.83736	0.9926	2064.32325	0.9949	1986.80913	0.99568
2139.79752	0.99505	2062.2834	0.99541	1984.76929	0.99549
2137.75767	0.99701	2060.24356	0.99545	1982.72944	0.99392
2135.71783	0.99661	2058.20371	0.99648	1980.6896	0.99288
2133.67798	0.99458	2056.16387	0.99785	1978.64975	0.99424
2131.63814	0.99256	2054.12402	0.99835	1976.60991	0.99693
2129.59829	0.99191	2052.08418	0.99839	1974.57006	0.99859
2127.55844	0.99302	2050.04433	0.9983	1972.53022	0.99831
2125.5186	0.99478	2048.00449	0.99804	1970.49037	0.99718
2123.47875	0.99575	2045.96464	0.99779	1968.45053	0.99699
2121.43891	0.99582	2043.9248	0.99711	1966.41068	0.99875
2119.39906	0.99579	2041.88495	0.99547	1964.37084	1.00026
2117.35922	0.99605	2039.84511	0.9937	1962.33099	0.99861
2115.31937	0.99601	2037.80526	0.99311	1960.29115	0.99544
2113.27953	0.99543	2035.76542	0.99314	1958.2513	0.9941
2111.23968	0.99514	2033.72557	0.99382	1956.21146	0.99427
2109.19984	0.99603	2031.68572	0.99597	1954.17161	0.99437
2107.15999	0.99729	2029.64588	0.99708	1952.13177	0.9951
2105.12015	0.99717	2027.60603	0.99581	1950.09192	0.99735
2103.0803	0.99637	2025.56619	0.99521	1948.05208	0.99927
2101.04046	0.99637	2023.52634	0.99543	1946.01223	0.99822
2099.00061	0.99666	2021.4865	0.99488	1943.97239	0.99611
2096.96077	0.99606	2019.44665	0.99521	1941.93254	0.99596
2094.92092	0.99509	2017.40681	0.99634	1939.8927	0.99629
2092.88108	0.99539	2015.36696	0.99561	1937.85285	0.99612
2090.84123	0.99609	2013.32712	0.99348	1935.813	0.99677
2088.80139	0.99547	2011.28727	0.9923	1933.77316	0.99763

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1909.29502	0.99535	1831.7809	0.99367	1754.26679	0.9916
1907.25517	0.99508	1829.74106	0.99347	1752.22695	0.99119
1905.21533	0.99567	1827.70121	0.99422	1750.1871	0.99094
1903.17548	0.99562	1825.66137	0.99464	1748.14726	0.99096
1901.13564	0.99467	1823.62152	0.99415	1746.10741	0.99108
1899.09579	0.99367	1821.58168	0.994	1744.06757	0.99115
1897.05595	0.99301	1819.54183	0.99455	1742.02772	0.99108
1895.0161	0.99303	1817.50199	0.99489	1739.98787	0.99071
1892.97626	0.99377	1815.46214	0.99454	1737.94803	0.99025
1890.93641	0.99405	1813.4223	0.99413	1735.90818	0.9899
1888.89657	0.99361	1811.38245	0.99396	1733.86834	0.98963
1886.85672	0.99358	1809.34261	0.9938	1731.82849	0.98984
1884.81688	0.99419	1807.30276	0.99365	1729.78865	0.99026
1882.77703	0.99484	1805.26292	0.99356	1727.7488	0.99052
1880.73719	0.99474	1803.22307	0.9935	1725.70896	0.99052
1878.69734	0.99411	1801.18323	0.99329	1723.66911	0.99046
1876.6575	0.99396	1799.14338	0.99304	1721.62927	0.99055
1874.61765	0.99467	1797.10354	0.99338	1719.58942	0.99067
1872.57781	0.99555	1795.06369	0.99406	1717.54958	0.99059
1870.53796	0.99598	1793.02385	0.9941	1715.50973	0.99015
1868.49812	0.99571	1790.984	0.99341	1713.46989	0.98984
1866.45827	0.99467	1788.94416	0.99317	1711.43004	0.98972
1864.41843	0.99393	1786.90431	0.99342	1709.3902	0.98968
1862.37858	0.99392	1784.86447	0.9935	1707.35035	0.98976
1860.33874	0.99389	1782.82462	0.99301	1705.31051	0.98974
1858.29889	0.99385	1780.78478	0.99229	1703.27066	0.98959
1856.25905	0.99443	1778.74493	0.9921	1701.23082	0.98959

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1850.13951	0.99482	1772.6254	0.99242	1695.11128	0.9899
1848.09967	0.99527	1770.58555	0.99226	1693.07144	0.98998
1846.05982	0.99555	1768.54571	0.99237	1691.03159	0.98982
1844.01998	0.99494	1766.50586	0.99257	1688.99175	0.9896
1841.98013	0.99373	1764.46602	0.99273	1686.9519	0.98942
1839.94029	0.99318	1762.42617	0.9924	1684.91206	0.98928
1837.90044	0.99327	1760.38633	0.99191	1682.87221	0.98948
1835.86059	0.99365	1758.34648	0.99197	1680.83237	0.98979
1833.82075	0.99395	1756.30664	0.99197	1678.79252	0.98981
1621.67686	0.98541	1546.20259	0.98584	1470.72832	0.86658
1619.63701	0.98498	1544.16274	0.9858	1468.68848	0.8421
1617.59717	0.98447	1542.1229	0.98591	1466.64863	0.82389
1615.55732	0.98345	1540.08305	0.98573	1464.60879	0.81031
1613.51748	0.98235	1538.04321	0.98499	1462.56894	0.8022
1611.47763	0.98122	1536.00336	0.98467	1460.5291	0.79677
1609.43779	0.98002	1533.96352	0.98433	1458.48925	0.79226
1607.39794	0.97925	1531.92367	0.9839	1456.44941	0.79299
1605.3581	0.97921	1529.88383	0.98359	1454.40956	0.80028
1603.31825	0.97967	1527.84398	0.98281	1452.36972	0.80945
1391.17436	0.96089	1313.66025	0.967	1236.14613	0.97355
1389.13452	0.95439	1311.6204	0.96618	1234.10629	0.97379
1387.09467	0.94198	1309.58056	0.96578	1232.06644	0.9739
1385.05483	0.92705	1307.54071	0.96565	1230.0266	0.97398
1383.01498	0.91369	1305.50087	0.96558	1227.98675	0.97399
1380.97514	0.89902	1303.46102	0.96568	1225.94691	0.97387
1378.93529	0.88414	1301.42118	0.96602	1223.90706	0.97378
1376.89545	0.87703	1299.38133	0.96653	1221.86722	0.97383

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1}))	Transmittance	Wavenumber (cm^{-1})	Transmittance
1676.75268	0.98955	1601.27841	0.98035	1525.80414	0.98161
1674.71283	0.98958	1599.23856	0.98109	1523.76429	0.98082
1672.67299	0.99003	1597.19872	0.98171	1521.72445	0.98015
1670.63314	0.98982	1595.15887	0.98207	1519.6846	0.97956
1668.5933	0.98918	1593.11903	0.9825	1517.64476	0.97865
1666.55345	0.9894	1591.07918	0.98318	1515.60491	0.9771
1664.51361	0.98987	1589.03934	0.98379	1513.56507	0.9759
1662.47376	0.98979	1586.99949	0.98426	1511.52522	0.97511
1660.43392	0.98943	1584.95965	0.98445	1509.48538	0.9743
1658.39407	0.98946	1582.9198	0.98441	1507.44553	0.97277
1656.35423	0.98953	1580.87996	0.98458	1505.40569	0.97113
1654.31438	0.98935	1578.84011	0.98503	1503.36584	0.97095
1652.27454	0.98933	1576.80027	0.98557	1501.326	0.97097
1650.23469	0.98924	1574.76042	0.9858	1499.28615	0.9703
1648.19485	0.98856	1572.72058	0.98575	1497.24631	0.96864
1646.155	0.98783	1570.68073	0.98572	1495.20646	0.96684
1644.11515	0.9878	1568.64089	0.98577	1493.16662	0.96572
1642.07531	0.98767	1566.60104	0.98582	1491.12677	0.9647
1640.03546	0.98734	1564.5612	0.98581	1489.08693	0.96334
1637.99562	0.9872	1562.52135	0.98607	1487.04708	0.96174
1635.95577	0.98697	1560.48151	0.98664	1485.00724	0.95965
1633.91593	0.98656	1558.44166	0.98646	1482.96739	0.95644
1631.87608	0.98646	1556.40182	0.98573	1480.92755	0.95165
1629.83624	0.98666	1554.36197	0.98536	1478.8877	0.94558
1627.79639	0.98694	1552.32213	0.9852	1476.84786	0.93773
1625.75655	0.98682	1550.28228	0.98539	1474.80801	0.92517
1623.7167	0.98615	1548.24243	0.98568	1472.76817	0.89964

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1450.32987	0.82006	1372.81576	0.89908	1295.30164	0.96743
1448.29002	0.83242	1370.77591	0.91145	1293.2618	0.96762
1446.25018	0.84684	1368.73607	0.91718	1291.22195	0.96766
1444.21033	0.86175	1366.69622	0.91923	1289.18211	0.96796
1442.17049	0.87689	1364.65638	0.92343	1287.14226	0.96866
1440.13064	0.89051	1362.61653	0.93367	1285.10242	0.96927
1438.0908	0.90323	1360.57669	0.94492	1283.06257	0.96944
1436.05095	0.91828	1358.53684	0.95164	1281.02273	0.96942
1434.01111	0.93021	1356.497	0.95519	1278.98288	0.96941
1431.97126	0.93807	1354.45715	0.95704	1276.94304	0.96933
1429.93142	0.94539	1352.4173	0.95814	1274.90319	0.96923
1427.89157	0.95147	1350.37746	0.95919	1272.86335	0.96923
1425.85173	0.95582	1348.33761	0.96006	1270.8235	0.96929
1423.81188	0.9594	1346.29777	0.96054	1268.78366	0.96938
1421.77204	0.96202	1344.25792	0.96081	1266.74381	0.9695
1419.73219	0.96414	1342.21808	0.96094	1264.70397	0.96978
1417.69235	0.96615	1340.17823	0.96114	1262.66412	0.97028
1415.6525	0.96725	1338.13839	0.96204	1260.62428	0.97081
1413.61266	0.96775	1336.09854	0.96349	1258.58443	0.97127
1411.57281	0.96825	1334.0587	0.96503	1256.54458	0.97155
1409.53297	0.96903	1332.01885	0.96629	1254.50474	0.97155
1407.49312	0.96987	1329.97901	0.96707	1252.46489	0.97151
1405.45328	0.97038	1327.93916	0.96755	1250.42505	0.97162
1403.41343	0.97046	1325.89932	0.96786	1248.3852	0.97174
1401.37359	0.97027	1323.85947	0.96801	1246.34536	0.97205
1399.33374	0.96963	1321.81963	0.96809	1244.30551	0.97272
1397.2939	0.96854	1319.77978	0.96818	1242.26567	0.97332

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1217.78753	0.97382	1140.27341	0.97117	1062.7593	0.96847
1215.74768	0.97351	1138.23357	0.97157	1060.71945	0.96869
1213.70784	0.97313	1136.19372	0.972	1058.67961	0.96926
1211.66799	0.97292	1134.15388	0.9724	1056.63976	0.9698
1209.62815	0.97311	1132.11403	0.97272	1054.59992	0.97
1207.5883	0.97339	1130.07419	0.97289	1052.56007	0.9698
1205.54846	0.97336	1128.03434	0.97296	1050.52023	0.96939
1203.50861	0.97334	1125.9945	0.97311	1048.48038	0.96895
1201.46877	0.97342	1123.95465	0.97332	1046.44054	0.96856
1199.42892	0.97342	1121.91481	0.97378	1044.40069	0.96801
1197.38908	0.97349	1119.87496	0.97444	1042.36085	0.96745
1195.34923	0.97354	1117.83512	0.97469	1040.321	0.96702
1193.30939	0.97346	1115.79527	0.97433	1038.28116	0.96656
1191.26954	0.97339	1113.75543	0.97397	1036.24131	0.96613
1189.2297	0.97318	1111.71558	0.97387	1034.20147	0.96566
1187.18985	0.97302	1109.67574	0.97362	1032.16162	0.96527
1185.15001	0.97292	1107.63589	0.97309	1030.12178	0.96542
1183.11016	0.97242	1105.59605	0.97284	1028.08193	0.96581
1181.07032	0.97182	1103.5562	0.973	1026.04209	0.96573
1179.03047	0.97163	1101.51636	0.97308	1024.00224	0.96555
1176.99063	0.97149	1099.47651	0.97271	1021.9624	0.96591
1174.95078	0.97084	1097.43667	0.97207	1019.92255	0.96648
1172.91094	0.96954	1095.39682	0.97166	1017.88271	0.96674
1170.87109	0.9681	1093.35698	0.97166	1015.84286	0.96702
1168.83125	0.96741	1091.31713	0.97159	1013.80302	0.96745
1166.7914	0.9676	1089.27729	0.97123	1011.76317	0.96753
1164.75156	0.96813	1087.23744	0.97115	1009.72333	0.96735

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1162.71171	0.96852	1085.1976	0.97142	1007.68348	0.96715
1160.67186	0.96857	1083.15775	0.97127	1005.64364	0.96686
1158.63202	0.96853	1081.11791	0.97039	1003.60379	0.96661
1156.59217	0.96851	1079.07806	0.96924	1001.56395	0.96667
1154.55233	0.9684	1077.03822	0.96875	999.5241	0.96702
1152.51248	0.96853	1074.99837	0.96909	997.48426	0.96721
1150.47264	0.96901	1072.95853	0.96952	995.44441	0.96705
1148.43279	0.96964	1070.91868	0.96972	993.40457	0.96677
1146.39295	0.97026	1068.87884	0.96979	991.36472	0.9668
1144.3531	0.97063	1066.83899	0.96953	989.32488	0.96717
1142.31326	0.97085	1064.79915	0.96889	987.28503	0.96743
985.24519	0.96721	907.73107	0.96411	830.21696	0.95933
983.20534	0.96662	905.69123	0.96477	828.17711	0.96049
981.1655	0.96602	903.65138	0.96498	826.13727	0.96016
979.12565	0.9653	901.61154	0.96471	824.09742	0.95871
977.08581	0.96465	899.57169	0.9642	822.05758	0.95612
975.04596	0.96443	897.53185	0.9632	820.01773	0.95346
973.00612	0.96396	895.492	0.96176	817.97789	0.95122
970.96627	0.96317	893.45216	0.96013	815.93804	0.94835
968.92643	0.9628	891.41231	0.95874	813.8982	0.94489
966.88658	0.96266	889.37247	0.95827	811.85835	0.94189
964.84673	0.96236	887.33262	0.95854	809.81851	0.94056
962.80689	0.96228	885.29278	0.95862	807.77866	0.94129
960.76704	0.96275	883.25293	0.95861	805.73882	0.94335
958.7272	0.9633	881.21309	0.95867	803.69897	0.94662
956.68735	0.96351	879.17324	0.95793	801.65913	0.95087
954.64751	0.96349	877.1334	0.95682	799.61928	0.95443

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
948.52797	0.96425	871.01386	0.95608	793.49975	0.95434
946.48813	0.96424	868.97401	0.95626	791.4599	0.95305
944.44828	0.96446	866.93417	0.95764	789.42006	0.95187
942.40844	0.96469	864.89432	0.9598	787.38021	0.95081
940.36859	0.96434	862.85448	0.96109	785.34037	0.94859
938.32875	0.96411	860.81463	0.96139	783.30052	0.94575
936.2889	0.96461	858.77479	0.96144	781.26068	0.94485
934.24906	0.96513	856.73494	0.96123	779.22083	0.94612
932.20921	0.96544	854.6951	0.96061	777.18099	0.94737
930.16937	0.96548	852.65525	0.95935	775.14114	0.94681
928.12952	0.96533	850.61541	0.9578	773.10129	0.94423
926.08968	0.96551	848.57556	0.95701	771.06145	0.94069
924.04983	0.96576	846.53572	0.95752	769.0216	0.93756
922.00999	0.96561	844.49587	0.95839	766.98176	0.93655
919.97014	0.96519	842.45603	0.95906	764.94191	0.93885
917.9303	0.96478	840.41618	0.96002	762.90207	0.94267
915.89045	0.96481	838.37634	0.96031	760.86222	0.94521
913.85061	0.96495	836.33649	0.95896	758.82238	0.94586
911.81076	0.96451	834.29665	0.95738	756.78253	0.94545
909.77092	0.96394	832.2568	0.95756	754.74269	0.94388
697.62703	0.94748	620.11291	0.97017	542.5988	0.95809
695.58718	0.95094	618.07307	0.96915	540.55895	0.95903
693.54734	0.95533	616.03322	0.96961	538.51911	0.96094
691.50749	0.95878	613.99338	0.97	536.47926	0.96034
689.46765	0.96146	611.95353	0.96925	534.43942	0.95851
687.4278	0.96351	609.91369	0.96862	532.39957	0.95832
685.38796	0.96572	607.87384	0.96908	530.35973	0.96009

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
752.70284	0.94065	675.18873	0.9679	597.67462	0.96952
750.663	0.93739	673.14888	0.96817	595.63477	0.96837
748.62315	0.93518	671.10904	0.96848	593.59493	0.96644
746.58331	0.93233	669.06919	0.96875	591.55508	0.96592
744.54346	0.92845	667.02935	0.97127	589.51524	0.96626
742.50362	0.92521	664.9895	0.97344	587.47539	0.96607
740.46377	0.92435	662.94966	0.97322	585.43555	0.96583
738.42393	0.92636	660.90981	0.97182	583.3957	0.96556
736.38408	0.92958	658.86997	0.97086	581.35586	0.96506
734.34424	0.93186	656.83012	0.97086	579.31601	0.96535
732.30439	0.93181	654.79028	0.97137	577.27616	0.96609
730.26455	0.92858	652.75043	0.97101	575.23632	0.96681
728.2247	0.92402	650.71059	0.97025	573.19647	0.96709
726.18486	0.92144	648.67074	0.97065	571.15663	0.9653
724.14501	0.92077	646.6309	0.9716	569.11678	0.96268
722.10517	0.92118	644.59105	0.97196	567.07694	0.96194
720.06532	0.92489	642.55121	0.97107	565.03709	0.96298
718.02548	0.93236	640.51136	0.96973	562.99725	0.96412
715.98563	0.94008	638.47152	0.96938	560.9574	0.96339
713.94579	0.9459	636.43167	0.97007	558.91756	0.96116
711.90594	0.94991	634.39183	0.97098	556.87771	0.95979
709.8661	0.95254	632.35198	0.97057	554.83787	0.95977
707.82625	0.95419	630.31214	0.97005	552.79802	0.96094
705.78641	0.95429	628.27229	0.9707	550.75818	0.96243
703.74656	0.9525	626.23245	0.97094	548.71833	0.96227
701.70672	0.9497	624.1926	0.97096	546.67849	0.96086
699.66687	0.94731	622.15276	0.97108	544.63864	0.95929

APPENDIX H1 Wavenumbers vrs Transmittances of Naphtha (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
520.1605	0.96524	479.3636	0.95754	438.5667	0.95318
518.12066	0.96386	477.32375	0.9548	436.52685	0.95026
516.08081	0.96123	475.28391	0.95121	434.48701	0.94824
514.04097	0.95957	473.24406	0.94782	432.44716	0.94616
512.00112	0.96047	471.20422	0.94925	430.40732	0.94449
509.96128	0.96251	469.16437	0.95418	428.36747	0.9455
507.92143	0.96315	467.12453	0.95602	426.32763	0.94861
505.88159	0.96253	465.08468	0.95489	424.28778	0.95029
503.84174	0.96219	463.04484	0.95468	422.24794	0.94879
501.8019	0.96216	461.00499	0.95513	420.20809	0.94726
499.76205	0.96202	458.96515	0.95492	418.16825	0.95033
497.72221	0.96156	456.9253	0.95588	416.1284	0.95338
495.68236	0.96086	454.88546	0.9585	414.08856	0.95222
493.64252	0.9603	452.84561	0.96019	412.04871	0.95143
491.60267	0.9605	450.80577	0.96065	410.00887	0.95237
489.56283	0.96124	448.76592	0.96081	407.96902	0.94972
487.52298	0.96104	446.72608	0.95882	405.92918	0.94625
485.48314	0.95993	444.68623	0.95517	403.88933	0.9467
483.44329	0.95942	442.64639	0.95418	401.84949	0.94636
481.40344	0.95917	440.60654	0.95486	399.80964	0.94401

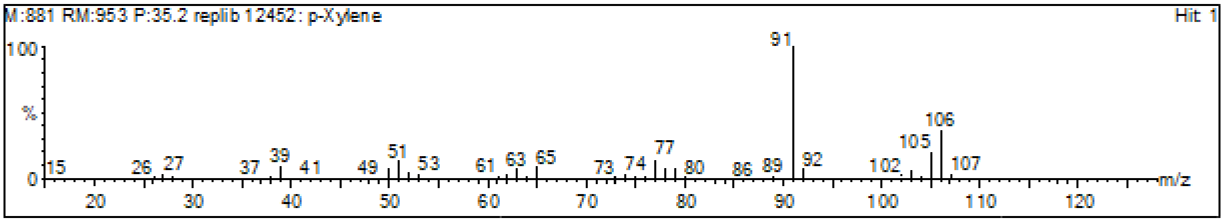
APPENDIX H2 QUALITATIVE REPORT OF COMPONENTS IN NAPHTHA

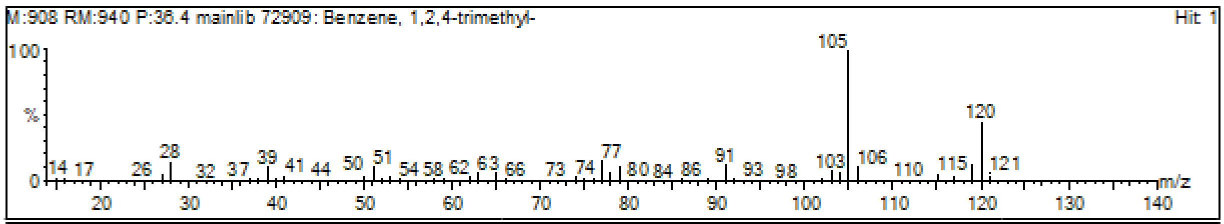
#	RT	Scan	Height	Area	Area %	Norm %	Name
1	4.679	168	1,218,589,568	83,362,152.0	0.414	9.42	
2	9.130	613	783,104,832	76,708,984.0	0.381	8.67	
3	9.460	646	909,844,800	81,670,112.0	0.406	9.23	
4	10.120	712	780,247,168	125,802,216.0	0.625	14.22	
5	12.950	995	1,366,996,864	174,026,752.0	0.865	19.67	
6	13.550	1055	702,201,216	102,594,680.0	0.510	11.59	
7	14.501	1150	512,387,552	86,277,424.0	0.429	9.75	
8	15.451	1245	674,117,184	132,689,352.0	0.660	14.99	
9	16.131	1313	2,181,505,536	339,068,608.0	1.686	38.31	
10	16.471	1347	1,304,641,920	237,782,160.0	1.182	26.87	
11	17.151	1415	536,099,744	97,550,960.0	0.485	11.02	
12	17.691	1469	502,632,864	90,408,040.0	0.449	10.22	
13	17.871	1487	707,798,080	100,748,216.0	0.501	11.38	Heptadecanoic acid,
14	18.171	1517	1,522,868,864	274,473,248.0	1.364	31.02	
15	18.811	1581	2,241,629,440	328,860,224.0	1.635	37.16	
16	19.082	1608	2,620,896,000	428,407,456.0	2.130	48.41	
17	19.302	1630	1,382,673,536	183,550,752.0	0.912	20.74	
18	19.432	1643	935,170,112	100,172,144.0	0.498	11.32	
19	20.032	1703	781,186,176	107,907,264.0	0.536	12.19	
20	20.352	1735	701,071,808	77,137,744.0	0.383	8.72	
21	20.792	1779	845,741,120	140,350,480.0	0.698	15.86	
22	21.032	1803	1,591,784,960	323,555,488.0	1.608	36.56	

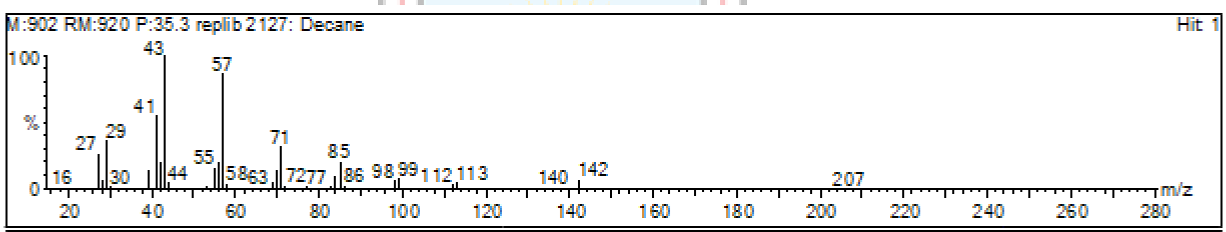
APPENDIX H2 Qualitative Report of Components in Naphtha (Continued)

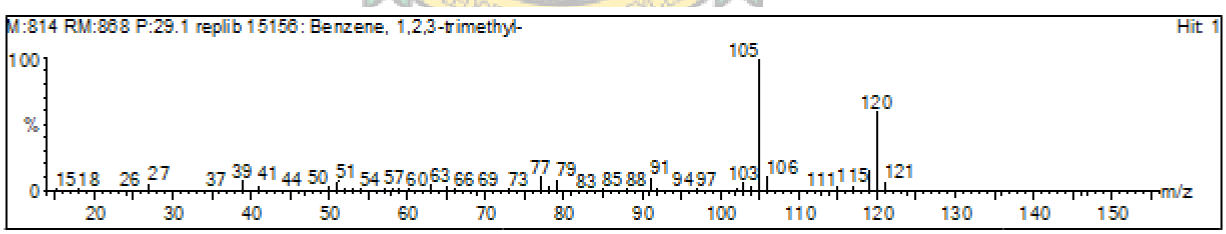
#	RT	Scan	Height	Area	Area %	Norm %	Name
23	21.812	1881	3,767,028,736	884,952,192.0	4.399	100.00	
24	22.352	1935	3,388,809,472	749,689,408.0	3.727	84.72	
25	22.802	1980	1,310,770,688	321,397,056.0	1.598	36.32	
26	23.262	2026	2,905,554,944	584,768,064.0	2.907	66.08	
27	23.832	2083	740,990,912	81,945,672.0	0.407	9.26	
28	24.263	2126	3,695,166,976	755,654,592.0	3.756	85.39	
29	24.403	2140	1,046,280,576	133,272,632.0	0.663	15.06	
30	24.883	2188	1,154,410,752	94,539,656.0	0.470	10.68	
31	24.993	2199	1,276,640,768	115,982,256.0	0.577	13.11	
32	25.433	2243	2,209,174,272	391,795,808.0	1.948	44.27	
33	25.683	2268	1,236,730,368	117,251,768.0	0.583	13.25	
34	25.793	2279	1,550,280,576	147,434,592.0	0.733	16.66	
35	26.293	2329	840,390,720	92,712,536.0	0.461	10.48	
36	26.663	2366	4,055,864,320	702,244,544.0	3.491	79.35	
37	26.733	2373	829,484,864	118,048,184.0	0.587	13.34	
38	27.673	2467	2,491,636,992	330,961,376.0	1.645	37.40	
39	27.783	2478	1,101,439,872	88,075,544.0	0.438	9.95	
40	28.923	2592	4,216,302,080	883,426,176.0	4.392	99.83	
41	29.023	2602	4,734,224,384	444,103,936.0	2.208	50.18	
42	29.223	2622	761,160,640	99,724,432.0	0.496	11.27	
43	29.474	2647	713,086,336	86,721,720.0	0.431	9.80	
44	30.004	2700	951,471,872	79,913,352.0	0.397	9.03	
45	31.014	2801	3,347,362,816	529,517,152.0	2.632	59.84	
46	31.154	2815	3,485,903,104	335,165,888.0	1.666	37.87	
47	31.604	2860	525,805,664	79,014,504.0	0.393	8.93	
48	32.124	2912	858,339,456	94,510,264.0	0.470	10.68	
49	32.684	2968	797,295,680	84,865,920.0	0.422	9.59	
50	33.004	3000	3,454,015,488	493,978,848.0	2.456	55.82	
51	34.915	3191	3,268,725,760	434,333,856.0	2.159	49.08	
52	36.185	3318	907,608,576	126,427,576.0	0.628	14.29	
53	36.745	3374	3,454,056,448	388,710,752.0	1.932	43.92	
54	38.485	3548	2,998,629,888	345,984,352.0	1.720	39.09	
55	40.176	3717	3,136,436,736	329,986,304.0	1.640	37.29	
56	40.366	3736	692,865,856	120,436,600.0	0.599	13.61	
57	41.776	3877	2,958,678,528	308,032,128.0	1.531	34.81	
58	43.326	4032	2,900,958,720	270,640,736.0	1.345	30.58	
59	44.827	4182	2,442,657,024	187,149,280.0	0.930	21.15	

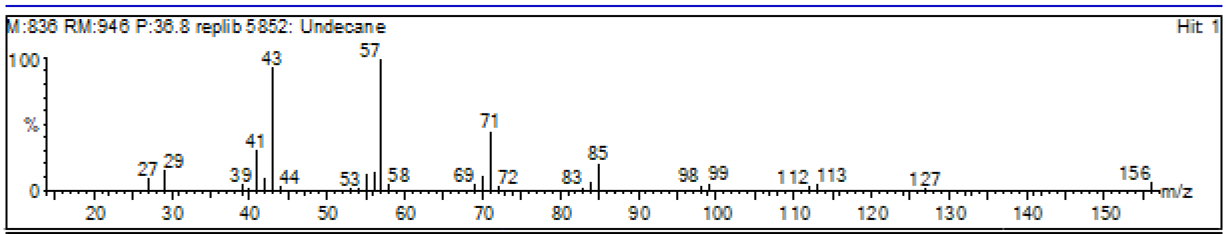
APPENDIX H3 NAPHTHA CHROMATOGRAM/SPECTRUM



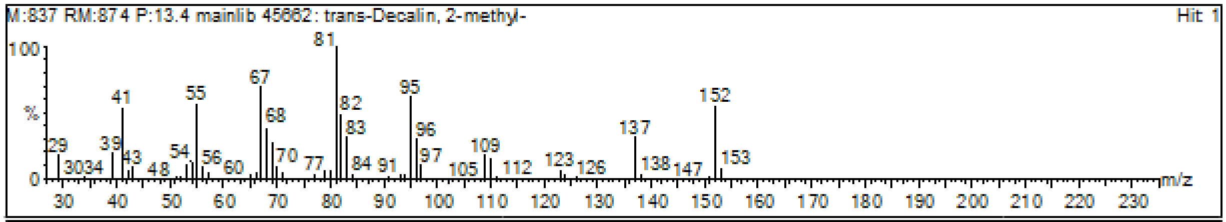


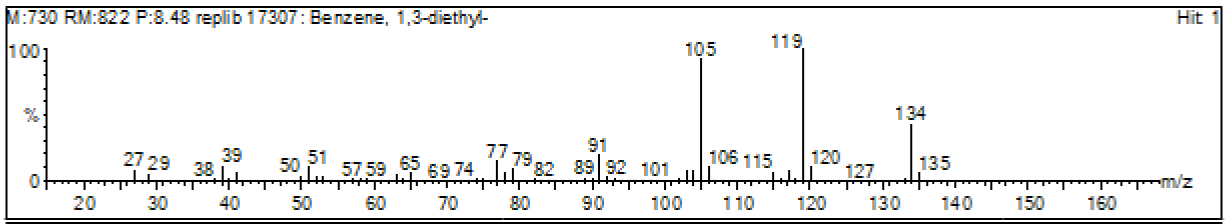


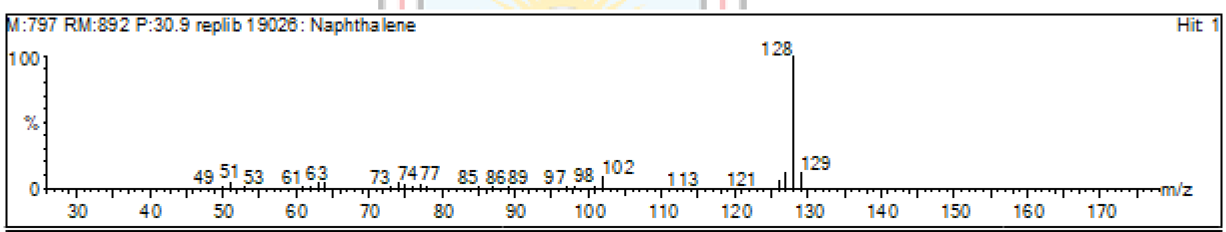


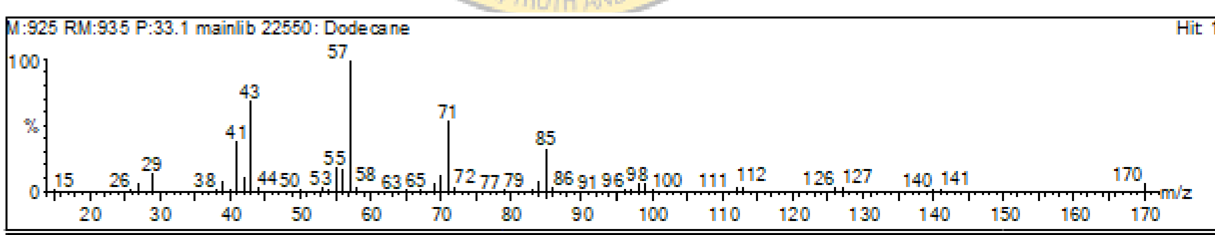


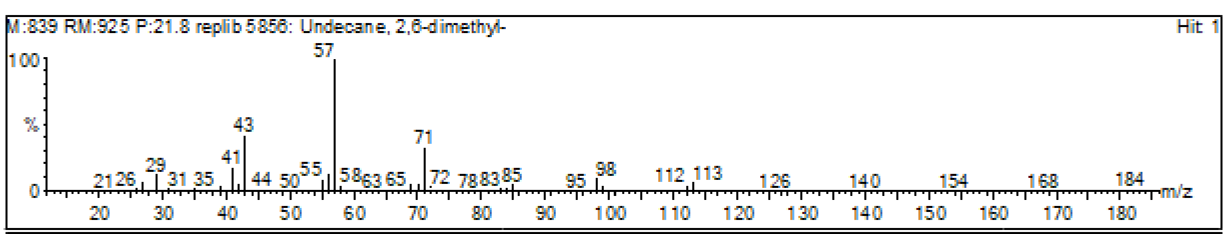
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



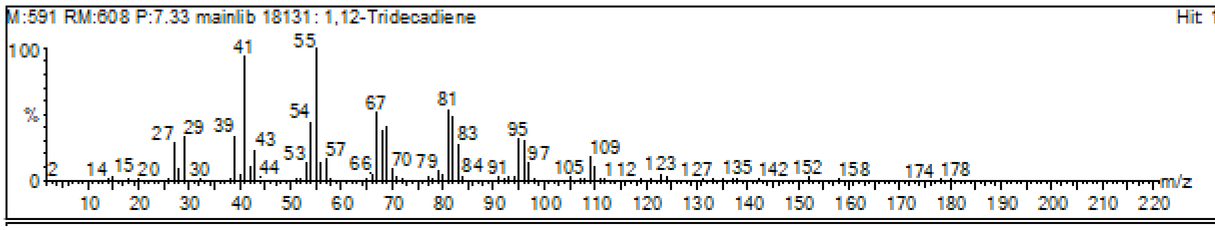


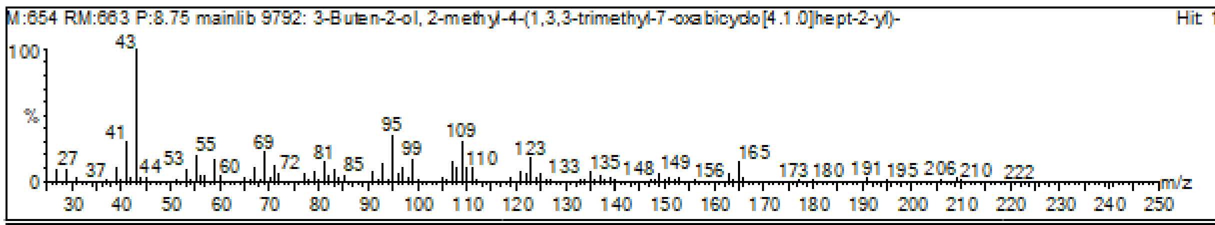


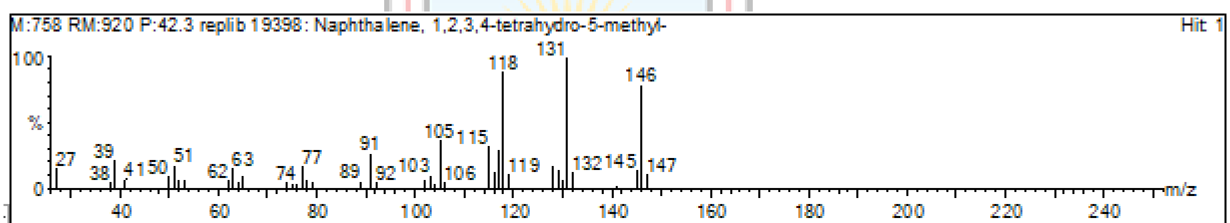


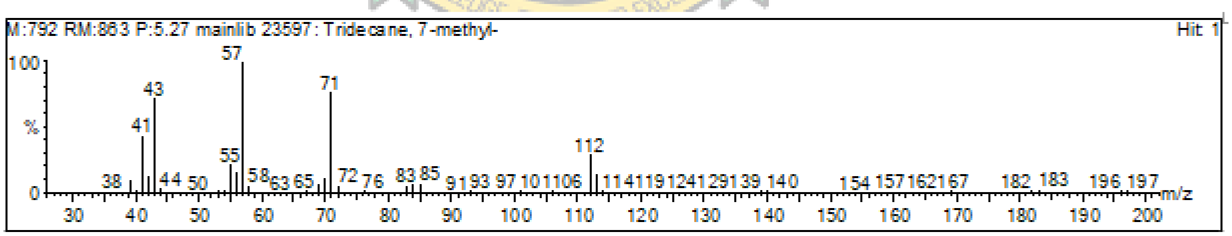


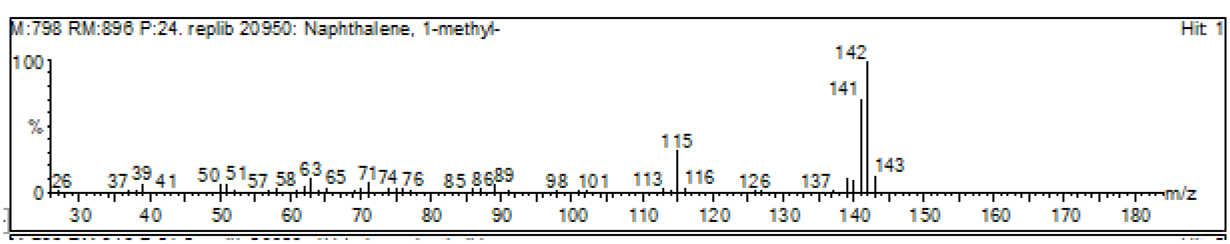
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



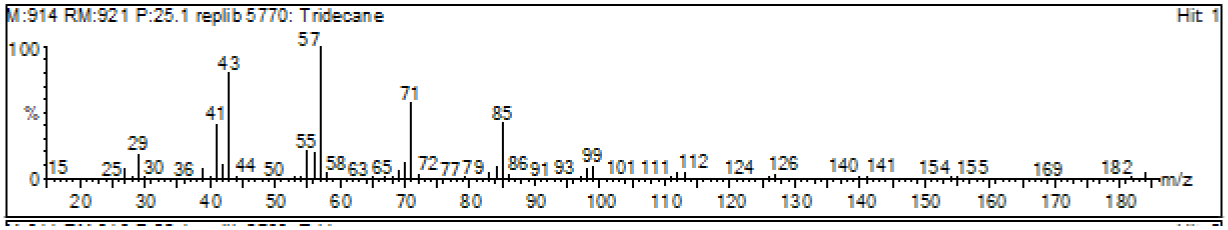


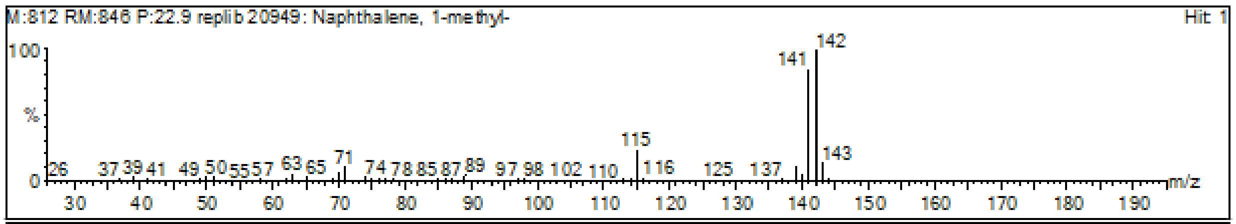


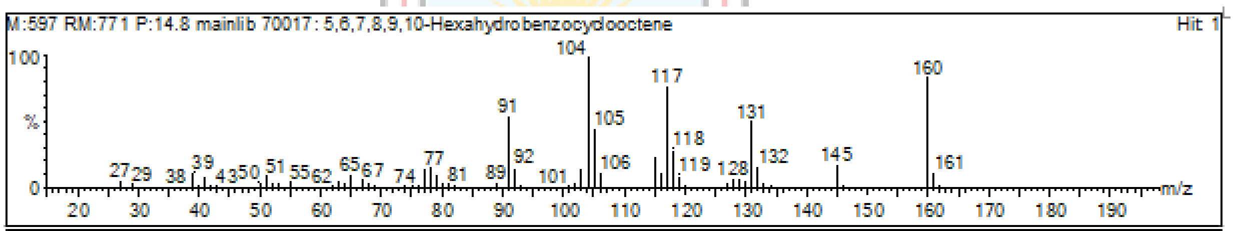


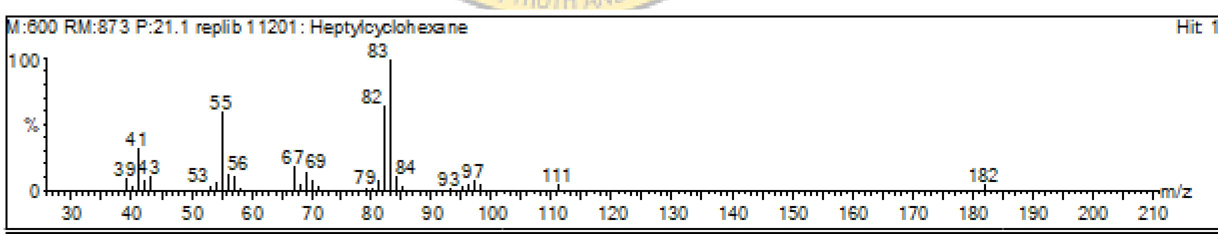


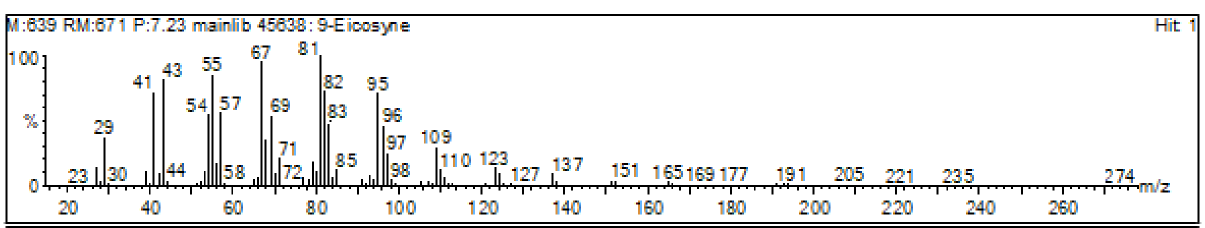
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



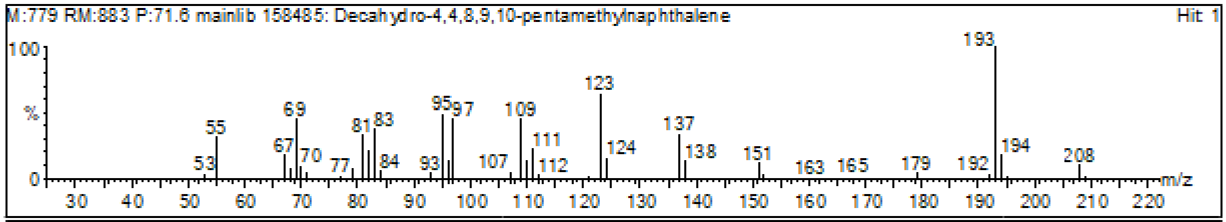


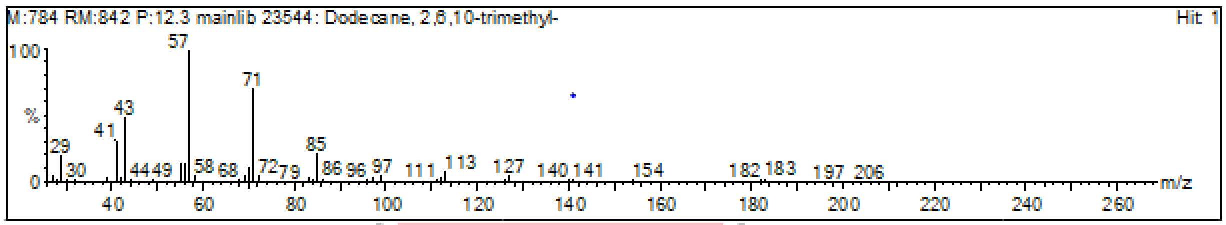


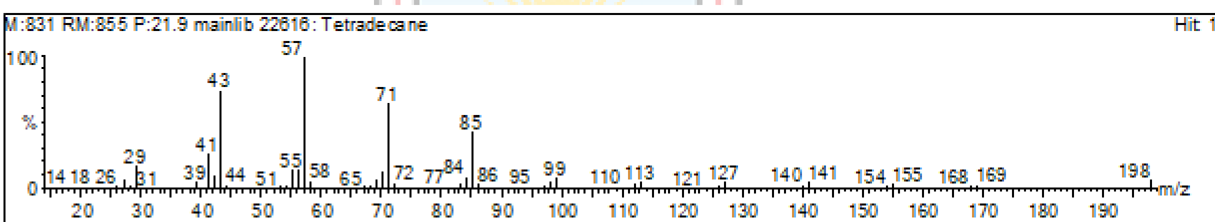


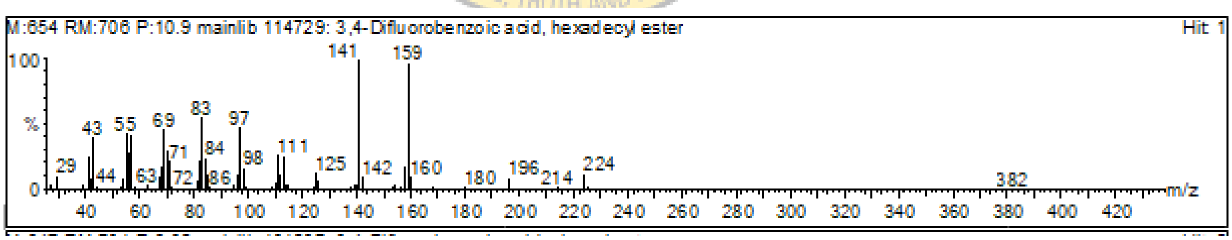


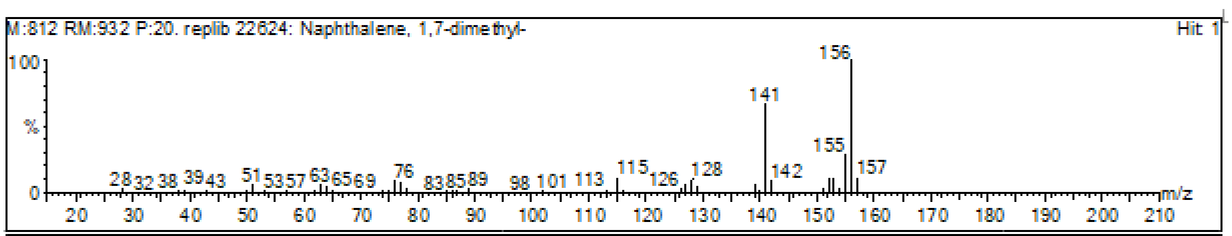
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



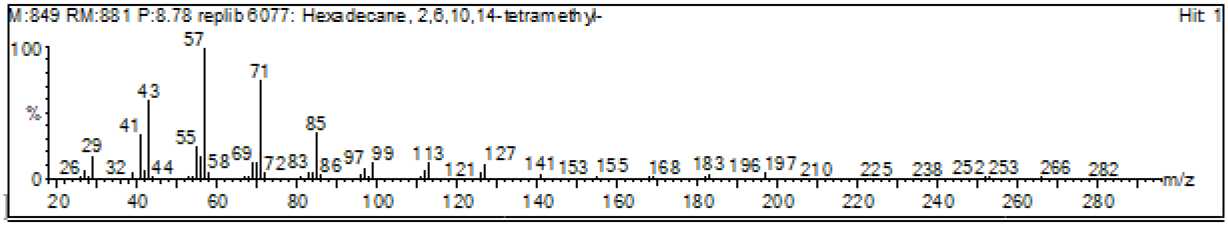


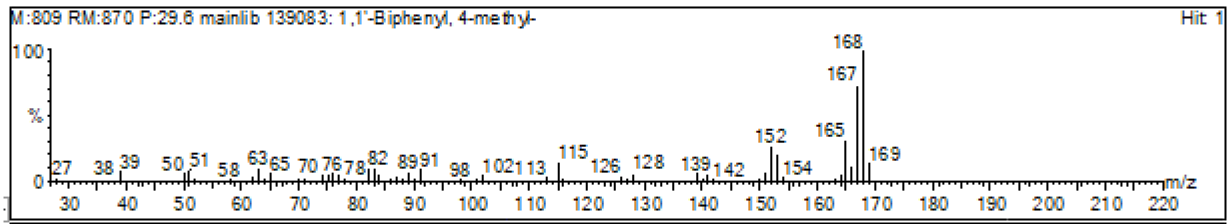


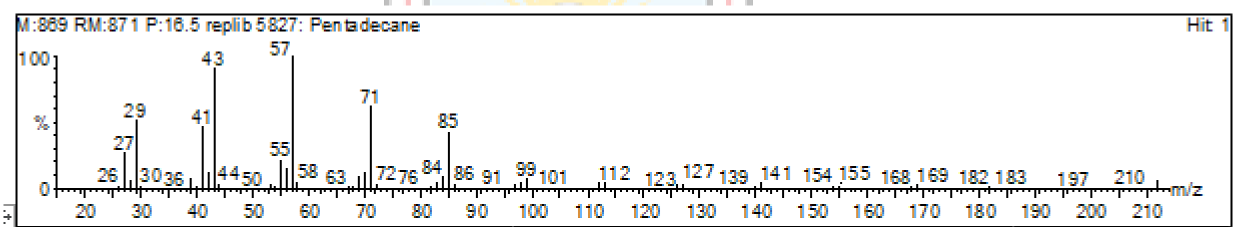


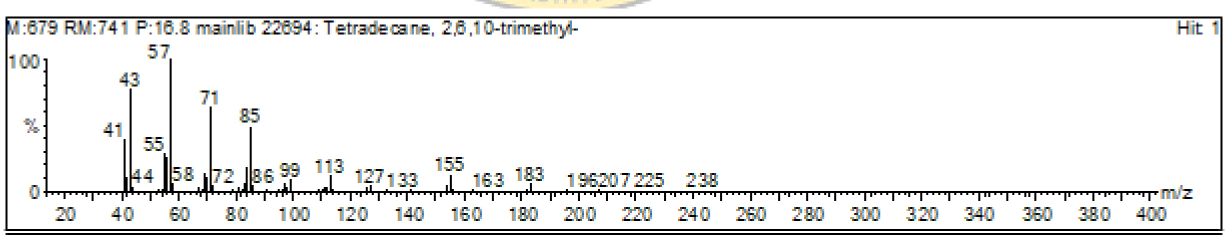


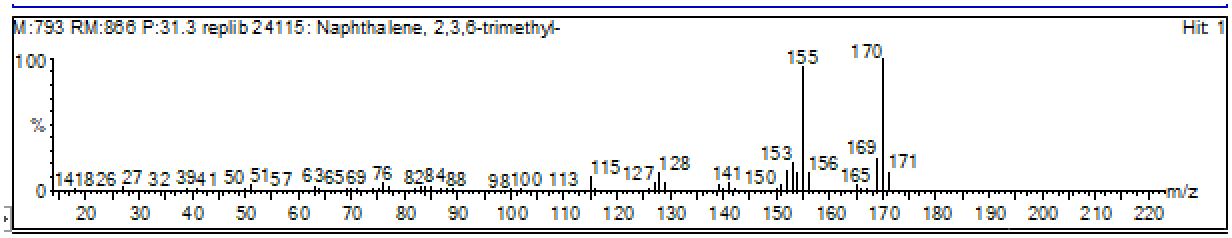
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



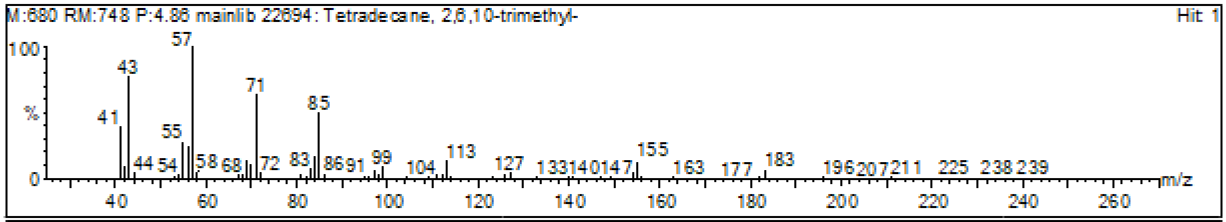


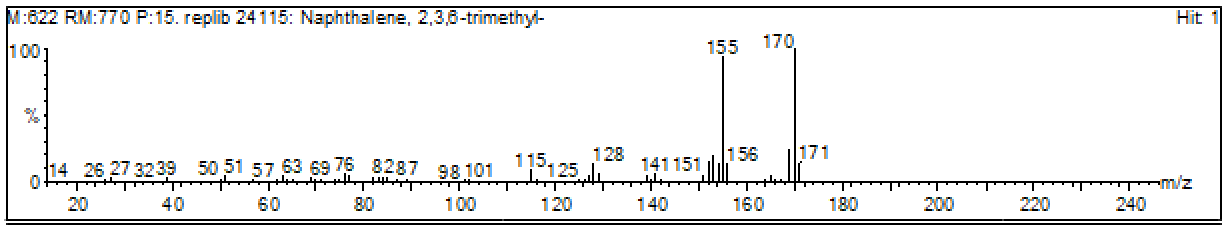


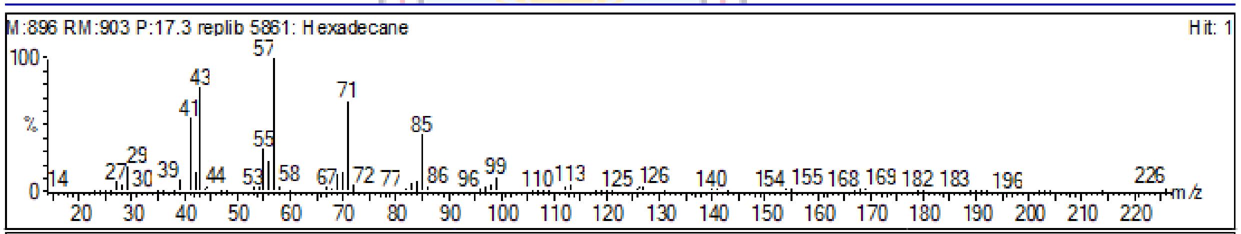


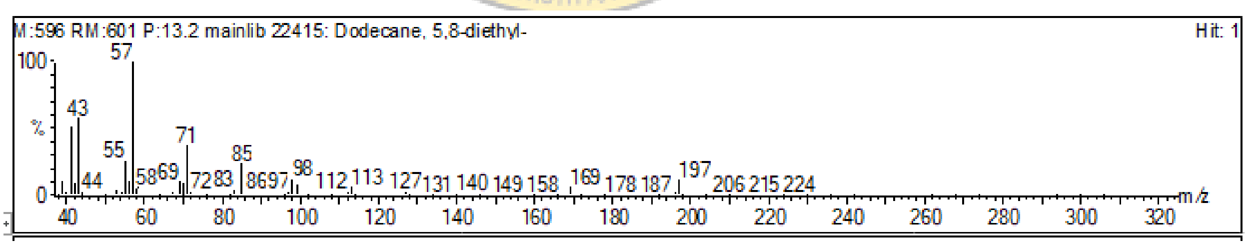


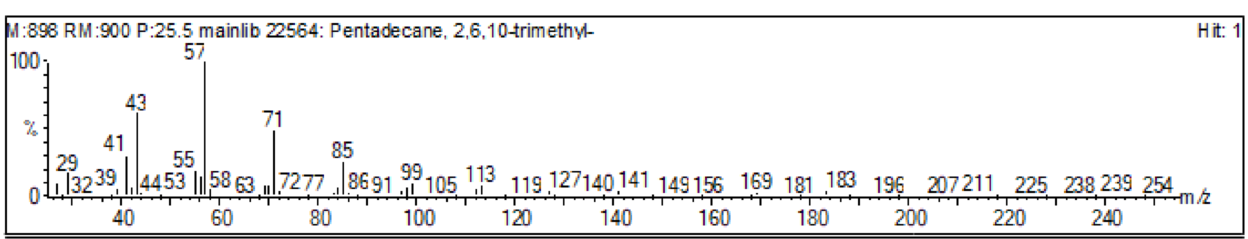
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



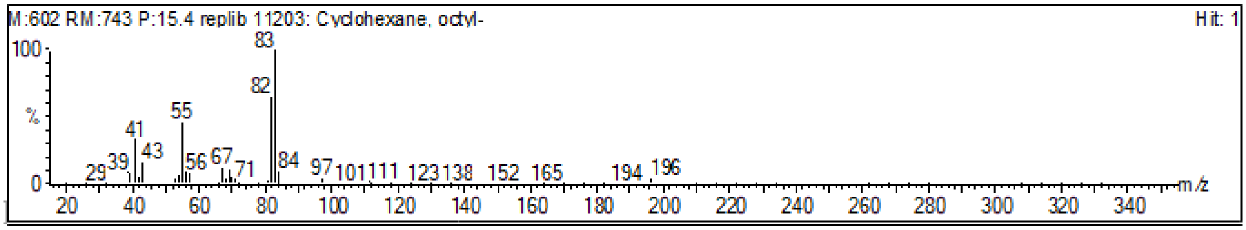


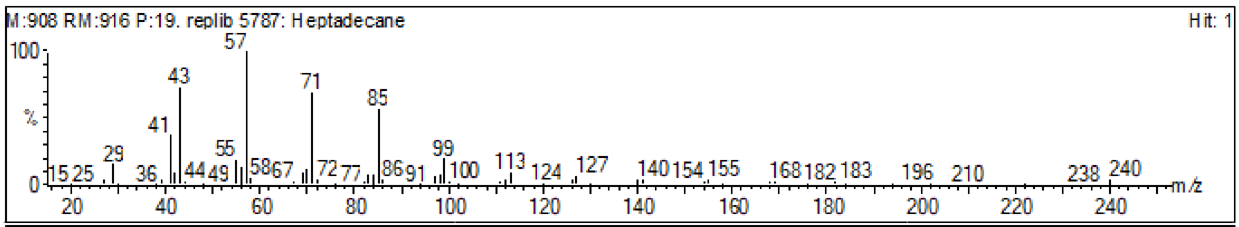


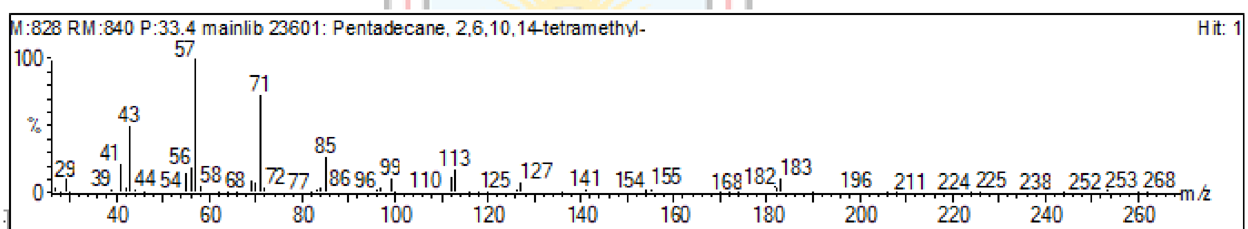


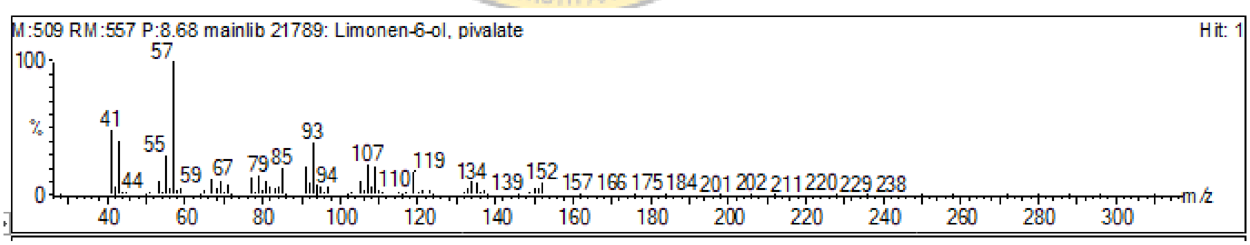


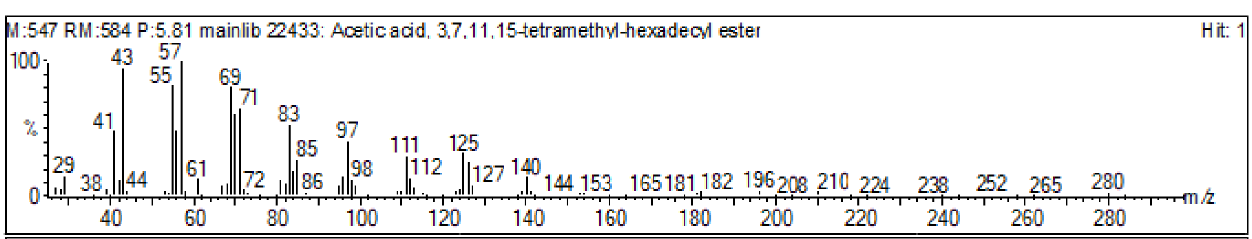
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



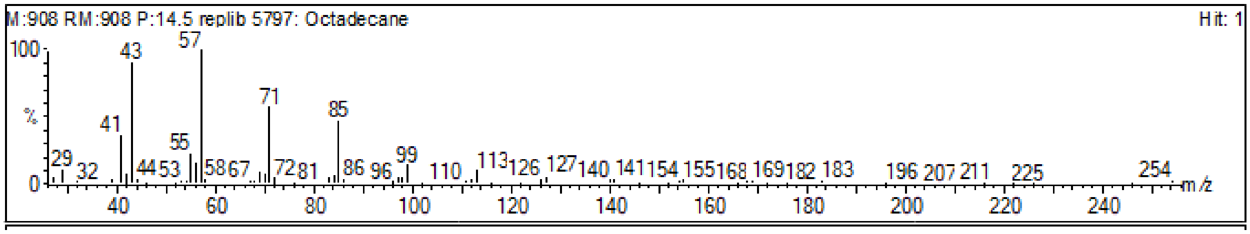


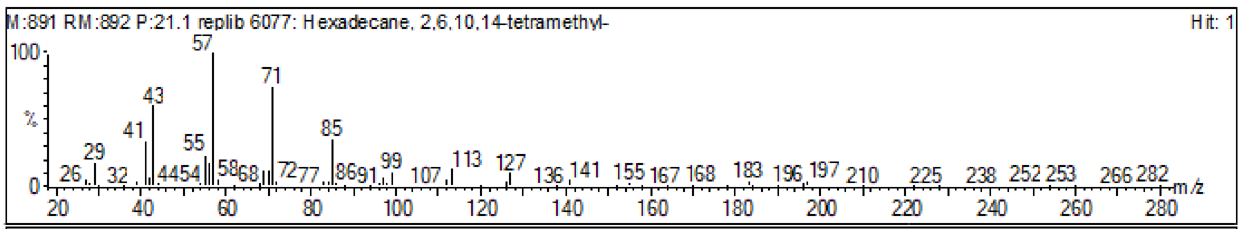


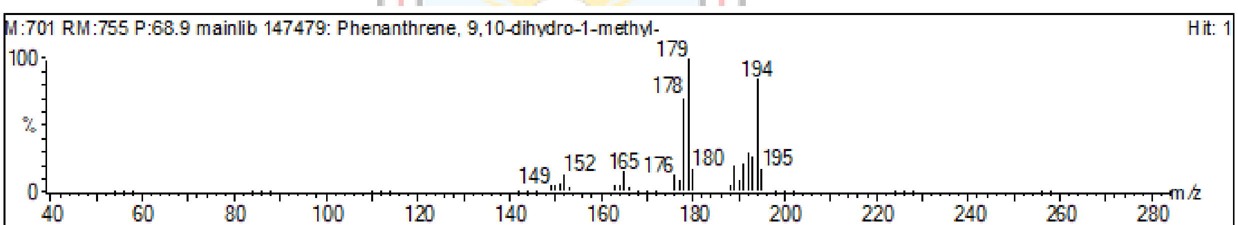


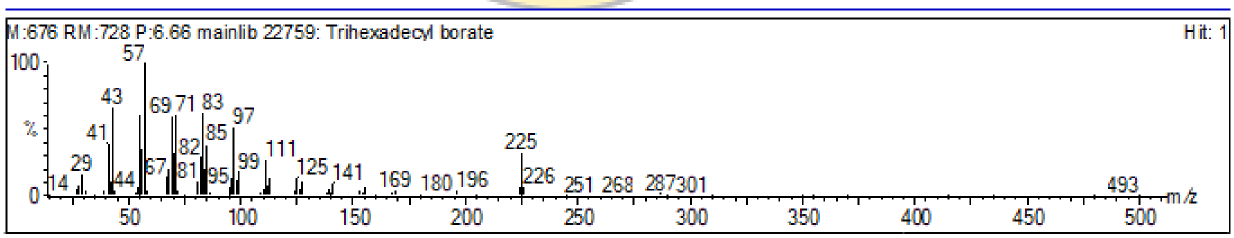


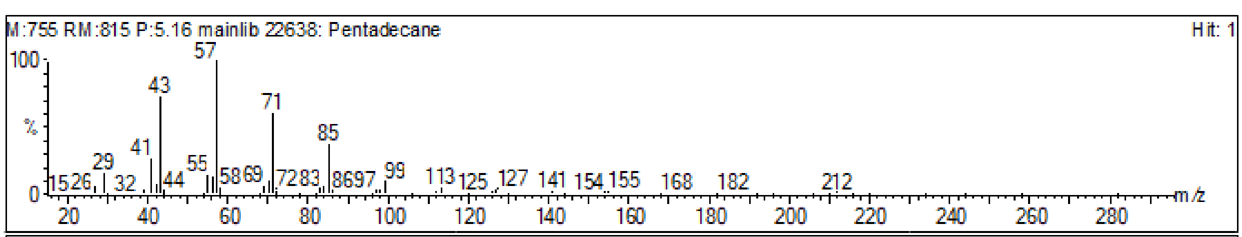
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



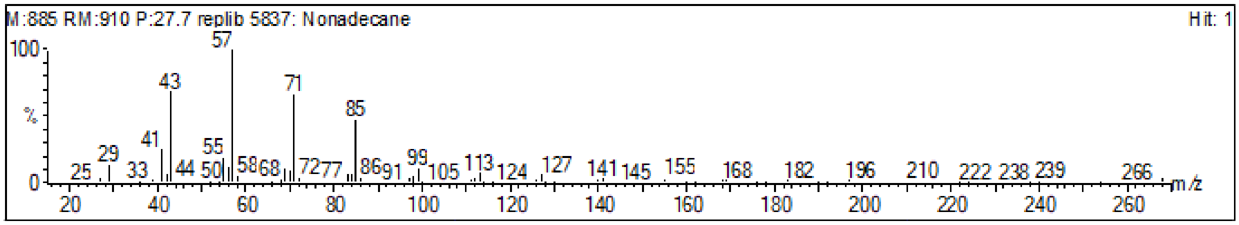


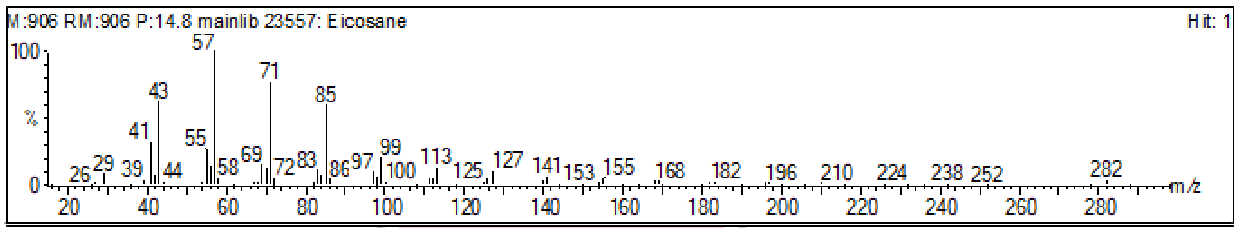


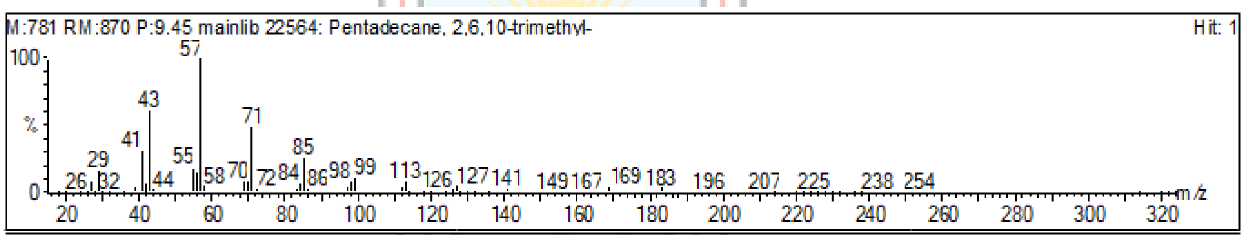


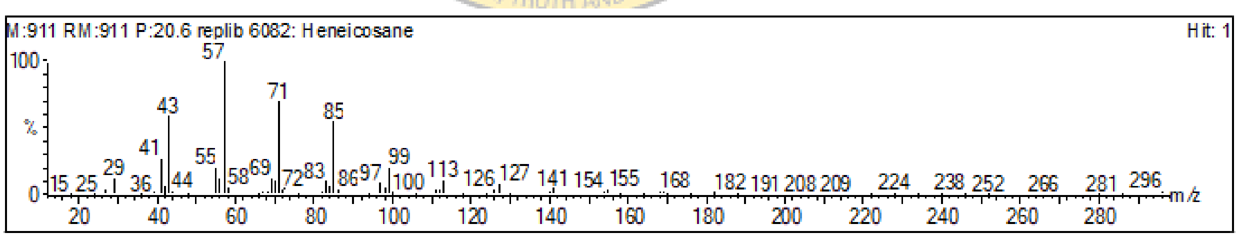


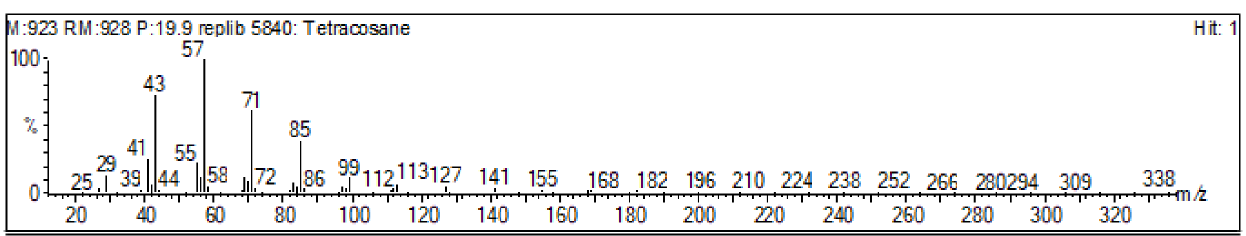
APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)



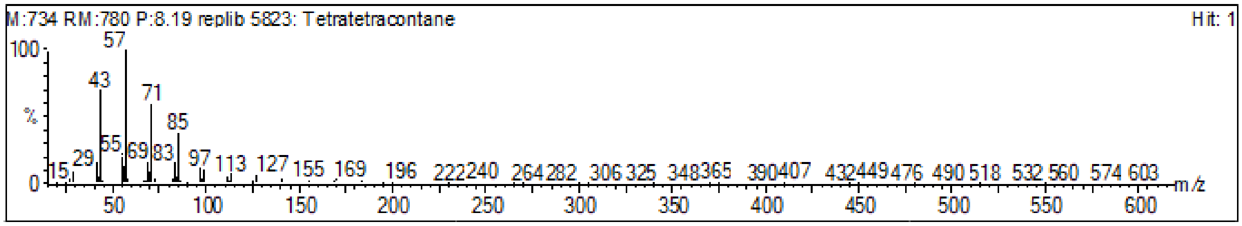


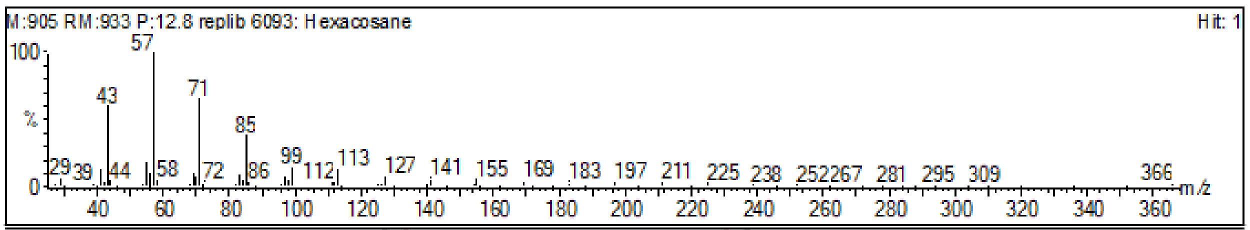


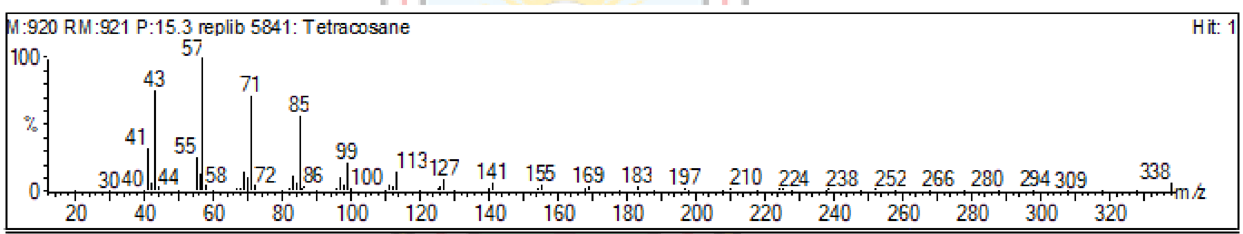




APPENDIX H3 Naphtha Chromatogram/Spectrum Peak (Continued)







APPENDIX I1 WAVENUMBERS VRS TRANSMITTANCES OF FUEL OIL

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3996.05656	0.99661	3918.54245	0.9979	3841.02833	0.99748
3994.01672	0.99632	3916.5026	0.99838	3838.98849	0.99798
3991.97687	0.99623	3914.46276	0.99774	3836.94864	0.99884
3989.93703	0.99659	3912.42291	0.99691	3834.9088	0.99886
3987.89718	0.9967	3910.38307	0.99657	3832.86895	0.9979
3985.85734	0.99633	3908.34322	0.99658	3830.82911	0.99706
3983.81749	0.99625	3906.30338	0.9967	3828.78926	0.99672
3981.77765	0.99681	3904.26353	0.99665	3826.74942	0.99643
3979.7378	0.99734	3902.22369	0.99644	3824.70957	0.99623
3977.69796	0.99726	3900.18384	0.99619	3822.66973	0.99655
3975.65811	0.99673	3898.144	0.99617	3820.62988	0.9974
3973.61827	0.99648	3896.10415	0.99654	3818.59004	0.99813
3971.57842	0.99666	3894.06431	0.997	3816.55019	0.99865
3969.53858	0.99668	3892.02446	0.99749	3814.51035	0.9984
3967.49873	0.99658	3889.98462	0.99789	3812.4705	0.99754
3965.45888	0.99677	3887.94477	0.99799	3810.43066	0.99718
3963.41904	0.9973	3885.90493	0.99802	3808.39081	0.99751
3961.37919	0.9976	3883.86508	0.99795	3806.35097	0.99778
3959.33935	0.9972	3881.82524	0.99761	3804.31112	0.99718
3957.2995	0.99664	3879.78539	0.99755	3802.27128	0.9963
3955.25966	0.99649	3877.74555	0.99771	3800.23143	0.99658
3953.21981	0.99663	3875.7057	0.9974	3798.19159	0.99781
3951.17997	0.9967	3873.66586	0.9972	3796.15174	0.99851
3949.14012	0.99639	3871.62601	0.99785	3794.1119	0.99853
3947.10028	0.99602	3869.58616	0.99801	3792.07205	0.99836
3945.06043	0.99628	3867.54632	0.99715	3790.03221	0.99794
3943.02059	0.99692	3865.50647	0.99641	3787.99236	0.99736

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3936.90105	0.99662	3859.38694	0.99737	3781.87283	0.99789
3934.86121	0.99643	3857.34709	0.99791	3779.83298	0.99816
3932.82136	0.99687	3855.30725	0.99807	3777.79314	0.99797
3930.78152	0.99734	3853.2674	0.9974	3775.75329	0.99759
3928.74167	0.99731	3851.22756	0.99661	3773.71344	0.9976
3926.70183	0.99716	3849.18771	0.99629	3771.6736	0.99798
3924.66198	0.99692	3847.14787	0.99619	3769.63375	0.99809
3922.62214	0.99667	3845.10802	0.99646	3767.59391	0.99792
3920.58229	0.99699	3843.06818	0.99704	3765.55406	0.99779
3763.51422	0.99745	3686.00011	0.9976	3608.48599	0.9976
3761.47437	0.99696	3683.96026	0.99708	3606.44615	0.99724
3759.43453	0.99676	3681.92042	0.99679	3604.4063	0.99725
3757.39468	0.99733	3679.88057	0.99713	3602.36646	0.99757
3755.35484	0.99828	3677.84072	0.9981	3600.32661	0.99779
3753.31499	0.99899	3675.80088	0.99837	3598.28677	0.99841
3751.27515	0.99954	3673.76103	0.99743	3596.24692	0.99929
3749.2353	1.00036	3671.72119	0.99728	3594.20708	0.99939
3747.19546	1.00096	3669.68134	0.99833	3592.16723	0.9985
3745.15561	1.00046	3667.6415	0.99897	3590.12739	0.99798
3743.11577	0.99879	3665.60165	0.99833	3588.08754	0.99882
3741.07592	0.99752	3663.56181	0.99751	3586.0477	0.99924
3739.03608	0.99726	3661.52196	0.99692	3584.00785	0.99842
3736.99623	0.99804	3659.48212	0.99633	3581.96801	0.9983
3734.95639	0.99937	3657.44227	0.9964	3579.92816	0.99904
3732.91654	0.9994	3655.40243	0.9976	3577.88831	0.99907
3730.8767	0.99825	3653.36258	0.99895	3575.84847	0.99814
3728.83685	0.99735	3651.32274	1.00012	3573.80862	0.99739

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3724.75716	0.996	3647.24305	1.00006	3569.72893	0.99724
3722.71732	0.9965	3645.2032	0.99876	3567.68909	0.99835
3720.67747	0.99791	3643.16336	0.99792	3565.64924	0.99954
3718.63763	0.99865	3641.12351	0.99722	3563.6094	0.99926
3716.59778	0.99853	3639.08367	0.99706	3561.56955	0.99883
3714.55794	0.99856	3637.04382	0.99789	3559.52971	0.99911
3712.51809	0.99885	3635.00398	0.99882	3557.48986	0.99921
3710.47825	0.99829	3632.96413	0.9986	3555.45002	0.99885
3708.4384	0.99762	3630.92429	0.99776	3553.41017	0.99877
3706.39856	0.99752	3628.88444	0.99739	3551.37033	0.99882
3704.35871	0.99752	3626.8446	0.9977	3549.33048	0.99868
3702.31887	0.99789	3624.80475	0.99803	3547.29064	0.99859
3700.27902	0.99852	3622.76491	0.99795	3545.25079	0.9986
3698.23918	0.99877	3620.72506	0.99793	3543.21095	0.99853
3696.19933	0.99866	3618.68522	0.99822	3541.1711	0.99814
3694.15949	0.99854	3616.64537	0.99782	3539.13126	0.9978
3692.11964	0.99856	3614.60553	0.99692	3537.09141	0.99774
3690.0798	0.99851	3612.56568	0.99663	3535.05157	0.99773
3688.03995	0.99814	3610.52584	0.99723	3533.01172	0.99769
3475.89606	0.99553	3398.38195	0.99621	3320.86783	0.9951
3473.85621	0.99579	3396.3421	0.99716	3318.82799	0.9951
3471.81637	0.9963	3394.30226	0.99736	3316.78814	0.99522
3469.77652	0.99631	3392.26241	0.99675	3314.7483	0.99538
3467.73668	0.99591	3390.22257	0.99607	3312.70845	0.99529
3465.69683	0.99584	3388.18272	0.99574	3310.66861	0.99499
3463.65699	0.99621	3386.14287	0.99586	3308.62876	0.99513
3461.61714	0.99665	3384.10303	0.99604	3306.58892	0.99561

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3298.42954	0.9951	3220.91542	0.99536	3143.40131	0.99328
3296.38969	0.99552	3218.87558	0.99473	3141.36146	0.99316
3294.34985	0.99609	3216.83573	0.99449	3139.32162	0.99335
3292.31	0.9965	3214.79589	0.9952	3137.28177	0.99373
3290.27015	0.99708	3212.75604	0.99597	3135.24193	0.99396
3288.23031	0.99727	3210.7162	0.99563	3133.20208	0.99373
3286.19046	0.99664	3208.67635	0.99479	3131.16224	0.99339
3284.15062	0.99608	3206.63651	0.99422	3129.12239	0.99352
3282.11077	0.99601	3204.59666	0.99416	3127.08255	0.99403
3280.07093	0.99571	3202.55682	0.99468	3125.0427	0.99442
3278.03108	0.99499	3200.51697	0.9951	3123.00286	0.99441
3275.99124	0.99459	3198.47713	0.99533	3120.96301	0.99411
3273.95139	0.99479	3196.43728	0.9958	3118.92317	0.9937
3271.91155	0.99508	3194.39744	0.99608	3116.88332	0.99328
3269.8717	0.99519	3192.35759	0.99569	3114.84348	0.99302
3267.83186	0.99525	3190.31774	0.99512	3112.80363	0.9929
3265.79201	0.99548	3188.2779	0.99495	3110.76379	0.99279
3263.75217	0.99575	3186.23805	0.99517	3108.72394	0.99262
3261.71232	0.99561	3184.19821	0.99549	3106.6841	0.99256
3259.67248	0.99525	3182.15836	0.99539	3104.64425	0.99279
3257.63263	0.99543	3180.11852	0.99469	3102.60441	0.99296
3255.59279	0.99593	3178.07867	0.99414	3100.56456	0.99259
3253.55294	0.99595	3176.03883	0.9942	3098.52472	0.99155
3251.5131	0.99598	3173.99898	0.9944	3096.48487	0.99038
3249.47325	0.99637	3171.95914	0.99437	3094.44502	0.98996
3247.43341	0.9964	3169.91929	0.99417	3092.40518	0.99011

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3237.23418	0.994	3159.72007	0.99489	3082.20595	0.98727
3235.19434	0.99439	3157.68022	0.99481	3080.16611	0.98609
3233.15449	0.99508	3155.64038	0.99451	3078.12626	0.9852
3065.88719	0.98168	2988.37308	0.9584	2910.85897	0.62133
3063.84735	0.98138	2986.33323	0.95514	2908.81912	0.64193
3061.8075	0.98092	2984.29339	0.95084	2906.77928	0.66015
3059.76766	0.97997	2982.25354	0.94493	2904.73943	0.67644
3057.72781	0.9788	2980.2137	0.93767	2902.69958	0.69106
3055.68797	0.97821	2978.17385	0.92922	2900.65974	0.70456
3053.64812	0.97821	2976.13401	0.91873	2898.61989	0.71725
3051.60828	0.97793	2974.09416	0.90561	2896.58005	0.72926
3049.56843	0.9774	2972.05432	0.89027	2894.5402	0.74152
3047.52859	0.97719	2970.01447	0.8728	2892.50036	0.75465
3045.48874	0.97727	2967.97463	0.85329	2890.46051	0.76803
3043.4489	0.97711	2965.93478	0.83277	2888.42067	0.78068
3041.40905	0.97673	2963.89494	0.81239	2886.38082	0.79209
3039.36921	0.97636	2961.85509	0.79295	2884.34098	0.80203
3037.32936	0.976	2959.81525	0.77559	2882.30113	0.80932
3035.28952	0.97579	2957.7754	0.7617	2880.26129	0.8123
3033.24967	0.97563	2955.73556	0.75238	2878.22144	0.81019
3031.20983	0.9752	2953.69571	0.74802	2876.1816	0.80317
3029.16998	0.97459	2951.65587	0.74832	2874.14175	0.79258
3027.13014	0.97404	2949.61602	0.75212	2872.10191	0.78185
3023.05045	0.97274	2945.53633	0.75942	2868.02222	0.77037
3021.0106	0.97215	2943.49649	0.75749	2865.98237	0.76617
3018.97076	0.97183	2941.45664	0.74959	2863.94253	0.75871

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3530.97188	0.99758	3453.45776	0.9961	3375.94365	0.99612
3528.93203	0.99762	3451.41792	0.99638	3373.9038	0.99562
3526.89219	0.99796	3449.37807	0.99639	3371.86396	0.9955
3524.85234	0.998	3447.33823	0.996	3369.82411	0.99571
3522.8125	0.99763	3445.29838	0.99581	3367.78427	0.99581
3520.77265	0.99751	3443.25854	0.99617	3365.74442	0.99572
3518.73281	0.99752	3441.21869	0.99641	3363.70458	0.99565
3516.69296	0.99735	3439.17885	0.99616	3361.66473	0.99563
3514.65312	0.99694	3437.139	0.99595	3359.62489	0.99567
3512.61327	0.99642	3435.09916	0.99571	3357.58504	0.99597
3510.57343	0.99634	3433.05931	0.99527	3355.5452	0.99645
3508.53358	0.99691	3431.01947	0.99522	3353.50535	0.99666
3506.49374	0.99771	3428.97962	0.99583	3351.46551	0.99644
3504.45389	0.998	3426.93978	0.99656	3349.42566	0.99599
3502.41405	0.99747	3424.89993	0.99691	3347.38582	0.99547
3500.3742	0.99696	3422.86009	0.99689	3345.34597	0.99526
3498.33436	0.99692	3420.82024	0.99649	3343.30613	0.99568
3496.29451	0.99697	3418.7804	0.99584	3341.26628	0.99633
3494.25467	0.99699	3416.74055	0.99579	3339.22644	0.99618
3492.21482	0.99692	3414.70071	0.99651	3337.18659	0.99532
3490.17498	0.99676	3412.66086	0.99696	3335.14675	0.99494
3488.13513	0.99645	3410.62102	0.99662	3333.1069	0.99518
3486.09529	0.99593	3408.58117	0.99602	3331.06706	0.99523
3484.05544	0.99593	3406.54133	0.99609	3329.02721	0.99497
3482.01559	0.99659	3404.50148	0.99675	3326.98737	0.99476
3479.97575	0.99672	3402.46164	0.99663	3324.94752	0.99491
3477.9359	0.99602	3400.42179	0.99594	3322.90768	0.99513

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3010.81138	0.97023	2933.29726	0.66217	2855.78315	0.68085
3008.77153	0.96988	2931.25742	0.63288	2853.7433	0.66432
3006.73169	0.96939	2929.21757	0.60345	2851.70346	0.66076
3004.69184	0.96883	2927.17773	0.57561	2849.66361	0.67258
3002.652	0.96852	2925.13788	0.55217	2847.62377	0.69699
3000.61215	0.96829	2923.09804	0.53666	2845.58392	0.72826
2998.5723	0.96779	2921.05819	0.53183	2843.54408	0.76151
2996.53246	0.96687	2919.01835	0.53825	2841.50423	0.79386
2994.49261	0.96536	2916.9785	0.55387	2839.46439	0.82356
2992.45277	0.96344	2914.93866	0.57515	2837.42454	0.84961
2990.41292	0.96117	2912.89881	0.59854	2835.3847	0.87165
2778.26903	0.98383	2700.75492	0.9885	2623.24081	0.99098
2776.22919	0.9845	2698.71507	0.9884	2621.20096	0.99136
2774.18934	0.98506	2696.67523	0.98837	2619.16112	0.99141
2772.1495	0.98548	2694.63538	0.98834	2617.12127	0.99153
2770.10965	0.98569	2692.59554	0.98832	2615.08143	0.99203
2768.06981	0.98599	2690.55569	0.98816	2613.04158	0.99256
2766.02996	0.9866	2688.51585	0.98798	2611.00173	0.99278
2763.99012	0.98718	2686.476	0.98808	2608.96189	0.99271
2761.95027	0.98748	2684.43616	0.9883	2606.92204	0.99258
2759.91043	0.98768	2682.39631	0.98819	2604.8822	0.99272
2757.87058	0.98785	2680.35647	0.98782	2602.84235	0.99309
2541.647	0.99492	2464.13289	0.99573	2386.61877	0.99452
2539.60716	0.99515	2462.09304	0.99628	2384.57893	0.99415
2537.56731	0.9951	2460.0532	0.99644	2382.53908	0.99369
2535.52747	0.99523	2458.01335	0.99619	2380.49924	0.99384
2533.48762	0.99529	2455.97351	0.99566	2378.45939	0.99457

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2833.34485	0.88984	2755.83074	0.98785	2678.31662	0.98772
2831.30501	0.90478	2753.79089	0.98774	2676.27678	0.98781
2829.26516	0.91713	2751.75105	0.98776	2674.23693	0.98779
2827.22532	0.92744	2749.7112	0.98788	2672.19709	0.98774
2825.18547	0.93584	2747.67136	0.9879	2670.15724	0.98783
2823.14563	0.94257	2745.63151	0.98797	2668.1174	0.988
2821.10578	0.94819	2743.59167	0.98793	2666.07755	0.98804
2819.06594	0.95297	2741.55182	0.98745	2664.03771	0.98815
2817.02609	0.9569	2739.51198	0.98663	2661.99786	0.98849
2814.98625	0.96011	2737.47213	0.9858	2659.95802	0.98876
2812.9464	0.96315	2735.43229	0.98531	2657.91817	0.98886
2810.90656	0.96591	2733.39244	0.98517	2655.87833	0.98914
2808.86671	0.96795	2731.3526	0.98496	2653.83848	0.98948
2806.82686	0.96974	2729.31275	0.98458	2651.79864	0.98934
2804.78702	0.97161	2727.27291	0.98448	2649.75879	0.98915
2802.74717	0.97318	2725.23306	0.98501	2647.71895	0.98945
2800.70733	0.97433	2723.19322	0.98586	2645.6791	0.98983
2798.66748	0.97531	2721.15337	0.98646	2643.63926	0.99014
2796.62764	0.97635	2719.11353	0.9868	2641.59941	0.99052
2794.58779	0.97733	2717.07368	0.98729	2639.55957	0.99073
2792.54795	0.9783	2715.03384	0.98766	2637.51972	0.99049
2790.5081	0.97921	2712.99399	0.98771	2635.47988	0.99019
2788.46826	0.98005	2710.95415	0.98787	2633.44003	0.99035
2786.42841	0.9809	2708.9143	0.98831	2631.40019	0.99089
2784.38857	0.9817	2706.87445	0.98883	2629.36034	0.99131
2782.34872	0.98245	2704.83461	0.98906	2627.3205	0.99114
2780.30888	0.98314	2702.79476	0.98881	2625.28065	0.99077

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2600.80251	0.99333	2523.2884	0.99563	2445.77428	0.99509
2598.76266	0.99352	2521.24855	0.99528	2443.73444	0.99545
2596.72282	0.99367	2519.20871	0.99526	2441.69459	0.99531
2594.68297	0.99327	2517.16886	0.99506	2439.65475	0.99478
2592.64313	0.99282	2515.12901	0.99495	2437.6149	0.99467
2590.60328	0.9931	2513.08917	0.99504	2435.57506	0.99527
2588.56344	0.99359	2511.04932	0.99498	2433.53521	0.99631
2586.52359	0.99374	2509.00948	0.99493	2431.49537	0.99708
2584.48375	0.99373	2506.96963	0.99507	2429.45552	0.99673
2582.4439	0.99356	2504.92979	0.99542	2427.41568	0.99574
2580.40406	0.9933	2502.88994	0.99578	2425.37583	0.99548
2578.36421	0.99332	2500.8501	0.99589	2423.33599	0.99615
2576.32437	0.99357	2498.81025	0.99585	2421.29614	0.99674
2574.28452	0.99395	2496.77041	0.99588	2419.25629	0.99662
2572.24468	0.99407	2494.73056	0.99578	2417.21645	0.9962
2570.20483	0.99387	2492.69072	0.996	2415.1766	0.99591
2568.16499	0.99381	2490.65087	0.99671	2413.13676	0.99563
2566.12514	0.99365	2488.61103	0.99671	2411.09691	0.99558
2564.0853	0.99334	2486.57118	0.99601	2409.05707	0.99578
2562.04545	0.99323	2484.53134	0.99561	2407.01722	0.99568
2560.00561	0.99338	2482.49149	0.99565	2404.97738	0.99533
2557.96576	0.9938	2480.45165	0.99582	2402.93753	0.9952
2555.92592	0.9945	2478.4118	0.99585	2400.89769	0.9953
2553.88607	0.99523	2476.37196	0.99543	2398.85784	0.99512
2551.84623	0.99566	2474.33211	0.99484	2396.818	0.99468
2549.80638	0.99567	2472.29227	0.99494	2394.77815	0.99476
2547.76654	0.99538	2470.25242	0.99528	2392.73831	0.99524

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2368.26017	0.99571	2290.74605	0.99557	2213.23194	0.99589
2366.22032	0.99578	2288.70621	0.99631	2211.19209	0.99591
2364.18048	0.99573	2286.66636	0.99694	2209.15225	0.99771
2362.14063	0.99584	2284.62652	0.99698	2207.1124	0.99944
2360.10079	0.99545	2282.58667	0.9969	2205.07256	0.99958
2358.06094	0.99419	2280.54683	0.99658	2203.03271	0.9996
2356.0211	0.99399	2278.50698	0.99634	2200.99287	0.99994
2353.98125	0.99556	2276.46714	0.99662	2198.95302	0.99956
2351.94141	0.99616	2274.42729	0.99694	2196.91318	1.00021
2349.90156	0.9955	2272.38745	0.99691	2194.87333	1.0023
2347.86172	0.99526	2270.3476	0.99705	2192.83349	1.00265
2345.82187	0.9955	2268.30776	0.99803	2190.79364	1.0012
2343.78203	0.99489	2266.26791	0.99898	2188.7538	1.0008
2341.74218	0.9934	2264.22807	0.99872	2186.71395	1.00179
2339.70234	0.9934	2262.18822	0.99778	2184.67411	1.00201
2337.66249	0.99558	2260.14838	0.99706	2182.63426	1.00084
2335.62265	0.99743	2258.10853	0.99674	2180.59442	1.00013
2333.5828	0.99681	2256.06869	0.99666	2178.55457	0.99908
2331.54296	0.9942	2254.02884	0.997	2176.51473	0.99704
2329.50311	0.99216	2251.989	0.99763	2174.47488	0.99746
2327.46327	0.99252	2249.94915	0.99776	2172.43504	1.00027
2325.42342	0.99391	2247.90931	0.99741	2170.39519	1.00195
2323.38358	0.99469	2245.86946	0.99776	2168.35535	1.00143
2321.34373	0.99516	2243.82962	0.9985	2166.3155	0.99955
2319.30388	0.99601	2241.78977	0.99829	2164.27566	0.99824
2317.26404	0.99658	2239.74993	0.99787	2162.23581	0.99851
2315.22419	0.99616	2237.71008	0.99783	2160.19597	0.99999

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2313.18435	0.99517	2235.67024	0.99773	2158.15612	1.00058
2311.1445	0.99467	2233.63039	0.99774	2156.11628	0.99865
2309.10466	0.99502	2231.59055	0.99748	2154.07643	0.99732
2307.06481	0.99551	2229.5507	0.99725	2152.03659	0.99741
2305.02497	0.99569	2227.51086	0.99767	2149.99674	0.99625
2302.98512	0.99588	2225.47101	0.99743	2147.9569	0.99468
2300.94528	0.99621	2223.43116	0.99638	2145.91705	0.99498
2298.90543	0.99633	2221.39132	0.99622	2143.87721	0.9963
2296.86559	0.99626	2219.35147	0.997	2141.83736	0.99637
2294.82574	0.9961	2217.31163	0.9974	2139.79752	0.99508
2292.7859	0.99568	2215.27178	0.99685	2137.75767	0.99475
2078.60216	0.99959	2001.08805	1.00233	1923.57393	0.99637
2076.56232	0.99869	1999.0482	1.00003	1921.53409	0.99567
2074.52247	0.99863	1997.00836	0.997	1919.49424	0.99487
2072.48263	0.99877	1994.96851	0.99616	1917.4544	0.9939
2070.44278	0.998	1992.92867	0.99699	1915.41455	0.99337
2068.40294	0.99732	1990.88882	0.99776	1913.37471	0.99369
2066.36309	0.99675	1988.84898	0.99796	1911.33486	0.99407
2064.32325	0.99574	1986.80913	0.99822	1909.29502	0.99392
2062.2834	0.99568	198.76929	0.99873	1907.25517	0.99388
1848.09967	0.99238	1770.58555	0.99001	1693.07144	0.98238
1846.05982	0.993	1768.54571	0.99015	1691.03159	0.98237
1844.01998	0.99342	1766.50586	0.99017	1688.99175	0.98232
1841.98013	0.99304	1764.46602	0.98996	1686.9519	0.98272
1839.94029	0.99285	1762.42617	0.98944	1684.91206	0.98333
1837.90044	0.99327	1760.38633	0.98903	1682.87221	0.98309
1835.86059	0.99366	1758.34648	0.98898	1680.83237	0.98258

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2135.71783	0.99527	2058.20371	0.99482	1980.6896	0.99854
2133.67798	0.99555	2056.16387	0.99448	1978.64975	0.99886
2131.63814	0.99699	2054.12402	0.99522	1976.60991	1.00076
2129.59829	0.99807	2052.08418	0.99596	1974.57006	1.00277
2127.55844	0.99656	2050.04433	0.99748	1972.53022	1.00292
2125.5186	0.99477	2048.00449	0.99983	1970.49037	1.00051
2123.47875	0.99479	2045.96464	1.00135	1968.45053	0.99813
2121.43891	0.99579	2043.9248	1.00214	1966.41068	0.99871
2119.39906	0.99655	2041.88495	1.00179	1964.37084	1.00036
2117.35922	0.99623	2039.84511	0.99935	1962.33099	1.0011
2115.31937	0.99526	2037.80526	0.99649	1960.29115	1.0007
2113.27953	0.99518	2035.76542	0.99468	1958.2513	0.99941
2111.23968	0.99618	2033.72557	0.99495	1956.21146	0.99784
2109.19984	0.99736	2031.68572	0.99644	1954.17161	0.99634
2107.15999	0.99831	2029.64588	0.99716	1952.13177	0.99561
2105.12015	0.99847	2027.60603	0.99757	1950.09192	0.99593
2103.0803	0.99719	2025.56619	0.99846	1948.05208	0.99659
2101.04046	0.9957	2023.52634	0.99967	1946.01223	0.99693
2099.00061	0.99591	2021.4865	1.00056	1943.97239	0.99725
2096.96077	0.99733	2019.44665	1.00095	1941.93254	0.9982
2094.92092	0.99768	2017.40681	1.00093	1939.8927	0.99892
2092.88108	0.99685	2015.36696	1.00001	1937.85285	0.99819
2090.84123	0.99701	2013.32712	0.99807	1935.813	0.99704
2088.80139	0.99817	2011.28727	0.99593	1933.77316	0.99644
2086.76154	0.99846	2009.24743	0.99438	1931.73331	0.99627
2084.7217	0.99831	2007.20758	0.99451	1929.69347	0.99679
2082.68185	0.99916	2005.16774	0.99741	1927.65362	0.99715

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1903.17548	0.99493	1825.66137	0.99392	1748.14726	0.98816
1901.13564	0.99454	1823.62152	0.99329	1746.10741	0.98819
1899.09579	0.9938	1821.58168	0.99258	1744.06757	0.98822
1897.05595	0.99329	1819.54183	0.99216	1742.02772	0.98835
1895.0161	0.99299	1817.50199	0.99214	1739.98787	0.98812
1892.97626	0.99317	1815.46214	0.99245	1737.94803	0.98759
1890.93641	0.99354	1813.4223	0.99267	1735.90818	0.98725
1888.89657	0.99344	1811.38245	0.99243	1733.86834	0.98706
1886.85672	0.9934	1809.34261	0.99212	1731.82849	0.98692
1884.81688	0.99392	1807.30276	0.99228	1729.78865	0.98674
1882.77703	0.99437	1805.26292	0.99261	1727.7488	0.98663
1880.73719	0.99458	1803.22307	0.9928	1725.70896	0.98669
1878.69734	0.99481	1801.18323	0.99272	1723.66911	0.98665
1876.6575	0.99495	1799.14338	0.99225	1721.62927	0.98639
1874.61765	0.99499	1797.10354	0.99177	1719.58942	0.98609
1872.57781	0.99492	1795.06369	0.99144	1717.54958	0.98567
1870.53796	0.99479	1793.02385	0.99105	1715.50973	0.98515
1868.49812	0.99476	1790.984	0.9911	1713.46989	0.98485
1866.45827	0.99469	1788.94416	0.99144	1711.43004	0.98459
1864.41843	0.9942	1786.90431	0.9912	1709.3902	0.98428
1862.37858	0.99387	1784.86447	0.99066	1707.35035	0.9839
1860.33874	0.99443	1782.82462	0.99067	1705.31051	0.98351
1858.29889	0.99482	1780.78478	0.99082	1703.27066	0.98339
1856.25905	0.99407	1778.74493	0.99044	1701.23082	0.98334
1854.2192	0.99304	1776.70509	0.99008	1699.19097	0.98282
1852.17936	0.99244	1774.66524	0.99005	1697.15113	0.98228
1850.13951	0.99219	1772.6254	0.98999	1695.11128	0.98221

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1670.63314	0.98182	1613.51748	0.96476	1556.40182	0.97897
1668.5933	0.98122	1611.47763	0.96342	1554.36197	0.97951
1666.55345	0.98099	1609.43779	0.96213	1552.32213	0.97989
1664.51361	0.98072	1607.39794	0.96086	1550.28228	0.98005
1662.47376	0.98021	1605.3581	0.95995	1548.24243	0.97991
1660.43392	0.97975	1603.31825	0.95986	1546.20259	0.97974
1658.39407	0.97952	1601.27841	0.9606	1544.16274	0.97976
1656.35423	0.97957	1599.23856	0.96162	1542.1229	0.98014
1654.31438	0.97979	1597.19872	0.96283	1540.08305	0.9801
1652.27454	0.97928	1595.15887	0.96441	1538.04321	0.97878
1650.23469	0.97855	1593.11903	0.966	1536.00336	0.97765
1648.19485	0.97805	1591.07918	0.96727	1533.96352	0.97692
1646.155	0.97688	1589.03934	0.96836	1531.92367	0.97661
1644.11515	0.97513	1586.99949	0.96944	1529.88383	0.97639
1642.07531	0.97369	1584.95965	0.97048	1527.84398	0.97594
1640.03546	0.97296	1582.9198	0.97134	1525.80414	0.97541
1637.99562	0.97309	1580.87996	0.97183	1523.76429	0.975
1635.95577	0.97363	1578.84011	0.9721	1521.72445	0.97422
1633.91593	0.97357	1576.80027	0.97274	1519.6846	0.97299
1631.87608	0.973	1574.76042	0.97383	1517.64476	0.97162
1629.83624	0.97225	1572.72058	0.9745	1515.60491	0.9699
1627.79639	0.97144	1570.68073	0.97504	1513.56507	0.96837
1625.75655	0.97092	1568.64089	0.97597	1511.52522	0.96723
1623.7167	0.97054	1566.60104	0.97687	1509.48538	0.96622
1621.67686	0.96987	1564.5612	0.9774	1507.44553	0.96468
1619.63701	0.96905	1562.52135	0.97766	1505.40569	0.96241
1617.59717	0.96799	1560.48151	0.97773	1503.36584	0.96109

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1499.28615	0.95903	1421.77204	0.93785	1344.25792	0.94391
1497.24631	0.9574	1419.73219	0.94121	1342.21808	0.94394
1495.20646	0.95573	1417.69235	0.9442	1340.17823	0.94436
1493.16662	0.95459	1415.6525	0.94629	1338.13839	0.94532
1491.12677	0.95381	1413.61266	0.94775	1336.09854	0.94638
1489.08693	0.95272	1411.57281	0.9491	1334.0587	0.94719
1487.04708	0.95068	1409.53297	0.95027	1332.01885	0.94783
1485.00724	0.94826	1407.49312	0.95098	1329.97901	0.94834
1482.96739	0.94524	1405.45328	0.95152	1327.93916	0.94849
1480.92755	0.94103	1403.41343	0.95184	1325.89932	0.94841
1478.8877	0.93582	1401.37359	0.95175	1323.85947	0.94831
1476.84786	0.92912	1399.33374	0.95168	1321.81963	0.94815
1474.80801	0.91844	1397.2939	0.95192	1319.77978	0.94782
1472.76817	0.89475	1395.25405	0.9519	1317.73994	0.9473
1470.72832	0.86086	1393.21421	0.95071	1315.70009	0.94684
1468.68848	0.83344	1391.17436	0.94799	1313.66025	0.9464
1466.64863	0.81175	1389.13452	0.94295	1311.6204	0.94572
1464.60879	0.79558	1387.09467	0.93356	1309.58056	0.94499
1462.56894	0.78687	1385.05483	0.92113	1307.54071	0.94458
1460.5291	0.78176	1383.01498	0.90758	1305.50087	0.94461
1458.48925	0.77771	1380.97514	0.89129	1303.46102	0.94498
1456.44941	0.77726	1378.93529	0.87438	1301.42118	0.94555
1454.40956	0.78198	1376.89545	0.86467	1299.38133	0.94649
1452.36972	0.78952	1374.8556	0.86853	1297.34149	0.94795
1450.32987	0.79912	1372.81576	0.88262	1295.30164	0.9494
1448.29002	0.80979	1370.77591	0.89591	1293.2618	0.95041
1446.25018	0.82012	1368.73607	0.90524	1291.22195	0.95135

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1266.74381	0.95648	1189.2297	0.95924	1111.71558	0.96415
1264.70397	0.95641	1187.18985	0.95933	1109.67574	0.96405
1262.66412	0.95647	1185.15001	0.95931	1107.63589	0.96405
1260.62428	0.95674	1183.11016	0.95937	1105.59605	0.96395
1258.58443	0.95704	1181.07032	0.9596	1103.5562	0.9636
1256.54458	0.95724	1179.03047	0.95992	1101.51636	0.96343
1254.50474	0.95735	1176.99063	0.96005	1099.47651	0.96351
1252.46489	0.95771	1174.95078	0.95983	1097.43667	0.96334
1250.42505	0.95819	1172.91094	0.95942	1095.39682	0.96279
1248.3852	0.95836	1170.87109	0.9589	1093.35698	0.96206
1246.34536	0.9584	1168.83125	0.95818	1091.31713	0.96133
1244.30551	0.95845	1166.7914	0.95748	1089.27729	0.96083
1242.26567	0.95837	1164.75156	0.95719	1087.23744	0.96056
1240.22582	0.95842	1162.71171	0.95726	1085.1976	0.96023
1238.18598	0.95866	1160.67186	0.95747	1083.15775	0.95977
1236.14613	0.95885	1158.63202	0.95771	1081.11791	0.95926
1234.10629	0.95892	1156.59217	0.95788	1079.07806	0.95877
1232.06644	0.95891	1154.55233	0.95805	1077.03822	0.95859
1230.0266	0.95889	1152.51248	0.95863	1074.99837	0.95848
1227.98675	0.95896	1150.47264	0.95959	1072.95853	0.95811
1225.94691	0.95893	1148.43279	0.96057	1070.91868	0.95783
1223.90706	0.95881	1146.39295	0.9613	1068.87884	0.9577
1221.86722	0.9589	1144.3531	0.96154	1066.83899	0.95711
1219.82737	0.95941	1142.31326	0.96144	1064.79915	0.9564
1217.78753	0.95999	1140.27341	0.96145	1062.7593	0.95646
1215.74768	0.96012	1138.23357	0.96182	1060.71945	0.95713
1213.70784	0.9599	1136.19372	0.96227	1058.67961	0.95771

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1011.76317	0.95502	934.24906	0.95534	856.73494	0.93103
1003.60379	0.95401	926.08968	0.9566	848.57556	0.92986
1001.56395	0.95296	924.04983	0.9558	846.53572	0.93029
999.5241	0.9517	922.00999	0.95416	844.49587	0.93105
997.48426	0.95047	919.97014	0.95168	842.45603	0.93106
995.44441	0.94926	917.9303	0.94853	840.41618	0.93089
993.40457	0.94854	915.89045	0.94441	838.37634	0.93065
991.36472	0.949	913.85061	0.93902	836.33649	0.92945
989.32488	0.95057	911.81076	0.93273	834.29665	0.92733
987.28503	0.95265	909.77092	0.92775	832.2568	0.92524
985.24519	0.95444	907.73107	0.92703	830.21696	0.92386
983.20534	0.95545	905.69123	0.93039	828.17711	0.92303
981.1655	0.95555	903.65138	0.9347	826.13727	0.92189
979.12565	0.95492	901.61154	0.93759	824.09742	0.9199
977.08581	0.95385	899.57169	0.93862	822.05758	0.91689
975.04596	0.95227	897.53185	0.93805	820.01773	0.9127
973.00612	0.95021	895.492	0.93624	817.97789	0.90736
970.96627	0.94785	893.45216	0.93343	815.93804	0.90165
966.88658	0.94295	889.37247	0.92544	811.85835	0.89429
964.84673	0.94206	887.33262	0.9223	809.81851	0.89349
962.80689	0.94309	885.29278	0.92091	807.77866	0.89468
960.76704	0.94543	883.25293	0.92059	805.73882	0.89717
958.7272	0.94796	881.21309	0.91988	803.69897	0.90054
746.58331	0.87958	669.06919	0.96033	591.55508	0.95199
744.54346	0.87755	667.02935	0.95984	589.51524	0.95161
742.50362	0.87907	664.9895	0.95855	587.47539	0.95233
740.46377	0.8841	662.94966	0.95767	585.43555	0.95155

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
801.65913	0.90453	724.14501	0.88769	646.6309	0.9551
799.61928	0.90846	722.10517	0.88407	644.59105	0.95471
797.57944	0.91298	720.06532	0.88703	642.55121	0.95426
795.53959	0.91806	718.02548	0.89615	640.51136	0.9535
793.49975	0.922	715.98563	0.90677	638.47152	0.9529
791.4599	0.92398	713.94579	0.91548	636.43167	0.95198
789.42006	0.92442	711.90594	0.92197	634.39183	0.95153
787.38021	0.92387	709.8661	0.92711	632.35198	0.95213
785.34037	0.92227	707.82625	0.93057	630.31214	0.95315
783.30052	0.92063	705.78641	0.93201	628.27229	0.95416
781.26068	0.92038	703.74656	0.93219	626.23245	0.95517
779.22083	0.9207	701.70672	0.93218	624.1926	0.95592
777.18099	0.92051	699.66687	0.93276	622.15276	0.95546
775.14114	0.91982	697.62703	0.93456	620.11291	0.95419
773.10129	0.91836	695.58718	0.93863	618.07307	0.95394
771.06145	0.91638	693.54734	0.94396	616.03322	0.95451
769.0216	0.91436	691.50749	0.94824	613.99338	0.9547
766.98176	0.91189	689.46765	0.95126	611.95353	0.95505
764.94191	0.90907	687.4278	0.95298	609.91369	0.95581
762.90207	0.90652	685.38796	0.95313	607.87384	0.95567
760.86222	0.90439	683.34811	0.95314	605.834	0.95423
758.82238	0.9024	681.30827	0.95403	603.79415	0.9537
756.78253	0.90022	679.26842	0.95504	601.75431	0.95535
754.74269	0.89777	677.22857	0.95569	599.71446	0.95692
752.70284	0.89434	675.18873	0.95605	597.67462	0.95645
750.663	0.88942	673.14888	0.95688	595.63477	0.95494
748.62315	0.884	671.10904	0.95866	593.59493	0.95347

APPENDIX I1 Wavenumbers vrs Transmittances of Fuel Oil (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
730.26455	0.90316	652.75043	0.95629	575.23632	0.9512
728.2247	0.89988	650.71059	0.95716	573.19647	0.95249
726.18486	0.89421	648.67074	0.95645	571.15663	0.95358
569.11678	0.95233	491.60267	0.9471	414.08856	0.93146
567.07694	0.94977	489.56283	0.94812	412.04871	0.93256
565.03709	0.94811	487.52298	0.9488	410.00887	0.93801
562.99725	0.94705	485.48314	0.94783	407.96902	0.94051
560.9574	0.9462	483.44329	0.94593	405.92918	0.93642
558.91756	0.94652	481.40344	0.94396	403.88933	0.93629
556.87771	0.94725	479.3636	0.94227	401.84949	0.94593
554.83787	0.94713	477.32375	0.9404	399.80964	0.9531
552.79802	0.94721	475.28391	0.93806	514.04097	0.94921
550.75818	0.9481	473.24406	0.93569	512.00112	0.94868
548.71833	0.9489	471.20422	0.93451	509.96128	0.95079
546.67849	0.94923	469.16437	0.93671	507.92143	0.95286
544.63864	0.94891	467.12453	0.94155	505.88159	0.95249
542.5988	0.94763	465.08468	0.94556	503.84174	0.95081
540.55895	0.9459	463.04484	0.94747	501.8019	0.94973
538.51911	0.94443	461.00499	0.94865	499.76205	0.94886
536.47926	0.94382	458.96515	0.95056	497.72221	0.94771
534.43942	0.94502	456.9253	0.95249	495.68236	0.94721
532.39957	0.94771	454.88546	0.95113	493.64252	0.94706
530.35973	0.94984	452.84561	0.94656	436.52685	0.93145
528.31988	0.95056	450.80577	0.94117	434.48701	0.93118
526.28004	0.95052	448.76592	0.93811	432.44716	0.93644
524.24019	0.95001	446.72608	0.93914	430.40732	0.94205
522.20035	0.9497	444.68623	0.93975	428.36747	0.94309

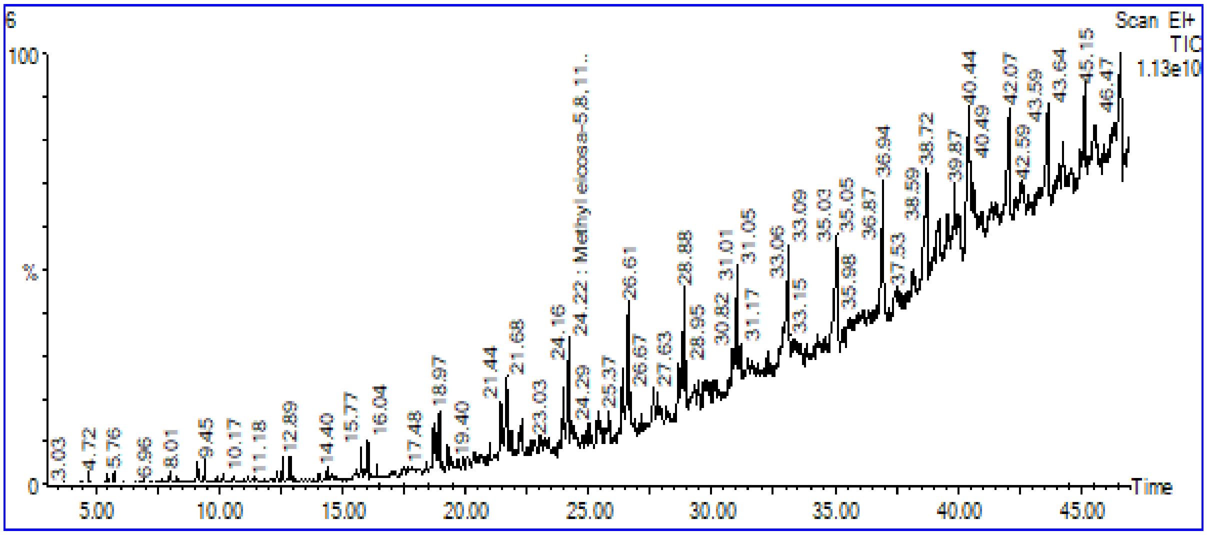
APPENDIX I2 QUALITATIVE REPORT FUEL OIL

#	RT	Scan	Height	Area	Area %	Norm %	Name
1	18.722	1572	1,327,735,936	98,901,304.0	0.622	14.29	
2	18.792	1579	1,086,583,040	94,817,704.0	0.596	13.70	
3	18.972	1597	1,652,910,080	126,952,488.0	0.798	18.34	
4	21.442	1844	1,336,610,048	105,468,016.0	0.663	15.24	
5	21.682	1868	1,922,685,696	140,481,552.0	0.883	20.30	
6	23.032	2003	562,759,872	70,887,768.0	0.446	10.24	
7	23.192	2019	492,676,000	62,652,112.0	0.394	9.05	
8	23.983	2098	1,764,186,624	172,438,896.0	1.084	24.92	
9	24.223	2122	2,988,524,032	310,709,088.0	1.954	44.90	Methyl eicosa-5,8,11,14,
10	25.373	2237	949,577,728	88,485,344.0	0.556	12.79	
11	25.823	2282	870,844,736	72,625,672.0	0.457	10.49	
12	26.393	2339	1,898,158,720	208,268,256.0	1.310	30.09	
13	26.613	2361	3,624,521,728	330,594,432.0	2.079	47.77	
14	26.673	2367	1,258,383,232	95,189,056.0	0.599	13.75	
15	27.633	2463	1,030,714,624	118,895,400.0	0.748	17.18	
16	27.803	2480	914,011,712	87,993,816.0	0.553	12.71	
17	28.664	2566	1,473,954,048	150,929,552.0	0.949	21.81	
18	28.884	2588	3,301,585,664	327,203,712.0	2.058	47.28	
19	28.954	2595	1,278,062,208	61,523,084.0	0.387	8.89	
20	29.444	2644	802,568,000	78,647,648.0	0.495	11.36	
21	29.784	2678	663,348,160	65,971,732.0	0.415	9.53	
22	30.844	2784	1,085,052,160	114,786,128.0	0.722	16.59	

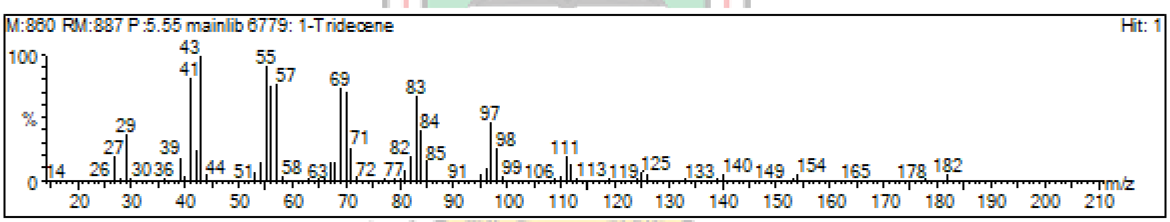
APPENDIX I2 Qualitative Report Fuel Oil (Continued)

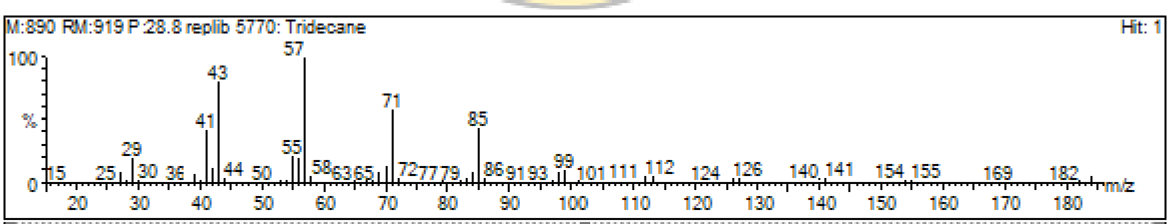
#	RT	Scan	Height	Area	Area %	Norm %	Name
23	31.054	2805	3,085,832,704	313,259,136.0	1.970	45.26	
24	32.924	2992	1,315,380,608	128,653,592.0	0.809	18.59	
25	33.094	3009	3,313,841,664	449,031,680.0	2.824	64.88	
26	33.255	3025	811,730,624	66,926,180.0	0.421	9.67	
27	33.385	3038	783,730,880	111,402,392.0	0.701	16.10	
28	33.625	3062	640,563,904	64,374,508.0	0.405	9.30	
29	34.855	3185	771,958,784	64,788,568.0	0.407	9.36	
30	35.055	3205	3,076,283,648	394,910,784.0	2.484	57.06	
31	35.335	3233	600,152,128	62,553,512.0	0.393	9.04	
32	36.165	3316	683,624,384	118,757,120.0	0.747	17.16	
33	36.935	3393	3,777,602,816	450,579,648.0	2.834	65.11	
34	37.465	3446	652,251,840	74,161,744.0	0.466	10.72	
35	37.525	3452	694,467,520	68,977,232.0	0.434	9.97	
36	38.135	3513	807,947,712	71,453,616.0	0.449	10.32	
37	38.716	3571	3,052,946,176	468,506,432.0	2.946	67.70	
38	38.986	3598	782,251,072	76,689,568.0	0.482	11.08	
39	39.156	3615	1,419,209,600	139,194,528.0	0.875	20.11	
40	39.236	3623	1,415,672,704	123,015,752.0	0.774	17.77	
41	39.556	3655	1,430,654,464	195,976,016.0	1.232	28.32	
42	39.866	3686	2,052,105,472	283,900,000.0	1.785	41.02	
43	40.046	3704	1,156,491,904	168,920,560.0	1.062	24.41	
44	40.436	3743	3,906,361,856	692,075,840.0	4.352	100.00	
45	40.606	3760	1,713,999,104	238,249,584.0	1.498	34.43	
46	41.326	3832	795,272,896	89,494,024.0	0.563	12.93	
47	42.066	3906	2,988,179,456	411,450,368.0	2.588	59.45	
48	42.536	3953	904,481,024	76,673,720.0	0.482	11.08	
49	42.586	3958	959,546,880	119,763,416.0	0.753	17.30	
50	43.637	4063	2,673,008,896	375,644,096.0	2.362	54.28	
51	44.077	4107	988,331,712	85,382,048.0	0.537	12.34	
52	44.267	4126	1,483,643,264	180,323,744.0	1.134	26.06	
53	44.937	4193	928,603,264	74,166,392.0	0.466	10.72	
54	45.147	4214	2,485,433,600	275,626,912.0	1.733	39.83	
55	45.497	4249	1,200,431,616	125,646,872.0	0.790	18.16	
56	45.537	4253	1,308,136,448	115,373,440.0	0.726	16.67	
57	45.927	4292	762,725,632	78,161,920.0	0.492	11.29	
58	46.157	4315	1,036,621,568	72,423,544.0	0.455	10.46	
59	46.307	4330	1,409,073,792	225,697,408.0	1.419	32.61	

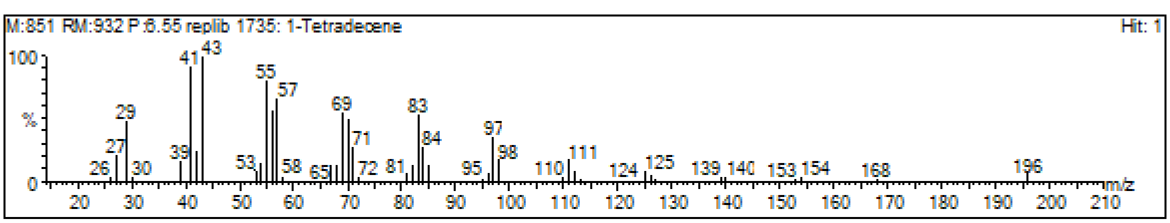
APPENDIX I3 METHYL EICOSA-5,8,11.. SPECTRUM IN FUEL OIL



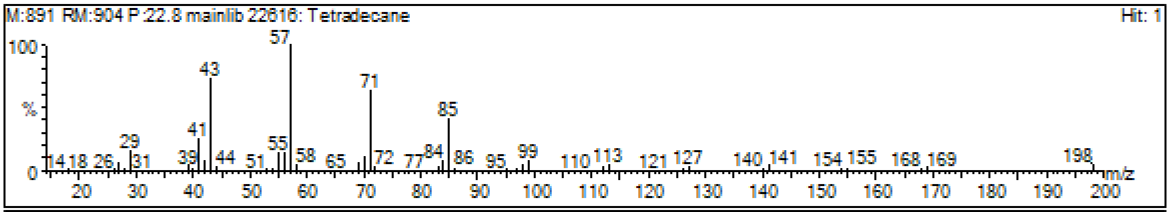
APPENDIX I4 FUEL OIL CHROMATOGRAM/SPECTRUM

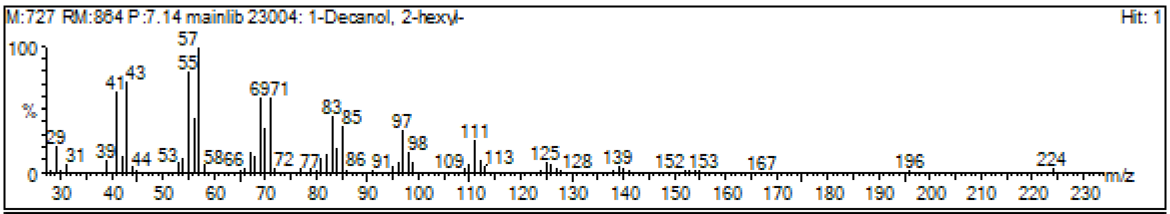


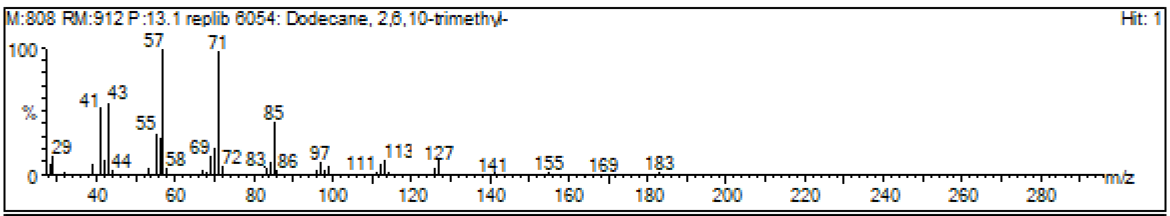


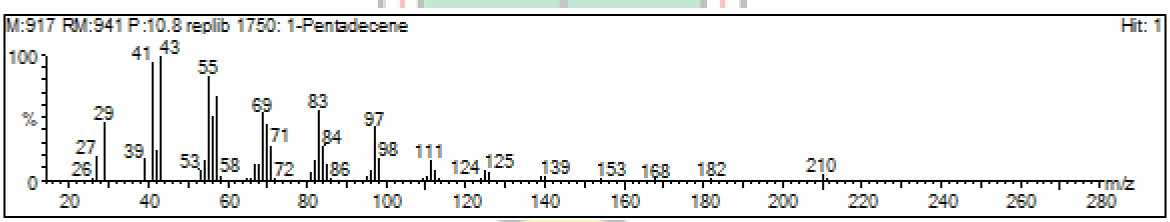


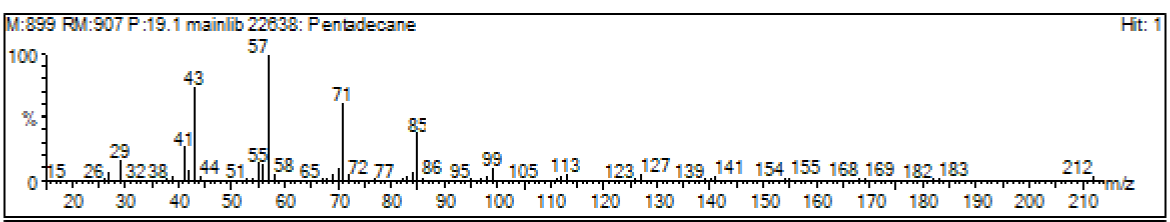
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)

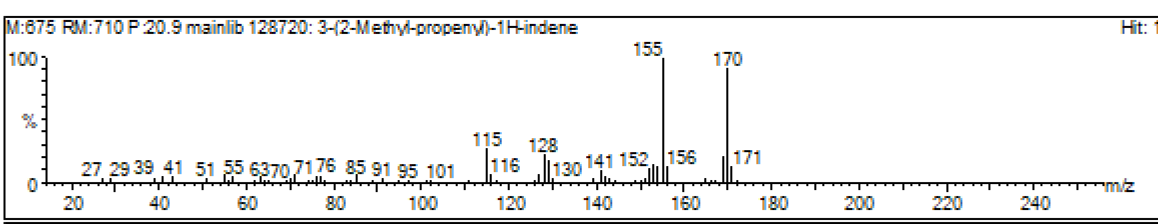




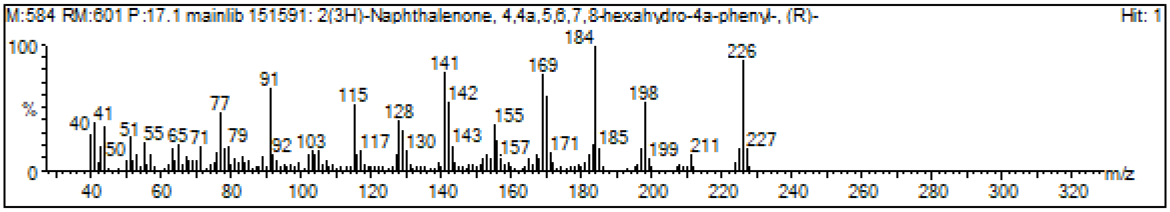


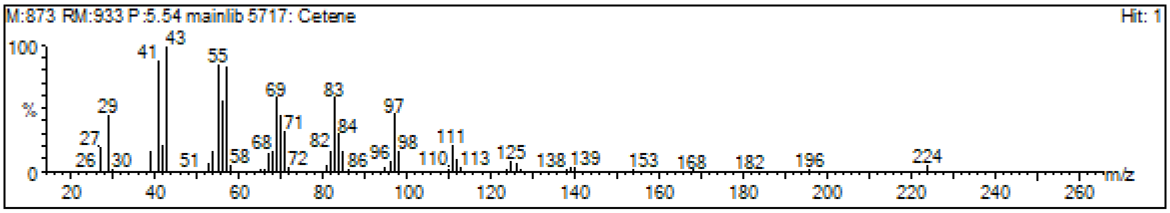


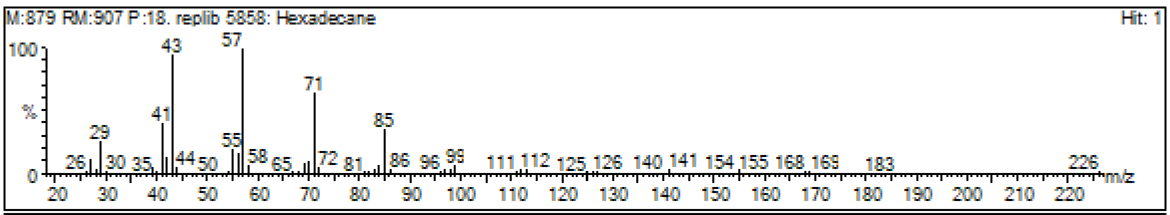


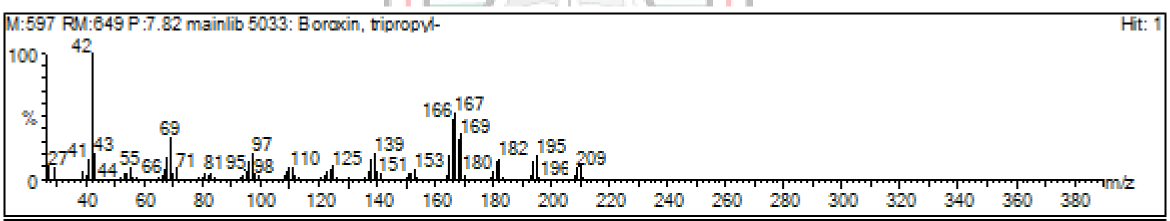


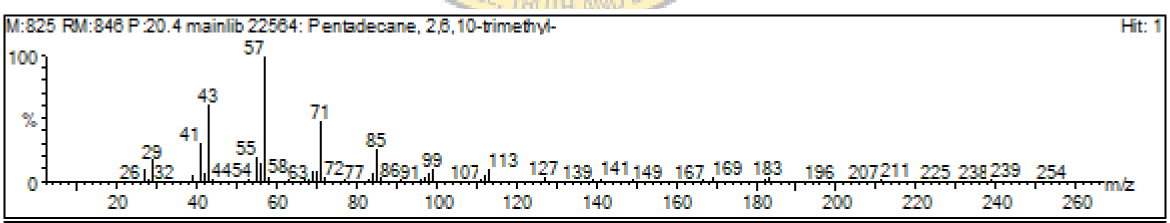
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)

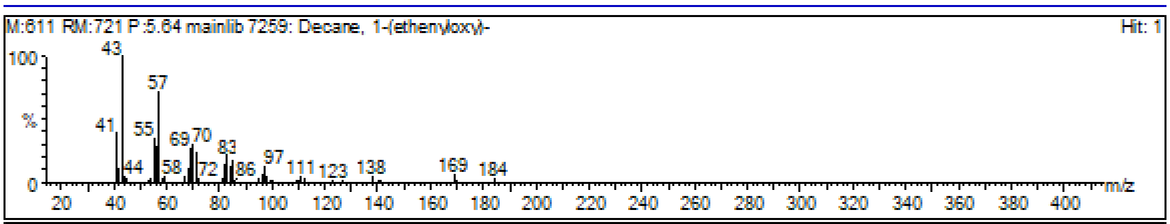




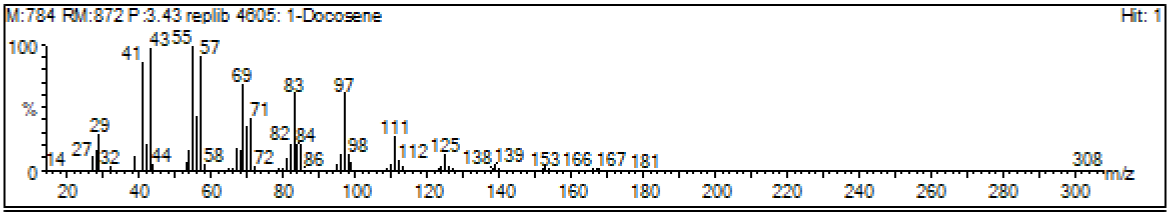


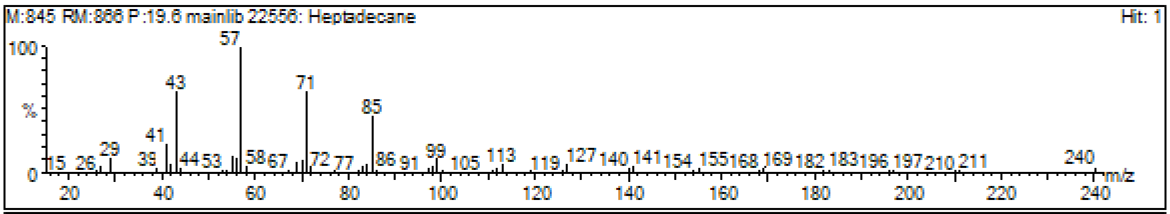


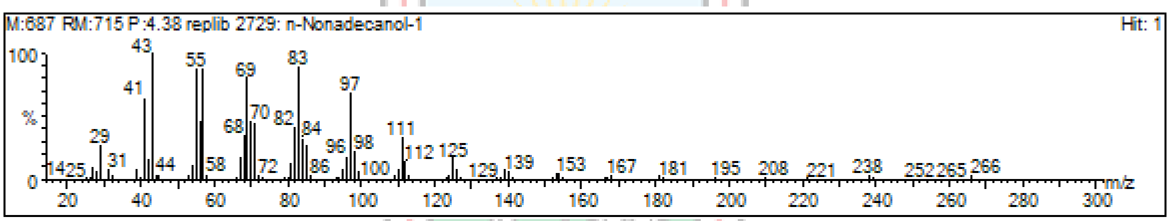


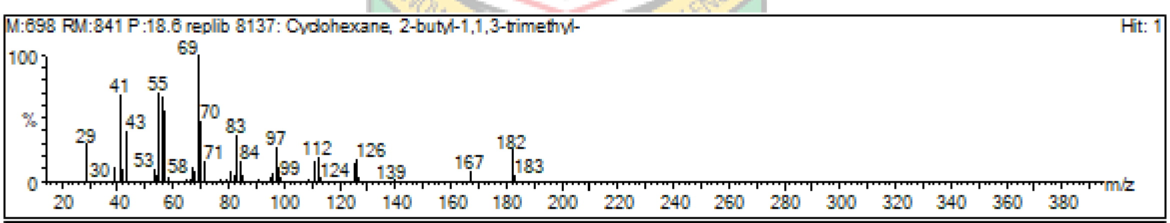


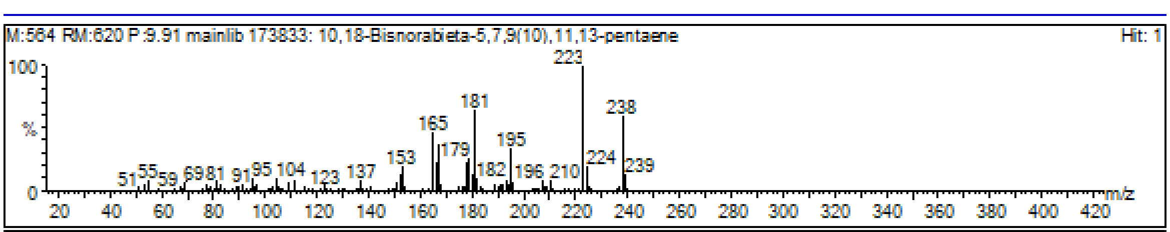
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



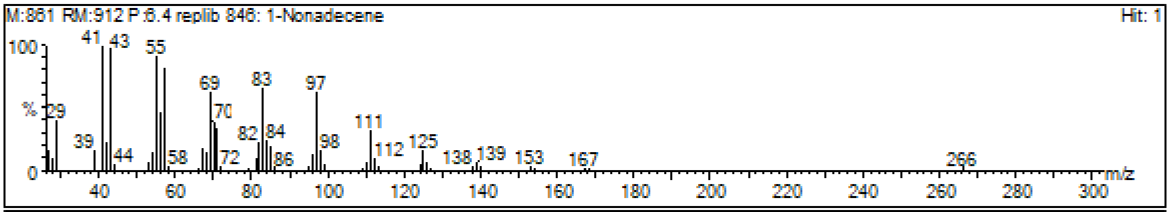


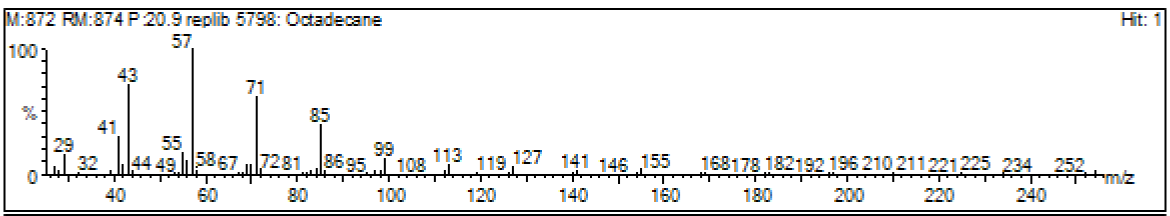


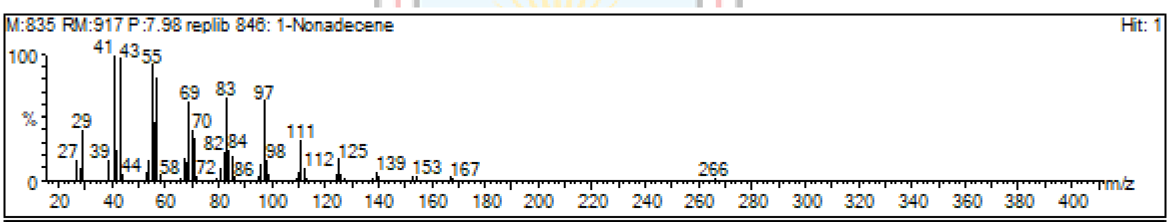


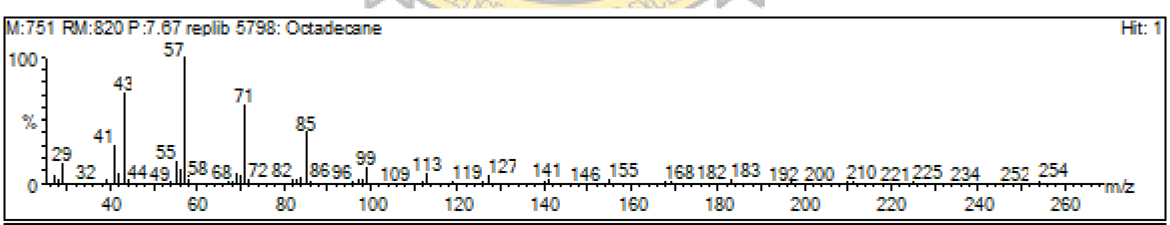


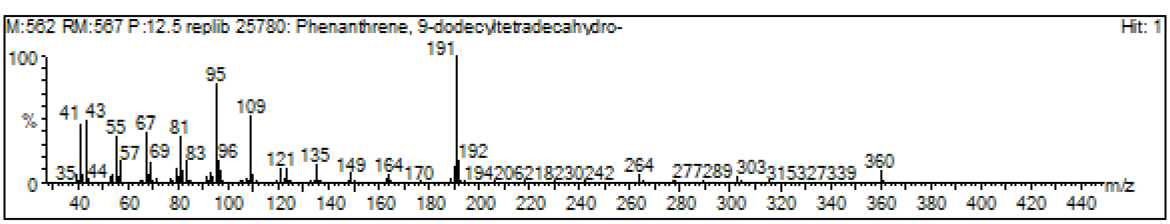
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



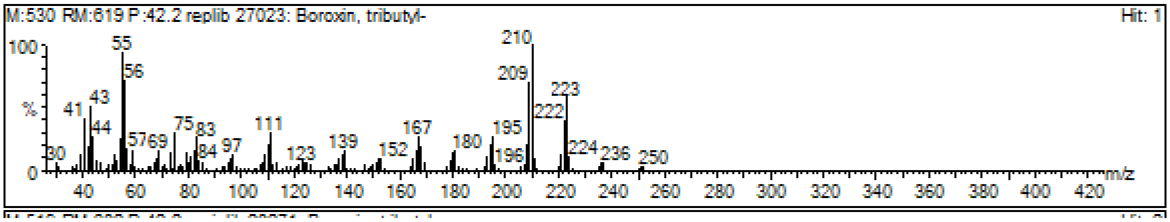


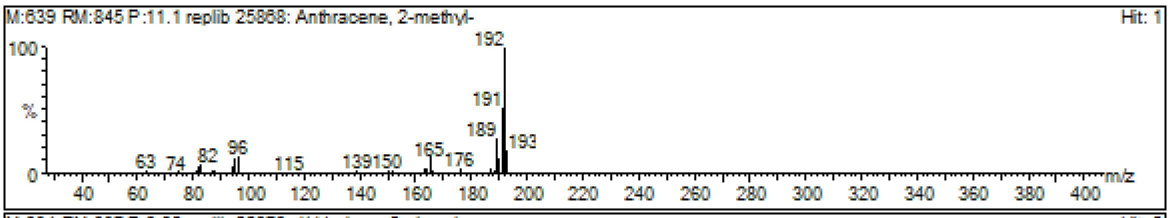


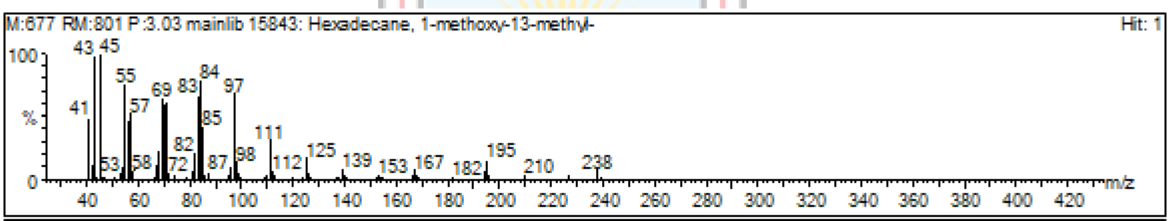


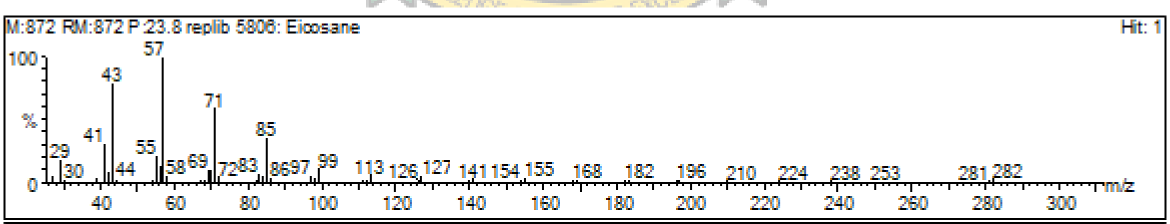


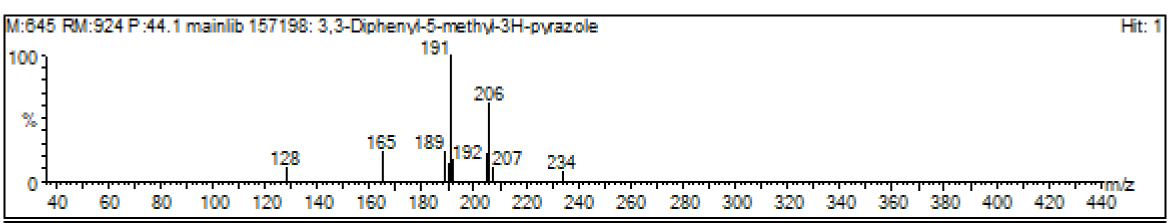
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



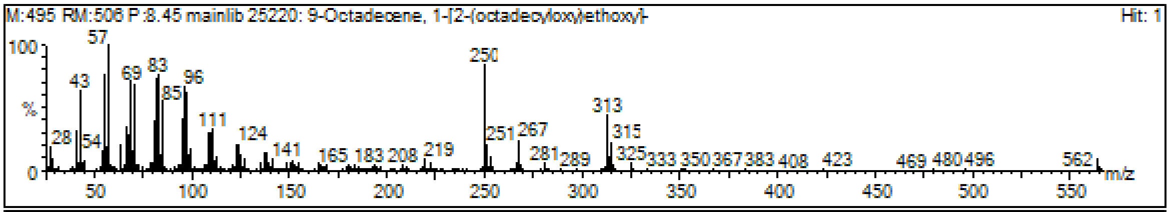


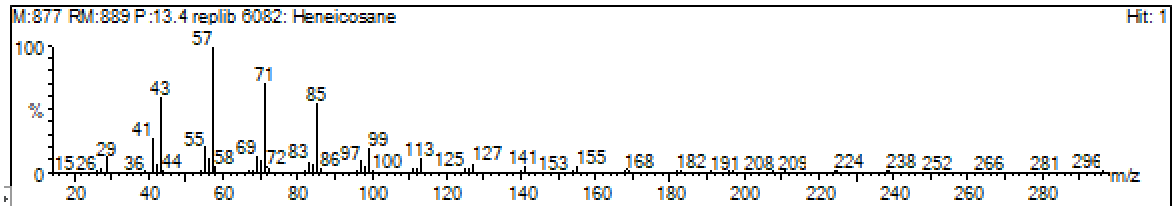


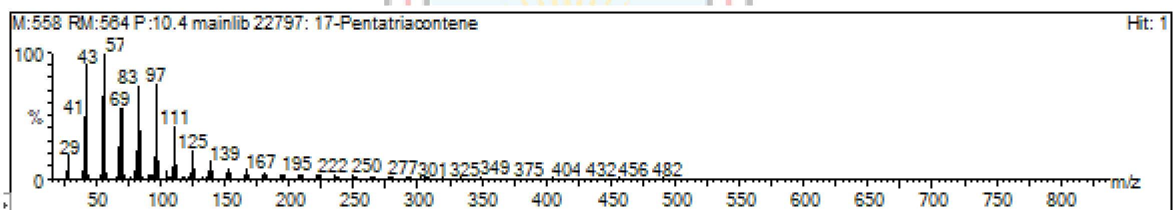


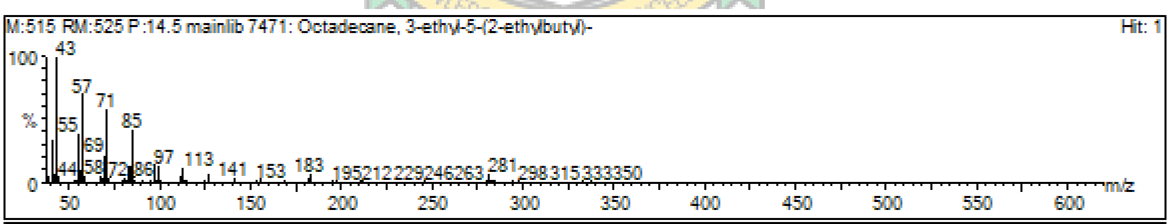


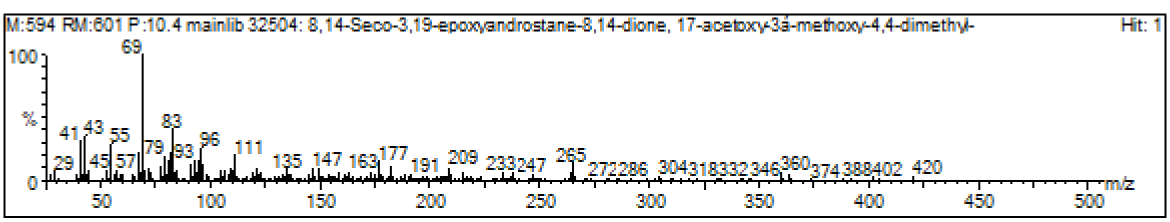
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



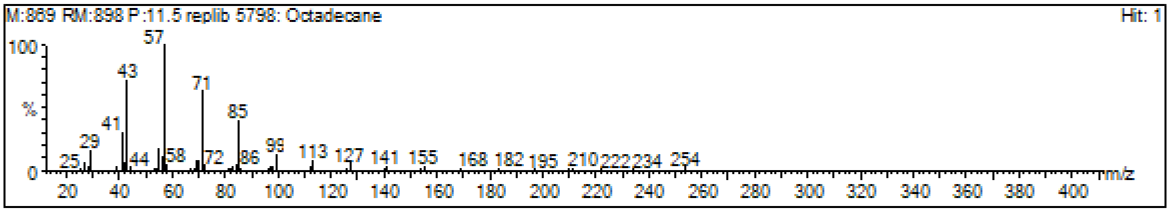


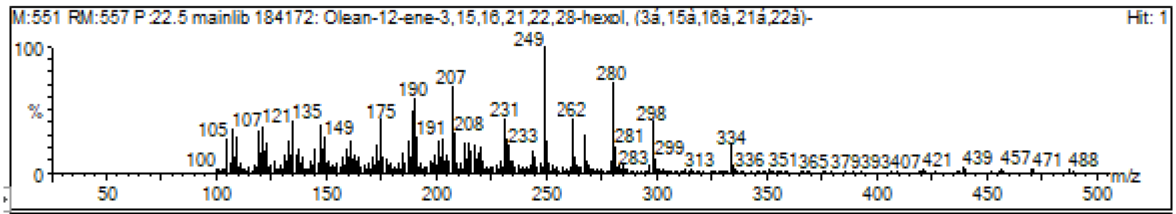


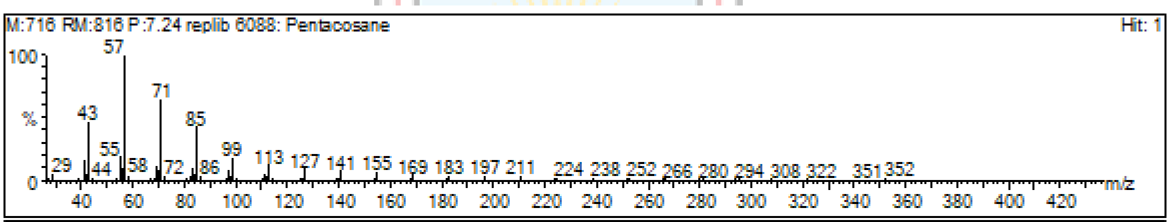


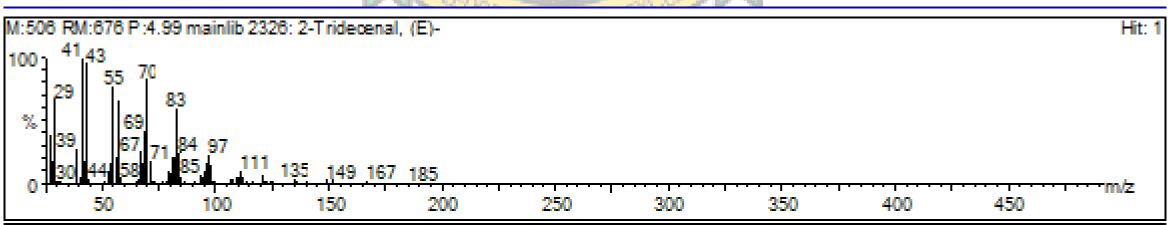


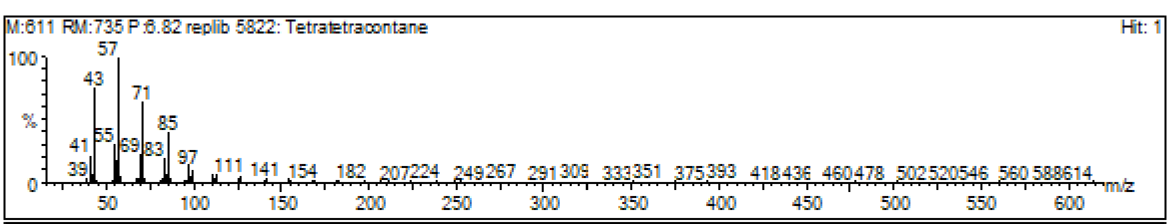
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



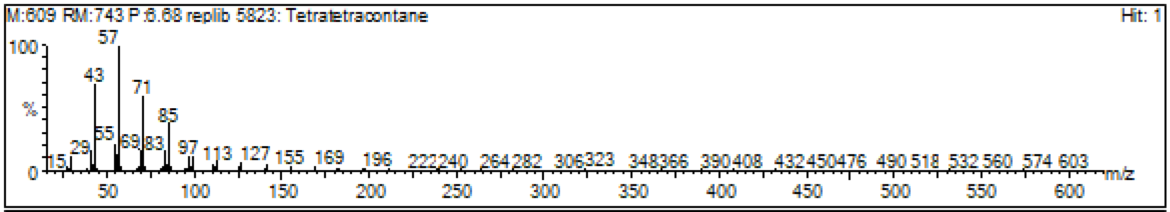


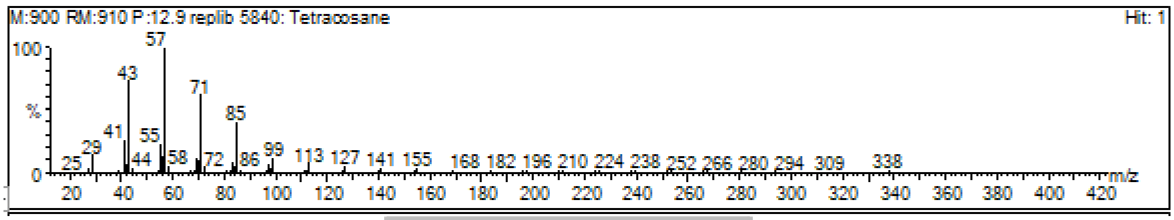


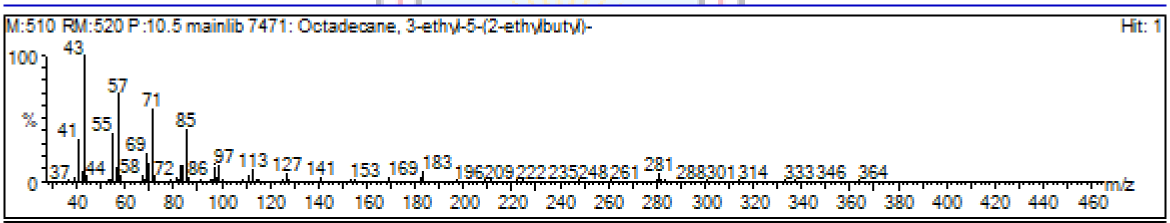


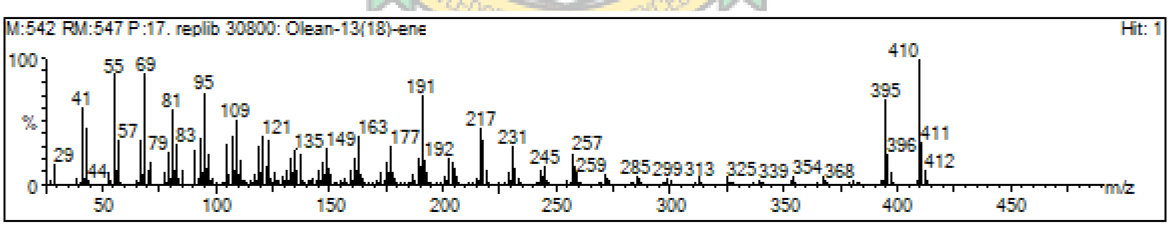


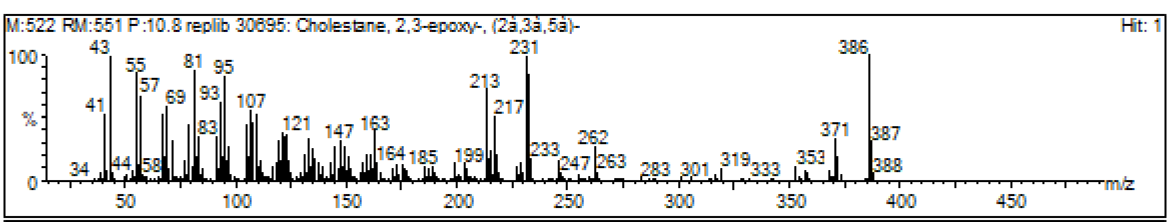
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



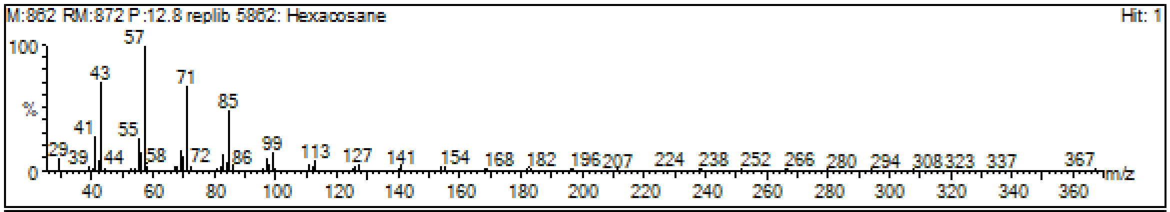


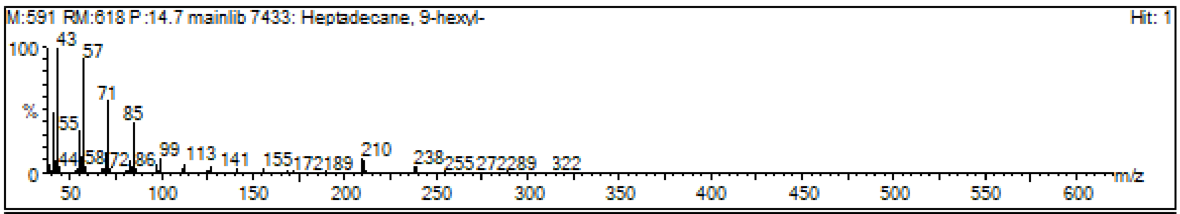


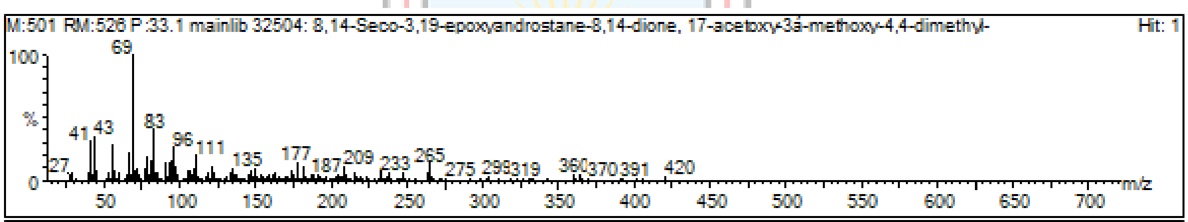


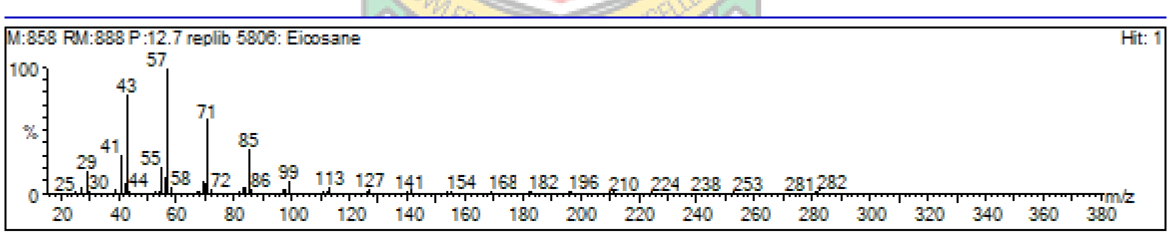


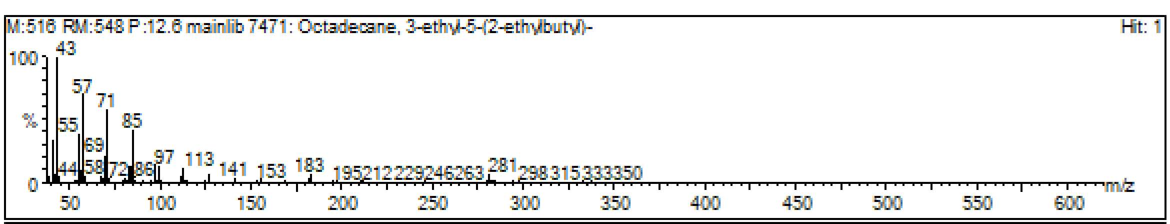
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



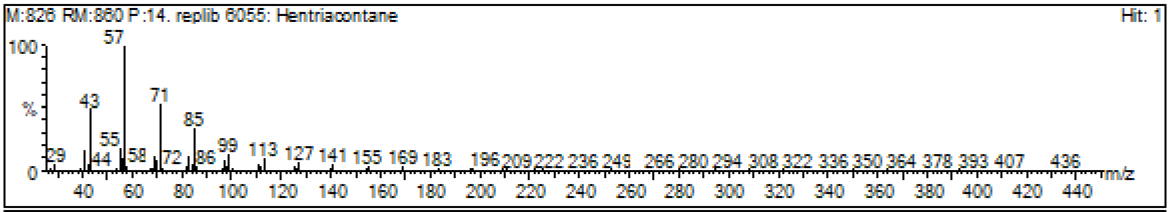


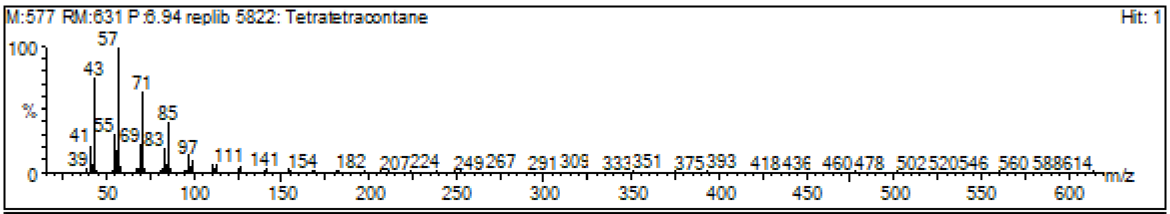


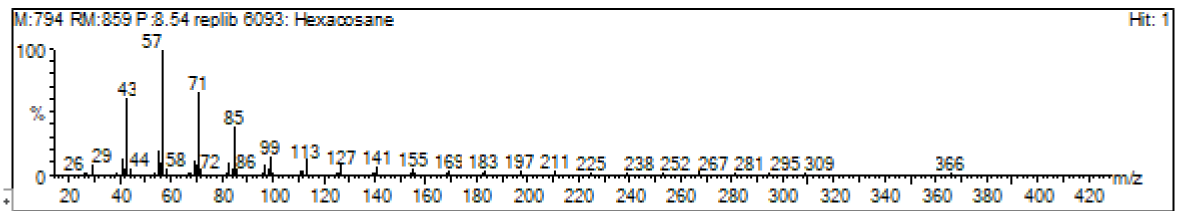


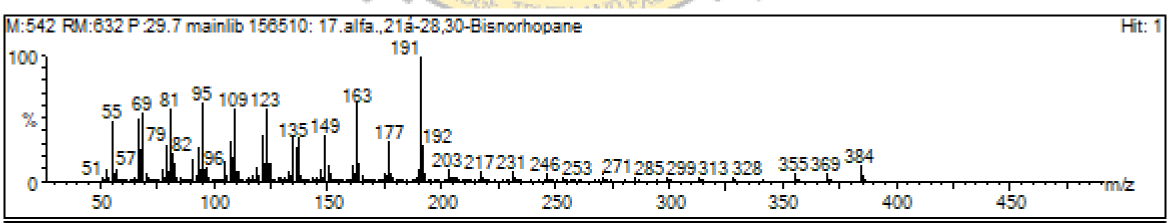


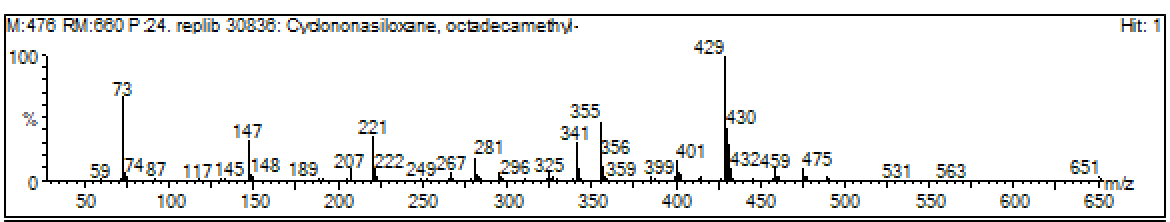
APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)



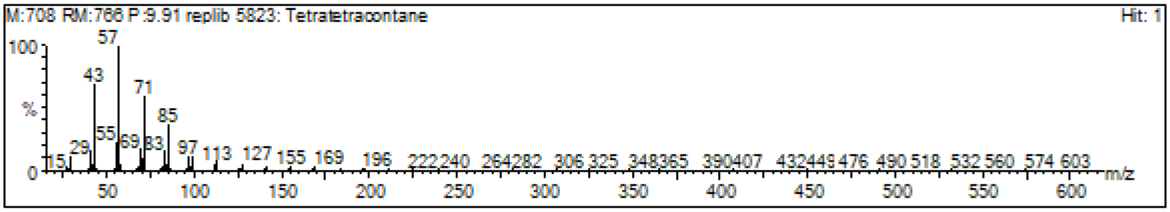


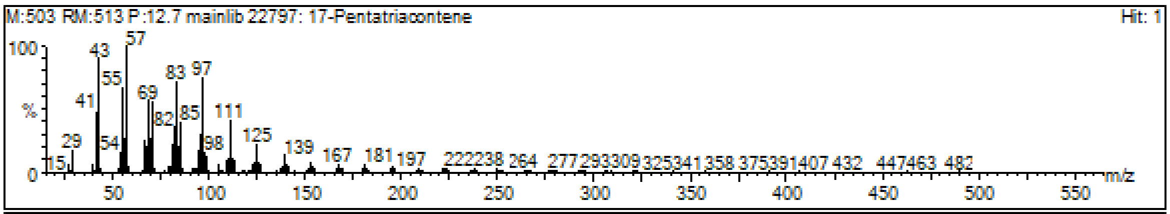


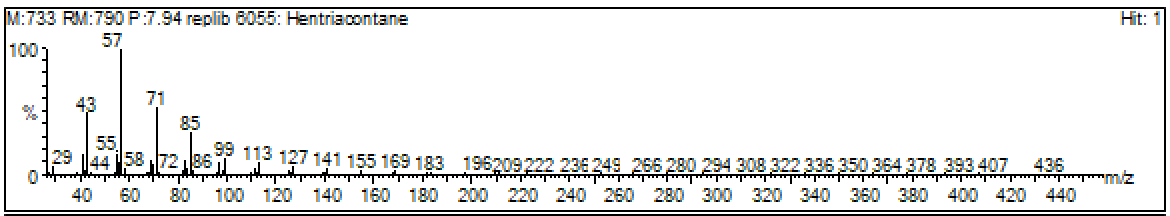


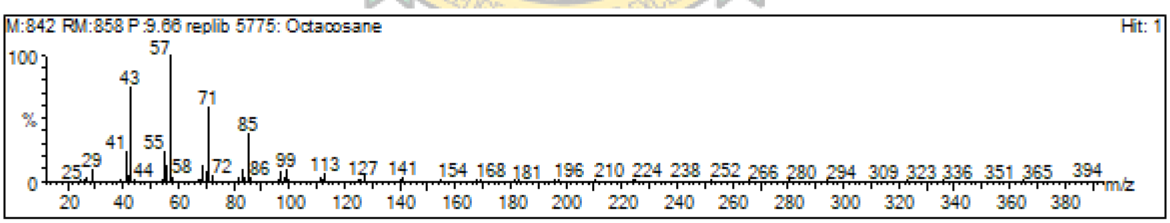


APPENDIX I4 Fuel Oil Chromatogram/Spectrum (Continued)









APPENDIX J1 WAVENUMBERS VRSTRANSMITTANCES OF BITUMEN

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3996.05656	0.99677	3918.54245	0.99731	3841.02833	0.99716
3994.01672	0.99708	3916.5026	0.99752	3838.98849	0.99702
3991.97687	0.99731	3914.46276	0.9982	3836.94864	0.99745
3989.93703	0.99687	3912.42291	0.99822	3834.9088	0.99771
3987.89718	0.99649	3910.38307	0.99796	3832.86895	0.99784
3985.85734	0.99672	3908.34322	0.99782	3830.82911	0.99758
3983.81749	0.9971	3906.30338	0.99738	3828.78926	0.99709
3981.77765	0.99725	3904.26353	0.99675	3826.74942	0.99722
3979.7378	0.99758	3902.22369	0.99687	3824.70957	0.99736
3977.69796	0.99797	3900.18384	0.99817	3822.66973	0.99646
3975.65811	0.99777	3898.144	0.99926	3820.62988	0.9952
3973.61827	0.9974	3896.10415	0.99873	3818.59004	0.99535
3971.57842	0.9976	3894.06431	0.99737	3816.55019	0.99638
3969.53858	0.99825	3892.02446	0.99647	3814.51035	0.99708
3967.49873	0.99867	3889.98462	0.99638	3812.4705	0.99712
3965.45888	0.99817	3887.94477	0.99652	3810.43066	0.99725
3963.41904	0.99739	3885.90493	0.99707	3808.39081	0.99758
3961.37919	0.99726	3883.86508	0.9979	3806.35097	0.99769
3959.33935	0.9974	3881.82524	0.99785	3804.31112	0.9981
3957.2995	0.99737	3879.78539	0.99752	3802.27128	0.99869
3955.25966	0.99697	3877.74555	0.99773	3800.23143	0.9985
3953.21981	0.99629	3875.7057	0.9976	3798.19159	0.99838
3951.17997	0.996	3873.66586	0.99683	3796.15174	0.99871
3949.14012	0.99646	3871.62601	0.99592	3794.1119	0.99871
3947.10028	0.99713	3869.58616	0.99543	3792.07205	0.99851
3945.06043	0.99753	3867.54632	0.99605	3790.03221	0.99815
3943.02059	0.99752	3865.50647	0.99715	3787.99236	0.99786

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3940.98074	0.99717	3863.46663	0.99786	3785.95252	0.99799
3938.9409	0.99695	3861.42678	0.99758	3783.91267	0.99815
3936.90105	0.997	3859.38694	0.99665	3781.87283	0.99812
3934.86121	0.9974	3857.34709	0.99558	3779.83298	0.99811
3932.82136	0.99802	3855.30725	0.9945	3777.79314	0.9983
3930.78152	0.99774	3853.2674	0.99524	3775.75329	0.99837
3928.74167	0.99695	3851.22756	0.99732	3773.71344	0.99834
3926.70183	0.99704	3849.18771	0.99737	3771.6736	0.99839
3924.66198	0.99773	3847.14787	0.99706	3769.63375	0.99833
3922.62214	0.99816	3845.10802	0.99729	3767.59391	0.99852
3920.58229	0.99789	3843.06818	0.99749	3765.55406	0.99906
3763.51422	0.99891	3686.00011	0.99783	3608.48599	0.99845
3761.47437	0.99791	3683.96026	0.99786	3606.44615	0.99806
3759.43453	0.99697	3681.92042	0.99778	3604.4063	0.9979
3757.39468	0.99697	3679.88057	0.99761	3602.36646	0.99811
3755.35484	0.99815	3677.84072	0.99711	3600.32661	0.99851
3753.31499	0.99977	3675.80088	0.99706	3598.28677	0.99882
3751.27515	1.00083	3673.76103	0.99819	3596.24692	0.99906
3749.2353	1.00084	3671.72119	0.99907	3594.20708	0.9995
3747.19546	1.00008	3669.68134	0.99905	3592.16723	0.99933
3745.15561	0.99886	3667.6415	0.99841	3590.12739	0.9983
3743.11577	0.99777	3665.60165	0.99828	3588.08754	0.99758
3741.07592	0.99778	3663.56181	0.99864	3586.0477	0.99804
3739.03608	0.99846	3661.52196	0.99875	3584.00785	0.99871
3736.99623	0.99903	3659.48212	0.99812	3581.96801	0.99862
3734.95639	0.99864	3657.44227	0.99748	3579.92816	0.99816
3732.91654	0.99791	3655.40243	0.99769	3577.88831	0.99806

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3726.79701	0.99684	3649.28289	0.99823	3571.76878	0.99809
3724.75716	0.99738	3647.24305	0.99906	3569.72893	0.99866
3722.71732	0.9981	3645.2032	0.99908	3567.68909	0.99893
3720.67747	0.99839	3643.16336	0.99896	3565.64924	0.99909
3718.63763	0.99862	3641.12351	0.99897	3563.6094	0.99943
3716.59778	0.99856	3639.08367	0.99882	3561.56955	0.9995
3714.55794	0.99795	3637.04382	0.99867	3559.52971	0.99912
3712.51809	0.99757	3635.00398	0.99875	3557.48986	0.99855
3710.47825	0.99839	3632.96413	0.99886	3555.45002	0.99829
3708.4384	0.99938	3630.92429	0.99891	3553.41017	0.99817
3706.39856	1.00011	3628.88444	0.9989	3551.37033	0.99804
3704.35871	1.00078	3626.8446	0.99863	3549.33048	0.99836
3702.31887	1.00081	3624.80475	0.99807	3547.29064	0.99896
3700.27902	0.99985	3622.76491	0.99791	3545.25079	0.9992
3698.23918	0.99854	3620.72506	0.99837	3543.21095	0.99886
3696.19933	0.99775	3618.68522	0.99839	3541.1711	0.99852
3694.15949	0.99762	3616.64537	0.99758	3539.13126	0.99872
3692.11964	0.99724	3614.60553	0.997	3537.09141	0.99901
3690.0798	0.99663	3612.56568	0.99728	3535.05157	0.99893
3688.03995	0.99718	3610.52584	0.99815	3533.01172	0.99875
3475.89606	0.99863	3398.38195	0.99805	3320.86783	0.998
3473.85621	0.99823	3396.3421	0.99843	3318.82799	0.99814
3471.81637	0.99788	3394.30226	0.99851	3316.78814	0.99777
3469.77652	0.99783	3392.26241	0.99803	3314.7483	0.99722
3467.73668	0.99778	3390.22257	0.99768	3312.70845	0.99714
3465.69683	0.99784	3388.18272	0.99787	3310.66861	0.99738
3463.65699	0.99786	3386.14287	0.99786	3308.62876	0.99726

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3530.97188	0.99852	3453.45776	0.9974	3375.94365	0.99741
3528.93203	0.99801	3451.41792	0.99775	3373.9038	0.99759
3526.89219	0.99751	3449.37807	0.99797	3371.86396	0.99778
3524.85234	0.9977	3447.33823	0.99817	3369.82411	0.99733
3522.8125	0.99868	3445.29838	0.99851	3367.78427	0.99636
3520.77265	0.99929	3443.25854	0.99864	3365.74442	0.99592
3518.73281	0.99907	3441.21869	0.99849	3363.70458	0.99645
3516.69296	0.99865	3439.17885	0.99804	3361.66473	0.99703
3514.65312	0.99838	3437.139	0.99755	3359.62489	0.99721
3512.61327	0.99815	3435.09916	0.99772	3357.58504	0.99732
3510.57343	0.99807	3433.05931	0.99799	3355.5452	0.99736
3508.53358	0.9986	3431.01947	0.99778	3353.50535	0.99731
3506.49374	0.99906	3428.97962	0.99768	3351.46551	0.99737
3504.45389	0.99847	3426.93978	0.99774	3349.42566	0.99745
3502.41405	0.99741	3424.89993	0.99749	3347.38582	0.9972
3500.3742	0.99703	3422.86009	0.99704	3345.34597	0.99685
3498.33436	0.99744	3420.82024	0.99709	3343.30613	0.99691
3496.29451	0.99806	3418.7804	0.99763	3341.26628	0.99734
3494.25467	0.99818	3416.74055	0.99797	3339.22644	0.99761
3492.21482	0.99797	3414.70071	0.998	3337.18659	0.99749
3490.17498	0.9981	3412.66086	0.99792	3335.14675	0.99723
3488.13513	0.99822	3410.62102	0.99781	3333.1069	0.99715
3486.09529	0.99786	3408.58117	0.99765	3331.06706	0.99737
3484.05544	0.9975	3406.54133	0.9974	3329.02721	0.99764
3482.01559	0.99746	3404.50148	0.9972	3326.98737	0.99739
3479.97575	0.99763	3402.46164	0.99726	3324.94752	0.99697
3477.9359	0.99823	3400.42179	0.99763	3322.90768	0.99733

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3298.42954	0.99719	3220.91542	0.99694	3143.40131	0.99567
3296.38969	0.9972	3218.87558	0.99711	3141.36146	0.99578
3294.34985	0.99752	3216.83573	0.99706	3139.32162	0.99587
3292.31	0.99795	3214.79589	0.99703	3137.28177	0.99572
3290.27015	0.998	3212.75604	0.99704	3135.24193	0.99548
3288.23031	0.99741	3210.7162	0.99707	3133.20208	0.99531
3286.19046	0.99669	3208.67635	0.99718	3131.16224	0.9953
3284.15062	0.9966	3206.63651	0.99695	3129.12239	0.99546
3282.11077	0.99679	3204.59666	0.99645	3127.08255	0.99571
3280.07093	0.99671	3202.55682	0.99603	3125.0427	0.99589
3278.03108	0.99675	3200.51697	0.99574	3123.00286	0.99572
3275.99124	0.99709	3198.47713	0.99579	3120.96301	0.99532
3273.95139	0.99737	3196.43728	0.99613	3118.92317	0.99512
3271.91155	0.9973	3194.39744	0.99631	3116.88332	0.9953
3269.8717	0.99705	3192.35759	0.99607	3114.84348	0.99537
3267.83186	0.9971	3190.31774	0.99577	3112.80363	0.99493
3265.79201	0.99722	3188.2779	0.99585	3110.76379	0.99477
3263.75217	0.997	3186.23805	0.99592	3108.72394	0.99513
3261.71232	0.99689	3184.19821	0.99573	3106.6841	0.9951
3259.67248	0.99701	3182.15836	0.99544	3104.64425	0.99445
3257.63263	0.99712	3180.11852	0.99516	3102.60441	0.9941
3255.59279	0.99724	3178.07867	0.9952	3100.56456	0.99408
3253.55294	0.99737	3176.03883	0.9955	3098.52472	0.99371
3251.5131	0.99756	3173.99898	0.99561	3096.48487	0.99334
3249.47325	0.99752	3171.95914	0.99552	3094.44502	0.99314
3247.43341	0.99713	3169.91929	0.99547	3092.40518	0.99271
3245.39356	0.99669	3167.87945	0.99554	3090.36533	0.99225

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3239.27403	0.99663	3161.75991	0.99519	3084.2458	0.99159
3237.23418	0.99688	3159.72007	0.99491	3082.20595	0.99152
3235.19434	0.997	3157.68022	0.99482	3080.16611	0.99102
3233.15449	0.99723	3155.64038	0.99494	3078.12626	0.99052
3231.11465	0.99724	3153.60053	0.99512	3076.08642	0.99016
3229.0748	0.99697	3151.56069	0.99532	3074.04657	0.98974
3227.03496	0.99711	3149.52084	0.9955	3072.00673	0.98939
3224.99511	0.99739	3147.481	0.99556	3069.96688	0.98891
3222.95527	0.99709	3145.44115	0.99562	3067.92704	0.98836
3065.88719	0.98829	2988.37308	0.96429	2910.85897	0.64704
3063.84735	0.98841	2986.33323	0.96059	2908.81912	0.6653
3061.8075	0.98823	2984.29339	0.95539	2906.77928	0.68162
3059.76766	0.98788	2982.25354	0.94919	2904.73943	0.69625
3057.72781	0.98732	2980.2137	0.94206	2902.69958	0.7098
3055.68797	0.98673	2978.17385	0.93326	2900.65974	0.72272
3053.64812	0.98651	2976.13401	0.92218	2898.61989	0.73518
3051.60828	0.9865	2974.09416	0.90835	2896.58005	0.74757
3049.56843	0.98631	2972.05432	0.8915	2894.5402	0.76038
3047.52859	0.98608	2970.01447	0.87191	2892.50036	0.77364
3045.48874	0.98586	2967.97463	0.8499	2890.46051	0.78683
3043.4489	0.98531	2965.93478	0.82609	2888.42067	0.79915
3041.40905	0.98462	2963.89494	0.80196	2886.38082	0.80972
3039.36921	0.9843	2961.85509	0.77923	2884.34098	0.81767
3037.32936	0.98423	2959.81525	0.759	2882.30113	0.82212
3035.28952	0.9842	2957.7754	0.74226	2880.26129	0.82183
3033.24967	0.98409	2955.73556	0.73043	2878.22144	0.81591
3031.20983	0.98355	2953.69571	0.72507	2876.1816	0.80466

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
3025.09029	0.98154	2947.57618	0.7431	2870.06206	0.7727
3023.05045	0.98076	2945.53633	0.75123	2868.02222	0.77024
3021.0106	0.97993	2943.49649	0.7549	2865.98237	0.76818
3018.97076	0.97942	2941.45664	0.75157	2863.94253	0.76326
3016.93091	0.97945	2939.4168	0.74072	2861.90268	0.75403
3014.89107	0.97954	2937.37695	0.72352	2859.86284	0.74048
3012.85122	0.97925	2935.33711	0.70157	2857.82299	0.7242
3010.81138	0.97888	2933.29726	0.67662	2855.78315	0.70866
3008.77153	0.97865	2931.25742	0.65012	2853.7433	0.69954
3006.73169	0.97809	2929.21757	0.62307	2851.70346	0.70264
3004.69184	0.97708	2927.17773	0.59713	2849.66361	0.71892
3002.652	0.97608	2925.13788	0.57561	2847.62377	0.74384
3000.61215	0.97496	2923.09804	0.56241	2845.58392	0.77195
2998.5723	0.97355	2921.05819	0.55999	2843.54408	0.80041
2996.53246	0.97221	2919.01835	0.56813	2841.50423	0.8284
2994.49261	0.97078	2916.9785	0.58425	2839.46439	0.85491
2992.45277	0.96893	2914.93866	0.60489	2837.42454	0.87811
2990.41292	0.96682	2912.89881	0.62666	2835.3847	0.89714
2833.34485	0.91273	2755.83074	0.98991	2678.31662	0.9898
2831.30501	0.92553	2753.79089	0.9899	2676.27678	0.98972
2829.26516	0.93555	2751.75105	0.98972	2674.23693	0.9893
2827.22532	0.9432	2749.7112	0.98968	2672.19709	0.98888
2825.18547	0.94922	2747.67136	0.98978	2670.15724	0.98884
2823.14563	0.9541	2745.63151	0.9898	2668.1174	0.98912
2821.10578	0.95814	2743.59167	0.98967	2666.07755	0.98936
2819.06594	0.96151	2741.55182	0.98939	2664.03771	0.98929
2817.02609	0.96442	2739.51198	0.98898	2661.99786	0.98915

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2810.90656	0.97114	2733.39244	0.98736	2655.87833	0.99001
2808.86671	0.97303	2731.3526	0.98704	2653.83848	0.99089
2806.82686	0.9745	2729.31275	0.98685	2651.79864	0.9914
2804.78702	0.97579	2727.27291	0.98661	2649.75879	0.99155
2802.74717	0.97716	2725.23306	0.98657	2647.71895	0.9916
2800.70733	0.97824	2723.19322	0.98699	2645.6791	0.99154
2798.66748	0.97878	2721.15337	0.98781	2643.63926	0.9915
2796.62764	0.97937	2719.11353	0.98859	2641.59941	0.99153
2794.58779	0.98032	2717.07368	0.9889	2639.55957	0.99147
2792.54795	0.98123	2715.03384	0.98891	2637.51972	0.99122
2790.5081	0.98203	2712.99399	0.98902	2635.47988	0.99091
2788.46826	0.98293	2710.95415	0.98925	2633.44003	0.99102
2786.42841	0.98358	2708.9143	0.98962	2631.40019	0.9917
2784.38857	0.98409	2706.87445	0.99014	2629.36034	0.99215
2782.34872	0.98499	2704.83461	0.99049	2627.3205	0.99183
2780.30888	0.98606	2702.79476	0.99047	2625.28065	0.99168
2778.26903	0.98698	2700.75492	0.99022	2623.24081	0.99195
2776.22919	0.9876	2698.71507	0.98998	2621.20096	0.99194
2774.18934	0.98789	2696.67523	0.98993	2619.16112	0.9919
2772.1495	0.98819	2694.63538	0.99009	2617.12127	0.99215
2770.10965	0.98881	2692.59554	0.99021	2615.08143	0.99229
2768.06981	0.98943	2690.55569	0.99015	2613.04158	0.9924
2766.02996	0.98955	2688.51585	0.99011	2611.00173	0.99279
2763.99012	0.98927	2686.476	0.99025	2608.96189	0.99304
2761.95027	0.9891	2684.43616	0.99033	2606.92204	0.99305
2759.91043	0.98924	2682.39631	0.99011	2604.8822	0.99329
2757.87058	0.98962	2680.35647	0.98984	2602.84235	0.99344

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance (%)	Wavenumber (cm^{-1})	Transmittance (%)	Wavenumber (cm^{-1})	Transmittance (%)
2600.80251	0.99302	2523.2884	0.99525	2445.77428	0.9967
2598.76266	0.99282	2521.24855	0.99555	2443.73444	0.99678
2596.72282	0.9933	2519.20871	0.9962	2441.69459	0.99678
2594.68297	0.99375	2517.16886	0.99639	2439.65475	0.99691
2592.64313	0.99396	2515.12901	0.99634	2437.6149	0.99673
2590.60328	0.99418	2513.08917	0.99629	2435.57506	0.99641
2588.56344	0.99428	2511.04932	0.99589	2433.53521	0.99674
2586.52359	0.99418	2509.00948	0.99576	2431.49537	0.99737
2584.48375	0.99418	2506.96963	0.99634	2429.45552	0.99738
2582.4439	0.99417	2504.92979	0.99671	2427.41568	0.99703
2580.40406	0.99415	2502.88994	0.9965	2425.37583	0.99686
2578.36421	0.99468	2500.8501	0.99647	2423.33599	0.99656
2576.32437	0.99541	2498.81025	0.99641	2421.29614	0.99613
2574.28452	0.99559	2496.77041	0.996	2419.25629	0.99613
2572.24468	0.99529	2494.73056	0.99613	2417.21645	0.99645
2570.20483	0.99495	2492.69072	0.99677	2415.1766	0.99663
2568.16499	0.9948	2490.65087	0.99697	2413.13676	0.99644
2566.12514	0.99483	2488.61103	0.99731	2411.09691	0.99606
2564.0853	0.99515	2486.57118	0.99802	2409.05707	0.99616
2562.04545	0.99561	2484.53134	0.99815	2407.01722	0.99675
2560.00561	0.99563	2482.49149	0.99769	2404.97738	0.9969
2557.96576	0.99546	2480.45165	0.99733	2402.93753	0.99644
2555.92592	0.99556	2478.4118	0.99735	2400.89769	0.99607
2553.88607	0.99581	2476.37196	0.99749	2398.85784	0.99598
2551.84623	0.99605	2474.33211	0.99726	2396.818	0.99601
2549.80638	0.99593	2472.29227	0.99667	2394.77815	0.99604
2547.76654	0.99573	2470.25242	0.99618	2392.73831	0.99604

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
2537.56731	0.99551	2460.0532	0.99766	2382.53908	0.99589
2535.52747	0.99457	2458.01335	0.9974	2380.49924	0.99554
2533.48762	0.99449	2455.97351	0.99722	2378.45939	0.99545
2531.44778	0.99545	2453.93366	0.99669	2376.41955	0.99618
2529.40793	0.99668	2451.89382	0.99625	2374.3797	0.99699
2527.36809	0.99671	2449.85397	0.99621	2372.33986	0.9964
2525.32824	0.99581	2447.81413	0.99639	2370.30001	0.99504
2368.26017	0.99632	2290.74605	0.9967	2213.23194	0.99873
2366.22032	0.9993	2288.70621	0.99724	2211.19209	0.99702
2364.18048	0.99883	2286.66636	0.99797	2209.15225	0.9973
2362.14063	0.99487	2284.62652	0.99836	2207.1124	0.99851
2360.10079	0.99316	2282.58667	0.99803	2205.07256	0.99878
2358.06094	0.99598	2280.54683	0.99727	2203.03271	0.99824
2356.0211	0.99767	2278.50698	0.99659	2200.99287	0.99781
2353.98125	0.9964	2276.46714	0.99675	2198.95302	0.99737
2351.94141	0.99599	2274.42729	0.99804	2196.91318	0.99714
2349.90156	0.99621	2272.38745	0.99874	2194.87333	0.99856
2347.86172	0.99599	2270.3476	0.99699	2192.83349	1.00145
2345.82187	0.99572	2268.30776	0.99532	2190.79364	1.00303
2343.78203	0.99513	2266.26791	0.99642	2188.7538	1.00224
2341.74218	0.99426	2264.22807	0.99735	2186.71395	1.00057
2339.70234	0.99496	2262.18822	0.99658	2184.67411	0.99886
2337.66249	0.99675	2260.14838	0.99696	2182.63426	0.99734
2335.62265	0.99686	2258.10853	0.99833	2180.59442	0.99579
2333.5828	0.99597	2256.06869	0.99822	2178.55457	0.99458
2331.54296	0.99672	2254.02884	0.9974	2176.51473	0.99508
2329.50311	0.99799	2251.989	0.9977	2174.47488	0.99642

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

2323.38358	0.99633	2245.86946	0.99775	2168.35535	0.99962
2321.34373	0.99672	2243.82962	0.99709	2166.3155	1.0013
2319.30388	0.99629	2241.78977	0.9963	2164.27566	1.00152
2317.26404	0.99591	2239.74993	0.997	2162.23581	1.0025
2315.22419	0.99582	2237.71008	0.99865	2160.19597	1.00247
2313.18435	0.99595	2235.67024	0.9998	2158.15612	0.99991
2311.1445	0.99651	2233.63039	0.99887	2156.11628	0.99878
2309.10466	0.99671	2231.59055	0.99677	2154.07643	0.99993
2307.06481	0.99635	2229.5507	0.99658	2152.03659	1.00091
2305.02497	0.99611	2227.51086	0.99768	2149.99674	1.00114
2302.98512	0.99604	2225.47101	0.9974	2147.9569	1.00026
2300.94528	0.99618	2223.43116	0.996	2145.91705	0.9992
2298.90543	0.99641	2221.39132	0.99566	2143.87721	0.99966
2296.86559	0.99648	2219.35147	0.99752	2141.83736	0.99978
2294.82574	0.99645	2217.31163	1	2139.79752	0.99772
2292.7859	0.99646	2215.27178	1.00051	2137.75767	0.99611
2135.71783	0.99675	2058.20371	0.9971	1980.6896	1.00162
2133.67798	0.99695	2056.16387	0.99849	1978.64975	1.00083
2131.63814	0.99637	2054.12402	0.99996	1976.60991	1.0006
2129.59829	0.99725	2052.08418	0.9995	1974.57006	1.00013
2127.55844	0.99895	2050.04433	0.9979	1972.53022	0.9988
2125.5186	0.99968	2048.00449	0.99681	1970.49037	0.9979
2123.47875	0.99873	2045.96464	0.99649	1968.45053	0.99895
2121.43891	0.99756	2043.9248	0.99721	1966.41068	1.0003
2119.39906	0.99793	2041.88495	0.99873	1964.37084	0.99977
2117.35922	0.99847	2039.84511	1.00086	1962.33099	0.99847
2115.31937	0.99803	2037.80526	1.00336	1960.29115	0.99802
2113.27953	0.99756	2035.76542	1.00335	1958.2513	0.99837
2111.23968	0.99788	2033.72557	1.00132	1956.21146	0.99854

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

2107.15999	0.99858	2029.64588	0.99913	1952.13177	0.99738
2105.12015	0.99748	2027.60603	0.99877	1950.09192	0.99742
2103.0803	0.99721	2025.56619	0.99927	1948.05208	0.99696
2101.04046	0.99737	2023.52634	0.99964	1946.01223	0.9964
2099.00061	0.99746	2021.4865	0.99957	1943.97239	0.99636
2096.96077	0.99839	2019.44665	0.99977	1941.93254	0.99697
2094.92092	0.99957	2017.40681	1.0007	1939.8927	0.99832
2092.88108	1.00014	2015.36696	1.00221	1937.85285	0.99914
2090.84123	0.99953	2013.32712	1.00348	1935.813	0.99839
2088.80139	0.9979	2011.28727	1.00217	1933.77316	0.99663
2084.7217	0.99821	2007.20758	0.99619	1929.69347	0.99385
2082.68185	0.99795	2005.16774	0.99742	1927.65362	0.99338
2080.64201	0.99762	2003.12789	0.99828	1925.61378	0.99389
2078.60216	0.99785	2001.08805	0.99913	1923.57393	0.99534
2076.56232	0.99715	1999.0482	1.001	1921.53409	0.99644
2074.52247	0.99585	1997.00836	1.0023	1919.49424	0.99693
2072.48263	0.99552	1994.96851	1.00117	1917.4544	0.99706
2070.44278	0.99624	1992.92867	0.99871	1915.41455	0.99651
2068.40294	0.9969	1990.88882	0.99797	1913.37471	0.99595
2066.36309	0.99753	1988.84898	0.99842	1911.33486	0.99612
2064.32325	0.99828	1986.80913	0.99831	1909.29502	0.99678
2062.2834	0.99822	1984.76929	0.99942	1907.25517	0.99734
2060.24356	0.99735	1982.72944	1.00146	1905.21533	0.99714
1903.17548	0.99593	1823.62152	0.9937	1744.06757	0.99086
1901.13564	0.99447	1821.58168	0.99373	1742.02772	0.99129
1899.09579	0.9938	1819.54183	0.99415	1739.98787	0.99156
1897.05595	0.99412	1817.50199	0.99454	1737.94803	0.99147

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

2062.2834	0.99822	1984.76929	0.99942	1907.25517	0.99734
2060.24356	0.99735	1982.72944	1.00146	1905.21533	0.99714
1903.17548	0.99593	1823.62152	0.9937	1744.06757	0.99086
1901.13564	0.99447	1821.58168	0.99373	1742.02772	0.99129
1899.09579	0.9938	1819.54183	0.99415	1739.98787	0.99156
1897.05595	0.99412	1817.50199	0.99454	1737.94803	0.99147
1895.0161	0.99501	1815.46214	0.99468	1735.90818	0.99121
1892.97626	0.99538	1813.4223	0.99454	1733.86834	0.99116
1890.93641	0.99506	1811.38245	0.9943	1731.82849	0.99143
1888.89657	0.99488	1809.34261	0.99421	1729.78865	0.99172
1886.85672	0.99492	1807.30276	0.99414	1727.7488	0.99161
1884.81688	0.99489	1805.26292	0.99406	1725.70896	0.99101
1882.77703	0.9947	1803.22307	0.99387	1723.66911	0.99046
1880.73719	0.99441	1801.18323	0.99333	1721.62927	0.9902
1878.69734	0.99426	1799.14338	0.99296	1719.58942	0.99006
1876.6575	0.99418	1797.10354	0.99304	1717.54958	0.99016
1874.61765	0.99417	1795.06369	0.99311	1715.50973	0.98985
1872.57781	0.99449	1793.02385	0.99309	1713.46989	0.98904
1870.53796	0.99496	1790.984	0.99311	1711.43004	0.9886
1868.49812	0.99481	1788.94416	0.99324	1709.3902	0.98853
1866.45827	0.99444	1786.90431	0.99344	1707.35035	0.98851
1864.41843	0.99486	1784.86447	0.99346	1705.31051	0.9885
1862.37858	0.99567	1782.82462	0.99321	1703.27066	0.98858
1860.33874	0.99593	1780.78478	0.99298	1701.23082	0.98868
1856.25905	0.99478	1776.70509	0.99239	1697.15113	0.99043
1854.2192	0.99498	1774.66524	0.99233	1695.11128	0.9903
1852.17936	0.99527	1772.6254	0.99257	1693.07144	0.98949
1850.13951	0.99486	1770.58555	0.99285	1691.03159	0.9889
1848.09967	0.99435	1768.54571	0.99271	1688.99175	0.98852

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1844.01998	0.99518	1764.46602	0.99187	1684.91206	0.98865
1841.98013	0.99511	1762.42617	0.99176	1682.87221	0.98869
1839.94029	0.99476	1760.38633	0.99184	1680.83237	0.98833
1837.90044	0.99438	1758.34648	0.99185	1678.79252	0.98807
1835.86059	0.99381	1756.30664	0.99135	1676.75268	0.98788
1833.82075	0.9934	1754.26679	0.99074	1674.71283	0.98768
1664.51361	0.9876	1586.99949	0.98298	1509.48538	0.97456
1662.47376	0.98768	1584.95965	0.98326	1507.44553	0.97434
1660.43392	0.98746	1582.9198	0.98337	1505.40569	0.97298
1658.39407	0.98712	1580.87996	0.98344	1503.36584	0.97181
1656.35423	0.98699	1578.84011	0.98349	1501.326	0.971
1654.31438	0.98685	1576.80027	0.98364	1499.28615	0.96981
1652.27454	0.98608	1574.76042	0.98402	1497.24631	0.96793
1650.23469	0.98545	1572.72058	0.98439	1495.20646	0.96643
1648.19485	0.98477	1570.68073	0.98466	1493.16662	0.96562
1646.155	0.98352	1568.64089	0.98484	1491.12677	0.96464
1644.11515	0.98241	1566.60104	0.98486	1489.08693	0.9634
1642.07531	0.98185	1564.5612	0.98487	1487.04708	0.96195
1640.03546	0.98193	1562.52135	0.9851	1485.00724	0.95997
1637.99562	0.98261	1560.48151	0.98561	1482.96739	0.95688
1635.95577	0.98379	1558.44166	0.98594	1480.92755	0.95205
1633.91593	0.98467	1556.40182	0.98567	1478.8877	0.94585
1631.87608	0.98492	1554.36197	0.9854	1476.84786	0.93791
1629.83624	0.98513	1552.32213	0.98511	1474.80801	0.9257
1627.79639	0.98529	1550.28228	0.98503	1472.76817	0.90167
1625.75655	0.98495	1548.24243	0.98505	1470.72832	0.87007
1623.7167	0.98423	1546.20259	0.98489	1468.68848	0.846

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1605.3581	0.97779	1527.84398	0.98295	1450.32987	0.81994
1603.31825	0.97826	1525.80414	0.98277	1448.29002	0.83156
1601.27841	0.97876	1523.76429	0.98271	1446.25018	0.84487
1599.23856	0.97949	1521.72445	0.98192	1444.21033	0.85824
1597.19872	0.98038	1519.6846	0.98031	1442.17049	0.87197
1595.15887	0.98109	1517.64476	0.97875	1440.13064	0.88471
1593.11903	0.98146	1515.60491	0.97707	1438.0908	0.897
1591.07918	0.98181	1513.56507	0.97567	1436.05095	0.91179
1589.03934	0.98241	1511.52522	0.97485	1434.01111	0.92375
1431.97126	0.93219	1354.45715	0.95503	1276.94304	0.96832
1429.93142	0.94048	1352.4173	0.95582	1274.90319	0.96815
1427.89157	0.94732	1350.37746	0.95666	1272.86335	0.96806
1425.85173	0.95194	1348.33761	0.95759	1270.8235	0.96826
1423.81188	0.95582	1346.29777	0.95834	1268.78366	0.96849
1421.77204	0.95892	1344.25792	0.95888	1266.74381	0.96832
1419.73219	0.96111	1342.21808	0.95926	1264.70397	0.96819
1417.69235	0.96282	1340.17823	0.95969	1262.66412	0.96852
1415.6525	0.964	1338.13839	0.96056	1260.62428	0.96892
1413.61266	0.96487	1336.09854	0.96165	1258.58443	0.9694
1411.57281	0.96558	1334.0587	0.96283	1256.54458	0.96993
1409.53297	0.96641	1332.01885	0.96417	1254.50474	0.9701
1403.41343	0.9679	1325.89932	0.96596	1248.3852	0.97072
1401.37359	0.96808	1323.85947	0.9659	1246.34536	0.97101
1399.33374	0.96796	1321.81963	0.96601	1244.30551	0.9711
1397.2939	0.96703	1319.77978	0.9661	1242.26567	0.97104

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1391.17436	0.95973	1313.66025	0.96512	1236.14613	0.97135
1389.13452	0.95357	1311.6204	0.96452	1234.10629	0.97133
1387.09467	0.94193	1309.58056	0.96404	1232.06644	0.97159
1385.05483	0.92787	1307.54071	0.96388	1230.0266	0.97216
1383.01498	0.91454	1305.50087	0.96389	1227.98675	0.97257
1380.97514	0.89928	1303.46102	0.9638	1225.94691	0.97265
1378.93529	0.88372	1301.42118	0.96387	1223.90706	0.97258
1376.89545	0.87599	1299.38133	0.96425	1221.86722	0.97251
1374.8556	0.88199	1297.34149	0.96477	1219.82737	0.97238
1372.81576	0.89724	1295.30164	0.96529	1217.78753	0.97218
1370.77591	0.90989	1293.2618	0.96578	1215.74768	0.97195
1368.73607	0.91665	1291.22195	0.9663	1213.70784	0.97157
1366.69622	0.91991	1289.18211	0.96688	1211.66799	0.97125
1364.65638	0.92448	1287.14226	0.96738	1209.62815	0.97132
1362.61653	0.93398	1285.10242	0.96783	1207.5883	0.97157
1360.57669	0.94416	1283.06257	0.96823	1205.54846	0.97179
1358.53684	0.95025	1281.02273	0.96842	1203.50861	0.97197
1356.497	0.95347	1278.98288	0.96842	1201.46877	0.97198
1199.42892	0.97191	1142.31326	0.97034	1085.1976	0.96953
1197.38908	0.97197	1140.27341	0.97076	1083.15775	0.96897
1195.34923	0.9721	1138.23357	0.97084	1081.11791	0.96818
1193.30939	0.97207	1136.19372	0.97081	1079.07806	0.96753
1191.26954	0.97183	1134.15388	0.97105	1077.03822	0.96738
1189.2297	0.97159	1132.11403	0.97154	1074.99837	0.96758
1187.18985	0.97147	1130.07419	0.97186	1072.95853	0.96787
1185.15001	0.97126	1128.03434	0.97179	1070.91868	0.96812
1183.11016	0.97098	1125.9945	0.97174	1068.87884	0.96825

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1176.99063	0.97061	1119.87496	0.97218	1062.7593	0.96791
1174.95078	0.96975	1117.83512	0.97266	1060.71945	0.9677
1172.91094	0.96856	1115.79527	0.97296	1058.67961	0.96801
1170.87109	0.96738	1113.75543	0.97275	1056.63976	0.96814
1168.83125	0.96673	1111.71558	0.97233	1054.59992	0.96774
1166.7914	0.96709	1109.67574	0.972	1052.56007	0.9671
1164.75156	0.96786	1107.63589	0.97177	1050.52023	0.96678
1162.71171	0.9683	1105.59605	0.97169	1048.48038	0.967
1160.67186	0.96841	1103.5562	0.9718	1046.44054	0.96719
1158.63202	0.96824	1101.51636	0.97155	1044.40069	0.96687
1156.59217	0.96792	1099.47651	0.97095	1042.36085	0.96614
1154.55233	0.9678	1097.43667	0.97075	1040.321	0.9651
1152.51248	0.96823	1095.39682	0.97081	1038.28116	0.96414
1150.47264	0.96904	1093.35698	0.97064	1036.24131	0.96375
1148.43279	0.96959	1091.31713	0.97029	1034.20147	0.96382
1146.39295	0.96964	1089.27729	0.97006	1032.16162	0.96395
1144.3531	0.96981	1087.23744	0.96986	1030.12178	0.96396
1028.08193	0.96394	950.56782	0.96241	873.05371	0.95265
1026.04209	0.96396	948.52797	0.96214	871.01386	0.95262
1024.00224	0.96402	946.48813	0.96204	868.97401	0.95365
1021.9624	0.96442	944.44828	0.96242	866.93417	0.95538
1019.92255	0.96494	942.40844	0.96295	864.89432	0.95721
1017.88271	0.96522	940.36859	0.96322	862.85448	0.95894
1015.84286	0.96556	938.32875	0.96326	860.81463	0.95983
1013.80302	0.96596	936.2889	0.96328	858.77479	0.95937
1011.76317	0.96569	934.24906	0.96332	856.73494	0.95876

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance	Wavenumber (cm^{-1})	Transmittance
1003.60379	0.96394	926.08968	0.96338	848.57556	0.95597
1001.56395	0.96304	924.04983	0.9632	846.53572	0.95577
999.5241	0.96199	922.00999	0.96248	844.49587	0.95593
997.48426	0.96101	919.97014	0.96114	842.45603	0.95671
995.44441	0.96009	917.9303	0.95915	840.41618	0.95789
993.40457	0.95919	915.89045	0.95616	838.37634	0.95809
991.36472	0.95904	913.85061	0.95149	836.33649	0.95733
989.32488	0.96005	911.81076	0.94598	834.29665	0.95655
987.28503	0.96146	909.77092	0.94266	832.2568	0.95656
985.24519	0.96224	907.73107	0.94332	830.21696	0.95737
983.20534	0.96224	905.69123	0.94706	828.17711	0.95768
981.1655	0.96207	903.65138	0.95158	826.13727	0.95682
979.12565	0.96183	901.61154	0.95499	824.09742	0.95564
977.08581	0.96123	899.57169	0.95695	822.05758	0.95468
975.04596	0.96041	897.53185	0.95766	820.01773	0.95347
973.00612	0.95933	895.492	0.95687	817.97789	0.95088
970.96627	0.95792	893.45216	0.95432	815.93804	0.94714
968.92643	0.95658	891.41231	0.95101	813.8982	0.9439
966.88658	0.9557	889.37247	0.94869	811.85835	0.94186
964.84673	0.95553	887.33262	0.94811	809.81851	0.94126
962.80689	0.95647	885.29278	0.94895	807.77866	0.94197
960.76704	0.95831	883.25293	0.95032	805.73882	0.94325
958.7272	0.96008	881.21309	0.95118	803.69897	0.94564
956.68735	0.96138	879.17324	0.95162	801.65913	0.94931
954.64751	0.96216	877.1334	0.95224	799.61928	0.95213
952.60766	0.96245	875.09355	0.95276	797.57944	0.95286
795.53959	0.95222	718.02548	0.93	640.51136	0.96816

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
795.53959	0.95222	718.02548	0.93	640.51136	0.96816
793.49975	0.95215	715.98563	0.93766	638.47152	0.96797
791.4599	0.95348	713.94579	0.94376	636.43167	0.96791
789.42006	0.95478	711.90594	0.94765	634.39183	0.96842
787.38021	0.95484	709.8661	0.95019	632.35198	0.96789
785.34037	0.95281	707.82625	0.95191	630.31214	0.96649
783.30052	0.9498	705.78641	0.9526	628.27229	0.96605
781.26068	0.94815	703.74656	0.95232	626.23245	0.96649
779.22083	0.94825	701.70672	0.95122	624.1926	0.96717
777.18099	0.94871	699.66687	0.94958	622.15276	0.9674
775.14114	0.94778	697.62703	0.94882	620.11291	0.96768
773.10129	0.94474	695.58718	0.95012	618.07307	0.96885
771.06145	0.93998	693.54734	0.9518	616.03322	0.96965
769.0216	0.93514	691.50749	0.95342	613.99338	0.96871
766.98176	0.93327	689.46765	0.9568	611.95353	0.96698
764.94191	0.93566	687.4278	0.96129	609.91369	0.96665
762.90207	0.93978	685.38796	0.96487	607.87384	0.96764
760.86222	0.94285	683.34811	0.96671	605.834	0.96814
758.82238	0.94397	681.30827	0.96722	603.79415	0.96816
756.78253	0.94342	679.26842	0.96726	601.75431	0.96791
754.74269	0.94167	677.22857	0.96678	599.71446	0.96714
752.70284	0.93951	675.18873	0.96657	597.67462	0.96651
750.663	0.93789	673.14888	0.96761	595.63477	0.9661
748.62315	0.9361	671.10904	0.96887	593.59493	0.96587
746.58331	0.93293	669.06919	0.96994	591.55508	0.96642
744.54346	0.92864	667.02935	0.97079	589.51524	0.96745
742.50362	0.92472	664.9895	0.97072	587.47539	0.96807

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
736.38408	0.93082	658.86997	0.97012	581.35586	0.965
734.34424	0.93217	656.83012	0.96836	579.31601	0.96381
732.30439	0.93021	654.79028	0.96757	577.27616	0.96375
730.26455	0.92506	652.75043	0.96784	575.23632	0.96456
728.2247	0.91926	650.71059	0.96805	573.19647	0.96456
726.18486	0.91654	648.67074	0.96867	571.15663	0.9639
724.14501	0.91664	646.6309	0.96977	569.11678	0.96364
722.10517	0.91815	644.59105	0.96961	567.07694	0.96337
720.06532	0.92263	642.55121	0.96854	565.03709	0.96277
562.99725	0.96361	522.20035	0.96108	481.40344	0.96095
560.9574	0.96679	520.1605	0.95989	479.3636	0.95925
558.91756	0.96876	518.12066	0.95924	477.32375	0.95895
556.87771	0.96803	516.08081	0.95967	475.28391	0.95727
554.83787	0.96685	514.04097	0.96156	473.24406	0.95523
552.79802	0.96517	512.00112	0.96388	471.20422	0.95752
550.75818	0.96365	509.96128	0.96524	469.16437	0.95976
548.71833	0.96332	507.92143	0.9638	467.12453	0.95805
546.67849	0.96312	505.88159	0.96023	465.08468	0.95633
544.63864	0.96397	503.84174	0.95936	463.04484	0.95762
542.5988	0.96558	501.8019	0.96192	461.00499	0.96021
540.55895	0.96456	499.76205	0.96285	458.96515	0.96124
538.51911	0.96244	497.72221	0.96142	456.9253	0.95931
536.47926	0.96258	495.68236	0.96042	454.88546	0.95677
534.43942	0.96325	493.64252	0.96099	452.84561	0.95863
532.39957	0.96338	491.60267	0.96243	450.80577	0.96361
530.35973	0.96434	489.56283	0.96309	448.76592	0.96571
528.31988	0.96564	487.52298	0.9631	446.72608	0.96386

APPENDIX J1 Wavenumbers vrsTransmittances of Bitumen (Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
440.60654	0.96004	426.32763	0.95515	412.04871	0.95938
438.5667	0.9579	424.28778	0.95651	410.00887	0.95626
436.52685	0.95993	422.24794	0.9595	407.96902	0.95625
434.48701	0.96163	420.20809	0.96397	405.92918	0.95765
432.44716	0.96019	418.16825	0.96276	403.88933	0.95742
430.40732	0.95681	416.1284	0.95806	401.84949	0.95962
428.36747	0.95496	414.08856	0.95905	399.80964	0.96202

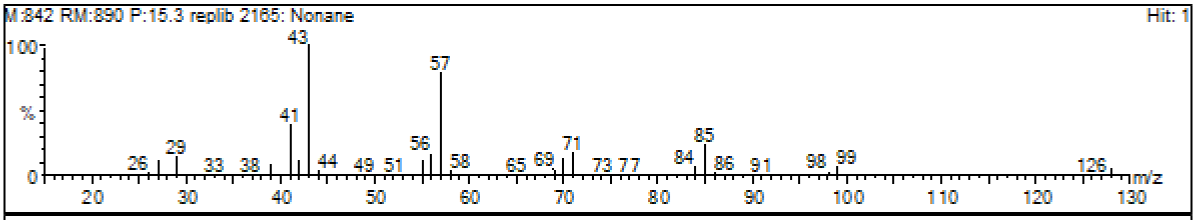
APPENDIX J2 QUALITATIVE REPORT OF COMPONENTS IN BITUMEN

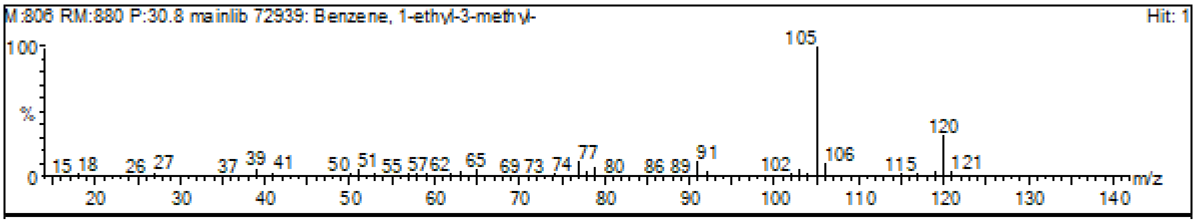
#	RT	Scan	Height	Area	Area %	Norm %	Name
1	4.739	174	1,901,754,880	154,528,400.0	0.796	28.49	
2	5.849	285	1,142,387,328	118,300,664.0	0.609	21.81	
3	8.049	505	783,212,288	93,713,056.0	0.482	17.28	
4	8.319	532	785,716,928	94,008,320.0	0.484	17.33	
5	9.210	621	1,244,527,488	138,851,440.0	0.715	25.60	
6	9.560	656	1,422,804,992	160,206,960.0	0.825	29.54	
7	10.220	722	1,173,211,648	169,423,600.0	0.872	31.24	
8	11.190	819	859,602,560	81,756,400.0	0.421	15.07	
9	13.020	1002	1,919,434,880	244,135,488.0	1.257	45.02	
10	14.541	1154	727,363,712	118,636,776.0	0.611	21.88	
11	15.501	1250	604,185,984	115,994,264.0	0.597	21.39	
12	15.771	1277	776,228,480	126,711,776.0	0.652	23.36	
13	16.131	1313	2,453,670,144	326,552,608.0	1.681	60.21	
14	16.501	1350	1,628,460,288	131,732,240.0	0.678	24.29	
15	17.901	1490	744,222,848	83,186,528.0	0.428	15.34	Heptadecanoic acid,
16	18.171	1517	1,570,637,056	179,240,528.0	0.923	33.05	
17	18.812	1581	2,154,121,728	333,079,648.0	1.715	61.42	
18	19.032	1603	3,004,194,816	390,763,584.0	2.012	72.05	
19	19.322	1632	1,339,548,672	119,111,736.0	0.613	21.96	
20	20.362	1736	699,504,192	88,086,112.0	0.453	16.24	
21	21.002	1800	1,603,599,232	120,448,072.0	0.620	22.21	
22	21.462	1846	1,003,171,456	127,438,408.0	0.656	23.50	

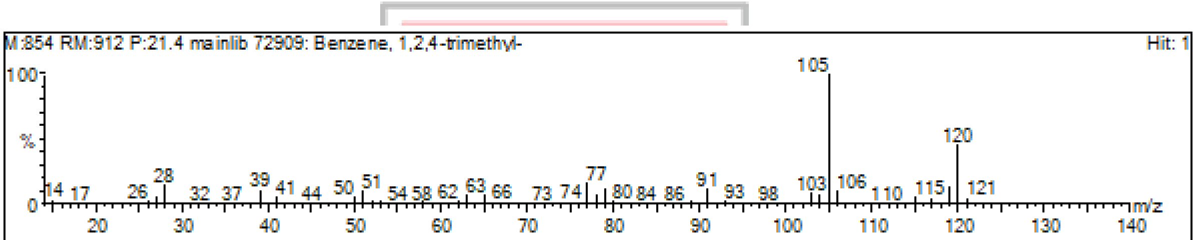
APPENDIX J2 Qualitative Report of Components in Bitumen (Continued)

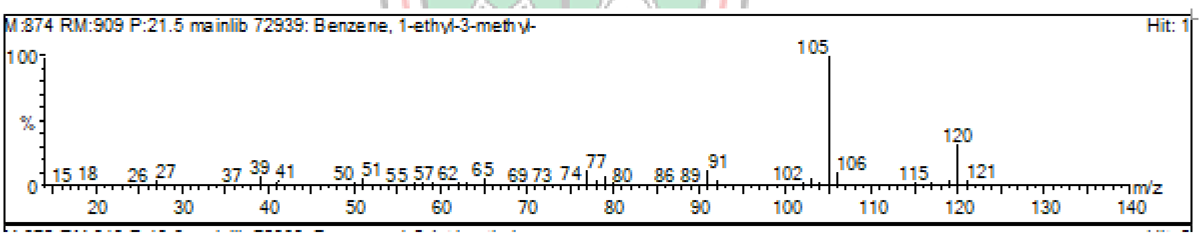
#	RT	Scan	Height	Area	Area %	Norm %	Name
23	21.742	1874	3,277,121,280	477,041,184.0	2.456	87.96	
24	21.902	1890	1,124,909,696	112,139,928.0	0.577	20.68	
25	22.242	1924	2,162,532,864	202,395,616.0	1.042	37.32	
26	22.312	1931	2,131,941,376	125,991,736.0	0.649	23.23	
27	22.772	1977	880,052,800	99,034,840.0	0.510	18.26	
28	23.202	2020	2,211,213,568	295,686,240.0	1.522	54.52	
29	23.933	2093	1,181,209,088	192,058,400.0	0.989	35.41	
30	24.233	2123	4,262,966,784	465,090,144.0	2.394	85.76	Methyl eicosa-5,8,11,14,
31	25.333	2233	1,578,202,752	143,969,168.0	0.741	26.55	
32	25.423	2242	1,415,292,928	125,598,432.0	0.647	23.16	
33	25.773	2277	1,112,724,736	101,325,968.0	0.522	18.68	
34	26.323	2332	1,406,165,760	174,869,456.0	0.900	32.24	
35	26.593	2359	4,650,289,152	542,331,136.0	2.792	100.00	
36	27.603	2460	1,982,636,288	184,543,440.0	0.950	34.03	
37	28.594	2559	1,007,708,288	114,687,872.0	0.590	21.15	
38	28.854	2585	3,830,894,848	523,675,328.0	2.696	96.56	
39	28.944	2594	4,017,198,848	287,791,680.0	1.482	53.07	
40	30.964	2796	3,043,646,464	326,360,288.0	1.680	60.18	
41	31.124	2812	2,481,396,992	182,440,016.0	0.939	33.64	
42	32.804	2980	1,002,313,984	122,191,256.0	0.629	22.53	
43	33.014	3001	3,489,716,224	368,986,784.0	1.900	68.04	
44	34.955	3195	3,023,668,224	340,012,448.0	1.750	62.69	
45	36.795	3379	3,243,075,584	408,441,984.0	2.103	75.31	
46	37.675	3467	830,671,936	131,502,496.0	0.677	24.25	
47	37.965	3496	671,590,208	86,985,536.0	0.448	16.04	
48	38.576	3557	3,289,239,040	385,647,104.0	1.985	71.11	
49	39.106	3610	697,767,168	86,767,208.0	0.447	16.00	
50	39.566	3656	633,441,088	84,131,704.0	0.433	15.51	
51	40.276	3727	3,074,873,344	368,043,424.0	1.895	67.86	
52	40.836	3783	665,783,040	112,085,232.0	0.577	20.67	
53	41.916	3891	3,152,264,704	398,893,952.0	2.054	73.55	
54	42.486	3948	684,400,000	128,024,704.0	0.659	23.61	
55	42.686	3968	720,792,192	89,292,664.0	0.460	16.46	
56	43.487	4048	3,015,369,216	386,555,552.0	1.990	71.28	
57	44.147	4114	860,240,128	132,020,480.0	0.680	24.34	
58	44.517	4151	582,185,984	92,551,984.0	0.476	17.07	
59	44.997	4199	2,864,757,504	308,357,536.0	1.588	56.86	

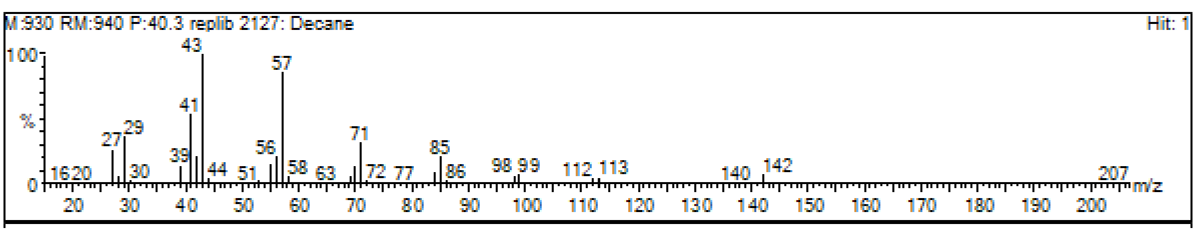
APPENDIX J3 BITUMEN CHROMATOGRAM/SPECTRUM

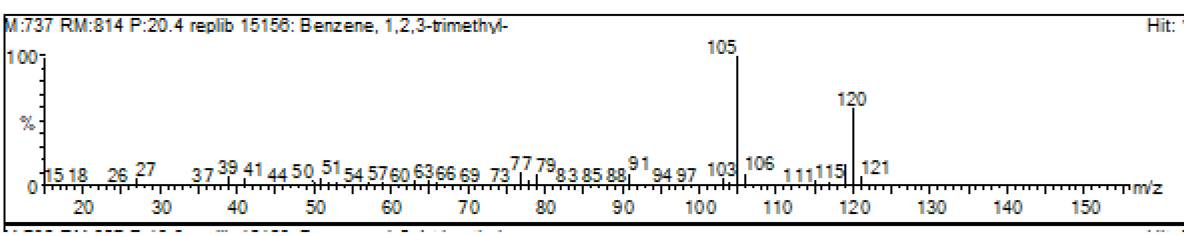




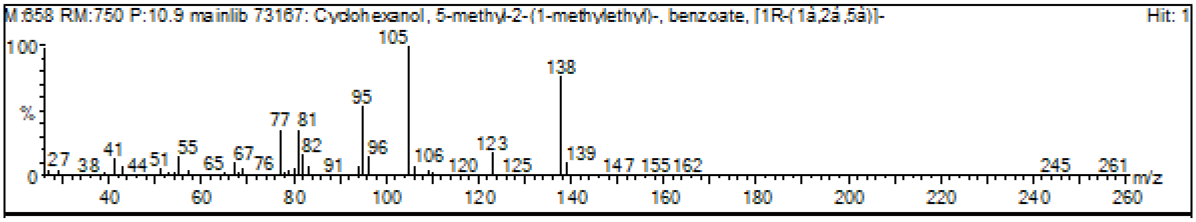


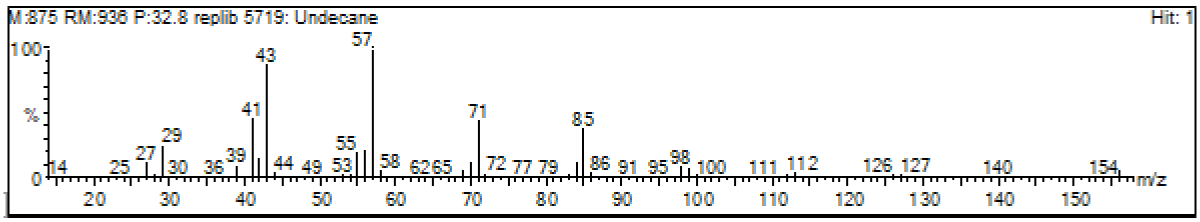


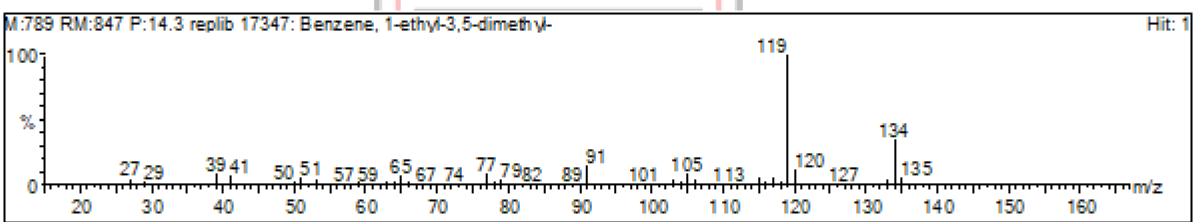


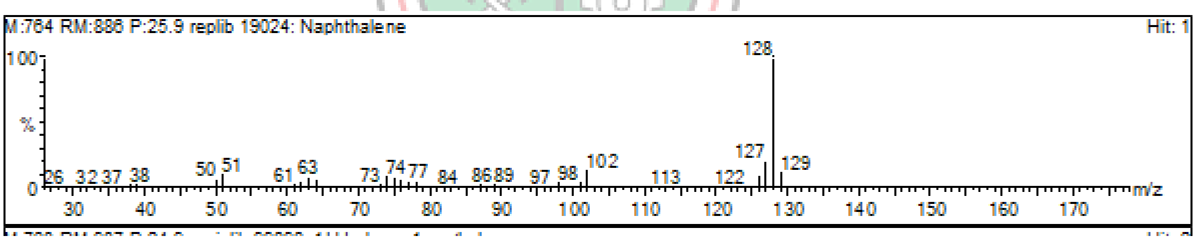


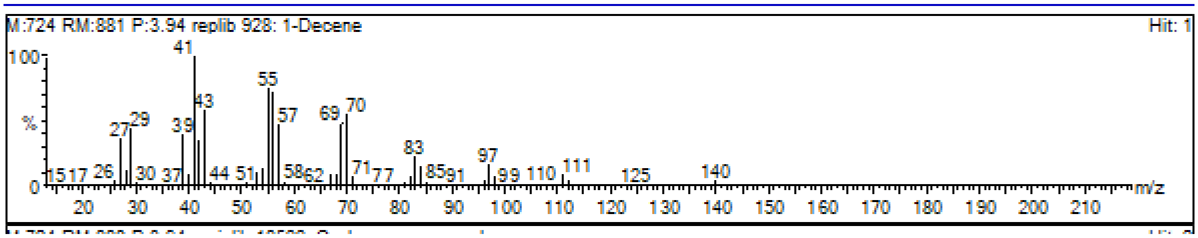
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)



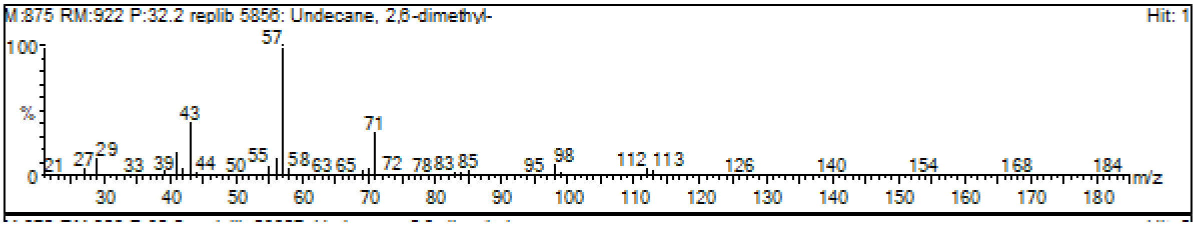


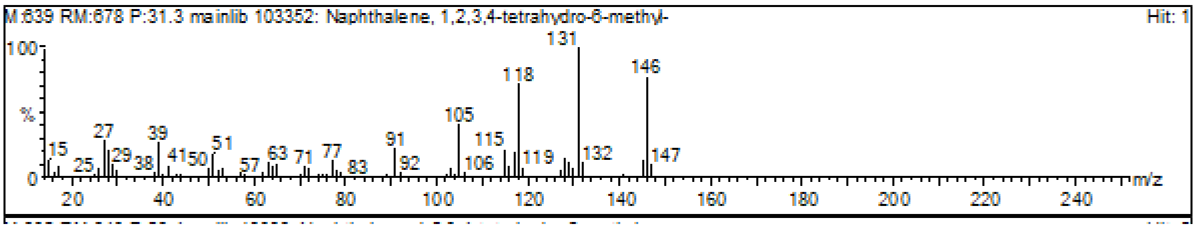


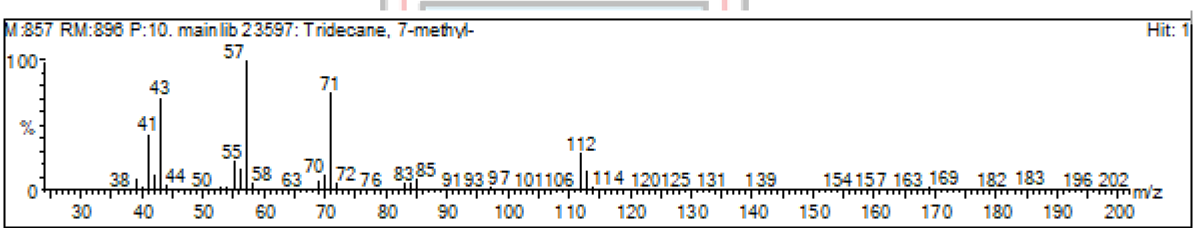


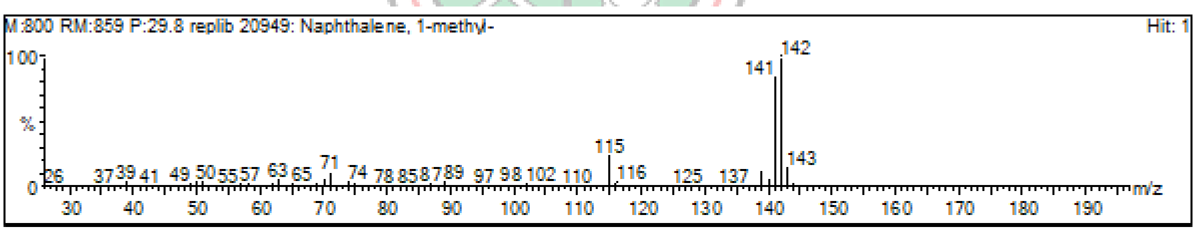


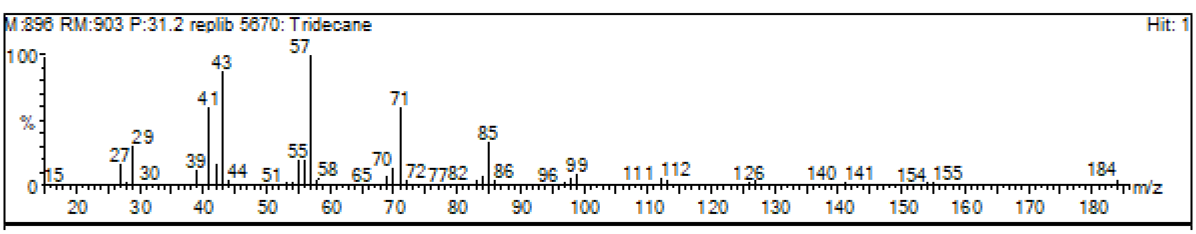
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

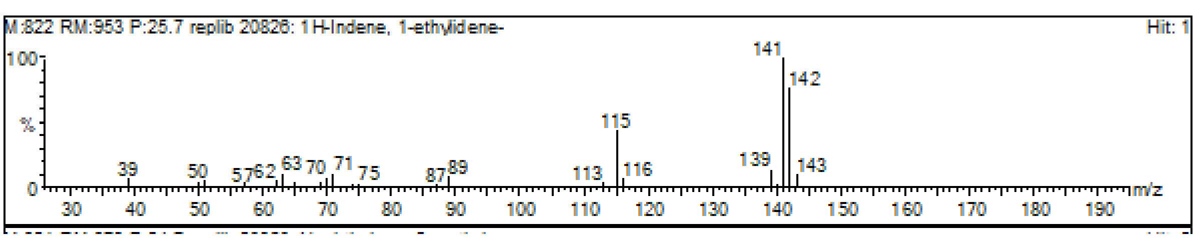




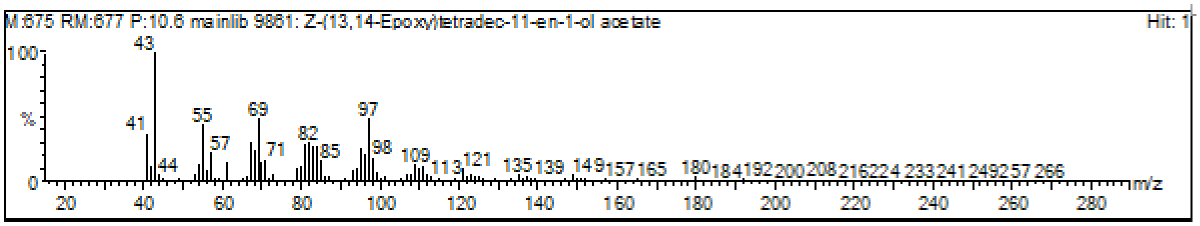


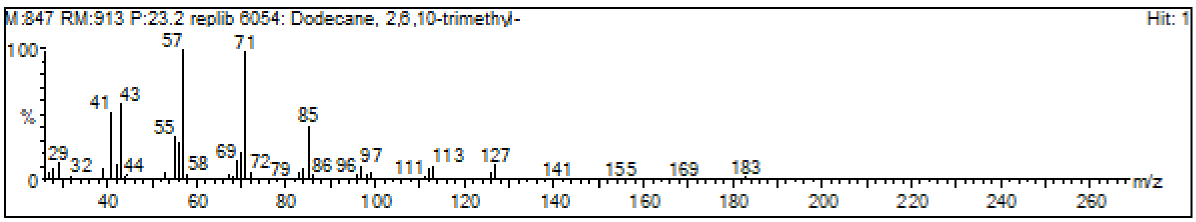


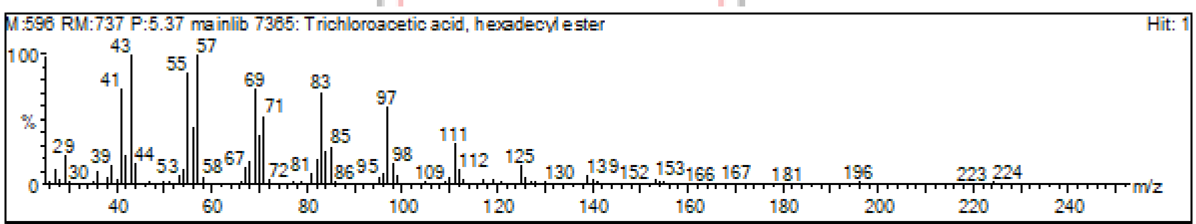


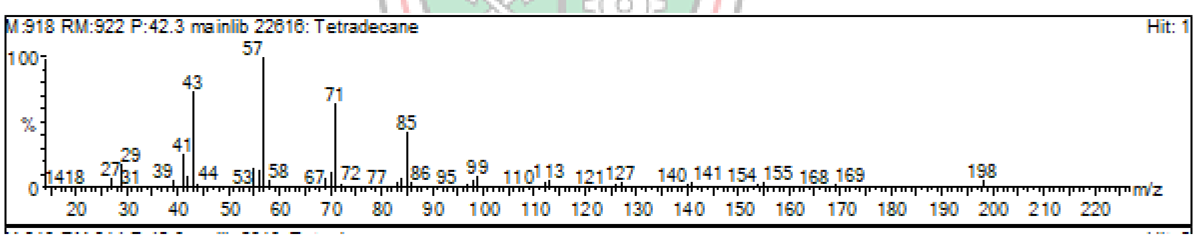


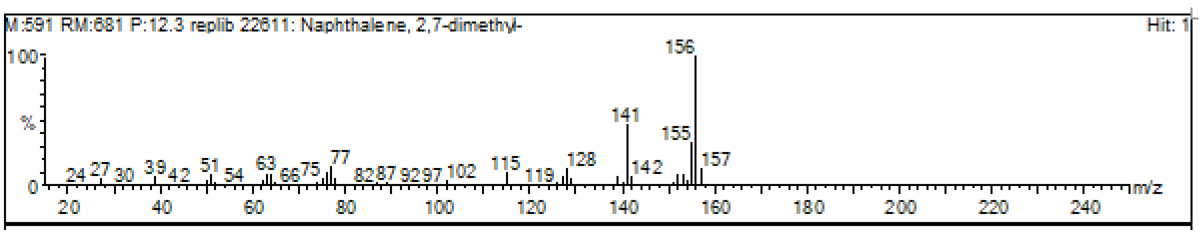
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

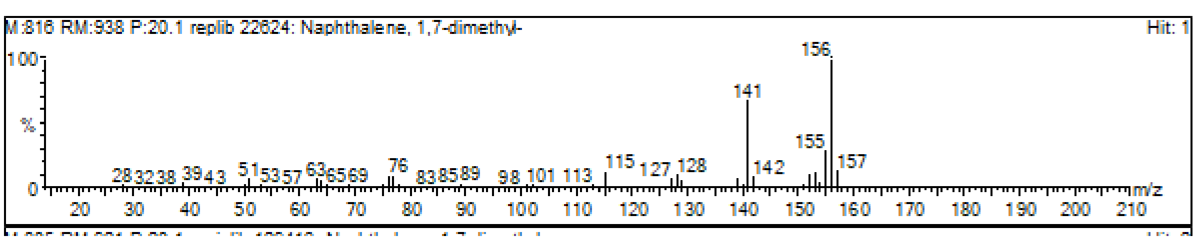




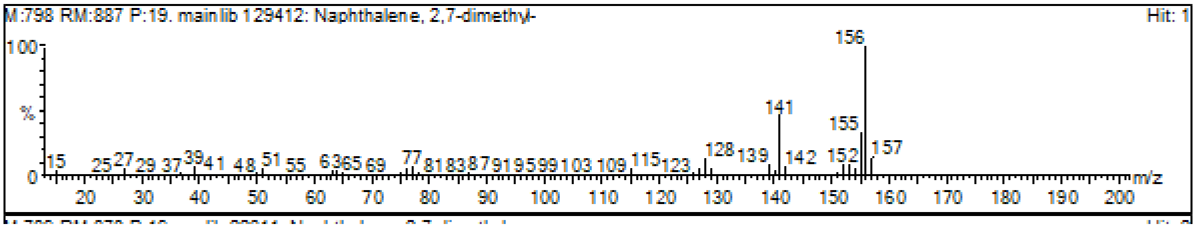


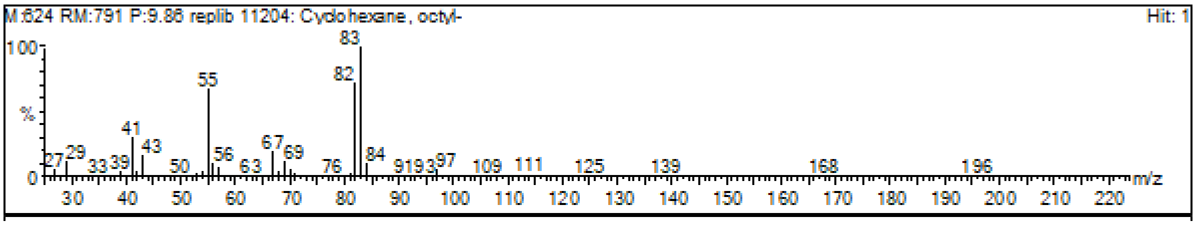


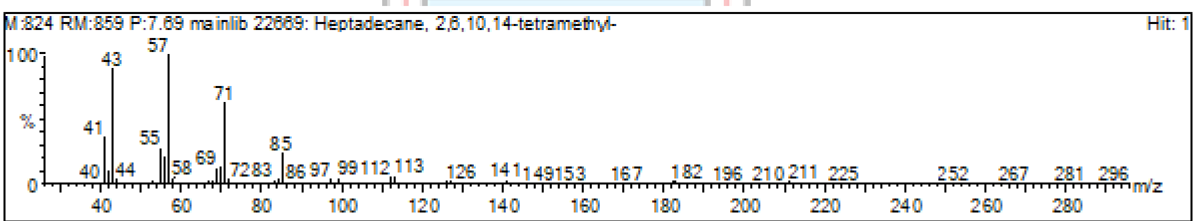


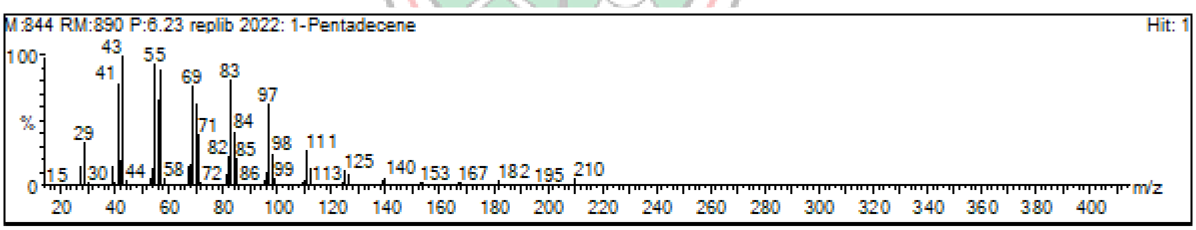


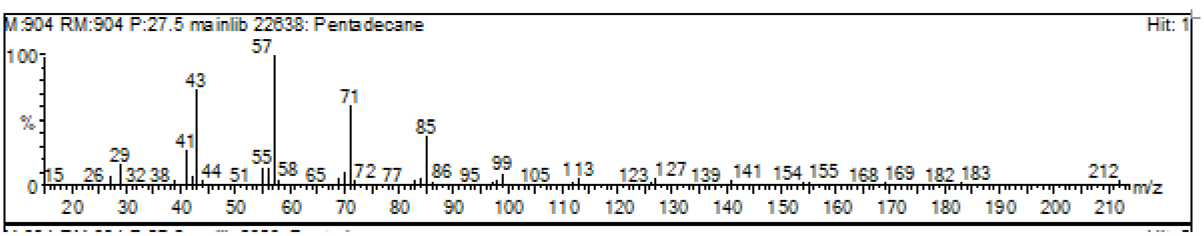
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

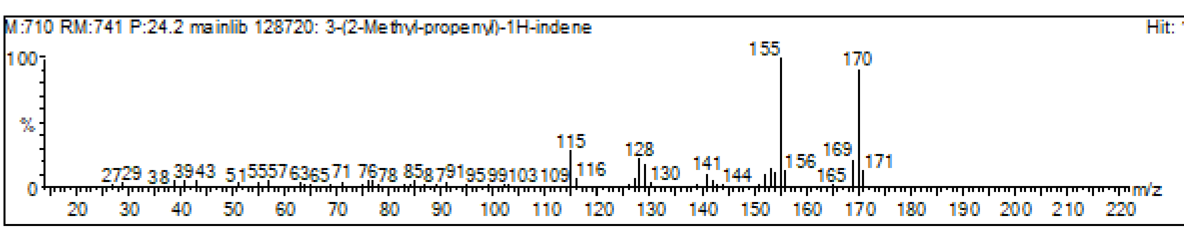




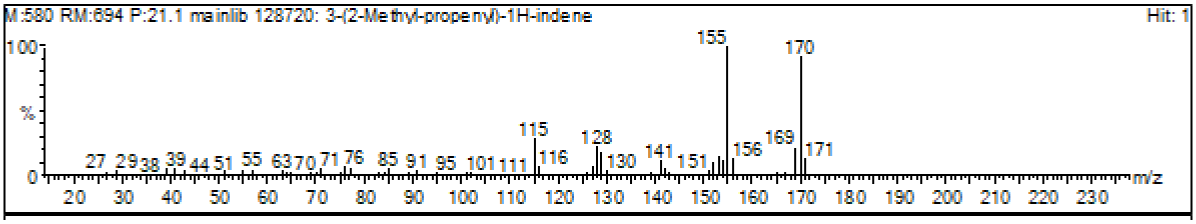


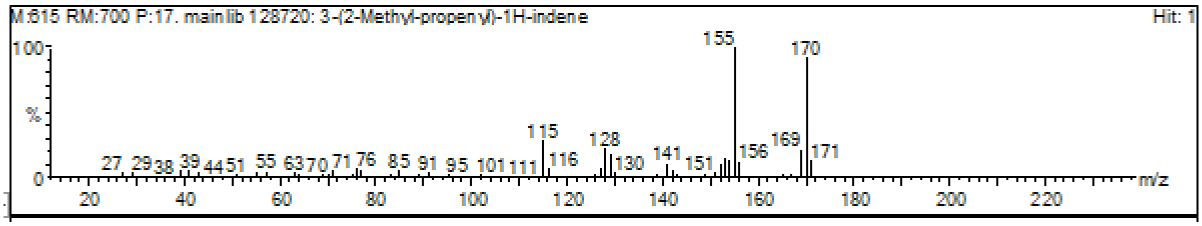


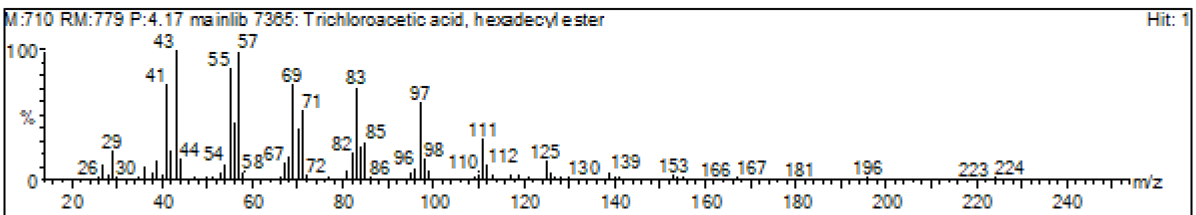


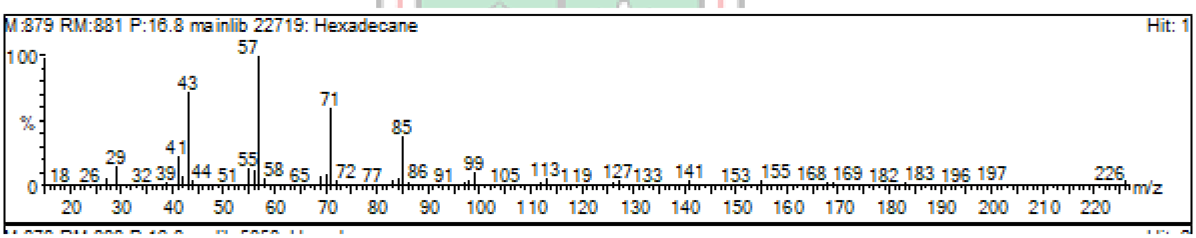


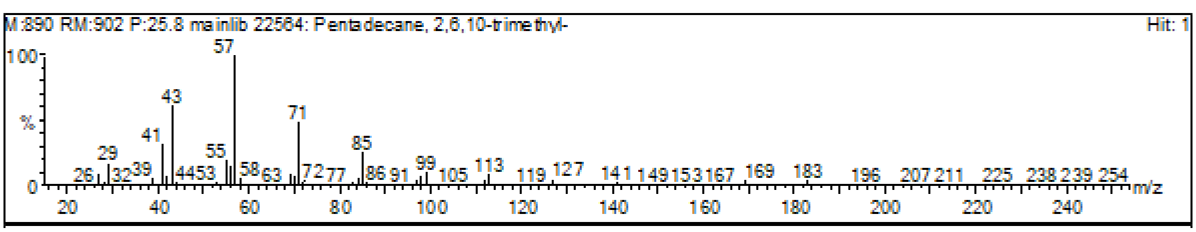
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

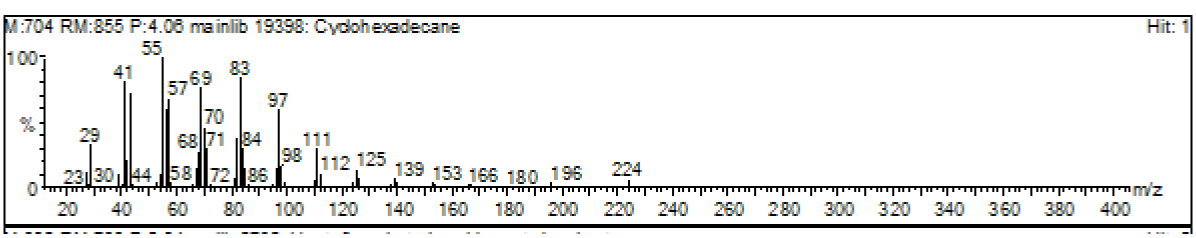




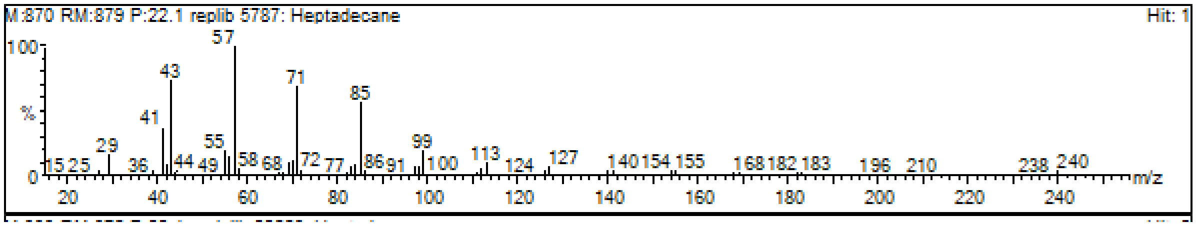


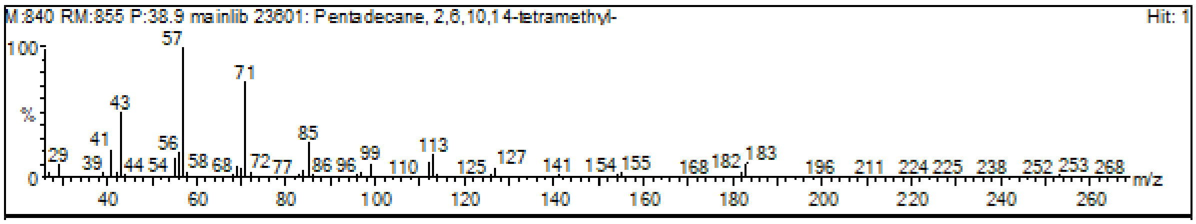


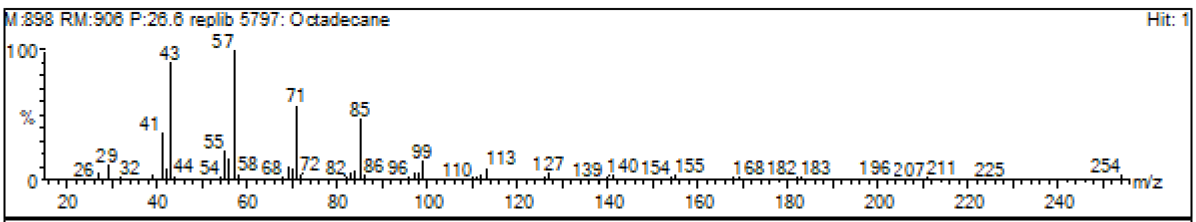


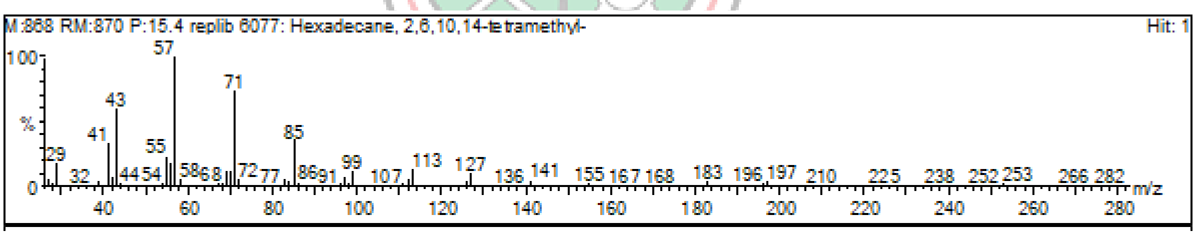


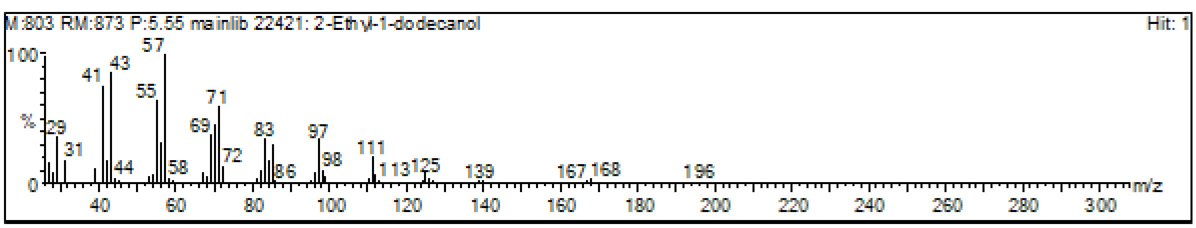
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

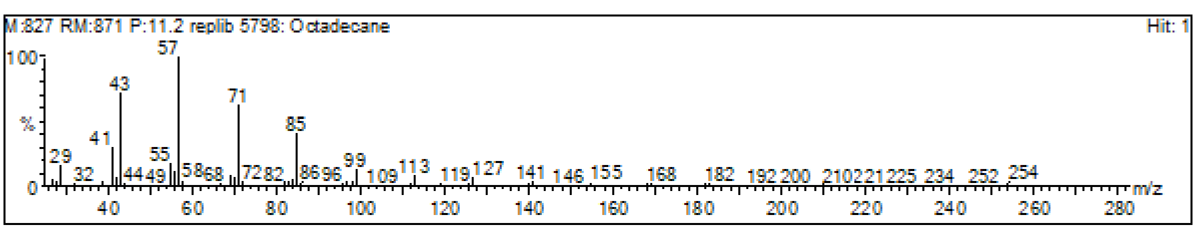




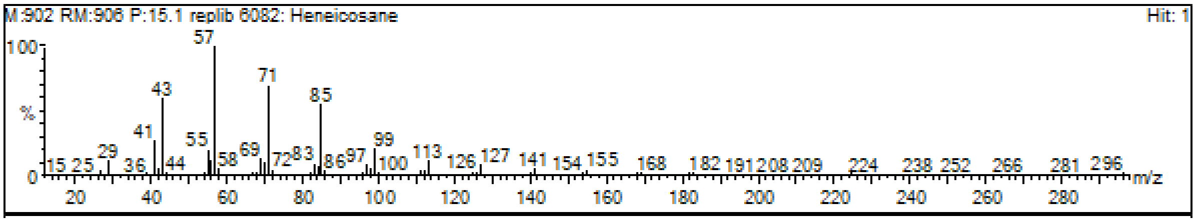


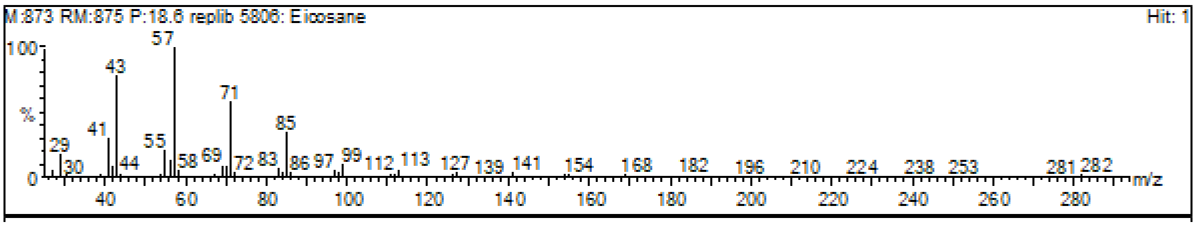


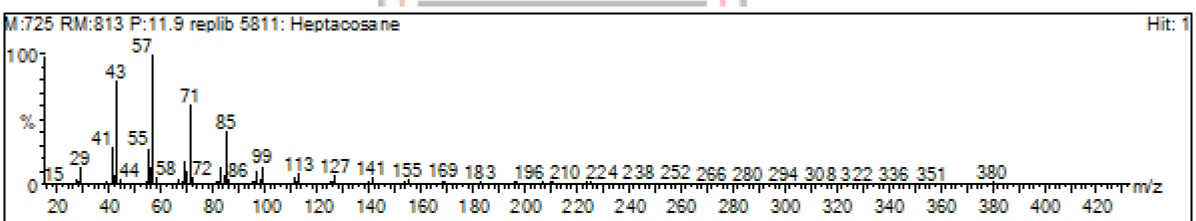


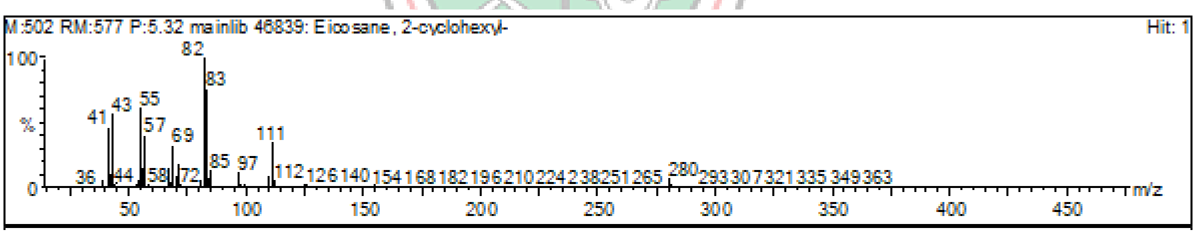


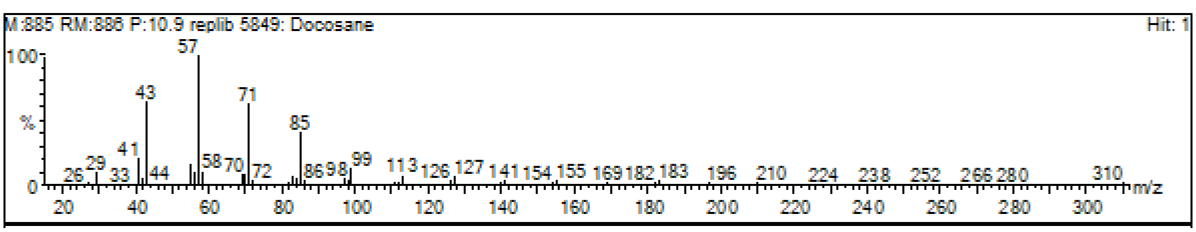
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

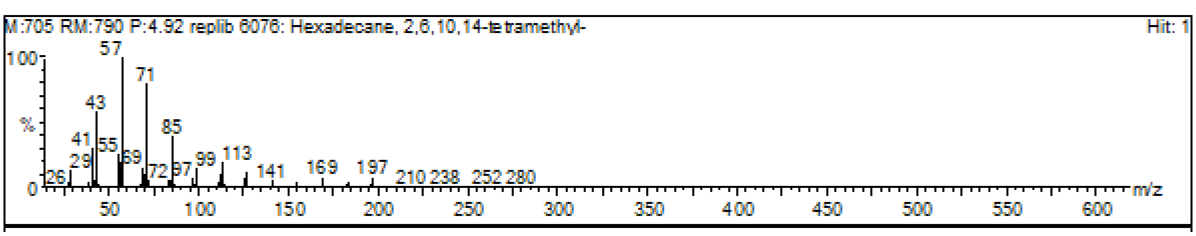




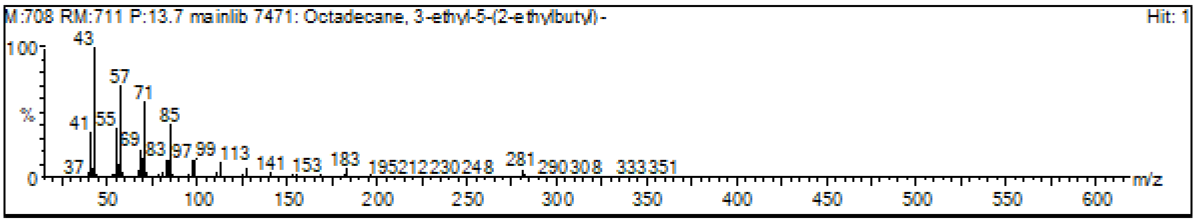


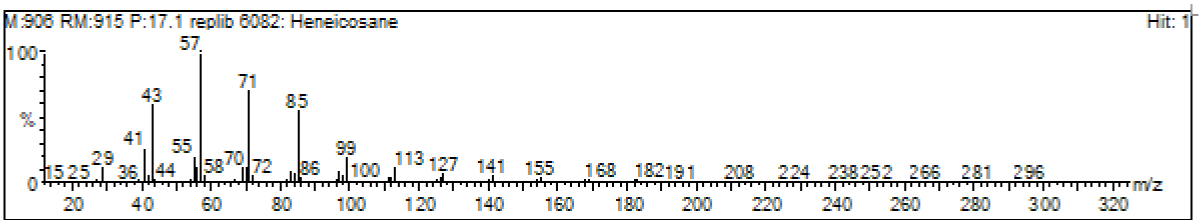


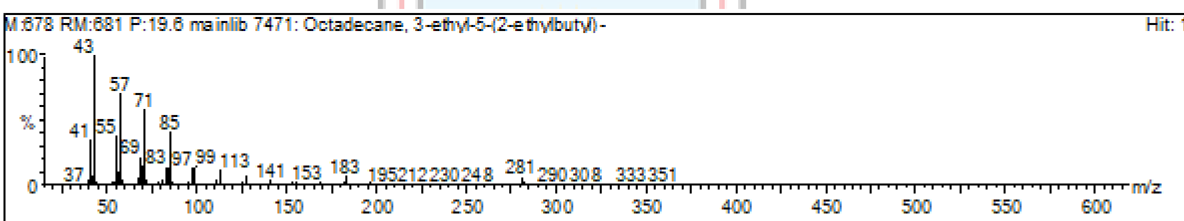


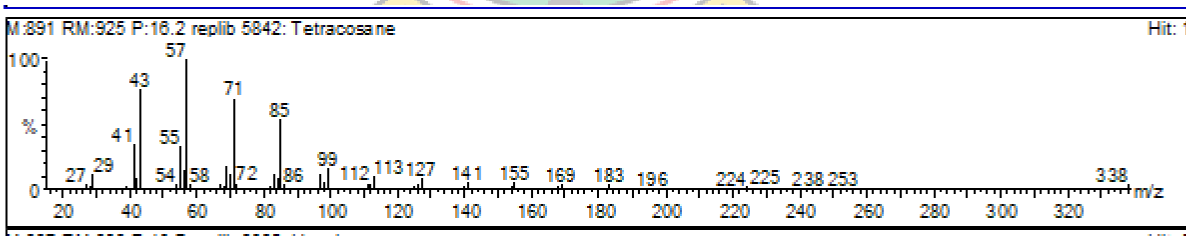


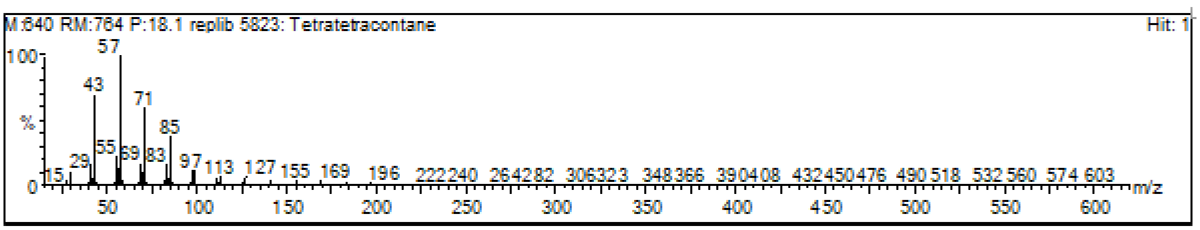
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)

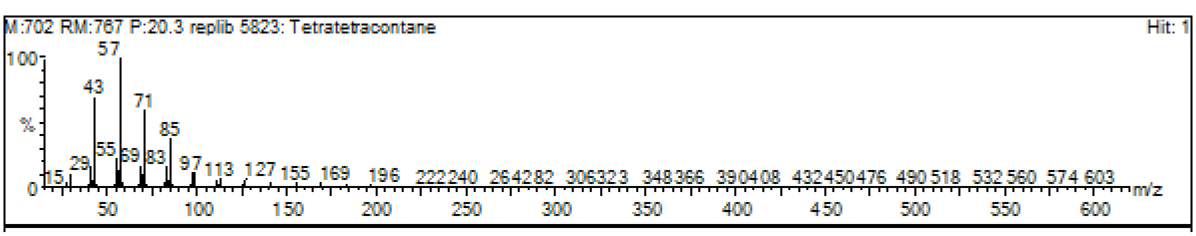




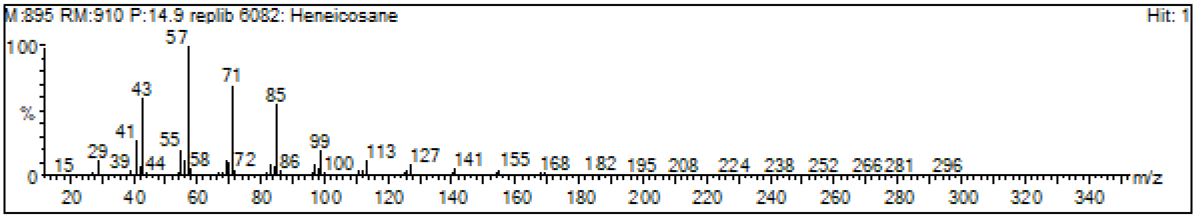


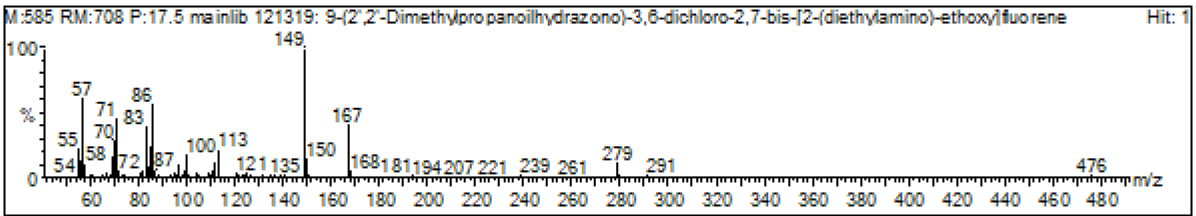


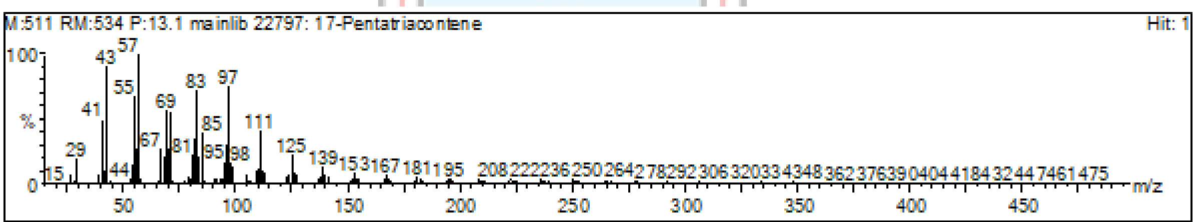


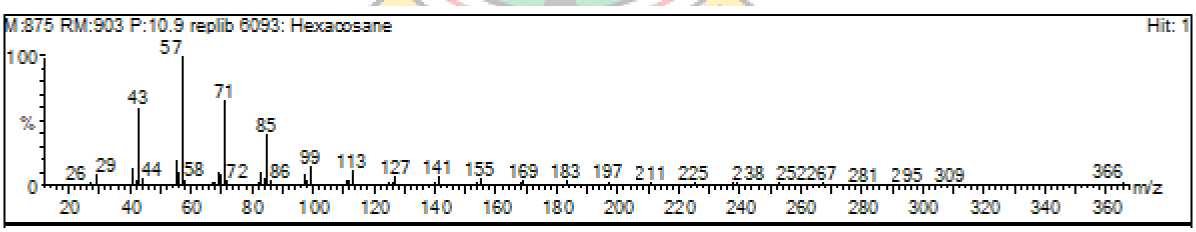


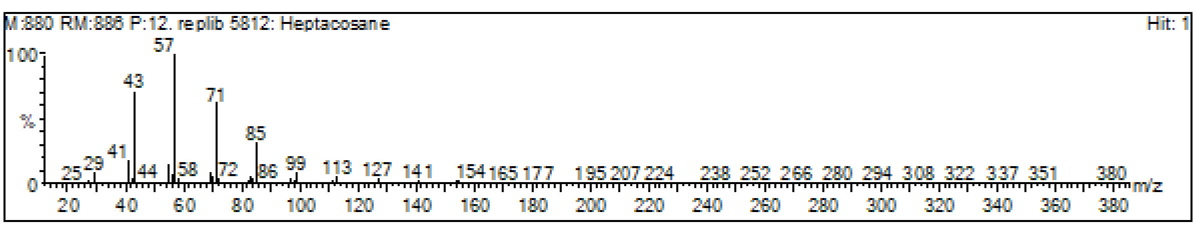
APPENDIX J3 Bitumen Chromatogram/Spectrum (Continued)











APPENDIX K1 WAVENUMBERS VRS TRANSMITTANCES OF CRUDE OIL

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
3996.05656	0.99907	3918.54245	0.99793	3841.02833	0.99683
3994.01672	0.99916	3916.5026	0.998	3838.98849	0.9979
3991.97687	0.99901	3914.46276	0.99858	3836.94864	0.99937
3989.93703	0.99881	3912.42291	0.99866	3834.9088	0.9996
3987.89718	0.99822	3910.38307	0.99843	3832.86895	0.99867
3985.85734	0.99781	3908.34322	0.99827	3830.82911	0.99793
3983.81749	0.99797	3906.30338	0.99768	3828.78926	0.99777
3981.77765	0.99801	3904.26353	0.99739	3826.74942	0.99768
3979.7378	0.9978	3902.22369	0.99771	3824.70957	0.99786
3977.69796	0.99756	3900.18384	0.99744	3822.66973	0.99842
3975.65811	0.99743	3898.144	0.99737	3820.62988	0.99905
3973.61827	0.99768	3896.10415	0.99759	3818.59004	0.99956
3971.57842	0.99793	3894.06431	0.99738	3816.55019	0.99972
3969.53858	0.99777	3892.02446	0.99729	3814.51035	0.99915
3967.49873	0.99748	3889.98462	0.99755	3812.4705	0.99864
3965.45888	0.99755	3887.94477	0.99765	3810.43066	0.99872
3963.41904	0.9978	3885.90493	0.99805	3808.39081	0.99892
3961.37919	0.99764	3883.86508	0.9988	3806.35097	0.9984
3959.33935	0.99735	3881.82524	0.99885	3804.31112	0.99719
3957.2995	0.99751	3879.78539	0.99829	3802.27128	0.99662
3955.25966	0.99811	3877.74555	0.99799	3800.23143	0.99778
3953.21981	0.99838	3875.7057	0.99774	3798.19159	0.99868
3951.17997	0.99817	3873.66586	0.99727	3796.15174	0.99798
3949.14012	0.9983	3871.62601	0.99719	3794.1119	0.99746
3947.10028	0.99847	3869.58616	0.99774	3792.07205	0.99813
3943.02059	0.99839	3865.50647	0.99778	3787.99236	0.99922

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
3934.86121	0.99848	3857.34709	0.99766	3779.83298	0.99792
3930.78152	0.99825	3853.2674	0.99857	3775.75329	0.99856
3928.74167	0.99843	3851.22756	0.99905	3773.71344	0.99853
3926.70183	0.99819	3849.18771	0.99888	3771.6736	0.99869
3924.66198	0.99786	3847.14787	0.99879	3769.63375	0.99873
3922.62214	0.99786	3845.10802	0.99813	3767.59391	0.99867
3920.58229	0.99806	3843.06818	0.99706	3765.55406	0.99898
3763.51422	0.9994	3686.00011	0.99826	3608.48599	0.99808
3761.47437	0.9995	3683.96026	0.99891	3606.44615	0.9989
3759.43453	0.99923	3681.92042	0.9991	3604.4063	0.99894
3757.39468	0.99874	3679.88057	0.99864	3602.36646	0.99812
3755.35484	0.9986	3677.84072	0.99759	3600.32661	0.99739
3753.31499	0.99871	3675.80088	0.99651	3598.28677	0.99718
3751.27515	0.99829	3673.76103	0.99686	3596.24692	0.99691
3749.2353	0.99761	3671.72119	0.998	3594.20708	0.99676
3747.19546	0.99797	3669.68134	0.99909	3592.16723	0.99735
3745.15561	0.99885	3667.6415	0.99999	3590.12739	0.99823
3743.11577	0.99894	3665.60165	1.00028	3588.08754	0.99876
3741.07592	0.99837	3663.56181	0.99997	3586.0477	0.99866
3739.03608	0.99754	3661.52196	0.99958	3584.00785	0.99861
3736.99623	0.99688	3659.48212	0.99931	3581.96801	0.99897
3734.95639	0.99799	3657.44227	0.99923	3579.92816	0.99882
3732.91654	0.99949	3655.40243	0.99949	3577.88831	0.99785
3730.8767	0.99941	3653.36258	0.99985	3575.84847	0.99743
3728.83685	0.99931	3651.32274	1.00049	3573.80862	0.99775
3726.79701	0.99971	3649.28289	1.00114	3571.76878	0.99788
3724.75716	1.00002	3647.24305	1.00038	3569.72893	0.99812

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
3718.63763	1.00017	3641.12351	0.99882	3563.6094	0.99794
3716.59778	0.99989	3639.08367	0.99895	3561.56955	0.99826
3714.55794	0.99927	3637.04382	0.99869	3559.52971	0.99941
3712.51809	0.9981	3635.00398	0.99831	3557.48986	1.00003
3710.47825	0.99687	3632.96413	0.9982	3555.45002	1.00005
3708.4384	0.99654	3630.92429	0.9982	3553.41017	1.00022
3706.39856	0.99724	3628.88444	0.99829	3551.37033	1.00036
3704.35871	0.99823	3626.8446	0.99872	3549.33048	0.99995
3702.31887	0.99851	3624.80475	0.99913	3547.29064	0.99893
3700.27902	0.99817	3622.76491	0.99927	3545.25079	0.99781
3698.23918	0.99784	3620.72506	0.99932	3543.21095	0.99747
3696.19933	0.99758	3618.68522	0.99909	3541.1711	0.99787
3694.15949	0.99769	3616.64537	0.99828	3539.13126	0.99833
3692.11964	0.99814	3614.60553	0.99752	3537.09141	0.99824
3690.0798	0.9983	3612.56568	0.99728	3535.05157	0.99801
3688.03995	0.99797	3610.52584	0.99746	3533.01172	0.99835
3530.97188	0.99866	3453.45776	0.99874	3375.94365	0.99748
3528.93203	0.99865	3451.41792	0.99912	3373.9038	0.99709
3526.89219	0.99878	3449.37807	0.99938	3371.86396	0.99717
3524.85234	0.99901	3447.33823	0.99894	3369.82411	0.99779
3522.8125	0.99881	3445.29838	0.99829	3367.78427	0.99823
3520.77265	0.998	3443.25854	0.99828	3365.74442	0.99802
3518.73281	0.99749	3441.21869	0.99878	3363.70458	0.99772
3516.69296	0.99768	3439.17885	0.99914	3361.66473	0.99781
3514.65312	0.99784	3437.139	0.99933	3359.62489	0.99794
3512.61327	0.99806	3435.09916	0.99935	3357.58504	0.99768
3510.57343	0.99866	3433.05931	0.99886	3355.5452	0.99754

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
3504.45389	0.99946	3426.93978	0.99817	3349.42566	0.99847
3502.41405	0.99936	3424.89993	0.99833	3347.38582	0.99762
3500.3742	0.99871	3422.86009	0.99836	3345.34597	0.99726
3498.33436	0.99832	3420.82024	0.99815	3343.30613	0.9974
3494.25467	0.99836	3416.74055	0.99792	3339.22644	0.99767
3492.21482	0.99873	3414.70071	0.99786	3337.18659	0.99773
3490.17498	0.99955	3412.66086	0.99792	3335.14675	0.99754
3488.13513	0.99991	3410.62102	0.998	3333.1069	0.99748
3486.09529	0.99914	3408.58117	0.99801	3331.06706	0.99788
3484.05544	0.99789	3406.54133	0.99797	3329.02721	0.99845
3482.01559	0.99707	3404.50148	0.99789	3326.98737	0.99878
3479.97575	0.99705	3402.46164	0.99778	3324.94752	0.99879
3477.9359	0.99757	3400.42179	0.99764	3322.90768	0.99836
3475.89606	0.99805	3398.38195	0.99757	3320.86783	0.99763
3473.85621	0.99808	3396.3421	0.99752	3318.82799	0.99732
3469.77652	0.99752	3392.26241	0.99733	3314.7483	0.99801
3467.73668	0.99814	3390.22257	0.99788	3312.70845	0.99793
3465.69683	0.99907	3388.18272	0.99842	3310.66861	0.99783
3463.65699	0.99954	3386.14287	0.99818	3308.62876	0.998
3461.61714	0.99937	3384.10303	0.99751	3306.58892	0.99822
3459.5773	0.99916	3382.06318	0.9974	3304.54907	0.99834
3457.53745	0.99914	3380.02334	0.9978	3302.50923	0.99839
3455.49761	0.99888	3377.98349	0.99787	3300.46938	0.99849
3298.42954	0.99842	3220.91542	0.99739	3143.40131	0.99597
3296.38969	0.998	3218.87558	0.99774	3141.36146	0.99594
3294.34985	0.99791	3216.83573	0.99778	3139.32162	0.99601
3292.31	0.99841	3214.79589	0.99762	3137.28177	0.99603

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
3286.19046	0.99843	3208.67635	0.99709	3131.16224	0.9948
3284.15062	0.99811	3206.63651	0.99685	3129.12239	0.99499
3282.11077	0.99812	3204.59666	0.99643	3127.08255	0.99531
3280.07093	0.99823	3202.55682	0.99615	3125.0427	0.99523
3278.03108	0.99797	3200.51697	0.99607	3123.00286	0.99502
3275.99124	0.99769	3198.47713	0.99626	3120.96301	0.99505
3273.95139	0.99766	3196.43728	0.99654	3118.92317	0.99509
3271.91155	0.99752	3194.39744	0.99633	3116.88332	0.99516
3269.8717	0.99735	3192.35759	0.99608	3114.84348	0.9953
3267.83186	0.99757	3190.31774	0.99638	3112.80363	0.99554
3265.79201	0.99771	3188.2779	0.99692	3110.76379	0.99592
3263.75217	0.99713	3186.23805	0.99717	3108.72394	0.9959
3261.71232	0.99662	3184.19821	0.99685	3106.6841	0.99529
3259.67248	0.99687	3182.15836	0.99618	3104.64425	0.99487
3257.63263	0.99719	3180.11852	0.99579	3102.60441	0.99518
3255.59279	0.99722	3178.07867	0.99584	3100.56456	0.99575
3253.55294	0.99772	3176.03883	0.99593	3098.52472	0.99576
3251.5131	0.99838	3173.99898	0.99579	3096.48487	0.99515
3249.47325	0.99827	3171.95914	0.99568	3094.44502	0.99457
3247.43341	0.99761	3169.91929	0.9958	3092.40518	0.99412
3245.39356	0.99706	3167.87945	0.99586	3090.36533	0.99355
3243.35372	0.99719	3165.8396	0.99589	3088.32549	0.99315
3241.31387	0.9977	3163.79976	0.996	3086.28564	0.99323
3239.27403	0.99786	3161.75991	0.99614	3084.2458	0.99325
3237.23418	0.99789	3159.72007	0.99636	3082.20595	0.99267
3235.19434	0.9979	3157.68022	0.99667	3080.16611	0.9918
3233.15449	0.99756	3155.64038	0.99699	3078.12626	0.99125

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
3065.88719	0.98938	2988.37308	0.96544	2910.85897	0.63354
3063.84735	0.98885	2986.33323	0.96181	2908.81912	0.6524
3061.8075	0.98857	2984.29339	0.95671	2906.77928	0.66918
3059.76766	0.98859	2982.25354	0.95055	2904.73943	0.68438
3057.72781	0.98863	2980.2137	0.94334	2902.69958	0.69851
3055.68797	0.98844	2978.17385	0.93417	2900.65974	0.7118
3053.64812	0.98813	2976.13401	0.92258	2898.61989	0.72458
3051.60828	0.98778	2974.09416	0.90876	2896.58005	0.73755
3049.56843	0.98733	2972.05432	0.8925	2894.5402	0.75095
3047.52859	0.98712	2970.01447	0.87337	2892.50036	0.76464
3045.48874	0.9873	2967.97463	0.85162	2890.46051	0.77856
3043.4489	0.98739	2965.93478	0.82831	2888.42067	0.79222
3227.03496	0.99782	3149.52084	0.9963	3072.00673	0.99083
3224.99511	0.99725	3147.481	0.99612	3069.96688	0.99041
3041.40905	0.98703	2963.89494	0.80484	2886.38082	0.80446
3039.36921	0.98641	2961.85509	0.7826	2884.34098	0.81386
3037.32936	0.98586	2959.81525	0.76274	2882.30113	0.81925
3035.28952	0.98537	2957.7754	0.74638	2880.26129	0.81992
3033.24967	0.98491	2955.73556	0.73486	2878.22144	0.81502
3031.20983	0.98464	2953.69571	0.7299	2876.1816	0.80433
3029.16998	0.98449	2951.65587	0.73215	2874.14175	0.7905
3027.13014	0.98419	2949.61602	0.73967	2872.10191	0.77842
3025.09029	0.98375	2947.57618	0.74886	2870.06206	0.77133
3023.05045	0.9833	2945.53633	0.75587	2868.02222	0.76814
3021.0106	0.98276	2943.49649	0.75756	2865.98237	0.76529
3018.97076	0.98215	2941.45664	0.7524	2863.94253	0.75934
3016.93091	0.98161	2939.4168	0.74011	2861.90268	0.74811

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
3027.13014	0.98419	2949.61602	0.73967	2872.10191	0.77842
3025.09029	0.98375	2947.57618	0.74886	2870.06206	0.77133
3023.05045	0.9833	2945.53633	0.75587	2868.02222	0.76814
3021.0106	0.98276	2943.49649	0.75756	2865.98237	0.76529
3018.97076	0.98215	2941.45664	0.7524	2863.94253	0.75934
3016.93091	0.98161	2939.4168	0.74011	2861.90268	0.74811
3029.16998	0.98449	2951.65587	0.73215	2874.14175	0.7905
3027.13014	0.98419	2949.61602	0.73967	2872.10191	0.77842
3025.09029	0.98375	2947.57618	0.74886	2870.06206	0.77133
3023.05045	0.9833	2945.53633	0.75587	2868.02222	0.76814
3021.0106	0.98276	2943.49649	0.75756	2865.98237	0.76529
3018.97076	0.98215	2941.45664	0.7524	2863.94253	0.75934
3016.93091	0.98161	2939.4168	0.74011	2861.90268	0.74811
3012.85122	0.98014	2935.33711	0.69808	2857.82299	0.7123
3010.81138	0.97975	2933.29726	0.67159	2855.78315	0.69346
3008.77153	0.97951	2931.25742	0.64319	2853.7433	0.68145
3006.73169	0.97905	2929.21757	0.61416	2851.70346	0.68261
3004.69184	0.97834	2927.17773	0.58653	2849.66361	0.69857
3002.652	0.97751	2925.13788	0.56351	2847.62377	0.72525
3000.61215	0.97691	2923.09804	0.54882	2845.58392	0.75681
2998.5723	0.97623	2921.05819	0.5454	2843.54408	0.78906
2994.49261	0.97308	2916.9785	0.56995	2839.46439	0.84915
2992.45277	0.97077	2914.93866	0.59084	2837.42454	0.87461
2990.41292	0.96819	2912.89881	0.6127	2835.3847	0.89561
3065.88719	0.98938	2988.37308	0.96544	2910.85897	0.63354
3063.84735	0.98885	2986.33323	0.96181	2908.81912	0.6524

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance	Wavelength (cm^{-1})	Transmittance
3055.68797	0.98844	2978.17385	0.93417	2900.65974	0.7118
3053.64812	0.98813	2976.13401	0.92258	2898.61989	0.72458
3051.60828	0.98778	2974.09416	0.90876	2896.58005	0.73755
3049.56843	0.98733	2972.05432	0.8925	2894.5402	0.75095
3047.52859	0.98712	2970.01447	0.87337	2892.50036	0.76464
3045.48874	0.9873	2967.97463	0.85162	2890.46051	0.77856
3043.4489	0.98739	2965.93478	0.82831	2888.42067	0.79222
3041.40905	0.98703	2963.89494	0.80484	2886.38082	0.80446
3039.36921	0.98641	2961.85509	0.7826	2884.34098	0.81386
3037.32936	0.98586	2959.81525	0.76274	2882.30113	0.81925
3035.28952	0.98537	2957.7754	0.74638	2880.26129	0.81992
3033.24967	0.98491	2955.73556	0.73486	2878.22144	0.81502
3031.20983	0.98464	2953.69571	0.7299	2876.1816	0.80433
3029.16998	0.98449	2951.65587	0.73215	2874.14175	0.7905
3027.13014	0.98419	2949.61602	0.73967	2872.10191	0.77842
3025.09029	0.98375	2947.57618	0.74886	2870.06206	0.77133
3023.05045	0.9833	2945.53633	0.75587	2868.02222	0.76814
3021.0106	0.98276	2943.49649	0.75756	2865.98237	0.76529
3018.97076	0.98215	2941.45664	0.7524	2863.94253	0.75934
3016.93091	0.98161	2939.4168	0.74011	2861.90268	0.74811
3014.89107	0.98091	2937.37695	0.72145	2859.86284	0.73177
3012.85122	0.98014	2935.33711	0.69808	2857.82299	0.7123
3010.81138	0.97975	2933.29726	0.67159	2855.78315	0.69346
3006.73169	0.97905	2929.21757	0.61416	2851.70346	0.68261
3004.69184	0.97834	2927.17773	0.58653	2849.66361	0.69857
3002.652	0.97751	2925.13788	0.56351	2847.62377	0.72525
3000.61215	0.97691	2923.09804	0.54882	2845.58392	0.75681

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
2994.49261	0.97308	2916.9785	0.56995	2839.46439	0.84915
2992.45277	0.97077	2914.93866	0.59084	2837.42454	0.87461
2990.41292	0.96819	2912.89881	0.6127	2835.3847	0.89561
2833.34485	0.91237	2755.83074	0.99005	2678.31662	0.98987
2831.30501	0.92524	2753.79089	0.98982	2676.27678	0.9896
2829.26516	0.93467	2751.75105	0.98994	2674.23693	0.98927
2827.22532	0.9421	2749.7112	0.98989	2672.19709	0.989
2825.18547	0.94849	2747.67136	0.98941	2670.15724	0.98883
2823.14563	0.95368	2745.63151	0.98891	2668.1174	0.98879
2821.10578	0.95776	2743.59167	0.98879	2666.07755	0.98902
2819.06594	0.96132	2741.55182	0.98884	2664.03771	0.98945
2817.02609	0.96457	2739.51198	0.98884	2661.99786	0.98979
2814.98625	0.9673	2737.47213	0.98876	2659.95802	0.98996
2812.9464	0.96945	2735.43229	0.98845	2657.91817	0.99015
2810.90656	0.97129	2733.39244	0.98786	2655.87833	0.99047
2808.86671	0.97291	2731.3526	0.9873	2653.83848	0.99067
2806.82686	0.9744	2729.31275	0.98708	2651.79864	0.99059
2804.78702	0.97585	2727.27291	0.98725	2649.75879	0.99063
2802.74717	0.97712	2725.23306	0.98754	2647.71895	0.9911
2800.70733	0.97827	2723.19322	0.98767	2645.6791	0.99162
2798.66748	0.97956	2721.15337	0.98769	2643.63926	0.99174
2796.62764	0.98077	2719.11353	0.98795	2641.59941	0.99175
2794.58779	0.98149	2717.07368	0.98845	2639.55957	0.99187
2792.54795	0.98202	2715.03384	0.98891	2637.51972	0.99184
2790.5081	0.98273	2712.99399	0.98933	2635.47988	0.99175
2788.46826	0.98356	2710.95415	0.98964	2633.44003	0.99173
2786.42841	0.98443	2708.9143	0.98976	2631.40019	0.99163

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
2780.30888	0.98616	2702.79476	0.9903	2625.28065	0.99208
2776.22919	0.98741	2698.71507	0.99034	2621.20096	0.99208
2774.18934	0.98796	2696.67523	0.99052	2619.16112	0.99219
2770.10965	0.98858	2692.59554	0.98976	2615.08143	0.99256
2768.06981	0.98895	2690.55569	0.98976	2613.04158	0.99274
2766.02996	0.98921	2688.51585	0.9901	2611.0013	0.99281
2763.99012	0.98929	2686.476	0.99003	2608.96189	0.99274
2761.95027	0.98967	2684.43616	0.98964	2606.92204	0.99268
2759.91043	0.9903	2682.39631	0.98959	2604.8822	0.99261
2757.87058	0.99045	2680.35647	0.98985	2602.84235	0.9925
2600.80251	0.99285	2523.2884	0.99609	2445.77428	0.99782
2598.76266	0.99371	2521.24855	0.99638	2443.73444	0.99865
2596.72282	0.99412	2519.20871	0.9965	2441.69459	0.99834
2594.68297	0.99374	2517.16886	0.99633	2439.65475	0.9979
2592.64313	0.99341	2515.12901	0.99646	2437.6149	0.99766
2590.60328	0.99358	2513.08917	0.99685	2435.57506	0.99781
2588.56344	0.99385	2511.04932	0.9969	2433.53521	0.99812
2586.52359	0.99399	2509.00948	0.99658	2431.49537	0.99762
2584.48375	0.99385	2506.96963	0.99646	2429.45552	0.99688
2582.4439	0.99383	2504.92979	0.99671	2427.41568	0.99691
2580.40406	0.99452	2502.88994	0.99697	2425.37583	0.99702
2578.36421	0.9953	2500.8501	0.99703	2423.33599	0.99661
2576.32437	0.99541	2498.81025	0.99706	2421.29614	0.99626
2574.28452	0.99496	2496.77041	0.99689	2419.25629	0.99604
2572.24468	0.99454	2494.73056	0.99647	2417.21645	0.9958
2570.20483	0.99467	2492.69072	0.99659	2415.1766	0.99577
2568.16499	0.9954	2490.65087	0.99732	2413.13676	0.99597

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
2562.04545	0.99732	2484.53134	0.9968	2407.01722	0.99579
2560.00561	0.99733	2482.49149	0.99702	2404.97738	0.99585
2557.96576	0.99712	2480.45165	0.99754	2402.93753	0.99584
2555.92592	0.99654	2478.4118	0.99817	2400.89769	0.99573
2553.88607	0.99565	2476.37196	0.99787	2398.85784	0.99609
2551.84623	0.99517	2474.33211	0.997	2396.818	0.99658
2549.80638	0.99567	2472.29227	0.99689	2394.77815	0.99661
2547.76654	0.99652	2470.25242	0.99712	2392.73831	0.99642
2545.72669	0.99646	2468.21258	0.99697	2390.69846	0.99634
2543.68685	0.99585	2466.17273	0.99703	2388.65862	0.99633
2541.647	0.99577	2464.13289	0.99744	2386.61877	0.99631
2539.60716	0.99607	2462.09304	0.99769	2384.57893	0.9964
2535.52747	0.99558	2458.01335	0.99709	2380.49924	0.99587
2533.48762	0.99533	2455.97351	0.99696	2378.45939	0.99528
2531.44778	0.99557	2453.93366	0.99707	2376.41955	0.99555
2527.36809	0.9961	2449.85397	0.99643	2372.33986	0.99654
2525.32824	0.99609	2447.81413	0.99656	2370.30001	0.99663
2368.26017	0.99712	2292.7859	0.99581	2217.31163	1.00059
2366.22032	0.99717	2290.74605	0.99624	2215.27178	0.99932
2364.18048	0.9958	2288.70621	0.99676	2213.23194	0.9981
2362.14063	0.9936	2286.66636	0.99696	2211.19209	0.99873
2360.10079	0.99276	2284.62652	0.99656	2209.15225	1.00024
2358.06094	0.99571	2282.58667	0.99568	2207.1124	1.00076
2356.0211	0.99865	2280.54683	0.99517	2205.07256	1.00088

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
2133.67798	0.99782	2056.16387	0.99849	1978.64975	1.00035
2131.63814	0.99773	2054.12402	0.99736	1976.60991	1.00015
2129.59829	0.99825	2052.08418	0.99597	1974.57006	1.00033
2127.55844	0.99854	2050.04433	0.99458	1972.53022	1.0009
2125.5186	0.99847	2048.00449	0.99451	1970.49037	1.00047
2123.47875	0.9978	2045.96464	0.99619	1968.45053	0.99953
2121.43891	0.99748	2043.9248	0.99721	1966.41068	0.99899
2119.39906	0.99841	2041.88495	0.99705	1964.37084	0.99939
2117.35922	0.9987	2039.84511	0.99765	1962.33099	0.99897
2115.31937	0.99786	2037.80526	0.99732	1960.29115	0.99751
2113.27953	0.9972	2035.76542	0.99509	1958.2513	0.9968
2111.23968	0.99654	2033.72557	0.99489	1956.21146	0.99633
2109.19984	0.99619	2031.68572	0.99668	1954.17161	0.99553
2107.15999	0.9971	2029.64588	0.99685	1952.13177	0.9948
2105.12015	0.99832	2027.60603	0.99634	1950.09192	0.99492
2103.0803	0.99805	2025.56619	0.99749	1948.05208	0.99595
2101.04046	0.99682	2023.52634	0.99936	1946.01223	0.99618
2099.00061	0.99658	2021.4865	0.9996	1943.97239	0.99469
2096.96077	0.99699	2019.44665	0.99693	1941.93254	0.99354
2094.92092	0.99742	2017.40681	0.99437	1939.8927	0.99512
2092.88108	0.99853	2015.36696	0.99591	1937.85285	0.9976
2090.84123	0.99962	2013.32712	0.99905	1935.813	0.99802
2088.80139	0.99983	2011.28727	1.00069	1933.77316	0.9973
2086.76154	0.99899	2009.24743	1.00069	1931.73331	0.99749
2084.7217	0.99751	2007.20758	0.99902	1929.69347	0.9975
2082.68185	0.99673	2005.16774	0.9974	1927.65362	0.9966
2080.64201	0.99694	2003.12789	0.99818	1925.61378	0.99637

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
2074.52247	0.99785	1997.00836	0.99984	1919.49424	0.99621
2072.48263	0.9982	1994.96851	0.99834	1917.4544	0.99552
2070.44278	0.99834	1992.92867	0.99701	1915.41455	0.99517
2068.40294	0.99798	1990.88882	0.99612	1913.37471	0.99476
2066.36309	0.99751	1988.84898	0.99611	1911.33486	0.99454
1909.29502	0.99519	1831.7809	0.9942	1754.26679	0.99176
1907.25517	0.99593	1829.74106	0.99421	1752.22695	0.99119
1905.21533	0.99614	1827.70121	0.9937	1750.1871	0.99055
1903.17548	0.9963	1825.66137	0.99336	1748.14726	0.98993
1901.13564	0.99608	1823.62152	0.99367	1746.10741	0.98938
1899.09579	0.99561	1821.58168	0.99386	1744.06757	0.9888
1897.05595	0.99558	1819.54183	0.99365	1742.02772	0.98804
1895.0161	0.99581	1817.50199	0.99367	1739.98787	0.9872
1892.97626	0.99596	1815.46214	0.99363	1737.94803	0.98681
1890.93641	0.99626	1813.4223	0.99331	1735.90818	0.98683
1888.89657	0.99643	1811.38245	0.99334	1733.86834	0.98703
1886.85672	0.99593	1809.34261	0.99393	1731.82849	0.98778
1884.81688	0.99572	1807.30276	0.99429	1729.78865	0.98865
1882.77703	0.99588	1805.26292	0.99416	1727.7488	0.98905
1880.73719	0.99533	1803.22307	0.99388	1725.70896	0.98914
1878.69734	0.99473	1801.18323	0.99362	1723.66911	0.98929
1876.6575	0.99505	1799.14338	0.99344	1721.62927	0.98942
1874.61765	0.99554	1797.10354	0.99304	1719.58942	0.98937
1872.57781	0.99554	1795.06369	0.99275	1717.54958	0.9896
1870.53796	0.99527	1793.02385	0.99318	1715.50973	0.98978
1868.49812	0.99541	1790.984	0.99339	1713.46989	0.98941
1866.45827	0.9957	1788.94416	0.99294	1711.43004	0.98916

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
1858.29889	0.99414	1780.78478	0.9923	1703.27066	0.9902
1856.25905	0.99464	1778.74493	0.99208	1701.23082	0.99082
1854.2192	0.99517	1776.70509	0.99202	1699.19097	0.9915
1852.17936	0.99495	1774.66524	0.99188	1697.15113	0.99098
1850.13951	0.99444	1772.6254	0.99207	1695.11128	0.99012
1848.09967	0.99427	1770.58555	0.99241	1693.07144	0.9897
1844.01998	0.99446	1766.50586	0.99164	1688.99175	0.98947
1841.98013	0.99493	1764.46602	0.99176	1686.9519	0.98964
1839.94029	0.99513	1762.42617	0.99207	1684.91206	0.98995
1837.90044	0.99469	1760.38633	0.99222	1682.87221	0.99021
1835.86059	0.99404	1758.34648	0.9923	1680.83237	0.99006
1833.82075	0.99393	1756.30664	0.99218	1678.79252	0.98971
1676.75268	0.9894	1599.23856	0.98001	1521.72445	0.9825
1674.71283	0.98914	1597.19872	0.98128	1519.6846	0.98126
1672.67299	0.98901	1595.15887	0.98236	1517.64476	0.97937
1670.63314	0.98922	1593.11903	0.98316	1515.60491	0.97727
1668.5933	0.9896	1591.07918	0.98368	1513.56507	0.9759
1666.55345	0.98972	1589.03934	0.9838	1511.52522	0.97522
1664.51361	0.98958	1586.99949	0.98379	1509.48538	0.9749
1662.47376	0.98915	1584.95965	0.98398	1507.44553	0.97443
1660.43392	0.98873	1582.9198	0.98422	1505.40569	0.97326
1658.39407	0.98872	1580.87996	0.9844	1503.36584	0.97266
1656.35423	0.98896	1578.84011	0.98462	1501.326	0.97234
1654.31438	0.98899	1576.80027	0.98484	1499.28615	0.9716
1652.27454	0.98832	1574.76042	0.985	1497.24631	0.97001
1650.23469	0.98788	1572.72058	0.98517	1495.20646	0.96834
1648.19485	0.98743	1570.68073	0.98547	1493.16662	0.96743

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
1642.07531	0.98586	1564.5612	0.98622	1487.04708	0.96269
1640.03546	0.98584	1562.52135	0.98624	1485.00724	0.96008
1637.99562	0.98622	1560.48151	0.98652	1482.96739	0.95633
1635.95577	0.98702	1558.44166	0.98634	1480.92755	0.95121
1633.91593	0.9871	1556.40182	0.98594	1478.8877	0.94529
1631.87608	0.98685	1554.36197	0.98614	1476.84786	0.93798
1629.83624	0.98695	1552.32213	0.98628	1474.80801	0.92595
1627.79639	0.98696	1550.28228	0.98612	1472.76817	0.9001
1625.75655	0.98661	1548.24243	0.9859	1470.72832	0.86566
1623.7167	0.98625	1546.20259	0.98576	1468.68848	0.83979
1621.67686	0.98576	1544.16274	0.98564	1466.64863	0.82053
1619.63701	0.98498	1542.1229	0.98565	1464.60879	0.80683
1617.59717	0.98385	1540.08305	0.98508	1462.56894	0.79959
1615.55732	0.98248	1538.04321	0.98429	1460.5291	0.79536
1613.51748	0.98166	1536.00336	0.98429	1458.48925	0.79276
1611.47763	0.98113	1533.96352	0.98452	1456.44941	0.79555
1609.43779	0.98051	1531.92367	0.98454	1454.40956	0.80325
1607.39794	0.97986	1529.88383	0.98437	1452.36972	0.81269
1603.31825	0.97889	1525.80414	0.98356	1448.29002	0.83656
1601.27841	0.97904	1523.76429	0.98314	1446.25018	0.85015
1444.21033	0.86303	1366.69622	0.91946	1289.18211	0.9639
1442.17049	0.87597	1364.65638	0.92374	1287.14226	0.96452
1440.13064	0.88808	1362.61653	0.9339	1285.10242	0.96533
1438.0908	0.89972	1360.57669	0.94481	1283.06257	0.96591
1436.05095	0.91376	1358.53684	0.95096	1281.02273	0.96606
1434.01111	0.92551	1356.497	0.95405	1278.98288	0.9659
1431.97126	0.93415	1354.45715	0.95568	1276.94304	0.96575

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
1427.89157	0.95021	1350.37746	0.9575	1272.86335	0.96561
1425.85173	0.95473	1348.33761	0.95842	1270.8235	0.9658
1423.81188	0.95838	1346.29777	0.95891	1268.78366	0.96639
1421.77204	0.96113	1344.25792	0.95901	1266.74381	0.96694
1419.73219	0.96314	1342.21808	0.95909	1264.70397	0.96744
1417.69235	0.96514	1340.17823	0.95972	1262.66412	0.9683
1415.6525	0.96651	1338.13839	0.96103	1260.62428	0.96919
1413.61266	0.9673	1336.09854	0.96244	1258.58443	0.96954
1411.57281	0.96795	1334.0587	0.96381	1256.54458	0.96972
1409.53297	0.96865	1332.01885	0.96512	1254.50474	0.97012
1407.49312	0.96934	1329.97901	0.96621	1252.46489	0.97052
1405.45328	0.96986	1327.93916	0.96693	1250.42505	0.97077
1403.41343	0.97019	1325.89932	0.96723	1248.3852	0.97106
1401.37359	0.9703	1323.85947	0.9672	1246.34536	0.97137
1399.33374	0.97008	1321.81963	0.96694	1244.30551	0.97157
1397.2939	0.96957	1319.77978	0.96665	1242.26567	0.97179
1395.25405	0.96832	1317.73994	0.96653	1240.22582	0.97209
1393.21421	0.96569	1315.70009	0.96638	1238.18598	0.97229
1391.17436	0.96165	1313.66025	0.96584	1236.14613	0.97236
1389.13452	0.95491	1311.6204	0.96501	1234.10629	0.97256
1387.09467	0.94271	1309.58056	0.96425	1232.06644	0.97291
1385.05483	0.92769	1307.54071	0.96383	1230.0266	0.97307
1383.01498	0.91386	1305.50087	0.96368	1227.98675	0.97301
1380.97514	0.89893	1303.46102	0.96348	1225.94691	0.97293
1378.93529	0.88388	1301.42118	0.9633	1223.90706	0.97287
1376.89545	0.87653	1299.38133	0.96334	1221.86722	0.97287
1372.81576	0.89899	1295.30164	0.96342	1217.78753	0.97262

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
1211.66799	0.97236	1134.15388	0.97093	1056.63976	0.96946
1209.62815	0.97243	1132.11403	0.9708	1054.59992	0.96908
1207.5883	0.9725	1130.07419	0.97092	1052.56007	0.96882
1205.54846	0.97242	1128.03434	0.97113	1050.52023	0.96887
1203.50861	0.97238	1125.9945	0.97126	1048.48038	0.96875
1201.46877	0.97269	1123.95465	0.97141	1046.44054	0.96829
1199.42892	0.97305	1121.91481	0.97179	1044.40069	0.96765
1197.38908	0.97303	1119.87496	0.97235	1042.36085	0.9671
1195.34923	0.97269	1117.83512	0.97283	1040.321	0.96641
1193.30939	0.97223	1115.79527	0.97305	1038.28116	0.96529
1191.26954	0.97183	1113.75543	0.97324	1036.24131	0.96442
1189.2297	0.97163	1111.71558	0.97349	1034.20147	0.96425
1187.18985	0.97161	1109.67574	0.97339	1032.16162	0.96436
1185.15001	0.97156	1107.63589	0.97297	1030.12178	0.9647
1183.11016	0.97141	1105.59605	0.97281	1028.08193	0.96544
1181.07032	0.97129	1103.5562	0.97271	1026.04209	0.96607
1179.03047	0.97129	1101.51636	0.97253	1024.00224	0.96606
1176.99063	0.97103	1099.47651	0.97254	1021.9624	0.96577
1174.95078	0.97021	1097.43667	0.97227	1019.92255	0.96579
1172.91094	0.96913	1095.39682	0.97168	1017.88271	0.96603
1170.87109	0.96818	1093.35698	0.97141	1015.84286	0.96643
1168.83125	0.96748	1091.31713	0.9715	1013.80302	0.96684
1166.7914	0.96714	1089.27729	0.97157	1011.76317	0.96684
1164.75156	0.96728	1087.23744	0.97146	1009.72333	0.96671
1162.71171	0.96779	1085.1976	0.97116	1007.68348	0.96681
1160.67186	0.96821	1083.15775	0.97055	1005.64364	0.96681
1158.63202	0.96828	1081.11791	0.96945	1003.60379	0.96633

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
1152.51248	0.96919	1074.99837	0.96759	997.48426	0.96416
1150.47264	0.96988	1072.95853	0.96802	995.44441	0.96423
1148.43279	0.96998	1070.91868	0.96825	993.40457	0.96485
1146.39295	0.96994	1068.87884	0.96831	991.36472	0.96536
1142.31326	0.9709	1064.79915	0.9684	987.28503	0.9664
1140.27341	0.97133	1062.7593	0.96849	985.24519	0.96648
1138.23357	0.97144	1060.71945	0.9688	983.20534	0.96593
1136.19372	0.97123	1058.67961	0.9693	981.1655	0.96536
979.12565	0.96512	901.61154	0.96155	824.09742	0.95431
977.08581	0.96496	899.57169	0.96178	822.05758	0.95108
975.04596	0.96451	897.53185	0.96105	820.01773	0.94915
973.00612	0.96383	895.492	0.96008	817.97789	0.94774
970.96627	0.96334	893.45216	0.95938	815.93804	0.94533
968.92643	0.96284	891.41231	0.95871	813.8982	0.94122
966.88658	0.96186	889.37247	0.95817	811.85835	0.93684
964.84673	0.96115	887.33262	0.95802	809.81851	0.93532
962.80689	0.9612	885.29278	0.95799	807.77866	0.93754
960.76704	0.96149	883.25293	0.95779	805.73882	0.94159
958.7272	0.96188	881.21309	0.9576	803.69897	0.94573
956.68735	0.9624	879.17324	0.95766	801.65913	0.94964
954.64751	0.96285	877.1334	0.95777	799.61928	0.95393
952.60766	0.96325	875.09355	0.9574	797.57944	0.95745
950.56782	0.96365	873.05371	0.95673	795.53959	0.95815
948.52797	0.96402	871.01386	0.95665	793.49975	0.95646
946.48813	0.96424	868.97401	0.95704	791.4599	0.95364
944.44828	0.96425	866.93417	0.95746	789.42006	0.95112
942.40844	0.96429	864.89432	0.95835	787.38021	0.94956

APPENDIX K1 Wavenumbers vrs Transmittances of Crude Oil Continued)

Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance	Wavennumber (cm^{-1})	Transmittance
936.2889	0.96429	858.77479	0.95987	781.26068	0.94286
934.24906	0.96419	856.73494	0.96005	779.22083	0.9455
932.20921	0.96424	854.6951	0.96036	777.18099	0.94786
930.16937	0.96429	852.65525	0.95975	775.14114	0.94725
928.12952	0.96457	850.61541	0.95794	773.10129	0.94458
926.08968	0.96461	848.57556	0.95638	771.06145	0.94217
924.04983	0.96426	846.53572	0.95615	769.0216	0.94145
922.00999	0.96373	844.49587	0.95699	766.98176	0.94137
919.97014	0.96306	842.45603	0.95838	764.94191	0.94163
917.9303	0.96262	840.41618	0.9601	762.90207	0.94291
915.89045	0.96221	838.37634	0.96145	760.86222	0.94427
909.77092	0.95584	832.2568	0.95814	754.74269	0.94141
907.73107	0.95604	830.21696	0.95907	752.70284	0.93775
905.69123	0.95813	828.17711	0.95976	750.663	0.93418
746.58331	0.92767	705.78641	0.95113	664.9895	0.96912
744.54346	0.92507	703.74656	0.95046	662.94966	0.96915
742.50362	0.92335	701.70672	0.94999	660.90981	0.96888
740.46377	0.92242	699.66687	0.94974	658.86997	0.96759
738.42393	0.92337	697.62703	0.95108	656.83012	0.96639
736.38408	0.9267	695.58718	0.9551	654.79028	0.96691
734.34424	0.9304	693.54734	0.96008	652.75043	0.96872
732.30439	0.93204	691.50749	0.96392	650.71059	0.96949
730.26455	0.93101	689.46765	0.96567	648.67074	0.96852
728.2247	0.92833	687.4278	0.96601	646.6309	0.9675
726.18486	0.92412	685.38796	0.96688	644.59105	0.96754
724.14501	0.91847	683.34811	0.96816	642.55121	0.96752
722.10517	0.91512	681.30827	0.96888	640.51136	0.96661

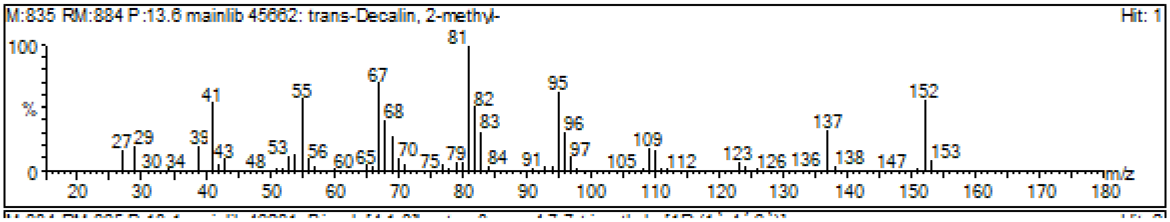
APPENDIX K2 QUALITATIVE REPORT OF CRUDE OIL

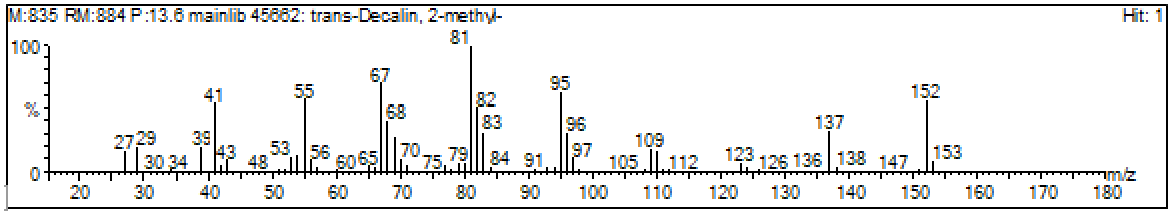
#	RT	Scan	Height	Area	Area %	Norm %	Name
1	12.940	994	1,354,681,344	146,274,176.0	0.638	13.60	
2	13.591	1059	804,514,432	100,156,928.0	0.437	9.31	
3	14.541	1154	584,794,688	96,100,768.0	0.419	8.94	
4	15.521	1252	927,133,184	155,651,488.0	0.679	14.47	
5	15.901	1290	510,775,168	99,772,512.0	0.435	9.28	
6	16.151	1315	2,475,177,472	351,061,856.0	1.531	32.64	
7	16.501	1350	1,528,998,912	142,872,224.0	0.623	13.28	
8	17.211	1421	619,830,592	102,950,200.0	0.449	9.57	
9	17.701	1470	615,617,856	107,083,224.0	0.467	9.96	
10	17.921	1492	844,047,040	110,565,928.0	0.482	10.28	Heptadecanoic acid,
11	18.211	1521	1,847,432,704	278,747,200.0	1.216	25.92	
12	18.872	1587	2,822,098,176	392,159,776.0	1.710	36.46	
13	19.132	1613	3,569,630,720	529,232,064.0	2.308	49.21	
14	19.372	1637	1,928,662,656	230,455,856.0	1.005	21.43	
15	19.472	1647	1,209,333,248	119,669,592.0	0.522	11.13	
16	20.112	1711	1,045,413,632	182,462,768.0	0.796	16.97	
17	20.402	1740	858,824,768	112,981,480.0	0.493	10.50	
18	20.832	1783	1,161,350,784	157,425,312.0	0.687	14.64	
19	21.072	1807	2,055,257,984	405,696,576.0	1.769	37.72	
20	21.852	1885	5,193,686,528	1,072,120,768.0	4.676	99.68	
21	21.982	1898	1,638,787,968	161,035,696.0	0.702	14.97	
22	22.422	1942	3,948,647,680	737,415,680.0	3.216	68.56	

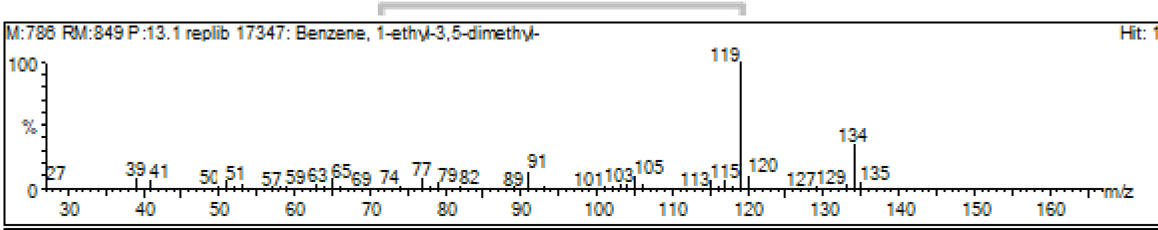
APPENDIX K2 Qualitative Report of Crude Oil (Continued)

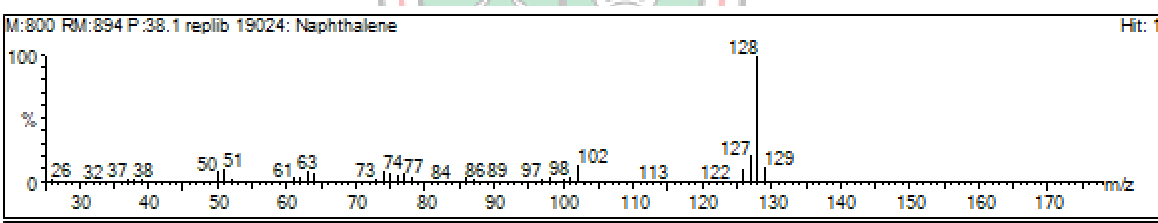
#	RT	Scan	Height	Area	Area %	Norm %	Name
23	22.842	1984	1,524,066,432	266,953,376.0	1.164	24.82	
24	23.142	2014	2,073,561,216	134,163,296.0	0.585	12.47	
25	23.323	2032	3,645,792,000	614,831,936.0	2.681	57.17	
26	23.483	2048	1,055,349,312	106,410,008.0	0.464	9.89	
27	24.383	2138	4,770,347,008	957,554,112.0	4.176	89.03	
28	24.463	2146	1,351,855,616	171,142,432.0	0.746	15.91	
29	24.943	2194	1,402,988,800	107,015,880.0	0.467	9.95	
30	25.093	2209	1,782,225,024	129,860,648.0	0.566	12.07	cis-11,14-Eicosadienoic
31	25.493	2249	2,362,803,456	429,358,304.0	1.873	39.92	
32	25.753	2275	1,264,211,328	121,690,752.0	0.531	11.31	
33	25.873	2287	2,033,686,400	196,864,992.0	0.859	18.30	
34	26.353	2335	1,208,186,752	153,387,696.0	0.669	14.26	
35	26.743	2374	4,541,894,656	888,612,736.0	3.876	82.62	
36	26.803	2380	1,097,641,984	150,657,280.0	0.657	14.01	
37	27.723	2472	3,215,412,992	433,691,104.0	1.891	40.32	
38	27.863	2486	1,689,744,128	153,786,752.0	0.671	14.30	
39	29.004	2600	5,151,209,472	1,075,516,928.0	4.691	100.00	
40	29.104	2610	5,238,583,808	442,183,904.0	1.929	41.11	4,7,10,13,16,19-
41	29.724	2672	1,141,398,656	148,420,832.0	0.647	13.80	
42	31.084	2808	3,107,750,912	480,373,920.0	2.095	44.66	
43	31.234	2823	3,761,773,056	274,753,312.0	1.198	25.55	
44	32.214	2921	1,031,108,096	101,717,136.0	0.444	9.46	
45	32.784	2978	1,144,857,344	141,304,272.0	0.616	13.14	
46	33.084	3008	4,371,640,832	647,064,896.0	2.822	60.16	
47	34.985	3198	3,859,720,192	512,265,120.0	2.234	47.63	
48	36.245	3324	817,452,928	105,531,616.0	0.460	9.81	
49	36.815	3381	3,984,199,424	461,154,944.0	2.011	42.88	
50	38.566	3556	3,353,279,744	368,966,016.0	1.609	34.31	
51	40.246	3724	3,335,604,224	298,427,744.0	1.302	27.75	
52	41.846	3884	2,691,655,424	231,635,504.0	1.010	21.54	
53	43.397	4039	2,245,594,368	162,319,472.0	0.708	15.09	
54	44.127	4112	704,030,784	131,489,712.0	0.573	12.23	
55	44.737	4173	1,060,168,768	141,015,264.0	0.615	13.11	
56	44.887	4188	2,042,361,600	173,482,784.0	0.757	16.13	
57	45.337	4233	793,537,280	159,044,576.0	0.694	14.79	
58	45.777	4277	1,054,894,016	163,298,592.0	0.712	15.18	
59	46.197	4319	1,240,074,112	316,517,088.0	1.380	29.43	

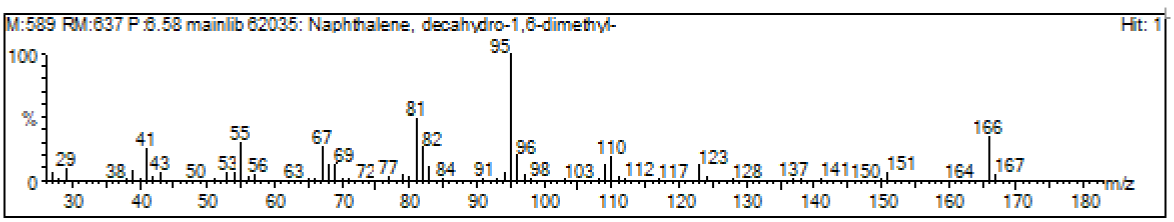
APPENDIX K3 CRUDE OIL CHROMATOGRAM/SPECTRUM

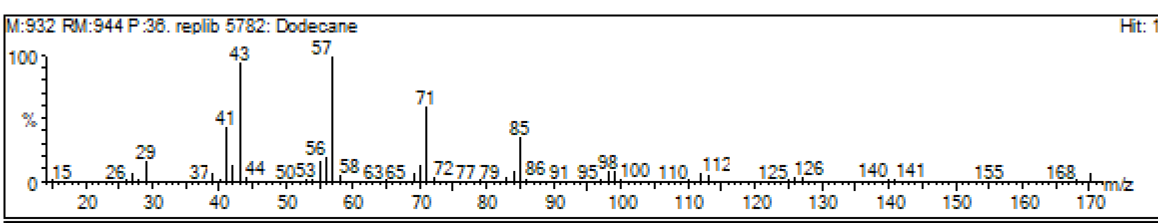




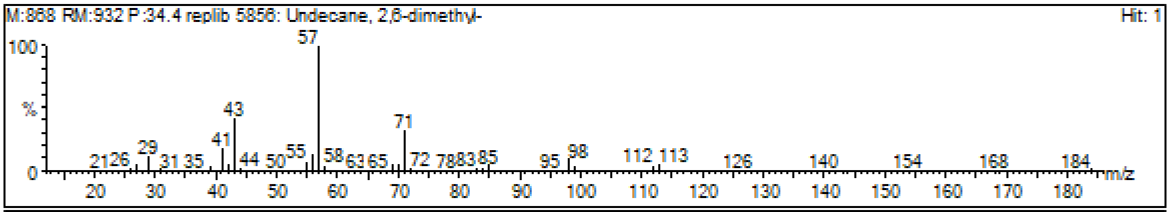


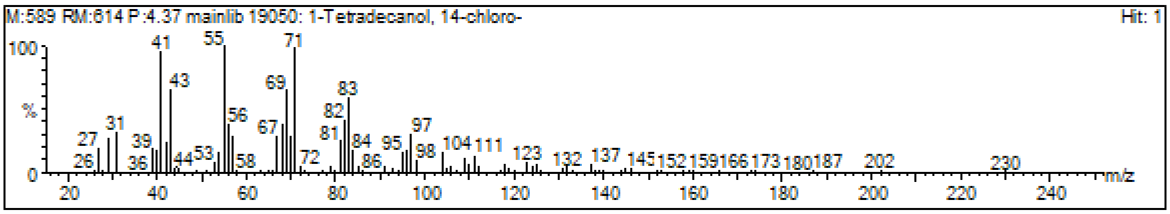


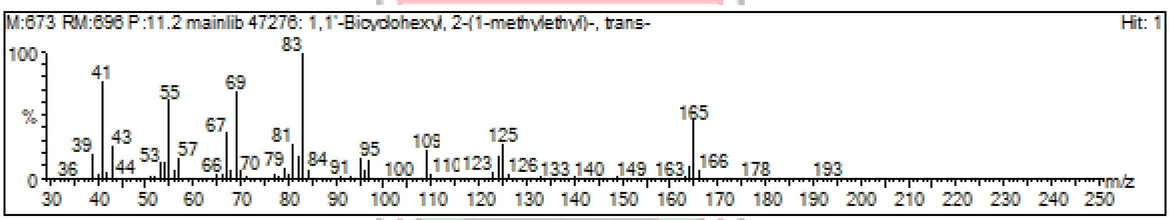


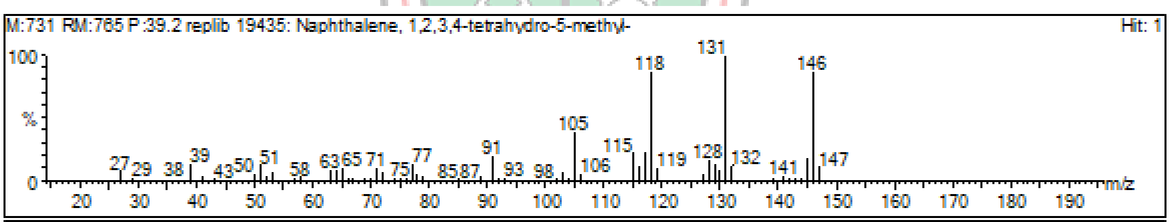


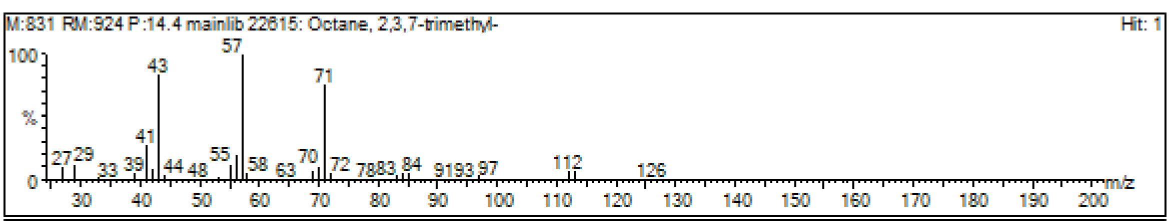
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

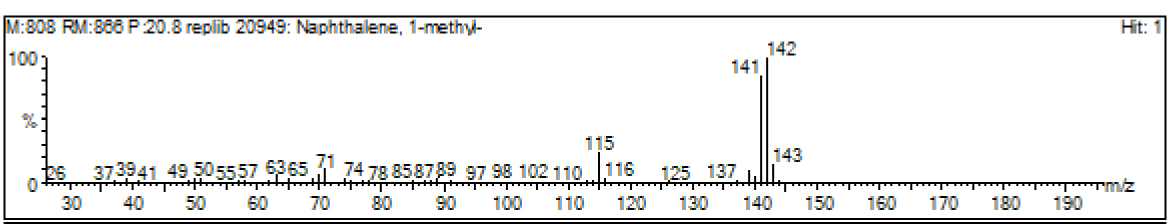




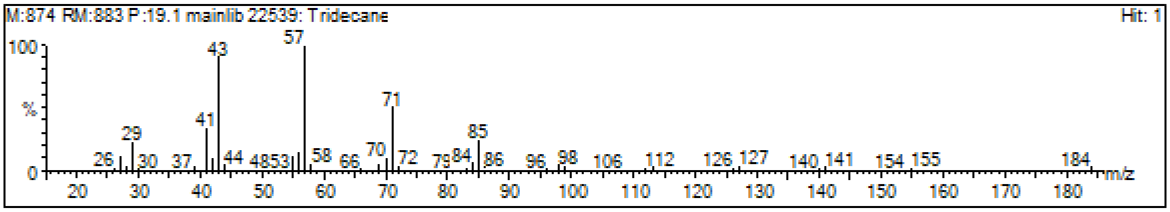


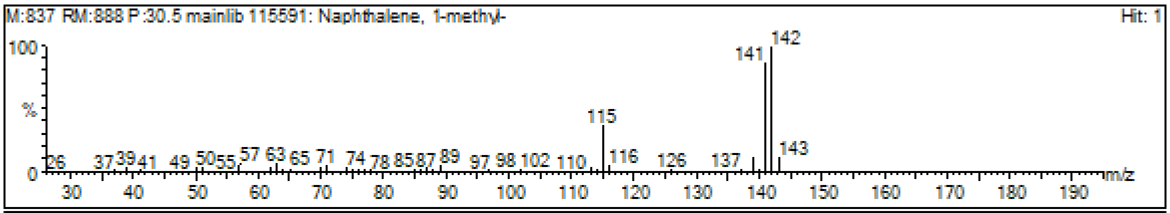


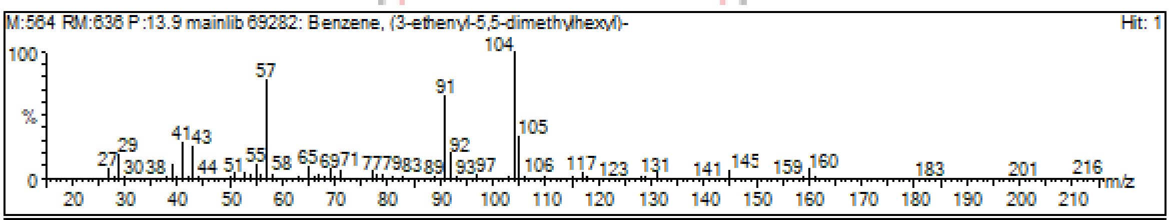


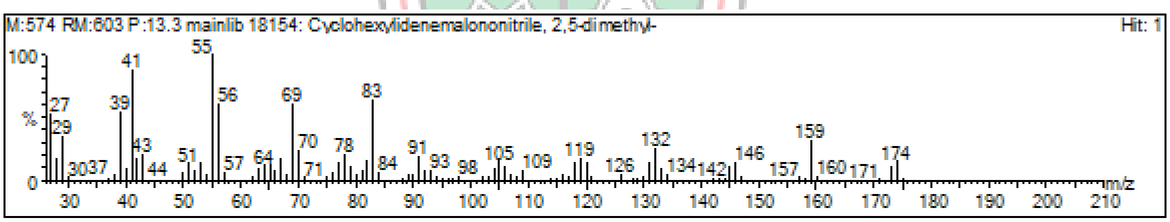


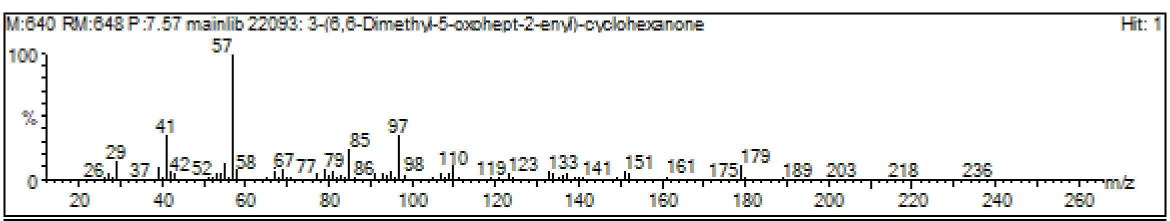
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

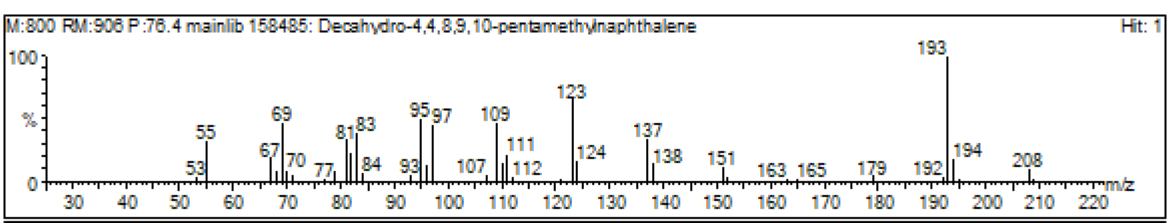




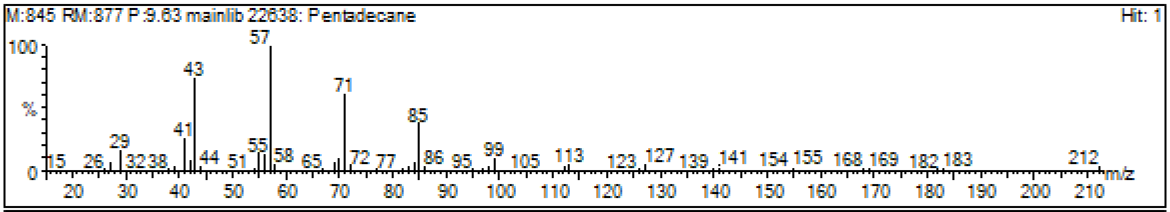


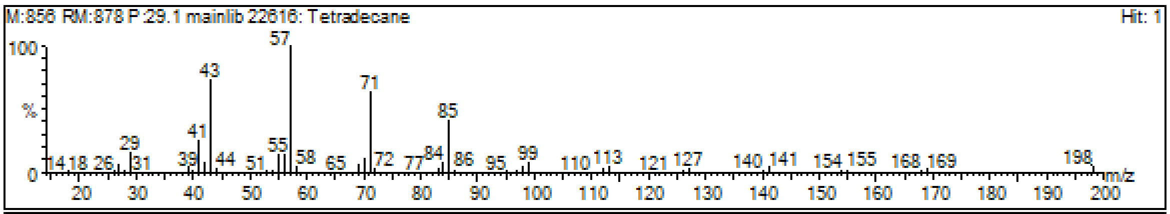


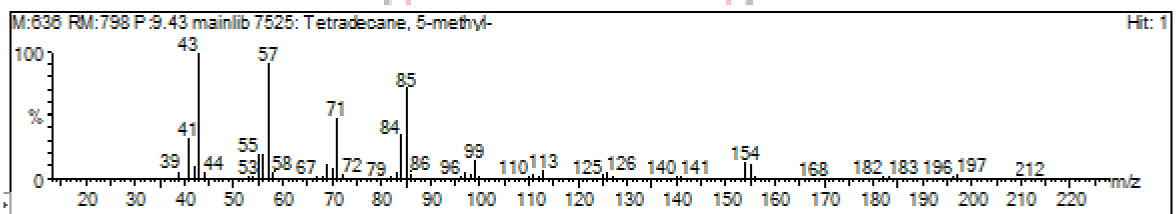


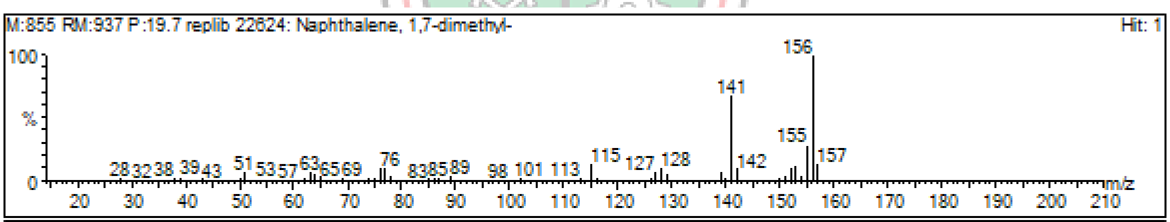


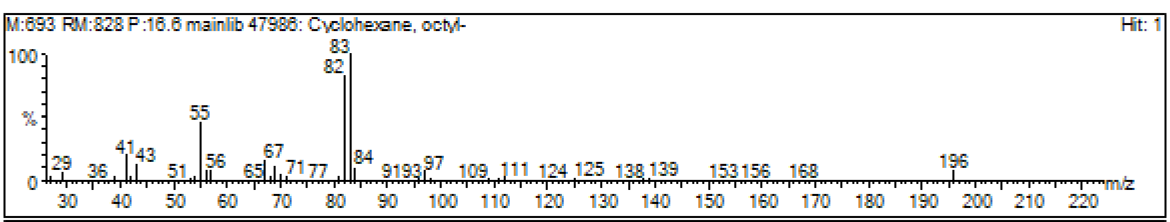
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

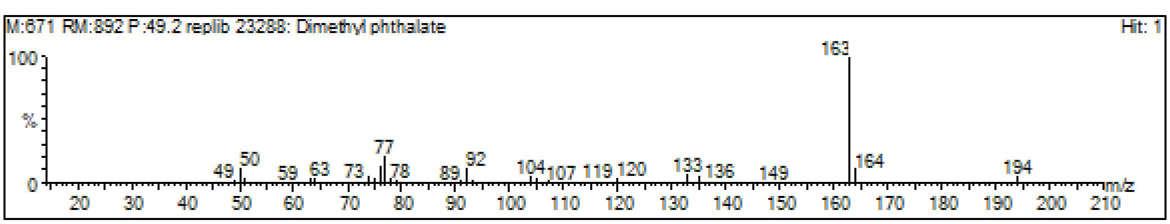




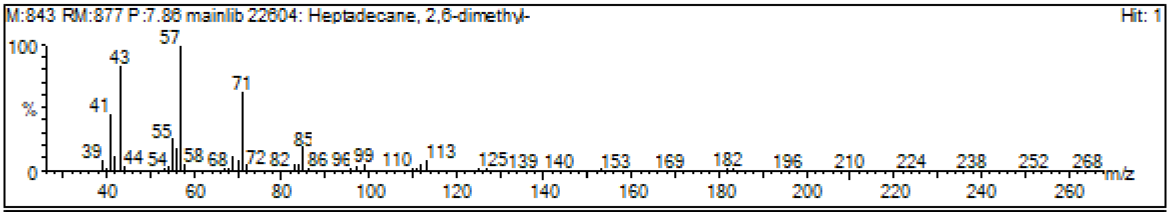


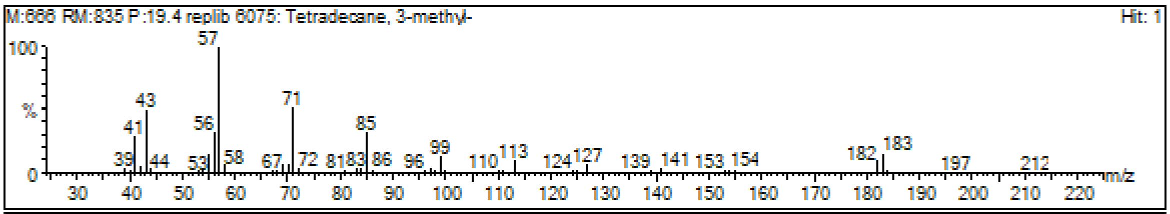


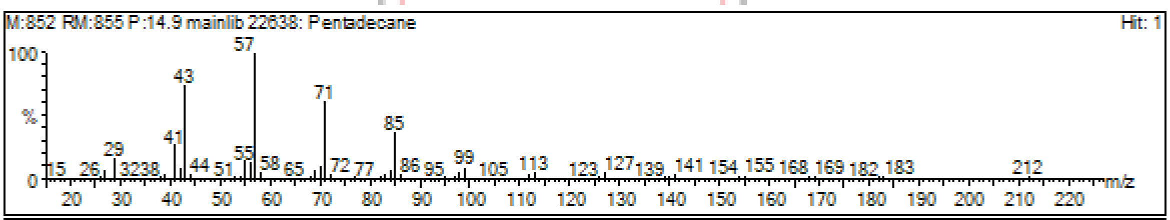


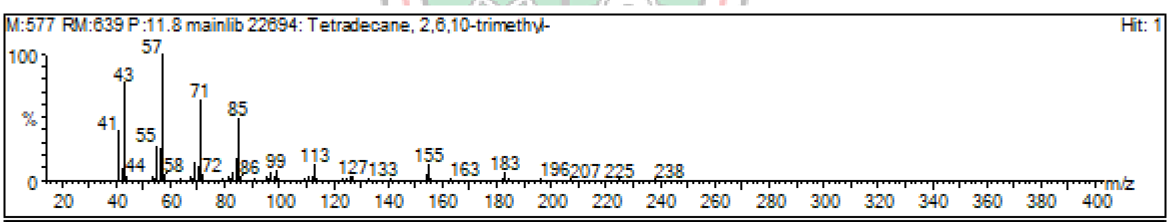


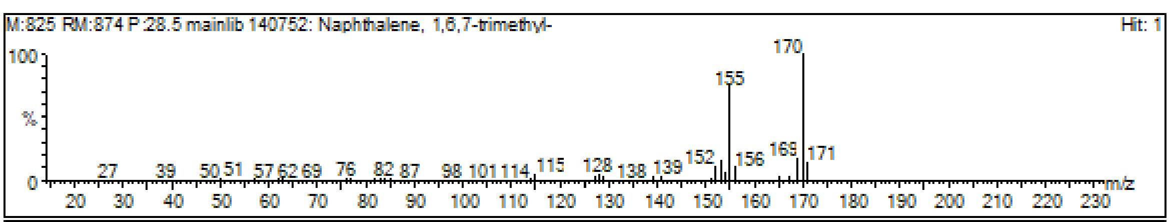
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

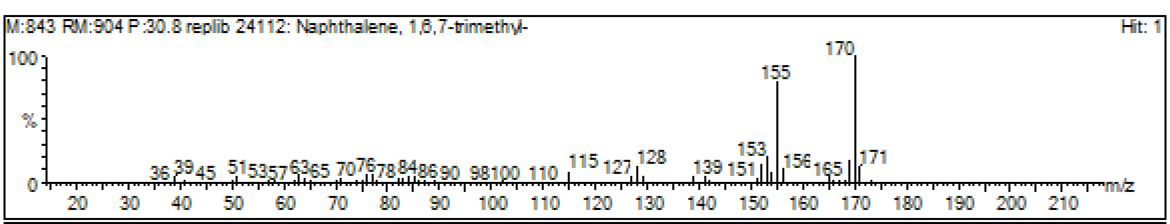




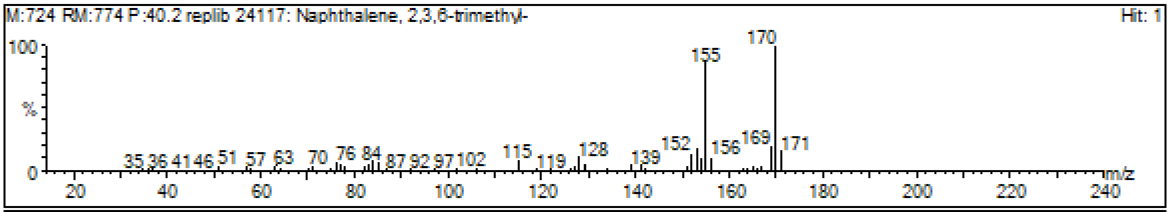


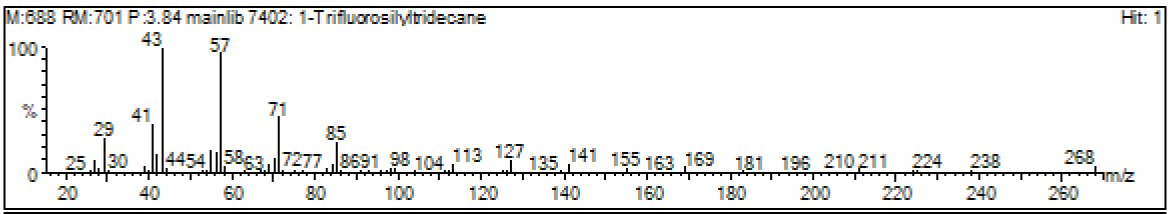


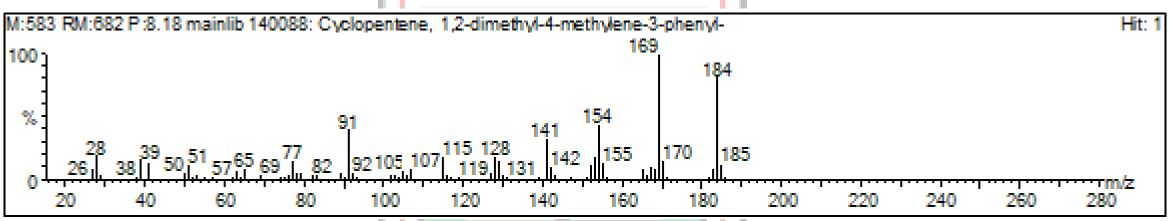


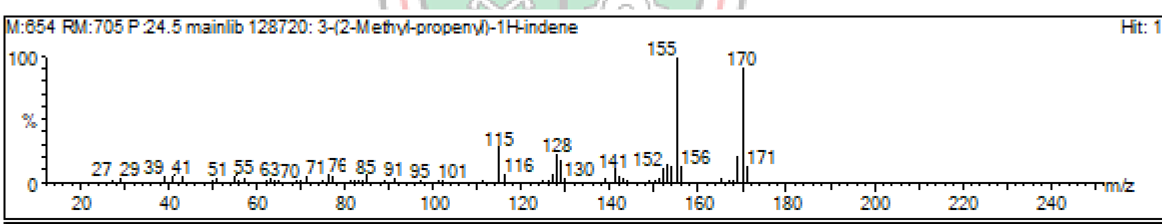


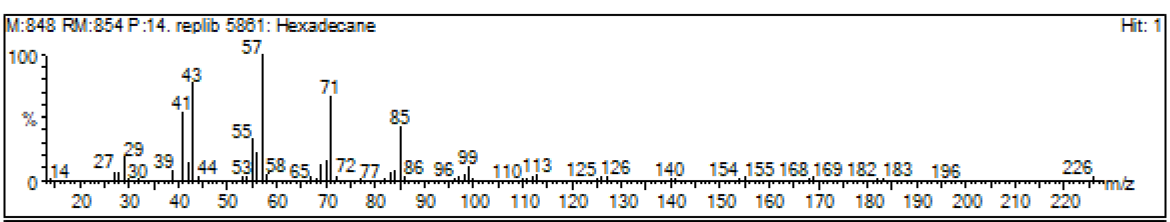
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

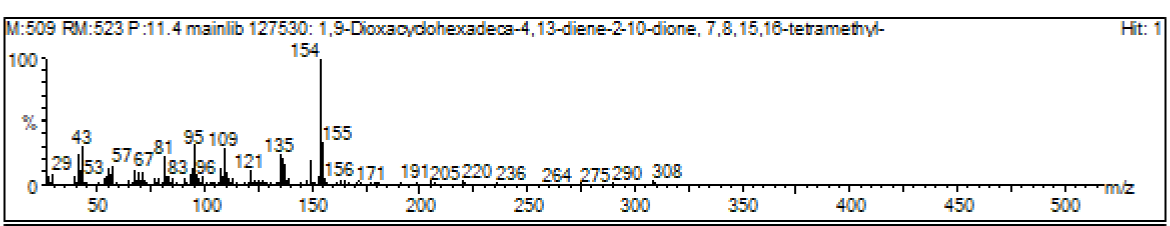




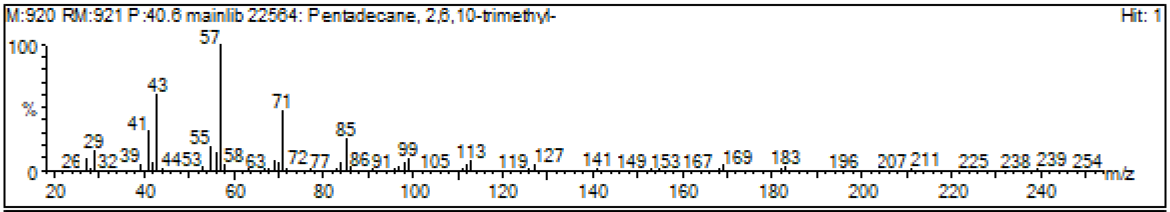


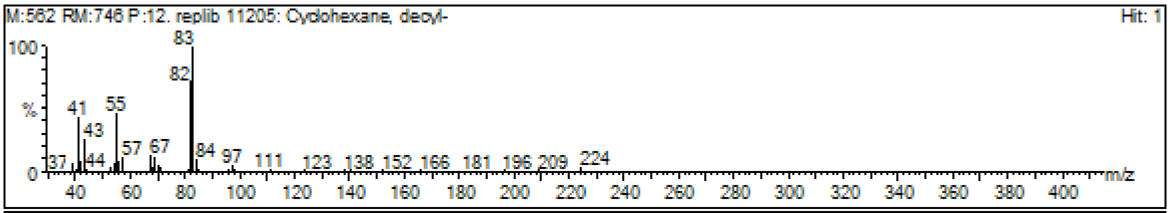


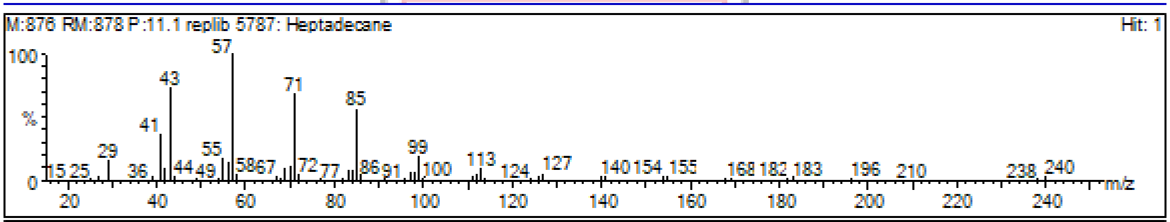


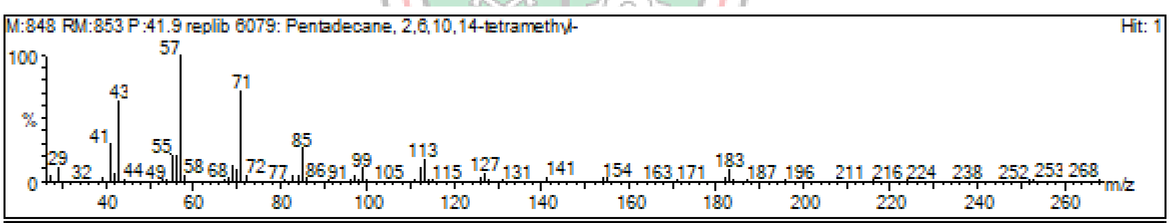


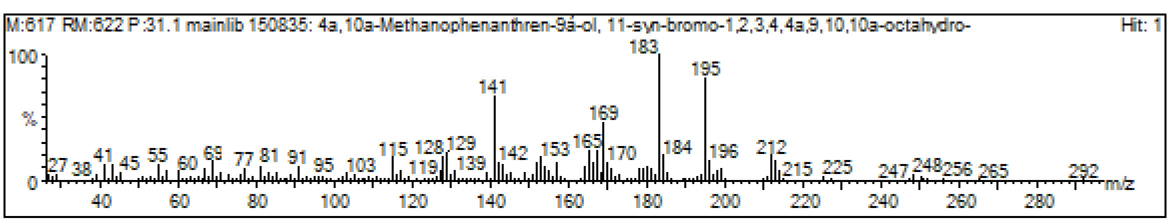
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

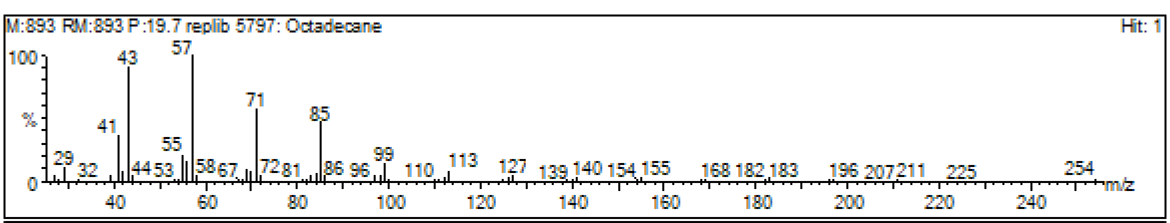




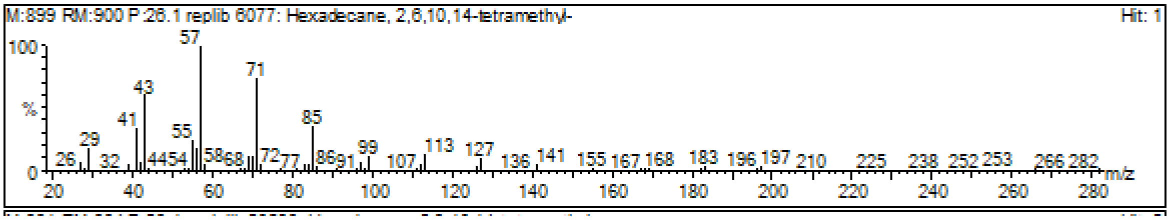


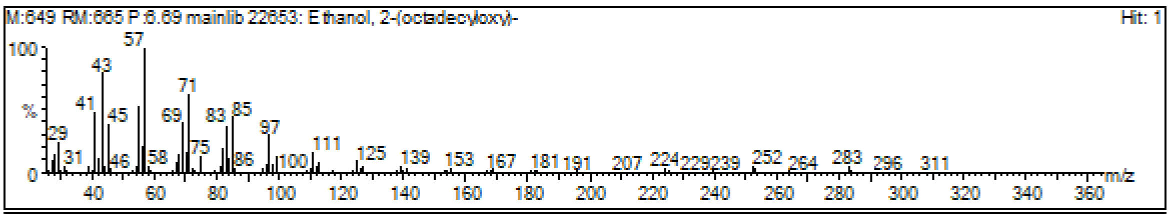


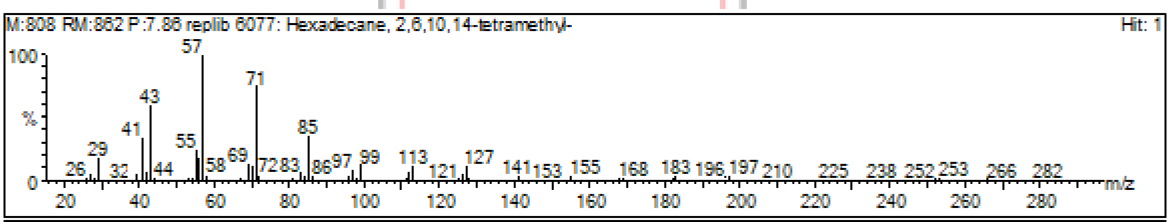


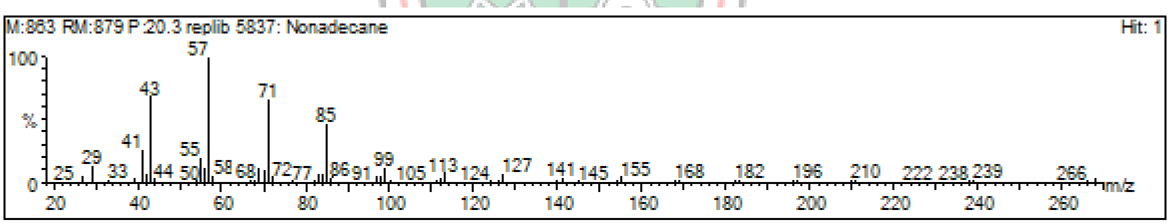


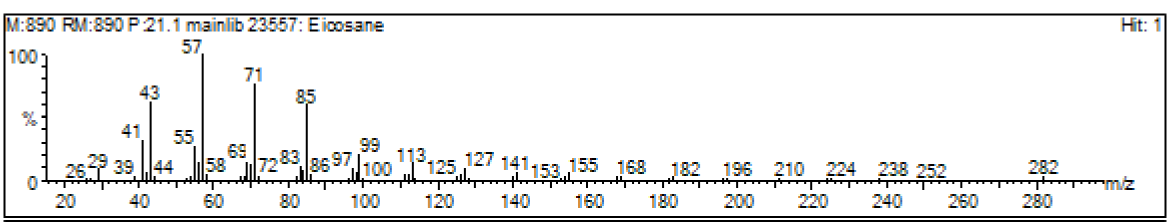
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

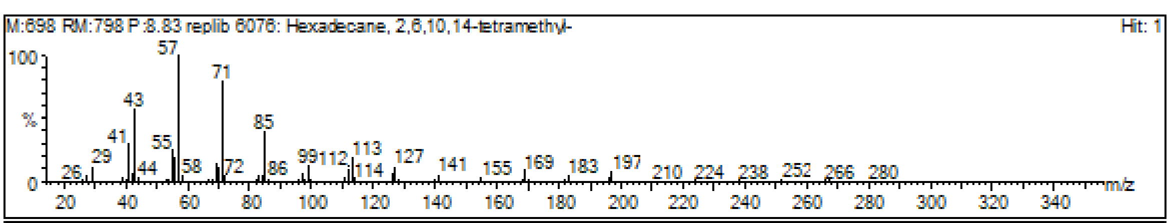




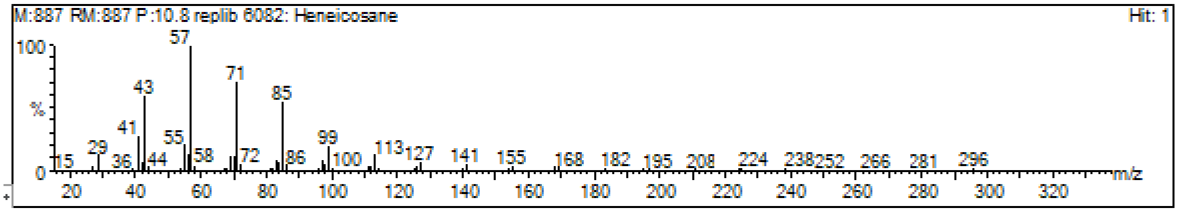


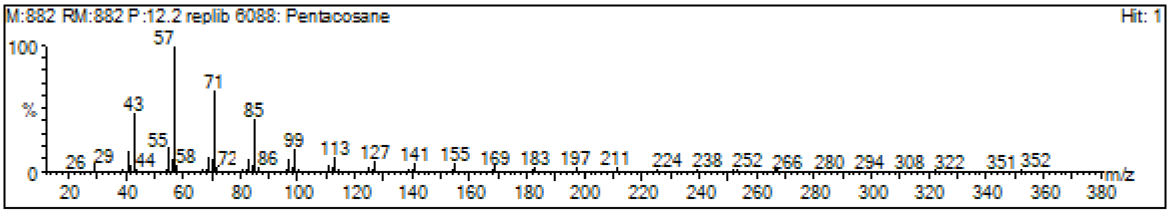


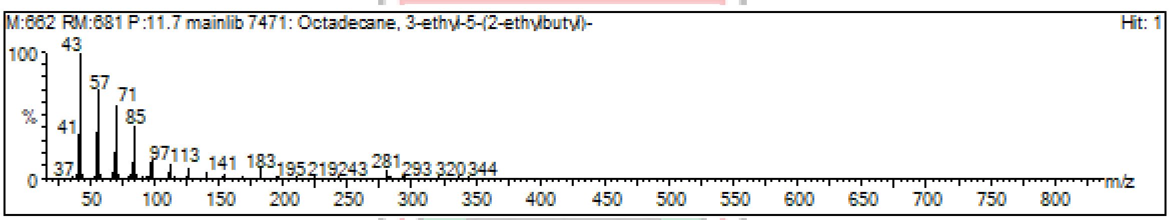


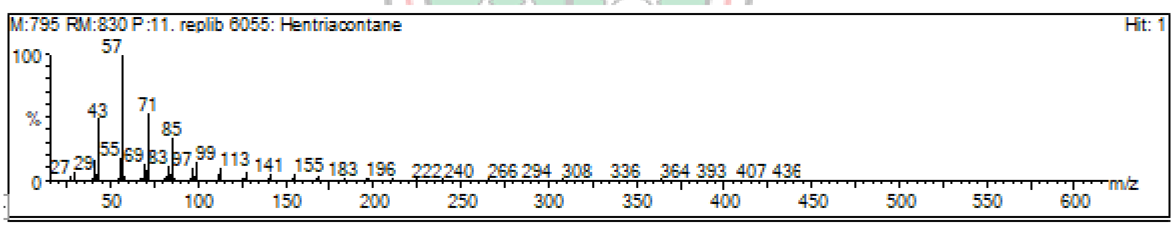


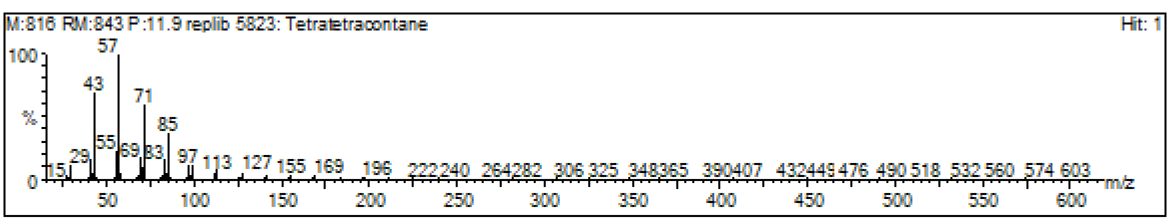
APPENDIX K3 Crude Oil Chromatogram/Spectrum (Continued)

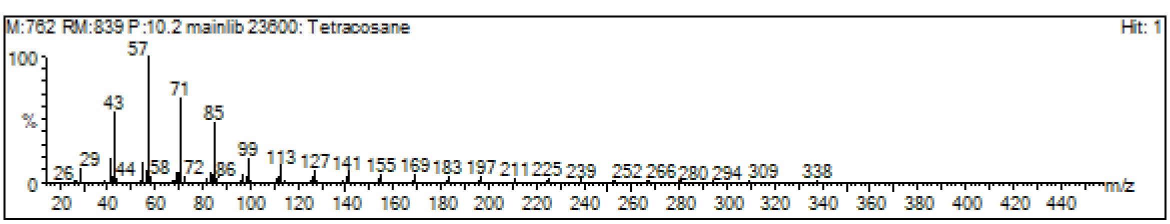




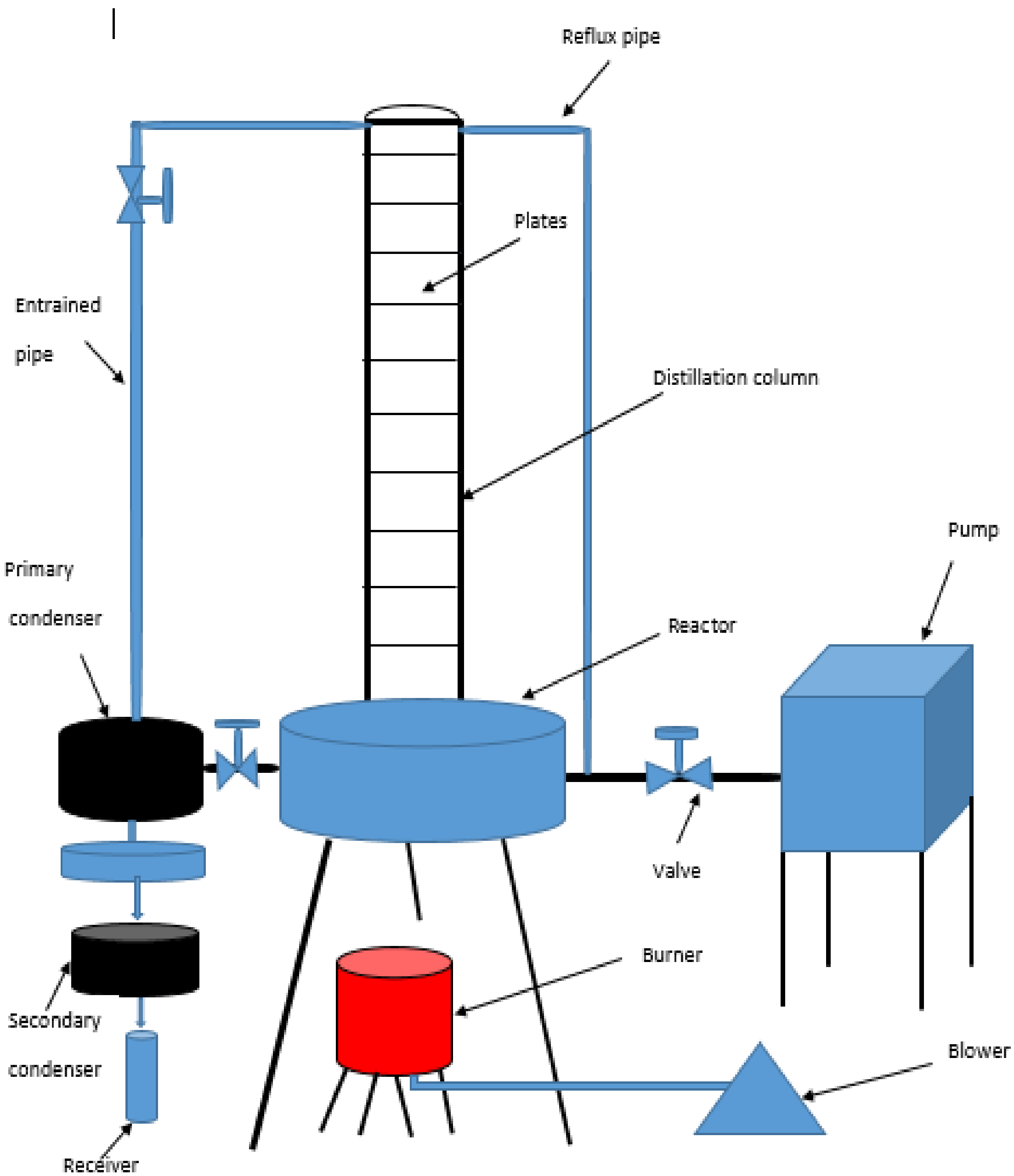








APPENDIX L1 DRAWINGS OF BEN ASANTE DISTILLATION COLUMN



BEN ASANTE DISTILLATION COLUMN

APPENDIX L2 DIMENSIONS OF BEN ASANTE DISTILLATION COLUMN

Dimensions of Ben Asante Distillation Column

Unit	Dimension (ft)	Dimension (m)	Volume (m^3)
Reactor radius	0.2976	0.09071	
Reactor height	0.5833	0.1730	
Reactor Volume			1.6090
Condenser radius	0.5833	0.0875	
Condenser length	1.2500	0.3710	
Condenser volume			8.8360×10^{-4}
H eight of reflux pipe	7.2500	2.1510	
Diameter of reflux pipe	0.0833	0.0247	
Height of entrain pipe	6.0000	1.7800	
Diameter of entrain pipe	0.0833	0.0247	
Pump power = 1 horsepower			
Reflux ratio =1			
Number of stages = 10			

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