Production of 5000 litiers/day of biodiesel using jatropha oil via transestarification process

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Abstracts:

Biodiesel is the solution to control the emissions and a alternative source of energy it a sustainable sure as the fuel prices and rising due to the increase in papulation biodiesel is a alternative source of renewable energy according to the literature review transesterification is the best method to produce biodiesel from jatropha oil as it gives the maximum yields and less heat input the biodiesel produced by this method is less viscous and can be used in the conventional diesel engines more than that jatropha is a multipurpose plant the production of jatropha is 9.3 million tons per year and the production of esterified jatropha oil in Pakistan is 2.3 million tons from which a large amount is produced by the Pakistan state oil (PSO) .we chose the capacity of our plant to be 5000 liters per day and calculated the material and energy balance of the plant. We designed the major equipment's of the plant and controlled the process by instrumentation and process control and we calculated the economic summary of the plant. And finally, we reviewed the socioeconomic effects of our plant. Our plant we provide jobs to local area and improve the country's economy . after all we concluded that we can produce biodiesel from transesterification.

1.Chapter 1

1.1 introduction

The depletion of fossil fuels along with environmental degradation issues demand an alternative source of petroleum-based fuels such as diesel fuels. Biodiesel (fatty acid methyl ester) from vegetable oil is the best candidate for diesel fuel substitute in diesel engines due to its similar properties. With rising demand for fossil fuels, a greater threat to the environment is posed, as fossil fuels are linked to emissions such as CO_2, CO, SO_x, NO_x, and particulate matter, and are currently the world's leading source of emissions. The harmful exhaust emissions from engines, as well as the rapid rise in the prices of petroleum products and the uncertainty of their supply, have rekindled researchers' interest in finding suitable alternative fuels. There are supporters for compressed natural gas, propane, hydrogen, and alcohol-based substances (gasohol, ethanol, methanol, and other neat alcohol) (Iribarren et al., 2012).

Fuel prices are arising around the world on a daily basis. For many years, people have been looking for ways to produce oil-substitute fuel. One renewable alternative under consideration is biodiesel made from vegetable oil. Biodiesel could be produced at a low cost because it could be extracted from non-edible oil sources. The most appropriate renewable alternative source of biodiesel was found to be Jatropha curcas (Linnaeus), a non-edible oil-bearing and drought-hardy shrub with ecological benefits from the Euphorbiaceous family (Harjanne & Korhonen, 2019).

Because of its high viscosity, the extracted oil could not be used directly in diesel engines. Pure vegetable oils with a high viscosity reduce fuel atomization and increase fuel spray penetration, resulting in high engine deposits and lubricating oil thickening. Biodiesel is a chemically altered or trans esterified vegetable oil that can be used in any diesel engine without requiring any modifications to the engine, injection system, or fuel lines. Pure biodiesel (B100) can be used in any petroleum diesel engine, though lower concentrations are more common. There are fewer formal studies about the effects of pure biodiesel in unmodified engines and vehicles in everyday use because biodiesel is more commonly used in a blend with petroleum diesel. Fuel that meets the standards and engine parts that can withstand the higher solvent properties of biodiesel are expected to run without any additional problems than petroleum diesel, and in some cases have been reported to do so.(Brophy, 1997)

1.2 Aims And Objectives

Given the fact that, as the world's population, standard of living, and urbanization rise, so does demand for petroleum products.
The increase in crude oil imports has an impact on the economy and development of the country. Today's diesel engines require a fuel that burns cleanly and consistently under a variety of conditions. Biodiesel is the only alternative fuel that can be used in any existing diesel engine without modification. Biodiesel can be blended with diesel fuel in any ratio because it has

properties similar to diesel fuel. As a result, the goal of this project is to design a cost-effective plant for producing biodiesel from jatropha oil.

1.3 Relevance of design to the society:

The following are some of the benefits of biodiesel.

- Produced from biological sources that are both sustainable and renewable.
- Fuel that is both environmentally friendly and oxygenated.
- Sulphur-free, lower emissions of CO, HC, particulate matter, and aromatic compounds
- A source of income for the rural community.
- Fuel properties are comparable to those of conventional fuel.
- Used in existing diesel engines that haven't been modified.
- Lower the cost of oil imports Non-toxic, biodegradable, and easy to handle.

Chapter 2 – Literature Reviews:

2.1Renewable energy

The word "renewable energy" refers to energy obtained from a wide range of resources, all of which are based on self-renewing energy sources including sunshine, wind, flowing water, the earth's internal heat, and biomass like energy crops, agricultural and industrial waste, and municipal garbage. These resources may be utilized to generate power for all economic sectors, transportation fuels, and heat for buildings and industrial operations, among other things

When compared to traditional energy sources, renewable energy technologies provide significant advantages. Renewable energy supplies are plentiful; the sun sends 1000 times more energy to the earth's surface than all fossil fuels combined discharge now.(Fournier, n.d.)

Table 2. 1**: Tells the amount of energy delivered per square meter of land for four renewable energy sources**.(Fournier, n.d.)

Sources	**Yearly delivered energy (KWh/m^2)**
Wind	11 (Average wind speed) 18 (Heigh wind speed)
Biomass	15 (Low efficiency) 45 (High efficiency)
Photovoltaic	50-100
Geothermal	160-200

In 2012, renewable energy accounted for around 19% of worldwide final energy consumption. Modern renewable methods account about 10% of the total, although biomass is still widely used. Renewables have grown rapidly over the world, with solar photovoltaic (42 percent annual increase over the previous decade) and wind seeing the most development (27 percent annual growth). In 2012, the global installed renewable energy capacity surpassed 1440 Geobios's, solar, and geothermal energy make for a growing percentage of final heat demand in the heating and cooling industry, with a global share of 10%.(Scarlet et al., 2015)

2.2 Major types of renewable energy:

2.2.*1* Geothermal energy

Geothermal energy is **heat within the earth**. The word geothermal comes from the Greek words geo (earth) and thermal (heat). Geothermal energy is a renewable energy source because heat is continuously produced inside the earth. People use geothermal heat for bathing, to heat buildings, and to generate electricity. Geothermal energy has been categorized as a renewable energy source by international organizations. This categorization has been in use for a long time; however, it is occasionally asserted that thermal depletion of geothermal reservoirs would take such a long time to recover, and that geothermal energy is not, strictly speaking, renewable.(Stefansson, n.d.)

2.2.1 Geothermal Resources Base:

The Earth's interior is a massive heat storage facility. The entire heat content is estimated to be roughly 1031 J, and it would take over 109 years for today's global heat flow to exhaust it. A more conservative estimate takes into account only the surface area of continents (about 2 1014 m2) and the continental crust to a depth of 1 km. This shell's heat content is still rather high, at 3.9 108 EJ. This heat would be adequate for a million years, based on the world's primary energy usage in 1995, which was 374 EJ.(Rybach et al., n.d.)

2.2.2 Solar energy

For the planet Earth, the sun is a primary source of unlimited free energy (solar energy). New methods are currently being used to create electricity from solar energy gathered. These methods have already been tested and are widely used around the world. In theory, solar energy has the ability to meet the world's energy needs if gathering and distribution technologies are easily available. Annually, about four million exajoules (1 EJ =1018J) of solar energy reach the planet, with approximately 5 104 EJ claimed to be easily harvestable [. Despite its enormous potential and growing awareness, solar energy's contribution to the world energy supply remains insignificant. (Kabir et al., 2018)

Pakistan is geologically situated in the world's zone of greatest solar isolation. During the long summer season, most of the locations experience significant sun radiation intensities. In Pakistan, a researcher researched the potential of solar and renewable energy extensively. Unfortunately, due to a lack of sound policies, a large portion of the output, up to 38 percent, is derived from expensive oil. Renewable energy sources are also not taken seriously. Solar cells with a capacity of 440 W were erected for village electrification in various places in the early 1990s, but they quickly became inoperable due to a lack of interest and follow-up. The Pakistan Council of Renewable Energy Technologies (PCRE) was founded in May 2001(Awan & Khan, 2014).

2.2.3.1 Limitations and benefits of solar energy technologies

Solar energy is a steady power source that has the potential to provide everyone with energy security and independence. This proclivity is critical not only for people, but also for the socioeconomic prosperity of businesses, society, states, and countries. Nonetheless, solar power is currently being used to meet energy needs in many developed and developing countries as a natural and significant aspect of electricity generation. However, there are a number of drawbacks as well as advantages to using it.

2.2.3.2 Limitations of solar energy technology

One of the most serious drawbacks of the solar energy system is the high initial installation cost; for example, the average price per watt for solar energy was $3.70. When the Federal solar tax credit is taken into account, a typical solar energy system of 5 kW per dwelling would cost $13,000. (Thereby reducing costs by 30 percent). Long payback periods and limited revenue streams, on the other hand, lower the value of credits for such systems. Furthermore, most household solar panels have efficiency of roughly 10%–20%, which is another limitation of solar technology. Solar panels that are more efficient (about 20%) are available at a higher cost. Other components' performance constraints, like as batteries and inverters, are also areas where there is opportunity for development. Another issue with solar energy systems is short battery lives and the proper disposal of expended batteries. Furthermore, batteries are frequently huge and heavy, necessitating a lot of storage space. Furthermore, because solar panels are constructed of rare or costly metals like silver, tellurium, or indium, there are insufficient recycling facilities. Another barrier is factors related to system maintenance, such as a shortage of experienced people to satisfy expanding needs for solar power system installation, maintenance, inspection, repair, and evaluation. Furthermore, a user's lack of fundamental technical knowledge of solar power systems (especially in rural parts of the developing world) can lead to irregular usage, overcharging the battery, polarity reversal, by-passing the charge controller, and other system damage. Furthermore, another evident flaw is that solar energy can only be harvested. harnessed during the day and performs best when the weather is sunny. As a result, solar energy is unlikely to be the most reliable source of energy in areas where the weather or climate are unsustainable. Furthermore, the amount of pollution in the installation region can have an impact on the efficiency of the solar cells. The current of silicon solar cells was shown to be reduced by 10% and 7%, respectively, when exposed to exhaust fumes and aerosols. Finally, significant areas of land are frequently necessary to create solar energy on a large scale. A 1 MW solar power facility with crystalline panels (around 18 percent efficiency) would require approximately 4 acres (16,187 m2) of land, whereas thin film technologies (12 percent efficiency) would require approximately 6 acres (24,281 m2)

2.2.3.3Benefits of solar energy technology

It is well known nothing can compare to the sun's energy potential. Solar power is more than capable of meeting the world's electricity demands because it is potentially abundant. Because solar energy is both sustainable and renewable, it is unnecessary to address the possibility that it will be depleted in the future. Global warming has apocalyptic potential, implying that it will have a negative impact on the climate, the ecosystem (including animals and plants), and human health.

Power facilities (particularly coal-fired power plants) are a major source of greenhouse gases (GHG), accounting for roughly 25% of all anthropogenic emissions. As a result, the GHG emissions connected with solar power generation (including manufacturing, installation, operation, and maintenance) are negligible. CO2 emissions per kilowatt-hour from coal, natural gas, and solar are expected to be 0.64 1.63, 0.27 0.91, and 0.03 0.09 kg, respectively (emission ratio of 18:9.5:1). As a result, this study reaffirms solar power's superior environmental friendliness over conventional forms of energy. As a result, solar power has emerged as one of the most viable solutions to the present global warming dilemma, which, if not addressed, may be enormously costly in terms of its possible consequences if allowed unabated. As a result, limiting global warming by replacing coal and gas-based power sources with solar power will eventually be advantageous to attaining sustainable development from an environmental, economic, and social standpoint.(Kannan & Vakeesan, 2016)

2.2.3 Wind energy:

Wind energy, the world's fastest-growing energy source, is a clean, renewable energy source that has been used in Europe for millennia and more recently in the United States and other countries. Large and small wind turbines generate electricity for utilities, homeowners, and rural villages. A new approach to wind energy paves the way for a more secure and wealthy future, as well as a more livable environment for humans and all living things. Renewable energy sources are widely available around the world. It is not only widely available, but it is also abundant in nature. Increased usage of wind and other renewable energy sources will help to boost economic growth and create jobs.(Saidur et al., 2010)=

2.2.4.1 Challenges of Wind Power

- On a cost basis, wind power must still compete with conventional generation sources.
- Good land-based wind sites are frequently found in rural regions, far from the cities that require electricity.
- Wind energy development may not be the most cost-effective use of land.
- Turbines have the potential to pollute the environment with noise and odors.
- Wind turbines have the potential to harm local wildlife.(Awan & Khan, 2014)

2.3 Bioenergy:

Biomass is organic matter that has bioenergy sources on the inside. We may use this biomass in a variety of ways, from basic things like burning wood for heat to more complex things like growing genetically modified microorganisms to make cellulosic ethanol. Bioenergy has the distinct advantage of being a renewable energy source because nearly all of it can be traced back to solar energy.

2.3.1Types of bio-energy

1. Biopellets
2. Bioethanol
3. Biogas
4. Biodiesel

2.3.2 Biopellets:

Today, wood pellets are an important and well-liked fuel in a lot of different countries, and the markets for them are likely to grow even more in the future, as well. For these reasons, it is feared that the lack of cheap wood as a feedstock for pellets will keep this market from growing. Using autumn leaves from urban areas, which are a waste material that is available for a short time, could be a good way to replace or add to wood. In many Western countries, wood pellets are becoming more and more important as a fuel for small furnaces used in homes and businesses as an alternative to crude oil or natural gas. There are a lot of good things about pelletized biomass, like that it's resistant to microbial decay, that it can be transported and stored easily, and that the process of making pellets is very simple.

2.3.3 Bioethanol:

Bioethanol is the most common biofuel in the world. By simple fermentation, it is made from sugars that come from wheat and corn, sugar beets, sugarcane, molasses, and any other sugar or starch source that can be used to make alcoholic beverages. This is what makes it. Using bioethanol as a replacement for gasoline in a car engine can help save money on gas. Bio refinery is the process of turning lignocelluloses into sugars that can be used to make bioethanol. This process has been the subject of a lot of research, because it is necessary for the production of bioethanol. Even though a lot of research has been done to deal with the possible problems of bioenergy, there is no self-sufficient process or technology that can turn the lignocellulose biomass into bioethanol today. For cars, bioethanol mixed with fossil fuel can cut petroleum use and GHG emissions significantly. Bioethanol can be made from many different types of raw materials, and these raw materials are broken down into three groups: simple sugars, starch, and lignocelluloses. Bioethanol made from sugarcane can be a clean fuel if it's made in the right way. It has a lot of advantages over gasoline made from petroleum, like reducing GHG emissions and improving air quality in cities. Cellulosic biomass resources like forest materials, agricultural residues, and waste from cities and towns can be used to make bio ethanol, but the process hasn't yet been commercialized.

2.3.3.1 Feedstock for Bioethanol:

In many parts of the world, there is a need to look for new and cheap carbohydrate sources that can be used to make bioethanol. In the present, a lot of attention is paid to biofuels made from renewable energy crops like sugarcane, corn, wheat, soybeans, and so on. Comparison of biomass in a given production line takes into account many factors, including how the biomass is grown, how it is used, how it is emitted, how much land is available, how it is used, how much soil is eroded, how much energy is used, how much biomass is used, how much water is needed, and how much transportation costs (transport and storage of the biomass)There are three main types of bioethanol feedstock: sugar-based feedstock, starchy feedstock, and lignocellulose feedstock (e.g. wood, straw, grasses, and corncob). In the short term, starch and sugars from food crops are used to make bioethanol, which is used as a fuel. Because bioethanol is made from starch and sugar, the feedstock can be expensive and used for other things. It is thought that lignocellulosic biomass will be the main source of raw materials for the production of bioethanol in the long run because it is cheap and easy to get.

2.3.4 Biogas:

Biogas is made from organic materials that are broken down by anaerobic digestion (AD), which happens inside the anaerobic bio digester. Some factors affect the chemical composition of this biogas, such as what kind of digester is used, what kind of organic material is used, and how often the feed is fed to the digester. CH4, CO2, and sulfuric components are the most important parts of biogas (H2S). The composition of biogas is very important, because it helps to figure out which purification system is best for getting rid of sulfuric gases and reducing the amount of water in the gas. This helps to improve the combustion fuel conditions. It's also important to look at other data from a biogas analysis to figure out how much electricity could be made from it. The low heat value, combined with the efficiency and the amount of biogas used, helps figure out how much electricity could be made. However, the amount of biogas that can be made varies a lot because of a lot of factors, like what kind of organic material is used. Biogas is made in three steps: hydrolysis and acid synthesis, acetone synthesis, and methane synthesis. During the hydrolysis process, organic material is broken down into smaller molecules. This material is then turned into soluble acids by acidogenesis, which makes it easier to drink. Next, the acetanogenese process turns the products from the first step into acetic acid, hydrogen, and carbon dioxide. This process is called acetanogenese. The last step is called metanogenese, which is when anaerobic bacteria make methane gas.

2.3.4.1 Biogas Feedstock:

AD can use a lot of different types of biomasses to make biogas. Animal manure and slurry, organic wastes from the food and agro industries, the organic fraction of municipal waste and food service and sewage sludge are all good sources of biogas. Recently, new feed stocks for biogas synthesis have been tried and used in many countries, including dedicated energy crops (DECs), which are crops grown only for energy and biogas production. This type of crop can be both herbaceous and woody. It can be made of grass, maize, or rapes, as well as woody crops like willow, poplar, and oak, but the woody crops need special treatment before AD.

2.4 Definition of biodiesel:

Biodiesel is a light to dark yellow liquid with a high boiling point and low vapors pressure that is immiscible with water. It can also refer to a diesel-equivalent processed fuel made from biodiesel sources (such as vegetable oils) that can be utilized in automobiles with unmodified diesel engines. It’s also biodegradable, non-toxic, and produces around 60% fewer net carbon dioxide (CO2) emissions than petroleum-based diesel.

2.4.1 History of biodiesel:

In fact, the concept of biodiesel dates back to 1912, when Rudolf Diesel (the inventor of the first diesel engine) stated, "The use of vegetable oil for engine fuels may seem insignificant today, but such oil may become, in the course of time, as important as petroleum and coal-tar products of today." 2007 (Biodiesel). Due to the rising popularity of biodiesel in Europe, some parts of America, and Asia, his words have been proven to be accurate. The main drivers of this increase are major environmental concerns including ozone depletion and the frightening rate of global warming. Biodiesel is a biofuel made from renewable biological sources such as edible and non-edible vegetable oils, as well as animal fats. Vegetable oils are generally glycol esters with varying chain lengths and saturation levels. Vegetables, as can be seen, have a significant quantity of oxygen in their molecules.

In practice, the higher viscosity of vegetable oils (30- 200 centistokes) compared to Diesel (5.8-6.4 centistokes) causes unfavorable pumping, inefficient fuel-air mixing causes incomplete combustion, and high flash points cause greater carbon deposit formation and inferior coking. Due to these issues, vegetable oil must be adjusted to match the qualities of Diesel oil in terms of combustion. The main goal of the fuel modification is to reduce viscosity and increase volatility. Biodiesel is a family of oxygenated fuels made from natural, renewable biological sources like vegetable oils. As the name implies, this fuel can be used in diesel engines as an alternative to diesel fuel. Biodiesel, like petroleum diesel, runs in compression ignition engines, therefore no special engine is required. It also has the same cargo capacity and range as traditional diesel. New or used vegetable oils and animal fats can be utilized to make biodiesel fuel. Pure biodiesel, unlike fossil fuel, is biodegradable, nontoxic, and almost completely free of Sulphur and aromatics.

2.4.2 Advantages of biodiesel:

1. Made from biological sources that are both sustainable and renewable.
2. Fuel that is both environmentally friendly and oxygenated
3. Sulphur-free, resulting in lower emissions of CO, HC, particulate matter, and aromatic compounds.
4. The rural community's income
5. Fuel qualities that are comparable to those of conventional fuel
6. Can be used in current diesel engines that haven't been modified.
7. Reduce the amount of money spent on oil imports.
8. It's non-toxic, biodegradable, and easy to work with.

2.4.3 First generation feedstocks:

First-generation Biofuels. First-generation biofuels include **ethanol and biodiesel** and are directly related to a biomass that is more than often edible. Ethanol is generally produced from the fermentation of C_6 sugars (mostly glucose) using classical or GMO yeast strains such as Saccharomyces cerevisiae. The two types of edible feedstock's used to make first-generation biofuels are starch- and sugar-based feedstock's. Potato, barley, corn, and wheat are examples of starch-based feedstock. Sugarcane and sugar beet are examples of sugar-based feedstock's. Monocultures are used to grow the feedstock's, which means that only one type of feedstock is grown in the same space at the same time. mono the sort of feedstock's used could also be an invasive species, causing the ecosystem's natural cycle to be disrupted. The manufacture of first-generation biofuels, on the other hand, has become widely marketed, accounting for around 50 billion litres of total biofuels output per year.(Mat Aron et al., 2020)

Table 2. 2First generation Feedstocks

Crops:	**Biofuel yield (L/kg)**	**Reference(s)**
Barley	0.41	(Cheroennet & Suwanmanee, 2017)
Corn	0.4-0.46	(Halder et al., 2019)(Cheroennet & Suwanmanee, 2017)
Cassava	0-15-0.20	
Oat	0.41	(Cheroennet & Suwanmanee, 2017)

Rice	0.48	(Cheroennet & Suwanmanee, 2017)
Sorghum	0.44	
Wheat	0.40	(Halder et al., 2019)
Sugarcane	0.25_0.5	(Halder et al., 2019)
jatropha	35-40	(Verma & Gaur, 2009)

2.4.4 Second generation Feedstocks:

Lignocellulosic crops are used to make second-generation biofuels. This generation technology separates a plant's lignin from cellulose, allowing cellulose to be fermented into alcohol. As biomass is defined as any source of organic carbon, these biofuels can be made from a variety of sources. The controversy surrounding the first-generation feedstock's impact on food security has prompted us to turn to the second-generation lignocellulosic feedstock as a biofuels and chemical production alternative. Through the combustion process, lignocellulosic feedstock is produced from dry agricultural wastes, industrial wastes, and forest residues. The yearly production of lignocellulosic biomass from agriculture and deforestation is estimated to be between 5 and 8 million tones per year, which is less than the annual use of traditional crude oil. When it comes to producing sustainable chemicals and biofuels, lignocellulose-based methods have the potential to cut GHG emissions.

Table 2. 3: Second generation feedstocks

Biomass feedstock	**Bioethanol production** **(L/kg dried biomass)**	**Reference**
Corn Stover	5.85	(da Silva et al., 2016)
Rice straw Barley	116.65	(Zhang et al., 2018)
Barley straw Corn	0.054	(Rooni et al., 2017)
Corn meal Palm	9.67 ± 0.11109	(Nikolić et al., 2011)
Palm oil residue	109 600-172 100	(Cardona et al., 2018)
Paddy straw	0.00086	(Arora et al., 2016)
Eucalyptus	0.612	(Wu et al., 2019)

Olive tree pruning	0.023	(Zabed et al., 2016)
Palm wood	0.0229	(Raja Sathendra et al., 2019)

2.4.5 Third generation Feedstock's:

Third generation biofuels are made from specially designed crops such as algae. These algae are cultivated and harvested in order to extract the oil contained therein. The oil can subsequently be turned into biodiesel using a technique similar to that used for first-generation biofuels, or refined into various fuels.

table 2. 4: Third generation feedstock's

Lignocellulose biomass	**Bioenergy**	**Conversion technologies**	**Environmental impacts**	**GHGs emission**	**Reference**
Rice straw	Coal power	Co-firing	Acidification, global warming, and toxicity	Acidification caused by the utilization of chemicals and fertilizers	(Shafie et al., 2013)
Wood residue	Bioelectricity	Co-firing	Global warming	894.3 g CO2 eq/ kWh	(Shafie et al., 2013)
Crops and wheat straw	Bioelectricity	Co-firing	Global warming	298-ton CO2 eq/TJ	(Sebastián et al., 2011)
Corn stover	Biofuels	Pyrolysis	Global warming	7.65-ton CO2 eq/ha 50.54	(Kauffman et al., 2011)(Han et al., 2013)
Poplar	Biofuels	Pyrolysis	Ozone layer depletion, global warming and acidification	50.54 kg CO2 eq/MJ and release of acid gases	(Iribarren et al., 2012)
Forest residue	Biofuels	Pyrolysis	Global warming	98-117 g CO2 eq/km	(Hsu, 2012)

Forest residue	Heat and power	Gasification	Ozone layer depletion, global warming and acidification	8.8-10.5 g CO2 eq/MJ	(Guest et al., 2011)
Willow biomass	Heat and power	Gasification	Global warming and acidification Toxicity,	Acidification caused by the utilization of chemicals and fertilizers	(Kimming et al., 2011)
Birch wood	Heat	Combustion	Global warming and acidification Toxicity,	80-110 g CO2 eq/ kWh	(Solli et al., 2009)
Rice husk	Bioelectricity	Combustion	Toxicity, global warming and acidification	217.33 kg CO2 eq/MWh	(Shafie et al., 2013)
Forest residue	Power	Combustion	Global warming	11–14 g CO2 eq/kWh	(Thakur et al., 2014)

2.5 Jatropha carcus:

Jatropha curcas is a tiny tree that grows three to eight meters tall and has smooth grey bark that produces a whitish colored, watery latex when cut. It grows in the tropics and subtropics. Fruit is produced in the winter when the shrub is leafless, but it can produce many crops throughout the year if the soil moisture is adequate and the temperature is high enough. Each inflorescence produces a cluster of 10 or more ovoid fruits. After two to four months from fertilization, the seeds become ripe when the capsule turns yellow. The seeds are poisonous and contain around 35% non-edible oil. Farmers all across the world utilize the plant as a live fence around their homes, gardens, and fields because it is not grazed by animals. Because the leaves and stems of Jatropha are harmful to animals, it is not browsed, but the seeds or seed cake could be utilized as animal feed following treatment. The seed cake is a good source of plant nutrition due to its high nitrogen content. Various components of the plant are therapeutic, the bark contains tannin, and the flowers attract bees, therefore the plant has the potential to produce honey. Jatropha, like all trees, absorbs carbon from the atmosphere, stores it in its woody tissues, and helps to produce soil carbon

2.5.1 The plant profile:

Jatropha curcus is a drought-tolerant perennial that thrives in poor soil. It's simple to grow, grows swiftly, and can produce seeds for up to 50 years. The wonder plant Jatropha yields seeds with a 37 percent oil content. The oil does not need to be processed before it can be used as a fuel. It produces a clean, smoke-free flame and has been successfully used as a fuel in a small diesel engine. The by-products include press cake, which is a good organic fertilizer, and oil, which also includes pesticide. It grows in many sections of the country, is tough in nature, can live with minimal inputs, and is simple to propagate. Cancer, piles, snakebite, paralysis, dropsy, and other disorders are treated with it medically. With little work, a good crop can be acquired. Oil can be recovered from jatropha nuts after two to five years, depending on soil quality and rainfall. The nut production varies from 0.5 to 12 tone’s per year. Oil makes up around 60% of the kernels, which can be converted into biodiesel fuel via transesterification.(Verma & Gaur, 2009)

2.5.2 Distribution and Habitat:

The exact location of the origin is unknown; however, it is thought to be in Mexico or Central America. It was first introduced to Africa and Asia, and it is currently grown all over the world. This drought-resistant plant thrives in dry and semi-arid environments. According to the present distribution, introduction has been more successful in dry tropical regions with annual rainfall of 300-1000 mm. It grows best at lower elevations (0-500 m) in locations with average annual temperatures well above 20°C, but it can also grow at higher elevations and tolerates minor cold. It thrives on well-drained, well-aerated soils and is well-suited to low-nutrient, marginal soils.(Verma & Gaur, 2009)

2.5.3 Botanical Features:

It's a little tree or shrub with smooth grey bark that, when cut, produces a whitish-colored, liquid latex. It normally grows to a height of three to five meters, but under the right conditions, it can reach eight or ten meters.

Leaves:

It has huge, three- to five-lobed leaves with a spiral phyllo taxi that are alternate to sub-opposite.

Flowers:

The length of the petiole varies from 6 to 23 mm. In the leaf axil, the inflorescence develops. Female blooms are significantly larger than male flowers and appear during the hot seasons. An imbalance of pistillate or staminate flower production results in a larger number of female flowers under settings where continuous growth occurs.

Fruits:

Fruits are produced in the winter when the shrub is leafless, although many crops may be produced throughout the year if soil moisture is adequate and temperatures are high enough. Each inflorescence produces a cluster of 10 or more ovoid fruits. After the seeds mature and the fleshy excerpt dries, three bi-valved cocci appear.

Seeds:

After two to four months from fertilization, the seeds become ripe when the capsule turns yellow. The oblong, blackish, thin-shelled seeds resemble little castor seeds.(Verma & Gaur, 2009)

2.5.4 Ecological Requirements:

Jatropha curcas thrives in a variety of conditions, including gravelly, sandy, and saline soils. It may grow in even the most stony soil. It can even thrive in rock fissures. The leaves that fall off during the winter months generate mulch around the plant's base. The organic matter in the fallen leaves encourages earthworm activity in the soil around the plant's root zone, which increases the soil's fertility. Jatropha curcas grows in the tropics and subtropics and prefers hot weather, although it may also thrive in cooler climates and can endure a mild cold. It has a very low water need and can withstand lengthy periods of drought by dropping the majority of its leaves to minimize transpiration loss. Jatropha curcas can also be used to minimize soil erosion and sand dune displacement.

Biophysical limits:

The average annual temperature is 20-28 degrees Celsius, and the average annual rainfall is 300-1000 millimeters or higher. Type of soil: It thrives on well-drained, well-aerated soils and is well-suited to low-nutrient, marginal soils. Root development is slowed in thick soils. Although Jatropha is a very adaptable species, it is not without its flaws.(Verma & Gaur, 2009)

2.5.5 Uses of jatropha **(Porter & Kong, 2009):**

1. **Medicinal Uses**: Curcin (a poisonous protein) and terpene ester are responsible for the seed's harmful properties. Jatropha latex includes an alkaloid called "Jatrophine," which is thought to have anticancer effects. It's also utilized as a piles' external application. Snake bites have been said to be treated using the roots.
2. **Fertilizer from Jatropha:** The leaves that fall off during the winter months generate mulch around the plant's base. Earthworm activity in the soil near the root zone of the plants is increased by organic matter from dropped leaves, which improves soil fertility. The pres cake, which is left behind after oil extraction, has proven to be an efficient organic manure, and adding humus and nutrients to the soil can boost the production of other mineral-rich agricultural products.
3. **Jatropha as dye:** The bark of Jatropha curcas generates a dark blue dye that is used to color cloth, fishing nets, and lines, and the roots aid in the production of yellow dye.

4. **Jatropha as feed:** The tusser silkworm eats jatropha leaves as food. Its bark is tanning, and the flowers attract bees, therefore the plant has the ability to produce honey.
5. **Jatropha as fuel:** Wood, fruit hulls, and seed shells can all be used as cooking fuel. The plant's main product is jatropha oil, which is used to supply the cooking and lighting needs of the rural people as well as boiler fuel for industrial uses. Due to the current oil crisis and fuel shortages, Jatropha has emerged as a viable alternative for environmentally benign and low-cost energy. Furthermore, Jatropha grows effectively in drought-stricken areas and wastes.
6. **Jatropha diesel:** It's worth noting that Jatropha curcas non-edible vegetable oil has the potential to be a promising and commercially viable alternative to diesel oil because it possesses physicochemical and performance properties that are comparable to diesel.(Verma & Gaur, 2009)

2.6 Jatropha as a source of biodiesel

The seeds have a 35-40% oil content, whereas the kernel has a 50-60% oil content. Saturated fatty acids account for 21% of the oil, whereas unsaturated fatty acids account for 79%. There are several chemical components in the seed that are toxic, making the oil unfit for human ingestion.(Verma & Gaur, 2009) An examination of Jatropha curcus seed reveals that(Abu-Hamdeh & Alnefaie, 2014)

Table 2. 5: Components in jatropha

Components	**Percentage**
Moisture	6.20
Protein	18
Fats	38
Carbohydrates	17
Fibers	15.50
Ash	5.30

2.6.1 Advantages of using jatropha for biodiesel.

- The oil output per hectare of plantation is one of the greatest among tree-borne oil seeds.
- It may be grown in low-rainfall areas (at least 500 mm per year) and on difficult soils. It may be grown with substantially higher yields in locations with considerable rainfall and irrigated areas.
- Jatropha is a simple to grow plant that grows quickly and is hardy.
- Jatropha lends itself to plantation on low fertility marginal, degraded, fallow, waste, and other sites such as along canals, roads, railway tracks, on the margins of farmers' fields as a boundary fence or live hedge in dry / semi-arid environments, and even on alkaline soils. As a result, it can be utilized to restore waste lands both inside and outside of forests.
- The fruits of the Jatropha plant are easy to collect because they are available to pick after the winter season and the plants are not very tall.
- Animals do not consume Jatropha.
- The seed cake is a great source of nitrogen for making Bio Fertilizer due to its high nitrogen content.
- The annual seed production ranges from roughly 0.4 ton/hectors to over 12 tons/hectors.
- After sowing, the plant produces seeds after a maximum of two years.
- Plant propagation in nurseries, planting and maintaining them, and seed collection are all labor-intensive tasks. Except for the expense of seeds, plastic bags, fertilizer, and plant transportation from the nursery, all activities in nurseries and planting are labor-intensive. Planting in 1 hector of land takes 311-man days. Various portions of the plant are therapeutic, the bark contains tannin, and the leaves are edible.(Fragoso, n.d.)

2.7 Production of jatropha in Pakistan:

The government is encouraging and promoting a cheap way to make biodegradable products. Many edible and non-edible seeds are used to make biodiesels. Biodiesel can be made from non-edible feedstock, but the Jatropha curcas plant, also known as Jatropha, is the best source for making it. It is a plant that makes oil seeds. Because it is hardy, grows quickly, and can be used in a lot of different ways, it is the most popular non-edible feed stock. There are a lot of places where it can grow: on the coast and in hot deserts. It can also grow in wetlands, waterlogged areas, moderately humid areas, hills, and soils that don't have much food. To make biodiesel, Jatropha needs a lot of nutrients in the soil. This caused the plant to produce a lot of oil, which led to a lot of biodiesel conversion and a smaller energy crisis. In a nutshell, the Jatropha can be grown anywhere, even on rocky, sandy, acidic, alkaline soils and on land that has been used. In that way, a lot of national and international businesses are setting up Jatropha nurseries in different parts of the country.

Table 2. 6: Production of jatropha in Pakistan

Company	**Jatropha Nursery**	**Reference**
Pakistan State Oil Company Ltd Karachi & Arid Zone Research Institute	22 acres at Pipri Karachi	(Surjs S, 2016)
Al-Wardah Agro Industries Farm	Bahawalpur & Cholistan 01 acre each	
One Gas (Pvt.) Ltd Lahore	50 acres at Karachi	
National University of S&T	85 acres near Karachi	
Contract with CIDA	2 acres in Bahawalpur	

Jatropha plantations can also be used for decoration. It was planted in parks and gardens, along roadsides, and to beautify railway tracks. Trimming and pruning were used to maintain its diverse heights and shapes, resulting in a pleasing appearance. The goal of this project was to conduct a feasibility analysis so that Jatropha biodiesel may be promoted in Pakistan. In this regard, a survey was undertaken on the occurrence of the Jatropha plant in Pakistan, its population, survival conditions, climatically active areas, and insect infestations. The next stage was to recover the oil production and put the press cake to good use. The conversion of Jatropha oil into Jatropha biodiesel was the third step. Last but not least, the physicochemical features of Jatropha biodiesel were determined.

Pakistan is processing 2.93 million ton of jatropha oil yearly from which a large amount is produced by PSO (Pakistan State Oil Company Limited)

2.7.1 Extraction of oil from jatropha seeds:

Enzymatic extraction, solvent extraction, and the screw press method are all used to extract Jatropha oil. The screw press method was used in this study because it yielded a considerable amount of oil(Karaj & Müller, 2011). The Jatropha seeds were prepared by washing, drying, splitting the hulls, and collecting the kernels. To acquire the most oil yield, the press cake was screwed squeezed several times. Because the press cake was high in phosphorus, nitrogen, and potassium, it was given to farmers as a soil improver(Karmakar et al., 2010). For the manufacturing of Jatropha biodiesel, screw pressed Jatropha oil was collected in an airtight, pre-sterilized bottle. Because Jatropha is a natural product, the oil content varies by location, depending on climatic, active component, geographical, and topographical factors.

Table 2. 7: Properties of Jatropha oils

Jatropha crude oil	**Obtained value**	**Reported values**	**Reference**
Density	0.919	0.921	(Karmakar et al., 2010)
K. Viscosity# 40 o C (mm2 /sec)	35.75	44.3	
Flash Point (0 C)	160	225.4	
Cloud Point (0 C)	3	2	
Pour Point (0 C)	0	4.76	
Sulfur (wt. %)	0.011	0.012	
FFA*(wt. %)	12.24	10.23	
Sap. ** value	195.5	196.4	

Note: the free fatty acid ratio is too heigh in the jatropha oil for it to be fesible for transesterification reaction so we need to lower the value of free fatty acid less then 2% otherwise the saponification(Saponification is a process that involves the conversion of fat, oil, or lipid, into soap and alcohol by the action of aqueous alkali(Prieto Vidal et al., 2018).) reaction will contaminates the product in order to remove the excess fatty acid we treat the jatropha oil through esterification reaction

2.8 Esterification reaction

The colour of crude unrefined jatropha oil was dark greenish yellow. Table 1 shows the fatty acid profile of jatropha oil. The amount of FFA in it was determined using a conventional titrimetric method. This oil had an initial acid value of 28mg $KOHg^{-}$ which corresponded to an FFA level of 14% percent, significantly exceeding the 2% limit for a successful transesterification reaction utilizing an alkaline catalyst. As a result, FFAs were first transformed to esters employing an acid catalyst in a pretreatment process with methanol (H2SO4). The acid value of the bottom-separated product was calculated. For the transesterification reaction, a product with an acid value of less than 2mg $KOHg^{-}$ was employed.

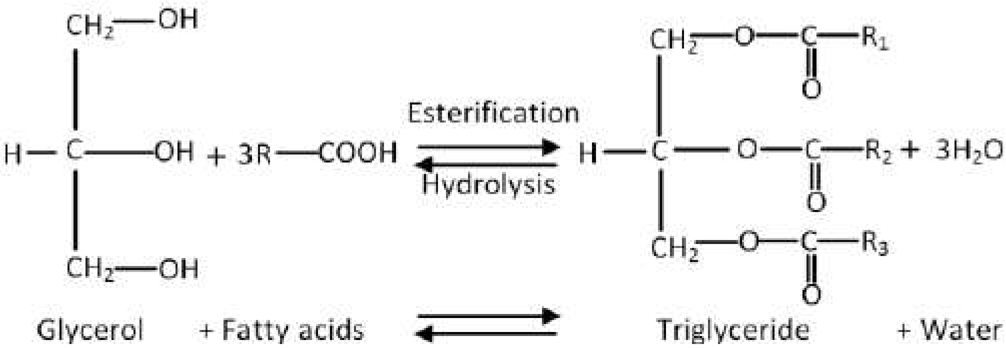


Figure 2. 1: Esterification Reaction

2.8.1 Production of esterified jatropha oil in Pakistan

Estimated amount of treated jatropha oil production is about 3.4million tons annually and the total production of jatropha seeds in Pakistan is about 9.3 million tons yearly the major treatment plants of oil treatment are in Karachi along with the jatropha nurseries and the major producers of jatropha are Pakistan state oil company and national university of S&W (S u r j s S, 2016)(No, 2004)

2.9 Chemistry of biodiesel production

An alkali, an acid, or an enzyme catalyst is used to transesterify large, branching triglycerides into smaller, straight chain molecules of methyl esters for use in biodiesel production. Using triglycerides as a starting point, three stepwise reactions with intermediate generation of diglycerides and monoglycerides are carried out, with the result being the production of three moles each of methyl esters and one mole each of glycol from the triglyceride starting point. The overall reaction is positive

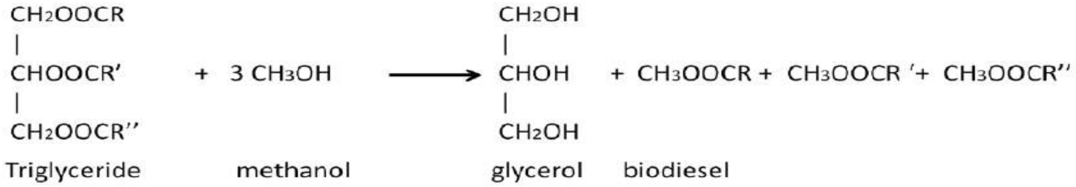


Figure 2. 2: Transesterification Reaction

The transesterification process involves the use of alcohols such as methanol, ethanol, propanol, butanol, and amyl alcohol, among others. Methanol and ethanol are the most commonly used solvents, with methanol being the most popular due to its inexpensive cost, as well as its physical and chemical properties. They react swiftly with triglycerides, and sodium hydroxide is easily dissolved in these alcohols due to their high solubility in water. It is necessary for transesterification to occur in a 3:1 stoichiometric molar ratio of alcohol to triglycerides. In practice, the ratio must be increased in order to drive the equilibrium to a maximum ester yield.

2.9.1Choice of catalyst

Table 2. 8:types of catalyst and dosage

Catalyst	**Catalyst dosage (wt.%)**	**Yield of biodiesel**	**Refrences**
ChOH	0.4	95.0 ± 1.7	(Fan et al., 2013)
ChOMe	0.4	88.3 ± 1.8	
ChIm	0.4	76.9 ± 1.9	
NaOH	0.3	98 ± 1	
KOH	0.3	92.4 ± 1.2	

From the data it is clear that NaOH is the best basic catalyst for our process as it is heterogeneous it can easily be separated from the product (Verma & Gaur, 2009)

2.9.2 Effect of catalyst dosage:

Biodiesel yields show obvious upward trends as the amount of catalyst used in the process is larger. After increasing catalyst dosage from 0.1 wt. percent to 0.3 wt. percent, the biodiesel yield grew dramatically from 73.8 percent to 98.0 percent, with a gradual plateauing at a catalyst dosage of >4 wt. it should be noted that the best catalyst dose for the generation of biodiesel was determined to be 0.3 weight percent by weight.(Fan et al., 2013)

2.9.3 Choice of alcohol used:

Table 2. 9: Alcohol type

Alcohol	**TG**	**DG**	**Conversion (%)**	**References**
Methanol		0.54 ± 0.02	99.33 ± 0.02	(Colucci et al., 2005)
Ethanol		0.67 ± 0.02	99.11 ± 0.04	
1-Butanol	1.90 ± 0.02	3.27 ± 0.03	92.02 ± 0.03	
2-Propanol	49.39 ± 0.02		29.21 ± 0.04	

The results confirmed that an excess of alcohol beyond the stoichiometric ratio was required in order to increase the conversion to esters during the experiment. A little number of glycerides was found in even the most favorable conditions for the synthesis of methyl esters, due to the equilibrium between products and reactants, which was maintained. When a molar ratio of 6:1 methanol/oil was utilized, the weight percentages of DG and TG remained less than 1% at equilibrium, indicating that they were stable.(Colucci et al., 2005)

2.9.4 Ratio of alcohol to triglycerides*:*

Table 2. 10: time of reaction

Molar ratio (oil: methanol)	**Time of completion (min)**	**Reference**
1:3	> 360**	(May, 2004)
1:4	360	
1:6	23	
1:8	12	
1:10	7	
1:11	7	
1:15.6	7	

The use of excessive methanol (15:1 molar ratio) following the reaction, as previously stated, results in natural separation of the ester and glycerol layers, which is undesirable. Although no two layers were visible at the theoretical ratio of 3:1, the reaction mixture/product remained semi-solid throughout the reaction and appeared to have reached equilibrium after 6 hours, with large levels of mono-, di-, and triacylglycerol’s still present. A natural separation of the ester and glycerol was observed in the reaction mixture at a 4:1 molar ratio, with a solid glycerol layer on the surface and a semi-solid reaction mixture on the surface during the reaction. The glycerol layer formed during the reaction with a 6:1 molar ratio solidified as well after being left overnight. A molar ratio of 8:1 or above resulted in good separation of the ester and the glycerol, which remained liquid and clear after being stored overnight. In order to complete 100% conversion, an excess of 233 percent methanol was necessary, which corresponded to a 10:1 molar ratio of methanol to acetone. Increasing the molar ratio further did not appear to have a meaningful effect on the rate of product production after this point.(May, 2004)

Experiments were carried out with various molar ratios of methanol to oil in the range of 3:1 to 11:1 in order to investigate the influence of molar ratio on the ester concentration and yield of the transesterification. The optimal catalyst concentration and reaction time, as determined in the preceding sections, were used in this experiment, with minor modifications. as a result of these experiments, the ester content and yield showed an asymptotic tendency. The stoichiometric transesterification reaction necessitates the use of three moles of methanol per mole of triglyceride in order to yield three moles of fatty methyl esters and one mole of glycerol from the triglyceride. In order to achieve this, the theoretical molar ratio of methanol to triglyceride should be 3:1. The highest ester yield, on the other hand, was found at a molar ratio of 6:1 for plain Canola oil. This larger ester conversion was achieved by using a higher molar ratio than the stoichiometric value, which increased the likelihood of a complete reaction. After increasing the ratio from 3:1 to 6:1, the ester content climbed from 80.3 percent to 98.0 percent while the yield improved from 78.7 percent to 90.0 percent. As a result, if the molar ratio was less than 6:1, the reaction was considered incomplete.(Leung & Guo, 2006)

2.9.5 Effect of temperature on reaction:

Results from the experiments revealed that the transesterification reaction could proceed within the temperature range investigated, but that the reaction time required to complete the reaction varied greatly depending on the reaction temperature used. The fact that a high product yield may be attained even at room temperature is evident; however, this would result in a significantly extended reaction time. It was also discovered that the highest yield was obtained for plain oil when the temperature range was between 40 and 45 degrees Celsius. When the temperature is lowered from 70 degrees Celsius to 45 degrees Celsius, the product yield can be increased from 90.4 percent to 93.5 percent, an increase of approximately 3 percent. However, the reaction time for completion of the transesterification is increased from 15 minutes to 60 minutes due to a lower reaction rate at 45 degrees Celsius than at 70 degrees Celsius. This statistically significant increase in ester yield at a lower temperature demonstrated that a higher temperature had a negative impact on the product yield for the transesterification of plain oil, as previously reported. The reason for this is that increasing the temperature causes the side saponification process of triglycerides to occur more quickly. However, it is clear that the influence of temperature was less significant than the effect of catalyst concentration. The ideal reaction temperature of 60 °C found for the UFO was, in reality, a result of rivalry between the main transesterification reaction and the side saponification reaction during the UFO's formation.(Leung & Guo, 2006)

2.10 Process choices on the base of catalyst:

2.10.1 Acid catalyzed transesterification:

Typically, Bronsted acids, such as sulfon and sulfuric acids, are used to catalyse the transesterification process. Although these catalysts provide extremely high yields in alkyl esters, the reactions are extremely sluggish. The molar ratio of alcohol to vegetable oil is one of the most important parameters that affects the transesterification process. The development of the products is aided by the presence of excessive alcohol. The recovery of glycerol, on the other hand, is made more difficult by the presence of an excessive amount of alcohol; therefore, the optimal alcohol/oil ratio must be determined empirically, taking into consideration each unique procedure. This animation demonstrates how fatty acids are esterified when an acid is used as the catalyst. Initially, the acid is protonated to produce an oxonium ion, which can then undergo an exchange reaction with an alcohol to produce an intermediate, which can then lose a proton to form an ester. The final step is the formation of an ester by losing a proton. Despite the fact that each step in the process is reversible, when there is a significant excess of alcohol in the mixture, the equilibrium point of the reaction is moved, and the esterification reaction proceeds almost to completion. demonstrates the mechanism of transesterification of vegetable oils by acid catalysis. The transesterification process takes place under identical circumstances. Initially, the ester is protonated, and then the exchange alcohol is added to produce the intermediate, which can then be dissociated via the transitions state to produce the ester.(Demirbas, 2008)

2.10.2 Base Catalyzed Transesterification:

When esters react with a base, such as an alcohol ateanion, they generate an anionic intermediate that can either dissociate back to the original ester or form a new ester, depending on the situation. As a result, transesterification can occur by this process when basic catalysis is used, but esterification is not possible. The transesterification of vegetable oils catalyzed by a base advance more quickly than the reaction mediated by an acid. It produces a very high yield of more than 98 percent, and it usually takes less than 30 minutes to finish. As a basic catalyst, sodium hydroxide is employed.(Demirbas, 2008)

2.10.3 Non-Catalytic Supercritical Alcohol transesterification:

Process variables that influence the synthesis of methyl esters include reaction temperature, pressure, molar ratio, water content, and the presence or absence of free fatty acids. In the presence of alcohol in a subcritical state, it is clear that the reaction rate is extremely low and increases gradually with increasing pressure or increasing temperature. As a result of raising the reaction temperature, particularly to supercritical conditions, it was discovered that the yield of ester conversion increased significantly. With an increase in the molar ratio of oil to alcohol, the yield of alkyl ester was enhanced. It is possible to achieve conversion yields of 50–95 percent during the first 10 minutes of the supercritical alcohol transesterification process.(Balat, 2008)

In the typical catalytic transesterification of vegetable oil, the amount of water present is a significant element. Free fatty acids and water are usually detrimental in the conventional transesterification of fats and vegetable oils for biodiesel generation because the presence of free fatty acids and water induces soap formation, consumes catalyst, and lowers the efficacy of the catalyst. It is known that the presence of water has a deleterious influence on the yields of methyl esters produced by catalyzed techniques. In our supercritical methanol approach, the presence of water, on the other hand, had a beneficial effect on the synthesis of methyl esters.

2.11 Conclusion:

Biodiesel is a fatty acid (m)ethyl ester in terms of chemistry. Given its ability to reduce emissions from Diesel engines for many air pollutant precursors, as well as the lower toxicity of Diesel particulate matter emissions compared to conventional Diesel, bio-diesel is expected to play an important role in meeting future fuel requirements. Bio-diesel is expected to play an even greater role in meeting future fuel requirements due to its ability to reduce emissions from Diesel engines for many air pollutant precursors, as well as the fact that it is obtained from renewable sources.

During the first 8 minutes of the supercritical alcohol transesterification process, the conversion yield increases to 50–95 percent, with a maximum of 95 percent. After 1 minute, the yield of conversion increases to 60–90 percent, which is a good result for the catalytic supercritical methanol transesterification process. The reaction between sodium methoxide in methanol and a vegetable oil is quite fast; for example, at ambient temperature, a vegetable oil can be entirely trans esterified in 4–6 minutes.(Demirbas, 2008)

2.12 Choice of process on the base of Equipment:

2.12.1Batch Process:

The Most straight forward way for manufacturing alcohol esters is to employ a batch, stirred tank reactor, which is quite inexpressive. There have been reports of alcohol to triglyceride ratios ranging from 4 :1 to 20 :1 (mole : mole), with a 6 :1 ratio being the most common. The reactor may be sealed or fitted with a reflux condenser, depending on the application. In practise, the working temperature is typically around 65°C, though temperatures ranging from 25°C to 85°C have been recorded. Potassium hydroxide and sodium hydroxide are the two most often used catalysts, with sodium hydrogen hydroxide being the most prévalent. The loading of catalyst varies widely, ranging from 0.3 percentage point to around 1.5 percentage point. It is vital to thoroughly mix the ingredients at the start of the reaction in order to bring the oil, catalyst, and alcohol into close contact. By allowing the inhibitory product glycerol to phase separate from the ester–oil phase towards the conclusion of the reaction, less mixing can aid in increasing the extent of the reaction by increasing the extent of the reaction. Completions range from 85 percent to 94 percent, according to the data. In order to raise the final reaction extent to 95 percent or more, some researchers use a two-stage process with glycerol removal between each phase. The completion can be increased by raising the temperature and increasing the alcohol oil ratio. Response times often range from 20 minutes to more than an hour. In order to charge the system, the oil must be introduced first, followed by the catalyst and the methanol. It is normal for the system to become agitated throughout the reaction time. The agitation is then brought to a halt. It is possible in some methods to allow the reaction mixture to settle in the reactor in order to achieve an initial separation of the esters and glycerol. In some techniques, the reaction mixture is pumped into a settling vessel or is separated using a centrifuge to complete the separation process. An evaporator or a flash unit is used to extract the alcohol from both the glycerol and the ester streams, respectively. The esters are neutralised, then gently washed with warm, slightly acid water to remove any remaining methanol and salts, and finally dried in the sun. After that, the finished biodiesel is sent to a storage facility. The glycerol stream is neutralised and rinsed with soft water once it has been neutralised. The glycerol is then transferred to the glycerol refining part of the plant for further processing.(Adebowale & Adedire, 2006)

2.12.2 Continuous Process System:

A prominent variation on the batch process is the use of continuous stirred tank reactors (CSTRs) in sequence, which is a popular variation on the batch process. The volume of the CSTRs can be changed to allow for a longer residence period in CSTR 1 and, as a result, a greater degree of reaction to occur. As soon as the initial product, glycerol, is decanted, the reaction in CSTR 2 accelerates, with completion rates of 98 percent or higher not uncommon. A critical component of the design of a CSTR is the provision of sufficient mixing input to guarantee that the composition of the reactor is largely consistent throughout the reactor. Because of this, the dispersion of the glycerol product in the ester phase is increased in the ester phase. A consequence of this is that the time necessary for phase separation is prolonged.

There are a number of techniques that require vigorous mixing, either from pumps or stationary mixers, to kickstart the esterification reaction and get it started. The reactor is tubular, which eliminates the need to allow time for the reaction to occur in an agitated tank. A continuous plug of reaction mixture travels through this type of reactor, with little mixing occurring in the axial direction. A plug-flow reactor (PFR) is a type of reactor that acts as if it were a succession of miniature CSTRs that have been connected together. As a result, a continuous system is created that requires just short residence times, as little as 6 to 10 minutes, for the reaction to be completed or nearly completed. The PFRs can be staged in the manner depicted to allow for the decanting of glycerol. This sort of reactor is frequently operated at elevated temperatures and pressures in order to accelerate the pace of reaction.

2.12.3 Esterification Followed by Transesterification*:*

The colour of crude unrefined jatropha oil was dark greenish yellow. Table 1 shows the fatty acid profile of jatropha oil. The amount of FFA in it was determined using a conventional titrimetric method. This oil had an initial acid value of 28mg KOH which corresponded to an FFA level of 14% percent, significantly exceeding the 2% limit for a successful transesterification reaction utilizing an alkaline catalyst. As a result, FFAs were first transformed to esters employing an acid catalyst in a pretreatment process with methanol (H2SO4). The acid value of the bottom-separated product was calculated. For the transesterification reaction, a product with an acid value of less than 2mg KOHg^{-} was employed.

It was decided to use 0.20 volume percent methanol to volume percent oil (i.e., 5:1 molar ratio) for the transesterification reaction, and 0.55 percent weight percent KOH was used as an alkaline catalyst. KOH (5.5 g l?1 of pretreatment jatropha oil) was calculated based on the amount required to neutralize the unreacted acids (i.e., 2 mg KOHg^{-1}) in the second stage product, plus 0.35 percent for virgin oil, to achieve the desired KOH concentration.

Afterwards, the reaction was carried out at 60^{o} C for half an hour, and the products were allowed to settle overnight before being separated in a separating funnel to obtain the ester layer on the top, which is referred to as biodiesel. The glycerol layer on the bottom was removed in a separating funnel to obtain the ester layer on the top, which is referred to as biodiesel.(Kumar Tiwari et al., 2007)

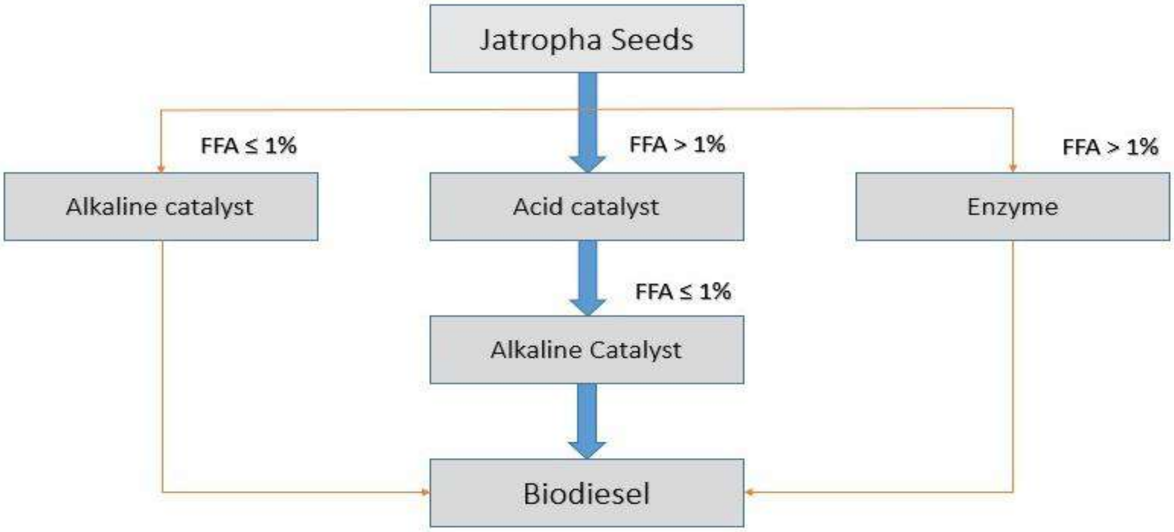


figure 2. 3:Transesterification of fatty acids

2.13 Properties of Biodiesel:

Table 2. 11:properties of bio diesel

	UNITS	LOWER LIMIT	UPPER LIMIT	References
Ester content	% (m/m)	96.5	–	(Karmakar et al., 2010) (Kumar Tiwari et al., 2007) (Adebowale & Adedire, 2006)
Density at 15 °C	kg/m3	860	900	
Viscosity at 40 °C	mm2/s	3.5	5.0	
Flash point	°C	>101		
Sulfur content	mg/kg	–	10	
Tar remnant (at 10% distillation remnant)	% (m/m)		0.3	
Cetane number	–	51.0	–	
Sulfated ash content	% (m/m)	–	0.02	
Water content	mg/kg	-	500	
Total contamination	mg/kg	–	24	

2. 14 Block diagram of process:

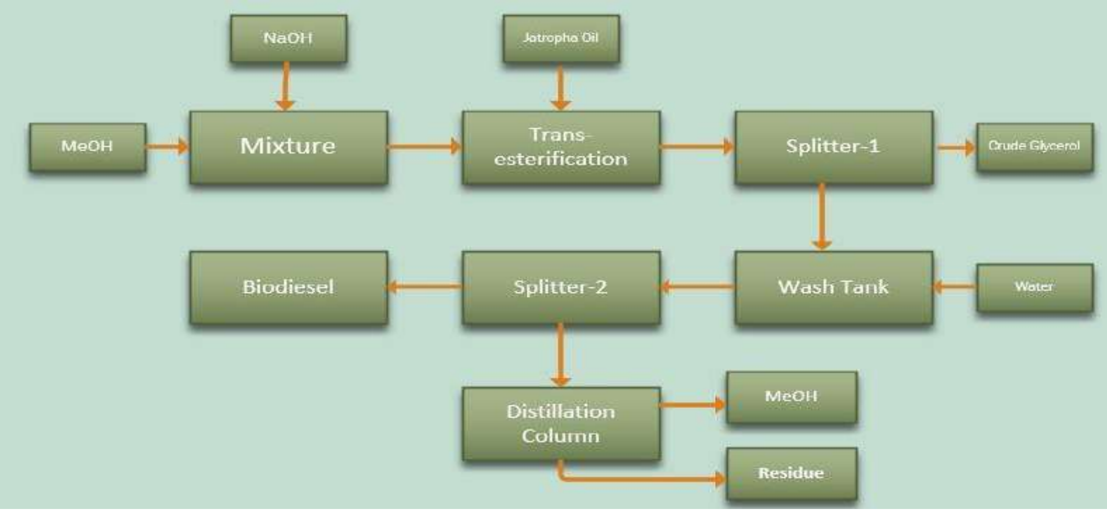


Figure 2. 4: Block Diagram for the production of Biodiesel

2.15 Process flow diagram:

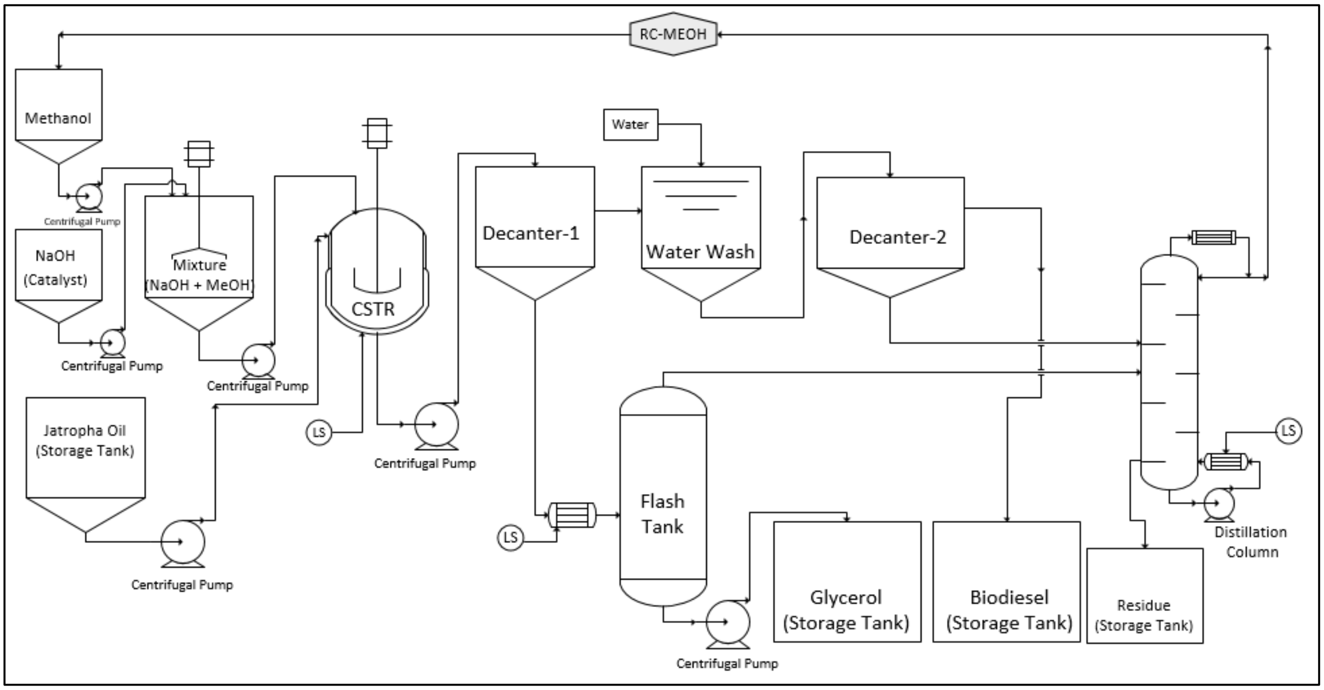


Figure 2. 5: Process Flow Diagram

2.16 Process flow description:

the process starts with the methanol stored in the storage tank mixing with the NaOH catalyst in the mixer in a ratio of 0.3% by wt to methanol which produce Sodium methoxide the catalyst mixture from the mixer and the jatropha oil from the storage is send to the CSTR(constant stirred tank reactor) at an pressure of 1 bar(1atm) and temperature of 60 degree C the reaction starts in the reactor and the residency time in the reactor is about 20-30 minutes after the reaction a conversion of 98% happens and the products formed are methyl esters, glycerol, the amount of free fatty acids in the feed is less then 1% and saponification commence at 2% free fatty acid concentration so there is no soap formation in the process

the product streams are then sent to a splitter where the biodiesel phase and the glycerol phase are separated by the function of gravity. The glycerol phase is directly sent to the flash tank along with the methanol present in it that the excess methanol present with the glycerol is vent to the atmosphere. On the other hand, the biodiesel phase is sent to a wash tank for water washing.

1 kg of water is feed per kg of biodiesel produced water absorb all the soluble impurities present in the biodiesel and then this water is separated out in the second splitter. The purified biodiesel is sent to the storage tank. And the residual stream from the splitter 2 is sent to a distillation column to extract the methanol produced which also contains soap and glycerol.

3. Chapter 3 – Material Balance:

The application of mass conservation to the analysis of physical systems is known as material balance (also known as mass balance). According to the rule of conservation of mass, mass cannot be created or destroyed. The foundation of process design is material balances. The quantity of raw materials required and goods generated will be determined by a material balance conducted over the entire process. The process stream fluxes and compositions are set by balances over particular process units.

The general form of material balance is given below

Input – Output + Generation – Consumption = Accumulation

The phrases consumption and generation are exclusive to systems that include chemical reactions. They are responsible for the consumption of reactants and the production of products, respectively. The accumulation term, on the other hand, is equal to zero when the system is considered to function at steady state (as in distillation columns). The material balance analysis for the plant is created with this background in mind.

3.1 Biodiesel Production

Aim: Production of 5000 liters of biodiesel fuel from jatropha oil.

Assumptions

One production day is equal to 24 hours

- One working day is equivalent to 24hrs
- Methanol used is 99.7% pure
- Methanol used is 100% excess of required
- Triglyceride oil used is 100% pure after purification as indicated in the process of flow diagram
- The accumulation of reactant and products in pipes and vessel is negligible
  Biodiesel product is made up of followings components.

The unreacted stock is jatropha oil

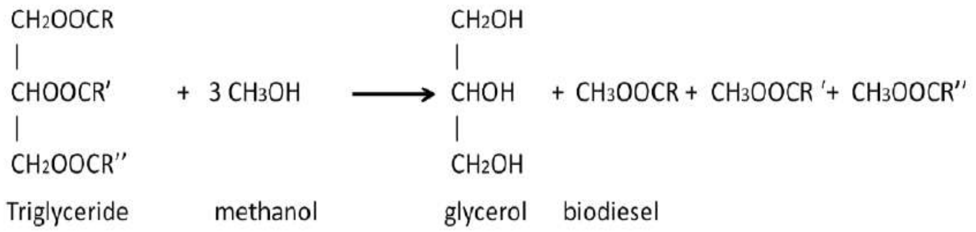


Figure 3.1: Biodiesel production reaction

To make 0.3% NaOH, sodium hydroxide is dissolved with methanol (mass). The supply of methanol is 100 % in excess then the need for complete conversion to methyl ester. The reactor is kept at 60°C, with a one-hour residence duration based on the feed volume. Using the feed and product composition data, the conversion of jatropha oil to methyl esters in the reactor will be determined. It's also safe to presume that all sodium in NaOH is converted to soap and ends up in the waste stream.

At 0.15 bar_{ab}, the vacuum flash vessel operates.

90% of the glycerol available is recovered as a saleable product.

A ratio of 1kg water per kg of biodiesel product is required for wash water.

Methanol that has been recycled must fulfil the same purity requirements as methanol that has been purchased.

3.2 Determination of the Average Molecular Weight of Jatropha Oil:

Table 3. 1: Average molecular weight of jatropha oil**.**

Component	**Mol wt**	**Mass fraction**	**weight**
Tripalmitic	807.33	16	12917.28
Trimyristic	723.17	0.38	274.8046
Tripalmitoleic	775.25	2	1550.5
Tristearate	891.49	6.5	5794.685
Trioleicate	885.45	40.75	36082.0875
Trilinoleic	879.4	33.57	29521.458
Trilinolenic	873.35	0.8	698.68
		100	86839.4951
Average Molecular weight			868.394951

Carbon number of jatropha oil is 19

3.1 Determination of the Average Molecular Weight of Biodiesel:

Table 3. 2: Average molecular weight of biodiesel.

Component	Mol wt	Mass Fraction	Weight
Methyl Myristate	242.4	0.38	92.112
Methyl Palmitate	270.45	16	4327.2
Methyl palmitoleate	268.44	2	536.88
Methyl stearate	313.54	6.5	2038.01
methyl oleate	296.49	40.75	12081.9675
Methyl linoleate	294.48	33.57	9885.6936
Methyl linolenate	292.5	0.8	234
		100	29195.8631
Average Molecular weight			291.958631

3.4 Molar & Mass Flow Rates Computation of the overall balance Table:

BIODIESEL:

Basis: 5000 litters of Biodiesel per day

Production in kg =5000*0.860=4300kg/day

Molecular weight = 291.9586kg/kmol

Molar flow = 179.166/291.95=0.61367

Excess Methyl Ester = 0.98 *0.61367 =0.6013966

flow rate of Methyl Ester= 0.601398052

JATROPHA OIL:

Molar flow = 0.61367/3= 0.204557161

Molecular Weight = 868.3950kg/kmol

Mass flow= 868.3950 * 0.204557161= 177.6364155

METHANOL:

Molar flow = 0.61367/1=0.61367

Molecular Weight = 32kg/kmol

Mass flow= 0.61367* 32 = 19.63748742 kg/hr

GLYCEROL:
3kmol of methanol 1kmol of glycerol
Molar flow = 0.61367/3= 0.204557161

Molecular Weight = 92.02kg/kmol

Mass flow=0.204557161* 92 = 18.82334992 kg/hr

WATER:

Mass Concentration = (100 – 99.7) %= 0.003%wt/wt

Water mass flow:

0.997% methanol produces 19.63748742kg/hr of methanol

Hence, 0.003% of water gives (0.003*19.6374874) = 0.059089731

Molecular weight = 18kg/kgmol

Molar flow = 0.059089731/18 = 0.003282763kmol/hr

NaOH:

Mass Concentration = 0.003%wt/wt

Mass flow: (water conc * (mass of water + mass of methanol)/ conc. Methanol

(0.003*(19.6374874+0.059089731))/0.997 = 0.059267534

Molecular weight = 40kg/kgmol

Molar flow = 0.059267534/40 = 0.001481688kmol/hr

Amount of biodiesel supplied allowing for 100% excess and 98% conversion of jatropha oil to methyl ester.

Excess Amount of methanol = (0.98* 0.601398052*2) = 1.17874018192kmol/hr
Mass flow rate of excess methanol= 1.17874018192*32 = 37.719685214kg/hr

If 98% of methyl ester made up the biodiesel. Therefore actual methyl ester formed = 0.98 * 175.583333 = 172.071666634kg kg/hr.

From stoichiometry:

3kmol of methanol gives 3kmol of methyl ester

Mole of methyl ester = 172.071666634/291.9586 = 0.58937009

Table 3. 3: Molar & Mass Flow Rates Computation of the overall balance

Streams:	**Quantity**	**Units**
Biodiesel production	5000	liters/day
Production in kg	4300	Kg/day
Hourly production	179.1666667	kg/day
Biodiesel Average Molecular weight	291.9586	kg/kmol
Molar flow	0.613671482	kmol/hr
Methyl Ester mass flow	175.5833333	kg/kmol
Methyl Ester molar flow	0.601398052	kmol/hr
Triglyceride + 3 Methanol Glycerol → 3 Methyl Esters		
Triglyceride Molar flow	0.204557161	kmol/hr
Triglyceride Average Molecular weight	868.395	kg/kmol
Triglyceride Mass flow	177.6364155	kmol/hr
Methanol		
Methanol Molar flow	0.613671482	kmol/hr
Methanol Average Molecular weight	32	kg/kmol
Methanol Mass flow	19.63748742	kg/kmol
Glycerol		
Glycerol Molar flow	0.204557161	kmol/hr

Glycerol Average Molecular weight	92.02	kg/kmol
Glycerol Mass flow	18.82334992	kmol/hr
Water		
For 99.7% pure methanol (0.3% H_2O)		
Mass Concentration	0.003	weight ratio
Water Mass flow	0.059089731	kmol/hr
Water Molecular weight	18	kg/kmol
Water Molar flow	0.003282763	kmol/hr
NaOH		
Mass Concentration	0.003	weight ratio
NaOH Mass flow	0.059267534	kmol/hr
NaOH Molecular weight	40	kg/kmol
NaOH Molar flow	0.001481688	kmol/hr

3. 5 Material balance around Each Unit Operation:

3.5.1 Balance Around Mixer**:**

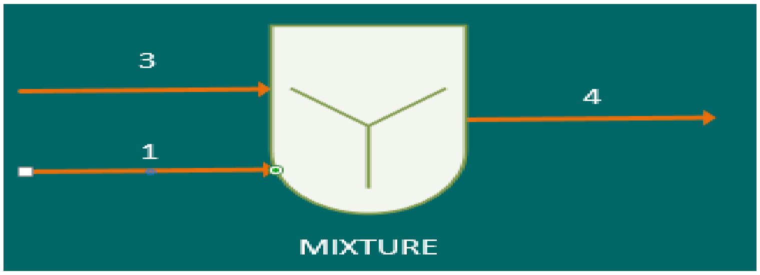


Figure 3. 1: Mixer

Input Streams:

S-1: Methanol

S-3: NaOH

Output Stream:

S-4: Methanol + NaOH

Reactants in:

S-1= 58.91kg/hr = 1.841kmol/hr

S-3= 0.059267534kg/hr = 0.001481688kmol/hr

Table 3. 4: Material balance on mixer.

Streams:	**Input**		**Output**		
	Mass	Mole	Mass	Mole	Fractions
Methanal	58.91246	1.841014	58.91246	1.841014	0.999195826
NaOH	0.059268	0.001482	0.059268	0.001482	0.000804174
Total:	58.97173	1.842496	58.97173	1.842496	1

3.5.2 Balance Around the Reactor:

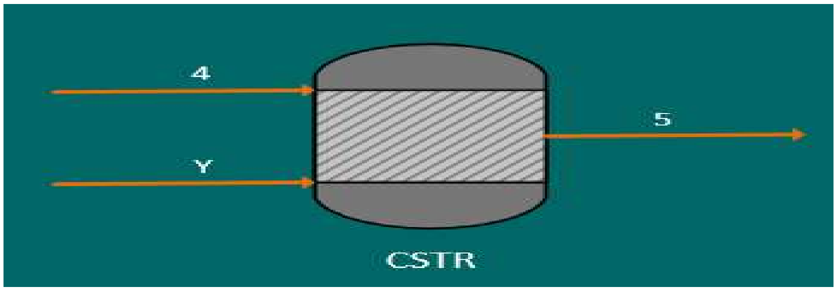


Figure 3. 2: Continuous stirred tank reactor

Input Streams:

S-4: Methanol + NaOH

S-Y: jatropha oil

Output Streams:

S-5: (Methyl Ester, Glycerol, unreacted jatropha oil, water, Methanol and Soap)

Here the main reaction occurred:

Reaction of jatropha with methanol to form biodiesel.

Inputs:

S-4 = 58.97kg/hr = 1.842kmol/hr

S-Y = 177.6364155kg/hr = 0.204557161kmol/hr

Table 3. 5: Input streams of reactor

Streams:	**Input**	
	Mass	**Moles**
Methonal + NaOH	58.97173	1.842496
Jatropha oil	177.6364	0.204557

Table 3. 6: Output streams of reactor

Streams:	**Output**		
	Mass	Moles	Mole fraction
Methyl Ester	172.0717	0.58937	0.291075578
Unreacted jatropha oil	5.963	0.006867	0.003391292
Glycerol	18.07795	0.196457	0.097025193
Water	0.05909	0.003283	0.001621277
Methanol	39.27497	1.227343	0.60615489
NaOH	0.059268	0.001482	0.00073177
Total:	235.5059	2.024801	1

3.5.3 Balance Around the Splitter:

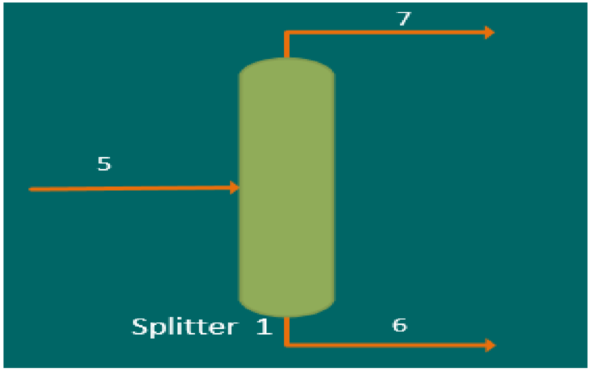


Figure 3. 3: Splitter-1 OR Decanter-1

Input streams:

S-5: (Methyl Ester, Glycerol, unreacted jatropha oil, water, Methanol and Soap)

Output Streams:

S-6: Glycerol phase

S-7: Biodiesel phase

Inputs:

S-5= 235.5059kg/hr =2.024801Kmol/hr

Outputs:

Table 3. 7: Output streams of decanter

Streams	**Output**		
	Mass	**Moles**	**Fraction**
Glycerol phase:			
Glycerol	16.27015	0.176811	0.151481088
Methanol	31.69293	0.990404	0.848518912
Total:	47.96308	1.167215	1
Biodiesel phase:			
Glycerol	1.807795	0.019646	0.022908113
Water	0.05909	0.003283	0.003827912
Methanol	7.582041	0.236939	0.276285853
NaOH	0.059268	0.001482	0.001727744
Methyl Ester	172.0717	0.58937	0.687243376
Unreacted jatropha oil	5.963	0.006867	0.008007003
Total:	187.5429	0.857586	1
Overall:	235.5059	2.024801	1

3.5.4 Balance around the Flash vessel:

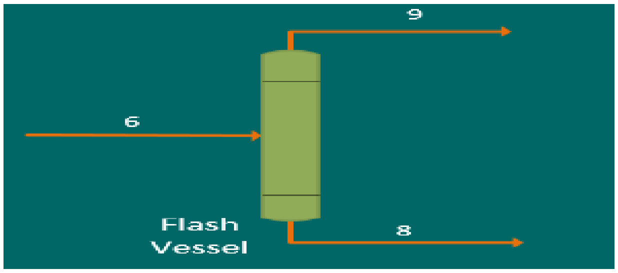


Figure 3. 4: Flash Vessel

Input Streams:

S-6**:** Glycerol phase

Output streams:

Table 3. 8: Output streams of flash vessel

Streams	**Output**		
	Mass	**Moles**	**Fraction**
Glycerol	16.27015	0.176811	0.856131747
Methanol	0.950788	0.029712	0.143868253
Total:	17.22094	0.206523	1
Vent section:			
Methanol	30.74215	0.960692	1
Total:	47.96308	1.167215	1

3.5.5 Balance around the Wash Tank:

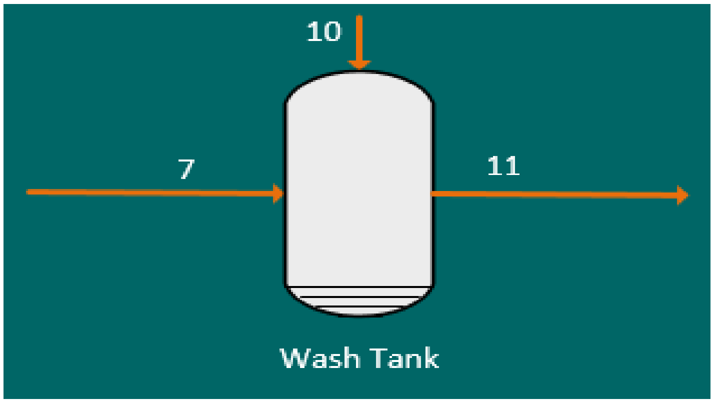


Figure 3. 5: Wash Tank

Input Streams:

S-7: Biodiesel phase

S-10: Wash Water

Outputs Streams:

S-11: Biodiesel phase

Inputs:

Table 3. 9: Input of wash tank

Streams	**Inputs**		
	Mass	**Moles**	**Fraction**
Biodiesel phase	187.5429	0.857586	0.146986867
Wash water	89.58333	4.976852	0.853013133
Total:	277.1262	5.834438	1

Outputs:

Table 3. 10: Output of wash tank

Streams:	**Output**		
	Mass	**Moles**	**Fraction**
Glycerol	1.807795	0.019646	0.003367192
Water	89.64242	4.980135	0.853575785
Methanol	7.582041	0.236939	0.040610392
NaOH	0.059268	0.001482	0.000253956
Methyl Ester	172.0717	0.58937	0.101015751
Unreacted jatropha oil	5.963	0.006867	0.001176924
Total:	277.1262	5.834438	1

3.5.6 Balance Around the Splitter-2:

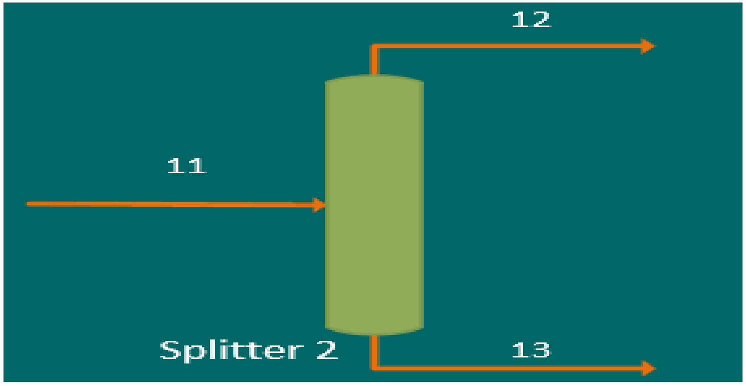


Figure 3. 6: Decanter-2

Inputs Streams:

S-11: Methanol + residue (soap, glycerol and water)

Output Streams:

S-12: Biodiesel phase (Methyl Ester, unreacted jatropha oil, water, glycerol, Methanol and Soap)

S-13: Biodiesel (Methyl Ester, unreacted jatropha oil, water, and glycerol,)

Product Streams out:

Outputs:

Table 3. 11: Output of decanter -2

Streams	**Output**		
	Mass	**Moles**	**Fraction**
Biodiesel:			
Glycerol	0.447917	0.004868	0.007901502
Methyl Ester	172.0717	0.58937	0.956715365
Water	0.26875	0.014931	0.02423654
Unreacted jatropha oil	5.963	0.006867	0.011146593
Total:	178.7513	0.616035	1
Residue:			
Glycerol	1.359878	0.014778	0.002831914
Water	89.37367	4.965204	0.951479682
NaOH	0.059268	0.001482	0.000283935
Methanol	7.582041	0.236939	0.045404468
Total:	98.37486	5.218403	1
Overall:	277.1262	5.834438	1

3.5.7 Balance Around the Distillation Column:

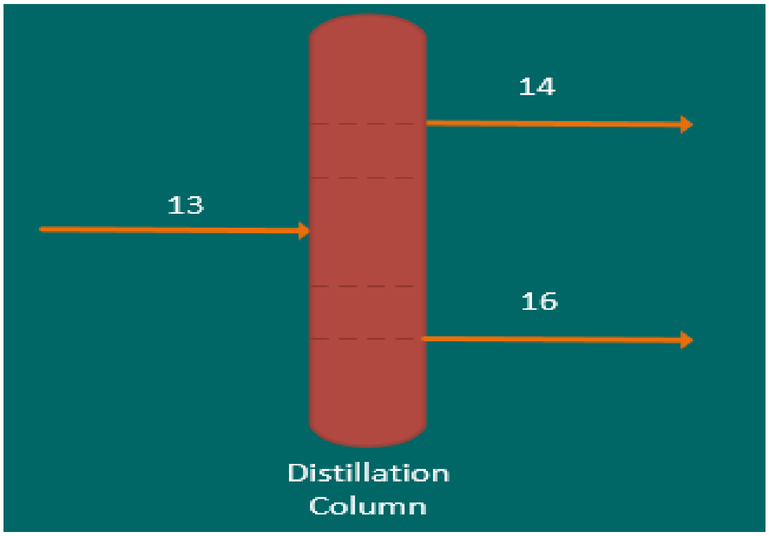


Figure 3. 7: Distillation column

Inputs Streams:

S-13: Methanol + residue

Output Streams:

S-14: Methanol

S-16: residue

Reactants Inputs:

Table 3. 12: Input of distillation column

Streams	**Input**		
	Mass	**Moles**	**Fractions**
Methanol	38.32419	0.236939	0.045404468
NaOH	0.059268	0.001482	0.000283935
Glycerol	1.359878	0.014778	0.002831914
Water	89.37367	4.965204	0.951479682
Total:	**129.117**	**5.218403**	**1**

Table 3. 13: Output of Distillation Column.

Streams:	**Output**					
	Top product			**Bottom product**		
	Mass	**Moles**	**Fractions**	**Mass**	**Moles**	**Fractions**
Methanol	38.20921	0.236939	0.704665621	0.114973	0.003592893	0

NaOH	0	0	0	0.059268	0.001481688	0.000297
Glycerol	0	0	0	1.359878	0.014778068	0.002967
Water	1.787473	0.099304	0.295334379	87.5862	4.965204059	0.996736
Total:	39.99669	0.336243	1	89.00534	4.981463816	1

3.5.8 Overall Material Balance:

Inputs Streams:

S-1: Methanol

S-3: NaOH

S-Y: Jatropha oil

S-10: Water

Outputs Streams:

S-8: Crude Glycerol

S-9: Methanol (Vent)

S-12: Biodiesel phase

S-14: Recycle Methanol

S-16: Residue

Inputs:

Table 3. 14: Overall Inputs balance

Streams	**Inputs**	
	Mass	**Moles**
Methanol	58.91246	1.84
NaOH	0.059268	0.001482
WATER	89.6424	4.980
Jatropha oil	177.6364	0.204557
Total:	326.2412	7.026

Outputs:

Table 3. 15: Overall output of material balance

Streams	**Mass**	**Moles**	**Fraction**
Crude Glycerol	18.07795	0.196499	0.027967
Biodiesel phase	178.7513	0.616035	0.087678
Recycle Methanol	39.16	1.22375	0.174172
Residue	89.00534	4.981464	0.708994
Total	326.2412	7.0261	1

Chapter 4 – Energy Balance:

4. 1 Introduction:

The conservation of energy principle argues that the entire amount of energy in a system, as well as the energy in the surrounding environment, can neither be created nor destroyed. This principle is based on rigorous experimental data that have been validated. A system's energy gain must be exactly equal to the quantity of energy lost by its surroundings during an interaction with its environment. It should be noted that energy conservation differs from the conservation of mass in that energy can be generated (or consumed) during a chemical reaction. Even though material can change shape and new molecular species can be generated by chemical reaction, at the steady state, the total mass flow into and out of a process unit must be equal to the total mass flow in. In the case of energy, this is not the case. For example, if energy is generated or spent in the processes, such as through heat of reaction, the total enthalpy of the outlet streams will be less than the total enthalpy of the entrance streams. Thermal energy, mechanical energy, and electrical energy are all sources of energy, and it is the overall amount of energy that is conserved in the universe. When designing a process, energy balances are used to calculate the energy requirements of the process, such as the amount of heating, cooling, and electricity required. A plant's energy balance (energy audit), which is performed during operation, will reveal the pattern of energy consumption and identify areas for energy conservation and savings. For the conservation of energy, the following generic equation can be written:

Energy out = Energy in + generation - consumption – accumulation

4.1.1 Energy Balance of a System

Consider a steady-state process, the conservation equation can be written to include the various forms of energy.

For a unit mass of material:

$$U_1 + P_1V_1 + u_1^2/2 + z_1g + Q = U_2 + P_2V_2 + u_2^2/2 + z_2g + W$$

The suffixes 1 and 2 represent the inlet and outlet points respectively. Q is the heat transferred across the system boundary; positive for heat entering the system, negative for heat leaving the system. W is the work done by the system; positive for work going from the system to the surroundings, and negative for work entering the system from the surroundings. In chemical processes, the kinetic and potential energy terms are usually small compared with the heat and work terms, and can normally be neglected. It is convenient, and useful, to take the terms U and PV together; defining the term enthalpy, usual symbol H, as

$$H = U + PV$$

If the kinetic and potential energy terms are neglected, equation 3.2 simplifies to:

$$H_2 - H_1 = Q - W$$

This simplified equation is usually sufficient for estimating the heating and cooling requirements of the various unit operations involved in chemical processes. As the flow-dependent terms have been dropped, the simplified equation is applicable to both static (non-flow) systems and flow systems. It can be used to estimate the energy requirement for batch processes. For many processes the work term will be zero, or negligibly small, and equation (4.4) reduces to the simple heat balance equation:

$Q = H_2 - H_1$

Where heat is generated in the system; for example, in a chemical reactor:

$Q = Q_p + Q_s$

Q_s = heat generated in the system. If heat is evolved (exothermic processes) Qs is taken as positive, and if heat is absorbed (endothermic processes) it is taken as negative.

Q_p = process heat added to the system to maintain required system temperature.

Hence:

$Q_p = H_2 – H_1 – Q_s$

H_1 = enthalpy of the inlet stream,

H_2 = enthalpy of the outlet stream.

The basis for the balance is 1 hr.

4.2 Calculations For Energy Balance:

Table 4. 1: Enthalpies

Components	**Chemical formula**	**ΔG°f (kJ/gmol)**	**ΔH°f (kJ/gmol)**	**ΔH°C (kJ/gmol)**
Methanol (l)	CH_3OH	-166.12	-238.655	-638.46
Water (l)	H_2O	-237.19	-285.84	-44.0
Glycerol(l)	C3H8O3	-475.5	-655.9	
Sodium Hydroxide (s)	NaOH	-379.4	-425.9	
Sodium methoxide	CH_3ONa		-288.64	

Jatropha oil			-1294.29	
Methyl Ester			-744.65	

4.3 Energy balance around mixer:

Table 4. 2: Energy balance on mixer

streams	**Input**			**output**	
	Cp	**mass flow**	**total heat**	**moles**	**total heat**
methanal	2.53	58.912462	1.242071079	1.841014	1.242071079
NaOH	2.36	0.0592675	0.001165595	0.001482	0.001165595
total			1.243236674		1.243236674

4.4 Balance around the reactor:

Input:

Table 4. 3: Energy balance input of reactor

Streams	input		
	Cp	mass	total heat
Methanal	2.53	58.91246	1.242071079
NaOH	2.36	0.059268	0.001165595
jatropha oil	2	0.734796	0.012246604
Total			1.255483278

Output:

Table 4. 4: Energy balance output of reactor

Streams	**outputs**		
	moles	Cp	total heat
Methanal	39.27497	2.6	0.850958
Methyl Ester	172.0717	2.15	3.082951
Glycerol	18.07795	2.55	0.384156
Soap	0.059268	2.36	0.001166
Unreacted oil	5.963	2.23	0.110812
Water	0.05909	4.187	0.002062
Total			4.432105

4.4 Energy balance around decanter-1:

Inputs:

Table 4. 5: Heat input of decanter-1

Streams	**Inputs**		
	Moles	**Cp**	**Total heat**
Methanal	39.27497	2.6	0.850957788
Methyl Ester	172.0717	2.15	3.082950694
Glycerol	18.07795	2.55	0.384156336
Soap	0.059268	2.36	0.001165595
Unreacted oil	5.963	2.23	0.110812417
Water	0.05909	4.187	0.002061739
Total			4.432104569

Output:

Table 4. 6: Heat output of decanter-1

Streams	**Outputs**		
	Mass	**Cp**	**Total heat**
Glycerol	16.27015	2.35	0.318623785
Methanol	31.69293	2.53	0.668192678
Glycerol	1.807795	2.35	0.035402643
Water	0.05909	4.18	0.002058292
Methanol	7.582041	2.53	0.159854708
Soap	0.059268	2.36	0.001165595
Methyl Ester	172.0717	2.13	3.054272083
Unreacted jatropha oil	5.963	2	0.099383333
Total			4.338953117

4.5 energy balance around wash tank

Input:

Table 4. 7: Heat input of wash tank

streams	**inputs**		
	mass	**Cp**	**total heat**
Glycerol	1.807795	2.35	0.035402643
Methyl Ester	172.0717	2.13	3.054272083
Water	0.05909	4.18	0.002058292
Soap	0.059268	2.36	0.001165595
Methanol	7.582041	2.53	0.159854708
Unreacted jatropha oil	5.963	2	0.099383333
			3.352136654

Output:

Table 4. 8: Heat output of wash tank

streams	**outputs**		
	moles	**Cp**	**total heat**
Glycerol	1.807795	2.35	0.035402643
Methyl Ester	172.0717	2.13	3.054272083
Water	0.05909	4.18	0.002058292
Soap	0.059268	2.36	0.001165595
Methanol	7.582041	2.53	0.159854708
Unreacted jatropha oil	5.963	2	0.099383333
			3.352136654

4.6 Energy balance around decanter-2:

Input:

Table 4. 9: Heat input of decanter-2

streams	**inputs**		
	mass	**Cp**	**total heat**
Glycerol	1.807795	2.35	0.035402643
Methyl Ester	172.0717	2.13	3.054272083
Water	89.64242	4.18	3.122544403
Soap	0.059268	2.36	0.001165595
Methanol	7.582041	2.53	0.159854708
Unreacted jatropha oil	5.963	2	0.099383333
			6.472622765

Output:

Table 4. 10: Heat output of decanter-2

Streams	**Outputs**		
	Moles	**Cp**	**total heat**
Glycerol	1.807795	2.35	0.035402643
Methyl Ester	172.0717	2.13	3.054272083
Water	89.64242	4.18	3.122544403
Soap	0.059268	2.36	0.001165595
Methanol	7.582041	2.53	0.159854708
Unreacted jatropha oil	5.963	2	0.099383333
			6.472622765

4.7 Balance around distillation column

Input:

Table 4. 11: Heat input of distillation column

Streams	**Inputs**		
	Mass	**Cp**	**Total heat**
Glycerol	1.359878	2.55	0.028897404
Water	89.37367	4.187	3.118396409
NaOH	0.059268	2.36	0.001165595
Methanol	38.32419	2.6	0.830357381

			3.97881679

Output:

Table 4. 12: Heat output of distillation column

Streams	**Inputs**		
	Mass	**Cp**	**Total heat**
Glycerol	1.359878	2.7	0.030597252
Water	89.37367	4.2	3.128078557
NaOH	0.059268	2.36	0.001165595
Methanol	38.32419	2.5	0.798420559
			3.958261963

5. Chapter 5:

5. 1 Equipment design:

Table 5. 1: Equipment's data sheet

Equipment Tag No	Meaning	Duty	Material	Temperature
MIX-100	Mixer	Helps in the mixing of NaOH and methanol for catalyst preparation	Mild steel	30°C
V-100	Conical fixed roof tank	Storage of glycerol	Iron high silicon	30°C
V-102	Conical fixed roof tank	Storage of biodiesel	Iron high silicon	30°C
CSTR-100	Continuous stirred tank reactor	For the reaction of jatropha oil with a combination of NaOH and methanol	Carbon steel	60-70°C
V-101	Flash vessel separator	Used for glycerol extraction from methanol and water	Mild steel	60-70C
T-100	Distillation column	Used to separate biodiesel, methanol, and residue.	Mild steel	
X-100	Component splitter	The product is separated from the reactor.	Carbon steel	30°C
X-101	Component splitter	The product is separated from the reactor.	Carbon steel	30°C

Design Specification for item:

5.*2* WATER PUMP:

Power=$\frac{Q*\rho*g*h}{100}$ (KW)

V=$\frac{m}{p}$

Mass flow rate of water = 89.5 kg/hr

Volumetric flow rate = $\frac{\text{mass flow rate}}{\text{density}}$

Density of water = 1000 kg/m^3

V = (89.5 kg/hr) *($\frac{24\text{hr}}{1000* 3600\ \text{S}}$)

V = 0.00059 m^3/s

Power = $\frac{(0.00059)*(1000)*(9.8)*(20)}{100}$ (KW)

Power = 1.15 KW

Considering the pump is operating at 70% efficacy then

Power = 1.15/0.70

Power = 1.64 KW

5.*3* BIODIESEL STORAGE STANK

Flow rate = 175.5833333kg/hr

Capacity = Volumetric flow rate x Time of residence

(Assuming the storage tank holds water for 1 week before draining)

Capacity = 29497kg

Volume of tank = $\frac{\text{Capacity (kg)}}{\rho\text{(biodiesel)}}$

ρ (biodiesel) = 886.3 kg/m^3

Volume = $\frac{29497}{886.3}$

Volume = 33.2m^3

Volume = $\pi r^2 h$

D = 3√33.2*4/Π H/D=1

D = 3.48m

H = 3.48m

Maximum operating volume will be 85% of the total volume

Max operating volume = 85%

= 28.22m^3

Pressure = 1atm

Operating temperature = 30 $^{\circ}$C

Cylindrical thickness

t = $\frac{\text{Pi x Di}}{\text{2SE – 1.2Pi}}$
Pi = Design pressure
(Taking the design pressure 10% above operating gauge pressure)
= (0.101325 N/mm^2) x 1.1
~ 0.111457 N/mm^2
Adding hydro static pressure = pgh
= 886*9.8*3.4=29521N/m^2 0.029521 N/mm^2
P_i = 0.111457+0.029521=0.14097
Design temperature = 30 $^{\circ}$C
Since the construction material is carbon steel.
maximum allowable stress S = 12.9 Ksi
D_i (diameter of tank) = 3.48 m
S (max allowable stress) = 88.94 N/mm
E (number of joints) = 1
T = $\frac{P_i \text{ x } D_i}{\text{2SE – 1.2}P_i}$
T = $\frac{\text{0.14097 x 3480}}{\text{2 x (88.94) – (1.2 x0.14097)}}$
= 2.7mm
Let a corrosion allowance of 2mm be used: adding corrosion allowance
= (2.7) + (2 mm)
= 4.7 mm

Doomed Head

Using a standard ellipsoidal head since it is economical
Pi = 0.151987 N/mm2
T = $\frac{\text{Pi x Di}}{\text{2SE – 0.2Pi}}$
Di = 3.48m
S = 88.94N/mm^2
E = 1
T = $\frac{\text{0.14097 x 3480}}{\text{(2 x 88.94 x 1) – (0.2 x 0.14097)}}$
= 2.7mm
Adding corrosion allowance of 2mm
= 2.7mm + 2mm
= 4.7mm

Table 5. 2: Storage tank specification

SPECIFICATIONS	**DETAILS**
Material of construction	Carbon Steel
Volume (m3)	33.2
Diameter (m)	3.48
Height (m)	3.48
Maximum operating volume (m3)	28.22
Pressure (atm)	1
Wall thickness (mm)	4.7
Head thickness (mm)	4.7
Capacity (kg)	29497kg
Flow rate (kg/hr)	175.5833333
Operating Pressure (N/mm2)	0.101325
Design pressure (N/mm2)	0 .151987
Support type	Skirt support

5.*4* Water Wash

Flow rate = 277.5 kg/hr

(Assuming the wash tank operates for 6hrs)

Storage Capacity = 1665 kg

Volume = $\frac{\text{Mass (capacity)}}{\rho}$

Volume = $\frac{1665\ \text{kg}}{942\ \text{kg/m3}}$

Volume = 1.75 m3

D = √1.75*4/Π

D = 1.49 m

Maximum operating volume = $\frac{85}{100}$x1.75

= 1.48 m3

Pressure = 1.0 atm

Output temperature = 30^{O}C

Thickness

Cylindrical Section (wall)

T = $\frac{\text{Pi x Di}}{\text{2SE – 1.2Pi}}$

Design temperature = $60^{O}C$

D = 1.5 m3

Taking pressure above 50% above operating pressure

= (0.101325 N/mm) x 1.5

~ 0.151987 N/mm

Since the construction material is carbon steel, the maximum allowable stress S is

S = 88,942,370 N/m^2

= 88.942370 N/mm^2

T = $\frac{\text{0.151198 x 1500}}{\text{(2 x 88.942,370 x 1) – (1.2 x 0.151198)}}$

T = 0.785 mm

Using a corrosion allowance of 2 mm

Wall thickness = 0.75 mm +2 mm

= 2.785 mm

Domed Head:

Using a standard disked head (tori spherical)

Crum radius = Rc =0.06 Di

= 0.06.5 m

Knuckle radius = 6% of D_i

= 0.09 m

= 90 mm

A head of this size would be formed by pressing no joints, so E = 1

T = $\frac{\text{0.885PiRc}}{\text{SE – 0.1Pi}}$

T = $\frac{0.885 \text{ x } 0.151987*90}{\text{(88.942,370 x 1) – (0.1 x 0.151987)}}$

= 2.2 mm

Using corrosion allowance of 2mm Wall thickness

= 2.2 mm + 2 mm

= 4.2 mm

Table 5. 3: Design specification of wash water

SPECIFICATIONS	**DETAILS**
Material of construction	Carbon Steel
Volume (m3)	1.75
Maximum operating volume (m3)	1.48
Pressure (atm)	1
Wall thickness (mm)	2.785
Head thickness (mm)	4.2
Capacity (kg)	1053.49998
Flow rate (kg/hr)	175.5833333
Operating Pressure (N/mm2)	0.101325
Design pressure (N/mm2)	0 .151987

5.5 Decanter:

Flow rate = 235.89 kg/hr

Settling Velocity U_d = d_d 2 x g x (ρ_d – ρ_c) 18μc

D_d= Droplet diameter (m) U_d = Settling velocity (m/s)

P_c= Density of continuous phase (kg/m3)

P_d = Density of dispersed phase (kg/m3)

μ_c = viscosity of continuous phase (N/m2)

g = Gravitational acceleration (9.81 m/s2)

Assumptions made

1). the decanter separates the biodiesel and the aqueous phase

2). the aqueous phase comprises majorly of water

Oil flow rate = 187.92 kg/hr

Density of biodiesel = 886.3 kg/m3

Viscosity of biodiesel = 5.384 mNs/m2

Water flow rate = 179.167 kg/hr

Density of water = 1000 kg/m3

Viscosity of water = 1 mNs/m2

Calculating settling time U_d = $\frac{dd\ 2 \text{ x } g \text{ x } (\rho d - \rho c)}{18\mu c}$

the droplet diameter = 150 μm

U_d = $\frac{[150 \text{ x } 10-6\ ]\ 2 \text{ x } 9.81 \text{ x } [886.3 - 1000]}{18 \text{ x } 1 \text{ x } 10-3}$

= 1.39 x 10-3 m/s

Since the flow rate is small, a vertical cylindrical vessel is needed.

L_c = $\frac{\text{Water flow rate}}{\text{Biodiesel flow rate}} \text{x} \frac{1}{\text{Time}}$

L_c = $\frac{179.167}{183.974} \text{ x } \frac{1}{3600}$

L_c = 2.75 x 10-4 m^3 /s

Continuous phase volumetric flow rate = 2.75 x 10-4 m^3 /s

Uc ≤ Ud,

and Uc = Lc Ai

Then A_i = $\frac{Lc}{Ud}$

A_i = $\frac{2.75 \text{ x } 10-4}{1.39 \text{ x } 10-3}$

A_i = 0.199 m^2

Area of interface = 0.199 m2

Radius of cylinder (r) = $\surd \frac{0.199}{\pi}$

R = 0.25 m

Diameter = 0.50 m

Assuming the height is twice the diameter: Considering it as a reasonable dimension for a decanter

Height = 2 x 0.50

= 1 m

Assuming the dispersion bed is 10% of the decanter’s height = 0.1 m

Residence time of the droplets in the dispersion bed

Interpolating:

$\frac{1m}{Ud}$ = $\frac{1\ \ m}{0.0014}$

= 714.29 sec or 11.9 mins

Velocity of biodiesel phase = $\frac{1000}{886.3} \text{ x } \frac{1}{3600} \text{ x } \frac{1}{0.199}$

= 1.57 x 10-3 m/s

Droplet diameter

$D_d \quad = \quad \frac{(Ud \times 18 \times \mu c)\ ½}{(g \times (\rho d - \rho c))\ ½}$

$D_d \quad = \quad \frac{(1.39 \times 10-3 \times 18 \times 5.384 \times 10-4\ )\ 1/2}{(9.81 \times [1000-886.3])\ 1/2}$

$= \quad 3.48 \times 10^{-4}$ m

Table 5. 4: Decanter Specification

SPECIFICATIONS	**DETAILS**
Design temperature	60^{o}C
Design pressure	1.5 atm
Mass flow rate	235.89 kg/hr
Diameter	0.5m
Height	1m
Interface area	0.2m^{2}
Droplet diameter	3.48 x 10^{-4}m

5.*6* Distillation Column:

Flow rate = 129.50 kg/hr

(Assuming the distillation column can operate for 6hrs)

Storage Capacity = 777 kg

Volume = $\frac{\text{Mass (capacity)}}{\rho}$

The feed is 20 percent methanal and 80 percent water so the total density would be 958)

$= \frac{777\ \text{kg}}{958}$

= 0.811 m^{3}

Maximum operating volume = $\frac{85}{100} \times 0.811$

= 0.68935 m^{3}

Thickness

The minimum thickness wall = $\frac{Pi \times Di}{2SE - 1.2Pi}$

Where Pi = internal pressure

D_i = diameter of the column

S = max allowable stress value

E = joint efficiency

Pi = 101.3 KPa

The operating pressure is 1 atm but we are designing it at 1.1atm pressure)

= 1.1(1atm)

= 1.1(101.3Pa)

= $0.1114N/mm^2$

Di = 0. S = 17500psi = 120,658,252.4Pa for carbon steel between 20°F - 650°F for grade SA-51570

E = 1(assuming full graze welding)

$$T = \frac{0.1114*798}{(2*120.658252*1)-(1.2*0.1114)}$$

T = 0.7mm

Using corrosion allowance of 2mm

T = 0.3mm+2mm

= 2.3mm

Flat Bottom

Calculating the thickness of the flat bottom

$$t = D_e\sqrt{\frac{CP}{SE}}$$

Hère C = design constant, dépendent on the Edge constant. Assume C = 0.55

D_e = 40mm

$$t = 0.040*0.55\sqrt{\frac{101300}{120658252*1}}$$

t = 0.7mm

adding the corrosion allowance = 0.002 m

= 0.7mm+2mm

= 2.7mm

$$\mathbf{t = \frac{0.885PjD}{SE-1.1pj}}$$

were

D = 0.8m

S = 120,658,252.4 Pa

= 120.568N/mm^2

Pi = 101.3 KPa

$$= \frac{0.855(101.310^3\text{pa})(0.8)}{120658252 * 1 - 1.1(101.3 * 10^3)}$$

T = 0.3mm

Adding the corrosion allowance

T =0.3mm+2mm

=2.3mm

Design Calculation

Mass flow rate of feed = 129.50kg/hr=6.17 kmol/hr

Molecular weight of methanol = 32 kg/kgmol

Molecular weight of water = 18 kg/kgmol

Boiling point of water = 100 C

Boiling point of methanal = 64.5 C

The more volatile component is methanal

The concentration of methanal in the feed is given as

% Of MeOH in the feed = $\frac{1.197}{6.17}$*100

= 19.4%

Assumptions

The overall residue i.e. bottoms is assumed to be composed of water only.

1. The feed is assumed to be a mixture of two components i.e methanol and water

Therefore; the feed is a mixture of 1%Methanbol and 99% water.

Requirements for separation are as follows;

- An overhead product containing 99.7% MeOH
- A bottom product containing 98% water.

Molecular weight of Methanol = 32 kg/kgmol

Molecular weight of water = 18 kg/kgmol

The amount of methanol in the feed in mole fraction; $X_f = \frac{\frac{20}{32}}{\frac{20}{32}+\frac{80}{18}} = 0.194$

The amount of methanol in the distillate in mole fraction; = $\frac{\frac{99.72}{32}}{\frac{99.7}{32}+\frac{0.3}{18}}$ =0.995

The amount of methanol in the bottom in mole fraction; = $\frac{\frac{0.3}{32}}{\frac{0.3}{32}+\frac{99.7}{18}}$ =0.0016

Calculation of amount of distillate and bottom product

These two values can calculate using simple material equations

Assumptions

At steady state there are no any material losses, material accumulation and material generation. There is no any chemical reaction inside the column

Mass balance:

Overall material balance around the envelope shown

Where F = Feed Flow rate in kgmol/hr

F = D + W……….

Where F = 129.50 kmol/hr,

129.50 = D + W

Component balance

$X_F F = X_D D + Xw\ W$ ………..

xf = 0.194, xD
= 0.995 and xW
= 0.016
(129.50 * 0.194) = 0.995D + 0.016W
10.60 = 0.995D + 0.016W
D = 129.50– W
25.123 = 0.995(129.50– W) + 0.0016W
25.123 = 128.85-0.995 W +0.0016 W
25.123 = 128.85-0.9934 W
W = 103.727/0.9934
W = 104.416

Then D = 108.46-97.317

D = 25.35 kg/hr

R_{min} graph

From the graph

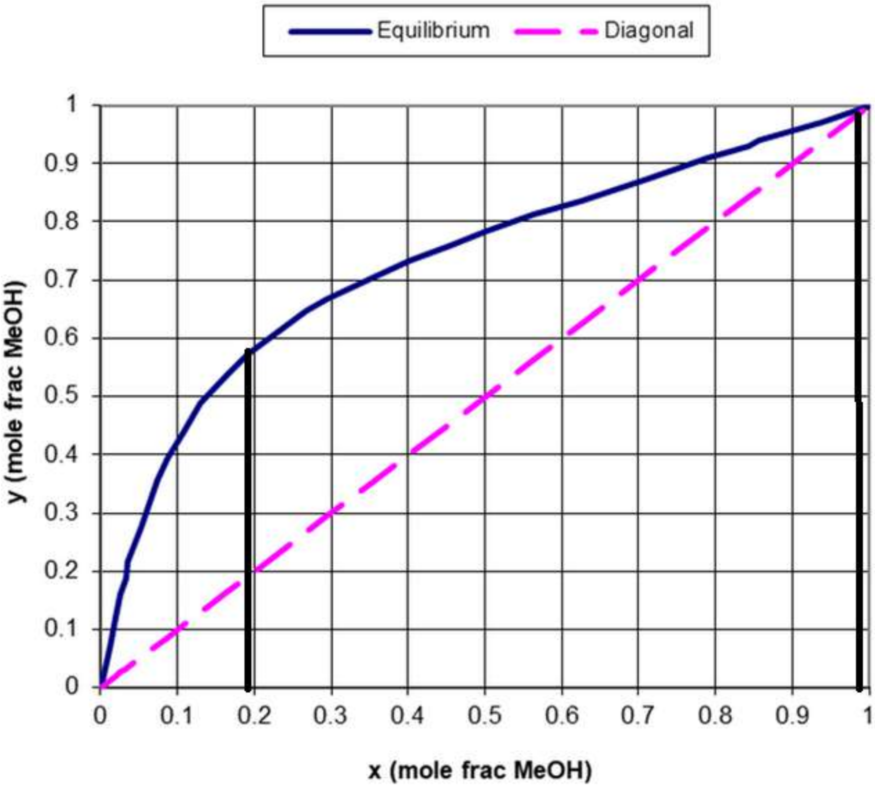


Figure 5. 1 VLE diagram of water and methanol

Using the slope line of the ROL i.e. S=$\frac{XD-y}{XD-x}$

Where xD = 0.995

Y = 0.57

X = 0.194

Δs = 0.995-0.57/0.995-0.194

= 0.473

R_{min} / R_{min} + 1 = 0.473

(Rmin+1)0.473 = R_{min}

0.473Rmin + 0.473 = R_{min}

0.473 = $0.527R_{min}$

Rmin = 1.214

Calculating the operating reflux ratio, the optimum in reflux ratio will lie between 1.1 to 1.5 times, the optimum in reflux ratio [R_{min}]

Assuming the reflux ration [R] is 1.2 times the R_{min}

R = 1.2 * Rmin

R = 1.2 * 1.214

R = 1.457

Calculation of the actual number of stages required:

Steps in determining the number of stages

1. Draw the VLE Diagram curve

2. Draw the Diagonal line

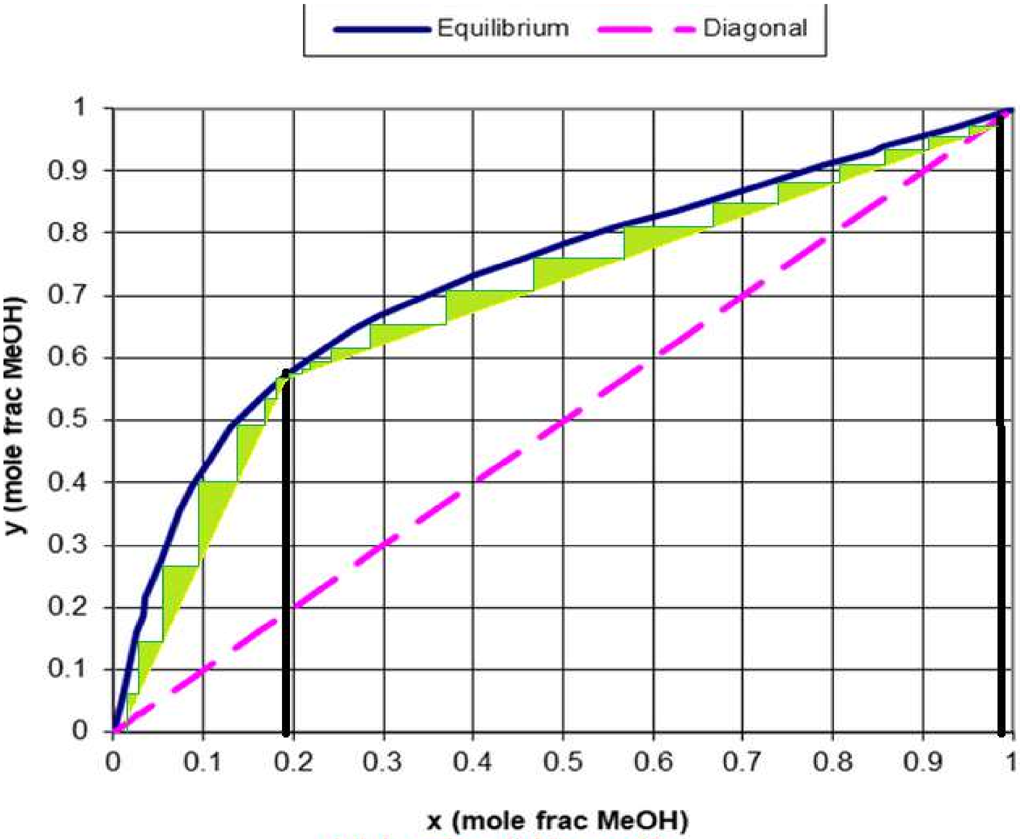
3. Indicate the x_w, x_f and x_d on the y=x line

4. Calculate the slope of q line [-q/(1-q)] and the q-line from (xF, xF)

5. Calculate B and D from overall balances

6. Calculate the liquid and vapors flow rates in the rectifying and stripping sections

7. Step off to know the amount of the practical stages required



total number of plates are 21
21 plate is reboiller plate
actual plates =21-20=1

Figure 5. 2: number of plates calculation

The number of stages is 21 stage (Theoretical)

Reboiler is stage 21

Number of plates (20-1) = 20 plates

The optimum feed location is stage 14 (theoretical)

Calculating of liquid and vapor amounts in both section

Rectifying section

R = $\frac{L}{D}$

1.457 = $\frac{L}{25.35}$

L = 37.53

As we know according to constant molar over flow = L=L=23.76

Vn = Lo + D

Vn = 37.53+25.35

= 62.88

According to given feed is at saturated liquid condition therefore all feeding liquid join with stripping section liquid

Lm = F + Ln

Lm = 129.50 +37.53

= 167.03

Vm = Vn

Vm = 62.88

Table 5. 5: Vapor and liquid density calculation

Position	**Temperature . (C)**	**Density-of H2O(Kg/M3)**		**Density of Methanol (Kg/M3)**		
liquid		liquid		vapor		
Feed	0.194	77	973	0.27	7.42	2.01
Distillate	0.995	65	980.53	0.165	752	1.12
Residue	0.0016	99	958.10	0.586	713	4.34

Density of liquid at feed point at 77 C

= 973*0.806+742*0.194

= 928

Density of vapor at feed point at 77 C

= 0.27*0.899+1.12*0.0978

= 0.434

Density of liquid at distillate at 65 C

= 752

Density of vapor at distillate at 65 C

= 1.12

Density of liquid at residue at 99 C

= 958.10

Density of vapor at residue at 99 C

= 0.586

Table 5. 6: densities of liquid mixture

Temperature (oC)	Density of Liquid mixture (Kg/m3)	Density of vapour mixture (Kg/m3)
77	982	0.434
65	752	1.12
99	958.10	0.586

Rectifying section densities

Rectifying is working between 77 to 65 temperature so its density will be its average

Density of liquid at rectifying section is

= (982.29+752)/2

= 867

Density of vapour at rectifying section

= (0.434+1.12)/2

= 0.777

Stripping section densities

Stripping section is working between 77 to 99 temperature so its density will be its average

Density of liquid at stripping section

= (752+958.10)/2

= 855.05

Density of vapours at stripping section

= (1.12+0.586)/2

= 0.853

Diameter of rectifying section

$$F_{lv} = \frac{L}{V}\sqrt{\frac{Pv}{Pl}}$$

$$F_{lv} = \frac{37.53}{62.88}\sqrt{\frac{0.777}{867}}$$

$$F_{lv} = 0.017$$

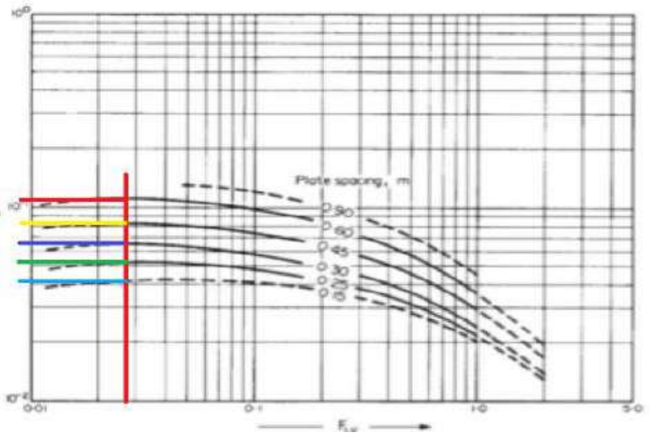


Figure 5. 3 vapor liquid factor graph

Table 5. 7: Try Spacing's

Tray spacing	**F_{lv} factor**
0.15	0.040
0.25	0.050
0.30	0.060
0.45	0.080
0.60	0.11

Assuming tray spacing = 0.15 m

According to graph

K1=0.040

$$U_f = K_1\sqrt{\frac{pl-pv}{pv}}$$

$$U_f = 0.040\sqrt{\frac{867-0.777}{0.777}}$$

$$= 1.33 \text{ m/s}$$

D_c column diameter

A_c column cross sectional area

A_d down corner area

A_a active area

A_h holes area

A_n net area

U_a Actual vapor velocity through the column

$A_{n\,=}\ A_c - A_d$

Assume A_d =12 % of A_c

$A_{n\,=}\ A_c - 0.12A_c$

$A_{n\,=}\ 0.88A_c$

Assume 80% flooding condition $U_a = 0.80U_f$

$U_a \quad = \quad 0.80*2.71$

$\quad = \quad 1.06$ m/s

Calculating average molecular weight when moisture is 50% methanal

32*.50+18*0.50=25

$$V = \frac{62*25}{3600}$$

$\quad = \quad 0.4366$ m/s

An = Un/UA

$$An = \frac{0.4366}{1.06}$$

$\quad = \quad 0.411\ m^2$

Now

$A_n \quad = \quad 0.88\ A_c$

$0.111 \quad = \quad 0.88\ A_c$

$\quad = \quad 0.468$

$$Ac = \frac{\Pi D_c}{4}$$

$Dc \quad = \quad \sqrt{0.126*4/\Pi}$

$\quad = \quad 0.7721$ m

Table 5. 8 parameters at different tray spacings

Tray spacing	**Diameter**	**Height**	**Area**
0.15	0.768581	4.725	3.631548

0.25	0.472574	7.125	4.898011
0.30	0.393812	8.325	5.224305
0.45	0.295359	11.925	6.48087
0.60	0.214806	15.525	7.195404

Diameter of stripping section section:

$F_{lv} = \frac{L}{V}\sqrt{\frac{Pv}{Pl}}$

$= \frac{37.53}{62.88}\sqrt{\frac{0.853}{855.05}}$

$= 0.018$

Assuming tray spacing= 0.15 m

According to graph

K1 = 0.040

$U_f = K_1\sqrt{\frac{pl-pv}{pv}}$

$U_f = 0.040\sqrt{\frac{855.05-0.853}{0.853}}$

= 1.265 m/s

Assume 80% flooding condition U_a =.80U_f

U_a = 0.80*1.265

= 1.012609m/s

V = 0.436

An = $\frac{0.436}{1.012}$

= 0.430571

A_n = 0.88A_c

0.430571 = 0.88A_c

A_c = 0.489285

Then

Dc = $\sqrt{}0.4892*4/\Pi$

D_c 0.789489

Number of Holes in a tray at the Rectifying section

$A_A = A_c-2A_d$

$A_A = A_c-(0.12*2A_c)$

$A_A = A_c-0.24A_c$

$A_A = 0.76A_c$

$A_c = 0.468$

$A_A = 0.76(0.468)$

$A_A = 0.3556$

Assume holes area is 15% of active area

$A_n = 0.15A_A$

$A_n = 0.15(0.3556)$

$= 0.0533$

Taking hole size to be 5mm in order to avoid entrainment

Hole diameter $= 5 \text{ x } 10^{-3}$ m

Area of holes $= \frac{\pi*0.005^2}{4}$

$= 1.96*10^{-5}$

Number of holes in a plate$= \frac{Ah}{Ahi}$

$= \frac{0.0533}{1.96*10^{-5}}$

$=$ 2700 holes

Number of Holes in a tray at the stripping section section:

$A_A = A_c-2A_d$

$A_A = A_c-(0.12*2A_c)$

$A_A = A_c-0.24A_c$

$A_A = 0.76A_c$

$A_c = 0.489285$

$A_A = 0.76(0.489285)$

A_A = 0.371

Assume holes area is 15% of active area

A_n = $0.15A_A$

A_n = 0.15(0.371)

=0.0557

Taking hole size to be 5mm in order to avoid entrainment

Hole diameter = 5×10^{-3} m

Area of holes = $\frac{\pi * 0.005^2}{4}$

= $1.96*10^{-5}$

Number of holes in a plate= $\frac{Ah}{Ahi}$

= $\frac{00.557.}{1.96*10^{-5}}$

= 2841 holes

Calculation of Column Efficiency

the "Van Winkle's Correlation", the efficiency of the column can be calculated thus:

E_{mv} = $0.07D_g^{0.14}S_c^{0.25}R_e^{0.08}$

where Dg: surface tension number = (δL/μLUv)

Uv : superficiel vapeur Velocity

δL: liquid surface tension

μL: liquid viscosity

Sc: liquid Schmidt number = (μL/ρLDLK)

ρL: liquid density

D_{lk} : liquid diffusivity, light key component

Re: Reynolds number = (hwUvρv/μL.FA)

Hw: weir height

Pv: vapor density

minimum and maximum temperature inside the column are 99 C and 65 C then we can find the average temperature of the column

Average temperature of the column is = $\frac{99+65}{2}$=*82C

Assuming the physical properties of the liquid equal to the properties of the water the

Surface tension of the3 liquid at 82C = 0.109 N/m

Superficial velocity is considered to be equal to height U_a

U_V = UA

U_V = 1.33 m/s

μL = 355×10^{-6} Ns/m2

calculating average densities of liquid and vapors in column

p_{v1} = $\frac{p_v+p'_v}{2} = \frac{0.777+0.853}{2} = 0.815$

p_{L1} = $\frac{p_L+p'_L}{2} = \frac{867+855.05}{2} = 861$

D_{LK} = $5*10^{-9}$ m^2/s

At 1 Atm pressure the weir height is taken 40_90 mm

H_W= weir height (the height of the side of plate)

Therefore, we consider to be 50 mm

H_w = 50 mm

Fractional Area Calculation

Fractional area = $\frac{\text{area of the holes}}{\text{total Column Cross Area}}$

F.A = $\frac{\frac{0.0557+0.0533}{2}}{\frac{0.468+0.489}{2}}$

= 0.1138

Surface Tension Number Calculation

D_g = $\frac{\delta_l}{\mu_l * U_v}$

= $\frac{0.109}{355 \times 10^{-6} * 1.33}$

= 230

Liquid Schmidt Number Calculation

S_c = $\frac{\mu_l}{pl_v * D_{LK}}$

= $\frac{355 \text{ x } 10^{-6}}{5*10^{-9}*861}$

= 82

Reynold Number Calculation

R_e = $\frac{H_w U_v p_{v1}}{\pi_l * FA}$

= $\frac{50*10^{-3}*1.33*0.851}{355 \text{ x } 10^{-6}*0.1138}$

= 1400

E_{mv} = $0.07 D_g^{0.14} S_c^{0.25} R_e^{0.08}$

= $0.07(230)^{0.14} 82^{0.25} 1400^{0.08}$

= 0.805*100

= 80%

The efficiency of the column ≈ 80%

Calculation of Actual Number of stages required

The number of theoretical stages required = 21 stages

The theoretical stages calculation is based on a 100% efficient column.

But the actual efficiency of the column is 80%

The number of actual stages is calculated thus:

$E_{mv} = \frac{\text{number of theortical stages}}{\text{actual stages}}$

= $\frac{21}{0.80}$

= 25.4

= 26

Calculation of Height of the column

Height of column $= H_c = \{N_{actual} - 1\} H_s + \Delta H +$ plates thickness

Actual number of plates, $N_{actual} = 26$

Tray spacing, Hs = 0.15 m

ΔH =0.5 m (each for liquid hold up and vapour disengagement)

Plate thickness is assumed to be 5mm

Total thickness of trays = 0.005 x 26

=0.130m

Height of column; Hc = [26 - 1] x 0.15 + 0.5 + 0.130

H_c = 4.725

Calculation of the Actual Feed Location

From the McCabe-Thiele stepping method;

The theoretical optimum feed tray location is stage 12

To calculate the actual feed tray location the stage number is divided by the column efficiency

Therefore, actual feed tray location = $\frac{15}{0.80}$

= 18.25

= 18th stage

Calculating pressure drop

H_t = $P_{hD} + (H_w+H_{ow}) + H_r$

H_w = 50 mm

Dry try pressure drop

H_d = $51(U_h/C_o)^2(r_v / r_v)$

U_h = Q_v/A_h=8.18 m/sec

Using Coulson fig 11.34 Co =orifice coefficient = 0,83

H_d = 33 mm

Weir crest

H_{ow} = 15 mm from Coulson 6th

Weir length9$L_{w)}$

L_w = $0.8*D_t$

= 0.6321 m

Residual head

H_r = $12.5*10^3/p_l$

= 14.9 mm

So

H_t = $H_d + (H_w+H_{ow}) +H_r$

= 33+50+15+15

= 113 mm

Total pressure drop

Δpt = $(9.8*10^{-3})/ Ht*p$

= 977 Pa

= 0.97 KPa

Table 5. 9: Specification of Distillation Column

SPECIFICATIONS	**DETAILS**
Actual number of stages	26
Actual feed plate	18
Thickness of cylinder	2.3mm
Thickness of head	2.3mm
Thickness of bottom	2.7 mm
Plate type	Sieve
Number of holes in top and bottom plates	2700 : 2841
Vapor velocity in top and bottom	1.33: 1.265
Diameter of top and bottom	0.7721 m: 0.789489 m
Weir height	50 mm
Height of column	5. m
Efficiency of column	80%
Plate spacing	0.15 m
Holes area top and bottom	0.0533 m: 0.0557 m

5.7 Design of Reactor:

Main reaction in Continuous stirred tank reactor:

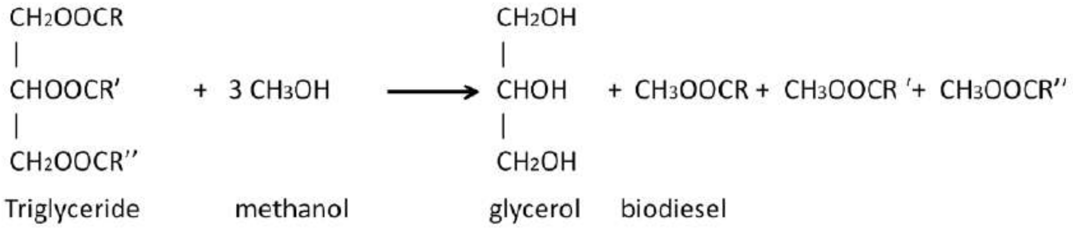


figure 5. 4: transesterification reaction

Design equation of C.S.T.R

$V = \frac{F_{Ao}X}{-r_A}$

$F_{Ao} = V_o C_{Ao}$

F_{Ao} = Initial molar flow rate of specie A

F_{Ao} = 0.20455 Kmol/hr

$-r = \frac{K_S\,(C_{tg}K_M C_M^3 - \frac{K_{ME}K_G}{K_S} C_{ME}^3 C_G)}{(K_M^{\frac{1}{3}} C_M + \frac{1}{3} K_{ME} C_{ME} + 1)^3}$

Above is the rate law equation of transesterification reaction of triglycerides

K_S = 0.0078

K_M = 0.0061

K_{ME} = $2.942*10^{-6}$

K_G = 0.9709

C_{ME} = 2.20

C_{TG} = 0.027855

C_G = 0.734

C_M = 4.59

Putting the values in the abo0ve equation

$$\frac{0.007(0.0061 * 0.027855 * 4.59^3 - 3.030 * 10^{-6} * 2.20^3 * 0.734)}{(0.1827 * 4.59 + 0.0145 * 2.20 + 1)^3}$$

= 0.0118

= $\frac{0.20456(0.98)}{0.0118}$

= 16 m^3

Optimum L/D ratio = 1.4

Volume of reactor = $\frac{\pi D^2}{4}L$

= $\frac{\pi D^2}{4}(1.4D)$

3.415 = $\frac{\pi D^2}{4}(1.4D)$

=D^3 = $\frac{16*4}{3.14*1.4}$

D = 2.4 m

L = 1.4 (2.4)

L = 3.14 m

Mechanical design of Reactor

Design pressure

Taken as 50% above operating gage pressure

Required pressure is 1 Atm

Design pressure would be 1.5(1 Atm)

= 1.5 atm

= 0.151987 N/mm^2

Design temperature

the required temperature is 60C

but we will use 1.1 times of required temperature

Design temperature would be 1.5(60)

= 90C

Material of construction

Material of construction is carbon steel

Maximum allowable stress= 12.9 Ksi

= 88.94237 N/mm^2

Thickness of cylinder

T = $\frac{P_i D_i}{2SE-1,2p_i}$

S = 88.94237N/mm^2

P_i = 0.1113N/mm^2

Hydrostatic head = pgh

756*9.8*3.14=23540

Total pressure = 0.1113+0.02354=0.13484N/mm^2

E = 1.0

D = 1.45m

= 14500mm

T = $\frac{0.13484*2400}{2*88.94237*1.2(0.13484)}$

= 1.8mm

Adding corrosion allowance of 2mm

= 1.8 + 2

= 3.8 mm (sheet)

Thickness of head

Ellipsoidal head

T = $\frac{P_i D_i}{2SE-.2p_i}$

S = 88.94237N/mm^2

P_i = 0.151987N/mm^2

E = 1.0

D = 2.4m

= 2400mm

t = $\frac{0.1348A*2400}{2*88.94237*.2(0.1348)}$

= 1.8mm

Adding corrosion allowance of 2mm

= 1.8

1.8 + 2

= 3.8 mm (sheet)

Design of stirrer of reactor

W = width of blades

D_{st} = diameter of impellers

DR = diameter of tank

N = turbine speed

Q = volumetric flow rate through impellers

Residence time in reactor =

T = $\frac{V_r}{v_o}$

= $\frac{16}{0.275}$=58.18sec

= 1 min

Stirrer clearance

C = $\frac{1}{2}D$

= $\frac{2.4}{2}$

= 1.2 m

Length of stirrer

L_{st} = H_r - C

= 3.14-1.2

= 2.96 m

Diameter of stirrer

D_{st} = $\frac{D_r}{4}$

$= \frac{2.4}{4}$

$= 0.6$ m

Blade width

W $= \frac{D_{ST}}{5}$

$= \frac{0.6}{5}$

$= 0.12$ m

Wall baffle

W $= \frac{D_r}{10}$

$= \frac{2.4}{10}$

$= 0.24$ m

Power consumption

Re $= \frac{nD_{St}p}{\mu}$

Density

The liquid is mainly a mixture of methanal and jatropha oil so the density is given as

$= 0.5(884) + 0.5(792)$

$= 883$

$\mu = 0.004$ pa.s

$= \frac{\frac{90}{60}2.4^2 883}{0.004}$

$= 1907280$

The liquid is turbulent flow so the power is not dependent on the flow of liquid

$P = KpD_{st}n^3$

$P = 6.30\frac{830}{1000}*(2.4)^5*(90/60)^3$

POWER $= 1.4$ KW

Table 5. 10: Specification of reactor

SPECIFICATIONS	**DETAILS**
r	0.0118

Volume of cylinder	16 m^3
Diameter or tank	2.4 m
Length of tank	3.14 m
Thickness of tank	4 mm
Thickness of head	4 mm
Length of stirrer	2.96 m
Diameter of stirrer	0.6 m
RPM of stirrer	90
Power of stirrer	1.4 KW
Material of construction	Carbon steel

5.*8* Design of Flash Drum:

F_l = 17.2

F_v = 30.74

Density of vapors at 70°C is 2.01

density of liquid at 70°C is 1250

P_l = 1250

P_v = 2.01

The F_{lv} factor is $\frac{f_l}{f_v}\sqrt{\frac{p_v}{p_l}}$

= 0.022

Now from the graph

= 1.24 m/s

Now calculating the volume flow rate of mixture

= 47.96 kg/hr

The density of the mixture is given as

= 0.8(792) +1250(0.20)

= 883 kg/m^3

V = $\frac{\text{mass flow rate}}{\text{density}}$

= $\frac{30.74}{2.01*3600}$

= $4.166*10^{-3}$ m^2

For a vertical flash tank, the minimum residence time is 5-7 min so we take it 5 min then the actual volume flow rate is

= $4.166*10^{-3}*300$

= 25 m^3

Now we can calculate the diameter and height of vessel

D = √1.25*4/Π

D = 1.26 m

The height of the flash vessel is

= 1.5 D + 0.4

= 1.5(1.26) +0.4

= 2.29 m

Table 5. 11: Specification of Flash Vessel

SPECIFICATIONS	**DETAILS**
Vapor velocity	1.24 m/s
volume	1.25 m^3
diameter	1.26 m
Height	2.29 m

6. Chapter 6 - Commentary on Process Control:

6. 1 Introduction:

All chemical industrial processes are susceptible to natural and unnatural disturbances that tend to alter operating conditions, stream compositions, and physical qualities. Control is implemented to limit the effects of these disturbances, particularly in terms of safety, product quality, and cost. It is preferable that the process variable to be monitored be measured directly; however, this is often impossible, and an easier-to-measure dependent variable is monitored instead.

The main aims of the design of a Biodiesel fuel plant from jatropha oil and methanol production process control are as described in the following:

- To achieve the targeted Biodiesel production rate.
- To ensure safe plant operation.
- To sustain Biodiesel production at the specified quality level.
- To maintain the lowest feasible operating costs.
- Maximize the yield within the specified quality parameters.
- To lessen feed material loss or waste.
- To minimize Energy

For this stage of the production process, referred to as Area B, three levels of process control and instrumentation are required:

- A system of alarms and warnings to ensure the safety of all process units, but particularly those where major risk is possible (i.e. the reactor).
- A regulatory control system used to maintain the constant operation of all process units and processes.
- A control system that employs advanced control techniques to maximize the profitability of critical unit operations (Methanol Column).

These procedures can be broken down in order to explain the various checks and balances involved in the implementation of process control for this production process.

6.2 Open / Close Loop System:

Open Loop:

Control system in which data about the manipulated variable is not used to alter any system inputs in order to compensate for volatility in the process variables. This word refers to the dynamics of an unregulated process.

Close Loop:

Control systems in which the measured controlled variable is utilised to trigger one of the process variables.

6.3 System for system feedback

In a closed loop control system, regulated information is relayed back and used to control a process variable. For automatic control, a measuring device is utilised to generate a signal. A controller receives the signal and compares it to a desired or predetermined value or set point. The controller delivers a signal to the final control element if a difference exists.

Advantage:

- Address disturbances before they disrupt the process.
- Deviation of the variable under control is minimised.

Disadvantage:

- Capable of measuring the disturbance.
- No corrective measures are taken for unmeasured disruptions.

6.4 Cascade Control System:

Cascade control is frequently employed to reduce disturbances entering a slow process. It also accelerates the system's response by decreasing the time constant between the modified variable process output and the system's response. Rather than altering the final control element, such as a control valve, the output of the primary controller becomes the set point of the secondary controller.

6.5 Ratio Control System:

Ratio control is a specialized form of feed forward control in which two disturbance loads are recorded and maintained in a constant ratio. Its primary function is to regulate the ratio of the two streams' flow rates. Each flow rate is measured, but only one can be adjusted.

6.6 Components of the Control Loop Final Control Elements:

It is the mechanism that modifies the values of controlled variables in response to output signals from an automated controller. In the majority of systems, the last element of control is an automatic control valve that regulates the flow of controlled variables.

6.7 I/P Transducer:

I/P converters are used in industrial control systems as current-to-pressure transducers. It is a tiny module used in applications to convert an analogue current signal (I) into a pneumatic output (P).

6.8 P/I Transducer:

A P/I converter or pneumatic pressure-to-current device. It transforms pressure input to a microampere range current. P/I converters are a typical component in automation systems. This apparatus converts pneumatic signals into electrical signals.

6.9 Controller:

The controller is responsible for comparing the process signal from the transmitter with the set point signal and sending the control valve the appropriate signal. There are three distinct types of controllers:

- Proportional action that pushes the control valve in inverse proportion to the error's magnitude.

- Integral action reset, which changes the control valve based on the time integral of the error; the aim of the integral action is to return the disturbed process to its fixed point.\

- The objective of the ideal derivative action is to predict the future of the process by analysing the error's time and rate of change.

As the interface between the process and its control system, transmitters are responsible for transforming the sensor signal into a control signal.Sensors are the process instruments that monitor qualities and significant factors such as temperature, pressure, flow rate, and level.

6.10 Commercial Controllers:

The three actions can be utilized independently or in combination with three fundamental controls.

• Proportional • Proportional integral (P.I) • Proportional integral derivative (P.I.D)

6.11 Customary Control Systems:

Any equipment containing an interface between two phases (e.g., liquid-vapor) must include a method for maintaining the interface at the required level. This may be included into the design of the equipment, as is typical for decanters, or achieved through automatic flow control from the device. Figure depicts a common level control system at the foot of a column. The control valve should be installed on the pump's discharge line.

6.12 Pressure Management:

Pressure control is required for the majority of systems that handle vapour or gas. The control mechanism will be determined by the nature of the process.

6.13 Flow Control:

Flow control is typically related with inventory management in storage tanks and other equipment. There must be a reservoir to accommodate fluctuating flow rates. A by-pass control would be used to provide flow control in a compressor or pump operating at a constant speed and deliver a nearly constant output volume.

6.14 Alarms, Safety Trips, and Interlocks:

Alarms are utilized to notify operators of significant and potentially hazardous process condition deviations. Switches and relays are installed on key instruments to activate audible and visual alerts on the control panels and enunciator panels. Where delay or inaction by the operator is expected to result in the rapid development of a dangerous condition, the instruments would be equipped with a trip system to respond automatically to avert the hazard, such as by switching off pumps, closing valves, and activating emergency systems.

These are the fundamental components of an automatic trip system.

- A sensor to monitor the control variable and generate an output signal when a predetermined value is exceeded.

- A link to transmit the signal to the actuator, often comprised of pneumatic or electrical relays.

6.15 Interlock System:

Where it is necessary to follow a defined sequence of actions, such as during plant startup and shutdown, or in batch operations, interlocks may be implemented into the control system design to prevent operators from deviating from the needed sequence. There are numerous proprietary lock and key systems available.

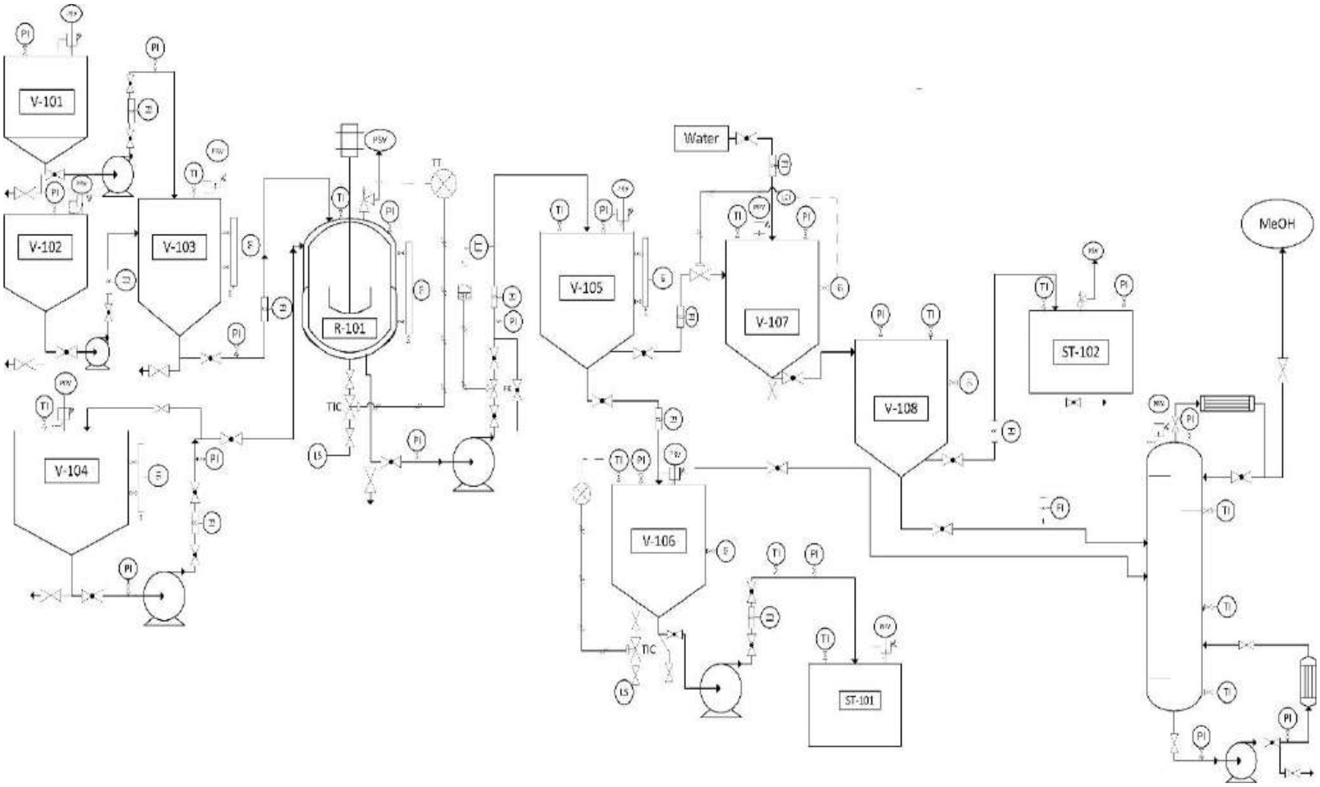


Figure 6. 1: P&I Diagram

6.16 Instrumentation Control System:

6.*16.1*Feed Control:

This element of the procedure addresses the introduction of feedstock to the mixture and reactor. In mixture, the feed (Methanol, and NaOH) flow rates or quantities are regulated by rotameter. Where liquid feed is given, the flow rate is regulated (using flow-rate indicators) and the valves are opened to permit the needed amount of feed. Level control indicator and transmitter are also installed for better control. Vacuum reducing valve is also installed because its one of the most important instrumentation tool which reduced the vacuum pressure in any closed vessel. Furthermore, drain valve and overflow valve also installed on mixture.

6.*16.2* Jatropha oil storage tank control:

Jatropha oil can be transported to the reactor by using centrifugal pump whose flow rate can be set by using flow indicator. To deal with any abnormality, by pass valve is also installed.

6.*16.3* Continues stirred reactor control:

Prior transported both feeds into reactor, it pressures, temperature and flow must be measured appropriately. Temperature regulation is of greatest importance as it ensures the normal reaction in the reactor. Our process would be affected if the temperature is too high, so a temperature indicator and temperature control device are placed. This should adjust the reactor's temperature by comparing predetermined set points. Emergency alarms can also be set to record any deviations.

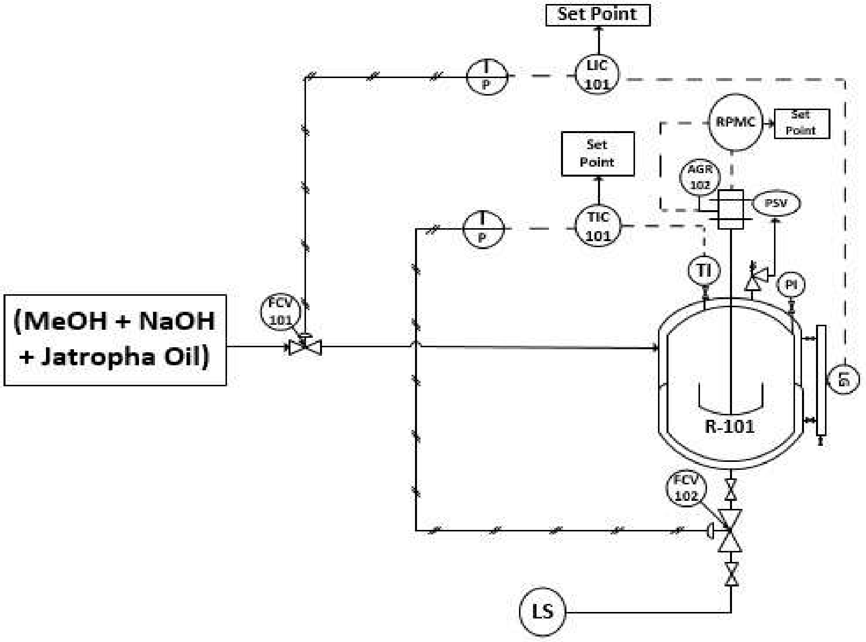


figure 6. 2: Instrumentation Design of reactor.

Moreover, our reactor is designed for low pressure so for dealing with any abnormal situation we also installed pressure safety valves which control the pressure inside the reactor. Vacuum reducing valve is also installed because it’s one of the most important instrumentation tool which reduced the vacuum pressure in any closed vessel. We also installed level indicators, a level indicator controller, and a level transmitter for level control. Moreover, for controlling the flow of steam for maintain temperature of the reactor flow control installed who takes the set point signal from temperature transmitter. Drain valve also placed for TA or Shutdowns purposes.

6.*16.4* Decenter-01 Control:

This portion of the operation deals the decanter's contribution. During this phase of the procedure, the stream's flow rates or quantity are also adjusted. Using flow-rate indicators and flow recording controllers, the flow rate is regulated and the valves are opened to permit the injection of the needed amount of feed from the reactor and the desired exit flowrate into the wash tank and Flash tank. The decanter, like the reactor, requires level control to prevent the level in the tank either decreasing too low or rising too high.

6.*16.5* Flash Tank Control:

This portion of the operation deals the flash tank contribution. During this phase of the procedure, the stream's flow rates or quantity are also adjusted. Using flow-rate indicators the flow rate is regulated and the control valves are opened to permit the injection of the needed amount of feed from the decenter by comparing the level gauge and the desired exit flowrate into the glycerol storage vessel. Flash tank requires level control to prevent the level in the tank either decreasing too low or rising too high. Pressure safety valve also a part of safety. For controlling temperature of the flash tank vessel control loop of temperature control system is installed which regulate the flow of steam by comparing required temperature after manipulating the signal from temperature transmitter. As condenser is installed, so for adjusting flow of cold water, Flow indicator is **installed.**

6.*16.*1 Glycerol Storage Vessel Control:

This portion of the operation deals the Glycerol storage vessel contribution. Using flow-rate indicators to regulate flow of centrifugal pump and the valves are opened to permit the flow. The level gauge and drain valve is also placed on vessel.

6.*16.*2 Wash Tank Control:

This section of the system covers the washing tank's feed. During this process, the stream's flow rates or quantities are regulated. The flow rate is regulated (using flow-rate indicators and flow recording controllers) and the valves are opened to allow the entry of the needed amount of water and product from the decenter for the operation. Rotameter (flow indicator) is also installed for controlling water flow rates. Likewise, the wash tank requires level control in order to maintain the proper level.

6.*16.*3 Decenter-2 Control:

This section covers the decanter's feedback. Throughout this phase of the process, the stream's flow rates or quantity are also regulated. The flow rate is regulated (using flow-rate indicators and flow recording controllers) and the valves are opened to allow feed to be introduced from the wash tank and the desired exit flowrate into the distillation column. The decanter, like the wash tank, requires level control to regulate the tank's level and outlet valve to send biodiesel into storage vessel.

6.*16.*4 Biodiesel Storage Tank:

This portion of the operation deals the Biodiesel storage vessel con. Using flow-rate indicators to regulate flow of centrifugal pump and the valves are opened to permit the flow. The level gauge and drain valve is also placed on the vessel.

6.*16.*5 Distillation Column Control**:**

For the distillation column, it is required that the Methanol's composition and purity meet the specified parameters. From the material and energy balance, both the top and bottom products' compositions have been determined. This is implemented into the process's control. At the bottom of each column, cascade control is implemented. The temperature of each column's exit stream is regulated so that the resulting product has the correct composition. The LC on the steam supply maintains the required heat input.

Also utilized at the top of the column is cascade control. The pressure of the vapor flow overhead is regulated. In addition, a TC (or composition controller) is installed to reset the reflux flow rate. In order to satisfy the purity specification, the control of the distillation columns is meticulously executed. In the presence of a rectification or stripping column, the control of the distillation column would require minimal or no detail. However, the lack of rectification and stripping columns necessitates that the product's purity be achieved at the distillation stage.

Throughout the process, the product's composition must be examined often. One or more process analyzers can reduce the number of required samples and tests while providing continuous process data. However, extensive and specialized maintenance will be necessary to ensure that the analyzers are appropriately calibrated and working. The reactor intake, reactor exit, stripping column bottoms, crude product storage tank, and end product should all be sampled on a daily basis in order to detect variations in feed composition that may necessitate process adjustments (rectification column distillate).

The temperature regulation is of the utmost importance since it ensures that only Methanol is returned to the reactor as a top product. If the temperature is too high, a mixture of Methanol and Residue will be returned to the reactor in wrong proportions, hence affecting the concentration of the reactor effluent. As the target range is between 30°C and 60°C, TC should be added to each feed plate to monitor any increase or reduction. At the point where the reaction mixture is pumped from the bottoms to the next column, an FRC should be installed.

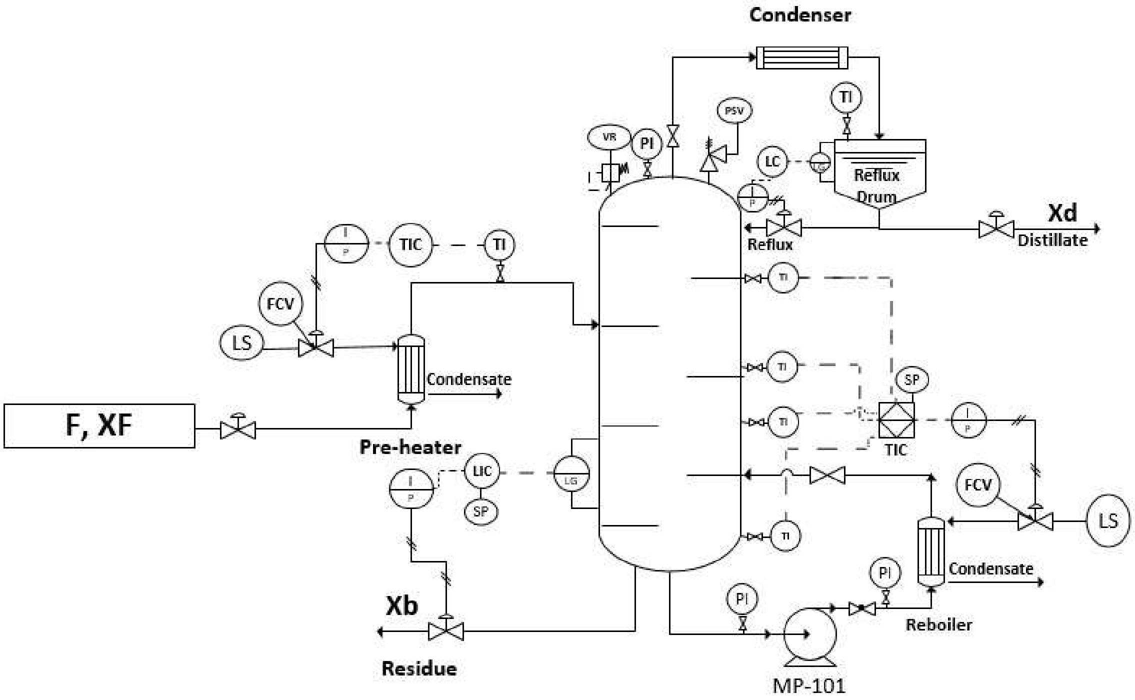


Figure 6. 3: Instrumentation design of Distillation column

6.*16*.6 Methanol Recycling Control:

Distillate from distillation column can be recycled to mixing tank by centrifugal pump. The flow can be adjusting by using flow indicator. The discharge valves are opened to introduced feed into mixing tank.

Chapter 7:

7. 1 Plant Layout

Plant location refers to the selection of a particular site that is best for setting up a plant. Plant location has a crucial effect on the profitability of a project and scope for future expansion and so it must be carefully analyzed.

The following factors will be considered;

Cost:

The cost of construction can be minimized by adopting layout that gives the shortest run of connecting pipes between equipment and the least amount of structural steel work; However this will not necessarily be the best arrangement for operation and maintenance.

Process Requirements:

in some processes some equipment will need to be placed at high altitudes while others are grounded. Provisions should be made for these kinds of equipment.

Operation:

Equipment that needs frequent attention should be placed in areas where they can be easily accessed.

C**onvenience of maintenance:**

equipment needs to be position in such a way that much difficulties won’t be faced when trying to access for maintenance purposes.

Safety:

the plant must be laid in such a way that hazards can be contained easily. For example, blast walls may be needed to isolate potentially hazardous equipment, and confine the effects of an explosion. At least two escape routes for operators must be provided from each level in process buildings.

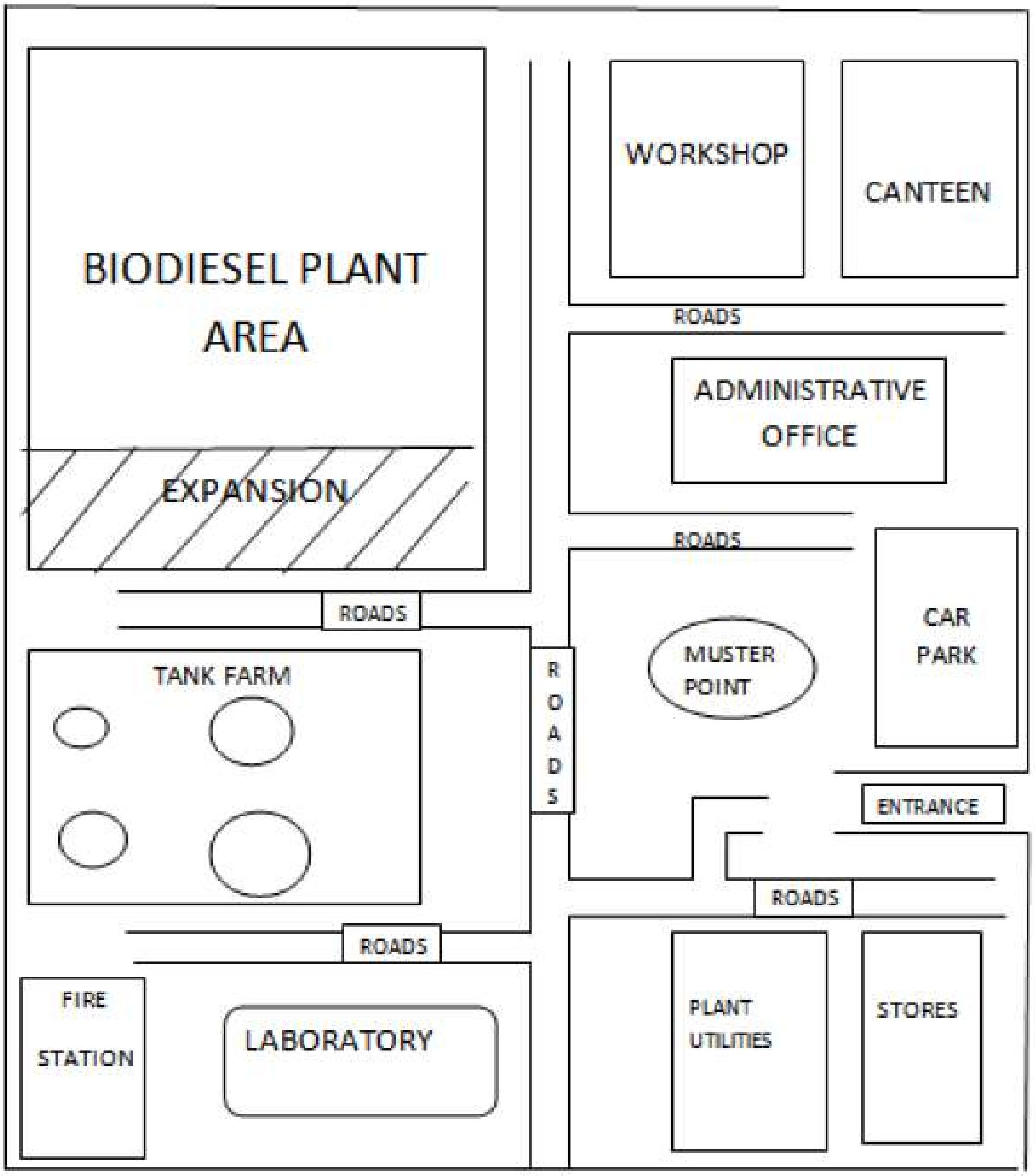
Future expansion:

Equipment should be located so that it can be conveniently tied in with any future expansion of the process. Also, space should be left on pipe alleys for future needs, and service pipes over-sized to allow for future requirements.

Modular construction:

this is a practice where some sections of the plants are bought, moved and assembled in the plant site instead of constructing them on the site. They include equipment, structural steel, piping and instrumentation.

The plant layout pattern that will be adopted for the Biodiesel plant will be the flow-through pattern shown below;


BIODIESEL PLANT AREA
EXPANSION
WORKSHOP
CANTEEN
ROADS
ADMINISTRATIVE OFFICE
ROADS
ROADS
CAR PARK
MUSTER POINT
TANK FARM
ROADS
ENTRANCE
ROADS
ROADS
FIRE STATION
LABORATORY
PLANT UTILITIES
STORES

7. 2 Economic summary:

Raw materials and input:

The major raw materials used to produce the biodiesel are Jatropha oil, Methanol, Sodium Hydroxide and Water. Jatropha oil will be delivered to the plant by the oil-producing company.

Raw and auxiliary materials requirement and cost:

Table 7. 1: **Raw materials cost**

Raw and auxiliary materials requirement and cost			
Description	Quantity	Unit price $	Total cost $
Jatropha oil	1556095	0.25	389023.7499
Methanol	172024.4	0.54	92893.17049
Sodium hydroxide	519.1836	0.5	259.5917989
Process Water	1565.307	0.031	48.52451328

Equipment's cost:

Cost of distillation column:

Type of column=sieve

Height =4.7m

Index in 2004= n = 444

Purchased cost in 2004 = 26000$

Increase in index 2022 is 23%

We know that the cost index 2021 is n= 771

Increasing total Index in 2022 = index in 2004 + (0.23*index in 2021)

Increasing total Index in 2022 = 771+(0.23×771)

Increasing total Index in 2022 = 948

Now in order to find purchased cost:

Purchased cost in 2022 = Purchase cost in 2004 *(index in 2022/index in 2004)

Purchased cost in 2022 = 55513 $

$$C_{BM} = C_p * F_{BM}$$

$$= 55513\ \$ * 1$$

$$C_{BM} = 55513\ \$$$

Cost of reactor:

Type of reactor=agitated

Volume =16 m^3

Index in 2004= n = 444

Purchased cost in 2004 = 18000$

Increase in index 2022 is 23%

We know that the cost index 2021 is n= 771

Increasing total Index in 2022 = index in 2004 + (0.23*index in 2021)

Increasing total Index in 2022 = 771+(0.23×771)

Increasing total Index in 2022 = 948

Now in order to find purchased cost:

Purchased cost in 2022 = Purchase cost in 2004 *(index in 2022/index in 2004)

Purchased cost in 2022 =38400 $

$$C_{BM} = C_p * F_{BM}$$

$$= 38400\ \$ * 1$$

$$C_{BM} = 38400\ \$$$

Cost of decanter:

Type of tank=vertical

Index in 2004= n = 444

Purchased cost in 2004 = 2900$

Increase in index 2022 is 23%

We know that the cost index 2021 is n= 771

Increasing total Index in 2022 = index in 2004 + (0.23*index in 2021)

Increasing total Index in 2022 = 771+(0.23×771)

Increasing total Index in 2022 = 948

Now in order to find purchased cost:

Purchased cost in 2022 = Purchase cost in 2004 *(index in 2022/index in 2004)

Purchased cost in 2022 =6191 $

$$C_{BM} = C_p * F_{BM}$$

$$= 6191\$ * 1$$

$$C_{BM} = 6191\ \$$$

cost of storage tank:

Type of tank=vertical

Index in 2004= n = 444

Purchased cost in 2004 = 2900$

Increase in index 2022 is 23%

We know that the cost index 2021 is n= 771

Increasing total Index in 2022 = index in 2004 + (0.23*index in 2021)

Increasing total Index in 2022 = 771+(0.23×771)

Increasing total Index in 2022 = 948

Now in order to find purchased cost:

Purchased cost in 2022 = Purchase cost in 2004 *(index in 2022/index in 2004)

Purchased cost in 2022 =6191 $

$$C_{BM} = C_p * F_{BM}$$

$$= 6191\$ * 1$$

$$C_{BM} = 6191\ \$$$

Table 7. 2: Cost of equipment's:

s/n	**Description**		**Estimated price**	
1	Reactor	1	38400	38400
2	Decanter	2	6191	12382
3	Storage tank	3	6191	18573
4	Distillation column	2	55513	111026
5	Recycle	1	10000	10000
Total				190417

Estimation of Fixed Capital Cost:

Table 7. 3estimation of fixed capital cost

Items	**Factors**
Equipment Erection	0.45
Piping	0.45
Instrumentation	0.15
Electrical	0.10
Building, Processes	0.10
Utilities	0.45

Storage	0.02
Site Development	0.05
Ancillary Buildings	0.20
Physical Plant Cost	**$375121**
Design and Engineering	0.25
Construction Fee	0.05
Contingency	0.10
Fixed Capital	**$150000**

Working capital =0.15 % of fixed capital

=0.15* 150000=22500$

Total Investment:

fixed capital + working capital =172500

Depreciation of plant equipment:

Table 7. 4: Depreciation cost of reactor

Depreciation for reactor			
purchase price	38400		
Depreciable value	24757.84833		
Salvage value	13642.15167		
Life (in years) 15.00			
Year	**Depreciation Expense**	**Accumulated Depreciation**	**Book Value**
1	2560	2560	35840
2	2389.333333	4949.333333	33450.67
3	2230.044444	7179.377778	31220.62
4	2081.374815	9260.752593	29139.25
5	1942.616494	11203.36909	27196.63
6	1813.108728	13016.47781	25383.52
7	1692.234812	14708.71263	23691.29
8	1579.419158	16288.13178	22111.87
9	1474.124548	17762.25633	20637.74
10	1375.849578	19138.10591	19261.89

11	1284.126273	20422.23218	17977.77
12	1198.517854	21620.75004	16779.25
13	1118.616664	22739.3667	15660.63
14	1044.04222	23783.40892	14616.59
15	974.4394052	24757.84833	13642.15

Table 7. 5: Depreciation cost of recycle system

Depreciation for recycle			
purchase price	10000		
Depreciable value	6447.356		
Salvage value	3552.644		
Life (in years) 15.00			
Year	Depreciation Expense	Accumulated Depreciation	Book Value
1	666.6667	666.6667	9333.333
2	622.2222	1288.889	8711.111
3	580.7407	1869.63	8130.37
4	542.0247	2411.654	7588.346
5	505.8897	2917.544	7082.456
6	472.1637	3389.708	6610.292
7	440.6861	3830.394	6169.606
8	411.3071	4241.701	5758.299
9	383.8866	4625.588	5374.412
10	358.2942	4983.882	5016.118
11	334.4079	5318.29	4681.71
12	312.114	5630.404	4369.596
13	291.3064	5921.71	4078.29
14	271.886	6193.596	3806.404
15	253.7603	6447.356	3552.644

Table 7. 6: Depreciation cost of distillation column

Depreciation for Distillation column			
purchase price	55,531		
Depreciable value	35802.81		
Salvage value	19728.19		

Life (in years) 15.00			
Year	**Depreciation Expense**	**Accumulated Depreciation**	**Book Value**
1	3702.067	3702.067	51828.93
2	3455.262	7157.329	48373.67
3	3224.911	10382.24	45148.76
4	3009.917	13392.16	42138.84
5	2809.256	16201.41	39329.59
6	2621.972	18823.39	36707.61
7	2447.174	21270.56	34260.44
8	2284.029	23554.59	31976.41
9	2131.761	25686.35	29844.65
10	1989.643	27675.99	27855.01
11	1857	29532.99	25998.01
12	1733.2	31266.19	24264.81
13	1617.654	32883.85	22647.15
14	1509.81	34393.66	21137.34

Table 7. 7: Depreciation cost of storage tank

Depreciation for storage tank			
purchase price	6191		
Depreciable value	3991.558		
Salvage value	2199.442		
Life (in years) 15.00			
Year	**Depreciation Expense**	**Accumulated Depreciation**	**Book Value**
1	412.7333	412.7333	5778.267
2	385.2178	797.9511	5393.049
3	359.5366	1157.488	5033.512
4	335.5675	1493.055	4697.945
5	313.1963	1806.252	4384.748
6	292.3166	2098.568	4092.432
7	272.8288	2371.397	3819.603
8	254.6402	2626.037	3564.963
9	237.6642	2863.701	3327.299

10	221.8199	3085.521	3105.479
11	207.0319	3292.553	2898.447
12	193.2298	3485.783	2705.217
13	180.3478	3666.131	2524.869
14	168.3246	3834.455	2356.545
15	157.103	3991.558	2199.442
Depreciation for decanter			
Depreciation for decanter			
purchase price	6191		
Depreciable value	3991.558		
Salvage value	2199.442		
Life (in years) 15.00			
Year	Depreciation Expense	Accumulated Depreciation	Book Value
1	412.7333	412.7333	5778.267
2	385.2178	797.9511	5393.049
3	359.5366	1157.488	5033.512
4	335.5675	1493.055	4697.945
5	313.1963	1806.252	4384.748
6	292.3166	2098.568	4092.432
7	272.8288	2371.397	3819.603
8	254.6402	2626.037	3564.963
9	237.6642	2863.701	3327.299
10	221.8199	3085.521	3105.479
11	207.0319	3292.553	2898.447
12	193.2298	3485.783	2705.217
13	180.3478	3666.131	2524.869
14	168.3246	3834.455	2356.545
15	157.103	3991.558	2199.442

7. 3 Annual production cost at full capacity between start-up and end of first year:

Index cost:

Table 7. 8: cost index

plant working time	0.9
operating time	328.5
total production	1642500
maintenance cost	15000

labor cost	22500
plant overhead	75000
capital chargers	15000
insurance	1500
local taxes	3000
royalties and license fee	7500

Total=126000$

TCI-deprecation

126000-12027.8

Product cost=113973$

Direct production cost

Total fixed cost + Total variable cost= 126000+482225.037

=606225$

Sales expense + General Over Head = 20% of direct production cost

=121245$

Annual Production Cost:

Manufacturing cost = fixed charges + plant overhead

=126000+75000=201000

Total product cost = 1478250+70810=1549060$

Gross Income = 1549060-606225$

Gross Income =942805$

Let 30 % taxes = 282841$

Net profit = Gross Income – taxes = 942805 $ - 282841 $

Net profit = 659964$

Rate of Return:

$$\text{Rate of return} = (\text{net profit} \times 100) / \text{total investment}$$

$$\text{Rate of return} = \frac{(\ 659963\ \$\times 100)}{}322500\ \$$$

=204%

$$\text{Rate of return } = \frac{204}{\text{year}}$$

Payback time = 1 year

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