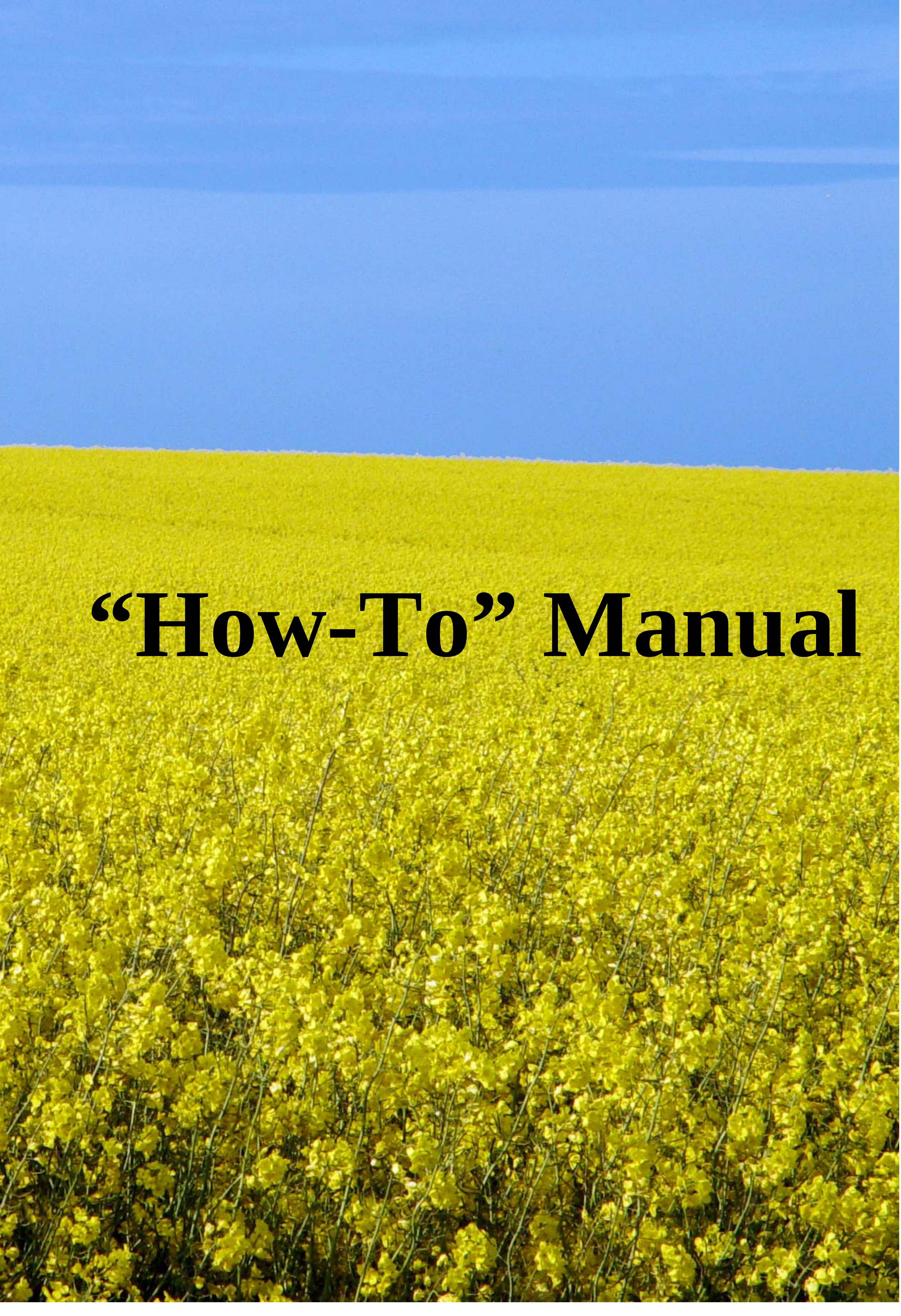


“How-To” Manual

DISCLAIMER

It is the reader's responsibility to check that the engines of the vehicles intended for biodiesel use are compatible. The processes set out in this manual are dangerous and the authors take no responsibility for any accidents or damage caused as a result of, or in reliance upon, any information supplied in this manual. Further, the reader undertakes the methods involved in this manual at their own risk.

It is the responsibility of the reader to ensure that all containers are safe and secure and no guarantee of fitness for purpose is given.

Any changes to legal requirements since print need to be taken into account by anyone planning to make biodiesel and are not the responsibility of the authors.

This manual only gives the guidelines for operating a small (100 litre batch) biodiesel plant; it is up to the person implementing the plant to ensure that the health and safety standards of the country where any biodiesel production or related processes are undertaken are adhered to.

Date of print: 09/05/07

CONTENTS

1. INTRODUCTION

This booklet outlines the basics of biodiesel and more specifically the processes used and equipment required to produce your own biodiesel. It is designed to give an overview of biodiesel, its production, implementation, hazards and uses. In addition to this there is a design for a biodiesel plant given along with a kit list and possible suppliers; guidance for implementation and instructions for construction and running, guidelines and standards are also included. The plant design is split into different sections as will be described later. This allows the purchase of the basic plant components primarily whilst allowing for the possibility of expansion and increased efficiency at a later date.

2. WHAT IS BIODIESEL?

Biodiesel is an alternative fuel that can be used to power conventional diesel engines. It comprises of mono-alkyl esters that are formed from chemically transforming vegetable oils or fats. The mono-alkyl esters are produced through a reaction of a simple alcohol (e.g. methanol or ethanol) with a fat or oil to form glycerol and biodiesel.

Its primary advantage is that it is one of the most renewable fuels currently available; it is also non-toxic and biodegradable.

In addition to the enhanced environmental properties of biodiesel, its lubrication properties are higher than in mineral diesel, hence results in longer life of an engine.

It is an opportunity to improve the environment and is acknowledged as an alternative fuel under the Energy Policy Act of 1992 (EPAct) amended in 1996 (USA).

2.1 Why not pure vegetable oil?

Pure vegetable oil is too viscous to be used directly in an engine. The use, without modification to the engine, would result in decreased engine life due to increased deposits within the engine’s filter.

2.2 Uses of biodiesel

Biodiesel is not only useful as a fuel for powering vehicles. It can also be used to power generators (producing electricity), in oil lamps for lighting or to burn as a source of heat.

2.3 Uses of by-products

The main by-product of the biodiesel production is glycerol. Although this is used in regular soap as well as many cosmetics, the glycerol that will be created during this process is not pure enough to be used in these applications. The glycerol can be heated to clear it of impurities or can be disposed of through the correct authorities.

2.4 Environmental Effects

Although the main focus is not on the environmental impact of biodiesel compared to the fuels which are being replaced, it is worth considering them.

Biodiesel, when compared to mineral diesel, shows reductions across many areas of emissions:

- Over 75% reduction in CO_2 emissions
- Decrease in toxic organic micro-pollutants
- SO_2 emissions virtually eliminated (decrease in acid rain)
- 38% lower hydrocarbon emissions
- 15% lower CO emissions
- No lead emissions

Furthermore there is 96% less hazardous solid waste and 79% less water waste due to production of biodiesel (when produced properly) compared to mineral diesel production.

Although there are reports that state biodiesel increases NO_x emissions this appears to be only in transport applications, when used in heating (static) applications the NO_x emissions remain similar to those of mineral diesel.

2.5 Implementation Requirements

Biodiesel takes very little change to implement it as a replacement for mineral diesel. The chemical conversion of vegetable oil to biodiesel reduces the viscosity to around the same value as mineral diesel so it can be used in conventional diesel engines with little or no modification, however vehicle manufacturers should be consulted before changing to biodiesel. Biodiesel can then be mixed with mineral diesel to be used in conjunction with or to totally eliminate the use of mineral diesel.

Biodiesel can be made from any oil input; the most common oils for particular regions are shown below:

Canola (rapeseed) oil	–	Europe
Soybean oil	–	USA and Brazil
Sunflower Oil	–	Italy and France
Palm Oil	–	Malaysia
Linseed Oil	–	Spain
Cotton Seed Oil	–	Greece
Jatropha	–	India, Nicaragua and South America

The same basic procedure applies for any oil input. In addition to these ‘clean’ straight vegetable oils (SVO), waste vegetable oil (WVO) can also be used. WVO can be collected from homes or restaurants (there can be charges for the disposal of waste oil so this may be of benefit to the establishment as well as to you!). The only difference in the procedure between waste and new oil is that the waste vegetable oil needs to be filtered before it is used in the plant; this removes any remaining traces of food or fat which may have collected in it or any sediment which may have formed over time. WVO may also have excess water in it and so heating it pre-reaction can help to reduce this.

Below are a few examples of the implementation techniques and directives set up in various countries:

Brazil – National Biodiesel Program launched in December 2004, biodiesel introduced into the domestic market in 2005. In January 2005 law LEI No.11.097 was passed, that authorises the voluntary sale of biodiesel fuel for three years with a mandatory B2 (2% biodiesel and 98% mineral diesel) content, starting in January 2008. In 2013 B5 (5% biodiesel and 95% mineral diesel) will be required.

Argentina – Currently there are approximately 10 plants with a total production capacity of 60,000 tons per year. Tax incentive structure wherein biodiesel producers receive a 15 year exemption from the country's 15 cents per litre diesel tax as well as other incentives.

The EU – Directive 2003/30/EC states the legislative standpoint of the EU on the promotion of the use of biofuels for transport. The EN 14214 standard controls the quality of biodiesel produced.

India – The country's Planning Commission encouraged the widespread planting of Jatropha curcas trees in 2003, with a view to them being used to produce oil for biodiesel plants. The progress is currently resting on the Ministry of Rural Development.

For more information refer to 'A Biodiesel Primer: Market and Public Policy Developments, Quality, Standards and Handling'. Found online at: http://www.biodiesel.org/resources/reportsdatabase/reports/gen/20060401-GEN369.pdf

3. THE BASICS OF BIODIESEL

The process which is described in this manual is that of a base catalyst reaction. This has been chosen as it is the most economical of all the possibilities; it uses low pressures and temperatures whilst still retaining a 98% conversion yield.

Transesterification is the most important part of biodiesel production as it changes the viscosity of the parent oil so that the biodiesel has a viscosity closer to that of mineral diesel. Biodiesel is obtained by replacing the glycerol with the simple alcohol to produce an alkyl ester. The generic chemical equation for this process is shown below.

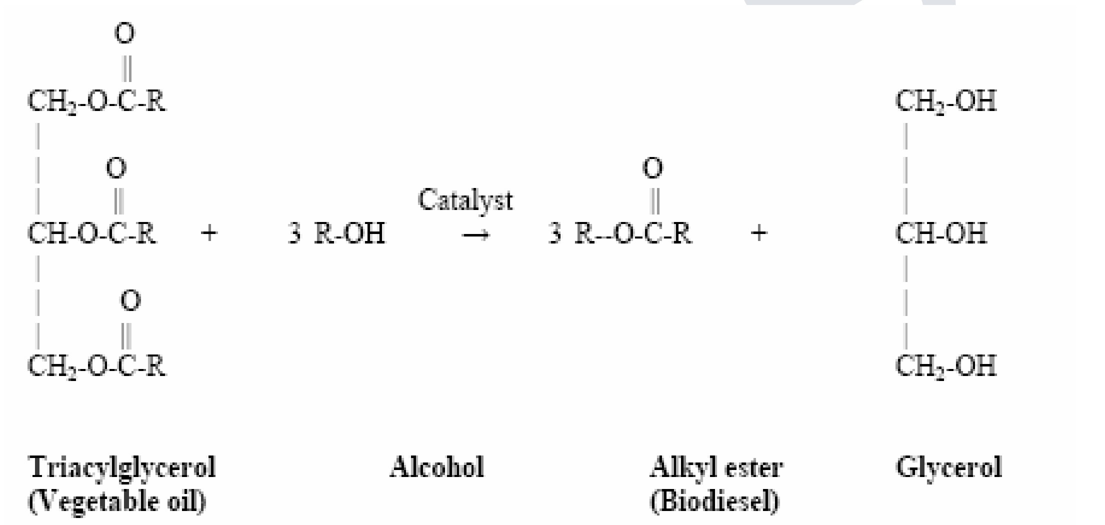


Figure 3.1: Generic Transesterification Reaction

A catalyst is required for the process to go to completion. A catalyst is a substance which is present in small quantities and accelerates the speed of the reaction (in many cases virtually no reaction will occur without it). The catalyst is added to accommodate the reaction and will, in theory, not be consumed; a base catalyst is used and will end up in the glycerol by-product produced and the wash water from the reaction.

The amount of catalyst required for new vegetable oil is fixed for each individual oil source; it is only when dealing with waste vegetable oil (WVO) that a titration needs to be performed. The titration determines the amount of Free Fatty Acids (FFA) in the oil. FFA's consist of the long carbon chains, if oil containing a FFA is used to produce biodiesel, the alkali catalyst typically used to encourage the reaction will react with this acid to form soap. This is undesirable as it binds the catalyst into a form that does not contribute to accelerate the reaction.

4. PROCESS

Experiments were carried out to determine which alcohol and catalyst would be most suitable for use in the intended plant. The results were also used to help define the correct process by which to obtain biodiesel.

4.1 Defined Process

There are seven stages that make up the method for producing biodiesel (the optimal technique established for the production of biodiesel has been split into modules, as shown in the design for the overall plant, Section 5).

1. Meth-oxide mixing
2. Reaction
3. Settling
4. Separation
5. Washing
6. Filter and dry
7. Storage

1. The catalyst and alcohol are mixed to create meth-oxide prior to addition to the oil. The purpose of mixing these two chemicals together is to allow the substances to react and form an oxide of the alcohol prior to the transesterification reaction, thus encouraging a better reaction. The catalyst and alcohol need to be mixed vigorously as the catalyst will not readily dissolve.

2. During the reaction it is essential to bring all of the chemicals into direct contact so as to initiate the reaction. Vigorous stirring is required at the early stage when all the chemicals have been added to the reaction tank. The stirring only needs to occur in a short burst as it is necessary to let the inhibiting by-product (glycerol) separate from the remaining reactors.

3. The settling time allows the heavier glycerol to sink to the bottom of the container. The biodiesel floats on top of this by-product layer. The settling begins immediately however the mixture should be allowed to stand for approximately 12 hours to settle fully.

4. It is now necessary to separate the biodiesel from the glycerol as there is only an allowance of ~0.24% glycerol in the final product. The biodiesel can be tapped off the top of the glycerol which can then be removed from the reaction tank and disposed of correctly.

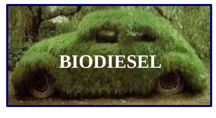
5. Washing is not an essential part of the biodiesel production process; however there will be small levels of impurities within the biodiesel at this stage which can be removed by washing. Water is misted over the top of the biodiesel and is allowed to pass through the biodiesel. The mixture is left to settle for approximately 5 hours, the wash water, which has settled to the bottom, is tapped off and the process can be repeated as many times as is necessary. Any impurities within the biodiesel (e.g. soap, excess methanol and water) dissolve in the wash water and are drawn out of the biodiesel.

6. The washed biodiesel is passed through a filter before storage which removes any particulates which may have accrued during the production process.

7. The biodiesel is now ready to be used or stored. The biodiesel should be stored in an air tight container away from the plant.

In addition to these seven stages are pre-treatment of waste vegetable oil (WVO) and disposal of by-products.

Pre-treatment only occurs if WVO is being used in the plant, in which case it is useful to remove any particulate that may have settled in the oil and also any excess water. This is achieved by filtering the oil through a 1mm^2 filter and then heat it to remove excess water. It is also advantageous to use heated oil as it speeds up the reaction.



The disposal of by-products from this reaction is largely dictated by governmental executives. Glycerol is used in soap, medicines and cosmetics; however, the glycerol produced during transesterification may contain up to 20% methanol along with other impurities and so has to be cleaned if it is to be used in industry. The methanol can be recovered using distillation and can then be used in the production again and the glycerol can be composted.

The waste water from the wash process contains soap and other impurities and so needs to be disposed of with due care and attention to the public and the environment.

4.2 Additional Results

From the experiments it was found that the use of an alkaline catalyst, Sodium Hydroxide (NaOH) and a simple alcohol, methanol suited the process best. As this is the case the meth-oxide should only be mixed immediately prior to the reaction as sodium meth-oxide "goes off" quickly.

Sodium hydroxide was chosen as the catalyst as it is most commonly used in batch processing and is readily available. It is used in drain cleaner and in the paper and textiles industries, it is also the most common base used in chemical laboratories. The accompanying alcohol to NaOH is methanol. Methanol is used as a solvent and as anti-freeze in pipelines and windscreen wash fluid.

It was found that the catalyst and alcohol need mixing prior to transesterification so as to produce a better reaction. Vigorous stirring or shaking produced satisfactory meth-oxide.

Although vigorous stirring is necessary at the initial stages of the reaction if this stirring was too vigorous white foam was produced and there was no further reaction. *Figure 2* shows such an incident.

Figure 4.2: The effect of overly vigorous stirring.

A temperature of 20-30^{o}C was found to allow the reaction, however a temperature of 30-40^{o}C provides a definite reaction in all cases. Heating above this temperature speeds up the reaction however it is not a necessary step. The boiling point of methanol is ~65^{o}C and so the temperature of the reaction should not approach, and should never be allowed above, this temperature.

It was determined that heating the oil to 40^{o}C prior to addition to the reaction tank provided enough heat to bring the reaction temperature of all the chemicals to the desired amount. The ambient temperature in India is found to be ~30-35 °C which is high enough not to need any heating of the inputs.

Although washing gets rid of any glycerol left in the biodiesel post separation, it was found that it is not entirely necessary to wash the biodiesel after separation from the glycerol. If washing was not to occur the settling time needs to be increased to allow most of the impurities to settle, as the catalyst and alcohol are more soluble in the glycerol phase most will be removed from the biodiesel given enough time.

5. DESIGN

Due to the results from our testing it was decided that a modular design would be produced. The basic kit for the plant consists of the meth-oxide and oil tanks, one reactor tank, a waste tank and biodiesel storage tank. The additional modules comprise of; increased quantity of reaction tanks; the addition of a water tank and wash tank; additional wash tanks; a filtration system; and a methanol recovery system.

Being a batch plant it allows the user to start and stop the plant whenever necessary. As the golden rule of biodiesel production is 'never leave a plant while in production' this negates the need for continual staff while not ruling out the possibility for batch production to run continually throughout both day and night if desired.

The figure on the following page shows the process flow of the system. The components enclosed in the yellow boxes are the basic components that form the plant. The additional components can be included to increase the quality of the biodiesel (in the case of the water and wash & filter tanks).

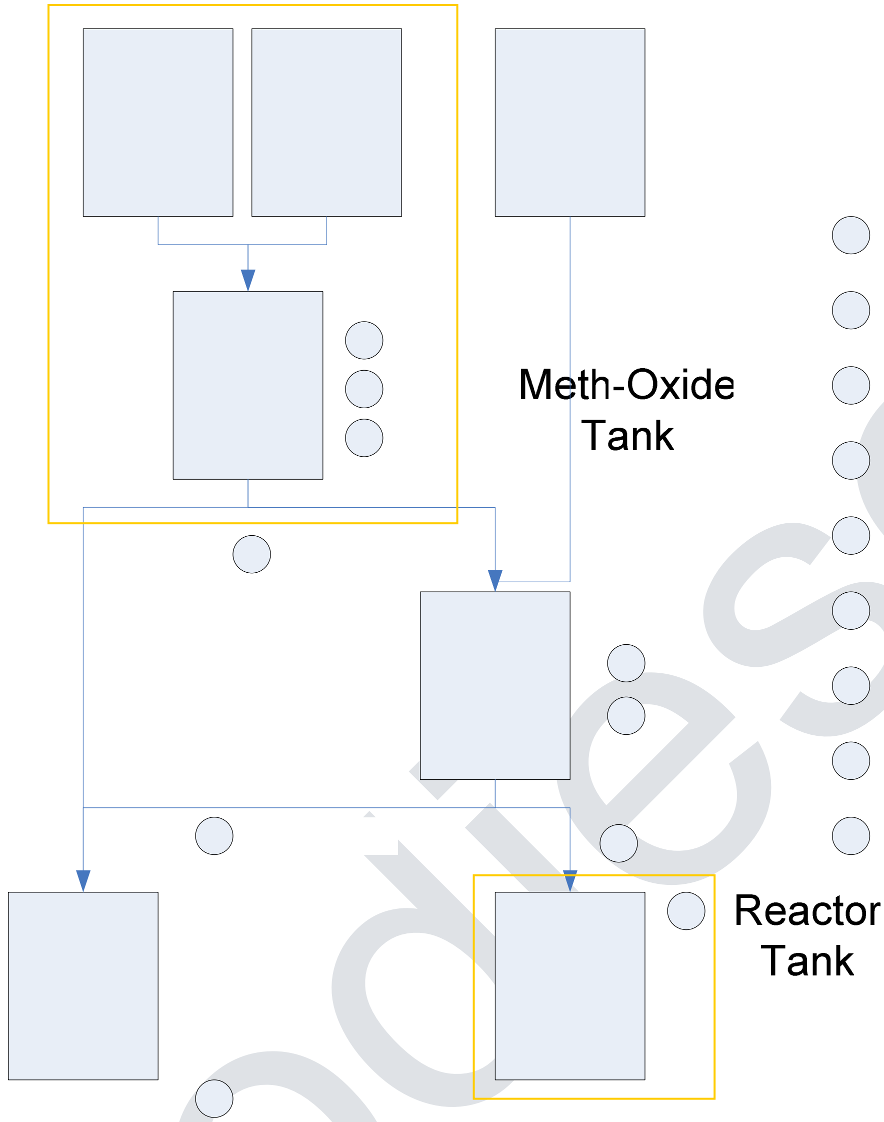


Figure 5.1: Process flow of the biodiesel plant

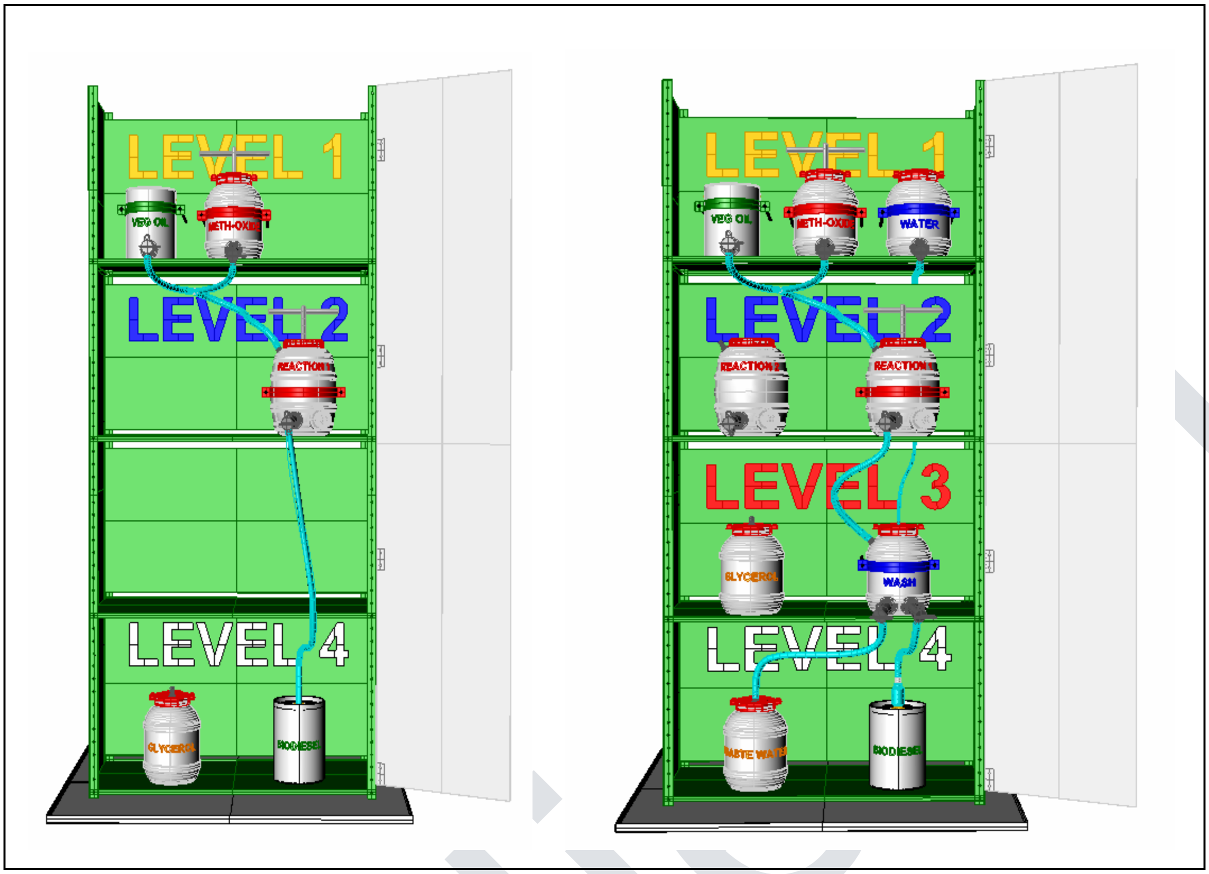


Figure 5.2: CAD Drawings of the basic kit and full kit..

Due to the chemicals used in the process the materials of all of the components are very important. In all components the temperature will not rise above the ambient temperature of the plant, unless otherwise stated.

6 BASIC PLANT COMPONENTS

6.1 Meth-Oxide Tank

Material: High Density Polyethylene (HDPE) or Polypropylene (PP)

Quantity: 1
Capacity: 60L
Cost: £15-£30

The meth-oxide tank contains methanol and sodium hydroxide. These would very rapidly corrode a steel container; therefore a non-reactive vessel must be used. Drums made of PP (polypropylene) or HDPE (High Density Polyethylene) are most suitable for this purpose.

The methanol and catalyst must be mixed vigorously in order to react and produce meth-oxide, the reactant in the transesterification process. This is achieved through addition of a stirring device (see section 6.4).

The meth-oxide vessel needs a tap to enable transfer to the reaction vessel, therefore must be relatively easy to drill into (i.e. not brittle).

In the UK a supplier of these types of HDPE/PP drums is Smiths of the Forest of Dean Ltd" [smithsofthedean.co.uk].
A suitable 60L clamp top barrel is available for £30, shown opposite:

6.2 Vegetable Oil Tank

Material: Steel or PP/HDPE

Quantity: 1

Capacity: 100-250L depending on setup

Cost: Salvageable / £30-40

The Vegetable Oil tank contains all the raw oil waiting to be reacted. This tank should allow for heating of the oil to speed the reaction if necessary. No heating is deemed necessary for countries with an ambient temperature of 30 °C or above and so there has been no additional module designed for this; however the possibility has not been disregarded. As was mentioned in the experimental section it is possible to heat the oil to a temperature of 40 °C and this will heat all chemicals in the reaction tank sufficiently. As vegetable oil will not corrode steel, this is a suitable material for the tank. An old oil drum would also be ideal for this purpose as long as it is thoroughly cleaned. The most efficient way to heat the tank is band heaters, however these can be very expansive and so a flame or even hot water can be used. If a generator is being powered using the biodiesel then it may be interesting to consider using the hot flue gases to heat the oil tank.

If heating is not necessary then a polymer (PP or HDPE) tank similar in construction to the meth-oxide tank can be used. The size of this tank depends on the size of batch planned, but more than one batch could be held and heated at the same time, allowing for multiple reactions to be run.

This drum also requires a tap to be installed to allow transfer to the reaction vessel. Most oil drums have closed tops, i.e. they just have one or two screw in caps, and this will make fitting the tap harder than if no top were present as reaching the inside walls is impossible. Cutting the top off might be necessary.

New oil drums can be purchased for £30-£40, which come with a removable lid, ideal for fitting the tap and then sealing the tank again for use
uline.com - S-10758 – Open topped steel drum - ~210L shown below:

6.3 Reaction Tank

Material: PP or HDPE

Quantity: 1
Capacity: 100-225L
Cost: £20-£40

The reaction tank contains the entire batch and therefore the size determines the maximum batch size that can be run. Sizes from 100-225L are available, but the tank shouldn't be filled right to the top for safety reasons, and practicality of stirring the mixture; filling to no more than 50-75% capacity is advised.
This tank will also need the addition of a stirring device.

In the UK a 225L HDPE tank can be found for £30 [smithsofthedean.co.uk].

A tank with conical bottom is sometimes used for reactors; however these are much more expensive than simple barrels.

6.4 Stirrer

Material: HDPE or PP

Quantity: 2
Cost: £20-£30

Both the meth-oxide and reaction tanks require stirring, and both contain corrosive chemicals meaning plain steel stirrers are not feasible. Materials such as HDPE and PP are ideal for this as they are simple to cut and also non-reactive. The easiest way to get a shaped stirrer is to cut up a tank from the same source as the reaction tank/meth-oxide tank. The stirrer rod needs to be held vertically in the centre of the tank to minimize radial movement.

The paddles should be large enough to affect the full height of fluid, but not so large as to just turn all the fluid round without mixing. Holes cut in the paddles can help the mixing process and two or more paddles should be cut from the drums.
Polymer rod can be sourced to act as the stirrer shaft, to which the paddles should be attached with stainless steel or brass bolts and nuts.

6.5 Settling Tank

Material: PP or HDPE

Quantity: 1
Capacity: 100-225L
Cost: £20-£40

The settling tank can be identical to the reaction tank, although ideally it should be transparent or translucent, however these are hard to find and potentially more expensive. If a translucent tank can't be found a simple alternative is to buy some clear plastic sheet and make a viewing window down the side of the tank to see the level at which settling has occurred (these must be sealed tightly to prevent leaks).

Taps should be fitted at various heights down the tank to remove the settled biodiesel without mixing with the by-products at the bottom. The tap fittings will be discussed in the "Fittings" section below.

6.6 Waste Tank

Material: High Density Polyethylene (HDPE)

Quantity: 2
Capacity: 60L
Cost: £30-£40

This tank is simply to collect the by-products tapped off the settling tank and also waste water if washing is performed. See section 6.1 – Meth-Oxide tank for details.

6.7 Biodiesel Storage Tank

Material: Mild Steel

Quantity: As many as required
Capacity: 100L-250L
Cost: Can be salvaged oil drums / ~£40 New

These are simply to store the biodiesel until use and therefore should be chosen for practicality for the given situation. A 250L drum would probably be far too heavy to be practically transferred when full, but for storage at a fixed location they are ideal. Closed top barrels need to be used for this purpose, to reduce the risk of spillage or fire.

6.8 Fittings

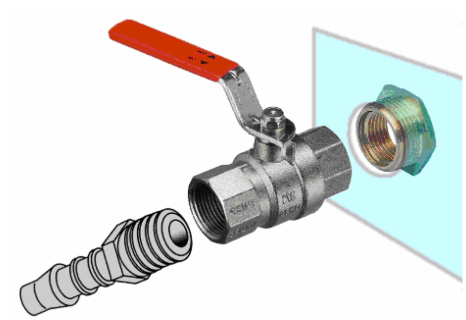
Material: Non-Corrosive: Stainless Steel, Non-Reactive Polymers, Brass etc.

Quantity: 5-10 Taps, 10-15m Pipe, depending on setup
Cost: £4-£8 per Tap, approx £1 per meter of Pipe

To transfer the fluids from one vessel to the next the various drums should be placed at different heights to allow gravity to force the flow, therefore removing the need for pumping. Putting the taps directly onto the drum simplifies the design and reduces any fluid loss. To drain the tank completely a tap should be placed on the bottom face. The drain tap should not be located on the bottom of the tank, as the handle needs clearance from the barrel to turn. The "drain pipe" which goes from the tank to the tap can then be set into the soil to give a solid foundation and still the option of fully draining the tank.
When drilling holes for taps it is best to avoid corners, curves or ridges in the tank, which may make sealing the tap more difficult. Also take care to avoid "seam lines" and "weld lines", which appear as slight ridges or lines in the surface of plastic tanks, and sprue marks which appear as circular divots. These are points of weakness and may split if drilled through.

The side taps are made from 3 main components:

- Tap
- Threaded Bush
- Threaded Push-on Pipe connector



The taps should be made of stainless steel or brass, not plain steel. The taps are all exposed to corrosive fluids which would ruin plain steel with time, however brass and stainless-steel are non-reactive and can be used. The easiest taps to source are simple ball valve taps, with standard screw thread fittings at each end. Simple polymer taps may also be used, but sourcing and fitting them may be harder.

The best way to seal the tap is to have a threaded flange going through the hole, and screwed tight into a thread on the opposite side. Care should be taken to avoid over tightening any fittings, as this may cause the drum to split or warp.

The fluid is transported from one container to another through piping; this has to be non-reactive with any of the chemicals. Ideally it should also be clear so that any blockages can be identified and also the colour of the liquids flowing through the various components is visible for inspection purposes. PVC piping is ideally suited to this task and should be relatively easy to source in a variety of diameters. The internal diameter of the pipe should be a standard size, and this should fit the push-on connectors used on the taps and drum input/output connectors.

To attach the piping to the input of the appropriate containers threaded push-on connectors can be fastened to the top of the drum with a nut. To prevent corrosion the nut can not be plain steel, instead stainless steel or brass should be used.

Due to the low pressures involved push fit connectors are acceptable for the connections, cable ties can be used to provide additional security if required. The output pipe of the settling tank needs to be easily detachable so that it can be moved between taps at different levels; this is aided by the use of push-on connectors.

6.9 Extras

Cable ties are very useful to securely fasten pipes onto push-on connectors and prevent them unintentionally detaching.

A simple thermometer might also be useful to monitor the reaction temperature, especially if heating is used.
PTFE Tape can be used to seal threaded connections to prevent leaks. Silicone sealant doesn't react with any of the fluids used and can therefore be used to seal the fittings to prevent leaks or to seal cracks.

6.10 Optional Expansion Modules

6.10.1 Filtration System

Material: HDPE container and fine cloth

Quantity: 1
Cost: £2- £3

To give higher quality diesel the output should be filtered to remove any solid impurities which are suspended in the fluid. The filter cloth should be chosen to allow biodiesel through at a steady rate, but to still remove most of the impurities.

The simplest type of filter to make is a sock type filter, manufactured by bunching up the filter material around an input pipe, then holding it in place (easiest with a cable tie). This whole assembly is then put inside the storage drum for the finished biodiesel.

6.10.2 Wash Module

This comprises of an additional two tanks, the wash tank and water tank shown below:

6.10.2.1 Water Tank

Material: HDPE or PP

Quantity: 1
Capacity: 60L
Cost: £20-£30

This tank simply holds water for the washing process, and provides pressure for the misting nozzle. As it contains water it should not be plain steel which would corrode. Suitable materials are polymers such as HDPE or PP.

A tap should be fitted to the bottom of the tank with a pipe connecting it to the spray nozzle on the top of the wash tank.

6.10.2.2 Wash Tank

Material: HDPE

Quantity: 1
Capacity: 100-250L depending on reactor size
Cost: £20-£40

This can be identical to the settling tank, and a removable lid would be recommended. The water should be dripped through the biodiesel in small droplets to remove impurities from the mixture. Smaller drops give more effective cleaning, and therefore a spray nozzle should be sourced.

6.10.2.3 Spray Nozzle

Material: Non-Corrodible

Quantity: 1

Cost: £1-£5 depending on type

The nozzle produces a fine mist of water to give more effective removal of impurities with less risk of mixing up the biodiesel and producing soap. The nozzle should be fastened to the lid of the wash tank and attached to the pipe from the wash tank.

Therefore when the water tank tap is turned on a fine mist of water droplets should be produced from the nozzle. This requires pressure and therefore if there is no mist produced, then the wash tank should be raised in the air on a tower until an adequate mist is produced. 3 meters is enough pressure to produce a fine mist.

6.10.3 Methanol Recovery System (addition suggestion not specifically designed)

As excess methanol is required to complete the reaction some of it is inevitably left in the glycerol layer. This means that the methanol is wasted if not otherwise recovered.

The recovery system heats the waste tank to evaporate off the methanol, and then condenses it back to methanol for collection and reuse.

This is made awkward due to methanol being **EXTREMELY FLAMMABLE** and therefore the use of an open flame is **EXTRELEMLY DANGEROUS**.

6.10.4 Waste Tank Heating System

Quantity: 1

Due to the volatile nature of methanol and its vapour in particular, it is extremely inadvisable to use an open flame in the recovery of methanol; therefore it is essential that the tank is *heated indirectly*. Hot gases or liquids can be used to heat the container.

As the waste tank is made from PP or HDPE the temperature has to be closely monitored as the materials should only be used under 100 C. As the temperature required is ~65 C this is acceptable.

6.10.5 Connections

Material: All connectors should be non-corrodible

The waste tank should be well sealed, with a pipe attached to the top of the tank to allow methanol vapours to separate out of the container. This pipe should be flexible and non-reactive, preferably the same as for all the other connections. This pipe must then connect to a copper or brass pipe which is being cooled to allow the methanol to condense back into a liquid for collection. The collection tank should be kept cool and fairly well sealed.

As methanol is a very toxic substance the recovery system should be kept well maintained and monitored for leaks.

7. TESTING OF THE DESIGN

A prototype plant implementing the seven stages of production was built and tested.

Figure 7.1: Prototype plant

The batch size of the plant is 5 litres; the input oil used was pure vegetable oil. For a 4ltr input of vegetable oil ~4.5ltrs of biodiesel and ~0.5ltrs of glycerol were produced. 2ltrs of water are required for the wash process and 2ltrs of waste wash water are recovered.

All the catalyst should be dissolved in the methanol before adding to the reaction tank. The meth-oxide is a clear liquid, if there is solid catalyst visible (as below) then the mixture will not produce an optimum reaction.

Figure 7.2: Meth-oxide solution with unreacted catalyst.

The glycerol is liquid when it has settled out from the biodiesel. The glycerol is darker and settles to the bottom of the tank.

Figure 7.3: Glycerol settled at the bottom.

The wash water is white and cloudy when it is removed from the bottom of the wash tank. This will become yellow and clear as the biodiesel layer is reached, the transition from waste water to biodiesel should be tapped into the waste until it is certain that there is no soap left. The biodiesel can then be tapped off into the storage tank.

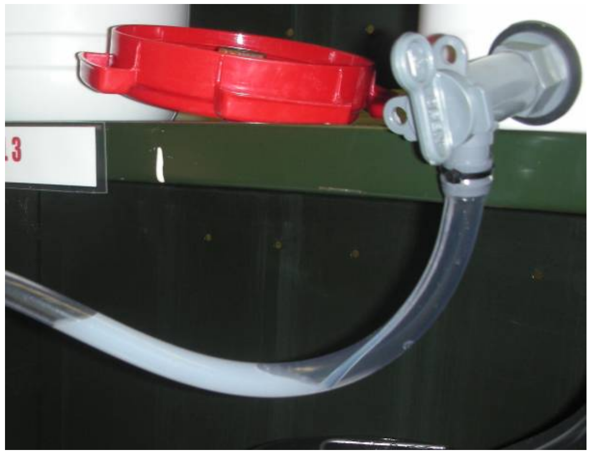


Figure 7.4: Tapped off washed water.

The colour of the biodiesel will vary slightly with different oil inputs.

From the continued testing of the process it was decided that only 3.5g of catalyst should be used per litre of vegetable oil inputted. This provided enough catalyst to accommodate the reaction however allowed for the catalyst to fully dissolve in the methanol. This also saves money as less catalyst is used per batch.

8. HAZARDS AND SAFETY

It is essential that all the hazards and risks are understood and dealt with before the plant is constructed.

Possible areas of risk are:

1. Dangerous chemicals
2. Slippery oils
3. Heavy containers

With the possible addition of:

4. The application of heat

The COSHH sheets for methanol and NaOH are included at the end of this booklet so that full safety procedures for the dangerous chemicals can be undertaken.

The vegetable oil storage container and input container should be clearly marked with a slip hazard pictorial.

The heavy containers should display an exclamation warning sign. Training of operators must include the correct technique for heavy lifting i.e. bend at the legs not at the back, if it is too heavy for one then there must be two people to lift it.

If there is a need for heat i.e. in the WVO pre-treatment then this should be done in an area remote from the plant and store of chemicals. However this now means that hot oil will have to be transported through to the plant; this must be done with due care and attention using a container that is clearly marked as 'hot vegetable oil'.

Safe working practices should be taught in training, these should include keeping all rubbish in a metal lidded bin, disposing of all chemical spills quickly, and keeping a clean work space with secure work stations and plenty of room.

8.1 Ventilation of toxic gases

As has been stated the vapour of methanol and sodium hydroxide are potentially harmful to health, therefore the area where the plant and storage facilities are located needs to be fully ventilated. In addition to ventilation for normal operating conditions there needs to be extra ventilation allowances for the eventuality of toxic gas leaks, this should include extra windows/hatches around areas where these leaks are most likely to occur, which can be opened to vent any gases to the outside of the plant.

8.2 Leakages

The outlines for clearing up leaks and spills of all dangerous chemicals used are provided in the COSHH sheets at the end of this manual; however the main point is that all leakages have to be cleared immediately and the waste disposed of in accordance with local guidelines and safety regulations.

All chemicals need to be stored and used in areas separated from water sources and supply routes as both sodium hydroxide and methanol contaminate water easily.

8.3 Location of the plant

It would be ideal to have the plant located away from habitats of people or animals, however the level of potential damage in conjunction with the amount of chemicals required in the plant at any one time and the safety procedures enforced makes the likelihood of a life threatening leak of liquid or gas very improbable.

8.4 Warning System

In the unlikely event of a toxic chemical leak it is imperative to have a warning system to alert all personnel and any public near to the plant to evacuate the area and meet at the designated meeting point, signified by a white tick on a green background. The whole population of the surrounding area would need to be informed of the procedure for this occurrence.

8.5 Hazard Signs

The procedure contains hazardous processes and also uses hazardous chemicals. It is important to display warning signs (in all necessary languages) when entering the plant and also on any containers which hold hazardous material.

This sign represents an explosive chemical.
It applies to methanol vapour in this case.

This sign represents a highly flammable chemical that may only need brief contact with an ignition source and may have a very low flash point or evolve quickly.
This applies to the methanol.

This sign represents a toxic chemical that at low levels cause damage to health.
It applies to the sodium hydroxide and methanol.

This sign represents a corrosive chemical that may destroy living tissue on contact.
This applies to the sodium hydroxide.

This sign represents a chemical which may be hazardous and harmful. The chemical may cause damage to health.

This applies to the sodium hydroxide and the methanol.

This sign represents a chemical that may present an immediate or delayed danger to one or more components of the environment.

It refers to any substance containing sodium hydroxide or methanol.

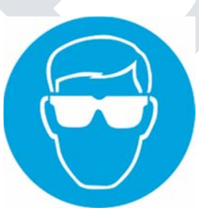
In addition to these signs the following signs are also used within the plant safety:

This sign represents a substance which poses a slip hazard. Due care and attention must be paid if the substance is spilt and clear up operations should take place immediately.

In this case this sign applies to the vegetable oil, water, methanol, biodiesel and all by-products within the system.

This sign represents a hazard and should be used to inform people that the operations inside the plant are hazardous and, more specifically that there are heavy containers being used.

Mandatory signs are also needed to inform personnel of areas which require special safety equipment:



This sign indicates that protective eye wear is to be worn at all times. This should be displayed at all entrances to the plant

This sign indicates that protective gloves are to be worn at all times. This should appear at all entrances to the plant.

This sign indicates that face masks should be worn and needs to be displayed in the area where the sodium hydroxide is to be handled.

Due to the nature of the chemicals used and the product being made it is essential that prohibition signs are displayed:

This sign should be placed on all entrances to the plant and on any doors where only authorised personnel may enter.

Due to the volatility of the chemicals used in this process there is to be no smoking anywhere near the plant. This sign should be displayed outside as well as inside of the building.

The three main safety signs which need to be displayed are provided at the end of the manual; however additional safety signs and symbols will have to be displayed as to local guidelines.

In addition to safety and hazard signs, signs indicating access and location are necessary:

This sign indicates the location of an eye wash station, a necessary safety precaution for the production methods described in this manual.

This sign indicates the location of the fire assembly point and should be placed at a suitable location away from the plant. Instructions on what to do in case of fire and also direction to the assembly point should be displayed at several points within the plant.

This sign indicates the location of an assembly point and should be used to denote the assembly point in case of a chemical leak from the plant. This location should be known by all residence as well as personnel of the plant.

8.6 Safety Procedures

Any accident which occurs either on the plant or due to the plant should be reported and a written record should be kept.

The water tank should only hold the correct amount for the batches to be done that day or should be changed regularly to avoid contamination.

Methanol can be absorbed into the body by inhalation, through the skin and by ingestion, therefore it is crucial to use methanol in a well ventilated area while wearing protective clothing (i.e. lab coat), gloves and goggles. After dealing with the substance the operator should always wash their hands.

Sodium Hydroxide can be absorbed into the body by inhalation and by ingestion. When using NaOH a face mask, gloves, protective clothing and goggles should be worn. Hands should always be washed after use.

If there is a spillage/leak then the area should be evacuated and ventilated fully. The spillage should be absorbed using sand which is then swept away and disposed of into a container which is clearly marked as hazardous (the contents of which need to be disposed of to governmental guidelines). The area of the spill should be washed with plenty of water and a fine water spray should be used to remove any vapour from the air.

For any major spillages/leaks self contained breathing apparatus and full protective clothing are required. There should also be an incident investigation within 48 hours so as to assess any safety issues that may have resulted.

The plant possesses a fire hazard, as do the chemicals used in the process. Any fire involving methanol should be treated with powder, alcohol resistant foam, carbon dioxide or water in large amounts. In case of fire keep methanol containers cool by spraying with water to prevent further fires or explosion.

9. STORAGE AND TRANSPORT

The storage of both the inputs and the products of the process are vitally important.

9.1 Chemicals

As has just been stated both the alcohol and the catalyst are hazardous chemicals. It is ideal to store them in their plastic, sealed containers in a flame proof cabinet. They should be stored away from any power or heat sources and a safe distance from the actual plant. Both should be stored away from food and feedstuffs.

Methanol should be stored separately from strong oxidants and sodium hydroxide should be separated from strong acids. Sodium hydroxide absorbs water from the air, when this occurs the catalyst performs poorly and decreases the efficiency and yield of the transesterification reaction. Minimise any time that the catalyst container is open for.

9.2 Biodiesel

It is known that biodiesel will absorb water from the air and so it needs to be kept in a sealed container. Algae may also grow in the biodiesel as this is undesirable it should be assured that the storage container is clean, dry and dark. Avoid copper, zinc or tin for long-term storage, instead use mild steel, aluminium, or polyethylene. It is also advisable to store the biodiesel away from the plant so as to decrease the likelihood of spillages and contamination.

9.3 By-Products

Not only do the by-products need to be disposed of correctly they also need to be stored properly, see COSHH sheets for guidance on storage of methanol and sodium hydroxide.

10. STARTING-UP

<u>Prior to start up it is vital that all safety instructions are read and understood by all personnel who will be working within the plant either directly or indirectly in contact with the chemicals.</u>

Vegetable oil, catalyst (NaOH) and alcohol (methanol) along with the basic package as described above (consisting of preparation tanks, reactor and stirrer, settling tank, by-product tank and storage tank) is all that is needed to begin biodiesel production.

- 3.5g of catalyst per litre of vegetable oil should be used per batch.
- There should be 25% by volume vegetable oil of methanol per batch.
- 50% by volume vegetable oil of water should be used in the wash phase per batch.

There is also the need for the following tools:

- Hand saw
- Power drill
- Pen knife

10.1 Step-By-Step Construction

1. Chose the location.

The plant needs to be set up within a secure perimeter and so the location is a very important aspect of the build. The location should be easily ventilated and ideally should be isolated from human and animal habitats.

2. Check amounts of materials.

Firstly the amounts of all materials and containers should be checked, this ensures that the required materials are available during the build.

3. Set up a secure base.

It is imperative that the plant is set up on a secure base. The base can be formed from the earth or from recycled materials, in the prototype a recycled shelving unit was used, this is not feasible for a larger scale plant but shows the aim of the base. As gravity is being utilised for the plant 4/5 levels need to be created, this can be done through digging down into the ground to provide the lowest levels whilst pilling the earth to form the higher levels.

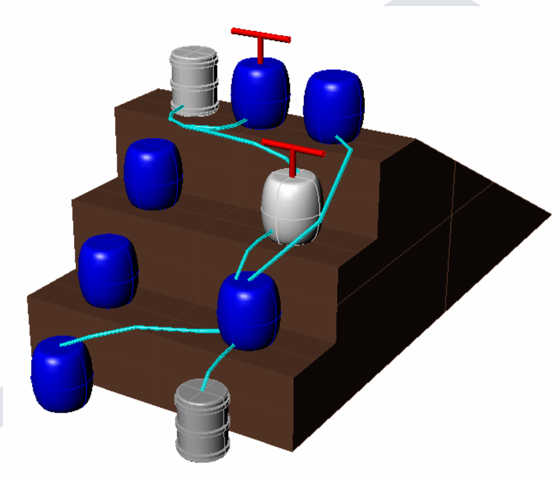


Figure 10.1: Showing how utilizing the ground can produce a stable base..

If the wash module is being employed then the level of the water tank is of main importance, it needs to be 2 to 3 meters above the wash tank. The difference in heights between the other levels does not need to be exact; however it should be taken into consideration the lengths of piping and ease of replacement and maintenance whilst constructing the base.

4. Place containers in appropriate positions and check space, location and accessibility

To confirm the layout all containers and piping should be placed where they are to be in the final plant, this allows the plant design to be checked for space, location and accessibility.

5. Fit taps to containers.

The taps need to be fitted to the bottom of the containers; this is done by drilling the appropriately sized hole near to the base of the container (avoiding weld lines and sprues).

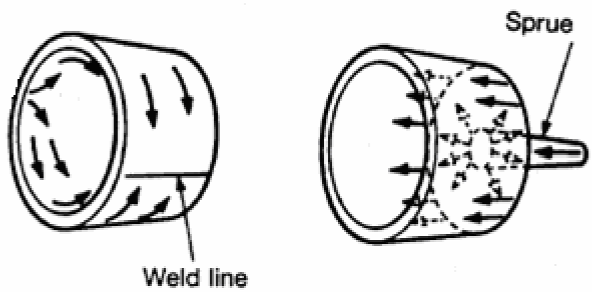


Figure 10.2: Weak locations on plastic barrels.

The tap should then be mounted in the container as explained in the fittings section 6.8. of this manual.

In addition the input openings also need to be added to the appropriate tanks. This is done by drilling an opening corresponding to the size of the connector into the correct position on the tank. The connector is then passed through the hole and is secured with a bolt on the underside.

Figure 10.3: Input connection and output tap connection.

6. Measure amount of pipe to connect the appropriate containers and cut to size.

With the containers set in their positions the pipe between the appropriate containers needs to be measured allowing for connections. The pipe then needs to be cut; this can be done using a hand saw.

7. Attach pipe to taps and secure.

The pipes need to be attached to the tanks via the connectors. At this stage it is vital to make sure that there are no kinks in the pipes. Secure the attachments with cable ties if required.

8. Make Stirrers.

Figure 10.4: Kit stirring devices

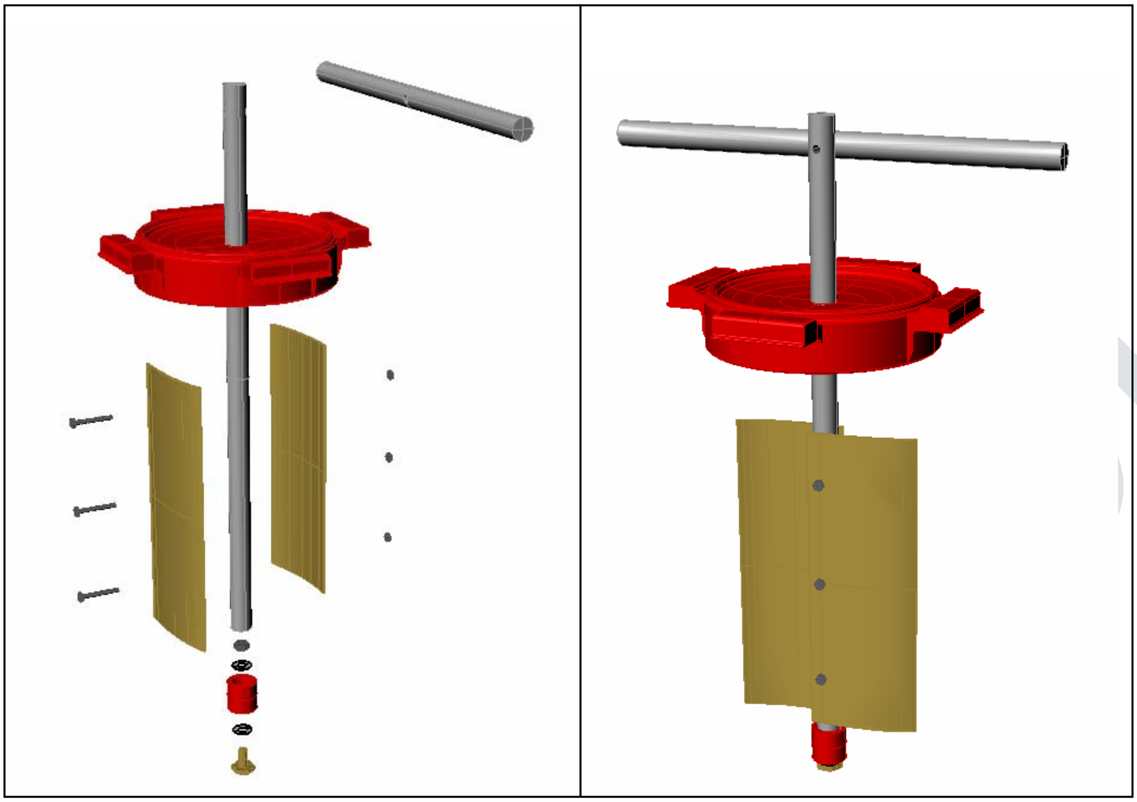


Figure 10.5: CAD showing an exploded and fully assembled stirring device.

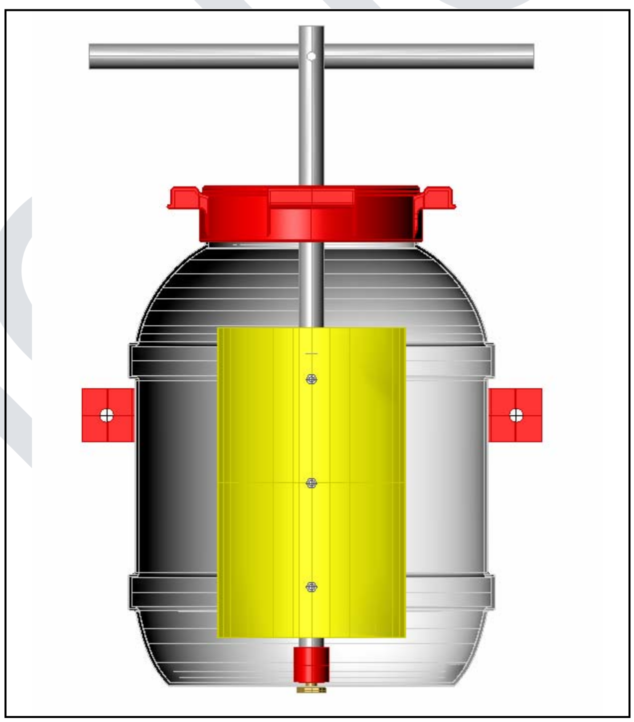


Figure 10.6: CAD showing stirring device in final position..

To make the stirrers follow the steps below:

1) Cut rods to length

The main rod should reach from the bottom of the tank to the about 30cm above the lid of the tank. The handle rod should be approximately 30cm in length.

2) Cut HDPE to make paddles

Using a HDPE container cut two rectangles out of the curved sides. The rectangles need to be able to fit inside the opening at the top of the container whilst attached to the main rod.

3) Attach with bolts

Holes need to be drilled into the paddles and main shaft corresponding to the size of the bolts to be used. The bolts need to be passed through the first paddle, the main shaft and then the second paddle and securely tighten. This can be seen in the picture above.

4) Attach a tube for stability

A small amount (~5cm length) of tube with an internal diameter slightly larger than the outer diameter of the main stirrer rod needs to be attached to the centre of the base of the tank. This can be secured with a nut and bolt through the underside of the barrel; silicon sealant can also be used as it does not react with any of the chemicals.

5) Drill hole in lid

An opening the diameter of the main shaft needs to be drilled into the lid of the container and the main rod (with paddles attached) needs to be placed through the opening of the container and inserted into the tube at the base.

6) Attach stirrer to lid

The lid is placed over the main rod which fits through the drilled hole. The handle rod can now be attached to the top of the main rod using cable ties; this is shown in the picture below.

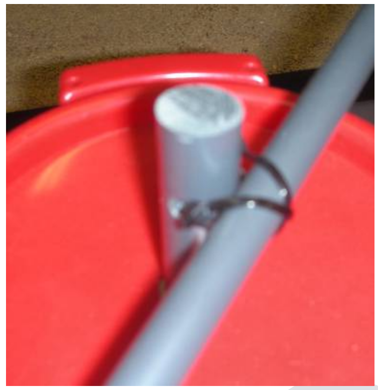


Figure 10.7: Stirring handle cable tied together.

The stirrer is easy to disassemble for maintenance or storage.

9. Drill small hole in input lids.

Due to the pressure drop as the input fluid is removed from the container a vacuum is formed preventing further liquid flowing out of the container. To overcome this problem a small hole, approximately 5mm diameter, is drilled into the lid/top of the input containers (vegetable oil and water). This is not acceptable for the meth-oxide tank due to the nature of the chemicals, as this mixture is only to be made for one batch per time this can be quickly emptied into the reaction tank and the meth-oxide tank can be sealed again.

10. Fit nozzle for wash (misting)

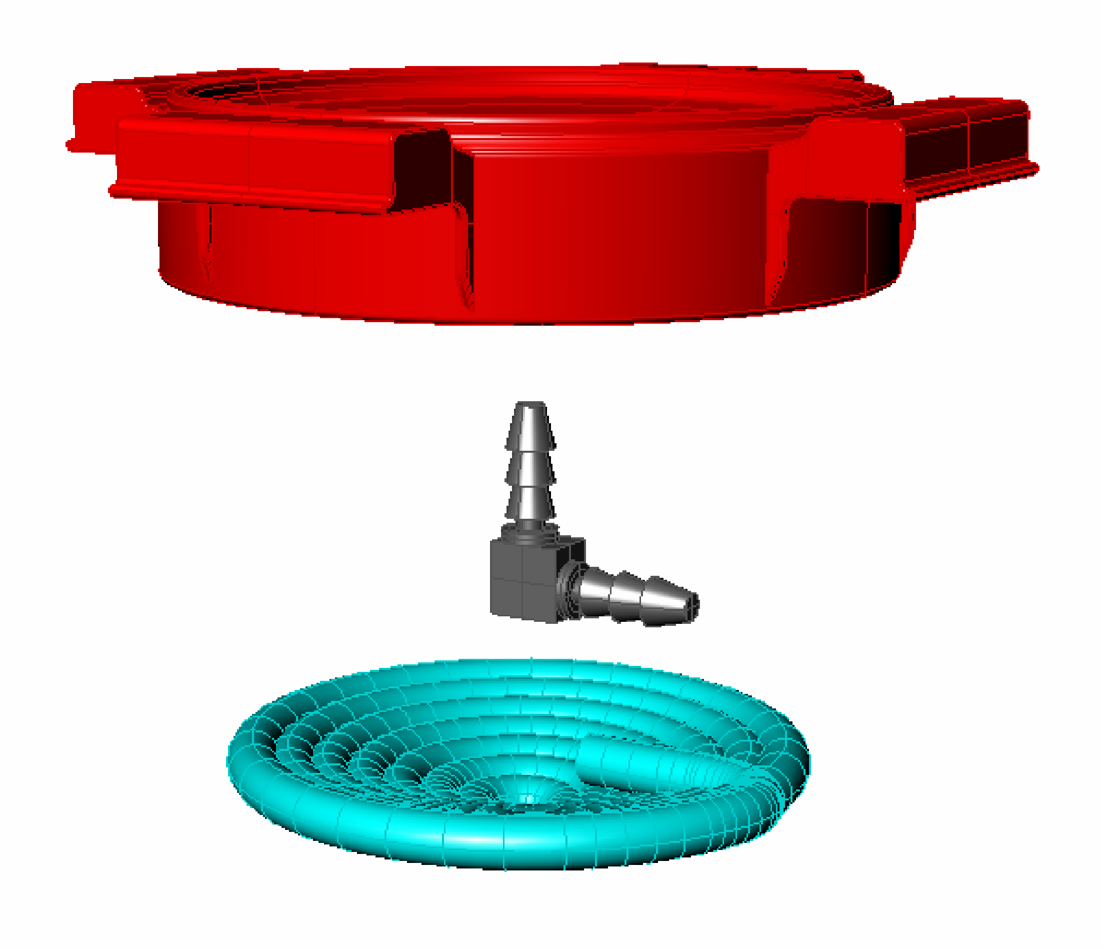


Figure 10.8: CAD showing washing device components..

The pipe needs to be connected to the lid of the wash tank from the water tank.

The thin pipe from the nozzle needs to be fed back through the pipe and the nozzle needs to be sealed to the connection on the underside of the lid.

11. Assembly of filter

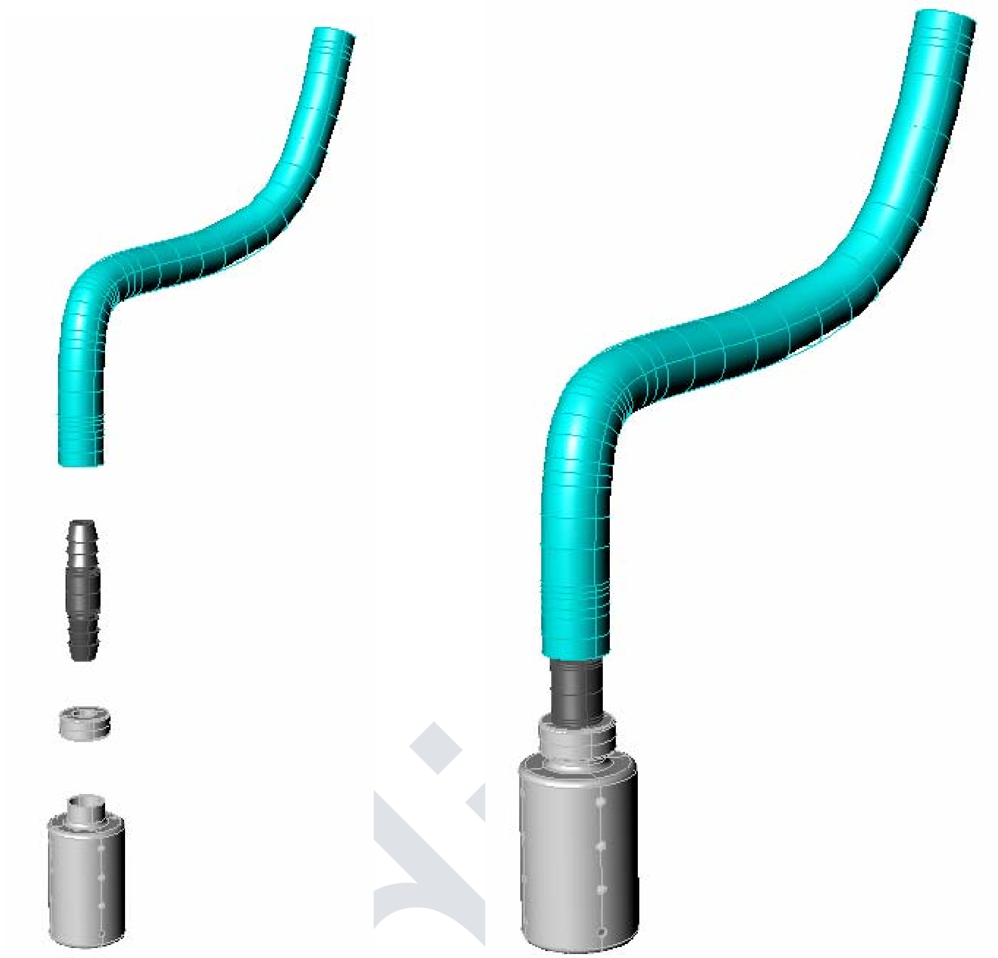


Figure 10.9: CAD showing washing device components.

Small holes (1mm) need to be created around the sides and bottom of the plastic container.

A hole corresponding to the diameter of the connector needs to be drilled in the lid of the plastic container, the lid is sealed to the push fit connector using silicon sealant.

A cloth is attached to the connector using a cable tie and is then carefully placed inside the plastic container. The plastic container is finally screwed onto the lid.

The whole system is then placed into an opening on the top of the biodiesel storage tank (most containers are supplied with a screw cap, however if not then an opening needs to be drilled).

Figure 10.10: Prototype Filter system.

12. Assemble entire plant.

The entire plant is now ready. Before production can begin, a final check to make sure that all components are present and that all relevant connections have been made is needed.

13. Check for leaks.

Running a small amount of water through the entire system is a simple way to make sure that the system is fully sealed before the chemicals are added. Do not include the vegetable oil tank in this check if it is steel as this will be corroded. The system needs to be dried thoroughly after this test to prevent any water infiltrating the biodiesel.

Any problem areas found during this test need to be dealt with before production begins, not only due to the nature of the chemicals used but also as any leaks will effect the safety, efficiency and reliability of the process and plant.

11. RUNNING THE PLANT

THE PLANT SHOULD NEVER BE LEFT UNATTENDED WHILST BIODIESEL IS BEING PRODUCED AND AT LEAST TWO PEOPLE SHOULD BE ON SITE AT ALL TIMES.

Safety signs must be displayed on both the plant and any entrances leading to the plant location. Full safety gear must be provided for all personnel and should be worn at all times by all operators. If any operators begin to feel ill medical advice should be sought immediately.

The total time for one batch to be produced from mixing the methanol and sodium hydroxide and inputting the oil to storing the final filtered biodiesel is ~19 hours.

N.B. Additional reaction tanks can be bought to allow for several reactions and settling procedures to take place at once, effectively increasing the output of the plant. It is also advisable to start another reaction and leave it to settle while the biodiesel from the previous reaction is being washed. Again additional wash modules can be bought to increase the output.

Due to the duration of biodiesel production it is advisable to have shift working patterns. Each shift must communicate clearly with each other and all times/procedures must be written down during the shift to be passed on to the following shift operators.

11.1 Security

As has already been mentioned the plant should not be left unattended and at least two personnel should be present at any one time. In addition to this there should be clear warning signs to inform of areas where only authorised personnel are allowed access, all storage and plant facilities should be secure.

Levels of chemicals should be recorded after every use so as to monitor for any leakage or missing chemicals.

11.2 Legal Requirements

There are various standards and legal requirements throughout the world which define and control the production of biodiesel as a fuel.

In addition there are strict regulations on the use of chemicals and also on the disposal of the by-products.

Listed below are areas of legal policy which should be referred to before producing biodiesel, these are constantly being updated from country to country and so it is imperative that personnel are made aware of their importance and how to keep up to date with their activities.

11.2.1 Customs and Excise

In order to maintain harmonious working conditions it is essential that any tax due is paid to the appropriate governing body. The penalties for not doing so can be severe.

From the 1st October 2007 biodiesel in the UK will be taxed at 30.35p per litre in line with Gordon Browns 2007-2008 budget. The current rates are available from http://customs.hmrc.gov.uk/.

P. Chidambaram (the Indian Minister of Finance) proposed in the 2007-2008 budget to fully exempt biodiesel from excise duty as it would reduce their dependency on fossil fuels. Further development of taxation in India can be found at http://india.gov.in/outerwin.htm?id=http://www.cbec.gov.in.

11.2.2 Environmental Agency

The environmental agency for the appropriate country should be contacted for advice and guidance. In general, if biodiesel is made for one's own consumption then it is not necessary to purchase a license or annual permit, if a large quantity of biodiesel or profit is to be made then these may be necessary. This may vary from country to country and so it is advisable to check with the appropriate governing body.

Due to the chemicals being used in the process it is worthwhile to inform the agency to make sure that all regulations are imposed correctly.

11.2.3 Planning Permission

It is important that you check with the local governing body that permission is granted for the construction of any new buildings or plants.

In the UK B1 planning permission (for industrial space) is required for a small commercial operation.

11.2.4 Health and Safety Executive

The countries health and safety policies should be referred to. In the UK the HSE governs all working practices and maintain safe working conditions for all employees.

Although India is known to have a very poor health and safety record without much implementation of health and safety legislation, this does not mean that it can not be improved. Of particular interest are:

- The Factories Act 1948, amended 1954, 1970, 1976, 1987
- The Explosives Act 1884
- The Manufacture, Storage and Import of Hazardous Chemicals Rule 1989

11.2.5 Insurance

In the UK a small commercial operation needs a combined contents, fire and theft insurance for premises, personal liability, and product liability. An employer’s liability is also needed if anyone else is employed. This is important and needs to be considered throughout the world, local governments should be referred to.

11.2.6 Weights and Measures

Local trading Standards departments will need to be dealt with if any biodiesel is to be sold in a forecourt-style operation. There are main standards for biodiesel in the EU and also the USA, however many developing countries are yet to provide standards themselves. The local governing bodies should be referred to, however it is advisable to produce biodiesel to the EU standard (EN 14214) as this is likely be more widely implemented in future years.

12. THE FIRST RUN

Mix one measure of methanol (30 litres) and one measure of sodium hydroxide (420g). This makes one measure of meth-oxide.

One measure of vegetable oil (120ltrs) and one measure of meth-oxide should be added to the reaction tank and the mixture needs to be stirred vigorously for 30 minutes. It then needs to be left to settle for 12 hours (48 hours if there is no wash system). During the settling period the glycerol will settle to the bottom of the container as it has a higher density it will form a darker layer and the lighter biodiesel will settle on top.

The glycerol is tapped off the bottom of the tank into the waste glycerol container.
The biodiesel is tapped off into the storage container, if the wash system is being used the biodiesel is tapped off into the wash tank. One measure of water (60 litres) needs to be passed through the wash (misting) device, the biodiesel needs to be left for 5 hours to settle. The water will pass through the biodiesel and will settle in a layer at the bottom, as this is tapped out into the waste water tank it will look white and cloudy. This process can be repeated if desired.

The biodiesel can now be tapped off into the biodiesel storage tank; if the filtration system is being used then the biodiesel will pass through the filter as it enters the storage container. When all the biodiesel from the batch has been filtered the storage tank needs to be sealed and moved to the storage facility.

12.1 Quality Control Tests

It is advisable to run some quality control tests on the first batch of biodiesel whenever different oil is used as an input, as the amount of methanol and NaOH may have to be altered to produce the same level and quality of biodiesel. Three tests are outlined below and should give a good overall evaluation of the biodiesel produced.

12.1.1 Mixing Test

Add water to a sample of biodiesel in a clear container. Slowly mix the top by gently shaking the container. Allow to separate and visually inspect. The boundary between the biodiesel and water should be clearly defined; if there are many bubbles the sample biodiesel contains soap and possibly other impurities. If the settling time is very fast repeat the process with increased shaking for more accurate analysis. Take note of the amount of shaking required to successfully mix the two layers.

If mixing can not be achieved or not fully achieved then the biodiesel sample is of a good quality.

12.1.2 Density Test

The density, ρ of a substance is calculated using the mass, m and volume, v.

$$\rho = m/ v$$

To measure the density of the fluid measure the weight of a container and then add a known volume of the fluid to the container and measure the weight again. Subtract the two weights. The weight of the fluid is related to its mass through the following equation:

$$m = W/g$$

Where, m is mass, W is weight and g is gravity (9.81).
The density can now be calculated using the formula above.
The density of vegetable oil: ~0.94 kg/m^3
The density of biodiesel: ~0.87 kg/m^3

12.1.3 Viscosity Test

The determination of the viscosity of a fluid is commonly done through use of finding the torque required to rotate a cylinder in the fluid. However there is a much simpler test that can be used, this uses the basic theory of the drag of falling spheres to obtain the viscosity of a fluid (in this case biodiesel).

Theory shows that a sphere falling in a liquid, at a very slow speed reaches a terminal or constant velocity where the acceleration is zero and all the forces acting on the sphere are in equilibrium. This gives:

$$\mu = gD^2 (\rho_s - \rho_f) / 18u_{inf}$$

Where, μ is viscosity,
g is gravity ($9.81 m/s^2$),
D is the diameter of the sphere,
ρ_s is density of the solid,
ρ_f is the density of the fluid,
u_{inf} is the terminal velocity of the sphere.

Drop a sphere of known dimensions and weight into a clear container of known height of the fluid. Begin measuring the time after the sphere has travelled down 5cm in the fluid, measure the time up until the sphere moves past a position of known distance from the top of the fluid.

The distance travelled by the sphere divided by the time taken gives the terminal velocity of the sphere. Using this and the density calculated in the previous test, calculate the viscosity using the equation above.

The viscosity of vegetable oil (40 C): ~23 cST (centistokes)
The viscosity of biodiesel (B100 at 40 C): ~3.6 cST (centistokes)

1 cST = $1 mm^2/s$

13. POSSIBLE INITIAL PROBLEMS

<u>No reaction occurring…</u>

This is probably due to a lack of reaction of catalyst and alcohol pre-reaction. Check that when the meth-oxide is mixed the catalyst is fully dissolved.

If the problem continues then the temperature of the reaction might not be sufficient. Measure the temperature of the oil input and also of the reaction mixture. Check this temperature against those required (section 4.2). If the temperature is lower than required try heating the oil before it is added to the reaction tank.

<u>Catalyst not dissolving in methanol…</u>

Increase the ferocity of the mixing, if this still fails to fully dissolve the catalyst try shaking the mixture in batches before adding to the reaction (ensure the container is securely sealed before shaking and that full protective clothing is worn).

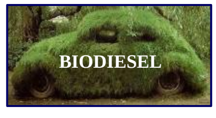
<u>Glycerol is solid…</u>

Tap the biodiesel off the top of the glycerol layer and the glycerol can be scrapped out using a scrapping implement and placed in the waste tank. Full protective clothing needs to be worn if this is to be done.

<u>No clear distinction of waste wash water to biodiesel / always some soap in final biodiesel…</u>

Repeat the wash cycle until a clear distinction is shown.

14. ADDITIONAL SOURCES OF INFORMATION



http://www.hse.gov.uk/	UK Government Health & Safety Executive
http://customs.hmrc.gov.uk/	UK Government Customs and Excise
http://www.eere.energy.gov/afdc/	US Department of Energy
http://www.biodiesel.org/	National Biodiesel Board
http://india.gov.in/	The National Portal of India
http://www.environment-agency.gov.uk/	UK Environmental Agency

15. COSHH SHEETS AND SAFETY SIGNS

METHANOL — **0057** — April 2000

CAS No: 67-56-1 RTECS No: PC1400000 UN No: 1230 EC No: 603-001-00-X	Methyl alcohol Carbinol Wood alcohol CH_4O / CH_3OH Molecular mass: 32.0

TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/SYMPTOMS	PREVENTION	FIRST AID/FIRE FIGHTING
FIRE	Highly flammable. See Notes.	NO open flames, NO sparks, and NO smoking. NO contact with oxidants.	Powder, alcohol-resistant foam, water in large amounts, carbon dioxide.
EXPLOSION	Vapour/air mixtures are explosive.	Closed system, ventilation, explosion-proof electrical equipment and lighting. Do NOT use compressed air for filling, discharging, or handling. Use non-sparking handtools.	In case of fire: keep drums, etc., cool by spraying with water.
EXPOSURE		**AVOID EXPOSURE OF ADOLESCENTS AND CHILDREN!**	
Inhalation	Cough. Dizziness. Headache. Nausea. Weakness. Visual disturbance.	Ventilation. Local exhaust or breathing protection.	Fresh air, rest. Refer for medical attention.
Skin	MAY BE ABSORBED! Dry skin. Redness.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse skin with plenty of water or shower. Refer for medical attention.
Eyes	Redness. Pain.	Safety goggles or eye protection in combination with breathing protection.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
Ingestion	Abdominal pain. Shortness of breath. Vomiting. Convulsions. Unconsciousness. (Further see Inhalation).	Do not eat, drink, or smoke during work. Wash hands before eating.	Induce vomiting (ONLY IN CONSCIOUS PERSONS!). Refer for medical attention.

SPILLAGE DISPOSAL	PACKAGING & LABELLING	
Evacuate danger area! Ventilation. Collect leaking liquid in sealable containers. Wash away remainder with plenty of water. Remove vapour with fine water spray. Chemical protection suit including self-contained breathing apparatus.	F Symbol T Symbol R: 11-23/24/25-39/23/24/25 S: (1/2-)7-16-36/37-45 UN Hazard Class: 3 UN Subsidiary Risks: 6.1 UN Pack Group: II	Do not transport with food and feedstuffs.

EMERGENCY RESPONSE	SAFE STORAGE
Transport Emergency Card: TEC (R)-30S1230 NFPA Code: H 1; F 3; R 0	Fireproof. Separated from strong oxidants, food and feedstuffs. Cool.

IPCS International Programme on Chemical Safety

UNEP

SEE IMPORTANT INFORMATION ON THE BACK.

SODIUM HYDROXIDE

0360
October 2000

CAS No: 1310-73-2 RTECS No: WB4900000 UN No: 1823 EC No: 011-002-00-6	Caustic soda Sodium hydrate Soda lye NaOH Molecular mass: 40.0

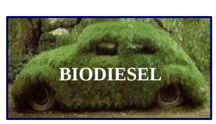
TYPES OF HAZARD/ EXPOSURE	ACUTE HAZARDS/SYMPTOMS	PREVENTION	FIRST AID/FIRE FIGHTING
FIRE	Not combustible. Contact with moisture or water may generate sufficient heat to ignite combustible substances.		In case of fire in the surroundings: use appropriate extinguishing media.
EXPLOSION			
EXPOSURE		**AVOID ALL CONTACT!**	**IN ALL CASES CONSULT A DOCTOR!**
Inhalation	Corrosive. Burning sensation. Sore throat. Cough. Laboured breathing. Shortness of breath. Symptoms may be delayed (see Notes).	Local exhaust or breathing protection.	Fresh air, rest. Half-upright position. Artificial respiration may be needed. Refer for medical attention.
Skin	Corrosive. Redness. Pain. Serious skin burns. Blisters.	Protective gloves. Protective clothing.	Remove contaminated clothes. Rinse skin with plenty of water or shower. Refer for medical attention.
Eyes	Corrosive. Redness. Pain. Blurred vision. Severe deep burns.	Face shield or eye protection in combination with breathing protection if powder.	First rinse with plenty of water for several minutes (remove contact lenses if easily possible), then take to a doctor.
Ingestion	Corrosive. Burning sensation. Abdominal pain. Shock or collapse.	Do not eat, drink, or smoke during work.	Rinse mouth. Do NOT induce vomiting. Give plenty of water to drink. Refer for medical attention.

SPILLAGE DISPOSAL	PACKAGING & LABELLING	
Sweep spilled substance into suitable containers. Wash away remainder with plenty of water. Personal protection: complete protective clothing including self-contained breathing apparatus.	C Symbol R: 35 S: (1/2-)26-37/39-45 UN Hazard Class: 8 UN Pack Group: II	Unbreakable packaging; put breakable packaging into closed unbreakable container. Do not transport with food and feedstuffs.

EMERGENCY RESPONSE	SAFE STORAGE
Transport Emergency Card: TEC (R)-80GC6-II+III NFPA Code: H 3; F 0; R 1	Separated from strong acids, metals, food and feedstuffs. Dry. Well closed. Store in an area having corrosion resistant concrete floor.

IPCS
International Programme on Chemical Safety

UNEP



SAFETY

While in use the plant should never be left unattended.

Protective gloves should be worn **<u>at all times</u>**.

When handling chemicals face masks, goggles and gloves **must** be worn.

Seek medical assistance if any operator begins to feel ill.

Disposal of **WASTE** tank contents: The waste comprises of glycerol, lye and excess methanol. Glycerol can be sold to industry or used as fertiliser or in composting; however it is not clean in this case. The glycerol needs to be cleaned; this can be done using the Methanol Recovery addition. The waste is heated to above the boiling point of methanol which is then distilled so that it can be reused in the biodiesel process.

SAFETY—METHANOL

Methanol is highly flammable and its vapour is explosive.

When using methanol ventilate the area well, use protective gloves and goggles and wash hands after use.

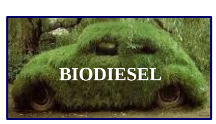
Store away from food and feedstuffs in a fireproof container separated from strong oxidants.

Methanol can be absorbed into the body by inhalation, though the skin and by ingestion.

If there is a spillage:

- **<u>Evacuate</u>** the area.
- **<u>Ventilate</u>** the area and pour absorber granules over the area.
- Sweep away into the waste container (green drum).
- Wash the area with plenty of water and remove vapour with a fine water spray.

Self contained breathing apparatus is required for major spillages.



SAFETY—NAOH

Sodium Hydroxide is corrosive and is toxic when particles are inhaled.

When using NaOH a face mask, gloves, protective clothing and goggles should be worn. Always wash hands after use.

Store away from food and feedstuffs in a well closed container separated from strong acids.

NaOH can be absorbed into the body by inhalation of its aerosol and by ingestion. Contact of NaOH with the skin can be treated with vinegar so as to neutralise it.

If there is a spillage:

- Pour absorber granules over the area.
- Sweep away into the waste container (green drum).
- Wash the area with plenty of water and remove vapour with a fine water spray.

Self contained breathing apparatus and complete protective clothing are required for major spillages.

16. ADDITION CHEMICAL SAFETY DATA

16.1 Methanol

Molecular Formula: CH_3OH

Substance Hazards: toxic (causes blindness), highly flammable with explosive vapours. The flame above burning methanol is virtually invisible and so it is very difficult to detect when methanol is alight.

Other names: Hydroxymethane, methyl alcohol, wood alcohol, carbinol.

Form: colourless liquid with a characteristic smell. Stable but highly flammable.

Melting point: -98 C
Boiling point: 64.7 C
Flash Point: 11 C

Flammable Limits in air (by volume) 6.72% - 36.50%

Solubility in water: Fully miscible.

Use in well ventilate area; avoid contact with skin, use nitrile gloves and safety goggles.

Spillage Clean Up: Remove all sources of ignition. Provide ventilation and absorb all spills with dry sand or earth, then place into a clearly labelled chemical waste container.

Disposal: trace amounts of methanol are acceptable to be washed down the sink with planet of water, unless local rules prohibit this. Larger amounts need to be collected in a non-chlorinated waste solvent container for disposal.

16.2 Sodium Hydroxide

Molecular Formula: NaOH

Substance Hazards: Corrosive. If it comes into contact with metals it may evolve flammable hydrogen gas.

Other names: Lye, Caustic Soda

Form: White solid, odourless.

Melting Point: 318 C
Boiling Point: 1390 C
Flash Point: Non-flammable

pH 14

Solubility in water: 111g/100ml (20 C)

When handling wear eye protection, gloves and protective clothing. Wash thoroughly after handling. Minimise dust generation and accumulation. Use adequate ventilation.

Spillages Clean Up: If in solid state sweep up and place in a clearly marked waste container. Avoid any contact with water or any run off into water supplies. Clean up spills immediately and provide ventilation. If dissolved in liquid place dry sand or earth over the spill and sweep up. Place into a clearly marked waste container.

Disposal: Observe current rules pf the local authority. Treat large spillages as special waste.